

Annual Report for Water Quality Monitoring Activities

City of Chattanooga and Hamilton County
of Chattanooga, TN

July 2023 – June 2024

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1 Introduction

In June 2021, Woolpert was retained to help the City of Chattanooga and Hamilton County enhance their current individual sampling efforts by developing a combined watershed monitoring program. Woolpert helped the City of Chattanooga and Hamilton County develop a comprehensive Monitoring Strategy (Strategy) to encompass needs across both communities related to water quality/quantity and to prioritize specific watersheds for more focused monitoring efforts. The Strategy included recommendations for continuous, real-time monitoring via permanently installed monitoring stations at key locations. In the Spring of 2022, the City of Chattanooga and Hamilton County began full implementation of the Strategy by collecting more targeted discrete samples during ambient/wet conditions in “Priority” watersheds and operating/maintaining four (4) permanent, continuous water quality monitoring stations in “High Priority” watersheds. In the Winter of 2023, the effort expanded to include an additional four permanent monitoring stations and their watersheds. Table 1 summarizes these stations, along with an accompanying overall map in Figure 1. Individual location maps for each station are included in the Appendix.

Table 1. Continuous Water Quality Monitoring Stations

Station Name	Description	Waterbody	Jurisdiction
Citico Creek	Citico Creek – adjacent to Waterwalk Place	Citico Creek	City of Chattanooga
Dobbs Park City	Cannon Avenue – Park City Park	Dobbs Branch	City of Chattanooga
Friar Branch Polymer	Polymer Drive – adjacent to Mayfield Dairy Farms	Friar Branch	City of Chattanooga
N. Chick Ivy Academy	Dayton Pike – Ivy Academy	North Chickamauga Creek	City of Chattanooga
N. Chick Greenway Farms	Walker Cemetery Road – Greenway Farms Parks	North Chickamauga Creek	City of Chattanooga
Stringers Signal Mountain	Signal Mountain Road – adjacent to Tire World & Auto Service	Stringers Branch	Hamilton County
South Chick at West Chick	South Chickamauga Creek Greenway – West Chickamauga Creek	South Chickamauga Creek	City of Chattanooga
Mountain Creek Elementary	North Runyan Drive – adjacent to Red Bank Elementary	Mountain Creek	City of Chattanooga

In order to align the monitoring results with the fiscal budget year for the City of Chattanooga and Hamilton County, the following report includes data collected from July 1, 2023, through June 30, 2024. The Methods section of the report includes information regarding the deployed monitoring equipment, calibration methods/frequencies, the data processing software and capabilities, and the volume of data included over the reporting term. The Results and Discussion section includes a general water quality analysis, in addition to seasonal trends and interpretation of results from the City of Chattanooga and Hamilton County’s discrete sampling program.

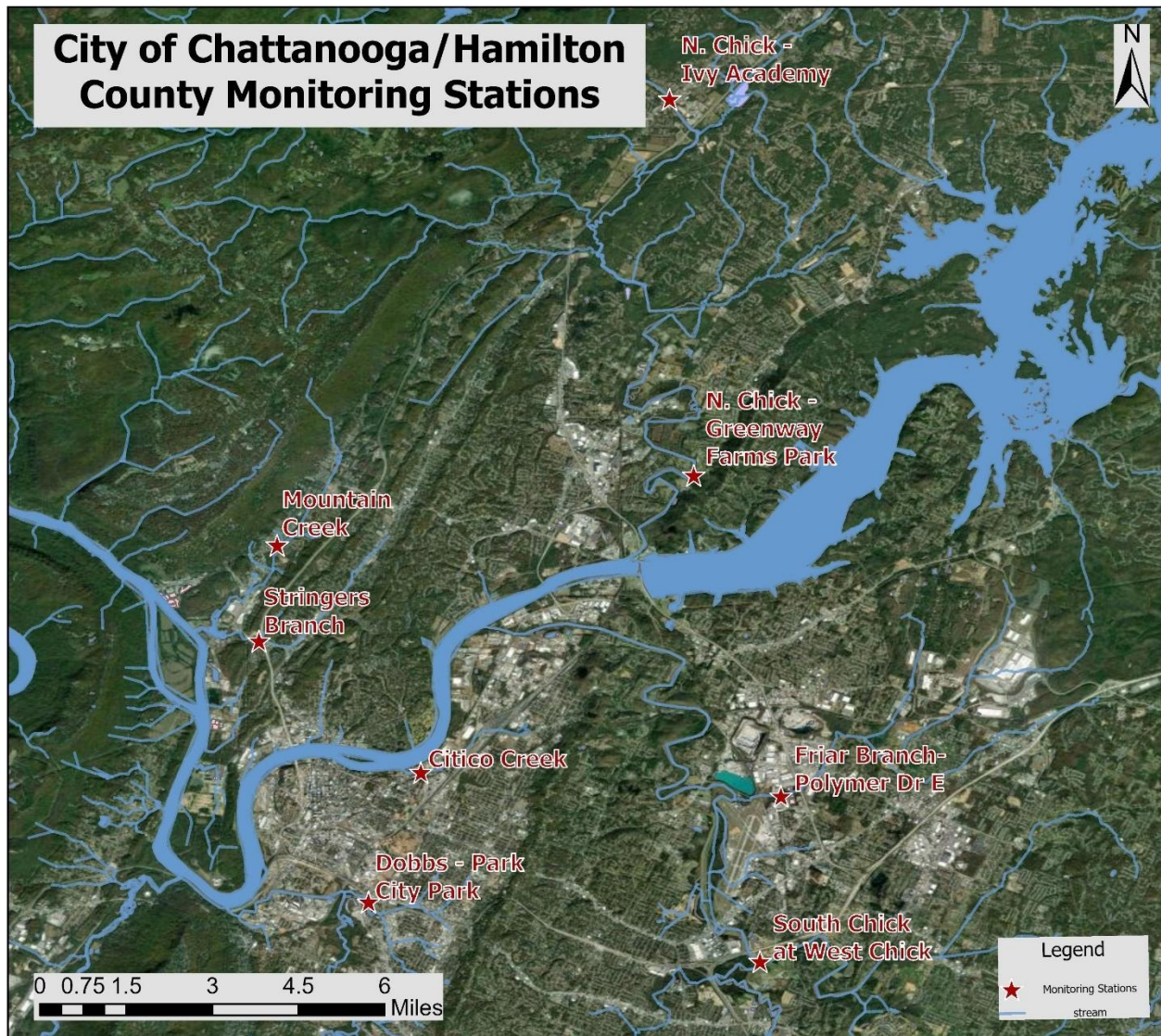


Figure 1. Overall Monitoring Station Location Map

2 Methods

This section describes the methods used in the collection of water quality data and rainfall data, as well as the methods used to perform the analyses presented in this report.

2.1 Data Collection

2.1.1 Continuous Water Quality Data

The City of Chattanooga and Hamilton County maintain YSI EXO Series sondes (EX02 and EX03) at the eight monitoring stations located on Citico Creek, Dobbs Branch, Friar Branch, Greenway Farms, Ivy

Academy, Mountain Creek, South Chick, and Stringers Branch. The sondes record water quality data in 15-minute time increments for stage, water temperature, specific conductivity, dissolved oxygen (DO), turbidity, and pH. The equipment deployed at the City of Chattanooga and Hamilton County's monitoring stations is maintained and calibrated according to the manufacturer's standards. These data collected at each monitoring station are recorded on-site by a Campbell Scientific data logger (CR1000x or CR300 series) and transmitted via a remote telemetry system to a server that hosts the data and displays it on the City of Chattanooga and Hamilton County's real-time monitoring website. This website allows for remote monitoring of the field equipment. Woolpert personnel routinely review the website to alert the City of Chattanooga and Hamilton County to any anomalies and/or maintenance needs. City of Chattanooga and Hamilton County personnel perform site visits to conduct maintenance on the sondes as directed by website observations.

The City of Chattanooga and Hamilton County perform calibrations of the sondes at least bi-monthly, or as needed, followed by a quarterly correction of the collected water quality data, modeled after procedures outlined in USGS Techniques and Method 1-D3: Guidelines and Standard Procedures for Continuous Water-Quality Monitoring Station Operation, Record Computation, and Data Reporting. Additionally, the City of Chattanooga and Hamilton County will perform spot checks using a YSI ProDSS handheld multiparameter digital water quality meter to ensure the accuracy of the sonde.

2.1.2 Discrete Sample Water Quality Data

The City of Chattanooga and Hamilton County collect discrete samples at seven of the water quality monitoring stations mentioned throughout this report. Under this program, discrete samples for *E. coli*, total suspended solids (TSS), nitrate/nitrite, total Kjeldahl nitrogen (TKN), and total phosphorus (TP) are collected under ambient conditions and during storm events. Samples are then analyzed by a certified laboratory. Samples can only be collected when conditions are safe for field personnel and sufficient time is allowed for the samples to be delivered to the lab within the required maximum holding time for bacteria samples. Summary statistics are calculated in Section 3.4 to provide an indication of the concentration of these parameters generally observed at the monitoring stations.

2.1.3 Rainfall Data

The City of Chattanooga and Hamilton County maintain eight (8) Hyquest Solutions TB-4 tipping bucket rain gauges. Each water quality monitoring station has a designated rain gauge. These rain gauges provide an accurate rainfall dataset by recording 5-minute incremental rainfall measurements to the nearest hundredth of an inch. Rain gauges are cleaned as needed and field-validated biannually according to manufacturer instructions.

2.2 Data Processing

Prior to analysis of the continuous water quality data, the raw dataset was corrected using specialized software named Aquarius by Aquatic Informatics, specifically designed for continuous water quality data preprocessing. Time series datasets are corrected so that erroneous data, which are not representative of true in-stream conditions, are not used in the data analysis process. This can be caused by sensor malfunction, entrapment of sediment or other debris in the stilling well or sonde guard, or other unpredictable equipment issues. These data are removed prior to analysis being performed to avoid introducing erroneous bias into the dataset. Approximating methods, such as linear interpolation and averaging techniques, are applied to fill data gaps of less than three hours during predictable conditions (e.g., baseflow). Longer gaps are not filled due to decreased confidence in the predictability of the water quality parameters.

2.3 Data Analysis

The City of Chattanooga and Hamilton County maintain a robust data collection program that results in extensive and insightful water quality datasets. The City of Chattanooga and Hamilton County's discrete sample monitoring program collected 28 *E. coli*, TSS, nitrate/nitrite, TKN, and TP samples across the eight monitoring stations over the one-year term. The continuous water quality monitoring program recorded over 947,000 water quality values across the five monitored watersheds during this monitoring period. By applying a set of statistical analyses, trends and observations are drawn from these datasets in Section 3 of this report.

In Section 3.1, basic summary statistics were calculated using the daily average values of the continuously monitored parameters. Daily averages were used instead of 15-minute continuous readings to portray general water quality trends better. This approach also mutes the impacts of individual data points that may be unreliable (i.e., organic debris temporarily blocking the optical sensor) but cannot be justifiably removed during the data correction process. These daily average datasets were used to generate a percent exceedance plot for each of the eight continuously monitored water quality parameters. A percent exceedance plot is a visualization method for graphing the detailed distribution of a dataset. In this analysis, each water quality value is plotted against the percentage of the monitoring period that the parameter was observed to be at or above that value. For example, for the coldest recorded temperature at a water quality station, the corresponding percent exceedance would be 100%, indicating that all recorded data were at or above this minimum temperature value during the monitoring period. The median value of the dataset is equivalent to the 50% exceedance value.

In Section 3.2, collected data were analyzed seasonally as defined by the corresponding solstices and equinoxes to address such trends in water quality across the monitoring year. For the purposes of this analysis, seasons were defined as follows:

- Fall: September 22 to December 20
- Winter: December 21 to March 19
- Spring: March 20 to June 20
- Summer: June 21 to September 21

In Section 3.3, collected data were analyzed to generate basic summary statistics of annual averages for each measured parameter, using the averaging techniques described in Section 3.1 for site comparison.

