# A Menu of Fire Response Water Quality Monitoring Options and Recommendations for Water Year 2019 and Beyond

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# Executive Summary

In October 2017, the Tubbs Fire and the Nuns Fire burned 93,400 acres of the Mark West Creek and Santa Rosa Creek watersheds, killing 22 people, and incinerating approximately 7,000 structures. After the fires, many agencies worked together to deploy water and sediment related best management practices (BMPs) in the burn area (e.g., waddles, emergency hydroseeding, and filter systems on storm drains) and worked on removing contaminated debris and soil from burned properties. The City of Santa Rosa conducted water quality sampling to verify that the BMPs were working. Water quality samples were collected at selected sites before and after flow interacted with the BMP; the City was generally pleased with the results. Subsequently, the North Coast Regional Water Quality Control Board (Water Board) developed a preliminary monitoring design for WY 2018 to measure potential water quality impacts of the fires in relation to beneficial uses. Selected streams were sampled for parameters that could be compared to regulatory water quality criteria. The attachment contains a summary of the results for WY 2018. Based on this initial dataset, the apparent early success of the BMP program, and the soil clean-ups that have occurred, the focus going forward should be on monitoring larger-scale and longer-term impacts. This document outlines monitoring options for consideration for WY 2019 and beyond for four categories: Water Chemistry, Hydromodification, Geomorphic Response, and Ecology.

**WY 2019: Water Chemistry:** Monitoring should continue to focus on analytes that can be compared to pre-fire condition and to appropriate water quality criteria in relation to beneficial uses. In WY 2019, the monitoring should continue to include dry-weather flow, first flush, and larger storm events. The sites and analytes monitored could be the same as WY 2018, However, if there is interest in cost savings, the following suggestions should be considered:

- Omit sediment-bound pollutant monitoring for the dry-weather flow (i.e., PAHs and trace metals unless dissolved phase and planned to be used to explain toxicity);
- Consider single-storm composites rather than taking multiple discrete samples thus potentially reducing the analytical and data management costs considerably; and
- Lower and upper Mark West sites could be omitted during first flush storms when runoff is expected to be minimal; wet season sampling could be triggered at these sites after 7 inches of antecedent rainfall.

The methods employed to date for nutrient analysis appear to be sensitive enough but the methods for trace metals and PAHs used during WY 2018 had detection limits above water quality guidelines. We recommend EPA Method 1638 for trace metals, EPA Method 1631 for mercury (Hg), and AXYS MLA-021 or equivalent for PAHs. For existing analytes and any new analytes, the appropriate analytical method should be chosen based on the water quality criteria against which each analyte will be compared. Additional analytes, storm conditions, and sites could be considered in WY 2019 but these would incur additional field staff effort, analytical, and data management costs. Further elements could include:

- Pesticides samples collected during storm events;
- Dry weather flow, an early season flush, and a late-season storm could be analyzed for toxicity;
- After sufficient antecedent rainfall (>7 inches during season to date), 1-2 larger flow events could be sampled due to the increased erosive processes likely occurring in the watershed. Should a very large storm be forecast (>2.5 inches in 6 hours or 5.5 inches in 24 hours), extra effort could be made to collect samples during that event;
- Dioxin and Hg bioaccumulation in Fountaingrove and Spring Lakes during the dry season; and

- A complete review of existing pre-fire data could reveal a rationale for adding or replacing sites and analytes, and sampling under differing flow conditions.

**WY 2019: Hydromodification:** Monitoring should focus upon flow measurements at the existing USGS gage stations. The local sponsors (Sonoma County Water Agency and the City of Santa Rosa) should work with the USGS to maintain the two gages over the next 5 years. Given the more significant predicted flow volume increase in the Mark West watershed, continuation of the Mark West Creek at Mirabel Heights gage is the higher priority, for both flow and sediment.

**WY 2019: Geomorphic Response:** Reinstate the USGS sediment load monitoring program at the Mark West Creek near Mirabel Heights gage (11466800) so that pre-fire loads (measured in WYs 2006-08) can be compared with post-fire loads;

**Future Consideration: Geomorphic Response:** Monitoring would document the amounts, locations, rates, and processes of sediment production, transport, and storage within the burn area and downstream, with a focus on the steepest areas reported to have the most intense heat. A program could include:

- What are the new or fire-exacerbated sediment sources? Elements could include:
    - Map landslides and debris flows within the burn area; and
    - Inspect and repair any sediment-related BMPs.
- How has sediment transport and steam morphology changed in relation to the fires? Elements could include:
    - Monitor dry weather turbidity during the dry season;
    - Measure channel cross sections to document changes in channel geometry;
    - Document sediment removal from channels or sediment basins; and
    - Make observations after high flows to document sediment inputs, storage, or other major channel changes.
- What geomorphic impacts did the fires have on habitat? Elements could include:
    - Collect a longitudinal profile to quantify aggradation or incision along the channel bed;
    - Map geomorphic channel features within important creek reaches;
    - Document sediment or wood removal from channels; and
    - Collect channel bed grain size data to compare with pre-fire distributions.

**Future Consideration: Ecology:** Monitoring should focus upon documenting physical habitat condition. Depending on the key questions of interest, a minimal program could include the following elements:

- Resurvey habitat condition using the California Rapid Assessment Method (CRAM);
- Collect benthic macroinvertebrate data, as an indicator of stream food web support and condition;
- Collect benthic algae data, as an indicator of stream nutrient condition;
- Conduct rapid habitat assessments that focus upon species of concern (e.g., Yellow Legged Frog);
- Collect data on large woody debris input and water temperature using CRAM; and
- Collect data on the presence or absence of species of concern.

# Introduction

The environmental effects of wildfire can vary widely in relation to the amount of fuel and the heat that the fire generates, the land use of the burn areas, the completeness of the burn, the slope and geology of the burn areas, and the socioeconomics of the communities that live there. Effects on aquatic resources can include chronic and acute toxicity, changes in water clarity, riparian cover, and substrate texture, changes to dry weather flow and water temperature, changes to habitat structure including bank, bar, and bed formations and wood debris supply, changes to food resources, and changes to the timing and severity of high flow events in relation to life stages for rare and endangered species. The timeline over which these changes take place is dependent on the hydroclimatology that occurs in the years following the fire. If a series of above average rainfall years occur with above average rainfall intensity and peak flows, the impacts to the landscape and to the adjacent and downstream aquatic resources and other beneficial uses will likely be more severe than if there are a series of below average climate years that allow for vegetation regrowth and other biological processes to restore the landscape and community, as well as enough time for removal of contaminated debris, repair of roads and bridges, and implementation of post-fire best management practices (BMPs).

In October 2017, the "Northern California firestorm" caused unprecedented damage with 12 wildfires burning simultaneously. Two fires are of special interest to the Water Board because of their large size and locations. The Tubbs Fire burned 36,800 acres. It killed 22 people and incinerated more than 5,600 structures, including more than 2,800 homes in the city of Santa Rosa (5% of the city's housing stock). The Nuns Fire burned a total of 56,600 acres and destroyed 1,400 structures.

In response to the catastrophic Tubbs Fire (northern burn) and the Nuns Fire (southern burn), a preliminary monitoring design was implemented by the North Coast Regional Water Quality Control Board in Water Year (WY) 2018 to assess water quality impacts associated with the fires. The focus of the initial design was water sampling and laboratory analysis for parameters that are easily compared to existing pre-fire data, and that relate directly to regulatory water quality criteria.

This document outlines future monitoring options for consideration, including modifications to the plan implemented in the 2018 wet season, directly following the fires, and an additional set of monitoring options using indirect indicators of impacts to beneficial uses during dry weather and wet weather conditions:

- Changes in flow;
- Changes in erosion, sediment concentrations, and sediment yields; and
- Changes in riparian habitat.

Additional direct indicators of changes in beneficial uses are also recommended for consideration:

- Changes in distribution of selected species of aquatic wildlife.

# Monitoring Elements for Future Consideration

## Water Chemistry

### Conceptual model of fire effects and connections to beneficial uses

Water chemistry is a product of the underlying geology and soils, erosion and dissolution rates, land uses, and pollutant discharges. Streams draining areas underlain by Tertiary volcanics (including the Tolay Volcanics and the Sonoma Volcanics) can be naturally rich in phosphorus. Streams draining areas underlain by serpentinite (including the Franciscan Melange, undifferentiated melange, serpentinite, detrital serpentinite, and Coast Range ophiolite serpentinized ultramafic rocks) can be naturally rich in chromium and nickel. Streams draining the Franciscan Formation, Great Valley Sequence, and marine sedimentary geological types tend to have higher sediment supply and may have higher suspended sediment concentrations and turbidity during all flow conditions, when compared to streams draining Tertiary volcanics and continental Mesozoic sedimentary units (Table 1).

Table 1. Geologic units and characteristics.

| **Basin Name** | **Tertiary Volcanics (%)** | **Serpentinite (%)** | **General erosivity** |
|---|---|---|---|
| Mark West Creek near Mirabel Heights, CA | 40 | 5 | moderate |
| Lower Mark West Creek at Fulton Road | 40 | <5 | moderate |
| Upper Mark West Creek at Leslie Road | 50 | 5-10 | low to moderate |
| Santa Rosa Creek at Willowside Road near Santa Rosa | 30 | 5 | moderate |
| Piner Creek at Marlow Road | 15 | 0 | low |

Fire affects water chemistry directly by the additional runoff of flame retardants that are used during firefighting (ammonium phosphate, ammonium sulfate). PFASs may be present also; although it is likely too expensive for broad use in most wildfires, it may be used in isolated instances by local firefighting crews. The process of burning the landscape also leads to additional direct supply of burn products in relation to the land use types. Industrial, commercial, residential, and transportation land uses can add a number of toxic organic (chlorinated, brominated, and fluoridated, and aromatic) compounds and a number of toxic metals and metalloids (e.g., Hg, Se, Cu, Pb, Zn) over and above pre-fire concentrations. When agricultural and open space land uses are burned, polycyclic aromatic hydrocarbons (PAHs), dioxins, Hg, nutrients, organic carbon, and metallic salts may affect water quality in downstream receiving waters. In the case of dioxins and Hg, increased bioaccumulation should be considered in water bodies downstream of the burned areas, especially where fishing occurs elevating risks to humans, and also to fish-eating wildlife (most notably, birds). In the post-fire environment, additional applications of pesticides and herbicides may be needed to control pests and weeds which may lead to toxic effects in downstream water bodies. Other direct water quality effects may occur from the melting and burning of plastic infrastructure such as culverts, road signs, and fences, directly supplying contaminants to stormwater.

Indirect effects of fire include the increased efficiency of pollutant transport, due to greater runoff and greater sediment erosion and transport (see later sections), causing a greater portion of pollutants derived from the atmosphere or associated with land uses to access stormwater conveyances and streams (sediment is an important vector for many toxic organic compounds and metals). Loss of riparian shading (see later section on ecology) can lead to increases in water temperature and loss of dry weather flow (see section on flow) that can lead to lower dilution rates and increases in concentrations. Increased sediment supply can also lead to increases in turbidity during dry weather flows.

Each of these effects can be harmful for both Warm Freshwater Habitat (WARM) and Cold Freshwater Habitat (COLD). Changes in water chemistry associated with fires can impact drinking water supply by the introduction of toxic compounds at concentrations above human health standards or more commonly, can cause an increase in the effort needed to treat water to potable standards by removing sediment and organics or controlling algae in water supply sources (affecting Municipal and Domestic Supply [MUN]). Worsening water chemistry can cause chronic and acute impacts to aquatic organisms, including rare and endangered species, and increases in water temperature and turbidity can cause increased stress or death to some species.

## Existing pre-fire data

Prior to the fires, several sites in the Mark West and Santa Rosa Creek watersheds were sampled under various programs including the Russian River MS4 Program, the Surface Water Ambient Monitoring Program, and the Total Maximum Daily Load program. Four sites were selected as pre-fire indicators for comparison to post-fire sampling. Most of the data collected at these sites and through these programs has been collected during low-flow conditions. The four sites and relevant identifying information are presented in Table 2 and are captured in the Watershed Atlas developed for the Russian River Regional Monitoring Program (R3MP).

## Existing water year 2018 monitoring design (post-fires)

Note that throughout the water quality section, we refer to the fires as occurring in 2017, while the data for post-fire monitoring was collected in what is called water year (WY) 2018, or the time period between Oct 1, 2017 and Sept 30, 2018. The basic elements of the existing WY 2018 monitoring design are presented in Table 3.

Table 2. Monitoring stations and sampling date ranges from other programs used to evaluate the fire monitoring results. These sites correspond to the purple dots in Figure 1.

| Program | Parent Project | Project | Station Name | Station Code | Sample Date Start | Sample Date End | Target Latitude | Target Longitude |
|---|---|---|---|---|---|---|---|---|
| **Russian River MS4 Program** | 2009 5 year Permit for Russian River MS4 Program | 2009 5 year Permit for RR_MS4 Program SCWA | C1 - Santa Rosa Creek down gradient of urban footprint | C1-SRC-D | 20-Jul-10 | 19-Jun-15 | 38.4452 | -122.7760 |
| **Surface Water Ambient Monitoring Program** | SWAMP RWB1 Monitoring | RWB1 Irrigated Lands Monitoring 2013 | Mark West Creek at River Road | 114MW2583 | 12-Dec-13 | 04-Feb-14 | 38.4827 | -122.8307 |
| **Surface Water Ambient Monitoring Program** | SWAMP RWB1 Monitoring | RWB1 Irrigated Lands Monitoring 2013 | Santa Rosa Creek at Willowside Road | 114SR0761_ SWAMP | 04-Feb-14 | 04-Feb-14 | 38.4452 | -122.8068 |
| **Surface Water Ambient Monitoring Program** | SWAMP RWB1 Monitoring | RWB1 Klamath Trinity Trend Monitoring Fys 2008 2009 | Santa Rosa Creek at Willowside Road | 114SR0761_ SWAMP | 06-Oct-08 | 20-Jul-09 | 38.4452 | -122.8068 |
| **Surface Water Ambient Monitoring Program** | SWAMP RWB1 Monitoring | RWB1 Russian River Monitoring FYs 2010 2011 | Santa Rosa Creek at Willowside Road | 114SR0761_ SWAMP | 30-Sep-10 | 29-Nov-11 | 38.4452 | -122.8068 |
| **Surface Water Ambient Monitoring Program** | SWAMP RWB1 Monitoring | RWB1 Russian River Trend Monitoring FYs 2004 2005 | Santa Rosa Creek at Willowside Road | 114SR0761_ SWAMP | 07-Oct-04 | 28-Jun-05 | 38.4452 | -122.8068 |
| **Total Maximum Daily Load** | RWQCB1 Russian River TMDL | RWQCB1 Russian River Pathogen Indicator TMDL | Piner Creek at Fulton Road | 114PI0729 | 11-Jun-08 | 29-Sep-08 | 38.4484 | -122.7695 |
| **Total Maximum Daily Load** | RWQCB1 Russian River TMDL | RWQCB1 Russian River Pathogen Indicator TMDL | Santa Rosa Creek at Willowside Road-114SR0761 | 114SR0761 | 11-Jun-08 | 29-Sep-08 | 38.4453 | -122.8067 |

Table 3. Water Year 2018 Monitoring Design. These sites correspond to the pink dots in Figure 1.

| **Monitoring Element** | **Monitoring Design** | **Rationale** | | |
|---|---|---|---|---|
| Site Locations | Upper Mark West Creek at Leslie Road (station code: 114MW6173) | 0.2% impervious cover | 34.5% burned by the Tubbs fire | Watershed predominantly rural area above home sites |
| | Lower Mark West Creek at Fulton Road (station codes: 114MW4198; 114MW3972) | 1% impervious cover | 50.4% burned by the Tubbs fire | Measured just below another tributary where homes are on larger lots (i.e. ~0.5 acres). |
| | Piner Creek at Marlow Road (station code: 114PI5786) | 34.5% impervious cover | 64.6% burned by the Tubbs fire | Measured just below Coffey Park where >1000 homes burned. |
| | Santa Rosa Creek at Willowside Road near Santa Rosa (station code: 114SR0761) | 14% impervious cover | 21.3% burned 11.5% burned by the Tubbs fire; 9.8% burned by the Nums fire | Selected because there are previous years of existing pre-fire data for comparison. This pre-fire data includes trace elements, nutrients, TOC and field measures (DO, pH, specific conductivity) |
| Analytes | Total Suspended Solids (TSS); Total Dissolved Solids (TDS); Nutrients (nitrate, ammonia, total phosphorus); Metals (aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, zinc); Sulfate, PAHs, Toxicity, Total Organic Carbon; Ancillary (temperature, specific conductance, dissolved oxygen, pH, turbidity, hardness, alkalinity) | Research shows that fertilizer (used in fire retardants) and contaminants associated with burned areas (nutrients, PAHs, metals) can increase in waterbodies downstream and threaten beneficial uses. Targeted monitoring analytes consider: 1) correlation to fire impacts, 2) potential impacts to water resources, and 3) potential for management practices to mitigate threats or impacts identified through this monitoring effort. | | |
| Dry Weather Monitoring | One dry weather event prior to start of rainy season. Single grab sample. | Dry weather concentrations are typically distinct from wet weather concentrations and may have different impacts on the animals that live in this ecosystem. | | |
| Wet Weather Monitoring | First two seasonal first flushes; in water year 2018, an additional large and later season storm event was also sampled. Single grab samples for each site during each storm. | Highest contaminant concentrations from urban runoff are expected during the seasonal first flush. Highest concentrations from pervious areas are expected during large storm events after soil saturation (typically later in the rainy season). | | |
| Timing of Sample Collection | Focused near peak of hydrograph | Highest concentrations are expected near the peak of the hydrograph | | |

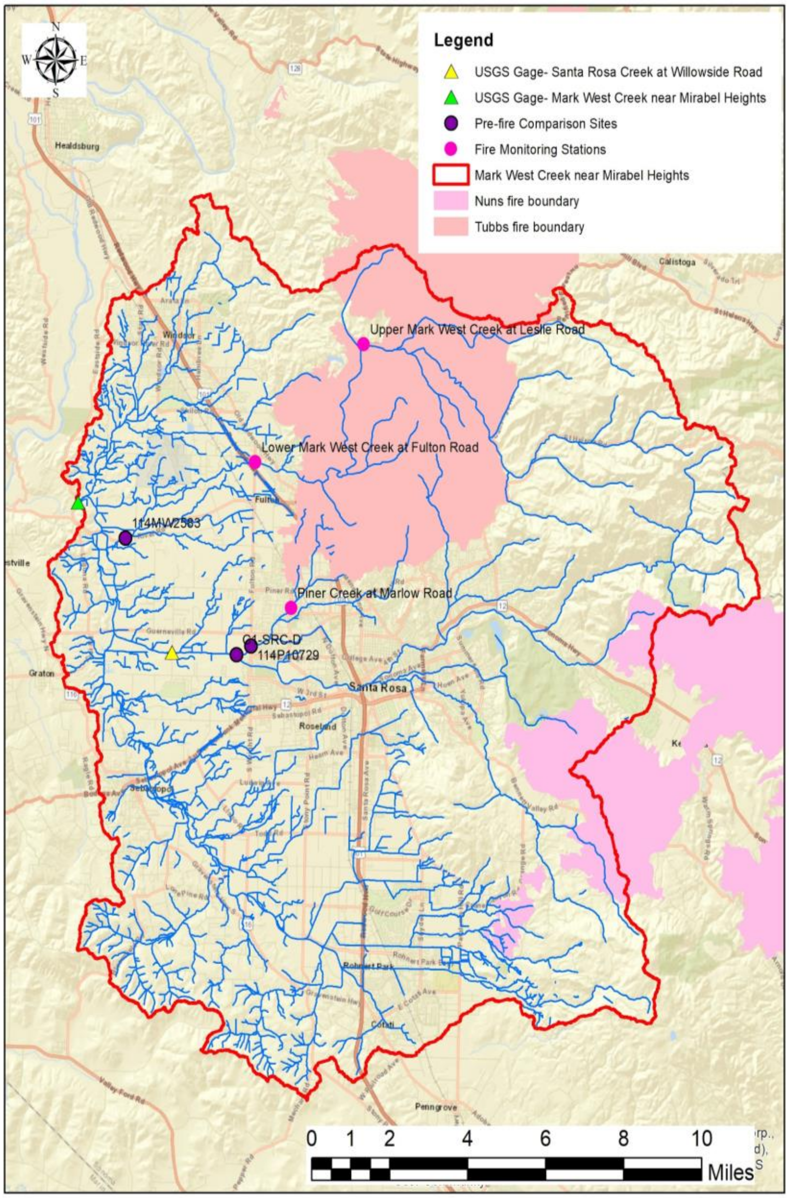


Figure 1. USGS gage sites, pre-fire comparison sites, and post-fire monitoring sites. In addition to a USGS gage site, the yellow triangle is also a pre- and post-fire comparison monitoring site.

Four events were sampled including a dry weather flow event (Event 1; not graphed) and three storm events (Figure 2). For each event, a single grab sample was collected at each site. The first two storm events (Event 2 and 3; Nov 8/9, 2018 and Nov 15/16, 2018) were both early season flushes, while Event 4 (March 21/22, 2018) was a later season flow event. Of the three storm events sampled, Event 4 had the smallest total rainfall, but had the greatest runoff due to more antecedent precipitation and therefore a saturated landscape. Because early season runoff is expected to be minimal from the most pervious watersheds such as Lower Mark West and Upper Mark West, these sites could be dropped from first flush sampling event. We recommend sampling these very pervious watersheds after antecedent rainfall exceeds minimally 7 inches for the season to date.

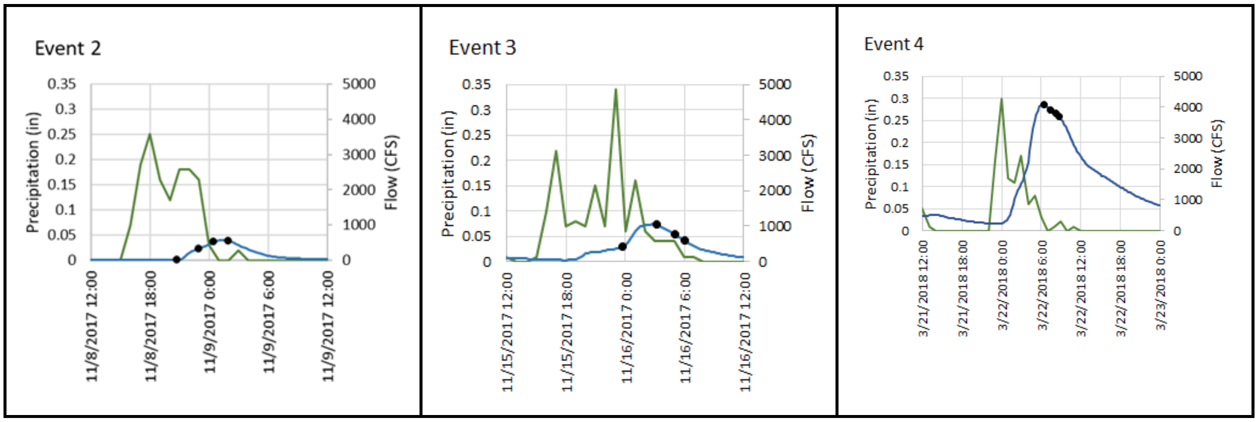


Figure 2. Hydrographs showing stream flow (blue line) and precipitation (green line) vs. sampling time (black dots) for Event 2 (a 1.36” storm on Nov. 8-9), Event 3 (a 1.95” storm on Nov. 15-16), and Event 4 (a 1.21” storm on March 22). Flow data was collected from the USGS flow gauge on Santa Rosa Creek at Willowside Road, USGS Gage #11466320. Precipitation data was collected from the Santa Rosa CalFire weather station. This figure is similar to that created by the North Coast Regional Water Quality Control Board for their “Santa Rosa Post-Fire Water Quality Monitoring” fact sheet (NCRWQCB, 2018).

**QA of WY 2018 results**

The 2017 Fire Response Monitoring data were formatted for uploading to the Regional Data Center and CEDEN, and reviewed by SFEI’s Quality Assurance Officer. Forty-six parameters were analyzed and reported for the total and/or dissolved water fraction from the four stations monitored by the 2017 Fire Response Monitoring project in the Mark West Creek watershed: 19 conventional water quality parameters (including 4 field measured parameters), 11 trace elements, and 16 PAHs (Table 4). A full QA review and method sensitivity evaluation is presented in Attachment A. Highlighted below are the most important elements of that review that may suggest modifications to the existing monitoring plan. The following primary issues were encountered during QA and basic analysis of the data:

- In some cases, the analytical method was not as sensitive as required to achieve detection or compare to water quality guidelines, and not as sensitive as methods used in other monitoring programs in Sonoma County.
- Non-detects were measured in some samples for 5 out of 15 of the inorganic conventional parameters including Nitrate as N and Nitrate + Nitrite as N, with extensive non-detects (where the number of NDs > 50%) measured for Ammonia as N, Nitrite as N, and Orthophosphate as P, with Orthophosphate as P results being 100% NDs. None of the MDLs for these inorganic conventional parameters were greater than water quality guidelines, however, few water quality guidelines are in place for these parameters.
- Non-detects were reported in 7 out of 11 of the trace elements (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, and Selenium). Extensive non-detects (number of NDs > 50%) were measured for Arsenic, Cadmium, and Selenium. Most trace elements were analyzed using EPA Method 200.7 and reported in units of mg/L. Mercury was analyzed using EPA Method 245.1 and reported in units of ug/L. Other historical monitoring programs in Sonoma County (e.g. SWAMP

Table 4. Parameters/analytes measured in the Water Year 2018 Monitoring Program.

| **Parameter class** | **Measured in WY 2018** | | | |
|---|---|---|---|---|
| Physiochemical parameters | Temperature<br>Turbidity<br>Alkalinity | Specific Conductance<br>Total Suspended Solids | Dissolved Oxygen<br>Total Dissolved Solids | pH<br>Hardness |
| Nutrients | Nitrate | Nitrite | Ammonia | Total Phosphorus |
| Macro organics | Total Organic Carbon | | | |
| Metals and metalloids | Aluminum<br>Copper<br>Mercury | Arsenic<br>Iron<br>Nickel | Cadmium<br>Lead<br>Selenium | Chromium<br>Manganese<br>Zinc |
| Polycyclic Aromatic Hydrocarbons (PAHs) | Acenapthene<br>Benzo(a)pyrene<br>Chrysene<br>Indeno(1,2,3-c,d)pyrene | Acenapthylene<br>Benzo(b)fluoranthene<br>Dibenz(a,h)anthracene<br>Napthalene | Anthracene<br>Benzo(g,h,i)perylene<br>Fluoranthene<br>Phenanthrene | Benz(a)anthracene<br>Benzo(k)fluoranthene<br>Fluorene<br>Pyrene |
| Toxicity | Toxicity | | | |

and RB1 TMDL programs) used analytical EPA Method 1638M for most trace elements (reported in units of ug/L) and EPA Method 1631EM for mercury (reported in units of ng/L).

- A comparison of the reported MDLs between programs (Appendix B) indicated that most of the Fire Monitoring project trace element results reported MDLs that were between 2 to 50 times greater than reported at the nearby historical SWAMP monitoring sites used as comparative sites in this analysis (Station Codes 114MW2583 and 114SR0761).
- Total Lead MDLs were over 100 times higher than the historical SWAMP sites and Total Mercury MDLs were more than 500 times higher. In addition, Aquatic Life guidelines were much lower than the average MDLs reported for Arsenic, Lead, Mercury, and Selenium.
- A review of method detection limit sensitivity indicated extensive non-detects (NDs>50%) for all sixteen PAHs reported. The percent of ND results ranged from 87.5% to 100%. Only four out of the sixteen PAHs analyzed reported detected concentrations: Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Fluoranthene, and Pyrene. The San Francisco Bay Regional Monitoring Program for Water Quality employs more sensitive analytical methods for PAHs (Axys MLA-021) and reports results at the pg/L level. Results for the San Pablo Bay monitoring stations in Sonoma County have a high proportion of detected PAH concentrations. The human health-based water quality objectives are well below the MDLs reported by the Fire Response Monitoring Project (Appendix B).

**Data Review**

Appendix C lists the Fire Response Monitoring Results and the maximum results from other surveys. Selected plots are presented below (Table 6, Figures 3-5), while all plots of analytes with reported results that were above the MDL are provided in Appendix D. The comparison site data (Comp) presented in the plots are the maximum result reported at each site by program (during any sampling event).

