FREDERICK COUNTY
ASSESSMENT OF CONTROLS:
PETER PAN RUN MONITORING
JULY 2016 - JUNE 2017

Prepared for

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and Environmental Resources
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1.0 INTRODUCTION

1.1 REGULATORY REQUIREMENT

The performance of long-term monitoring in Peter Pan Run fulfills requirements specified in Frederick County's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit No. 11-DP-3321, MD0068357. This third-generation Phase I NPDES MS4 permit, which took effect December 30, 2014 and covers stormwater discharges from the municipal separate storm sewer system in Frederick County, was in force during this reporting period (July 1, 2016 – June 30, 2017). This monitoring report is the first to document Peter Pan monitoring activities to meet requirements under the new permit.

This Peter Pan Run monitoring report follows specific sections presented under Part IV, Standard Permit Conditions, Subpart F, Assessment of Controls to describe and document required monitoring efforts in Peter Pan Run. Monitoring in Peter Pan Run is designed to build a long-term database of water quality and biological conditions and to assess the cumulative effects of restoration projects in the watershed. Activities described herein continue the long-term program initiated in 1999 to monitor and assess the effects of stormwater runoff stemming from development.

1.2 DESCRIPTION OF STUDY AREA

With MDE's approval, the County selected Peter Pan Run as the study stream because of construction of The Villages of Urbana planned unit development (PUD) within its headwaters. Peter Pan Run is located within the Bush Creek watershed which flows westward into the Monocacy River near Frederick Junction.

The Villages of Urbana is a mixed-use development consisting of 3,500 residential units, along with substantial commercial and office space. Initial construction activities within the PUD began in early 1999, with major construction activities beginning in August of that year. Estimates in the County's regional plan (FCDPZ 2004) indicated that between 200 and 300 new residential lots would be recorded each year in the Urbana PUD, accounting for most of the expected growth within the Urbana Planning Region through 2010. During FY 2017, construction of the PUD continued within the remaining unbuilt sections of the community, while many other sections have been completed and are occupied by residents. In addition to new residential construction in one neighborhood within the PUD along its south-western edge by Giant, significant commercial development activity has occurred as well in this same area outside of the PUD. Activity includes: redevelopment of the site of the former Cracked Claw/Peter Pan Inn, construction of a new commercial building by the Royal Farms, and redevelopment of the Landon House site. Construction of the Urban Green development – located just outside of the catchment area, south of Urbana Pike – started late in 2014 and will result in reconstruction of Urbana Pike along its frontage. While not resulting in a significant amount of new paved area, this road work occurs at the headwaters of Tributary 2 and drainage patterns will be altered.

Figure 1-1 provides a series of aerial photographs illustrating changes in land use that have occurred within the catchment of Peter Pan Run over the course of the PUD's construction.

1.3 LONG-TERM MONITORING PLAN

In May 1999, the County initiated a long-term monitoring program for the Peter Pan Run study area to establish baseline, pre-construction conditions in the catchment and subsequently to monitor conditions as development progresses within the Peter Pan Run watershed in order to assess potential long-term impacts associated with the new land use. The program involves monitoring flow volumes and water quality from both instream and SWM pond outfall stations, as well as collecting physical and biological data from four permanent stream monitoring stations on the mainstem and its tributaries (Figure 1-2). In particular, monitoring is focused on the long-term problems commonly associated with residential development, which could occur within Peter Pan Run. These potential problems include sedimentation and erosion resulting from increased runoff from impervious surfaces, pollutant runoff from roads and parking lots, elevated nutrient loading caused by the application of lawn fertilizers, and the illegal disposal of oil and other household chemicals via storm drains.

Frederick County has compiled data to characterize the catchment upstream of the Peter Pan Run instream monitoring station and the Pond R outfall station. Data on catchment area, land uses, and station location are provided in the geodatabase that comprises the County's Annual Report submittal. Land use was derived from 2010 Maryland Department of Planning GIS data, which is the most recent data available. At present, the County's SWM database indicates that 43 structural SWM facilities (21 extended detention dry ponds, 10 extended detention wet ponds, five combination sand filter and extended detention ponds, three sand filters, two infiltration trenches, one wet pond, and one oil and grit separator) have been constructed within the Peter Pan Run catchment area. The three non-structural BMPs within this catchment include two shallow marshes and one reforestation of a 0.25-acre area of urban pervious land. These data will be updated in future years as needed.

Monitoring activities within the study area were initially described in the County's Long-Term Monitoring Plan for the Peter Pan Run Watershed, Frederick County, Maryland (Southerland et al. 1999), which laid out methods for biological, physical, and water chemistry monitoring of the stream. To keep pace with the changing program needs and evolving science, Frederick County continues to make periodic revisions and improvements to its monitoring efforts, as documented in the County's NPDES Annual Reports. Two quality assurance/quality control documents have been developed for the County's monitoring efforts: *Quality Assurance Project Plan for Water Chemistry Monitoring in Peter Pan Run* (Jones and Roth 2005), and *Quality Assurance Project Plan for Biological and Physical Monitoring in Peter Pan Run and Other Selected Watersheds* (Morgan and Roth 2005).

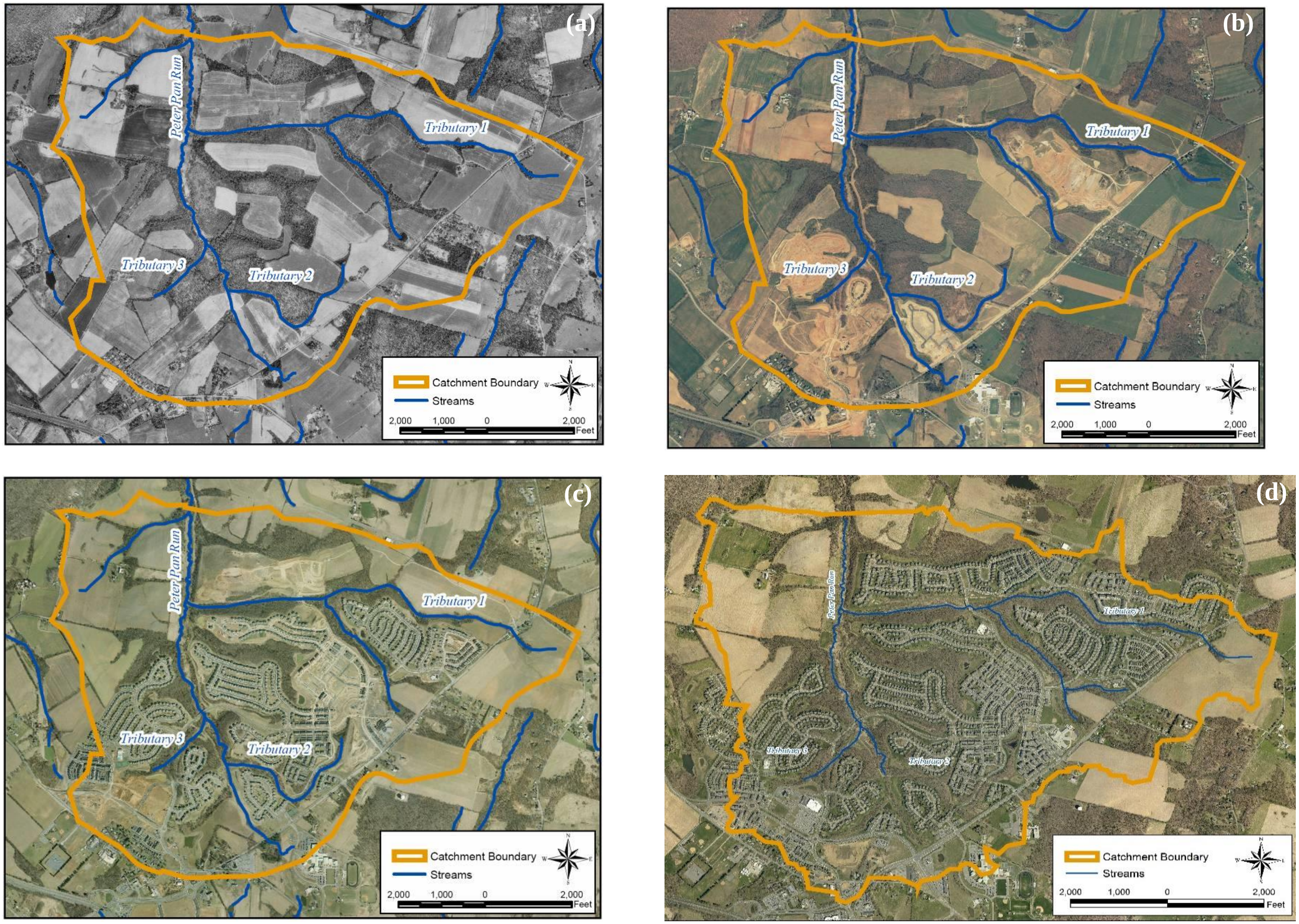

Figure 1-1. Aerial photographs of the Urbana Planned Unit Development (PUD) showing changes in the area over time. (a.) predevelopment conditions in April 1988 (Source: USGS), (b.) initial stages of development in March 2000 (Source: Frederick County), (c.) conditions in March-April 2005 (Source: Frederick County), and (d.) conditions in 2014 (Source: Frederick County).

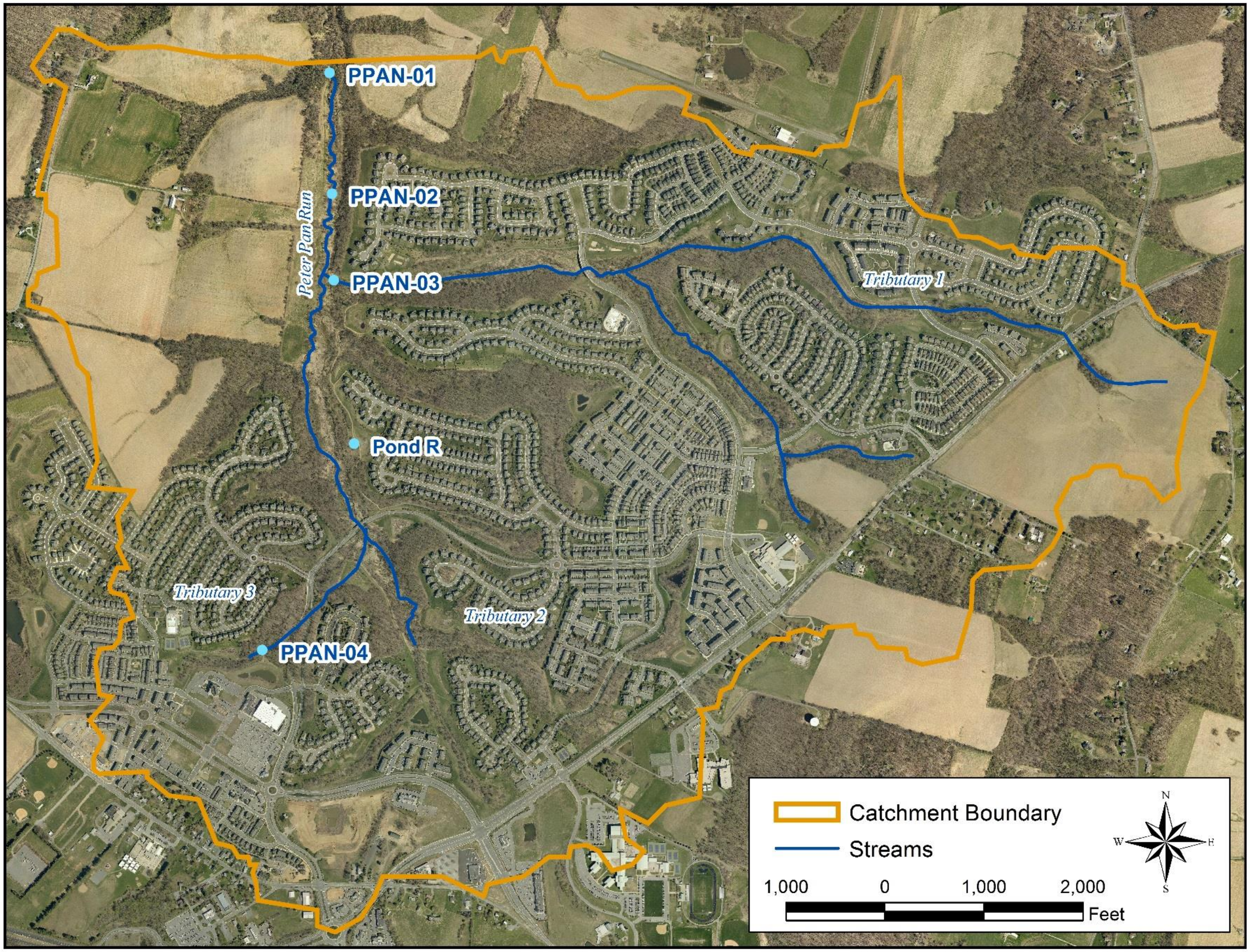

Figure 1-2. Annotated aerial photograph of Peter Pan Run in Lower Bush Creek watershed, Frederick County, Maryland showing the Peter Pan Run monitoring stations. (Image source: Frederick County 2014)

1.4 MONITORING METHODS

Currently, and as approved by Maryland Department of the Environment (MDE), methodology to assess streams in Frederick County is comparable to that used by other counties in Maryland, which facilitates integration of Frederick County's monitoring efforts with those of state and county programs. Methods for biological and physical stream assessments were developed by the Maryland Department of Natural Resources (DNR) for its Maryland Biological Stream Survey (MBSS), a statewide biological and physical habitat assessment program. MBSS methods (Stranko et al. 2014) are a regional application of EPA's Rapid Bioassessment Protocols (RBP, Plafkin et al. 1989, Barbour et al. 1999). Methods developed by Montgomery County Department of Environmental Protection were also employed from 1999 through 2006, in part, for quantitative physical habitat assessments. Beginning in 2007, it was determined that this additional dataset was not significantly adding to the understanding of stream conditions, and so use of the Montgomery County protocols was discontinued. In keeping with the sampling schedule established by these model programs, physical, biological, and water chemistry monitoring activities follow the annual schedules presented in Tables 1-1 and 1-2.

Table 1-1. Annual physical and biological sampling schedule for watershed monitoring stations

Spring (March through April)	**Summer** (June through September)
Physical habitat: • MBSS Spring Habitat assessment • Quantitative Geomorphologic assessment	Physical habitat: • MBSS Summer Habitat assessment
Ambient water quality: • dissolved oxygen, specific conductivity, pH, turbidity, and water temperature	Ambient water quality: • dissolved oxygen, specific conductivity, pH, turbidity, and water temperature
Biological monitoring: • benthic macroinvertebrates	Biological monitoring: • fish

Table 1-2. Annual stream chemistry sampling schedule for the instream and outfall stations

Baseflow (Monthly)	**Wet Weather** (up to 2 storms per quarter)
Chemical water quality: • dissolved oxygen, specific conductivity, pH, and water temperature • baseflow samples for laboratory analysis	Chemical water quality: • dissolved oxygen, specific conductivity, pH, and water temperature • storm samples for laboratory analysis

The County has also used these physical and biological monitoring methods to assess ecological stream conditions elsewhere in Frederick County. Specifically, the County began assessing watersheds in order of priority as part of its Permit. The County initiated watershed monitoring in the Lower Bush Creek watershed in 1999, and resurveyed conditions again in 2001 and 2006. The County's second priority watershed, Ballenger Creek, was assessed in 2000 and 2002/2003. Lower Linganore Creek, the County's third priority watershed, was assessed initially in 2001 and again in 2005. Bennett and Catoctin Creeks were assessed in 2007 as part of a pilot program for the Frederick County Stream Survey (FCSS), a countywide stream monitoring program. Starting in 2008 and continuing through 2011, every watershed in the county was evaluated as part of the FCSS. In 2013, the second four-year round of countywide stream sampling as part of the FCSS began. Additional stream monitoring to support watershed restoration efforts continued in 2017 as described in *Frederick County Restoration Site Monitoring Report, July 2016 – June 2017* (Versar 2017).

2.0 MONITORING RESULTS AND DISCUSSION

2.1 CHEMICAL MONITORING

As specified in the Permit, the County has established, and maintains, two long-term chemical stormwater monitoring stations within the Urbana PUD to characterize stormwater discharges from both a stormwater outfall draining a specific land use (Pond R) and an associated in-stream station (station PPAN-01; Figure 1-2).

<u>Peter Pan Run Instream Station</u>

Long-term chemical monitoring has continued at the Peter Pan Run instream monitoring station (located at PPAN-01) since May 1999. Photographs of the monitoring equipment and related site features are presented in Figures 2-1a and 2-1b.

Figure 2-1a. The "storm box" at the ambient instream monitoring station at Peter Pan Run in the Lower Bush Creek watershed, Frederick County, MD. The storm box contains an ISCO sampler, streamflow meter, battery, and a data recording unit. Photograph taken in January 2010.

Figure 2-1b. Ambient instream monitoring station at Peter Pan Run in the Lower Bush Creek watershed, Frederick County, MD. The instream station includes sample intake tubing located in the center of the stream, a staff gauge and flow meter sensor against the left bank, and a “storm box” located in a clearing near the bank. Photograph taken in December 2015.

Land use immediately surrounding the Peter Pan Run instream station remains primarily agricultural; however, construction within the Urbana PUD has occurred within approximately 500 yards of the station. The instream station is located on the west bank of Peter Pan Run. The station is bordered by agricultural fields to the immediate west and east with patches of densely forested and shrub areas along the stream and tributaries. A sanitary sewer pipeline (completed winter 1999/2000) runs parallel to the east side of the stream, extending the full length of Peter Pan Run, south to the Urbana PUD area. A branch sanitary sewer line extends eastward, along the north side of Tributary 1.

Outfall Station

Within the Urbana PUD, the outfall at Pond R (Figure 2-2) is monitored as a land use-specific stormwater management structure. Installation of water chemistry monitoring and automated sampling equipment was completed on December 24, 2002. Initial monitoring characterized water quality at the outfall of the basin during residential construction. Conversion of the Pond R sediment trap began in approximately late March 2004 and concluded during the first week of July 2004. Monitoring at this station continues as specified in the Permit.

Figure 2-2. Villages of Urbana “Pond R” outfall water chemistry monitoring station and rain gauge. Photograph taken December 2015.

Land use upstream of Pond R consists of medium-density residential housing comprising 30.4 acres (38.8%) of the total 78.4 acres of the Village VII section of the Urbana PUD.

2.1.1 Chemistry Monitoring Procedures

As part of the program, Frederick County conducted monthly baseflow monitoring at both the Peter Pan Run ambient instream (PPAN-01) and the Pond R outfall (POND-R) stations in Fiscal year (FY) 2016 to develop a dry weather flow database. Baseflow monitoring included manual grab sampling with parameter-specific sampling bottles containing the appropriate preservative. Calibrated field instruments were used to measure basic physical water quality parameters (e.g., water temperature, dissolved oxygen, specific conductivity, and pH). Field notes and data were recorded on preprinted, project-specific field sheets. During weekly inspections of the monitoring stations, field teams checked equipment for proper operation and maintained equipment logs. Baseflow monitoring at the outfall station has occurred only when flow is present since its conversion to a stormwater BMP in July 2004; this condition had been infrequent through 2016, but became more frequent in 2017.

Beginning in 2015, the Permit required eight storms per year; a new storm event frequency was implemented to capture two events per quarter. Bi-quarterly storm sampling of Peter Pan Run and Pond R was performed using ISCO automated samplers and flow meters located at each water chemistry monitoring station. Storm event monitoring at the ambient station (PPAN-01) and the outfall station (POND-R) began in May 1999 and February 2003, respectively. For each storm, the equipment at each station was used to prepare volume-weighted, composite samples that represent the rising, peak, and falling limbs of each storm hydrograph. Manual grab samples were collected for "first flush" parameters (oil and grease, TPH, phenols, and fecal coliform) using dedicated bottles containing preservative. An electronic rain gauge located at the outfall station recorded data to determine storm event validity (i.e., rainfall quantity greater than 0.10"). At each station, the flow meter measured stage height and converted the value to a discharge rate. Flow rate at the instream station was determined automatically by comparing stage heights to rating curve data collected during the year. Discharge measurements were collected using the USGS' stream velocity profile measurement technique (USGS 1982), and updated, as needed. The flow rate of water exiting the outfall pipe at the Pond R monitoring station was calculated using Manning's Equation. These continuous level, flow, and rainfall measurements were downloaded at least twice monthly.

Following NPDES permit guidelines, all baseflow and stormflow samples were analyzed for the parameters listed in Table 2-1. Samples were stored on ice or in dedicated sample refrigerators until they could be transported under chain of custody to the laboratory. Sample analysis was performed by Martel Laboratories, Inc., of Towson, MD. Field and laboratory results from the monitored storms are discussed in the sections below.

Table 2-1. Parameters and detection limits for Frederick County's Water Chemistry Monitoring Program

Parameter	Detection Limit	Method
Biochemical Oxygen Demand (5-day)	2 - 8 mg/l	SM 5210 B
Total Kjeldahl Nitrogen (TKN)	0.5 mg/l	SM4500NH3-C
Total Phosphorus	0.01 mg/l	SM 4500P-E
Total Suspended Solids (TSS)	1 mg/l	SM 2540 D
Zinc	20 µg/l	EPA 200.8
Copper	2 µg/l	EPA 200.8
Lead	2 µg/l	EPA 200.8
Total Petroleum Hydrocarbons (TPH)	5 mg/l	EPA 1664
E. coli	1/100 ml	SM 9223B
Nitrate and Nitrite	0.05 mg/l	SM 4500NO3-H
Hardness	1 mg/l	SM 2340C

2.1.2 Storm Information

Versar field staff successfully monitored eight storm events at the Peter Pan Run instream and Pond R outfall stations during the sampling period July 1, 2016 through June 30, 2017. During the July 28 storm, field staff obtained a grab sample for the falling (07:00) limb at the Peter Pan instream station due to the rainfall lasting longer than the sampler autosequence period.

Of the eight storms, Versar field staff obtained a total of seven first flush samples. Six of the first flush samples were obtained during monitored storm events while the seventh first flush (December 6) was a make-up event to fill data gaps due to missed sampling opportunities. Field staff was unsuccessful at obtaining first flush grabs for the July 28 and February 9 storm events.

In these cases, the storm events began or were projected to begin between midnight and 6 a.m., which prevented staff from obtaining a first flush for each monitored event.

Baseflow monitoring was carried out at a targeted once-monthly rate for the entire year. Versar field staff obtained twelve monthly baseflow samples at the Peter Pan Run instream station and five samples at Pond R outfall station. The laboratory accidentally broke the sample bottle for most parameters for the March 30 baseflow monitoring event at the instream station, so a make-up sample was taken on June 12 to fill in data gaps. Normal baseflow conditions at the Pond R outfall were dry with no flow available to sample during the first half of the year. During the last half of the year when the pond held more water and made baseflow sampling possible.

As presented in Table 2-2, storm rainfall ranged in quantity from 0.29 to 1.81 inches during qualifying events, and in duration from 2.75 hours to 53.00 hours. Average rainfall intensities monitored ranged from 0.019 to 0.658 inches/hour.

Table 2-2. Summary of storm events monitored in FY 2017* at Peter Pan Run

Date	Start Time	Rainfall Duration (hrs)	Rainfall (in)	Avg. Intensity (in/hr)	Storm as % of Total Rainfall for Month
7/28/2016	19:00	13.00	1.17	0.09	24%
9/28/2016	16:10	53.00	1.42	0.03	79%
11/29/2016	05:00	19.75	0.55	0.03	46%
1/23/2017	08:40	25.00	1.02	0.04	33%
2/9/2017	01:00	12.00	0.31	0.03	36%
2/28/2017	18:00	15.25	0.29	0.03	34%
4/6/2017	03:00	8.75	1.28	0.15	47%
6/19/2017	14:25	2.75	1.81	0.66	71%

* FY denotes "Fiscal Year," defined as July to June. For this report FY 2017 refers to the period July 1, 2016 to June 30, 2017.

Table 2-3 compares monthly rainfall totals recorded at the Peter Pan Run stations to monthly data collected at a local National Oceanic and Atmospheric Administration (NOAA) weather monitoring station (NOAA 2017). The NOAA weather stations at Emmitsburg, MD and Clarksburg, MD are approximately 25 miles north and 6 miles south-southeast, respectively, of the Urbana PUD. Rainfall amounts recorded during monitored storms are presented in Figure 2-3. Note that the project rain gauge was located at Peter Pan Run instream station until early 2003 and then at the Pond R outfall station afterward.

For the twelve-month monitoring period in FY 2017, rainfall near the site, as recorded at NOAA's Clarksburg gauge (40.09 inches) was less than 1% below normal compared to the long-term annual average of 40.4 inches recorded in Frederick County (Figure 2-4). NOAA's Clarksburg gauge rainfall data was not available for WY 2015. Note that November 2008, December 2008, September 2009, and May 2012 rainfall data were missing from the Clarksburg station, and the Emmitsburg gauge was offline during WY 2006 to WY 2008. During the current period, Versar's rain gauge located at Pond R recorded 32.53 inches, 19.5% below the normal amount for the twelve-month period. The Versar gauge recorded lower than normal rainfalls compared to Frederick County averages for eight months during the twelve-month sampling period (Figure 2-5). Total discharge volume at the Peter Pan Run instream monitoring station was 35.2% lower than the same period in the prior year (Figure 2-6).

Table 2-3. Rainfall data (totals by month; inches)

Month	Versar[(a)]	Clarksburg[(b)]	Emmitsburg[(b)]	Normal[(c)]	Departure from Normal[(c)]
July-16	4.85	9.24	4.48	3.7	1.15
August-16	4.59	3.81	2.36	3.5	1.09
September-16	1.82	3.51	3.87	3.6	-1.78
October-16	0.31	0.66	0.81	3.1	-2.79
November-16	1.19	2.42	1.45	3.3	-2.11
December-16	2.02	2.65	4.05	2.9	-0.88
January-17	3.08	3.05	3.22	2.8	0.28
February-17	0.85	0.95	1.58	2.7	-1.85
March-17	3.28	4.57	2.09	3.3	-0.02
April-17	2.72	2.72	5.55	3.3	-0.58
May-17	5.28	4.48	6.53	4.3	0.98
June-17	2.54	2.03	2.15	3.9	-1.36

(a) Versar rainfall data from ISCO gauge at Peter Pan Run outfall station.

(b) Clarksburg and Emmitsburg rainfall data from National Oceanic and Atmospheric Administration.

(c) Based on Frederick County regional long-term rainfall data from National Oceanic and Atmospheric Administration.

