2023 Water Quality Adaptive Management Plan Report

Cabin Creek Pumped Storage Hydroelectric Project (FERC No. 2351)

Prepared for:
Public Service Company of Colorado
Clear Creek County, Colorado

Prepared by:
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March 2024

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Abbreviations and Acronyms

CPW	Colorado Parks and Wildlife
EPT taxa	mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa
FERC or Commission	Federal Energy Regulatory Commission
Project	Cabin Creek Pumped Storage Hydroelectric Project (FERC No. 2351)
PSCo	Public Service Company of Colorado
USFS	U.S. Forest Service
WQAMP	Water Quality Adaptive Management Plan
WQCD	Colorado Water Quality Control Division
WQCC	Colorado Water Quality Control Commission

1.0 Introduction

Public Service Company of Colorado (PSCo) owns and operates the Cabin Creek Pumped Storage Hydroelectric Project (Project) located on South Clear Creek and its tributary, Cabin Creek, in Clear Creek County, Colorado. On May 27, 2014, the Federal Energy Regulatory Commission (FERC or Commission) issued a new license under FERC Project No. 2351 for the continued operation of the Project, including direction to PSCo to implement the Water Quality Adaptive Management Plan (WQAMP or Plan) as filed with FERC on March 15, 2013 (PSCo 2013), including annual reporting on Plan activities.

PSCo filed the first annual report under the WQAMP on March 31, 2015, reporting on activities conducted in 2014. FERC acknowledged receipt of the report by letter dated June 3, 2015, and stated that the report satisfied the reporting requirements for the WQAMP for that year. In the June 3, 2015, letter, FERC staff advised that, while they will continue to review the annual report filings, staff will not issue acknowledgement letters for future filings under this license requirement, unless further Commission action is needed.

This report presents a summary of actions completed by PSCo under the WQAMP during 2023, towards the goal of minimizing the impacts of iron and manganese precipitate in South Clear Creek downstream of the Project. This is the final report under the WQAMP.

This report will be provided by March 31, 2024, to FERC, the U.S. Forest Service (USFS), Colorado Parks and Wildlife (CPW), and Colorado Water Quality Control Division (WQCD). As a courtesy, this report will also be provided to the Upper Clear Creek Watershed Association.

2.0 Activities Conducted During 2023

2.1 Water Quality and Precipitate Monitoring

PSCo contracted with HDR Engineering to conduct seasonal water quality monitoring in 2023, including surface water monitoring and metals precipitation monitoring, using methods consistent with previous efforts. Methods, results, and discussion are included in the report presented in Appendix A. Iron and manganese concentrations in 2023 are generally similar to historical results based on data collected annually since 2010. Precipitate accumulation monitoring results in 2023 continue to present higher iron accumulation at sites downstream of the Collection Ditch compared to sites upstream; the magnitude of manganese accumulation is generally very low and differences among sites may be within the margin of error for this type of sampling. In summary, consistent with previous years' studies, the 2023 results continue to support the theory that the Collection Ditch is the primary source of iron and manganese into South Clear Creek.

2.2 Fish and Macroinvertebrate Sampling

PSCo contracted with GEI Consultants to sample macroinvertebrates and fish during 2023, using methods consistent with previous efforts. Macroinvertebrate and fish sampling methods, results, and discussion are included in the reporting presented in Appendix B. Analysis of the 2023 macroinvertebrate data did not indicate attainment of the WQAMP goals for macroinvertebrate assemblages. MMI scores for two of the three downstream sites did not exceed the threshold indicating attainment of the aquatic life use in 2023, nor was statistically significant improvement observed between the pooled downstream samples from 2023 compared to pooled pre-treatment samples collected in years 2011, 2013, 2014, and 2015 for the number of metal intolerant taxa, number of EPT taxa, number of taxa, and number of mayfly taxa.

Fish sampling efforts indicated that Brook Trout are maintaining a viable, self-sustaining population in South Clear Creek below the Project, with increased density and biomass values relative to baseline data. However, relative weights of Brook Trout were not significantly different from pre-WQAMP conditions, and WQAMP goals for mean relative weight have not been met.

3.0 Post-WQAMP Activities

The year 2023 was the tenth and final year for WQAMP field implementation. During 2023, PSCo conducted the following activities:

- Continued water quality monitoring activities in 2023 with no change to 2022 protocols. Precipitate monitoring pavers were all removed from sample sites.
- Conducted macroinvertebrate sampling in fall 2023, with no change to 2022 sampling locations and methods.
- Conducted fish sampling in fall 2023, with no change to 2020 sampling location and methods.
- Prepared the tenth and final WQAMP annual report.

Under the WQAMP, success is defined as attainment of the MMI threshold at Sites D, E, and F; statistically significant improvement over baseline at Sites D, E, and F of the four individual macroinvertebrate metrics; Brook Trout mean population relative weight of 100 for fish over 130 mm in Year 10; and increase in Brook Trout biomass over baseline, with confidence intervals that do not overlap. Based on results from the 2023 Fish and Macroinvertebrate Report, these criteria for success have not been met.

WQAMP failure is defined as not meeting the goals identified for macroinvertebrate scores and metrics, and fish metrics by Year 10. Under this outcome, the WQAMP calls for PSCo to consult with USFS, CPW, and WQCD to develop a mutually agreed-upon off-site mitigation program to support fish habitat, or water quality restoration efforts in the Clear Creek basin, which may include petitioning the Colorado Water Quality Control Commission (WQCC) for site-specific standards if appropriate.

The WQAMP indicates that if PSCo is to proceed to an off-site mitigation program, consultation with the WQCD, USFS, and CPW shall include discussion to ensure that on-site measures conducted up to this time under the WQAMP are considered complete and representative of what feasibly could be conducted prior to investment in off-site measures. This may require petitioning of the WQCC for a site-specific evaluation of appropriate MMI values to describe the highest “attainable” aquatic life uses for the reach of stream between Lower Cabin Creek Reservoir and Clear Lake. The off-site mitigation could then proceed if the WQCC approved such a petition for this stream reach. If the petition was not approved, then further consultation would occur with the agencies regarding future on-site activities.

The WQCC held an Issues Scoping Hearing in November 2023, in advance of the Regulation No. 38 Rulemaking Hearing (for the South Platte River Basin) currently scheduled to occur in June 2025. PSCo provided written and verbal testimony during the November hearing indicating that it is exploring site-specific standards, as well as considering other regulatory options such as revisions to the water body segmentation and/or use classification. PSCo will continue to work with the agencies to evaluate the appropriate regulatory pathway for this portion of South Clear Creek.

4.0 References

Public Service Company of Colorado. 2013. Cabin Creek Pumped Storage Energy Project (FERC No. 2351), Water Quality Adaptive Management Plan. Public Service Company of Colorado. March 2013.

Appendix A.
Water Quality Monitoring Report

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2023 Water Quality Report

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January 2024

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1.0 Introduction

By Order Issuing New License dated May 27, 2014, the Federal Energy Regulatory Commission (FERC) issued a license to Public Service Company of Colorado (PSCo) for the Cabin Creek Pumped Storage Hydroelectric Project, FERC No. 2351 (Project) located on South Clear Creek and Cabin Creek in Clear Creek County, Colorado (FERC 2014). The Project's major features include an upper and lower dam and reservoirs, a power tunnel, two penstocks, a powerhouse, two step-up transformers, and access roads. The Project's authorized capacity is 336 MW.

PSCo is required by the new license to implement a Water Quality Adaptive Management Plan (WQAMP), which was filed with FERC on March 15, 2013 (PSCo 2013). This plan specifies 10 years of water quality monitoring, which concluded with the 2023 sampling. Macroinvertebrate and fish surveys were conducted by GEI prior to filing the WQAMP, during the FERC relicensing process, and during WQAMP implementation. Based on the macroinvertebrate surveys, the benthic macroinvertebrate community in South Clear Creek immediately downstream of the Lower Reservoir is stressed, likely a result of degraded water quality (GEI 2014; GEI 2017; GEI 2020; GEI 2022). Results of the fish surveys indicated a viable, self-sustaining brook trout population in South Clear Creek downstream of the Lower Reservoir; however, the numbers of adult fish, biomass, and fish condition were lower than sites surveyed upstream of the Project. In 2011, the brook trout were found to be below average in body mass, likely a result of inadequate food sources related to the reduced community of macroinvertebrates (PSCo 2013). The 2017 fish results indicated an increase in numbers, and an increase in average mean lengths and weights of brook trout; however, brook trout weights remained less than the relative weight goal of 100 percent (GEI 2017). Groundwater captured by the relief well system within the Lower Reservoir dam and the Collection Ditch system is discharged to South Clear Creek below the Lower Reservoir. The discharged water contains elevated concentrations of reduced ferrous iron, which oxidizes when exposed to the atmosphere. The oxidizing iron is believed to be impacting the macroinvertebrate population (PSCo 2013).

Construction of a modified relief well gravity system on the east side of the emergency spillway was completed in September 2017. This system was designed to improve system drainage and provide increased aeration and on-site precipitation of metals. The work also included reconstruction of the Collection Ditch. This monitoring year, 2023, was the sixth full year of monitoring since these changes were implemented. Flow from the relief well overflow (RWO) stopped during the 2017 construction and had yet to resume in 2023. Additionally, the groundwater spring (SP) appears to have been intercepted by the reconstructed Collection Ditch as no flow has been observed since the reconstruction. As such, no samples were collected from these two sample sites in 2023, similar to recent years.

Activities since the WQAMP was first implemented in 2014 have included water quality monitoring and research activities related to the presence and chemistry of metals in South Clear Creek downstream of the Lower Reservoir, seasonal water quality monitoring, and installation and monitoring of iron and manganese precipitate monitoring tiles. PSCo also implemented a yearlong pilot study program including tailored water quality data collection September 2020 through August 2021. Results of water quality data collection efforts specific to the pilot study are presented in the Aeration Pilot Study Report (HDR 2021b).

This report documents the water quality monitoring activities conducted in 2023, the final year of monitoring under the WQAMP.

2.0 2023 Water Quality Monitoring Activities

2.1 Water Quality Monitoring

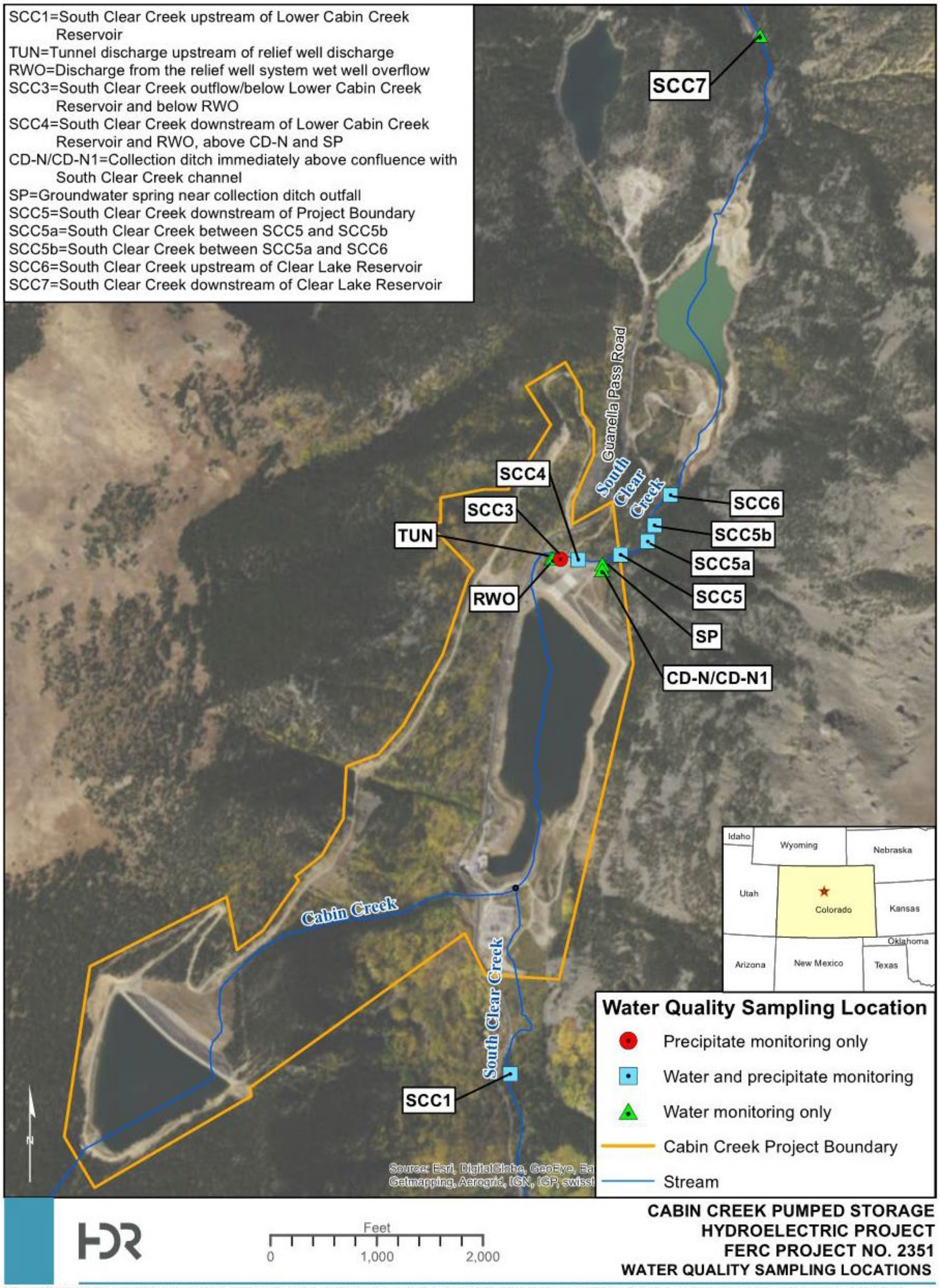
A detailed description of the water quality monitoring program is provided in the WQAMP (PSCo 2013). Routine water quality samples are collected from the following locations, listed in successive order from upstream to downstream:

- SCC1 – South Clear Creek upstream of the Lower Reservoir;
- TUN – Tunnel discharge upstream of the relief well discharge;
- RWO – Discharge from the relief well system overflow. This site has been dry and not sampled since 2017;
- SCC4 – South Clear Creek downstream of the Lower Reservoir and RWO, above the (old and new) Collection Ditch and SP;
- CD-N – Collection Ditch above the confluence with South Clear Creek channel. This sample identifier refers to the “old” Collection Ditch installed and active prior to the July 2017 construction of the new ditch. This site is no longer sampled;
- CD-N1 – Collection Ditch above confluence with South Clear Creek channel. This sample identifier refers to the “new” Collection Ditch completed in August 2017;
- SP – Groundwater spring near Collection Ditch outfall. Due to the 2017 construction, the spring no longer flows in this location and appears to have been intercepted by the reconstruction of the Collection Ditch. Samples have not been collected since 2017;
- SCC5 – South Clear Creek downstream of Project boundary;
- SCC5a – South Clear Creek between SCC5 and SCC5b;
- SCC5b – South Clear Creek between SCC5a and SCC6;
- SCC6 – South Clear Creek upstream of the Clear Lake Reservoir; and
- SCC7 – South Clear Creek downstream of the Clear Lake Reservoir.

Sampling locations are shown on **Figure 1**. The sampling locations in the WQAMP are identical to sampling locations used in HDR’s previous surface water quality characterization of the site, with two exceptions (HDR 2011; HDR 2015). The exceptions are SCC5b and SCC7, which have since been added to the monitoring program. SCC5b is located between SCC5a and SCC6 and sampling was initiated in 2015 to better characterize the oxidation of iron and manganese. SCC7 is located downstream of Clear Lake and sampling was initiated in 2016 to document concentrations of metals below the lake.

Routine water quality monitoring was conducted in April, June, August, September, and October 2023 at the above-listed locations for the following parameters: field measurements of temperature, dissolved oxygen (DO), pH, specific conductance, and oxidation-reduction (redox) potential (ORP); and laboratory analysis of total recoverable iron, dissolved iron, total recoverable manganese, dissolved manganese, and total hardness. A detailed description of field sampling methods is provided in the WQAMP (PSCo 2013).

Figure 1. Water Quality Sampling Locations



2.2 Metals Precipitation Monitoring

PSCo initiated a precipitate monitoring program in South Clear Creek in 2014. A detailed description of the methods used for this monitoring is included in the 2014 Water Quality Report (HDR 2015). In summary, unglazed porcelain tiles are fastened to paver blocks and immersed in South Clear Creek for varying durations ranging from two to 10 months. At the end of the designated immersion period, the tiles are removed from the stream, detached from the paver blocks, and digested in an acid bath. The bath is then chemically analyzed for iron and manganese. The precipitate monitoring program was continued through 2023 with sets of tiles placed at six locations (SCC3, SCC4, SCC5, SCC5a, SCC5b, and SCC6). Location SCC3 is just downstream of the RWO, and all other locations coincide with surface water quality sampling locations described in **Section 2.1**.

Table 1 shows the scheduled immersion periods for each set of tiles (identified as P1, P2, P3, etc.) during the 2023 precipitate monitoring. Tile sets were retrieved and analyzed in April, June, August, and October 2023. Note that tiles identified as P4 no longer exist within the sampling program; these tiles of 12-month duration were removed from the sampling program in 2020 (PSCo 2020). The precipitate monitoring is complete, and all tile sets have been removed from sample locations.

Table 1. Scheduled Immersion Periods for 2023 Precipitate Monitoring

Paver Number	Jun '22		Aug '22		Oct '22						Apr '23		Jun '23		Aug '23		Oct '23
											P1						
											P2						
											P3						
													P5				
															P6		
					P7 (2022)												
													P8				
	P9 (2022)																
			P10 (2022)														

3.0 2023 Monitoring Results

Field measurements and analytical results for each 2023 water quality sampling event are included in **Appendix A**. These data have been compiled into a table and charts with historic data in **Appendix B**. When a sample result was non-detect, half of the reporting limit was used for the charts presented in **Appendix B**. Results of the 2023 precipitate monitoring are provided in **Appendix C** and other various tables or graphs in this report. U.S. Geological Survey (USGS) flow data were obtained for gages located within the study area, including USGS 06714400 South Clear Creek upstream of Cabin Creek Lower Reservoir, which is located near SCC1; and USGS 06714500 South Clear Creek at the Cabin Creek Lower Reservoir outlet tunnel, which is located near TUN. The South Clear Creek hydrographs have been included in **Appendix D**.

3.1 Deviations and Modifications from the Monitoring Plan

Minor deviations were encountered from the precipitation monitoring plan during the 2023 monitoring, as several pavers were out of water or overturned. These instances are detailed below:

- September 2022, SCC5, the mesh containing P10 (2022) was found to be flipped over. All tiles were submerged, but found upside down, which may have influenced accumulation. The mesh was returned to proper position upon discovery, and tiles were subsequently collected for analysis in April 2023.
- April 2023, SCC4, P10 (2022) and P9 (2022) mesh was submerged in place, but pavers were out of water due to varying water levels. These paver sets were collected for analysis.
- April 2023, SCC3, P7 (2022) mesh was submerged in place, but pavers were out of water due to varying water levels. This paver set was collected for analysis.
- April 2023, SCC6, P9 (2022) mesh was submerged in place, but pavers were out of water due to varying water levels. This paver set was collected for analysis.
- August 2023, SCC5B, P5 mesh was submerged in place, but pavers were out of water due to varying water levels. This paver set was collected for analysis.

The pavers are checked only during the April to October timeframe during sampling events and they could be unsubmerged at times during the winter months.

The only water quality monitoring deviations from the schedule were at sites SCC7, RWO, and SP. These sites were dry during some or all sampling events and as such were not sampled.

3.2 Surface Water Quality Results

The complete results of water chemistry monitoring, including results not discussed below, are tabulated by sampling event in **Appendix A**. These data have been compiled into a table and charts with historic data dating back to 2014 in **Appendix B**.

A brief summary of water chemistry analysis results for the dissolved and total recoverable iron, dissolved and total recoverable manganese, DO, and pH is provided below. Iron and manganese are included as the target parameters of the WQAMP, and pH and DO are parameters important to controlling the rates of oxidation of iron and manganese (HDR 2014). Additional data evaluation and discussion are included in **Section 4** of this report.

Iron

Iron concentrations in 2023 are generally similar to historical results with few outliers. The location specific minima for dissolved iron at SCC7 (20.6 µg/L) was observed in September. No other location specific minima or maxima for total or dissolved iron were observed in the 2023 sampling.

The following sample results were greater than the historic mean plus the standard deviation:

- Total iron:
    - April, SCC5 (1590 µg/L)
    - April, SCC6 (1230 µg/L)

- Dissolved iron:
    - April, SCC5 (1360 µg/L)
    - April, SCC5a (1290 µg/L)
    - April, SCC5b (715 µg/L)

There were no total iron sample results less than the historic mean minus the standard deviation. The following dissolved iron sample results were less than the historic mean minus the standard deviation:

- Dissolved iron:
    - June, CD-N1 (2970 µg/L)
    - September, SCC7 (20.6 µg/L), also the location specific minima as previously noted
    - October, SCC7 (27.8 µg/L)

The other total and dissolved iron sample results were within one standard deviation above and below the historical mean, suggesting that most sample results from 2023 are typical to previous values. Iron results at CD-N1 are consistently greater than instream measurements. The 2023 sample results are summarized in **Tables 2** and **3** below along with historical data.

Table 2. Total Iron Summary Statistics 2010 – 2022 and 2023 Data (μg/L)

	SCC1	TUN	RWO	SCC4	CD-N	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
Historic Samples (2010-2022)												
Count	47	48	20	49	20	35	20	54	52	46	52	23
Minimum	55	33	10	34	20	3310	7800	96	170	200	190	68
Maximum	490	3700	6700	620	2500	8000	15000	2500	4100	3300	1500	1450
Mean	171	233	2624	144	1053	4422	12588	750	942	811	574	315
Std Dev (σ)	95	654	2280	111	913	1026	2199	689	772	655	313	393
Mean – σ	75.7	-421	344	33.1	139	3396	10389	60.4	170	157	261	-78.5
Mean + σ	266	886	4904	256	1966	5448	14787	1439	1714	1466	887	708
2023 Samples												
4/24/2023	126	150	no sample	147	no sample	3520	no sample	**1590**	1700	1400	**1230**	no sample
6/21/2023	159	110	no sample	111	no sample	3430	no sample	141	228	257	262	151
8/3/2023	184	72.0	no sample	81.9	no sample	3530	no sample	176	317	284	452	166
9/20/2023	109	63.4	no sample	64.0	no sample	3700	no sample	118	328	303	315	114
10/27/2023	82.2	153	no sample	108	no sample	3690	no sample	498	529	461	693	224

Bold underline Greater than Mean + σ

Table 3. Dissolved Iron Summary Statistics 2010 – 2023 and 2024 Data (µg/L)

	SCC1	TUN	RWO	SCC4	CD-N	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
Historic Samples (2010-2022)												
Count	47	48	20	49	20	35	20	54	52	46	52	23
Minimum	23.0	2.5	2.5	2.5	14.0	2930	3700	24.0	33.0	60.0	57.0	27.0
Maximum	138	2500	6200	290	2400	7200	14000	1900	1620	1180	576	150
Mean	59.4	79.5	2469.1	45.1	902.5	3787	11326	523.3	540.7	411.0	243.0	59.6
Std Dev (σ)	27.4	361.7	2049.2	65.0	832.8	732.3	3096.6	564.2	454.4	286.2	135.4	26.7
Mean – σ	32.0	-282	420	-19.9	69.7	3055	8229	-40.9	86.2	125	108	32.9
Mean + σ	86.8	441	4518	110	1735	4520	14423	1088	995	697	378	86.3
2023 Samples												
4/24/2023	55.8	22.5	no sample	24.6	no sample	3200	no sample	**<u>1360</u>**	**<u>1290</u>**	**<u>715</u>**	377	no sample
6/21/2023	39.3	33.7	no sample	33.6	no sample	***2970***	no sample	54.4	117	133	120	57.8
8/3/2023	49.3	15.7	no sample	16.9	no sample	3150	no sample	90.7	186	142	117	48.3
9/20/2023	45.2	< 10	no sample	< 10	no sample	3280	no sample	40.7	189	156	122	***20.6***
10/27/2023	35.6	< 10	no sample	< 10	no sample	3340	no sample	232	336	235	169	***27.8***

[shaded] Location-specific minima

<u>Bold underline</u> Greater than Mean + σ   ***Bold Italic*** Less than Mean – σ

Manganese

Manganese concentrations in 2023 are similar to historical results; however, some outliers were observed. The location specific minima for dissolved manganese at CD-N1 (418 µg/L) was observed in April. Several dissolved manganese sample results were non-detected above the reporting limit (2.00 µg/L), which has previously occurred. These "non-detect" results are indicated in Table 5, as "<2.00 µg/L". Dissolved manganese <2.00 µg/L matched the location specific minima at TUN (June and August), SCC4 (June, August, and September), and SCC7 (June and August). No other location specific minima or maxima for total or dissolved manganese were observed in the 2023 sampling.

The following sample results were greater than the historic mean plus the standard deviation:

- Total manganese:
    - April, SCC5a (243 µg/L)
    - April, SCC5b (233 µg/L)
    - April, SCC6 (213 µg/L)
- Dissolved manganese:
    - April, SCC5 (203 µg/L)
    - April, SCC5a (244 µg/L)
    - September, SCC7 (2.50 µg/L)
    - October, SCC7 (3.60 µg/L)

The following sample results were less than the historic mean minus the standard deviation:

- Total manganese:
    - April, SCC1 (3.07 µg/L)
    - April, CD-N1 (423 µg/L)
    - June, CD-N1 (429 µg/L)
    - June, SCC5a (20.5 µg/L)
    - June, SCC5b (23.4 µg/L)
    - June, SCC6 (23.6 µg/L)
    - October, SCC1 (3.60 µg/L)
- Dissolved manganese:
    - April, SCC1 (2.40 µg/L)
    - April, CD-N1 (418 µg/L), also the location specific minima as previously noted
    - June, SCC1 (2.00 µg/L)
    - June, CD-N1 (440 µg/L)
    - June, SCC5a (18.8 µg/L)
    - June, SCC5b (20.9 µg/L)
    - June, SCC6 (20.2 µg/L)
    - August, CD-N1 (439)
    - September, CD-N1 (451 µg/L)

The other total and dissolved manganese sample results were within one standard deviation above and below the historical mean. Manganese results at CD-N1 are consistently greater than instream measurements.

The 2023 sample results are summarized in **Tables 4** and **5** below along with historical data.

Table 4. Total Manganese Summary Statistics 2010 – 2022 and 2023 Data (in µg/L)

	SCC1	TUN	RWO	SCC4	CD-N	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
Historic Samples (2010-2022)												
Count	36	36	7	36	7	35	8	43	43	42	43	23
Minimum	3.00	1.00	400	2.10	200	377	1600	6.90	12.0	17.0	21.0	3.00
Maximum	16.0	40.5	520	74.0	490	1200	2000	340	350	320	270	217
Mean	6.07	5.71	437	10.9	337	576	1888	107	135	125	112	26.6
Std Dev (σ)	2.35	6.21	43.9	14.3	106	133	136	102	102	92.9	77.6	50.9
Mean – σ	3.71	-0.51	393	-3.44	231	443	1752	5.14	33.7	32.3	34.0	-24.3
Mean + σ	8.42	11.92	481	25.1	444	709	2023	209	237	218	189	77.6
2023 Samples												
4/24/2023	***3.70***	10.5	no sample	9.60	no sample	***423***	no sample	195	**<u>243</u>**	**<u>233</u>**	**<u>213</u>**	no sample
6/21/2023	5.50	4.50	no sample	4.40	no sample	***429***	no sample	8.50	***20.5***	***23.4***	***23.6***	15.7
8/3/2023	7.00	3.90	no sample	4.80	no sample	468	no sample	17.2	41.4	38.7	42.5	16.3
9/20/2023	4.40	3.50	no sample	3.60	no sample	447	no sample	10.5	39.5	38.2	36.9	12.4
10/27/2023	***3.60***	8.20	no sample	6.80	no sample	499	no sample	44.5	70.7	61.7	66.0	30.2

<u>Bold underline</u> Greater than Mean + σ ***Bold Italic*** Less than Mean – σ

Table 5. Dissolved Manganese Summary Statistics 2010 – 2022 and 2023 Data (in µg/L)

	SCC1	TUN	RWO	SCC4	CD-N	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
Historic Samples (2010-2022)												
Count	41	43	20	44	20	30	20	48	47	41	47	19
Minimum	< 2.00	< 2.00	< 2.00	< 2.00	4.70	430	1200	< 2.00	5.20	9.00	8.20	< 2.00
Maximum	7.80	450	1200	74.0	510	1100	2100	330	320	300	270	5.20
Mean	4.11	21.7	470	9.96	207	580	1710	98.8	115	115	95.7	1.38
Std Dev (σ)	1.65	91.4	365	17.7	152	117	256	101	96.6	88.0	73.2	1.04
Mean – σ	2.46	-69.7	105	-7.76	55	463	1454	-2.0	18.7	27.4	22.5	0.34
Mean + σ	5.76	113	835	27.7	358	697	1965	200	212	203	169	2.42
2023 Samples												
4/24/2023	***2.40***	3.70	no sample	4.80	no sample	***418***	no sample	**203**	**244**	227	206	no sample
6/21/2023	***2.00***	< 2.00	no sample	< 2.00	no sample	***440***	no sample	5.20	***18.8***	***20.9***	***20.2***	< 2.00
8/3/2023	3.10	< 2.00	no sample	< 2.00	no sample	***439***	no sample	15.6	37.8	36.2	32.6	< 2.00
9/20/2023	2.90	3.10	no sample	< 2.00	no sample	***451***	no sample	11.1	41.5	38.0	33.8	**2.50**
10/27/2023	5.40	2.60	no sample	5.00	no sample	486	no sample	47.0	70.3	61.5	57.1	**3.60**

Location-specific minima

Bold underline Greater than Mean + σ ***Bold Italic*** Less than Mean – σ

Dissolved Oxygen

DO measurements in 2023 are generally similar to historical results with few outliers. No location specific minima or maxima for DO was observed in the 2023 sampling.

The following DO measurements were greater than the historic mean plus the standard deviation:

- April, SCC1 (11.41 mg/L)
- April, SCC5a (9.14 mg/L)
- June, SCC7 (9.21 mg/L)
- September, SCC1 (10.55 mg/L)
- September, TUN (9.53 mg/L)
- September, SCC4 (9.24 mg/L)
- September, CD-N1 (6.84 mg/L)
- September, SCC7 (8.80 mg/L)

The following DO measurements were less than the historic mean minus the standard deviation:

- June, TUN (7.28 mg/L)
- June, SCC4 (7.19 mg/L)
- August, SCC7 (7.04 mg/L)

The other DO measurements were within one standard deviation above and below the historical mean. DO measurements at CD-N1 are lower than instream measurements. DO data are summarized in **Table 6**.

Table 6. Dissolved Oxygen Summary Statistics 2010 – 2022 and 2023 Data (in mg/L)

	SCC1	TUN	RWO	SCC4	CD-N	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
Historic Samples (2010-2022)												
Count	47	48	20	49	20	35	20	54	52	46	52	23
Minimum	7.58	6.78	3.25	6.44	5.24	4.69	0.34	6.60	6.59	6.55	6.67	6.76
Maximum	12.1	10.4	8.40	10.6	8.89	7.13	7.00	12.3	10.4	10.4	10.5	9.53
Mean	9.43	8.47	5.10	8.19	7.26	5.95	1.65	8.27	8.08	8.29	8.31	7.93
Std Dev (σ)	1.01	0.99	1.56	0.94	0.92	0.54	1.63	1.06	0.90	1.08	0.97	0.72
Mean – σ	8.42	7.48	3.54	7.25	6.33	5.41	0.018	7.22	7.18	7.21	7.35	7.21
Mean + σ	10.4	9.45	6.66	9.13	8.18	6.49	3.28	9.33	8.98	9.38	9.28	8.65
2023 Samples												
4/24/2023	**<u>11.41</u>**	10.04	no sample	9.72	no sample	6.37	no sample	8.92	**<u>9.14</u>**	7.89	7.70	no sample
6/21/2023	10.13	***7.28***	no sample	***7.19***	no sample	5.97	no sample	8.57	8.85	***7.10***	7.28	**<u>9.21</u>**
8/3/2023	9.73	8.77	no sample	8.36	no sample	6.15	no sample	8.18	8.06	7.22	7.26	***7.04***
9/20/2023	**<u>10.55</u>**	**<u>9.53</u>**	no sample	**<u>9.24</u>**	no sample	**<u>6.84</u>**	no sample	9.17	8.75	8.42	8.51	**<u>8.80</u>**
10/27/2023	9.36	9.25	no sample	9.10	no sample	5.78	no sample	8.52	8.53	8.68	7.95	7.96

<u>Bold underline</u> Greater than Mean + σ ***Bold Italic*** Less than Mean – σ

pH

pH measurements in 2023 are generally similar to historical results with some outliers. The location specific maxima was observed in August at the following sites: SCC5b (8.34 standard units), SCC6 (8.40 standard units), and SCC7 (8.32 standard units). No location specific pH minima was observed in the 2023 sampling.

The following pH measurements were greater than the historic mean plus the standard deviation:

- August, SCC4 (8.41 standard units)
- August, CD-N1 (7.47 standard units)
- August, SCC5 (8.27 standard units)
- August, SCC5b (8.34 standard units), also the location specific maxima as previously noted
- August, SCC6 (8.40 standard units), also the location specific maxima as previously noted
- August, SCC7 (8.32 standard units), also the location specific maxima as previously noted
- September, SCC5 (8.16 standard units)
- September, SCC5a (7.94 standard units)
- September, SCC5b (8.03 standard units)
- September, SCC6 (8.07 standard units)

The following pH measurements were less than the historic mean minus the standard deviation:

- April, SCC5 (7.18 standard units)
- June, SCC7 (7.14 standard units)

The other pH measurements were within one standard deviation above and below the historical mean. pH data are summarized in **Table 7**.

Table 7. pH Summary Statistics 2010 – 2022 and 2023 Data (in Standard Units)

	SCC1	TUN	RWO	SCC4	CD-N	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
Historic Samples (2010-2022)												
Count	59	48	20	57	20	35	21	62	52	46	60	23
Minimum	6.50	6.64	6.60	6.12	6.83	5.89	6.07	6.74	6.74	6.64	6.70	6.80
Maximum	8.55	8.87	7.64	8.96	8.06	7.52	7.86	8.62	8.46	8.13	8.17	8.09
Mean	7.48	7.84	7.14	7.73	7.41	7.06	7.10	7.59	7.59	7.54	7.63	7.60
Std Dev (σ)	0.42	0.51	0.32	0.52	0.35	0.29	0.38	0.37	0.35	0.35	0.35	0.31
Mean – σ	7.06	7.33	6.81	7.21	7.06	6.78	6.72	7.22	7.24	7.20	7.28	7.29
Mean + σ	7.89	8.34	7.46	8.26	7.76	7.35	7.48	7.95	7.93	7.89	7.98	7.91
2023 Samples												
4/24/2023	7.25	7.40	no sample	7.67	no sample	7.00	no sample	***7.18***	7.38	7.42	7.68	no sample
6/21/2023	7.70	7.56	no sample	7.53	no sample	7.04	no sample	7.64	7.69	7.36	7.69	***7.14***
8/3/2023	7.85	8.30	no sample	**8.41**	no sample	**7.47**	no sample	**8.27**	8.11	**8.34**	**8.40**	**8.32**
9/20/2023	7.86	8.07	no sample	8.26	no sample	7.28	no sample	**8.16**	**7.94**	**8.03**	**8.07**	7.62
10/27/2023	7.80	7.97	no sample	8.07	no sample	7.30	no sample	7.94	7.82	7.87	7.92	7.67

Location-specific maxima

Bold underline Greater than Mean + σ ***Bold Italic*** Less than Mean – σ

3.3 Metals Precipitation Results

The results of metals precipitation monitoring are tabulated in **Appendix C**. The paver schedule and naming convention are shown in **Table 1** for reference. The table shows the paver number and the duration of paver inundation. This convention is consistent between the sample sites and is used to display sample results in **Tables 8** and **9**. The iron precipitation monitoring results are summarized in **Table 8**, and the manganese precipitation results are summarized in **Table 9**. Each sample paver is composed of three individual tiles that are affixed to the paver. The values in **Tables 8** and **9** are the average of the three tile samples for the respective immersion periods indicated in the table. The averages were used to aid in the data interpretation and to reduce any variability between the individual tiles.

Deviations from the sampling schedule are detailed in **Section 3.1** of this report. Relating to the metals precipitation monitoring, these deviations occurred when the tiles were observed partially or entirely unsubmerged upon collection, or when other abnormalities occurred. Such results have been reported in the table below with appropriate qualification. Tiles observed partially or entirely unsubmerged are reported as estimated, with a possible low bias. This assumes that if these tiles had been submerged for the entire scheduled period, more accumulation would have occurred, producing a higher result. Typically, such pavers were still in the sampling location, but found to be out of the water due to flow variations in South Clear Creek.

A discussion of the metals precipitation results is included in **Section 4** of this report.

Table 8. Average Iron Precipitate Accumulation Study Year 2023 (in mg/tile)

	2022							2023									
	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
SCC3											1.69		1.64		2.10		
SCC3	2.33										3.05						
SCC3			11.3								8.87						
SCC3					1.20								14.1				
SCC4											0.954		1.68		5.93		
SCC4	11.4										4.00						
SCC4			1.46								2.08						
SCC4					1.10								2.88				
SCC5											2.91		7.65		8.09		
SCC5	79.2										13.5						
SCC5			53.6								5.24						
SCC5					33.1								34.1				
SCC5a											11.1		19.2		20.9		
SCC5a	71.3										31.1						
SCC5a			64.2								44.4						
SCC5a					55.5								30.2				
SCC5b											9.91		1.82		32.8		
SCC5b	51.2										27.5						
SCC5b			35.7								10.4						
SCC5b					123.7								17.0				
SCC6											11.0		9.27		11.2		
SCC6	38.8										18.7						
SCC6			52.6								27.8						
SCC6					45.0								26.8				

Shaded orange cells indicate potentially compromised sample and are considered estimated with a possible low bias

Table 9. Average Manganese Precipitate Accumulation Study Year 2023 (in mg/tile)

	2022							2023									
	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct
SCC3												0.0739		0.267		0.111	
						0.119							0.165				
							0.657							0.510			
								0.0689							0.743		
SCC4												0.0651		0.0742		0.284	
						0.675							0.238				
							0.0853							0.116			
								0.057							0.134		
SCC5												0.0273		0.447		0.3320	
						1.39							0.375				
							0.579							0.178			
								0.426							0.508		
SCC5a												0.0667		0.574		0.424	
						2.42							0.849				
							1.36							1.75			
								1.21							1.75		
SCC5b												0.178		0.0507		0.561	
						1.25							1.26				
							0.949							0.420			
								1.760							0.566		
SCC6												0.126		0.534		0.280	
						0.585							0.757				
							0.728							1.14			
								0.358							0.601		

Shaded orange cells indicate potentially compromised sample and are considered estimated with a possible low bias

4.0 Discussion

Consistent with previous results, levels of iron and manganese in South Clear Creek were lower than those observed at CD-N1, the only remaining non-stream site. The results continue to support the theory that the realignment of the Collection Ditch and subsequent cessation of the flows from the RWO and spring (SP) result in the Collection Ditch as the primary source of iron and manganese into South Clear Creek, as detailed in previous reports. This section provides additional discussion of the water quality and precipitate accumulation data. Additionally, a yearly accumulation summary is provided to evaluate the accumulation concentrations for each site over time.

4.1 Water Quality Discussion

The 2023 iron and manganese water quality data are shown on **Figures 2 – 5**. Sites with a green pattern (SCC1, TUN, and SCC4) are upstream of the Collection Ditch (CD-N1). The CD-N1 site is indicated with a gold fill. Sites with a blue pattern (SCC5, SCC5a, SCC5b, SCC6, and SCC7) are downstream of the Collection Ditch. The highest iron and manganese concentrations were observed in the Collection Ditch for all sampling events. Generally, iron and manganese concentrations upstream of the Collection Ditch are lower than those downstream of this site; however, there are a few exceptions. Furthermore, iron and manganese concentrations at the downstream sample sites appear to have an inverse relationship with discharge in South Clear Creek, i.e., concentrations are higher in months with low creek flows, and concentrations are lowest in months with higher creek flows. Hydrographs from South Clear Creek at the USGS gages near SCC1 and TUN are included for reference in **Appendix D**.

4.1.1 Total Iron

Total iron data are shown in **Figure 2**. The highest total iron concentrations were observed in the Collection Ditch and concentrations ranged from 3430 µg/L to 3700 µg/L over the course of the year. The lowest instream total iron concentrations were observed at TUN and SCC4, and the highest varied among the downstream sites through the year. The monthly results are discussed below:

April: The highest instream total iron concentrations in April were observed at SCC5a (1700 µg/L). The lowest instream total iron concentration in April was observed at SCC1 (126 µg/L). April downstream sample results ranged from 1230 µg/L to 1700 µg/L, and the upstream sample results ranged from 126 µg/L to 150 µg/L.

June: The highest instream total iron concentration in June occurred at SCC6 (262 µg/L). The lowest instream total iron concentration in June occurred at TUN (110 µg/L). June downstream sample results ranged from 141 µg/L to 262 µg/L, and the upstream sample results ranged from 110 µg/L to 159 µg/L.

August: The highest instream total iron concentration in August occurred at SCC6 (452 µg/L). The lowest instream total iron concentration in August occurred at TUN (72.0 µg/L). The August downstream sample results ranged from 166 µg/L to 452 µg/L, and the upstream sample results ranged from 72.0 to 184 µg/L.

September: The highest instream total iron concentration in September occurred at SCC5a (328 µg/L). The lowest instream total iron concentration in September occurred at TUN (63.4 µg/L). The

September downstream sample results ranged from 114 µg/L to 328 µg/L, and the upstream sample results ranged from 63.4 µg/L to 109 µg/L.

October: The highest instream total iron concentration in October occurred at SCC6 (693 µg/L). The lowest instream total iron concentration in October occurred at SCC1 (82.2 µg/L). The October downstream sample results ranged from 224 µg/L to 693 µg/L, and the upstream sample results ranged from 82.2 µg/L to 153 µg/L.

4.1.2 Dissolved Iron

Dissolved iron data are generally similar to total iron data and are shown in **Figure 3**. The highest dissolved iron concentrations were observed in the Collection Ditch. Collection Ditch concentrations ranged from 2970 µg/L to 3340 µg/L over the course of the year. The lowest dissolved iron was observed at SCC1, TUN, and SCC4; and the highest was most often observed at SCC5a, but also at SCC5 and SCC5b. The monthly results are discussed below:

April: The highest instream dissolved iron concentration in April occurred at SCC5 (1360 µg/L). The lowest instream dissolved iron concentration in April occurred at TUN (22.5 µg/L). April downstream sample results ranged from 377 µg/L to 1360 µg/L, and the upstream sample results ranged from 22.5 µg/L to 55.8 µg/L.

June: The highest instream dissolved iron concentration in June occurred at SCC5b (133 µg/L). The lowest instream dissolved iron concentration in June occurred at SCC1 (17.3 µg/L). June downstream sample results ranged from 54.4 µg/L to 133 µg/L, and the upstream sample results ranged from 33.6 µg/L to 39.3 µg/L.

August: The highest instream dissolved iron concentration in August occurred at SCC5a (186 µg/L). The lowest instream dissolved iron concentration in August occurred at TUN (15.7 µg/L). August downstream sample results ranged from 48.3 µg/L to 186 µg/L, and the upstream sample results ranged from 15.7 µg/L to 49.3 µg/L.

September: The highest instream dissolved iron concentration in September occurred at SCC5a (189 µg/L). The lowest instream dissolved iron concentration in September occurred at TUN and SCC4 (< 10 µg/L). September downstream sample results ranged from 20.6 µg/L to 189 µg/L, and the upstream sample results ranged from < 10 µg/L to 45.2 µg/L.

October: The highest instream dissolved iron concentration in October occurred at SCC5a (336 µg/L). The lowest instream dissolved iron concentration in October occurred at TUN and SCC4 (< 10 µg/L). October downstream sample results ranged from 27.8 µg/L to 336 µg/L, and the upstream sample results ranged from < 10 µg/L to 35.6 µg/L.

4.1.3 Total Manganese

Total manganese data are shown in **Figure 4**. The highest total manganese concentrations were observed in the Collection Ditch. Collection Ditch concentrations ranged from 423 µg/L to 499 µg/L over the course of the year. The lowest total manganese varied across the instream sample sites through the year, and the highest instream total manganese occurred at SCC5a and SCC6. The monthly results are discussed below:

April: The highest instream total manganese concentration in April occurred at SCC5a (243 µg/L). The lowest instream total manganese concentration in April occurred at SCC1 (3.70 µg/L). April downstream sample results ranged from 195 µg/L to 243 µg/L, and the upstream sample results ranged from 3.70 µg/L to 10.5 µg/L.

June: The highest instream total manganese concentration in June occurred at SCC6 (23.6 µg/L). The lowest instream total manganese concentration in June occurred at SCC4 (4.40 µg/L). June downstream sample results ranged from 8.50 µg/L to 23.6 µg/L, and the upstream sample results ranged from 4.40 µg/L to 5.50 µg/L.

August: The highest instream total manganese concentration in August occurred at SCC6 (42.5 µg/L). The lowest instream total manganese concentration in August occurred at TUN (3.90 µg/L). August downstream sample results ranged from 16.3 µg/L to 42.5 µg/L, and the upstream sample results ranged from 3.90 µg/L to 7.00 µg/L.

September: The highest instream total manganese concentration in September occurred at SCC5a (39.5 µg/L). The lowest instream total manganese concentration in September occurred at TUN (3.50 µg/L). September downstream sample results ranged from 10.5 µg/L to 39.5 µg/L, and the upstream sample results ranged from 3.50 µg/L to 4.40 µg/L.

October: The highest instream total manganese concentration in October occurred at SCC5a (70.7 µg/L). The lowest instream total manganese concentration in October occurred at SCC1 (3.60 µg/L). October downstream sample results ranged from 30.2 µg/L to 70.7 µg/L, and the upstream sample results ranged from 3.60 µg/L to 8.20 µg/L.

4.1.4 Dissolved Manganese

Dissolved manganese data are shown in **Figure 5**. The highest dissolved manganese concentrations were observed in the Collection Ditch. Collection Ditch concentrations ranged from 418 µg/L to 486 µg/L over the course of the year. The lowest dissolved manganese varied across the instream sample sites through the year and was observed at SCC7 in June and August. The highest, instream dissolved manganese was most often observed at SCC5a, but also at SCC5b. The monthly results are discussed below:

April: The highest instream dissolved manganese concentration in April occurred at SCC5a (244 µg/L). The lowest instream dissolved manganese concentration in April occurred at SCC1 (2.40 µg/L). April downstream sample results ranged from 203 µg/L to 244 µg/L, and the upstream sample results ranged from 2.40 µg/L to 4.80 µg/L.

June: The highest instream dissolved manganese concentration in June occurred at SCC5b (20.9 µg/L). Non-detect results occurred at TUN, SCC4, and SCC7. June downstream sample results ranged from non-detect to 20.9 µg/L, and the upstream sample results ranged from non-detect to 2.00 µg/L.

August: The highest instream dissolved manganese concentration in August occurred at SCC5a (37.8 µg/L). Non-detect results occurred at TUN, SCC4, and SCC7. August downstream sample results ranged from non-detect to 37.8 µg/L, and the upstream sample results ranged from non-detect to 3.10 µg/L.

September: The highest instream dissolved manganese concentration in September occurred at SCC5a (41.5 µg/L). Non-detect results occurred at SCC4. September downstream sample results ranged from 2.50 µg/L to 41.5 µg/L, and the upstream sample results ranged from non-detect to 3.10 µg/L.

October: The highest instream dissolved manganese concentration in October occurred at SCC5a (70.3 µg/L). The lowest instream dissolved manganese concentration in October occurred at TUN (2.60 µg/L). October downstream sample results ranged from 3.60 µg/L to 70.3 µg/L, and the upstream sample results ranged from 2.60 µg/L to 5.40 µg/L.

