National Pollutant Discharge Elimination System
Municipal Separate Storm Sewer System
Permit No. 11-DP-3313 MD0068276
Permit Term October 9, 2015 to October 8, 2020

Fifth Annual Report
October 9, 2020

Submitted to:

Sediment, Stormwater, and Dam Safety Program
Water and Science Administration
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230

Submitted by:

Maryland Department of Transportation
State Highway Administration
Office of Environmental Design
707 North Calvert Street, C-303
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MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

Larry Hogan
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Boyd K. Rutherford
Lt. Governor
Gregory Slater
Secretary
Tim Smith, P.E.
Administrator

October 9, 2020

Mr. Stewart Comstock, Chief
Sediment, Stormwater & Dam Safety Program
Water and Science Administration
Maryland Department of the Environment
1800 Washington Boulevard, Suite 440
Baltimore MD 21230

Dear Mr. Comstock:

The Maryland Department of Transportation State Highway Administration (MDOT SHA) Office of Environmental Design (OED) is pleased to submit the enclosed fifth annual report addressing conditions under the MDOT SHA National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System (NPDES MS4) discharge permit (#11-DP-33133 MD 0068276) effective October 9, 2015 through October 8, 2020. The report covers compliance efforts for fiscal year 2020 from July 1, 2019 to June 30, 2020. Point-by-point responses to the March 11 MDE comments on the MDOT SHA 2019 MS4 annual report are also enclosed.

If you have any questions or need additional information regarding this delivery, please contact Ms. Karen Coffman at 410-545-8407 and kcoffman@mdot.maryland.gov or me at 410-545-8640 and sram@mdot.maryland.gov. Ms. Coffman and I will be happy to assist you.

Sincerely,

Sonal Ram

Sonal Ram, P.E.
Director
Office of Environmental Design

Enclosures

cc: Mr. Brian Cooper, SSDSP, WSA, MDE
Ms. Dorothy Morrison, Director, Office of Environment, MDOT
Ms. Karen Coffman, Chief, Water Programs Division, OED, MDOT SHA
Mr. Kevin Wilsey, Deputy Director, OED, MDOT SHA

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Introduction

The following annual report was prepared by the Maryland Department of Transportation State Highway Administration (MDOT SHA) to demonstrate compliance from July 1, 2019 to June 30, 2020 (a.k.a., fiscal year 2020; referred to hereafter as "FY20") in accordance with conditions in Part V.A.1 of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) discharge permit number 11-DP-3313 MD0068276, effective October 9, 2015 and scheduled for expiration on October 8, 2020 (referred to hereafter as the "MS4 Permit"). MDOT SHA submitted its reapplication for NPDES stormwater discharge permit coverage as Attachment B to its fourth year, FY19 MS4 annual report received by the Maryland Department of the Environment (MDE) on October 8, 2019.

MDOT SHA officially requested a modification of its current MS4 Permit on February 13, 2019, to allow the use of nutrient trading to meet the 20 percent impervious surface restoration requirement by the end of the current permit term (i.e., October 8, 2020). MDE determined the use of nutrient credits by MDOT SHA for meeting the 20 percent impervious surface restoration requirement is acceptable and issued its final determination to modify the MS4 Permit on November 8, 2019. MDE modifications added a new paragraph, permitting nutrient trading to meet the restoration requirement described in Part IV.E.3, and renamed Part IV.E.3 and Part IV.E.4 from the original MS4 Permit as Part IV.E.4 and Part IV.E.5, respectively.

On September 1, 2020, MDOT released its Draft FY21 through FY26 Consolidated Transportation Program (CTP), which details MDOT's $13.4 billion six-year capital budget. The Draft CTP shows a $2.9 billion reduction compared to the $16.3 billion Final FY20 through FY25 CTP released in January 2020. This $2.9 billion reduction reflects capital budget reductions of $1.9 billion necessitated by revenue declines associated with the COVID-19 pandemic health crisis as well as project cash flow changes and completions following record-setting investments in transportation over the last several years. MDOT also is reducing its FY21 operating budget by $98 million to respond to the revenue decline. Incorporated into the CTP reductions are more than $900 million and $21 million of cuts applied respectively to MDOT SHA FY21 capital and operating budgets. The MS4 program at MDOT SHA has seen significant budget cuts for FY20 and FY21 that will impact some of the activities required under the permit as indicated throughout this report. Additional information regarding budgetary cuts, is provided on the MDOT website at the following address:

http://www.mdot.maryland.gov/News/Releases2020/September_1_2020_FY_2021_FY_2026_CTP.html

MDOT SHA has submitted, with this FY20 MS4 annual report, Geographic Information System (GIS) data (hereafter referred to as the "MS4 geodatabase") in electronic format and in accordance with Part V.A.2 of the MS4 Permit and Version 1.2 of the MDE NPDES MS4 Geodatabase Design and User's Guide distributed to permitted MS4s in May 2017. Additional data submitted electronically with this FY20 MS4 annual report include:

- Two independent geodatabases containing supplementary inventory information for MDOT SHA stormwater infrastructure and industrial sources not otherwise captured by the MDE MS4 geodatabase design. These data sets are submitted to demonstrate

compliance with conditions in Part IV.C of the MS4 Permit as described in the *Source Identification* section of this FY20 MS4 annual report.
- A Microsoft Excel workbook containing a comprehensive list of restoration Best Management Practices (BMPs) completed from 2011 to October 8, 2020, separated by contract, with associated location, impervious treatment, and cost information in accordance with conditions in Part IV.E.5.c of the MS4 Permit.

During each year of the current MS4 Permit term, MDOT SHA expended considerable resources and consistently made and reported progress toward meeting stormwater WLAs developed under approved TMDLs. Prior to the submittal date for this FY20 MS4 annual report, MDE has provided written comments in follow up to its review for each of the MDOT SHA FY16 through FY19 MS4 annual reports. In accordance with conditions in Part V.A.3 of the MS4 Permit MDOT SHA has provided written responses to all MDE comments and has implemented all applicable program modifications as requested by MDE.

MDOT SHA provided responses, dated March 19, 2020, to the MDE comments related to the FY18 MS4 annual report, dated September 16, 2019, as committed in the Introduction section of the FY19 MS4 annual report. MDE supplied MDOT SHA comments, dated March 11, 2020, related to the FY19 MS4 annual report and data submittal. MDOT SHA responses addressing the March 11, 2020 MDE comments are submitted in tandem to this FY20 MS4 annual report.

Permit Administration and Legal Authority

The MS4 Permit was administered during FY20 by the MDOT SHA Office of Environmental Design (OED) as described in Section A of the FY19 MS4 annual report. Contact information provided for the program liaison/coordinator and manager is consistent with that previous reporting. In accordance with conditions in Part IV.A of the MS4 Permit, MDOT SHA has provided an updated organizational chart describing staff roles in relation to NPDES stormwater tasks in Appendix IV.A to this FY20 MS4 annual report.

In accordance with conditions in Part IV.B of the MS4 Permit relative to 40 CFR 122.26, MDOT SHA maintained adequate legal authority for compliance with all permit conditions during the FY20 reporting period and carried out all inspection, surveillance, and monitoring procedures necessary to demonstrate compliance with MS4 Permit conditions. MDOT SHA has provided associated information within Appendices B and C to this FY20 MS4 annual report.

Status of Implementing the Stormwater Management Program

In the following subsections, MDOT SHA has provided the status of implementing the components of its stormwater management program that are established as conditions in the MS4 Permit. Stormwater program components reported in this FY20 MS4 annual report in accordance with conditions in Part V.A.1.a of the MS4 Permit include:

- Source Identification
- Stormwater Management
- Erosion and Sediment Control

- Illicit Discharge Detection and Elimination
- Trash and Litter
- Property Management and Maintenance
- Public Education
- Watershed Assessment
- Restoration Plans
- TMDL Compliance
- Assessment of Controls
- Program Funding

Source Identification

In accordance with conditions in Part IV.C.1 of the MS4 Permit and throughout FY20, MDOT SHA continued to maintain and improve its inventory of storm drain infrastructure, major outfalls, stormwater management facilities, and associated drainage areas as described in Section C.1 of the FY19 MS4 annual report. Due to time and budgetary constraints, data to update the inventory for surrounding stormwater facilities/infrastructure was captured during respective BMP/facility preventative maintenance inspections. This resulted in updates to the inventory across the MS4 permitted area during FY20.

During FY20 a new Outfall Inspection tool, as referenced in Section C.1 of the FY19 MS4 annual report, completed development and was launched to add condition information, including drainage areas, to inventory updates. Only a small sample of outfall inspections were implemented during FY20 utilizing the new tool since the product development, testing, and launch activities also occurred during the reporting period. As part of a MDOT SHA agencywide Asset Management effort that is under development, it is anticipated that additional funding and focus on this new aspect of inspections may grow once budgetary issues have been resolved.

MDOT SHA has provided the outfall structure information in the Outfall and OutfallDrainageArea feature classes in the MS4 geodatabase submitted with this FY20 MS4 annual report. Information for conveyance and other structures not represented by the MDE MS4 geodatabase design are provided in a supplemental geodatabase submitted with this FY20 MS4 annual report in a format consistent with the FY19 submission.

In accordance with conditions in Part IV.C.2 of the MS4 Permit, MDOT SHA has identified industrial sites within MDOT SHA right-of-way that have the potential to contribute pollutants to MDOT SHA storm drain systems. These include MDOT SHA-owned NPDES 12-SW permitted industrial sites but also salt storage areas, parking lots, rest areas, and other highly trafficked or material storage areas as requested by MDE. There are no commercial sites on MDOT SHA properties.

MDOT SHA has provided location and other information for NPDES 12-SW permitted industrial sites in the MunicipalFacilities feature class of the MS4 geodatabase submitted with this FY20 MS4 annual report. Information for non-permitted industrial sites identified by MDOT SHA is provided in a supplemental geodatabase submitted with this FY20 MS4 annual report in a format similar to the FY19 submission except MDOT SHA did not include sites located outside the MS4 permitted area or sites that are already represented in the MunicipalFacilities feature class of the MS4 geodatabase submitted with this FY20 MS4 annual report.

During FY20, updates to the inventory of Urban BMPs/SWM Facilities continued, including adjustments to the number of 2A grass swales on account of MDE comments, dated September 16, 2019, related to the MDOT SHA Impervious Area Assessment. In addition, the new version of the Water Quality Summary Sheet prompted changes to the database to include a distinction between new development and redevelopment SWM Facilities in design. Many existing facilities were not designed with this designation in mind and, in some cases, extensive research and analysis will be needed to include this information retroactively. This additional research and analysis is on hold due to the recent budget cuts. MDOT SHA has provided Urban BMP information in the BMPPOI feature class and the BMP table of the MS4 geodatabase submitted with this FY20 MS4 annual report.

As described in Section C.3 of the FY19 MS4 annual report, the MDOT SHA revised baseline analysis submitted in June 2018 included GIS data for its impervious surfaces. MDE found it acceptable that this information was not resubmitted with the FY19 MS4 annual report and MDOT SHA has similarly excluded it from the FY20 MS4 annual report. MDOT SHA has provided updates to the ImperviousSurface table of the MS4 geodatabase submitted with this FY20 MS4 annual report.

Monitoring site locations, established to meet conditions described in Part IV.F of the MS4 Permit, were revised as described in Section F.1 the FY19 MS4 annual report. These locations did not change during FY20. MDOT SHA has provided information for its monitoring sites in the MonitoringSite and MonitoringDrainageArea feature classes of the MS4 geodatabase submitted with this FY20 MS4 annual report.

In the MS4 geodatabase submitted with this FY20 MS4 annual report, MDOT SHA has provided information for its water quality improvement projects in the RestBMP, AltBMPLine, and AltBMPPoly feature classes as well as the StrmRestProtocols table. Submitted data includes projects completed through the end of the permit term as well as projects under construction that MDOT SHA expects to complete during FY21 and claim for restoration credit. It is anticipated, based on agreement with MDE, that excess restoration accomplished for this permit will be applicable to the next MS4 Permit term as restoration credit (rather than baseline).

Stormwater Management

MDOT SHA continues to comply with State and federal laws and regulations regarding SWM as well as MDE permit requirements. MDOT SHA also continues to implement the practices established in the 2000 Maryland Stormwater Design Manual and the MDOT SHA Sediment and Stormwater Guidelines and Procedures (October 6, 2017) for all projects and remains in compliance with the Stormwater Management Act of 2007 (2007 SW Act), including the revised Chapter 5 of the 2000 Maryland Stormwater Design Manual, by implementing environmental site design (ESD) to the MEP for all new and redevelopment projects.

As described in Section D.1.a of the FY19 MS4 annual report, the MDOT SHA Plan Review Division (PRD) under the Office of Highway Development (OHD) is the approving authority for both erosion and sediment control and stormwater management for all MDOT SHA projects. During the FY20 reporting period, PRD has coordinated with MDE to update the PRD Sediment and Stormwater Guidelines and Procedures and Current Technical Practices documents in preparation of PRD being designated as an approval authority of NRCS-MD Code 378 Small Ponds on behalf of the MDE Dam Safety Permits Division. As of the submission of the FY20 annual report, this coordination has not been completed. Therefore, as agreed upon with MDE, updated versions of these documents have not been provided. The development and updating of these guidance documents in coordination with MDE will continue into FY21.

MDOT SHA maintained SWM and construction inspection information during FY20 utilizing the processes described in Sections D.1.b. and D.1.c of the FY19 MS4 annual report. In accordance with conditions in Part IV.B of the MS4 Permit, a summary of construction inspections, non-compliance findings, and the actions taken by MDOT SHA district is referenced in Section 1.11 of, and is provided as electronic data with, the *MDOT SHA Annual Report for Delegation of Sediment and Stormwater Approval Authority* submitted in tandem with this FY20 MS4 annual report. Information for the MDOT SHA SWM program; including required documentation in accordance with conditions in Parts IV.D.1.b, IV.D.1.c, and IV.D.1.d of the MS4 Permit; is provided in the SWM table of MS4 geodatabase submitted with this FY20 MS4 annual report.

Under COMAR 26.17.02.03.A.3, MDE is designated as the responsible agency for inspecting and enforcing stormwater management for State construction projects subject to COMAR 26.17.02. Under the MS4 permit, in Part IV.D.1.d, MDE delegates its inspection authority to MDOT SHA by stating MDOT SHA is responsible for conducting preventative maintenance inspections, according to COMAR 26.17.02, of all ESD treatment systems and structural stormwater management facilities at least on a triennial basis. MS4 reporting to date has reflected this and MDOT SHA understands its inspection responsibility to include initial/as-built, triennial, and remediation follow-up/verification inspections, all of which are components of the current MDOT SHA preventative maintenance program and are reported in the “MAIN_INIT” and “MAIN_FLW” fields of the SWM table in the MS4 geodatabase submitted with this FY20 MS4 annual report.

The MS4 permit does not however delegate authority to MDOT SHA for stormwater management enforcement activities, such as those described in COMAR 26.17.02.11.C. MDOT SHA recognizes that its relationship to the regulation of stormwater management is different than other MS4-permitted jurisdictions due to the fact that MDOT SHA is a State agency and is not operating under ordinances that provide procedures to ensure deficiencies indicated by inspections are rectified. The preventative maintenance program established by MDOT SHA does not include any regulatory processes to enforce COMAR 26.17.02, or to address any subsequent violations, against itself. MDOT SHA has reported three (3) preventative maintenance enforcement activities and zero (0) violations for FY20 in the respective “MAIN_ENF” and “MAIN_VIO” fields of the SWM table in the MS4 geodatabase submitted with this FY20 MS4 annual report.

In a communication to MDOT SHA on July 13, 2020, MDE stated that MDOT SHA may use the necessary mechanisms to ensure that maintenance work performed by contractors or District maintenance shops is acceptable and that MDOT SHA may also work with the MDE compliance program when needed to ensure proper facility maintenance. MDOT SHA would like to work with MDE to identify appropriate activities within the MDOT SHA preventative maintenance program to enforce proper facility maintenance and track enforcement in accordance with the MS4 reporting requirements.

During the FY20 reporting period, MDOT SHA conducted 4007 preventative maintenance inspections of SWM facilities applying processes described in Section D.1.d of the FY19 MS4 annual report and in accordance with COMAR 26.17.02 and conditions in Part IV.D.1.d of the MS4 Permit. MDOT SHA has provided the inspection program information in the BMPInspections, RestBMPInpsections, AltBMPLineInspections, and AltBMPPolyInspections tables of the MS4 geodatabase submitted with this FY20 MS4 annual report.

During FY20, MDOT SHA performed 73 initial inspections of SWM facilities. These inspections are completed by default during construction as part of the SWM facility as-built certification process. Construction inspections occur as specified in COMAR 26.17.02.10 and documented on plans with photos and logs by the As-Built Engineer (ABE). This information is the best and most-accurate information available to confirm that SWM facility will perform as designed and regulatorily permitted, and thus is designated as the initial inspection. In 2018, the MDOT SHA Standard Specifications for Construction and Materials were updated to include Section 317, a permanent addition to the specifications that significantly updated, revised, and clarified the process requirements during the construction phase of projects. More information regarding the 2020 Standard Specifications for Construction and Materials can be found online at the following web address:

https://www.roads.maryland.gov/mdotsha/Pages/sscm.aspx?PageId=853&lid=SSP

The submissions of the SWM facility as-built certification package are made electronically through the Quality Assurance (QA) Toolkit that is not only used for the erosion and sediment control modification process but also as a SWM tool as well. A designated team of engineers reviews these packages for completeness and accuracy before they are forwarded to PRD for structural approval. Final acceptance has been delegated to the OHD Highway Hydraulics Division (HHD) by PRD and it is only when HHD issues final acceptance that the data is entered into the data set.

At this time, there is no automated system for transitioning data from the QA Toolkit to the NPDES database. The HHD SWM Asset management team has been working with the MDOT SHA Office of Planning and Preliminary Engineering Data Governance Division (DGD) to create a process for this coordination. The addition of this information into the NPDES schema was in development during FY20; however, it had not yet reached user-acceptance testing before funding issues halted progress. The teams will continue work on this system in upcoming years when funding is again available for such efforts.

MDOT SHA continued to perform routine and remediation maintenance for SWM facilities during FY20 applying processes described in Section IV.D.1.d of the MS4 annual report.

District operation manuals for SWM and drainage assets were updated to include common problems and simplified maintenance schedules. More information and links to District-specific operation manuals can be found online at the following MDOT SHA webpage:

https://www.roads.maryland.gov/mdotsha/pages/Index.aspx?PageId=363

Design and/or construction contracts were opened to address major maintenance and remediation needs for SWM facilities and MDOT SHA completed remediation of three (3) facilities during the FY20 reporting period. A total of four (4) Remediation Verifications were completed for repairs made to SWM facilities in FY20. An additional four facilities were repaired; however, the final acceptance records have not been submitted by the contractor at this time so MDOT SHA cannot verify that status of their functionality. One MDOT SHA remediation construction contract had major delays due to contractor challenges associated with work bundled into the contract. This remediation contract was cancelled at the end of FY20.

Though fewer SWM facility remediations were under construction in FY20, relative to FY19, many more were under design. Through FY20, considerable effort was put into development of remediation work orders for major repairs on SWM facilities. As a result of this effort, many facilities were screened for the feasibility of repair work to be performed. Also as a result of this effort and the difficulty in finding plans for facilities that had been retrofit many years ago, a new process for enhancing the tracking system was put in place. This tracking would now allow for abandonment. A new procedure has been developed to facilitate abandonment that includes review and approval at several levels culminating in submission to PRD for final concurrence that the permit requirements surrounding the facility will be adjusted.

During the current MS4 Permit term, a total of 50 facilities have been remediated by MDOT SHA. A total of 257 SWM facilities still require major maintenance or retrofit. A remediation maintenance resolution schedule is provided in **Table IV.D.1.d** located in Appendix B to this FY20 MS4 annual report in accordance with conditions in Part IV.B of the MS4 Permit. Maintenance work has been prioritized and expected completion dates are between June 2023 and June 2026. Due to resource constraints during FY20 and uncertainty surrounding resource availability for FY21 and FY22, MDOT SHA has updated its remediation completion commitment dates to reflect greater resource availability anticipated in FY23.

Erosion and Sediment Control

During the FY20 reporting period, MDOT SHA maintained compliance with Maryland State and federal laws and regulations for erosion and sediment control (ESC) as well as MDE requirements for permitting, including compliance with the General Permit for Stormwater Associated with Construction Activity (NPDES-CA) for projects that disturb at least one acre of land. MDOT SHA continued to submit applications for coverage under the NPDES-CA (State discharge permit number 14GP, effective January 1, 2015; expired December 31, 2019), for all qualifying roadway projects as described in Section D.2.d of the FY19 MS4 annual report. During the FY20 reporting period, a total of 49 MDOT SHA construction projects receiving Notice to Proceed (NTP) required coverage under an NPDES-CA permit.

MDE has allowed MDOT SHA the option of continuing to operate under the terms of the expired NPDES-CA permit until the new permit is issued; however, additional conditions apply. Specifically, MDOT SHA must submit a Declaration of Intent (DOI) which declares the intent to comply with the terms of the expired permit as well as the yet unknown terms of the new permit once it is issued. In addition, MDOT SHA must also submit additional information for projects that are located within Tier II watersheds and demonstrate that greater measures are used to protect the watershed. Both of these conditions took effect on or about May 20, 2020 and retroactively affected all projects with active NPDES-CA coverage as well as any new Notice-of-Intent (NOI) applications submitted after May 20, 2020.

Alternatively, MDOT SHA can obtain individual NPDES-CA permit coverage on a project-by-project basis; however, MDOT SHA has opted to continue coverage under the expired permit for consistency and expediency. Projects requiring coverage will also continue to operate this way until a new permit is issued. MDE has not established a date for the new permit, but MDOT SHA received a draft of the upcoming permit on September 16, 2020. Authorization letters received to-date state the following "This coverage will continue until the deadline for new registrations required under a new general permit, the date you obtain coverage under an individual permit or general permit, or the date the Consent Order is terminated, whichever occurs first." It is the intent of MDOT SHA to comply.

In accordance with conditions in Part IV.D.2.c of the MS4 Permit, MDOT SHA has provided the ESC program information in the ErosionSedimentControl table and the grading permit program information in the QuarterlyGradingPermits feature class and the QuarterlyGradingPmtInfo table in the MS4 geodatabase submitted with this FY20 MS4 annual report.

In accordance with conditions in Part IV.D.b of the MS4 Permit and in cooperation with the Maryland Transportation Builders and Materials Association (MTBMA), MDOT SHA continued to offer updated ESC training, as described in Section D.2.b of the FY19 MS4 annual report, and issued 188 ESC (a.k.a., "Yellow Card") certifications and 236 re-certifications during the FY20 reporting period. Responsible Personnel Certification training was administered through MDE's online Responsible Personnel Course. More information regarding ESC certification is available at the following MDOT SHA webpage:

https://www.roads.maryland.gov/mdotsha/pages/Index.aspx?PageId=56

Illicit Discharge Detection and Elimination

The MDOT SHA Office of Environmental Design, Environmental Compliance Division (ECD) coordinated illicit discharge detection and elimination screenings during the FY20 reporting period. During the FY20 outfall selection process, ECD considered pollution potential, selecting outfalls located in commercial and industrial areas determined to be "stormwater hotspots" with extra focus on permitted counties where IDDE screenings were less concentrated in previous years. Stormwater pipes 12 inches in diameter and greater were selected throughout Carrol, Charles, Harford, and Howard Counties.

In accordance with conditions in Part IV.D.3.a of the MS4 Permit, MDOT SHA exceeded the 150 minimum annual requirement for primary field screenings during FY20. Additional IDDE investigations were conducted during FY20 for illicit discharge (ID) sites whose status was reported as "open" in the FY19 MS4 annual report. Citizen reporting or other MDOT SHA contractors working within MDOT SHA right of way (ROW) also identified potential IDs requiring investigation. Investigations related to this type of notification were completed during FY20 in Baltimore, Frederick, and Cecil Counties.

In accordance with conditions in Parts IV.B, IV.D.3.d, and IV.D.3.e of the MS4 Permit, a summary of outfalls screened and potential IDs with associated jurisdictional contacts/resolution schedules for each is provided in **Tables IV.D.3.a and IV.D.3.d** located in Appendix C to this FY20 MS4 annual report. In the MS4 geodatabase submitted with this FY20 MS4 annual report, MDOT SHA has provided the illicit discharge detection and elimination program information in the IDDE associated table.

In accordance with conditions in Part IV.D.3.b of the MS4 Permit, during FY20, ECD performed a total of 293 inspections across 146 MDOT SHA industrial facilities (inspecting 32 NPDES 12-SW permitted sites and 114 non-permitted sites) identified by MDOT SHA, per Part IV.C.2 of the MS4 Permit, as having the potential to contribute significant pollutants to MDOT SHA storm drain systems.

The types of inspections performed by ECD for identified industrial areas as well as the associated inspection tracking system remain unchanged relative to descriptions provided for each in the FY19 MS4 annual report. A total of 177 stormwater related findings were generated by facility inspections during FY20 and applicable records were uploaded to the MDOT SHA web-based tracking system. Of those findings, 131 were resolved during FY20 whereas 46 findings remain unresolved. Corrections for some of the findings require further maintenance planning and possible engineering controls while other corrections were delayed during the FY20 reporting period due to staff reductions caused by aforementioned budget cuts. In accordance with Part IV.B of the MS4 Permit, a summary of the most recent quarterly inspection report for each of the NPDES 12-SW permitted sites located within the MS4 Permit areas is provided in Appendix C to this FY20 MS4 annual report.

As part of its overarching program to respond to illegal discharges, dumping, and spills; ECD continued to coordinate with MDE, surrounding jurisdictions, and property owners during the FY20 reporting period to eliminate IDs and clean up spills and dumping. Implementation of a new IDDE management tool that was planned for completion during FY21, as reported by MDOT SHA in the FY19 MS4 annual report, will be delayed at least one fiscal year due to budget shortfalls.

Trash and Litter

MDOT SHA provided comprehensive descriptions of its "multi-pronged" trash/litter reduction strategy in the FY18 and FY19 MS4 annual reports. The approach utilizes MDOT SHA employees, contractors, correctional services, as well as labor donated through the Sponsor-A-Highway (SAH) program and partnerships with Adopt-A-Highway (AAH) volunteers.

In accordance with conditions in Part IV.D.4.d of the MS4 Permit, trash/litter removed by MDOT SHA trash reduction strategies during the FY20 reporting period is documented in **Table IV.D.4.d** below. Implementation of the AAH and SAH programs in FY20 resulted in 106 highway miles adopted and 388 miles sponsored. Relative to implementation reported for the FY19 period, this is an increase of 4 and a decrease of 6 miles respectively for the two programs.

Table IV.D.4.d: Trash and Litter Removed During FY20 by MDOT SHA Trash Reduction Strategies

Jurisdiction	Truckloads	Conversion to Pounds
Anne Arundel	439	159,420
Baltimore	1,444	510,089
Carroll	73	25,477
Cecil	153	53,410
Charles	226	81,390
Frederick	179	63,548
Harford	132	46,352
Howard	378	133,420
Montgomery	440	154,505
Prince George’s	1,134	405,100
Washington	161	58,073
Salisbury	85	29,901
Totals	**4,845**	**1,720,683**

MDOT SHA maintained its “Educational Outreach” webpage content during FY20, as described in Section D.4.b of the FY19 MS4 annual report. The MDOT SHA website was updated during FY20 and the Educational Outreach webpage is now located at the following address:

https://www.roads.maryland.gov/mdotsha/pages/index.aspx?PageId=48

Additional public education and outreach activities implemented by MDOT SHA during FY20 to reduce littering, in accordance with conditions in Part IV.D.4.b of the MS4 Permit, are incorporated into the summary describing public education programs submitted as Appendix D to this FY20 MS4 annual report per Part V.A.1.d of the MS4 Permit.

The MDOT Excellerator program, as described in Section D.4.c of the FY19 MS4 annual report, remains the primary performance management system for tracking the effectiveness of MDOT SHA trash reduction strategies. The most recent biannual report was made publicly accessible on June 26, 2020 at the following web address and included, in charts 9.2D.1, 9.2D.2, and 9.2D.3, an evaluation of quarterly implementation and associated expenditures by MDOT for litter pickup in FY19 and FY20:

http://www.mdot.maryland.gov/newMDOT/Planning/Excellerator/MDOTExcellerator

Property Management and Maintenance

During FY20, MDOT SHA continued to update Storm Water Pollution Prevention Plans (SWPPP) and maps following site changes and renovations and continued providing annual SWPPP training to its maintenance personnel. As previously described in the *IDDE* section of this FY20 MS4 annual report, the MDOT SHA maintenance facility staff continued to perform monthly inspections and ECD continued to perform inspections at all MDOT SHA facilities through its District Environmental Coordinators throughout the FY20 reporting period. ECD managed resultant maintenance issues identified in accordance with the process previously described in Section D.3.b of the FY19 MS4 annual report.

For each municipal facility within the MS4 permitted jurisdictions covered under the General Discharge Permit (12-SW), MDOT SHA has provided, in **Table IV.D.5.a**, a summary of updates to facility SWPPPs and associated trainings for staff in accordance with conditions in Parts IV.D.5.a and IV.D.5.b.v of the MS4 Permit. Please note that the Thurmont facility is considered a "satellite" site of the Frederick facility meaning no MDOT SHA staff report to the Thurmont facility directly. MDOT SHA staff work at the Thurmont facility routinely but are technically staff from the Frederick facility. The Thurmont facility is a 12-SW permitted site and consequently requires an associated SWPPP; however, the staff training is accounted for within the Frederick facility's staff training totals in **Table IV.D.5.a**. In the MS4 geodatabase submitted with this FY20 MS4 annual report, MDOT SHA has provided information regarding 12-SW permitted facilities in the MunicipalFacilities feature class.

Table IV.D.5.a: Summary of SWPPP Status and Training for MDOT SHA Municipal Facilities

District	Maintenance Facility	12-SW Permit Type	Date of Most Recent SWPPP Update (Month-YR)	Date of Most Recent SWPPP Training (Month-YR)	Number of Individuals Trained
1	Cambridge	General	January-17	October-19	30
	Salisbury	General	December-19	October-19	32
2	Elkton	General	April-19	September-19	35
3	Fairland	General	January-19	November-19	37
	Gaithersburg	General	February-19	June-20	14
	Laurel	General	February-19	November-19	37

Table IV.D.5.a: Summary of SWPPP Status and Training for MDOT SHA Municipal Facilities

District	Maintenance Facility	12-SW Permit Type	Date of Most Recent SWPPP Update (Month-YR)	Date of Most Recent SWPPP Training (Month-YR)	Number of Individuals Trained
	Marlboro	General	February-19	November-19	25
4	Churchville	General	March-19	June-20	26
	Golden Ring	General	March-19	June-20	28
	Hereford	General	March-19	June-20	37
	Owings Mills	General	March-19	June-20	20
5	Annapolis	General	March-19	September-19	39
	Glen Burnie	General	March-19	September-19	47
	La Plata	General	March-19	September-19	31
	Hanover Auto Shop	General	June-20	December-19	16
6	Hagerstown	General	February-20	September-19	37
7	Dayton	General	April-20	October-19	43
	Frederick	General	April-20	October-19	38
	Thurmont	General	May-20	-	-
	Westminster	General	May-20	November-19	34
				Total	**606**

MDOT SHA continued to sweep a selection of roads seasonally and clean inlets using vacuum technology as described in Section D.5.b of the FY19 MS4 annual report. Information for implementation of inlet cleaning and storm drain vacuuming operations during FY20 is provided in **Table IV.D.5.b**. below.

Table IV.D.5.b: Tons Collected in FY20 from Inlets Cleaning and Storm Drain Vacuuming

County	MDOT SHA Maintenance Shop	Total Number of Inlets Cleaned	Tons* Collected	Tons Collected from Storm Drain Vacuuming
Anne Arundel	Annapolis	117	12	8
	Glen Burnie	426	45	10
Baltimore	Golden Ring	537	56	8
	Hereford	185	19	32
	Owings Mills	349	37	10
Carrol	Westminster	13	1	23
Cecil	Elkton	0	0	-
Charles	La Plata	12	1	4
Frederick	Frederick	0	0	-
Harford	Churchville	288	30	16
Howard	Dayton	4	1	1
Montgomery	Fairland	1249	131	52
	Gaithersburg	837	88	12
Prince George's	Laurel	528	55	33
	Upper Marlboro	115	12	9
Wicomico County	Salisbury	0	0	-
	Totals	**4660**	**488**	**218**

In accordance with conditions in Part IV.D.5 of the MS4 Permit, MDOT SHA has provided its statewide usage during FY20 for herbicide, fertilizer, and deicing chemicals, including percent change for each chemical type based on amounts reported for the FY19 period, in the ChemicalApplication associated table of the MS4 geodatabase submitted with this FY20 MS4 annual report.

A significant increase can be observed in quantities of herbicide applied in FY20 relative to the FY19 reporting period. While the overall quantity of herbicide used increased, MDOT SHA decreased its use of non-selective herbicide during the reporting period through statewide initiatives to minimize the application of glyphosate on guardrails while promoting greater use of plant growth regulators (especially trinexapac-ethyl) and selective herbicides as alternatives.

Work continued in FY20 on the MDOT SHA Landscape Management Guide (LMG), as described in Section D.5.b.iii of the FY19 MS4 annual report, and a final draft is nearing completion. Key concepts and draft chapters of the LMG were discussed at all MDOT SHA pesticide applicator training sessions in FY20. MDOT SHA continued all four of its pesticide applicator training classes, as described in Section D.5.b.iii of the FY19 MS4 annual report, training 196 MDOT SHA pesticide applicators in FY20.

MDOT SHA has concluded its multi-year cooperative research effort with the Maryland Department of Agriculture (MDA) on biocontrol of invasive plants using the Mile-a-Minute Vine Weevil (*Rhinoncomimus latipes*). MDA released the weevil at 38 locations on MDOT SHA property during FY20.

As described in Section D.5.b.iii of the FY19 MS4 annual report, MDOT SHA is shifting its research focus to Japanese Knotweed Psyllid (*Aphalara itadori*), an insect biocontrol with potential to suppress the growth and spread of Japanese Knotweed (*Polygonum cuspidatum*). The USDA permit for Japanese Knotweed Psyllid was approved March 20, 2020. MDA is currently propagating Knotweed and will rear Psyllids in late 2020 for release in 2021.

In December 2019, MDOT SHA completed its research with the University of Maryland, Appalachian Lab that tested the efficacy of planting alternative roadside grasses and seed mixtures. Side-oats grama appeared to be the most promising roadside grass treatment because it established fast, was low in stature, and was competitive against weeds. The final report was made publicly available at the following web address:

https://www.roads.maryland.gov/OPR_Research/MD-19-SHA-UMCES-7-01_Turfgrass2_Report.pdf

During FY20, MDOT SHA continued to test and evaluate new winter materials, equipment, and strategies in an on-going effort to improve the level of service provided to motorists during winter storms while minimizing the impact of its operations on the environment. Minimization practices described in Section D.5.b.iv of the FY19 MS4 annual report continued during the FY20 reporting period. A description of MDOT SHA winter operations and a link to the current version of the MDOT SHA Salt Management Plan, most recently updated in October 2019, is publicly accessible at the following web address:

https://www.roads.maryland.gov/mdotsha/pages/index.aspx?PageId=352

Within the MS4-permitted areas, MDOT SHA applied a total of 17,445 tons of sodium chloride (rock or solar salt) during the 2019-2020 winter season. MDOT SHA uses a metric of pounds of road salt per total lane miles per inch of snow (lbs/lm/inch) in its year-to-year comparisons of road salt usage. For the FY20 reporting period, the value for this metric was 313 lbs/lm/inch which is a decrease of 248 lbs/lm/inch when compared to amounts reported for the FY19 period.

This decrease can be attributed to a very mild winter with record average low frozen precipitation totals across the state during FY20.

As described in Section D.5.b.iv of the FY19 MS4 annual report, MDOT SHA continued its "Annual Snow College" training during FY20 in accordance with conditions in Part IV.D.5.b.v of the MS4 Permit. Snow College was canceled in MDOT SHA Districts 1 and 2 in FY19, due to unanticipated circumstances, but was implemented statewide in FY20 with greater than average participation across all MDOT SHA Districts. FY20 Snow College events trained 127 operators in snow removal and salt management, including new hire and refresher training. Additionally, MDOT SHA continued administration of annual maintenance shop winter meetings and hired equipment operator trainings during FY20, training approximately 1,000 State employees and 2,100 hired equipment operators respectively.

Public Education

MDOT SHA continued to operate its Customer Care Management System, as described in Section D.6.a of the FY19 MS4 annual report, throughout FY20 for submission of complaints and concerns. In FY20, this system received approximately 21,000 service requests. There were approximately 2,800 service requests regarding littering and illegal dumping related issues of which 2,700 are closed. These figures have decreased since FY19 in which 28,000 service requests were received with 3,000 being related to illegal dumping.

During the FY20 reporting period, MDOT SHA maintained its public education webpage, providing links to several interactive maps and educational resources as previously described in the *Trash and Litter* section of this FY20 MS4 annual report. MDOT SHA also participated in numerous educational opportunities described in Appendix D to this FY20 MS4 annual report.

Watershed Assessment

In accordance with conditions in Part IV.E.1 of the MS4 Permit, MDOT SHA continued to reference County watershed assessments to identify specific watershed issues and restoration project opportunities, as described in Section E.1 of the FY19 MS4 annual report, during development of individual watershed TMDL Implementation Plans in FY20. Additionally, throughout the current permit term, MDOT SHA has committed resources to advocating for, drafting, negotiating, executing, and amending long-term Memorandums of Understanding/Agreements with 15 different county, State, and federal government agencies in order to facilitate collaborative watershed restoration and monitoring activities. These interagency partnerships have facilitated data exchanges, right-of-way/easement acquisition, pooled stormwater and restoration monitoring and research, and construction of new restoration stormwater management, tree planting, outfall stabilization, impervious area removal, and stream restoration BMPs.

Restoration Plans

In accordance with conditions in Part IV.E.2.a of the MS4 Permit, MDOT SHA submitted impervious surface area assessments (as described in Section E.2.a of the FY19 MS4 annual report) and implemented restoration efforts for more than the required 4,621 equivalent acres of impervious surfaces before the end of FY20. Restoration implemented was consistent with the methodology described in the MDE 2014 document titled, "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated, Guidance for National Pollutant Discharge Elimination System Stormwater Permits" and all subsequently provided MDE guidance. MDOT SHA has provided **Table IV.E.2** below to document progress relative to restoration benchmarks established in Part II.D of the MDOT SHA *Impervious Restoration and Coordinated TMDL Implementation Plan*, submitted with Appendix B to the FY19 MS4 annual report.

Table IV.E.2: Percentage of Impervious Treatment, Benchmark versus Achieved

Fiscal Year	Benchmarks		Actual Achieved	
	% Progress Toward Restoration Goal (Revised 2018)	Cumulative Acres of Restoration Projected (Revised 2019)	Cumulative Acres of Restoration Achieved	% Progress Toward Restoration Goal
October 21, 2010 to 2015	20%	924	1,845	40%
2016	30%	1,386	2,473	54%
2017	40%	1,848	2,828	61%
2018	45%	2,079	3,216	70%
2019	50%	2,311	3,646	79%
2020	95%	4,390	7,268	157%
2021	100%	4,621		

In accordance with conditions in Part IV.E.3 of the MS4 Permit, MDOT SHA has provided the cumulative impervious acres restored achieved through FY20 under the current permit compliance period in **Table IV.E.3** below. For operational activities, MDOT SHA has adjusted its reporting method to include actual annual implementation whereas previous methodologies used a consistent annual target goal. Due to budgetary impacts, resources were not available to complete reconciliation of credit for annual BMPs reported in Table IV.E.3 below with credit reported in the AltBMPPoly feature class of MS4 geodatabase submitted with this FY20 MS4 annual report. In response, MDOT SHA has excluded records from the AltBMPPoly feature class that report annual BMP implementation. When resources become available to perform the work, MDOT SHA will complete the reconciliation effort and provide MDE an updated AltBMPPoly feature class that accurately reflects actual implementation of inlet cleaning and street sweeping operations during the compliance period, as reported in Table IV.E.3 below.

Table IV.E.3: Impervious Acres Restored Achieved During the MS4 Permit Compliance Period

BMP Type	Oct. 21, 2010 to 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	Jul. 1, 2020 to Oct. 8, 2020	Report Date Totals	Oct. 9, 2020 to Jun. 30, 2021[3]	Anticipated Final Permit Totals
Impervious Surface Elimination to Pervious	0.48	0	1.85	0.03	0.11	0.69	0	**3.16**	0	**3.16**
New Stormwater Control Structures	85.75	53.57	55.17	51.41	35.57	0	0	**281.47**	0.89	**282.36**
Grass Swales	0	9.07	11.60	0	0	0	0	**20.67**	0	**20.67**
Outfall Stabilization	0	11.92	11.36	169.91	72.83	209.76	119.55	**595.33**	308.88	**904.21**
Retrofit Existing Stormwater Control Structures	0	99.27	3.96	71.54	64.54	16.87	29.39	**285.57**	23.17	**308.74**
Stream Restoration	1,275.09	392.17	209.10	7.14	175.67	3,371.06	311.99	**5,742.22**	542.68	**6,284.90**
Tree Planting	483.60	62.13	20.58	78.15	73.51	24.16	0.69	**742.83**	8.54	**751.37**
Redevelopment Credit	0	0	41.70	9.71	7.82	0	0	**59.23**	0	**59.23**
Built BMP Subtotals =	**1,845**	**628**	**355**	**388**	**430**	**3,622**	**462**	**7,730**	**884**	**8,614**
Inlet Cleaning[1]	N/A	N/A	195.00	175.20	166.60	282.41	N/A	**204.80**	N/A	**204.80**
Street Sweeping[1]	N/A	N/A	52.00	34.04	25.96	34.53	N/A	**36.63**	N/A	**36.63**
Credit Acquisition	0	0	0	0	0	0	0	**0**	0	**0**
Final Totals =								**7,972**	**884**	**8,856**
20% Restoration Requirement =								4,621		4,621
% Untreated Impervious Surface Area[2] Restored =								35%		38%
% Progress Towards Restoration Requirement =								173%		192%

1 Total acres achieved for inlet cleaning and street sweeping annual BMPs is presented here as the average annual implementation across the four years for which MDOT SHA has reported acres restored by annual BMPs. MDOT SHA will revise MS4 geodatabase information to accurately reflect credit totals reported here.

2 On September 16, 2019 MDE approved the MDOT SHA baseline at 23,104.8 acres of untreated impervious surface area

3 BMPs included in restoration for current permit term that were funded, designed, advertised, and initiated construction under the current permit, but construction schedules extended beyond the current MS4 Permit expiration date.

TMDL Compliance

The United States Environmental Protection Agency (EPA) approved 6 new TMDLs during FY19. In accordance with conditions in Part IV.E.2.b of the MS4 Permit, MDOT SHA submitted 3 new TMDL Implementation Plans to MDE by their respective FY20 due dates. The names and submission dates of the 3 plans are as follows:

- Non-Tidal Patuxent River Lower Watershed Sediment TMDL Implementation Plan, July 2, 2019
- Non-Tidal Patuxent River Middle Watershed Sediment TMDL Implementation Plan, July 2, 2019
- Sediments in the Non-Tidal West River Watershed, April 24, 2020

Each of the public comment periods for the 3 Implementation Plans that were submitted to MDE were announced in the Baltimore Sun, Washington Post, and on MDOT SHA's website during FY20 in accordance with conditions in Part IV.E.4 of the MS4 Permit. No comments were received during the respective comment periods.

Three newly approved TMDLs in FY19 did not require an implementation plan to be submitted for the following reasons:

- Piscataway Creek and Mattawoman Creek Tidal Fresh PCB TMDL, approved on February 19, 2019

  No Implementation Plan needed due to the TMDL document stating that "reductions to PCB loads from non-regulated watershed runoff, contaminated sites, and NPDES regulated stormwater do not have to be addressed directly, as they will be achieved through reductions in atmospheric deposition."

- Non-Tidal Upper Chester River Sediment TMDL, approved on April 8, 2019

  No Implementation Plan needed due to a 0% reduction for NPDES Regulated Stormwater Sector WLA.

- Lower Patuxent River Bacteria TMDL, approved on May 21, 2019

  No Implementation Plan needed due to no point source reduction requirement included in the TMDL document.

In FY20, 4 new TMDLs were approved by the United States Environmental Protection Agency (EPA). Per Part IV.E.2.b of the MS4 Permit, MDOT SHA completed and submitted TMDL Implementation Plans for 3 of the new TMDLs by their respective FY21 due dates. The names and submission dates of the 3 required plans are as follows:

- Marsh Run Sediment TMDL Implementation Plan, September 29, 2020
- Piscataway Creek Sediment TMDL Implementation Plan, October 3, 2020
- Port Tobacco River Sediment TMDL Implementation Plan, October 9, 2020

In accordance with conditions in Part IV.E.5 of the MS4 Permit, MDOT SHA has provided the required FY20 TMDL Assessment Report as Appendix E to this FY20 MS4 annual report. MDOT SHA has also provided Bay and local TMDL compliance information, respectively, in the CountywideStormwaterWatershedAssessment and LocalStormwaterWatershedAssessment tables of MS4 geodatabase submitted with this FY20 MS4 annual report.

Assessment of Controls

The MDE-approved monitoring plans, developed by MDOT SHA to satisfy conditions in Part IV.F of the MS4 Permit, were appended to the FY16 and FY17 MS4 annual reports. Those approved monitoring plans contained a schedule for monitoring activities proposed by MDOT SHA based on project schedules at the time the plans were developed. Sampling schedules changed during the course of the current MS4 Permit term due to the respective project design/construction schedules beginning later than anticipated and, in the case of the Little Catoctin Creek stream restoration, construction delays caused by a severe flooding event, as described in Section F.1 of the FY19 MS4 annual report. **Table IV.F** below summarizes the proposed and actual monitoring schedules respectively.

In accordance with conditions in Part IV.F.1 of the MS4 Permit, MDOT has fulfilled its obligations for Watershed Restoration Assessment, as proposed in the associated MDE-approved monitoring plan, for all monitoring phases except CHEM 4 and BIO 4. These two remaining activities have been deferred due to impacts to available resources in FY20 and FY21 resultant from the budget cuts.

MDOT SHA committed to two full years (24 months) of chemical monitoring during the post-construction phase and implemented 15 months of monitoring before activities were disrupted in FY20 by impacts to state budgets. The CHEM 3 monitoring phase was completed however completion of the CHEM 4 monitoring phase has been deferred. Due to the uncertainty of resource availability for FY21 and beyond and the deferment of associated monitoring activities, chemical monitoring stations were removed in June 2020. BIO 4 activities, including the analysis of benthic macroinvertebrate samples collected during the 2020 spring index period and all planned summer 2020 index period stream habitat assessments, could not be completed and have also been deferred due to the aforementioned budgetary constraints.

In accordance with conditions in Part IV.F.1.a.iv of the MS4 Permit, MDOT SHA has met its obligations by recording continuous flow measurements throughout all monitoring phases completed to date. The Watershed Restoration Assessment monitoring site is not located within the watershed of any EPA approved TMDLs with WLAs attributed to MDOT SHA and MDOT SHA does not calibrate watershed assessment models. Collection of continuous flow measurements ceased in June 2020 with the removal of chemical monitoring stations.

In accordance with conditions in Parts IV.F.1.d and V.A.1.b of the MS4 Permit, MDOT SHA has provided Watershed Restoration Assessment information in the ChemicalMonitoring and BiologicalMonitoring tables of the MS4 geodatabase and Appendix F submitted with this FY20 MS4 annual report. In accordance with conditions in Part. IV.F.1.c.iii of the MS4 Permit, MDOT SHA has also provided the required hydraulic model as a component of Appendix F.

In accordance with conditions in Part IV.F.1.d.iii of the MS4 Permit, MDOT SHA is hereby requesting a modification to the MDE-approved monitoring plan/program for Watershed Restoration Assessment at the Little Catoctin Creek in Frederick County to remove the second year of post-construction chemical and biological monitoring. This would eliminate the CHEM 4 and BIO 4 monitoring phases in the approved plan (see **Table IV.F** below). The PHYS 4 phase was completed and is submitted with the monitoring report included in Appendix F along with the required hydraulic modeling. Although the MDE-approved monitoring plan only prescribed a single year of pre-construction monitoring, delays in the construction schedule allowed MDOT SHA to perform an additional year of pre-construction monitoring in 2017 for both the biological and physical components of the plan. No physical monitoring work was proposed during the construction period (PHYS 2), however MDOT SHA orchestrated supplementary surveys in July/August 2018 to evaluate changes resulting from the severe flood event that impacted the site on May 15, 2018. In addition to the aforementioned budgetary constraints, MDOT SHA requests that MDE also consider these additional pre-construction and construction phase monitoring activities and reporting by MDOT SHA during 2017 and 2018 as justification for the requested modifications MDOT SHA is requesting to the MDE-approved monitoring plan.

Table IV.F: Assessment of Controls Monitoring Schedules and Progress

Monitoring Phase	Proposed Dates	Actual Dates	Construction Phase	Comments
Part IV.F.1 - Watershed Restoration Assessment				
CHEM 1	October 2016 to October 2017	September 2016 to December 2017	Pre-construction	Upstream station installed September 2016 and downstream station installed December 2016. Results and analysis reported in FY17 MS4 annual report.
BIO 1	March 2016	April 2016 to September 2017	Pre-construction	Monitoring performed annually in 2016 and 2017 to establish range for baseline. Results and analysis reported in FY17 MS4 annual report.
PHYS 1	April 2015	September 2017 to February 2018	Pre-construction	Monitoring performed annually in 2017 and 2018 to establish range for baseline. Results and analysis reported in FY17 MS4 annual report.
CHEM 2	October 2017 to October 2018	January 2018 to March 2019	Construction	Monitoring work extended and performed throughout the construction phase. Results and analysis reported in FY18 and FY19 MS4 annual reports.
BIO 2	N/A	N/A	Construction	Activity not to be performed during construction
PHYS 2	N/A	N/A	Construction	Activity not to be performed during construction but supplementary surveys conducted in July/August 2018 to evaluate changes resulting from severe flood event. Results and analysis reported in FY18 MS4 annual report.
CHEM 3	October 2018 to October 2019	April 2019 to April 2020	Post-construction	CHEM 3 completed April 2020; results and analysis reported with FY20 MS4 annual report.
BIO 3	March 2018 to March 2019	April 2019 to April 2020	Post-construction	BIO 3 completed in (spring & summer). Results and analysis reported with FY20 MS4 annual report.
PHYS 3	March 2018 to March 2019	April 2019 to June 2019	Post-construction	PHYS 3 completed in (spring) 2019. Results and analyse reported with the FY19 MS4 annual report.

Table IV.F: Assessment of Controls Monitoring Schedules and Progress

Monitoring Phase	Proposed Dates	Actual Dates	Construction Phase	Comments
CHEM 4	October 2019 to October 2020	April 2020 to June 2020	Post-construction	CHEM 4 partially completed but work stopped June 2020 and remaining activities have been deferred. CHEM 4 was planned to extend through April 2021. MDOT SHA has deferred reporting of results and analysis for the CHEM 4 monitoring phase. **MDOT SHA is requesting removal of this phase per Part IV.F.1.d.iii of the MS4 Permit.**
BIO 4	March 2019 to March 2020	April 2020 to June 2020	Post-construction	Benthic macroinvertebrate data collection and sub-sampling completed for BIO 4 during spring 2020 index period but taxonomic identification, data entry, and IBI calculation was not completed before work stopped in June 2020. Required BIO 4 stream habitat assessment and supplementary fish, crayfish, mussel, reptile, or amphibian sampling were planned for completion during the summer 2020 index period but have been deferred. MDOT SHA has deferred reporting of results and analysis for the BIO 4 monitoring phase. **MDOT SHA is requesting removal of this phase per Part IV.F.1.d.iii of the MS4 Permit.**
PHYS 4	March 2019 to March 2020	April 2020 to June 2020	Post-construction	Monitoring completed in 2020. Results and analysis, including the required hydraulic model, submitted with FY20 MS4 annual report.
Part IV.F.2 - Stormwater Management Assessment				
Year 1	January 2018 to October 2018	May 2018 to June 2018	Pre-construction	Monitoring completed with results and analysis reported in FY18 MS4 annual report.
Year 2	November 2018 to October 2019	July 2018 to June 2019	Pre-construction	Monitoring completed with results and analysis reported in FY19 MS4 annual report.
Year 3	November 2019 to October 2020	July 2019 to June 2020	Pre-construction	Monitoring completed with results and analysis reported in FY20 MS4 annual report.
Year 4	November 2020 to October 2021	Deferred	Post-construction	**Construction delayed until at least 2021**. Post-construction monitoring deferred.

In accordance with conditions in Parts IV.F.2 and V.A.1.b, MDOT SHA has provided Stormwater Management Assessment information in Appendix G to this FY20 MS4 annual report. As described in Section F.2 of the FY19 MS4 annual report, the construction schedule for the MDOT SHA-owned BMPs referenced in the MDE-approved monitoring plan for Stormwater Management Assessment is integrated with and dependent on the construction schedule for a Howard County bridge replacement project. MDOT SHA has fulfilled its Stormwater Management Assessment monitoring obligations by monitoring for at least two full years during the pre-construction period. MDOT SHA did not commit to any construction phase monitoring activities in the MDE-approved monitoring plan for Stormwater Management Assessment.

MDOT SHA performed continuous flow measurements throughout the pre-construction period and evaluated the effects of continuous flow on channel geometry in its previously submitted MS4 annual reports. Hydrologic and/or hydraulic modeling was not performed in the fourth year of the MS4 Permit term in accordance with conditions in Part IV.F.2.c because the pre-requisite BMP construction did not initiate during the current MS4 Permit term.

Program Funding

In accordance with conditions in Parts IV.G.1 and V.A.1.c of the MS4 Permit, MDOT SHA has provided program funding information in the FiscalAnalysis table of the MS4 geodatabase submitted with this FY20 MS4 annual report. **Table V.A.1.c** below contains a supplemental summary of this information. In accordance with conditions in Part IV.G.2 of the MS4 Permit, adequate funding has been maintained to ensure compliance. Cumulative MDOT SHA expenditures across the permit term (FY16 through FY20) total more than $516 million, averaging $103 each FY with above average expenditures reported for the last 3 years of the permit term.

Table V.A.1.c: MS4 Expenditures for FY20 and Proposed Budget for FY21

Fund	FY20 Expenditures (Millions*)	FY21 Budget (Millions*)
Fund 82 – TMDL/MS4	$84.7	$49.3
Fund 74 – Drainage	$13.4	$2.8
Fund 49 – Industrial	$2.0	$0.1
Operations/ Maintenance	$10.9	$6.5
Totals:	**$111.0**	**$58.7**
*Funding numbers are rounded to nearest $0.1 Million		

As described in Section G of the FY19 MS4 annual report, MDOT SHA does not impose fees or generate funding for watershed protection and restoration and all MS4 funding is sourced from the State Transportation Fund. The significant budget reduction for FY21 reported by MDOT SHA is a consequence of impacts to the State Transportation Fund and the budget cuts described in the Introduction section to this FY20 MS4 annual report.

National Pollutant Discharge Elimination System
Municipal Separate Storm Sewer System
Permit No. 11-DP-3313 MD0068276
Permit Term October 9, 2015 to October 8, 2020

Fifth Annual Report
October 9, 2020

Appendices

:

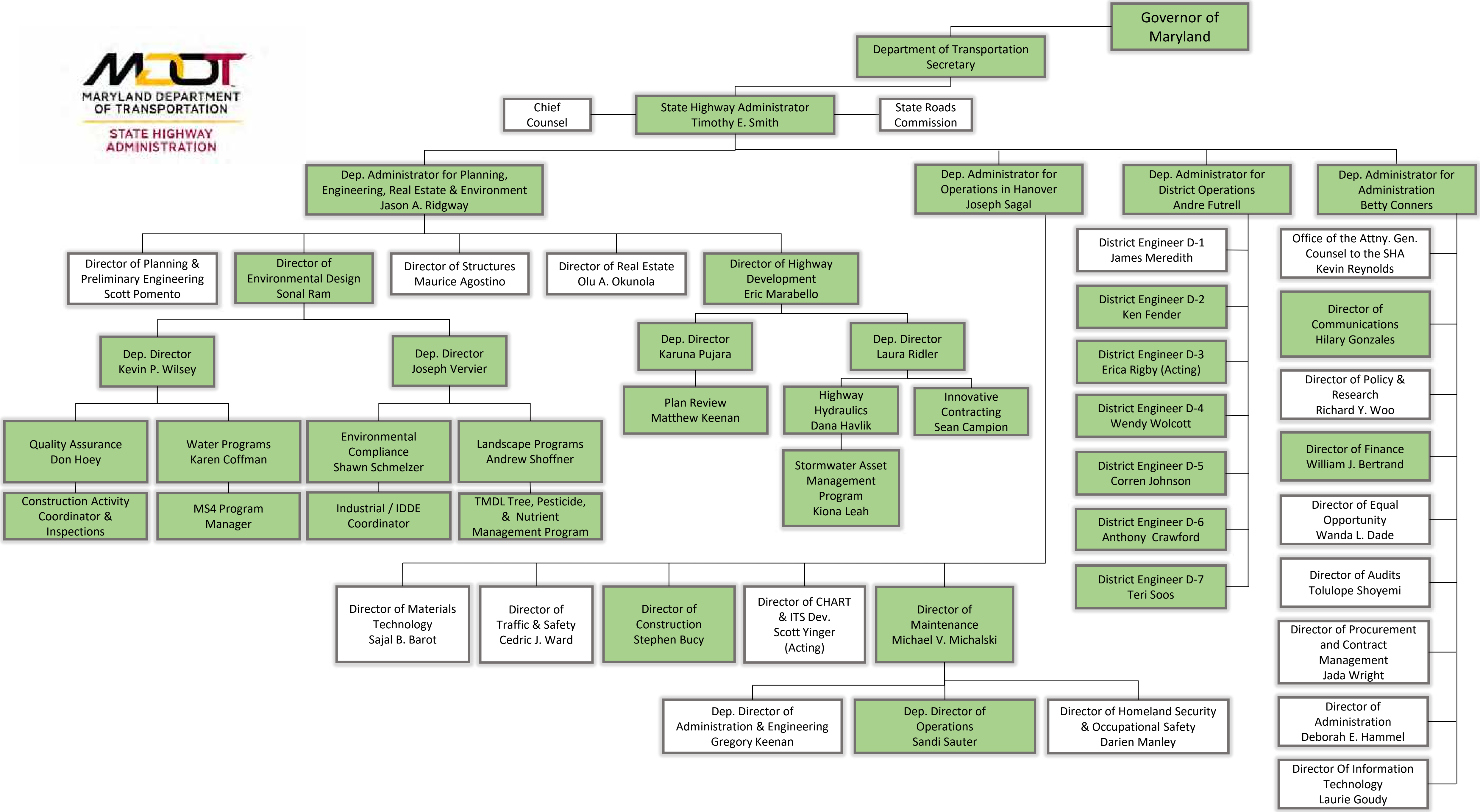
Maryland Department of Transportation
State Highway Administration
Office of Environmental Design
707 North Calvert Street, C-303
Baltimore, MD 21202

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

List of Appendices

Appendix A:
MDOT SHA NPDES MS4 FY20
Program Organizational Chart

MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION



Appendix B: Stormwater Preventative Maintenance Inspections and Remediation Summary

Table IV.D.1.d below represents the resolution schedule for failing stormwater BMPs that require maintenance. This table is similar (with respect to its presentation and content) to Table 4 provided in Section D.1.d of the FY19 MS4 annual report. The table provides comments indicating status, identifies BMP remediation projects that may require additional approvals (such as a JPA permit or a small pond, dam safety, or NRCS Code 378 review), and provides commitment dates for maintenance completion.

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
020013	Wet pond	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
020026	Wet pond	Fail	XX1725174[a]	9/30/2024[c]	Recommended for Retrofit
020048	Infiltration basin	Fail	XX1725174[a]	6/30/2026	BMP Added to List in FY20. Work Order Approved, Construction Pending Funding
020052	Infiltration basin	Fail		6/30/2025[c]	BMP Added to List in FY19
020061	Infiltration basin	Fail		9/30/2025[c]	
020090	Wet extended detention pond	Fail		6/30/2026	BMP Added to List in FY20
020092	Infiltration trench	Fail	AZ044A11[b]	9/30/2024[c]	In Design and Permitting Process
020094	Infiltration trench	Fail	XX1725174	6/30/2020	**FY20 Construction Complete**, Awaiting As-Builts
020103	Wet pond	Fail	XX1725174[a]	6/30/2025[c]	BMP Added to List in FY19, In Design and Permitting Process
020110	Wet pond	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved – Construction Pending Funding
020113	Wet pond	Fail			BMP Added to List in FY20
020114	Wet pond	Fail	XX1725174[a]	6/30/2025[c]	BMP Added to List in FY19, In Design and Permitting Process

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
020124	Wet pond	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved – Construction Pending Funding
020167	Dry pond	Fail		9/30/2023[c]	
020177	Dry swale	Fail		9/30/2024[c]	
020231	Infiltration trench	Fail		6/30/2025[c]	BMP Added to List in FY19
020244	Infiltration trench	Fail	AX3565274[b]	6/30/2024[c]	In Design and Permitting Process
020257	Wet pond	Fail	AX7665D82[b]	6/30/2025[c]	
020258	Infiltration basin	Fail	AA8225174	6/30/2021	**FY20 Construction Complete**, Awaiting As-Builts
020260	Infiltration basin	Fail	AA8225174	6/30/2021	**FY20 Construction Complete**, Awaiting As-Builts
020268	Infiltration basin	Fail	AA8225174	6/30/2021[c]	Retrofit Under Construction
020271	Infiltration basin	Fail	AZ044A11[b]	6/30/2024[c]	BMP Added to List in FY19, In Design and Permitting Process
020272	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
020273	Dry pond	Fail		6/30/2026	BMP Added to List in FY20
020276	Wet pond	Fail	AX7665D82[b]	6/30/2025[c]	
020277	Wet pond	Fail		N/A	BMP Added to List in FY19, **BMP Abandoned**
020298	Wet pond	Fail		6/30/2026	BMP Added to List in FY20
020308	Infiltration trench	Fail	AZ044A11[b]	6/30/2024[c]	BMP Added to List in FY19, In Design and Permitting Process
020322	Infiltration trench	Fail	AZ044A11[b]	6/30/2024	BMP Added to List in FY20, In Design and Permitting Process
020338	Infiltration basin	Fail		9/30/2025[c]	
020339	Infiltration basin	Fail		6/30/2024[c]	
020357	Infiltration trench	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved – Construction Pending Funding
020363	Infiltration basin	Fail		9/30/2024[c]	
020388	Infiltration basin	Fail		9/30/2024[c]	
020393	Infiltration basin	Fail		6/30/2026	BMP Added to List in FY20
020394	Infiltration basin	Fail		9/30/2024[c]	

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
020396	Infiltration basin	Fail	XX1725174[a]	6/30/2023[c]	BMP Added to List in FY19, Work Order Approved – Construction Pending Funding
020399	Infiltration basin	Fail		6/30/2024[c]	
020403	Infiltration trench	Fail	XX1725174[a]	6/30/2023[c]	BMP Added to List in FY19, Work Order Approved – Construction Pending Funding
020406	Dry pond	Fail	XX1725174[a]	6/30/2024[c]	BMP Added to List in FY19, Recommended for Retrofit
020409	Infiltration trench	Fail	AZ044A11[b]	6/30/2024[c]	Recommended for Retrofit
020410	Infiltration trench	Fail	AZ044A11[b]	6/30/2024[c]	Recommended for Retrofit
020429	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
020480	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
020484	Infiltration trench	Fail	XX1725174[a]	6/30/2023[c]	BMP Added to List in FY19, Work Order Approved – Construction Pending Funding
020486	Wet pond	Fail	XX1725174[a]	6/30/2023[c]	BMP Added to List in FY19, Work Order Approved – Construction Pending Funding
020489	Infiltration basin	Fail	AZ044A11[b]	9/30/2025[c]	In Design and Permitting Process
020490	Infiltration trench	Fail	AX7665D82[b]	6/30/2019	**Remediation / Maintenance not completed on schedule; enforcement needed to rectify deficiencies**.
020494	Infiltration basin	Fail		6/30/2025[c]	
020514	Infiltration basin	Fail		6/30/2025[c]	
020516	Infiltration trench	Fail	XX1725174[a]	6/30/2023[c]	Work Order Approved – Construction Pending Funding
020517	Infiltration trench	Fail		6/30/2025[c]	
020520	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	Work Order Approved – Construction Pending Funding
020522	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
020532	Infiltration trench	Fail		6/30/2025[c]	BMP Added to List in FY19
020544	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
020561	Infiltration basin	Fail		6/30/2025[c]	

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
020565	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
020584	Wet extended detention pond	Fail		6/30/2025[c]	BMP Added to List in FY19
020603	Bioretention	Fail		6/30/2025[c]	BMP Added to List in FY19
020608	Bioretention	Fail		6/30/2025[c]	BMP Added to List in FY19
020747	Grass Swale	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
020757	Infiltration basin	Fail	XX1725174[a]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
020760	Infiltration basin	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
020761	Infiltration basin	Fail		6/30/2025[c]	BMP Added to List in FY19
020764	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
020774	Infiltration trench	Fail	XX1725174[a]	6/30/2024[c]	BMP Added to List in FY19, In Design and Permitting Process
020782	Infiltration trench	Fail	XX1725174[a]	6/30/2024[c]	BMP Added to List in FY19, In Design and Permitting Process
020787	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
020795	Infiltration trench	Fail	AX3565274[b]	6/30/2024[c]	BMP Added to List in FY19, In Design and Permitting Process
020801	Infiltration basin	Fail	AX7665D82[a]	N/A	**Abandonment pending**
020807	Infiltration trench	Fail		N/A	BMP Added to List in FY19, **BMP Abandoned**
020810	Infiltration trench	Fail		6/30/2025[c]	BMP Added to List in FY19
020811	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
020817	Surface sand filter	Fail		6/30/2025[c]	BMP Added to List in FY19
020818	Surface sand filter	Fail	AX7665D82[b]	6/30/2025[c]	
020820	Surface sand filter	Fail		6/30/2025[c]	BMP Added to List in FY19
020823	Infiltration basin	Fail	AX7665D82[b]	6/30/2024[c]	
020827	Wet pond	Fail	AZ044A11[b]	6/30/2024[c]	BMP Added to List in FY19, Recommended for Retrofit
020845	Infiltration basin	Fail	XX1725174[a]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
020850	Infiltration basin	Fail		9/30/2024[c]	
020875	Infiltration basin	Fail	XX1725174[a]	6/30/2024	BMP Added to List in FY20, In Design and Permitting Process
020880	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
020892	Infiltration trench	Fail		N/A	BMP Added to List in FY19, **BMP Abandoned**
020893	Infiltration trench	Fail		N/A	BMP Added to List in FY19, **BMP Abandoned**
020896	Grass Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
021012	Micropool extended detention pond	Fail		6/30/2026	BMP Added to List in FY20
021018	Infiltration basin	Fail		6/30/2026	BMP Added to List in FY20
021472	Bio-swale	Fail		6/30/2026	BMP Added to List in FY20
021473	Bio-swale	Fail		6/30/2026	BMP Added to List in FY20
021796	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
022013	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
022037	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
022066	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
030001	Grass Channel Credit	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
030005	Grass swale	Fail	AZ044A11[b]	6/30/2024	BMP Added to List in FY20, In Design and Permitting Process
030011	Wet pond	Fail	AZ044A11[b]	6/30/2024[c]	In Design and Permitting Process
030109	Infiltration Basin	Fail		6/30/2026	BMP Added to List in FY20
030113	Infiltration trench	Fail		6/30/2025[c]	BMP Added to List in FY19
030116	Infiltration basin	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030124	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030136	Infiltration basin	Fail		6/30/2024[c]	
030137	Infiltration basin	Fail		9/30/2025[c]	
030175	Dry pond	Fail		6/30/2024[c]	
030183	Infiltration basin	Fail		6/30/2025[c]	BMP Added to List in FY19
030189	Infiltration basin	Fail		9/30/2024[c]	

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
030198	Infiltration trench	Fail		6/30/2025[c]	BMP Added to List in FY19
030200	Infiltration basin	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030214	Infiltration basin	Fail		9/30/2024[c]	
030215	Infiltration basin	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030220	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030227	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19. BMP Failed Post Remediation, Recommended for Retrofit
030244	Infiltration trench	Fail		6/30/2026[c]	BMP Added to List in FY19. BMP Failed Post Remediation, Recommended for Retrofit
030245	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030252	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
030253	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
030256	Infiltration trench	Fail	AX3565274[b]	6/30/2019	**Remediation / Maintenance not completed on schedule; enforcement needed to rectify deficiencies.** Remediation in Design and Permitting Process.
030269	Dry pond	Fail		6/30/2025[c]	BMP Added to List in FY19
030274	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
030284	Bioretention	Fail		6/30/2025[c]	BMP Added to List in FY19
030333	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030385	Surface sand filter	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
030505	Micro-Bioretention	Fail		6/30/2025[c]	BMP Added to List in FY19
060104	Dry pond	Fail	AX7665D82[b]	N/A	**Site determined to be privately owned; removed from list in FY20.**
060106	Dry pond	Fail		6/30/2025	BMP Added to List in FY20
070003	Infiltration basin	Fail	AZ044A11[b]	6/30/2025	BMP Added to List in FY20, In Design and Permitting Process
070004	Infiltration basin	Fail	AZ044A11[b]	6/30/2025	BMP Added to List in FY20, In Design and Permitting Process

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
080007	Wet pond	Fail		6/30/2025[c]	
080019	Infiltration basin	Fail		6/30/2025[c]	BMP Added to List in FY19
080027	Wet Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
080028	Wet Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
080069	Wet pond	Fail		6/30/2024[c]	BMP Added to List in FY19
080070	Wet pond	Fail		6/30/2024[c]	BMP Added to List in FY19
080071	Wet pond	Fail		6/30/2024[c]	BMP Added to List in FY19
080074	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
082187	Underground detention	Fail		6/30/2026	BMP Added to List in FY20
100001	Bioretention	Fail		6/30/2026	BMP Added to List in FY20
100004	Surface sand filter	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
100012	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
100060	Infiltration basin	Fail	AX7665D82[b]	6/30/2025[c]	
100061	Infiltration basin	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
100065	Dry pond	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
100099	Wet pond	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
100126	Grass swale	Fail	AZ044A11[b]	6/30/2023	BMP Added to List in FY20, Work Order Approved – Construction Pending Funding
100129	Wet swale	Fail		6/30/2024[c]	BMP Added to List in FY19
100143	Dry swale	Fail		6/30/2024[c]	BMP Added to List in FY19
100310	Bio-swale	Fail		6/30/2026	BMP Added to List in FY20
100471	Other filtering	Pass			**Per Latest Inspection, BMP is Functioning as Designed and Only Needs Minor Maintenance**
120008	Dry pond	Fail	AX7665D82[b]	6/30/2025[c]	
120009	Dry pond	Fail		6/30/2025[c]	
120017	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
120019	Infiltration trench	Fail		6/30/2025[c]	BMP Added to List in FY19
120039	Infiltration trench	Fail	HA4285174[b]	9/30/2024[c]	
120042	Infiltration trench	Fail	HA4285174[b]	9/30/2024[c]	

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
120063	Infiltration trench	Fail	AX3565274[b]	6/30/2025[c]	In Design and Permitting Process
120066	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
120095	Infiltration basin	Fail		6/30/2025[c]	
120105	Dry extended detention pond	Fail		9/30/2025[c]	
120106	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
120112	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
120133	Infiltration basin	Fail		9/30/2025[c]	
120203	Wet extended detention pond	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
120208	Surface sand filter	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
120291	Wet pond	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
122335	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
130013	Dry extended detention pond	Fail		6/30/2025[c]	BMP Added to List in FY19
130027	Dry extended detention pond	Fail		9/30/2025[c]	
130050	Infiltration basin	Fail		6/30/2025[c]	BMP Added to List in FY19
130072	Dry extended detention pond	Fail	AX7665282	9/30/2021[c]	Retrofit under construction
130073	Wet pond	Fail	AX7665282	9/30/2021[c]	Retrofit under construction
130074	Micropool extended detention pond	Fail	AX9295482[a]	9/30/2024[c]	Recommended for Retrofit
130077	Wet pond	Fail		9/30/2025[c]	
130078	Dry pond	Fail		6/30/2025[c]	BMP Added to List in FY19
130134	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
130136	Infiltration trench	Fail		6/30/2026[c]	BMP Added to List in FY19, BMP Failed Post Remediation, Recommended for Retrofit
130167	Infiltration basin	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
130180	Grass Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
130204	Infiltration basin	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
130206	Wet pond	Fail		9/30/2025[c]	

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
130208	Infiltration trench	Fail	AX9295482[a]	6/30/2024[c]	Recommended for Retrofit
130210	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
130220	Dry extended detention pond	Fail		9/30/2025[c]	
130237	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
130251	Surface sand filter	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
130259	Surface sand filter	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
130263	Surface sand filter	Fail		6/30/2025[c]	BMP Added to List in FY19
130271	Dry pond	Fail	AX7665D82[b]	6/30/2025 [c]	
130292	Other infiltration	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
130294	Other infiltration	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
130317	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
130319	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
130332	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
130341	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
130357	Infiltration trench	Fail		N/A	BMP Added to List in FY19, **BMP Abandoned**
130366	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19, BMP Failed Post Remediation, Recommended for Retrofit
130369	Shallow marsh	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
130375	Infiltration basin	Fail		N/A	**BMP is Privately Owned and Maintained**
130417	Grass Swale	Fail	AX9295482[a]	6/30/2023[c]	Work Order Approved - Construction Pending Funding
130421	Wet pond	Fail		6/30/2025[c]	
130544	Bio-Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
130629	Bio-Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
130631	Bio-Swale	Fail		6/30/2024[c]	BMP Added to List in FY19
130632	Bio-Swale	Fail		6/30/2024[c]	BMP Added to List in FY19

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
132056	Micro-Bioretention	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
150036	Infiltration trench	Fail		6/30/2025[c]	
150059	Wet pond	Fail		6/30/2025[c]	**BMP Removed by SHA Contract MO3515172**
150066	Dry pond	Fail		6/30/2025[c]	
150079	Infiltration basin	Fail	AZ044A11[b]	6/30/2026	BMP Added to List in FY20. In Design and Permitting Process
150081	Infiltration basin	Fail		6/30/2025[c]	
150201	Infiltration trench	Fail		6/30/2024[c]	BMP Added to List in FY19
150217	Infiltration basin	Fail		6/30/2024[c]	BMP Added to List in FY19
150232	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
150285	Dry pond	Fail		6/30/2025[c]	
150295	Bioretention	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
150304	Surface sand filter	Fail		6/30/2025[c]	
150312	Dry extended detention pond	Fail		9/30/2025[c]	
150348	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
150352	Dry pond	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
150355	Wet pond	Fail		6/30/2025[c]	
150400	Dry pond	Fail		6/30/2025[c]	BMP Added to List in FY19
150638	Infiltration basin	Fail		N/A	BMP Added to List in FY19, **BMP Abandoned**
150643	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
150650	Dry pond	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
150680	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
150706	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
150749	Other	Fail		6/30/2024[c]	BMP Added to List in FY19
150750	Other	Fail		6/30/2024[c]	BMP Added to List in FY19
151370	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
160012	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160061	Wet pond	Fail		6/30/2024[c]	BMP Added to List in FY19
160126	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160127	Wet extended detention pond	Fail		6/30/2026	BMP Added to List in FY20
160131	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
160136	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160151	Infiltration trench	Fail	AZ044A11[b]	6/30/2026	BMP Added to List in FY20. In Design and Permitting Process
160176	Dry extended detention pond	Fail		6/30/2025[c]	
160181	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160187	Wet swale	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
160197	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	BMP Added to List in FY19, In Design and Permitting Process
160203	Shallow marsh	Fail		6/30/2024[c]	
160211	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160218	Dry pond	Fail		6/30/2026	BMP Added to List in FY20
160224	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
160225	Infiltration trench	Fail	AZ044A11[b]	9/30/2023[c]	In Design and Permitting Process
160230	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
160232	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
160246	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160247	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160250	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160301	Dry pond	Fail		6/30/2026	BMP Added to List in FY20
160305	Wet pond	Fail		6/30/2026	BMP Added to List in FY20
160351	Wet pond	Fail		6/30/2026	BMP Added to List in FY20
160378	Dry pond	Fail		6/30/2025[c]	
160402	Infiltration trench	Fail		6/30/2026	BMP Added to List in FY20
160408	Infiltration trench	Fail	AX3565274[b]	6/30/2023[c]	In Design and Permitting Process
160427	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process

Table IV.D.1.d: MDOT SHA SWM Facilities for Remediation Work Orders

SWM Facility Number	Facility Type	MDE Pass / Fail	Contract	Completion Commitment Date	Remediation Comments
160429	Infiltration trench	Fail	AZ044A11[b]	6/30/2023[c]	In Design and Permitting Process
160505	Wet pond	Fail	AZ044A11[b]	6/30/2024[c]	In Design and Permitting Process
160624	Infiltration trench	Fail		6/30/2024[c]	**BMP is Being Removed by Purple Line**
160662	Wet pond	Fail		6/30/2025[c]	BMP Added to List in FY19
160732	Wet pond	Fail		6/30/2026	BMP Added to List in FY20
160747	Wet extended detention pond	Fail	AZ044A11[b]	6/30/2024[c]	BMP Added to List in FY19, In Design and Permitting Process
160749	Infiltration trench	Fail		6/30/2023[c]	**BMP is Being Removed by Purple Line**
160806	Wet pond	Fail		6/30/2025[c]	
161953	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
162131	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
162242	2A Grass swale	Fail		6/30/2026	BMP Added to List in FY20
210003	Dry swale	Fail	XY1695174[a]	6/30/2023[c]	In Design and Permitting Process
210009	Infiltration basin	Fail	XY1695174[a]	6/30/2019	**Remediation / Maintenance not completed on schedule; enforcement needed to rectify deficiencies.** Remediation in Design and Permitting Process
210233	Dry Pond	Fail	XX1695174[a]	6/30/2025	BMP Added to List in FY20. In Design and Permitting Process
210938	Bio-swale	Fail		6/30/2026	BMP Added to List in FY20

[a] Refers to a contract that went to construction during FY19 or FY20 that had to be cancelled due to budgetary impacts. These facilities will be prioritized first when resources are allocated for construction.

[b] Refers to a charge number created during FY20 for which work began for design and permitting only. These facilities will be prioritized second when resources are allocated for construction.

[c] Completion commitment date changed due to unanticipated FY20/21 budget cuts.

Appendix C: Illicit Discharge Detection and Elimination Program Summaries

Table IV.D.3.a below summarizes primary and additional field screening efforts for the FY20 reporting period. In the MS4 geodatabase submitted with this FY20 MS4 annual report, MDOT SHA has provided the applicable illicit discharge detection and elimination program information in the IDDE associated table.

Table IV.D.3.a: Primary Field Screening Summary

County	Number of Outfalls Field Screened FY 20	Discharges Requiring Follow-up
Carrol	45	0
Charles	64	2
Harford	44	2
Howard	37	0
Totals	190	4

Table IV.D.3.b below summarizes information from the most recent quarterly facility inspection performed at each of the NPDES 12-SW permitted sites within the MDOT SHA MS4 Permit area. Included in the summary is a description of each issue identified during those inspections and the associated resolutions made by MDOT SHA during the FY20 reporting period.

Table IV.D.3.b: Summary of the Most Recent Quarterly Inspection for NPDES 12-SW Permitted Facilities

Facility Name	Quarter Number and Fiscal Year for Last Inspection	Date of Last Quarterly Inspection	Number of Issues Identified	Uploaded to Web-based Tracking (Yes or No)	Issue Details	Resolved? (Yes or No)	Comments
Cambridge	2nd QTR 2020	05/18/2020	1	Yes	Brine tank leaking fitting	Yes	Resolved by facility personnel on 5/20/20. No further leaking.
Salisbury	2nd QTR 2020	05/20/2020	1	Yes	Storm Water/Material Storage- Storm Water Management Facilities Not Properly Maintained - Storm drain outside of the shop is clogged with sediment, mulch, and	Yes	Area around storm drain was cleared on 5/21/2020.

Table IV.D.3.b: Summary of the Most Recent Quarterly Inspection for NPDES 12-SW Permitted Facilities

Facility Name	Quarter Number and Fiscal Year for Last Inspection	Date of Last Quarterly Inspection	Number of Issues Identified	Uploaded to Web-based Tracking (Yes or No)	Issue Details	Resolved? (Yes or No)	Comments
					debris. This needs to be cleared out to allow the drain to function properly.		
Elkton	2nd QTR 2020	05/11/2020	0	N/A	N/A	N/A	
Fairland	2nd QTR 2020	05/08/2020	0	N/A	N/A	N/A	
Gaithersburg	2nd QTR 2020	05/11/2020	0	N/A	N/A	N/A	
Laurel	2nd QTR 2020	05/15/2020	0	N/A	N/A	N/A	
Marlboro	2nd QTR 2020	05/18/2020	2	Yes	1. Storm Water/Material Storage-Storage Pile Management Problems - Material Stockpiles; a load of topsoil sitting uncovered. 2. Storm Water/Material Storage-Floatable Debris Not Properly Contained - Behind Material Stockpiles; there is a lot of trash and it is floating around the water that has ponded.	Yes	1. Resolved by facility personnel by adding tarp on 6/6/2020. 2. Trash cleaned up and area organized 6/16/20.
Golden Ring	2nd QTR 2020	05/26/2020	1	Yes	Storm Water/Material Storage- Storm Water Management Facilities Not Properly Maintained - . - Grate over stream bed pipe is filled 3/4 way with various debris.	Yes	Inlet grate removed and debris cleaned out by facility personnel on 6/16/2020.
Hereford	2nd QTR 2020	05/28/2020	1	Yes	Storm Water/Material Storage - Floatable Debris Not Properly Contained - trash is overflowing in refuse can behind parking spot B8. Trash can be found near and in	Yes	Identified trash was cleaned up by facility personnel on 6/19/20.

Table IV.D.3.b: Summary of the Most Recent Quarterly Inspection for NPDES 12-SW Permitted Facilities

Facility Name	Quarter Number and Fiscal Year for Last Inspection	Date of Last Quarterly Inspection	Number of Issues Identified	Uploaded to Web-based Tracking (Yes or No)	Issue Details	Resolved? (Yes or No)	Comments
					stormwater pond area and near stormwater outfalls. Various debris around yard needs to be cleaned up.		
Owings Mills	2nd QTR 2020	05/15/2020	3	Yes	1. Storm Water/Material Storage-Storage Pile Management Problems - As a BMP, stockpile of wood chips needs to be tarped. 2. Storm Water/Material Storage-Brine Tank and/or Maker Problems - Brine tanks showing signs of leaking with salt buildup around fittings. 3. Storm Water/Material Storage-Floatable Debris Not Properly Contained - garbage is behind dumpster	Yes	1. Wood chips can remain uncovered as long as they are not transported downstream during storm events. Will continue to monitor. 2. Fittings corrected on 6/23/20 by facility staff. 3. Trash cleaned up by shop staff on 6/23/2020.
Churchville	2nd QTR 2020	05/27/2020	0	N/A	N/A	N/A	N/A
Annapolis	2nd QTR 2020	05/07/2020	1	YEs	Storm Water/Material Storage- Storage Pile Management Problems - Asphalt stockpile not covered in back. Sandbags are ripped open and not covered near stormwater sample site 3.	Yes	All stockpiles covered during 6/29/20 re-inspection.
Glen Burnie	2nd QTR 2020	05/21/2020	2	Yes	1. Storm Water/Material Storage-Brine Tank and/or Maker Problems - Storm Water/Material Storage- Brine Tank and/or Maker Problems - Brine tanks are not labeled with content, volume, NFPA labels. Tanks showing	Yes	1. Fittings tightened during follow up inpsection on 7/17/20. Issue resolved.

Table IV.D.3.b: Summary of the Most Recent Quarterly Inspection for NPDES 12-SW Permitted Facilities

Facility Name	Quarter Number and Fiscal Year for Last Inspection	Date of Last Quarterly Inspection	Number of Issues Identified	Uploaded to Web-based Tracking (Yes or No)	Issue Details	Resolved? (Yes or No)	Comments
					evidence of brine leakage around fittings. 2. Storm Water/Material Storage-Floatable Debris Not Properly Contained - Various floatable debris in swale. Needs to be cleaned up.		2. Swale cleaned before 7/17/20 inspection. Issue resolved.
Hanover	2nd QTR 2020	05/28/2020	1	Yes	Storm Water/Material Storage - Materials Not Stored Under Cover/Contained - Old fuel tanks and fuel pumps are currently stored outdoors. Old tarps are no longer sufficient to cover the pumps/tanks.	No	N/A
LaPlata	2nd QTR 2020	05/14/2020	1	Yes	Storm Water/Material Storage- Brine Tank and/or Maker Problems - Salt accumulation around maker connections indicating potential leaks.	Yes	Seals tightened on 5/21/2020 by facility staff. No further leaking observed.
Hagerstown	2nd QTR 2020	05/19/2020	2	Yes	1. Storm Water/Material Storage- Brine Tank and/or Maker Problems - minor leak started tank2 plumbing 2. Storm Water/Material Storage- Management Control Problems - No cover hot box cold patch asphalt	No	1. Issue remains open. Minor brine dripping but temporarily managed by spill pan. 2. Asphalt patching covered on 8/3/20.
Frederick	2nd QTR 2020	05/13/2020	2	Yes	1. Storm Water/Material Storage-Storage Pile Management Problems - a lot of sediment in front of the stockpile bins topsoil cold patch. Requires clean up.	Yes	1. Cleaned up by re-inspection on 7/15/20.

Table IV.D.3.b: Summary of the Most Recent Quarterly Inspection for NPDES 12-SW Permitted Facilities

Facility Name	Quarter Number and Fiscal Year for Last Inspection	Date of Last Quarterly Inspection	Number of Issues Identified	Uploaded to Web-based Tracking (Yes or No)	Issue Details	Resolved? (Yes or No)	Comments
					2. Storm Water/Material Storage-Floatable Debris Not Properly Contained - Trash out of and around the dumpster		2. Trash by dumpster cleaned up on 7/21/20.
Thurmont	2nd QTR 2020	05/15/2020	0	N/A	N/A	N/A	N/A
Dayton	2nd QTR 2020	05/12/2020	0	N/A	N/A	N/A	N/A
Westminster	2nd QTR 2020	05/18/2020	0	N/A	N/A	N/A	N/A

Table IV.D.3.d below summarizes the illicit discharges that required follow-up during the FY20 period. Included in this summary are the discharges requiring follow-up that are referenced in Table IV.D.3.a above.

Table IV.D.3.d: Illicit Discharges Requiring Further Investigation During Reporting Period

Reference No.	County	MDOT SHA Structure or BMP#	Date of ID	Potential Pollutant	Status
1	Cecil	710145.002	10/14/2019	Discoloration	Closed
2	Frederick	1010084.001	05/15/2020	TSS & Discoloration	Closed
3	Prince Georges	BMP #160660	05/15/2020	pH & Copper	Open, referred to MDE
4	Harford	1200366.001	06/03/2020	Chlorine	Open, referred to County
5	Harford	1203856.001	06/03/2020	Chlorine	Open, referred to County
6	Charles	807025.012	06/04/2020	Phenol & Detergent	Closed
7	Baltimore	300806.001	06/04/2020	Chlorine	Open, referred to County
8	Charles	807019.001	06/24/2020	Phenol & pH	Open, referred to County
9	Frederick	BMP #210631	06/19/2020	Discoloration & Odor	Closed

The following updates summarize the jurisdiction contacts/resolution schedule for IDs whose status was designated as “open” or “reopened” in previously submitted MS4 annual reports as well as any FY20 ID’s that required investigation. Updates below are numbered in alignment with the “Reference No.” field of **Table IV.D.3.d** above.

1. A potential IDDE was reported by MDOT SHA contractors working in our ROW during October 2019. The contactor reported discolored standing water within a swale located along MD 213 in Chesapeake City, MD. On October 14, 2019, ECD responded to the notification and performed screening of the site. Discernible dry weather flow was observed in MDOT SHA structure #0710145.002. The flow was tracked upstream and found to be traveling through a culvert pipe located underneath a driveway at the intersection of Bohemia Manor Farm Lane and MD 213 near Chateau Bu-De Winery. Testing of flow yielded no pollutant loading; however, some iron bacteria was observed and noted by field inspectors. The flow was determined to be generated by a natural water source. MDOT SHA considers this investigation “closed” during the FY20 reporting period. Unfortunately, due to timing and the ongoing development of the MDOT SHA inspection tool, this site screening could not be logged into the geodatabase and therefore is not illustrated on Table #7.

2. During FY18, MDOT SHA first reported an ID investigation in Frederick County at Rising Ridge Road in Mt. Airy associated with structural BMP # 100085 and structure #1010084.001. The location of this ID is a 15” reinforced concrete pipe flowing from an inlet on an off-site property. A grey milky discharge flowing into the BMP was found to be the result of a stone cutting operation in the parking lot and adjacent building. The

flow was causing additional sedimentation from the cutting byproduct and staining of the downstream channel material. ECD contacted Frederick County representatives who then contacted the Mt. Airy Department of Public Works to address the ID. This ID was added to the list of IDDE's for screening during FY20. On May 15, 2020 this site was re-inspected and the BMP was found to have no flow. This ID has been addressed and the investigation is considered "closed" following this effort.

3. Beginning in the FY18 annual report, MDOT SHA reported an ID located in Prince George's County at structure #1600828.001, which discharges into structural BMP# 160660. This ID was identified in a commercially developed area along the on-ramp to Interstate 495 from Ritchie Marlboro Road in Largo, MD. Since the initial identification, ECD has repetitively worked with Prince George's (PG) County code enforcement to eliminate the ID. PG County initially performed site visits, compiled stormwater mapping, and met with property owners. However, it appears as though no responsible party was identified and no resolution has yet occurred. During the FY20 reporting period, ECD performed an additional follow up inspection and field testing. This follow up effort was conducted on May 15, 2020 and confirmed that issues with dry weather flow, low pH and copper remain. This location remains an "open" ID and was again referred to MDE's Water and Science Administration, Compliance Program for closure on May 26, 2020. This location will be added to the FY21 primary screening queue to verify correction has occurred.

4. As a result of FY20 primary outfall screening, structure #1200366.001, which is located near the intersection of US 40 and Mountain Road in Harford County, possessed high rates of dry weather flow. Following sampling and testing, this location was found by field staff to exceed the established chlorine action limit (<0.40 mg/l) and is indicative of an underground potable water line break. On June 12, 2020, ID investigation findings were sent to the County representatives requesting assistance with correction. Unless Harford County representatives contact ECD to verify correction has occurred, this ID will remain in "open" status and will be rescreened during FY21.

5. As a result of FY20 primary outfall screening, structure #1203856.001, which is located near the intersection of Porter Drive and Emmorton Road in Harford County, possessed dry weather flow. Initial primary screenings were performed on May 20th and 21st 2020. Both inspections yielded elevated chlorine levels. Following this ID being internally reported, MDOT SHA directed MES to perform a follow up investigation and determine the source. On June 3, 2020, MES field inspectors visited the site and inspected the structure. Again, dry weather flow was found; however, MES found that chlorine was only detected below action levels. As a BMP, this location was also reported to Harford County on June 12, 2020. Unless Harford County representatives contact ECD and verify correction has occurred, this ID will remain in "open" status and will be rescreened during FY21.

6. In June 4, 2020, primary IDDE screenings detected both phenols and detergents above action levels at structure #0807025.012. This structure is located at the cloverleaf area, northeast of the MD Route 301 and Action Lane intersection in Waldorf, Maryland. ECD responded to the reported ID on June 24, 2020. On behalf of MDOT SHA, MES

field personnel performed follow up testing and further investigated the reported ID to determine the source of the issue. Field screening yielded detectable levels of detergents, copper, and chlorine. However, all levels detected were well below action limits. MES determined that the source of the pollutants was not from incoming flow upstream, but rather from a backflow of standing water captured in an open water stormwater pond. The identified pond receives flow from the Walmart parking lot at 11930 Action Lane. It is likely that some pollutant loading is occurring from surface runoff from the Walmart parking lot. Because the source is not an illicit connection and follow up sampling yielded test results below action levels, this suspected ID was deemed "closed" during FY20 reporting period.

7. In the FY19 annual report MDOT SHA structure #0300806.001 was identified as ID. The structure is located near to 5212 Baltimore National Pike was originally found to have clear, clean flow at a moderate rate of speed during dry weather conditions. To ensure that the chlorinated discharge was addressed, MDOT SHA added this location to the list of FY20 screenings. On June 4, 2020 rescreening of this open ID occurred. Both dry weather flow and chlorine levels above the action limit (<0.40 mg/l) were detected. The FY20 findings were immediately reported to Baltimore County. On June 16, 2020, the Baltimore County Bureau of Utilities responded to the notification. The Bureau of Utilities indicated that the water main break was verified and forwarded to Baltimore City for correction under work order #356584. Unless ECD receives verification from Baltimore City or the Bureau of Utilities that corrections have occurred, this ID will remain "open" and will be rescreened during FY21.

8. During FY20 primary screenings, structure #807019.001 located along Route 301 in Charles County was found by field staff to exceed the established phenol detection limit (<0.17 mg/l). Follow up inspections verified the ID by yielded lower phenol levels, but an acidic pH. Inspectors were able to track dry weather flow back to the source, which appeared to be a nearby car dealership. Because MDOT SHA does not possess jurisdiction to pursue this matter further with private landowners, the issue was referred to Charles County for assistance with correction on June 29, 2020. MDOT SHA received a response from the Charles County Inspections Superintendent on July 1, 2020 indicating that the County is actively working to address the ID. This ID remains "open" status and will be rescreened during FY21 unless County representatives contact MDOT SHA and verify correction has occurred.

9. During June 2020 a contractual work crew performing stormwater structure assessments on behalf of MDOT SHA along Sharpsburg Pike in Frederick, Maryland reported a sewer smell at structural BMP #210631. This potential ID was investigated on June 19, 2020 by MES field inspectors. Field inspectors did not encounter a sewage smell as originally reported. There was also no flow or standing water present at the time of inspection. The inspection findings were documented in the inspection tool and the ID is considered "closed."

Appendix D: Public Education Programs

In accordance with Part V.A.1.d of the MS4 Permit, MDOT SHA provides the following summary describing its public education programs implemented during the FY20 reporting period in accordance with conditions in Parts IV.D.4 and IV.D.6 of the MS4 Permit.

PARK(ing) Day

On September 20, 2019, the MDOT SHA Environmental Action Team (formerly Earth Day Team) and over 75 visitors participated again in celebration of the global PARK(ing) Day event.   As described in Section IV.D.4.b of the FY19 MS4 annual report, PARK(ing) Day encourages participants to simulate a "day in the park" through transformation of an outdoor parking space into a park or greenspace for the day. Visitors to the MDOT SHA event participated in activities such as games of miniature golf, cornhole, and trivia.

Figure 1: MDOT SHA "Day in the Park" display for FY20 PARK(ing) Day event

The golf course, designed by MDOT SHA landscape architects (see **Figure 1**), featured repurposed materials to promote "upcycling", reuse of everyday materials to create course elements and reduce waste. Trivia questions educated participants and tested their knowledge about local and State parks and trail systems.

The MDOT SHA Rec Trails Program featured a map of all MDOT SHA sponsored projects. A program representative was on sight to directly engage the public in education about parks suitable to their individual outdoor needs and MDOT SHA's stewardship through the Rec Trails Program (see **Figure 2**).

Figure 2: MDOT SHA Rec Trails Program engagement

Earth Day

Organization of activities to celebrate Earth Day were impacted by the sudden onset of the COVID-19 pandemic during the preceding month and implementation of associated social distancing policies. On April 22, 2020 however, MDOT disseminated an email newsletter to its workforce of more than 11,000 individuals titled, “Earth Day 2020: Reducing Our Carbon Footprint” (see **Figure 3**) that sought to educate recipients about, among other environmental topics, “actions you can take at home and at work” to aim for zero waste, including practicing “the four Rs: Reduce, Reuse, Re-purpose, and Recycle”.

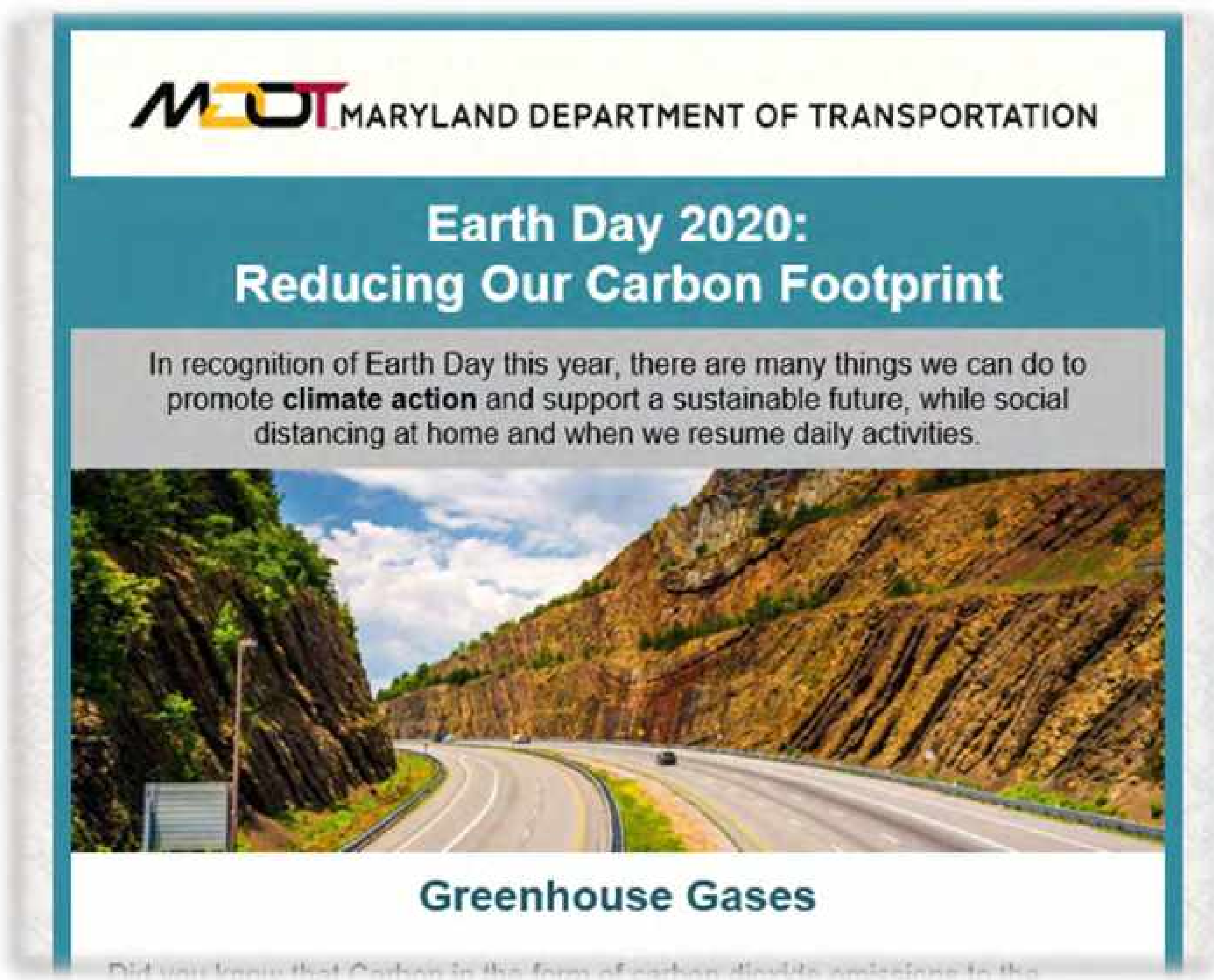


Figure 3: MDOT Earth Day newsletter excerpt

Keep Maryland Beautiful Grant Program

Maryland Environmental Trust awarded 81 *Keep Maryland Beautiful* grants in 2020 to support the removal of thousands of pounds of litter and the revitalization of public lands and waterways. Four different grants were offered to help volunteer and nonprofit groups, communities, and land trusts support environmental education projects, litter removal, citizen stewardship, and solve natural resource issues in urban and rural areas. Funding for the *Keep Maryland Beautiful* grants program is provided by MDOT, Maryland Department of Housing and Community Development, the Forever Maryland Foundation, and Maryland Environmental Trust. MDOT pledged $50,000 a year to the program for five years (starting in FY18) totaling $250,000.

Be Street Wise

In 2020, MDOT SHA launched the *Be Street Wise* initiative to educate Marylander's on best practices to Drive Safe, Walk Safe and Bike Safe. For Bike Safe, the reminder to both bicyclists and drivers is that "We're On This Road Together". That means that all roadway users must follow the laws of the road and look out for each other. Through a combination of grassroots outreach, social media, marketing and public relations, the campaign's goal is to raise awareness, reinforce safe riding and driving behaviors and reduce the number of bicycle-related crashes. COVID-19 constrained public outreach by the MDOT SHA Office of Communication after mid-March, and efforts thereafter relied heavily on social media and public service announcements (see **Figure 4**). For more information please go to roads.maryland.gov/bikesafey.

Figure 4: Be Street Wise promotional material

Bike to Work Day

The 2020 Bike to Work Day for the Baltimore Region was morphed into Bike to Work Week. Bike to Work Week celebrates bicycling as a healthy commuting option, while promoting public awareness of its safety and environmental benefits. In 2020, the usual rallies and pit stop gatherings were replaced with online networking and encouragement for all riders. Riders who registered for Bike to Work Week 2020 and rode during the week of September 21-27 could pick up a free t-shirt at over a dozen area bike shops (open to the first 2,500 registrants) and had that chance to win prizes. Riders could sign up for the *Cycle September Challenge* to participate in a friendly month-long competition and become eligible to win even more prizes. For more information, please go to biketoworkmd.com.

Artscape 2019

MDOT SHA participated in bike safety outreach efforts at the annual Artscape event in Baltimore City held July 19-21, 2019. The MDOT SHA booth engaged approximately 20,000 visitors, engaging them in art activities and distributing more than 10,000 educational items (see **Figure 5**). Visitors created almost 1000 fun pictures with our stationary spin art bikes. In addition, MDOT SHA staff administered over 500 bike safety surveys to gauge the efficacy of its campaign.

Figure 5: MDOT SHA booth at Artscape 2019 event

Chesapeake Bay Field Trips

Annual Chesapeake Bay field trips are offered through the MDOT SHA On-line Learning Center, College of Engineering, environmental design training (ENV400) and are led by the Chesapeake Bay Foundation. It is a class that requires no pre-requisite training and is offered to all MDOT SHA employees seeking to improve their environmental awareness. Attendees are a mixture of employees from all over the state with varied levels of experience and educational background. The trips demonstrate the link between highway runoff and its impacts on streams, rivers, and the health of the Chesapeake Bay. It is a great opportunity for MDOT SHA employees to learn about one another's careers as well as habits and actions in daily work and home environments that may affect the health of the Chesapeake Bay.

The training includes visits to important environmental sites including wetlands, streams, forests, and a boat trip on the Bay. Two trips were held during the FY20 reporting period, on November 13, 2019 and November 14, 2019 (see **Figure 6**), with 23 MDOT SHA employees attending in all. Two additional trainings were scheduled for April 23, 2020 and April 28, 2019 but had to be canceled due to the COVID-19 pandemic.

Figure 6: Chesapeake Bay Field Trip, November 2019

Appendix E: TMDL Compliance Progress

MDOT SHA has prepared and is submitting this FY20 TMDL assessment report with tables in accordance with conditions in Part IV.E.5 of the MS4 Permit.

A complete description of MDOT SHA restoration modeling protocol, used to evaluate whether MDOT SHA restoration plans are effectively working toward achieving compliance with EPA approved TMDLs, was provided as Appendix D to the FY19 MS4 annual report. That protocol was used to develop progress reporting presented in this FY20 TMDL assessment report.

Table V.A.1.e is provided below in accordance with conditions in Parts IV.E.5.a, estimated net change in pollutant load reductions from completed projects and programs, IV.E.5.b, comparison of net change in load reductions with established benchmarks, and V.A.1.e, annual reporting of above conditions, of the MS4 Permit. Progress toward attainment of benchmarks and applicable WLAs developed under EPA approved TMDLs is also documented in the CountywideStormwaterWatershedAssessment and LocalStormwaterWatershedAssessment tables of the MS4 geodatabase submitted with the FY20 MS4 annual report.

Table V.A.1.e: Progress Toward Attainment of Benchmarks and Applicable WLAs Developed Under EPA Approved TMDLs

						FY20 Progress		
Watershed Name	**County**	**Pollutant**	**Unit**	**Total Reduction**	**2020 Interim Target**	**Reduction Achieved as of 6/30/2020**	**% Total Reduction**	**% 2020 Interim Target**
Chesapeake Bay TMDLs								
MS4 Area Wide	NA	Nitrogen	DEL-lbs/yr	88,281	44,140*	36,660	42%	83%
MS4 Area Wide	NA	Phosphorus	DEL-lbs/yr	25,994	12,997*	12,470	48%	96%
MS4 Area Wide	NA	Sediment	DEL-lbs/yr	14,910,510	7,455,255*	6,035,715	40%	81%
Note: The modeling was conducted for the entire permitted area. MDOT SHA assumed a baseline year of 2011. * Progress reporting for 2019 mistakenly changed the interim targets for 2020 from the 2018 reported targets. The 2018 reported 2020 targets are used here for progress reporting in this 2020 report.								
Nutrient and Sediment TMDLs								
Anacostia River - Nontidal	MO	Nitrogen	EOS-lbs/yr	21,633	3,342	3,721	17.2%	111.4%
		Phosphorus	EOS-lbs/yr	1,793	1,793	2,493	139.0%	139.0%
		Sediment	EOS-lbs/yr	462,742	462,742	1,347,535	291.2%	291.2%
Anacostia River - Tidal	MO, PG	Nitrogen	EOS-lbs/yr	4,910	42	52	1.1%	123.9%
		Phosphorus	EOS-lbs/yr	575	17	17	2.9%	102.0%
		Sediment	EOS-lbs/yr	157,500	5,011	6,027	3.8%	120.3%

Table V.A.1.e: Progress Toward Attainment of Benchmarks and Applicable WLAs Developed Under EPA Approved TMDLs

						FY20 Progress		
Watershed Name	**County**	**Pollutant**	**Unit**	**Total Reduction**	**2020 Interim Target**	**Reduction Achieved as of 6/30/2020**	**% Total Reduction**	**% 2020 Interim Target**
Antietam Creek	WA	Phosphorus	EOS-lbs/yr	277	102	61	22.2%	60.3%
		Sediment	EOS-lbs/yr	1,007,480	108,098	88,801	8.8%	82.1%
Bynum Run	HA	Sediment	EOS-lbs/yr	24,316	16,469	5,175	21.3%	31.4%
Cabin John Creek	MO	Sediment	EOS-lbs/yr	231,907	79,327	357,313	154.1%	450.4%
Catoctin Creek	FR	Phosphorus	EOS-lbs/yr	153	153	31	20.3%	20.3%
		Sediment	EOS-lbs/yr	594,338	280,379	49,558	8.3%	17.7%
Conococheague Creek	WA	Sediment	EOS-lbs/yr	522,112	43,821	38,913	7.5%	88.8%
Double Pipe Creek	CL, FR	Phosphorus	EOS-lbs/yr	1,040	585	38	3.6%	6.5%
		Sediment	EOS-lbs/yr	455,050	371,013	15,609	3.4%	4.2%
Gwynns Falls	BA	Sediment	EOS-lbs/yr	498,014	37,415	22,111	4.4%	59.1%
Jones Falls	BA	Sediment	EOS-lbs/yr	94,768	64,214	73,740	77.8%	114.8%
Liberty Reservoir	BA, CL	Phosphorus	EOS-lbs/yr	563	82	91	16.2%	111.8%
		Sediment	EOS-lbs/yr	506,848	68,649	71,239	14.1%	103.8%
Little Patuxent River	AA, HO	Sediment	EOS-lbs/yr	524,969	524,969	385,403	73.4%	73.4%
Loch Raven Reservoir	BA, CL, HA	Phosphorus	EOS-lbs/yr	186	186	195	105.0%	105.0%
Lower Gunpowder Falls	BA	Sediment	EOS-lbs/yr	170,420	170,420	233,647	137.1%	137.1%
Lower Monocacy River	CL, FR, MO	Phosphorus	EOS-lbs/yr	1,119	1,108	727	65.0%	65.6%
		Sediment	EOS-lbs/yr	1,002,040	384,523	136,209	13.6%	35.4%
Marsh Run	WA	Sediment	EOS-lbs/yr	162,630	19,640	19,444	12.0%	99.0%
Mattawoman Creek	CH, PG	Nitrogen	EOS-lbs/yr	2,871	545	455	15.8%	83.5%
		Phosphorus	EOS-lbs/yr	326	73	37	11.5%	51.1%
Non-Tidal Back River	BA	Nitrogen	EOS-lbs/yr	1,306	552	373	28.5%	67.4%
		Phosphorus	EOS-lbs/yr	128	128	93	72.9%	72.9%

Table V.A.1.e: Progress Toward Attainment of Benchmarks and Applicable WLAs Developed Under EPA Approved TMDLs

Watershed Name	County	Pollutant	Unit	Total Reduction	2020 Interim Target	FY20 Progress: Reduction Achieved as of 6/30/2020	FY20 Progress: % Total Reduction	FY20 Progress: % 2020 Interim Target
		Sediment	EOS-lbs/yr	242,234	50,294	49,893	20.6%	99.2%
Other West Chesapeake	AA	Sediment	EOS-lbs/yr	18,232	829	251	1.4%	30.2%
Patapsco River LN Branch	AA, BA, HO	Sediment	EOS-lbs/yr	473,754	309,836	299,983	63.3%	96.8%
Patuxent River Lower	AA, CH, PG	Sediment	EOS-lbs/yr	25,690	1,706	1,573	6.1%	92.2%
Patuxent River Middle	AA, PG	Sediment	EOS-lbs/yr	58,863	5,129	3,971	6.7%	77.4%
Patuxent River Upper	AA, HO, PG	Sediment	EOS-lbs/yr	39,183	39,183	14,974	38.2%	38.2%
Piscataway Creek	PG	Sediment	EOS-lbs/yr	78,460	60,270	8,391	10.7%	13.9%
Port Tobacco River	CH	Sediment	EOS-lbs/yr	28,121	2,843	2,731	9.7%	96.1%
Potomac River MO County	MO	Sediment	EOS-lbs/yr	320,708	48,320	25,210	7.9%	52.2%
Potomac River WA County	WA	Sediment	EOS-lbs/yr	201,345	55,562	55,839	27.7%	100.5%
Prettyboy Reservoir	BA, CL	Phosphorus	EOS-lbs/yr	18	18	397	2186.0%	2186.0%
Rock Creek	MO	Phosphorus	EOS-lbs/yr	354	354	1,085	306.5%	306.5%
		Sediment	EOS-lbs/yr	666,193	661,381	693,203	104.1%	104.8%
Rocky Gorge Reservoir	HO, MO, PG	Phosphorus	EOS-lbs/yr	49	16	15	30.1%	95.1%
Seneca Creek	MO	Sediment	EOS-lbs/yr	596,436	363,663	296,496	49.7%	81.5%
South River	AA	Sediment	EOS-lbs/yr	66,125	66,125	191,180	289.1%	289.1%
Swan Creek	HA	Sediment	EOS-lbs/yr	7,675	5,400	2,602	33.9%	48.2%
Triadelphia Reservoir (Brighton Dam)	HO, MO	Phosphorus	EOS-lbs/yr	49	3	2	3.2%	57.0%
Upper Monocacy River	CL, FR	Phosphorus	EOS-lbs/yr	54	54	101	186.1%	186.1%
		Sediment	EOS-lbs/yr	412,831	65,776	58,206	14.1%	88.5%
West River	AA	Sediment	EOS-lbs/yr	13,323	256	189	1.4%	73.8%
PCB TMDLs								
Anacostia River - NE Branch	MO, PG	PCBs	g/yr	7.784	0.225	0.619	8.0%	274.6%

Table V.A.1.e: Progress Toward Attainment of Benchmarks and Applicable WLAs Developed Under EPA Approved TMDLs

Watershed Name	County	Pollutant	Unit	Total Reduction	2020 Interim Target	FY20 Progress: Reduction Achieved as of 6/30/2020	FY20 Progress: % Total Reduction	FY20 Progress: % 2020 Interim Target
Anacostia River - NW Branch	MO, PG	PCBs	g/yr	7.554	0.356	0.739	9.8%	207.9%
Anacostia River Tidal	PG	PCBs	g/yr	16.084	0.973	0.947	5.9%	97.3%
Back River Oligohaline Tidal	BA	PCBs	g/yr	10.313	0.359	0.739	7.2%	205.9%
Baltimore Harbor Embayment	AA, BA	PCBs	g/yr	5.652	1.355	0.146	2.6%	10.8%
Bear Creek	AA, BA	PCBs	g/yr	5.793	0.641	0.458	7.9%	71.5%
Bird River	HA	PCBs	g/yr	0.878	0.078	0.080	9.1%	102.1%
Bush River Oligohaline	HA	PCBs	g/yr	6.855	0.336	0.397	5.8%	118.0%
Curtis Creek/Bay	AA, BA	PCBs	g/yr	29.262	1.385	3.148	10.8%	227.3%
Lake Roland*	BA	PCBs	g/yr	4.707	0.219	0.539	11.5%	246.2%
Patuxent River Tidal Fresh	AA, HO, MO, PG	PCBs	g/yr	5.094	0.137	0.146	2.9%	106.6%
Potomac River Upper Tidal	CH, PG	PCBs	g/yr	1.144	0.008	0.012	1.0%	141.9%
Trash TMDLs								
Anacostia River MO County	MO	Trash	lbs/yr	6,044	3,273	6,628	109.7%	202.5%
Anacostia River PG County	PG	Trash	lbs/yr	14,134	5,604	3,103	22.0%	55.4%
Patapsco - Gwynns Falls	BA	Trash & Debris	lbs/yr	2,415	2,415	3,198	132.4%	132.4%
Patapsco - Jones Falls	BA	Trash & Debris	lbs/yr	1,490	1,490	2,535	170.1%	170.1%
Note: For the Trash WLA MDOT SHA is required to continue practicing trash removal activities that are captured in the baseline and remove 100% of the WLA set in the TMDL documents. It is estimated that approximately 5 lbs. of trash is removed from an inlet during cleaning based on a literature review of inlet cleaning characterization studies and physically viewing MDOT SHA inlet cleaning operation.								
Bacteria TMDLs								
Anacostia River, Downstream of NEB/NWB Confluence	PG	Bacteria - enterococci	billion MPN /day	88,819	1,022	1,022	1.2%	100.0%

Table V.A.1.e: Progress Toward Attainment of Benchmarks and Applicable WLAs Developed Under EPA Approved TMDLs

						FY20 Progress		
Watershed Name	**County**	**Pollutant**	**Unit**	**Total Reduction**	**2020 Interim Target**	**Reduction Achieved as of 6/30/2020**	**% Total Reduction**	**% 2020 Interim Target**
Anacostia River, Upstream of NEB/NWB Confluence	MO, PG	Bacteria - enterococci	billion MPN /day	262,217	2,367	2,367	0.9%	100.0%
Antietam Creek	WA	Bacteria - E.coli	billion MPN /year	167,004	3,587	3,587	2.1%	100.0%
Baltimore Harbor - Furnace Creek	AA	Bacteria - enterococci	billion counts/day	26,525	1,300	885	3.3%	68.1%
Baltimore Harbor - Marley Creek	AA	Bacteria - enterococci	billion counts/day	15,678	3,050	2,573	16.4%	84.4%
Cabin John Creek	MO	Bacteria - E.coli	billion MPN /day	28,203	512	512	1.8%	100.0%
Conococheague Creek	WA	Bacteria - E.coli	billion MPN /year	104,802	830	830	0.8%	100.0%
Double Pipe Creek	CL, FR	Bacteria - E.coli	billion MPN /year	71,326	0	0	0.0%	100.0%
Gwynns Falls	BA	Bacteria - E.coli	billion MPN /day	156,079	0	0	0.0%	100.0%
Herring Run	BA	Bacteria - E.coli	billion MPN /year	28,318	0	0	0.0%	100.0%
Jones Falls	BA	Bacteria - E.coli	billion MPN /day	84,191	0	0	0.0%	100.0%
Liberty Reservoir	BA, CL	Bacteria - E.coli	billion MPN /year	113,824	6,811	6,811	6.0%	100.0%
Loch Raven Reservoir	BA, CL, HO	Bacteria - E.coli	BN MPN/yr	99,289	1,818	861	0.9%	47.4%
Lower Monocacy River	CL, FR, MO	Bacteria - E.coli	billion MPN /year	217,952	2,789	2,768	1.3%	99.2%
Lower Patuxent River - Indian Creek	CH	Bacteria - fecal coliform	billion counts/day	2,427	151	151	6.2%	100.0%
Magothy River - subsegment	AA	Bacteria - fecal coliform	billion counts/day	3,929	0	86	2.2%	>100.0%
Other West Chesapeake - Tracy and Rockhold Creeks	AA	Bacteria - fecal coliform	billion counts/day	5,936	0	0	0.0%	100.0%
Patapsco River LN Branch	AA, BA, CL, HO	Bacteria - E.coli	BN MPN/yr	34,276	1,829	1,136	3.3%	62.1%
Patuxent River Upper	AA, PG	Bacteria - E.coli	BN MPN/yr	11,869	45	28	0.2%	62.2%

Table V.A.1.e: Progress Toward Attainment of Benchmarks and Applicable WLAs Developed Under EPA Approved TMDLs

						FY20 Progress		
Watershed Name	**County**	**Pollutant**	**Unit**	**Total Reduction**	**2020 Interim Target**	**Reduction Achieved as of 6/30/2020**	**% Total Reduction**	**% 2020 Interim Target**
Piscataway Creek	PG	Bacteria - E.coli	billion MPN /day	13,654	682	682	5.0%	100.0%
Rock Creek - Non-Tidal	MO	Bacteria - enterococci	billion MPN /day	116,713	856	856	0.7%	100.0%
Severn River - Mill Creek	AA	Bacteria - fecal coliform	billion counts/day	8,560	220	220	2.6%	100.0%
Severn River - subsegment	AA	Bacteria - fecal coliform	billion counts/day	16,809	2,078	2,091	12.4%	100.6%
Severn River - Whitehall & Meredith Creeks	AA	Bacteria - fecal coliform	billion counts/day	6,844	558	498	7.3%	89.2%
South River - Ramsey Lake	AA	Bacteria - fecal coliform	billion counts/day	189	0	0	0.0%	100.0%
South River - subsegment	AA	Bacteria - fecal coliform	billion counts/day	31,283	4,946	1,780	5.7%	36.0%
Upper Monocacy River	CL, FR	Bacteria - E.coli	billion MPN /year	76,636	1,398	1,398	1.8%	100.0%
West River - Bear Neck Creek	AA	Bacteria - fecal coliform	billion counts/day	1,026	0	0	0.0%	100.0%
West River - Cadle Creek	AA	Bacteria - fecal coliform	billion counts/day	691	0	0	0.0%	100.0%
West River - subsegment	AA	Bacteria - fecal coliform	billion counts/day	1,258	0	0	0.0%	100.0%

In accordance with conditions in Part IV.E.5.c, itemized costs for completed projects, programs or initiatives, of the MS4 Permit, a Microsoft Excel workbook containing a summary table and comprehensive list of restoration BMPs completed from 2011 to October 8, 2020; separated by contract and including associated location, impervious treatment, and cost information; is submitted electronically with the FY20 MS4 annual report.

In accordance with conditions in Part IV.E.5.d, cost estimates for completing all projects, programs, and alternatives necessary, of the MS4 Permit, MDOT SHA has provided in **Table IV.E.5.d** below the amounts of MDOT SHA capital funding programmed through the MDOT SHATMDL Restoration Fund (“Fund 82”).

Table IV.E.5.d: TMDL Restoration Fund Allocations

Fiscal Year	Allocations (Millions)
2021	$49.3
2022	$4.4
2023	$14.3
2024	$14.3
2025	$21.7
2026	$35.6
Total 2021 - 2026	**$139.7**

MDOT SHA has met the majority of 2020 interim targets for WLAs assigned, meeting or exceeding 90% of the 2020 Interim Targets including:

- Phosphorus: 53% (8 out of 15 WLAs)
- Nitrogen: 50% (2 out of 4 WLAs)
- Sediment: 45% (14 out of 31 WLAs)
- PCBs: 83% (10 out of 12 WLAs)
- Trash: 75% (3 out of 4 WLAs)
- Bacteria: 65% (13 out of 20 with assigned interim 2020 target greater than zero).

Implementation has fallen short of 90% of the 2020 interim target for many of the watersheds, however. In accordance with conditions in Part IV.E.5.e, plan for additional actions, of the MS4 Permit, because of current FY20 and potential FY21 budget cuts, MDOT SHA will proceed to develop a tiered approach for addressing deficient watershed implementation to both ensure we continue to stay on target for meeting those at 90% or greater and to target those with less than 90% with additional BMP implementation to improve progress. Additionally, interim targets and end dates may be adjusted to defer implementation until after current budget shortfalls as necessary.

<u>Appendix F:</u>
Watershed Restoration Assessment of Controls

Little Catoctin Creek Watershed Monitoring Implementation Document

MARYLAND DEPARTMENT OF TRANSPORTATION

STATE HIGHWAY ADMINISTRATION

October 2020

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1 Introduction

The Maryland Department of Transportation State Highway Administration (MDOT SHA) Water Programs Division (WPD) has completed a stream restoration project on Little Catoctin Creek (LCC). The restoration extents originate at MDOT SHA bridge structure number 10081 along MD 180 (Jefferson Pike) and continues downstream approximately 3,100 LF of the existing channel. The floodplain restoration project consisted of stabilization and relocation of approximately 3,000 linear feet of Little Catoctin Creek, south of MD-180. The goals of the stream and floodplain restoration were to restore impaired vital ecosystems, and return hydrology, geomorphic, and hydraulic stream functions back to pre-development conditions within the 100-year floodplain. Construction of the Little Catoctin Creek stream restoration project was completed in April 2019.

MDOT SHA is in the process of monitoring the physical, chemical, and biological features of the project stream for four years: This report documents the findings from the fourth year of monitoring per the NPDES/MS4 Assessment of Controls for Stream Restoration of Little Catoctin Creek at U.S. 340. The following sections of this yearly report include activities for physical, chemical, and biological monitoring activities performed between July 2017 and June 2020. It should be noted that due to delays in reporting by our agency partners, sections discussing the chemical and biological monitoring results are included as attachments to this report.

2 Study Area

The Little Catoctin Creek watershed occupies 17.72 square miles (11,340.3 acres) in the southwestern corner of Frederick County in the Blue Ridge physiographic province. It flows 8.5 stream-miles southeast from its headwaters on the eastern side of South Mountain to the mouth east of the town of Brunswick and drains directly into the Potomac River. Land use in the watershed is primarily agricultural. Approximately 20 percent of the watershed draining to the study reach is forested. Impervious surface comprises less than 3 percent of the watershed (SHA 2016).

The study area is located north of the town of Rosemont between US-340 at the upstream end and Petersville Road (MD-79) at the downstream end. Within the study area, Little Catoctin Creek flows through active and old pasture. Prior to restoration, much of the riparian area (especially in reaches adjacent to MD-180) contained few trees – leaving much of the stream open to direct sunlight. Stream banks within the open pasture were steep and heavily eroded. Riffle and run habitats within the creek were predominantly cobble and gravel. Heavy deposits of fine silt and sand were found in pools and depositional areas.

Physical, chemical, and biological monitoring locations were established above, within, and below the stream restoration project area as outlined in the monitoring plan. Detailed mapping showing each of the monitoring locations in included as **Attachment A – Monitoring Locations**.

3 Physical Monitoring

Physical monitoring of Little Catoctin Creek in FY20 concludes the final phase of physical monitoring (PHYS 4) as outlined in the NPDES/MS4 Assessment of Controls monitoring plan. Additionally, a hydraulic model is presented herein to satisfy the NPDES/MS4 Permit the reporting requirements for hydrologic and/or hydraulic modeling to analyze the effects of rainfall and discharge rates on channel geometry.

3.1 Geomorphic Assessment Methods

A geomorphic assessment was performed at six (6) locations; three (3) throughout the project reach, one (1) upstream of the project limits and two (2) downstream of the project limits. The initial geomorphic survey from September 2017 establishes a baseline for the pre-restoration project area. Two additional surveys were conducted in January 2018 and July/August 2018 to depict the channel morphological changes for pre-construction conditions. Left and right bank pins were established at each cross section. Cross sections P-1, P-5, and P-6 are outside of the project limits and remain intact for post-construction monitoring. Cross sections P-2, P-3, and P-4 are located within the project limits and were re-established in the first year of post-construction monitoring (June 2019). All six (6) locations will continue to be assessed for the remainder of post-construction monitoring.

For each surveyed cross section, the total area, bankfull channel dimensions, water surface slope, and riffle surface material are compared. Bankfull was identified in the field in 2017 only. To compare with the following year's surveys, these cross-section characteristics were adjusted based on bankfull indicators. Using this information, bankfull was either presumed at an elevation within this range above the water surface (incised channel, no bankfull indicator), or selected at a slope break/bench feature that was created at this elevation (Table 1). Starting in 2019, sections within the restoration reach (P-2 through P-4) had bankfull dimensions calculated from the top of bank. Top of bank was based on design plans and is anticipated to be surveyed in the future. Top of bank elevation was selected at a fixed elevation in each cross-section to allow for comparison (Table 1). Cross-sectional area was calculated using the specific bankfull elevation for each section. Top of bank area was calculated using a fixed elevation around the low bank height for each section to quantify erosion (or deposition) occurring throughout the entire cross section. Bankfull elevations were assessed in 2020. No obvious changes in the bankfull elevations were observed, therefore no additional analyses were required.

Table 1: Bankfull and Top of Bank elevations used for calculations.

Cross Section	Bankfull Elevation (ft)	Top of Bank Elevation (ft
XS 1**	419.70	423.40
XS 2*	413.54	413.54
XS 3*	409.60	409.60
XS 4*	404.43	404.43
XS 5**	399.70	403.46
XS 6**	397.50	400.00
*Restoration reaches, elevations changed in 2019 **Bankfull identified in 2017		

The cross section, thalweg profile, and riffle pebble count data collected in September 2017, January/April 2018, July/August 2018, June 2019, and April/May 2020 were compared to depict the bank erosion and channel morphological changes during this period. A brief discussion about each section is included below.

Construction of the restoration project was completed in April 2019. As of the June 2019 survey, sections 2, 3, and 4 were re-established in new locations along the restored stream channel. The cross sections and longitudinal profiles of the newly established sites are graphed separately due to disparities in locations and elevations following restoration activities..

3.2 Precipitation

Monthly precipitation data was obtained from USGS Little Catoctin gage (1636845) and NOAA's Hagerstown area gage. Data from the NOAA Hagerstown area gage, which is located approximately 25 miles north of Little Catoctin Creek, was supplemented when data was unavailable from the USGS Little Catoctin gage. Data from the USGS Little Catoctin gage was unavailable May 2018, June 2018, and from January 2019 to May 2019. For Maryland, 2018 was the wettest year on record. The annual precipitation for 2018 was 57.44 inches. The annual precipitation for 2019 was 42.91 inches. Frederick County averages about 43 inches of precipitation annually. Greater runoff and higher in-stream velocities due to large precipitation events can contribute to accelerated stream bank erosion. Precipitation for 2020, thus far, is 19.36 inches. Figure 1 shows the yearly precipitation recorded by the gages from 2018 through 2020. The 2020 data contains analysis from January 1, 2020 through June 22, 2020.

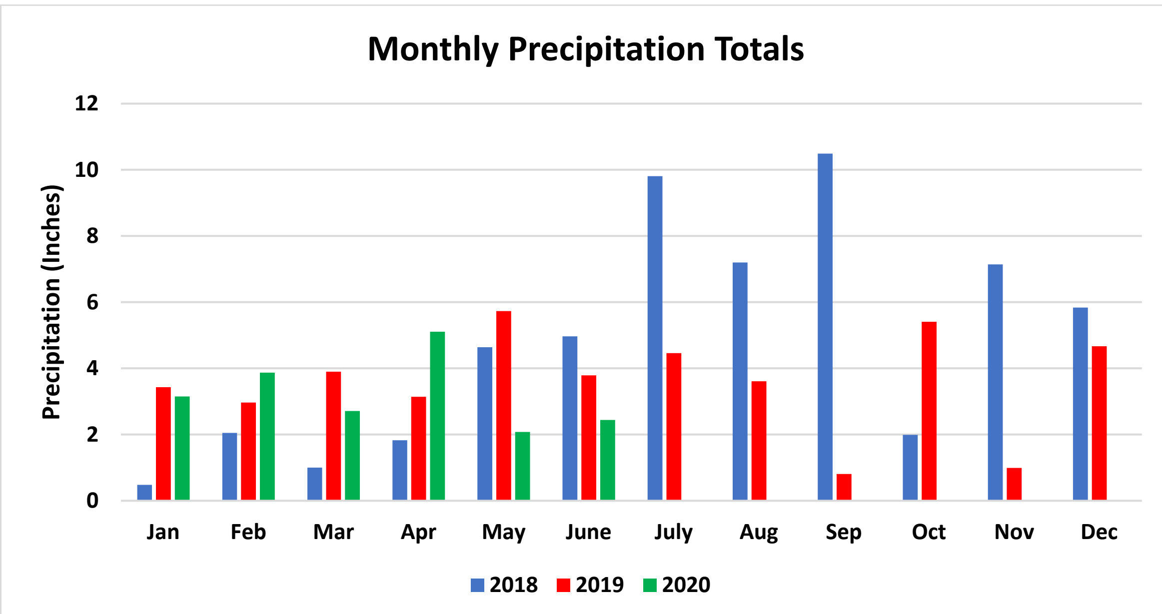


Figure 1 - Monthly Precipitation Totals from January 2018 through June 2020.

3.3 Hydraulics

The as-built (current conditions) hydraulic model for this report was developed for Year 2 post-construction monitoring. This model was created using U.S. Army Corps of Engineers HEC-RAS, version 5.0.7. The existing and proposed condition models were originally developed by JMT using HEC-RAS, version 4.1.0. WSP is tasked with completing a comprehensive review comparing as-built conditions to the proposed model conditions by JMT. The same hydrology parameters developed by JMT were applied to the as-built hydraulic model. The as-built hydraulic model is based on JMT's proposed condition model. Similar model parameters and methodology utilized in the existing and proposed condition models were applied to the as-built hydraulic model. Complete results from the hydraulic model can be found in **Attachment B – Hydraulic Modeling Data**.

Reach Boundary Conditions

The reach boundary condition at the downstream end is set at normal depth with a downstream slope of 0.004 ft/ft. The reach boundary condition in the as-built hydraulic model was set to the same conditions as the existing and proposed condition models.

Cross Sections

The cross-section locations utilized in the existing and proposed JMT model were used in the development of the as-built model. The model of the Little Catoctin tributary consisted of 33 cross sections. Cross section located within the as-built survey include 3450 through 1024. Cross sections located upstream of 3450 and downstream of 1024, as well as the overbank areas are based on LIDAR and may slightly differ from the LIDAR used by JMT to develop the proposed condition model. Cross sections for the as-built model were created using data from the full as-built and augmented with the most current county public GIS LIDAR information (Maryland imap LIDAR Frederick County DEM-Feet). Cross sections for the existing and proposed JMT models were created using data augmented with GIS contour data provided by MDOT SHA (prior to 2017).

Cross Section naming convention is different between models. For each model, HEC-RAS mapper automatically renames the cross sections. For comparison purposes, tables in the following sections include both the proposed and the as-built cross section naming conventions.

Manning's N-Values

Originally, roughness values were selected using the USGS guide for selecting Manning's N-values for natural channels and floodplains based on field verification by JMT. The main channel n-value in existing and proposed conditions is 0.030, the woods in existing and proposed conditions is 0.080, the floodplain/grazing area in existing conditions (and proposed conditions outside of the project limits) is 0.040 and the floodplain in proposed conditions (that will be heavily vegetated and protected from livestock grazing) is 0.060. While a different Manning's N range may be appropriate for this model based on current conditions, in order to make a direct comparison to JMT's proposed model, the Manning's N-values remained the same. For the purposes of this analysis, the Manning's N-values for the as-built model were maintained similarly to the proposed condition model.

Contraction and Expansion Coefficients

Contraction and expansion coefficients of 0.1 and 0.3 for gradual transitions and 0.3 and 0.5 for the area directly downstream from the culvert outfall were utilized in the as-built conditions. This was the same approach utilized in the proposed conditions developed by JMT.

Ineffective Flow Areas

Ineffective areas at the culvert were projected to RS 83952.77, RS 83884.32, RS 83821.78 and RS 83746.11 in proposed conditions, and RS 3581, RS 3513, RS 3450, RS 3375 in as-built conditions. The areas were projected as an extension of the downstream wing walls (approximately 4:1 in the direction of flow) along both sides of the channel until full expansion of flow was realized.

The ineffective flow areas were not designated at the intermediate culvert cross sections 3445 through 3379, which are located directly downstream of the culvert, in the proposed condition model. While ineffective flow areas are recommended at the intermediate culvert cross sections, in order to make a direct comparison to JMT's proposed model, the ineffective flow areas were not designated.

3.3.1 Hydraulic Model Findings

The stream restoration encompasses cross-sections 200 through 3450. Overall, peak water surface elevations, velocities, shear stresses, and Froude number within the restoration reach remained consistent with or decreased from proposed model conditions. There were some significant instances of increase between as-built and proposed conditions, which will be discussed in the following sections.

Water Surface Elevations

Comparison of water surface elevations between the proposed conditions and as-built conditions during varying storm events is summarized in Table 2. Intermediate culvert cross sections 3445 through 3379, which are located directly downstream of the culvert, are not included in the following channel parameter summary tables. See hydraulic data for more information regarding the cross sections intermediate culvert cross sections. Modeling results indicate the maximum increase of 2-yr water surface elevation is 0.21 foot, and the maximum decrease of 2-yr water surface elevation is 1.20 feet. Model analysis for 10-yr water surface elevation shows that the maximum increase is 0.07 foot, and the maximum decrease of 10-yr water surface elevation is 0.74 foot. The maximum increase of 100-yr water surface elevation is 0.34 foot and the maximum decrease of 100-yr water surface elevation is 0.29 foot. Water surface elevations increased less than 0.5 feet for all storm events.

At as-built cross section 200, the water surface elevation difference of 1.20 feet is due to LIDAR differences between the proposed and as-built model. The minimum channel elevation in the proposed model is elevation 395, whereas the as-built condition model is elevation 393.61. The as-built survey was compared to the geomorphology cross sections survey information, summarized later in this report. The minimum channel elevation of the geomorphology cross-sections was very similar to the as-built survey.