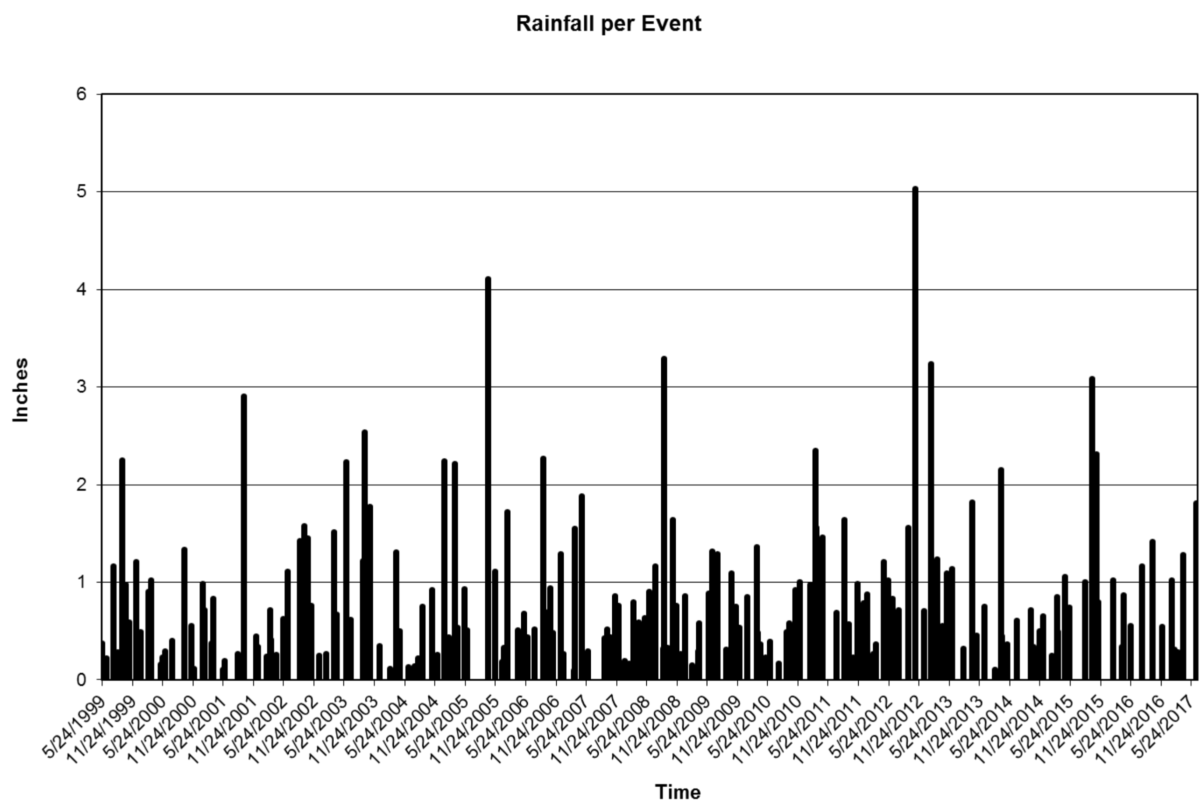

Figure 2-3. Rainfall totals for sampled storm events (May 1999 to June 2017)

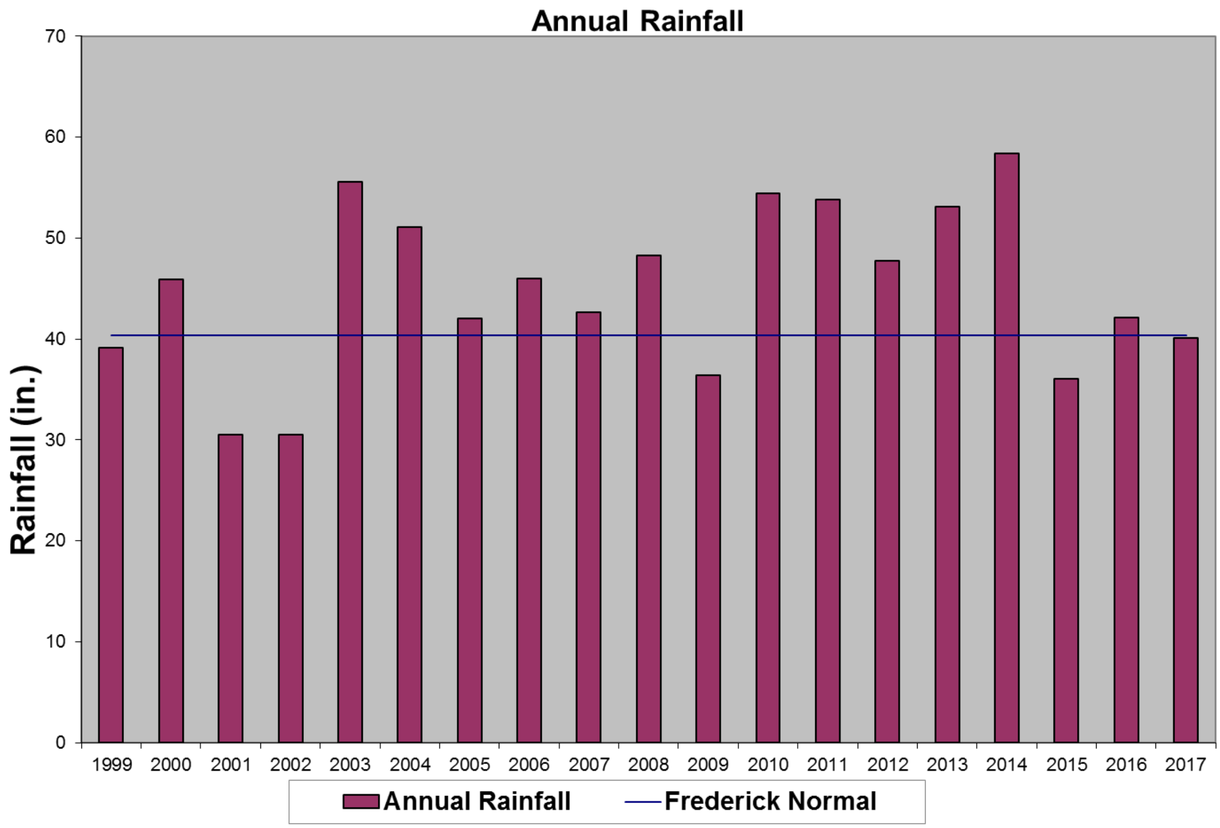

Figure 2-4. Annual rainfall recorded at NOAA's Emmitsburg, MD station, WY 1999-2004, 2015 and at NOAA's Clarksburg, MD station, WY 2005-2014 and FY 2016-2017. Note: Clarksburg data for WY 2006 do not include November 2005; Clarksburg data for WY 2009 do not include November 2008, December 2008, and September 2009; Clarksburg data for WY 2012 do not include May 2012.

2.1.3 Water Chemistry Analysis

<u>Laboratory and Field Results</u>

A summary of analytical results for baseflow and storm event water chemistry monitoring at the Peter Pan Run instream station and Pond R outfall station from July 2016 through June 2017 is shown in Tables 2-4a through 2-4c. Baseflow monitoring at the Pond R station includes five samples during the period July 2016 to June 2017.

A total of seven first flush grab (TPH and *E. coli*) samples were collected at both stations, including six during complete storms monitored at the Peter Pan Run instream and Pond R outfall stations, and one extra first flush-only event (Table 2-4d).

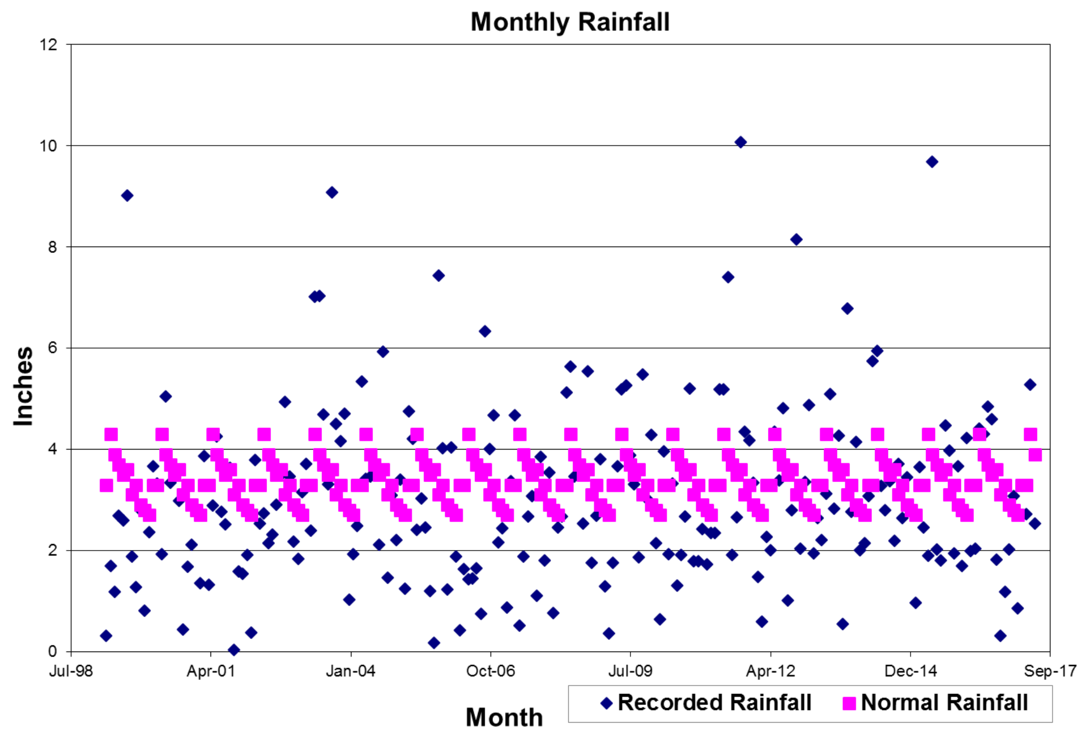

Figure 2-5. Monthly rainfall recorded at the Peter Pan site (at instream station prior to early 2003; at Pond R after early 2003) and NOAA's long-term Frederick County regional average monthly (i.e., normal) rainfall, WY 1999 – FY 2017

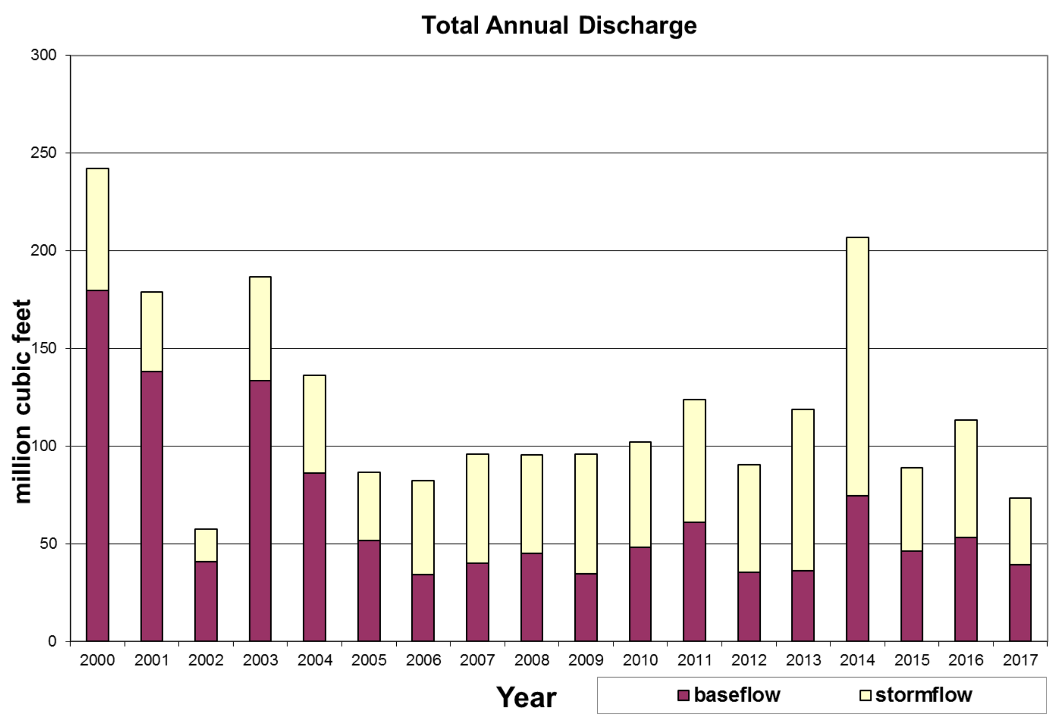

Figure 2-6. Annual discharge volume measured at Peter Pan Run instream monitoring station, WY 2000 – FY 2017

Table 2-4a. Water chemistry results for instream storm event monitoring at Peter Pan Run (mg/l). *E. coli* results are in MPN/ 100 ml. Metals results are in µg/l.[1]

DATE	STAT	BOD	TKN	Phosph	TSS	Copper	Lead	Zinc	*E. coli*	TPH	Nitrate+Nitrite	Hardness
7/28/2016	Rising	3	< 0.5	0.17	110	2	2.11	< 20	N/A	N/A	2.3	160
7/28/2016	Peak	6	2.2	0.69	560	5.82	9.59	31.8	N/A	N/A	1.1	80
7/28/2016	Falling	5	1.0	0.24	160	3.48	3.5	21	N/A	N/A	0.98	81
9/28/2016	Rising	< 4	1.2	0.22	20	< 2	< 2	< 20	727	< 5	2	150
9/28/2016	Peak	< 4	0.9	0.29	38	< 2	< 2	< 20	N/A	N/A	0.8	85
9/28/2016	Falling	< 4	< 0.5	0.05	5	< 2	< 2	< 20	N/A	N/A	0.95	110
11/29/2016	Rising	< 4	< 0.5	0.02	2	< 2	< 2	< 20	67	<5	2.6	170
11/29/2016	Peak	< 4	< 0.5	0.05	11	< 2	< 2	< 20	N/A	N/A	2.3	180
11/29/2016	Falling	< 4	< 0.5	0.04	4	< 2	< 2	< 20	N/A	N/A	2.1	160
1/23/2017	Rising	5	2.2	0.31	570	9.37	8.99	55.8	56	< 5	1.8	130
1/23/2017	Peak	5	1.7	0.3	510	8.23	7.5	43.9	N/A	N/A	1.1	78
1/23/2017	Falling	< 4	< 0.5	0.06	20	< 2	< 2	< 20	N/A	N/A	1.5	98
2/9/2017	Rising	< 4	< 0.5	0.03	7	< 2	< 2	< 20	N/A	N/A	2.8	160
2/9/2017	Peak	< 4	< 0.5	0.03	6	< 2	< 2	< 20	N/A	N/A	2.6	180
2/9/2017	Falling	< 4	< 0.5	0.02	1	< 2	< 2	< 20	N/A	N/A	2.4	170
2/28/2017	Rising	< 4	< 0.5	0.01	2	< 2	< 2	< 20	43	<5	2.7	170
2/28/2017	Peak	< 4	< 0.5	0.02	7	< 2	< 2	< 20	N/A	N/A	2.5	180
2/28/2017	Falling	< 4	< 0.5	0.01	3	< 2	< 2	< 20	N/A	N/A	2.4	220
4/6/2017	Rising	5	1.8	0.55	520	6.18	6.57	27.1	261	<5	1.5	100
4/6/2017	Peak	8	3.8	1.2	1100	23.4	21.2	98.3	N/A	N/A	1.1	68
4/6/2017	Falling	< 4	1.1	0.19	160	3.6	2.56	< 20	N/A	N/A	1.2	66
6/19/2017	Rising	8	2.7	0.77	1000	17.6	16.4	96.7	29900	6	2.7	60
6/19/2017	Peak	7	3.2	0.8	720	16.8	12.5	75.4	N/A	N/A	1.9	40
6/19/2017	Falling	2	1.8	0.18	62	4.81	< 2	23.4	N/A	N/A	0.9	61

N/A = Not analyzed

Shaded values indicate results that exceeded Maryland surface water quality criteria

[1] Water quality criteria for metals are based on dissolved forms; water chemistry data provided are for total metal concentration.

Table 2-4b. Water chemistry results for outfall storm event monitoring at Pond R (mg/l). *E. coli* results are in MPN/100 ml. Metals results are in μg/l.[1]

DATE	STAT	BOD	TKN	Phosph	TSS	Copper	Lead	Zinc	*E. coli*	TPH	Nitrate+Nitrite	Hardness
7/28/2016	Rising	6	< 0.5	0.06	4	2.19	< 2	< 20	N/A	N/A	0.45	28
7/28/2016	Peak	4	0.8	0.09	5	2.25	< 2	< 20	N/A	N/A	0.34	22
7/28/2016	Falling	< 2	< 0.5	0.06	2	< 2	< 2	< 20	N/A	N/A	0.27	19
9/28/2016	Rising	5	0.6	0.17	28	3.27	< 2	< 20	1986	< 5	0.69	27
9/28/2016	Peak	< 4	0.6	0.1	2	< 2	< 2	< 20	N/A	N/A	0.36	29
9/28/2016	Falling	< 4	0.7	0.11	5	3.87	< 2	< 20	N/A	N/A	0.13	71
11/29/2016	Rising	6	1.1	0.31	10	4.17	< 2	31.7	1203	< 5	1	44
11/29/2016	Peak	5	0.7	0.33	8	5.91	< 2	28.7	N/A	N/A	0.71	44
11/29/2016	Falling	5	1.1	0.36	4	5.06	< 2	31.4	N/A	N/A	1.7	52
1/23/2017	Rising	< 4	< 0.5	0.08	12	4.3	< 2	22	115	< 5	0.15	20
1/23/2017	Peak	< 4	< 0.5	0.1	12	< 2	< 2	< 20	N/A	N/A	0.12	22
1/23/2017	Falling	7	0.8	0.12	8	2.79	< 2	22.8	N/A	N/A	0.41	48
2/9/2017	Rising	< 4	0.6	0.21	12	3.09	< 2	23.8	N/A	N/A	0.87	32
2/9/2017	Peak	< 4	0.8	0.2	3	2.07	< 2	< 20	N/A	N/A	0.83	35
2/9/2017	Falling	< 4	< 0.5	0.21	2	< 2	< 2	< 20	N/A	N/A	0.89	38
2/28/2017	Rising	< 4	< 0.5	0.11	4	5.9	< 2	20.2	36	6	0.62	36
2/28/2017	Peak	< 4	< 0.5	0.12	3	3.2	< 2	< 20	N/A	N/A	0.7	38
2/28/2017	Falling	< 4	< 0.5	0.12	3	3	< 2	< 20	N/A	N/A	0.79	39
4/6/2017	Rising	< 4	1.3	0.13	7	3.23	< 2	28.7	411	< 5	0.15	46
4/6/2017	Peak	< 4	1.0	0.15	18	5.33	< 2	21.4	N/A	N/A	0.17	32
4/6/2017	Falling	< 4	1.2	0.16	13	3.8	< 2	< 20	N/A	N/A	0.18	35
6/19/2017	Rising	8	2.1	0.52	110	9.87	3.12	128	30800	6	0.72	19
6/19/2017	Peak	6	2.4	0.35	30	10.1	< 2	56.5	N/A	N/A	0.58	46
6/19/2017	Falling	4	2.2	0.28	11	7.62	< 2	33.6	N/A	N/A	0.85	27

N/A = Not analyzed
Shaded values indicate results that exceeded Maryland surface water quality criteria
[1] Water quality criteria for metals are based on dissolved forms; water chemistry data provided are for total metal concentration.

Table 2-4c. Water chemistry results for baseflow monitoring at instream Peter Pan Run and outfall Pond R (mg/l). *E. coli* results are in MPN/100 ml. Metals results are in µg/l.[1]

DATE	STAT	Location	BOD	TKN	Phosph	TSS	Copper	Lead	Zinc	*E. coli*	TPH	Nitrate+Nitrite	Hardness
7/18/2016	Baseflow	Instream	< 2	< 0.5	0.03	3	< 2	< 2	< 20	613	< 5	2.8	160
8/19/2016	Baseflow	Instream	< 2	< 0.5	0.05	13	2.41	< 2	< 20	980	< 5	1.2	86
9/13/2016	Baseflow	Instream	< 2	< 0.5	0.01	2	< 2	< 2	< 20	866	< 5	2.8	160
10/18/2016	Baseflow	Instream	< 2	< 0.5	0.01	2	< 2	< 2	< 20	≥ 2420	< 5	2	160
11/21/2016	Baseflow	Instream	< 4	< 0.5	0.02	< 1	< 2	< 2	< 20	24	< 5	2.9	180
12/20/2016	Baseflow	Instream	< 2	< 0.5	0.01	3	2.05	< 2	< 20	44	< 5	2.8	180
1/30/2017	Baseflow	Instream	< 2	< 0.5	< 0.01	< 1	< 2	< 2	< 20	36	< 5	2.6	160
2/3/2017	Baseflow	Instream	< 2	< 0.5	0.03	< 1	< 2	< 2	< 20	86	< 5	3.3	160
3/30/2017	Baseflow	Instream	< 4	< 0.5	0.01	2	< 2	< 2	< 20	68	< 5	2.3	80
4/27/2017	Baseflow	Instream	< 2	0.7	0.02	2	< 2	< 2	< 20	105	< 5	2.3	160
5/30/2017	Baseflow	Instream	N/A	N/A	N/A	N/A	N/A	N/A	N/A	145	< 5	N/A	N/A
6/12/2017*	Baseflow	Instream	< 2	< 0.5	0.02	2	< 2	< 2	< 20	N/A	N/A	2.6	160
6/27/2017	Baseflow	Instream	< 2	< 0.5	0.03	< 1	< 2	< 2	< 20	488	< 5	2.1	150
8/19/2016	Baseflow	Outfall	< 8	1.0	0.24	5	4.33	< 2	< 20	≥ 2420	< 5	0.05	69
3/30/2017	Baseflow	Outfall	< 4	0.8	0.13	11	4.06	< 2	28	649	< 5	0.18	43
4/27/2017	Baseflow	Outfall	4	0.8	0.14	9	< 2	< 2	< 20	10	< 5	0.1	57
5/30/2017	Baseflow	Outfall	< 2	0.9	0.19	4	< 2	< 2	28.7	687	6	< 0.05	62
6/27/2017	Baseflow	Outfall	< 2	0.8	0.14	1	2.49	< 2	< 20	96	< 5	0.13	36

N/A = Not analyzed

[1] Water quality criteria for metals are based on dissolved forms; water chemistry data provided are for total metal concentration.

* Denotes make-up for broken bottle on 5/30/2017

Table 2-4d. Water chemistry results for first-flush only samples at Peter Pan Run and Pond R. *E.coli* results are in MPN/100 ml, TPH in mg/l.

Date	Station	*E. coli*	TPH
12/6/2016	Instream	105	< 5
12/6/2016	Outfall	1120	< 5

Calculation of Event Mean Concentration

Storm event mean concentrations (EMC) of the various pollutants at each station were calculated from laboratory results and flow rate data from the monitored storms. To arrive at the EMC of a particular pollutant, a volume-weighted average was calculated for the rising, peak, and falling limbs of each storm hydrograph. At the Peter Pan Run instream station, flow rate data were collected continuously and used to calculate discharge represented by the hydrograph limbs. At the Pond R outfall monitoring station, flow rate data were estimated using continuous stage data and applying Manning's equation.

Table 2-5 presents the annual, calculated average EMCs, Maryland freshwater acute and chronic water quality criteria, average EMC values reported by the MDE for NPDES Part 2 sampling from jurisdictions across the State (Bahr 1997), and values reported in two national datasets. The National Urban Runoff Program (NURP) average EMC values were taken from median urban site concentration results. The National Stormwater Quality Database (Maestre and Pitt 2005) average values are from a more recent national compilation of data from stormwater runoff in a variety of conveyances in residential land use.

Comparisons with Maryland water quality criteria are presented only as a general aid to interpreting the data and are not intended as a regulatory review to assess compliance with standards. Maryland Drinking Water Criteria are listed because Peter Pan Run is designated as a "Use Class I-P" stream (potential public water supply), as are many waterways in Frederick County, and as such are subject to State drinking water criteria. Flow-weighted EMC data for each pollutant for each storm event have been submitted electronically as part of the County's Annual Report geodatabase submission.[1] Note that for the purpose of discussion, EMCs and baseflow mean concentrations (MCs) were calculated with non-detectible results set to zero.

Instream Concentrations

During FY 2017, average annual storm EMCs for all pollutants, except for BOD, phosphorus, combined nitrate and nitrite and hardness, decreased from FY 2016 levels. During baseflow conditions, only BOD, TKN, combined nitrate and nitrite, and hardness decreased from FY 2016 levels. Remaining unchanged (not detected) between the current year and last year were zinc and lead (baseflow).

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[1]In the electronic database containing storm EMCs and baseflow concentrations, the following apply: (1) storm duration signifies the time period between the beginning of the rising limb and the ending of the falling limb of a particular storm; (2) data fields with entries "-9" denote samples not collected, tests not performed or field not applicable; (3) flow-weighted mean temperatures were determined by obtaining the flow-weighted mean of individual temperature measurements as taken by an *in-situ* recording device (e.g., YSI ProPlus multi-parameter sonde) over the course of the monitoring of the storm event from the beginning of the rising limb to the end of the falling limb; (4) flow-weighted mean pH values were obtained by calculating the flow-weighted mean of laboratory pH measurements on samples representing the rising, peak, and falling limbs; (5) "First flush" storm event parameters *E.coli* and TPH are presented in the database as actual concentrations, rather than a calculated event mean.

