# CHEMICAL, BIOLOGICAL, AND PHYSICAL CHARACTERIZATION OF THE CHURCH CREEK AND PAROLE PLAZA NPDES MONITORING STATIONS: 2018 - 2019

Prepared for

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# 1 INTRODUCTION

In 1998, Anne Arundel County began implementing a long-term monitoring program that satisfies requirements for its Countywide National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit (Permit). Monitoring has continued to be required as part of the terms of each renewed permit. Currently, monitoring is required to satisfy conditions outlined in Section F: Assessment of Controls of the County's Permit issued in February 2014. The monitoring program includes chemical, biological, and physical monitoring in the Church Creek subwatershed located within the larger South River watershed. This document describes the monitoring effort undertaken during County Fiscal Year 2019 (July 2018 through June 2019). Versar, Inc. (Versar) was contracted by the County to perform the required monitoring for this reporting period.

Biological and physical monitoring take place at monumented locations along the study reach, as described in more detail below. The chemical monitoring activities take place at two stations in the Church Creek subwatershed:

- Downstream of two intensely developed commercial land use outfalls, called the Parole Plaza monitoring station
- An instream station downstream of the Route 2 culvert, called the Church Creek monitoring station

The basic permit requirements for storm event monitoring include sampling a target of 12 storms per year (three in each quarter) that are characterized by three representative (rising, peak, and falling limbs of the hydrograph) discrete samples per storm event, the collection of baseflow samples during extended dry periods, laboratory analysis of water quality parameters specified in the permit, biological and physical characterizations of the study reach, and continuous flow monitoring.

The County is interested in determining the extent to which stormwater management retrofit and stream restoration activities in the watershed have improved the quality of the stormwater effluent from the site. Retrofit and restoration efforts have included a) redevelopment of Parole Plaza (now known as the Annapolis Towne Centre at Parole); b) stream restoration in Church Creek; and c) stormwater pond retrofit at Annapolis Harbour Center.

Construction associated with the redevelopment of the Parole Plaza site (Annapolis Towne Centre at Parole), including installation of modified stormwater infrastructure and treatment, began in 2004 and the bulk of the site work was completed by late 2008. During late 2015 into early 2016, the South River Federation (now Arundel Rivers Federation), in cooperation with Anne Arundel County, undertook restoration of a portion of Church Creek behind the Annapolis Harbour Center and nearby the County's existing biological and physical monitoring sites. This work consisted of 1,500 linear feet of stream restoration and implementation of step-pool storm conveyance, riffle weirs, and grade control structures to improve habitat and increase floodplain connectivity. The retrofit of the stormwater pond at Annapolis Harbour Center took place during July to September 2017. The retrofit pond includes increased storage, additional forebays, a wetland berm, and wetland benches. The County's existing biological and physical monitoring locations downstream of these restoration and retrofit projects will be useful in assessing the cumulative effects of this work.

# 2 METHODS

## 2.1 CHEMICAL MONITORING

During the 2019 sampling period, July 2018 through June 2019, nine storm events were sampled and analyzed. This section describes the equipment and techniques used in this sampling program. It includes discussions of sample collection, sample analysis, flow data collection, and basin rainfall characterization. A summary of maintenance activities is also included. Data and quarterly data reports (Versar 2018, 2019a, and 2019b) were used to prepare this annual summary report.

### 2.1.1 Monitoring Sites

The long-term chemical monitoring program is performed at one outfall station, Parole Plaza, and one instream station, Church Creek. The two stations are described below:

**Parole Monitoring Station.** This station is a restoration station located at the head of the Parole Tributary to Church Creek. There are two outfalls draining to the sampling station. The first is a 60” corrugated metal pipe (CMP) that has been the historical sampling location for the monitoring of this station. The second is a 54” reinforced concrete pipe (RCP) that was connected to the drainage network during the summer of 2007 and is associated with the redevelopment of the Parole Plaza (aka Annapolis Towne Center).

**Church Creek Monitoring Station.** This station is an instream station on the mainstem of Church Creek. It is located approximately 500 feet downstream of the confluence of the Parole Tributary that carries the runoff from the Parole Plaza monitoring station. The samples are collected in the 96” CMP culvert that carries Church Creek underneath Maryland State Highway 2 (Solomons Island Road). The bottom of this culvert is lined with concrete that extends 1.8 feet in height up the sides of the corrugated metal culvert.

Location information and land use data were taken from the *Annapolis Towne Centre @ Parole Stormwater Management Report* (Greenhorne & O’Mara 2005), and summarized for each site in Tables 2-1 and 2-2. Using updated (2017) Anne Arundel County LIDAR data, impervious surface and catchment areas were updated for this 2019 report. Updates were performed to reflect current and more accurate drainage area information that is also utilized in calculation of certain habitat metrics.

| Table 2-1. Drainage areas and site locations of monitoring stations in Church Creek watershed | | | |
|---|---|---|---|
| **Monitoring Station** | **Station Type** | **Location** | **Area (acres)** |
| Parole Plaza | Restoration/Outfall | Southwest corner of Forest Drive and MD State Highway 2 | 106.04 |
| Church Creek | Instream | Downstream (east) of MD State Highway 2 | 281.49 |

| Table 2-2. Land use summary for the monitoring stations in the Church Creek subwatershed | | | | |
|---|---|---|---|---|
| **Land Use** | **Land Use Area (acres)** | | **Percent of Total Acreage** | |
| | **Parole Plaza** | **Church Creek** | **Parole Plaza** | **Church Creek** |
| Impervious | 83.19 | 194.67 | 78.5 | 69.2 |
| Open Space | 22.84 | 86.82 | 21.5 | 30.8 |
| **TOTAL** | **106.04** | **281.49** | **100** | **100** |

### 2.1.2 Water Sample Collection and Data Analysis

The sample period for this reporting cycle extended from July 2018 through June 2019. Samples are analyzed for the presence of the pollutants listed in Table 2-3.

| Table 2-3. Analytes, detection limits, and analytical methods for the Church Creek and Parole Plaza Monitoring stations | | |
|---|---|---|
| **Parameter** | **Detection Limit (mg/L)** | **Analytical Method** |
| Biochemical Oxygen Demand (5 Day) | 2/4 | SM 5210 B-01 |
| Total Kjeldahl Nitrogen | 0.5 | SM 4500-NH3 C97 |
| Nitrate + Nitrite | 0.05 | SM 4500-NO3 H00 |
| Total Phosphorus | 0.01 | SM 4500-P E99 |
| Total Suspended Solids | 1 | SM 2540 D-97 |
| Total Copper (µg/L) | 2 | EPA 200.8 |
| Total Lead (µg/L) | 2 | EPA 200.8 |
| Total Zinc (µg/L) | 20 | EPA 200.8 |
| Total Petroleum Hydrocarbons | 5 | EPA 1664 |
| *E. coli* (MPN/100 mL) | 1, 10, 100 | SM 9223 B |
| Hardness | 1 | SM 2340 C |

During the sampling period, nine storm samples were collected; four baseflow samples were taken in lieu of storm samples. Table 2-4 summarizes the sample dates and sample type.

Overall, two of the sampled events during each calendar quarter were storm events. Information pertinent to both baseflow and storm event samples is provided in the text below.

Table 2-4. Fiscal Year 2019 Sample Dates and Sample Type

| Sample Date | Sample Type |
|---|---|
| August 17, 2018 | B |
| August 21, 2018 | S |
| September 21, 2018 | B |
| October 11, 2018 | S |
| October 26, 2018 | S |
| November 9, 2018 | S |
| December 6, 2018 | B |
| January 19, 2019 | S |
| February 24, 2019 | S |
| March 21, 2019 | S |
| May 11, 2019 | S |
| June 13, 2019 | S |
| June 26, 2019 | B |

B: Baseflow Event
S: Storm Event

**Baseflow Monitoring**

- **August 17, 2018**

Summer quarter conditions, prior to August 17, were not amenable to sampling a storm event. Dry conditions prevailed before a major storm that inundated the area over the weekend of July 21–22. Trained field crew were unavailable to capture that storm when it began due to schedule conflicts. The severity of the storm, which delivered 6.5 inches of rain, and the subsequent days of continuing rain resulted in saturated conditions at the monitoring sites. Versar monitored the weather conditions to determine the next available 72-hour dry period prior to collecting the baseflow event on August 17.

- **September 21, 2018**

On two occasions in early September, field crews attempted to capture two storms; in both cases, the storms dissipated before depositing enough rainfall to satisfy program requirements. Subsequently, a Versar field crew collected samples to document baseflow conditions at both stations on September 21.

At Parole Plaza, staff observed flowing discharge in both pipes. At the 60-inch CMP, field staff documented a water level of 0.01 feet, and at the 54-inch RCP, water level height was 0.02 feet. Staff measured 0.578 feet of water at the outfall at Church Creek.

- **December 6, 2018**

Per County request, a Versar field team collected samples to document baseflow conditions at both stations on December 6, 2018. At Parole Plaza, staff observed flowing discharge only from the RCP in which field staff documented a water level of 0.03 feet. Staff measured 0.612 feet of water at the outfall at Church Creek.

- **June 26, 2019**

After the storm event on June 13, the Versar field team was ready to sample again but either missed the "pop-up" storms or the rain dissipated, and no sampling took place. On June 26, the field team collected baseflow samples. At Parole Plaza, staff observed flowing discharge only from the RCP in which field staff documented a water level of 0.09 feet. Staff measured 0.581 feet of water at the outfall at Church Creek.

**Storm Event Monitoring**

Below is a discussion of the storm events that were sampled during the monitoring period. Additional discussion of these events can be found in Appendix A.

- **August 21, 2018**

The storm event on August 21, 2018 delivered 1.13 inches of rain. The storm lasted approximately four hours. These measurements were based on data from the Church Creek rain gauge.

- **October 11, 2018**

The storm event on October 11, 2018 delivered 2.26 inches of rainfall and storm lasted approximately eight hours. These measurements were based on data from the Church Creek rain gauge.

- **October 26, 2018**

The storm delivered 0.98 inches of total rainfall and lasted approximately eight hours. These measurements are based on data from the Church Creek rain gauge.

- **November 9, 2018**

The storm delivered 0.47 inches of total rainfall and lasted approximately nine hours. These measurements are based on data from the Church Creek rain gauge.

- **January 19, 2019**

The storm event on January 19, 2019, delivered 0.55 inches of rainfall and lasted approximately five hours. These measurements were based on data from the Church Creek rain gauge.

- **February 24, 2019**

The storm delivered 0.62 inches of total rainfall and lasted approximately eleven hours. These measurements are based on data from the Church Creek rain gauge.

- **March 21, 2019**

The storm delivered 0.83 inches of total rainfall and lasted approximately fourteen hours. These measurements are based on data from the Church Creek rain gauge.

- **May 11, 2019**

The total rainfall for this event was 0.39 inches; the storm lasted approximately twelve hours. These measurements were based on data from the Church Creek rain gauge.

- **June 13, 2019**

The total rainfall for this event was 1.57 inches; the storm lasted approximately nine hours. These measurements were based on data from the Church Creek rain gauge.

Approximately 56.71 inches of precipitation was recorded at the Church Creek station during the 2019 reporting period. Rainfall was measured using a tipping bucket rain gauge located at the Church Creek station.

Table 2-5 lists the total rainfall for each sampled event. Hydrographs are provided in Appendix A. These data, along with stream level readings collected at five-minute intervals from a permanently mounted pressure transducer, were logged into an ISCO 6712FR automated sampler.

The ISCO sampler located at the Church Creek station is configured to hold 24 one-liter polyethylene bottles, and can be used to collect samples directly from the 96" CMP. However, this station is generally manned for the entire duration of each event. Therefore, all samples are typically taken as grabs from the culvert outfall. Total petroleum hydrocarbon and *E. coli* samples are always collected as manual grab samples per appropriate sampling protocol for these analytes. The grab sample location is approximately six feet downstream of the intake for the automated sampler and therefore is considered effectively the same sampling location as for the other parameters using the automated sampler.

| Table 2-5. Rainfall data for sampled storm events | |
|---|---|
| **Date** | **Rainfall (inches)** |
| 21 August 2018 | 1.13 |
| 11 October 2018 | 2.26 |
| 26 October 2018 | 0.98 |
| 09 November 2018 | 0.47 |
| 19 January 2019 | 0.55 |
| 24 February 2019 | 0.62 |
| 21 March 2019 | 0.83 |
| 11 May 2019 | 0.39 |
| 13 June 2019 | 1.57 |

When the 54” RCP was put in service at the Parole Plaza monitoring station in the summer of 2007, portions of the drainage that had historically been passing through the 60” CMP began flowing through the new pipe. To maintain consistency in the characterization of the watershed, it was determined that samples were required from both pipes. Pressure transducers were permanently mounted in the 60” CMP and 54” RCP. These measured water depth at 5-minute intervals, and stored data for up to three months. Data were downloaded bi-weekly. Stage/discharge relationships were developed for each outfall pipe, to determine the discharge based on depth measurements from the pressure transducer. The relationships are based on a combination of field measurements and extrapolated values. The extrapolation is necessary to characterize major storm events where directly measured values are not currently available. The rating tables are included in Appendix A.

A spreadsheet was developed to allow the field sampling crews to input field-measured level data. The spreadsheet interpolated the corresponding flow from the rating curves developed as described above. The flows from the 60” CMP and the 54” RCP were totaled and the resulting combined hydrograph for each event was plotted in real-time. This method allowed the field crews to determine when the rising, peak, and falling limbs for the combined hydrograph occurred. The spreadsheet also calculated the percentage of the combined flow that each outfall pipe was contributing. Using volumetric containers, the sampling team prepared composite samples using these percentages, and distributed them to the sample containers. A Technical Memorandum describing the composite sampling procedures in detail was submitted to the Maryland Department of the Environment in May 2008, and is included in Appendix A. To identify which pipe (CMP or RCP) discharged elevated concentrations of *E. coli*, the County requested that *E. coli* samples be collected and analyzed separately, beginning in summer 2017. Previously the samples collected during each limb were composited during the storm event as described above and the results were provided as single values. Using the new method, the discharge volume weighted average of the two results per limb was calculated in the EMC spreadsheet to arrive at a single, composite result.

Water quality instruments for measuring pH, temperature, and conductivity were used at both stations. At Parole, an In-Situ Troll 9500 unit mounted within each pipe was used to obtain measurements during storm events, providing measurements every five minutes. Measurements for these parameters were not available when personnel were not present due to the low flow conditions at this station. Permanently installed probes would likely dry out and need to be replaced often, thus these units are engaged only during storm events. At the Church Creek station, a YSI 600 XL multiparameter sonde was permanently mounted within the culvert and was connected directly to the ISCO automated sampler; providing measurements every five minutes. This unit operates continuously.

Samples were distributed into appropriate bottles provided by Martel Laboratories and delivered within 48 hours, except for *E. coli* samples which were delivered to Water Testing Labs of Maryland due to a shorter, six hour, holding time.

Event Mean Concentrations (EMCs) for each parameter were calculated for each storm and applied to total stormflow discharges to calculate stormflow pollutant loads for each site. An EMC is a statistical parameter used to represent the flow-weighted average concentration of a given parameter during a storm event (USEPA 2002). The EMC for a storm event where discrete samples have been collected (i.e., samples collected during the rise, peak, and falling limb of a storm event), was calculated using the following formula:

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i}$$

where,

V: volume of flow during period *i*, which is determined from the interval associated with the samples collected during each limb

C: analytical result associated with period *i*

n: total number of limbs taken during event

The stormflow pollutant load for each parameter was calculated using:

$$Load = EMC_j V_j$$

where,

V: total volume of flow during period *j* (entire storm event).

Average annual EMCs were calculated by taking the arithmetic average of EMCs calculated when non-detects were set to zero and when non-detects were set to the detection limit. Since the true concentration of non-detect samples falls somewhere between the detection limit and the null value, this calculation represents a more accurate estimate than using EMCs with non-detects set to either zero or the detection limit. Seasonal loads (also referred to as quarterly loads) for monitored events were calculated by summing all monitored event loads for a specific season. Total seasonal loads were calculated by multiplying the average seasonal EMC by the total volume for the season. Annual loads were calculated by summing all seasonal loads.

### 2.1.3 Monitoring Station Maintenance and Concerns

Maintenance was conducted at each sampling station on a biweekly basis. Maintenance included calibration of all probes, inspection of the sampling equipment, intake lines, and programming; and an overall cleaning and organization of the stations. A few issues concerning the replacement of monitoring equipment and the loss of data occurred during the monitoring period; below is a summary of these issues:

- Versar staff downloaded data from the ISCO sampler and Global Water WL-16 loggers during maintenance visits and the attempted storm sampling events. During the routine maintenance visit to Parole Plaza on July 13, 2018 staff determined that the level recorded by the Global Water logger for the CMP was not within the range of the levels measured manually. Field staff calibrated the logger successfully on August 20, at approximately 11 a.m., before the storm event on August 21. For the data records, Versar analysts adjusted the data values that were out of range to match field measurements recorded during baseflow monitoring on August 17. The analysts also reviewed the stage record, removed erroneous readings, and adjusted values to baseflow level.

  During the routine maintenance on July 13, Versar staff observed a split in the internal wire on the cap of the Global Water logger at the RCP at Parole Plaza. Field staff attempted a temporary repair during the field visit. On the next routine visit, field staff observed that the wire was not properly attached. The staff reviewed the data record from the logger and noted that the device had stopped recording within 24 hours after the repair. Staff installed a temporary logger in the pipe on August 11, at approximately 5:30 p.m., and returned the damaged device to Versar's Columbia office. Staff later shipped the logger to the appropriate service facility for repair. Field staff realized later that the calibration was performed incorrectly on the logger for the RCP while being installed. Since the water level is usually very low, the logger cannot read it accurately, so the field team calibrated the logger to 0.02 feet to enable accurate measurements. Field staff recalibrated the logger on August 20, at 11:40 a. m., before the storm event on August 21. For the data records documenting the period between the installation and recalibration at the RCP, data analysts adjusted the values representing the water level to 0.02 feet; this estimate accounts for the characteristic flow that field crews typically observe in the RCP.

- During the routine maintenance visit to Parole Plaza on November 20, staff determined that the level recorded by the Global Water logger for the CMP was drifting to an unacceptable negative value. Field staff calibrated the logger to correct the stage measurements. During the next biweekly maintenance visit, field staff noted that the readings were about 1.0 feet with dry pipe conditions. Field staff replaced the logger because the accuracy of measurements continued to degrade. Versar removed the erroneous data from the continuous record.

- During the routine maintenance visit to Parole Plaza on March 6, Versar staff documented a positive level logger reading coming from the CMP during a period of no flow. While investigating the issue, the field staff found and removed ice, which had built up on the logger and caused inflated stage values to be recorded. Staff substituted 0 feet as a surrogate for the logger data that were recorded during the affected time period. Data records are missing from March 28 at 11:40 p.m. until April 8 at 12:40 p.m. due to a discharged battery for the Global Water logger in the CMP.

- While downloading the equipment during the routine maintenance visit to Parole Plaza, Versar staff noted the batteries had died in the stage logger in the RCP on June 19 at 1 p.m.. Data are missing until the batteries were replaced during the subsequent maintenance visit on June 26 at 11:30 a.m.

## 2.2 BIOLOGICAL MONITORING

All biological assessment data were collected in accordance with the Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan (Anne Arundel County 2017), which incorporates many elements of Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS). Geomorphic assessment data were collected in accordance with the standard operating procedures (SOPs) approved for the County's NPDES Program. All methods are consistent with previous years' methods (with applicable updates) to ensure data comparability between years. Collection methods are summarized below. Field data were collected in 2019 by Versar, Inc.

### 2.2.1 Sampling Locations

The study area is located in the northern portion of the Church Creek subwatershed, within the larger South River watershed in Anne Arundel County, Maryland (Figure 2-1). A total of four 75-meter biological monitoring sites are positioned along the study reach and are monitored annually. Three sites were established and first monitored in 2006; one site is located on the Parole Plaza Tributary just below Forest Drive, and two sites are located along the Church Creek mainstem, on either side of Solomons Island Road (Maryland State Highway 2). A fourth site, located just upstream of the confluence with the Parole Plaza Tributary, was added in 2007 to monitor the effects of runoff from the Festival at Riva shopping center.

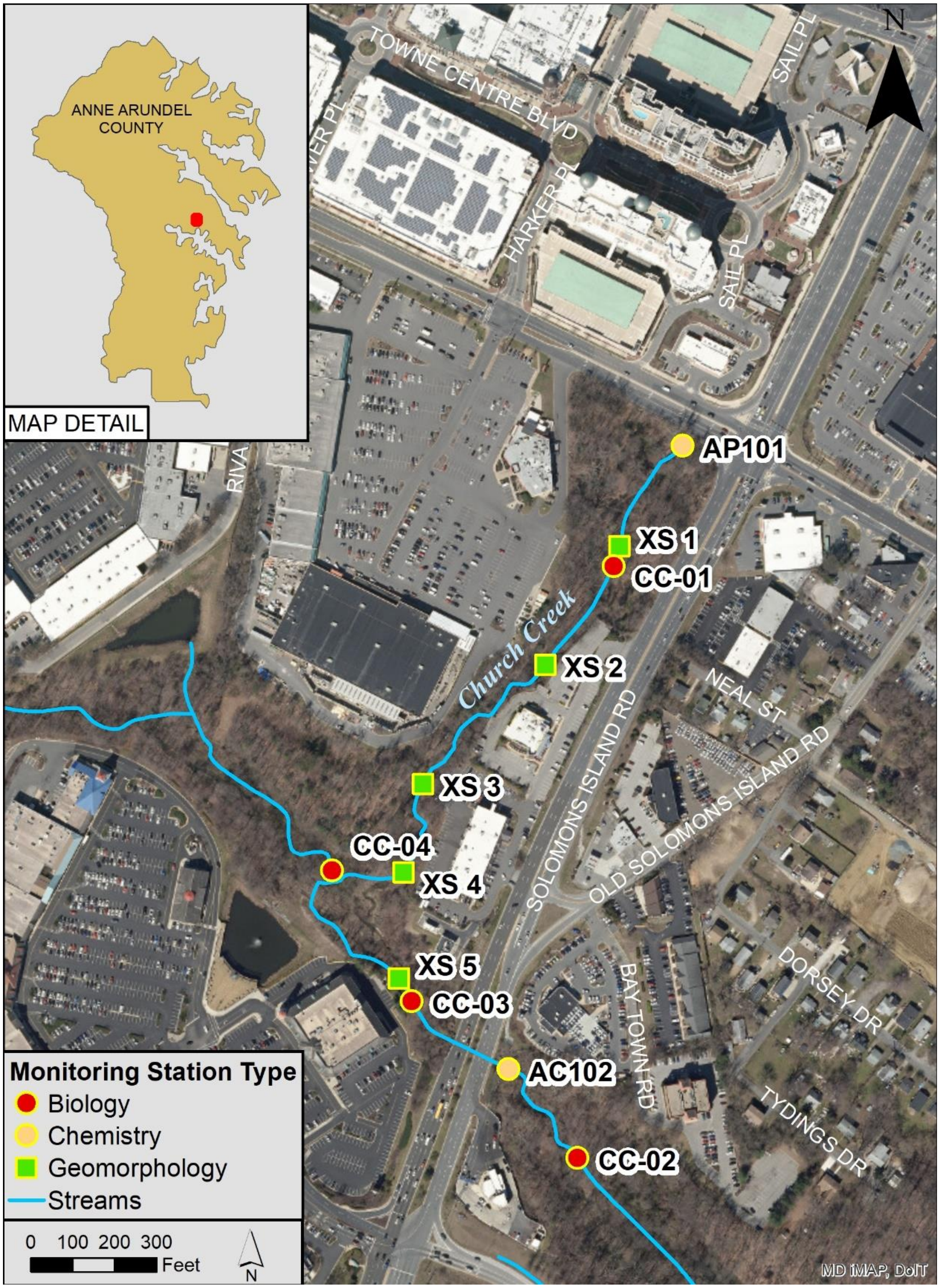


Figure 2-1. Church Creek study area and stream monitoring locations

### 2.2.2 Stream Habitat Evaluation

To support the biological monitoring, a visual assessment of physical habitat was completed at each monitoring site to evaluate the reach's ability to support aquatic life. Both the MBSS Physical Habitat Index (PHI; Paul et al. 2003) and the U.S. Environmental Protection Agency (U.S. EPA) Rapid Bioassessment Protocol (RBP) habitat assessment for low gradient streams (Barbour et al. 1999) were used to visually assess the physical habitat at each site in conjunction with the spring benthic monitoring. Both habitat assessments consist of a review of biologically significant habitat parameters that evaluate a stream's ability to support an acceptable level of biological health.

To calculate PHI at each site, six parameters were given a numerical score and a categorical rating: instream habitat, epifaunal substrate, remoteness, instream woody debris and rootwads, shading, and bank stability. The raw scores are then transformed into a scaled score (0-100 scale) as described in Paul et al. (2003), and the six scaled scores are averaged into an aggregate final PHI score. Narrative condition descriptions and scoring ranges for the PHI are displayed in Table 2-6.

Table 2-6. Maryland Biological Stream Survey PHI scoring

| Score | Narrative |
|---|---|
| 81-100 | Minimally Degraded |
| 66-80.9 | Partially Degraded |
| 51-65.9 | Degraded |
| 0-50.9 | Severely Degraded |

The Rapid Bioassessment Protocol (RBP) habitat assessment consists of a review of ten biologically significant habitat parameters that assess a stream's ability to support an acceptable level of biological health: Epifaunal substrate/available cover, Embeddedness, Velocity/depth regime, Sediment deposition, Channel flow status, Channel alteration, Frequency of riffles/ bends, Bank stability, Vegetative protection, and Riparian vegetative zone width. In the field, each parameter was given a numerical score from 0-20 (20=best, 0=worst), or 0-10 (10=best, 0=worst) for individual bank parameters, and a categorical rating of optimal, suboptimal, marginal or poor (Barbour et al. 1999). As overall habitat quality increases, the total score for each site typically increases. The individual RBP habitat parameters for each reach were summed to obtain an overall RBP assessment score. Because adequate reference conditions currently do not exist for Anne Arundel County, the percent comparability was calculated based on western coastal plain reference site conditions obtained from work done in Prince George's County streams (Stribling et al. 1999). The percent of reference score, or percent comparability score, was then used to place each site into corresponding narrative rating categories. The ranges are shown in Table 2-7.

| Table 2-7. EPA Rapid Bioassessment Protocol (RBP) scoring | |
|---|---|
| **Percent of Reference Score** | **Narrative** |
| 90 - 100 | Comparable to Reference |
| 75.1 - 89.9 | Supporting |
| 60.1 - 75 | Partially Supporting |
| 0 - 60 | Non-Supporting |

### 2.2.3 Water Quality Measurement

*In situ* water quality was measured at each site with a YSI ProDSS multiparameter water quality sonde. Turbidity was measured once at the upstream end of the site, all other parameters were measured from three locations within each sampling reach (upstream end, mid-point, and downstream end) and results were averaged to minimize variability and better represent water quality conditions throughout the entire sampling reach. Data were compared to the standards listed in the Code of Maryland Regulations (COMAR) 26.08.02.03-3 – Water Quality (MDE 2016) and shown in Table 2-8.

| Table 2-8. Maryland COMAR water quality standards for use I Streams | |
|---|---|
| **Parameter** | **Standard** |
| pH | 6.5 to 8.5 |
| Dissolved Oxygen (mg/L) | Minimum of 5 mg/L |
| Conductivity (µS/cm) | No existing standard |
| Turbidity (NTU) | Maximum of 150 NTU and maximum monthly average of 50 NTU |
| Temperature (°C) | Maximum of 32 °C (90 °F) or ambient temperature, whichever is greater |
| Source: Code of Maryland Regulations (COMAR) 26.08.02.03-3-Water Quality | |

### 2.2.4 Biological Sample Collection

Benthic macroinvertebrate samples were collected in April 2019 following the MBSS Spring index period protocols (MD DNR 2017) and as specified in *Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan* (QAPP; Anne Arundel County 2017). This methodology emphasizes the community composition and relative abundance of benthic macroinvertebrates inhabiting the most taxonomically diverse, or productive, instream habitats. In this sampling approach, a total of twenty jabs are distributed among the most productive habitats present within the 75-meter reach and sampled in proportion to their occurrence within the segment. The most productive stream habitats are riffles followed by rootwads, rootmats, and woody debris and associated snag habitat; leaf packs; submerged macrophytes and associated substrate; and undercut banks. Other less preferred habitats include gravel, broken peat, clay lumps and detrital or sand areas in runs; however, of the aforementioned habitat types, those that are located within moving water are preferred over those in still water.

### 2.2.5 Biological Sample Processing and Identification

Benthic macroinvertebrate samples were processed and subsampled according to Maryland Biological Stream Survey methods described in the MBSS laboratory methods manual (Boward and Freidman, 2000) and as briefly summarized in the Anne Arundel County Biological Monitoring and Assessment Program: Quality Assurance Project Plan (Anne Arundel County 2017). Subsampling is conducted to standardize the sample size and reduce variation caused by field collection methods. In brief, the sample was washed of preservative in a 0.595 mm screen and spread evenly across a tray comprised of 100 numbered 5cm x 5cm grids. A random number between one and 100 was selected and the selected gird was picked entirely of macroinvertebrates under a bright light source. This process was repeated until a count of 120 was reached. The 120 organism target was used following MBSS methods to allow for specimens that are missing parts or are early instars, which cannot be properly identified.

The samples were taxonomically identified by Versar taxonomists certified by the Society for Freshwater Science (SFS) (formerly known as the North American Benthological Society, NABS). The taxonomic hierarchical level for most organisms was genus level when possible with the exception of Oligochaeta, which were identified to the family level. Early instars or damaged specimens were identified to the lowest possible level. Oligochaeta and Chironomidae specimens were permanently slide mounted for identification. Counts and identifications were recorded on a laboratory bench sheet and entered into a master database for analysis. A list of all taxa identified is provided in Appendix B: Master Taxa List.

### 2.2.6 Biological Data Analysis

Benthic macroinvertebrate data were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and/or habitat impairment. The metrics selected fall into five major groups including taxa richness, composition measures, tolerance to perturbation, trophic classification, and habit measures.

Raw values from each metric are given a score of 1, 3, or 5 based on ranges of values developed for each metric. The results are combined into a scaled BIBI score ranging from 1.0 to 5.0 and a corresponding narrative rating is assigned. Table 2-9 shows the thresholds for the determination of the metric scoring. Three sets of metric calculations have been developed for Maryland streams based on broad physiographic regions: Coastal Plain, Piedmont and Combined Highlands. The Coastal Plain and Piedmont regions are divided by the Fall Line. The current study area is located within the Coastal Plain region. The metrics calculated for Coastal Plain streams are as follows:

***Total Number of Taxa*** – Equals the richness of the community in terms of the total number of genera at the genus level or higher. A large variety of genera typically indicate better overall water quality, habitat diversity and/or suitability, and community health.

***Number of EPT Taxa*** – Equals the richness of genera within the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EPT taxa are generally considered pollution sensitive, thus higher levels of EPT taxa would be indicative of higher water quality.

***Number of Ephemeroptera Taxa*** – Equals the total number Ephemeroptera Taxa in the sample. Ephemeroptera are generally considered pollution sensitive, thus communities dominated by Ephemeroptera usually indicate lower disturbances in water quality.

***Percent Intolerant Urban*** – Percentage of sample considered intolerant to urbanization. Equals the percentage of individuals in the sample with a tolerance value of 0-3 out of 10. As impairment increases the percent of intolerant taxa decreases.

***Percent Ephemeroptera*** – Equals the percent of Ephemeroptera individuals in the sample. Ephemeroptera are generally considered pollution sensitive, thus communities dominated by Ephemeroptera usually indicate lower disturbances in water quality.

***Number Scraper Taxa*** – Equals the number of scraper taxa in the sample, those taxa that scrape food from the substrate. As the levels of stressors or pollution rise there is an expected decrease in the numbers of Scraper taxa.

***Percent Climbers*** – Equals the percentage of the total number of individuals who are adapted to living on stem type surfaces. Higher percentages of climbers typically represent a decrease in stressors and overall better water quality.

All of the metric scores are summed and then averaged to obtain the final BIBI score. Table 2-10 shows the scores and narrative rankings of the MBSS BIBI. The biological assessment results are included in Appendix C. The QA/QC information is included in Appendix D.

Table 2-9. Biological condition scoring for the coastal plains metrics

| **Metric** | **Score** | | |
|---|---|---|---|
| | **5** | **3** | **1** |
| Total Number of Taxa | ≥ 22 | 14-21 | < 14 |
| Number of EPT Taxa | ≥ 5 | 2-4 | < 2 |
| Number of Ephemeroptera Taxa | ≥ 2 | 1.9-1.0 | < 1.0 |
| Percent Intolerant Urban | ≥ 28 | 10-27 | < 10 |
| Percent Ephemeroptera | ≥ 11 | 0.8-10.9 | < 0.8 |
| Number of Scraper Taxa | ≥ 2 | 1.9-1.0 | < 1.0 |
| Percent Climbers | ≥ 8.0 | 0.9-7.9 | < 0.9 |

| Table 2-10. Maryland Biological Stream Survey BIBI scoring | | |
|---|---|---|
| **BIBI Score** | **Narrative Ranking** | **Characteristics** |
| 4.0-5.0 | Good | Comparable to reference conditions, stream considered to be minimally impacted, biological metrics fall within upper 50th percentile of reference site conditions. |
| 3.0-3.9 | Fair | Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of minimally impacted streams. |
| 2.0-2.9 | Poor | Significant deviation from reference conditions, indicating some degradation. On average, biological metrics fall below the 10th percentile of reference site values. |
| 1.0-1.9 | Very Poor | Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of minimally impacted streams, indicating severe degradation. On average, most or all metrics fall below the 10th percentile of reference site values. |

## 2.3 PHYSICAL MONITORING

### 2.3.1 Monitoring Sites

Five cross-sections (XS), four of which were established in 2003 and one which was established in 2007, have been measured annually through 2019. Four of these cross-sections are located along the Parole Plaza Tributary, and one cross-section is located on the Church Creek mainstem, just upstream of Solomon's Island Road (Maryland State Highway 2; Figure 2-1). Cross-section monuments, placed on each bank, consist of capped steel reinforcement bars set within six inches of the ground surface. Field data collected by Versar, Inc. during 2019 were used to prepare this annual summary report.

### 2.3.2 Physical Data Collection and Analysis

Geomorphic assessments include a longitudinal profile survey, cross-section surveys, and representative pebble counts. A spreadsheet tool, *The Reference Reach Spreadsheet* version 4.3L (Mecklenburg 2006), was used to facilitate data entry and analyses. This spreadsheet was used to compile, manipulate, and plot field data and to analyze dimension, profile, and channel material characteristics of the Church Creek study area.

Data from geomorphic assessments were used to determine the stream type of each reach as categorized by the Rosgen Stream Classification methodology (Rosgen 1996). In this classification methodology, streams are categorized based on their measured field values of entrenchment ratio, width/depth ratio, sinuosity, water surface slope, and channel materials according to the table in Appendix E. As illustrated in Appendix E, the Rosgen Stream Classification categorizes streams into broad stream types, which are identified by the letters Aa, A, B, C, D, DA, E, F, and G. Table 2-11 includes general descriptions of each Rosgen stream type. A summary of the stream types identified within this study is included in Appendix F.

Table 2-11. Rosgen stream classification types

| Channel Type | General Description |
|---|---|
| Aa+ | Very steep, deeply entrenched, debris transport, torrent streams. |
| A | Steep, entrenched, confined, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel. |
| B | Moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Moderate width/depth ratio. Narrow, gently sloping valleys. Very stable plan and profile. Stable banks. |
| C | Low gradient, meandering, slightly entrenched, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains. |
| D | Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. Active lateral adjustment, high bedload and bank erosion. |
| DA | Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks. |
| E | Low gradient, Highly sinuous, riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander/width ratio. |
| F | Entrenched, meandering riffle/pool channel on low gradients with high width/depth ratio and high bank erosion rates. |
| G | Entrenched "gully" step/pool and low width/depth ratio on moderate gradients. Narrow valleys. Unstable, with grade control problems and high bank erosion rates. |

Source: Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado

The cross-section surveys were performed at the five permanent cross-section locations, and photos were taken of upstream, downstream, left bank, and right bank views at each cross-section location. Cross-section surveys consisted of measuring the topographic variability of the associated stream bed, floodplains, and terraces, including:

- Monument elevations
- Changes in topography
- Top of each channel bank
- Elevations of bankfull indicators
- Edge of water during the time of survey
- Thalweg or deepest elevation along active channel
- Depositional and erosional features within the channel

During the cross-sectional survey, the following measurements and calculations of the bankfull channel, which are critical for determining the Rosgen stream type of each reach, also were collected:

- Bankfull Width (Wbkf): the width of the channel at the elevation of bankfull discharge or at the stage that defines the bankfull channel.
- Mean Depth (dbkf): the mean depth of the bankfull channel.
- Bankfull Cross-sectional Area (Abkf): the area of the bankfull channel, estimated as the product of bankfull width and mean depth.
- Width Depth Ratio (Wbkf/dbkf): the ratio of the bankfull width versus mean depth.
- Maximum Depth (dmbkf): the maximum depth of the bankfull channel, or the difference between the thalweg elevation and the bankfull discharge elevation.
- Width of Floodprone Area (Wfpa): the width of the channel at a stage of twice the maximum depth. If the width of the floodprone area was far outside of the channel, its value was visually estimated or paced off.
- Entrenchment Ratio (ER): the ratio of the width of the floodprone area versus bankfull width.
- Sinuosity (K): ratio of the stream length versus the valley length or the valley slope divided by the channel slope. Sinuosity was visually estimated or the valley length was paced off so that an estimate could be calculated.

To quantify the distribution of channel substrate particles sizes within the study area, a modified Wolman pebble count (Rosgen 1996) was performed at each cross-section location. Reach-wide proportional counts were used. Each pebble count consists of stratifying the reach based on the frequency of channel features in that reach (e.g., riffle, run, pool, glide) and measuring 100 particles across ten transects (i.e., 10 particles in each of 10 transects). The transects are allocated across all feature types in the proportion at which they occur within the reach. The intermediate axis of each measured pebble is recorded. The goal of the pebble count is to measure 100 particles across the bankfull width of the channel and calculate the median substrate particle size (i.e., $D_{50}$) of the reach. This value is used for categorizing the sites into the Rosgen Stream Classification (Rosgen 1996). If a channel was clearly a sand or silt bed channel with no distinct variation in material size, the pebble count was not performed, and the $D_{50}$ was visually estimated. However, if the channel did have variation in bed material size from feature to feature, a full pebble count was performed.

# 3 RESULTS

## 3.1 POLLUTANT CONCENTRATIONS

During this sampling period, 59 water chemistry samples were analyzed. In some instances, analyte concentrations fell below the specified detection limits. Table 3-1 shows the percentage of samples that were below the detection limit.

Table 3-1. The percentage of non-detects by parameter

| Parameter | Detection Limit | Wet Weather | Dry Weather |
|---|---|---|---|
| $BOD_5$ (mg/L) | 2/4 | 72 | 67 |
| TKN (mg/L) | 0.5 | 75 | 67 |
| Nitrate + Nitrite (mg/L) | 0.05 | 0 | 0 |
| Total Phosphorus (mg/L) | 0.01 | 0 | 0 |
| TSS (mg/L) | 1 | 0 | 0 |
| Total Copper (µg/L) | 2 | 0 | 17 |
| Total Lead (µg/L) | 2 | 49 | 83 |
| Total Zinc (µg/L) | 20 | 0 | 0 |
| TPH (mg/L) | 5 | 85 | 83 |
| *E. coli* (MPN/100 mL) | 1, 10, 100 | 0 | 0 |
| Hardness (mg/L) | 1 | 0 | 0 |

Table 3-2 and Table 3-3 show the maximum values observed for dry and wet weather samples for both stations. The maximum value for each parameter during wet weather monitoring, station of occurrence, and storm date of observation are listed in Table 3-4. Of the two stations, Parole Plaza had the highest values for six of the thirteen parameters measured during wet weather sampling in 2019. Four of the maximum wet weather values for the parameters were measured during the June 13 storm event. The maximum *E. coli* concentration at Church Creek was 23,590 MPN/100 mL and was observed during the August 26 storm. Chemical monitoring summaries can be found in Appendix G.

| Table 3-2. Maximum dry weather values observed during sampling period | | |
|---|---|---|
| **Parameter** | **Church Creek** | **Parole Plaza** |
| Water Temperature (°F) | 75.20 | 77.76 |
| pH | 6.9 | 7.7 |
| $BOD_5$ (mg/L) | BDL | 59 |
| TKN (mg/L) | BDL | 9.0 |
| Nitrate + Nitrite (mg/L) | 1.00 | 6.00 |
| Total Phosphorus (mg/L) | 0.08 | 0.75 |
| TSS (mg/L) | 8 | 530 |
| Total Copper (µg/L) | 4 | 102 |
| Total Lead (µg/L) | BDL | 22 |
| Total Zinc (µg/L) | 47 | 596 |
| TPH (mg/L) | BDL | 6 |
| *E. coli* (MPN/100 mL) | 538 | 24,196 |
| Hardness (mg/L) | 120 | 270 |
| BDL: Below Detection Limit | | |

| Table 3-3. Maximum wet weather values observed during sampling period | | |
|---|---|---|
| **Parameter** | **Church Creek** | **Parole Plaza** |
| Water Temperature (°F) | 78.26 | 79.06 |
| pH | 7.1 | 9.5 |
| $BOD_5$ (mg/L) | 26 | 25 |
| TKN (mg/L) | 5.6 | 2.6 |
| Nitrate + Nitrite (mg/L) | 2.00 | 2.40 |
| Total Phosphorus (mg/L) | 3.30 | 0.36 |
| TSS (mg/L) | 340 | 330 |
| Total Copper (µg/L) | 70 | 72 |
| Total Lead (µg/L) | 61 | 14 |
| Total Zinc (µg/L) | 702 | 684 |
| TPH (mg/L) | 9 | 24 |
| *E. coli* (MPN/100 mL) | 23,590 | 17,586 |
| Hardness (mg/L) | 170 | 180 |
| BDL: Below Detection Limit | | |

| Table 3-4. Storm dates for wet weather maximum values | | | |
|---|---|---|---|
| **Parameter** | **Date of Storm** | **Site** | **Maximum Value** |
| Water Temperature (°F) | 8/21/18 | Parole Plaza | 79.06 |
| pH | 6/13/19 | Parole Plaza | 9.5 |
| $BOD_5$ (mg/L) | 6/13/19 | Church Creek | 26 |
| TKN (mg/L) | 6/13/19 | Parole Plaza | 5.6 |
| Nitrate + Nitrite (mg/L) | 10/26/18 | Parole Plaza | 2.40 |
| Total Phosphorus (mg/L) | 10/11/18 | Church Creek | 3.30 |
| TSS (mg/L) | 10/26/18 | Church Creek | 340 |
| Total Copper (µg/L) | 1/19/19 | Parole Plaza | 72 |
| Total Lead (µg/L) | 6/13/19 | Church Creek | 61 |
| Total Zinc (µg/L) | 8/21/18 | Church Creek | 702 |
| TPH (mg/L) | 1/19/19 | Parole Plaza | 24 |
| *E. coli* (MPN/100 ml) | 8/21/18 | Church Creek | 23,590 |
| Hardness (mg/L) | 1/19/19 | Parole Plaza | 180 |

## 3.2 EVENT MEAN CONCENTRATIONS AND POLLUTANT LOADINGS

Flow-weighted EMC values are presented in Table 3-5. EMCs for $BOD_5$, TKN, total phosphorus, nitrate-nitrite, TSS, lead, and hardness were higher at Church Creek than at Parole Plaza.

| Table 3-5. Average EMCs observed during July 2018 to June 2019 | | |
|---|---|---|
| **Parameter** | **Church Creek** | **Parole Plaza** |
| Water Temperature (°F) | 61.52 | 62.56 |
| pH | 6.6 | 8.0 |
| $BOD_5$ (mg/L) | 2 | 2 |
| TKN (mg/L) | 0.3 | 0.3 |
| Nitrate + Nitrite (mg/L) | 0.32 | 0.28 |
| Total Phosphorus (mg/L) | 0.14 | 0.07 |
| TSS (mg/L) | 35 | 17 |
| Total Copper (µg/L) | 9 | 11 |
| Total Lead (µg/L) | 4 | 1 |
| Total Zinc (µg/L) | 67 | 98 |
| TPH (mg/L) | 3 | 4 |
| *E. coli* (MPN/100 mL) | 5,275 | 5,720 |
| Hardness (mg/L) | 33 | 23 |

Summed, annual loads for the sampled events monitored during the July 2018 to June 2019 sampling period are shown in Table 3-6. Per-acre loading rates for monitored events were higher at Church Creek than at Parole Plaza for all parameters.

Table 3-6. Estimated pollutant loadings for all observed events, in pounds, for the July 2018 to June 2019 sampling period

| Parameter | Church Creek | | Parole Plaza | |
|---|---|---|---|---|
| | Total | Per Acre | Total | Per Acre |
| $BOD_5$ | 1,043 | 3.70 | 87 | 0.82 |
| TKN | 162 | 0.58 | 11 | 0.10 |
| Nitrate + Nitrite | 153 | 0.55 | 11 | 0.11 |
| Total Phosphorus | 66 | 0.24 | 3 | 0.03 |
| TSS | 16,547 | 58.8 | 687 | 6.5 |
| Total Copper | 4 | 0.01 | 0.4 | 0.004 |
| Total Lead | 2 | 0.007 | 0.06 | 0.001 |
| Total Zinc | 32 | 0.11 | 4 | 0.04 |
| TPH | 1,292 | 4.60 | 149 | 1.41 |
| Hardness | 15,512 | 55.1 | 932 | 8.8 |

## 3.3 BIOLOGICAL ASSESSMENT

Biological and physical habitat assessments were completed on April 25, 2019, within the Spring Index Period of March-April as established by the MBSS. Presented below are the summary results for each assessment site. For full bioassessment data and results, refer to Appendix C. A complete taxonomic list can be found in Appendix B. QA/QC information is in Appendix D. As introduced in Section 1, the South River Federation (now Arundel Rivers Federation), in cooperation with the County, undertook restoration of Church Creek in the vicinity of the existing biological and physical monitoring sites beginning in late January 2016. This work consisted of 1,500 linear feet of stream restoration and implementation of step-pool storm conveyance, riffle weirs, and grade control structures to improve habitat and increase floodplain connectivity. All of the CC-04 and part of the CC-03 biological monitoring sites were within the restored reach of the stream.