Table 2: Water Surface Elevation Comparison

Proposed Station	Asbuilt Station	2-YR WSEL (FT.)			10-YR WSEL (FT.)			100-YR WSEL (FT.)		
		Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential
Upstream Control										
83952.77	3581	420.80	420.59	-0.21	425.87	425.86	-0.01	428.09	428.04	-0.05
83884.32	3513	419.95	419.32	-0.63	425.83	425.82	-0.01	428.04	428.00	-0.04
Restoration Reach										
83821.78	3450	418.45	417.49	-0.96	419.81	419.57	-0.24	422.86	422.78	-0.08
83746.11	3375	417.00	416.94	-0.06	418.23	418.15	-0.08	419.83	419.79	-0.04
83553.53	3195	415.77	415.79	-0.02	416.90	416.97	0.07	418.49	418.53	-0.04
83464.67	3113	415.36	415.36	0.00	416.53	416.54	-0.01	418.2	418.20	0.00
83249.52	2921	414.50	414.61	0.11	415.73	415.79	0.06	417.45	417.49	0.04
83056.75	2745	413.65	413.64	-0.01	414.87	414.80	-0.07	416.51	416.42	-0.09
82834.61	2554	412.62	412.57	-0.05	413.74	413.67	-0.07	415.22	415.27	0.05
82707.86	2438	411.80	411.67	-0.13	412.87	412.77	-0.10	414.35	414.26	-0.09
82506.13	2271	410.68	410.67	-0.01	411.73	411.67	-0.06	413.24	413.12	-0.12
82293.55	2074	409.50	409.36	-0.14	410.61	410.41	-0.20	412.24	412.02	-0.22
82049.29	1855	408.16	407.87	-0.29	409.20	408.93	-0.27	410.88	410.75	-0.13
81832.26	1686	406.85	406.80	-0.05	407.89	407.75	-0.14	410.08	410.11	0.03
81500.63	1420	405.34	404.90	-0.44	406.61	406.41	-0.20	409.59	409.62	0.03
81293	1245	403.76	403.97	0.21	406.18	406.08	-0.10	409.4	409.47	0.07
81028.44	1024	403.19	403.34	0.15	405.98	405.93	-0.05	409.27	409.38	0.11
Downstream Control										
80829.99	830	401.69	401.80	0.11	403.75	403.76	0.01	406.55	406.89	0.34
80200	200	398.72	397.52	-1.20	400.36	399.62	-0.74	402.24	401.95	-0.29

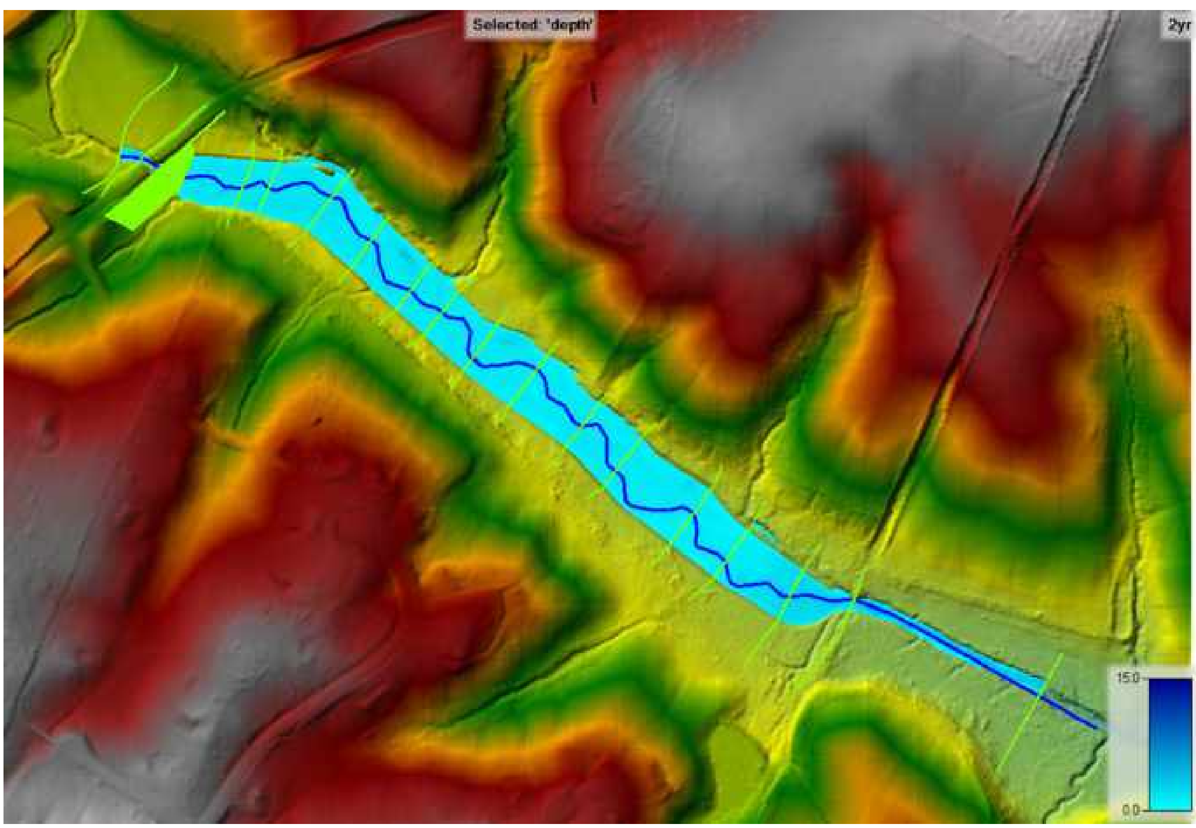


Figure 2 - 2-Year As-built Water Depth

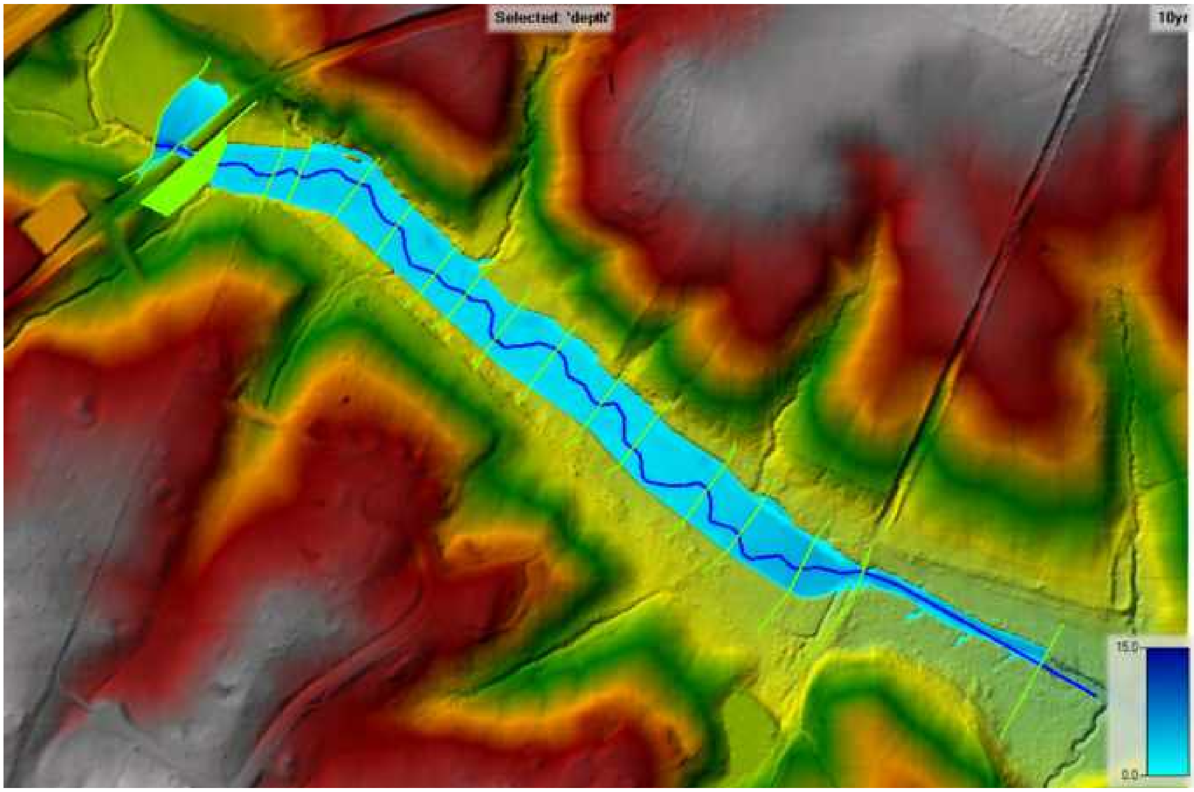


Figure 3 – 10-Year As-built Water Depth

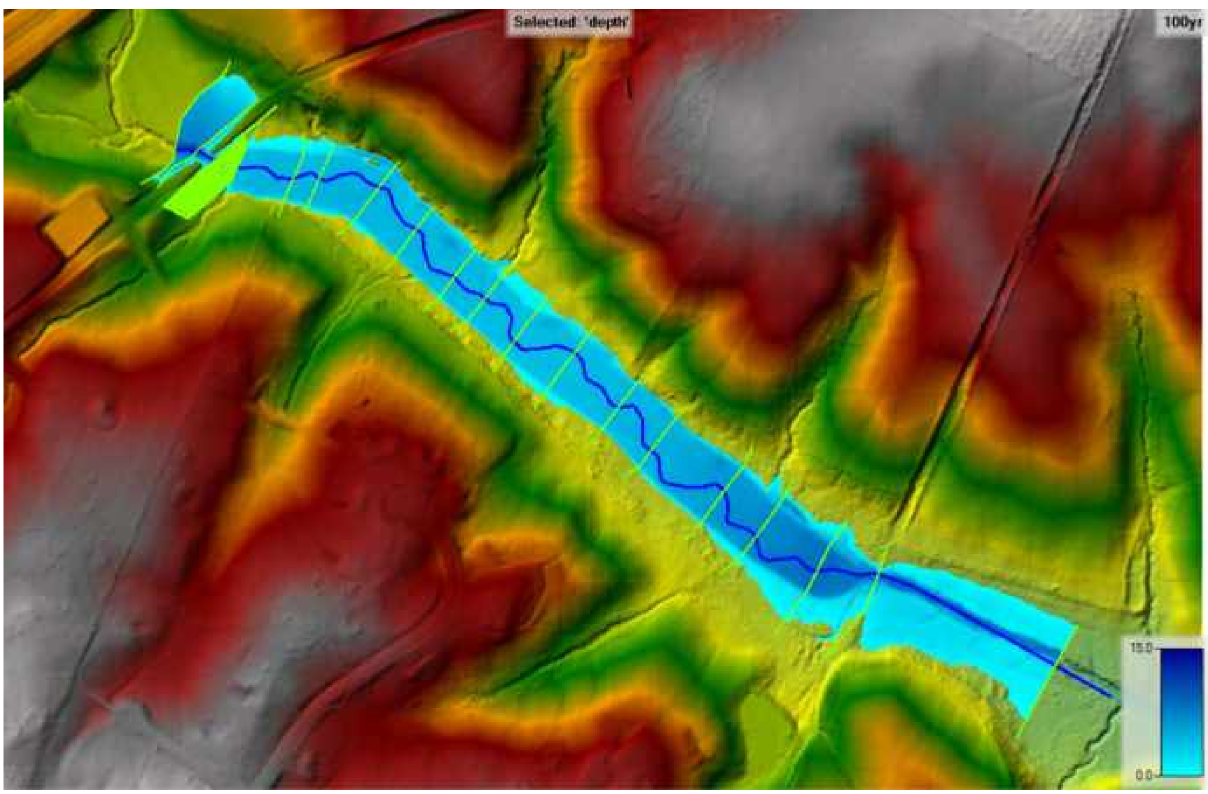


Figure 4 – 100-Year As-built Water Depth

Channel Velocity

Comparison of channel velocities between the proposed conditions and as-built conditions during varying storm events is summarized in Table 3. See hydraulic data for more information regarding the cross sections intermediate culvert cross sections. Modeling results indicate the maximum differential increase of 2-yr velocity is 54%, and the maximum decrease of 2-yr velocity is 40%. Model analysis for 10-yr velocity shows that the maximum differential increase is 18%, and the maximum differential decrease of 10-yr velocity is 19%. The maximum differential increase of 100-yr velocity is 11% and the maximum differential decrease of 100-yr velocity is 18%. Table cells are highlighted when channel velocities increased greater than 50%. The differential differences are greater during the 2-yr storm event versus 100-yr storm event. The channel velocities are more consistent during the 10-yr and 100-yr storm events.

At as-built cross section 3513, the velocity shows a significant increase from 5.98 ft/s in proposed conditions to 9.19 in as-built conditions. This difference is due to LIDAR differences between the proposed and as-built model. The as-built model at cross section 3513 shows the channel is narrower and deeper compared to cross section 83884.32 of the proposed model. The increased velocity is due to the narrowing of the channel at this cross section.

Table 3: Channel Velocity Comparison

Proposed Station	Asbuilt Station	2-YR Channel Velocity (FT/S)			10-YR Channel Velocity (FT/S)			100-YR Channel Velocity (FT/S)		
		Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential
Upstream Control										
83952.77	3581	6.50	8.00	23.1%	1.89	2.10	11.1%	2.73	2.92	7.0%
83884.32	3513	5.98	9.19	53.7%	2.91	2.85	-2.1%	3.99	3.91	-2.0%
Restoration Reach										
83821.78	3450	6.23	8.69	39.5%	11.63	12.02	3.4%	16.08	15.89	-1.2%
83746.11	3375	7.10	7.70	8.5%	10.48	10.79	3.0%	15.40	14.74	-4.3%
83553.53	3195	6.15	6.01	-2.3%	8.43	8.27	-1.9%	11.12	11.68	5.0%
83464.67	3113	5.62	5.53	-1.6%	7.33	7.61	3.8%	9.29	9.72	4.6%
83249.52	2921	5.37	5.09	-5.2%	7.14	6.81	-4.6%	9.22	8.91	-3.4%
83056.75	2745	5.59	7.11	27.2%	7.59	8.92	17.5%	10.16	11.32	11.4%
82834.61	2554	6.16	6.19	0.5%	8.55	8.24	-3.6%	11.56	10.69	-7.5%
82707.86	2438	6.66	7.36	10.5%	8.96	9.25	3.2%	11.68	12.25	4.9%
82506.13	2271	6.28	5.90	-6.1%	8.52	8.57	0.6%	11.08	11.46	3.4%
82293.55	2074	5.99	7.68	28.2%	7.76	9.10	17.3%	9.80	10.72	9.4%
82049.29	1855	6.00	5.66	-5.7%	8.45	7.87	-6.9%	10.86	9.95	-8.4%
81832.26	1686	6.97	6.07	-12.9%	8.97	8.68	-3.2%	9.56	9.03	-5.5%
81500.63	1420	5.03	5.71	13.5%	6.47	6.19	-4.3%	6.51	6.01	-7.7%
81293	1245	8.99	5.39	-40.0%	5.62	4.53	-19.4%	5.93	4.89	-17.5%
81028.44	1024	3.77	3.26	-13.5%	4.09	3.90	-4.6%	5.00	4.72	-5.6%
Downstream Control										
80829.99	830	7.81	8.23	5.4%	11.11	10.74	-3.3%	13.62	12.32	-9.5%
80200	200	5.34	5.54	3.7%	7.69	7.50	-2.5%	10.02	9.87	-1.5%

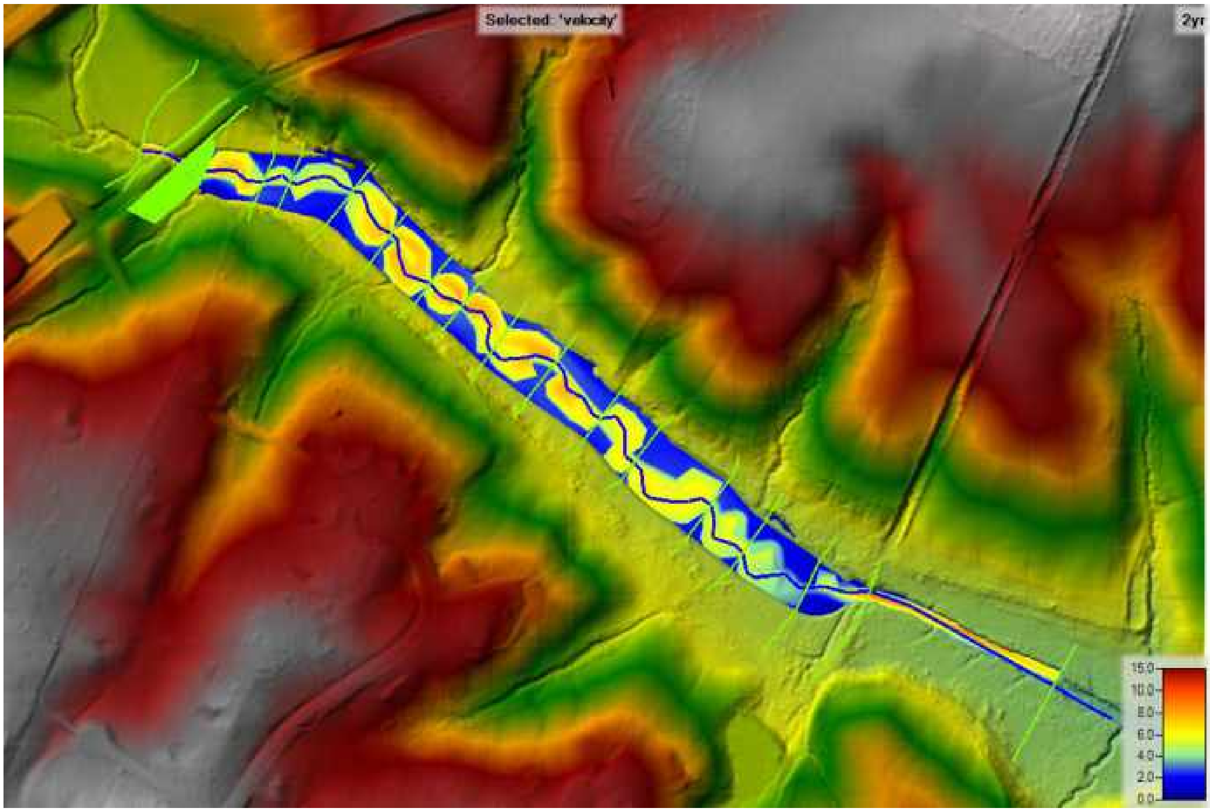


Figure 5 – 2-Year As-built Velocity

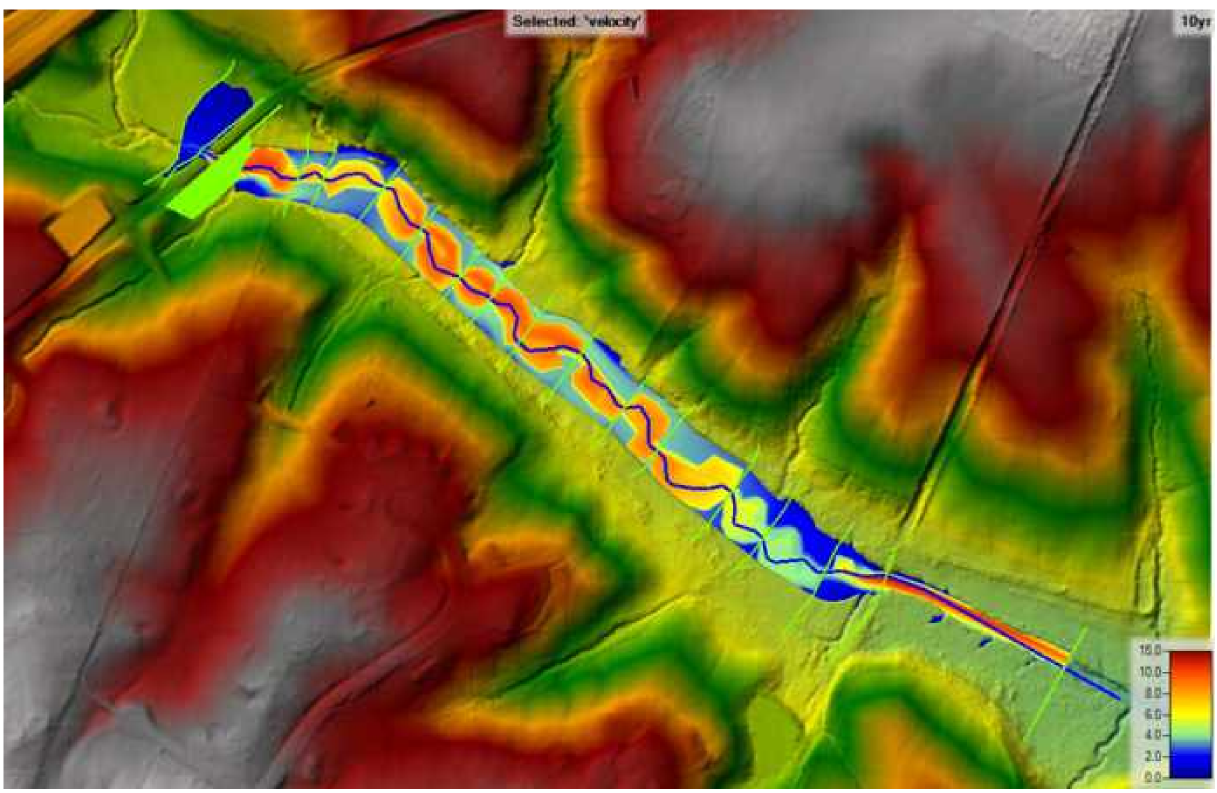


Figure 6 – 10-Year As-built Velocity

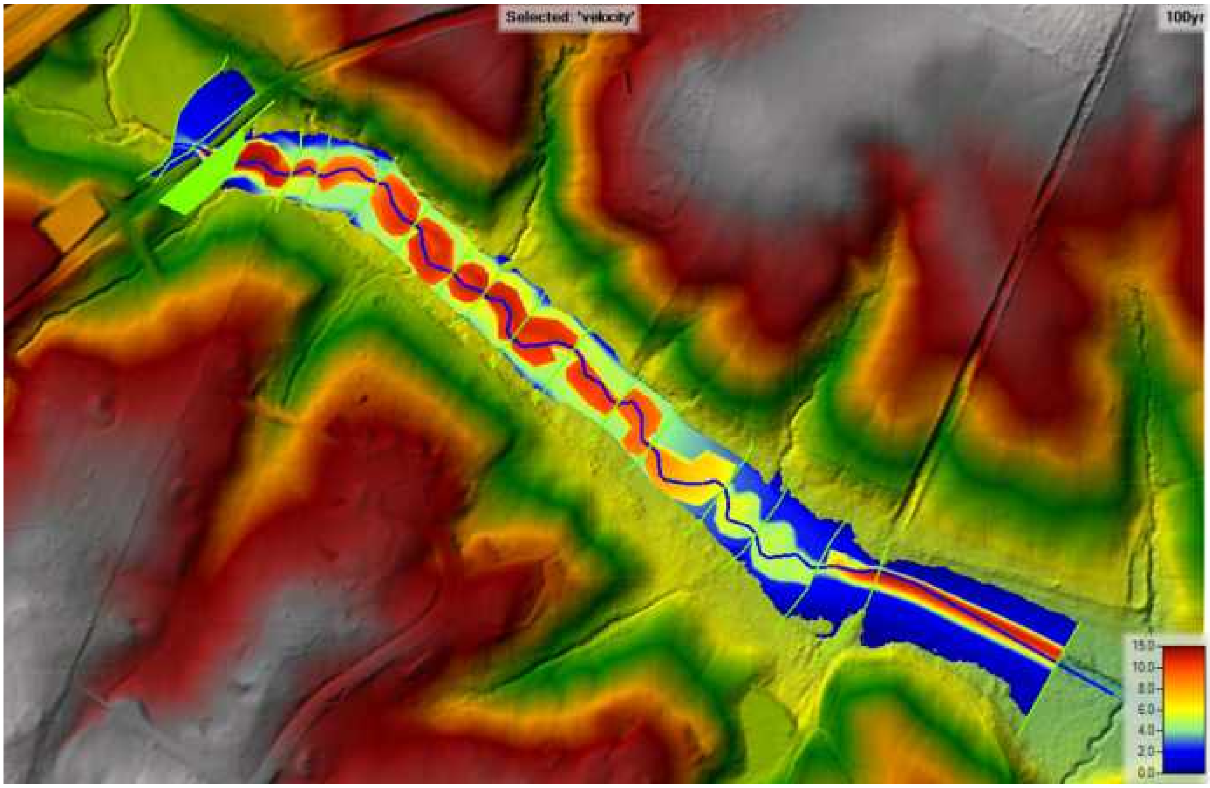


Figure 7 – 100-Year As-built Velocity

Shear Channel Stresses

Shear channel and shear total stresses are used to estimate bed-load transport in open-channel flows. Comparison of shear channel stresses between the proposed conditions and as-built conditions during varying storm events is summarized in Table 4. See hydraulic data for more information regarding the cross sections intermediate culvert cross sections. Modeling results indicate the maximum differential increase of 2-yr shear channel stresses is 187%, and the maximum decrease of 2-yr shear channel stresses is 66%. Model analysis for 10-yr shear channel stresses shows that the maximum differential increase is 20%, and the maximum differential decrease of 10-yr shear channel stresses is 51%. The maximum differential increase of 100-yr shear channel stresses is 22% and the maximum differential decrease of 100-yr shear channel stresses is 31%. Table cells are highlighted when shear channel stresses differential increased greater than 50%. The differential differences are greater during the 2-yr storm event versus 10-yr and 100-yr storm events. For the 10-yr storm event, 16 out of 19 cross sections showed decreases in shear channel stresses. For the 100-yr storm event, 11 out of 19 cross sections showed decreases in shear total stresses. Overall, shear channel stresses in as-built conditions decreased compared to proposed conditions, especially during the 10-yr and 100-yr storm events. The shear channel stresses vary throughout the project because of the difference in both the LIDAR and local slopes of the channel between cross sections.

Table 4: Shear Channel Stresses Comparison

Proposed Station	Asbuilt Station	2-YR Shear Channel (lb/sq. ft.)			10-YR Shear Channel (lb/sq. ft.)			100-YR Shear Channel (lb/sq. ft.)		
		Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential
Upstream Control										
83952.77	3581	0.87	1.31	50.6%	0.05	0.06	20.0%	0.09	0.1	11.1%
83884.32	3513	0.53	1.52	186.8%	0.10	0.10	0.0%	0.17	0.17	0.0%
Restoration Reach										
83821.78	3450	0.67	1.47	119.4%	2.08	2.26	8.7%	3.36	3.28	-2.4%
83746.11	3375	0.98	1.14	16.3%	1.85	1.46	-21.1%	3.54	3.21	-9.3%
83553.53	3195	0.77	0.72	-6.5%	1.25	0.90	-28.0%	1.89	2.06	9.0%
83464.67	3113	0.64	0.61	-4.7%	0.94	0.76	-19.1%	1.31	1.42	8.4%
83249.52	2921	0.58	0.50	-13.8%	0.88	0.58	-34.1%	1.28	1.17	-8.6%
83056.75	2745	0.62	0.94	51.6%	0.99	0.87	-12.1%	1.55	1.89	21.9%
82834.61	2554	0.76	0.74	-2.6%	1.28	0.83	-35.2%	2.05	1.72	-16.1%
82707.86	2438	0.91	1.12	23.1%	1.42	1.16	-18.3%	2.12	2.33	9.9%
82506.13	2271	0.82	0.68	-17.1%	1.30	0.94	-27.7%	1.92	2.01	4.7%
82293.55	2074	0.75	1.18	57.3%	1.07	0.96	-10.3%	1.48	1.76	18.9%
82049.29	1855	0.74	0.66	-10.8%	1.27	0.90	-29.1%	1.81	1.5	-17.1%
81832.26	1686	1.03	0.74	-28.2%	1.47	0.99	-32.7%	1.38	1.19	-13.8%
81500.63	1420	0.51	0.70	37.3%	0.72	0.54	-25.0%	0.59	0.5	-15.3%
81293	1245	1.79	0.61	-65.9%	0.51	0.25	-51.0%	0.47	0.31	-34.0%
81028.44	1024	0.26	0.19	-26.9%	0.24	0.17	-29.2%	0.31	0.27	-12.9%
Downstream Control										
80829.99	830	1.14	1.37	20.2%	1.91	1.63	-14.7%	2.45	2.07	-15.5%
80200	200	0.56	0.59	5.4%	0.96	0.92	-4.2%	1.43	1.4	-2.1%

Shear Total Stresses

Comparison of shear total stresses between the proposed and as-built conditions during varying storm events is summarized in Table 5. See hydraulic data for more information regarding the cross sections intermediate culvert cross sections. Modeling results indicate the maximum differential increase of 2-yr shear total stresses is 237%, and the maximum decrease of 2-yr shear total stresses is 65%. Model analysis for 10-yr shear total stresses shows that the maximum differential increase is 96%, and the maximum differential decrease of 10-yr shear total stresses is 39%. The maximum differential increase of 100-yr shear total stresses is 14% and the maximum differential decrease of 100-yr shear total stresses is 36%. Table cells are highlighted when shear total stresses differential increased greater than 50%. The differential differences are greater during the 2-yr storm event versus 10-yr and 100-yr storm events. For the 10-yr storm event, 10 out of 19 cross sections showed decreases in shear total stresses. For the 100-yr storm event, 12 out of 19 cross sections showed decreases in shear total stresses. Overall, shear total stresses in as-built conditions decreased compared to proposed conditions, especially during the 10-yr and 100-yr storm events. The shear total stresses vary throughout the project because of the difference in both the LIDAR and local slopes of the channel between cross sections.

Table 5: Shear Total Stresses Comparison

Proposed Station	Asbuilt Station	2-YR Shear Total (lb/sq. ft.)			10-YR Shear Total (lb/sq. ft.)			100-YR Shear Total (lb/sq. ft.)		
		Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential	Proposed	Asbuilt	Differential
Upstream Control										
83952.77	3581	0.45	1.31	191.1%	0.03	0.03	0.0%	0.06	0.06	0.0%
83884.32	3513	0.38	1.28	236.8%	0.03	0.04	33.3%	0.07	0.08	14.3%
Restoration Reach										
83821.78	3450	0.66	1.45	119.7%	2.06	2.24	8.7%	3.32	3.26	-1.8%
83746.11	3375	0.75	0.73	-2.7%	1.55	1.46	-5.8%	2.93	2.51	-14.3%
83553.53	3195	0.55	0.50	-9.1%	1.00	0.90	-10.0%	1.32	1.37	3.8%
83464.67	3113	0.44	0.42	-4.5%	0.74	0.76	2.7%	1.02	1.04	2.0%
83249.52	2921	0.42	0.32	-23.8%	0.69	0.58	-15.9%	1.04	0.89	-14.4%
83056.75	2745	0.45	0.49	8.9%	0.79	0.87	10.1%	1.28	1.41	10.2%
82834.61	2554	0.54	0.44	-18.5%	0.99	0.83	-16.2%	1.63	1.34	-17.8%
82707.86	2438	0.62	0.72	16.1%	1.06	1.16	9.4%	1.59	1.77	11.3%
82506.13	2271	0.57	0.44	-22.8%	1.03	0.94	-8.7%	1.41	1.33	-5.7%
82293.55	2074	0.52	0.63	21.2%	0.84	0.96	14.3%	1.11	1.23	10.8%
82049.29	1855	0.53	0.49	-7.5%	1.03	0.90	-12.6%	1.55	1.22	-21.3%
81832.26	1686	0.70	0.48	-31.4%	1.16	0.99	-14.7%	1.14	0.97	-14.9%
81500.63	1420	0.37	0.49	32.4%	0.59	0.54	-8.5%	0.49	0.42	-14.3%
81293	1245	1.15	0.40	-65.2%	0.41	0.25	-39.0%	0.33	0.21	-36.4%
81028.44	1024	0.20	0.15	-25.0%	0.20	0.17	-15.0%	0.17	0.14	-17.6%
Downstream Control										
80829.99	830	1.01	1.37	35.6%	0.97	1.63	68.0%	1.09	0.93	-14.7%
80200	200	0.41	0.59	43.9%	0.47	0.92	95.7%	0.57	0.43	-24.6%

Froude Number

The Froude number is a dimensionless value that summarizes different flow regimes of channel flow. Comparison of Froude number between the proposed conditions and as-built conditions during varying storm events is summarized in Table 6. See hydraulic data for more information regarding the cross sections intermediate culvert cross sections. A Froude number less than 1 indicates a subcritical flow, which is a slow and stable flow. A Froude number greater than 1 indicates a supercritical flow, which is shallow and fast. A Froude number range between 0.85 and 1.15 indicates the stream is typically transitioning from subcritical to supercritical flow. A stream is considered in equilibrium when the Froude number is 1. Table cells are highlighted when the Froude number is greater than 1.15. The highlighted Froude numbers are within the proposed model. Froude number results were below 1.15 in as-built conditions. The Froude number between proposed and as-built conditions remained consistent.

Table 6: Froude Number Comparison

Proposed Station	Asbuilt Station	2-YR Froude # Channel		10-YR Froude # Channel		100-YR Froude # Channel	
		Proposed	Asbuilt	Proposed	Asbuilt	Proposed	Asbuilt
Upstream Control							
83952.77	3581	0.83	1.00	0.13	0.14	0.16	0.17
83884.32	3513	0.47	0.96	0.15	0.16	0.19	0.2
Resotration Reach							
83821.78	3450	0.61	1.01	0.96	1.01	1.02	1.02
83746.11	3375	0.82	0.89	0.98	1.01	1.20	1.14
83553.53	3195	0.76	0.73	0.84	0.81	0.9	0.94
83464.67	3113	0.69	0.67	0.72	0.74	0.77	0.77
83249.52	2921	0.66	0.59	0.69	0.64	0.73	0.69
83056.75	2745	0.67	0.77	0.73	0.81	0.8	0.86
82834.61	2554	0.75	0.69	0.84	0.76	0.94	0.83
82707.86	2438	0.83	0.94	0.90	0.94	0.97	1.02
82506.13	2271	0.80	0.69	0.87	0.84	0.92	0.93
82293.55	2074	0.76	0.93	0.79	0.90	0.8	0.87
82049.29	1855	0.75	0.73	0.86	0.81	0.88	0.8
81832.26	1686	0.92	0.74	0.94	0.88	0.75	0.69
81500.63	1420	0.62	0.77	0.63	0.61	0.46	0.42
81293	1245	1.26	0.71	0.49	0.39	0.39	0.31
81028.44	1024	0.39	0.33	0.30	0.29	0.29	0.28
Downstream Control							
80829.99	830	0.85	1.01	0.90	0.99	0.88	0.83
80200	200	0.63	0.62	0.69	0.67	0.74	0.71

3.3.2 Hydraulic Analysis Conclusion

A comprehensive hydraulic review was completed comparing as-built conditions to the proposed model conditions by JMT. Channel variables compared during the hydraulic review include water surface elevation, channel velocity, shear channel stresses, shear total stresses, and Froude Number. Each of this channel variables are important in assessing channel stability.

A few channel variable results showed an increase greater than 50%. These increases appear to be due to LIDAR differences between the proposed and as-built model. The as-built model had a lower minimum channel elevation compared to the proposed model. Additionally, the channel at cross section 3513, which is located directly upstream of the culvert, showed a narrower and deeper channel than compared to the proposed model. This results in an increase in velocity. The LIDAR differences between the as-built and proposed model caused great differences in lower storm events. The velocities and the shear stresses vary throughout the project because of the difference in both the LIDAR and local slopes of the channel between cross sections.

There is evidence that the geomorphic conditions directly upstream and downstream of the restoration reach are still very fluid. The upstream and downstream control cross sections typically showed greater differential increases than the restored section. The as-built condition model establishes a post-construction hydraulic baseline at Little Catoctin. While there are small differences between the results of the proposed model and as-built model, the as-built model uses better refined and current available LIDAR and survey information. Overall, the channel variable results remained consistent and similar between the as-built and proposed model.

3.4 Physical Monitoring Results

Geomorphic stream assessment results and comparisons over time are presented below for each cross section survey reach. Field survey data results can be found in **Attachment C – Geomorphic Data**.

<u>Cross Section P-1 – Upstream Control Site</u>

Cross Section P-1 is now located at the max depth of a pool compared to 2019 when the cross section was located at the start of a glide. Sediment deposition appears to shift regularly through the bottom of the channel in this reach. At Cross Section P-1, the left bank eroded 1.8 feet between 2017 and 2020 while the right bank aggraded vertically 0.4 feet (Figure 8). In 2020, additional erosion occurred along the left bank at the top of bank, widening the channel approximately 1.4’ and lowering the vegetated bench by approximately 1.0’. Between 2019 and 2020, the thalweg has remained relatively unchanged as well as the right bank which is heavily vegetated. The channel thalweg downcut by 0.2’, which is consistent with the profile comparison. Cross section P-1 is depicted as the yellow horizontal tape in Photo 1 and Photo 2.
Historically, between the August 2018 and June 2019 surveys, the channel thalweg experienced significant scouring that resulted in the thalweg dropping roughly 1.5 feet as the cross section is now crossing through a pool.

Photo 1 – Section 1 Cross Section Looking Upstream – April 2020

Photo 2 - Section 1 Cross Section looking downstream – April 2020

Figure 8 - Cross Section P-1 Comparison (2017 to 2020)

Cross Section P-1 is located at the max depth of a pool. In May of 2020, the channel was still split, and the confluence did not significantly change locations. In 2020, the downstream end of the pool feature at the cross-section has migrated downstream approximately 10'. The following downstream riffle has eroded by about 0.4' and deposition of approximately the same amount has taken place at the downstream pool. The channel slope at Section 1 became steeper compared to 2019. The channel slope was 1.1% in 2019 and 1.3% in 2020.

The historical results of this section show a grade control feature appears to have formed between 2017 and April 2018 at station 1+10 (Figure 9). With the exception of a large depositional feature filling in the pool between station 0+70 and 0+90, the profile was largely unchanged between April and August of 2018. As of 2019, scour occurred at the confluence at station 0+59 creating a large pool where the cross section is located. A mid channel bar that was observed in 2018, has now split the channel flow beginning approximately 100 feet upstream of the cross section just upstream of the start of the profile. The confluence of the split channel is approximately 15 feet upstream of the cross section at station 0+59.5. This is causing the large scour pool and significant shift in the profile.

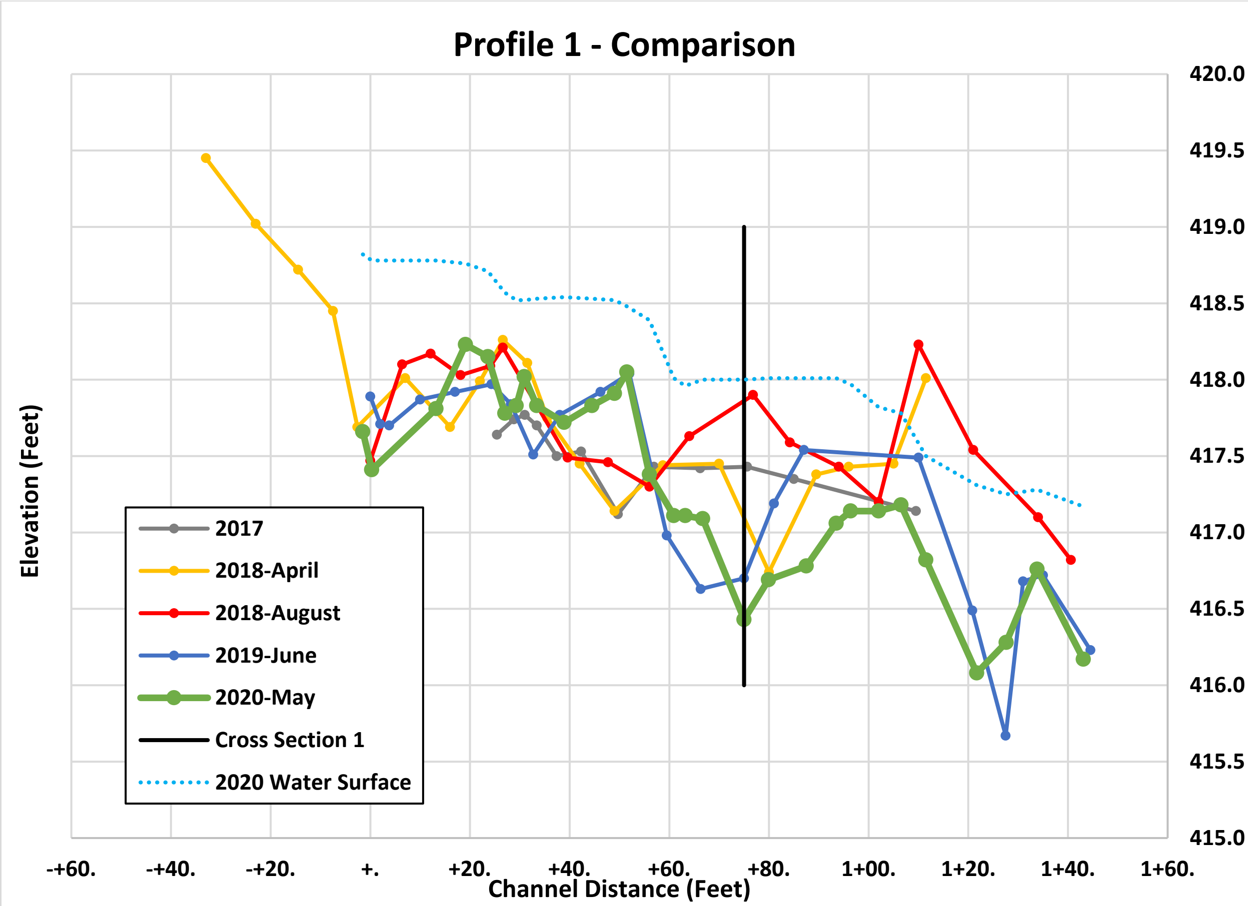


Figure 9 - Profile P-1 Comparison (2017 to 2020)

In 2020, coarse material was observed in Section 1 (Figure 10). The D50 increased to 25mm (coarse gravel) and the D84 to 150mm (large cobble) in 2020. This is a significant increase in size from previous years suggesting a bimodal distribution where larger material is now present but a large amount of fine sediments are moving through the reach. The finer materials are transporting out of this section.

Based on historical pebble counts, the channel material appears to have coarsened between 2017 and 2018 and in 2019 deposition of finer material was deposited. The D50 and D84 increased from 12.3mm (medium gravel) and 31.3mm (coarse gravel) in 2017 to 33mm (very coarse gravel) and 62mm (very coarse gravel) in 2018. As of June 2019, the D50 decreased (18mm) closer to what was observed in 2017 (12.3mm). The D84 decreased in 2019 but was still classified as very coarse gravel.

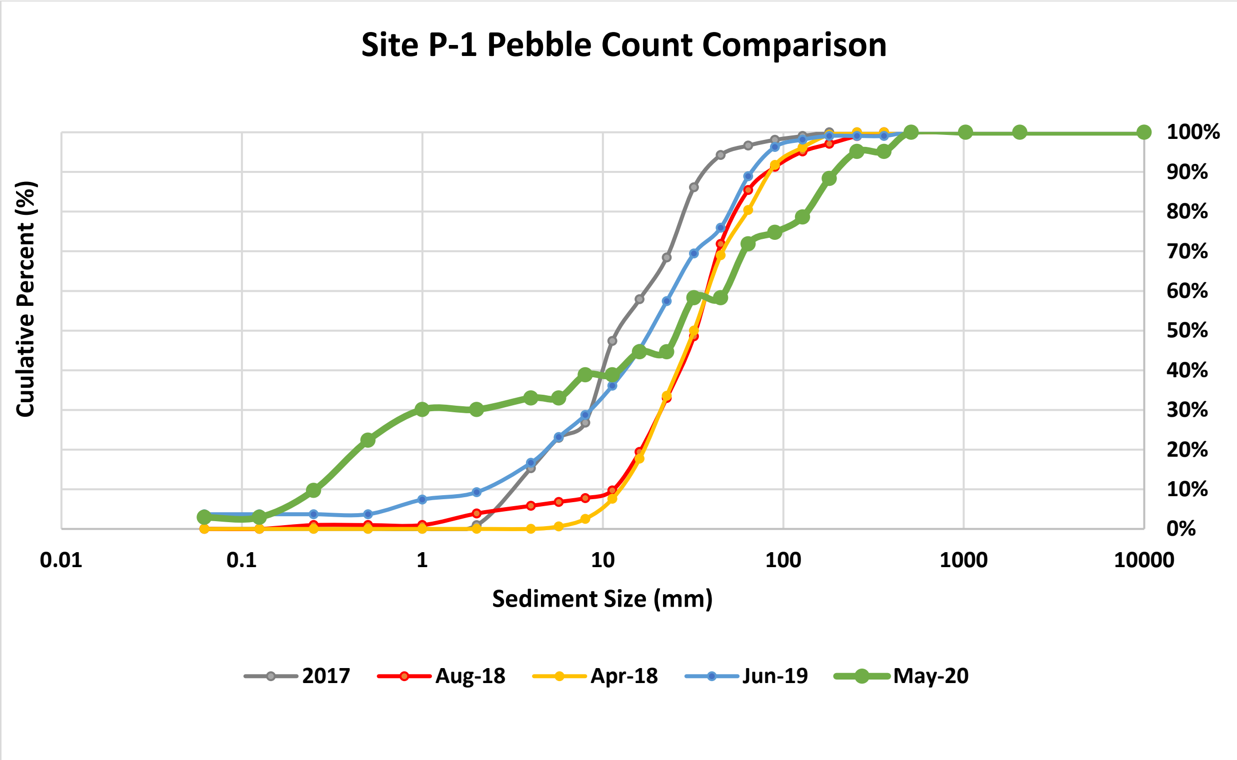


Figure 10 – Section P-1 Riffle Bed Material Comparison (2017 to 2020)

<u>Cross Section P-2 – Restoration Reach</u>

Figure 11 shows the first and second years of post-restoration cross-section surveys. Cross Section 2 is located within a riffle. Between 2019 and 2020 some minor erosion has taken place along the left bank with the top of the left bank eroding 0.4’. Deposition of a similar quantity has taken place at the top of the right bank along this cross-section as well. The channel has minor vertical erosion of about 0.2’. Overall, the channel geometry has remained very similar from 2019 to 2020. The elevated survey point at 0+45.3 is due to a dense grass located on the floodplain. Cross section P-2 is depicted as the yellow horizontal tape in Photo 3 and Photo 4.

Prior to restoration, the left bank of Cross Section 2 had eroded approximately 4 feet (horizontally) between January and July of 2018, exposing two (2) vertical feet of the left pin. Historical surveys indicated that the gravel deposition along the banks of the channel is regularly mobilized – the 2017 survey shows a widened channel when compared to 2015. From 2017 to 2018, bed material has aggraded along the right bank.

Photo 3 – Cross Section P-2 – Looking upstream – April 2020

Photo 4 - Cross Section P-2 – Looking downstream – April 2020

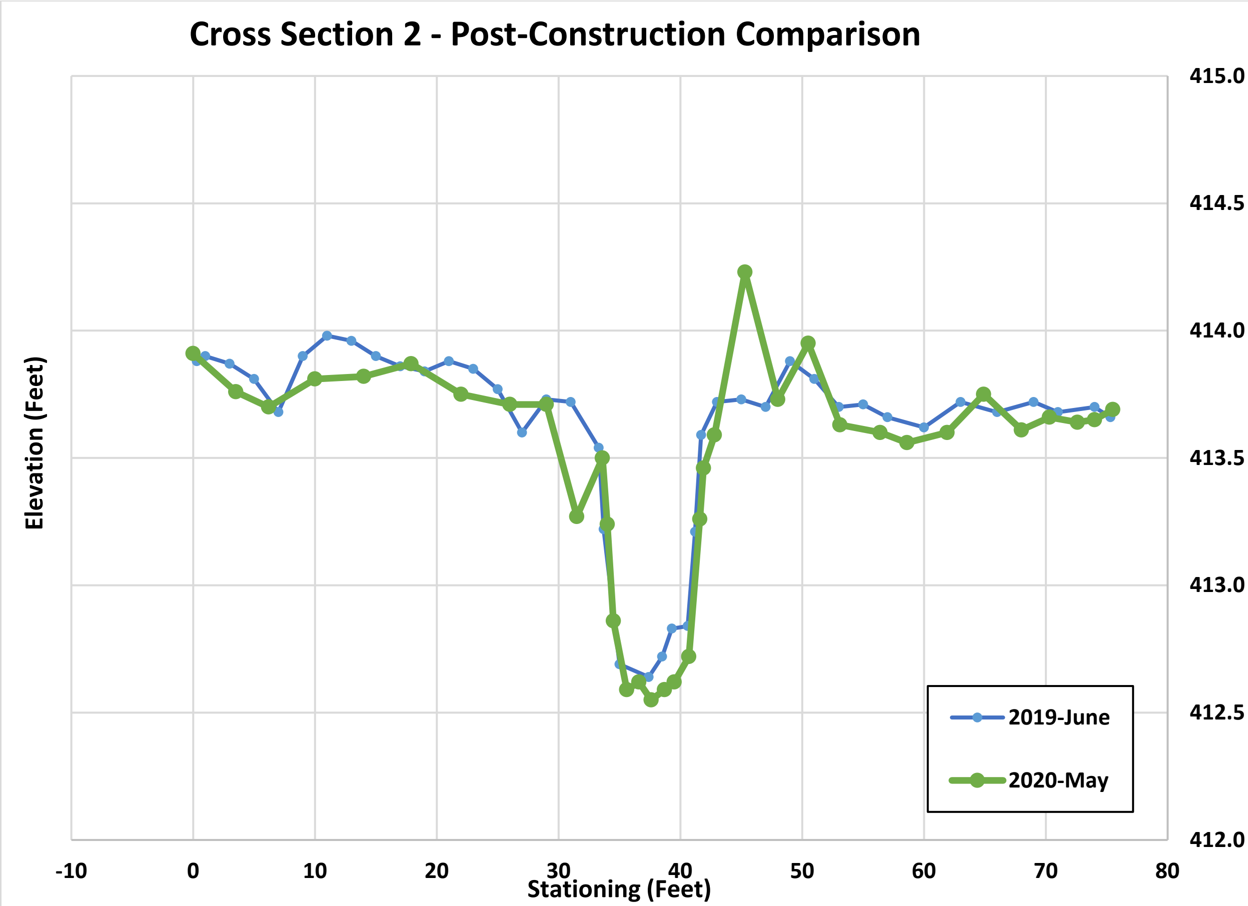


Figure 11 - Cross Section P-2 – Post-construction (2019-2020)

Cross Section 2 is located at a riffle. Figure 12 shows the first and second year of post-restoration longitudinal profile surveys. The channel slope at Section 2 became steeper compared to 2019. The slope was 0.49% in 2020 and 0.40% in 2019. The overall profile remained very similar from 2019 to 2020. The profile shows some slight downcutting in the riffle and dmax of the pools, but the bed features did not shift significantly upstream or downstream between the years. Based on field observations, downcutting was not observed and the profile result may be due to variation of the survey methodology.

Prior to restoration, the pools and riffles have demonstrated adjustment of grade features in pre-restoration surveys. The overall grade had flattened from 1.154% in 2017 to 1% in 2018 when comparing the water surface slope. The grade control feature that appeared in July 2018 was the downstream end of the scour pool immediately downstream of the MD 180 bridge. The post-restoration monitoring reach has been relocated further downstream to avoid any influence of the MD 180 bridge.

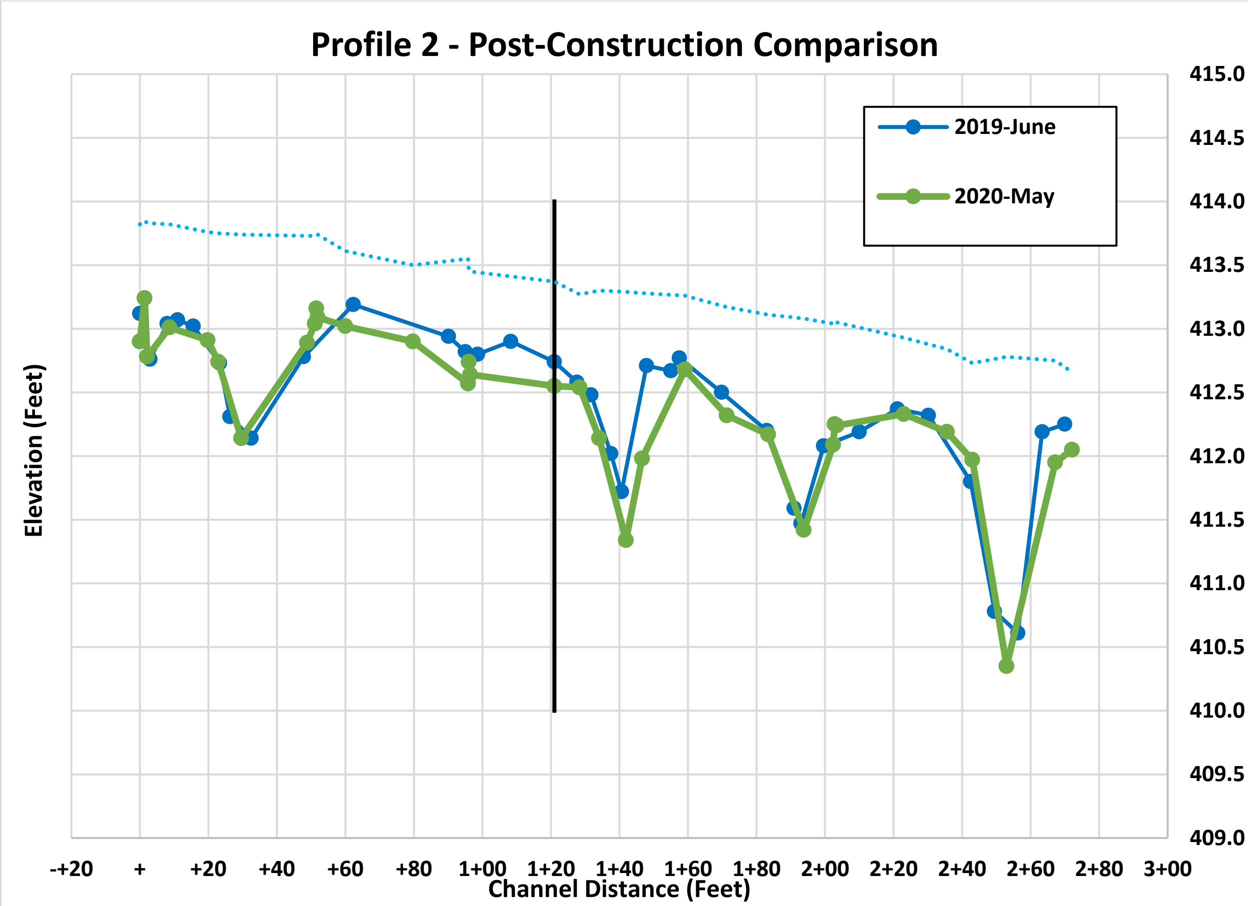


Figure 12 - Profile P-2 Comparison – Post-Construction (2019-2020)

The channel material remained relatively the same in 2020 (Figure 13). In 2020, the post-construction channel had a D50 of 12mm (medium gravel) and D84 of 30mm (very coarse gravel) compared to 2019 with a D50 of 11mm and D84 of 28mm. Comparison of the channel material below indicates that in 2020 the riffle material remains coarsened due to the restoration and is predominantly a gravel/cobble channel. The differences in pebble count results are most likely due to variations in sampling methodology.

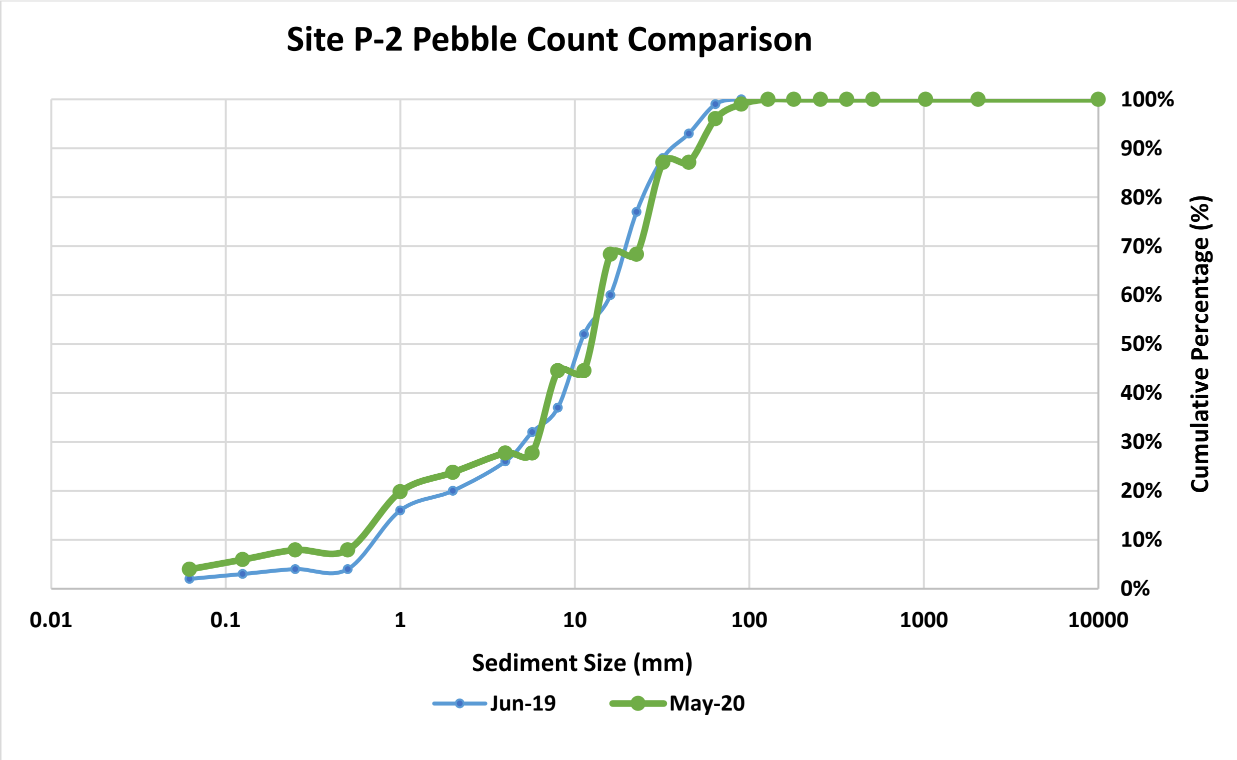


Figure 13 – Section P-2 Riffle Bed Material Comparison

Cross Section P-3 - Restoration Reach

Figure 14 shows the first and second years of post-construction cross-section surveys for Section 3. The cross-section, which is located within a riffle, has remained unchanged between 2019 and 2020. Cross section P-3 is depicted as the yellow horizontal tape in Photo 5 and Photo 6.

Pre-restoration changes from January to July of 2018 included 2-4 inches of fine sediment deposited on the right floodplain. Minor erosion and a small depositional bar at the left toe were documented during pre-restoration surveys.

Photo 5 – Cross Section P-3 – Looking upstream – May 2020

Photo 6 - Cross Section P-3 - Looking downstream – May 2020

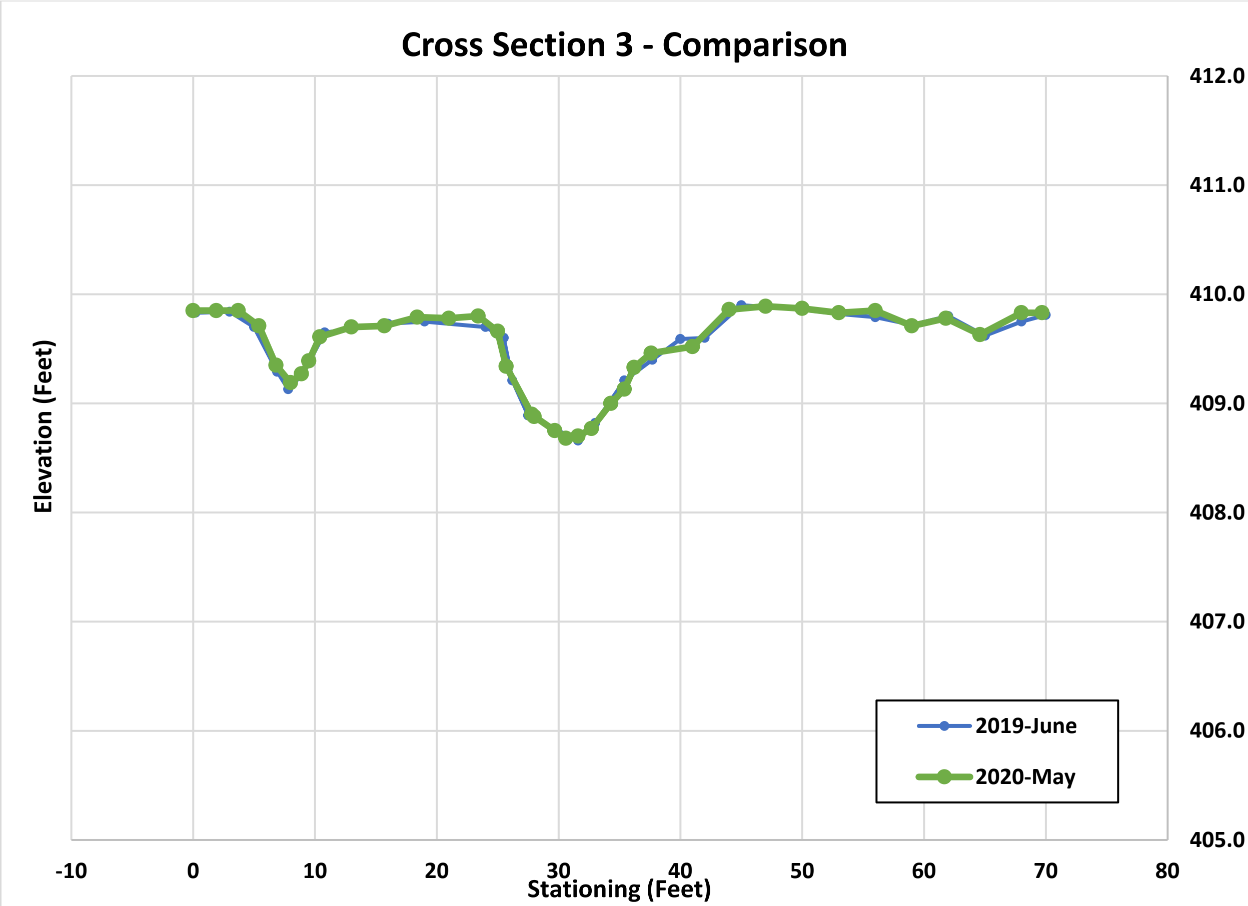


Figure 14 - Cross Section P-3 - Post-Construction (2019-2020)

Cross Section 3 is located at a riffle. Figure 15 shows the first and second year of post-restoration longitudinal profile surveys. Between 2019 and 2020, bed features upstream of the cross section have shifted downstream by approximately five (5) feet on average. The shift of channel features downstream could be the result in variations of survey methodology. Downstream features remain relatively unchanged likely due to the grade control feature upstream of the cross-section. This portion of the restoration reach contains three grade control structures (i.e., log sills). The post-restoration channel slope remained relatively the same at 0.56% in 2020, as compared to 0.58% in 2019.

Prior to restoration, the overall channel morphology was unchanged between 2017 and 2018. The pre-restoration slope for P-3 was 0.94%.

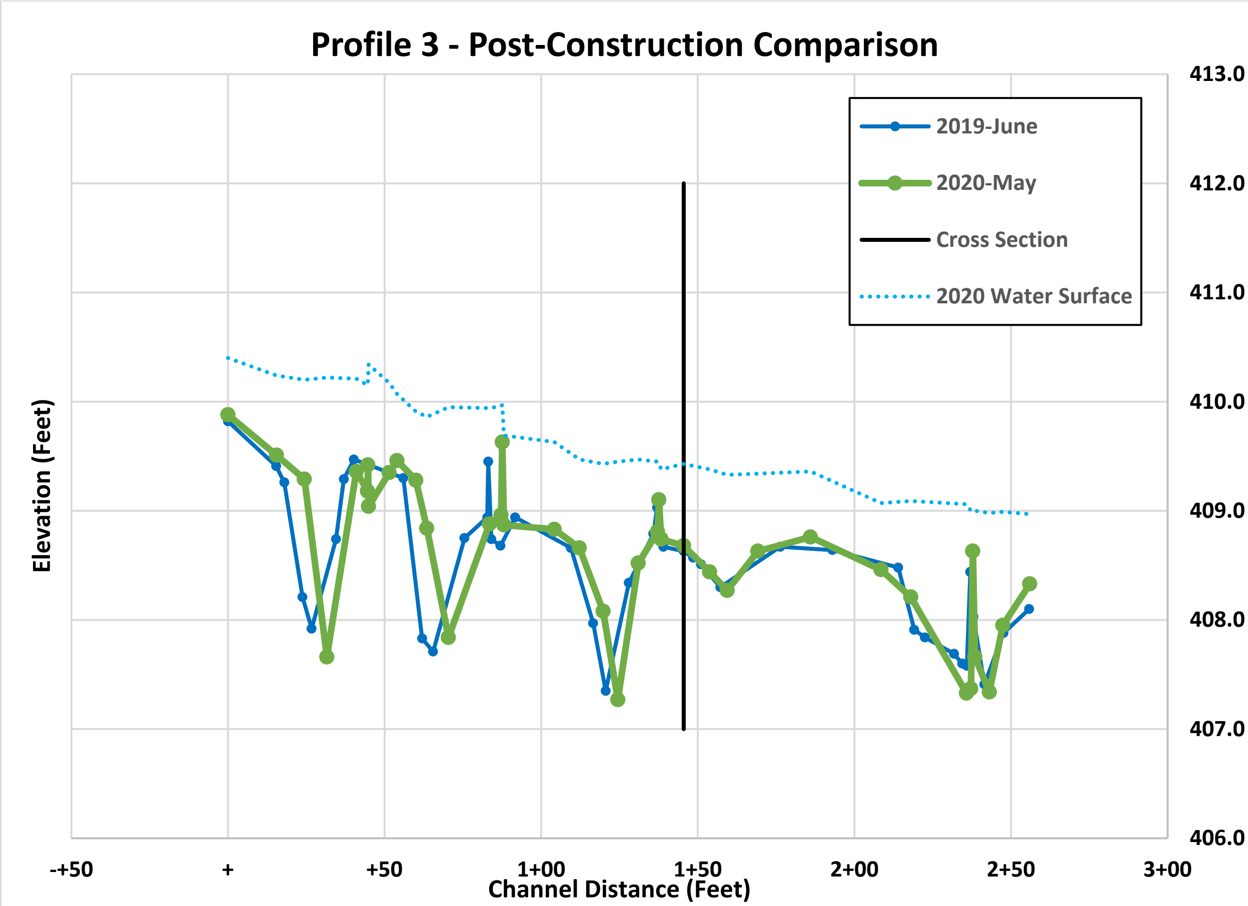


Figure 15 - Profile P-3 Comparison - Post-Construction (2019-2020)

Overall, the observed channel material was smaller in 2020 (Figure 16) at this section. In 2020, the post-construction channel had a D50 of 13mm (medium gravel) and D84 of 52mm (very coarse gravel) compared to 2019 with a D50 of 23mm (medium gravel) and D84 of 56mm (very coarse gravel). The differences in pebble count results are most likely due to variations in sampling methodology.

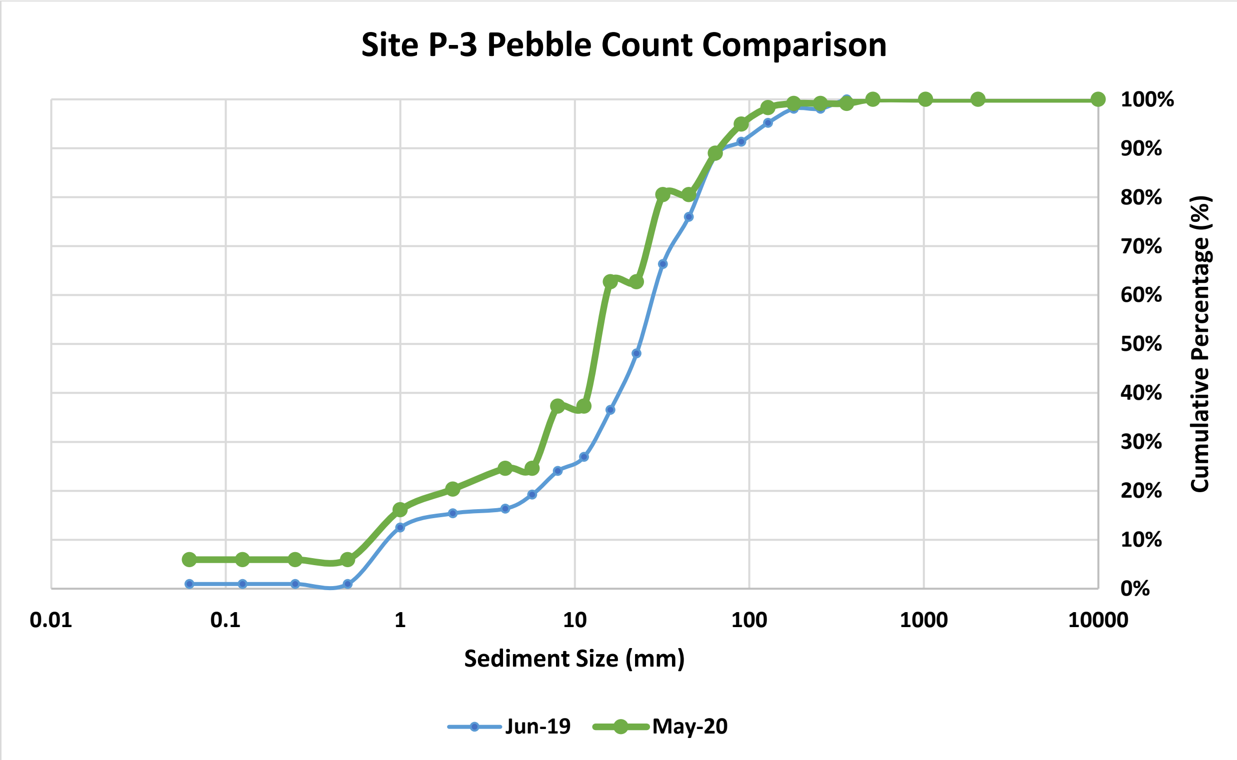


Figure 16 – Section P-3 Riffle Bed Material Comparison

Cross Section P-4 - Restoration Reach

Figure 17 shows the first and second years of post-construction cross-section surveys for Section 4. Post-Construction results indicate this cross section, which is located at a riffle, has remained consistent between 2019 and 2020. Some slight deposition of fine sediments and vegetation growth have taken place along the flood plain. Cross section P-4 (post-construction) is depicted as the yellow horizontal tape in Photo 7 and Photo 8.

Historically, P-4 was highly unstable during the pre-construction phase. The left pin was exposed by two feet and the right bank had eroded by four feet between January and July of 2018. A large gravel bar had formed on the left bank and the entire channel had shifted over the two-year pre-construction monitoring period.

Photo 7 – Cross Section P-4 – Looking upstream – May 2020

Photo 8 - Cross Section P-4 – Looking downstream – May 2020

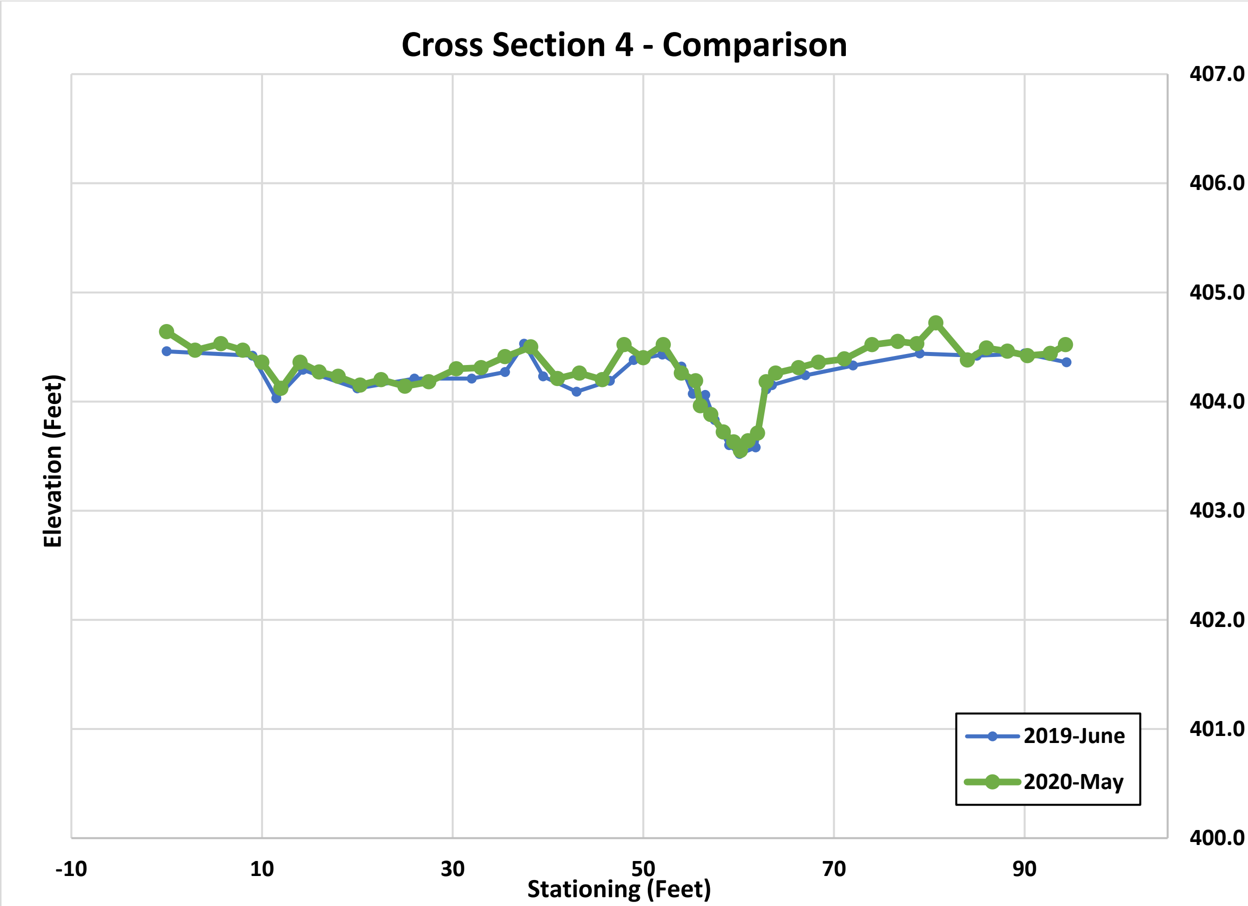


Figure 17 - Cross Section P-4 – Post-Construction (2019-2020)

Cross Section 4 is located at a riffle. Figure 18 shows the first and second year of post-restoration longitudinal profile surveys. The post restoration channel slope remained the same at 0.58% in both 2019 and 2020. The run into the downstream pool steeped and may indicate minor instability downstream of this reach.

Prior to restoration, the pre-construction cross section for P-4 was surveyed at a riffle in 2017, but downstream migration of the riffle resulted in the formation of a pool at the cross-section location in 2018. During pre-construction, the upstream riffle migrated approximately 70 feet in the downstream direction. While the channel bed thalweg had remained at approximately the same elevation, the downstream channel had aggraded during pre-construction. The pre-construction slope for this reach in 2018 was 0.41%.

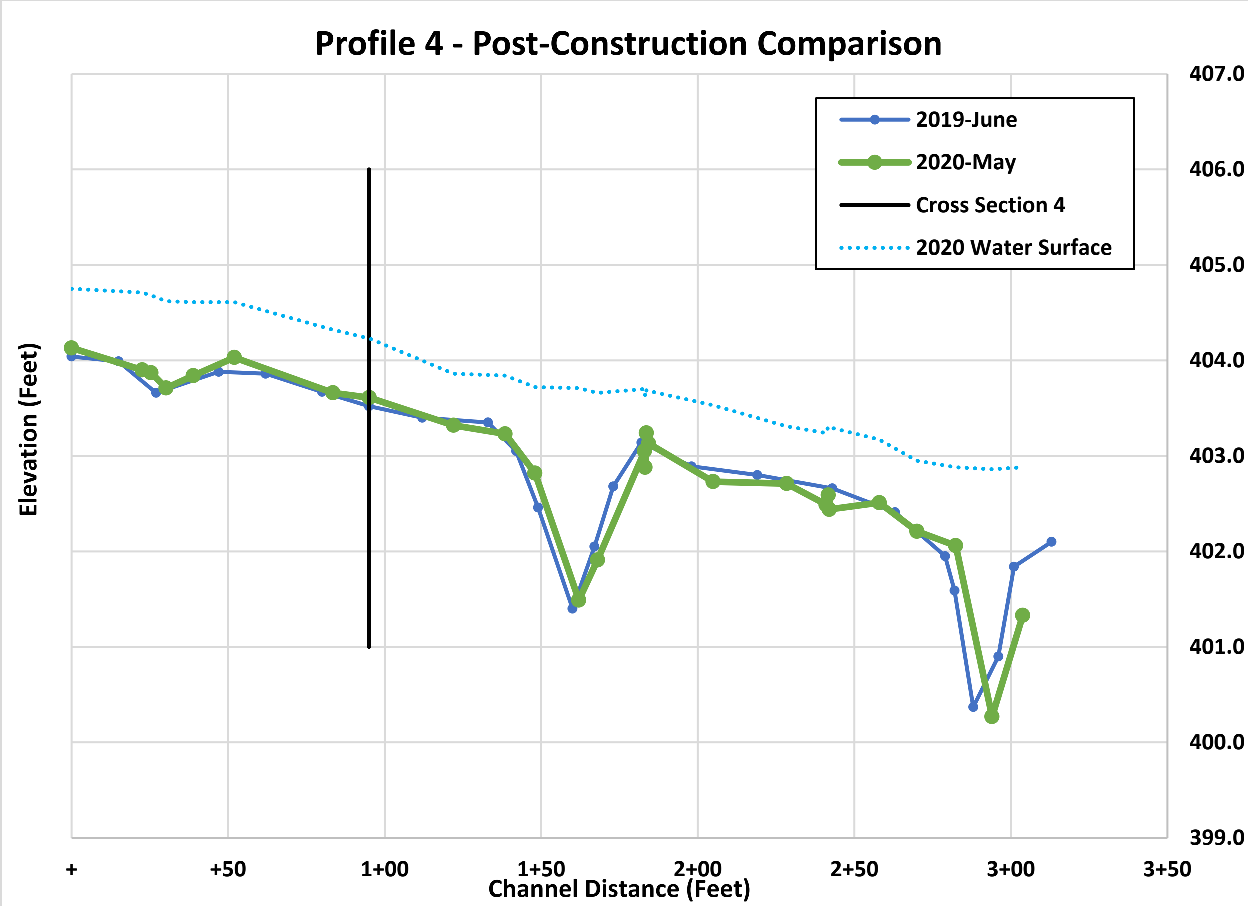


Figure 18 - Profile P-4 Comparison – Post-Construction (2019-2020)

Overall channel material was observed to be the same in 2020 (Figure 19) at this section. The material of the grade control riffle feature is predominantly gravel throughout each survey. The D50 remained the same between 2019 and 2020 at 16mm (coarse gravel). The D84 increased but remained similar between 2019 (35mm) and 2020 (57mm) within the very coarse gravel category. The differences in the D84 pebble count results are most likely due to variations in sampling methodology.

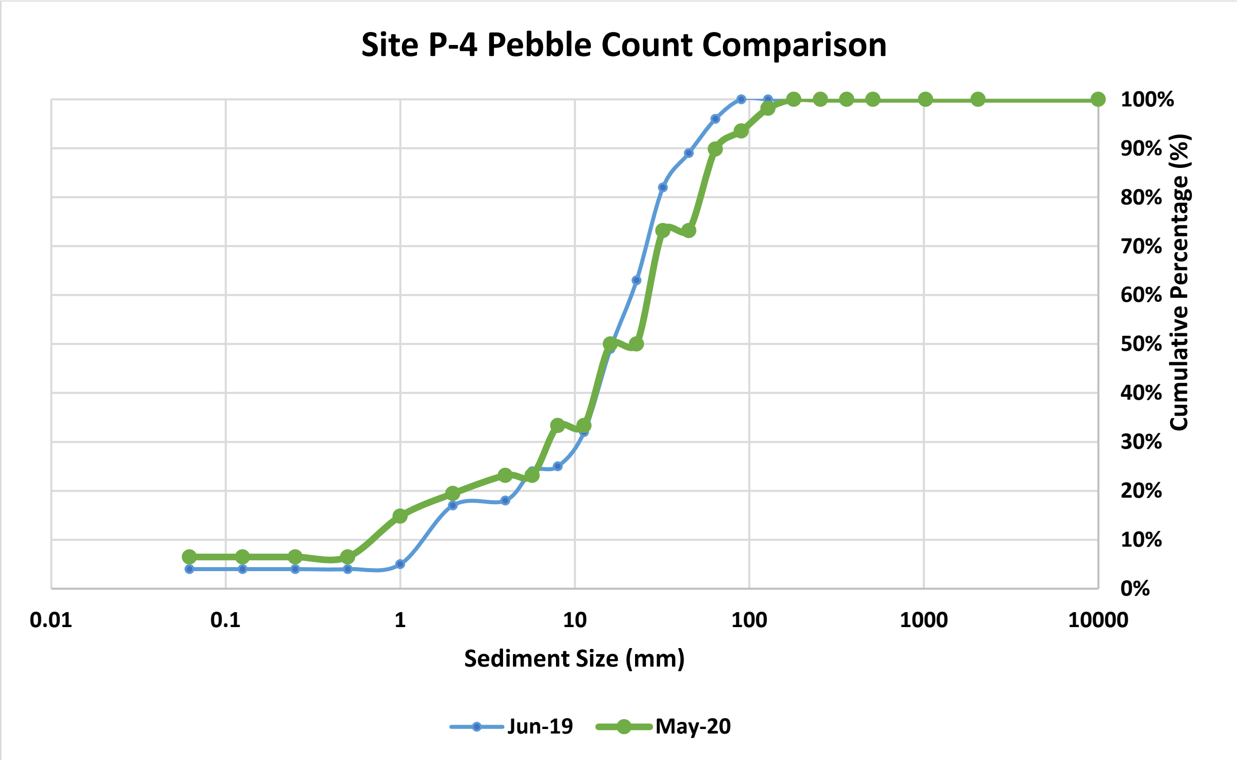


Figure 19 – Section P-4 Riffle Bed Material Comparison

<u>Cross Section P-5 - Downstream Reach</u>

The cross section, located within a transition between a riffle and pool, did not significantly change from 2019 to 2020 (Figure 20). There was some deposition along the left bank towards the middle of the channel, but the thalweg elevation remained consistent. Cross section P-5 is depicted in Photo 9 and Photo 10.

Historically, the left toe scoured down approximately one foot between April 2018 and August 2018, which likely occurred during the extreme flooding event in May 2018. The rest of the channel remained largely unchanged and both banks are fully vegetated.

Photo 9 – Cross Section P-5 – Looking upstream – May 2020

Photo 10 - Cross Section P-5 – Looking downstream – May 2020

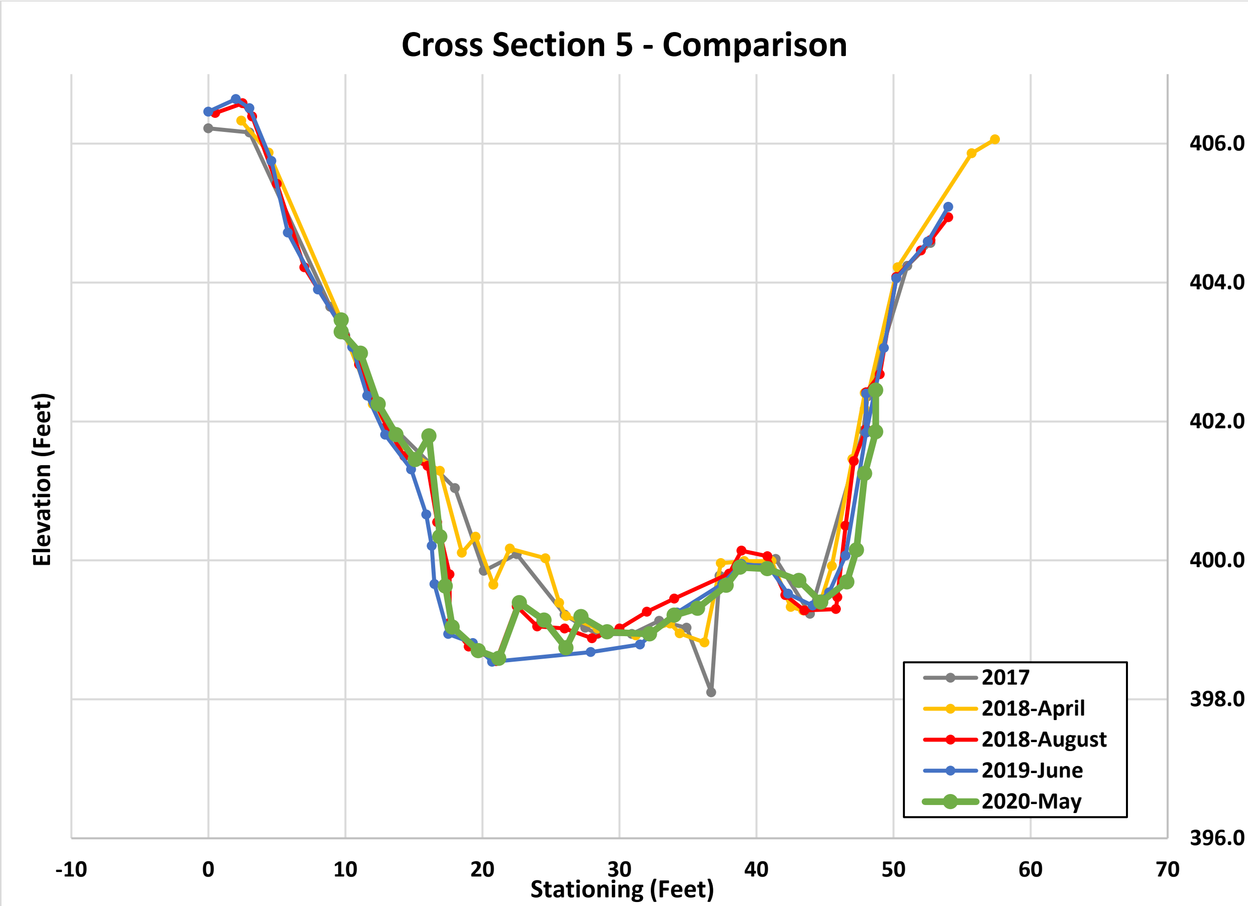


Figure 20 - Cross Section P-5 Comparison (2017 to 2020)

Cross Section 5 is located at the transition between a riffle and pool. The scour pool for a constructed cross vane is immediately upstream of the profile. The profile remained mostly unchanged from 2019 to 2020. The pool depth remained consistent however shifted upstream about 13’ in 2020. This is likely due to deposition from upstream restoration material. As the channel has had time to respond to changes in channel geometry, the channel bed profile remains mostly consistent between 2019 and 2020. The geomorphology changes observed can be directly attributed to the extreme flood event that occurred in May 2018 and increased precipitation in the region.

Historical survey results indicate the channel slope at Section 5 became steeper compared to 2019. The slope was 0.66% in 2019 and 0.70% in 2020. The area upstream of Station 0+60 received flows approaching 1800 cfs through a confined section of the floodplain which caused large shifts in the bed profile between 2018 and 2019.

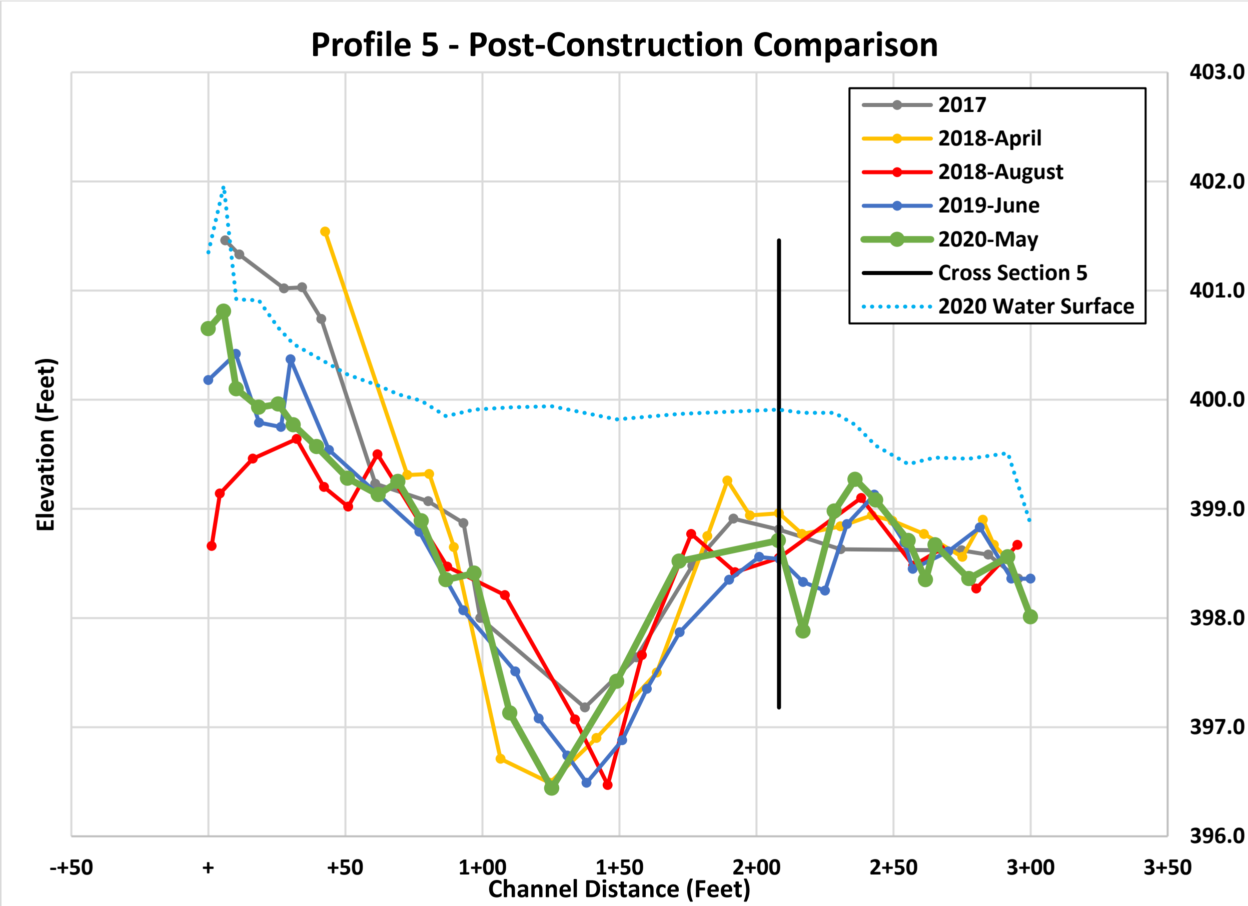


Figure 21 - Profile P-5 Comparison (2017 to 2020)

In 2020, the material became less coarse compared to 2019. The D50 was 25mm (coarse gravel), and the D84 (very coarse gravel) was 58mm in 2020 as compared to a D50 of 42mm (very coarse gravel) and D84 of 110mm (medium cobble) in 2019. The riffle material has coarsened since 2017 but remains dominated by fine gravel and cobble (Figure 21). The pebble count results in 2017 indicated the D50 and D84 was 9.1mm (medium gravel) and 28.6mm (coarse gravel) respectively. While in August of 2018, the D50 increased to 17mm (coarse gravel) and the D84 increased substantially to 73mm (small cobble). This suggests the deposition of larger bed material in the study area of Profile 5. The bed material fluidity in this section can be attributed to the extreme flood event that occurred in May 2018 and increased frequency of larger precipitation events in the region.

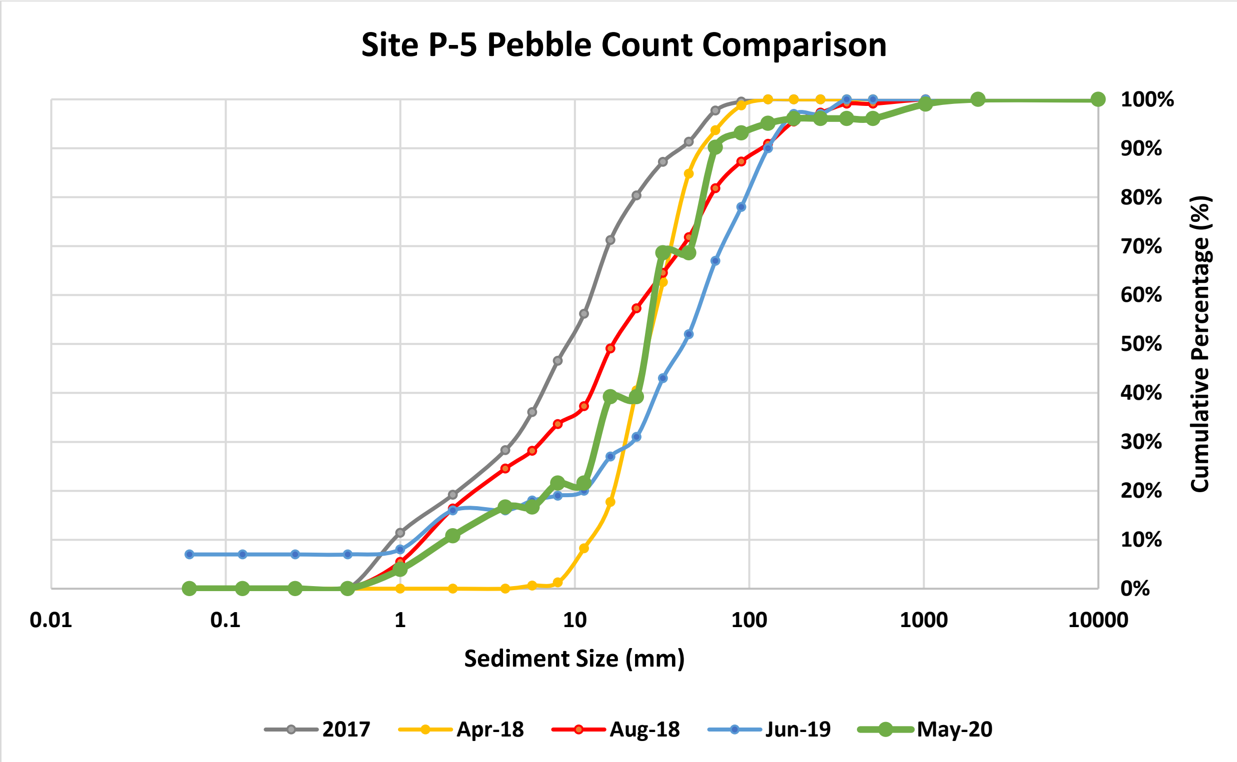


Figure 22 – Section P-5 Riffle Bed Material Comparison

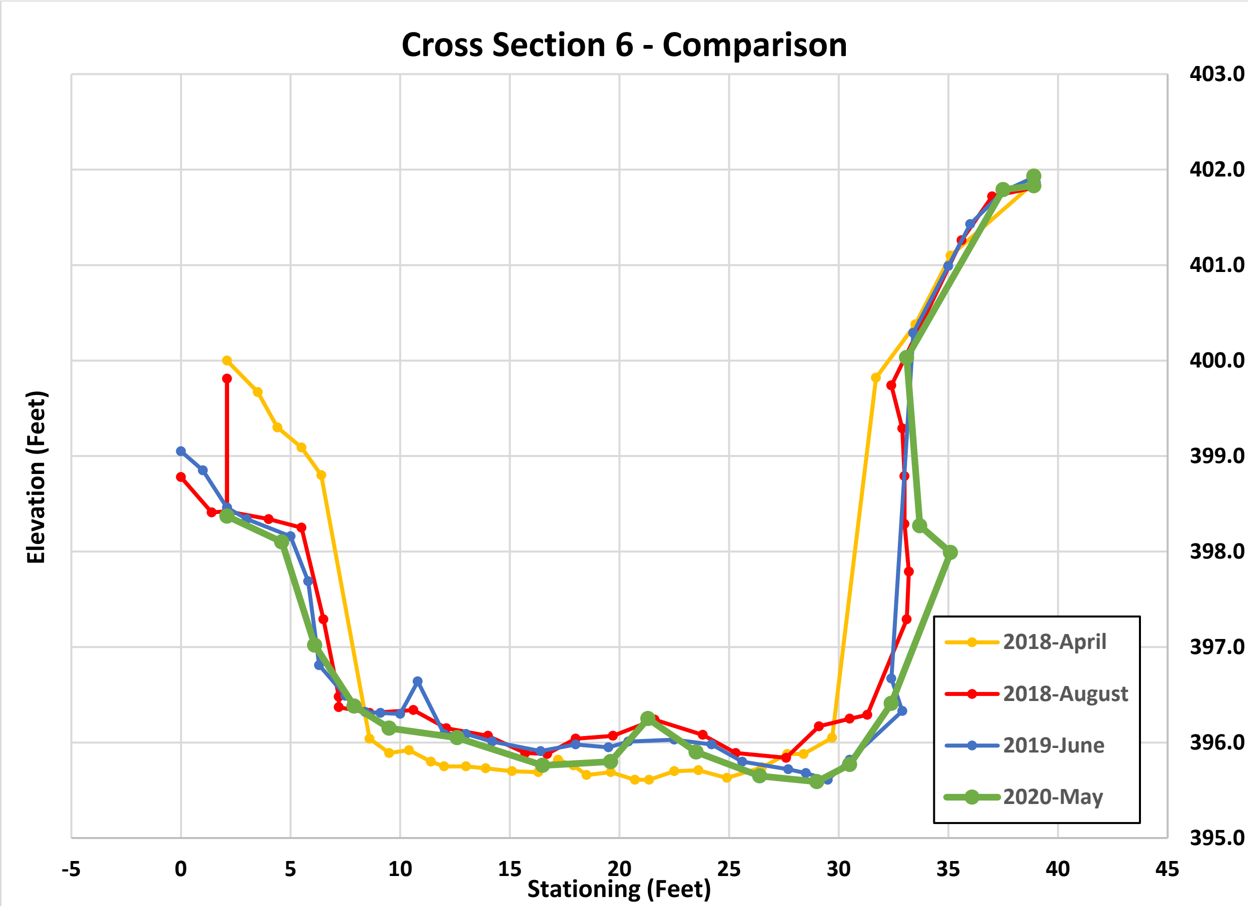
<u>Cross Section P-6 - Downstream Reach</u>

This channel section was established and surveyed in April 2018 and surveyed again in August of 2018, June 2019 and May 2020. Cross Section 6 is located at a riffle (Figure 23). The soil at this cross section is a loosely consolidated sand. The right bank has continued to undercut by approximately two feet. Some deposition is forming towards the middle of the channel. The channel is widening since 2019. In 2019 and 2020, the left bank remained consistent and the pin was still exposed approximately 1.5 feet. The right bank showed continues to erode, but the bank remained mostly intact and still had root protection to hold it together. Cross section P-6 is depicted as the yellow horizontal tape in Photo 11 and Photo 12.

Due to a large rain event in 2018 this section eroded significantly on the left bank where the monument pin is now exposed by 1.5 feet. In 2019, the right bank has undercut by 3.5 feet. Between 2018 and 2019, the entire channel bed has aggraded by approximately 4 inches across the section. It is likely that the majority of changes observed can be directly attributed to the extreme flood event that occurred in May 2018 and increased frequency of larger precipitation events in the region.

Photo 11 – Cross Section P- 6 – Looking downstream – May 2020

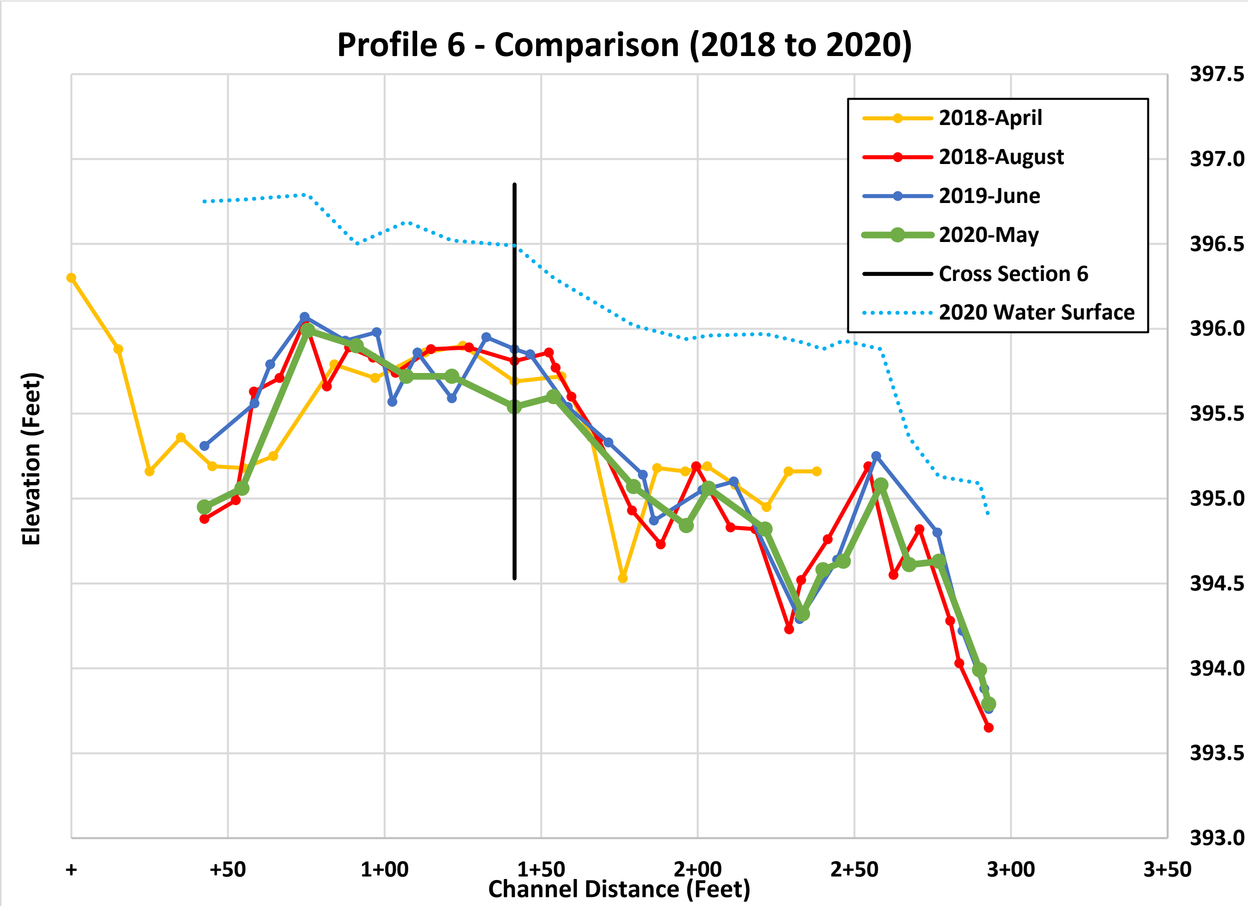
Photo 12 - Cross Section P-6 – Looking downstream, right bank eroded – May 2020



Note: Elevations are not set to known datum

Figure 23 - Cross Section P-6 Comparison (2018 to 2020)

Cross Section 6 is located at a riffle. Between 2019 and 2020, the profile survey shows that the upstream pool and the lower portion of the riffle where the cross section was taken have eroded compared to the previous year which had aggraded (Figure 24). In 2020, degradation is evident at Sta. 2+50. The profile slope increased in 2020 to 0.50% compared to 2019 with a slope of 0.42%. Aside from the change in slope the bed features throughout the profile remain similar with some minor shifting of pool features downstream.



Note: Elevations are not set to known datum

Figure 24 - Profile P-6 Comparison (2018 to 2020)

The riffle material size seems similar between 2019 and 2020. In 2020, the D50 was 26mm, and the D84 was 67mm. The reach maintained a D50 in the coarse gravel category and a D84 shifted from medium cobble to small cobble (Figure 25). The differences in the D84 pebble count results are most likely due to variations in sampling methodology.

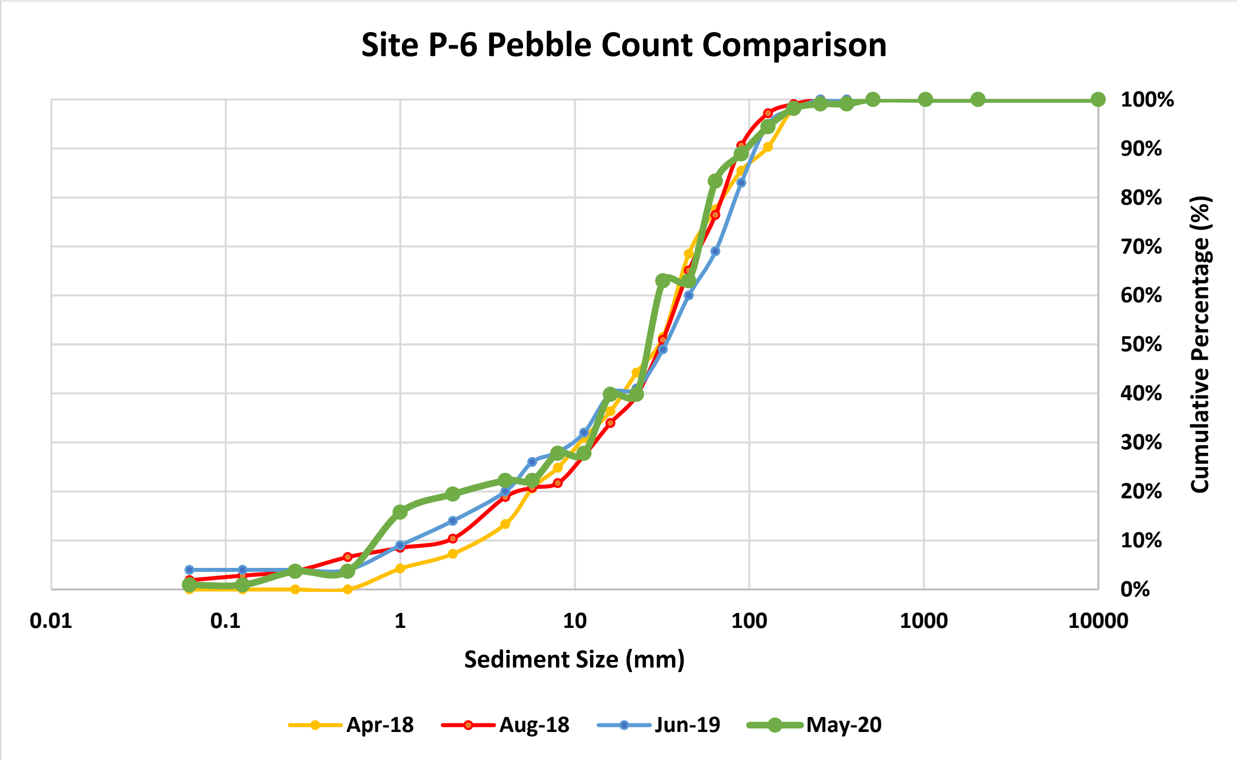


Figure 25 – Section P-6 Riffle Bed Material Comparison

3.5 Physical Monitoring Discussion

Following the pre-construction surveys, conducted from September 2017 through August 2018, there is substantial evidence that the geomorphic conditions in the monitored reaches of Little Catoctin Creek are very fluid. With three separate geomorphic surveys conducted in the span of just one year, erosion and channel instability were documented. Construction of the restoration reach was completed in May 2019. Post-construction surveys of the 3 existing and 3 newly established sites were conducted in June 2019 and April/May 2020. A summary of the surveys both pre-and post-construction is detailed for Section 1, 5, and 6. A summary of the surveys for post-construction is detailed within the restoration reaches at Sections 2 through 4.

Table 7 summarizes the cross-section dimensions including cross-section area, width, mean depth, max depth, width to depth ratio, and top area. The percent change represents the change between 2019 and 2020 surveys for all sections. Table 8 summarizes the profile slope for the surveyed sections. Table 9 summarizes the D50 and D84 sediment size classes. The following discussion refers to Table 7 through Table 9.

Section 1

Section 1 is located within the upstream control reach at a pool, prior to the roadway culvert. Channel slopes increased between 2019 and 2020. Geomorphology of Section 1 remains very fluid from year to year. In 2020, the pool feature at this cross-section has migrated approximately 10 feet downstream. Between 2017 and 2020, the riffle immediately downstream continues to show signs of downcut by approximately 0.4 - 1.0 feet. There is evidence based on the pebble count that the finer materials are transporting out of this section. Movement of channel features and increase in d50 and d84 material size indicates channel instability.

Historic surveys confirm the geomorphology fluidity between yearly surveys at Section 1. In 2019, there was minor lateral erosion near the top of the left bank of about 1.5 feet. The channel was significantly impacted by increased deposition and aggradation on the right bank were the bank aggraded vertically by 1 foot. This deposition has led to a decrease in bankfull cross-sectional area and top of bank area since 2017 (Table 7). In 2019, most of that deposition had eroded away leading to a 50% increase in the cross-sectional area compared to 2017. In 2020, erosion continued within the center of the channel as well as along the left bank further increasing the cross-sectional area. As indicated by Table 9, there was an increase in the presence of coarse particles such as large gravel and cobble. In previous years deposition was observed in Section 1 resulting in a lower particle distribution. In 2019 there was a bimodal distribution of the fine deposition and the native cobble/gravel bed. The two peaks observed in the particle sizes representing fine sediments and native bed material, suggest that the fine sediments observed in 2019 were moved through the channel and exposed the native channel material under those deposits. Channel slopes decreased over the course of the first three surveys. The decrease is due either to the grade control structure and aggrading that occurred between 2017 and 2018, or to the difference in the lengths of the profile caused by split flows in the upstream section of the reach (Table 8). Between 2018 and 2019, the channel upstream of this section has become more unstable by forming a mid-channel bar/split flow. This could also have contributed to the increase in channel slope between 2018 and 2019 as the split flow resulted in a new thalweg location.

Section 2

Section 2 is located within the restoration reach at a riffle. Post restoration, between 2019 and 2020, minor erosion was observed along the top of the left bank and deposition along the top of the right bank of Cross-Section 2, though the geometry of the channel remained similar. The overall channel slope increased between 2019 and 2020 with some minor downcutting along the riffles and max depth of the pools. Based on field observations, downcutting was not observed and the profile result may be due to variation of the survey methodology. Channel material remains consistent post restoration between 2019 and 2020. The differences in profile results are most likely due to variations in survey methodology. Post-construction geomorphology indicates stability at Section 2.

Section 3

Section 3 is located within the restoration reach at a riffle. Between 2019 and 2020, the post construction cross-section 3 survey remain mostly unchanged. Between 2019 and 2020 the features upstream of the cross-section shifted downstream by approximately five (5) feet while features downstream of the cross-section remained relatively unchanged. The channel slope decreased between 2019 and 2020 by 0.02%. Channel material of this section also decreased being comprised of medium and very coarse gravel. The differences in profile and pebble count results are most likely due to variations in survey and sampling methodology. Post-construction geomorphology indicates stability at Section 3.

Section 4

Section 4 is located within the restoration reach at a riffle. In 2020, the cross-section of this reach remained relatively unchanged compared to 2019 with some minor deposition of fine sediments and vegetation growth taking place (Figure 17). Overall channel slope remained consistent between 2019 and 2020 at 0.58%. The profile also showed several pools shifting in the downstream section of this reach which might indicate some instability and should continue to be monitored in future years. Channel material remained consistent between 2019 and 2020 comprised of coarse and very coarse gravel. The differences in pebble count results are most likely due to variations in sampling methodology.

Section 5

Section 5 is located at a transition between a riffle and pool within the downstream control reach. The profile shows channel features that have migrated since 2017, potentially due to two large storm events in May 2018 and August 2018, and overall increased frequency of larger precipitation events within the region (Figure 20). The cross section was stable from the initial survey in 2017 to the second survey in April 2018 until a large storm event caused extensive scour (1 foot) and lateral erosion on the left bank (2 feet) that was documented in the August 2018 survey (Table 7). The cross-sectional area increased while the top of bank area increased by a much smaller amount which indicates most of the changes are occurring at or below the bankfull stage (Table 7). The cross-section between 2019 and 2020 remained mostly unchanged with some deposition occurring along the left bank and towards the center of the channel. Along the profile the upstream pool depth did not change but migrated upstream by approximately 13 feet (Figure 21). The channel slope increased in 2020. Since 2019 channel material has decreased in size to a D50 of 25mm and D84 of 58mm (Figure 22). This deposition of smaller material is likely a result of upstream restoration. Channel feature movement suggests fluidity and instability at this cross section.

Section 6

Section 6 is located at a riffle within the downstream control reach. Section 6 was established in 2018 and therefore only had two surveys conducted in 2018 and one in 2019. The cross-section in this reach experienced significant erosion from April 2018 to August 2018 (Figure 23). The left bank eroded about 0.8 feet and the right bank eroded 3.5 feet (Figure 23). Although, bank erosion occurred, the aggrading of the stream bed by 0.35 feet at this cross section minimized the loss in cross-sectional area (Table 7). In 2020 it was observed that the right bank had undercut by approximately 2 feet in this location. Due to root protection, the bank is still mostly intact though monitoring of this area should continue in future years. The channel slope increased in 2020 to 0.50% compared to 0.42% in 2019. Some pools also shifted downstream though the overall profile remains consistent between 2019 and 2020. Channel material in this section decreased between 2019 and 2020 with the D84 shifting from medium cobble to small cobble. Channel feature movement and active erosion along the right bank suggests fluidity and instability at this cross section. Larger precipitation events during the monitoring period attributed to the degradation at Section 6.

Bankfull

Table 7 summarizes bankfull parameters of the channel cross section. The bankfull elevations used to determine the measurements did not change from 2019, but there was natural variations in the cross sections within the restoration reach based on variation in survey.

In the restoration reaches, there were slight changes in the shape of the channel or banks of the cross sections. At XS 4, the change in width is due to sediment deposition on the right bank. The bank had a gentle slope, but the comparison graph is showing some deposition above the bankfull elevation. This deposition resulted in a decrease in cross-sectional area and bankfull width in 2020. Similarly, the degradation that occurred on the left bank resulted in an increase in cross section area and width at XS 2. The cross-sectional differences did not indicate a change in bankfull elevation however did show a change in cross sectional area and width mentioned in Table 7. The bankfull channels in the restoration reach are fairly small, therefore any changes can have a large influence on the percent change.

Table 7: Cross-section dimension comparison.

Bankfull							
		Cross-Sectional Area (ft^2)	**Width (ft)**	**Mean Depth (ft)**	**Max Depth (ft.)**	**Width/Depth Ratio**	**Top of Bank Area (ft^2)***
XS 1	Sep 2017	19.5	16.9	1.2	2.1	14.6	143.6
	Apr 2018	13.5	19.9	0.7	1.7	29.5	137.0
	Aug 2018	15.3	13.5	1.1	1.6	11.8	123.7
	June 2019	29.7	17.9	1.7	3.0	10.8	141.7
	May 2020	37.4	21.5	1.7	3.3	12.3	154.4
	% Change	**+26%**	**+20%**	**0%**	**+10%**	**+14%**	**+9%**
XS 2	June 2019	5.8	8.3	0.7	0.9	12.0	5.8
	May 2020**	7.1	12.5	0.6	1	22.1	7.1
	% Change	**+22%**	**+51%**	**-14%**	**+11%**	**+84%**	**+22%**
XS 3	June 2019	7.8	16.5	0.5	0.9	35.0	7.8
	May 2020**	7.9	16.6	0.5	0.9	34.6	7.9
	% Change	**+1%**	**+1%**	**0%**	**0%**	**-1%**	**+1%**
XS 4	June 2019	7.6	26.4	0.3	0.9	91.9	7.6
	May 2020**	6.2	19.2	0.3	0.9	59.9	6.2
	% Change	**-19%**	**-10%**	**+0%**	**+13%**	**-2%**	**-19%**
XS 5	Sep 2017	26.9	26.7	1.0	2.4	26.5	160.1
	Apr 2018	26.1	28.0	0.9	1.6	30.1	159.2
	Aug 2018	35.0	29.7	1.2	2.0	25.3	169.4
	June 2019	40.3	30.8	1.3	1.9	23.5	178.1
	May 2020	13.6	24.2	0.6	1.1	43.2	59.4
	% Change	**-66%**	**-21%**	**-54%**	**-42%**	**+84%**	**-67%**
XS 6	Apr 2018	38.2	23.0	1.7	1.9	13.9	101.9
	Aug 2018	35.5	26.9	1.3	1.7	20.3	112.5
	June 2019	38.6	26.7	1.4	1.9	18.5	115.6
	May 2020	40.5	27.2	1.5	1.9	18.2	119.7
	% Change	**+5%**	**+2%**	**+7%**	**0%**	**-2%**	**+4%**
**Top of bank area calculated from an established fixed elevation unrelated to bankfull*							

Table 8: Profile slope comparison

Profile		Water Surface Slope %
Profile 1	Sep 2017	0.76%
	Apr 2018	0.59%
	Aug 2018	0.40%
	Jun 2019	1.10%
	May 2020	1.10%
Profile 2	Jun 2019	0.40%
	May 2020	0.43%
Profile 3	Jun 2019	0.58%
	May 2020	0.56%
Profile 4	Jun 2019	0.58%
	May 2020	0.62%
Profile 5	Sep 2017	0.995%
	Apr 2018	0.94%
	Aug 2018	0.42%
	Jun 2019	0.66%
	May 2020	0.83%
Profile 6	Apr 2018	0.45%
	Aug 2018	0.48%
	Jun 2019	0.42%
	May 2020	0.49%

Table 9: Bed material particle comparison

Site		D50	Size Class	D84	Size Class
Section 1	Sep 2017	12.3	Medium gravel	31.3	Coarse gravel
	Apr 2018	32	Coarse gravel	71	Small cobble
	Aug 2018	33	Very coarse gravel	62	Very coarse gravel
	Jun 2019	18	Coarse gravel	56	Very coarse gravel
	May 2020	25	Coarse gravel	150	Large cobble
Section 2	Jun 2019	11	Medium gravel	28	Coarse gravel
	May 2020	12	Medium gravel	30	Coarse gravel
Section 3	Jun 2019	23	Coarse gravel	56	Very coarse gravel
	May 2020	13	Medium gravel	52	Very coarse gravel
Section 4	Jun 2019	16	Coarse gravel	35	Very coarse gravel
	May 2020	16	Coarse gravel	57	Very coarse gravel
Section 5	Sep 2017	9.1	Medium gravel	28.6	Coarse gravel
	Apr 2018	26	Coarse gravel	44	Very coarse gravel
	Aug 2018	17	Coarse gravel	73	Small cobble
	Jun 2019	42	Very coarse gravel	110	Medium cobble
	May 2020	25	Coarse gravel	58	Very coarse gravel
Section 6	Apr 2018	30	Coarse gravel	85	Small cobble
	Aug 2018	31	Coarse gravel	77	Small cobble
	Jun 2019	33	Coarse gravel	93	Medium cobble
	May 2020	26	Coarse gravel	67	Small Cobble

4 Chemical Monitoring

Per the NPDES/MS4 Assessment of Controls monitoring plan, chemical monitoring of the Little Catoctin Creek was performed as specified in the chemical monitoring methodology. The monitoring efforts through January 31, 2018 fall under phase CHEM 1 activity to establish pre-restoration conditions. Monitoring efforts beginning February 1, 2018 through April 15, 2019 occurred during the construction phase (CHEM 2). Monitoring efforts beginning on April 16, 2019 and continuing through June 2020, are conducted under the post-construction phase (CHEM 3). Stage, discharge, velocity, continuous water quality measurements, and discrete water quality sample analyses are reported on the U.S. Geological Survey's National Water Information Service (NWIS) and are available online at https://www.waterqualitydata.us/.

Chemical monitoring samples collected in FY20 started with a base-flow on July 31, 2019 through a storm event on April 30, 2020. All available data were appended to the geodatabase Chemical Monitoring data table for submittal to MDE. A discussion of the chemical monitoring data and results can be found in **Attachment D – Chemical Monitoring Results**.

Field measurements, nutrient and bacteriologic data for FY20 samples are complete except for some analytes. Missing data are still in the process of being analyzed and therefore, are not included in the final geodatabase table of EMCs. Missing data include select metals analyses in samples collected after April 13, 2020. The status of these analyses is unknown; if the analyses have been performed and the data are undergoing laboratory checking, then these data will ultimately be reported through NWIS. All missing EMC values in samples collected in FY20 are reported as '9999' in the data table.

Chemical data released by the USGS NWQL typically have gone through laboratory review followed by further review by the District Water Quality Specialist. At present, the FY20 chemical data, along with field measurements of QW parameters, have not yet been through District review, and therefore, are subject to change. A percentage of discharge, gage height data, and water quality parameters (temperature, specific conductance, pH) are reported as "provisional". These data are subject to change during District QA review scheduled for the fall of 2020. If upon review, discharge values change, then Event Mean Concentrations for FY20 may be affected and will be appended in subsequent geodatabase submittals to MDE.

5 Biological Monitoring

Biological monitoring activities in FY20 were performed by the Maryland Department of Natural Resources (MDNR) Resource Assessment Service. Data analysis and reporting efforts in FY20 include analyzing fish and physical habitat assessment data collected in July 2020 as part of phase BIO 3, which were not collected in time to be included in the FY19 report. This data has been included in the Biological Monitoring table of the geodatabase submittal to MDE. Biological monitoring results and comprehensive analysis of pre- and post-restoration biological conditions are presented in **Attachment E – Biological Monitoring Results.**

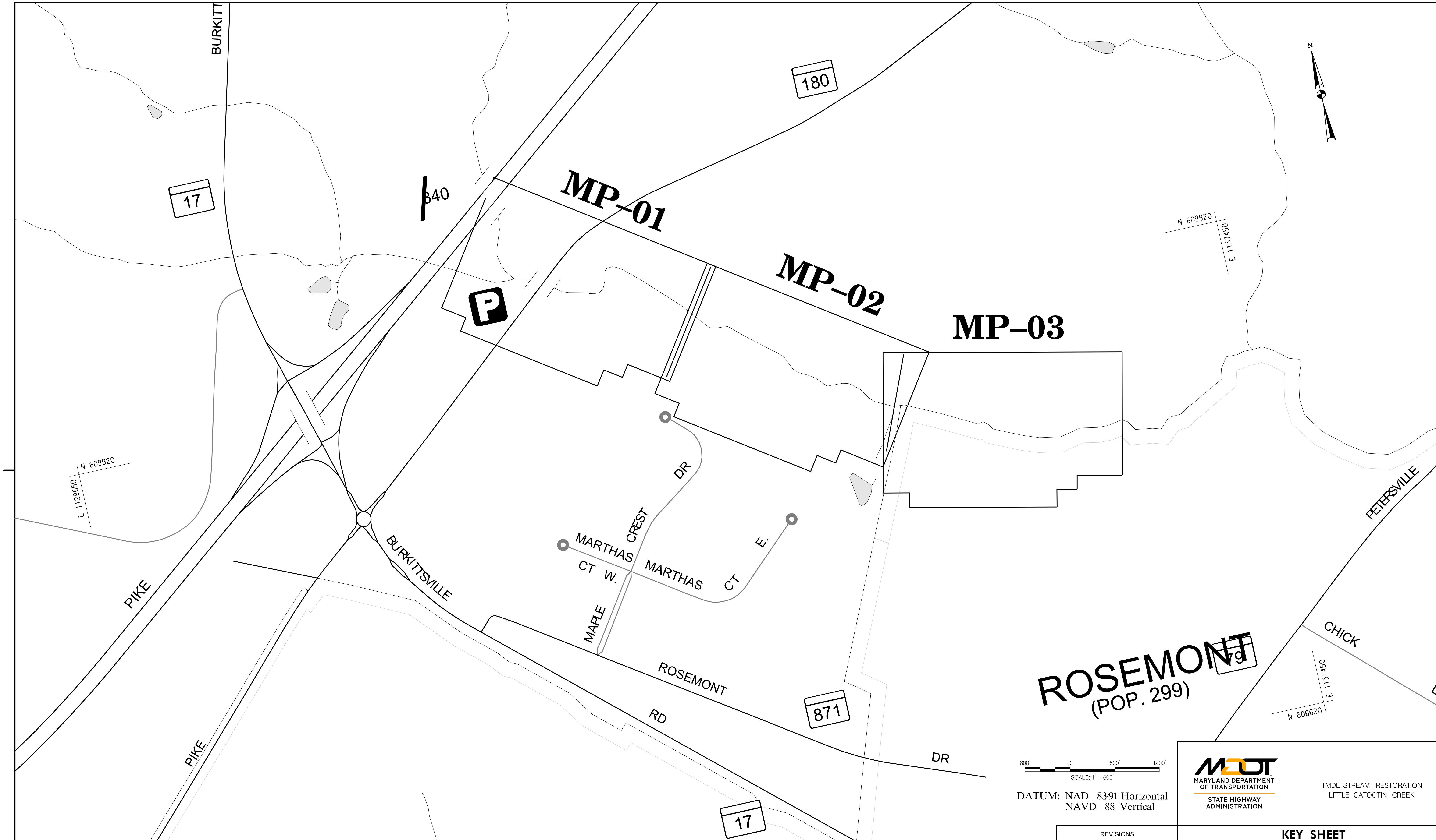
Biological data representing the final year of post-construction monitoring (BIO 4) were collected during the spring index period (March 1 - April 30) in 2020. However, it should be noted that although benthic macroinvertebrate samples were collected and subsampled in FY20, taxonomic identification has yet to be completed and BIBI values have not been calculated. Therefore, biological data for FY20 representing the final year of restoration monitoring will be incorporated in the FY21 submittal to MDE.

6 References

State Highway Administration (SHA), Maryland Department of Transportation. 2016. NPDES/MS4 assessment of controls for stream restoration of Little Catoctin Creek at U.S. 340 in Frederick County, Maryland. Baltimore, Maryland.

State Highway Administration (SHA), Maryland Department of Transportation. 2017. National Pollutant Discharge Elimination System Annual Report. Baltimore, Maryland.

