SILVER CREEK STREAM SAMPLE RESULT SUMMARY: WY 2014 to 2021

A report to:

NEW Water

By:

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Introduction

The Silver Creek watershed has a drainage area of approximately 19.4 km^2. It is located within the Duck Creek watershed (392 km^2), which is a part of the Lower Fox River sub-basin in northeastern Wisconsin. This report provides a brief summary of the analytical results from water samples collected from a stream monitoring network within the Silver Creek watershed.

Water samples were collected from seven stream locations: SL-172; SL-COU; SL-CKR; SL-FCR, SL-ADR, SL-OVR and Silver Creek at Florist Drive, where the continuous stage USGS station with automated sampling equipment is located (USGS # 04072076). Samples from these seven locations were collected at fixed intervals by NEW Water. Additional samples from the USGS station were collected by the USGS and UW-Green Bay during low flow conditions; plus, event samples were automatically collected at the station and later collected and processed by UW-Green Bay. *NEW Water did not begin water sampling at SL-ADR and SL-OVR until WY2016; whereas samples were collected from the other sites starting in WY2014.* All samples were analyzed at the NEW Water laboratory. Data from the USGS station is referred to in this summary report as Silver, even though the fixed interval samples collected from this site were originally labeled as SL-FLD when collected by NEW Water or as grab samples by the USGS or UW-Green Bay.

SL – 172: at the stream crossing on the south side of Hwy 172

SL – FLD (i.e. Silver): USGS gauging station north of stream crossing with Florist Drive Rd

SL – COU: at the stream crossing on the south side of County Hwy U

SL – CKR: at the stream crossing on the south side of Crook Rd

SL – FCR: at the stream crossing on the south side of Fish Creek Rd

SL – ADR: at small tributary crossing with Adams Rd (wetland study)

SL – OVR: at small tributary crossing of Overland Rd (wetland study)

A brief summary of water monitoring results from samples collected to the end of September 2021 is provided in this report. Excluding QA/QC and tile outlet samples, a total of about 1,766 water samples were analyzed for total suspended solids (TSS), 1,770 for total phosphorus (TP), and 1,122 for dissolved total phosphorus (DP).

Problems with sampling and flow measurement data were rare, and much less frequent in Water Years 2015 to 2021 than in WY2014. Stage readings from the bubbler equipment were improved when a nitrogen bubbler system was installed. In addition, power outages which affected automatic sampling due to high current draws from the former solar-powered battery system were no longer a problem after grid power was installed.

Results

Potential outliers --- first cut: As was done in previous years, four samples from the USGS Silver Creek station which were collected from 4/13 to 4/14/2014 were not included in the analysis because they appeared to be potential outliers which were not likely to have been representative of the stream water (SL-3159, 3160, 3161, 3162).

Excluding the small tributary SL-ADR and SL-OVR wetland study sites, samples collected at the SL-CKR site had TP and DP concentrations that were significantly higher ($p < 0.05$) than all of the other sites even though the samples were collected the same day as the other sites, which was mostly during base flow or non-event conditions (Figure 2 and 3). The fairly high TP and DP concentrations relative to low TSS concentrations may have been due to ponded stagnant water during summer months at that site, high concentration of phosphorus in sediment or debris, fish re-suspending fine sediment rich in phosphorus at the site, or a nearby high phosphorus discharge from a concentrated runoff or pipe source (for example: a tile line, drainage from a barnyard or milking parlor, or drainage through manure laden soil).

Preliminary summary analysis: Preliminary analysis of the results are presented in the following tables and box plot figures. The summary statistics and figures were generated with the SAS 9.4 statistical software program. Sample concentrations that were below the limit of detection (LOD) were assumed to be at the LOD in the box plots and summary statistics. Samples SL-3159, 3160, 3161 and 3162 were excluded from this analysis for the reasons previously stated in the 2014 data report. The TP concentration (0.98 mg/L) associated with sample SL-3155 was included in this preliminary analysis; however, this concentration was very high relative to the fairly low TSS (11 mg/L) and DP concentrations (0.031 mg/L). Sample SL-3158 also had a very high TP concentration (0.807 mg/L) and low TSS concentration (12 mg/L), whereas the two samples collected between these event samples had TP and DP concentrations of less than 0.1 mg/L. Therefore, it is recommended that the TP and DP concentrations from these samples be considered outliers and excluded from a more formal analysis. Some of the DP concentrations were higher than the TP concentrations. No correction for this issue has been made with the presented results; however, a potentially acceptable way of fixing this discrepancy is to switch the DP and TP concentrations where the differences are not overly large.

Summary statistics for all samples (event, fixed interval and low flow) collected at the Silver Creek USGS monitoring station in Water Years 2014 to 2021, and combined years, are listed in Table 1. Box plots comparing TSS, TP and DP concentrations at Baird (USGS #040851325) and Plum (USGS #04084911) creeks to those at Silver Creek are also provided for low flow conditions (Figures 4 to 6), and under event and low flow conditions combined (Figures 7 and 8, TSS and TP respectively). Under low flow conditions in WY2014 to WY2021 the median TP concentrations were 0.121 mg/L at Silver (n=342), 0.29 mg/L at Plum (n=161) and 0.15 mg/L at Baird (n=73); the median DP concentrations were 0.084 mg/L at Silver (n=300), 0.22 mg/L at Plum (n=110) and 0.13 mg/L at Baird (n=53); and the median TSS concentrations were 5.7 mg/L at Silver (n=342), 18 mg/L at Plum (n=162) and 4.7 mg/L at Baird (n=72) (Figures 4 to 6).

A first cut ANOVA statistical analysis of mean natural log transformed concentrations of TSS, TP and DP from low flow and fixed interval samples collected from Baird, Plum and Silver creeks was performed to determine if there were any differences during the WY2014 to WY2021 monitored period. The Tukey multiple comparison test was applied to test for differences between the three streams. Silver Creek mean natural log TSS concentrations were significantly lower than Plum Creek ($p < 0.05$), but significantly higher than those from Baird Creek. Silver Creek mean natural log TP and DP concentrations were significantly lower than Baird Creek, which were significantly lower than Plum Creek ($p < 0.05$). Similar results were found with the Wilcoxon non-parametric test.

Table 1. Summary statistics for all event, low flow and fixed interval samples collected at the Silver Creek USGS monitoring station in Water Years 2014 to 2021 and combined. Some potential outliers were excluded from this analysis.