Figure 2. Total Iron Water Quality Results 2023

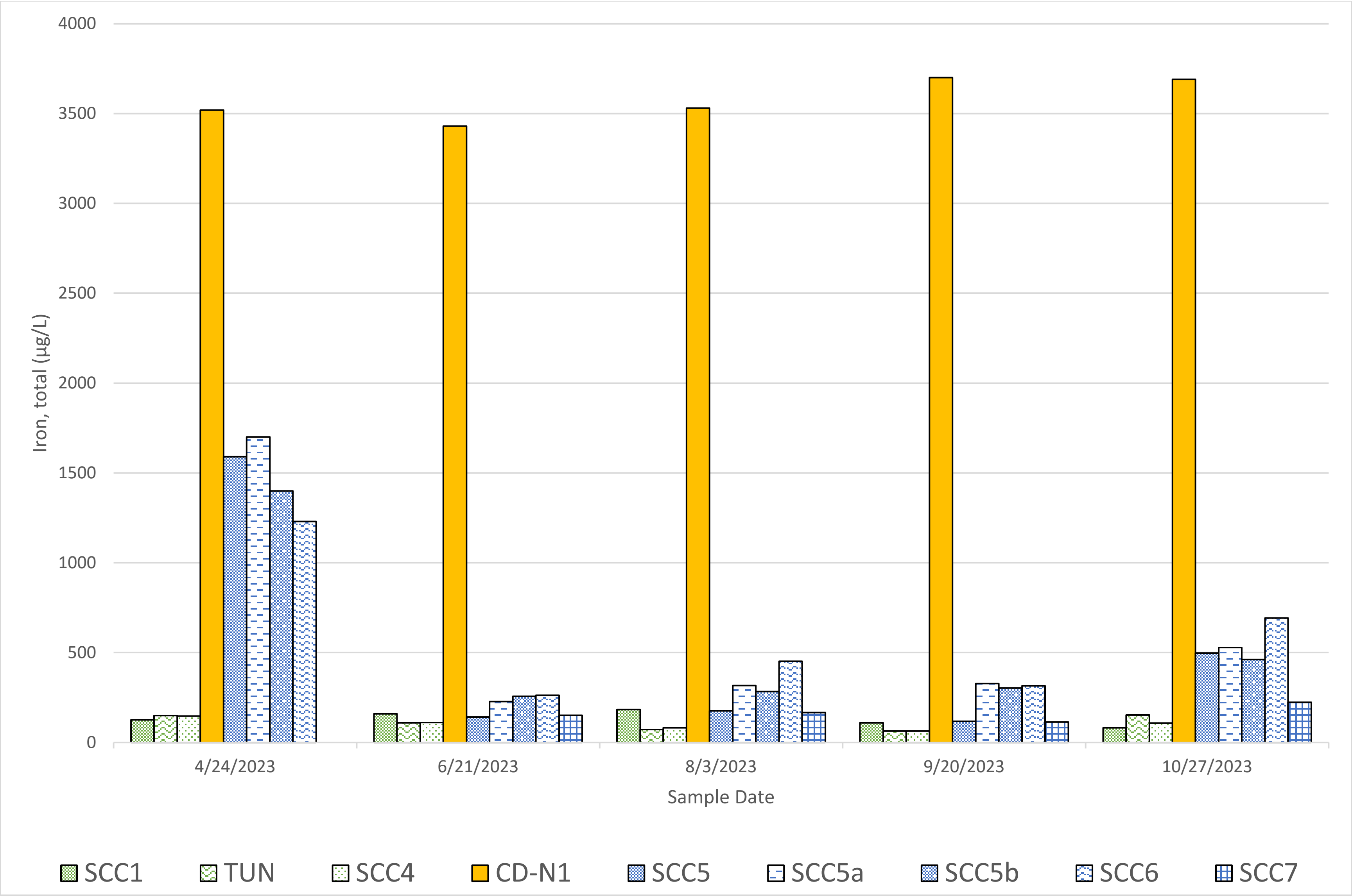


Figure 3. Dissolved Iron Water Quality Results 2023

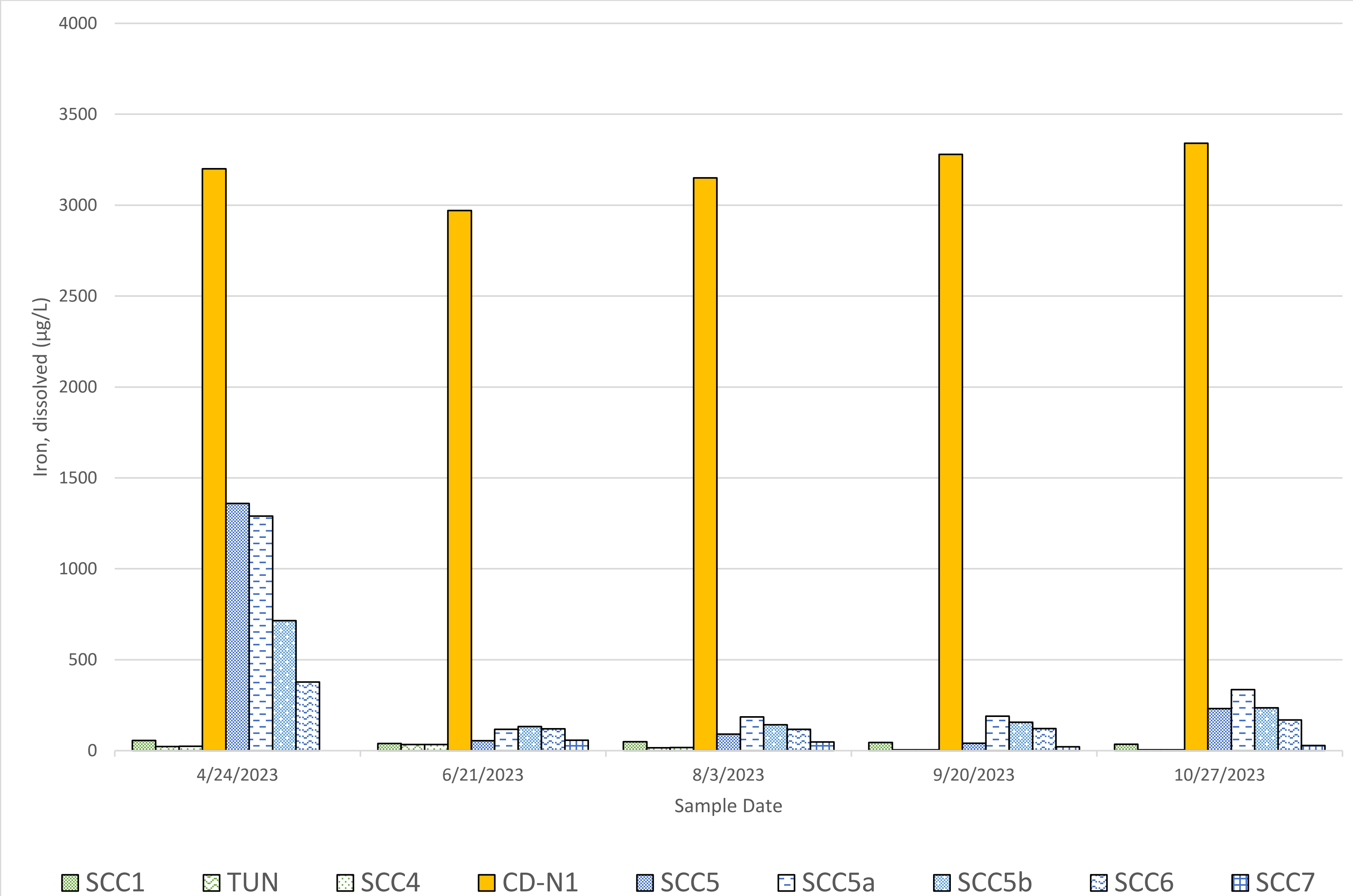


Figure 4. Total Manganese Water Quality Results 2023

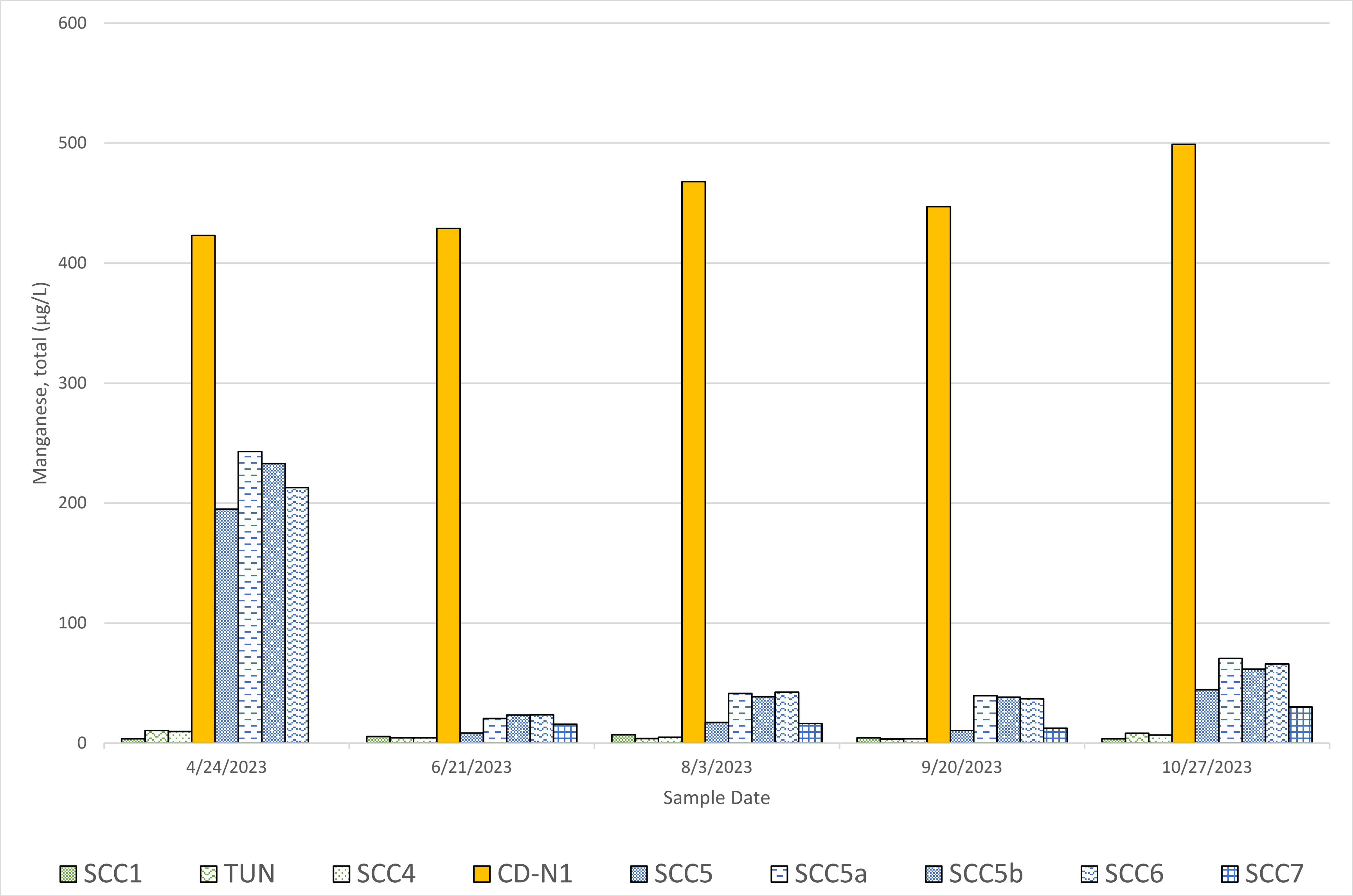
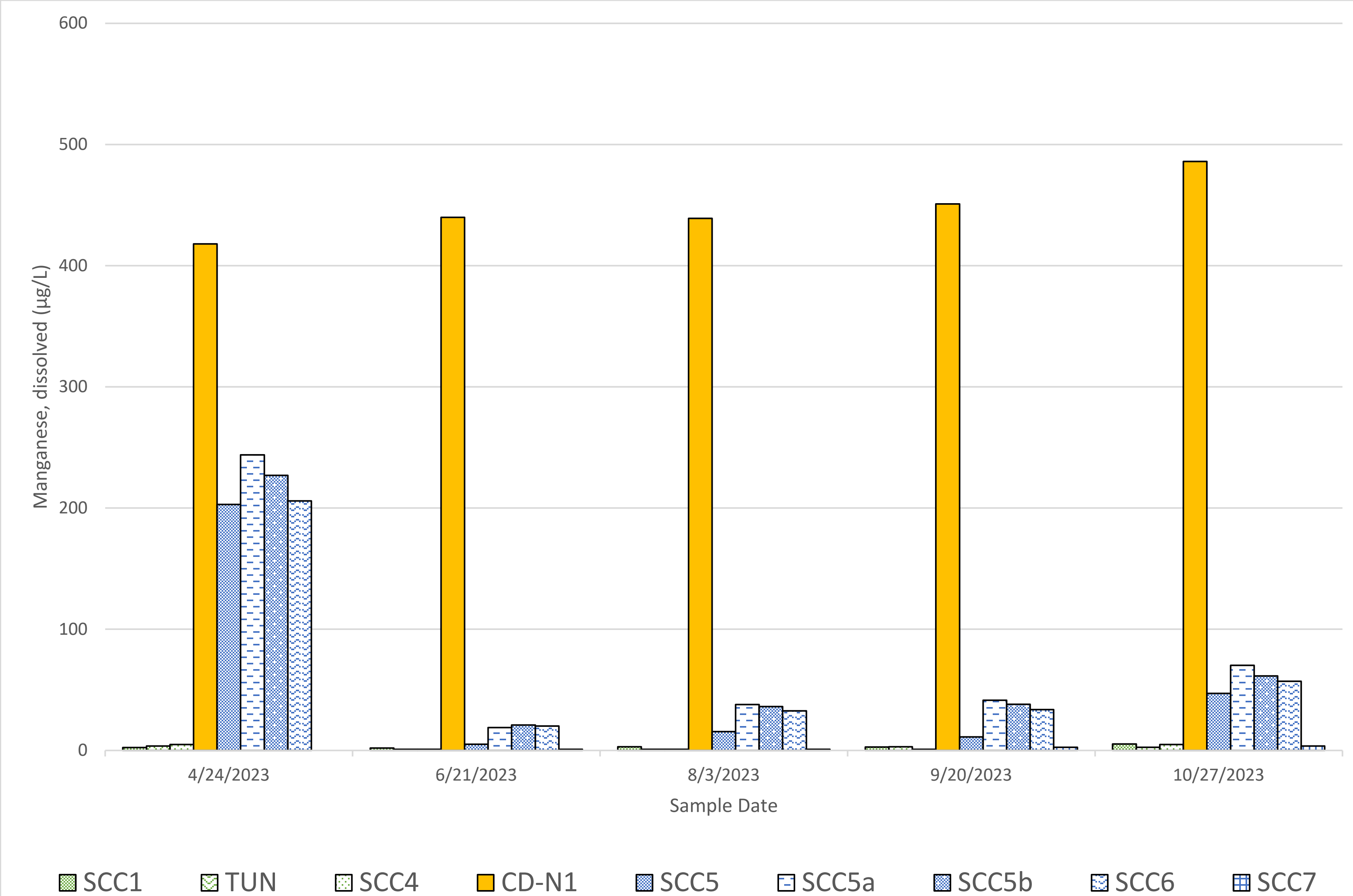


Figure 5. Dissolved Manganese Water Quality Results 2023



4.2 Precipitate Discussion

Iron and manganese precipitate data collected in 2023 are shown by paver number on **Figures 6 – 23**. See **Tables 8** and **9** for data qualifications. Precipitate sampling sites upstream of the Collection Ditch are SCC3 and SCC4. Precipitate sampling sites downstream of the Collection Ditch are SCC5, SCC5a, SCC5b, and SCC6. The location of the Collection Ditch is also called out on **Figures 6 – 23** for reference. The paver set is defined as the results of each particular paver duration for all sample sites; for example, the P1 paver set comprises the P1 sample results at SCC3, SCC4, SCC5, SCC5a, SCC5b, and SCC6.

The lowest iron accumulations within any given paver set occur at the two sites upstream of the Collection Ditch, SCC3 and SCC4. The lowest manganese accumulations within the various paver sets were also observed at SCC3 and SCC4, but also at the downstream sites SCC5 and SCC5b.

The highest iron and manganese accumulations within all paver sets occurred at SCC5, SCC5a, and SCC5b, which are all sites downstream of the Collection Ditch. Specific paver set results are discussed in further detail in this section with **Figures 6 – 23.**

The sample results are important to consider along with the relative difference between the paver sites, in particular for the manganese results. The magnitude of all manganese results is generally very low (ranging from 0.0273 mg – 2.42 mg) and some of the differences in results between pavers may be within the margin of error for this type of sampling.

Sample results for iron from pavers with longer immersion periods were lower than those with shorter immersion periods in some instances. For example, the P9 (2022) paver was immersed for 10 months, and the P10 (2022) paver was immersed for 8 months. The SCC6 P9 (2022) paver iron result was 38.8 mg, and the P10 (2022) paver iron result was 52.6 mg. This result may appear counterintuitive at first glance; however, it is important to consider that some paver durations do not overlap and, therefore, a paver with a longer immersion period but smaller metal result may be due to varying precipitation rates or patterns. Additionally, it may suggest the tiles saturate and are unable to collect any additional precipitate. Tiles with longer immersion periods also may experience precipitate wash-off during higher flows. These observations may also highlight the variability in this type of monitoring.

The precipitate monitoring program over the course of the WQAMP monitoring has been helpful in determining the relative accumulations of iron and manganese in various locations along South Clear Creek and also has helped identify changes in precipitation patterns after changes to the South Clear Creek and Cabin Creek hydrology. This program has not been without challenges and shortfalls. Maintaining pavers submerged between sampling periods was challenging due to varying water levels, and in some instances, pavers were tampered with when sites were publicly accessible. It remains unknown if pavers reached a maximum accumulation level due to the nature of the precipitate and surface area of the tile. Similarly, it is unknown if precipitate washed off the tiles while in the creek, and if this wash off influenced sample results. Additionally, site specific hydraulics were not considered as a variable in paver placement location. It is unknown how hydraulics influences precipitate accumulation at any given location.

Paver set data and figures are shown and discussed below.

Paver Set Charts

The highest Paver P7 (2022) (October 2022 – April 2022) iron sample results occurred at SCC5b (124 mg), and the lowest occurred at SCC4 (1.10 mg). Similarly, the highest manganese sample result also occurred at SCC5b (1.76 mg) and the lowest occurred at SCC4 (0.0573 mg). Iron and manganese P7 (2022) sample results are shown in **Figures 6** and **7** below.

Figure 6. Paver P7 (2022) Iron Precipitate Results

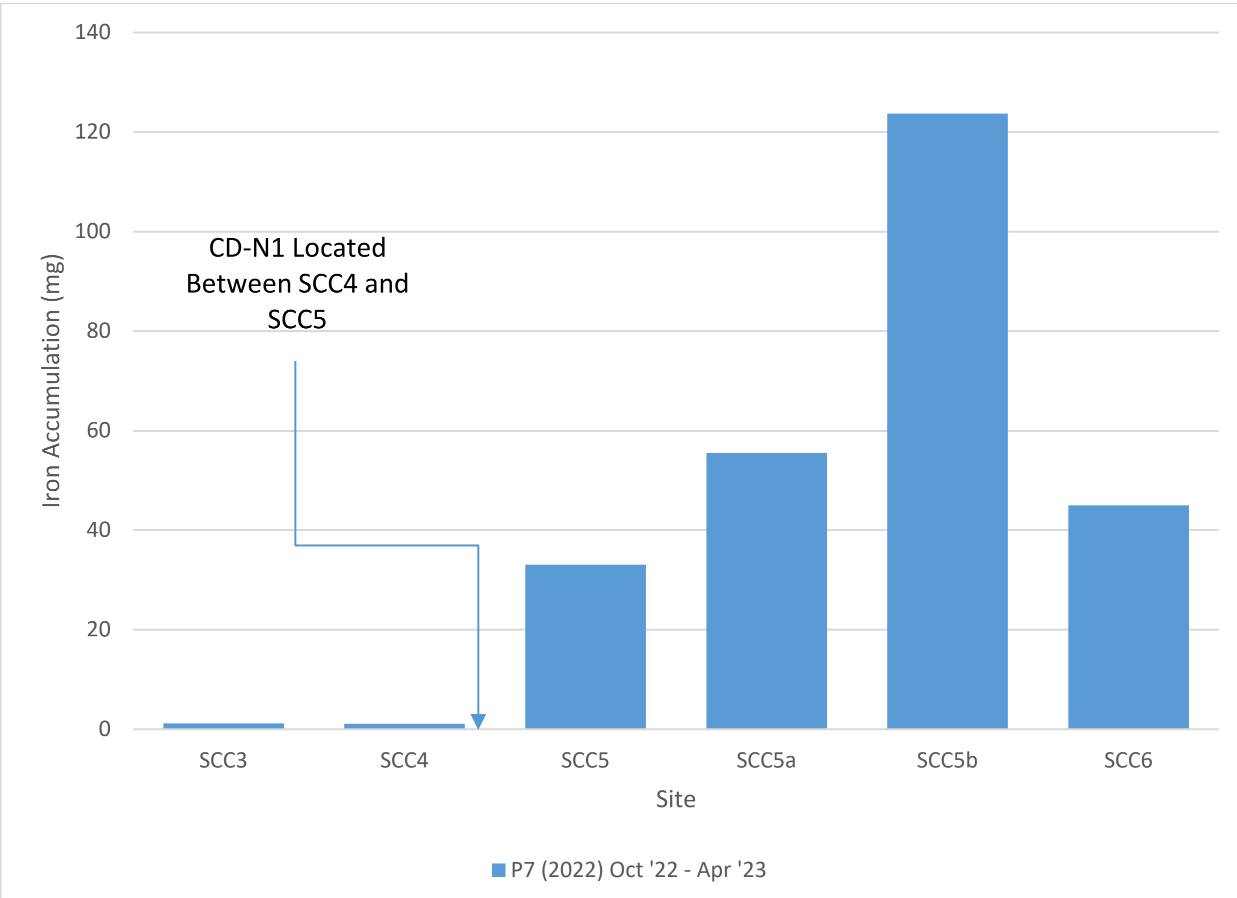
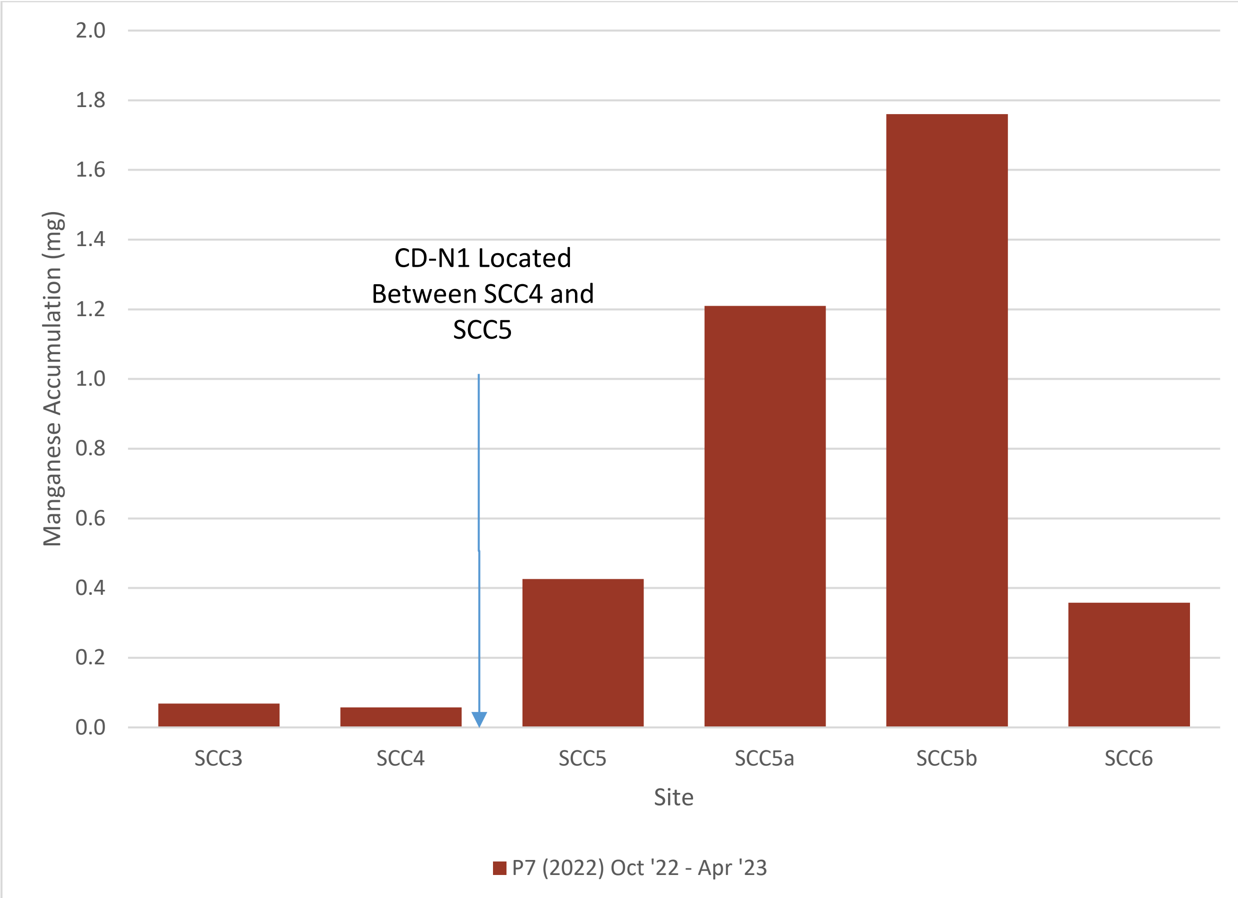


Figure 7. Paver P7 (2022) Manganese Precipitate Results



The highest Paver P9 (2022) (June 2022 – April 2023) iron sample results occurred at SCC5 (79.2 mg), and the lowest occurred at SCC3 (2.33 mg). The highest manganese sample result occurred at SCC5a (2.42 mg) and the lowest occurred at SCC3 (0.119 mg). Iron and manganese P9 (2022) sample results are shown in **Figures 8** and **9** below.

Figure 8. Paver P9 (2022) Iron Precipitate Results

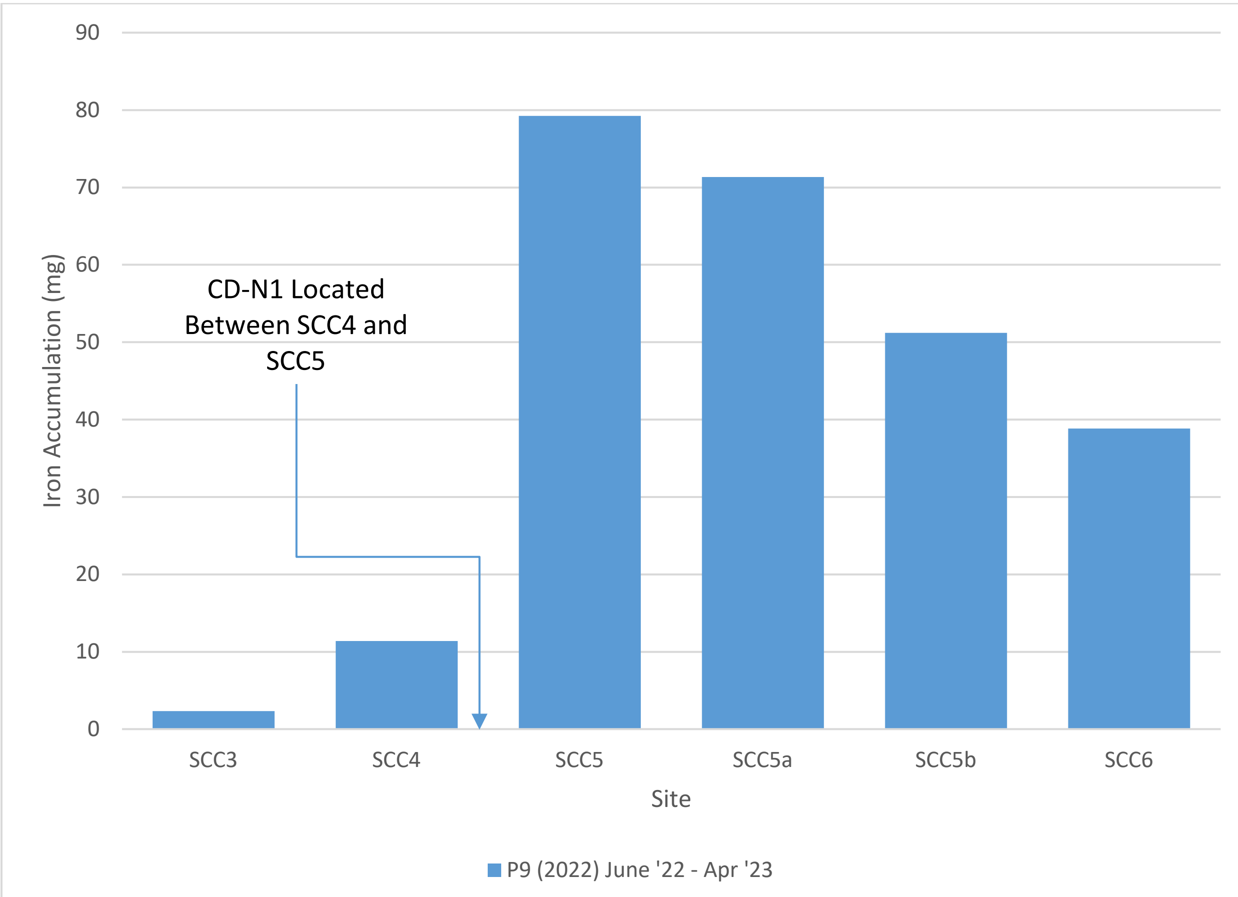
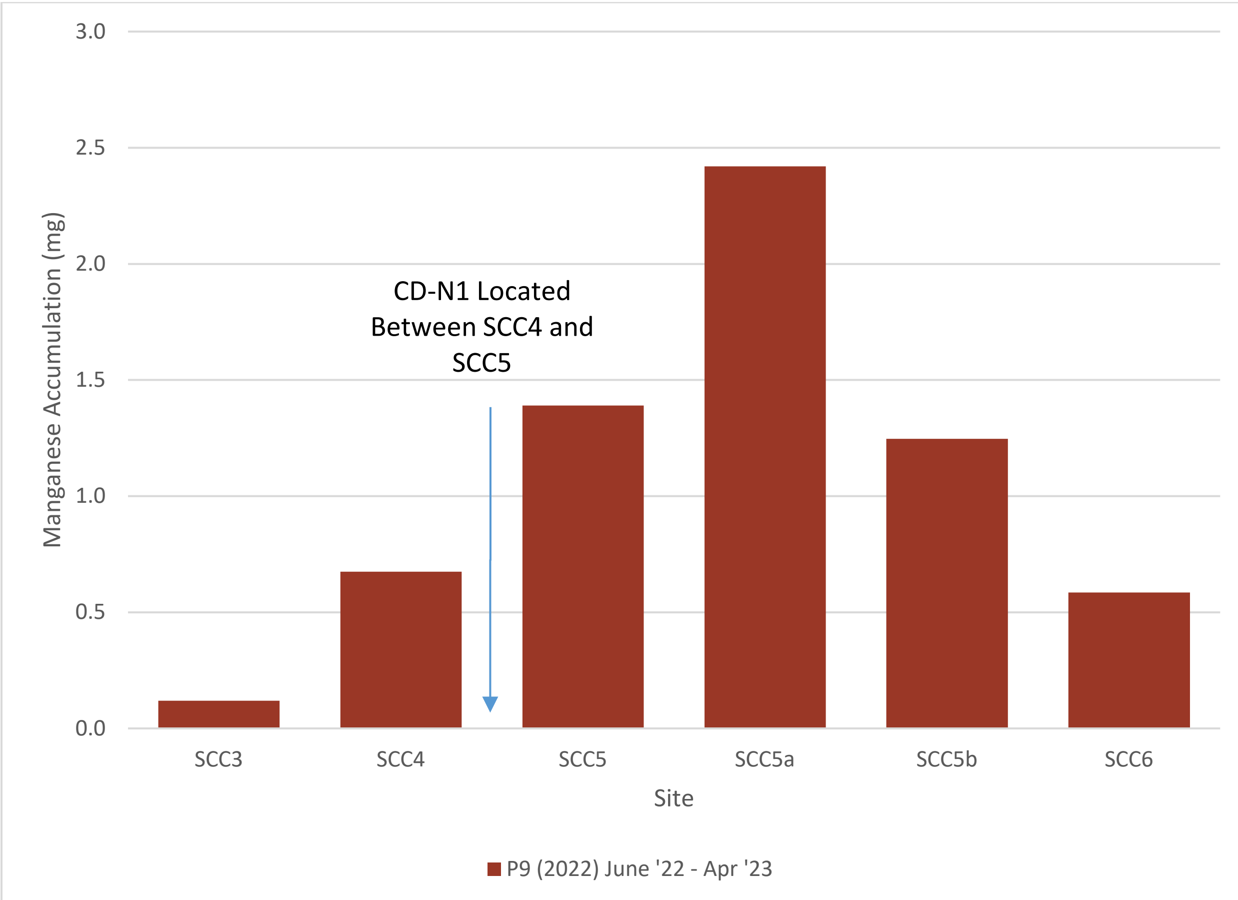


Figure 9. Paver P9 (2022) Manganese Precipitate Results



The highest Paver P10 (2022) (August 2022 – April 2023) iron sample results occurred at SCC5a (64.2 mg), and the lowest occurred at SCC4 (1.46 mg). Similarly, the highest manganese sample result also occurred at SCC5a (1.36 mg) and the lowest occurred at SCC4 (0.0853 mg). Iron and manganese P10 (2022) sample results are shown in **Figures 10** and **11** below.

Figure 10. Paver P10 (2022) Iron Precipitate Results

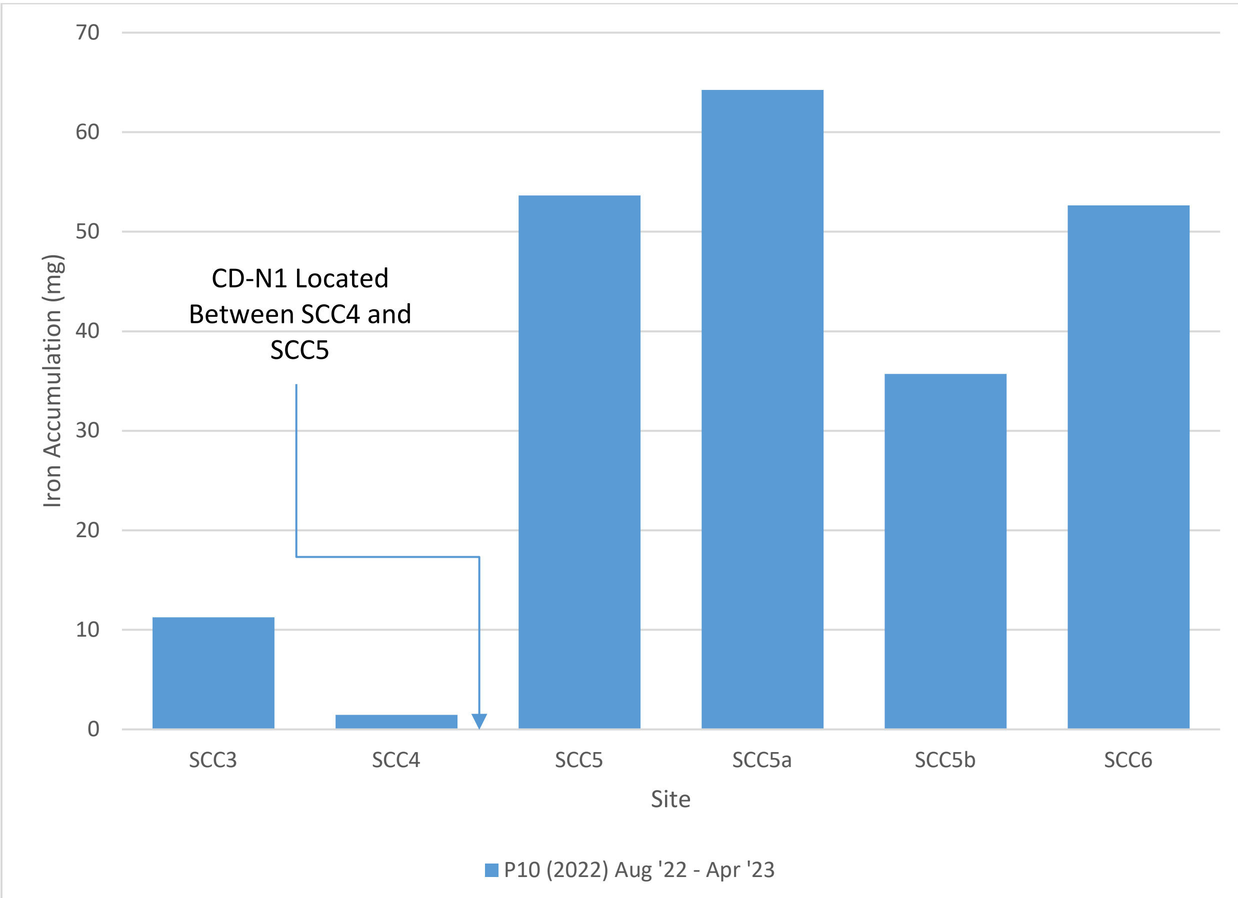
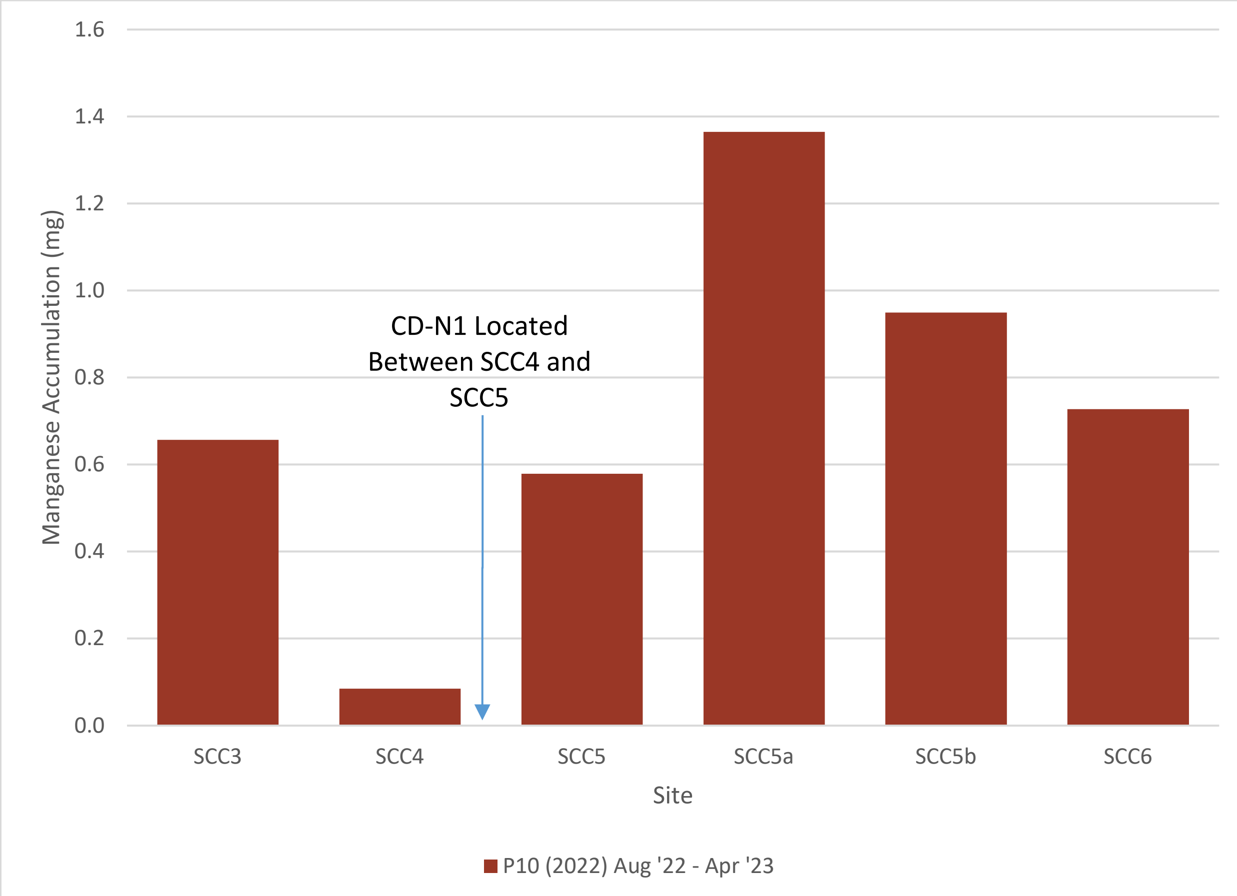


Figure 11. Paver P10 (2022) Manganese Precipitate Results



The highest Paver P1 (April 2023 – June 2023) iron sample results occurred at SCC5a (11.1 mg), and the lowest occurred at SCC4 (0.954 mg). The highest manganese sample result occurred at SCC5b (0.178 mg) and the lowest occurred at SCC5 (0.0273 mg). Iron and manganese P1 sample results are shown in **Figures 12** and **13** below.

Figure 12. Paver P1 Iron Precipitate Results

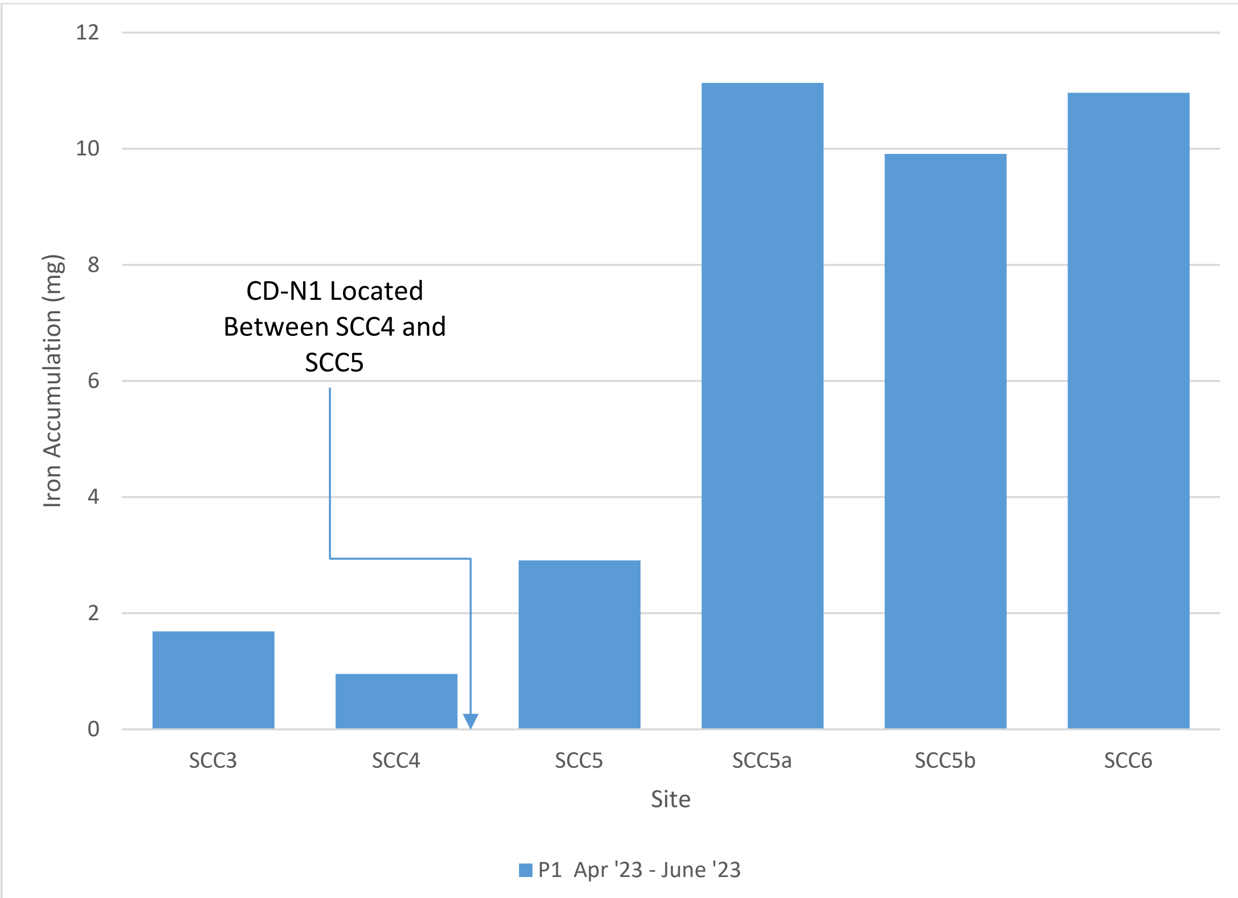
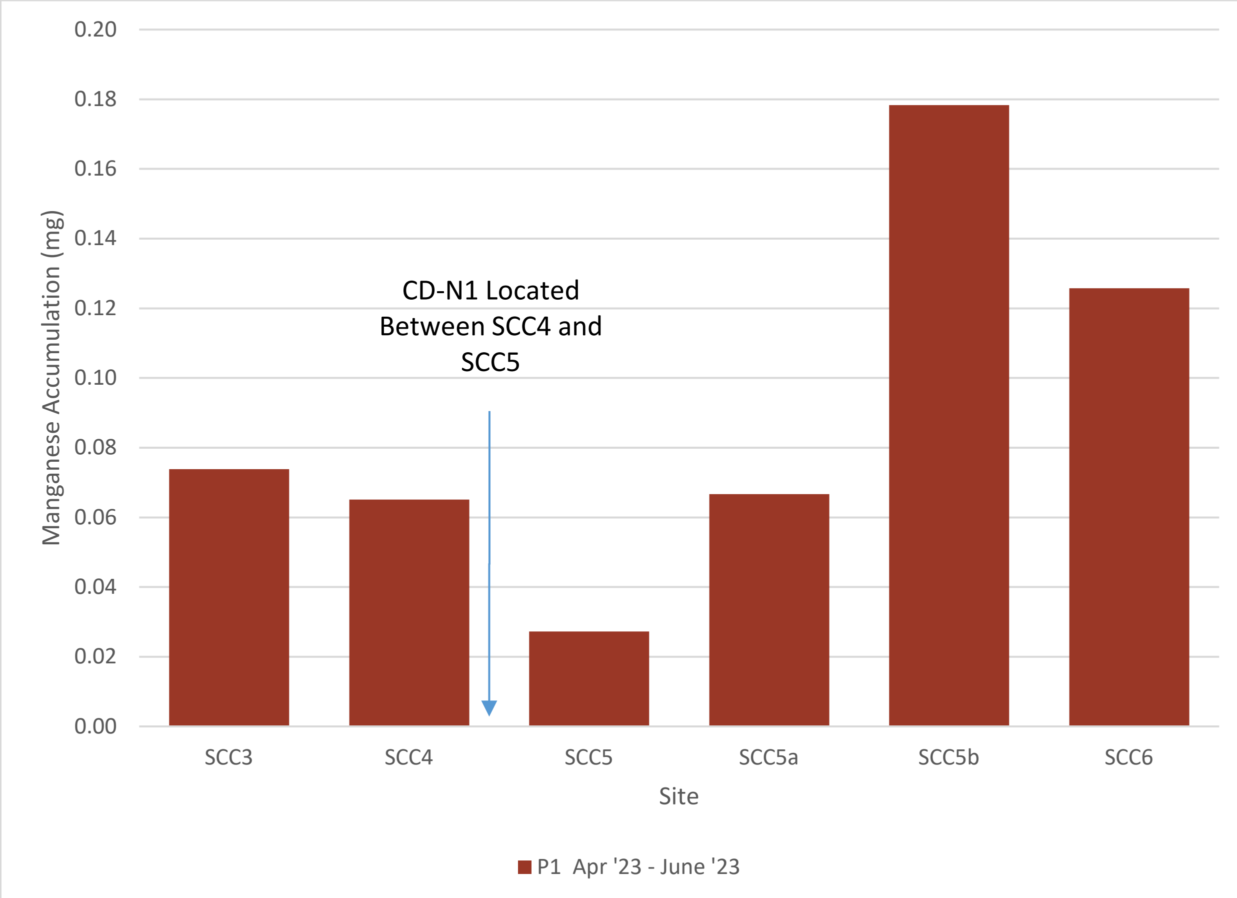


Figure 13. Paver P1 Manganese Precipitate Results



The highest Paver P2 (April 2023 – August 2023) iron sample results occurred at SCC5a (31.1 mg), and the lowest occurred at SCC3 (3.05 mg). The highest manganese sample result occurred at SCC5b (1.26 mg) and the lowest occurred at SCC3 (0.165 mg). Iron and manganese P2 sample results are shown in **Figures 14** and **15** below.

Figure 14. Paver P2 Iron Precipitate Results

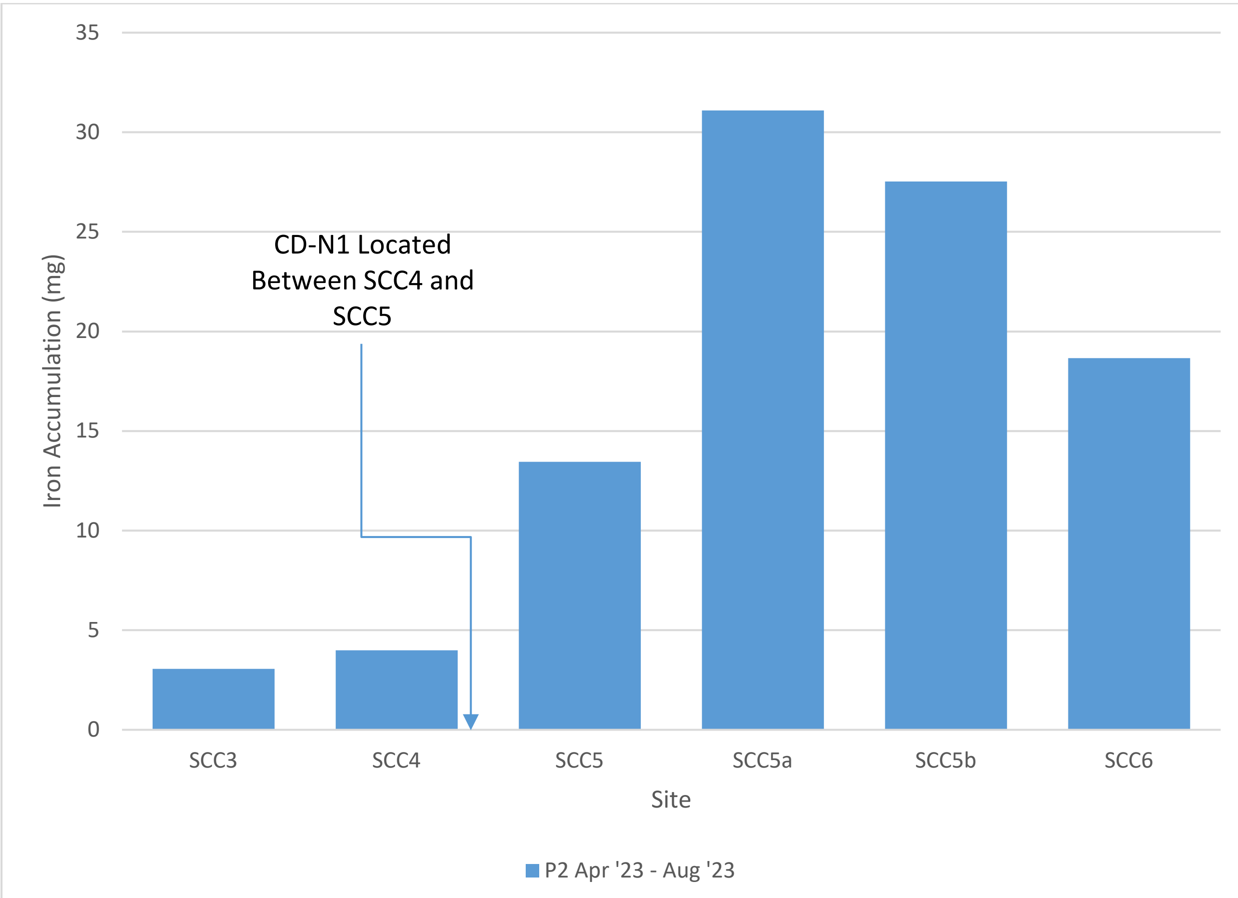
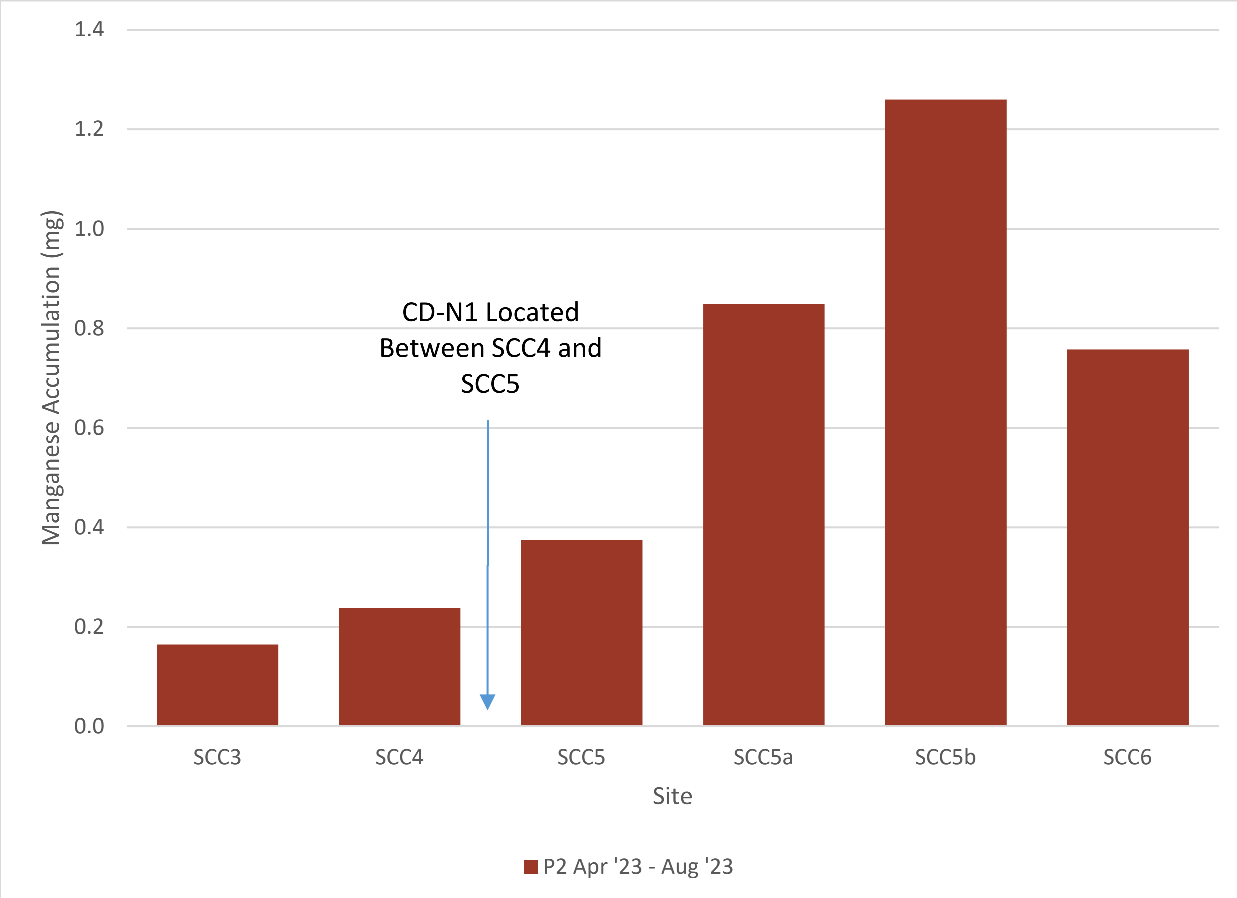


Figure 15. Paver P2 Manganese Precipitate Results



The highest Paver P5 (June 2023 – August 2023) iron sample results occurred at SCC5a (19.2 mg), and the lowest occurred at SCC3 (1.64 mg). The highest manganese sample result occurred at SCC5b (0.574 mg) and the lowest occurred at SCC5a (0.0507 mg). Iron and manganese P5 sample results are shown in **Figures 16** and **17** below.

