BRIDGETON TOWNSHIP DELAWARE RIVER STREAMBANK EROSION STUDY
November 2020

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1.0 Introduction

Bridgeton Township (herein referred to as Bridgeton) contracted Rippled Waters Engineering, LLC (herein referred to as RWE) to conduct an erosion analysis on several areas of concern (herein referred to as AOCs) within the Township. There are seven Areas of Concern within the scope of this report as listed below:

- Area of Concern #1 – Located at the northern end of Trails End Lane
- Area of Concern #2 – Located just north of the intersection of Trails End Lane and River Road along Trails End Lane
- Area of Concern #3 – Located near the discharge from an unnamed tributary to the Delaware across the street from Riverside Antiques
- Area of Concern #4 – Located between Area of Concern #3 and Area of Concern #5 along River Road
- Area of Concern #5 – Located immediately north of the Milford/Upper Black Eddy Bridge crossing the Delaware
- Area of Concern #6 – Located south of the bridge in an area where the roadway and the top of the streambank are very close
- Area of Concern #7 – Located near the municipal border with Tinicum Township

Generally, the AOCs are located along a 1.9-mile stretch of River Road (PA Route 32) from the border with Tinicum township to the beginning of Trails End Lane and the full extent of Trails End Lane representing a total of 2.3 miles of linear distance along these roadways. Based on our understanding, the project goals are as follows: (1) to analyze selected erosion sites, (2) determine the cause of erosion and to (3) propose stabilization measures to abate further erosion.

This report includes the results of our investigation into the erosion sites. In addition, it will give an overview of the soils, geology, and streams within the study area. Potential solutions will be reviewed for river and stormwater erosion including relative costs for implementation, an outline of the regulatory process for the solution implementation, as well as recommendations for moving forward.

2.0 Site Overview

The project area is located in Bridgeton Township, Bucks County, Pennsylvania. The project limits are bounded to the south by Tinicum Township, to the west by River Road, to the north by the termination of Trails End Lane, and to the east by the Delaware River. The Areas of Concern are located on both private and government-owned properties. A site map can be found in Appendix A.

RWE conducted a desktop assessment of available data for the project site as part of the overall project. To that end, RWE reviewed information related to flooding, soils, geology, hydrology, and topography among others. The results of the desktop assessment are summarized herein.

Flooding Information

The entirety of the AOCs are within the Federal Emergency Management Agency (FEMA) Zone AE[1] of the Delaware River and they are also located within the mapped floodway of the Delaware River. Appendix A contains FEMA mapping of the AOCs with the floodway data highlighted for all AOC cross-sections and includes a cross-section above and below each AOC. The drainage areas to the gauge at Riegelsville and to a point downstream of the Tohickon Creek were evaluated in the FIS and are 6,328 and 6,588 square miles respectively. Cross-sections in the vicinity of Bridgeton Township are EO through ES and have anticipated velocities ranging between 9.6 and 12.6 feet per second during a 100-year storm event (equivalent to a 1-percent annual chance flood). Excerpts from the Bucks County FEMA Flood Insurance Study (FIS) has been included in Appendix E of this report for reference.

Based on information provided by Bridgeton, the erosion of the banks became more concerning beginning at a point after the heavy Delaware River floods during the summer of 2006 between June 24th and 28th. The flooding was attributed to several weather factors that included the stalling of the jet stream west of the Appalachian Mountains and a Bermuda High over the Atlantic Ocean. A tropical low off the North Carolina Coast kept a constant stream of tropical moisture entering the Mid-Atlantic, which resulted in heavy and prolonged rains that caused the Delaware River flooding. The USGS gauge at Riegelsville (located upstream of Bridgeton) recorded a peak crest of 32.98 feet, which was the fourth highest ever recorded.

A United States Geological Survey (USGS) Station is located in the Delaware River at Station 01458200 located in Upper Black Eddy; however, no data was available from this station for review in preparing this report. A USGS stream gauge is located downstream of Bridgeton in Frenchtown, New Jersey (Station 01458500) that continuously collects temperature, dissolved oxygen, pH, specific conductance, and turbidity in addition to water depth. The gauge has been collecting data since 1936, however continuous data at the station has only been collected since 2008. The maximum flood recorded at the gauge was recorded on August 20, 1955 when the gage height reached 27.79 feet. Information on the gauge height during the 2006 storms was not available at the time of the study, however, it is as being the most significant flooding along the Delaware in this region in recent memory.

[1] FEMA Zone AE represents the area inundated by a 1% annual chance flooding for which Base Flood Elevations (BFEs) have been determined.

Soils Information

RWE reviewed the United States Department of Agriculture Natural Resource Conservation Service (USDA NRCS) Web Soil Survey for the AOCs. As shown on the soils map included in Appendix A of this report, the site is underlain primarily by Delaware fine sandy loam (DaA) with small portions of Bowmansville-Knauers silt loam (Bo) and Hatboro-Codorus complex (HbA).

Delaware fine sandy loam is the dominant soil type within the AOCs. Delaware fine sandy loam generally consists of fine sandy loam to loamy fine sand through its profile extending 87 inches below grade. The depth to bedrock tends be 72 to 99 inches. The soils in this series are associated with alluvial fans and terraces. Delaware fine sandy loams have an erosion factor K[2] value of 0.24, which represents the susceptibility of the soil to sheet and rill erosion from the influence of water. In addition, RWE reviewed the wind erodibility group[3] (WEG) and found that Delaware fine sandy loams are in group 3. Although these soils are not as susceptible to erosion by surface runoff as others in the project area, the WEG rating means that the soils are susceptible to erosion by other forces and because the soil is a sandy loam it lacks cohesion necessary to resist the shear stresses anticipated from higher flows in the Delaware River.

Bowmansville-Knauers silt loam is present in two locations of the AOCs - at the end of Trails End Lane, encompassing AOC#1 and just upstream, but not including AOC#6. Bowmansville-Knauers silt loams are generally associated with floodplains and have alluvial deposit parent materials. The soils have a typical profile of 17 inches of silt loam underlain by 7 inches of gravelly sandy loam and then stratified sand to gravelly sandy loam extending from 24 to 60 inches below the surface. The depth to bedrock in this soil series are typically 72 to 99 inches. Bowmansville-Knauers silt loams have an erosion factor K value of 0.43, which tends to be one of the highest potential soils for erosion from runoff. In addition, RWE reviewed the wind erodibility group (WEG) and found that Bowmansville-Knauers silt loams are in group 5. The K value for these soils indicates that they are extremely susceptible to erosion by surface runoff.

Hatboro-Codorus complex soils, which comprise approximately 307 linear feet of riverbank within AOC#2, typically consist of silt loam extending for a depth of 44 inches below existing grade underlain with silty clay loam of 10 inches in thickness and then sandy loam to a depth of 80 inches below grade.

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[2] Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) to predict average annual rates of soil loss by sheet and rill erosion in tons per acre per year. Estimates generated are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity.

[3] WEG consists of soils that have similar properties affecting their susceptibility to wind erosion. Soils are assigned to a group between 1 and 8 with soils in group 1 most susceptible to wind erosion and those in group 8 least susceptible.

The soils are associated with loamy alluvium derived from phyllite parent material and are generally associated with floodplains. Hatboro-Codorus complex soils have an erosion factor K value of 0.49, which tends to be one of the highest potential soils for erosion from runoff. In addition, RWE reviewed the wind erodibility group (WEG) and found that Hatboro-Codorus complex soils are in group 5. The K value for these soils indicates that they are extremely susceptible to erosion by surface runoff.

Complete information on the soil types mapped for the AOCs is located in Appendix B of this report for reference.

Geology Information

The AOCs are underlain by bedrock consisting of Trenton Gravel from the Quaternary age. The major lithologic constituents are unconsolidated clay and sand while unconsolidated silt and gravel make up the minor constituents. The deposits are alluvial in nature with the clay and silt stratifying to form clay-silt beds while the sand and gravel are interstratified with cross bedded sand. A map showing the geology of the project site is included in Appendix A of this report for reference.