Table 2-5. Comparison of annual average Peter Pan Run event mean concentrations (EMCs) from storms sampled between July 1, 2016 and June 30, 2017, with Maryland state average EMCs for all land uses, with values from two national datasets, and with Maryland water quality standards

Parameter	Average Annual Peter Pan Run EMC[a] (mg/l)	Average Annual Pond R Outfall EMC[a] (mg/l)	Average MD EMC[b] (mg/l)	NSQD Residential Median[c] (mg/l)	NURP Runoff Water Quality EMC[d] (mg/l)	Part 2 Outfall EMC (mg/l)[e]	MD Freshwater Acute Criteria (mg/l)	MD Freshwater Chronic Criteria (mg/l)	MD Drinking Water Criteria (mg/l)
BOD	4.456 – 5.637	1.871 - 4.530	14.44	9	9	4.34			
TKN	2.086- 2.142	0.557 - 0.699	1.94	1.5	1.5	1.03			
Phosphorus	0.564	0.147	0.33	0.31	0.33	0.13			
Copper	0.010 - 0.011	0.002-0.003	0.0179	0.012	0.034	0.0095	0.013	0.009	1.3
Zinc	0.046 - 0.052	0.009 - 0.022	0.1433	0.073	0.16	0.0644	0.12	0.12	
Lead	0.009 - 0.010	0-0.002	0.0125	0.012	0.144	0.0046	0.065	0.0025	0.015
TSS	527.716	9.657	66.57	49	100	15.21			
Nitrite+Nitrate	1.359	0.409	0.85	0.6	0.68				
Hardness	82.825	33.242		32					

(a) Where concentrations reported at the detection limit, loadings are presented as range of possible values, setting concentrations below the detection limit to zero or the detection limit.
(b) Maryland State average values from Bahr 1997.
(c) National Stormwater Quality Database values from Maestre and Pitt 2005.
(d) National Urban Runoff Program values from U.S. EPA 1983.
(e) Frederick County Part 2 Outfall Sampling Results from Third Annual Report 1999.
EMC = volume-weighted event mean concentration

In 2017, annual storm EMCs for copper and zinc decreased from FY 2016 values (Figures 2-7 and 2-8). Corresponding annual mean concentrations in baseflow samples increased 232% for copper and decreased 100% for zinc in comparison to FY 2016 levels (Figure 2-7), and were likewise within their respective historical ranges. Lead was not detected in baseflow samples for a seventh consecutive year (Figure 2-8).

Calculated EMCs for metals may be compared to the standards listed in Table 2-5. However, it is important to note that Maryland State water quality criteria for metals are presented in terms of dissolved metals only and results are reported as total metals. Only the dissolved portion of metals is readily available for biological uptake. Because metals tend to sorb to suspended solids and organic matter, the portion of the particulate form of the metal is often larger than the portion of the dissolved form. NPDES stormwater samples are analyzed for total metal concentrations (as required by the NPDES permit and MDE's recommended protocols) making it more difficult to draw a direct comparison. Therefore, our analysis is not meant to specifically determine whether these constituents meet State water quality standards. Rather we present this information to provide a general indication of overall stream quality. All average annual storm EMCs and average annual MCs for metals did not exceed their respective acute and chronic criteria.

Three copper storm runoff results exceeded their respective Maryland freshwater criteria at the instream station (Figure 2-9). The high concentrations occurred during the April and June storms. These storms were within the historical range of rainfall depth and intensity and therefore the exceedances may be attributed to variability in storm runoff concentration data.

Home construction, natural sources, and automobile use are likely primary contributors to high metal concentrations in watershed runoff. Atmospheric deposition is a source of copper and zinc. Zinc and cadmium are deposited on surfaces as a result of tire wear. Wear on brake pad linings contributes to copper in runoff. Vehicle emissions are a primary source of lead in storm runoff (San Diego Regional Water Quality Control Board 2000). Used motor oil contains zinc, cadmium, lead, and other heavy metals (USDHHS 1997).

Detectible combined nitrate and nitrite concentrations were ubiquitous in both storm runoff and baseflow samples in Peter Pan Run and average baseflow concentrations have steadily increased between WY 2009 and WY 2013 by an overall 62%. After a slight decrease in WY 2014, baseflow nitrate and nitrite increased again in WY 2015 by 6.9% and then decreased by 3.0% in FY 2016. In FY 2017 combined nitrate and nitrite baseflow concentrations decreased 25%. The average annual storm EMC for nitrate and nitrite increased during FY 2017 by 19.5%. Baseflow TKN levels in FY 2017 were, on average, 65.3% lower than in FY 2016; storm runoff TKN levels in FY 2017 decreased by 27.1% compared to FY 2017 (Figure 2-10).

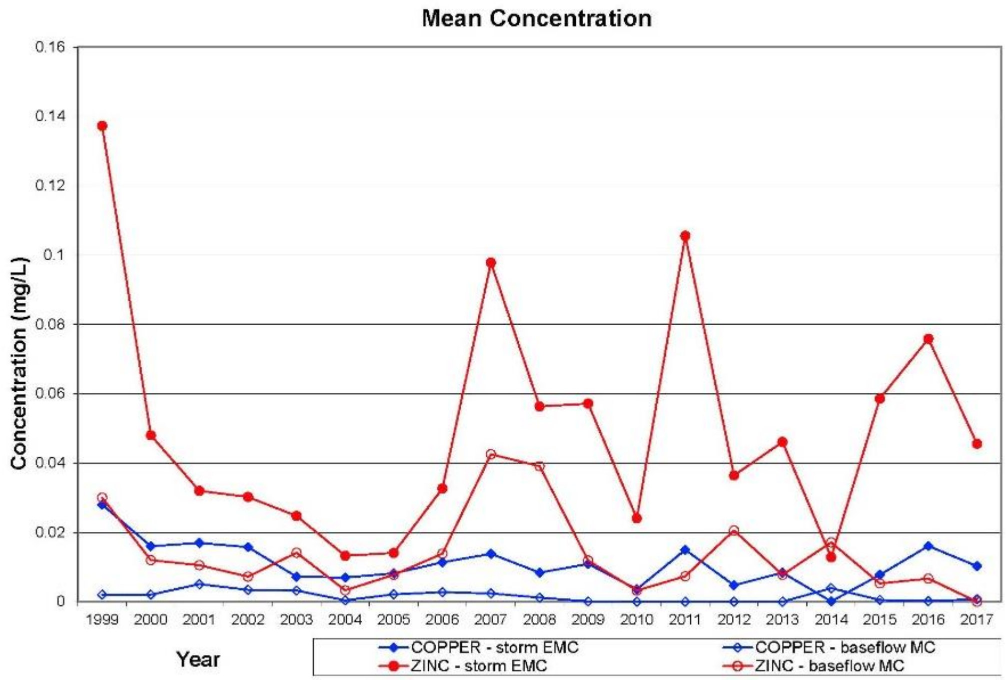

Figure 2-7. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of copper and zinc at Peter Pan Run instream station (WY 1999 – FY 2017)

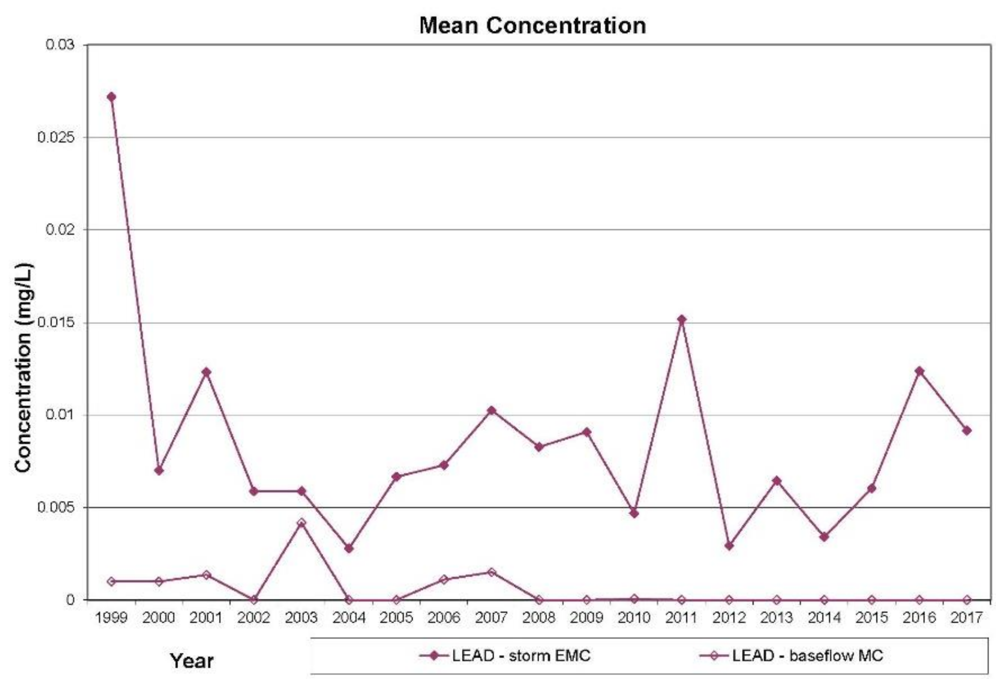

Figure 2-8. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of lead at Peter Pan Run instream station (WY 1999 – FY 2017)

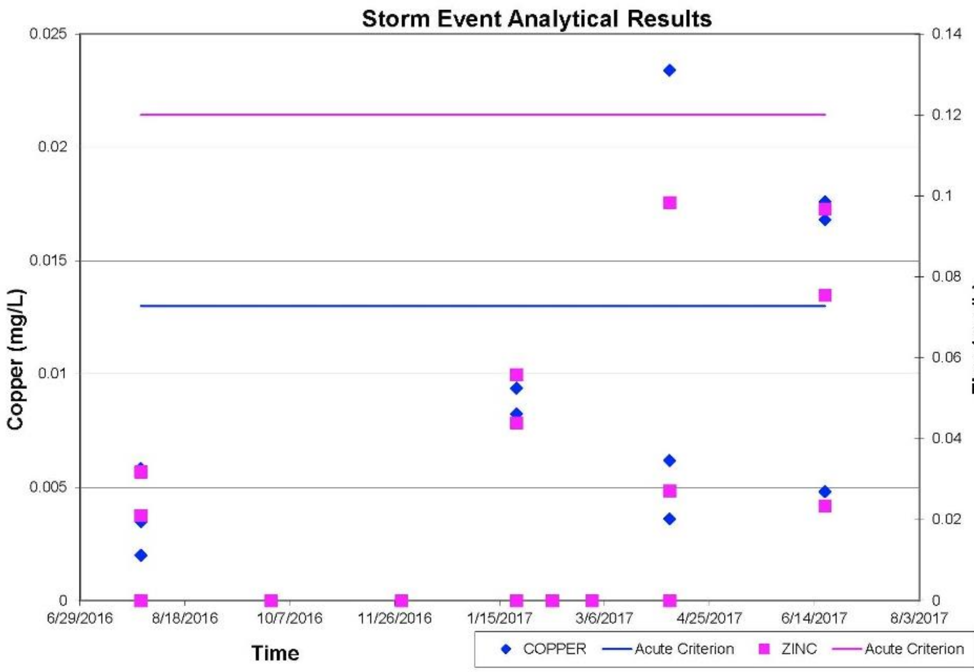

Figure 2-9. Copper and zinc analytical results in storm runoff at the instream station (FY 2017)

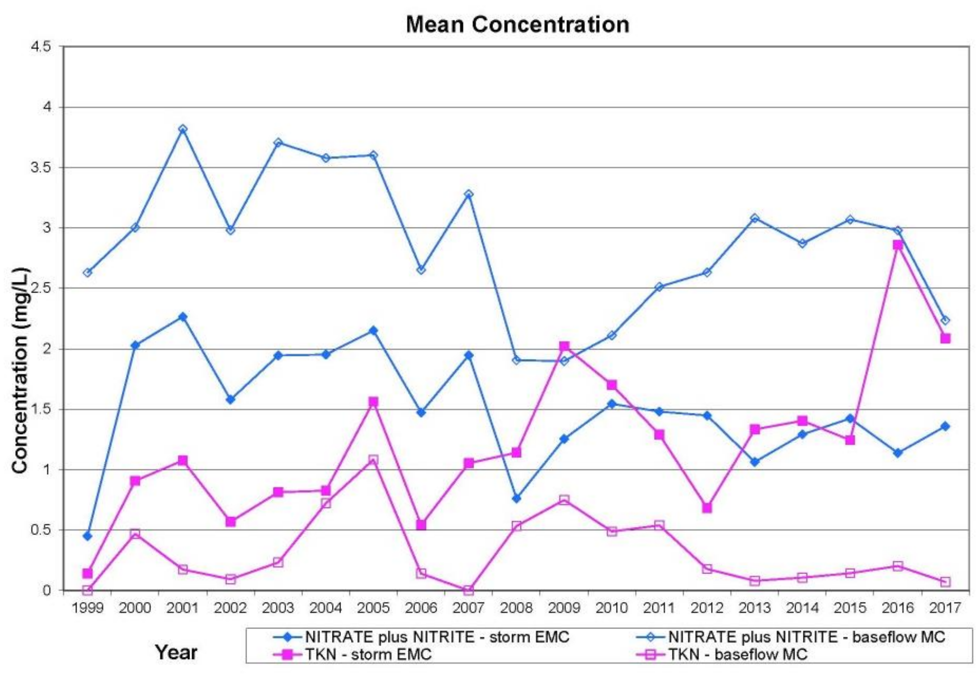

Figure 2-10. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of TKN and nitrate and nitrite at Peter Pan Run instream station (WY 1999 – FY 2017)

Storm runoff concentrations of phosphorus increased in the past year by 52% (Figure 2-11), while TSS concentrations decreased by 32% (Figure 2-12). The average baseflow MC for phosphorus increased by 102.4%. Except for a spike in concentration level in WY 2009, baseflow phosphorus has, overall, shown a declining trend with minor fluctuations since WY 2004. The average stormflow concentration of phosphorus in FY 2017 was slightly higher than values detected in each year since WY 2012.

TPH was not detected in any of the seven first flush samples nor in any of the monthly baseflow samples taken at the instream station during FY 2017.

E. coli was detected in all but two baseflow samples (outfall 8/19/2016 and instream 10/18/2016), and in all seven instream and outfall first flush samples. The highest concentrations of *E. coli* are generally found during the warmer months, which was reflected in the maximum value found at the outfall station (30,800 MPN/100 ml in June). The maximum result found during baseflow sampling at the instream station was 980 MPN/100 ml in August. With the exception of the June stormflow sampling at the instream and outfall stations, baseflow *E. coli* concentrations on a monthly basis were fairly consistent during the FY 2017 monitoring year (Figure 2-13). Typical sources of *E. coli* in surface waters in a watershed include wildlife, pet waste, and malfunctioning septic or sewage treatment systems (Vann et al. 2002).

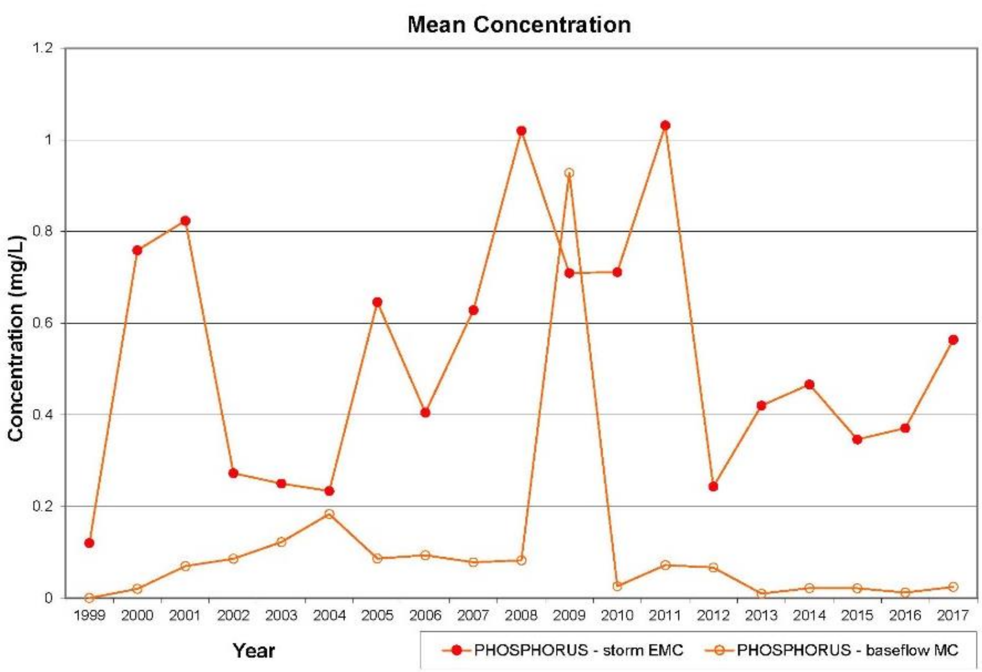

Figure 2-11. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of phosphorus at Peter Pan Run instream station (WY 1999 – FY 2017)

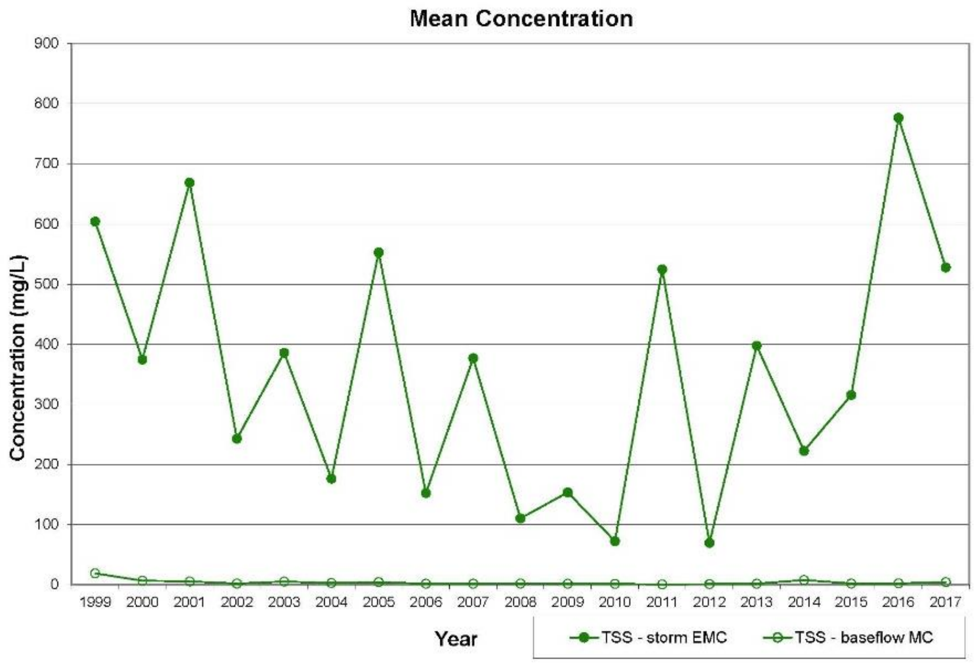

Figure 2-12. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of TSS at Peter Pan Run instream station (WY 1999 – FY 2017)

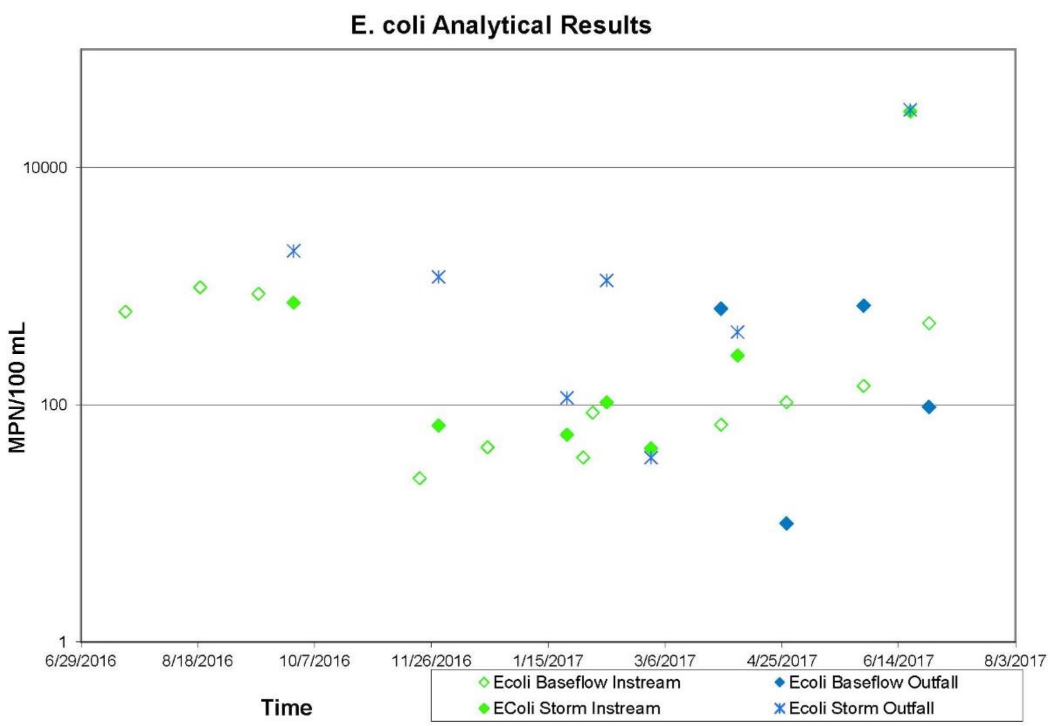

Figure 2-13. Analytical results of instream and outfall storm event and baseflow *E. coli* concentrations (FY 2017)

Outfall Concentrations

Storm EMCs at the Pond R outfall were calculated in a similar fashion as instream for each parameter. Average annual storm EMCs at the outfall decreased for most parameters compared to last year; exceptions included phosphorus, nitrate plus nitrite, and hardness. TPH was non-detectible in all storm runoff samples and therefore did not increase or decrease. Lead was not detected in any baseflow samples in FY 2017.

The average annual storm EMC for zinc was 59.3% lower in FY 2017 than in FY 2016. Copper decreased by 58.3% in FY 2017 from FY 2016 levels, but remained within the historical range of average annual storm EMC values (Figure 2-14). Lead concentrations decreased by 84% in FY 2017 compared to FY 2016. One zinc concentration result exceeded the freshwater acute criterion (June; Figure 2-15).

The average annual storm EMC for phosphorus at Pond R increased during FY 2017, but remained within its overall historical range (Figure 2-16). The average annual storm EMC for TSS decreased by 33.7% in the current year (Figure 2-16). The storm EMC for TKN decreased by 3.4% and combined nitrate and nitrite carried by stormflow increased by 24.3% in FY 2017 compared to FY 2016 (Figure 2-17).

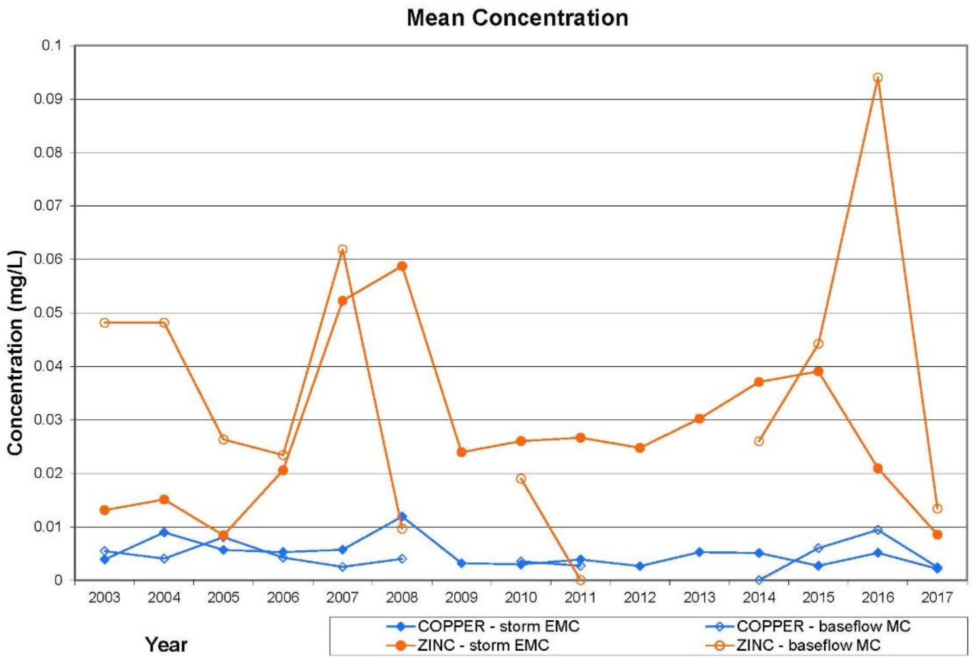

Figure 2-14. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of copper and zinc at Pond R outfall site (WY 2003 – FY 2017)

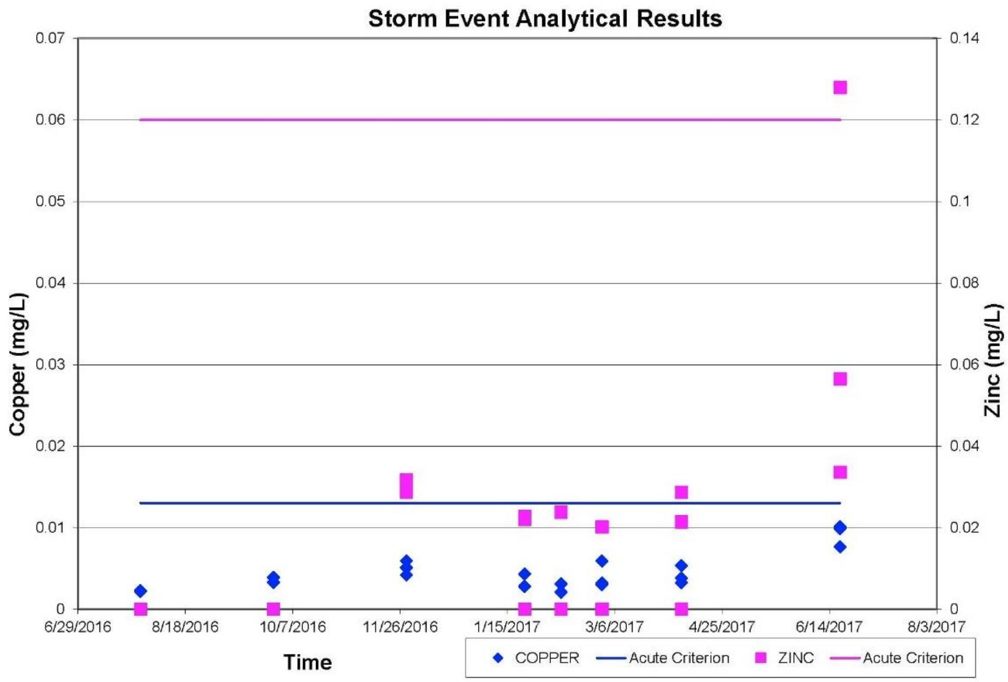

Figure 2-15. Copper and zinc analytical results in storm runoff at the outfall station (FY 2017)