Attachment A - Monitoring Locations



DATUM: NAD 83/91 Horizontal
NAVD 88 Vertical

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

TMDL STREAM RESTORATION
LITTLE CATOCTIN CREEK

REVISIONS

KEY SHEET

SCALE 1" = 600' ADVERTISED DATE OCTOBER 2017 CONTRACT NO. AT62813

DESIGNED BY ____ COUNTY FREDERICK
DRAWN BY ____ LOGMILE ____
CHECKED BY ____
MDE/PRD ____

DRAWING NO. KY-01 OF 01 SHEET NO. 1 OF 4

PLOTTED: Tuesday, October 03, 2017 AT 03:39 PM
FILE: \\balsrv02\v2011\2011\11110_SHANEPA\Task41_TMDL Support\Assessmt_of_Cntrls\SR\CADD\Plans\pMP-key_MD180.dgn

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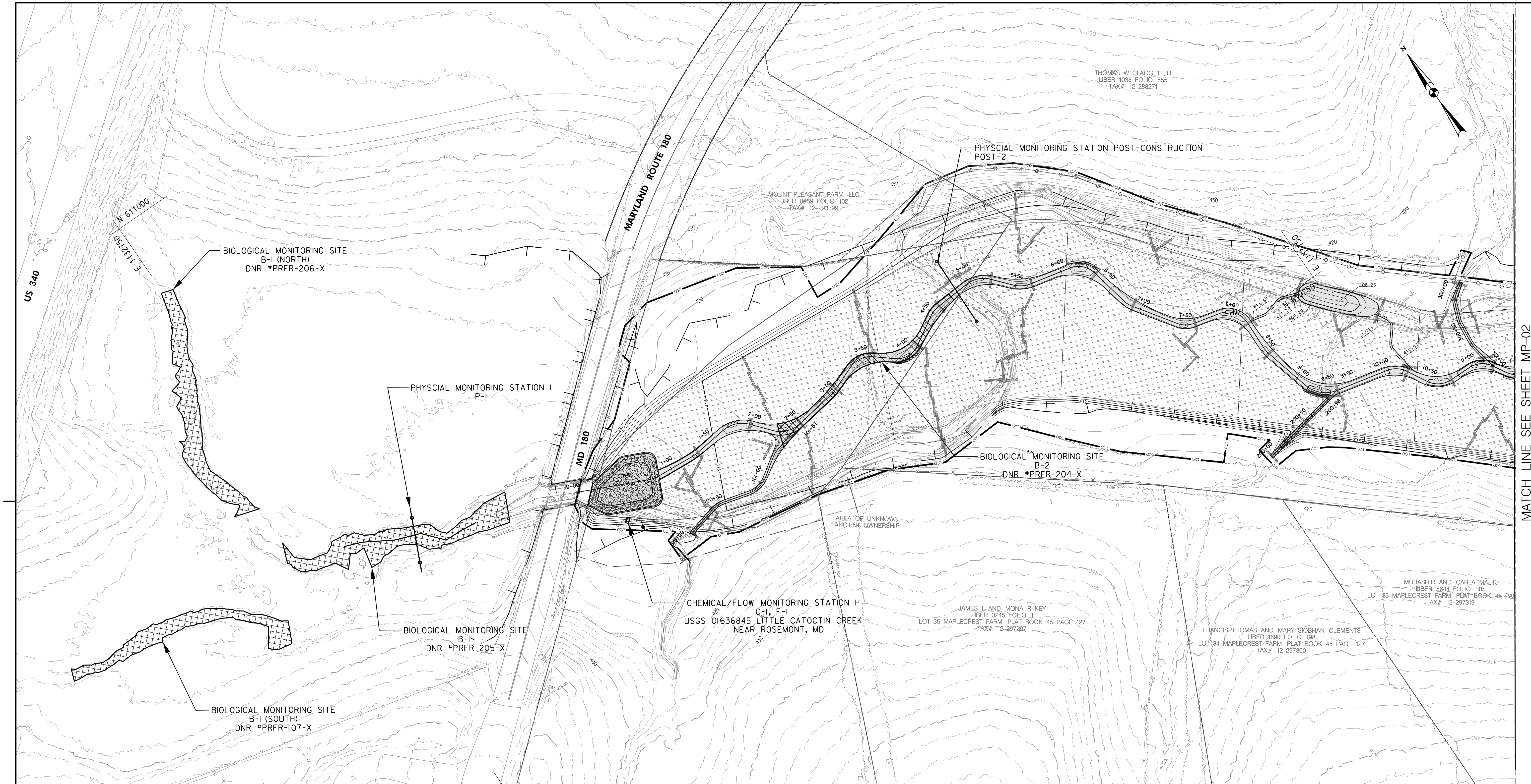
BY: dblack -



100' 0 100' 200'
SCALE: 1" = 100'

DATUM: NAD 83/91 Horizontal
NAVD 88 Vertical

MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

TMDL STREAM RESTORATION
LITTLE CATOCTIN CREEK

REVISIONS

MONITORING LOCATION PLAN

SCALE 1" = 100' ADVERTISED DATE SEPT 2019 CONTRACT NO. AT62813

DESIGNED BY
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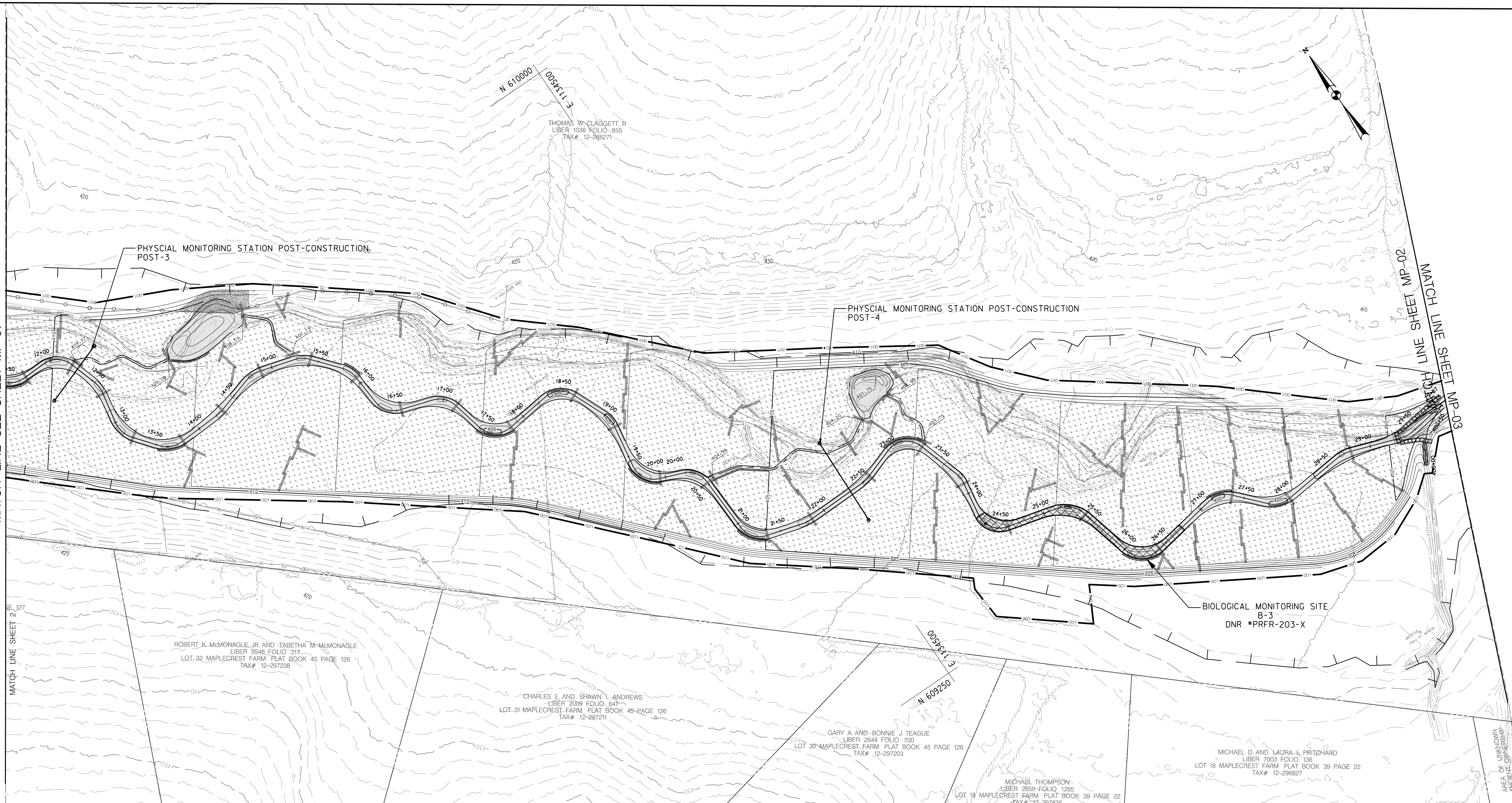
COUNTY FREDERICK
LOGMILE

DRAWING NO. MP-01 OF 03 SHEET NO. 2 OF 4

PLOTTED: Tuesday, September 17, 2019 AT 11:06 AM
FILE: T:\186681 - BCS 2014-09H Enviro Design\WAT\Task 04 MS4 Monitoring - Little Catoctin\CADD\Plans\pMP-0001_MD180.dgn

BY: MoxleyK -



100' 0 100' 200'
SCALE: 1" = 100'

DATUM: NAD 83/91 Horizontal
NAVD 88 Vertical

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TMDL STREAM RESTORATION
LITTLE CATOCTIN CREEK

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DRAWING NO. MP-02 OF 03 SHEET NO. 3 OF 4

PLOTTED: Tuesday, September 17, 2019 AT 11:08 AM
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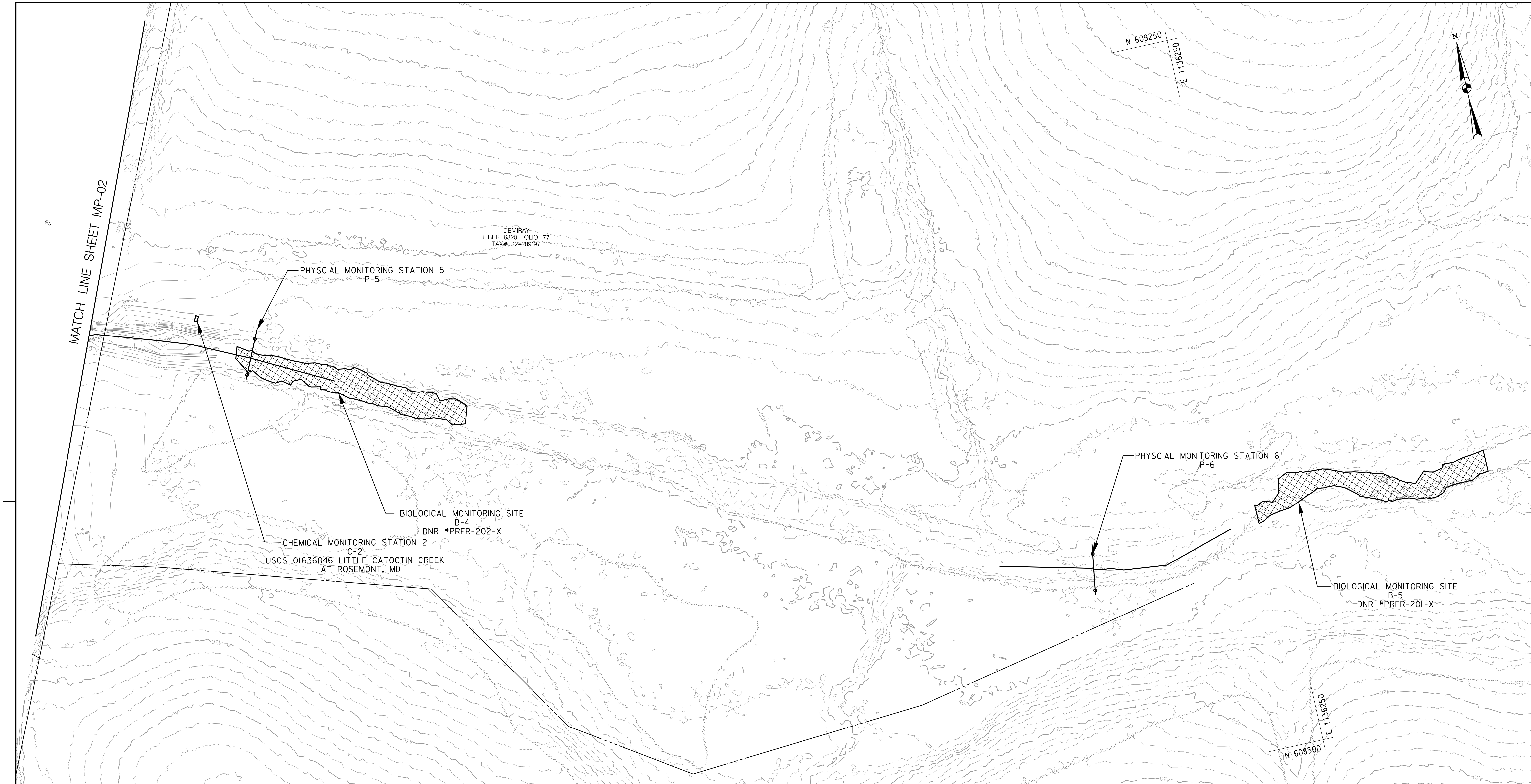
BY: MoxleyK -



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DATUM: NAD 83/91 Horizontal
NAVD 88 Vertical

MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

TMDL STREAM RESTORATION
LITTLE CATOCTIN CREEK

REVISIONS

MONITORING PLAN LOCATIONS

SCALE 1" = 100' ADVERTISED DATE SEPT 2019 CONTRACT NO. AT62813

DESIGNED BY ______ COUNTY FREDERICK
DRAWN BY ______ LOGMILE ______
CHECKED BY ______
MDE/PRD ______

DRAWING NO. MP-03 OF 03 SHEET NO. 4 OF 4

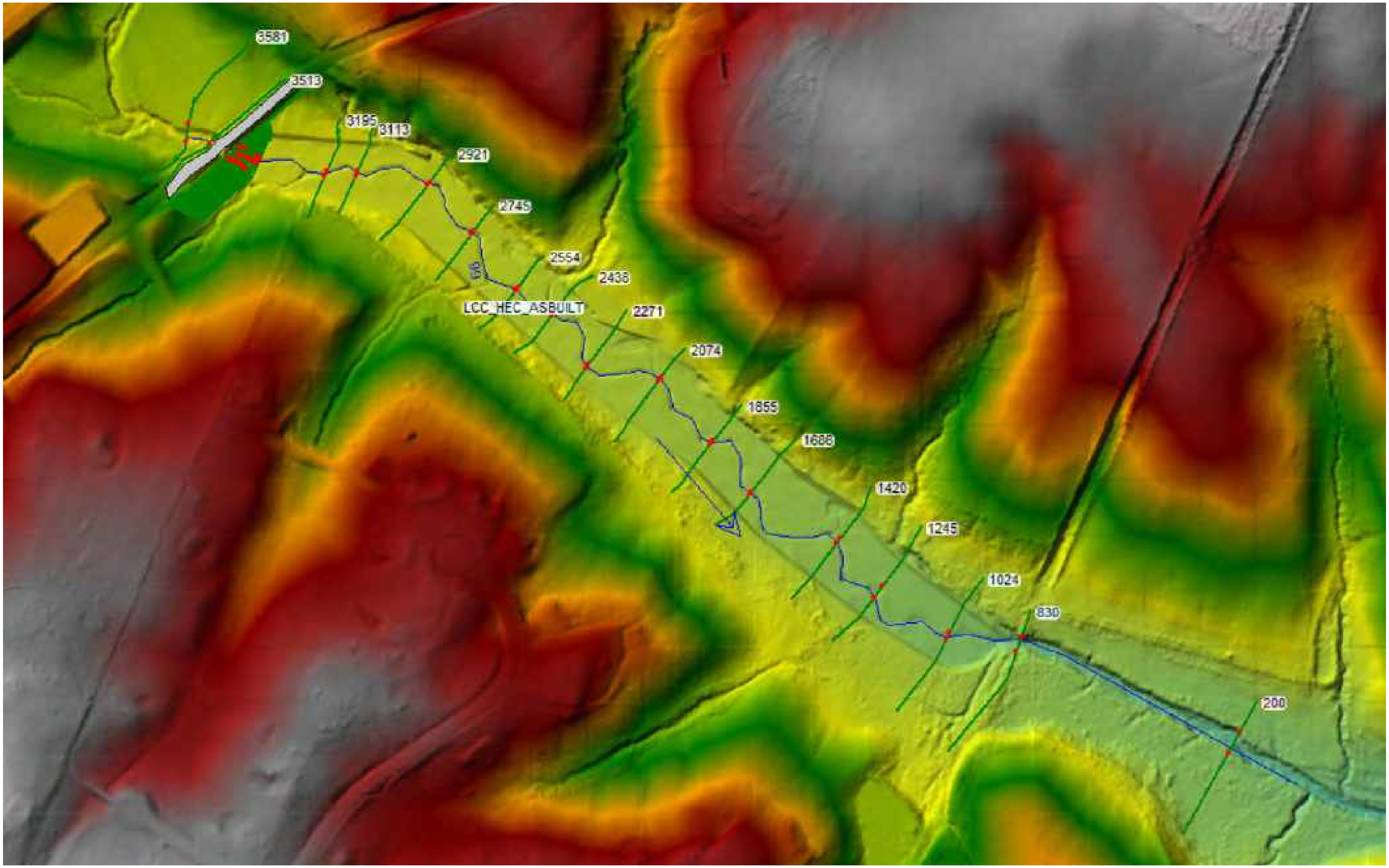
E 1135250
N 608500

BY: MoxleyK -

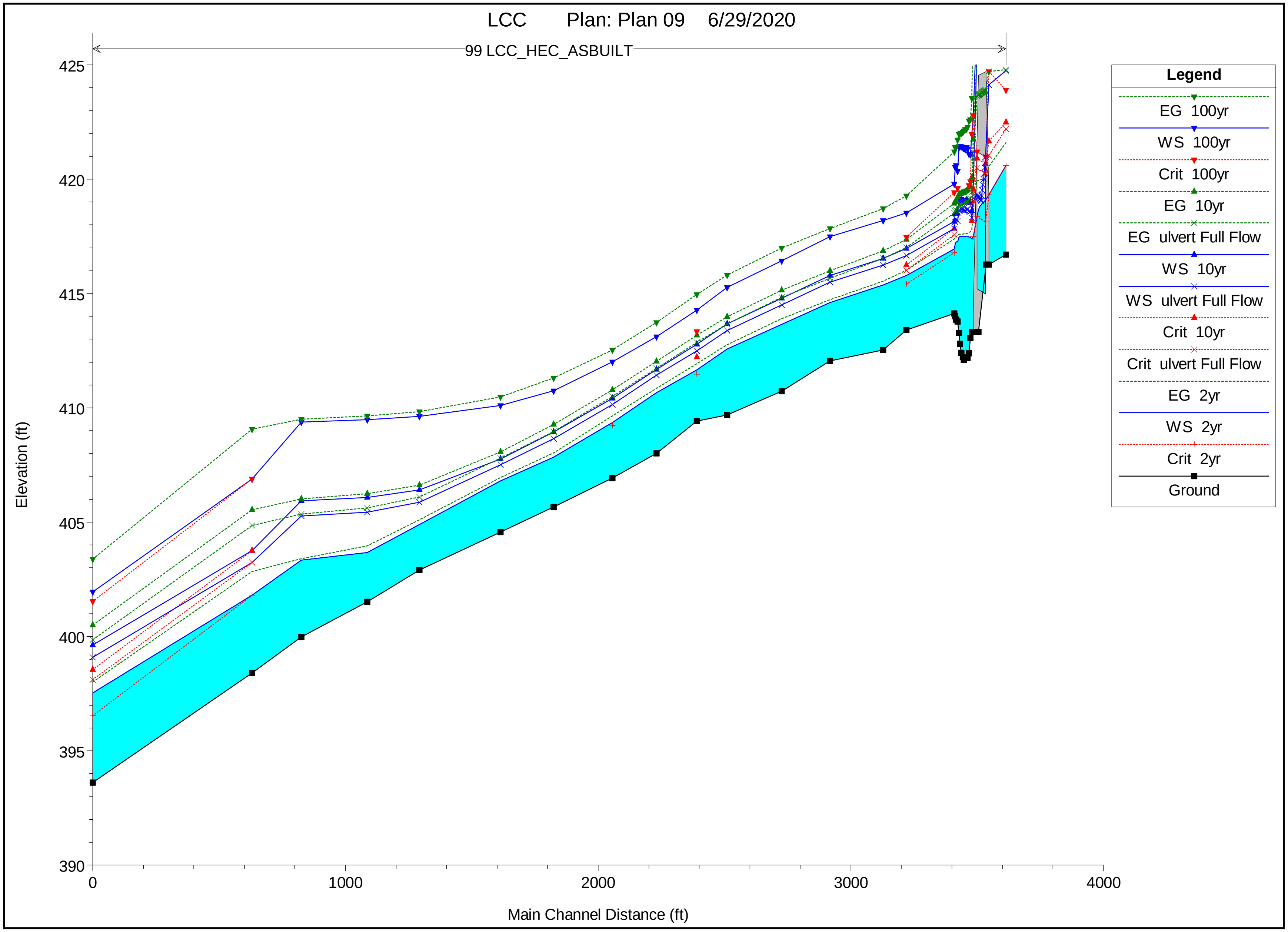
PLOTTED: Tuesday, September 17, 2019 AT 10:24 AM
FILE: T:\186681 - BCS 2014-09H Enviro Design\WAT\Task 04 MS4 Monitoring - Little Catoctin\CADD\Plans\pMP-0003_MD18001.dgn

Attachment B - Hydraulic Modeling Data

HECRAS GEOMETRIC DATA – ASBUILT

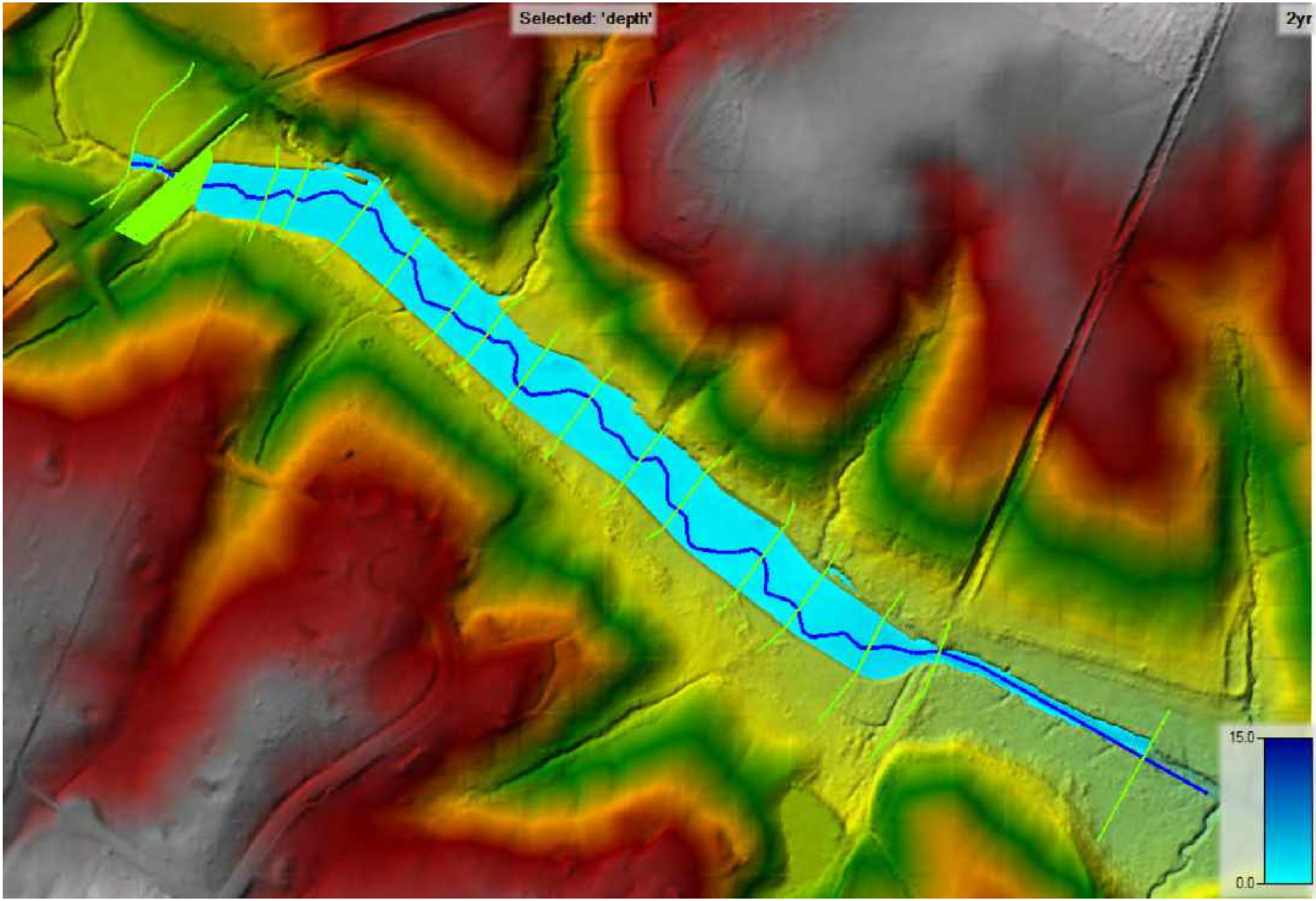


RAS MAPPER RESULTS

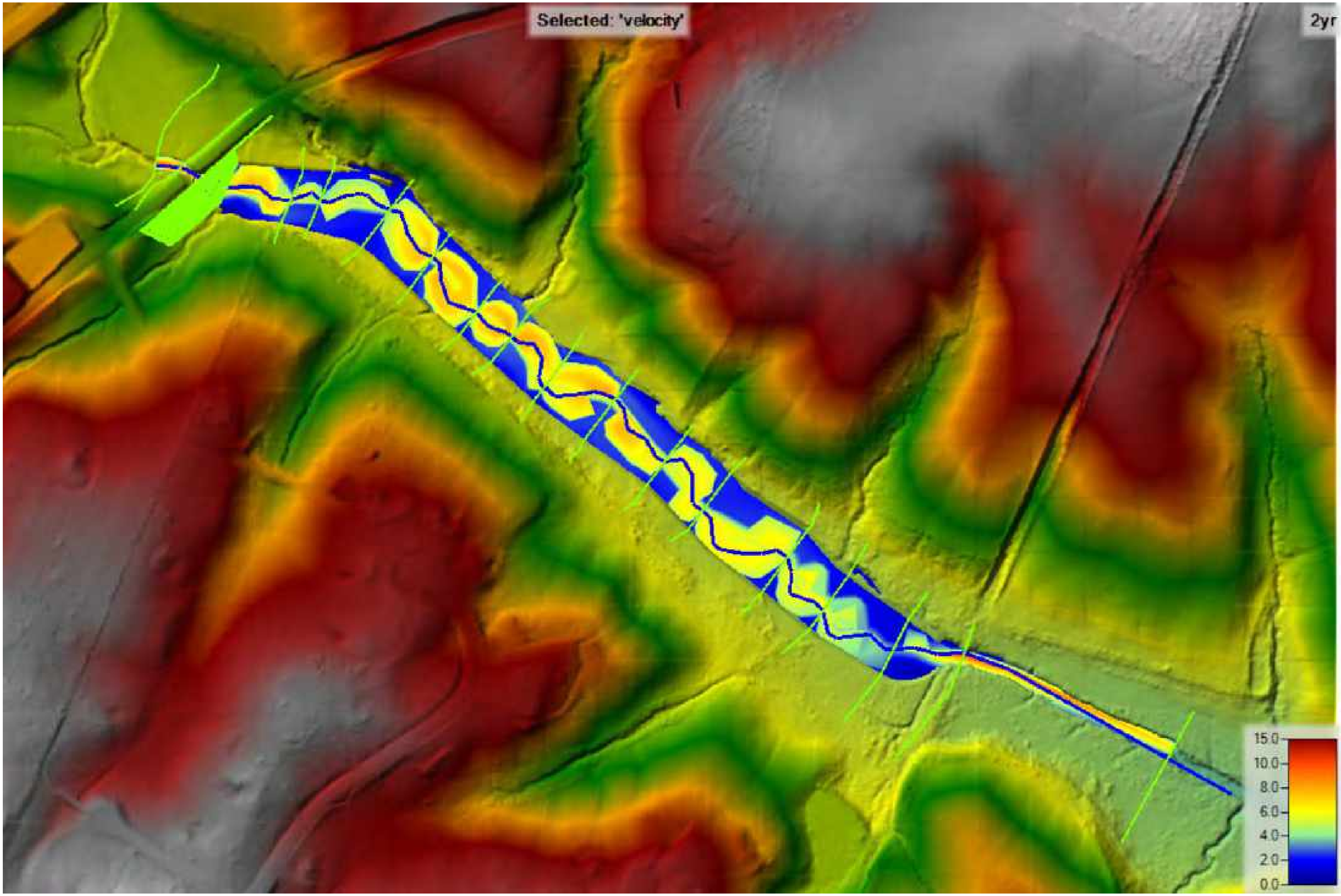


LCC Plan: Plan 09 6/29/2020
99 LCC_HEC_ASBUILT
Elevation (ft)
Main Channel Distance (ft)
425
420
415
410
405
400
395
390
0
1000
2000
3000
4000
Legend
EG 100yr
WS 100yr
Crit 100yr
EG 10yr
EG ulvert Full Flow
WS 10yr
WS ulvert Full Flow
Crit 10yr
Crit ulvert Full Flow
EG 2yr
WS 2yr
Crit 2yr
Ground

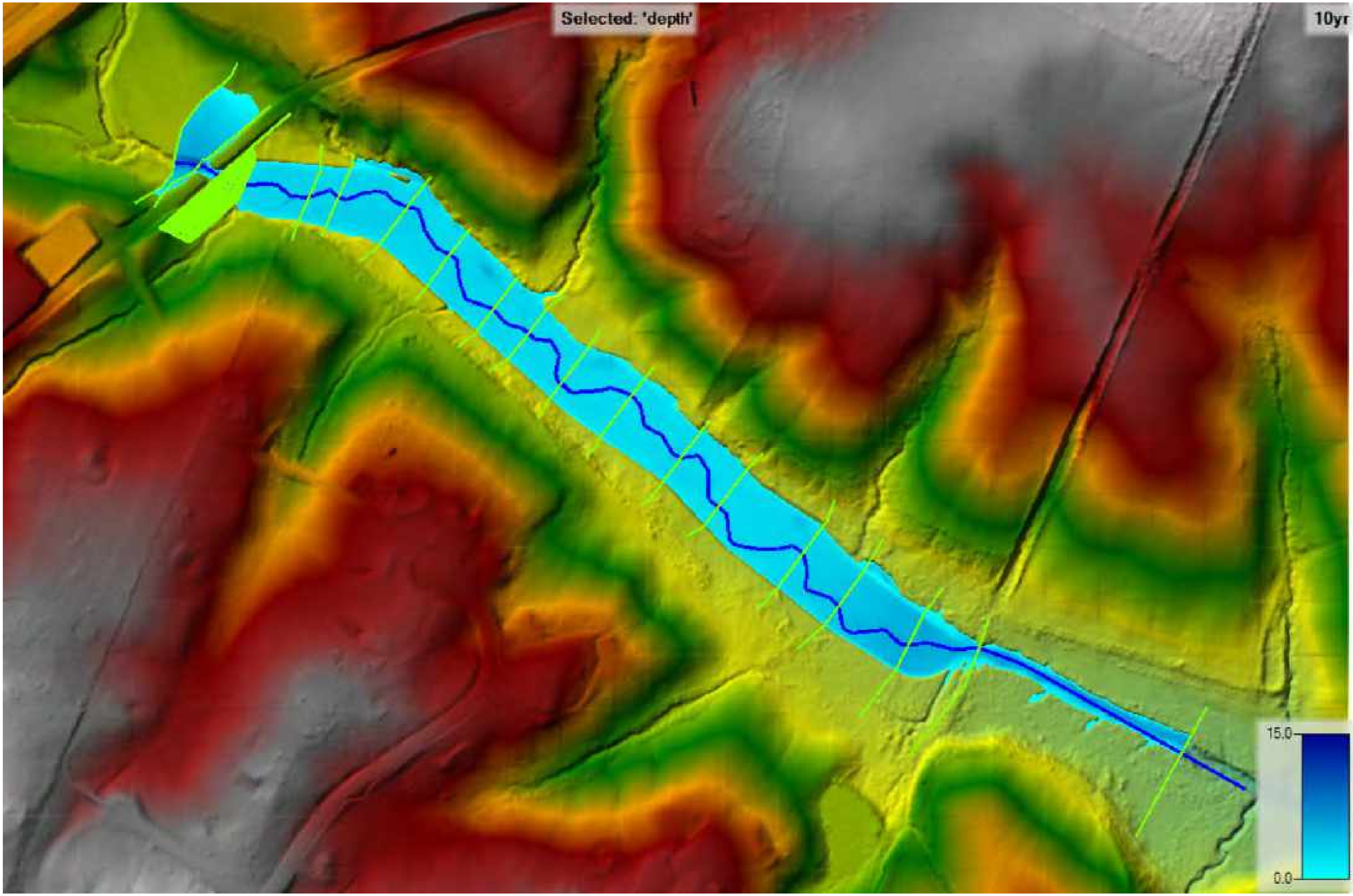
2-YR WATER DEPTH - ASBUILT



2-YR VELOCITY - ASBUILT



10-YR WATER DEPTH - ASBUILT



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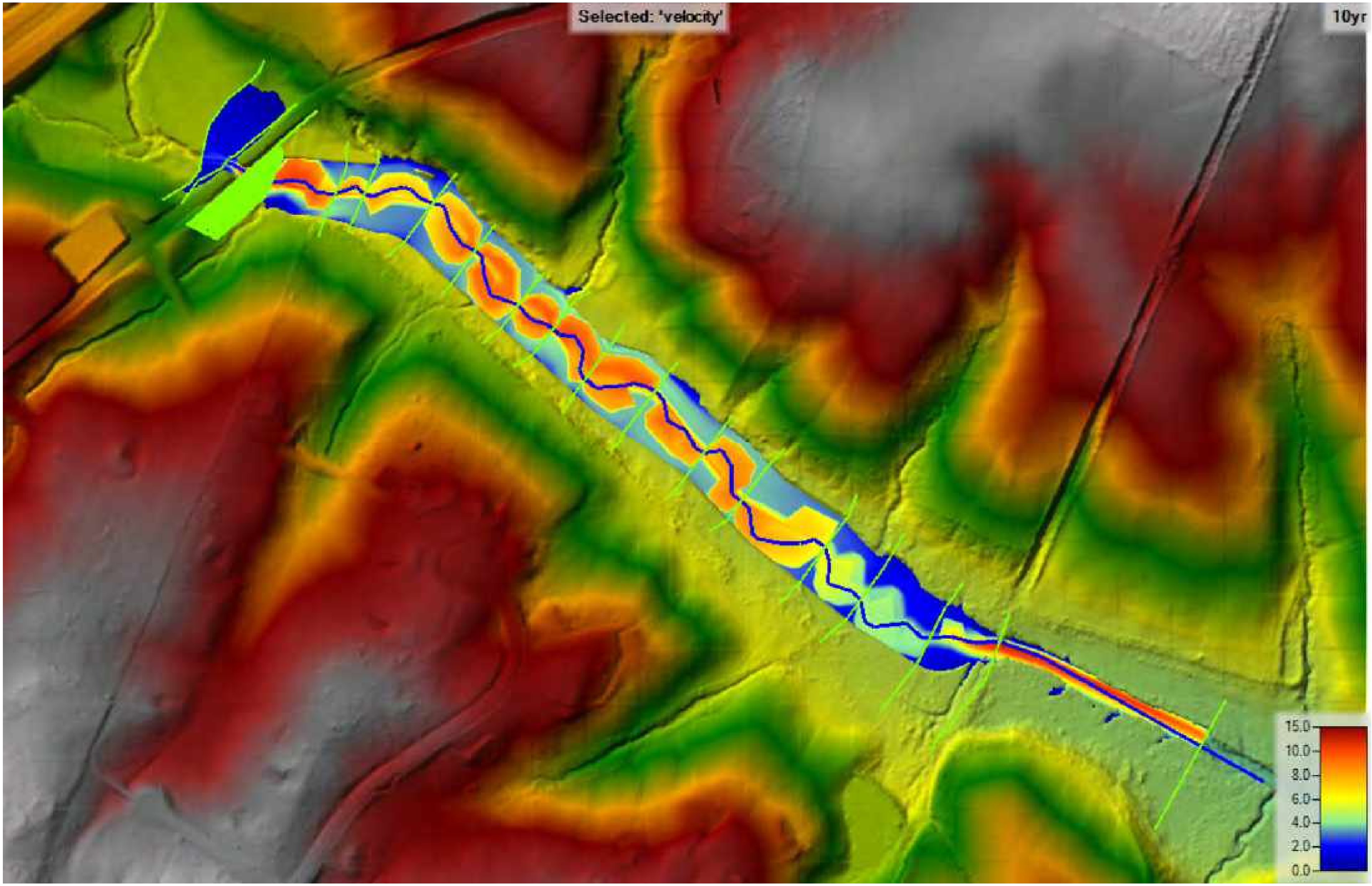
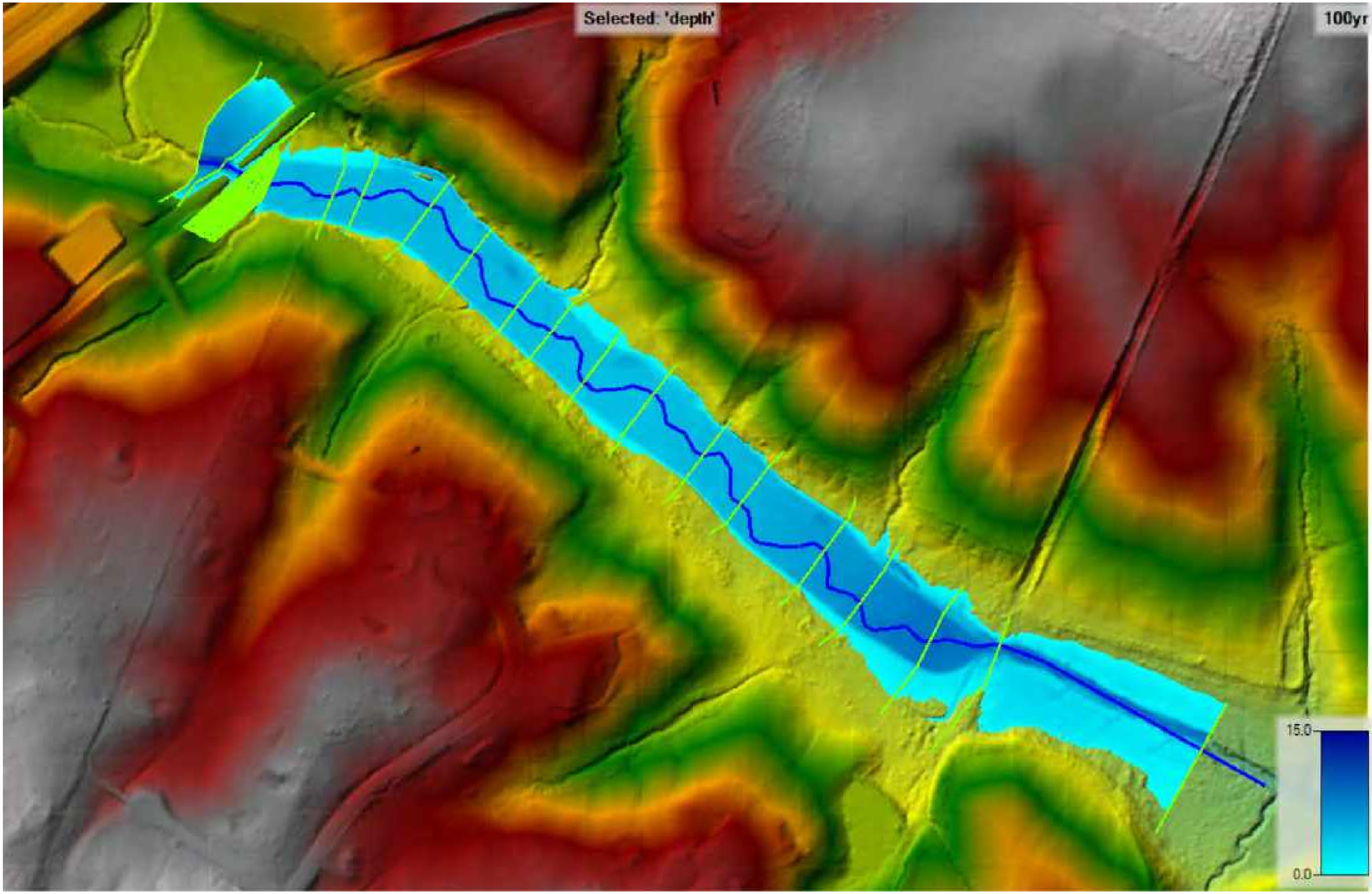
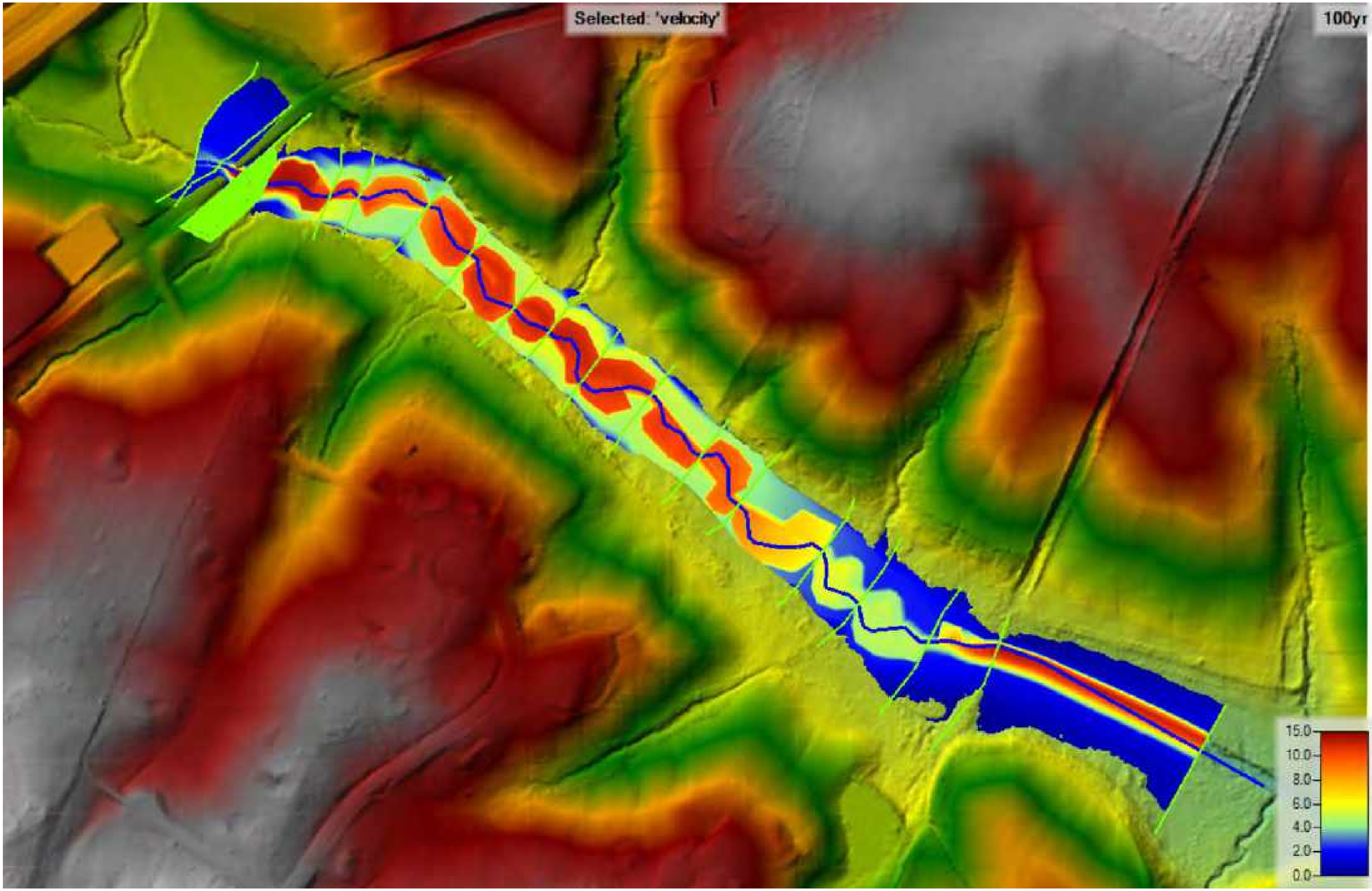


100-YR WATER DEPTH - ASBUILT



100-YR VELOCITY - ASBUILT



HECRAS SUMMARY TABLES

HEC-RAS Plan: ASBUILT River: 99 Reach: LCC_HEC_ASBUILT

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear LOB	Shear Chan	Shear ROB	Shear Total
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
LCC_HEC_ASBUILT	3581	BKFL	19.20	416.71	417.59	417.47	417.72	0.008523	2.90	6.62	12.90	0.71		0.27		0.27
LCC_HEC_ASBUILT	3581	2yr	635.00	416.71	420.59	420.59	421.59	0.010837	8.00	79.35	39.86	1.00		1.31		1.31
LCC_HEC_ASBUILT	3581	10yr	1683.00	416.71	425.86	422.49	425.89	0.000142	2.10	1356.74	365.68	0.14	0.03	0.06	0.03	0.03
LCC_HEC_ASBUILT	3581	100yr	3864.00	416.71	428.04	423.89	428.11	0.000189	2.92	2209.94	412.56	0.17	0.06	0.10	0.05	0.06
LCC_HEC_ASBUILT	3513	BKFL	19.20	416.26	416.73	416.73	416.88	0.019095	3.13	6.14	19.81	0.99		0.37		0.37
LCC_HEC_ASBUILT	3513	2yr	635.00	416.26	419.32	419.32	420.56	0.008634	9.19	75.25	33.69	0.96	0.81	1.52	0.55	1.28
LCC_HEC_ASBUILT	3513	10yr	1683.00	416.26	425.82	421.66	425.88	0.000170	2.85	1230.75	335.85	0.16	0.04	0.10	0.03	0.04
LCC_HEC_ASBUILT	3513	100yr	3864.00	416.26	428.00	424.71	428.09	0.000241	3.91	2030.39	400.42	0.20	0.07	0.17	0.07	0.08
LCC_HEC_ASBUILT	3508.68		Culvert													
LCC_HEC_ASBUILT	3450	BKFL	19.20	413.32	415.43	415.43	415.55	0.023992	2.77	7.18	33.78	1.04	0.32	0.33	0.28	0.32
LCC_HEC_ASBUILT	3450	2yr	635.00	413.32	417.49	417.49	418.63	0.010387	8.69	76.75	43.48	1.01	1.43	1.47	1.29	1.45
LCC_HEC_ASBUILT	3450	10yr	1683.00	413.32	419.57	419.57	421.74	0.008371	12.02	147.14	51.46	1.01	2.21	2.26	2.06	2.24
LCC_HEC_ASBUILT	3450	100yr	3864.00	413.32	422.78	422.78	426.57	0.007010	15.89	255.66	266.69	1.02	3.21	3.28	3.04	3.26
LCC_HEC_ASBUILT	3445	BKFL	19.20	413.32	415.33		415.33	0.000070	0.46	42.26	39.09	0.07	0.00	0.01	0.00	0.00
LCC_HEC_ASBUILT	3445	2yr	635.00	413.32	417.38		417.80	0.002431	5.30	132.06	48.16	0.52	0.18	0.48	0.19	0.40
LCC_HEC_ASBUILT	3445	10yr	1683.00	413.32	418.61	418.17	420.07	0.005591	9.96	194.30	53.58	0.83	0.63	1.54	0.63	1.22
LCC_HEC_ASBUILT	3445	100yr	3864.00	413.32	421.98	421.98	423.54	0.003282	11.11	560.95	233.66	0.70	0.28	1.59	0.34	0.49
LCC_HEC_ASBUILT	3440	BKFL	19.20	413.06	415.33		415.33	0.000019	0.28	67.65	44.73	0.04		0.00		0.00
LCC_HEC_ASBUILT	3440	2yr	635.00	413.06	417.47		417.69	0.001061	3.77	176.75	57.78	0.35	0.06	0.24	0.05	0.20
LCC_HEC_ASBUILT	3440	10yr	1683.00	413.06	418.97		419.67	0.002211	6.86	278.41	75.56	0.54	0.20	0.70	0.20	0.50
LCC_HEC_ASBUILT	3440	100yr	3864.00	413.06	421.07	419.89	422.61	0.003248	10.46	482.07	152.82	0.69	0.25	1.45	0.46	0.63
LCC_HEC_ASBUILT	3434	BKFL	19.20	412.39	415.33		415.33	0.000009	0.27	93.91	52.75	0.03	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3434	2yr	635.00	412.39	417.48		417.68	0.000942	4.13	229.06	71.75	0.34	0.15	0.26	0.09	0.18
LCC_HEC_ASBUILT	3434	10yr	1683.00	412.39	418.97		419.64	0.002257	7.70	345.25	83.95	0.55	0.48	0.83	0.33	0.56
LCC_HEC_ASBUILT	3434	100yr	3864.00	412.39	421.10	419.74	422.54	0.003577	11.83	574.67	160.70	0.73	0.60	1.78	0.61	0.78
LCC_HEC_ASBUILT	3429	BKFL	19.20	412.17	415.33		415.33	0.000006	0.23	115.57	61.46	0.02	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3429	2yr	635.00	412.17	417.51		417.65	0.000633	3.53	268.34	78.27	0.28	0.12	0.19	0.08	0.13
LCC_HEC_ASBUILT	3429	10yr	1683.00	412.17	419.07		419.53	0.001510	6.57	401.49	92.16	0.46	0.35	0.59	0.26	0.40
LCC_HEC_ASBUILT	3429	100yr	3864.00	412.17	421.34		422.28	0.002330	9.97	680.01	209.99	0.60	0.39	1.24	0.28	0.46
LCC_HEC_ASBUILT	3424	BKFL	19.20	412.21	415.33		415.33	0.000005	0.18	115.53	63.83	0.02	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3424	2yr	635.00	412.21	417.52		417.63	0.000455	2.84	279.24	84.03	0.24	0.06	0.13	0.06	0.09
LCC_HEC_ASBUILT	3424	10yr	1683.00	412.21	419.11		419.48	0.001048	5.27	424.50	98.01	0.38	0.18	0.39	0.19	0.28
LCC_HEC_ASBUILT	3424	100yr	3864.00	412.21	421.39		422.21	0.001619	8.11	722.74	224.87	0.49	0.19	0.83	0.22	0.32
LCC_HEC_ASBUILT	3419	BKFL	19.20	412.21	415.33		415.33	0.000006	0.23	121.94	66.71	0.02	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3419	2yr	635.00	412.21	417.49		417.62	0.000653	3.59	294.71	90.16	0.29	0.12	0.19	0.09	0.13
LCC_HEC_ASBUILT	3419	10yr	1683.00	412.21	419.03		419.46	0.001544	6.63	443.04	101.87	0.46	0.38	0.61	0.29	0.41
LCC_HEC_ASBUILT	3419	100yr	3864.00	412.21	421.31		422.18	0.002330	9.97	740.28	217.12	0.60	0.42	1.24	0.35	0.49
LCC_HEC_ASBUILT	3414	BKFL	19.20	412.09	415.33		415.33	0.000005	0.22	136.51	68.91	0.02	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3414	2yr	635.00	412.09	417.49		417.61	0.000584	3.51	319.56	94.84	0.28	0.11	0.18	0.09	0.12
LCC_HEC_ASBUILT	3414	10yr	1683.00	412.09	419.05		419.43	0.001402	6.50	476.24	106.43	0.45	0.36	0.57	0.30	0.39
LCC_HEC_ASBUILT	3414	100yr	3864.00	412.09	421.35		422.12	0.002140	9.80	796.11	250.25	0.58	0.40	1.18	0.26	0.42
LCC_HEC_ASBUILT	3409	BKFL	19.20	412.22	415.33		415.33	0.000005	0.20	135.92	70.73	0.02	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3409	2yr	635.00	412.22	417.50		417.60	0.000514	3.16	329.82	99.74	0.26	0.09	0.15	0.08	0.10
LCC_HEC_ASBUILT	3409	10yr	1683.00	412.22	419.07		419.39	0.001192	5.82	495.22	111.05	0.41	0.30	0.47	0.25	0.33
LCC_HEC_ASBUILT	3409	100yr	3864.00	412.22	421.40		422.06	0.001761	8.72	837.13	263.76	0.52	0.33	0.94	0.19	0.35
LCC_HEC_ASBUILT	3404	BKFL	19.20	412.40	415.33		415.33	0.000007	0.22	119.63	69.24	0.03	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3404	2yr	635.00	412.40	417.50		417.59	0.000536	3.07	320.65	103.31	0.26	0.09	0.15	0.07	0.10
LCC_HEC_ASBUILT	3404	10yr	1683.00	412.40	419.08		419.37	0.001140	5.50	492.70	113.95	0.40	0.28	0.42	0.22	0.30
LCC_HEC_ASBUILT	3404	100yr	3864.00	412.40	421.43		422.01	0.001628	8.19	847.01	266.83	0.50	0.31	0.84	0.16	0.32
LCC_HEC_ASBUILT	3399	BKFL	19.20	412.81	415.33		415.33	0.000010	0.24	105.73	74.06	0.03	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3399	2yr	635.00	412.81	417.50		417.59	0.000583	3.02	314.66	106.64	0.27	0.10	0.15	0.07	0.11
LCC_HEC_ASBUILT	3399	10yr	1683.00	412.81	419.08		419.36	0.001156	5.30	491.95	117.23	0.39	0.28	0.40	0.19	0.30
LCC_HEC_ASBUILT	3399	100yr	3864.00	412.81	421.44		421.99	0.001567	7.79	854.66	261.36	0.49	0.30	0.78	0.14	0.32
LCC_HEC_ASBUILT	3394	BKFL	19.20	413.28	415.33		415.33	0.000021	0.30	84.04	68.87	0.04	0.00	0.00	0.00	0.00
LCC_HEC_ASBUILT	3394	2yr	635.00	413.28	417.47		417.58	0.000828	3.40	295.18	109.76	0.31	0.12	0.19	0.10	0.14
LCC_HEC_ASBUILT	3394	10yr	1683.00	413.28	419.02		419.34	0.001526	5.84	473.99	120.35	0.45	0.35	0.50	0.27	0.37
LCC_HEC_ASBUILT	3394	100yr	3864.00	413.28	421.38		421.97	0.001884	8.30	836.55	256.36	0.53	0.36	0.89	0.21	0.38
LCC_HEC_ASBUILT	3389	BKFL	19.20	413.78	415.32		415.33	0.000105	0.59	56.65	61.55	0.09	0.00	0.01	0.01	0.01
LCC_HEC_ASBUILT	3389	2yr	635.00	413.78	417.26		417.53	0.002765	5.63	245.25	111.65	0.56	0.30	0.55	0.41	0.38
LCC_HEC_ASBUILT	3389	10yr	1683.00	413.78	418.50		419.21	0.005096	9.51	389.18	120.34	0.80	0.87	1.40	1.08	1.02
LCC_HEC_ASBUILT	3389	100yr	3864.00	413.78	420.35	419.60	421.72	0.006679	13.75	630.88	155.79	0.97	1.34	2.61	1.97	1.67
LCC_HEC_ASBUILT	3384	BKFL	19.20	413.85	415.32		415.32	0.000296	0.91	34.23	51.54	0.15	0.01	0.02	0.01	0.01
LCC_HEC_ASBUILT	3384	2yr	635.00	413.85	417.27		417.49	0.002782	5.48	225.15	114.94	0.55	0.29	0.53	0.34	0.34
LCC_HEC_ASBUILT	3384	10yr	1683.00	413.85	418.59		419.07	0.004024	8.38	383.32	123.91	0.71	0.70	1.09	0.77	0.77
LCC_HEC_ASBUILT	3384	100yr	3864.00	413.85	420.59		421.42	0.004523	11.42	661.70	171.32	0.80	0.92	1.79	1.20	1.08
LCC_HEC_ASBUILT	3379	BKFL	19.20	414.00	415.29		415.32	0.000864	1.35	18.19	41.34	0.25	0.01	0.05	0.01	0.02
LCC_HEC_ASBUILT	3379	2yr	635.00	414.00	417.18		417.45	0.003884	6.08	203.93	117.28	0.64	0.38	0.67	0.39	0.42
LCC_HEC_ASBUILT	3379	10yr	1683.00	414.00	418.48		419.03	0.005027	8.93	362.63	126.18	0.78	0.85	1.27	0.85	0.90
LCC_HEC_ASBUILT	3379	100yr	3864.00	414.00	420.53		421.39	0.005010	11.69	651.40	174.49	0.83	1.01	1.91	1.23	1.16
LCC_HEC_ASBUILT	3375	BKFL	19.20	414.12	415.22	414.92	415.30	0.003617	2.16	8.98	25.23	0.48	0.00	0.14	0.01	0.08
LCC_HEC_ASBUILT	3375	2yr	635.00	414.12	416.94	416.79	417.39	0.007888	7.70	170.63	118.76	0.89	0.70	1.14	0.64	0.73
LCC_HEC_ASBUILT	3375	10yr	1683.00	414.12	418.15	417.84	418.93	0.008942	10.79	310.22	127.36	1.01	1.47	1.95	1.31	1.46
LCC_HEC_ASBUILT	3375	100yr	3864.00	414.12	419.79	419.42	421.20	0.010029	14.74	509.15	143.67	1.14	2.51	3.21	2.33	2.51
LCC_HEC_ASBUILT	3195	BKFL	19.20	413.41	414.15	414.04	414.29	0.008583	2.95	6.78	21.67	0.72		0.28	0.02	0.17
LCC_HEC_ASBUILT	3195	2yr	635.00	413.41	415.79	415.41	416.01	0.005570	6.01	223.86	156.29	0.73	0.46	0.72	0.50	0.50
LCC_HEC_ASBUILT	3195	10yr	1683.00	413.41	416.97	416.24	417.36	0.005840	8.27	412.57	165.51	0.81	0.87	1.18	0.89	0.90
LCC_HEC_ASBUILT	3195	100yr	3864.00	413.41	418.53	417.47	419.27	0.006929	11.68	691.11	216.85	0.94	1.18	2.06	1.61	1.37
LCC_HEC_ASBUILT	3113	BKFL	19.20	412.54	413.81		413.88	0.002491	2.08	12.28	64.42	0.41		0.12	0.01	0.03
LCC_HEC_ASBUILT	3113	2yr	635.00	412.54	415.36		415.55	0.004737	5.53	247.74	172.49	0.67	0.37	0.61	0.44	0.42
LCC_HEC_ASBUILT	3113	10yr	1683.00	412.54	416.54		416.86	0.004982	7.61	456.91	187.16	0.74	0.68	1.00	0.79	0.76
LCC_HEC_ASBUILT	3113	100yr	3864.00	412.54	418.20		418.70	0.004729	9.72	810.03	228.98	0.77	0.89	1.42	1.16	1.04
LCC_HEC_ASBUILT	2921	BKFL	19.20	412.06	412.95	412.84	413.08	0.006376	2.93	10.41	85.55	0.64	0.03	0.25	0.02	0.05
LCC_HEC_ASBUILT	2921	2yr	635.00	412.06	414.61		414.73	0.003533	5.09	298.89	204.67	0.59	0.28	0.50	0.33	0.32
LCC_HEC_ASBUILT	2921	10yr	1683.00	412.06	415.79		416.00	0.003652	6.81	549.59	215.71	0.64	0.52	0.78	0.60	0.58
LCC_HEC_ASBUILT	2921	100yr	3864.00	412.06	417.49		417.84	0.003682	8.91	925.12	237.35	0.69	0.89	1.17	0.87	0.89
LCC_HEC_ASBUILT	2745	BKFL	19.20	410.72	411.76		411.91	0.005842	3.08	6.25	8.39	0.62	0.01	0.27		0.26
LCC_HEC_ASBUILT	2745	2yr	635.00	410.72	413.64		413.89	0.005988	7.11	234.93	180.04	0.77	0.39	0.94	0.51	0.49
LCC_HEC_ASBUILT	2745	10yr	1683.00	410.72	414.80		415.15	0.005834	8.92	445.59	185.17	0.81	0.78	1.32	0.90	0.87

HEC-RAS Plan: ASBUILT River: 99 Reach: LCC_HEC_ASBUILT (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear LOB	Shear Chan	Shear ROB	Shear Total
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
LCC_HEC_ASBUILT	2745	100yr	3864.00	410.72	416.42		416.99	0.005848	11.32	752.60	192.56	0.86	1.30	1.89	1.45	1.41
LCC_HEC_ASBUILT	2554	BKFL	19.20	409.69	411.05		411.12	0.002351	2.25	10.49	30.25	0.40	0.02	0.13	0.00	0.05
LCC_HEC_ASBUILT	2554	2yr	635.00	409.69	412.57		412.75	0.005095	6.19	245.66	176.45	0.69	0.44	0.74	0.40	0.44
LCC_HEC_ASBUILT	2554	10yr	1683.00	409.69	413.67		413.99	0.005536	8.24	443.50	182.14	0.76	0.84	1.15	0.78	0.83
LCC_HEC_ASBUILT	2554	100yr	3864.00	409.69	415.27		415.80	0.005730	10.69	742.19	196.52	0.83	1.39	1.72	1.23	1.34
LCC_HEC_ASBUILT	2438	BKFL	19.20	409.42	410.31	410.30	410.54	0.014096	3.85	5.34	16.79	0.92	0.03	0.47	0.05	0.28
LCC_HEC_ASBUILT	2438	2yr	635.00	409.42	411.67	411.47	411.93	0.009704	7.36	200.57	167.37	0.94	0.69	1.12	0.71	0.72
LCC_HEC_ASBUILT	2438	10yr	1683.00	409.42	412.77	412.21	413.18	0.008313	9.25	388.55	173.05	0.94	1.13	1.52	1.14	1.16
LCC_HEC_ASBUILT	2438	100yr	3864.00	409.42	414.26	413.34	414.96	0.008513	12.25	661.49	197.35	1.02	1.67	2.33	1.81	1.77
LCC_HEC_ASBUILT	2271	BKFL	19.20	408.01	409.07	408.90	409.18	0.005460	2.74	8.25	36.01	0.59	0.02	0.22	0.01	0.08
LCC_HEC_ASBUILT	2271	2yr	635.00	408.01	410.67		410.85	0.004939	5.90	246.24	172.58	0.69	0.44	0.68	0.38	0.44
LCC_HEC_ASBUILT	2271	10yr	1683.00	408.01	411.67		412.03	0.006398	8.57	420.69	176.04	0.84	0.95	1.27	0.85	0.94
LCC_HEC_ASBUILT	2271	100yr	3864.00	408.01	413.12		413.73	0.007018	11.46	713.52	231.91	0.93	1.28	2.01	1.39	1.33
LCC_HEC_ASBUILT	2074	BKFL	19.20	406.92	407.90	407.72	408.05	0.007588	3.19	6.02	9.15	0.69		0.30		0.30
LCC_HEC_ASBUILT	2074	2yr	635.00	406.92	409.36	409.24	409.66	0.009329	7.68	209.45	193.20	0.93	0.59	1.18	0.60	0.63
LCC_HEC_ASBUILT	2074	10yr	1683.00	406.92	410.41		410.79	0.007622	9.10	420.66	207.51	0.90	0.89	1.45	0.96	0.96
LCC_HEC_ASBUILT	2074	100yr	3864.00	406.92	412.02		412.54	0.006120	10.72	768.82	236.91	0.87	1.20	1.76	1.21	1.23
LCC_HEC_ASBUILT	1855	BKFL	19.20	405.67	406.45	406.37	406.52	0.005587	2.28	14.46	100.03	0.58	0.03	0.17	0.03	0.05
LCC_HEC_ASBUILT	1855	2yr	635.00	405.67	407.84		408.02	0.005722	5.66	234.66	171.77	0.73	0.48	0.66	0.46	0.49
LCC_HEC_ASBUILT	1855	10yr	1683.00	405.67	408.93		409.28	0.006003	7.87	425.27	176.67	0.81	0.89	1.10	0.86	0.90
LCC_HEC_ASBUILT	1855	100yr	3864.00	405.67	410.75		411.30	0.005073	9.95	756.80	194.04	0.80	1.18	1.50	1.23	1.22
LCC_HEC_ASBUILT	1686	BKFL	19.20	404.56	405.48	405.26	405.57	0.003886	2.58	13.16	91.81	0.52	0.02	0.19	0.04	0.03
LCC_HEC_ASBUILT	1686	2yr	635.00	404.56	406.80		406.96	0.005704	6.07	252.00	187.08	0.74	0.47	0.74	0.44	0.48
LCC_HEC_ASBUILT	1686	10yr	1683.00	404.56	407.75		408.08	0.007089	8.68	431.73	190.57	0.88	1.00	1.33	0.94	0.99
LCC_HEC_ASBUILT	1686	100yr	3864.00	404.56	410.11		410.47	0.003576	9.03	893.14	202.30	0.69	0.99	1.19	0.90	0.97
LCC_HEC_ASBUILT	1420	BKFL	19.20	402.90	403.48	403.47	403.58	0.011901	2.82	10.48	44.07	0.81	0.13	0.28		0.18
LCC_HEC_ASBUILT	1420	2yr	635.00	402.90	404.90		405.10	0.006633	5.71	237.09	198.66	0.77	0.53	0.70	0.43	0.49
LCC_HEC_ASBUILT	1420	10yr	1683.00	402.90	406.41		406.62	0.003351	6.19	542.09	207.44	0.61	0.55	0.66	0.52	0.54
LCC_HEC_ASBUILT	1420	100yr	3864.00	402.90	409.62		409.82	0.001250	6.01	1240.67	227.25	0.42	0.41	0.50	0.42	0.42
LCC_HEC_ASBUILT	1245	BKFL	19.20	401.52	402.06		402.11	0.004826	1.80	10.66	28.07	0.52		0.11		0.11
LCC_HEC_ASBUILT	1245	2yr	635.00	401.52	403.67		403.96	0.005385	5.39	208.18	174.09	0.71	0.34	0.61	0.35	0.40
LCC_HEC_ASBUILT	1245	10yr	1683.00	401.52	406.08		406.25	0.001228	4.53	648.34	200.75	0.39	0.22	0.32	0.25	0.25
LCC_HEC_ASBUILT	1245	100yr	3864.00	401.52	409.47		409.66	0.000653	4.89	1426.79	278.36	0.31	0.20	0.31	0.18	0.21
LCC_HEC_ASBUILT	1024	BKFL	19.20	399.97	400.84	400.64	400.90	0.004481	2.07	10.20	38.39	0.52	0.01	0.14	0.01	0.07
LCC_HEC_ASBUILT	1024	2yr	635.00	399.97	403.34		403.41	0.001006	3.26	385.19	163.03	0.33	0.14	0.19	0.15	0.15
LCC_HEC_ASBUILT	1024	10yr	1683.00	399.97	405.93		406.02	0.000628	3.90	836.98	190.12	0.29	0.16	0.22	0.18	0.17
LCC_HEC_ASBUILT	1024	100yr	3864.00	399.97	409.38		409.50	0.000484	4.72	1705.47	358.00	0.28	0.16	0.27	0.12	0.14
LCC_HEC_ASBUILT	830	BKFL	19.20	398.41	399.10	399.10	399.33	0.017498	3.84	5.00	11.00	1.00		0.49		0.49
LCC_HEC_ASBUILT	830	2yr	635.00	398.41	401.80	401.80	402.85	0.011087	8.23	77.13	37.50	1.01		1.37		1.37
LCC_HEC_ASBUILT	830	10yr	1683.00	398.41	403.76	403.76	405.55	0.008909	10.74	158.89	51.71	0.99	0.06	1.94	0.15	1.63
LCC_HEC_ASBUILT	830	100yr	3864.00	398.41	406.89	406.89	409.08	0.005145	12.32	458.99	155.63	0.83	0.44	2.07	0.48	0.93
LCC_HEC_ASBUILT	200	BKFL	19.20	393.61	394.22	394.04	394.28	0.004003	1.84	10.45	23.12	0.48		0.11		0.11
LCC_HEC_ASBUILT	200	2yr	635.00	393.61	397.52	396.54	398.00	0.003997	5.54	114.56	46.31	0.62		0.59		0.59
LCC_HEC_ASBUILT	200	10yr	1683.00	393.61	399.62	398.55	400.49	0.004004	7.50	224.53	57.18	0.67		0.92		0.92
LCC_HEC_ASBUILT	200	100yr	3864.00	393.61	401.95	401.54	403.37	0.004001	9.87	596.36	340.91	0.71	0.22	1.40	0.19	0.43

HECRAS OUTPUT

HEC-RAS Version 4.1.0 Jan 2010
U.S. Army Corps of Engineers
Hydrologic Engineering Center
609 Second Street
Davis, California

```
X     X  XXXXXX    XXXX        XXXX       XX      XXXX
X     X  X        X    X       X   X     X  X    X
X     X  X        X            X   X    X    X   X
XXXXXXX  XXXX     X      XXX   XXXX     XXXXXX    XXXX
X     X  X        X            X  X     X    X       X
X     X  X        X    X       X   X    X    X       X
X     X  XXXXXX    XXXX        X    X   X    X   XXXXX
```

PROJECT DATA
Project Title: LCC
Project File : LCC.prj
Run Date and Time: 10/7/2016 4:49:47 PM

Project in English units

PLAN DATA

Plan Title: Proposed
Plan File : q:\SMD\120079_017_Little_Catoctin_Cree\Working Data\Final Design\HECRAS\LCC.p02

```
            Geometry Title: Proposed
            Geometry File : q:\SMD\120079_017_Little_Catoctin_Cree\Working Data\Final
Design\HECRAS\LCC.g04

            Flow Title    : LCCpr
            Flow File     : q:\SMD\120079_017_Little_Catoctin_Cree\Working Data\Final
Design\HECRAS\LCC.f03

Plan Summary Information:
Number of:  Cross Sections =   33    Multiple Openings  =    0
            Culverts       =    1    Inline Structures  =    0
            Bridges        =    0    Lateral Structures =    0

Computational Information
    Water surface calculation tolerance  =  0.01
```

Critical depth calculation tolerance = 0.01
Maximum number of iterations = 20
Maximum difference tolerance = 0.3
Flow tolerance factor = 0.001

Computation Options
Critical depth computed only where necessary
Conveyance Calculation Method: At breaks in n values only
Friction Slope Method: Average Conveyance
Computational Flow Regime: Subcritical Flow

FLOW DATA

Flow Title: LCCpr
Flow File : q:\SMD\120079_017_Little_Catoctin_Cree\Working Data\Final Design\HECRAS\LCC.f03

Flow Data (cfs)

River	Reach	RS	BKFL	2yr	10yr	100yr	ulvert Full Flow
99	LCC_HEC_PR	83952.77	19.2	635	1683	3864	1375

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
99	LCC_HEC_PR	BKFL		Normal S = 0.004
99	LCC_HEC_PR	2yr		Normal S = 0.004
99	LCC_HEC_PR	10yr		Normal S = 0.004
99	LCC_HEC_PR	100yr		Normal S = 0.004

GEOMETRY DATA

Geometry Title: Proposed
Geometry File : q:\SMD\120079_017_Little_Catoctin_Cree\Working Data\Final Design\HECRAS\LCC.g04

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83952.77

INPUT
Description: STA. 83952.77
Station Elevation Data num= 16

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	432	40	428	71	426	114	424	187	422
300	420	315	420	335	418	337	417.5	339	418
359	420	367	420	408	422	429	425	457	428
501	434								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	315	.03	359	.04

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
315	359	132	68	44	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	235.82	424.71	F
399.86	501	424.71	F

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83884.32

INPUT
Description: STA. 83884.32
Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429	44.7	426	118.6	423	194.5	421	226.9	420
241.6	418	248.2	415	252.2	414.6	257	414.9	260.4	414.8
263.1	415	266.9	416	276.9	420	279.7	421	284.5	422
357.4	423	368.5	424	403.1	428	429.1	430		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	248.2	.03	263.1	.04

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
248.2	263.1	53	63	57	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	240.9	424.71	F
277.9	429.1	424.71	F

CULVERT

RIVER: 99
REACH: LCC_HEC_PR RS: 83880

INPUT
Description:
Distance from Upstream XS = 11
Deck/Roadway Width = 30.67
Weir Coefficient = 2.6
Upstream Deck/Roadway Coordinates
num= 12

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	430.5		29.3	430		102.3	427	
156.3	426		242.3	425		242.4	425	
257	424.71		271.6	425.13		271.7	425.13	
288.3	426		333.3	427		430.3	430	

Upstream Bridge Cross Section Data
Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429	44.7	426	118.6	423	194.5	421	226.9	420
241.6	418	248.2	415	252.2	414.6	257	414.9	260.4	414.8
263.1	415	266.9	416	276.9	420	279.7	421	284.5	422
357.4	423	368.5	424	403.1	428	429.1	430		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	248.2	.03	263.1	.04

Bank Sta: Left	Right	Coeff Contr.	Expan.
248.2	263.1	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	240.9	424.71	F
277.9	429.1	424.71	F

Downstream Deck/Roadway Coordinates

num= 12

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
7	431		25	430		102	427	
164	426		251	424.99		251.1	424.99	
265.7	424.54		280.2	424.96		280.3	424.96	
310	426		368	427		459	430	

Downstream Bridge Cross Section Data

Station Elevation Data num= 94

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.84	12.29	428.74	26.67	426.63	27.84	426.5	53.24	423.74
63.72	422.79	66.86	422.67	109.13	422.11	110.46	422.21	135.5	421.33
157.46	421.58	158.95	421.6	159.55	421.58	160.34	421.55	162.04	421.65
163.16	421.64	166.16	421.6	198.73	421.66	200.65	421.57	203.98	421.43
214.93	421	223.02	420.08	223.72	420	224.57	419.9	225.38	419.8
226.76	419.62	228.2	419.45	228.66	419.4	230.43	419.17	230.78	419.13
231.71	419	233.55	418.76	234.71	418.57	235.89	418.41	237.21	418.16
238.09	418	241.53	417.2	241.92	417	243.72	416.41	244.44	416
245.89	415.55	246.58	415.25	247.41	414.89	247.64	414.4	249.11	414.23
249.52	414	252.41	413.26	253.42	413	254.08	413	260.47	413
265.38	413	266.63	413	269.79	413	270.28	413	270.92	413
271.64	413	272.31	413	273.33	413	273.93	413	275.26	413.43
277.02	414	277.19	414.4	279.85	415.2	281.35	415.82	282.7	416.58
283.6	417	284.28	417.4	284.68	417.6	285.41	418	285.92	418.29
286.8	418.71	287.38	419	288.97	419.64	289.39	419.81	289.81	420
290.62	420.39	291.92	421	292.69	421.06	320.14	422.27	321.92	422.35
323.41	422.42	324.66	422.47	325.73	422.52	326.66	422.57	339.88	423.01
350.95	423.51	390.06	424.97	398.19	426.34	410.04	428.21	420.28	430.1
439.32	431.56	448.4	434.43	474.96	435.24	484.79	435.74		

Manning's n Values num= 5

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	214.93	.06	247.64	.03	277.19	.06	292.69	.04

Bank Sta: Left	Right	Coeff Contr.	Expan.
247.64	277.19	.3	.5

Ineffective Flow num= 3

Sta L	Sta R	Elev	Permanent
0	247.06	424.71	F
247.06	279.3	415.21	T
280.62	450	424.71	F

Upstream Embankment side slope = 2 horiz. to 1.0 vertical
Downstream Embankment side slope = 2 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow = .98
Elevation at which weir flow begins = 424.71
Energy head used in spillway design =
Spillway height used in design =
Weir crest shape = Broad Crested

```
Number of Culverts =  1

Culvert Name     Shape      Rise    Span
Culvert #1           Box       6      20
FHWA Chart # 8 - flared wingwalls
FHWA Scale # 1 - Wingwall flared 30 to 75 deg.
Solution Criteria = Highest U.S. EG
Culvert Upstrm Dist  Length    Top n  Bottom n  Depth Blocked  Entrance Loss Coef
Exit Loss Coef
                 12      34     .013     .017        0                  .4
      1
Upstream   Elevation =  414.98
           Centerline Station =  257
Downstream Elevation =  415.21
           Centerline Station =  265

CULVERT OUTPUT  Profile #BKFL  Culv Group:  Culvert #1

  Q Culv Group (cfs)         19.20    Culv Full Len (ft)
  # Barrels                      1    Culv Vel US (ft/s)          1.37
  Q Barrel (cfs)             19.20    Culv Vel DS (ft/s)          2.92
  E.G. US. (ft)             415.72    Culv Inv El Up (ft)       414.98
  W.S. US. (ft)             415.69    Culv Inv El Dn (ft)       415.21
  E.G. DS (ft)              415.59    Culv Frctn Ls (ft)          0.04
  W.S. DS (ft)              415.54    Culv Exit Loss (ft)         0.08
  Delta EG (ft)               0.13    Culv Entr Loss (ft)         0.01
  Delta WS (ft)               0.15    Q Weir (cfs)
  E.G. IC (ft)              415.47    Weir Sta Lft (ft)
  E.G. OC (ft)              415.72    Weir Sta Rgt (ft)
  Culvert Control           Outlet    Weir Submerg
  Culv WS Inlet (ft)        415.68    Weir Max Depth (ft)
  Culv WS Outlet (ft)       415.54    Weir Avg Depth (ft)
  Culv Nml Depth (ft)                 Weir Flow Area (sq ft)
  Culv Crt Depth (ft)         0.31    Min El Weir Flow (ft)     424.72


CULVERT OUTPUT  Profile #2yr  Culv Group:  Culvert #1

  Q Culv Group (cfs)        635.00    Culv Full Len (ft)
  # Barrels                      1    Culv Vel US (ft/s)          7.73
  Q Barrel (cfs)            635.00    Culv Vel DS (ft/s)          9.79
  E.G. US. (ft)             420.39    Culv Inv El Up (ft)       414.98
  W.S. US. (ft)             419.95    Culv Inv El Dn (ft)       415.21
  E.G. DS (ft)              419.03    Culv Frctn Ls (ft)          0.07
  W.S. DS (ft)              418.45    Culv Exit Loss (ft)         0.91
  Delta EG (ft)               1.36    Culv Entr Loss (ft)         0.37
  Delta WS (ft)               1.49    Q Weir (cfs)
  E.G. IC (ft)              420.06    Weir Sta Lft (ft)
```

E.G. OC (ft)	420.39	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	419.09	Weir Max Depth (ft)	
Culv WS Outlet (ft)	418.45	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	3.15	Min El Weir Flow (ft)	424.72

CULVERT OUTPUT Profile #10yr Culv Group: Culvert #1

Q Culv Group (cfs)	1540.86	Culv Full Len (ft)	
# Barrels	1	Culv Vel US (ft/s)	12.84
Q Barrel (cfs)	1540.86	Culv Vel DS (ft/s)	18.14
E.G. US. (ft)	425.88	Culv Inv El Up (ft)	414.98
W.S. US. (ft)	425.83	Culv Inv El Dn (ft)	415.21
E.G. DS (ft)	421.82	Culv Frctn Ls (ft)	0.29
W.S. DS (ft)	419.81	Culv Exit Loss (ft)	2.75
Delta EG (ft)	4.07	Culv Entr Loss (ft)	1.02
Delta WS (ft)	6.02	Q Weir (cfs)	142.14
E.G. IC (ft)	425.88	Weir Sta Lft (ft)	166.43
E.G. OC (ft)	424.95	Weir Sta Rgt (ft)	286.05
Culvert Control	Inlet	Weir Submerg	0.00
Culv WS Inlet (ft)	420.98	Weir Max Depth (ft)	1.17
Culv WS Outlet (ft)	419.46	Weir Avg Depth (ft)	0.57
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	68.08
Culv Crt Depth (ft)	5.69	Min El Weir Flow (ft)	424.72

Warning: Since the culvert has supercritical flow, the program should be run in mixed flow in order to
check if the cross section downstream of the culvert has supercritical flow.
Note: The flow in the culvert is entirely supercritical.

CULVERT OUTPUT Profile #100yr Culv Group: Culvert #1

Q Culv Group (cfs)	1688.07	Culv Full Len (ft)	34.00
# Barrels	1	Culv Vel US (ft/s)	14.07
Q Barrel (cfs)	1688.07	Culv Vel DS (ft/s)	14.07
E.G. US. (ft)	428.12	Culv Inv El Up (ft)	414.98
W.S. US. (ft)	428.04	Culv Inv El Dn (ft)	415.21
E.G. DS (ft)	426.68	Culv Frctn Ls (ft)	0.21
W.S. DS (ft)	422.86	Culv Exit Loss (ft)	0.00
Delta EG (ft)	1.44	Culv Entr Loss (ft)	1.23
Delta WS (ft)	5.19	Q Weir (cfs)	2175.93
E.G. IC (ft)	428.02	Weir Sta Lft (ft)	74.93
E.G. OC (ft)	428.12	Weir Sta Rgt (ft)	369.68
Culvert Control	Outlet	Weir Submerg	0.00
Culv WS Inlet (ft)	420.98	Weir Max Depth (ft)	3.42

Culv WS Outlet (ft)	421.21	Weir Avg Depth (ft)	1.90
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	560.13
Culv Crt Depth (ft)	6.00	Min El Weir Flow (ft)	424.72

Note: Culvert critical depth exceeds the height of the culvert.

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83821.78

INPUT
Description: STA. 83821.78
Station Elevation Data num= 94

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.84	12.29	428.74	26.67	426.63	27.84	426.5	53.24	423.74
63.72	422.79	66.86	422.67	109.13	422.11	110.46	422.21	135.5	421.33
157.46	421.58	158.95	421.6	159.55	421.58	160.34	421.55	162.04	421.65
163.16	421.64	166.16	421.6	198.73	421.66	200.65	421.57	203.98	421.43
214.93	421	223.02	420.08	223.72	420	224.57	419.9	225.38	419.8
226.76	419.62	228.2	419.45	228.66	419.4	230.43	419.17	230.78	419.13
231.71	419	233.55	418.76	234.71	418.57	235.89	418.41	237.21	418.16
238.09	418	241.53	417.2	241.92	417	243.72	416.41	244.44	416
245.89	415.55	246.58	415.25	247.41	414.89	247.64	414.4	249.11	414.23
249.52	414	252.41	413.26	253.42	413	254.08	413	260.47	413
265.38	413	266.63	413	269.79	413	270.28	413	270.92	413
271.64	413	272.31	413	273.33	413	273.93	413	275.26	413.43
277.02	414	277.19	414.4	279.85	415.2	281.35	415.82	282.7	416.58
283.6	417	284.28	417.4	284.68	417.6	285.41	418	285.92	418.29
286.8	418.71	287.38	419	288.97	419.64	289.39	419.81	289.81	420
290.62	420.39	291.92	421	292.69	421.06	320.14	422.27	321.92	422.35
323.41	422.42	324.66	422.47	325.73	422.52	326.66	422.57	339.88	423.01
350.95	423.51	390.06	424.97	398.19	426.34	410.04	428.21	420.28	430.1
439.32	431.56	448.4	434.43	474.96	435.24	484.79	435.74		

Manning's n Values num= 5

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	214.93	.06	247.64	.03	277.19	.06	292.69	.04

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.64	277.19	1.22	5	5.74	.3	.5

Ineffective Flow num= 3

Sta L	Sta R	Elev	Permanent
0	247.06	424.71	F
247.06	279.3	415.21	T
280.62	450	424.71	F

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83816.6*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.79	8.1	429.07	12.29	428.68	21.28	427.36	25.18	426.8
26.66	426.58	27.83	426.45	53.22	423.7	58.95	423.17	60.73	423.02
63.7	422.76	66.83	422.64	83.03	422.4	106.36	422.1	107.02	422.1
109.09	422.07	110.42	422.16	120.74	421.8	135.45	421.33	137.62	421.35
157.4	421.49	158.89	421.5	159.49	421.48	160.28	421.45	161.98	421.54
162.24	421.54	163.1	421.53	165.54	421.49	166.1	421.48	171.18	421.48
175.62	421.46	176.36	421.44	176.78	421.43	178.34	421.4	179.56	421.38
180.59	421.36	182.76	421.32	184.78	421.28	185.95	421.26	186.69	421.23
187.37	421.21	198.65	421.23	200.57	421.15	203.9	421.02	214.85	420.61
222.94	419.76	223.64	419.68	224.48	419.59	225.29	419.5	226.67	419.33
228.11	419.17	228.57	419.12	230.34	418.91	230.69	418.87	231.62	418.75
233.46	418.53	234.62	418.35	235.8	418.2	237.12	417.97	238	417.82
241.44	417.07	241.83	416.89	243.63	416.33	244.35	415.95	245.8	415.53
246.49	415.25	247.32	414.92	247.55	414.46	248.99	414.27	249.39	414.05
250.23	413.83	252.22	413.34	253.21	413.09	253.82	413.09	259.78	413.09
264.36	413.09	265.52	413.09	268.47	413.09	268.93	413.09	269.52	413.09
270.19	413.09	270.82	413.09	271.77	413.09	272.33	413.09	273.68	413.5
274.07	413.62	275.47	414.08	275.64	414.46	278.31	415.21	279.82	415.78
281.18	416.49	282.08	416.89	282.77	417.26	283.17	417.44	283.9	417.82
284.41	418.09	285.3	418.48	285.88	418.75	287.48	419.35	287.9	419.51
288.32	419.68	289.14	420.05	290.44	420.61	291.22	420.67	312.92	421.56
313.7	421.63	315.59	421.78	316.63	421.85	318.02	421.95	318.66	421.99
318.81	422	320.6	422.11	321.05	422.14	322.07	422.19	322.09	422.19
323.35	422.25	324.03	422.28	324.43	422.3	324.82	422.32	325.36	422.35
330.53	422.56	333.48	422.66	334.46	422.7	335.7	422.74	338.65	422.83
339.21	422.86	340.11	422.9	345.01	423.12	349.77	423.33	358.55	423.65
375.72	424.31	379.02	424.43	389.08	424.8	397.25	426.09	404.13	427.11
409.16	427.87	419.45	429.67	427.39	430.26	432.93	430.67	438.59	431.09
442.66	432.3	447.72	433.81	462.08	434.32	466.76	434.48	474.41	434.74
484.29	435.26								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	171.18	.056	214.85	.059	247.55	.03	275.64	.06
291.22	.041	339.21	.04	484.29	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.55	275.64	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83811.5*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.75	8.1	429.02	12.28	428.62	21.27	427.3	25.17	426.74
26.65	426.54	27.82	426.41	53.2	423.65	58.93	423.12	60.7	422.97
63.67	422.73	66.81	422.61	83	422.35	106.32	422.05	106.98	422.05
109.05	422.02	110.38	422.1	120.7	421.74	135.4	421.32	137.57	421.35
157.34	421.4	158.83	421.41	159.43	421.39	160.22	421.36	161.92	421.43
162.18	421.43	163.04	421.41	165.47	421.37	166.03	421.36	171.11	421.36
175.55	421.3	176.3	421.27	176.71	421.25	178.28	421.18	179.49	421.13
180.52	421.09	182.69	421	184.71	420.92	185.88	420.87	186.62	420.82
187.3	420.78	198.58	420.8	200.5	420.72	203.83	420.6	214.77	420.23
222.85	419.43	223.55	419.36	224.4	419.28	225.21	419.19	226.59	419.04
228.03	418.89	228.49	418.85	230.26	418.65	230.6	418.61	231.53	418.5
233.37	418.29	234.53	418.13	235.71	417.99	237.03	417.77	237.91	417.64
241.35	416.94	241.74	416.77	243.54	416.26	244.25	415.91	245.7	415.52
246.39	415.26	247.22	414.95	247.45	414.52	248.86	414.32	249.25	414.11
250.08	413.88	252.02	413.42	252.99	413.19	253.56	413.19	259.09	413.19
263.34	413.19	264.42	413.19	267.15	413.19	267.57	413.19	268.13	413.19
268.75	413.19	269.33	413.19	270.21	413.19	270.73	413.19	272.1	413.58
272.49	413.69	273.91	414.16	274.09	414.52	276.78	415.21	278.29	415.75
279.66	416.41	280.56	416.77	281.25	417.12	281.66	417.29	282.39	417.64
282.91	417.89	283.8	418.25	284.38	418.5	285.99	419.05	286.41	419.2
286.84	419.36	287.66	419.7	288.97	420.23	289.75	420.28	311.56	421.1
312.34	421.21	314.24	421.42	315.29	421.53	316.68	421.66	317.33	421.71
317.47	421.73	319.27	421.88	319.73	421.92	320.75	421.97	320.78	421.97
322.04	422.03	322.72	422.06	323.12	422.08	323.51	422.1	324.06	422.14
329.26	422.37	332.22	422.49	333.2	422.52	334.45	422.56	337.41	422.66
337.98	422.68	338.88	422.72	343.8	422.95	348.6	423.15	357.41	423.47
374.68	424.14	377.99	424.27	388.1	424.63	396.31	425.84	403.23	426.8
408.28	427.52	418.63	429.23	426.6	429.81	432.17	430.21	437.86	430.62
441.95	431.75	447.03	433.2	461.47	433.78	466.17	433.95	473.86	434.24
483.79	434.77								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	171.11	.056	214.77	.058	247.45	.03	274.09	.06
289.75	.042	337.98	.04	483.79	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.45	274.09	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83806.4*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.7	8.1	428.97	12.28	428.55	21.27	427.24	25.16	426.69
26.64	426.49	27.81	426.36	53.18	423.61	58.9	423.07	60.68	422.93
63.65	422.69	66.78	422.58	82.97	422.3	106.28	422.01	106.94	422.01
109.01	421.98	110.33	422.05	120.65	421.69	135.35	421.32	137.52	421.34
157.28	421.31	158.77	421.31	159.37	421.29	160.16	421.26	161.86	421.32
162.12	421.32	162.97	421.3	165.41	421.25	165.97	421.24	171.05	421.23
175.49	421.14	176.23	421.09	176.64	421.06	178.21	420.97	179.42	420.89
180.45	420.83	182.62	420.69	184.64	420.57	185.81	420.49	186.55	420.42
187.23	420.35	198.5	420.37	200.42	420.3	203.75	420.19	214.69	419.84
222.77	419.11	223.47	419.05	224.31	418.97	225.12	418.89	226.5	418.74
227.94	418.61	228.4	418.57	230.17	418.39	230.52	418.35	231.45	418.25
233.28	418.06	234.44	417.91	235.62	417.78	236.94	417.58	237.82	417.45
241.26	416.81	241.64	416.66	243.44	416.18	244.16	415.86	245.61	415.5
246.3	415.26	247.13	414.97	247.36	414.58	248.74	414.36	249.12	414.16
249.93	413.93	251.83	413.5	252.78	413.28	253.3	413.28	258.4	413.28
262.31	413.28	263.31	413.28	265.83	413.28	266.22	413.28	266.73	413.28
267.3	413.28	267.84	413.28	268.65	413.28	269.13	413.28	270.52	413.65
270.92	413.75	272.36	414.25	272.54	414.58	275.24	415.22	276.76	415.71
278.13	416.32	279.05	416.66	279.74	416.97	280.14	417.13	280.88	417.45
281.4	417.68	282.3	418.02	282.88	418.25	284.5	418.76	284.93	418.9
285.35	419.05	286.17	419.36	287.49	419.84	288.28	419.89	310.2	420.65
310.98	420.79	312.89	421.07	313.95	421.2	315.35	421.38	316	421.44
316.14	421.45	317.95	421.64	318.41	421.69	319.43	421.74	319.46	421.74
320.73	421.8	321.42	421.84	321.82	421.86	322.21	421.88	322.76	421.92
327.98	422.19	330.96	422.31	331.95	422.34	333.21	422.38	336.18	422.48
336.75	422.51	337.65	422.55	342.6	422.78	347.42	422.97	356.28	423.28
373.63	423.97	376.96	424.1	387.12	424.46	395.37	425.6	402.32	426.5
407.4	427.18	417.8	428.8	425.81	429.37	431.42	429.76	437.13	430.15
441.24	431.21	446.35	432.58	460.86	433.24	465.58	433.43	473.31	433.73
483.29	434.29								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	171.05	.057	214.69	.057	247.36	.03	272.54	.06
288.28	.043	336.75	.04	483.29	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.36	272.54	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83801.3*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.65	8.09	428.93	12.27	428.49	21.26	427.18	25.15	426.64
26.63	426.44	27.8	426.31	53.16	423.56	58.88	423.02	60.66	422.88
63.62	422.66	66.76	422.55	82.94	422.25	106.24	421.96	106.9	421.97
108.96	421.93	110.29	421.99	120.6	421.64	135.29	421.31	137.46	421.34
157.22	421.22	158.71	421.22	159.31	421.19	160.1	421.16	161.79	421.21
162.05	421.21	162.91	421.19	165.35	421.13	165.91	421.12	170.98	421.11
175.42	420.98	176.16	420.91	176.57	420.88	178.14	420.75	179.36	420.65
180.38	420.56	182.55	420.38	184.57	420.21	185.74	420.11	186.47	420.01
187.16	419.93	198.43	419.94	200.35	419.88	203.67	419.77	214.6	419.46
222.68	418.79	223.38	418.73	224.23	418.66	225.04	418.58	226.42	418.45
227.85	418.33	228.31	418.29	230.08	418.12	230.43	418.09	231.36	418
233.2	417.82	234.35	417.69	235.53	417.57	236.85	417.39	237.73	417.27
241.16	416.69	241.55	416.54	243.35	416.11	244.07	415.81	245.52	415.48
246.21	415.26	247.03	415	247.26	414.64	248.61	414.41	248.99	414.21
249.78	413.98	251.64	413.58	252.56	413.38	253.04	413.38	257.71	413.38
261.29	413.38	262.2	413.38	264.51	413.38	264.87	413.38	265.33	413.38
265.86	413.38	266.35	413.38	267.09	413.38	267.53	413.38	268.94	413.72
269.35	413.82	270.81	414.33	270.99	414.64	273.7	415.23	275.23	415.68
276.61	416.23	277.53	416.54	278.22	416.83	278.63	416.98	279.38	417.27
279.9	417.48	280.79	417.79	281.39	418	283.01	418.47	283.44	418.59
283.87	418.73	284.69	419.01	286.02	419.46	286.8	419.5	308.84	420.2
309.62	420.38	311.54	420.72	312.6	420.88	314.01	421.09	314.66	421.17
314.81	421.18	316.62	421.4	317.08	421.46	318.12	421.52	318.14	421.52
319.42	421.58	320.11	421.62	320.51	421.64	320.91	421.66	321.46	421.7
326.71	422.01	329.7	422.14	330.7	422.17	331.96	422.21	334.95	422.31
335.52	422.33	336.43	422.37	341.4	422.6	346.24	422.79	355.15	423.1
372.58	423.81	375.93	423.94	386.14	424.29	394.44	425.35	401.42	426.19
406.53	426.84	416.97	428.37	425.03	428.92	430.66	429.3	436.4	429.68
440.53	430.66	445.66	431.97	460.24	432.7	464.99	432.9	472.76	433.23
482.79	433.81								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.98	.057	214.6	.055	247.26	.03	270.99	.06
286.8	.044	335.52	.04	482.79	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.26	270.99	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83796.2*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.6	8.09	428.88	12.27	428.43	21.25	427.12	25.14	426.59
26.62	426.39	27.79	426.27	53.14	423.52	58.86	422.97	60.64	422.84
63.6	422.63	66.73	422.52	82.91	422.2	106.2	421.92	106.86	421.93
108.92	421.89	110.25	421.94	120.56	421.59	135.24	421.31	137.41	421.33
157.16	421.13	158.65	421.12	159.25	421.1	160.04	421.06	161.73	421.1
161.99	421.09	162.85	421.08	165.29	421.01	165.84	421.01	170.92	420.98
175.35	420.82	176.1	420.73	176.51	420.69	178.07	420.53	179.29	420.4
180.31	420.29	182.48	420.07	184.5	419.86	185.67	419.73	186.4	419.6
187.09	419.5	198.35	419.51	200.27	419.45	203.59	419.36	214.52	419.07
222.6	418.47	223.3	418.41	224.14	418.35	224.95	418.28	226.33	418.16
227.77	418.05	228.23	418.01	229.99	417.86	230.34	417.84	231.27	417.75
233.11	417.59	234.26	417.47	235.44	417.36	236.76	417.19	237.64	417.09
241.07	416.56	241.46	416.43	243.26	416.04	243.98	415.76	245.42	415.47
246.11	415.27	246.94	415.03	247.17	414.7	248.49	414.45	248.85	414.26
249.63	414.04	251.44	413.66	252.35	413.47	252.79	413.47	257.02	413.47
260.27	413.47	261.1	413.47	263.19	413.47	263.51	413.47	263.94	413.47
264.41	413.47	264.86	413.47	265.53	413.47	265.93	413.47	267.36	413.79
267.77	413.89	269.26	414.41	269.44	414.7	272.17	415.23	273.71	415.64
275.09	416.15	276.01	416.43	276.71	416.69	277.12	416.82	277.87	417.09
278.39	417.28	279.29	417.56	279.89	417.75	281.52	418.17	281.95	418.29
282.38	418.41	283.21	418.67	284.54	419.07	285.33	419.11	307.47	419.74
308.26	419.96	310.19	420.36	311.26	420.55	312.67	420.8	313.33	420.89
313.48	420.91	315.3	421.17	315.76	421.23	316.8	421.29	316.83	421.29
318.11	421.36	318.8	421.4	319.21	421.42	319.61	421.44	320.16	421.49
325.43	421.83	328.44	421.96	329.44	421.99	330.71	422.03	333.71	422.13
334.29	422.16	335.2	422.19	340.2	422.43	345.06	422.62	354.01	422.91
371.54	423.64	374.9	423.78	385.16	424.12	393.5	425.1	400.52	425.88
405.65	426.49	416.15	427.93	424.24	428.48	429.9	428.84	435.67	429.21
439.82	430.12	444.98	431.35	459.63	432.15	464.4	432.37	472.21	432.73
482.29	433.32								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.92	.057	214.52	.054	247.17	.03	269.44	.06
285.33	.045	334.29	.04	482.29	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.17	269.44	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83791.1*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.56	8.09	428.83	12.26	428.37	21.24	427.05	25.13	426.54
26.61	426.35	27.78	426.22	53.12	423.48	58.84	422.92	60.61	422.8
63.58	422.6	66.71	422.49	82.88	422.15	106.16	421.87	106.82	421.89
108.88	421.84	110.21	421.89	120.51	421.54	135.19	421.3	137.36	421.33
157.1	421.05	158.59	421.03	159.19	421	159.98	420.97	161.67	420.99
161.93	420.98	162.79	420.96	165.22	420.89	165.78	420.89	170.85	420.86
175.29	420.66	176.03	420.56	176.44	420.5	178.01	420.31	179.22	420.16
180.24	420.03	182.41	419.75	184.43	419.5	185.6	419.35	186.33	419.2
187.02	419.07	198.28	419.08	200.19	419.03	203.52	418.94	214.44	418.69
222.51	418.14	223.21	418.09	224.06	418.04	224.87	417.98	226.24	417.87
227.68	417.77	228.14	417.74	229.91	417.6	230.25	417.58	231.18	417.5
233.02	417.36	234.18	417.24	235.35	417.15	236.67	417	237.55	416.91
240.98	416.43	241.37	416.31	243.17	415.96	243.88	415.72	245.33	415.45
246.02	415.27	246.85	415.06	247.08	414.76	248.36	414.5	248.72	414.32
249.48	414.09	251.25	413.74	252.13	413.57	252.53	413.57	256.33	413.57
259.25	413.57	259.99	413.57	261.87	413.57	262.16	413.57	262.54	413.57
262.97	413.57	263.37	413.57	263.97	413.57	264.33	413.57	265.78	413.87
266.2	413.95	267.7	414.49	267.89	414.76	270.63	415.24	272.18	415.61
273.57	416.06	274.49	416.31	275.2	416.55	275.61	416.67	276.36	416.91
276.88	417.08	277.79	417.33	278.39	417.5	280.03	417.88	280.46	417.98
280.89	418.09	281.73	418.33	283.07	418.69	283.86	418.72	306.11	419.29
306.91	419.54	308.84	420.01	309.92	420.23	311.33	420.52	312	420.62
312.14	420.64	313.98	420.93	314.44	421	315.49	421.07	315.51	421.07
316.8	421.14	317.5	421.18	317.9	421.2	318.3	421.22	318.86	421.27
324.16	421.64	327.18	421.79	328.19	421.82	329.46	421.85	332.48	421.96
333.06	421.98	333.98	422.02	339	422.26	343.89	422.44	352.88	422.73
370.49	423.47	373.87	423.61	384.18	423.95	392.56	424.85	399.61	425.57
404.77	426.15	415.32	427.5	423.45	428.03	429.14	428.38	434.94	428.74
439.11	429.58	444.29	430.74	459.02	431.61	463.81	431.84	471.66	432.23
481.79	432.84								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.85	.058	214.44	.053	247.08	.03	267.89	.06
283.86	.046	333.06	.04	481.79	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
247.08	267.89	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83785.9*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.51	8.08	428.79	12.26	428.3	21.23	426.99	25.12	426.49
26.6	426.3	27.77	426.17	53.1	423.43	58.81	422.87	60.59	422.75
63.55	422.57	66.68	422.46	82.85	422.1	106.11	421.83	106.78	421.85
108.84	421.8	110.17	421.83	120.47	421.49	135.14	421.3	137.31	421.32
157.04	420.96	158.53	420.93	159.13	420.91	159.91	420.87	161.61	420.88
161.87	420.87	162.73	420.85	165.16	420.78	165.72	420.77	170.79	420.73
175.22	420.5	175.96	420.38	176.37	420.32	177.94	420.09	179.15	419.91
180.17	419.76	182.34	419.44	184.36	419.14	185.53	418.97	186.26	418.79
186.94	418.64	198.2	418.65	200.12	418.6	203.44	418.53	214.36	418.3
222.43	417.82	223.13	417.78	223.97	417.72	224.78	417.67	226.16	417.58
227.59	417.49	228.05	417.46	229.82	417.34	230.17	417.32	231.09	417.25
232.93	417.12	234.09	417.02	235.26	416.94	236.58	416.81	237.46	416.72
240.89	416.3	241.28	416.2	243.07	415.89	243.79	415.67	245.24	415.43
245.93	415.27	246.75	415.08	246.98	414.83	248.24	414.54	248.59	414.37
249.33	414.14	251.06	413.82	251.92	413.66	252.27	413.66	255.64	413.66
258.22	413.66	258.88	413.66	260.55	413.66	260.81	413.66	261.14	413.66
261.52	413.66	261.88	413.66	262.41	413.66	262.73	413.66	264.2	413.94
264.63	414.02	266.15	414.58	266.34	414.83	269.09	415.25	270.65	415.57
272.04	415.97	272.98	416.2	273.68	416.41	274.1	416.51	274.85	416.72
275.38	416.88	276.29	417.1	276.89	417.25	278.54	417.59	278.97	417.68
279.41	417.78	280.25	417.98	281.59	418.3	282.39	418.34	304.75	418.84
305.55	419.12	307.49	419.66	308.57	419.91	310	420.23	310.66	420.34
310.81	420.37	312.65	420.69	313.12	420.78	314.17	420.84	314.2	420.84
315.49	420.91	316.19	420.95	316.6	420.98	317	421	317.56	421.05
322.89	421.46	325.92	421.61	326.93	421.64	328.21	421.68	331.25	421.78
331.83	421.81	332.75	421.84	337.8	422.08	342.71	422.26	351.75	422.55
369.44	423.3	372.84	423.45	383.2	423.78	391.62	424.6	398.71	425.26
403.89	425.81	414.49	427.07	422.67	427.59	428.38	427.93	434.21	428.27
438.4	429.03	443.61	430.12	458.41	431.07	463.22	431.31	471.11	431.72
481.29	432.36								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.79	.058	214.36	.052	246.98	.03	266.34	.06
282.39	.047	331.83	.04	481.29	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.98	266.34	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83780.8*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.46	8.08	428.74	12.25	428.24	21.22	426.93	25.11	426.44
26.59	426.25	27.76	426.13	53.08	423.39	58.79	422.82	60.57	422.71
63.53	422.53	66.66	422.42	82.81	422.05	106.07	421.78	106.74	421.8
108.8	421.76	110.12	421.78	120.42	421.44	135.09	421.29	137.26	421.32
156.98	420.87	158.47	420.83	159.07	420.81	159.85	420.77	161.55	420.77
161.81	420.76	162.66	420.74	165.1	420.66	165.66	420.65	170.72	420.6
175.15	420.34	175.9	420.2	176.31	420.13	177.87	419.87	179.08	419.67
180.11	419.49	182.27	419.13	184.29	418.79	185.46	418.59	186.19	418.39
186.87	418.21	198.13	418.22	200.04	418.18	203.36	418.12	214.28	417.92
222.34	417.5	223.04	417.46	223.89	417.41	224.7	417.37	226.07	417.28
227.51	417.21	227.97	417.18	229.73	417.08	230.08	417.06	231.01	417
232.84	416.89	234	416.8	235.17	416.73	236.49	416.61	237.37	416.54
240.8	416.17	241.19	416.08	242.98	415.81	243.7	415.62	245.14	415.41
245.83	415.28	246.66	415.11	246.89	414.89	248.11	414.59	248.46	414.42
249.18	414.19	250.86	413.9	251.71	413.76	252.01	413.76	254.95	413.76
257.2	413.76	257.78	413.76	259.23	413.76	259.45	413.76	259.75	413.76
260.08	413.76	260.39	413.76	260.85	413.76	261.13	413.76	262.62	414.01
263.05	414.09	264.6	414.66	264.79	414.89	267.56	415.25	269.12	415.54
270.52	415.89	271.46	416.08	272.17	416.26	272.58	416.36	273.34	416.54
273.87	416.67	274.79	416.87	275.39	417	277.05	417.29	277.48	417.37
277.92	417.46	278.76	417.64	280.12	417.92	280.92	417.95	303.39	418.38
304.19	418.71	306.14	419.3	307.23	419.58	308.66	419.95	309.33	420.07
309.48	420.1	311.33	420.46	311.8	420.55	312.85	420.61	312.88	420.62
314.18	420.69	314.89	420.73	315.29	420.76	315.7	420.78	316.26	420.84
321.61	421.28	324.66	421.44	325.68	421.47	326.97	421.5	330.01	421.61
330.6	421.63	331.53	421.66	336.6	421.91	341.53	422.08	350.61	422.36
368.4	423.14	371.81	423.28	382.22	423.61	390.68	424.36	397.81	424.96
403.01	425.46	413.67	426.63	421.88	427.14	427.62	427.47	433.48	427.8
437.69	428.49	442.92	429.51	457.79	430.53	462.63	430.79	470.56	431.22
480.78	431.88								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.72	.058	214.28	.051	246.89	.03	264.79	.06
280.92	.048	330.6	.04	480.78	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.89	264.79	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83775.7*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.41	8.08	428.69	12.25	428.18	21.22	426.87	25.11	426.39
26.58	426.21	27.74	426.08	53.06	423.35	58.77	422.77	60.54	422.66
63.5	422.5	66.63	422.39	82.78	422	106.03	421.73	106.7	421.76
108.76	421.71	110.08	421.73	120.38	421.39	135.04	421.29	137.2	421.32
156.92	420.78	158.41	420.74	159.01	420.71	159.79	420.68	161.49	420.66
161.75	420.65	162.6	420.62	165.03	420.54	165.59	420.53	170.66	420.48
175.09	420.18	175.83	420.03	176.24	419.95	177.8	419.65	179.02	419.42
180.04	419.23	182.2	418.81	184.22	418.43	185.39	418.21	186.12	417.98
186.8	417.78	198.05	417.79	199.97	417.76	203.28	417.7	214.2	417.53
222.26	417.17	222.96	417.14	223.8	417.1	224.61	417.06	225.99	416.99
227.42	416.93	227.88	416.91	229.64	416.82	229.99	416.8	230.92	416.75
232.75	416.66	233.91	416.58	235.08	416.52	236.4	416.42	237.28	416.36
240.71	416.04	241.09	415.97	242.89	415.73	243.61	415.57	245.05	415.4
245.74	415.28	246.57	415.14	246.79	414.95	247.99	414.63	248.32	414.47
249.03	414.24	250.67	413.98	251.49	413.85	251.75	413.85	254.26	413.85
256.18	413.85	256.67	413.85	257.91	413.85	258.1	413.85	258.35	413.85
258.63	413.85	258.9	413.85	259.29	413.85	259.53	413.85	261.04	414.09
261.48	414.15	263.05	414.74	263.24	414.95	266.02	415.26	267.59	415.5
269	415.8	269.94	415.97	270.65	416.12	271.07	416.2	271.83	416.36
272.37	416.47	273.29	416.64	273.89	416.75	275.56	417	275.99	417.07
276.43	417.14	277.28	417.29	278.64	417.53	279.45	417.56	302.02	417.93
302.83	418.29	304.79	418.95	305.88	419.26	307.32	419.66	308	419.79
308.14	419.82	310	420.22	310.48	420.32	311.54	420.39	311.56	420.39
312.87	420.47	313.58	420.51	313.99	420.54	314.4	420.56	314.96	420.62
320.34	421.09	323.4	421.26	324.42	421.29	325.72	421.32	328.78	421.43
329.37	421.46	330.3	421.49	335.4	421.74	340.36	421.9	349.48	422.18
367.35	422.97	370.78	423.12	381.24	423.44	389.74	424.11	396.9	424.65
402.13	425.12	412.84	426.2	421.09	426.69	426.86	427.01	432.75	427.33
436.98	427.94	442.24	428.89	457.18	429.99	462.05	430.26	470.01	430.72
480.28	431.39								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.66	.058	214.2	.05	246.79	.03	263.24	.06
279.45	.049	329.37	.04	480.28	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.79	263.24	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83770.6*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.37	8.07	428.65	12.24	428.12	21.21	426.81	25.1	426.34
26.57	426.16	27.73	426.03	53.04	423.3	58.75	422.72	60.52	422.62
63.48	422.47	66.61	422.36	82.75	421.94	105.99	421.69	106.65	421.72
108.72	421.67	110.04	421.67	120.33	421.34	134.99	421.29	137.15	421.31
156.86	420.69	158.35	420.64	158.94	420.62	159.73	420.58	161.43	420.55
161.69	420.54	162.54	420.51	164.97	420.42	165.53	420.41	170.59	420.35
175.02	420.02	175.76	419.85	176.17	419.76	177.73	419.43	178.95	419.18
179.97	418.96	182.13	418.5	184.15	418.08	185.32	417.83	186.05	417.57
186.73	417.36	197.98	417.36	199.89	417.33	203.21	417.29	214.11	417.15
222.17	416.85	222.87	416.82	223.72	416.79	224.53	416.76	225.9	416.7
227.33	416.65	227.79	416.63	229.56	416.56	229.9	416.54	230.83	416.5
232.66	416.42	233.82	416.36	235	416.31	236.31	416.23	237.19	416.18
240.61	415.92	241	415.85	242.8	415.66	243.51	415.53	244.96	415.38
245.64	415.28	246.47	415.17	246.7	415.01	247.86	414.68	248.19	414.53
248.88	414.29	250.48	414.06	251.28	413.95	251.49	413.95	253.56	413.95
255.16	413.95	255.56	413.95	256.59	413.95	256.75	413.95	256.95	413.95
257.19	413.95	257.4	413.95	257.74	413.95	257.93	413.95	259.46	414.16
259.9	414.22	261.49	414.82	261.69	415.01	264.48	415.27	266.06	415.47
267.48	415.72	268.42	415.85	269.14	415.98	269.56	416.05	270.33	416.18
270.86	416.27	271.79	416.41	272.4	416.5	274.07	416.71	274.51	416.76
274.95	416.82	275.8	416.95	277.16	417.15	277.97	417.17	300.66	417.48
301.47	417.87	303.45	418.6	304.54	418.94	305.99	419.37	306.66	419.52
306.81	419.55	308.68	419.98	309.15	420.09	310.22	420.16	310.25	420.16
311.56	420.25	312.27	420.29	312.68	420.32	313.09	420.34	313.66	420.4
319.06	420.91	322.14	421.09	323.17	421.11	324.47	421.15	327.55	421.26
328.14	421.28	329.07	421.31	334.2	421.56	339.18	421.72	348.35	421.99
366.3	422.8	369.75	422.96	380.27	423.26	388.81	423.86	396	424.34
401.25	424.78	412.01	425.76	420.31	426.25	426.1	426.56	432.01	426.86
436.27	427.4	441.55	428.28	456.57	429.44	461.46	429.73	469.46	430.22
479.78	430.91								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.59	.059	214.11	.048	246.7	.03	261.69	.06
277.97	.05	328.14	.04	479.78	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.7	261.69	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83765.5*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.32	8.07	428.6	12.24	428.05	21.2	426.75	25.09	426.28
26.56	426.11	27.72	425.98	53.02	423.26	58.72	422.67	60.5	422.58
63.45	422.44	66.58	422.33	82.72	421.89	105.95	421.64	106.61	421.68
108.67	421.62	110	421.62	120.28	421.28	134.93	421.28	137.1	421.31
156.8	420.6	158.29	420.55	158.88	420.52	159.67	420.48	161.36	420.44
161.62	420.43	162.48	420.4	164.91	420.3	165.47	420.29	170.53	420.23
174.95	419.86	175.69	419.67	176.1	419.58	177.67	419.21	178.88	418.93
179.9	418.69	182.06	418.19	184.08	417.72	185.25	417.45	185.98	417.17
186.66	416.93	197.9	416.93	199.81	416.91	203.13	416.87	214.03	416.76
222.09	416.53	222.79	416.51	223.63	416.48	224.44	416.46	225.81	416.41
227.25	416.37	227.71	416.35	229.47	416.29	229.82	416.28	230.74	416.25
232.58	416.19	233.73	416.14	234.91	416.1	236.22	416.03	237.1	415.99
240.52	415.79	240.91	415.74	242.7	415.58	243.42	415.48	244.86	415.36
245.55	415.29	246.38	415.19	246.61	415.07	247.74	414.72	248.06	414.58
248.72	414.34	250.29	414.14	251.06	414.04	251.23	414.04	252.87	414.04
254.13	414.04	254.46	414.04	255.27	414.04	255.39	414.04	255.56	414.04
255.74	414.04	255.91	414.04	256.18	414.04	256.33	414.04	257.88	414.23
258.33	414.29	259.94	414.9	260.14	415.07	262.95	415.27	264.53	415.43
265.96	415.63	266.91	415.74	267.62	415.84	268.05	415.89	268.82	415.99
269.36	416.07	270.28	416.18	270.9	416.25	272.57	416.41	273.02	416.46
273.46	416.51	274.32	416.61	275.69	416.76	276.5	416.78	299.3	417.02
300.11	417.46	302.1	418.24	303.2	418.61	304.65	419.09	305.33	419.24
305.48	419.28	307.36	419.75	307.83	419.87	308.9	419.94	308.93	419.94
310.25	420.02	310.97	420.07	311.38	420.1	311.79	420.12	312.36	420.18
317.79	420.73	320.88	420.91	321.92	420.94	323.22	420.97	326.32	421.08
326.91	421.11	327.85	421.13	332.99	421.39	338	421.54	347.22	421.81
365.26	422.64	368.72	422.79	379.29	423.09	387.87	423.61	395.09	424.03
400.38	424.43	411.19	425.33	419.52	425.8	425.34	426.1	431.28	426.39
435.56	426.86	440.87	427.66	455.96	428.9	460.87	429.2	468.91	429.72
479.28	430.43								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.53	.059	214.03	.047	246.61	.03	260.14	.06
276.5	.051	326.91	.04	479.28	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.61	260.14	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83760.4*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.27	8.07	428.55	12.23	427.99	21.19	426.69	25.08	426.23
26.55	426.06	27.71	425.94	53	423.21	58.7	422.62	60.47	422.53
63.43	422.41	66.56	422.3	82.69	421.84	105.91	421.6	106.57	421.64
108.63	421.58	109.96	421.56	120.24	421.23	134.88	421.28	137.05	421.3
156.74	420.51	158.23	420.45	158.82	420.42	159.61	420.38	161.3	420.33
161.56	420.32	162.42	420.28	164.85	420.18	165.4	420.17	170.46	420.1
174.89	419.7	175.63	419.5	176.04	419.39	177.6	418.99	178.81	418.69
179.83	418.43	181.99	417.88	184.01	417.37	185.18	417.07	185.91	416.76
186.59	416.5	197.83	416.5	199.74	416.49	203.05	416.46	213.95	416.38
222.01	416.2	222.7	416.19	223.55	416.17	224.35	416.15	225.73	416.12
227.16	416.09	227.62	416.08	229.38	416.03	229.73	416.02	230.66	416
232.49	415.95	233.64	415.92	234.82	415.89	236.13	415.84	237.01	415.81
240.43	415.66	240.82	415.62	242.61	415.51	243.33	415.43	244.77	415.35
245.46	415.29	246.28	415.22	246.51	415.13	247.62	414.77	247.92	414.63
248.57	414.4	250.09	414.22	250.85	414.14	250.97	414.14	252.18	414.14
253.11	414.14	253.35	414.14	253.95	414.14	254.04	414.14	254.16	414.14
254.3	414.14	254.42	414.14	254.62	414.14	254.73	414.14	256.3	414.3
256.76	414.35	258.39	414.99	258.59	415.13	261.41	415.28	263	415.4
264.43	415.54	265.39	415.62	266.11	415.7	266.53	415.74	267.31	415.81
267.85	415.87	268.78	415.95	269.4	416	271.08	416.12	271.53	416.15
271.98	416.19	272.83	416.26	274.21	416.38	275.03	416.39	297.93	416.57
298.75	417.04	300.75	417.89	301.85	418.29	303.31	418.8	303.99	418.97
304.15	419.01	306.03	419.51	306.51	419.64	307.59	419.71	307.61	419.71
308.94	419.8	309.66	419.85	310.07	419.88	310.49	419.91	311.06	419.97
316.52	420.54	319.63	420.74	320.66	420.76	321.97	420.79	325.08	420.91
325.67	420.93	326.62	420.95	331.79	421.22	336.82	421.36	346.08	421.63
364.21	422.47	367.69	422.63	378.31	422.92	386.93	423.37	394.19	423.72
399.5	424.09	410.36	424.9	418.73	425.36	424.59	425.64	430.55	425.92
434.85	426.31	440.18	427.05	455.34	428.36	460.28	428.68	468.36	429.21
478.78	429.94								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.46	.059	213.95	.046	246.51	.03	258.59	.06
275.03	.052	325.67	.04	478.78	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.51	258.59	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83755.3*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.23	8.07	428.5	12.23	427.93	21.18	426.63	25.07	426.18
26.54	426.02	27.7	425.89	52.98	423.17	58.68	422.57	60.45	422.49
63.41	422.37	66.53	422.27	82.66	421.79	105.87	421.55	106.53	421.6
108.59	421.53	109.92	421.51	120.19	421.18	134.83	421.27	136.99	421.3
156.68	420.42	158.17	420.36	158.76	420.33	159.55	420.29	161.24	420.22
161.5	420.21	162.36	420.17	164.78	420.06	165.34	420.05	170.4	419.98
174.82	419.54	175.56	419.32	175.97	419.2	177.53	418.77	178.74	418.44
179.76	418.16	181.92	417.56	183.94	417.01	185.11	416.69	185.84	416.35
186.52	416.07	197.75	416.07	199.66	416.06	202.97	416.05	213.87	415.99
221.92	415.88	222.62	415.87	223.46	415.86	224.27	415.85	225.64	415.83
227.07	415.8	227.53	415.8	229.29	415.77	229.64	415.77	230.57	415.75
232.4	415.72	233.55	415.7	234.73	415.68	236.04	415.65	236.92	415.63
240.34	415.53	240.73	415.51	242.52	415.43	243.23	415.39	244.68	415.33
245.36	415.29	246.19	415.25	246.42	415.19	247.49	414.81	247.79	414.68
248.42	414.45	249.9	414.3	250.64	414.23	250.72	414.23	251.49	414.23
252.09	414.23	252.24	414.23	252.63	414.23	252.69	414.23	252.76	414.23
252.85	414.23	252.93	414.23	253.06	414.23	253.13	414.23	254.73	414.38
255.18	414.42	256.84	415.07	257.04	415.19	259.87	415.29	261.47	415.36
262.91	415.46	263.87	415.51	264.6	415.56	265.02	415.58	265.8	415.63
266.34	415.66	267.28	415.71	267.9	415.75	269.59	415.83	270.04	415.85
270.49	415.87	271.35	415.92	272.74	415.99	273.56	416	296.57	416.12
297.4	416.62	299.4	417.54	300.51	417.96	301.98	418.52	302.66	418.69
302.81	418.74	304.71	419.27	305.19	419.41	306.27	419.49	306.3	419.49
307.63	419.58	308.35	419.63	308.77	419.66	309.18	419.69	309.76	419.75
315.24	420.36	318.37	420.56	319.41	420.59	320.73	420.62	323.85	420.73
324.44	420.76	325.4	420.78	330.59	421.04	335.65	421.19	344.95	421.44
363.16	422.3	366.66	422.47	377.33	422.75	385.99	423.12	393.29	423.41
398.62	423.75	409.53	424.46	417.95	424.91	423.83	425.18	429.82	425.46
434.14	425.77	439.5	426.43	454.73	427.82	459.69	428.15	467.81	428.71
478.28	429.46								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.4	.06	213.87	.045	246.42	.03	257.04	.06
273.56	.053	324.44	.04	478.28	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.42	257.04	1.22	5	5.74	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83750.2*

INPUT
Description:
Station Elevation Data num= 146

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.18	8.06	428.46	12.22	427.87	21.18	426.57	25.06	426.13
26.53	425.97	27.69	425.84	52.96	423.13	58.66	422.52	60.43	422.45
63.38	422.34	66.51	422.24	82.63	421.74	105.83	421.51	106.49	421.55
108.55	421.49	109.87	421.46	120.15	421.13	134.78	421.27	136.94	421.29
156.62	420.33	158.11	420.26	158.7	420.23	159.49	420.19	161.18	420.11
161.44	420.1	162.29	420.06	164.72	419.95	165.28	419.94	170.33	419.85
174.75	419.38	175.49	419.14	175.9	419.02	177.46	418.56	178.67	418.2
179.69	417.89	181.86	417.25	183.87	416.65	185.04	416.3	185.77	415.95
186.45	415.64	197.67	415.64	199.58	415.64	202.9	415.63	213.79	415.61
221.84	415.56	222.53	415.55	223.38	415.55	224.18	415.54	225.56	415.53
226.99	415.52	227.45	415.52	229.21	415.51	229.55	415.51	230.48	415.5
232.31	415.49	233.46	415.48	234.64	415.47	235.95	415.45	236.83	415.45
240.25	415.4	240.64	415.39	242.43	415.36	243.14	415.34	244.58	415.31
245.27	415.3	246.1	415.28	246.33	415.25	247.37	414.86	247.66	414.74
248.27	414.5	249.71	414.38	250.42	414.32	250.46	414.32	250.8	414.32
251.07	414.32	251.14	414.32	251.31	414.32	251.33	414.32	251.37	414.32
251.41	414.32	251.44	414.32	251.5	414.32	251.53	414.32	253.15	414.45
253.61	414.49	255.28	415.15	255.49	415.25	258.34	415.29	259.94	415.33
261.39	415.37	262.35	415.39	263.08	415.41	263.51	415.42	264.29	415.45
264.84	415.46	265.78	415.48	266.4	415.5	268.1	415.53	268.55	415.54
269	415.55	269.87	415.58	271.26	415.61	272.09	415.61	295.21	415.66
296.04	416.2	298.05	417.18	299.17	417.64	300.64	418.23	301.33	418.42
301.48	418.47	303.39	419.04	303.87	419.18	304.95	419.26	304.98	419.26
306.32	419.36	307.05	419.41	307.46	419.44	307.88	419.47	308.46	419.53
313.97	420.18	317.11	420.39	318.15	420.41	319.48	420.44	322.62	420.56
323.21	420.58	324.17	420.6	329.39	420.87	334.47	421.01	343.82	421.26
362.12	422.13	365.63	422.3	376.35	422.58	385.05	422.87	392.38	423.11
397.74	423.4	408.71	424.03	417.16	424.47	423.07	424.73	429.09	424.99
433.43	425.23	438.82	425.82	454.12	427.27	459.1	427.62	467.25	428.21
477.78	428.98								

Manning's n Values num= 8

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.33	.06	213.79	.044	246.33	.03	255.49	.06
272.09	.054	323.21	.04	477.78	.04				

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.33	255.49	.97	4	4.59	.3	.5

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83746.11

INPUT
Description: STA. 83746.11
Station Elevation Data num= 57

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	429.14	8.06	428.42	21.17	426.52	25.05	426.09	58.64	422.48
60.41	422.41	82.6	421.7	105.8	421.47	106.46	421.52	120.11	421.09
136.9	421.29	161.39	420.01	164.67	419.85	170.28	419.75	174.7	419.25
175.44	419	175.85	418.87	177.41	418.38	178.62	418	179.64	417.68
181.8	417	183.81	416.37	184.98	416	185.71	415.62	186.39	415.3
246.25	415.3	248.15	414.54	250.25	414.4	252.35	414.54	254.25	415.3
294.12	415.3	294.95	415.87	296.97	416.9	298.09	417.38	299.57	418
300.26	418.2	302.81	419	303.9	419.08	306	419.23	306.84	419.29
312.95	420.03	316.1	420.25	317.15	420.27	318.48	420.3	322.23	420.44
323.19	420.46	328.43	420.73	342.91	421.11	361.28	422	364.81	422.17
391.66	422.86	416.53	424.11	422.46	424.36	432.86	424.79	453.63	426.84
458.63	427.2	477.38	428.59						

Manning's n Values num= 5

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	170.28	.06	246.25	.03	254.25	.06	322.23	.04

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
246.25	254.25	187	176	212	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	186.39	424.71	F
329.12	477.38	424.71	F

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 83553.53

INPUT
Description: STA. 83553.53
Station Elevation Data num= 26

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	420.86	14.77	417.94	21.34	417.98	21.85	417.98	55.93	418.05
58.03	418	58.41	417.88	61.02	417	63.22	416.29	64.11	416
66.28	415.29	67.15	415	68.97	414.35	151.72	414.35	153.62	413.59
155.72	413.45	157.82	413.59	159.72	414.35	222.55	414.35	228.38	414.85
230.11	415	230.92	415.36	248.47	422.74	254.25	423.35	278.2	425.79

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  280.68  426.14

Manning's n Values        num=       5
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   58.03     .06  151.72     .03  159.72     .06  228.38     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
        151.72  159.72              82      75      72              .1       .3
Ineffective Flow     num=       1
   Sta L   Sta R    Elev  Permanent
       5   55.93  418.05       F

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 83464.67

INPUT
Description: STA. 83464.67
Station Elevation Data    num=      37
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
  -11.46     420       0  417.98    8.51  417.29    16.5  417.16   18.28  417.13
   18.88  417.12   19.33  417.12    20.4   417.1   21.98  417.08   23.08  417.06
   26.11   416.9   28.31  416.84   28.93  416.72   29.81  416.53   32.36     416
    33.4  415.71   35.85     415   38.53  414.28   39.74 413.945  113.41 413.945
  115.31 413.185  117.41 413.045  119.51 413.185  121.41 413.945  201.06 413.945
  205.81  413.98  209.12     414  209.71     414  211.08   414.1  211.78  414.15
  212.92  414.23  213.94  414.31  221.94  414.99  225.75  415.31  229.87  416.06
   233.6  418.98  236.33   422.1

Manning's n Values        num=       5
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
  -11.46     .04   28.31     .06  113.41     .03  121.41     .06  209.12     .04

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
        113.41  121.41             207     167     163              .1       .3

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 83249.52

INPUT
Description: STA. 83249.52
Station Elevation Data    num=      27
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  420.93   10.83  420.28   41.71  418.42   44.71  418.24   51.74  417.82
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   55.99  417.57   64.05  417.08   65.36     417   67.56   415.9   69.44  414.96
   71.36     414    71.7  413.83   73.19  413.05   100.8  413.05   102.7  412.29
   104.8  412.15   106.9  412.29   108.8  413.05  255.16  413.05  255.93  413.33
  257.26  413.75     258     414  282.71   416.3  289.19  421.53  293.91  425.37
  296.92     426  304.08  427.66

Manning's n Values        num=       5
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   65.36     .06   100.8     .03   108.8     .06  282.71     .08

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
         100.8   108.8              176     172     173              .1       .3

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 83056.75

INPUT
Description: STA. 83056.75
Station Elevation Data    num=      26
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  420.72    3.04  419.91    18.2  415.65   21.58  415.23   25.44  414.73
   27.19  414.46   31.51   413.8   36.72     413   40.41  412.27   40.95  412.12
   91.46  412.12   93.36  411.36   95.46  411.22   97.56  411.36   99.46  412.12
  197.94  412.12  199.62     413   201.6  413.99  203.62     415   205.6  415.99
  207.62     417  209.62     418  211.24  418.11  242.05   420.2  253.38  420.75
  257.31  420.96

Manning's n Values        num=       6
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   40.95     .06   91.46     .03   99.46     .06  197.94     .04
  242.05     .08

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
         91.46   99.46              187     184     185              .1       .3

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 82834.61

INPUT
Description: STA. 82834.61
Station Elevation Data    num=      29
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  416.07   22.68  413.57   27.88     413   31.53   412.6   34.61  412.26
```

43.22	411.33	44.63	411.13	112.98	411.13	114.88	410.37	116.98	410.23
119.08	410.37	120.98	411.13	187.19	411.13	187.55	411.35	188.84	412
189.3	412.23	190.84	413	191.31	413.23	192.84	414	193.3	414.23
194.84	415	196.03	415.59	199.26	415.69	213.05	416.19	220.48	416.55
237.06	417.9	239.74	418.42	260.32	421.68	264.26	422.31		

Manning's n Values num= 6

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	44.63	.06	112.98	.03	120.98	.06	187.19	.04
237.06	.08								

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
112.98	120.98	117	117	117	.1	.3

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 82707.86

INPUT
Description: STA. 82707.86
Station Elevation Data num= 24

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-43.66	416	0	413.98	17.36	412.8	26.82	412.15	41.71	411.03
42.96	411	43.84	410.43	101.01	410.43	102.91	409.67	105.01	409.53
107.11	409.67	109.01	410.43	192.17	410.43	193.98	411.33	195.32	412
196.66	412.67	197.32	413	198.24	413.46	199.32	414	200.41	414.54
200.89	414.77	203.79	415.12	218	416.21	257.68	421.12		

Manning's n Values num= 6

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
-43.66	.04	43.84	.06	101.01	.03	109.01	.06	192.17	.04
200.89	.08								

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
101.01	109.01	155	159	157	.1	.3

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 82506.13

INPUT
Description: STA. 82506.13
Station Elevation Data num= 27

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	413.65	14.34	412.87	17.77	412.71	22.8	412.63	27.88	412.44

```
   29.34  412.41   29.82   412.4   48.84     412   56.84     410   59.36  409.37
  180.09  409.37  181.99  408.61  184.09  408.47  186.19  408.61  188.09  409.37
  228.36  409.37  231.33  410.86   233.5  411.94  235.62     413  236.06  413.22
  236.84  413.26  240.67  413.42   247.3  413.82  251.29  414.21  263.67  416.11
  284.83  419.32  296.47     421

Manning's n Values         num=       6
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   59.36     .06  180.09     .03  188.09     .06  228.36     .04
   247.3     .08

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
        180.09  188.09              182     175     175             .1       .3

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 82293.55

INPUT
Description: STA. 82293.55
Station Elevation Data    num=      26
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  416.62    6.42  415.62   11.78  414.57   25.46   413.1    32.8   412.3
   36.81  411.57   43.12  410.42   46.12     410   51.52  409.23   58.81   408.2
   99.42   408.2  101.32  407.44  103.42   407.3  105.52  407.44  107.42   408.2
  237.96   408.2  239.58     409   240.8  409.61  241.57     410  243.01  410.72
  243.57     411  244.11  411.02  258.72  411.45  278.32  412.31   295.5  415.25
     316  418.62

Manning's n Values         num=       6
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   58.81     .06   99.42     .03  107.42     .06  237.96     .04
  278.32     .08

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
         99.42  107.42              213     211     211             .1       .3

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 82049.29

INPUT
Description: STA. 82049.29
Station Elevation Data    num=      35
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
```

0	416.03	3.68	415.75	19.6	413.23	31.28	411.11	31.64	411.04
34.74	410.52	35.26	410.08	38.49	407.46	39.05	407.01	39.34	406.78
127.77	406.78	129.67	406.02	131.77	405.88	133.87	406.02	135.77	406.78
208.4	406.78	209.97	407.56	210.85	408	211.56	408.36	212.84	409
213.44	409.3	214.85	410	215.24	410.2	215.62	410.39	216.85	411
217.35	411.04	225.6	411.66	229.91	411.98	232.16	412.14	241.4	412.77
265.78	414.08	273.15	414.46	274.42	414.54	275.57	414.63	300.1	416.07

Manning's n Values num= 6

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	39.34	.06	127.77	.03	135.77	.06	208.4	.04
232.16	.08								

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
127.77	135.77	164	164	165	.1	.3

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 81832.26

INPUT
Description: STA. 81832.26
Station Elevation Data num= 31

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	420.74	23.87	415.15	28.73	414.11	32.24	413.75	32.88	413.69
38.42	413.16	59.06	410.81	59.61	410.35	63.54	409.43	65.05	408.95
67.53	408.16	75.42	405.68	189.26	405.68	191.16	404.92	193.26	404.78
195.36	404.92	197.26	405.68	250.05	405.68	251.6	406.45	252.69	407
253.92	407.61	254.69	408	255.32	408.31	256.7	409	258.53	409.92
260.4	409.98	261.06	410.01	291.74	410.7	292.82	410.76	296.14	410.91
318.26	412.07								

Manning's n Values num= 5

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	75.42	.06	189.26	.03	197.26	.06	250.05	.04

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
189.26	197.26	262	263	263	.1	.3

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 81500.63

INPUT
Description: STA. 81500.63

```
Station Elevation Data    num=      41
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  418.08   18.74  413.69   25.87  412.88   47.63  410.89   63.32  409.95
   70.76   409.5   72.26  409.42    72.8  409.36   74.04  409.23   76.12     409
   78.24  408.35   79.39     408   82.54  407.05   85.76     406   87.21  405.56
   89.03     405   89.98  404.74   92.63     404   93.16  403.91  172.07  403.91
  173.97  403.15  176.07  403.01  178.17  403.15  180.07  403.91  287.73  403.91
  289.89     405  291.36  405.75  291.88     406  292.38  406.24   293.9     407
     295  407.55   295.9     408  297.05  408.57   297.9     409  298.43  409.05
  306.14  409.77  313.55  410.01  325.67  410.62  339.88  411.41  358.72   412.3
  372.04     413

Manning's n Values        num=       6
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   93.16     .06  172.07     .03  180.07     .06  287.73     .04
  298.43     .08

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
        172.07  180.07             169     166     166             .1       .3

CROSS SECTION


RIVER: 99
REACH: LCC_HEC_PR         RS: 81293.00

INPUT
Description: STA. 81293.00
Station Elevation Data    num=      27
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
       0  413.22   17.03  411.82   32.82  410.43   46.96  408.95   69.12  408.43
   70.09     408   108.7     404  109.74  403.65   111.7     403   112.3   402.8
  222.25   402.8  224.15  402.04  226.25   401.9  228.35  402.04  230.25   402.8
  282.16   402.8  283.91  403.68  286.38  404.93  288.55     406  290.34  406.89
  292.56     408  293.29  408.37   293.8  408.39  299.82  408.74  336.53  410.21
  344.09   410.5  390.95  413.17

Manning's n Values        num=       6
     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val     Sta   n Val
       0     .04   112.3     .06  222.25     .03  230.25     .06  282.16     .04
  344.09     .08

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
        222.25  230.25             203     215     231             .1       .3

CROSS SECTION


RIVER: 99
```

REACH: LCC_HEC_PR RS: 81028.44

INPUT

Description: STA. 81028.44

Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	410.27	26.33	408.22	34.7	407.9	58.11	407.14	60.93	406.93
87.68	404.96	90.03	404.01	90.64	403.77	91.37	403.57	91.81	403.45
95.96	401.68	96.51	401.62	97.11	401.55	97.47	401.51	98.48	401.39
100.1	401.21	101.83	401.02	102.6	400.99	106.63	400.95	177.46	400.95
179.36	400.19	181.46	400.05	183.56	400.19	185.46	400.95	249.06	400.95
250.04	401.44	250.36	401.6	253.06	402.95	255.16	404	257.16	405
259.16	406	261.16	407	262.14	407.05	267.44	407.14	306.61	407.93
326.5	408.34	362.07	409.12	363.33	409.15	366.84	409.27	423.12	411.15

Manning's n Values num= 6

Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
0	.04	106.63	.06	177.46	.03	185.46	.06	249.06	.04
362.07	.08								

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
177.46	185.46	174	184	200	.1	.3

CROSS SECTION

RIVER: 99

REACH: LCC_HEC_PR RS: 80829.99

INPUT

Description: STA. 80829.99

Station Elevation Data num= 42

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	408.76	29.75	407.73	37.32	407.5	62.14	406.11	72.11	404.85
73.24	404.31	76.57	401.538	79.87	398.79	80.71	398.19	81	398.16
82.87	398.37	83.85	398.1	85.05	397.78	85.37	397.76	85.79	397.74
86.37	397.8	86.9	397.82	92.2	398.42	93.38	398.49	97.94	398.87
100.24	399.51	107.26	401.4	122.11	402.4	143.06	403.35	166.13	403.97
196.27	405.67	201.17	405.95	202.22	406	218.54	406.55	253.9	407.61
255.46	407.64	261.89	407.88	300.62	408.25	310.35	408.66	336.75	409.79
339.15	409.87	341.21	409.95	347.45	410.12	389.01	410.99	413.72	411.64
438.46	412.53	441.62	412.5						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.08	76.57	.03	107.26	.08

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
76.57	107.26	637	630	615	.1	.3

CROSS SECTION

RIVER: 99
REACH: LCC_HEC_PR RS: 80200

INPUT
Description: STA. 80200
Station Elevation Data num= 11

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	404	26.32	402	72.44	400	115.66	398	131.54	396
146.13	395	149.72	396	168.29	398	192.31	400	363.49	402
405.76	404								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.08	115.66	.03	168.29	.08

Bank Sta: Left	Right	Lengths: Left	Channel	Right	Coeff Contr.	Expan.
115.66	168.29	0	0	0	.1	.3

SUMMARY OF MANNING'S N VALUES

River:99

Reach	River Sta.	n1	n2	n3	n4	n5	n6	n7	n8
LCC_HEC_PR	83952.77	.04	.03	.04					
LCC_HEC_PR	83884.32	.04	.03	.04					
LCC_HEC_PR	83880	Culvert							
LCC_HEC_PR	83821.78	.04	.06	.03	.06	.04			
LCC_HEC_PR	83816.6*	.04	.056	.059	.03	.06	.041	.04	.04
LCC_HEC_PR	83811.5*	.04	.056	.058	.03	.06	.042	.04	.04
LCC_HEC_PR	83806.4*	.04	.057	.057	.03	.06	.043	.04	.04
LCC_HEC_PR	83801.3*	.04	.057	.055	.03	.06	.044	.04	.04

```
LCC_HEC_PR          83796.2*         .04      .057      .054       .03       .06
    .045       .04       .04
LCC_HEC_PR          83791.1*         .04      .058      .053       .03       .06
    .046       .04       .04
LCC_HEC_PR          83785.9*         .04      .058      .052       .03       .06
    .047       .04       .04
LCC_HEC_PR          83780.8*         .04      .058      .051       .03       .06
    .048       .04       .04
LCC_HEC_PR          83775.7*         .04      .058       .05       .03       .06
    .049       .04       .04
LCC_HEC_PR          83770.6*         .04      .059      .048       .03       .06
     .05       .04       .04
LCC_HEC_PR          83765.5*         .04      .059      .047       .03       .06
    .051       .04       .04
LCC_HEC_PR          83760.4*         .04      .059      .046       .03       .06
    .052       .04       .04
LCC_HEC_PR          83755.3*         .04       .06      .045       .03       .06
    .053       .04       .04
LCC_HEC_PR          83750.2*         .04       .06      .044       .03       .06
    .054       .04       .04
LCC_HEC_PR          83746.11         .04       .06       .03       .06       .04

LCC_HEC_PR          83553.53         .04       .06       .03       .06       .04

LCC_HEC_PR          83464.67         .04       .06       .03       .06       .04

LCC_HEC_PR          83249.52         .04       .06       .03       .06       .08

LCC_HEC_PR          83056.75         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          82834.61         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          82707.86         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          82506.13         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          82293.55         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          82049.29         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          81832.26         .04       .06       .03       .06       .04