Site	Parameter	N	Median (mg/L)	Mean (mg/L)	Std Dev (mg/L)	Min. (mg/L)	Max. (mg/L)	Lower 95% CL for Mean (mg/L)	Upper 95% CL for Mean (mg/L)
2014	**TSS**	97	7.90	20.747	33.093	2.0	172	14.077	27.42
	Total_P	97	0.130	0.252	0.659	0.026	6.379	0.119	0.384
	Diss_P	27	0.058	0.074	0.051	0.026	0.192	0.054	0.094
2015	**TSS**	111	6.75	25.224	71.320	1.0	576	11.809	38.64
	Total_P	112	0.159	0.225	0.195	0.038	1.131	0.188	0.261
	Diss_P	48	0.082	0.102	0.074	0.031	0.365	0.081	0.124
2016	**TSS**	155	7.10	30.423	74.141	1.0	500	18.659	42.19
	Total_P	156	0.124	0.166	0.156	0.030	1.00	0.141	0.190
	Diss_P	63	0.059	0.085	0.093	0.030	0.707	0.062	0.109
2017	**TSS**	132	6.03	19.374	33.940	1.0	192	13.530	25.22
	Total_P	132	0.188	0.222	0.147	0.030	0.644	0.196	0.247
	Diss_P	56	0.105	0.135	0.113	0.028	0.564	0.105	0.165
2018	**TSS**	126	10.0	15.782	17.218	2.0	128	12.746	18.82
	Total_P	126	0.210	0.316	0.276	0.028	1.440	0.267	0.364
	Diss_P	54	0.120	0.181	0.171	0.028	0.969	0.135	0.228
2019	**TSS**	211	13.7	32.488	43.913	1.0	288	26.528	38.45
	Total_P	210	0.267	0.289	0.151	0.055	0.778	0.268	0.309
	Diss_P	66	0.145	0.169	0.087	0.039	0.353	0.147	0.190
2020	**TSS**	114	29.5	73.184	168.43	2.89	1280	41.931	104.4
	Total_P	114	0.216	0.253	0.168	0.061	1.374	0.221	0.284
	Diss_P	40	0.117	0.129	0.084	0.023	0.413	0.102	0.156
2021	**TSS**	109	68.0	177.70	422.68	2.86	3680	97.460	257.96
	Total_P	109	0.255	0.353	0.687	0.039	6.53	0.223	0.484
	Diss_P	55	0.083	0.112	0.084	0.024	0.309	0.089	0.135
Combined	**TSS**	1055	11.5	46.106	159.98	1.0	3680	36.442	55.771
	Total_P	1056	0.191	0.258	0.343	0.026	6.53	0.237	0.279
	Diss_P	409	0.098	0.127	0.108	0.023	0.969	0.117	0.138

The median TSS concentrations during low flow or fixed interval conditions for samples collected during the WY2014 to WY2021 period were 5.7 mg/L at Silver, 6.0 mg/L at SL-172, 3.7 mg/L at SL-CKR, 4.7 mg/L at SL-COU and 4.8 mg/L at SL-FCR (Table 2, Figure 1). The median TP concentrations during low flow or fixed interval conditions were 0.12 mg/L at Silver, 0.14 mg/L at SL-172, 0.36 mg/L at SL-CKR, 0.12 mg/L at SL-COU and 0.14 mg/L at SL-FCR (Table 2, Figure 2). The median DP during low flow or fixed interval conditions were 0.08 mg/L at Silver, 0.10 mg/L at SL-172, 0.24 mg/L at SL-CKR, 0.09 mg/L at SL-COU and 0.08 mg/L at SL-FCR (Table 2, Figure 3). Data presented in the figures are for all eight USGS water years. Note that the averages displayed as diamonds and listed in the figures are means, and not medians.

A first cut ANOVA statistical analysis of mean natural log transformed concentrations of TSS, TP and DP from low flow and fixed interval samples collected from all of the Silver creek sites was performed to determine if there were any differences between sites during the WY2014 to WY2021 monitored period. The Tukey multiple comparison test was applied to test for specific differences between the streams. *The SL-ADR and SL-OVR sites were excluded from this analysis because data collection started in WY2016, so the number of samples was much less and the period of analysis was not the same; plus, these samples were from much smaller tributaries.* Mean natural log TP and DP concentrations were determined to be significantly higher at the SL-CKR site ($p < 0.05$); however, TSS was not significantly higher than the other sites. Instead, mean natural log TSS concentration at SL-CKR was significantly lower than at SL-172, SL-FCR and Silver ($p < 0.05$).

Table 2. Summary statistics for fixed interval samples collected at Silver Creek monitoring stations, including additional low flow samples at USGS station: WY2014 to WY2021.

Site	Parameter	N	Median (mg/L)	Mean (mg/L)	Std Dev (mg/L)	Min. (mg/L)	Max. (mg/L)	Lower 95% CL for Mean (mg/L)	Upper 95% CL for Mean (mg/L)
Silver USGS station	TSS	342	5.65	12.841	20.940	1.0	147	10.614	15.069
	Total_P	342	0.121	0.144	0.112	0.026	0.955	0.132	0.156
	Diss_P	300	0.084	0.102	0.072	0.023	0.424	0.094	0.110
SL-172	TSS	149	6.00	8.572	11.026	1.0	98.2	6.787	10.357
	Total_P	150	0.137	0.157	0.108	0.028	0.787	0.139	0.174
	Diss_P	149	0.098	0.116	0.083	0.028	0.520	0.103	0.130
SL-CKR	TSS	147	3.70	8.303	21.835	1.0	225	4.744	11.862
	Total_P	148	0.360	0.438	0.399	0.030	2.456	0.373	0.503
	Diss_P	148	0.243	0.304	0.278	0.030	1.386	0.259	0.349
SL-COU	TSS	182	4.65	10.478	26.433	1.0	322	6.612	14.344
	Total_P	183	0.121	0.153	0.134	0.028	0.868	0.133	0.172
	Diss_P	183	0.088	0.114	0.100	0.028	0.655	0.099	0.128
SL-FCR	TSS	101	4.80	14.907	48.871	1.0	453	5.259	24.554
	Total_P	101	0.137	0.185	0.168	0.030	1.147	0.152	0.218
	Diss_P	101	0.079	0.123	0.120	0.028	0.783	0.099	0.146
SL-ADR	**TSS**	66	3.15	6.195	6.860	1.0	33.3	4.509	7.881
	Total_P	66	0.296	0.366	0.285	0.063	1.494	0.296	0.436
	Diss_P	66	0.260	0.292	0.219	0.030	1.084	0.238	0.346
SL-OVR	**TSS**	66	2.69	9.310	39.440	1.0	323	-0.386	19.005
	Total_P	66	0.168	0.189	0.132	0.030	0.650	0.156	0.221
	Diss_P	66	0.076	0.108	0.082	0.028	0.393	0.088	0.128

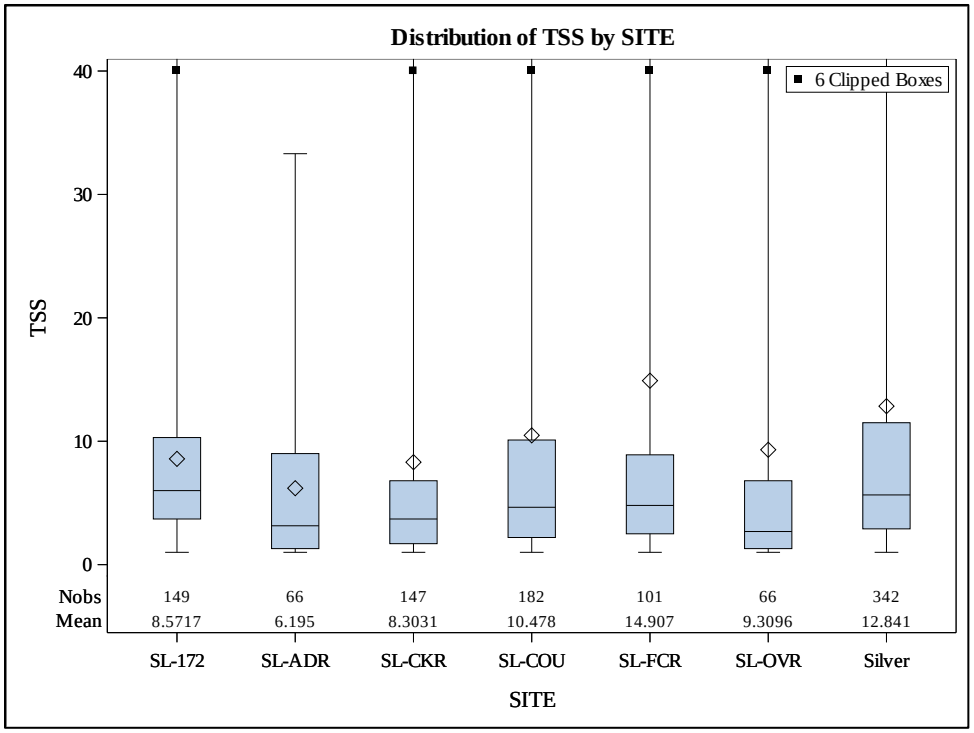

Figure 1. Box plots of TSS concentrations (mg/L) from Silver Creek sites during low flow and fixed interval conditions in WY2014 to WY2021.