Figure 16. Paver P5 Iron Precipitate Results

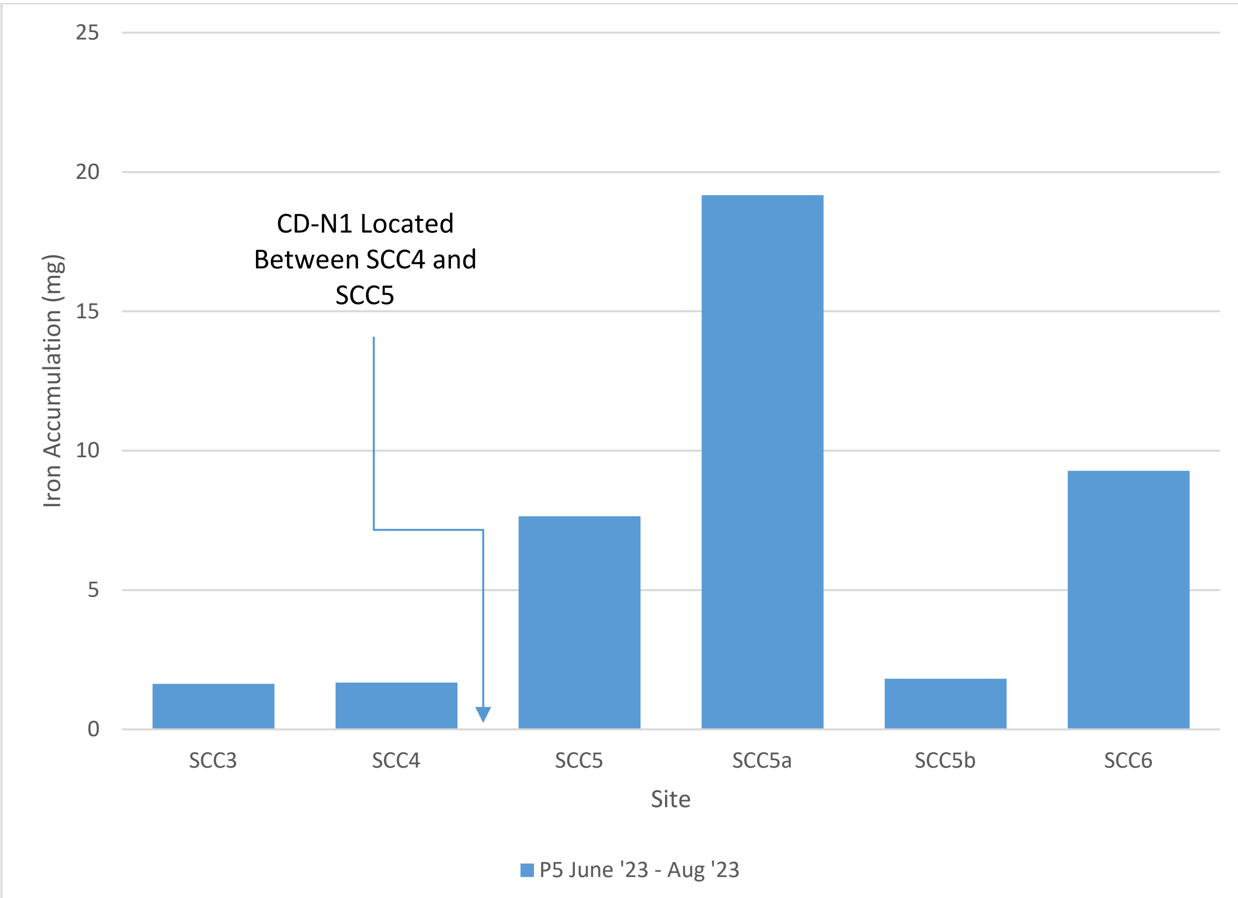
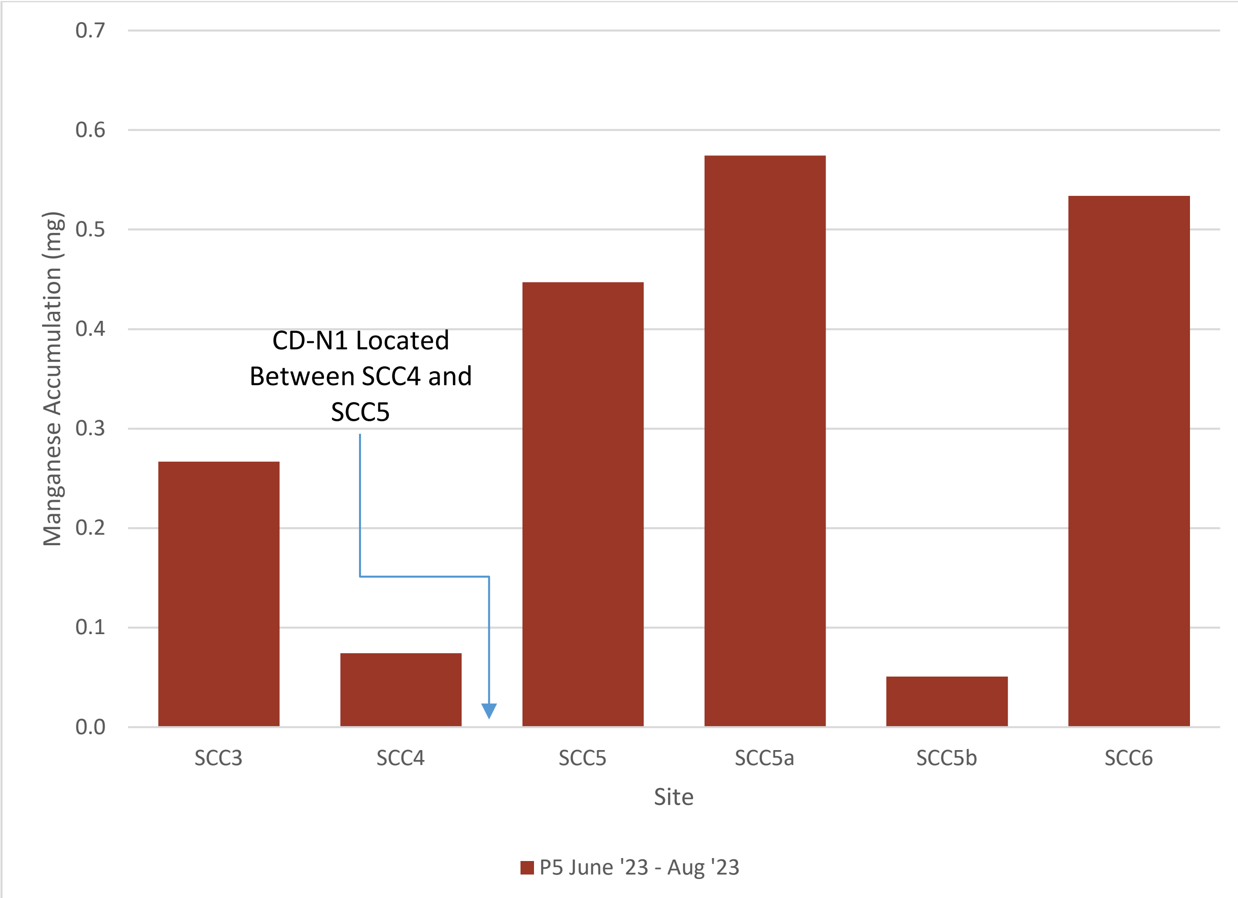


Figure 17. Paver P5 Manganese Precipitate Results



The highest Paver P3 (April 2023 – October 2023) iron sample results occurred at SCC5a (44.4 mg), and the lowest occurred at SCC4 (2.08 mg). The highest manganese sample result occurred at SCC5a (1.75 mg) and the lowest occurred at SCC4 (0.116 mg). Iron and manganese P3 sample results are shown in **Figures 18** and **19** below.

Figure 18. Paver P3 Iron Precipitate Results

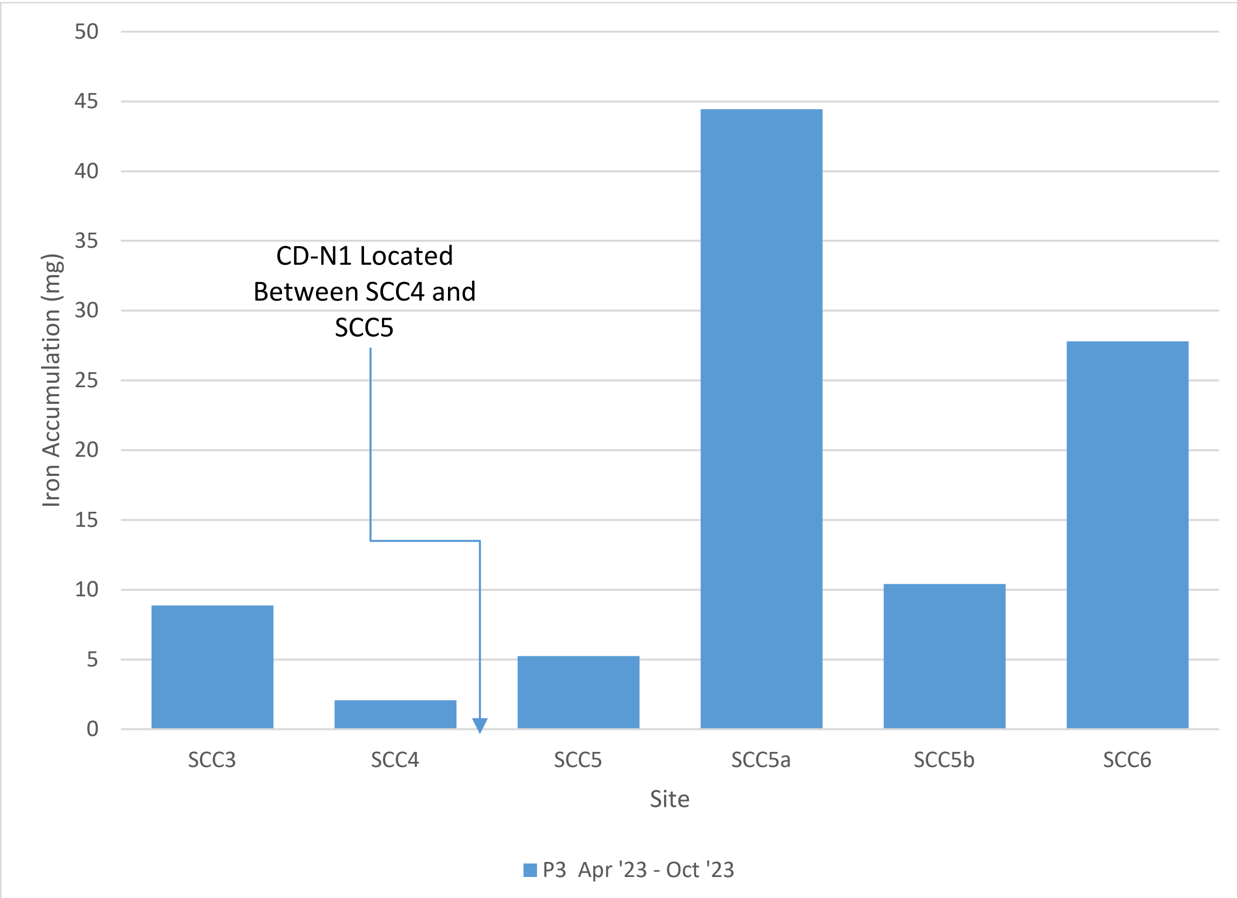
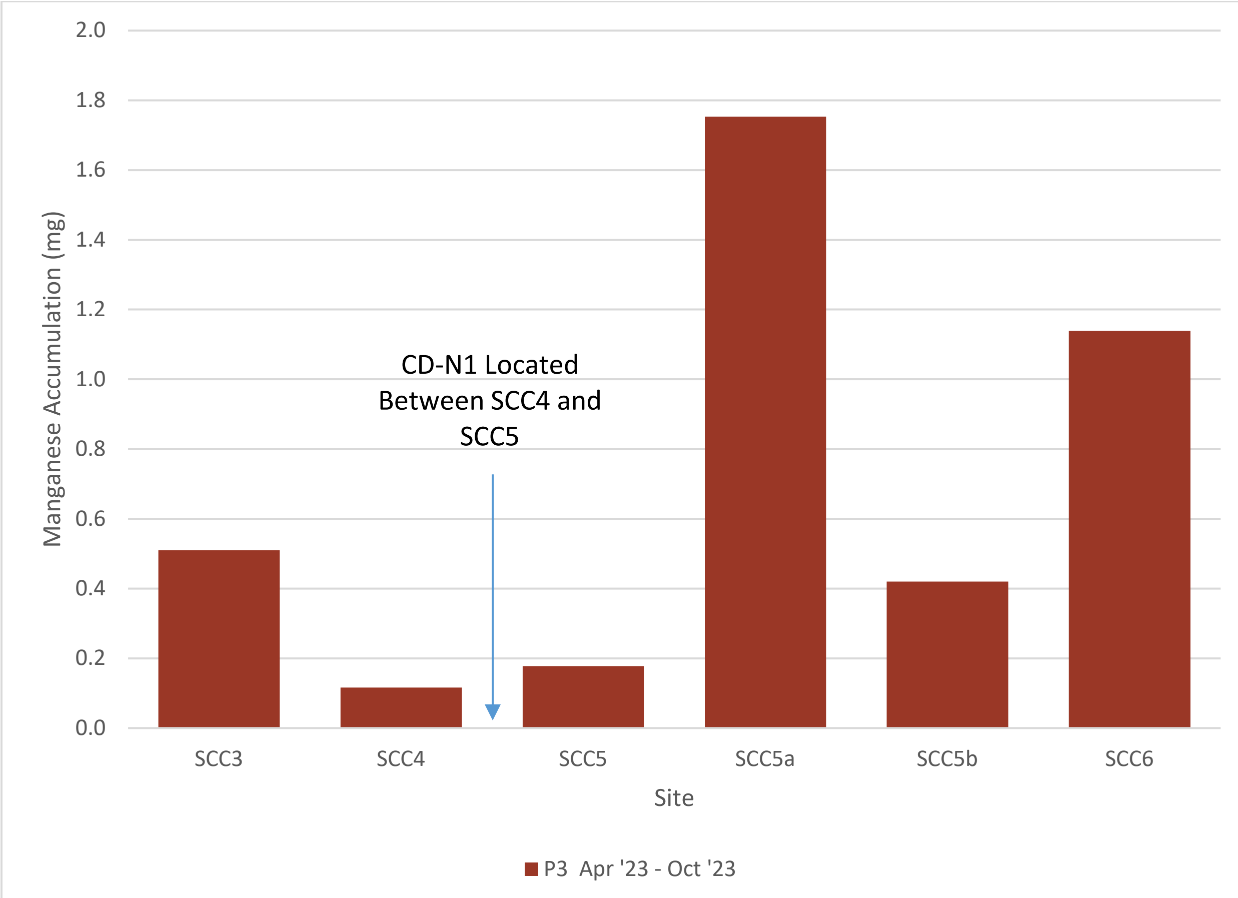


Figure 19. Paver P3 Manganese Precipitate Results



The highest Paver P6 (August 2023 – October 2023) iron sample results occurred at SCC5b (32.8 mg), and the lowest occurred at SCC3 (2.10 mg). The highest manganese sample result occurred at SCC5b (0.561 mg) and the lowest occurred at SCC3 (0.111 mg). Iron and manganese P6 sample results are shown in **Figures 20** and **21** below.

Figure 20. Paver P6 Iron Precipitate Results

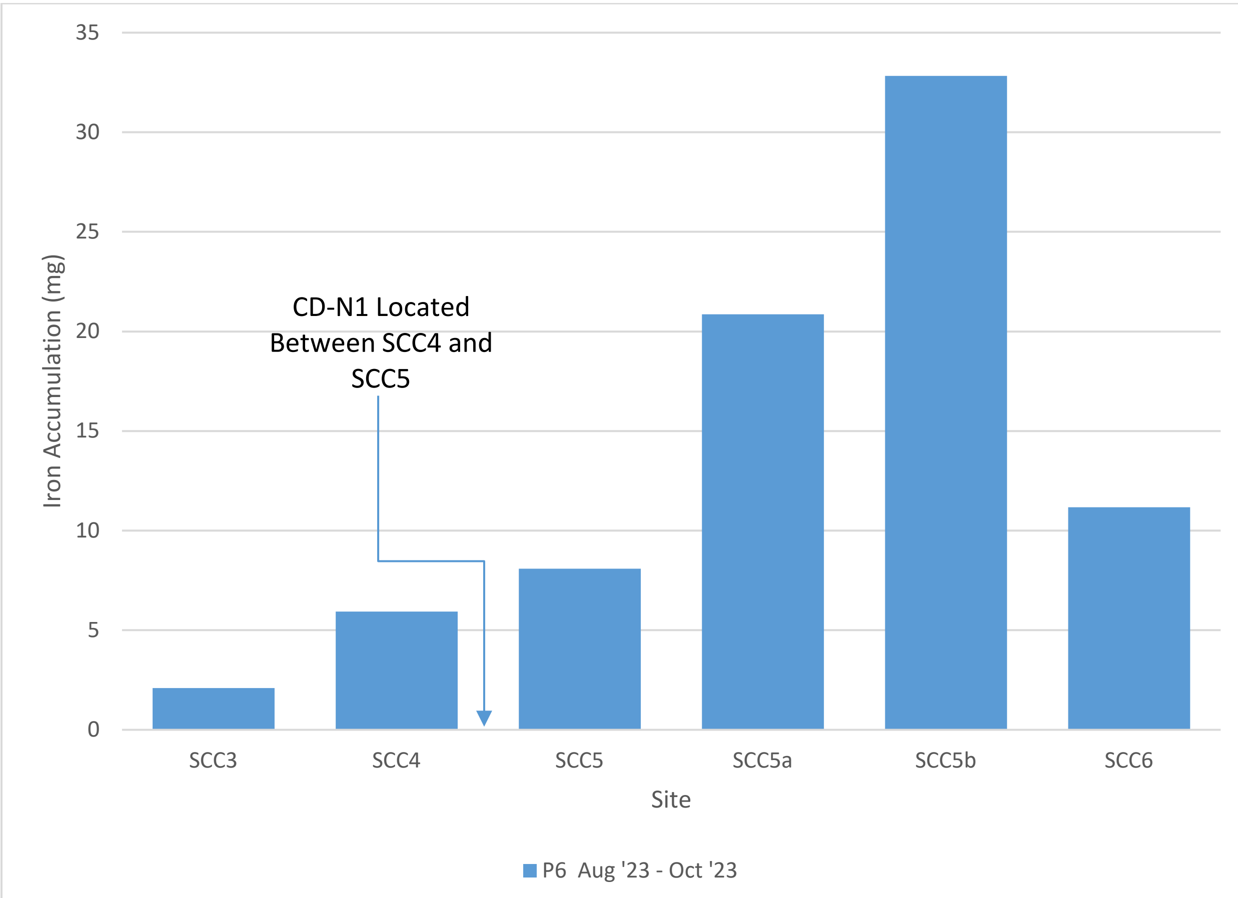
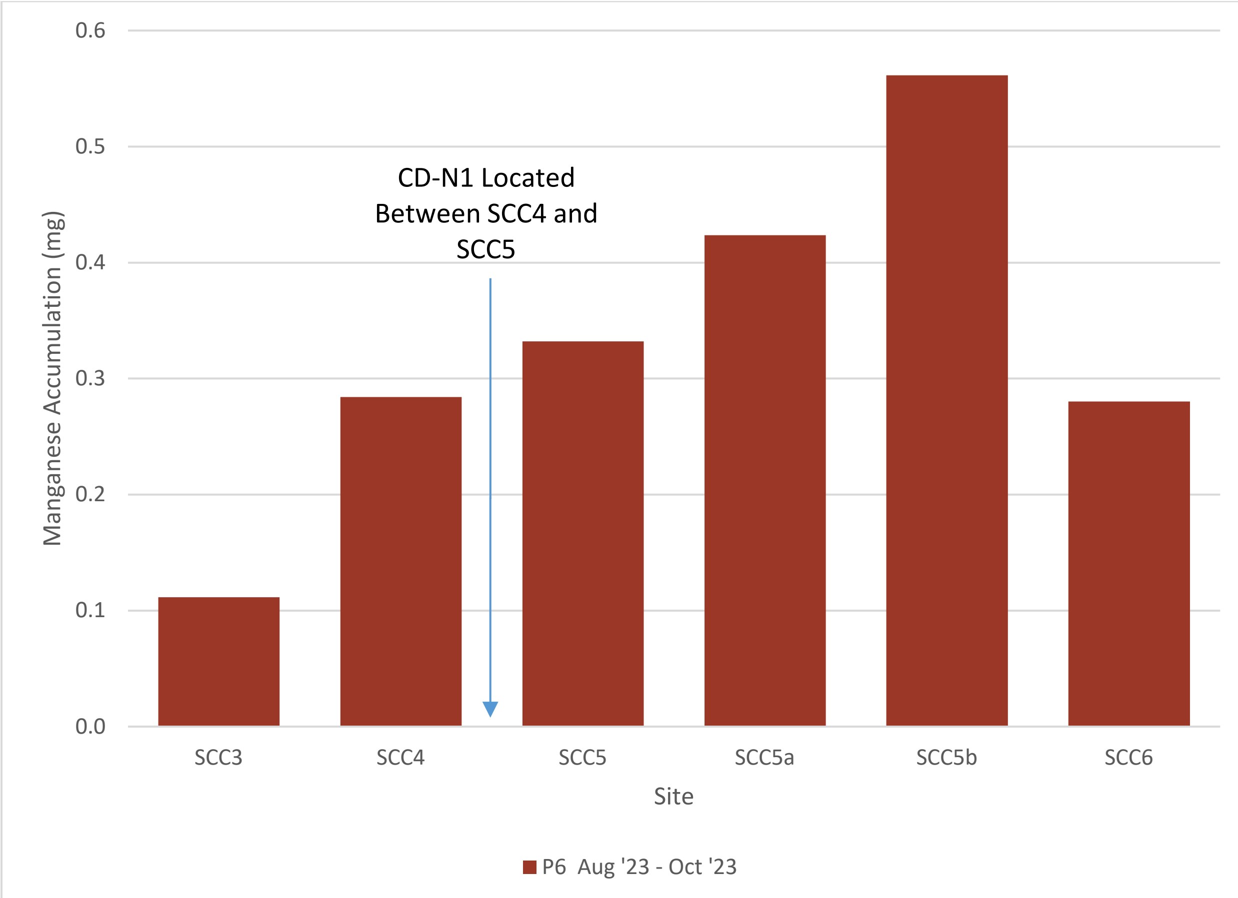


Figure 21. Paver P6 Manganese Precipitate Results



The highest Paver P8 (June 2023 – October 2023) iron sample results occurred at SCC5 (34.1 mg), and the lowest occurred at SCC4 (2.88 mg). The highest manganese sample results occurred at SCC5a (1.75 mg) and the lowest occurred at SCC4 (0.134mg). Iron and manganese P8 sample results are shown in **Figures 22** and **23** below.

Figure 22. Paver P8 Iron Precipitate Results

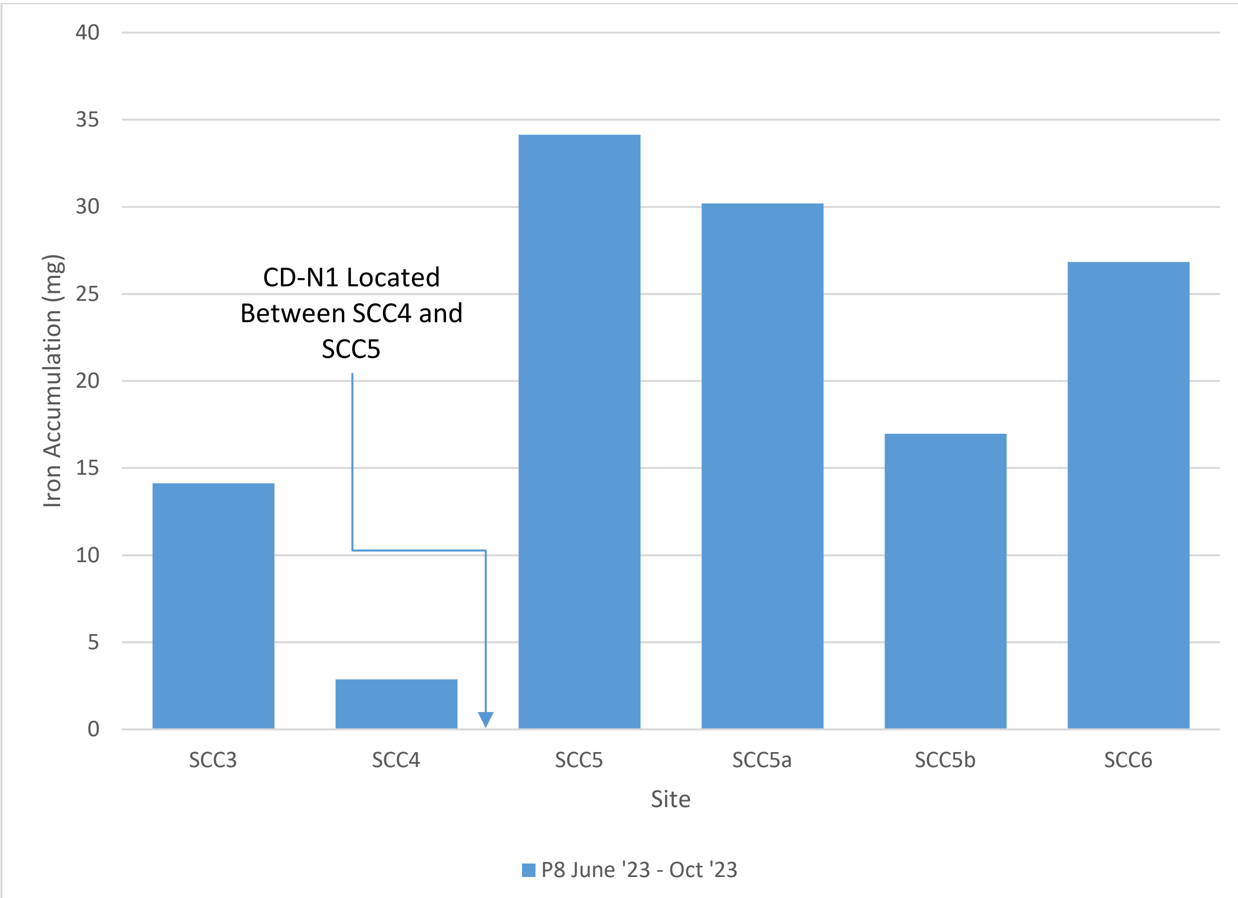
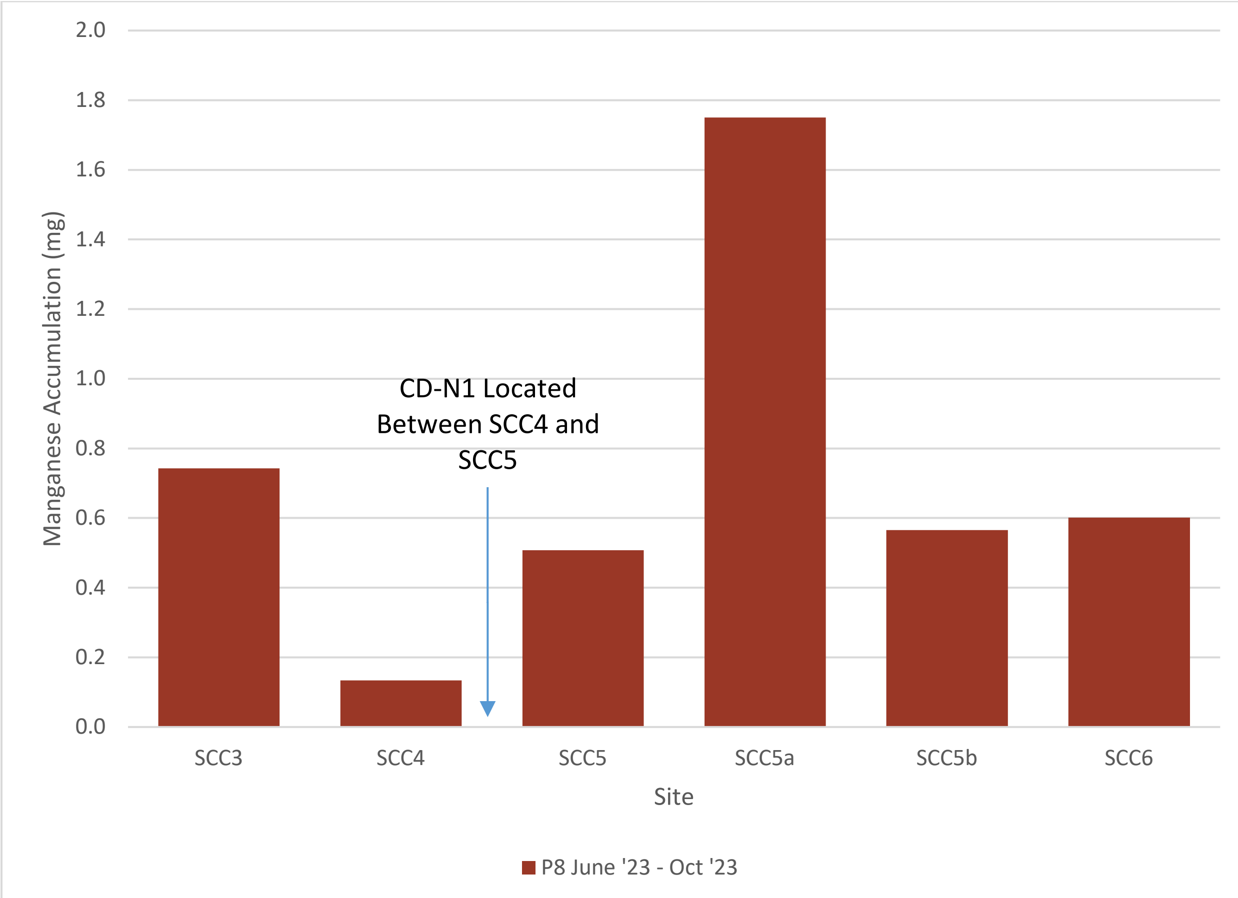


Figure 23. Paver P8 Manganese Precipitate Results



4.3 Annual Precipitate Accumulations

The total yearly precipitate accumulation at each paver site was calculated to evaluate and compare concentrations between sites. This was completed by taking an average of the three tiles per paver and adding all nine paver sets at each site for a given year. P4 was discontinued in the 2020 monitoring year; therefore, those results were excluded from this analysis. To ensure comparability of results, sites were excluded from this analysis when the paver immersion period was disrupted due to site conditions, or if pavers were lost/damaged during their immersion period. Estimated data has been included in the comparison. Data were collected in 2014; however, only five pavers were placed and, as such, 2014 data were not included in the evaluation. There were no 2023 pavers P7, P9, and P10. Following a typical schedule, these would have been scheduled to be removed in April 2024. A separate tabulation of pavers excluding P7, P9, and P10 was also prepared to allow for some evaluation of 2023 data.

For historical context in reviewing the tables, the following milestones occurred on the Project: in September 2015, the relief well vault near TUN was converted from an intermittent pumping discharge to a continuous overflow discharge. The system repairs of the gravity pipe outfall, relief well system, and realignment of the Collection Ditch were completed in September 2017. As such, 2018 was the first full year of sample results to account for these changes. Aeration in the Collection Ditch began in September 2020 and continued through the end of 2021 when it was terminated.

Annual iron accumulations are shown in **Tables 10 and 11**. For the “all-site” paver data set, as shown on **Table 10**, SCC3 was the site with the greatest annual iron accumulation in study years 2015 and 2016. SCC3 was also the site with the greatest annual iron accumulation in 2016 in the set, excluding P7, P9, and P10 (“limited” set, shown on **Table 11**). This may have been related to the contributions from the relief well water being discharged at a point between the TUN and Collection Ditch. Relief well system repairs were completed in 2017, and since then relief well outlet flows have ceased. Accordingly, the iron accumulation at SCC3 has decreased in both the all-site paver data set and the limited set. Iron accumulations at SCC4 have also decreased from 2015 and 2016 levels since the 2017 relief well system repairs. Beginning in 2017 and continuing through 2023, the highest iron accumulations were primarily observed downstream of the Collection Ditch at site SCC5a in both data sets with the exception being 2021 when the highest values were observed at SCC5 in both the limited and all-site paver sets. The aeration system operated in the Collection Ditch as part of the pilot study may have contributed to this additional precipitation at SCC5 closer to Collection Ditch outfall.

Table 10. Yearly Iron Accumulation for All Site Pavers (mg)

Year	SCC1	SCC3	SCC4	SCC5	SCC5a	SCC5b	SCC6
2015	10.6	**412**	168	233	216	*a*	307
2016	14.4	**247**	162	217	199	103	195
2017	35.7	176	25.4	107	**342**	219	*a*
2018	*a*	172	40.1	227	**807**	*a*	*a*
2019	*a*	35.7	30.5	117	**546**	*a*	*a*
2020	*b*	67.3	77.8	365	**424**	244	276
2021	*b*	21.8	11.3	**530**	454	249	226
2022	*b*	51.0	64	291	**459**	316	312

Notes:
Highest yearly value bolded for reference.
a: Not displayed. Results not comparable due to lost pavers or varying immersion periods.
b: SCC1 removed from sample schedule in 2020.

Table 11. Yearly Iron Accumulation for Site Pavers, Excluding P7, P9, and P10 (mg)

Year	SCC1	SCC3	SCC4	SCC5	SCC5a	SCC5b	SCC6
2015	6.75	103	94.3	**137**	89.2	*a*	135
2016	8.45	**134**	64.8	103	98.1	52.5	78.7
2017	24.5	116	16.2	61.6	**154**	66.7	*a*
2018	*a*	61.0	9.68	86.4	**237**	*a*	*a*
2019	*a*	25.4	27.0	41.5	**117**	*a*	*a*
2020	*b*	26.2	51.1	91.5	**325**	183	177
2021	*b*	11.2	5.99	**334**	137	135	107
2022	*b*	36.2	50.1	125	**268**	105	175
2023	*b*	31.5	17.5	71	**157**	99	105

Notes:
Highest yearly value bolded for reference.
a: Not displayed. Results not comparable due to lost pavers or varying immersion periods.
b: SCC1 removed from sample schedule in 2020.

Results of the annual manganese accumulation evaluation are overall lower and less dramatic than iron, similar to the other precipitation and water quality results. SCC5a was the site with the greatest annual manganese accumulation in 2018–2020, similar to iron, in both data sets. In contrast to the iron results, the highest annual manganese accumulations in 2021 were both observed at SCC5b. The highest manganese accumulation in 2022 and 2023 were observed at SCC5a. The manganese results are shown in **Tables 12 and 13** below.

Table 12. Yearly Manganese Accumulation for All Site Pavers (mg)

Year	SCC1	SCC3	SCC4	SCC5	SCC5a	SCC5b	SCC6
2015	0.278	9.80	3.33	4.54	4.78	a	**16.2**
2016	0.397	5.02	5.67	5.85	**6.42**	5.28	**6.42**
2017	0.766	7.60	1.25	2.97	3.62	**7.70**	*a*
2018	*a*	9.50	2.85	4.41	**14.7**	*a*	*a*
2019	*a*	1.83	1.84	2.45	**10.4**	*a*	*a*
2020	*b*	4.54	4.19	8.33	**13.9**	12.6	8.3
2021	*b*	0.95	0.83	2.26	6.72	**6.75**	2.72
2022	*b*	2.56	3.66	3.48	**10.2**	7.38	4.24

Notes:
Highest yearly value bolded for reference.
a: Not displayed. Results not comparable due to lost pavers or varying immersion periods.
b: SCC1 removed from sample schedule in 2020.

Table 13. Yearly Manganese Accumulation for Site Pavers, Excluding P7, P9, and P10 (mg)

Year	SCC1	SCC3	SCC4	SCC5	SCC5a	SCC5b	SCC6
2015	0.212	1.89	2.70	2.49	2.69	*a*	**6.66**
2016	0.257	2.65	3.29	3.58	**3.77**	2.23	2.95
2017	0.487	**5.37**	0.623	2.36	2.77	1.95	*a*
2018	*a*	3.83	0.834	2.26	**5.29**	*a*	*a*
2019	*a*	1.34	1.69	0.960	**3.94**	*a*	*a*
2020	*b*	1.50	2.74	2.61	**9.92**	9.04	5.78
2021	*b*	0.570	0.363	0.808	3.08	**4.67**	1.91
2022	*b*	1.72	2.85	1.09	**5.22**	3.42	2.57
2023	*b*	1.87	0.91	1.87	**5.42**	3.04	3.44

Notes:
Highest yearly value bolded for reference.
a: Not displayed. Results not comparable due to lost pavers or varying immersion periods.
b: SCC1 removed from sample schedule in 2020.

5.0 Recommendations

1. PSCo proposes that 2023 remains the final year of water quality monitoring activities, per the WQAMP schedule.

2. Evaluate WQAMP attainment status after 10 years of data collection, and consult with U.S. Forest Service, Colorado Parks and Wildlife, and Colorado Department of Public Health and Environment Water Quality Control Division for next steps.

6.0 References

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Appendix A: 2023 Surface Water Quality Monitoring Data

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Water Chemistry Results
Water Quality Adaptive Management Plan
April 2023 Sampling Event

Parameter	Location	SCC1	TUN	RWO	SCC4	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
	Sample Date	4/24/2023	4/24/2023	No Sample	4/24/2023	4/24/2023	No Sample	4/24/2023	4/24/2023	4/25/2023	4/25/2023	No Sample
Laboratory Analyses												
Total Hardness	mg/L as CaCO3	54.7	52.4	-	51.4	60.3	-	55.4	57.1	56.7	56.7	-
Dissolved Iron	µg/L	55.8	22.5	-	24.6	3200	-	1360	1290	715	377	-
Dissolved Manganese	µg/L	2.4	3.7	-	4.8	418	-	203	244	227	206	-
Total Iron	µg/L	126	150	-	147	3520	-	1590	1700	1400	1230	-
Total Manganese	µg/L	3.7	10.5	-	9.6	423	-	195	243	233	213	-
Calculated Results												
Dissolved/Total Iron		0.44	0.15	-	0.17	0.91	-	0.86	0.76	0.51	0.31	-
Field-measured Parameters												
Temperature	degrees C	0.38	3.47	-	a	6.22	-	5.21	5.69	4.36	5.13	-
pH		7.25	7.4	-	7.67	7.00	-	7.18	7.38	7.42	7.68	-
DO	mg/L	11.41	10.04	-	9.72	6.37	-	8.92	9.14	7.89	7.7	-
DO	%	78.9	76.9	-	77.8	51.5	-	70.3	73	60.8	60.8	-
ORP	mV	188.5	-2.0	-	-23.8	-36.7	-	-41.1	-47.2	-67.2	-56.4	-
Specific Conductivity	µs/cm	88	110	-	109	135	-	122	123	122	110	-
Conductivity	µs/cm	47	65	-	69	86	-	76	78	74	68	-

Note:Dissolved/Total Iron is the ratio of the concentrations of dissolved to total iron. It is a general indicator of the redox state of the sample, with lower ratios indicating a more oxidized state.

a: Temperature was mis-recorded at SCC4 and result is unavailable

Water Chemistry Results
Water Quality Adaptive Management Plan
June 2023 Sampling Event

Parameter	Location	SCC1	TUN	RWO	SCC4	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
	Sample Date	6/21/2023	6/22/2023	No Sample	6/22/2023	6/21/2023	No Sample	6/21/2023	6/21/2023	6/22/2023	6/22/2023	6/21/2023
Laboratory Analyses												
Total Hardness	mg/L as CaCO3	38.9	41.8	-	41.6	61.5	-	41.3	42.1	42.1	42.4	43.8
Dissolved Iron	µg/L	39.3	33.7	-	33.6	2970	-	54.4	117	133	120	57.8
Dissolved Manganese	µg/L	2	< 2	-	< 2	440	-	5.2	18.8	20.9	20.2	< 2
Total Iron	µg/L	159	110	-	111	3430	-	141	228	257	262	151
Total Manganeese	µg/L	5.5	4.5	-	4.4	429	-	8.5	20.5	23.4	23.6	15.7
Calculated Results												
Dissolved/Total Iron		0.25	0.31	-	0.30	0.87	-	0.39	0.51	0.52	0.46	0.38
Field-measured Parameters												
Temperature	degrees C	3.6	8.4	-	8.5	6.0	-	8.2	8.2	8.0	7.9	8.6
pH		7.70	7.56	-	7.53	7.04	-	7.64	7.69	7.36	7.69	7.14
DO	mg/L	10.13	7.28	-	7.19	5.97	-	8.57	8.85	7.1	7.28	9.21
DO	%	77.3	62.0		61.5	48.0		73.2	75.9	59.8	61.2	79.4
ORP	mV	227.1	112.4	-	100.9	-25.2	-	90.6	3.6	1.1	21.9	79.2
Specific Conductivity	µs/cm	79.6	87.8	-	88.7	130.2	-	84.0	86.0	90.0	90.0	88.8
Conductivity	µs/cm	47.1	60.2		60.7	82.9		57.1	58.4	60.7	60.6	61.0

Note: Dissolved/Total Iron is the ratio of the concentrations of dissolved to total iron. It is a general indicator of the redox state of the sample, with lower ratios indicating a more oxidized state.

Water Chemistry Results
Water Quality Adaptive Management Plan
August 2023 Sampling Event

Parameter	Location	SCC1	TUN	RWO	SCC4	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
	Sample Date	8/30/2023	8/30/2023	No Sample	8/30/2023	8/30/2023	No Sample	8/30/2023	8/30/2023	8/31/2023	8/31/2023	8/31/2023
Laboratory Analyses												
Total Hardness	mg/L as CaCO3	41.6	40.1	-	40.3	61.6	-	41.3	41.4	42.3	42.2	43.3
Dissolved Iron	µg/L	49.3	15.7	-	16.9	3150	-	90.7	186	142	117	48.3
Dissolved Manganese	µg/L	3.1	<2	-	<2	439	-	15.6	37.8	36.2	32.6	<2
Total Iron	µg/L	184	72	-	81.9	3530	-	176	317	284	452	166
Total Manganeese	µg/L	7	3.9	-	4.8	468	-	17.2	41.4	38.7	42.5	16.3
Calculated Results												
Dissolved/Total Iron		0.27	0.22	-	0.21	0.89	-	0.52	0.59	0.50	0.26	0.29
Field-measured Parameters												
Temperature	degrees C	5.9	13.9	-	14.0	6.4	-	13.8	13.2	12.8	12.7	13.4
pH		7.85	8.30	-	8.41	7.47	-	8.27	8.11	8.34	8.40	8.32
DO	mg/L	9.73	8.77	-	8.36	6.15	-	8.18	8.06	7.22	7.26	7.04
DO	%	78.0	85.0	-	82.3	49.6	-	78.9	77.0	68.2	68.5	67.5
ORP	mV	146.3	9.5	-	-41.0	-43.5	-	-82.9	-51.7	22.9	-8.8	108.1
Specific Conductivity	µs/cm	84.8	82.3	-	82.3	131	-	80.7	85.7	71.2	83.8	87.9
Conductivity	µs/cm	53.8	64.7	-	65.1	a	-	63.4	66.3	54.6	64.0	68.4

Note: Dissolved/Total Iron is the ratio of the concentrations of dissolved to total iron. It is a general indicator of the redox state of the sample, with lower ratios indicating a more oxidized state.

a: Conductivity was mis-recorded at CD-N1 and result is unavailable

Water Chemistry Results
Water Quality Adaptive Management Plan
September 2023 Sampling Event

Parameter	Location	SCC1	TUN	RWO	SCC4	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
	Sample Date	9/20/2023	9/20/2023	No Sample	9/20/2023	9/20/2023	No Sample	9/20/2023	9/20/2023	9/20/2023	9/20/2023	9/20/2023
Laboratory Analyses												
Total Hardness	mg/L as CaCO3	44.4	41.9	-	41.5	63.3	-	41.8	43.8	43.1	43.3	44.8
Dissolved Iron	µg/L	45.2	< 10	-	< 10	3280	-	40.7	189	156	122	20.6
Dissolved Manganese	µg/L	2.9	3.1	-	< 2	451	-	11.1	41.5	38	33.8	2.5
Total Iron	µg/L	109	63.4	-	64	3700	-	118	328	303	315	114
Total Manganese	µg/L	4.4	3.5	-	3.6	447	-	10.5	39.5	38.2	36.9	12.4
Calculated Results												
Dissolved/Total Iron		0.41	0.16	-	0.16	0.89	-	0.34	0.58	0.51	0.39	0.18
Field-measured Parameters												
Temperature	degrees C	4.3	12	-	12.3	6.2	-	11.9	11.5	11.3	11.2	11.9
pH		7.86	8.07	-	8.26	7.28	-	8.16	7.94	8.03	8.07	7.62
DO	mg/L	10.55	9.53	-	9.24	6.84	-	9.17	8.75	8.42	8.51	8.8
DO	%	81.1	88.4	-	86.1	55.4	-	84.9	79.8	77.4	77.2	81.3
ORP	mV	20.1	21.6	-	-72.9	-82.2	-	-73.8	-72.8	-71.2	-33.4	38.2
Specific Conductivity	µs/cm	98.7	94	-	93.9	147.6	-	94.7	98	97.8	97.8	100.4
Conductivity	µs/cm	59.5	70.6	-	71.1	94.5	-	71	72.6	72.3	72.0	75.3

Note: Dissolved/Total Iron is the ratio of the concentrations of dissolved to total iron. It is a general indicator of the redox state of the sample, with lower ratios indicating a more oxidized state.

Water Chemistry Results
Water Quality Adaptive Management Plan
October 2023 Sampling Event

Parameter	Location	SCC1	TUN	RWO	SCC4	CD-N1	SP	SCC5	SCC5a	SCC5b	SCC6	SCC7
	Sample Date	10/17/2023	10/18/2023	No Sample	10/18/2023	10/18/2023	No Sample	10/17/2023	10/17/2023	10/18/2023	10/18/2023	10/18/2023
Laboratory Analyses												
Total Hardness	mg/L as CaCO3	46.5	43.5		43.4	61.3		44.8	46	46.2	45.8	46.4
Dissolved Iron	µg/L	35.6	< 10		< 10	3340		232	336	235	169	27.8
Dissolved Manganese	µg/L	5.4	2.6		5	486		47	70.3	61.5	57.1	3.6
Total Iron	µg/L	82.2	153		108	3690		498	529	461	693	224
Total Manganese	µg/L	3.6	8.2		6.8	499		44.5	70.7	61.7	66	30.2
Calculated Results												
Dissolved/Total Iron		0.43	0.07		0.09	0.91		0.47	0.64	0.51	0.24	0.12
Field-measured Parameters												
Temperature	degrees C	2.2	7.3		7.5	5.9		8.2	7.8	6.8	6.6	8.1
pH		7.8	7.97		8.07	7.30		7.94	7.82	7.87	7.92	7.67
DO	mg/L	9.36	9.25		9.1	5.78		8.52	8.53	8.68	7.95	7.96
DO	%	67.8	77.3		76.2	46.4		72.3	72.0	71.0	65.0	67.5
ORP	mV	20.3	80.5		125	-20.4		-90.0	-65.0	-20.0	26.0	56.7
Specific Conductivity	µs/cm	96.5	91.6		91.5	135.0		92.3	95.8	96.6	95.6	97.4
Conductivity	µs/cm	54.7	60.7		61.0	85.6		62.7	64.4	63.0	62.2	66.0

Note: Dissolved/Total Iron is the ratio of the concentrations of dissolved to total iron. It is a general indicator of the redox state of the sample, with lower ratios indicating a more oxidized state.