Physical habitat quality was evaluated using the MBSS PHI, and rated “Partially Degraded” for one site (CC-03) and “Degraded” for three sites (CC-01, CC-02, and CC-04; Table 3-7). Index scores ranged from a low of 57.38 at CC-02 to a high of 66.67 at CC-03. All sites received very low scores for remoteness due to the proximity of the stream channel to roads and development. The instream woody debris score was low for all sites, but the dewatered woody debris score was high for all sites. Instream habitat scores were rated “Marginal” at CC-01, CC-02, and CC-04, and “Sub-Optimal” at CC-03. Epifaunal substrates scores were rated “Poor” for CC-01, CC-02, and CC-04; CC-03 epifaunal substrate score was rated as “Sub-Optimal”.

Individual parameter results are listed in Appendix C. Overall, PHI scores decreased throughout the study area in 2019 and indicate that some habitat conditions may be limiting the potential for healthy biological communities.

The RBP score was also used to evaluate the physical habitat quality and rated “Non-supporting” at CC-01 and CC-02, “Partially Supporting” at CC-04, and “Supporting” at CC-03 (Table 3-7). Scores ranged from 51 at CC-01 to 80 at CC-03. Low epifaunal substrate/cover, bank stability and vegetative protections scores were the primary driver of low RBP scores at CC-01 and CC-02. CC-03, the site with the highest RBP rating, had channel alteration, pool variability, and channel flow status scores in the “Optimal” category; there was no metric that scored in the “Poor” category for this site. Overall, RBP scores throughout the study area indicate that physical habitat conditions at some sites could limit the potential for healthy, stable biological communities, similar to what was found using the PHI.

Table 3-7. PHI and RBP physical habitat assessment results – April 2019

| Site | PHI Score | PHI Narrative Rating | RBP Score | RBP Narrative Rating |
|---|---|---|---|---|
| CC-01 | 58.49 | Degraded | 51 | Non-Supporting |
| CC-02 | 57.38 | Degraded | 60 | Non-Supporting |
| CC-03 | 66.67 | Partially Degraded | 80 | Supporting |
| CC-04 | 60.44 | Degraded | 69 | Partially Supporting |

BIBI score narrative ratings at the Church Creek sites ranged from “Very Poor” at CC-01, CC-03, and CC-04 to “Poor” at CC-02, with scores between 1.57 and 2.14, indicating a highly impaired benthic macroinvertebrate community. Low BIBI scores were driven by low metric scores for Number of EPT taxa, Number of Ephemeroptera, Percent Ephemeroptera, and Percent Intolerant to Urban at all sites. Only one EPT taxon was found at each of CC-02 and CC-04 in 2019, with the remaining two sites being absent of EPT taxa. The Percent Clingers metric received average to high scores for all sites. The sub-samples at each station contained between 11 and 15 taxa and the majority of individuals were from the pollution tolerant Naididae and Tubificidae families and Chironomus genus, accounting for over 57% of all sub-sampled individuals. Poor habitat conditions and marginal water quality parameters may contribute to low BIBI scores at the Church Creek sites. BIBI scores and ratings are summarized in Table 3-8.

Table 3-8. Benthic macroinvertebrate assessment results – April 2019

| Site | BIBI Score | Narrative Rating |
|---|---|---|
| CC-01 | 1.57 | Very Poor |
| CC-02 | 2.14 | Poor |
| CC-03 | 1.86 | Very Poor |
| CC-04 | 1.86 | Very Poor |

To supplement the biological assessment data, *in situ* water quality parameters were measured at each biological monitoring site prior to sample collection. Table 3-9 shows the water quality data for each site. Temperature and turbidity were within Maryland COMAR water quality values for Use I streams. Dissolved oxygen at CC-04 was just below the threshold criteria of 5 mg/L, with an average reading of 4.92 mg/L, and pH at CC-01 was just below the threshold criteria of 6.5, with an average reading of 6.46; all other dissolved oxygen and pH readings at the four sampling locations were within Maryland COMAR water quality values for Use I streams. Church Creek conductivity values were elevated, particularly at CC-01, compared to most coastal plain streams, and exceeded the 75th percentile of values (i.e., 307 µS/cm) measured during Round One (2004-2008) of the Countywide Biological Monitoring and Assessment Program (Hill and Pieper, 2011), as well as higher than the range of those found in other urban, or highly impervious, drainage areas in Maryland (MD DNR, 2001, 2003, 2005; KCI, 2009; Hill and Crunkleton, 2009). Stream conductivity is affected by inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions or sodium, magnesium, calcium, iron, and aluminum cations, many of which are generally found at elevated concentrations in urban streams (Paul and Meyer, 2001). Increased stream ion concentrations (measured as conductivity) in urban systems are typically a result of runoff over impervious surfaces, passage through pipes, and exposure to other infrastructure (Cushman 2006). Seasonal use of road salt has most likely caused conductivity values to be high.

Table 3-9. *In situ* water quality results – April 2019

| **Site** | **pH** | **Temperature** | **Dissolved Oxygen** | **Turbidity** | **Conductivity** |
|---|---|---|---|---|---|
| | **SU** | **°C** | **mg/L** | **NTU** | **µS/cm** |
| CC-01 | 6.46 | 17.37 | 5.46 | 30.2 | 1065 |
| CC-02 | 6.74 | 17.40 | 7.33 | 20.5 | 662 |
| CC-03 | 6.87 | 17.37 | 7.74 | 7.6 | 664 |
| CC-04 | 6.88 | 18.27 | 4.92 | 18.6 | 638 |

## 3.4 GEOMORPHIC ASSESSMENT

Due to the highly altered conditions of the drainage area (i.e., high imperviousness, altered flow regime, numerous stormwater outfalls) and stream channel (i.e., channelization, stabilization) in the study area, reliable bankfull indicators were often difficult to locate in the field. In the absence of reliable bankfull indicators, bankfull elevations were adjusted to match the predicted values for bankfull area provided by the bankfull channel geometry relationship for urban streams developed specifically for Anne Arundel County (AADPW 2002). Furthermore, categorization of segments into the Rosgen Classification scheme for natural rivers required professional judgment, in some cases, to interpret the data. When assigning the stream classification types, values for some parameters fit into the prescribed ranges according to the Rosgen Classification while others would not. Many of the features at the existing cross-section locations have shifted from riffle features to pool features, which can skew the channel dimensions since classifications are based on riffle dimensions. Consequently, it was sometimes necessary to apply best professional judgment and incorporate supplemental information (e.g., presence of depositional features) to assign the most appropriate stream classifications. The Rosgen classification system is summarized in Appendix E and 2019 data for Church Creek sites are in Appendix F. Also noteworthy, prior to the 2016 geomorphic survey, stream restoration occurred downstream of XS-4, on an unnamed tributary, and upstream of XS-5 on the mainstem Church Creek in the vicinity of the Annapolis Harbor Center. As a result of this stream restoration construction and channel reengineering, the longitudinal profile length shortened between the 2015 and 2016 surveying. The 2019 geomorphic survey provides a look at changes three years after the restoration was completed between XS-4 and XS-5.

The most upstream reach on the Parole Plaza Tributary, XS-1, has been undergoing a transition from a Rosgen C4/5 channel to a F4 channel, as evidenced by changes in the width/ depth and entrenchment ratios. Previous monitoring in 2010 suggested that this reach was shifting from an E to a C channel because of channel degradation, a notable increase in sediment deposition, and point bar formation along the right bank just downstream. Additional degradation between 2010 and 2012 suggest that the channel had lost connectivity to the floodplain and had likely shifted to an F stream type. Mid-channel degradation continued between 2014 and 2019 showing approximately a 0.85-foot difference. In 2019, geomorphic assessment parameters continue to support the classification of this reach as an F4 channel. The channel evolution is supported by an 82.1% increase in channel cross-sectional area since 2003 and considerable widening and mid-channel bar formation immediately downstream, which is indicative of a channel that is not stable and is undergoing a widening and degradation phase. Cross-sectional area at this location has been increasing every year since 2009. Left bank widening was also apparent between 2013 and 2014 monitoring years, remained consistent during 2015 through 2018, and continued to widen in 2019. However, it is important to acknowledge that this cross-section is no longer located in a riffle feature and is now in a pool feature, which affects the channel dimensions and complicates classification using the Rosgen system.

The next site downstream on the Parole Plaza Tributary, XS-2, was classified as a Rosgen G4c channel based on its continued low width/depth ratio, low slope, and gravel substrate. Since 2012 its entrenchment ratio was slightly higher than those typical of G streams, but in 2017-2019 the ratio of entrenchment decreased. This reach was previously classified as an E type channel; however, it was noted that the reach was actively degrading and widening. While E streams are typically more sinuous, this segment has been noticeably straightened and stabilized by a retaining wall and rubble/fill along the left bank (facing downstream). The lack of sinuosity in the channel has likely resulted in instability, and consequently resulted in a shift to a less-stable form.

Site XS-3, located along the restored segment of Parole Plaza Tributary, was not classified until 2013, allowing 3 years after restoration for the area to settle and stabilize. In 2013 and 2014 it was classified as a Rosgen G4c channel based on its low entrenchment ratio, low width/depth ratio, and low slope. In 2015 XS-3 remained a G type channel; however, the substrate had become coarser resulting in a G4/3c classification. Variable coarseness caused XS-3 to return to a G4c during the 2016 survey and it has maintained that classification since. Before restoration, this cross-section was classified as a Rosgen G5c channel; however, since the Rosgen scheme was developed to classify natural channels, or those that are shaped naturally by fluvial processes, it was deemed inappropriate to classify immediately after construction. This section is still heavily armored and reliable bankfull indicators are not easily identified. Little change has been documented at XS-3 but the erosion behind the armored bank documented in the 2016 and 2017 surveys has aggraded.

The most downstream site on the Parole Plaza Tributary, XS-4, has transitioned from a Rosgen E5 channel to a C4/5 back to an E4/5 channel and now an E5 channel due to fluctuations in substrate size and in width/depth ratio. A large woody debris jam located just downstream of the cross-section location resulted in a considerable accumulation of fine sediment and debris across the channel and, consequently, led to aggradation and a reduction in the cross-sectional area up until 2016. In 2016, before the cross-section survey was performed, restoration on the reach had begun and was completed just downstream of XS-4. Construction activities included the removal of the woody debris jam. Following construction, it is likely that fine sediment behind the debris jam cleared and resulted in increased substrate size. Between 2011 and 2015 cross-sectional area had consistently been lower than baseline monitoring in 2003. Restoration in 2016 caused cross-sectional area to increase by 9.8% from 2003 monitoring. Subsequently, in 2019 the cross-sectional area decreased from 2016 by 7.6% and has increased by 1.4 % since the 2003 monitoring.

Located on the mainstem of Church Creek, upstream of the MD Rt. 2 culvert, XS-5 has transformed from a Rosgen C3/5 channel into a F4 channel due to a significantly decreased entrenchment ratio from 4.0 to 1.5 between 2012 and 2019. Between 2015 and 2016 sediment in this portion of the reach had become slightly less coarse from a $D_{50}$ of 61 mm to 24 mm. In 2018, sediment coarsened substantially with a $D_{50}$ particle size of 85 mm, but decreased in 2019 to a $D_{50}$ particle size of 32 mm. This segment shows evidence of previous alteration in the form of cobble-sized riprap armoring along the bed and lower banks to protect a sewer line crossing and obvious channel straightening, which explains the lack of sinuosity typical of F type streams. The substantial amount of cobble-sized rip-rap in the stream channel has resulted in a bi-modal distribution of substrate particles within this reach, with a predominance of gravel in the pools and artificial cobbles in the riffles. Between 2017 and 2019, the cross-sectional area and the width/depth ratio remained similar.

# 4 DISCUSSION

Results from the July 2018-June 2019 study period are discussed in the following section. Water quality, biological, and geomorphological data are interpreted, presented and compared to previous data. A discussion of the characteristics of the watershed is also included.

## 4.1 WATER CHEMISTRY

Water quality criteria are presented in Table 4-1. The measured data are compared, where possible, to these criteria to assess the extent of the pollution in this tributary.

Table 4-1. State and Federal water quality criteria available for parameters sampled at Church Creek

| Parameter (mg/L, except as noted) | Chronic | Acute | Reference |
|---|---|---|---|
| Lead (µg/L) | 2.5 | 65 | COMAR 26.08.02.03-2 |
| Copper (µg/L) | 9 | 13 | COMAR 26.08.02.03-2 |
| Zinc (µg/L) | 120 | 120 | COMAR 26.08.02.03-2 |
| Total P | 0.0225 | | USEPA 2000 |
| $BOD_5$ | 7 | | USEPA 1986 |
| Nitrate + Nitrite | 0.095 | | USEPA 2000 |
| TSS | 500 | | USEPA 1974 |
| TKN | None | | |
| TPH | None | | |
| *E. coli** (MPN/100 mL) | 126 | | COMAR 26.08.02.03-3 |
| Hardness | None | | |

* Updated in 2019. Used most restrictive standard for *E. coli* as a conservative approach: water contact recreation criterion.

Criteria are used to protect against both short-term and long-term effects. Numeric criteria are important where the cause of toxicity is known or for protection against pollutants with potential human health impacts or bioaccumulation potential. Narrative criteria can be the basis for limiting toxicity in discharges where a specific pollutant can be identified as contributing to the toxicity. Biological criteria can be used to complement traditional, chemical-specific criteria as indicators of aquatic health and impacts to the aquatic ecosystem.

Tables 4-2 and 4-3 compare baseflow and storm event results to the Federal and State acute and chronic criteria. Comparison and interpretation of Church Creek pollutant concentrations to Federal and State water quality criteria, and relating these conditions to ultimate ecological outcomes in the system, however, are difficult. Criteria do not exist for all parameters measured at the monitoring stations. In addition, a clear cause and effect relationship between water quality and ecological condition is difficult to determine. However, these comparisons can be used as general indicators of water quality impairment. Both State and Federal criteria are based on ambient stream conditions. Chronic criteria consider the maximum levels at which aquatic life can survive if continuously subjected to a pollutant concentration. Acute criteria reflect the maximum level at which an aquatic organism can survive if periodically subjected to a pollutant concentration. Since storm events represent a periodic condition, wet-weather samples are compared only to acute criteria.

Table 4-2. Maximum concentrations observed for baseflow samples compared to appropriate criteria

| Parameter (mg/L, except as noted) | Chronic | Acute | Church Creek | Parole Plaza |
|---|---|---|---|---|
| Lead (µg/L) | 2.5 | 65 | BDL | 22* |
| Copper (µg/L) | 9 | 13 | 4 | 102* |
| Zinc (µg/L) | 120 | 120 | 47 | 596* |
| Total P | 0.0225 | | 0.08* | 0.75* |
| $BOD_5$ | 7 | | BDL | 59* |
| Nitrate + Nitrite | 0.095 | | 1.00* | 6.00* |
| TSS | 500 | | 8 | 530* |
| TKN | None | | BDL | 9.0 |
| TPH | None | | BDL | 6 |
| *E. coli*** (MPN/100 mL) | 126 | | 538* | 24,196* |
| Hardness | None | | 120 | 270 |

* Criterion exceeded
** Updated in 2019. Used most restrictive standard for *E. coli* as a conservative approach: water contact recreation criterion.
BDL: Below Detection Limit

As in previous years, comparisons to water quality criteria indicate elevated pollutant concentrations in the Church Creek watershed. As shown in Table 4-2, established water quality criteria were exceeded for all parameters at Parole Plaza and for total phosphorus, combined nitrate and nitrite, and *E. coli* at Church Creek during baseflow sampling. The exceedances of the water quality criteria at Parole Plaza during baseflow sampling were possibly caused by an illicit discharge that was discovered by Versar in late FY2018 and further investigated by Anne Arundel County. Table 4-3 shows the maximum wet weather concentrations for each sampling site, and compares these to the corresponding criteria. In particular, copper, zinc, total phosphorous, $BOD_5$, nitrate-nitrite, and *E. coli* frequently exceeded criteria at both sampling stations.

Table 4-4 shows the percentage of wet weather samples for which criteria were exceeded. *E. coli* concentrations decreased at both stations throughout the 2019 monitoring period; however, the water quality criterion was exceeded 100 percent of the time at both Church Creek and Parole Plaza. Total phosphorus and combined nitrate and nitrite samples exceeded the corresponding criteria 100% of the time at both stations. Both parameters could have been elevated by the abundant rain that fell during sampling year. During several storm events throughout 2019, total phosphorus and combined nitrate and nitrite concentrations for the rising limb were higher than usual.

Table 4-3. Maximum concentrations observed for wet weather samples compared to appropriate criteria

| Parameter (mg/L, except as noted) | Criteria | Church Creek | Parole Plaza |
|---|---|---|---|
| Lead (µg/L) | 65 | 61 | 14 |
| Copper (µg/L) | 13 | 70* | 72* |
| Zinc (µg/L) | 120 | 702* | 684* |
| Total P | 0.0225 | 3.30* | 0.36* |
| $BOD_5$ | 7 | 26* | 25* |
| Nitrate + Nitrite | 0.095 | 2.00* | 2.40* |
| TSS | 500 | 340 | 330 |
| TKN | None | 5.6 | 2.6 |
| TPH | None | 9 | 24 |
| *E. coli*** (MPN/100 mL) | 126 | 23,590* | 17,586* |
| Hardness | None | 170 | 180 |

* Criterion exceeded
** Updated in 2019. Used most restrictive standard for *E. coli* as a conservative approach: water contact recreation criterion.

Table 4-4. Percentage of all wet weather samples that exceed appropriate criteria

| Parameter (mg/L, except as noted) | Criteria | Church Creek (%) | Parole Plaza (%) |
|---|---|---|---|
| Lead (µg/L) | 65 | 0 | 0 |
| Copper (µg/L) | 13 | 33 | 46 |
| Zinc (µg/L) | 120 | 26 | 38 |
| Total P | 0.0225 | 100 | 100 |
| $BOD_5$ | 7 | 7 | 8 |
| Nitrate + Nitrite | 0.095 | 100 | 100 |
| TSS | 500 | 0 | 0 |
| TKN | None | NA | NA |
| TPH | None | NA | NA |
| *E. coli** (MPN/100 mL) | 126 | 100 | 100 |
| Hardness | None | NA | NA |

* Updated in 2019. Used most restrictive standard for *E. coli* as a conservative approach: water contact recreation criterion.

During the monitoring year, zinc and copper exceeded their corresponding acute criteria in between 26% and 46% of wet weather samples at both stations. The maximum concentrations at Church Creek station occurred during the rising limb for the August 21 storm event at Church

Creek. At Parole Plaza, copper and zinc concentrations were high during both the August 21 and January 19 storm events and samples exceeded their corresponding criteria. The high levels of zinc and copper recorded during these and other events may have been associated with leachate from building materials and automobile parts in the runoff during the initial stages of the event. Additionally, zinc coating is often used in the manufacture of corrugated metal pipe, such as the outfall pipe at the Parole Plaza location.

Table 4-5 shows the annual average EMCs (encompassing both storm event and baseflow concentrations) that exceeded water quality criteria. As can be seen from the table, total phosphorous, nitrate-nitrite, and *E. coli* consistently exceeded their corresponding criteria at both stations. At Parole Plaza, the annual average EMC for copper exceeded only the chronic criterion. The annual average EMC for lead exceeded the chronic criterion at Church Creek.

High levels of pollutants observed in the watershed are typical for commercial and retail land uses that are coupled with high levels of automobile traffic and impervious surface area (U.S. EPA 1983). As shown in Table 2-2, 78% of the watershed to the Parole monitoring station and 69% of the watershed to the Church Creek station is impervious.

In 2007, loading rates (Tables 4-6 and 4-7) increased sharply at both stations. Loading rates in 2008 were still high, when compared to historical values, but dropped dramatically from the 2007 levels. During the 2009 reporting year, loading rates dropped further, and aligned more closely with historical values. High loading rates in 2007 likely resulted from redevelopment construction activity that was underway immediately upstream of the Parole Plaza station. Since the majority of the site was stabilized by the end of 2008, the cessation of construction likely caused pollutant loads to decrease.

Table 4-5. Annual average EMCs and criteria (parameters that exceeded appropriate criteria are indicated)

| Parameter (mg/L, except as noted) | Chronic Criteria | Acute Criteria | Church Creek | Parole Plaza |
|---|---|---|---|---|
| Lead (µg/L) | 2.5 | 65 | 4* | 1 |
| Copper (µg/L) | 9 | 13 | 9 | 11* |
| Zinc (µg/L) | 120 | 120 | 67 | 98 |
| Total P | 0.0225 | | 0.14* | 0.07* |
| $BOD_5$ | 7 | | 2 | 2 |
| Nitrate + Nitrite | 0.095 | | 0.32* | 0.28* |
| TSS | 500 | | 35 | 17 |
| TKN | None | | 0.3 | 0.3 |
| TPH | None | | 3 | 4 |
| *E. coli*** (MPN/100 mL) | 126 | | 5,275* | 5,720* |
| Hardness | None | | 33 | 23 |

* Criterion exceeded
** Updated in 2019. Used most restrictive standard for *E. coli* as a conservative approach: water contact recreation criterion.

Table 4-6. Total annual loading rates, in pounds, observed at the Parole Plaza Sampling Station from 2002 to 2019

| Year | $BOD_5$ | TSS | TP | TKN | $NO_3$+ $NO_2$ | Zinc | Lead | Copper | Hardness | Fecal Coliform[a] |
|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 2,912 | 26,585 | 1,178 | 388 | 323 | 58 | 14 | 1 | NA | 1,152,001 |
| 2003 | 21,665 | 86,385 | 372 | 1,477 | 714 | 176 | 69 | 15 | NA | 5,350,164 |
| 2004 | 8.025 | 57,447 | 293 | 655 | 391 | 57 | 7 | 8 | NA | 402,127 |
| 2005 | 4,573 | 33,015 | 184 | 483 | 350 | 50 | 12 | 8 | NA | 665,232 |
| 2006 | 13,562 | 94,306 | 650 | 1,867 | 410 | 177 | 13 | 25 | NA | 3,360,952 |
| | | | | | | | | | | ***E. coli***[a] |
| 2007 | 40,009 | 848,116 | 1,649 | 2,328 | 1,401 | 349 | 26 | 162 | NA | 11,017 |
| 2008[b] | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 2009 | 2,175 | 11,787 | 59 | 490 | 117 | 56 | 0.8 | 6.5 | NA | 2,115 |
| 2010 | 2,209 | 17,609 | 89 | 309 | 120 | 40 | 1.2 | 4.1 | NA | 1,740 |
| 2011 | 2,114 | 13,894 | 42 | 371 | 131 | 58 | 1.1 | 6.3 | 6,987 | 2,682 |
| 2012 | 3,660 | 15,335 | 62 | 284 | 214 | 57 | 1.0 | 6.6 | 14,578 | 10,209 |
| 2013 | 1,481 | 6,079 | 34 | 155 | 108 | 34 | 0.5 | 4.9 | 8,586 | 16,041 |
| 2014 | 2,040 | 18,953 | 54 | 536 | 497 | 50 | 1.0 | 8.1 | 36,945 | 12,716 |
| 2015 | 940 | 14,606 | 45 | 232 | 162 | 38 | 1.1 | 5.3 | 29,023 | 3,333 |
| 2016 | 1,308 | 10,887 | 29 | 218 | 103 | 36 | 1.0 | 9.3 | 14,779 | 18,268 |
| 2017 | 1,120 | 19,913 | 50 | 318 | 161 | 57 | 1.2 | 8.3 | 18,876 | 7,366 |
| 2018 | 1,467 | 16,532 | 52 | 187 | 173 | 60 | 1.0 | 8.0 | 15,554 | 16,965 |
| 2019 | 1,405 | 8,784 | 40 | 147 | 162 | 53 | 0.8 | 6.3 | 11,616 | 5,720 |
| 2002-2006 Mean | 8,544 | 59,548 | 535 | 974 | 438 | 104 | 23 | 11 | NA | 2,186,095 |
| 2009-2019 Mean | 1,822 | 14,034 | 51 | 298 | 178 | 50 | 1 | 7 | 17,534 | 8,851[c] |
| **2002-2019 Mean** | 6,046 | 76,484 | 287 | 616 | 326 | 83 | 9 | 17 | 17,534 | 9,031 |

(a) Units of Fecal Coliform and *E. coli* are MPN/100 mL.
(b) In 2008, monitoring was conducted for both outfalls at Parole Plaza, but continuous level monitoring was not available for the 54" RCP; therefore, loads could not be calculated.
(c) Mean *E. coli* value, does not include pre-2007 Fecal Coliform data.

Table 4-7. Total annual loading rates, in pounds, observed at the Church Creek Sampling Station from 2002 to 2019

| Year | $BOD_5$ | TSS | TP | TKN | $NO_3$+ $NO_2$ | Zinc | Lead | Copper | Hardness | Fecal Coliform* |
|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 6,408 | 58,501 | 2,593 | 854 | 711 | 127 | 32 | 3 | NA | 2,534,970 |
| 2003 | 47,673 | 190,090 | 818 | 3,250 | 1,571 | 387 | 151 | 32 | NA | 11,773,001 |
| 2004 | 17,660 | 126,411 | 645 | 1,441 | 860 | 126 | 19 | 18 | NA | 884,887 |
| 2005 | 10,062 | 72,648 | 405 | 1,062 | 771 | 109 | 27 | 16 | NA | 1,463,839 |
| 2006 | 29,844 | 207,520 | 1,431 | 4,109 | 902 | 390 | 29 | 54 | NA | 7,395,753 |
| | | | | | | | | | | ***E. coli**** |
| 2007 | 265,499 | 3,312,794 | 8,381 | 20,330 | 436,206 | 3,663 | 277 | 652 | NA | 1,755 |
| 2008 | 60,843 | 458,185 | 3,037 | 12,468 | 4,444 | 693 | 37 | 36 | NA | 3,857 |
| 2009 | 35,521 | 206,184 | 1,296 | 9,377 | 2,505 | 531 | 30 | 57 | NA | 3,912 |
| 2010 | 49,256 | 341,877 | 2,066 | 9,561 | 2,912 | 739 | 39 | 77 | NA | 3,358 |
| 2011 | 42,883 | 214,820 | 1,340 | 7,410 | 3,606 | 704 | 30 | 41 | 259,076 | 3,995 |
| 2012 | 40,145 | 150,490 | 1,103 | 3,714 | 3,018 | 551 | 20 | 31 | 250,747 | 5,549 |
| 2013 | 43,980 | 180,946 | 899 | 3,326 | 2,782 | 558 | 27 | 57 | 314,179 | 2,399 |
| 2014 | 31,969 | 299,830 | 1,065 | 12,177 | 6,019 | 551 | 27 | 78 | 646,801 | 8,638 |
| 2015 | 19,643 | 344,419 | 1,057 | 5,743 | 3,148 | 665 | 35 | 99 | 455,627 | 2,100 |
| 2016 | 46,587 | 335,422 | 1,026 | 6,648 | 3,081 | 818 | 41 | 92 | 344,729 | 8,049 |
| 2017 | 23,557 | 230,599 | 855 | 4,699 | 2,044 | 468 | 34 | 71 | 257,816 | 5,597 |
| 2018 | 19,360 | 358,077 | 1,135 | 3,182 | 2,137 | 491 | 38 | 75 | 244,708 | 6,813 |
| 2019 | 19,742 | 257,269 | 1,072 | 2,624 | 2,432 | 487 | 31 | 67 | 236,796 | 5,275 |
| 2002-2006 Mean | 22,329 | 131,034 | 1,178 | 2,143 | 963 | 228 | 52 | 25 | NA | 4,810,490 |
| 2009-2019 Mean | 33,877 | 265,448 | 1,174 | 6,224 | 3,062 | 597 | 32 | 68 | 334,498 | 5,062 |
| **2002-2019 Mean** | 45,035 | 408,115 | 1,679 | 6,221 | 26,619 | 670 | 51 | 86 | 334,498 | 4,715 |

* Units of Fecal Coliform and *E. coli* are MPN/100 mL.
** Mean *E. coli* value, does not include pre-2007 Fecal Coliform data.

When compared to the 2018 reporting year, 2019 loading rates decreased for all sampled parameters at the Parole Plaza Station. At the Church Creek Station, 2019 reporting year loading rates also decreased for all sampled parameters when compared to 2018, except for $BOD_5$ and combined nitrate and nitrite.

A comparison of mean annual loading rates for the pre-redevelopment period (2002-2006) with the post-redevelopment period (2009 to 2019), indicates the mean loading rates for all parameters at the Parole Plaza station were lower during the post-redevelopment period. However, at the Church Creek station, all mean post-redevelopment parameters except for lead, total phosphorus, and *E. coli* (compared to fecal coliform) exceeded the mean pre-redevelopment (2002-2006) annual loads. Because annual average EMCs for most parameters have gradually declined since 2004 (see discussion below), the likely cause of the higher annual loadings during the post-redevelopment period is higher annual flow volume during the post-redevelopment period than the pre-redevelopment period.

Seasonal pollutant loads in 2019 are provided in Table 4-8. At Church Creek, the seasons in which the highest pollutant loads occurred were summer and winter. Metals, TSS, and hardness were higher in the winter while the other parameters were higher in the summer. At Parole Plaza, most parameters were at their highest during the summer except for total phosphorus, TKN, and hardness, which were at their highest during the fall.

Table 4-8. Seasonal loading rates, in pounds, observed at the Church Creek and Parole Plaza sampling stations in 2019

| Season | $BOD_5$ | TSS | TP | TKN | $NO_3$+$NO_2$ | Zinc | Lead | Copper | Hardness | *E. coli** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Church Creek** | | | | | | | | | | |
| Summer | 9,437 | 65,294 | 341 | 793 | 705 | 116 | 8.5 | 18 | 51,060 | 21,390 |
| Fall | 3,653 | 55,912 | 258 | 553 | 599 | 106 | 5.2 | 10 | 47,386 | 5,761 |
| Winter | 3,544 | 86,845 | 244 | 679 | 499 | 152 | 11 | 24 | 88,165 | 739 |
| Spring | 3,108 | 49,211 | 227 | 599 | 629 | 97 | 6.8 | 14 | 50,185 | 2,730 |
| **Parole Plaza** | | | | | | | | | | |
| Summer | 719 | 3,271 | 12 | 43 | 64 | 18 | 0.3 | 3 | 2,937 | 9,652 |
| Fall | 437 | 1,831 | 17 | 63 | 47 | 18 | 0.3 | 2 | 3,932 | 7,789 |
| Winter | 133 | 2,830 | 5 | 20 | 22 | 10 | 0.2 | 1 | 3,019 | 458 |
| Spring | 116 | 852 | 5 | 21 | 29 | 7 | 0 | 1 | 1,728 | 4,867 |

* Units of *E. coli* are MPN/100 mL

Annual average EMCs were plotted for each monitoring year. Plots were constructed to illustrate the impact that construction activity and redevelopment of the Annapolis Towne Centre site has had on water quality within the study reach. Figures 4-1 through 4-5 show how EMCs have changed from 2004 to 2019 at the Parole Monitoring Station. Nearly every concentration rose substantially between 2006 and 2007 when the majority of the site work took place at the Towne Centre. These concentrations fell notably in 2008, as the site stabilized. This downward trend continued in 2009. The reduction in pollutant concentrations stabilized in 2010 and 2011 possibly indicating that the stream had reached a post-construction baseline. The 2013 rise in TPH was due to an increase in the detection limit, and may not be associated with an actual increase in concentration, as greater than 95% of TPH concentrations fell below the detection limit. It is important to note that the 2013 data included in these plots do not include summer season data (Versar 2013), which is often the season that produces the highest EMCs for many of the parameters. At Parole Plaza, annual pollutant concentrations in 2019 decreased for most parameters, except for TPH which increased. Overall, with the exception of *E. coli*, there is evidence of a moderate downward trend in EMC values at Parole Plaza since approximately 2006. For *E. coli*, the trend is sharply upward, despite lower concentrations in 2019, and is the only parameter at the Parole Plaza station showing such a trend.

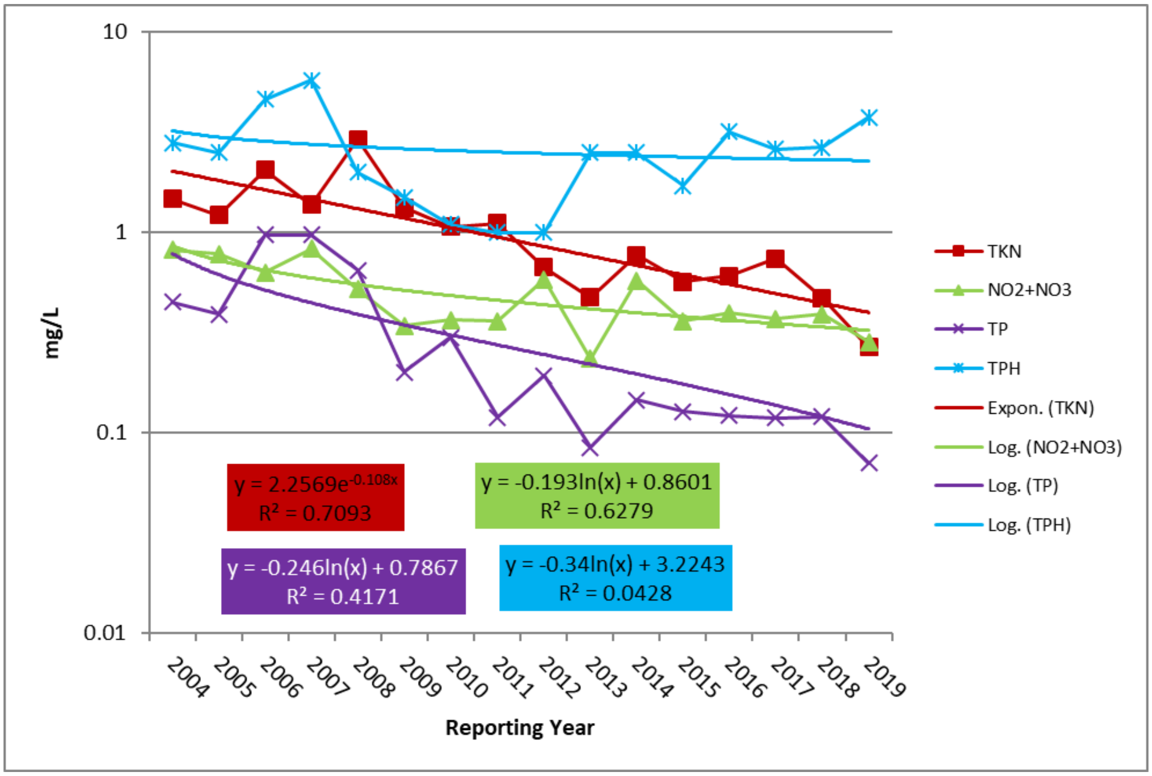


Figure 4-1. Parole Plaza station long-term monitoring: annual EMCs (TKN, $NO_2$+$NO_3$, TP, TPH; mg/L)

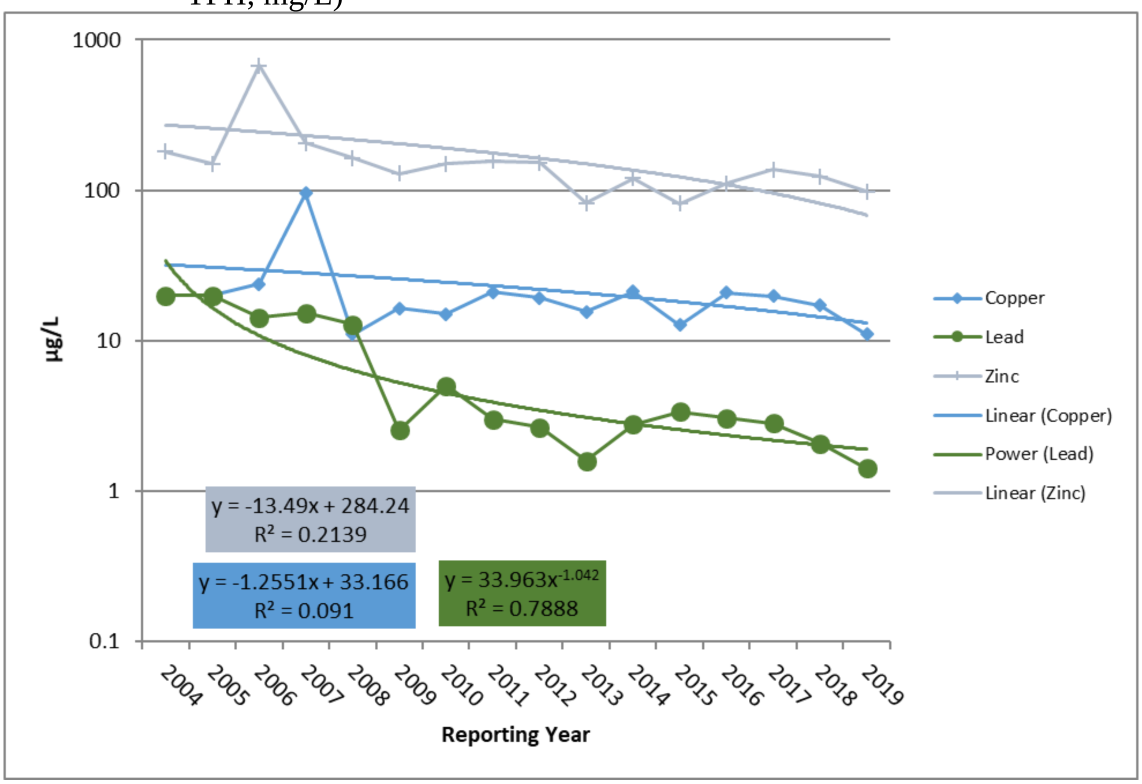


Figure 4-2. Parole Plaza station long-term monitoring: annual EMCs (Cu, Pb, Zn; µg/L)

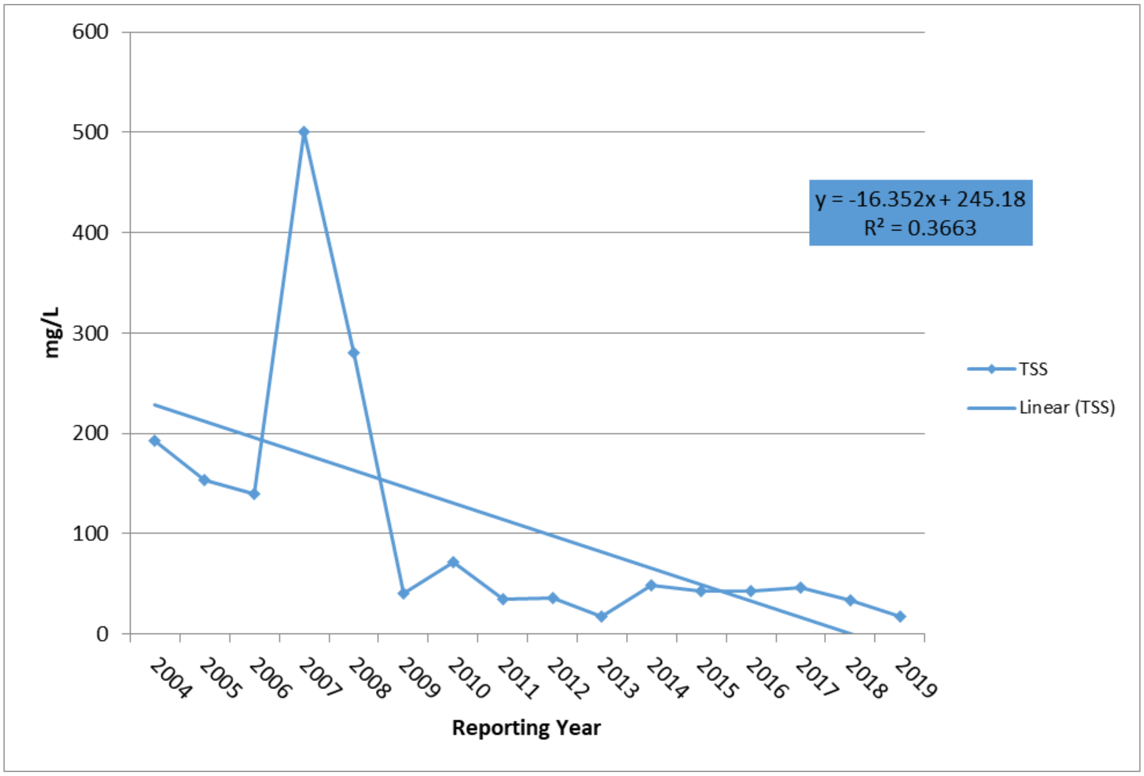


Figure 4-3. Parole Plaza station long-term monitoring: annual EMCs (TSS; mg/L)

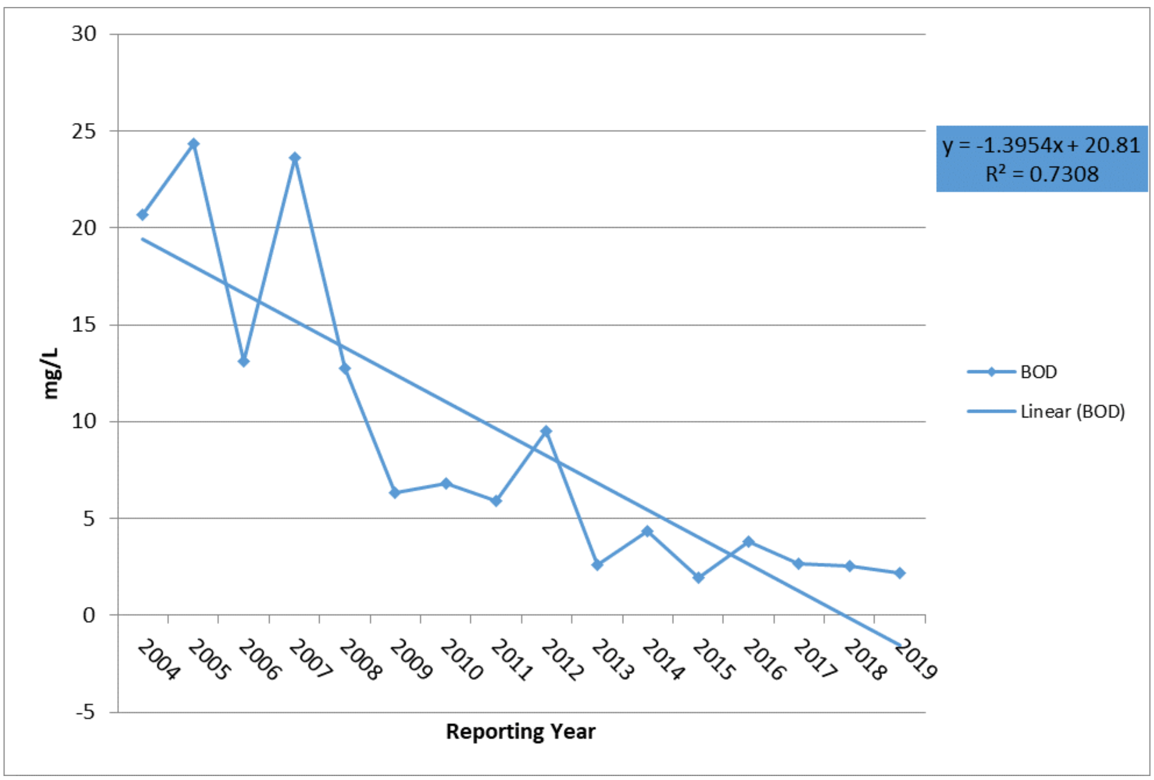


Figure 4-4. Parole Plaza station long-term monitoring: annual EMCs ($BOD_5$; mg/L)

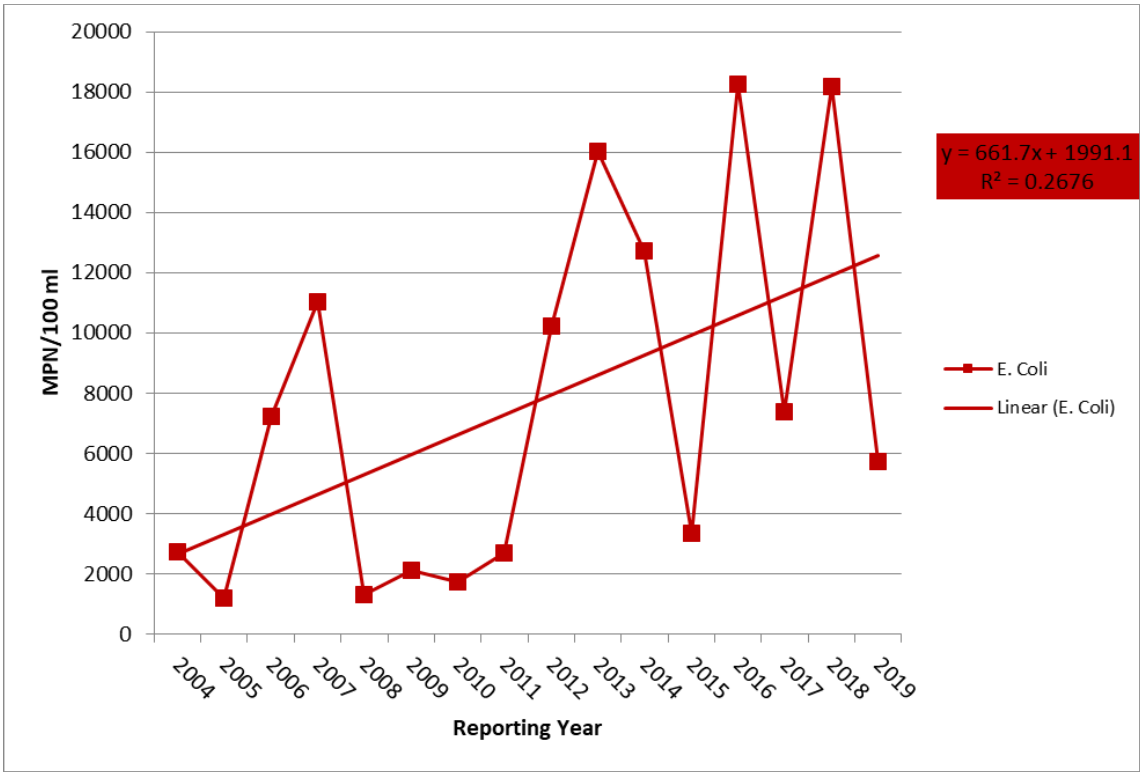


Figure 4-5. Parole Plaza station long-term monitoring: annual EMCs (*E. coli*; MPN/100 mL)

Figures 4-6 through 4-10 show trends in average annual EMCs for the Church Creek monitoring station. Most pollutant concentrations decreased at Church Creek in 2019 compared to 2018 EMCs except for combined nitrate and nitrite. Note that the apparent rise in TPH at Church Creek in 2013 was due to an increase in the detection limit. Also, summer season concentrations were not included with the 2013 EMC data (Versar 2013).