LCC_HEC_PR          81500.63         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          81293.00         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          81028.44         .04       .06       .03       .06       .04
     .08
LCC_HEC_PR          80829.99         .08       .03       .08
```

LCC_HEC_PR	80200	.08	.03	.08

SUMMARY OF REACH LENGTHS

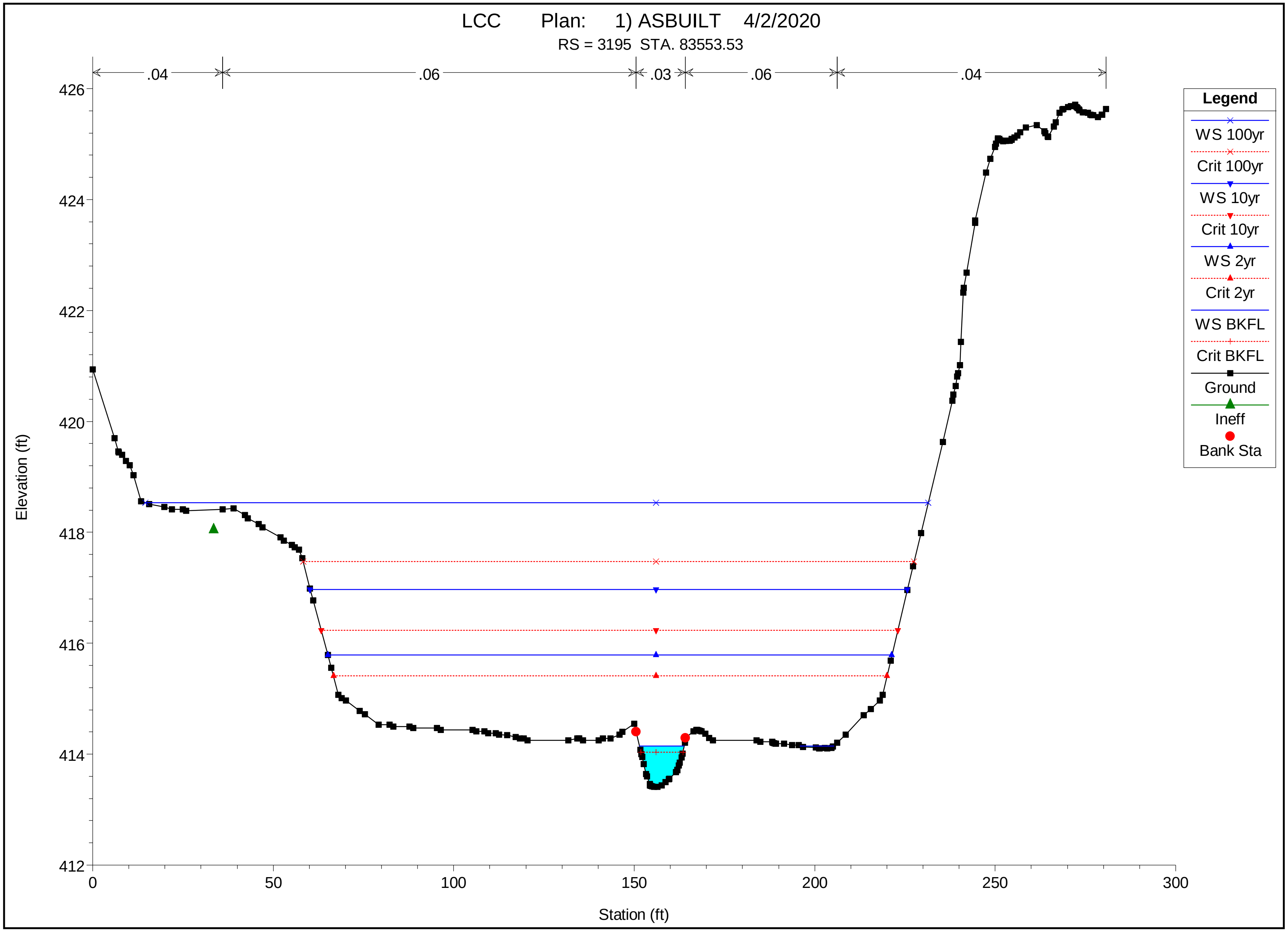
River: 99

Reach	River Sta.	Left	Channel	Right
LCC_HEC_PR	83952.77	132	68	44
LCC_HEC_PR	83884.32	53	63	57
LCC_HEC_PR	83880	Culvert		
LCC_HEC_PR	83821.78	1.22	5	5.74
LCC_HEC_PR	83816.6*	1.22	5	5.74
LCC_HEC_PR	83811.5*	1.22	5	5.74
LCC_HEC_PR	83806.4*	1.22	5	5.74
LCC_HEC_PR	83801.3*	1.22	5	5.74
LCC_HEC_PR	83796.2*	1.22	5	5.74
LCC_HEC_PR	83791.1*	1.22	5	5.74
LCC_HEC_PR	83785.9*	1.22	5	5.74
LCC_HEC_PR	83780.8*	1.22	5	5.74
LCC_HEC_PR	83775.7*	1.22	5	5.74
LCC_HEC_PR	83770.6*	1.22	5	5.74
LCC_HEC_PR	83765.5*	1.22	5	5.74
LCC_HEC_PR	83760.4*	1.22	5	5.74
LCC_HEC_PR	83755.3*	1.22	5	5.74
LCC_HEC_PR	83750.2*	.97	4	4.59
LCC_HEC_PR	83746.11	187	176	212
LCC_HEC_PR	83553.53	82	75	72
LCC_HEC_PR	83464.67	207	167	163
LCC_HEC_PR	83249.52	176	172	173
LCC_HEC_PR	83056.75	187	184	185
LCC_HEC_PR	82834.61	117	117	117
LCC_HEC_PR	82707.86	155	159	157
LCC_HEC_PR	82506.13	182	175	175
LCC_HEC_PR	82293.55	213	211	211
LCC_HEC_PR	82049.29	164	164	165
LCC_HEC_PR	81832.26	262	263	263
LCC_HEC_PR	81500.63	169	166	166
LCC_HEC_PR	81293.00	203	215	231
LCC_HEC_PR	81028.44	174	184	200
LCC_HEC_PR	80829.99	637	630	615
LCC_HEC_PR	80200	0	0	0

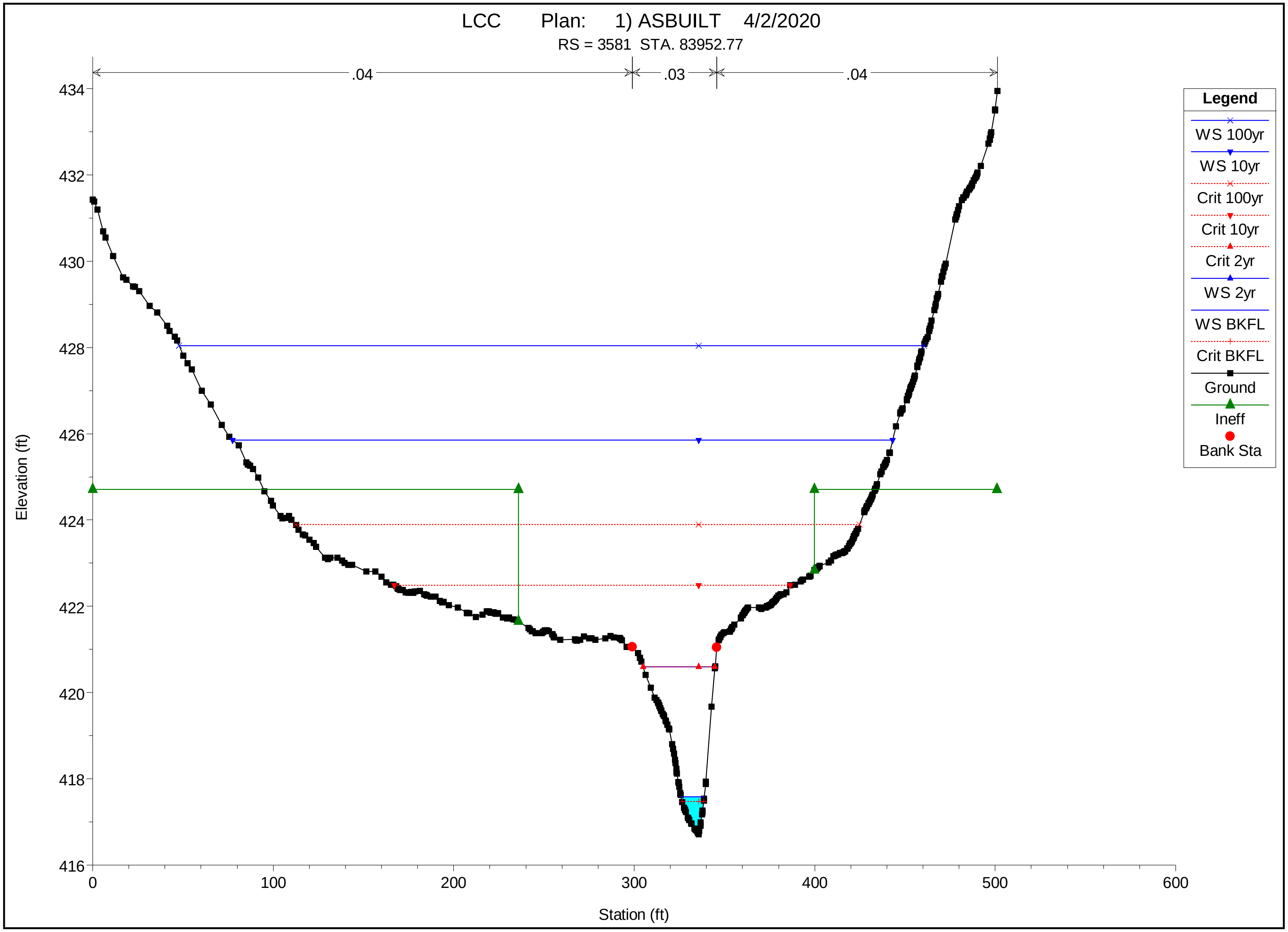
SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: 99

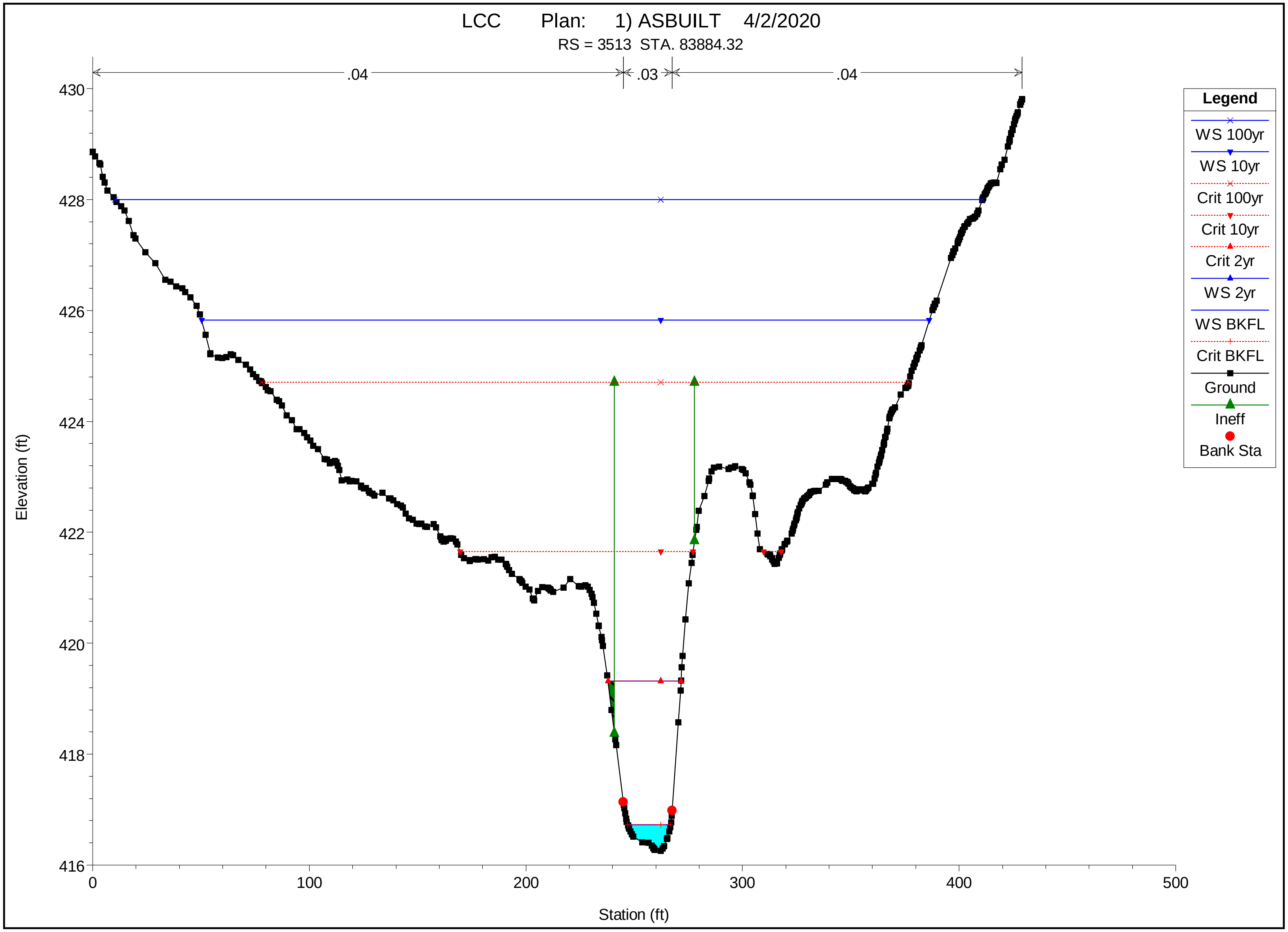
Reach	River Sta.	Contr.	Expan.
LCC_HEC_PR	83952.77	.1	.3
LCC_HEC_PR	83884.32	.1	.3
LCC_HEC_PR	83880	Culvert	
LCC_HEC_PR	83821.78	.3	.5
LCC_HEC_PR	83816.6*	.3	.5
LCC_HEC_PR	83811.5*	.3	.5
LCC_HEC_PR	83806.4*	.3	.5
LCC_HEC_PR	83801.3*	.3	.5
LCC_HEC_PR	83796.2*	.3	.5
LCC_HEC_PR	83791.1*	.3	.5
LCC_HEC_PR	83785.9*	.3	.5
LCC_HEC_PR	83780.8*	.3	.5
LCC_HEC_PR	83775.7*	.3	.5
LCC_HEC_PR	83770.6*	.3	.5
LCC_HEC_PR	83765.5*	.3	.5
LCC_HEC_PR	83760.4*	.3	.5
LCC_HEC_PR	83755.3*	.3	.5
LCC_HEC_PR	83750.2*	.3	.5
LCC_HEC_PR	83746.11	.3	.5
LCC_HEC_PR	83553.53	.1	.3
LCC_HEC_PR	83464.67	.1	.3
LCC_HEC_PR	83249.52	.1	.3
LCC_HEC_PR	83056.75	.1	.3
LCC_HEC_PR	82834.61	.1	.3
LCC_HEC_PR	82707.86	.1	.3
LCC_HEC_PR	82506.13	.1	.3
LCC_HEC_PR	82293.55	.1	.3
LCC_HEC_PR	82049.29	.1	.3
LCC_HEC_PR	81832.26	.1	.3
LCC_HEC_PR	81500.63	.1	.3
LCC_HEC_PR	81293.00	.1	.3
LCC_HEC_PR	81028.44	.1	.3
LCC_HEC_PR	80829.99	.1	.3
LCC_HEC_PR	80200	.1	.3

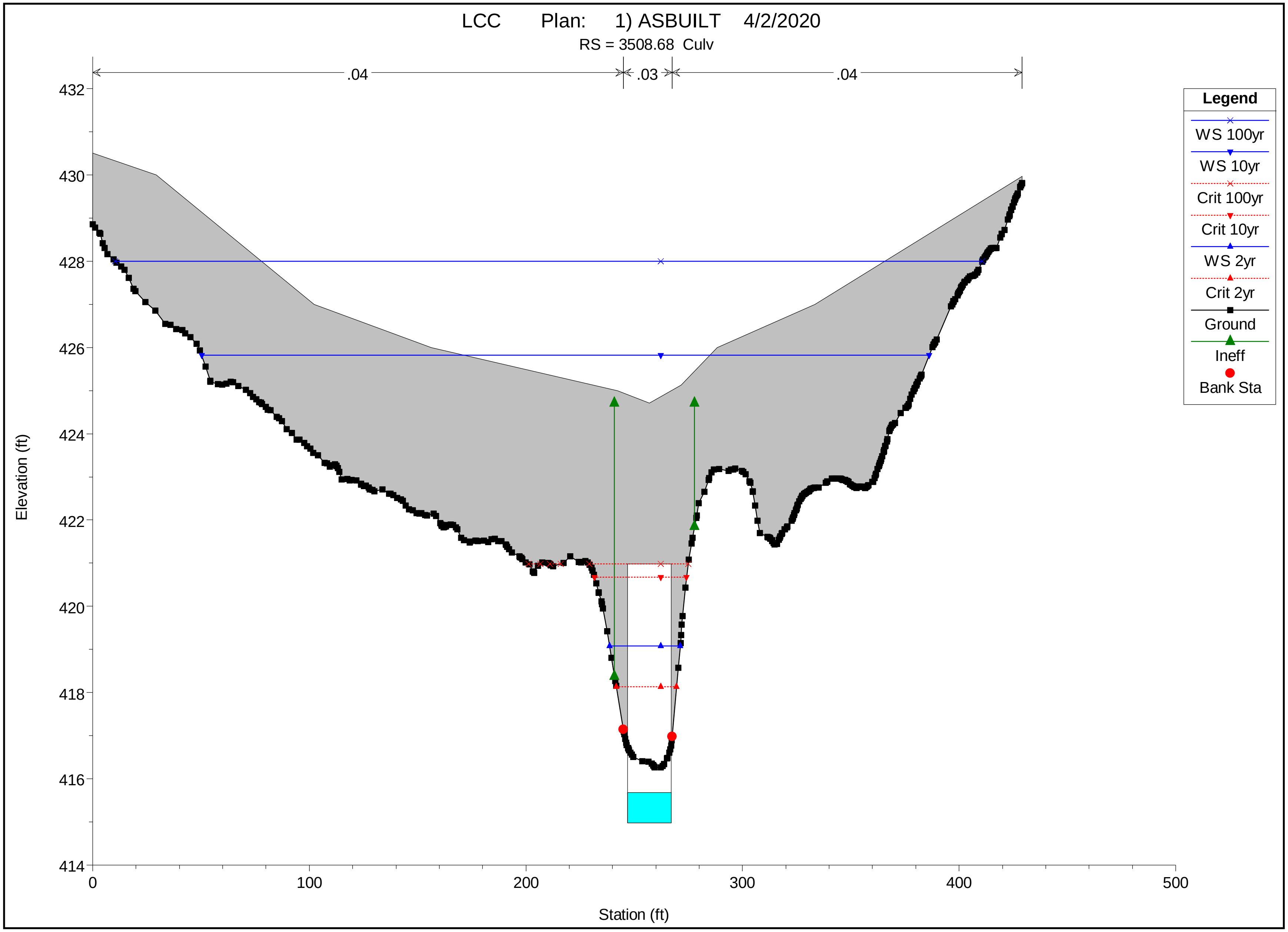
HECRAS CROSS SECTIONS



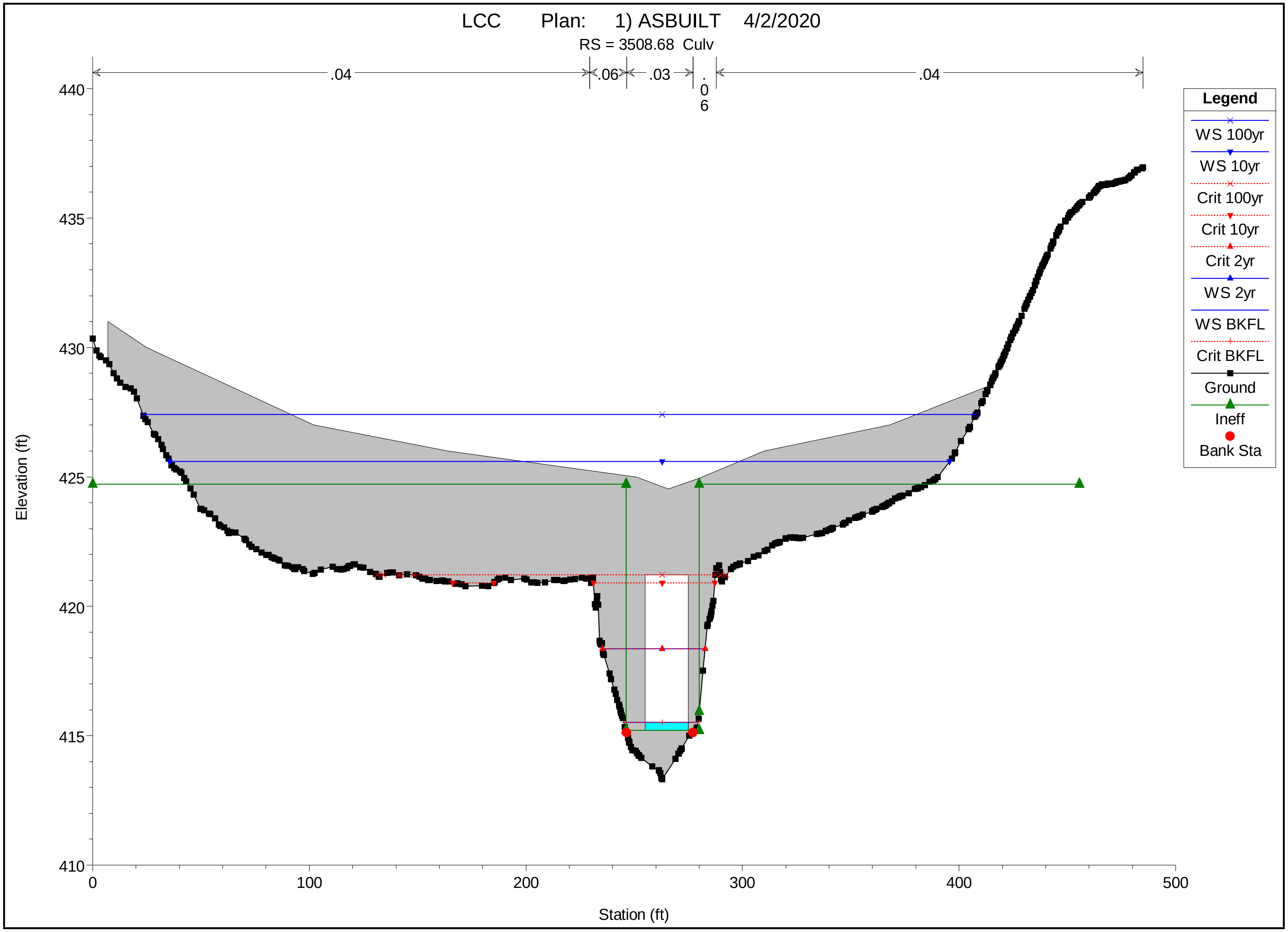
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3195 STA. 83553.53
.04
.06
.03
.06
.04
Elevation (ft)
426
424
422
420
418
416
414
412
0
50
100
150
200
250
300
Station (ft)
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Ineff
Bank Sta

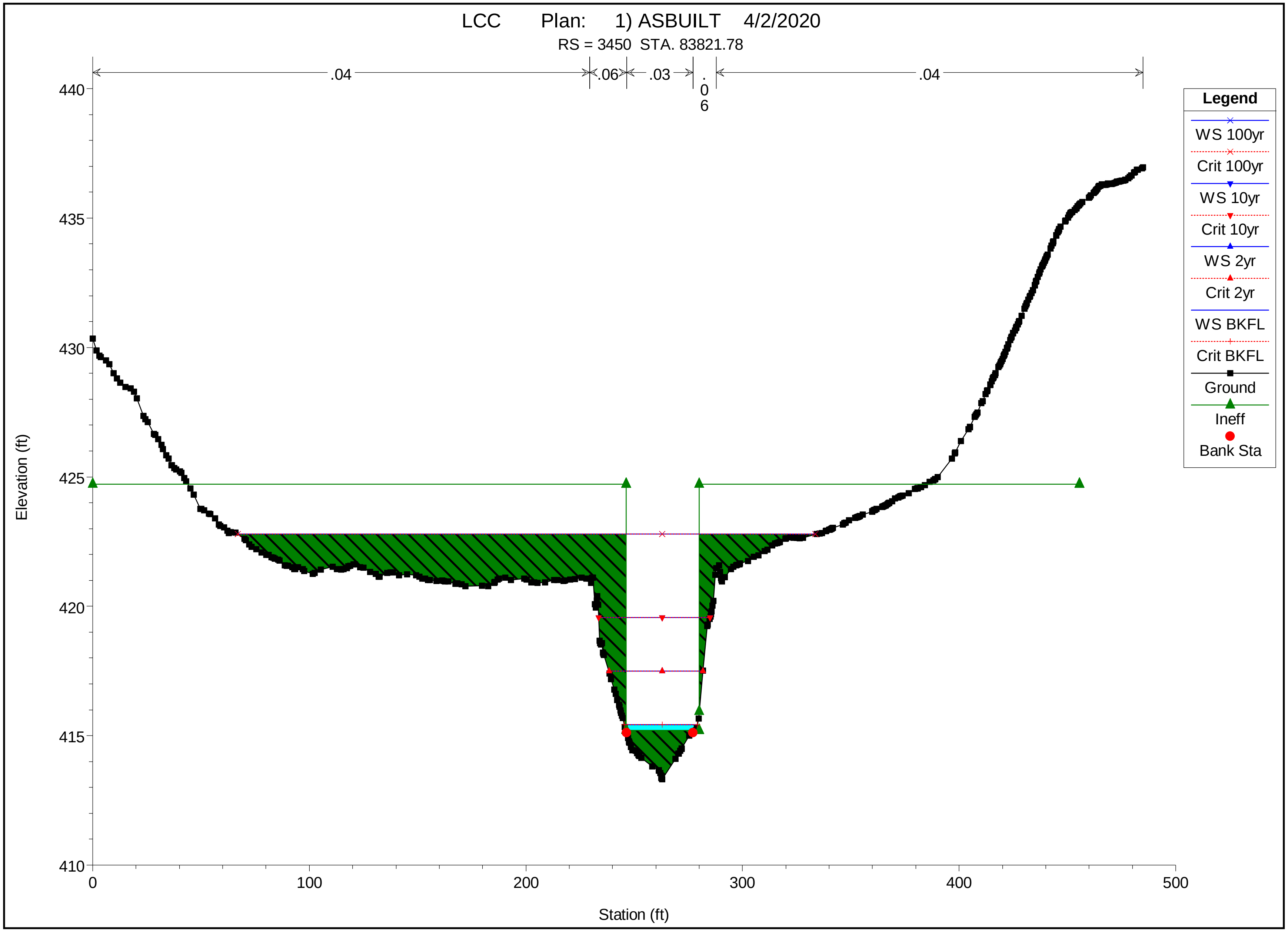

LCC Plan: 1) ASBUILT 4/2/2020
RS = 3581 STA. 83952.77
.04
.03
.04
Elevation (ft)
Station (ft)
434
432
430
428
426
424
422
420
418
416
0
100
200
300
400
500
600
Legend
WS 100yr
WS 10yr
Crit 100yr
Crit 10yr
Crit 2yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Ineff
Bank Sta


LCC Plan: 1) ASBUILT 4/2/2020
RS = 3513 STA. 83884.32
.04
.03
.04
Legend
WS 100yr
WS 10yr
Crit 100yr
Crit 10yr
Crit 2yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
430
428
426
424
422
420
418
416
0
100
200
300
400
500



LCC Plan: 1) ASBUILT 4/2/2020
RS = 3508.68 Culv
.04
.03
.04
Legend
WS 100yr
WS 10yr
Crit 100yr
Crit 10yr
WS 2yr
Crit 2yr
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
432
430
428
426
424
422
420
418
416
414
0
100
200
300
400
500


LCC Plan: 1) ASBUILT 4/2/2020
RS = 3508.68 Culv
.04
.06
.03
.06
.04
Legend
WS 100yr
WS 10yr
Crit 100yr
Crit 10yr
Crit 2yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
410
415
420
425
430
435
440
0
100
200
300
400
500


LCC Plan: 1) ASBUILT 4/2/2020
RS = 3450 STA. 83821.78
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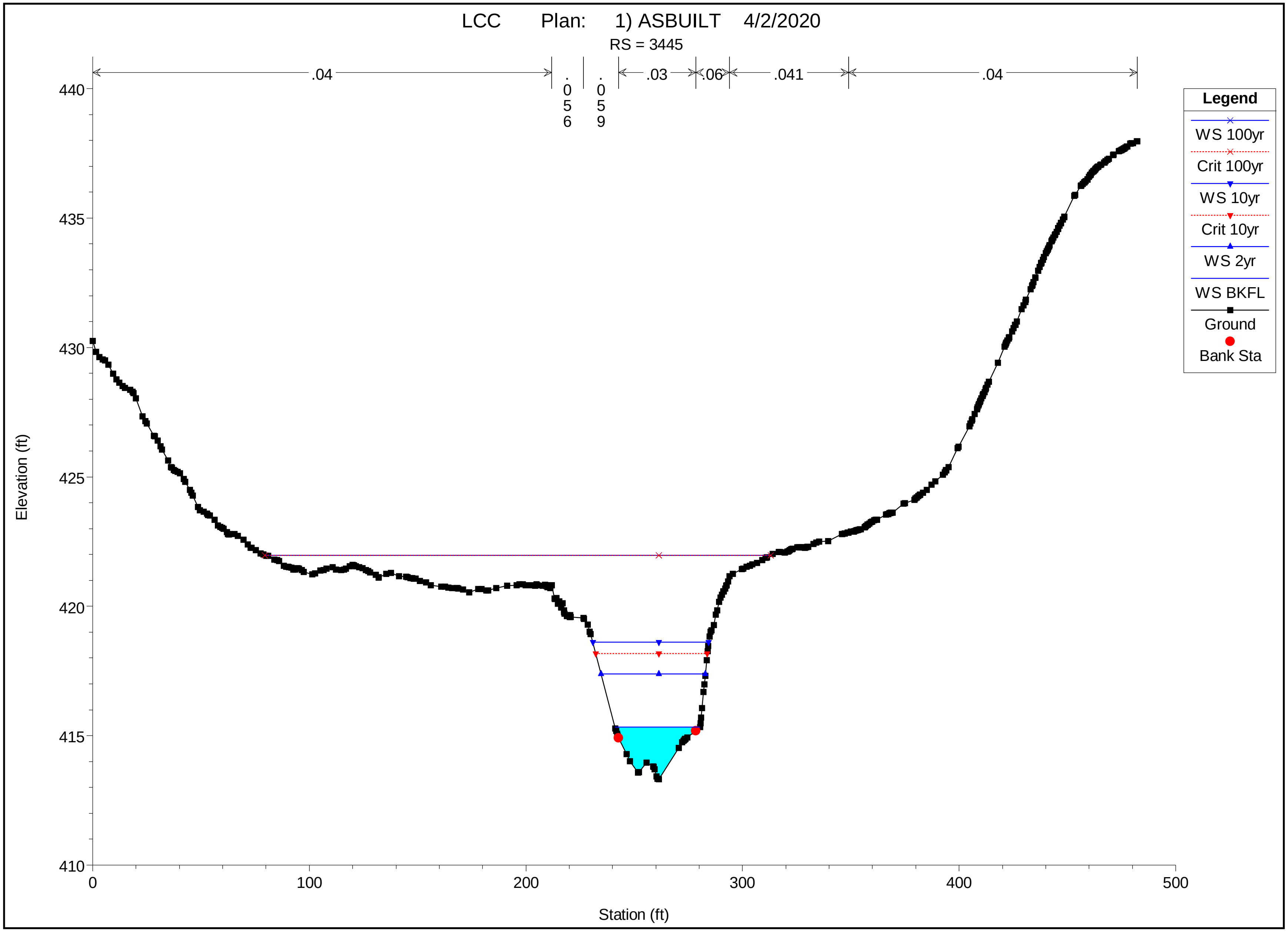
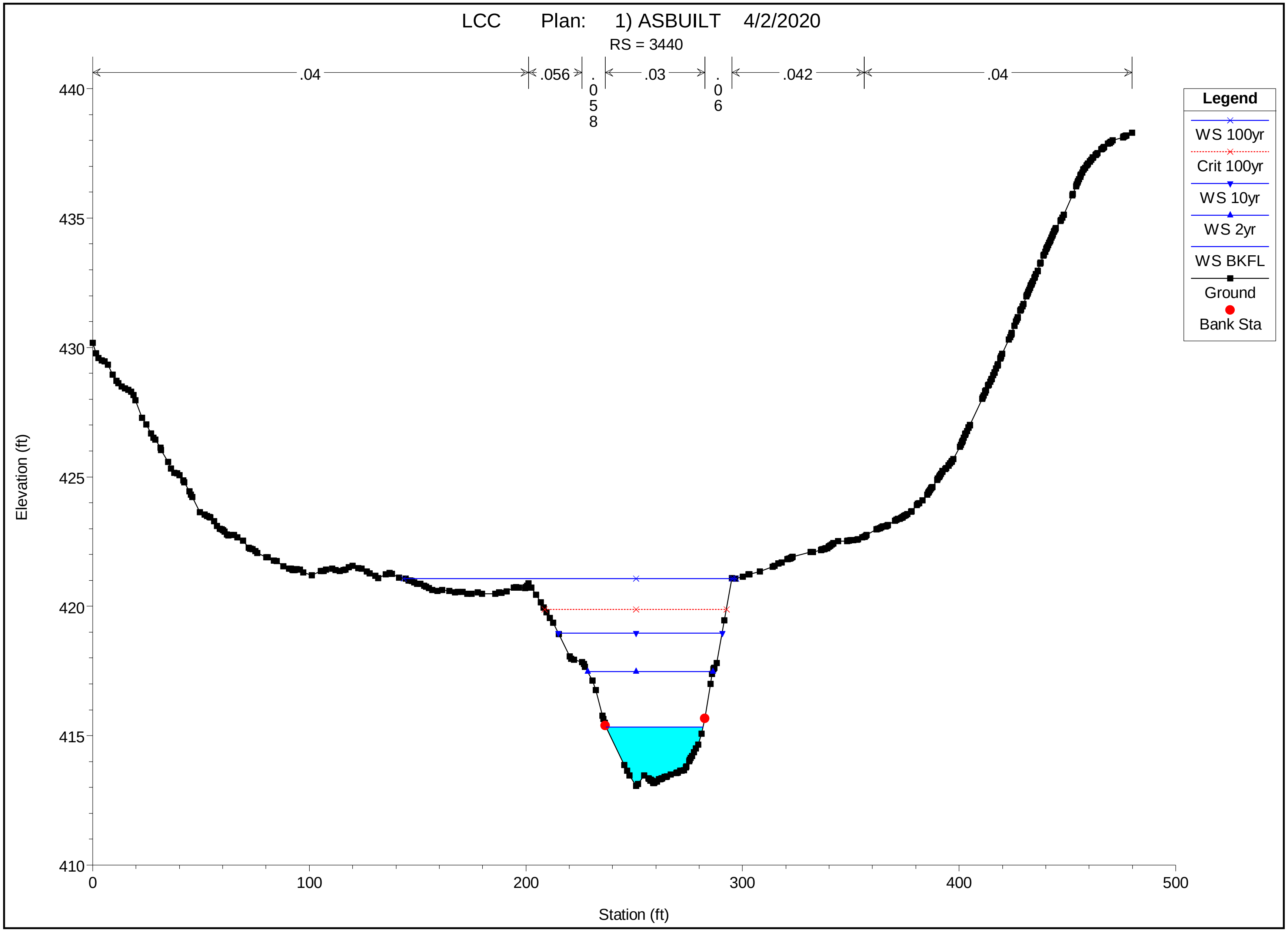
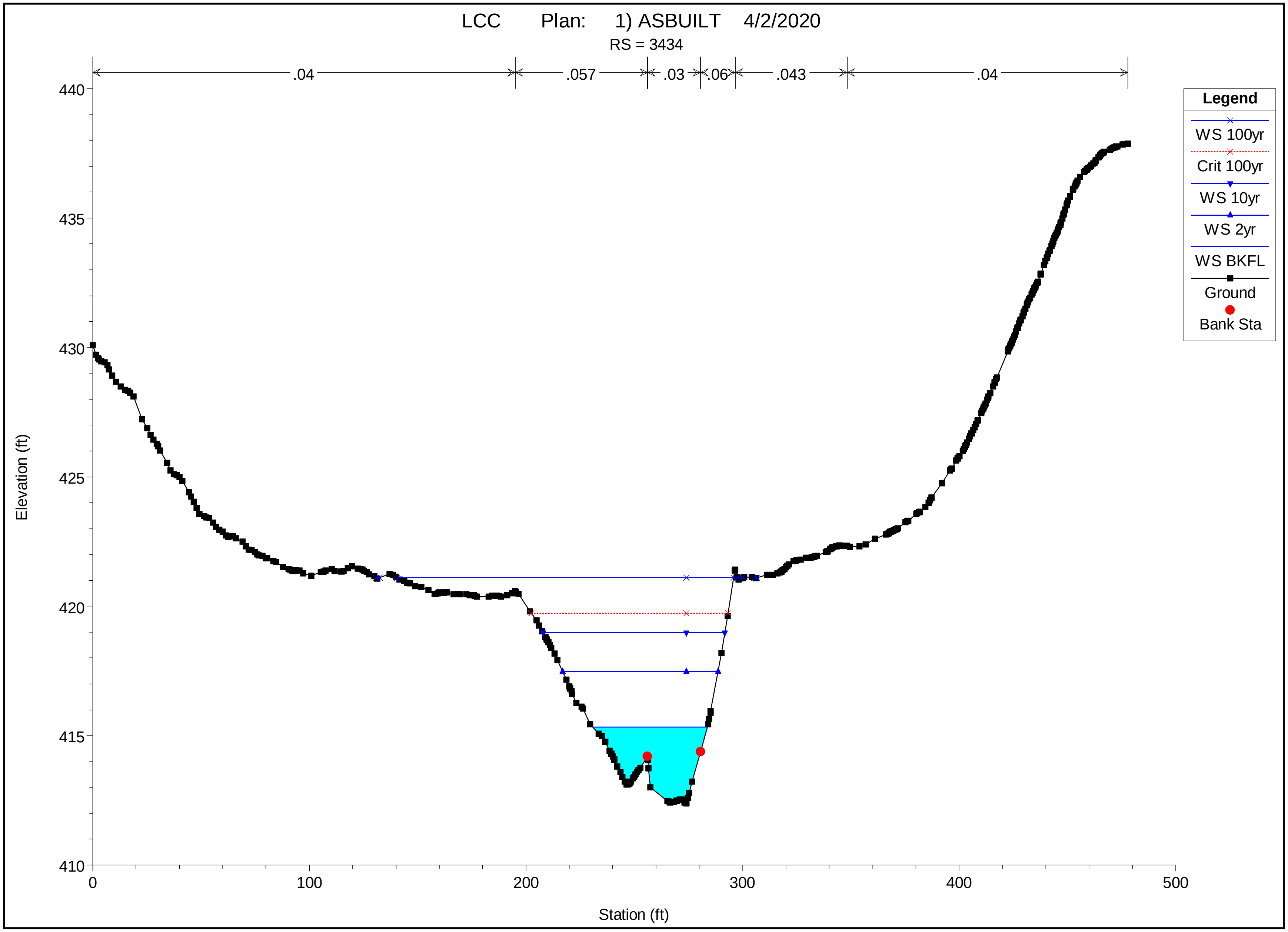
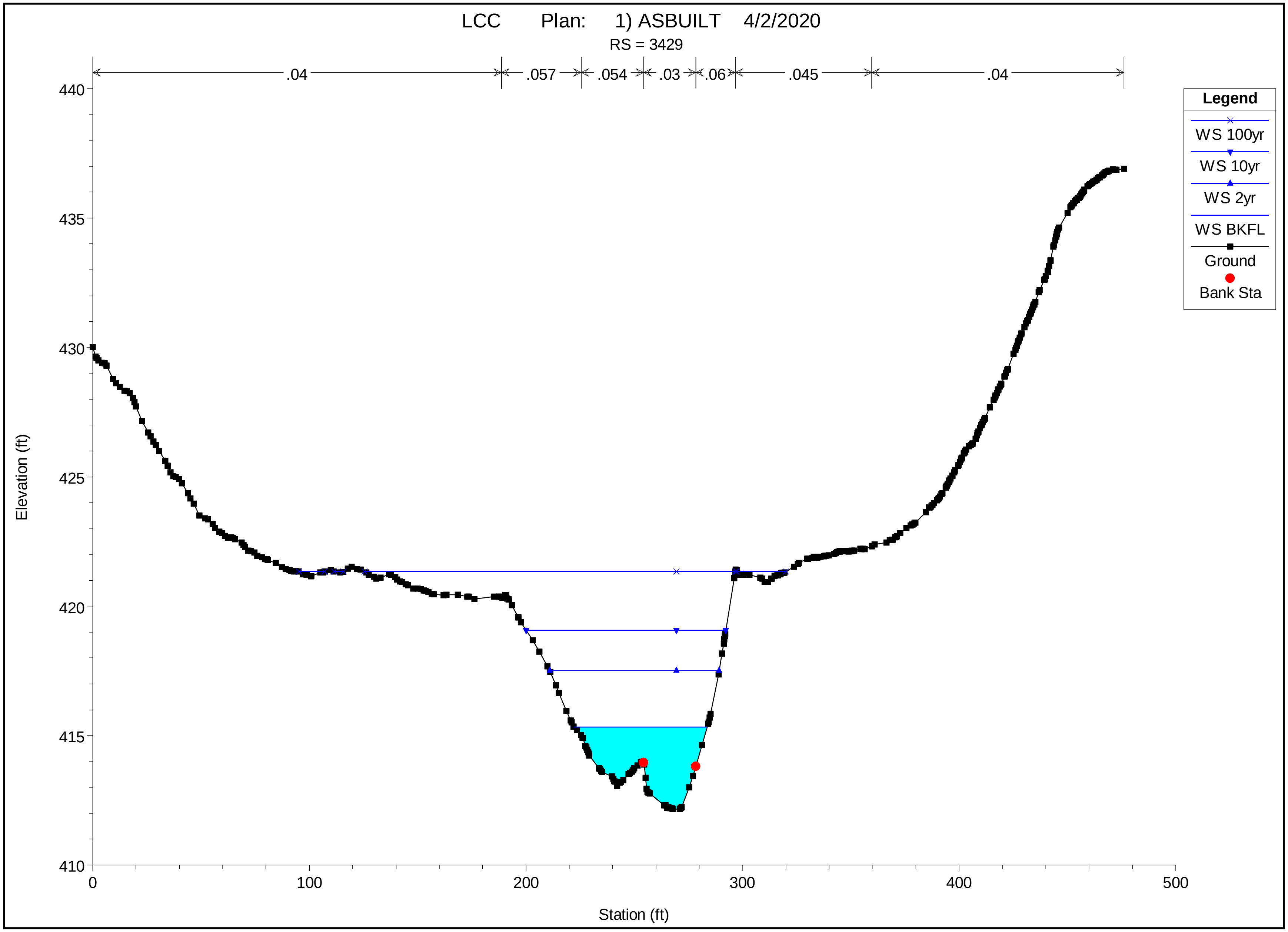
.06
.03
.06
.04
Elevation (ft)
Station (ft)
410
415
420
425
430
435
440
0
100
200
300
400
500
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Ineff
Bank Sta

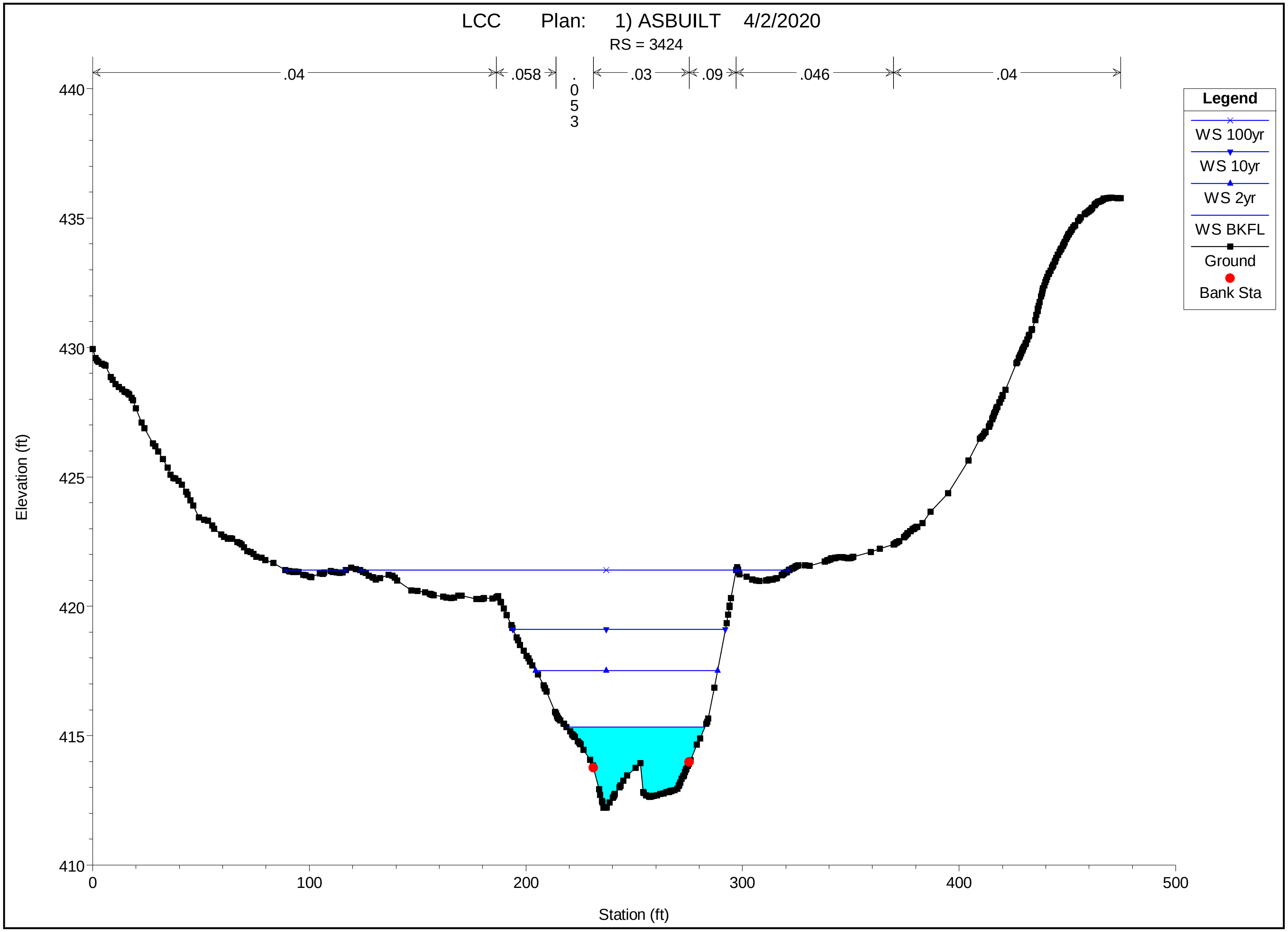

LCC Plan: 1) ASBUILT 4/2/2020
RS = 3445
.04
.056
.059
.03
.06
.041
.04
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
410
415
420
425
430
435
440
0
100
200
300
400
500



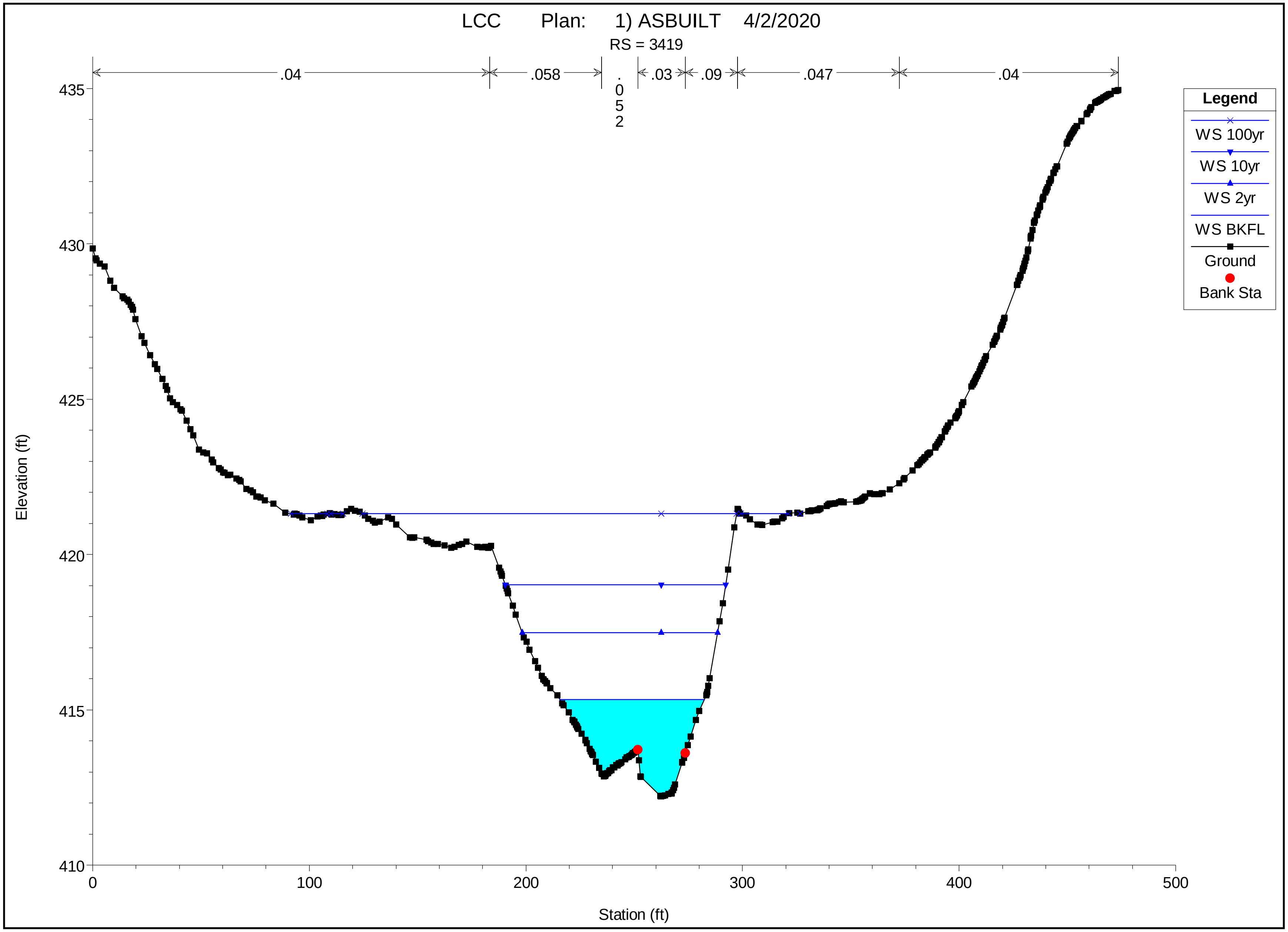
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3440
.04
.056
.058
.03
.06
.042
.04
Legend
WS 100yr
Crit 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
440
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)


LCC Plan: 1) ASBUILT 4/2/2020
RS = 3434
.04
.057
.03
.06
.043
.04
Legend
WS 100yr
Crit 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
440
435
430
425
420
415
410
0
100
200
300
400
500

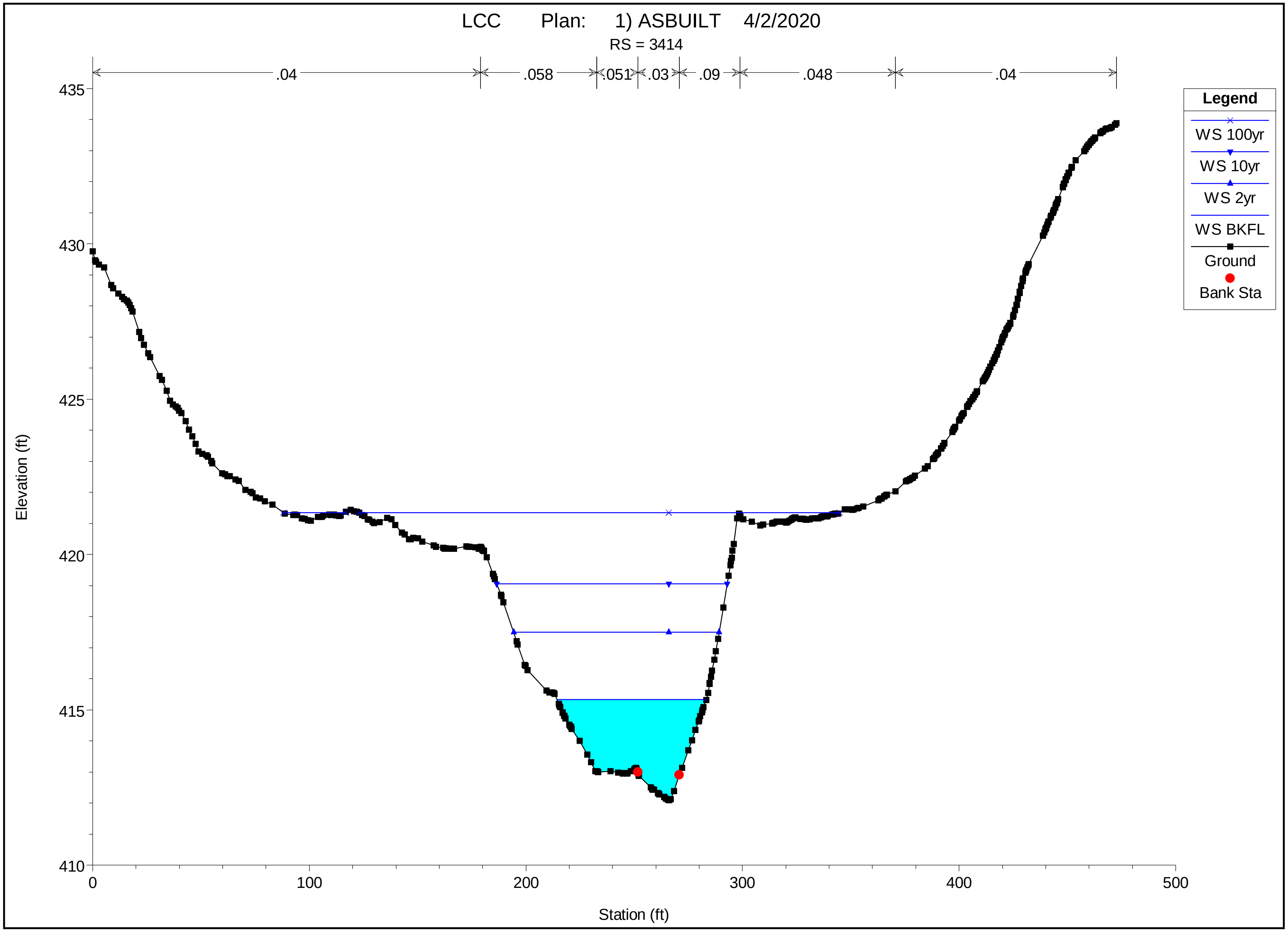

LCC Plan: 1) ASBUILT 4/2/2020
RS = 3429
.04
.057
.054
.03
.06
.045
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
440
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)



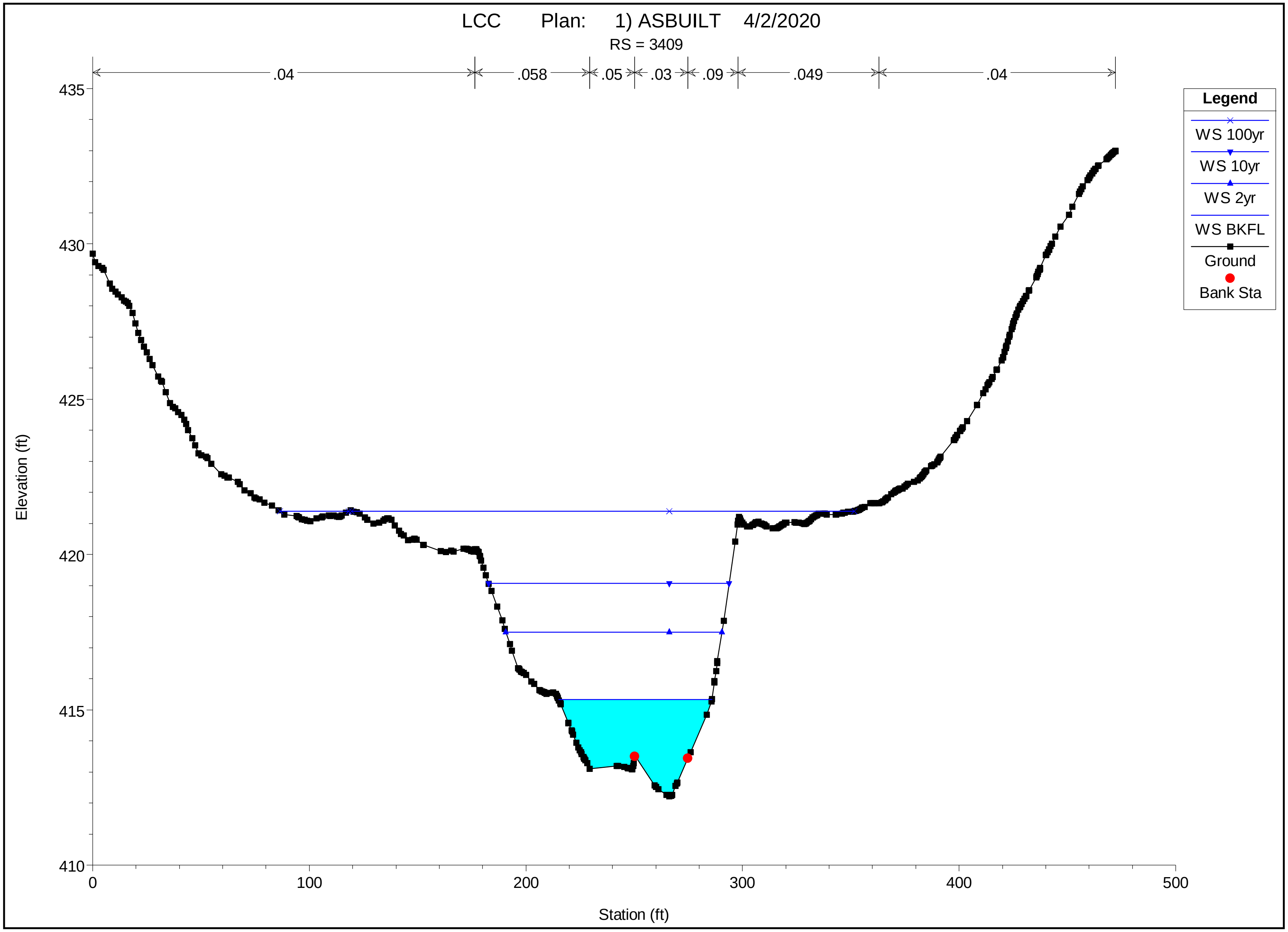
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3424
.04
.058
.053
.03
.09
.046
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
440
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)



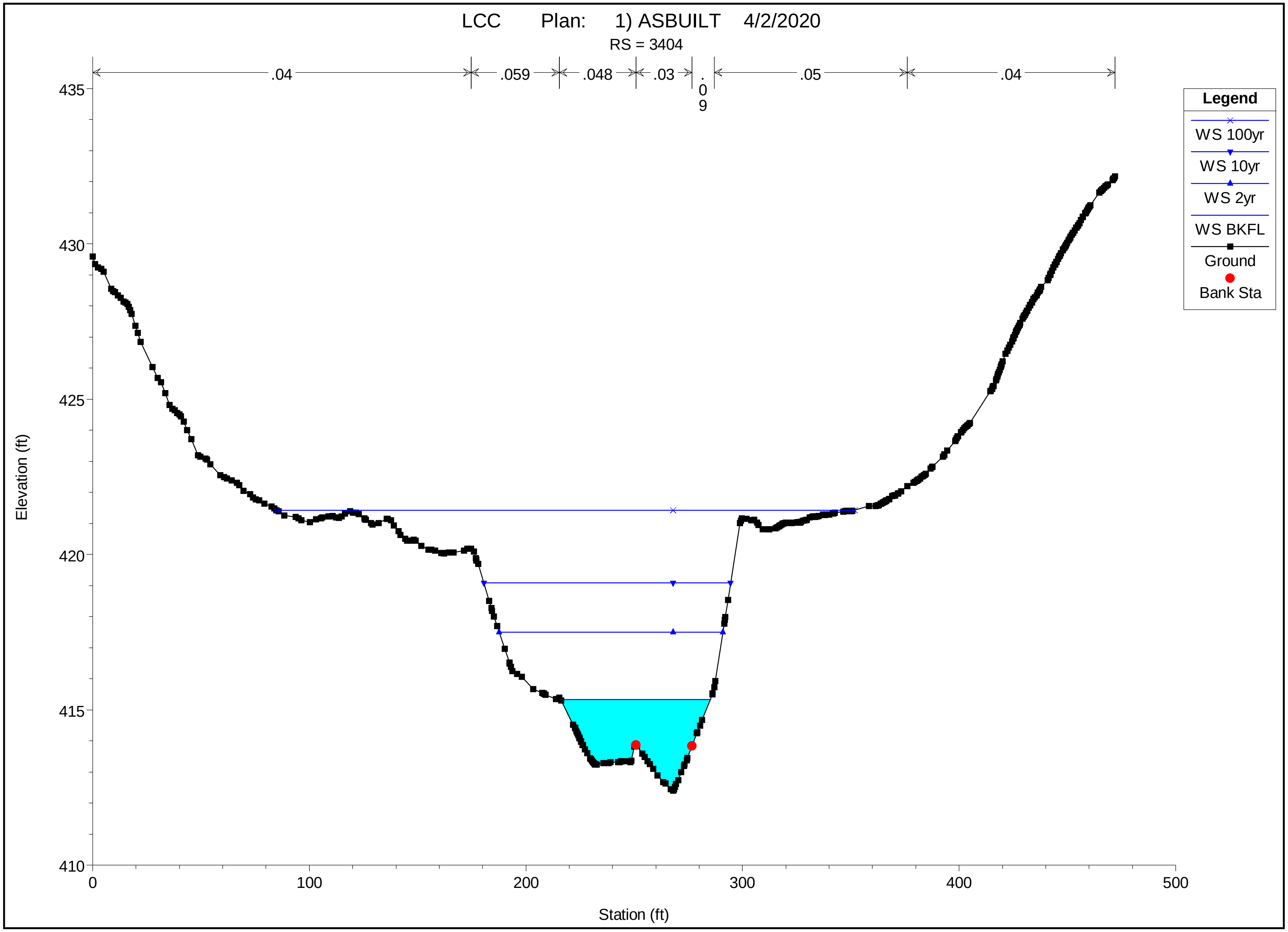
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3419
.04
.058
.052
.03
.09
.047
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)



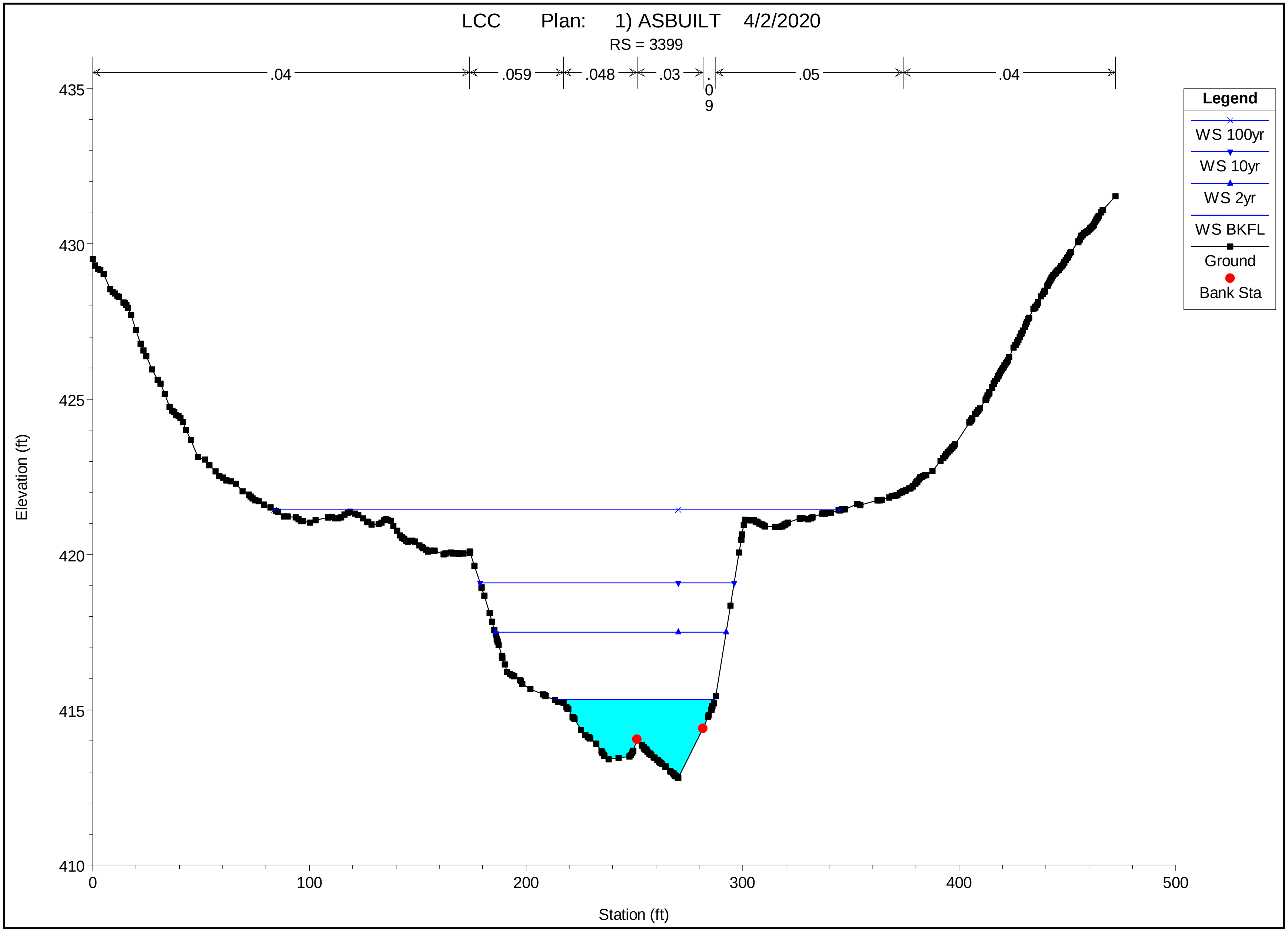
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3414
.04
.058
.051
.03
.09
.048
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
435
430
425
420
415
410
0
100
200
300
400
500
Elevation (ft)
Station (ft)



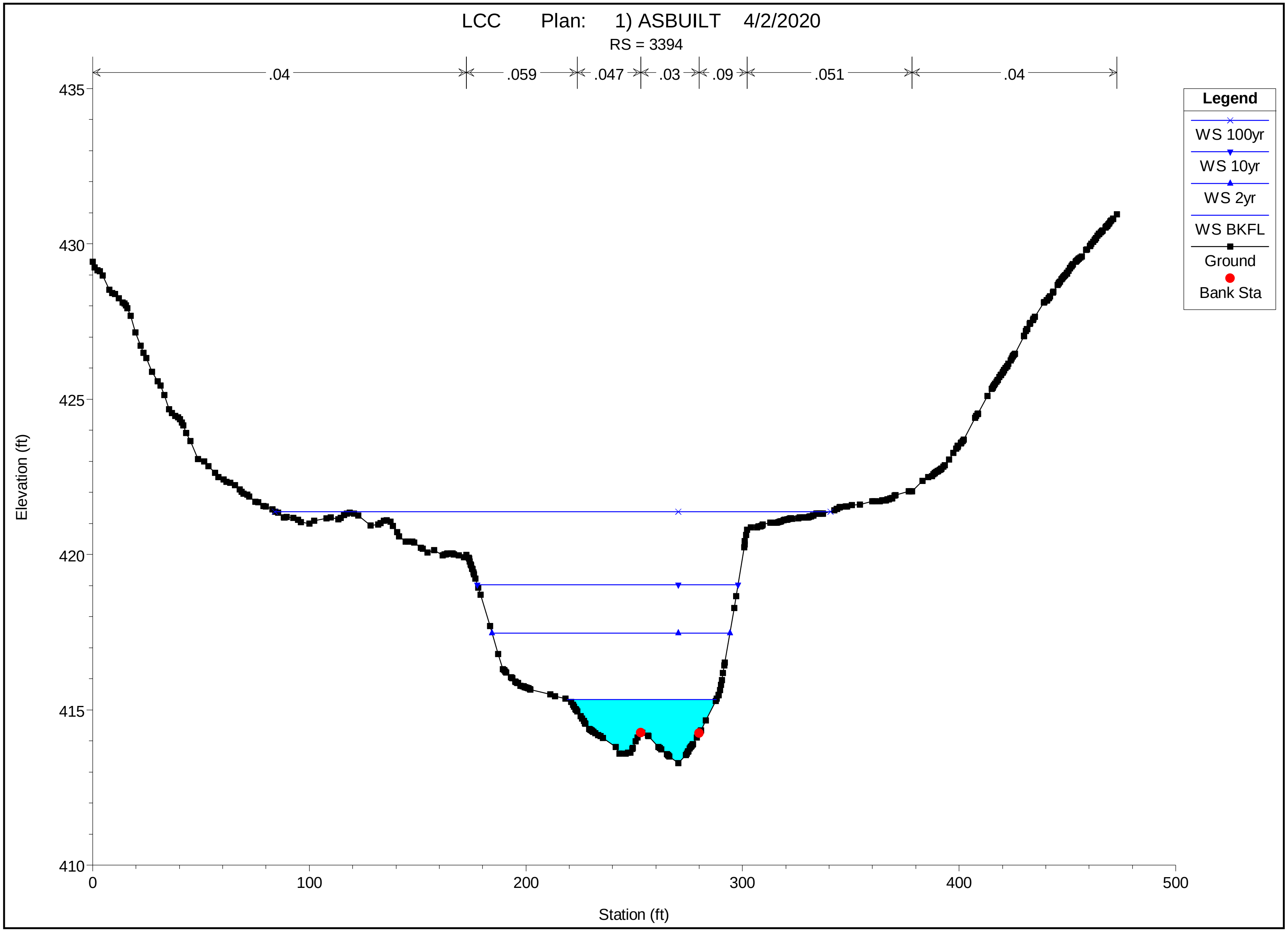
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3409
.04
.058
.05
.03
.09
.049
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)



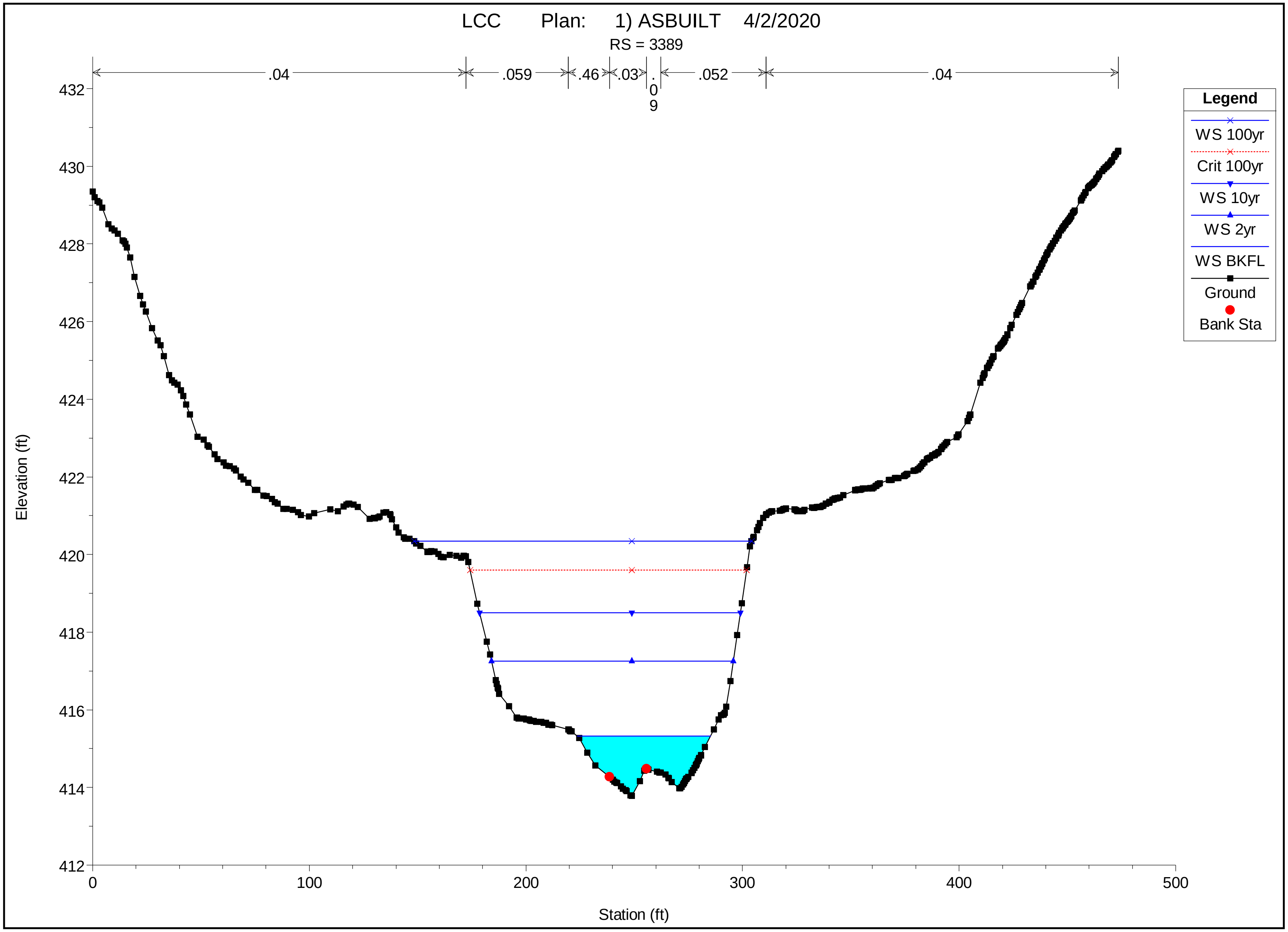
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3404
.04
.059
.048
.03
.09
.05
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)



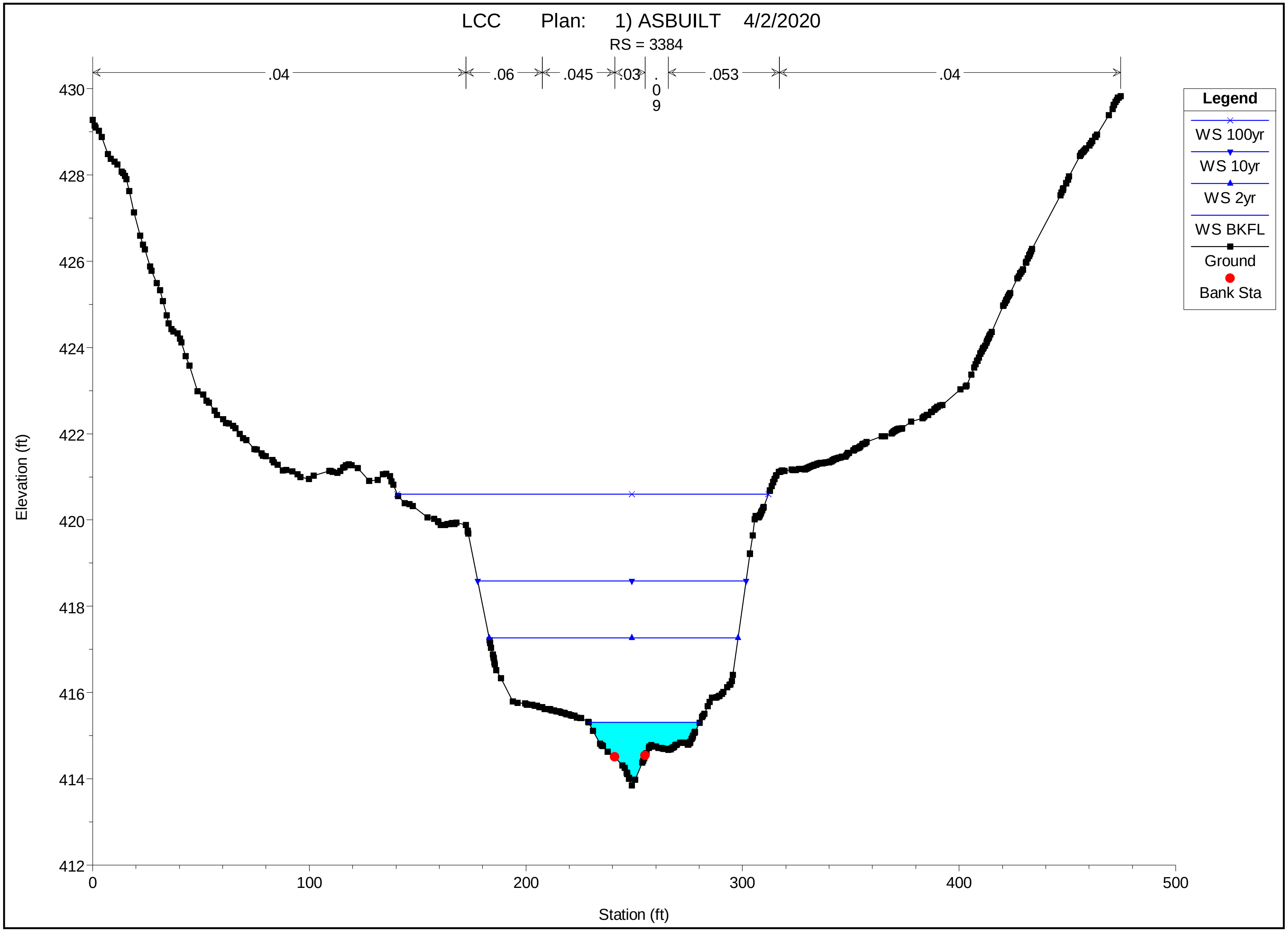
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3399
.04
.059
.048
.03
.
0
9
.05
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)



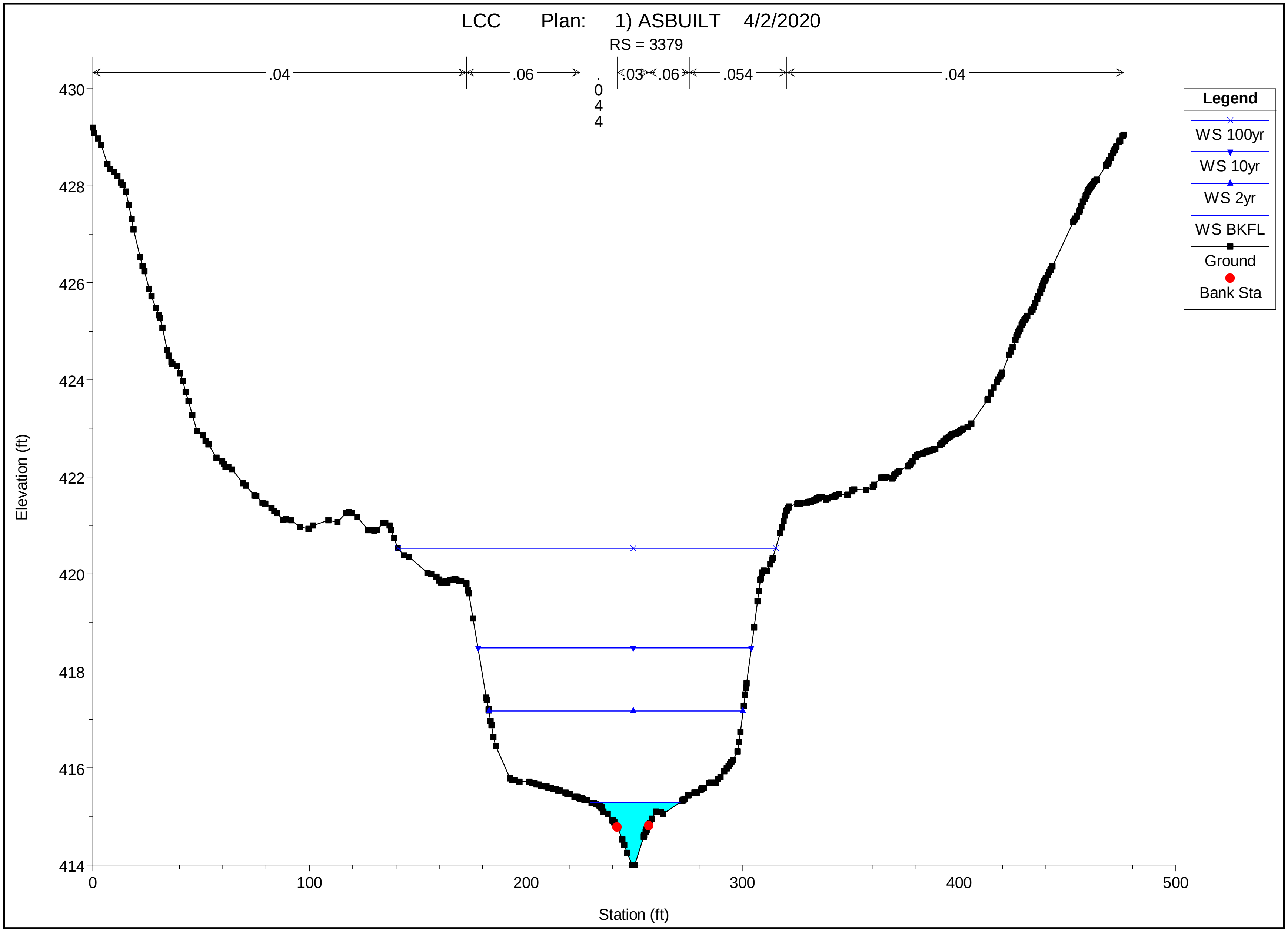
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3394
.04
.059
.047
.03
.09
.051
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
435
430
425
420
415
410
0
100
200
300
400
500
Station (ft)

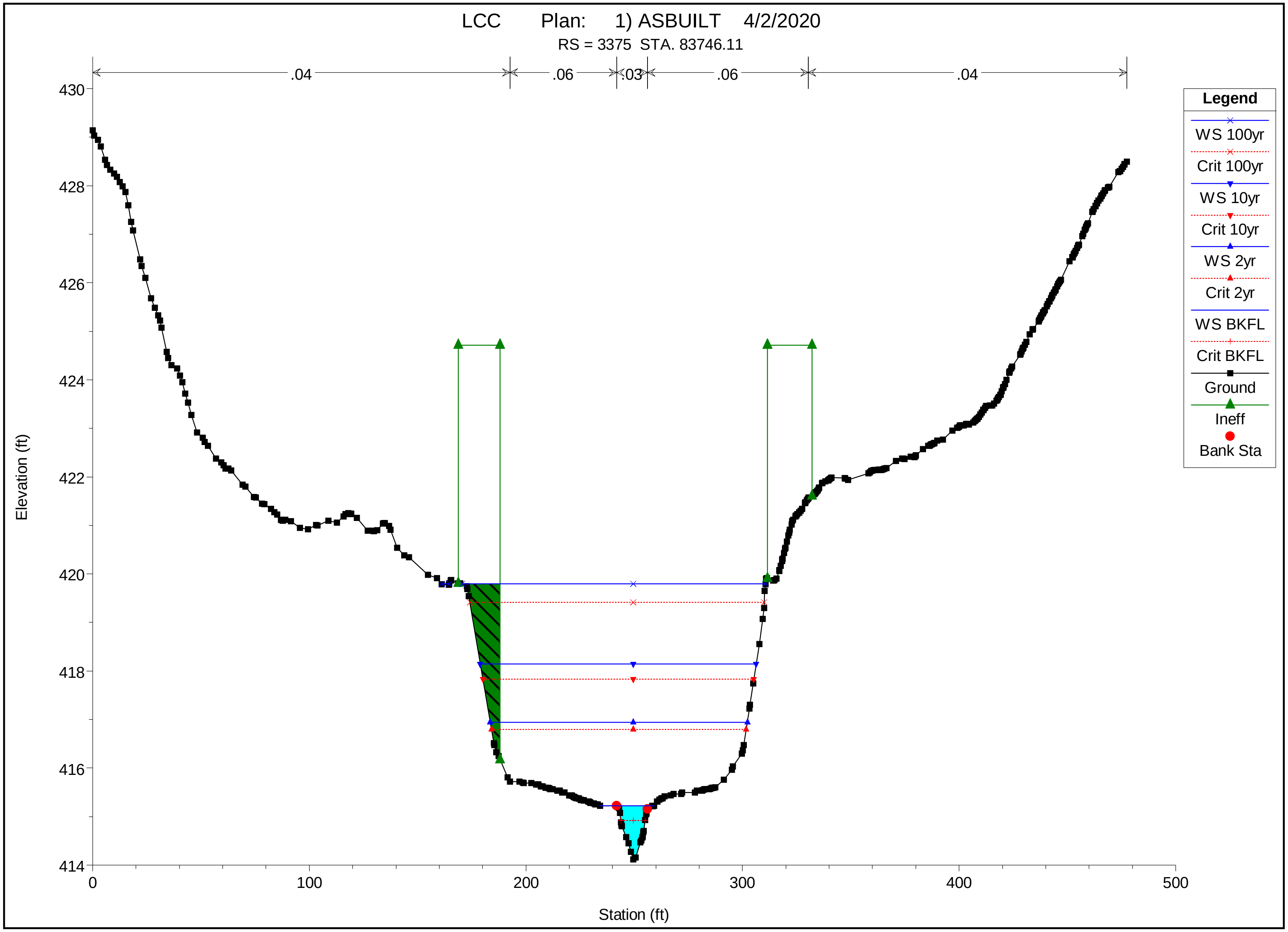


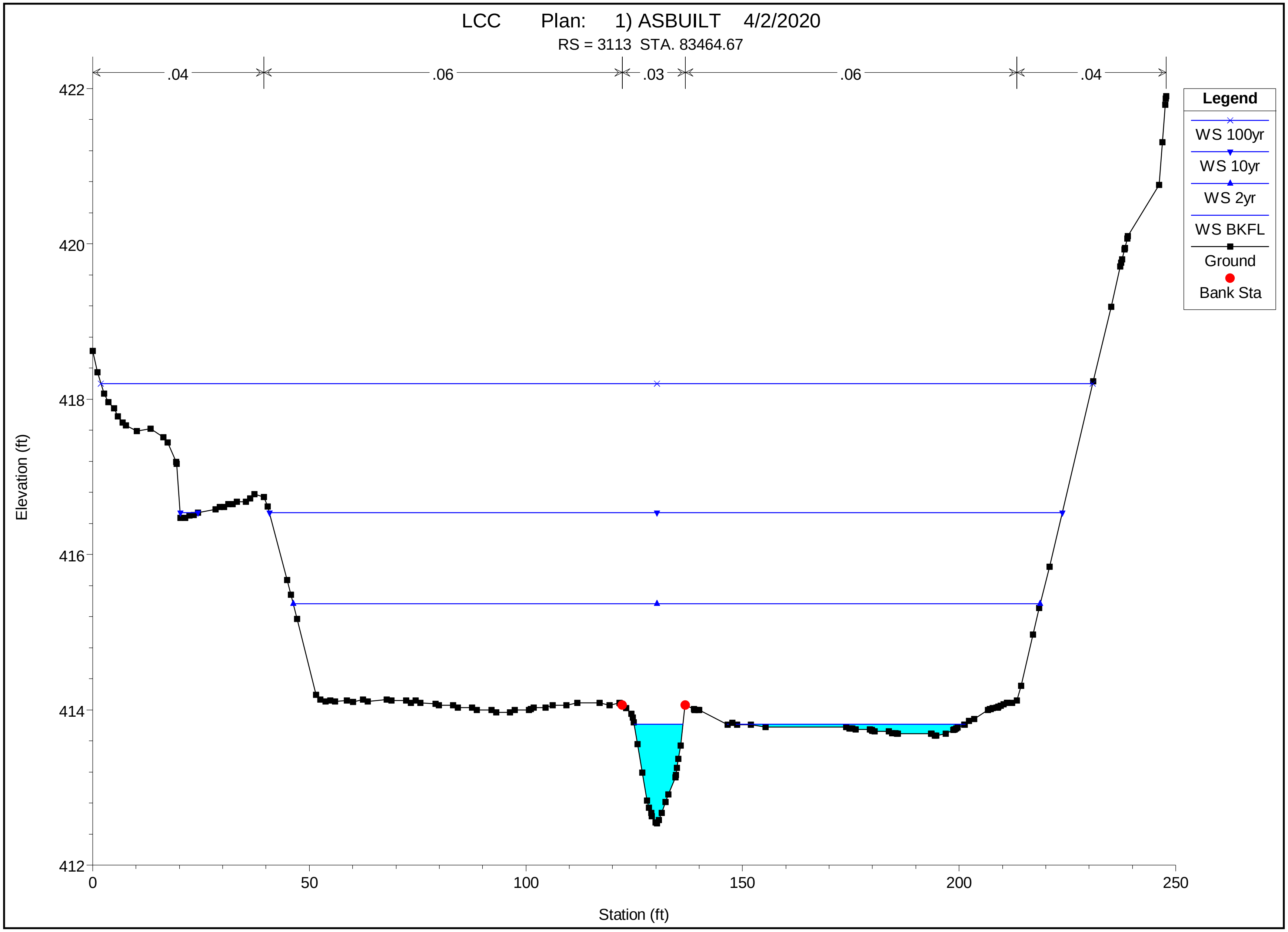
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3389
.04
.059
.46
.03
.09
.052
.04
Legend
WS 100yr
Crit 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
412
414
416
418
420
422
424
426
428
430
432
0
100
200
300
400
500
Station (ft)



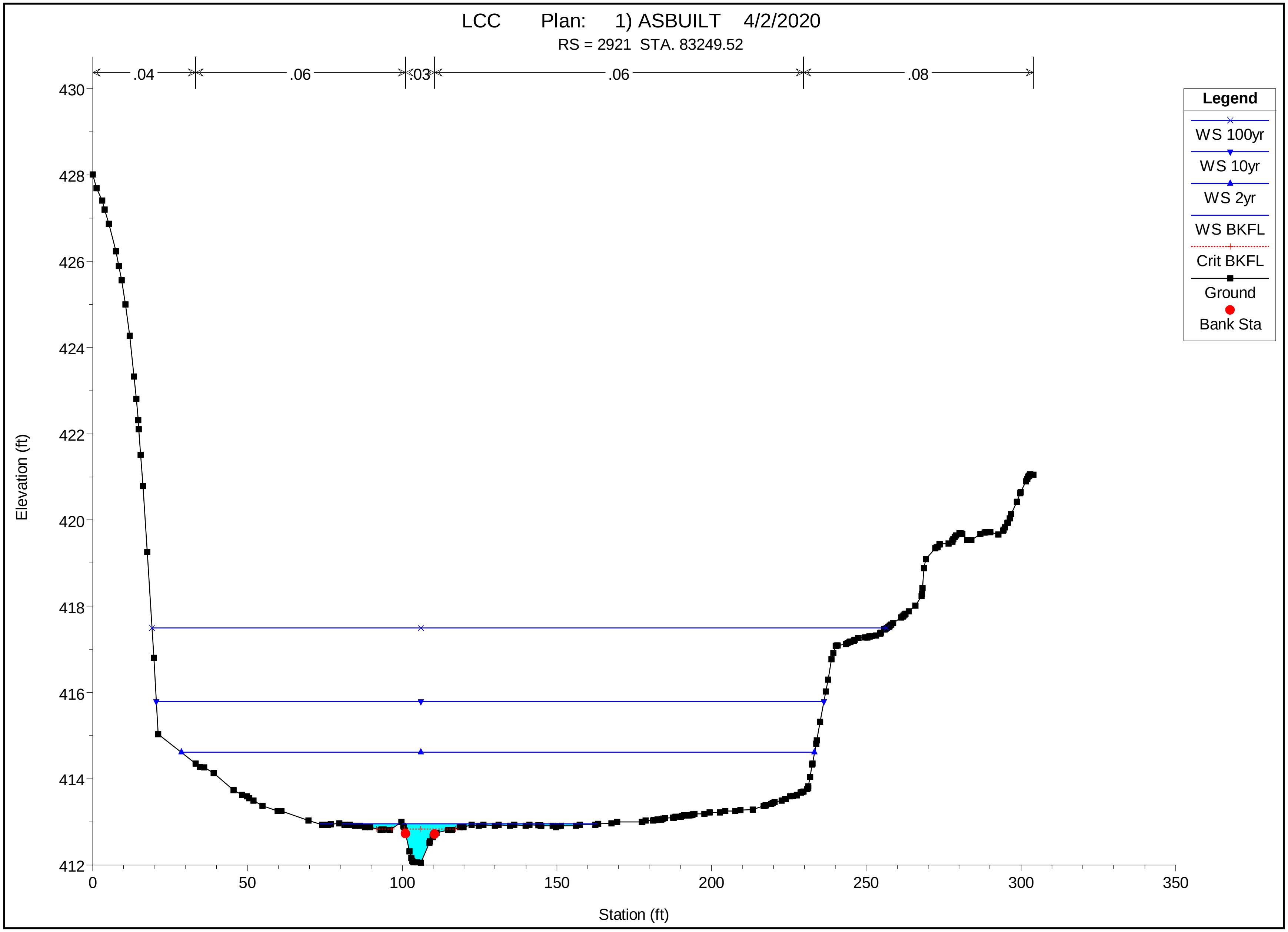
LCC Plan: 1) ASBUILT 4/2/2020
RS = 3384
.04
.06
.045
.03
.09
.053
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
430
428
426
424
422
420
418
416
414
412
0
100
200
300
400
500


LCC Plan: 1) ASBUILT 4/2/2020
RS = 3379
.04
.06
.044
.03
.06
.054
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
430
428
426
424
422
420
418
416
414
0
100
200
300
400
500
Station (ft)

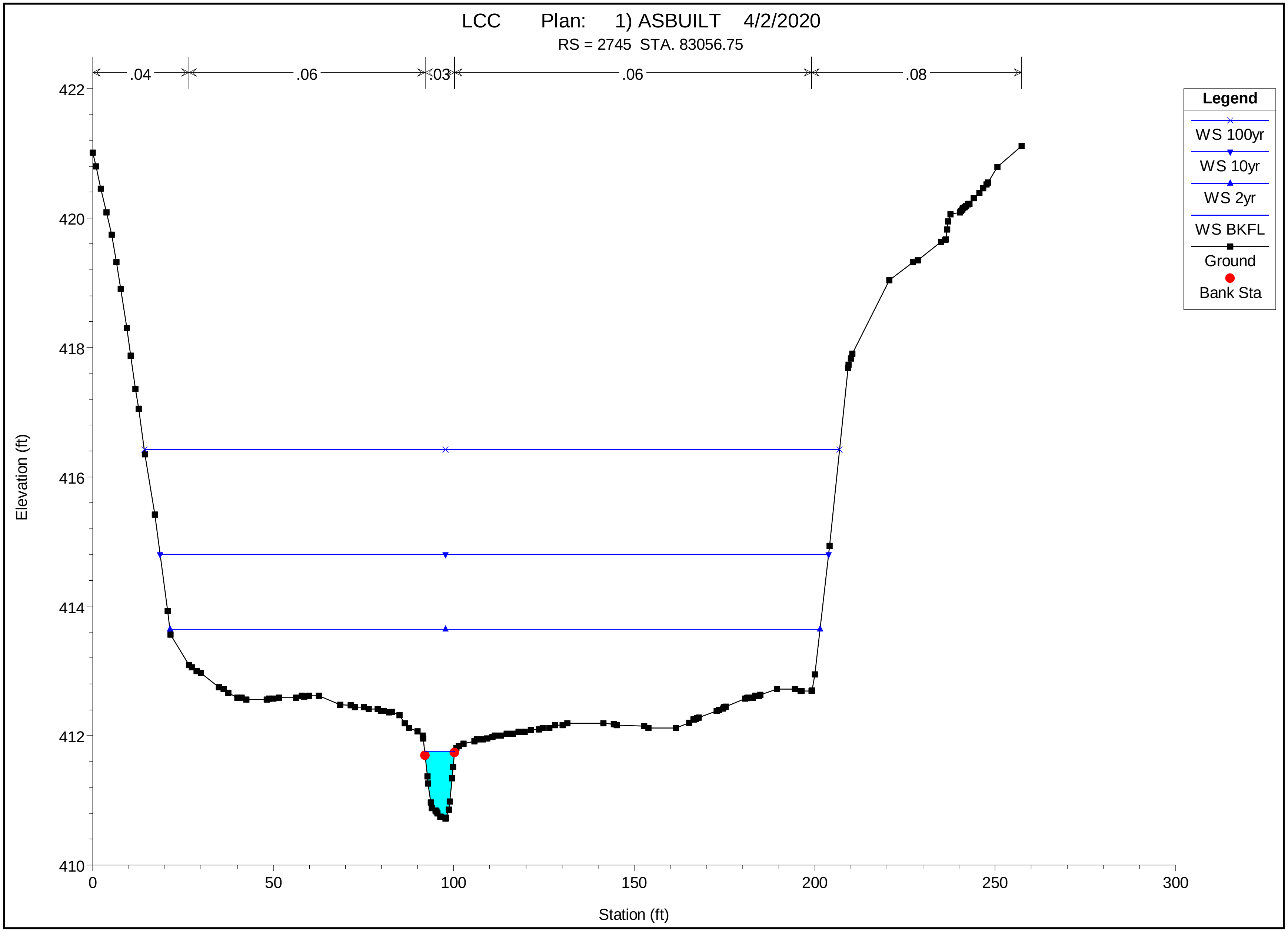

LCC Plan: 1) ASBUILT 4/2/2020
RS = 3375 STA. 83746.11
.04
.06
.03
.06
.04
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Ineff
Bank Sta
Elevation (ft)
430
428
426
424
422
420
418
416
414
0
100
200
300
400
500
Station (ft)

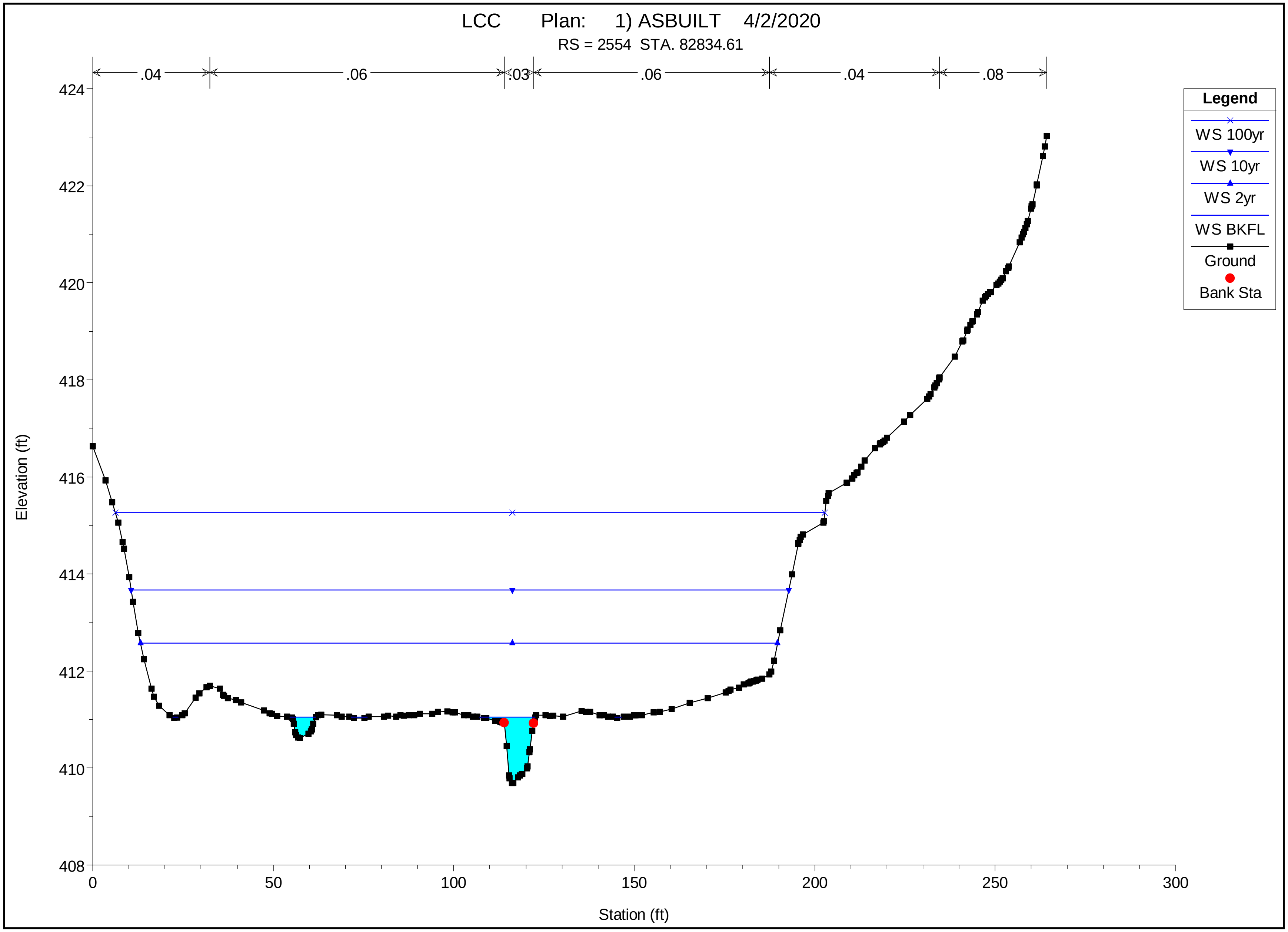


LCC Plan: 1) ASBUILT 4/2/2020
RS = 3113 STA. 83464.67
.04
.06
.03
.06
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
422
420
418
416
414
412
0
50
100
150
200
250
Station (ft)

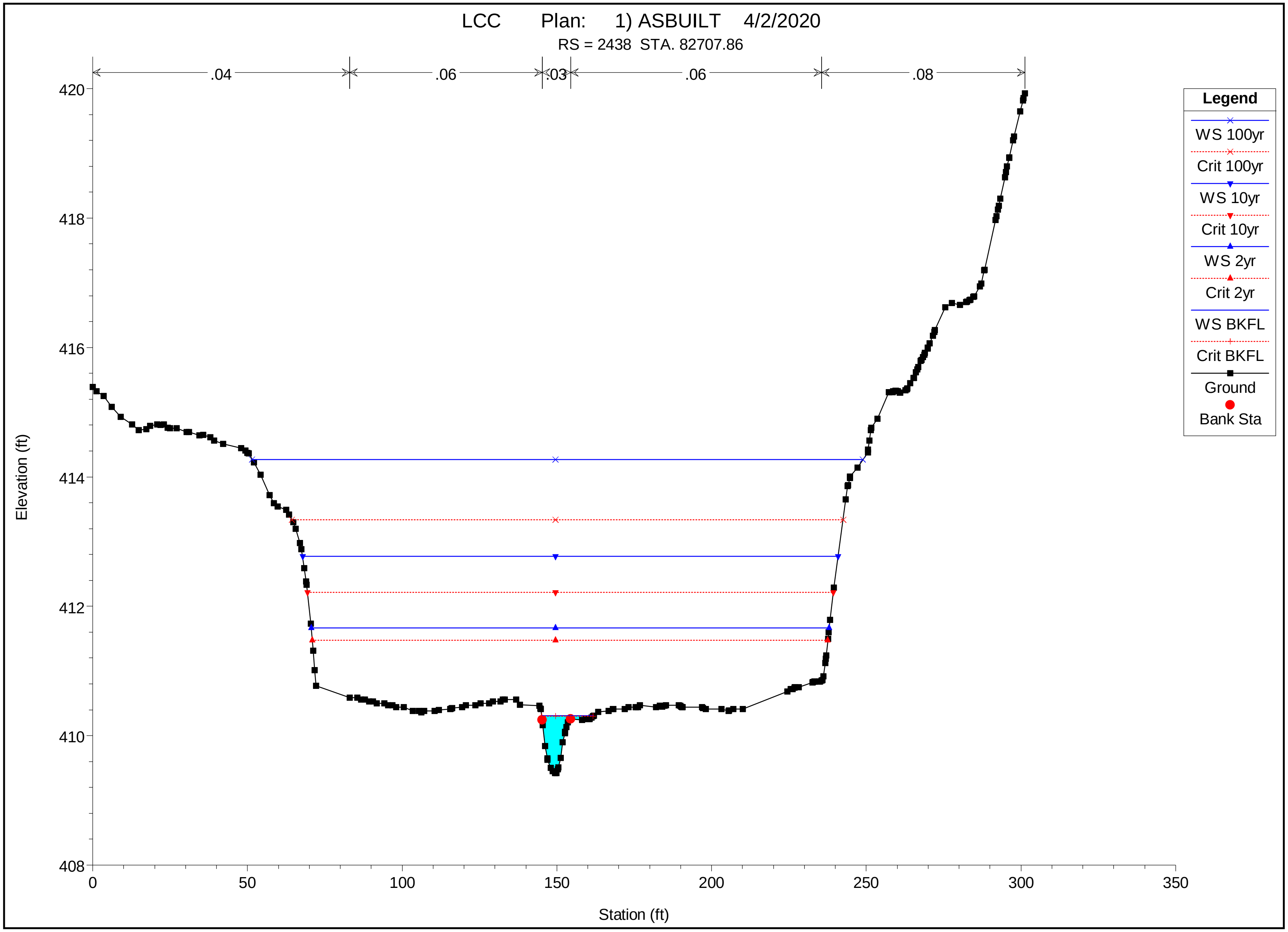


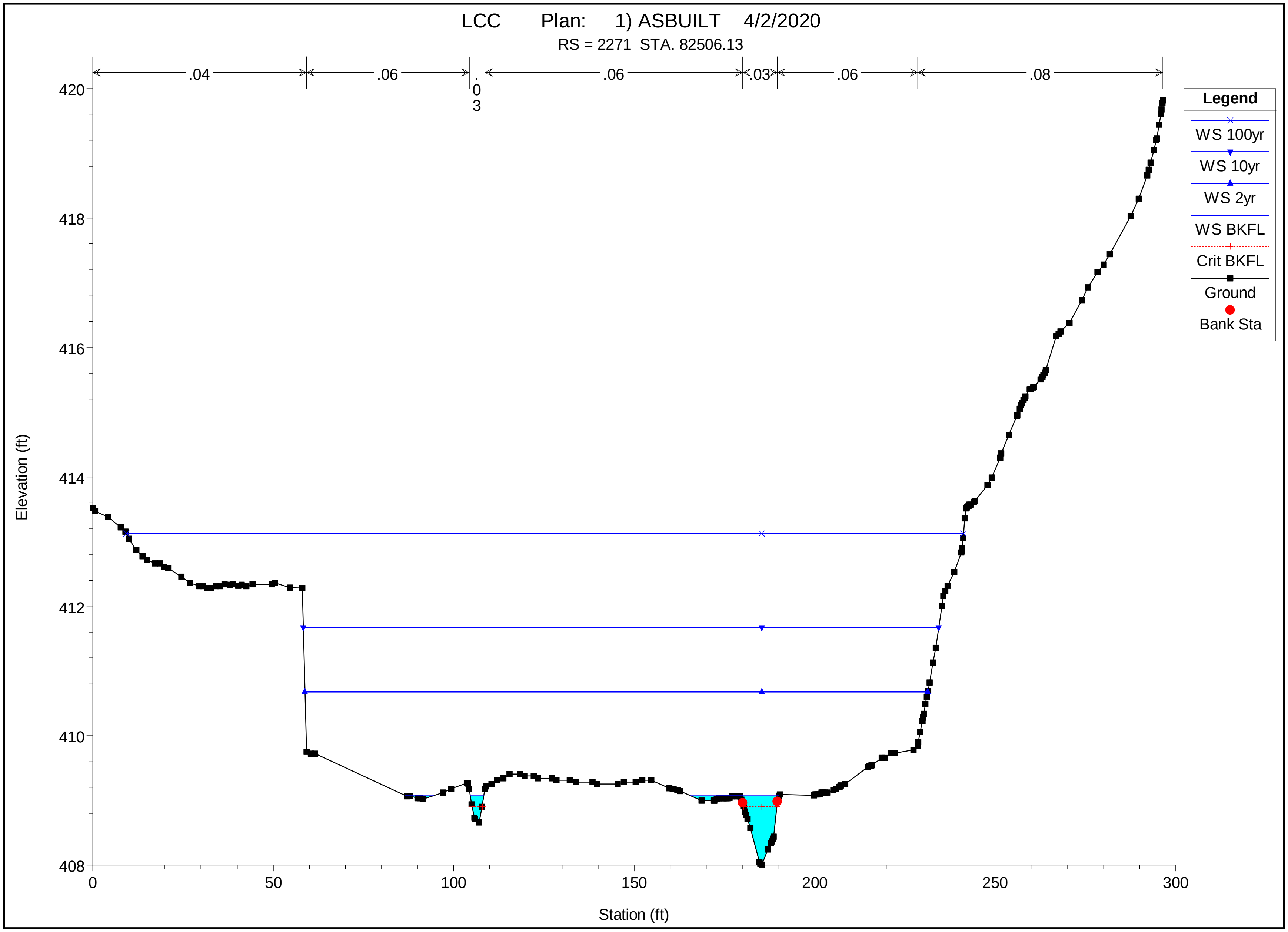
LCC Plan: 1) ASBUILT 4/2/2020
RS = 2921 STA. 83249.52
.04
.06
.03
.06
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
430
428
426
424
422
420
418
416
414
412
0
50
100
150
200
250
300
350
Station (ft)

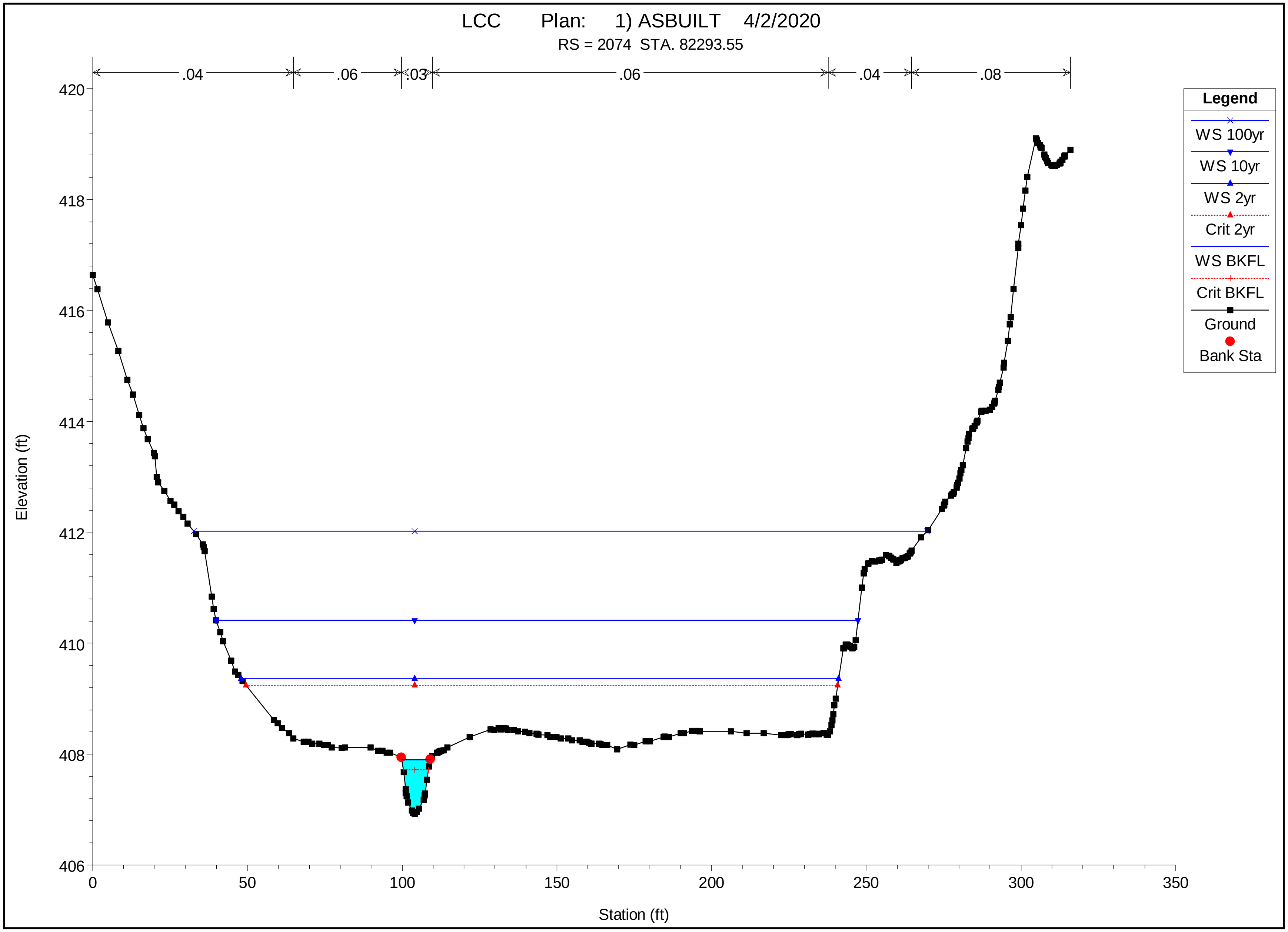

LCC Plan: 1) ASBUILT 4/2/2020
RS = 2745 STA. 83056.75
.04
.06
.03
.06
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
422
420
418
416
414
412
410
0
50
100
150
200
250
300



LCC Plan: 1) ASBUILT 4/2/2020
RS = 2554 STA. 82834.61
.04
.06
.03
.06
.04
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
424
422
420
418
416
414
412
410
408
0
50
100
150
200
250
300
Station (ft)


LCC Plan: 1) ASBUILT 4/2/2020
RS = 2438 STA. 82707.86
.04
.06
.03
.06
.08
Elevation (ft)
Station (ft)
408
410
412
414
416
418
420
0
50
100
150
200
250
300
350
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta


LCC Plan: 1) ASBUILT 4/2/2020
RS = 2271 STA. 82506.13
.04
.06
.03
.06
.03
.06
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
420
418
416
414
412
410
408
0
50
100
150
200
250
300
Station (ft)



LCC Plan: 1) ASBUILT 4/2/2020
RS = 2074 STA. 82293.55
.04
.06
.03
.06
.04
.08
Legend
WS 100yr
WS 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
420
418
416
414
412
410
408
406
0
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100
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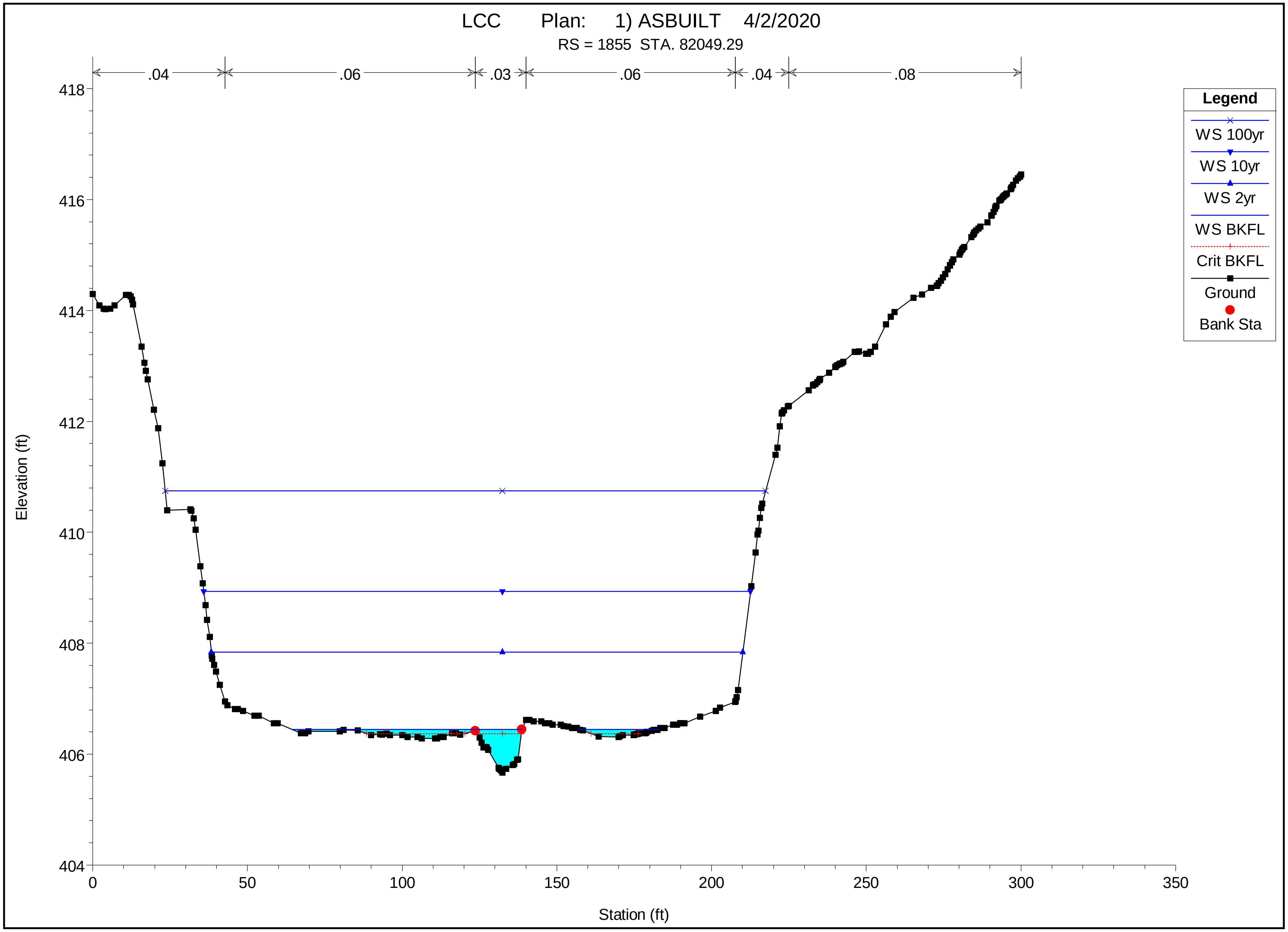
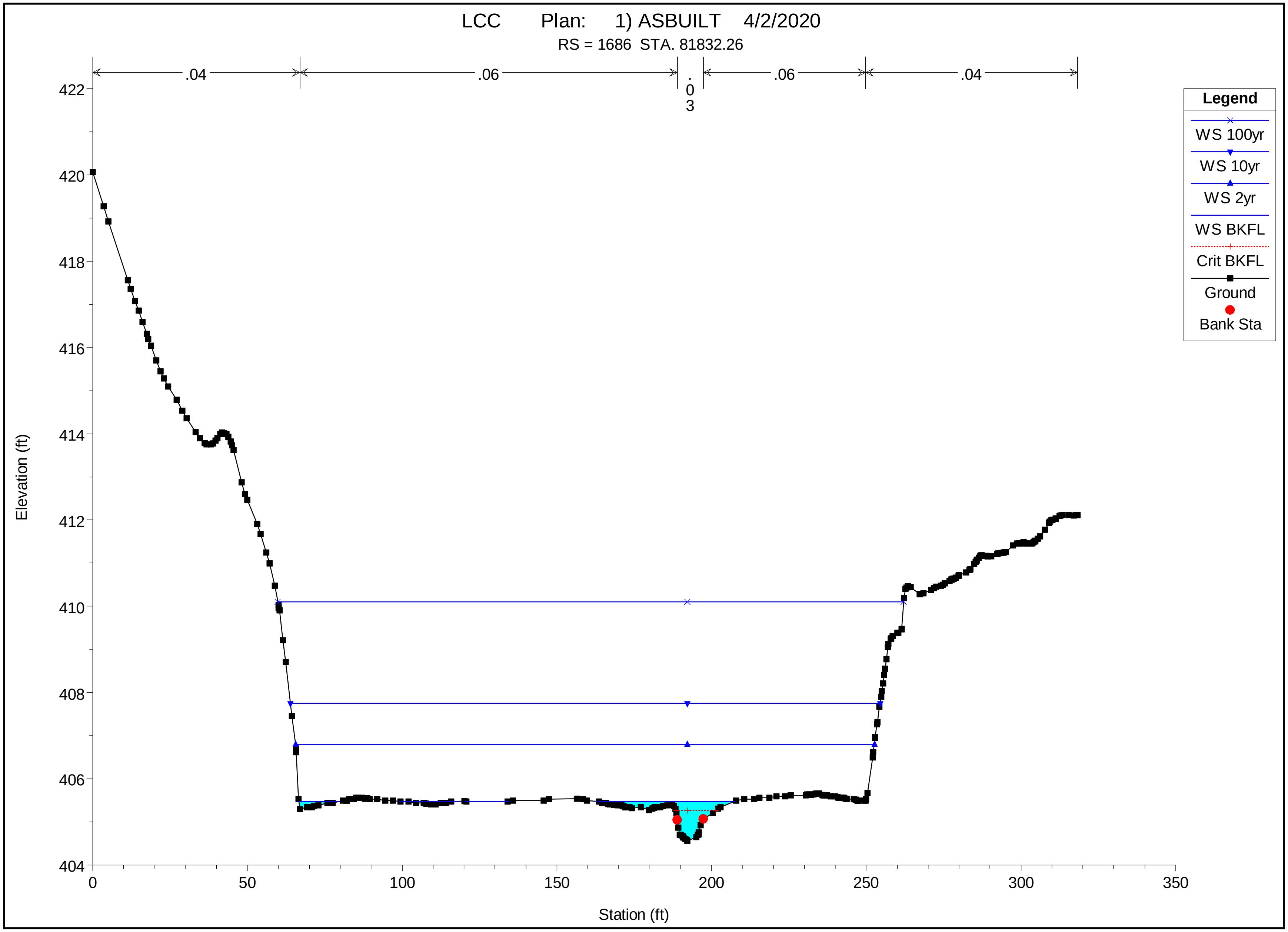
300
350


LCC Plan: 1) ASBUILT 4/2/2020
RS = 1855 STA. 82049.29
.04
.06
.03
.06
.04
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
404
406
408
410
412
414
416
418
0
50
100
150
200
250
300
350


LCC Plan: 1) ASBUILT 4/2/2020
RS = 1686 STA. 81832.26
.04
.06
.03
.06
.04
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
422
420
418
416
414
412
410
408
406
404
0
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100
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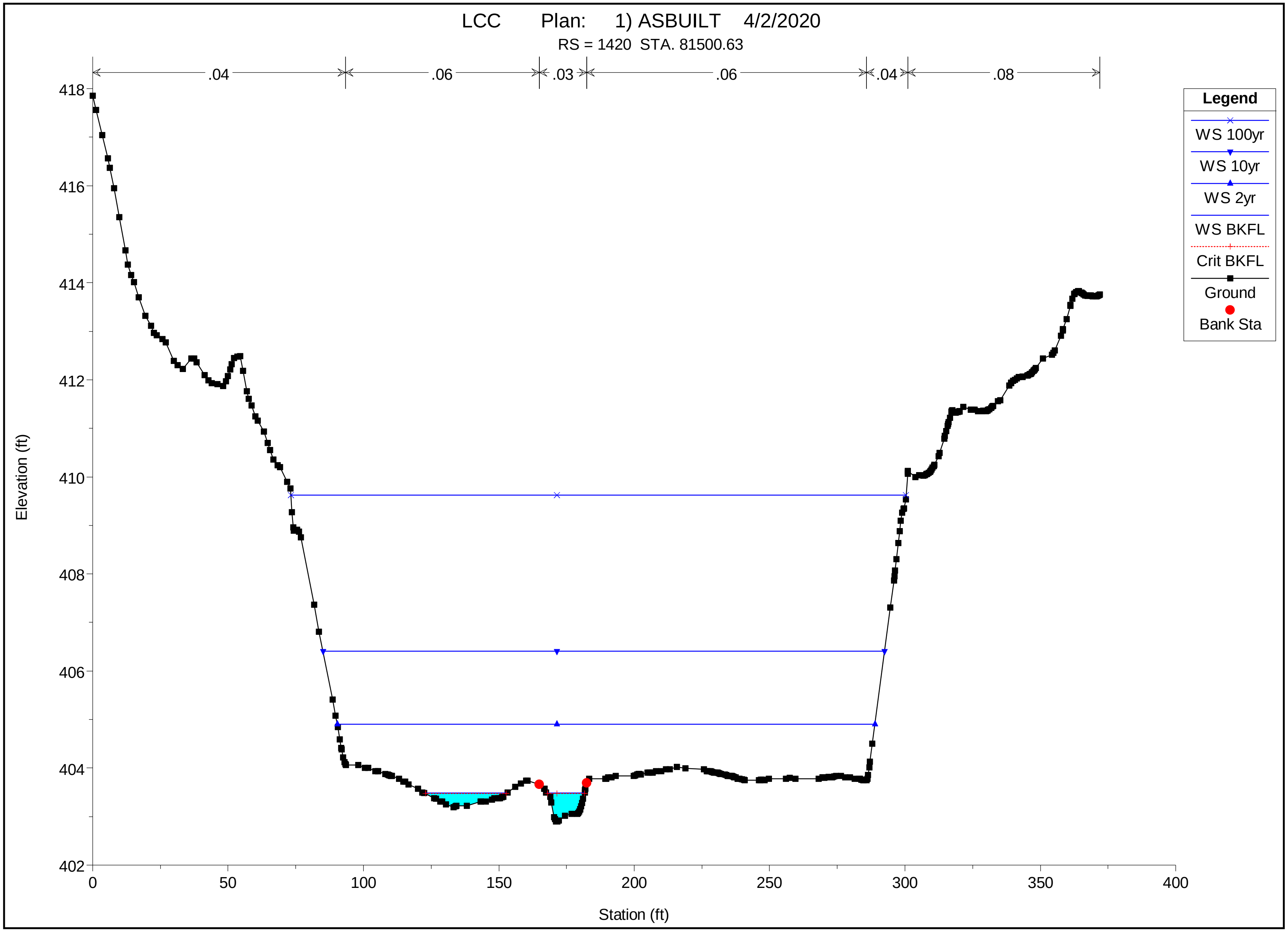
300
350


LCC Plan: 1) ASBUILT 4/2/2020
RS = 1420 STA. 81500.63
.04
.06
.03
.06
.04
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
418
416
414
412
410
408
406
404
402
0
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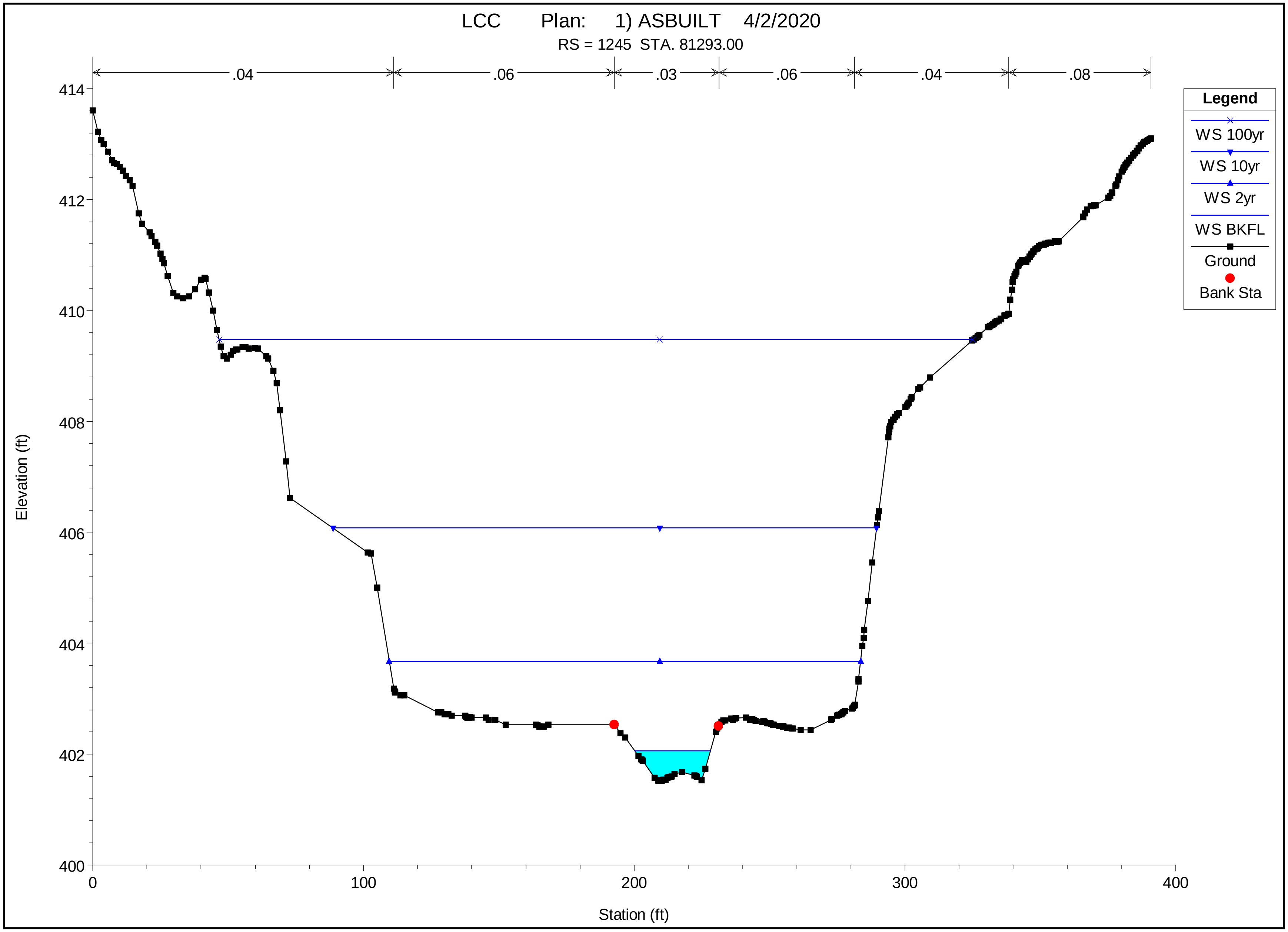
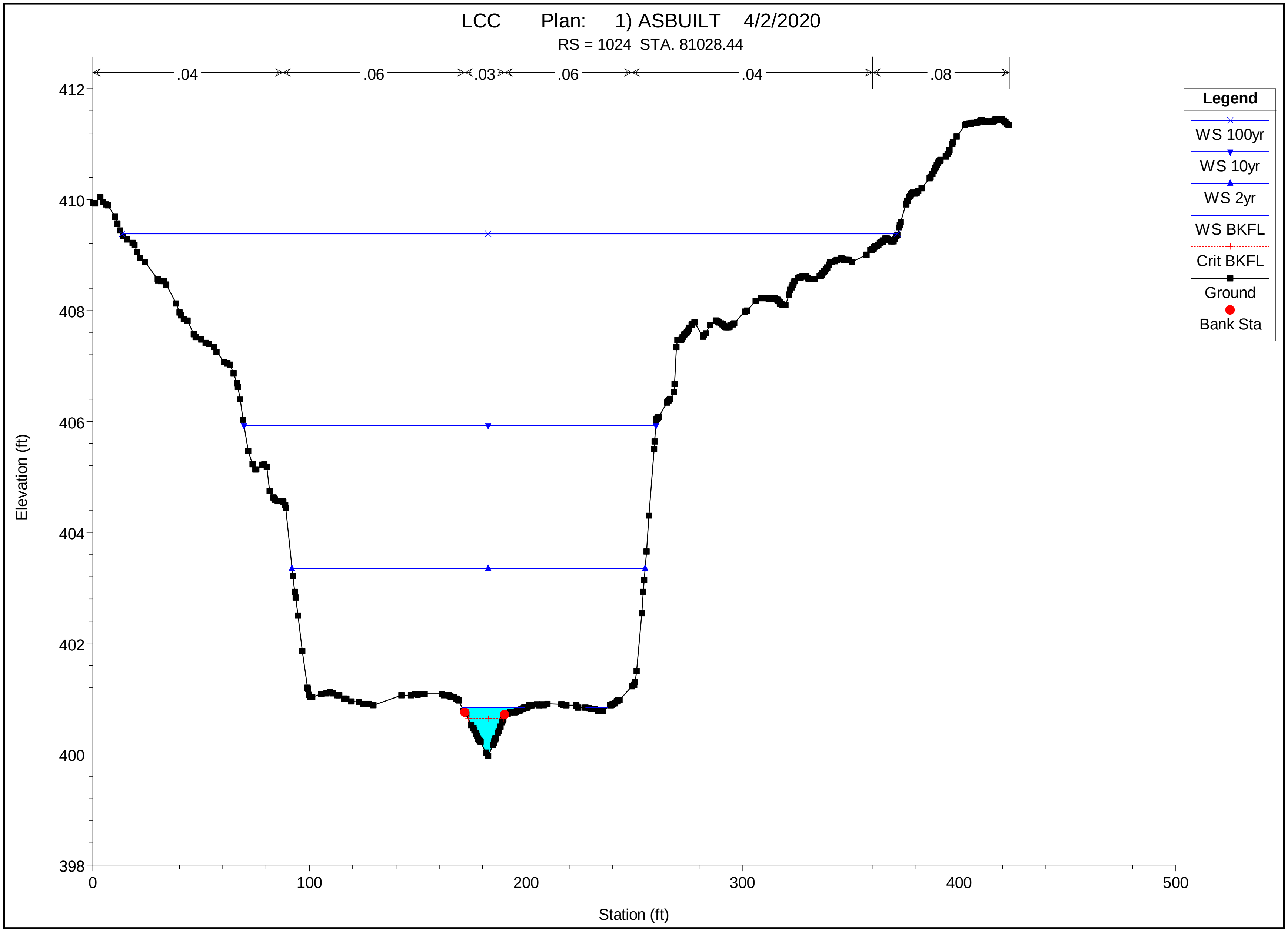
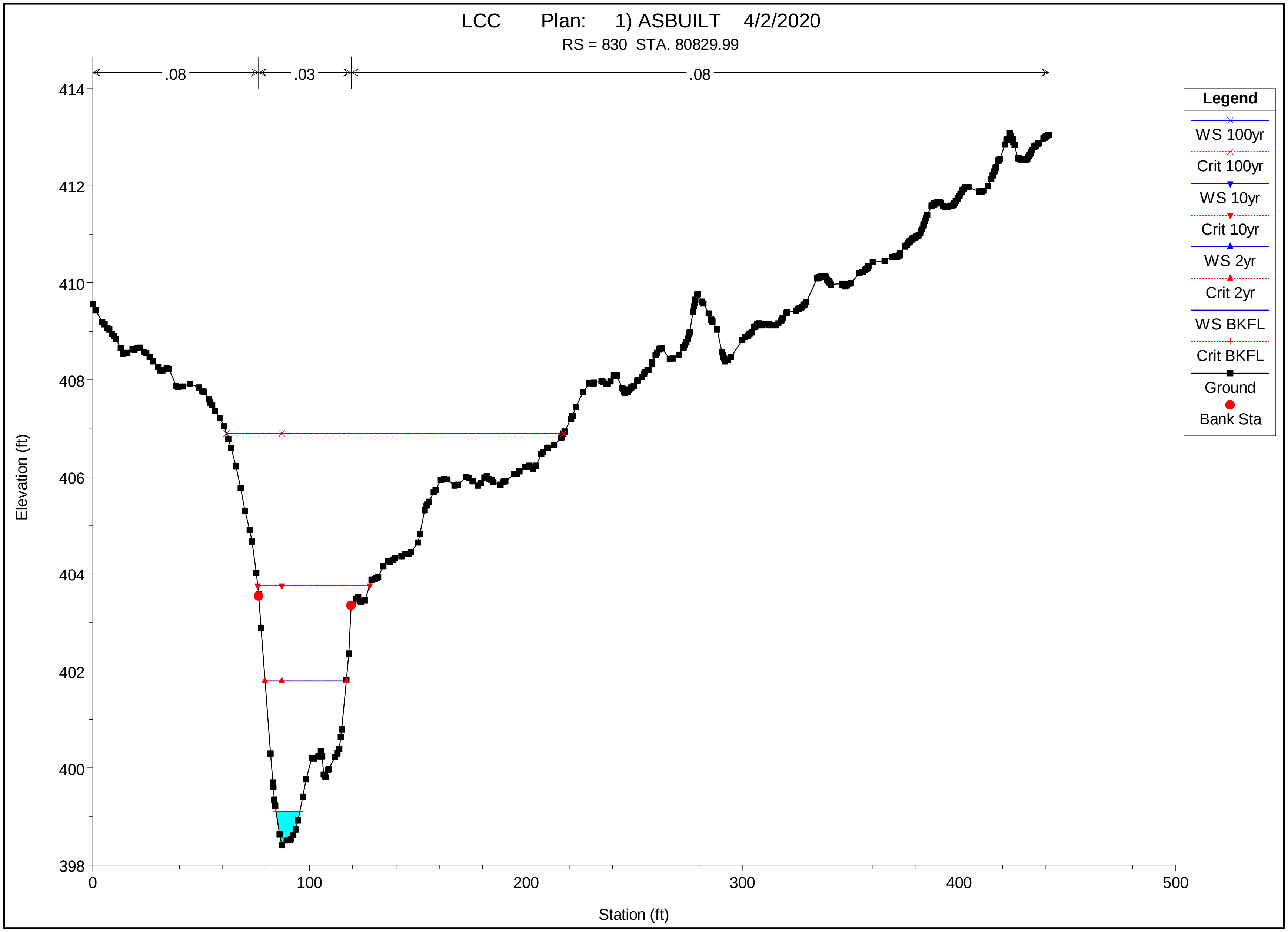
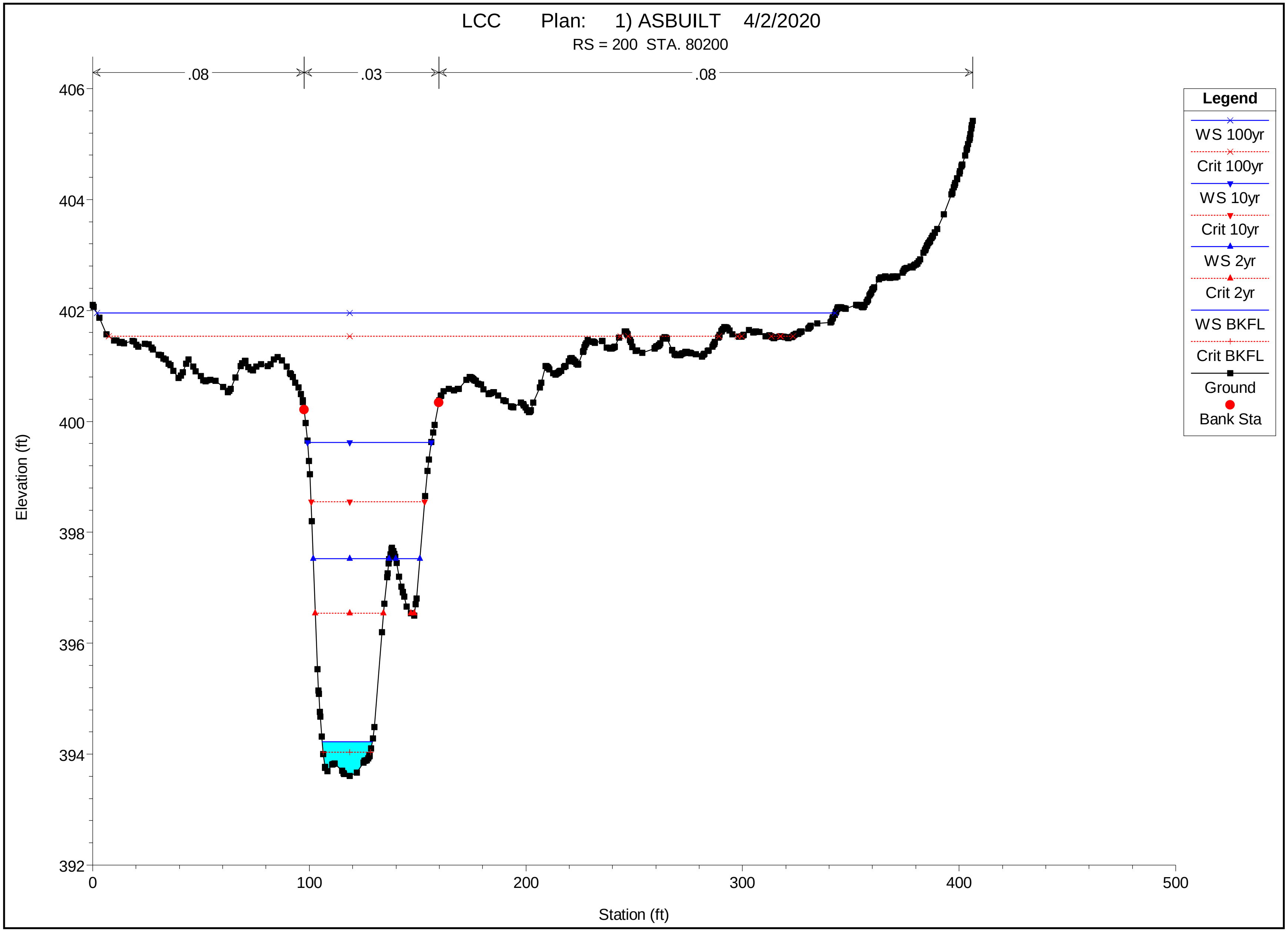
100
150
200
250
300
350
400
Station (ft)


LCC Plan: 1) ASBUILT 4/2/2020
RS = 1245 STA. 81293.00
.04
.06
.03
.06
.04
.08
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Ground
Bank Sta
Elevation (ft)
414
412
410
408
406
404
402
400
0
100
200
300
400
Station (ft)

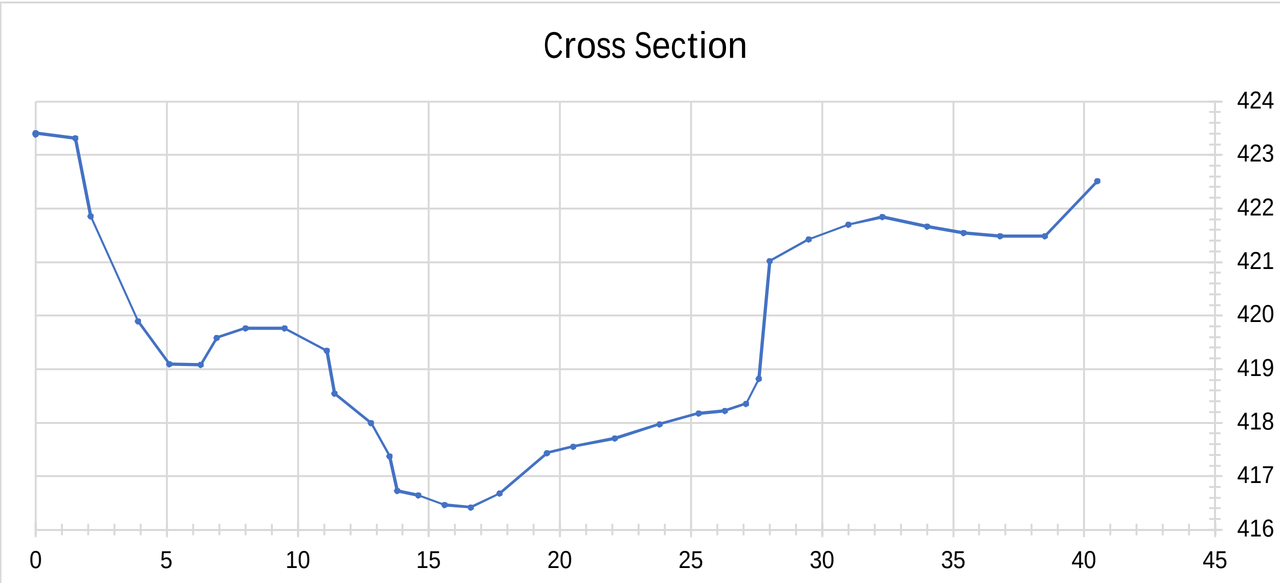

LCC Plan: 1) ASBUILT 4/2/2020
RS = 1024 STA. 81028.44
.04
.06
.03
.06
.04
.08
412
410
408
406
404
402
400
398
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
WS 100yr
WS 10yr
WS 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta


LCC Plan: 1) ASBUILT 4/2/2020
RS = 830 STA. 80829.99
.08
.03
.08
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
Station (ft)
414
412
410
408
406
404
402
400
398
0
100
200
300
400
500


LCC Plan: 1) ASBUILT 4/2/2020
RS = 200 STA. 80200
.08
.03
.08
Legend
WS 100yr
Crit 100yr
WS 10yr
Crit 10yr
WS 2yr
Crit 2yr
WS BKFL
Crit BKFL
Ground
Bank Sta
Elevation (ft)
406
404
402
400
398
396
394
392
0
100
200
300
400
500
Station (ft)

Attachment C - Geomorphic Data

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 1 - Cross Section Monitoring
Date: 4/28/2020



Benchmark Elevation: 423.39 LPIN
Height of Instrument: 428.48

	Survey Data		Section Comparison Data		
Pnt Num	Survey Data Station	Survey Rod Height	Station	Elevation	Notes
	(ft)	(ft)	(ft)	(ft)	
1	0	5.09	0	423.39	LPIN
2	0	5.07	0	423.41	LPIN-gnd
3	1.5	5.17	1.5	423.31	TOB
4	2.1	6.62	2.1	421.86	
5	3.9	8.58	3.9	419.90	Gully
6	5.1	9.38	5.1	419.10	Gully
7	6.3	9.4	6.3	419.08	
8	6.9	8.9	6.9	419.58	
9	8	8.72	8	419.76	
10	9.5	8.72	9.5	419.76	
11	11.1	9.14	11.1	419.34	TOB
12	11.4	9.94	11.4	418.54	Rock Ledge
13	12.8	10.49	12.8	417.99	LEOW
14	13.5	11.11	13.5	417.37	Edge of Ledge
15	13.8	11.75	13.8	416.73	Btm of Ledge
16	14.6	11.84	14.6	416.64	
17	15.6	12.01	15.6	416.47	

18	16.6	12.06	16.6	416.42	TW (D=1.55')
19	17.7	11.8	17.7	416.68	
20	19.5	11.05	19.5	417.43	
21	20.5	10.93	20.5	417.55	
22	22.1	10.77	22.1	417.71	
23	23.8	10.51	23.8	417.97	REOW
24	25.3	10.3	25.3	418.18	
25	26.3	10.26	26.3	418.22	
26	27.1	10.13	27.1	418.35	Toe of Bank
27	27.6	9.66	27.6	418.82	
28	28	7.46	28	421.02	
29	29.5	7.06	29.5	421.42	TOB
30	31	6.78	31	421.70	
31	32.3	6.64	32.3	421.84	
32	34	6.81	34	421.67	
33	35.4	6.94	35.4	421.54	
34	36.8	7	36.8	421.48	
35	38.5	6.99	38.5	421.49	start of slope
36	40.5	5.97	40.5	422.51	
37	43.7	4.54	43.7	423.94	
38	45.7	4.5	45.7	423.98	
39	47.5	4.64	47.5	423.84	RPIN-gnd

Project:	Little Catoctin Creek Monitoring
Project Number:	BCS 2014-09H
Site:	Section 1 - Profile Monitoring
Date:	4/28/2020

Benchmark Elevation	423.39
Rod Height at BM	5.09
HI from Benchmark Elev.	428.48

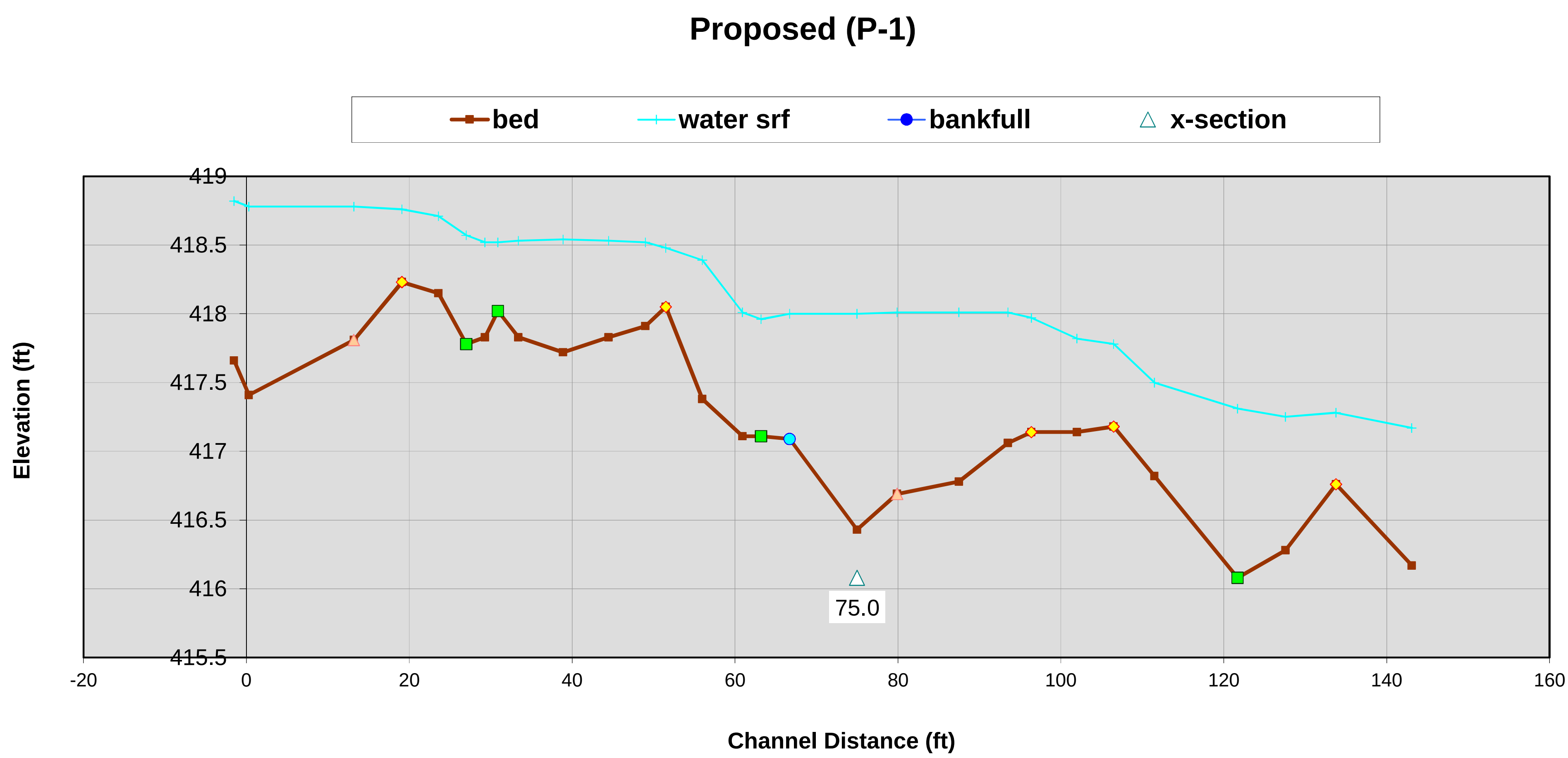
Cross Section Station	76.5
XS Station Adjustment	-1.5
XS Crossing Processed	75

Slope: 1.30%

	Survey Sta.	Adjust Sta.	WS Elev.
Start Sta.	20.60	19.1	418.76
End Sta.	144.60	143.1	417.17

	Survey Data				Profile Comparison Data			
Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Water (ft)	Depth or Surface	Adjusted Station (ft)	Ground Elevation (ft)	Water Surface Elevation	Notes
1	0.00	10.82	9.66	Surface	-1.50	417.66	418.82	
2	1.80	11.07	9.70	Surface	0.30	417.41	418.78	dmax=1.42 '
3	14.70	10.67	9.70	Surface	13.20	417.81	418.78	Glide
4	20.60	10.25	9.72	Surface	19.10	418.23	418.76	Riffle
5	25.10	10.33	9.77	Surface	23.60	418.15	418.71	Riffle
6	28.50	10.70	9.91	Surface	27.00	417.78	418.57	Run
7	30.80	10.65	9.96	Surface	29.30	417.83	418.52	Run
8	32.40	10.46	9.96	Surface	30.90	418.02	418.52	Run
9	34.90	10.65	9.95	Surface	33.40	417.83	418.53	Run
10	40.40	10.76	9.94	Surface	38.90	417.72	418.54	Run
11	46.00	10.65	9.95	Surface	44.50	417.83	418.53	Run
12	50.50	10.57	9.96	Surface	49.00	417.91	418.52	Run
13	53.00	10.43	10.00	Surface	51.50	418.05	418.48	Cascade
14	57.50	11.10	10.09	Surface	56.00	417.38	418.39	Cascade
15	62.40	11.37	10.47	Surface	60.90	417.11	418.01	Confluence
16	64.70	11.37	10.52	Surface	63.20	417.11	417.96	Run
17	68.20	11.39	10.48	Surface	66.70	417.09	418.00	Pool
18	76.50	12.05	10.48	Surface	75.00	416.43	418.00	dmax=1.59
19	81.40	11.79	10.47	Surface	79.90	416.69	418.01	Glide
20	89.00	11.70	10.47	Surface	87.50	416.78	418.01	Glide
21	95.00	11.42	10.47	Surface	93.50	417.06	418.01	Glide
22	97.90	11.34	10.51	Surface	96.40	417.14	417.97	Riffle
23	103.50	11.34	10.66	Surface	102.00	417.14	417.82	Riffle
24	108.00	11.30	10.70	Surface	106.50	417.18	417.78	Cascade
25	113.00	11.66	10.98	Surface	111.50	416.82	417.50	Cascade
26	123.20	12.40	11.17	Surface	121.70	416.08	417.31	Run
27	129.10	12.20	11.23	Surface	127.60	416.28	417.25	Run

28	135.30	11.72	11.20	Surface	133.80	416.76	417.28	Riffle
29	144.60	12.31	11.31	Surface	143.10	416.17	417.17	Riffle



Proposed (P-1)
bed
water srf
bankfull
x-section
Elevation (ft)
419
418.5
418
417.5
417
416.5
416
415.5
75.0
-20
0
20
40
60
80
100
120
140
160
Channel Distance (ft)

1) Individual Pebble Count

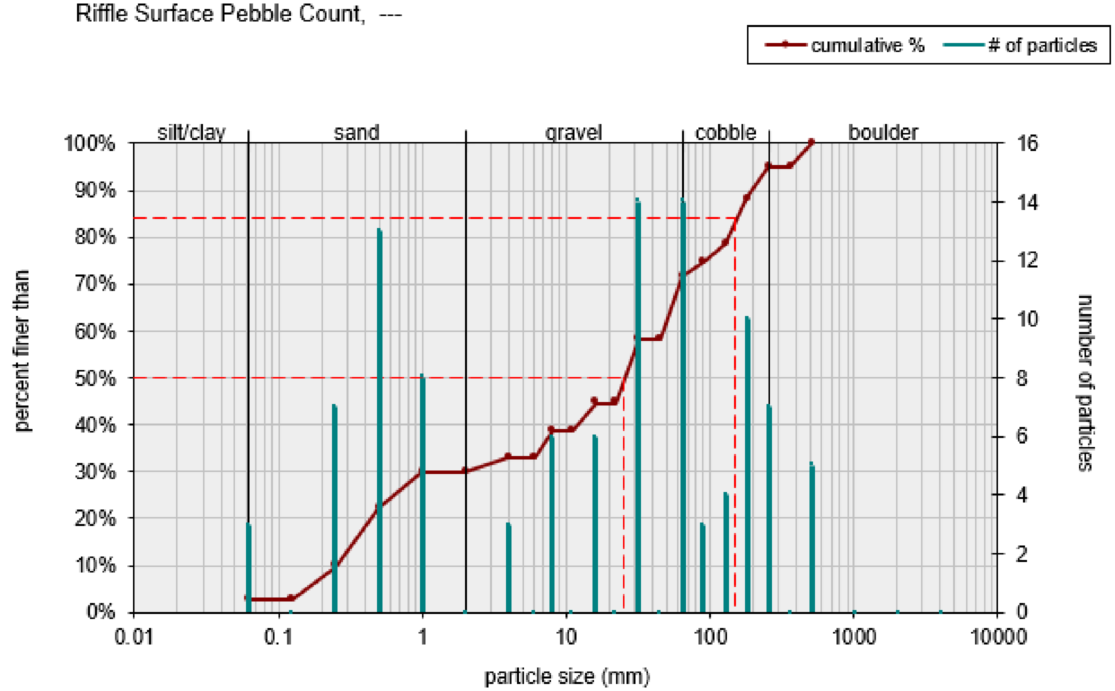
Two individual samples may be entered below. Select sample type for each.

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	3
very fine sand	0.062 - 0.125	0
fine sand	0.125 - 0.25	7
medium sand	0.25 - 0.5	13
coarse sand	0.5 - 1	8
very coarse sand	1 - 2	0
very fine gravel	2 - 4	3
fine gravel	4 - 6	0
fine gravel	6 - 8	6
medium gravel	8 - 11	0
medium gravel	11 - 16	6
coarse gravel	16 - 22	0
coarse gravel	22 - 32	14
very coarse gravel	32 - 45	0
very coarse gravel	45 - 64	14
small cobble	64 - 90	3
medium cobble	90 - 128	4
large cobble	128 - 180	10
very large cobble	180 - 256	7
small boulder	256 - 362	0
small boulder	362 - 512	5
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		103
bedrock	-------------	
clay hardpan	-------------	
detritus/wood	-------------	
artificial	-------------	
total count:		103

Note: XS 1

Riffle Surface Pebble Count, ---

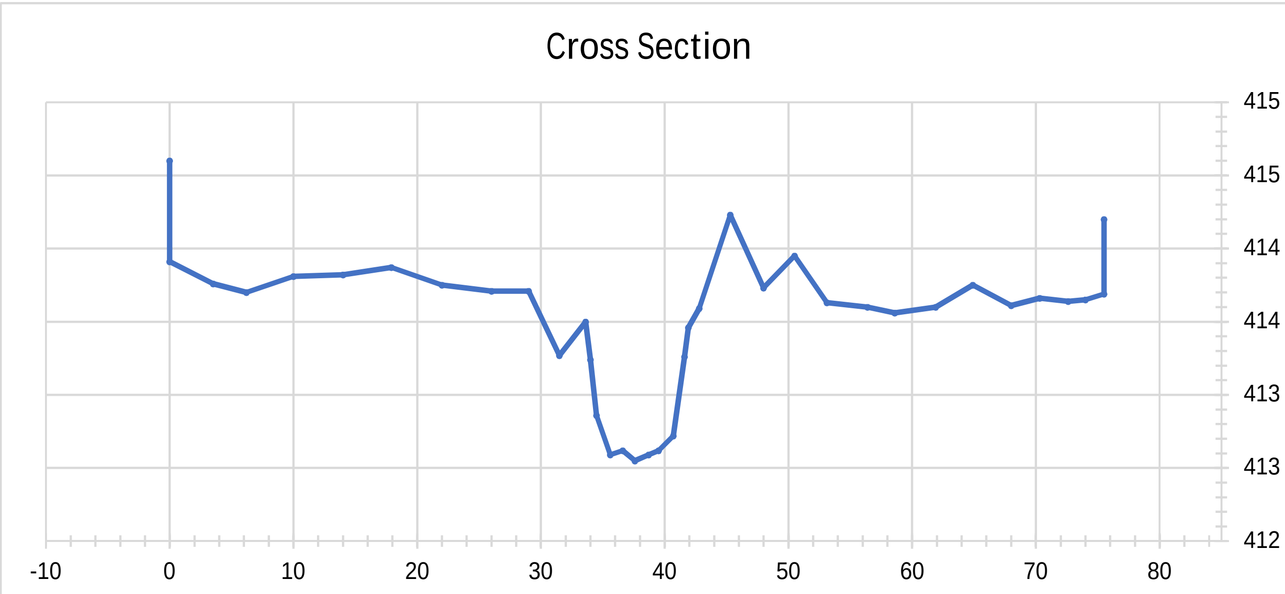


Size (mm)	
D16	0.35
D35	6.6
D50	25
D65	54
D84	150
D95	250

Size Distribution	
mean	7.2
dispersion	38.7
skewness	-0.33

Type	
silt/clay	3%
sand	27%
gravel	42%
cobble	23%
boulder	5%

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 2 - Cross Section Monitoring
Date: 5/5/2020



Benchmark Elevation: 414.60 RPIN
Height of Instrument: 419.67

Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Section Comparison Data Station (ft)	Elevation (ft)	Notes
1	0.00	5.07	0.00	414.60	LPIN
2	0.00	5.76	0.00	413.91	Ground Next to Pin
3	3.50	5.91	3.50	413.76	
4	6.20	5.97	6.20	413.70	
5	10.00	5.86	10.00	413.81	
6	14.00	5.85	14.00	413.82	
7	17.90	5.80	17.90	413.87	
8	22.00	5.92	22.00	413.75	
9	26.00	5.96	26.00	413.71	
10	29.00	5.96	29.00	413.71	
11	31.50	6.40	31.50	413.27	
12	33.60	6.17	33.60	413.50	TOB
13	34.00	6.43	34.00	413.24	EOW
14	34.50	6.81	34.50	412.86	

15	35.60	7.08	35.60	412.59	
16	36.60	7.05	36.60	412.62	
17	37.60	7.12	37.60	412.55	TW D=0.75'
18	38.70	7.08	38.70	412.59	
19	39.50	7.05	39.50	412.62	
20	40.70	6.95	40.70	412.72	
21	41.60	6.41	41.60	413.26	EOW
22	41.90	6.21	41.90	413.46	TOB
23	42.80	6.08	42.80	413.59	
24	45.30	5.44	45.30	414.23	
25	48.00	5.94	48.00	413.73	
26	50.50	5.72	50.50	413.95	
27	53.10	6.04	53.10	413.63	
28	56.40	6.07	56.40	413.60	
29	58.60	6.11	58.60	413.56	
30	61.90	6.07	61.90	413.60	
31	64.90	5.92	64.90	413.75	
32	68.00	6.06	68.00	413.61	
33	70.30	6.01	70.30	413.66	
34	72.60	6.03	72.60	413.64	
35	74.00	6.02	74.00	413.65	
36	75.50	5.98	75.50	413.69	Ground Next to Pin
37	75.50	5.47	75.50	414.20	RPIN

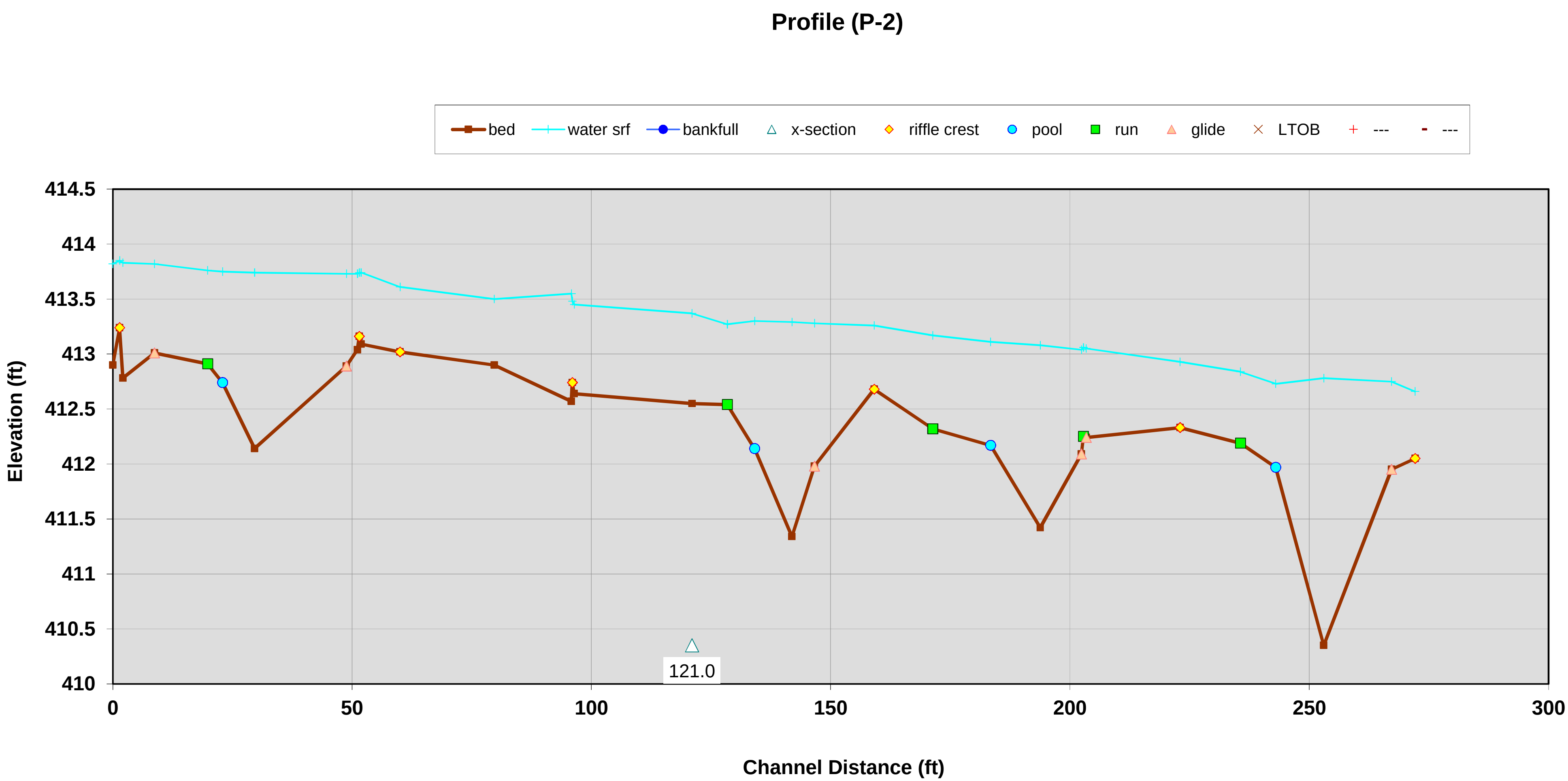
Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 2 - Profile Monitoring
Date: 5/5/2020

Benchmark Elevation	414.98
Rod Height at BM	5.07
HI from Benchmark Elev.	420.05

Cross Section Station	121		Slope:	0.49%		
XS Station Adjustment	0			Survey Sta.	Adjust Sta.	WS Elev.
XS Crossing Processed	121	0.00	Start Sta.	0.00	0	413.82
	410.35	413.24	End Sta.	272.10	272.1	412.66

	Survey Data				Profile Comparison Data			
Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Water (ft)	Depth or Surface	Adjusted Station (ft)	Ground Elevation (ft)	Water Surface Elevation	Notes
1	0.00	7.15	0.92	Depth	0.00	412.90	413.82	Front of Log
2	1.40	6.81	0.61	Depth	1.40	413.24	413.85	Top of Log
3	2.10	7.27	1.05	Depth	2.10	412.78	413.83	Back of Log/Glide
4	8.70	7.04	0.81	Depth	8.70	413.01	413.82	Glide
5	19.80	7.14	0.85	Depth	19.80	412.91	413.76	Run
6	22.90	7.31	1.01	Depth	22.90	412.74	413.75	Pool
7	29.60	7.91	1.60	Depth	29.60	412.14	413.74	Pool dmax
8	48.80	7.16	0.84	Depth	48.80	412.89	413.73	Glide
9	51.10	7.01	0.69	Depth	51.10	413.04	413.73	Front of Log
10	51.50	6.89	0.58	Depth	51.50	413.16	413.74	Top of Log
11	51.90	6.96	0.65	Depth	51.90	413.09	413.74	Back of Log
12	60.00	7.03	0.59	Depth	60.00	413.02	413.61	Head of Riffle
13	79.70	7.15	0.60	Depth	79.70	412.90	413.50	mid-riffle
14	95.80	7.48	0.98	Depth	95.80	412.57	413.55	Front of Log
15	96.00	7.31	0.74	Depth	96.00	412.74	413.48	Top of Log
16	96.40	7.41	0.81	Depth	96.40	412.64	413.45	Back of Log
17	121.00	7.50	0.82	Depth	121.00	412.55	413.37	XS2
18	128.40	7.51	0.73	Depth	128.40	412.54	413.27	Run
19	134.10	7.91	1.16	Depth	134.10	412.14	413.30	Pool
20	141.90	8.71	1.95	Depth	141.90	411.34	413.29	Pool dmax
21	146.60	8.07	1.30	Depth	146.60	411.98	413.28	Glide
22	159.10	7.37	0.58	Depth	159.10	412.68	413.26	Riffle
23	171.30	7.73	0.85	Depth	171.30	412.32	413.17	Run
24	183.40	7.88	0.94	Depth	183.40	412.17	413.11	Pool
25	193.80	8.63	1.66	Depth	193.80	411.42	413.08	Pool dmax

26	202.40	7.96	0.95	Depth	202.40	412.09	413.04	Front of Log/Glide
27	202.80	7.80	0.81	Depth	202.80	412.25	413.06	Top of Log
28	203.40	7.81	0.81	Depth	203.40	412.24	413.05	Back of Log/Glide
29	223.00	7.72	0.60	Depth	223.00	412.33	412.93	Riffle
30	235.60	7.86	0.65	Depth	235.60	412.19	412.84	Run
31	243.00	8.08	0.76	Depth	243.00	411.97	412.73	Pool
32	253.00	9.70	2.43	Depth	253.00	410.35	412.78	Pool dmax
33	267.20	8.10	0.80	Depth	267.20	411.95	412.75	Glide
34	272.10	8.00	0.61	Depth	272.10	412.05	412.66	Head of Riffle



Profile (P-2)
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LTOB

Elevation (ft)
414.5
414
413.5
413
412.5
412
411.5
411
410.5
410
121.0
0
50
100
150
200
250
300
Channel Distance (ft)

1) Individual Pebble Count

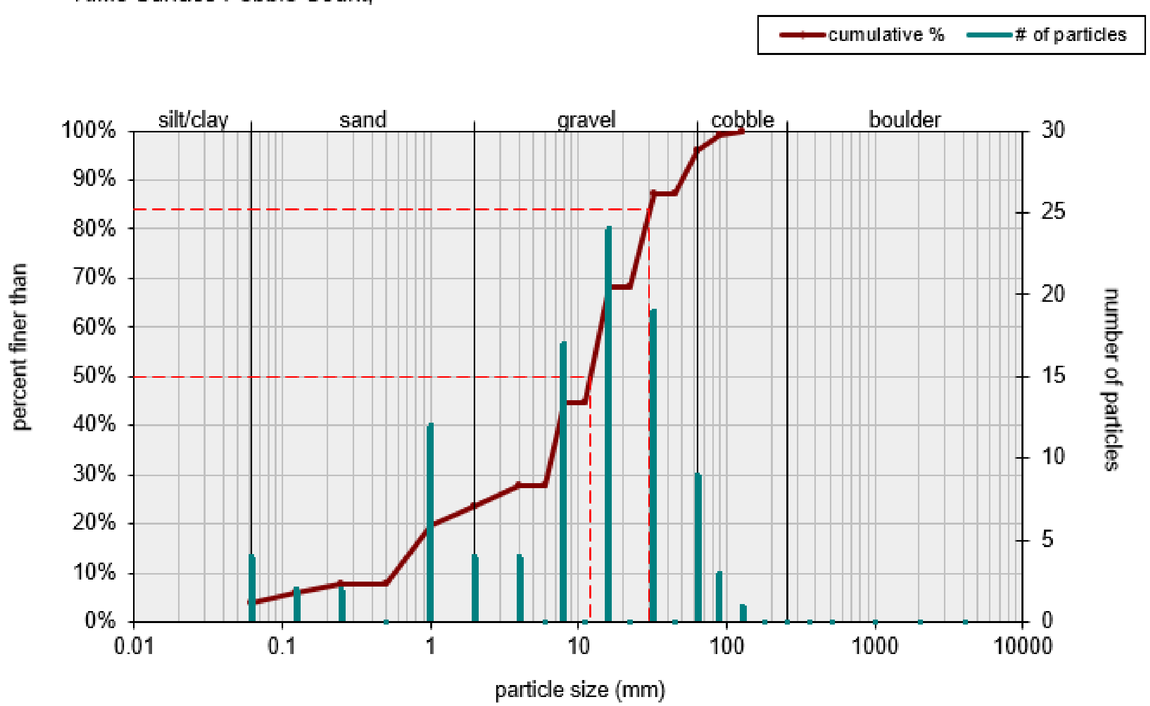
Two individual samples may be entered below. Select sample type for each.

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	4
very fine sand	0.062 - 0.125	2
fine sand	0.125 - 0.25	2
medium sand	0.25 - 0.5	0
coarse sand	0.5 - 1	12
very coarse sand	1 - 2	4
very fine gravel	2 - 4	4
fine gravel	4 - 6	0
fine gravel	6 - 8	17
medium gravel	8 - 11	0
medium gravel	11 - 16	24
coarse gravel	16 - 22	0
coarse gravel	22 - 32	19
very coarse gravel	32 - 45	0
very coarse gravel	45 - 64	9
small cobble	64 - 90	3
medium cobble	90 - 128	1
large cobble	128 - 180	0
very large cobble	180 - 256	0
small boulder	256 - 362	0
small boulder	362 - 512	0
medium boulder	512 - 1024	0
large boulder	1024 - 2048	0
very large boulder	2048 - 4096	0
total particle count:		101
bedrock	-------------	
clay hardpan	-------------	
detritus/wood	-------------	
artificial	-------------	
total count:		101

Note:

Riffle Surface Pebble Count, ---

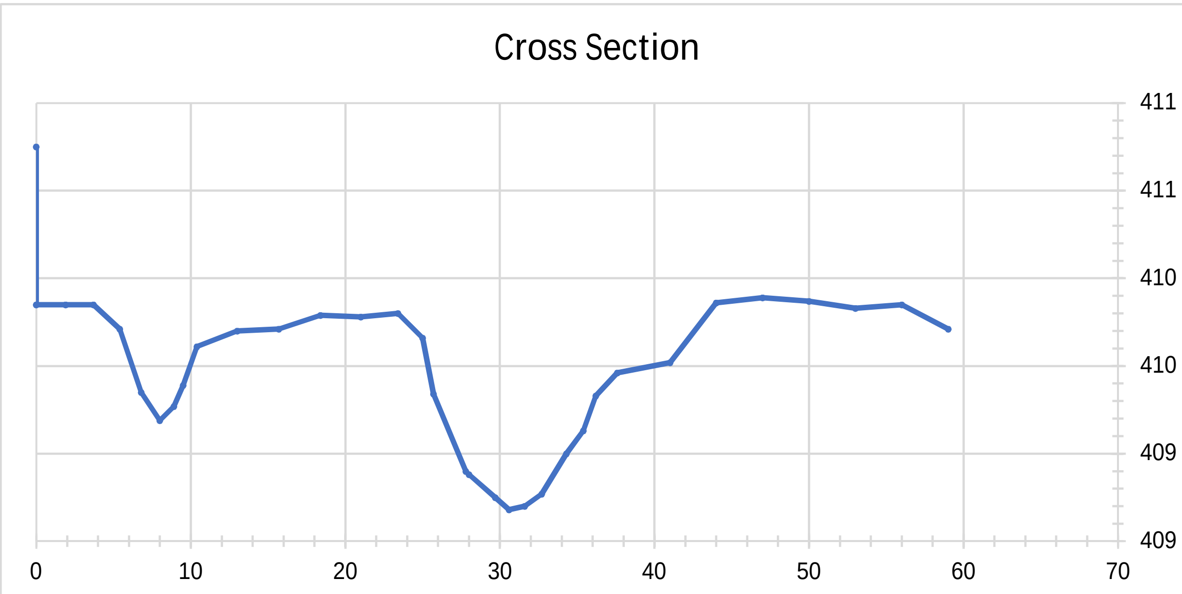


Size (mm)	
D16	0.8
D35	6.8
D50	12
D65	15
D84	30
D95	61

Size Distribution	
mean	4.9
dispersion	8.8
skewness	-0.31

Type	
silt/clay	4%
sand	20%
gravel	72%
cobble	4%
boulder	0%

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 3 - Cross Section Monitoring
Date: 5/5/2020



Benchmark Elevation: 410.75 LPIN
Height of Instrument: 415.18

Pnt Num	Survey Data: Survey Data Station (ft)	Survey Data: Survey Rod Height (ft)	Section Comparison Data: Station (ft)	Section Comparison Data: Elevation (ft)	Notes
1	0.00	4.43	0.00	410.75	LPIN
2	0.00	5.33	0.00	409.85	LPIN Ground
3	1.90	5.33	1.90	409.85	Floodplain
4	3.70	5.33	3.70	409.85	Floodplain
5	5.40	5.47	5.40	409.71	Floodplain
6	6.80	5.83	6.80	409.35	REOW (small farm side channel)
7	8.00	5.99	8.00	409.19	D=0.19'
8	8.90	5.91	8.90	409.27	
9	9.50	5.79	9.50	409.39	LEOW (small farm side channel)
10	10.40	5.57	10.40	409.61	Floodplain

11	13.00	5.48	13.00	409.70	Floodplain
12	15.70	5.47	15.70	409.71	Floodplain
13	18.40	5.39	18.40	409.79	Floodplain
14	21.00	5.40	21.00	409.78	Floodplain
15	23.40	5.38	23.40	409.80	Floodplain
16	25.00	5.52	25.00	409.66	TOB
17	25.70	5.84	25.70	409.34	LEOW
18	27.80	6.28	27.80	408.90	in-channel
19	28.00	6.30	28.00	408.88	in-channel
20	29.70	6.43	29.70	408.75	in-channel
21	30.60	6.50	30.60	408.68	TW D=0.75'
22	31.60	6.48	31.60	408.70	in-channel
23	32.70	6.41	32.70	408.77	in-channel
24	34.30	6.18	34.30	409.00	in-channel
25	35.40	6.05	35.40	409.13	in-channel
26	36.20	5.85	36.20	409.33	REOW
27	37.60	5.72	37.60	409.46	Floodplain
28	41.00	5.66	41.00	409.52	Floodplain
29	44.00	5.32	44.00	409.86	Floodplain
30	47.00	5.29	47.00	409.89	Floodplain
31	50.00	5.31	50.00	409.87	Floodplain
32	53.00	5.35	53.00	409.83	Floodplain
33	56.00	5.33	56.00	409.85	Floodplain
34	59.00	5.47	59.00	409.71	Floodplain
35	61.80	5.40	61.80	409.78	Floodplain
36	64.60	5.55	64.60	409.63	Floodplain
37	68.00	5.35	68.00	409.83	Floodplain
38	69.70	5.35	69.70	409.83	RPIN Ground
39	69.70	4.25	69.70	410.93	RPIN

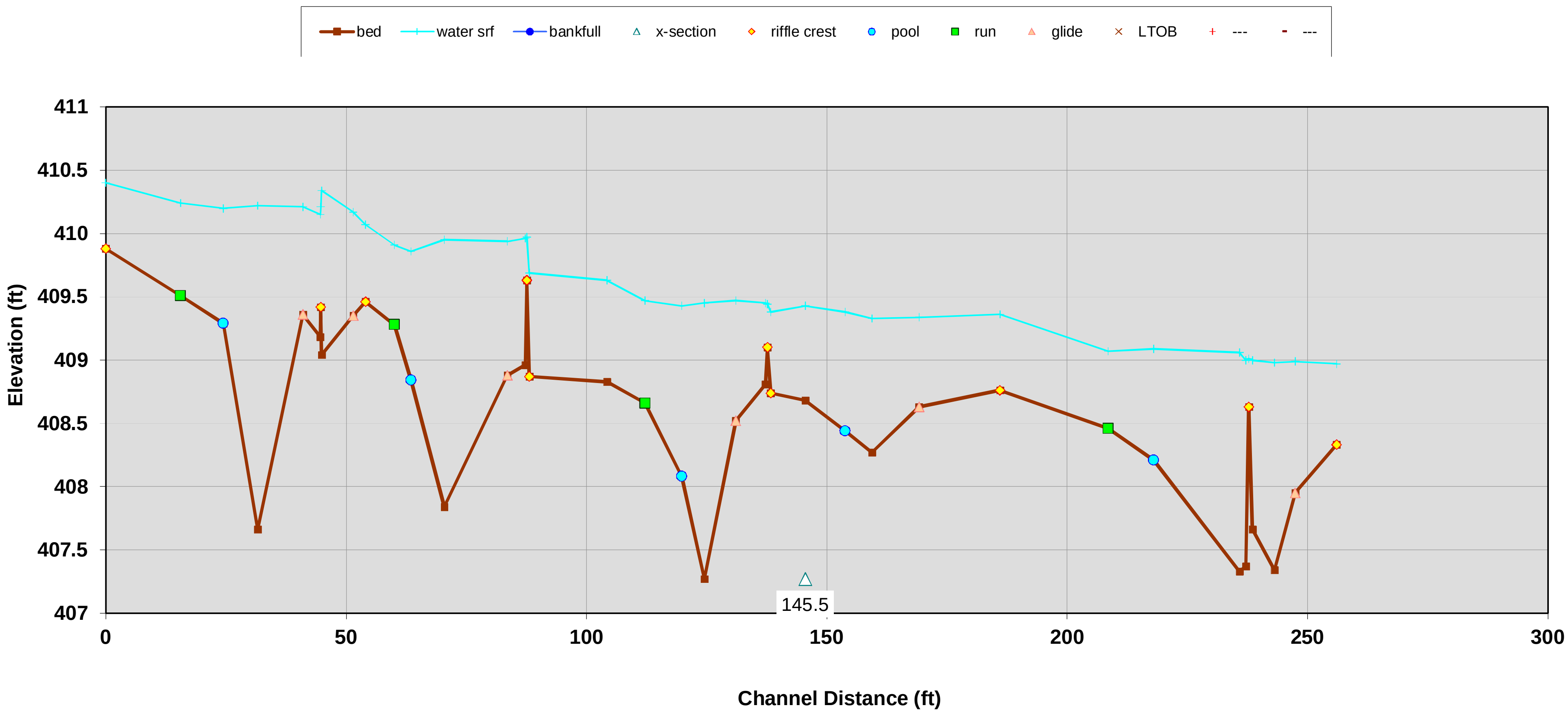
Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 3 - Profile Monitoring
Date: 5/5/2020

Benchmark Elevation	410.75
Rod Height at BM	4.43
HI from Benchmark Elev.	415.18

Cross Section Station	145.5		Slope:	0.56%		
XS Station Adjustment	0			Survey Sta.	Adjust Sta.	WS Elev.
XS Crossing Processed	145.5	145.50	Start Sta.	0.00	0	410.4
	407.27	409.88	End Sta.	256.00	256	408.97

	Survey Data				Profile Comparison Data			
Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Water (ft)	Depth or Surface	Adjusted Station (ft)	Ground Elevation (ft)	Water Surface Elevation	Notes
1	0.00	5.30	0.52	Depth	0.00	409.88	410.40	Riffle
2	15.50	5.67	0.73	Depth	15.50	409.51	410.24	Run
3	24.40	5.89	0.91	Depth	24.40	409.29	410.20	Pool
4	31.60	7.52	2.56	Depth	31.60	407.66	410.22	Pool dmax
5	41.00	5.82	0.85	Depth	41.00	409.36	410.21	small side channel confluence /Glide
6	44.60	6.00	0.97	Depth	44.60	409.18	410.15	Front of Log
7	44.70	5.76	0.79	Depth	44.70	409.42	410.21	Top of Log
8	44.90	6.14	1.30	Depth	44.90	409.04	410.34	Back of Log
9	51.50	5.83	0.82	Depth	51.50	409.35	410.17	Glide
10	54.00	5.72	0.61	Depth	54.00	409.46	410.07	Head of
11	60.00	5.90	0.63	Depth	60.00	409.28	409.91	Run
12	63.50	6.34	1.02	Depth	63.50	408.84	409.86	Pool
13	70.40	7.34	2.11	Depth	70.40	407.84	409.95	Pool dmax
14	83.50	6.30	1.06	Depth	83.50	408.88	409.94	Glide
15	87.20	6.22	1.00	Depth	87.20	408.96	409.96	Front of
16	87.60	5.55	0.34	Depth	87.60	409.63	409.97	Top of Log
17	88.10	6.31	0.82	Depth	88.10	408.87	409.69	Back of
18	104.20	6.35	0.80	Depth	104.20	408.83	409.63	mid-riffle
19	112.20	6.52	0.81	Depth	112.20	408.66	409.47	Run
20	119.80	7.10	1.35	Depth	119.80	408.08	409.43	Pool
21	124.50	7.91	2.18	Depth	124.50	407.27	409.45	Pool dmax
22	131.00	6.66	0.95	Depth	131.00	408.52	409.47	Glide
23	137.20	6.37	0.64	Depth	137.20	408.81	409.45	Front of Log
24	137.60	6.08	0.34	Depth	137.60	409.10	409.44	Top of Log
25	138.30	6.44	0.64	Depth	138.30	408.74	409.38	Back of Log/Head of Riffle
26	145.50	6.50	0.75	Depth	145.50	408.68	409.43	XS-3
27	153.80	6.74	0.94	Depth	153.80	408.44	409.38	micro-pool
28	159.40	6.91	1.06	Depth	159.40	408.27	409.33	Pool dmax
29	169.20	6.55	0.71	Depth	169.20	408.63	409.34	Glide
30	186.00	6.42	0.60	Depth	186.00	408.76	409.36	Riffle
31	208.50	6.72	0.61	Depth	208.50	408.46	409.07	Run
32	218.00	6.97	0.88	Depth	218.00	408.21	409.09	Pool
33	235.80	7.85	1.73	Depth	235.80	407.33	409.06	Pool dmax
34	237.20	7.81	1.63	Depth	237.20	407.37	409.00	Front of Log
35	237.80	6.55	0.38	Depth	237.80	408.63	409.01	Top of Log
36	238.50	7.52	1.34	Depth	238.50	407.66	409.00	Back of Log
37	243.10	7.84	1.64	Depth	243.10	407.34	408.98	Pool dmax after log
38	247.40	7.23	1.04	Depth	247.40	407.95	408.99	Glide
39	256.00	6.85	0.64	Depth	256.00	408.33	408.97	Head of Riffle

Profile (P-3)



bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LTOB

Elevation (ft)
411
410.5
410
409.5
409
408.5
408
407.5
407
0
50
100
150
200
250
300
145.5
Channel Distance (ft)

1) Individual Pebble Count

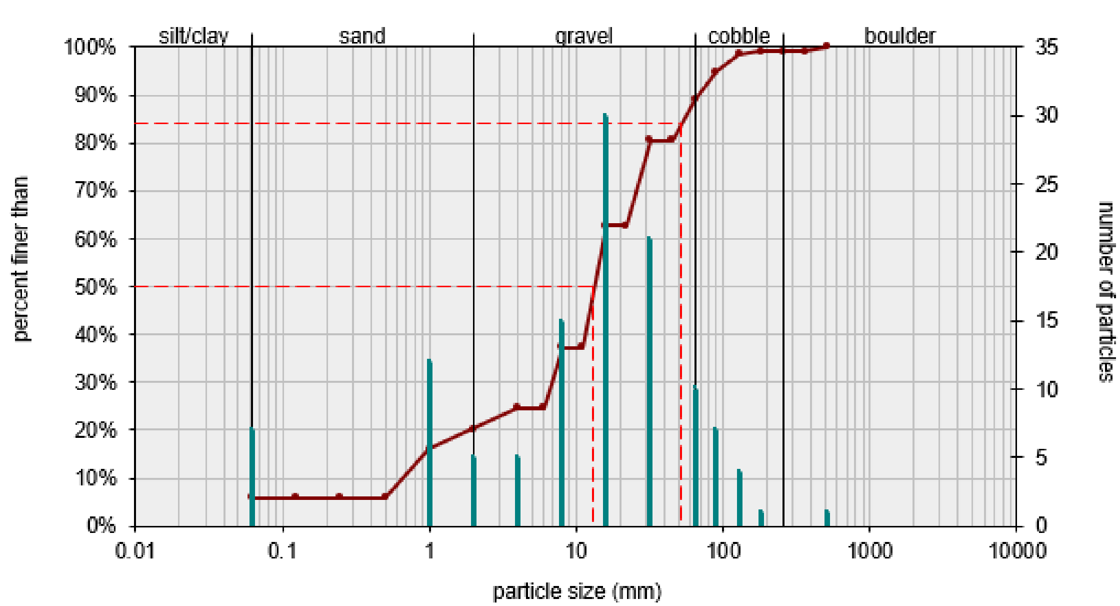
Two individual samples may be entered below. Select sample type for each.

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	7
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	12
very coarse sand	1 - 2	5
very fine gravel	2 - 4	5
fine gravel	4 - 6	
fine gravel	6 - 8	15
medium gravel	8 - 11	
medium gravel	11 - 16	30
coarse gravel	16 - 22	
coarse gravel	22 - 32	21
very coarse gravel	32 - 45	
very coarse gravel	45 - 64	10
small cobble	64 - 90	7
medium cobble	90 - 128	4
large cobble	128 - 180	1
very large cobble	180 - 256	
small boulder	256 - 362	
small boulder	362 - 512	1
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		118
bedrock	------------	
clay hardpan	------------	
detritus/wood	------------	
artificial	------------	
total count:		118

Note: XS 3

Riffle Surface Pebble Count, ---

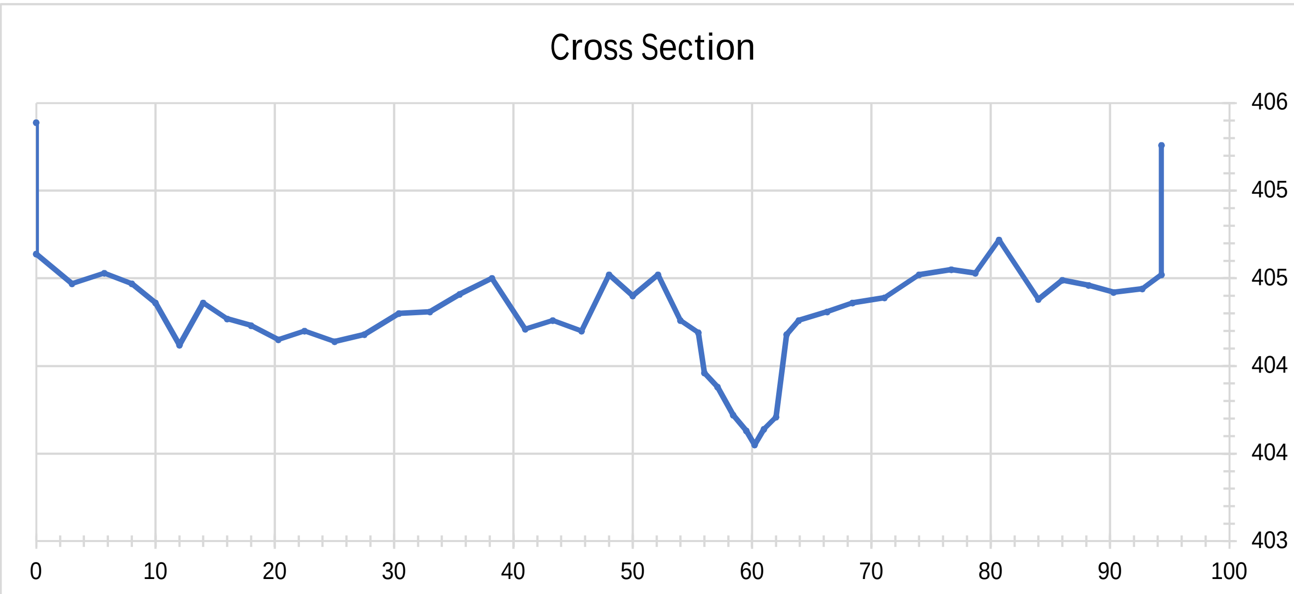


Size (mm)	
D16	0.99
D35	7.6
D50	13
D65	23
D84	52
D95	91

Size Distribution	
mean	7.2
dispersion	8.6
skewness	-0.20

Type	
silt/clay	6%
sand	14%
gravel	69%
cobble	10%
boulder	1%

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 4 - Cross Section Monitoring
Date: 5/5/2020



Benchmark Elevation: 405.39 LPIN
Height of Instrument: 409.40

	Survey Data		Section Comparison Data		
Pnt Num	Survey Data Station	Survey Rod Height	Station	Elevation	Notes
	(ft)	(ft)	(ft)	(ft)	
1	0.00	4.01	0.00	405.39	LPIN
2	0.00	4.76	0.00	404.64	LPIN Ground
3	3.00	4.93	3.00	404.47	Floodplain
4	5.70	4.87	5.70	404.53	Floodplain
5	8.00	4.93	8.00	404.47	Floodplain
6	10.00	5.04	10.00	404.36	Floodplain
7	12.00	5.28	12.00	404.12	Floodplain
8	14.00	5.04	14.00	404.36	Floodplain
9	16.00	5.13	16.00	404.27	Floodplain
10	18.00	5.17	18.00	404.23	Floodplain
11	20.30	5.25	20.30	404.15	Floodplain
12	22.50	5.20	22.50	404.20	Floodplain
13	25.00	5.26	25.00	404.14	Floodplain
14	27.50	5.22	27.50	404.18	Floodplain
15	30.40	5.10	30.40	404.30	Floodplain

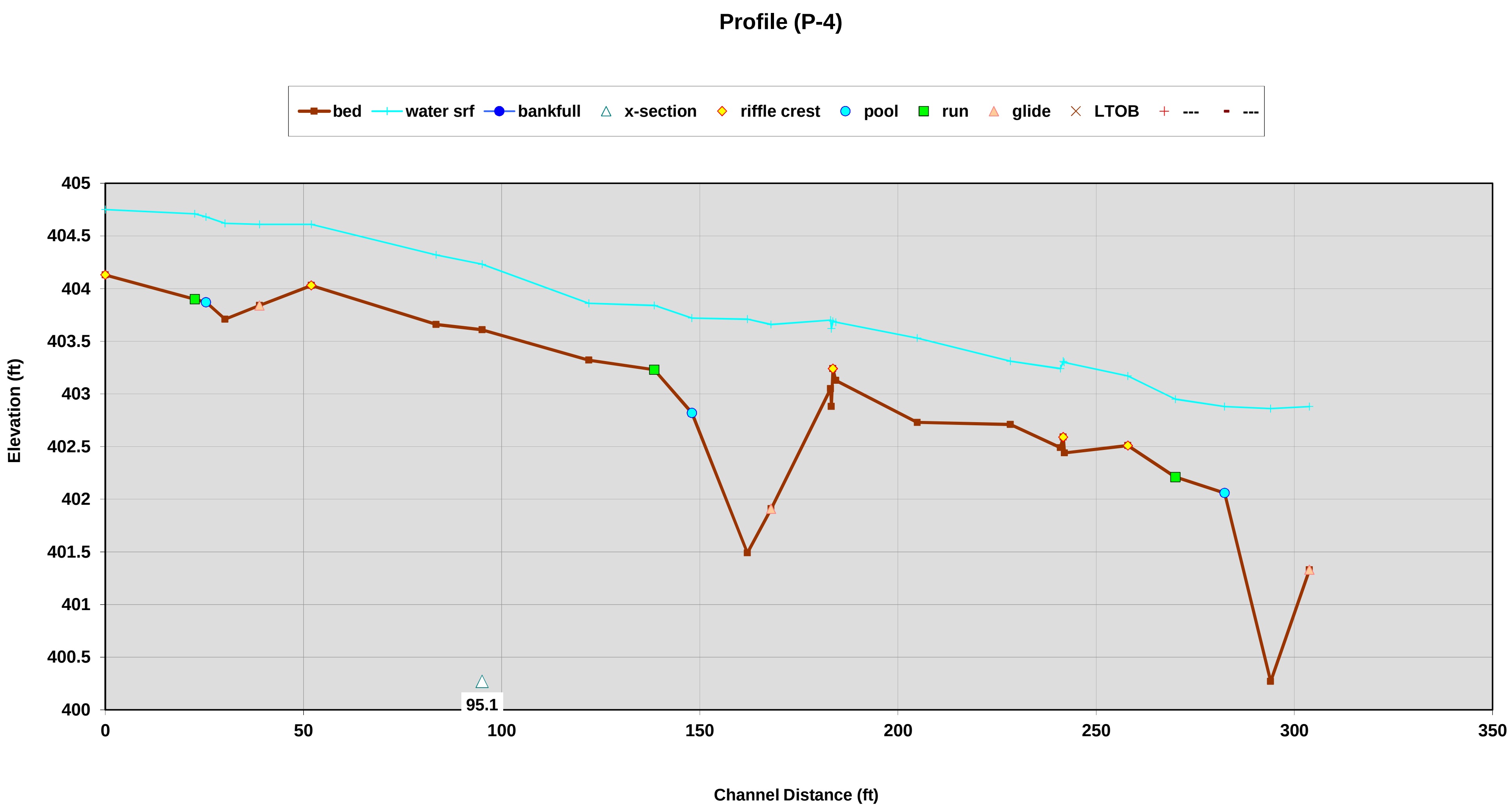
16	33.00	5.09	33.00	404.31	Floodplain
17	35.50	4.99	35.50	404.41	Floodplain
18	38.20	4.90	38.20	404.50	Floodplain
19	41.00	5.19	41.00	404.21	Floodplain
20	43.30	5.14	43.30	404.26	Floodplain
21	45.70	5.20	45.70	404.20	Floodplain
22	48.00	4.88	48.00	404.52	Floodplain
23	50.00	5.00	50.00	404.40	Floodplain
24	52.10	4.88	52.10	404.52	Floodplain
25	54.00	5.14	54.00	404.26	Floodplain
26	55.50	5.21	55.50	404.19	LEOW
27	56.00	5.44	56.00	403.96	in-channel
28	57.10	5.52	57.10	403.88	in-channel
29	58.40	5.68	58.40	403.72	in-channel
30	59.50	5.77	59.50	403.63	in-channel
31	60.20	5.85	60.20	403.55	TW D=0.73'
32	61.00	5.76	61.00	403.64	in-channel
33	62.00	5.69	62.00	403.71	in-channel
34	62.90	5.22	62.90	404.18	REOW
35	63.90	5.14	63.90	404.26	Floodplain
36	66.30	5.09	66.30	404.31	Floodplain
37	68.40	5.04	68.40	404.36	Floodplain
38	71.10	5.01	71.10	404.39	Floodplain
39	74.00	4.88	74.00	404.52	Floodplain
40	76.70	4.85	76.70	404.55	Floodplain
41	78.70	4.87	78.70	404.53	Floodplain
42	80.70	4.68	80.70	404.72	Floodplain
43	84.00	5.02	84.00	404.38	Floodplain
44	86.00	4.91	86.00	404.49	Floodplain
45	88.20	4.94	88.20	404.46	Floodplain
46	90.30	4.98	90.30	404.42	Floodplain
47	92.70	4.96	92.70	404.44	Floodplain
48	94.30	4.88	94.30	404.52	RPIN Ground
49	94.30	4.14	94.30	405.26	RPIN

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 4 - Profile Monitoring
Date: 6/17/2019

Benchmark Elevation 405.39
Rod Height at BM 4.14
HI from Benchmark Elev. 409.53

Cross Section Station	95		Slope:	0.58%		
XS Station Adjustment	0			Survey Sta.	Adjust Sta.	WS Elev.
XS Crossing Processed	95	95.00	Start Sta.	0.00	0	404.45
	400.37	404.04	End Sta.	313.00	313	402.64

	Survey Data				Profile Comparison Data			
Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Water (ft)	Depth or Surface	Adjusted Station (ft)	Ground Elevation (ft)	Water Surface Elevation	Notes
1	0.00	5.49	0.41	Depth	0.00	404.04	404.45	riffle
2	15.00	5.54	0.43	Depth	15.00	403.99	404.42	mid riffle
3	27.00	5.87	0.74	Depth	27.00	403.66	404.40	run
4	47.00	5.65	0.51	Depth	47.00	403.88	404.39	run
5	62.00	5.67	0.42	Depth	62.00	403.86	404.28	riffle
6	80.00	5.86	0.49	Depth	80.00	403.67	404.16	mid-riffle
7	95.00	6.01	0.55	Depth	95.00	403.52	404.07	XS-4 mid-
8	112.00	6.13	0.39	Depth	112.00	403.40	403.79	riffle
9	133.00	6.18	0.29	Depth	133.00	403.35	403.64	riffle
10	142.00	6.48	0.45	Depth	142.00	403.05	403.50	run
11	149.00	7.07	1.05	Depth	149.00	402.46	403.51	pool
12	160.00	8.13	2.12	Depth	160.00	401.40	403.52	max depth
13	167.00	7.48	1.47	Depth	167.00	402.05	403.52	mid pool
14	173.00	6.85	0.84	Depth	173.00	402.68	403.52	glide
15	182.00	6.39	0.32	Depth	182.00	403.14	403.46	riffle /
16	198.00	6.64	0.45	Depth	198.00	402.89	403.34	mid riffle
17	219.00	6.73	0.40	Depth	219.00	402.80	403.20	mid riffle
18	243.00	6.87	0.42	Depth	243.00	402.66	403.08	mid riffle
19	263.00	7.12	0.37	Depth	263.00	402.41	402.78	mid riffle
20	279.00	7.58	0.74	Depth	279.00	401.95	402.69	run
21	282.00	7.94	1.10	Depth	282.00	401.59	402.69	pool
22	288.00	9.16	2.32	Depth	288.00	400.37	402.69	max depth
23	296.00	8.63	1.79	Depth	296.00	400.90	402.69	mid pool
24	301.00	7.69	0.85	Depth	301.00	401.84	402.69	glide
25	313.00	7.43	0.54	Depth	313.00	402.10	402.64	riffle /lp end



Profile (P-4)
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LTOB

Elevation (ft)
405
404.5
404
403.5
403
402.5
402
401.5
401
400.5
400
95.1
0
50
100
150
200
250
300
350
Channel Distance (ft)

1) Individual Pebble Count

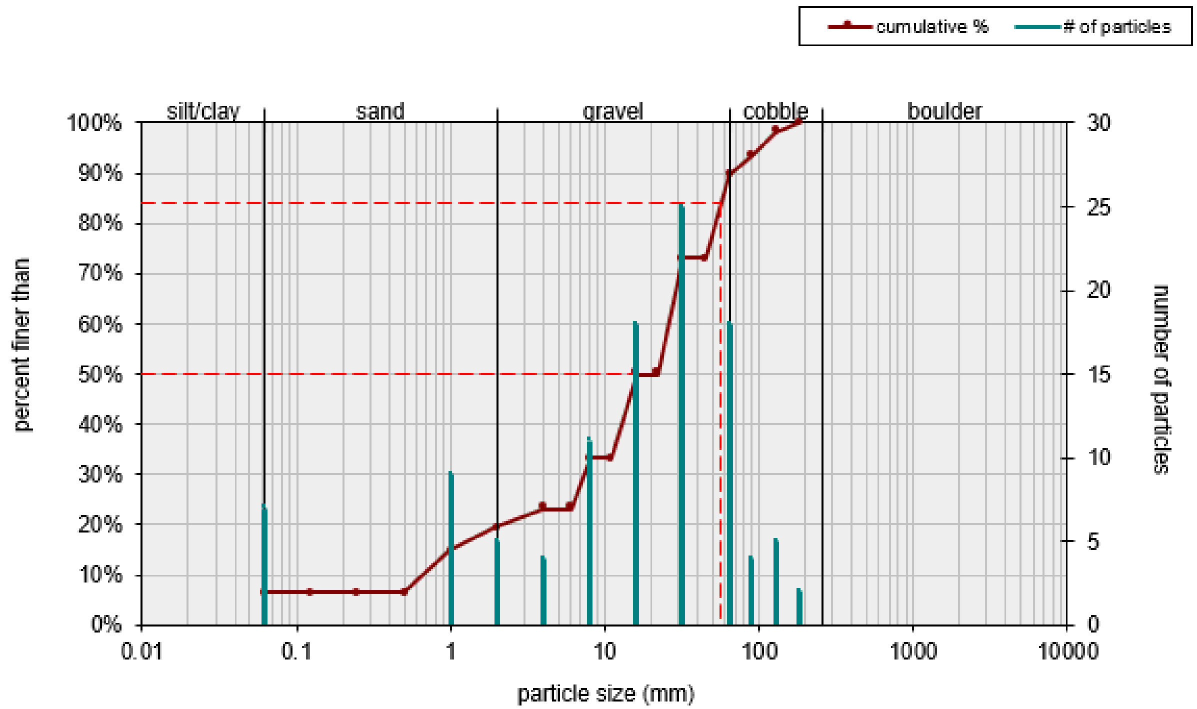
Two individual samples may be entered below. Select sample type for each.

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	7
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	9
very coarse sand	1 - 2	5
very fine gravel	2 - 4	4
fine gravel	4 - 6	
fine gravel	6 - 8	11
medium gravel	8 - 11	
medium gravel	11 - 16	18
coarse gravel	16 - 22	
coarse gravel	22 - 32	25
very coarse gravel	32 - 45	
very coarse gravel	45 - 64	18
small cobble	64 - 90	4
medium cobble	90 - 128	5
large cobble	128 - 180	2
very large cobble	180 - 256	
small boulder	256 - 362	
small boulder	362 - 512	
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
	total particle count:	108
bedrock		
clay hardpan		
detritus/wood		
artificial		
	total count:	108

Note: XS 4

Riffle Surface Pebble Count, ---

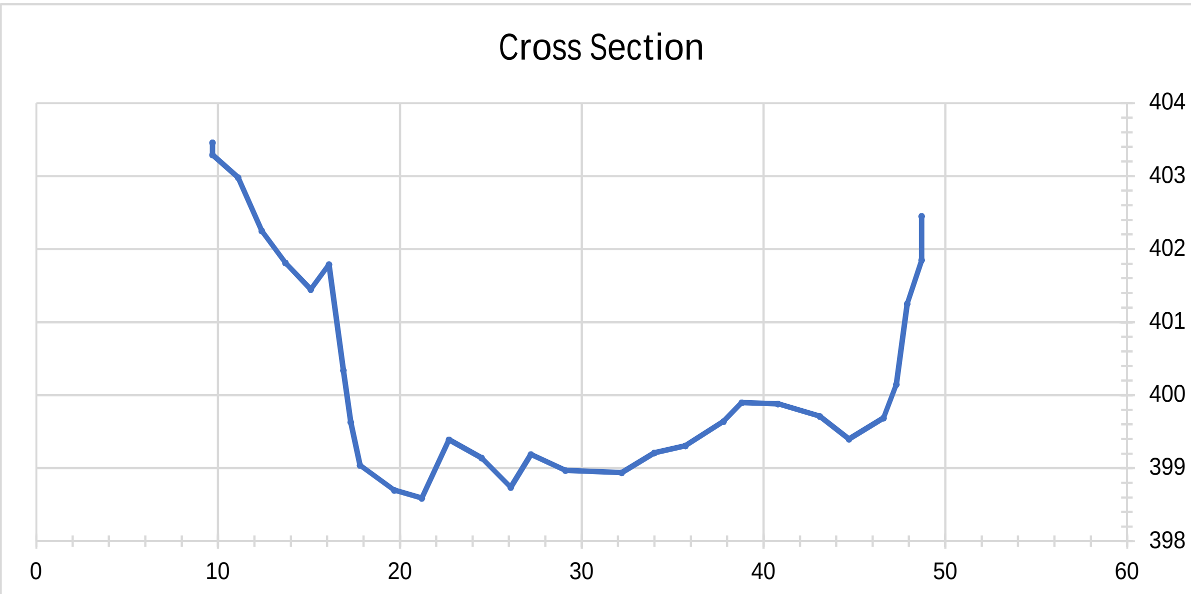


Size (mm)	
D16	1.2
D35	11
D50	16
D65	28
D84	57
D95	100

Size Distribution	
mean	8.3
dispersion	8.4
skewness	-0.22

Type	
silt/clay	6%
sand	13%
gravel	70%
cobble	10%
boulder	0%

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 5 - Cross Section Monitoring
Date: 5/4/2020



Benchmark Elevation: 403.46 LPIN
Height of Instrument: 405.21

Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Station (ft)	Elevation (ft)	Notes
	Survey Data		Section Comparison Data		
1	0.00	1.75	9.70	403.46	LPIN
2	0.00	1.92	9.70	403.29	LPIN Ground
3	1.40	2.23	11.10	402.98	
4	2.70	2.96	12.40	402.25	
5	4.00	3.40	13.70	401.81	
6	5.40	3.76	15.10	401.45	
7	6.40	3.42	16.10	401.79	TOB
8	7.20	4.87	16.90	400.34	Face of Slope
9	7.60	5.58	17.30	399.63	LEOW
10	8.10	6.17	17.80	399.04	
11	10.00	6.51	19.70	398.70	
12	11.50	6.62	21.20	398.59	TW D=1.32'
13	13.00	5.82	22.70	399.39	Boulder
14	14.80	6.07	24.50	399.14	Boulder
15	16.40	6.47	26.10	398.74	

16	17.50	6.02	27.20	399.19	Sediment deposit behind boulder
17	19.40	6.24	29.10	398.97	
18	22.50	6.27	32.20	398.94	
19	24.30	6.00	34.00	399.21	
20	26.00	5.90	35.70	399.31	
21	28.10	5.57	37.80	399.64	mid-channel bar left
22	29.10	5.31	38.80	399.90	REOW
23	31.10	5.33	40.80	399.88	mid-channel bar
24	33.40	5.50	43.10	399.71	mid-channel bar LEOW
25	35.00	5.81	44.70	399.40	mid-channel bar right
26	36.90	5.52	46.60	399.69	REOW
27	37.60	5.06	47.30	400.15	Face of Slope
28	38.20	3.96	47.90	401.25	Face of Slope
29	39.00	3.36	48.70	401.85	RPIN Ground
30	39.00	2.76	48.70	402.45	RPIN

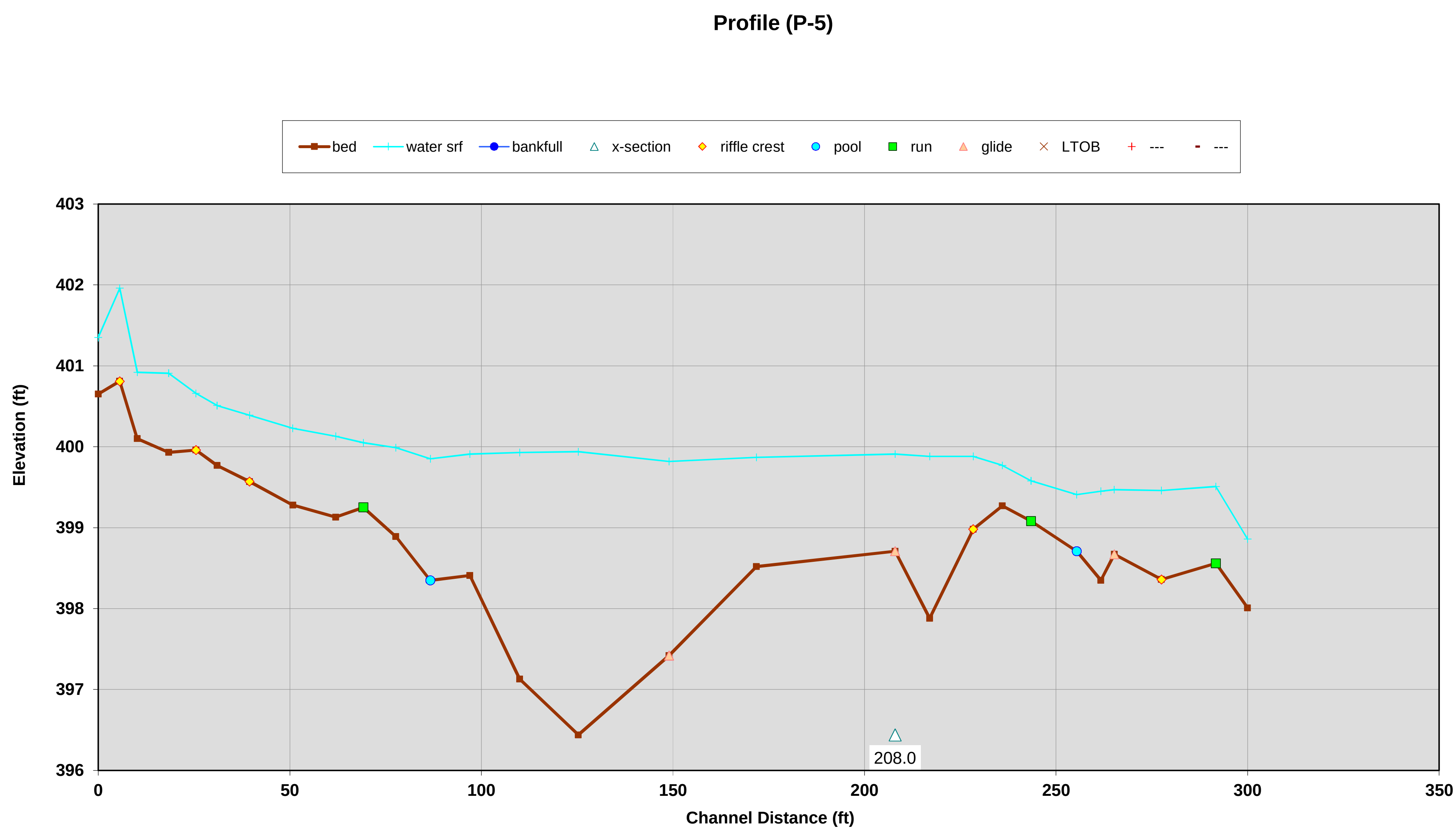
Project:	Little Catoctin Creek Monitoring
Project Number:	BCS 2014-09H
Site:	Section 5 - Profile Monitoring
Date:	5/4/2020

Benchmark Elevation	403.46
Rod Height at BM	1.75
HI from Benchmark Elev.	405.21

Cross Section Station	208	Slope:	0.70%		
XS Station Adjustment	0		Survey Sta.	Adjust Sta.	WS Elev.
XS Crossing Processed	208	Start Sta.	25.50	25.5	400.66
		End Sta.	277.50	277.5	399.46

	Survey Data				Profile Comparison Data			
Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Water (ft)	Depth or Surface	Adjusted Station (ft)	Ground Elevation (ft)	Water Surface Elevation	Notes
1	0.00	4.56	0.70	Depth	0.00	400.65	401.35	Side Confluence /Cascade
2	5.60	4.40	1.15	Depth	5.60	400.81	401.96	Cascade
3	10.20	5.11	0.82	Depth	10.20	400.10	400.92	Cascade
4	18.40	5.28	0.98	Depth	18.40	399.93	400.91	Cascade
5	25.50	5.25	0.70	Depth	25.50	399.96	400.66	Head of Cascade
6	31.00	5.44	0.74	Depth	31.00	399.77	400.51	mid-cascade
7	39.50	5.64	0.82	Depth	39.50	399.57	400.39	Riffle
8	50.80	5.93	0.95	Depth	50.80	399.28	400.23	Riffle
9	62.00	6.08	1.00	Depth	62.00	399.13	400.13	mid-Riffle
10	69.20	5.96	0.80	Depth	69.20	399.25	400.05	Run
11	77.70	6.32	1.10	Depth	77.70	398.89	399.99	mid-run
12	86.70	6.86	1.50	Depth	86.70	398.35	399.85	Pool
13	97.00	6.80	1.50	Depth	97.00	398.41	399.91	Pool
14	110.00	8.08	2.80	Depth	110.00	397.13	399.93	Pool
15	125.30	8.77	3.50	Depth	125.30	396.44	399.94	Pool dmax
16	149.00	7.79	2.40	Depth	149.00	397.42	399.82	Glide
17	171.80	6.69	1.35	Depth	171.80	398.52	399.87	Glide
18	208.00	6.50	1.20	Depth	208.00	398.71	399.91	XS 5/Glide
19	217.00	7.33	2.00	Depth	217.00	397.88	399.88	Glide
20	228.40	6.23	0.90	Depth	228.40	398.98	399.88	Riffle
21	236.00	5.94	0.50	Depth	236.00	399.27	399.77	Riffle
22	243.50	6.13	0.50	Depth	243.50	399.08	399.58	Run
23	255.40	6.50	0.70	Depth	255.40	398.71	399.41	Pool
24	261.70	6.86	1.10	Depth	261.70	398.35	399.45	Pool dmax

25	265.20	6.54	0.80	Depth	265.20	398.67	399.47	Glide
26	277.50	6.85	1.10	Depth	277.50	398.36	399.46	Riffle
27	291.70	6.65	0.95	Depth	291.70	398.56	399.51	Run
28	300.00	7.20	0.85	Depth	300.00	398.01	398.86	Run



Profile (P-5)
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LTOB

Elevation (ft)
403
402
401
400
399
398
397
396
0
50
100
150
200
250
300
350
Channel Distance (ft)
208.0

1) Individual Pebble Count

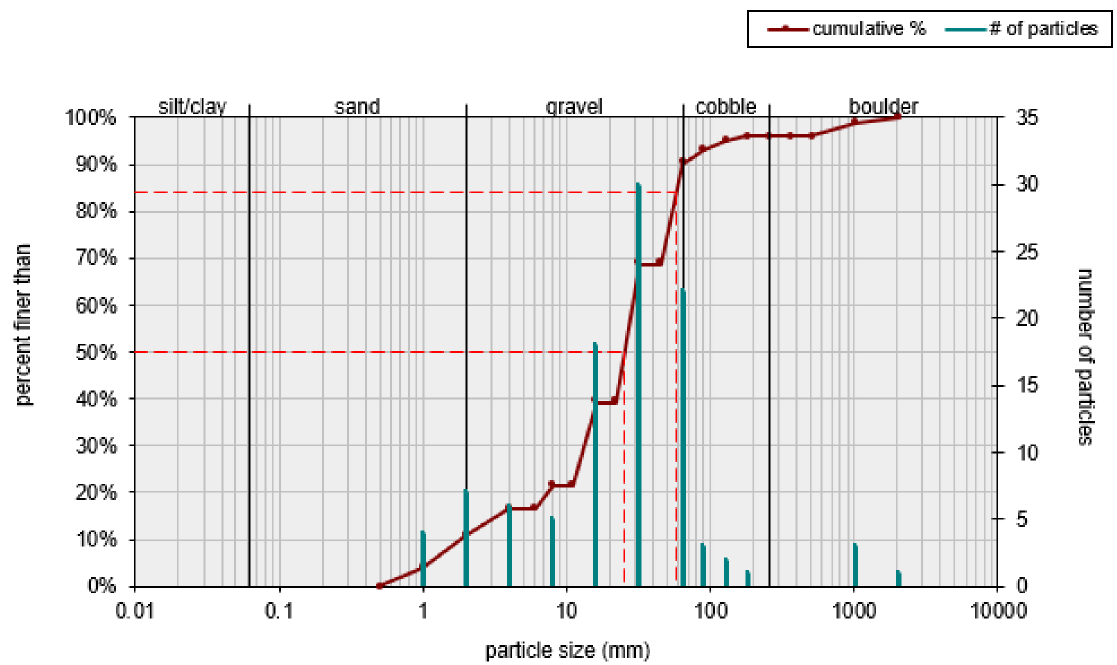
Two individual samples may be entered below. Select sample type for each.

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	4
very coarse sand	1 - 2	7
very fine gravel	2 - 4	6
fine gravel	4 - 6	
fine gravel	6 - 8	5
medium gravel	8 - 11	
medium gravel	11 - 16	18
coarse gravel	16 - 22	
coarse gravel	22 - 32	30
very coarse gravel	32 - 45	
very coarse gravel	45 - 64	22
small cobble	64 - 90	3
medium cobble	90 - 128	2
large cobble	128 - 180	1
very large cobble	180 - 256	
small boulder	256 - 362	
small boulder	362 - 512	
medium boulder	512 - 1024	3
large boulder	1024 - 2048	1
very large boulder	2048 - 4096	
total particle count:		102
bedrock	------------	
clay hardpan	------------	
detritus/wood	------------	
artificial	------------	
total count:		102

Note: XS-5

Riffle Surface Pebble Count, ---



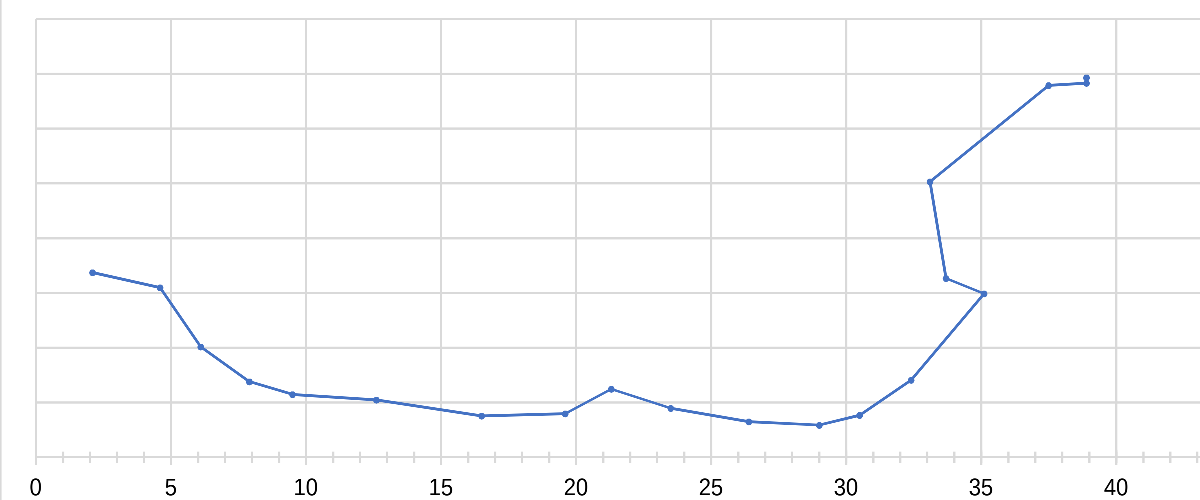
Size (mm)	
D16	3.7
D35	15
D50	25
D65	31
D84	58
D95	130

Size Distribution	
mean	14.6
dispersion	4.5
skewness	-0.21

Type	
silt/clay	0%
sand	11%
gravel	79%
cobble	6%
boulder	4%

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 6 - Cross Section Monitoring
Date: 5/4/2020

Cross Section



Benchmark Elevation: 401.93 RPIN
Height of Instrument: 403.99

Pnt Num	Survey Data: Survey Data Station (ft)	Survey Data: Survey Rod Height (ft)	Section Comparison Data: Station (ft)	Section Comparison Data: Elevation (ft)	Notes
1	2.1	5.62	2.1	398.37	ground
2	4.6	5.89	4.6	398.10	TOB
3	6.1	6.97	6.1	397.02	Face of Slope
4	7.9	7.61	7.9	396.38	LEOW
5	9.5	7.84	9.5	396.15	in-channel
6	12.6	7.94	12.6	396.05	in-channel
7	16.5	8.23	16.5	395.76	in-channel
8	19.6	8.19	19.6	395.80	in-channel
9	21.3	7.74	21.3	396.25	Channel
10	23.5	8.09	23.5	395.90	in-channel
11	26.4	8.34	26.4	395.65	in-channel
12	29	8.4	29	395.59	TW D=0.90'
13	30.5	8.22	30.5	395.77	in-channel
14	32.4	7.58	32.4	396.41	REOW
15	35.1	6	35.1	397.99	undercut bank
16	33.7	5.72	33.7	398.27	bank

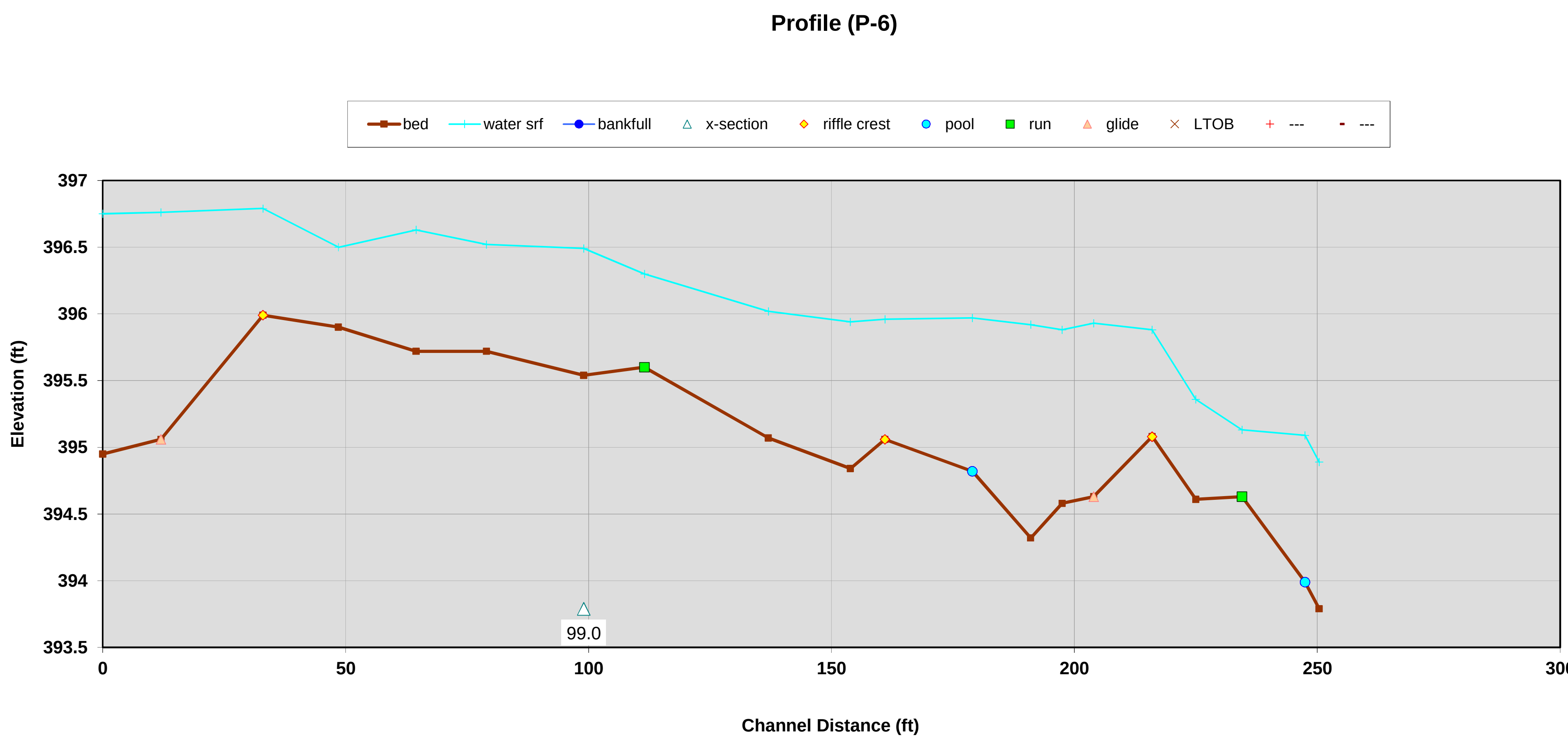
17	33.1	3.96	33.1	400.03	Face of Slope
18	37.5	2.2	37.5	401.79	TOB
19	38.9	2.16	38.9	401.83	RPIN Ground
20	38.9	2.06	38.9	401.93	RPIN

Project: Little Catoctin Creek Monitoring
Project Number: BCS 2014-09H
Site: Section 6 - Profile Monitoring
Date: 5/4/2020

Benchmark Elevation	401.93
Rod Height at BM	2.06
HI from Benchmark Elev.	403.99

Cross Section Station	99		Slope:	0.50%		
XS Station Adjustment	42.5			Survey Sta.	Adjust Sta.	WS Elev.
XS Crossing Processed	141.5	141.50	Start Sta.	0.00	42.5	396.75
	393.79	395.99	End Sta.	250.40	292.9	394.89

	Survey Data				Profile Comparison Data			
Pnt Num	Survey Data Station (ft)	Survey Rod Height (ft)	Water (ft)	Depth or Surface	Adjusted Station (ft)	Ground Elevation (ft)	Water Surface Elevation	Notes
1	0.00	9.04	1.80	Depth	42.50	394.95	396.75	Pool/Side Stream Confluence
2	12.00	8.93	1.70	Depth	54.50	395.06	396.76	Glide
3	33.00	8.00	0.80	Depth	75.50	395.99	396.79	Riffle
4	48.50	8.09	0.60	Depth	91.00	395.90	396.50	mid-riffle
5	64.50	8.27	0.91	Depth	107.00	395.72	396.63	mid-riffle
6	79.00	8.27	0.80	Depth	121.50	395.72	396.52	mid-riffle
7	99.00	8.45	0.95	Depth	141.50	395.54	396.49	XS 6
8	111.50	8.39	0.70	Depth	154.00	395.60	396.30	Head of Run
9	137.00	8.92	0.95	Depth	179.50	395.07	396.02	End of Run
10	153.90	9.15	1.10	Depth	196.40	394.84	395.94	Micro-Pool
11	161.00	8.93	0.90	Depth	203.50	395.06	395.96	Riffle
12	179.00	9.17	1.15	Depth	221.50	394.82	395.97	Pool
13	191.00	9.67	1.60	Depth	233.50	394.32	395.92	Pool dmax
14	197.50	9.41	1.30	Depth	240.00	394.58	395.88	Pool
15	204.00	9.36	1.30	Depth	246.50	394.63	395.93	Glide
16	216.00	8.91	0.80	Depth	258.50	395.08	395.88	Start of
17	225.00	9.38	0.75	Depth	267.50	394.61	395.36	mid-Cascade
18	234.50	9.36	0.50	Depth	277.00	394.63	395.13	Cascade
19	247.50	10.00	1.10	Depth	290.00	393.99	395.09	Pool
20	250.40	10.20	1.10	Depth	292.90	393.79	394.89	Pool


Profile (P-6)
bed
water srf
bankfull
x-section
riffle crest
pool
run
glide
LTOB

397
396.5
396
395.5
395
394.5
394
393.5
Elevation (ft)
99.0
0
50
100
150
200
250
300
Channel Distance (ft)

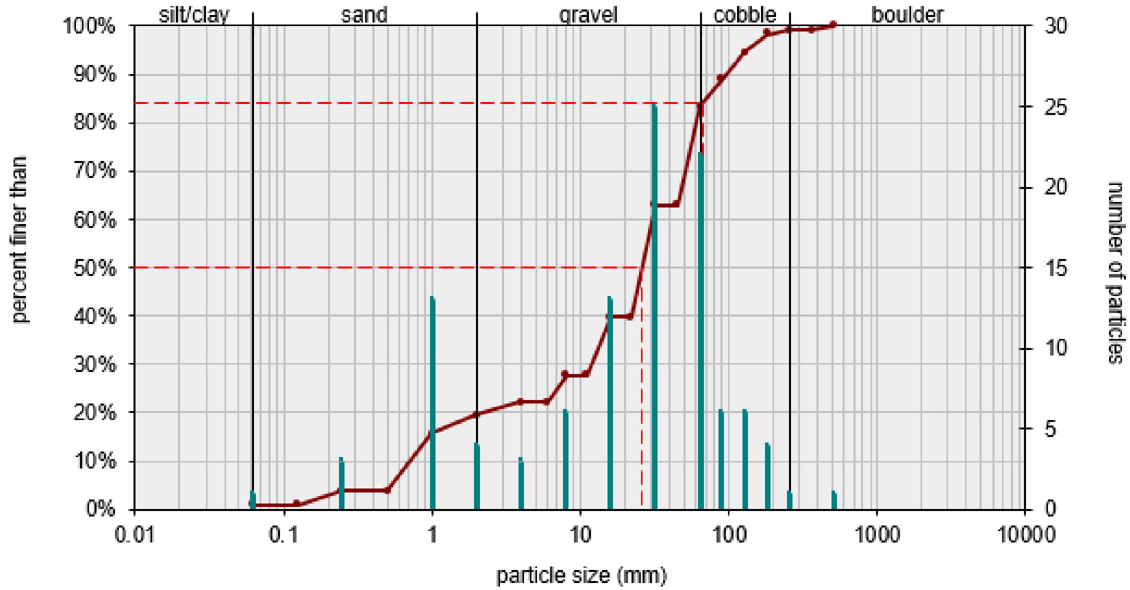
1) Individual Pebble Count

Two individual samples may be entered below. Select sample type for each.

Riffle Surface

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	1
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	3
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	13
very coarse sand	1 - 2	4
very fine gravel	2 - 4	3
fine gravel	4 - 6	
fine gravel	6 - 8	6
medium gravel	8 - 11	
medium gravel	11 - 16	13
coarse gravel	16 - 22	
coarse gravel	22 - 32	25
very coarse gravel	32 - 45	
very coarse gravel	45 - 64	22
small cobble	64 - 90	6
medium cobble	90 - 128	6
large cobble	128 - 180	4
very large cobble	180 - 256	1
small boulder	256 - 362	
small boulder	362 - 512	1
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		108
bedrock	------------	
clay hardpan	------------	
detritus/wood	------------	
artificial	------------	
total count:		108

Note: XS-6



Size (mm)	
D16	1
D35	14
D50	26
D65	47
D84	67
D95	130

Size Distribution	
mean	8.2
dispersion	14.3
skewness	-0.37

Type	
silt/clay	1%
sand	19%
gravel	64%
cobble	16%
boulder	1%

Attachment D - Chemical Monitoring Results

3.0 Chemical Monitoring

Per the NPDES/MS4 Assessment of Controls monitoring plan, chemical monitoring of the Little Catoctin Creek was performed as specified in the chemical monitoring methodology. The monitoring efforts through January 31, 2018 fall under phase CHEM 1 activity to establish pre-restoration conditions. Monitoring efforts between February 1, 2018 through April 15, 2019 occurred during the construction phase (CHEM 2). Monitoring efforts beginning on April 16, 2019 and ending in May 2020, were conducted under the post-construction phase (CHEM 3). Stage, discharge, velocity, continuous water quality measurements, and discrete water quality sample analyses made during this effort are available through the U.S. Geological Survey's National Water Information Service (NWIS) online at: https://www.waterqualitydata.us/. At time of writing (September 2020) a large percentage of the hydrologic and continuous water-quality monitoring data have been reviewed and are "approved" by the USGS; data not yet approved are subject to revision. The monitoring locations referenced in the following sections of the report can be found in **Figure 1.**

It should also be noted that chemical data submitted to MDE in FY19 is being overwritten with new data in the FY20 submittal because the previous submittal included some observations still flagged by USGS as provisional. Moving forward with the submission of some data in this state was necessary to meet the 2019 reporting deadline and was done so with the understanding that subsequent files would update any provisional entries accordingly.

3.1 Surface Water Stage/Discharge/Velocity

In September 2016, U.S. Geological Survey established Site 01636845 (Little Catoctin Creek Near Rosemont, MD; upstream)**;** this station is equipped with a radar level sensor and acoustic doppler velocity meter (ADVM) for measuring stage and velocity, respectively. In the pre-construction and construction phases of the study, 82 discrete discharge measurements were made for the purpose of calibrating these instruments, covering a range of 0.49 cubic feet per second (ft^3/s) to 307 ft^3/s. These measurements establish the relation between stage-velocity and discharge. Thirty-six manual calibration measurements were made between July 1, 2018 – June 30, 2019, which includes the period when the gage was decommissioned following the historic flood in 2018 and again at the start of the stream reconstruction work (January 18, 2019 – May 23, 2019). The gage was rebuilt using a radar water-level measuring system mounted aside the Rte. 180 bridge **(Figure 2)** and began operating in April 2019; since then 39 additional discharge measurements were made thru July 2020 to recalibrate the stage-discharge relation. Because of the construction of the pond directly downstream of the bridge, the ADVM equipment could not be reinstalled at the upstream station, so water velocity entering at the upstream station (the pond) is not available for the post-construction period. Current and historic observations can be found online at: *https://nwis.waterdata.usgs.gov/md/nwis/uv/?site_no=01636845*

In December 2016, U.S. Geological Survey established the downstream site 01636846 (Little Catoctin Creek at Rosemont, MD), this site was instrumented with an ADVM to measure stream velocity **(Figure 3)**. In September 2017, a bubbler-style gage unit was installed at this site to record stage needed for the computing discharge. Current and historic observations can be found at:

https://waterdata.usgs.gov/nwis/inventory/?site_no=01636846&agency_cd=USGS

Figure 1. Chemical Monitoring Locations

Figure 2. U.S. Geological Survey upstream station (Site ID01636845) on Little Catoctin Creek near Rosemont, MD

Figure 3. U.S. Geological Survey downstream station (Site ID 01636846) on Little Catoctin Creek near Rosemont, MD.

Discharge at the downstream station was deemed necessary because of the possibility that construction would enhance groundwater flow into the stream through the channel bottom. In addition, numerous springs and seeps were observed along the banks of the Little Catoctin Creek that undoubtedly contribute to the stream flow. Measurement of volumetric discharge concurrently at both the upstream and downstream stations allows quantification of the changes through the reach, and changes that may be attributed to the restoration effort. Methods used in this work follow USGS procedures in USGS Techniques of Water-Resources Investigations (Book 3, Chapter A8) available at https://pubs.usgs.gov/tm/tm3-a7/tm3a7.pdf and https://pubs.usgs.gov/twri/twri3a8/.

During the study, 284 and 261 discrete discharge measurements were made at the upstream and downstream sites during sampling, respectively, covering a range of 0.54 ft^3/s to 824 ft^3/s at the upstream site, and 0.49 to 2,100 ft^3/s at the downstream site. The difference in ranges covered by the measurements is the result of the disruption the upstream station caused by the 2018 flood. These discrete measurements help ensure the accuracy of the continuous discharge measurements required for evaluating the rehabilitation.

3.2 Summary of Discharge and Velocity Data

The continuous discharge and water velocity data were downloaded, tabulated and inspected for completeness; completeness is defined as the percent of time when measurements were recorded compared to the total time of gage operation. Completeness is an important consideration when attempting to compare hydrologic and chemical parameters among time periods. For example, extended periods of missing data will greatly hinder the ability to compare volumes and loadings among pre- and post-construction periods. Data loss is the result of equipment failures, icing, or other unforeseen incidents such as major floods. Another factor is the percentage of data "approved" by the USGS for use. Hydrologic data collected by the USGS undergoes a rigorous review process before becoming "approved" – data classified as "provisional" are subject to change upon USGS review.

A summary of the continuous hydrologic data is presented in **table 3.1** for both the FY20 (July 1, 2019 through June 30, 2020) and for the entire study period (10/1/17 through 6/1/2020). The data are divided into four intervals (1) the entire study period (1/3/17 – 6/30/20); (2) the pre-construction period from the initiation of sampling (1/3/17) until construction started on 1/31/18; (3) the construction period between 2/1/18 and 4/15/19; and (4) the post-construction period from 4/16/19 through 6/30/2020 when the study was suspended. As previously discussed, the gaging equipment at the upstream station was removed for 126 days (begging in on 1/18/19) because of the floodplain restoration work. The gage was reinstalled and began operating again at the end of the construction work. This explains the low percentage of the discharge record in **table 3.1** for the construction period.

FY20 covers almost the entire post construction period. During the FY20 period, the record contains approximately 50% "approved" discharge and gage height data; ***water velocity at the downstream station has not yet been posted on the public NWIS web sites.***

As was the case in the pre- and construction phases, discharge and gage heights during the post-construction phase are higher at the downstream station than in the upstream station – indicating the Catoctin Creek study is a gaining reach. Median discharges for post- construction are 2.86 ft^3/s (maximum of 842 ft^3/s) upstream and 3.53 ft^3/s (maximum 918 ft^3/s) downstream. The difference in medians between upstream and downstream (downstream minus upstream = 0.67 ft^3/s) can be interpreted as the yearly groundwater input to the stream over this period. A smaller difference, 0.14 ft^3/s, existed between the medians of the upstream and downstream stations during the pre-construction period.

Comparing discharge measured concurrently at the upstream and downstream stations indicates that discharge increases by approximately 15% through the stream reach (8% difference for the pre-construction phase, and 21% for the post construction phase). Any “missing” discharge values, such as occurred at the upstream station during the construction period, can be estimated as being roughly 80% of the discharge measured downstream.

Figure 4 shows a plot of cumulative percentage of time the indicated discharge occurred during the pre- and post-construction phases at the upstream sampling station. This plot can be considered as showing “percent exceedance” – for example, 90% of the study period flow exceeded 0.7 ft3/s, and less than 10% of the time flow exceeded 8 ft^3/s. At 250 ft^3/s the cumulative percentages in >99%, indicating that discharges at or above this value only occurred <1% of the time during the study (note that during the pre-construction period the maximum discharge reached was 454 ft^3/s, while during the post-construction period a maximum discharge was 842 ft^3/s). The offset between the pre- and post-construction curves is the result of high stream discharges occurring more frequently during the post construction monitoring period.

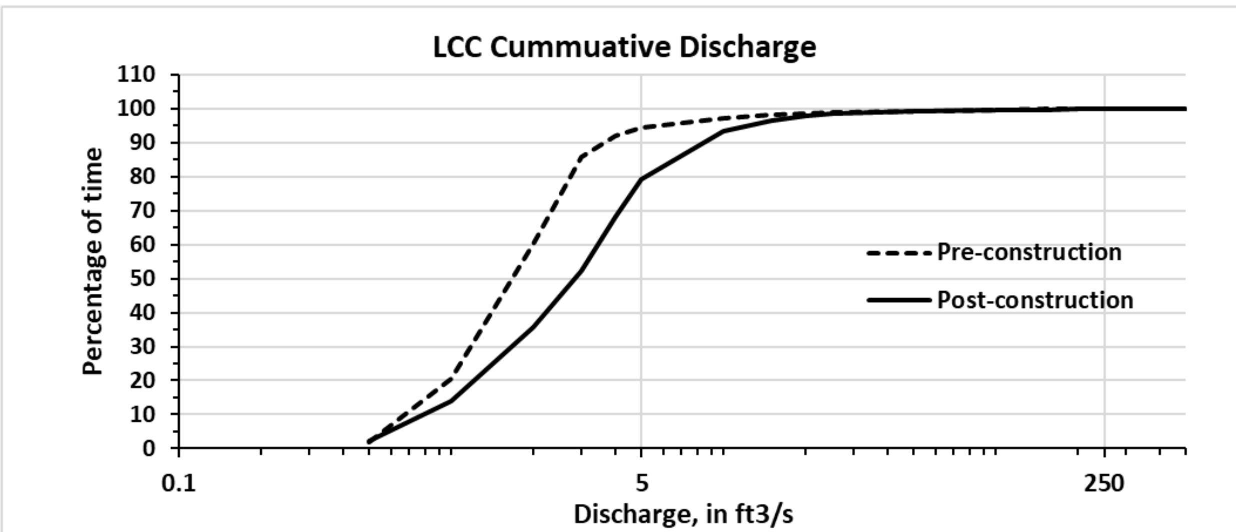


Figure 4. Plot of cumulative frequency of discharge measured during the pre- and post-construction periods at the upper station (01636845).

Velocity data for the two stations in FY20, and the post-construction period of the study, are still under evaluation by USGS surface water technicians; and the raw data were not fully available at the time this report was being produced. As shown in table 3.1, only about 11% of the possible velocity measurements for the post-construction period were available for inspection at the time this report was prepared, and as mentioned previously, velocity data were only obtained at the downstream station. Velocities in this reduced data set ranged from 0.001 to 7.34 ft/s with a median of 0.235 ft/s. Until the velocity data are fully processed and approved, it is not possible to evaluate the effects the restoration work had on the water velocity through the reach.

T**able 3.2** provides a summary of monthly precipitation data for the site during the project study period. The rain gage the site began operation on 2/25/18, so precipitation data were not available the pre-construction monitoring period. The precipitation record is sporadic through the construction and post-construction period due to problems with the rain collection equipment. Therefore, the precipitation record from the Fredrick Airport (station KFDK) station, retrieved from MesoWest (https://mesowest.utah.edu/), was used to calculate precipitation totals and intensities for the sampled storm events. However, to maintain consistency with the physical monitoring portion of the Little Catoctin Creek comprehensive monitoring effort, the precipitation record from the Hagerstown Regional Airport, retrieved from NOAA web site (https://www.ncdc.noaa.gov/data-access) was used to calculate monthly and periodic precipitation totals. As is evident in this table, total precipitation varied considerably during the pre-, construction, and post construction periods. During FY20, 32.25 inches of precipitation fell over the 367 days (start and end dates inclusive) in the year. During the construction period, several very large storms occurred, including the 100-year record storm, resulting in over 2 times more precipitation than was measured in the pre- and post-construction periods. Roughly 1.5 inches more precipitation fell in the post-construction interval than in the pre-construction.

Table 3.1. Summary statistics of gage height, discharge, water velocity and precipitation measured during the construction phases at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.

[ft, feet; ft^3/s, cubic feet per second; ft/s, feet per second; in, inches; min, minutes; --, not available]

	Gage height (ft)	Discharge (ft^3/s)	[2]Velocity (ft/s)	[1]Precipitation (in. per 5 min.)
	UPSTREAM (1636845)			
	FY20 6/1/19 to 6/30/20			
% of data available	85	84	na	98
% of data "Approved"	37	37	na	100
Maximum	4.51	842	na	0.52
Minimum	1.93	0.32	na	0.00
Median	2.58	2.48	na	<0.01
	Pre-construction 1/3/17 – 2/1/18			
% of data available	98	92	97	na
% of data "Approved"	100	100	0	na
Maximum	5.59	454	2.92	na
Minimum	0.16	0.36	0.0	na
Median	1.12	1.74	0.10	na
	Construction 2/2/18 – 4/15/19			
% of data available	70	97	23	54
% of data "Approved"	100	100	0	100
Maximum	8.96	9050	7.28	0.30
Minimum	0.88	1.08	0.00	0.00
Median	1.75	5.78	0.20	<0.01
	Post-construction 4/16/19 to 6/30/20			
% of data available	78	87	na	86
% of data "Approved"	44	49	na	100
Maximum	4.51	842	na	0.48
Minimum	1.93	0.32	na	0.00
Median	2.58	2.86	na	<0.01

[1] Statistics are for precipitation recorded at the upstream USGS station, which began operation on 2/25/18. Precipitation is collected at 5-minute intervals.

[2] Data for velocity measured in FY20 at the downstream station are still be processed and were not available at the time this report was being prepared. The velocity measuring equipment was removed at the upstream site in April 2019 after construction on the pond was started.

Table 3.1. Summary statistics of gage height, discharge, water velocity and precipitation measured during the construction phases at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[ft, feet; ft^3/s, cubic feet per second; ft/s, feet per second; in, inches; min, minutes; --, not available]

	Gage height (ft)	Discharge (ft^3/s)	[2]Velocity (ft/s)
	DOWNSTREAM (1636846)		
	FY20 6/1/19 to 6/30/20		
% of data available	98	98	nd
% of data "Approved	33	33	nd
Maximum	4.82	918	nd
Minimum	1.32	0.46	nd
Median	1.47	3.12	nd
	Pre-construction 1/3/17 – 2/1/18		
% of data available	35	95	97
% of data "Approved	100	100	68
Maximum	5.03	562	2.92
Minimum	1.32	0.38	-0.23
Median	1.44	1.88	0.11
	Construction 2/1/18 – 4/15/19		
% of data available	99	98	26
% of data "Approved	99	98	0
Maximum	12.1	9,630	7.28
Minimum	1.22	0.33	-0.64
Median	1.65	6.95	0.20
	Post-construction 4/16/19 to 6/30/20		
% of data available	98	98	11
% of data "Approved	45	45	0
Maximum	4.82	918	7.34
Minimum	1.32	0.46	0.001
Median	1.40	3.53	0.235

[1] Statistics are for precipitation recorded at the upstream USGS station, which began operation on 2/25/18. Precipitation is collected at 5-minute intervals.

[2] Data for velocity measured in FY20 at the downstream station are still be processed and were not available at the time this report was being prepared. The velocity measuring equipment was removed at the upstream site in April 2019 after construction on the pond was started.

Table 3.2 Summary of monthly precipitation at Hagerstown Regional Airport during the pre-construction, construction, and post construction phases of the study.

Pre-construction 1/3/18 to 2/1/18		Construction 2/2/18 to 7/15/19		Post construction 4/16/19 to 6/1/20		FY20 6/1/19 to 7/1/20	
Month and year	Total ppt. inches	Month and year	Total ppt. inches	Month and year	Total ppt. inches	Month and year	Total ppt. inches
Jan-17	2.75	Feb-18	3.88	Apr-19	3.14	Jun-19	2.12
Feb-17	1.35	Mar-18	1.96	May-19	5.73	Jul-19	4.37
Mar-17	2.83	Apr-18	4.12	Jun-19	2.12	Aug-19	2.4
Apr-17	2.37	May-18	4.64	Jul-19	4.37	Sep-19	0.48
May-17	5.32	Jun-18	4.97	Aug-19	2.4	Oct-19	5.25
Jun-17	2.74	Jul-18	5.96	Sep-19	0.48	Nov-19	0.8
Jul-17	5.35	Aug-18	6.24	Oct-19	5.25	Dec-19	3.05
Aug-17	2.9	Sep-18	9.31	Nov-19	0.8	Jan-20	2.75
Sep-17	1.45	Oct-18	1.63	Dec-19	3.05	Feb-20	1.71
Oct-17	3.54	Nov-18	2.46	Jan-20	2.75	Mar-20	2.57
Nov-17	1.62	Dec-18	4.87	Feb-20	1.71	Apr-20	4.53
Dec-17	0.81	Jan-19	3.43	Mar-20	2.57	May-20	1.55
Jan-18	2.62	Feb-19	2.97	Apr-20	4.53	Jun-20	1.66
		Mar-19	4.21	May-20	1.55		
		4/16/2019 end	0.99				
Total precipitation	35.65		61.64		40.45		32.25
Total days	395		438		413		367

3.2 Continuous Water Quality

In November and December 2016, multiparameter water quality sondes (YSI EXO-2) were installed at site 01636845 and 01636846, respectively (**figures 3 and 5).** These sondes measure temperature, specific conductivity, pH, and turbidity at 5-minute intervals. The sondes have been operational since installation and data are available in near- real time on the NWIS website listed above. These data have been approved by the USGS through 1/18/19- after which, data are considered “provisional” and subject to change. As mentioned previously, due to the restoration activities, the upstream data sonde was removed 1/18/19 and returned to operation on 4/9/19.

Figure 5. U.S. Geological Survey the downstream station (Site ID 01636846) on Little Catoctin Creek near Rosemont, MD. The photo shows the temporary gage station and the discharge and water-quality sonde installed in the river.

3.2.1 Summary of Available Continuous Water Quality Data

The continuous water-quality data measured using the data sondes were retrieved from NWIS, inspected for completeness, and tabulated. Short periods of missing data were replaced using the average of the measurement at the beginning and end of each missing interval. Temperature, specific conductance, pH, and turbidity data are summarized in **table 3.3**.

Several characteristics are noteworthy in these summary data:

1. pH – the elevated pH values, above 8.0 and even 9.0 standard units, in the FY20 data set remain marked as "provisional" data and thus are subject to change upon review. However, pH's>9.0 are found in the pre-construction, construction, and post-construction continuous record. The presence of pH's >8.0 at both the upstream and downstream stations, occurring in all construction periods, supports that elevated pH's are real and not the result of instrument artifacts.

   In all construction periods, pH's >8.0 occur between May and October at both the upstream and downstream stations. pH's above 8.0 were not found in any of the chemical samples collected during the study (discussed below).

2. pH's >8.0 occur when specific conductance ranges from approximately 200-370 µS/cm. At both the upstream and downstream stations, SC's over 2,000 µS/cm were measured at both stations. There does not appear to be a clear relation between elevated pH's and SC.

3. Temperature – Water temperatures in excess of 90^{o}F have been measured in the stream at both stations. However, these elevated temperatures occur during <1% of the total time covered by each of the project phases. Temperatures exceeding 80^{o}F occur during less than 5% of the time covered in each construction interval. Higher temperatures occur during the summer months, and correlate with low gage heights and discharges.

4. Turbidity – Turbidity correlates with discharge and water velocity (where data are available), as expected – during storms high discharges increases the mass of sediment transported in the stream. Median turbidity values show that in both the pre- and post-construction periods, higher turbidity was measured at the upstream station compared with the downstream station. Very high turbidity was measured at both the upstream and downstream stations during the construction period, however, the downstream station had a higher median turbidity. It should be noted that the median turbidities are very low for natural waters; the best indicator for the effect of the construction activity would be the number of peaks in turbidity at the downstream station not associated with rain events.

Table 3.3. Summary statistics of continuous water quality data recorded during the construction phases at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.

[FNU, formazin nephelometric units; µS/cm, micro-siemens per centimeter; F, degrees Fahrenheit]

	Turbidity (FNU)	Specific conductance (µS/cm)	Water temperature (°F)	[3]pH (standard Units)
UPSTREAM (1636845)				
All Data 1/3/17 to 6/30/19				
% of data available[1]	87	89	86	90
% of data “Approved”[2]	87	87	92	88
Maximum	2,260	2,470	91.8	9.4
Minimum	0.8	54	31.6	5.3
Median	6.1	322	56.8	7.3
Pre-construction 1/3/17 – 2/1/18				
% of data available	82	84	86	84
Maximum	2,010	1,980	80.4	8.8
Minimum	1.3	135	31.6	6.9
Median	6.1	349	53.9	7.3
Construction 2/1/18 – 4/15/19				
% of data available	67	69	67	70
Maximum	2,260	2,470	87.8	9.4
Minimum	0.8	54	32.0	5.3
Median	5.1	295	54.7	7.4
Post-construction 4/16/19 to 6/31/20				
% of data available	94	98	98	94
% of data “Approved”[2]	82	83	83	82
Maximum	2,220	879	91.8	9.5[3]
Minimum	1.2	61	32.0	6.9
Median	6.5	283	59.0	7.5
FY 20 6/1/19 to 6/30/20				
% of data available	95	98	98	98
% of data “Approved”[2]	879	80	80	80
Maximum	2,220	879	91.8	9.5[3]
Minimum	1.2	61	32.2	6.9
Median	5.5	299	55.4	7.5

1. Percent of data available is equal to the total number of recorded measurements divided by the total number of possible measurements in the time period, times 100. Measurements were made at 5-minute intervals.
2. Percent of data approved is equal to the total number of recorded measurements that are stamped “Approved” divided by the total number of measurements made, times 100.
3. The very high pH values were reported in data still labeled as “provisional” and are subject to change.

Table 3.3. Summary statistics of continuous water quality data recorded during the construction phases at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[FNU, formazin nephelometric units; µS/cm, micro-siemens per centimeter; F, degrees Fahrenheit]

	Turbidity (FNU)	Specific conductance (µS/cm)	Water temperature (°F)	pH (stnd. Units)
DOWNSTREAM (1636846)				
All Data 1/3/17 to 6/30/19				
% of data available[1]	89	88	90	87
% of data “Approved”[2]	99	99	89	99
Maximum	270	2,070	94.6	9.8[3]
Minimum	1.3	47	31.6	6.8
Median	5.1	325	57.2	7.4
Pre-construction 1/3/17 – 2/1/18				
% of data available	78	76	80	78
Maximum	2,040	1,300	86.5	9.4
Minimum	1.3	51	31.6	7.1
Median	4.0	361	56.3	7.4
Construction 2/1/18 – 4/15/19				
% of data available	99	98	100	95
Maximum	2,170	2,070	88.7	9.8[3]
Minimum	1.3	47	31.8	6.8
Median	6.0	300	51.4	7.4
Post-construction 4/16/19 to 6/30/20				
% of data available	96	99	99	97
% of data “Approved”[2]	100	100	100	100
Maximum	2,170	643	94.6	9.6
Minimum	1.1	99	32.2	7.0
Median	5.5	296	59.9	7.5
FY 20 6/1/19 to 6/30/20				
% of data available	96	99	99	96
% of data “Approved”[2]	100	100	100	100
Maximum	1,380	643	94.6	9.6
Minimum	1.1	99	32.2	7.0