Streams Information

There are three (3) mapped tributaries within the boundaries of Bridgeton Township that discharge into the Delaware River. Appendix A contains a map with the locations of the tributaries as they relate to the AOCs. The northernmost, and largest, is High Falls Creek that discharges just north of AOC#1. High Falls Creek has a drainage area of 2.37 square miles with estimated peak flow rates of 1,990 cubic feet per second (cfs) during a 1-percent frequency storm (100-year recurrence interval). RWE believes that flows from High Falls Creek are traveling subsurface through layers of gravel and sand in the soils along the riverbank resulting in erosion of the soils due the pressure build up of the groundwater in these areas. Seeps are not uncommon along the hillslopes west of River Road and these result in additional pressures on the soils of the streambanks.

Moving south, the next tributary is unnamed and discharges across the street from Riverview Antiques, there is a catch basin where the driveway meets River Road that is connected to the culvert conveying this unnamed tributary. The unnamed tributary has a drainage area of 0.6 square miles and has a peak discharge of 849 cfs during a 1-percent frequency storm (100-year recurrence interval). Given that the pipe associated with this discharge has a diameter of only 15 inches, there is a need for an increased culvert size to accommodate the flows from this tributary.

Mill Spring Creek crosses River Road just north of Berm Lane and has a drainage area of 0.52 square miles. The peak discharge is 776 cfs during the 1-percent frequency storm (100-year recurrence interval).

To understand potential influences of the streams on the erosion along the riverbanks, RWE also reviewed a tributary located south of the Bridgeton/Tinicum Township border. The tributary located in

Tinicum Township is known as Lodi Creek. Lodi Creek has a drainage area of 1.55 square miles and a peak discharge of 1,540 cfs during the 1-percent frequency storm (100-year recurrence interval).

Information reviewed for each of the tributaries in the Township was obtained from the USGS StreamStats tool and the full detail from StreamStats can be found in Appendix C.

PennDOT Drainage System

Along River Road north of the Bridgeton/Tinicum border and before the intersection of Trails End Lane, there are 14 culverts, some of which convey stormwater runoff under River Road and discharge it towards the Delaware River. As part of the preparation of this report, RWE obtained Straight Line Diagrams from PennDOT to review the sizing of the various pipes and their location within the Township. Three of the culverts convey mapped streams underneath River Road and 11 of the pipes convey stormwater runoff. Copies of the SLDs are included in Appendix D of this report for reference.

3.0 Detailed Review of Erosion Areas of Concern:

Based on RWE's review of the desktop data available and the site observations made on October 5th and October 28th, 2020, the AOCs experience erosion from a variety of causes. Some are experiencing erosion as a result of more frequent elevated water levels in the Delaware River. Others are experiencing erosion from stormwater runoff in the area of River Road from uncontrolled sheet flow or from existing stormwater outfall pipes. Still others are experiencing erosion from the presence of underground streams traveling along the silt and clay lenses within the soil profiles near the tributaries to the Delaware.

Area of Concern 1

At the terminus of Trails End Lane (in the yard of house number 1870) is a sinkhole forming adjacent to the bank of the Delaware River. The sinkhole is approximately 240 feet south of the High Falls Creek confluence. Along with a concrete pad on the downstream side of the confluence that is accumulating woody debris these conditions could produce a local eddy causing erosion. The bank is experiencing planar erosion which has created a void in the soil profile inducing cavitation. Continued failure at this site would lead to property loss and potential tree loss. The streambanks in AOC#1 is eroding, however, the erosion was not active during the site visits RWE conducted. The erosion of the bank may be a result of subsurface flows associated with the confluence of High Falls Creek.

Area of Concern 2

A portion of the streambank extending for a length of 90 feet is eroding in close proximity to the travel lane of Trails End Lane. AOC#2 is located across the street from 1810 Trails End Lane. High flows from the Delaware River continue to erode this bank as steep unvegetated slopes (~3H:1V) were noted. Tree fall has weakened past attempts at bank stabilization and further soil loss can be expected due to the active erosion at the site. A large log running beneath an existing staircase and parallel to the bank may be exacerbating local erosion by inadvertently directing the stream flows into the bank. Nearby hardscaping is beginning to slide down the bank as a result of the erosion as well. Further erosion at this site may ultimately erode the active travelway of Trails End Lane.

RWE collected measurements of the embankment at AOC#2 and developed typical cross-section A-A' of the streambank. The cross-section details the slopes of the bank from the edge of water at the Delaware River up to the top of the embankment along the roadway. and the cross-sections are shown on the map included in Appendix A.

Area of Concern 3

Across from Riverview Antiques along River Road, there is a 15" diameter cast iron stormwater outfall pipe inside a corrugated metal sleeve. It appears that the sleeve was intended to direct the runoff from the pipe to the bottom of the streambank. The top of the sleeve extends above the pavement surface, so the water itself no longer enters the pipe from the pavement itself. The condition of the outfall pipe was difficult to view given its location within the corrugated metal pipe, however, it can be assumed that the sleeve was also installed to protect the pipe's integrity. Currently, stormwater runoff is eroding the soil in and around the corrugated pipe back migrating upwards from the bottom of the sleeve towards the road. This erosion has exposed the guardrail I-beams. As erosion continues the structural integrity of the guardrail and the pavement may become compromised.

Area of Concern 4

Across from 1750 River Road, approximately 100 linear feet of the streambank is eroding because of both high flows in the Delaware as well as stormwater runoff from River Road. The latter is causing rills and gullies to form along the bank which has begun to result in tree loss. There are sections where very little land is left between the bank and the roadway pavement and further erosion may result in damage to River Road and loss of the active travelway.

Area of Concern 5

Just north of the Upper Black Eddy/Milford bridge there is significant streambank erosion extending for a length of ~175 feet. This erosion is caused by a combination of the flows in the river together with local stormwater runoff erosion. An existing stormwater pipe crossing under River Road is nearly level with the guardrail I-beams. The proximity of the

stormwater outfall discharge to the roadway elevation without the presence of conduit outlet protection is causing severe erosion in this location. The erosion has continued to a point where several of the guardrail beams are completely exposed. The location of this erosion is also such that it is at a point where the cross-section of the Delaware River is narrower. This results in increased near bank erosion and shear stresses acting on the streambank. The erosion has progressed to a point where it is going to cause collapse of River Road and without remediation significant road damage is to be expected. Typical Cross-Section B-B’ is included in Appendix A.

Area of Concern 6

At AOC#6, there is an extensive area of exposed bedrock at the bottom of the bank. The banks in this area were observed to have near vertical slopes in several locations and are only a few feet from impacting the active travelway of River Road. The length of this area of the streambank extends for 1,800 feet, however, erosion of the banks is intermittent and is estimated to be less than 300 linear feet in total. Tree fall may result in significant sloughing of the streambank could cause detrimental impacts to the roadway. Eddies are forming along the edge of the pavement where concentrated street flow is collecting in low lying depressions. This stormwater pooling will likely promote additional tree fall in the area and could result in increased erosion of the overall bank given its vertical configuration.

Area of Concern 7

Located just to the north of the Bridgeton/Tinicum border, this AOC extends over a length of 350 feet with intermittent rills and gullies forming from stormwater running of as sheet flow from River Road. The gullies if left untreated could expose guardrail I-beams and rilling could cause tree fall and bank erosion. Typical Cross-Section C-C' was developed for the banks in this reach and is located in Appendix A.

4.0 Potential Solutions for the Erosion

To address the various modes of erosion observed along the streambanks of the Delaware River throughout the AOCs, RWE reviewed various options for potential stabilization. Given the causes of erosion throughout the AOCs vary, there are multiple potential solutions for stabilizing the streambanks. Techniques are divided into two categories: erosion as a result of stream flows or stormwater-based erosion. The techniques reviewed and detailed herein include the following:

- VMSE,
- timber crib walls,
- riprap (including half dense riprap technique),
- gabions,
- sheet piling, and
- traditional retaining walls.