The restoration work conducted during the 2016 monitoring period may have affected pollutant concentrations at Church Creek in the 2017-2019 monitoring periods. Changes in annual EMCs of most parameters between the 2016 and the current monitoring period appear to be within the normal variability of historical (2004 to present) values or continuations of already decreasing trends (e.g., $BOD_5$ and TKN). Total phosphorus concentrations in 2017-2019 were comparable to 2016. The average TKN and $BOD_5$ concentrations have declined notably by 58% and 70%, respectively since 2016, but the decline in combined nitrate and nitrite concentration was more modest (26%). Since 2016, average metals concentrations have declined by between 29% and 41%. Overall, similar to Parole Plaza, EMCs are generally trending downward, except for *E. coli*. The upward trend in *E. coli* at this station appears to be a bit weaker than the trend observed at Parole Plaza.

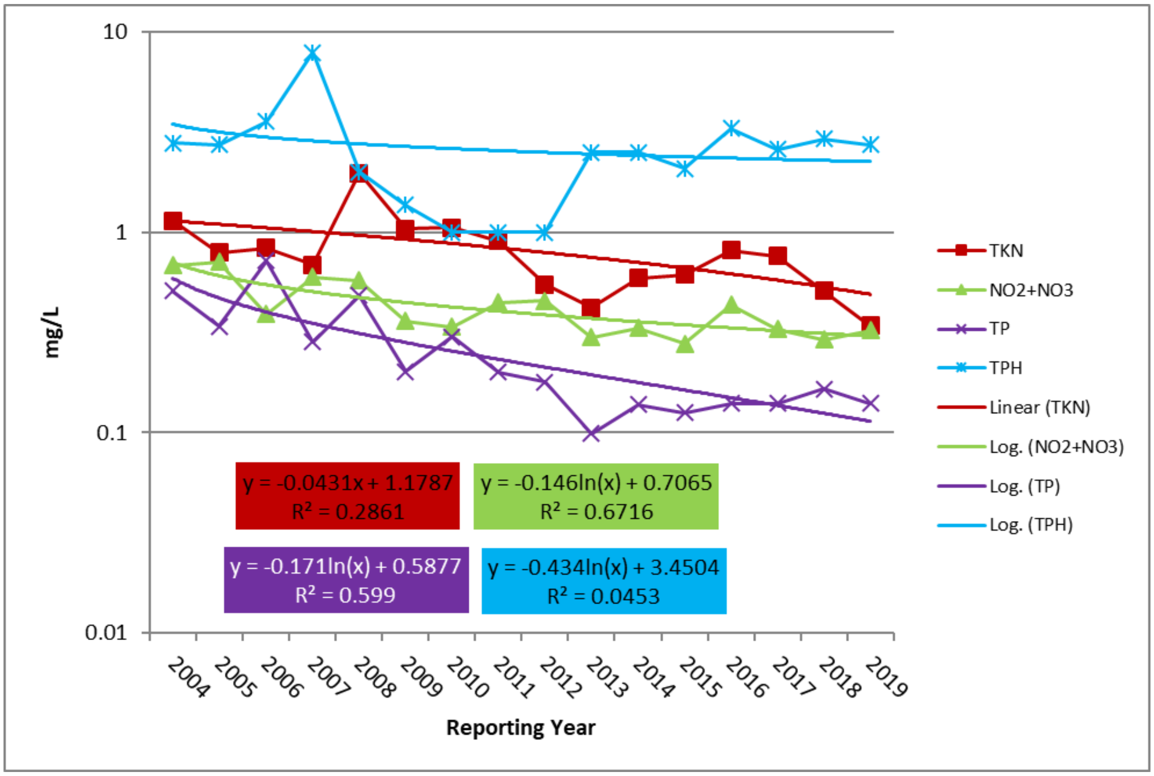


Figure 4-6. Church Creek station long-term monitoring: annual EMCs (TKN, $NO_2$+$NO_3$, TP, TPH; mg/L)

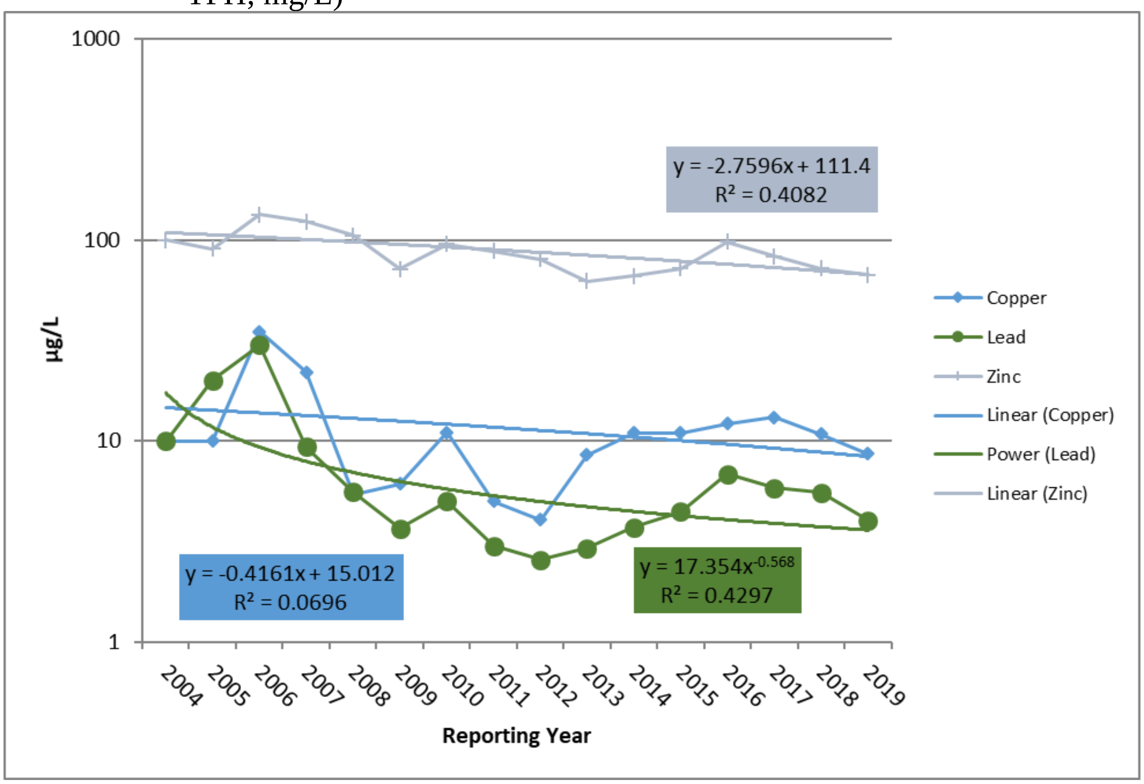


Figure 4-7. Church Creek station long-term monitoring: annual EMCs (Cu, Pb, Zn; µg/L)

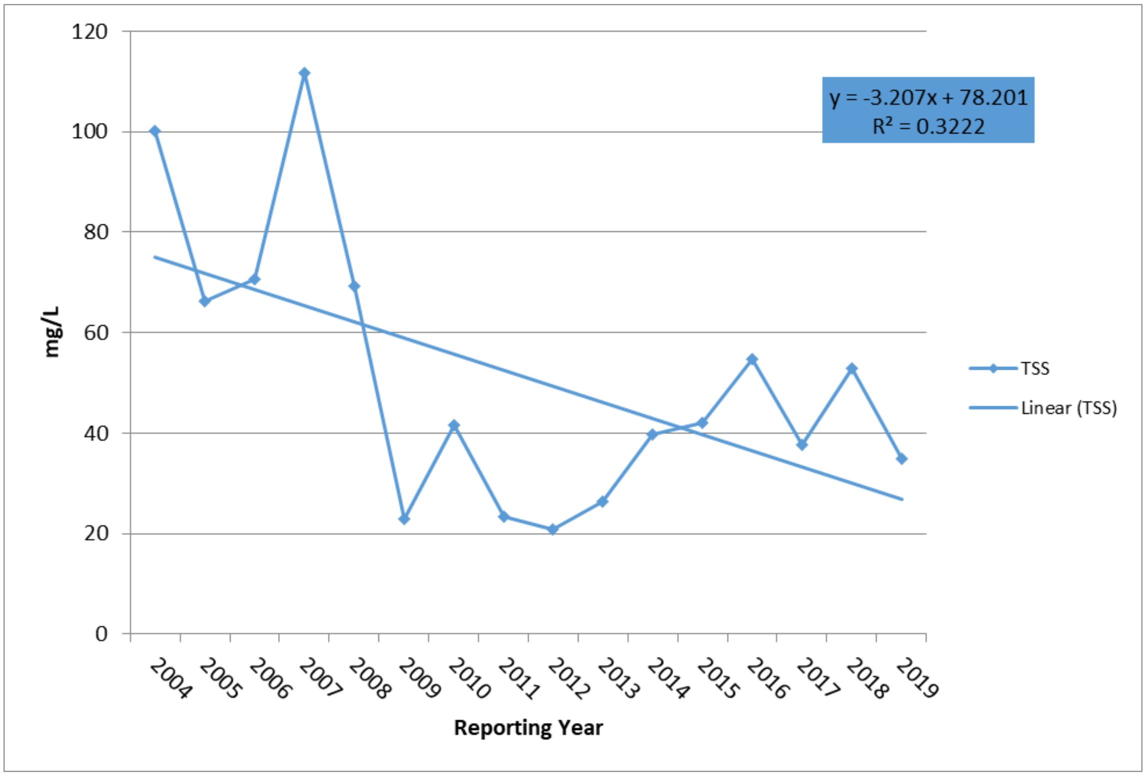


Figure 4-8. Church Creek station long-term monitoring: annual EMCs (TSS; mg/L)

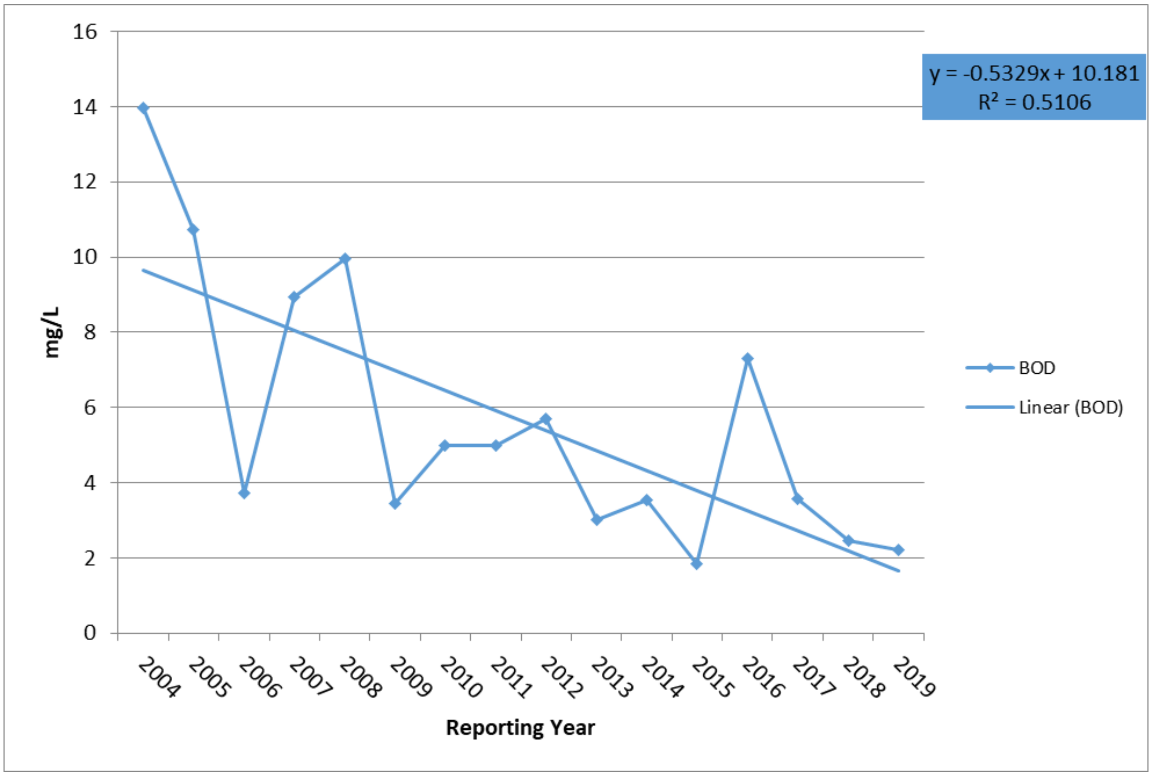


Figure 4-9. Church Creek station long-term monitoring: annual EMCs ($BOD_5$; mg/L)

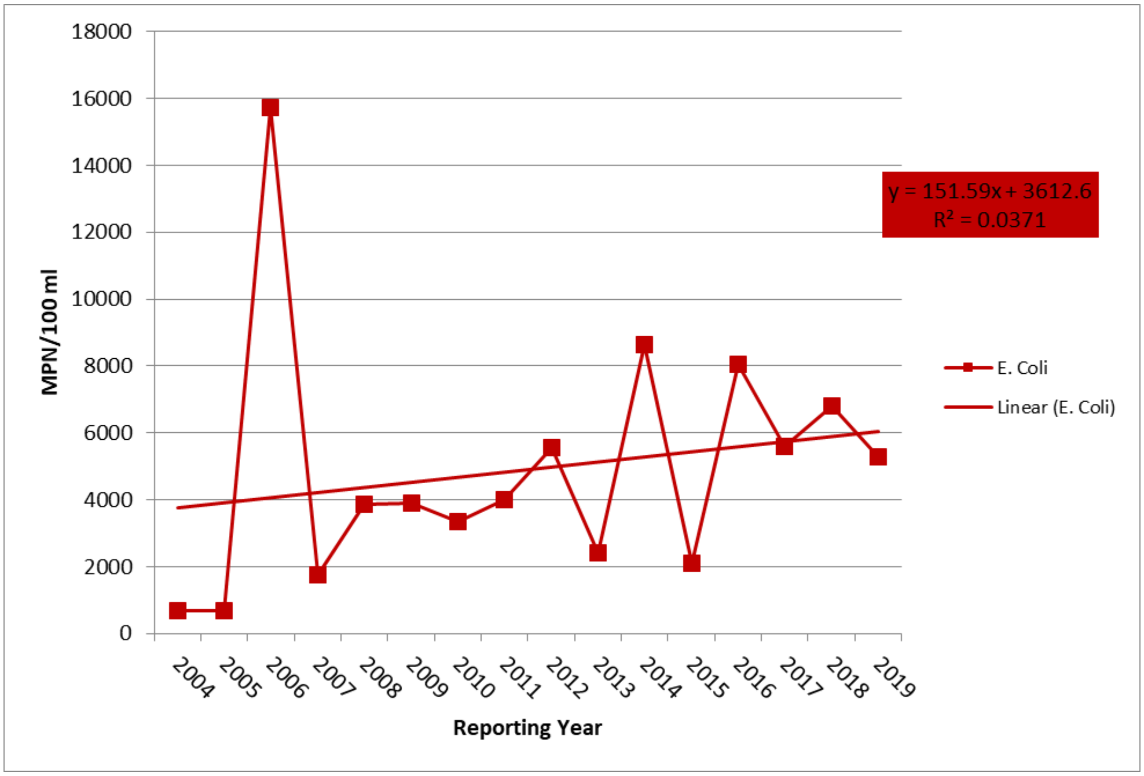


Figure 4-10. Church Creek station long-term monitoring: annual EMCs (*E. coli*; MPN/ 100 mL)

## 4.2 PHYSICAL HABITAT AND BIOLOGICAL CONDITIONS

Physical habitat and biological conditions within the Church Creek study area continue to be impaired by urbanization within the surrounding watershed. Stream physical habitat remains degraded throughout the entire study reach and appears to have changed very little from the previous year (Table 4-9, Figure 4-11, Figure 4-12). PHI scores at three sites decreased in 2019, which were sufficient to shift the associated narrative rating into a lower category than that observed in 2018 at two of these sites (CC-01 and CC-04). Similarly, RBP scores at three sites decreased in 2019, which were sufficient to shift the associated narrative rating into a lower category than that observed in 2018 at two of these sites (CC-01 and CC-04); RBP score and narrative rating increased at site CC-03 from 2018 to 2019. Reductions in epifaunal substrate and velocity/depth diversity scores were the main driving factors in the lower narrative ratings between 2019 and 2018. Also, urban stressors such as hydrologic alteration (i.e., increased runoff, increased frequency of peak flows, reduced infiltration) within the watershed have resulted in a reduction of stable banks and marginal to suboptimal instream habitat may limit the capacity of the stream to support a diverse and healthy macroinvertebrate community. In addition, elevated conductivity levels reflect high levels of dissolved solids during baseflow conditions, which typically indicate the presence of water quality stressors.

Table 4-9. PHI and RBP scores from 2006 to 2019

| | Site | CC-01 | CC-02 | CC-03 | CC-04 |
|---|---|---|---|---|---|
| 2006 | PHI Score | 51.1 | 55.4 | 56.8 | No Data Collected |
| | Rating | Degraded | Degraded | Degraded | |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2007 | PHI Score | 61.2 | 59.1 | 65.7 | 60.8 |
| | Rating | Degraded | Degraded | Degraded | Degraded |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2008 | PHI Score | 57.1 | 56.8 | 66.6 | 62.6 |
| | Rating | Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2009 | PHI Score | 73.2 | 59.6 | 69.2 | 65.2 |
| | Rating | Partially Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2010 | PHI Score | 64.3 | 53.9 | 65.0 | 62.3 |
| | Rating | Degraded | Degraded | Degraded | Degraded |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2011 | PHI Score | 67.4 | 55.3 | 66.9 | 61.5 |
| | Rating | Partially Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2012 | PHI Score | 69.2 | 51.5 | 62.5 | 58.3 |
| | Rating | Partially Degraded | Degraded | Degraded | Degraded |
| | RBP Score | No Data Collected | No Data Collected | No Data Collected | No Data Collected |
| | Rating | | | | |
| 2013 | PHI Score | 63.0 | 53.5 | 66.6 | 57.5 |
| | Rating | Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | 76 | 64 | 82 | 73 |
| | Rating | Supporting | Partially Supporting | Supporting | Partially Supporting |
| 2014 | PHI Score | 65.85 | 56.16 | 70.79 | 61.01 |
| | Rating | Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | 70 | 65 | 81 | 70 |
| | Rating | Partially Supporting | Partially Supporting | Supporting | Partially Supporting |
| 2015 | PHI Score | 66.35 | 52.93 | 66.68 | 62.70 |
| | Rating | Partially Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | 67 | 59 | 66 | 66 |
| | Rating | Partially Supporting | Non-supporting | Partially Supporting | Partially Supporting |
| 2016 | PHI Score | 64.80 | 58.47 | 68.64 | 62.70 |
| | Rating | Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | 71 | 61 | 62 | 76 |
| | Rating | Partially Supporting | Partially Supporting | Partially Supporting | Supporting |
| 2017 | PHI Score | 67.41 | 60.97 | 71.72 | 67.92 |
| | Rating | Partially Degraded | Degraded | Partially Degraded | Partially Degraded |
| | RBP Score | 74 | 61 | 70 | 78 |
| | Rating | Partially Supporting | Partially Supporting | Partially Supporting | Supporting |

Table 4-9. Continued

| Site | | CC-01 | CC-02 | CC-03 | CC-04 |
|---|---|---|---|---|---|
| 2018 | PHI Score | 67.29 | 56.87 | 73.06 | 75.82 |
| | Rating | Partially Degraded | Degraded | Partially Degraded | Partially Degraded |
| | RBP Score | 62 | 57 | 70 | 77 |
| | Rating | Partially Supporting | Non-supporting | Partially Supporting | Supporting |
| 2019 | PHI Score | 58.49 | 57.38 | 66.67 | 60.44 |
| | Rating | Degraded | Degraded | Partially Degraded | Degraded |
| | RBP Score | 51 | 60 | 80 | 69 |
| | Rating | Non-supporting | Non-supporting | Supporting | Partially Supporting |

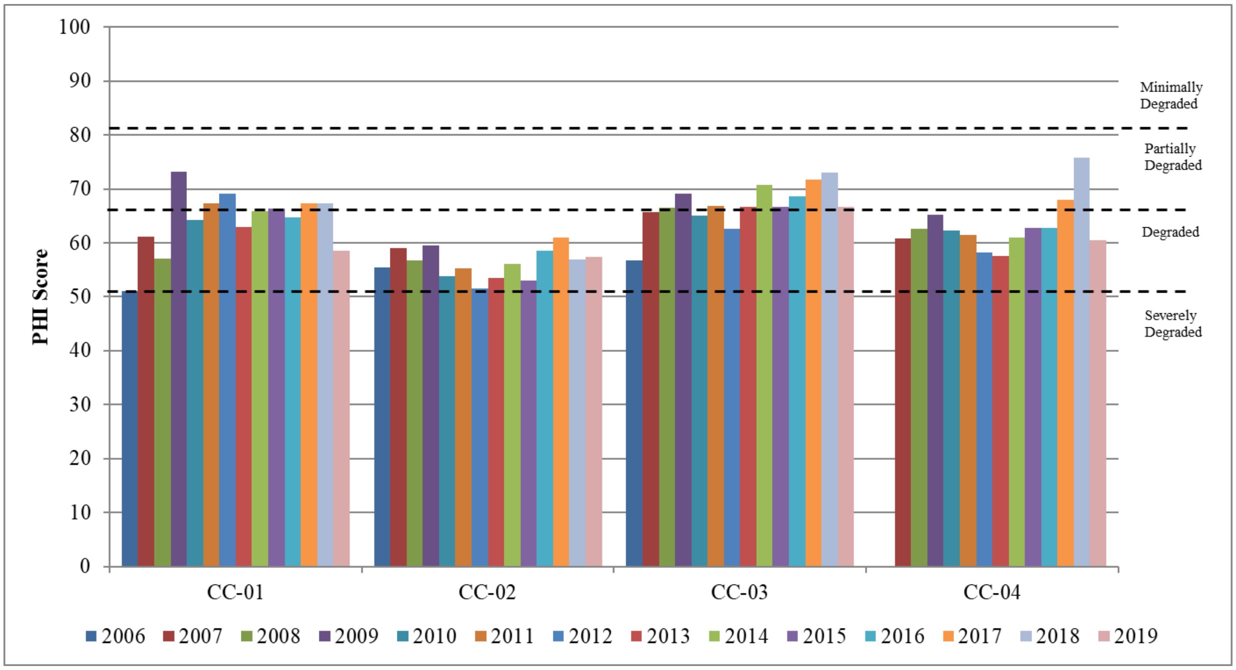


Figure 4-11. Comparison of PHI scores from 2006 to 2019

In 2013 and 2014, the updated MBSS PHI methods (Paul et al. 2003) were used to calculate PHI instead of the original MBSS methods which had been used in the Church Creek watershed reports from previous years. Scores for 2006-2012 shown in Table 4-9 and Figure 4-11 were calculated using the original method, while scores for 2013-2019 were calculated using the updated method.

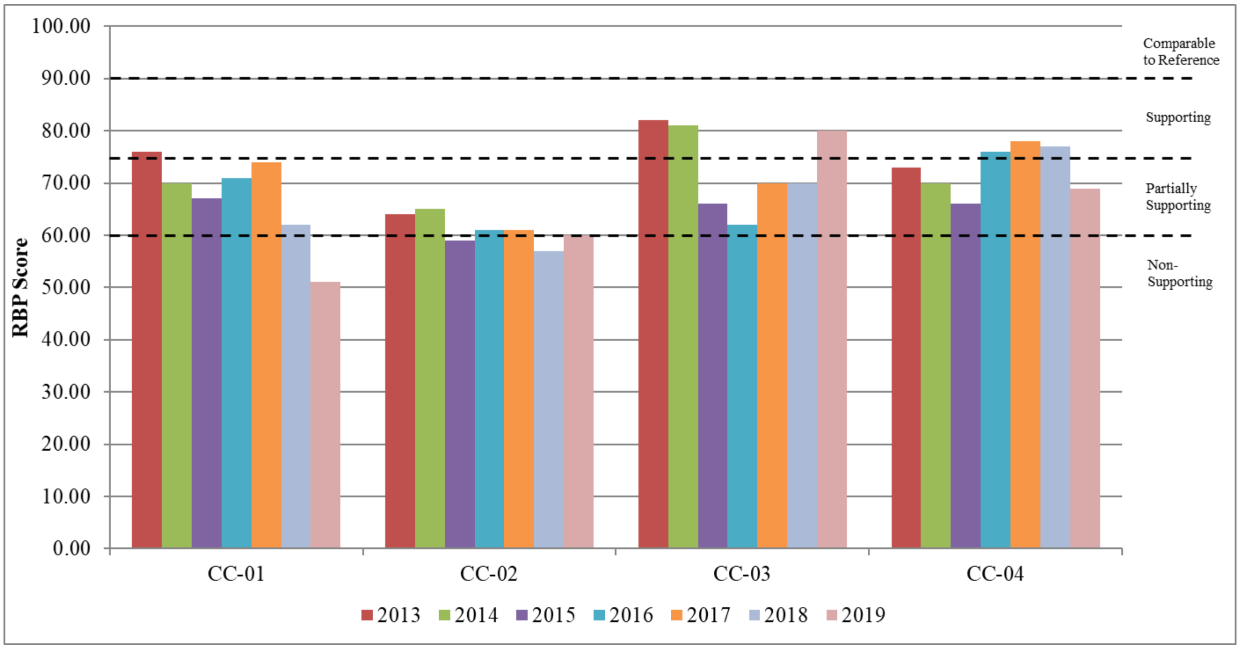


Figure 4-12. Comparison of RBP scores from 2013 to 2019

Biological impairment is evident within this watershed as reflected by the macroinvertebrate communities found throughout the study reach. A comparison of BIBI scores from 2006 through 2019 (Table 4-10) shows no substantial change in biological conditions throughout the study reach. Low BIBI scores can be explained by the lack of pollution-sensitive taxa (reflected in both the EPT taxa metric and the pollution intolerant taxa metric), as well as by generally low taxonomic diversity. While BIBI scores tend to fluctuate from year to year, overall classifications have changed very little with sites consistently rating either "Poor" or "Very Poor"; no clear trends have been established (Figure 4-13). It appears that the biological community continues to be limited by the presence of urban stressors and degraded physical condition of the stream, and annual shifts in BIBI scores are likely related to random and systematic variability inherent in the assessment process.

Table 4-10. BIBI scores from 2006 to 2019

| Site | | CC-01 | CC-02 | CC-03 | CC-04 |
|---|---|---|---|---|---|
| 2006 | BIBI Score | 1.86 | 2.43 | 1.86 | No Data |
| | Rating | Very Poor | Poor | Very Poor | Collected |
| 2007 | BIBI Score | 1.00 | 1.86 | 2.71 | 2.71 |
| | Rating | Very Poor | Very Poor | Poor | Poor |
| 2008 | BIBI Score | 2.43 | 2.43 | 2.43 | 2.14 |
| | Rating | Poor | Poor | Poor | Poor |
| 2009 | BIBI Score | 1.86 | 1.86 | 2.14 | 2.43 |
| | Rating | Very Poor | Very Poor | Poor | Poor |
| 2010 | BIBI Score | 1.29 | 1.86 | 1.57 | 2.14 |
| | Rating | Very Poor | Very Poor | Very Poor | Poor |
| 2011 | BIBI Score | 1.57 | 1.86 | 1.57 | 2.14 |
| | Rating | Very Poor | Very Poor | Very Poor | Poor |
| 2012 | BIBI Score | 1.86 | 2.43 | 1.57 | 2.43 |
| | Rating | Very Poor | Poor | Very Poor | Poor |
| 2013 | BIBI Score | 1.57 | 2.43 | 1.86 | 1.29 |
| | Rating | Very Poor | Poor | Very Poor | Very Poor |
| 2014 | BIBI Score | 1.57 | 1.86 | 1.29 | 1.57 |
| | Rating | Very Poor | Very Poor | Very Poor | Very Poor |
| 2015 | BIBI Score | 1.57 | 1.57 | 2.14 | 1.86 |
| | Rating | Very Poor | Very Poor | Poor | Very Poor |
| 2016 | BIBI Score | 1.86 | 1.57 | 2.14 | 2.71 |
| | Rating | Very Poor | Very Poor | Poor | Poor |
| 2017 | BIBI Score | 2.14 | 2.14 | 2.43 | 1.86 |
| | Rating | Poor | Poor | Poor | Very Poor |
| 2018 | BIBI Score | 1.57 | 1.29 | 2.14 | 2.14 |
| | Rating | Very Poor | Very Poor | Poor | Poor |
| 2019 | BIBI Score | 1.57 | 2.14 | 1.86 | 1.86 |
| | Rating | Very Poor | Poor | Very Poor | Very Poor |

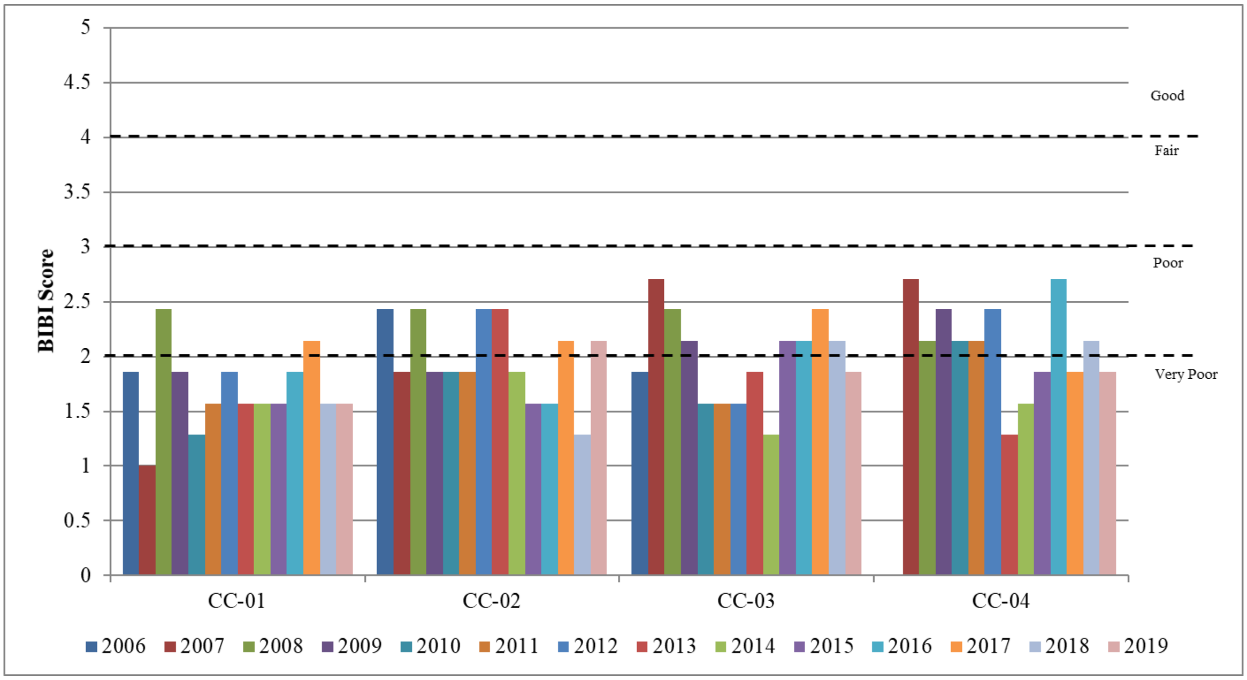


Figure 4-13. Comparison of BIBI scores from 2006 to 2019

## 4.3 GEOMORPHIC CONDITIONS

The Church Creek study area has a very high percentage of impervious surface cover (approximately 64 percent), and no reach was classified as a C channel, which are generally considered stable stream types due to adequate floodplain connectivity. Four reaches were classified as either F or G channels, which are more entrenched and less stable. The most downstream reach of the Parole Plaza Tributary was classified as an E channel and maintains some limited connectivity to its floodplain even though there are significant stormwater inputs feeding into the stream, which typically result in accelerated channel erosion and degradation. There were no changes in the overall classifications of each stream reach from 2017 to 2018, and stream types remained the same in 2019, apart from XS-1 which changed from an F4 to an F5 stream type as its substrate became less coarse. Evolution of channel type over the course of the study at each cross-section is presented in Table 4-11. It is likely that current stormwater management and wetland storage on the Church Creek mainstem, as well as the presence of an intact riparian vegetative buffer along much of the stream corridor, contributes to minimizing some of the adverse effects of the high imperviousness in the watershed. Additionally, grade controls such as the culvert at Solomon's Island Road and cobble rip-rap armoring at XS-5 likely prevent some degradation from occurring in the channel upstream. Nonetheless, there are clear indications of channel instability (i.e., degradation, aggradation, widening) in the upper reaches of the Parole Plaza Tributary, and thus, a need for additional stormwater management to prevent further channel erosion.

Table 4-11. Past Rosgen classifications

| Cross-section | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XS-1 | E5 | C5 | E4 | E5 → C5 | E5 → C4/5 | C4/5 → F4/5 | F5 | F4 | F5/4 | F4 | F4 | F4 | F4 | F5 |
| XS-2 | E5 | E5 | E5 | E5 | E5 | G5c | G5c | G5c | G4c | G4 | G4c | G4c | G4c | G4c |
| XS-3 | G5c | G5c | G5c | G5c | G5c | No Data | No Data | G4c | G4c | G4/3c | G4c | G4c | G4c | G4c |
| XS-4 | E5 | E5 | E5 | E5 | E5 | E5 | E5 | C5 | C5 | C5 | E5/4 | E4/5 | E4/5 | E5 |
| XS-5 | E5b | C5 | C5 | C5 | C3/5 | C3/5 | C3/5 | F4/3 | F3 | F3/4 | F4 | F4 | F4 | F4 |

Bankfull channel dimensions (cross-sectional area, width, depth) in the Church Creek study area showed departure from expected values, as derived from Maryland Coastal Plain regional relationships of bankfull channel geometry (McCandless 2003). Almost all dimensions were generally larger in the Church Creek study area (see Figures 4-14, 4-15, and 4-16), and were often more similar to relationships of bankfull channel geometry derived from gaged urban watersheds located in the Coastal Plain. These relationships were previously developed for an urban stream restoration project in Anne Arundel County (AADPW 2002). Recent dimensions have been slightly higher than previous assessment values. This reflects the higher level of imperviousness in the study area, as compared to the lower impervious levels in the drainage areas used to develop the regional relationship data. The results suggest that this stream has become enlarged as a result of the high imperviousness, and is both wider and deeper than stable C and E type channels located in rural/suburban watersheds of the coastal plain. It should be noted, however, that locating bankfull elevations in the field on actively eroding, previously stabilized, or incising channels is difficult and not recommended due to unreliable and/or misleading indicators, and instead bankfull elevations should be estimated using the aforementioned regional curves (Rosgen, personal communication, May 2011). Where bankfull indicators were suspect or questionable, the indicator approximating the rural/suburban regional curve for bankfull area was used to estimate bankfull elevations. Additionally, the Rosgen method is best used on streams that are free to adjust their lateral boundaries under the current discharge regime experienced by the system (Rosgen 1996). Given the high levels of rip rap and/or concrete rubble armoring found in the reaches containing cross-sections 2, 3 and 5, the accurate determination of the bankfull indicators in the field at these locations is problematic.

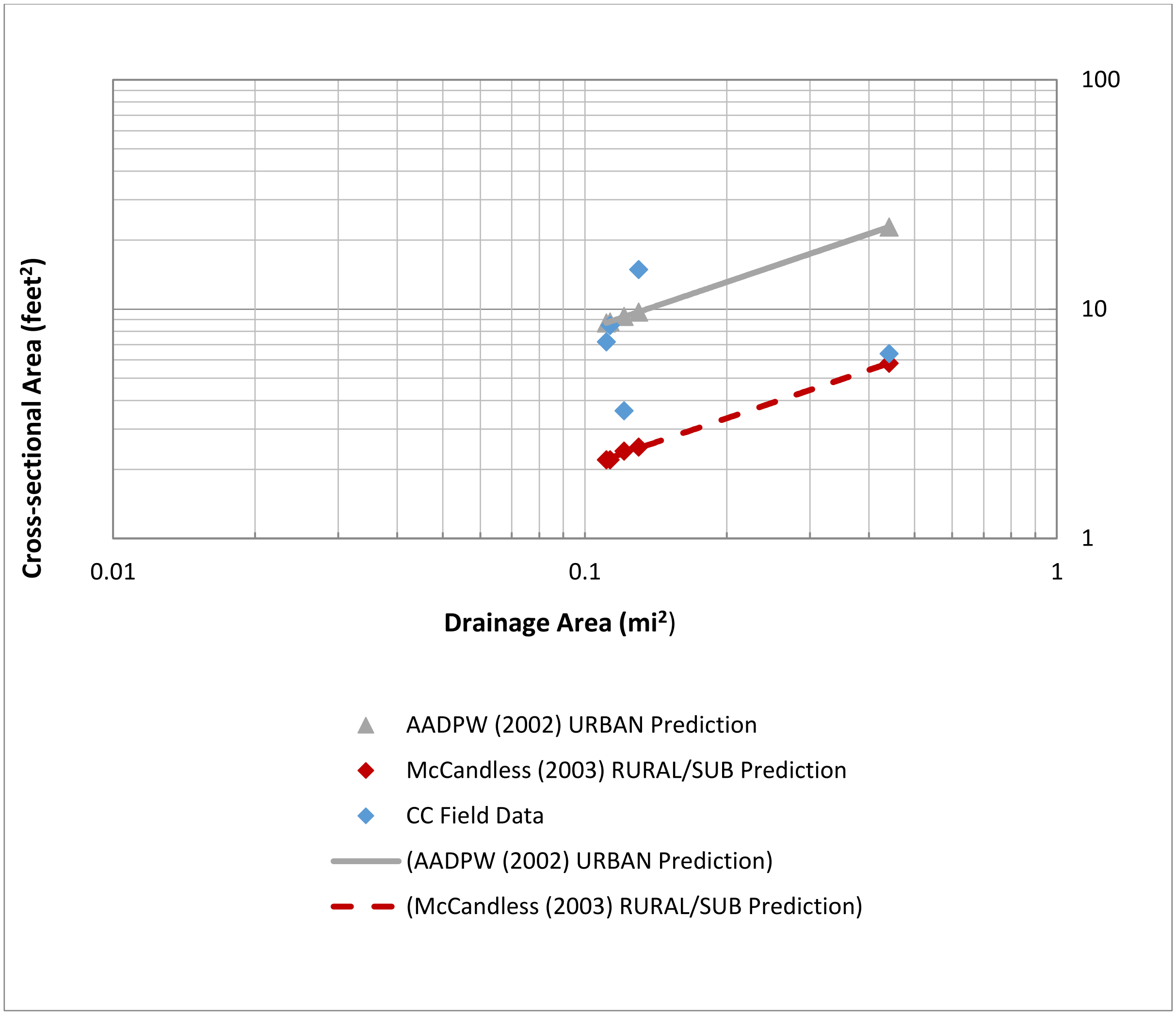


Figure 4-14. Comparison of bankfull channel cross-sectional area to drainage area (CC = Church Creek, 2019 data)

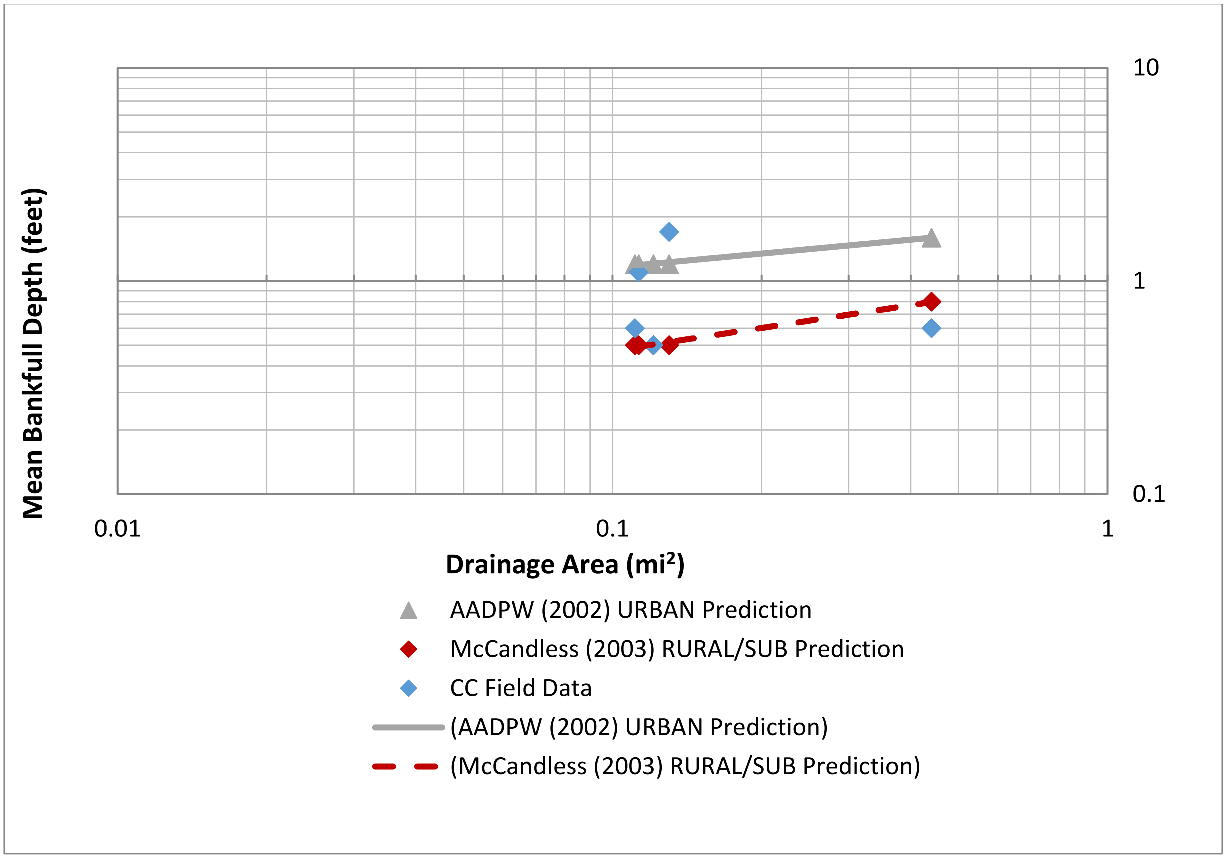


Figure 4-15. Comparison of mean bankfull depth to drainage area (CC = Church Creek, 2019 data)

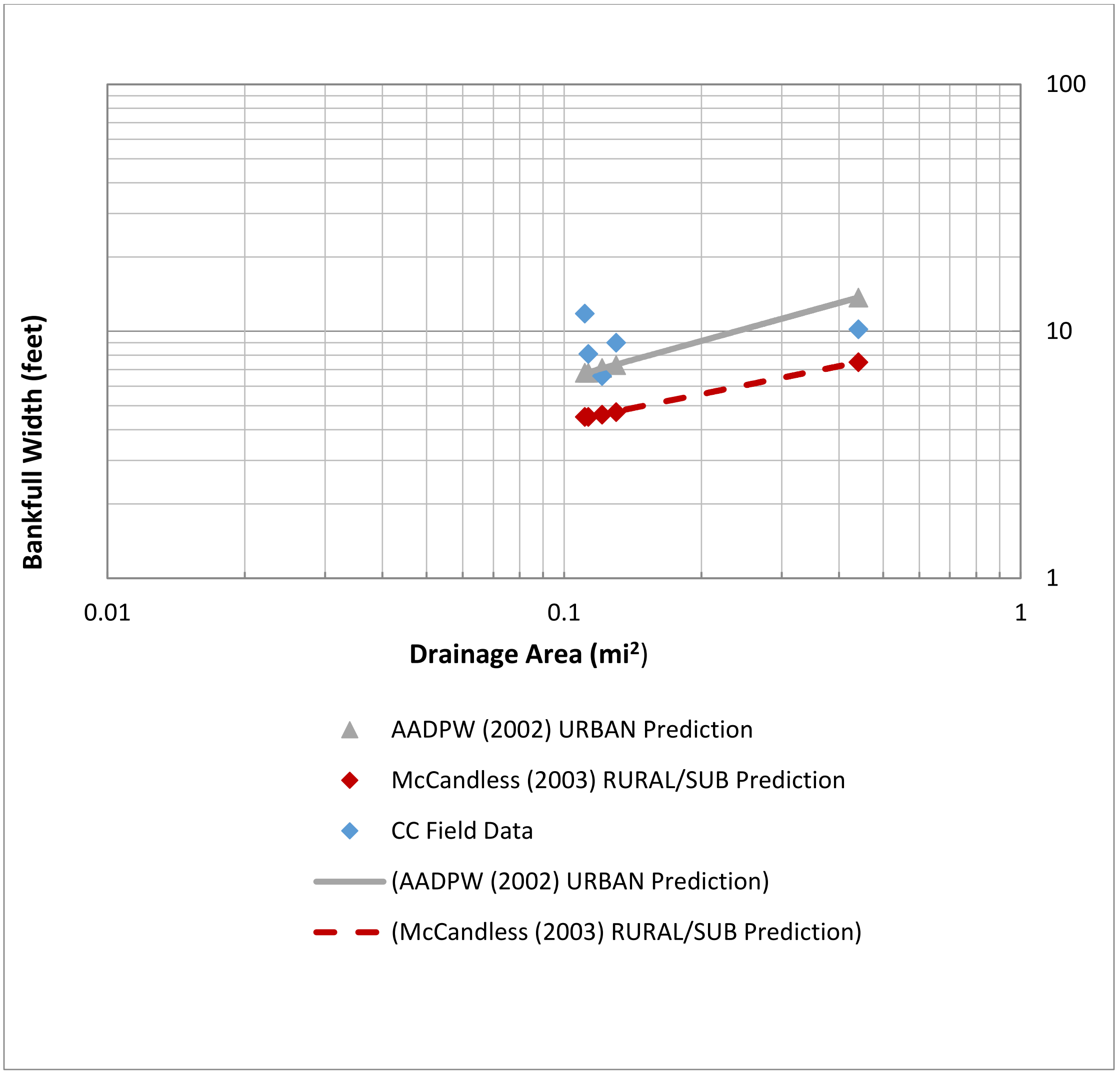


Figure 4-16. Comparison of bankfull width to drainage area (CC = Church Creek, 2019 data)

Looking at percent change over time, three of the five cross-sections (XS-1, XS-2, XS-4) showed enlargement from channel erosion while the other two (XS-3, XS-5) showed aggradation as compared to baseline measurements (Table 4-12). Due to the replacement of XS-3 following channel restoration, data were compared to 2007 at this location only, whereas all other comparisons were made to 2003 data. Cross-sectional area from 2011 through 2019 was calculated using the top of bank elevation from the baseline survey in order to standardize comparisons and reduce variability among more subjective bankfull elevation reference points, or even changes that can occur to top of bank elevation from year to year. It is important to note that calculations prior to 2011 did not use the baseline reference elevation, instead they used the corresponding year's top of bank elevation for calculating cross-sectional area, and consequently these values are not directly comparable to the cross-sectional areas reported in 2011 through 2019. Comparison of baseline cross-sectional area is, however, comparable to 2011 through 2019 since all calculations are made using the same top of bank elevation.

| Table 4-12. Summary of cross-sectional area changes over time | | | | | |
|---|---|---|---|---|---|
| **Cross-section[a]** | XS-1 | XS-2 | XS-3 | XS-4 | XS-5 |
| **July 2003** | 16.8 | 8.9 | ND | 14.3 | 9.7 |
| **Jan 2005** | 20.7 | 10.0 | ND | 14.4 | 9.9 |
| **March 2006** | 19.4 | 8.0 | ND | 18.4 | 9.5 |
| **March 2007** | 19.4 | 8.9 | 19.8 | 17.4 | 9.0 |
| **May 2008** | 20.1 | 10.1 | 16.7 | 18.0 | 8.9 |
| **July 2009** | 19.6 | 9.8 | 21.0 | 15.4 | 8.3 |
| **May 2010** | 19.8 | 10.3 | 20.4 | 16.4 | 8.5 |
| **July 2011[b]** | 21.3 | 15.9 | 20.6 | 7.8 | 10.5 |
| **April 2012[b]** | 21.6 | 15.4 | 19.2 | 11.7 | 5.9 |
| **July 2013[b]** | 21.0 | 15.5 | 20.2 | 11.7 | 6.9 |
| **June 2014 [b]** | 22.4 | 16.2 | 20.6 | 6.8 | 6.7 |
| **May 2015 [b]** | 22.6 | 16.4 | 18.6 | 9.2 | 6.7 |
| **March 2016 [b]** | 25.7 | 23.0 | 18.7 | 15.7 | 6.6 |
| **February 2017 [b]** | 27.1 | 18.7 | 18.2 | 13.3 | 6.5 |
| **April 2018 [b]** | 28.4 | 21.4 | 19.3 | 14.2 | 6.8 |
| **March 2019 [b]** | 30.6 | 19.8 | 18.6 | 14.5 | 7.3 |
| **% Change 2003-2019** | 82.1 | 122.5 | -6.1[c] | 1.4 | -24.7 |
| **% Change 2011-2019** | 43.7 | 24.5 | -9.7 | 85.9 | -30.5 |

[a] All values listed here are for top of bank area and are listed in square feet
[b] Values obtained using reference elevations (top of bank) from baseline measurements
[c] % change from 2007
ND = No Data

Using the current reference elevation comparison method, the upstream cross-sections (XS-1 and XS-2) showed fairly substantial enlargement, with increases of 82.1%, and 122.5% respectively, since baseline measurements began in 2003. Cross-section area comparisons since 2011 show more moderate channel enlargement of 43.7% for XS-1 and 24.5% for XS-2. The bed elevation at XS-1 appears to have dropped about 1.1 feet since 2003 with a substantial amount of bed scour occurring between 2014 and 2018 (Appendix F). Scouring near the right bank occurred between 2008 and 2009 but has remained stable since. The left bank however, has both widened and deepened since 2012 and as of 2019, this trend appears to be continuing. The channel at XS-2 has widened notably since 2003, with considerable erosion along the right bank. The left bank had been generally stable, showing minimal erosion until 2016. In 2016 the channel had both widened along the left bank and deepened mid channel, although in 2017 the channel returned to more narrow and shallow conditions seen before 2016. In 2018, there was slight widening of the channel on both the right and left banks. The left bank continued to exhibit erosion in 2019, while aggradation occurred along the right bank (Appendix F).