Table 5. Comparison of the average MDLs of the Fire Response Monitoring Project sites to MDLs reported by other local monitoring efforts in the region for select analytes. The water quality guidelines for Aquatic Health or Human Health are listed for comparison. This selection is for parameters where the RB1 Fire Monitoring MDLs are above the water quality guidelines (US EPA). Information for all parameters is located in a table in Appendix B.

| Group1 | Group2 | CEDEN Analyte and Fraction | Unit | RB1 Fire | SWAMP | TMDL | WQ Guide-line | Guide-line Type |
|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Arsenic, Dissolved | mg/L | 0.00230 | 0.00004 | | 0.000004 | Human Health |
| Inorganics | Trace Elements | Arsenic, Total | mg/L | 0.00230 | 0.00006 | | 0.000004 | Human Health |
| Inorganics | Trace Elements | Lead, Dissolved | mg/L | 0.00140 | 0.00002 | | 0.00054 | Aquatic Life |
| Inorganics | Trace Elements | Lead, Total | mg/L | 0.00140 | 0.00001 | | 0.00054 | Aquatic Life |
| Inorganics | Trace Elements | Mercury, Total | ug/L | 0.10469 | 0.00019 | 0.00020 | 0.012 | Aquatic Life |
| Inorganics | Trace Elements | Selenium, Dissolved | mg/L | 0.00180 | 0.00060 | | 0.0015 | Aquatic Life |
| Inorganics | Trace Elements | Selenium, Total | mg/L | 0.00180 | 0.00044 | | 0.0015 | Aquatic Life |
| Organics | PAHs | Benz(a)anthracene, Total | ug/L | 0.03 | | | 0.0012 | Human Health |
| Organics | PAHs | Benzo(a)pyrene, Total | ug/L | 0.03 | | | 0.00012 | Human Health |
| Organics | PAHs | Benzo(b)fluoranthene, Total | ug/L | 0.03 | | | 0.0012 | Human Health |
| Organics | PAHs | Benzo(k)fluoranthene, Total | ug/L | 0.03 | | | 0.012 | Human Health |
| Organics | PAHs | Dibenz(a,h)anthracene, Total | ug/L | 0.04 | | | 0.00012 | Human Health |
| Organics | PAHs | Indeno(1,2,3-c,d)pyrene, Total | ug/L | 0.05 | | | 0.0012 | Human Health |

Table 6. Station name, station code, and bar color on the bar plots.

| Station Name | Station Code | Bar Color |
|---|---|---|
| Fire monitoring: Lower Mark West Creek | 114MW4198; 114MW3972 | Grey |
| Fire monitoring: Upper Mark West Creek | 114MW6173 | Grey |
| Fire monitoring: Piner Creek | 114PI5786 | Blue |
| Fire monitoring: Santa Rosa Creek at Willowside Road | 114SR0761 | Blue |
| C1 - Santa Rosa Creek down gradient of urban footprint | C1-SRC-D | White |
| Mark West Creek at River Road | 114MW2583 | White |
| Santa Rosa Creek at Willowside Road | 114SR0761 | White |
| Piner Creek at Fulton Road | 114PI0729 | White |

A few observations stand out:

- Some analytes were highest during dry weather flows (Event 1) (Figure 3). These analytes included: Alkalinity, Ammonia as N, Calcium, Hardness, Magnesium, Selenium and specific conductivity. It is logical that these analytes are highest during dry weather: Ammonia is often associated with septic sources or some other illicit discharge and is less diluted and may not be immediately oxidized to nitrite or nitrate during dry weather flows. Calcium, Mg, Se and alkalinity are all associated with groundwater dissolution, which is most concentrated during low flow and becomes diluted during storm flows. Because strongly sediment bound pollutants (PAHs, trace metals) are not transported in high concentrations during dry season flow, such pollutants could be dropped from sampling in the dry season unless they are being collected to help explain toxicity.
- Some analytes were highest during Event number 4 (Figure 4), including: Aluminum, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Total Phosphorus, and TSS. However, for most of these analytes, Piner Creek did not follow this pattern. Event number 4 was the highest flow event. These results are mostly logical. Aluminum and Fe have a geological source; therefore, greater concentrations are likely to occur during events that cause soil erosion. Chromium, Cu, Pb, Hg, Ni and TP are all particle associated and therefore will have the highest concentrations along with high TSS during higher flow events.
- Piner Creek had a unique signal. While many analytes were highest during the 4th event, Piner Creek was typically highest during the 3rd event (e.g., Zn, Pb, Cu, TSS) (Figure 5). Also, many analytes that were non-detects in all other cases had a detected concentration during the 3rd event at Piner Creek (e.g., As, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Fluoranthene, Pyrene). The Piner Creek sampling location is directly downstream of Coffey Park, where >1000 homes burned, and does not have a large upper watershed relative to the other monitoring sites. Therefore, it is reasonable that the Piner Ck sampling location did not respond to the later-season larger-flow event in the same way that the other sites did, and it is also reasonable that Piner Ck

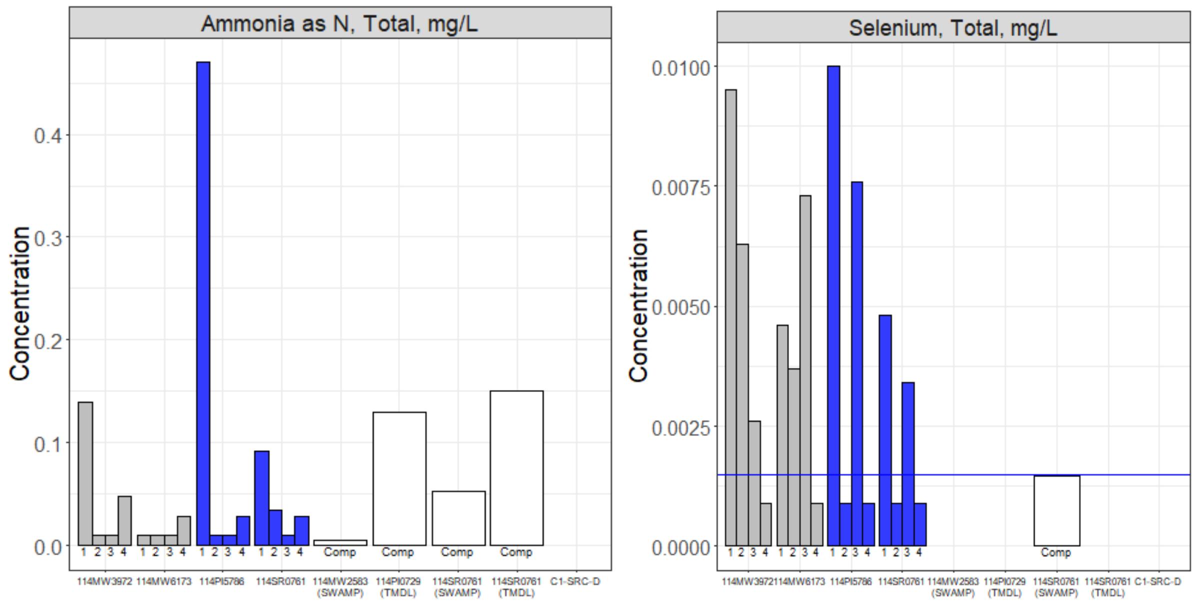


Figure 3. Examples of analytes which had higher concentrations in the dry weather flow than in the storms. Grey bars are for the Mark West Creek fire monitoring sites (dry season), the blue bars are for the Piner and Santa Rosa Creek fire monitoring sites (dry season), and the white bars are for all comparative sites (all seasons). The blue line indicates the aquatic life criterion (US EPA).

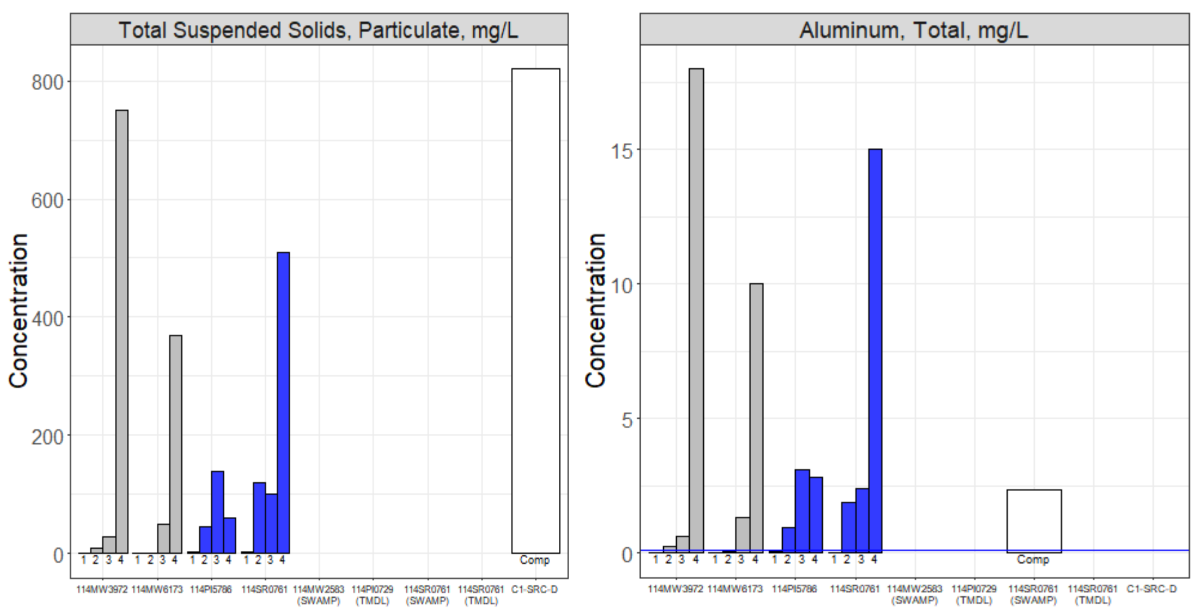


Figure 4. Examples of analytes which had higher concentrations in the 4th event, which was a later season high flow event. Grey bars are for the Mark West Creek fire monitoring sites, the blue bars are for the Piner and Santa Rosa Creek fire monitoring sites, and the white bars are for all comparative sites (all seasons). The blue line indicates the aquatic life criterion (US EPA).

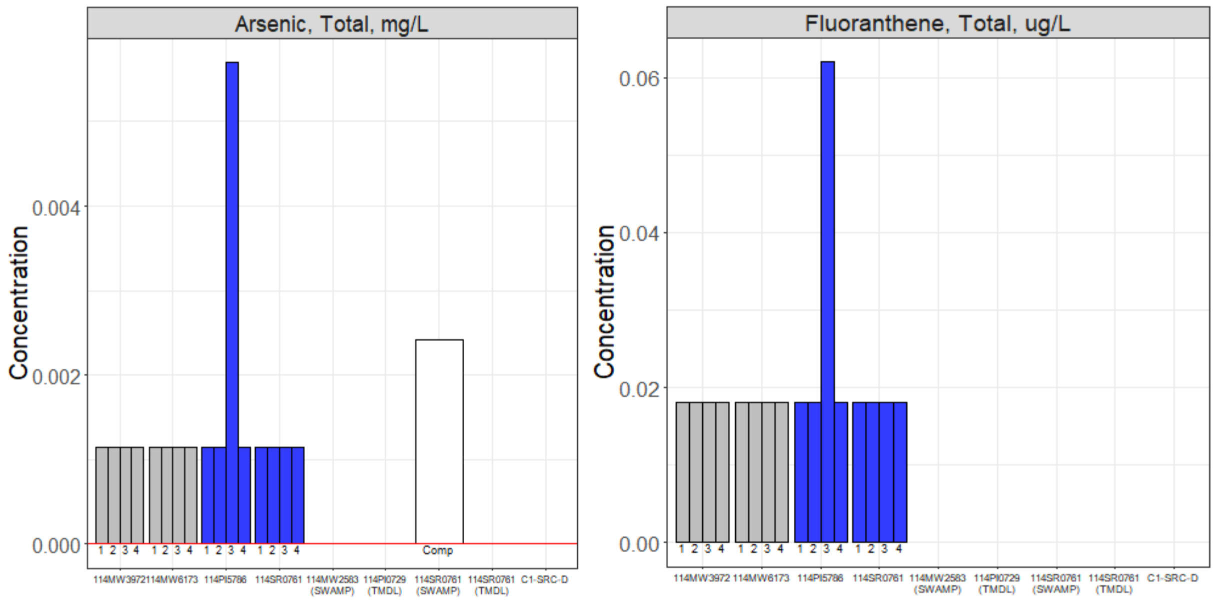


Figure 5. Examples of analytes which had signals only at Piner during the 3rd event, which was the second early season flush with a relatively higher rainfall intensity than the other storms. Grey bars are for the Mark West Creek fire monitoring sites, the blue bars are for the Piner and Santa Rosa Creek fire monitoring sites, and the white bars are for all comparative sites (all seasons). The red line indicates the Human Health and Welfare Protection Criterion (US EPA).

transported higher concentrations and loads of the pollutants that are more urban-associated. There is uncertainty as to why the second storm event transported higher concentrations than the first storm event, but one hypothesis is that the second event was still an early season flush and it had a more intense rainfall than the first storm. Although these are hypotheses based on a relatively small dataset, this suggests that it might be most important to sample an intense early season storm at this site (similar to other watersheds in the Bay Area).

- As reported in the fact sheet, toxicity tests were performed and all results were zero for toxicity. However, only the March 22nd storm event was sampled for toxicity. We recommend sampling for toxicity during the dry season, an early season flush, and a late-season storm.

## Proposed monitoring elements for future consideration

The monitoring design for WY 2018 was generally sound and well-executed. We offer the following recommendations for enhancing future monitoring.

1. **Analytes:** We recommend continuing with the current analyte list but with changes to the analytical methods (further detailed in the next recommendation).
   If there is interest in cost savings, the following suggestions could be considered.

- Strongly sediment bound pollutants could be dropped in the dry season (PAHs, trace metals).
- Lower and upper Mark West sites could be dropped during 1st flush storms when runoff is expected to be minimal until antecedent rainfall exceeds 7 inches for the season to date.

For some additional cost, the following could be considered.

- During storm events, we recommend measuring all analytes and also considering the addition of pesticides. There could be an indirect effect of increases in pesticide application (professional and consumer use) given the new growth of desirable and undesirable plants and pests on the burned landscape.
- We recommend sampling for toxicity during an early season flush in addition to a larger, later season storm. In WY 2018, toxicity was sampled in only the larger, later season storm.
- Monitoring for dioxin and Hg bioaccumulation in Fountaingrove Lake and Spring Lake during the dry season.

2. **Analytical Methods:** For the water year (WY) 2018 monitoring effort, the nutrient analytical methods were appropriate for comparison to guidelines, but the trace elements and PAH methods were not sensitive enough.
    - For example, we recommend a review of the methods for the trace elements to determine if a more sensitive method may be warranted in future monitoring in order to compare results to the Mercury Aquatic Life Objective of 0.012 ug/L. The Fire Monitoring survey in WY 2018 employed EPA Method 245.1 for Mercury with an average MDL of 0.105 ug/L, while the historical SWAMP and TMDL Methods employed EPA 1631 EM and E respectively with average MDLs of 0.0002, which is below the Aquatic Life Objective.
    - If detection below human health protection criteria is desired, a more sensitive method for PAHs (e.g., AXYS method MLA-021, a variant of the EPA Methods 1624 and 8270) should be used.

    We recommend that for every analyte measured, determine the criteria (Aquatic Life, Human Health, Basin Plan, other) against which it will be measured. Based on that criteria, select analytical methods that will enable comparison to those criteria.

3. **Targeted Storm Events**: We recommend continuing a dry weather sampling event, along with an early season flush event with a storm rainfall intensity >0.35 inches/hr; this rainfall intensity was chosen based on the maximum intensity of Event 3, which mobilized greater concentrations and more varied pollutants in the more impervious Piner Creek watershed. Based on NOAA forecast predictions, knowing a storm intensity on the front end is not possible, but we recommend that the 6-hr precipitation be forecasted for minimally 0.75 inches. A second early season flush should be sampled only if the first early season flush did not have rainfall intensity >0.35 in/hr. This early season flush is particularly important to see fire-associated signals from urban areas such as Coffey Park in the Piner Creek watershed.

    Larger storms, especially after sufficient antecedent rainfall to saturate the landscape, induce erosive processes that lead to large amounts of sediment transport. Pollutants of concern are often particle-associated and will be disproportionately transported along with that sediment.

Consequently, we recommend sampling 1-2 events later in the season under larger-flow conditions (see section Geomorphic Response (Erosion and sediment yield), subsection Existing pre-fire data; Hillslope processes, below). The recommended forecast to trigger sampling a larger event includes a 12 hour precipitation total prediction for >2 inches, and should only be sampled after 7 inches of antecedent precipitation for the water year. Should an even larger storm larger storm occur, extra effort should be made to sample these conditions for pollutants. The recommended forecast threshold for this larger storm event should be either 2.5 inches over 6 hrs or 5.5 inches in 24 hrs. See Geomorphic Response section below for further details.

4. **Sampling Methodology:** A single grab sample at each site was collected during each storm event. Because there can be great variation in concentrations throughout a storm, we recommend collecting several samples over the course of the hydrograph to achieve better representation. Multiple grabs per storm can be expensive to analyze, and so for cost-effectiveness we recommend a composite sample made of multiple sub-samples that results in lower analytical costs while improving representation of pollutant concentrations during each storm. Sub-samples should be flow paced if interested in loads or time paced if interested in toxicity. A disadvantage with composite design is that the resulting data cannot be compared to previously collected grab data collected during storms. That should be considered.

5. **Comparison to Pre-fire Data:** Comparison to appropriate pre-fire data is limited due to differences in the analyte lists measured at different sites as well as most pre-fire sampling being done during dry weather flows.
   - For example, the only pre-fire data collected during storm events was at C1-SRC-D and did not include measurement of trace elements or organics.
   - In addition, PAHs were not measured in any of the comparison sites used in this report.

   We recommend extensively mining all possible available pre-fire data and determining what was collected during storm flow events. If there is a good comparison site with data on relevant analytes, it may be useful to consider adding another fire monitoring location or replacing one of the existing locations.

## Methods of interpretation

Data from WY 2019 and subsequent years can be directly compared to water quality guidelines or pre-fire records should there be good pre-fire data to compare to. Pre-fire record data should be mined for suitable comparison data. Water quality guidelines should be determined for all analytes. Grab data can be compared to previously collected grab data. Composite data may only be compared to previously collected composite data. Grab data should never be compared to composite data without careful consideration.

## Connections to other programs

Several post 2017 fire water quality monitoring efforts are being conducted by the USGS, the San Francisco Bay Regional Water Board, the Sonoma County Water Agency, and possibly other organizations. Those agencies are sampling in Napa and Sonoma counties targeting many of the same water quality parameters as this Region 1 survey. Several of these monitoring studies are also uploading their analytical results to the Regional Data Center and CEDEN. The San Francisco Bay Regional

Monitoring Program is also working with Region 1 & 2 Water Boards to analyze whole water samples for non-targeted polar and nonpolar contaminants including: organophosphate flame retardants, pesticides, per and polyfluorinated alkyl substances (PFASs), and other as yet unknown combustion products.

The Region 1 Water Board is working with SFEI to coordinate the R3MP that is initially focusing on surface water quality in the Russian River watershed. The first Steering Committee meeting of the program occurred in early May, 2018. Although the R3MP is just getting coordinated, one of its goals is to convene a workgroup of the stormwater monitoring agencies and the fire monitoring agencies to help support coordinated monitoring in the North Coast region. That workgroup will likely convene in the spring or summer of 2019. Being able to share data and monitoring survey designs through CEDEN and the R3MP Watershed Atlas (https://r3mp.ecoatlas.org/map.php) will help coordination and adaptive management of the various water quality monitoring efforts related to the 2017 North Coast Fires.

## Hydromodification

### Conceptual model of fire effects and connections to beneficial uses

When fire burns a landscape, runoff volume and peak flow usually increase due to the loss of vegetation cover, and, depending on the heat and soil properties, changes to the aggregate stability of the soils and hydrophobic and impervious soil layers that reduce infiltration can be created. These fire effects can lead to large landscape-scale changes to the water budget (the portions of rainfall that runs off, sinks in to soils or recharges groundwater, and the amount of evapotranspiration), potentially affecting the Groundwater Recharge (GWR) beneficial use. This can cause temporary or semi-permanent increases in drainage density and decreases in groundwater recharge and summertime dry weather flows. These changes can cause impacts to beneficial uses including reductions in groundwater available for extraction for drinking water and irrigation supply, and changes to the peak flow, volume, and timing of runoff potentially impacting capture and recharge facilities, bridges, and other infrastructure on the creeks downstream from the burn areas. In addition, increased flow can cause changes to the morphology of creeks including bed and bank erosion (see sediment erosion section), that can change habitat structure, pool-riffle frequency, and wood recruitment processes. Lowered groundwater recharge can lead to reductions in summer dry weather flows and increases in water temperature impacting Wildlife Habitat (WILD) and Rare, Threatened, and Endangered Species (RARE).

### Existing pre-fire data

Pre-fire flow monitoring data are available at two locations through a collaboration between the Sonoma County Water Agency and the City of Santa Rosa (the local sponsors) and the US Geological Survey (USGS) relevant to monitoring fire effects from the Tubbs and Nuns fires (Table 6).

### Existing water year 2018 monitoring design (post-fires)

Flow monitoring occurred during WY 2018 in the wet season following the Tubbs and Nuns fires. These data are currently draft and will be published by the USGS as the official flow record in approximately April 2019. These data are of sufficient quality for use in an assessment of fire effects on runoff.

Table 6. Flow records available for assessments of runoff changes associated with fires in the vicinity of Santa Rosa.

| Location | USGS gage number | Period of record | Portion of burned area upstream (%) | Quality of record |
|---|---|---|---|---|
| Mark West Creek near Mirabel Heights, CA (local sponsor: Sonoma County Water Agency) | 11466800 | Water Year 2006 to present | 16 (12.6 Tubbs, 3.4 Nuns) | Records fair. Backwater conditions from the Russian River can occur during high flow periods. No regulation upstream of station, some diversion for irrigation of about 11,000 acres. |
| Santa Rosa Creek at Willowside Road near Santa Rosa, CA (local sponsor: City of Santa Rosa) | 11466320 | Water Year 1999 to present | 21.3 (11.5 Tubbs, 9.8 Nuns) | Records good except for estimated daily discharges, which are fair. Backwater conditions from Laguna de Santa Rosa can occur during periods of heavy rainfall. Diversions upstream from station for irrigation of about 7,000 acres. |

## Proposed monitoring elements for future consideration

Flow measurements at these two USGS gage stations should continue, with flow recorded every 15 minutes year-round. This will capture potential changes in both flood runoff response to rainfall and baseflow response to changes in infiltration. We recommend contacting the local sponsors (Sonoma County Water Agency and the City of Santa Rosa) and the USGS to confirm that these gages will be maintained over the next 5 years. Based on the Watershed Emergency Response Team (WERT) reports (see next section on sediment erosion and transport), the three small sub-basins burned in the Nuns fire (flowing into Santa Rosa Creek) are predicted to only have a 1% increase in flow volume (for a 10 year return interval (RI) flow). However, since the Tubbs fire burned a much larger proportion of the Mark West watershed with a greater burn severity, the WERT report predicted a 8 to 69% increase in flow volume (for a 10 year RI flow) for multiple small sub-basins, and a 25% increase in flow volume for the entire watershed area draining to the Lower Mark West Creek monitoring location. Thus, of the two gages, continuation of the Mark West Creek near Mirabel Heights, gage is the higher priority. This is true also for the sediment record (see next section).

## Methods of interpretation

Data from WY 2019 and subsequent years can be directly compared with the pre-fire records. Analysis of changes to peak flow, timing of peak flow compared to peak rainfall, unit runoff, and baseflow timing and amount can be conducted for pre-fire to post-fire and between post-fire years.

## Connections to other programs

This monitoring will be conducted by the USGS with support from the local sponsors (Sonoma County Water Agency and City of Santa Rosa). It is imperative that these agencies be included in discussions about the records and use of the data collected at these two gages. In addition, flow monitoring is essential for being able to estimate sediment loads for the watershed (using turbidity surrogate methods and SSC samples) and for determining habitat conditions (e.g., steelhead) (see later sections). All monitoring should be coordinated through the R3MP to assure the maximum utility and minimum costs of the data.

## Geomorphic response (Erosion and sediment yield)

### Conceptual model of fire effect and connections to beneficial uses

Geomorphology is the suite of processes that build and modify the landscape, control the flow of water and sediment, and create the physical habitat for both species in general and species of concern. Fire modifies geomorphic rates and processes, altering the amount of sediment delivered downstream from the landscape. Fire affects sediment production from the landscape primarily by three processes:

- Reducing vegetation cover, and thus increasing direct raindrop impacts on the soil surface;
- Causing changes to soil stability, by creating an impervious soil layer that reduces infiltration and increases runoff, disaggregates organic components, and aggregates if recrystallization of minerals such as Fe and Al oxyhydroxides occurs; and
- Reducing root binding of the soils over the course of several years as root structures rot, and trees fall.

These processes lead to many changes in the watershed sediment budget including increased splash erosion, increased sheet erosion as soil particles detached by rainfall impact are easily transported, increased rill erosion on the hillslopes as sheet flow becomes condensed by soil irregularities, increased gully erosion as velocity in rills increases causing deepening and widening and headwall failures, increased channel erosion due to increased volume, velocity, and/or duration of flow (see flow section conceptual model). In addition, increases in landslide and debris flow activity can occur due to reductions in root binding, increased soil saturation increasing soil mass, increased pore pressure, and liquefaction causing massive new shallow or deep-seated slope failures or re-activation of dormant failures.

These geomorphic processes and changes in sediment supply from the landscape have direct linkages with beneficial uses. For example, increased sedimentation in the channel could have a negative effect upon the Cold Freshwater Habitat (COLD), or Spawning, Reproduction, and/or Early Development (SPWN). Changes in the supply of wood to the channel can occur in reaches where the riparian zone has been completely burnt. Alternatively, the supply of wood can increase in reaches that experience post-fire bank erosion, undercutting the roots of woody vegetation, causing it to be recruited into the channel, and potentially further exacerbating bank erosion negatively affecting Wildlife Habitat (WILD). In addition, increased sediment load delivered downstream into the Laguna could negatively affect Flood Peak Attenuation/Flood Water Storage (FLD).

### Existing pre-fire data

Geomorphic data within the basin can be divided into three separate parts: hillslope processes, fluvial processes and stream morphology, and sediment transport.

*Hillslope Processes*

The bedrock geology that underlies the watershed determines the slope and relief of the hillslopes, what soils develop, the chemical composition of the bedrock and soils, and the types and rates of erosion. These watershed characteristics determine the amount of sediment produced from the hillslopes, which can be exacerbated by fire. Table 7 describes the basin characteristics.

Table 7. Basin characteristics for the five monitoring watersheds (as calculated by USGS Stream Stats).

| **Basin Name** | **Size ($mi^2$)** | **Mean Basin Slope (%)** | **Relief (ft)** | **Maximum elevation (ft)** | **Outlet elevation (ft)** | **Portion burned in 2017 (%)** |
|---|---|---|---|---|---|---|
| Mark West Creek near Mirabel Heights, CA | 251 | 12.9 | 2646 | 2692 | 45 | 16.0<br>(12.6 Tubbs, 3.4 Nuns) |
| Lower Mark West Creek at Fulton Road | 43.1 | 26 | 2232 | 2364 | 137 | 50.4 Tubbs |
| Upper Mark West Creek at Leslie Road | 30.5 | 27.4 | 1932 | 2364 | 435 | 35.4 Tubbs |
| Santa Rosa Creek at Willowside Road near Santa Rosa | 77.6 | 16.8 | 2692 | 2692 | 63 | 21.3<br>(11.5 Tubbs, 9.8% Nuns) |
| Piner Creek at Marlow Road | 5.0 | 5.7 | 714 | 827 | 113 | 64.6 Tubbs |

The bedrock geology of the area has been mapped at various scales by various authors; the most detailed mapping is at the 1:24,000 scale. At this scale, nine individual 7.5' topographic quadrangle maps cover the entire area, and were georeferenced in ArcGIS with the watershed boundaries drawn on top (McLaughlin et al. (2004, 2008), Delattre (2007, 2008, 2011, 2013), Bezore (2003), Clahan (2003), and Wagner (2003)). From this map, best professional judgment was used to determine general erosivity of each watershed based upon literature discussion of each major rock unit. Understanding the bedrock geology from which sediment is being sourced and delivered downstream via the channel network will assist in interpreting the water quality data collected as part of the longer-term monitoring.

In addition to understanding the bedrock geology, it is also important to understand the style and magnitude of mass wasting (landslides, earthflows, debris flows) in the watersheds, because this is the primary mechanism of significant sediment delivery. Landslide mapping exists for the region (Huffman and Armstrong, 1980), and illustrates the large number of landslides in the upper watershed, although most are not currently active. The USGS (Open File Report 97-745) has characterized the landscape by degree of landslide density, and again shows high density of landslide in the upper watershed area. Future mass movement is most likely to occur within and around the places that have previously failed. The USGS Landslide Hazard Program has mapped the post-fire debris flow hazard, showing the likelihood of a debris flow occurring (in %) for each small sub-watershed, potential volume of material, and relative hazard. Approximately 1/3 of the Tubbs Fire area (within the Mark West Creek watershed) has a probability of 40% or higher, while most of the Nuns Fire area (within the Santa Rosa Creek watershed) has a probability of up to 20%.

Mass movements can be triggered by short bursts of intense rainfall, or longer duration sustained rainfall, after a certain amount of antecedent rainfall has occurred. Many authors have studied the thresholds of movement as defined by the intensity of rainfall and the duration of rainfall. While the rainfall amounts vary based upon geology, slope, annual precipitation, antecedent moisture, and vegetation type, values from the literature will provide guidance for which rainfall events may trigger erosion events in the Santa Rosa area. Wilson and Jayko (USGS Open File Report 97-735-F, 1997) developed rainfall thresholds for the intensity of rain (normalized to rainy day normal, the mean annual precipitation divided by mean annual number of rainy days) needed to trigger debris flows for short and for long duration storms.

The short duration map (6 hour) shows the lower part of the watershed requires 2.5 inches (64 mm) of rainfall in a 6-hour period, while the upper part of the watershed requires 3.0 inches (76 mm) of rainfall in a 6-hour period. The long duration map (24 hour) shows the lower part of the watershed requires 5.5 inches (140 mm) of rainfall, while the upper requires 6.0 inches (152 mm) of rainfall in a 24-hour period. These maps however do not specify antecedent moisture but experience in the Bay Area shows that approximately 7 to 10 inches of rainfall is likely needed (McKee et al., 2003). In San Mateo County, Wilson and Wieczorek (1995) determined that 8.5 mm/hr of rainfall was needed to initiate debris flows, but only after 280 mm (11 inches) of antecedent rain had already accumulated. And also in the Bay Area, Wiezorek (1987) documented hillslope failure in two different types of events: 1) Moderate intensity (10 mm/hr and 10.7 mm/hr, respectively for two separate storms) and long duration (at least 2.5mm/hr for 9 hours and 19 hours, respectively), and 2) High intensity (24.4 mm/hr) and short duration (4 hours). Cannon and Ellen (1985) produced a Bay Area rainfall duration curve, that begins at about 18 mm/hr, and decreases to about 10 mm/hr for a 10-hour duration, then quickly decreases in intensity after the 10-hour duration. These resources can be used to design the Santa Rosa water quality monitoring program.

Calfire and partners conducted a WERT analysis for the Nuns Fire area[1] and the Tubbs Fire area[2]. These documents are excellent resources for understanding potential increases in flow, debris flow hazard, and likely increase in sediment load. Although just a small portion of the Nuns Fire is within the Santa Rosa Creek watershed boundary, and the burn severity was low, there will still likely be a fire effect in those burned areas. They predict just a 1% increase in flow volume (for a 10 year return interval (RI) flow) for smaller sub-basins within the burn area, up to a 20% probability of debris flows, and a projected order of magnitude increase in erosion during the first post-burn winter (with a value of 0-10 tons/acre of erosion). In contrast, the Tubbs Fire burned a much larger proportion of the Mark West watershed, and generally had greater burn severity. In this area they predict an 8 to 69% increase in flow volume (for a 10 year RI flow) for various sub-basins within the burn area, meaning that for many sub-basins, a previous 10-year flow event will now be equivalent to a 50 to 100-year flow event. The Lower Mark West Creek watershed is expected to have approximately a 25% increase in flow volume, integrating the many smaller sub-basins. Approximately half of the burn area has greater than 40% probability of a debris flow occurring, while the other half has less than 40% probability. Most of the burn area is projected to have a 5-10 fold increase in erosion during the first post-burn winter (with rates ranging between 0 and 16 tons/acre of additional erosion).

*Fluvial processes and stream morphology*

The channel network extends from the small rills on the hillslopes and the zero-order basins in headwater areas all the way downstream to Santa Rosa Creek, the Laguna de Santa Rosa, and Mark West Creek. The

[1] http://www.fire.ca.gov/communications/downloads/Watershed_reports/20171115_NunsWERT.pdf
[2] http://www.fire.ca.gov/communications/downloads/Watershed_reports/20171115_TubbsWERT.pdf

channel receives sediment (e.g., from hillslope sources, and instream sources such as bank erosion and bed incision), stores sediment (in bars, floodplain deposits, behind debris jams), and transports sediment (suspended sediment and bedload). Each of these processes can affect the water quality and habitat quality in relation to the plants and animals that live there. Changes in sediment transport and stream morphology due to fire should be expected, along with geomorphic impacts upon habitat. Without a lot of digging around in local agency reports it hard to know exactly what exists but geomorphic data in the channel network likely includes:

- Physical Habitat (Phab): 2 or 3 locations (SWAMP stream pollution group)
- CRAM: 30 riverine sites across the Santa Rosa Plain (Collins, et al., 2014)
- California Stream Condition Index CSCI: 6 sites within the watershed
- Channel cross sections and longitudinal profiles
- Channel geomorphic mapping
- Grain size mapping/bulk sediment samples/characterization of grain size for fish

*Sediment transport*

The USGS through a collaboration with the Sonoma County Water Agency and City of Santa Rosa (the local sponsors) operates two stream gages within the area of interest:

- 11466320 Santa Rosa Creek at Wilowside Road, near Santa Rosa
- 11466800 Mark West Creek near Mirabel Heights, CA

Suspended sediment concentration, grain size, and loads were measured at one of these gages, the Mark West Creek gage, during the wet seasons of Water Year 2006, 2007 and 2008. Peak flows for the nine years of record at this gage have ranged between 3,720 and 11,300 cfs. Flow, during the years monitored for sediment, was around or above average. Sampling occurred at flows up to ~6,000 cfs. Thus, as a pre-fire data set, this represents an excellent starting point for evaluation of changes associated with the fires.

## Existing water year 2018 monitoring design (post-fires)

During WY18, a few grab samples were collected at the Water Board monitoring locations and analyzed for turbidity and suspended sediment concentration (SSC). However, these samples do not provide information useful for describing relative erosion rates because they were not collected alongside flow data and concentration alone is not a conservative measure (it is influenced not only by erosion but also by the amount of flow volume at any moment in time). During WY 2018, turbidity was measured at the USGS Mark West Creek gage (11466800) by the USGS. This was a very useful addition to the flow record and, if continued and calibrated using a concurrent suspended sediment data collation field program, it could be used to generate a post-fire suspended sediment load record. This probe was put in by the USGS during WY 2018 at their own cost but was pulled and won’t be replaced unless there is local agency interest in supporting it. We strongly recommend supporting the reinstatement of this probe and the collection of water samples analyzed for suspended sediment using the USGS standard protocols for a sediment daily program.