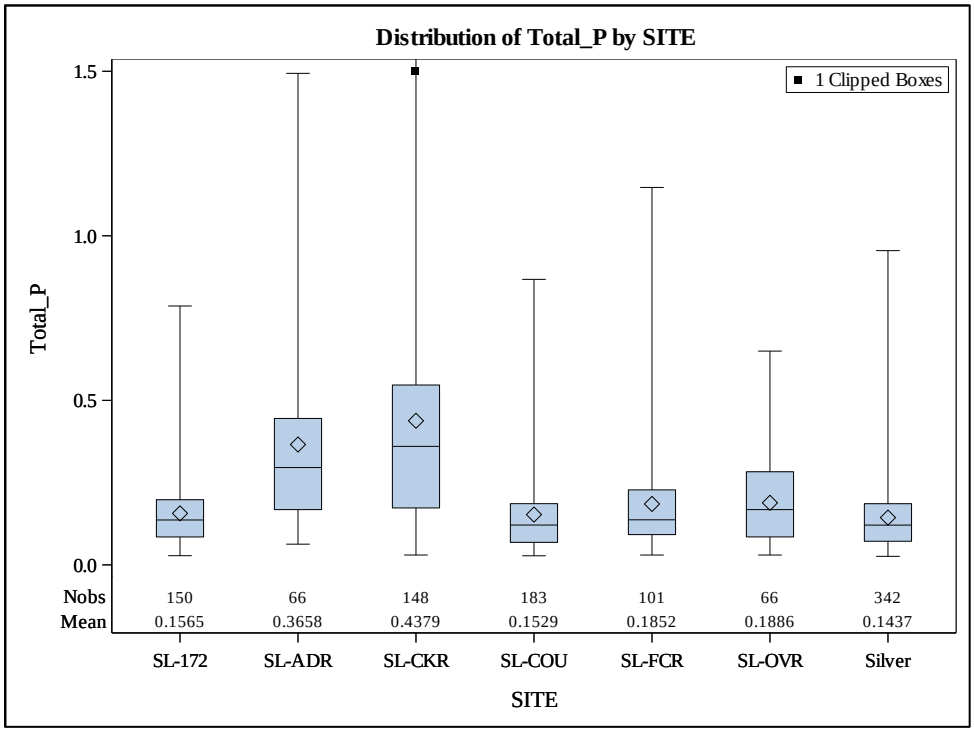

Figure 2. Box plots of total phosphorus concentrations (mg/L) from Silver Creek sites during low flow and fixed interval conditions in WY2014 to WY2021.

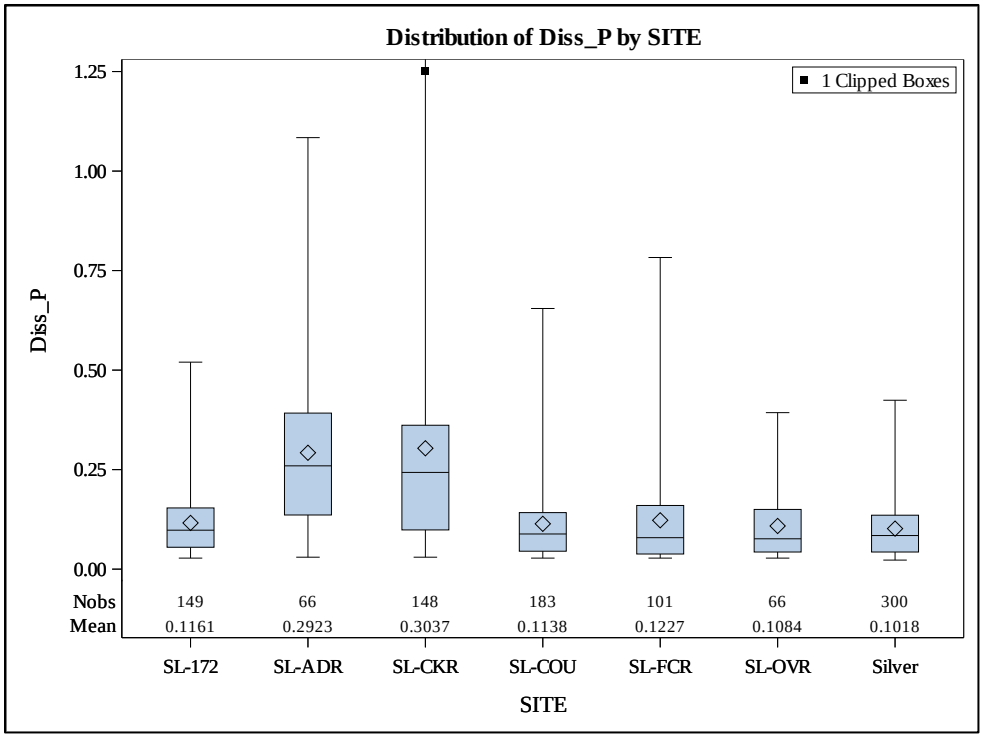

Figure 3. Box plots of total dissolved phosphorus concentrations (mg/L) from Silver Creek sites during low flow and fixed interval conditions in WY2014 to WY2021.