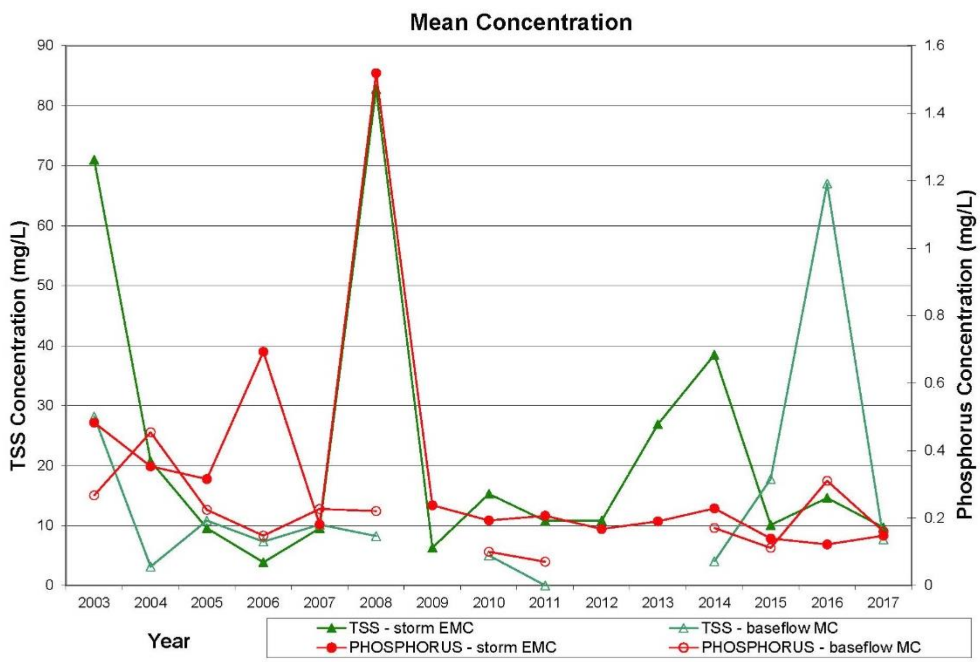

Figure 2-16. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of TSS and phosphorus at Pond R outfall station (WY 2003 – FY 2017)

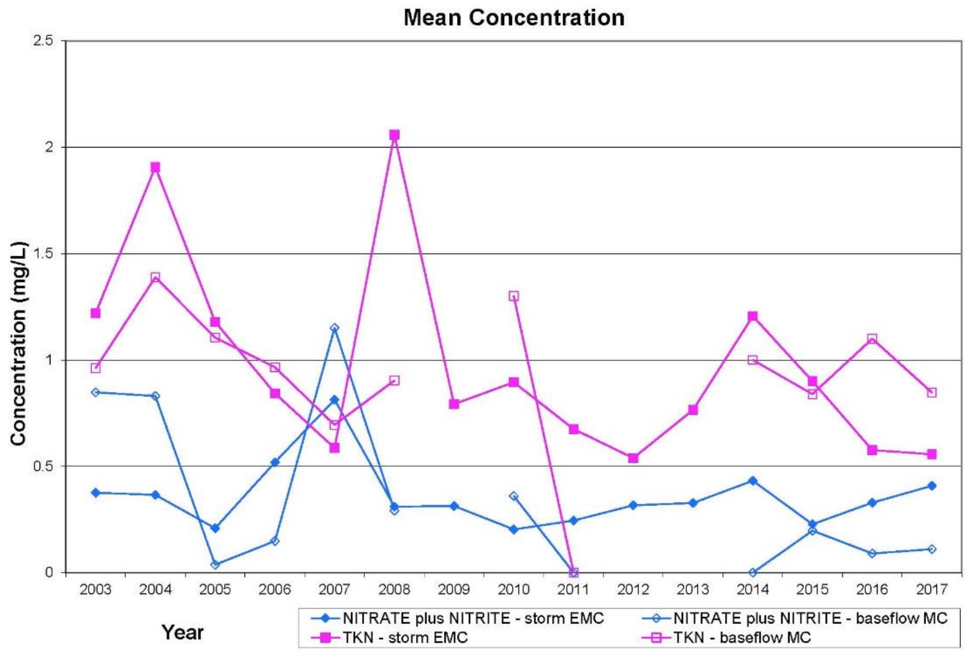

Figure 2-17. Annual flow-weighted average of baseflow mean concentrations and storm event mean concentrations of TKN and nitrate and nitrite at Pond R outfall station (WY 2003 – FY 2017)

2.1.4 Pollutant Loading Estimates for Peter Pan Run and Pond R Outfall

Pollutant loading estimates, as required by the conditions of this Permit, were calculated for each storm event for both the instream and outfall stations (Tables 2-6a and 2-6b). Total storm event loadings were calculated by multiplying the storm EMC for each parameter, the corresponding total volume for that storm event calculated from flow rate data collected by the ISCO flow meter, and the appropriate conversion factor to obtain pounds. Methods for determining calculation factors are outlined in Appendix B.

Annual and seasonal loading estimates were calculated using flow and concentration data collected from both the Peter Pan Run instream station and the Pond R outfall station over a twelve-month period (July 2016 through June 2017). The flow-weighted EMC for a given pollutant over a given period for all monitored storms at each station was determined from the total mass of pollutant from the monitored storms divided by total volume from the monitored storms. Tables 2-7a and 2-7b show comparative estimated results of baseflow and stormflow nine-month pollutant loadings at Peter Pan Run and Pond R. An analogous calculation was used to determine seasonal loading estimates. Seasonal estimates for the instream station are presented in Tables 2-8a through 2-8d and for the outfall station in Tables 2-9a through 2-9d. Note that loadings estimates are based on calculations from nearly all flow rate data as well as data from a subset of the actual storms that occurred in the watershed. Storm characteristics (i.e., size, duration, intensity, time of year, antecedent dry time) of the storms actually monitored may affect loadings calculations in a given year.

Table 2-6a. Storm event flow volume in cubic feet and acre-feet. Pollutant loads in pounds per storm event at Peter Pan Run.*

Date	Total Storm Volume (acre-ft)	Total Storm Volume (cf)	BOD	TKN	Phos	Copper	TPH	Zinc	Lead	TSS	Nitrate-Nitrite
7/28/2016	18.68	813,811	269.26	76.83-79.6	23.64	0.23	NC	1.235-1.345	0.33	18373.17	60.25
9/28/2016	21.94	955,870	0-238.69	48.15-53.83	13.49	0-0.119	0-298.36	0-1.193	0-0.119	612.87-1612.87	68.1
11/29/2016	3.14	136,932	0-34.19	0-4.27	0.34	0-0.017	0-42.74	0-0.171	0-0.017	58.53	19.71
1/23/2017	35.62	1,551,620	391.88-465.83	143.09-152.34	24.82	0.667-0.704	0-484.32	3.675-4.045	0.617-0.654	41523.7	127.74
2/9/2017	3.52	153,396	0-38.3	0-4.79	0.27	0-0.019	0-47.88	0-0.192	0-0.019	50.06	25.13
2/28/2017	2.44	106,365	0-26.56	0-3.32	0.09	0-0.013	0-33.2	0-0.133	0-0.013	28.71	16.71
4/6/2017	65.22	2,840,990	1037.94-1184.59	516.56	156.82	2.921	0-886.78	11.751-12.484	2.649	143690.89	210.44
6/19/2017	31.52	1,372,910	538.43	245.84	58.73	1.269	514.25	5.979	0.938-0.968	55743.96	159.16

NC = sample not collected.
*Where concentrations reported below detection limit, loadings are presented as range of possible values setting concentrations to either zero or the detection limit.

Table 2-6b. Storm event flow volume in cubic feet and acre-feet. Pollutant loads in pounds per storm event at Pond R Outfall.*

Date	Total Storm Volume (acre-ft)	Total Storm Volume (cf)	BOD	TKN	Phos	Copper	TPH	Zinc	Lead	TSS	Nitrate-Nitrite
7/28/2016	0.25	10,880	1.92-2.41	0.27-0.44	0.05	0.001	NC	0-0.014	0-0.001	2.57	0.22
9/28/2016	9.11	396,794	30.25-105.13	15.14	2.93	0.03-0.062	0-123.85	0-0.495	0-0.05	215.08	10.28
11/29/2016	1.58	68,988	22.14	3.55	1.43	0.024	0-21.53	0.127	0-0.009	32.78	3.95
1/23/2017	10.13	441,331	52.62-132.76	6.01-16.03	2.85	0.034-0.068	0-137.76	0.236-0.578	0-0.055	300.55	5.57
2/9/2017	0.88	38,468	0-9.61	1.56-1.77	0.49	0.004-0.005	0-12.01	0.003-0.049	0-0.005	8.04	2.02
2/28/2017	0.16	6,801	0-1.7	0-0.21	0.05	0.002	2.55	0.002-0.009	0-0.001	1.35	0.31
4/6/2017	4.47	194,828	0-48.65	13.82	1.82	0.053	0-60.81	0.178-0.271	0-0.024	169.02	2.07
6/19/2017	1.33	57,957	19.22	8.32	1.2	0.033	21.71	0.187	0.001-0.007	98.28	2.53

NC = sample not collected.
*Where concentrations reported below detection limit, loadings are presented as range of possible values setting concentrations to either zero or the detection limit.

Table 2-7a. Baseflow and stormflow concentrations with estimated baseflow and stormflow loads in Peter Pan Run*					
	Average Storm EMC (mg/l)	**Average Baseflow MC (mg/l)**	**Storm Load (lbs)**	**Baseflow Load (lbs)**	**Total Estimated FY 2017 Load (lbs)**
BOD	4.456-5.637	0-2.301	9,496-12,014	0-5,649	9,496-17,662
Copper	0.0103-0.0107	0.0007-0.0021	22-23	2-5	24-28
Hardness	82.825	136.023	176,511	333,879	510,390
Lead	0.009-0.01	0-0.002	20-21	0-5	20-25
Nitrate+Nitrite	1.359	2.235	2,896	5,485	8,381
Phos	0.564	0.024-0.025	1,202	60-62	1,261-1,263
TKN	2.086-2.142	0.071-0.52	4,445-4,565	173-1,277	4,618-5,841
TPH	0.896-5.149	0-5	1,910-10,974	0-12,273	1,910-23,247
TSS	527.716	4.205-4.45	1,124,637	10,320-10,922	1,134,957-1,135,559
Zinc	0.046-0.052	0-0.02	97-110	0-49	97-159
* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.					

Table 2-7b. Baseflow and stormflow concentrations with estimated baseflow and stormflow loads in Pond R Outfall*					
	Average Storm EMC (mg/l)	**Average Baseflow MC (mg/l)**	**Storm Load (lbs)**	**Baseflow Load (lbs)**	**Total Estimated FY 2016 Load (lbs)**
BOD	1.871-4.53	1.031-4.271	838-2,030	122-504	960-2,534
Copper	0.0021-0.0031	0.0024-0.0032	1.0-1.4	0.3-0.4	1-2
Hardness	33.242-33.242	52.753	14,893	6,231	21,125
Lead	0-0.002	0-0.002	0-1	0.0-0.2	0-1
Nitrate+Nitrite	0.409-0.409	0.111-0.117	183	13-14	196-197
Phos	0.147-0.147	0.16	66	19	85
TKN	0.557-0.699	0.847	249-313	100	349-413
TPH	0.096-5.016	0.717-5.12	43-2,247	85-605	128-2,852
TSS	9.657-9.657	7.673	4,327	906	5,233
Zinc	0.009-0.022	0.013-0.024	4-10	2-3	5-13
* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.					

Table 2-8a. Baseflow and stormflow concentrations with estimated summer (July-September 2016) baseflow and stormflow loads in Peter Pan Run*

	Average Storm EMC (mg/l)	Average Baseflow MC (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Summer Load (lbs)
BOD	1.997-4.49	0-2	1,885-4,239	0-1,390	1,885-5,628
Copper	0.0017-0.003	0.0016-0.0023	2-3	1-2	3-4
Hardness	100.061	111.464	94,462	77,444	171,906
Lead	0.002-0.004	0-0.002	2-3	0-1	2-5
Nitrate+Nitrite	1.158	1.751	1,093	1,216	2,310
Phos	0.316	0.041	299	28	327
TKN	1.073-1.153	0-0.5	1,013-1,088	0-347	1,013-1,435
TPH	0-5	0-5	0-4,720	0-3,474	0-8,194
TSS	153.111	9.441	144,543	6,559	151,102
Zinc	0.009-0.022	0-0.02	9-21	0-14	9-35

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.

Table 2-8b. Baseflow and stormflow concentrations with estimated fall (October-December 2016) baseflow and stormflow loads in Peter Pan Run*

	Average Storm EMC (mg/l)	Average Baseflow MC (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Fall Load (lbs)
BOD	0-4	0-2.434	0-295	0-1,467	0-1,762
Copper	0-0.002	0.0007-0.002	0.0-0.1	0-1	0-1
Hardness	171.632	170.849	12,657	102,972	115,629
Lead	0-0.002	0-0.002	0.0-0.1	0-1	0-1
Nitrate+Nitrite	2.305	2.456	170	1,480	1,650
Phos	0.04	0.012	3	7	10
TKN	0-0.5	0-0.5	0-37	0-301	0-338
TPH	0-5	0-5	0-369	0-3,014	0-3,382
TSS	6.847	1.892-2.109	505	1,140-1,271	1,645-1,776
Zinc	0-0.02	0-0.02	0-1	0-12	0-14

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit

Table 2-8c. Baseflow and stormflow concentrations with estimated winter (January-March 2017) baseflow and stormflow loads in Peter Pan Run*

	Average Storm EMC (mg/l)	Average Baseflow MC (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Winter Load (lbs)
BOD	3.686-4.737	0-2.822	1,286-1,654	0-1,381	1,286-3,035
Copper	0.0063-0.0068	0-0.002	2.2-2.4	0-1	2-3
Hardness	100.268	127.108	34,999	62,215	97,213
Lead	0.0058-0.0063	0-0.002	2.0-2.2	0-1	2-3
Nitrate+Nitrite	1.43	2.671	499	1,307	1,807
Phos	0.235	0.012-0.016	82	6-8	88-90
TKN	1.346-1.477	0-0.5	470-516	0-245	470-760
TPH	0-5	0-5	0-1,745	0-2,447	0-4,193
TSS	390.968	0.822-1.411	136,468	402-691	136,870-137,158
Zinc	0.035-0.04	0-0.02	12-14	0-10	12-24

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit

Table 2-8d. Baseflow and stormflow concentrations with estimated spring (April-June 2017) baseflow and stormflow loads in Peter Pan Run*

	Average Storm EMC (mg/l)	Average Baseflow MC (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Spring Load (lbs)
BOD	5.979-6.562	0-2	3,646-4,001	0-1,294	3,646-5,295
Copper	0.016	0-0.002	10	0-1	10-11
Hardness	65.228	157.378	39,772	101,812	141,584
Lead	0.0138-0.00139	0-0.002	8.4-8.5	0-1	8-10
Nitrate+Nitrite	1.385	2.305	844	1,491	2,335
Phos	0.825	0.023	503	15	518
TKN	2.899	0.383-0.609	1,768	248-394	2,015-2,162
TPH	1.796-5.299	0-5	1,095-3,231	0-3,235	1,095-6,466
TSS	762.914	1.476-1.738	465,175	955-1,124	466,129-466,299
Zinc	0.067-0.07	0-0.02	41-43	0-13	41-56

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.

Table 2-9a. Baseflow and stormflow concentrations with estimated summer (July-September 2016) baseflow and stormflow loads in Pond R Outfall*

	Average Storm EMC (mg/l)	Average Baseflow MC (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Fall Load (lbs)
BOD	1.293-4.213	0-8	292-951	0-7	292-958
Copper	0.0012-0.0025	0.0043	0-1	0.004	0-1
Hardness	32.648	69	7,372	58	7,430
Lead	0-0.002	0-0.002	0.0-0.5	0.000-0.002	0.0-0.5
Nitrate+Nitrite	0.411	0.05	93	0.04	93
Phos	0.116	0.24	26	0.2	26
TKN	0.602-0.613	1	136-138	0.8	137-139
TPH	0-5	0-5	0-1,129	0-4	0-1,133
TSS	8.463	5	1,911	4	1,915
Zinc	0-0.02	0-0.02	0-5	0.0-0.02	0-5

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.
NC = Samples not collected.

Table 2-9b. Baseflow and stormflow concentrations with estimated fall (October-December 2016) baseflow and stormflow loads in Pond R Outfall*

	Average Storm EMC (mg/l)	Average Baseflow (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Fall Load (lbs)
BOD	5.14	NC	209	NC	209
Copper	0.0055	NC	0.2	NC	0.2
Hardness	45.34	NC	1,841	NC	1,841
Lead	0-0.002	NC	0.0-0.08	NC	0.0-0.08
Nitrate+Nitrite	0.917	NC	37	NC	37
Phos	0.332	NC	13	NC	13
TKN	0.823	NC	33	NC	33
TPH	0-5	NC	0-203	NC	0-203
TSS	7.611	NC	309	NC	309
Zinc	0.03	NC	1	NC	1

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.
NC = Samples not collected.

Table 2-9c. Baseflow and stormflow concentrations with estimated winter (January-March 2017) baseflow and stormflow loads in Pond R Outfall*

	Average Storm EMC (mg/l)	Average Baseflow (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Winter Load (lbs)
BOD	1.641-4.703	0-4	143-409	0-21	143-430
Copper	0.0013-0.0024	0.0041	0.1-0.2	0.02	0.1-0.2
Hardness	29.841	43	2,597	222	2,819
Lead	0-0.002	0-0.002	0.0-0.2	0.00-0.01	0.0-0.2
Nitrate+Nitrite	0.29	0.18	25	0.9	26
Phos	0.116	0.13	10	0.7	11
TKN	0.267-0.599	0.8	23-52	4	27-56
TPH	0.202-5.034	0-5	18-438	0-26	18-464
TSS	9.84	11	856	57	913
Zinc	0.008-0.021	0.028	1-2	0.1	1-2

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.

Table 2-9d. Baseflow and stormflow concentrations with estimated spring (April-June 2017) baseflow and stormflow loads in Pond R Outfall*

	Average Storm EMC (mg/l)	Average Baseflow (mg/l)	Storm Load (lbs)	Baseflow Load (lbs)	Total Estimated Spring Load (lbs)
BOD	1.189-4.294	2.191-3.096	70-252	231-327	301-578
Copper	0.0054	0.0005-0.0021	0.3	0.1-0.2	0.4-0.5
Hardness	36.093	54.115	2,116	5,709	7,825
Lead	0-0.002	0-0.002	0.0-0.1	0.0-0.2	0.0-0.3
Nitrate+Nitrite	0.288	0.081-0.093	17	8-10	25-27
Phos	0.191	0.153	11	16	27
TKN	1.397	0.825	82	87	169
TPH	0.487-5.081	1.525-5.254	29-298	161-554	190-852
TSS	16.868	6.146	989	648	1,637
Zinc	0.023-0.029	0.007-0.022	1-2	1-2	2-4

* Where concentrations are reported at the detection limit, loadings are presented as a range of possible values setting concentrations to either zero or the detection limit.
NC = Samples not collected.

Annual estimated pollutant loadings at the instream station decreased for all parameters during FY 2017 compared to FY 2016. A likely factor in smaller loading estimates during FY 2017 was the reduced total discharge (35.2% lower) in Peter Pan Run compared to FY 2016. Loading decreases ranged from 16.2% for phosphorus to 79.5% for combined nitrate and nitrite. The annual loading values for all parameters were within their respective historical ranges for the instream station. For non-first flush parameters that were detected in outfall samples during FY 2016, the estimated contribution of Pond R to the total loading of the watershed ranged from between 0.1% (lead) and 8.8% (BOD).

2.2 BIOLOGICAL MONITORING RESULTS FOR PETER PAN RUN

Frederick County annually monitors biological conditions within Peter Pan Run's approximately 3-square mile catchment. Annual monitoring of Peter Pan Run began in June 1999 and continues to date. The following is a summary of the biological data collected at the four Peter Pan Run stream monitoring stations in 2017 (Figure 1-2), with sites named PPAN-01 to 04 (also known as BUSL-201, 202, 103 and 104, respectively). Data from this year's survey, along with data from past years, have been compiled in Appendix A.

Benthic macroinvertebrate sampling and qualitative habitat assessments were conducted on March 21, 2017, within the MBSS Spring Index Period for benthos. Quantitative geomorphic assessments surveys, including cross-sectional measurements, longitudinal profiles, and pebble counts, were conducted in Spring 2017. Summer sampling was conducted on June 28 and July 26, 2017, and included *in situ* water quality measurements, further qualitative and quantitative physical habitat assessment, and electrofishing surveys.

The Quality Assurance Project Plan (QAPP) for Frederick County's biological and physical stream monitoring program in Peter Pan Run (Morgan and Roth 2005) was followed for all sampling. Following EPA guidelines, the QAPP documents a set of quality assurance and quality control procedures used for field and laboratory practices. The QAPP ensures the gathering of high-quality, accurate data that will meet a study or project's objectives and goals. It also serves as a reference when questions arise about field or laboratory procedures.

Benthic macroinvertebrate and fish data were collected and used to calculate Index of Biotic Integrity (IBI) scores for each of the four stations in the Peter Pan Run catchment. Fish and benthic IBI ratings for all sites were calculated in accordance with the Maryland Biological Stream Survey (MBSS) revised scoring methods (Southerland et al. 2005; Appendix A, Tables A-4 and A-5). The IBI scores are divided into four classes as shown in Table 2-10.

Table 2-10. Scoring classes for the Index of Biotic Integrity used by the MBSS indices.

Class	Range
Good	4.0 - 4.9
Fair	3.0 - 3.9
Poor	2.0 - 2.9
Very Poor	1.0 - 1.9

IBI scores for data collected in year 2017 sampling are summarized in Table 2-11. The biological communities in Peter Pan Run have experienced land use-related impacts due to previous agri-culture and current residential development. It is likely that these benthic communities now have less inherent stability, and will therefore continue to fluctuate from year to year due to minor impacts or localized changes to the stream that otherwise would not lead to noticeable change (i.e., annual changes to BIBI narrative categories).

Table 2-11. Summary of 2017 results from Peter Pan Run using the MBSS 2005 IBIs				
Station	**Benthic IBI Score**	**Benthic IBI Rating**	**Fish IBI Score**	**Fish IBI Rating**
BUSL-201-T	3.25	Fair	4.33	Good
BUSL-202-T	2.25	Poor	3.67	Fair
BUSL-103-T	2.50	Poor	4.33	Good
BUSL-104-T	1.75	Very Poor	1.67	Very Poor

In 2017, the benthic IBI (BIBI) ratings were Poor at all sites except BUSL-201-T and BUSL-104-T, which received a rating of Fair and Very Poor, respectively. Ratings for BUSL-201-T and BUSL-202-T have remained relatively stable since 2003, rating each year in either the Fair or Poor categories. BUSL-103-T remained in the Poor rating category in 2017 after rating in the Very Poor category in 2015 for the first time since 2003, when the stream was recovering from drought conditions in 2002. BUSL-104-T has been similarly stable, rating in the Very Poor or Poor category the past four years. BUSL-104-T is located in a very small, shallow stream and seems to be sensitive to dry conditions, which leads to the site scoring in the Very Poor category during years when stream levels are low and habitat availability is very limited.

FIBI numeric scores and narrative ratings remained in the Fair category for BUSL-202-T, improved to the Good category for BUSL-103-T and BUSL-201-T, and dropped to the Very Poor category for BUSL-104-T. A slight increase in the number of species and total abundance and decrease in the percentage of tolerant species collected were the main driving factors in the increased FIBI scores at BUSL-103-T and BUSL-201-T; a slight decrease in the total abundance and increase in the percentage of tolerant species collected contributed to the decreased FIBI scores at BUSL-104-T. Water levels at the time of sampling were also low, resulting in less available habitat for fish species at these sites.

Numeric FIBI values have not changed appreciably from FIBI scores in previous years and all sites have remained fairly consistent since 1999, either remaining in the same category or moving back and forth between the same two categories each year. A site typically moves from the high end of one scoring range to the low end of the next scoring range, or the reverse. These numbers indicate a relatively stable, though not necessarily high quality, fish community that is able to withstand fluctuations in stream conditions. In context with previous years' data, this stability shows that biota were affected by, but still able to withstand, the stressful impacts of the drought years. The record-setting drought and precipitation conditions during 2002 and early 2003 likely caused significant environmental stress to biota, possibly masking or exacerbating any changes that may have occurred as a result of construction and/or stormwater impacts during this period. Barring further changes within the watershed (i.e. development or restoration), an unusual or severe weather pattern, climate change, or restoration activities, the condition of these biotic communities may be expected to remain in their present state at all sites.

In situ water quality monitoring was performed during the spring and summer visits in 2017 (Appendix A, Table A-3). All data for temperature, DO, pH, and conductivity were consistent with data collected in previous years, and all values were within the normal and expected ranges. In the summer, DO concentrations tend to decrease due to elevated water temperature. The lowest concentration measured was 8.86 mg/l, which is greater than Maryland's established minimum surface water criterion is 5.0 mg/l, considered necessary for the health of aquatic biota.

2.3 PHYSICAL STREAM ASSESSMENTS

Physical stream conditions within Peter Pan Run in 2017 were generally similar to those in years past, although certain stream parameters are beginning to show a pattern of incremental change over time. A summary of historical and current data is provided in Appendix A. Field surveys are typically performed at least 24 hours after a major storm event and when conditions approximate baseflow.

Over the years, small variations in embeddedness at BUSL-103-T have occurred, coinciding with small changes in the stream's epifaunal substrate scores. Embeddedness was highest in 2008, 2009, and 2010, but has decreased steadily since this time. In 2017, percent embeddedness was 45 percent, and since 2013, embeddedness and average particle size (D50; Figure 2-18) have remained stable, ranging from 25 to 45 percent and from 15 to 40 mm, respectively. In 2017, the D50 for BUSL-103-T was in the "Medium Gravel" category (Table 2-12).