Median	5.1	312	55.8	7.5

1. Percent of data available is equal to the total number of recorded measurements divided by the total number of possible measurements in time period, times 100. Measurements were made at 5-minute intervals.
2. Percent of data approved is equal to the total number of recorded measurements that are stamped “Approved” divided by the total number of measurements made, times 100.
3. The very high pH values were reported in data still labeled as “provisional” and are subject to change.

3.3 Summary of Discrete Water Quality Sampling

The goals of the water-quality sampling are: (1) to fulfill monitoring requirements outlined in the NPDES/MS4 assessment of controls permit; (2) to facilitate calculation of nutrient and sediment loads or yields; and (3) to document the changes in loads of sediment and nutrients caused by the floodplain restoration. Water-quality sampling was also used to verify cross-channel homogeneity in suspended sediment (SS) and dissolved species, and to provide data for generating relationships between turbidity and suspended-sediment concentration (SSC).

During storm events, it was planned that samples were to be collected during the rise, peak, and falling stages of the hydrograph. These three samples, termed sub-samples, are weighted using the stream discharge at the time of sampling, and then summed to determine the mean concentration for the event, termed EMC:

$$\text{EMC} = \sum_{1}^{n} \left(\frac{\text{Qt}}{\text{QTotal}}\right) * \text{Ct}$$

Where:

EMC is the event mean concentration

Qt is the instantaneous discharge at the time (t) of sub-sample was collected

Q_{Total} is the sum of the instantaneous discharges at times the sub-samples were collected

C_t is the concentration of component measured in sub-sample collected at time t

n is the number of sub-samples collected (2 to 5)

During most storm events, three sub-samples were obtained at each station; however, on some occasions, fewer sub-samples were obtained because of equipment failure or other unavoidable conditions. A few events multiple sub-samples, up to 5, were collected to provide replicate data needed to evaluate variability and precision. When available, replicate samples were included in the calculation of EMC.

Sub-samples were collected either manually by wading or by using automatic samplers. When the stream was wadable (during low-flow and sometimes during the falling stage), composite samples were prepared from 10 vertically depth-integrated grab samples obtained at equally spaced intervals across the stream. These grab samples are composited in a plastic churn, mixed, and sub-sampled for the various analytic protocols. During storm events when wading is not possible (typically the rising and cresting stages), the autosamplers are used to collect discrete samples for nutrient and sediment (either suspended-sediment concentration SSC, or total suspended solids (TSS) and bacteriological constituents. In contrast to wading, automatic samplers collect a sample from a point in the stream. Total petroleum hydrocarbon (TPH) samples were always collected manually (whenever possible), resulting in fewer sub-samples for this constituent.

Over the course of the study, the autosamplers were calibrated by making cross-sectional measurements of turbidity and specific conductance (SC) while the autosampler was collecting point samples for SSC, conductivity, and turbidity. Cross-channel turbidity is used to evaluate the distribution of suspended materials across the channel, while SC is used to evaluate the cross-channel mixing of dissolved constituents by turbulence. SSC can be related to turbidity (and possibly also to discharge), thereby allowing the continuous turbidity record to be used as a surrogate of SSC. The data collected to date show the stream is well mixed with respect to suspended and dissolved materials, and therefore, samples collected by autosamplers are comparable to those collected manually and are considered to accurately represent conditions in the stream. Calibration sampling was re-initiated at this station after sampling equipment was re-installed in April 2019.

Samples collected during times of low-flow are used to represent baseflow chemistry - these may not represent "baseflow" in the strict hydrologic sense; that is, baseflow being the groundwater contribution of the channel flow. Baseflow sampling was conducted only if precipitation had not occurred within 7 days prior to sampling and the stage was low and steady. As discussed below, baseflow discharge ranged from 0.60 to 1.63 ft^3/s, with higher values generally in winter months and during the construction period.

Samples for analysis of constituents that make up TPH were collected manually as grab samples (during both storm and baseflow) and were not composited across the stream. TPH samples are collected using a stainless-steel weighted sampler that holds multiple VOC vials. Because samples for TPH were collected manually, some storm events are represented by only 1 or 2 sub-samples (because of non-wadable conditions). During storms, samples for bacteriological analysis were collected into sterilized plastic bottles by the autosamplers.

Table 3.4 summarizes the number of storm and baseflow events, and the discrete sub-samples collected for nutrients, bacteriological, and TPH constituents. In total, 62 events were sampled at the upstream site, and 63 at the downstream site. Baseflow was sampled 16 times at the upstream site and 14 times at the downstream station. A total of 322 sub-samples were collected at the upstream station for chemical analysis, 72% were obtained using an autosampler. At the downstream site, of the 314 sub-samples collected for chemical analysis, 71% were obtained using the autosampler. A total of 327 samples have been collected at the upstream and 309 at the downstream for SSC; fewer samples were collected for TSS (157 and 150, respectively). Bacteriological samples were collected during all of the storms, totaling 159 and 155 samples at the upstream and downstream stations, respectively. TPH sub-samples totaled 106 and 101 at the upstream and downstream stations, respectively. As mentioned earlier, fewer samples for TPH constituents were collected because of the need to use manual collection methods. As shown in **table 3.4**, the number of samples for which EMCs were calculated was identical (20) in the pre- and post-construction period. Almost two-times as many samples for SSC were collected in the pre- than in the post-construction phase, which is due to the calibration of the autosamplers.

Upon completion of analyses, results are uploaded into the U.S. Geological Survey's NWIS and are made available at https://water.usgs.gov/owq/data.html#USGS. In addition to the storm and baseflow events, a variety of field and equipment blanks were prepared and analyzed for quality assurance purposes. These data can also be available from the USGS-Md Water Science Center.

Table 3.4. Summary of samples collected during construction phases at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.

	Total number of samples for EMC calculation	Number of sample sets collected during storms (2 or 3 sub-samples)	Number of sample sets collected during baseflow (1 sample)	Number of sub-samples collected for chemical analyses	Number of sub-samples collected for SSC	Number of sub-samples collected for TSS	Number of sub-samples collected for bacteria	Number of sub-samples collected for TPH
UPSTREAM 1636845								
All samples 1/3/17 to 6/30/20	6	46	15	162	327	157	159	106
Samples collected in FY20	14	13	1	37	37	37	37	15
Samples collected during preconstruction 1/23/17 to 1/31/18	20	14	7	52	127	49	50	39
Samples collected during construction 2/1/18 to 4/15/19	21	18	4	56	147	54	54	40
Samples collected during post-construction 4/16/19 to 6/30/20	19	17	2	54	53	54	55	27
DOWNSTREAM 1636846								
All samples 1/3/17 to 6/30/20	63	49	14	154	309	150	155	101
Samples collected in FY20	13	12	1	37	36	37	37	15
Samples collected during preconstruction 1/23/17 to 1/31/18	19	11	8	46	115	43	46	37
Samples collected during construction 2/1/18 to 4/15/19	24	19	5	55	144	54	56	39
Samples collected during post-construction 4/16/19 to 6/30/20	20	17	3	53	50	53	53	25

FY20 includes samples collected during the post-construction phase between 7/1/18 to 6/30/19

3.4 Conditions During Sampled Storms and Low-flow

The discharge and precipitation during each event were tabulated and inspected for completeness. To calculate the total discharge for an event, the volume of water passing the gage during each 5-minute interval between measurement was calculated and then summed for the period of interest:

$$Q_{total} = \sum_{start}^{finish} \Delta t * Qt * K$$

Where

Qt is the total volume of water in liters

Δt is the time step between measurements, typically 5 minutes

Qt is the instantaneous discharge measured at time t

K is a constant to change ft^3/s to liters/minute (1699)

It is important to standardize the time over which discharge volumes were calculated for an event. Summation of discharge started at 0:00 on the day when the stream gage height first responded to precipitation and continued to 23:55 on the day the gage height returned to (or near) pre-storm heights. For some events, precipitation occurred again after sampling was completed but before the stage returned to its original pre-storm level. In these cases, the volume summation was ended at the time when the lowest post-storm gage height was reached. Volumes for baseflow samples were calculated for the 24-hours (0:00 to 23:55) of the sampling date, which results in volumes in units of L/day.

As mentioned above, the precipitation record at the upstream site was sporadic, so it was necessary to use precipitation data collected at the Frederick Airport. Data are recorded at the airport station every time 0.01-in of rain was collected. Rainfall amount and intensity was determined by summing the precipitation volume that occurred over the defined interval of the event. Intensity was then calculated by dividing the total precipitation by the minutes between the times when the first and the final precipitation were recorded.

A summary of the conditions at LCC during the storm and baseflow events is provided in **table 3.5,** and includes the date the first sample of the event was collected, the phase of the study (pre-construction, construction, and post-construction), whether upstream or downstream samples were collected, the rainfall amount and intensity, the maximum discharge reached at the upper sampling station, and the total volumes of water passing the two stations. Because the precipitation data listed in this table is from the Airport, it is possible that an event may be labeled as being a “storm” although precipitation did not occur at the airport – isolated summer thunderstorms may have impacted the only LCC basin but did not hit the Airport.

In order to evaluate how the sampling effort represented the flow regimes that occur in LCC, discharge recorded at the upstream station at the time each sub-sample was collected was compared with the percentile rankings of discharge in the river for the period October 1 2016 through June 2020 (**Table 3.6**). The percentile discharges at the downstream station (not shown) are slightly greater than those at the upstream station, again indicating this is a gaining reach of the stream. The largest number of sub-samples were collected during times when the discharge was at or above the 99^{th} percentile (>75.7 ft^3/s) – the highest flow, followed by samples collected at moderate flows (4.64-8.89 ft^3/s). Thus, the sampling effort produced data that provides a good representation of the water-quality during moderate and high flow regimes. Almost equal numbers of samples were collected in the pre- and post-construction phases when discharge was very low, in the 10^{th} percentile range <1.33 ft^3/s.

3.1 Event Mean Concentrations

Event Mean Concentrations (EMCs) for all samples collected in this study (January 3, 2017 through June 30, 2020) are summarized in **table 3.7**. With the exception of TPH, the EMCs values presented in this table are calculated with "non-detect" concentration in a sub-sample replaced with the corresponding MDL concentration. For the TPH, the EMC values were calculated with 'non-detected' values replaced with a null concentration (not considered in the EMC calculation). Samples with TPH reported as "nd" indicates that all components of TPH were below their respective MDLs. EMCs for the sampled events are presented in **table 3.8.**

The following points summarize and help understand how EMCs were calculated.

1. Concentrations of all compounds except THP in sub-samples that were reported as less-than the method detection level (MDL) were ***replaced with the MDL for the purpose of calculating EMCs***. Few sub-samples had inorganic species reported below their MDL; only zinc and total suspended solids (TSS) had multiple analyses reported below the MDLs. Because MDL values were used, any load calculated using these EMCs should be considered to be estimated maximum loads.
2. Event mean concentrations were also calculated by replacing non-detected (below MDL) concentrations with 0. These EMCs are not discussed in this report, and any load calculated with these EMCs should be considered a minimum.
3. Total Kjeldahl nitrogen was calculated as the sum of the dissolved organic nitrogen and dissolved ammonia.
4. Because EMCs were calculated as sums of sub-sample concentrations weighted by discharge, some EMCs are below the MDL for the constituent. This occurred in only a few cases and are noted in tables.
5. TPH. Several analytic methods are available for measuring TPH in water samples; different methods may produce different TPH depending on the analytes included in the method. In this work, five organic compounds were summed to obtain a TPH value, these compounds are: toluene (before 9/2018 MDL = 0.05 µg/L; then increased to 0.20 ug/L); benzene (MDL=0.026 µg/L); ethylbenzene (MDL=0.036 µg/L); o-xylene (MDL=0.032 µg/L); and methyl tert-butyl ether (MTBE, MDL = 0.1). Note the detection levels for toluene changed over the study. Because the TPH is calculated by summing various constituent compounds, the MDL for TPH cannot be lower than the highest MDL for any one constituent – in this case, the MDL for TPH is set by the toluene MDL of 0.1 or 0.2 ug/L (depending upon date of sample).

   However, if one component was found at a quantifiable concentration (that is, above its individual MDL) in only 1 of the sub-samples collected for a storm, and was below the toluene MDL, then the TPH_EMC0 concentration was reported as the quantifiable concentration. In other words, the toluene concentration is considered to actually be 0. When the TPH_EMC0 value was calculated and no individual component of the TPH was found quantifiable in any sub-sample, then the concentration is reported as 0 with the MDL for toluene of 0.1 or 0.2 ug/L used for TPH. It should be noted that although an EMC is provided for TPH (set by the MDL of toluene), ***in most sub- samples none of the TPH***

constituents were found in a quantifiable concentrations; there is no evidence that TPH was present in the stream water during these events.

A few noteworthy observations can be made regarding TPH in the LCC samples from either the upstream of downstream sampling stations.

A. In FY20 samples, compounds that comprise TPH were found at quantifiable concentrations in only 3 sub-samples at the upstream station, that being for benzene (0.01 ug/L sampled on 10/7/19 and 0.02 ug/L sampled on 10/22/19 and 0.02 for the sample collected on 11/24/19). For FY20 samples from the downstream station, quantifiable concentrations were found in three samples: 0.02 ug/L for benzene in the sample from 10/22/19; 0.02 ug/L for benzene in the sample from 10/30/19; and 0.02 ug/L for xylene in the 4/30/20 sample.
B. Prior to FY20, quantifiable concentrations of organic constituents in the sub-samples were found in samples collected on 1/23/17 (both stations), 3/1/17 (upstream), 3/31/17 (both), 4/6/17 (both), 5/5/17 (both), 5/25/17 (both), 6/19/17 (both), 7/6/17 (both), 2/7/18 (upstream), 2/11/18 (both), 3/23/18 (both), 4/6/18 (upstream), 12/15/18 (both) and 3/21/19 (both).
C. Toluene was the only compound detected prior to 3/21/18, after which date only benzene was detected (samples collected on 3/23/18, 12/15/18, and 3/21/19).
D. The highest quantifiable TPH concentration was 0.95 µg/L in one sub-sample collected at the upstream station during the 3/1/17 event, which produced an EMC of 0.49 µg/L for this event.
E. At the downstream station the highest TPH concentration was 0.17 µg/L for a subsample collected during the 1/23/17 event (producing an EMC of 0.16 µg/L).
F. There appears to be no seasonal relation in the presence of the toluene or benzene, as “hits” were observed in samples collected during both winter and summer, and “hits” were observed in both upstream and downstream samples.
G. Finally, it should be noted that any quantifiable concentration was very-much lower than would be expected if “free-product” such as gasoline or diesel fuel were in the creek. While the data might be interpreted to indicate that petroleum is occasionally present in the stream, it is more likely these “hits” are random low-level contamination introduced either from sampling equipment or laboratory equipment.

Table 3.5. Summary of precipitation, maximum discharge reached, and total discharge during sampling events at upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.

[in, inches; in/hr, inches per hour; ft3/s, cubic feet per second; L, liters]

Date	Stream status	Sample collected downstream?	Sample collected upstream?	Event type	Precipitation amount (in)	Rainfall intensity (in/hr)	**UPSTREAM** maximum discharge reached (ft3/s)	**UPSTREAM** total volume (L)	**DOWNSTREAM** total volume (L)	**Percent difference upstream to downstream**
1/3/17	Pre	N	Y	Storm	0.06	0.011	84.9	8.403E+07	9.191E+07	9.0
1/23/17	Pre	Y	Y	Storm	0.09	0.009	198	1.420E+08	1.552E+08	8.9
2/23/17	Pre	Y	Y	Base	0	--	1.85	4.430E+06	4.844E+06	8.9
3/1/17	Pre	Y	Y	Storm	0.19	0.095	7.53	1.419E+07	1.552E+07	9.0
3/31/17	Pre	Y	Y	Storm	0.08	0.137	73.7	6.365E+07	6.962E+07	9.0
4/6/17	Pre	Y	Y	Storm	0.00	--	181	1.350E+08	1.475E+08	8.9
5/5/17	Pre	Y	Y	Storm	1.23	0.049	90.9	6.587E+07	7.205E+07	9.0
5/25/17	Pre	Y	Y	Storm	1.15	0.052	123	1.383E+08	1.512E+08	8.9
6/19/17	Pre	Y	Y	Storm	0.00	--	22.0	1.439E+07	1.574E+07	9.0
7/6/17	Pre	Y	Y	Storm	0.30	0.033	303	1.117E+08	1.222E+08	9.0
8/7/17	Pre	Y	Y	Base[1]	0.00	--	2.07	7.257E+06	7.902E+06	8.5
8/24/17	Pre	Y	Y	Base	0	--	0.79	1.682E+06	1.781E+06	5.7
9/26/17	Pre	Y	Y	Base	0	--	0.60	1.371E+06	1.212E+06	-12
10/9/17	Pre	Y	Y	Storm	0.73	0.090	7.7	8.743E+06	1.294E+07	39
10/24/17	Pre	Y	Y	storm	0.45	0.064	4.99	7.490E+06	9.203E+06	21
10/29/17	Pre	Y	Y	Storm	0.46	0.060	122	9.983E+07	9.641E+07	-3.5
11/29/17	Pre	Y	Y	Base	0	--	1.11	2.635E+06	2.981E+06	12
12/20/17	Pre	Y	N	Base	0	--	0.91	2.101E+06	2.871E+06	31
12/24/17	Pre	N	Y	Base	0	--	2.6	4.095E+06	5.124E+06	22
1/12/18	Pre	Y	Y	Storm	1.16	0.048	454	1.748E+08	2.359E+08	30
1/26/18	Pre	Y	Y	Base	0	--	2.5	5.735E+06	6.087E+06	6.0

Note: Light shaded dates represent storm or baseflow events when only 1 station was sampled

1. On 8/7/17 0.02-in of precipitation was recorded at Frederick Airport.

Table 3.5. Summary of precipitation, maximum discharge reached, and total discharge during sampling events at upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.--Continued

[in, inches; in/hr, inches per hour; ft^3/s, cubic feet per second; L, liters]

Date	Stream status	Sample collected downstream?	Sample collected upstream?	Event type	Precipitation amount (in)	Rainfall intensity (in/hr)	**UPSTREAM** maximum discharge reached (ft3/s)	**UPSTREAM** total volume (L)	**DOWNSTREAM** total volume (L)	**Percent difference upstream to downstream**
2/7/18	Const.	Y	Y	Storm	0.03	0.040	88.5	7.209E+07	8.542E+07	17
2/11/18	Const.	Y	Y	Storm	0.52	0.047	48.3	6.619E+07	7.914E+07	18
2/23/18	Const.	Y	Y	Storm	0.17	0.039	26.0	9.864E+07	9.660E+07	-2.1
3/1/18	Const.	Y	N	Storm	0.53	0.169	19.6	2.806E+07	1.312E+08	129
3/23/18	Const.	Y	Y	Base	0	--	12.0	2.502E+07	3.025E+07	19
4/15/18	Const.	Y	Y	Storm	2.69	0.336	235	2.392E+08	2.555E+08	6.6
4/27/18	Const.	Y	Y	Storm	0.34	0.132	7.51	1.157E+07	1.402E+07	19
5/6/18	Const.	N	Y	Base	0.28	0.070	5.99	1.651E+07	2.799E+07	52
5/13/18	Const.	Y	Y	Storm[2]	7.7	0.052	9,050	2.623E+09	1.506E+09	-54
5/22/18	Const.	Y	Y	Storm	0	--	397	1.180E+08	1.208E+08	2.4
6/2/18	Const.	Y	N	Storm	1.4	0.030	1,820	3.351E+08	3.912E+08	15
6/20/18	Const.	Y	N	Storm	0.01	0.002	62.2	2.146E+07	2.790E+07	26
7/16/18	Const.	Y	Y	Base	0	--	1.86	4.068E+06	5.038E+06	21
8/21/18	Const.	Y	N	Storm	0.98	0.363	327	9.671E+07	1.191E+08	21
9/9/18	Const.	N	Y	Storm	1.55	0.049	471	4.279E+08	4.932E+08	14
9/17/18	Const.	Y	Y	Storm	0.36	0.360	410	1.399E+08	1.616E+08	14
10/26/18	Const.	Y	Y	Storm	0.63	0.067	32.8	6.899E+07	8.426E+07	20

Note: Light shaded dates represent storm or baseflow events when only 1 station was sampled

2. Rainfall between 5/13/18 @7:15am on 5/13/18 and 10:45 am on 5/19/18 (147.75 hours) totaled 7.7-inches, however, this precipitation occurred in 7 distinct intervals. The maximum precipitation was 1.9 inches that occurred over 8 minutes at 0:55 am on 5/16/18.

Table 3.5. Summary of precipitation, maximum discharge reached, and total discharge during sampling events at upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.—continued.

[in, inches; in/hr, inches per hour; ft^3/s, cubic feet per second; L, liters]

Date	Stream status	Sample collected downstream?	Sample collected upstream?	Event type	Precipitation amount (in)	Rainfall intensity (in/hr)	**UPSTREAM** maximum discharge reached (ft^3/s)	**UPSTREAM** total volume (L)	**DOWNSTREAM** total volume (L)	**Percent difference upstream to downstream**
11/9/18	Const.	Y	Y	Storm	0	--	94.4	7.334E+07	8.221E+07	11
11/29/18	Const.	Y	Y	Base	0	--	6.3	1.486E+07	1.876E+07	23
12/15/18	Const.	Y	Y	Storm	1.24	0.037	308	3.823E+08	4.644E+08	19
12/20/18	Const.	Y	Y	Storm	0.48	0.051	81.5	7.403E+07	8.169E+07	9.8
2/3/19	Const.	Y	Y	Base	0	--	9.1	3.36E+07	3.951E+07	15
2/6/19	Const.	Y	Y	Storm	0	--	8.8	3.54E+07	4.168E+07	15
2/11/19	Const.	Y	Y	Storm	0.45	0.014	168	1.77E+08	2.088E+08	15
2/21/19	Const.	Y	Y	Storm	0.03	0.007	53.5	7.08E+07	8.335E+07	15
3/21/19	Const.	Y	Y	Storm	0.24	0.012	739	5.32E+08	6.257E+08	15

Table 3.5. Summary of precipitation, maximum discharge reached, and total discharge during sampling events at upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.--Continued

[in, inches; in/hr, inches per hour; ft^3/s, cubic feet per second; L, liters]

Date	Stream status	Sample collected downstream?	Sample collected upstream?	Event type	Precipitation amount (in)	Rainfall intensity (in/hr)	**UPSTREAM** maximum discharge reached (ft^3/s)	**UPSTREAM** total volume (L)	**DOWNSTREAM** total volume (L)	**Percent difference upstream to downstream**
4/19/19	Post	Y	Y	Storm	0.82	0.154	41.5	5.445E+07	5.954E+07	8.9
4/26/19	Post	Y	Y	Storm	0.3	0.039	7.28	4.768E+07	5.218E+07	9.0
5/23/19	Post	Y	Y	Storm	0	--	38.6	3.879E+07	4.685E+07	19
5/30/19	Post	Y	Y	Base	0	--	4.43	9.970E+06	1.122E+07	12
6/13/19	Post	Y	Y	Storm	0.800	0.069	35.7	3.491E+07	4.692E+07	29
6/27/19	Post	Y	Y	Base	0.75	0.900	16.0	9.105E+06	1.166E+07	25
6/29/19	Post	Y	Y	Storm	0.07	0.030	6.11	1.834E+07	2.243E+07	20
7/31/2019	Post	Y	Y	Base	0.00	0.000	1.58	3.649E+06	4.236E+06	15
8/18/2019	Post	Y	Y	Storm	1.07	1.834	30.7	1.814E+07	1.917E+07	5.5
9/30/2019	Post	Y	Y	Storm	0.22	0.115	0.94	3.333E+06	3.927E+06	16
10/7/2019	Post	Y	Y	Storm	0.19	0.019	3.23	7.516E+06	9.642E+06	25
10/22/2019	Post	Y	Y	Storm	0.34	0.047	5.13	8.385E+06	1.190E+07	35
10/30/2019	Post	Y	Y	Storm	0.27	0.030	206	1.227E+08	1.996E+08	48
11/24/2019	Post	Y	Y	Storm	0.50	0.058	5.69	1.638E+07	1.975E+07	19
1/25/2020	Post	Y	Y	Storm	1.08	0.139	369	1.463E+08	1.782E+08	20
2/6/2020	Post	Y	Y	Storm	0.55	0.079	289	2.231E+08	2.928E+08	27
3/13/2020	Post	Y	Y	Storm	0.21	0.079	704	4.130E+07	4.686E+07	13
4/13/2020	Post	Y	Y	Storm	0.68	0.073	31.9	3.769E+07	4.493E+07	18
4/24/2020	Post	Y	Y	Storm	0.29	0.040	21.7	6.585E+07	7.921E+07	18
4/30/2020	Post	Y	Y	Storm	0.21	0.011	302	2.493E+08	3.433E+08	32

Note: Light shaded dates represent storm or baseflow events when only 1 station was sampled

Dark shaded volumes at upstream station were estimated from discharge measured at downstream station

Table 3.6. Number of sub-samples collected at the upper station (1636845) under different flow-regimes and construction phases on Little Catoctin Creek, Md from 2016-2020.

[ft^3/s; cubic feet per second]

Percentile range	Upstream station discharge 10/1/16 to 6/30/20 (ft^3/s)	Discharge range (ft^3/s)	Pre-Construction Number of subsamples [1] collected during indicated flow range during pre-construction phase	Construction Number of subsamples [1] collected during indicated flow range during construction phase	Post-Construction Number of subsamples [1] collected during indicated flow range during post-construction phase
99	75.7	>75.7	51	56	54
95	8.89	8.89--75.7	8	12	2
75	4.64	4.64--8.89	20	30	16
50	2.44	2.44--4.64	3	11	15
25	1.33	1.33--2.44	9	2	11
10	0.81	0.81--1.33	7	1	5
		0--0.81	1	0	2

[1.] Storm events when 2-3 subsamples were collected, or baseflow events when 1 sub-sample was collected.

Table 3.7. Summary of event mean concentrations calculated for samples collected from upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md.
[EMC, event mean concentration; kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MPN, most probable number; MDL, method detection level]

	Average[1] temperature C	Average pH (stnd. Units)	BOD-5 (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)	Suspended sediment (mg/L)	TSS (mg/L)	Total copper (µg/L)
UPSTREAM									
Count	60	58	53	61	61	61	58	60	59
Maximum	81	7.9	39.8	3.63	5.10	3.435	1,828	1,460	52.2
Minimum	33.8	7.1	0.01	0.06	0.37	0.048	3	15	0.7
Median	53.5	7.4	7.9	0.93	2.78	0.434	53	48	7.4
# of EMCs below MDL	0	0	1	2	0	0	0	13	0
DOWNSTREAM									
Count	62	62	55	63	63	63	61	62	62
Maximum	77.6	8.8	41.3	4.01	4.91	3.459	1376	1197	48.3
Minimum	34.7	6.7	0.8	0.01	0.03	0.033	1	15	0.30
Median	56.4	7.5	5.5	0.76	2.60	0.314	46	40	7.6
# of EMCs below MDL	0	0	0	**3**	0	0	0	16	0

	Total lead (µg/L)	Total zinc (µg/L)	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	[2]TPH (µg/L)
UPSTREAM						
Count	59	57	59	59	59	17
Maximum	32.3	124	129	1,000,000	16,500,000	0.49
Minimum	0.07	2	37	51	1,100	0.01
Median	1.10	11	86	1,920	207,000	0.09
# of EMCs below MDL	0	7	0	0	0	51
DOWNSTREAM						
Count	61	60	62	63	63	14
Maximum	288	107	133	1,710,000	5,180,000	0.19
Minimum	0.05	1	29	21	990	0.01
Median	1.07	8	90	23,700	79,900	0.05
# of EMCs below MDL	0	12	0	0	0	42

4. Summary statistics for all constituents except TPH were calculated after replacing non-detected concentrations with respective MDLs.
5. EMC's for TPH were calculated with non-quantifiable measurements (below MDL) replaced with null values.

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; -- not measured; nd, not detected above MDL]

UPSTREAM (1636845)							
Event date	Stream condition	Average temperature (°F)	Average pH (stnd. units)	BOD-5 (mg/L)	Total Kjeldahl nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)
MDL	--	--	--	2	0.05	0.01	0.004
Pre-Construction Samples							
1/3/17	Storm	43	7.6	--	1.8	1.88	1.43
1/23/17	Storm	38	7.4	18	1.3	1.18	3.08
2/23/17	Baseflow	54	7.5	2.0	0.49	4.38	0.048
3/1/17	Storm	55	7.4	13	0.78	2.91	0.590
3/31/17	Storm	48	7.5	12	2.6	1.81	2.18
4/6/17	Storm	54	7.4	18	1.7	0.92	2.40
5/5/17	Storm	62	7.3	15	2.5	2.02	1.38
5/25/17	Storm	70	7.2	11	1.9	3.14	1.83
6/19/17	Storm	75	7.3	40	1.8	2.09	1.24
7/6/17	Storm	75	7.1	8.0	2.0	3.43	1.63
8/7/17	Baseflow	69	7.1	26	3.0	3.36	0.558
8/24/17	Baseflow	70	7.5	1.2	0.38	3.30	0.098
9/26/17	Baseflow	73	7.6	--	0.26	2.36	0.102
10/9/17	Storm	71	7.2	30	1.2	2.13	0.990
10/24/17	Storm	63	7.2	--	3.6	2.57	1.28
10/29/17	Storm	51	7.4	29	1.7	2.89	3.44
11/29/17	Baseflow	46	7.6	1.7	0.22	4.41	0.050
12/24/17	Baseflow	43	7.4	--	1.0	3.55	0.212
1/12/18	Storm	42	7.3	0.4	1.78	3.10	2.43
1/26/18	Baseflow	37	7.3	2.5	0.73	5.10	0.067

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)							
Event date	Stream condition	Average temperature (ºF)	Average pH (stnd. units)	BOD-5 (mg/L)	Total Kjeldahl nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)
MDL	--	--	--	2	0.05	0.01	0.004
Construction samples							
2/7/18	Storm	33	7.3	--	1.0	2.37	0.594
2/11/18	Storm	38	7.4	--	1.4	3.06	0.759
2/23/18	Storm	47	7.4	--	0.95	3.07	0.339
3/23/18	Baseflow	41	7.6	6.4	0.40	4.35	0.095
4/15/18	Storm	48	7.1	4.6	1.5	1.65	1.42
4/27/18	Storm	55	7.4	8.6	0.82	2.84	0.170
5/6/18	Baseflow	60	7.5	--	2.1	2.69	0.434
5/14/18	Storm	65	7.3	3.1	1.47	2.25	2.59
5/22/18	Storm	71	7.3	11	1.5	1.45	1.25
7/16/18	Baseflow	81	7.8	2.3	0.11	3.75	0.085
9/9/18	Storm	65	7.0	6.5	0.74	0.66	1.21
9/17/18	Storm	71	7.4	6.7	0.86	2.62	0.497
10/26/18	Storm	50	7.5	7.9	0.93	2.84	0.521
11/9/18	Storm	48	7.2	--	0.68	2.04	0.733
11/29/18	Baseflow	40	7.4	2.7	0.51	4.96	0.051
12/15/18	Storm	43	7.5	23	1.8	1.60	2.18
12/20/18	Storm	45	7.4	9.6	0.86	2.56	0.345
2/3/19	Baseflow	40	7.3	22	0.72	4.62	0.096
2/6/19	Storm	45	7.4	3.7	0.47	3.90	0.070
2/11/19	Storm	35	7.4	7.0	0.63	1.71	0.881
2/21/19	Storm	43	7.4	6.9	0.78	2.82	0.390
3/21/19	Storm	44	7.3	15	1.4	1.96	2.86

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL. EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)							
Event date	Stream condition	Average temperature (ºF)	Average pH (stnd. units)	BOD-5 (mg/L)	Total Kjeldahl nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)
MDL	--	--	--	2	0.05	0.01	0.004
Post construction samples							
4/19/2019	Storm	62	7.5	2.4	0.56	1.50	0.156
4/26/2019	Storm	64	7.5	12	0.93	3.08	0.182
5/23/2019	Storm	70	7.6	13	0.72	3.20	0.522
5/30/2019	Baseflow	75	7.6	1.6	0.56	3.62	0.085
6/13/2019	Storm	66	7.7	5.4	0.73	2.95	0.178
6/27/2019	Baseflow	74	7.7	2.7	0.43	3.41	0.109
6/29/2019	Storm	78	7.5	8.0	0.06	2.82	0.240
7/31/2019	Baseflow	75	7.8	2.9	0.46	3.53	0.104
8/18/2019	Storm	75	7.3	19	1.28	2.49	1.595
9/30/2019	Storm	69	7.6	1.5	0.42	2.59	0.104
10/7/2019	Storm	63	7.5	8.5	0.79	2.78	0.396
10/22/2019	Storm	58	7.5	5.6	0.62	2.34	0.263
10/30/2019	Storm	60	7.4	13	1.74	2.00	0.463
11/24/2019	Storm	43	7.5	12	1.30	3.25	0.412
1/25/2020	Storm	40	7.6	7.2	0.88	1.10	2.111
2/6/2020	Storm	43	7.5	6.0	2.38	0.98	0.389
3/13/2020	Storm	53	7.5	3.8	0.69	3.61	0.085
4/13/2020	Storm	56	7.5	6.3	1.00	1.72	0.416
4/24/2020	Storm	52	7.4	13	0.98	2.08	0.280
4/30/2020	Storm	57	7.2	15	1.05	0.37	1.330

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)						
Event date	Stream condition	Suspended sediment (mg/L)	Total suspended solids (mg/L)	Total copper (µg/L)	Total lead (µg/L)	Total zinc (µg/L)
MDL	--	0.5	15	1.4	0.04	2
Pre-construction samples						
1/3/17	Storm	264	217	15	5.1	30
1/23/17	Storm	1,250	1,250	35	25	109
2/23/17	Baseflow	4	15	0.9	0.07	2
3/1/17	Storm	102	77	4.8	2.4	17
3/31/17	Storm	583	497	20	11	54
4/6/17	Storm	833	618	26	17	78
5/5/17	Storm	202	162	12	3.7	21
5/25/17	Storm	402	381	29	8.3	46
6/19/17	Storm	147	141	9.6	4.1	32
7/6/17	Storm	396	354	19	7.6	37
8/7/17	Baseflow	15	16	3.1	0.31	7.0
8/24/17	Baseflow	5	15	1.3	0.09	2.0
9/26/17	Baseflow	6	15	1.5	0.19	2.0
10/9/17	Storm	57	43	5.8	0.78	11
10/24/17	Storm	29	31	6.2	0.57	12
10/29/17	Storm	723	525	26	13	85
11/29/17	Baseflow	1	15	1.2	0.07	2.0
12/24/17	Baseflow	12	15	3.8	0.29	4.0
1/12/18	Storm	861	660	26.4	13.0	77
1/26/18	Baseflow	4	15	0.8	0.12	2.0

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Shaded values had one or more sub-samples with a concentration reported below the MDL.

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)						
Event date	Stream condition	Suspended sediment (mg/L)	Total suspended solids (mg/L)	Total copper (µg/L)	Total lead (µg/L)	Total zinc (µg/L)
MDL	--	1	15	1.4	0.04	2
Construction samples						
2/7/18	Storm	132	100	7.4	2.4	12
2/11/18	Storm	141	128	8.2	3.4	17
2/23/18	Storm	38	25	--	--	--
3/23/18	Baseflow	3	15	1.3	0.08	2.0
4/15/18	Storm	440	328	8.5	2.3	13
4/27/18	Storm	16	16	2.1	0.37	5.4
5/6/18	Baseflow	21	15	4.1	0.32	10
5/22/18	Storm	351	356	11	8.2	31
7/16/18	Baseflow	7	15	1.1	0.12	2.0
9/9/18	Storm	59	318	13	6.7	29
9/17/18	Storm	80	83	6.7	1.8	10
10/26/18	Storm	50	56	5.2	1.1	8.1
11/9/18	Storm	146	116	6.4	3.0	17
11/29/18	Baseflow	4	15	0.7	0.10	2.0
12/15/18	Storm	942	616	34	18	82
12/20/18	Storm	62	50	10	1.4	11
2/3/19	Baseflow	7	--	--	--	--
2/6/19	Storm	6	15	2.4	0.18	2.7
2/11/19	Storm	539	467	14	11	42
2/21/19	Storm	159	138	5.3	3.0	19
3/21/19	Storm	1,440	1,300	41	29	120

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Shaded values had one or more sub-samples with a concentration reported below the MDL.

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)						
Event date	Stream condition	Suspended sediment (mg/L)	Total suspended solids (mg/L)	Total copper (µg/L)	Total lead (µg/L)	Total zinc (µg/L)
MDL	--	1	15	1.4	0.04	2
Post-construction Samples						
4/19/2019	Storm	7	32	7.6	1.10	7
4/26/2019	Storm	19	16	1.7	0.48	5
5/23/2019	Storm	113	133	10.8	3.33	20
5/30/2019	Baseflow	11	15	1.3	0.27	3
6/13/2019	Storm	20	21	2.3	0.51	4
6/27/2019	Baseflow	10	15	1.3	0.24	2
6/29/2019	Storm	8	46	7.4	1.09	9
7/31/2019	Baseflow	6	15	1.4	0.15	2
8/18/2019	Storm	446	415	22.7	9.68	57
9/30/2019	Storm	10	16	3.9	0.27	3
10/7/2019	Storm	28	31	12.7	0.78	9
10/22/2019	Storm	29	30	5.4	0.76	6
10/30/2019	Storm	15	15	16.3	0.46	8
11/24/2019	Storm	25	19	6.6	0.60	8
1/25/2020	Storm	1,850	1,480	52.8	32.6	126
2/6/2020	Storm	55	53	17.0	1.52	14
3/13/2020	Storm	13	15	12.2	0.31	5
4/13/2020	Storm	66	65	15.2	1.63	12
4/24/2020	Storm	29	23	11.2	0.80	--
4/30/2020	Storm	962	877	25.9	18.5	--

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)					
Event date	Stream condition	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	TPH (µg/L)
MDL	--	1	--	--	0.1/0.2
Pre-construction samples					
1/3/17	Storm	73	23,500	207,000	0.04
1/23/17	Storm	52	43,400	230,000	0.14
2/23/17	Baseflow	106	1,300	1,900	nd
3/1/17	Storm	107	45,000	120,000	0.49
3/31/17	Storm	62	37,400	203,000	0.15
4/6/17	Storm	50	62,200	231,000	0.15
5/5/17	Storm	73	155,000	240,000	0.09
5/25/17	Storm	64	175,000	2,240,000	0.10
6/19/17	Storm	91	192,000	1,630,000	0.11
7/6/17	Storm	48	105,000	4,180,000	0.12
8/7/17	Baseflow	127	26,000	240,000	nd
8/24/17	Baseflow	129	2,400	31,000	nd
9/26/17	Baseflow	128	1,300	31,000	nd
10/9/17	Storm	109	1,000,000	2,400,000	0.22
10/24/17	Storm	114	274,000	6,510,000	nd
10/29/17	Storm	70	712,000	16,500,000	nd
11/29/17	Baseflow	107	930	14,000	nd
12/24/17	Baseflow	95	--	--	nd
1/12/18	Storm	60	19,200	240,000	nd
1/26/18	Baseflow	110	63	2,900	nd

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

		UPSTREAM (1636845)			
Event date	Stream condition	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	[1]TPH (µg/L)
MDL	--	1	--	--	0.1/0.2
		Construction samples			
2/7/18	Storm	59	2,200	69,800	0.09
2/11/18	Storm	81	2,600	194,000	0.01
2/23/18	Storm	--	--	--	nd
3/23/18	Baseflow	122	350	3,000	0.01
4/15/18	Storm	49	22,800	188,000	nd
4/27/18	Storm	88	8,820	54,800	nd
5/6/18	Baseflow	102	33,000	170,000	nd
5/22/18	Storm	50	65,700	2,290,000	nd
7/16/18	Baseflow	99	1,400	17,000	nd
9/9/18	Storm	38	42,500	2,330,000	nd
9/17/18	Storm	95	97,900	2,370,000	nd
10/26/18	Storm	89	55,400	2,210,000	nd
11/9/18	Storm	73	38,000	702,000	nd
11/29/18	Baseflow	88	580	3,100	nd
12/15/18	Storm	54	26,700	601,000	0.01
12/20/18	Storm	74	7,930	130,000	nd
2/3/19	Baseflow	--	51	1,100	nd
2/6/19	Storm	86	338	8,820	nd
2/11/19	Storm	49	1,930	24,900	nd
2/21/19	Storm	91	2,900	10,200	nd
3/21/19	Storm	48	17,400	665,400	0.01

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

UPSTREAM (1636845)					
Event date	Stream condition	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	TPH (µg/L)
MDL	--	1	--	--	0.1/0.2
Post- construction samples					
4/19/2019	Storm	80	14,200	680,000	nd
4/26/2019	Storm	86	47,200	98,800	nd
5/23/2019	Storm	81	83,700	576,000	nd
5/30/2019	Baseflow	105	5,200	19,000	nd
6/13/2019	Storm	90	17,200	240,000	nd
6/27/2019	Baseflow	96	1,400	19,000	nd
6/29/2019	Storm	96	8,520	313,000	nd
7/31/2019	Baseflow	105	860	28,000	nd
8/18/2019	Storm	70	128,000	240,000	nd
9/30/2019	Storm	118	3,860	54,800	nd
10/7/2019	Storm	107	47,400	240,000	0.02
10/22/2019	Storm	104	46,800	214,000	0.01
10/30/2019	Storm	113	239,000	1,400,000	nd
11/24/2019	Storm	103	16,300	178,000	nd
1/25/2020	Storm	48	9,740	230,000	nd
2/6/2020	Storm	77	12,200	53,700	nd
3/13/2020	Storm	89	6,400	11,500	nd
4/13/2020	Storm	71	52,800	206,000	nd
4/24/2020	Storm	80	19,100	125,000	nd
4/30/2020	Storm	37	72,100	226,000	nd

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured]; nd, not detected above MDL]

DOWNSTREAM (1636846)

Event date	Stream condition	Average temperature (ºF)	pH (standard units)	BOD-5 (mg/L)	Total Kjeldahl nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)
MDL	--	--	--	2	0.05	0.01	0.004
Pre-construction samples							
1/23/17	Storm	40	7.5	5.4	1.34	1.3	3.459
2/23/17	Baseflow	51	7.6	1.1	0.12	4.2	0.046
3/1/17	Storm	54	7.6	1.9	0.48	3.0	0.138
3/31/17	Storm	47	7.4	9.2	3.09	1.8	2.126
4/6/17	Storm	55	7.5	22	1.45	1.3	3.057
5/5/17	Storm	57	7.2	18	2.40	2.1	1.738
5/25/17	Storm	58	7.4	11	1.91	2.4	1.573
6/19/17	Storm	76	7.3	27	1.42	1.9	1.120
7/6/17	Storm	73	7.2	7.9	1.72	3.2	1.663
8/7/17	Baseflow	69	7.4	1.0	0.40	3.1	0.093
8/24/17	Baseflow	73	7.5	1.0	0.38	2.7	0.102
9/26/17	Baseflow	70	7.5	1.0	0.46	2.1	0.081
10/9/17	Storm	71	7.3	9.0	0.73	2.0	0.546
10/24/17	Storm	63	7.4	0.0	0.45	1.2	0.216
10/29/17	Storm	52	7.3	41	1.65	2.5	2.075
11/29/17	Baseflow	43	7.8	1.9	0.09	4.0	0.039
12/20/17	Storm	43	7.6	1.7	4.01	0.0	0.033
1/12/18	Storm	33	7.3	8.6	1.08	3.1	0.363
1/26/18	Baseflow	33	7.4	2.2	0.60	4.83	0.067

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; not detected above MDL]

DOWNSTREAM (1636846)							
Event date	Stream condition	Average temperature (ºF)	pH (standard units)	BOD-5 (mg/L)	Total Kjeldahl nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)
MDL	--	--	--	2	0.05	0.01	0.004
Construction samples							
2/7/18	Storm	35	7.4	--	0.61	4.3	0.134
2/11/18	Storm	38	7.4	--	1.15	3.0	0.743
2/23/18	Storm	45	7.5	--	0.92	2.6	0.930
3/2/18	Storm	44	7.5	5.5	0.57	2.7	0.314
3/23/18	Baseflow	37	8.1	2.9	0.01	4.2	0.036
4/16/18	Storm	47	7.3	10.1	1.25	1.7	1.458
4/27/18	Storm	56	7.7	4.3	0.63	2.8	0.097
5/14/18	Storm	67	7.1	3.6	0.76	2.2	0.451
5/22/18	Storm	70	7.5	16	0.87	2.0	5.13
6/2/18	Storm	74	6.7	13.1	1.45	1.3	1.960
6/20/18	Storm	75	8.5	--	1.60	3.2	0.934
7/16/18	Baseflow	77	7.7	--	0.36	3.4	0.079
8/21/18	Storm	72	7.2	11	1.05	1.3	1.68
9/17/18	Storm	72	7.6	6.9	0.68	3.2	0.508
10/26/18	Storm	51	7.6	6.8	0.85	2.7	0.586
11/9/18	Storm	--	--	0.0	0.68	2.6	0.847
11/29/18	Baseflow	40	7.6	2.3	0.37	4.9	0.049
12/15/18	Storm	43	7.6	17	1.73	2.4	2.529
12/21/18	Storm	46	7.6	8.0	0.85	1.7	0.500
2/3/19	Baseflow	39	7.5	22	0.81	4.4	0.090
2/6/19	Storm	45	7.7	5.3	0.57	3.9	0.129
2/11/19	Storm	35	7.5	6.6	0.64	1.7	0.908
2/21/19	Storm	45	7.5	6.3	0.68	3.1	0.249
3/21/19	Storm	44	7.4	13	1.40	2.0	2.396

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)							
Event date	Stream condition	Average temperature (ºF)	pH (standard units)	BOD-5 (mg/L)	Total Kjeldahl nitrogen (mg/L)	Nitrite + Nitrate (mg/L)	Total phosphorous (mg/L)
MDL	--	--	--	2	0.05	0.01	0.004
Post-construction samples							
4/19/19	Storm	64	7.8	2.8	0.60	2.70	0.118
4/26/19	Storm	64	7.8	8.7	0.76	2.99	0.128
5/23/19	Storm	73	7.6	10	0.80	3.14	0.393
5/30/19	Baseflow	76	8.0	1.8	0.60	3.50	0.075
6/13/19	Storm	65	7.5	3.8	0.71	2.95	0.543
6/27/19	Baseflow	77	8.8	3.1	0.43	2.93	0.091
6/29/19	Storm	78	7.7	15	0.65	2.60	0.206
7/31/2019	Baseflow	75	7.8	2.4	0.51	2.76	0.092
8/18/2019	Storm	75	7.2	14	0.93	2.31	0.920
9/30/2019	Storm	69	7.3	2.8	0.44	2.01	0.106
10/7/2019	Storm	63	7.2	4.7	0.63	2.21	0.287
10/22/2019	Storm	57	7.4	2.6	0.46	2.02	0.201
10/30/2019	Storm	60	7.5	3.1	0.69	1.86	0.221
11/24/2019	Storm	42	7.4	7.6	0.92	2.70	0.325
1/25/2020	Storm	38	7.5	14	1.02	1.80	1.713
2/6/2020	Storm	43	7.5	3.9	2.25	0.97	0.230
3/13/2020	Storm	52	7.7	1.9	0.61	3.30	0.068
4/13/2020	Storm	57	7.5	5.3	0.89	1.51	0.300
4/23/2020	Storm	52	7.4	12	0.91	2.03	0.254
4/30/2020	Storm	57	7.2	15	0.98	1.14	1.034

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)						
Event date	Stream condition	Suspended sediment (mg/L)	Total suspended solids (mg/L)	Dissolved copper (µg/L)	Dissolved lead (µg/L)	Dissolved zinc (µg/L)
MDL		1	15	1.4	0.04	2
Pre-construction samples						
1/23/17	Storm	1,380	1,110	31.7	22.9	107
2/23/17	Baseflow	4	15	0.9	0.1	2
3/1/17	Storm	23	18	2.2	0.5	2
3/31/17	Storm	543	332	16.6	8.0	37
4/6/17	Storm	1,250	901	30.3	22.0	95
5/5/17	Storm	375	271	14.9	6.2	32
5/25/17	Storm	398	356	20.9	8.2	44
6/19/17	Storm	147	162	9.3	3.5	24
7/6/17	Storm	518	477	20.7	10.5	49
8/7/17	Baseflow	7	15	1.1	0.2	2
8/24/17	Baseflow	8	15	1.2	0.1	2
9/26/17	Baseflow	3	15	1.5	0.1	2
10/9/17	Storm	27	26	4.4	0.5	4
10/24/17	Storm	15	15	1.7	0.1	1
10/29/17	Storm	364	321	15.7	7.0	41
11/29/17	Baseflow	1	15	1.4	0.1	2
12/20/17	Storm	3	15	3.2	0.1	2
1/12/18	Storm	37	35	3.5	0.7	4
1/26/18	Baseflow	2	18	0.3	--	2

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)						
Event date	Stream condition	Suspended sediment (mg/L)	Total suspended solids (mg/L)	Dissolved copper (µg/L)	Dissolved lead (µg/L)	Dissolved zinc (µg/L)
MDL		1	15	1.4	0.04	2
Construction samples						
2/7/18	Storm	9	15	1.7	0.3	2
2/11/18	Storm	145	130	7.5	3.3	16
2/23/18	Storm	294	280	15.8	7.9	31
3/2/18	Storm	46	43	5.8	1.3	6
3/23/18	Baseflow	5	15	1.0	0.1	2
4/16/18	Storm	480	361	21.7	6.6	36
4/27/18	Storm	11	16	1.7	0.3	2
5/14/18	Storm	127	78	6.0	2.4	12
5/22/18	Storm	564	530	16.0	11.8	48
6/2/18	Storm	812	696	22.9	14.9	64
6/20/18	Storm	337	254	10.1	6.3	33
7/16/18	Baseflow	10	15	2.5	0.2	2
8/21/18	Storm	1,000	812	26.4	16.9	79
9/17/18	Storm	155	150	7.3	3.0	15
10/26/18	Storm	182	176	8.4	3.7	19
11/9/18	Storm	246	201	9.9	6.3	29
11/29/18	Baseflow	9	15	1.0	0.1	2
12/15/18	Storm	1178	771	36.4	20.6	93
12/21/18	Storm	110	85	8.6	2.4	14
2/3/19	Baseflow	--	--	--	--	--
2/6/19	Storm	107	26	3.8	0.7	6
2/11/19	Storm	537	435	13.4	10.3	41
2/21/19	Storm	85	73	3.2	1.5	12
3/21/19	Storm	1,310	1,160	35.5	23.4	103

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)						
Event date	Stream condition	Suspended sediment (mg/L)	Total suspended solids (mg/L)	Dissolved copper (µg/L)	Dissolved lead (µg/L)	Dissolved zinc (µg/L)
MDL	--	1	15	1.4	0.04	2
Post-construction samples						
4/19/19	Storm	82	24	2.6	0.62	4
4/26/19	Storm	15	15	1.6	0.38	4
5/23/19	Storm	68	90	11.0	2.36	14
5/30/19	Baseflow	12	15	1.4	0.24	2
6/13/19	Storm	81	108	6.0	2.00	12
6/27/19	Baseflow	8	15	1.0	0.16	2
6/29/19	Storm	4	15	8.7	0.27	8
7/31/2019	Baseflow	6	15	1.5	0.14	2
8/18/2019	Storm	169	152	12.7	3.29	21
9/30/2019	Storm	6	18	5.7	0.14	3
10/7/2019	Storm	24	23	7.6	0.43	4
10/22/2019	Storm	12	15	3.6	0.23	11
10/30/2019	Storm	14	15	8.9	0.27	4
11/24/2019	Storm	42	36	6.6	0.84	7
1/25/2020	Storm	1,210	1,005	48.3	20.6	104
2/6/2020	Storm	28	26	11.2	0.76	6
3/13/2020	Storm	15	15	7.8	0.33	4
4/13/2020	Storm	46	45	11.7	1.07	9
4/23/2020	Storm	308	28	13.9	0.78	--
4/30/2020	Storm	641	648	18.1	288	--

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number--, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)					
Event date	Stream condition	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	TPH (µg/L)
MDL		1	--	--	0.1/0.2
Pre-construction samples					
1/23/17	Storm	62	46,100	216,000	0.15
2/23/17	Baseflow	105	640	1,400	nd
3/1/17	Storm	102	2,390	18,800	nd
3/31/17	Storm	54	41,700	228,000	0.06
4/6/17	Storm	61	50,500	212,000	0.12
5/5/17	Storm	70	129,000	240,000	nd
5/25/17	Storm	63	132,000	1,720,000	0.08
6/19/17	Storm	95	994,000	2,070,000	0.05
7/6/17	Storm	51	83,800	2,770,000	0.12
8/7/17	Baseflow	116	2,200	80,000	nd
8/24/17	Baseflow	124	830	61,000	nd
9/26/17	Baseflow	133	590	41,000	nd
10/9/17	Storm	116	699,000	2,090,000	0.03
10/24/17	Storm	44	126,000	3,230,000	nd
10/29/17	Storm	62	365,000	5,180,000	nd
11/29/17	Baseflow	114	980	17,000	nd
12/20/17	Storm	103	310	16,000	nd
1/12/18	Storm	78	3,490	214,000	nd
1/26/18	Baseflow	39	21	4,500	nd

Notes: The EMCs presented here for all species except TPH were calculated by replacing 'non-detects" with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)					
Event date	Stream condition	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	TPH (µg/L)
MDL	--	1	--	--	0.1/0.2
Construction samples					
2/7/18	Storm	92	310	34,000	nd
2/11/18	Storm	82	3,240	115,000	0.01
2/23/18	Storm	85	9,100	82,000	nd
3/2/18	Storm	94	2,600	39,000	nd
3/23/18	Baseflow	120	300	3,700	0.01
4/16/18	Storm	46	11,100	227,000	nd
4/27/18	Storm	91	8,020	60,200	nd
5/14/18	Storm	63	19,600	305,000	nd
5/22/18	Storm	54	40,000	2,250,000	nd
6/2/18	Storm	54	38,000	2,400,000	nd
6/20/18	Storm	101	79,000	2,400,000	nd
7/16/18	Baseflow	104	590	25,000	nd
8/21/18	Storm	58	307,000	2,400,000	nd
9/17/18	Storm	99	130,000	2,600,000	nd
10/26/18	Storm	90	23,700	1,920,000	nd
11/9/18	Storm	77	--	--	nd
11/29/18	Baseflow	91	210	3,500	nd
12/15/18	Storm	62	22,200	533,000	0.01
12/21/18	Storm	57	6,740	174,000	nd
2/3/19	Baseflow	--	52	2,500	nd
2/6/19	Storm	89	1,070	12,600	nd
2/11/19	Storm	52	1,660	24,900	nd
2/21/19	Storm	98	3,750	12,800	nd
3/21/19	Storm	52	13,600	57,700	0.01

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Table 3.8. Event mean concentrations measured in samples collected during storms and low-flow at the upstream (**1636845**) and downstream (**1636846**) stations on Little Catoctin Creek, Md. – continued.

[kg/L, kilograms per liter; mg/L, milligrams per liter; µg/L, micrograms per liter; MDL, method detection level; MPN, most probable number; --, not measured; nd, not detected above MDL]

DOWNSTREAM (1636846)					
Event date	Stream condition	Hardness (mg/L)	*Enterococcus* (MPN)	*E. coli* (MPN)	TPH (µg/L)
MDL	--	1	--	--	0.1/0.2
Post-construction samples					
4/19/19	Storm	90	2,770	19,400	nd
4/26/19	Storm	90	34,800	127,000	nd
5/23/19	Storm	84	62,700	539,000	nd
5/30/19	Baseflow	90	1,500	20,000	nd
6/13/19	Storm	94	60,100	240,000	nd
6/27/19	Baseflow	96	2,500	18,000	nd
6/29/19	Storm	100	9,460	1,190,000	nd
7/31/2019	Baseflow	110	39,000	990	nd
8/18/2019	Storm	79	1,710,000	12,3000	nd
9/30/2019	Storm	113	125,000	3,440	nd
10/7/2019	Storm	119	240,000	172,000	nd
10/22/2019	Storm	121	172,000	7,320	nd
10/30/2019	Storm	116	132,000	14,800	0.02
11/24/2019	Storm	106	161,000	7,020	nd
1/25/2020	Storm	58	217,000	21,800	nd
2/6/2020	Storm	83	35,400	3,540	nd
3/13/2020	Storm	95	6,400	1,650	nd
4/13/2020	Storm	71	163,000	19,000	nd
4/23/2020	Storm	82	198,000	19,700	nd
4/30/2020	Storm	29	90,800	79,900	0.19

Notes: The EMCs presented here for all species except TPH were calculated by replacing ‘non-detects” with respective MDL.

EMC for TPH were calculated by replacing non-detected values with null (0) concentration. Values reported as nd (not detected) indicates that all components of TPH were below their respective MDL

Attachment E - Biological Monitoring Results

Post-Restoration Biological and Habitat Conditions in Little Catoctin Creek

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Introduction

The Maryland State Highway Administration (SHA) Water Programs Division has planned a restoration project on Little Catoctin Creek downstream of MD-180 (Jefferson Pike) in Frederick County. The project aims to restore a 3,100-linear foot stream reach within a pasture that is heavily impacted by current and legacy agricultural land use in the adjacent flood plain and upstream catchment. The goal of the restoration is to reduce stream bank erosion and associated nitrogen and phosphorous pollutants that impact water quality in both the study reach and downstream areas. The restoration design aims to restore natural hydrologic, hydraulic, geomorphic, and biological function and stability to the study reach and floodplain, and to increase sediment and nutrient processing. Construction on this stream reach began in the fall of 2017 and continued through early 2019. SHA has partnered with the US Geological Survey (USGS) and the Maryland Department of Natural Resources (DNR) to conduct geomorphological, chemical, and biological monitoring, respectively, before and following restoration to assess potential changes in stream function associated with the project. Monitoring by all partners was initiated in 2016.

This report summarizes biological monitoring data collected from March 2016 to September 2019 under Project AT628A13 by the DNR Resource Assessment Service. This report provides a synopsis of the biological and physical habitat conditions within Little Catoctin Creek prior to and following restoration. It was compiled to support SHA's MS4 reporting requirements (FY20) for this restoration project.

Study Area Overview

The Little Catoctin Creek watershed occupies 17.72 square miles (11,340.3 acres) in the southwestern corner of Frederick County in the Blue Ridge physiographic province (Figure 1). It flows 8.5 stream-miles southeast from its headwaters on the eastern side of South Mountain to the mouth east of the town of Brunswick and drains into the Potomac River. Land use in the watershed is primarily agricultural. Approximately 20 percent of the watershed draining to the study reach is forested. Impervious surface comprises less than 3 percent of the watershed (SHA 2016).

The study area is located north of the town of Rosemont between US-340 at the upstream end and Petersville Road (MD-79) at the downstream end. Within the study area, Little Catoctin Creek flows through active and old pasture. Much of the riparian area (especially in reaches adjacent to MD-180) contains few trees – leaving a large area of the stream open to direct sunlight. Stream banks within the open pasture are steep and heavily eroded. Riffle and run habitats within the creek are predominantly cobble and gravel. Heavy deposits of fine silt and sand are found in pools and depositional areas.

Monitoring Study Design

SHA and DNR identified three stream reaches on Little Catoctin Creek to monitor over the course of the study to assess changes in biological condition and stream physical habitat quality associated with the restoration. The study reaches included:

- A control reach west of MD-180 (upstream of the planned restoration);
- A restoration reach extending approximately 3,100 linear feet east of MD-180;
- A downstream reach located east (downstream) of the restoration reach.

We allocated two sites to each of these study reaches (Figure 1). When possible, biological monitoring sites were co-located at proposed geomorphological transects (SHA) and chemical monitoring stations (USGS) to improve interpretation of all monitoring data over the course of the study. We also monitored a seventh site on a small tributary entering the Control reach just west of MD-180 to assess its potential influence on conditions in the Little Catoctin Creek mainstem. Only benthic macroinvertebrates were sampled at this site. Fish and physical habitat were not assessed at this site.

To provide an understanding of natural variability in stream biological conditions, DNR monitors 29 reference streams known as the Maryland Biological Stream Survey (MBSS) Sentinel site network (Saville et al. 2014). Although monitoring of these sites is not related to nor funded under this project, data from these nearby reference sites are used to better interpret pre- and post-restoration biological conditions in Little Catoctin Creek. Specifically, annual data collected from the sites during the course of this project provide the ability to differentiate natural changes in stream conditions occurring within the region from changes associated with the restoration. Two of these sites, Fifteen Mile Creek (FIMI-207-S) in Washington County, and Jones Falls (JONE-315-S) in Baltimore County, are of similar size to Little Catoctin Creek. Data from these reference sites are presented in this post-restoration report.

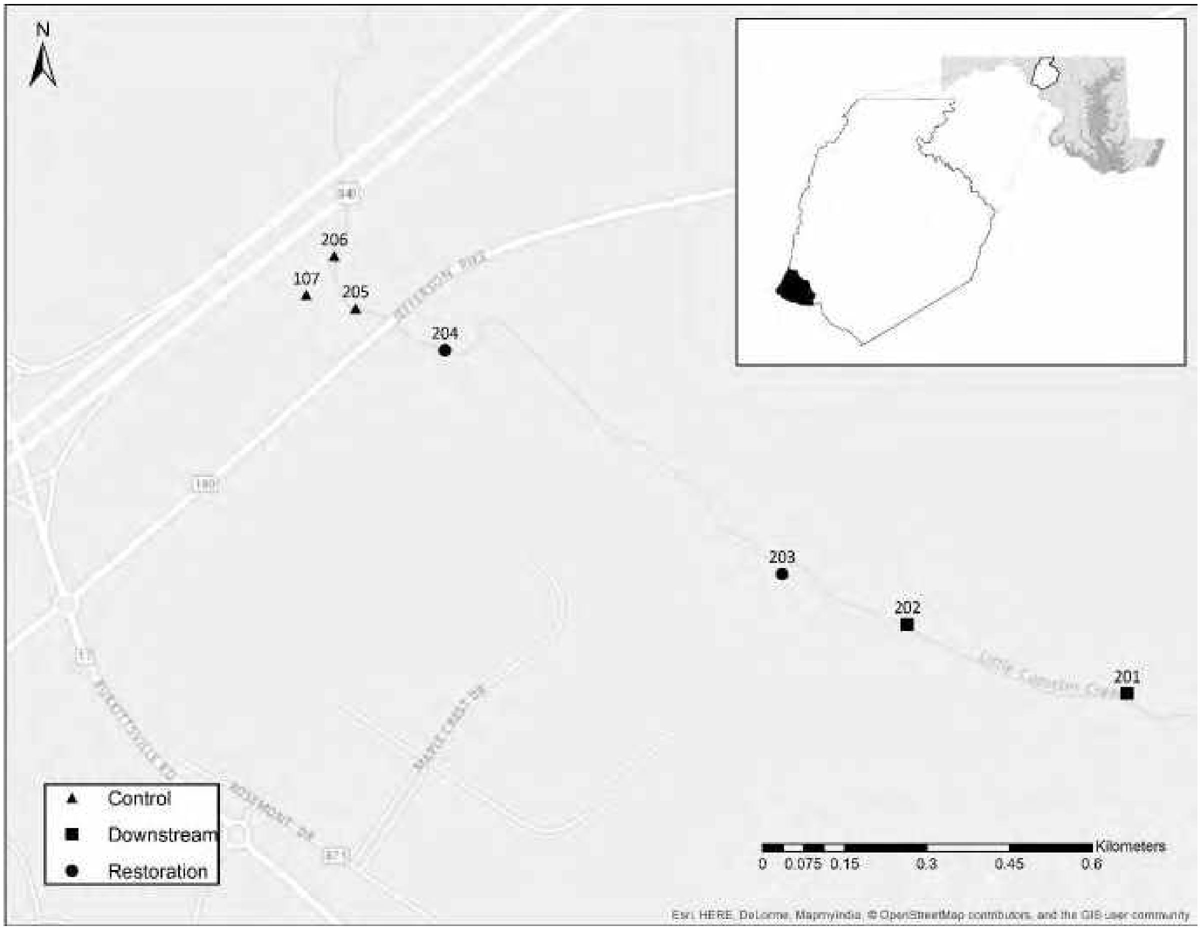

Figure 1. Locations of the seven biological monitoring sites in Little Catoctin Creek

Description of sampling methods

Biological and physical habitat assessments at all sites summarized in this report were conducted following MBSS sampling protocols. Detailed descriptions of these protocols are provided by Stranko et al. (2014). However, a brief description of sampling protocols used for this project are as follows:

Spring MBSS Methods

Sites were surveyed during the spring index period (March 1 - April 30). The stream was measured following the thalweg, and marked at the site boundaries (0 m, 75 m) and at two transects (25 m, 50 m). The location and access routes were described, and the stream was photographed from the midpoint in both upstream and downstream directions.

Physical habitat quality was assessed at each site. Habitat parameters measured included riparian buffer, channelization, aesthetic score, distance from the nearest road, surrounding land use, descriptions of any road culverts in the site, and vernal pool presence or absence.

Benthic macroinvertebrate sampling targeted the most productive habitats in each site. Twenty 0.09 m^2 (1-ft^2) sub-samples were collected using a 540-µm mesh D-net and compiled into a single sample and preserved in denatured ethanol. DNR's benthic laboratory in Annapolis processed the sample by picking an approximately 100-organism subsample for calculation of a Benthic Index of Biotic Integrity (BIBI). Along with the approximately 100-organism benthic macroinvertebrate subsample for BIBI calculation, another 100 benthic macroinvertebrates were taken from the sample to provide greater resolution and a more complete understanding of community composition in the study reach. Hereafter the combined two 100-count subsamples are referred to as the 200-organism subsample (Boward et al. 2019).

The organisms were identified to genus or the lowest practical taxonomic level primarily using the benthic macroinvertebrate key by Merrett et al. (2008). The subsequent taxa list and counts were analyzed following methods described in Southerland et al. (2008), resulting in a BIBI score. Potential scores range from 1 (worst) to 5 (best), indicating the health of the benthic community in the site (Table 1).

Table 1. MBSS IBI scoring and narrative ranking

IBI Score	Narrative Ranking
4.0 – 5.0	Good
3.0 – 3.9	Fair
1.0 – 2.9	Poor

While at each site, qualitative data were also collected on any reptiles, amphibians (seen or heard), crayfish (or their burrows), freshwater mussels and Asiatic clams.

Summer MBSS Methods

Fish sampling was conducted using two-pass electrofishing. Each 75-m reach was enclosed by block nets at the upstream and downstream ends. All fish were counted, identified to species and weighed in aggregate. As with the BIBI score, a Fish Index of Biotic Integrity (FIBI) score was calculated using methods described in Southerland et al. (2008) using the same scale of 1 to 5.

Summer physical habitat quality assessment included the following parameters: velocity/depth diversity, riffle/run quality, pool/glide/eddy quality, embeddedness, shading, habitat suitability for benthic macroinvertebrates (epifaunal substrate) and fish (instream habitat), extent and severity of bank erosion, bar formation and substrate, and counts of woody debris and rootwads. Stream discharge, maximum depth and thalweg depth, width, and current velocity at the four predetermined transects within the site (at 0 m, 25 m, 50 m and 75 m) were also measured. Additionally, any exotic plants within the site or in the surrounding riparian area were recorded.

Quantitative data for stream salamanders and crayfish, as well as incidental captures of other herpetofauna, freshwater mussels and Asiatic clams were also recorded at each site during the summer sampling visit.

Post-Restoration Biological and Physical Habitat Results

Biological and physical habitat data collected at all seven sites in 2019 are summarized below. We compared conditions documented in the spring survey of the three study reaches and also present data collected during the same period from the two reference sites (MBSS Sentinel sites).

Biological Conditions

Benthic Macroinvertebrates: 100-organism Subsample

A total of 60 benthic macroinvertebrate taxa were collected in the approximately 100-organism subsamples in Little Catoctin Creek after construction, compared to the 59 taxa in the two years before construction. Combined across all years of sampling, there was a taxa richness of 91. Taxa richness at each site ranged from 13 to 27 taxa, generally decreasing in an upstream direction throughout the study reaches. The reference sites had taxa richnesses of 27 at Jones Falls and of 22 at Fifteen Mile Creek in 2019.

Control sites had from one to four Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa in 2019, restoration sites had from two to three EPT taxa, and downstream sites had three EPT taxa present (Table 3a-c). These numbers are generally comparable to taxa collected before restoration occurred. By comparison, the Jones Falls Sentinel site had 10 EPT taxa in 2019, while the Fifteen Mile Creek Sentinel site had 14 in 2019 (Table 3d).

Presence of pollution-intolerant taxa showed a similar pattern in the study area, spanning from one to five in 2019. Samples from the upstream control sites contained from one to three intolerant taxa, those from the restoration sites had two intolerant taxa, and those from the downstream sites contained from one to five intolerant taxa (Table 3a-c). The Jones Falls Sentinel site had 15 intolerant taxa and the Fifteen Mile Creek Sentinel site had seven intolerant taxa in 2019 (Table 3d).

The presence of taxa tolerant to pollution was comparable among all sites across the study reach in 2019. Control sites had from six to 11 tolerant taxa present, restoration reach sites had from 10 to 13 tolerant taxa present, and downstream sites had from 10 to 11 tolerant taxa present (Table 3a-c). The Fifteen Mile Creek Sentinel site had two tolerant taxa present, and the Jones Falls Sentinel site had nine tolerant taxa present (Table 3d).

BIBI scores varied little between years at sites in the study area and ranged from 1.75 to 2.75 in 2019 (Table 2a-c). The Fifteen Mile Creek site, which scored 3.00 in 2016 and attained a site-maximum score of 4.75 in 2017, scored 4.25 in 2019. Jones Falls scored 3.67 in 2019, which was unchanged from previous study years' BIBI scores (Table 2d).

Table 2a. Benthic and fish index of biotic integrity scores from the downstream study reach in Little Catoctin Creek.

Reach	Downstream					
Site	201			202		
Year	2016	2017	**2019**	2016	2017	**2019**
BIBI	2.00	1.75	**2.75**	2.25	1.50	**2.50**
FIBI	4.33	4.00	**4.00**	3.33	3.67	**4.00**

Table 2b. Benthic and fish index of biotic integrity scores from the restoration study reach in Little Catoctin Creek.

Reach	Restoration					
Site	203			204		
Year	2016	2017	**2019**	2016	2017	**2019**
BIBI	2.00	1.75	**2.25**	1.75	1.75	**2.00**
FIBI	3.33	3.67	**4.33**	3.33	3.00	**4.33**

Table 2c. Benthic and fish index of biotic integrity scores from the control study reach in Little Catoctin Creek.

Reach	Control								
Site	205			206			107		
Year	2016	2017	**2019**	2016	2017	**2019**	2016	2017	**2019**
BIBI	1.50	1.75	**2.25**	1.50	1.25	**1.75**	2.00	1.50	**2.00**
FIBI	3.00	3.33	**3.33**	3.33	3.00	**3.67**	NM	NM	**NM**

NM = Not measured (Only benthic macroinvertebrates sampled at this site)

Table 2d. Benthic and fish index of biotic integrity scores from representative MBSS Sentinel sites.

	Reference Sites					
Site	Fifteen Mile Creek			Jones Falls		
Year	2016	2017	**2019**	2016	2017	**2019**
BIBI	3.00	4.75	**4.25**	4.00	3.67	**3.67**
FIBI	4.33	4.33	**4.33**	3.67	3.33	**4.00**

Table 3a. Numbers of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa and pollution-intolerant and tolerant benthic macroinvertebrate taxa from the downstream study reach in Little Catoctin Creek.

Reach	Downstream					
Site	201			202		
Year	2016	2017	**2019**	2016	2017	**2019**
Number of EPT taxa	7	3	**3**	6	1	**3**
Number of intolerant taxa	7	2	**5**	3	1	**1**
Number of tolerant taxa	13	8	**10**	15	9	**11**

Table 3b. Numbers of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa and pollution-intolerant and tolerant benthic macroinvertebrate taxa from the restoration study reach in Little Catoctin Creek.

Reach	Restoration					
Site	203			204		
Year	2016	2017	**2019**	2016	2017	**2019**
Number of EPT taxa	5	3	**3**	1	0	**2**
Number of intolerant taxa	3	1	**2**	2	3	**2**
Number of tolerant taxa	12	12	**13**	10	10	**10**

Table 3c. Numbers of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa and pollution-intolerant and tolerant benthic macroinvertebrate taxa from the control study reach in Little Catoctin Creek.

Reach	Control								
Site	205			206			107		
Year	2016	2017	**2019**	2016	2017	**2019**	2016	2017	**2019**
Number of EPT taxa	1	0	**4**	1	0	**1**	3	1	**2**
Number of intolerant taxa	3	1	**3**	2	1	**1**	3	2	**2**
Number of tolerant taxa	7	14	**9**	7	11	**6**	11	9	**11**

Table 3d. Numbers of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa and pollution-intolerant and tolerant benthic macroinvertebrate taxa from representative MBSS Sentinel sites.

Reach	Reference Sites					
Site	Fifteen Mile Creek			Jones Falls		
Year	2016	2017	**2019**	2016	2017	**2019**
Number of EPT taxa	10	24	**14**	13	8	**10**
Number of intolerant taxa	13	25	**15**	12	9	**7**
Number of tolerant taxa	2	2	**2**	8	7	**9**

Benthic Macroinvertebrates: 200-organism Subsample Metrics and IBI Scores

Of the four metrics explored in Table 4 and Figure 2 using the 200-organism benthic macroinvertebrate data, only the BIBI score mean was significantly different between pre- and post-restoration groups (One-Way ANOVA; $p < 0.05$). Both the Shannon-Weiner Diversity Index and the Simpson's Evenness Index showed no significant difference among the four site types. Although taxa richness showed no significant difference between pre- and post- restoration groups, there was a significant difference between the downstream control group and both restoration groups, as well as between the upstream control group and both restoration groups.

Table 4. Mean metric values among treatment groups and monitoring years using 200-organism benthic data (BIBI is calculated using the first 100 benthic count). Restoration and downstream control groups are means of two sites; upstream control is a mean of 3 sites. * = post-restoration means, S-W (D') = Shannon-Weiner Diversity Index.

	Year	**Taxa Richness**	**S-W (D')**	**Simpson's**	**BIBI**	**Ranking**
Restoration	2016	31.00	2.60	0.86	1.63	Very Poor
	2017	21.50	1.93	0.73	1.75	Very Poor
	2019*	27.00	2.37	0.86	2.13	Poor
Upstream	2016	26.67	2.34	0.84	1.50	Very Poor
	2017	18.00	2.11	0.81	1.5	Very Poor
	2019	23.00	2.34	0.86	2.00	Poor
Downstream	2016	41.00	2.68	0.84	2.13	Poor
	2017	24.50	2.16	0.82	1.75	Very Poor
	2019	35.00	2.52	0.85	2.63	Poor

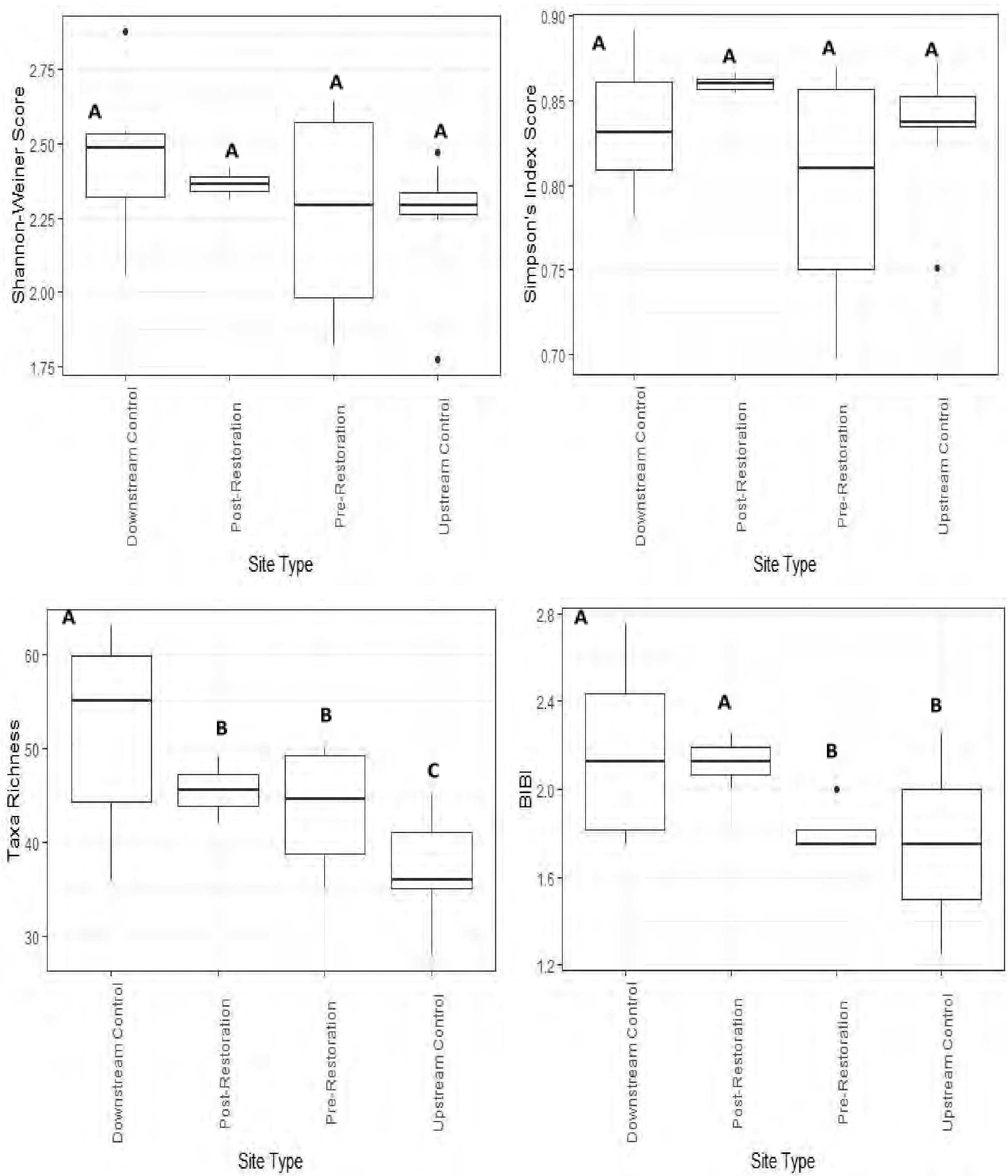

Figure 2. Boxplots of select metrics explored using 200-count benthic macroinvertebrate data. Site types sharing the same letter are not statistically different, using a Tukey's HSD pair-wise comparison.

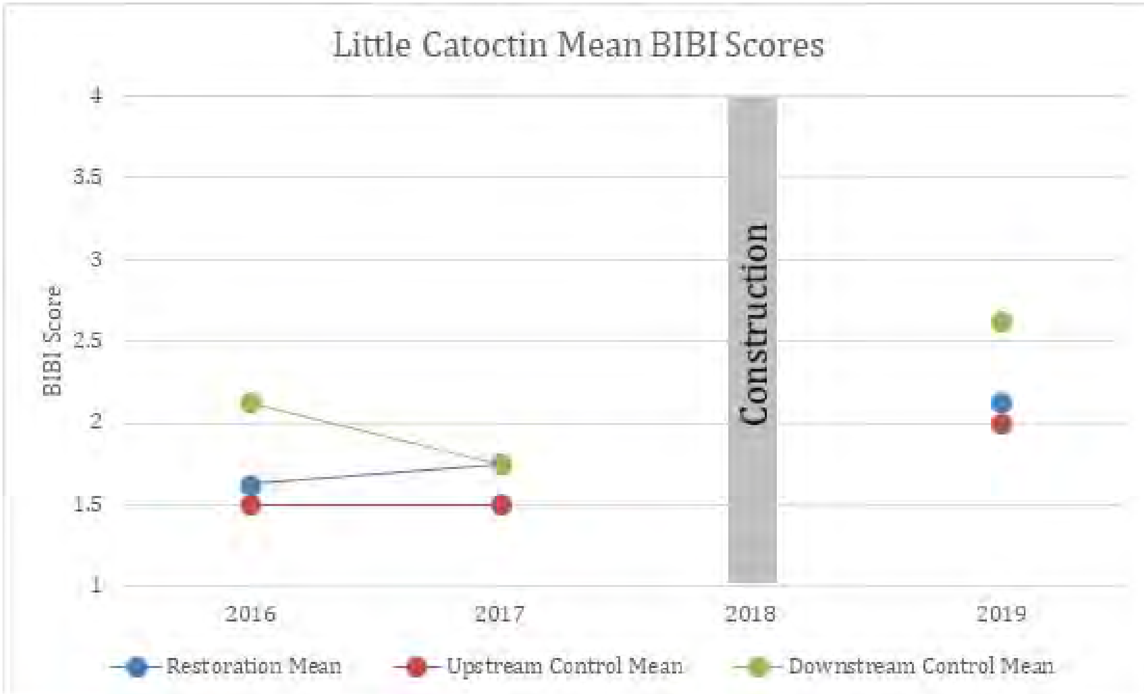

Figure 3. Mean Maryland BIBI Scores within restoration reach and controls. 2016 and 2017 represent pre-restoration years; 2019 represent post-restoration year. Vertical grey box indicates construction period.

Figure 4. Mean Maryland BIBI Scores among restoration sites. Site 203 is most downstream site, site 204 is most upstream site. 2016 and 2017 represent pre-restoration years; 2019 represent post-restoration year. Vertical grey box indicates construction period.

Benthic Macroinvertebrates: 200-organism Subsample Functional Feeding Groups