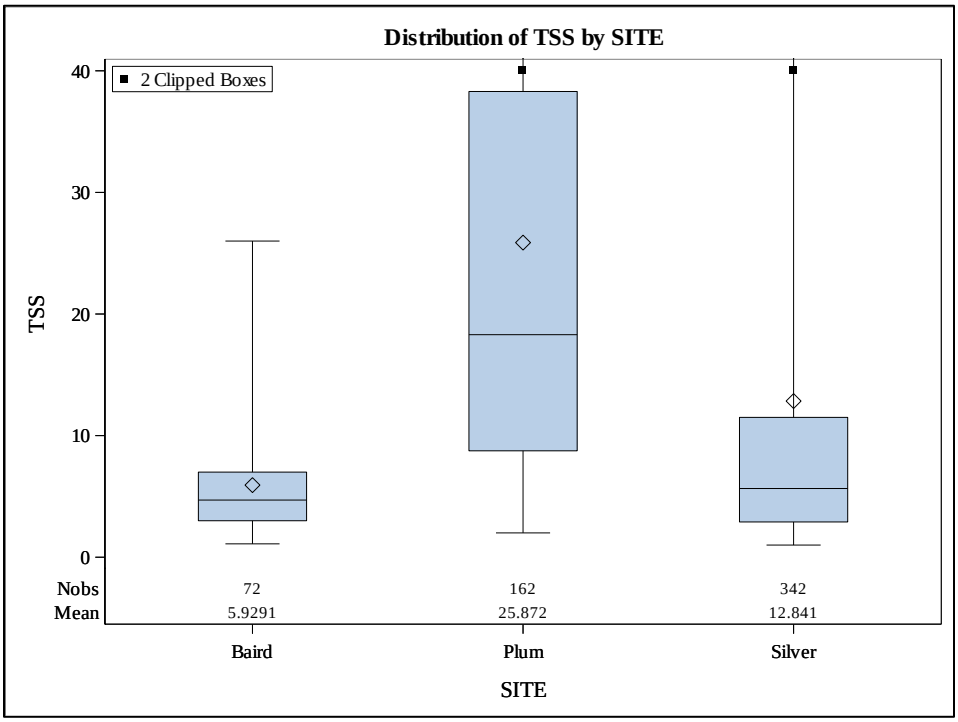

Figure 4. Box plots of TSS concentrations (mg/L) from Baird, Plum and Silver creek USGS stations during low flow conditions in WY2014 to WY2021.

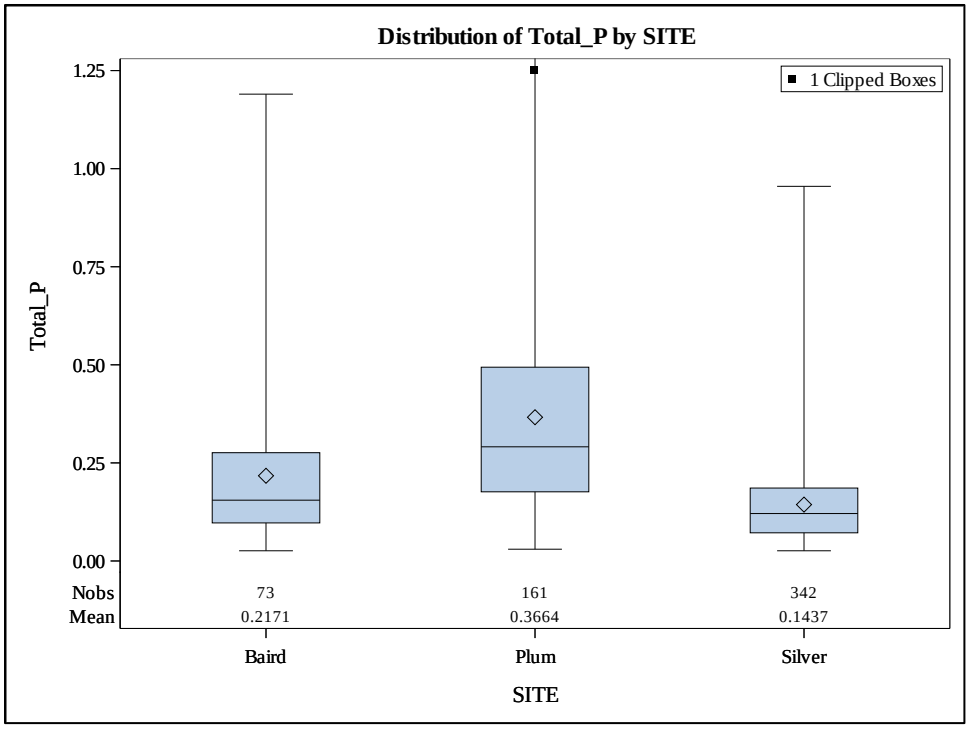

Figure 5. Box plots of total phosphorus concentrations (mg/L) from Baird, Plum and Silver creek USGS stations during low flow conditions in WY2014 to WY2021.

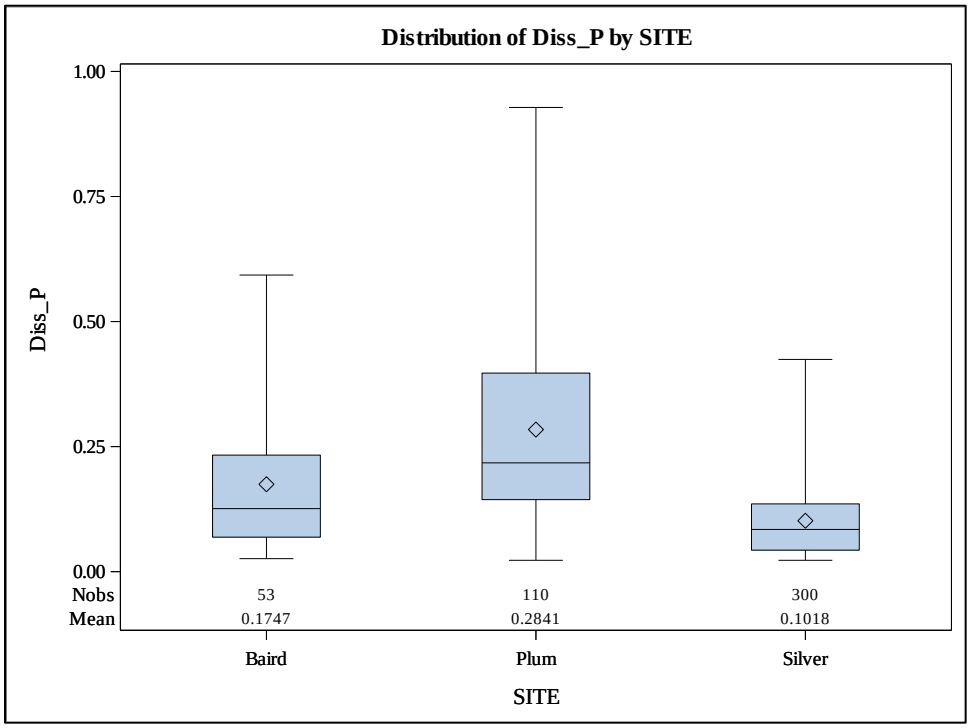

Figure 6. Box plots of total dissolved phosphorus concentrations (mg/L) from Baird, Plum and Silver creek USGS stations during low flow conditions in WY2014 to WY2021.