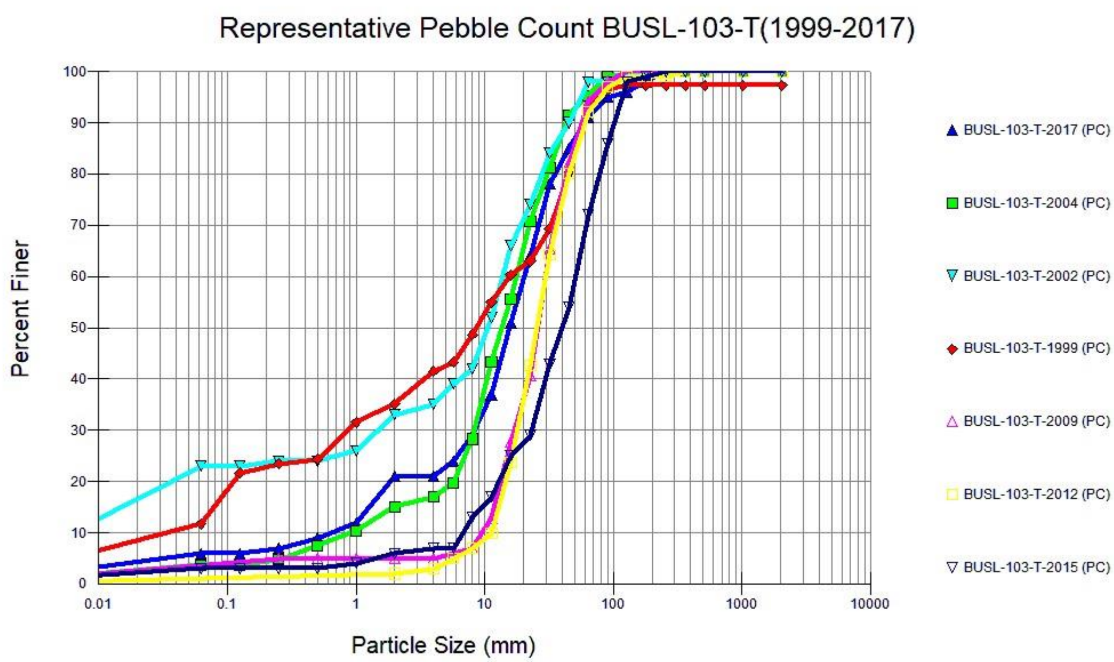

Figure 2-18. Particle size distribution at BUSL-103-T, 1999-2017

Table 2-12. Stream particle grain-size classifications			
		Median (mm)	**Range (mm)**
SILT/CLAY	Silt/Clay	0.01	< 0.062
SAND	Very Fine	0.02	0.062 - 0.13
	Fine	0.19	0.13 - 0.25
	Medium	0.38	0.25 - 0.50
	Coarse	0.75	0.50 - 1.0
	Very Coarse	1.5	1.0 - 2
GRAVEL	Very Fine	3	2 - 4
	Fine	5	4 - 6
	Fine	7	6 - 8
	Medium	10	8 - 11
	Medium	14	11 - 16
	Coarse	20	16 - 22
	Coarse	28	22 - 32
	Very Coarse	40	32 - 45
	Very Coarse	56	45 - 64
COBBLE	Small	80	64 - 90
	Small	109	90 - 128
	Large	154	128 - 180
	Large	218	180 - 256
BOULDER	Small	309	256 - 362
	Small	438	362 - 512
	Medium	768	512 - 1024
	Large	1500	1024 - 2048
	Very Large	3072	2048 - 4096
BEDROCK	Bedrock		> 4096

A similar trend occurred at BUSL-104-T, with embeddedness highest during the 2008-2010 time period. In 2017, embeddedness at BUSL-104-T was 65 percent, an increase from the stabilized values (between 35 and 45 percent) over the past four years. This increase in percent embeddedness closely resembles the embeddedness value of 70 percent in 2012. It is important to note that this change may be a result of a lower-flow events than in the past, causing finer sediments to be retained in the segment, or from new construction upstream, increasing sediment inputs into the system. The decrease in embeddedness from 2013-2016 may have only be temporary, as bank erosion continues to be a problem at this site. An increase in the sediment supply may again fill the interstitial space around cobble and gravel and smother benthic habitat. It is likely that high embeddedness, and the resulting lack of benthic habitat, has been responsible for the perpetually poor BIBI scores at this location. If embeddedness continues to remain high, as scored in 2017, epifaunal substrate quality and BIBI scores will continue to remain low as a result of degraded benthic habitat conditions.

Average particle size (D50; Figure 2-19) at BUSL-104-T has remained in the “Medium” or “Coarse Gravel” category since 2002. While the D50 at BUSL-104-T has been largely stable, small changes in average particle size have generally followed the same trend as embeddedness. In 2008, the year with the highest percent embeddedness, the D50 was only 10.8 mm. This is the smallest D50 recorded at the site in the last 15 years of monitoring. Likewise, epifaunal substrate quality has generally scored in the “Marginal” or “Suboptimal” categories, but coincident with embeddedness and D50, ranked in the “Poor” category in 2008. In 2017, the epifaunal substrate quality score was in the “Marginal” category. This trend in embeddedness, D50, and epifaunal substrate quality is likely linked with the removal of trees in the stream’s riparian buffer during 2008, as well as construction activity in the watershed upstream of the site, resulting in increased bank erosion and sedimentation of the stream channel.

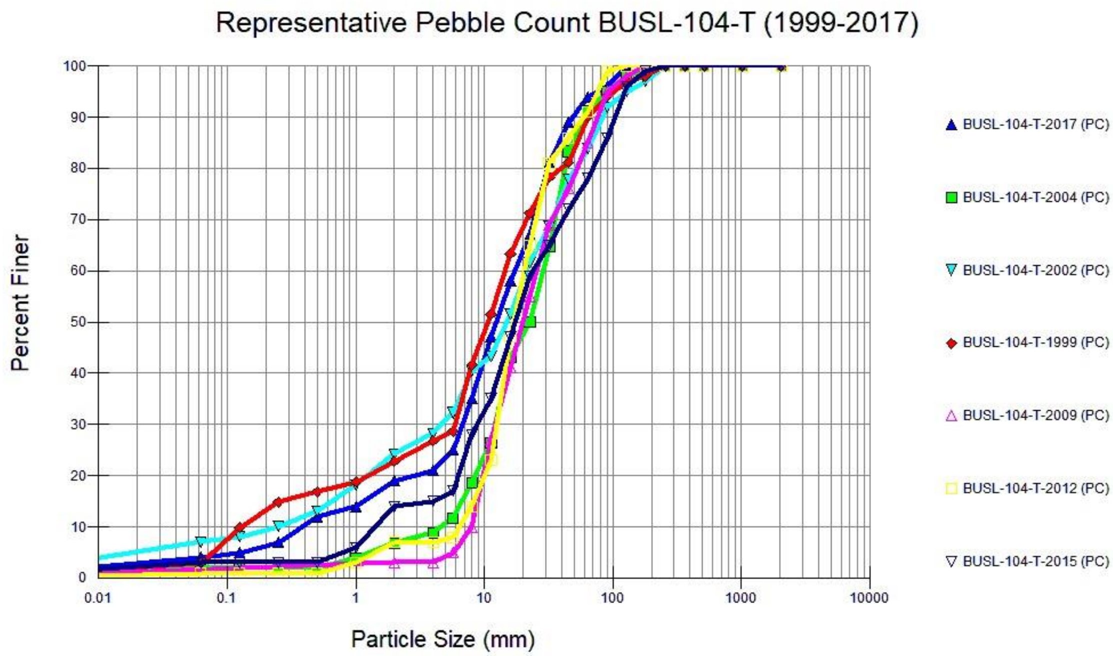

Figure 2-19. Particle size distribution at BUSL-104-T, 1999-2017

Since BUSL-201-T and BUSL-202-T are located on a larger stream than BUSL-103-T and BUSL-104-T, less variation in embeddedness, D50, and epifaunal substrate quality scores are likely to occur following small changes in their hydrology. At BUSL-201-T, embeddedness has remained around 50 percent and fluctuated very little since monitoring began in 1999; embeddedness was 50 percent in 2017. Similarly, the D50 at BUSL-201-T (Figure 2-20) has mainly been “Medium” or “Coarse Gravel” and epifaunal substrate quality scores have mainly been in the “Suboptimal” category. The D50 was “Medium Gravel” and epifaunal substrate quality was “Suboptimal” in 2017.

While percent embeddedness at BUSL-202-T has remained stable around 50 percent since monitoring began in 1999, a slight downward trend was noted over the past four years; percent embeddedness was only 35% in 2013, 2014, and 2016. However, percent embeddedness increased to 50 percent in 2017, resembling normal stream conditions measured at this site over time. The D50 at BUSL-202-T (Figure 2-21) was still in the “Gravel” category in 2017, as it has been every year since 1999, although it fell into the lowest subcategory of gravel in 2017, with a D50 of 3.0. The epifaunal substrate quality was scored as “Marginal” in 2017, staying within the “Marginal” or “Suboptimal” category ratings it has received since 1999.

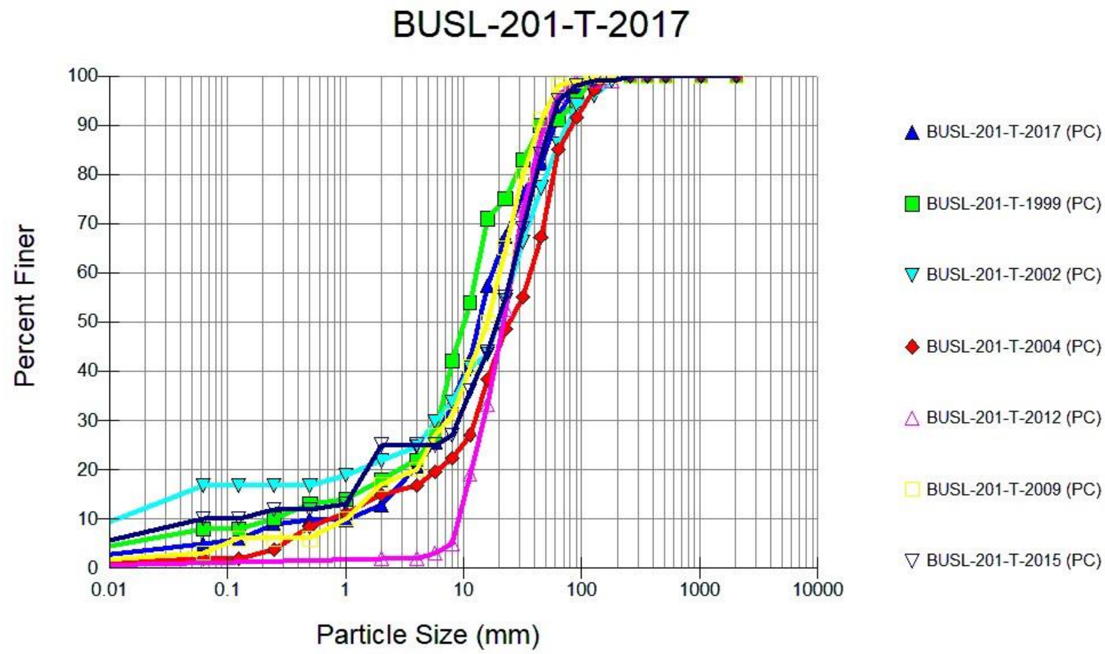

Figure 2-20. Particle size distribution at BUSL-201-T, 1999-2017

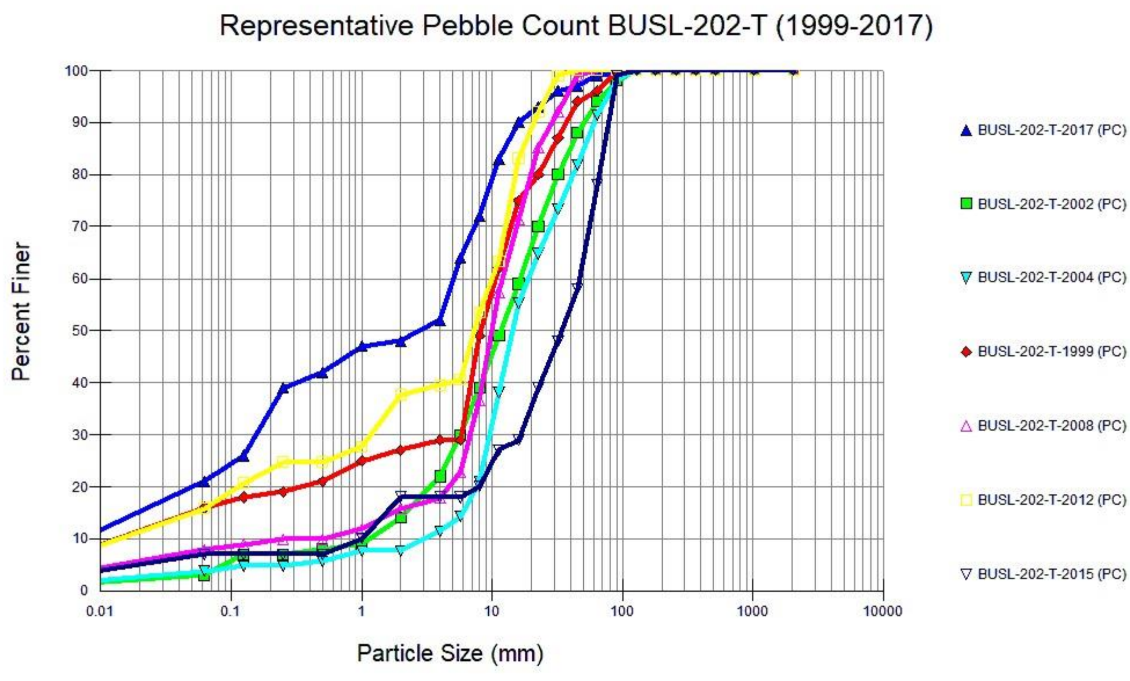

Figure 2-21. Particle size distribution at BUSL-202-T, 1999-2017

Stream slope at all stations was low (Appendix A, Table A-1). Stream gradient has been stable at BUSL-201-T during the past eight years, remaining around 0.8%. In 2001, BUSL-202-T appeared to have aggraded. Since that time and continuing through 2017, stream slope has remained stable at around 0.5%. In April 2000, slope at BUSL-103-T decreased significantly as a result of channel elevation changes associated with a sewer line crossing between the station and its confluence with Peter Pan Run. Slope then increased in 2005 and 2006. From 2007 through 2017, slope increased or decreased slightly from year to year; however, in the past three years, slope has remained consistent at 1.0%. Slope at BUSL-104-T has remained stable at approximately 1.4% for the past 12 years.

Cross-sectional surveys were conducted at monumented locations at each station; bank pins were installed to measure bank erosion rates in Peter Pan Run since 1999. The banks at BUSL-201-T continued to erode between 2013 and 2017; however, the bank pin at this location was lost between 2012 and 2013 sampling. Previously, measurements at BUSL-201-T for 2005 and 2006 recorded the two greatest amounts of bank loss in a single year (30 cm and 29 cm, respectively; Figure 2-22). A new bank pin has not been installed as there is concern that the bank pin may have contributed to and slightly increased localized erosion at the pin's location; bank erosion will continue to be monitored through the cross-sectional survey data.

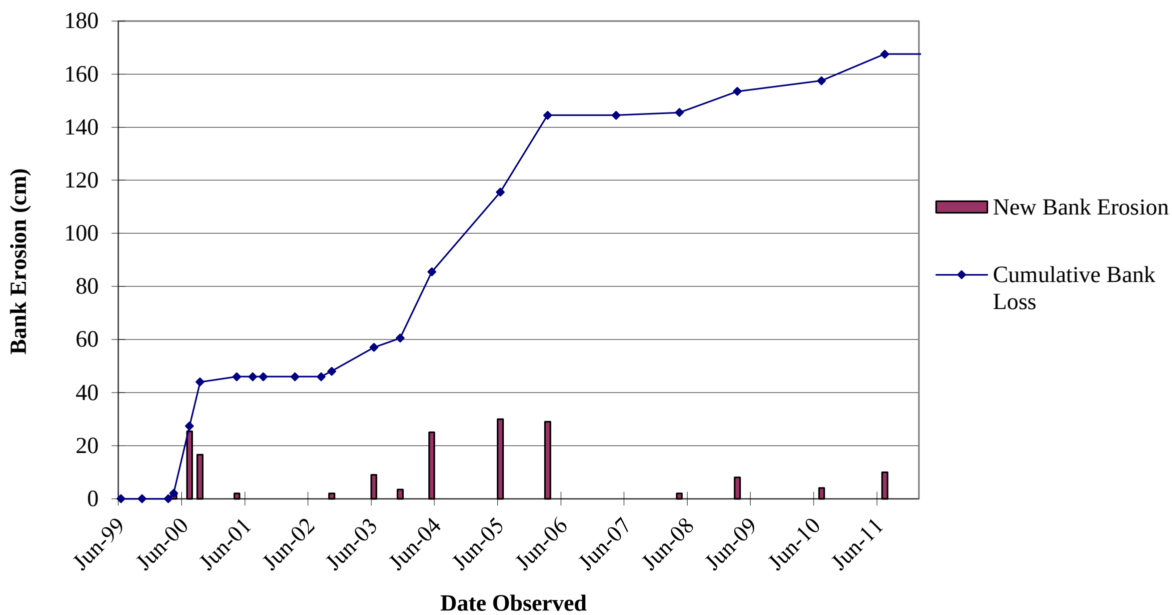

Figure 2-22. Bank loss as measured by the bank pin at BUSL-201-T. Note that the right bank eroded 167.5 cm (5.5 feet) between June 1999 and July 2011.

The cross-sectional survey at BUSL-201-T illustrates channel widening, as it expanded by 3.0 feet to the left between 1999 and 2005, and by an additional 1.9 feet between 2005 and 2009 (Figure 2-23). The left bank at BUSL-201-T continues to erode each year, having scoured an additional foot between 2013 and 2017. A large gravel bar has filled in the center and the right half of the channel. Between 2015 and 2017, material continued to deposit, increasing bar height by 0.1 feet. In 2017, the bar shifted to the left as the right side of the channel underwent significant scour of about 1.05 feet, since 2016, potentially creating a new thalweg.

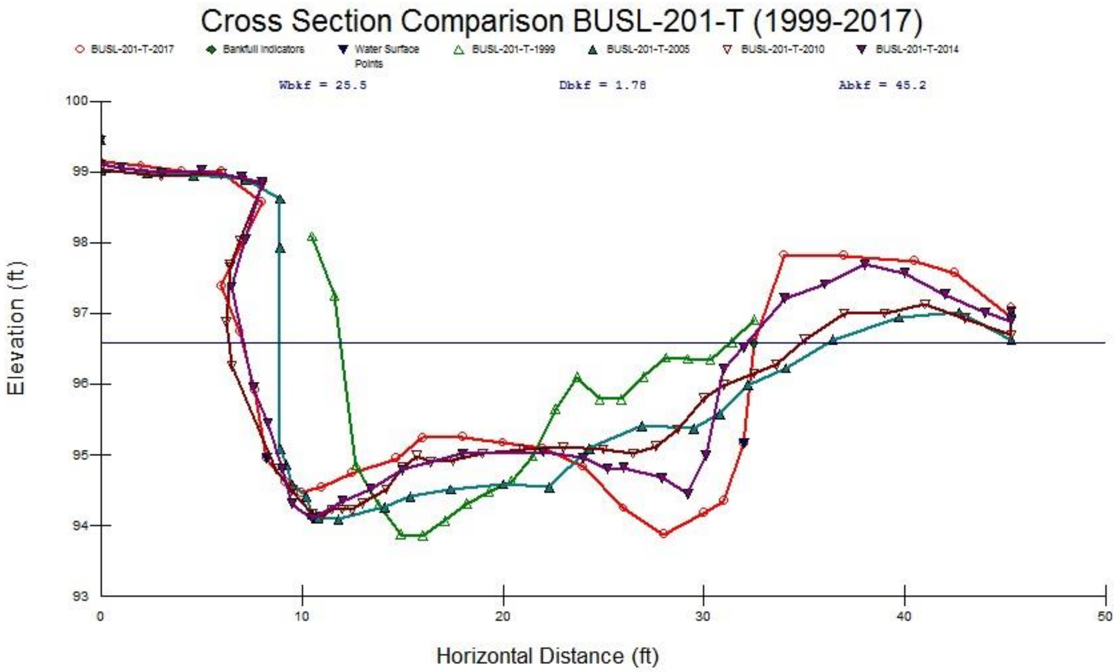

Figure 2-23. Cross-sectional changes at BUSL-201-T between 1999 and 2017. Note that the cross-section is shown facing downstream.

At BUSL-202-T, material was removed by downward scouring between 2003 and 2008. From 2009-2011, a fallen tree was jammed at the cross-section location. Approximately two feet of bed material was scoured out below the log jam. After the log was dislodged and moved downstream of the cross-section in 2012, depositional material filled in the scoured area at the cross-section. Between 2013 and 2015 (Figure 2-24), streambed erosion and deposition appeared to have stabilized, however, from 2015 to 2016 slight aggradation was noticed along the left bank and the right side of the stream channel scoured down 0.95 feet. In 2017, the left side of the channel scoured slightly (0.4 feet) and the right side continued to scour down by an additional 0.25 feet from 2016.

A few minor changes to the channel occurred at BUSL-103-T between 2009 and 2013 (Figure 2-25). The left bank eroded 1.6 feet, and the channel bottom downcut along the right bank. In 2014 and 2015, the channel continued to downcut along the left bank, while the channel thalweg along the right bank filled in slightly. From 2015 to 2016, the right side of the channel downcut 0.75 feet, removing the depositional material which accumulated in 2014 and 2015. In 2017, the left side of the channel scoured slightly and the right bank experienced some accumulating deposition just above the water surface, narrowing the channel by 0.5 feet.

Cross-sectional surveys of BUSL-104-T suggest only minor alterations within its channel (Figure 2-26). Previous data had indicated that BUSL-104-T was downcutting slightly, as evidenced by increased values for stream slope and average thalweg depth, and the decreased average channel width. Conditions at the site were stable from 2008 to 2016, however, in 2017

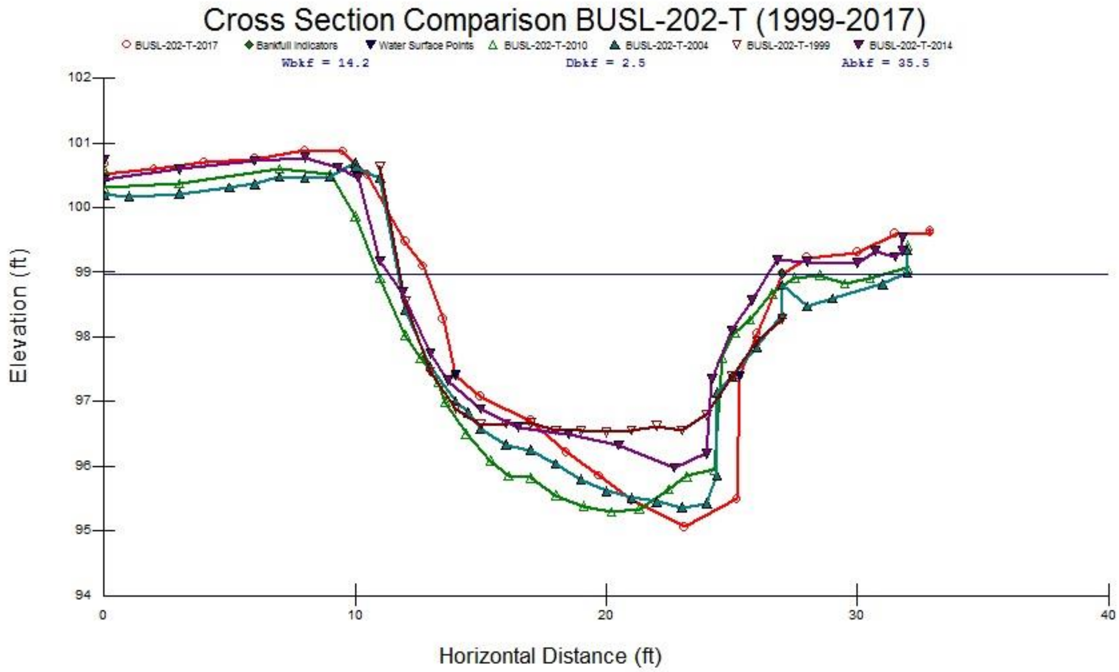

Figure 2-24. Cross-sectional changes at BUSL-202-T between 1999 and 2017. Note that the cross-section is shown facing downstream

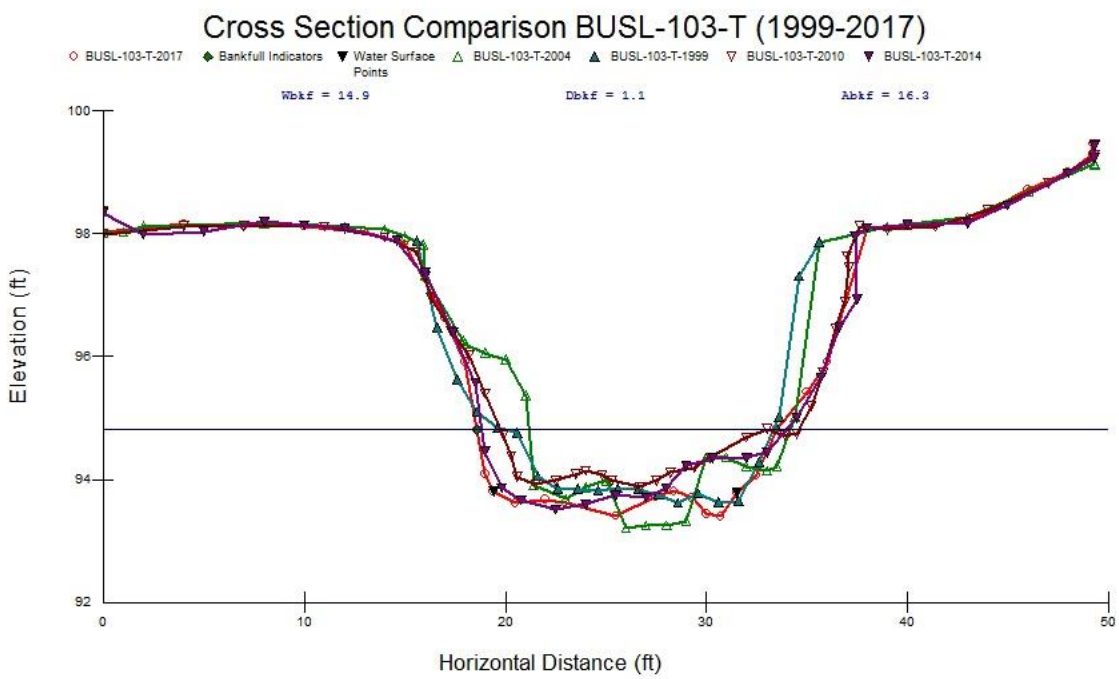

Figure 2-25. Cross-sectional changes at BUSL-103-T between 1999 and 2017. Note that the cross-section is shown facing downstream

the left side of the channel scoured by about 0.18 feet. This scour caused the wetted perimeter of the stream to narrow by almost 4 feet.