Of the five functional feeding group (FFG) metrics explored in Figure 5, percent shredders were significantly higher in the post-restoration group compared to the pre-restoration group (One-Way ANOVA; p = 0.012). In addition, percent predators were significantly lower in the post-restoration group compared to the pre-restoration group (One-Way ANOVA; p = 0.033). There was no significant difference among any other pairings (p > 0.05).

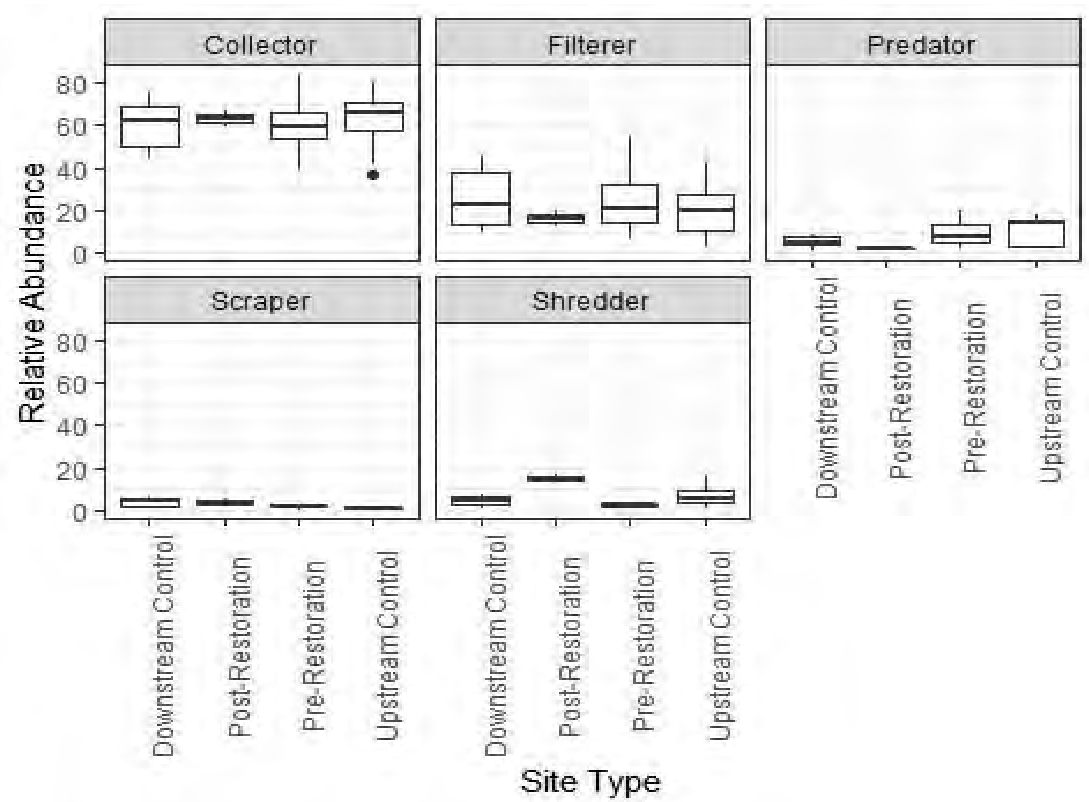

Figure 5. Boxplots of functional feeding groups among site types at the Little Catoctin restoration.

Benthic Macroinvertebrates: 200-organism Subsample Benthic Community Responses to Restoration

Benthic macroinvertebrate data were explored using a non-metric multidimensional scaling (NMDS) technique to visually observe differences in community compositions and relative abundances of taxa among pre-restoration, post-restoration, upstream control, and downstream control groups. The NMDS technique used in below examples uses a Bray-Curtis distance measure and log-transformed abundances, omitting rare taxa observed in less than 5% of samples, as suggested by McCune et al. (2002).

The NMDS graphic seen in Figure 6 suggests that there is some community similarity between the pre-restoration group and the downstream control group, whereas there is no overlap in ordination space between the upstream control and pre-restoration group, nor between the upstream control and downstream control. One of the two post-restoration samples does fall within the upstream control group, but when viewing Figure 7 it is evident that sampling year influences community similarity more than site type, particularly in 2019 sampling.

The NMDS technique was also used to visualize habitat data collected during the summer index period, as well as functional feeding groups, to see if any of these metrics influenced the three major groupings as shown in Figures 6 and 7. An R-squared cut-off value of 0.400 was used in this analysis, as suggested by McCune et al. (2002). Several habitat metrics were highly correlated with the downstream control group, as seen in Figure 8. These metrics include percent shading, epifaunal substrate score, number of rootwads, number of dewatered rootwads, and instream habitat score. Additionally, percent shredder seems to be highly correlated with the post-restoration group and other 2019 samples, as seen in Figures 8 and 5.

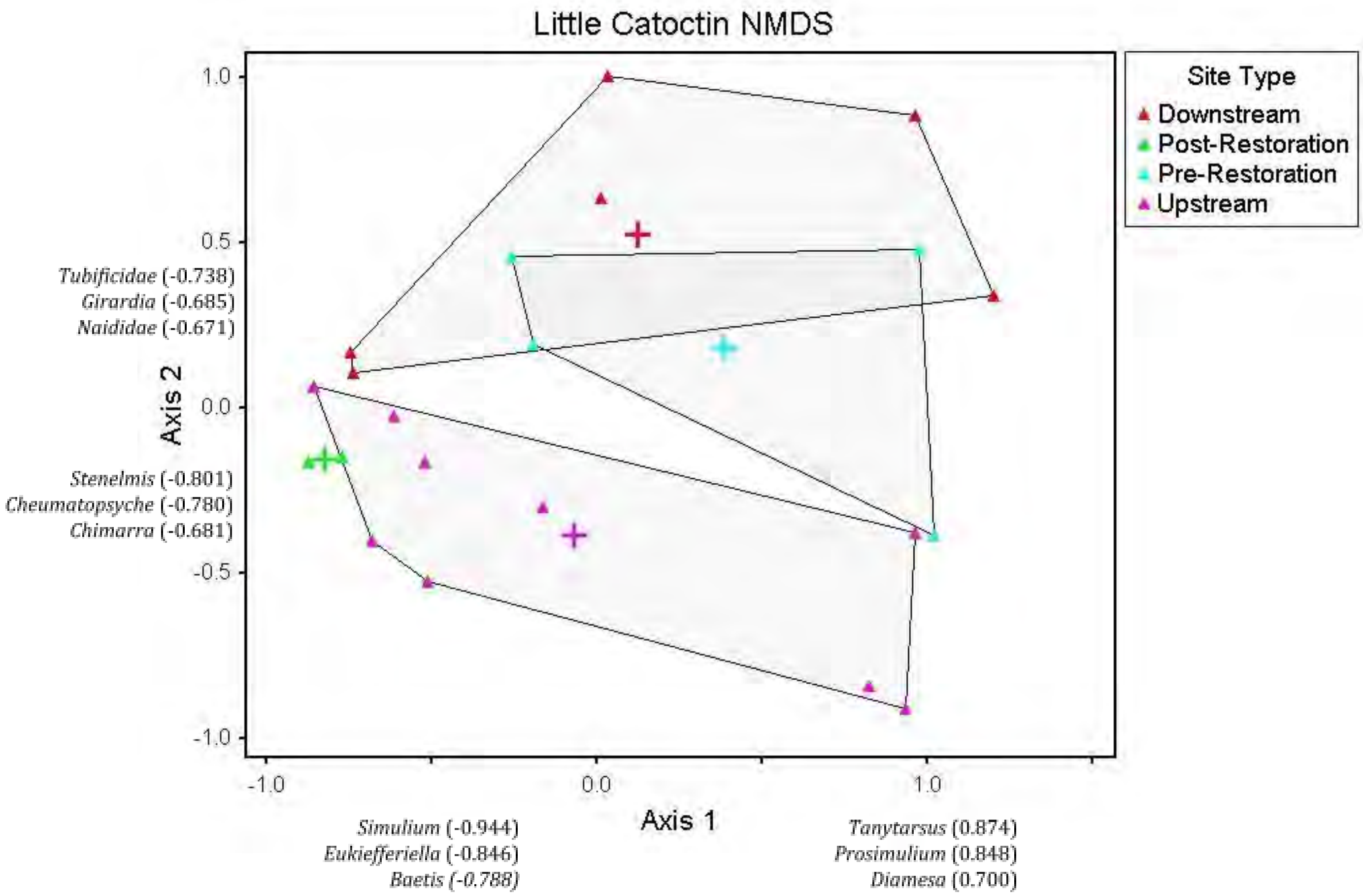

Figure 6. Mean NMDS ordination of 200 count benthic macroinvertebrate samples (triangles) grouped by site type (enclosed by convex hulls). Centroids of each site type are displayed as plus signs. Top three taxa correlated with each axis are provided. Mean stress = 0.1941, which falls into the category of an excellent representation of the data.

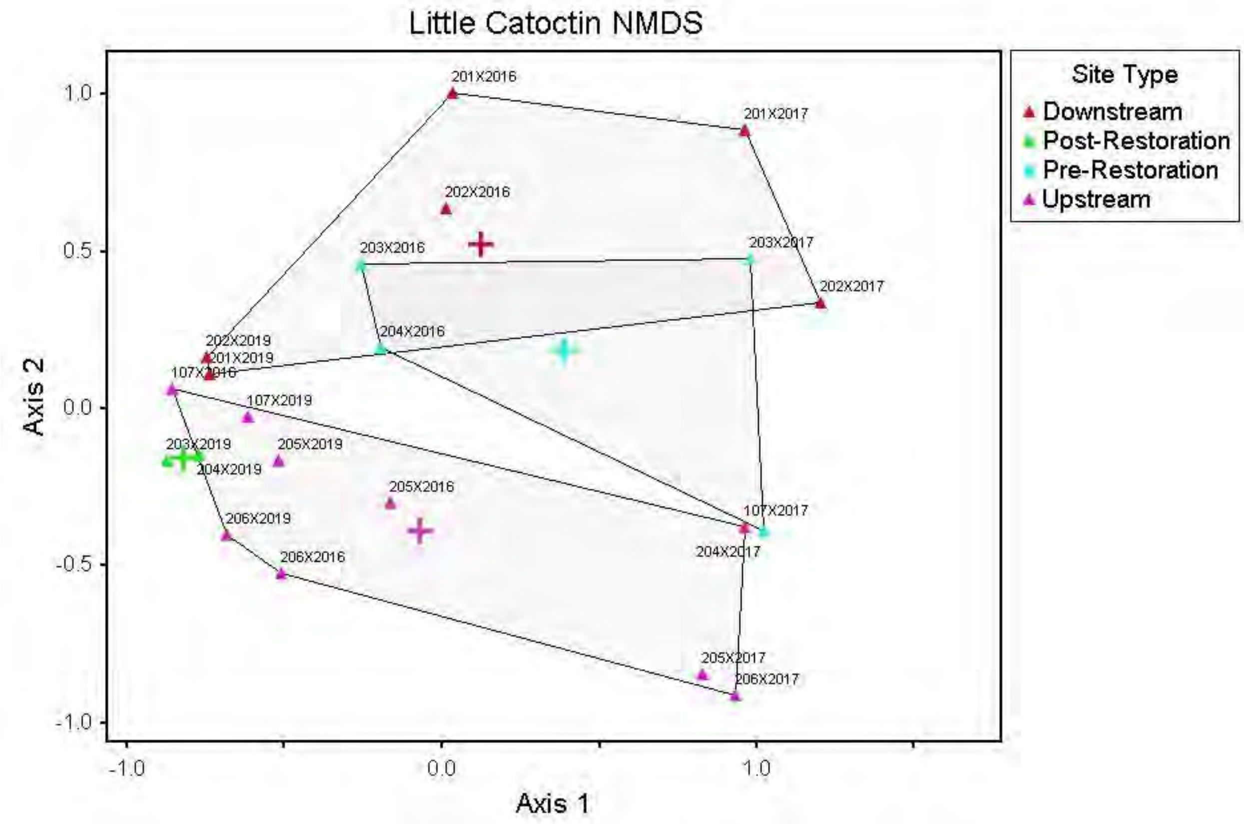

Figure 7. Mean NMDS ordination of 200 count benthic macroinvertebrate samples (triangles) grouped by site type (enclosed by convex hulls). Individual samples are labeled in this graphic. Centroids of each site type are displayed as plus signs. Mean stress = 0.1941, which falls into the category of an excellent representation of the data.

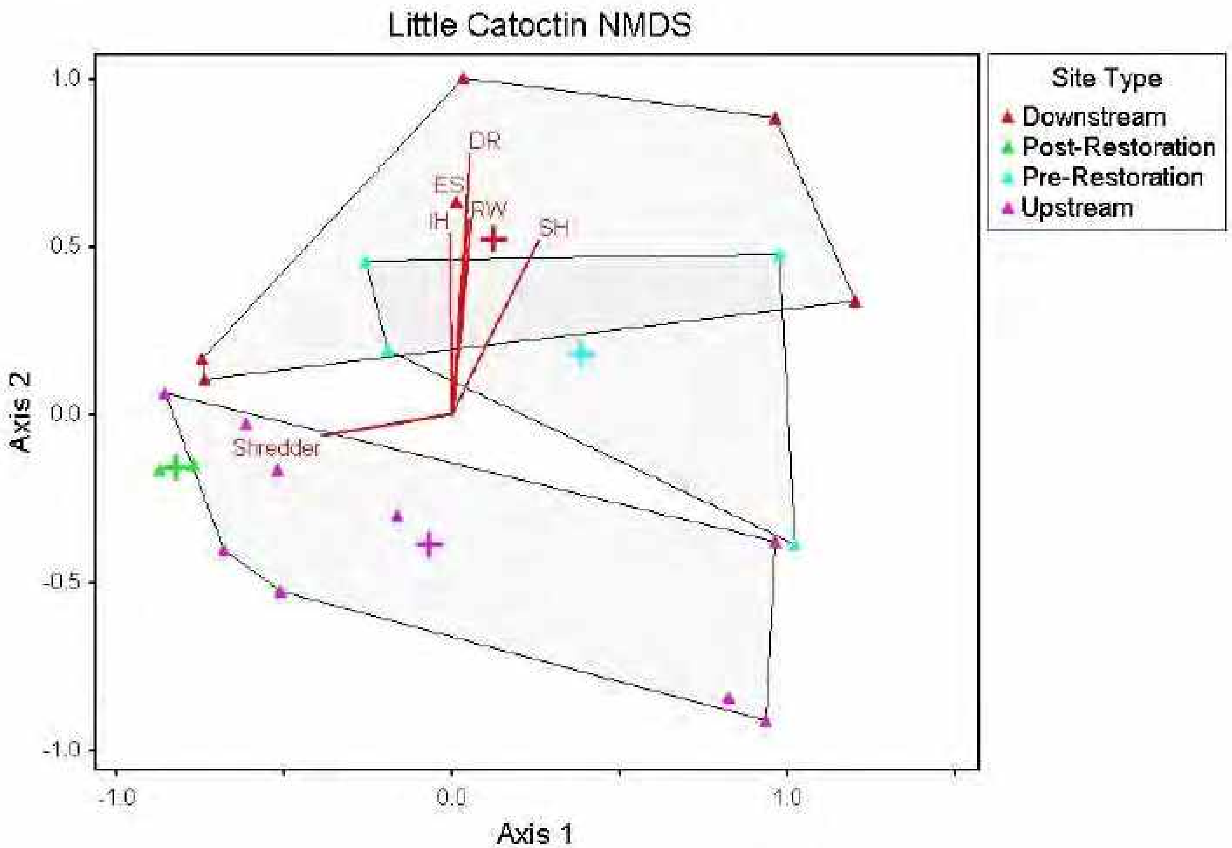

Figure 8. Mean NMDS ordination of 200 count benthic macroinvertebrate samples (triangles) grouped by site type (enclosed by convex hulls). Centroids of each site type are displayed as plus signs. Mean stress = 0.1941, which falls into the category of an excellent representation of the data. Joint biplots (red lines) are any metric that has a cutoff r squared value of greater than 0.400. SH = shading, RW = rootwads, IH = instream habitat, ES = epifaunal substrate, DR = dewatered rootwads, Shredder = percent shredder.

To further understand what taxa caused the clustering observed in NMDS graphics, an Indicator Species Analysis (ISA) was conducted for the four site types for the 200 count benthic macroinvertebrate data. The ISA uses a Monte-Carlo test of significance and gives each indicator taxon a p-value and an indicator value ranging from 0 to 100, with 0 suggesting that it is a poor indicator and 100 suggesting that it is a perfect indicator of a particular group. Any taxon with a p-value greater than 0.05 was excluded from Table 5.

The ISA suggested that pre-restoration samples were influenced by only one taxon, Potthastia (Table 5). It is a non-biting midge taxon that is extremely sensitive to urbanization with a tolerance value of 0.0. Although it had a fairly low p-value (0.005), its ISA indicator value is low (30.3) and may not be the best representation of pre-restoration taxa. In comparison, the ISA suggested that the post-restoration group was influenced by five different taxa, four of which are within the Family Chironomidae (Table 5). These four taxa have a wide range in tolerance values (2.1 to 9.6) and are considered either collectors or shredders. In addition, the taxon Baetis was considered a fairly strong indicator of the post-restoration group. Baetis is a moderately tolerant taxon (3.9) and is considered to be a very fast, seasonal developer with high tendencies of using drift as a means for dispersal (Poff et al. 2006).

Table 5. Indicator Species Analysis among four site types. FFG = functional feeding group, TV = tolerance value, IV = Indicator Value.

Taxon	Site Type	FFG	TV	IV	p-value
Baetis	Post-Restoration	Collector	3.9	56	0.0178
Chaetocladius	Downstream Control	Collector	7	50	0.0352
Chimarra	Downstream Control	Filterer	4.4	74	0.0042
Chironomini	Post-Restoration		5.9	67	0.0288
Cricotopus	Post-Restoration	Shredder	9.6	59	0.0018
Dicrotendipes	Post-Restoration	Collector	9	49	0.0212
Ephydridae	Downstream Control	Collector		50	0.0292
Girardia	Upstream Control	Predator	9.3	78	0.0002
Micropsectra	Post-Restoration	Collector	2.1	61	0.01
Potthastia	Pre-Restoration	Collector	0	30	0.0052

Fish Assemblages

Twenty-two different fish species were collected from the study area in the post-construction period. Of the fish species detected in the study reach, there were five members of the sunfish (Centrarchidae) family, two of which were game fish, and 12 members of the minnow (Cyprinidae) family, including bluehead chub (*Nocomis leptocephalus*), an introduced species.

Other species collected included white sucker (*Catostomus commersoni*), yellow bullhead (*Ameiurus natalis*), greenside darter (*Etheostoma blennioides*), fantail darter (*Etheostoma flabellare*), and banded killifish (*Fundulus diaphanus*). Five of the species found in the study area are intolerant of pollution: central stoneroller (*Campostoma anomalum*), common shiner (*Luxilus cornutus*), mimic shiner (*Notropis volucellus*), bluehead chub (*Nocomis leptocephalus*), and river chub (*Nocomis micropogon*). No federally- or state-listed rare, threatened or endangered fish species were detected at the study sites at any time during the period. Each site contained between 16 and 19 species. Fish assemblage integrity in Little Catoctin Creek is comparable to that of the two reference sites (Table 2d).

FIBI scores within the study reach ranged from Fair to Good in 2019, with the highest scores (4.33) observed at the two sites within the restoration reach (Table 2). In a similar pattern to the BIBI scores, the lowest FIBI scores (3.33, 3.67) were observed in the upstream control reach.

Table 6. Thresholds of metrics used in calculating the Fish Index of Biotic Integrity (FIBI score) for the Warmwater Highlands physiographic region, where Little Catoctin Creek is located. (Southerland et al. 2005)

Fish IBIs (metrics)	Thresholds		
	5	3	1
Abundance per square meter	≥ 0.65	0.31 – 0.64	< 0.31
Number of Benthic species (adjusted for catchment size)	≥ 0.25	0.11 – 0.24	< 0.11
% Tolerant	≤ 39	40 – 80	> 80
% Generalist, Omnivores, Invertivores	≤ 61	62 – 96	> 96
% Insectivores	≥ 33	1 – 32	< 1
% Abundance of Dominant Taxa	≤ 38	39 - 89	> 89

To tease out why FIBI scores are generally higher in the restoration reach after construction than before, it is worth reviewing how the score was calculated. The metrics that are used to construct the FIBI are presented in the IBI metric threshold table (Table 6).

Table 7. Application of FIBI thresholds to survey results in the Little Catoctin Creek restoration sites. Calculated metrics and score based on threshold shown.

SITE	PRFR-203-X			PRFR-204-X		
YEAR	2016	2017	2019	2016	2017	2019
Abundance per square meter	3.68	3.68	7.09	1.02	1.25	7.98
% Abundance of Dominant Taxa	22.10	19.86	31.05	38.48	33.24	27.23
Number of Benthic species (adjusted)	0	0.53	0.53	0.54	0	0.54
% Generalist, Omnivores, Invertivores	90.99	81.21	85.34	97.56	95.34	88.82
% Insectivores	0	0.10	1.45	0.27	0	1.09
% Tolerant	36.48	43.52	23.82	68.56	68.22	37.64
Score: Abundance per square meter	5	5	5	5	5	5
Score: Number of Benthic species (adjusted)	1	5	5	5	1	5
Score: % Tolerant	5	3	5	3	3	5
Score: % Generalist, Omnivores, Invertivores	3	3	3	1	3	3
Score: % Abundance of Dominant Taxa	5	5	5	3	5	5
Score: % Insectivores	1	1	3	1	1	3
FIBI_05	3.33	3.67	4.33	3	3	4.33

Based on the thresholds for component metric scores, the 'percent insectivores' and 'percent tolerant individual fish' metrics tend to influence the overall FIBI score. In 2019, no component score was lower than any component score of the FIBIs in previous years, and certain component scores, percent tolerant and percent insectivores at PRFR-204-X and percent insectivores at PRFR-203-X, were higher than in pre-construction years. Insectivore species found at these sites were fantail darter (*Etheostoma flabellare*) and greenside darter (*Etheostoma blennioides*) (see Appendix).

Table 8. Comparison of fish size and abundance over the study period.

	2016				2017				2019			
Site	Total Fish Count	Abundance /m^2	Total Biomass (g)	Mean Fish Mass (g)	Total Fish Count	Abundance /m^2	Total Biomass (g)	Mean Fish Mass (g)	Total Fish Count	Abundance /m^2	Total Biomass (g)	Mean Fish Mass (g)
PRFR-201-X	578	1.48	6260	10.83	581	1.55	4694	8.08	1290	2.90	3744	2.90
PRFR-202-X	893	2.05	12515	14.01	802	1.77	13830	17.24	1698	3.87	3734	2.20
PRFR-203-X	932	3.68	8247	8.85	1027	3.68	7814	7.61	1037	7.09	3739	3.61
PRFR-204-X	369	1.02	2875	7.79	343	1.25	2287	6.67	1557	7.98	2182	1.40
PRFR-205-X	488	4.07	6472	13.26	489	2.75	6882	14.07	2186	9.02	3966	1.81
PRFR-206-X	174	1.054	4386	25.21	535	3.14	36577	68.37	918	3.20	4326	4.71

Additionally, the mean size of the fish caught dropped substantially across all sites in 2019 relative to prior surveys. Most notably, PRFR-206-X, the site farthest upstream, had a reduction in mean fish mass of over 93% from 2017 to 2019. The 2019 sample incorporated many young individuals.

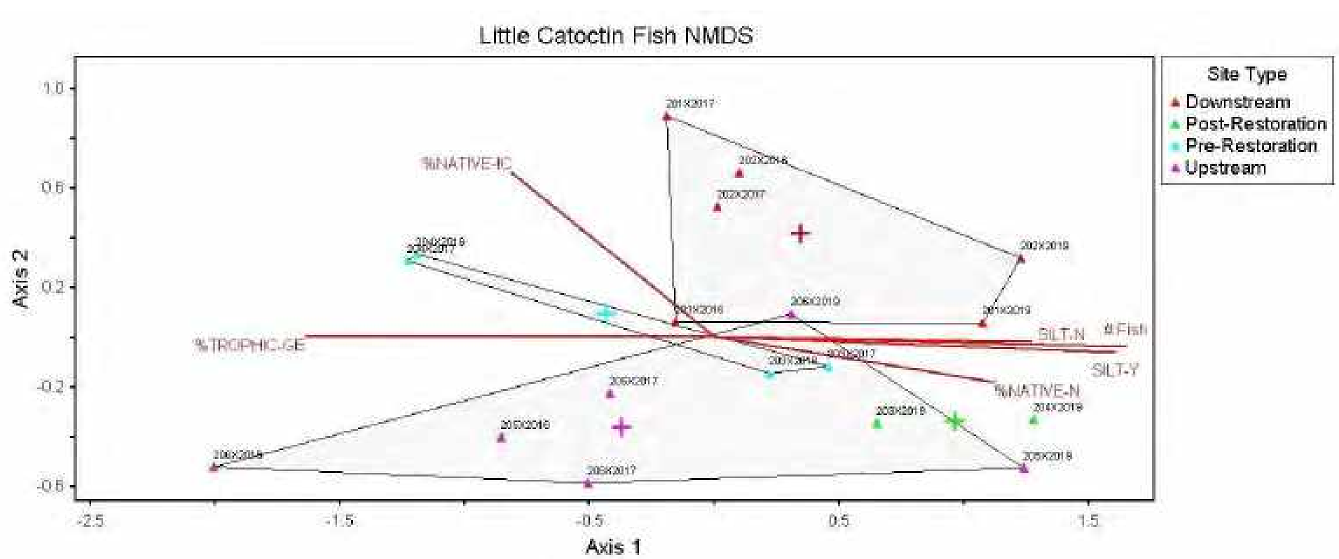

Figure 9. Mean NMDS ordination of fish species collected at the Little Catoctin Creek study area.

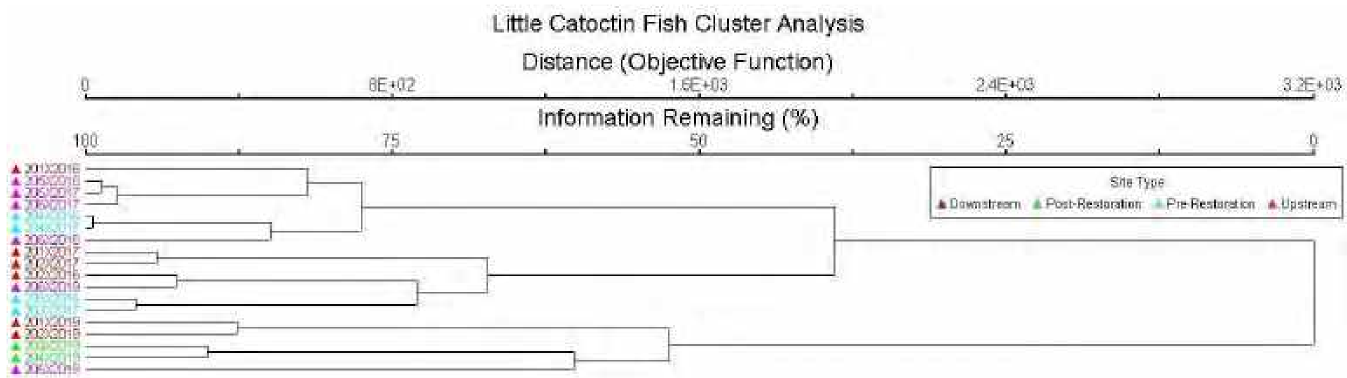

Figure 10. Cladogram likeness of sites by fish species collected at the Little Catoctin Creek study area.

Much like with the benthic macroinvertebrates, the fish assemblages found in the restoration reach post-construction most closely resembled the upstream reach sites (Figure 9), but did not overlap the polygon for the pre-construction restoration reach sites. This difference is driven by a more native, less generalist assemblage of fish occurring post-restoration, as well as physical habitat shifts through the study reach to more closely resemble upstream site conditions.

Physical Habitat Conditions

A number of physical habitat measures were assessed at the time of the surveys. As might be expected from both high erosive flows and the disturbance of bank sediments during construction as the stream channel was moved laterally, embeddedness was higher at the restoration reach in 2019. The fine sediment appears to have settled throughout the study area, particularly where water velocity slowed in the pool features. Shading of the stream channel was also reduced when vegetation was cleared for construction activity (Table 9).

Overall, there was an increase in the extent of riffle and run features in the study sites, with a matched decrease in the extent of pool and glide features. In 2019 there is also a slight decline in instream habitat, epifaunal substrate, and pool and glide quality. Other measures assessed of the physical habitat held roughly steady over the study period.

Table 9. Physical habitat scores for sites in the Little Catoctin Creek study area.

Site	Year	Study Group	Instream Habitat	Epifaunal Substrate	Velocity & Depth Diversity	Pool & Glide Quality	Extent of Pool & Glide (m)	Riffle & Run Quality	Extent of Riffle & Run (m)	Percent Embedded	Percent Shading
PRFR-201-X	2016	Down-stream	15	15	14	15	54	16	23	40	60
PRFR-201-X	2017	Down-stream	12	15	12	13	66	13	16	50	70
PRFR-201-X	**2019**	**Down-stream**	**12**	**13**	**12**	**12**	**55**	**11**	**20**	**40**	**50**
PRFR-202-X	2016	Down-stream	18	17	14	17	55	16	23	25	40
PRFR-202-X	2017	Down-stream	15	12	12	15	62	12	17	55	35
PRFR-202-X	**2019**	**Down-stream**	**13**	**13**	**13**	**12**	**30**	**14**	**45**	**50**	**35**
PRFR-203-X	2016	Pre-restoration	16	15	14	16	61	16	28	25	20
PRFR-203-X	2017	Pre-restoration	14	12	12	15	61	14	26	25	35
PRFR-203-X	**2019**	**Post-restoration**	**10**	**11**	**11**	**11**	**37**	**15**	**38**	**35**	**5**
PRFR-204-X	2016	Pre-restoration	13	16	13	12	36	17	51	15	20
PRFR-204-X	2017	Pre-restoration	11	12	13	12	44	12	33	25	35
PRFR-204-X	**2019**	**Post-restoration**	**8**	**10**	**9**	**8**	**24**	**10**	**51**	**40**	**5**
PRFR-205-X	2016	Upstream control	15	12	13	13	41	16	38	30	10
PRFR-205-X	2017	Upstream control	10	11	9	9	49	15	35	20	25
PRFR-205-X	**2019**	**Upstream control**	**11**	**9**	**9**	**8**	**42**	**13**	**43**	**40**	**5**
PRFR-206-X	2016	Upstream control	12	11	12	11	41	11	35	40	15
PRFR-206-X	2017	Upstream control	8	11	11	11	38	13	41	25	20
PRFR-206-X	**2019**	**Upstream control**	**13**	**9**	**11**	**12**	**54**	**10**	**24**	**30**	**5**

At the time the sites were visited during the 2019 spring index period, all five unrestored sites in the Little Catoctin Creek study area exhibited damage from flooding during the 2018 extreme rain events.

Figure 11a. Photos displaying stream channel alteration occurring between 2017 and 2019, respectively, at control site PRFR-205-X.

Figure 11b. Photos displaying stream channel alteration occurring between 2017 and 2019, respectively, at control site PRFR-206-X.

Crews noted "much channel alteration" due to high flows at upstream control sites during 2019. Riparian buffer consisted primarily of pasture, tall grasses, and regenerating deciduous trees and shrubs. Few mature trees were observed in the riparian zone at PRFR-206-X-2019. This site was channelized for 11 meters on the left bank and three meters on the right bank. Site PRFR-107-X-2019, located on the tributary to Little Catoctin Creek, exhibited minimal buffers totaling 9 meters between the two banks, beyond which was pasture in both riparian areas. The left bank, right bank, and bottom of the stream was channelized for 5 meters by concrete. A cattle crossing passed through the site's midpoint (Figure 12).

Figure 12. Photo of the cattle crossing at tributary control site PRFR-107-X-2019.

Bank reshaping in the restoration reach had evidently occurred shortly before the sites were surveyed in spring 2019. Banks were largely unvegetated for more than 50 meters on each side and stabilized only with staked landscaping matting (Figure 13).

Figure 13. Photo of the restored reach viewed from the Jefferson Pike (Route 180) road crossing.

Downstream sites, PRFR-201-X-2019 and PRFR-202-X-2019, also showed evidence of bank alteration due to flow. The 50-meter riparian buffer at PRFR-201-X-2019 was fully vegetated by forest on the left bank and by tall grass, young and regenerating deciduous trees on the right bank. Buffers at PRFR-202-X-2019 included 50 meters of forest on the left bank and 39 meters of grass and forest on the right bank, followed by cropland beyond. No channelization or buffer breaks were noted at the downstream sites.

The reference sites Jones Falls, JONE-315-S-2019, and Fifteen Mile Creek, FIMI-207-S-2019, had riparian buffers of mixed forest. The Jones Falls buffer extended more than 50 meters on each bank, and the Fifteen Mile Creek buffer extended more than 50 meters on the right bank and 43 meters on the left bank, beyond which was a paved road. The

Fifteen Mile Creek site had significant new erosion on the left bank, but no unusual erosion was noted at the Jones Falls site. Neither site had any channelization nor buffer breaks.

Water Quality Observations from USGS Gage Data

Two USGS real-time stream gages were deployed in the study area in October 2016. Gage 01636845 was positioned at the upstream end of the restoration reach at the Jefferson Pike Bridge and has a catchment of 4.16 mi^2. Gage 01636846 was positioned approximately 3100 feet below the bridge at the downstream end of the restoration reach and has a catchment of 4.55 mi^2. Both gages recorded data in five-minute intervals. The data from the gages are available online https://waterdata.usgs.gov/md/nwis/rt (US Geological Survey 2016). Certain extreme values were estimated after the fact according to standard USGS protocols (Dalrymple et al. 1968). Values from November 27, 2019 through July 2020 were considered provisional at the time of report writing and may be subject to change.

Table 10. Observation periods of water quality parameters measured at the two USGS gages on upstream and downstream ends of the restoration reach.

	Upstream Gage 01636845	Downstream Gage 01636846
Gage Height	10/1/2016 – 7/1/2020	9/13/2017 – 7/1/2020
Temperature	11/29/2016 – 7/1/2020	12/27/2016 – 7/1/2020
Specific Conductance	11/29/2020 – 7/1/2020	12/27/2106 – 7/1/2020
pH	11/29/2016 – 7/1/2020	12/27/2016 – 7/1/2020
Turbidity	11/29/2016 – 7/1/2020	12/27/2016 – 7/1/2020
Discharge	10/1/2016 – 7/1/2020	10/1/2016 – 7/1/2020
Water Velocity	10/6/2016 – 12/17/2018	12/21/2016 – 7/1/2020
Precipitation	2/25/2018 – 7/1/2020	Not sampled
Suspended Sediment	Not sampled	7/6/2017 – 2/28/2018

Based on the discharge measurements from the gages, the most notable observation is the frequent elevated discharge that occurred from May 2018 – May 2019 that coincided largely with restoration reach construction. This period includes the flash flood event of May 15, 2018, which caused the gages to register maximum discharge measurements of 9050 cfs upstream and 9630 cfs downstream, with the daily averages of 317.14 cfs and 436.64 cfs, respectively (Figure 14 a-b). These peaks were reached 55-65 minutes after a baseline discharge reading. Additional storm events occurred approximately monthly through May of 2019.

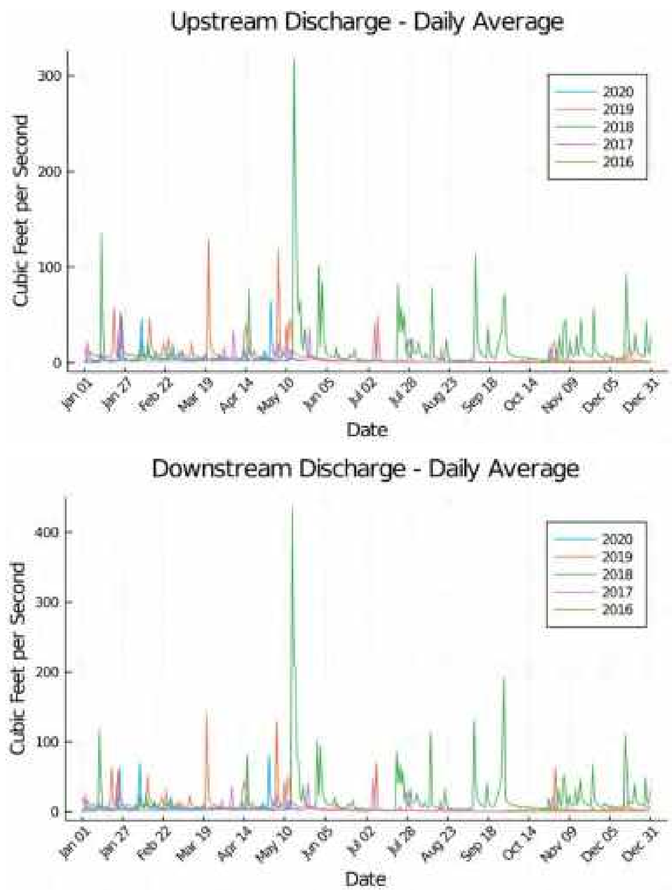

Figure 14a-b. Daily averages of USGS gage discharge (cfs) data 2016 through 2020.

In addition to discharge measurements, temperature and specific conductance were also collected at the USGS gages. There were no discernable differences in average daily temperatures between data collected before and after construction, and minimal temperature differences between upstream and downstream gages. The maximum average daily temperature occurred on July 21, 2019, with the upstream average reaching 29.1ºC (33.2ºc maximum measurement) and the downstream average reaching 29.9ºC (34.8ºC maximum measurement) (Figure 15a-b).

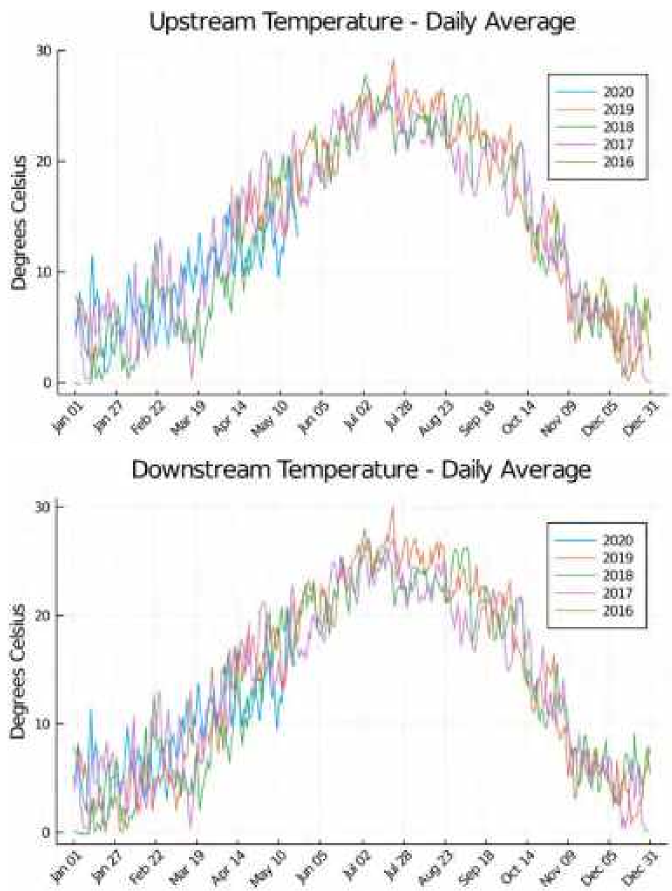

Figure 15a-b. Daily averages of USGS gage temperature data 2016 through 2020.

Specific conductance measurements from the USGS gages predictably spiked in the winter and early spring across all years of data. The runoff following snow and/or ice precipitation is known to carry with it a volume of dissolved salt and other minerals that correlates with increased specific conductance readings. On February 7, 2018, the gages recorded maximum measurements of 2470 µS upstream and 2070 µS downstream. The maximum daily averages occurred on March 21, 2018, with the maximum upstream daily average of 737.9 µS and the maximum downstream daily average of 770.2 µS. Most daily averages hovered between 200 µS and 400 µS, with 2017 containing slightly elevated measurements overall. (Figure 16a-b)

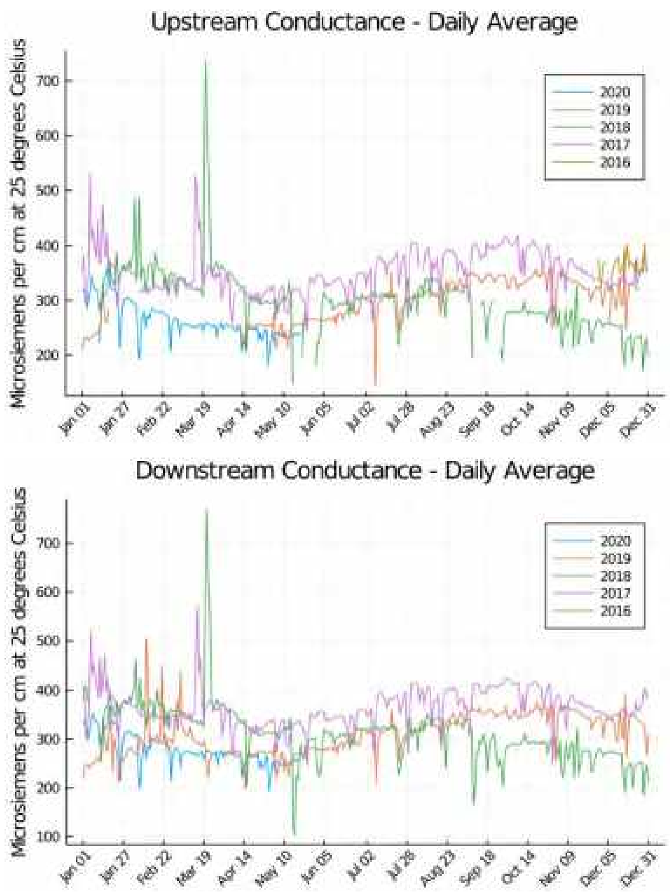

Figure 16a-b. Daily averages of USGS gage specific conductance data 2016 through 2020.

Conclusions

BIBI scores were variable at all study sites between years, but this variation was well within what would be considered normal for benthic macroinvertebrate communities. Similar variation has been documented at other MBSS Sentinel sites and can likely be attributed to variability in biotic responses associated with precipitation and other naturally occurring factors, as well as sampling variability. In nearly all cases, the BIBI and FIBI scores are higher in 2019 than in pre-restoration surveys. Since these results also apply to the upstream control sites, the difference may not be related to the stream restoration. Although taxa richness showed no significant difference between pre- and post-restoration groups, there was a significant difference between the downstream control group and both restoration groups, as well as between the upstream control group and both restoration groups. These differences in taxa richness may be attributable to stream size and available habitat, as the upstream control represents the headwaters of the Little Catoctin watershed, the restoration reach is somewhat larger, and the downstream reach is larger, deeper, and has a somewhat forested buffer compared to both upstream groups.

The significantly higher BIBI score in the post-restoration group compared to the pre-restoration group was explored more closely to determine what metric components of the BIBI may have contributed to the difference. The two component BIBI metrics that were slightly higher in 2019 compared to 2016 and 2017 were 'percent scrapers' and 'percent swimmers.' In other restoration research conducted by MDNR, it typically takes several years of monitoring before BIBI scores approach pre-restoration levels, and rarely do they surpass pre-restoration scores (Palmer et al. 2009). BIBI scores in both control groups also seem to be higher in 2019 compared to 2016 and 2017 monitoring (Figure 3, Table 4), indicating the possibility of unusually advantageous conditions for biota throughout all of these sites in 2019, which is corroborated by the 2019 BIBI scores at the reference sites (Table 2d) and at many other sites in the MBSS Sentinel Site Network across all of Maryland's physiographic regions.

In other restoration studies conducted by MDNR and throughout restoration literature, percent collectors tends to be higher in initial post-restoration periods compared to pre-restoration periods (Palmer et al. 2009), but this pattern was not evident in the Little Catoctin restoration project. Collectors tend to be more generalist taxa (Merritt et al. 2008) and typically dominate after major restoration projects that involve reshaping channel form and function (Palmer et al. 2014). The percentage of collectors is high in each site type, regardless of time period, and may indicate that the more specialized feeding groups such as shredders and scrapers are lower due to underlying water quality issues or lack of allochthonous and autochthonous organic material. The percentage of shredders being significantly higher in the post-restoration period compared to the pre-restoration period is an interesting observation; one that may suggest that the upstream control is serving as a source population for recolonization, perhaps via stream drift. Shredders tend to be highest in headwater streams (Vannote et al. 1980), and it's possible that the shredders from the upstream control sites are some of the first colonizers in post-restoration conditions. Alternatively, the benthic macroinvertebrate community may be responding to storm damage and construction alterations to habitat in the study reach (Table 9), where the end result more closely resembles the upstream control reach. One of the two samples from the restoration reach does fit closely with the upstream control group, but Figure 7 indicates that sampling year more influences community similarity than site type, particularly in 2019 sampling. The physical habitat alterations occurring during restoration activity and 2018 storm damage may be the driver behind these influences on the benthic community.

The mean size of the fish caught dropped substantially across all study sites in 2019 relative to prior surveys. One possible explanation for such a large drop in mean mass is that spawning was enhanced post-construction, and the young fish dispersed throughout the entire study reach. Additionally, the high flows and construction disturbance in 2018 may have displaced larger fish and created a reduction in predator presence allowing for the elevated spawning success rate and survival that predicated the abundance of relatively many small fish found in 2019. It is also possible that following construction and 2018 storm effects, habitat in the restoration reach more closely resembled habitat occurring in the upstream control reach, and the fish community is in the process of adjusting to the new habitat conditions.

Next Steps

This report summarizes those data collected and finalized in calendar year 2019 for Little Catoctin Creek. Further sampling of the study and restoration reaches was conducted during spring 2020. Several years of post-restoration sampling are considered necessary to make more substantive conclusions about the effects of this restoration project on Little Catoctin Creek.

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Appendix

Site Profiles

UT Little Catoctin Creek (PRFR-107-X)

Little Catoctin Creek (PRFR-201-X)

Little Catoctin Creek (PRFR-202-X)

Little Catoctin Creek (PRFR-203-X)

Little Catoctin Creek (PRFR-204-X)

Little Catoctin Creek (PRFR-205-X)

Little Catoctin Creek (PRFR-205-X)

North Branch Jones Falls (JONE-315-S)

Fifteen Mile Creek (FIMI-207-S)

UT Little Catoctin Creek (PRFR-107-X)

This site was sampled on April 20, 2016, March 27, 2017, and April 24, 2019. It is located on a tributary whose confluence with the mainstem of Little Catoctin Creek occurs in the control reach at site PRFR-205-X.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The area surrounding this site contained paved road, residential areas, pasture, cropland, and old fields, as well as deciduous and coniferous forest. The stream buffer was on average 1-5 meters wide, and was broken by a tractor and cattle crossing area of moderate severity at the middle of the site. A 5-meter portion of the stream channel exhibited channelization using concrete, with a smaller portion channelized with riprap.

Table A1. Upstream land use for site PRFR-107-X

Urban	Agricultural	Forest	Other	Source
3.18%	60.68%	30.17%	5.97%	NLCD 2011

Indices of Biotic Integrity & Species

Benthic macroinvertebrates were collected from 17 riffle and three undercut banks in 2016, 20 riffle in 2017, and 18 riffle and 2 from other habitats, specifically dead grass, in 2019. Taxa richness was 24 in 2016, 16 in 2017, and 22 in 2019. The Benthic Indices of Biotic Integrity (BIBI score) were 2.00, 1.75, and 2.00 respectively, which is considered Poor. Differences in BIBI scores of less than or equal to one are not considered significant. Fish were not sampled at this site.

Table B1. BIBI scores for site PRFR-107-X

Year	BIBI
2016	2.00
2017	1.75
2019	2.00

Table C1. Benthic macroinvertebrates (100-count subsample) detected at PRFR-107-X

	Year	2016	2017	2019
Taxon	Order			
Stenelmis	Coleoptera			1
Chironomini	Diptera		1e	
Corynoneura	Diptera	1		1
Cricotopus	Diptera	13		
Diamesa	Diptera		12	1
Diamesinae	Diptera	1e	5e	
Dicrotendipes	Diptera			1
Eukiefferiella	Diptera			3
Hemerodromia	Diptera	4		1
Limnophyes	Diptera	2		3
Micropsectra	Diptera	3		12
Microtendipes	Diptera	1		
Nanocladius	Diptera			2
Orthocladiinae	Diptera	1e	17e	2e
Orthocladius	Diptera	10	45	28
Pagastia	Diptera	1		
Parakiefferiella	Diptera	1		
Parametriocnemus	Diptera	6		
Paraphaenocladius	Diptera			2
Polypedilum	Diptera	2	3	1
Potthastia	Diptera		1	
Prosimulium	Diptera		3	
Rheocricotopus	Diptera		4	
Rheotanytarsus	Diptera		3	
Simulium	Diptera	46	2	25
Tanypodinae	Diptera	4e		
Tanytarsus	Diptera		4	
Thienemanniella	Diptera	2		1
Thienemannimyia Group	Diptera	9	5	4
Tvetenia	Diptera	3		5
Acentrella	Ephemeroptera	1		
Baetis	Ephemeroptera	7		21
Caenis	Ephemeroptera	2	1	4
Naididae	Haplotaxida	3	3	15
Argia	Odonata	1		
Calopteryx	Odonata			1
Girardia	Tricladida	3	13	1

Table D1. Additional taxa present at PRFR-107-X

Year	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	Northern two-lined salamander	Not sampled
2017	No crayfish observed	No herpetofauna observed	Not sampled
2019	No crayfish observed	No herpetofauna observed	Not sampled

Little Catoctin Creek (PRFR-201-X)

This site was sampled on 4/20 and 6/28 in 2016, 3/27 and 7/25 in 2017, and 2/25 and 7/16 in 2019. It is located at the downstream end of the downstream reach of the study area.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

During the spring evaluation, the site was surrounded by cropland, old fields, and deciduous forest. The buffer extended at least 50 meters on the left bank and 30 meters on the right bank, and was uninterrupted for the 75-meter length of the site. No road culverts or channelization were present in the site. Both banks of the stream exhibited minimal erosion in 2016, but the left bank erosion was scored as moderate severity in 2017. Both banks were moderately eroded in 2019. Bar formation was severe in 2016 and 2017, with substrate consisting of cobble, gravel and sand sized particles, but lessened to moderate severity in 2019.

Table A2. Upstream land use for site PRFR-201-X

Urban	Agricultural	Forest	Other	Source
7.75%	69.08%	19.84%	3.33%	NLCD 2011
5.95%	72.22%	20.30%	1.53%	NLCD 2016

Table B2. Physical habitat scores for site PRFR-201-X

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	15	15	14	15	54	16	23	3	40	60	18
2017	12	15	12	13	66	13	16	3	50	70	15
2019	12	13	12	12	55	11	20	2	40	50	8

Indices of Biotic Integrity & Species

Benthic macroinvertebrates were collected from 17 riffle, two rootwad/woody debris habitats, and one undercut bank in 2016, 19 riffle and one rootwad/woody debris habitat in 2017, and 14 riffle, one rootwad/woody debris habitat, and five from other habitats, specifically dead grass, in 2019. There were 32 benthic macroinvertebrate taxa present in the 2016 subsample, 20 taxa in the 2017 subsample, and 26 taxa in the 2019 subsample. The BIBIs were calculated to be 2.00 in 2016, 1.75 in 2017, and 2.75 in 2019, all considered Poor.

Electrofishing efforts detected 17 fish taxa in 2016, 15 fish taxa in 2017, and 17 fish taxa in 2019, which resulted in a Fish Index of Biotic Integrity (FIBI score) of 4.33, 4.00, and 4.00, respectively. The fish community was made up of mostly minnow and sunfish species.

Table C2. IBI scores for site PRFR-201-X

Year	BIBI	FIBI
2016	2.00	4.33
2017	1.75	4.00
2019	2.75	4.00

Table D2. Benthic macroinvertebrates (100-count subsample) detected at PRFR-201-X

	Year	2016	2017	2019
Taxon	Order			
Crangonyx	Amphipoda			1
Ferrissia	Basommatophora		1	
Stagnicola	Basommatophora			1
Gyrinidae	Coleoptera			1
Stenelmis	Coleoptera	8	1	5
Chaetocladius	Diptera	1		1
Chironominae	Diptera		1	2e
Chironomus	Diptera			1
Corynoneura	Diptera		1	
Cricotopus	Diptera	1		2
Diamesa	Diptera	2		
Ephydridae	Diptera	1		
Eukiefferiella	Diptera			2
Hemerodromia	Diptera		1	
Hydrobaenus	Diptera	1		
Limnophyes	Diptera			1
Micropsectra	Diptera	1		31
Nanocladius	Diptera	1	1	
Orthocladiinae	Diptera	7e	4e	5e
Orthocladius	Diptera	27	21	9
Parakiefferiella	Diptera	4		
Parametriocnemus	Diptera	12	1	
Paratanytarsus	Diptera		1	4
Paratendipes	Diptera	1	1	
Polypedilum	Diptera	1	9	5
Prosimulium	Diptera	1	2	
Rheocricotopus	Diptera		34	1
Rheotanytarsus	Diptera	1	39	
Simulium	Diptera	4	4	25
Stictochironomus	Diptera			1
Synorthocladius	Diptera	1		
Tanytarsus	Diptera		4	
Thienemanniella	Diptera	3		
Thienemannimyia Group	Diptera	6		
Tvetenia	Diptera	39		3
Baetidae	Ephemeroptera	1e	1	1
Baetis	Ephemeroptera			17
Caenis	Ephemeroptera			1
Plauditus	Ephemeroptera	2		
Naididae	Haplotaxida	6	2	9
Prostoma	Hoplonemertea			1
Caecidotea	Isopoda	1		1
Corydalus	Megaloptera			1
Argia	Odonata	2		
Enallagma	Odonata	1		
Amphinemura	Plecoptera	1		
Cheumatopsyche	Trichoptera	2	4	
Chimarra	Trichoptera	2	16	
Diplectrona	Trichoptera	1		
Ironoquia	Trichoptera	1		

Table E2. Fish species present at PRFR-201-X

		Year	2016	2017	2019
Taxon	Scientific Name	Family			
White Sucker	Catostomus commersoni	Catostomidae	7	11	36
Rock Bass	Amblopites rupestris	Centrarchidae	2		
Redbreast Sunfish	Lepomis auritus	Centrarchidae	44	28	4
Green Sunfish	Lepomis cyanellus	Centrarchidae	36	14	34
Bluegill	Lepomis macrochirus	Centrarchidae	15	139	1
Largemouth Bass	Micropterus salmoides	Centrarchidae	3	10	11
Smallmouth Bass	Micropterus dolomieu	Centrarchidae			2
Central Stoneroller	Campostoma anomalum	Cyprinidae	5	18	140
Common Shiner	Luxilus cornutus	Cyprinidae	38	22	93
Bluehead Chub	Nocomis leptocephalus	Cyprinidae	64	46	136
Silverjaw Minnow	Notropis buccatus	Cyprinidae	70	16	217
Bluntnose Minnow	Pimephales notatus	Cyprinidae	62	26	228
Longnose Dace	Rhinichthys cataractae	Cyprinidae	97	83	51
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	58	107	194
Creek Chub	Semotilus atromaculatus	Cyprinidae	15	31	47
Banded Killifish	Fundulus diaphanus	Fundulidae	2		7
Yellow Bullhead	Ameiurus natalis	Ictaluridae	41	20	67
Fantail Darter	Etheostoma flabellare	Percidae	21	10	22

Table F2. Other taxa present at PRFR-201-X

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	Eastern snapping turtle	Bull thistle Garlic mustard Japanese honeysuckle Japanese hops Japanese stiltgrass Mile-a-minute Multiflora rose Shrub honeysuckle Tree of heaven Wineberry
2017	No crayfish observed	Eastern snapping turtle	Garlic mustard Japanese honeysuckle Japanese hops Japanese stiltgrass Mile-a-minute Multiflora rose Tree of heaven Wineberry
2019	Faxonius virilis Cambarus bartonii	Northern two-lined salamander Northern green frog	Multiflora rose Wineberry Japanese hops Garlic mustard Japanese honeysuckle Japanese stiltgrass Mile-a-minute

Little Catoctin Creek (PRFR-202-X)

This site was sampled on 4/20 and 6/29 in 2016, 3/27 and 7/25 in 2017, and 4/25 and 7/16 in 2019. It is located at the upstream end of the downstream reach of the study area.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The area surrounding the site was observed to have cropland, old fields, pasture, and residential uses. An uninterrupted buffer extended at least 50 meters on the left bank and between seven and 30 meters on the right bank, and consisted of cropland, grasses, and deciduous forest. No channelization was evident. In 2016 and 207, there was minimal erosion on each bank of the stream and minimal bar formation, consisting largely of cobble and gravel. This rose to erosion of moderate severity for both banks along the whole 75 meter site and moderate bar formation in 2019.

Table A3. Upstream land use for site PRFR-202-X

Urban	Agricultural	Forest	Other	Source
7.39%	68.88%	20.30%	3.42%	NLCD 2011
5.61%	71.98%	20.80%	1.61%	NLCD 2016

Table B3. Physical habitat scores for site PRFR-202-X

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	18	17	14	17	55	16	23	1	25	40	18
2017	15	12	12	15	62	12	17	1	55	35	16
2019	12	13	12	12	30	11	45	2	40	50	10

Indices of Biotic Integrity & Species

Benthic macroinvertebrate samples were collected from 16 riffle and four rootwad/woody debris habitats in 2016 and 2017, and 15 riffle, four rootwad/woody debris habitats, and one leafpack in 2019. There were 34 taxa in the 2016 subsample, 15 taxa in the 2017 subsample, and 30 taxa in the 2019 subsample. The BIBI scores of 2.25 in 2016, 1.75 in 2017, and 2.50 in 2019, all Poor, are not significantly different from each other.

When sampled in the summer, electrofishing resulted in 18 taxa in 2016, 15 taxa in 2017, and 19 taxa in 2019. Most species detected were from the sunfish and minnow families. FIBI scores were 3.33, 3.67, and 4.00, respectively.

Table C3. IBI scores for site PRFR-202-X

Year	BIBI	FIBI
2016	2.25	3.33
2017	1.75	3.67
2019	2.50	4.00

Table D3. Benthic macroinvertebrates (100-count subsample) detected at PRFR-202-X

	Year	2016	2017	2019
Taxon	Order			
Crangonyx	Amphipoda			2
Physa	Basommatophora			8
Ancyronyx	Coleoptera			1
Microcylloepus	Coleoptera			1
Dytiscidae	Coleoptera	1		
Psephenus	Coleoptera	1		
Stenelmis	Coleoptera	6	3	3
Ablabesmyia	Diptera	1	1	
Antocha	Diptera	3		
Chaetocladius	Diptera	1		
Chironominae	Diptera			1e
Chironomus	Diptera			1
Corynoneura	Diptera	3		
Cricotopus	Diptera			9
Diamesa	Diptera	2	2	
Diamesinae	Diptera			1
Dicrotendipes	Diptera		1	
Ephydridae	Diptera	1		
Eukiefferiella	Diptera	3		1
Micropsectra	Diptera	3		48
Nanocladius	Diptera	3		
Orthocladiinae	Diptera	4e		3e
Orthocladius	Diptera	58	52	3
Pagastia	Diptera	1		
Parachironomus	Diptera			1
Parametriocnemus	Diptera	3		1
Paraphaenocladius	Diptera			1
Paratanytarsus	Diptera		6	
Paratendipes	Diptera	2		
Phaenopsectra	Diptera		1	
Polypedilum	Diptera		2	2
Prosimulium	Diptera		2	
Rheocricotopus	Diptera		7	1
Rheotanytarsus	Diptera	1	30	11
Simulium	Diptera	2	1	22
Sublettea	Diptera	1		
Tanypodinae	Diptera			1e
Tanytarsus	Diptera		36	
Thienemanniella	Diptera	1		
Thienemannimyia Group	Diptera	12	4	4
Tvetenia	Diptera	7		1
Baetis	Ephemeroptera	3		6
Caenis	Ephemeroptera	2		
Plauditus	Ephemeroptera	1		
Naididae	Haplotaxida	7		1
Corydalus	Megaloptera	1		
Argia	Odonata	1		1
Coenagrionidae	Odonata	2e		1
Cheumatopsyche	Trichoptera	6		1
Chimarra	Trichoptera	2	2	2
Hydropsyche	Trichoptera	2		
Musculium	Veneroida	1		
Pisidiidae	Veneroida			1

Table E3. Fish species present at PRFR-202-X

		Year	2016	2017	2019
Taxon	Scientific Name	Family			
White Sucker	Catostomus commersoni	Catostomidae	22	31	75
Redbreast Sunfish	Lepomis auritus	Centrarchidae	81	60	8
Green Sunfish	Lepomis cyanellus	Centrarchidae	48	44	41
Bluegill	Lepomis macrochirus	Centrarchidae	89	170	14
Redear Sunfish	Lepomis microlophus	Centrarchidae	2		
Largemouth Bass	Micropterus salmoides	Centrarchidae	6	17	11
Central Stoneroller	Campostoma anomalum	Cyprinidae	23	79	112
Spotfin Shiner	Cyprinella spiloptera	Cyprinidae			2
Common Shiner	Luxilus cornutus	Cyprinidae	69	110	56
Bluehead Chub	Nocomis leptocephalus	Cyprinidae	59	54	135
Silverjaw Minnow	Notropis buccatus	Cyprinidae	11	6	276
Mimic Shiner	Notropis volucellus	Cyprinidae			1
Bluntnose Minnow	Pimephales notatus	Cyprinidae	374	72	499
Longnose Dace	Rhinichthys cataractae	Cyprinidae	31	40	208
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	46	75	121
Creek Chub	Semotilus atromaculatus	Cyprinidae	2	12	41
Banded Killifish	Fundulus diaphanus	Fundulidae	3		16
Yellow Bullhead	Ameiurus natalis	Ictaluridae	20	27	33
Greenside Darter	Etheostoma blennioides	Percidae	1		2
Fantail Darter	Etheostoma flabellare	Percidae	6	5	47

Table F3. Other taxa present at PRFR-202-X

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	No herpetofauna observed	Garlic mustard Japanese honeysuckle Japanese hops Japanese stiltgrass Mile-a-minute Multiflora rose Tree of heaven Wineberry
2017	No crayfish observed	Eastern snapping turtle Northern two-lined salamander	Garlic mustard Japanese barberry Japanese stiltgrass Mile-a-minute Multiflora rose Tree of heaven Wineberry
2019	Cambarus bartonii Faxonius virilis	Northern water snake Eastern snapping turtle Northern green frog American bullfrog	Wineberry Japanese hops Japanese stiltgrass Multiflora rose

Little Catoctin Creek (PRFR-203-X)

This site was sampled on 4/20 and 6/29 in 2016, 3/27 and 8/24 in 2017, and 4/25 and 7/17 in 2019. It is located at the downstream end of the restoration reach of the study area.

Before construction

Upstream

Downstream

After construction

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The riparian buffer around the site extended at least 50 meters along both banks and consists largely of grass on the left bank and cropland on the right bank prior to construction. Beyond the buffer zone, old fields, cropland, pasture, deciduous forest, and residential areas were observed. No channelization of the stream was present within the site. Both banks of the stream exhibited erosion in 2016, with the left bank rated severe and the right bank rated moderate. Bar formation was moderate, with bar substrate consisting of cobble, gravel and sand sized particles.

Following construction, the area immediately surrounding the site had changed to soil without a vegetative buffer. No erosion or bar formation was observed.

Table A4. Upstream land use for site PRFR-203-X

Urban	Agricultural	Forest	Other	Source
6.60%	68.50%	21.37%	3.53%	NLCD 2011
4.90%	71.84%	21.57%	1.69%	NLCD 2016

Table B4. Physical habitat scores for site PRFR-203-X

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	16	15	14	16	61	16	28	2	25	20	18
2017	14	12	12	15	61	14	26	2	25	35	16
2019	10	11	11	11	37	15	38	0	35	5	13

Indices of Biotic Integrity & Species

Benthic macroinvertebrates were collected from 17 riffle and three rootwad/woody debris habitats in 2016, 18 riffle and two rootwad/woody debris habitats in 2017, and 17 riffle, one rootwad/woody debris habitats, and two from other habitats, specifically landscape matting, in 2019. Subsamples contained 25 taxa, 22 taxa, and 26 taxa, respectively, leading to BIBI scores of 2.00, 1.75, and 2.25, were all considered Poor.

Summer electrofishing revealed 15 fish species in 2016, 18 fish species in 2017, and 16 fish species in 2019, with the fish community dominated by minnow and sunfish species. The FIBI score was calculated to be 3.33 (Fair) in 2016, 3.67 (Fair) in 2017, and 4.33 (Good) in 2019.

Table C4. IBI scores for site PRFR-203-X

Year	BIBI	FIBI
2016	2.00	3.33
2017	1.75	3.67
2019	2.25	4.33

Table D4. Benthic macroinvertebrates (100-count subsample) detected at PRFR-203-X

Taxon	Order	2016	2017	2019
Crangonyx	Amphipoda			1
Physa	Basommatophora			6
Microcylloepus	Coleoptera		1	
Psephenus	Coleoptera			1
Stenelmis	Coleoptera	2	6	1
Antocha	Diptera	1		
Chironominae	Diptera			3e
Chironomini	Diptera			1e
Cricotopus	Diptera		5	15
Diamesa	Diptera		7	1
Dicrotendipes	Diptera			4
Eukiefferiella	Diptera	1		4
Hemerodromia	Diptera	2		1
Hexatoma	Diptera	1		
Limnophyes	Diptera			1
Micropsectra	Diptera			50
Nanocladius	Diptera	1	1	
Nilotanypus	Diptera			1
Orthocladiinae	Diptera	3e	3e	13e
Orthocladius	Diptera	45	45	22
Parakiefferiella	Diptera	3		
Parametriocnemus	Diptera	2		
Paraphaenocladius	Diptera	1		
Paratanytarsus	Diptera		12	
Polypedilum	Diptera		1	7
Potthastia	Diptera	1	1	
Prosimulium	Diptera		1	
Rheocricotopus	Diptera		5	
Rheotanytarsus	Diptera	5	75	
Simulium	Diptera	19	2	34
Tanypodinae	Diptera	2		2e
Tanytarsini	Diptera		1e	
Tanytarsus	Diptera		17	
Thienemanniella	Diptera	4		1
Thienemannimyia group	Diptera	6	5	2
Tvetenia	Diptera	8		
Baetis	Ephemeroptera	5		17
Caenis	Ephemeroptera	1		
Maccaffertium	Ephemeroptera			1
Enchytraeidae	Haplotaxida			1
Naididae	Haplotaxida	11	2	6
Cheumatopsyche	Trichoptera	8	8	
Chimarra	Trichoptera		6	
Hydropsyche	Trichoptera	2	1	1
Hydroptila	Trichoptera	2		
Girardia	Tricladida	1	1	

Table E4. Fish species present at PRFR-203-X

Taxon	Scientific Name	Family	2016	2017	2019
White Sucker	Catostomus commersoni	Catostomidae	5	16	20
Redbreast Sunfish	Lepomis auritus	Centrarchidae	38	55	15
Green Sunfish	Lepomis cyanellus	Centrarchidae	45	24	48
Bluegill	Lepomis macrochirus	Centrarchidae	22	18	
Largemouth Bass	Micropterus salmoides	Centrarchidae	5	5	3
Smallmouth Bass	Micropterus dolomieu	Centrarchidae		1	
Central Stoneroller	Campostoma anomalum	Cyprinidae	79	186	134
Rosyside Dace	Clinostomus elongatus	Cyprinidae	5	3	
Common Shiner	Luxilus cornutus	Cyprinidae	206	134	162
Bluehead Chub	Nocomis leptocephalus	Cyprinidae	101	48	42
Silverjaw Minnow	Notropis buccatus	Cyprinidae	65	22	60
Bluntnose Minnow	Pimephales notatus	Cyprinidae	118	165	95
Longnose Dace	Rhinichthys cataractae	Cyprinidae	83	66	322
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	130	204	61
Creek Chub	Semotilus atromaculatus	Cyprinidae	15	15	20
Mimic Shiner	Notropis volucellus	Cyprinidae			1
Banded Killifish	Fundulus diaphanus	Fundulidae		12	6
Yellow Bullhead	Ameiurus natalis	Ictaluridae	16	52	33
Greenside Darter	Etheostoma blennioides	Percidae		1	
Fantail Darter	Etheostoma flabellare	Percidae			15

Table F4. Other taxa present at PRFR-203-X

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	Northern green frog Eastern snapping turtle	Garlic mustard Japanese honeysuckle Japanese hops Japanese stiltgrass Mile-a-minute Multiflora rose Shrub honeysuckle Wineberry
2017	Faxonius virilis	Eastern snapping turtle	Bush honeysuckle Japanese honeysuckle Japanese hops Japanese stiltgrass Multiflora rose Tree of heaven
2019	Faxonius virilis	Northern green frog	Japanese hops

Little Catoctin Creek (PRFR-204-X)

This site was sampled on 4/20 and 6/30 in 2016, 3/27 and 8/24 in 2017, and 4/25 and 7/17 in 2019. It is located at the upstream end of the restoration reach of the study area.

Before construction

Upstream

Downstream

After construction

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

During the spring evaluation of the surrounding land use and stream buffer, the area immediately surrounding the site consisted primarily of pasture prior to construction. The buffer extended about 30 meters on either bank, and was uninterrupted for the 75-meter length of the site in 2016 and 2017. No road culverts or channelization were present in the site. Both banks of the stream exhibited moderate erosion, and bar formation was minimal, with bar substrate shifting from sand and silt in 2016 to cobble and gravel in 2017.

Following construction, the area immediately surrounding the site had changed to soil without a vegetative buffer. No erosion or bar formation was observed.

Table A5. Upstream land use for site PRFR-204-X

Urban	Agricultural	Forest	Other	Source
5.47%	68.41%	22.43%	3.69%	NLCD 2011
3.91%	71.29%	23.03%	1.77%	NLCD 2016

Table B5. Physical habitat scores for site PRFR-204-X

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	13	16	13	12	36	17	51	1	15	20	18
2017	11	12	13	12	44	12	33	1	25	35	12
2019	8	10	9	8	24	10	51	1	40	5	13

Indices of Biotic Integrity & Species

Benthic macroinvertebrate samples were collected from 15 riffle and five rootwad/woody debris habitats in 2016 and 2017, and 17 riffle, one rootwad/woody debris habitats, and two from other habitats, specifically landscape matting, in 2019. There were 23 taxa in the 2016 subsample, 18 taxa in the 2017 subsample, and 21 taxa in the 2019 subsample. The BIBI scores were 1.75, 1.75, and 2.00, respectively.

When sampled in the summer, electrofishing resulted in 13 taxa in 2016 and in 2017, and 16 taxa in 2019. Most species detected were from the minnow family. FIBI scores were 3.33, 3.00, and 4.33, respectively.

Table C5. IBI scores for site PRFR-204-X

Year	BIBI	FIBI
2016	1.75	3.33
2017	1.75	3.00
2019	2.00	4.33

Table D5. Benthic macroinvertebrates (100-count subsample) detected at PRFR-204-X

	Year	2016	2017	2019
Taxon	Order			
Stenelmis	Coleoptera	2	1	1
Ceratopogonidae	Diptera			1
Chironomus	Diptera			1
Cladotanytarsus	Diptera	1		
Corynoneura	Diptera	2		
Cricotopus	Diptera			36
Diamesinae	Diptera		1e	
Dicrotendipes	Diptera	2	1	7
Eukiefferiella	Diptera	2		
Hemerodromia	Diptera	2		
Hydrobaenus	Diptera			1
Limnophyes	Diptera			1
Micropsectra	Diptera			35
Microtendipes	Diptera	1		
Orthocladiinae	Diptera	8e	3e	10e
Orthocladius	Diptera	46	75	15
Parakiefferiella	Diptera	2		
Parametriocnemus	Diptera	1		2
Paratanytarsus	Diptera	4	2	5
Polypedilum	Diptera	2	4	5
Potthastia	Diptera	1	1	
Prosimulium	Diptera		1	
Rheocricotopus	Diptera		1	
Rheotanytarsus	Diptera		2	1
Simulium	Diptera	13		13
Tabanidae	Diptera		1	
Tanytarsus	Diptera		5	
Thienemanniella	Diptera	2		1
Thienemannimyia group	Diptera	7	9	4
Tvetenia	Diptera	2		2
Baetis	Ephemeroptera			26
Caenis	Ephemeroptera			2
Naididae	Haplotaxida	7	18	2
Caecidotea	Isopoda	3		
Argia	Odonata	1		
Hydropsyche	Trichoptera	1		
Dugesiidae	Tricladida		1	
Tubificidae	Tubificida		4	
Pisidiidae	Veneroida	1	1	

Table E5. Fish species present at PRFR-204-X

		Year	2016	2017	2019
Taxon	Scientific Name	Family			
White sucker	Catostomus commersoni	Catostomidae			4
Redbreast Sunfish	Lepomis auritus	Centrarchidae	8	12	7
Green Sunfish	Lepomis cyanellus	Centrarchidae	57	42	16
Bluegill	Lepomis macrochirus	Centrarchidae	4	12	
Largemouth Bass	Micropterus salmoides	Centrarchidae	6	6	5
Central Stoneroller	Campostoma anomalum	Cyprinidae	2	10	152
Rosyside Dace	Clinostomus elongatus	Cyprinidae		1	
Common Shiner	Luxilus cornutus	Cyprinidae	11	6	142
Bluehead Chub	Nocomis leptocephalus	Cyprinidae	36	3	28
Silverjaw Minnow	Notropis buccatus	Cyprinidae			99
Rosyface Shiner	Notropis rubellus	Cyprinidae			1
Bluntnose Minnow	Pimephales notatus	Cyprinidae	142	114	283
Longnose Dace	Rhinichthys cataractae	Cyprinidae	33	39	424
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	37	42	198
Creek Chub	Semotilus atromaculatus	Cyprinidae	7	18	80
Banded killifish	Fundulus diaphanus	Fundulidae			12
Yellow Bullhead	Ameiurus natalis	Ictaluridae	25	38	89
Fantail Darter	Etheostoma flabellare	Percidae	1		17

Table F5. Other taxa present at PRFR-204-X

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	Northern two-lined salamander	Japanese stiltgrass Multiflora rose Tree of heaven Wineberry
2017	No crayfish observed	Eastern painted turtle Eastern snapping turtle	Japanese hops Japanese stiltgrass Multiflora rose Tree of heaven
2019	Faxonius virilis Cambarus bartonii	Gray treefrog Northern green frog Eastern snapping turtle Northern two-lined salamander	Japanese hops Tree of heaven Wineberry

Little Catoctin Creek (PRFR-205-X)

This site was sampled on 4/20 and 7/11 in 2016, 3/27 and 8/10 in 2017, and 4/24 and 7/25 in 2019. It is located at the downstream end of the control reach of the study area.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The land use for the area surrounding the site was primarily pasture. The uninterrupted buffer extended only four to eight meters on either bank, and consisted of grasses. No channelization was evident. There was moderate erosion on each bank of the stream in all years surveyed. Minimal bar formation in 2016 consisting of sand and silt was no longer present in 2017, but rose to moderate levels in 2019.

Table A6. Upstream land use for site PRFR-205-X

Urban	Agricultural	Forest	Other	Source
6.35%	72.55%	18.57%	2.53%	NLCD 2011
4.47%	75.32%	19.09%	1.11%	NLCD 2016

Table B6. Physical habitat scores for site PRFR-205-X

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	15	12	13	13	41	16	38	1	30	10	14
2017	10	11	9	9	49	15	35	0	20	25	13
2019	11	9	9	8	42	13	43	2	40	5	11

Indices of Biotic Integrity & Species

The benthic macroinvertebrate sample was compiled from 20 riffle habitats in 2016 and in 2017, and 13 riffle, two rootwad, one undercut bank, and four from other habitats, specifically dead grass. There were 17 taxa present in the 2016 subsample, 18 taxa in the 2017 subsample, and 23 taxa in the 2019 subsample. The BIBIs were calculated to be 1.50 in 2016, 1.75 in 2017, and 2.25 in 2019, all considered Poor.

Electrofishing turned up 16 fish taxa in 2016, 15 fish taxa in 2017, and 17 fish taxa in 2019, which resulted in a Fish Index of Biotic Integrity (FIBI score) of 3.00, 3.33, and 3.33, respectively. The fish community was made up of mostly minnow and sunfish species.

Table C6. IBI scores for site PRFR-205-X

Year	BIBI	FIBI
2016	1.50	3.00
2017	1.75	3.33
2019	2.25	3.33

Table D6. Benthic macroinvertebrates (100-count subsample) detected at PRFR-205-X

Taxon	Order	2016	2017	2019
Crangonyx	Amphipoda		2	1
Erpobdellidae	Arhynchobdellida		1	
Physa	Basommatophora		3	
Ablabesmyia	Diptera			1
Chironominae	Diptera			1e
Chironomus	Diptera			2
Corynoneura	Diptera	1		
Cricotopus	Diptera		3	10
Diamesa	Diptera		12	
Diamesinae	Diptera		4e	
Dicrotendipes	Diptera	1	3	1
Eukiefferiella	Diptera			2
Limnophyes	Diptera			6
Micropsectra	Diptera	2		10
Orthocladiinae	Diptera	5e	4e	6e
Orthocladius	Diptera	46	25	25
Parakiefferiella	Diptera	2		
Parametriocnemus	Diptera	3		
Paratanytarsus	Diptera		1	1
Polypedilum	Diptera	3	3	2
Prosimulium	Diptera		1	
Rheotanytarsus	Diptera		1	1
Simulium	Diptera	16		42
Synorthocladius	Diptera	1		
Tanytarsus	Diptera		4	
Thienemanniella	Diptera	6		2
Thienemannimyia group	Diptera	1	4	1
Tvetenia	Diptera	4		2
Baetidae	Ephemeroptera			1
Baetis	Ephemeroptera			9
Caenis	Ephemeroptera	2		1
Naididae	Haplotaxida	24	21	11
Cheumatopsyche	Trichoptera			1
Girardia	Tricladida	6	15	
Tubificidae	Tubificida	4	1	

Table E6. Fish species present at PRFR-205-X

Taxon	Scientific Name	Family	2016	2017	2019
White Sucker	Catostomus commersoni	Catostomidae		3	3
Redbreast Sunfish	Lepomis auritus	Centrarchidae	45	41	6
Green Sunfish	Lepomis cyanellus	Centrarchidae	79	44	29
Bluegill	Lepomis macrochirus	Centrarchidae	11	7	25
Largemouth Bass	Micropterus salmoides	Centrarchidae	1	12	1
Central Stoneroller	Campostoma anomalum	Cyprinidae	8	34	188
Rosyside Dace	Clinostomus elongatus	Cyprinidae	6		10
Common Shiner	Luxilus cornutus	Cyprinidae	43	77	170
Bluehead Chub	Nocomis leptocephalus	Cyprinidae	72	79	64
River Chub	Nocomis micropogon	Cyprinidae	5		
Silverjaw Minnow	Notropis buccatus	Cyprinidae	19	27	53
Bluntnose Minnow	Pimephales notatus	Cyprinidae	109	86	870
Longnose Dace	Rhinichthys cataractae	Cyprinidae	19	14	388
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	8	16	241
Creek Chub	Semotilus atromaculatus	Cyprinidae	12	21	32
Fantail Darter	Etheostoma flabellare	Percidae			7
Banded Killifish	Fundulus diaphanus	Fundulidae	3	1	7
Yellow Bullhead	Ameiurus natalis	Ictaluridae	48	27	92

Table F6. Other taxa present at PRFR-205-X

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	Eastern snapping turtle Northern two-lined salamander	Japanese honeysuckle
2017	No crayfish observed	No herpetofauna observed	Japanese honeysuckle
2019	Faxonius virilis	No herpetofauna observed	Japanese hops

Little Catoctin Creek (PRFR-206-X)

This site was sampled on 4/20 and 7/11 in 2016, 3/27 and 8/10 in 2017, and 4/24 and 7/25 in 2019. It is located at the upstream end of the control reach of the study area.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The riparian buffer around the site extends about five meters out from each bank and consists of grass, mature deciduous trees, and regenerating deciduous trees and shrubs on the left bank and grass and regenerating deciduous trees and shrubs on the right bank. A storm drain interrupts the buffer on the left bank. Beyond the buffer zone, deciduous forest, coniferous forest, residential areas, old field, and pasture were observed. The stream was channelized with concrete for 24 meters on the left bank and three meters on the right bank, with an additional six meters of rip-rap on the right bank within the site.

Both banks of the stream exhibited moderate erosion in 2016, but no erosion in 2017, returning to minimal left bank and moderate right bank erosion in 2019. Bar formation was minimal in 2016, with bar substrate consisting of gravel, sand, and silt particle sizes, but no bar formation was observed in 2017. In 2019, bar formation was observed to be moderate.

Table A7. Upstream land use for site PRFR-206-X

Urban	Agricultural	Forest	Other	Source
6.24%	72.59%	18.69%	2.47%	NLCD 2011
4.50%	75.32%	19.02%	1.16%	NLCD 2016

Table B7. Physical habitat scores for site PRFR-206-X

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	12	11	12	11	41	11	35	1	40	15	15
2017	8	11	11	11	38	13	41	0	25	20	15
2019	13	9	11	12	54	10	24	2	30	5	10

Indices of Biotic Integrity & Species

Benthic macroinvertebrates were collected from 18 riffle and two rootwad/woody debris habitats in 2016, 20 riffle habitats in 2017, and 13 riffle, two rootwad/woody debris habitats, and five from other habitats, specifically dead grass, in 2019. Subsamples contained 18 taxa, 14 taxa, and 15 taxa, respectively, leading to BIBI scores of 1.50, 1.25, and 1.75, all considered Poor.

Summer electrofishing detected 13 fish species in 2016 and in 2017, and 19 fish species in 2019, with the fish community dominated by minnow and sunfish species. The FIBI score was calculated to be 3.33 in 2016, 3.00 in 2017, and 3.67 in 2019, all considered Fair, with the difference in scores not considered to be significant.

Table C7. IBI scores for site PRFR-206-X

Year	BIBI	FIBI
2016	1.50	3.33
2017	1.25	3.00
2019	1.75	3.67

Table D7. Benthic macroinvertebrates (100-count subsample) detected at PRFR-206-X

	Year	2016	2017	2019
Taxon	Order			
Crangonyx	Amphipoda			4
Menetus	Basommatophora		1	
Physa	Basommatophora		1	
Stenelmis	Coleoptera	1		
Bezzia	Diptera	1		
Cardiocladius	Diptera			1
Cricotopus	Diptera	38		7
Diamesa	Diptera		7	
Diamesinae	Diptera		2e	
Dicrotendipes	Diptera	1	1	3
Eukiefferiella	Diptera	1		2
Micropsectra	Diptera	2		24
Orthocladiinae	Diptera	2e	2e	2e
Orthocladius	Diptera	5	63	25
Parakiefferiella	Diptera	3		
Parametriocnemus	Diptera	4		
Polypedilum	Diptera	1	2	3
Prosimulium	Diptera		1	
Simulium	Diptera	28		33
Tanytarsini	Diptera			1e
Tanytarsus	Diptera		4	
Thienemanniella	Diptera	2		
Thienemannimyia group	Diptera		3	2
Tvetenia	Diptera	1		1
Baetis	Ephemeroptera	1		22
Naididae	Haplotaxida	19	31	16
Girardia	Tricladida	15	19	
Tubificidae	Tubificida		10	
Pisidium	Veneroida	1		

Table E7. Fish species present at PRFR-206-X

		Year	2016	2017	2019
Taxon	Scientific Name	Family			
American Eel	Anguilla rostrata	Anguillidae	1		
White Sucker	Catostomus commersoni	Catostomidae			3
Redbreast Sunfish	Lepomis auritus	Centrarchidae	14	17	25
Green Sunfish	Lepomis cyanellus	Centrarchidae	18	26	51
Bluegill	Lepomis macrochirus	Centrarchidae	10	8	63
Largemouth Bass	Micropterus salmoides	Centrarchidae	3	8	9
Smallmouth Bass	Micropterus dolomieu	Centrarchidae			1
Rosyside Dace	Clinostomus elongatus	Cyprinidae			1
Central Stoneroller	Campostoma anomalum	Cyprinidae	4	28	54
Common Shiner	Luxilus cornutus	Cyprinidae	22	130	131
Bluehead Chub	Nocomis leptocephalus	Cyprinidae	32	59	35
Silverjaw Minnow	Notropis buccatus	Cyprinidae	1	14	38
Rosyface Shiner	Notropis rubellus	Cyprinidae			1
Bluntnose Minnow	Pimephales notatus	Cyprinidae	13	192	268
Longnose Dace	Rhinichthys cataractae	Cyprinidae	7	15	115
Blacknose Dace	Rhinichthys obtusus	Cyprinidae		2	47
Creek Chub	Semotilus atromaculatus	Cyprinidae	12	21	22
Banded Killifish	Fundulus diaphanus	Fundulidae			14
Yellow Bullhead	Ameiurus natalis	Ictaluridae	36	15	32
Fantail Darter	Etheostoma flabellare	Percidae			8

Table F7. Other taxa present at PRFR-206-X

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius virilis	Northern green frog Northern red salamander	Japanese honeysuckle
2017	Faxonius virilis	Eastern snapping turtle	Japanese honeysuckle Japanese stiltgrass
2019	Faxonius virilis	No herpetofauna observed	Japanese hops Callery/bradford pear Japanese stiltgrass

North Branch Jones Falls (JONE-315-S)

This site, surveyed annually, was sampled on 3/1 and 8/2 in 2016, 3/22 and 8/17 in 2017, and 3/11 and 8/7 in 2019.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The uninterrupted buffer extended more than 50 meters on either bank, and consisted of mature and young deciduous forest and regenerating deciduous trees and shrubs. No channelization was evident. There was moderate erosion on the left bank of the stream and minimal erosion on the right bank recorded in 2016, 2017, and 2019. Moderate bar formation consisting of cobble, gravel, and sand was observed in 2016 and 2017, rising to severe bar formation in 2019.

Table A8. Upstream land use for site JONE-315-S

Urban	Agricultural	Forest	Other	Source
24.54%	15.56%	56.65%	3.25%	NLCD 2011
24.63%	17.17%	57.25%	0.95%	NLCD 2016

Table B8. Physical habitat scores for site JONE-315-S

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	16	17	14	15	38	15	37	2	25	60	16
2017	16	17	15	14	44	16	58	2	30	75	18
2019	18	17	14	17	43	15	34	3	20	55	15

Indices of Biotic Integrity & Species

Benthic macroinvertebrates were collected from 18 riffle and two rootwad and woody debris habitats in 2016, 18 riffle, one rootwad and woody debris habitat, and one leaf pack habitat in 2017, and 20 riffle in 2019. Subsamples in the lab contained 28 taxa, 29 taxa, and 28 taxa, respectively, leading to BIBI scores of 4.00 (Good), 3.67 (Fair), and 3.67 (Fair).

Summer electrofishing detected 8 fish species in 2016, 10 in 2017, and 12 in 2019. The FIBI score was calculated to be 3.67 in 2016, 3.33 in 2017, and 4.00 in 2019, with the difference in scores not considered to be significant.

Table C8. IBI scores for site JONE-315-S

Year	BIBI	FIBI
2016	4.00	3.67
2017	3.67	3.33
2019	3.67	4.00

Table D8. Benthic macroinvertebrates (100-count subsample) detected at JONE-315-S

Taxon	Order	2016	2017	2019
Optioservus	Coleoptera	1	3	
Oulimnius	Coleoptera		5	3
Orconectes	Decapoda	1		
Antocha	Diptera	4	3	6
Cladotanytarsus	Diptera			1
Clinocera	Diptera		2	4
Corynoneura	Diptera	1		
Diamesa	Diptera	3		7
Diamesinae	Diptera			3e
Dicranota	Diptera	1	2	
Eukiefferiella	Diptera		16	2
Micropsectra	Diptera	2		1
Nilotanypus	Diptera			1
Orthocladiinae	Diptera	1		1e
Orthocladius	Diptera	9	3	16
Parametriocnemus	Diptera		3	
Polypedilum	Diptera		4	1
Prosimulium	Diptera	1	3	
Rheotanytarsus	Diptera			4
Simulium	Diptera	1	1	2
Stempellinella	Diptera		1	
Sympotthastia	Diptera	14		5
Tanytarsus	Diptera		3	
Thienemanniella	Diptera		2	
Tipula	Diptera		1	
Tvetenia	Diptera	1	1	2
Acentrella	Ephemeroptera		1	
Ameletus	Ephemeroptera	1		
Baetis	Ephemeroptera	28		13
Ephemerella	Ephemeroptera		5	1
Isonychia	Ephemeroptera	6	8	1
Leucrocuta	Ephemeroptera		1	
Maccaffertium	Ephemeroptera	5	19	3
Naididae	Haplotaxida		2	7
Prostoma	Hoplonemertea		1	
Nigronia	Megaloptera		1	
Gomphidae	Odonata		1	
Leuctridae	Plecoptera			2
Nemouridae	Plecoptera	1		
Cheumatopsyche	Trichoptera	5	11	10
Chimarra	Trichoptera	7	15	3
Diplectrona	Trichoptera	1		
Glossosoma	Trichoptera	1		
Hydropsyche	Trichoptera	12	6	8
Lype	Trichoptera	1		
Neophylax	Trichoptera	5		3
Pycnopsyche	Trichoptera			1
Rhyacophila	Trichoptera	1		
Girardia	Tricladida	1	1	
Tubificidae	Tubificida			1

Table E8. Fish species present at JONE-315-S

Taxon	Scientific Name	Family	2016	2017	2019
American Eel	Anguilla rostrata	Anguillidae			1
White Sucker	Catostomus commersoni	Catostomidae	22	47	50
Green Sunfish	Lepomis cyanellus	Centrarchidae	5	4	33
Pumpkinseed	Lepomis gibbosus	Centrarchidae		1	
Bluegill	Lepomis macrochirus	Centrarchidae		15	4
Largemouth Bass	Micropterus salmoides	Centrarchidae			2
Rosyside Dace	Clinostomus elongatus	Cyprinidae			1
Cutlip Minnow	Exoglossum maxilingua	Cyprinidae	11	23	20
Longnose Dace	Rhinichthys cataractae	Cyprinidae	52	57	36
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	75	67	41
Creek Chub	Semotilus atromaculatus	Cyprinidae	16	59	12
Tessellated Darter	Etheostoma olmstedi	Percidae	20	36	5
Brown Trout	Salmo trutta	Salmonidae	92	55	82

Table F8. Other taxa present at JONE-315-S

	Crayfish	Herpetofauna	Exotic Plants
2016	Faxonius sp. Faxonius virilis	Northern two-lined salamander Pickerel frog Wood frog	Burning bush Garlic mustard Japanese barberry Japanese stiltgrass Mimosa Multiflora rose Privet Vinca vine (common periwinkle) Wineberry
2017	Faxonius virilis	American bullfrog Northern green frog Northern two-lined salamander	Garlic mustard Japanese barberry Japanese honeysuckle Japanese stiltgrass Multiflora rose Privet Wineberry
2019	Faxonius virilis Cambarus bartonii	Northern two-lined salamander Pickerel frog Northern green frog	Japanese barberry Japanese stiltgrass Multiflora rose Wavyleaf basketgrass Wineberry

Fifteen Mile Creek (FIMI-207-S)

This site, surveyed annually, was sampled on 4/5 and 7/13 in 2016, 4/13 and 8/18 in 2017, and 3/20 and 6/19 in 2019.

Upstream

Downstream

Land Use/Land Cover & Physical Habitat