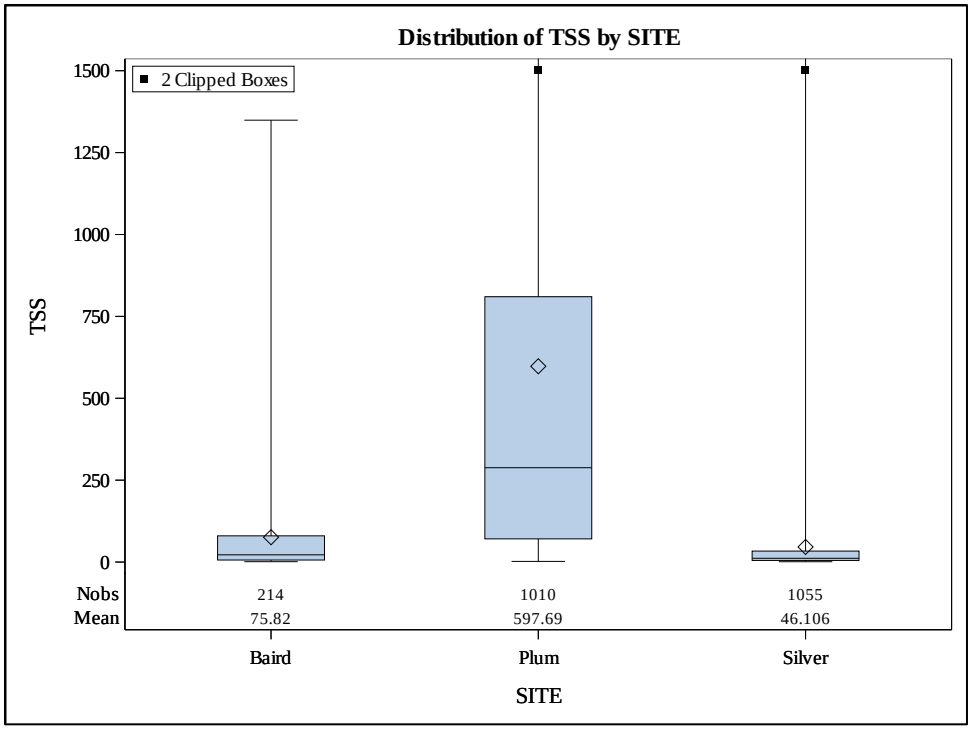

Figure 7. Box plots of TSS concentrations (mg/L) from Baird, Plum and Silver creek USGS stations during event and low flow conditions in WY2014 to WY2021.

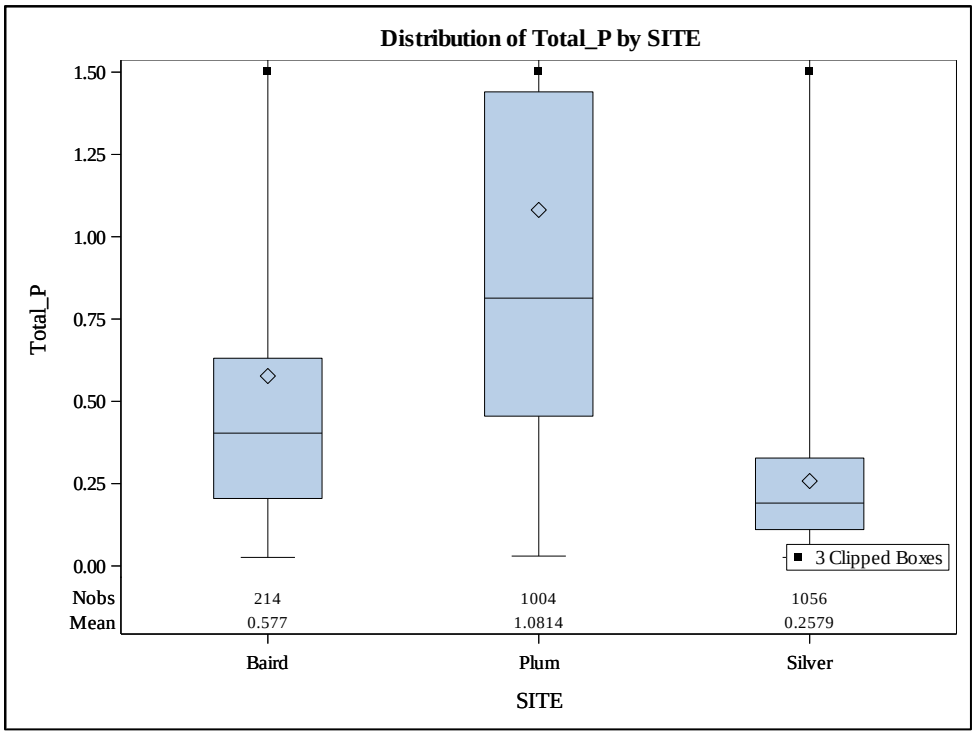

Figure 8. Box plots of total phosphorus concentrations (mg/L) from Baird, Plum and Silver creek USGS stations during event and low flow conditions in WY2014 to WY2021.

Preliminary trend analysis at Silver Creek Florist Drive station: Box plots of TSS, TP and DP concentrations by water year were created to assess whether there were temporal trends in fixed interval and low flow water samples collected from the USGS Silver Creek monitoring station located at Florist Drive (Figures 9 to 11). For TSS concentrations, a slight downward trend may have occurred prior to WY2016, followed by an upward trend which markedly increased from WY2019 to WY2021 (Figure 9). An increasing trend in TP and DP concentrations is also apparent in Figures 10 and 11; however, it is followed by a decrease in WY2020 and WY2021. In addition, a preliminary regression analysis was conducted to determine if there was a temporal trend in the natural log of TSS, TP and DP concentrations in samples collected during fixed interval and low flow conditions at the USGS Silver Creek monitoring site over the WY2014 to WY2021 period. At this time, only seasonal (sine and cosine functions) and date-time components were used in this first cut trend analysis. The results of the regression analysis are summarized in Table 3. There was an upward trend in the natural log of TSS concentrations over time (DEC-TIME coefficient was positive), and it was statistically significant ($p < 0.0001$). This finding is consistent with a Wilcoxon non-parametric test of TSS concentrations by water year ($p < 0.0001$), and the distribution of Wilcoxon test scores for TSS by water year shown in Figure 14. However, a major dip was seen in 2016.

Table 3. Regression model estimates, standard errors, and P-values of coefficients in the Silver Creek log-transformed TSS, total phosphorus (LN_TP) and dissolved phosphorus (LN_DP) regression models for USGS water years 2014-21: low flow and fixed-interval samples only.

		Intercept (a0)	SIN_DAY (a1)	COS_DAY (a2)	DEC_TIME (a3)‡	N
LN_TSS	**Coefficient (a0 to a3)**	1.68349	-0.22547	-0.53313	0.22345	342
	t-value	33.27	-3.61	-7.00	10.65	
	std error	0.05060	0.06244	0.07617	0.02099	
	VIF§	0	1.01788	1.03820	1.02020	
	P value	<0.0001	0.0004	<0.0001	***<0.0001***	
	Overall model: F value = 64.7 adjusted R-sq. = 0.36 $p < 0.0001$					
LN_TP	**Coefficient (a0 to a3)**	-2.34181	-0.34680	-0.47072	0.08551	342
	t-value	-70.51	-8.48	-9.38	6.20	
	std error	0.03321	0.04090	0.05018	0.01379	
	VIF§	0	1.01792	1.03791	1.01996	
	P value	<0.0001	<0.0001	<0.0001	***<0.0001***	
	Overall model: F value = 66.2 adjusted R-sq. = 0.36 $p < 0.0001$					
LN_DP	**Coefficient (a0 to a3)**	-2.66907	-0.36352	-0.46767	0.05035	300
	t-value	-75.13	-8.12	-8.71	3.35	
	std error	0.03553	0.04476	0.05370	0.01504	
	VIF	0	1.02126	1.04513	1.02410	
	P value	<0.0001	<0.0001	<0.0001	***<0.0009***	
	Overall model: F value = 48.3 adjusted R-sq. = 0.32 $p < 0.0001$					

‡ DEC_TIME was centered by subtracting 2017.75 from the actual DEC_TIME (date)
§ VIF = variance inflation factor