## Proposed monitoring elements for future consideration

Discrete types of geomorphic data are best used to answer specific questions. For instance, stakeholders may be most interested in knowing if hillslope sediment supply was exacerbated by the fire, or if sediment transport processes have been altered, or if the fire impacts have changed channel morphology or habitat. Depending on the key questions of interest, a program could include collecting some of the specific data types listed below:

Proposed dry season monitoring to begin as early as the summer/fall of 2018, so that changes due to WY 2019 flows can be detected:

1. Survey a longitudinal profile for the channel reach through and immediately downstream from the burn areas (using hardened structures for elevational control) to monitor changes in bed aggradation or incision. Resurvey after significant large storms (R.I. > 5 years) and at the end of the wet season. Since changes in stream morphology are likely to be larger, Mark West Creek is a higher priority than Santa Rosa Creek.
2. Select representative channel cross sections on Mark West Creek (through the burn area and downstream, including at the monitoring locations) and survey a channel cross section, using monumented stable end points to monitor changes in channel cross sectional geometry. Look for locations with existing cross sectional data. Resurvey after significant large storms (R.I. > 5 years) and at the end of each wet season. Consider one or two cross sections in burned reaches of the Santa Rosa Creek watershed.
3. If existing pre-fire bed grain size data exists, collect post-fire data at the same locations and via same methods to characterize changes in substrate grain size (e.g. increase in fine sediment). Some data may be available from Phab sites.
4. Geomorphically map important reaches of creek (e.g. containing sensitive species, important infrastructure, etc.) including features such as pools, riffles, bars, debris jams, bank erosion, bed incision/aggradation, tributary confluence features, etc., in addition to facies mapping of grain size. Repeat mapping after significant storms that caused channel change.
5. Mapping landslides/debris flows in the burn area, either on the ground or using high resolution aerial photography. If significant slides occur, and aerial photography is not available, can use drone technology to collect appropriate imagery (Note SFEI has such capacity as do other organizations). Re-map after each major storm or after each wet season that failures occurred.
6. Dry weather flow monitoring of turbidity at the Mark West Creek at Mirabel Heights gage. Monitoring should occur once a week during the period May 1 to the first flush flow event (likely in October or November).

Proposed wet season monitoring to begin as early as the 2018-2019 wet season:

1. This is the highest priority of all the recommendations. Reinstate the USGS sediment load monitoring program at the Mark West Creek near Mirabel Heights gage (11466800). In addition to flow, the USGS would add measurements of turbidity and SSC to estimate a seasonal suspended sediment load. In addition to the collection of WY 2019 data, the turbidity data collected during WY 2018 could be calibrated and an estimate of the suspended sediment daily record could be back-calculated.
2. Observations during/immediately after larger flow events, inspecting reaches of creek for bank erosion, undercutting or falling in woody riparian vegetation, landslides/debris flows impacting

the channel, debris jams, significant deposits of sediment, incision/aggradation, floodplain deposition. Walk as much as is possible of the reach between the Lower and Upper Mark West Creek monitoring locations. Spot-check a handful of locations between the Mirabel Heights and Lower Mark West Creek monitoring locations.

3. Documentation of any sediment removal or wood removal from channels (e.g. at bridge locations), likely conducted by City or County agency staff.
4. Monitor sediment deposition or removal from any on-channel sediment basins. Likely conducted by City or County agency staff.
5. Inspection, documentation and annual repair of any BMPs to ensure their reliable operation and effectiveness. Likely conducted by City or County agency staff.

## Methods of interpretation

Collected data will be used in four primary ways: to quantify change from pre-fire condition, to quantify change through time, to provide evidence for sediment source areas and to quantify changes in sediment supply that might be observed in the water quality monitoring, and to qualify/describe changes in the physical habitat that are likely affecting beneficial uses and species.

1. Newly collected data can be directly compared to existing pre-fire data (e.g. existing surveyed cross sections, existing landslide mapping) to quantify any change that has occurred during WY 2018 because of the fire. Data should be site specific, and only compared to existing data from that specific location. Some data can also be compared with published thresholds; for example, turbidity measures can be compared with published thresholds to determine potential detriment to aquatic life due to elevated turbidity.
2. Data collected in future years can be compared to data collected in WY 2018 to quantify the change/recovery of the hillslopes and channels for 3-5 years after the fire.
3. Data can be used to document and describe source areas of sediment supply from the hillslopes and the channels, and the ability of the channel network to transport that sediment downstream or store the sediment within the system. Sediment load monitoring will allow quantification of sediment loads, and comparison with previous and future years.
4. Maps and data can be used to illustrate how habitat in specific locations or for certain species has changed due to the fire, and document how it is recovering. This will require collaboration with ecologists/biologists.
5. Suspended sediment grain size, concentrations and loads measured at the Mark West Creek near Mirabel Heights gage (11466800) in the post-fire period can be compared to the existing pre-fire data collected during WYs 2006-08 taking into account flow conditions to provide an accurate estimate of change.

## Connections to other programs

Some geomorphic data has likely been collected by local/state/federal agency staff in the past. Partnerships should be developed to help collect this data in the future, for cost-sharing, for access to land, and because other agencies likely manage/have jurisdiction over areas that the Regional Board does not. All monitoring should be coordinated through the R3MP to assure the maximum utility and minimum costs of the data. Potential partnerships include:

- USGS- landslide mapping, debris flow mapping
- CDFW- channel grain size mapping or characterization for fish habitat, management of the Laguna;
- Sonoma County Water Agency- Channel cross sections, longitudinal profiles, sediment or wood removal;
- City of Santa Rosa- channel cross sections, longitudinal profiles, management;
- Sonoma County Agricultural Preservation and Open Space District- land management of hillslope areas;
- Sonoma County Regional Parks;
- Caltrans- sediment removal under bridges;
- Laguna de Santa Rosa Foundation; and
- Sonoma State University.

## Ecology

### Connection to beneficial uses

Effects on aquatic resources can include chronic and acute toxicity, changes in water clarity, riparian cover, substrate texture, changes to base flow and water temperature, changes to habitat structure including changes to bank, bar and bed formations, wood debris supply, changes to food resources, and changes to the timing and severity of high flow events in relation to life stage for rare and endangered species. This area is likely habitat for many species of concern, including steelhead, yellow legged frog, tiger salamander, freshwater shrimp, and red legged frog. The Nuns and Tubbs fires could potentially have negative effects upon many beneficial uses, such as Warm and Cold Freshwater Habitat (WARM) (COLD), Wildlife Habitat (WILD), Rare, Threatened, or Endangered Species (RARE), Spawning, Reproduction, and/or Early Development (SPWN), and Wetland Habitat (WET). Monitoring aspects of the physical habitat or directly monitoring the presence and number of species of interest will allow impacts to beneficial uses to be documented, and the recovery tracked through time.

### Existing pre-fire data

Partnerships should be built to identify previous monitoring data that could be utilized as pre-fire condition data. For example, a few potentially useful data sets include:

- Habitat condition using CRAM- 2013 ambient survey of wetland condition (riverine, depressional, slope wetlands) across the Santa Rosa Plain, describes the condition of 82 specific wetland sites, and provides a Cumulative Distribution Function (CDF) plot to describe the condition of the entire population of wetland resources. CRAM directly relates to many detailed ecological datasets (e.g. bird population and use, benthic macroinvertebrates, vegetation richness and cover, invasive species, etc.). The sample frame includes the Santa Rosa plain, but does not extend up into the upper areas of the Mark West Creek watershed.
- Benthic macroinvertebrates- BMIs integrate many aspects of channel condition and water quality, and can be very useful as indicators of condition.
- Steelhead and Chinook spawning and young of the year (Y-O-Y) surveys.
- Riparian zone mapping or characterization.

- CDFW habitat description/condition work.
- Presence/absence surveys for specific species related to individual project monitoring.

### Existing water year 2018 monitoring design (post-fires)

That we are presently aware of, there was no direct monitoring of ecological aspects during WY 2018. However, it is likely that there was data collection occurring, so relevant agencies should be contacted as part of building a monitoring coalition to build an inventory of existing data. All monitoring should be coordinated through the R3MP to assure the maximum utility and minimum costs of the data.

### Proposed monitoring elements for future consideration

Future monitoring could focus upon documenting physical habitat condition. For instance:

- Resurvey channel condition using CRAM- conduct a survey of the riverine and slope (associated with the Laguna) sites, and compare the resulting CDF to the CDF from 2013. The survey could be a repeat ambient survey of those wetland types, or could just be targeted assessments of specific chosen locations (e.g. in and below the burn areas). Can reassess sites each year (for 5 years) to track the recovery of the system;
- Collect benthic macroinvertebrate data, as an indicator of stream condition;
- Collect benthic algae data, as an indicator of stream condition;
- Conduct rapid habitat assessment methods that focus upon species of concern (e.g. Yellow Legged Frog);
- Collect data on riparian cover and water temperature (especially in and below the burn areas); and
- Collect data on the presence/absence of species of concern.

### Methods of interpretation

Data will be best interpreted by comparing to pre-fire condition, comparing to future data to track change, and comparing to published expected condition. For instance, a repeat survey using CRAM would show the change in condition of specific sites and/or the channel network as a whole. Data such as rapid habitat assessment, riparian cover, temperature, and presence/absence of species can be used to track change through time as the system recovers. If relevant previous benthic macroinvertebrate data does not exist, current data can be compared to the published BMI index of what is expected to be present in these types of channels. Comparing observed to expected will essentially be a proxy for comparing observed to pre-fire values.

### Connections to other programs

Partnerships with other programs will be essential in monitoring the ecologic response to the fires. All monitoring should be coordinated through the R3MP to assure the maximum utility and minimum costs of the data. Primary organizations could include:

- CDFW;
- Sonoma County Agricultural Preservation and Open Space District;
- Sonoma County Regional Parks;
- Laguna de Santa Rosa Foundation;
- Point Blue Conservation Science; and
- Sonoma State University

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# Attachment A: QA Review, Method Sensitivity Evaluation, and Plotted Data

This attachment outlines the QA Review and method sensitivity evaluation. In addition to this review, there are 4 appendices in this document:

Appendix A: summarises the 2018 fire monitoring data including number of samples, sample date range, % non-detects (NDs), range of results, and average MDL by parameter.

Appendix B: lists the average MDLs reported by program for the post fire monitoring parameters along with the associated water quality guideline.

Appendix C: lists the fire response monitoring results maximum results from other surveys.

Appendix D: provides plots of all fire monitoring data compared to existing thresholds.

## QA Review and Method Sensitivity Evaluation

The 2017 Fire Response Monitoring data were formatted for uploading to the Regional Data Center and CEDEN, and reviewed by SFEI's Quality Assurance Officer (QAO). There were four target water quality monitoring stations that were sampled for four events in the winter of 2018, between November 2017 and March 2018. Target parameters listed in the Fire Response Monitoring Plan (Table A-1, below) were analyzed and reported for most water quality samples collected. In addition, some non-target conventional water quality parameters were reported (e.g. Nitrite as N, Nitrogen (Total Kjeldahl), Nitrate + Nitrite as N), and some trace elements were reported for both the dissolved and total water fractions for some samples and/or events. The following target parameters were not reported for all 16 samples: Temperature (not reported), Specific Conductivity (12), Dissolved Oxygen (12), pH (12), Nitrate as N (6). However Nitrate + Nitrite as N was reported for 14 samples. Field sampled parameters were not provided to SFEI (except in Rich F.'s preliminary plotted dataset) and therefore were not formatted for upload to CEDEN. 46 parameters were analyzed and reported for the total and/or dissolved water fraction from the four targeted stations monitored by the 2017 Fire Response Monitoring project in the Mark West Creek watershed: 19 conventional water quality parameters (including 4 field measured parameters), 11 trace elements, and 16 PAHs (Table A-2).

Analytical results were generally acceptable with the exception of blank contamination found in some laboratory batches as described in SFEI's detailed QA Reports and summarized below. Significant blank contamination was reported in one or more laboratory batches for ammonia and four trace elements, which resulted in sample results from those laboratory batches being flagged with a ‘Rej’ qualifier in the *compliance* field (QA Code = “VRIP”) of the formatted data submitted to the Regional Data Center and CEDEN. However, most of those sample results were also qualified as NDs or DNQs (detected but not quantified, essentially less than the Reporting Limit). Data management staff and the QAO assumed that the data were not blank corrected since it was not mentioned in any of the original data reports.

Table A-1. List of Targeted Parameters Listed in the Monitoring Plan.

| **Parameters measured** | | | |
|---|---|---|---|
| Temperature | Nitrate | Aluminum | Manganese |
| Specific Conductance | Ammonia | Arsenic | Mercury |
| Dissolved Oxygen | Total Phosphorus | Cadmium | Nickel |
| pH | Total Organic Carbon | Chromium | Selenium |
| Turbidity | Hardness | Copper | Zinc |
| Total Suspended Solids | Alkalinity | Iron | PAHs (16 parameters) |
| Total Dissolved Solids | Sulfate | Lead | Water Toxicity |

Table A-2. Summary of the number of water quality parameters reported for each sampling station and event by parameter type.

| Parameter Type | Station Code | 11/1/2017 | 11/8 or 11/9/2017 | 11/15 or 11/16/2017 | 3/22/2018 |
|---|---|---|---|---|---|
| Conventional | 114MW3972 | 19 | 19 | 19 | |
| Conventional | 114MW4198* | | | | 19 |
| Conventional | 114MW6173 | 19 | 19 | 19 | 18 |
| Conventional | 114PI5786 | 18 | 19 | 19 | 19 |
| Conventional | 114SR0761 | 18 | 19 | 19 | 19 |
| Trace Elements | 114MW3972 | 11 | 11 | 11 | |
| Trace Elements | 114MW4198* | | | | 22 D&T |
| Trace Elements | 114MW6173 | 11 | 11 | 11 | 12 |
| Trace Elements | 114PI5786 | 11 | 11 | 11 | 22 D&T |
| Trace Elements | 114SR0761 | 11 | 11 | 11 | 22 D&T |
| PAHs | 114MW3972 | 16 | 16 | 16 | |
| PAHs | 114MW4198* | | | | 16 |
| PAHs | 114MW6173 | 16 | 16 | 16 | 16 |
| PAHs | 114PI5786 | 16 | 16 | 16 | 16 |
| PAHs | 114SR0761 | 16 | 16 | 16 | 16 |

* 114MW4198 was sampled instead of 114MW3972 in March 2018 because of unsafe sampling conditions at the target site due to weather and stream conditions. 114MW4198 is just upstream from the target site.

## CONVENTIONAL WATER QUALITY

Inorganic conventional water quality results were reported for 4 water samples for 4 sampling events and nineteen parameters. Nitrate as N, Nitrogen (Total Kjeldahl), and Total Nitrogen were only measured in the March 2018 samples, and Iron was reported for both the Dissolved and Total fractions in March of 2018. Overall the data were acceptable with the exception that three Ammonia as N results that were flagged with the censoring QA code of "VRIP" because of blank contamination and were assigned the compliance code of "Rej". However, results were reported with QA Codes of ND and DNQ.

*MDLs sensitivity*

Non-detects were measured is some samples for 5 out of 15 of the inorganic conventional parameters including Ammonia as N, Nitrate as N, Nitrite as N, Nitrate + Nitrite as N, and Orthophosphate as P). Extensive non-detects (where the number of NDs > 50%) were measured for Ammonia as N, Nitrite as N, and Orthophosphate as P with Orthophosphate as P results being 100% NDs.

## TRACE ELEMENTS

Trace Element results were reported for 4 water samples for 4 sampling events and eleven parameters for both the dissolved and total water fraction. Overall the data quality was acceptable. However, blank contamination was found in some laboratory batches for Cadmium, Lead, Mercury and Selenium, which led to flagging results as 'Rej' due to contamination. However, most of those sample results were reported with a QA Code of ND or DNQ.

*MDLs sensitivity*

NDs were reported in 7 out of 11 of the trace elements (Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, and Selenium). Extensive non-detects (number of NDs > 50%) were measured for Arsenic, Cadmium, and Selenium.

Most trace elements were analyzed using EPA Method 200.7 and reported in units of mg/L. Mercury was analyzed using EPA Method 245.1 and reported in units of ug/L. Other historical monitoring programs in Sonoma County (e.g. SWAMP and RB1 TMDL programs) used analytical EPA Method 1638M for most trace elements (reported in units of ug/L) and EPA Method 1631EM for mercury (reported in units of ng/L).

A comparison of the reported MDLs between programs (Appendix B) indicated that most of Fire Monitoring project trace element results reported MDLs that were between 2 to 50 times greater than reported at the nearby historical SWAMP monitoring sites used as comparative sites in this analysis (Station Codes 114MW2583 and 114SR0761).

Total Lead MDLs were over 100 times higher than the historical SWAMP sites and Total Mercury MDLs were more than 500 times higher. In addition, Aquatic Life guidelines were much lower than the average MDLs reported for Arsenic, Lead, Mercury, and Selenium. SFEI recommends a review of the methods for those trace elements to determine if a more sensitive method may be warranted in future monitoring in order to compare results to the Mercury Aquatic Life Objective of 0.012 ug/L. For example, the Fire Monitoring survey employed EPA Method 245.1 for Mercury with an average MDL of 0.105 ug/L, while the historical SWAMP and TMDL Methods employed EPA 1631 EM and E respectively with average MDLs of 0.0002, which is below the Aquatic Life Objective.

## PAHs

Organic (PAH) results were reported for 4 water samples for 4 sampling events and for 16 parameters. Overall the data quality was acceptable. Laboratory methods employed EPA Method 8270C and results were reported in units of ug/L. Review of method detection limit sensitivity indicated extensive non-detects (NDs>50%) for all sixteen PAHs were reported. The percent of ND results ranged from 87.5% to 100%. Only four out of the sixteen PAHs analyzed reported detected concentrations: Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Fluoranthene, and Pyrene.

There are few publicly available water quality data for PAHs in Sonoma County. Two assessments include a SWAMP station (206PET010) sampled in 2003 using EPA Method 8270M, and a reference site station (ASBS-REF_Kruse Creek) for a study called “Special Protections for Areas of Special Biological Significance” sampled in 2014 using a more sensitive EPA Method 625. Both surveys reported results in ug/L. The MDLs for the EPA 625 method were about 10x lower than for Methods 8270C or M. The Kruse Creek assessment also reported mostly NDs at the reference site.

The SF Bay Regional Monitoring Program for Water Quality employs more sensitive analytical methods for PAHs (AXYS MLA-021) and reports results at the pg/L detection level. Results for the San Pablo Bay monitoring stations in Sonoma County have a high proportion of detected PAH concentrations.

The Human Health water quality objectives are well below the MDLs reported by the Fire Response Monitoring Project (see Appendix B).

# Attachment A Appendix A: Summary of 2017 Fire Response Monitoring Results (November 2017 through March 2018) by Parameter

Summary includes the number of water quality samples collected (N), sample date range, % non-detect results (NDs), range of results (average, minimum, maximum), and average MDL by parameter. ND results were analyzed using 1/2 the MDL.

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Min Of Sample Date | Max Of Sample Date | N | % NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WQ-Field | Conventional | Oxygen, Dissolved, Total | mg/L | 01-Nov-17 | 16-Nov-17 | 12 | | 9 | 5 | 11 | |
| WQ-Field | Conventional | pH | none | 01-Nov-17 | 16-Nov-17 | 12 | | 7.4 | 7.2 | 7.7 | |
| WQ-Field | Conventional | Specific Conductivity, Total | uS/cm | 01-Nov-17 | 16-Nov-17 | 12 | | 298 | 89 | 615 | |
| WQ-Field | Conventional | Turbidity, Total | ntu | 01-Nov-17 | 16-Nov-17 | 12 | | 29 | 1 | 89 | |
| Inorganics | Conventional | Alkalinity as CaCO3, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 106 | 22 | 250 | 0.23 |
| Inorganics | Conventional | Ammonia as N, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 75% | 0.059 | 0.010 | 0.470 | 0.031 |
| Inorganics | Conventional | Calcium, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 20 | 9 | 41 | 0.008 |
| Inorganics | Conventional | Dissolved Organic Carbon, Dissolved | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 6.2 | 2.9 | 8.9 | 0.385 |
| Inorganics | Conventional | Hardness as CaCO3, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 110 | 42 | 240 | 0.056 |
| Inorganics | Conventional | Iron, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.51 | 0.28 | 0.68 | 0.017 |
| Inorganics | Conventional | Iron, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 4.64 | 0.04 | 22.00 | 0.017 |
| Inorganics | Conventional | Magnesium, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 14 | 4 | 35 | 0.009 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Min Of Sample Date | Max Of Sample Date | N | % NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Nitrate + Nitrite as N, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 14 | 14% | 0.47 | 0.01 | 1.00 | 0.025 |
| Inorganics | Conventional | Nitrate as N, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 6 | 33% | 0.35 | 0.00 | 0.75 | 0.005 |
| Inorganics | Conventional | Nitrite as N, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 14 | 86% | 0.06 | 0.01 | 0.44 | 0.011 |
| Inorganics | Conventional | Nitrogen, Total Kjeldahl, Total | mg/L | 22-Mar-18 | 22-Mar-18 | 4 | | 1.80 | 1.10 | 2.40 | 0.130 |
| Inorganics | Conventional | Nitrogen, Total, Total | mg/L | 22-Mar-18 | 22-Mar-18 | 4 | | 2.33 | 1.90 | 3.00 | 0.130 |
| Inorganics | Conventional | Orthophosphate as P, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 100% | 0.002 | 0.001 | 0.003 | 0.003 |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.314 | 0.073 | 0.620 | 0.026 |
| Inorganics | Conventional | Sulfate, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 12.7 | 1.8 | 26.0 | 0.011 |
| Inorganics | Conventional | Total Dissolved Solids, Dissolved | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 198 | 81 | 370 | 9 |
| Inorganics | Conventional | Total Organic Carbon, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 7.38 | 2.90 | 13.00 | 0.47 |
| Inorganics | Conventional | Total Suspended Solids, Particulate | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 137.0 | 0.6 | 750.0 | 0.7 |
| Inorganics | Trace Elements | Aluminum, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.673 | 0.360 | 0.960 | 0.007 |
| Inorganics | Trace Elements | Aluminum, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 3.525 | 0.009 | 18.000 | 0.007 |
| Inorganics | Trace Elements | Arsenic, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | 100% | 0.001 | 0.001 | 0.001 | 0.002 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Min Of Sample Date | Max Of Sample Date | N | % NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Arsenic, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 94% | 0.001 | 0.001 | 0.006 | 0.002 |
| Inorganics | Trace Elements | Cadmium, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | 33% | 0.0004 | 0.0001 | 0.0006 | 0.0002 |
| Inorganics | Trace Elements | Cadmium, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 75% | 0.0002 | 0.0001 | 0.0004 | 0.0002 |
| Inorganics | Trace Elements | Chromium, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0023 | 0.0017 | 0.0027 | 0.0009 |
| Inorganics | Trace Elements | Chromium, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 38% | 0.0133 | 0.0005 | 0.0690 | 0.0009 |
| Inorganics | Trace Elements | Copper, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0029 | 0.0024 | 0.0037 | 0.0010 |
| Inorganics | Trace Elements | Copper, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 31% | 0.0105 | 0.0005 | 0.0310 | 0.0010 |
| Inorganics | Trace Elements | Lead, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0025 | 0.0016 | 0.0043 | 0.0014 |
| Inorganics | Trace Elements | Lead, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | 50% | 0.0043 | 0.0007 | 0.0150 | 0.0014 |
| Inorganics | Trace Elements | Manganese, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0068 | 0.0053 | 0.0085 | 0.0002 |
| Inorganics | Trace Elements | Manganese, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.2257 | 0.0170 | 0.7000 | 0.0002 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Min Of Sample Date | Max Of Sample Date | N | % NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Mercury, Dissolved | ug/L | 22-Mar-18 | 22-Mar-18 | 4 | 50% | 0.163 | 0.105 | 0.230 | 0.210 |
| Inorganics | Trace Elements | Mercury, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | 31% | 0.125 | 0.018 | 0.350 | 0.105 |
| Inorganics | Trace Elements | Nickel, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0055 | 0.0049 | 0.0058 | 0.0005 |
| Inorganics | Trace Elements | Nickel, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.0236 | 0.0015 | 0.1200 | 0.0005 |
| Inorganics | Trace Elements | Selenium, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | 67% | 0.0016 | 0.0009 | 0.0030 | 0.0018 |
| Inorganics | Trace Elements | Selenium, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.0041 | 0.0009 | 0.0100 | 0.0018 |
| Inorganics | Trace Elements | Zinc, Dissolved | mg/L | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0267 | 0.0190 | 0.0420 | 0.0008 |
| Inorganics | Trace Elements | Zinc, Total | mg/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.0318 | 0.0004 | 0.1200 | 0.0008 |
| Organics | PAHs | Acenaphthene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.018 | 0.018 | 0.018 | 0.035 |
| Organics | PAHs | Acenaphthylene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.016 | 0.016 | 0.016 | 0.031 |
| Organics | PAHs | Anthracene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.020 | 0.020 | 0.020 | 0.040 |
| Organics | PAHs | Benz(a)anthracene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.013 | 0.013 | 0.013 | 0.025 |
| Organics | PAHs | Benzo(a)pyrene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.017 | 0.017 | 0.017 | 0.034 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Min Of Sample Date | Max Of Sample Date | N | % NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Organics | PAHs | Benzo(b)fluoranthene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.015 | 0.013 | 0.048 | 0.025 |
| Organics | PAHs | Benzo(g,h,i)perylene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.013 | 0.012 | 0.033 | 0.024 |
| Organics | PAHs | Benzo(k)fluoranthene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.016 | 0.016 | 0.016 | 0.031 |
| Organics | PAHs | Chrysene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.012 | 0.012 | 0.012 | 0.024 |
| Organics | PAHs | Dibenz(a,h)anthracene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.020 | 0.020 | 0.020 | 0.039 |
| Organics | PAHs | Fluoranthene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.021 | 0.018 | 0.062 | 0.036 |
| Organics | PAHs | Fluorene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.018 | 0.018 | 0.018 | 0.036 |
| Organics | PAHs | Indeno(1,2,3-c,d)pyrene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.024 | 0.024 | 0.024 | 0.047 |
| Organics | PAHs | Naphthalene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.020 | 0.020 | 0.020 | 0.040 |
| Organics | PAHs | Phenanthrene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.020 | 0.020 | 0.020 | 0.040 |
| Organics | PAHs | Pyrene, Total | ug/L | 01-Nov-17 | 22-Mar-18 | 16 | | 0.021 | 0.018 | 0.059 | 0.035 |

# Attachment A Appendix B: Fire Response Monitoring Results: maximum results from other Surveys

Water quality monitoring data from other programs with monitoring stations located at the same or near the Fire Monitoring sites were downloaded from CEDEN in June 2018. Those data were used to compare the maximum results from all projects and to evaluate the Fire Monitoring project's MDLs.