In Section 3.4, discrete sampling results are summarized and compared to applicable TDEC water quality standards. Statistical summaries are provided for samples collected during ambient and storm conditions.

3 Results and Discussion

The City of Chattanooga and Hamilton County's continuous water quality monitoring program uses sondes at each of the eight monitoring stations to collect information on five water quality parameters: temperature, turbidity, pH, specific conductivity, and DO. The continuous water quality data records are in 15-minute increments. This dataset is supplemented with discrete sample data, which is analyzed in a laboratory to provide information on water quality parameters, such as *E. coli*, which can not be measured with an in-stream sensor. Sections 3.1, 3.2, and 3.3 summarize the continuous, in-stream dataset. Data collected under the discrete sampling program are summarized in Section 3.4 of this report. Both the

continuous water quality and discrete sample data results are reported in the City of Chattanooga and Hamilton County’s quarterly water quality monitoring reports. These reports are available on the City of Chattanooga and Hamilton County websites and provide a high-level summary of results, but do not include data interpretation.

3.1 General Water Quality Analysis

The tables below contain summary statistics calculated from the water quality dataset collected by the continuous monitoring equipment at the five stations throughout the City of Chattanooga and Hamilton County. The datasets range from July 2023 through June 2024. In Table 2, summary statistics are calculated from a dataset of daily average values, providing a numeric representation of the water quality during this monitoring period. Results are also presented in graphical form in Figure 2 through Figure 6, which display percent exceedance distributions for each water quality parameter.

Table 2. Annual Statistics from Daily Average Water Quality Data

Temperature (°C)						
	Mean	Std Deviation	Median	Minimum	Maximum	Range
Citico Creek*	14.26	4.66	14.09	5.81	23.65	17.83
Dobbs Branch	17.15	5.75	16.95	3.25	26.70	23.46
Friar Branch	17.30	5.87	17.60	3.05	26.07	23.02
Greenway Farms	15.99	5.48	15.88	3.24	26.02	22.78
Ivy Academy**	16.74	2.74	16.80	11.38	21.49	10.12
Mountain Creek	15.54	5.33	14.82	3.10	25.00	21.91
South Chick**	13.48	5.40	12.80	2.63	23.61	20.99
Stringers Branch	15.45	2.09	15.45	9.63	19.34	9.71
Dissolved Oxygen (mg/L)						
	Mean	Std Deviation	Median	Minimum	Maximum	Range
Citico Creek*	6.96	1.95	7.32	2.42	10.28	7.86
Dobbs Branch	5.45	3.52	5.15	0.10	12.56	12.46
Friar Branch	8.25	1.55	7.78	4.74	12.70	7.96
Greenway Farms	7.82	1.85	7.47	3.9	12.31	8.41
Ivy Academy	9.62	0.83	9.70	7.52	10.88	3.35
Mountain Creek	8.55	2.02	8.31	3.21	13.51	10.30
South Chick**	10.45	1.60	10.71	6.69	14.20	7.51
Stringers Branch	9.72	0.59	9.73	8.47	11.50	3.03
Specific Conductivity (µS/cm)						
	Mean	Std Deviation	Median	Minimum	Maximum	Range
Citico Creek*	370.52	84.15	397.56	145.31	471.61	326.31
Dobbs Branch	403.71	63.72	420.55	181.00	666.95	485.95
Friar Branch	353.49	67.64	364.35	127.54	460.90	333.36
Greenway Farms	179.85	75.71	160.97	36.95	328.06	291.11
Ivy Academy**	25.46	8.60	24.91	12.10	60.54	48.44
Mountain Creek	280.05	60.54	275.32	146.15	459.19	313.05
South Chick**	231.37	46.05	239.31	82.39	308.82	226.43
Stringers Branch	303.85	30.83	315.78	164.28	422.64	258.36
pH						
	Mean	Std Deviation	Median	Minimum	Maximum	Range
Citico Creek*	7.49	0.10	7.49	7.20	7.71	0.51
Dobbs Branch	7.51	0.14	7.52	7.16	7.94	0.78
Friar Branch	7.85	0.16	7.87	7.21	8.11	0.90
Greenway Farms	7.46	0.19	7.50	6.71	7.83	1.13
Ivy Academy**	6.50	0.17	6.52	6.05	6.94	0.90
Mountain Creek	7.85	0.14	7.84	7.48	8.23	0.75
South Chick**	8.00	0.18	8.04	7.15	8.32	1.17
Stringers Branch	7.67	0.13	7.66	7.37	7.90	0.53

Turbidity (FNU)						
	Mean	Std Deviation	Median	Minimum	Maximum	Range
Citico Creek*	14.60	27.56	6.46	3.62	244.75	241.14
Dobbs Branch	9.23	9.49	5.03	0.93	63.82	62.89
Friar Branch	7.33	9.98	3.75	0.63	86.42	85.79
Greenway Farms	6.83	6.97	4.74	1.63	68.89	67.26
Ivy Academy**	32.62	25.23	21.17	9.21	83.01	73.80
Mountain Creek	6.99	13.56	3.62	0.49	143.34	142.85
South Chick**	29.24	70.61	10.45	4.07	699.23	695.16
Stringers Branch	5.92	7.52	3.47	1.67	62.62	60.95

*Data between 7/1/2023 – 12/13/2023 are not available due to equipment failures.

**Data between 7/1/2023– 12/8/2023 are not available due to sensor maintenance.

Figure 2 displays the percent exceedance plot for daily average water temperature values during the monitoring period at all eight stations within the City of Chattanooga and Hamilton County's monitoring network. As indicated by no values falling within the red area of the figure, all daily average values were below the 30.5 °C TDEC maximum standard.

Overall, the temperature distributions are typical for a year-long dataset, with higher and lower temperatures due to seasonal influences. The Dobbs Branch and Friar Branch datasets show the greatest variability in distribution. This distribution pattern is typical of shallow flows as they are more susceptible to ambient temperature fluxes. Ivy Academy and Stringers Branch shows a relatively flat distribution compared to the other six sites with a year-long dataset, which have typical temperature swings on each end of the distribution. The Ivy Academy dataset displays little variability due to data only being collected at that site between December 9, 2023, and June 30, 2024, which is not indicative of the annual distribution but rather two seasonal distributions. Contrastingly, the Stringers Branch dataset is representative of the entire monitoring period. Therefore, the distribution displayed could be due to a combination of the sonde being mounted against a high concrete wall, upstream conveyance through a large, concrete box culvert under the interstate, and tree canopy shading the stream. These site conditions could have led to the water being insulated in this location, leading to water temperatures that are less sensitive to changes in air temperature compared to the other monitoring locations.

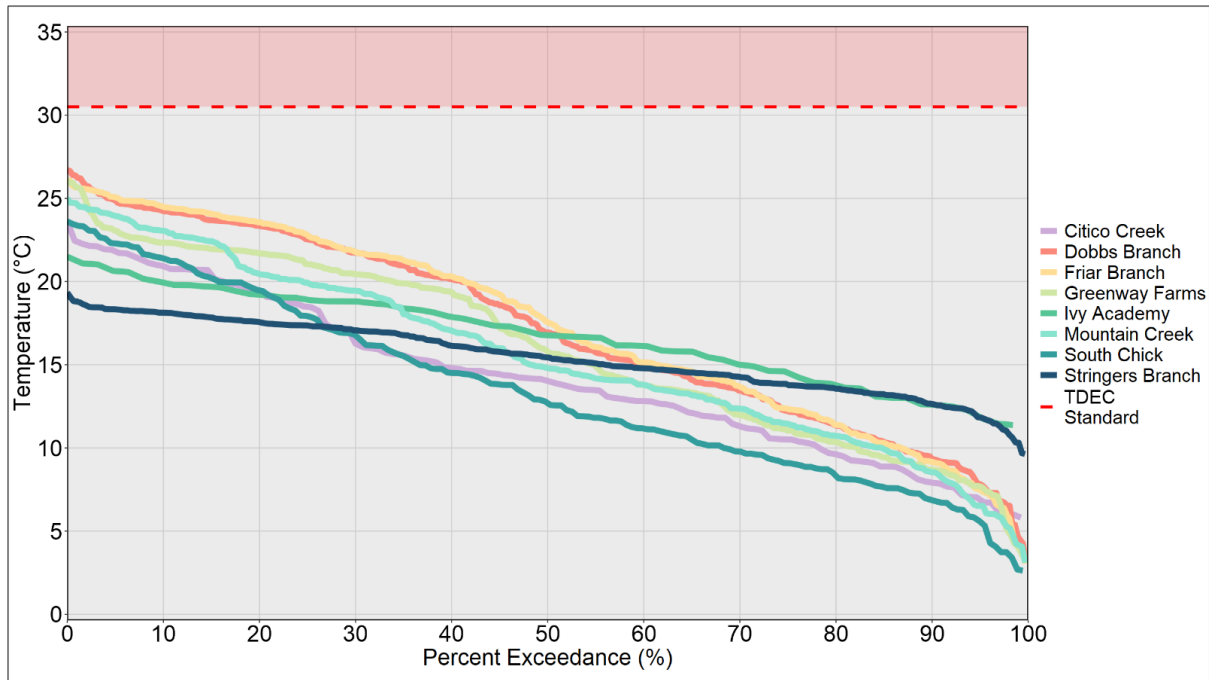


Figure 2. Percent Exceedance Distributions – Daily Average Data – Temperature

Figure 3 displays the percent exceedance distributions for daily DO values during the monitoring period at each of the eight stations. As stated previously, Ivy Academy's dataset is incomplete, and this parameter only displays data between March 31, 2023, and May 11, 2024, of the monitoring period. This likely biases the overall DO distribution to be more attuned to seasonal distribution rather than annual. Dobbs Branch experienced the largest variability in overall distribution when compared to the other seven sites. This is most likely a result of experiencing the largest variability in temperature, which inversely correlates with DO storage capacity within a watershed in tandem with surrounding urban influence.

The daily DO average fell below the 5.0 mg/L minimum daily average TDEC standard at the Citico Creek station for 22 of the 130 monitored days within this monitoring period. The incomplete dataset, as a result of equipment failure, skews the overall distribution to lower levels due to data being recorded during warmer periods. The daily average DO at the Dobbs Branch station fell below the 5.0 mg/L minimum daily average TDEC standard for 176 of the 362 monitored days during this monitoring period. This is indicative of a highly impaired waterway with a multitude of possible causes, given the urban influence within this watershed. Chemical oxygen demand and biological oxygen demand could be due to a large number of SSOs or other illicit discharges within the Dobbs Branch watershed. The daily average DO at the Greenway Farms station fell below the 5.0 mg/L minimum daily standard for 20 of the 347 monitored days during this monitoring period. This could be due to long periods without significant rainfall, leading to stagnant conditions and increased DO consumption by algae and other aquatic life. This is indicated by the recovery of DO levels following a significant rain event during those times.