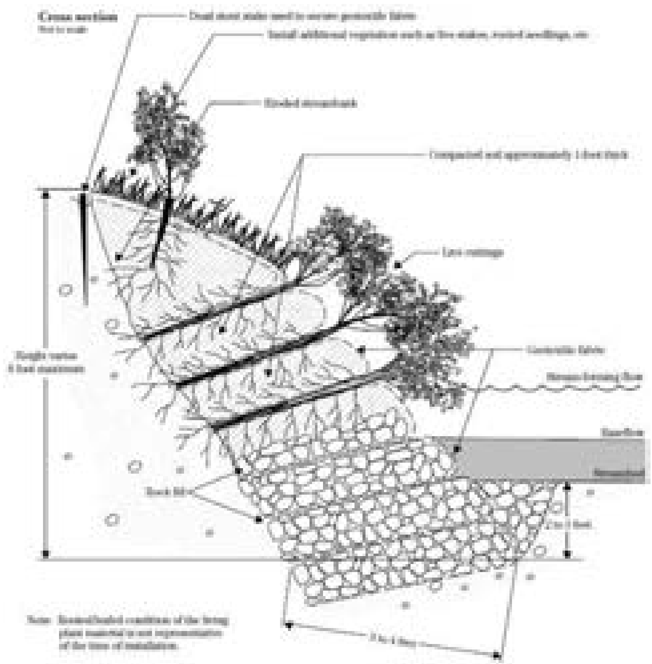
For stormwater-based erosion, the stabilization techniques reviewed include:

- Drop manholes,
- Vegetated swales,
- Vegetated filter strips, and
- Level spreaders.

The discussion below includes descriptions of the techniques, pros and cons of each, and general costs that can be anticipated for design and construction of the techniques.

Potential River-based Erosion Solutions

Vegetated Mechanically Stabilized Earth (VMSE) Wall



Vegetated Mechanically Stabilized Earth walls consist of alternating layers of live branches and compacted soil backfill to repair small, localized slumps and holes in streambanks. These are also knowns as vegetated geogrids and use natural or synthetic geotextile materials that are wrapped around each soil lift between the layers of live branch cuttings. VMSE walls can be constructed on slopes of 1H:1V or steeper. Soil lifts tend to be 12 to 18 inches in thickness.

Pros and Cons

Below is a short summary of potential pros and cons of using VMSE walls to stabilize streambanks in the AOCs.

Figure 1. Typical VMSE detail (from USDA NRCS Engineering Handbook)

Pros	Cons
Uses natural materials and incorporates vegetation	Can be complex to build
Useful in restoring bends in the streambank	Can be expensive if soils need to be imported
Provide habitat for wildlife and macroinvertebrates	Must be built during low-flow conditions
	Should be used in areas where velocities are generally less than 8 feet per second

Costs

Costs for construction for this type of application along the Delaware River can be expected to be on the order of \$500/linear foot to \$750/linear foot depending on the amount of soil that must be imported to the site. Costs associated with design and permitting for the project can be assumed to be between 20 and 33 percent of the construction costs for this technique.

RWE recommends this technique be considered for AOC#1, AOC#2 and AOC#5. In these locations, VMSE walls may be suitable as there is sufficient area to construct this type of technique and the technique will provide long-term stabilization.

Timber Cribwalls

A timber cribwall consists of a box-like interlocking arrangement of untreated log or timber members. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members. Timber crib walls should be tilted back or battered if the system is built on a smooth, evenly sloped surface. These timber crib walls are appropriate to use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness. These can be used in areas both above and below water were stable streambeds exist.

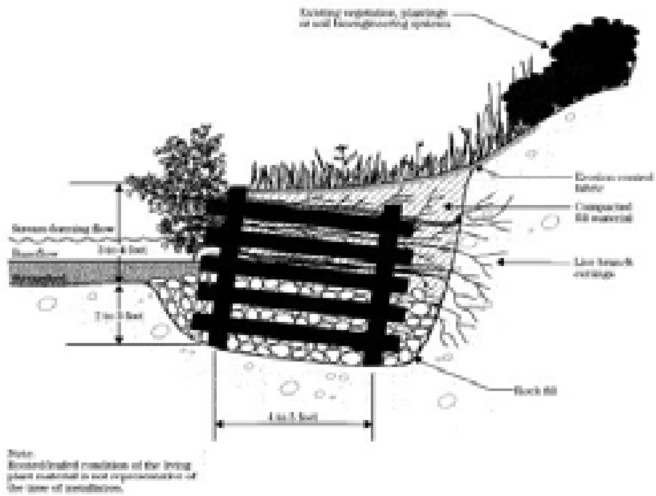


Figure 2. Typical timber crib wall detail (from USDA NRCS Engineering Handbook)

Pros and Cons

Below is a short summary of potential pros and cons of using timber walls to stabilize streambanks in the AOCs.

Pros	Cons
Uses natural materials and incorporates vegetation and maintains a natural appearance	Can be complex to build
Effective in areas where strong currents are present	Can be expensive if trees/timber need to be imported
Provide habitat for wildlife and macroinvertebrates	Can be expensive to maintain
Useful in areas where space is limited, and a more vertical structure is required	

Costs

Costs for construction for this type of application along the Delaware River can be expected to be on the order of $750/linear foot to $1,500/linear foot depending on the number of trees/timber that must be imported to the site. Costs associated with design and permitting for the project can be assumed to be between 20 and 33 percent of the construction costs for this technique.

RWE recommends this technique be considered for AOC#5. In this location, a timber crib wall may be suitable and will provide long-term stabilization.

Riprap (or Half Dense Riprap)

Rock riprap, properly designed and placed, can be an effective method of streambank protection, however, frequently the design or the installation of rock riprap is flawed, and the result is a significant failure of the bank. Riprap banks cannot be graded steeper than 1.5H:1V. Half dense riprap is a variation of the riprap bank stabilization technique that involves the placement of vegetation in gaps amongst the riprap to ensure some level of vegetative cover. Use of the half dense method offers the potential for a bioengineered solution that still achieves the stabilization that the riprap provides.

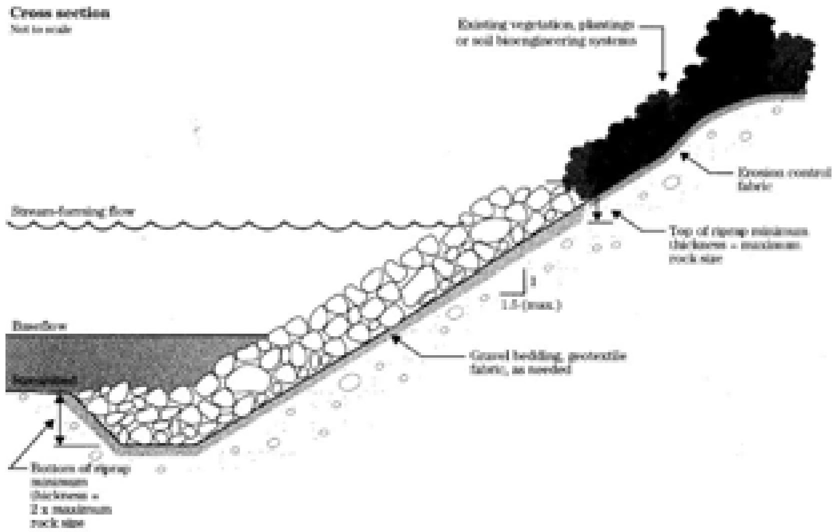


Figure 3. Typical detail of riprap slope (from USDA NRCS Engineering Handbook)

Pros and Cons

Below is a short summary of potential pros and cons of using riprap or half dense riprap to stabilize streambanks in the AOCs.