Table B1. Monitoring stations and sampling date ranges from other Programs used to evaluate the Fire Monitoring results.

| Program | Parent Project | Project | Station Name | Station Code | Sample Date Start | Sample Date End | Target Latitude | Target Longitude |
|---|---|---|---|---|---|---|---|---|
| Russian River MS4 Program | 2009 5 year Permit for Russian River MS4 Program | 2009 5 year Permit for RR_MS4 Program SCWA | C1 - Santa Rosa Creek down gradient of urban footprint | C1-SRC-D | 20-Jul-10 | 19-Jun-15 | 38.4452 | -122.776 |
| Surface Water Ambient Monitoring Program | SWAMP RWB1 Monitoring | RWB1 Irrigated Lands Monitoring 2013 | Mark West Creek at River Road | 114MW2583 | 12-Dec-13 | 4-Feb-14 | 38.4827 | -122.8307 |
| Surface Water Ambient Monitoring Program | SWAMP RWB1 Monitoring | RWB1 Irrigated Lands Monitoring 2013 | Santa Rosa Creek at Willowside Road | 114SR0761_SWAMP | 4-Feb-14 | 4-Feb-14 | 38.4452 | -122.8068 |
| Surface Water Ambient Monitoring Program | SWAMP RWB1 Monitoring | RWB1 Klamath Trinity Trend Montoring Fees 2008 2009 | Santa Rosa Creek at Willowside Road | 114SR0761_SWAMP | 6-Oct-08 | 20-Jul-09 | 38.4452 | -122.8068 |
| Surface Water Ambient Monitoring Program | SWAMP RWB1 Monitoring | RWB1 Russian River Monitoring FYs 2010 2011 | Santa Rosa Creek at Willowside Road | 114SR0761_SWAMP | 30-Sep-10 | 29-Nov-11 | 38.4452 | -122.8068 |
| Surface Water Ambient Monitoring Program | SWAMP RWB1 Monitoring | RWB1 Russian River Trend Monitoring FYs 2004 2005 | Santa Rosa Creek at Willowside Road | 114SR0761_SWAMP | 7-Oct-04 | 28-Jun-05 | 38.4452 | -122.8068 |

| Program | Parent Project | Project | Station Name | Station Code | Sample Date Start | Sample Date End | Target Latitude | Target Longitude |
|---|---|---|---|---|---|---|---|---|
| Total Maximum Daily Load | RWQCB1 Russian River TMDL | RWQCB1 Russian River Pathogen Indicator TMDL | Piner Creek at Fulton Road | 114PI0729 | 11-Jun-08 | 29-Sep-08 | 38.4484 | -122.7695 |
| Total Maximum Daily Load | RWQCB1 Russian River TMDL | RWQCB1 Russian River Pathogen Indicator TMDL | Santa Rosa Creek at Willowside Road-114SR0761 | 114SR0761 | 11-Jun-08 | 29-Sep-08 | 38.4453 | -122.8067 |

Table B2. Comparison of the average MDL of the Fire Response Monitoring Project sites to MDLs reported by other local monitoring efforts in the region. The water quality guidelines for Aquatic Health or Human Health are listed for comparison. Yellow highlights indicate parameters where the RB1 Fire Monitoring MDLs are above the water quality guidelines.

| Group1 | Group2 | CEDEN_Analyte and Fraction | Unit | MS4SCWA | RB1Fire | SWAMP | TMDL | WQ Guideline | G-Line Type |
|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Alkalinity as CaCO3, Total | mg/L | | 0.23 | | | 20 | Aquatic Life |
| Inorganics | Conventional | Ammonia as N, Total | mg/L | | 0.03 | 0.02 | 0.02 | | |
| Inorganics | Conventional | Calcium, Total | mg/L | | 0.01 | | | | |
| Inorganics | Conventional | Dissolved Organic Carbon, Dissolved | mg/L | | 0.39 | 0.50 | | | |
| Inorganics | Conventional | Hardness as CaCO3, Total | mg/L | | 0.06 | 2.11 | | | |
| Inorganics | Conventional | Iron, Dissolved | mg/L | | 0.02 | | | 1 | Aquatic Life |
| Inorganics | Conventional | Iron, Total | mg/L | | 0.02 | | | 1 | Aquatic Life |
| Inorganics | Conventional | Magnesium, Total | mg/L | | 0.01 | | | | |
| Inorganics | Conventional | Nitrate + Nitrite as N, Total | mg/L | | 0.02 | | | | |

| Group1 | Group2 | CEDEN_Analyte and Fraction | Unit | MS4SCWA | RB1Fire | SWAMP | TMDL | WQ Guideline | G-Line Type |
|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Nitrate as N, Total | mg/L | 0.04 | 0.01 | 0.01 | 0.01 | | |
| Inorganics | Conventional | Nitrite as N, Total | mg/L | 0.01 | 0.01 | | | | |
| Inorganics | Conventional | Nitrogen, Total Kjeldahl, Total | mg/L | 0.15 | 0.13 | 0.10 | 0.10 | | |
| Inorganics | Conventional | Nitrogen, Total, Total | mg/L | | 0.13 | 0.02 | | | |
| Inorganics | Conventional | OrthoPhosphate as P, Total | mg/L | 0.02 | 0.003 | | | | |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | 0.02 | 0.03 | 0.01 | 0.02 | | |
| Inorganics | Conventional | Sulfate, Dissolved | mg/L | | | 2.26 | | | |
| Inorganics | Conventional | Sulfate, Total | mg/L | | 0.01 | | | 250 | Human Health |
| Inorganics | Conventional | Total Dissolved Solids, Dissolved | mg/L | | 9.09 | 10.00 | | | |
| Inorganics | Conventional | Total Organic Carbon, Total | mg/L | | 0.48 | 0.39 | | | |
| Inorganics | Conventional | Total Suspended Solids, Particulate | mg/L | 0.42 | 0.70 | | | | |
| Inorganics | Trace Elements | Aluminum, Dissolved | mg/L | | 0.00720 | 0.00170 | | 0.087 | Aquatic Life |
| Inorganics | Trace Elements | Aluminum, Total | mg/L | | 0.00720 | 0.00120 | | 0.087 | Aquatic Life |
| Inorganics | Trace Elements | Arsenic, Dissolved | mg/L | | 0.00230 | 0.00004 | | 0.000004 | Human Health |
| Inorganics | Trace Elements | Arsenic, Total | mg/L | | 0.00230 | 0.00006 | | 0.000004 | Human Health |

| Group1 | Group2 | CEDEN_Analyte and Fraction | Unit | MS4SCWA | RB1Fire | SWAMP | TMDL | WQ Guideline | G-Line Type |
|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Cadmium, Dissolved | mg/L | | 0.00020 | 0.00001 | | 0.0008 | Aquatic Life |
| Inorganics | Trace Elements | Cadmium, Total | mg/L | | 0.00020 | 0.00001 | | 0.0008 | Aquatic Life |
| Inorganics | Trace Elements | Chromium, Dissolved | mg/L | | 0.00091 | 0.00010 | | 0.057 | Aquatic Life |
| Inorganics | Trace Elements | Chromium, Total | mg/L | | 0.00091 | 0.00008 | | 0.057 | Aquatic Life |
| Inorganics | Trace Elements | Copper, Dissolved | mg/L | | 0.00095 | 0.00004 | | 0.0027 | Aquatic Life |
| Inorganics | Trace Elements | Copper, Total | mg/L | | 0.00095 | 0.00003 | | 0.0027 | Aquatic Life |
| Inorganics | Trace Elements | Lead, Dissolved | mg/L | | 0.00140 | 0.00002 | | 0.00054 | Aquatic Life |
| Inorganics | Trace Elements | Lead, Total | mg/L | | 0.00140 | 0.00001 | | 0.00054 | Aquatic Life |
| Inorganics | Trace Elements | Manganese, Dissolved | mg/L | | 0.00017 | 0.00003 | | 0.05 | |
| Inorganics | Trace Elements | Manganese, Total | mg/L | | 0.00017 | 0.00002 | | 0.05 | Human Health |
| Inorganics | Trace Elements | Mercury, Dissolved | ug/L | | 0.21000 | | | 0.012 | Aquatic Life |

| Group1 | Group2 | CEDEN_Analyte and Fraction | Unit | MS4SCWA | RB1Fire | SWAMP | TMDL | WQ Guideline | G-Line Type |
|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Mercury, Total | ug/L | | 0.10469 | 0.00019 | 0.00020 | 0.012 | Aquatic Life |
| Inorganics | Trace Elements | Nickel, Dissolved | mg/L | | 0.00051 | 0.00001 | | 0.016 | Aquatic Life |
| Inorganics | Trace Elements | Nickel, Total | mg/L | | 0.00051 | 0.00001 | | 0.016 | Aquatic Life |
| Inorganics | Trace Elements | Selenium, Dissolved | mg/L | | 0.00180 | 0.00060 | | 0.0015 | Aquatic Life |
| Inorganics | Trace Elements | Selenium, Total | mg/L | | 0.00180 | 0.00044 | | 0.0015 | Aquatic Life |
| Inorganics | Trace Elements | Zinc, Dissolved | mg/L | | 0.00080 | 0.00050 | | 0.036 | Aquatic Life |
| Inorganics | Trace Elements | Zinc, Total | mg/L | | 0.00080 | 0.00038 | | 0.036 | Aquatic Life |
| Organics | PAHs | Acenaphthene, Total | ug/L | | 0.04 | | | 20 | Human Health |
| Organics | PAHs | Acenaphthylene, Total | ug/L | | 0.03 | | | | |
| Organics | PAHs | Anthracene, Total | ug/L | | 0.04 | | | | |
| Organics | PAHs | Benz(a)anthracene, Total | ug/L | | 0.03 | | | 0.0012 | Human Health |
| Organics | PAHs | Benzo(a)pyrene, Total | ug/L | | 0.03 | | | 0.00012 | Human Health |

| Group1 | Group2 | CEDEN_Analyte and Fraction | Unit | MS4SCWA | RB1Fire | SWAMP | TMDL | WQ Guideline | G-Line Type |
|---|---|---|---|---|---|---|---|---|---|
| Organics | PAHs | Benzo(b)fluoranthene, Total | ug/L | | 0.03 | | | 0.0012 | Human Health |
| Organics | PAHs | Benzo(g,h,i)perylene, Total | ug/L | | 0.02 | | | | |
| Organics | PAHs | Benzo(k)fluoranthene, Total | ug/L | | 0.03 | | | 0.012 | Human Health |
| Organics | PAHs | Chrysene, Total | ug/L | | 0.02 | | | 0.12 | Human Health |
| Organics | PAHs | Dibenz(a,h)anthracene, Total | ug/L | | 0.04 | | | 0.00012 | Human Health |
| Organics | PAHs | Fluoranthene, Total | ug/L | | 0.04 | | | | |
| Organics | PAHs | Fluorene, Total | ug/L | | 0.04 | | | | |
| Organics | PAHs | Indeno(1,2,3-c,d)pyrene, Total | ug/L | | 0.05 | | | 0.0012 | Human Health |
| Organics | PAHs | Naphthalene, Total | ug/L | | 0.04 | | | | |
| Organics | PAHs | Phenanthrene, Total | ug/L | | 0.04 | | | | |
| Organics | PAHs | Pyrene, Total | ug/L | | 0.04 | | | 20 | Human Health |

## Attachment A Appendix C: Comparison of Fire Response Monitoring Results to Results from other Programs (stations listed in Appendix B).

Table C1. Number of Fire Monitoring samples by station, non-detects (NDs), average, minimum and maximum of results, and average MDL by Parameter and Program. The maximum result from other nearby stations monitored by other programs, and whose data are publically available on CEDEN, are included (SWAMP, RB1 TMDL, and SCWA-MS4 Permit). ND results were analyzed as 1/2 the reported MDL. It should be noted that the other programs did not intentionally target high flow storm events so their maximum values may not be from samples during storm events. The MS4_SCWA program sampled monthly for five years and that program did inadvertently sample on days of high flow storm events.

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Alkalinity as CaCO3, Total | mg/L | RB1Fire | SM 2320 B | 01-Nov-17 | 22-Mar-18 | 16 | | 106 | 22 | 250 | 0.23 |
| Inorganics | Conventional | Ammonia as N, Total | mg/L | RB1Fire | EPA 350.1 | 01-Nov-17 | 22-Mar-18 | 16 | 12 | 0.059 | 0.010 | 0.470 | 0.03 |
| Inorganics | Conventional | Ammonia as N, Total | mg/L | SWAMP | EPA 350.3 | 07-Oct-04 | 28-Jun-05 | 5 | 3 | 0.032 | 0.020 | 0.053 | 0.04 |
| Inorganics | Conventional | Ammonia as N, Total | mg/L | SWAMP | SM 4500-NH3 H v21 | 11-Apr-11 | 04-Feb-14 | 8 | 3 | 0.011 | 0.001 | 0.036 | 0.01 |
| Inorganics | Conventional | Ammonia as N, Total | mg/L | TMDL | EPA 350.1 | 11-Jun-08 | 29-Sep-08 | 10 | | 0.100 | 0.070 | 0.150 | 0.02 |
| Inorganics | Conventional | Calcium, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | | 20 | 9 | 41 | 0.01 |
| Inorganics | Conventional | Dissolved Organic Carbon, Dissolved | mg/L | RB1Fire | SM 5310 B | 01-Nov-17 | 22-Mar-18 | 16 | | 6.23 | 2.90 | 8.90 | 0.39 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Dissolved Organic Carbon, Dissolved | mg/L | SWAMP | EPA 415.1M | 12-Dec-13 | 04-Feb-14 | 3 | | 3.51 | 2.45 | 4.91 | 0.50 |
| Inorganics | Conventional | Hardness as CaCO3, Total | mg/L | RB1Fire | SM 2340 B | 01-Nov-17 | 22-Mar-18 | 16 | | 110 | 42 | 240 | 0.06 |
| Inorganics | Conventional | Hardness as CaCO3, Total | mg/L | SWAMP | EPA 130.1 | 11-Apr-11 | 04-Feb-14 | 7 | | 166 | 129 | 246 | 2.33 |
| Inorganics | Conventional | Hardness as CaCO3, Total | mg/L | SWAMP | SM 2340 C | 07-Oct-04 | 28-Jun-05 | 5 | | 188 | 112 | 235 | 1.80 |
| Inorganics | Conventional | Iron, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.5 | 0.3 | 0.7 | 0.02 |
| Inorganics | Conventional | Iron, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | | 4.6 | 0.04 | 22 | 0.02 |
| Inorganics | Conventional | Magnesium, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | | 14 | 4 | 35 | 0.01 |
| Inorganics | Conventional | Nitrate + Nitrite as N, Total | mg/L | RB1Fire | SM 4500-NO3 F | 01-Nov-17 | 22-Mar-18 | 14 | 2 | 0.47 | 0.01 | 1.00 | 0.02 |
| Inorganics | Conventional | Nitrate as N, Total | mg/L | RB1Fire | EPA 300.0 | 01-Nov-17 | 22-Mar-18 | 6 | 2 | 0.351 | 0.004 | 0.750 | 0.005 |
| Inorganics | Conventional | Nitrate as N, Total | mg/L | MS4SCWA | EPA 300.0 | 20-Jul-10 | 19-Jun-15 | 60 | 10 | 0.286 | 0.015 | 2.500 | 0.039 |
| Inorganics | Conventional | Nitrate as N, Total | mg/L | SWAMP | SM 4500-NO3 I v21 | 12-Dec-13 | 04-Feb-14 | 3 | 2 | 0.039 | 0.003 | 0.111 | 0.005 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Nitrate as N, Total | mg/L | TMDL | EPA 353.2 | 11-Jun-08 | 29-Sep-08 | 10 | 4 | 0.020 | 0.005 | 0.060 | 0.010 |
| Inorganics | Conventional | Nitrite as N, Total | mg/L | RB1Fire | EPA 300.0 | 01-Nov-17 | 22-Mar-18 | 14 | 12 | 0.062 | 0.006 | 0.440 | 0.01 |
| Inorganics | Conventional | Nitrite as N, Total | mg/L | MS4SCWA | EPA 300.0 | 20-Jul-10 | 19-May-11 | 11 | 9 | 0.032 | 0.001 | 0.100 | 0.01 |
| Inorganics | Conventional | Nitrogen, Total Kjeldahl, Total | mg/L | RB1Fire | EPA 351.2 | 22-Mar-18 | 22-Mar-18 | 4 | | 1.80 | 1.10 | 2.40 | 0.13 |
| Inorganics | Conventional | Nitrogen, Total Kjeldahl, Total | mg/L | MS4SCWA | SM 4500-N org B | 20-Jul-10 | 19-Jun-15 | 60 | 3 | 0.47 | 0.10 | 3.30 | 0.15 |
| Inorganics | Conventional | Nitrogen, Total Kjeldahl, Total | mg/L | SWAMP | EPA 351.2 | 07-Oct-04 | 01-Dec-10 | 10 | | 0.50 | 0.18 | 1.19 | 0.10 |
| Inorganics | Conventional | Nitrogen, Total Kjeldahl, Total | mg/L | TMDL | EPA 351.2 | 11-Jun-08 | 29-Sep-08 | 10 | 1 | 0.28 | 0.05 | 0.40 | 0.10 |
| Inorganics | Conventional | Nitrogen, Total, Total | mg/L | RB1Fire | Not Recorded | 22-Mar-18 | 22-Mar-18 | 4 | | 2.33 | 1.90 | 3.00 | 0.13 |
| Inorganics | Conventional | Nitrogen, Total, Total | mg/L | SWAMP | SM 4500-N CM v21 | 30-Sep-10 | 04-Feb-14 | 10 | | 0.37 | 0.10 | 0.73 | 0.02 |
| Inorganics | Conventional | Orthophosphate as P, Total | mg/L | RB1Fire | EPA 300.0 | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.002 | 0.001 | 0.003 | 0.003 |
| Inorganics | Conventional | OrthoPhosphate as P, Total | mg/L | MS4SCWA | EPA 300.0 | 29-Mar-13 | 24-Apr-13 | 2 | 1 | 0.290 | 0.010 | 0.570 | 0.020 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | OrthoPhosphate as P, Total | mg/L | MS4SCWA | SM 4500-P E | 20-Jul-10 | 19-Jun-15 | 58 | | 0.218 | 0.020 | 0.540 | 0.020 |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | RB1Fire | EPA 365.4 | 01-Nov-17 | 22-Mar-18 | 16 | | 0.314 | 0.073 | 0.620 | 0.026 |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | MS4SCWA | SM 4500-P E | 20-Jul-10 | 19-Jun-15 | 60 | 7 | 0.144 | 0.026 | 0.500 | 0.020 |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | SWAMP | QC 10115011D | 07-Oct-04 | 28-Jun-05 | 5 | | 0.075 | 0.048 | 0.093 | 0.030 |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | SWAMP | SM 4500-P H | 06-Oct-08 | 04-Feb-14 | 14 | | 0.141 | 0.037 | 0.466 | 0.005 |
| Inorganics | Conventional | Phosphorus as P, Total | mg/L | TMDL | SM 4500-P E | 11-Jun-08 | 29-Sep-08 | 10 | | 0.131 | 0.080 | 0.190 | 0.020 |
| Inorganics | Conventional | Sulfate, Dissolved | mg/L | SWAMP | EPA 300.0 | 07-Oct-04 | 04-Feb-14 | 19 | | 17.972 | 8.270 | 29.000 | 2.258 |
| Inorganics | Conventional | Sulfate, Total | mg/L | RB1Fire | EPA 300.0 | 01-Nov-17 | 22-Mar-18 | 16 | | 13 | 2 | 26 | 0.01 |
| Inorganics | Conventional | Total Dissolved Solids, Dissolved | mg/L | RB1Fire | SM 2540 C | 01-Nov-17 | 22-Mar-18 | 16 | | 198 | 81 | 370 | 9 |
| Inorganics | Conventional | Total Dissolved Solids, Dissolved | mg/L | SWAMP | SM 2540 C | 07-Oct-04 | 04-Feb-14 | 19 | | 280 | 152 | 700 | 10 |
| Inorganics | Conventional | Total Organic Carbon, Total | mg/L | RB1Fire | SM 5310 B | 01-Nov-17 | 22-Mar-18 | 16 | | 7.30 | 2.90 | 13.00 | 0.48 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Conventional | Total Organic Carbon, Total | mg/L | SWAMP | EPA 415.1 | 07-Oct-04 | 28-Jun-05 | 5 | | 3.52 | 2.80 | 4.30 | 0.10 |
| Inorganics | Conventional | Total Organic Carbon, Total | mg/L | SWAMP | EPA 415.1M | 06-Oct-08 | 04-Feb-14 | 14 | | 4.90 | 2.24 | 12.90 | 0.50 |
| Inorganics | Conventional | Total Suspended Solids, Particulate | mg/L | RB1Fire | SM 2540 D | 01-Nov-17 | 22-Mar-18 | 16 | | 137 | 0.6 | 750 | 0.7 |
| Inorganics | Conventional | Total Suspended Solids, Particulate | mg/L | MS4SCWA | SM 2540 D | 20-Jul-10 | 19-Jun-15 | 60 | 2 | 22 | 0.2 | 820 | 0.4 |
| Inorganics | Conventional | Turbidity, Total | NTU | SWAMP | FieldMeasure | 07-Oct-04 | 11-Apr-11 | 12 | | 7.78 | 0.40 | 58.20 | |
| Inorganics | Trace Elements | Aluminum, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.6733 | 0.3600 | 0.9600 | 0.0072 |
| Inorganics | Trace Elements | Aluminum, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | 1 | 0.0009 | 0.0009 | 0.0009 | 0.0017 |
| Inorganics | Trace Elements | Aluminum, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | | 3.5249 | 0.0087 | 18.0000 | 0.0072 |
| Inorganics | Trace Elements | Aluminum, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | | 0.2403 | 0.0171 | 2.3440 | 0.0012 |
| Inorganics | Trace Elements | Arsenic, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | 3 | 0.0012 | 0.0012 | 0.0012 | 0.0023 |
| Inorganics | Trace Elements | Arsenic, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | | 0.0016 | 0.0016 | 0.0016 | 0.00004 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Arsenic, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 15 | 0.0014 | 0.0012 | 0.0057 | 0.00230 |
| Inorganics | Trace Elements | Arsenic, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | | 0.0015 | 0.0009 | 0.0024 | 0.00006 |
| Inorganics | Trace Elements | Cadmium, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | 1 | 0.0004 | 0.0001 | 0.0006 | 0.00020 |
| Inorganics | Trace Elements | Cadmium, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.00001 |
| Inorganics | Trace Elements | Cadmium, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 12 | 0.0002 | 0.0001 | 0.0004 | 0.00020 |
| Inorganics | Trace Elements | Cadmium, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | 7 | 0.0000 | 0.0000 | 0.0001 | 0.00001 |
| Inorganics | Trace Elements | Chromium, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0023 | 0.0017 | 0.0027 | 0.00091 |
| Inorganics | Trace Elements | Chromium, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | 1 | 0.0001 | 0.0001 | 0.0001 | 0.00010 |
| Inorganics | Trace Elements | Chromium, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 6 | 0.0133 | 0.0005 | 0.0690 | 0.00091 |
| Inorganics | Trace Elements | Chromium, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | 1 | 0.0045 | 0.0001 | 0.0531 | 0.00008 |
| Inorganics | Trace Elements | Copper, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0029 | 0.0024 | 0.0037 | 0.00095 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Copper, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | | 0.0009 | 0.0009 | 0.0009 | 0.00004 |
| Inorganics | Trace Elements | Copper, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 5 | 0.0105 | 0.0005 | 0.0310 | 0.00095 |
| Inorganics | Trace Elements | Copper, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | | 0.0017 | 0.0006 | 0.0055 | 0.00003 |
| Inorganics | Trace Elements | Lead, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0025 | 0.0016 | 0.0043 | 0.00140 |
| Inorganics | Trace Elements | Lead, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.00002 |
| Inorganics | Trace Elements | Lead, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 8 | 0.0043 | 0.0007 | 0.0150 | 0.00140 |
| Inorganics | Trace Elements | Lead, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | 2 | 0.0002 | 0.0000 | 0.0014 | 0.00001 |
| Inorganics | Trace Elements | Manganese, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0068 | 0.0053 | 0.0085 | 0.00017 |
| Inorganics | Trace Elements | Manganese, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | | 0.0224 | 0.0224 | 0.0224 | 0.00003 |
| Inorganics | Trace Elements | Manganese, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | | 0.2257 | 0.0170 | 0.7000 | 0.00017 |
| Inorganics | Trace Elements | Manganese, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | | 0.1303 | 0.0182 | 1.0370 | 0.00002 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Mercury, Dissolved | ug/L | RB1Fire | EPA 245.1 | 22-Mar-18 | 22-Mar-18 | 4 | 2 | 0.1625 | 0.1050 | 0.2300 | 0.21000 |
| Inorganics | Trace Elements | Mercury, Total | ug/L | RB1Fire | EPA 245.1 | 01-Nov-17 | 22-Mar-18 | 16 | 5 | 0.1245 | 0.0175 | 0.3500 | 0.10469 |
| Inorganics | Trace Elements | Mercury, Total | ug/L | SWAMP | EPA 1631EM | 07-Oct-04 | 29-Nov-11 | 16 | | 0.0033 | 0.0010 | 0.0184 | 0.00019 |
| Inorganics | Trace Elements | Mercury, Total | ug/L | TMDL | EPA 1631E | 26-Jun-08 | 26-Jun-08 | 2 | | 0.0020 | 0.0011 | 0.0030 | 0.00020 |
| Inorganics | Trace Elements | Nickel, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0055 | 0.0049 | 0.0058 | 0.00051 |
| Inorganics | Trace Elements | Nickel, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | | 0.0027 | 0.0027 | 0.0027 | 0.00001 |
| Inorganics | Trace Elements | Nickel, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | | 0.0236 | 0.0015 | 0.1200 | 0.00051 |
| Inorganics | Trace Elements | Nickel, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | | 0.0064 | 0.0021 | 0.0384 | 0.00001 |
| Inorganics | Trace Elements | Selenium, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | 2 | 0.0016 | 0.0009 | 0.0030 | 0.00180 |
| Inorganics | Trace Elements | Selenium, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | 1 | 0.0003 | 0.0003 | 0.0003 | 0.00060 |
| Inorganics | Trace Elements | Selenium, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 6 | 0.0041 | 0.0009 | 0.0100 | 0.00180 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inorganics | Trace Elements | Selenium, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | 5 | 0.0007 | 0.0003 | 0.0015 | 0.00044 |
| Inorganics | Trace Elements | Zinc, Dissolved | mg/L | RB1Fire | EPA 200.7 | 22-Mar-18 | 22-Mar-18 | 3 | | 0.0267 | 0.0190 | 0.0420 | 0.00080 |
| Inorganics | Trace Elements | Zinc, Dissolved | mg/L | SWAMP | EPA 1638M | 12-Dec-13 | 12-Dec-13 | 1 | 1 | 0.0003 | 0.0003 | 0.0003 | 0.00050 |
| Inorganics | Trace Elements | Zinc, Total | mg/L | RB1Fire | EPA 200.7 | 01-Nov-17 | 22-Mar-18 | 16 | 4 | 0.0318 | 0.0004 | 0.1200 | 0.00080 |
| Inorganics | Trace Elements | Zinc, Total | mg/L | SWAMP | EPA 1638M | 07-Oct-04 | 29-Nov-11 | 16 | 3 | 0.0050 | 0.0003 | 0.0302 | 0.00038 |
| Organics | PAHs | Acenaphthene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0175 | 0.0175 | 0.0175 | 0.0350 |
| Organics | PAHs | Acenaphthylene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0155 | 0.0155 | 0.0155 | 0.0310 |
| Organics | PAHs | Anthracene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0200 | 0.0200 | 0.0200 | 0.0400 |
| Organics | PAHs | Benz(a)anthracene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0125 | 0.0125 | 0.0125 | 0.0250 |
| Organics | PAHs | Benzo(a)pyrene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0170 | 0.0170 | 0.0170 | 0.0340 |
| Organics | PAHs | Benzo(b)fluoranthene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 15 | 0.0147 | 0.0125 | 0.0480 | 0.0250 |

| Group1 | Group2 | CEDEN_Analyte Name and Fraction | Unit | Program Short Name | Method Name | Min Sample Date | Max Sample Date | N Samples | Cnt NDs | Avg Of Result | Min Of Result | Max Of Result | Avg Of MDL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Organics | PAHs | Benzo(g,h,i)perylene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 15 | 0.0133 | 0.0120 | 0.0330 | 0.0240 |
| Organics | PAHs | Benzo(k)fluoranthene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0155 | 0.0155 | 0.0155 | 0.0310 |
| Organics | PAHs | Chrysene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0120 | 0.0120 | 0.0120 | 0.0240 |
| Organics | PAHs | Dibenz(a,h)anthracene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0195 | 0.0195 | 0.0195 | 0.0390 |
| Organics | PAHs | Fluoranthene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 15 | 0.0208 | 0.0180 | 0.0620 | 0.0360 |
| Organics | PAHs | Fluorene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0180 | 0.0180 | 0.0180 | 0.0360 |
| Organics | PAHs | Indeno(1,2,3-c,d)pyrene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0235 | 0.0235 | 0.0235 | 0.0470 |
| Organics | PAHs | Naphthalene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0200 | 0.0200 | 0.0200 | 0.0400 |
| Organics | PAHs | Phenanthrene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 16 | 0.0200 | 0.0200 | 0.0200 | 0.0400 |
| Organics | PAHs | Pyrene, Total | ug/L | RB1Fire | EPA 8270C | 01-Nov-17 | 22-Mar-18 | 16 | 14 | 0.0212 | 0.0175 | 0.0590 | 0.0350 |

[1] Calcium, Magnesium, and Iron are reported as inorganic conventional water quality parameters.
[2] Over the five-year monitoring period ((July 20, 2010 through June 19, 2015) there were 16 days when the average daily stream flow in Santa Rosa Creek exceeded 1,000 cfs. and there were three times when water quality sampling events coincided with average daily stream flows >1,000 cfs.

# Attachment A Appendix D: Plots of water year 2018 Fire Monitoring Results

This section includes plots of all analytes with reported results that were above the Method Detection Limit. The histograms are grouped by color: the grey bars are for the Mark West Creek fire monitoring sites, the blue bars are for the Piner and Santa Rosa Creek fire monitoring sites, and the white bars are for all comparative sites. The comparison site data (Comp) presented in the plots are the maximum result reported at each site by program (during any sampling event). In the plots, the sites are labeled by their station code.

Table D1. Station code, station names and bar color on plots.

| Station Name | Station Code | Bar Color |
|---|---|---|
| Fire monitoring: Lower Mark West Creek | 114MW4198; 114MW3972 | Grey |
| Fire monitoring: Upper Mark West Creek | 114MW6173 | Grey |
| Fire monitoring: Piner Creek | 114PI5786 | Blue |
| Fire monitoring: Santa Rosa Creek at Willowside Road | 114SR0761 | Blue |
| C1 - Santa Rosa Creek down gradient of urban footprint | C1-SRC-D | White |
| Mark West Creek at River Road | 114MW2583 | White |
| Santa Rosa Creek at Willowside Road | 114SR0761 | White |
| Piner Creek at Fulton Road | 114PI0729 | White |

In the plots, for analytes in which water quality guidelines (US EPA, National Recommended Water Quality Criteria) are available, the water quality guideline is plotted. Red horizontal lines indicate concentrations for Human Health and Welfare Protection criteria, and blue lines indicate Aquatic Life Criteria. For analytes/parameters in which a water quality guideline is available but off the chart, it is indicated in the figure caption.

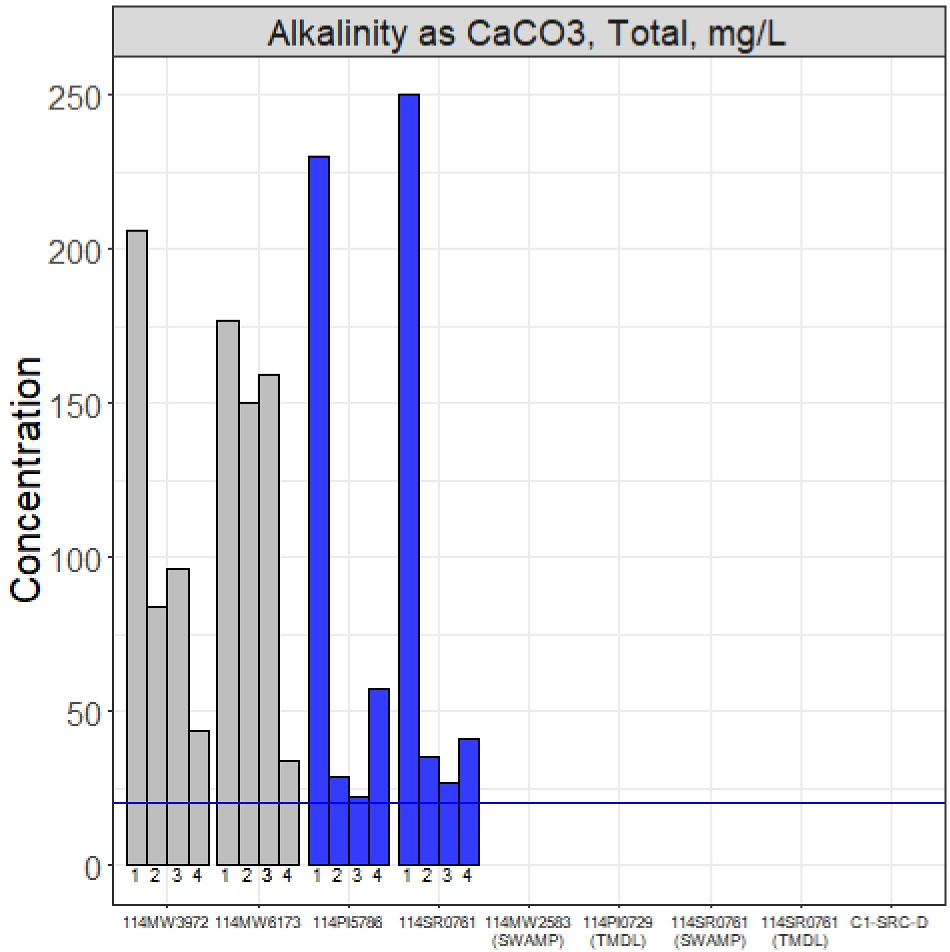


Figure D1. Concentrations of Alkalinity measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for alkalinity is 20 mg/L. No Human Health and Welfare Protection Criteria is available.

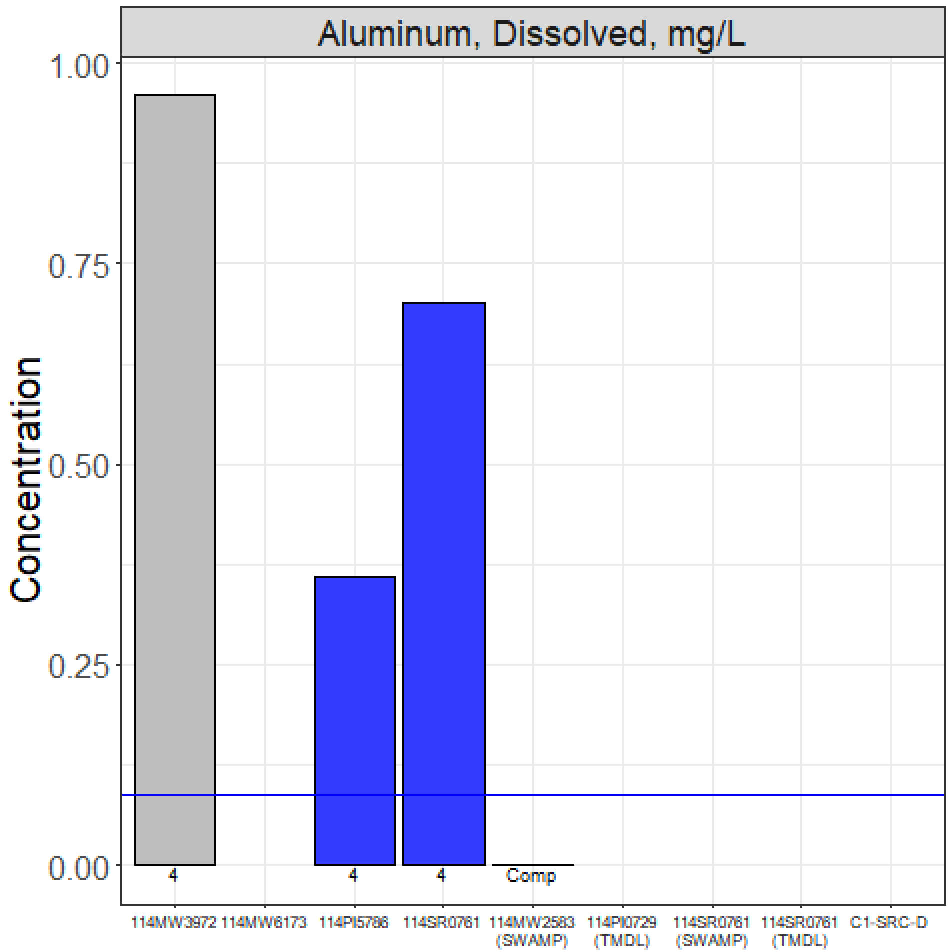


Figure D2. Concentrations of Dissolved Aluminum measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** aluminum is 0.087 mg/L. No Human Health and Welfare Protection Criteria is available.