Cross-section XS-3 has had very minimal changes in cross-sectional area with a 6.1% decrease since 2007 baseline measurements and -9.7% change between 2011 and 2019. Between 2009 and 2011, the XS-3 channel appeared to be enlarging, as the right bank and bottom of the right bank eroded and the cross-sectional area increased (Appendix F). Between 2011 and 2016 the right bank aggraded across the stream bed and the toe of the right bank, narrowing the stream channel (Appendix F). In 2017 erosion began occurring behind the armored right bank and some scouring was evident on both sides of the channel bed, however, these previously eroded areas were filled in by the time of the 2018 cross-section survey and remained intact in 2019. Cross-section XS-3 continues to have yard waste (i.e., grass clippings, leaves, and branches) dumped along the left bank.

Cross-section XS-4 has had the most variation throughout the years. Between 2010 and 2011 cross-section XS-4 had shown moderate signs of aggradation, with a decrease in cross-sectional area of 8.6 $ft^2$. Within the next year, the channel bed eroded, particularly along the right hand side of the stream. In the 2013 survey, signs of aggradation were again present and the stream bed characteristics resembled those of the 2011 survey. In 2014 the stream bed remained elevated as in 2011 and 2013 however there was slight widening along the right bank. A debris jam at XS-4 which formed between 2011 and 2012 and caused sediment accumulation, was removed during stream restoration construction prior to the 2016 survey. Consequently, the channel scoured significantly and resulted in cross-sectional area increase of 6.5 $ft^2$. Channel scour at this cross-section slowed since the 2016 survey, although the left bank has exhibited erosion annually between 2014-2019. Cross-sectional area has increased only 1.4% between 2003 and 2019 but increased 85.9% between 2011 and 2019.

Cross-section XS-5 has been armored with cobble-sized rip rap in its bed to protect the sewer line. Between 2012 and 2013, XS-5 appeared eroded by several inches of sediment, most notably near the left bank. Cross-sectional area has decreased by 30.5% since 2011 and decreased by 24.7% since 2003. During the past four years, however, there has been little change in both stream bed elevation and bank stability (Appendix F). Cross-sectional area has remained relatively stable from 2014 to 2019 with little to no change year to year.

## 4.4 GENERAL CONCLUSIONS

Water chemistry data collected in 2019 continue to show general, gradually decreasing pollutant levels at the Parole Plaza outfall and in Church Creek, but at concentrations that continue to exceed surface water criteria for certain parameters.

During the 2019 monitoring year, annual average EMCs for $BOD_5$, TKN, total phosphorus, nitrate-nitrite, TSS, lead, and hardness were higher at Church Creek than at Parole Plaza. Annual average EMCs for total phosphorous, nitrate-nitrite, and *E. coli* exceeded their corresponding criteria at both stations. The annual average EMCs for copper and lead exceeded chronic criteria at Parole Plaza and Church Creek, respectively.

Concentrations of phosphorus, combined nitrate and nitrite, and *E. coli* exceeded surface water criteria in 100% of wet weather samples collected at both Church Creek and Parole Plaza in 2019. Zinc and copper exceeded their corresponding acute criteria in between 26% and 46% of wet weather samples at both stations. $BOD_5$ exceeded its criterion in 7% and 8% of samples, respectively at Church creek and Parole Plaza.

For most parameters, annual loads at Church Creek exceeded those at Parole Plaza during 2019 except for *E. coli*. The mean annual loading rates for all parameters at the Parole Plaza station were lower during post-redevelopment (2009 to 2019) than pre-redevelopment (2002-2006). However, at the Church Creek station, all mean annual post-redevelopment parameters except for lead, total phosphorus, and *E. coli* (compared to fecal coliform) exceeded the mean annual pre-redevelopment loads, likely due to higher annual flow volume during the post-redevelopment period than the pre-redevelopment period.

At Parole Plaza, average annual pollutant concentrations decreased between 2018 and 2019 for all parameters, except for TPH. Most average annual pollutant concentrations decreased at Church Creek in 2019 except for combined nitrate and nitrite. Overall, there is a moderate downward trend in EMC values at Parole Plaza since approximately 2006, except for *E. coli*, which is trending upward. EMCs of parameters at Church Creek are trending in a similar fashion to Parole Plaza.

Recent stream restoration (2016) and stormwater pond retrofit (2017) projects in the Church Creek watershed may have affected pollutant concentrations in the 2017-2019 annual monitoring periods. Though time series of most parameters show long-term declining trends that predate the 2016-2017 period, the following local (2017-2019) exceptions are evident:

- Total phosphorus EMCs in 2017-2019 were slightly higher than in 2016;
- Average TKN and $BOD_5$ concentrations declined by 58% and 70%, respectively since 2016; and
- Average metals concentrations declined by between 29% and 41% from the 2016 level.

Given the size of the treated area in relation to the overall watershed, water quality improvement may be difficult to discern from natural variations in pollutant levels, especially in the short timespan in which post-restoration data are available.

Although the stream channel has been stabilized along several reaches, the positive effects on biota are yet to be seen from these efforts. In 2016, stream restoration occurred at the Parole Plaza tributary confluence downstream of cross-section 4 and on the reach above the confluence and upstream of cross-section 5. All of the CC-04 and part of the CC-03 biological monitoring sites were within this restored reach of stream. Eventually, the restoration project should result in less sediment transported downstream, increased stability at physical monitoring stations, and could positively affect the biota at monitoring stations through habitat improvement. In the two years since restoration was completed, cross-section 5, downstream of the restored reach has maintained stability in its geomorphic parameters including consistent cross-sectional area. Future monitoring efforts will be used to evaluate the effects of this restoration.

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# APPENDIX A

## STORM EVENT HYDROGRAPHS, NARRATIVES AND COMPOSITE SAMPLING METHOD TECHNICAL MEMORANDUM

KCI TECHNOLOGIES

# TECHNICAL MEMORANDUM

**TO:** Janis Markusic, AACO DPW

**FROM:** James Tomlinson

**DATE:** 5/12/08

**SUBJECT:** Proposed Modifications to Sampling Procedures
Church Creek/Parole Plaza NPDES Monitoring 2008
KCI Job Order No. 01-032333.38

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Dear Ms. Markusic,

Monitoring at the Parole Plaza station has historically entailed collecting storm water samples from a 60" corrugated metal pipe (CMP) outfall draining the Parole Plaza site. The rising, peak, and falling limb of each storm event was sampled and analyzed in the lab. In the summer of 2007, a newly-installed 54" reinforced concrete pipe (RCP) was connected to the Church Creek drainage network (refer to Figure 1). The new 54" RCP drains the *Annapolis Towne Center at Parole* construction site and contains portions of the drainage that had historically been passing through the 60" CMP. Based on plan reviews, on-site discussions with County staff /inspectors, and discussions with Mr. Matthew Kelly of Greenhorne & O'Mara Inc. (Head Engineer) it was determined that runoff from the *Annapolis Towne Centre at Parole* site would be discharging from both the 60" CMP and 54" RCP outfalls under post-construction conditions.

In order to maintain consistency in the characterization of the watershed, samples are being collected from both pipes. As in the 2006-2007 reporting year, the 2007-2008 reporting year has also encountered the challenge of determining the active drainage configuration during each sampled event. To address this problem, samples were collected for each limb of an event and taken to the laboratory for each pipe separately. In 2007, storm samples were collected and analyzed for both outfall pipes for three storm events (9/11/07, 10/9/07, and 10/19/07) at the Parole Plaza station. In 2008, storm samples were collected and analyzed for both outfall pipes for two storm events (1/10/08 and 1/17/08) at the Parole Plaza station.

Stage/discharge relationships were developed for both pipes, to determine the discharge from each pipe based on field-measured depths. The rating tables were used to determine discharges and total flow volumes for each limb of the storm. The reported concentrations for each limb were then weighted by the flow for that limb of the storm to determine the event mean concentration for each pipe. The event mean concentrations for each pipe were then flow weighted again for the total discharge through each pipe to determine the total event mean concentration for the *Annapolis Towne Center at* Parole site.

In March 2008, the sampling methodology was modified such that only one flow-weighted composite sample per event limb is collected and analyzed at the lab. The goal of compositing the discharge from both pipes is to ensure a comprehensive analysis of the storm water leaving the *Annapolis Towne Center at Parole* site during and after construction. The flow-weighted composite sample for each limb of an event is determined by the combined discharge of the 60" CMP and 54"RCP outfalls. Stage/discharge relationships were developed for both pipes, to determine the discharge from each pipe based on field-measured depths. The relationships are based on modeled values and are currently being validated by field-measured data. A sample

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is collected for each limb of a storm by proportioning the appropriate volume of RCP/CMP sample into a sample container, based on each pipes contribution to the total runoff. To determine the appropriate amount of sample to collect from each pipe for each limb, the discharge from the CMP and RCP is computed and totaled. The CMP and RCP discharge is then divided by the total discharge to determine the percent contribution to the total discharge. Once the percent contribution is determined, then volumetric containers are utilized to proportion each pipe sample to create one composite sample. The composite sample is then distributed into the laboratory bottles.

At this time, three storm events (3/19/08, 4/20/08, and 4/26/08) have been sampled utilizing the flow-weighted composite method. Currently, no automated equipment is available for the RCP. Level, pH, and temperature are taken manually during sampled events. All of the flow data and discharge characteristics for each outfall pipe are recorded during the storm event into a laptop spreadsheet that automatically calculates the correct sample proportions. General notes, field-measured velocity data, and a hydrograph are also recorded on the laptop spreadsheet during the storm event (see Figure 2).

As discussed in the field on April 10, 2008, KCI feels that this is an appropriate method for maintaining consistency with the historical data, while reducing the costs of sampling and testing both outfalls individually.

If you have any questions or comments, please feel free to contact me at the number below.

Sincerely,

James A. Tomlinson, PE
Project Manager
(410) 316-7864

ND/jt

cc: Christopher Victoria, AACo DPW
Nathan Drescher/KCI

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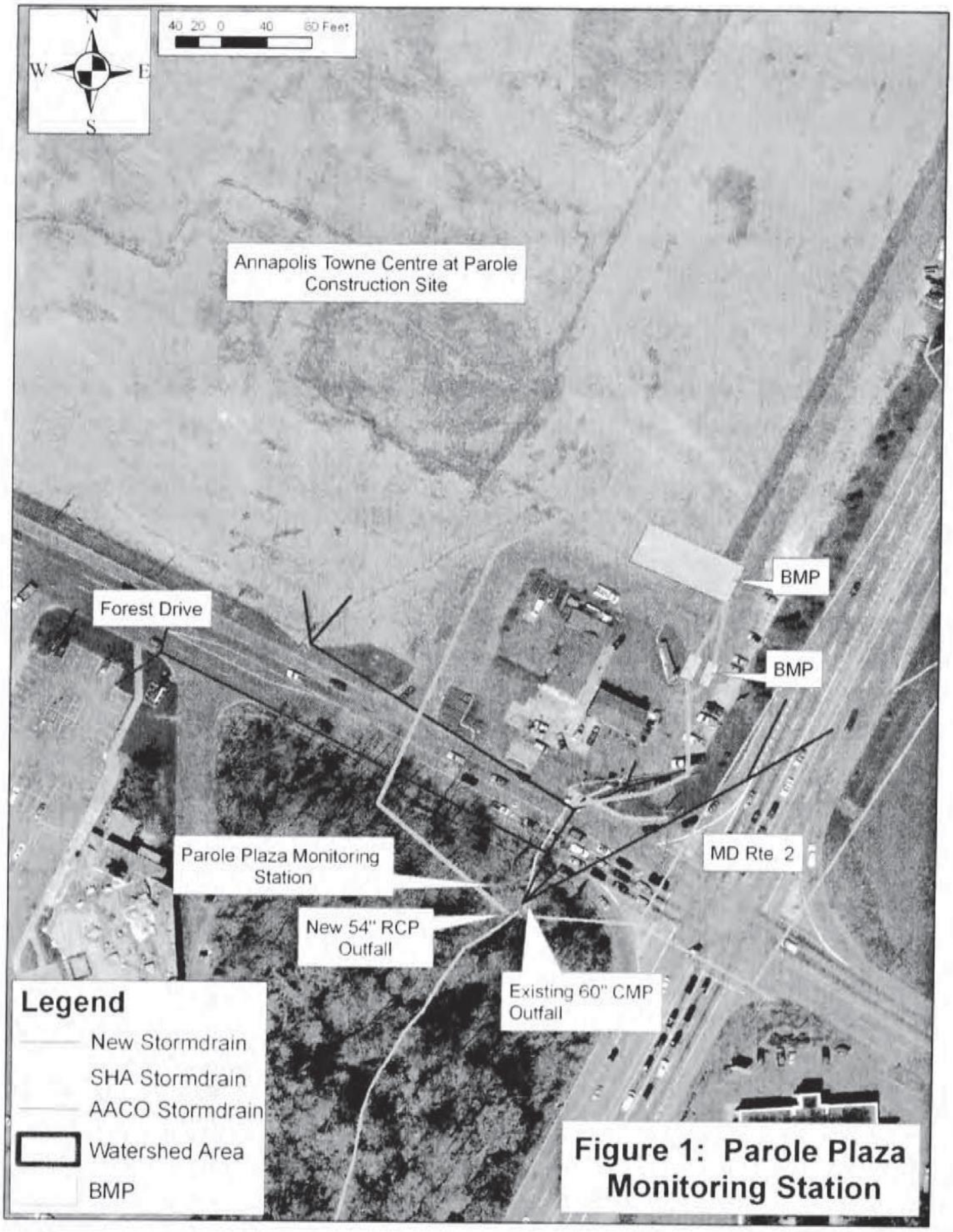


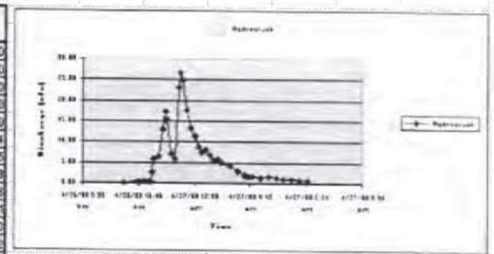

Figure 1: Parole Plaza Monitoring Station

Proposed Modifications to Sampling Procedures
Church Creek/Parole Plaza NPDES Monitoring 2008
KCI Job Order No. 01-032333.38
Page 4 of 4
5/12/08

# Figure 2

**Parole Plaza Combined Hydrograph**

| Date | Time | CMP Level (ft) | RCP Level (ft) | CMP Q (cfs) | RCP Q (cfs) | RCP pH | RCP Temp Celsius | Combined Q (cfs) | RCP Prop. % | CMP Prop. % |
|---|---|---|---|---|---|---|---|---|---|---|
| 4/26/08 | 4/26/08 10:30 PM | 0.00 | 0.05 | 0.00 | 0.04 | - | - | 0.04 | 100 | 0 |
| 4/26/08 | 4/26/08 10:47 PM | 0.00 | 0.15 | 0.00 | 0.19 | 6.70 | 15.40 | 0.19 | 100 | 0 |
| 4/26/08 | 4/26/08 10:50 PM | 0.00 | 0.18 | 0.00 | 0.26 | 6.70 | 15.40 | 0.26 | 100 | 0 |
| 4/26/08 | 4/26/08 10:55 PM | 0.00 | 0.16 | 0.00 | 0.21 | 6.60 | 15.80 | 0.21 | 100 | 0 |
| 4/26/08 | 4/26/08 11:00 PM | 0.00 | 0.15 | 0.00 | 0.19 | 6.60 | 15.80 | 0.19 | 100 | 0 |
| 4/26/08 | 4/26/08 11:03 PM | 0.10 | 0.15 | 0.15 | 0.19 | 6.00 | 16.00 | [redacted] | 56 | 44 |
| 4/26/08 | 4/26/08 11:06 PM | 0.25 | 0.40 | 1.10 | 1.36 | 6.00 | 16.00 | 2.46 | 55 | 45 |
| 4/26/08 | 4/26/08 11:08 PM | 0.43 | 0.52 | 3.36 | 2.37 | 5.80 | 16.10 | 5.74 | 41 | 59 |
| 4/26/08 | 4/26/08 11:15 PM | 0.45 | 0.55 | 3.71 | 2.68 | 6.20 | 15.80 | 6.39 | 42 | 58 |
| 4/26/08 | 4/26/08 11:20 PM | 0.65 | 0.75 | 7.95 | 5.06 | 6.10 | 15.50 | 13.01 | 39 | 61 |
| 4/26/08 | 4/26/08 11:22 PM | 0.70 | 0.95 | 9.21 | 8.17 | 5.90 | 15.50 | 17.38 | 47 | 53 |
| 4/26/08 | 4/26/08 11:25 PM | 0.65 | 0.90 | 7.95 | 7.31 | 5.90 | 15.60 | 15.26 | 48 | 52 |
| 4/26/08 | 4/26/08 11:30 PM | 0.43 | 0.65 | 3.36 | 3.78 | 6.90 | 15.60 | 7.14 | 53 | 47 |
| 4/26/08 | 4/26/08 11:35 PM | 0.40 | 0.58 | 2.85 | 2.98 | 7.00 | 15.60 | 5.83 | 51 | 49 |
| 4/26/08 | 4/26/08 11:40 PM | 0.90 | 0.93 | 15.45 | 7.83 | 6.90 | 15.60 | 23.28 | 34 | 66 |
| 4/26/08 | 4/26/08 11:42 PM | 0.85 | 1.20 | 13.73 | 12.96 | 7.00 | 15.60 | [redacted] | 48 | 52 |
| 4/26/08 | 4/26/08 11:45 PM | 0.80 | 1.10 | 13.13 | 11.55 | 6.90 | 15.60 | 24.67 | 47 | 53 |
| 4/26/08 | 4/26/08 11:50 PM | 0.72 | 0.90 | 9.79 | 7.83 | 7.10 | 15.80 | 17.62 | 44 | 56 |
| 4/26/08 | 4/26/08 11:55 PM | 0.62 | 0.80 | 7.19 | 6.22 | 7.10 | 15.80 | 13.40 | 46 | 54 |
| 4/27/08 | 4/27/08 12:00 AM | 0.57 | 0.77 | 6.04 | 5.34 | 7.20 | 15.30 | 11.38 | 47 | 53 |
| 4/27/08 | 4/27/08 12:05 AM | 0.51 | 0.68 | 4.77 | 4.10 | 7.10 | 15.40 | 8.90 | 46 | 54 |
| 4/27/08 | 4/27/08 12:10 AM | 0.46 | 0.64 | 3.88 | 3.66 | 7.40 | 15.30 | 7.53 | 49 | 51 |
| 4/27/08 | 4/27/08 12:15 AM | 0.48 | 0.65 | 4.22 | 3.78 | 7.20 | 15.30 | 7.99 | 47 | 53 |
| 4/27/08 | 4/27/08 12:20 AM | 0.42 | 0.65 | 3.19 | 3.78 | 8.00 | 15.30 | 6.97 | 54 | 46 |
| 4/27/08 | 4/27/08 12:25 AM | 0.36 | 0.60 | 2.33 | 3.18 | 7.90 | 15.30 | 5.51 | 58 | 42 |
| 4/27/08 | 4/27/08 12:30 AM | 0.38 | 0.60 | 2.59 | 3.18 | 7.80 | 15.30 | 5.77 | 55 | 45 |
| 4/27/08 | 4/27/08 12:35 AM | 0.36 | 0.55 | 2.33 | 2.68 | 7.60 | 15.40 | 5.01 | 53 | 47 |
| 4/27/08 | 4/27/08 12:45 AM | 0.30 | 0.55 | 1.55 | 2.68 | 7.30 | 15.30 | 4.23 | 63 | 37 |
| 4/27/08 | 4/27/08 12:55 AM | 0.25 | 0.45 | 1.10 | 1.77 | 7.20 | 15.30 | 2.87 | 62 | 38 |
| 4/27/08 | 4/27/08 1:05 AM | 0.18 | 0.40 | 0.55 | 1.36 | 7.30 | 15.30 | 1.91 | 71 | 29 |
| 4/27/08 | 4/27/08 1:10 AM | 0.17 | 0.37 | 0.50 | 1.17 | 7.20 | 15.30 | 1.67 | 70 | 30 |
| 4/27/08 | 4/27/08 1:15 AM | 0.16 | 0.35 | 0.45 | 1.05 | 7.40 | 15.30 | [redacted] | 70 | 30 |
| 4/27/08 | 4/27/08 1:25 AM | 0.13 | 0.33 | 0.30 | 0.93 | 7.20 | 15.30 | 1.23 | 76 | 24 |
| 4/27/08 | 4/27/08 1:35 AM | 0.13 | 0.40 | 0.30 | 1.36 | 7.30 | 15.30 | 1.66 | 82 | 18 |
| 4/27/08 | 4/27/08 1:45 AM | 0.13 | 0.35 | 0.30 | 1.05 | 7.40 | 15.30 | 1.35 | 78 | 22 |
| 4/27/08 | 4/27/08 1:55 AM | 0.13 | 0.30 | 0.30 | 0.74 | 7.20 | 15.30 | 1.04 | 71 | 29 |
| 4/27/08 | 4/27/08 2:05 AM | 0.11 | 0.30 | 0.20 | 0.74 | 7.60 | 15.30 | 0.94 | 79 | 21 |
| 4/27/08 | 4/27/08 2:15 AM | 0.10 | 0.25 | 0.15 | 0.53 | 7.30 | 15.30 | 0.68 | 78 | 22 |
| 4/27/08 | 4/27/08 2:25 AM | 0.09 | 0.25 | 0.14 | 0.53 | 7.40 | 15.30 | 0.66 | 80 | 20 |



**RCP - Velocity Probe**

| Depth | Velocity | SNR | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**CMP - Velocity Probe**

| Depth | Velocity | SNR | Notes |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**Comments**

| Pipe | Time | Comment |
|---|---|---|
| -- | 3:22 PM | CMP dry, RCP with small baseflow (0.05), Church normal |
| -- | 10:19 PM | Started to rain |
| | 10:35 PM | Steady Light Rain/Thunder |
| | 10:47 PM | RCP: Turbid flow |
| CMP | 11:03 PM | smells bad, trash |
| CMP | 11:50 PM | Muddy Water |
| | | |
| | | |
| | | |
| | | |
| | | |

# Storm Event Narratives

## Storm: August 21, 2018

The storm event on August 21, 2018 delivered 1.13 inches of rain. The storm lasted approximately four hours. These measurements were based on data from the Church Creek rain gauge.

At Church Creek, two of the parameter Event Mean Concentrations (EMCs) were greater than their respective long-term average concentrations, as measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for Total Petroleum Hydrocarbons (TPH) exceeded the average by 464.6%. The concentrations for TPH were 6 mg/L in the sample for the rising limb and 5 mg/L in the sample for the falling limb; for context, TPH is typically non-detectible in samples from all limbs throughout a storm event. The *E. coli* concentrations in the samples collected during the storm measured 1,970 MPN/100 ml (rising limb), 13,540 MPN/100 ml (peak), and 23,590 MPN/100 ml (falling limb). The EMC for *E. coli* exceeded its corresponding average by 232.7%.

At Parole Plaza, the EMC for TPH also exceeded the program's corresponding long-term average concentrations. The EMC for TPH exceeded the historical average by 64.6%.

## Storm: October 11, 2018

The storm event on October 11, 2018 delivered 2.26 inches of rainfall and storm lasted approximately eight hours. These measurements were based on data from the Church Creek rain gauge.

At Church Creek, only one of the parameter Event Mean Concentrations (EMCs) was greater than its respective long-term average concentration, as measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for *E. coli* exceeded the long-term average by 22%. The individual *E. coli* concentrations in the samples collected during the storm measured 9,208 MPN/100 ml (rising limb), 14,136 MPN/100 ml (peak), and 5,172 MPN/100 ml (falling limb) and fell within the expected range of results (0 to 20,000 MPN/100 ml) for stormflow samples.

At Parole Plaza, only the EMC for *E. coli* exceeded its corresponding long-term average concentration for the program. The EMC for *E. coli* exceeded the average by 6.1% with individual concentrations that were high (example 17,586 MPN/100 ml during the peak limb) but were within the expected range of results observed since 2012 for this station. Due to technician error, the field team did not obtain a rising limb sample at the Parole Plaza station.

**Storm: October 26, 2018**

The storm delivered 0.98 inches of total rainfall and lasted approximately eight hours. These measurements are based on data from the Church Creek rain gauge.

At both stations, none of the parameter EMCs exceeded the long-term average concentrations for the program. During this storm event. none of the discrete concentrations exceeded levels that would require immediate reporting to the County.

**Storm: November 9, 2018**

The storm delivered 0.47 inches of total rainfall and lasted approximately nine hours. These measurements are based on data from the Church Creek rain gauge.

At both stations, none of the parameter EMCs exceeded the long-term average concentrations for the program. During this storm event, none of the discrete concentrations exceeded levels that would require immediate reporting to the County.

**Storm: January 19, 2019**

The storm event on January 19, 2019, delivered 0.55 inches of rainfall and lasted approximately five hours. These measurements were based on data from the Church Creek rain gauge.

At Church Creek, four of the parameter Event Mean Concentrations (EMCs) were greater than their respective long-term average concentrations, as measured during storms monitored for the program (i.e., since December 12, 2012). The EMCs for the metals exceeded the long-term average by 15.3% to 31.3%. The zinc concentration in the sample collected during the rising limb of the storm was 281 µg/L; this was not above the County's threshold of 2,500 µg/L to classify it as a concern. The high levels of zinc may have been associated with leachate from building materials, automobile parts, and pieces of metal in the runoff during the initial stages of the event. The hardness EMC was above the long-term average level by 4.9%, with a reading of 170 mg/L in the sample collected during the rising limb of the storm event. The use of de-icing compounds during the winter months may have contributed to higher-than-average hardness levels.

At Parole Plaza, only the EMC for Total Petroleum Hydrocarbons (TPH) exceeded its corresponding long-term average concentration for the program. The EMC for TPH exceeded the average by 1150%, with concentrations in contributing, discrete samples that were excessively high. During the peak limb, the TPH level was 24 mg/L; during the rising limb, the level was 12 mg/L. The peak results for TPH were the highest documented for the program since 2012. These high concentrations could have derived from vehicles leaking oils and fuels onto paved surfaces in the watershed.

**Storm: February 24, 2019**

The storm delivered 0.62 inches of total rainfall and lasted approximately eleven hours. These measurements are based on data from the Church Creek rain gauge.

At Church Creek, only one of the parameter Event Mean Concentrations (EMCs) was greater than its corresponding long-term average concentration, as measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for Total Suspended Solids (TSS) exceeded the long-term average by 6%. In the sample collected during the peak limb of the storm, the TSS concentration was 190 mg/L. The additional sediment may have been released from the stream banks during erosion, as frozen precipitation melted. The field team noted, however, that the extent of the erosion resulting from the storm had not been significant.

At Parole Plaza, none of the parameter EMCs exceeded the long-term average concentrations for the program. During this storm event, none of the discrete concentrations exceeded threshold levels, established by the County, that would be a concern.

**Storm: March 21, 2019**

The storm delivered 0.83 inches of total rainfall and lasted approximately fourteen hours. These measurements are based on data from the Church Creek rain gauge.

At both stations, none of the parameter EMCs exceeded the long-term average concentrations for the program. During the storm event, none of the discrete concentrations exceeded threshold levels, established by the County, that would be a concern.

**Storm: May 11, 2019**

The storm delivered 0.39 inches of total rainfall and lasted approximately twelve hours. These measurements are based on data from the Church Creek rain gauge.

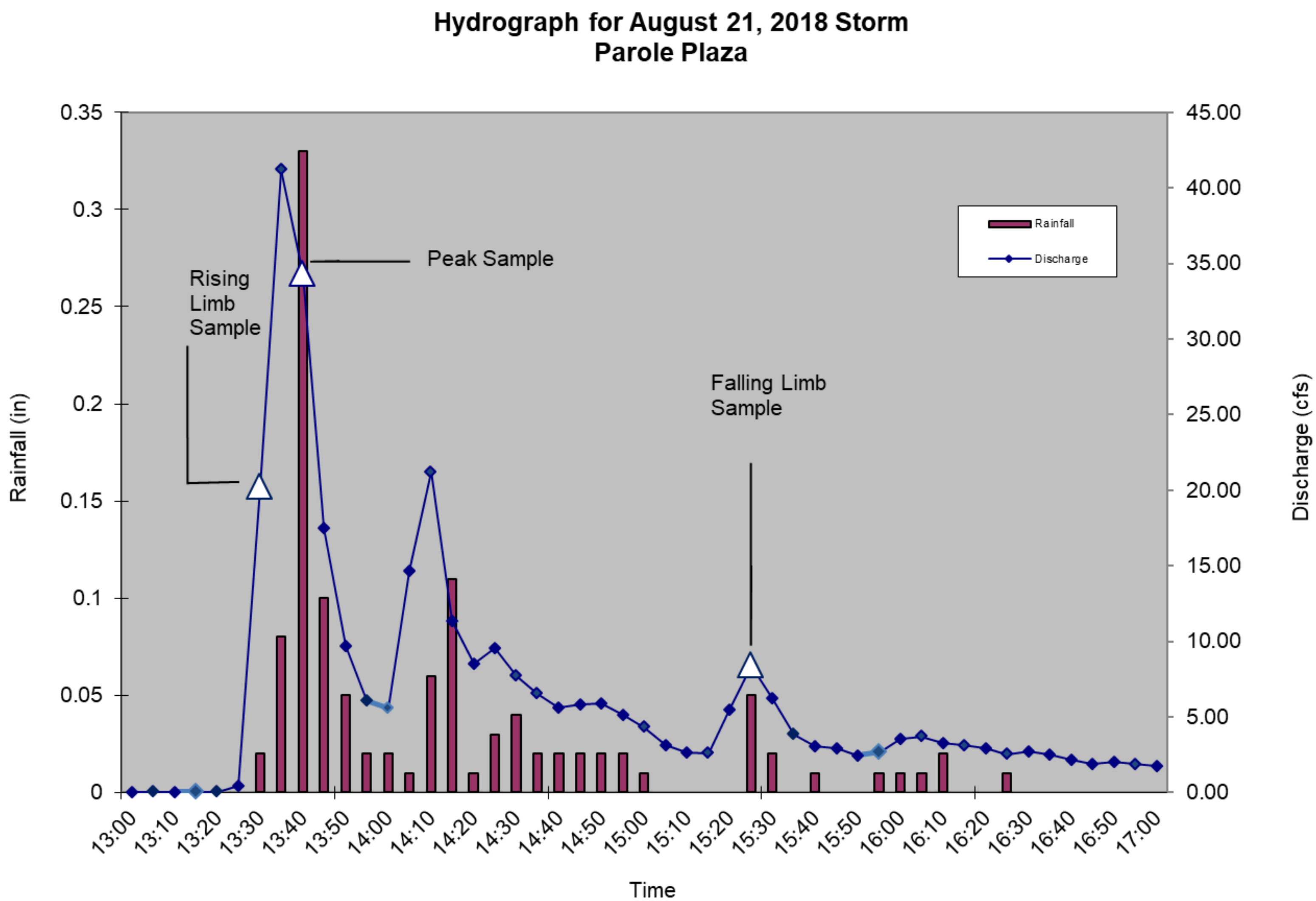
At Church Creek, eight of the parameter Event Mean Concentrations (EMCs) was greater than its corresponding long-term average concentration, as measured during storms monitored for the program (i.e., since December 12, 2012). The EMC for 5-day Biochemical Oxygen Demand ($BOD_5$) was 5% higher than the long-term average, with a value of 3 mg/L. Kjeldahl Nitrogen, Nitrate +Nitrite, and Phosphorus parameters were higher by 3%, 2%, and 1% respectively, with values of 0.4 mg/L, 0.66 mg/L, and 0.15 mg/L. Other metal parameters had higher than average EMCs including Copper, Lead, and Zinc. Copper was 1% greater than average with 12.1 mg/L, Lead was 1% higher with 4.4 mg/L, and Zinc was 1% higher than average with 73 mg/L. Finally, hardness was 1% higher than average with a value of 42 mg/L.

At Parole Plaza, two of the parameter EMCs exceeded the long-term average concentrations for the program. Nitrate + Nitrite had levels of 0.49 mg/L which is 1.75% higher than the long-term average. Also, zinc exceeded the long-term average with a value of 109 mg/L and was 1% higher than average. During this storm event, none of the discrete concentrations exceeded threshold levels, established by the County.

**Storm: June 13, 2019**

The storm delivered 1.57 inches of total rainfall and lasted approximately nine hours. These measurements are based on data from the Church Creek rain gauge.

At both stations, none of the parameter EMCs exceeded the long-term average concentrations for the program. During the storm event, none of the discrete concentrations exceeded threshold levels, established by the County, that would be a concern.


Hydrograph for August 21, 2018 Storm
Parole Plaza
Rainfall (in)
Discharge (cfs)
Time
Rising Limb Sample
Peak Sample
Falling Limb Sample
Rainfall
Discharge
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
13:00
13:10
13:20
13:30
13:40
13:50
14:00
14:10
14:20
14:30
14:40
14:50
15:00
15:10
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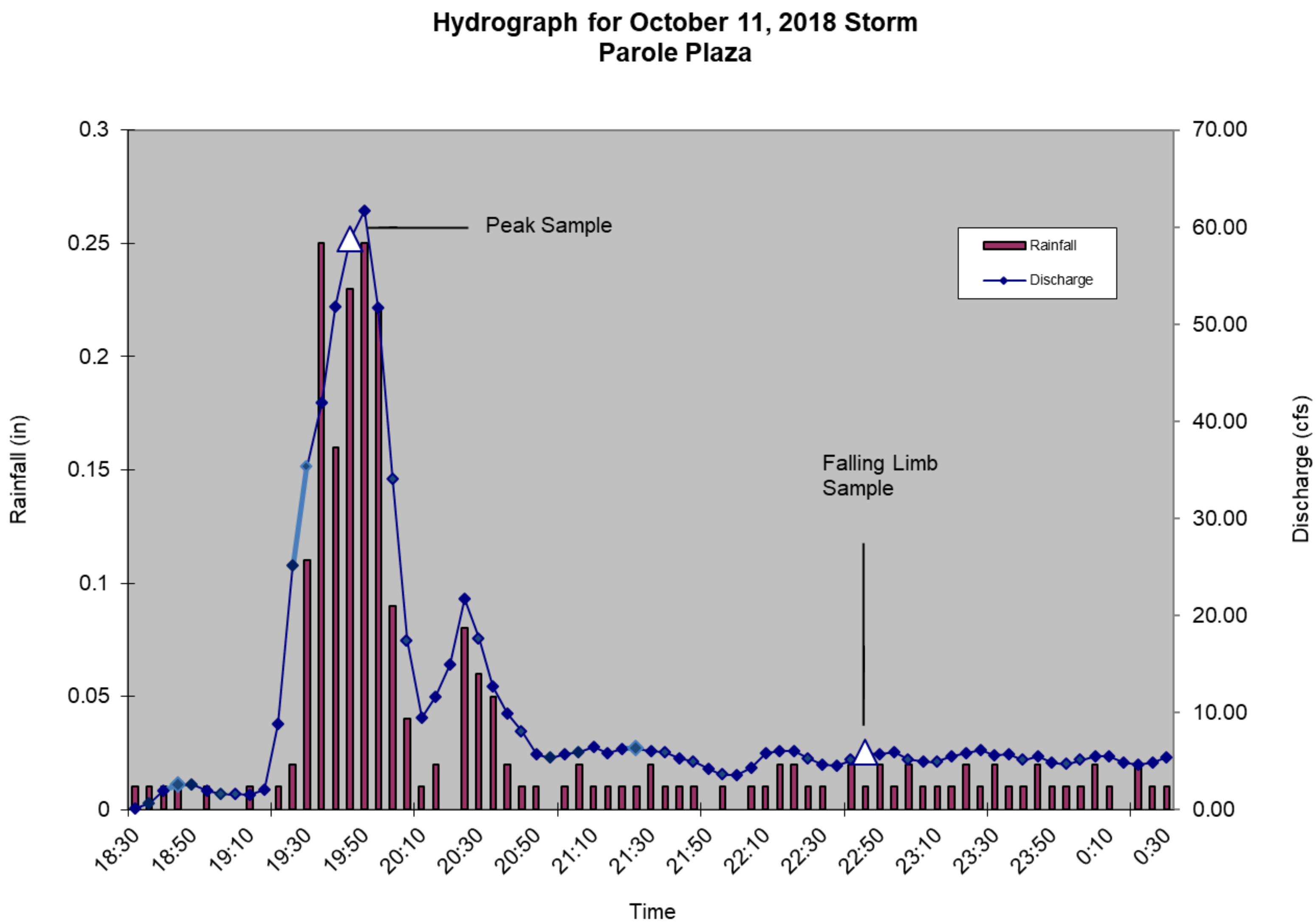
16:00
16:10
16:20
16:30
16:40
16:50
17:00