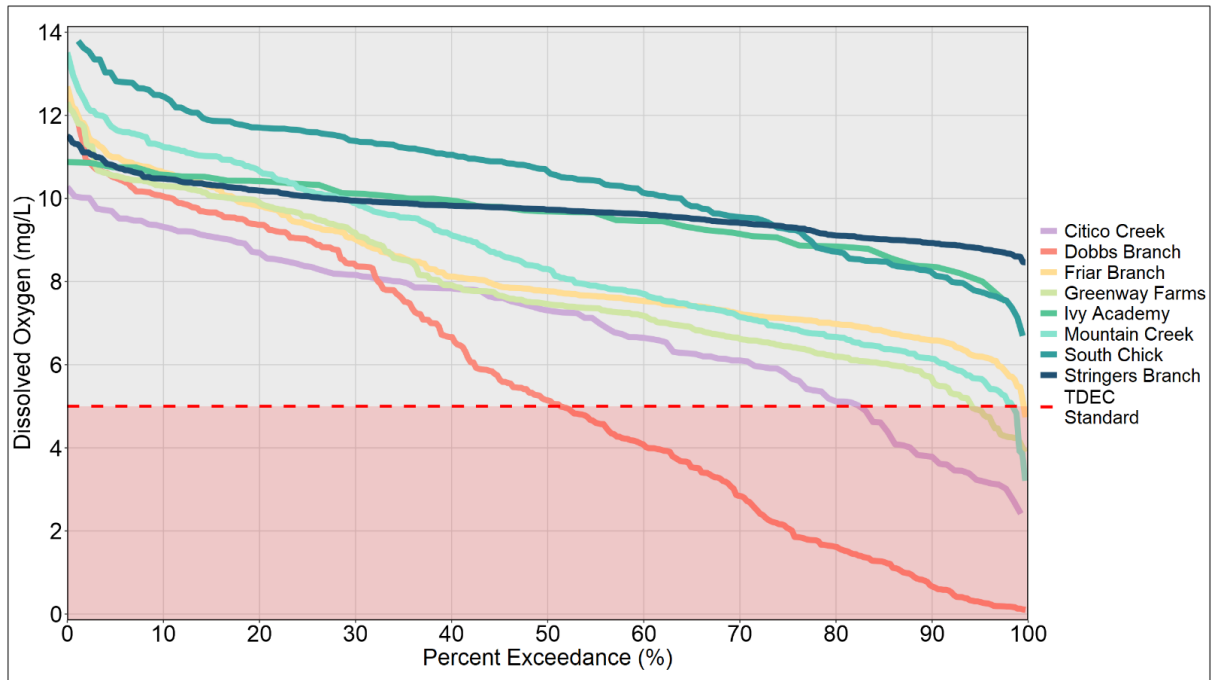


Figure 3. Percent Exceedance Distributions – Daily Average Data – Dissolved Oxygen

Figure 4 shows the percent exceedance distributions of daily average pH values at the eight City of Chattanooga and Hamilton County monitoring stations during the monitoring period. The figure displays the most conservative lower and upper TDEC standard of 6.5 – 9 pH units, respectively. All stations, with the exception of Ivy Academy, fell within the acceptable range for this monitoring period. Ivy Academy fell below the TDEC lower pH limit of 6.5 for roughly 45% of the days pH was monitored in this watershed, with daily averages ranging between 6.4 and 6.1 pH units. Potential causes of this could be due to an illicit discharge occurring during this time period. This could also potentially be due to a faulty reading, due to numerous pH sensor issues around this time.

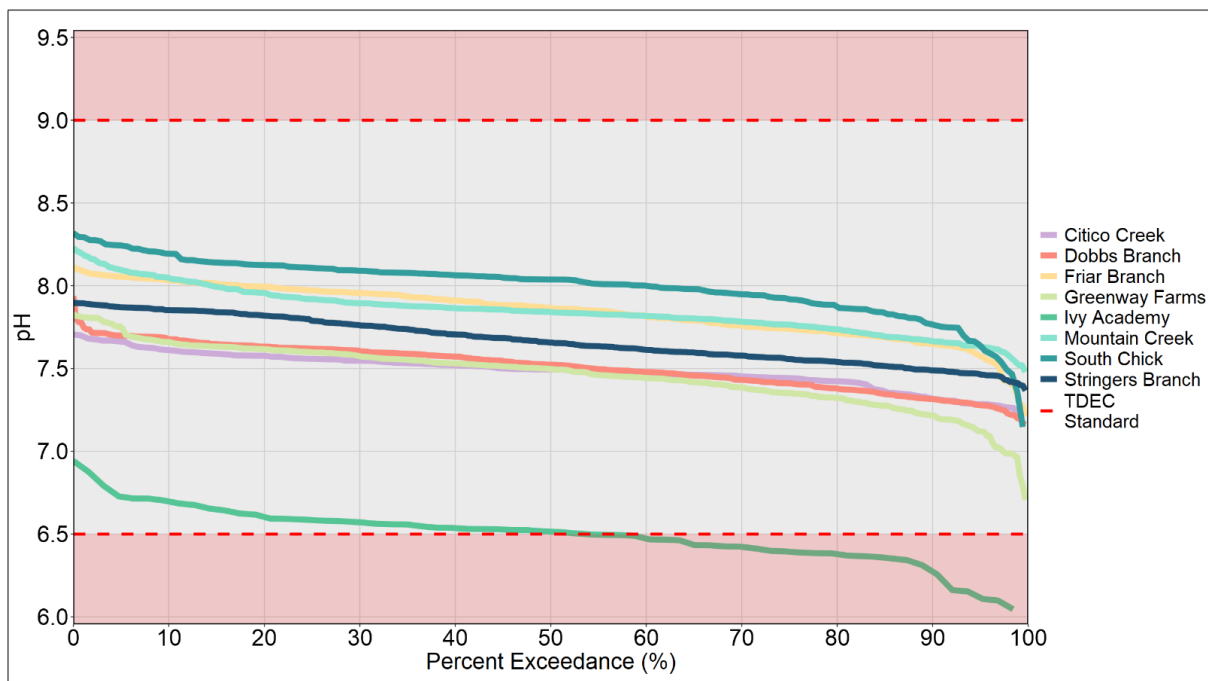


Figure 4. Percent Exceedance Distributions – Daily Average Data – pH

Figure 5 displays the percent exceedance distributions of daily average specific conductivity values at each of the eight stations monitored by the City of Chattanooga and Hamilton County. There is no established TDEC standard for this parameter. Stringers Branch and Ivy Academy (limited monitoring period) displayed a very steady specific conductivity distribution throughout the monitoring period.

The tail on the upper end of the percent exceedance distribution at Dobbs Branch occurred on March 15, 2024. This increase coincides with a recorded storm event and is not likely the result of an illicit discharge occurring during this time period. Dobbs Branch measured specific conductivity daily average was higher than any other watershed for the entirety of the monitoring period. Similar to the reason for frequent low DO values at this site, this is likely caused by continuous discharges other than stormwater in the watershed. The tail on the upper end of the percent exceedance distribution at Ivy Academy occurred between February 11-13, 2024. Given that this did coincide with multiple small storm events during projected freezing temperatures, it is likely the result of an illicit discharge occurring from de-icing attempts during this time. Ivy Academy had consistently lower specific conductivity throughout the recorded distribution. This could be due to a lower recurrence of SSOs in the watershed and lower baseflow total dissolved solids; however, due to the incomplete monitoring period, this distribution displays a singular seasonal variance from winter to spring.

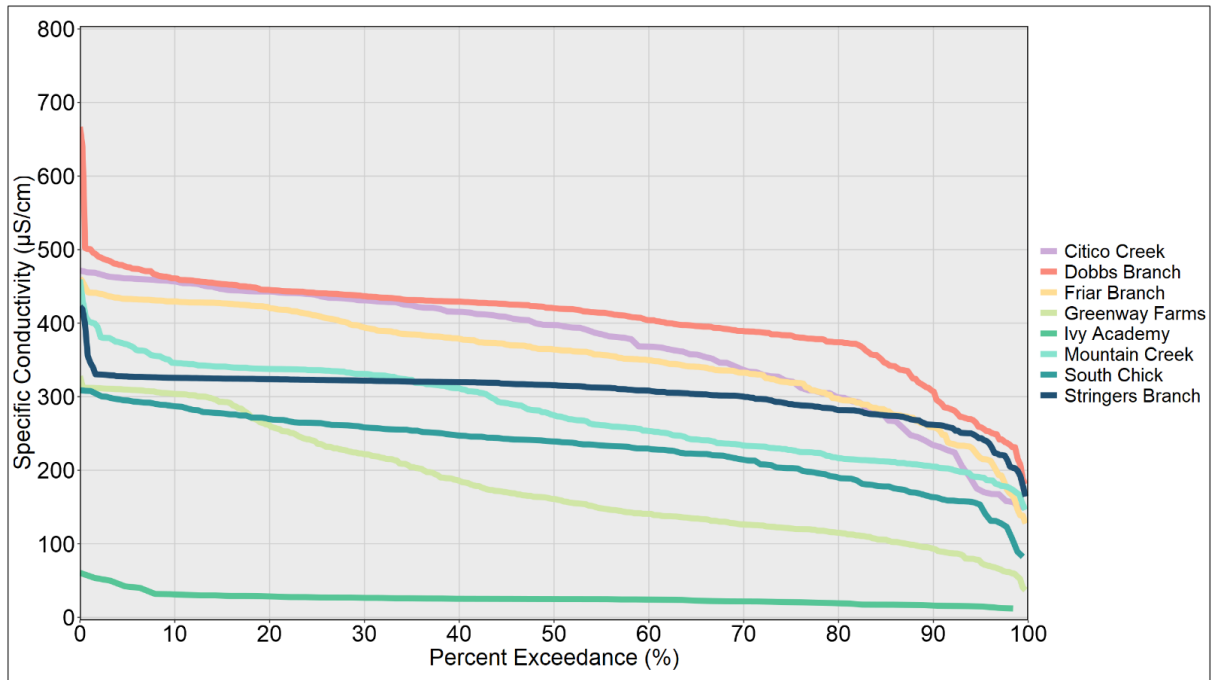


Figure 5. Percent Exceedance Distributions – Daily Average Data – Specific Conductivity

Figure 6 displays the percent exceedance distributions for daily average turbidity values. There is no explicit, numerical TDEC standard established for this parameter. Seven of the eight stations exhibit values approaching 300 - 700 FNU on the upper end of the distributions. These elevated turbidity readings are in response to significant storm events that produce flashy runoff and high flow in the waterway. Turbidity is likely increased due to stream bank erosion and resuspension of prior sediment deposition in-stream. Dobbs Branch measured a higher daily average turbidity than any of the other four stations with complete datasets during approximately 70% of the monitoring period. This is likely the result of more exposed sediment due to erosion near this station. The three highest average turbidities displayed within this figure belong to incomplete datasets and are not indicative of the entire monitoring period.

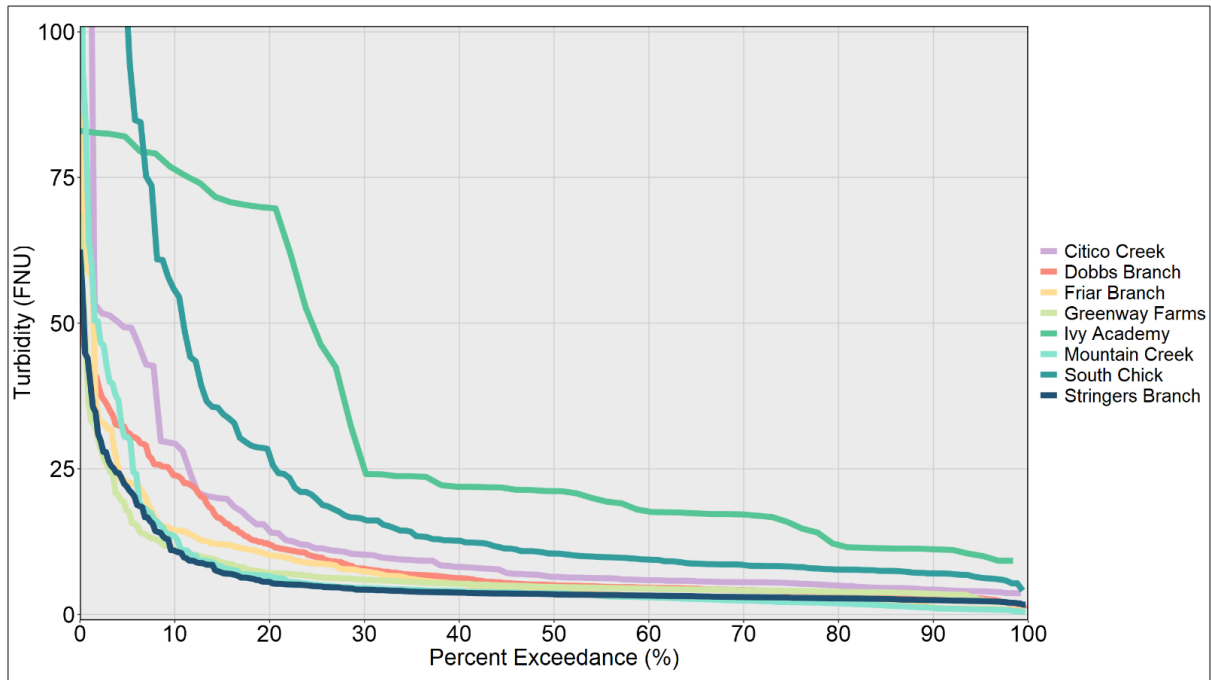


Figure 6. Percent Exceedance Distributions – Daily Average Data – Turbidity

3.2 Seasonal Trends

The datasets were divided into seasonal groups, as described in Section 2.3 to assess trends occurring in water quality seasonally across the monitoring year. For each seasonal group, a bar graph for each station summarizing the data are displayed in Figure 7 through Figure 11. Each bar represents the average daily data collected during the monitoring period. Patterns were evident with some parameters, while other parameters showed very little seasonal variability.