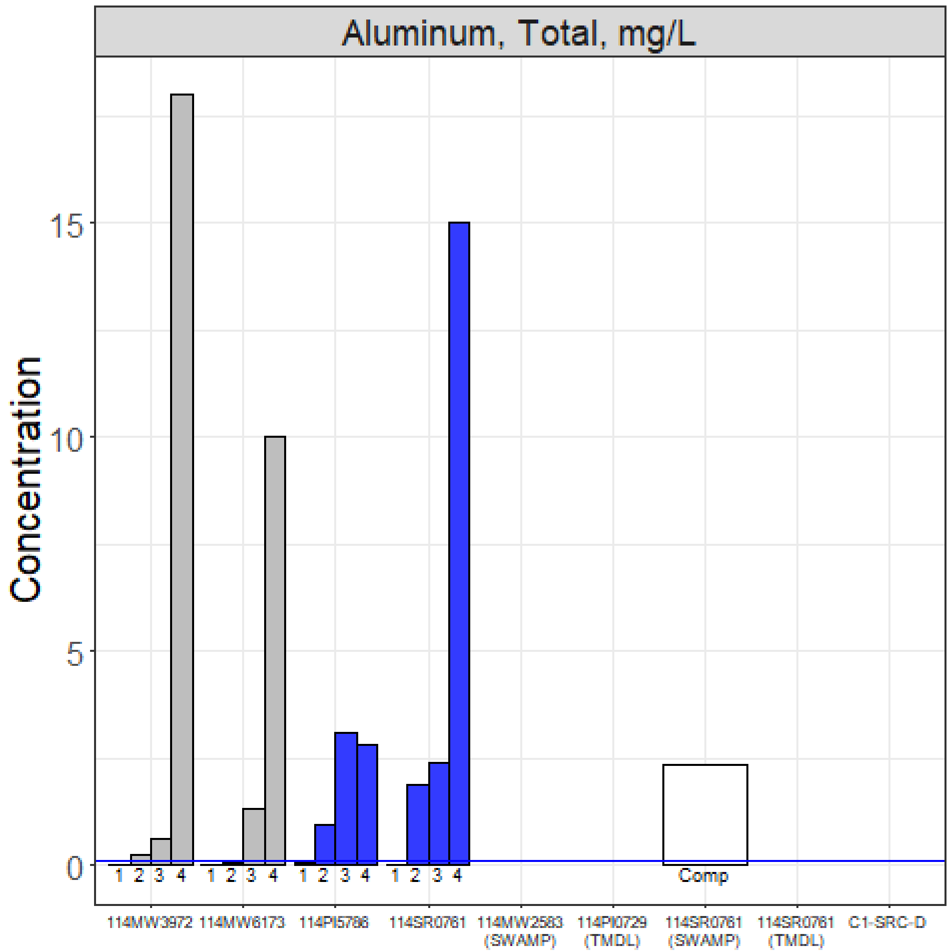


Figure D3. Concentrations of Total Aluminum measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total aluminum is 0.087 mg/L. No Human Health and Welfare Protection Criteria is available.

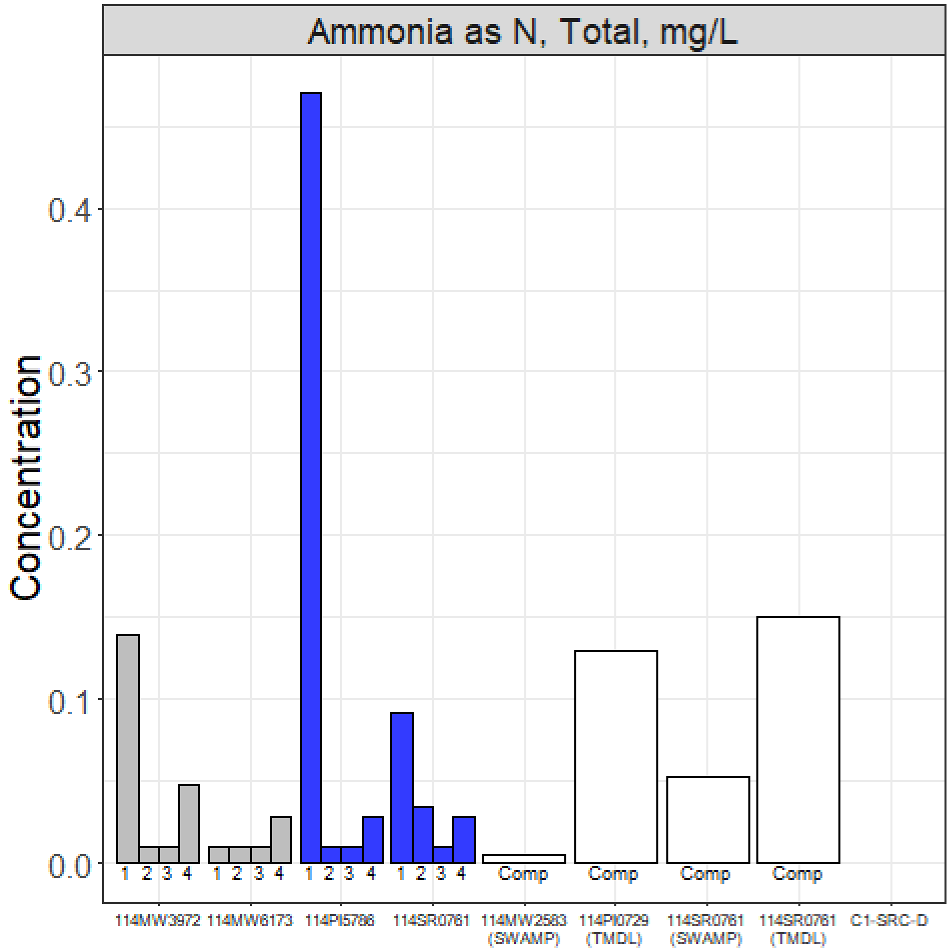


Figure D4. Concentrations of Total Ammonia (as N) measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for ammonia is not shown as it is pH and temperature dependent. No Human Health and Welfare Protection Criteria is available.

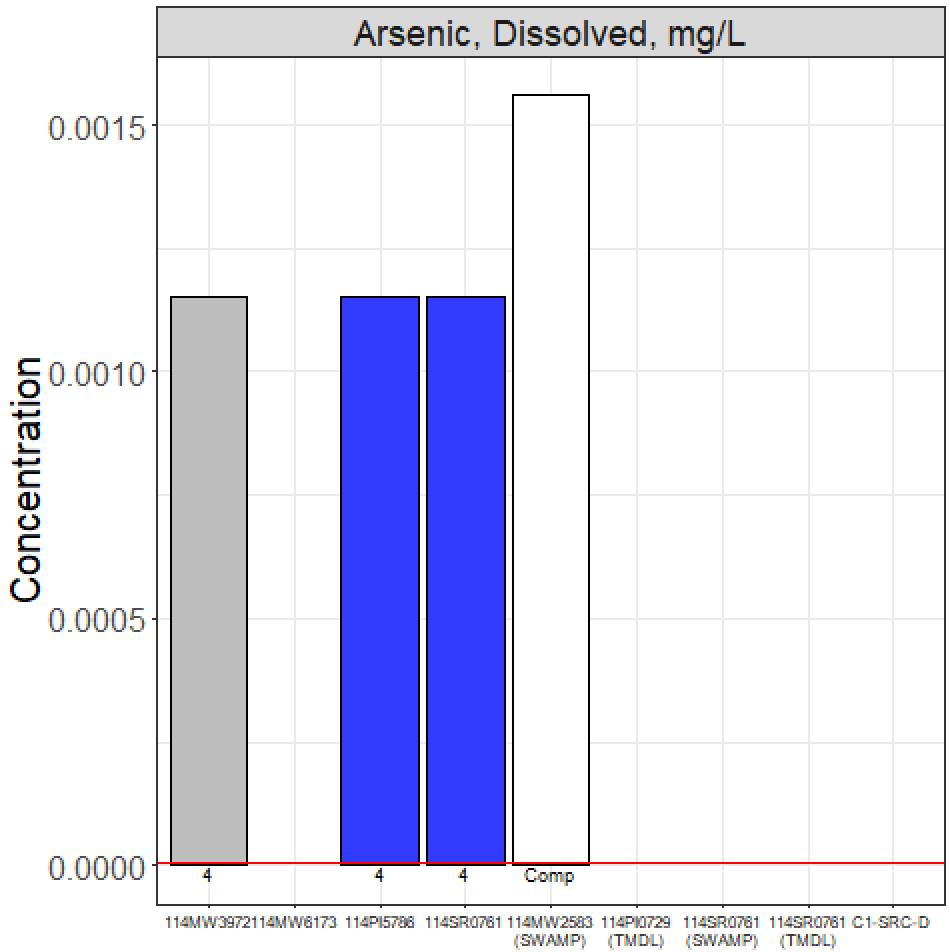


Figure D5. Concentrations of Dissolved Arsenic measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** arsenic is 0.15 mg/L and not shown as it is off the chart area. The Human Health and Welfare Protection Criteria is shown in 0.000004 mg/L.

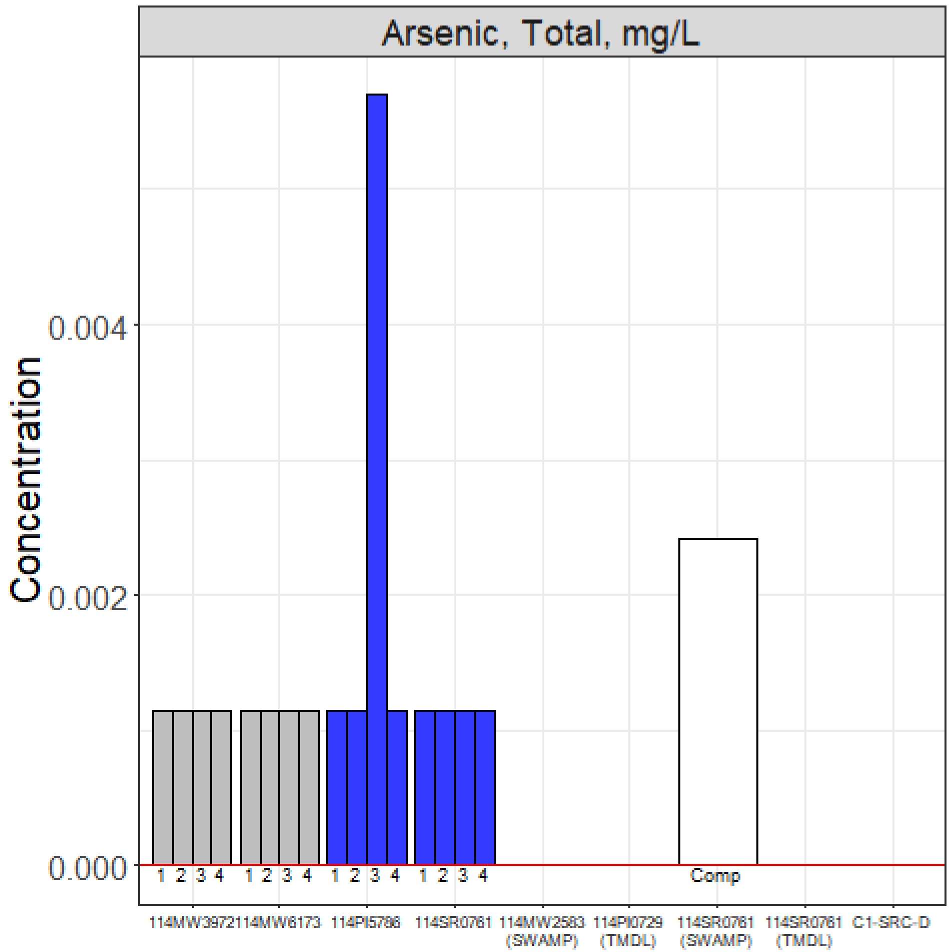


Figure D6. Concentrations of Total Arsenic measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total arsenic is 0.15 mg/L and not shown as it is off the chart area. The Human Health and Welfare Protection Criteria is shown in 0.000004 mg/L.

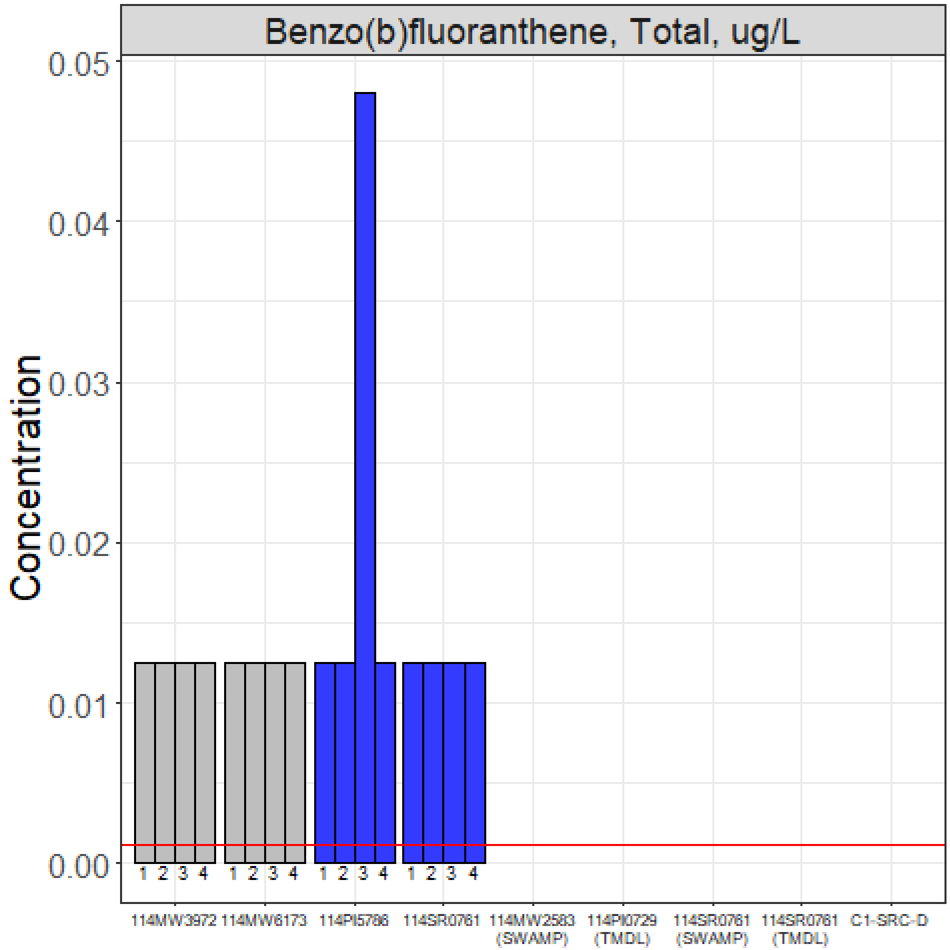


Figure D7. Concentrations of Benzo(b)fluoranthene measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for Benzo(b)fluoranthene. The Human Health and Welfare Protection Criteria is shown in 0.0012 ug/L.

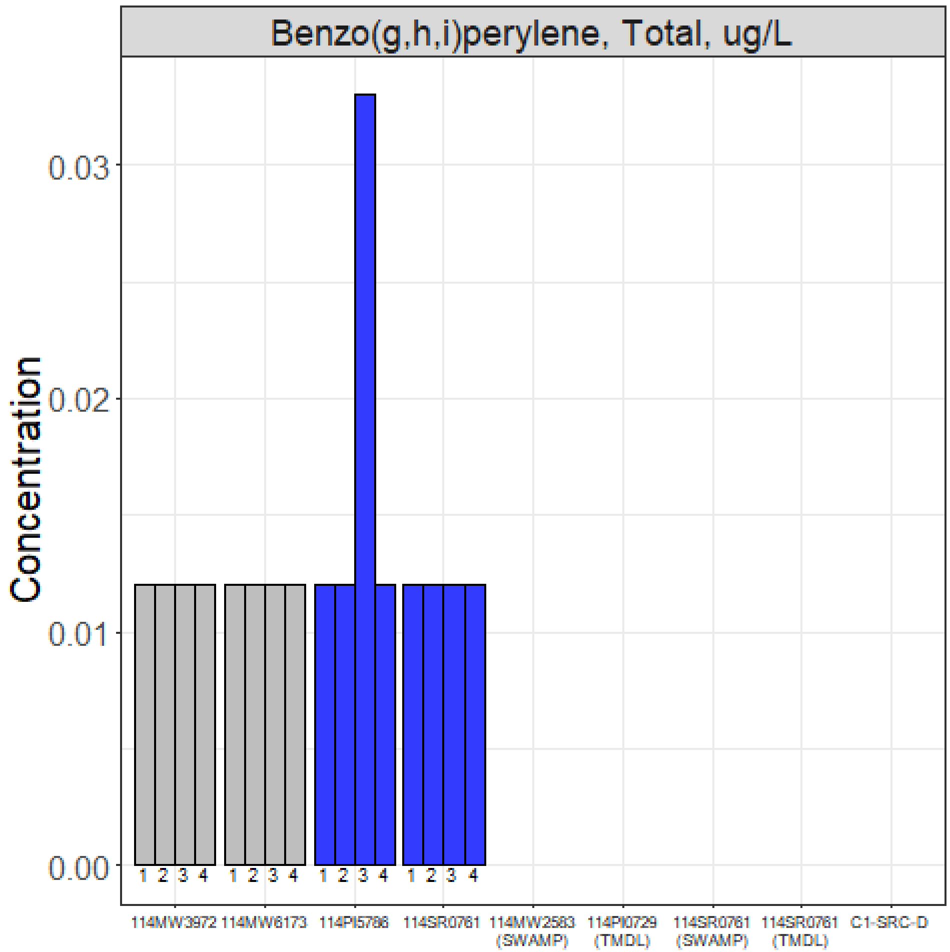


Figure D8. Concentrations of Benzo(g,h,i)perylene measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria or Human Health and Welfare Protection Criteria for Benzo(g,h,i)perylene.

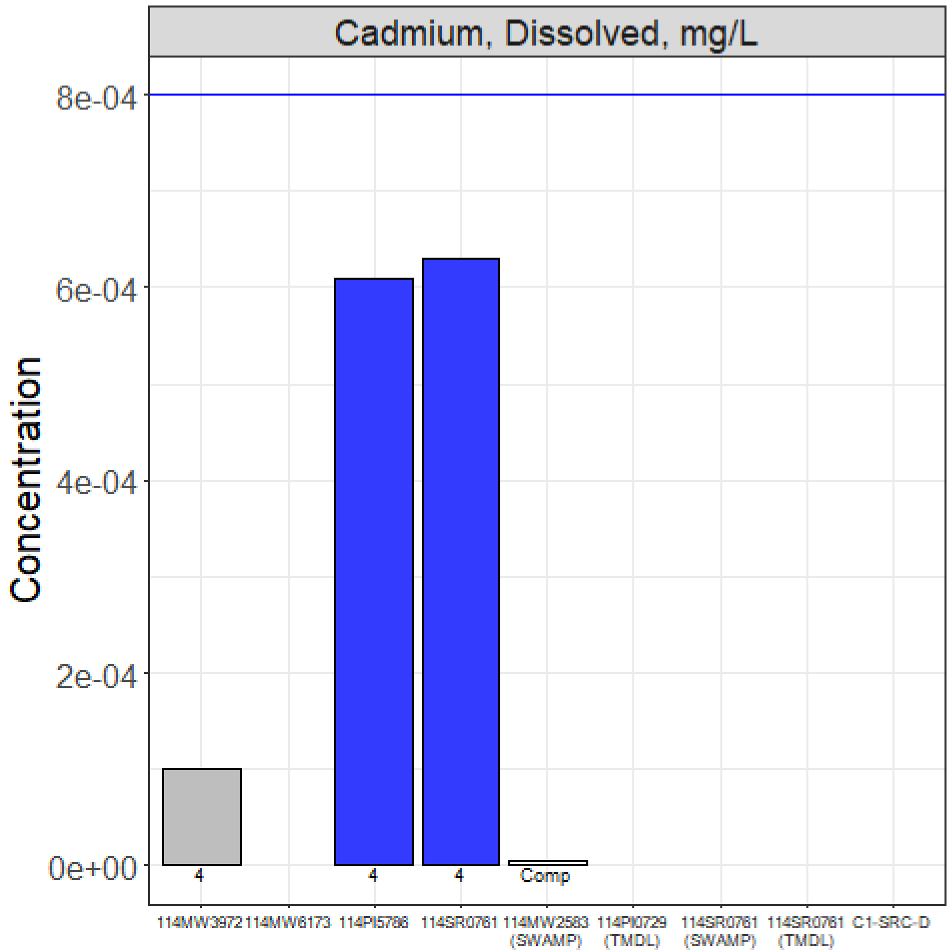


Figure D9. Concentrations of Dissolved Cadmium measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** cadmium is 0.0008 mg/L. There is no Human Health and Welfare Protection Criteria.

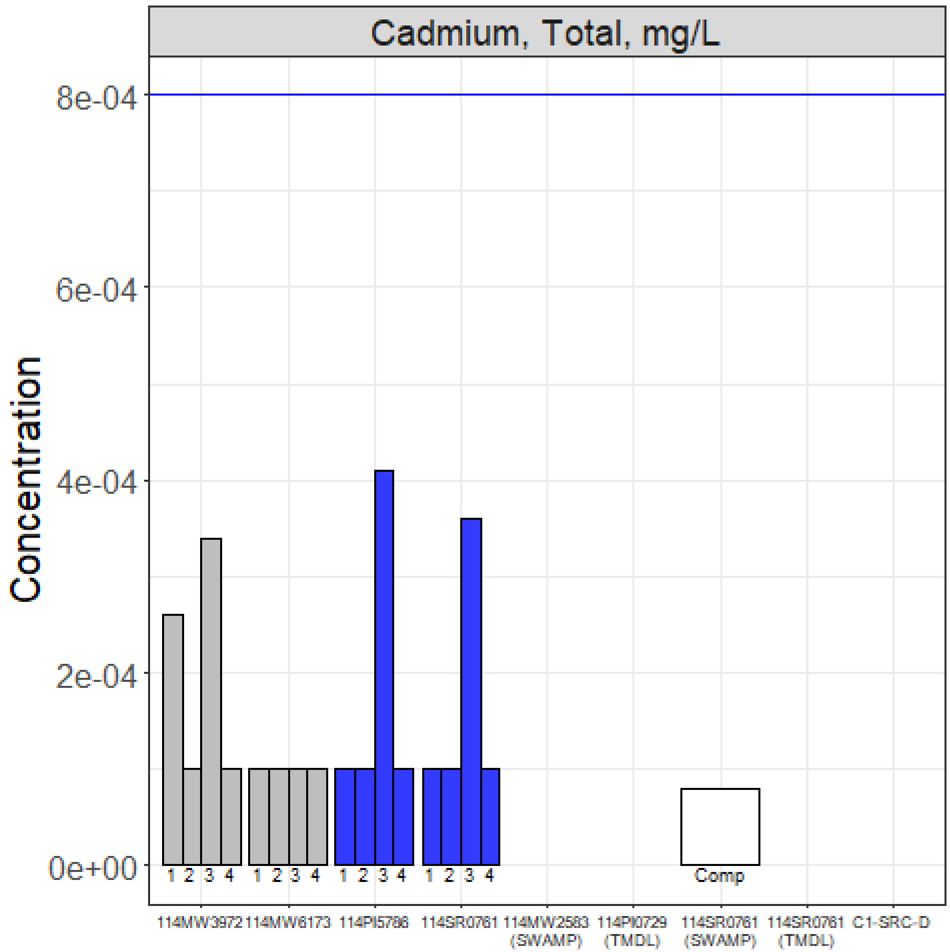


Figure D10. Concentrations of Total Cadmium measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total cadmium is 0.0008 mg/L. There is no Human Health and Welfare Protection Criteria.

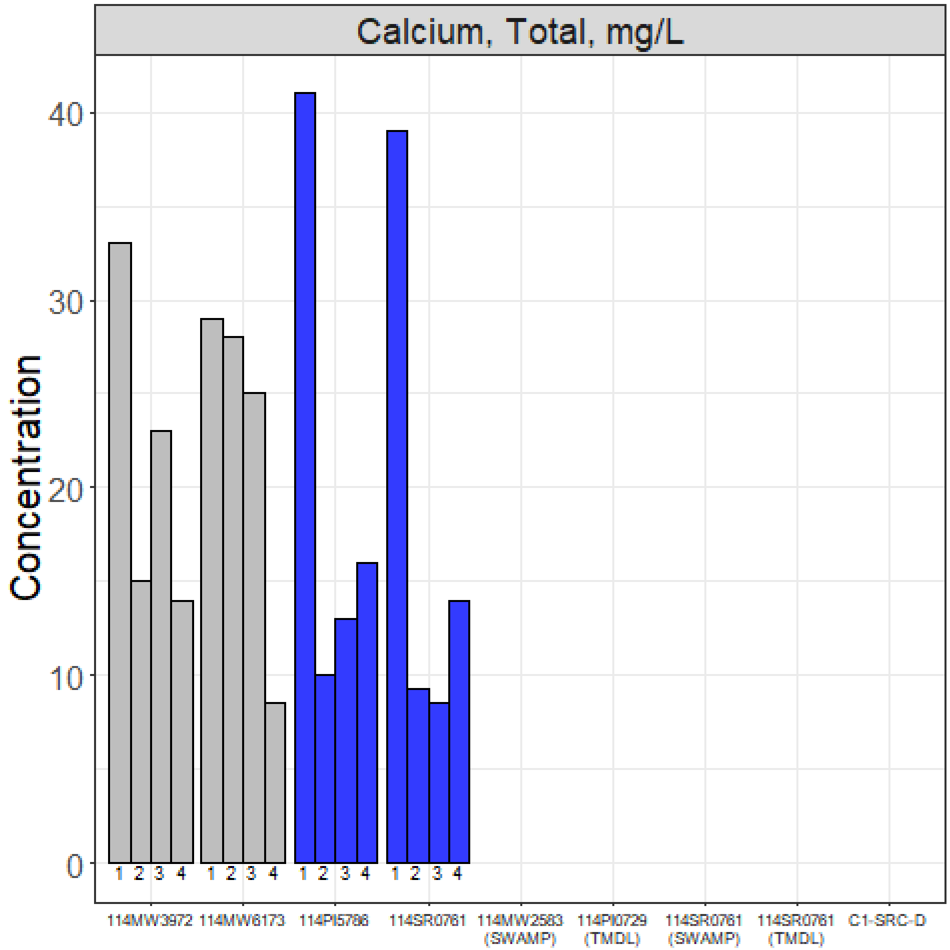


Figure D11. Concentrations of Calcium measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria or Human Health and Welfare Protection Criteria for Calcium.

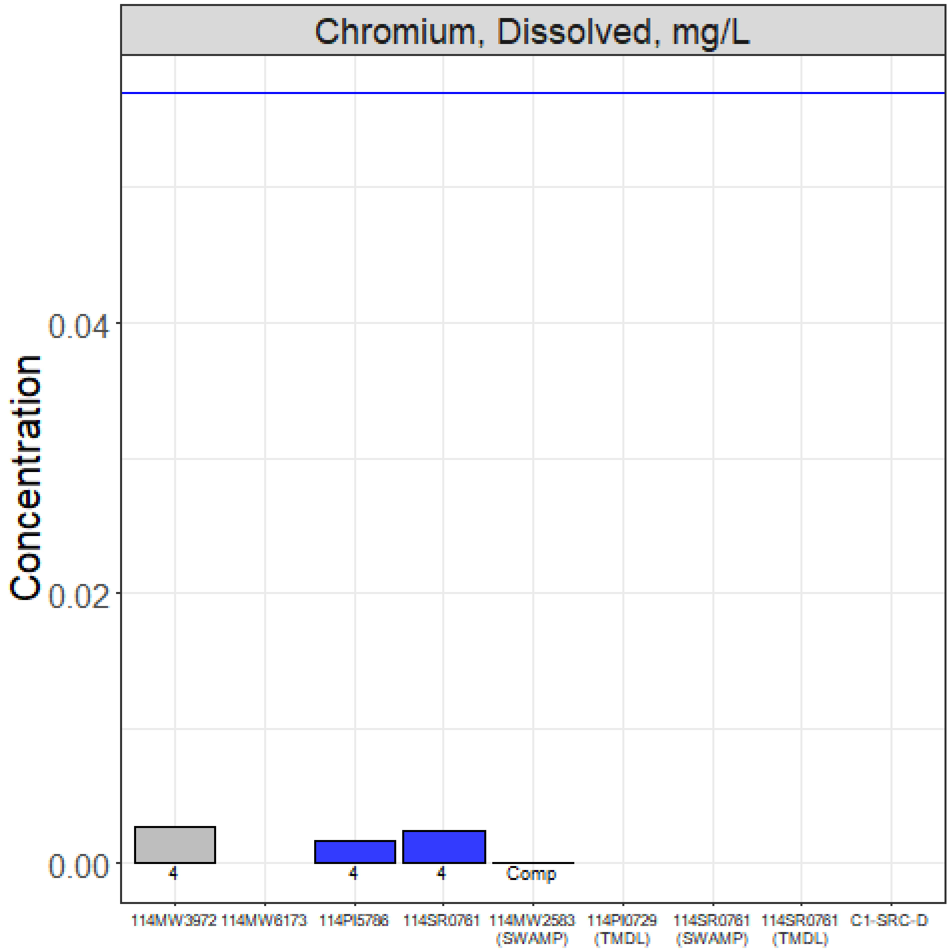


Figure D12. Concentrations of Dissolved Chromium measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** chromium is 0.057 mg/L. There is no Human Health and Welfare Protection Criteria.

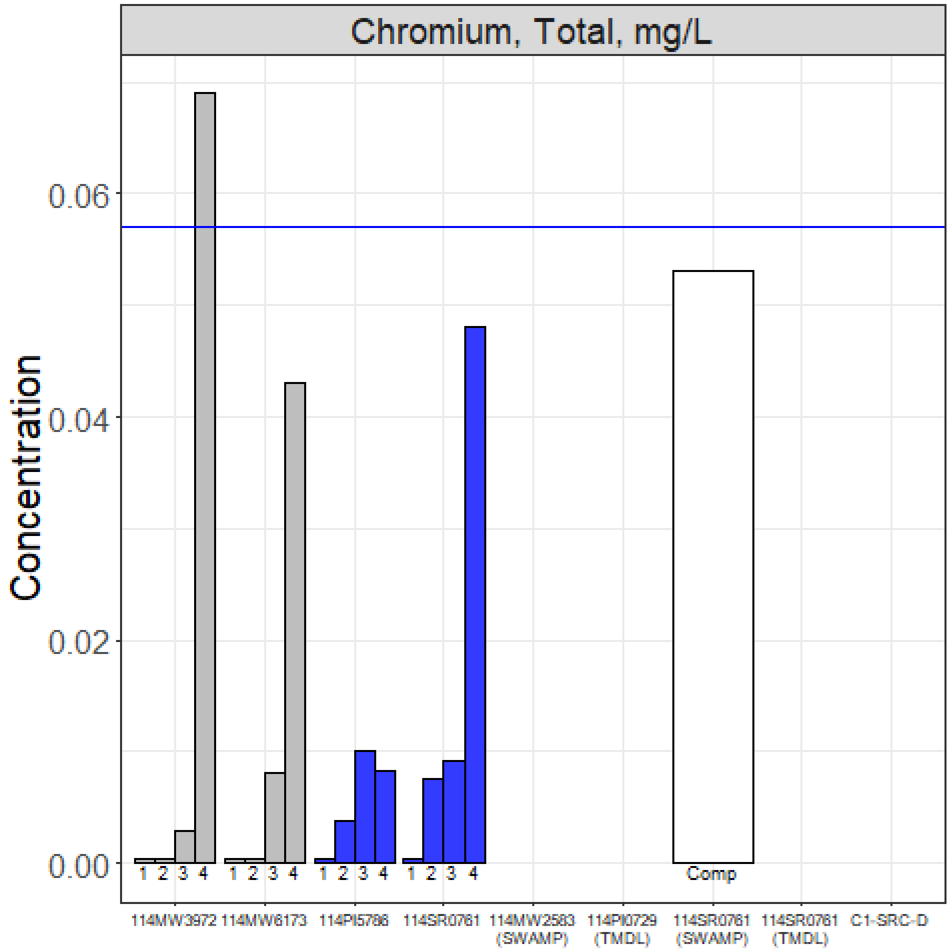


Figure D13. Concentrations of Total Chromium measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total chromium is 0.057 mg/L. There is no Human Health and Welfare Protection Criteria.