Hydrograph for October 11, 2018 Storm
Parole Plaza
Peak Sample
Falling Limb
Sample
Rainfall
Discharge
Rainfall (in)
Discharge (cfs)
Time
0
0.05
0.1
0.15
0.2
0.25
0.3
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
18:30
18:50
19:10
19:30
19:50
20:10
20:30
20:50
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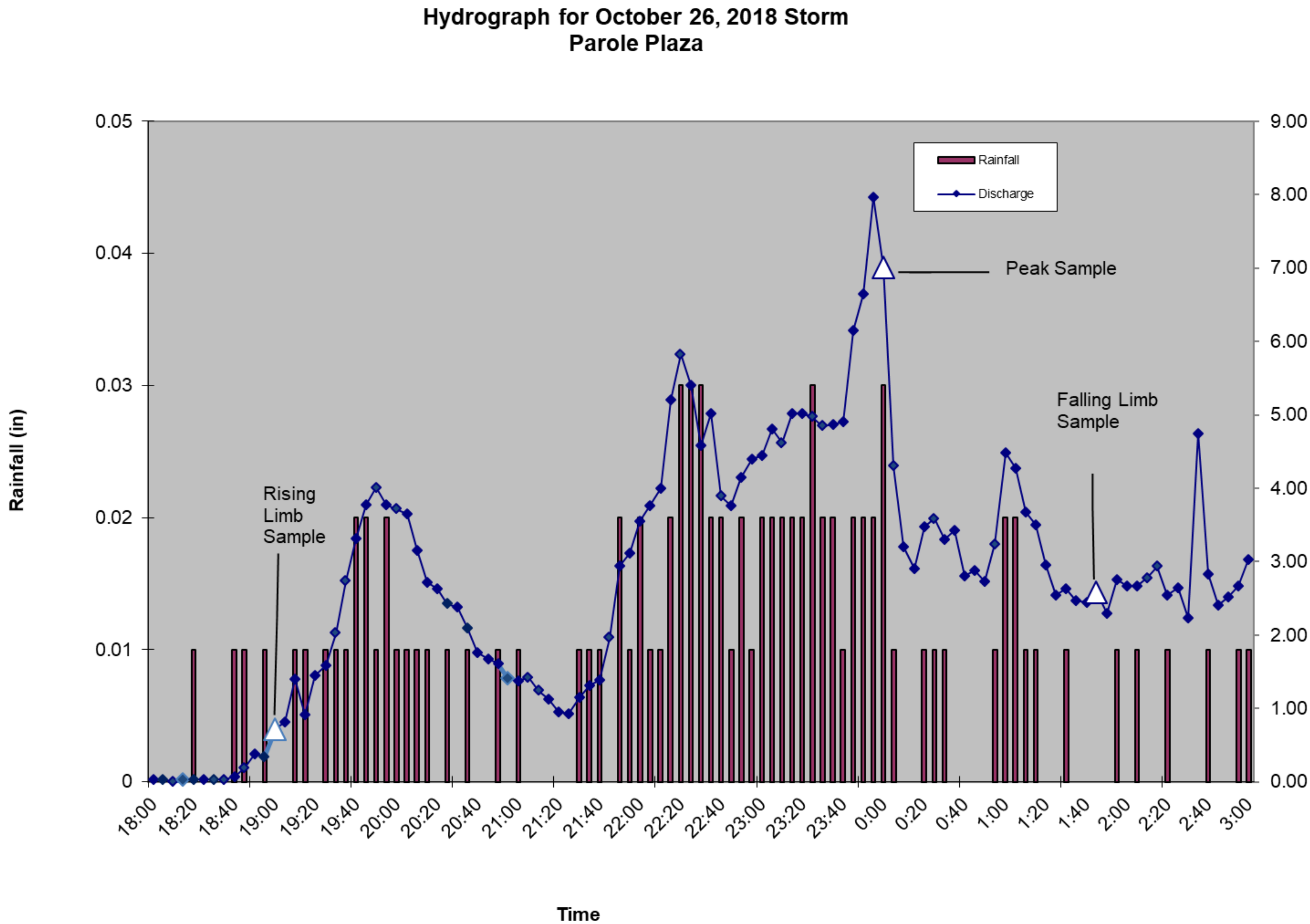
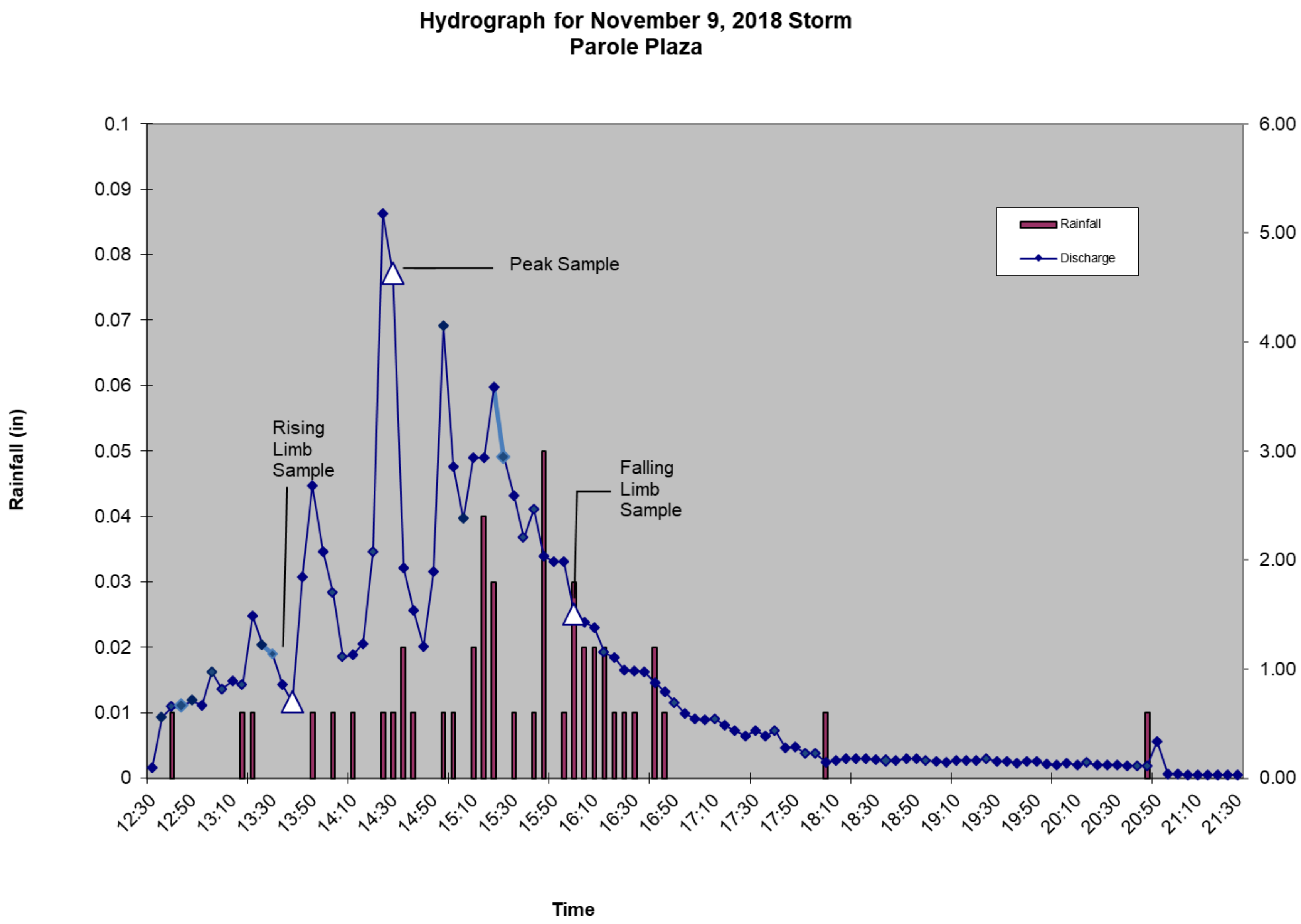
23:30
23:50
0:10
0:30

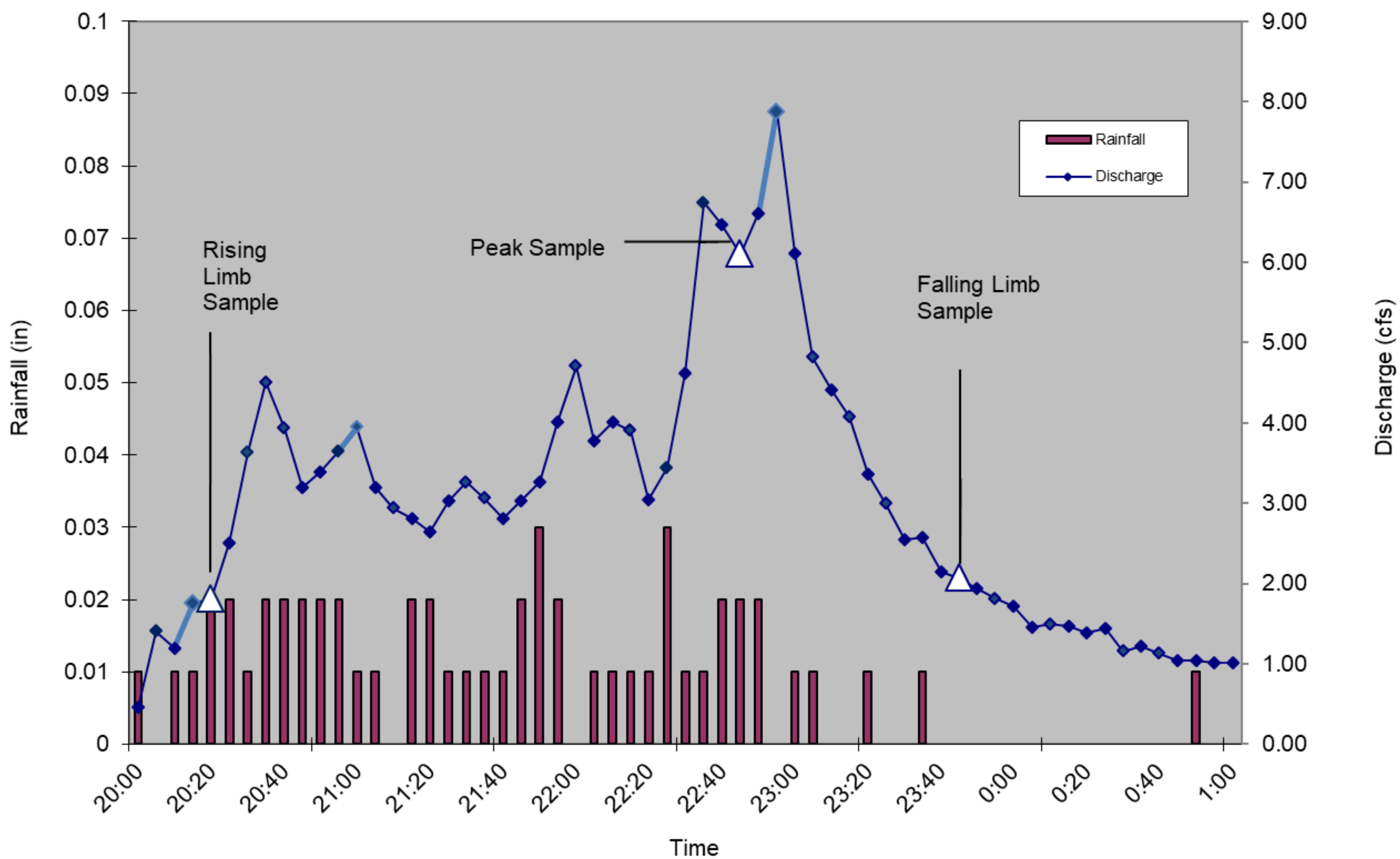

Hydrograph for October 26, 2018 Storm
Parole Plaza
Rainfall
Discharge
Peak Sample
Falling Limb Sample
Rising Limb Sample
Rainfall (in)
Time
0.05
0.04
0.03
0.02
0.01
0
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
18:00
18:20
18:40
19:00
19:20
19:40
20:00
20:20
20:40
21:00
21:20
21:40
22:00
22:20
22:40
23:00
23:20
23:40
0:00
0:20
0:40
1:00
1:20
1:40
2:00
2:20
2:40
3:00



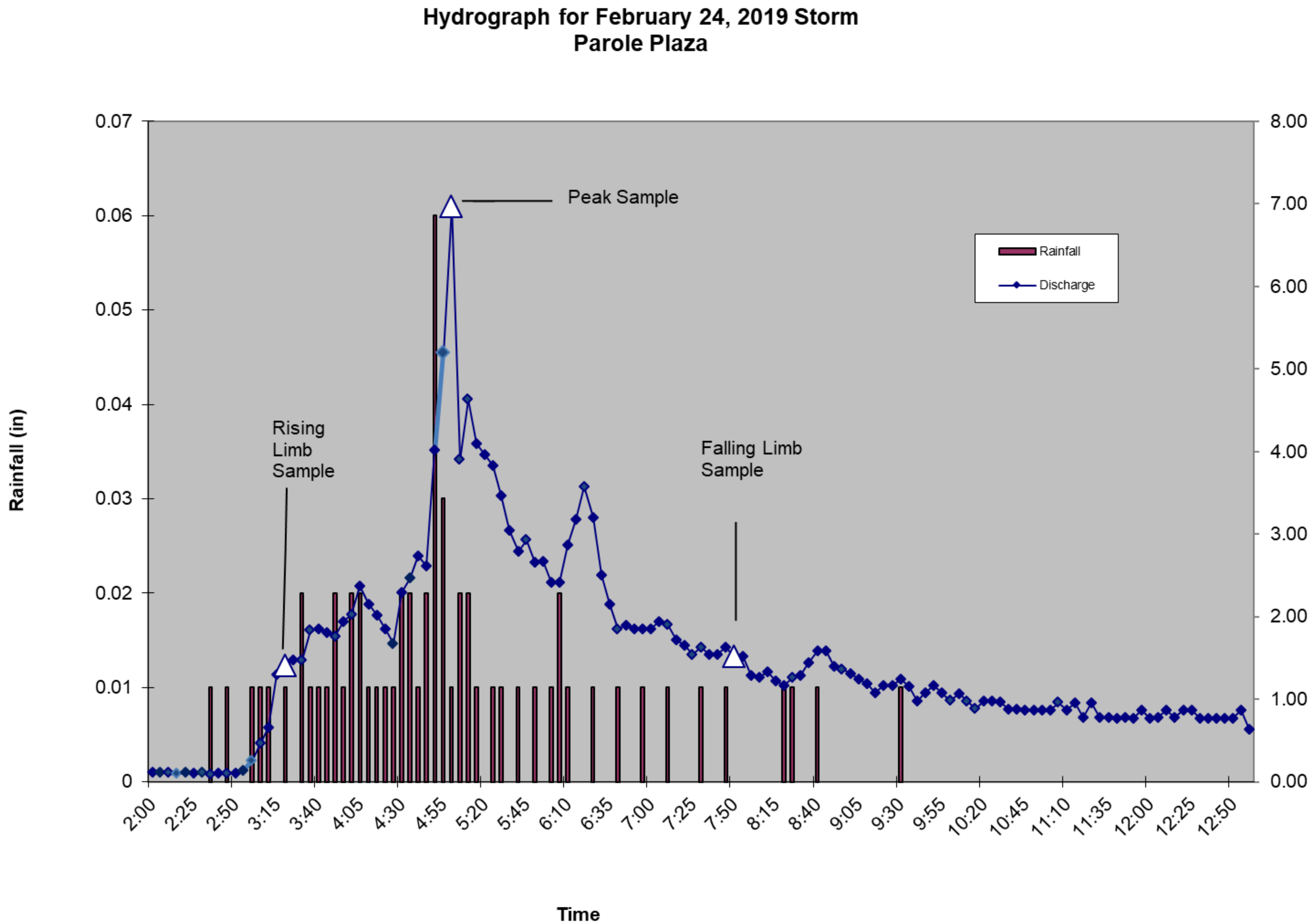
Hydrograph for November 9, 2018 Storm
Parole Plaza
Rainfall (in)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Rainfall
Discharge
Peak Sample
Rising Limb Sample
Falling Limb Sample
12:30
12:50
13:10
13:30
13:50
14:10
14:30
14:50
15:10
15:30
15:50
16:10
16:30
16:50
17:10
17:30
17:50
18:10
18:30
18:50
19:10
19:30
19:50
20:10
20:30
20:50
21:10
21:30
Time

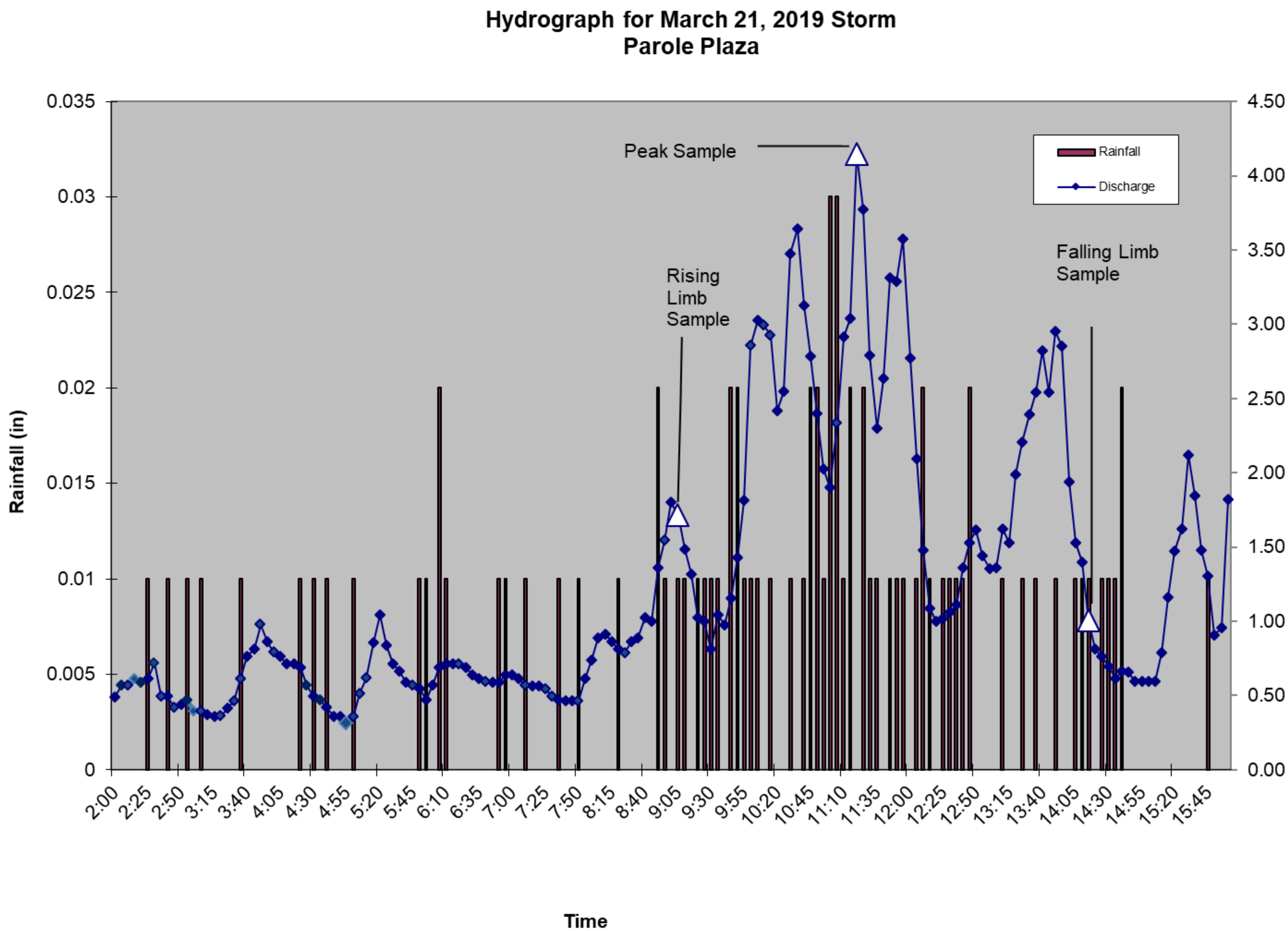

A-15

**Hydrograph for January 19, 2019 Storm**
**Parole Plaza**

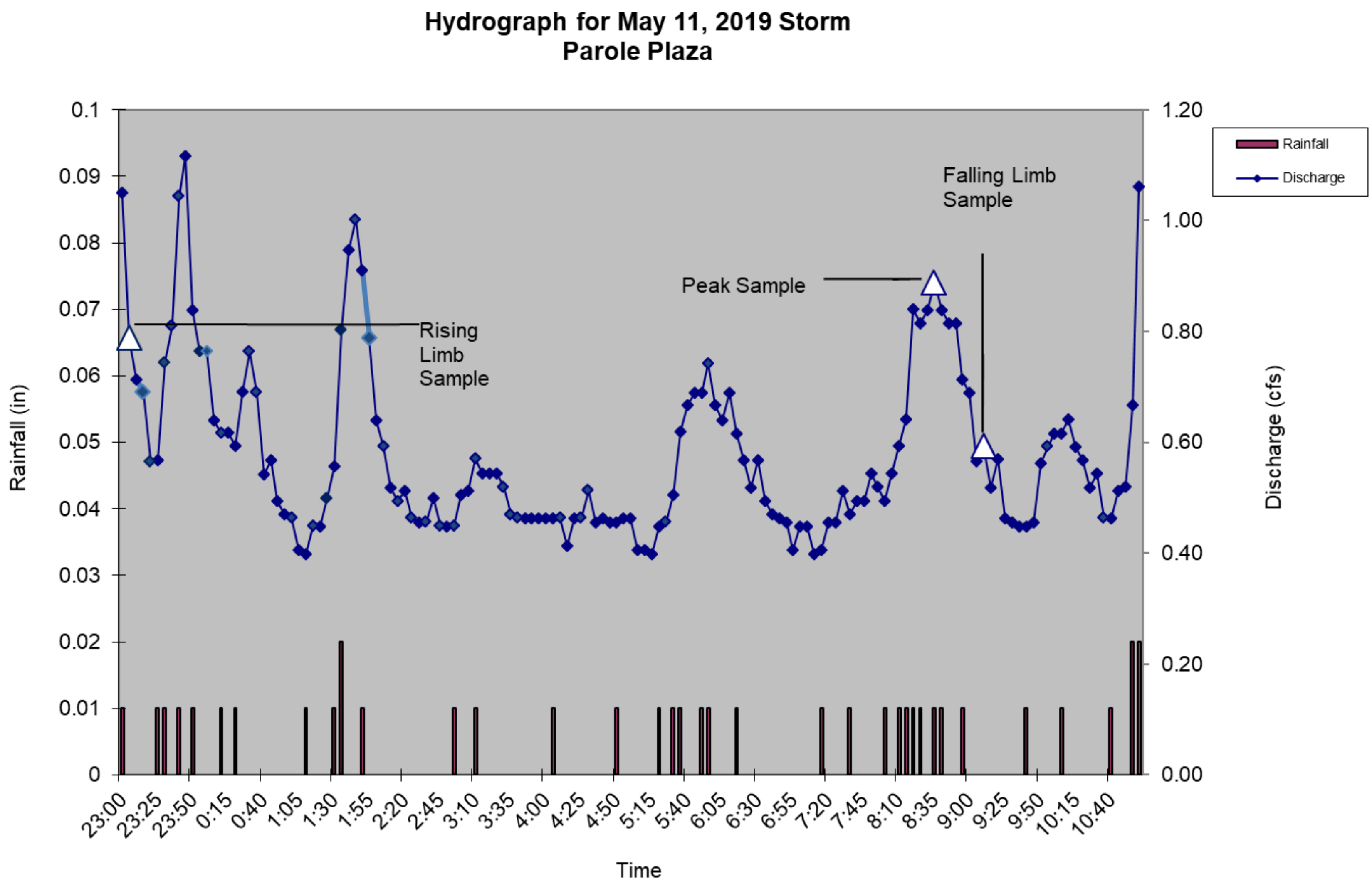


A-17

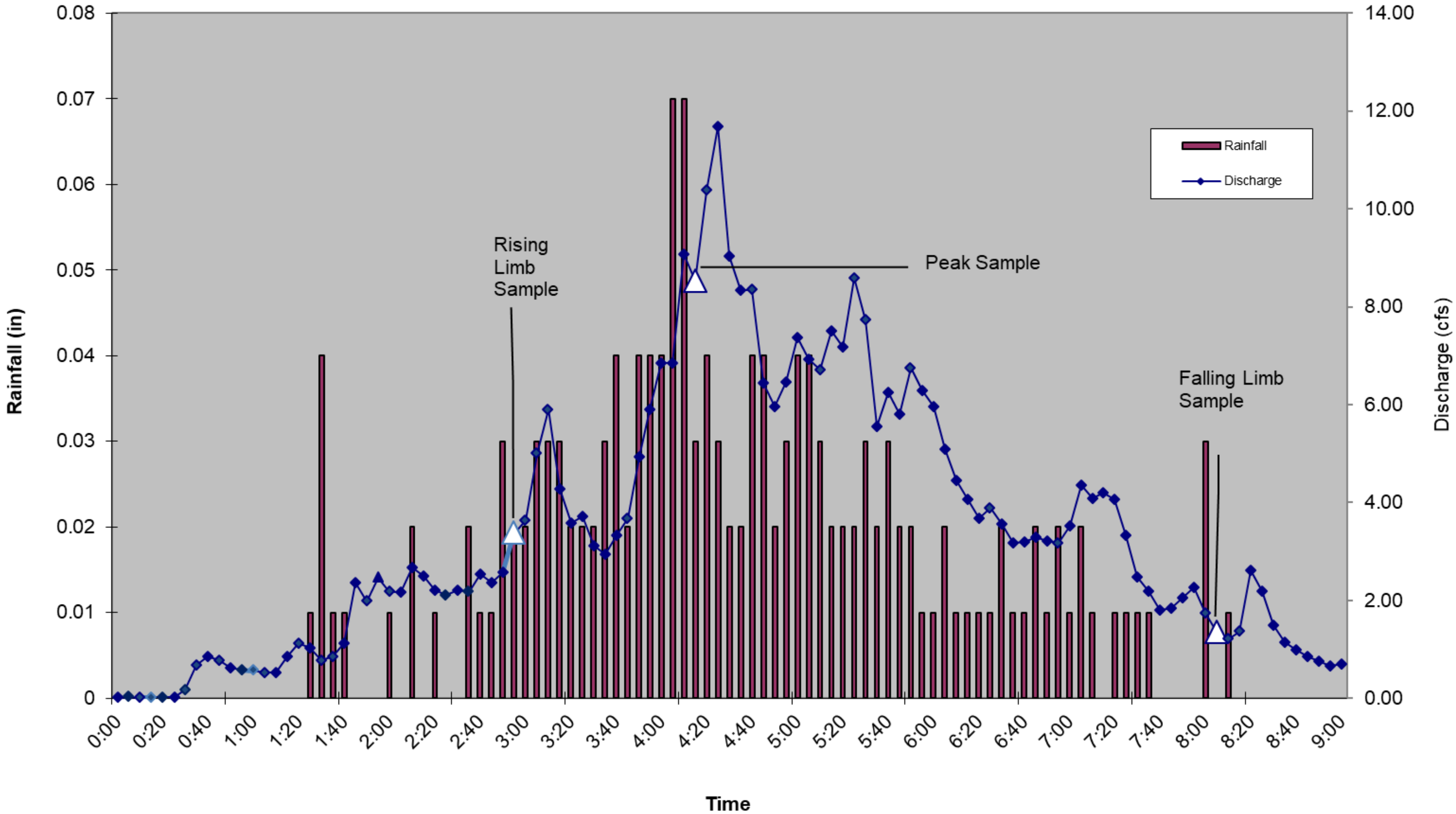

Hydrograph for February 24, 2019 Storm
Parole Plaza
Rainfall (in)
Time
Peak Sample
Rising Limb Sample
Falling Limb Sample
Rainfall
Discharge
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2:00
2:25
2:50
3:15
3:40
4:05
4:30
4:55
5:20
5:45
6:10
6:35
7:00
7:25
7:50
8:15
8:40
9:05
9:30
9:55
10:20
10:45
11:10
11:35
12:00
12:25
12:50



Hydrograph for March 21, 2019 Storm
Parole Plaza
Rainfall (in)
Time
Peak Sample
Rising Limb Sample
Falling Limb Sample
Rainfall
Discharge
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2:00
2:25
2:50
3:15
3:40
4:05
4:30
4:55
5:20
5:45
6:10
6:35
7:00
7:25
7:50
8:15
8:40
9:05
9:30
9:55
10:20
10:45
11:10
11:35
12:00
12:25
12:50
13:15
13:40
14:05
14:30
14:55
15:20
15:45

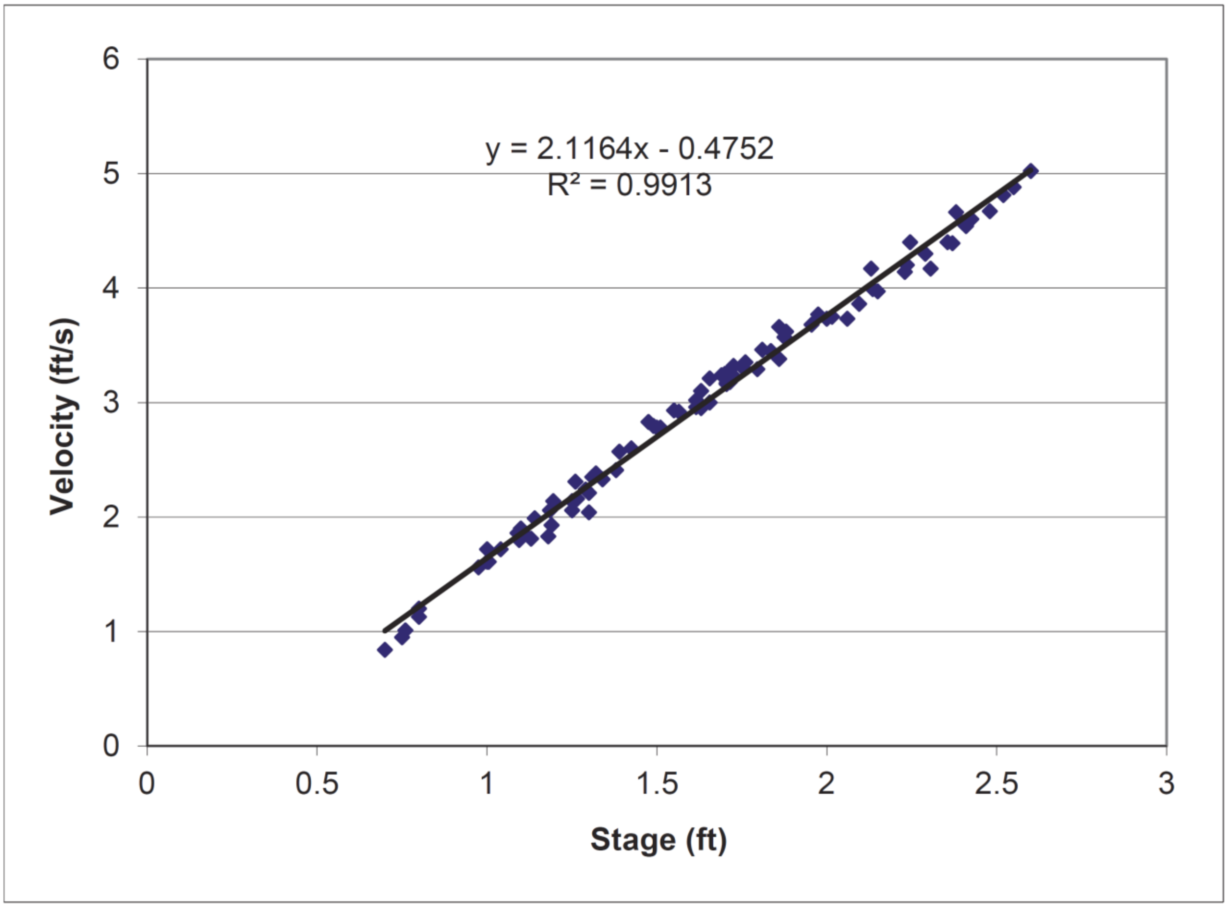

Hydrograph for May 11, 2019 Storm
Parole Plaza
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Rising
Limb
Sample
Peak Sample
Falling Limb
Sample
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1.20
1.00
0.80
0.60
0.40
0.20
0.00
23:00
23:25
23:50
0:15
0:40
1:05
1:30
1:55
2:20
2:45
3:10
3:35
4:00
4:25
4:50
5:15
5:40
6:05
6:30
6:55
7:20
7:45
8:10
8:35
9:00
9:25
9:50
10:15
10:40

**Hydrograph for June 13, 2019 Storm**
**Parole Plaza**

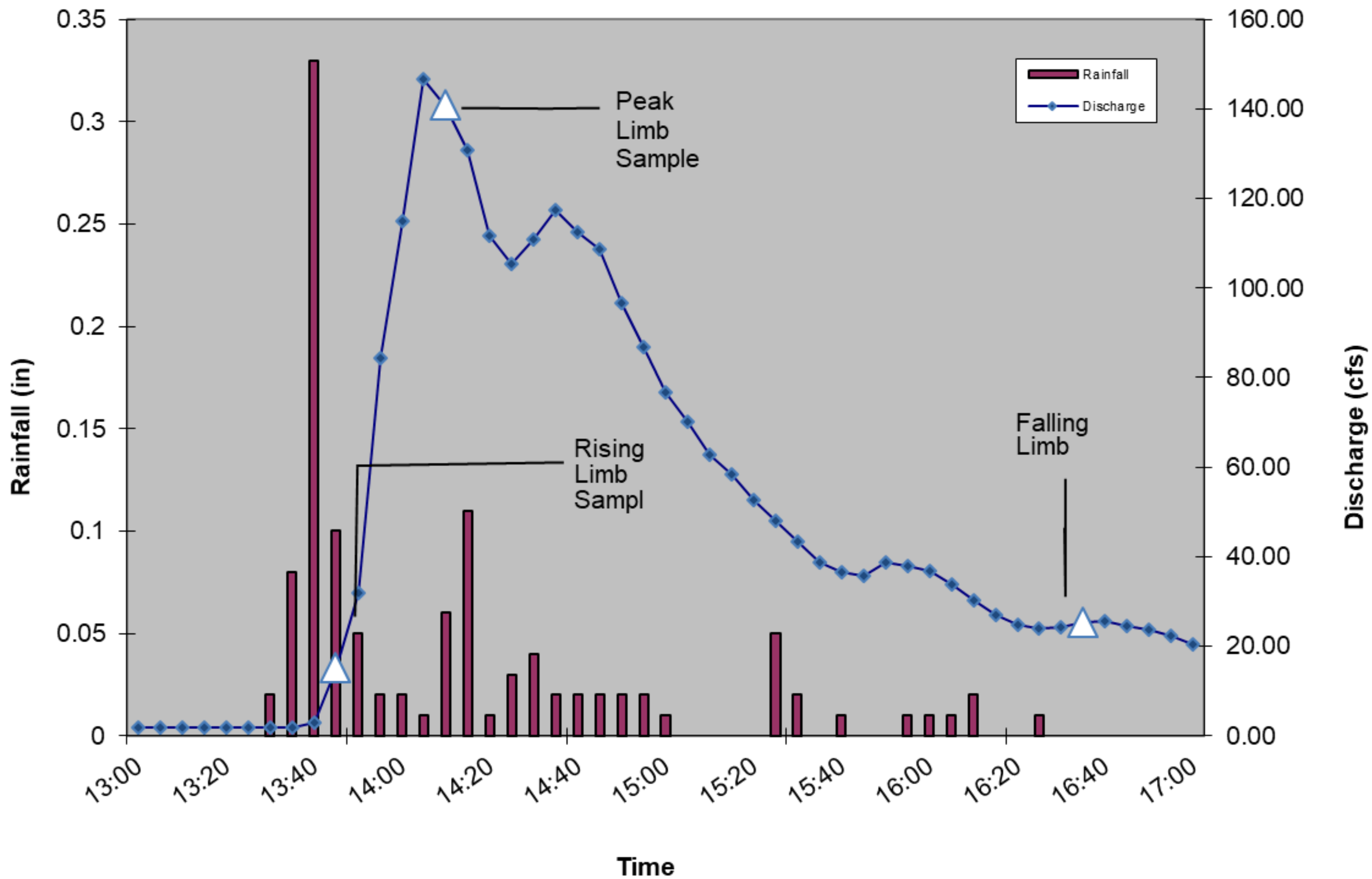


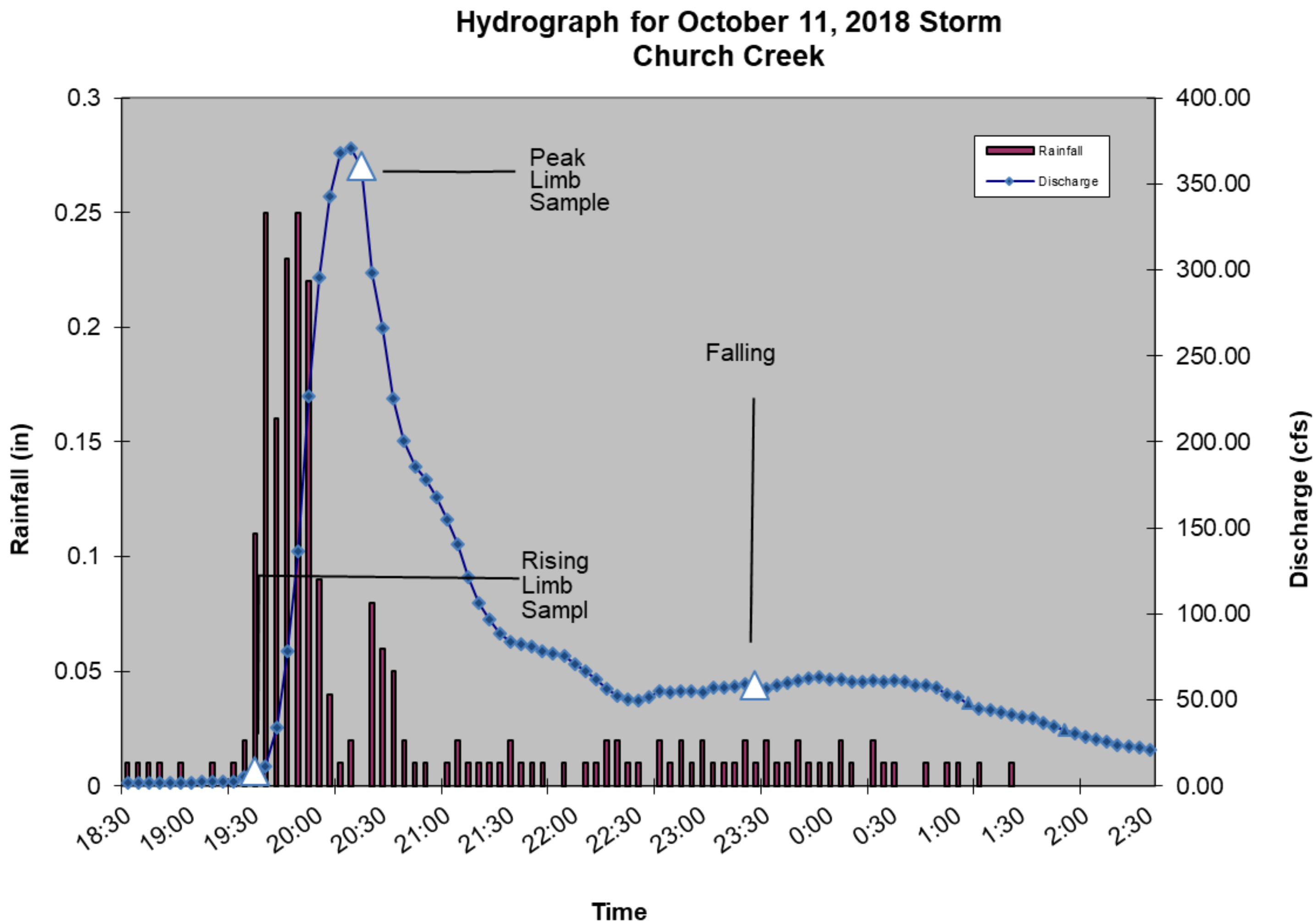
Church Creek Discharge Rating Table

| Stage (ft) | Flow Area ($ft^2$) | Wetted Perimeter (ft) | Top Width (ft) | Velocity, (ft/s) | Discharge (cfs) |
|---|---|---|---|---|---|
| 0.0 | 0 | 0 | 0 | 0.00 | 0.00 |
| 0.1 | 0.21 | 2.77 | 2.75 | 0.00 | 0.00 |
| 0.2 | 0.53 | 3.62 | 3.57 | 0.00 | 0.00 |
| 0.3 | 0.91 | 4.03 | 3.93 | 0.16 | 0.15 |
| 0.4 | 1.31 | 4.36 | 4.19 | 0.37 | 0.49 |
| 0.5 | 1.75 | 4.83 | 4.58 | 0.58 | 1.02 |
| 0.6 | 2.22 | 5.09 | 4.73 | 0.79 | 1.76 |
| 0.7 | 2.70 | 5.34 | 4.88 | 1.01 | 2.72 |
| 0.8 | 3.20 | 5.73 | 5.20 | 1.22 | 3.90 |
| 0.9 | 3.74 | 6.14 | 5.54 | 1.43 | 5.35 |
| 1.0 | 4.31 | 6.48 | 5.81 | 1.64 | 7.07 |
| 1.1 | 4.90 | 6.75 | 5.98 | 1.85 | 9.08 |
| 1.2 | 5.50 | 7.01 | 6.16 | 2.06 | 11.35 |
| 1.3 | 6.13 | 7.28 | 6.33 | 2.28 | 13.95 |
| 1.4 | 6.77 | 7.53 | 6.49 | 2.49 | 16.84 |
| 1.5 | 7.43 | 7.80 | 6.66 | 2.70 | 20.06 |
| 1.6 | 8.10 | 8.08 | 6.86 | 2.91 | 23.58 |
| 1.7 | 8.80 | 8.37 | 7.06 | 3.12 | 27.48 |
| 1.8 | 9.51 | 8.65 | 7.26 | 3.33 | 31.71 |
| 1.9 | 10.25 | 8.93 | 7.44 | 3.55 | 36.35 |
| 2.0 | 11.00 | 9.15 | 7.52 | 3.76 | 41.33 |
| 2.1 | 11.75 | 9.35 | 7.54 | 3.97 | 46.64 |
| 2.2 | 12.51 | 9.55 | 7.57 | 4.18 | 52.30 |
| 2.3 | 13.26 | 9.75 | 7.60 | 4.39 | 58.24 |
| 2.4 | 14.03 | 9.96 | 7.63 | 4.60 | 64.60 |
| 2.5 | 14.79 | 10.16 | 7.65 | 4.82 | 71.23 |
| 2.6 | 15.56 | 10.36 | 7.68 | 5.03 | 78.23 |
| 2.7 | 16.33 | 10.56 | 7.71 | 5.24 | 85.55 |
| 2.8 | 17.10 | 10.76 | 7.73 | 5.45 | 93.21 |
| 2.9 | 17.87 | 10.96 | 7.76 | 5.66 | 101.19 |
| 3.0 | 18.65 | 11.17 | 7.79 | 5.87 | 109.55 |
| 3.1 | 19.43 | 11.37 | 7.81 | 6.09 | 118.24 |
| 3.2 | 20.21 | 11.57 | 7.84 | 6.30 | 127.27 |
| 3.3 | 21.00 | 11.77 | 7.87 | 6.51 | 136.69 |
| 3.4 | 21.79 | 11.97 | 7.89 | 6.72 | 146.44 |
| 3.5 | 22.58 | 12.18 | 7.92 | 6.93 | 156.53 |
| 3.6 | 23.37 | 12.38 | 7.95 | 7.14 | 166.95 |
| 3.7 | 24.17 | 12.58 | 7.98 | 7.36 | 177.78 |

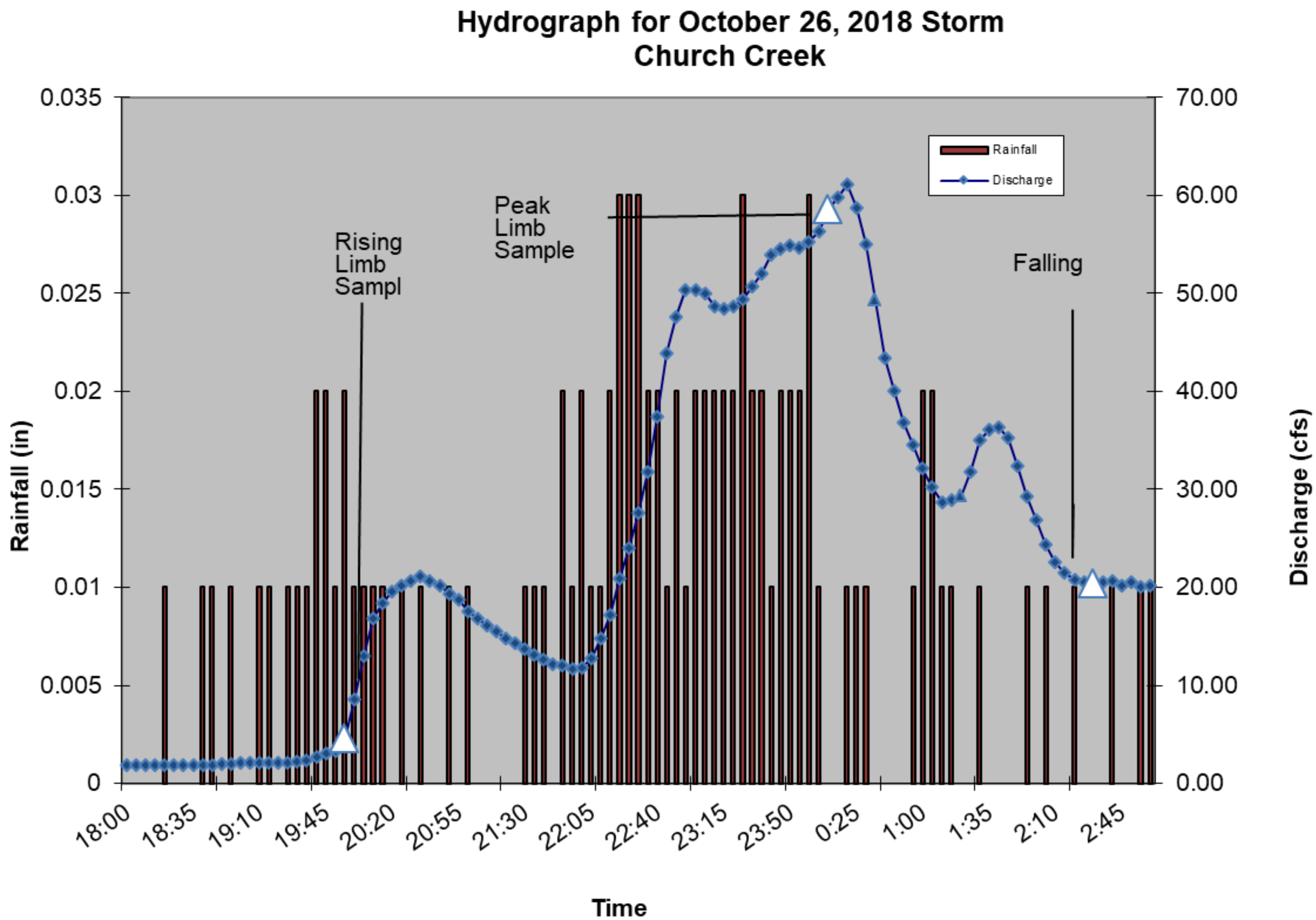

y = 2.1164x - 0.4752
R² = 0.9913
Velocity (ft/s)
Stage (ft)
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
3