Figure 7 below displays the seasonal mean values for water temperature at each of the eight watersheds. Incomplete monitoring periods are visible for Citico Creek, Ivy Academy, and South Chick. As expected, the temperature varies seasonally at each station due to seasonal changes in ambient air temperature. Average water temperature is warmest during the summer seasons and coolest during the winter seasons.

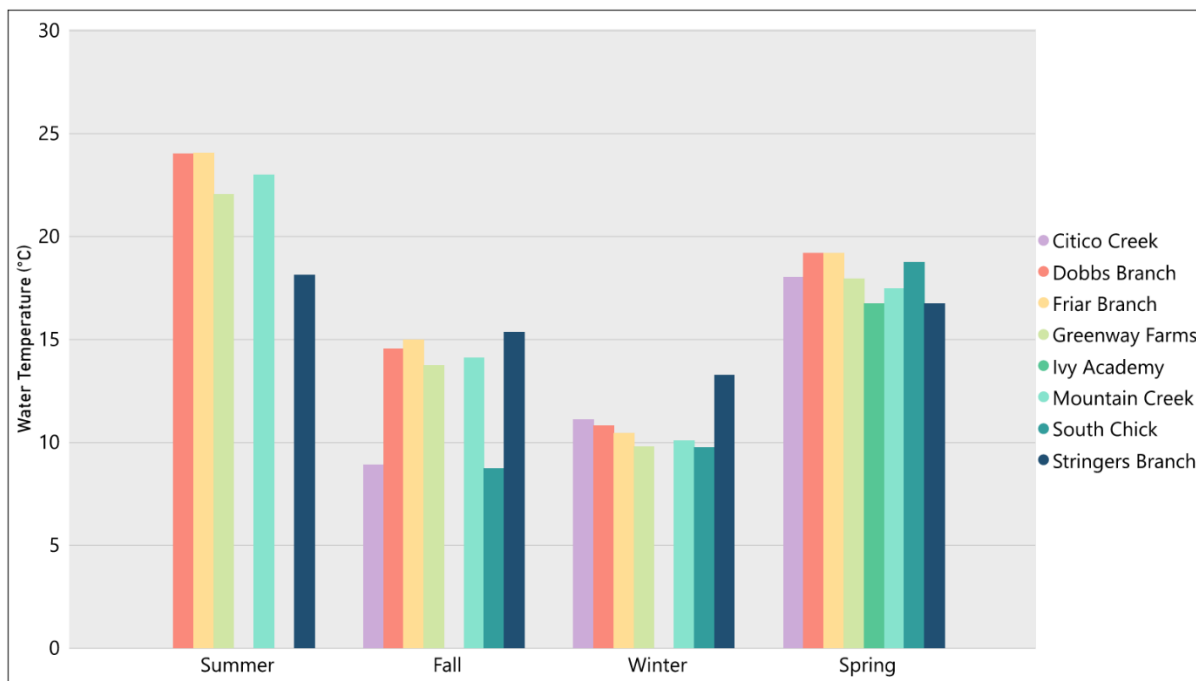


Figure 7. Seasonal Mean Water Temperature Values – Daily Average Data

Figure 8 displays the seasonal mean DO values at all monitored stations during the monitoring period. There is a clear seasonal trend in DO that mirrors the seasonal trend in water temperature. The lowest DO occurs in the summer season, while the highest DO occurs during the winter season. This relationship is expected because the DO levels in a body of water are dependent upon the water temperature, among several other factors. Water with a lower temperature has the capacity to hold more DO than water at a higher temperature. When water temperatures increase during the summer months, the streams cannot physically hold as much oxygen, so the DO levels decrease.

Algal and other phytoplanktonic organisms produce oxygen in streams during the process of photosynthesis, which also influences DO concentrations in streams. Populations of photosynthetic organisms increase in the summer and early fall months, which increases their rate of photosynthetic production. This seasonal process causes a slight increase in DO levels in the summer; however, as Figure 8 indicates, this increase is not enough to outweigh the impacts of high water temperatures in the summer, so there is still a large net decrease in DO levels in the summer months. The average seasonal DO was below the 5 mg/L TDEC standard for both summer and fall seasons at Dobbs Branch, and it was lower than all other recorded stations during these seasons. This is evidence of a highly impaired waterway with a large amount of oxygen-demanding substances reducing the DO levels below the standard. This is exacerbated in the summer by higher water temperatures and stagnation due to periods of infrequent rainfall.

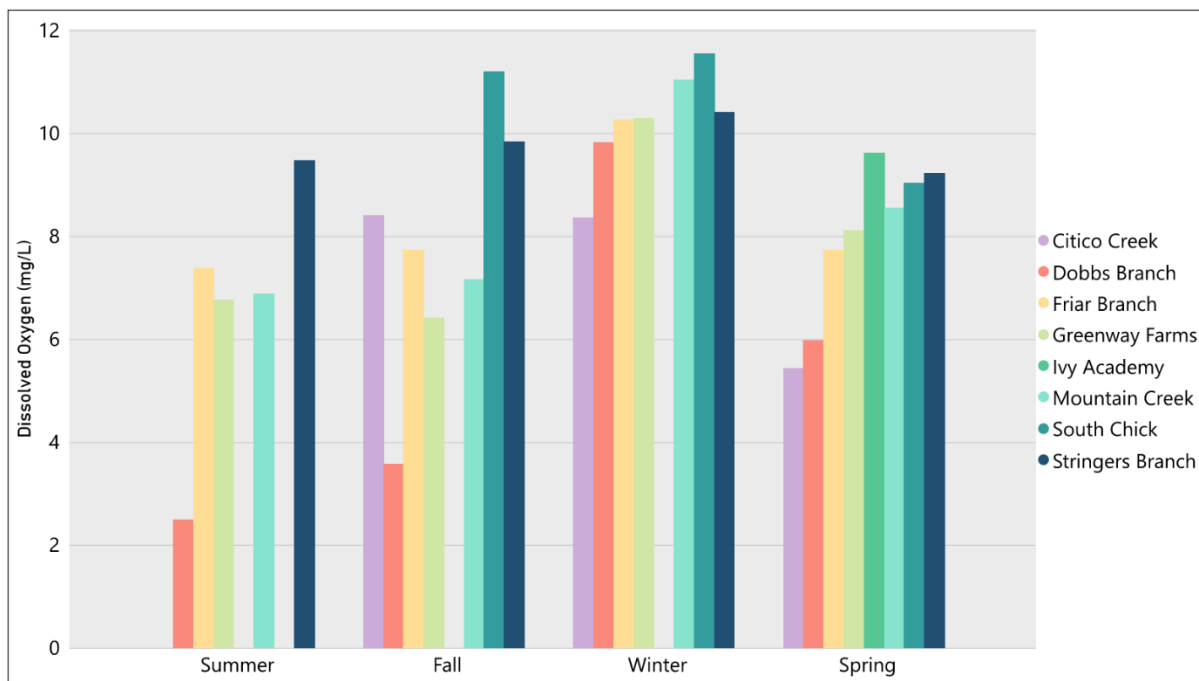


Figure 8. Seasonal Mean Dissolved Oxygen Values – Daily Average Data

Figure 9 and Figure 10 display the seasonal mean pH and specific conductivity levels at the City of Chattanooga and Hamilton County's eight monitoring stations. As seen in the figures below, there is little to no evident seasonal impact on pH and specific conductivity for each individual station, with the exception of lower pH occurring during the spring at the Ivy Academy station. This station's pH probe has historically experienced malfunctions from sediment entrapment; therefore, these readings may not be accurate representations of the stream's conditions. Further monitoring will be required to assess seasonal patterns. Specific conductivity at Mountain Creek averaged notably lower during the winter and spring months than during the summer and fall months. This appears to be due to the winter and spring seasons recording much more frequent storm events than the other two seasons, leading to a consistent dilution of dissolved ions in the stream, which tend to increase during dry periods.