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Appendix B: Surface Water Quality Time Series and Plots

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Parameter	Sample Location	4/23/2014	6/17/2014	8/19/2014	9/23/2014	10/13/2014	4/21/2015	6/16/2015	8/18/2015	9/15/2015	10/13/2015	4/26/2016	6/14/2016	8/23/2016	9/12/2016	10/18/2016
Iron, Dissolved (ug/L)	SCC1	130	46	47	87	100	72	67	78	56	58	83	67	53	46	40
	TUN	2500	34	18	11	420	5.6	39	26	63	13	2.5	24	33	15	9.3
	RWO	2100	5.1	16	2.5	2.5	2600	23	2.5	4000	3100	2600	2300	2400	2700	2700
	SCC4	8.8	33	14	49	6.4	280	35	32	190	100	290	37	59	54	76
	CD-N	2100	1900	300	410	62	510	2000	200	560	950	1800	1200	1200	410	1900
	CD-N1															
	SP		11000	12000	13000	3700	13000	11000	13000	13000	14000	13000	14000	14000	14000	14000
	SCC5	45	37	170	140	800	220	170	65	160	380	1500	36	170	220	670
	SCC5a	350	76	220	180	160	270	76	94	270	390	1300	55	290	270	600
	SCC5b						560	73	310	210	260	730	74	210	200	350
	SCC6	220	82	92	210	95	140	210	74	170	190	330	70	170	160	190
	SCC7											27	48	150	70	29
Iron, Total (ug/L)	SCC1	390	200	130	150	180	390	410	180	210	100	190	260	130	110	86
	TUN	3700	190	77	80	2900	49	210	86	79	80	83	140	120	85	99
	RWO	36	26	77	10	17	3800	63	25	4300	3400	2800	2700	2700	2800	3400
	SCC4	78	190	82	140	84	620	230	88	250	200	460	170	170	160	210
	CD-N	2500	2300	380	490	340	680	2200	290	690	1000	2000	1400	1300	580	2200
	CD-N1															
	SP		11000	13000	13000	14000	14000	13000	13000	14000	13000	14000	14000	14000	14000	15000
	SCC5	190	210	250	260	1500	340	330	170	260	550	1900	160	330	370	910
	SCC5a	530	310	260	350	320	2100	330	320	440	700	2100	250	850	470	1100
	SCC5b						860	300	860	380	530	1100	260	1200	420	700
	SCC6	400	290	250	500	310	290	480	190	350	470	700	260	400	400	560
	SCC7											98	200	340	230	1300
Manganese, Dissolved (ug/L)	SCC1	5.9	3.2	5	6.8	6	4	2.5	6.7	5.5	6.7	4.9	3.4	5.3	5.3	4.5
	TUN	410	2.4	1	1	450	1	1	1	2.9	1	1	1	1	1	1
	RWO	360	120	1	88	110	620	83	30	690	540	440	390	390	430	420
	SCC4	2.2	1	1	15	1	51	1	1	74	26	66	6.3	11	15	20
	CD-N	360	340	92	100	82	140	320	77	150	210	400	320	320	200	390
	CD-N1															
	SP		1700	1900	1900	1800	1500	1600	1700	1800	1900	1800	1900	2000	1900	1900
	SCC5	23	3.4	48	37	250	49	29	10	37	89	330	2.3	46	53	140
	SCC5a	91	15	61	56	45	75	11	20	68	110	320	12	81	74	150
	SCC5b						150	12	72	61	98	300	19	74	66	130
	SCC6	81	19	46	82	42	57	41	19	53	85	270	19	66	56	110
	SCC7											1	2.5	1	1	1

Parameter	Sample Location	3/28/2017	4/18/2017	6/28/2017	8/23/2017	9/12/2017	10/11/2017	4/17/2018	6/20/2018	8/21/2018	9/25/2018	10/17/2018	4/17/2019	6/11/2019	8/13/2019	9/17/2019	10/8/2019
Iron, Dissolved (ug/L)	SCC1	46	93	35	61	70	75	96	47	46	36	27	44	75	40	33	27
	TUN		2.5	25	20	16	7	2.5	9.5	29	12	7.7	2.5	33	26	16	6.9
	RWO		2400														
	SCC4		190	26	20	19	5	2.5	18	33	11	6.9	7.8	33	28	16	6.9
	CD-N		2400														
	CD-N1				7200	4800	4700	4100	4000	4100	3700	3900	3900	3600	3800	3800	3600
	SP		14000	7300													
	SCC5	1000	960	27	58	140	170	1500	28	320	1200	710	600	36	33	180	450
	SCC5a		990	33	170	290	460	1400	170	390	1100	1100	600	76	93	290	420
	SCC5b		440	140	180	230	370	880	150	320	490	690		78	92	240	410
	SCC6		220	120	140	180	290	490	150	300	270	460	420	72	79	200	280
	SCC7			60	47	76	63		58					61	75	63	
Iron, Total (ug/L)	SCC1	91	170	230	180	170	150	170	150	170	70	100	89	490	120	83	62
	TUN		78	140	85	97	91	56	80	95	80	67	62	230	85	74	63
	RWO		2500														
	SCC4		310	160	85	190	88	63	82	100	83	82	63	230	120	76	62
	CD-N		2500														
	CD-N1				8000	5000	5000	4500	4500	4300	4000	4300	4400	4200	4300	4100	4000
	SP		15000	9300													
	SCC5	1400	1300	160	170	250	240	1800	130	510	1500	950	710	230	1100	270	570
	SCC5a		1500	170	290	450	670	2100	310	840	2300	1500	820	300	220	500	740
	SCC5b		740	330	320	390	570	3100	320	780	1400	3300		320	200	410	670
	SCC6		570	320	290	360	550	820	310	800	1200	990	710	340	250	420	550
	SCC7			250	120	150	130		1100					220	230	110	
Manganese, Dissolved (ug/L)	SCC1	3.4	5.7	2	4.6	5.7	7.8	5.6	3.2	3.7	4.1	4.6	3.3	3.3	3	3.6	3.1
	TUN		1	1	1	1	1	2.7	1	2	1	1	1	2.2	1	1	1
	RWO		410														
	SCC4		46	1	1	3.6	1	1	1	1	1	1	1	2.2	1	1	1
	CD-N		510														
	CD-N1				1100	690	670	570	570	610	580	550	560	550	570	550	550
	SP		2100	1600													
	SCC5	230	240	1	15	30	32	240	8.9	75	220	120	97	1	2	32	83
	SCC5a		290	5.2	39	63	89	270	36	82	240	220	120	14	18	58	96
	SCC5b		220	33	45	58	83	300	36	74	230	210		14	18	57	110
	SCC6		200	30	41	54	77	220	33	61	190	180	130	14	16	51	96
	SCC7			1	1	1	1		1					2.5	1	1	

Parameter	Sample Location	4/28/2020	6/15/2020	8/25/2020	9/16/2020	10/13/2020	11/30/2020	12/17/2020	1/20/2021	2/24/2021	3/30/2021	4/29/2021	5/20/2021	6/22/2021	7/13/2021	8/24/2021	9/21/2021
	SCC1	120	47	28	32	23						75.8		37.9		57	31.9
	TUN	2.5	50	17	16	2.5						24.6		51.3		23.2	16.9
	RWO																
	SCC4	2.5	50	24	13	5.8						21.5		47.1		24.3	17.5
	CD-N																
Iron, Dissolved (ug/L)	CD-N1	3900	3700	3500	3100	3100	3810	3640	3910	4520	3640	3500	3190	3250	3470	3580	3590
	SP																
	SCC5	1900	200	24	1100	1000	253	601	1320	1370	1410	1500	1670	240	45.5	49.2	115
	SCC5a	1400	170	58	1200	1200	552	963	1190	1020	1050	813	1430	240	160	245	527
	SCC5b	450	150	60	810	890	347	683	837	700	696	850	938	230	137	208	420
	SCC6	300	140	57	410	490	231	576	465	399	353	290	383	204	119	149	292
	SCC7		56	85		67								93.4		54.8	30.4
	SCC1	250	140	84	77	55						237		146		146	79.4
	TUN	53	130	72	64	33						320		133		81.9	64.5
	RWO																
	SCC4	57	150	81	56	34						247		124		185	64.3
	CD-N																
Iron, Total (ug/L)	CD-N1	4400	4300	4000	3500	3400	4030	3930	4330	5280	6120	7830	4210	3750	4010	3970	4340
	SP																
	SCC5	2500	330	96	1600	1300	326	940	1550	1700	1750	2000	2220	413	126	132	153
	SCC5a	4100	1400	250	1500	1600	611	1220	1480	1340	1440	1630	2000	408	261	375	737
	SCC5b	700	310	200	1400	1400	522	999	1180	1010	1130	1420	1520	394	265	352	664
	SCC6	1100	300	260	980	1500	424	748	835	679	780	930	1060	414	253	345	606
	SCC7		170	290		89								177		111	68.4
	SCC1	5.3	1	1	2.1	3						3.5		1		3	3.9
	TUN	1	1	1	1	1						23		2.6		1	1
	RWO											-		-			
	SCC4	1	1	1	1	1						18.4		2.1		1	1
	CD-N																
Manganese, Dissolved (ug/L)	CD-N1	560	570	560	450	430	579	483	552	720	643	593	518	477	541	533	502
	SP																
	SCC5	310	34	1	170	160	44.9	94.1	199	230	253	280	276	36.4	8.8	6.7	19.9
	SCC5a	300	32	8.1	220	230	91	165	219	223	245	266	297	40	29.3	45.7	93.2
	SCC5b	110	31	9	210	220	88.4	157	206	204	226	245	273	40	29.2	42.9	88.6
	SCC6	100	29	8.2	190	210	81.8	146	190	179	199	214	243	38.6	27.7	41.2	81.9
	SCC7		1	1		5.2								1		1	1

Parameter	Sample Location	10/21/2021	3/28/2022	4/26/2022	6/22/2022	8/17/2022	9/15/2022	10/18/2022	3/28/2023	4/24/2023	6/21/2023	8/30/2023	9/20/2023	10/27/2023
Iron, Dissolved (ug/L)	SCC1	50.1	30.4	80.6	35.2	138	76	47.6	17.2	55.8	39.3	49.3	45.2	35.6
	TUN	22.8		5.4	17.3	16.2	22.3	10.1		22.5	33.7	15.7	5	5
	RWO													
	SCC4	20.5		9.9	17.8	18.3	21.2	10.2		24.6	33.6	16.9	5	5
	CD-N													
	CD-N1	3920		3260	3170	3440	3240	2930		3200	2970	3150	3280	3340
	SP													
	SCC5	295	38.9	1880	150	213	84.7	603	2430	1360	54.4	90.7	40.7	232
	SCC5a	473		1620	162	281	454	724		1290	117	186	189	336
	SCC5b	385		1180	146	160	350	591		715	133	142	156	235
	SCC6	282		538	126	123	263	372		377	120	117	122	169
	SCC7				37.3	37.8	51.8	30.2			57.8	48.3	20.6	27.8
Iron, Total (ug/L)	SCC1	110	195	140	139	305	198	129	62.9	126	159	184	109	82.2
	TUN	49.7		74.1	88.9	88.6	91.8	50.7		150	110	72	63.4	153
	RWO							-						
	SCC4	50.2		61.9	91.7	97.7	89	54.9		147	111	81.9	64	108
	CD-N													
	CD-N1	4500		3800	3580	3780	3800	3310		3520	3430	3530	3700	3690
	SP							-						
	SCC5	402	185	2200	158	319	191	875	2720	1590	141	176	118	498
	SCC5a	637		2200	318	497	672	1180		1700	228	317	328	529
	SCC5b	565		1650	281	453	593	860		1400	257	284	303	461
	SCC6	554		1280	288	527	508	1130		1230	262	452	315	693
	SCC7				99	98.7	1450	210			151	166	114	224
Manganese, Dissolved (ug/L)	SCC1	2.4	1	3.1	1	4.6	4	3.20	1	2.4	2	3.1	2.9	5.4
	TUN	1		1	1	1	1	1		3.7	1	1	3.1	2.6
	RWO							-						
	SCC4	1		1	1	1	1	1		4.8	1	1	1	5
	CD-N													
	CD-N1	569		440	472	475	424	366		418	440	439	451	486
	SP							-						
	SCC5	45.9	7.8	259	26.1	36	13.8	87.7	357	203	5.2	15.6	11.1	47
	SCC5a	86.2		281	30.5	55.1	76.3	118		244	18.8	37.8	41.5	70.3
	SCC5b	82.6		263	29.5	38.1	71.2	114		227	20.9	36.2	38	61.5
	SCC6	77.7		247	27.9	35.2	65.9	112		206	20.2	32.6	33.8	57.1
	SCC7				1	1	1	1			1	1	2.5	3.6

Parameter	Sample Location	4/23/2014	6/17/2014	8/19/2014	9/23/2014	10/13/2014	4/21/2015	6/16/2015	8/18/2015	9/15/2015	10/13/2015	4/26/2016	6/14/2016	8/23/2016	9/12/2016	10/18/2016
Manganese, Total (ug/L)	SCC1										7	7.1	7.9	7.2	6.7	5.2
	TUN										4.7	5.1	7.4	7.6	5.9	5.4
	RWO										520	460	400	400	440	440
	SCC4										27	74	12	16	18	21
	CD-N										210	410	330	320	200	400
	CD-N1															
	SP										1800	1900	1900	2000	2000	1900
	SCC5										91	340	8	46	57	140
	SCC5a										110	350	18	98	77	160
	SCC5b										99	310	24	120	71	130
	SCC6										88	270	24	68	62	120
	SCC7											3.9	14	11	9.9	150
DO	SCC1	8.96	10.54	8.63	10.64	9.71	9.62	9.05	8.67	8.46	9.46	10.62	8.73	9.16	10.22	9.36
	TUN	8.31	10.01	7.57	7.43	8.21	9.74	8	7.55	7.3	7.52	10.28	8.15	7.44	7.65	7.8
	RWO	6.95	8.4	6.27	7.91	6.84	4.14	5.12	5.74	3.35	3.25	4.03	4.63	3.65	3.87	3.29
	SCC4	8.35	7.53	6.74	8.35	9.06	8.8	7.9	7.22	7.11	7.18	8.76	7.32	7.7	8.24	7.72
	CD-N	6.95	7.9	7.6	8.26	7.92	7.98	8.89	7.26	6.78	5.87	7.12	6.6	7.09	7.88	5.56
	CD-N1															
	SP		2.11	0.76	0.95	7	1.74	1.4	0.55	0.75	0.67	0.5	0.46	0.4	0.69	0.36
	SCC5	8.86	10.08	7.62	8.64	8.66	12.32	7.91	7.16	7.11	6.6	7.71	7.85	7.34	7.26	7.7
	SCC5a	8.87	8	7.75	8.29	8.83	8.59	7.85	7.02	6.78	7.14	8.49	7.61	6.88	6.93	7.35
	SCC5b						8.85	7.97	7.6	6.65	7.42	7.67	7.86	7.44	7.26	8.26
	SCC6	8.92	8.48	7.5	8.94	8.69	8.95	8.03	7.42	7.11	7.53	7.25	8.06	7.37	7.74	8.23
	SCC7											8.01	7.56	7.4	8.19	8
ORP	SCC1	267.9	154.5	360.8	293	149.4	241.7	230.7	149.3	80	97.8	127	131.9	127.2	130.8	140.3
	TUN	-10	-44.4	374.6	285.8	92.2	240.3	80.1	140.2	-41.5	76.2	85.8	137.9	75.6	59.9	123.1
	RWO	-22.3	53.3	388.4	313	170.7	42.7	139.4	159.5	-96.1	-14.1	15.8	10.7	40.3	79.8	-7
	SCC4	3.9	56.4	232.7	-46.9	215	-23.7	146.5	94.8	-121.2	-81.8	-42.9	63.4	37.1	62.5	-36.6
	CD-N	-22.3	5.8	75.1	-6.5	86.2	-52.7	63.7	70.1	-82	-48.6	-25.6	-5.7	-1.5	56.9	-56
	CD-N1															
	SP		-92.6	78	-102.6	-44.6	-78.4	-4.5	-84.2	-155	-130.4	95.2	-78.8	-49.2	71.9	-138.2
	SCC5	18.8	82.9	183.1	-59.7	16	84.8	14.1	42.8	-131.1	-103.6	-68.1	-8.1	-43.8	49.3	-85.6
	SCC5a	-38.8	60.9	220.6	-63.9	72	-43	43.6	-12.2	-111.5	-116	83.4	9.7	15.4	50.4	-79.8
	SCC5b						-91.9	54.9	-51.9	-67.4	-110.8	-90.2	-25.4	-13.1	67.7	-47.5
	SCC6	-24.8	34.7	301.4	47.3	110.7	-15.1	16	30.4	-47.5	-75.1	124	-16.7	89.6	62.5	17.7
	SCC7											-28.90	65.10	23.50	67.50	25.70

Parameter	Sample Location	3/28/2017	4/18/2017	6/28/2017	8/23/2017	9/12/2017	10/11/2017	4/17/2018	6/20/2018	8/21/2018	9/25/2018	10/17/2018	4/17/2019	6/11/2019	8/13/2019	9/17/2019	10/8/2019
Manganese, Total (ug/L)	SCC1		6.6	7.5	7.1	6.5	9.1	6.9	5.8	6.9	4.8	6.4	3.9	16	5.1	4.3	3.6
	TUN		6.3	7.4	3.8	6.1	5.1	3.5	5.2	4.9	4.6	3.2	2.3	8.4	5.5	4.5	4.1
	RWO		400														
	SCC4		47	8.3	3.8	14	5.3	3.6	5.6	5.5	4.8	4.2	2.6	8.6	6.3	4.5	4.1
	CD-N		490														
	CD-N1				1200	700	690	590	590	620	590	570	580	570	590	560	570
	SP		2000	1600													
	SCC5		230	8.7	15	30	29	250	12	64	210	130	93	8.8	71	31	73
	SCC5a		280	12	41	65	92	280	39	91	290	220	120	20	21	63	100
	SCC5b		220	37	47	63	87	320	39	83	240	260		21	21	58	110
	SCC6		200	36	44	57	84	230	35	74	200	190	130	23	21	56	100
	SCC7			17	5.9	6.5	6		15					18	19	4.4	
DO	SCC1	10.37	9.71	8.41	9.53	8.79	11.4	9.01	10.22	9.43	8.8	10.17	10.31	10.75	11.58	8.75	7.7
	TUN		8.54	7.83	7.7	7.97	9.25	10.08	8.95	7.71	7.7	8.44	10.41	9.79	8.12	8.21	8.64
	RWO		4.11														
	SCC4		7.86	7.6	7.76	8.21	8.83	9.89	8.63	7.94	7.62	8.5	10.29	9.12	8.06	8.14	8.66
	CD-N		5.24														
	CD-N1				7.13	4.69	5.73	6.04	6.18	5.93	6.4	6.41	5.43	7.01	5.83	5.77	6.1
	SP		0.34	1.84													
	SCC5	8.64	7.55	7.68	7.67	7.91	8.6	8.9	8.19	7.4	7.78	7.77	9.4	9.74	7.94	7.66	7.9
	SCC5a		7.63	7.58	7.46	7.71	8.6	8.75	8.63	7.69	7.51	7.4	9.11	9.5	8.08	7.53	8.42
	SCC5b		8.42	7.44	7.38	7.55	8.76	9.93	8.03	6.89	7.5	8.24		9.35	10.38	7.56	8.4
	SCC6		8.48	7.36	7.59	7.58	8.48	10.28	8.48	7.55	7.92	8.64	8.88	9.52	8.02	6.99	8.4
	SCC7			7.54	7.42	8.31	8.6		8.68					9.53	8.03	7.12	
ORP	SCC1	356.1	300	108.2	193.6	-64.4	195.7	326.9	218.5	240	220	139.3	182.4	264.1	136.2	6	115.3
	TUN		264.5		181.8	-53.9	219.8	342.2	198.5	226	201.2	106.5	182.1	198.6	93.2	-80.2	81.4
	RWO		159.9														
	SCC4		139.2	86.9	125.4	-65.4	-22.1	65.5	69	145	163.6	77.5	26.6	175.9	99.5	-95.9	99.3
	CD-N		160														
	CD-N1				-55.7	14.6	-70.6	-36.5	52	5.2	-54	74.9	-58.6	-13	-26.5	-73.4	-31.1
	SP		16	63.9													
	SCC5	-26.2		112	96.9	-26.7	-49.5	21.7	-34	-91	-71.8	70.8		272	-18.3	-132.9	-91.5
	SCC5a		164.5	98.6	-40.6	-58.8	-72.3	-25.8	-65.5	98	-57.8	95.1	-70.5	51.1	-67.8	114.7	-96
	SCC5b		120	81.1	-52.7	-38.8	-78.1	-3	-37.5	199.7	-45	43.5		20	-64	-112.8	-57.4
	SCC6		137	100.5	-35.4	-21	-68.2	25	-16	215	21.5	79.5	-36.1	79.5	-44.1	-113	-66.2
	SCC7			86.60	129.00	-23.60	201.00		182.00					297.20	62.30	-89.50	

Parameter	Sample Location	4/28/2020	6/15/2020	8/25/2020	9/16/2020	10/13/2020	11/30/2020	12/17/2020	1/20/2021	2/24/2021	3/30/2021	4/29/2021	5/20/2021	6/22/2021	7/13/2021	8/24/2021	9/21/2021
Manganese, Total (ug/L)	SCC1	6.8	4.4	3.6	3	3.4						7.4		4.8		5.3	4
	TUN	2.9	6.6	5.0	5.5	2.4						40.5		7.6		3.7	3
	RWO																
	SCC4	3.5	6.7	6.0	4.6	2.7						28.8		6.9		12.4	3.5
	CD-N																
	CD-N1	510	580	570	470	460	599	504	573	732	663	631	545	482	554	547	502
	SP																
	SCC5	300	35	6.9	170	180	45.2	117	205	236	262	289	285	38.1	11.9	10.5	14.4
	SCC5a	310	56	19	230	240	94.6	170	225	227	250	274	297	42.2	32	47.4	94
	SCC5b	110	34	17	220	230	90.8	163	213	209	233	255	280	42.1	32.9	45.3	90.9
	SCC6	110	32	24	200	220	84.3	152	195	184	203	226	247	41.8	31.5	43.5	87.3
	SCC7		16	29		8.1								14.2		6.8	3
DO	SCC1	10.79	8.92	7.75	7.58	12.13						9.11		9.18		9.39	9.82
	TUN	9.86	8.26	8.06	7.20	8.90						8.83		10.35		8.78	8.57
	RWO																
	SCC4	10.58	7.19	7.59	7.30	9.16						9.13		9.17		6.93	8.19
	CD-N																
	CD-N1	6.07	5.73	5.52	5.30	5.60	6.11	6.75	5.94	6.40	6.67	5.88	6.67	6.06	6.30	6.15	5.60
	SP																
	SCC5	8.36	8.08	8.14	7.03	8.41	10.08	10.55	8.86	9.35	9.15	7.94	9.15	9.4	8.08	7.65	7.75
	SCC5a	8.94	7.87	8.21	6.87	8.71	10.4	10.26	8.85	9.05	8.76	7.83	8.76	9.67	8.22	7.48	7.7
	SCC5b	10.21	7.37	7.21	7.55	8.93	10.12	10.18	9.5	10.1	9.7	9.39	9.7	8.94	8.09	7.92	7.67
	SCC6	9.8	7.95	6.88	7.11	8.95	10.49	9.75	9.55	10.22	9.66	9.09	9.66	8.69	8.12	7.75	7.86
	SCC7		8.51	8.71		8.61								8.9		7.45	7.23
ORP	SCC1	381.3	148.3	139.5	258.2	233.1						143.5		81.1		-73.9	253.1
	TUN	205.9	377.3	55.0	163	222.0						180.1		102.0		-53.5	84.7
	RWO																
	SCC4	200.9	295.4	-31.1	93.1	184.1						71.4		24.5		54.5	66.9
	CD-N																
	CD-N1	-59.6	-25.4	-43.9	-40.2	-13.8	-64.6	-79.9	-44.3	-70.3	-61.8	-67.4	-61.8	-51.1	-64.2	-59.7	-55.4
	SP																
	SCC5	-69.1	72.1	83.2	68.8	1.5	-57.5	-62.5	-31.7	-70.4	-60	-64.8	-60	43	34.6	-50.1	-54
	SCC5a	-98.4	-44.4	83.0	64.5	13.8	-31.8	-49.5	-38.8	-53.9	-37.4	-17.6	-37.4	64.1	0.8	65	-65.5
	SCC5b	-12.6	44.0	102.6	-7.9	13.2	-10.8	-37.6	-29.8	-53.1	-54.4	-104.1	-54.4	-10.9	28.5	-86.6	53.3
	SCC6	13.7	13.8	105.2	-40.6	-17.8	103.5	-6	-25	-33.2	23.5	-31.8	23.5	-10.1	40.7	-81.6	-29.7
	SCC7		188.9	130.6		147.7								158.4		-80.2	120.8

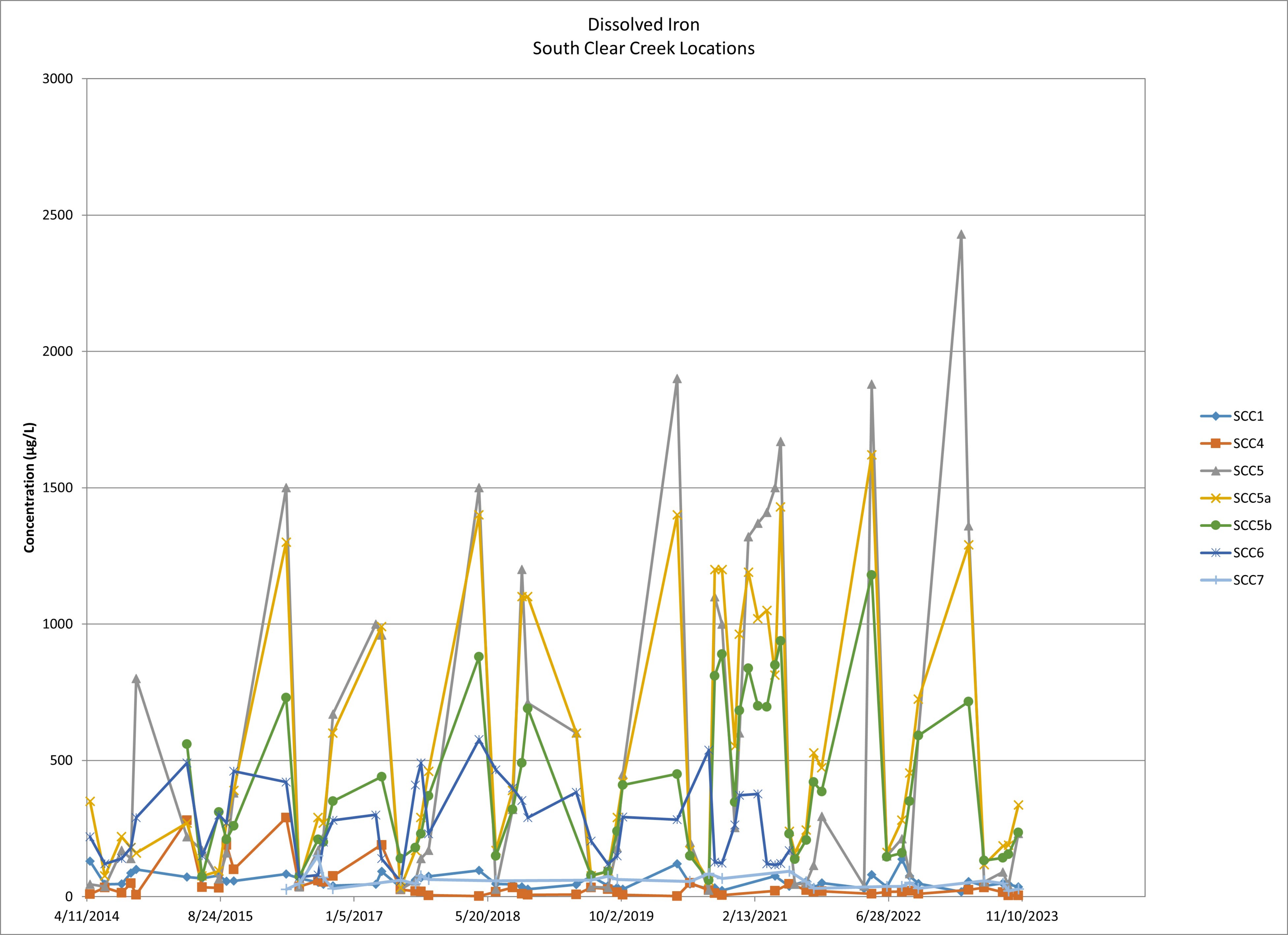
Parameter	Sample Location	10/21/2021	3/28/2022	4/26/2022	6/22/2022	8/17/2022	9/15/2022	10/18/2022	3/28/2023	4/24/2023	6/21/2023	8/30/2023	9/20/2023	10/27/2023
Manganese, Total (ug/L)	SCC1	3.9		4.3	4.5	9	7.5	4.90	2.7	3.7	5.5	7	4.4	3.6
	TUN	< 2		3.5	3.7	3.9	3	2.1		10.5	4.5	3.9	3.5	8.2
	RWO							-						
	SCC4	2.1		3	4.1	4.5	3.3	2.5		9.6	4.4	4.8	3.6	6.8
	CD-N													
	CD-N1	582		444	479	499	433	377		423	429	468	447	499
	SP							-						
	SCC5	48.1		257	12.1	36.3	15.4	101	376	195	8.5	17.2	10.5	44.5
	SCC5a	88.5		284	32.7	59.5	78.7	125		243	20.5	41.4	39.5	70.7
	SCC5b	85.1		269	32	44.4	76.2	126		233	23.4	38.7	38.2	61.7
	SCC6	82.2		254	30.7	44	70.7	123		213	23.6	42.5	36.9	66
	SCC7				8.1	6.6	217	23.5			15.7	16.3	12.4	30.2
DO	SCC1	9.14	8.37	8.31	8.54	8.36	9.61	9.34	11.4	11.41	10.13	9.73	10.55	9.36
	TUN	10.24		9.15	7.4	6.96	6.78	8.11		10.04	7.28	8.77	9.53	9.25
	RWO													
	SCC4	9.7		8.81	6.51	6.44	7.13	8.02		9.72	7.19	8.36	9.24	9.1
	CD-N													
	CD-N1	5.65		5.76	5.64	5.55	5.07	5.1		6.37	5.97	6.15	6.84	5.78
	SP													
	SCC5	9.44	9.01	7.61	7.38	6.61	6.97	8.19	7.1	8.92	8.57	8.18	9.17	8.52
	SCC5a	9.32		7.23	6.94	6.59	6.73	7.79		9.14	8.85	8.06	8.75	8.53
	SCC5b	9.53		7.8	7.12	6.55	6.92	8.22		7.89	7.1	7.22	8.42	8.68
	SCC6	9.36		7.86	7.27	6.67	7.01	8.28		7.7	7.28	7.26	8.51	7.95
	SCC7				7.16	6.91	6.76	7.72			9.21	7.04	8.8	7.96
ORP	SCC1	135.1	205.3	44.4	176	167	211.4	128	155.7	188.5	227.1	146.3	20.1	20.3
	TUN	100.2		52.9	146.1	84.6	148.9	142.3		-2.0	112.4	9.5	21.6	80.5
	RWO													
	SCC4	50.1		34.8	165	46.4	96.4	74.7		-23.8	100.9	-41	-72.9	125
	CD-N													
	CD-N1	-24.1		-35.2	-55.2	-19.2	-36.8	-45.7		-36.7	-25.2	-43.5	-82.2	-20.4
	SP													
	SCC5	-52.6	35.1	-75	-24.1	-27.9	-56.8	-70	-3.2	-41.1	90.6	-82.9	-73.8	-90.0
	SCC5a	-37.4		-60.8	-21.6	7.2	24.2	-23.9		-47.2	3.6	-51.7	-72.8	-65.0
	SCC5b	-25.5		-86.5	-45.8	-20.4	-42.2	-65.8		-67.2	1.1	22.9	-71.2	-20.0
	SCC6	-7.3		-67.5	-23.5	-24.2	-52.4	-78.8		-56.4	21.9	-8.8	-33.4	26.0
	SCC7				73.8	101.6	158.7	139.9			79.2	108.1	38.2	56.7

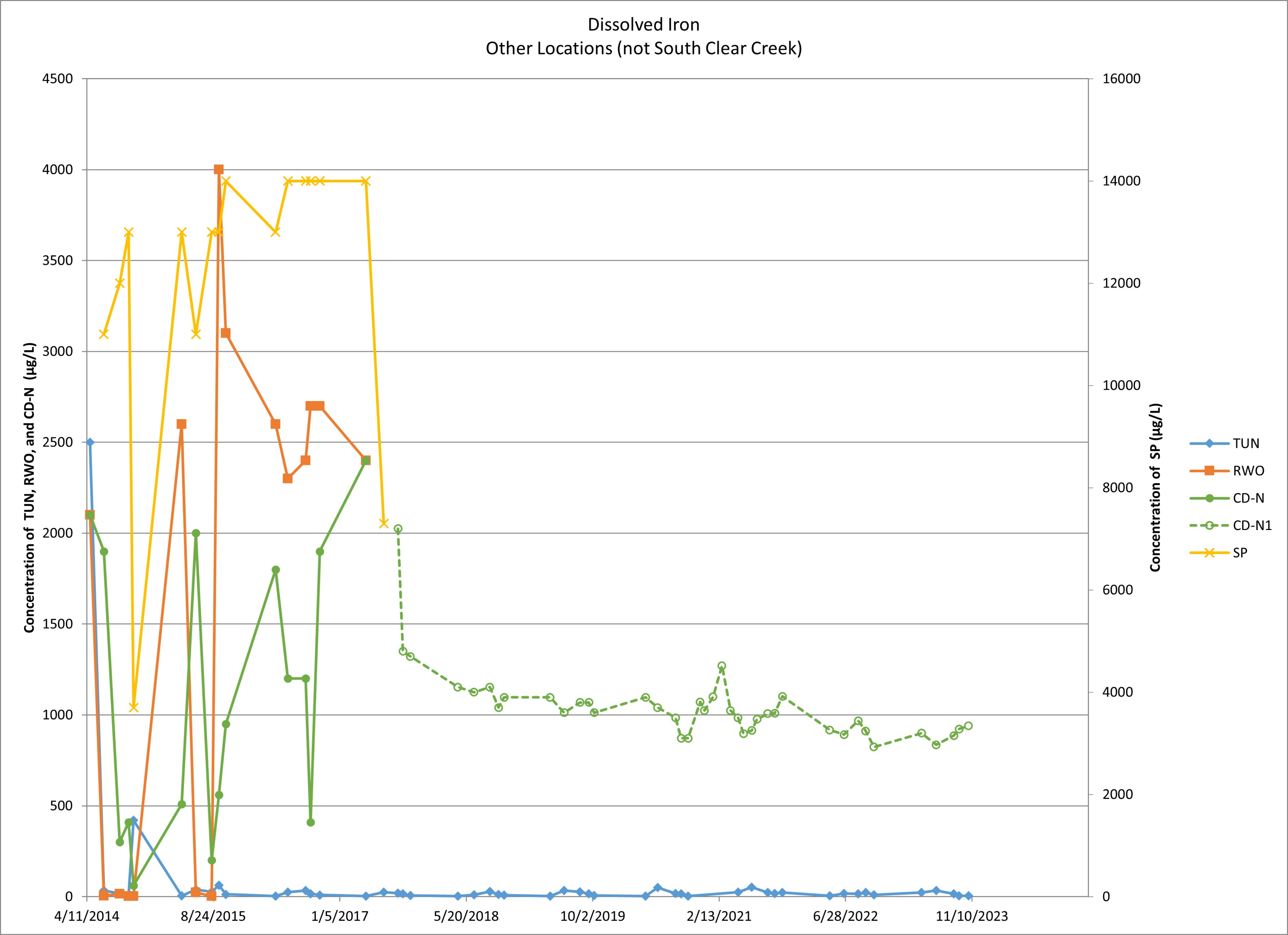
Parameter	Sample Location	4/23/2014	6/17/2014	8/19/2014	9/23/2014	10/13/2014	4/21/2015	6/16/2015	8/18/2015	9/15/2015	10/13/2015	4/26/2016	6/14/2016	8/23/2016	9/12/2016	10/18/2016
pH	SCC1	7.22	7.05	7.07	7.54	7.83	7.17	6.79	7.26	7.42	7.7	7.52	7.75	7.54	6.5	7.02
	TUN	7.37	7.6	7.95	8.09	7.22	8.18	7.23	7.8	8.14	8.35	8.12	8.07	8.09	7.73	7.31
	RWO	7.11	7.58	7.64	7.43	7.49	7.13	7	7.5	7.23	7.37	7.22	7.21	6.98	6.61	6.65
	SCC4	7.57	7.84	7.74	8.02	8.06	7.38	7.25	7.82	7.87	7.94	7.69	8.01	7.75	7.39	7.27
	CD-N	7.11	7.14	7.31	7.41	7.41	7.36	6.94	7.36	7.51	7.45	7.35	7.36	7.22	7.55	6.85
	CD-N1															
	SP		7.06	7.2	7.25	7.2	7.12	6.72	7.09	7.16	7.33	7.08	7.25	7.86	6.55	6.85
	SCC5	7.77	7.96	7.96	7.96	7.66	7.93	7.2	7.6	7.74	7.82	7.46	8.05	7.74	7.2	7.11
	SCC5a	7.62	7.94	7.89	7.91	7.96	7.81	7.36	7.76	7.81	7.87	7.53	8.04	7.69	7.48	7.2
	SCC5b						7.73	7.15	7.46	7.99	8.03	7.59	7.91	7.56	7.47	7.16
	SCC6	7.72	8.17	8.01	7.96	7.9	7.98	7.19	7.6	8.03	8.16	7.52	7.74	7.55	7.61	7.02
	SCC7											7.63	8.09	7.66	7.55	7.15
Specific Conductivity (Æv2fp ,	SCC1	112.3	217	77.5	87.5	88.2	105.2	75.1	91	80.8	18.4	110.4	74.1	87	91.5	108.3
	TUN	120.8	127	83.6	87.6	124.3	99.9	92.2	90	76.6	74	104.6	86	89	88.8	102.6
	RWO	140.8	258	162.4	175.3	174.2	158.4	197.2	180	134.9	120.2	143.7	135.7	147	145.3	159.7
	SCC4	104.6	130	94.3	88.1	87.8	119.3	92.1	90	81.8	77	111.9	86.7	91	90.3	106.6
	CD-N	140.8	188	134.6	134.2	130.6	127.5	143.5	148	118.2	110.3	132.5	125.5	137	130.4	148.3
	CD-N1															
	SP		291	182.2	180.6	173.3	177.6	192.4	194	156.9	146.5	180.5	171.9	183	179.4	193.8
	SCC5	102.7	133	84.7	89.8	106.8	102.9	92.3	78	80.2	78.9	122.8	83.3	93	91.2	113.2
	SCC5a	109.7	169	86.9	91.5	88.7	104.6	91.3	92	81.2	80.9	122.9	85.1	95	94	114.3
	SCC5b						116.1	91	144	81.2	80.5	125.5	82.4	92	93.8	446.2
	SCC6	108.8	139	93.1	97.6	91.3	104.9	95.1	132	80.8	80.1	199	82.6	71	93.5	438.6
	SCC7											113.7	87.2	98	100.8	127.8
Temperature (° C)	SCC1	4.8	6.6	6.9	5.8	5.5	0.1	5.4	5.6	6	2.5	0.5	3.6	5.7	4.6	2
	TUN	5.6	10.7	13.8	12.8	9.4	5.3	10.4	13.8	12.9	11.5	4.7	10.7	14.7	13.2	8.5
	RWO	7.5	8	8.8	8.2	6.1	4.8	6.6	8.6	6.9	6.7	6.7	7.2	7.3	7.1	6.8
	SCC4	6.1	10.9	14.9	12.7	9.6	6.4	10.7	14.4	13	11.4	6.9	11.1	14.6	13.4	9.7
	CD-N	7.5	9.7	7.4	6.5	7.5	8.1	7.6	9	8.1	6.7	8.5	8.6	7.3	7.2	6.9
	CD-N1															
	SP		8.1	7.8	7.4	6.9	4.7	6.5	7.8	7.7	7.2	4.9	6.7	7.7	7.4	6.7
	SCC5	5.5	12	13.9	12.5	8.8	6.2	10.2	14.1	13	11.2	6.6	10.8	14	13.4	8.8
	SCC5a	5.9	12.6	14.1	12.3	9.7	6.4	10.7	13.9	13	11	6.2	10.8	13.7	13.1	8.7
	SCC5b						6	10.3	12.9	12.5	11.2	4.4	10.5	13.2	13.1	7.3
	SCC6	4.5	9.8	13.2	11.6	9	6.1	10.1	13.22	12.6	11	2	10.4	13.1	13.1	6.4
	SCC7											3.6	10.3	12.6	11.6	7.1

Parameter	Sample Location	3/28/2017	4/18/2017	6/28/2017	8/23/2017	9/12/2017	10/11/2017	4/17/2018	6/20/2018	8/21/2018	9/25/2018	10/17/2018	4/17/2019	6/11/2019	8/13/2019	9/17/2019	10/8/2019
pH	SCC1	6.93	7.62	6.92	7.17	6.5	6.83	6.98	7.69	7.58	7.53	7.7	8.02	7.09	8.04		7.78
	TUN		8.08	6.64	6.97	6.98	7.6	6.8	7.73	8.45	8.87	8.62	8.11	7.29	8.18	8.23	8.25
	RWO		7.21														
	SCC4		7.67	6.81	7.55	7.09	7.63	6.92	7.86	8.96	8.96	8.32	8.07	6.99	8.05	8.31	8.14
	CD-N		7.35					-	-	-	-	-					
	CD-N1				7.21	5.89	7.02	6.58	7.1	7.08	7.32	7.52	7.36	7.07	7.16	7.21	7.17
	SP		7.04	6.07													
	SCC5	6.82	7.54	7.07	7.73	6.74	7.68	6.77	7.88	8.39	7.6	7.7	7.87	7.23	8.12	7.88	7.86
	SCC5a		7.51	6.82	7.38	6.75	7.37	6.74	7.62	8.2	7.55	7.61	7.84	7.25	8.02	7.72	7.74
	SCC5b		7.72	6.67	7.35	6.64	7.4	6.86	7.69	8.13	7.69	7.65		6.96	8.09	7.73	7.6
	SCC6		7.9	7.05	6.99	6.7	7.61	6.88	7.57	7.87	7.91	7.96	7.99	6.83	7.85	7.91	7.79
	SCC7			7.27	7.6	6.8	7.82		7.48					7.15	7.9	7.64	
Specific Conductivity (Æv2fp ,	SCC1	111	113.2	70	80.3	71	92	99	86.1	89	99.1	104.1	115.5	67.6	69.6	81.6	89.3
	TUN		107.6	84	83	65	85	95	102	95.5	98.7	96.3	109.1	92.4	72.8	78.2	83
	RWO		145.1														
	SCC4		118.4	64	82.5	66	83	92	101.4	95.4	98.1	97.4	88.9	93.7	72.5	77.9	80.3
	CD-N		136.3														
	CD-N1				150.8	109	135	140	144.3	140.9	143.7	139.9	137.8	142.4	143.9	139.2	146.6
	SP		186.3	175													
	SCC5	120	122.3	84	83.1	71	86	94	100.8	98.1	113.2	106.5	107	91.4	72.7	82.8	88.1
	SCC5a		122.5	83	85.3	77	91	124	103	99.7	116.3	114.2	114.5	92.3	74.4	84.6	93.4
	SCC5b		146	82	93.7	77	91	175	102.9	100	115	111.9		92.7	74.9	84.1	95.7
	SCC6		144.5	82	93.6	83	90	261	102.9	99.8	113.7	111.2	115.3	92.7	74.9	84	71.3
	SCC7			89	88	75	94		108.2					102.6	79.2	84.7	
Temperature (° C)	SCC1	0.56	0.787	7.99	5.8	9.97	0.1	3.7	4.5	7.6	2.2	0	1.4	2.4	6.3	6.2	1.8
	TUN		5.92	12.52	13.7	13.74	8.61	5	13.5	14.7	12.6	7.7	2.9	8.8	12.8	12.7	9.4
	RWO		6.78														
	SCC4		7.65	12.79	13.6	14.7	8.82	4.79	13.8	14.8	12.5	7.9	3.4	8.9	13	12.9	9.7
	CD-N		7.9														
	CD-N1				8.5	7.8	6.62	6.75	7.4	7.2	6.9	7	7.4	7.9	7.7	6.7	7.4
	SP		5.29	7.84													
	SCC5	4.68	8.42	12.62	13.7	13.91	8.5	5.23	13.2	13.8	10.7	7.1	4.1	8.7	13	12.5	9.8
	SCC5a		8.55	12.78	13.4	13.64	8.3	5.34	13.5	13.8	10.1	7	5	8.7	12.9	12.4	9.5
	SCC5b		6.26	12.38	12.8	12.91	8.7	4.75	13.5	14	10.1	7.4		8.6	12.8	12.5	8.3
	SCC6		5.6	12.31	12.7	12.75	8.76	4.14	13.8	14	9.7	7	3.6	8.6	13	12.6	8.2
	SCC7			12.89	13.1	12.55	8.63		12.5					9.3	12.9	12.2	

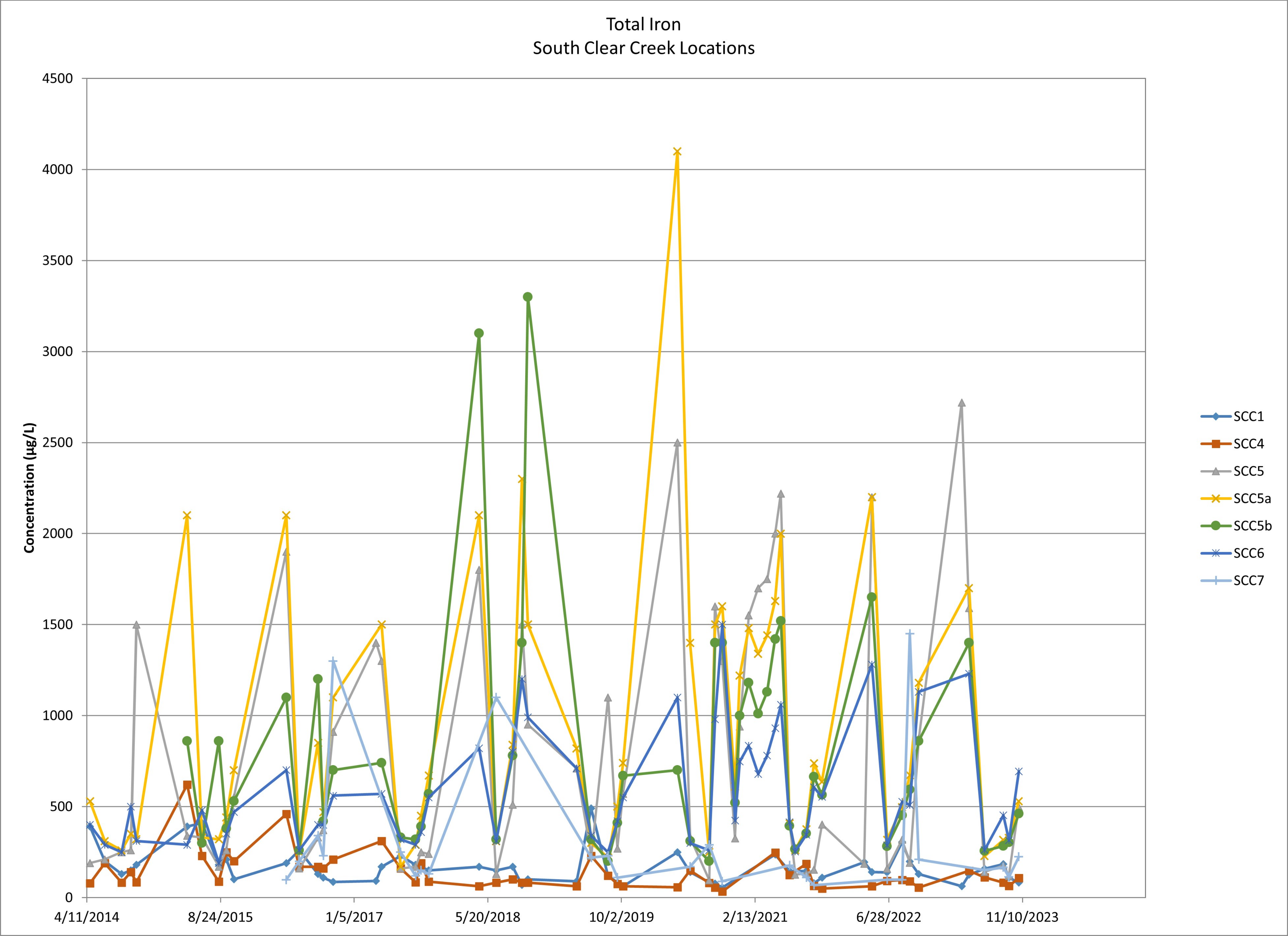
Parameter	Sample Location	4/28/2020	6/15/2020	8/25/2020	9/16/2020	10/13/2020	11/30/2020	12/17/2020	1/20/2021	2/24/2021	3/30/2021	4/29/2021	5/20/2021	6/22/2021	7/13/2021	8/24/2021	9/21/2021
pH	SCC1	7.85	7.72	7.51	8.19	7.32						7.85		7.99		7.74	8.05
	TUN	8.24	8.10	8.72	7.46	7.62						7.74		7.83		8.04	7.98
	RWO																
	SCC4	7.95	8.16	8.84	8.17	7.71						7.45		7.63		7.95	7.75
	CD-N																
	CD-N1	7.33	7.03	6.68	7.04	6.89	7.14	7.29	7.26	7.34	6.98	7.24	6.98	7.11	6.95	7.3	7.12
	SP																
	SCC5	7.23	8.10	8.62	7.37	7.28	7.55	7.48	7.44	7.64	7.23	7.55	7.23	7.47	7.38	7.87	7.86
	SCC5a	7.51	7.90	8.46	7.34	7.19	7.57	7.56	7.57	7.68	7.39	7.91	7.39	7.63	7.29	7.66	7.67
	SCC5b	7.79	7.63	8.08	7.64	7.00	7.70	7.50	7.56	7.77	7.44	7.61	7.44	7.57	7.25	7.85	7.76
	SCC6	7.85	7.83	8.01	7.73	7.35	7.78	7.44	7.6	7.67	7.76	7.48	7.76	7.7	7.23	7.82	7.89
	SCC7		8.03	7.59		7.47								7.65		7.62	7.98
Specific Conductivity (Æv2fp ,	SCC1	97.9	84.6	82.0	90.5	93.1						124.8		80.1		89.1	98.7
	TUN	98.4	91.3	89.8	92.5	93.7						142.2		90.4		90.6	95.9
	RWO																
	SCC4	58.3	93.1	88.8	92.3	93.8						140.2		90.1		90.8	97.4
	CD-N																
	CD-N1	140.9	142.0	142.1	141.0	139.3	139.5	138.6	143.7	145.7	150.7	173.5	150.7	146.6	147.9	150.8	153.4
	SP																
	SCC5	120.0	89.1	88.5	109.5	107.7	104.1	109.3	126.3	117	128.6	154.2	128.6	89.4	87.9	90.7	97.9
	SCC5a	120.8	93	89.1	115.2	115.6	104.7	112.7	119.8	116.6	127.7	153.4	127.7	93.7	90	95.7	106.3
	SCC5b	104.9	92.9	89.1	114.1	114.7	104.7	113.7	120.4	117.3	127.4	152.1	127.4	93.51	90.5	95.4	106.1
	SCC6	101.2	92.8	88.7	113.1	112.9	104	113.2	119.6	115.5	117.3	151.1	117.3	93.3	90.3	95.3	105.3
	SCC7		101.8	96.2		106.4								99.2		98.4	104.5
Temperature (° C)	SCC1	3.0	7.1	9.6	9.9	1.4						5.8		8.3		5.3	2.3
	TUN	4.1	10.4	13.1	10.4	7.6						3.3		7.4		13.3	11.9
	RWO																
	SCC4	5.6	11.4	13.2	11.8	8.1						5.3		7.9		14.9	12.3
	CD-N																
	CD-N1	7.2	7.8	7.0	6.6	6.8	6.7	6.4	6.7	6.8	7.4	8.1	7.4	7	7.2	7.3	6.5
	SP																
	SCC5	7.3	10.9	13.2	9.6	8	2.8	2.4	3.9	4.7	5.9	7.7	5.9	7.7	11	13.2	11.9
	SCC5a	7.4	10.9	13.1	9.1	7.5	2.9	3.1	3.7	4.4	5.3	7.4	5.3	7.7	10.9	12.8	10.8
	SCC5b	4.5	10.7	13	8.5	6.5	2.5	2.9	2.7	1.7	3.1	4.9	3.1	7.7	11.1	12.8	10.7
	SCC6	4.8	10.8	13.1	8.3	6.7	1.9	2.2	2.1	0.5	1.5	3.2	1.5	7.9	11.1	12.7	10.3
	SCC7		10.3	13.3		8.4								8.8		12.8	11.8