The area surrounding the site was observed to have deciduous and coniferous forest cover. An uninterrupted buffer extended 33 meters on the left bank and at least 50 meters on the right bank, and consisted of young, regenerating, and mature deciduous forest. No channelization was evident. There was severe erosion on the left bank of the stream and moderate erosion on the right bank recorded in 2016, 2017, and 2019. Severe bar formation consisting of cobble, gravel, and sand was observed in 2016, 2017, and 2019.

Table A9. Upstream land use for site FIMI-207-S

Urban	Agricultural	Forest	Other	Source
4.85%	6.44%	87.59%	1.12%	NLCD 2011
5.38%	6.50%	86.32%	1.79%	NLCD 2016

Table B9. Physical habitat scores for site FIMI-207-S

Year	Instream Habitat Score	Epifaunal Substrate Score	Velocity/Depth Diversity Score	Pool/Glide/Eddy Quality Score	Extent of Pool/Glide/Eddy Habitat (m)	Riffle/Run Quality Score	Extent of Riffle/Run Habitat (m)	Bar Formation Severity	Embeddedness (%)	Shading (%)	Aesthetic Score
2016	9	10	8	8	61	8	15	3	0	40	19
2017	10	10	9	9	44	12	37	3	0	65	19
2019	9	8	11	11	60	12	25	3	0	30	19

Indices of Biotic Integrity & Species

Benthic macroinvertebrates were collected from 18 riffle and two rootwad and woody debris habitats in 2016, 15 riffle, four rootwad and woody debris habitat, and one leaf pack habitat in 2017, and 15 riffle, four rootwad and woody debris habitat, and one leaf pack habitat in 2019. There were 19 taxa present in the 2016 subsample, 38 taxa in the 2017 subsample, and 26 taxa in the 2019 subsample. The BIBIs were calculated to be 3.00 in 2016, 4.75 in 2017, and 4.25 in 2019.

Electrofishing turned up 11 fish taxa in 2016, 10 fish taxa in 2017, and seven fish taxa in 2019, which resulted in a FIBI score of 4.33 each year.

Table C9. IBI scores for site FIMI-207-S

Year	BIBI	FIBI
2016	3.00	4.33
2017	4.75	4.33
2019	4.25	4.33

Table D9. Benthic macroinvertebrates (100-count subsample) detected at FIMI-207-S

Taxon	Order	2016	2017	2019
Optioservus	Coleoptera		1	
Psephenus	Coleoptera		3	
Cambarus	Decapoda		1	
Chironomidae	Diptera			2e
Corynoneura	Diptera	1		
Hexatoma	Diptera		1	1
Micropsectra	Diptera	9	5	3
Orthocladius	Diptera	1	3	3
Parametriocnemus	Diptera			6
Polypedilum	Diptera		7	7
Probezzia	Diptera	1	1	
Prosimulium	Diptera	69	3	13
Rheocricotopus	Diptera		1	
Simulium	Diptera		2	
Tanytarsini	Diptera			1e
Tanytarsus	Diptera		2	
Thienemannimyia Group	Diptera	1	2	1
Tvetenia	Diptera	1		2
Acentrella	Ephemeroptera		5	
Acerpenna	Ephemeroptera		3	10
Ameletus	Ephemeroptera	2	1	
Cinygmula	Ephemeroptera	7	5	4
Diphetor	Ephemeroptera		1	4
Drunella	Ephemeroptera	1	1	
Epeorus	Ephemeroptera		14	19
Ephemerella	Ephemeroptera	1	11	10
Heterocloeon	Ephemeroptera		1	
Leptophlebiidae	Ephemeroptera		1	1
Leucrocuta	Ephemeroptera			3
Maccaffertium	Ephemeroptera		1	
Serratella	Ephemeroptera		1	5
Stenonema	Ephemeroptera		1	
Gomphidae	Odonata		2	
Alloperla	Plecoptera			3
Amphinemura	Plecoptera	24	8	
Chloroperlidae	Plecoptera	1		9e
Haploperla	Plecoptera		3	
Isoperla	Plecoptera	6	2	9
Leuctridae	Plecoptera		3	7
Ostrocerca	Plecoptera	1		
Perlodidae	Plecoptera	2		3e
Prostoia	Plecoptera			1
Sweltsa	Plecoptera	1	4	
Cheumatopsyche	Trichoptera		1	1
Chimarra	Trichoptera		3	
Lepidostoma	Trichoptera	1		
Neophylax	Trichoptera	1		
Nyctiophylax	Trichoptera		1	
Polycentropus	Trichoptera		1	
Rhyacophila	Trichoptera		1	1
Wormaldia	Trichoptera		1	

Table E9. Fish species present at FIMI-207-S

Taxon	Scientific Name	Family	2016	2017	2019
White Sucker	Catostomus commersoni	Catostomidae	3	5	
Rock Bass	Amblopites rupestris	Centrarchidae	8	13	
Green Sunfish	Lepomis cyanellus	Centrarchidae	1		
Smallmouth Bass	Micropterus dolomieu	Centrarchidae		3	
Potomac Sculpin	Cottus girardi	Cottidae	65	90	90
Central Stoneroller	Campostoma anomalum	Cyprinidae	8	4	3
Bluntnose Minnow	Pimephales notatus	Cyprinidae	20	104	6
Longnose Dace	Rhinichthys cataractae	Cyprinidae	4		10
Blacknose Dace	Rhinichthys obtusus	Cyprinidae	58	59	68
Creek Chub	Semotilus atromaculatus	Cyprinidae	10	45	11
Greenside Darter	Etheostoma blennioides	Percidae	4	21	
Fantail Darter	Etheostoma flabellare	Percidae	9	13	8

Table F9. Other taxa present at FIMI-207-S

	Crayfish	Herpetofauna	Exotic Plants
2016	Cambarus bartonii Faxonius obscurus	Gray treefrog Northern black racer Northern two-lined salamanders Northern watersnake	Japanese stiltgrass Multiflora rose
2017	Cambarus bartonii Faxonius obscurus	Northern spring salamander Northern two-lined salamander	Japanese stiltgrass Multiflora rose
2019	Cambarus bartonii Faxonius obscurus	Eastern snapping turtle Gray treefrog Northern water snake	Japanese stiltgrass Multiflora rose

<u>Appendix G:</u>
Stormwater Management
Assessment of Controls

NPDES/MS4 Assessment of Controls - Environmental Site Design for Interstate 70

Year 3 Monitoring Report – FY 2020

June 30, 2020

Prepared For:

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1 Executive Summary

The Maryland Department of Transportation State Highway Administration (MDOT SHA) is currently planning the installation of several stormwater infiltration features, or best management practices (BMPs), within the existing SHA right-of-way along I-70. A bioretention facility is planned for the interior of the entrance ramp, and three bioswales/two grass swales are planned for the median of I-70 near the Marriottsville Road Interchange in Ellicott City, Maryland. The bioretention facility will capture runoff from Marriottsville Road and the east bound ramp to I-70 while the bioswales and grass swales will capture runoff from a portion of the I-70 east and west bound lanes. The facilities are expected to attenuate peak discharges, limit geomorphological change, and protect channel stability during runoff events within the receiving waterway, the Little Patuxent River (LPR).

MDOT SHA has developed a monitoring plan to determine the effectiveness of these BMPs and make a conclusion about their utility for stormwater management. The monitoring plan includes continuous flow monitoring, physical monitoring of channel geomorphology, and sediment mobility assessments within the LPR. The continuous flow monitoring involves recording stream stage over time at two locations and recording flow volume and velocity over time in one location. The continuous flow monitoring before and after the installation of the BMPs will enable assessment of their ability to attenuate peak discharges. The physical monitoring includes surveys of two permanently established channel cross sections and a longitudinal profile of the monitoring reach, a portion of the LPR downstream of the outfall from the BMPs. The sediment mobility assessment includes two Wolman Pebble Count surveys at the cross sections within the monitoring reach, which are used to determine boundary and critical shear stresses within the stream. Monitoring channel geomorphology before and after the installation of the proposed BMPs will enable assessment of their ability to promote stability within the receiving channel.

This report presents the results of monitoring from Year 1 through 3, which are all within the pre-construction period. Year 1 began on June 12, 2018 and ended on June 30, 2018 (FY2018). Year 2 began July 1, 2018 and ended on June 30, 2019 (FY2019). Year 3 began July 1, 2019 and ended on June 30, 2020 (FY2020). Continuous flow data were collected at the three flow stations during this period to contribute to the characterization of baseline hydrology of the monitoring reach prior to the installation of upstream BMPs. An analysis of discharge, flow volume, and temperature over the total monitoring period and during peak events revealed that runoff from the target catchment areas, as measured by Flow Station 2 and the additional drainage inputs, has a larger effect on the downstream receiving channel, as measured by Flow Station 3, than previously observed in Year 2. During pre-construction conditions, runoff and low flow from the target catchment areas appear to contribute 8.1% of total flow volume. Continued monitoring of the site throughout the construction of roadway expansions and installation of associated BMPs and post-construction will allow an assessment of how effectively the BMPs offset impacts from the roadway expansions.

Physical monitoring was performed periodically throughout the monitoring period to characterize geomorphology of the monitoring reach after storm events. Six surveys were performed during this period. The Year 1 baseline survey occurred on June 14, 2018. Two surveys were performed on July 26, 2018 and September 11, 2018 after significant rain events with the potential to alter geomorphology. The Year 2 annual survey occurred on June 20, 2019. Two surveys were performed for Year 3 on April 16, 2020 after a significant rain event and May 8, 2020 after a large rain event. Overall, the monitoring reach appears to be degrading over time, becoming further incised.

2 Introduction

2.1 Project Description

The Maryland Department of Transportation State Highway Administration (MDOT SHA) is currently planning, designing, and constructing stormwater best management practices (BMPs) with the intent to improve stormwater quality. The efforts are geared towards implementing the Chesapeake Bay Total Maximum Daily Load (Bay TMDL) and Municipal Separate Storm Sewer System (MS4) impervious restoration requirements. In compliance with the MDOT SHA MS4 Phase I Permit Part IV.F, Assessment of Controls, Section 2, Stormwater Management Assessment, MDOT SHA is required to determine the effectiveness of BMPs for stream channel protection as implemented under the latest stormwater regulations.

Currently, Howard County has proposed the dualization of Marriottsville Road over Interstate 70 (I-70). The primary objective of the Howard County Marriottsville Road project is to alleviate roadway congestion. Currently, both the bridge and approaching roadways have only two lanes. Under proposed conditions, the bridge will be widened to accommodate four traffic lanes and two bike lanes. Both entrance ramps to I-70 will also be expanded to aid in controlling increased traffic. As a result, the Little Patuxent River watershed will experience an overall increase in impervious area that must be treated with stormwater management practices. The Little Patuxent River (LPR) runs parallel to Marriottsville Road and flows under I-70 through a double box culvert. Currently, stormwater runoff from I-70 and Marriottsville Road is directed to the LPR through a number of outfalls. The proposed BMPs should ensure that the LPR is not impacted by the increased impervious surface.

Howard County has proposed two bio-swales along the west side of Marriottsville Road north of the bridge and a micro-bioretention facility in the gore area north of the bridge along the east side of Marriottsville Road. MDOT SHA has proposed two grass swales and three bio-swales along I-70 and a bioretention facility in the gore area southeast of the Marriottsville Road bridge. See Figure 1 below for a map showing the location of the proposed BMPs and their drainage areas.

MDOT SHA's proposed swales along I-70 will capture runoff from I-70 before it drains to the existing inlets in the median which direct stormwater through a thirty-inch reinforced concrete pipe outfall to the LPR just downstream of the I-70 box culvert. The bioretention facility will capture runoff from Marriottsville Road and the east bound ramp of I-70 before it drains into the same outfall.

The purpose and need for the proposed BMPs is primarily reducing impacts to water quality and not necessarily controlling water quantity. The BMPs are not designed for physical rain events above one inch and, therefore, may not reduce peak discharges for storms greater than one inch. Additionally, they may have limited influence on changes in channel stability. Since the size of the watershed draining to the LPR downstream of this site is large (1,249 acres) compared to the areas treated by the proposed BMPs, MDOT SHA does not anticipate significant impacts to the channel itself through implementation of these BMPs.

Nonetheless, MDOT SHA has developed a comprehensive monitoring plan to assess the effectiveness of the BMPs to attenuate peak discharges and preserve channel stability. This report presents the baseline monitoring conditions (Years 1 through 3) from which future, post-construction conditions can be compared.

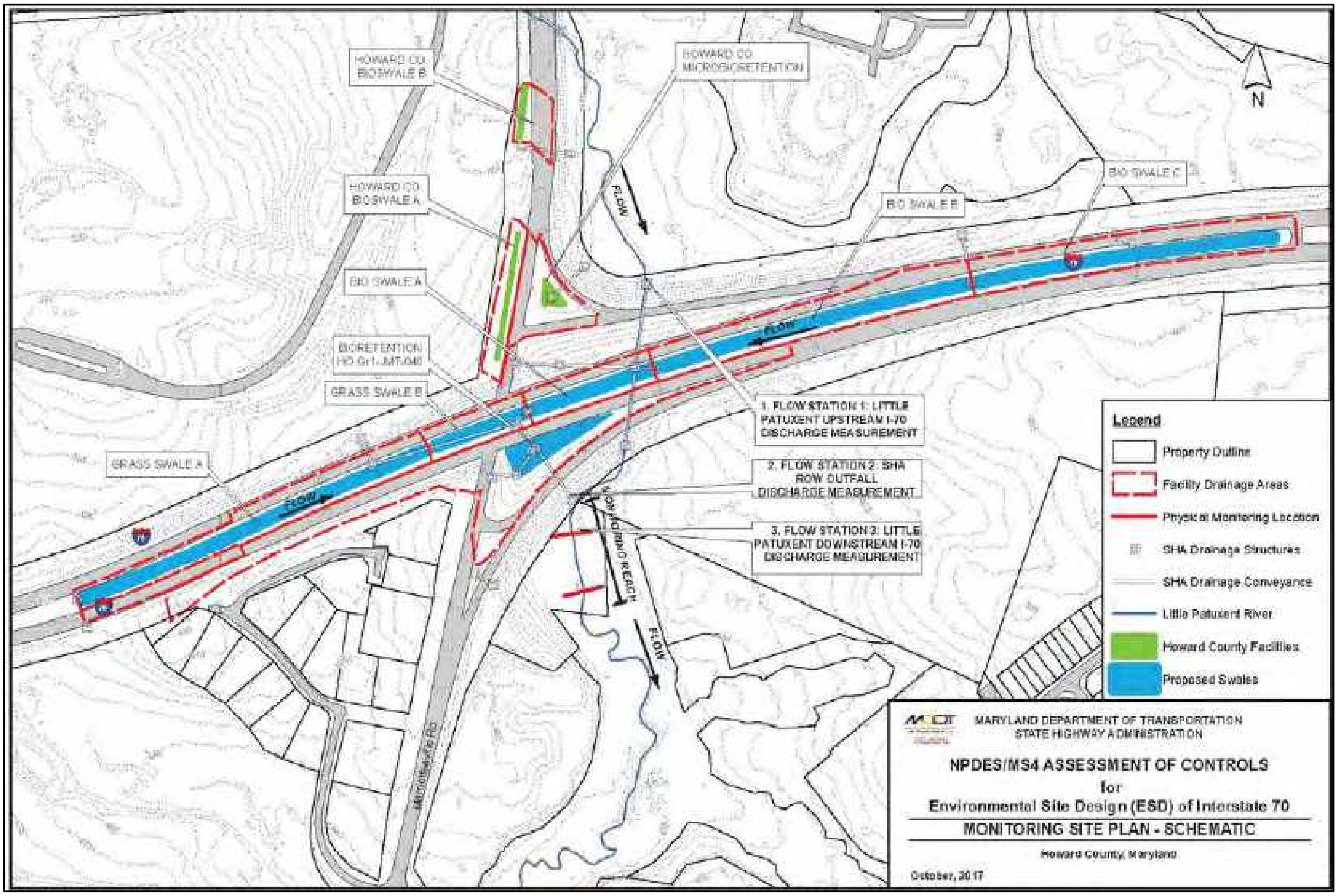

Figure 1. Location of proposed BMPs and project monitoring components (MDOT SHA, October 2017)

The primary goal of this monitoring is to answer several questions pertaining to BMP effectiveness and stream channel response, including:

- Will the peak discharge coming from controlled catchments be reduced once controls have been implemented?
- Will there be a geomorphological response by the Little Patuxent River once controls are in place?
- What are the thresholds for stream stability and do the catchment controls improve stream stability through peak discharge attenuation?
- Can a partnership with Howard County on a larger watershed monitoring plan increase the opportunity to observe a difference in discharge and channel stability?

This report presents the monitoring data collected during Year 1-3 (June 12, 2018 through June 23, 2020) and provides a characterization of baseline conditions. This report also presents a discussion of the baseline conditions and the ability of continued monitoring to effectively answer the proposed questions.

2.2 Site Description

The proposed BMPs and the monitoring project site are within the Little Patuxent River watershed (02131105) and the stream channel being assessed is the Little Patuxent River (LPR) main stem. The LPR is classified as surface-water use designation IV-P, *Recreational Trout Water and Public Water Supply*. Use IV-P waters allow any reasonable and lawful use if surface water is not adversely affected. Table 1 provides a summary of existing conditions for the LPR upstream watershed (MDOT SHA, October 2017). See Appendix A for the LPR watershed mapping, provided by MDOT SHA as a part of the project monitoring plan.

Land use data from 2010 were obtained from the Maryland Department of Planning (MDP) and visually verified in comparison to recent aerial imagery. In conjunction with Soil Survey Geographic Database (SSURGO) hydrologic soil group (HSG) classifications, the MDP land use categories were related to similar land use descriptions from the Natural Resource Conservation Service (NRCS) Technical Release 55 (TR55) to develop Runoff Curve Numbers (RCN) values. Soils data for the HSG were obtained from NRCS's Web Soil Survey, known as the SSURGO soils database.

Table 1. LPR Watershed Parameters

Total Drainage Area	1,248.90 Acres
	1.95 Mi^2
MDOT SHA Impervious Area	20.49 Acres
	1.64%
Total Impervious Area	110.21 Acres
	8.82%
2010 MDP RCN	74
Zoning RCN	77
Forest Cover	325.96 Acres
	26.10%

Physiographic provinces are geographic regions that are subdivided based on characteristic geomorphology. These are then subdivided into a hierarchical organization of the physiographic subdivisions of Province, Section, Region and District. The LPR watershed is entirely within the Piedmont Plateau Province, Piedmont Upland Section and the Harford Plateaus and Gorges Region. The upstream LPR watershed is entirely within the Hampstead Upland District. The geology in this district is characterized as coarse-grained quartz schists (Loch Raven Schist) and fine-to-medium grained mafic schists (Piney Run, Pleasant Grove, and Prettyboy Formations), along with lesser amounts of metagraywacke, boulder gneiss, metaconglomerate, and isolated ultramafic bodies. The Hampstead Upland District is composed of rolling to hilly uplands interrupted by steep-walled gorges. Differential weathering of adjacent, contrasting lithologies produces distinctive ridges, hills, barrens, and valleys. Streams may have short segments of narrow, steep-sided valleys. (MDOT SHA, October 2017)

3 Monitoring

3.1 Overview

Monitoring has been performed as outlined in the project monitoring plan. The objectives of the monitoring are to quantify flow from the target catchments, to quantify overall flow at the receiving downstream channel, and to characterize the geomorphology of the monitoring reach of the LPR. Two categories of monitoring are used to achieve these objectives – continuous flow monitoring and physical monitoring.

3.1.1 Continuous Flow Monitoring

Three flow monitoring stations were installed within the study area for measuring water levels and quantifying discharge (Figure 2). The most upstream station, Flow Station 1, is located upstream of I-70 at a double box culvert that conveys the LPR under I-70. Flow Station 1 was installed to quantify the amount of flow entering the monitoring reach before the addition of flow from the target catchments. Flow Station 2 is located at the outfall of the target catchments and the proposed BMPs. Flow Station 2 was installed to quantify the amount of existing flow from the target catchments and the flow after the roadways have been widened and the BMPs have been installed. Flow Station 3 is located within the monitoring reach downstream of both I-70 and the outfall of the proposed BMPs and is representative of the receiving LPR channel. Flow Station 3 was installed downstream of Flow Station 1 and 2 to verify the estimated upstream discharges and measure the hydrologic response of the LPR to storm events. The data collected from all three stations will be used to determine the magnitude of discharge attenuation provided by the BMPs. MDOT SHA also installed a rain gauge onsite to record local rainfall amounts in order to better understand the nature of the peak discharges at the flow stations.

3.1.2 Physical Monitoring

The physical monitoring of the LPR occurs entirely within the designated monitoring reach. The purpose of this monitoring reach analysis is to estimate the sediment threshold and hydraulic parameters of the stream channel for the LPR to allow for a comparison of the anticipated motion of channel bed material with the capability of channel flows to initiate that motion. This is accomplished through sediment mobility analysis comparing critical shear stress to hydraulic parameters (boundary shear stress).

To obtain the information needed to perform the analysis, two channel cross sections and a longitudinal profile of the existing ground and water surface are periodically surveyed. Annual surveys of the cross sections and profile, along with surveys after significant rain events, will support an analysis of any erosion or aggradation of the LPR within the monitoring reach in response to pre- and post-BMP installation discharges. Wolman pebble counts are also performed during these survey events. Baseline surveys and pebble counts occur annually at the end of each monitoring year (mid-June), to capture pre- and post-BMP installation conditions over the term of the MS4 permit. The annual baseline survey for Year 3, which would have occurred in June of 2020, did not occur due to funding constraints and COVID-19 related issues. Additional surveys and pebble counts were performed after significant storm events and/or abrupt changes to the stream channel, up to two events per monitoring year. Significant storm events are considered to be precipitation totals of greater than or equal to 1.5 inches in a 24-hour period. One significant rain event, occurring on April 13, 2020, was targeted for post-storm monitoring within the Year 3 monitoring cycle. A storm event with precipitation totals of 1.1 inches in less than a 24-hour period, occurring on April 30, 2020, was also targeted for post-storm monitoring. MDOT SHA performed physical monitoring on April 16, 2020 and May 8, 2020, respectively.

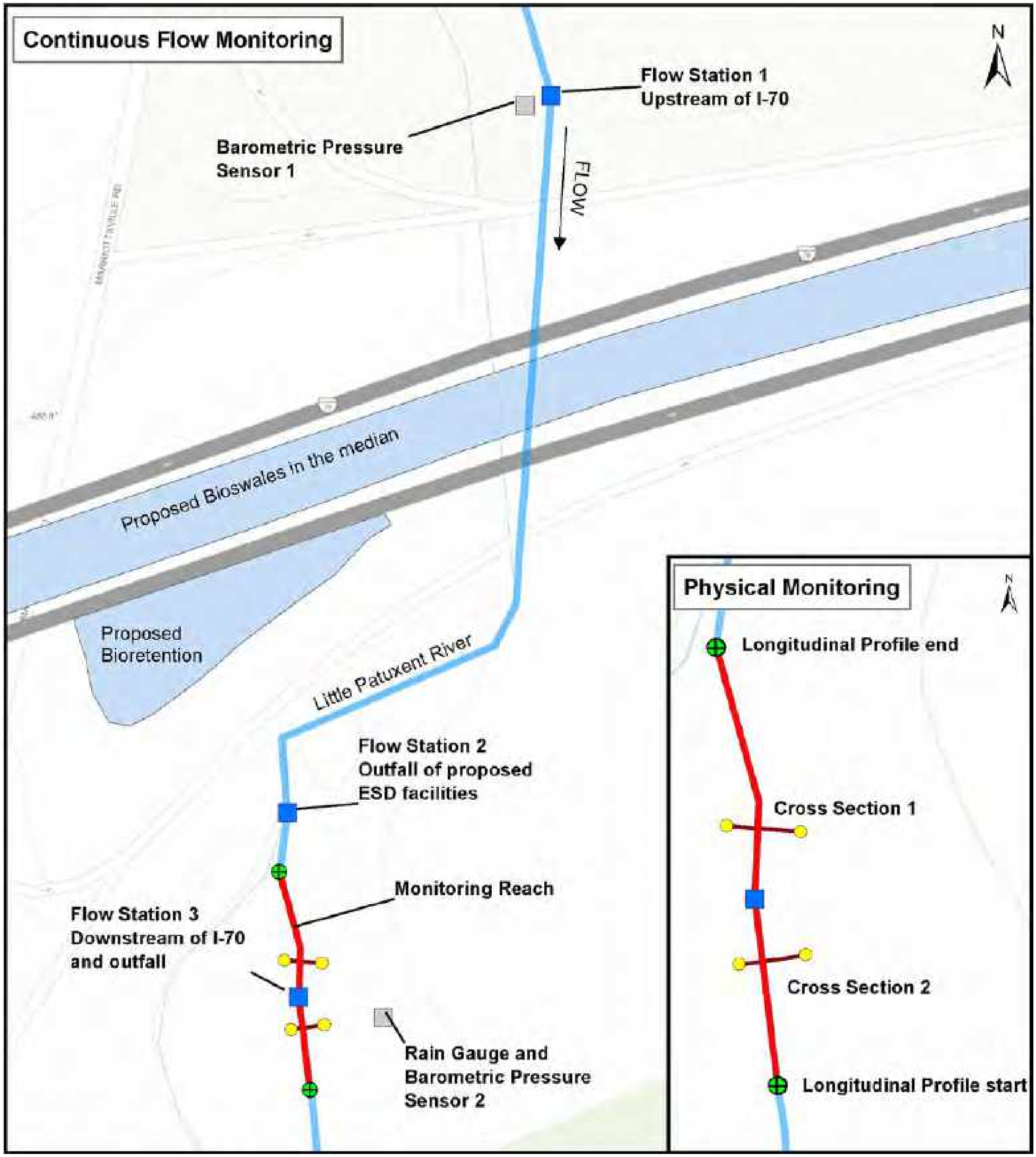

Figure 2. Continuous Flow and Physical Monitoring Locations

3.2 Methods

Detailed descriptions of calibration, quality control and data interpolation methods for the continuous monitoring can be found in Appendix I.

3.2.1 Continuous Flow and Precipitation Monitoring

Flow Stations 1 & 2: Water levels are monitored at Flow Stations 1 and 2 (FS-1 and FS-2) using paired pressure data loggers (Onset HOBO® U20L pressure data loggers). At each station, one logger is installed within the water flow to measure water pressure (water level logger) and one is installed in open air to measure barometric pressure (barometric pressure logger). The water level logger housing is made from perforated PVC, mounted to the bottom of each water conveyance structure (Figure 3). The barometric pressure logger housing is also made from perforated PVC, mounted off the ground in an upland area in the vicinity of the conveyance structures (Figure 4). The loggers were set to record data continuously at 10-minute intervals. During Year 1, water pressure data were compensated with barometric pressure data to determine water level or stage. During Year 2 and Year 3, MDOT SHA used reference water levels from manual measurements in the field instead of barometric pressure to determine stage from the water pressure data. Manual measurements of water level were taken every month.

During Year 1, FS-2 was dry except during rain events. During Year 3, after observing that the outfall at FS-2 contained low flow conditions that is difficult to measure with depth loggers, MDOT SHA installed a weir at the end of the outfall to increase water levels in order to improve the accuracy of FS-2 water depth measurements (Figure 3).

Figure 3. Depth logger mounted at box culvert bottom upstream of I-70 (left; Flow Station 1) and at the outfall of the proposed ESDs with weir (right; Flow Station 2)

Figure 4. Barometric pressure logger set-up

Discharge was calculated at each flow station using the stage data and stage/discharge rating curves developed for the structure at each flow station (Appendix D). For FS-1, discharge was calculated by using Manning's equation to estimate the velocity. The flow area and slope were determined from the as-builts of the box culvert (Appendix E). The roughness value, n, used in the Manning's equation was determined from the sediment mobility assessments presented in Section 4.2.3. FS-1 is located at the upstream interface of the channel and box culvert; therefore, the n value was used as the roughness coefficient instead of the box culvert material to more accurately estimate the flow in the upstream reach, which is primarily open channel with stones and weeds as opposed to the box culvert which is concrete. Stage and discharge rating curves were developed using this information. Since the monitoring equipment is located at the interface of only one of the double box culverts, an assumption was made that the flow conditions are identical for the other box culvert so that a total discharge for the entire channel could be estimated.

For FS-2, discharge was calculated by using Manning's equation to estimate the velocity. The cross-sectional area and slope were determined from the as-builts for the outfall (Appendix E). The roughness value, n, used in the Manning's equation was based on the concrete material of outfall pipe. Stage and discharge rating curves were developed using this information.

In addition to pressure, all data loggers measure temperature. Water temperature and air temperature were measured continuously at 10-minute intervals.

Flow Station 3: Instream discharge is measured at Flow Station 3 (FS-3) using a SonTek-IQ Standard acoustic Doppler area-velocity meter (AVM), which records velocity, area, and depth, and is capable of computing discharge and volume of total flow. The recording interval is 10 minutes. The meter was installed in the LPR receiving channel monitoring reach, secured to a mounting plate. The meter was then staked into position onto the stream bed at the thalweg, which is the lowest elevation within a stream channel cross section (Figure 5). A cross section of the meter location was surveyed prior to installation in order to provide accurate data for the internal flow calculations performed by the unit. During Year 2, MDOT SHA discovered a limitation of the AVM. The AVM underestimated out-of-bank flows due to the limit of the initial survey boundaries. MDOT SHA resurveyed the cross section on December 18, 2019 and extended the survey boundaries to the floodplain extents so that out-of-bank flows would be accurately measured. Barometric pressure compensation is not required for these units because the IQ measures water depth acoustically with a vertical beam. These data are used to perform internal calibrations of the pressure sensor to remove atmospheric pressure, automatically compensating for barometric pressure. Stage is calculated from the measured water depth by adding the distance from the bottom of the device to the depth sensor, which was determined during installation. The AVM also measures water temperature.

Figure 5. Area-velocity meter (AVM) within the monitoring reach, downstream of I-70 (Flow Station 3)

Rain Gauge Station: Precipitation is recorded using an Onset HOBO® RG3 rain gauge and data logging system, which is capable of recording precipitation rates up to 5 inches per hour. The system is comprised of a tipping-bucket rain gauge, where each bucket tip is equal to 0.01 inches of rainfall, coupled with an event data logger that records the date and time of each tip. The rain gauge is mounted on a post in an unobstructed area free from canopy cover (Figure 6).

Figure 6. Rain gauge station

3.2.2 Physical Monitoring

Longitudinal Profile and Water Surface Elevations (WSEL): The monitoring reach is surveyed once annually in June to determine the year-end baseline condition and also after significant rain events to determine the elevations of the existing ground and water surface for the reach profile. The longitudinal profile starts in a pool downstream and ends in a pool upstream of the cross-section locations (Figure 2 and Figure 7). Bed elevations and water-surface elevations are recorded along the thalweg approximately every ten feet and at key feature slope breaks (i.e., riffles, runs, pools and glides). The elevations are measured using a Spectra Precision Laser level and stadia rod. The full profile is surveyed from a single set-up location.

Figure 7. Longitudinal profile

Cross Sections: Two permanently monumented cross sections were established at representative riffles within the monitoring reach (Figure 8). The cross sections are used to track channel dimensions representative of the monitoring reach. Capped rebar monuments were installed for each cross section, and the locations and elevations of each were surveyed (Table 2).

Table 2. Cross Section Monument Benchmark Data

		Latitude (feet, NAD83)	Longitude (feet, NAD83)	Elevation (feet, NAVD88)
Cross Section 1	Left Bank Monument	39.303098	-76.898270	438.30
	Right Bank Monument	39.303107	-76.898389	438.72
Cross Section 2	Left Bank Monument	39.302945	-76.898261	437.76
	Right Bank Monument	39.302933	-76.898366	437.82

The cross sections are surveyed with a Spectra Precision Laser level and stadia rod. The laser level has an accuracy of ± 1/16-inch per 100 ft. Survey pins are used to secure the survey measuring tape across the cross section. Both the monumented benchmarks and the pins are surveyed during the physical monitoring. Key features surveyed within the cross section include top of bank, edge of water, major slope breaks, and the thalweg.

Figure 8. Cross-section survey layout

Wolman Pebble Counts: Wolman Pebble Count surveys are performed to collect data for a sediment mobility assessment (described below). The surveys are performed at the two permanent cross section locations. The Wolman Pebble Count procedure (Wolman, 1954) requires the observer to measure random pebbles of all sizes along a cross section. Pebbles are chosen at random by using a step-toe procedure. The observer takes one step into the water perpendicular to flow and, while averting one's eyes, picks up the first pebble touching one's index finger next to one's big toe. The observer then measures the intermediate axis of the pebble. The observer takes another step across the stream, picks up and measures another pebble. This is repeated until he reaches the opposite side. In general, 100 measurements are needed in order to accurately quantify pebble distributions. Given the narrowness of the monitoring reach, this means crossing back and forth over the stream in a zig-zag pattern moving downstream from the first transect.

<u>Sediment Mobility Assessment:</u> The MDOT SHA monitoring plan provides the sediment mobility assessment approach and procedure for determining the stable channel threshold (MDOT SHA, October 2017), which is described in detail in the excerpt below.

> *The stable channel threshold, as defined in the project monitoring plan, is when boundary shear stress is twenty percent higher than the critical shear stress as determined from the project site's bed material. The methods used for determining boundary and critical shear stress are described below.*
>
> *A major premise of the sediment mobility analysis is that threshold conditions defined by any critical shear stress method represent a condition of very low transport rate* (Wilcock, 1988)*. The second assumption is that statically armored riffles satisfy the conditions of near-equal mobility; that is, the largest sediments in a sediment mixture require slightly higher shear stresses than do smaller sizes. Very large particles from colluvial material or large fragments of bedrock plucked from the streambed or bank during infrequent high flows may not be mobile, although they can effectively hide or shelter other smaller particles. The largest particles (D_i) on the bars or in the sub-surface represent the maximum size present in the bedload. Methods considered in the project monitoring plan for the computation of the critical dimensionless shear stress condition for marginal transport of a specific size fraction in mixed-grain sediments* (Andrews, 1995) *have the form:*
>
> $$\tau^*_{ci} = a\,(D_1/D_2)^b$$
>
> *where τ^*_{ci} is the critical dimensionless shear stress for a very low transport rate for the specific size fraction in the matrix armor layer. This equation is used to estimate the conditions under which marginal transport will exist in the channel. An assumption is made that the minimum shear stress under bankfull conditions in the assessment riffle should be that which mobilizes the largest particles in the bedload. The variables D_1 and D_2 are representative sizes of the sediment samples. Using Andrews' 1995 equation, D_1 is equal to D_i identified below, and D_2 is the mean diameter particle size of the riffle surface using the Wolman pebble count method. Coefficient 'a' and exponent 'b' are 0.0376 and -0.994, respectively, for the equation.*
>
> *The critical shear stress for marginal transport rate of the largest size fraction in the bedload corresponding to τ^*_{ci}, which relates shear stress to bedload material, is given as:*
>
> $$\tau_{ci} = \tau^*_{ci}\,(s-1)\,\gamma\,D_i$$
>
> *where τ_{ci} is the critical shear stress required to mobilize D_i, which represents the largest size fraction that is considered to be mobile, s is the specific gravity of the sediment (typically 2.65) and γ is the specific weight of water (62.4 psf). The average boundary shear stress produced by the threshold discharge over each assessment reach riffle was computed as described above.*

The use of critical shear stress (τ_{ci}) and boundary shear stress (τ_b) methodologies provides a sound approach for estimating the threshold at the riffles studied. Our analysis for this monitoring plan aims to compare sediment mobility and threshold/ bankfull parameters on LPR. The methodology used for this analysis was derived by Andrews from specific bed-load data sets for streams located in the western United States and therefore may not be directly applicable to LPR. However, it provides an estimate of the expected shear stress required for mobility of coarse, mixed-grain sediments.

The energy slope (friction slope), Sf, for LPR was estimated for bankfull flow conditions based on field survey measurements. The slope is a critical parameter in determining threshold conditions. The range of slope over an assessment riffle is bound by 1) the water surface slope over just the riffle feature itself (maximum threshold slope) and 2) the water surface slope from the head of the study riffle to the head of the next riffle downstream (minimum threshold slope). Threshold conditions will typically occur somewhere between the minimum threshold slope and the maximum threshold slope. The sediment mobility analysis is used to determine the specific slope at which threshold conditions are met.

Channel roughness is caused primarily by the roughness of the channel bed. Estimates of Manning roughness coefficient, n, are based on the Limerinos relation given here as:

$$n = {R_h}^{1/6} * \frac{0.0926}{1.16 + 2LOG\frac{R_h}{D_{84}}}$$

where R_h is the hydraulic radius (feet) and D_{84} (feet) is the particle size for which 84 percent of the particles are smaller based on the pebble count of the riffle surface (Limerinos, 1970). *As indicated by this relationship, the n value changes with flow conditions. A Wolman pebble-counting method was used to describe the surface particle size distribution over the active channel portion of the riffle surface. Particle sizes necessary for roughness estimates ($D_{84\ riffle}$) and for evaluation of the bed surface mobility ($D_{50\ riffle}$) were measured through the pebble count analysis.*

The average boundary shear stress produced by the bankfull discharge over each riffle was computed as:

$$\tau_b = \gamma R_h Sf$$

where τ_b is the cross section average boundary shear stress (in psf) over the riffle, R_h is the hydraulic radius, and Sf is the bankfull energy slope. Because the channel width-to-depth ratio was much less than 10 (bank resistance considered major at bankfull conditions) and backwater effects on the steep riffles were minor, the average boundary stress is a good approximation for the average stress on the active channel bed.

4 Years 1-3 Monitoring Results

This section of the report summarizes data collected during Years 1 through 3 (June 12, 2018 to June 23, 2020). Continuous flow data were collected at the three flow stations during this period to contribute to the characterization of baseline hydrology of the monitoring reach prior to the installation of upstream BMPs.

Physical monitoring was performed periodically throughout the monitoring period to contribute to the characterization of baseline geomorphology of the monitoring reach. Two surveys were performed during Year 3 on April 16, 2020 and May 8, 2020 after rain events with the potential to alter geomorphology.

4.1 Continuous Flow Monitoring Results

4.1.1 Total Flow Volume

Total flow volume during Year 1 through Year 3 was analyzed and the results are presented in Table 3 below. In theory, the total volume recorded at FS-3 should exceed the combined total volume recorded at FS-1 and FS-2 because of the additional drainage inputs positioned between FS-1 and FS-3 that are not included in the continuous monitoring, as seen in Figure 1 and Appendix E.

The total volume recorded at FS-3 was 103.67% of the combined volume at FS-1 and FS-2. The 12,079,434 ft^3 exceedance is assumed to have been contributed by the additional drainage inputs. The runoff from the target catchments (FS-2) contributed 8.1%, of the total flow volume received by the downstream receiving channel (FS-3) during Years 1 through 3. In total, drainage inputs to the monitoring reach contributed 11.6% of the total volume in the downstream receiving channel (i.e., the monitoring reach).

Table 3. Total Flow Volume for Years 1 through 3 at all flow stations

	Total Volume* (ft^3)	**Percent of volume contributed to receiving channel (%)**
FS-1 LPR upstream	301,262,633	88.4 %
FS-2 Flow from target catchments	27,694,085	8.1 %
Additional inputs** Flow from unmonitored drainage inputs	12,079,434	3.5 %
FS-3 LPR downstream receiving channel	341,036,152	N/A

*Total flow volume was calculated for the period of July 14, 2018 through June 23, 2020.
**This volume was not measured by a data logger, but rather the calculated discrepancy between the total volume measured at FS-3 and the combined total volume measured at FS-1 and FS-2.

4.1.2 Peak Flow Events

Year 3 peak flow events are presented in this section. See the reports for Year 1 and Year 2 for the analyses of peak flows from those years. The data collected during one significant and one large rain event were analyzed and are presented below. Significant storm events are considered to be precipitation totals of more than or equal to 1.5 inches within a 24-hour period, according to the project monitoring plan. The large rain event totaled 1.11 inches in a 10-hour period. Although a total of 5 significant rain events occurred during

Year 3, the significant and large rain events that were followed by physical monitoring were chosen for analysis. These rain events occurred on April 13, 2020 (Storm 1) and April 30, 2020 (Storm 2). Storm 1 was also the largest discharge event for all flow stations.

4.1.2.1 Storm 1

Storm 1 occurred on April 13, 2020. The cumulative rainfall for Storm 1 was 3.04 inches in 13.44 hours. This storm event is considered to have greater than a 2-year return interval based on its intensity and greater than a 1-year return interval based on precipitation depth. The storm had an average storm intensity of 0.22 in/hr with a maximum intensity of 5.0 in/hr.

Peak stage and discharge occurred at different times and varied in magnitude across the flow stations. Due to storm debris and turbulent flow, the entire hydrograph was not captured for FS-2 and FS-3 for Storm 1. FS-1 and FS-3 measured the entire peak while FS-2 measured the rising peak of the hydrograph. Table 4 provides a comparison of the results across flow stations during the storm event while data was collected. Figure 9 through Figure 11 show peak discharge at each flow station.

Table 4. Response to Storm 1 at all flow stations

	Time of Peak	Peak Stage (ft)	Peak Discharge (ft^3/s)	Total Flow Volume ** (ft^3)	Percent of volume contributed to receiving channel (%)
FS-1 LPR upstream	14:40	1.74	301.46	4,970,704	-
FS-2*** Flow from target catchments	7:10	0.90	18.93	241,609	-
Additional inputs* Flow from unmonitored drainage inputs	-	-	-	2,216	-
FS-3 LPR downstream receiving channel	14:33	3.84	440.89	5,214,529	-

*This volume was not measured by a data logger, but rather the calculated discrepancy between the total volume measured at FS-3 and the combined total volume measured at FS-1 and FS-2.

** Volume computed from time range where data was valid for comparison purposes. Last data points were: FS-1 - 4/13/20 at 15:40, FS-2 – 4/13/20 at 12:10, FS-3 – 4/13/20 at 15:53

***The data for FS-2 represents an early peak during the storm, but the later peak was not captured because the data logger was ejected from the culvert before that time

The total flow volume for Storm 1 could not be accurately estimated since the entire hydrographs for FS-2 and FS-3 were not captured. Peak discharge occurred slightly earlier at FS-3 than FS-1. Based on FS-1's time of peak and the falling limb of FS-3's hydrograph, FS-3's peak appears to be completely captured. This is likely due to stormwater runoff traveling faster across the impervious surfaces of the highway and the concrete outfalls that contribute to FS-3's drainage area.

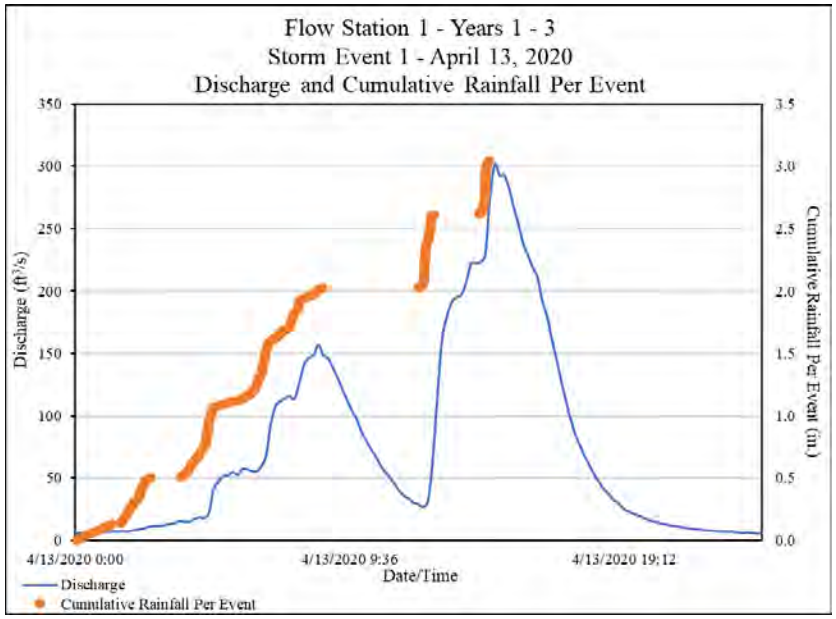

Figure 9. Discharge at FS-1 and rainfall during storm event 1 (April 13, 2020)

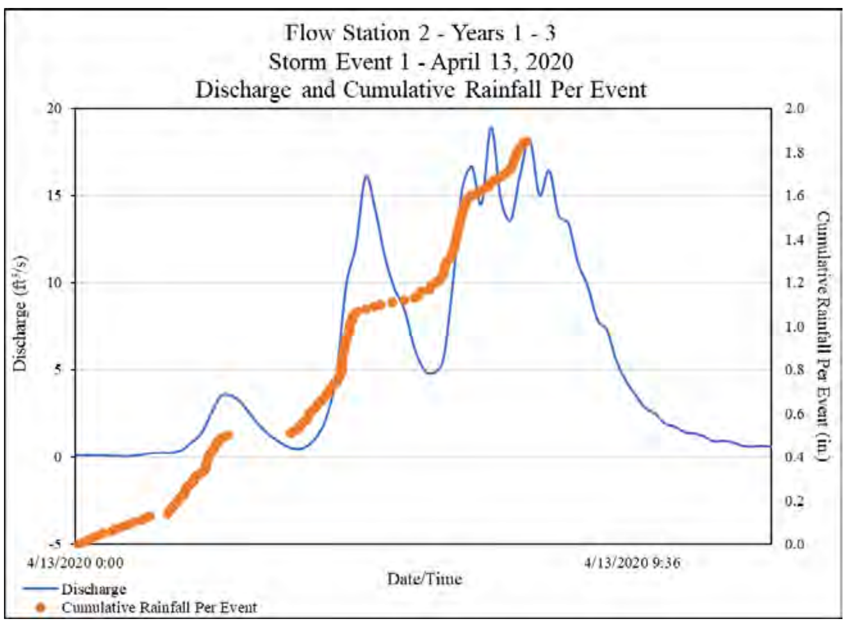

Figure 10. Discharge at FS-2 and rainfall during storm event 1 (April 13, 2020); no valid stage data is available after 12:10 to calculate discharge because the data logger was ejected from behind the weir during the storm

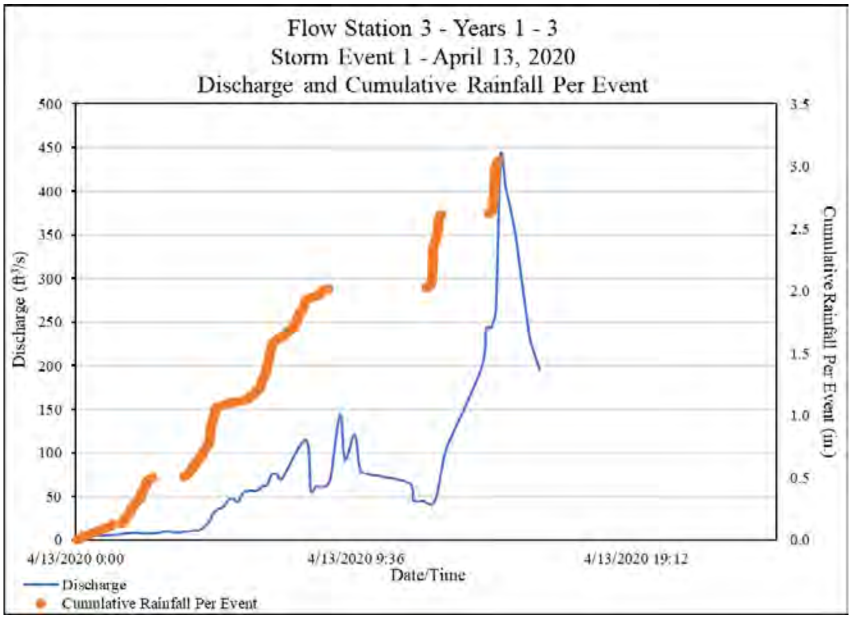

Figure 11. Discharge at FS-3 and rainfall during storm event 1 (April 13, 2020); no valid stage data is available after 15:53 to calculate discharge because storm debris interfering with equipment

4.1.2.2 Storm 2

Storm 2 occurred on April 30, 2020. The cumulative rainfall for Storm 2 was 1.12 inches over 10.2 hours. The storm had an average storm intensity of 0.11 in/hr with a maximum intensity of 5.0 in/hr.

Peak stage and discharge occurred at different times and varied in magnitude across the flow stations. Table 5 provides a comparison of the results across flow stations during the storm event. Figure 12 through Figure 14 demonstrate peak discharge at each flow station.

Table 5. Response to Storm 2 at all flow stations

	Time of Peak	Peak Stage (ft)	Peak Discharge (ft^3/s)	Total Flow Volume (ft^3)	Percent of volume contributed to receiving channel (%)
FS-1 LPR upstream	18:10	.47	25.63	1,037,614	60.96%
FS-2 Flow from target catchments	16:40	.51	6.49	114,262	6.71%
Additional inputs* Flow from unmonitored drainage inputs	-	-	-	550,325	32.33%
FS-3 LPR downstream receiving channel	17:57	1.88	39.26	1,702,201	-

*This volume was not measured by a data logger, but rather the calculated discrepancy between the total volume measured at FS-3 and the combined total volume measured at FS-1 and FS-2.

The runoff from the target catchments (FS-2) contributed 6.71% of the total flow volume received by the downstream receiving channel (FS-3) during Storm 1. Peak discharge occurred slightly earlier at FS-2 and FS-3. This may be because stormwater runoff travels quickly across the impervious surface within the catchment area and also travels quickly through the concrete outfalls that contribute to FS-3 total drainage area. The additional drainage inputs contributed an estimated 32.33% of the total volume during Storm 2, which is a significantly higher percentage than the 3.5% estimated contribution to total flow volume from Year 1 to Year 3 monitoring (see Table 3 above).

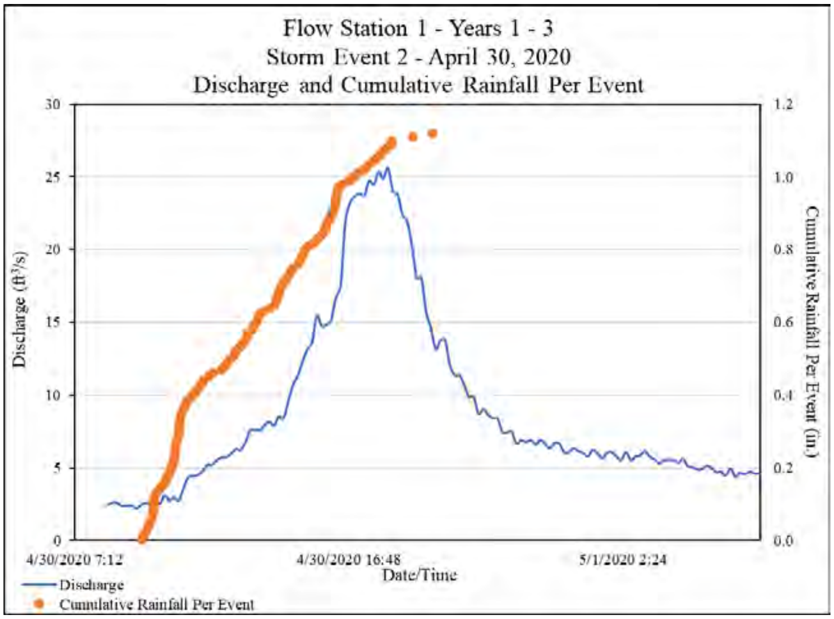

Figure 12. Discharge at FS-1 and rainfall during storm event 2 (April 30, 2020)

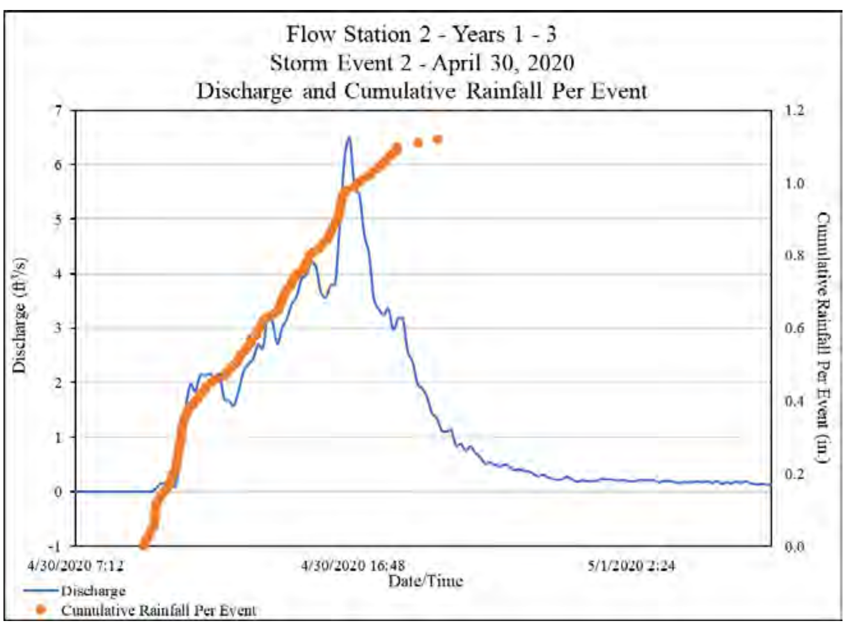

Figure 13. Discharge at FS-2 and rainfall during storm event 2 (April 30, 2020)

Figure 14. Discharge at FS-3 and rainfall during storm event 2 (April 30, 2020)

4.1.3 Mean Discharge

The annual mean discharge for Years 1 through 3 was estimated to be 4.71 ft^3/sec at FS-1, 0.06 ft^3/sec at FS-2, and 4.63 ft^3/sec at FS-3. Daily mean discharge at all flow stations for Years 1 through 3 is displayed in Appendix G. Minimum, maximum and average stage and discharge values per flow station are presented in Table 6 through Table 8 below.

Table 6. Flow Station 1 Summary Statistics

	Stage (ft)	Discharge (ft^3/s)
Minimum	0.002	0.003
Maximum	2.78	406.43
Average	0.15	4.71

Table 7. Flow Station 2 Summary Statistics

	Stage (ft)	Discharge (ft^3/s)*
Minimum	0.00	0.00
Maximum	0.91	18.93
Average	0.043	0.12

*Suspect or unverifiable data not represented. See Appendix I

Table 8. Flow Station 3 Summary Statistics

	Stage (ft)	Discharge (ft^3/s)
Minimum	0.37	0.02
Maximum	3.95	440.89
Average	1.04	4.63

4.1.4 Water Temperature

The maximum daily temperatures were analyzed for Years 1 through 3 and are presented in Table 9. Since Flow Station 2 does not always have continuous flow, temperatures were only used when there was water flowing through the outfall (i.e. the stage was above 0.00 feet). This ensures that measurements of ambient air temperatures were excluded.

High water temperature can negatively impact instream habitat. Of particular concern is habitat for adult trout. The LPR is designated as a Use IV-P stream, which means it is a Recreational Trout Water capable of holding or supporting adult trout for put-and-take fishing. The mortality temperature by brown and rainbow trout is 80 and 77 degrees Fahrenheit, respectively (Adams & et al, Rainbow trout (Oncorhynchus mykiss) Species and Conservation Assessment, 2008a) (Adams & et al, Brown Trout (Salmo trutta) Species and Conservation Assessment, 2008b). The data were analyzed to determine how often water temperatures exceeded 75 degrees, which was chosen so that temperatures approaching the mortality temperature were included in analysis. This threshold was exceeded on 67 days at FS-1, 15 days at FS-2 and 58 days at FS-3 during Years 1 through 3 of the monitoring period. The maximum temperature tolerated by macroinvertebrates is reported to be 86° F (Thorp, 2009), which was never observed at any flow station.

Table 9. Water Temperature Summary Statistics for Years 1 through 3

	Maximum Water Temperature (°F)	**Number of days water temperature exceeded 75°F**
FS-1 LPR upstream	80.2	67
FS-2 Flow from target catchments	80.4	15
FS-3 LPR downstream receiving channel	80.2	58

4.1.5 Precipitation

This section provides the results of the precipitation data collected from the on-site rain gauge. The figure in Appendix J shows the cumulative rainfall totals for Year 1 through 3. Table 10 provides a summary of the significant or qualifying rain events that occurred throughout the monitoring period. A significant rain event was determined to be rainfall totaling more than 1.5-inches in 24-hours, based on guidance from the monitoring plan.

The precipitation data were also analyzed to determine the return interval, based on the cumulative results of the storm. The intensity and precipitation depth during the storm were also analyzed to determine if a return interval occurred at some point during the rain event. The return interval depth and intensity frequencies were determined from the NOAA Atlas 14 Point Precipitation frequency data server (Hydrometeorological Design Studies Center, 2018). A non-qualifying event means it did not meet the criteria determined for the return interval analysis.

Table 10. Cumulative Rainfall Totals for Years 1 and 2

Rain Event Start Date	Cumulative Rainfall (in)	Total Duration (hr)	Average Storm Intensity (in/hr)	Precipitation Frequency (intensity)	Precipitation Frequency (depth)
7/5/2018	1.02	2.42	0.42	Not a Qualifying Rain Event	≥ 1 Year Storm NOAA 14 requirement occurred during storm
7/21/2018	3.8	13.83	0.27	≥ 2 Year Storm NOAA 14 requirement	≥ 2 Year Storm NOAA 14 requirement
9/9/2018	2.1	18.30	0.11	Not a Qualifying Rain Event	Significant Event with ≥ 1.5" of rainfall
9/27/2018	1.71	14.28	0.12	Not a Qualifying Rain Event	Significant Event with ≥ 1.5" of rainfall
11/15/2018	1.54	10.48	0.15	Not a Qualifying Rain Event	Significant Event with ≥ 1.5" of rainfall
11/24/2018	1.94	6.88	0.28	Not a Qualifying Rain Event	≥ 1 Year Storm NOAA 14 requirement occurred during storm
12/15/2018	2.87	26.70	0.11	≥ 1 Year Storm NOAA 14 requirement	≥ 1 Year Storm NOAA 14 requirement
3/21/2019	2.86	23.85	0.12	≥ 1 Year Storm NOAA 14 requirement	≥ 1 Year Storm NOAA 14 requirement
5/10/2019	1.29	1.47	0.88	≥ 1 Year Storm NOAA 14 requirement occurred during storm	≥ 2 Year Storm NOAA 14 requirement occurred during storm
5/30/2019	0.67	0.87	0.77	Not a Qualifying Rain Event	≥ 1 Year Storm NOAA 14 requirement occurred during storm
10/16/2019	4.76	0.36	1.70	≥ 1 Year Storm NOAA 14 requirement	Significant Event with ≥ 1.5" of rainfall
10/27/2019	9.00	0.17	1.57	Not a Qualifying Rain Event	Significant Event with ≥ 1.5" of rainfall

Rain Event Start Date	Cumulative Rainfall (in)	Total Duration (hr)	Average Storm Intensity (in/hr)	Precipitation Frequency (intensity)	Precipitation Frequency (depth)
10/31/2019	1.68	0.90	1.51	≥ 2 Year Storm NOAA 14 requirement	≥ 1 Year Storm NOAA 14 requirement
1/25/2020	7.34	0.22	1.60	≥ 1 Year Storm NOAA 14 requirement	Significant Event with ≥ 1.5" of rainfall
4/13/2020	13.44	0.23	3.04	≥ 2 Year Storm NOAA 14 requirement	≥ 1 Year Storm NOAA 14 requirement
4/30/2020	10.16	0.11	1.12	Not a Qualifying Rain Event	Not a Qualifying Rain Event

4.2 Physical Monitoring Results

4.2.1 Cross Sections

Cross section surveys were performed at each cross section during each of the six physical monitoring events to detect change over time. See Figure 15 and Figure 16 below for a comparison of all six cross section surveys. Left bank for the cross sections is located on the left side of the figures and vice versa for the right bank. See Appendix C for the raw data and Appendix H for full-size versions of Figure 15 and Figure 16.

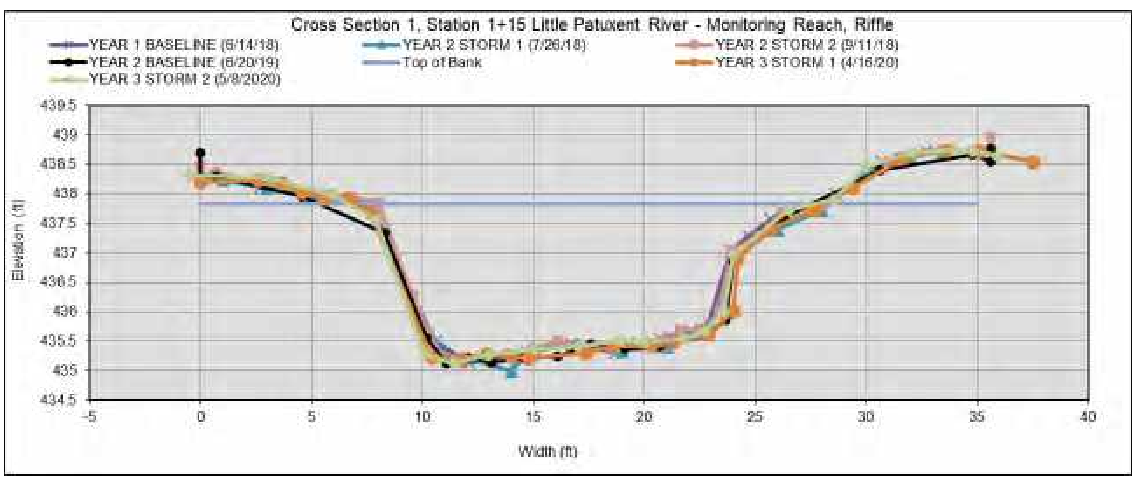

Figure 15. Cross Section 1 Survey Comparison

At Cross Section 1, the left bank has eroded vertically by about 6 inches while the right bank has eroded laterally approximately 6 inches between the Year 1 baseline (06/14/18) and Year 3 Storm 2 (05/08/20). Minor erosion of the riverbed can also be observed between Stations 10 and 23.

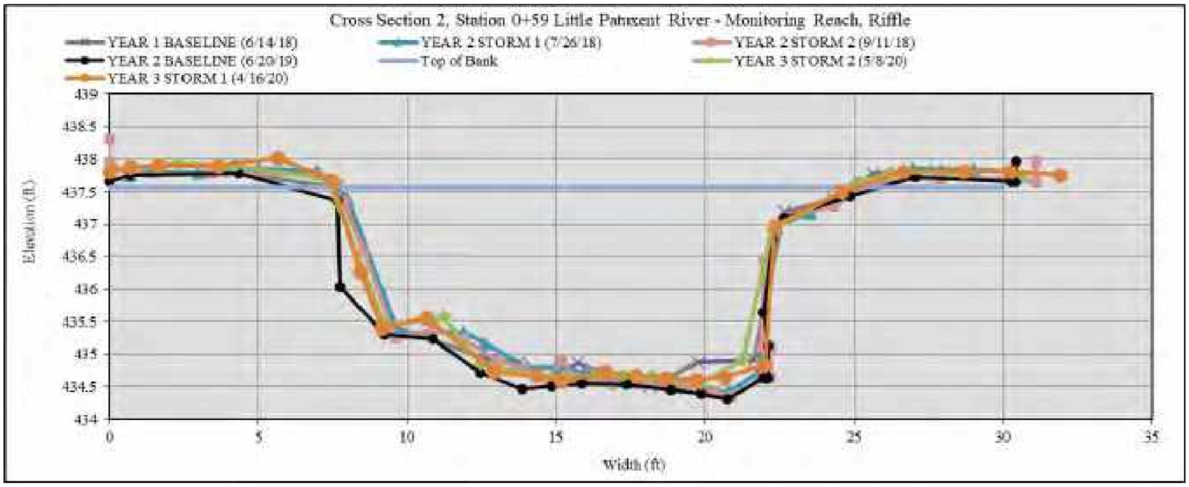

Figure 16. Cross Section 2 Survey Comparison

At Cross Section 2, the left bank eroded laterally approximately 2 feet during Year 2. During Year 3, the material accumulated on the gravel bar at the base of the left bank, which stabilized the left bank preventing further erosion. The toe of the right bank started to develop a 6-inch undercut during Year 2 and this bank stabilized to a vertical bank during Year 3. Erosion of the riverbed for Cross Section 2 can be seen from Station 11 to 22 during Year 2, where the elevation decreased approximately 6-inches. The thalweg for Cross Section 2 has also migrated laterally from Station 18.75 to 20.75 during Year 2. Year 3 observed an increase in riverbed elevation, but the thalweg remained on the right side of the channel.

Due to actively eroding banks and poor visual indicators, it was not possible to accurately identify the bankfull elevation in the field. Instead, regression equations that estimated the bankfull cross sectional area as a function of the upstream drainage area were used (Maryland Hydrology Panel, 2010). That area was then applied to the surveyed cross sections. Drainage area and the hydro-physiographic region were used to derive the bankfull cross sectional area. The delineated drainage area was provided in the monitoring plan, and the hydro-physiographic region was determined to be the Piedmont providence in Maryland. Next, appropriate regression equations were taken from the *Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region* (USFWS, 2002). The following equation was used to estimate the bankfull cross sectional area:

$$Cross\ Sectional\ Area = 17.42 * DA^{0.73}$$

Using this equation, the bankfull cross sectional area was estimated to be 28.36 ft^2. Using this, the surveyed cross-sectional bankfull width and mean depth were then estimated at each cross section.

An average bankfull width and depth for the reach was used to determine the bankfull elevation. Based on the results from the regression equations for bankfull width and depth, an average value of 15.65 feet for width and 1.82 feet for mean bankfull depth were used so that the computed bankfull characteristics were comparable between cross sections. The Year 1 baseline top of bank elevation for each cross section was selected as the baseline to use for comparing survey results so that geomorphic change over time can be observed. Top of bank elevations are more stable and repeatable; therefore, those elevations were used for comparisons over time. See Table 11 for a summary of the Year 1 baseline elevations.

Table 11. Bankfull and Top of Bank Elevations

Reach	Bankfull Elevation (ft)	Top of Bank Elevation (ft)
CS-1	437.00	437.83
CS-2	436.30	437.57

4.2.2 Longitudinal Profile Survey

Longitudinal profile surveys of the LPR bed and water surface were performed during each of the six physical monitoring events to detect change over time. See Figure 17 below for a comparison of all six surveys. See Appendix C for the raw data and Appendix H for a full-size version of Figure 17. The starting stations for Year 2 and Year 3 profiles were adjusted so that the Cross Section 2 locations are aligned for all profiles to allow for comparison between surveys. Water surface slopes between CS-1 and CS-2, both riffle features, are shown below with the elevations exaggerated for plotting purposes.

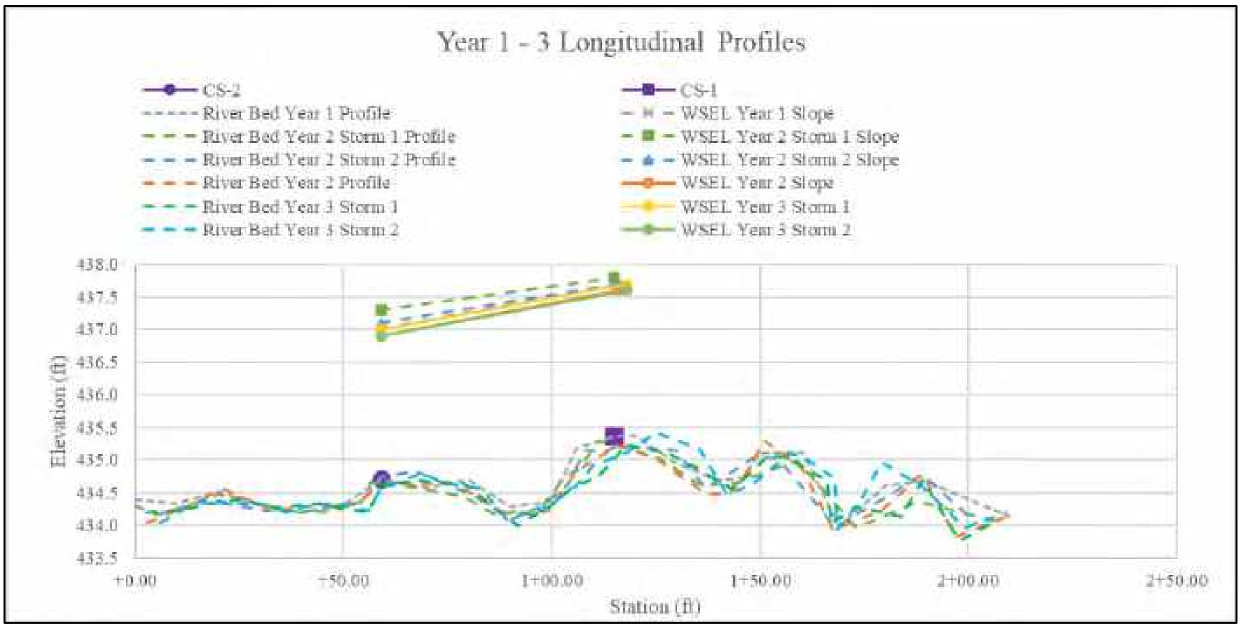

Figure 17. Year 1 & 2 Riverbed and Water Surface Elevation Profiles

Minor changes along the longitudinal profile between Year 1 baseline (06/14/18) and Year 3 Storm 2 (05/08/20) surveys have been observed. The initial downstream pool of the profile is deeper but the riverbed between the pool and 3.5 feet downstream of Cross Section 2 has remained stable. Erosion is occurring 3 feet downstream of Cross Section 2 at Station 0+53. From Cross Section 2 to 15 feet upstream of Cross Section 1, Station 0+59 to Station 1+30, the riverbed has degraded by approximately 4 inches. The top of riffle at Cross Section 1 has migrated upstream approximately 7 feet. The riffle at Station 1+50 and pool at Station 1+67 have overall remained stable, though some degradation and aggradation occurred between the annual surveys. The riverbed near Station 2+05 has also degraded by approximately 9.5-inches, forming a pool.

4.2.3 Sediment Mobility Assessment

Wolman pebble counts were performed at each cross section during each of the six physical monitoring events to detect change over time. See Figure 18 and Figure 19 below for a comparison of the results of all six surveys at each cross section. See Appendix C for the pebble count raw data and Appendix F for the complete results.

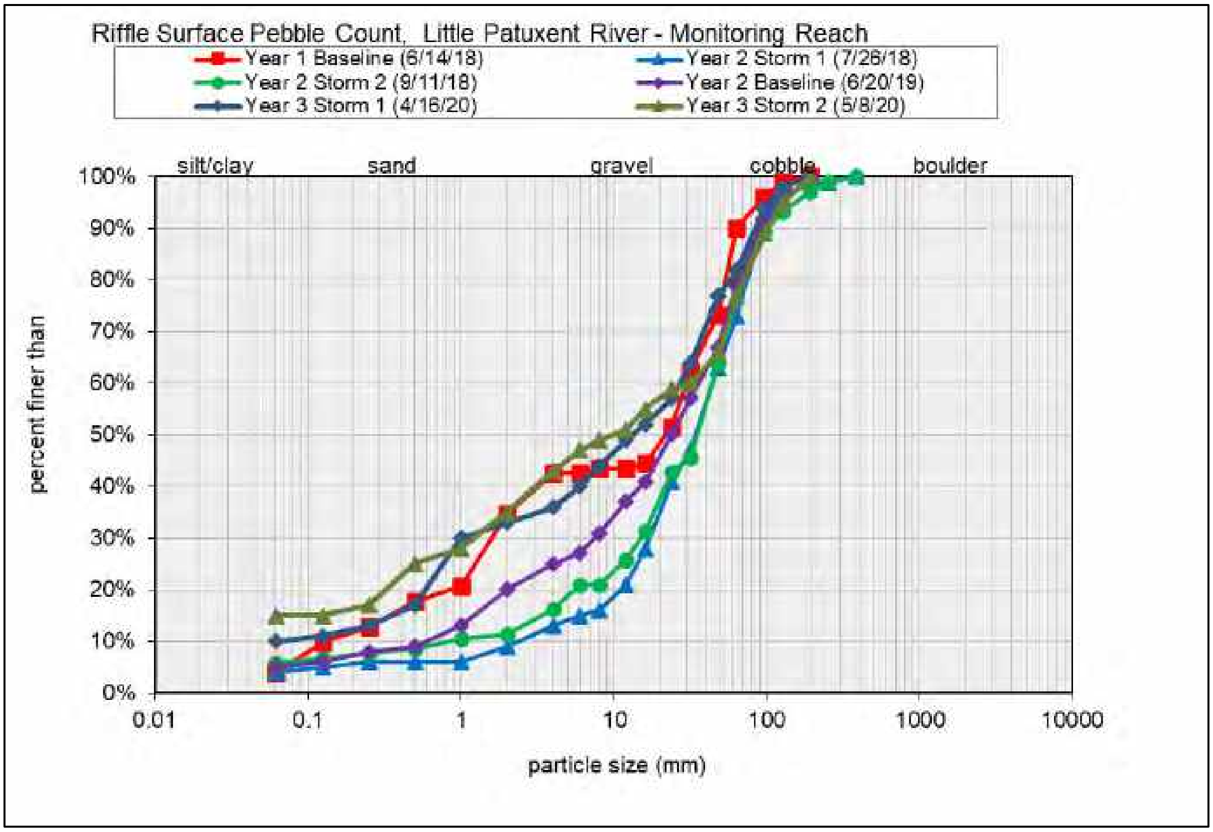

Figure 18. Cross Section 1 Bed Material Comparison

The material for Cross Section 1 coarsened between the Year 1 and Year 2 annual surveys but has trended to finer material during Year 3, with D50 decreasing from 22 to 9.8mm but with D84 increasing from 58 mm to 81 mm.

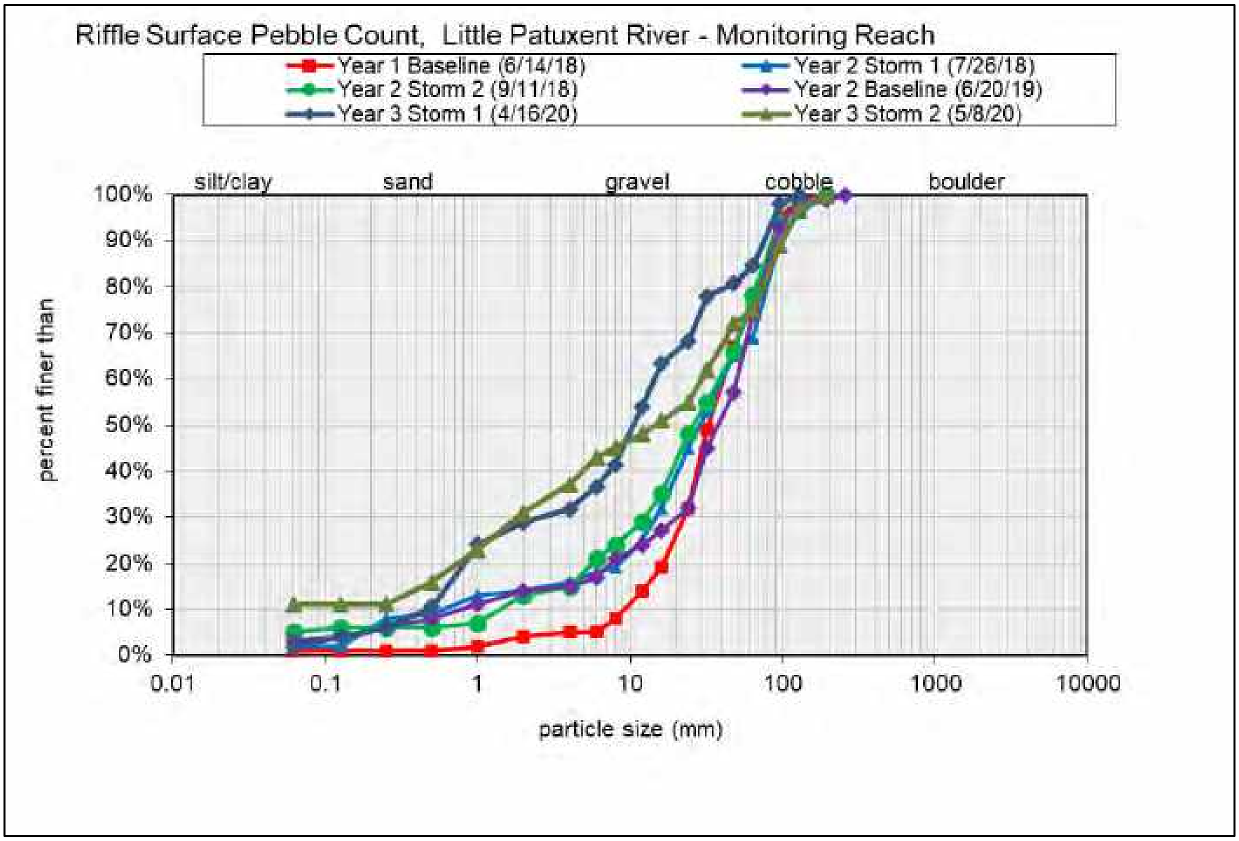

Figure 19. Cross Section 2 Bed Material Comparison

The material for Cross Section 2 has also trended to finer material Year 2 and Year 3 surveys, with D50 decreasing from 33 to 15mm but with D84 increasing from 76 mm to 83mm. However, 50% of the material for this riffle section appears to be trending towards finer substrate. This can be seen by an increase in the skewness from Year 1 baseline survey to Year 2. An increase in skewness indicates an excess in finer bed materials.

5 Discussion

5.1 Continuous Flow Monitoring

The monitoring reach of the LPR receives water from the LPR upstream via a box culvert that directs the LPR underneath I-70 and from roadway stormwater runoff that is conveyed through a local outfall pipe. Roadway stormwater runoff and low flow baseflow, as measured by Flow Station 2, contributed 8.1% of the total volume measured at the monitoring reach over the course of Years 1 through 3. More notably, runoff contributed from FS-2, which was previously believed to be negligible, increased during Year 3 to 6.7% of peak volumes within the monitoring reach based on the Year 3 Storm 2 data. The improved accuracy of depth measurements at FS-2 shows that the roadway runoff contributes more discharge during rain events than previously believed. The low flow conditions at FS-2, observed in Year 2 and 3 and likely from an increase in the local groundwater table as discussed in Year 2 report, also contributes more to the receiving reach than what was previously observed.

The percent of total runoff volume from additional drainage inputs during Year 3 Storm 2 is larger than what was determined for Year 1 through Year 3 percent of total flow volume from additional drainage inputs. This is likely due to the shorter duration of total flow volume for the peak storm analysis since the average flow for FS-1 and FS-3 are comparable. Therefore, the additional drainage inputs contribute more additional runoff mainly during storm events, and is negligible during normal baseflow conditions.

5.2 Physical Monitoring

Top of bank cross-sectional area and bankfull dimensions were calculated for CS-1 and CS-2. See Table 12 for a summary of the results. CS-1 saw an overall increase in bankfull and top of bank cross sectional area, 4.70% and 4.03% respectively. After Year 3 Storm 1, which had a 2-year return interval, CS-1 saw an increase in cross-sectional area. The riverbed slope and D50 decreased, as seen in the longitudinal profile summary (Table 13) and the bed material particle comparison (Table 14). The riverbed elevation at CS-2 remained relatively stable; however, most of the surveyed reach had a much lower bed elevation when compared to the Year 1 profile.

For Year 3 Storm 2, which had less than a 1-year return interval, CS-1 saw an increase in cross-sectional area. The riverbed slope also decreased, but the D50 remained stable. This storm was less than significant, and did not have the same magnitude as Storm 1 and appears to have had no overall erosional effect on the reach, which instead seems to have aggregated and stabilized since the Year 3 Storm 1 event. Deposition of material can be seen throughout the reach when comparing the Year 3 Storm 1 and Storm 2 profiles. The D50 for CS-2 was slightly increased.

The monitoring plan states that the channel is considered stable if the boundary shear stress is 20% more than the critical shear stress. Table 15 below summarizes this information. The boundary shear stress calculated using the methods discussed in Section 3.2.2 is at least 35% greater than the critical shear stress (monitoring plan states it should be at 20%, not 20% or more), indicating channel instability and that particles become mobile more frequently. These results, combined with the stream geomorphology results, suggest that monitoring reach will continue to degrade.

Table 12. Cross Section comparison

		Bankfull					Top of Bank Area (ft^2)*
		Cross Sectional Area (ft^2)	**Width (ft)**	**Mean Depth (ft)**	**Max Depth (ft)**	**Width/Depth Ratio**	
CS-1	Baseline (6/14/18)	21.98	15.27	1.44	1.86	10.61	36.22
	Year 2 Storm 1 (7/26/18)	22.66	15.67	1.45	2.00	10.84	37.68
	% Change from Baseline	3.09%	2.63%	0.45%	7.36%	2.17%	4.01%
	Year 2 Storm 2 (9/11/18)	21.74	15.09	1.44	1.77	10.47	35.94
	% Change from Baseline	-1.07%	-1.20%	0.13%	-4.98%	-1.32%	-0.78%
	Year 2 Annual (6/20/19)	23.58	15.81	1.49	1.87	10.60	38.80
	% Change from Baseline	7.29%	3.52%	3.64%	0.38%	-0.12%	7.11%
	Year 3 Storm 1 (4/13/20)	23.98	16.02	1.50	1.81	10.71	38.99
	% Change from Baseline	9.09%	4.91%	3.98%	-2.84%	0.90%	7.64%
	Year 3 Storm 2 (4/30/20)	23.01	15.69	1.47	1.88	10.70	37.68
	% Change from Baseline	4.70%	2.75%	1.90%	0.92%	0.83%	4.03%
CS-2	Baseline (6/14/18)	18.06	13.43	1.34	1.80	9.99	36.73
	Year 2 Storm 1 (7/26/18)	18.53	13.32	1.39	1.88	9.57	37.09

		Bankfull					Top of Bank Area (ft^2)*
		Cross Sectional Area (ft^2)	**Width (ft)**	**Mean Depth (ft)**	**Max Depth (ft)**	**Width/Depth Ratio**	
	% Change from Baseline	2.56%	-0.85%	3.44%	4.36%	-4.15%	0.99%
	Year 2 Storm 2 (9/11/18)	19.43	13.21	1.47	1.94	8.98	38.22
	% Change from Baseline	7.57%	-1.65%	9.37%	8.15%	-10.08%	4.06%
	Year 2 Annual (6/20/19)	22.00	14.39	1.53	1.99	9.42	41.63
	% Change from Baseline	21.78%	7.16%	13.64%	10.65%	-5.70%	13.34%
	Year 3 Storm 1 (4/13/20)	19.11	13.83	1.38	1.71	10.00	38.05
	% Change from Baseline	5.78%	2.92%	2.77%	-4.92%	0.14%	3.60%
	Year 3 Storm 2 (4/30/20)	17.88	13.42	1.33	1.75	10.07	36.76
	% Change from Baseline	-1.01%	-0.09%	-0.93%	-2.70%	0.85%	0.09%

*Top of bank area calculated from an established fixed elevation unrelated to bankfull

Table 13. Baseline Riverbed and Water Surface Elevation Slopes for the Monitoring Reach

	Riverbed Slope	Water Surface Slope
Year 1 Baseline	1.18%	1.20%
Year 2 Storm 1	1.27%	0.93%
Year 2 Storm 2	0.84%	1.05%
Year 2 Annual	1.06%	1.23%
Year 3 Storm 1	1.01%	1.17%
Year 3 Storm 2	0.85%	1.18%

Table 14. Bed Material Particle Size Comparison (mm)

Site		D50	Size Class	D84	Size Class
CS-1	Baseline (6/14/18)	22	Coarse gravel	58	Very coarse gravel
	Year 2 Storm 1 (7/26/18)	35	Very coarse gravel	82	Small cobble
	Year 2 Storm 2 (9/11/18)	35	Very coarse gravel	78	Small cobble
	Year 2 Annual (6/20/19)	24	Coarse gravel	75	Small cobble
	Year 3 Storm 1 (7/26/18)	13	Medium gravel	69	Small cobble
	Year 3 Storm 2 (9/11/18)	9.8	Medium gravel	81	Small cobble
CS-2	Baseline (6/14/18)	33	Very coarse gravel	76	Small cobble
	Year 2 Storm 1 (7/26/18)	29	Coarse gravel	85	Small cobble
	Storm 2 (9/11/18)	26	Coarse gravel	75	Small cobble
	Year 2 Annual (6/20/19)	38	Very coarse gravel	79	Small cobble
	Year 3 Storm 1 (7/26/18)	11	Medium gravel	61	Very coarse gravel
	Year 3 Storm 2 (9/11/18)	15	Medium gravel	83	Small cobble

Table 15. Percent Boundary Shear Stress Greater Than Critical Shear Stress

	Cross Section 1	Cross Section 2	Overall Monitoring Reach
Year 1 Baseline	71%	53%	62%
Year 2 Storm 1	58%	62%	60%
Year 2 Storm 2	35%	47%	38%
Year 2 Annual	66%	44%	55%
Year 3 Storm 1	84%	85%	85%
Year 3 Storm 2	87%	78%	82%

In addition to shear stress calculation, the Wolman pebble-count results were used to determine the channel roughness factor. As mentioned in the FS-1 results section, the roughness factor *n* is used to convey characteristics about the wetted portion (bottom and sides) of the channel. See Table 16 for the results of this calculation for Cross Section 1, Cross Section 2, and the overall monitoring reach. Ultimately, the average of the overall reach results (0.037) was used for Flow Station 1 roughness coefficient because this is assumed to represent the typical conditions of the LPR. See Appendix F for the calculations of channel roughness.

Table 16. Channel roughness (n) results

	Cross Section 1	Cross Section 2	Overall Monitoring Reach
Year 1 Baseline	0.034	0.038	0.036
Year 2 Storm 1	0.038	0.039	0.039
Year 2 Storm 2	0.038	0.038	0.037
Year 2 Annual	0.037	0.038	0.037
Year 3 Storm 1	0.036	0.035	0.035
Year 3 Storm 2	0.038	0.039	0.038

5.3 Riparian Observations

Since the riparian zone is affected by channel conditions, it is important to observe changes in the riparian zone over time. The riparian zone is forested with dense ground cover by herbaceous plants. Despite being densely vegetated, the riverbanks are eroding from the high energy within the stream channel. This is demonstrated by the exposed roots along the channel banks (Figure 20 through Figure 24).

Figure 20. Vegetated top of banks with exposed roots along monitoring reach on July 26, 2018

Figure 21. Exposed roots on left bank at Cross Section 1 on December 5, 2018

Figure 22. Exposed roots on left bank at Cross Section 1 on June 20, 2019

Figure 23. Vegetated top of banks with exposed roots along Cross Section 2 reach on June 20, 2019

Figure 24. Vegetated top of banks with exposed roots along Cross Section 1 reach on May 8, 2020

Figure 24. Vegetated top of banks with exposed roots along Cross Section 1 reach on May 8, 2020

5.4 Key Project Questions

The primary goal of the monitoring study is to answer several questions pertaining to ESD controls and stream channel response. The questions are as follows:

1. Will the peak discharge coming from controlled catchments be reduced once controls have been implemented?
2. Will there be geomorphological response to the LPR once controls are in place?
3. What are the thresholds for stream stability, and do the catchment controls improve stream stability through peak discharge attenuation?
4. Can a partnership with Howard County on a larger watershed monitoring plan increase the opportunity to observe a difference in discharge and channel stability?

The project is currently in its third year of monitoring, and the data collected has been used to establish a baseline for the LPR stream characteristics. Since the proposed ESD controls have not been installed, these questions cannot currently be answered or analyzed but will be addressed in furture monitoring reports.

6 Conclusion