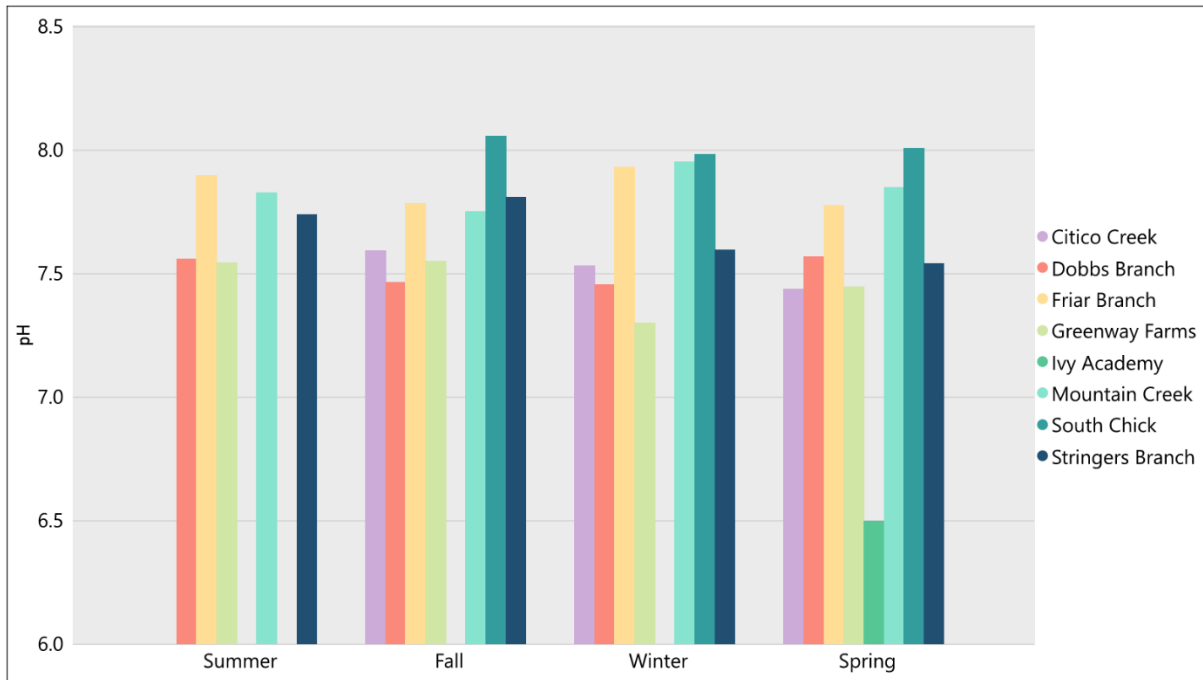


Figure 9. Seasonal Mean pH Values – Daily Average Data

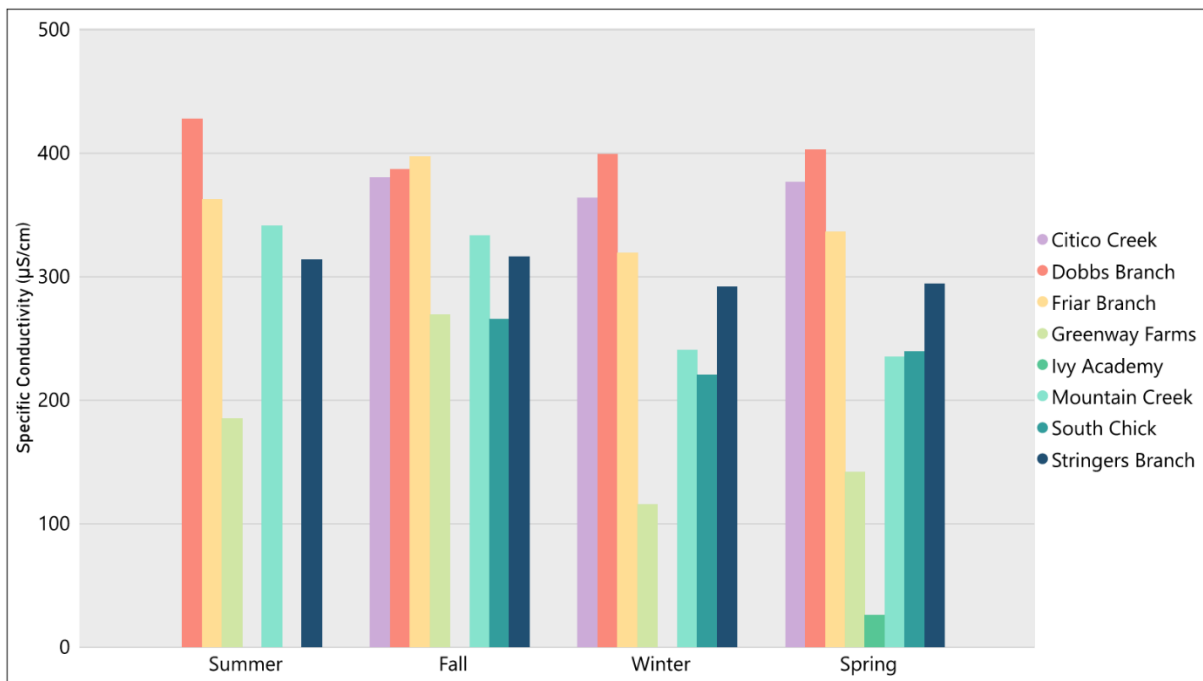


Figure 10. Seasonal Mean Specific Conductivity Values – Daily Average Data

Figure 11 displays the seasonal average turbidity levels recorded at each of the eight stations. Table 3 shows the seasonal sum of precipitation across the watersheds. Storm events drive turbidity levels in

water quality data, so turbidity can be found to have a seasonal pattern in a location with elevated seasonal rainfall and/or rainfall intensities. However, this monitoring period notably opposes historical trends regarding the seasonal average turbidity, where spring would be expect to display the lowest averages and summer displaying the highest. This trend is most notably defied at stations South Chick and Ivy Academy, perhaps due to lower erosion rates or lower rainfall intensities in those watersheds. South Chick measured notably higher average turbidity in the Fall and Winter seasons despite little to no rainfall amounts records. This is possibly due to there being more frequent, smaller storm events causing increased turbidity values for a larger portion of the winter season, as opposed to other seasons with less frequent, larger storm events. Additionally, Ivy Academy measured notably higher turbidity values in comparison to all other stations during Spring, most likely as a result of regular sediment impaction.

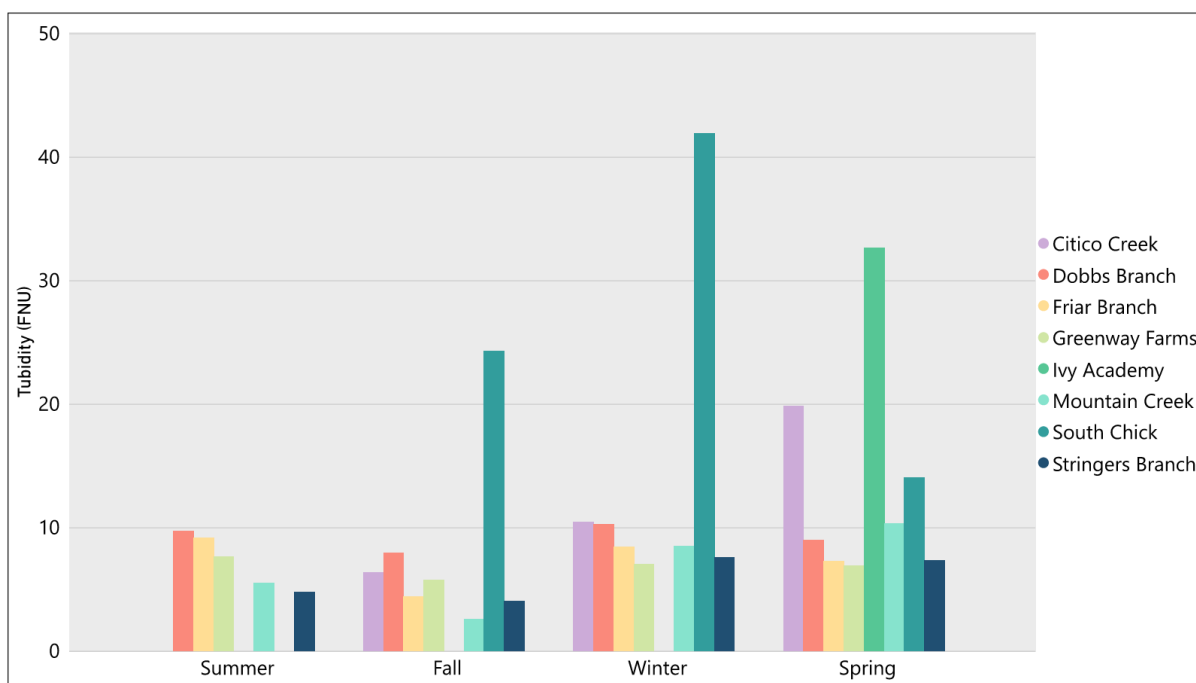


Figure 11. Seasonal Mean Turbidity Values – Daily Average Data

Table 3. Seasonal Precipitation Totals

Station	Summer	Fall	Winter	Spring	Total
Citico Creek*	---	---	8.21	10.87	19.08
Dobbs Branch	11.03	8.53	15.52	13.82	48.90
Friar Branch	13.07	7.81	15.51	13.49	49.88
Greenway Farms	12.02	8.14	16.84	3.22	40.22
Ivy Academy*	0.22	---	16.09	15.34	31.65
Mountain Creek*	---	2.09	16.82	4.73	23.64
South Chick*	0.3	---	3.84	11.53	15.67
Stringers Branch	10.45	7.24	17.72	4.43	39.84

*Seasonal data not available due to equipment failures.

3.3 Annual Trends

The datasets were divided into seasonal groups, as described in Section 2.3 to assess trends occurring in water quality annually across the monitoring period. For each seasonal group, a boxplots for each station summarizing the data are displayed in Figures 12 through 16. Whiskers represent the minimum and maximum value recorded, while the black dot represents the mean of the data. The upper and lower edges of the colored boxes are representative of the 75th and 25th percentiles, respectively. Average ranges were consistent with some parameters, while other parameters showed extreme variability.

Figure 12 below displays the annual mean values for water temperature at each of the eight watersheds. As expected, the temperature varies only slightly at each of the stations with the overall average water temperature consistently hovering around 15°C, falling below the 30.5 °C TDEC maximum standard.

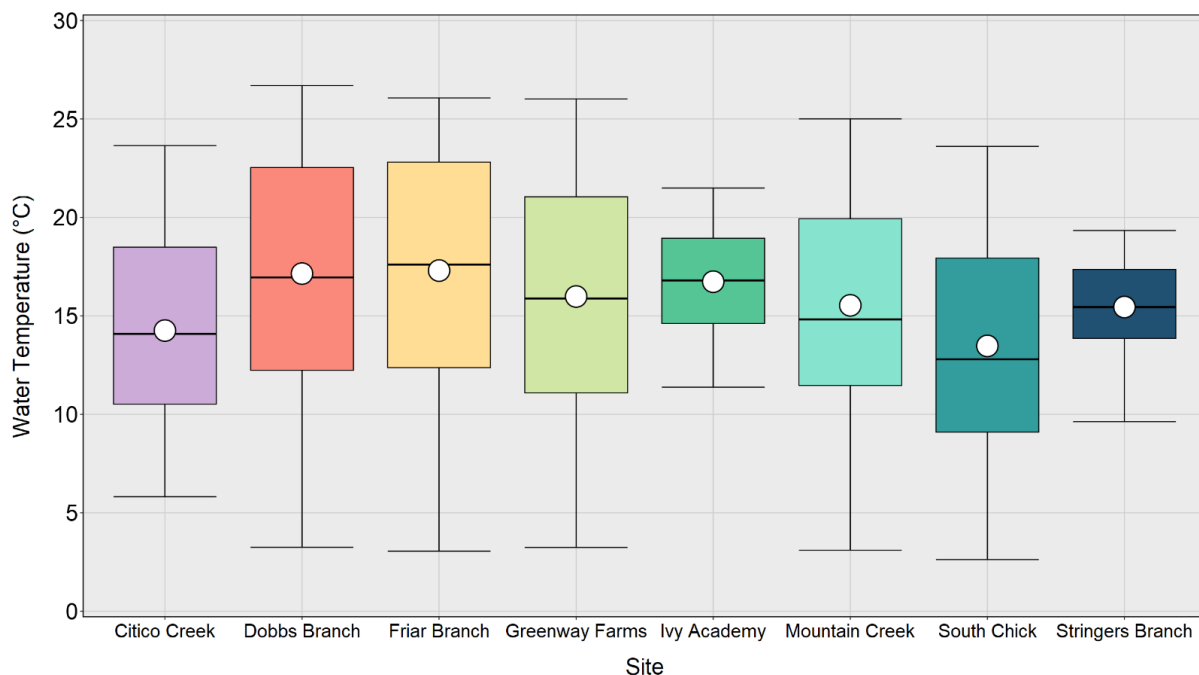


Figure 12. Annual Mean Water Temperature Values – Daily Average Data

Figure 13 displays the annual mean DO values at all monitored stations during the monitoring period. The lowest DO was observed at Dobbs Branch with the largest range, while the second highest DO was observed at Stringers Branch with the smallest range of recorded measurements. These variabilities are visible within section 3.2, seasonal analysis. However, the observed averages were above the 5.0 mg/L average TDEC standard when considering the entire monitoring period.