As summarized in Table 3, the natural log of total and dissolved phosphorus concentrations both appear to have increased in the regression analysis, as the DEC-TIME coefficients were both positive and highly significant ($p < 0.001$). However, the seasonally-adjusted residuals of log-transformed total and dissolved phosphorus concentrations only show an upward trend until WY2019, after which they seem to decrease in WY2020 and WY2021 (Figures 12 and 13). Therefore, the perceived phosphorus trends are not valid over the whole project period because they are non-linear; that is, they both increase and decrease over the project period, with the peak in WY2019. Residuals, or model error, essentially remove the effect of seasonality on log-transformed TP and DP concentrations. Therefore, the residuals plotted in Figures 12 and 13 express the variation in log-transformed TP and DP over time, over and above the variation due to seasonality. If there were no change in phosphorus concentrations over time, the residuals of the seasonally-adjusted phosphorus regression models would show no apparent trend over time because the residuals would be evenly distributed along the zero axis. Again, the perceived increasing trend in log-transformed total and dissolved phosphorus concentrations listed in Table 3 are not valid for the project period. Therefore, time is not an important explanatory variable to include in the phosphorus regression models over the WY2014 to WY2021 timeframe. The rising and falling patterns in phosphorus concentrations shown in Figures 12 and 13 are consistent with the Wilcoxon non-parametric test scores of TP and DP concentrations by water year (not log transformed, Figures 15 and 16).

The increasing portion of the phosphorus trend may be due to many factors, including more frequent and higher than normal runoff events after WY2016, which may have contributed to higher phosphorus concentrations during low flow conditions due to residual sediment deposits. When runoff events are frequent, there is less time between events for the sediment to be resuspended and transported out of the system. This situation is particularly true during summer, when major runoff events are not normally expected. Notably, there seems to be a decrease in WY2020 and WY2021 low-flow and fixed interval TP and DP concentrations with all three methods of analysis: log transformed boxplots shown in Figures 10 and 11, seasonally adjusted log-transformed phosphorus regression plots shown in Figures 12 and 13, and Wilcoxon score boxplots shown in Figures 15 and 16, respectively. This apparent decrease may be due to a return to near-normal flow conditions in WY2020 and WY2021. The increase in TSS concentrations after WY2019 (Figures 9 and 14) may be due to a re-meandering project conducted in 2020, as well as discharge from a ditch or gully opposite of the Silver Creek station house that enlarged during recent years. Summary statistics for TSS concentrations from event and low flow samples in WY2020 and WY2021 are also much higher than prior years (Table1).

Little difference was observed when the 2014 to 2018 trend results were double-checked by using the standard phosphorus method analytical results instead of the low level phosphorus analytical results (both analytical methods were only performed in WY2018). Only provisional flow data were available for WY2021, so water discharge was not included as an explanatory variable in the regression models, even though doing so might improve the ability to more accurately detect a trend, and permit the trend analysis to be extended to include samples collected during runoff events. Although the trend analysis did not specifically include event samples, it is possible that the fixed interval samples from more recent years had higher flows than in previous years, which could affect the results presented here as flow was not factored into the regression model. The whole data set has not been fully analyzed yet, nor has this analysis been reviewed by others, so caution should be used when interpreting results presented in this report.

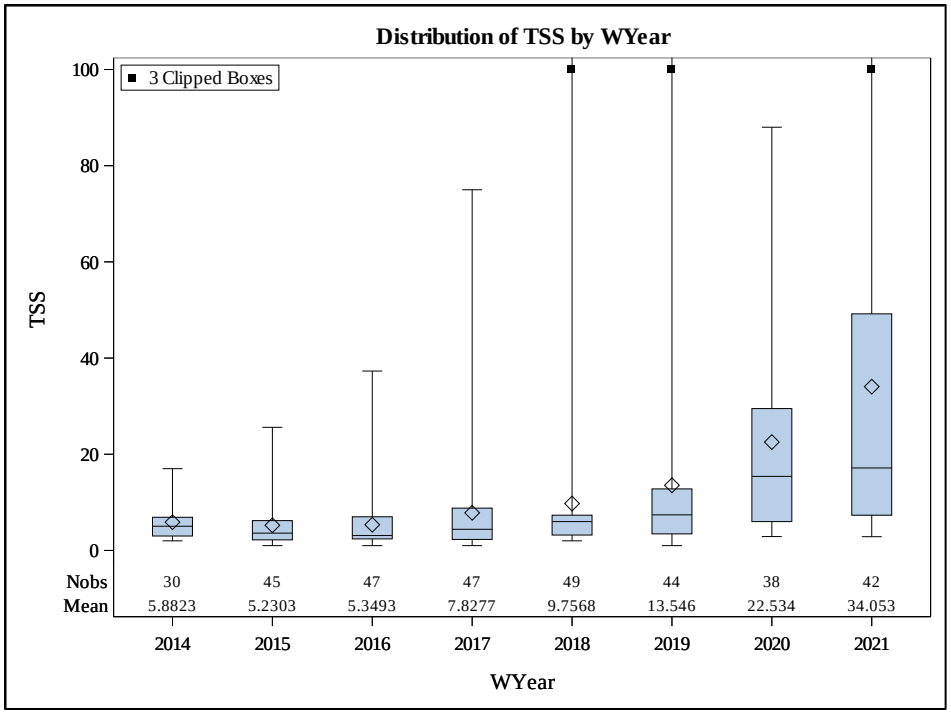

Figure 9. Box plots of annual TSS concentrations (mg/L) from the USGS Silver Creek Florist Drive site during low flow and fixed interval conditions from WY2014 to WY2021.

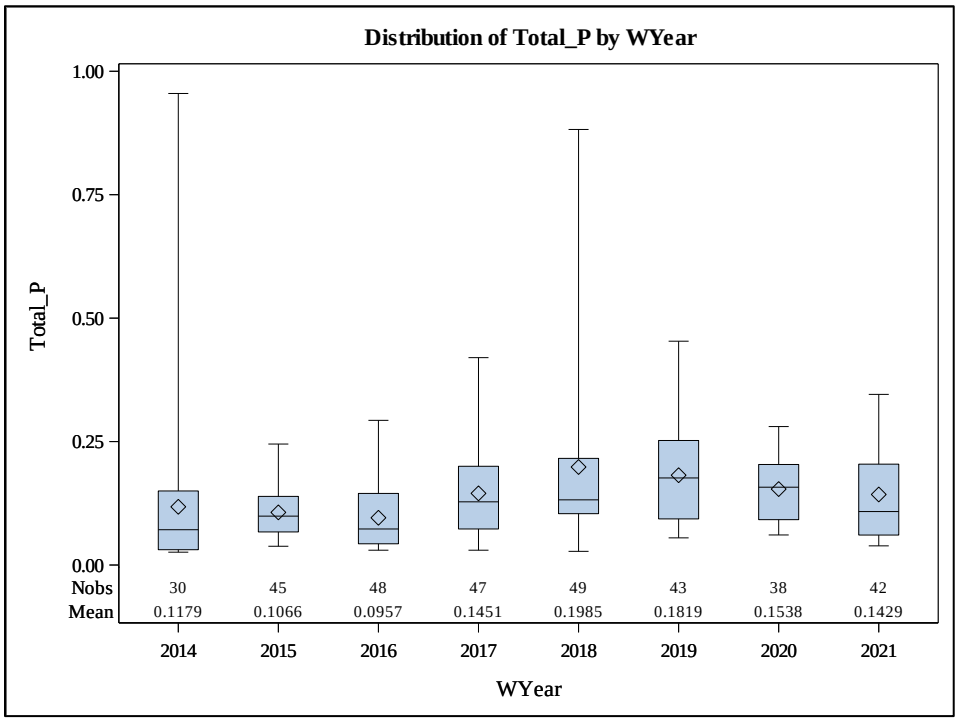

Figure 10. Box plots of annual total phosphorus concentrations (mg/L) from USGS Silver Creek Florist Drive site during low flow and fixed interval conditions from WY2014 to WY2021.