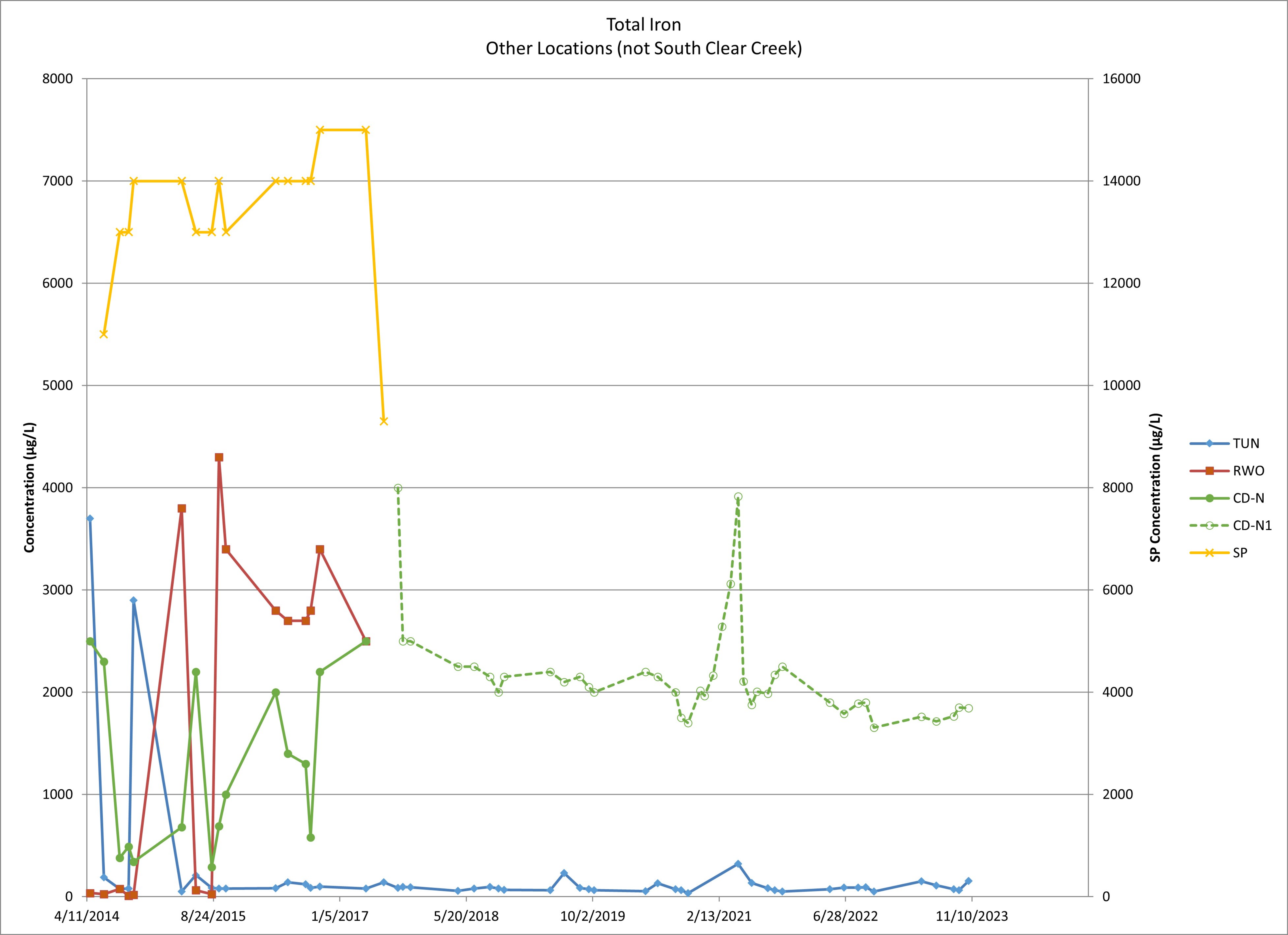
Parameter	Sample Location	10/21/2021	3/28/2022	4/26/2022	6/22/2022	8/17/2022	9/15/2022	10/18/2022	3/28/2023	4/24/2023	6/21/2023	8/30/2023	9/20/2023	10/27/2023
pH	SCC1	7.83	7.75	7.62	7.51	7.93	7.42	7.42	7.68	7.25	7.7	7.85	7.86	7.8
	TUN	8.34		7.74	7.76	8.04	7.9	7.61		7.4	7.56	8.3	8.07	7.97
	RWO													
	SCC4	8.32		7.51	7.87	8.3	8.14	7.84		7.67	7.53	8.41	8.26	8.07
	CD-N													
	CD-N1	6.94		6.67	7.04	7.24	6.97	7.02		7.00	7.04	7.47	7.28	7.30
	SP													
	SCC5	7.69	7.57	7.11	7.75	8.11	7.64	7.57	7.28	7.18	7.64	8.27	8.16	7.94
	SCC5a	7.06		7.12	7.76	7.93	7.61	7.31		7.38	7.69	8.11	7.94	7.82
	SCC5b	7.34		7.29	7.6	7.96	7.57	7.39		7.42	7.36	8.34	8.03	7.87
	SCC6	7.54		7.42	7.58	7.95	7.59	7.58		7.68	7.69	8.4	8.07	7.92
	SCC7				7.62	7.37	7.89	7.83			7.14	8.32	7.62	7.67
Specific Conductivity (Æv2fp ,	SCC1	99.4	117.9	114	83.8	86.2	95	101.5	120.8	88	79.6	84.8	98.7	96.5
	TUN	99.9		107	94.9	84.9	96.3	102.4		110	87.8	82.3	94	91.6
	RWO													
	SCC4	98.6		27.4	82.6	89.3	96.2	102.4		109	88.7	82.3	93.9	91.5
	CD-N													
	CD-N1	151.5		143.1	130.5	137.2	143.4	142.5		135	130.2	131	147.6	135.0
	SP													
	SCC5	102.3	101.9	126	88.1	89.2	97.3	103.2	137.7	122	84.0	80.7	94.7	92.3
	SCC5a	107.2		129.7	95	93.9	103	113.8		123	86.0	85.7	98	95.8
	SCC5b	107.6		127.8	90.9	87.4	102.8	114.5		122	90.0	71.2	97.8	96.6
	SCC6	106.3		126.9	97.1	77.1	102.2	113.3		110	90.0	83.8	97.8	95.6
	SCC7				104.4	98.1	101.8	110.3			88.8	87.9	100.4	97.4
Temperature (° C)	SCC1	5	2.2	2.5	4.9	5.7	5.6	3	0	0.38	3.6	5.9	4.3	2.2
	TUN	4.2		2.2	10.5	14.2	12.9	7.1		3.47	8.4	13.9	12	7.3
	RWO													
	SCC4	4.5		4	11	14.4	13.3	7.4			8.5	14	12.3	7.5
	CD-N													
	CD-N1	6.1		5.9	6.1	6.6	6.3	6.2		6.22	6	6.4	6.2	5.9
	SP													
	SCC5	4.1	2.2	5.4	10.6	14.2	12.3	7.2	4.7	5.21	8.2	13.8	11.9	8.2
	SCC5a	4.2		6	10.5	13.3	11.7	6.4		5.69	8.2	13.2	11.5	7.8
	SCC5b	3.9		5.1	10.4	13.4	11.6	6.2		4.36	8	12.8	11.3	6.8
	SCC6	3.7		4.4	10.4	13.1	11.5	5.9		5.13	7.9	12.7	11.2	6.6
	SCC7				10.5	13.7	12.3	7.9			8.6	13.4	11.9	8.1

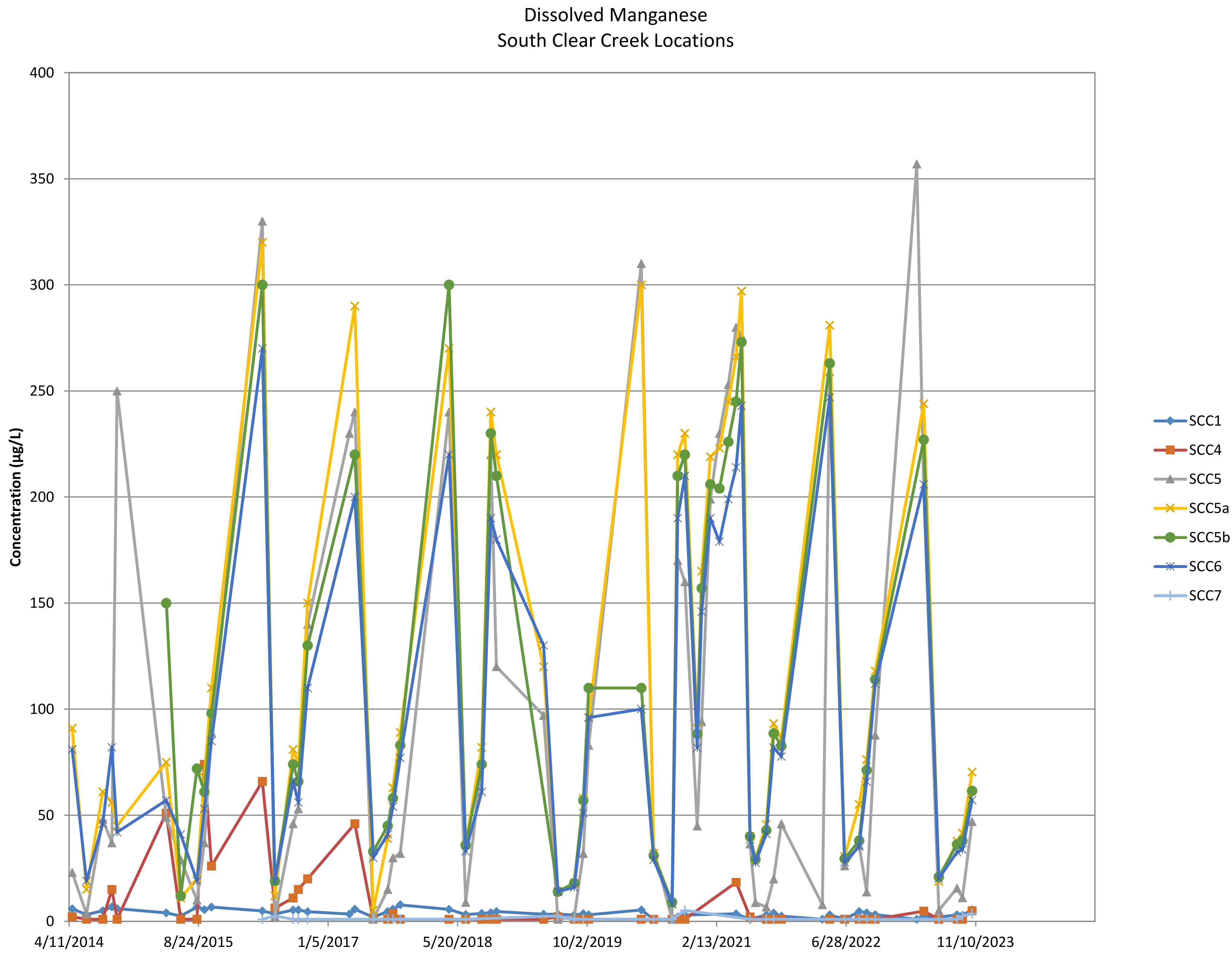

Dissolved Iron
South Clear Creek Locations
Concentration (µg/L)
3000
2500
2000
1500
1000
500
0
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
SCC1
SCC4
SCC5
SCC5a
SCC5b
SCC6
SCC7

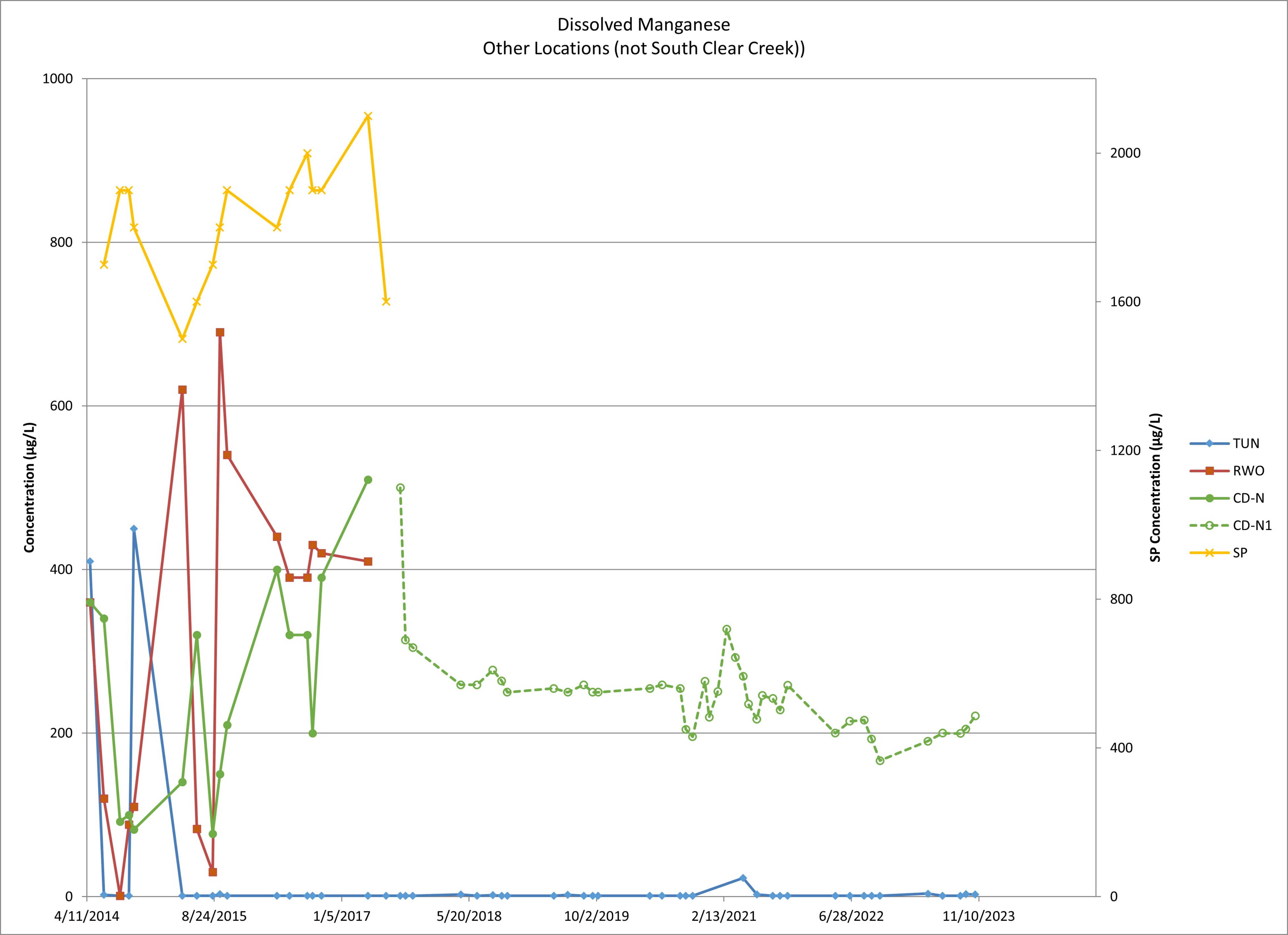


Dissolved Iron
Other Locations (not South Clear Creek)
Concentration of TUN, RWO, and CD-N (µg/L)
Concentration of SP (µg/L)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
16000
14000
12000
10000
8000
6000
4000
2000
0
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
TUN
RWO
CD-N
CD-N1
SP

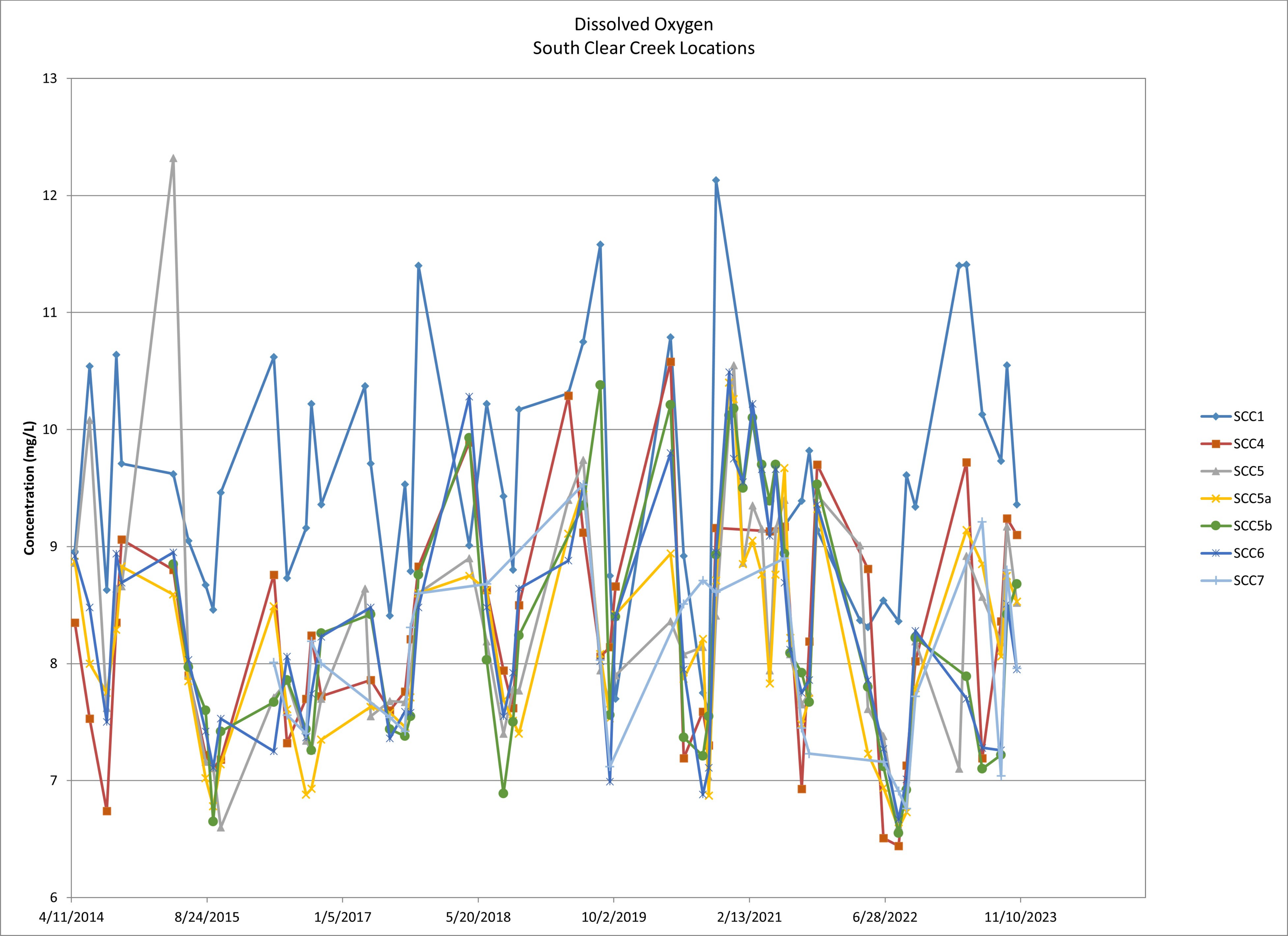

Total Iron
South Clear Creek Locations
Concentration (µg/L)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
SCC1
SCC4
SCC5
SCC5a
SCC5b
SCC6
SCC7

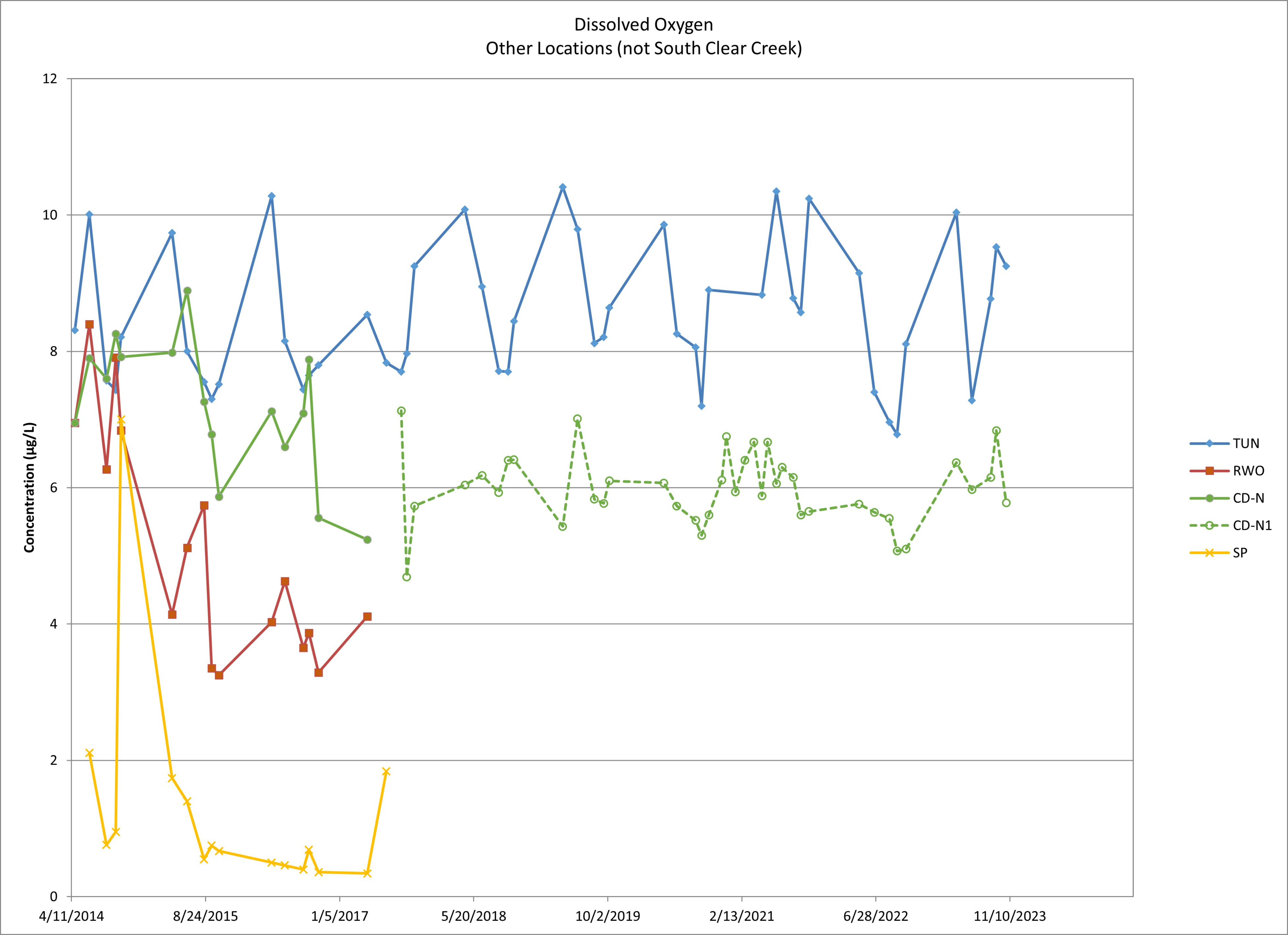

Total Iron
Other Locations (not South Clear Creek)
Concentration (µg/L)
SP Concentration (µg/L)
8000
7000
6000
5000
4000
3000
2000
1000
0
16000
14000
12000
10000
8000
6000
4000
2000
0
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
TUN
RWO
CD-N
CD-N1
SP


Dissolved Manganese
South Clear Creek Locations
Concentration (µg/L)
400
350
300
250
200
150
100
50
0
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
SCC1
SCC4
SCC5
SCC5a
SCC5b
SCC6
SCC7

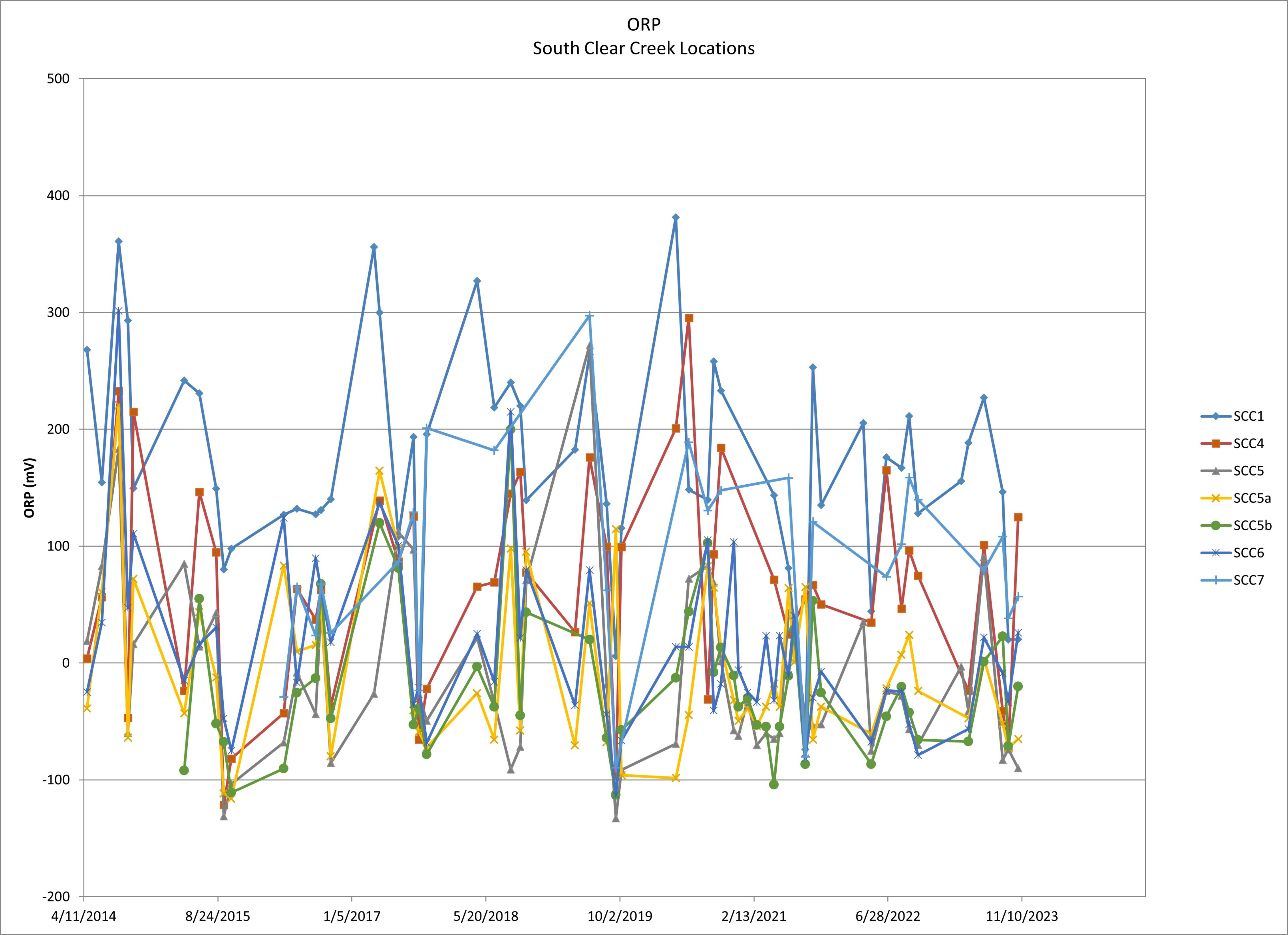


Dissolved Manganese
Other Locations (not South Clear Creek))
Concentration (µg/L)
SP Concentration (µg/L)
1000
800
600
400
200
0
2000
1600
1200
800
400
0
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
TUN
RWO
CD-N
CD-N1
SP

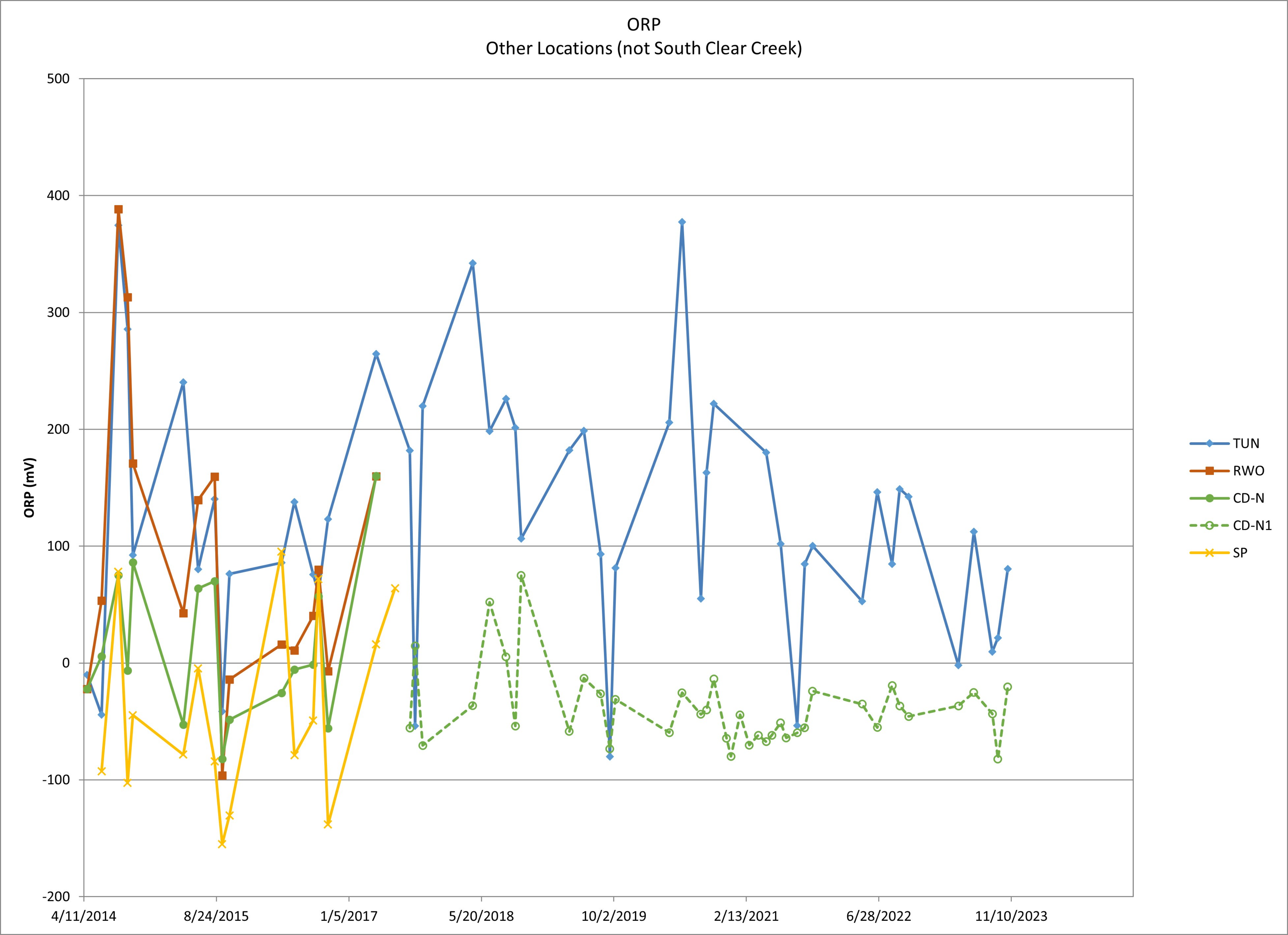

Dissolved Oxygen
South Clear Creek Locations
Concentration (mg/L)
13
12
11
10
9
8
7
6
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
SCC1
SCC4
SCC5
SCC5a
SCC5b
SCC6
SCC7



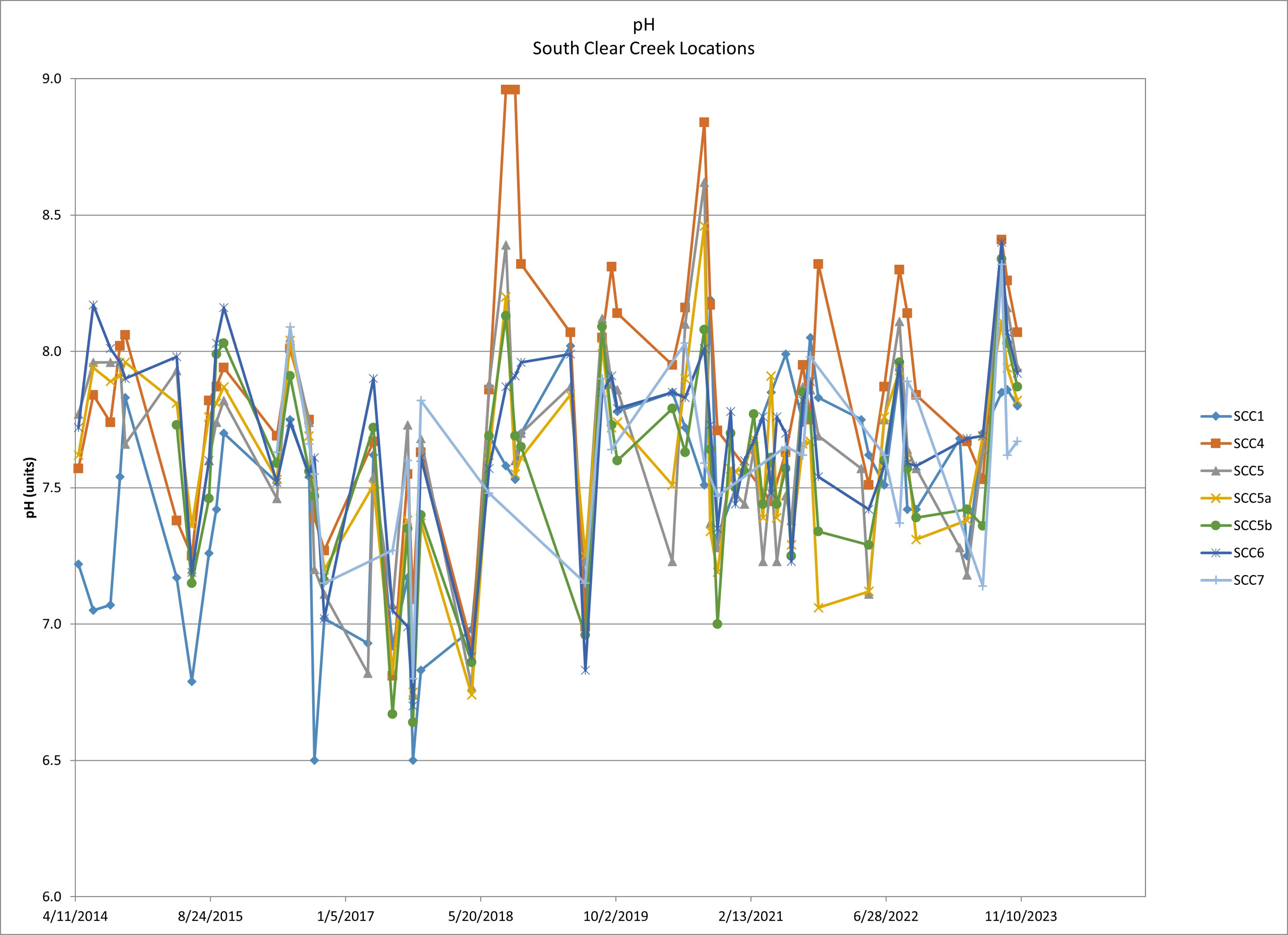
Dissolved Oxygen
Other Locations (not South Clear Creek)
Concentration (µg/L)
0
2
4
6
8
10
12
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
TUN
RWO
CD-N
CD-N1
SP

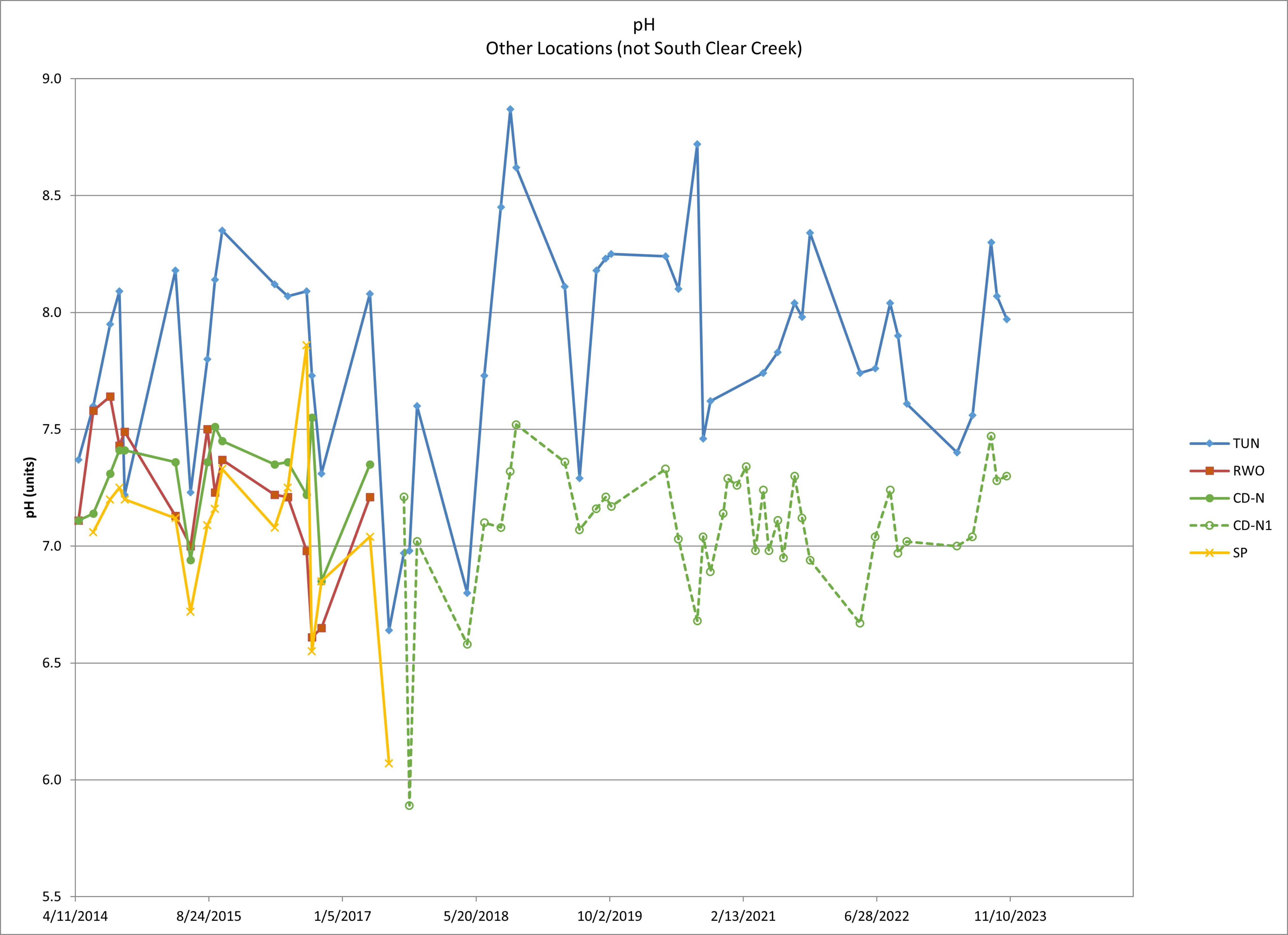


ORP
South Clear Creek Locations
ORP (mV)
500
400
300
200
100
0
-100
-200
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
SCC1
SCC4
SCC5
SCC5a
SCC5b
SCC6
SCC7



ORP
Other Locations (not South Clear Creek)
ORP (mV)
500
400
300
200
100
0
-100
-200
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
TUN
RWO
CD-N
CD-N1
SP


pH
South Clear Creek Locations
9.0
8.5
8.0
7.5
7.0
6.5
6.0
pH (units)
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
SCC1
SCC4
SCC5
SCC5a
SCC5b
SCC6
SCC7


pH
Other Locations (not South Clear Creek)
pH (units)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
4/11/2014
8/24/2015
1/5/2017
5/20/2018
10/2/2019
2/13/2021
6/28/2022
11/10/2023
TUN
RWO
CD-N
CD-N1
SP

Appendix C: Metal Precipitation Data, 2023 Monitoring Year

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Location	Paver ID	Tile A		Tile B		Tile C		Average	
		Fe (mg/tile)	Mn (mg/tile)	Fe (mg/tile)	Mn (mg/tile)	Fe (mg/tile)	Mn (mg/tile)	Fe (mg)	Mn (mg)
SCC3	P7 (2022)	0.636	0.0226	0.914	0.0391	2.06	0.145	1.20	0.0689
	P9 (2022)	1.42	0.0691	2.12	0.0998	3.44	0.188	2.33	0.119
	P10 (2022)	5.25	0.156	13.40	0.850	15.10	0.964	11.25	0.657
	P1	1.31	0.0556	1.55	0.0630	2.20	0.103	1.69	0.0739
	P2	3.12	0.198	3.22	0.183	2.82	0.113	3.05	0.165
	P5	1.55	0.680	2.18	0.0722	1.18	0.0480	1.64	0.2667
	P3	6.62	0.329	11.2	0.584	8.80	0.616	8.9	0.51
	P6	3.21	0.154	1.43	0.0772	1.66	0.103	2.10	0.111
	P8	12.9	0.677	17.8	0.796	11.7	0.755	14.13	0.743
SCC4	P7 (2022)	1.89	0.0873	0.898	0.0578	0.526	0.0267	1.10	0.057
	P9 (2022)	1.16	0.0579	4.87	0.307	28.1	1.66	11.38	0.675
	P10 (2022)	1.23	0.0680	1.69	0.104	1.45	0.0838	1.46	0.0853
	P1	0.627	0.0216	0.825	0.0327	1.41	0.141	0.954	0.0651
	P2	7.16	0.490	3.02	0.148	1.81	0.0754	4.00	0.238
	P5	1.85	0.0750	1.82	0.0783	1.36	0.0692	1.68	0.0742
	P3	0.924	0.0467	1.47	0.0553	3.86	0.247	2.1	0.12
	P6	5.91	0.275	7.85	0.412	4.03	0.165	5.93	0.284
	P8	1.45	0.0683	2.38	0.103	4.80	0.231	2.9	0.13
SCC5	P7 (2022)	39.9	0.561	20.0	0.249	39.3	0.469	33.1	0.426
	P9 (2022)	97.6	1.700	78.3	1.18	61.8	1.29	79.2	1.390
	P10 (2022)	57.8	0.695	49.0	0.516	54.1	0.525	53.6	0.579
	P1	1.74	0.0145	2.84	0.0360	4.16	0.0313	2.91	0.0273
	P2	9.37	0.312	12.8	0.363	18.2	0.449	13.5	0.375
	P5	10.5	0.608	7.32	0.423	5.13	0.310	7.65	0.447
	P3	6.38	0.227	4.87	0.193	4.47	0.113	5.2	0.178
	P6	10.1	0.431	8.22	0.385	5.94	0.180	8.1	0.3320
	P8	40.5	0.456	21.1	0.338	40.8	0.730	34.1	0.508
SCC5a	P7 (2022)	60.9	1.43	50.4	1.10	55.2	1.10	55.5	1.210
	P9 (2022)	106	4.10	49.4	1.59	58.6	1.57	71.3	2.420
	P10 (2022)	94.5	2.04	54.0	0.894	44.2	1.16	64.2	1.365
	P1	11.4	0.0621	11.1	0.0780	10.9	0.0600	11.1	0.067
	P2	29.7	0.705	29.1	0.936	34.5	0.906	31.1	0.849
	P5	22.3	0.672	16.6	0.508	18.6	0.543	19.2	0.574
	P3	30.4	0.778	70.2	3.42	32.7	1.06	44.4	1.75
	P6	13.7	0.223	25.6	0.425	23.3	0.623	20.9	0.42
	P8	28.5	3.05	30.1	1.08	32.0	1.12	30.2	1.75
SCC5b	P7 (2022)	140	1.94	201	2.95	30.1	0.390	123.7	1.760
	P9 (2022)	43.4	1.19	37.4	1.11	72.8	1.44	51.2	1.25
	P10 (2022)	52.9	1.22	37.4	1.00	16.8	0.628	35.7	0.949
	P1	7.43	0.118	10.0	0.166	12.3	0.251	9.9	0.178
	P2	24.3	1.13	33.0	1.58	25.3	1.07	27.5	1.260
	P5	1.53	0.0188	1.91	0.0592	2.01	0.0741	1.8	0.051
	P3	10.3	0.438	10.7	0.416	10.2	0.407	10.4	0.42
	P6	31.8	0.556	35.9	0.611	30.8	0.517	32.8	0.561
	P8	22.8	0.799	13.0	0.455	15.1	0.443	17.0	0.566
SCC6	P7 (2022)	49.5	0.443	40.2	0.291	45.3	0.339	45.0	0.358
	P9 (2022)	27.6	0.505	35.9	0.562	53.0	0.689	38.8	0.585
	P10 (2022)	34.7	0.501	55.6	0.750	67.6	0.932	52.6	0.728
	P1	11.1	0.0784	11.3	0.158	10.5	0.141	11.0	0.126
	P2	16.9	0.456	21.1	1.33	18.0	0.486	18.7	0.757
	P5	9.30	0.686	8.42	0.518	10.1	0.398	9.3	0.534
	P3	26.6	1.32	28.6	1.17	28.2	0.926	27.8	1.139
	P6	10.5	0.307	11.8	0.323	11.2	0.211	11.2	0.280
	P8	32.0	0.674	26.1	0.589	22.4	0.540	26.8	0.601

Appendix D: South Clear Creek Hydrographs

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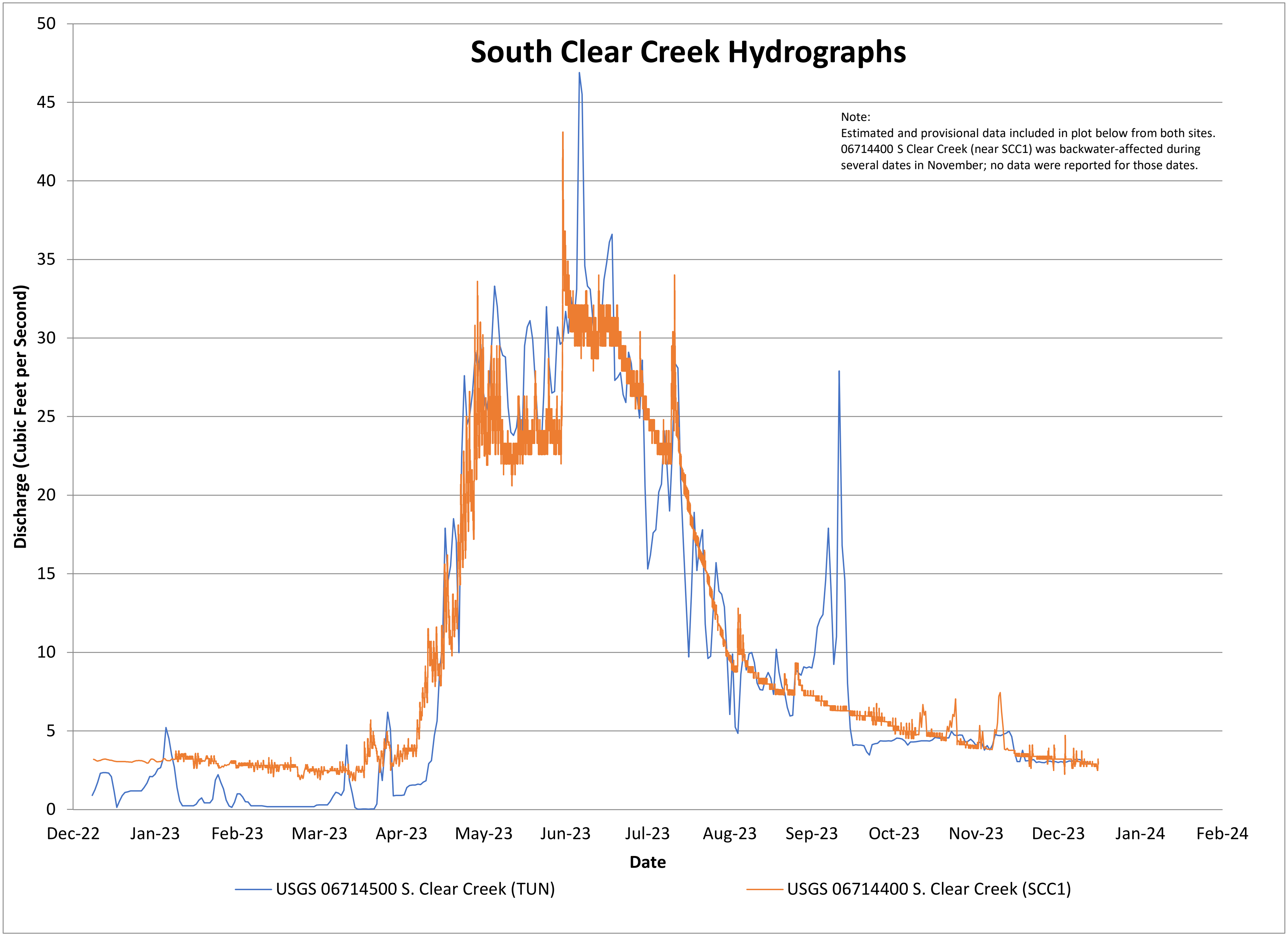
South Clear Creek Hydrographs
Note:
Estimated and provisional data included in plot below from both sites.
06714400 S Clear Creek (near SCC1) was backwater-affected during
several dates in November; no data were reported for those dates.
Discharge (Cubic Feet per Second)
0
5
10
15
20
25
30
35
40
45
50
Dec-22
Jan-23
Feb-23
Mar-23
Apr-23
May-23
Jun-23
Jul-23
Aug-23
Sep-23
Oct-23
Nov-23
Dec-23
Jan-24
Feb-24
Date
USGS 06714500 S. Clear Creek (TUN)
USGS 06714400 S. Clear Creek (SCC1)

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Appendix B. 2023 Fish and Macroinvertebrate Sampling Report

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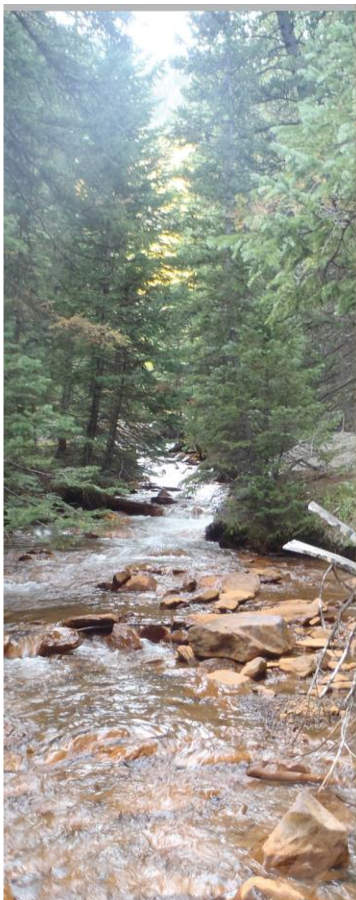


GEI Consultants

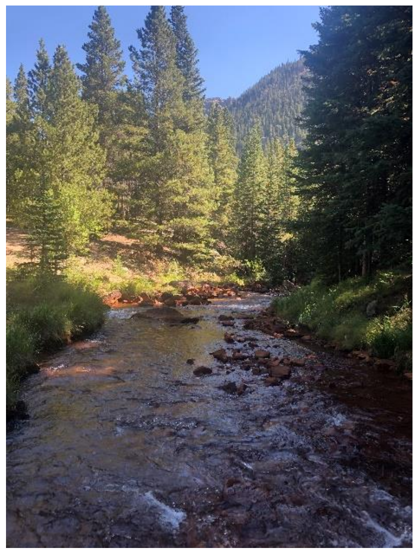
Consulting Engineers and Scientists

Cabin Creek Pumped Storage Hydroelectric Project (FERC No. 2351) 2023 Fish and Macroinvertebrate Sampling Report

February 2024

Cabin Creek Pumped Storage Hydroelectric Project (FERC No. 2351)

2023 Fish and Macroinvertebrate Sampling Report



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1. Introduction

Public Service Company of Colorado (PSCo) owns and operates the Cabin Creek Pumped Storage Hydroelectric Project under License No. 2351 issued by the Federal Energy Regulatory Commission (FERC). The Project is located on South Clear Creek and its tributary, Cabin Creek, in Clear Creek County, Colorado. PSCo, Colorado Parks and Wildlife (CPW), and Arapaho-Roosevelt National Forest jointly conducted fish population sampling in South Clear Creek upstream and downstream of the Cabin Creek Pumped Storage Project in 2008. The sampling found trout populations to be similar in numbers, with fish of similar length upstream and downstream of the Project. While numbers and lengths were similar, trout collected at the site downstream of Lower Cabin Creek Reservoir (Lower Reservoir) had significantly lower average individual weights for comparable-sized fish (PSCo 2009a). One hypothesis for this observation is that the difference in weight could be a result of reduced food availability (i.e., macroinvertebrate populations) potentially caused by diminished water quality due to the apparent presence of an iron-based precipitate observed on substrates downstream of the Lower Reservoir in South Clear Creek. The U.S. Forest Service (USFS) stated in a study request submitted to FERC on June 22, 2009, that they had concerns that the presence of visible iron precipitate could indicate that other metals could also be present.