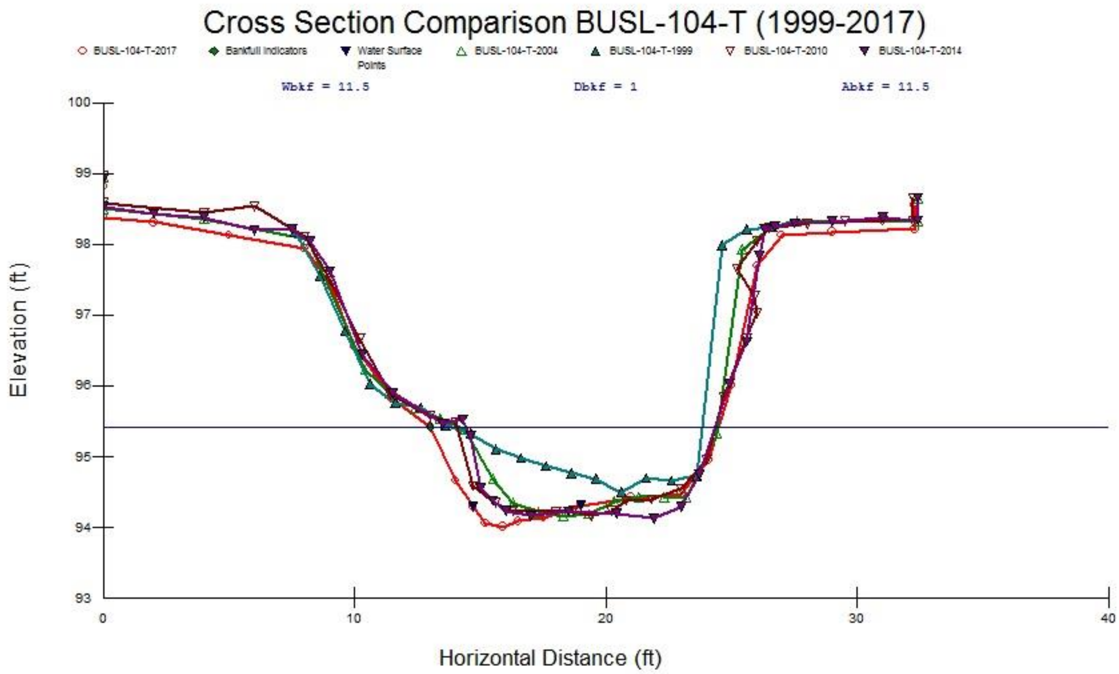

Figure 2-26. Cross-sectional changes at BUSL-104-T between 1999 and 2017. Note that the cross-section is shown facing downstream.

In December 2015, longitudinal profiles were established at each site. Benchmark pins were installed at the starting point (i.e., station 0+00) and to mark the end of the survey profile. Each profile is approximately 300 feet in length and encompasses the previously established cross-sections. Both left and right bank cross-section pins were surveyed into the longitudinal profile to obtain relevant elevations. Profiles were established along the center of the channel and included a survey of breakpoints in and between bed features, as well as delineation of riffles, runs, pools, and glides. A survey of the bankfull elevation (where discernible), top of bank, and water surface was also performed.

As monitoring of the sites' longitudinal profile only began in 2015, few major changes have occurred to date (Figures 2-27 through 2-30). Bed features at each of the four sites remained stable between 2015 and 2016. Bed features may have shifted upstream or downstream by a few feet in some cases, but for the most part, remained the same from 2015 to 2016. The only clear change of bed feature occurred at BUSL-104-T near station 2+00, where a riffle in 2015 changed to a pool in 2016. In 2017, both BUSL-201-T and BUSL-202-T had increased deposition on point bars that caused the features and the cross-sections to move upstream in station by a few feet due to the increase in sinuosity. BUSL-202-T saw significant shifts in pools at station 0+20 and 0+53 and the pool at station 1+05 in 2016 was a riffle in 2017. BUSL-103-T had a tree come down around station 2+30 that resulted in the creation of a step pool just downstream.

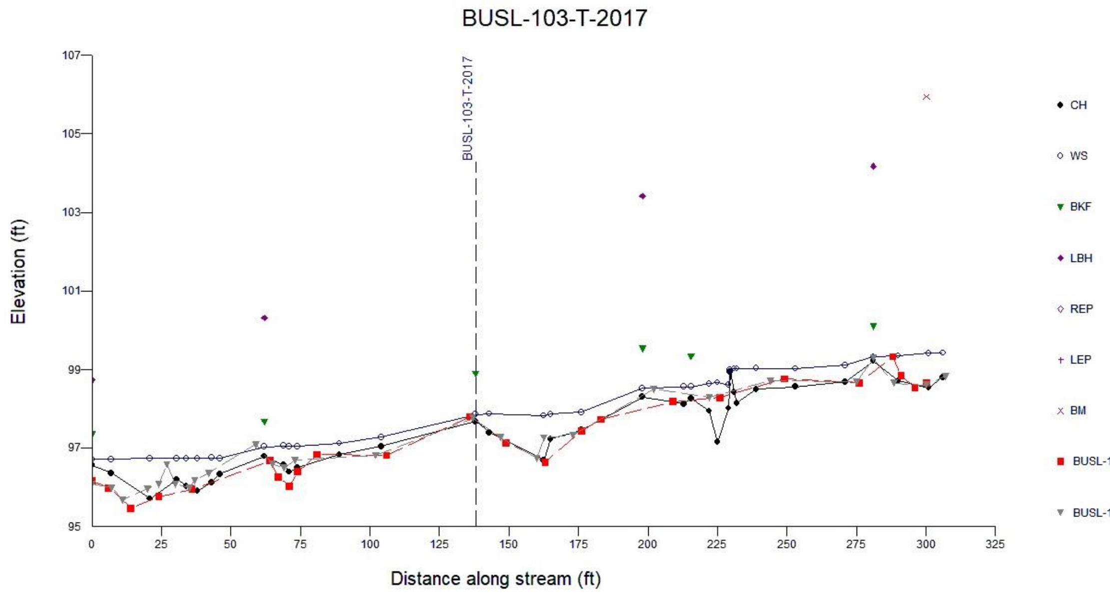

Figure 2-27. Longitudinal profile at BUSL-103-T from 2015-2017. Water surface elevation is displayed only for the most recent year.

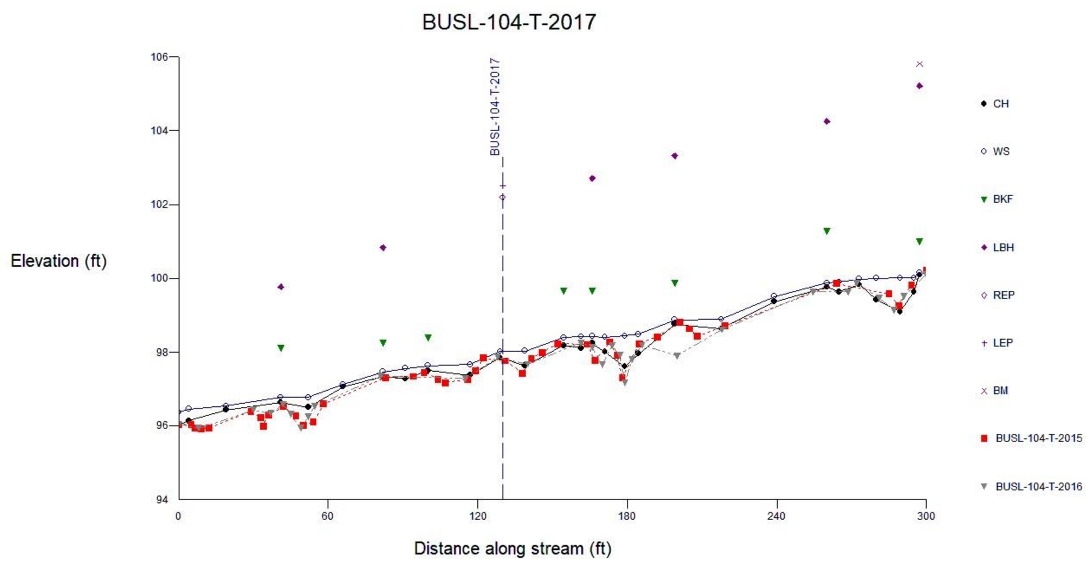

Figure 2-28. Longitudinal profile at BUSL-104-T from 2015-2017. Water surface elevation is displayed only for the most recent year.

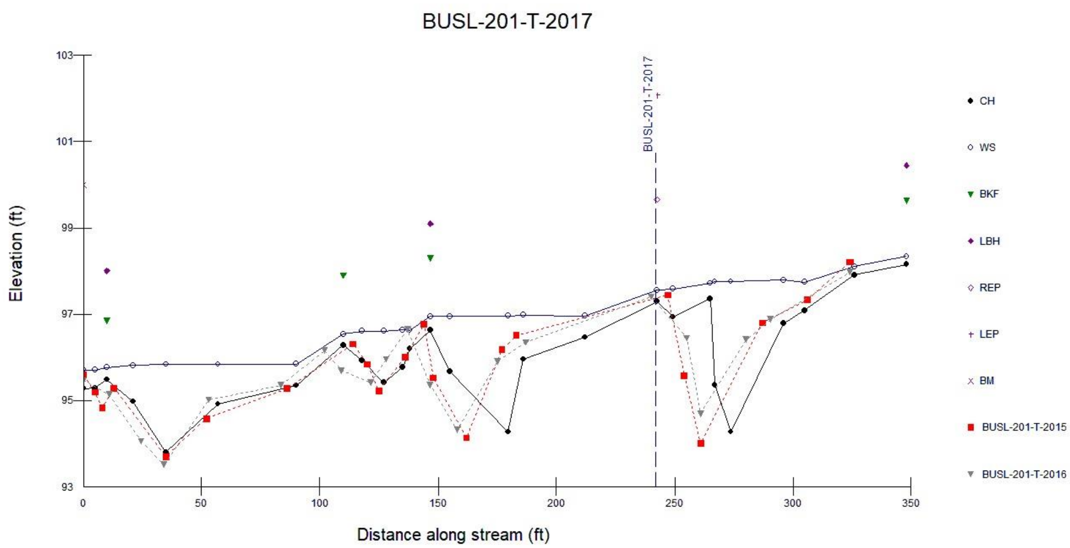

Figure 2-29. Longitudinal profile at BUSL-201-T from 2015-2017. Water surface elevation is displayed only for the most recent year.

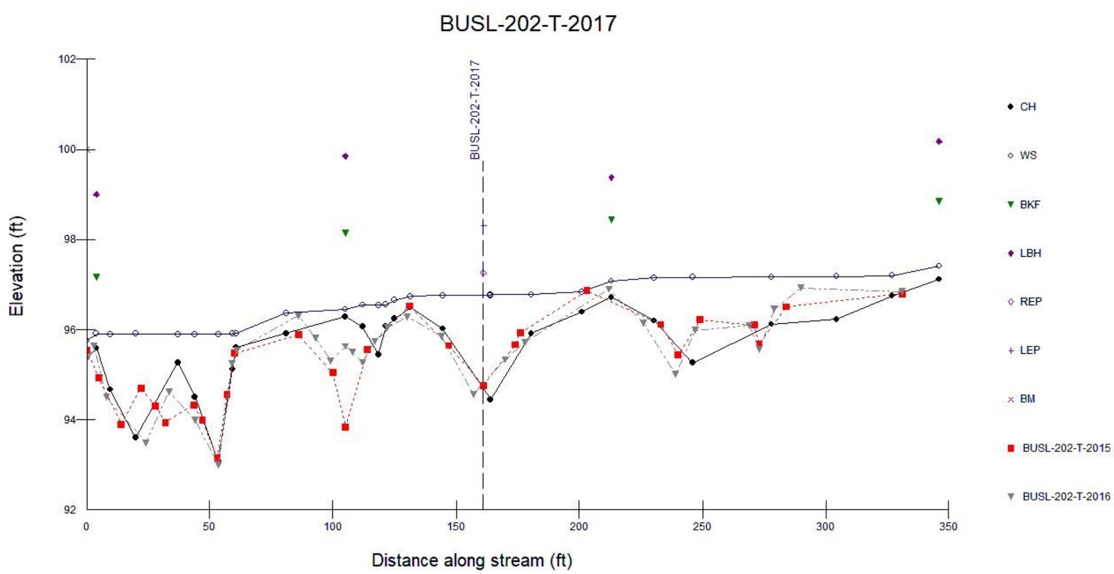

Figure 2-30. Longitudinal profile at BUSL-202-T from 2015-2017. Water surface elevation is displayed only for the most recent year.

2.4 INTEGRATED ANALYSIS OF FIELD RESULTS

Frederick County has collected and analyzed considerable data to assess physical, chemical, and biological conditions in the Peter Pan Run watershed since monitoring began in May 1999. During that time, land clearing and related development activities have occurred in phases, with construction starting in new sections as others are completed. Additionally, natural variation in precipitation patterns has occurred over the study years, with six very dry (WYs 2001, 2002, 2009, 2015, 2016, and 2017) and six very wet years (WYs 2003, 2010, 2011, 2013, and 2014).

These development and weather factors present a complex set of variables affecting conditions within the study area. While these factors should be considered in drawing conclusions about the stressors affecting stream conditions, data generally indicate that there are some adverse effects associated with construction and development within the catchment. It should also be noted that the on-going development is not the only factor influencing conditions within the study area; based on pre-construction, baseline-monitoring data, the effects of historical and pre-development land use activities within the catchment are also evident.

2.4.1 Hydrology and Water Chemistry

Loading estimates provide an illustration of total quantity of pollutants transported out of a watershed, but vary widely on an annual basis due to variability in stream discharge. For this reason, the determination of trends in pollutant loadings, therefore, is challenging. To determine whether pollutant levels in Peter Pan Run have been changing significantly since the beginning of PUD construction and required chemistry monitoring, statistical analysis was performed on the individual storm EMC data from WY 1999 to present. A Kendall's Tau-b correlation for trend (Kendall 1948) on the individual storm EMC data showed a statistically significant upward trend for TKN (T_b = 0.503, p = 0.0035) and downward trend for copper (T_b = -0.359, p = 0.0372) and combined nitrate and nitrite (T_b = -0.477, p = 0.0057) at the instream station. Individual storm EMC data showed a statistically significant upward trend for TKN (T_b = 0.346, p = 0.0447) and a significant downward trend for combined nitrate and nitrite (T_b = -0.673, $p < 0.0001$), copper (T_b = -0.464, p = 0.0072), and lead (T_b = -0.373, p = 0.0308) at the outfall station.

Annual loadings of zinc at Pond R outfall and Peter Pan Run instream stations have been generally increasing in tandem since WY 2005, but the corresponding change in average annual EMCs over time was found to be not statistically significant (Figure 2-31). Individual storm EMC data for other metals tested at the instream station are presented in Figure 2-32; no trends in EMCs or loadings for the remaining metals are evident. TSS loading at the outfall station, over time, has borne a resemblance to that of the instream station only since 2012, but has fluctuated widely otherwise since the beginning of monitoring. A plot of EMCs for TSS by storm event likewise does not show any discernible trend (Figure 2-33). Time series of average annual EMCs for TSS at the instream station shows a general, gradual decline from 1999 to about 2009 and subsequently a plateau until FY 2016, in which a large increase was noted. The average annual EMC for TSS at the instream station in FY 2017 returned to similar levels noted from 2009 to 2015. The corresponding average annual EMC for TSS at the outfall station, however, did not vary from the historical range.

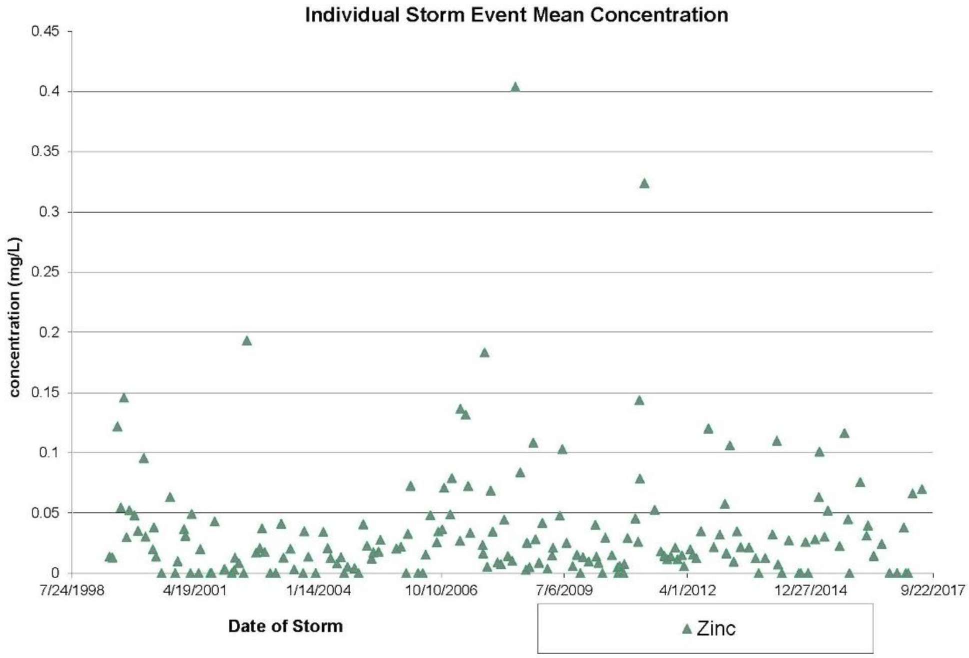

Figure 2-31. Storm event mean concentrations for zinc (May 1999 to June 2017) at the instream station. Values below detection limit are set to zero. Note that zinc is presented separately so that the scale is appropriate for the concentration range.

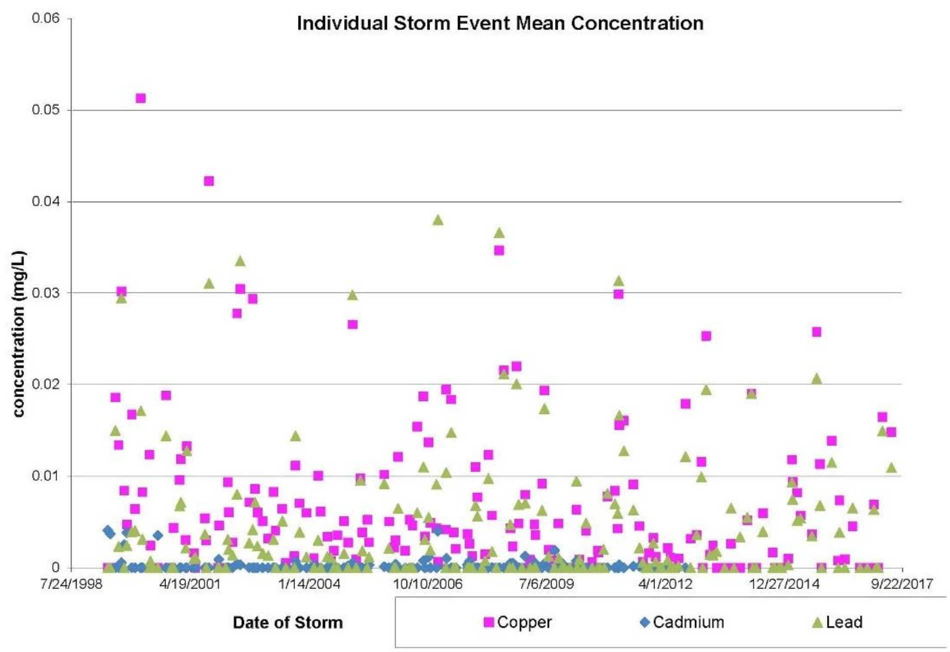

Figure 2-32. Storm event mean concentrations for copper, cadmium, and lead (May 1999 to June 2017) at the instream station. Values below detection limit are set to zero. Note that cadmium has not been analyzed since WY 2012.

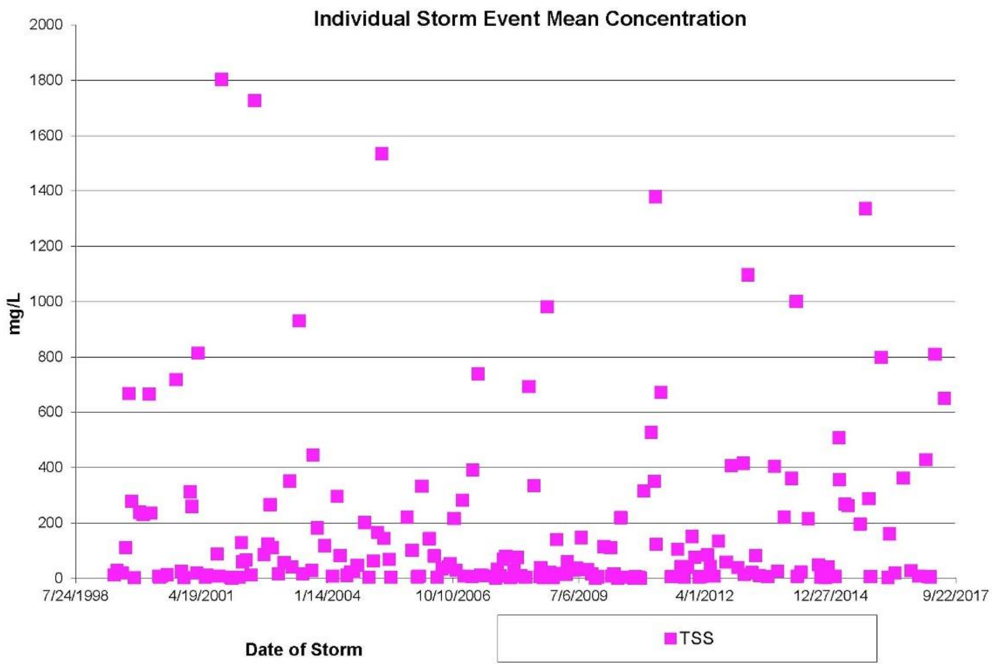

Figure 2-33. Storm event mean concentrations for TSS (May 1999 to June 2017) at the instream station

For both baseflow and stormflow conditions at the instream station, concentrations of nitrogen measured as nitrate plus nitrite have nearly always been greater than 1 mg/l, (see storm EMCs, Figure 2-34). This concentration level indicates nitrogen contributions from anthropogenic sources (Roth et al. 1999). Individual storm EMCs for copper and combined nitrate and nitrite have gradually, but significantly, declined since 1999 as shown by the Kendall's Tau-b statistical analysis. Storm EMCs for TKN, conversely, have gradually increased. The nitrate and nitrite reduction may be the result of gradually increasing impervious cover in the watershed, which reduces groundwater (the primary contributor of nitrogen) input to streams. As in the case of metals, annual nutrient loadings at the instream station have been variable with no apparent trend evident (Figure 2-35).

At the Pond R outfall, individual storm EMCs for combined nitrate and nitrite and TSS declined shortly after the conversion of Pond R from a sediment basin to a SWM facility in July 2004 (Figures 2-36 and 2-37). Since the onset of monitoring at the Pond R outfall station in WY 2003, only copper, lead, and combined nitrate and nitrite concentrations have continued to significantly decline as shown by Kendall's Tau-b results, despite several concentrations of nitrate and nitrite in FY 2017 that were the highest recorded since 2011. Similar to the instream station, TKN concentrations during storms have shown a gradual, though statistically significant, increase over time.

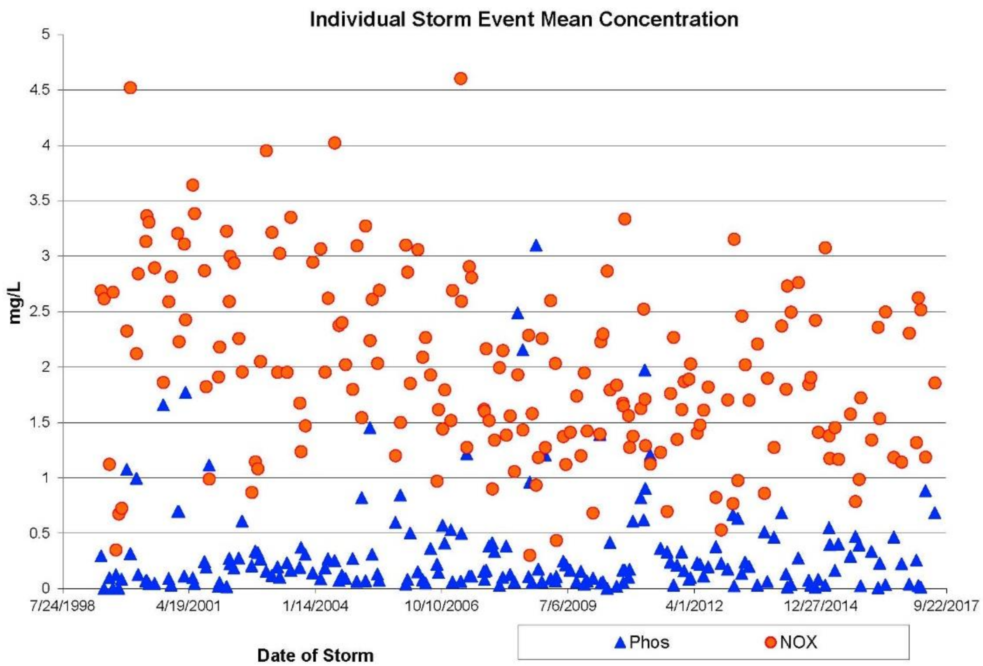

Figure 2-34. Storm event mean concentrations for phosphorus and nitrate + nitrite (May 1999 to June 2017) at the instream station. Values below detection limit are set to zero.