Pros	Cons
Has structural flexibility. It can be designed to self-adjust to eroding conditions.	Can lead to significant bank failures if designed or constructed incorrectly.
Has a long-life span	Limited to slopes of 1.5H:1V
Can be designed for high velocity conditions.	Typically limited to toe protection applications
	Difficult to permit due to environmental restrictions

Costs

Costs for construction for this type of application along the Delaware River can be expected to be on the order of $250/linear foot to $500/linear foot depending on the location of the riprap that must be imported to the site. The cost of quarrying, transporting, and placing stone and the large quantity of stone that may be needed must be considered. Costs associated with design and permitting for the project can be assumed to be 20 percent of the construction costs for this technique.

RWE recommends this technique be considered for AOC#5. In this location, half dense riprap may be suitable and will provide long-term stabilization.

Gabions

Rock gabions consist of rectangular containers fabricated from a triple twisted, hexagonal mesh of heavily galvanized steel wire. Empty gabions are placed in position, wired to adjoining gabions, filled with stones, and then folded shut and wired at the ends and sides. Gabions can be used on steeper slopes (greater than 1.5H:1V) and are effective where the size of riprap is larger than can be reasonably sourced for the site. Vegetation can be incorporated into rock gabions, if desired, by placing live branches on each consecutive layer between the rock-filled baskets (fig. 15). These gabions take root inside the gabion baskets and in the soil behind the structures. In time the roots consolidate the structure and bind it to the slope.

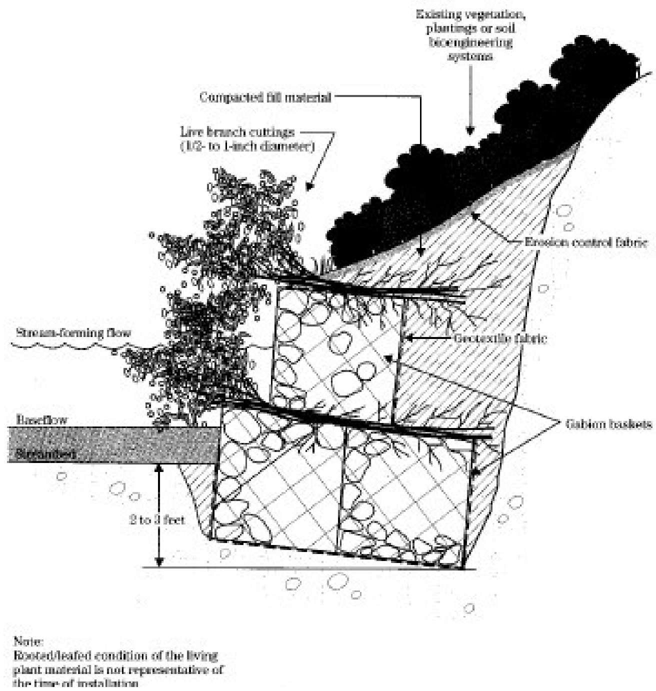


Figure 4. Typical gabion basket detail (from USDA NRCS Engineering Handbook)

Pros and Cons

Below is a short summary of potential pros and cons of using gabions to stabilize streambanks in the AOCs.

Pros	Cons
.	Have a limited life expectancy.
Lower cost than many structural techniques	Prone to vandalism
Work well at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness.	Difficult to permit due to environmental restrictions
Tolerate limited foundation movement.	Not designed to resist large lateral earth stresses and should have a maximum height of five feet.

Costs

Typical costs for construction tend to be on the order of $200/linear foot to $400/linear foot. Costs associated with design and permitting for the project can be assumed to be 20 percent of the construction costs for this technique.

RWE does not recommend the use of gabion baskets except potentially at AOC#2. This would need to be carefully reviewed before being implemented as it relates to velocities and shear stresses within the Delaware before proceeding.

Sheet Piling

There are numerous sheet piling techniques used for streambank stabilization. RWE reviewed two techniques typically associated with bioengineering applications for their applicability to the AOCs. Sheet piling revetments built with wire or geotextile fencing are continuous single or double row of pilings with a facing of woven wire or geogrid material. The space between double rows of pilings is filled with rock and brush. Piling revetments with slotted boards were, however, considered. This type of revetment consists of slotted board fencing made of wood pilings and horizontal wood Timbers. (Variations include different fence heights, double rows of slotted fence, and use of woven wire in place of timber boards. The size and spacing of pilings, cross members, and vertical fence boards depend on height of fence, stream velocity, and sediment load.

Given the limitations of bioengineered sheet piling in the placement along the Delaware River, these techniques were eliminated from consideration. Traditional sheet piling applications include plastic, prestressed concrete, and steel and could be utilized along the banks of the Delaware.

Pros and Cons

Below is a short summary of potential pros and cons of using sheet piling to stabilize streambanks in the AOCs.

Pros	Cons
Low maintenance	Extremely expensive
Prevents erosion and scouring	Requires heavy equipment to install
Works well in areas with limited area for installation of other stabilization techniques	Difficult to permit due to environmental restrictions
	May exacerbate downstream erosion if not designed or installed properly

Costs

Typical costs for construction tend to be on the order of $500/linear foot to $2,000/linear foot. Costs associated with design and permitting for the project can be assumed to be 33 percent of the construction costs for this technique.

RWE does not recommend the use of sheet piling for any stabilization in the AOCs.

Retaining Walls

RWE considered the use of traditional retaining walls for the slope stabilization along the Delaware. Retaining walls are created to retain soils. This method can be used in stream channels of all types and sizes and is suitable for channels with widely fluctuating water levels and high velocities.

Pros and Cons

Below is a short summary of potential pros and cons of using retaining walls to stabilize streambanks in the AOCs.

Pros	Cons
Low maintenance	Extremely expensive
Prevents erosion and scouring	Requires heavy equipment to install
Works well in areas with limited area for installation of other stabilization techniques	Difficult to permit due to environmental restrictions
	May exacerbate downstream erosion if not designed or installed properly

Costs

Typical costs for construction tend to be on the order of $1,000/linear foot to $3,000/linear foot. Costs associated with design and permitting for the project can be assumed to be 33 percent of the construction costs for this technique.

RWE recommends that retaining walls be considered for AOC#2 and AOC#6 if needed. It can be costly to design and permit this solution, however, it may be the only viable option in areas where there is limited work area to construct other measures.

Potential Solutions: Stormwater Erosion

Drop Manholes

Drop manhole structures can be used to lower the elevation of stormwater conveyance pipes crossing River Road. Most of the outfalls within Bridgeton Township discharge at or near the elevation of the road surface which is significantly higher than the normal water surface within the Delaware River. As a result, the banks of the stream are being eroded from sheet flow and concentrated flow of stormwater runoff from the roadway itself. Drop manholes allow the water to be safely conveyed to a lower elevation where the discharge can be across an area with a shallower slope and reduce the potential for erosion.

Pros and Cons

Below is a short summary of potential pros and cons of using vegetated swales for stormwater erosion in the AOCs.

Pros	Cons
Reduces erosion potential of the slope	May be negatively impacted by high river flows
Relatively low cost	Not suitable for space constrained applications

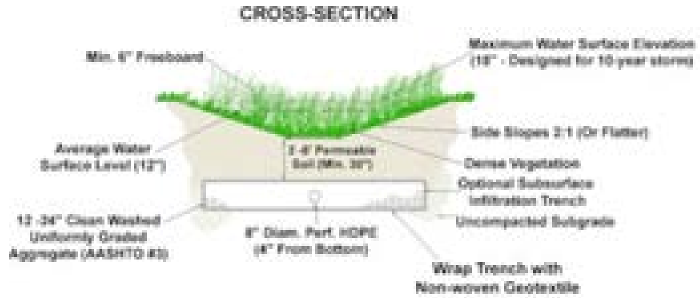
Costs

Typical costs for construction tend to be on the order of $5,000 to $10,000 each for the manhole structures and it can be assumed that additional pipe runs, and outfall structures will also be necessary to ensure proper functionality. Costs associated with design and permitting for the project can be assumed to be 33 percent of the construction costs for this technique.