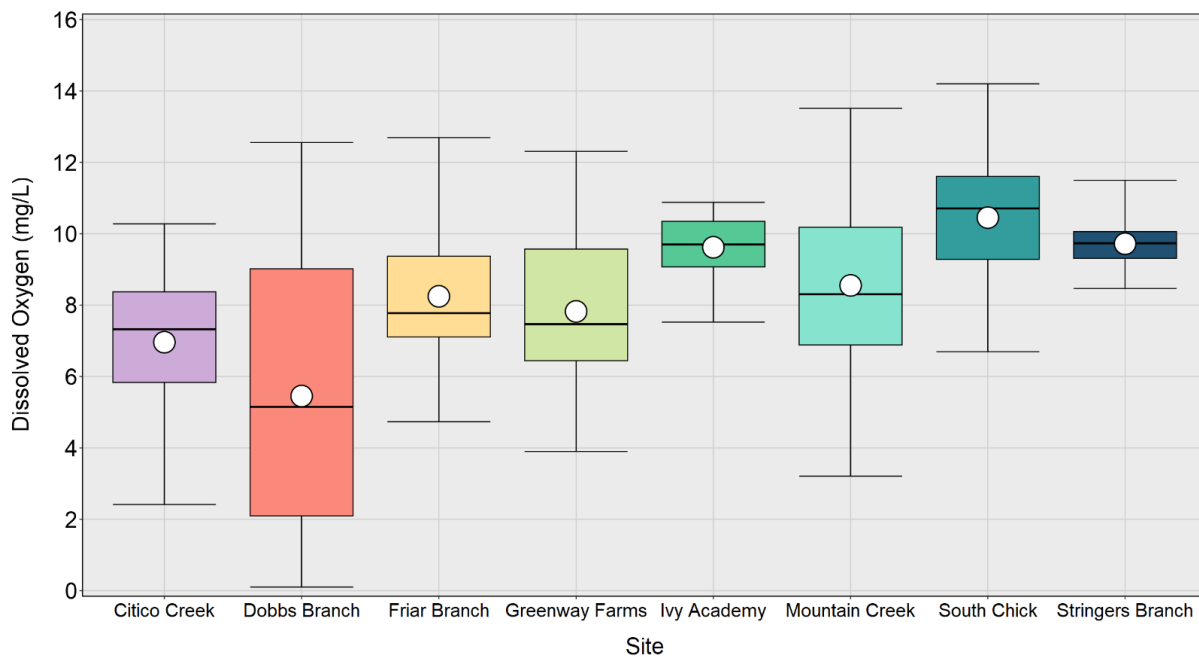


Figure 13. Annual Mean Dissolved Oxygen Values – Daily Average Data

Figure 14 and Figure 15 display the annual mean pH and specific conductivity levels at the City of Chattanooga and Hamilton County's eight monitoring stations. As seen in the figures below, there is largest variability in recorded measurements among pH and specific conductivity for each individual station. The annual average for Ivy Academy falls just above the TDEC lower pH limit of 6.5 as a result of 45% of the recorded period falling below this standard. Specific conductivity does not have an established TDEC standard limit; nonetheless, Ivy Academy consistently maintained the lowest average DO readings throughout the incomplete monitored period, as illustrated by the percentiles and range of values displayed in the figure. The stations with more complete datasets appear to trend more closely throughout the monitoring year. The variability among these stations is expected as these two parameters are the most easily impacted by rainfall and salinity levels.

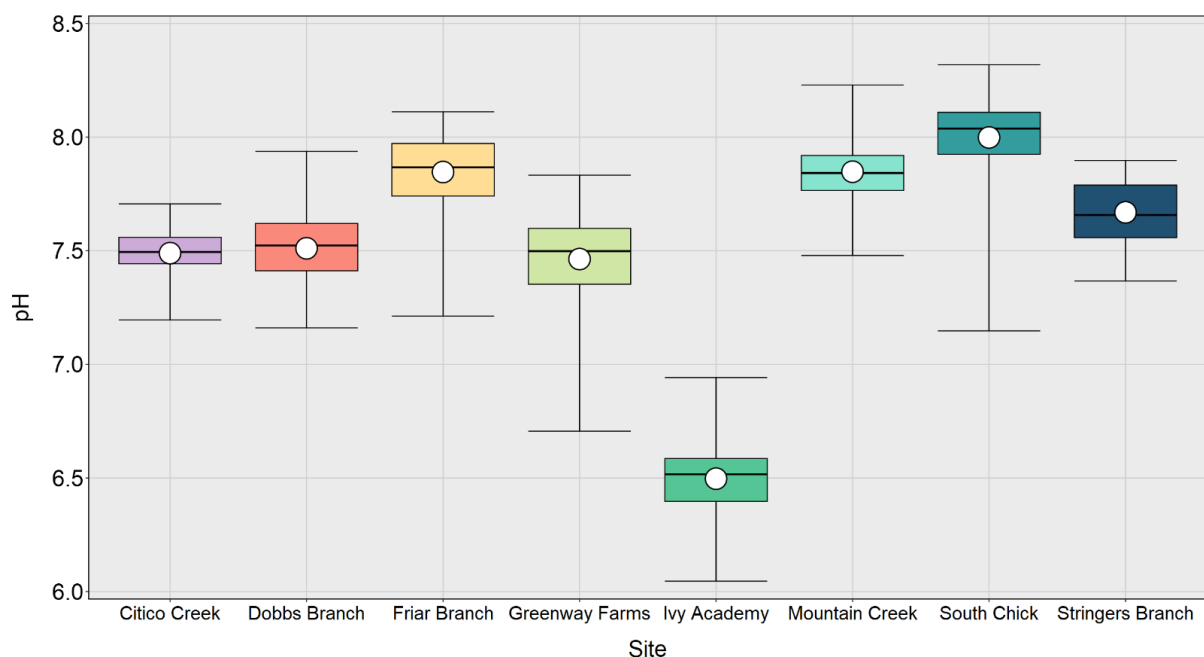


Figure 14. Annual Mean pH Values – Daily Average Data

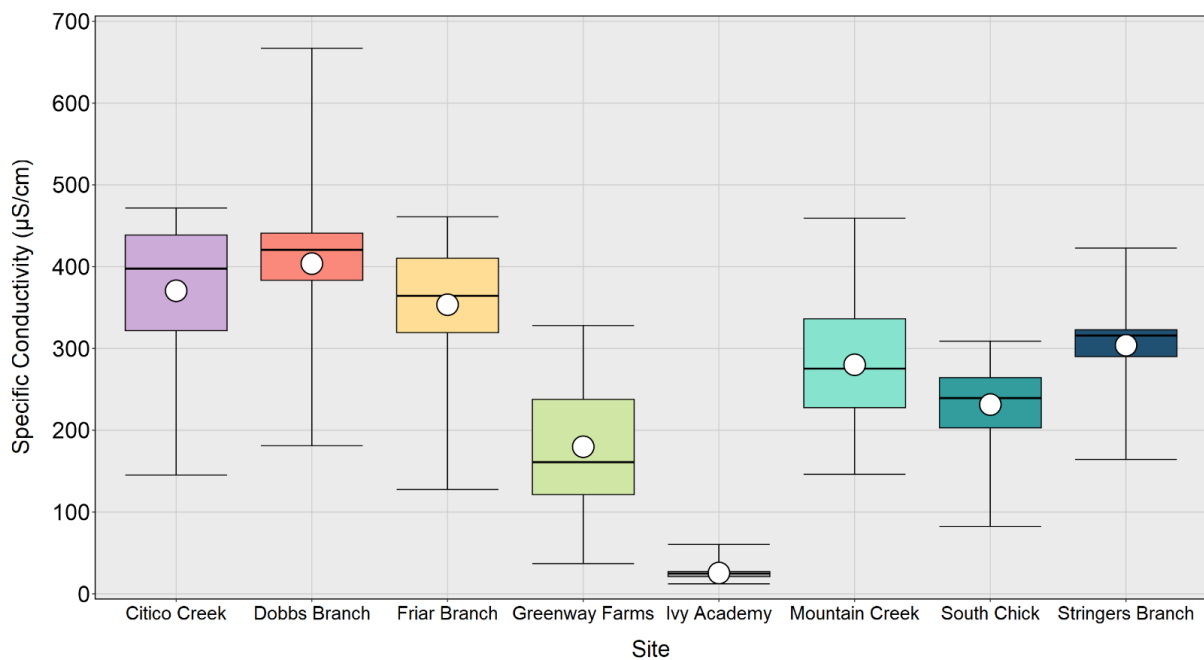


Figure 15. Annual Mean Specific Conductivity Values – Daily Average Data

Figure 16 displays the annual average turbidity levels recorded at each of the eight stations. Table 3 shows the yearly sum of precipitation across the watersheds. Storm events typically drive turbidity levels in water quality data, so turbidity can be found to have a pattern in a location with elevated seasonal rainfall and/or rainfall intensities. However, this monitoring period notably opposes historical

trends regarding the annual average turbidity, where Friar Branch would have been expected to display the highest average and South Chick displaying the lowest. Instead, Ivy Academy displayed the highest average, and Mountain Creek displayed the lowest throughout the monitoring period. This is possibly due to there being more frequent, smaller storm events causing increased turbidity values as opposed to other sites experiencing less frequent, larger storm events. However, four stations experienced periodic equipment failures affecting seasonal rainfall totals and should be noted.

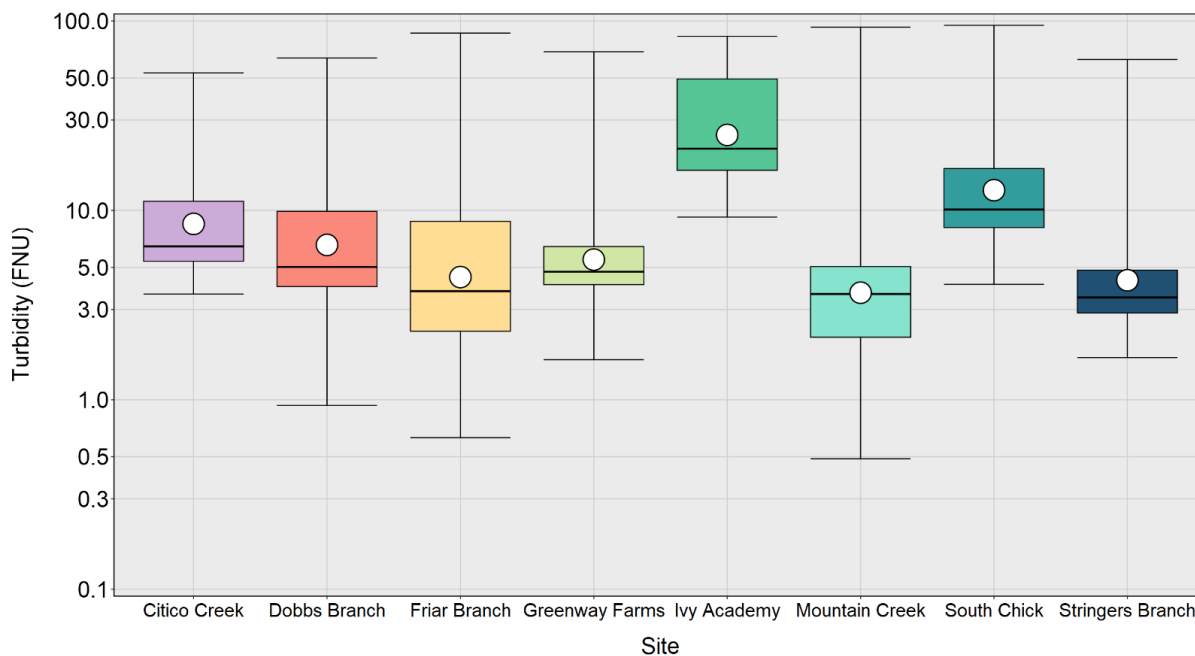


Figure 16. Annual Mean Turbidity Values – Daily Average Data

3.4 Discrete Sample Analysis

Discrete samples were collected periodically at the City of Chattanooga and Hamilton County's monitoring stations during the reporting period. Samples were collected during both ambient conditions and during storm events throughout the year. Summary statistics for each collected parameter are provided in the sections below.

3.4.1 *E. coli*

As part of their discrete sample collection program, the City of Chattanooga and Hamilton County collected a total of 28 *E. coli* samples throughout the monitored watersheds (Table 4). This includes 10 samples collected during storm conditions and 18 samples collected during ambient conditions. TDEC's single sample *E. coli* criteria for recreation is 487 CFU/100ml for exceptional waters and 941 CFU/100ml for other waters. As seen in Table 4 below, samples from Dobbs Branch and Citico Creek exceeded both of these standards. These two sites with the highest *E. coli* concentrations during the year both have an approved TMDL for *E. coli*. These watersheds were identified in the City of Chattanooga / Hamilton County Monitoring Strategy as high-priority watersheds with several possible sources of high *E. coli* that may be investigated in an attempt to determine the primary sources within these watersheds. As expected, *E. coli* concentrations were measured to be higher at most stations during storm conditions due to runoff. The

exception is the Citico Creek station, which had no *E. coli* samples collected during storm conditions during the monitoring year. Therefore, this dataset is not a large enough dataset to draw conclusions about the difference between ambient and storm conditions at this station.