Years 1 through 3 of pre-construction monitoring included data collected from June 12, 2018 to June 23, 2020. This report is prepared to support MDOT SHA MS4 compliance needs. The data were analyzed to characterize baseline conditions of the project site and to form a basis upon which to answer the questions from the monitoring plan and to provide insight into the effectiveness of stormwater management practices for stream channel protection.

Continuous flow data were collected at the three flow stations during this period to characterize baseline hydrology of the monitoring reach prior to the installation of upstream BMPs. An analysis of discharge, flow volume, and temperature over the total monitoring period and during peak events revealed that runoff from the target catchment areas, as measured by Flow Station 2 and the additional drainage inputs, has a larger effect on the downstream receiving channel, as measured by Flow Station 3, than previously observed in Year 2. During pre-construction conditions, runoff and low flow from the target catchment areas appear to contribute 8.1% of total flow volume. Continued monitoring of the site through post-construction of roadway expansions and installation of associated BMPs will allow an assessment of how effectively the BMPs offset impacts from the roadway expansions.

Physical monitoring was performed periodically throughout the monitoring period to characterize geomorphology of the monitoring reach after storm events. Six surveys were performed during this period. The Year 1 baseline survey occurred on June 14, 2018. Two surveys were performed on July 26, 2018 and September 11, 2018 after significant rain events with the potential to alter geomorphology. The Year 2 annual survey occurred on June 20, 2019. Two surveys were performed for Year 3 on April 16, 2020 after a significant rain event and May 8, 2020 after a large rain event. Overall, the monitoring reach appears to be degrading over time, becoming further incised.

7 References

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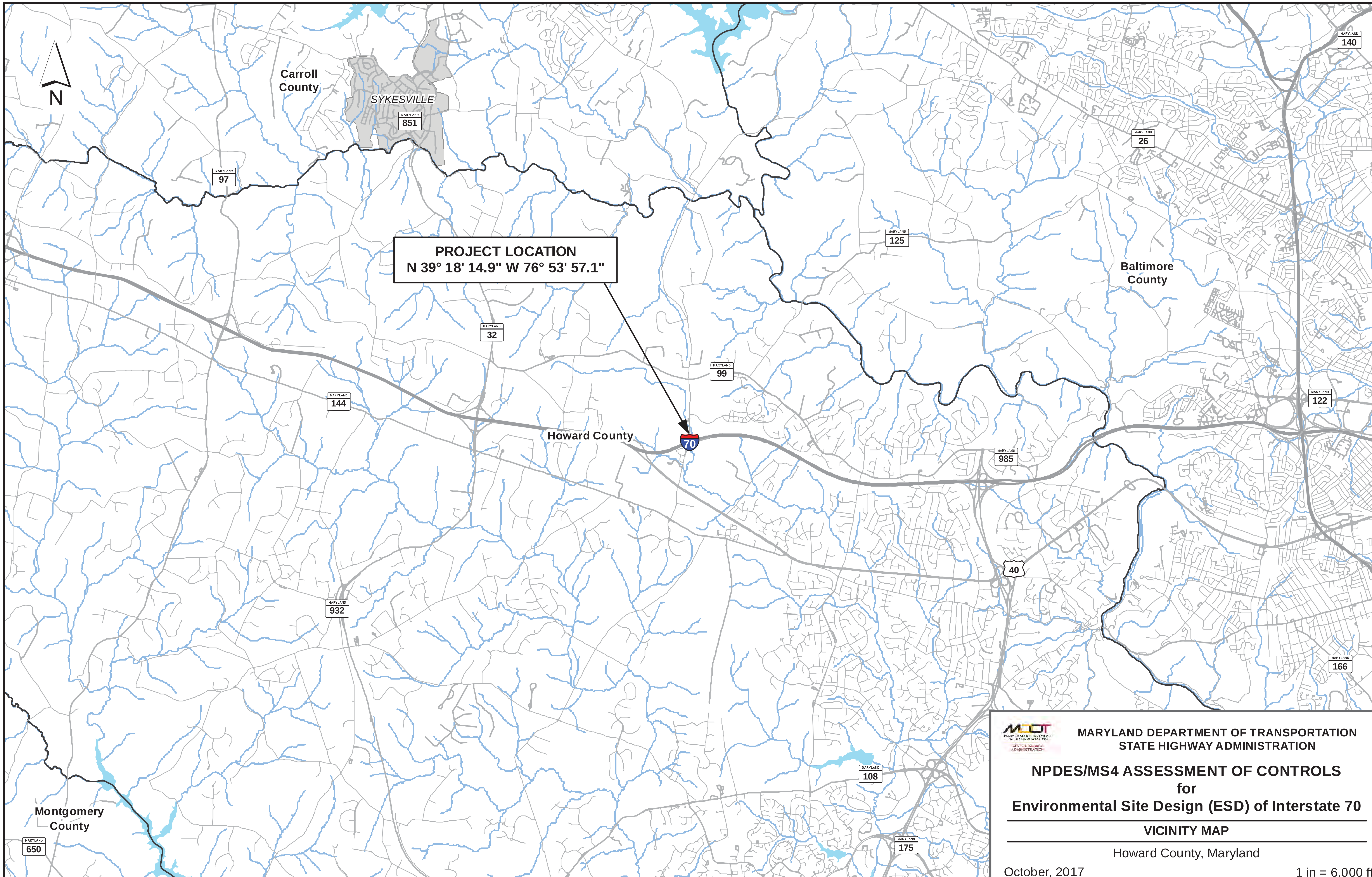
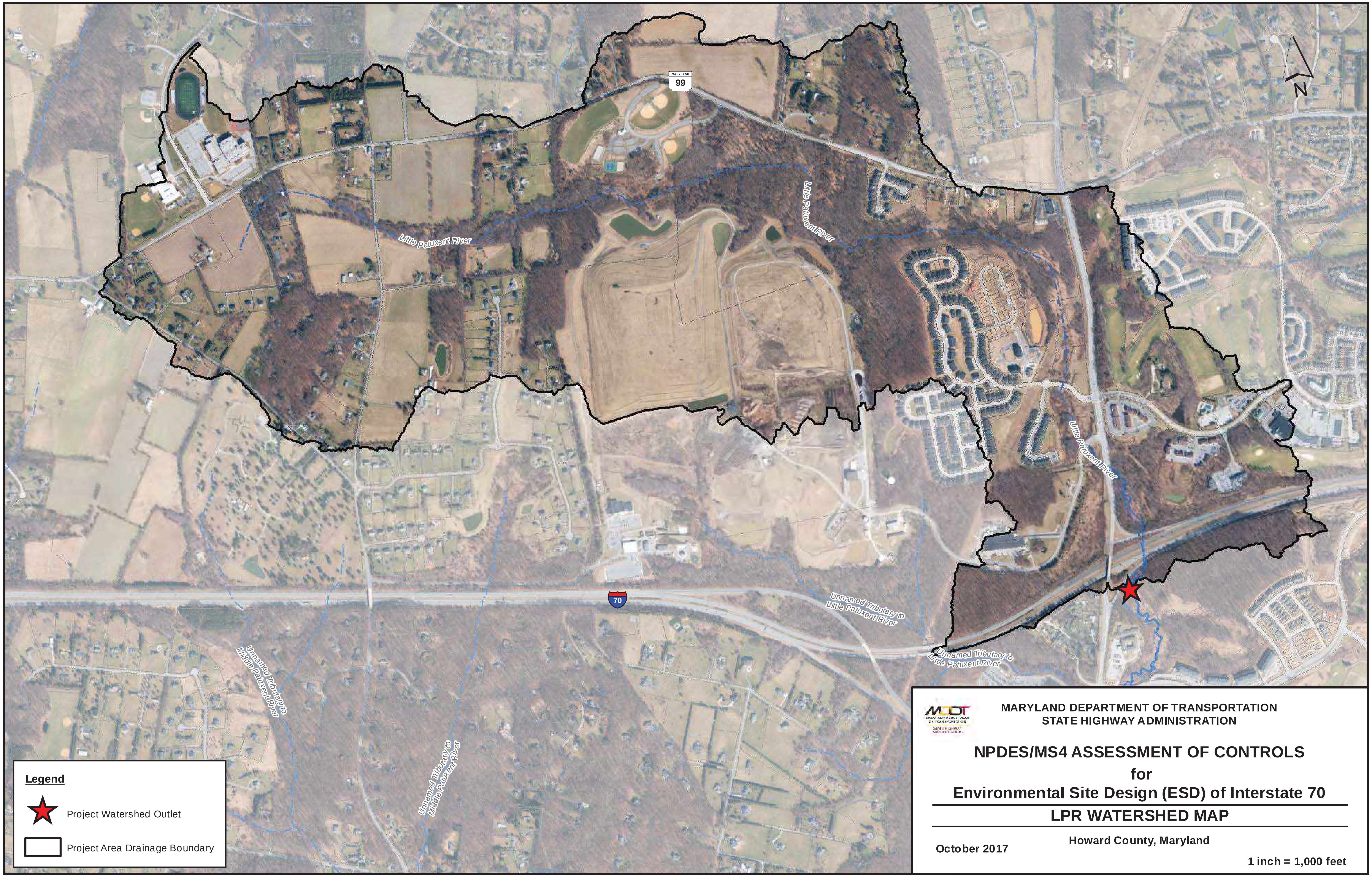
Appendix A

Little Patuxent River Project Mapping


N
Carroll County
SYKESVILLE
851
97
140
26
125
Baltimore County
PROJECT LOCATION
N 39° 18' 14.9" W 76° 53' 57.1"
32
99
144
Howard County
70
122
985
40
932
166
108
175
Montgomery County
650
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION
NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70
VICINITY MAP
Howard County, Maryland
October, 2017
1 in = 6,000 ft



Legend

Project Watershed Outlet

Project Area Drainage Boundary

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

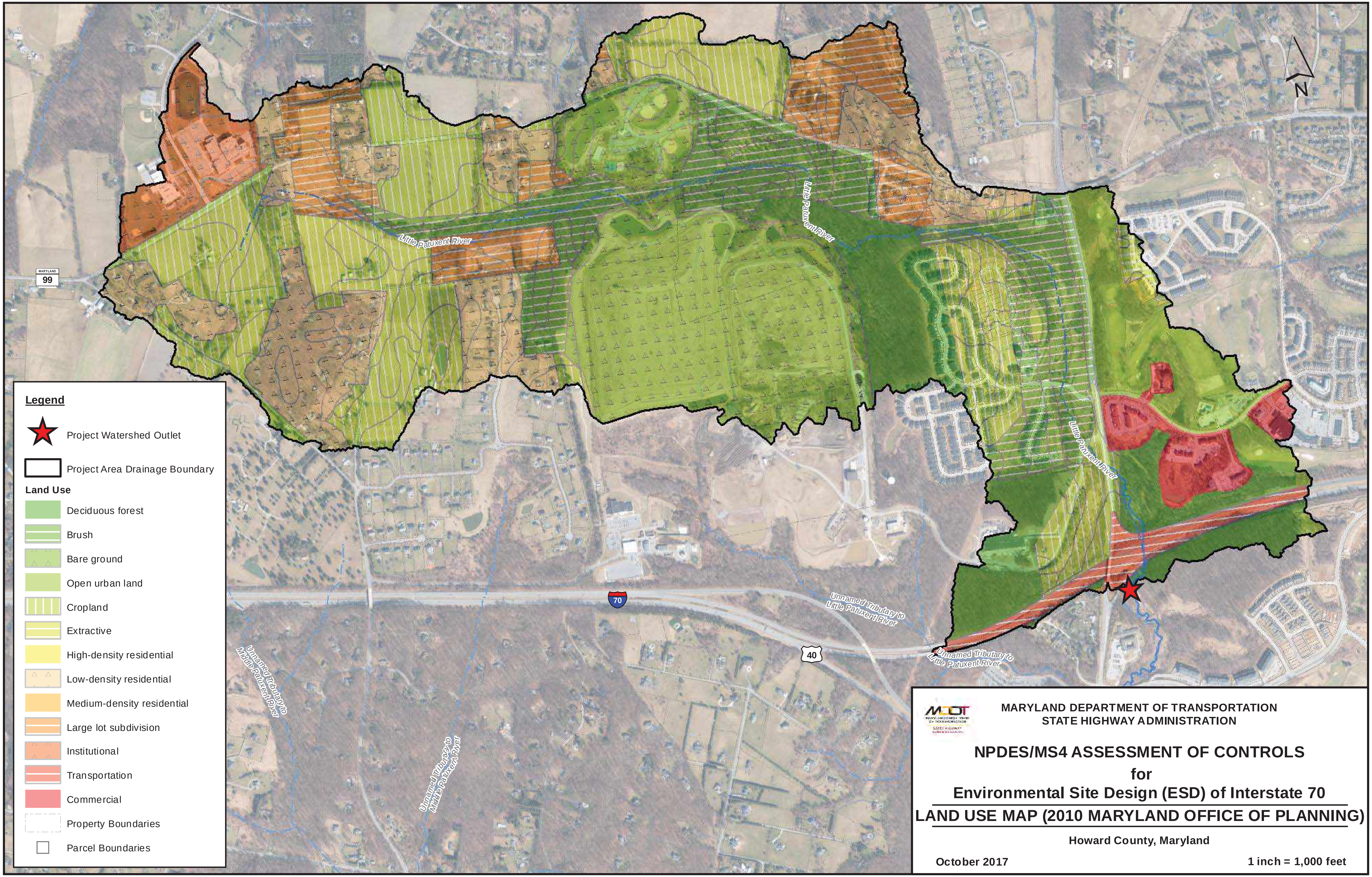
NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70

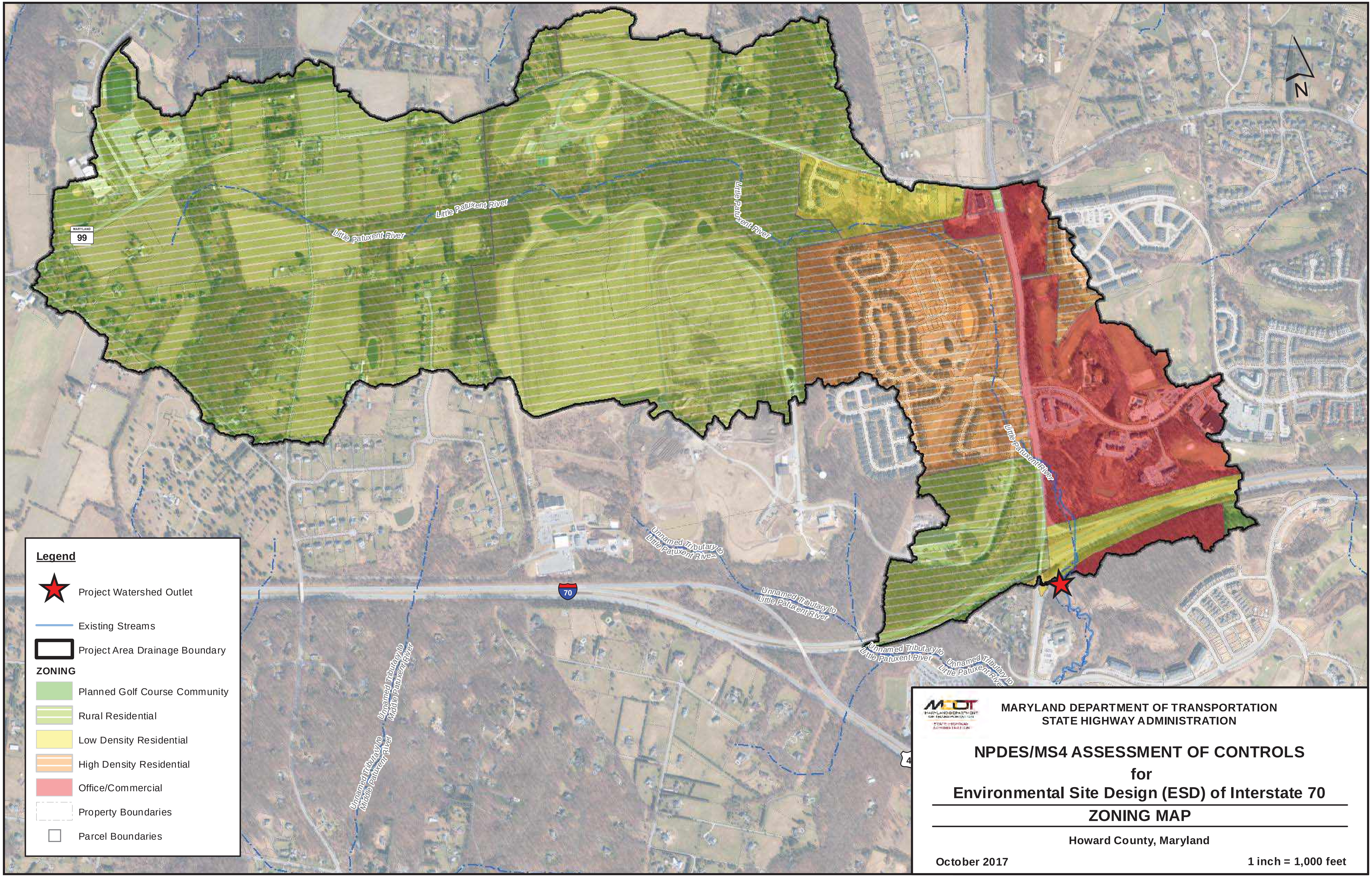
LPR WATERSHED MAP

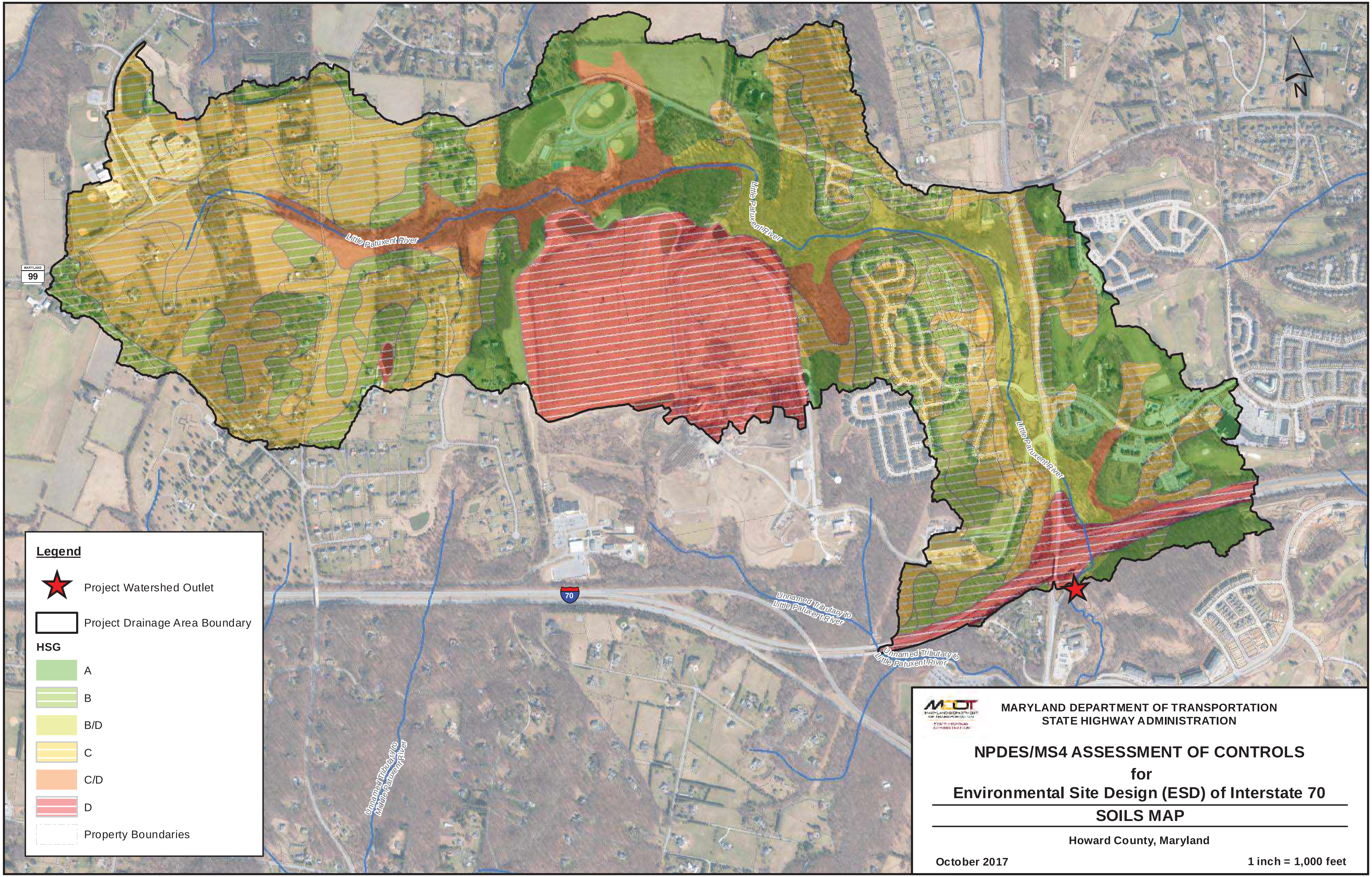
Howard County, Maryland

October 2017

1 inch = 1,000 feet


N
MARYLAND
99
70
40
Little Patuxent River
Little Patuxent River
Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Middle Patuxent River
Unnamed Tributary to Middle Patuxent River
Legend
Project Watershed Outlet
Project Area Drainage Boundary
Land Use
Deciduous forest
Brush
Bare ground
Open urban land
Cropland
Extractive
High-density residential
Low-density residential
Medium-density residential
Large lot subdivision
Institutional
Transportation
Commercial
Property Boundaries
Parcel Boundaries
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION
NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70
LAND USE MAP (2010 MARYLAND OFFICE OF PLANNING)
Howard County, Maryland
October 2017
1 inch = 1,000 feet


MARYLAND
99
Little Patuxent River
Little Patuxent River
Little Patuxent River
Little Patuxent River
N
70
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Middle Patuxent River
Unnamed Tributary to Middle Patuxent River
Legend
Project Watershed Outlet
Existing Streams
Project Area Drainage Boundary
ZONING
Planned Golf Course Community
Rural Residential
Low Density Residential
High Density Residential
Office/Commercial
Property Boundaries
Parcel Boundaries
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION
NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70
ZONING MAP
Howard County, Maryland
October 2017
1 inch = 1,000 feet


N
MARYLAND
99
70
Little Patuxent River
Little Patuxent River
Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Little Patuxent River
Unnamed Tributary to Middle Patuxent River
Legend
Project Watershed Outlet
Project Drainage Area Boundary
HSG
A
B
B/D
C
C/D
D
Property Boundaries
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION
NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70
SOILS MAP
Howard County, Maryland
October 2017
1 inch = 1,000 feet

MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

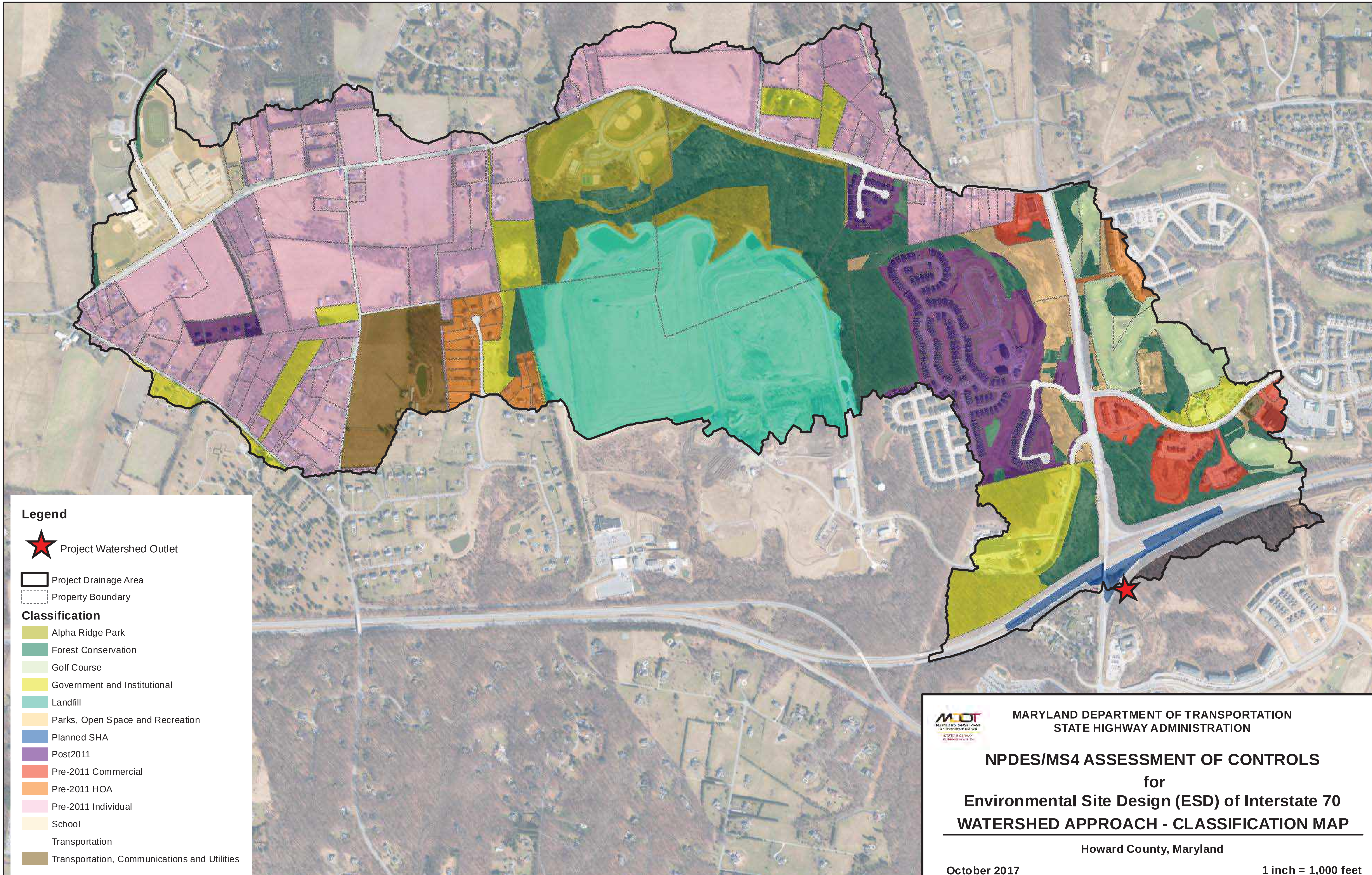
NPDES / MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70

SHA TMDL EFFORTS

Howard County, Maryland

August 31, 2016

1 inch = 650 feet



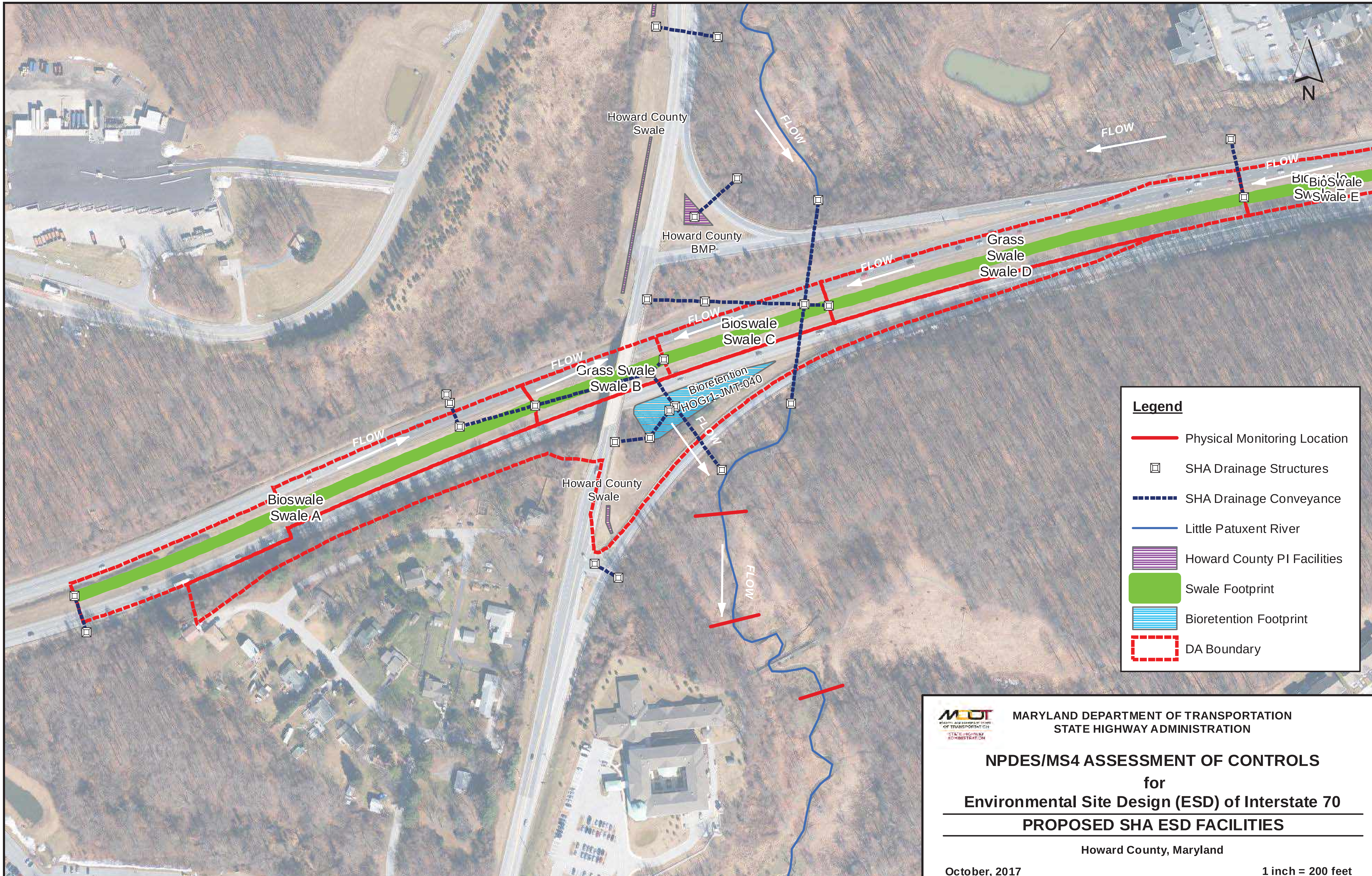
MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70
WATERSHED APPROACH - CLASSIFICATION MAP

Howard County, Maryland

October 2017

1 inch = 1,000 feet



MARYLAND DEPARTMENT OF TRANSPORTATION
STATE HIGHWAY ADMINISTRATION

NPDES/MS4 ASSESSMENT OF CONTROLS
for
Environmental Site Design (ESD) of Interstate 70

PROPOSED SHA ESD FACILITIES

Howard County, Maryland

October, 2017 1 inch = 200 feet

Appendix B

Photo Log

Photograph 1. 7/18/2018: Downstream of Flow Station 1, looking upstream. Monthly download.

Photograph 2. 7/18/2018: Upstream of Flow Station 1, looking downstream. Monthly download.

Photograph 3. 7/18/2018: Flow Station 2, monthly download.

Photograph 4. 7/18/2018: Flow Station 3, monthly download.

Photograph 5. 7/26/2018: Longitudinal profile for Year 2 Storm 1, looking downstream from right bank

Photograph 6. 7/26/2018: Upstream extent of longitudinal profile for Year 2 Storm 1

Photograph 7. 7/26/2018: Longitudinal profile for Year 2 Storm 1, looking upstream from right bank

Photograph 8. 7/26/2018: Downstream extent of longitudinal profile for Year 2 Storm 1

Photograph 9. 7/26/2018: Longitudinal profile for Year 2 Storm 1, at Cross Section 2

Photograph 10. 7/26/2018: Longitudinal profile for Year 2 Storm 1, slightly downstream of Cross Section 1

Photograph 11. 7/26/2018: Longitudinal profile for Year 2 Storm 1, looking downstream to Cross Section 2

Photograph 12. 7/26/2018: Longitudinal profile for Year 2 Storm 1, looking upstream to Cross Section 1

Photograph 13. 7/26/2018: Longitudinal profile for Year 2 Storm 1, looking downstream from Cross Section 2

Photograph 14. 7/26/2018: Longitudinal profile for Year 2 Storm 1, looking upstream from Cross Section 2

Photograph 15. 7/26/2018: Downstream extent of longitudinal profile for Year 2 Storm 1

Photograph 16. 8/29/2018: Flow Station 1, monthly download

Photograph 17. 8/29/2018: Sediment being cleaned out of Flow Station 1 housing

Photograph 18. 8/29/2018: Sediment being cleaned out of Flow Station 1 housing

Photograph 19. 8/29/2018: Flow Station 1 reset after maintenance

Photograph 20. 8/29/2018: Flow Station 1 reset after maintenance

Photograph 21. 8/29/2018: Flow Station 2, monthly download. Before maintenance.

Photograph 22. 8/29/2018: Flow Station 3, monthly download. Flow display before download

Photograph 23. 8/29/2018: Flow Station 3, monthly download. Area-velocity meter

Photograph 24. 8/29/2018: Barometer and rain gauge location, monthly download. Before maintenance.

Photograph 25. 8/29/2018: Barometer and rain gauge location, monthly download. After maintenance.

Photograph 26. 9/11/2018: Longitudinal profile for Year 2 Storm 2. Looking downstream to Cross Section 1

Photograph 27. 9/11/2018: Longitudinal profile for Year 2 Storm 2. Looking downstream to Cross Section 1

Photograph 28. 9/11/2018: Longitudinal profile for Year 2 Storm 2. Looking downstream from Cross Section 1

Photograph 29. 9/11/2018: Longitudinal profile for Year 2 Storm 2. Looking downstream to Cross Section 2

Photograph 30. 9/11/2018: Longitudinal profile for Year 2 Storm 2. Looking upstream to Cross Section 1

Photograph 31. 9/11/2018: Longitudinal profile for Year 2 Storm 2. Downstream extent of profile

Photograph 32. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, looking at left bank (LB)

Photograph 33. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, looking to right bank (RB)

Photograph 34. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, RB

Photograph 35. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, looking at LB

Photograph 36. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, looking downstream

Photograph 37. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, looking to RB

Photograph 38. 9/11/2018: Cross Section 1 Survey for Year 2 Storm 2, looking upstream

Photograph 39. 9/11/2018: Cross Section 2 Survey for Year 2 Storm 2, looking to LB

Photograph 40. 9/11/2018: Cross Section 2 Survey for Year 2 Storm 2, looking to LB

Photograph 41. 9/11/2018: Cross Section 2 Survey for Year 2 Storm 2, looking downstream

Photograph 42. 9/11/2018: Cross Section 2 Survey for Year 2 Storm 2, looking to RB

Photograph 43. 9/11/2018: Cross Section 2 Survey for Year 2 Storm 2, looking upstream

Photograph 44. 9/11/2018: Data download at Flow Station 3

Photograph 45. 9/11/2018: Barometer and rain gauge, data download

Photograph 46. 9/11/2018: Flow Station 1, before maintenance

Photograph 47. 9/11/2018: Flow Station 1, after maintenance

Photograph 48. 10/08/2018: Flow Station 3, monthly download. Before maintenance

Photograph 49. 10/08/2018: Flow Station 3, monthly download. Before maintenance

Photograph 50. 10/08/2018: Flow Station 3, monthly download. Before maintenance

Photograph 51. 10/08/2018: Flow Station 2, monthly download. Before maintenance

Photograph 52. 10/08/2018: Barometer and rain gauge, monthly download. Before maintenance

Photograph 53. 10/08/2018: Flow Station 1, monthly download. Before maintenance

Photograph 54. 11/01/2018: Barometer, monthly download

Photograph 55. 11/01/2018: Flow Station 1 with collected debris, monthly download before maintenance

Photograph 56. 11/01/2018: Flow Station 2, monthly download before maintenance

Photograph 57. 11/01/2018: Flow Station 3 with collected debris, monthly download before maintenance

Photograph 58. 11/01/2018: Rain gauge with collected debris, monthly download before maintenance

Photograph 59. 12/05/2018: Flow Station 2 with collected debris, monthly download before maintenance

Photograph 60. 12/05/2018: Barometer, monthly download before maintenance

Photograph 61. 12/05/2018: Rain gauge with collected debris, monthly download before maintenance

Photograph 62. 12/05/2018: Rain gauge tipper with collected ice, monthly download before maintenance

Photograph 63. 12/05/2018: Flow Station 3 with collected debris, monthly download before maintenance

Photograph 64. 12/05/2018: Exposed roots along monitoring reach

Photograph 65. 12/05/2018: Flow Station 1 with collected debris, monthly download before maintenance

Photograph 66. 12/05/2018: Debris jam at box culvert for Flow Station 1

Photograph 67. 12/05/2018: Debris jam at box culvert for Flow Station 1

Photograph 68. 12/14/2018: After clearing of debris jam at box culvert for Flow Station 1

Photograph 69. 03/15/2019: Flow Station 2 before and after monthly maintenance

Photograph 70. 03/15/2019: Flow Station 3 before and after monthly maintenance

Photograph 71. 04/16/2019: Flow Station 1 before monthly maintenance

Photograph 72. 04/16/2019: Flow Station 2 before monthly maintenance

Photograph 73. 04/16/2019: Flow Station 3 before monthly maintenance – connection cord pulled downstream by leaf litter (left) and velocity meter completely covered in debris (right)

Photograph 74. 05/10/19: Monthly download - rain gauge and downstream barometer

Photograph 75. 05/10/19: Monthly download - Flow Station 1

Photograph 76. 05/10/19: Monthly download - Flow Station 2

Photograph 77. Monthly download - Flow Station 3

Photograph 78. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing upstream from Station 0

Photograph 79. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing right bank at Station 0

Photograph 80. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing left bank at Station 0

Photograph 81. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing upstream from Station 70

Photograph 82. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing downstream from Station 70

Photograph 83. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing upstream from Station 162

Photograph 84. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Longitudinal Profile, facing downstream from Station 162

Photograph 85. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 1, facing upstream

Photograph 86. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 1, facing downstream

Photograph 87. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 1, facing left bank

Photograph 88. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 1, facing right bank

Photograph 89. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 2, facing upstream

Photograph 90. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 2, facing downstream

Photograph 91. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 2, facing left bank

Photograph 92. 06/20/19: Year 2 Baseline Physical Monitoring Survey – Cross Section 2, facing right bank

Photograph 93. 07/01/19: Year 2 Monthly Download and Maintenance – Flow Station 1

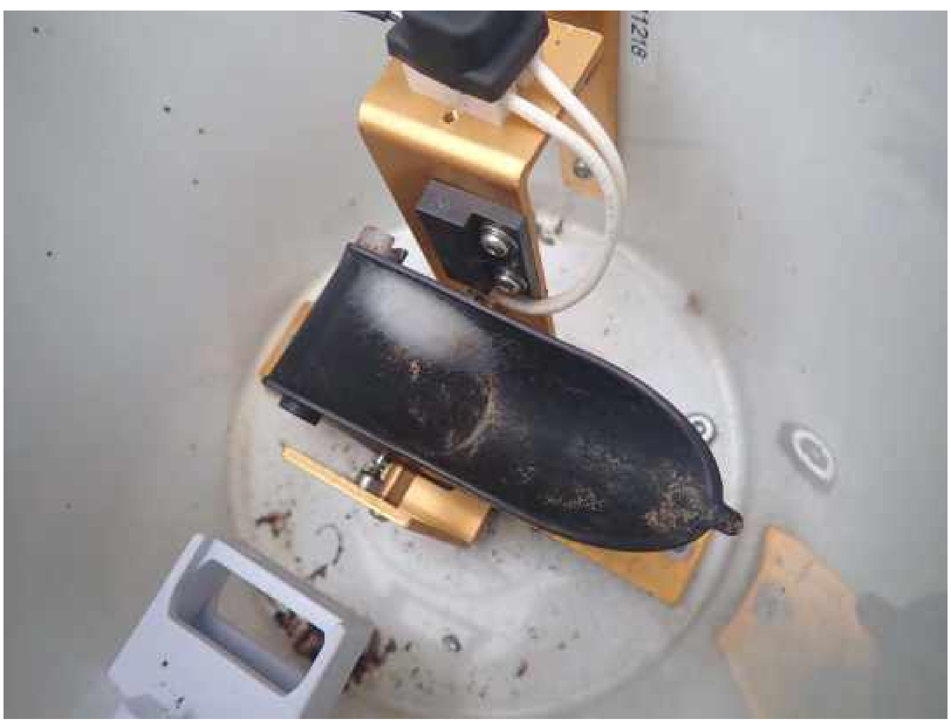
Photograph 94. 07/01/19: Year 2 Monthly Download and Maintenance – Flow Station 2

Photograph 95. 07/01/19: Year 2 Monthly Download and Maintenance – Flow Station 3

Photograph 96. 9/6/2019: Year 3 Monthly Download and Maintenance, Down Stream Barometer

Photograph 97. 9/6/2019: Year 3 Monthly Download and Maintenance, Rain Gauge

Photograph 98. 9/6/2019: Year 3 Monthly Download and Maintenance, Rain Gauge



Photograph 99. 9/6/2019: Year 3 Monthly Download and Maintenance, Flow Station 1, Downstream

Photograph 100. 9/6/2019: Year 3 Monthly Download and Maintenance, Flow Station 1, Upstream

Photograph 101. 9/6/2019: Year 3 Monthly Download and Maintenance, Flow Station 1

Photograph 102. 9/6/2019: Year 3 Monthly Download and Maintenance, Flow Station 2

Photograph 103. 9/6/2019: Year 3 Monthly Download and Maintenance, Flow Station 3

Photograph 104. 9/6/2019: Year 3 Monthly Download and Maintenance, Flow Station 3, Downstream

Photograph 105. 9/6/2019 Year 3 Monthly Download and Maintenance, Flow Station 3, Upstream

.

Photograph 106. 10/14/2019: Year 3 Monthly Download and Maintenance, Flow Station 1

Photograph 107. 10/14/2019: Year 3 Monthly Download and Maintenance, Flow Station 2

Photograph 108. 10/14/2019: Year 3 Monthly Download and Maintenance, Flow Station 3

Photograph 109. 10/14/2019 Year 3 Monthly Download and Maintenance, Rain Gauge and Downstream Barometer

Photograph 110. 11/22/2019 Year 3 Monthly Download and Maintenance, Flow Station 2 with collected debris before maintenance

Photograph 111. 11/22/2019 Year 3 Monthly Download and Maintenance, rain gauge and downstream barometer

Photograph 112. 11/22/2019 Year 3 Monthly Download and Maintenance, Flow Station 3

Photograph 113. 11/22/2019 Year 3 Monthly Download and Maintenance, Flow Station 3 covered in debris before maintenance

Photograph 114. 11/22/2019 Year 3 Monthly Download and Maintenance, Flow Station 1 covered in debris before maintenance

Photograph 115. 11/22/2019 Year 3 Monthly Download and Maintenance, Flow Station 1after maintenance

Photograph 116. 11/22/2019 Year 3 Monthly Download and Maintenance, Upstream Barometer

Photograph 117. 12/18/2019 Year 3 Monthly Download and Maintenance, Flow Station 2 old set-up

Photograph 118. 12/18/2019 Year 3 Monthly Download and Maintenance, Flow Station 2 weir installation

Photograph 119. 12/18/2019 Year 3 Monthly Download and Maintenance, rain gauge and downstream barometer

Photograph 120. 12/18/2019 Year 3 Monthly Download and Maintenance, newly fallen tree at Cross Section 1

Photograph 121. 12/18/2019 Year 3 Monthly Download and Maintenance, newly fallen tree at Cross Section 1, debris build up

Photograph 122. 12/18/2019:

Photograph 123. 12/18/2019 Year 3 Monthly Download and Maintenance, performing cross section survey at FS-3 to include banks

Photograph 124. 12/18/2019 Year 3 Monthly Download and Maintenance, Flow Station 1

Photograph 125. 1/15/2020 Year 3 Monthly Download and Maintenance, Flow Station 2

Photograph 126. 1/15/2020: Year 3 Monthly Download and Maintenance, rain gauge and downstream barometer

Photograph 127. 1/15/2020: Year 3 Monthly Download and Maintenance, Rain gauge with collected debris before maintenance

Photograph 128. 1/15/2020: Year 3 Monthly Download and Maintenance, Flow Station 1

Photograph 129. 2/12/2020 Year 3 Monthly Download and Maintenance, Flow Station 2 with water level logger ejected from behind weir

Photograph 130. 2/12/2020 Year 3 Monthly Download and Maintenance, Flow Station 2, logger replaced

Photograph 131. 2/12/2020: Year 3 Monthly Download and Maintenance, Flow Station 3

Photograph 132. 2/12/2020: Year 3 Monthly Download and Maintenance, rain gauge and downstream barometer

Photograph 133. 2/12/2020 Year 3 Monthly Download and Maintenance, Flow Station 1

Photograph 134. 2/12/2020 Year 3 Monthly Download and Maintenance, Flow Station 1 with debris before maintenance

Photograph 135. 3/18/2020: Year 3 Monthly Download and Maintenance, Flow Station 2

Photograph 136. 3/18/2020: Year 3 Monthly Download and Maintenance, rain gauge and downstream barometer

Photograph 137. 3/18/2020: Year 3 Monthly Download and Maintenance, Flow Station 3

Photograph 138. 3/18/2020: Year 3 Monthly Download and Maintenance, Flow Station 1

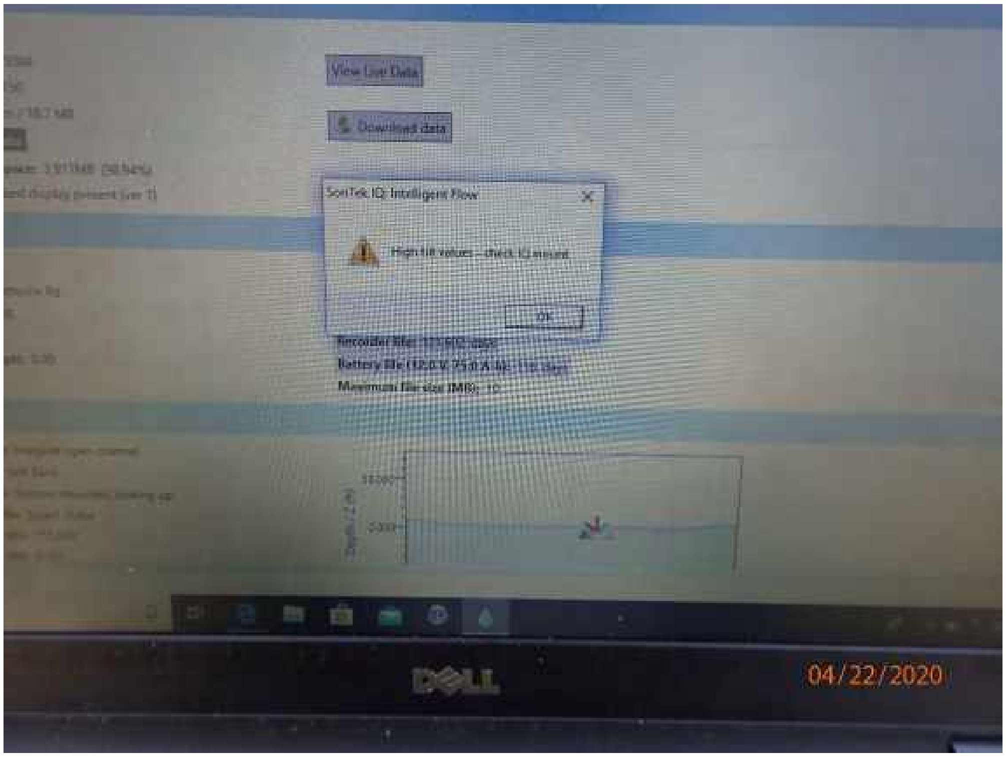
Photograph 139. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 2 with debris build-up and logger ejected

Photograph 140. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 2 with debris build-up

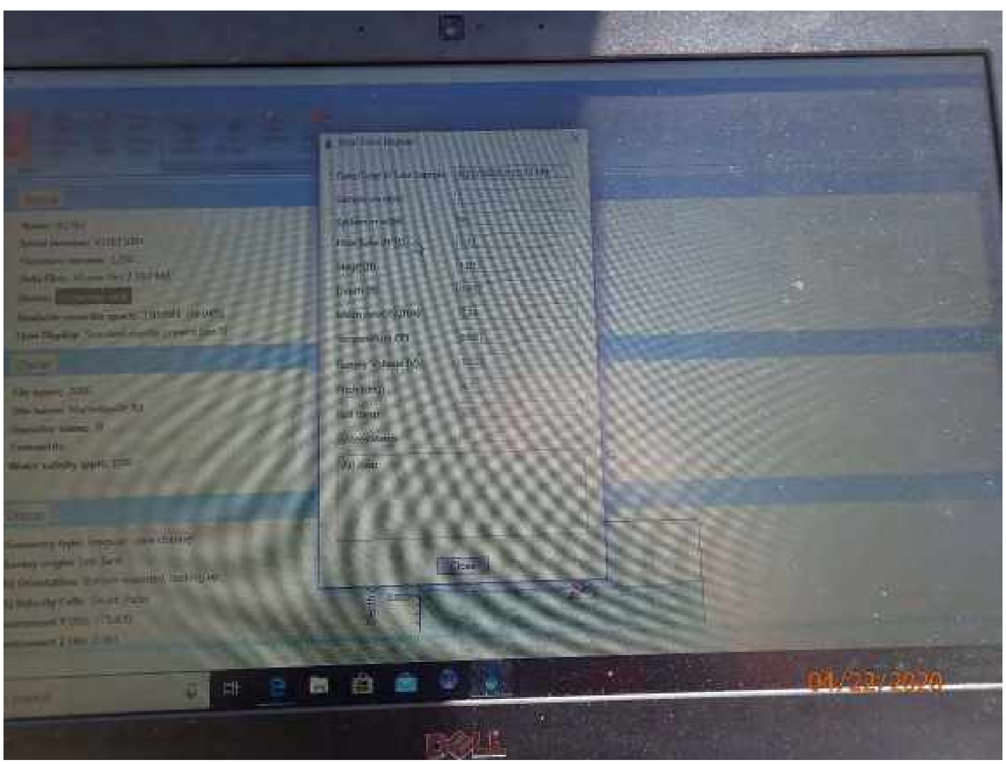
Photograph 141. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 2 secured logger to housing

Photograph 142. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 3 flow display before maintenance

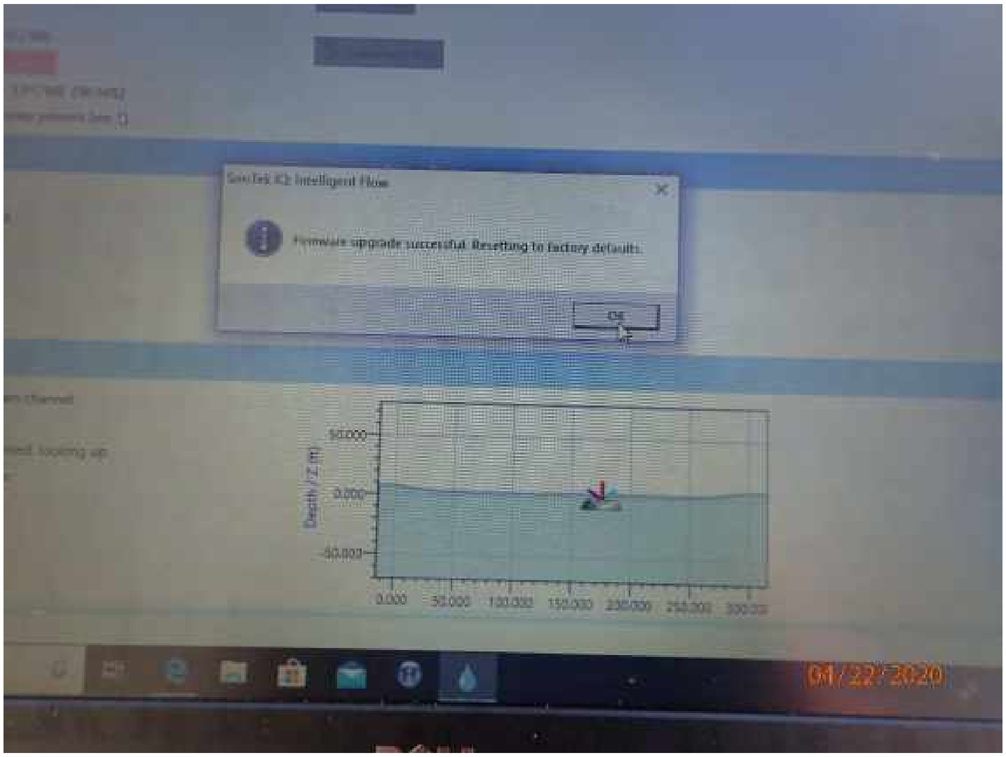
Photograph 143. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, reason for error



Photograph 144. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, errors resolved



Photograph 145. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, firmware upgrade performed



Photograph 146. 4/22/2020: Year 3 Monthly Download and Maintenance, rain gauge and downstream barometer

Photograph 147. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 1, debris build-up

Photograph 148. 4/22/2020: Year 3 Monthly Download and Maintenance, Flow Station 1, dislodged and out of position under weight of debris

Photograph 149. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 215

Photograph 150. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 215

Photograph 151. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 163

Photograph 152. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 163

Photograph 153. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 140

Photograph 154. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 140

Photograph 155. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Cross Section 1, facing left bank

Photograph 156. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Cross Section 1, facing right bank

Photograph 157. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 107

Photograph 158. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 107

Photograph 159. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 80

Photograph 160. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 80

Photograph 161. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Cross Section 2, facing left bank

Photograph 162. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Cross Section 2, facing right bank

Photograph 163. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 39

Photograph 164. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 39

Photograph 165. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing upstream from station 1

Photograph 166. 5/8/2020: Year 3 Storm 2 Post-Storm Monitoring, Longitudinal Profile, facing downstream from station 1

Photograph 167. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 2

Photograph 168. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 2, download

Photograph 169. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, display unit

Photograph 170. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 3

Photograph 171. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, facing downstream

Photograph 172. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, facing downstream

Photograph 173. 6/23/2020: Year 3 Monthly Download and Maintenance, Downstream Barometer

Photograph 174. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 3, Rain Gauge

Photograph 175. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 1

Photograph 176. 6/23/2020: Year 3 Monthly Download and Maintenance, Flow Station 1

Appendix C

Geomorphic Data

Year 3 - Storm 1

Physical

Monitoring 04/16/20

MARYLAND STREAM STUDY

CROSS SECTION

STREAM Little Patuxent River XS #1	DATE 4/16/20
USGS #	CREW TH SJ
FWS #	

Begin on left, facing downstream (all measurements are in feet unless otherwise noted)

NOTE	DIST.	ELEV. / DEPTH	NOTE	DIST.	ELEV. / DEPTH
LB Pin (grnd)	0.0	5.3			
LB Mon	2.1	[illegible]			
LB	4.0	5.26			
LB	5.0	5.31			
	6.0	5.47			
	7.0	5.56			
	8.0	5.57			
TOLB	9.1	5.83			
BOLB EOW	11.8	8.27			
AC	13.1	8.31			
	14.3	8.24			
Thalweg	15.4	8.26			
AC	16.2	8.28			
	18.8	8.20			
	20	8.05			
	21.7	8.08			
	22.7	8.07			
EOW BORB	24.3	7.89			
RB	25.4	7.48			
	25.6	6.59			
	27.0	6.11			
	29	5.78			
TORB	30.8	5.39			
RB	33	4.00			
	35	4.76			
RB Mon	36.5	4.78			
RB Pin (grnd)	38.9	4.95			

STATION OR DISTANCE FROM GAGE	
DIRECTION FROM GAGE	

NOTATIONS

NOTE	ABBREV
Left	L
Right	R
Pin	P
Edge of Water	EW
Water Surface	WS
Active Channel	AC
Scour Line	SL
Bankfull	BF
Top of Bank	TOB
Monument	MON
BOB	bottom of bank

ENTRENCHMENT

FLOODPRONE WIDTH	
BANKFULL WIDTH	
ENTRENCHMENT	

GPS Coordinates

Left Monument	
Latitude	
Longitude	
Error	
Right Monument	
Latitude	
Longitude	
Error	

Instrument (Prop.#)

5.06

MARYLAND STREAM STUDY

CROSS SECTION

STREAM Little Patuxent River XS 2	DATE 4/16/20
USGS #	CREW TH JJ
FWS #	

Begin on left, facing downstream (all measurements are in feet unless otherwise noted)

NOTE	DIST.	ELEV. / DEPTH	NOTE	DIST.	ELEV. / DEPTH
LB Pin (in)	0.0	5.36			
LB mon	1' 4"	5.29			
LB	2.0	5.26			
	4.0	5.27			
	6.0	5.15			
TOLB	7' 10"	5.49			
LB	8' 9"	6.89			
BOLB	9 6"	7.76			
gravel bar	11.0	7.61			
EOW	13 3"	8.44			
AC	14 8"	8.50			
Thalweg	15 6"	8.58			
AC	17	8.44			
	18	8.50			
	19	8.53			
	20	8.56			
	21	8.52			
BORB EOW	22 4"	8.33			
RB	22 8"	6.19			
TORB	24 6"	5.67			
RB	27	5.35			
	29	5.35			
RB mon	30 7"	5.35			
RB Pin mon	32 6"	5.41			

STATION OR DISTANCE FROM GAGE	
DIRECTION FROM GAGE	

NOTATIONS

NOTE	ABBREV
Left	L
Right	R
Pin	P
Edge of Water	EW
Water Surface	WS
Active Channel	AC
Scour Line	SL
Bankfull	BF
Top of Bank	TOB
Monument	MON

ENTRENCHMENT

FLOODPRONE WIDTH	
BANKFULL WIDTH	
ENTRENCHMENT	

GPS Coordinates

Left Monument	
Latitude	
Longitude	
Error	
Right Monument	
Latitude	
Longitude	
Error	

Instrument (Prop.#)

5.03

MARYLAND STREAM STUDY
LONGITUDINAL PROFILE

STREAM: Little Patuxent River - Monitoring Reach | DATE: 04/16/20 | CREW: J. Jahn, T. Hay

USGS #
ALL MEASUREMENTS IN FEET UNLESS OTHERWISE NOTED.

FWS #
REFERENCE POINT ELEVATION AND DESCRIPTION:

Identifier	Backsight	Height of Instrument	Station	o Bed Surface Foresight	Bed Surface Elevation	o Water Surface Foresight	Water Surface Elevation	Bankfull Foresight	Bankfull Elevation	Top of Bank Foresight	Top of Bank Elevation	Water depth Other Foresight	Other Elevation
CX-1 RA mon	4.78	5.06											
Run		9.59	0	Tree	in way							0.79	
Run		9.63	3									0.86	
Run		9.31	9									0.55	
B riffle		9.26	18									0.55	
riffle		9.17	24									0.50	
T riffle		9.10	31									0.50	
run		9.23	47									0.61	
run		9.16	50									0.56	
B riffle		9.30	62									0.70	
riffle XS #2		8.88	65									0.35	
T riffle		8.81	74									0.55	
Glide		8.86	85									0.59	
B Pool		9.21	92									0.96	
Pool FS 3		9.51	98									1.25	
T Pool		9.37	101									1.14	
run		9.20	106									0.98	
B riffle		8.91	111									0.68	
riffle		8.76	117									0.63	
riffle XS #1		8.27	124									0.47	
T riffle		8.24	129									0.55	
Glide		8.39	134									0.62	
BW Pool		8.59	140									0.74	
Pool		8.54	149									1.16	
T Pool		8.74	153									0.88	
Glide		8.42	158									0.73	
B Pool		8.45	167			CX2	LB Mon	5.66				0.78	
Pool		8.81	172			CX2	RB Mon	5.72				1.56	
Pool		9.48	173									1.74	
Pool		9.21	179									1.44	
Pool		9.36	190									1.62	
Pool		8.80	195									1.62	
Pool		9.34	200									1.60	

Pool 9.74 204 1.52
Pool 9.41 213 1.65

‾

MARYLAND STREAM STUDY
REACH AVERAGE PEBBLE COUNT

c X - L

TEAM	Little Patuxent River, [illegible] Road	DATE	04/16/10
USGS #		CREW	J Jab[illegible], T. [illegible]
FWS #		PARTICLE TALLY COUNTS BY TRANSECT	

FEET	PARTICLE	MILLIMETERS		1	2	3	4	5	6	7	8	9	10	TOT#	ITEM%	%CUM
	Silt/Clay	< .062	S/C	II												
	Very Fine	.062 - .125	S	II												
	Fine	.125 - .25	A	II												
	Medium	.25 - .50	N	卌												
	Coarse	.50 - 1.0	D	卌	卌	IIII										
	Vry Coarse	1.0 - 2	S	卌												
	Very Fine	2 - 4		III												
	Fine	4 - 6	G	卌												
	Fine	6 - 8	R	卌												
	Medium	8 - 12	A	卌	卌	III										
	Medium	12 - 16	V	卌II	卌											
	Coarse	16 - 24	E	卌												
	Coarse	24 - 32	L	卌	卌											
	Vry Coarse	32 - 48	S	III												
	Vry Coarse	48 - 64		IIII												
0.21-0.31	Small	64 - 96	C	卌	卌	IIII										
0.31-0.42	Small	96 - 128	O	II												
0.42-0.63	Large	128 - 192	B													
0.63-0.84	Large	192 - 256	L													
0.84-1.26	Small	256 - 384	B													
1.26-1.68	Small	384 - 512	L													
1.68-3.36	Medium	512 - 1024	D													
3.36-6.72	Lrg	1024 - 2048	R													
6.72-13.43	Vry Lrg	2048-4096														
	Bedrock	>4096	BDRK													
	CHANNEL WIDTH AT TRANSECT															

	LENGTH	PROPORTION	NO. UNITS	SAMPLED
REACH				
POOL				
RIFFLE				
RUN				

卌 卌 卌 卌 卌 | 卌 卌 卌 卌 卌
卌 卌 卌 卌 卌 | 卌 卌 卌 卌 卌

TRANSECT	FEATURE	LENGTH	LOCATION	COUNT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

MARYLAND STREAM STUDY
REACH AVERAGE PEBBLE COUNT

STREAM	Little Patuxent River	**DATE**	4/16/20
USGS #		**CREW**	TK JT
FWS #			

PARTICLE TALLY COUNTS BY TRANSECT

FEET	PARTICLE	MILLIMETERS		1	2	3	4	5	6	7	8	9	10	TOT#	ITEM%	%CUM
	Silt/Clay	< .062	S/C													
	Very Fine	.062 - .125	S													
	Fine	.125 - .25	A													
	Medium	.25 - .50	N													
	Coarse	.50 - 1.0	D													
	Vry Coarse	1.0 - 2	S													
	Very Fine	2 - 4														
	Fine	4 - 6	G													
	Fine	6 - 8	R													
	Medium	8 - 12	A													
	Medium	12 - 16	V													
	Coarse	16 - 24	E													
	Coarse	24 - 32	L													
	Vry Coarse	32 - 48	S													
	Vry Coarse	48 - 64														
0.21-0.31	Small	64 - 96	C													
0.31-0.42	Small	96 - 128	O													
0.42-0.63	Large	128 - 192	B													
0.63-0.84	Large	192 - 256	L													
0.84-1.26	Small	256 - 384	B													
1.26-1.68	Small	384 - 512	L													
1.68-3.36	Medium	512 - 1024	D													
3.36-6.72	Lrg	1024 - 2048	R													
6.72-13.43	Vry Lrg	2048-4096														
	Bedrock	>4096	BDRK													
	CHANNEL WIDTH AT TRANSECT															

	LENGTH	PROPORTION	NO. UNITS	SAMPLED
REACH				
POOL				
RIFFLE				
RUN				

TRANSECT	FEATURE	LENGTH	LOCATION	COUNT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Year 3 - Storm 2

Physical

Monitoring 05/08/20

MARYLAND STREAM STUDY

CROSS SECTION

STREAM Little Patuxent Cross Section 1	DATE 5/8/2020
USGS #	CREW JJ + BK
FWS #	

Begin on left, facing downstream (all measurements are in feet unless otherwise noted)

NOTE	Station DIST.	ELEV. / DEPTH	NOTE	DIST.	ELEV. / DEPTH
LP	—				
LFP	6"	5.08			
LMON	0	—			
LFP	4'	5.12			
LFP	7'	5.42			
LTOB	8' 11"	5.55			
LBOB/EOW	11' 1"	8.13			
Thalweg	12' 5"	8.28			
AC	14'	8.12			
AC	16'	8.04			
AC	18'	7.99			
AC	19' 11"	7.89			
AC	21'	7.92			
AC	22' 9"	7.85			
RBOB/EOW	23' 8"	7.75			
RB	24' 7"	7.40			
RB	25'	6.44			
RB	27' 6"	5.68			
RB TOB	29' 6"	5.50			
RFP	31'	4.93			
RFP	33'	4.70			
RFP	35'	4.65			
RMON	35' 9.5"	4.68			
RP	36' 11"	4.76			

STATION OR DISTANCE FROM GAGE	
DIRECTION FROM GAGE	

NOTATIONS	
NOTE	**ABBREV**
Left	L
Right	R
Pin	P
Edge of Water	EW
Water Surface	WS
Active Channel	AC
Scour Line	SL
Bankfull	BF
Top of Bank	TOB
Monument	MON

ENTRENCHMENT	
FLOODPRONE WIDTH	
BANKFULL WIDTH	
ENTRENCHMENT	

GPS Coordinates	
Left Monument	
Latitude	
Longitude	
Error	
Right Monument	
Latitude	
Longitude	
Error	

Instrument (Prop.#)

4.44

MARYLAND STREAM STUDY

CROSS SECTION

STREAM Little Patuxent Cross Section 2	DATE 5/8/2020
USGS #	CREW [illegible] + BK
FWS #	

Begin on left, facing downstream (all measurements are in feet unless otherwise noted)

NOTE	Station DIST.	ELEV. / DEPTH	NOTE	DIST.	ELEV. / DEPTH
LP	----	5.55			
L Mon	0.45	5.62			
LFP	2.00	5.44			
LFP	4.00	5.47			
LTOB	7.1	5.69			
LBOB	9.0	7.49			
Gravel Bar	[illegible]	7.81			
LEOW	12.2	8.57			
AC	14.0	8.71			
AC	15.0	8.74			
AC	16.0	8.71			
AC	17.0	8.71			
AC	18.0	8.71			
thalweg	[illegible]	8.83			
REOW/RBOB	[illegible]	8.47			
RTB	22.0	6.47			
RTOB	23.9	5.73			
RFP	26	5.58			
RFP	28	5.56			
R Mon	30.[illegible]	5.56			
RP	30.[illegible]	5.52			

STATION OR DISTANCE FROM GAGE

DIRECTION FROM GAGE

NOTATIONS

NOTE	ABBREV
Left	L
Right	R
Pin	P
Edge of Water	EW
Water Surface	WS
Active Channel	AC
Scour Line	SL
Bankfull	BF
Top of Bank	TOB
Monument	MON

ENTRENCHMENT

FLOODPRONE WIDTH

BANKFULL WIDTH

ENTRENCHMENT

GPS Coordinates

Left Monument

Latitude

Longitude

Error

Right Monument

Latitude

Longitude

Error

Instrument (Prop.#)

4.94

MARYLAND STREAM STUDY
REACH AVERAGE PEBBLE COUNT

STREAM	Cross Section 1 [illegible]	DATE	08/ 08/ 2020
USGS #		CREW	JJ + ZK
FWS #		PARTICLE TALLY COUNTS BY TRANSECT	

FEET	PARTICLE	MILLIMETERS		1	2	3	4	5	6	7	8	9	10	TOT#	ITEM%	%CUM
	Silt/Clay	< .062	S/C													
	Very Fine	.062 - .125	S													
	Fine	.125 - .25	A													
	Medium	.25 - .50	N													
	Coarse	.50 - 1.0	D													
	Vry Coarse	1.0 - 2	S													
	Very Fine	2 - 4														
	Fine	4 - 6	G													
	Fine	6 - 8	R													
	Medium	8 - 12	A													
	Medium	12 - 16	V													
	Coarse	16 - 24	E													
	Coarse	24 - 32	L													
	Vry Coarse	32 - 48	S													
	Vry Coarse	48 - 64														
0.21-0.31	Small	64 - 96	C													
0.31-0.42	Small	96 - 128	O													
0.42-0.63	Large	128 - 192	B													
0.63-0.84	Large	192 - 256	L													
0.84-1.26	Small	256 - 384	B													
1.26-1.68	Small	384 - 512	L													
1.68-3.36	Medium	512 - 1024	D													
3.36-6.72	Lrg	1024 - 2048	R													
6.72-13.43	Vry Lrg	2048-4096														
	Bedrock	>4096	BDRK													
	CHANNEL WIDTH AT TRANSECT															

	LENGTH	PROPORTION	NO. UNITS	SAMPLED
REACH				
POOL				
RIFFLE				
RUN				

TRANSECT	FEATURE	LENGTH	LOCATION	COUNT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

MARYLAND STREAM STUDY
REACH AVERAGE PEBBLE COUNT

STREAM	Cross Section 2 [illegible]	**DATE**	05/08/2020
USGS #		**CREW**	JT + BK
FWS #			

PARTICLE TALLY COUNTS BY TRANSECT

FEET	PARTICLE	MILLIMETERS		1	2	3	4	5	6	7	8	9	10	TOT#	ITEM%	%CUM
	Silt/Clay	< .062	S/C	卌	卌	I										
	Very Fine	.062 - .125	S													
	Fine	.125 - .25	A													
	Medium	.25 - .50	N	卌 I												
	Coarse	.50 - 1.0	D	卌	II											
	Vry Coarse	1.0 - 2	S	卌 I	III											
	Very Fine	2 - 4		卌	I											
	Fine	4 - 6	G	卌	I											
	Fine	6 - 8	R	II												
	Medium	8 - 12	A	III												
	Medium	12 - 16	V	III												
	Coarse	16 - 24	E	IIII												
	Coarse	24 - 32	L	卌	II											
	Vry Coarse	32 - 48	S	卌	卌											
	Vry Coarse	48 - 64		III												
0.21-0.31	Small	64 - 96	C	卌	卌	IIII										
0.31-0.42	Small	96 - 128	O	卌	III											
0.42-0.63	Large	128 - 192	B	III												
0.63-0.84	Large	192 - 256	L													
0.84-1.26	Small	256 - 384	B													
1.26-1.68	Small	384 - 512	L													
1.68-3.36	Medium	512 - 1024	D													
3.36-6.72	Lrg	1024 - 2048	R													
6.72-13.43	Vry Lrg	2048-4096														
	Bedrock	>4096	BDRK													
	CHANNEL WIDTH AT TRANSECT															

	LENGTH	PROPORTION	NO. UNITS	SAMPLED
REACH				
POOL				
RIFFLE				
RUN				

卌 卌 卌 卌 卌   卌 卌 卌 卌 卌

卌 卌 卌 卌 卌   卌 卌 卌 卌 卌

TRANSECT	FEATURE	LENGTH	LOCATION	COUNT
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

MARYLAND STREAM STUDY
LONGITUDINAL PROFILE

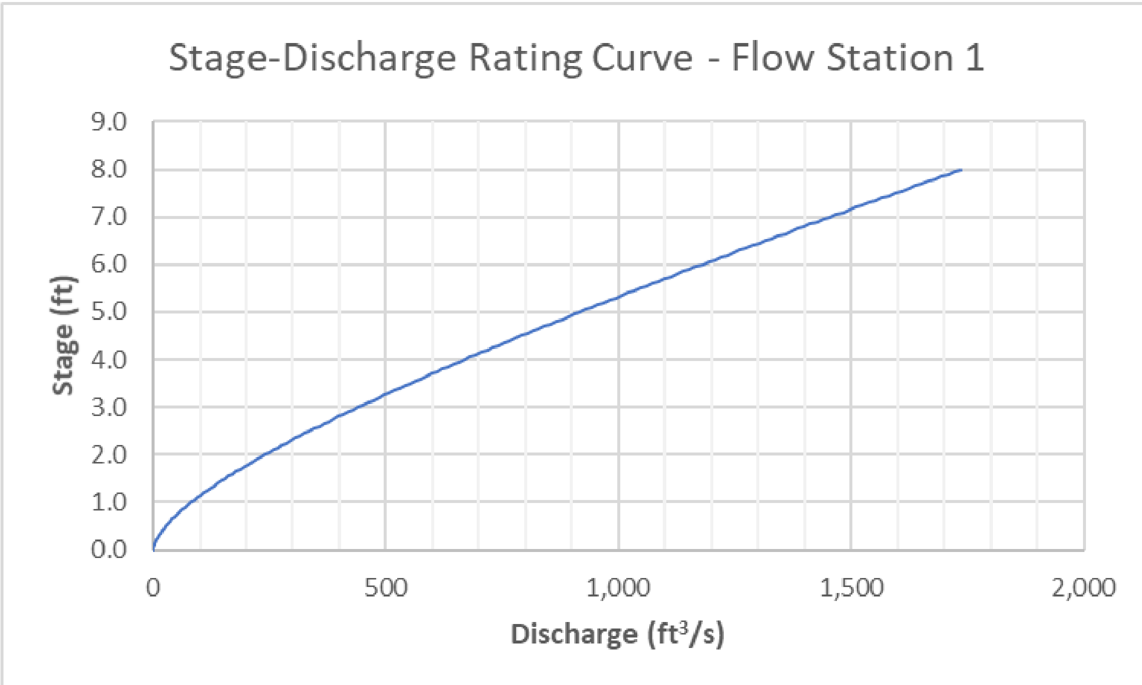
STREAM: Little Patuxent			DATE: 5/[illegible]	CREW: JJ + BK
USGS #	ALL MEASUREMENTS IN FEET UNLESS OTHERWISE NOTED.			
FWS #	REFERENCE POINT ELEVATION AND DESCRIPTION:			

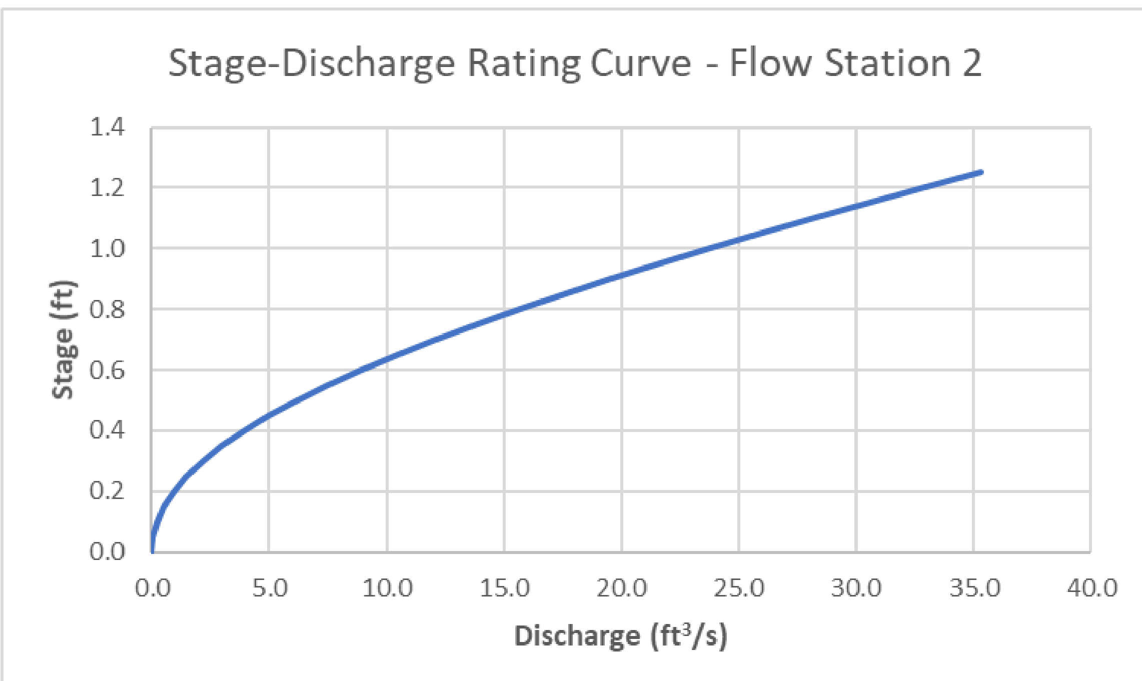
Identifier	Backsight	Height of Instrument	Station	Bed Surface Foresight	Bed Surface Elevation	Water Surface Foresight	Water Surface Elevation	Bankfull Foresight	Bankfull Elevation	Top of Bank Foresight	Top of Bank Elevation	~~Other~~ WDH Foresight	Other Elevation
[illegible]	cont measur[illegible]	[illegible]	—										
[illegible]	4.68												
[illegible]	5.51												
[illegible]	5.57												
[illegible]			0	9.[illegible]								0.55	
[illegible]			2.0	9.[illegible]								0.5[illegible]	
N			12	9.[illegible]								0.5[illegible]	
TN/[illegible]			18.9	9.1[illegible]								0.42	
N			22.5	9.00								0.5[illegible]	
TR/BN			28.9	9.[illegible]								0.45	
N			34.0	9.09								0.50	
N			42.0	9.21								0.35	
N			48.3	9.35								0.52	
TN/BR			55.0	9.07								0.52	
R			62	9.[illegible]								0.65	
[illegible]			65	[illegible]								0.3[illegible]	
[illegible]			[illegible]	[illegible]								0.[illegible]	
G			[illegible]	8.76								0.5[illegible]	
TG/BR			89	8.34								[illegible]	
F			95	9.45								1.34	
TF/BR			103.8	9.16								0.9[illegible]	
N			108	8.95								0.7[illegible]	
TN/BR			[illegible]2	8.8[illegible]								0.63	
R			116	8.45								0.57	
[illegible]			[illegible]	[illegible]								0.50	
TR/[illegible]			13[illegible]	7.97								0.28	
T[illegible]/BR			141.5	[illegible]								0.55	
F			148	8.92								1.2[illegible]	
TP/BG			154	8.77								1.37	
T[illegible]/BR			163.2	8.29								0.69	
R			166.7	8.54								0.95	
R			174	8.68								1.20	
F			174.[illegible]	8.47								1.35	

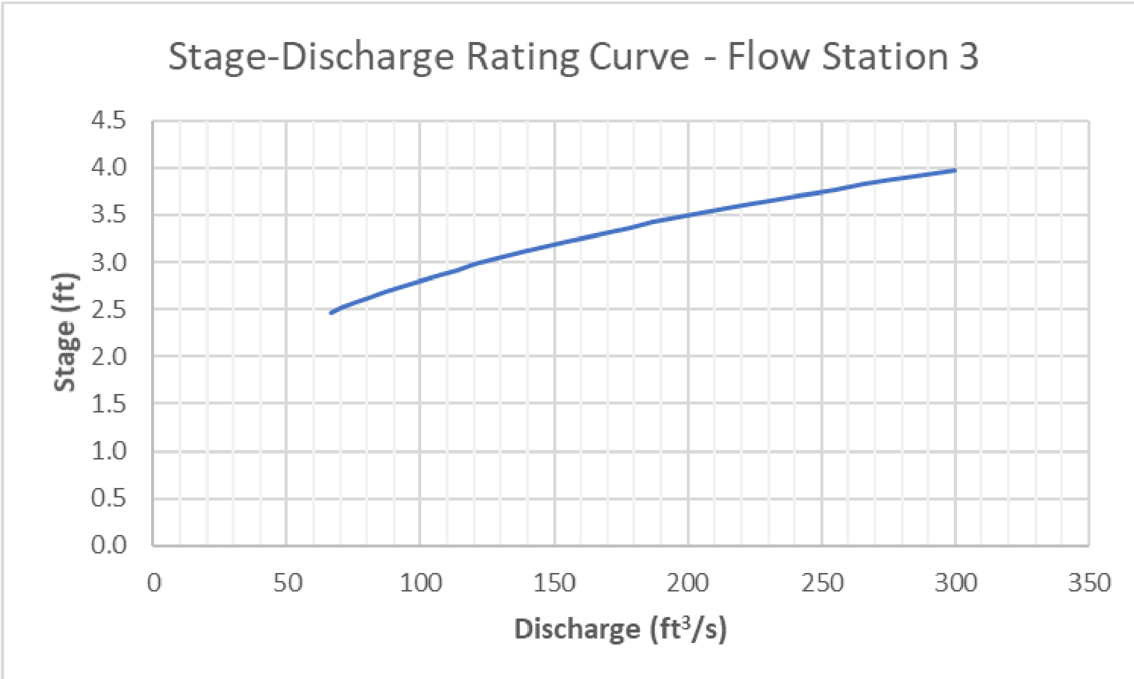
ID	Station	Water depth	[illegible]
P	180	1.43	9.04
P	185	0.87	5.44
P	195	1.22	8.31
F	205	1.32	9.44
P	215	1.56	9.21

Appendix D

Stage-Discharge Relationships


Stage-Discharge Rating Curve - Flow Station 1
Stage (ft)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
500
1,000
1,500
2,000
Discharge (ft³/s)

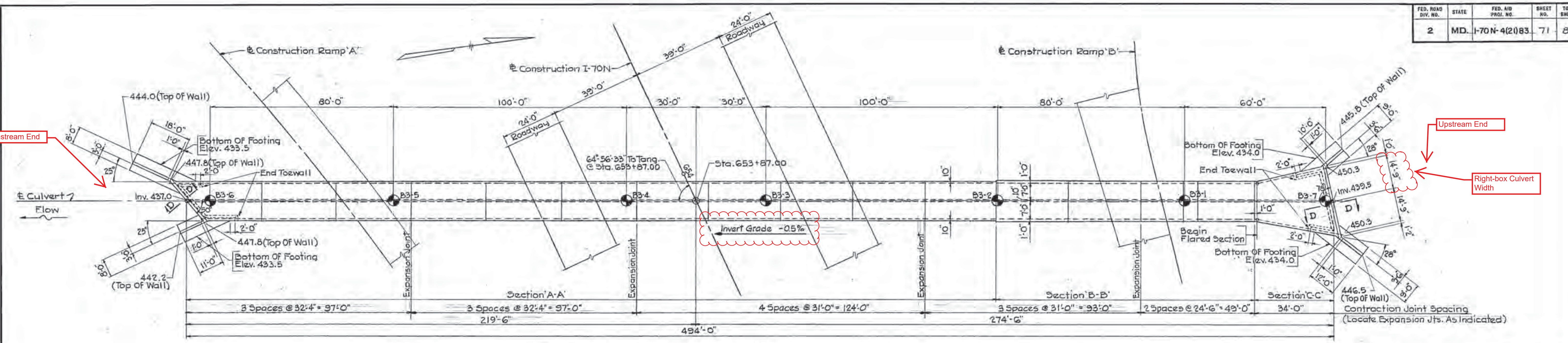

Stage-Discharge Rating Curve - Flow Station 2
Stage (ft)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Discharge (ft³/s)


Stage-Discharge Rating Curve - Flow Station 3
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Stage (ft)
0
50
100
150
200
250
300
350
Discharge (ft3/s)

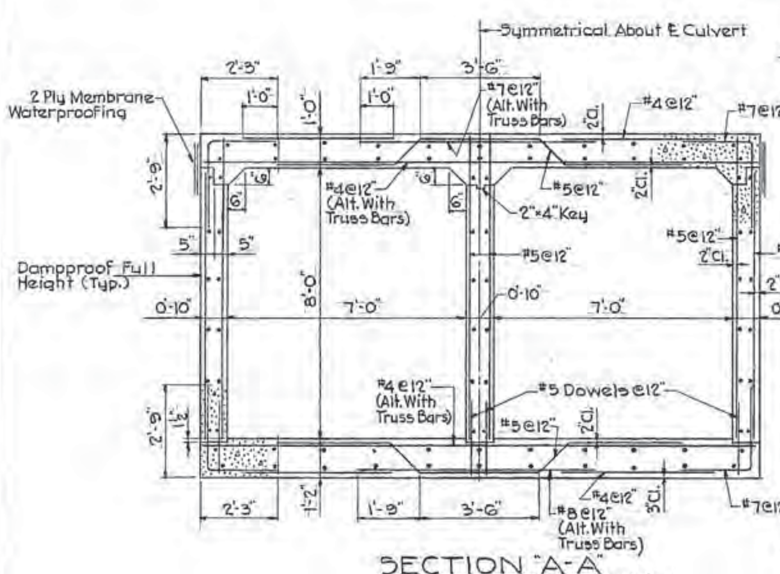
Appendix E

Flow Station As-Builts

FED. ROAD DIV. NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
2	MD.	I-70N-4(21)83	71	85

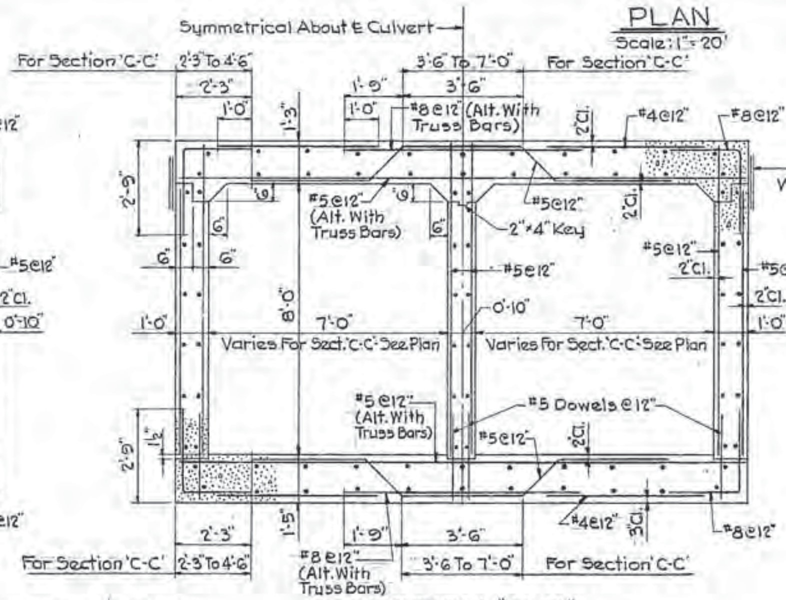


PLAN
Scale: 1" = 20'

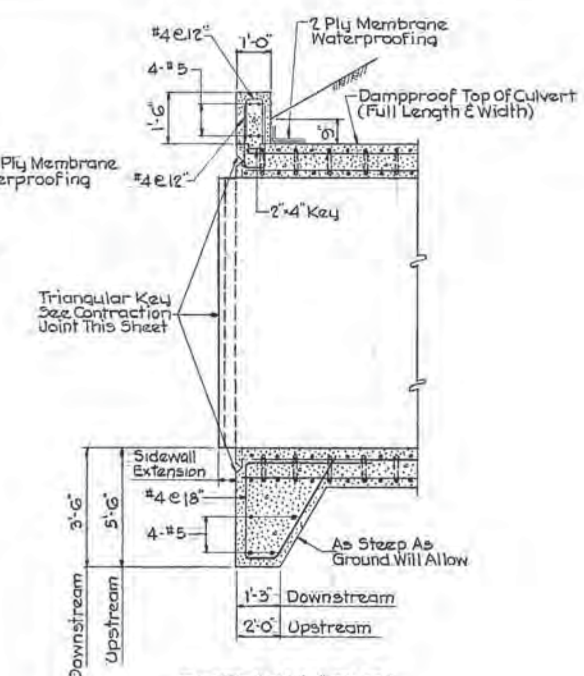


SECTION "A-A"
Scale: 3/8" = 1'-0"

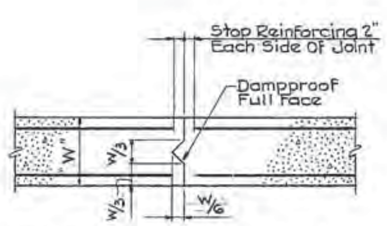
Note: All Longitudinal Reinforcement To Be #4 Spaced As Shown For Section 'A-A' & Section 'B-B' And #4 Spaced At 18" Max. For Section 'C-C'.



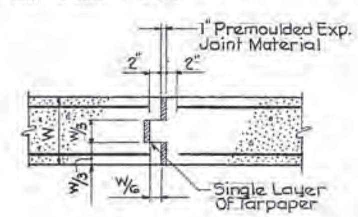
SECTION "B-B"
SECTION "C-C" (Similar Except As Noted)
Scale: 3/8" = 1'-0"



SECTION "D-D"
Scale: 3/8" = 1'-0"



CONTRACTION JOINT



EXPANSION JOINT

ESTIMATED QUANTITIES

ITEM Nº	ITEM	UNIT	QUANTITY
303	Selected Backfill Using #6 Aggregate	C.Y.	130
304	Selected Backfill Using CR-6 Or Type 2 Sub-Base	C.Y.	130
401	Class #3 Excavation For Structures	C.Y.	3,200
~~416~~	~~Contingent Concrete For Box Culvert~~	C.Y.	5
426	Class C Concrete Subfoundation	C.Y.	5
431	Double 7.0 Ft. x 8.0 Ft. Reinf. Concrete Box Culv. At Sta. 653+	—	L.S.

GENERAL NOTES

SPECIFICATIONS: A.A.S.H.O. Standard Specifications For Highway Bridges, Dated 1961; And A.A.S.H.O. Interim Specifications, Dated 1961, 1962, 1963 And 1964 For Design. Maryland S.R.C. Specifications, Dated January 1962, Addenda And Errata Thereto; And "Special Provisions" For Materials And Construction.

LOADING: HS 20-44

CONCRETE: Class "A-1" f'c = 3,000 p.s.i., Class "C" f'c = 1,500 p.s.i. All Exposed Edges Shall Be Chamfered 3/4" x 3/4".

REINFORCING BARS: Reinforcing Steel Shall Be Deformed Bars Of Intermediate Grade. Allowable Design Stress 20,000 p.s.i. Splices And Embedment Shall Be 24 Diameters Unless Otherwise Noted.

BORINGS: Borings Are Numbered And Indicated Thus. For Boring Logs See Sheet Nº 72

SELECTED BACKFILL: Selected Backfill To Be Placed For Entire Length Of Culvert To Depth As Directed By The Engineer To Suit Field Conditions.

Maximum Design Foundation Pressure = 1.0 Tons/Sq. Ft.

FLOW STATION 1 AS-BUILTS

HYDRAULIC DATA

DRAINAGE AREA		1.8 SQ. MI. = 1152 ACRES
STORMWATER DISCHARGE	c.f.s.	= 1350
TIDAL FLOW	c.f.s.	=
TOTAL MAXIMUM DISCHARGE	c.f.s.	= 1350
MAXIMUM FLOW DEPTH AT H.W.	FEET	= 9.75
OPENING BY TALBOT		
OPENING TO H.W.	SQ. FT.	= 224±
VELOCITY AT OUTLET	FT. PER SEC.	= 14.0

EXISTING STRUCTURE

TYPE
WATERWAY
UNDERCLEARANCE
DATE BUILT
OWNERSHIP
DISPOSITION
REMARKS

UTILITIES

STORM SEWERS
SANITARY SEWERS
WATER MAINS
GAS MAINS
ELECTRIC WIRES { OVERHEAD / UNDERGROUND
OTHER

TRAFFIC DATA

TRAFFIC COUNT = DATE
DESIGN SPEED = m.p.h.

DATUM

REVISIONS

STATE OF MARYLAND
STATE ROADS COMMISSION
BALTIMORE, MD.
INTERSTATE ROUTE 70N
DOUBLE 7'-0" x 8'-0" BOX CULVERT
AT STA. 653+87
PLAN & SECTIONS

SCALE As Shown DATE April 11, 1966 CONTRACT HO-305-5-742

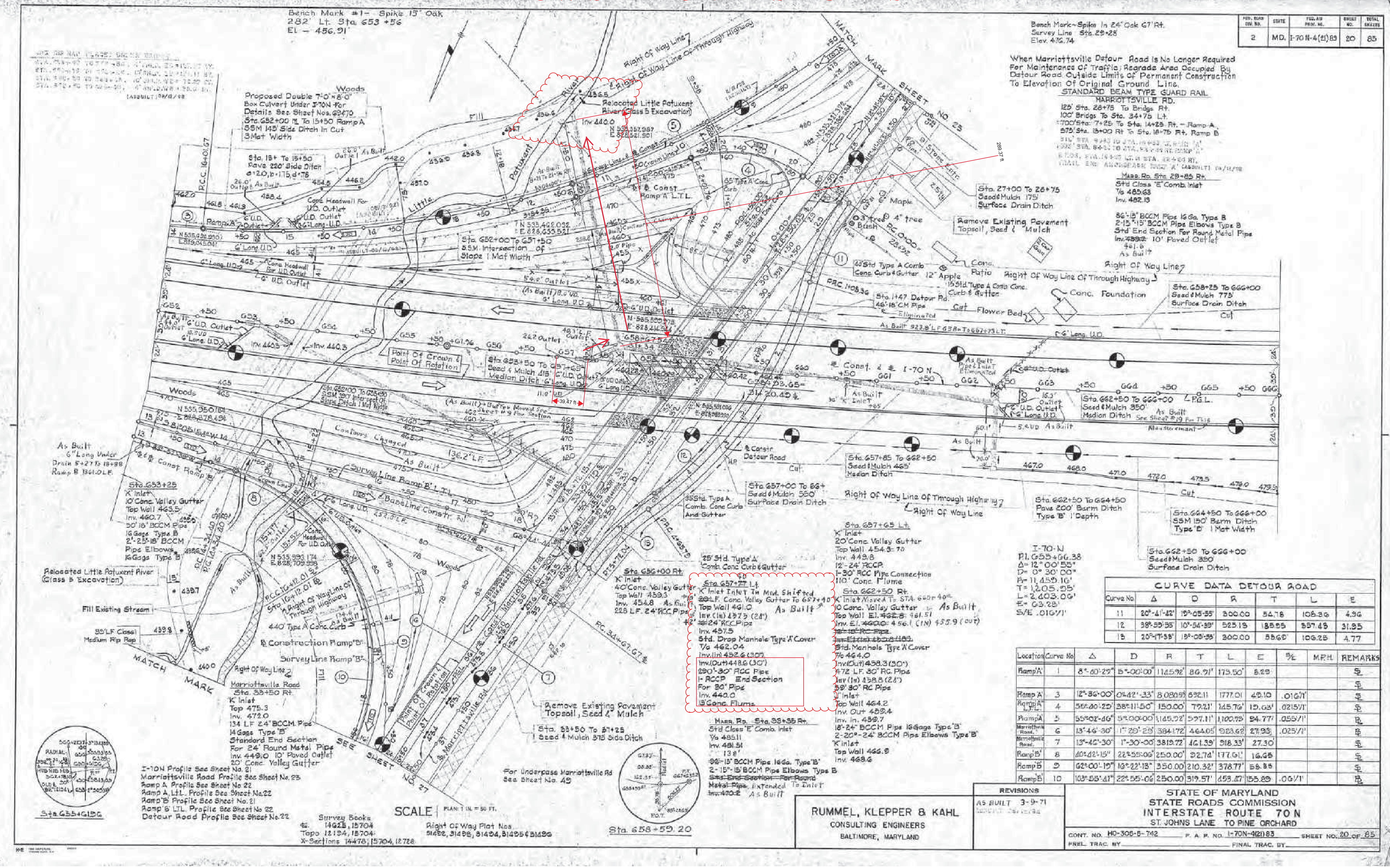
MADE BY W.F.H.
TRACED BY W.F.H.
CHECKED BY E.P.R.

5/16/66 CHIEF, BUREAU OF BRIDGES

SHEET NO. 71 OF 85

BRIDGE No. 1312.8X0 Survey Book No. File No. 2 Pocket No. 13 Folder No. 4 INDEXED

FLOW STATION 2 AS-BUILTS



FED. ROAD DIV. NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
2	MD.	I-70N-4(21)83	20	85

CURVE DATA DETOUR ROAD

Curve No	Δ	D	R	T	L	E
11	20°-41'-42"	19°-05'-55"	300.00	54.78	108.36	4.96
12	38°-55'-55"	10°-54'-39"	525.19	185.55	357.48	31.95
13	20°-17'-38"	19°-05'-55"	300.00	53.60'	106.28	4.77

Location	Curve No	Δ	D	R	T	L	E	S/E	M.P.H.	REMARKS
Ramp 'A'	1	8°-40'-29"	5°-00'-00"	1145.92'	86.91'	173.50'	5.29			SL
										SL
Ramp 'A'	3	12°-36'-00"	0°-42'-33"	8,080.93	892.11	1777.01	49.10	.016'/1'		SL
Ramp 'A' Lt.L.	4	55°-40'-25"	38°-11'-50"	150.00'	79.21'	145.76'	19.03'	.0215'/1'		SL
Ramp 'A'	5	55°-02'-46"	5°-00'-00"	1,145.92'	597.11'	1,100.79	94.77'	.055'/1'		BL
Marriottsville Road	6	13°-46'-30"	1°-29'-29"	3841.72'	464.05	923.62	27.93	.025'/1'		BL
Marriottsville Road	7	13°-46'-30"	1°-30'-00"	3819.72'	461.39'	918.33'	27.30'			SL
Ramp 'B'	8	40°-42'-15"	22°-55'-06"	250.00'	92.74'	177.61'	16.65			SL
Ramp 'B'	9	62°-00'-19"	16°-22'-13"	350.00	210.32'	378.77'	58.38			SL
Ramp 'B'	10	103°-58'-41"	22°-55'-06	250.00	319.57'	453.47'	155.89	.06'/1'		BL

REVISIONS
AS BUILT 3-9-71

RUMMEL, KLEPPER & KAHL
CONSULTING ENGINEERS
BALTIMORE, MARYLAND

STATE OF MARYLAND
STATE ROADS COMMISSION
INTERSTATE ROUTE 70 N
ST. JOHNS LANE TO PINE ORCHARD

CONT. NO. HO-305-5-742 F. A. P. NO. I-70N-4(21)83 SHEET NO. 20 OF 85
PREL. TRAC. BY FINAL TRAC. BY

Appendix F

Sediment Mobility Assessment Calculations

Cross Section 1 Year 3 Storm 1 (4/16/2020)

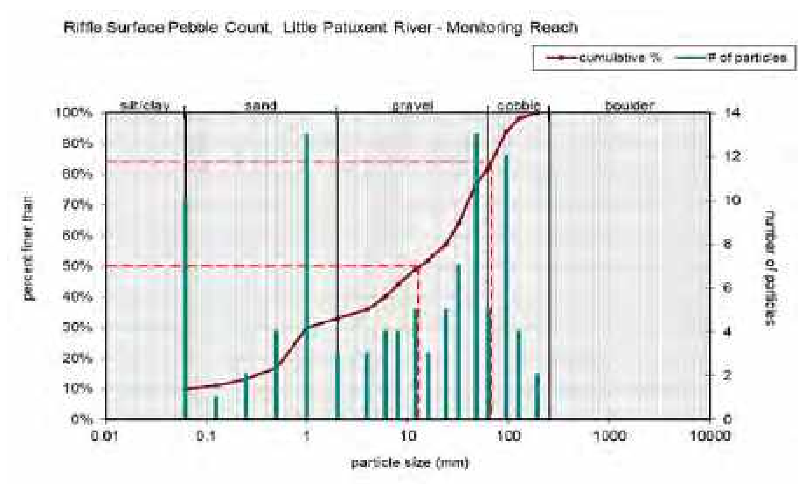
Critical Dimensionless Shear Stress	
$\tau^*_{ci} = a * (D_1/D_2)^b$	
D_1 = Largest size fraction considered mobile = D_i = D_{95}	100
D_2 = D_{50} bed matieral	13
a = constant	0.0376
b = constant	-0.994
τ^*_{ci}	0.004948

Critical Shear Stress, psf	
$\tau_{ci} = \tau^*_{ci} * (s-1) * \gamma * D_i$	
τ^*_{ci} = Critical Dimensionless Shear Stress	0.004948203
s = specific gravity for sediment	2.65
γ = specific weight of water, psf	62.4
D_1 = Largest size fraction considered mobile = D_i, ft	0.3281
τ_{ci} (psf)	0.1671

Average Boundary Shear Stress, psf	
$\tau_b = \gamma * Rh * S_f$	
γ = specific weight of water, psf	62.4
R_h = Bankfull Hydraulic Radius, ft	1.37
S_f = Bankfull energy slope, ft/ft	0.0119
τ_b, psf	1.0173

Channel Roughness	
$n = R_h^{1/6} * \frac{0.0926}{1.16 + 2LOG\frac{R_h}{D_{84}}}$	
R_h = Bankfull Hydraulic Radius, ft	1.37
D_{84} = Particle size larger than 84% other particles, ft	0.2264
n	0.036

Cross Section 1 Hydraulic Radius	
Rh	1.37



Cross Section 2 Year 3 Storm 1 (4/16/2020)

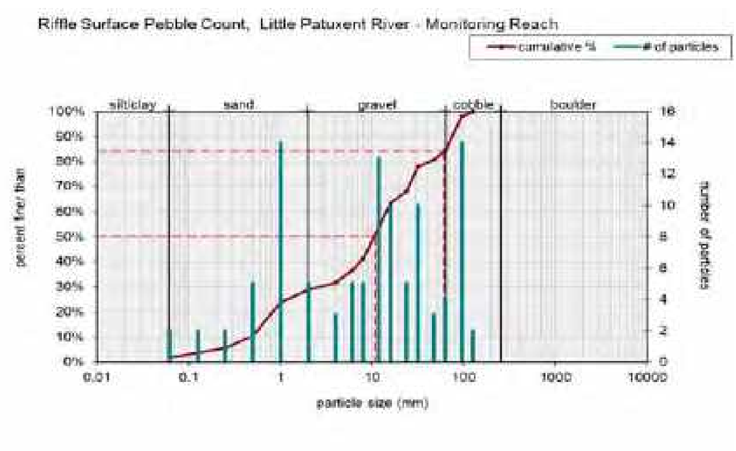
Critical Dimensionless Shear Stress	
$\tau^*_{ci} = a * (D_1/D_2)^b$	
D_1 = Largest size fraction considered mobile = D_i = D_{95}	88
D_2 = D_{50} bed matieral	11
a = constant	0.0376
b = constant	-0.994
τ^*_{ci}	0.00476

Critical Shear Stress, psf	
$\tau_{ci} = \tau^*_{ci} * (s-1) * \gamma * D_i$	
τ^*_{ci} = Critical Dimensionless Shear Stress	0.00476
s = specific gravity for sediment	2.65
γ = specific weight of water, psf	62.4
D_1 = Largest size fraction considered mobile = D_i, ft	0.2887
τ_{ci} (psf)	0.1415

Average Boundary Shear Stress, psf	
$\tau_b = \gamma * Rh * S_f$	
γ = specific weight of water, psf	62.4
R_h = Bankfull Hydraulic Radius, ft	1.25
S_f = Bankfull energy slope, ft/ft	0.0119
τ_b, psf	0.9282

Channel Roughness	
$n = R_h^{1/6} * \frac{0.0926}{1.16+2LOG\frac{R_h}{D_{84}}}$	
R_h = Bankfull Hydraulic Radius, ft	1.25
D_{84} = Particle size larger than 84% other particles, ft	0.2001
n	0.035

Cross Section 2 Hydraulic Radius	
Rh	1.25



Combined Reach Year 3 Storm 1 (4/16/2020)

Critical Dimensionless Shear Stress

$$\tau^*_{ci} = a * (D_1/D_2)^b$$

D_1 = Largest size fraction considered mobile = D_i = D_{95}	93
D_2 = D_{50} bed matieral	11
a = constant	0.0376
b = constant	-0.994
τ^*_{ci}	0.00450

Critical Shear Stress, psf

$$\tau_{ci} = \tau^*_{ci} * (s-1) * \gamma * D_i$$

τ^*_{ci} = Critical Dimensionless Shear Stress	0.00450
s = specific gravity for sediment	2.65
γ = specific weight of water, psf	62.4
D_1 = Largest size fraction considered mobile = D_i, ft	0.3051
τ_{ci} (psf)	0.1415

Average Boundary Shear Stress, psf

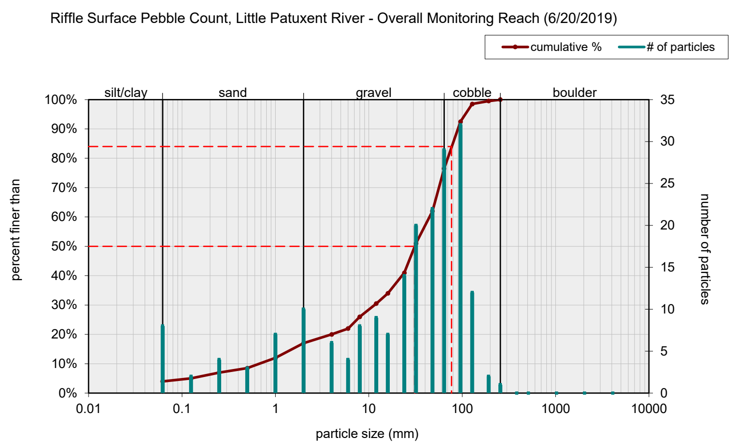
$$\tau_b = \gamma * Rh * S_f$$

γ = specific weight of water, psf	62.4
R_h = Bankfull Hydraulic Radius, ft (average of CS-1 & CS-2	1.31
S_f = Bankfull energy slope, ft/ft	0.0119
τ_b, psf	0.9728

Channel Roughness

$$n = R_h^{1/6} * \frac{0.0926}{1.16 + 2LOG\frac{R_h}{D_{84}}}$$

R_h = Bankfull Hydraulic Radius, ft	1.31
D_{84} = Particle size larger than 84% other particles, ft	0.2133
n	0.035



Year 3 Storm 1 (4/16/2020)

	Cross Section 1	Cross Section 2	Overall Monitoring Reach
Critical Dimensionless Shear Stress	0.0049	0.0048	0.0045
Critical Shear Stress (psf)	0.1671	0.1415	0.1415
Average Boundary Shear Stress (psf)	1.0173	0.9282	0.9728

Year 3 Storm 1 (4/16/2020)

	Cross Section 1	Cross Section 2	Overall Monitoring Reach
Channel Roughness, n	0.036	0.035	0.035

Cross Section 1 Year 3 Storm 2 (5/8/2020)

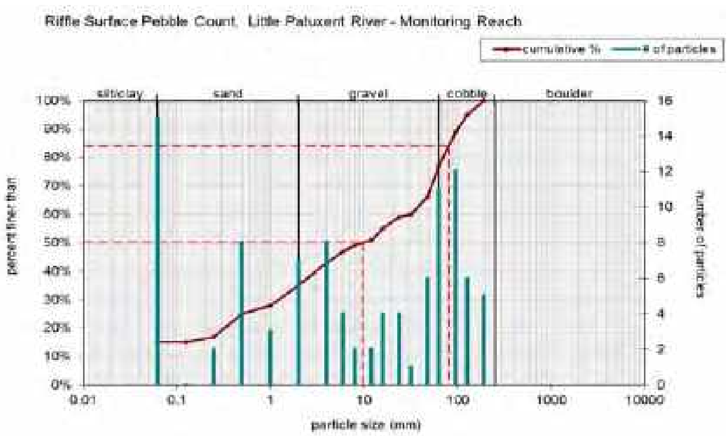
Critical Dimensionless Shear Stress	
$\tau^*_{ci} = a * (D_1/D_2)^b$	
D_1 = Largest size fraction considered mobile = D_i = D_{95}	130
D_2 = D_{50} bed matieral	9.8
a = constant	0.0376
b = constant	-0.994
τ^*_{ci}	0.002879

Critical Shear Stress, psf	
$\tau_{ci} = \tau^*_{ci} * (s-1) * \gamma * D_i$	
τ^*_{ci} = Critical Dimensionless Shear Stress	0.002878769
s = specific gravity for sediment	2.65
γ = specific weight of water, psf	62.4
D_1 = Largest size fraction considered mobile = D_i, ft	0.4265
τ_{ci} (psf)	0.1264

Average Boundary Shear Stress, psf	
$\tau_b = \gamma * Rh * S_f$	
γ = specific weight of water, psf	62.4
R_h = Bankfull Hydraulic Radius, ft	1.33
S_f = Bankfull energy slope, ft/ft	0.0118
τ_b, psf	0.9793

Channel Roughness	
$n = R_h^{1/6} * \frac{0.0926}{1.16+2LOG\frac{R_h}{D_{84}}}$	
R_h = Bankfull Hydraulic Radius, ft	1.33
D_{84} = Particle size larger than 84% other particles, ft	0.2657
n	0.038

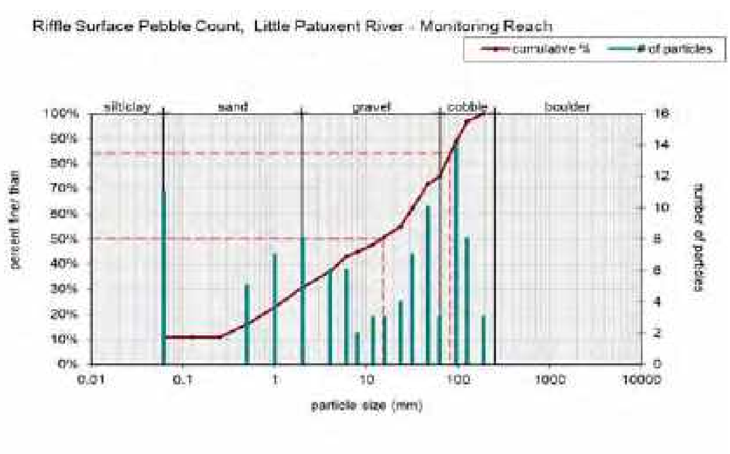
Cross Section 1 Hydraulic Radius	
Rh	1.33



Cross Section 2 Year 3 Storm 2 (5/8/2020)

Critical Dimensionless Shear Stress	
$\tau^*_{ci} = a * (D_1/D_2)^b$	
D_1 = Largest size fraction considered mobile = D_i = D_{95}	120
D_2 = D_{50} bed matieral	15
a = constant	0.0376
b = constant	-0.994
τ^*_{ci}	0.00476

Critical Shear Stress, psf	
$\tau_{ci} = \tau^*_{ci} * (s-1) * \gamma * D_i$	
τ^*_{ci} = Critical Dimensionless Shear Stress	0.00476
s = specific gravity for sediment	2.65
γ = specific weight of water, psf	62.4
D_1 = Largest size fraction considered mobile = D_i , ft	0.3937
τ_{ci} (psf)	0.1929



Average Boundary Shear Stress, psf	
$\tau_b = \gamma * Rh * S_f$	
γ = specific weight of water, psf	62.4
R_h = Bankfull Hydraulic Radius, ft	1.2
S_f = Bankfull energy slope, ft/ft	0.0118
τ_b , psf	0.8836

Channel Roughness	
$n = {R_h}^{1/6} * \frac{0.0926}{1.16+2LOG\frac{R_h}{D_{84}}}$	
R_h = Bankfull Hydraulic Radius, ft	1.2
D_{84} = Particle size larger than 84% other particles, ft	0.2723
n	0.039

Cross Section 2 Hydraulic Radius	
Rh	1.20

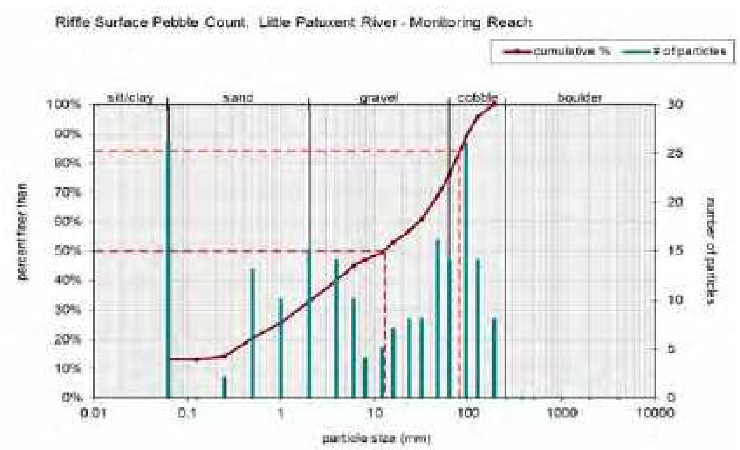
Combined Reach Year 3 Storm 2 (5/8/2020)

Critical Dimensionless Shear Stress $\tau^*_{ci} = a * (D_1/D_2)^b$	
D_1 = Largest size fraction considered mobile = D_i = D_{95}	120
D_2 = D_{50} bed matieral	13
a = constant	0.0376
b = constant	-0.994
τ^*_{ci}	0.00413

Critical Shear Stress, psf $\tau_{ci} = \tau^*_{ci} * (s-1) * \gamma * D_i$	
τ^*_{ci} = Critical Dimensionless Shear Stress	0.00413
s = specific gravity for sediment	2.65
γ = specific weight of water, psf	62.4
D_1 = Largest size fraction considered mobile = D_i, ft	0.3937
τ_{ci} (psf)	0.1673

Average Boundary Shear Stress, psf $\tau_b = \gamma * Rh * S_f$	
γ = specific weight of water, psf	62.4
R_h = Bankfull Hydraulic Radius, ft (average of CS-1 & CS-2	1.265
S_f = Bankfull energy slope, ft/ft	0.0118
τ_b, psf	0.9314

Channel Roughness $n = R_h^{1/6} * \frac{0.0926}{1.16 + 2LOG\frac{R_h}{D_{84}}}$	
R_h = Bankfull Hydraulic Radius, ft	1.265
D_{84} = Particle size larger than 84% other particles, ft	0.2690
n	0.038



Year 3 Storm 2 (5/8/2020)

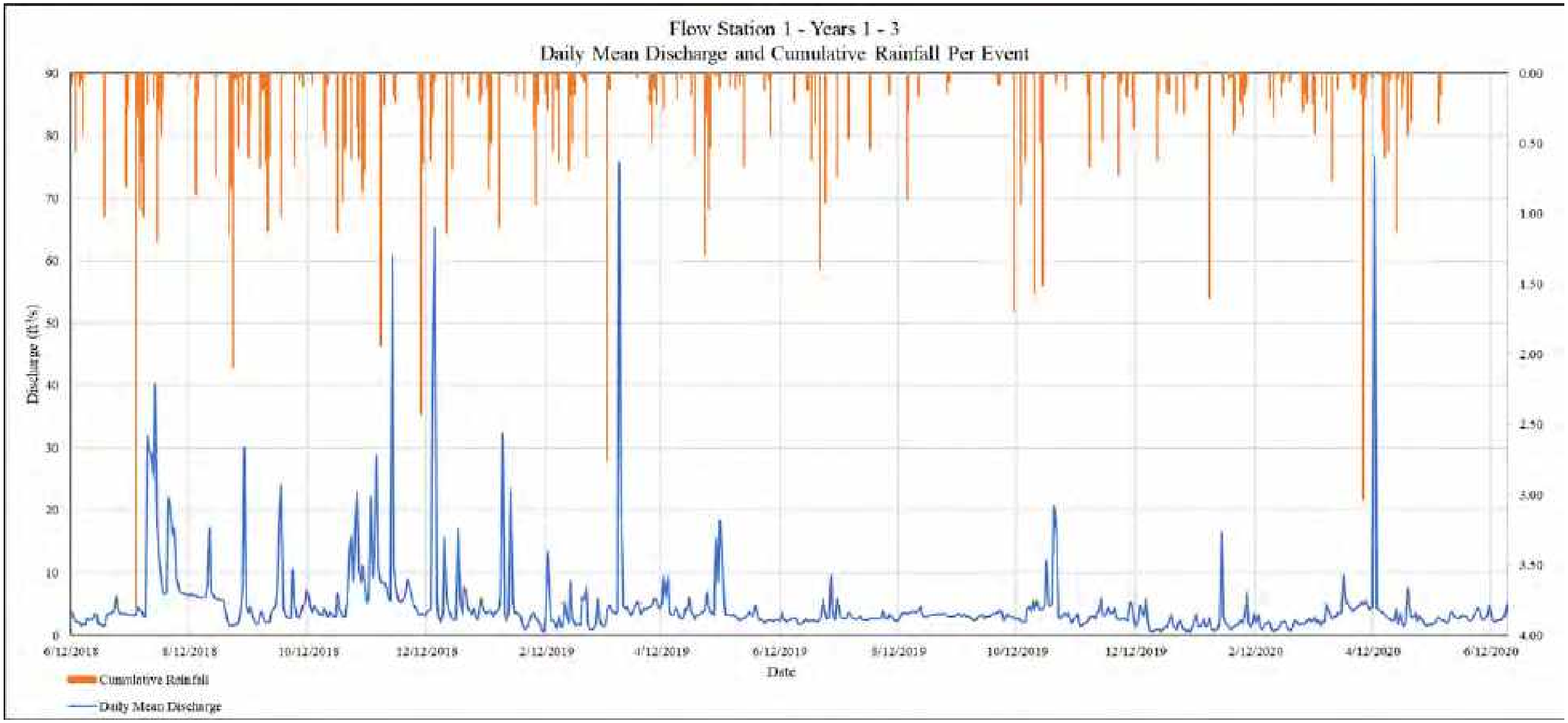
	Cross Section 1	Cross Section 2	Overall Monitoring Reach
Critical Dimensionless Shear Stress	0.0029	0.0048	0.0041
Critical Shear Stress (psf)	0.1264	0.1929	0.1673
Average Boundary Shear Stress (psf)	0.9793	0.8836	0.9314

Year 3 Storm 2 (5/8/2020)

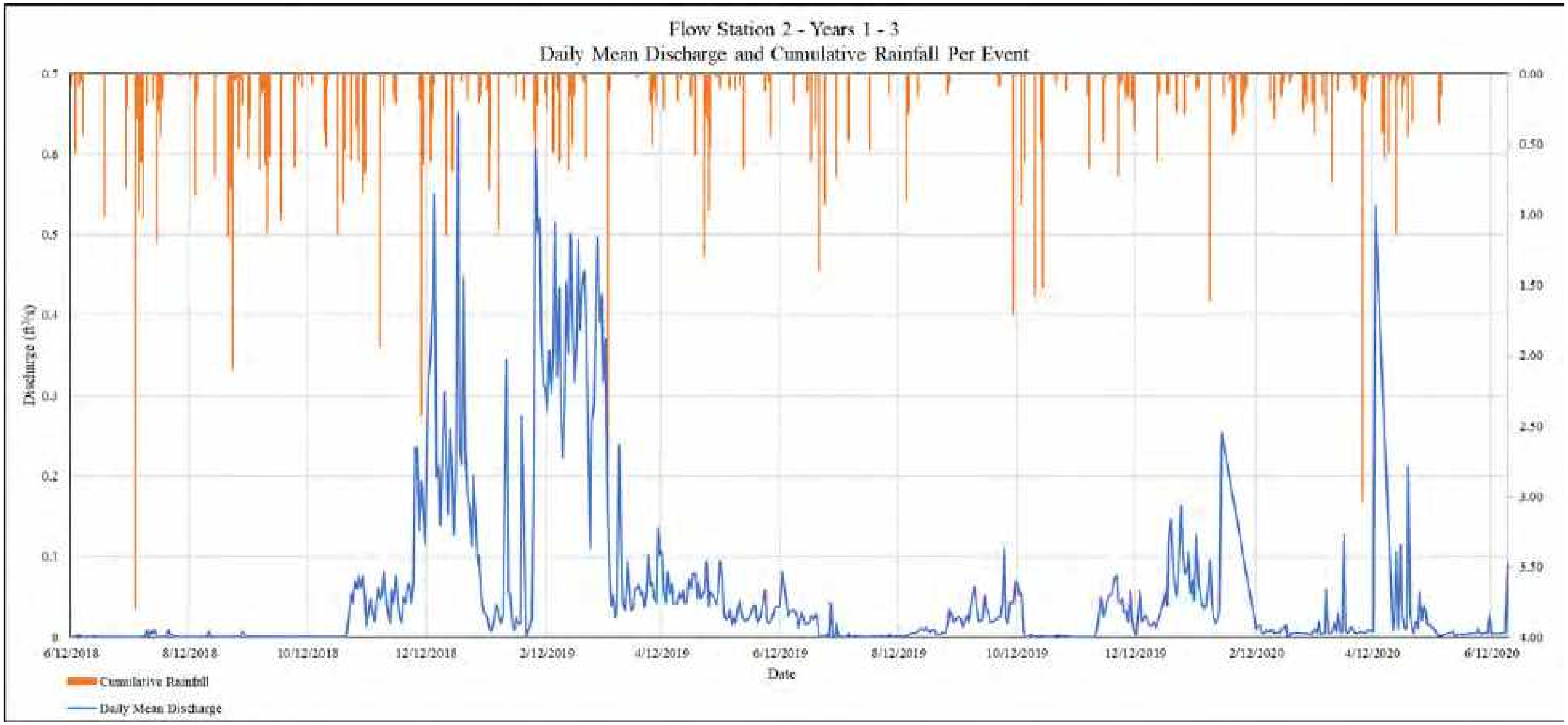
	Cross Section 1	Cross Section 2	Overall Monitoring Reach
Channel Roughness, n	0.038	0.039	0.038

Appendix G

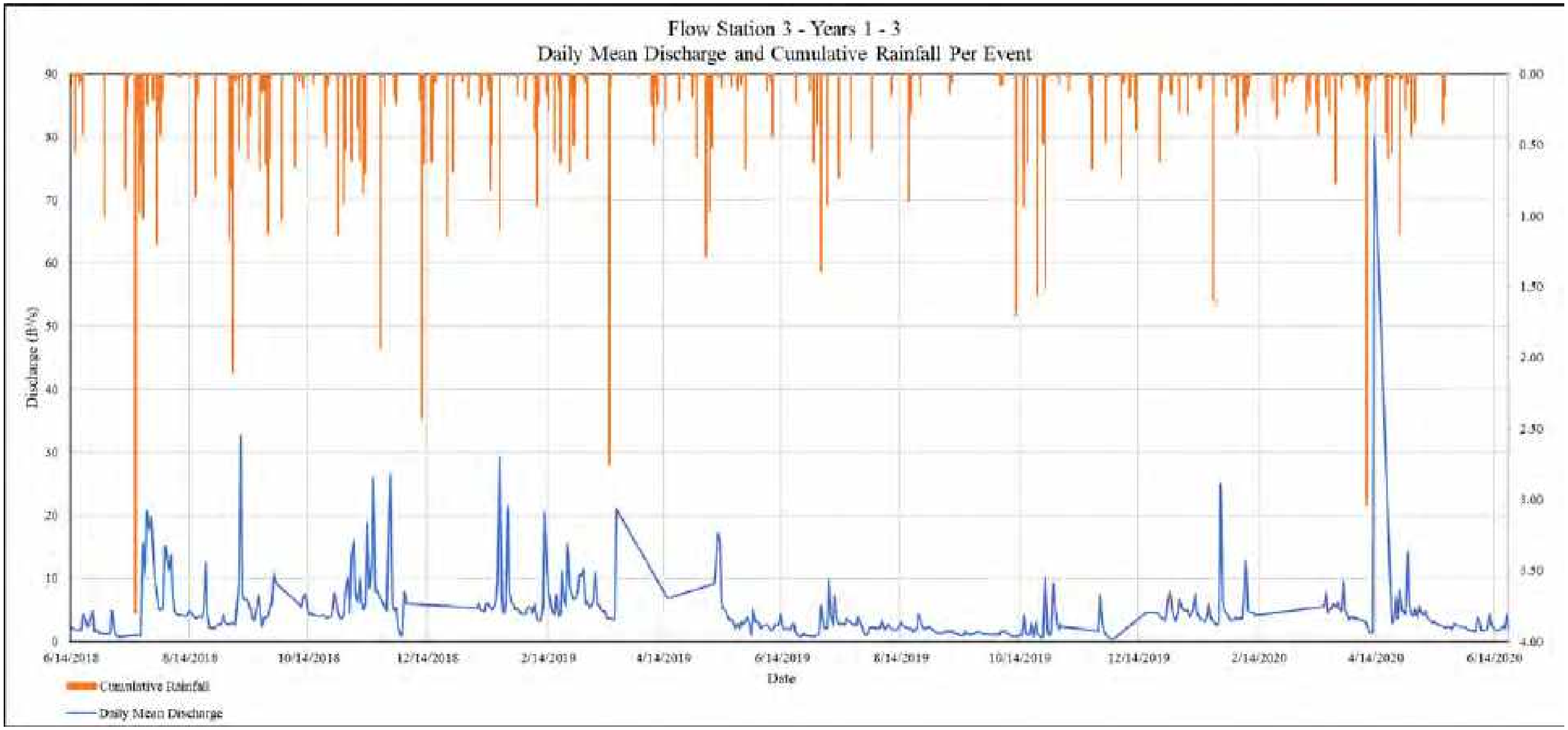
Daily Mean Discharge



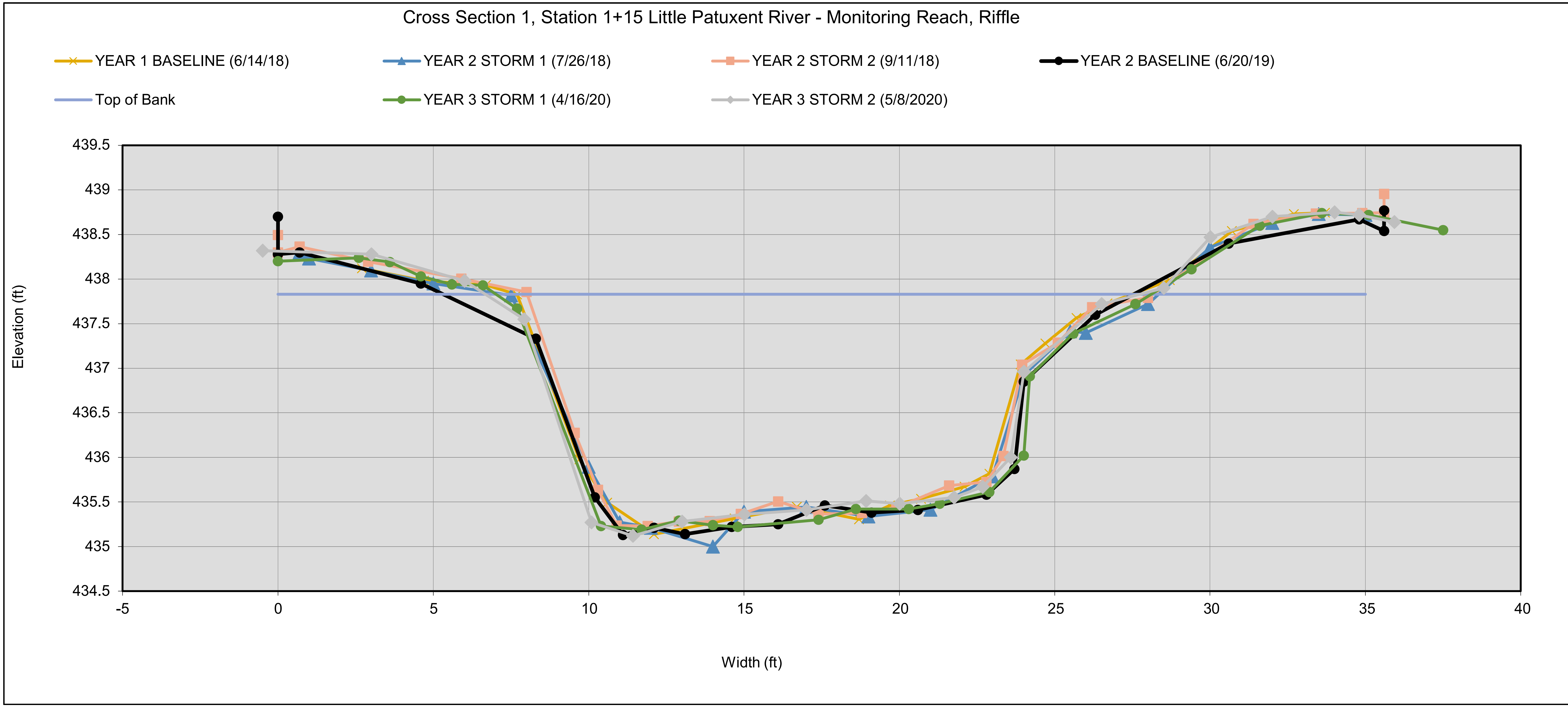
Flow Station 1 - Years 1 - 3
Daily Mean Discharge and Cumulative Rainfall Per Event
Discharge (ft³/s)
Date
Cumulative Rainfall
Daily Mean Discharge
6/12/2018
8/12/2018
10/12/2018
12/12/2018
2/12/2019
4/12/2019
6/12/2019
8/12/2019
10/12/2019
12/12/2019
2/12/2020
4/12/2020
6/12/2020

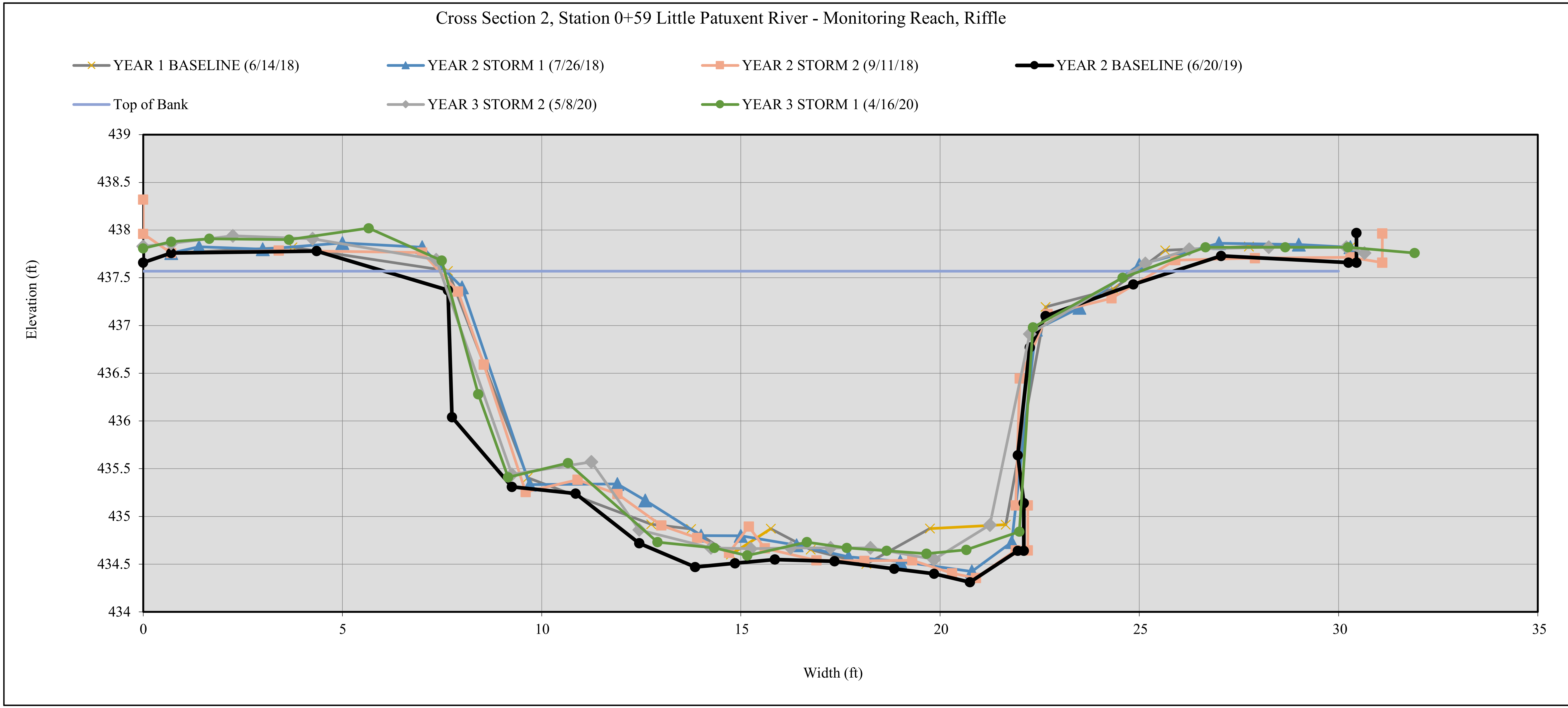


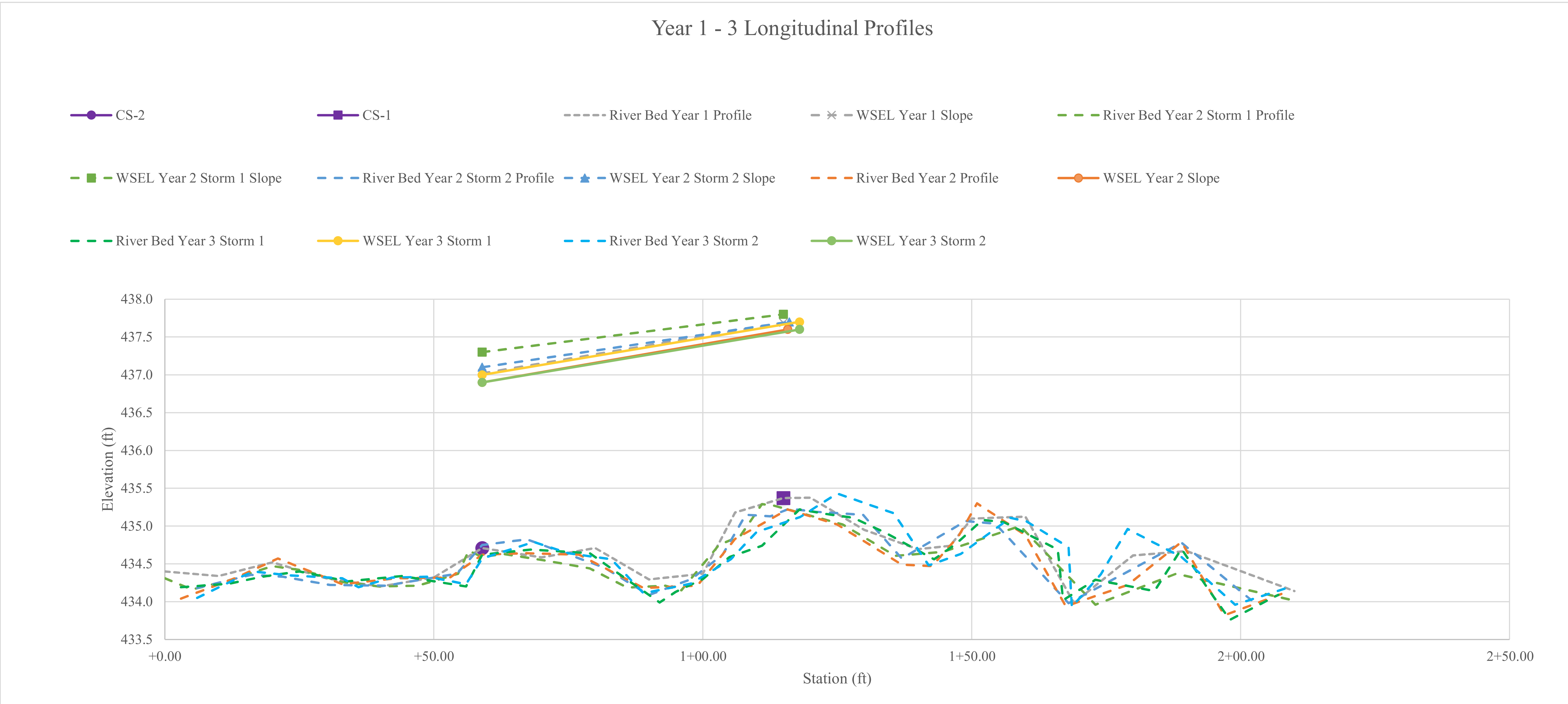
Flow Station 2 - Years 1 - 3
Daily Mean Discharge and Cumulative Rainfall Per Event
Discharge (ft³/s)
Date
6/12/2018
8/12/2018
10/12/2018
12/12/2018
2/12/2019
4/12/2019
6/12/2019
8/12/2019
10/12/2019
12/12/2019
2/12/2020
4/12/2020
6/12/2020
Cumulative Rainfall
Daily Mean Discharge


Flow Station 3 - Years 1 - 3
Daily Mean Discharge and Cumulative Rainfall Per Event
Discharge (ft³/s)
Date
Cumulative Rainfall
Daily Mean Discharge
6/14/2018
8/14/2018
10/14/2018
12/14/2018
2/14/2019
4/14/2019
6/14/2019
8/14/2019
10/14/2019
12/14/2019
2/14/2020
4/14/2020
6/14/2020

Appendix H
Physical Monitoring
Figures


Cross Section 1, Station 1+15 Little Patuxent River - Monitoring Reach, Riffle
YEAR 1 BASELINE (6/14/18)
YEAR 2 STORM 1 (7/26/18)
YEAR 2 STORM 2 (9/11/18)
YEAR 2 BASELINE (6/20/19)
Top of Bank
YEAR 3 STORM 1 (4/16/20)
YEAR 3 STORM 2 (5/8/2020)
Elevation (ft)
439.5
439
438.5
438
437.5
437
436.5
436
435.5
435
434.5
-5
0
5
10
15
20
25
30
35
40
Width (ft)


Cross Section 2, Station 0+59 Little Patuxent River - Monitoring Reach, Riffle
YEAR 1 BASELINE (6/14/18)
YEAR 2 STORM 1 (7/26/18)
YEAR 2 STORM 2 (9/11/18)
YEAR 2 BASELINE (6/20/19)
Top of Bank
YEAR 3 STORM 2 (5/8/20)
YEAR 3 STORM 1 (4/16/20)
Elevation (ft)
439
438.5
438
437.5
437
436.5
436
435.5
435
434.5
434
0
5
10
15
20
25
30
35
Width (ft)


Year 1 - 3 Longitudinal Profiles
CS-2
CS-1
River Bed Year 1 Profile
WSEL Year 1 Slope
River Bed Year 2 Storm 1 Profile
WSEL Year 2 Storm 1 Slope
River Bed Year 2 Storm 2 Profile
WSEL Year 2 Storm 2 Slope
River Bed Year 2 Profile
WSEL Year 2 Slope
River Bed Year 3 Storm 1
WSEL Year 3 Storm 1
River Bed Year 3 Storm 2
WSEL Year 3 Storm 2
Elevation (ft)
438.0
437.5
437.0
436.5
436.0
435.5
435.0
434.5
434.0
433.5
+0.00
+50.00
1+00.00
1+50.00
2+00.00
2+50.00
Station (ft)

Appendix I

Calibration, Quality Control and Interpolations

<u>Continuous Flow</u>

<u>Calibration:</u> Calibration was performed on June 21, 2018, for Flow Station 3 after the area-velocity meter was installed as part of the initial calibration of the field equipment. There was a discrepancy between the recorded field measurement of 11.25-inches at 11:15AM and the reported stage of 13.2 inches at 11:16AM. The system configuration was reviewed for the source of the error. Final calibration for the area-velocity meter occurred on June 27, 2018. The parameter adjusted for calibration was the difference in height of where the depth readings are taken and the bottom of the area-velocity meter and mounting plate. This affects what the area-velocity meter computes as stage for LPR. After correcting the system calculation for stage, the recorded value of stage was 0.856 feet at 10:24AM on June 27, 2018. Comparing this value to the measured field measurement of 0.854 feet at 10:33AM confirms that the correction correctly calibrated the instrument. The corrected parameter is measurable, so this difference could be applied to the uncalibrated stage measurements to give a reasonable estimate of the actual stage measurement. This corrected stage measurement did have an effect on the flow and total flow volume computed by the instrument, so these parameters were also corrected. A simple field test was performed on June 21, 2018, to determine if the velocity values were reasonable. A piece of paper was placed in the stream and was timed as it traveled along a measured distance. Two tests at two different intervals—25 feet and 10 feet—were performed. The estimated velocity of the water yielded an average value of 1.19 ft/sec. This value was compared to the area-velocity beam that was closest to the path the paper traveled along the stream. This was chosen because the average velocity calculated by the area-velocity meter uses four separate beams that cover the entire cross sections and different depths. The chosen beam is directed towards the water surface on the left side of the channel. The average value recorded during the test was 1.17 ft/sec which is comparable to the average value calculated from the field tests.

At Flow Station 2, during Years 1 and 2, there were several periods during which there was no water within the pipe. During these periods, the pressure measured by the logger was so low that, after compensation for barometric pressure, the values for stage were negative. When analyzing the data, all negative values were entered as 0.00 feet. Values below 0.00 feet should be considered as no flow at the outfall. MDOT SHA also needed to increase the stage for this station by 0.156-inches to account for the thickness of the PVC pipe logger housing. This correction is only applied during flow events so that the correction does not account for depth when no water is in the outfall.

<u>Quality Control</u>: Quality control was performed for the continuous flow monitoring equipment each month after downloading data. This was performed to ensure that the data collected was complete, representative, comparable, and of known quality. The data was plotted as needed and verified through visual inspection. The data from all logging devices were also inspected for accuracy. Data anomalies that occurred from equipment handling during monthly data download, low battery, clogged sensors, or malfunctioning equipment were documented and removed from analysis. The majority of data anomalies were relatively short period of times, 24 hours or less. Data anomalies that caused gaps longer than this are discussed below. Field measurements of water depth during monthly site visits were compared to the monitoring equipment logs to ensure the accuracy of the results. During Year 3, these measurements were also used to calibrate the water level data at Flow Station 1 & 2, as noted in the Section 3.2.1. Since a reference water level was used for Flow Station 1 and 2, the field measurements reflect the measured depth for that time. Since Flow Station 3 self-adjusts for barometric pressure so a reference water level was not used during barometric compensation. The differences between field measurements and data points used for analysis at Flow Station 3 had a maximum difference of less than one inch. The largest differences occurred when comparing the stage values. Stage is not a measured parameter but calculated based on the depth sensor and the distance from the bottom of the meter to the depth sensor. This distance was measured when the meter

was installed and is a static value. The differences are believed to be due to the fact that the stage directly beneath the area-velocity meter cannot be measured due to the area-velocity meter itself. Therefore, stage measurements were taken adjacent to the meter. Since the stream bottom will slightly vary from the stream bottom at the area-velocity meter, this is likely the difference in the field and equipment stage measurements. The comparison of water depth for Flow Station 3 is less variable, with the maximum difference in measurements being 0.36 inches and the average as 0.01 inches. This would have an average potential difference of 0.75% on the calculated flow. This difference is likely due to the inaccuracy of field measurements, where the turbulence of the stream flow causes exact water depth measurements to be difficult. The turbulence of the water will cause the water line along the measuring device to slightly fluctuate up and down when it obstructs the flow. The differences between the field measurements and the equipment logged values is negligible and all data is believed to be representative of the site conditions.

Two peak stage and discharge events at Flow Station 2 were removed from analysis. These events occurred on January 21, 2019 and January 31, 2019. MDOT SHA removed these events because they were not supported by local rainfall data and appear to be anomalous. The events could have been from an ice build-up, based on the time of year they occurred.

Quality control was performed on the rain gauge when it was installed. The rain gauge in Figure 1 shows data recorded on June 20, 2018. Using the raw data file containing tip timestamps and known amount of rain per tip (.01”), cumulative rainfall (primary axis) and intensity (secondary axis) were calculated.

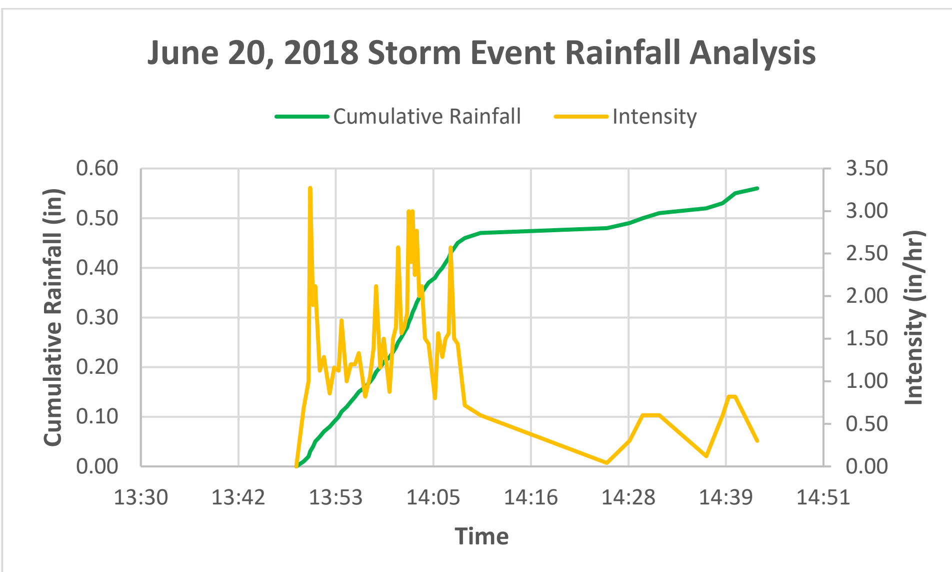


Figure 1. June 20, 2018 storm event rainfall analysis

To determine the validity of the results, MDOT SHA compared this rain event to a near-by independent rain gauge. The closest rain gauge with readily available data is the Thompson Drive (KMDELLIC68) weather station from Weather Underground (https://www.wunderground.com/personal-weather-station/dashboard?ID=KMDELLIC68). The rain gauge is approximately 1.20 miles west of the project rain gauge and is considered comparable due to its proximity. Figure 2 shows the cumulative rainfall recorded by the Weather Underground rain gauge and the project rain gauge from the rain event on June 20, 2018.

The lag between the events is explained by the difference in rain gauge locations. The difference between cumulative rainfall results is minimal and probably due to the path of the storm.

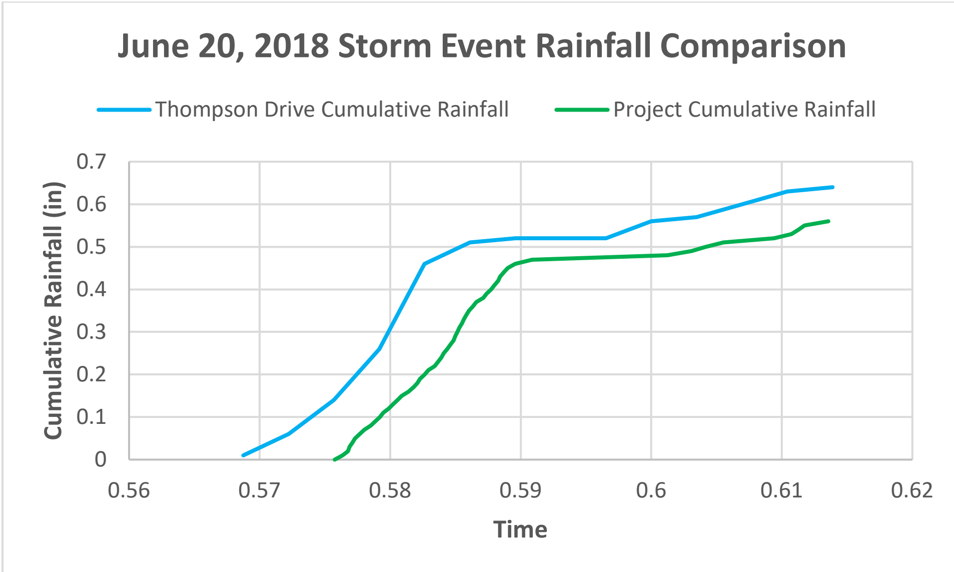


Figure 2. June 20, 2018 storm event rainfall comparison

Quality control of the recorded water temperature values was performed on July 18, 2018. A YSI Professional Plus water quality instrument was used for a field measurement while on-site at Flow Station 3. The field measurement at 10:11 AM yielded a value of 20.3 degrees Celsius or 68.5 degrees Fahrenheit. Comparing this to the recorded value of 68.9 degrees Fahrenheit at 9:54 AM for Flow Station 3, the equipment is believed to be operating correctly. Furthermore, the parallel values recorded between Flow Station 1 and 3 also confirm that the temperature is being measured accurately. The difference in Flow Station 2 water temperature when compared to Flow Station 1 and Flow Station 3 is likely due to the fact that the water from Flow Station 2 is runoff from I-70. This runoff travels across dark-colored impervious surfaces, which has the ability to retain heat and therefore transfer this energy to the water as it travels across its surface. See Figure 3 below for a comparison of water temperatures during Year 1 monitoring.

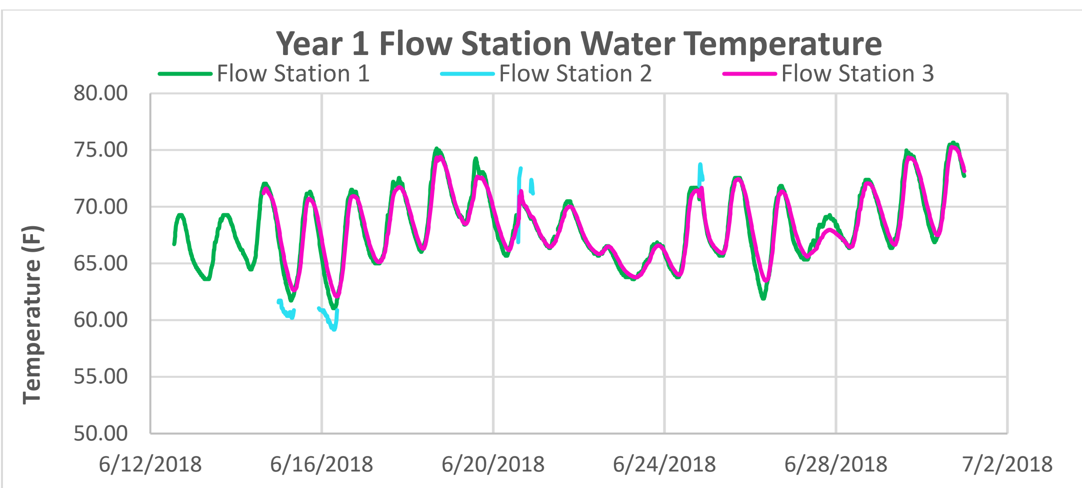


Figure 3. Year 1 Flow Station Water Temperature

Data interpolation: Data interpolation for the flow stations was performed to fill in gaps in the collected data due to equipment malfunction and data removed due to irregularities so that total discharge volume for the monitoring period could be calculated. Most of the time periods for which interpolation was used are relatively short, between 10 minutes and 24 hours. For these instances, the last recorded discharge value was applied to the period of time missing to estimate the total flow volume. Flow Station 3 was the only continuous flow monitoring station where interpolations greater than 24-hours occurred. Total discharge volume was estimated for these periods by averaging the daily mean discharge recorded at Flow Station 1 and applying the value to the gap in discharges for Flow Station 3. By using the average daily mean discharge at Flow Station 1 for that time period, a more accurate estimate of the flow conditions was used when interpolating. Flow Station 1 was chosen because it is the only other flow station on site with discharge data for those time periods. The alternative would be to use the last known data point at Flow Station 3, but that would not account for the change in discharge during the time gap. Table 1 provides a breakdown of when data interpolation was performed for periods exceeding 24-hours at Flow Station 3.

Table 1. Flow Station 3 Total Discharge Volume Interpolation Summary

Start Date of Interpolation	Start Time of Interpolation	End Date of Interpolation	End Time of Interpolation	Reason Interpolation Needed	Discharge Value Used in Interpolation
7/11/2018	3:24	7/18/2018	11:23	Debris wedged under velocity meter caused it to exceed tilt values	3.78
9/27/2018	21:24	10/9/2018	15:43	Power failure - low battery and firmware malfunction	7.31
11/11/2018	16:23	11/12/2018	20:13	System Error - errant data values due to debris jams	5.77
11/25/2018	8:13	11/26/2018	16:43	System Error - errant data values due to debris jams	10.16
12/3/2018	8:13	1/8/2019	10:13	Equipment malfunction - defaulted back to idle mode after monthly download	7.92
1/10/2019	16:33	1/12/2019	11:53	System Error - errant data values due to debris jams	4.06
3/21/2019	18:13	4/16/2019	11:10	Power failure - low battery	8.54
4/16/2019	11:40	5/10/2019	11:08	Power failure - faulty battery	4.49
6/12/2019	0:58	6/13/2019	3:48	System Error - errant data values due to debris jams	3.15
9/26/2019	2:53	10/3/2019	22:43	System Error - errant data values due to debris jams	8.46

11/5/2019	14:43	11/22/2019	16:03	System Error - errant data values due to debris jams	11.85
12/1/2019	14:43	12/18/2019	12:43	Ash tree fell across study reach causing debris jam	10.12
12/18/2019	13:15	12/24/2019	16:06	Equipment malfunction during battery replacement	5.90
2/12/2020	15:26	3/18/2020	10:53	Equipment malfunction - defaulted back to idle mode after monthly download	3.34
4/13/2020	15:53	4/22/2020	14:27	System Error – errant data values due to debris jam and power failure - low battery	4.91

Physical Monitoring

Quality Control: Survey 1 or Year 1 baseline survey was performed on June 13, 2018. During quality control checks of the cross-sectional data, an error was discovered based on the difference in calculated elevations of the monuments when compared to the GPS survey results. After examination of the survey results, it was concluded that the laser level used during Survey 1 was not self-leveling due to an incorrect setting. The data from the survey was analyzed to determine corrective actions. A correction function for the data was calculated using two assumptions. The first assumption is that the error for the right bank monument is zero. For Survey 1, the laser level was set-up along the right bank of the LPR. This would indicate that the error from the surveyed data points would increase linearly as the survey progressed further from the laser level. The second assumption was that the elevations calculated for the monuments is accurate. Using these assumptions, the difference between the survey left bank elevation and the GPS elevation was calculated. A linear function representing the survey error across the cross section was determined and used to correct the survey data points collected in the field.

To validate the results of this correction to Survey 1, another survey of the cross sections, Survey 2, was performed on August 7, 2018, using the proper self-leveling settings for the laser level. Results of Survey 2 compared to the benchmark elevations at Cross Section 1 were within .04 feet of each other, while Cross Section 2 was within 0.12 feet. A real-time kinematic GPS unit was used to survey the elevations of the benchmarks. Depending on the exact GPS unit used and the distance to the base station, an accuracy of 0.15 feet can be expected. Since the survey results are within this range, it is believed that the results from the survey are reasonable.

Survey 2 results were then overlaid with the Survey 1 to see how they compared. The top of bank elevations were determined to have minimal elevation differences while some change can be seen along the stream bottom, which is to be expected for an active stream where the riverbed material is dynamic. Based on these results and the accuracy to be expected from this type of physical monitoring, the corrected data from Survey 1 is believed to be acceptable and was used as the Year 1 baseline survey for the project.

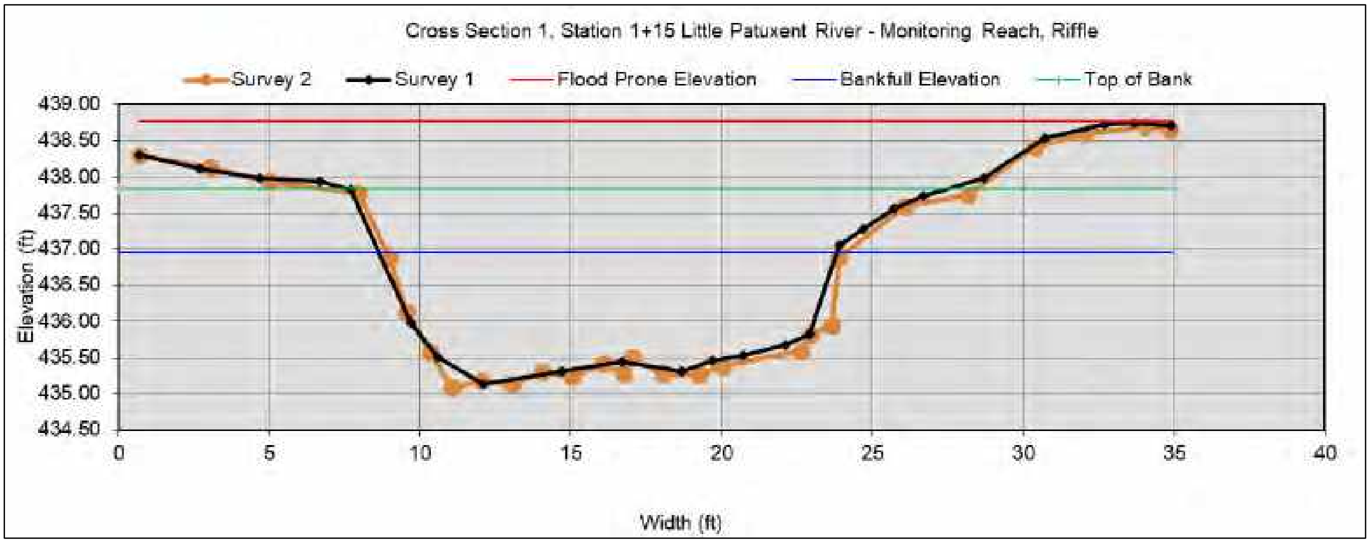


Figure 4. Survey 1 and 2 comparison at Cross Section 1

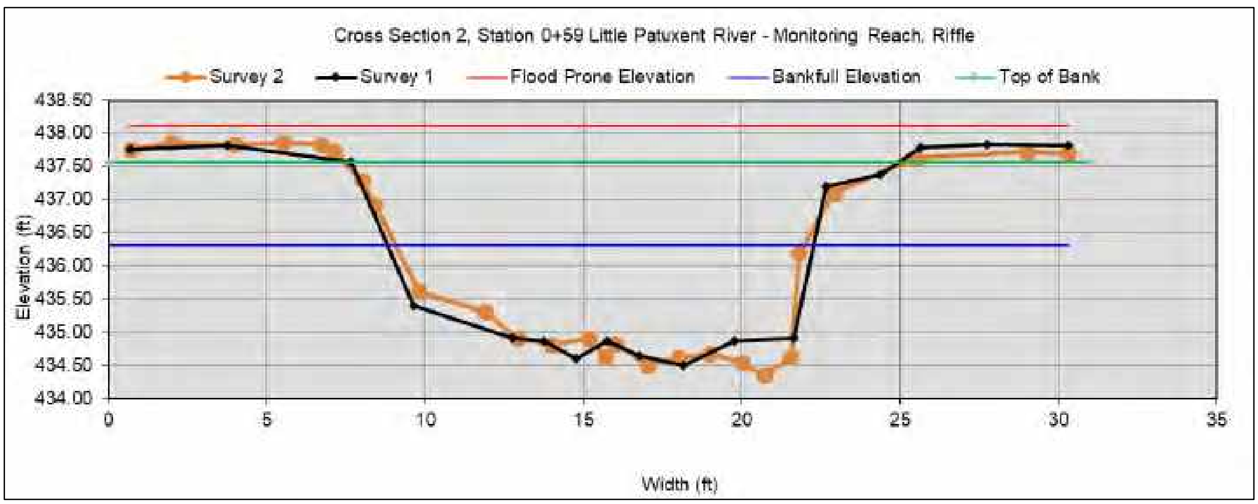
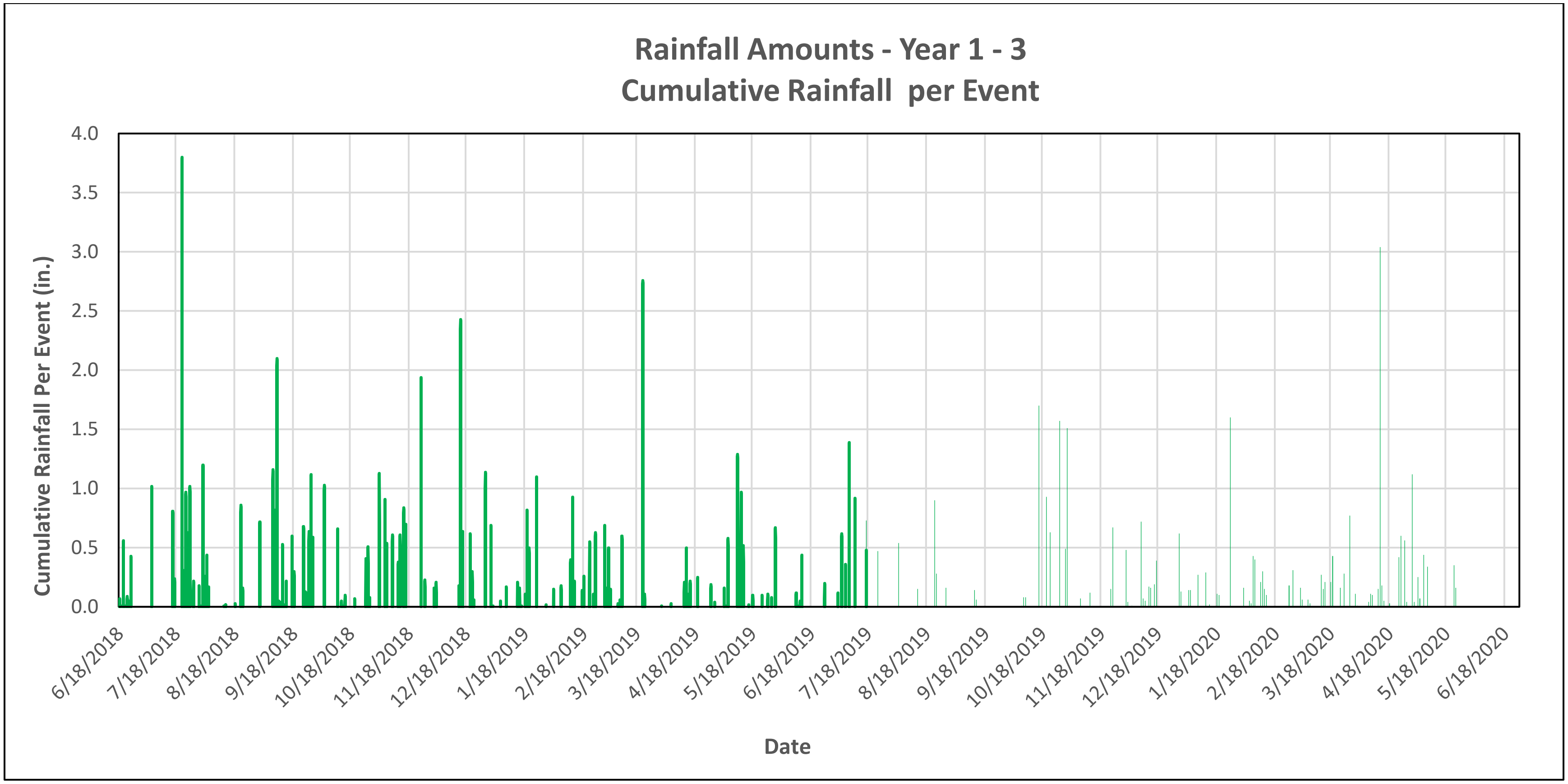


Figure 5. Survey 1 and 2 comparison at Cross Section 2

Appendix J

Cumulative Rainfall per Rain Event over Years 1 and 2


Rainfall Amounts - Year 1 - 3
Cumulative Rainfall per Event
Cumulative Rainfall Per Event (in.)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
6/18/2018
7/18/2018
8/18/2018
9/18/2018
10/18/2018
11/18/2018
12/18/2018
1/18/2019
2/18/2019
3/18/2019
4/18/2019
5/18/2019
6/18/2019
7/18/2019
8/18/2019
9/18/2019
10/18/2019
11/18/2019
12/18/2019
1/18/2020
2/18/2020
3/18/2020
4/18/2020
5/18/2020
6/18/2020
Date