At that time, there was little specific information on the macroinvertebrate populations in the Cabin Creek Project vicinity. A revised study plan was developed by PSCo to collect additional site-specific information to document current macroinvertebrate populations both upstream and downstream of the Lower Reservoir to evaluate potential Project effects on macroinvertebrate populations in South Clear Creek (PSCo 2009b). FERC approved the study plan in January 2010. In accordance with the approved study plan, GEI Consultants, Inc. (GEI) sampled the macroinvertebrate populations in October 2011 at sites on South Clear Creek upstream and downstream of the Lower Reservoir as baseline information. As described below, additional sampling of the macroinvertebrate populations was also conducted in September 2013. The sites sampled were selected through collaboration in the field by a group of stakeholders including PSCo, USFS, and CPW.

PSCo was issued a new license on May 27, 2014, from FERC to continue to operate the Cabin Creek Project. A Water Quality Adaptive Management Plan ([WQAMP] PSCo 2013) has been developed and is being implemented over the first ten years of the new Project license period to reduce the adverse effects of continued Project operation and any operational changes PSCo takes to address water quality issues on South Clear Creek downstream of the Lower Reservoir Dam. The WQAMP is intended to progressively and systematically address Project effects related to water quality (i.e., iron and manganese precipitation), macroinvertebrate populations, and the Brook Trout (*Salvelinus fontinalis*) population in South Clear Creek downstream of the Lower Reservoir.

The WQAMP states that PSCo will sample the macroinvertebrate populations each fall for ten years starting in 2014 to evaluate changes in operation, and conduct fish population sampling in the fall of 2017, 2020, and 2023. In accordance with the WQAMP schedule, the first change in operation was completed in 2015. PSCo converted the relief well intermittent pumping system to a continuous, gravity flow system in 2015. The conversion was completed on September 9, 2015, the same date that GEI collected macroinvertebrate population samples for 2015. Therefore, the macroinvertebrate sampling results from 2011 (GEI 2012a), 2013 (GEI 2014), 2014 (GEI 2015), and 2015 (GEI 2016) form the pre-treatment baseline data. In July 2017, construction began on a modified relief well gravity system on the east side of the emergency spillway to improve drainage of the system and to provide increased aeration and on-site precipitation of metals. The work also included reconstruction of the collection ditch. Water was turned into the new collection ditch in mid-August and the project was completed on September 20, 2017. This project was identified as an operational change in the WQAMP.

In the summer of 2020, a one-year pilot aeration system was installed in the collection ditch. The aeration pilot started operation September 3, 2020, and continued through August 2021. The goal of the aeration pilot was to increase precipitation of iron and manganese onsite in the collection ditch to reduce iron and manganese concentrations in South Clear Creek downstream of the Project. The aeration pilot was ineffective in reducing concentrations in South Clear Creek (HDR 2021). Macroinvertebrate samples taken in 2016 and thereafter (GEI 2017, 2018. 2019, 2020, 2021, 2022, 2023) provide post-treatment data which is compared to pre-treatment baseline data.

The goals under the WQAMP include significant improvement from baseline conditions at the downstream sites for fish and macroinvertebrate population parameters, with recognition that flexibility is reserved for discussion of minor misses of this goal among consulting parties at the time of WQAMP review. To assess the fish communities, the WQAMP requires PSCo, at a minimum, to follow trends in relative weight (W_r) and biomass of Brook Trout. The specific goals are to have a Brook Trout population with a mean relative weight value of 100 and to observe an upward trend in Brook Trout biomass compared to the baseline data. Goals were to be met by 2023. Macroinvertebrate goals include attainment for MMI scores and statistically significant improvement from pre-treatment conditions for number of taxa, the number of metal intolerant taxa, number of EPT taxa, and number of mayfly taxa at sites downstream of the lower reservoir by 2023.

The purpose of this report is to present an evaluation of the fish and macroinvertebrate population data collected in 2023 during the final year in which the WQAMP was to be implemented and to evaluate whether the goals of the WQAMP were met with respect to the fish and macroinvertebrate assemblages. This report evaluates species abundance, community structure, and species composition data from the macroinvertebrate population samples collected during annual sampling events from 2016 to present and compares these data with the 2011, 2013, 2014, and 2015 baseline data to evaluate the effects from changing the relief well intermittent pumping system to a continuous gravity flow system, the modifications to the collection ditch, and the aeration pilot in the collection ditch.

2. Methods

The study methodology described here is designed to provide information on the current fish and macroinvertebrate populations at four sites in South Clear Creek upstream and downstream of the Lower Reservoir. This methodology has been developed in consultation with USFS, CPW, and stakeholders as documented in the 2013 WQAMP (PSCo 2013).

2.1 Study Sites

Macroinvertebrate population sampling locations in 2011 consisted of six separate stream sampling sites in South Clear Creek, with two sites upstream of the Project area and four sites downstream of the Lower Reservoir (Figure 1). Sites A and B were located upstream of the Lower Reservoir in South Clear Creek within 1 mile of the Project. Site C was located downstream of the Lower Reservoir discharge and upstream of the Project Boundary fence; and sites D, E, and F were located in the short stream reach of South Clear Creek that extends from below the Project Boundary fence where the collection ditch enters South Clear Creek downstream to just above Clear Lake. To the extent feasible, macroinvertebrate population sampling locations were consistent with sampling sites selected for the water quality monitoring and fish population studies that were conducted as part of Project relicensing.

The WQAMP (PSCo 2013) requires fish sampling at one of the six original sampling locations in 2023, Site D, and annual macroinvertebrate sampling in 2023 at four of the six original sampling locations on South Clear Creek, including one site upstream of the Project area and three sites downstream of the Lower Reservoir (Figure 1). Sites B, D, E, and F described below, were sampled for macroinvertebrates annually in 2013 through 2023.

Site B: This site is unaffected by the Project and is located on South Clear Creek approximately 600 meters (m) upstream of the Lower Reservoir.

Site D: Located on South Clear Creek downstream of the Lower Reservoir, this site is approximately 60 m downstream of the Project Boundary fence.

Site E: This site is on South Clear Creek approximately 140 m downstream of Site D.

Site F: Located on South Clear Creek approximately 160 m downstream of Site E, just upstream of Clear Lake. This site is approximately 50 m upstream of the high-water mark of Clear Lake.

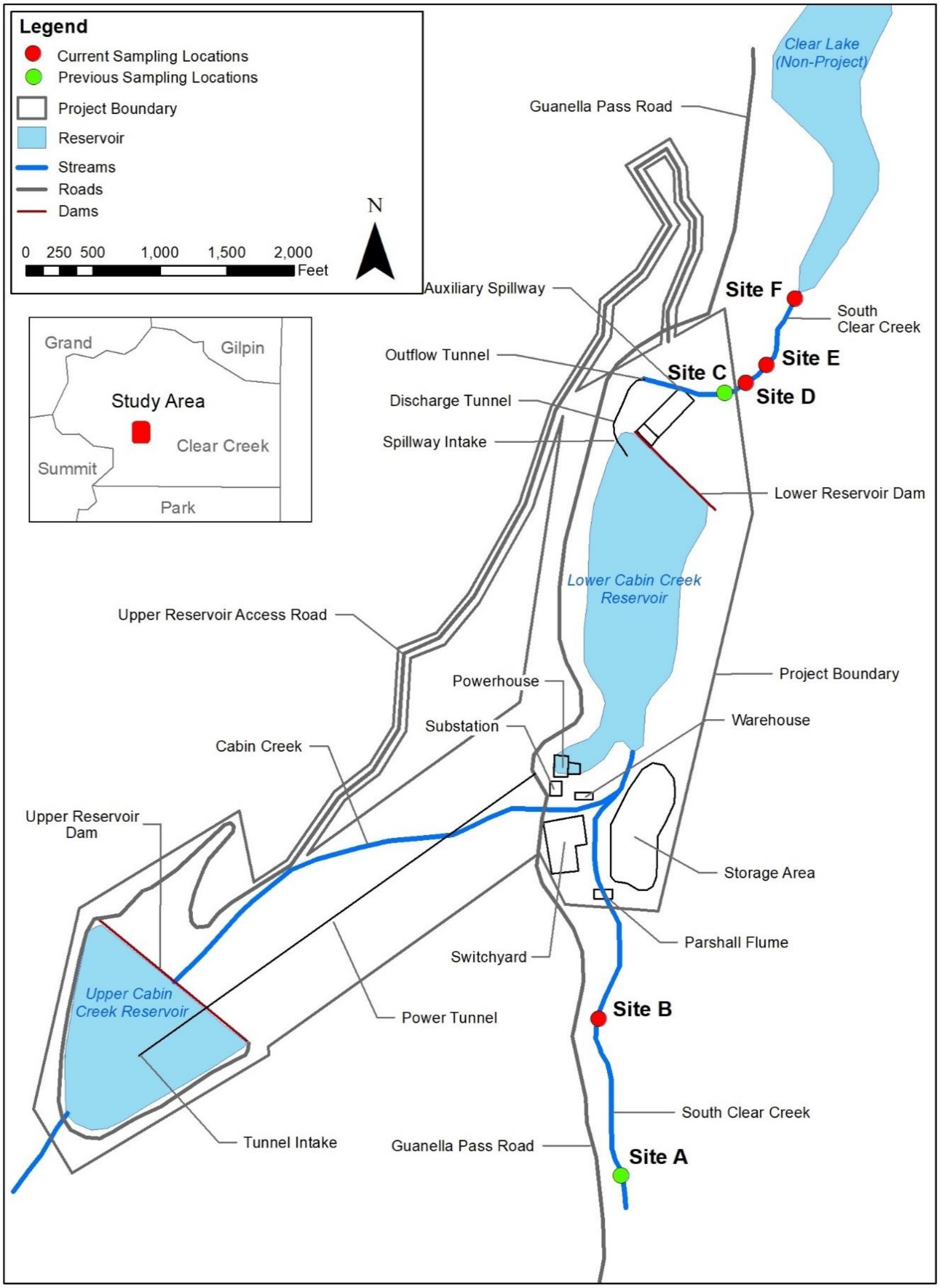

Figure 1: Current and previous macroinvertebrate population sampling sites on South Clear Creek near the Cabin Creek Pumped Storage Hydroelectric Project.

2.2 Sampling Methods

Fish population sampling was conducted using backpack electrofishing units at Site D in 2011, 2017, 2020, and 2023. Macroinvertebrate population samples were collected at the sites using two different sampling methods (a Hess sampler and a kick net that was utilized following Colorado's Multimetric Macroinvertebrate Index [MMI] protocols), each described below. All macroinvertebrate samples were collected in cobble-gravel riffle habitat. During the October 2011 sampling, the flow was low. At the time of sampling in September 2013 through 2023, the flow in the stream was higher.

2.2.1 Fish Sampling

Sampling was conducted by GEI on September 7, 2011, September 19, 2017, September 23, 2020, and September 21, 2023 in the reach downstream of the Lower Reservoir, Site D, using two backpack electrofishing units. Two electrofishing probe operators along with one netter were used. Multiple-pass depletion sampling (Moran 1951; Zippin 1956; Reynolds 1996) was utilized. Three passes were made through the sample segment. Sampling passes continued until the catch equals 10 percent or less of the total fish collected in the preceding passes. The upstream and downstream ends of each site were placed at natural breaks in habitat units, such as steep riffles or plunge pools, to discourage movement of fish out of the site. The widths and lengths of the sampling site were measured after sampling to calculate the area sampled to estimate density (number/hectare [#/ha]), and biomass (kilogram/hectare [kg/ha]) for each species.

Captured fish were retained in flow-through live cars until all passes were completed. All fish were identified to species, counted, measured to the nearest millimeter (mm, total length), weighed by spring scale to the nearest gram (g), and then released back into the sampling site. Mortalities and notable fish conditions (deformities, spinal trauma, branding from electrofishing shock) were noted and recorded prior to release. An effort was made to ensure sampling activities minimized potential injury or mortality to fish. All data were recorded on a standardized electrofishing data form.

2.2.2 Macroinvertebrate Sampling

2.2.2.1 Hess Sampling

The macroinvertebrate populations at all sites were sampled by GEI personnel on October 3, 2011, and annually in September from 2013 through 2023 following the methods in Canton and Chadwick (1988), as prescribed in the Revised Study Plan (PSCo 2009b) and in the WQAMP (PSCo 2013). Three replicate samples were collected from riffle habitat at each site using a modified Hess sampler, a quantitative sampler which fully encloses an area of 0.086 square meters (m^2) and has a net mesh size of 500 micrometers (µm; Canton and Chadwick 1984). The sampler was set in place within the stream and the substrate within the sampler was agitated thoroughly to dislodge invertebrates, which were washed downstream by the current to be collected in a net. Each replicate consisted of taking two individual Hess samples and combining them. Three replicate samples at a site provide an adequate measure of macroinvertebrate density in streams and are sufficient to capture the natural small-scale variability of macroinvertebrate populations (Canton and Chadwick 1988). A sample size of three also allows the use of accepted statistical analyses.

2.2.2.2 MMI Sampling

The MMI method was developed by the Colorado Department of Public Health and Environment (CDPHE) as a tool to help evaluate aquatic life classification and use attainment in rivers and streams (Jessup 2010; CDPHE 2010). In August 2017, the policy was recalibrated using additional data collected from 601 Colorado streams since 2008 (Jessup and Stribling 2017). Over 104 metrics were evaluated to detect the difference between reference and stressed sites. Eight new metrics were selected for each Biotype, and aquatic life thresholds were established based on the analysis of the biological condition at reference sites in each of three Biotypes (CDPHE 2017, 2020).

The MMI sample collection method requires that a single semi-quantitative kick sample be taken at each site. MMI sampling was conducted in a 1 m^2 section of riffle habitat that is sampled by vigorously agitating the substrate upstream of a 500 µm mesh kick net for 60 seconds such that the dislodged macroinvertebrates drift into the net (CDPHE 2017, 2020). Macroinvertebrate sampling using the CDPHE MMI method was conducted at each site, concurrent with Hess sample collection, following the guidance in Policy 10-1 (CDPHE 2017, 2020). MMI scores prior to 2016 were recalculated using this updated policy to allow for comparison of pre- and post-treatment data.

2.2.2.3 Laboratory Analysis

All samples were transferred to individually labeled sample containers, preserved in the field with 95 percent ethanol, and delivered to the GEI laboratory in Denver, Colorado, for analysis. In the laboratory, organisms were sorted from the debris, identified, and counted. In most cases, whole samples were sorted. Forty-five percent of the samples were subsampled due to very large numbers of organisms (greater than 300 individuals per replicate) which involved sorting a minimum of 300 organisms from at least 2/30^{ths} of the replicate samples, with a subsequent search for rare or uncommon taxa in the remaining sample (Vinson and Hawkins 1996; Carter and Resh 2001). Quality assurance (QA) for sorting was conducted on all samples and documented on ten percent of the samples for quality control (QC). QA/QC procedures indicated more than 97 percent thoroughness for sorting in 2023.

The sorted specimens were identified by GEI personnel to the lowest practical taxonomic level (Lenat and Resh 2001), which depended upon the age and condition of each specimen, and each taxon was counted. QA/QC for identifications and counts (Whittaker 1975; Stribling et al. 2003) was randomly conducted on 10 percent of the samples and indicated a minimum of 97 percent agreement for taxonomic and count accuracy in 2023.

In 2011, 2013, 2014, and 2015, chironomid larvae and oligochaetes were mounted permanently on glass slides and cleared prior to identifications and counting and identified by a taxonomist outside of GEI. In 2016 through 2023, chironomid larvae were identified and counted in alcohol within a watch glass. Samples containing excessive number of chironomids and oligochaetes (i.e., greater than 30 individuals) were subsampled to obtain at least 10 percent of the total number (minimum of 30 individuals) before identifying. From 2016 through 2023, chironomids and oligochaetes were identified by GEI personnel certified by the Stroud Water Research Center for the Society for Freshwater Sciences in both chironomid and oligochaete taxonomy.

2.3 Data Analysis

2.3.1 Fish Data

Following a quality control/quality assurance review, fish population sampling data were entered into an Excel spreadsheet. Most parameters were analyzed in Excel while other parameters were analyzed using published public domain scientific software developed for the USFS (Microfish 3.0 [Van Deventer 2020]) for calculating stream fish population statistics. This sampling effort is a closed sample approach that allows for statistical assessments. The sampling is intended to characterize and evaluate the fish population just downstream of the Lower Reservoir, and to evaluate differences in fish populations and conditions between the pre- and post-treatment fish data.

Fish length and weight data were summarized by species and year at Site D. Summaries included minimum, maximum, and mean total length and weight (Appendix A, Appendix B, Appendix C, and Appendix D). Additionally, species composition, and estimates of density and biomass for each species were included. The estimates included 95 percent confidence intervals for density for all three years.

Length-frequency data were used to analyze the size structure of the populations in both reaches to determine whether natural reproduction was occurring near the sites (Everhart and Youngs 1981; Anderson and Neumann 1996; Neumann and Allen 2007; Brouder et al. 2009). The data were evaluated to assess whether the three expected life stages of a viable, functional stable population were present: fry (or young-of-the-year; YOY), juveniles, and adults. The size structure of the fish at the sampling site was analyzed to determine the extent to which meaningful differences existed between the fish populations for pre- and post-treatment. Characteristics of the population that were compared between the pre- and post-treatment included size range of fish, mean lengths, the presence/absence of the three life stages, and relative abundance of the three life stages. The size structure of the fish populations between pre- and post-treatment were considered similar if there were no substantial differences in the characteristics listed above.

The condition or well-being of trout were inferred using the relative weight (Wr) equations (Wege and Anderson 1978; Anderson and Gutreuter 1983; Anderson and Neumann 1996;

Blackwell et al. 2000; Pope and Kruse 2007; Brouder et al. 2009; Hyatt and Hubert 2001). To determine Wr, measured individual fish weights were compared to length-specific standard weight equations constructed to represent the species as a whole. Expected values of the mean Wr index for a sample of fish have the same general range across species. Relative weight values generally fall between 70 and 130 (Murphy and Willis 1991). Relative weight values between 95 and 105 are considered optimal for most species (Anderson 1980; Anderson and Neumann 1996). The relative weight equations used for this analysis were the Brook Trout-specific equation developed by Hyatt and Hubert (2001) for Brook Trout 130 mm and greater in length, as well as the Rainbow Trout-specific equation developed by Blackwell et al. (2000) for Rainbow Trout (*Oncorhynchus mykiss*) equal or greater than 120 mm in length.

Comparisons were made of the relative weights of Brook Trout collected at Site D between the pre-treatment (2011) and post-treatment (2017, 2020, and 2023) sampling events. The data were not normally distributed and a nonparametric Kruskal Wallis One-Way ANOVA on ranks was conducted. Additionally, all fish population parameters were calculated using all ages classes of fish which were collected during the sampling event. Of the parameters mentioned above, the WQAMP requires density (number of age 1 year and older fish/ha) and biomass (kg of fish age-1 year and older/ha). Because the survival of YOY over their first winter can vary from year to year, CPW recommends YOY should not be included in density and biomass estimates. For this report, based upon length-frequency analyses conducted at this site, Brook trout less than 100 mm in total length are considered less than 1 year of age. Those 100 mm in total length or greater are considered age 1 or older.

For the purposes of this report, the focus is on the Brook Trout populations in the fish sampling reach downstream of the Lower Reservoir. Rainbow Trout were collected at the downstream reach in some years, and were stocked by CPW into Clear Lake the day prior to sampling in 2011. Rainbow Trout were also stocked in June and July of 2017, a few months prior to sampling. Stocked Rainbow Trout were also collected in September 2023. Rainbow Trout are not included in the data analysis and comparisons between the reaches as they are not part of a viable, functional, self-sustaining population and their numbers are artificially maintained by stocking.

2.3.2 Macroinvertebrate Data

2.3.2.1 Hess Samples

For Hess samples, taxa lists and estimates of density (number of organisms/m^2) were generated after identifications were completed. Several population metrics were calculated from the data, and these are described more fully below.

The taxa lists provide the total number of taxa present at each site, with stressed sites expected to have fewer taxa present than unstressed sites. In mountain streams such as South Clear Creek, the presence of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa (collectively referred to as the "EPT taxa") are an indicator of good water quality (Lydy et al. 2000). These insect groups are sensitive to a wide range of pollutants (Hynes 1970; Wiederholm 1984; Klemm et al. 1990; Barbour et al. 1999; Merritt et al. 2008).

Of the EPT taxa, mayflies are considered particularly sensitive to metals (Clements et al. 1988; Clements 1991, 1994) and caddisflies less sensitive (Kiffney and Clements 1993; Clements and Kiffney 1994). Specifically, mayflies in the family Heptageniidae are considered especially sensitive to metals (Kiffney and Clements 1994; Clements et al. 2002). This has been demonstrated in both descriptive and experimental studies (Clements et al. 2002). The absence of heptageniid mayflies is a way to potentially detect low concentrations of metals; therefore, the percentage of mayflies, number of mayfly taxa, and the percentage of heptageniid mayflies were calculated.

In addition, multiple insect taxa have been identified as especially intolerant of metals in the Southern Rockies (Fore 2002). These metal intolerant taxa include the mayfly species *Drunella doddsii*, the mayfly genera *Cinygmula*, *Epeorus*, *Rhithrogena*, and *Paraleptophlebia*, the stonefly genera *Skwala*, *Suwallia*, and *Sweltsa*, the caddisfly genus *Rhyacophila*, and the true fly (Diptera) genus *Pericoma*. The number of metal intolerant taxa was calculated from the macroinvertebrate community data and is expected to decline as metal concentrations in the water increase.

The Shannon-Weaver Diversity Index (H') was calculated on the macroinvertebrate community data. The U.S. Environmental Protection Agency (EPA) recommends using this index to measure stress on macroinvertebrate communities (Klemm et al. 1990). Values for this index generally range from 0.00 to over 4.00, with values greater than 2.50 considered to be indicative of a healthy macroinvertebrate community (Wilhm 1970). Diversity values less than 1.00 indicate a stream community under severe stress (Wilhm 1970; Klemm et al. 1990; Bukantis 1998) because this type of community is typically dominated by a few tolerant taxa.

Of these metrics, the WQAMP requires the total number of taxa, number of metal intolerant taxa, number of EPT taxa, and number of mayfly taxa to be reported annually for each site sampled (PSCo 2013).

2.3.2.2 Statistical Analysis of Hess Samples

The metrics from the Hess samples were evaluated by comparing the mean and total values for the metrics discussed among the four sites. Differences among sites, and between pre- and post-treatment years, were described and evaluated by statistical tests to determine whether differences in metrics were a function of natural variability or some other cause. The replicate data from the Hess samples were used in the statistical analyses, since replicate samples allow for the use of statistical tests to compare macroinvertebrate population data among the sites (Snedecor and Cochran 1967; Zar 1999). The population metric data from these samples were compared among sites to determine any significant differences. Diversity data (H') were not analyzed statistically because this parameter was based on one composite value per site, not on the individual replicates.

Statistical tests with a 95 percent significance level ($\alpha = 0.05$) were used for all analyses. Mean density data were transformed using logarithms prior to statistical analysis when necessary to achieve or approximate a normal distribution to meet the assumptions of statistical analyses (Elliott 1977). Analysis of variance (ANOVA) tests were conducted to determine if significant differences existed among sites in 2023 in density, number of taxa, number of EPT taxa, percent density of Ephemeroptera, percent density of heptageniid mayflies, number of mayfly taxa, or number of metal intolerant taxa among the South Clear Creek sites using the replicate data (Elliott 1977; Zar 1999). If significant differences were detected for parameter values among sites, then the Tukey-Kramer multiple comparison test was performed to determine specifically which sites were different and to compare the differences between those specific sites. If transformations could not achieve or approximate a normal distribution in the data, a nonparametric Kruskal-Wallis one-way ANOVA on ranks was used and Kruskal-Wallis multiple-comparison Z-value test was used instead of Tukey-Kramer multiple comparison tests.

T-tests were utilized to statistically compare mean metric values between the post-treatment data collected annually in 2016 through 2023 and the pooled pre-treatment data collected in 2011 through 2015 at the downstream sites. If the data failed normality tests, nonparametric Mann-Whitney U tests were conducted comparing median metric values. As with the pre- and post-treatment comparisons, metrics analyzed for each site included density, number of taxa, number of EPT taxa, percent density of Ephemeroptera, percent density of heptageniid mayflies, and number of metal intolerant taxa.

2.3.3 MMI Samples

The MMI incorporates numerous individual metrics, developed from statewide sampling by the CDPHE from reference and stressed sites (CDPHE 2020). The index is designed as a tool to help evaluate aquatic life classification and use attainment in streams and is organized by geographical site classes (Biotype) delineated primarily by level IV ecoregions (Chapman et al. 2006), which denote areas of general similarity in ecosystems based on EPA, USFS, and other governmental agencies. The study area is located in Ecoregion 21b and is classified as Biotype 2, which is described as high elevation, cold water sites (mountain ecosystem) (CDPHE 2020).

During the development of the 2017 policy, samples were excluded if the total individual count was below 150 individuals to standardize comparisons among samples. Samples with less than 150 individuals should be analyzed with caution because a small sample size may not always indicate a stressed site (CDPHE 2020). The target subsample range size is 240-360 individuals. Large samples (above 360 individuals) were reduced to the subsample target range through a random re-sampling simulation in Colorado’s Ecological Data Application System (EDAS).

For the MMI samples, eight macroinvertebrate population metrics were used in the calculation of the Colorado MMI for Biotype 2, as described in Policy 10-1 (CDPHE 2020, Jessup and Stribling 2017), include the following:

1. **Total Taxa:** sum of the total number of taxa
2. **Total Ephemeroptera, Plecoptera, and Trichoptera (EPT):** sum of the total number of EPT taxa
3. **Percent of EPT no Baetidae:** percent of EPT taxa excluding Baetidae of all individuals
4. **Clinger Taxa:** sum of the total number of clinger taxa
5. **Intolerant Taxa:** sum of the total number of intolerant taxa
6. **Percent of Individual Indicator Sensitive Decreaser Taxa:** percent of the sensitive decreaser indicator individuals in Biotype 2
7. **Facultative Predator Taxa:** sum of the total number of facultative predator taxa
8. **Percent Facultative Scraper:** percent facultative scraper individuals of all individuals

Functional feeding groups (FFG), tolerance values (TV) and habit classifications for benthic macroinvertebrate data collected were assigned by EDAS using the Colorado Water Quality Control Division (WQCD) database. The FFG classifications were used for the Facultative Predator Taxa and Percent Facultative Scraper metrics. The term ‘facultative’ assumes that a taxon with multiple feeding mechanisms might use all the mechanisms depending on life stage. The habit group classifications were used for the Clinger Taxa metric. Likewise, tolerance values, which range from 0 (intolerant organisms) to 10 (tolerant organisms), were used for the Intolerant Taxa metric. Intolerant taxa are taxa with tolerance values from 0 to 3. The percent EPT taxa excluding the mayfly family Baetidae metrics removes the very common and moderately tolerant Baetidae taxa.

The metric for individual indicator sensitive decreaser taxa was based on the presence of invertebrate families that have been identified as organisms that decrease in abundance in response to stress within Biotype 2 sites. They include the families/genera Ameletidae (mayfly), Chloroperlidae (stonefly), *Dicranota sp.* (crane fly), Elmidae (riffle beetle), Ephemerellidae (mayfly), Heptageniidae (mayfly), *Micrasema sp*. (caddisfly), Nemouridae (stonefly), Perlidae (stonefly), Perlodidae (stonefly), *Rhyacophila sp.* (caddisfly), and *Stempellinella sp.* (midge).

After all metric calculations are complete, values for each metric were scored and normalized according to equations in Policy 10-1 (CDPHE 2020). The scoring formula for one of the eight metrics (EPT taxa) incorporated an adjustment based on Julian Day. Scores greater than

100 for any of the eight metrics were reset to 100. Normalized scores for each metric were averaged to create a final MMI score between 0 and 100.

Aquatic Life Use Thresholds in Policy 10-1 (CDPHE 2020) are used as a tool to identify impairment or attainment of the aquatic life use classification. Sites in Biotype 2 with a final MMI score less than 40 are classified as impaired, while sites with a final MMI score greater than or equal to 48 are classified as attaining the aquatic life use for that stream. Sites with scores between those thresholds are in the gray zone and require additional analysis of auxiliary metrics to determine if the sites are classified as attaining or impaired. Waters for this project are classified as Class 1 Cold Water Aquatic Life and are expected to be capable of sustaining or currently sustaining a wide variety of cold water biota, including sensitive species.

The auxiliary metrics include the Hilsenhoff Biotic Index (HBI), which must be less than 4.9, and the Shannon-Weaver Diversity Index (H'), which must be above 3.2. If the site fails to meet either criterion, the site is considered impaired. The HBI is a pollution tolerance index used to evaluate water quality and is calculated as an abundance-weighted average of individual tolerance values for all taxa present in the sample (Hilsenhoff 1987). Higher HBI values would be expected at more stressed sites compared to less stressed sites because the community would be comprised of more tolerant (higher scoring) organisms.

The MMI scores were compared between the pre- and post-treatment data. The goal of the WQAMP is to have aquatic life use attainment at sites D, E, and F by 2023.

3. Results and Discussion

3.1 Fish Population Comparisons

Fish population data was collected at Site D on September 7, 2011, September 19, 2017, September 23, 2020, and September 21, 2023 (Table 1, Appendix A). Both Brook Trout and stocked Rainbow Trout were captured. The site population estimates of Brook Trout had 95 percent confidence intervals of less than ten percent of the total population estimate at Site D, indicating efficient sampling and relatively precise estimates in the 2023 fish data.

The site population estimates at Site D in 2011 indicated the total population of Brook Trout in the reach downstream of the reservoir and the fence was 90 fish. The Brook Trout had an average mean length of 130 millimeters (mm) and an average weight of 31 g in 2011. In the fall of 2017, a higher number of Brook Trout, 111 fish, were estimated at Site D. Additionally in 2017, the averaged mean lengths and weights of Brook Trout increased to 146 mm and 40 g, respectively. In 2020, estimated Brook Trout population at Site D was higher at 172 fish. The Brook Trout had an average mean length of 133 mm and average weight of 33 g, similar to 2011. In 2023, the population estimate for Brook Trout at Site D decreased from 2020 values to near 2017 values and higher than 2011 values at 102 fish, with a mean length and weight of 159 mm and 43 g. The mean measurement values in 2023 indicate that the Brook Trout were on average bigger than in the previous years. .

Table 1: Trout summary population parameters for Site D, sampled on South Clear Creek, September 7, 2011, September 19, 2017, September 23, 2020, and September 21, 2023.

Year	Species	Number Collected	Site Population Estimate ± 95% CI (#/Site)	Mean Length (mm)	Mean Weight (g)	Relative Weight (W_r)
2011	Brook trout	87	90 ± 5.0	130	31	87.0
	Rainbow trout	17	17 ± 1.5	236	138	94.9
2017	Brook trout	104	111 ± 9.0	146	40	88.3
	Rainbow trout	1	1 ± --	237	138	95.9
2020	Brook trout	166	172 ± 7.0	133	33	85.1
2023	Brook trout	101	102 ± 3.0	159	43	84.8
	Rainbow trout	8	8 ± 0.0	277	195	84.2

In 2023, eight Rainbow Trout were collected at Site D. Seventeen rainbow trout were collected at Site D in 2011, one rainbow trout in 2017, and none in 2020 (Table 1). All Rainbow Trout were larger than 191 mm (7.5 inches) and appeared to be stocked fish based on fish length and observations of fish body condition during sampling. Rainbow Trout average lengths have ranged from 236 to 277 mm at this site during the four fish surveys, much larger than the Brook Trout. Colorado Parks and Wildlife routinely stocks Rainbow Trout in Clear Lake (CPW unpublished stocking records), and there are no barriers to upstream movements of the stocked fish into the reach of South Clear Creek downstream of the Lower Reservoir. The CPW stocking truck was observed at Clear Lake on September 6, 2011, the day prior to sampling. CPW does not stock Rainbow Trout in South Clear Creek upstream of the Lower Reservoir. Brook Trout are not stocked in South Clear Creek or in Clear Lake. Rainbow Trout apparently do not maintain viable, functional, self-sustaining populations in South Clear Creek; no additional detailed discussion of population parameters of this species is provided.

3.1.1 Density and Biomass

Density and biomass estimates were initially calculated for all Brook Trout and then recalculated to estimate density of juvenile and adult Brook Trout only at Site D in 2011, 2017, 2020, and 2023 (Table 2; Appendices A – D). With all size classes of Brook Trout included, the mean density estimates from 2011, 2017, and 2020 increased from 1,169 Brook Trout per hectare (fish/ha) to 1,708 fish/ha and then 2,606 fish/ha. In 2023, the density value decreased to 1,417 fish/ha, a value between the ones estimated in 2011 and 2017. Similarly, there was an increase in the estimated biomass over the years from 35.9 kg/ha of Brook Trout to 67.5 kg/ha and then 87.0 kg/ha, followed by a decrease in 2023 to 61.5 kg/ha. As with densities, this biomass value was between the values recorded in 2011 and 2017.

Table 2: Density and Biomass estimates for all Brook Trout, and juvenile and adult Brook Trout for Site D on South Clear Creek, 2011, 2017, 2020, and 2023.

Year	All Brook Trout		Juvenile and Adult Brook Trout	
	Density ± 95% CI (fish/ha)	Biomass (kg/ha)	Density ± 95% CI (fish/ha)	Biomass (kg/ha)
2011	1,169 ± 65	35.9	714 ± 36	34.3
2017	1,708 ± 139	67.5	1,338 ± 123	66.5
2020	2,606 ± 106	87.0	1,470 ± 3	81.6
2023	1,417 ± 42	61.5	1,236 ± 42	60.7

The YOY Brook Trout collected in fall were hatched in the spring of the same year and had not yet survived a winter. Winter can be a stressful period for trout, especially YOY trout, and some will not survive to become part of the resident population. At the request of CPW, smaller (YOY) trout were excluded from density and biomass estimates from the 2011, 2017, 2020, and 2023 data, with 34, 23, 69, and 13 YOY excluded, respectively, for each of these years.

The 2023 density and biomass estimates of juvenile and adult Brook Trout were higher than these values for 2011 but lower than values from 2017 and 2020 (Table 2). Biomass estimates using all Brook Trout and those using only juvenile and adult Brook Trout both followed similar trends from 2011 to 2023. Biomass values were similar to those with YOY included, as the small YOY Brook Trout weigh very little and don't contribute much to total biomass when compared to larger trout. One of the specific goals of the WQAMP is to observe an upward trend in Brook Trout biomass compared to the baseline data. While a consistent increasing trend in biomass from year to year has not been observed, the higher values for biomass in 2017, 2020, and 2023 compared to 2011 suggest that this goal is being met.

3.1.2 Length Frequency Distribution

Young of year, juvenile, and adult Brook Trout were present at Site D in 2011 (Figure 2; Appendix D). YOY Brook Trout present in the fall are trout resulting from spawning from the previous fall. The eggs incubate over winter and hatch in the spring. At Site D in 2011, a distinct YOY size/year class of 34 trout were present with lengths of 53 to 100 mm (Figure 2). The transition of Brook Trout from juveniles to adults likely occurs over a range of sizes depending on site-specific conditions. Therefore, juveniles and adult trout were not differentiated. A total of 53 juvenile and adult Brook Trout were collected at Site D in 2011, and their size ranged from 101 to 224 mm in 2011 (Figure 2; Appendix D).

All three life stages of Brook Trout were present from the sampling in 2017 at Site D. The length-frequency data show a smaller number of 23 YOY Brook Trout than in 2011 (Figure 2). The number of juveniles and adults increased to 81 trout, and the range of lengths was 101 mm up to 265 mm. The increase in maximum length of the Brook Trout in 2017 indicates there were a few more older Brook Trout at Site D in 2017.

In 2020, the Brook Trout length-frequency data showed the number of YOY more than doubled to 69 Brook Trout from the previous two sampling periods (Figure 2). The number of juveniles and adults increased to 97 trout, and their size ranged from 101 to 245 mm, similar to the previous sampling periods.

Length-frequency data collected in 2023 showed a decrease in YOY trout from previous years (Figure 2), with only 13 YOY trout collected. The population of juvenile and adult trout, however, remained robust, with 88 individuals present within Site D in September 2023. YOY trout ranged from 57 to 99 mm in length. The size range for juvenile and adult trout ranged from 102 to 236 mm, which is a similar size range measured in the Brook Trout population in 2020. The size range of trout in all sampling years is typical of the size range of Brook Trout found in similar streams in the mountains of central Colorado. Fluctuations in numbers of YOY from year to year can be influenced by things like the magnitude and duration of runoff due to snowmelt, severity of winter conditions, and predation by larger trout. The changes in the Brook Trout population over time at Site D appear within the normal range of fluctuations that would be expected in a wild trout population in a small stream in the Rocky Mountains.

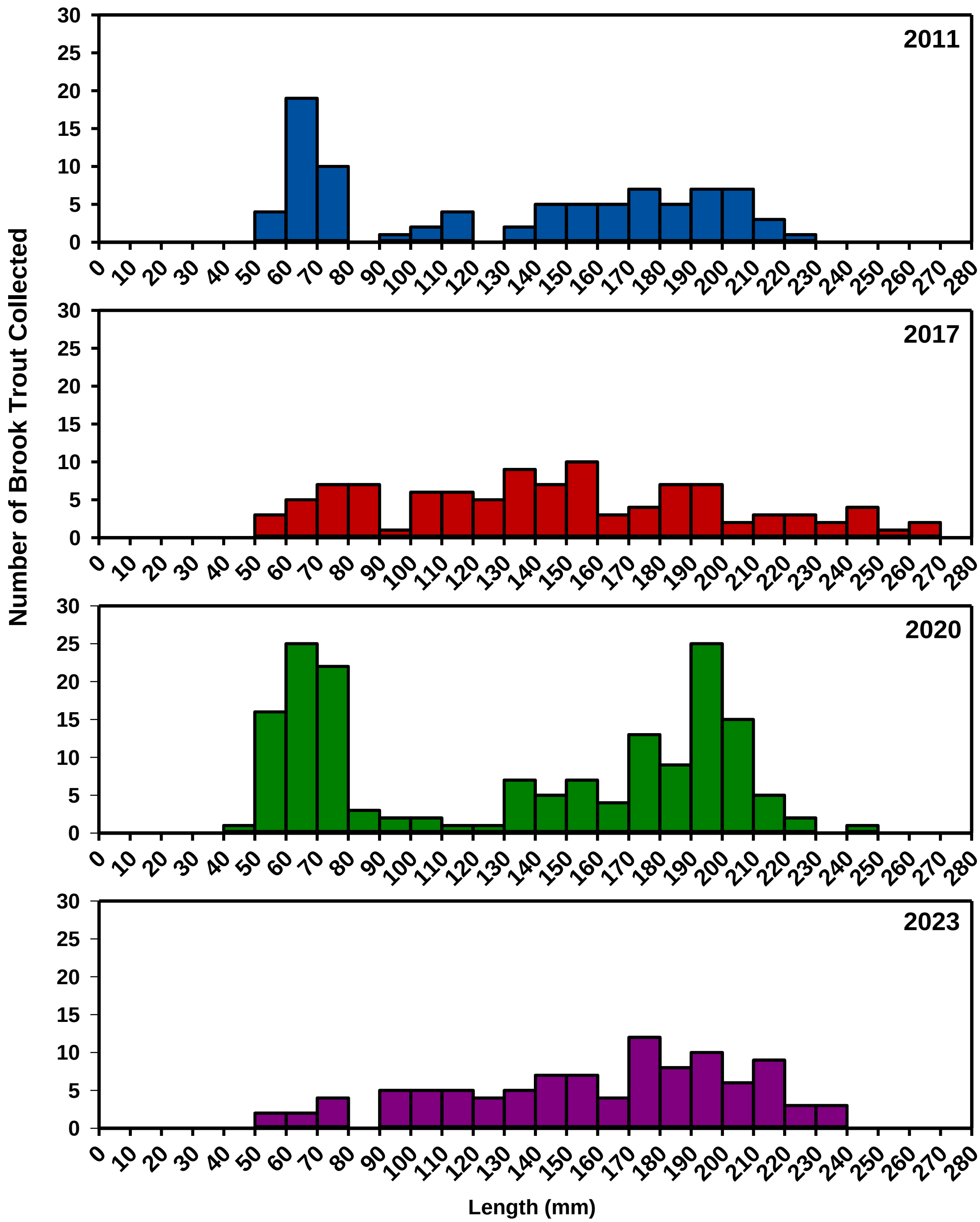

Figure 2: Length frequency histograms of Brook Trout just downstream, Site D, of the Lower Reservoir from South Clear Creek, 2011, 2017, 2020, and 2023.

The presence of YOY in all four sampling events, and especially the high numbers in 2020, suggests that water quality is sufficient to support a self-sustaining and naturally reproducing Brook Trout population. Brook Trout are not stocked in Clear Lake. Spawning to maintain the population occurs in the section of South Clear Creek between the Project and Clear Lake.

3.1.3 Fish Condition (Relative Weights)

For adult and juvenile Brook Trout that were large enough for the relative weight calculation (greater than 130 mm in length) in the downstream reach in 2011, 2017, 2020, and 2023, the mean relative weights were 87.0, 88.3, 85.1, and 84.8, respectively (Table 1; Appendices A – D). The relative weight data for adult Brook Trout were not normally distributed and the non-parametric Kruskal Wallis One-Way ANOVA on ranks was used for the comparison between years. The median relative weight values for adult Brook Trout were not significantly different among years ($p = 0.110$), nor were they different when sampling data were grouped into pre-treatment and post-treatment data sets ($p = 0.700$). This indicates adult Brook Trout were in similar condition in all four years at Site D, and that there was no significant change in the Brook Trout relative weights between the pre- and post-treatment sampling events. The 2023 mean relative weight was 84.8 and remains below the WQAMP Brook Trout mean population relative weight specific goal of 100. While the relative weight values were within the range of 70 to 130 that is generally observed (Murphy and Willis 1991), these values were less than the project specific goal and the optimal range of 95 to 105 for most species (Anderson 1980; Anderson and Neumann 1996). It appears that Brook Trout are still experiencing problems with food availability.

3.2 Macroinvertebrate Population Comparisons

3.2.1 Hess Samples

3.2.1.1 Pre-Treatment Samples 2011 and 2013, 2014, and 2015

A variety of macroinvertebrates were collected from the South Clear Creek sites in 2011, 2013, 2014, and 2015 (GEI 2016; Appendix F). Mayflies (Ephemeroptera) were present each year in high abundance at the upstream site but were uncommon or absent at the downstream sites. Stoneflies (Plecoptera) and caddisflies (Trichoptera) were present each year at both upstream and downstream sites with higher abundances observed at the upstream site in most or all years. Beetles (Coleoptera) were present all years with greater abundance at the upstream site but absent most of the years at some downstream sites. True flies (Diptera) were present at all sites, with the ubiquitous midge family Chironomidae comprising the majority of the true flies collected in the samples. Segmented worms (Oligochaeta) were also present at all sites each year but were more abundant at downstream sites. Water mites (Hydracarina), flatworms (Turbellaria), roundworms (Nematoda), snails (Gastropoda), and clams (Pelecypoda) were also present in low numbers at some sites during different years.

At Site B, upstream of the Lower Reservoir, mayflies or stoneflies were the most abundant group collected in most years. The mean number of taxa collected in individual replicate samples at Site B from 2011 through 2015 ranged from 25 to 33 taxa, with up to a total of 50 taxa present when the data from the three replicate Hess samples were combined. The mean number of EPT taxa at this site ranged from 11 to 19 over the sampling years, and mayflies comprised 10 to 36 percent of the macroinvertebrate population on average. Heptageniid mayflies were present in all years and comprised from 6 to 13 percent of total density in the replicate samples. There were 8 to 10 metal intolerant taxa present at this site when all Hess replicate samples were combined. The Shannon Weaver Diversity Index was 3.72 or higher each year. These values were well above the threshold of 2.50 indicating a balanced macroinvertebrate population at Site B throughout the sampled years.

Downstream of the Lower Reservoir at sites D, E, and F, oligochaetes were the dominant group in each year at most sites (Appendix F). Oligochaete abundance was particularly high in 2011. Two of the sensitive groups, mayflies and caddisflies, were absent at the downstream sites or had much lower densities when compared to Site B. Among the sensitive insect groups, stoneflies had higher abundances at the downstream sites compared to Site B in 2014. True flies, a tolerant group, had higher densities at the three downstream sites compared to the upstream site. The mean number of taxa ranged from 8 to 22 among the years, and the mean number of EPT taxa ranged from 3 to 9. Up to 13 EPT taxa were present at the downstream sites when the replicate data were combined. Heptageniid mayflies were absent in all years, and there were only 2 or 3 metal intolerant taxa present at each site. The Shannon Weaver Diversity Index was below the 2.50 threshold most years for all downstream sites. However, Site F in 2013 and sites D, E, and F in 2014 had values above the 2.50, indicating more diverse populations were present.

The upstream and downstream sites had clear differences in the composition of their macroinvertebrate assemblages. The upstream site had a much higher abundance of insect groups, including the sensitive mayflies and caddisflies. All downstream sites had low abundance of mayflies and caddisflies or they were absent. Stoneflies, particularly taxa from the Nemourid family, were present in the downstream sites in considerable densities, particularly in 2014. Downstream sites also had a high abundance of oligochaetes. Oligochaete families, especially the Naididae and Enchytraeidae families, are tolerant of many different kinds of pollutants in waters, including fine sediments, metals, and organic pollutants, and their presence can be used as a monitoring tool (Lafont 1984; Rodriguez and Reynoldson 2011). High densities of oligochaetes are also commonly found in hyporheic zones (Strayer 2001), areas where groundwater and surface water mix, especially where upwelling of ground water occurs (Lafont and Vivier 2006). The oligochaete densities for all downstream sites were mostly comprised of *Nais* sp. (family Naididae) (GEI 2017), indicating a pollutant tolerant community, the presence of groundwater inputs, or both.

Density at the upstream Site B and two downstream sites D and E was similar during many of the pre-treatment years (Appendix F). At Site F in 2011, the mean density value was much higher than the remaining sites, primarily due to a large number of oligochaetes (GEI 2017 and Appendix F). In 2013, 2014, and 2015 the density values at Site F continued to be higher than the other downstream sites but not as substantially as in 2011, with fewer oligochaetes present. However, when data were pooled each year for the downstream sites, there was no statistically significant difference in mean density values between the upstream Site B and the downstream sites ($p > 0.05$) in 2011, 2013, and 2015. In 2014, there was a significant difference in mean densities between upstream and downstream sites ($p < 0.05$) with the downstream site having a lower mean density compared to the upstream site.

The pre-treatment macroinvertebrate population results indicate an overall reduction in nearly all other replicate and composite metrics from the upstream to the downstream sites in 2011, 2013, 2014, and 2015 (Appendix B). The mean number of taxa and EPT taxa were higher at the upstream site than at the pooled downstream sites in all years except 2013 ($p < 0.05$). In 2013, the mean number of EPT taxa was higher at the upstream site compared to the downstream sites ($p < 0.05$), but the mean number of taxa was similar between the two site categories ($p > 0.05$). The mean percent density of Ephemeroptera, mean percent density of heptageniid mayflies, and mean number of metal intolerant taxa metrics were also higher ($p < 0 .05$) at the upstream site than at the downstream sites in all years. The metal sensitive heptageniid mayflies were present each year at Site B but absent at all three downstream sites. The total number of metal intolerant taxa at the upstream site ranged from 8 to 10, while the mean number of intolerant taxa was 2 or 3 at all downstream sites each year. Based on these comparisons of the replicate and composite summary metrics for the upstream site to the three downstream sites, the data indicate that stressors were present below the dam. This was further supported by the high proportion of relatively tolerant oligochaetes at the three downstream sites each year.

3.2.1.2 Post-Treatment Samples 2016 through 2023

Hess sample data collected in 2023 at all the sites were similar to metrics quantified in the 2016 through 2022 samples. There were only some slight differences between the species composition and abundance between the six post-treatment years (Appendix E, Appendix F). A variety of macroinvertebrate groups were collected from the South Clear Creek in 2023 at all study sites (Table 3; Appendix E).