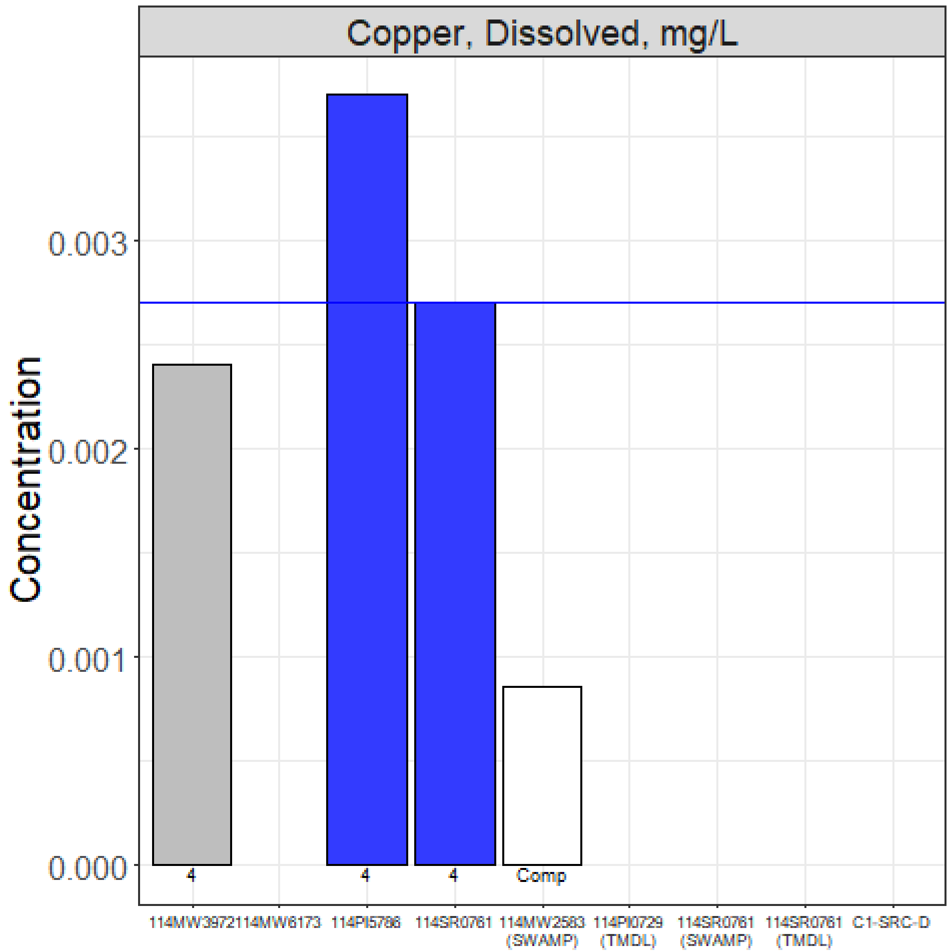


Figure D14. Concentrations of Dissolved Copper measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** copper is 0.0027 mg/L. There is no Human Health and Welfare Protection Criteria.

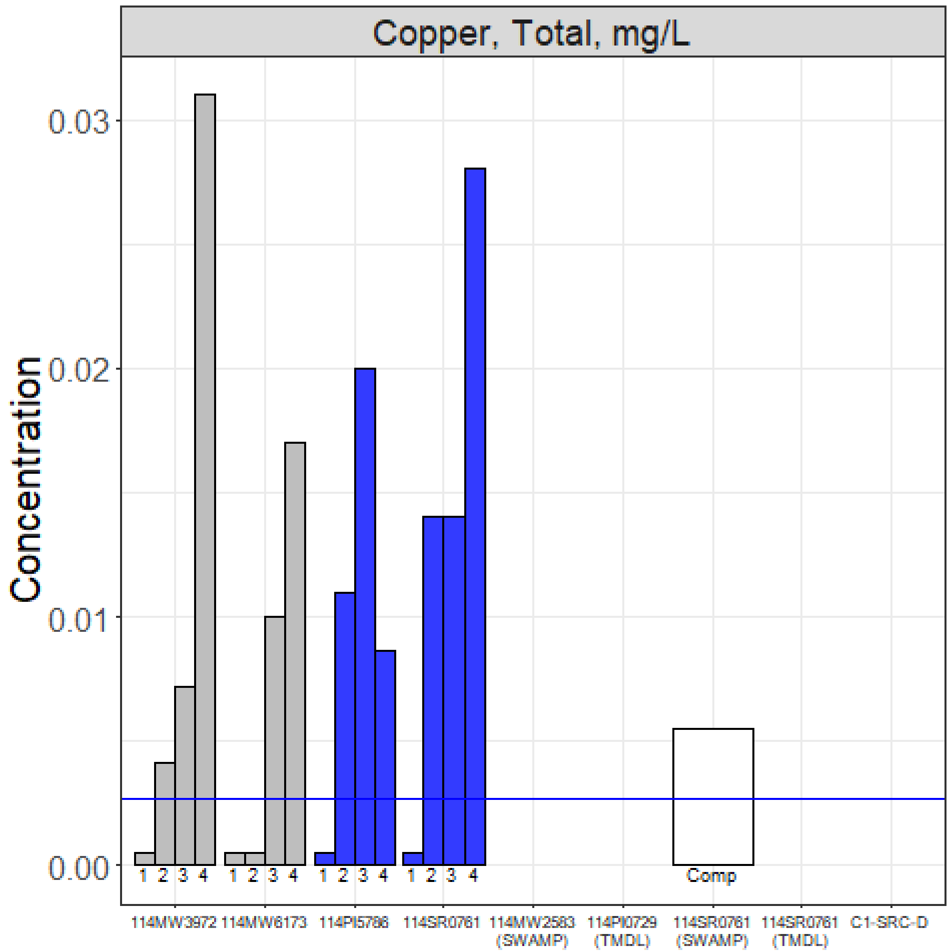


Figure D15. Concentrations of Total Copper measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total copper is 0.0027 mg/L. There is no Human Health and Welfare Protection Criteria.

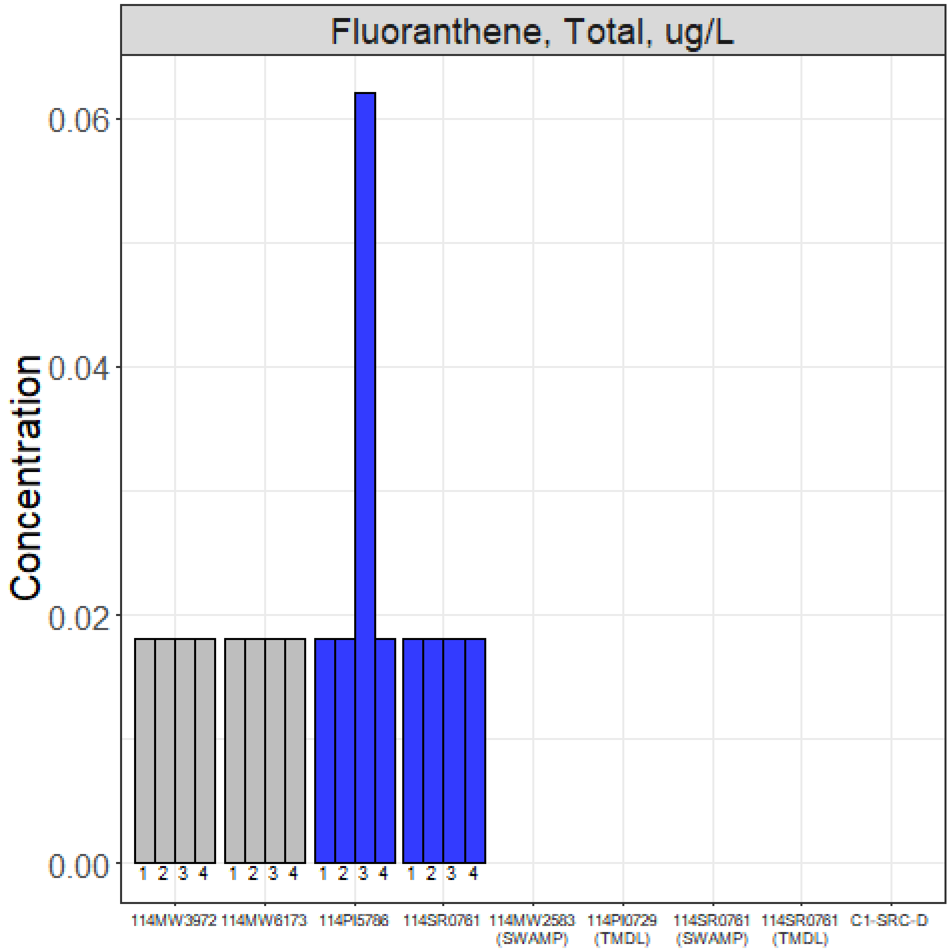


Figure D16. Concentrations of Fluoranthene measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for Fluoranthene. The Human Health and Welfare Protection Criteria is 50 ug/L but not shown as it is off the chart.

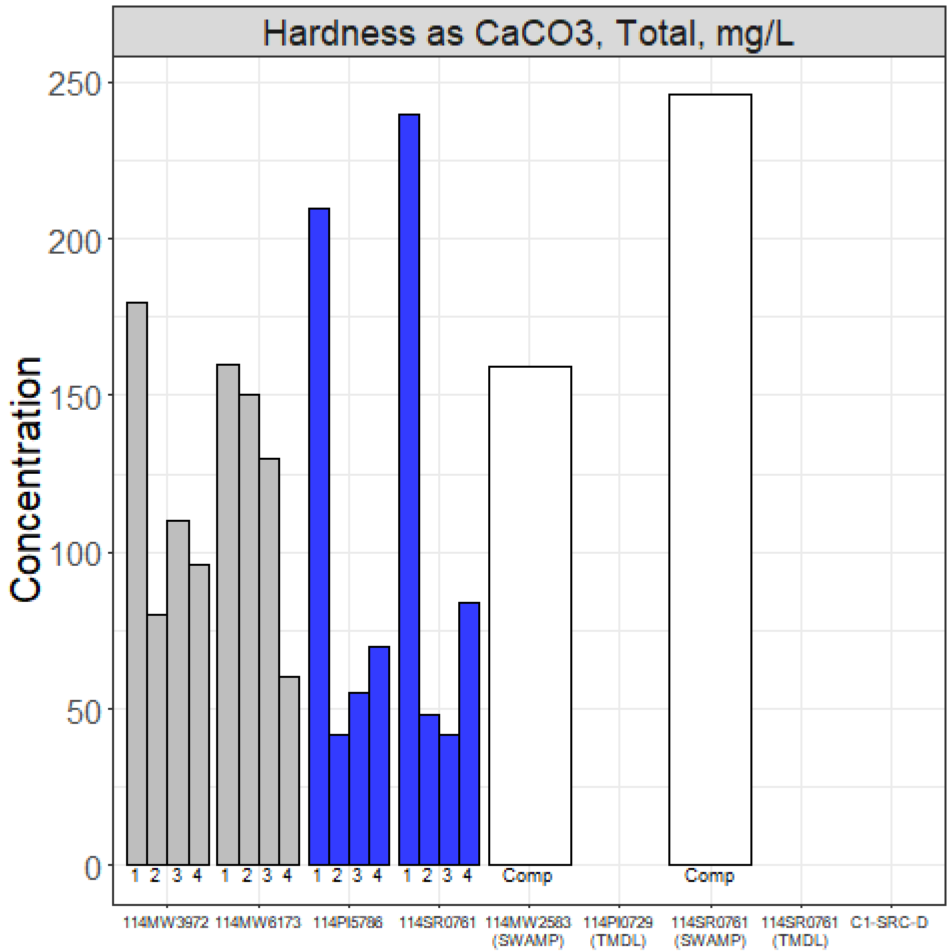


Figure D17. Concentrations of Hardness measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for hardness.

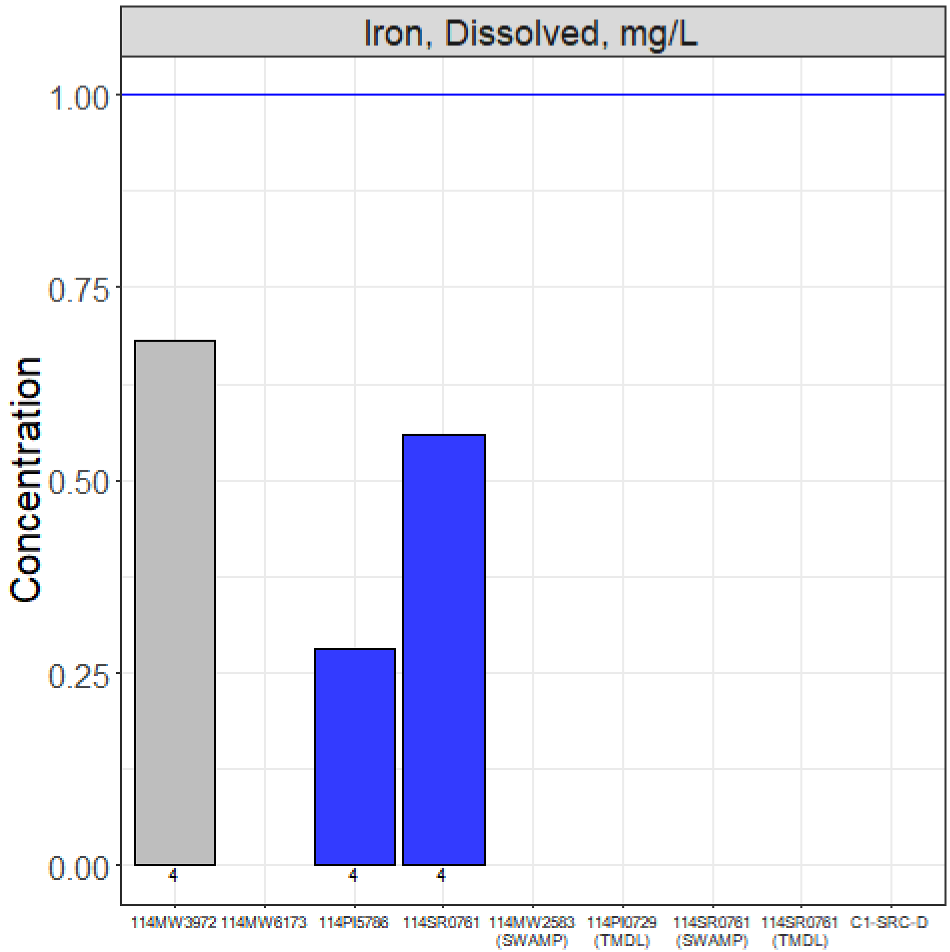


Figure D18. Concentrations of Dissolved Iron measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** iron is 1 mg/L. There is no Human Health and Welfare Protection Criteria.

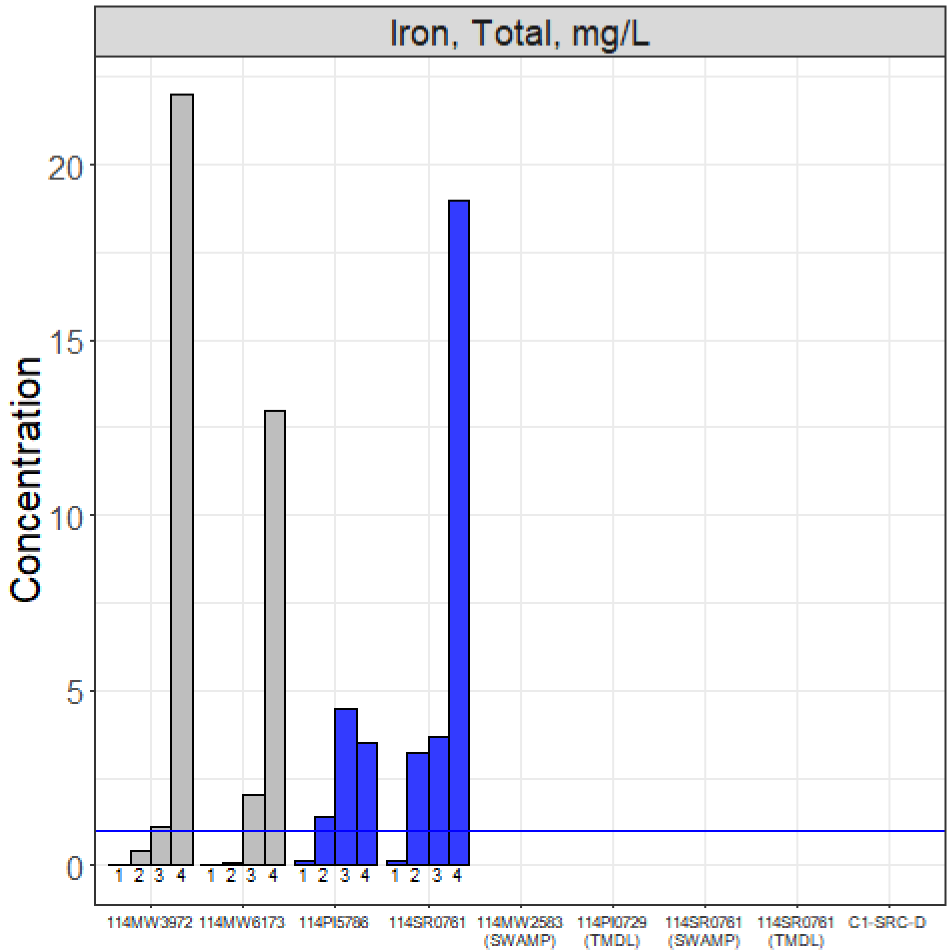


Figure D19. Concentrations of Total Iron measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total iron is 1 mg/L. There is no Human Health and Welfare Protection Criteria.

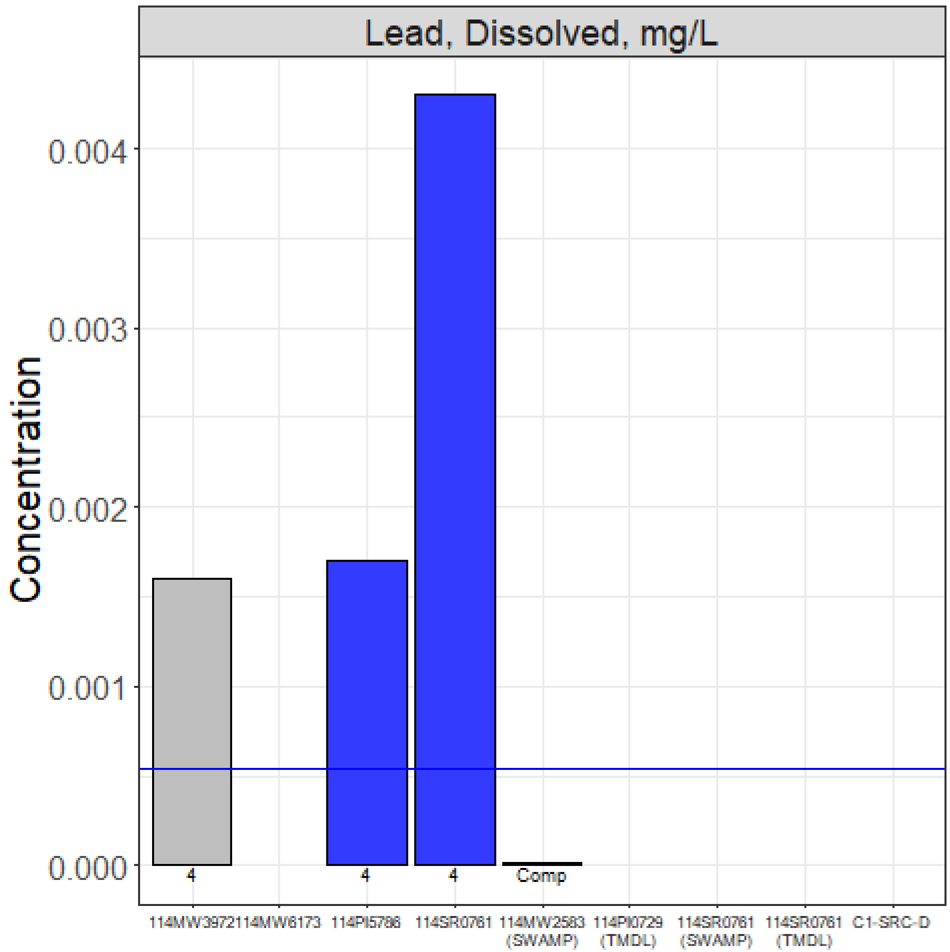


Figure D20. Concentrations of Dissolved Lead measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** lead is 0.00054 mg/L. There is no Human Health and Welfare Protection Criteria.

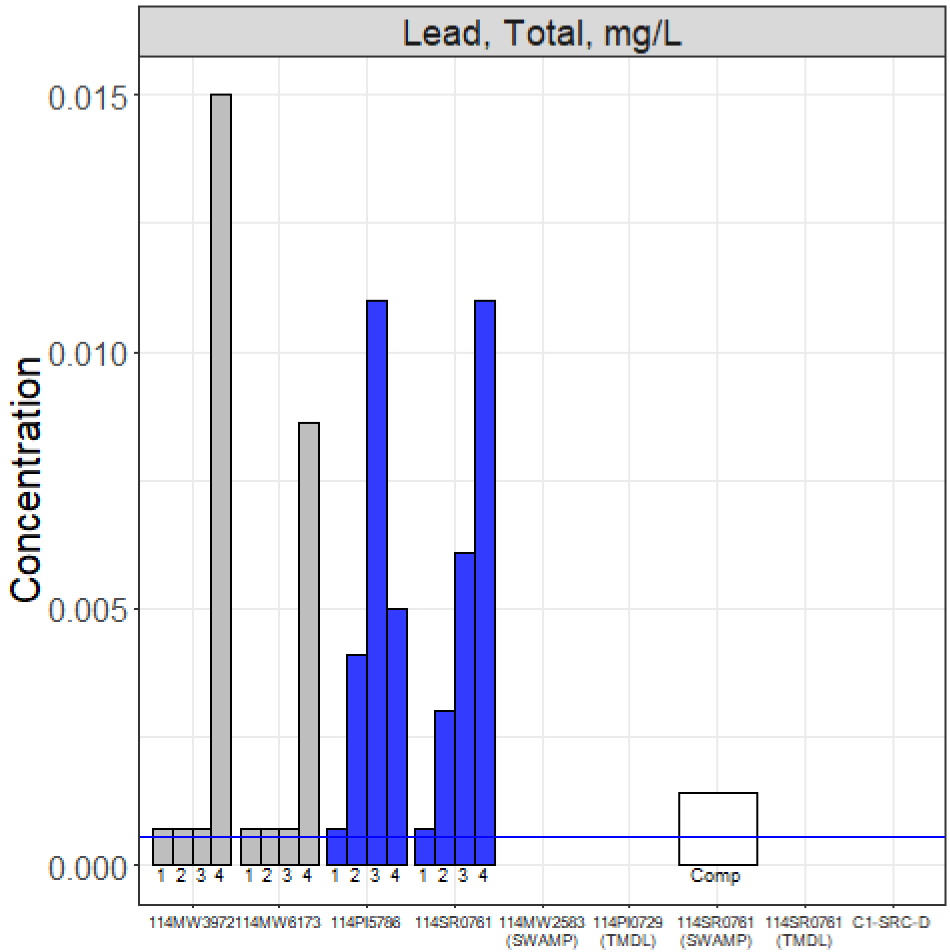


Figure D21. Concentrations of Total Lead measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total lead is 0.00054 mg/L. There is no Human Health and Welfare Protection Criteria.

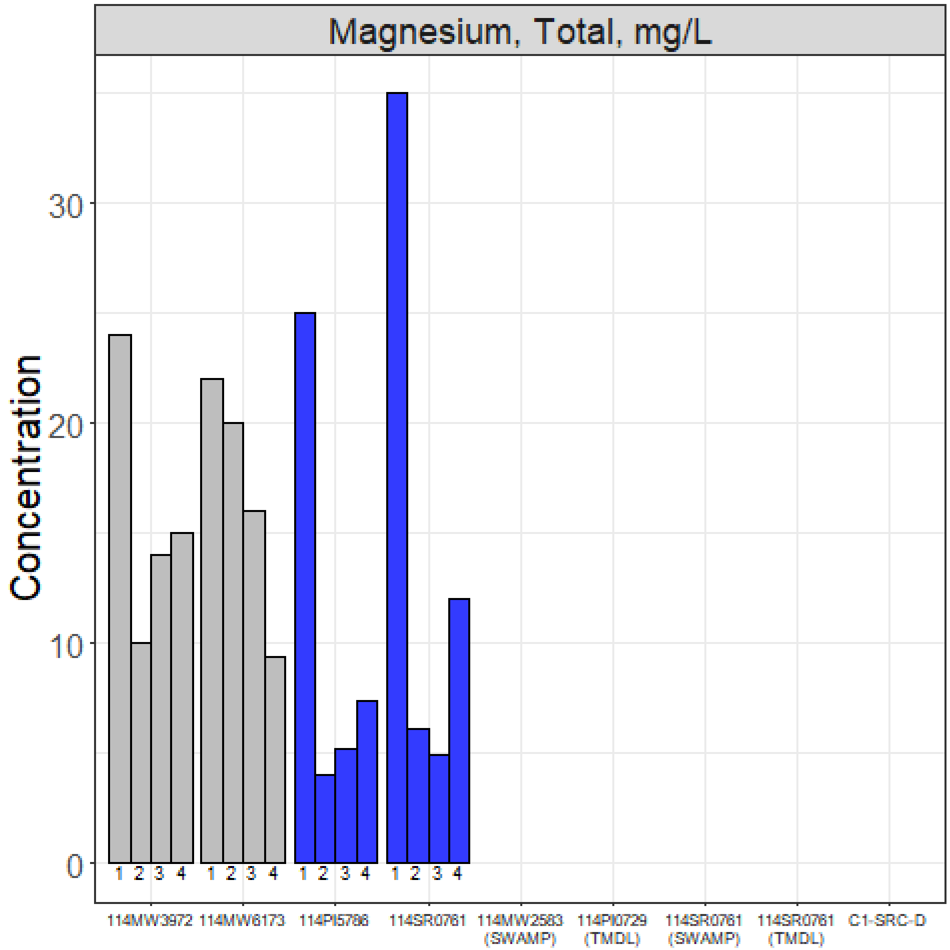


Figure D22. Concentrations of Total Magnesium measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for total magnesium.

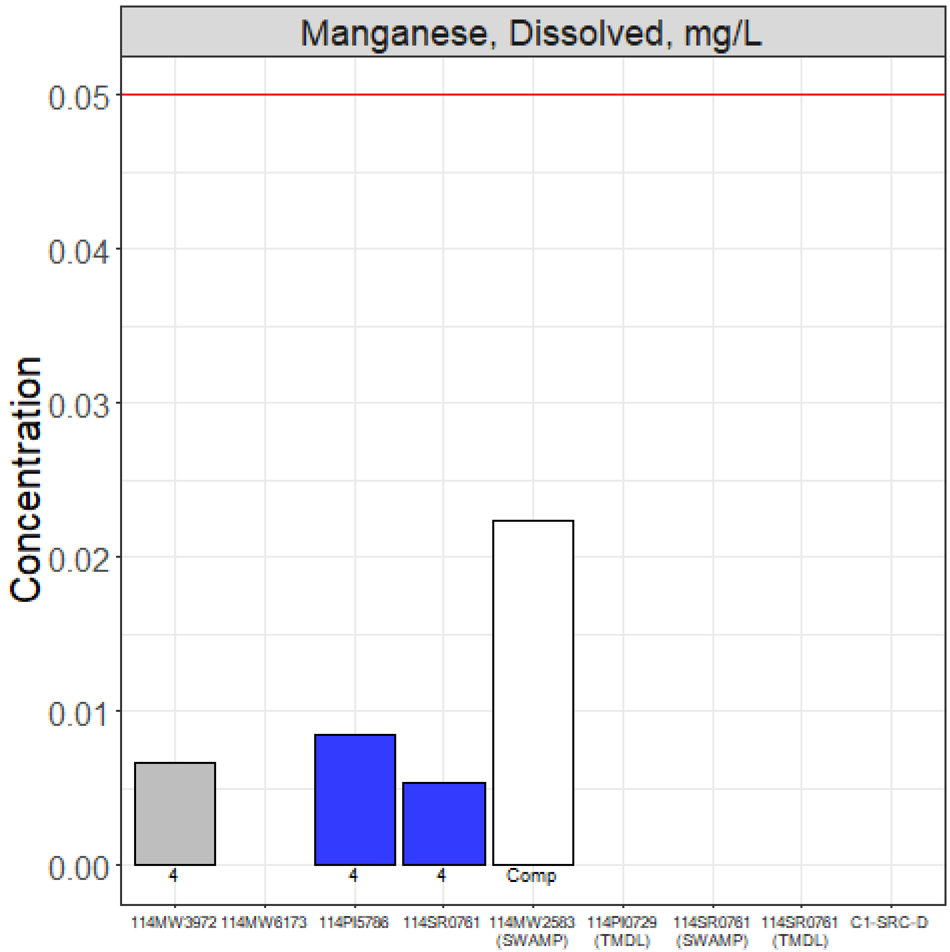


Figure D23. Concentrations of Dissolved Manganese measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for manganese. The Human Health and Welfare Protection Criteria for **total** manganese is 0.05 mg/L.