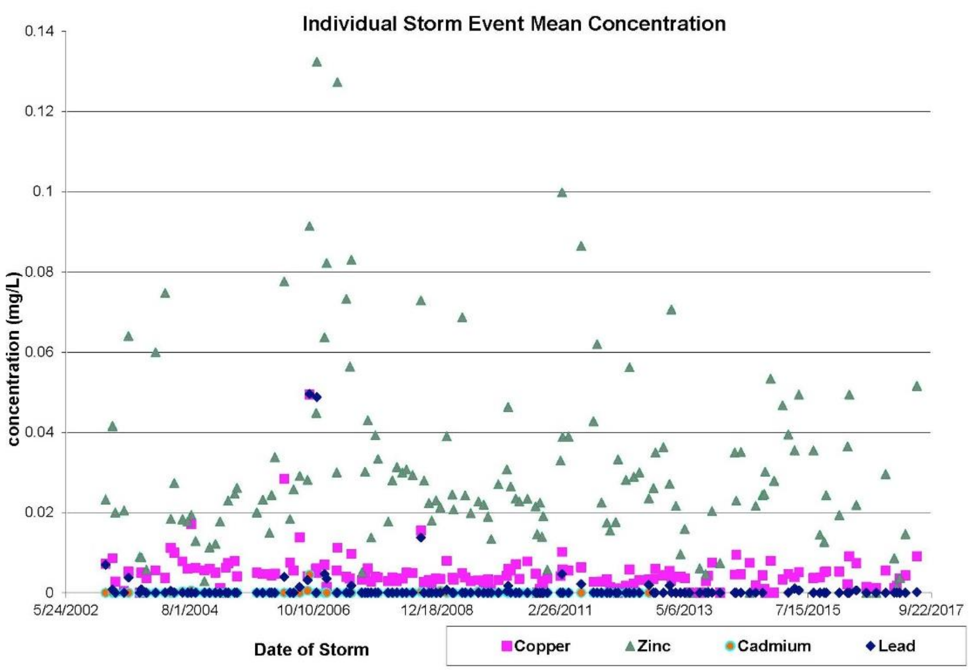

Figure 2-35. Storm event mean concentrations for metals (February 2003 to June 2017) at the outfall station. Values below detection limit are set to zero. Note that cadmium has not been analyzed since WY 2012.

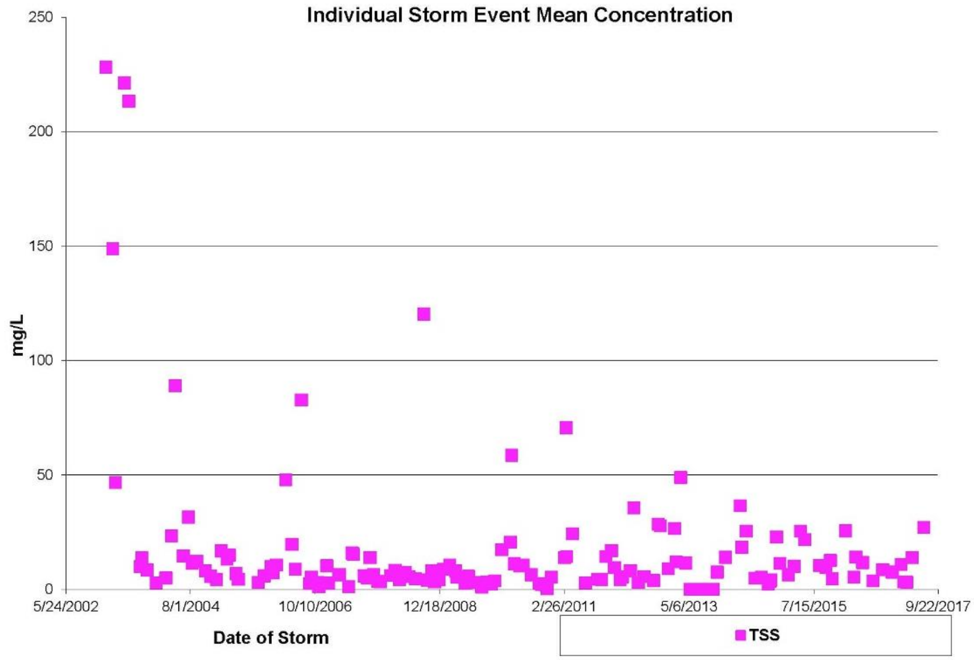

Figure 2-36. Storm event mean concentrations for TSS (February 2003 to June 2017) at the outfall station. Values below detection limit are set to zero.

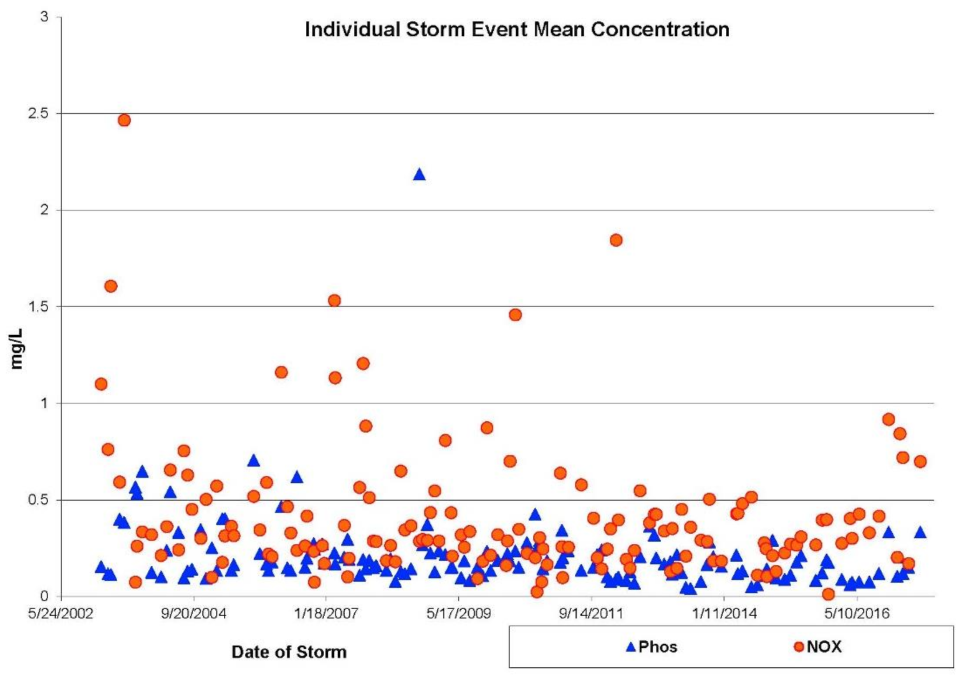

Figure 2-37. Storm event mean concentrations for phosphorus and nitrate + nitrite (February 2003 to June 2017) at the outfall station. Values below detection limit are set to zero.

2.4.2 Biological Indicators

This year's fish score ratings were Very Poor for BUSL-104-T, Fair for BUSL-202-T, and Good for BUSL-103T and BUSL-201-T (Figure 2-38). The diversity of fish species was relatively low at the BUSL-104-T station, and the percent of intolerant species was slightly higher than in the past, which resulted in reduced FIBI ratings at this site. BUSL-104-T differs from other sites in this study, as it is narrower and shallower, and therefore, has far fewer areas available to provide habitat for fish. Fish scores at all four stations are about the same as observations made in the study's initial years (1999-2001).

Benthic score ratings this year were Poor at all stations except BUSL-201-T and BUSL-104-T, which received a rating of Fair and Very Poor, respectively (Figures 2-38 and 2-39). These results fit with the long-term pattern of sites oscillating between the Fair and Poor categories (BUSL-201-T, BUSL-202-T, and BUSL-103-T) or between the Poor and Very Poor categories (BUSL-104-T). A regionally very dry year in 2012 may have impacted benthic macroinvertebrate populations. Benthic communities began to rebound from these dry conditions in 2013 but declined again in 2014 and have remained low through this year. Changes in the watershed landscape, such as the conversion of forest to impervious surface, leave a stream less able to withstand stressful climatic conditions, such as drought. Direct infiltration is reduced and lower baseflows leave stream biota vulnerable to increased temperature, decreased dissolved oxygen levels and flow-related fluctuations in available habitat.

Dating back to 1999, BIBI and FIBI scores during the pre-construction period fell short of the top category for biological integrity (e.g., FIBI scores were in the Poor to Fair range). This likely indicates that prior to development, the agricultural land use within the watershed was having a negative impact on the stream biota. During a period of very active construction in 2003 and 2004, BIBI scores dropped to Poor or Very Poor across the board at all four sites. Although fish IBI scores have shown some improvement in recent years, the continued year to year fluctuations of the benthic IBI scores (between the Fair and Poor rating categories) reflect the noted changes in physical habitat, in particular the highly mobile substrate and bed features. The stream is capable of providing adequate habitat for the benthic community, however this habitat is vulnerable to disruption due to flashy flows and excessive sediment loads moving through the system and periodically covering benthic habitats. Fish, because they are more mobile and somewhat less dependent on bottom substrate for cover, are slightly more tolerant of frequent disturbances to the stream bed and depositional processes.

2.4.3 Physical Habitat

Physical habitat, namely increased bank erosion and sediment deposition, is the most obvious sign that the stream has suffered negative impacts as a result of the disturbance from on-going upstream construction. While the most intensive phases of construction in the Urbana PUD have been completed, and the amount of construction in the watershed was minor this year relative to previous years, no signs of recovery were noted in the field data. The channel does not presently appear to be morphologically stable. Historical and pre-development land use activities within the catchment also continue to impact current stream conditions.

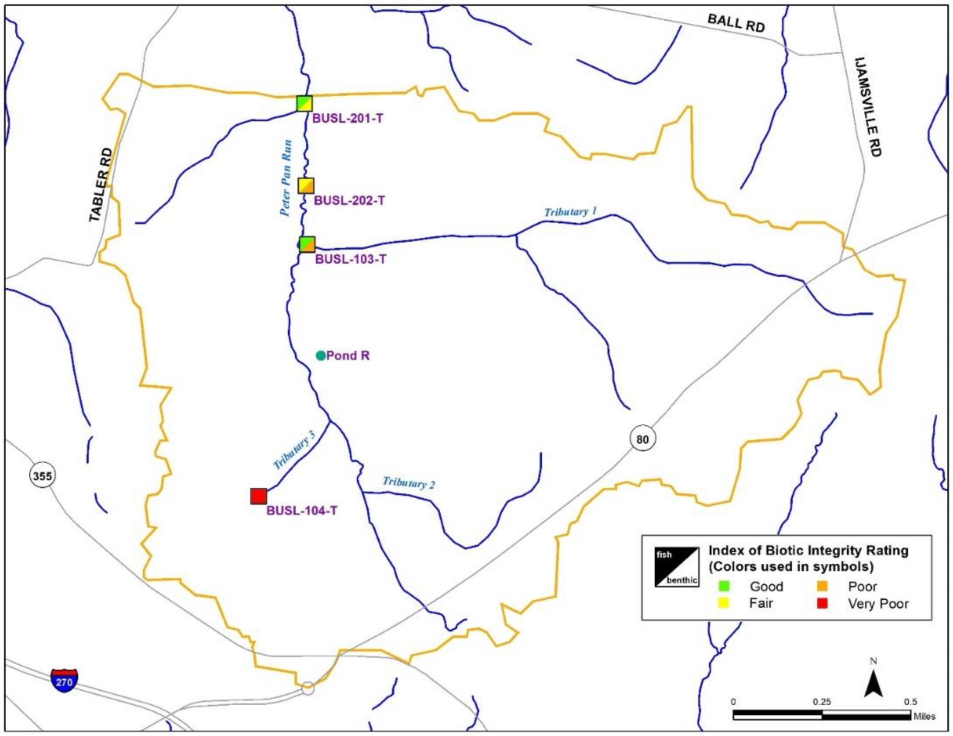

Figure 2-38. Index of Biological Integrity classes for Peter Pan Run monitoring in 2017

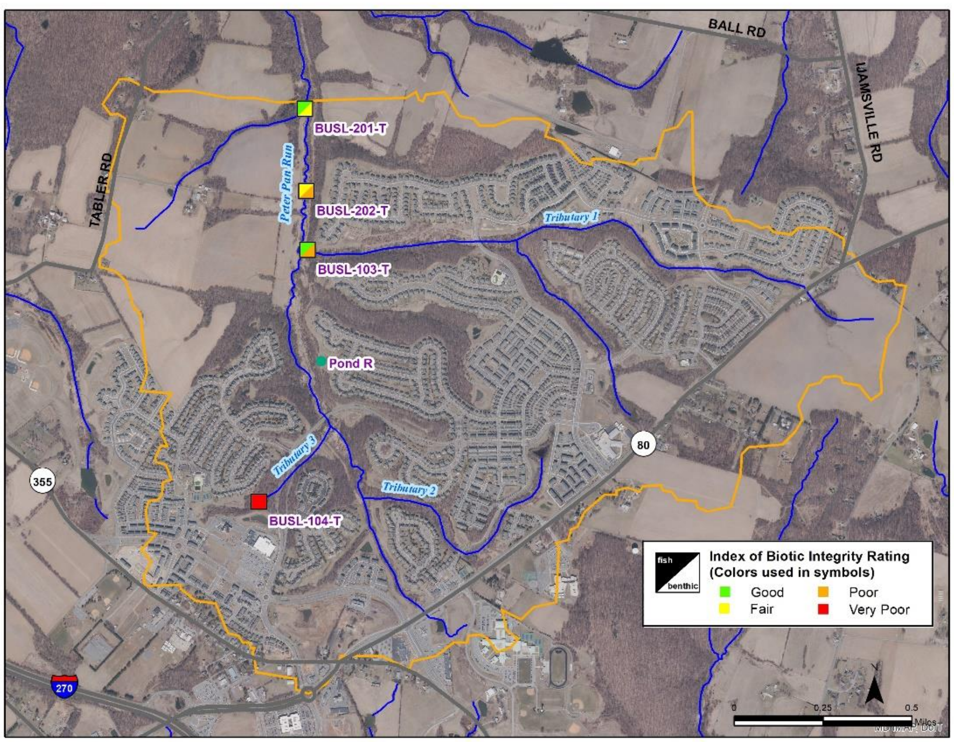

Figure 2-39. Index of Biological Integrity classes for Peter Pan Run monitoring in 2017 with aerial overlay

Physical changes within the stream channel over time, probably as a result of channel adjustment in response to an altered flow regime, are readily apparent. Changes in the stream channel that were observed include a temporary increase in deposition of fine sediments (most notably during the early period of most extensive land clearing), substantial bank erosion as measured using bank pins (Figure 2-22), changes in channel cross-section geometry (Figures 2-23 through 2-26), and field observations of channel bar formation and lateral channel migration.

2.4.4 Plans for Future Long-Term Monitoring

As discussed in greater detail in the 2017 annual restoration monitoring report (Versar 2017), Frederick County has worked with its consultant Versar, Inc., and developed a Watershed Restoration and Stormwater Management Assessment and Monitoring program. In addition, Frederick County is investing significant resources in replacing all of the chemical storm event sampling equipment late Summer/early Fall 2017 as the existing equipment is showing signs of failing. Further information regarding the new sampling equipment will be provided during the 2018 Annual Report submission.

Implementation of this approach has involved various elements of the current monitoring effort, as indicated in Table 2-13.

Table 2-13. Summary of changes to Frederick County's long-term monitoring efforts

Monitoring Effort	Location	Plans
Chemical Storm Event Monitoring	Peter Pan Run: instream and outfall stations	Storm event monitoring procedures changed in January 2015 from 12 events (3/quarter) to 8 events (2/quarter) based on the County's new NPDES permit
Biological and Physical Monitoring	4 stream stations in Peter Pan Run	No change to current monitoring procedures. Will continue with annual biological and physical monitoring, and surveying of geomorphic cross-sections
Stormwater Management Assessment	4 stream stations in Peter Pan Run	Survey geomorphic longitudinal profiles beginning in FY16, as well as hydrologic and/or hydraulic modeling in the 5th year of the new permit

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APPENDIX A

SUMMARY OF BIOLOGICAL AND PHYSICAL MONITORING DATA FOR PETER PAN RUN

Table A-1. Summary of field habitat data from Peter Pan Run

Station ID	Date Sampled	Avg. Wetted Width (m)	Avg. Thalweg Depth (m)	Slope	Discharge (cfs)	Discharge (m^3/s)	D50 (mm)	Riparian Width Left Bank (m)	Riparian Width Right Bank (m)
	7/12/2001	3.20	0.150	0.007	0.949	0.027	0.20	25	35
	8/22/2002	1.88	0.105	0.007	0.022	0.001	0.20	50	50
	7/17/2003	3.03	0.275	0.008	2.452	0.069	22.60	35	50
	9/24/2004	3.70	0.223	0.008	0.872	0.025	23.80	50	50
	6/23/2005	3.63	0.205	0.008	1.091	0.031	23.00	50	50
	6/06/2006	3.23	0.268	0.009	8.543	0.242	25.00	50	50
	7/03/2007	3.33	0.198	0.009	0.565	0.016	30.70	50	50
	8/07/2008	3.63	0.310	0.008	0.721	0.020	28.90	50	50
BUSL-201-T	9/09/2009	3.90	0.158	0.008	1.085	0.031	16.00	50	50
	8/19/2010	3.23	0.148	0.007	1.482	0.042	23.84	50	50
	7/13/2011	2.43	0.208	0.006	1.156	0.033	20.77	50	40
	8/20/2012	2.85	0.213	0.007	1.442	0.041	21.73	50	50
	8/19/2013	2.93	0.250	0.009	1.442	0.041	25.89	50	50
	7/22/2014	3.03	0.195	0.009	1.330	0.038	24.05	50	50
	7/01/2015	3.95	0.208	0.008	3.800	0.108	19.60	50	50
	7/01/2016	3.33	0.178	0.008	2.170	0.061	29.39	50	50
	6/28/2017	4.70	0.290	0.008	1.193	0.034	13.65	50	50
	7/25/2001	2.20	0.100	0.003	0.007	0.000	7.50	15	2
	8/22/2002	2.13	0.085	0.007	0.028	0.001	11.80	50	5
	7/17/2003	2.65	0.220	0.006	1.587	0.045	16.00	50	12
	9/27/2004	2.45	0.225	0.006	1.083	0.031	14.30	50	50
	6/23/2005	3.65	0.280	0.007	0.806	0.023	18.00	50	50
	6/06/2006	3.10	0.320	0.006	0.909	0.026	22.00	50	50
	7/03/2007	2.53	0.240	0.006	0.510	0.014	*	50	50
	8/07/2008	2.68	0.220	0.006	0.441	0.012	10.10	50	50
BUSL-202-T	9/09/2009	2.43	0.225	0.006	0.936	0.026	*	50	50
	8/27/2010	2.15	0.225	0.007	0.738	0.021	*	50	50
	7/13/2011	3.00	0.310	0.007	4.075	0.115	10.85	50	50
	8/20/2012	3.13	0.358	0.005	1.437	0.041	7.38	50	50
	8/16/2013	3.45	0.348	0.002	1.311	0.037	18.54	50	50
	7/22/2014	3.35	0.358	0.005	0.928	0.026	26.36	50	50
	7/01/2015	3.25	0.275	0.005	3.837	0.109	34.60	50	50
	7/08/2016	3.18	0.430	0.005	1.509	0.043	8.97	50	50
	6/28/2017	3.18	0.348	0.005	0.685	0.019	3.00	50	50

Table A-1. (Continued)

Station ID	Date Sampled	Avg. Wetted Width (m)	Avg. Thalweg Depth (m)	Slope	Discharge (cfs)	Discharge (m^3/s)	D50 (mm)	Riparian Width Left Bank (m)	Riparian Width Right Bank (m)
BUSL-103-T	7/11/2001	2.03	0.155	0.007	0.160	0.005	4.80	15	50
	7/18/2003	2.08	0.245	0.007	0.667	0.019	15.80	30	50
	9/24/2004	2.23	0.115	0.007	0.400	0.011	13.50	20	50
	6/23/2005	1.80	0.150	0.015	0.192	0.005	15.00	50	50
	6/09/2006	1.48	0.175	0.014	0.195	0.006	22.70	15	50
	6/26/2007	2.00	0.165	0.008	0.162	0.005	24.10	25	50
	8/15/2008	1.53	0.115	0.005	0.164	0.005	26.70	50	50
	9/15/2009	2.13	0.175	0.008	0.239	0.007	26.20	50	50
	8/19/2010	2.03	0.135	0.007	0.359	0.010	40.67	50	50
	7/14/2011	2.00	0.220	0.004	0.363	0.010	11.19	50	50
	7/25/2012	1.85	0.208	0.009	0.689	0.019	25.81	50	50
	8/16/2013	1.90	0.200	0.007	0.557	0.016	24.26	50	50
	7/17/2014	1.90	0.145	0.010	0.242	0.007	26.52	50	50
	6/17/2015	1.53	0.125	0.011	0.400	0.011	40.27	50	50
	6/30/2016	1.83	0.168	0.010	0.661	0.019	20.84	50	50
	7/26/2017	1.63	0.130	0.010	0.325	0.009	15.66	50	50
BUSL-104-T	7/10/2001	1.70	0.053	0.018	0.131	0.004	4.50	10	40
	8/22/2002	1.10	0.045	0.017	0.020	0.001	14.90	20	50
	7/18/2003	1.50	0.095	0.019	0.055	0.002	24.00	40	50
	8/27/2004	1.63	0.065	0.015	0.112	0.003	22.00	35	50
	6/23/2005	1.45	0.055	0.015	0.054	0.002	25.00	25	50
	6/09/2006	2.03	0.075	0.014	0.048	0.001	27.50	25	50
	6/26/2007	1.43	0.068	0.014	0.109	0.003	28.50	30	50
	8/15/2008	1.45	0.053	0.014	0.051	0.001	10.80	17	50
	9/09/2009	1.88	0.063	0.014	0.117	0.003	20.20	20	50
	8/27/2010	1.63	0.060	0.014	0.073	0.002	29.06	30	50
	7/14/2011	1.65	0.080	0.014	0.134	0.004	14.43	20	50
	7/25/2012	2.65	0.095	0.014	0.397	0.011	17.10	20	50
	8/15/2013	1.65	0.065	0.015	0.375	0.011	23.59	30	50
	8/14/2014	2.18	0.078	0.014	0.063	0.002	16.00	30	50
	6/17/2015	2.08	0.078	0.014	0.151	0.004	17.65	20	50
	6/30/2016	2.28	0.075	0.014	0.097	0.003	13.18	20	50
	7/26/2017	1.45	0.063	0.013	0.063	0.002	12.58	20	50

* Water depth at cross-section location was too deep to perform a pebble count.

Table A-2. Summary of historic qualitative habitat data from Peter Pan Run following Montgomery County, MD protocols

Station ID	Date Sampled	Instream Cover (Fish) (0-20)	Epifaunal Substrate (0-20)	Embed-dedness (0-20)	Channel Alteration (0-20)	Sediment Deposition (0-20)	Frequency of Riffles (0-20)	Channel Flow Status (0-20)	Bank Vegetative Protection Left Bank (0-10)	Bank Vegetative Protection Right Bank (0-10)	Bank Stability Left Bank (0-10)	Bank Stability Right Bank (0-10)	Riparian Vegetative Zone Width Left Bank (0-10)	Riparian Vegetative Zone Width Right Bank (0-10)	Total Qualitative Habitat Score (Max. 200)	Habitat Assessment Category
BUSL-201-T	6/7/99	8	14	9	18	15	14	15	8	9	7	8	8	7	140	Sub-Optimal
	10/6/99	6	12	10	18	3	18	16	3	3	3	3	7	8	110	Marginal to Sub-Optimal
	4/20/00	12	18	6	19	8	18	14	3	6	1	3	9	9	126	Sub-Optimal
	10/6/00	11	13	8	18	3	14	15	4	5	2	5	10	4	112	Marginal to Sub-Optimal
BUSL-202-T	6/8/99	8	11	8	13	7	16	10	7	8	7	7	3	6	111	Marginal to Sub-Optimal
	10/6/99	12	15	6	17	7	9	15	5	5	1	2	1	2	97	Marginal
	4/20/00	14	16	7	18	7	18	11	2	7	1	3	9	5	118	Sub-Optimal
	10/6/00	2	11	5	18	4	18	14	3	5	0	0	8	6	94	Marginal
BUSL-103-T	6/8/99	11	15	10	16	11	16	10	3	3	3	4	10	10	122	Sub-Optimal
	10/6/99	11	8	4	16	6	12	19	1	2	3	4	9	9	104	Marginal to Sub-Optimal
	4/19/00	8	13	6	17	3	11	10	4	8	2	6	10	9	107	Marginal to Sub-Optimal
	10/6/00	15	16	8	19	9	14	7	2	3	3	4	9	5	114	Sub-Optimal
BUSL-104-T	6/21/99	10	12	11	18	6	16	12	3	3	2	2	8	3	106	Marginal to Sub-Optimal
	10/7/99	4	12	2	16	3	19	7	2	2	3	4	3	5	82	Marginal
	4/19/00	12	19	8	19	5	18	10	1	1	1	1	10	9	114	Sub-Optimal
	10/3/00	4	14	2	12	2	18	6	2	2	2	2	10	5	81	Marginal

Table A-3. Summary of *in situ* water quality data for Peter Pan Run						
Station ID	**Date Sampled**	**Water Temperature (˚C)**	**Dissolved Oxygen (mg/l)**	**pH**	**Specific Conductance (mS/cm)**	**Turbidity (NTU)**
BUSL-201-T	11-Jun-99	19.26	8.74	7.53	0.250	4.1
	12-Oct-99	10.19	10.92	7.43	0.151	12.3
	20-Apr-00	10.60	7.51	7.01	0.190	4.0
	28-Sep-00	11.63	10.93	6.97	0.224	19.5
	23-Apr-01	14.26	11.78	8.16	0.245	0.6
	12-Jul-01	16.60	11.20	7.40	0.244	14.4
	21-Mar-02	6.80	12.02	5.08	0.226	19.7
	22-Aug-02	20.20	7.36	6.89	0.282	4.9
	26-Mar-03	*	*	*	*	*
	17-Jul-03	17.87	3.90	6.77	0.288	0.0
	29-Apr-04	16.52	*	7.69	0.265	*
	24-Sep-04	16.30	8.70	6.60	0.284	9.2
	04-Mar-05	4.70	12.00	6.98	0.318	96.1
	23-Jun-05	15.70	9.20	7.52	0.318	19.2
	01-Mar-06	5.33	13.91	8.60	0.286	3.2
	06-Jun-06	18.20	9.60	7.54	0.652	2.3
	09-Apr-07	3.40	15.10	6.12	0.632	5.7
	03-Jul-07	15.40	9.70	6.47	0.730	10.5
	23-Apr-08	12.60	10.10	7.53	0.331	23.0
	07-Aug-08	19.10	8.10	7.85	0.377	11.5
	10-Mar-09	5.90	7.80	7.46	0.469	13.1
	09-Sep-09	17.80	8.70	7.74	0.414	16.0
	24-Mar-10	7.80	*	7.07	0.353	*
	19-Aug-10	20.40	8.80	7.66	0.380	-11.0
	06-Apr-11	6.30	14.20	7.09	0.322	7.7
	13-Jul-11	20.70	8.70	7.70	0.413	16.4
	21-Mar-12	13.49	9.52	7.99	0.379	6.1
	20-Aug-12	19.00	9.10	7.38	0.348	9.2
	11-Mar-13	6.60	12.30	6.93	0.517	25.2
	19-Aug-13	17.00	9.00	7.42	0.437	15.9
	09-Apr-14	7.20	12.80	8.03	0.598	1.1
	22-Jul-14	18.70	7.82	7.42	0.466	7.4
	20-Mar-15	4.00	12.70	7.66	0.675	3.5
	01-Jul-15	18.00	8.70	7.57	0.488	4.7
	07-Mar-16	5.60	13.60	7.89	0.488	1.0
	01-Jul-16	17.20	8.79	7.50	0.452	3.5
	21-Mar-17	8.00	12.30	7.63	0.626	0.2
	28-Jun-17	13.50	9.64	7.66	0.482	5.5
BUSL-202-T	08-Jun-99	20.68	8.27	7.37	0.252	32.5
	06-Oct-99	10.37	11.00	7.26	0.159	13.3
	20-Apr-00	8.10	6.76	7.04	0.193	8.1
	06-Oct-00	17.97	8.17	7.97	0.299	8.5
	23-Apr-01	14.19	11.62	8.06	0.254	13.3