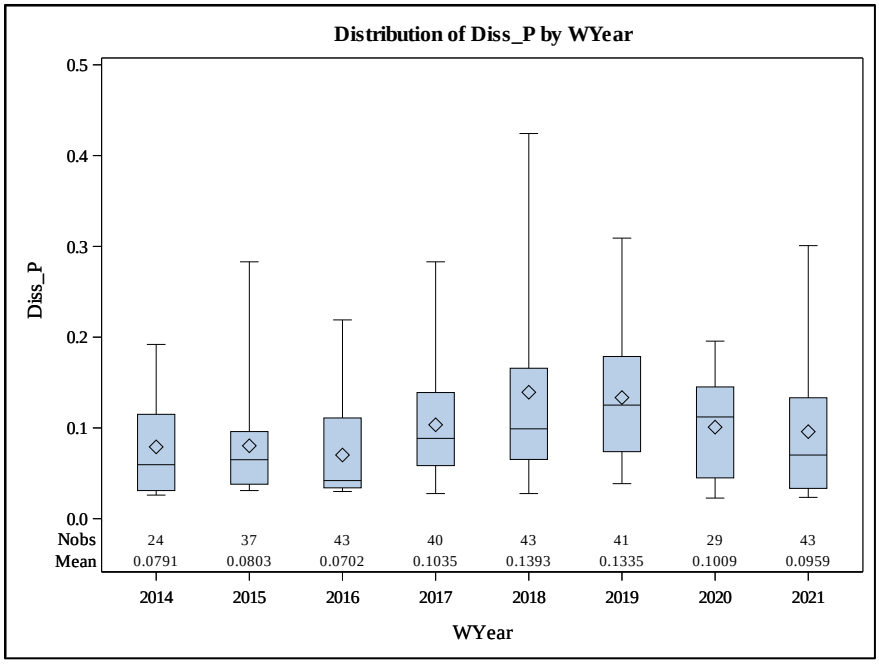

Figure 11. Box plots of annual dissolved phosphorus concentrations (mg/L) from the USGS Silver Creek Florist Drive site during low flow and fixed interval conditions from WY2014 to WY2021.

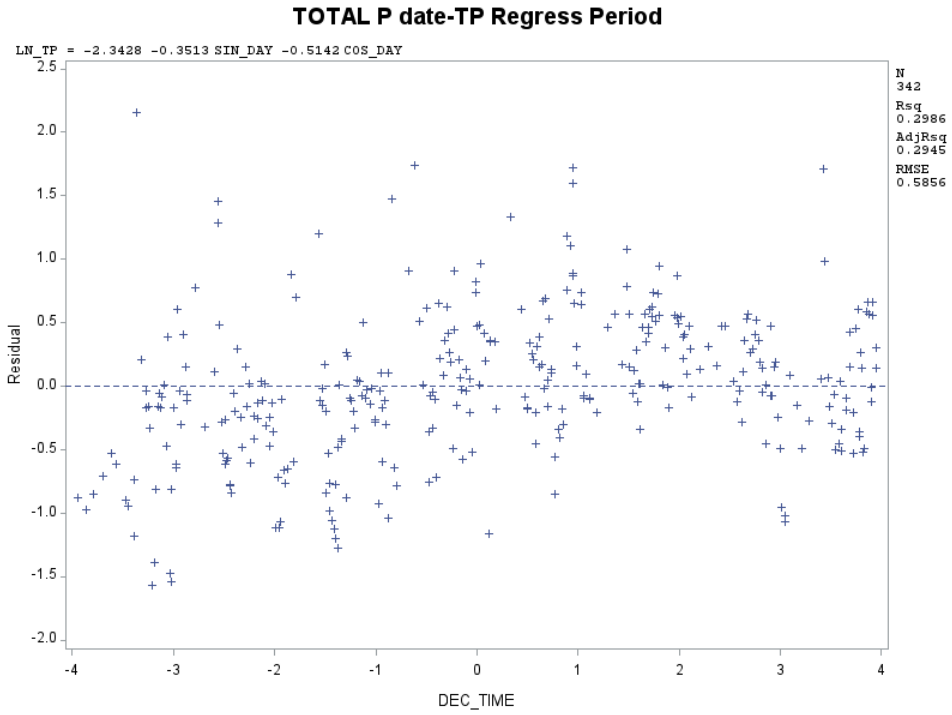

Figure 12. Potential increasing and decreasing temporal trend of seasonally adjusted residuals of log-transformed total phosphorus concentrations collected from fixed-interval and low flow samples at USGS Silver Creek station. Dec-Time is the date minus the mid-point of WY2014 to WY2021 (2017.75).

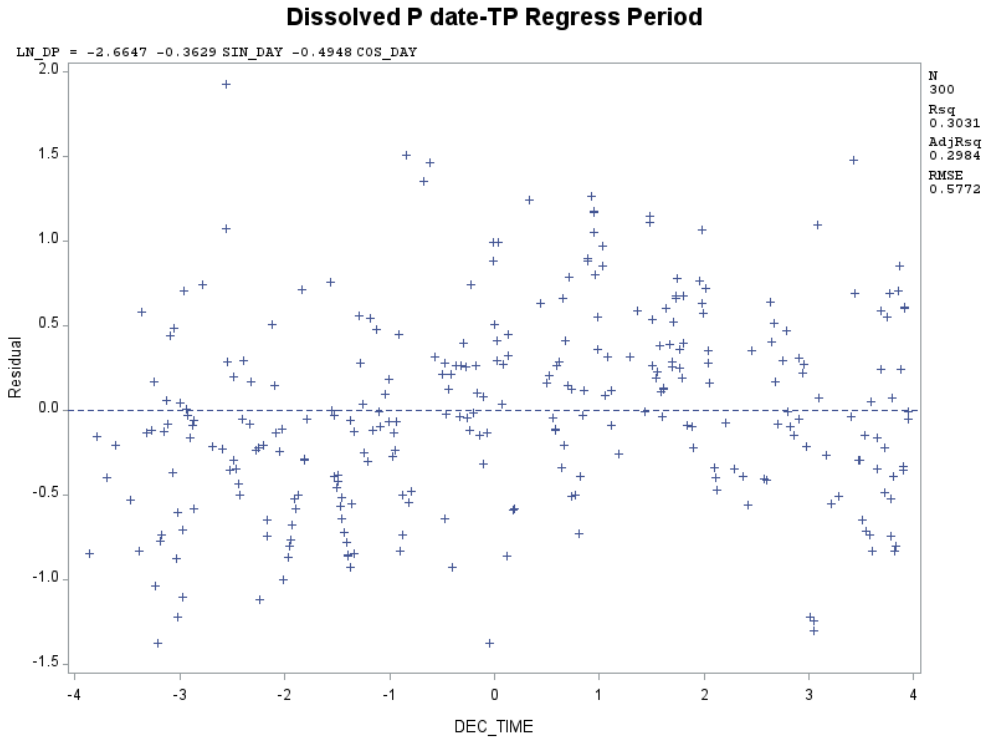

Figure 13. Potential increasing and decreasing temporal trend of seasonally adjusted residuals of log-transformed dissolved phosphorus concentrations collected from fixed-interval and low flow samples at USGS Silver Creek station. Dec-Time is the date minus the mid-point of WY2014 to WY2021 (2017.75).