Table 4. *E. coli* (MPN/100 mL) Sample Dataset Summary Statistics

<i>E. coli</i> (MPN/100mL) – Combined Storm/Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	1165	1464	1165	130	2200	2070	2
Dobbs Branch	12,823	16,341	740	40	40,000	39,960	7
Friar Branch	469	516	290	20	1,200	1,180	7
Greenway Farms	169	94	190	60	320	260	7
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	340	170	340	220	460	240	2
South Chick	140	14	140	130	150	20	2
Stringers Branch*	80	-	80	80	80	-	1
<i>E. coli</i> (MPN/100mL) – Storm Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	-	-	-	-	-	-	-
Dobbs Branch	29,333	9,238	24,000	24,000	40,000	16,000	3
Friar Branch	930	468	1,200	390	1,200	810	3
Greenway Farms	141	86	100	82	240	158	3
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	-	-	-	-	-	-	-
South Chick	-	-	-	-	-	-	-
Stringers Branch*	80	-	80	80	80	-	1
<i>E. coli</i> (MPN/100mL) – Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	1165	1464	1165	130	2200	2070	2
Dobbs Branch	440	308	490	40	740	700	4
Friar Branch	123	117	91	20	290	270	4
Greenway Farms	190	106	190	60	320	260	4
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	340	170	340	220	460	240	2
South Chick	140	14	140	130	150	20	2
Stringers Branch	-	-	-	-	-	-	-

*Due to a single sample being collected, the mean displayed here reflects the results of that sample.

3.4.2 Total Suspended Solids

As part of their discrete sample collection program, the City of Chattanooga and Hamilton County collected a total of 28 TSS samples throughout the monitored watersheds (Table 5). This includes 10 samples during storm conditions and 18 samples during ambient conditions. As expected, measured TSS concentrations tended to be higher during storm event samples, with the exception of Greenway Farms, where little variation was observed between averages. Notably, Dobbs Branch had a mean of 10.7 mg/l during ambient conditions and 200 mg/L during storm conditions. This is indicative of a significant amount of erosion and/or bed sediment re-suspension occurring upstream of this station.

Table 5. Total Suspended Solids (mg/L) Sample Dataset Summary Statistics

Total Suspended Solids (mg/L) – Combined Storm/Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	5.9	1.6	5.9	4.8	7	2.2	2
Dobbs Branch	91.8	102.8	15.6	5.6	232.0	226.4	7
Friar Branch	6.3	4.6	5.2	2.0	13.6	11.6	7
Greenway Farms	6.6	3.9	5.2	2.0	12.8	10.8	7
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	4.0	1.7	4.0	2.8	5.2	2.4	2
South Chick	11.2	2.8	11.2	9.2	13.2	4	2
Stringers Branch*	2.0	-	2.0	2.0	2.0	-	1
Total Suspended Solids (mg/L) – Storm Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	-	-	-	-	-	-	-
Dobbs Branch	200	31	198	170	232	62	3
Friar Branch	10.7	3.2	11.2	7.2	13.6	6.4	3
Greenway Farms	6.5	3.8	5.2	3.6	10.8	7.2	3
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	-	-	-	-	-	-	-
South Chick	-	-	-	-	-	-	-
Stringers Branch*	2.0	-	2.0	2.0	2.0	-	1
Total Suspended Solids (mg/L) – Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	5.9	1.6	5.9	4.8	7	2.2	2
Dobbs Branch	10.7	4.1	10.7	5.6	15.6	10	4
Friar Branch	3.1	1.4	2.6	2.0	5.2	3.2	4
Greenway farms	6.7	4.6	6.0	2.0	12.8	10.8	4
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	4.0	1.7	4.0	2.8	5.2	2.4	2
South Chick	11.2	2.8	11.2	9.2	13.2	4	2

Stringers Branch	-	-	-	-	-	-	-
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*Due to a single sample being collected, the mean displayed here reflects the results of that sample.

3.4.3 Nutrients

The City of Chattanooga and Hamilton County collected 28 nitrate/nitrite, TKN, and TP samples as part of their discrete sample collection program. This includes 10 samples of each collected during storm conditions and 18 samples of each collected during ambient conditions. Nitrate+nitrite results are shown separately for comparison to the *Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion* document developed by TDEC (Table 6). Total Nitrogen (TN) in Table 7 below is representative of the sum of nitrate+nitrite and TKN. TP results are summarized in Table 8. Undetectable concentrations were considered as zero (0) values for the purpose of the summary tables below.

According to the *Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion* document developed by TDEC, Chattanooga falls within Level III ecoregion 67 of Nutrient Ecoregion XI. This corresponds to a TDEC recommended interpretation of the existing narrative criteria of 1.22 mg/L for nitrate+nitrite for this ecoregion. As seen in Table 6, all nitrate+nitrite samples collected are below this recommended interpretation criteria and, therefore, do not represent a concerning concentration of nitrate+nitrite. Although no recommend interpretation criteria is provided for TN or TKN, it is worth noting that TKN was only detected at the Dobbs Branch and Stringers Branch stations. This is likely due to the relatively high detection limits of 0.5 – 1 mg/L for parameters measured using the current lab method at all stations other than Stringers Branch. It would be beneficial to request the lab utilize a technique with a lower detection limit in order to accurately assess conditions of the remaining stations.

Table 6. Nitrate+Nitrite (mg/L) Sample Dataset Summary Statistics

Nitrate+Nitrite (mg/L) – Combined Storm/Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	0.99	0.24	0.99	0.82	1.16	0.34	2
Dobbs Branch	0.72	0.47	0.65	0.14	1.36	1.22	7
Friar Branch	1.09	0.24	1.14	0.68	1.45	0.77	7
Greenway Farms	0.52	0.11	0.50	0.39	0.73	0.34	7
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	0.41	0.04	0.41	0.38	0.44	0.06	2
South Chick	0.75	0.14	0.75	0.65	0.85	0.20	2
Stringers Branch	0.04	-	0.04	0.04	0.4	-	1
Nitrate+Nitrite (mg/L) – Storm Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	-	-	-	-	-	-	-
Dobbs Branch	0.67	0.05	0.65	0.64	0.734	0.09	3
Friar Branch	1.16	0.02	1.17	1.13	1.17	0.04	3
Greenway Farms	0.54	0.16	0.45	0.45	0.73	0.28	3
Ivy Academy	-	-	-	-	-	-	-

	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	<0.50	-	<0.50	<0.50	<0.50	<0.50	2
Dobbs Branch	<0.5	-	<0.5	<0.5	<0.55	-	4
Friar Branch	<0.5	-	<0.5	<0.5	<0.5	-	4
Greenway Farms	<0.5	-	<0.5	<0.5	<0.5	-	4
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	<0.5	-	<0.5	<0.5	<0.5	-	2
South Chick	<0.5	-	<0.5	<0.5	<0.5	-	2
Stringers Branch	-	-	-	-	-	-	-

*Due to a single sample being collected, the mean displayed here reflects the results of that sample.

The recommended interpretation of the existing narrative criteria provided by TDEC is 0.04 mg/L for TP within this ecoregion. All samples collected at Dobbs Branch and Stringers Branch measured above this recommended criteria. In conjunction with the high *E. coli* measurements at Stringers Branch, SSOs are a likely cause for the increased TP concentrations at this station. Other possible sources of TP are organic detritus and fertilizer use. The high detection limit of 0.5 mg/L at the other four stations leads to difficulty interpreting the results given that TP is generally found at much lower concentrations within streams. Similar to TKN, it is recommended that a lab method with a lower detection limit, similar to that used at Stringers Branch, be applied to measurements at these stations.

Table 8. Total Phosphorus (mg/L) Sample Dataset Summary Statistics

Total Phosphorus (mg/L) – Combined Storm/Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	<0.500	-	<0.500	<0.500	<0.500	<0.500	2
Dobbs Branch**	-	-	0.548	<0.500	0.548	-	7
Friar Branch	<0.500	-	<0.500	<0.500	<0.500	-	7
Greenway Farms	<0.500	-	<0.500	<0.500	<0.500	-	7
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	<0.500	-	<0.500	<0.500	<0.500	-	2
South Chick	<0.500	-	<0.500	<0.500	<0.500	-	2
Stringers Branch*	0.070	-	0.070	0.070	0.070	-	1
Total Phosphorus (mg/L) – Storm Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citico Creek	-	-	-	-	-	-	-
Dobbs Branch**	-	-	<0.500	<0.500	0.548	-	3
Friar Branch	<0.500	-	<0.500	<0.500	<0.500	-	3
Greenway Farms	<0.500	-	<0.500	<0.500	<0.500	-	3
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	-	-	-	-	-	-	-

South Chick	-	-	-	-	-	-	-
Stringers Branch*	0.070	-	0.070	0.070	0.070	-	1
Total Phosphorus (mg/L) – Ambient Samples							
	Mean	Std Deviation	Median	Minimum	Maximum	Range	Count
Citco Creek	<0.500	-	<0.500	<0.500	<0.500	-	2
Dobbs Branch	<0.500	-	<0.500	<0.500	<0.550	-	4
Friar Branch	<0.500	-	<0.500	<0.500	<0.500	-	4
Greenway Farms	<0.500	-	<0.500	<0.500	<0.500	-	4
Ivy Academy	-	-	-	-	-	-	-
Mountain Creek	<0.500	-	<0.500	<0.500	<0.500	-	2
South Chick	<0.500	-	<0.500	<0.500	<0.500	-	2
Stringers Branch	-	-	-	-	-	-	-

*Due to a single sample being collected, the mean displayed here reflects the results of that sample.

**Mean, standard deviation and range are not displayed due to only a single sample being above the detection limit of 0.500 mg/L. The maximum value displayed here reflects the results of that sample.