RWE recommends the use of this technique at AOC#3. This will address the erosion in and around the existing outfall pipe.

Vegetated Swale

Vegetated swales are broad, shallow channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Vegetated Swales provide an environmentally superior alternative to conventional curb and gutter conveyance systems, while providing partially treated (pretreatment) and partially distributed stormwater flows



to subsequent BMPs. Swales are often heavily vegetated with a dense and diverse selection of native, close-growing, water-resistant plants with high pollutant removal potential. The various pollutant removal mechanisms of a swale include: sedimentary filtering by the swale vegetation (both on side slopes and on bottom), filtering through a subsoil matrix, and/or infiltration into the underlying soils with the full array of infiltration-oriented pollutant removal mechanisms.

Pros and Cons

Below is a short summary of potential pros and cons of using vegetated swales for stormwater erosion in the AOCs.

Pros	Cons
Environmentally sensitive	Have a limited life expectancy.
Lower cost than many structural techniques	Not suitable for steep slopes
Reduces the overall time of concentration for stormwater runoff to the river	Not suitable for space constrained applications

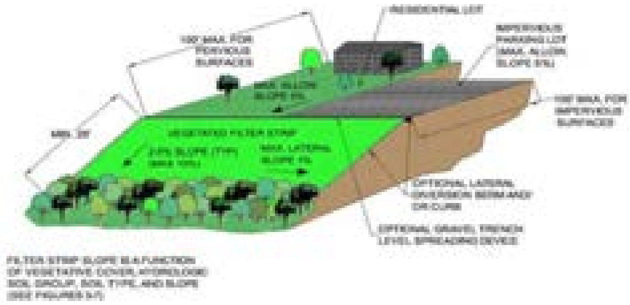
Costs

Typical costs for construction tend to be on the order of $25/linear foot to $40/linear foot. Costs associated with design and permitting for the project can be assumed to be 20 percent of the construction costs for this technique.

RWE recommends this technique be considered for AOC#4, AOC#6 and AOC#7. There appears to be room to install swales to collect runoff and convey them to existing outfalls in this region,

Vegetated Filter Strip

Filter strips are gently sloping, densely vegetated areas that filter, slow, and infiltrate sheet flowing stormwater.



Pros and Cons

Below is a short summary of potential pros and cons of using vegetated filter strips for stormwater erosion in the AOCs.

Pros	Cons
Environmentally sensitive	Can be costly depending on the vegetation selected and the width of the filter strip

Lower cost than many structural techniques	Not suitable for steep slopes
Reduces the overall time of concentration for stormwater runoff to the river	Not suitable for space constrained applications

Costs

Typical costs for construction tend to be on the order of $20/linear foot to $100/linear foot. Costs associated with design and permitting for the project can be assumed to be 20 percent of the construction costs for this technique.

Although there are no areas within the project limits that this technique can be applied, RWE recommends Bridgeton encourage residents to install filter strips along the riverbanks wherever possible to reduce erosion.

Level Spreader

Level Spreaders are measures that reduce the erosive energy of concentrated flows by distributing runoff as sheet flow to stabilized vegetative surfaces. Level Spreaders, of which there are many types, may also promote infiltration and improved water quality.

Pros and Cons

Below is a short summary of potential pros and cons of using level spreaders for stormwater erosion in the AOCs.

Pros	Cons
Diffuse concentrated flows from stormwater collection systems	Not effective when discharging onto steep slopes
Can be combined with bioengineered streambank stabilization techniques	High maintenance
	Not suitable for space constrained applications

Costs

Typical costs for construction tend to be on the order of $10/linear foot to $75/linear foot depending on the size of the stormwater conveyance pipe connected to the level spreader. Additional construction costs may include additional piping and ancillary structures such as manholes. Costs associated with design and permitting for the project can be assumed to be 33 percent of the construction costs for this technique.

RWE recommends the installation of level spreaders be considered to address the runoff in AOC#4.

5.0 Recommendations

RWE recommends Bridgeton pursue options to stabilize the various AOCs in the near-term. Based on the preliminary investigations completed and the review of the stabilization techniques available, it is recommended that Bridgeton consider the following stabilization techniques for each of the Areas of Concern:

- AOC#1 – A VMSE wall should be considered. The sinkhole should be monitored and flows from High Falls Creek should be monitored to determine if continued groundwater influence will affect the area in the future.
- AOC#2 – A VMSE wall or gabions should be considered. The area is narrow, and the erosion has the potential to encroach into the active travelway within the next few years.
- AOC#3 – A drop manhole structure is recommended. This pipe is undersized and not placed appropriately to capture the runoff from the roadway.
- AOC#4 – This area
- AOC#5 – A VMSE wall, half dense riprap, or a timber crib wall should be considered in this location. The area is actively eroding and will encroach in the active travelway after a large storm event or high flow event along the Delaware.
- AOC#6 – The use of vegetated swales and potentially retaining walls should be considered for this AOC. The area needs a detailed engineering analysis of the existing drainage systems from River Road to determine the placement of the stabilization measures and the need for these measures at this time.
- AOC#7 – This area is not actively eroding and does not show erosion warranting corrective measures at this time. RWE recommends monitoring this area in the future and utilizing one of the measures included in this study at such time that it is warranted.

Regulatory Review

Regardless of the design approach selected, it is anticipated that approvals will be necessary from the following regulatory agencies at a minimum:

- United States Army Corps of Engineers
- Pennsylvania Department of Environmental Protection
- Pennsylvania Department of Transportation
- Bucks County Conservation District

Prior to commencing with the design phase, RWE recommends completing a pre-application meeting with the United States Army Corps of Engineers and the Pennsylvania Department of Environmental Protection to ensure that the design approach is acceptable.

Anticipated Timeline

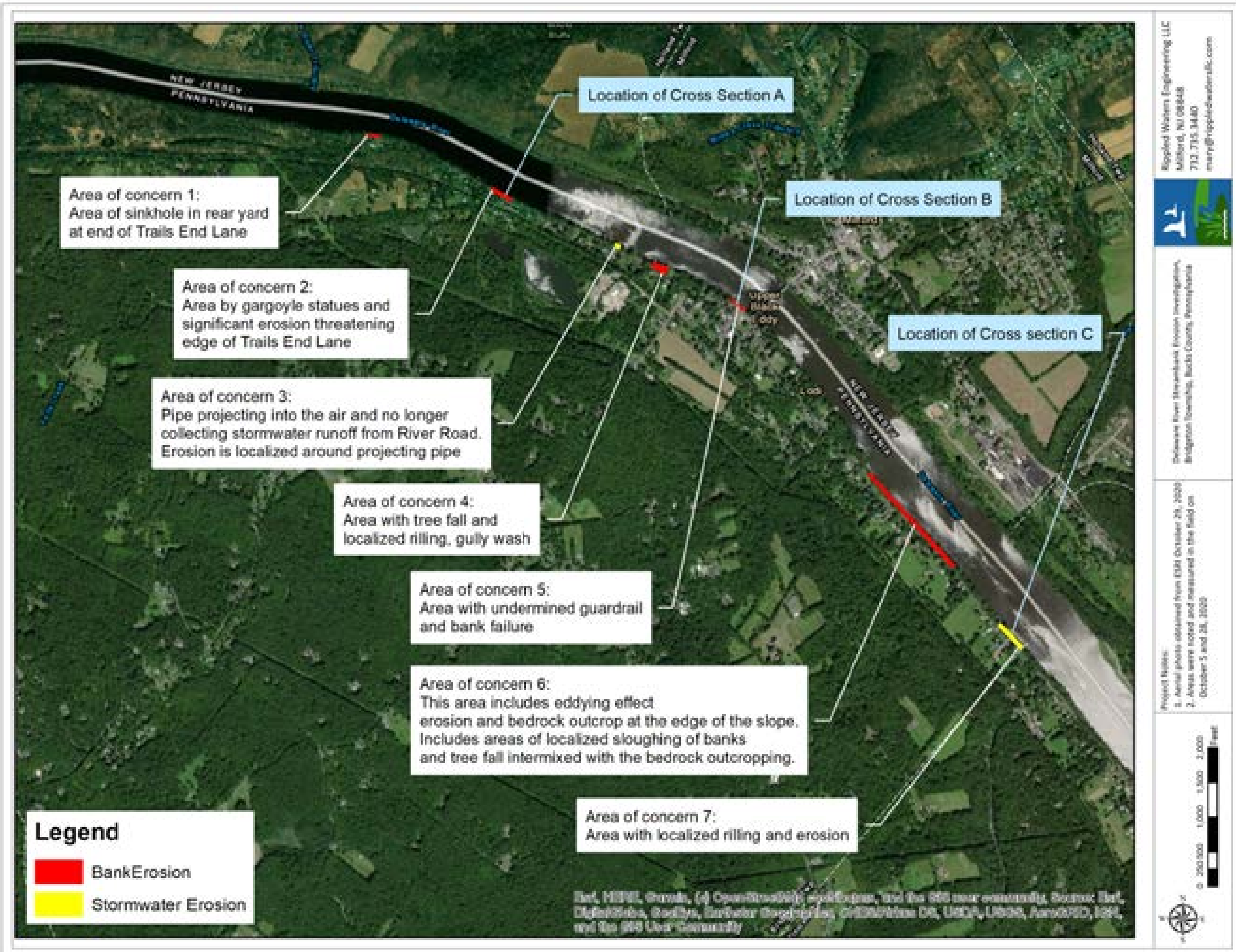
It is anticipated that the following general project timeline can be anticipated for the work:

- Design Phase – 4-8 months
- Permitting Phase – 9-18 months
- Construction Phase 3-6 months

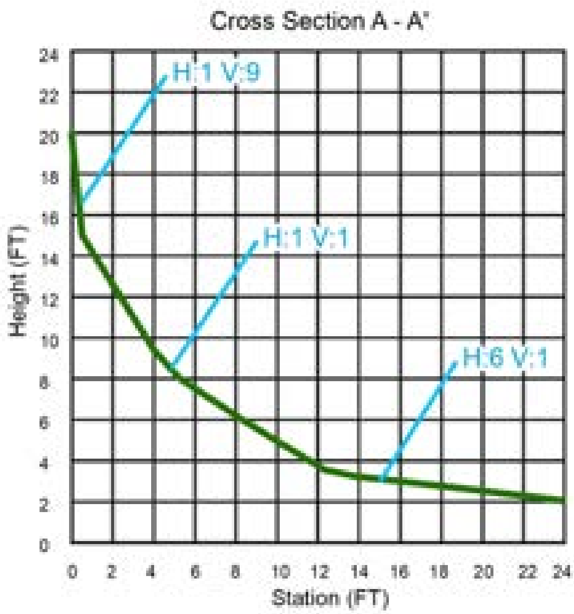
As such, the overall timeframe for completion of the work can be assumed to be between 16 and 32 months.

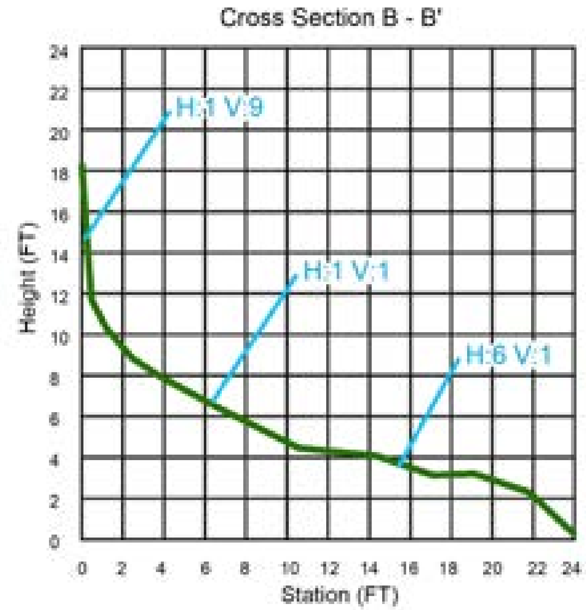
Appendix A

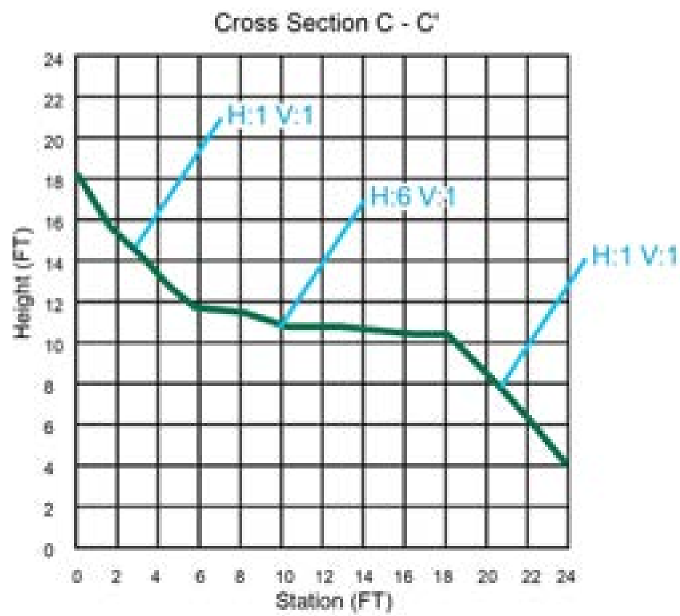
Supporting Maps



NEW JERSEY
PENNSYLVANIA
Location of Cross Section A
Location of Cross Section B
Location of Cross section C
Area of concern 1:
Area of sinkhole in rear yard
at end of Trails End Lane
Area of concern 2:
Area by gargoyle statues and
significant erosion threatening
edge of Trails End Lane
Area of concern 3:
Pipe projecting into the air and no longer
collecting stormwater runoff from River Road.
Erosion is localized around projecting pipe
Area of concern 4:
Area with tree fall and
localized rilling, gully wash
Area of concern 5:
Area with undermined guardrail
and bank failure
Area of concern 6:
This area includes eddying effect
erosion and bedrock outcrop at the edge of the slope.
Includes areas of localized sloughing of banks
and tree fall intermixed with the bedrock outcropping.
Area of concern 7:
Area with localized rilling and erosion
Legend
BankErosion
Stormwater Erosion
0 250 500 1,000 1,500 2,000
Feet
Project Notes:
1. Aerial photo obtained from ESRI October 29, 2020
2. Areas were noted and measured in the field on October 5 and 28, 2020
Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania
Rippled Waters Engineering LLC
Milford, NJ 08848
732.735.3440
mary@rippledwatersllc.com







Project Notes:
1. Areas were noted and measured on October 5 & 28, 2020
2. Site overview map calls out locations of cross sections.

Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania

Cross Sections

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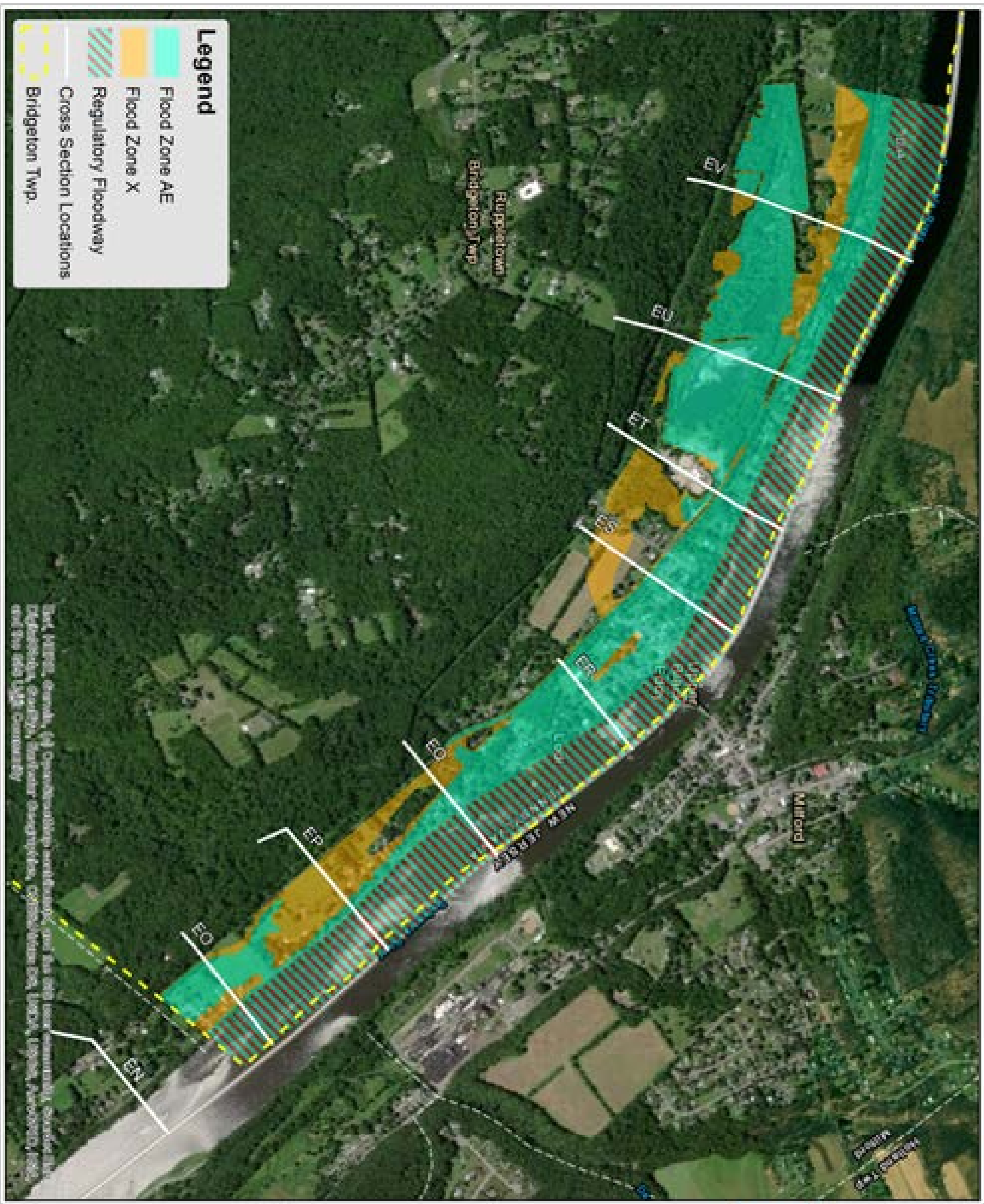

0 375 750 1,500
Feet

Project Notes:
1. Aerial photo obtained from ESRI, November 13, 2020
2. Flood information obtained from FEMA, November 13, 2020

Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania

FEMA Flood Zone & Cross Section Map

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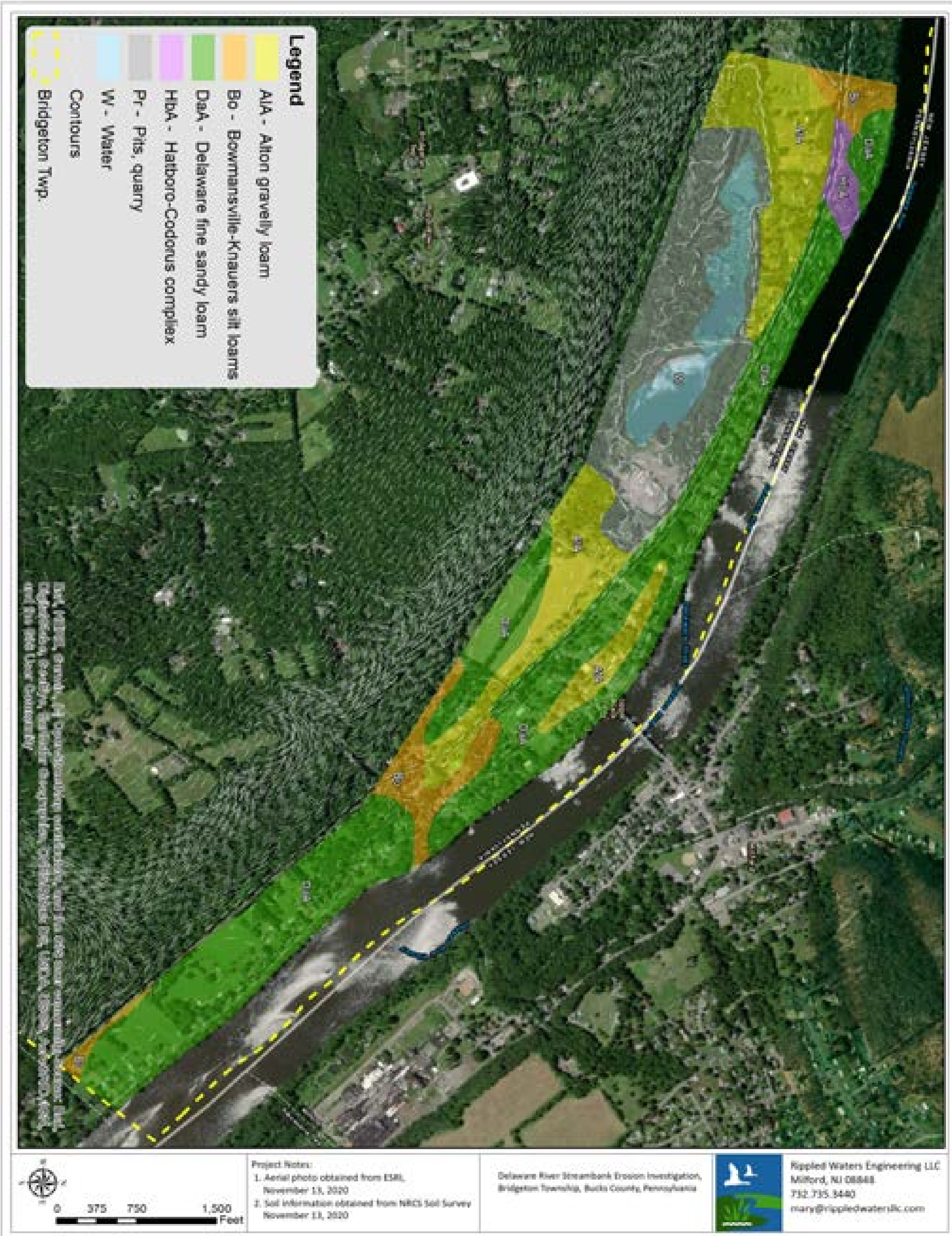