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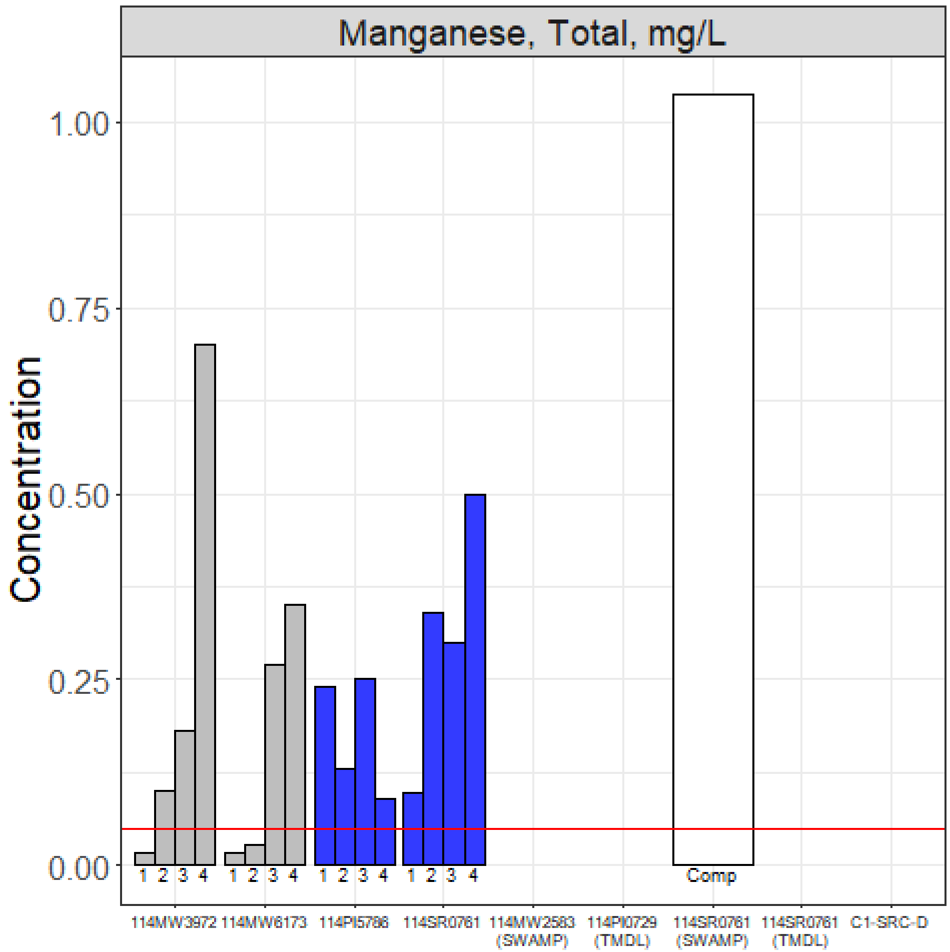


Figure D24. Concentrations of Total Manganese measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for manganese. The Human Health and Welfare Protection Criteria for total manganese is 0.05 mg/L.

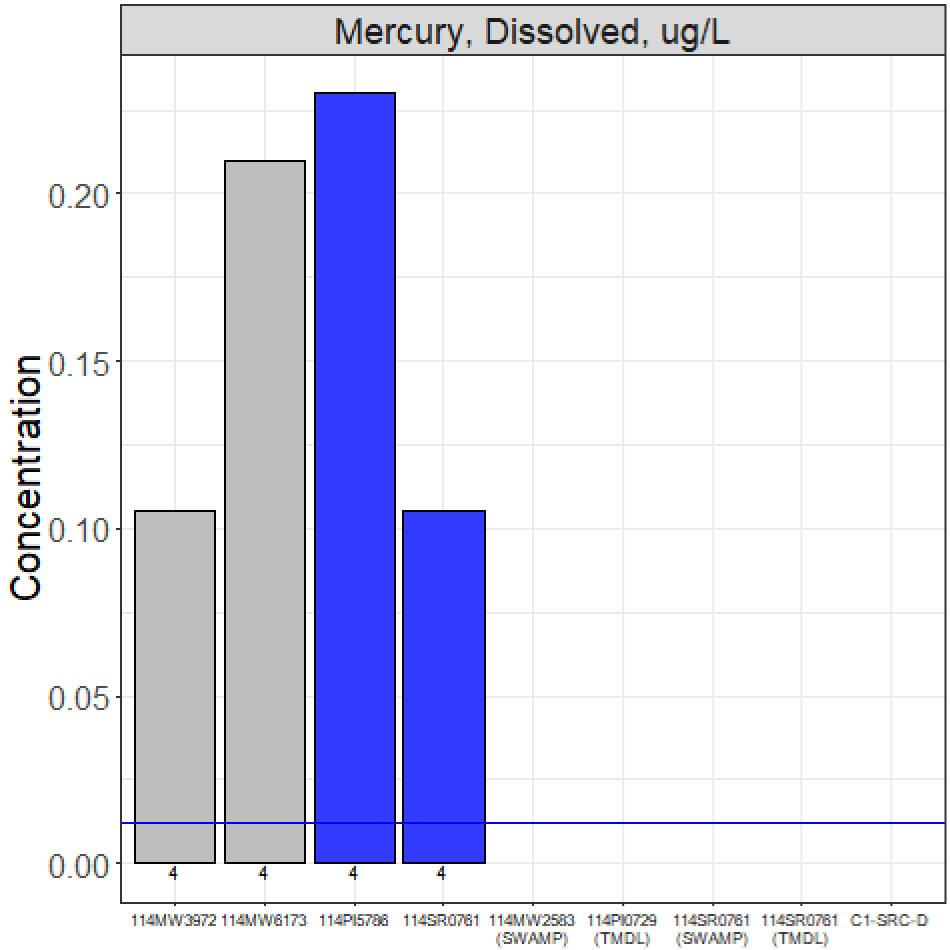


Figure D25. Concentrations of Dissolved Mercury measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** mercury is 0.012 ug/L. There is no Human Health and Welfare Protection Criteria.

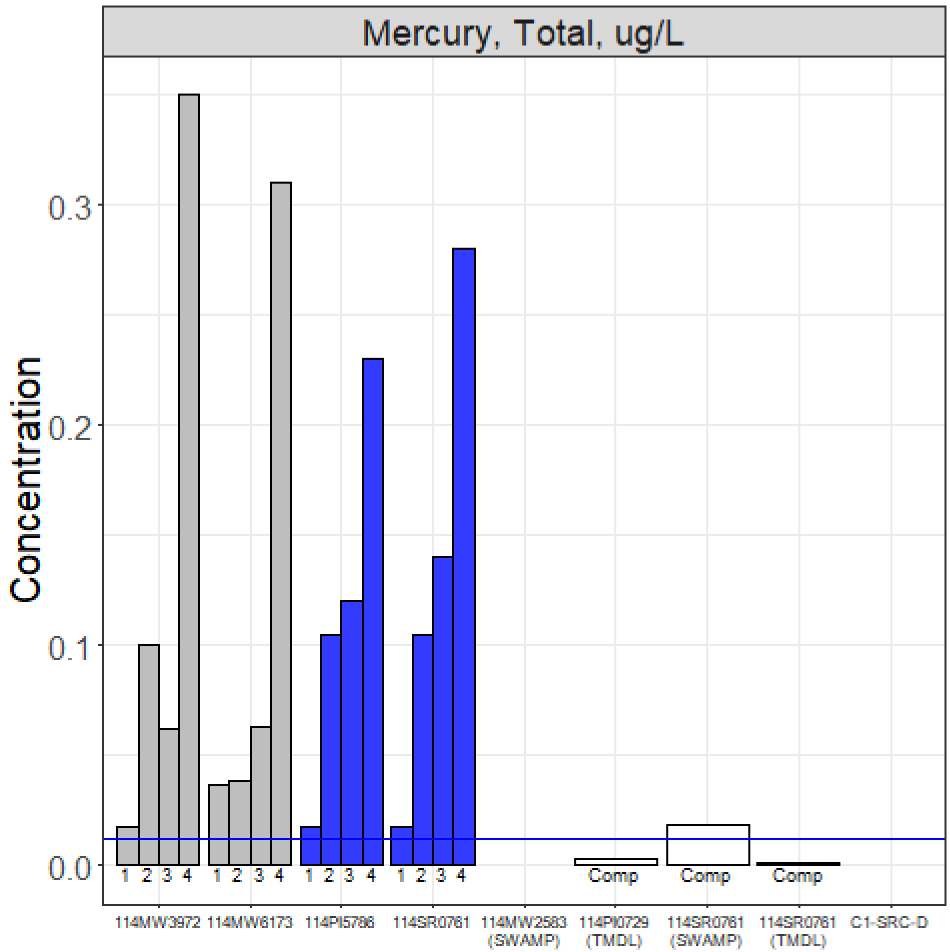


Figure D26. Concentrations of Total Mercury measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total mercury is 0.012 ug/L. There is no Human Health and Welfare Protection Criteria.

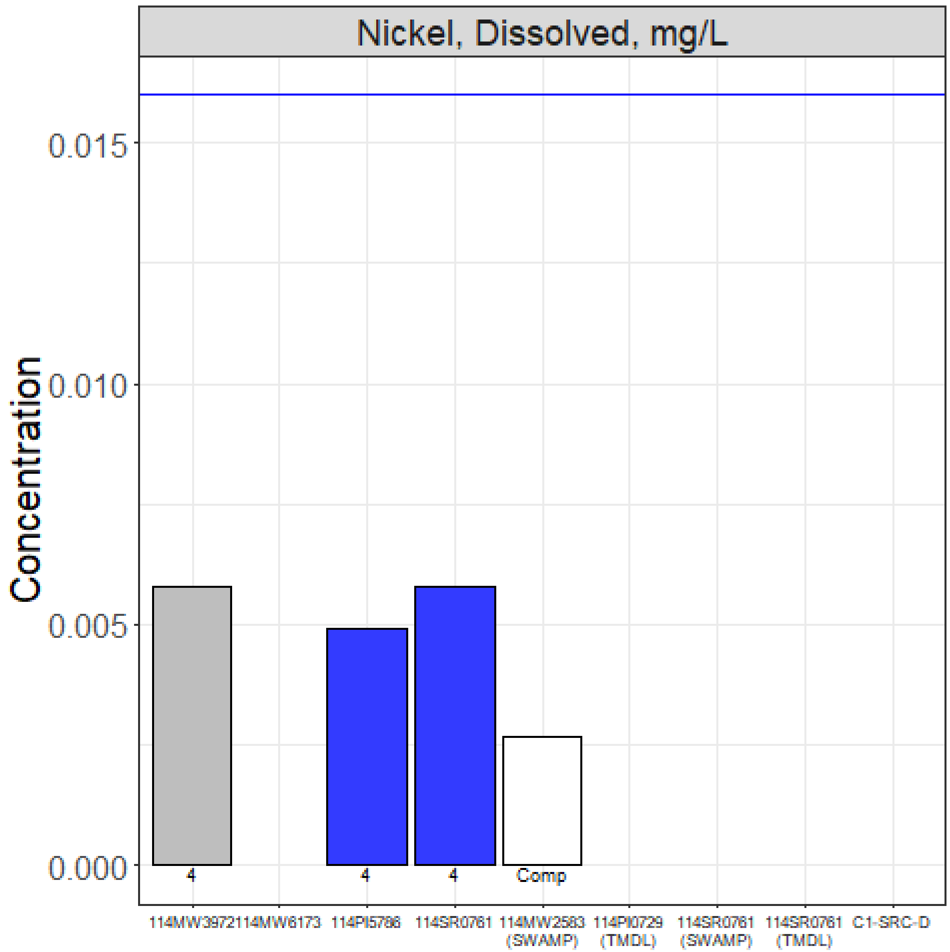


Figure D27. Concentrations of Dissolved Nickel measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** nickel is 0.016 mg/L. There is no Human Health and Welfare Protection Criteria.

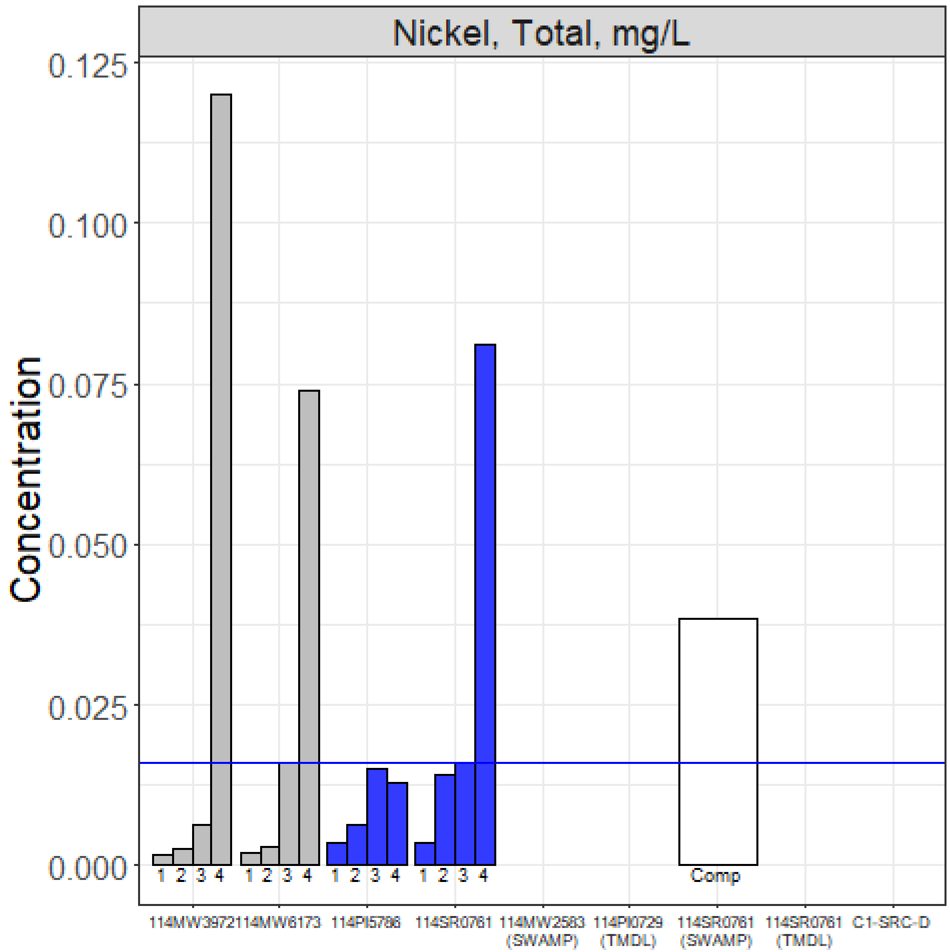


Figure D28. Concentrations of Total Nickel measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total nickel is 0.016 mg/L. There is no Human Health and Welfare Protection Criteria.

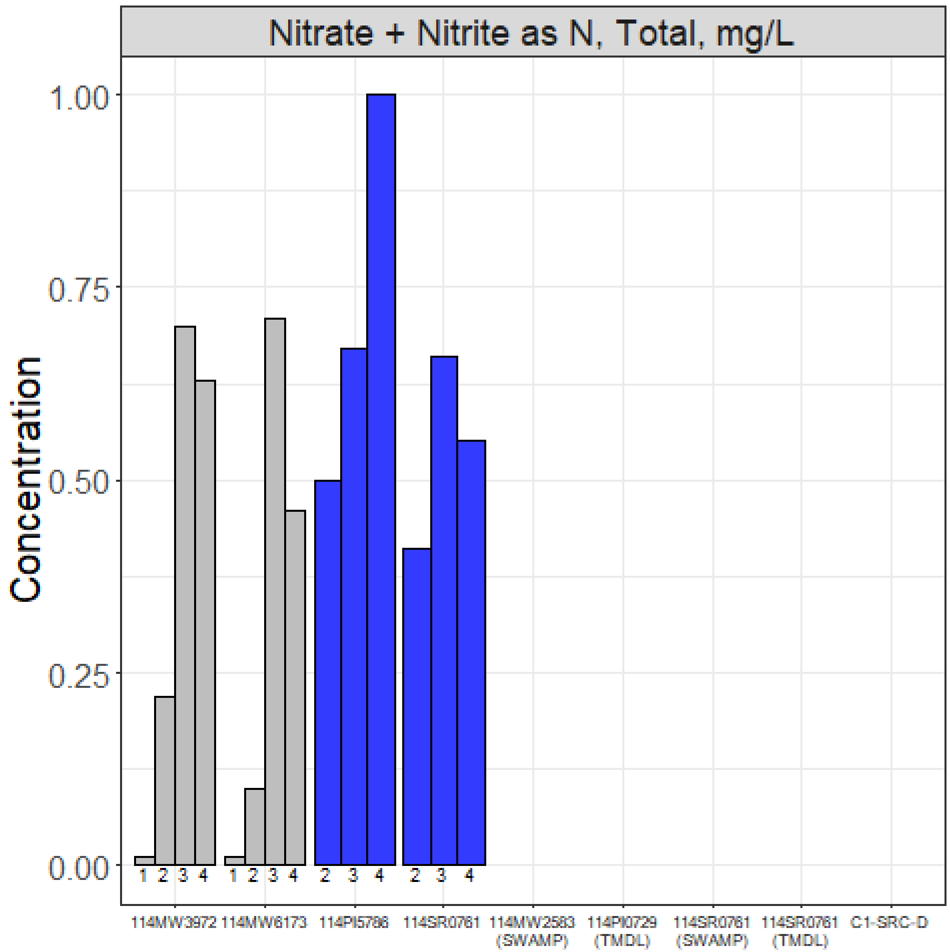


Figure D29. Concentrations of Nitrate + Nitrite as N measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for Nitrate + Nitrite as N.

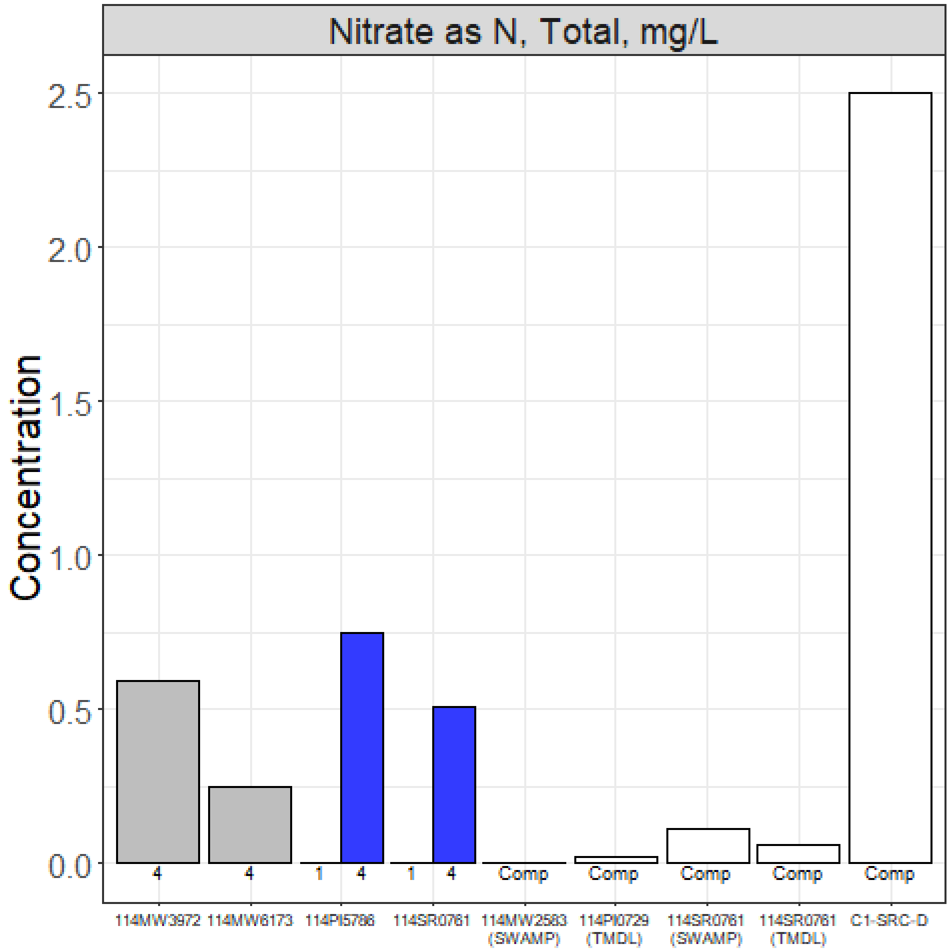


Figure D30. Concentrations of Nitrate as N measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for Nitrate as N. The Basin Plan Objective concentration is 10 mg/L but it is not plotted as it is off the chart area.

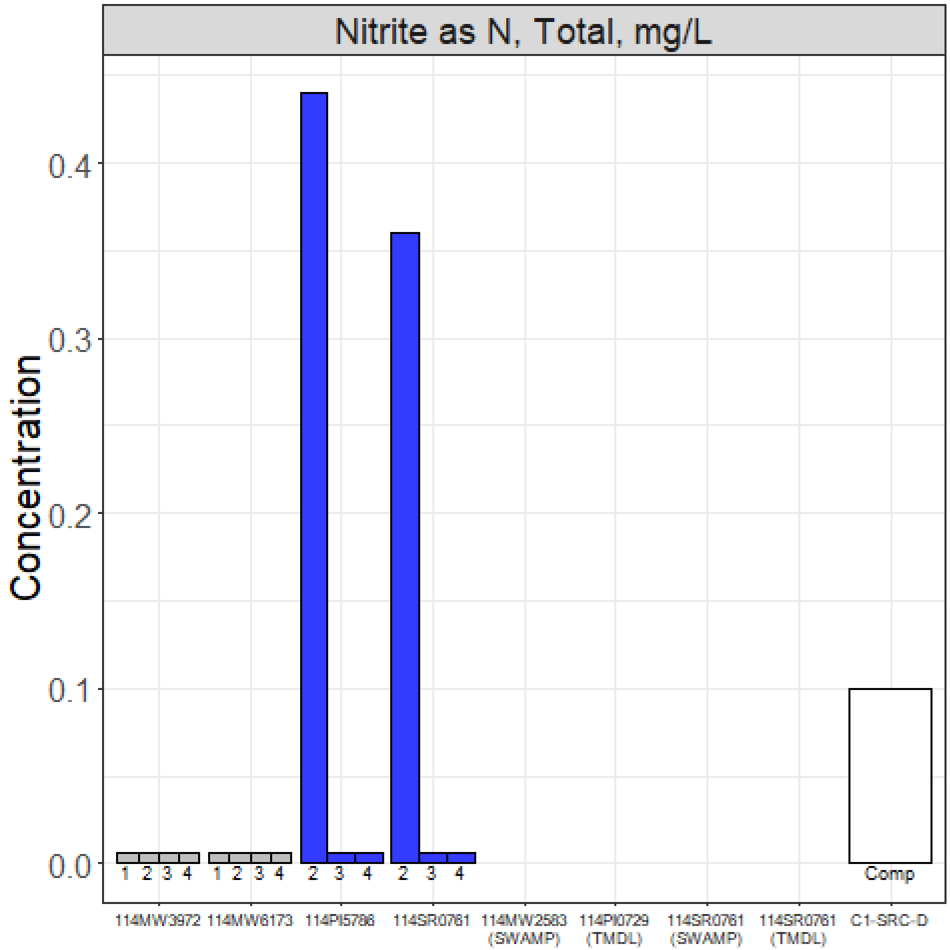


Figure D31. Concentrations of Nitrite as N measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for Nitrite as N. The Basin Plan Objective concentration is 1 mg/L but it is not plotted as it is off the chart area.

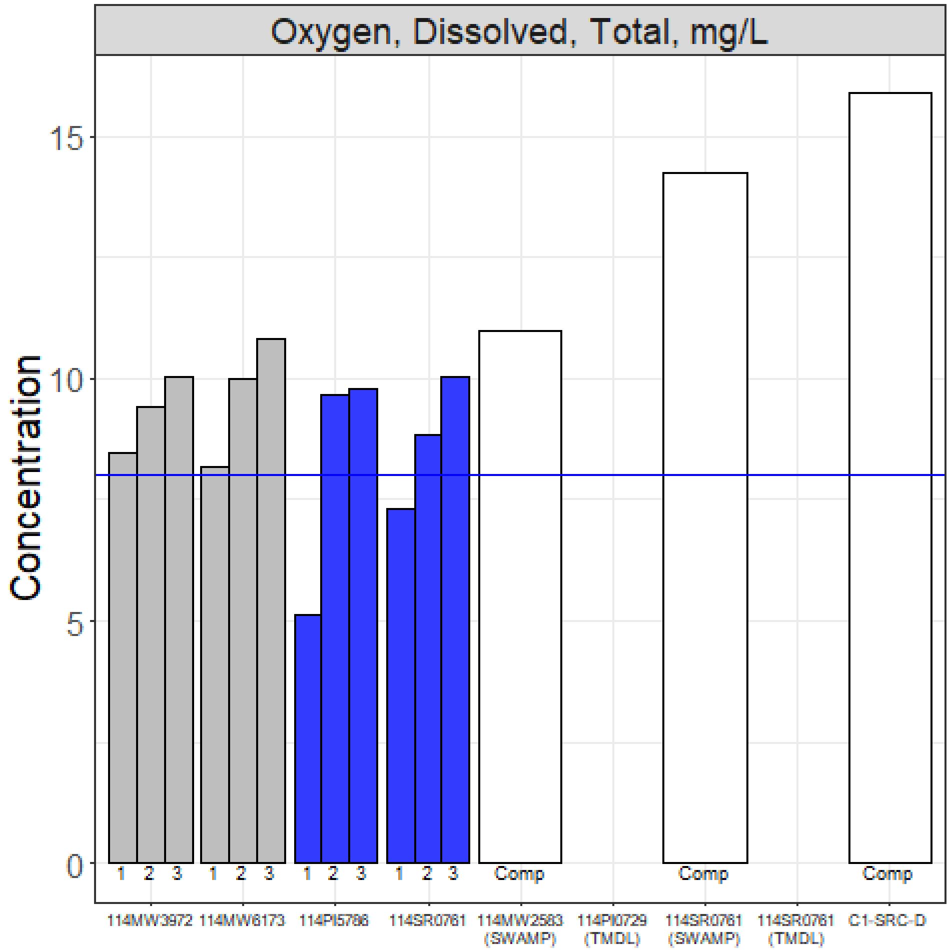


Figure D32. Concentrations of Dissolved Oxygen measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for Dissolved Oxygen is 8 mg/L. There is no Human Health and Welfare Protection Criteria.

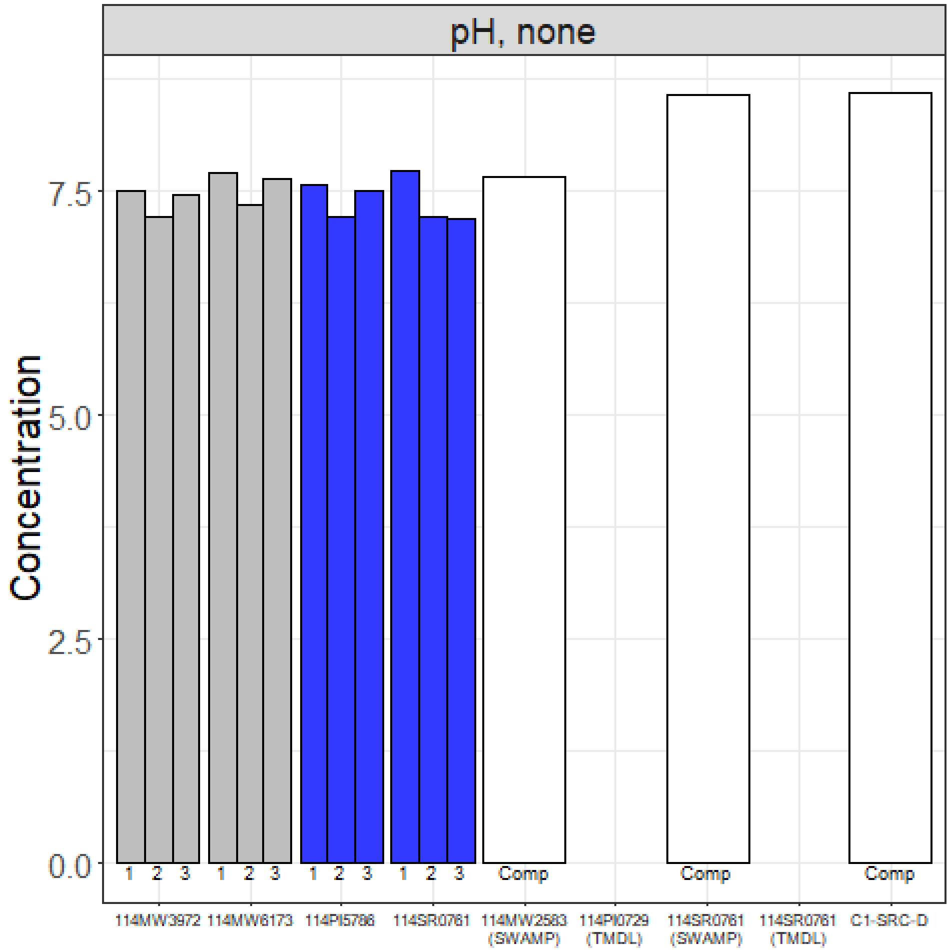


Figure D33. pH measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for pH is 6.5-9; the range is not depicted in the graph. The Human Health and Welfare Protection Criteria and the Basin Plan Objective is 6.5-8.5, also not depicted on the graph.

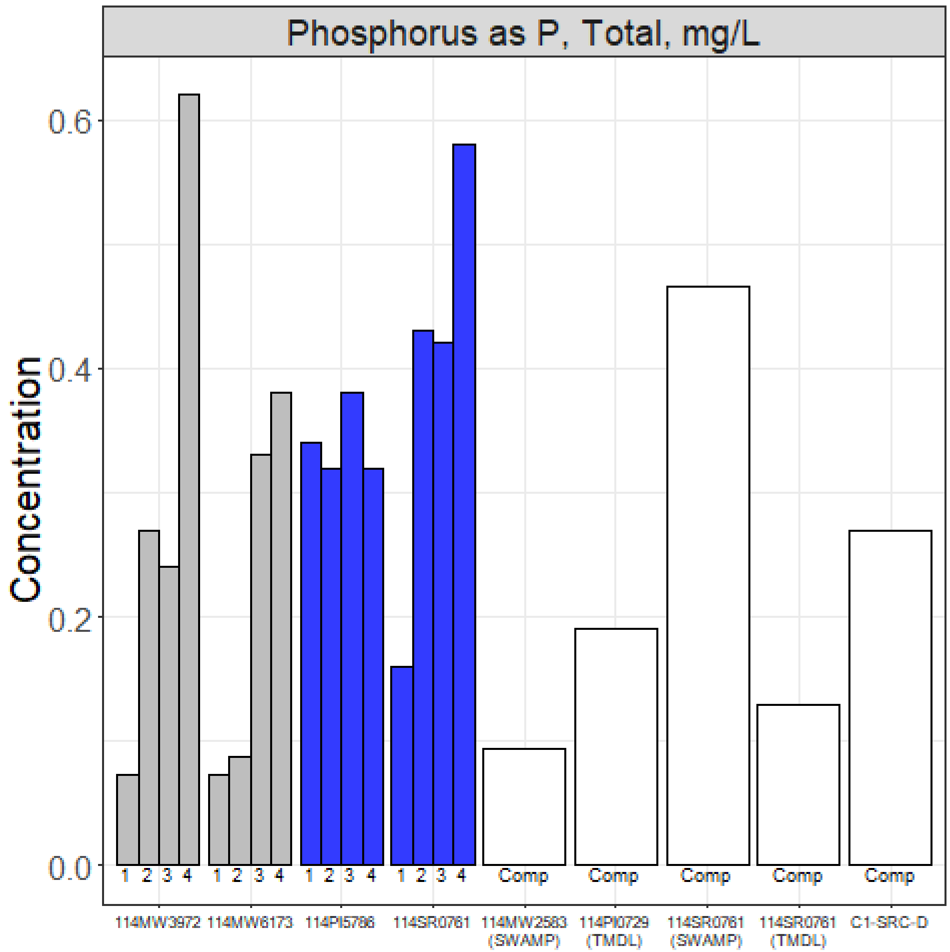


Figure D34. Concentrations of Total Phosphorus measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for Total Phosphorus.