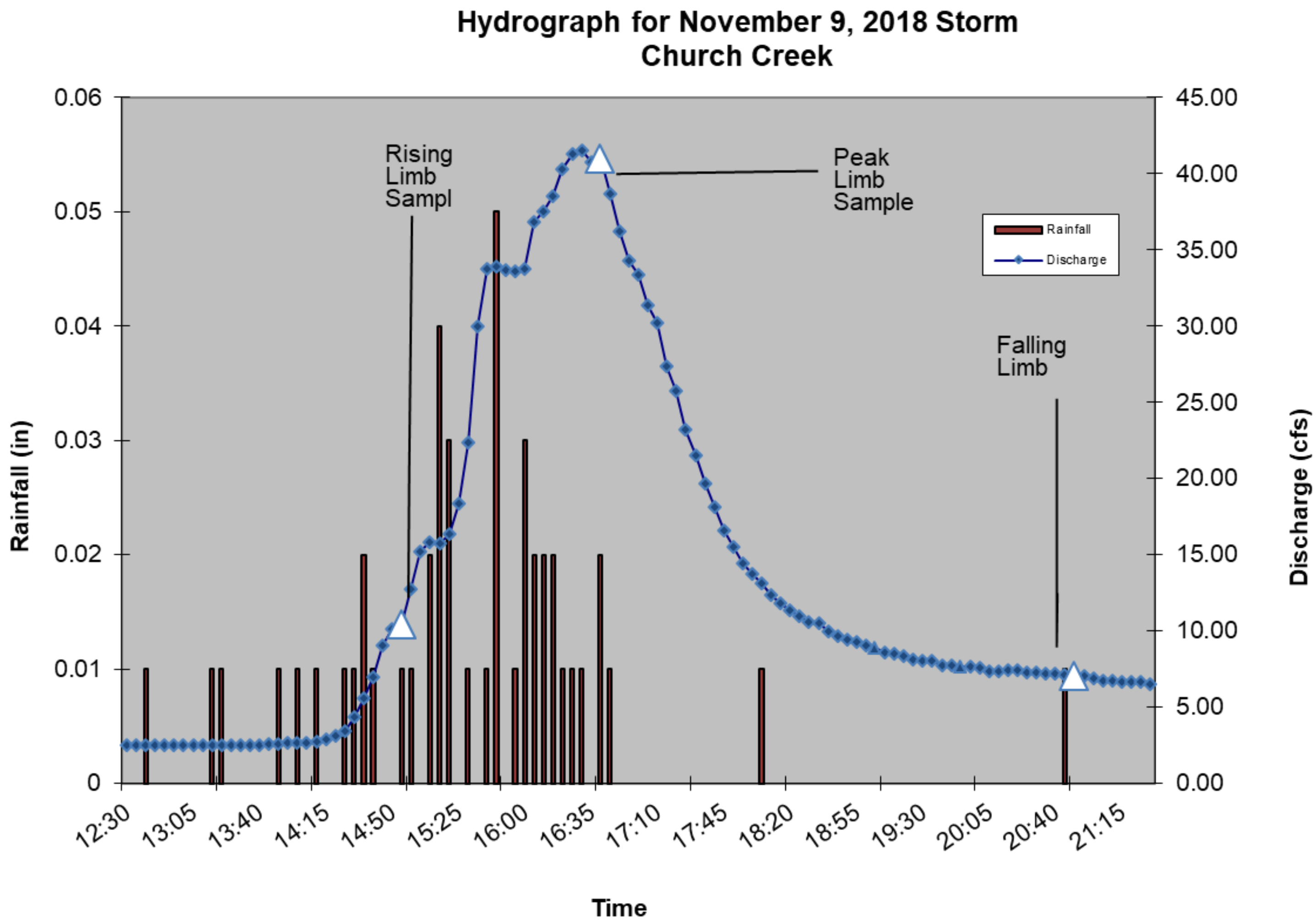
**Hydrograph for August 21, 2018 Storm**
**Church Creek**



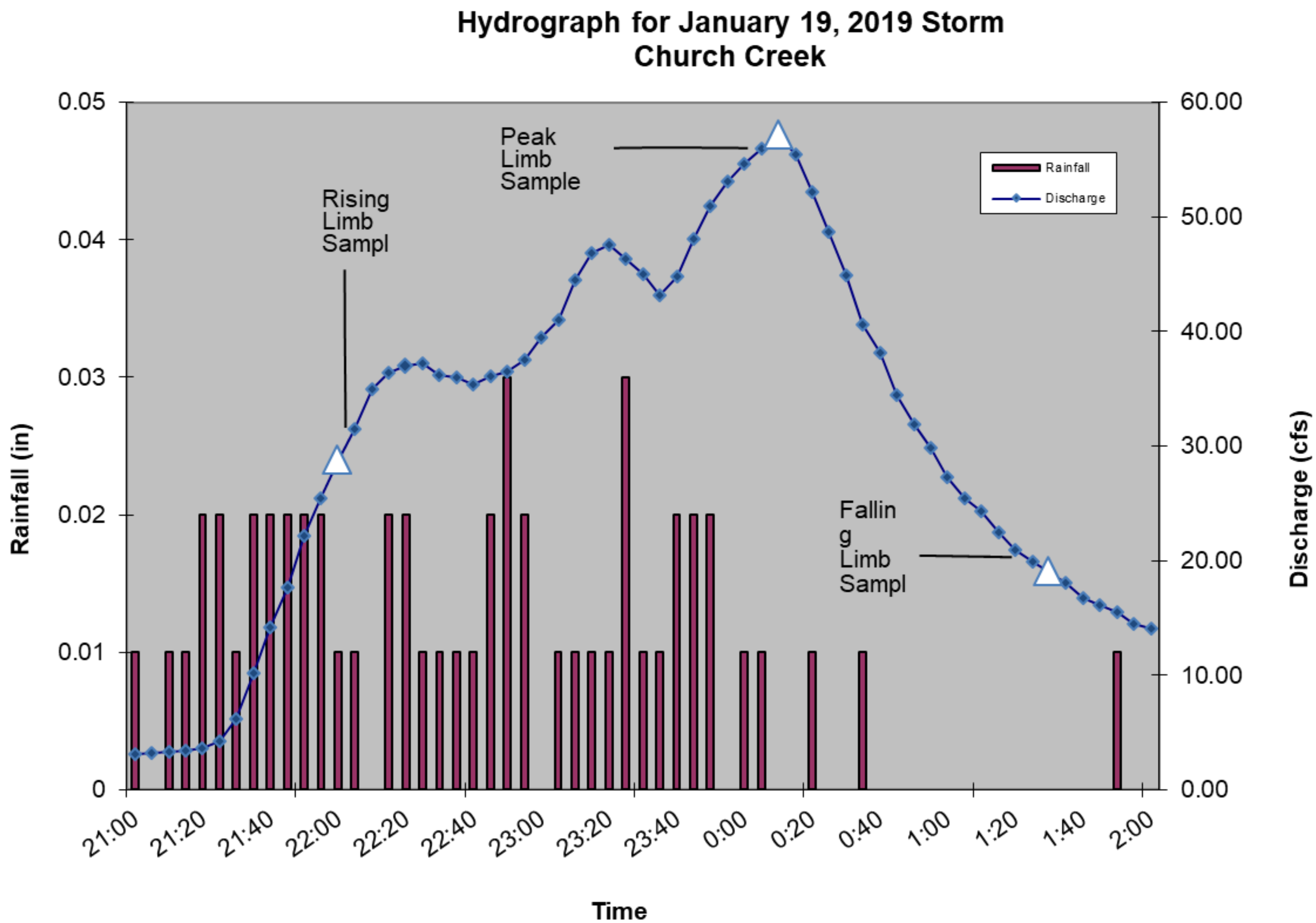


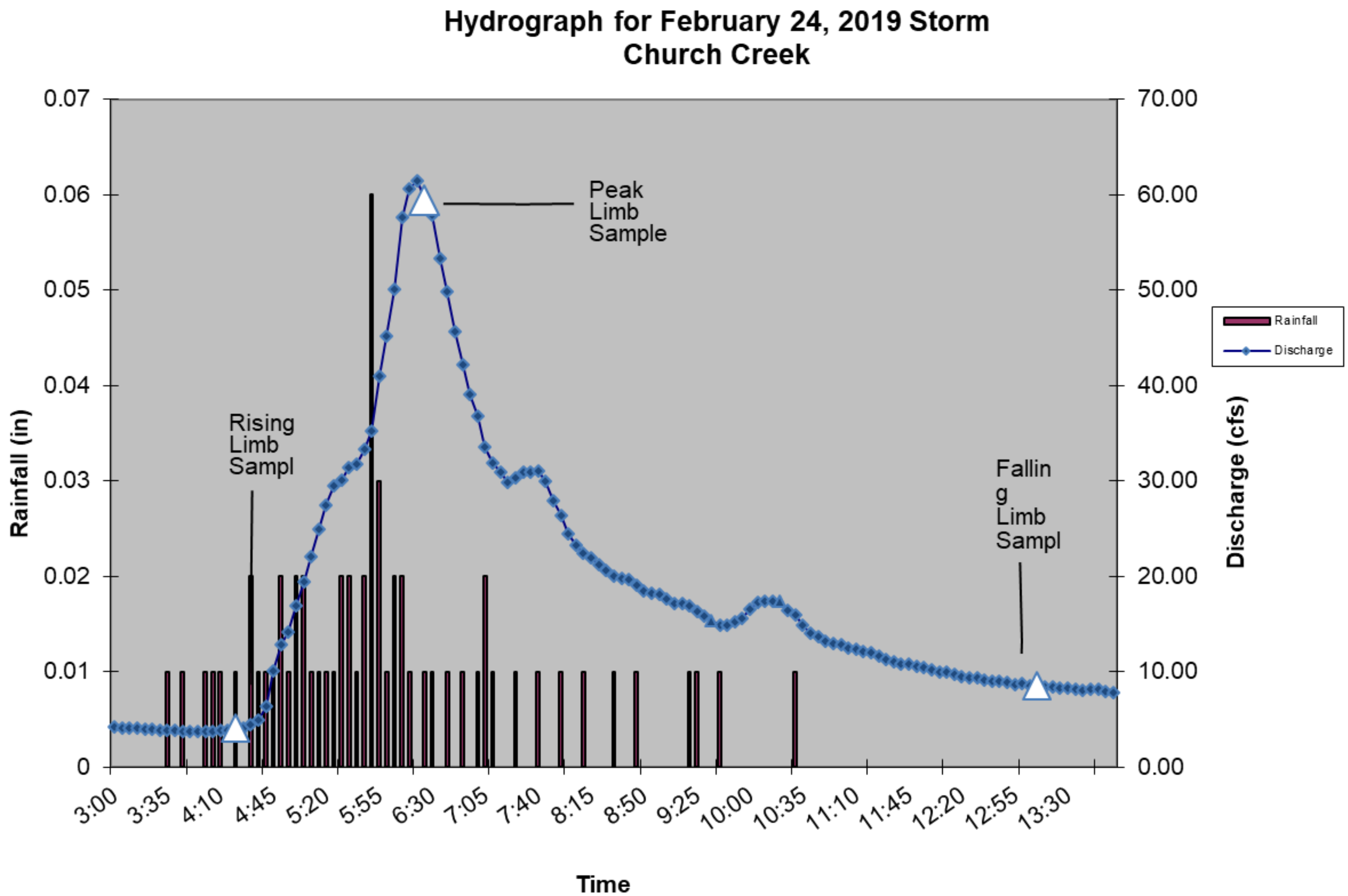
Hydrograph for October 11, 2018 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Rainfall
Discharge
Peak Limb Sample
Rising Limb Sampl
Falling
0.3
0.25
0.2
0.15
0.1
0.05
0
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
0:00
0:30
1:00
1:30
2:00
2:30

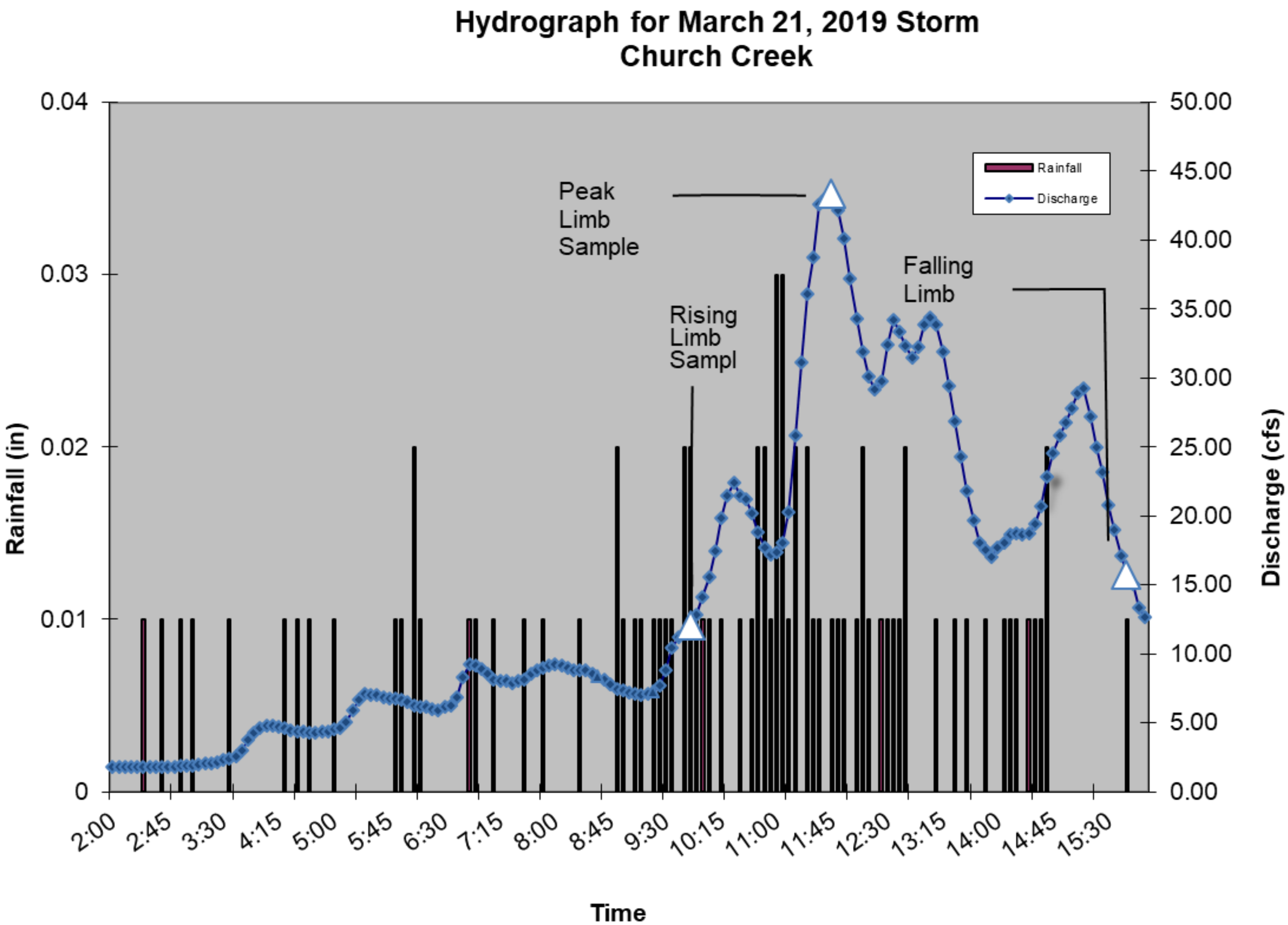

Hydrograph for October 26, 2018 Storm
Church Creek
Rainfall
Discharge
Rising
Limb
Sampl
Peak
Limb
Sample
Falling
Rainfall (in)
Discharge (cfs)
Time
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
18:00
18:35
19:10
19:45
20:20
20:55
21:30
22:05
22:40
23:15
23:50
0:25
1:00
1:35
2:10
2:45



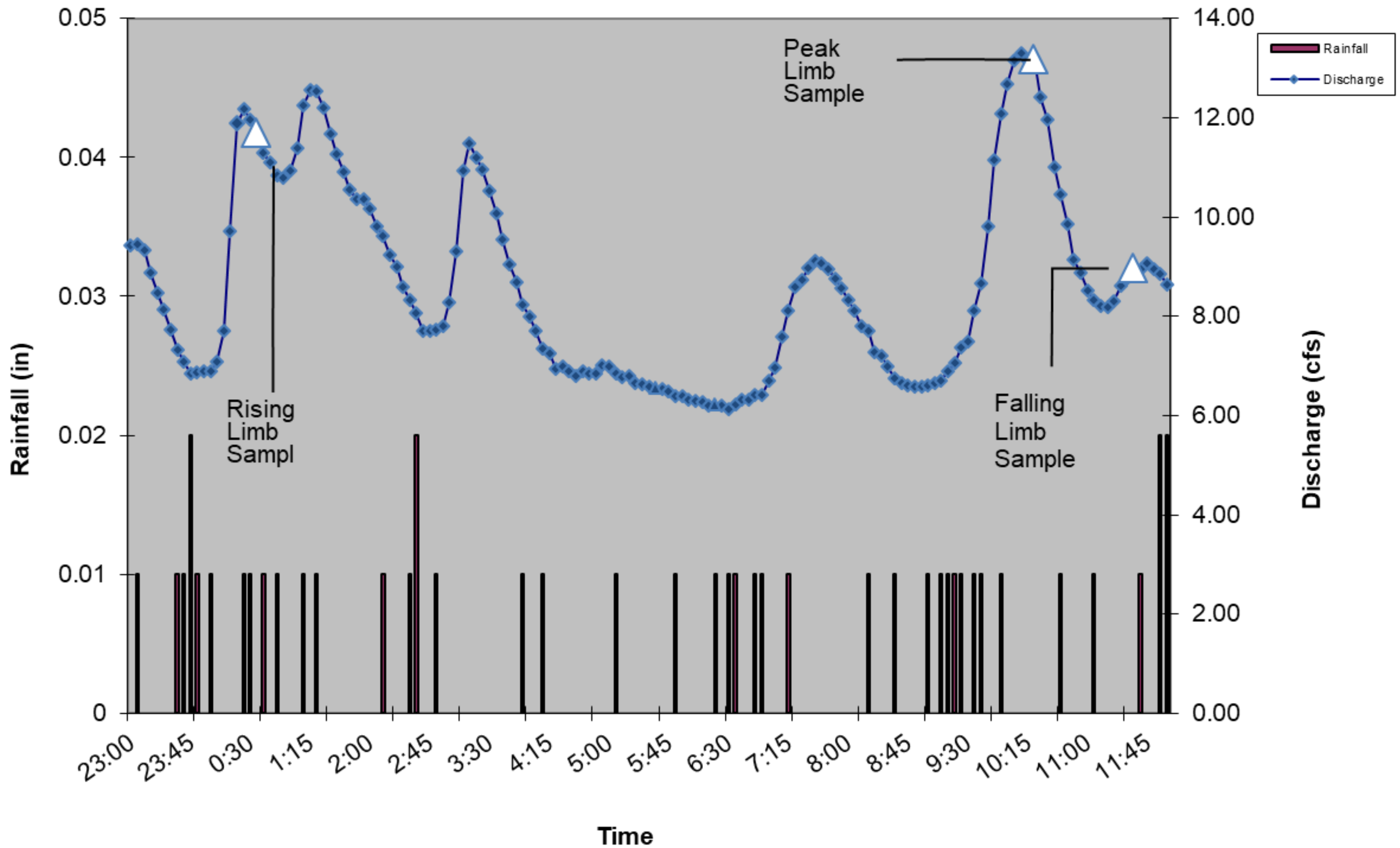
Hydrograph for November 9, 2018 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Rising Limb Sampl
Peak Limb Sample
Falling Limb
Rainfall
Discharge
0.06
0.05
0.04
0.03
0.02
0.01
0
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
12:30
13:05
13:40
14:15
14:50
15:25
16:00
16:35
17:10
17:45
18:20
18:55
19:30
20:05
20:40
21:15


Hydrograph for January 19, 2019 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
Rising Limb Sampl
Peak Limb Sample
Fallin g Limb Sampl
Rainfall
Discharge
0.05
0.04
0.03
0.02
0.01
0
60.00
50.00
40.00
30.00
20.00
10.00
0.00
21:00
21:20
21:40
22:00
22:20
22:40
23:00
23:20
23:40
0:00
0:20
0:40
1:00
1:20
1:40
2:00

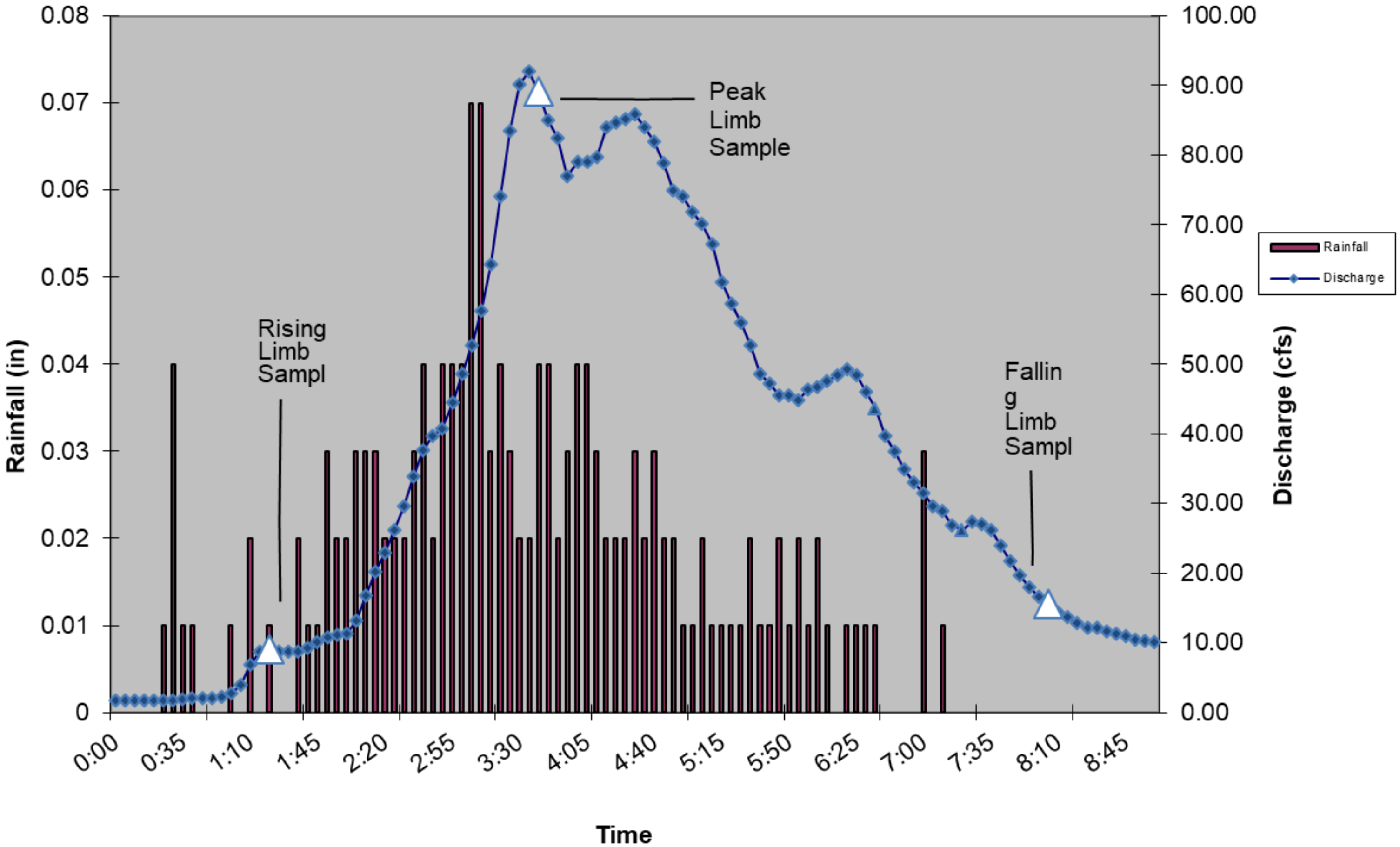

Hydrograph for February 24, 2019 Storm
Church Creek
Rainfall (in)
Discharge (cfs)
Time
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
3:00
3:35
4:10
4:45
5:20
5:55
6:30
7:05
7:40
8:15
8:50
9:25
10:00
10:35
11:10
11:45
12:20
12:55
13:30
Rising Limb Sampl
Peak Limb Sample
Fallin g Limb Sampl
Rainfall
Discharge


Hydrograph for March 21, 2019 Storm
Church Creek
Rainfall
Discharge
Peak
Limb
Sample
Rising
Limb
Sampl
Falling
Limb
Rainfall (in)
Discharge (cfs)
Time
0.04
0.03
0.02
0.01
0
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2:00
2:45
3:30
4:15
5:00
5:45
6:30
7:15
8:00
8:45
9:30
10:15
11:00
11:45
12:30
13:15
14:00
14:45
15:30

**Hydrograph for May 11, 2019 Storm**
**Church Creek**



**Hydrograph for June 13, 2019 Storm**
**Church Creek**



# APPENDIX B

# MASTER TAXA LIST

| Order | Family | Genus | Taxon | FFG[a] | Habit[b] | Tolerance Value[c] |
|---|---|---|---|---|---|---|
| Amphipoda | Gammaridae | Gammarus | Gammarus | Shredder | sp | 6.7 |
| Arhynchobdellida | Erpobdellidae | | Erpobdellidae | Predator | sp | 10 |
| Basommatophora | Physidae | Physa | Physa | Scraper | cb | 7 |
| Diptera | Chironomidae | Chaetocladius | Chaetocladius | Collector | sp | 7 |
| Diptera | Chironomidae | Chironomus | Chironomus | Collector | bu | 4.6 |
| Diptera | Chironomidae | Cricotopus | Cricotopus | Shredder | cn, bu | 9.6 |
| Diptera | Chironomidae | Eukiefferiella | Eukiefferiella | Collector | sp | 6.1 |
| Diptera | Chironomidae | Hydrobaenus | Hydrobaenus | Scraper | sp | 7.2 |
| Diptera | Chironomidae | Limnophyes | Limnophyes | Collector | sp | 8.6 |
| Diptera | Chironomidae | Micropsectra | Micropsectra | Collector | cb, sp | 2.1 |
| Diptera | Chironomidae | Orthocladius | Orthocladius | Collector | sp, bu | 9.2 |
| Diptera | Chironomidae | Paratanytarsus | Paratanytarsus | Collector | sp | 7.7 |
| Diptera | Chironomidae | Polypedilum | Polypedilum | Shredder | cb, cn | 6.3 |
| Diptera | Chironomidae | Rheocricotopus | Rheocricotopus | Collector | sp | 6.2 |
| Diptera | Chironomidae | Thienemannimyia group | Thienemannimyia group | Predator | sp | 8.2 |
| Diptera | Culicidae | | Culicidae | | | 8 |
| Diptera | Psychodidae | Psychoda | Psychoda | Collector | bu | 4 |
| Haplotaxida | Enchytraeidae | | Enchytraeidae | Collector | bu | 9.1 |
| Haplotaxida | Naididae | | Naididae | Collector | bu | 8.5 |
| Isopoda | Asellidae | Caecidotea | Caecidotea | Collector | sp | 2.6 |
| Lumbricida | Lumbricidae | | Lumbricidae | Collector | | 10 |
| Odonata | Coenagrionidae | Argia | Argia | Predator | cn, cb, sp | 9.3 |
| Trichoptera | Hydropsychidae | Cheumatopsyche | Cheumatopsyche | Filterer | cn | 6.5 |
| Tubificida | Tubificidae | | Tubificidae | Collector | cn | 8.4 |
| Veneroida | Pisidiidae | Pisidium | Pisidium | Filterer | bu | 5.7 |

(a) Functional Feeding Group

(b) Primary habit or form of locomotion, includes bu - burrower, cn - clinger, cb - climber, sk - skater, sp - sprawler, sw - swimmer
Some information for the particular taxa was not available.

(c) Tolerance Values, based on Hilsenhoff, modified for Maryland

# APPENDIX C

# BIOLOGICAL ASSESSMENT RESULTS

# Church Creek Site CC-01

Sampled: 4/25/2019

## Biological Condition

Benthic Macroinvertebrate IBI

| | |
|---|---|
| Narrative Rating | Very Poor |
| BIBI Score | 1.57 |

| Metric | Value | Score |
|---|---|---|
| Total Taxa | 13 | 1 |
| EPT Taxa | 0 | 1 |
| Number Ephemeroptera | 0 | 1 |
| % Intolerant to Urban | 0 | 1 |
| % Ephemeroptera | 0 | 1 |
| Scraper Taxa | 1 | 3 |
| % Climbers | 7.09 | 3 |

Benthic Macroinvertebrate Taxa List

| Taxa | Count |
|---|---|
| Argia | 2 |
| Chironomus | 43 |
| Cricotopus | 3 |
| Culicidae | 1 |
| Enchytraeidae | 2 |
| Gammarus | 3 |
| Limnophyes | 1 |
| Lumbricidae | 1 |
| Naididae | 6 |
| Physa | 6 |
| Polypedilum | 1 |
| Psychoda | 2 |
| Tubificidae | 56 |

## Physical Habitat

Maryland Biological Stream Survey PHI

| | |
|---|---|
| Narrative Rating | Degraded |
| PHI Score | 58.49 |

| Metric | Score |
|---|---|
| Drainage area (acres) | 108.96 |
| Remoteness | 23.05 |
| Percent Shading | 63.55 |
| Epifaunal Substrate | 48.89 |
| Instream Habitat | 65.97 |
| Instream Woody Debris | 95.23 |
| Bank Stability | 54.24 |

Rapid Bioassessment Protocol

| | |
|---|---|
| Narrative Rating | Non-supporting |
| RBP Score | 51 |

| Metric | Score |
|---|---|
| Epifaunal Substrate / Cover | 3 |
| Embeddedness | 6 |
| Velocity / Depth Regime | 6 |
| Sediment Deposition | 7 |
| Channel Flow Status | 10 |
| Channel Alteration | 17 |
| Frequency of Riffles | 11 |
| Bank Stability | 1(Left)/3(Right) |
| Vegetative Protection | 3(Left)/3(Right) |
| Riparian Veg Zone Width | 6(Left)/9(Right) |

## Water Chemistry

| | |
|---|---|
| Dissolved Oxygen (mg/L) | 5.46 |
| pH | 6.46 |
| Specific Conductance (µS/cm) | 1065 |
| Temperature (°C) | 17.37 |
| Turbidity (NTUs) | 30.2 |

# Church Creek Site CC-02

Sampled: 4/25/2019

## Biological Condition

Benthic Macroinvertebrate IBI

| | |
|---|---|
| Narrative Rating | Poor |
| BIBI Score | 2.14 |

| Metric | Value | Score |
|---|---|---|
| Total Taxa | 15 | 3 |
| EPT Taxa | 1 | 1 |
| Number Ephemeroptera | 0 | 1 |
| % Intolerant to Urban | 2 | 1 |
| % Ephemeroptera | 0 | 1 |
| Scraper Taxa | 2 | 5 |
| % Climbers | 1.57 | 3 |

Benthic Macroinvertebrate Taxa List

| Taxa | Count |
|---|---|
| Caecidotea | 2 |
| Cheumatopsyche | 1 |
| Chironomus | 39 |
| Cricotopus | 6 |
| Gammarus | 36 |
| Hydrobaenus | 2 |
| Limnophyes | 2 |
| Micropsectra | 1 |
| Naididae | 23 |
| Orthocladius | 6 |
| Paratanytarsus | 4 |
| Physa | 1 |
| Rheocricotopus | 1 |
| Thienemannimyia group | 1 |
| Tubificidae | 2 |

## Physical Habitat

Maryland Biological Stream Survey PHI

| | |
|---|---|
| Narrative Rating | Degraded |
| PHI Score | 57.38 |

| Metric | Score |
|---|---|
| Drainage area (acres) | 292.45 |
| Remoteness | 20.96 |
| Percent Shading | 68.32 |
| Epifaunal Substrate | 42.46 |
| Instream Habitat | 78.06 |
| Instream Woody Debris | 69.26 |
| Bank Stability | 65.20 |

Rapid Bioassessment Protocol

| | |
|---|---|
| Narrative Rating | Non-supporting |
| RBP Score | 60 |

| Metric | Score |
|---|---|
| Epifaunal Substrate / Cover | 7 |
| Embeddedness | 8 |
| Velocity / Depth Regime | 9 |
| Sediment Deposition | 10 |
| Channel Flow Status | 13 |
| Channel Alteration | 13 |
| Frequency of Riffles | 9 |
| Bank Stability | 4(Left)/3(Right) |
| Vegetative Protection | 3(Left)/3(Right) |
| Riparian Veg Zone Width | 9(Left)/9(Right) |

## Water Chemistry

| | |
|---|---|
| Dissolved Oxygen (mg/L) | 7.33 |
| pH | 6.74 |
| Specific Conductance (µS/cm) | 662 |
| Temperature (°C) | 17.4 |
| Turbidity (NTUs) | 20.5 |

# Church Creek Site CC-03

Sampled: 4/25/2019

## Biological Condition

Benthic Macroinvertebrate IBI

| | |
|---|---|
| Narrative Rating | Very Poor |
| BIBI Score | 1.86 |

| Metric | Value | Score |
|---|---|---|
| Total Taxa | 14 | 3 |
| EPT Taxa | 0 | 1 |
| Number Ephemeroptera | 0 | 1 |
| % Intolerant to Urban | 0.76 | 1 |
| % Ephemeroptera | 0 | 1 |
| Scraper Taxa | 1 | 3 |
| % Climbers | 1.53 | 3 |

Benthic Macroinvertebrate Taxa List

| Taxa | Count |
|---|---|
| Argia | 1 |
| Caecidotea | 1 |
| Chaetocladius | 1 |
| Chironomus | 28 |
| Cricotopus | 12 |
| Eukiefferiella | 1 |
| Gammarus | 12 |
| Limnophyes | 1 |
| Naididae | 41 |
| Orthocladius | 7 |
| Paratanytarsus | 7 |
| Physa | 1 |
| Pisidium | 1 |
| Tubificidae | 17 |

## Physical Habitat

Maryland Biological Stream Survey PHI

| | |
|---|---|
| Narrative Rating | Partially Degraded |
| PHI Score | 66.67 |

| Metric | Score |
|---|---|
| Drainage area (acres) | 271.67 |
| Remoteness | 18.60 |
| Percent Shading | 54.42 |
| Epifaunal Substrate | 95.22 |
| Instream Habitat | 84.36 |
| Instream Woody Debris | 78.97 |
| Bank Stability | 68.47 |

Rapid Bioassessment Protocol

| | |
|---|---|
| Narrative Rating | Supporting |
| RBP Score | 80 |

| Metric | Score |
|---|---|
| Epifaunal Substrate / Cover | 14 |
| Embeddedness | 15 |
| Velocity / Depth Regime | 16 |
| Sediment Deposition | 14 |
| Channel Flow Status | 16 |
| Channel Alteration | 18 |
| Frequency of Riffles | 7 |
| Bank Stability | 4(Left)/7(Right) |
| Vegetative Protection | 5(Left)/5(Right) |
| Riparian Veg Zone Width | 7(Left)/6(Right) |

## Water Chemistry

| | |
|---|---|
| Dissolved Oxygen (mg/L) | 7.74 |
| pH | 6.87 |
| Specific Conductance (µS/cm) | 664 |
| Temperature (°C) | 17.37 |
| Turbidity (NTUs) | 7.6 |

# Church Creek Site CC-04

Sampled: 4/25/2019

## Biological Condition

Benthic Macroinvertebrate IBI

| | |
|---|---|
| Narrative Rating | Very Poor |
| BIBI Score | 1.86 |

| Metric | Value | Score |
|---|---|---|
| Total Taxa | 11 | 1 |
| EPT Taxa | 1 | 1 |
| Number Ephemeroptera | 0 | 1 |
| % Intolerant to Urban | 10.24 | 3 |
| % Ephemeroptera | 0 | 1 |
| Scraper Taxa | 1 | 3 |
| % Climbers | 3.94 | 3 |

Benthic Macroinvertebrate Taxa List

| Taxa | Count |
|---|---|
| Caecidotea | 13 |
| Cheumatopsyche | 1 |
| Chironomus | 15 |
| Cricotopus | 14 |
| Erpobdellidae | 1 |
| Gammarus | 50 |
| Lumbricidae | 1 |
| Naididae | 11 |
| Physa | 5 |
| Pisidium | 4 |
| Tubificidae | 12 |

## Physical Habitat

Maryland Biological Stream Survey PHI

| | |
|---|---|
| Narrative Rating | Degraded |
| PHI Score | 60.44 |

| Metric | Score |
|---|---|
| Drainage area (acres) | 118.19 |
| Remoteness | 24.93 |
| Percent Shading | 63.55 |
| Epifaunal Substrate | 48.36 |
| Instream Habitat | 65.14 |
| Instream Woody Debris | 91.35 |
| Bank Stability | 69.29 |

Rapid Bioassessment Protocol

| | |
|---|---|
| Narrative Rating | Partially Supporting |
| RBP Score | 69 |

| Metric | Score |
|---|---|
| Epifaunal Substrate / Cover | 4 |
| Embeddedness | 6 |
| Velocity / Depth Regime | 6 |
| Sediment Deposition | 7 |
| Channel Flow Status | 15 |
| Channel Alteration | 19 |
| Frequency of Riffles | 16 |
| Bank Stability | 8(Left)/8(Right) |
| Vegetative Protection | 5(Left)/5(Right) |
| Riparian Veg Zone Width | 8(Left)/9(Right) |

## Water Chemistry

| | |
|---|---|
| Dissolved Oxygen (mg/L) | 4.92 |
| pH | 6.88 |
| Specific Conductance (µS/cm) | 638 |
| Temperature (°C) | 18.27 |
| Turbidity (NTUs) | 18.6 |

| Select physical habitat parameters (raw scores) 2019 | | | |
|---|---|---|---|
| **Site** | **Epifaunal Substrate (0 – 20)** | **Instream Habitat (0-20)** | **Embeddedness (0 – 100%)** |
| CC-01 | 4 | 6 | 85 |
| CC-02 | 4 | 10 | 80 |
| CC-03 | 13 | 11 | 45 |
| CC-04 | 4 | 6 | 90 |

# APPENDIX D

# QA/QC INFORMATION

D-2

# Quality Assurance/Quality Control Summary for NPDES Monitoring Activities

This section describes all Quality Assurance/Quality Control (QA/QC) procedures implemented for this project including field sampling, laboratory sorting and subsampling, data entry, metric calculation, final IBI calculation, geomorphic field sampling, and classification of stream types.

*Storm Monitoring*

The field manager routinely reviews all QA/QC materials and provides them both verbally and in writing to all staff involved in storm events at the internal kickoff meeting at the start of each sampling year and during storm events. New Versar staff are briefed on all protocols prior to involvement in field work for Anne Arundel County. Project specific SOPs are also available at all times to all field staff in binders located at the project site. These SOPs are updated as necessary by the field crew leader and approved by either the project manager or the QA/QC officer. Verbal reminders of specific QA/QC policies – and any changes or updates – will be made by the field crew leader prior to staff deployment on all storm events. Additionally, staff are cross trained in all tasks involving stormwater monitoring in order to provide back-up to others on all QA/QC procedures.

*Biological and Geomorphological Field Sampling and Assessments*

Initial QA/QC procedures for benthic macroinvertebrate field sampling included formal training for field crew leaders in MBSS Sampling Protocols. All field crew members have attended at least one MBSS Spring Index Period Training. At least one crew member extensively trained and certified in MBSS sampling protocols was present for each field sampling day. Also, during field sampling, each data sheet was double checked for completeness and sample bottle labels were double checked for accuracy. Geomorphic assessment field crews have more than one year of experience conducting similar assessment using the Rosgen Stream Classification Methodology and final data QA/QC is performed by staff with two or more levels of Rosgen training.

Geomorphic assessment survey equipment is calibrated annually and regularly inspected to ensure proper functioning. Cross-section and profile data were digitally plotted and analyzed in Ohio Department of Natural Resources (ODNR) Reference Reach Spreadsheet Version 4.3L for accuracy.

For biological monitoring, water quality QA/QC procedures include calibration of the YSI multiprobe meter daily during the sampling season. Dissolved oxygen probe membranes were inspected regularly and replaced when dirty or damaged.

*Laboratory Sorting and Subsampling*

Sorting QA/QC was conducted on one sample since only seven samples were collected for this survey (The four samples from Church Creek are analyzed concurrently with three samples taken in Picture Spring Branch). This check consisted of entirely resorting the sorted grid cells of one randomly selected sample. This QC met the sorting efficiency criterion of 90%, so no further action was required. As a taxonomic QC, one sample was re-identified completely by another Versar SFS-certified taxonomist following the same identification methods stated above. The Percent Difference in Enumeration (PDE) and the Percent Taxonomic Disagreement (PTD) were calculated, and no further action was required since both the PDE and PTD met MBSS and County MQO requirements.

*Data Entry*

All data entered were double checked by someone other than the person who performed the initial data entry. Any errors found during QA/QC were corrected to ensure 100% accuracy of the data.

*Metric and IBI Calculations*

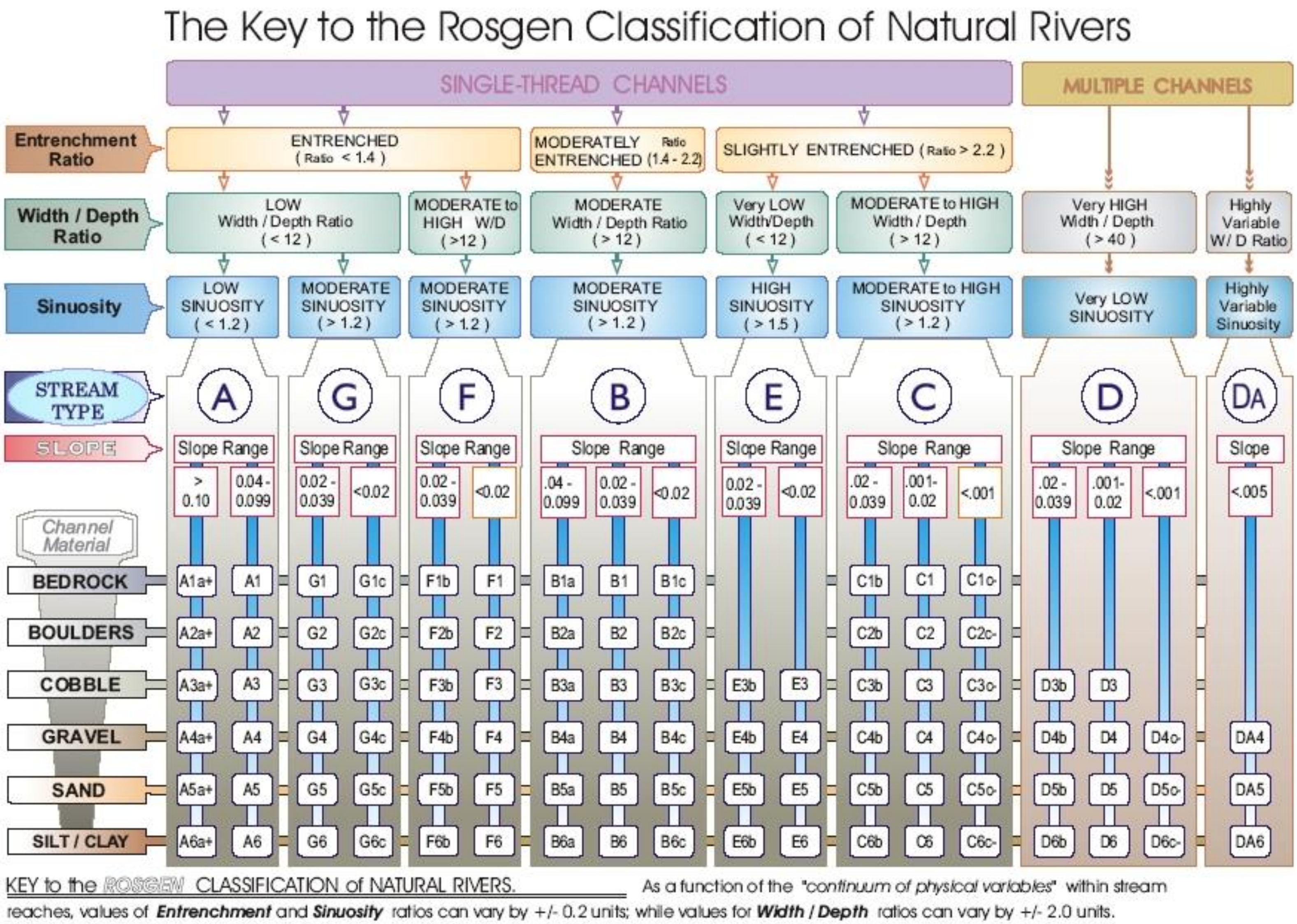
Ten percent of metric and IBI calculations were checked by hand using a calculator to ensure correct calculation by the Access database. Any discrepancies were addressed at that time.

*Identification of Stream Types*

All stream types were determined by hand based on the methods of the Rosgen Stream Classification (Rosgen 1996). Due to the natural variability, or continuum, of streams, adjustments in the values of Width Depth Ratio (+/- 2.0) and Entrenchment Ratio (+/-0.2) are allowed, which may result in assigning a different stream type. Therefore, all stream types assigned were checked and any necessary adjustments were made.