Mayflies, stoneflies, caddisflies, beetles, and true flies were usually abundant at the upstream site (Site B) in 2016 through 2022 (Appendix F). This was again true for data from the 2023 samples. Beetles were the most abundant group at Site B in 2023, followed by true flies. At the downstream sites most of these groups of insects, particularly mayflies and beetles, were usually present in very low numbers or absent from samples collected during the post-treatment period. This excludes stoneflies in the genus *Zapada* which were sometimes relatively abundant, as they were again at the three downstream sites in 2023. Stoneflies in the genus *Sweltsa* were also relatively abundant at sites E and F in 2023. Stoneflies were the most abundant group at sites D, E, and F in 2023. Oligochaetes and true flies were also abundant at all three downstream sites in 2023. Densities for all groups present were lower at the three downstream sites than at Site B in 2023, with the exception of stoneflies at Site F. Caddisflies and mayflies were present in higher abundance at the upstream site compared to the downstream sites in all years. Beetles were absent from sites D and E and in low abundance at Site F in 2023. Springtails (Collembola), water mites, flatworms, roundworms, snails, and clams were also typically present in low numbers at one, two, or three sites annually from 2016 to 2022. No springtails or clams were observed at these sites in 2023.

Table 3: Macroinvertebrate density (number/m^2) collected during Hess sampling and summary population parameters for sites on South Clear Creek, September 2023.

	Upstream	Downstream		
	Site B	Site D	Site E	Site F
INSECTA				
Ephemeroptera (Mayflies)	371	--	2	8
Plecoptera (Stoneflies)	293	186	233	374
Coleoptera (Beetles)	941	--	--	18
Trichoptera (Caddisflies)	320	--	31	35
Diptera (True flies)	711	111	155	146
HYDRACARINA (Water mites)	18	--	--	--
TURBELLARIA (Flatworms)	72	--	--	2
NEMATODA (Roundworms)	37	6	2	6
ANNELIDA				
Oligochaeta (Segmented worms)	205	138	60	75
Hirudinida (Leeches)	--	--	--	2
MOLLUSCA				
Gastropoda (snails)	--	2	--	--
Replicate Data Summary				
Mean Density (organisms/m^2)	2,968	443	483	666
Mean Number of Taxa	34	17	14	20
Mean Number of EPT Taxa	17	3	5	7
Mean Percent Density Ephemeroptera	13	0	<1	1
Mean Percent Density Heptageniid Mayflies	4	0	0	<1
Mean Number Metal Intolerant Taxa	5	1	1	3
Composite Data Summary				
Total Number of Taxa	45	27	23	34
Total Number of EPT Taxa	19	4	8	11
Total Number of Ephemeroptera Taxa	6	0	1	3
Total Number of Metal Intolerant Taxa	5	1	2	5
Shannon-Weaver Diversity (H')	3.85	3.43	3.23	3.52

At Site B there were 41 to 51 total taxa in the composited samples from 2016 through 2022 (Appendix BF), with the 45 total taxa present in 2023 falling within this range (Table 3). Downstream of the Lower Reservoir, fewer taxa were present at the three sites, with the number of total taxa ranging from only 10 to 37 at each site from 2016 through 2022 (Appendix BF). Total taxa values are often slightly higher at Site F than at sites D and E. Total taxa values at these three sites in 2023 ranged from 27 to 34, with the highest number of taxa observed at Site F (Table 3).

Upstream of the reservoir at Site B, there was a good representation of EPT taxa in all years from 2016 through 2022 (Table 3; Appendix B). This site contained between 18 and 28 total EPT taxa from 2016 through 2022. In 2023, 19 total EPT taxa were collected at Site B. Mayflies comprised 10 to 34 percent of the mean density from 2016 to 2022; in 2023 they comprised 13 percent of the mean density. Heptageniid mayflies comprised 14 percent of the mean density from the replicates in 2016 but were present in lower relative abundances in 2017 through 2023, comprising 5 and 4 percent of the density in 2022 and 2023, respectively. The site had a total of 8 to 11 metal intolerant taxa present in annual samples from 2016 to 2022. In 2023, only 5 metal intolerant taxa were collected at Site B. The Shannon Weaver Diversity index values in all eight years were well above the threshold of 2.50, indicating a balanced macroinvertebrate population is typically found at Site B. In general, the data from 2023 at Site B are consistent with data from 2016 through 2022, with the exception of the slightly lower number of metal intolerant taxa in 2023.

The total number of EPT taxa for at each of the three downstream sites was less than at Site B with 14 or fewer of these taxa present in all years from 2016 through 2022 (Table 3; Appendix F). Four to eleven total EPT taxa were collected at the three downstream sites in 2023 (Table 3), with the number of these taxa increasing in a downstream direction. Heptageniid mayflies comprised one percent or less of the total density at these sites since 2016 and were often absent; in 2023, heptageniid mayflies were absent from sites D and E and were present in very low numbers at Site F. Four or less metal intolerant taxa were present from 2016 to 2022 at each of the downstream sites. This was again true in 2023 samples at sites D and E, while Site F contained five metal intolerant taxa. The numbers of metal intolerant taxa at sites B and F were equal at five taxa in 2023; this is the highest total number of metals intolerant taxa observed at any of the downstream sites since sampling was initiated.

The Shannon-Weaver Diversity Index values at the three downstream sites were lower than at Site B at almost all sites from 2016 through 2022; however, with the exception of Site F in 2018 and 2020, these values were close to or above the threshold of 2.50. All three downstream sites have had diversity values greater than 3.00 in 2022 and 2023. This suggests that despite relatively low densities at these sites the benthic macroinvertebrate community is evenly distributed among the taxa than are present. The macroinvertebrate population at Site F in 2018 and 2020 was dominated by a high density of a single taxon, a tolerant segmented worm, resulting in a much lower diversity index during these years.

One of the greatest differences in taxa composition between upstream and downstream sites was the consistently higher abundance and richness of mayflies at Site B compared to the three downstream sites (Appendix F). Many species of mayflies are sensitive to stressors such as metals pollution; their absence could indicate the presence of metals. In 2023, six mayfly taxa were present upstream at Site B compared to one to five mayfly taxa being present at sites D, E, and F (Table 3). As with the number of EPT taxa as a whole, the number of mayfly taxa present at each of the three sites in 2023 increased from site to site downstream.

Segmented worms were more abundant at the downstream sites in most years and were comprised mainly of the widely tolerant family Naididae. Downstream sites have consistently had higher abundances of oligochaetes compared to Site B in most years of the study. However, this was less evident in 2022 and 2023 when oligochaetes were less abundant at sites E and F than at sites B and D (Table 3). In addition, of the segmented worms present at sites D, E, and F in 2023, most of them were the less tolerant taxon, *Eiseniella tetraedra*, instead of the more tolerant *Nais* sp. This was less evident at Site B; *E. tetraedra* was also present at Site B but *Nais* sp. and the oligochaete family Enchytraeidae, which is similarly tolerant to *Nais* sp., were more abundant (Appendix E).

Similar to 2016 through 2022, almost all metric values at Site B upstream of the Lower Reservoir were more favorable than those at the downstream sites in 2023 (Table 3; Appendix B). ANOVA comparisons of the replicate Hess sample data found statistically significant differences for densities, numbers of taxa, numbers of EPT taxa, percent mayflies, percent heptageniid mayflies, and numbers of metal intolerant taxa ($p < 0.001$ for all comparisons). For all comparisons, Site B had significantly higher values than all other sites. Interestingly, the number of metals intolerant taxa comparison showed that Site F had a significantly higher value than sites D and E. This illustrates the improvement in the benthic macroinvertebrate community further downstream as distance from the reservoir increases. For several metrics, values decreased most significantly downstream from Site B to Site D, then remained low at Site E and rebounded slightly at Site F to values similar to or higher than at Site D in 2023 samples.

A pilot aeration system was functioning from September 2020 through August 2021. When comparing summary metrics between the upstream and downstream sites in 2016 through 2019 before the pilot aeration system was installed, and then in 2020 and 2021 during and immediately following the pilot project, the data indicate that stressors are still present below the dam. This is supported by the high proportion of oligochaetes in many years, lack of or low density of heptageniid mayflies, and the low number of metal sensitive taxa at the three downstream sites. In many cases, Site F, the site farthest downstream of the Lower Reservoir, tends to have more favorable metric values than sites D and E. This was true for data from 2016 through 2019 (Appendix F) but was true for only a few metrics in 2020 and not readily apparent in Hess sample data in 2021 (Table 3). In 2022 and 2023, metrics again followed this pattern, with a noticeable improvement at Site F when comparing numbers of total taxa, total EPT taxa, total Ephemeroptera taxa, and total metal intolerant taxa.

3.2.1.3 Comparison of Pre- and Post-Treatment Hess Samples

Both pre-treatment and post-treatment Hess data showed that most of the evaluated metrics had higher values at Site B than the downstream sites (Appendix F). All metrics that assess metals stress, including number of taxa, number of EPT taxa, percent density of Ephemeroptera, number of Ephemeroptera taxa, percent density of heptageniid mayflies, and number of metal intolerant taxa, were higher at the upstream site than the downstream sites for each year. The one exception to this was the number of metals intolerant taxa in 2023 which were equal at sites B and F in 2023. Higher metric values at the upstream site indicate a healthier macroinvertebrate community than those at the downstream sites. Metrics at the downstream sites in every year from 2016 to 2023 continue to indicate that stressors are present below the Lower Reservoir, despite PSCo’s changes in operation. Many metric values at Site F were higher than those at sites D and E, indicating some longitudinal recovery in populations downstream of the Lower Reservoir, at least in some years.

Macroinvertebrate metrics for the pooled downstream sites in 2023 were compared to pooled pre-treatment data for these same sites. Density was higher during the pre-treatment time period when compared to the 2023 replicate data ($p = 0.006$). It should be noted that high benthic macroinvertebrate densities are not necessarily indicators of more or less healthy communities; high densities can sometimes be due to the dominance of a single, tolerant species. Density at Site F in 2023 was the lowest value measured since sampling began while other metrics at this site were more favorable, illustrating that high density is not a predictor of a healthy or unhealthy benthic macroinvertebrate community. Density values were also low at Sites D and E in 2023.

Comparisons of heptageniid densities during the pre-treatment period with replicated 2023 data found that heptageniid densities were slightly higher during the post treatment period ($p = 0.046$). While Heptageniids are still quite sparse at sites D through F, this could indicate a slight improvement in conditions in 2023 for this sensitive group of mayflies. Comparisons of numbers of taxa, numbers of EPT taxa, percentages of mayflies, percentages of metals intolerant taxa, and the numbers of mayfly taxa were all not statistically significant between the pre-treatment period and the 2023 data ($p \geq 0.268$ for all comparisons).

Comparisons of metrics during the pre-treatment and post-treatment periods reveal mostly similar trends. Minimum, average, and maximum values among sites for numbers of total taxa (Figure 3), total EPT taxa (Figure 4), numbers of metal intolerant taxa (Figure 5), and density (Figure 6) between 2023 and the pre-treatment years are mostly similar. In 2023, the number of metal intolerant taxa at Site F was the highest value recorded at this site since sampling began, and equal to the value at Site B (Figure 5). At Site B, the number of metal intolerant taxa in 2023 was the lowest value measured since sampling began. It is unclear what led to a reduced number of metal intolerant taxa at Site B, which is upstream of the Lower Reservoir.

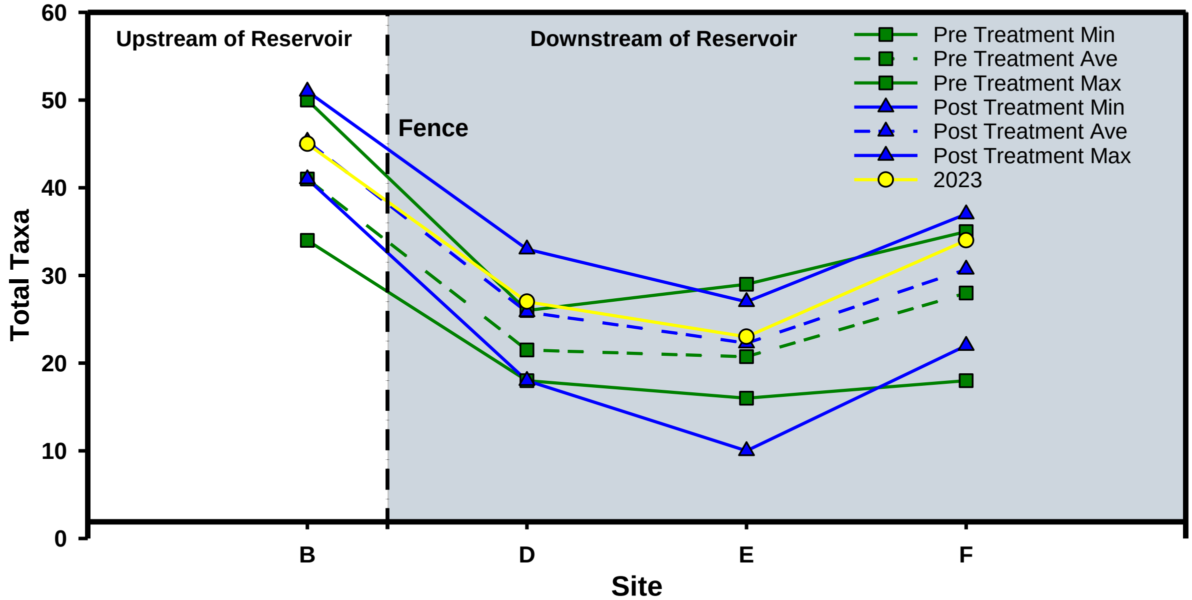

Figure 3: Minimum, average, and maximum total taxa values from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

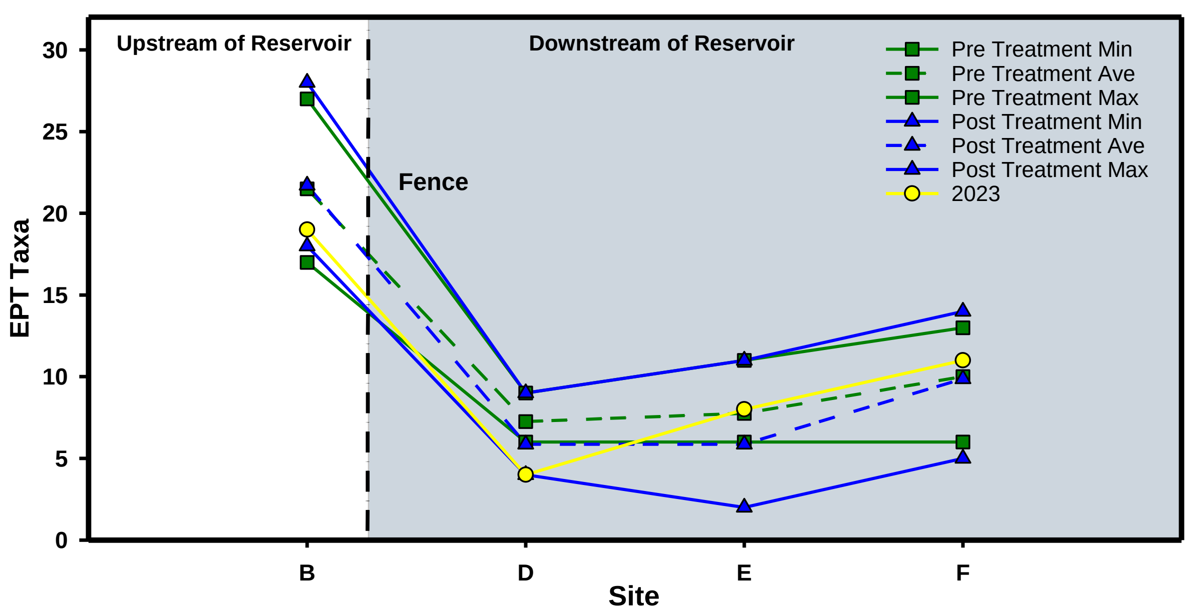

Figure 4: Minimum, average, and maximum EPT taxa values from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

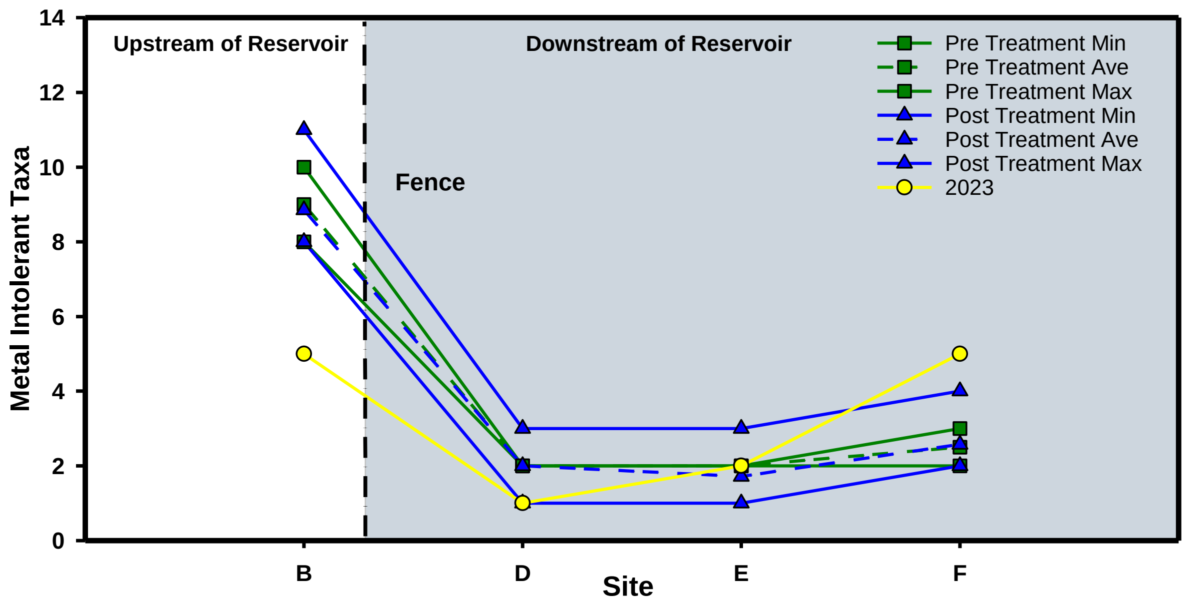

Figure 5: Minimum, average, and maximum metal intolerant taxa values from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

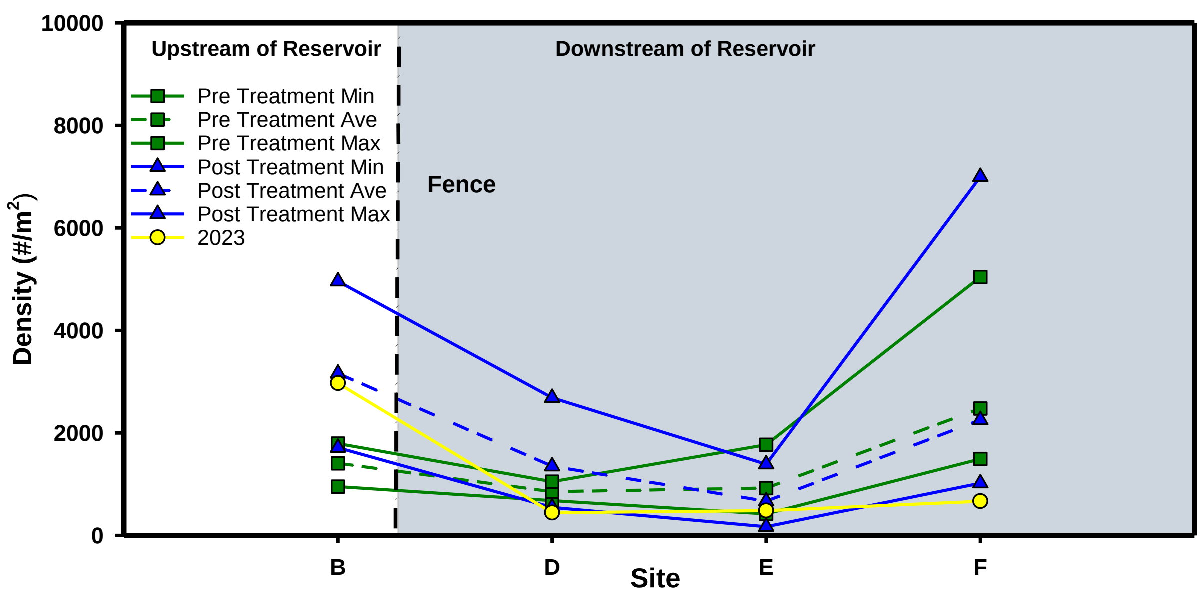

Figure 6: Minimum, average, and maximum density values from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

The Shannon-Weaver Diversity Index (H') scores at Site B were similar between the pre- and post-treatment years, with values well above the 2.50 threshold, indicating diverse, balanced macroinvertebrate communities were present (Figure 7). All H' scores at the downstream sites were lower than the upstream site since 2011, with the exception of 2022 when the H' value at Site E exceeded the value at Site B (Figure 7, Table 3). The H' values in 2022 were higher than all previous values at sites D and E, and higher than most values at Site F (Figure

7). In 2023, H’ values were lower than in 2022 at all sites, but values at sites D, E, and F were all above pre and post-treatment mean values. The relatively high H’ scores in 2014, 2019, 2022, and 2023 indicate the diversity of macroinvertebrate populations at downstream sites can be favorable; the reduced densities of aquatic segmented worms appear to be helping scores for this metric at the downstream sites (Appendix F).

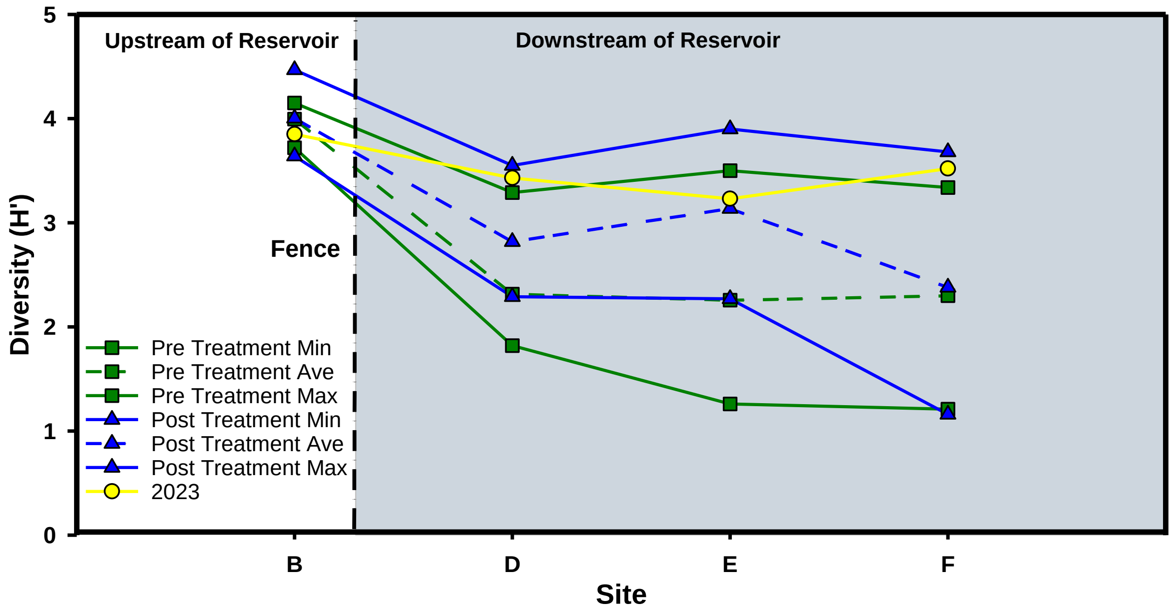

Figure 7: Minimum, average, and maximum Shannon-Weaver Diversity index values from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

The total number of Ephemeroptera (mayfly) taxa at sites B and D were low in 2023, when compared to previously measured values for these sites (Figure 8). Values at sites E and F fell within the ranges of previously measured values at these sites. Numbers of mayfly taxa ranged from none at Site D to six at Site B in 2023. Mayflies were also sometimes absent at the downstream sites in the pre-treatment years. In 2017, no mayfly taxa were collected in the Hess samples at all three downstream sites. The presence of multiple mayfly taxa is an indicator of good water quality. The lower densities, lower total numbers, and occasional absence at some sites of Ephemeroptera taxa downstream of the Lower Reservoir continue to indicate stress to the macroinvertebrate community. As with many other metrics, values rebound somewhat at Site F when compared to sites D and E in some years.

Overall, the longitudinal trends observed for replicate Hess samples in 2023 and during pre-treatment years were similar. The Shannon-Weaver Diversity Index scores, total number of taxa, number of metal intolerant taxa, number of EPT taxa, and number of mayfly taxa found during the pre-treatment sampling years all suggested that diminished water quality at the downstream sites was due to the presence of metals (GEI 2016). The results from 2023 suggest that there are no apparent changes in the status of the macroinvertebrate assemblages in the post-treatment samples that would suggest improved water quality at the downstream sites, despite some improvements in Shannon-Weaver Diversity values and numbers of metals intolerant taxa in 2023. Metrics from 2023 Hess samples continue to indicate metals are present at elevated levels at the downstream sites with some minor improvement in metrics at Site F, farthest downstream of the Lower Reservoir.

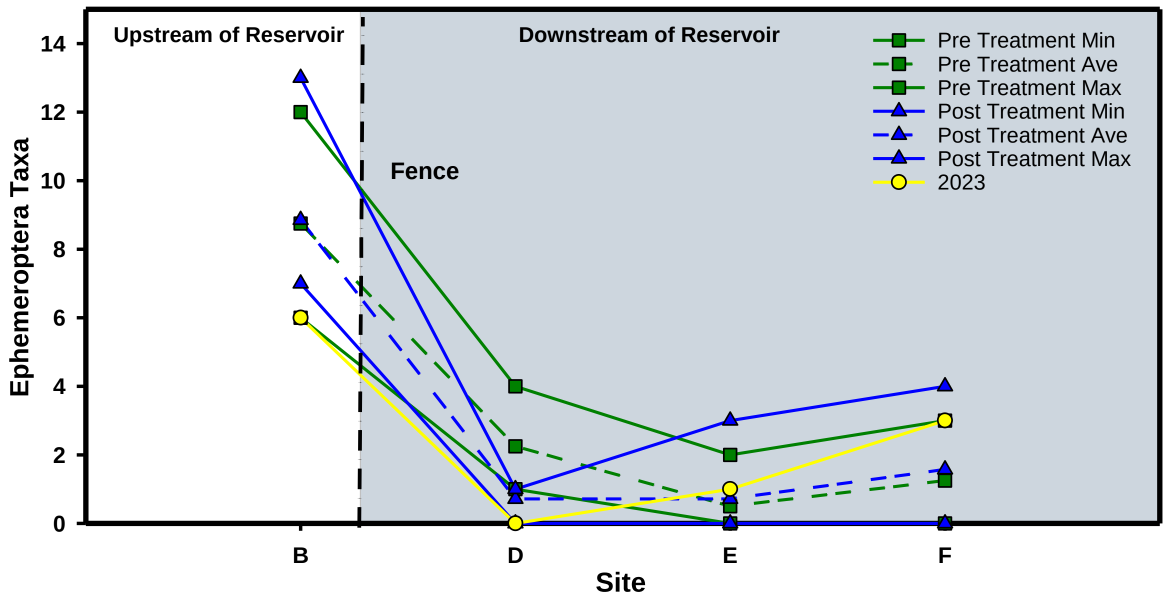

Figure 8: Minimum, average, and maximum Ephemeroptera taxa values from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

3.2.2 MMI Samples

3.2.2.1 Pre-Treatment Samples 2011, 2013, 2014, and 2015

Site B had a final MMI score greater than the attainment threshold of 48 for all years during the pre-treatment period (Appendix G), indicating that this reach of South Clear Creek is in support of its aquatic life use. The final MMI scores at the downstream sites D, E, and F were all below the impairment threshold of 40 for Biotype 2, except at Site E in 2014 with a score of 41 which is within the gray zone and required additional analysis of the auxiliary metrics. The 2014 Site E sample failed to meet both the requirements of the additional auxiliary metrics (HBI < 4.9, H' > 3.2) and thus would not be considered in support of the aquatic life use. These scores indicate that all three downstream sites were not in attainment of their aquatic life uses during the pre-treatment years.

3.2.2.2 Post-Treatment Samples 2016 through 2023

The MMI scores from 2016 through 2021 at sites B, D, E and F were similar to the pre-treatment trends (Figure 9, Appendix G). In all post-treatment years, Site B had scores that indicate attainment while all three downstream sites were below the attainment threshold.

Although Site F in 2016 had an MMI score of 40 that placed it in the gray zone, it failed to meet both requirements for the auxiliary metrics and the site was categorized as impaired.

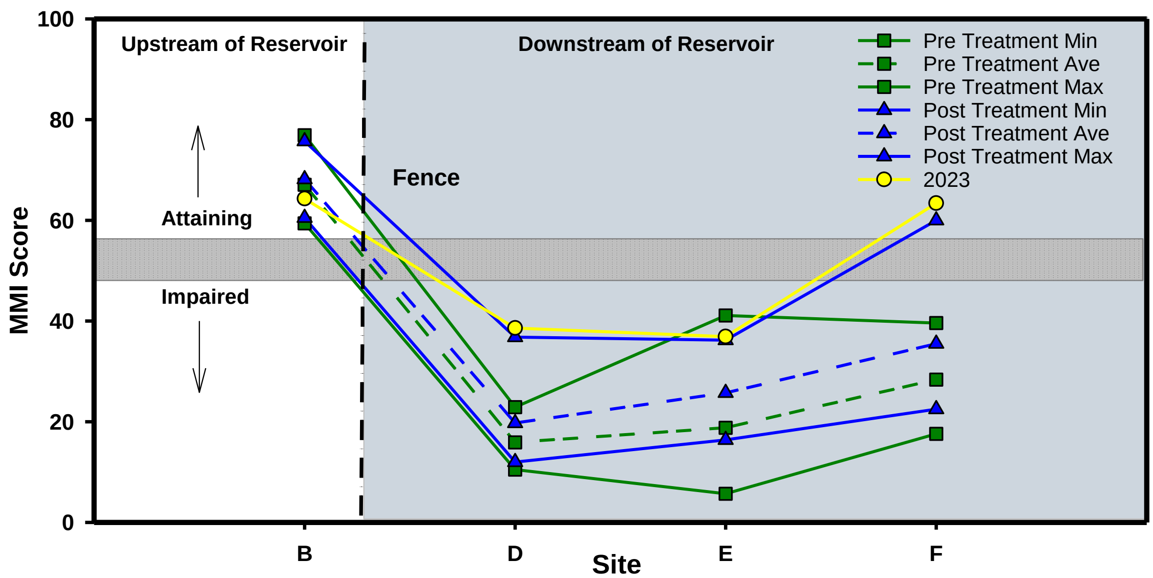

Figure 9: Minimum, average, and MMI scores from the pre- and post-treatment periods for the biomonitoring sites on Cabin Creek; 2011 and 2013-2023.

MMI values in 2022 were similar to those in 2016 through 2021 at Sites B, D, and E (Table 4; Appendix G). The MMI score at Site B was above the attainment threshold, while sites D and E scored below the attainment threshold. Sites D and E showed very slight improvements from previously measured values, but these sites were still classified as impaired. Site F scored above the attainment threshold in 2022 and 2023, which had not occurred previously during the monitoring period (Figure 9).

The 2023 MMI samples collected at sites B, D, E, and F contained a variety of groups of macroinvertebrates (Table 4). Water mites, flatworms, and roundworms were only found at sites B and F. Both mayflies and caddisflies were relatively abundant at site B but were absent from or found in very low numbers at sites D, E, and F. Of note, the total abundance at Site E in 2023 was less than 150 organisms, MMI scores with less than 150 individuals should be evaluated with caution (Jessup and Stribling 2017). Stoneflies, dominated by the genus *Zapada*, were the most abundant group collected at sites D, E, and F. True flies were also abundant at all three of the downstream sites. All community metrics were more favorable at Site B than at sites D and E in 2023 (Table 4). Sites D and E had low numbers of EPT taxa and metal intolerant taxa, and mayflies and heptageniid mayflies were absent or present in very low densities at these sites. Metrics at Site F were much more favorable, with higher numbers of taxa, EPT taxa, and metal intolerant taxa. The number of taxa and metal intolerant taxa at Site F exceeded the values at Site B in 2023, and the numbers of EPT taxa were very similar between these two sites.

Table 4: Macroinvertebrate population density (number/m^2) and composition collected during MMI sampling on South Clear Creek, September 2023.

Taxa	Upstream	Downstream		
	Site B	Site D	Site E	Site F
INSECTA				
Ephemeroptera (Mayflies)	310	--	1	14
Plecoptera (Stoneflies)	225	306	57	181
Coleoptera (Beetles)	450	2	--	13
Trichoptera (Caddisflies)	105	10	--	5
Diptera (True flies)	465	203	31	122
HYDRACARINA (Water mites)	15	--	--	1
TURBELLARIA (Flatworms)	20	--	--	2
NEMATODA (Roundworms)	25	--	--	1
ANNELIDA				
Oligochaeta (Segmented worms)	190	228	7	31
MOLLUSCA				
Gastropoda (Snails)	--	--	--	--
Data Summary				
Density (organisms/m^2)	1,805	749	96	370
Number of Taxa	32	24	19	37
Number of EPT Taxa	17	5	3	16
Percent Density Ephemeroptera	17	0	1	4
Percent Density Heptageniid Mayflies	4	0	0	1
Number Metal Intolerant Taxa	5	2	2	8

Site B had a final MMI score of 64.3, a score slightly higher than the threshold of 62 that categorizes the site as a "high scoring water" and much higher than the attainment threshold of 48 (CDPHE 2020), indicating that aquatic life use was attained at this site (Table 5). CDPHE (2020) designates extra protection for "high scoring waters" as such sites would be flagged as impaired if the score decreased by 22 points or more from year to year. Downstream sites D and E had much lower final MMI scores, at 38.6 and 36.9, respectively. The final MMI scores at these two sites were below the impairment threshold of 40 for this biotype, and, as noted previously, there was an insufficient number of organisms in the sample at Site E. The score at Site F was categorized as in attainment for the second time since monitoring began with a score of 63.4. Site F was also in attainment in 2022. This indicates the aquatic life use was not attained at the two sites immediately downstream of the Project Boundary Fence, but metrics improved significantly at Site F in 2022 and 2023 (Table 5). Site F had comparable scores to Site B for multiple individual metrics, and had a higher score for the percent EPT no Baetidae and the percent indicator sensitive decreaser metrics. This resulted in a less than one-point difference in the final MMI scores between these two sites.

Table 5: MMI analysis for macroinvertebrate populations sampled at sites on South Clear Creek, September 2023.

Metric	Site B		Site D		Site E		Site F	
	Value	Score	Value	Score	Value	Score	Value	Score
Total Taxa	31	73.8	21	50.0	19	45.2	32	76.2
Total EPT	17	69.4	5	20.4	3	12.2	12	49.0
% EPT no Baetidae	30.2	38.0	43.4	54.8	60.4	76.2	52.9	66.8
Clinger Taxa	16	80.0	5	25.0	3	15	10	50.0
Intolerant Taxa	15	71.4	7	33.3	5	23.8	16	76.2
% Indicator Sensitive Decreaser Taxa	51.2	70.8	43.4	60.1	61.5	85	61.2	84.7
Facultative Predator Taxa	11	84.6	7	53.8	4	30.8	12	92.3
% Facultative Scraper	11.5	26.1	5.2	11.7	3.1	7.1	5.2	11.7
Final Index Score	**64.3**		**38.6**		**36.9[1]**		**63.4**	
Decision	**Attaining**		**Impaired**		**Impaired**		**Attaining**	

[1] Insufficient number of organisms for MMI calculation; MMI scores with counts less than 150 individuals should be used with caution.

3.2.3 Comparison of Pre- and Post-Treatment MMI Samples

The final MMI score from 2023 for Site B was within the range of previously measured pre and post-treatment MMI scores (Figure 9; Appendix G). Site D scored the highest it ever has in 2023, exceeding the previous high score from 2022, but was still below the attainment threshold. Site E was near the high end of previously scored values, but still also categorized as impaired. Site F, as discussed previously, was in attainment for the second year in a row. Sites D, E, and F have all shown improvements in MMI scores, but sites D and E remain below the attainment threshold. Site B had final MMI scores well above the attainment threshold in pre- and post-treatment years, indicating that South Clear Creek above the Lower Reservoir is consistently in attainment for aquatic life use. Final MMI scores continue to show a substantial decrease when moving from Site B, upstream of the Lower Reservoir, to Site D, the first downstream site below the Project Boundary fence, during the post-treatment period. However, the score at Site D in 2023, while still classified as impaired, was the highest value measured at this site since 2011. Site E also scored better than in many years, with the 2022 MMI score only being exceeded in 2014 (Appendix G).

Improvements in MMI index scores at sites D, F, and to a lesser extent E, in 2022 and 2023 are in large part due to improvements in several of the same MMI metrics. The percent indicator sensitive decreaser taxa metric has shown marked improvements at sites D, E, and F during the last 1-3 years. The percent EPT no Baetidae metric has also shown marked improvements at sites D, E, and F during the past 1-3 years and was also more favorable than in the last several years at sites D and F. Site F also had more favorable values for many metrics in 2022 and 2023, particularly the intolerant taxa and facultative predator taxa. Despite improvements in some metrics, index scores were still classified as impaired at sites D and E.

Final MMI values in the post-treatment years of 2016 through 2021 for sites D, E, and F and in 2022 for sites D and E downstream of the Lower Reservoir, were lower than the impairment threshold of 40 or were within the gray zone but also failed to meet the requirements for the auxiliary metrics. These results indicate that the stream below the Project Boundary fence on South Clear Creek remains impaired. The MMI score is a helpful tool that is used to detect stress in a community; however, it does not directly identify the underlying stressor causing the impairment. The consistent low scores in both the pre- and post-treatment samples indicate stressors are affecting the macroinvertebrate community and have not been alleviated by changes in operations in the post-treatment period. The improved MMI score at Site D in 2022 and 2023 still scores below the impairment threshold. However, this metric and the improvement at sites E and F in 2023 indicate that communities at these sites can be slightly more favorable during some years, possibly due to environmental factors such as precipitation and stream flow.

For water quality indicator metrics, low numbers of metal intolerant taxa and heptageniid mayflies downstream of the Lower Reservoir during both pre-treatment and post-treatment sampling years signify that metals present in the water are likely causing a substantial impact on the macroinvertebrate community. These data agree with aquatic macroinvertebrate data from the Hess samples, which also clearly indicate that a stressor is influencing benthic macroinvertebrate communities downstream of the Lower Reservoir, and also show low density and numbers of taxa sensitive to metals.

4. Conclusions

Brook trout were sampled at Site D, just downstream of the fence, during pre-treatment (2011) and post-treatment (2017, 2020, and 2023) years. Stocked rainbow trout were also collected in 2011, 2017, and 2023. Rainbow trout are routinely stocked in Clear Lake and are found at Site D but do not maintain viable, functional, self-sustaining populations in South Clear Creek.

Density values for Brook Trout at Site D have been higher in all post-treatment sampling events (2017, 2020, 2023) than in the pre-sampling event conducted in 2011. Density values for adult and juvenile Brook Trout, excluding YOY, have been 73 to 106 percent higher in the post-treatment years than in the pre-treatment year. Biomass estimates at Site D for both the entire Brook Trout population as well as only juveniles and adults have also been notably higher in 2017, 2020, and 2023 than in 2011. This indicates that conditions have been more favorable to support Brook Trout at Site D during the post-treatment time period. The presence of multiple size/age classes of Brook Trout at Site D, including the presence of YOY in each year, indicates that Brook Trout are maintaining a viable, functional, self-sustaining population being maintained by successful natural reproduction in South Clear Creek downstream of the Lower Reservoir. This has continued from 2011 to 2023.

The average relative weight for Brook Trout at Site D in 2011 was 87.0. Relative weights of the Brook Trout in 2017, 2020, and 2023 have ranged from 84.8 to 88.3, with the highest value measured in 2017. Statistical analyses showed that these values were not significantly different between years or between pre and post-treatment time periods. It appears that food availability may potentially be affecting Brook Trout body condition at Site D.

Two of the goals of the WQAMP related to the Brook Trout population: 1) to have a Brook Trout population with a mean relative weight value of 100 and to observe an upward trend in Brook Trout biomass compared to the baseline data. Despite the changes in operation and an initiation of a pilot project, the first goal was not met in this final year of sampling specified under the WQAMP, as relative weight values in the post-treatment years were similar to the value in 2011. For the second goal, while a consistent increasing trend in biomass from year to year has not been observed, the higher values for biomass in each year that fish have been sampled (2017, 2020, and 2023) in the post-treatment time period compared to 2011 suggest that this goal is being met.

The increased density value since 2011 and the continued presence of YOY Brook Trout indicate the population in South Clear Creek is sustaining itself, and biomass values are also higher than during the baseline period. However, an increase in the mean relative weight values over the time period since the WQAMP was initiated have not occurred.

Benthic macroinvertebrate data collected in 2023 represent the eighth year of data after the first operational modification described in the WQAMP. The post-treatment data from 2016 through 2023 were compared to the pre-treatment data collected in 2011, 2013, 2014, and 2015 to evaluate the effects of WQAMP implementation in South Clear Creek. Following the initial relief well system modification and the second relief well system modification, population metrics and trends showed similar patterns as in the pre-treatment years, although some improvements in macroinvertebrate metrics were noted at sites D, E, and F downstream of the Project Boundary Fence in 2021 through 2023. It is unclear if this indicates improvements due to relief well system modifications or is simply due to more favorable environmental conditions in South Clear Creek unrelated to the treatment system.

The composition of the macroinvertebrate assemblages in the 2023 samples varied among sites. Mayflies, beetles, and true flies were the most abundant organisms at Site B, while stoneflies and true flies were the dominant groups at the downstream sites. Few mayflies, beetles, and caddisflies were found at the downstream sites in 2023, with heptageniid mayflies also being rare or absent at the most downstream sites. The number of metal intolerant taxa was also limited to one or two taxa at sites D and E but higher at Site F in both the Hess and MMI samples in 2023.

Similar to the pre-treatment data collected from 2011 through 2015, Hess and MMI sample data for South Clear Creek upstream of the Cabin Creek Project indicate the presence of a healthy, diverse community of macroinvertebrates at Site B. Based on the MMI, South Clear Creek upstream of the Lower Reservoir is in attainment for aquatic life use. Downstream of the Project on South Clear Creek, the composition of benthic macroinvertebrate communities indicates the presence of a stressed community in pre- and post-treatment years. The health of the macroinvertebrate community appears to recover slightly in some years as the distance downstream from the Project Boundary increases. This was particularly noticeable in 2022 and 2023, when the MMI scores at Site F were in attainment for the first time since data collection began. Numbers of taxa, EPT taxa, and mayfly and metal intolerant taxa were also noticeably better at this site than at sites D and E. However, the results of the MMI analysis continue to show that sites D and E have scored below the attainment threshold during all years of the study, even though individual metrics such as the percent EPT no Baetidae and the percent indicator sensitive decreaser taxa metrics have scored more favorably at these sites during the last 2 to 3 years.

Water quality indicator metrics, including the number of EPT taxa, number of Ephemeroptera taxa, number of metal intolerant taxa, percent density of heptageniid mayflies, and percent density of Ephemeroptera have had greater values at Site B than at the downstream sites in post-treatment years, with the exception of some metrics at Site F in 2023. The decline in many of the metrics at the sites downstream of the Lower Reservoir when compared to the upstream site indicates that degraded water quality is a stressor to the macroinvertebrate community downstream of the Lower Reservoir. The low numbers or absence of heptageniid mayflies and other metal intolerant taxa indicates that metals concentrations are contributing to the degradation of the water quality and effecting the benthic macroinvertebrate community.

The goal under the WQAMP for macroinvertebrate assemblages is attainment of the aquatic life threshold for MMI scores at sites D, E, and F by 2023, as well as statistically significant improvement from pre-treatment conditions at the three downstream sites for number of taxa, the number of metal intolerant taxa, number of EPT taxa, and number of mayfly taxa during the same time period. While the MMI score for Site F has been in attainment in 2022 and 2023, sites D and E remain impaired. Following the operational changes, statistical analyses also do not indicate significant improvements in these four taxa-based metrics in the 2023 data at the three downstream sites, indicating that WQAMP goals have not been met.

The WQAMP was to be implemented over the first ten years of the license period; 2023 is the 10^{th} year since sampling was initiated under the plan. One of the two goals specific to the Brook Trout population has been met, with biomass estimates having been consistently higher in the post-treatment years compared to the baseline data collected in 2011, but the remaining goals relative to fish and macroinvertebrate assemblages have not been met despite the operational changes that were initiated during this time period.