Appendix

Monitoring Station Location Maps

City of Chattanooga/Hamilton County Monitoring Stations - Citico Creek



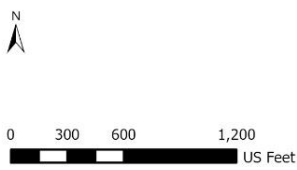
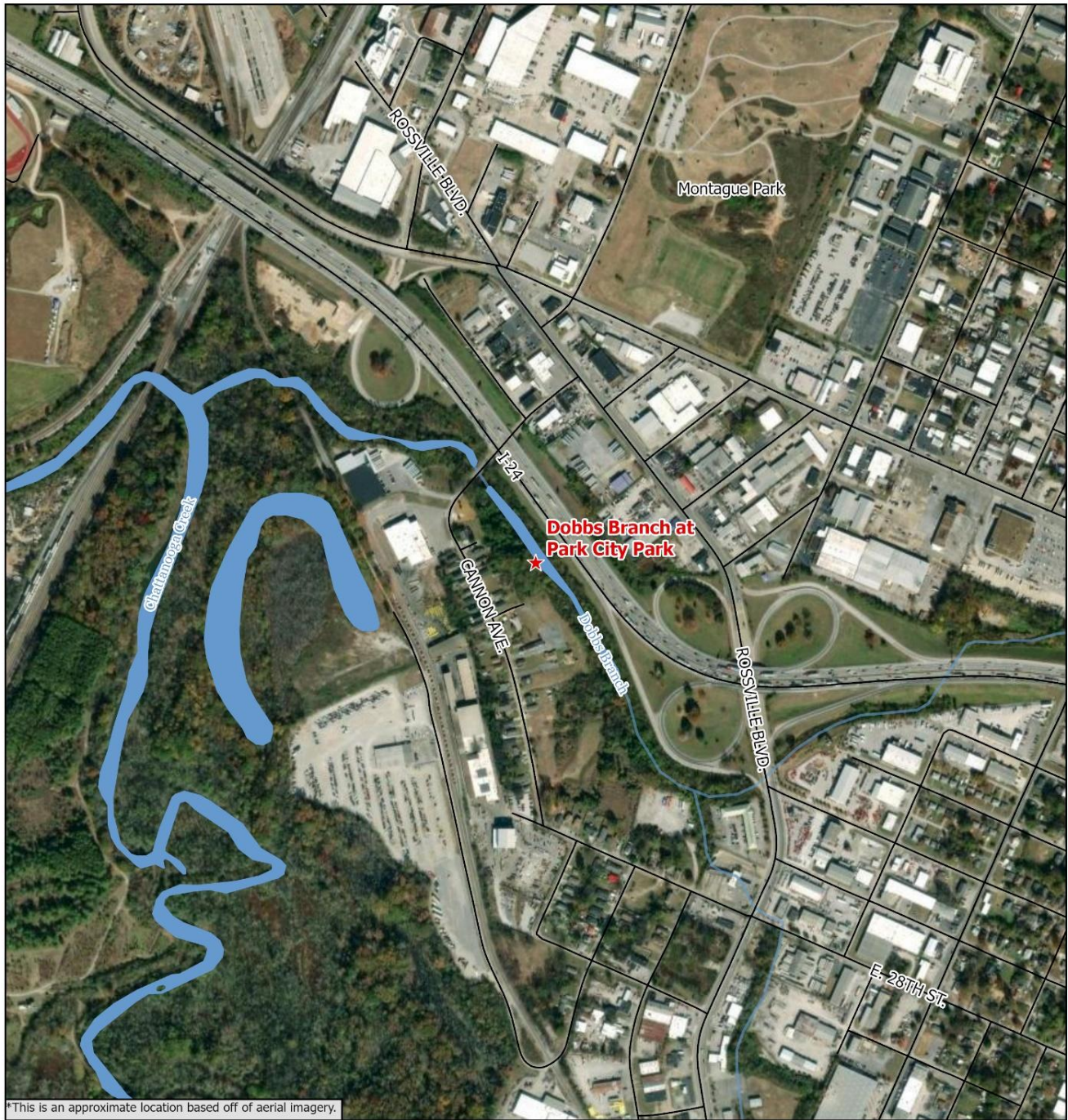
0 300 600 900 1,200
US Feet

Legend

- ★ Monitoring Station
- Road
- Hydro Layer
- Stream



City of Chattanooga/Hamilton County Monitoring Stations - Dobbs Branch at Park City Park



Legend

Monitoring Station

Stream

Waterbody

Road

City of Chattanooga/Hamilton County Monitoring Stations - Friar Branch at Polymer Drive



0 300 600 1,200
US Feet

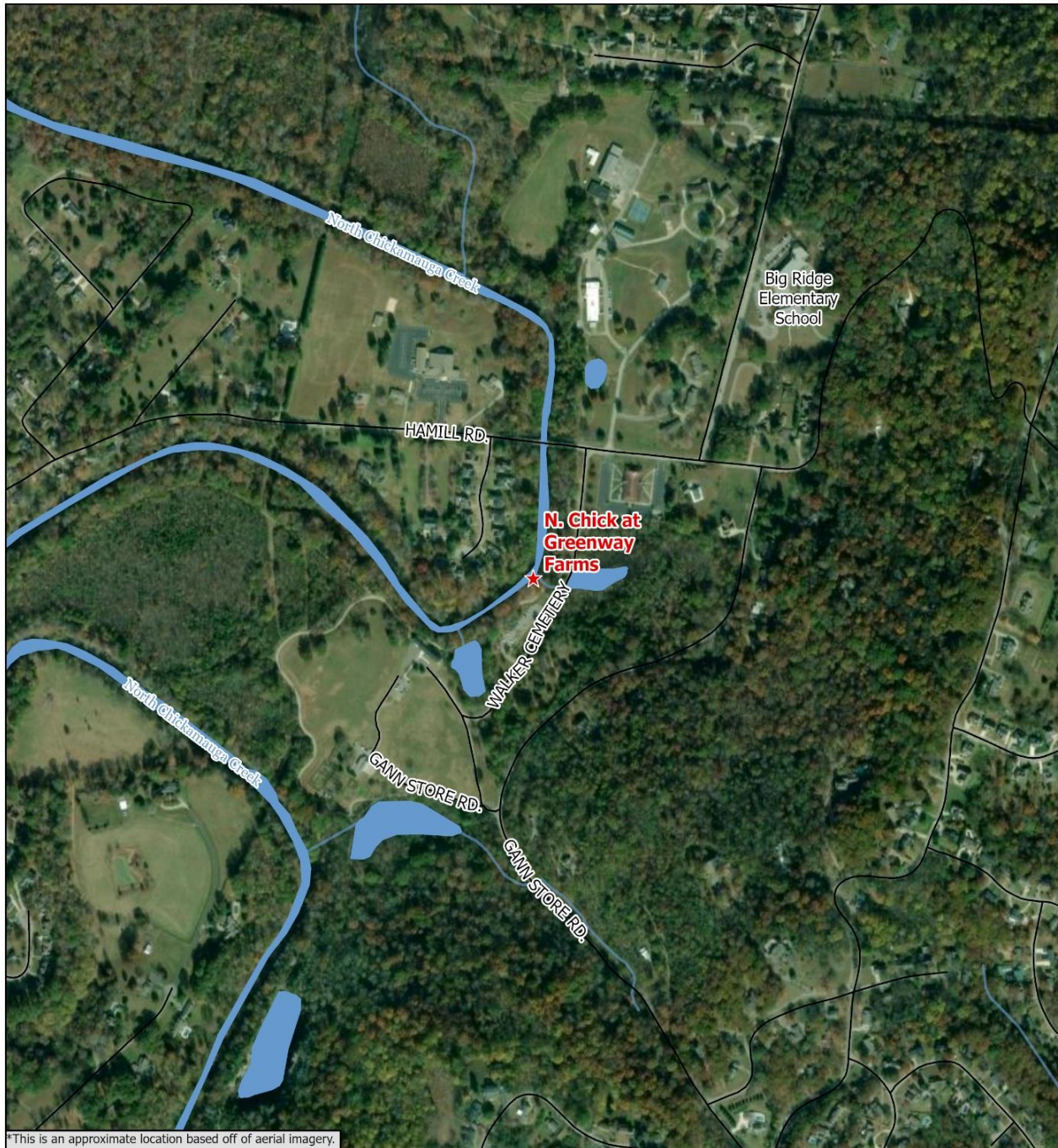
Legend

- ★ Monitoring Station
- Road
- Stream
- Waterbody



WOOLPERT

City of Chattanooga/Hamilton County Monitoring Stations - North Chickamauga Creek at Greenway Farms



0 300 600 1,200
US Feet

Legend

★ Monitoring Station
— Road

— Stream
■ Waterbody



WOOLPERT

City of Chattanooga/Hamilton County Monitoring Stations - North Chickamauga Creek at Ivy Academy



0 300 600 900 1,200
US Feet

Legend

- ★ Monitoring Station
- Road
- Hydro Layer
- Stream



City of Chattanooga/Hamilton County Monitoring Stations - Mountain Creek at Red Bank Elementary



0 300 600 1,200
US Feet

Legend



Monitoring
Station

— Road

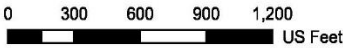
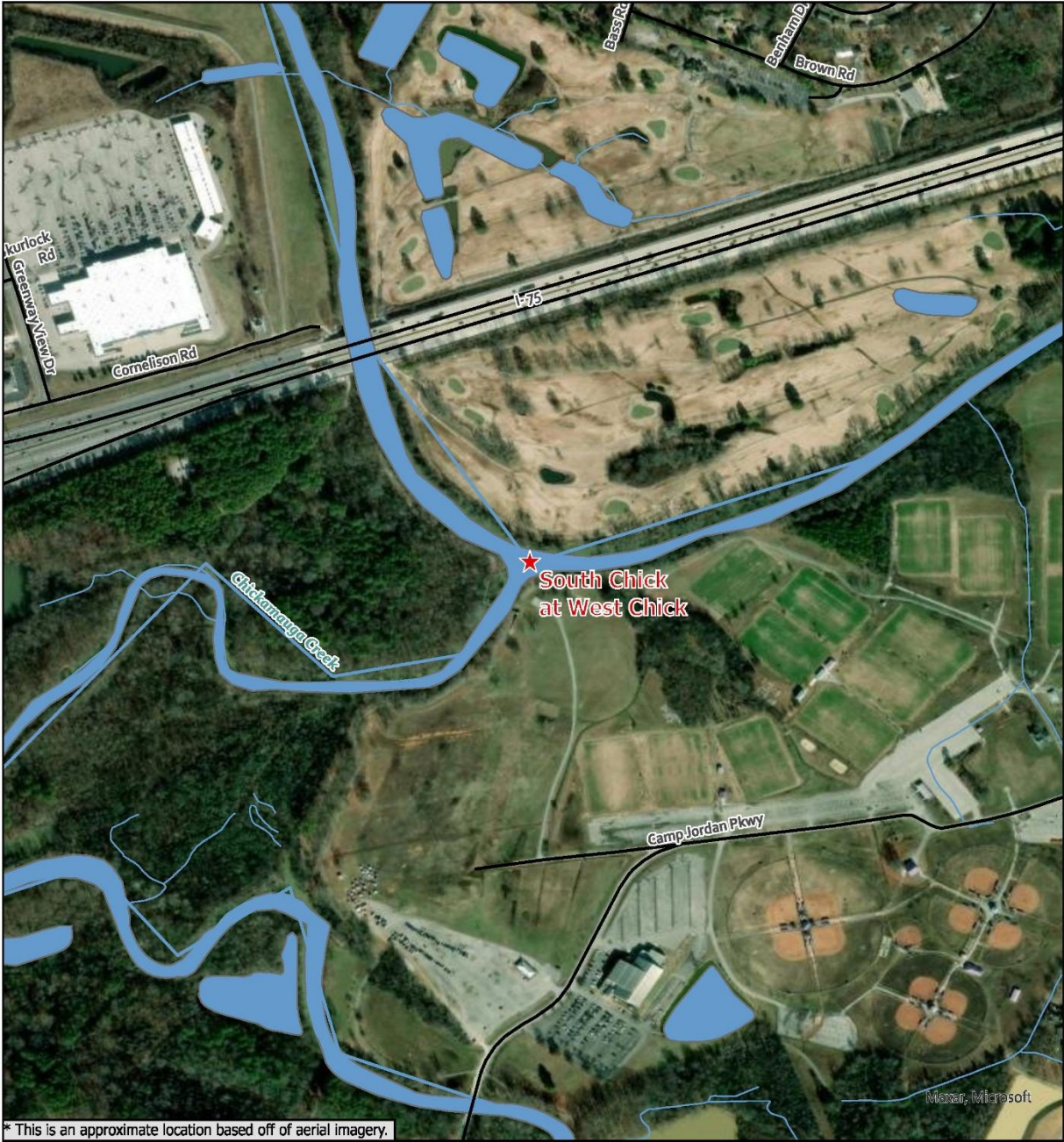
— Stream

Waterbody



WOOLPERT

City of Chattanooga/Hamilton County Monitoring Stations - South Chickamauga Creek at West Chickamauga



Legend

★	Monitoring Station	—	Hydro Layer
—	Road	—	Stream



City of Chattanooga/Hamilton County Monitoring Stations - Stringers Branch at Signal Mountain Road



0 300 600 1,200
US Feet

Legend

- ★ Monitoring Station
- Road
- Stream
- Waterbody



WOOLPERT