Table A-3. (Continued)						
Station ID	**Date Sampled**	**Water Temperature (˚C)**	**Dissolved Oxygen (mg/l)**	**pH**	**Specific Conductance (mS/cm)**	**Turbidity (NTU)**
BUSL-202-T (Continued)	25-Jul-01	24.50	9.10	7.56	0.261	11.4
	21-Mar-02	9.99	11.19	5.54	0.242	18.3
	22-Aug-02	22.00	8.27	6.68	0.271	9.4
	26-Mar-03	*	*	*	*	*
	17-Jul-03	21.07	5.13	6.83	0.307	0.9
	29-Apr-04	18.75	*	7.60	0.275	*
	27-Sep-04	16.40	8.80	6.83	0.336	11.6
	04-Mar-05	4.60	12.40	6.57	0.552	83.1
	23-Jun-05	21.20	11.40	7.84	0.332	73.9
	01-Mar-06	3.02	12.90	7.72	0.342	3.2
	06-Jun-06	15.60	9.80	7.38	0.682	18.7
	09-Apr-07	3.30	15.70	6.08	0.626	5.9
	03-Jul-07	18.80	10.50	7.72	1.121	11.7
	23-Apr-08	13.40	10.00	7.50	0.346	21.2
	07-Aug-08	20.70	8.40	7.91	0.392	11.5
	11-Mar-09	7.20	12.50	7.99	0.329	16.4
	09-Sep-09	19.30	8.60	7.93	0.435	29.8
	24-Mar-10	8.20	*	7.44	0.377	*
	27-Aug-10	16.50	9.30	7.63	0.459	15.3
	06-Apr-11	7.50	13.90	7.13	0.531	4.3
	13-Jul-11	22.30	9.50	7.89	0.435	16.2
	21-Mar-12	13.84	9.82	8.09	0.400	7.6
	20-Aug-12	19.80	9.90	7.65	0.356	10.3
	11-Mar-13	7.90	14.40	7.80	0.541	37.9
	16-Aug-13	17.20	10.30	7.64	0.446	31.5
	09-Apr-14	10.70	13.40	8.54	0.631	1.9
	22-Jul-14	19.90	7.88	7.70	0.500	4.1
	20-Mar-15	4.00	13.30	7.63	0.743	6.6
	01-Jul-15	19.50	8.70	7.67	0.525	4.4
	07-Mar-16	6.90	13.70	7.85	0.519	1.7
	08-Jul-16	20.80	8.64	7.63	0.490	7.3
	21-Mar-17	8.80	12.20	7.86	0.667	8.1
	28-Jun-17	16.20	10.06	7.77	0.503	5.5
BUSL-103-T	08-Jun-99	18.25	7.14	7.10	0.200	172.0
	06-Oct-99	11.32	11.25	7.47	0.136	2.2
	19-Apr-00	14.80	8.37	7.13	0.181	4.9
	23-Sep-00	14.75	9.87	6.85	0.229	4.1
	23-Apr-01	13.95	12.05	7.80	0.232	0.6
	11-Jul-01	18.90	5.80	6.65	0.143	10.6
	21-Mar-02	11.26	10.73	5.76	0.218	10.3
	22-Aug-02	**	**	**	**	**
	26-Mar-03	*	*	*	*	*

Table A-3. (Continued)						
Station ID	**Date Sampled**	**Water Temperature (˚C)**	**Dissolved Oxygen (mg/l)**	**pH**	**Specific Conductance (mS/cm)**	**Turbidity (NTU)**
BUSL-103-T (Continued)	18-Jul-03	18.02	13.50	6.78	0.260	0.0
	29-Apr-04	21.65	*	7.54	0.260	*
	24-Sep-04	16.10	13.00	6.83	0.281	4.6
	04-Mar-05	4.80	11.70	6.59	0.302	56.6
	23-Jun-05	17.00	9.70	6.96	0.300	15.5
	03-Mar-06	2.99	13.88	7.19	0.292	4.1
	09-Jun-06	16.50	8.20	7.45	0.318	6.8
	13-Apr-07	7.10	12.30	6.28	0.558	8.5
	26-Jun-07	19.00	9.00	7.61	1.072	15.2
	23-Apr-08	15.70	10.00	7.52	0.348	26.5
	15-Aug-08	18.80	8.20	7.45	0.369	29.0
	11-Mar-09	8.40	13.30	8.06	0.324	15.2
	15-Sep-09	16.60	8.10	7.65	0.432	14.9
	24-Mar-10	10.80	*	7.66	0.360	*
	19-Aug-10	21.50	8.60	7.56	0.417	8.8
	06-Apr-11	10.20	13.80	7.42	0.479	3.5
	14-Jul-11	19.10	8.90	7.71	0.345	11.7
	20-Mar-12	15.07	10.31	7.70	0.496	8.4
	25-Jul-12	20.10	9.00	7.49	0.379	2.7
	11-Mar-13	9.40	14.50	8.53	0.461	28.4
	16-Aug-13	15.50	10.40	7.99	0.416	27.0
	14-Apr-14	15.00	10.90	8.04	0.536	1.0
	17-Jul-14	18.70	8.51	7.36	0.490	2.0
	13-Mar-15	4.10	14.10	7.32	0.789	2.2
	17-Jun-15	18.60	8.60	7.78	0.597	2.6
	07-Mar-16	5.10	14.30	7.77	0.488	0.8
	30-Jun-16	17.60	9.09	7.76	0.456	0.8
	21-Mar-17	7.20	12.30	7.17	0.631	6.9
	26-Jul-17	16.30	9.24	7.15	0.454	6.1
BUSL-104-T	24-Jun-99	14.04	8.89	7.40	0.197	7.9
	07-Oct-99	13.99	9.97	7.51	0.124	164.0
	19-Apr-00	9.93	12.87	7.03	0.166	25.0
	03-Oct-00	18.22	8.23	7.77	0.160	57.8
	23-Apr-01	12.77	11.53	7.85	0.220	14.4
	10-Jul-01	23.10	6.50	6.82	0.112	44.3
	22-Mar-02	4.46	11.94	5.03	0.341	261.8
	22-Aug-02	21.30	7.70	6.63	0.222	14.4
	26-Mar-03	*	*	*	*	*
	18-Jul-03	16.86	8.40	6.69	0.224	8.3
	29-Apr-04	17.13	*	7.32	0.205	*
	27-Aug-04	19.10	10.00	6.84	0.241	37.6
	04-Mar-05	5.60	12.90	6.44	0.576	75.6

Table A-3. (Continued)

Station ID	Date Sampled	Water Temperature (˚C)	Dissolved Oxygen (mg/l)	pH	Specific Conductance (mS/cm)	Turbidity (NTU)
BUSL-104-T (continued)	23-Jun-05	17.10	11.10	7.33	0.257	20.4
	03-Mar-06	6.31	13.45	7.63	0.216	5.6
	09-Jun-06	16.30	8.90	7.49	0.273	17.0
	13-Apr-07	8.40	12.30	5.64	0.558	437.7
	26-Jun-07	18.90	6.20	7.69	1.106	21.2
	23-Apr-08	16.60	9.00	7.47	0.276	5.3
	15-Aug-08	22.00	7.80	7.60	0.173	25.5
	10-Mar-09	8.20	14.50	7.64	0.403	23.8
	09-Sep-09	19.00	8.30	8.00	0.272	24.2
	24-Mar-10	11.20	*	7.08	0.616	*
	27-Aug-10	18.10	9.20	7.76	0.380	12.0
	06-Apr-11	10.40	12.70	7.28	0.710	10.2
	14-Jul-11	22.20	8.00	7.65	0.466	13.5
	20-Mar-12	16.40	9.61	7.23	0.813	9.3
	25-Jul-12	21.50	8.60	7.60	0.358	5.6
	13-Mar-13	9.30	11.10	7.48	0.338	156.2
	15-Aug-13	17.80	9.80	7.75	0.423	31.3
	14-Apr-14	14.80	10.50	7.82	0.650	4.1
	14-Aug-14	18.70	7.87	7.37	0.363	7.2
	13-Mar-15	4.70	12.60	7.10	0.900	11.3
	17-Jun-15	20.00	8.20	7.69	0.413	20.1
	07-Mar-16	6.50	12.90	7.75	0.599	2.1
	30-Jun-16	16.60	8.69	7.64	0.442	8.7
	21-Mar-17	9.00	12.20	7.43	0.942	8.1
	26-Jul-17	17.80	8.86	7.65	0.418	4.9

* - Data not collected due to equipment malfunction.
** - Stream was dry.

Table A-4. Summary of benthic macroinvertebrate data from Peter Pan Run using MBSS 2005 IBI

Station ID	Date Sampled	Number of Taxa	Benthic IBI Score	Benthic IBI Rating
BUSL-201-T	4/23/2001	20	1.50	Very Poor
	3/21/2002	38	3.25	Fair
	3/26/2003	17	2.25	Poor
	4/29/2004	21	1.50	Very Poor
	3/04/2005	25	2.50	Poor
	3/01/2006	34	2.50	Poor
	4/09/2007	16	2.00	Poor
	4/23/2008	25	2.50	Poor
	3/10/2009	28	2.25	Poor
	3/24/2010	29	3.00	Fair
	4/06/2011	31	2.25	Poor
	3/21/2012	22	2.00	Poor
	3/11/2013	37	3.25	Fair
	4/09/2014	25	2.50	Poor
	3/20/2015	27	2.00	Poor
	3/07/2016	35	2.00	Poor
	3/21/2017	35	3.25	Fair
BUSL-202-T	4/23/2001	19	2.00	Poor
	3/21/2002	33	3.25	Fair
	3/26/2003	22	2.25	Poor
	4/29/2004	26	2.00	Poor
	3/04/2005	32	2.75	Poor
	3/01/2006	39	2.25	Poor
	4/09/2007	20	2.25	Poor
	4/23/2008	39	3.50	Fair
	3/11/2009	34	2.25	Poor
	3/24/2010	33	3.50	Fair
	4/06/2011	25	2.75	Poor
	3/21/2012	33	2.25	Poor
	3/11/2013	33	3.50	Fair
	4/09/2014	18	2.00	Poor
	3/20/2015	26	2.75	Poor
	3/07/2016	39	2.25	Poor
	3/21/2017	22	2.25	Poor
BUSL-103-T	4/23/2001	32	3.50	Fair
	3/21/2002	29	3.75	Fair
	3/26/2003	14	1.75	Very Poor
	4/29/2004	24	2.50	Poor
	3/04/2005	26	3.25	Fair
	3/03/2006	29	2.75	Poor
	4/13/2007	29	2.50	Poor
	4/23/2008	38	3.00	Fair
	3/11/2009	31	2.25	Poor
	3/24/2010	23	2.75	Poor
	4/06/2011	28	3.25	Fair

Table A-4. (Continued)				
Station ID	**Date Sampled**	**Number of Taxa**	**Benthic IBI Score**	**Benthic IBI Rating**
BUSL-103-T (continued)	3/20/2012	19	2.00	Poor
	3/11/2013	27	3.00	Fair
	4/14/2014	31	2.75	Poor
	3/13/2015	20	1.75	Very Poor
	3/07/2016	32	2.25	Poor
	3/21/2017	30	2.5	Poor
BUSL-104-T	4/23/2001	25	2.00	Poor
	3/22/2002	23	2.50	Poor
	3/26/2003	31	2.00	Poor
	4/29/2004	11	1.75	Very Poor
	3/04/2005	18	2.00	Poor
	3/03/2006	34	2.50	Poor
	4/13/2007	17	2.00	Poor
	4/23/2008	29	2.25	Poor
	3/10/2009	22	1.50	Very Poor
	3/24/2010	32	2.25	Poor
	4/06/2011	22	1.75	Very Poor
	3/20/2012	20	1.50	Very Poor
	3/13/2013	15	2.25	Poor
	4/14/2014	22	2.00	Poor
	3/13/2015	20	2.00	Poor
	3/07/2016	25	1.75	Very Poor
	3/21/2017	15	1.75	Very Poor

Table A-5. Summary of fish data from Peter Pan Run using MBSS 2005 IBI

Station ID	Date Sampled	Number of Taxa	Number of Fish Captured	Percent of Tolerant Individuals	Fish IBI Score	Fish IBI Rating
BUSL-201-T	10/12/1999	9	373	81.23	3.33	Fair
	9/28/2000	10	390	77.69	3.67	Fair
	7/12/2001	5	684	66.96	3.67	Fair
	8/22/2002	5	429	74.13	3.67	Fair
	7/17/2003	12	424	53.30	4.33	Good
	9/24/2004	11	1166	71.44	3.67	Fair
	6/23/2005	12	1033	58.57	4.33	Good
	6/06/2006	11	1059	57.98	4.00	Good
	7/03/2007	10	901	60.60	4.00	Good
	8/07/2008	14	645	66.82	3.67	Fair
	9/09/2009	12	703	74.96	3.67	Fair
	8/19/2010	12	772	69.04	3.67	Fair
	7/13/2011	13	706	56.94	3.67	Fair
	8/20/2012	15	680	60.15	3.67	Fair
	8/19/2013	17	672	45.39	4.33	Good
	7/22/2014	15	896	39.96	4.67	Good
	7/01/2015	12	527	50.47	3.67	Fair
	7/01/2016	15	954	49.90	3.67	Fair
	6/28/2017	17	1166	48.03	4.33	Good
BUSL-202-T	10/06/1999	*	*	*	*	Not Rated
	10/06/2000	*	*	*	*	Not Rated
	7/25/2001	9	767	74.97	3.67	Fair
	8/22/2002	9	555	89.91	3.33	Fair
	7/17/2003	10	319	70.22	3.67	Fair
	9/27/2004	12	1013	64.96	3.67	Fair
	6/23/2005	8	678	63.42	4.00	Good
	6/06/2006	10	560	63.57	3.67	Fair
	7/03/2007	9	405	60.99	4.00	Good
	8/07/2008	14	350	61.14	3.67	Fair
	9/09/2009	13	320	55.94	3.67	Fair
	8/27/2010	15	1047	61.60	3.67	Fair
	7/13/2011	16	772	54.79	4.33	Good
	8/20/2012	14	400	58.75	3.67	Fair
	8/16/2013	16	570	51.05	4.00	Good
	7/22/2014	11	489	54.19	3.67	Fair
	7/01/2015	14	551	56.26	3.67	Fair
	7/08/2016	12	765	61.83	3.67	Fair
	6/28/2017	15	1051	56.52	3.67	Fair

Table A-5. (Continued)

Station ID	Date Sampled	Number of Taxa	Number of Fish Captured	Percent of Tolerant Individuals	Fish IBI Score	Fish IBI Rating
BUSL-103-T	10/06/1999	2	36	94.44	2.33	Poor
	9/23/2000	5	260	94.23	3.00	Fair
	7/11/2001	5	403	86.85	3.33	Fair
	7/18/2003	3	157	80.89	3.33	Fair
	9/24/2004	5	607	88.14	3.33	Fair
	6/23/2005	7	574	86.24	3.33	Fair
	6/09/2006	5	521	79.27	3.67	Fair
	6/26/2007	6	446	77.35	3.67	Fair
	8/15/2008	5	545	76.88	3.67	Fair
	9/15/2009	4	590	82.54	3.33	Fair
	8/19/2010	9	583	81.65	3.33	Fair
	7/14/2011	8	726	67.63	3.67	Fair
	7/25/2012	7	389	69.92	3.67	Fair
	8/16/2013	8	732	55.05	4.33	Good
	7/17/2014	7	726	47.11	4.33	Good
	6/17/2015	4	513	61.60	4.00	Good
	6/30/2016	4	585	75.38	3.67	Fair
	7/26/2017	6	774	56.98	4.33	Good
BUSL-104-T	10/07/1999	*	*	*	*	Not Rated
	10/03/2000	1	12	100.00	1.00	Very Poor
	7/10/2001	2	63	100.00	1.33	Very Poor
	8/22/2002	2	54	100.00	1.67	Very Poor
	7/18/2003	4	79	100.00	1.67	Very Poor
	8/27/2004	2	118	100.00	1.67	Very Poor
	6/23/2005	3	52	100.00	1.33	Very Poor
	6/09/2006	3	147	98.64	2.00	Poor
	6/26/2007	3	55	94.55	2.00	Poor
	8/15/2008	4	249	98.80	2.00	Poor
	9/09/2009	3	135	100.00	1.67	Very Poor
	8/27/2010	4	177	99.44	1.67	Very Poor
	7/14/2011	3	104	98.08	2.00	Poor
	7/25/2012	5	227	97.80	2.00	Poor
	8/15/2013	3	343	99.42	1.67	Very Poor
	8/14/2014	5	259	90.35	2.67	Poor
	6/17/2015	2	191	98.43	2.00	Poor
	6/30/2016	3	229	98.69	2.00	Poor
	7/26/2017	3	135	99.26	1.67	Very Poor

* Fish data not collected

Table A-6. Qualitative habitat scores using MBSS protocols for Peter Pan Run.

Station ID	Date Sampled	Instream Habitat (0-20)	Epifaunal Substrate (0-20)	Velocity-Depth Diversity (0-20)	Pool-Glide Quality (0-20)	Riffle-Run Quality (0-20)	Embed-dedness (%)	Shading (%)	Physical Habitat Index Score	Physical Habitat Index Rating
BUSL-201-T	10/12/1999	7	13	*	*	*	50	63	*	Not Rated
	9/28/2000	12	15	*	*	*	70	51	*	Not Rated
	7/12/2001	13	11	13	8	13	25	90	70.15	Partially Degraded
	8/22/2002	10	14	6	7	8	35	85	85.53	Minimally Degraded
	7/17/2003	10	12	14	12	13	30	70	73.64	Partially Degraded
	9/24/2004	17	12	13	13	14	50	60	74.67	Partially Degraded
	6/23/2005	13	11	14	14	13	50	65	76.39	Partially Degraded
	6/06/2006	13	10	14	13	10	45	60	70.34	Partially Degraded
	7/03/2007	12	9	13	12	13	50	65	67.68	Partially Degraded
	8/07/2008	12	10	14	13	12	50	70	69.95	Partially Degraded
	9/09/2009	16	15	15	14	14	60	65	74.94	Partially Degraded
	8/19/2010	14	13	14	15	13	50	50	70.84	Partially Degraded
	7/13/2011	10	9	13	13	13	60	60	66.78	Partially Degraded
	8/20/2012	12	10	14	13	13	50	50	66.19	Partially Degraded
	8/19/2013	14	13	13	14	17	55	40	65.29	Degraded
	7/22/2014	14	15	12	13	15	35	70	81.99	Minimally Degraded
	7/01/2015	10	12	15	16	13	50	75	74.53	Partially Degraded
	7/01/2016	14	14	14	17	14	40	60	75.39	Partially Degraded
	6/28/2017	13	11	12	16	12	50	85	76.31	Partially Degraded
BUSL-202-T	10/06/1999	10	13	*	*	*	53	60	*	Not Rated
	10/06/2000	10	13	*	*	*	43	57	*	Not Rated
	7/25/2001	7	12	14	10	10	70	20	47.43	Severely Degraded
	8/22/2002	8	12	6	7	8	30	75	71.67	Partially Degraded
	7/17/2003	11	8	14	12	8	30	75	66.99	Partially Degraded
	9/27/2004	17	12	13	13	14	50	55	75.26	Partially Degraded
	6/23/2005	13	11	13	13	12	60	65	80.02	Partially Degraded
	6/06/2006	12	9	13	13	10	40	70	75.16	Partially Degraded
	7/03/2007	10	8	8	9	11	50	65	62.63	Degraded
	8/07/2008	11	9	12	12	11	45	65	65.45	Degraded
	9/09/2009	14	13	14	13	13	60	65	61.23	Degraded
	8/27/2010	11	11	13	13	10	60	70	66.14	Partially Degraded
	7/13/2011	12	6	12	10	12	50	60	60.88	Degraded

Table A-6. (Continued)

Station ID	Date Sampled	Instream Habitat (0-20)	Epifaunal Substrate (0-20)	Velocity-Depth Diversity (0-20)	Pool-Glide Quality (0-20)	Riffle-Run Quality (0-20)	Embed-dedness (%)	Shading (%)	Physical Habitat Index Score	Physical Habitat Index Rating
BUSL-202-T (continued)	8/20/2012	10	9	13	11	13	55	60	66.42	Partially Degraded
	8/16/2013	14	13	14	12	15	35	60	63.68	Degraded
	7/22/2014	14	11	13	12	14	35	65	71.83	Partially Degraded
	7/01/2015	8	8	13	13	10	45	65	67.61	Partially Degraded
	7/08/2016	11	11	13	13	14	35	70	71.91	Partially Degraded
	6/28/2017	11	9	12	16	11	50	50	66.10	Partially Degraded
BUSL-103-T	10/06/1999	11	12	*	*	*	63	67	*	Not Rated
	9/23/2000	11	15	*	*	*	30	53	*	Not Rated
	7/11/2001	9	10	11	10	9	20	95	72.16	Partially Degraded
	7/18/2003	8	7	10	6	8	35	90	65.49	Degraded
	9/24/2004	13	11	9	8	8	45	40	60.07	Degraded
	6/23/2005	12	11	8	9	8	60	70	73.26	Partially Degraded
	6/09/2006	12	8	8	10	7	50	60	49.08	Severely Degraded
	6/26/2007	13	10	8	8	11	60	65	57.13	Degraded
	8/15/2008	11	8	8	8	9	70	65	57.97	Degraded
	9/15/2009	12	11	9	9	13	55	50	56.81	Degraded
	8/19/2010	12	10	8	9	11	65	40	51.15	Degraded
	7/14/2011	13	13	8	7	14	50	70	62.58	Degraded
	7/25/2012	12	12	8	8	14	55	60	59.67	Degraded
	8/16/2013	12	11	8	6	13	40	75	68.30	Partially Degraded
	7/17/2014	13	15	9	8	14	25	70	72.38	Partially Degraded
	6/17/2015	8	11	8	8	9	30	75	69.82	Partially Degraded
	6/30/2016	9	9	9	7	12	35	70	66.34	Partially Degraded
	7/26/2017	8	7	7	6	12	45	65	63.05	Degraded
BUSL-104-T	10/07/1999	7	12	*	*	*	17	90	*	Not Rated
	10/03/2000	8	16	*	*	*	70	87	*	Not Rated
	7/10/2001	9	8	6	2	12	30	95	53.81	Degraded
	8/22/2002	7	15	6	6	10	25	95	65.77	Degraded
	7/18/2003	7	8	7	6	9	45	95	58.17	Degraded
	8/27/2004	12	12	8	8	10	45	95	67.80	Partially Degraded
	6/23/2005	7	5	7	6	6	75	90	55.21	Degraded
	6/09/2006	12	11	7	8	7	50	85	52.64	Degraded

Table A-6. (Continued)

Station ID	Date Sampled	Instream Habitat (0-20)	Epifaunal Substrate (0-20)	Velocity-Depth Diversity (0-20)	Pool-Glide Quality (0-20)	Riffle-Run Quality (0-20)	Embed-dedness (%)	Shading (%)	Physical Habitat Index Score	Physical Habitat Index Rating
BUSL-104-T (continued)	6/26/2007	9	11	7	5	7	70	90	61.71	Degraded
	8/15/2008	9	5	8	8	7	75	90	52.21	Degraded
	9/09/2009	11	11	7	8	7	60	90	58.23	Degraded
	8/27/2010	10	8	7	7	8	70	85	49.66	Severely Degraded
	7/14/2011	8	8	7	7	8	70	80	54.41	Degraded
	7/25/2012	8	7	7	7	9	70	85	50.86	Severely Degraded
	8/16/2013	10	9	9	8	11	45	90	61.48	Degraded
	8/14/2014	12	13	8	8	12	40	75	61.72	Degraded
	6/17/2015	8	7	6	8	6	35	80	58.86	Degraded
	6/30/2016	7	11	8	7	9	40	90	63.49	Degraded
	7/26/2017	7	8	7	6	7	65	80	55.56	Degraded

* Physical habitat data not collected

APPENDIX B

METHODS FOR ESTIMATING POLLUTANT LOADING IN PETER PAN RUN

Methods for Estimating Pollutant Loading in Peter Pan Run

Calculation factors used to estimate pollutant loadings at Peter Pan Run and at Pond R Outfall were determined as follows:

- Flow rate data (in cfs) used for loading determination were measured from July 1, 2016 to June 30, 2017, by an ISCO flowmeter. Stormflow and baseflow were separated by noting where the hydrograph increased due to rain and then decreased to a base level. Stormflows are considered flows that occurred during periods of elevated level due to rain. Baseflows are the flows measured at all other times. The average stormflow rate and baseflow rate were calculated for each month. Those averages were combined together to obtain a stormflow grand average and baseflow grand average for the period of record. The proportion of discharge characterized as baseflow and stormflow are given in Table B-1.

Table B-1. Proportion of discharge characterized as baseflow and stormflow at both Peter Pan Run stations

Location	Percent Baseflow	Percent Stormflow	Days Baseflow	Days Stormflow	Volume Baseflow (acre ft)	Volume Stormflow (acre ft)
Outfall	87.7%	12.3%	320	45	43.4	164.8
Instream*	87.1%	12.9%	302	45	902.6	783.7

* Due to a flowmeter malfunction at the instream monitoring station, erroneous data were excluded from analyses, and resultant days of flow are less than the 365-day calendar year.

- With the total volume of water calculated, and the concentrations given, the total pollutant loads were calculated.

- Some pollutant concentrations were below the detection limit for the method used to analyze the pollutant in the sample. In these cases a range of values are offered. The lower value was calculated assuming the pollutant concentration was zero. The higher value was calculated assuming the pollutant concentration was the concentration of the detection limit.