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Appendix A 2023 Fish Data

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/21/2023
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	235	105	0.81	134.9	77.8
1	BRK	231	102	0.83	128.1	79.6
1	BRK	221	104	0.96	111.9	92.9
1	BRK	218	92	0.89	107.4	85.7
1	BRK	215	86	0.87	102.9	83.5
1	BRK	215	86	0.87	102.9	83.5
1	BRK	215	68	0.68	102.9	66.1
1	BRK	213	100	1.03	100.1	99.9
1	BRK	213	74	0.77	100.1	74.0
1	BRK	211	85	0.90	97.2	87.4
1	BRK	211	84	0.89	97.2	86.4
1	BRK	210	79	0.85	95.8	82.4
1	BRK	204	74	0.87	87.7	84.3
1	BRK	200	85	1.06	82.6	102.9
1	BRK	200	74	0.93	82.6	89.6
1	BRK	198	67	0.86	80.1	83.6
1	BRK	197	76	0.99	78.9	96.3
1	BRK	197	68	0.89	78.9	86.2
1	BRK	196	70	0.93	77.7	90.1
1	BRK	196	62	0.82	77.7	79.8
1	BRK	193	70	0.97	74.1	94.4
1	BRK	190	66	0.96	70.7	93.4
1	BRK	190	63	0.92	70.7	89.1
1	BRK	189	55	0.81	69.5	79.1
1	BRK	189	53	0.79	69.5	76.2
1	BRK	187	69	1.06	67.3	102.5
1	BRK	187	57	0.87	67.3	84.7
1	BRK	186	60	0.93	66.2	90.6
1	BRK	184	58	0.93	64.1	90.5
1	BRK	182	58	0.96	62.0	93.5
1	BRK	177	41	0.74	57.0	72.0
1	BRK	176	46	0.84	56.0	82.2
1	BRK	175	52	0.97	55.0	94.5
1	BRK	175	39	0.73	55.0	70.9
1	BRK	174	43	0.82	54.1	79.5
1	BRK	173	46	0.89	53.1	86.6
1	BRK	173	43	0.83	53.1	80.9
1	BRK	172	49	0.96	52.2	93.9
1	BRK	172	43	0.85	52.2	82.4
1	BRK	165	39	0.87	46.0	84.8
1	BRK	164	44	1.00	45.2	97.4
1	BRK	159	35	0.87	41.1	85.2
1	BRK	157	38	0.98	39.5	96.1
1	BRK	157	33	0.85	39.5	83.4
1	BRK	154	28	0.77	37.3	75.1
1	BRK	153	35	0.98	36.6	95.7
1	BRK	152	33	0.94	35.8	92.1
1	BRK	148	29	0.89	33.0	87.8
1	BRK	147	38	1.20	32.4	117.4
1	BRK	147	20	0.63	32.4	61.8
1	BRK	140	24	0.87	27.9	86.0

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/21/2023
Site: Site D, South Clear Creek

1	BRK	140	22	0.80	27.9	78.8
1	BRK	137	28	1.09	26.1	107.2
1	BRK	137	20	0.78	26.1	76.6
1	BRK	132	18	0.78	23.3	77.2
1	BRK	130	16	0.73	22.3	71.8
1	BRK	129	19	0.89		
1	BRK	128	21	1.00		
1	BRK	126	16	0.80		
1	BRK	124	16	0.84		
1	BRK	118	12	0.73		
1	BRK	109	11	0.85		
1	BRK	107	11	0.90		
1	BRK	104	8.3	0.74		
1	BRK	102	8.1	0.76		
1	BRK	99	8.1	0.83		
1	BRK	92	7.0	0.90		
1	BRK	91	8.5	1.13		
1	BRK	70	4.2	1.22		
1	BRK	69	3.6	1.10		
1	BRK	64	2.3	0.88		
1	BRK	59	2.4	1.17		
1	RBT	308	254	0.87	318.0	79.9
1	RBT	290	226	0.93	265.0	85.3
1	RBT	285	224	0.97	251.4	89.1
1	RBT	279	204	0.94	235.8	86.5
1	RBT	270	180	0.91	213.5	84.3
1	RBT	270	165	0.84	213.5	77.3
1	RBT	252	158	0.99	173.3	91.2
2	BRK	236	96	0.73	136.7	70.2
2	BRK	222	65	0.59	113.5	57.3
2	BRK	204	86	1.01	87.7	98.0
2	BRK	202	63	0.76	85.1	74.0
2	BRK	200	66	0.83	82.6	79.9
2	BRK	199	60	0.76	81.4	73.7
2	BRK	198	76	0.98	80.1	94.9
2	BRK	185	61	0.96	65.2	93.6
2	BRK	178	39	0.69	57.9	67.3
2	BRK	175	52	0.97	55.0	94.5
2	BRK	169	39	0.81	49.5	78.8
2	BRK	166	39	0.85	46.9	83.2
2	BRK	146	25	0.80	31.7	78.9
2	BRK	140	23	0.84	27.9	82.4
2	BRK	135	19	0.77	25.0	76.1
2	BRK	119	15	0.89		
2	BRK	118	19	1.16		
2	BRK	114	11	0.74		
2	BRK	111	12	0.88		
2	BRK	104	9.4	0.84		
2	BRK	98	8.2	0.87		
2	BRK	90	6.3	0.86		
2	BRK	75	3.9	0.92		
2	BRK	74	4.3	1.06		
2	BRK	70	2.8	0.82		

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/21/2023
Site: Site D, South Clear Creek

2	BRK	57	1.8	0.97		
2	RBT	259	151	0.87	188.3	80.2
3	BRK	221	98	0.91	111.9	87.5
3	BRK	173	43	0.83	53.1	80.9
3	BRK	159	32	0.80	41.1	77.9

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	101	101	101	74
	MIN:	57	1.8	0.59	57
	MAX:	236	105	1.22	117
	MEAN:	159.3	43.4	0.88	84.8

RBT		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	8	8	8	8
	MIN:	252	151	0.84	77.3
	MAX:	308	254	0.99	91.2
	MEAN:	276.6	195.3	0.92	84.2

	1st Pass	2nd Pass	3rd Pass	Pop Est		95% CI	Site Area (acre)	Density (#/acre)		95% CI	Biomass (lbs/acre)
BRK	72	26	3	102	±	3	0.178	573	±	17	54.86
RBT	7	1	0	8	±	0	0.178	45	±	0	19.37

	1st Pass	2nd Pass	3rd Pass	Pop Est		95% CI	Site Area (ha)	Density (#/ha)		95% CI	Biomass (kg/ha)
BRK	72	26	3	102	±	3	0.072	1417	±	42	61.54
RBT	7	1	0	8	±	0	0.072	111	±	0	21.67

Appendix B 2020 Fish Data

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/23/20
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	245	126	0.86	153.2	82.3
1	BRK	228	104	0.88	123.1	84.5
1	BRK	221	96	0.89	111.9	85.8
1	BRK	219	116	1.10	108.9	106.5
1	BRK	218	88	0.85	107.4	82.0
1	BRK	210	73	0.79	95.8	76.2
1	BRK	208	82	0.91	93.1	88.1
1	BRK	207	82	0.92	91.7	89.4
1	BRK	207	76	0.86	91.7	82.9
1	BRK	205	72	0.84	89.1	80.8
1	BRK	205	71	0.82	89.1	79.7
1	BRK	205	70	0.81	89.1	78.6
1	BRK	202	77	0.93	85.1	90.4
1	BRK	201	74	0.91	83.9	88.2
1	BRK	201	73	0.90	83.9	87.0
1	BRK	200	81	1.01	82.6	98.1
1	BRK	200	74	0.93	82.6	89.6
1	BRK	199	84	1.07	81.4	103.2
1	BRK	199	64	0.81	81.4	78.7
1	BRK	198	71	0.91	80.1	88.6
1	BRK	198	71	0.91	80.1	88.6
1	BRK	198	69	0.89	80.1	86.1
1	BRK	197	72	0.94	78.9	91.3
1	BRK	197	71	0.93	78.9	90.0
1	BRK	197	69	0.90	78.9	87.5
1	BRK	197	69	0.90	78.9	87.5
1	BRK	197	68	0.89	78.9	86.2
1	BRK	197	60	0.78	78.9	76.0
1	BRK	196	66	0.88	77.7	85.0
1	BRK	195	71	0.96	76.5	92.8
1	BRK	195	71	0.96	76.5	92.8
1	BRK	195	67	0.90	76.5	87.6
1	BRK	194	71	0.97	75.3	94.3
1	BRK	193	60	0.83	74.1	80.9
1	BRK	192	66	0.93	73.0	90.5
1	BRK	192	58	0.82	73.0	79.5
1	BRK	192	58	0.82	73.0	79.5
1	BRK	192	57	0.81	73.0	78.1
1	BRK	190	62	0.90	70.7	87.7
1	BRK	190	58	0.85	70.7	82.1
1	BRK	187	61	0.93	67.3	90.6
1	BRK	187	58	0.89	67.3	86.1
1	BRK	186	63	0.98	66.2	95.1
1	BRK	186	54	0.84	66.2	81.5
1	BRK	185	57	0.90	65.2	87.5
1	BRK	185	52	0.82	65.2	79.8
1	BRK	184	54	0.87	64.1	84.2
1	BRK	182	45	0.75	62.0	72.6
1	BRK	178	57	1.01	57.9	98.4
1	BRK	177	59	1.06	57.0	103.6
1	BRK	177	52	0.94	57.0	91.3

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/23/20
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	177	48	0.87	57.0	84.3
1	BRK	176	55	1.01	56.0	98.2
1	BRK	175	49	0.91	55.0	89.0
1	BRK	175	48	0.90	55.0	87.2
1	BRK	175	42	0.78	55.0	76.3
1	BRK	172	45	0.88	52.2	86.2
1	BRK	171	48	0.96	51.3	93.6
1	BRK	167	42	0.90	47.7	88.0
1	BRK	166	35	0.77	46.9	74.7
1	BRK	165	31	0.69	46.0	67.4
1	BRK	160	37	0.90	41.9	88.3
1	BRK	159	34	0.85	41.1	82.7
1	BRK	156	31	0.82	38.8	79.9
1	BRK	156	25	0.66	38.8	64.5
1	BRK	153	31	0.87	36.6	84.8
1	BRK	149	24	0.73	33.7	71.2
1	BRK	146	22	0.71	31.7	69.4
1	BRK	143	26	0.89	29.8	87.4
1	BRK	143	24	0.82	29.8	80.6
1	BRK	138	20	0.76	26.7	74.9
1	BRK	135	21	0.85	25.0	84.1
1	BRK	130	19	0.86	22.3	85.3
1	BRK	130	19	0.86	22.3	85.3
1	BRK	124	17	0.89		
1	BRK	109	11	0.85		
1	BRK	105	10	0.86		
1	BRK	93	6.3	0.78		
1	BRK	84	3.9	0.66		
1	BRK	79	3.6	0.73		
1	BRK	79	3.3	0.67		
1	BRK	78	2.6	0.55		
1	BRK	76	3.2	0.73		
1	BRK	75	3.1	0.73		
1	BRK	75	2.8	0.66		
1	BRK	74	2.7	0.67		
1	BRK	73	2.9	0.75		
1	BRK	72	3.2	0.86		
1	BRK	72	2.9	0.78		
1	BRK	72	2.3	0.62		
1	BRK	70	2.9	0.85		
1	BRK	70	2.8	0.82		
1	BRK	70	2.6	0.76		
1	BRK	70	2.4	0.70		
1	BRK	70	2.3	0.67		
1	BRK	69	2.2	0.67		
1	BRK	65	2.2	0.80		
1	BRK	65	1.9	0.69		
1	BRK	65	1.8	0.66		
1	BRK	64	1.7	0.65		
1	BRK	63	1.8	0.72		
1	BRK	63	1.6	0.64		

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/23/20
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	62	1.5	0.63		
1	BRK	62	1.4	0.59		
1	BRK	62	1.1	0.46		
1	BRK	61	1.6	0.70		
1	BRK	60	1.3	0.60		
1	BRK	59	1.3	0.63		
1	BRK	58	1.2	0.62		
1	BRK	58	1.1	0.56		
1	BRK	56	1.3	0.74		
1	BRK	56	1.2	0.68		
1	BRK	56	1.1	0.63		
1	BRK	52	1.0	0.71		
2	BRK	215	84	0.85	102.9	81.6
2	BRK	212	87	0.91	98.6	88.2
2	BRK	208	89	0.99	93.1	95.6
2	BRK	205	74	0.86	89.1	83.1
2	BRK	202	75	0.91	85.1	88.1
2	BRK	202	64	0.78	85.1	75.2
2	BRK	195	78	1.05	76.5	102.0
2	BRK	187	50	0.76	67.3	74.3
2	BRK	172	46	0.90	52.2	88.1
2	BRK	170	41	0.83	50.4	81.4
2	BRK	156	32	0.84	38.8	82.5
2	BRK	147	26	0.82	32.4	80.3
2	BRK	136	22	0.87	25.5	86.1
2	BRK	135	18	0.73	25.0	72.1
2	BRK	115	14	0.92		
2	BRK	81	3.9	0.73		
2	BRK	81	3.3	0.62		
2	BRK	79	3.7	0.75		
2	BRK	77	3.3	0.72		
2	BRK	76	3.4	0.77		
2	BRK	75	2.4	0.57		
2	BRK	74	2.9	0.72		
2	BRK	69	2.8	0.85		
2	BRK	68	2.3	0.73		
2	BRK	67	2.1	0.70		
2	BRK	66	2.4	0.83		
2	BRK	65	2.2	0.80		
2	BRK	64	1.8	0.69		
2	BRK	63	1.9	0.76		
2	BRK	62	1.7	0.71		
2	BRK	62	1.5	0.63		
2	BRK	61	1.7	0.75		
2	BRK	60	1.2	0.56		
2	BRK	59	1.2	0.58		
2	BRK	57	1.4	0.76		
2	BRK	57	1.1	0.59		
2	BRK	55	1.0	0.60		
2	BRK	51	0.6	0.45		
2	BRK	44	1.2	1.41		

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/23/20
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
3	BRK	194	58	0.79	75.3	77.0
3	BRK	177	55	0.99	57.0	96.6
3	BRK	154	35	0.96	37.3	93.9
3	BRK	150	26	0.77	34.4	75.5
3	BRK	137	19	0.74	26.1	72.7
3	BRK	94	7.2	0.87		
3	BRK	70	2.6	0.76		
3	BRK	68	2.1	0.67		
3	BRK	62	1.9	0.80		
3	BRK	57	1.3	0.70		
3	BRK	57	1.2	0.65		
3	BRK	56	1.2	0.68		
3	BRK	51	0.8	0.60		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	166	166	166	93
	MIN:	44	0.6	0.45	64.5
	MAX:	245	126	1.41	106.5
	MEAN:	133.2	33.4	0.80	85.1

	1st Pass	2nd Pass	3rd Pass	Pop Est	95% CI		Site Area (acre)	Density (#/acre)	95% CI		Biomass (lbs/acre)
BRK	114	39	13	172	±	7	0.163	1055	±	43	77.68

	1st Pass	2nd Pass	3rd Pass	Pop Est	95% CI		Site Area (ha)	Density (#/ha)	95% CI		Biomass (kg/ha)
BRK	114	39	13	172	±	7	0.066	2606	±	106	87.04

Appendix C 2017 Fish Data

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/19/2017
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	265	142	0.76	194.5	73.0
1	BRK	264	148	0.80	192.3	77.0
1	BRK	243	126	0.88	149.4	84.3
1	BRK	237	114	0.86	138.5	82.3
1	BRK	230	141	1.16	126.4	111.6
1	BRK	227	100	0.85	121.4	82.3
1	BRK	227	82	0.70	121.4	67.5
1	BRK	226	106	0.92	119.8	88.5
1	BRK	219	82	0.78	108.9	75.3
1	BRK	217	81	0.79	105.9	76.5
1	BRK	202	72	0.87	85.1	84.6
1	BRK	197	73	0.95	78.9	92.5
1	BRK	197	39	0.51	78.9	49.4
1	BRK	195	60	0.81	76.5	78.4
1	BRK	188	61	0.92	68.4	89.1
1	BRK	186	58	0.90	66.2	87.6
1	BRK	183	54	0.88	63.0	85.7
1	BRK	183	53	0.86	63.0	84.1
1	BRK	180	58	0.99	60.0	96.7
1	BRK	176	49	0.90	56.0	87.5
1	BRK	171	49	0.98	51.3	95.5
1	BRK	170	48	0.98	50.4	95.3
1	BRK	169	52	1.08	49.5	105.1
1	BRK	168	47	0.99	48.6	96.7
1	BRK	162	33	0.78	43.5	75.9
1	BRK	158	35	0.89	40.3	86.8
1	BRK	157	41	1.06	39.5	103.7
1	BRK	154	38	1.04	37.3	101.9
1	BRK	152	36	1.03	35.8	100.5
1	BRK	151	33	0.96	35.1	93.9
1	BRK	150	33	0.98	34.4	95.9
1	BRK	147	31	0.98	32.4	95.8
1	BRK	143	32	1.09	29.8	107.5
1	BRK	142	30	1.05	29.1	103.0
1	BRK	142	24	0.84	29.1	82.4
1	BRK	140	24	0.87	27.9	86.0
1	BRK	136	21	0.83	25.5	82.2
1	BRK	135	21	0.85	25.0	84.1
1	BRK	135	19	0.77	25.0	76.1
1	BRK	134	24	1.00	24.4	98.3
1	BRK	128	19	0.91		
1	BRK	128	19	0.91		
1	BRK	127	21	1.03		
1	BRK	122	17	0.94		
1	BRK	120	16	0.93		
1	BRK	118	15	0.91		
1	BRK	117	16	1.00		
1	BRK	112	13	0.93		
1	BRK	108	12	0.95		
1	BRK	107	8.4	0.69		
1	BRK	105	10	0.86		
2	BRK	249	122	0.79	160.9	75.8
2	BRK	243	120	0.84	149.4	80.3
2	BRK	240	120	0.87	143.9	83.4
2	BRK	212	86	0.90	98.6	87.2
2	BRK	208	78	0.87	93.1	83.8
2	BRK	199	78	0.99	81.4	95.9
2	BRK	195	55	0.74	76.5	71.9
2	BRK	182	68	1.13	62.0	109.7
2	BRK	180	55	0.94	60.0	91.7
2	BRK	157	39	1.01	39.5	98.6

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/19/2017
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
2	BRK	152	35	1.00	35.8	97.7
2	BRK	146	29	0.93	31.7	91.5
2	BRK	145	31	1.02	31.0	99.8
2	BRK	138	22	0.84	26.7	82.4
2	BRK	136	23	0.91	25.5	90.0
2	BRK	130	18	0.82	22.3	80.8
2	BRK	112	12	0.85		
2	BRK	112	12	0.85		
2	BRK	109	12	0.93		
2	BRK	106	11	0.92		
3	BRK	254	141	0.86	171.0	82.5
3	BRK	196	68	0.90	77.7	87.5
3	BRK	191	62	0.89	71.8	86.3
3	BRK	177	53	0.96	57.0	93.0
3	BRK	158	36	0.91	40.3	89.3
3	BRK	154	36	0.99	37.3	96.5
3	BRK	131	20	0.89	22.8	87.7
3	BRK	130	20	0.91	22.3	89.8
3	BRK	114	14	0.94		
3	BRK	105	11	0.95		

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	104	104	104	64
	MIN:	52	1.2	0.51	49.4
	MAX:	265	148	1.16	111.6
	MEAN:	146.1	39.5	0.90	88.3

RBT		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	1	1	1	1
	MIN:	237	138.0	1.04	95.9
	MAX:	237	138.0	1.04	95.9
	MEAN:	237	138.0	1.04	95.9

	1st Pass	2nd Pass	3rd Pass	Pop Est		95% CI	Site Area (acre)	Density (#/acre)		95% CI	Biomass (lbs/acre)
BRK	65	28	11	111	±	9	0.161	689	±	56	60.00
RBT	0	1	0	1	±	--	0.161	6	±	--	1.83

	1st Pass	2nd Pass	3rd Pass	Pop Est		95% CI	Site Area (ha)	Density (#/ha)		95% CI	Biomass (kg/ha)
BRK	65	28	11	111	±	9	0.065	1708	±	139	67.47
RBT	0	1	0	1	±	--	0.065	15	±	--	2.07

Appendix D 2011 Fish Data

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/7/2011
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	BRK	224	115	1.02	116.6	98.6
1	BRK	217	72	0.70	105.9	68.0
1	BRK	210	85	0.92	95.8	88.7
1	BRK	208	74	0.82	93.1	79.5
1	BRK	207	74	0.83	91.7	80.7
1	BRK	205	95	1.10	89.1	106.7
1	BRK	201	84	1.03	83.9	100.2
1	BRK	199	95	1.21	81.4	116.8
1	BRK	199	59	0.75	81.4	72.5
1	BRK	197	65	0.85	78.9	82.4
1	BRK	196	61	0.81	77.7	78.5
1	BRK	190	55	0.80	70.7	77.8
1	BRK	190	48	0.70	70.7	67.9
1	BRK	189	54	0.80	69.5	77.6
1	BRK	186	56	0.87	66.2	84.5
1	BRK	184	57	0.92	64.1	88.9
1	BRK	179	44	0.77	58.9	74.6
1	BRK	177	58	1.05	57.0	101.8
1	BRK	177	50	0.90	57.0	87.8
1	BRK	176	52	0.95	56.0	92.9
1	BRK	175	49	0.91	55.0	89.0
1	BRK	175	43	0.80	55.0	78.1
1	BRK	171	45	0.90	51.3	87.7
1	BRK	166	33	0.72	46.9	70.4
1	BRK	164	44	1.00	45.2	97.4
1	BRK	161	43	1.03	42.7	100.7
1	BRK	160	39	0.95	41.9	93.1
1	BRK	160	37	0.90	41.9	88.3
1	BRK	158	33	0.84	40.3	81.8
1	BRK	155	39	1.05	38.0	102.5
1	BRK	153	26	0.73	36.6	71.1
1	BRK	151	30	0.87	35.1	85.4
1	BRK	150	31	0.92	34.4	90.1
1	BRK	149	29	0.88	33.7	86.0
1	BRK	144	31	1.04	30.4	102.0
1	BRK	140	24	0.87	27.9	86.0
1	BRK	131	19	0.85	22.8	83.3
1	BRK	117	15	0.94		
1	BRK	116	13	0.83		
1	BRK	112	12	0.85		
1	BRK	97	7.0	0.77		
1	BRK	78	4.4	0.93		
1	BRK	78	3.9	0.82		
1	BRK	75	3.4	0.81		
1	BRK	72	3.6	0.96		
1	BRK	71	3.3	0.92		
1	BRK	70	3.0	0.87		
1	BRK	70	2.7	0.79		
1	BRK	67	2.9	0.96		
1	BRK	67	2.5	0.83		
1	BRK	67	2.3	0.76		
1	BRK	66	2.5	0.87		
1	BRK	65	2.5	0.91		
1	BRK	64	2.1	0.80		
1	BRK	62	1.8	0.76		
1	BRK	61	2.1	0.93		
1	BRK	61	1.8	0.79		
1	BRK	60	1.8	0.83		
1	BRK	60	1.6	0.74		
1	BRK	59	1.1	0.54		
1	BRK	57	1.4	0.76		
1	RBT	257	167	0.98	183.9	90.8

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/7/2011
Site: Site D, South Clear Creek

PASS	SPECIES	LENGTH (mm)	WEIGHT (g)	K	Ws	Wr
1	RBT	242	143	1.01	153.3	93.3
1	RBT	240	167	1.21	149.5	111.7
1	RBT	240	128	0.93	149.5	85.6
1	RBT	231	136	1.10	133.2	102.1
1	RBT	225	129	1.13	123.0	104.9
1	RBT	215	71	0.71	107.2	66.2
1	RBT	207	105	1.18	95.6	109.8
1	RBT	200	79	0.99	86.2	91.7
1	RBT	191	73	1.05		
2	BRK	210	79	0.85	95.8	82.4
2	BRK	205	73	0.85	89.1	82.0
2	BRK	190	55	0.80	70.7	77.8
2	BRK	186	69	1.07	66.2	104.2
2	BRK	139	23	0.86	27.3	84.2
2	BRK	115	12	0.79		
2	BRK	109	10	0.77		
2	BRK	102	8.0	0.75		
2	BRK	73	3.2	0.82		
2	BRK	69	3.1	0.94		
2	BRK	65	2.4	0.87		
2	BRK	63	2.5	1.00		
2	BRK	62	2.2	0.92		
2	BRK	61	3.3	1.45		
2	BRK	61	1.7	0.75		
2	BRK	60	1.7	0.79		
2	BRK	59	1.7	0.83		
2	BRK	53	1.3	0.87		
2	RBT	267	149	0.78	206.4	72.2
2	RBT	261	185	1.04	192.7	96.0
2	RBT	255	179	1.08	179.6	99.6
2	RBT	208	90	1.00	97.0	92.8
3	BRK	207	76	0.86	91.7	82.9
3	BRK	205	74	0.86	89.1	83.1
3	BRK	188	62	0.93	68.4	90.6
3	BRK	145	30	0.98	31.0	96.6
3	BRK	145	27	0.89	31.0	87.0
3	BRK	70	2.7	0.79		
3	BRK	70	2.4	0.70		
3	BRK	61	2.1	0.93		
3	RBT	240	154	1.11	149.5	103.0

SUMMARY:

BRK		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	87	87	87	47
	MIN:	53	1.1	0.54	67.9
	MAX:	224	115	1.45	116.8
	MEAN:	130.1	30.7	0.87	87.0

RBT		LENGTH (mm)	WEIGHT (g)	K	Wr
	N:	17	17	17	16
	MIN:	191	71	0.71	66.2
	MAX:	268	223	1.21	111.7
	MEAN:	235.5	138.1	1.03	94.9

DATA: FISH DENSITY
Client: Xcel Energy - South Clear Creek
Date: 9/7/2011
Site: Site D, South Clear Creek

	1st Pass	2nd Pass	3rd Pass	Pop Est		95% CI	Site Area (acre)	Density (#/acre)		95% CI	Biomass (lbs/acre)
BRK	61	18	8	90	±	5.0	0.190	474	±	26.3	32.08
RBT	12	4	1	17	±	1.5	0.190	89	±	7.9	27.10

	1st Pass	2nd Pass	3rd Pass	Pop Est		95% CI	Site Area (ha)	Density (#/ha)		95% CI	Biomass (kg/ha)
BRK	61	18	8	90	±	5.0	0.077	1169	±	64.9	35.89
RBT	12	4	1	17	±	1.5	0.077	221	±	19.5	30.52

Appendix E 2023 Macroinvertebrate Data

DATA: MACROINVERTEBRATE DENSITY
Client: XCEL - CABIN CREEK
Sampled: 9/21/2023
Site: SOUTH CLEAR CREEK, SITE B

TAXA	MMI KICK[1] (#/sq.meter)	EDAS Subsample Output[2]	2 Hess Composite Rep 1	2 Hess Composite Rep 2	2 Hess Composite Rep 3	Composite of Reps
INSECTA						
EPHEMEROPTERA	**310**	**55**	**342**	**261**	**512**	**371**
Ameletus sp.			6			2
Baetis tricaudatus cx.	100	19	105	58	116	93
Cinygmula sp.	15	2	46	17	105	56
Drunella coloradensis	5	1				
Drunella doddsii	95	17	122	70	105	99
Epeorus longimanus	10	2				
Rhithrogena sp.	50	8	46	64	116	75
Serratella micheneri	35	6	17	52	70	46
PLECOPTERA	**225**	**38**	**267**	**262**	**348**	**293**
Capniidae			17	17	23	19
Leuctridae			23	17		13
Megarcys signata	25	3	29	12	23	21
Plumiperla diversa	10	1	17	35	46	33
Sweltsa sp.	25	4	35	35	70	47
Taeniopterygidae	50	9	134	70	128	111
Zapada cinctipes	10	2	6	6	12	8
Zapada oregonensis gr.	105	19	6	70	46	41
COLEOPTERA	**450**	**73**	**906**	**616**	**1,301**	**941**
Heterlimnius corpulentus	450	73	906	616	1,301	941
TRICHOPTERA	**105**	**15**	**301**	**262**	**395**	**320**
Glossosoma sp.	10	1	46	35	23	35
Hydropsychidae				12		4
Rhyacophila brunnea gr.			46	6	35	29
Rhyacophila brunnea/vao	50	6				
Rhyacophila sibirica gr.	40	7	192	209	325	242
Thremmatidae	5	1	17		12	10
DIPTERA	**465**	**73**	**632**	**472**	**1,024**	**711**
Brillia sp.			6			2
Ceratopogoninae			17	12	81	37
Chaetocladius sp.				6		2
Chelifera/Metachela sp.	20	1	52	58	46	52
Diamesa sp.	15	3		6		2
Dicranota sp.			6			2
Eukiefferiella sp.	120	20	145	76	70	97
Heleniella sp.					12	4
Limnophila sp.					12	4
Micropsectra sp.	250	40	354	267	674	432
Oreogeton sp.	5	1		12	23	12
Orthocladius/Cricotopus gr.			6	6		4

DATA: MACROINVERTEBRATE DENSITY
Client: XCEL - CABIN CREEK
Sampled: 9/21/2023
Site: SOUTH CLEAR CREEK, SITE B

TAXA	MMI KICK[1] (#/sq.meter)	EDAS Subsample Output[2]	2 Hess Composite Rep 1	2 Hess Composite Rep 2	2 Hess Composite Rep 3	Composite of Reps
DIPTERA (cont.)						
Pagastia sp.			23		12	12
Parachaetocladius sp.				6	35	14
Parametriocnemus sp.			6		12	6
Parorthocladius sp.	10	2				
Simulium sp.	35	6	17	17		11
Stempellinella sp.					12	4
Tvetenia sp.	10	--		6	35	14
HYDRACARINA	**15**	**3**	**6**		**46**	**18**
Lebertia sp.	5	1	6		23	10
Sperchon sp.	10	2			23	8
TURBELLARIA	**20**	**3**	**46**	**41**	**128**	**72**
Polycelis coronata	20	3	46	41	128	72
NEMATODA	**25**	**4**	**23**	**41**	**46**	**37**
Unid. Nematoda	25	4	23	41	46	37
ANNELIDA						
OLIGOCHAETA	**190**	**31**	**291**	**46**	**278**	**205**
Eiseniella tetraedra				6		2
Enchytraeidae	75	14	93	17	46	52
Nais sp.	115	17	198	23	232	151
TOTAL (#/sq. meter)	1,805	295	2,814	2,001	4,078	2,968
NUMBER OF TAXA	32	31[3]	34	34	35	45
SHANNON-WEAVER (H')	3.96	3.92				3.85
TOTAL EPT TAXA	17	17	18	17	16	19
EPT INDEX (% of Total Taxa)	53	55	53	50	46	42
EPHEMEROPTERA ABUNDANCE (% of Total Density)	17	19	12	13	13	13
CO MMI Score (Policy 10-1 2020)		64.3				

[1]Based on high abundance of organisms; 6/30 of the sample was sorted and identified.

[2]Statistically-derived subsample from Colorado's Ecological Data Application System (EDAS), not reported as #/sq. meter.

[3]Some taxa excluded based on EDAS subsampling requirements determined in EDAS.

DATA: MACROINVERTEBRATE DENSITY
Client: XCEL - CABIN CREEK
Sampled: 9/21/2023
Site: SOUTH CLEAR CREEK, SITE C

TAXA	MMI KICK[1] (#/sq.meter)	EDAS Subsample Output[2]	2 Hess Composite Rep 1	2 Hess Composite Rep 2	2 Hess Composite Rep 3	Composite of Reps
INSECTA						
EPHEMEROPTERA	**74**	**13**	**46**	**93**		**47**
Acentrella sp.	4	1				
Baetis rhodani gr.				17		6
Ephemerellidae	7	--	17			6
Heptageniidae			6			2
Paraleptophlebia sp.	63	12	23	76		33
PLECOPTERA	**137**	**21**	**255**	**343**	**174**	**257**
Capniidae			23		29	17
Isoperla sp.			6	76	29	37
Skwala americana	7	2		17	29	15
Sweltsa sp.	19	4	81			27
Zapada cinctipes	107	15	116	250	29	132
Zapada oregonensis gr.	4	--	29		58	29
COLEOPTERA			**17**	**17**		**11**
Heterlimnius corpulentus			17	17		11
TRICHOPTERA	**4**	**1**	**18**			**6**
Limnephilidae			6			2
Rhyacophila brunnea/vao			6			2
Rhyacophila vagrita			6			2
Rhyacophilidae	4	1				
DIPTERA	**951**	**158**	**1,532**	**3,892**	**3,893**	**3,106**
Ceratopogoninae					29	10
Chelifera/Metachela sp.			6			2
Conchapelopia/Thienemannimyia gr.			23	46		23
Cricotopus trifascia			46			15
Diamesa sp.	59	12	46	192	174	137
Diplocladius sp.	11	2		46		15
Eukiefferiella sp.				192	320	171
Neoplasta sp.					58	19
Orthocladius/Cricotopus gr.	544	84	1,005	1,499	2,353	1,619
Pagastia sp.	26	6	23	639	378	347
Potthastia sp.	11	2	46		58	35
Simulium sp.	215	36	198	1,133	465	599
Synorthocladius sp.	85	16	116	145	58	106
Tvetenia sp.			23			8
NEMATODA			**139**	**29**	**174**	**114**
Unid. Nematoda			139	29	174	114

DATA: MACROINVERTEBRATE DENSITY
Client: XCEL - CABIN CREEK
Sampled: 9/21/2023
Site: SOUTH CLEAR CREEK, SITE C

TAXA	MMI KICK[1] (#/sq.meter)	EDAS Subsample Output[2]	2 Hess Composite Rep 1	2 Hess Composite Rep 2	2 Hess Composite Rep 3	Composite of Reps
ANNELIDA						
OLIGOCHAETA	**507**	**96**	**3,318**	**1,673**	**12,898**	**5,964**
Eiseniella tetraedra	237	42	1,720	1,162	4,590	2,491
Enchytraeidae			732	465	3,515	1,571
Nais sp.	211	42	465		4,532	1,666
Ophidonais serpentina				46		15
Unid. Immature Tubificidae w/o Capilliform Chaetae	59	12	401		261	221
MOLLUSCA						
GASTROPODA			**6**			**2**
Physa sp.			6			2
PELECYPODA	**4**	**1**	**6**		**29**	**12**
Pisidium sp.			6			2
Sphaeriidae	4	1			29	10
TOTAL (#/sq. meter)	1,677	290	5,337	6,047	17,168	9,519
NUMBER OF TAXA	19	17[3]	29	18	20	37
SHANNON-WEAVER (H')	3.08	3.16				3.11
TOTAL EPT TAXA	8	6[3]	11	5	5	13
EPT INDEX (% of Total Taxa)	42	35	38	28	25	35
EPHEMEROPTERA ABUNDANCE (% of Total Density)	4	4	1	2	0	<1
CO MMI Score (Policy 10-1 2020)		24.1				

[1]Based on high abundance of organisms; 8/30 of the sample was sorted and identified.

[2]Statistically-derived subsample from Colorado's Ecological Data Application System (EDAS), not reported as #/sq. meter.

[3]Some taxa excluded based on EDAS subsampling requirements.

DATA: MACROINVERTEBRATE DENSITY
Client: XCEL - CABIN CREEK
Sampled: 9/21/2023
Site: SOUTH CLEAR CREEK, SITE D

TAXA	MMI KICK[1] (#/sq.meter)	EDAS Subsample Output[2]	2 Hess Composite Rep 1	2 Hess Composite Rep 2	2 Hess Composite Rep 3	Composite of Reps
INSECTA						
PLECOPTERA	**306**	**121**	**146**	**187**	**227**	**186**
Capniidae	8	4				
Leuctridae			6	12	6	8
Sweltsa sp.	28	13	41	41		27
Zapada cinctipes	270	104	99	134	215	149
Zapada oregonensis gr.					6	2
COLEOPTERA	**2**	**--**				
Heterlimnius corpulentus	2	--				
TRICHOPTERA	**10**	**5**				
Limnephilidae	8	4				
Rhyacophila sibirica gr.	2	1				
DIPTERA	**203**	**74**	**128**	**101**	**101**	**111**
Brillia sp.	28	9		6		2
Ceratopogoninae	4	1				
Chelifera/Metachela sp.	2	--	6	6	6	6
Conchapelopia/Thienemannimyia gr.			6			2
Diamesa sp.	6	3		6	6	4
Dicranota sp.	23	8	29	12	12	18
Diplocladius sp.	13	6		12	35	16
Eloeophila sp.			6			2
Eukiefferiella sp.	21	8		6	12	6
Micropsectra sp.	8	3			6	2
Neoplasta sp.	9	3				
Orthocladius/Cricotopus gr.	36	15	46	35	6	29
Pagastia sp.	26	12	23	12		12
Parametriocnemus sp.				6		2
Rhabdomastix sp.					6	2
Simulium sp.	17	2	12		6	6
Synorthocladius sp.	6	3				
Tvetenia sp.					6	2
Unid. Diptera	2	--				
Wiedemannia sp.	2	1				
NEMATODA				**6**	**12**	**6**
Unid. Nematoda				6	12	6
ANNELIDA						
OLIGOCHAETA	**228**	**90**	**175**	**87**	**151**	**138**
Eiseniella tetraedra	11	5	99	46	52	66

DATA: MACROINVERTEBRATE DENSITY
Client: XCEL - CABIN CREEK
Sampled: 9/21/2023
Site: SOUTH CLEAR CREEK, SITE D

TAXA	MMI KICK[1] (#/sq.meter)	EDAS Subsample Output[2]	2 Hess Composite Rep 1	2 Hess Composite Rep 2	2 Hess Composite Rep 3	Composite of Reps
Enchytraeidae	98	38	41	29	35	35
Nais sp.	119	47	35	12	46	31
OLIGOCHAETA (cont.)						
Ophidonais serpentina					6	2
Pristina sp.					6	2
Unid. Oligochaeta					6	2
MOLLUSCA						
GASTROPODA				**6**		**2**
Physa sp.				6		2
TOTAL (#/sq. meter)	749	290	449	387	491	443
NUMBER OF TAXA	24	21[3]	13	17	20	27
SHANNON-WEAVER (H')	3.24	3.19				3.43
TOTAL EPT TAXA	5	5	3	3	3	4
EPT INDEX (% of Total Taxa)	21	24	23	18	15	15
EPHEMEROPTERA ABUNDANCE (% of Total Density)	0	0	0	0	0	0
CO MMI Score (Policy 10-1 2020)		38.6				

[1]Based on high abundance of organisms; 16/30 of the sample was sorted and identified.

[2]Statistically-derived subsample from Colorado's Ecological Data Application System (EDAS), not reported as #/sq. meter.

[3]Some taxa excluded based on EDAS subsampling requirements.

Appendix F Summary of Macroinvertebrate Population Parameters for Hess Samples, 2011 and 2013-2023

Table F-1: Macroinvertebrate density (number/m^2) collected during Hess sampling and summary population parameters for sites on South Clear Creek 2011, 2013-2023.

	2011				2013				2014				2015			
	Upstream	Downstream			Upstream	Downstream			Upstream	Downstream			Upstream	Downstream		
	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F
INSECTA																
Collembola (Springtails)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ephemeroptera (Mayflies)	339	4	--	4	134	2	--	27	654	16	8	--	335	4	--	--
Plecoptera (Stoneflies)	332	66	121	244	199	28	70	133	191	262	302	528	338	150	93	252
Coleoptera (Beetles)	285	--	--	2	414	--	--	--	333	10	2	2	153	--	--	--
Trichoptera (Caddisflies)	265	17	27	53	221	8	6	16	190	28	26	33	37	2	4	4
Diptera (True flies)	284	120	49	159	225	92	85	262	360	272	184	389	72	388	171	284
HYDRACARINA (Water mites)	4	--	--	2	4	--	2	--	6	4	2	2	2	--	--	--
TURBELLARIA (Flatworms)	6	--	--	15	8	--	--	10	12	--	--	--	4	2	2	6
NEMATODA (Roundworms)	53	4	--	4	54	2	--	14	21	--	--	2	--	--	--	--
ANNELIDA																
Oligochaeta (Segmented worms)	6	573	1,570	4,562	39	544	628	1,199	26	301	190	537	10	503	148	1,150
MOLLUSCA																
Gastropoda (Snails)	--	--	--	--	--	4	--	--	--	--	--	--	--	--	--	--
Pelecypoda (Clams)	--	--	--	--	--	--	--	--	--	4	--	--	--	--	2	--
Replicate Data Summary																
Mean Density (organisms/m^2)	1,574	784	1,767	5,045	1,298	680	791	1,661	1,793	897	714	1,493	951	1,049	420	1,696
Mean Number of Taxa	30	12	12	19	25	14	12	22	33	19	17	22	25	10	8	10
Mean Number of EPT Taxa	19	5	6	8	11	3	3	9	18	6	6	8	16	3	3	3
Mean Percent Density Ephemeroptera	22	1	0	<1	10	<1	0	2	36	2	1	0	35	<1	0	0
Mean Percent Density Heptageniid Mayflies	6	0	0	0	6	0	0	0	11.5	0	0	0	13.1	0	0	0
Mean Number Metal Intolerant Taxa	7	2	2	2	7	1	1	2	8	2	2	2	9	1	<1	<1
Composite Data Summary																
Total Number of Taxa	42	18	17	28	38	22	21	31	50	26	29	35	34	20	16	18
Total Number of EPT Taxa	23	8	8	10	17	6	6	13	27	9	11	11	19	6	6	6
Total Number of Ephemeroptera Taxa	9	1	0	2	6	1	0	3	12	4	2	0	8	2	0	0
Total Number of Metal Intolerant Taxa	8	2	2	2	8	2	2	3	10	2	2	3	10	2	2	2
Shannon-Weaver Diversity (H')	4.01	2.00	1.26	1.21	3.72	1.82	2.15	2.90	4.15	3.29	3.50	3.34	4.10	2.15	2.12	1.75

	2016				2017				2018				2019			
	Upstrea	Downstream			Upstream	Downstream			Upstream	Downstream			Upstream	Downstream		
	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F
INSECTA																
Collembola (Springtails)	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--
Ephemeroptera (Mayflies)	593	2	6	8	432	--	--	--	482	--	--	33	581	2	--	10
Plecoptera (Stoneflies)	137	401	294	467	248	159	97	180	1,047	115	203	443	472	68	70	243
Coleoptera (Beetles)	596	2	--	--	573	--	--	4	839	2	--	2	1,042	--	--	--
Trichoptera (Caddisflies)	130	16	16	30	172	8	--	38	208	18	58	39	277	18	8	35
Diptera (True flies)	138	688	355	195	554	36	10	114	1,995	249	585	316	802	173	97	363
HYDRACARINA (Water mites)	12	--	4	2	16	--	2	--	23	--	2	8	22	--	--	4
TURBELLARIA (Flatworms)	6	--	--	2	23	2	2	2	41	--	2	--	99	--	--	--
NEMATODA (Roundworms)	8	--	--	2	37	2	--	2	21	2	--	--	17	2	--	6
ANNELIDA																
Oligochaeta (Segmented worms)	105	773	292	1,308	89	392	59	679	307	1,095	534	6,157	30	282	82	480
MOLLUSCA																
Gastropoda (Snails)	--	4	--	--	--	--	--	--	--	4	2	--	--	--	--	--
Pelecypoda (Clams)	--	--	--	2	--	--	--	--	--	--	2	--	--	--	--	--
Replicate Data Summary																
Mean Density (organisms/m^2)	1,725	1,886	967	2,016	2,146	599	170	1,019	4,963	1,485	1,388	6,998	3,342	545	257	1,141
Mean Number of Taxa	31	18	15	20	31	12	6	14	34	18	13	23	39	14	13	24
Mean Number of EPT Taxa	16	4	6	8	14	3	2	4	17	4	4	7	21	4	4	9
Mean Percent Density Ephemeroptera	34	<1	<1	<1	20	0	0	0	10	0	0	<1	17	<1	0	1
Mean Percent Density Heptageniid Mayflies	14	0	<1	0	<1	0	0	0	3.6	0	0	0	6	0	0	0
Mean Number Metal Intolerant Taxa	8	1	2	2	7	2	1	2	6	1	1	2	7	2	1	2
Composite Data Summary																
Total Number of Taxa	46	27	26	33	41	18	10	22	46	26	27	34	51	24	21	37
Total Number of EPT Taxa	21	7	11	13	18	4	2	5	21	5	5	9	24	6	5	13
Total Number of Ephemeroptera Taxa	9	1	3	2	5	0	0	0	7	0	0	1	11	1	0	3
Total Number of Metal Intolerant Taxa	10	2	2	3	8	2	1	2	8	2	2	2	8	2	1	3
Shannon-Weaver Diversity (H')	3.71	3.17	3.07	2.30	4.03	2.30	2.27	2.26	4.28	2.68	3.30	1.16	4.13	3.31	3.51	3.68

	2020				2021				2022				2023			
	Upstream	Downstream			Upstream	Downstream			Upstream	Downstream			Upstream	Downstream		
	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F	Site B	Site D	Site E	Site F
INSECTA																
Collembola (Springtails)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ephemeroptera (Mayflies)	1,110	2	--	--	373	2	2	2	486	4	2	16	371	--	2	8
Plecoptera (Stoneflies)	478	43	80	240	129	293	417	1,271	114	271	104	489	293	186	233	374
Coleoptera (Beetles)	697	--	--	2	507	--	--	2	680	--	2	6	941	--	--	18
Trichoptera (Caddisflies)	476	10	4	12	150	--	18	27	274	20	14	26	320	--	31	35
Diptera (True flies)	1,131	207	91	65	420	344	273	360	1,969	471	144	423	711	111	155	146
HYDRACARINA (Water mites)	46	--	--	--	6	2	2	--	--	--	--	2	18	--	--	--
TURBELLARIA (Flatworms)	64	--	--	--	27	--	--	--	39	--	--	--	72	--	--	2
NEMATODA (Roundworms)	66	--	--	--	14	2	--	8	50	2	--	6	37	6	2	6
ANNELIDA																
Oligochaeta (Segmented worms)	320	531	301	741	85	2,041	342	825	209	677	80	68	205	138	60	75
Aphanoneura (Terrestrial worms)	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--
MOLLUSCA																
Gastropoda (Snails)	--	--	2	--	--	--	--	--	--	--	--	--	--	2	--	--
Pelecypoda (Clams)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Replicate Data Summary																
Mean Density (organisms/m^2)	4,388	793	478	1,060	1,713	2,684	1,054	2,495	3,821	1,445	346	1,036	2,968	443	483	666
Mean Number of Taxa	36	14	12	15	31	19	19	19	31	22	15	23	34	17	14	20
Mean Number of EPT Taxa	20	3	3	5	18	2	5	5	15	5	3	8	17	3	5	7
Mean Percent Density Ephemeroptera	25	<1	0	0	22	<1	<1	<1	19	<1	<1	1	13	0	<1	1
Mean Percent Density Heptageniid Mayflies	11	<1	0	0	6	0	0	0	5	0	0	0	4	0	0	<1
Mean Number Metal Intolerant Taxa	9	1	1	1	8	<1	2	1	7	2	1	2	5	1	1	3
Composite Data Summary																
Total Number of Taxa	49	24	21	24	42	29	27	29	42	33	24	36	45	27	23	34
Total Number of EPT Taxa	28	5	4	7	21	5	8	8	19	9	6	14	19	4	8	11
Total Number of Ephemeroptera Taxa	13	1	0	0	8	1	1	1	7	1	1	4	6	0	1	3
Total Number of Metal Intolerant Taxa	11	3	2	2	9	1	3	2	8	2	1	4	5	1	2	5
Shannon-Weaver Diversity (H')	4.47	2.44	2.96	1.74	3.77	2.29	2.95	2.35	3.64	3.55	3.9	3.18	3.85	3.43	3.23	3.52

Appendix G MMI Scores for Sites on South Clear Creek, 2011 and 2013-2023

Table G-1: MMI scores and metrics for macroinvertebrate populations sampled at sites on South Clear Creek 2011, 2013- 2022. ***Samples were below the recommended abundance range and the resulting MMI scores likely indicate stressed conditions, but not always, so a decision was not reached on whether the site was attaining or impaired.**

Metric	Site B																	
	Pre-Treatment										Post-Treatment							
	2011		2013		2014		2015		2016		2017		2018		2019		2020	
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
Total Taxa	31	73.8	34	81	32	76.2	25	59.5	34	81	30	71.4	29	69	34	81	32	76
Total EPT	20	81.6	15	16.2	19	77.6	15	61.2	18	73.8	15	61.2	13	53.1	19	78	18	74
% EPT no Baetidae	59.3	74.7	34.4	43.4	36.9	46.6	67.1	84.6	29.9	37.7	38.8	48.9	43.3	54.7	50	63	43	54
Clinger Taxa	17	85	12	60	16	80	14	70	17	85	14	70	14	70	18	90	19	95
Intolerant Taxa	20	95.2	16	76.2	16	76.2	14	66.7	18	85.7	12	57.1	15	71.4	18	86	17	81
% Indicator Sensitive Decreaser Taxa	62.6	86.6	54.1	74.9	46.5	64.3	67.6	93.5	49.7	68.7	63.6	88	29.4	40.6	56	77	55	76
Facultative Predator Taxa	12	0	11	0	11	0	11	0	15	0	13	0	8	61.5	10	77	11	85
% Facultative Scraper	18.2	41.2	7.6	17.3	9.5	21.6	21.6	48.9	10.1	22.8	11.2	25.4	31.4	71	24	55	23	52
Final Index Score	**76.9**		**59.4**		**63.9**		**68.2**		**66.4**		**60.5**		**61.4**		**75.7**		**73.9**	
Decision	**Attaining**		**Attaining**		**Attaining**		**Attaining**		**Attaining**		**Attaining**		**Attaining**		**Attaining**		**Attaining**	

Metric	Site B					
	Post-Treatment					
	2021		2022		2023	
	Value	Value	Score	Value	Value	Value
Total Taxa	37	88	31	73.8	31	73.8
Total EPT	18	74	16	65.3	17	69.4
% EPT no Baetidae	45	56	32	40.3	30.2	38
Clinger Taxa	18	90	16	80	16	80
Intolerant Taxa	17	81	18	85.7	15	71.4
% Indicator Sensitive Decreaser Taxa	52	72	72.7	100	51.2	70.8
Facultative Predator Taxa	10	77	9	69.2	11	84.6
% Facultative Scraper	14	32	13.5	30.5	11.5	26.1
Final Index Score	**71.2**		**68.1**		**64.3**	
Decision	**Attaining**		**Attaining**		**Attaining**	

Table G-1 continued.

Metric	Site D																			
	Pre-Treatment								Post-Treatment											
	2011		2013		2014		2015		2016		2017		2018		2019		2020		2021	
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
Total Taxa	9	21.4	12	28.6	16	38.1	14	33.3	17	40.5	11	26.2	14	33.3	15	36	15	38	18	43
Total EPT	4	16.3	2	8.2	4	16.3	6	24.5	4	16.4	4	16.3	3	12.2	3	12	2	8	2	8
% EPT no Baetidae	5.4	6.8	1.1	1.4	11.6	14.7	16.1	20.3	23.6	29.8	8.5	10.7	2.1	2.6	3	3	3	4	11	14
Clinger Taxa	2	10	3	15	3	15	3	15	4	20	2	10	3	15	4	20	3	15	5	25
Intolerant Taxa	4	19	3	14.3	4	19	5	23.8	5	23.8	4	19	3	14.3	3	14	2	10	4	19
% Indicator Sensitive Decreaser Taxa	5.4	7.4	1.1	1.5	12	16.7	15.8	21.8	22.5	31.2	6.7	9.3	1.2	1.6	3	4	2	3	13	18
Facultative Predator Taxa	4	0	3	0	4	0	6	0	8	0	5	0	2	15.4	3	23	3	23	3	23
% Facultative Scraper	0	0	0	0	1.2	2.7	2.5	5.7	1.5	3.3	1.4	3.2	0.6	1.3	4	9	3	6	8	17
Final Index Score	**13**		**10.5**		**17.2**		**22.9**		**25.4**		**14.7**		**12**		**15.1**		**13**		**21.0**	
Decision	**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**	

Metric	Site D			
	Post-Treatment			
	2022		2023	
	Value	Value	Value	Value
Total Taxa	25	59.5	21	50
Total EPT	6	24.5	5	20.4
% EPT no Baetidae	30	37.8	43.4	54.8
Clinger Taxa	5	25	5	25
Intolerant Taxa	7	33.3	7	33.3
% Indicator Sensitive Decreaser Taxa	31	42.9	43.4	60.1
Facultative Predator Taxa	8	61.5	7	53.8
% Facultative Scraper	4.3	9.8	5.2	11.7
Final Index Score	**36.8**		**38.6**	
Decision	**Impaired**		**Impaired**	

Table G-1 continued.

Metric	Site E																			
	Pre-Treatment								Post-Treatment											
	2011		2013		2014		2015		2016		2017		2018		2019		2020		2021	
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
Total Taxa	4	9.5	11	26.2	18	42.9	11	26.2	19	45.2	9	21.4	14	33.3	21	50	14	33	19	45
Total EPT	2	8.2	1	4.1	8	32.7	4	16.3	6	24.6	3	12.2	6	24.5	3	12	2	8	4	16
% EPT no Baetidae	3.2	4.1	1	1.2	50.5	63.7	21.8	27.5	36.9	46.5	21.1	26.5	17.9	22.6	2	2	30	38	36	45
Clinger Taxa	2	10	1	5	6	30	3	15	7	35	4	20	5	25	6	30	3	15	5	25
Intolerant Taxa	2	9.5	2	9.5	8	38.1	5	23.8	7	33.3	3	14.3	7	33.3	4	19	3	14	5	24
% Indicator Sensitive Decreaser Taxa	3.2	4.5	1	1.4	45.5	62.9	21.8	30.2	35.9	49.7	21.1	29.1	15.4	21.3	1	2	30	42	37	51
Facultative Predator Taxa	2	0	4	0	6	0	4	0	6	0	5	0	4	30.8	2	15	2	16	4	31
% Facultative Scraper	0	0	0	0	9.1	20.6	0.7	1.6	2.3	5.3	0	0	2.6	5.8	10	22	0	0	6	13
Final Index Score	**5.7***		**8.8**		**41.1***		**19.5***		**31.9**		**16.4***		**24.6***		**19.1**		**20.7**		**31.2**	
Gray Zone	--		--		**Yes**		--		--		--		--		--		--		--	
Auxiliary Thresholds (HBI < 4.9, H' > 3.2)	--		--		**Failed**		--		--		--		--		--		--		--	
Decision	**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**	

Metric	Site E			
	Post-Treatment			
	2022		2023	
	Value	Score	Value	Score
Total Taxa	27	64.3	19	45.2
Total EPT	8	32.7	3	12.2
% EPT no Baetidae	32.5	41	60.4	76.2
Clinger Taxa	4	20	3	15
Intolerant Taxa	8	38.1	5	23.8
% Indicator Sensitive Decreaser Taxa	33.7	46.7	61.5	85
Facultative Predator Taxa	6	46.2	4	30.8
% Facultative Scraper	0.4	0.9	3.1	7.1
Final Index Score	**36.2**		**36.9***	
Decision	**Impaired**		**Impaired**	

Table G-1 continued.

Metric	Site F																			
	Pre-Treatment								Post-Treatment											
	2011		2013		2014		2015		2016		2017		2018		2019		2020		2021	
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
Total Taxa	11	26.2	16	38.1	21	50	19	45.2	19	45.2	14	33.3	17	40.5	24	57	19	45	15	36
Total EPT	4	16.3	4	16.3	9	36.7	7	28.6	7	28.7	4	16.3	6	24.5	9	37	5	20	5	20
% EPT no Baetidae	9.8	12.3	1.7	2.2	38.6	48.6	52.6	66.3	51.6	65.1	32.2	40.6	6.5	8.2	26	33	17	21	73	92
Clinger Taxa	2	10	4	20	7	35	4	20	7	35	5	25	3	15	7	35	5	25	6	30
Intolerant Taxa	5	23.8	5	23.8	8	38.1	7	33.3	7	33.3	5	23.8	6	28.6	9	43	5	24	5	24
% Indicator Sensitive Decreaser Taxa	9.8	13.5	1.4	1.9	38.2	52.8	52.6	72.7	50.2	69.4	32.2	44.5	5.8	8	24	33	16	22	72	99
Facultative Predator Taxa	6	0	6	0	9	0	8	0	9	0	7	0	7	53.8	6	46	5	39	1	8
% Facultative Scraper	0	0	0.3	0.8	4.1	9.3	1.4	3.1	2.1	4.8	0.3	0.8	0.7	1.5	1	3	1	2	4	8
Final Index Score	**17.6**		**17.7**		**39.6**		**38.5**		**40**		**25.9**		**22.5**		**35.9**		**24.7**		**39.5**	
Gray Zone	--		--		--		--		**Yes**		--		--		--		--		--	
Auxiliary Thresholds (HBI < 4.9, H' > 3.2)	--		--		--		--		**Failed**		--		--		--		--		--	
Decision	**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**		**Impaired**	

Metric	Site F			
	Post-Treatment			
	2022		2023	
	Value	Score	Value	Score
Total Taxa	30	71.4	32	76.2
Total EPT	13	53.1	12	49
% EPT no Baetidae	64.7	81.5	52.9	66.8
Clinger Taxa	12	60	10	50
Intolerant Taxa	12	57.1	16	76.2
% Indicator Sensitive Decreaser Taxa	68.2	94.3	61.2	84.7
Facultative Predator Taxa	7	53.8	12	92.3
% Facultative Scraper	3.9	8.8	5.2	11.7
Final Index Score	**60**		**63.4**	
Decision	**Attaining**		**Attaining**	

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