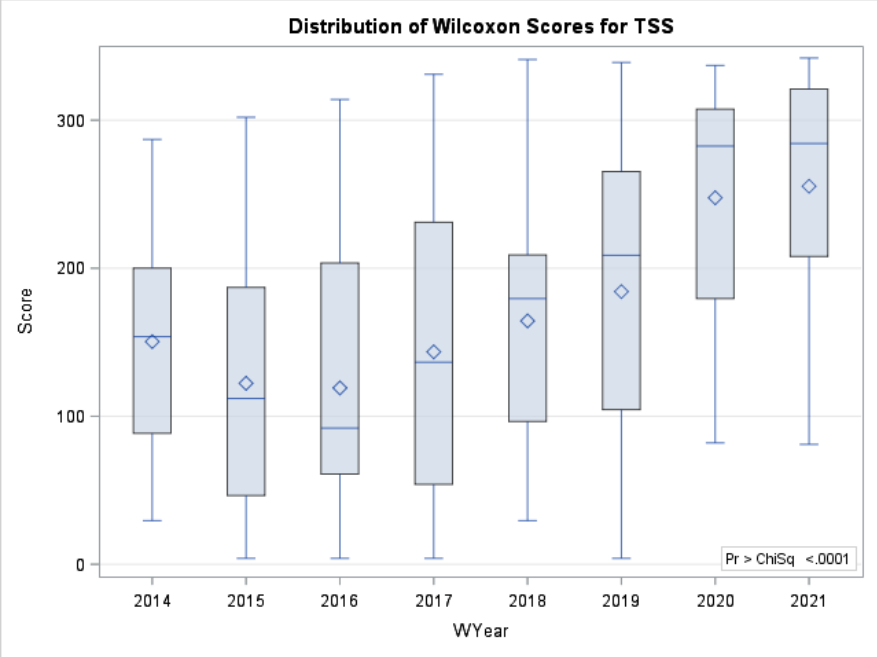

Figure 14. The distribution of non-parametric Wilcoxon test scores by water year for TSS concentrations from fixed interval and low flow water samples collected at the USGS Silver Creek monitoring station from WY2014 to WY2021.

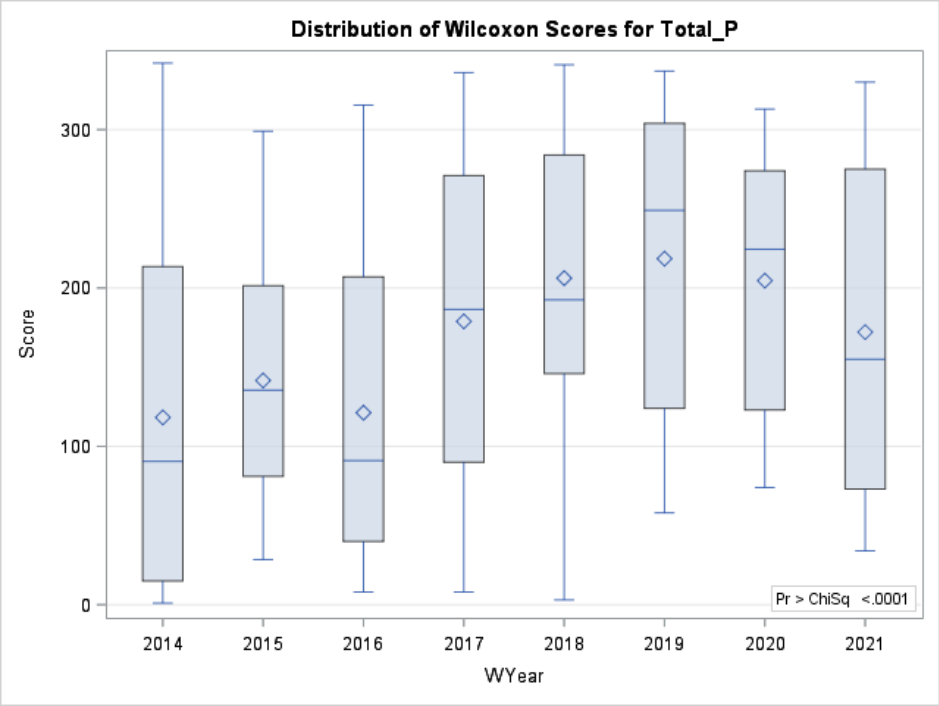

Figure 15. The distribution of non-parametric Wilcoxon test scores by water year for total phosphorus concentrations from fixed interval and low flow water samples collected at the USGS Silver Creek monitoring station from WY2014 to WY2021.

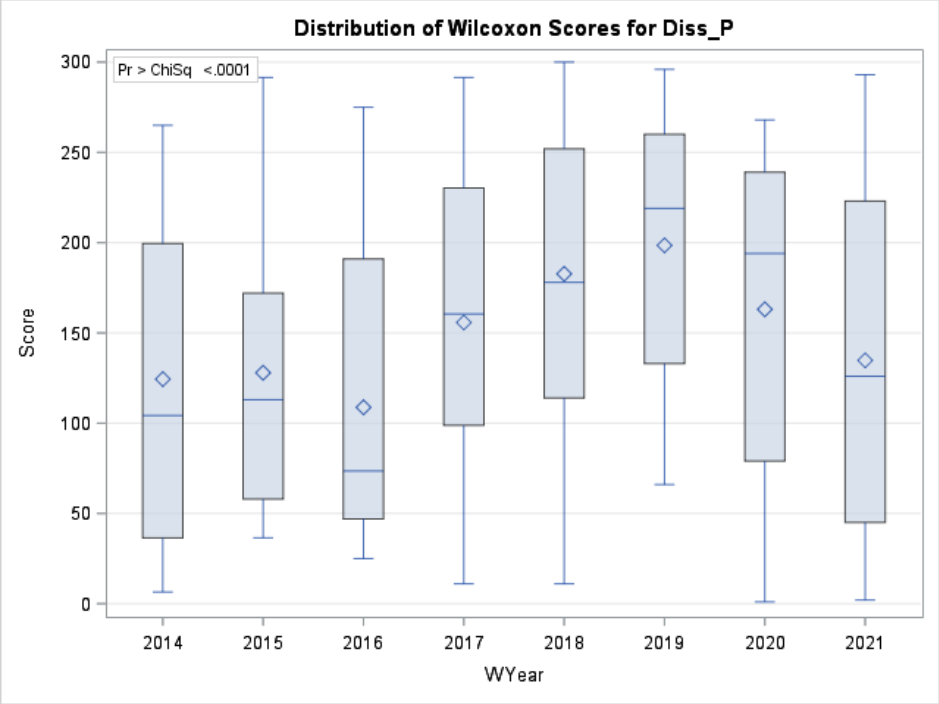

Figure 16. The distribution of non-parametric Wilcoxon test scores by water year of dissolved phosphorus concentrations from fixed interval and low flow water samples collected at the USGS Silver Creek monitoring station from WY2014 to WY2021.