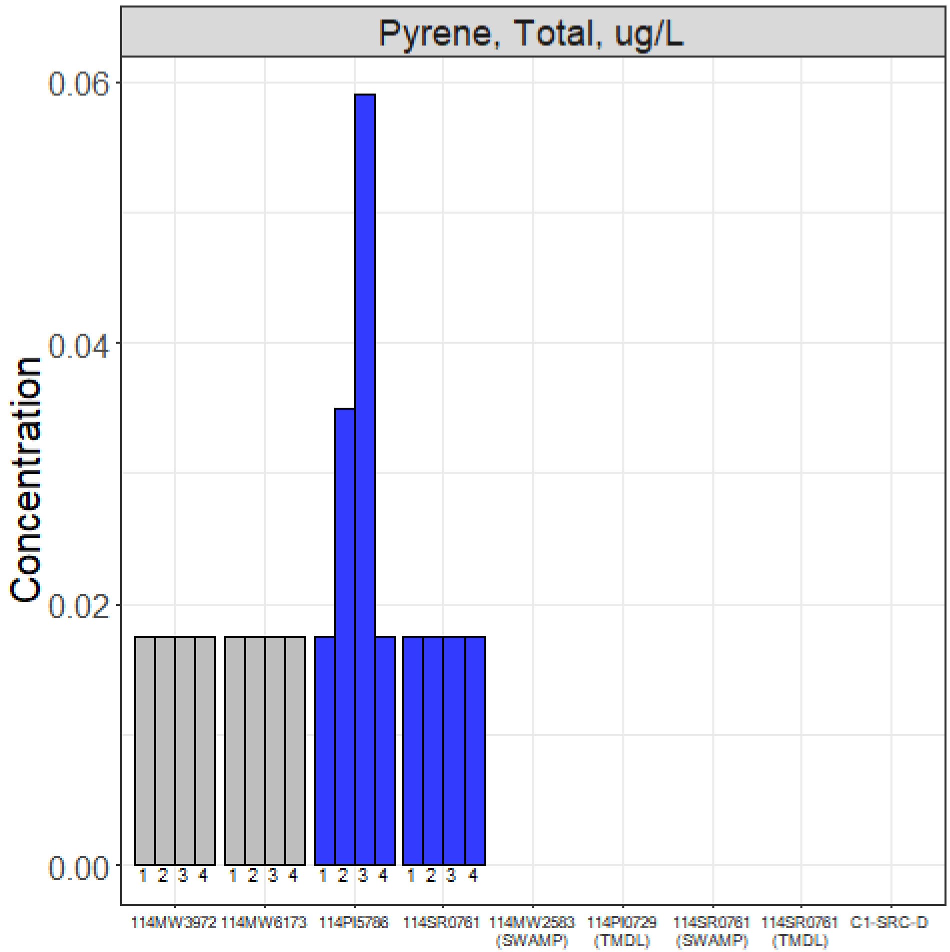


Figure D35. Concentrations of Pyrene measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for Pyrene. The Human Health and Welfare Protection Criteria is 20 ug/L but it is not plotted as it is off the chart area.

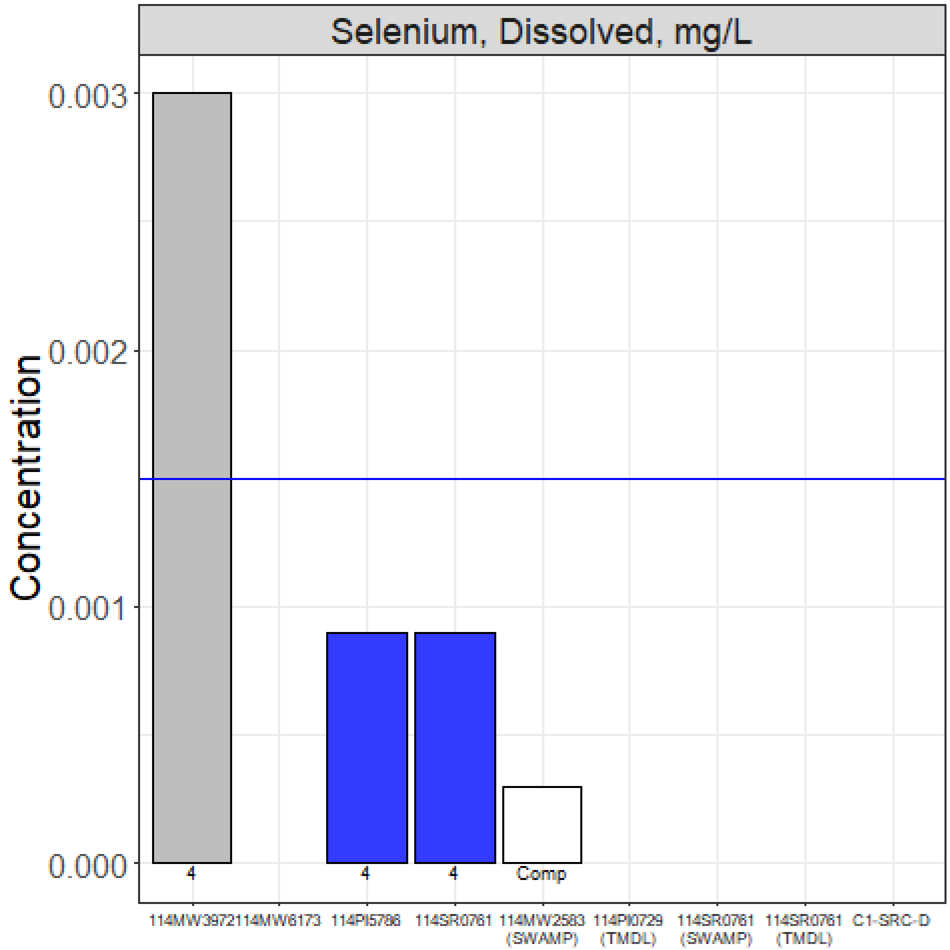


Figure D36. Concentrations of Dissolved Selenium measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** selenium is 0.0015 mg/L. There is no Human Health and Welfare Protection Criteria.

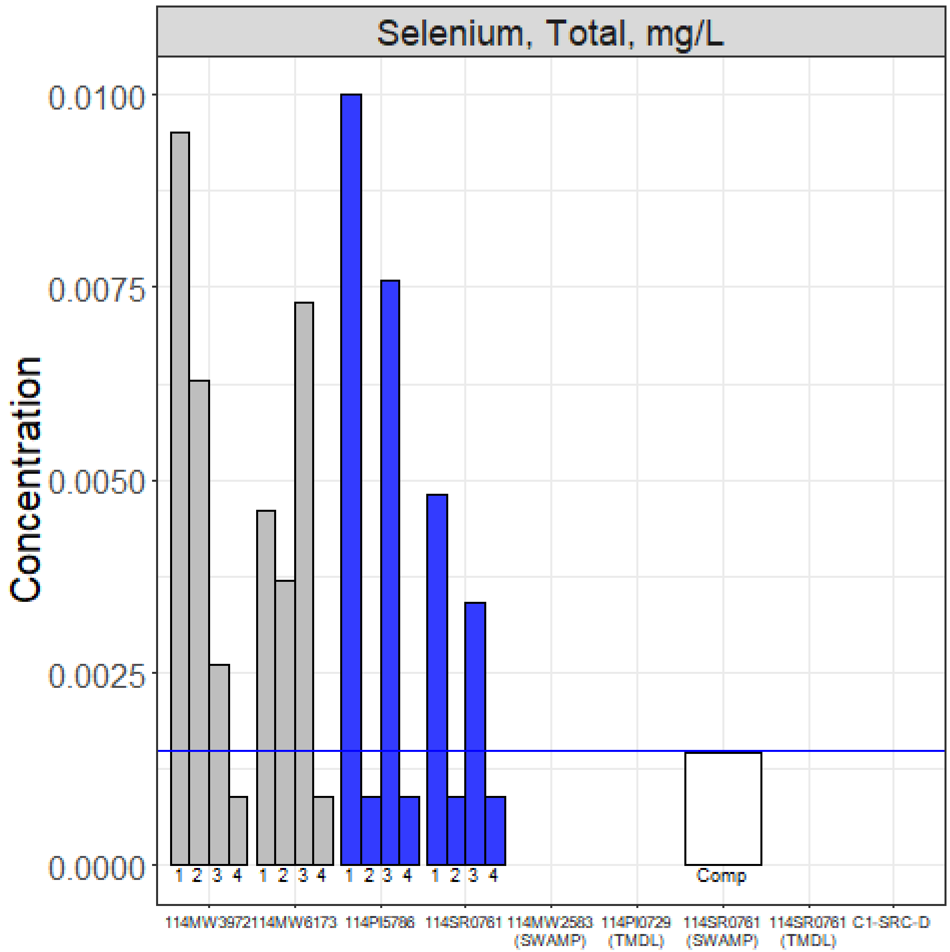


Figure D37. Concentrations of Total Selenium measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total selenium is 0.0015 mg/L. There is no Human Health and Welfare Protection Criteria.

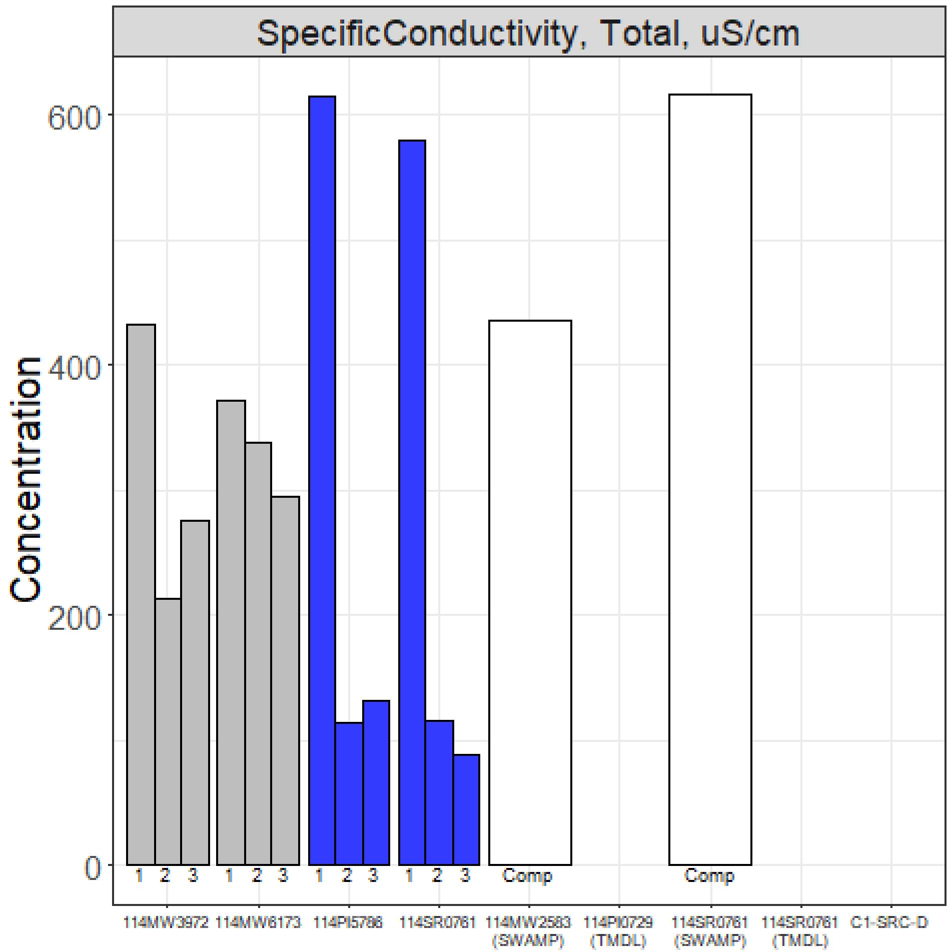


Figure D38. Specific Conductivity measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for specific conductivity. The Human Health and Welfare Protection Criteria is 900 ug/L (not graphed) and the Basin Plan Objective is 250-320 Mho (also not graphed).

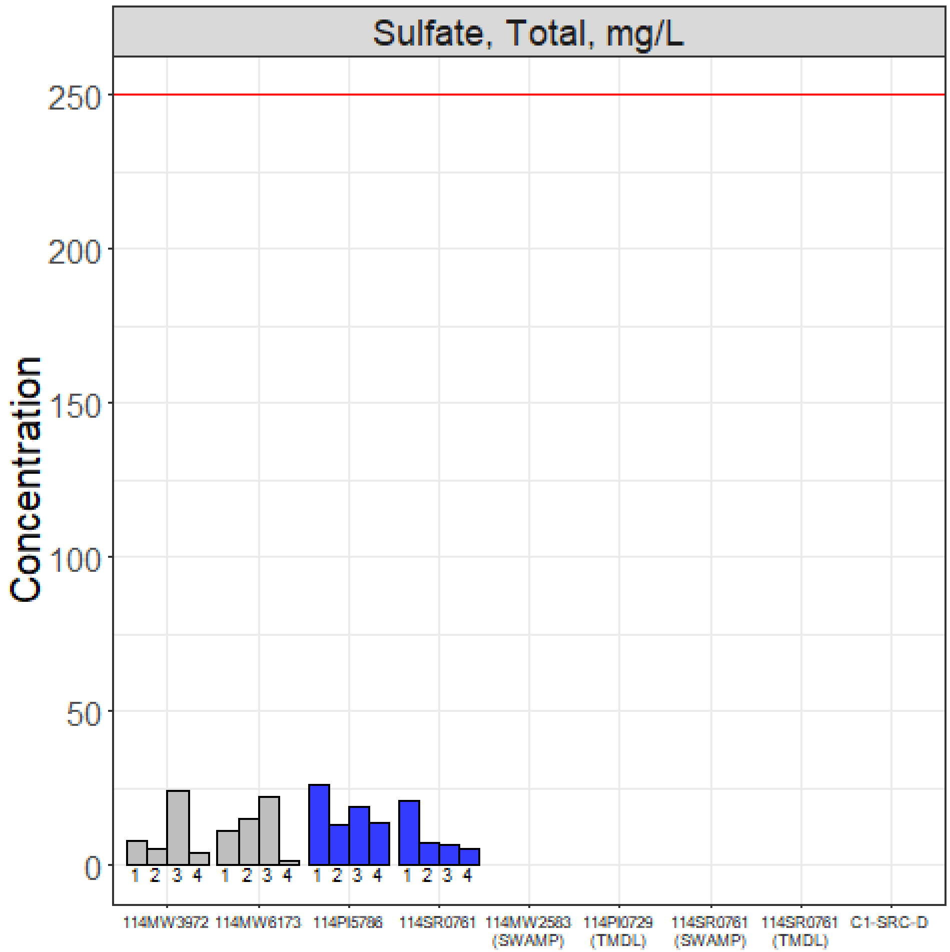


Figure D39. Concentrations of Total Sulfate measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for total sulfate. The Human Health and Welfare Protection Criteria is 250 mg/L.

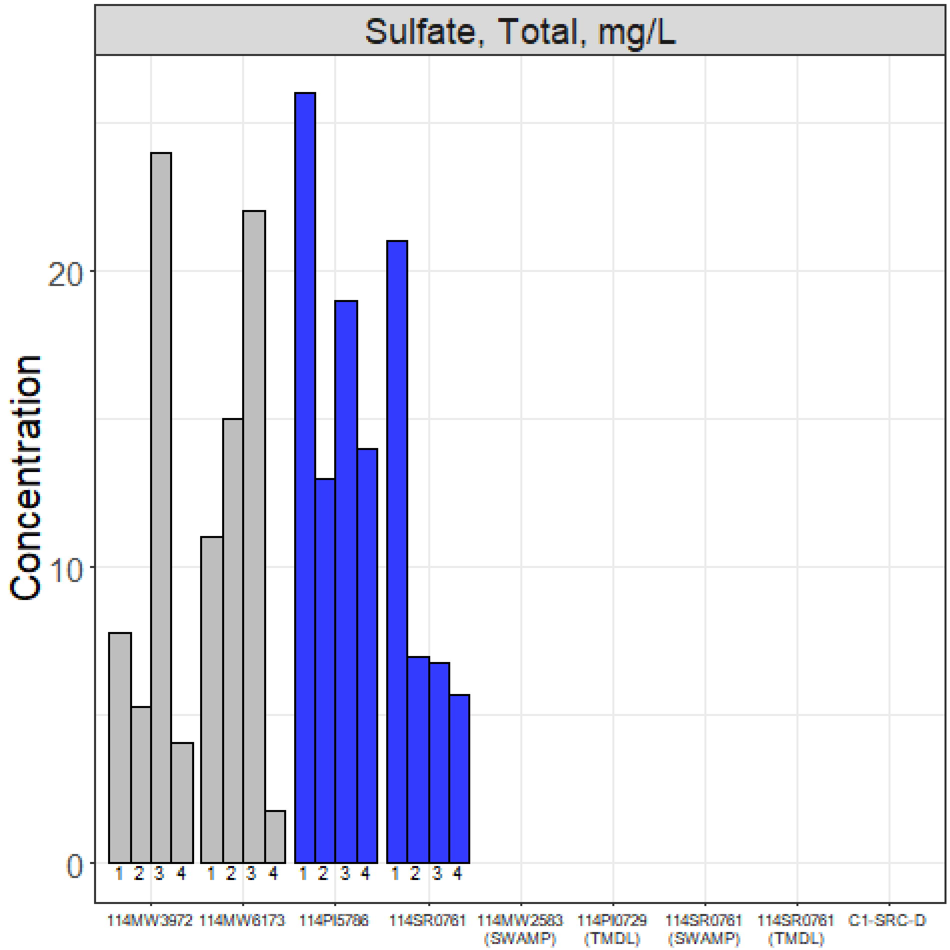


Figure D40. Concentrations of Total Sulfate measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for total sulfate. The Human Health and Welfare Protection Criteria is 250 mg/L (not graphed).

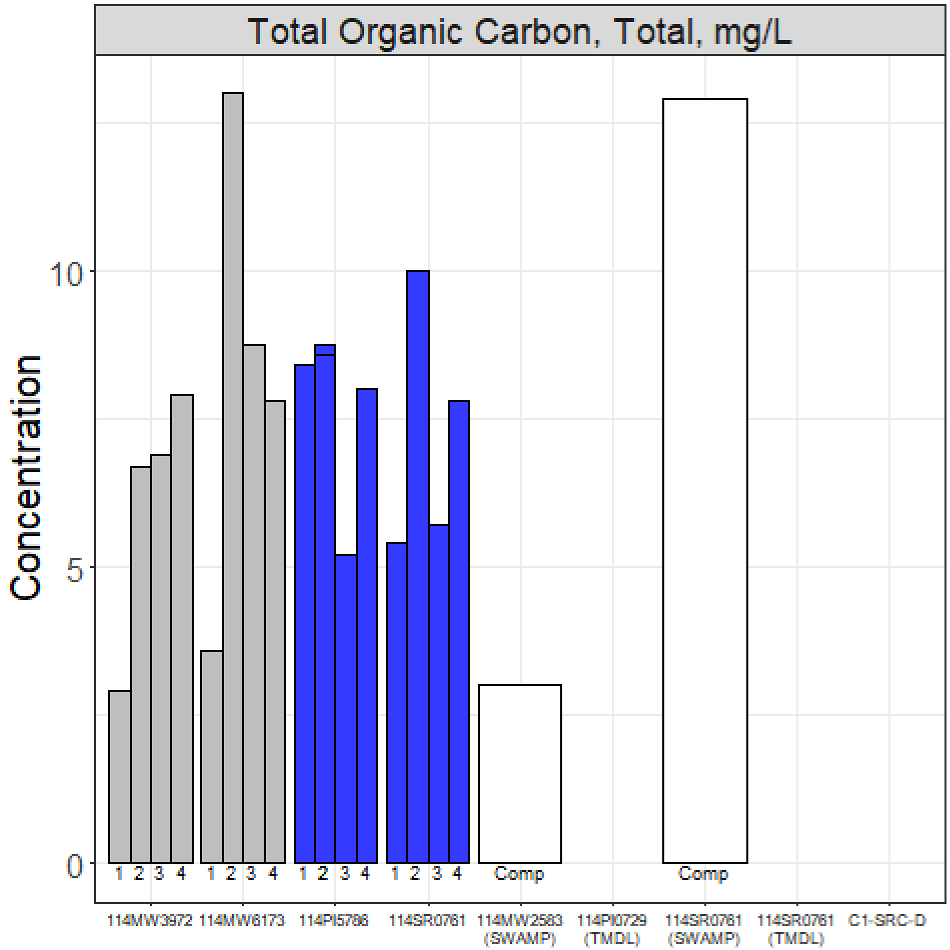


Figure D41. Concentrations of Total Organic Carbon measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for total organic carbon.

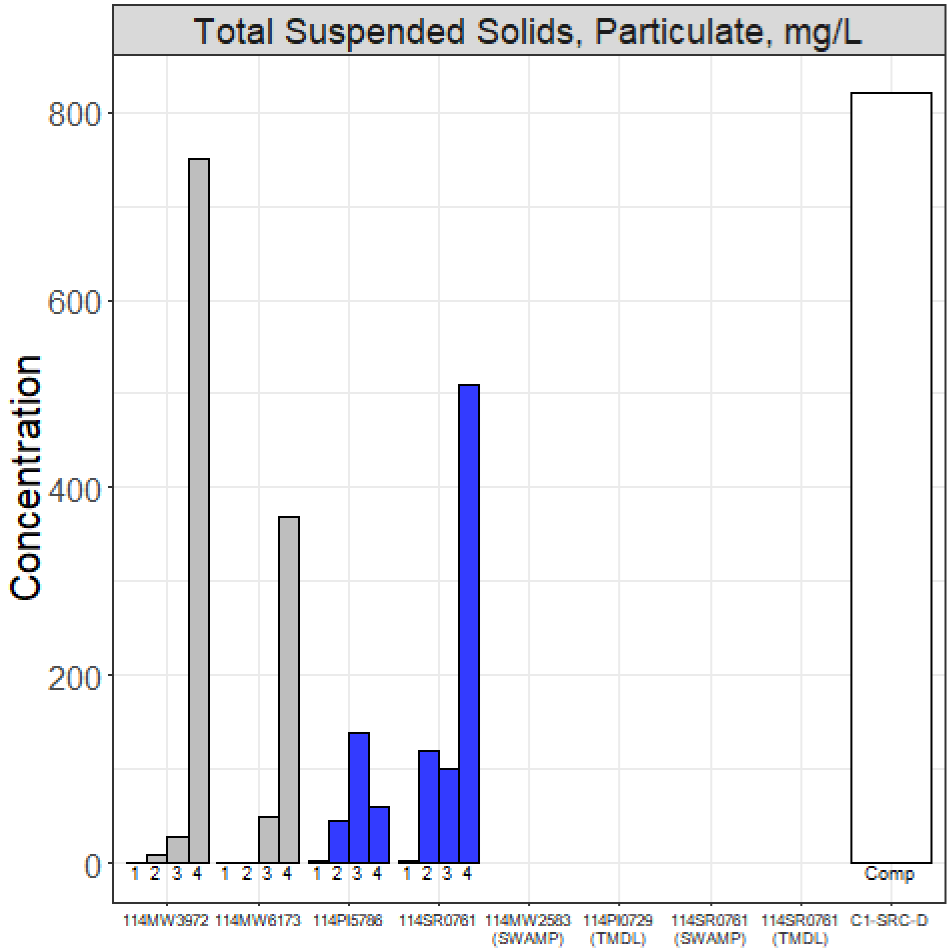


Figure D42. Concentrations of Total Suspended Solids measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria nor Human Health and Welfare Protection Criteria for total suspended solids.

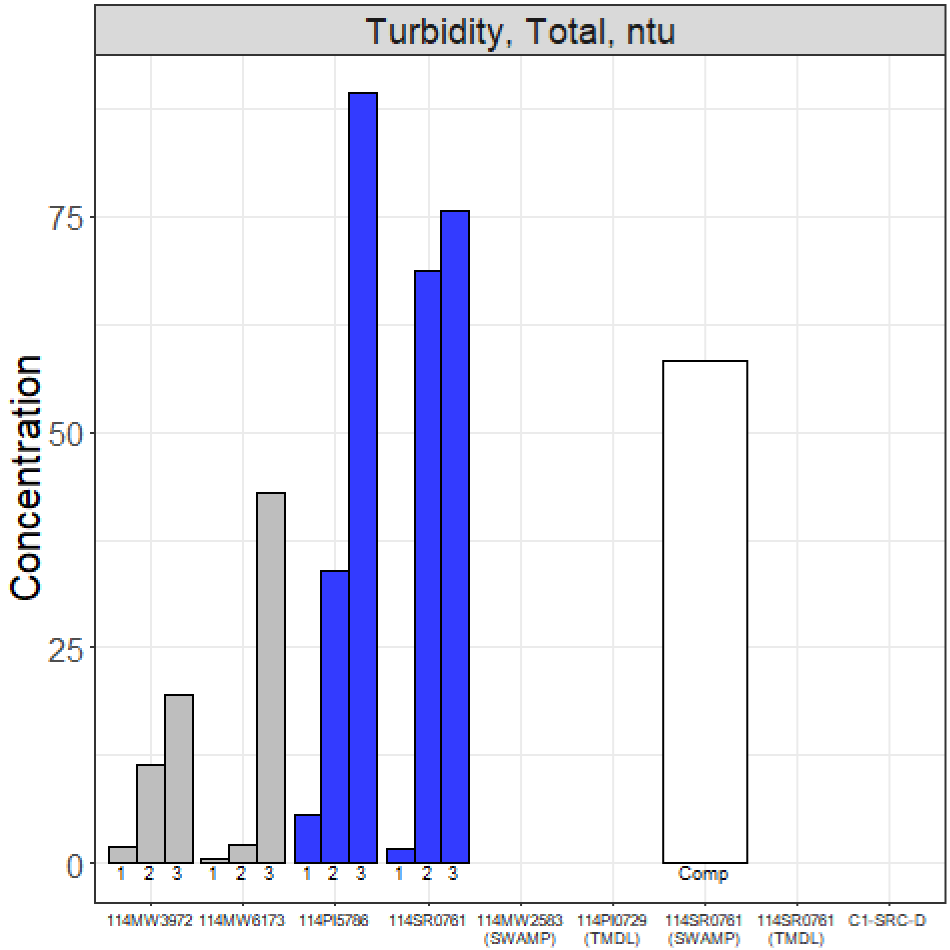


Figure D43. Turbidity measured in the fire monitoring stations and maximum of comparison sites, where available. There is no Aquatic Life Criteria for turbidity. The Human Health and Welfare Protection Criteria for turbidity is 1.0 ug/L.

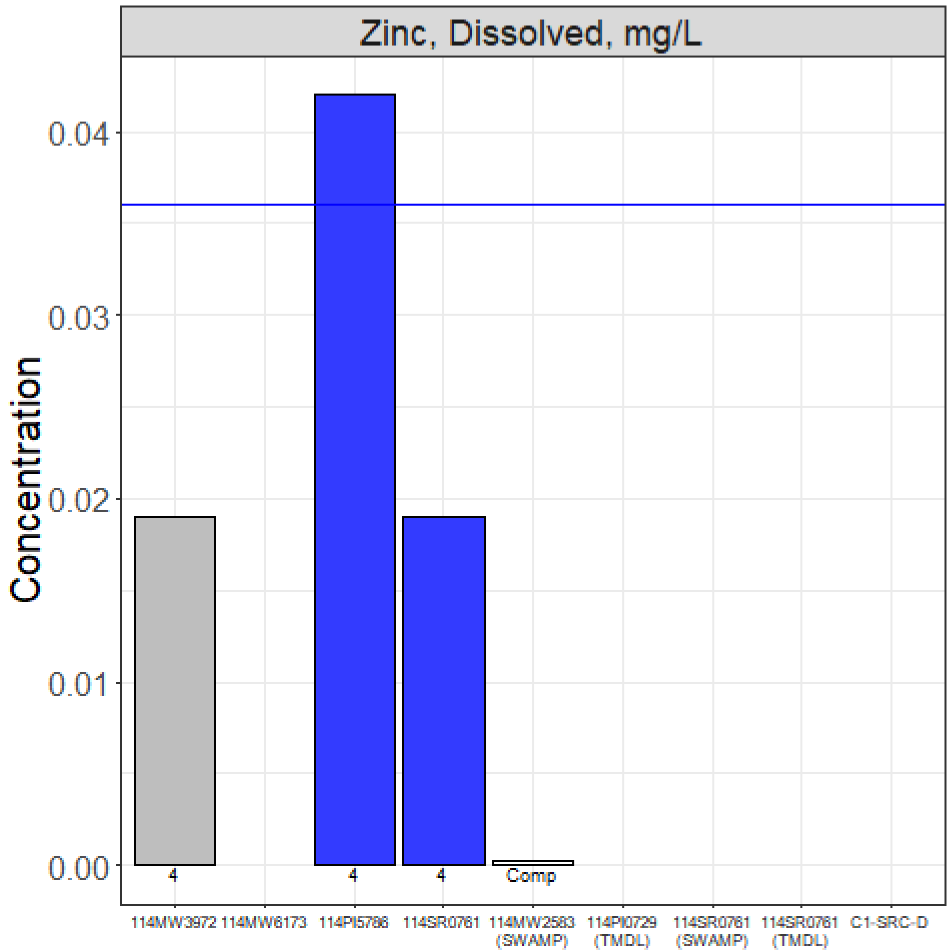


Figure D44. Concentrations of Dissolved Zinc measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for **total** zinc is 0.036 mg/L. The Human Health and Welfare Protection Criteria for total zinc is 5 mg/L and not graphed as it is off the chart.

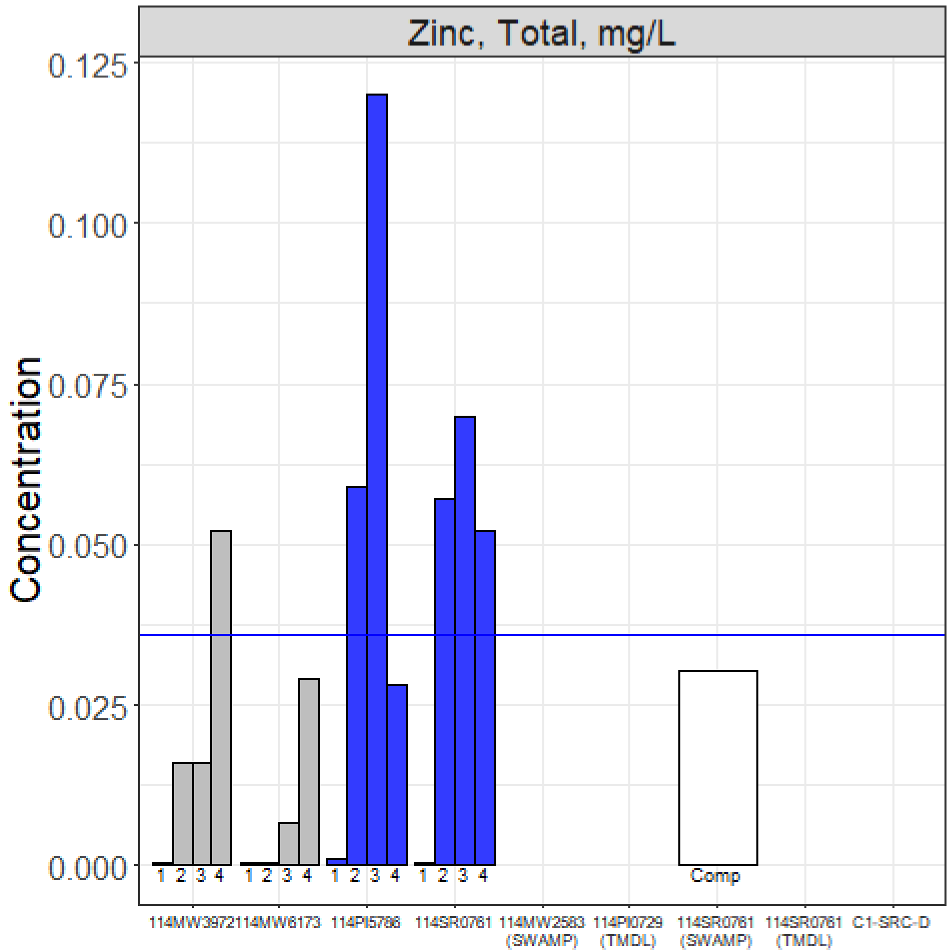


Figure D45. Concentrations of Total Zinc measured in the fire monitoring stations and maximum of comparison sites, where available. The Aquatic Life Criteria for total zinc is 0.036 mg/L. The Human Health and Welfare Protection Criteria for total zinc is 5 mg/L and not graphed as it is off the chart.