# APPENDIX E

# ROSGEN CLASSIFICATION SCHEME




Source: Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

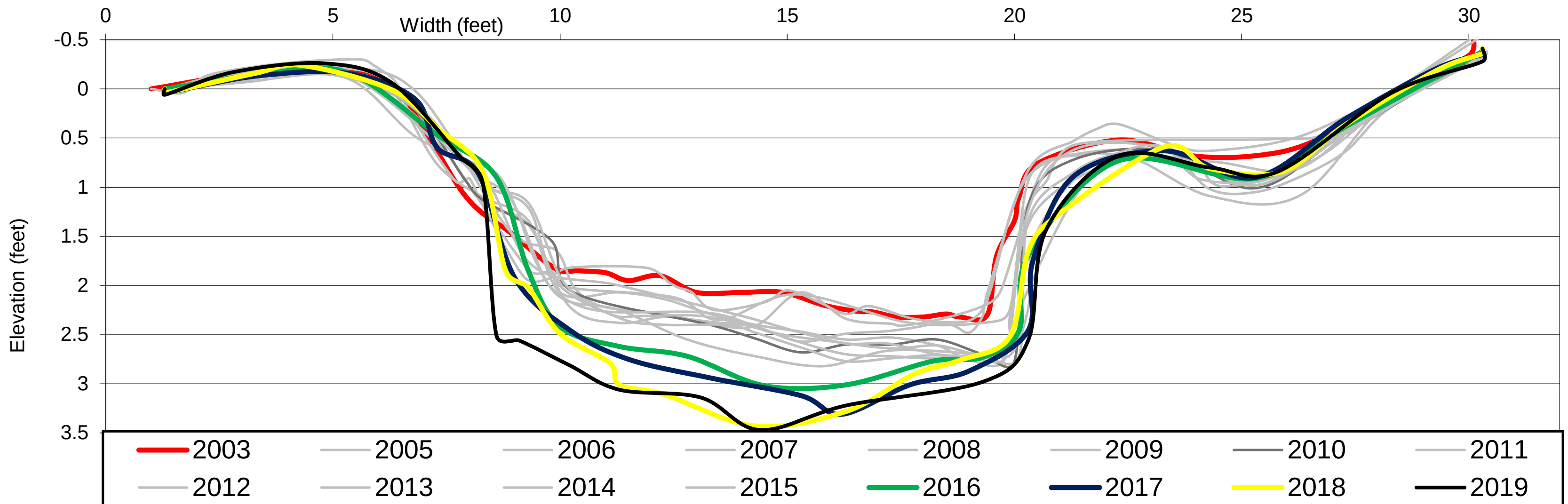
# APPENDIX F

# GEOMORPHOLOGICAL DATA

# Church Creek
# 2019 Geomorphic Assessment Results Summary

| Assessment Parameter | Cross-section | | | | |
|---|---|---|---|---|---|
| | XS-1 Glide @ sta 3+70.5 | XS-2 Glide @ sta 6+82 | XS-3 Pool @ sta 11+00 | XS-4 Pool @ sta 13+53 | XS-5 Riffle @ sta 17+10 |
| **Classification** | F5 | G4c | G4c | E5 | F4 |
| **Bankfull Width (ft)** | 11.8 | 8.1 | 6.6 | 9 | 10.2 |
| **Mean Depth (ft)** | 0.6 | 1.1 | 0.5 | 1.7 | 0.6 |
| **Bankfull X-Sec Area (sq ft)** | 7.2 | 8.5 | 3.6 | 14.9 | 6.4 |
| **Width:Depth Ratio** | 19.2 | 7.6 | 12.2 | 5.4 | 16.4 |
| **Flood-Prone Width (ft)** | 12.6 | 12.6 | 8.3 | 38 | 14.8 |
| **Entrenchment Ratio** | 1.1 | 1.6 | 1.3 | 4.2 | 1.5 |
| **D50(mm)** | 1.2 | 11.0 | 13.0 | 1.6 | 32.0 |
| **Water Surface Slope (ft/ft)** | 0.0003 | 0.014 | 0.009 | 0.009 | 0.012 |
| **Sinuosity** | <1.2 | <1.2 | <1.2 | <1.2 | <1.2 |
| **Drainage Area (mi2)** | 0.111 | 0.113 | 0.121 | 0.130 | 0.441 |
| **Adjustments?** | Sin ↑ | Sin ↑, ER ↓ | Sin ↑, W/D ↓ | Sin ↑ | Sin ↑, ER ↓ |

## CROSS-SECTION 1




Upstream View

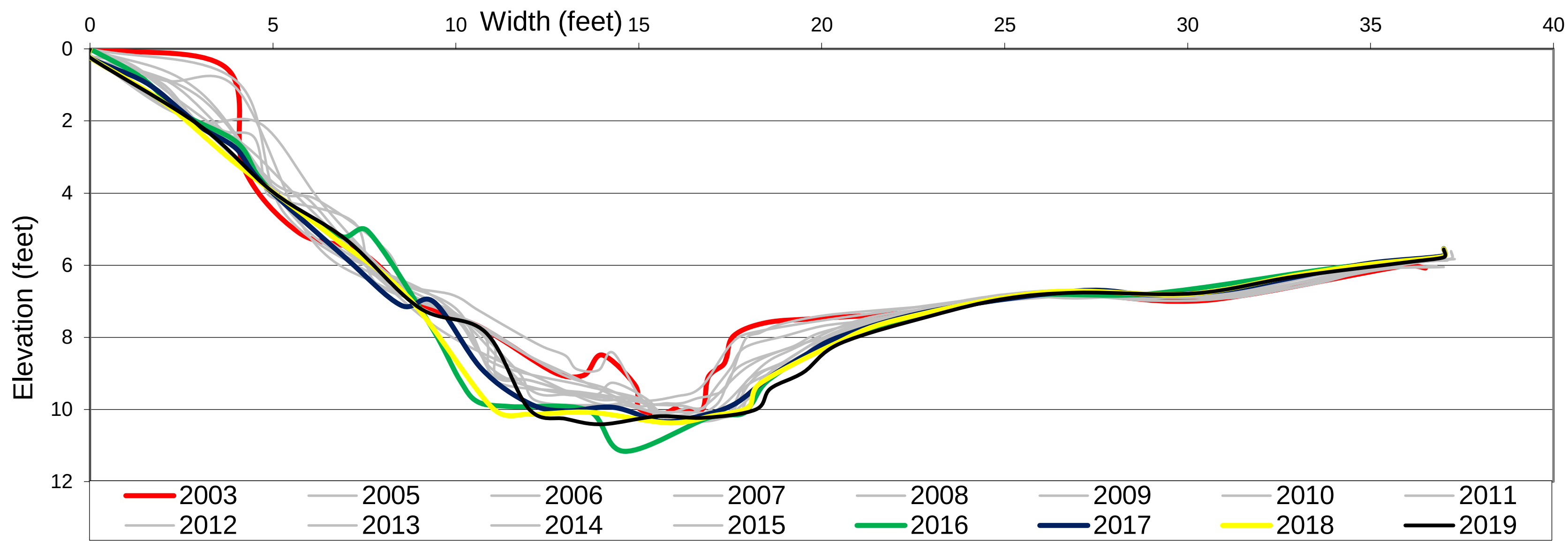
Downstream View

Left Bank View

Right Bank View

| 2019 Geomorphic Assessment Results | |
|---|---|
| Bankfull Width ($W_{bkf}$) (feet) | 11.8 |
| Mean Depth ($d_{bkf}$) (feet) | 0.6 |
| Bankfull Cross-sectional Area ($A_{bkf}$) (feet$^2$) | 7.2 |
| Width/Depth Ratio ($W_{bkf}/d_{bkf}$) | 19.2 |
| Width of Flood-prone Area ($W_{fpa}$) (feet) | 12.6 |
| Entrenchment Ratio (ER) = $W_{fpa}/W_{bkf}$ | 1.1 |
| Channel Materials $D_{50}$ (millimeters) | 1.2 |
| Water Surface Slope (S) | 0.0003 |
| Sinuosity (K) = stream length/valley length | <1.2 |
| Adjustments? | Sin ↑ |
| **STREAM TYPE** | **F5** |

# CROSS-SECTION 2




Upstream View

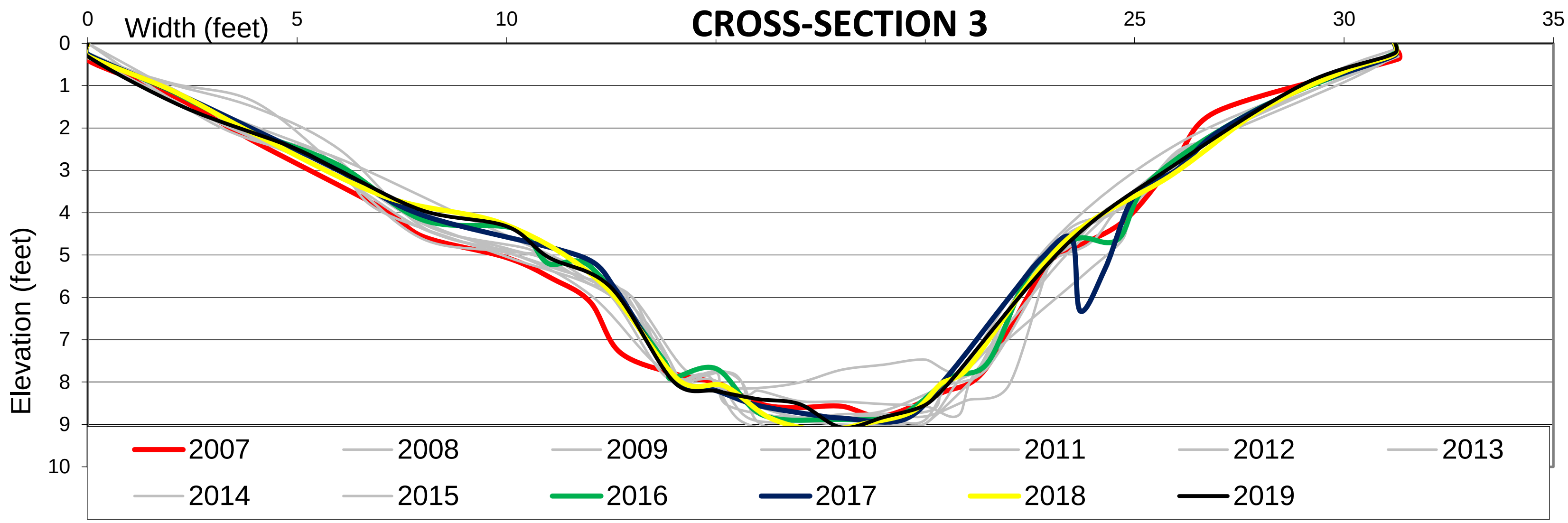
Downstream View

Left Bank View

Right Bank View

## 2019 Geomorphic Assessment Results

| | |
|---|---|
| Bankfull Width ($W_{bkf}$) (feet) | 8.1 |
| Mean Depth ($d_{bkf}$) (feet) | 1.1 |
| Bankfull Cross-sectional Area ($A_{bkf}$) (feet$^2$) | 8.5 |
| Width/Depth Ratio ($W_{bkf}/d_{bkf}$) | 7.6 |
| Width of Flood-prone Area ($W_{fpa}$) (feet) | 12.6 |
| Entrenchment Ratio (ER) = $W_{fpa}/W_{bkf}$ | 1.6 |
| Channel Materials $D_{50}$ (millimeters) | 11.0 |
| Water Surface Slope (S) | 0.014 |
| Sinuosity (K) = stream length/valley length | <1.2 |
| Adjustments? | Sin ↑, ER ↓ |
| **STREAM TYPE** | **G4c** |





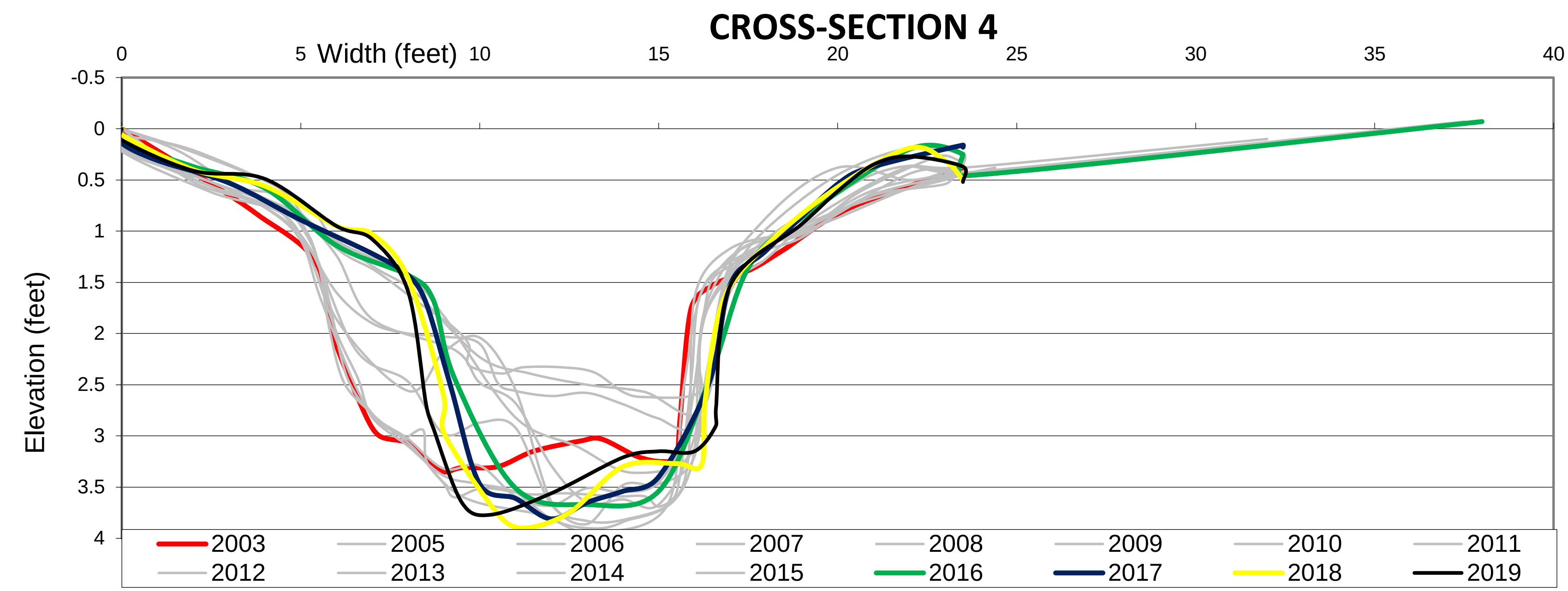
Upstream View


Downstream View


Left Bank View


Right Bank View

| 2019 Geomorphic Assessment Results | |
|---|---|
| Bankfull Width ($W_{bkf}$) (feet) | 6.6 |
| Mean Depth ($d_{bkf}$) (feet) | 0.5 |
| Bankfull Cross-sectional Area ($A_{bkf}$) (feet$^2$) | 3.6 |
| Width/Depth Ratio ($W_{bkf}/d_{bkf}$) | 12.2 |
| Width of Flood-prone Area ($W_{fpa}$) (feet) | 8.3 |
| Entrenchment Ratio (ER) = $W_{fpa}/W_{bkf}$ | 1.3 |
| Channel Materials $D_{50}$ (millimeters) | 13 |
| Water Surface Slope (S) | 0.009 |
| Sinuosity (K) = stream length/valley length | <1.2 |
| Adjustments? | Sin ↑, W/D ↓ |
| **STREAM TYPE** | **G4c** |




Upstream View

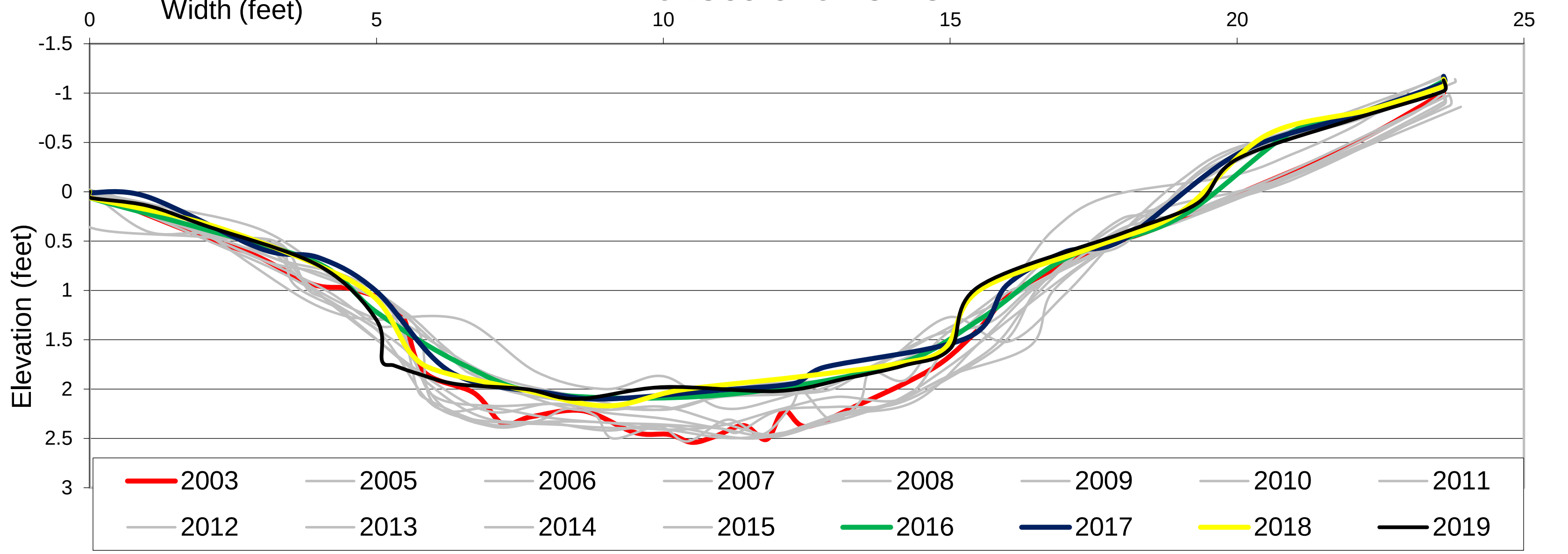
Downstream View

Left Bank View

Right Bank View

| 2019 Geomorphic Assessment Results | |
|---|---|
| Bankfull Width ($W_{bkf}$) (feet) | 9.0 |
| Mean Depth ($d_{bkf}$) (feet) | 1.7 |
| Bankfull Cross-sectional Area ($A_{bkf}$) (feet$^2$) | 14.9 |
| Width/Depth Ratio ($W_{bkf}/d_{bkf}$) | 5.4 |
| Width of Flood-prone Area ($W_{fpa}$) (feet) | 38 |
| Entrenchment Ratio (ER) = $W_{fpa}/W_{bkf}$ | 4.2 |
| Channel Materials $D_{50}$ (millimeters) | 1.6 |
| Water Surface Slope (S) | 0.009 |
| Sinuosity (K) = stream length/valley length | <1.2 |
| Adjustments? | Sin ↑ |
| **STREAM TYPE** | **E5** |

## CROSS-SECTION 5




Upstream View

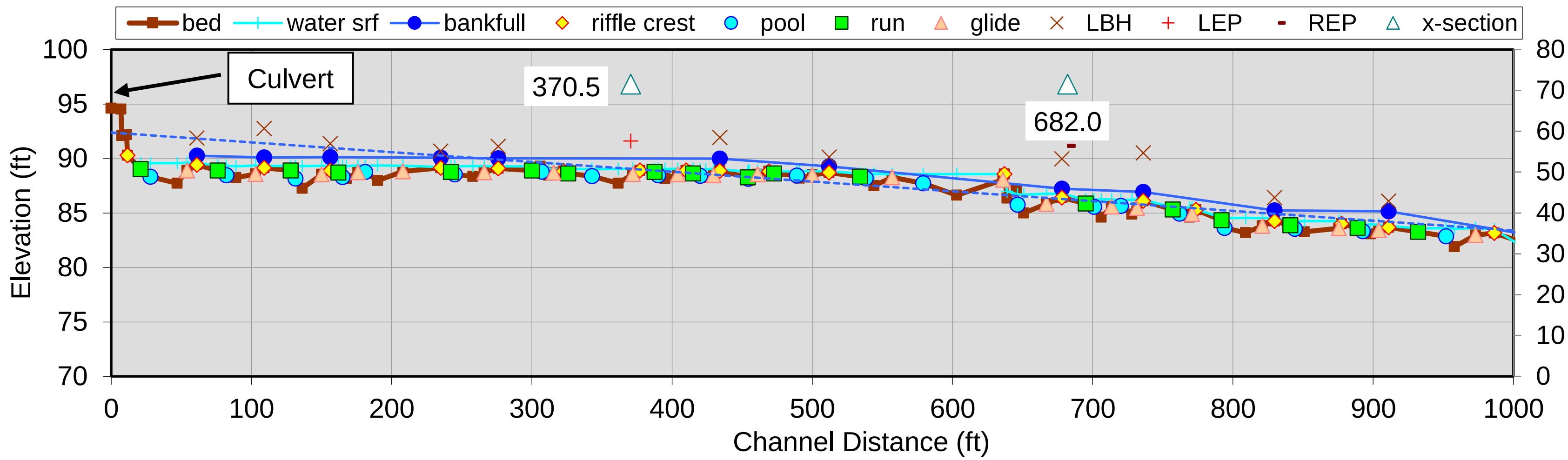
Downstream View

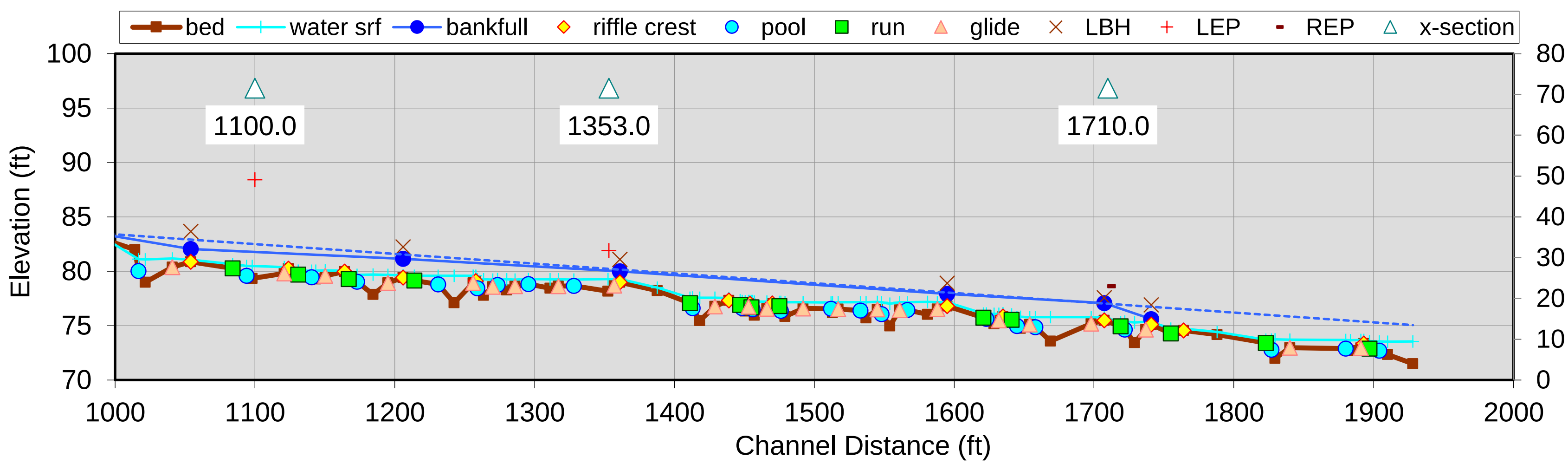
Left Bank View

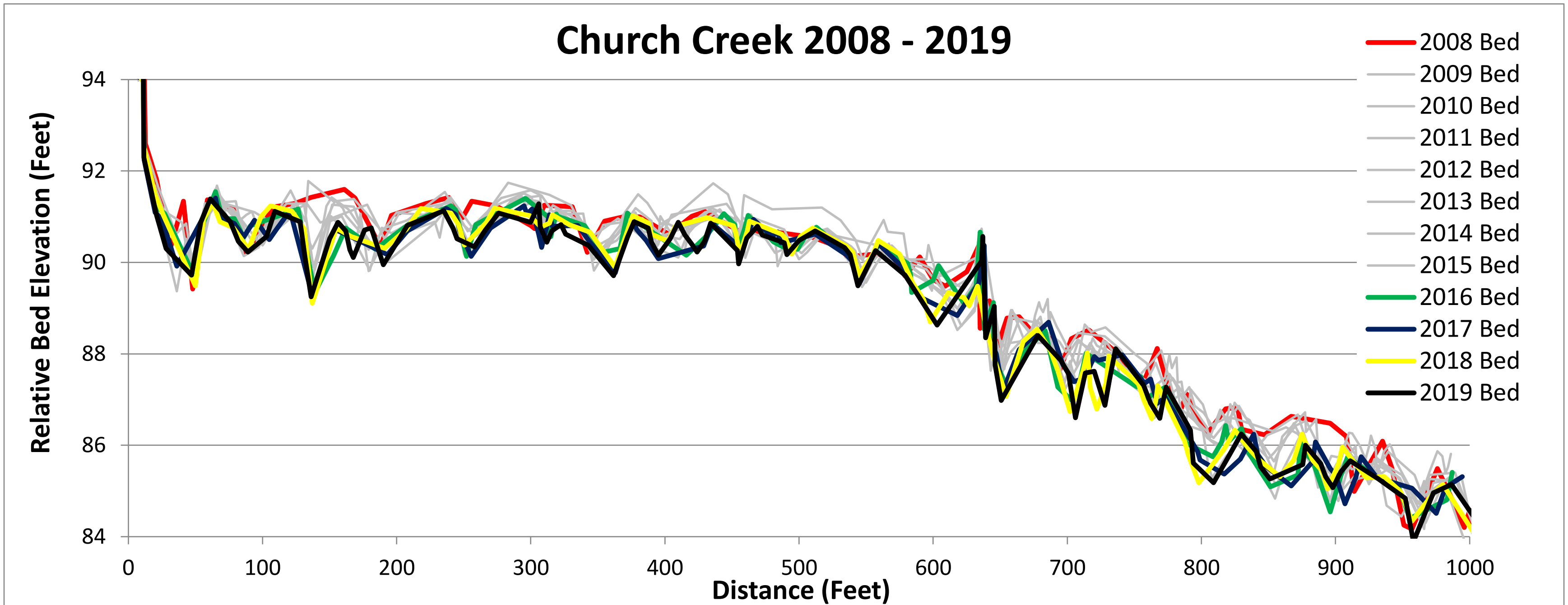
Right Bank View

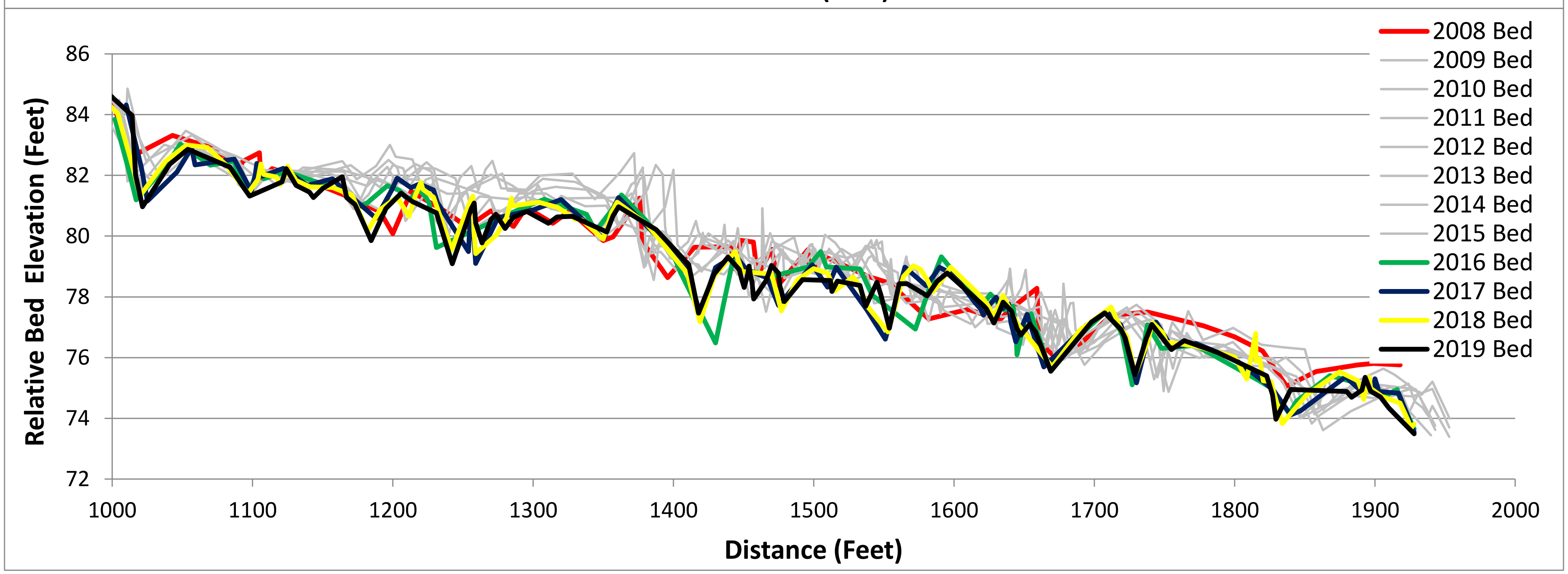
| 2019 Geomorphic Assessment Results | |
|---|---|
| Bankfull Width ($W_{bkf}$) (feet) | 10.5 |
| Mean Depth ($d_{bkf}$) (feet) | 0.6 |
| Bankfull Cross-sectional Area ($A_{bkf}$) (feet$^2$) | 6.4 |
| Width/Depth Ratio ($W_{bkf}/d_{bkf}$) | 16.4 |
| Width of Flood-prone Area ($W_{fpa}$) (feet) | 14.8 |
| Entrenchment Ratio (ER) = $W_{fpa}/W_{bkf}$ | 1.5 |
| Channel Materials $D_{50}$ (millimeters) | 32 |
| Water Surface Slope (S) | 0.012 |
| Sinuosity (K) = stream length/valley length | <1.2 |
| Adjustments? | Sin ↑, ER ↓ |
| **STREAM TYPE** | **F4** |

# Church Creek Longitudinal Profile




Church Creek 2008 - 2019
Relative Bed Elevation (Feet)
Distance (Feet)
94
92
90
88
86
84
0
100
200
300
400
500
600
700
800
900
1000
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed
2019 Bed


Relative Bed Elevation (Feet)
Distance (Feet)
86
84
82
80
78
76
74
72
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2008 Bed
2009 Bed
2010 Bed
2011 Bed
2012 Bed
2013 Bed
2014 Bed
2015 Bed
2016 Bed
2017 Bed
2018 Bed
2019 Bed

# APPENDIX G

# CHEMICAL MONITORING RESULTS

# Anne Arundel County NPDES
# Sampling and EMC Data – 2019 Reporting Year
# Parole Plaza Station

| Sampler | ID | Jurisdiction | Date | Time | Site | Outfall or Instream | Storm or Baseflow | Depth | Duration | Intensity | Temperature - field | Flow | pH - field | dt for BOD | BOD | BOD | dt for Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen | dt for Nitrate+ Nitrite - N | Nitrate+ Nitrite - N | Nitrate+ Nitrite - N | dt for Total Phosphorus | Total Phosphorus | Total Phosphorus | dt for TSS | TSS | TSS | dt for Copper | Copper | Copper | dt for Lead | Lead | Lead | dt for Zinc | Zinc | Zinc | dt for TPH | TPH | TPH | dt for E-COLI | E-COLI | E-COLI | dt for HARDNESS | HARDNESS | HARDNESS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Inches | Hours | In/Hr | oF | CF | pH | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | µg/L | (0) µg/L | (dt) µg/L | µg/L | (0) µg/L | (dt) µg/L | µg/L | (0) µg/L | (dt) µg/L | mg/L | (0) mg/L | (dt) mg/L | MPN | (0) MPN | (dt) MPN | mg/L | (0) mg/L | (dt) mg/L |
| Versar | 1 | AP | 8/17/2018 | 1045 | 101 | O | B | | | | 67.36 | 22 | 6.0 | 4 | 59 | 59 | 0.5 | 2.2 | 2.2 | 0.05 | 3.60 | 3.60 | 0.01 | 0.38 | 0.38 | 1 | 13 | 13 | 2.0 | 25.5 | 25.5 | 2.0 | 0.0 | 2.0 | 20 | 152 | 152 | 5.0 | 6.0 | 6.0 | 10 | 24196 | 24196 | 1 | 200 | 200 |
| | | | | | | | | | | **Event Mean Concentration:** | **67.36** | | **6.0** | **4** | **59** | **59** | **0.5** | **2.2** | **2.2** | **0.05** | **3.60** | **3.60** | **0.01** | **0.38** | **0.38** | **1** | **13** | **13** | **2.0** | **25.5** | **25.5** | **2.0** | **0.0** | **2.0** | **20** | **152** | **152** | **5.0** | **6.0** | **6.0** | **10** | **24196** | **24196** | **1** | **200** | **200** |
| Versar | 1 | AP | 8/21/2018 | 1330 | 101 | O | S | 1.13 | 4.0 | 0.28 | 78.81 | 3241 | 7.0 | 10 | 25 | 25 | 0.5 | 2.6 | 2.6 | 0.05 | 1.10 | 1.10 | 0.01 | 0.36 | 0.36 | 1 | 170 | 170 | 2.0 | 66.2 | 66.2 | 2.0 | 8.8 | 8.8 | 20 | 684 | 684 | 5.0 | 7.0 | 7.0 | 100 | 9741 | 9741 | 1 | 80 | 80 |
| Versar | 2 | AP | 8/21/2018 | 1340 | 101 | O | S | | | | 78.23 | 20550 | 6.9 | 10 | 0 | 10 | 0.5 | 0.0 | 0.5 | 0.05 | 0.28 | 0.28 | 0.01 | 0.14 | 0.14 | 1 | 53 | 53 | 2.0 | 37.1 | 37.1 | 2.0 | 3.8 | 3.8 | 20 | 192 | 192 | 5.0 | 6.0 | 6.0 | 100 | 7103 | 7103 | 1 | 25 | 25 |
| Versar | 3 | AP | 8/21/2018 | 1525 | 101 | O | S | | | | 79.06 | 54127 | 7.1 | 10 | 0 | 10 | 0.5 | 0.0 | 0.5 | 0.05 | 0.58 | 0.58 | 0.01 | 0.07 | 0.07 | 1 | 8 | 8 | 2.0 | 15.3 | 15.3 | 2.0 | 0.0 | 2.0 | 20 | 101 | 101 | 5.0 | 0.0 | 5.0 | 100 | 10615 | 10615 | 1 | 20 | 20 |
| | | | | | | | | | | **Event Mean Concentration:** | **78.83** | | **7.0** | **10** | **1** | **11** | **0.5** | **0.1** | **0.6** | **0.05** | **0.52** | **0.52** | **0.01** | **0.10** | **0.10** | **1** | **27** | **27** | **2.0** | **23.2** | **23.2** | **2.0** | **1.4** | **2.8** | **20** | **149** | **149** | **5** | **1.9** | **5** | **100** | **9653** | **9653** | **1** | **24** | **24** |
| Versar | 1 | AP | 9/21/2018 | 1015 | 101 | O | B | | | | 67.00 | 9 | 6.4 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 4.30 | 4.30 | 0.01 | 0.03 | 0.03 | 1 | 1 | 1 | 2.0 | 5.2 | 5.2 | 2.0 | 0.0 | 2.0 | 20 | 100 | 100 | 5.0 | 0.0 | 5.0 | 10 | 916 | 916 | 1 | 200 | 200 |
| | | | | | | | | | | **Event Mean Concentration:** | **67.00** | | **6.4** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **4.30** | **4.30** | **0.01** | **0.03** | **0.03** | **1** | **1** | **1** | **2.0** | **5.2** | **5.2** | **2.0** | **0.0** | **2.0** | **20** | **100** | **100** | **5.0** | **0.0** | **5.0** | **10** | **916** | **916** | **1** | **200** | **200** |
| Versar | 1 | AP | 10/11/2018 | | 101 | O | S | 2.26 | 8.0 | 0.28 | sample was not collected | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 2 | AP | 10/11/2018 | 1945 | 101 | O | S | | | | 74.44 | 51287 | 6.9 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.11 | 0.11 | 0.01 | 0.09 | 0.09 | 1 | 14 | 14 | 2.0 | 10.1 | 10.1 | 2.0 | 0.0 | 2.0 | 20 | 101 | 101 | 5.0 | 0.0 | 5.0 | 10 | 17586 | 17586 | 1 | 10 | 10 |
| Versar | 3 | AP | 10/11/2018 | 2245 | 101 | O | S | | | | 73.00 | 127802 | 7.4 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.21 | 0.21 | 0.01 | 0.06 | 0.06 | 1 | 5 | 5 | 2.0 | 4.3 | 4.3 | 2.0 | 0.0 | 2.0 | 20 | 53 | 53 | 5.0 | 0.0 | 5.0 | 10 | 8164 | 8164 | 1 | 18 | 18 |
| | | | | | | | | | | **Event Mean Concentration:** | **73.41** | | **7.2** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.18** | **0.18** | **0.01** | **0.07** | **0.07** | **1** | **8** | **8** | **2.0** | **6.0** | **6.0** | **2.0** | **0.0** | **2.0** | **20** | **67** | **67** | **5.0** | **0.0** | **5.0** | **10** | **10862** | **10862** | **1** | **16** | **16** |
| Versar | 1 | AP | 10/26/2018 | 1900 | 101 | O | S | 0.98 | 9.0 | 0.11 | 54.39 | 466 | 7.0 | 2 | 18 | 18 | 0.5 | 1.5 | 1.5 | 0.05 | 2.40 | 2.40 | 0.01 | 0.24 | 0.24 | 1 | 42 | 42 | 2.0 | 65.0 | 65.0 | 2.0 | 2.4 | 2.4 | 20 | 291 | 291 | 5.0 | 0.0 | 5.0 | 10 | 7686 | 7686 | 1 | 73 | 73 |
| Versar | 2 | AP | 10/26/2018 | 0005 | 101 | O | S | | | | 51.95 | 58692 | 7.1 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.15 | 0.15 | 0.01 | 0.06 | 0.06 | 1 | 5 | 5 | 2.0 | 5.1 | 5.1 | 2.0 | 0.0 | 2.0 | 20 | 71 | 71 | 5.0 | 0.0 | 5.0 | 10 | 2778 | 2778 | 1 | 12 | 12 |
| Versar | 3 | AP | 10/26/2018 | 145 | 101 | O | S | | | | 53.77 | 20896 | 7.1 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.20 | 0.20 | 0.01 | 0.05 | 0.05 | 1 | 4 | 4 | 2.0 | 5.6 | 5.6 | 2.0 | 0.0 | 2.0 | 20 | 64 | 64 | 5.0 | 0.0 | 5.0 | 10 | 2883 | 2883 | 1 | 19 | 19 |
| | | | | | | | | | | **Event Mean Concentration:** | **52.44** | | **7.1** | **2** | **0** | **2** | **0.5** | **0.0** | **0.5** | **0.05** | **0.18** | **0.18** | **0.01** | **0.06** | **0.06** | **1** | **5** | **5** | **2.0** | **5.6** | **5.6** | **2.0** | **0.0** | **2.0** | **20** | **70** | **70** | **5** | **0.0** | **5** | **10** | **2834** | **2834** | **1** | **14** | **14** |
| Versar | 1 | AP | 11/9/2018 | 1340 | 101 | O | S | 0.47 | 9.0 | 0.05 | 57.09 | 3567 | 7.3 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.65 | 0.65 | 0.01 | 0.12 | 0.12 | 1 | 17 | 17 | 2.0 | 16.3 | 16.3 | 2.0 | 0.0 | 2.0 | 20 | 181 | 181 | 5.0 | 0.0 | 5.0 | 10 | 1057 | 1057 | 1 | 35 | 35 |
| Versar | 2 | AP | 11/9/2018 | 1430 | 101 | O | S | | | | 55.51 | 6507 | 7.4 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.21 | 0.21 | 0.01 | 0.07 | 0.07 | 1 | 24 | 24 | 2.0 | 12.3 | 12.3 | 2.0 | 0.0 | 2.0 | 20 | 112 | 112 | 5.0 | 0.0 | 5.0 | 10 | 688 | 688 | 1 | 18 | 18 |
| Versar | 3 | AP | 11/9/2018 | 1600 | 101 | O | S | | | | 54.56 | 13412 | 7.3 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.18 | 0.18 | 0.01 | 0.08 | 0.08 | 1 | 7 | 7 | 2.0 | 8.2 | 8.2 | 2.0 | 0.0 | 2.0 | 20 | 76 | 76 | 5.0 | 0.0 | 5.0 | 10 | 1558 | 1558 | 1 | 18 | 18 |
| | | | | | | | | | | **Event Mean Concentration:** | **55.20** | | **7.3** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.26** | **0.26** | **0.01** | **0.08** | **0.08** | **1** | **13** | **13** | **2.0** | **10.6** | **10.6** | **2.0** | **0.0** | **2.0** | **20** | **102** | **102** | **5** | **0.0** | **5** | **10** | **1241** | **1241** | **1** | **21** | **21** |
| Versar | 1 | AP | 12/6/2018 | 1150 | 101 | O | B | | | | 52.34 | 7 | 6.5 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 6.00 | 6.00 | 0.01 | 0.00 | 0.01 | 1 | 2 | 2 | 2.0 | 0.0 | 2.0 | 2.0 | 0.0 | 2.0 | 20 | 98 | 98 | 5.0 | 0.0 | 5.0 | 10 | 0 | 10 | 1 | 270 | 270 |
| | | | | | | | | | | **Event Mean Concentration:** | **52.34** | | **6.5** | **2** | **0** | **2** | **0.5** | **0.0** | **0.5** | **0.05** | **6.00** | **6.00** | **0.01** | **0.00** | **0.01** | **1** | **2** | **2** | **2.0** | **0.0** | **2.0** | **2.0** | **0.0** | **2.0** | **20** | **98** | **98** | **5.0** | **0.0** | **5.0** | **10** | **0** | **10** | **1** | **270** | **270** |

| Sampler | ID | Jurisdiction | Date | Time | Site | Outfall or Instream | Storm or Baseflow | Depth (Inches) | Duration (Hours) | Intensity (In/Hr) | Temperature - field (oF) | Flow (CF) | pH - field (pH) | dt for BOD (mg/L) | BOD ((0) mg/L) | BOD ((dt) mg/L) | dt for Total Kjeldahl Nitrogen (mg/L) | Total Kjeldahl Nitrogen ((0) mg/L) | Total Kjeldahl Nitrogen ((dt) mg/L) | dt for Nitrate+ Nitrite - N (mg/L) | Nitrate+ Nitrite - N ((0) mg/L) | Nitrate+ Nitrite - N ((dt) mg/L) | dt for Total Phosphorus (mg/L) | Total Phosphorus ((0) mg/L) | Total Phosphorus ((dt) mg/L) | dt for TSS (mg/L) | TSS ((0) mg/L) | TSS ((dt) mg/L) | dt for Copper (µg/L) | Copper ((0) µg/L) | Copper ((dt) µg/L) | dt for Lead (µg/L) | Lead ((0) µg/L) | Lead ((dt) µg/L) | dt for Zinc (µg/L) | Zinc ((0) µg/L) | Zinc ((dt) µg/L) | dt for TPH (mg/L) | TPH ((0) mg/L) | TPH ((dt) mg/L) | dt for E-COLI (MPN) | E-COLI ((0) MPN) | E-COLI ((dt) MPN) | dt for HARDNESS (mg/L) | HARDNESS ((0) mg/L) | HARDNESS ((dt) mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Versar | 1 | AP | 1/19/2019 | 2020 | 101 | O | S | 0.55 | 5.0 | 0.11 | 42.04 | 1647 | 8.9 | 4 | 7 | 7 | 0.5 | 1.6 | 1.6 | 0.05 | 0.83 | 0.83 | 0.01 | 0.12 | 0.12 | 1 | 330 | 330 | 2.0 | 72.3 | 72.3 | 2.0 | 13.6 | 13.6 | 20 | 601 | 601 | 5.0 | 12.0 | 12.0 | 1 | 234 | 234 | 1 | 180 | 180 |
| Versar | 2 | AP | 1/19/2019 | 2245 | 101 | O | S | | | | 40.36 | 32244 | 9.1 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.32 | 0.32 | 0.01 | 0.06 | 0.06 | 1 | 36 | 36 | 2.0 | 13.2 | 13.2 | 2.0 | 0.0 | 2.0 | 20 | 113 | 113 | 5.0 | 24.0 | 24.0 | 1 | 416 | 416 | 1 | 35 | 35 |
| Versar | 3 | AP | 1/19/2019 | 2345 | 101 | O | S | | | | 40.20 | 15482 | 8.9 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.34 | 0.34 | 0.01 | 0.04 | 0.04 | 1 | 19 | 19 | 2.0 | 10.1 | 10.1 | 2.0 | 0.0 | 2.0 | 20 | 91 | 91 | 5.0 | 0.0 | 5.0 | 1 | 329 | 329 | 1 | 47 | 47 |
| | | | | | | | | | | **Event Mean Concentration:** | **40.37** | | **9.0** | **4** | **0** | **4** | **0.5** | **0.1** | **0.5** | **0.05** | **0.34** | **0.34** | **0.01** | **0.06** | **0.06** | **1** | **40** | **40** | **2.0** | **14.2** | **14.2** | **2.0** | **0.5** | **2.4** | **20** | **122** | **122** | **5** | **16.1** | **18** | **1** | **382** | **382** | **1** | **44** | **44** |
| Versar | 1 | AP | 2/24/2019 | 320 | 101 | O | S | 0.62 | 11.0 | 0.06 | 46.08 | 1388 | 9.1 | 2 | 2 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.30 | 0.30 | 0.01 | 0.07 | 0.07 | 1 | 28 | 28 | 2.0 | 13.0 | 13.0 | 2.0 | 0.0 | 2.0 | 20 | 149 | 149 | 5.0 | 0.0 | 5.0 | 1 | 230 | 230 | 1 | 26 | 26 |
| Versar | 2 | AP | 2/24/2019 | 500 | 101 | O | S | | | | 39.68 | 14327 | 9.4 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.12 | 0.12 | 0.01 | 0.07 | 0.07 | 1 | 85 | 85 | 2.0 | 21.4 | 21.4 | 2.0 | 5.2 | 5.2 | 20 | 158 | 158 | 5.0 | 0.0 | 5.0 | 1 | 420 | 420 | 1 | 50 | 50 |
| Versar | 3 | AP | 2/24/2019 | 750 | 101 | O | S | | | | 41.23 | 26700 | 9.0 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.35 | 0.35 | 0.01 | 0.04 | 0.04 | 1 | 9 | 9 | 2.0 | 4.7 | 4.7 | 2.0 | 0.0 | 2.0 | 20 | 95 | 95 | 5.0 | 0.0 | 5.0 | 1 | 350 | 350 | 1 | 42 | 42 |
| | | | | | | | | | | **Event Mean Concentration:** | **40.87** | | **9.1** | **2** | **0** | **2** | **0.5** | **0.0** | **0.5** | **0.05** | **0.27** | **0.27** | **0.01** | **0.05** | **0.05** | **1** | **35** | **35** | **2.0** | **10.6** | **10.6** | **2.0** | **1.8** | **3.1** | **20** | **118** | **118** | **5** | **0.0** | **5** | **1** | **369** | **369** | **1** | **44** | **44** |
| Versar | 1 | AP | 3/21/2019 | 905 | 101 | O | S | 0.83 | 14.0 | 0.06 | 48.68 | 16816 | 9.2 | 2 | 4 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.28 | 0.28 | 0.01 | 0.11 | 0.11 | 1 | 48 | 48 | 2.0 | 24.3 | 24.3 | 2.0 | 2.8 | 2.8 | 20 | 214 | 214 | 5.0 | 0.0 | 5.0 | 1 | 430 | 430 | 1 | 40 | 40 |
| Versar | 2 | AP | 3/21/2019 | 1120 | 101 | O | S | | | | 50.35 | 17821 | 9.1 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.15 | 0.15 | 0.01 | 0.09 | 0.09 | 1 | 55 | 55 | 2.0 | 18.1 | 18.1 | 2.0 | 2.3 | 2.3 | 20 | 135 | 135 | 5.0 | 0.0 | 5.0 | 1 | 685 | 685 | 1 | 35 | 35 |
| Versar | 3 | AP | 3/21/2019 | 1415 | 101 | O | S | | | | 51.51 | 21864 | 8.8 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.28 | 0.28 | 0.01 | 0.06 | 0.06 | 1 | 10 | 10 | 2.0 | 13.1 | 13.1 | 2.0 | 3.0 | 3.0 | 20 | 95 | 95 | 5.0 | 0.0 | 5.0 | 1 | 637 | 637 | 1 | 25 | 25 |
| | | | | | | | | | | **Event Mean Concentration:** | **50.30** | | **9.0** | **2** | **1** | **3** | **0.5** | **0.0** | **0.5** | **0.05** | **0.24** | **0.24** | **0.01** | **0.08** | **0.08** | **1** | **36** | **36** | **2.0** | **18.0** | **18.0** | **2.0** | **2.7** | **2.7** | **20** | **143** | **143** | **5** | **0.0** | **5** | **1** | **590** | **590** | **1** | **33** | **33** |
| Versar | 1 | AP | 5/11/2019 | 2305 | 101 | O | S | 0.39 | 12.0 | 0.03 | 62.71 | 276 | 8.9 | 2 | 2 | 2 | 0.5 | 0.8 | 0.8 | 0.05 | 0.63 | 0.63 | 0.01 | 0.06 | 0.06 | 1 | 19 | 19 | 2.0 | 12.6 | 12.6 | 2.0 | 0.0 | 2.0 | 20 | 110 | 110 | 5.0 | 0.0 | 5.0 | 1 | 2313 | 2313 | 1 | 20 | 20 |
| Versar | 2 | AP | 5/12/2019 | 835 | 101 | O | S | | | | 60.56 | 19458 | 9.3 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.48 | 0.48 | 0.01 | 0.05 | 0.05 | 1 | 11 | 11 | 2.0 | 10.8 | 10.8 | 2.0 | 0.0 | 2.0 | 20 | 109 | 109 | 5.0 | 0.0 | 5.0 | 1 | 2248 | 2248 | 1 | 24 | 24 |
| Versar | 3 | AP | 5/12/2019 | 910 | 101 | O | S | | | | 60.33 | 1553 | 9.0 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.61 | 0.61 | 0.01 | 0.04 | 0.04 | 1 | 4 | 4 | 2.0 | 10.2 | 10.2 | 2.0 | 0.0 | 2.0 | 20 | 103 | 103 | 5.0 | 0.0 | 5.0 | 1 | 2851 | 2851 | 1 | 25 | 25 |
| | | | | | | | | | | **Event Mean Concentration:** | **60.57** | | **9.3** | **2** | **0** | **2** | **0.5** | **0.0** | **0.5** | **0.05** | **0.49** | **0.49** | **0.01** | **0.05** | **0.05** | **1** | **11** | **11** | **2.0** | **10.8** | **10.8** | **2.0** | **0.0** | **2.0** | **20** | **109** | **109** | **5** | **0.0** | **5** | **1** | **2293** | **2293** | **1** | **24** | **24** |
| Versar | 1 | AP | 6/13/2019 | 255 | 101 | O | S | 1.57 | 9.0 | 0.17 | 71.00 | 13611 | 9.5 | 2 | 5 | 5 | 0.5 | 0.0 | 0.5 | 0.05 | 0.76 | 0.76 | 0.01 | 0.09 | 0.09 | 1 | 20 | 20 | 2.0 | 15.9 | 15.9 | 2.0 | 0.0 | 2.0 | 20 | 147 | 147 | 5.0 | 0.0 | 5.0 | 1 | 1136 | 1136 | 1 | 25 | 25 |
| Versar | 2 | AP | 6/13/2019 | 415 | 101 | O | S | | | | 67.85 | 23620 | 9.2 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.11 | 0.11 | 0.01 | 0.06 | 0.06 | 1 | 21 | 21 | 2.0 | 9.8 | 9.8 | 2.0 | 0.0 | 2.0 | 20 | 89 | 89 | 5.0 | 0.0 | 5.0 | 1 | 3629 | 3629 | 1 | 17 | 17 |
| Versar | 3 | AP | 6/13/2019 | 805 | 101 | O | S | | | | 66.51 | 71672 | 8.9 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.32 | 0.32 | 0.01 | 0.07 | 0.07 | 1 | 5 | 5 | 2.0 | 8.6 | 8.6 | 2.0 | 0.0 | 2.0 | 20 | 76 | 76 | 5.0 | 0.0 | 5.0 | 1 | 6750 | 6750 | 1 | 21 | 21 |
| | | | | | | | | | | **Event Mean Concentration:** | **67.36** | | **9.0** | **2** | **1** | **2** | **0.5** | **0.0** | **0.5** | **0.05** | **0.33** | **0.33** | **0.01** | **0.07** | **0.07** | **1** | **10** | **10** | **2.0** | **9.8** | **9.8** | **2.0** | **0.0** | **2.0** | **20** | **88** | **88** | **5** | **0.0** | **5** | **1** | **5371** | **5371** | **1** | **21** | **21** |
| Versar | 1 | AP | 6/26/2019 | 1140 | 101 | O | B | | | | 77.76 | 18 | 7.7 | 4 | 19 | 19 | 0.5 | 9.0 | 9.0 | 0.05 | 2.50 | 2.50 | 0.01 | 0.75 | 0.75 | 1 | 530 | 530 | 2.0 | 102.0 | 102.0 | 2.0 | 21.5 | 21.5 | 20 | 596 | 596 | 5.0 | 0.0 | 5.0 | 10 | 201 | 201 | 1 | 120 | 120 |
| | | | | | | | | | | **Event Mean Concentration:** | **77.76** | | **7.7** | **4** | **19** | **19** | **0.5** | **9.0** | **9.0** | **0.05** | **2.50** | **2.50** | **0.01** | **0.75** | **0.75** | **1** | **530** | **530** | **2.0** | **102.0** | **102.0** | **2.0** | **21.5** | **21.5** | **20** | **596** | **596** | **5.0** | **0.0** | **5.0** | **10** | **201** | **201** | **1** | **120** | **120** |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SUMMER QUARTER (JULY, AUGUST, SEPTEMBER)** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Summer Quarter Flow-Weighted EMC (8/21/18):** | 78.82 | 7.0 | 1 | 11 | 0.11 | 0.59 | 0.52 | 0.52 | 0.10 | 0.10 | 27 | 27 | 23 | 23 | 1 | 3 | 149 | 149 | 2 | 5 | 9652 | 9652 | 24 | 23.88 |
| **Average:** | | | 6 | mg/l | 0.35 | mg/l | 0.52 | mg/l | 0.10 | mg/l | 27 | mg/l | 23 | µg/l | 2 | µg/l | 149 | µg/l | 4 | mg/l | 9652 | MPN/100mL | 24 | mg/l |
| | | | 0.0003649 | lb/cf | 0.0000217 | lb/cf | 0.0000327 | lb/cf | 0.0000063 | lb/cf | 0.0016603 | lb/cf | 0.0000014 | lb/cf | 0.0000001 | lb/cf | 0.0000093 | lb/cf | 0.0002254 | lb/cf | | | 0.0014907 | lb/cf |
| **Total Volume (Quarter Events):** | | | 77,950 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter Events):** | | | 28 | lbs | 2 | lbs | 3 | lbs | 0.5 | lbs | 129 | lbs | 0 | lbs | 0 | lbs | 1 | lbs | 18 | lbs | | | 116 | lbs |
| **Total Volume (Quarter):** | | | 1,970,085 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter):** | | | 719 | lbs | 43 | lbs | 64 | lbs | 12 | lbs | 3,271 | lbs | 3 | lbs | 0 | lbs | 18 | lbs | 444 | lbs | | | 2,937 | lbs |
| **FALL QUARTER (OCTOBER, NOVEMBER, DECEMBER)** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Fall Quarter Flow-Weighted EMC (10/11/18, 10/26/18, 11/9/18):** | 65.96 | 7.2 | 0 | 3 | 0.00 | 0.5 | 0.19 | 0.19 | 0.07 | 0.07 | 7 | 7 | 6 | 6 | 0 | 2 | 71 | 71 | 0 | 5 | 7789 | 7789 | 16 | 15.69 |
| **Average:** | | | 2 | mg/l | 0.3 | mg/l | 0.19 | mg/l | 0.07 | mg/l | 7 | mg/l | 6 | µg/l | 1 | µg/l | 71 | µg/l | 3 | mg/l | 7789 | MPN/100mL | 16 | mg/l |
| | | | 0.0001089 | lb/cf | 0.0000157 | lb/cf | 0.0000116 | lb/cf | 0.0000042 | lb/cf | 0.0004559 | lb/cf | 0.0000004 | lb/cf | 0.0000001 | lb/cf | 0.0000044 | lb/cf | 0.0001560 | lb/cf | | | 0.0009792 | lb/cf |
| **Total Volume (Quarter Events):** | | | 282,628 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter Events):** | | | 31 | lbs | 4 | lbs | 3 | lbs | 1 | lbs | 129 | lbs | 0 | lbs | 0. | lbs | 1 | lbs | 44 | lbs | | | 277 | lbs |
| **Total Volume (Quarter):** | | | 4,015,981 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter):** | | | 437 | lbs | 63 | lbs | 47 | lbs | 17 | lbs | 1,831 | lbs | 2 | lbs | 0 | lbs | 18 | lbs | 627 | lbs | | | 3,932 | lbs |
| **WINTER QUARTER (JANUARY, FEBRUARY, MARCH)** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Fall Quarter Flow-Weighted EMC (1/19/19, 2/24/19, 3/21/19):** | 44.30 | 9.1 | 1 | 3 | 0.0 | 0.5 | 0.28 | 0.28 | 0.07 | 0.07 | 37 | 37 | 15 | 15 | 2 | 3 | 129 | 129 | 5 | 9 | 458 | 458 | 40 | 39.58 |
| **Average:** | | | 2 | mg/l | 0.3 | mg/l | 0.28 | mg/l | 0.07 | mg/l | 37 | mg/l | 15 | µg/l | 2 | µg/l | 129 | µg/l | 7 | mg/l | 458 | MPN/100mL | 40 | mg/l |
| | | | 0.0001085 | lb/cf | 0.0000165 | lb/cf | 0.0000176 | lb/cf | 0.0000041 | lb/cf | 0.0023155 | lb/cf | 0.0000009 | lb/cf | 0.0000001 | lb/cf | 0.0000081 | lb/cf | 0.0004544 | lb/cf | | | 0.0024705 | lb/cf |
| **Total Volume (Quarter Events):** | | | 148,290 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter Events):** | | | 16 | lbs | 2 | lbs | 3 | lbs | 1 | lbs | 343 | lbs | 0 | lbs | 0 | lbs | 1 | lbs | 67 | lbs | | | 366 | lbs |
| **Total Volume (Quarter):** | | | 1,221,993 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter):** | | | 133 | lbs | 20 | lbs | 22 | lbs | 5 | lbs | 2,830 | lbs | 1 | lbs | 0 | lbs | 10 | lbs | 555 | lbs | | | 3,019 | lbs |
| **SPRING QUARTER (APRIL, MAY, JUNE)** | | | | | | | | | | | | | | | | | | | | | | | | |
| **Spring Quarter Flow-Weighted EMC (4/28/18, 5/31/18):** | 66.25 | 9.1 | 1 | 2 | 0.0 | 0.5 | 0.36 | 0.36 | 0.07 | 0.07 | 10 | 10 | 10 | 10 | 0 | 2 | 91 | 91 | 0 | 5 | 4867 | 4867 | 21 | 21.20 |
| **Average:** | | | 1 | mg/l | 0.3 | mg/l | 0.36 | mg/l | 0.07 | mg/l | 10 | mg/l | 10 | µg/l | 1 | µg/l | 91 | µg/l | 3 | mg/l | 4867 | MPN/100mL | 21 | mg/l |
| | | | 0.0000888 | lb/cf | 0.0000158 | lb/cf | 0.0000222 | lb/cf | 0.0000042 | lb/cf | 0.0006527 | lb/cf | 0.0000006 | lb/cf | 0.0000001 | lb/cf | 0.0000057 | lb/cf | 0.0001560 | lb/cf | | | 0.0013232 | lb/cf |
| **Total Volume (Quarter Events):** | | | 130,208 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter Events):** | | | 12 | lbs | 2 | lbs | 3 | lbs | 1 | lbs | 85 | lbs | 0 | lbs | 0 | lbs | 1 | lbs | 20 | lbs | | | 172 | lbs |
| **Total Volume (Quarter):** | | | 1,305,895 | cf | | | | | | | | | | | | | | | | | | | | |
| **Pollutant Load (Quarter):** | | | 116 | lbs | 21 | lbs | 29 | lbs | 5 | lbs | 852 | lbs | 1 | lbs | 0 | lbs | 7 | lbs | 204 | lbs | | | 1,728 | lbs |
| **AVERAGE ANNUAL EMCs:** | 62.56 | 8.0 | 2 | mg/l | 0.3 | mg/l | 0.28 | mg/l | 0.07 | mg/l | 17 | mg/l | 11 | mg/l | 1 | mg/l | 98 | mg/l | 4 | mg/l | 5719.86 | mg/l | 23 | mg/l |
| **TOTAL ANNUAL POLLUTANT LOAD (EVENTS):** | | | 87 | lbs | 11 | lbs | 11 | lbs | 3 | lbs | 687 | lbs | 0 | lbs | 0 | lbs | 4 | lbs | 149 | lbs | | | 932 | lbs |
| **Per Acre:** | | | 0.82 | | 0.100 | | 0.107 | | 0.03 | | 6.48 | | 0.00 | | 0.001 | | 0.04 | | 1.41 | | - | | 8.79 | |
| **TOTAL 2018 POLLUTANT LOAD:** | | | 1,405 | lbs | 147 | lbs | 162 | lbs | 40 | lbs | 8,784 | lbs | 6 | lbs | 1 | lbs | 53 | lbs | 1,830 | lbs | | | 11,616 | lbs |

# Anne Arundel County NPDES
# Sampling and EMC Data – 2019 Reporting Year
# Church Creek Station

| | | | | | | | | Inches | Hours | In/Hr | oF | cf | pH | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | µg/L | (0) µg/L | (dt) µg/L | µg/L | (0) µg/L | (dt) µg/L | µg/L | (0) µg/L | (dt) µg/L | mg/L | (0) mg/L | (dt) mg/L | MPN | (0) MPN | (dt) MPN | (dt) mg/L | mg/L | (0) mg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sampler | ID | Jurisdiction | Date | Time | Site | Outfall or Instream | Storm or Baseflow | Depth | Duration | Intensity | Temperature - field | Flow | pH - field | dt for BOD | BOD | BOD | dt for Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen | dt for Nitrate+ Nitrite - N | Nitrate+ Nitrite - N | Nitrate+ Nitrite - N | dt for Total Phosphorus | Total Phosphorus | Total Phosphorus | dt for TSS | TSS | TSS | dt for Copper | Copper | Copper | dt for Lead | Lead | Lead | dt for Zinc | Zinc | Zinc | dt for TPH | TPH | TPH | dt for E-COLI | E-COLI | E-COLI | dt for HARDNESS | HARDNESS | HARDNESS |
| Versar | 1 | AC | 8/17/2018 | 940 | 102 | I | B | | | | 75.2 | 507 | 6.6 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.93 | 0.93 | 0.01 | 0.08 | 0.08 | 1 | 6 | 6 | 2.0 | 3.6 | 3.6 | 2.0 | 0.0 | 2.0 | 20 | 23 | 23 | 5.0 | 0.0 | 5.0 | 10 | 538 | 538 | 1 | 120 | 120 |
| | | | | | | | | | | **Event Mean Concentration:** | **75.20** | | **6.6** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.93** | **0.93** | **0.01** | **0.08** | **0.08** | **1** | **6** | **6** | **2.0** | **3.6** | **3.6** | **2.0** | **0.0** | **2.0** | **20** | **23** | **23** | **5.0** | **0.0** | **5.0** | **10** | **538** | **538** | **1** | **120** | **120** |
| Versar | 1 | AC | 8/21/2018 | 1345 | 102 | I | S | 1.13 | 4.0 | 0.28 | 76.82 | 7049 | 6.7 | 10 | 0 | 10 | 0.5 | 0.7 | 0.7 | 0.05 | 0.44 | 0.44 | 0.01 | 0.76 | 0.76 | 1 | 98 | 98 | 2.0 | 70.1 | 70.1 | 2.0 | 32.4 | 32.4 | 20 | 702 | 702 | 5.0 | 6.0 | 6.0 | 100 | 1970 | 1970 | 1 | 97 | 97 |
| Versar | 2 | AC | 8/21/2018 | 1410 | 102 | I | S | | | | 77.36 | 136754 | 6.3 | 10 | 0 | 10 | 0.5 | 1.1 | 1.1 | 0.05 | 0.42 | 0.42 | 0.01 | 0.40 | 0.40 | 1 | 87 | 87 | 2.0 | 14.8 | 14.8 | 2.0 | 6.4 | 6.4 | 20 | 83 | 83 | 5.0 | 0.0 | 5.0 | 100 | 13540 | 13540 | 1 | 27 | 27 |
| Versar | 3 | AC | 8/21/2018 | 1635 | 102 | I | S | | | | 78.26 | 559435 | 6.4 | 10 | 0 | 10 | 0.5 | 0.0 | 0.5 | 0.05 | 0.36 | 0.36 | 0.01 | 0.12 | 0.12 | 1 | 21 | 21 | 2.0 | 7.8 | 7.8 | 2.0 | 3.7 | 3.7 | 20 | 48 | 48 | 5.0 | 5.0 | 5.0 | 100 | 23590 | 23590 | 1 | 26 | 26 |
| | | | | | | | | | | **Event Mean Concentration:** | **78.07** | | **6.4** | **10** | **0** | **10** | **0.5** | **0.2** | **0.6** | **0.05** | **0.37** | **0.37** | **0.01** | **0.18** | **0.18** | **1** | **35** | **35** | **2.0** | **9.7** | **9.7** | **2.0** | **4.5** | **4.5** | **20** | **61** | **61** | **5.0** | **4.0** | **5.0** | **100** | **21419** | **21419** | **1** | **27** | **27** |
| Versar | 1 | AC | 9/21/2018 | 925 | 102 | I | B | | | | 71.06 | 480 | 6.6 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.67 | 0.67 | 0.01 | 0.05 | 0.05 | 1 | 4 | 4 | 2.0 | 0.0 | 2.0 | 2.0 | 0.0 | 2.0 | 20 | 23 | 23 | 5.0 | 0.0 | 5.0 | 10 | 309 | 309 | 1 | 110 | 110 |
| | | | | | | | | | | **Event Mean Concentration:** | **71.06** | | **6.6** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.67** | **0.67** | **0.01** | **0.05** | **0.05** | **1** | **4** | **4** | **2.0** | **0.0** | **2.0** | **2.0** | **0.0** | **2.0** | **20** | **23** | **23** | **5.0** | **0.0** | **5.0** | **10** | **309** | **309** | **1** | **110** | **110** |
| Versar | 1 | AC | 10/11/2018 | 1930 | 102 | I | S | 2.26 | 8.0 | 0.28 | 74.48 | 9845 | 6.4 | 4 | 0 | 4 | 0.5 | 3.8 | 3.8 | 0.05 | 1.30 | 1.30 | 0.01 | 3.30 | 3.30 | 1 | 130 | 130 | 2.0 | 12.4 | 12.4 | 2.0 | 9.1 | 9.1 | 20 | 130 | 130 | 5.0 | 0.0 | 5.0 | 10 | 9208 | 9208 | 1 | 100 | 100 |
| Versar | 2 | AC | 10/11/2018 | 2020 | 102 | I | S | | | | 74.3 | 614694 | 6.1 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.30 | 0.30 | 0.01 | 0.20 | 0.20 | 1 | 66 | 66 | 2.0 | 8.3 | 8.3 | 2.0 | 7.2 | 7.2 | 20 | 71 | 71 | 5.0 | 0.0 | 5.0 | 10 | 14136 | 14136 | 1 | 18 | 18 |
| Versar | 3 | AC | 10/11/2018 | 2325 | 102 | I | S | | | | 73.4 | 1502888 | 6.2 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.29 | 0.29 | 0.01 | 0.09 | 0.09 | 1 | 13 | 13 | 2.0 | 3.2 | 3.2 | 2.0 | 0.0 | 2.0 | 20 | 40 | 40 | 5.0 | 0.0 | 5.0 | 10 | 5172 | 5172 | 1 | 22 | 22 |
| | | | | | | | | | | **Event Mean Concentration:** | **73.67** | | **6.2** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.30** | **0.30** | **0.01** | **0.14** | **0.14** | **1** | **29** | **29** | **2.0** | **4.7** | **4.7** | **2.0** | **2.1** | **3.5** | **20** | **49** | **49** | **5.0** | **0.0** | **5.0** | **10** | **7781** | **7781** | **1** | **21** | **21** |
| Versar | 1 | AC | 10/26/2018 | 1955 | 102 | I | S | 0.98 | 9.0 | 0.11 | 51.44 | 15100 | 6.5 | 2 | 3 | 3 | 0.5 | 2.2 | 2.2 | 0.05 | 1.30 | 1.30 | 0.01 | 0.05 | 0.05 | 1 | 340 | 340 | 2.0 | 36.6 | 36.6 | 2.0 | 22.6 | 22.6 | 20 | 398 | 398 | 5.0 | 0.0 | 5.0 | 10 | 12997 | 12997 | 1 | 120 | 120 |
| Versar | 2 | AC | 10/26/2018 | 0010 | 102 | I | S | | | | 51.44 | 446210 | 6.4 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.27 | 0.27 | 0.01 | 0.09 | 0.09 | 1 | 23 | 23 | 2.0 | 4.4 | 4.4 | 2.0 | 0.0 | 2.0 | 20 | 49 | 49 | 5.0 | 0.0 | 5.0 | 10 | 2603 | 2603 | 1 | 17 | 17 |
| Versar | 3 | AC | 10/26/2018 | 230 | 102 | I | S | | | | 52.88 | 300111 | 6.4 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.28 | 0.28 | 0.01 | 0.09 | 0.09 | 1 | 11 | 11 | 2.0 | 2.5 | 2.5 | 2.0 | 0.0 | 2.0 | 20 | 36 | 36 | 5.0 | 0.0 | 5.0 | 10 | 2489 | 2489 | 1 | 23 | 23 |
| | | | | | | | | | | **Event Mean Concentration:** | **52.01** | | **6.4** | **2** | **0** | **2** | **0.5** | **0.0** | **0.5** | **0.05** | **0.29** | **0.29** | **0.01** | **0.09** | **0.09** | **1** | **25** | **25** | **2.0** | **4.3** | **4.3** | **2.0** | **0.4** | **2.4** | **20** | **50** | **50** | **5.0** | **0.0** | **5.0** | **10** | **2764** | **2764** | **1** | **21** | **21** |
| Versar | 1 | AC | 11/9/2018 | 1455 | 102 | I | S | 0.47 | 9.0 | 0.05 | 52.7 | 30728 | 6.5 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 1.00 | 1.00 | 0.01 | 0.22 | 0.22 | 1 | 56 | 56 | 2.0 | 9.2 | 9.2 | 2.0 | 7.2 | 7.2 | 20 | 91 | 91 | 5.0 | 0.0 | 5.0 | 10 | 857 | 857 | 1 | 110 | 110 |
| Versar | 2 | AC | 11/9/2018 | 1640 | 102 | I | S | | | | 52.16 | 185362 | 6.4 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.23 | 0.23 | 0.01 | 0.18 | 0.18 | 1 | 35 | 35 | 2.0 | 10.3 | 10.3 | 2.0 | 4.5 | 4.5 | 20 | 89 | 89 | 5.0 | 0.0 | 5.0 | 10 | 933 | 933 | 1 | 37 | 37 |
| Versar | 3 | AC | 11/9/2018 | 2050 | 102 | I | S | | | | 52.7 | 214447 | 6.4 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.18 | 0.18 | 0.01 | 0.09 | 0.09 | 1 | 10 | 10 | 2.0 | 5.3 | 5.3 | 2.0 | 0.0 | 2.0 | 20 | 41 | 41 | 5.0 | 0.0 | 5.0 | 10 | 1254 | 1254 | 1 | 23 | 23 |
| | | | | | | | | | | **Event Mean Concentration:** | **52.47** | | **6.4** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.26** | **0.26** | **0.01** | **0.14** | **0.14** | **1** | **24** | **24** | **2.0** | **7.7** | **7.7** | **2.0** | **2.4** | **3.4** | **20** | **65** | **65** | **5.0** | **0.0** | **5.0** | **10** | **1087** | **1087** | **1** | **35** | **35** |
| Versar | 1 | AC | 12/6/2018 | 1050 | 102 | I | B | | | | 41.72 | 565 | 6.3 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 1.00 | 1.00 | 0.01 | 0.05 | 0.05 | 1 | 8 | 8 | 2.0 | 0.0 | 2.0 | 2.0 | 0.0 | 2.0 | 20 | 47 | 47 | 5.0 | 0.0 | 5.0 | 10 | 41 | 41 | 1 | 120 | 120 |
| | | | | | | | | | | **Event Mean Concentration:** | **41.72** | | **6.3** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **1.00** | **1.00** | **0.01** | **0.05** | **0.05** | **1** | **8** | **8** | **2.0** | **0.0** | **2.0** | **2.0** | **0.0** | **2.0** | **20** | **47** | **47** | **5.0** | **0.0** | **5.0** | **10** | **41** | **41** | **1** | **120** | **120** |

| Sampler | ID | Jurisdiction | Date | Time | Site | Outfall or Instream | Storm or Baseflow | Depth | Duration | Intensity | Temperature - field | Flow | pH - field | dt for BOD | BOD | BOD | dt for Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen | Total Kjeldahl Nitrogen | dt for Nitrate+ Nitrite - N | Nitrate+ Nitrite - N | Nitrate+ Nitrite - N | dt for Total Phosphorus | Total Phosphorus | Total Phosphorus | dt for TSS | TSS | TSS | dt for Copper | Copper | Copper | dt for Lead | Lead | Lead | dt for Zinc | Zinc | Zinc | dt for TPH | TPH | TPH | dt for E-COLI | E-COLI | E-COLI | dt for HARDNESS | HARDNESS | HARDNESS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Inches | Hours | In/Hr | oF | cf | pH | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | mg/L | (0) mg/L | (dt) mg/L | µg/L | (0) µg/L | (dt) µg/L | µg/L | (0) µg/L | (dt) µg/L | µg/L | (0) µg/L | (dt) µg/L | mg/L | (0) mg/L | (dt) mg/L | MPN | (0) MPN | (dt) MPN | (dt) mg/L | mg/L | (0) mg/L |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 1 | AC | 1/19/2019 | 2200 | 102 | I | S | 0.55 | 5.0 | 0.11 | 41.54 | 38854 | 6.6 | 4 | 7 | 7 | 0.5 | 1.8 | 1.8 | 0.05 | 0.73 | 0.73 | 0.01 | 0.29 | 0.29 | 1 | 240 | 240 | 2.0 | 39.1 | 39.1 | 2.0 | 16.1 | 16.1 | 20 | 281 | 281 | 5.0 | 9.0 | 9.0 | 10 | 1336 | 1336 | 1 | 170 | 170 |
| Versar | 2 | AC | 1/19/2019 | 0010 | 102 | I | S | | | | 39.74 | 329800 | 6.8 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.24 | 0.24 | 0.01 | 0.13 | 0.13 | 1 | 25 | 25 | 2.0 | 23.4 | 23.4 | 2.0 | 11.9 | 11.9 | 20 | 153 | 153 | 5.0 | 0.0 | 5.0 | 10 | 488 | 488 | 1 | 63 | 63 |
| Versar | 3 | AC | 1/19/2019 | 130 | 102 | I | S | | | | 39.92 | 166440 | 6.8 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.35 | 0.35 | 0.01 | 0.07 | 0.07 | 1 | 22 | 22 | 2.0 | 10.1 | 10.1 | 2.0 | 5.3 | 5.3 | 20 | 79 | 79 | 5.0 | 0.0 | 5.0 | 10 | 504 | 504 | 1 | 61 | 61 |
| | | | | | | | | | | **Event Mean Concentration:** | **39.93** | | **6.8** | **2** | **1** | **2** | **0.5** | **0.1** | **0.6** | **0.05** | **0.31** | **0.31** | **0.01** | **0.12** | **0.12** | **1** | **40** | **40** | **2.0** | **20.4** | **20.4** | **2.0** | **10.1** | **10.1** | **20** | **139** | **139** | **5.0** | **0.7** | **5.3** | **10** | **555** | **555** | **1** | **70** | **70** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 1 | AC | 2/24/2019 | 420 | 102 | I | S | 0.62 | 11.0 | 0.06 | 42.98 | 18594 | 6.8 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.57 | 0.57 | 0.01 | 0.06 | 0.06 | 1 | 17 | 17 | 2.0 | 8.0 | 8.0 | 2.0 | 0.0 | 2.0 | 20 | 59 | 59 | 5.0 | 0.0 | 5.0 | 10 | 387 | 387 | 1 | 73 | 73 |
| Versar | 2 | AC | 2/24/2019 | 625 | 102 | I | S | | | | 40.1 | 211978 | 7.0 | 2 | 2 | 2 | 0.5 | 0.9 | 0.9 | 0.05 | 0.25 | 0.25 | 0.01 | 0.36 | 0.36 | 1 | 190 | 190 | 2.0 | 27.5 | 27.5 | 2.0 | 18.8 | 18.8 | 20 | 181 | 181 | 5.0 | 0.0 | 5.0 | 10 | 1733 | 1733 | 1 | 59 | 59 |
| Versar | 3 | AC | 2/24/2019 | 1305 | 102 | I | S | | | | 42.8 | 474608 | 6.9 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.38 | 0.38 | 0.01 | 0.07 | 0.07 | 1 | 14 | 14 | 2.0 | 5.0 | 5.0 | 2.0 | 0.0 | 2.0 | 20 | 46 | 46 | 5.0 | 0.0 | 5.0 | 10 | 345 | 345 | 1 | 55 | 55 |
| | | | | | | | | | | **Event Mean Concentration:** | **41.99** | | **6.9** | **2** | **1** | **2** | **0.5** | **0.3** | **0.6** | **0.05** | **0.35** | **0.35** | **0.01** | **0.16** | **0.16** | **1** | **67** | **67** | **2.0** | **11.8** | **11.8** | **2.0** | **5.7** | **7.1** | **20** | **87** | **87** | **5.0** | **0.0** | **5.0** | **10** | **763** | **763** | **1** | **57** | **57** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 1 | AC | 3/21/2019 | 950 | 102 | I | S | 0.83 | 14.0 | 0.06 | 48.2 | 167233 | 6.90 | 2 | 6 | 6 | 0.5 | 0.0 | 0.5 | 0.05 | 0.39 | 0.39 | 0.01 | 0.12 | 0.12 | 1 | 36 | 36 | 2.0 | 12.4 | 12.4 | 2.0 | 3.5 | 3.5 | 20 | 98 | 98 | 5.0 | 0.0 | 5.0 | 10 | 1334 | 1334 | 1 | 24 | 24 |
| Versar | 2 | AC | 3/21/2019 | 1145 | 102 | I | S | | | | 50 | 162389 | 7.1 | 2 | 6 | 6 | 0.5 | 0.8 | 0.8 | 0.05 | 0.16 | 0.16 | 0.01 | 0.32 | 0.32 | 1 | 74 | 74 | 2.0 | 16.5 | 16.5 | 2.0 | 6.9 | 6.9 | 20 | 114 | 114 | 5.0 | 0.0 | 5.0 | 10 | 794 | 794 | 1 | 40 | 40 |
| Versar | 3 | AC | 3/21/2019 | 1545 | 102 | I | S | | | | 51.62 | 383437 | 7.1 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.18 | 0.18 | 0.01 | 0.08 | 0.08 | 1 | 33 | 33 | 2.0 | 7.8 | 7.8 | 2.0 | 0.0 | 2.0 | 20 | 54 | 54 | 5.0 | 0.0 | 5.0 | 10 | 670 | 670 | 1 | 33 | 33 |
| | | | | | | | | | | **Event Mean Concentration:** | **50.45** | | **7.1** | **2** | **3** | **4** | **0.5** | **0.2** | **0.6** | **0.05** | **0.22** | **0.22** | **0.01** | **0.14** | **0.14** | **1** | **43** | **43** | **2.0** | **10.9** | **10.9** | **2.0** | **2.4** | **3.5** | **20** | **78** | **78** | **5.0** | **0.0** | **5.0** | **10** | **854** | **854** | **1** | **32** | **32** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 1 | AC | 5/11/2019 | 035 | 102 | I | S | 0.39 | 12.0 | 0.03 | 63.68 | 167233 | 6.9 | 2 | 8 | 8 | 0.5 | 1.1 | 1.1 | 0.05 | 0.83 | 0.83 | 0.01 | 0.16 | 0.16 | 1 | 56 | 56 | 2.0 | 14.7 | 14.7 | 2.0 | 4.9 | 4.9 | 20 | 81 | 81 | 5.0 | 0.0 | 5.0 | 10 | 6488 | 6488 | 1 | 42 | 42 |
| Versar | 2 | AC | 5/12/2019 | 1020 | 102 | I | S | | | | 61.34 | 298062 | 7.1 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.61 | 0.61 | 0.01 | 0.15 | 0.15 | 1 | 20 | 20 | 2.0 | 11.4 | 11.4 | 2.0 | 4.7 | 4.7 | 20 | 74 | 74 | 5.0 | 0.0 | 5.0 | 10 | 2098 | 2098 | 1 | 43 | 43 |
| Versar | 3 | AC | 5/12/2019 | 1135 | 102 | I | S | | | | 61.16 | 43102 | 7.1 | 2 | 3 | 3 | 0.5 | 0.0 | 0.5 | 0.05 | 0.38 | 0.38 | 0.01 | 0.06 | 0.06 | 1 | 8 | 8 | 2.0 | 7.1 | 7.1 | 2.0 | 0.0 | 2.0 | 20 | 42 | 42 | 5.0 | 0.0 | 5.0 | 10 | 4106 | 4106 | 1 | 36 | 36 |
| | | | | | | | | | | **Event Mean Concentration:** | **62.09** | | **7.0** | **2** | **3** | **4** | **0.5** | **0.4** | **0.7** | **0.05** | **0.66** | **0.66** | **0.01** | **0.15** | **0.15** | **1** | **31** | **31** | **2.0** | **12.1** | **12.1** | **2.0** | **4.4** | **4.5** | **20** | **73** | **73** | **5.0** | **0.0** | **5.0** | **10** | **3712** | **3712** | **1** | **42** | **42** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 1 | AC | 6/13/2019 | 950 | 102 | I | S | 1.57 | 9.0 | 0.17 | 67.64 | 14574 | 6.7 | 2 | 26 | 26 | 0.5 | 5.6 | 5.6 | 0.05 | 2.00 | 2.00 | 0.01 | 2.10 | 2.10 | 1 | 340 | 340 | 2.0 | 54.8 | 54.8 | 2.0 | 61.4 | 61.4 | 20 | 397 | 397 | 5.0 | 6.0 | 6.0 | 10 | 4611 | 4611 | 1 | 130 | 130 |
| Versar | 2 | AC | 6/13/2019 | 1145 | 102 | I | S | | | | 69.98 | 200728 | 6.9 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.33 | 0.33 | 0.01 | 0.17 | 0.17 | 1 | 55 | 55 | 2.0 | 9.3 | 9.3 | 2.0 | 6.7 | 6.7 | 20 | 67 | 67 | 5.0 | 0.0 | 5.0 | 10 | 2247 | 2247 | 1 | 20 | 20 |
| Versar | 3 | AC | 6/13/2019 | 1545 | 102 | I | S | | | | 66.92 | 886890 | 7.0 | 2 | 0 | 2 | 0.5 | 0.0 | 0.5 | 0.05 | 0.25 | 0.25 | 0.01 | 0.11 | 0.11 | 1 | 22 | 22 | 2.0 | 6.8 | 6.8 | 2.0 | 2.8 | 2.8 | 20 | 51 | 51 | 5.0 | 0.0 | 5.0 | 10 | 2247 | 2247 | 1 | 28 | 28 |
| | | | | | | | | | | **Event Mean Concentration:** | **67.49** | | **6.7** | **2** | **0** | **2** | **0.5** | **0.1** | **0.6** | **0.05** | **0.29** | **0.29** | **0.01** | **0.15** | **0.15** | **1** | **32** | **32** | **2.0** | **7.9** | **7.9** | **2.0** | **4.3** | **4.3** | **20** | **58** | **58** | **5.0** | **0.1** | **5.0** | **10** | **2278** | **2278** | **1** | **28** | **28** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Versar | 1 | AC | 6/26/2019 | 1055 | 102 | I | B | | | | 72.14 | 487 | 6.9 | 4 | 0 | 4 | 0.5 | 0.0 | 0.5 | 0.05 | 0.73 | 0.73 | 0.01 | 0.06 | 0.06 | 1 | 4 | 4 | 2.0 | 2.7 | 2.7 | 2.0 | 0.0 | 2.0 | 20 | 26 | 26 | 5.0 | 0.0 | 5.0 | 10 | 85 | 85 | 1 | 120 | 120 |
| | | | | | | | | | | **Event Mean Concentration:** | **72.14** | | **6.9** | **4** | **0** | **4** | **0.5** | **0.0** | **0.5** | **0.05** | **0.73** | **0.73** | **0.01** | **0.06** | **0.06** | **1** | **4** | **4** | **2.0** | **2.7** | **2.7** | **2.0** | **0.0** | **2.0** | **20** | **26** | **26** | **5.0** | **0.0** | **5.0** | **10** | **85** | **85** | **1** | **120** | **120** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <u>SUMMER QUARTER (JULY, AUGUST, SEPTEMBER)</u> | | | | | | | | | | | | | | | | | | | | | | | | |
| Summer Quarter Flow-Weighted EMC ( 8/21/18): | 78.06 | 6.4 | 0.00 | 10 | 0.22 | 0.62 | 0.37 | 0.37 | 0.18 | 0.18 | 35 | 35 | 10 | 10 | 4 | 4 | 61 | 61 | 4 | 5 | 21390 | 21390 | 27 | 27.03 |
| Average: | | | 5 | mg/l | 0.42 | mg/l | 0.37 | mg/l | 0.18 | mg/l | 35 | mg/l | 10 | µg/l | 4 | µg/l | 61 | µg/l | 5 | mg/l | 21390 | MPN/100mL | 27 | mg/l |
| | | | 0.0003118 | lb/cf | 0.0000262 | lb/cf | 0.0000233 | lb/cf | 0.0000113 | lb/cf | 0.0021574 | lb/cf | 0.0000006 | lb/cf | 0.0000003 | lb/cf | 0.0000038 | lb/cf | 0.0002822 | lb/cf | | | 0.0016871 | lb/cf |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Volume (Quarter Events): | | | 704,225 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter Events): | | | 220 | lbs | 18 | lbs | 16 | lbs | 8 | lbs | 1,519 | lbs | 0 | lbs | 0. | lbs | 3 | lbs | 199 | lbs | | | 1,188 | lbs |
| Total Volume (Quarter): | | | 30,265,323 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter): | | | 9,437 | lbs | 793 | lbs | 705 | lbs | 341 | lbs | 65,294 | lbs | 18 | lbs | 8 | lbs | 116 | lbs | 8,540 | lbs | | | 51,060 | lbs |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| <u>FALL QUARTER (OCTOBER, NOVEMBER, DECEMBER)</u> | | | | | | | | | | | | | | | | | | | | | | | | |
| Fall Quarter Flow- Weighted EMC (10/11/18, 10/26/18, 11/9/18): | 65.94 | 6.3 | 0 | 4 | 0.0 | 0.5 | 0.29 | 0.29 | 0.13 | 0.13 | 27 | 27 | 5 | 5 | 2 | 3 | 52 | 52 | 0 | 5 | 5761 | 5761 | 23. | 23 |
| Average: | | | 2 | mg/l | 0.3 | mg/l | 0.29 | mg/l | 0.13 | mg/l | 27 | mg/l | 5 | µg/l | 3 | µg/l | 52 | µg/l | 3 | mg/l | 5761 | MPN/100mL | 23. | mg/l |
| | | | 0.0001111 | lb/cf | 0.0000168 | lb/cf | 0.0000182 | lb/cf | 0.0000079 | lb/cf | 0.0017003 | lb/cf | 0.0000003 | lb/cf | 0.0000002 | lb/cf | 0.0000032 | lb/cf | 0.0001560 | lb/cf | | | 0.0014411 | lb/cf |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Volume (Quarter Events): | | | 3,319,386 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter Events): | | | 369 | lbs | 56 | lbs | 61 | lbs | 26 | lbs | 5,644 | lbs | 1 | lbs | 1 | lbs | 11 | lbs | 518 | lbs | | | 4,783 | lbs |
| Total Volume (Quarter): | | | 32,882,662 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter): | | | 3,653 | lbs | 553 | lbs | 599 | lbs | 258 | lbs | 55,912 | lbs | 10 | lbs | 5 | lbs | 106 | lbs | 5,131 | lbs | | | 47,386 | lbs |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| <u>WINTER QUARTER (JANUARY, FEBRUARY, MARCH)</u> | | | | | | | | | | | | | | | | | | | | | | | | |
| Winter Quarter Flow- Weighted EMC (1/19/19, 2/24/19, 3/21/19): | 44.51 | 6.9 | 1 | 3 | 0.2 | 0.6 | 0.29 | 0.29 | 0.14 | 0.14 | 51 | 51 | 14 | 14 | 6 | 7 | 98 | 98 | 0 | 5 | 739 | 739 | 52 | 52 |
| Average: | | | 2 | mg/l | 0.4 | mg/l | 0.29 | mg/l | 0.14 | mg/l | 51 | mg/l | 14 | µg/l | 6 | µg/l | 98 | µg/l | 3 | mg/l | 739 | MPN/100mL | 52 | mg/l |
| | | | 0.0001293 | lb/cf | 0.0000248 | lb/cf | 0.0000182 | lb/cf | 0.0000089 | lb/cf | 0.0031685 | lb/cf | 0.0000009 | lb/cf | 0.0000004 | lb/cf | 0.0000061 | lb/cf | 0.0001641 | lb/cf | | | 0.0032166 | lb/cf |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Volume (Quarter Events): | | | 1,953,332 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter Events): | | | 253 | lbs | 4 | lbs | 36 | lbs | 17 | lbs | 6,189 | lbs | 2 | lbs | 1 | lbs | 12 | lbs | 321 | lbs | | | 6,283 | lbs |
| Total Volume (Quarter): | | | 27,409,301 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter): | | | 3,544 | lbs | 679 | lbs | 499 | lbs | 244 | lbs | 86,845 | lbs | 24 | lbs | 11 | lbs | 168 | lbs | 4,498 | lbs | | | 88,165 | lbs |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| <u>SPRING QUARTER (APRIL, MAY, JUNE)</u> | | | | | | | | | | | | | | | | | | | | | | | | |
| Spring Quarter Flow- Weighted EMC ( 5/11/19, 6/13/19): | 65.79 | 7.0 | 1 | 3 | 0.2 | 0.6 | 0.41 | 0.41 | 0.15 | 0.15 | 32 | 32 | 9 | 9 | 4 | 4 | 63 | 63 | 0 | 5 | 2730 | 2730 | 32 | 32 |
| Average: | | | 2 | mg/l | 0.4 | mg/l | 0.41 | mg/l | 0.15 | mg/l | 32 | mg/l | 9 | µg/l | 4 | µg/l | 63 | µg/l | 3 | mg/l | 2730 | MPN/100mL | 32 | mg/l |
| | | | 0.0001252 | lb/cf | 0.0000241 | lb/cf | 0.0000254 | lb/cf | 0.0000092 | lb/cf | 0.0019828 | lb/cf | 0.0000006 | lb/cf | 0.0000003 | lb/cf | 0.0000039 | lb/cf | 0.0001580 | lb/cf | | | 0.0020220 | lb/cf |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| Total Volume (Quarter Events): | | | 1,611,077 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter Events): | | | 202 | lbs | 39 | lbs | 41 | lbs | 15 | lbs | 3,194 | lbs | 1 | lbs | 0 | lbs | 6 | lbs | 255 | lbs | | | 3,258 | lbs |
| Total Volume (Quarter): | | | 24,818,898 | cf | | | | | | | | | | | | | | | | | | | | |
| Pollutant Load (Quarter): | | | 3,108 | lbs | 599 | lbs | 629 | lbs | 227 | lbs | 49,211 | lbs | 14 | lbs | 7 | lbs | 97 | lbs | 3,922 | lbs | | | 50,185 | lbs |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| AVERAGE ANNUAL EMCs: | 61.52 | 6.6 | 2 | mg/l | 0.3 | mg/l | 0.32 | mg/l | 0.14 | mg/l | 35 | mg/l | 9 | mg/l | 4 | mg/l | 67 | mg/l | 3 | mg/l | 5275 | mg/l | 33 | mg/l |
| | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ANNUAL POLLUTANT LOAD (EVENTS): | | | 1,043 | lbs | 162 | lbs | 153 | lbs | 66 | lbs | 16,547 | lbs | 4 | lbs | 2 | lbs | 32 | lbs | 1,292 | lbs | | | 15,512 | lbs |
| Per Acre: | | | 3.70 | | 0.574 | | 0.545 | | 0.24 | | 58.78 | | 0.01 | | 0.007 | | 0.11 | | 4.59 | | | | 55.11 | |
| TOTAL 2018 POLLUTANT LOAD: | | | 19,742 | lbs | 2,624 | lbs | 2,433 | lbs | 1,072 | lbs | 257,263 | lbs | 67 | lbs | 31 | lbs | 487 | lbs | 22,091 | lbs | | | 236,796 | lbs |