Legend
AlA - Alton gravelly loam
Bo - Bowmansville-Knauers silt loams
DaA - Delaware fine sandy loam
HbA - Hatboro-Codorus complex
Pr - Pits, quarry
W - Water
Contours
Bridgeton Twp.
0 375 750 1,500 Feet
Project Notes:
1. Aerial photo obtained from ESRI, November 13, 2020
2. Soil information obtained from NRCS Soil Survey November 13, 2020
Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania
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732.735.3440
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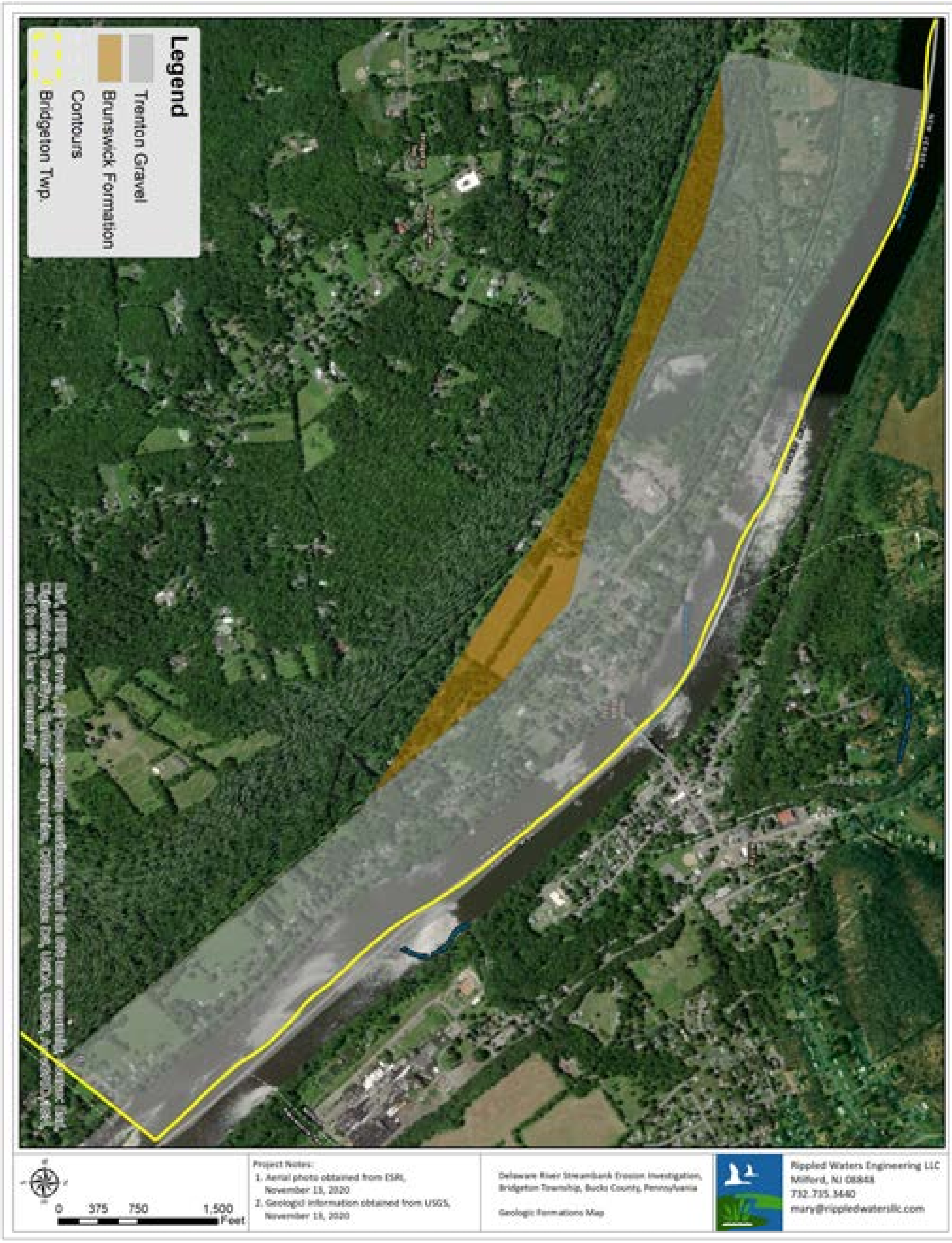

Legend
Trenton Gravel
Brunswick Formation
Contours
Bridgeton Twp.
0 375 750 1,500
Feet
Project Notes:
1. Aerial photo obtained from ESRI, November 13, 2020
2. Geologic information obtained from USGS, November 13, 2020
Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania
Geologic Formations Map
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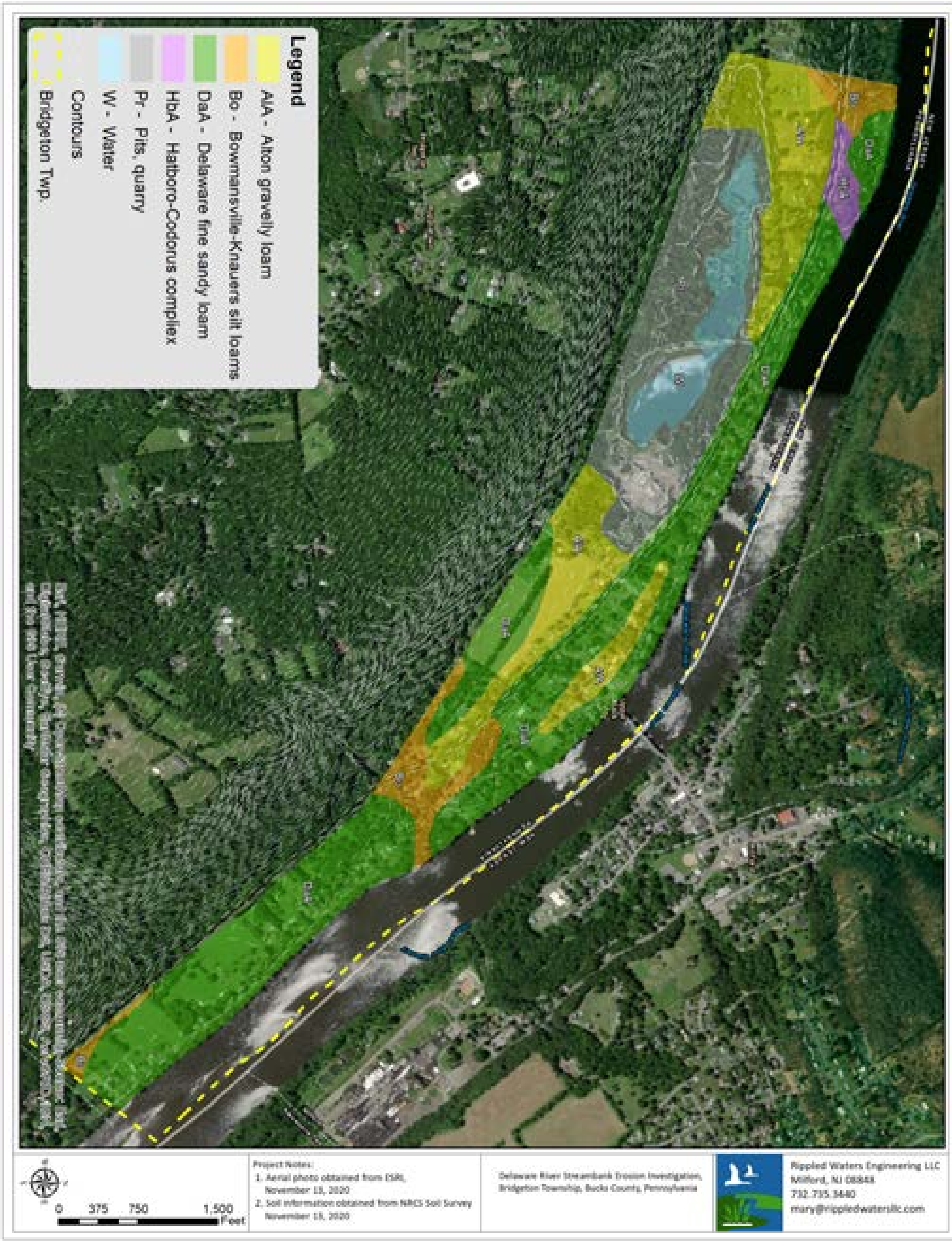
Legend
AlA - Alton gravelly loam
Bo - Bowmansville-Knauers silt loams
DaA - Delaware fine sandy loam
HbA - Hatboro-Codorus complex
Pr - Pits, quarry
W - Water
Contours
Bridgeton Twp.
0 375 750 1,500 Feet
Project Notes:
1. Aerial photo obtained from ESRI, November 13, 2020
2. Soil information obtained from NRCS Soil Survey November 13, 2020
Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania
Rippled Waters Engineering LLC
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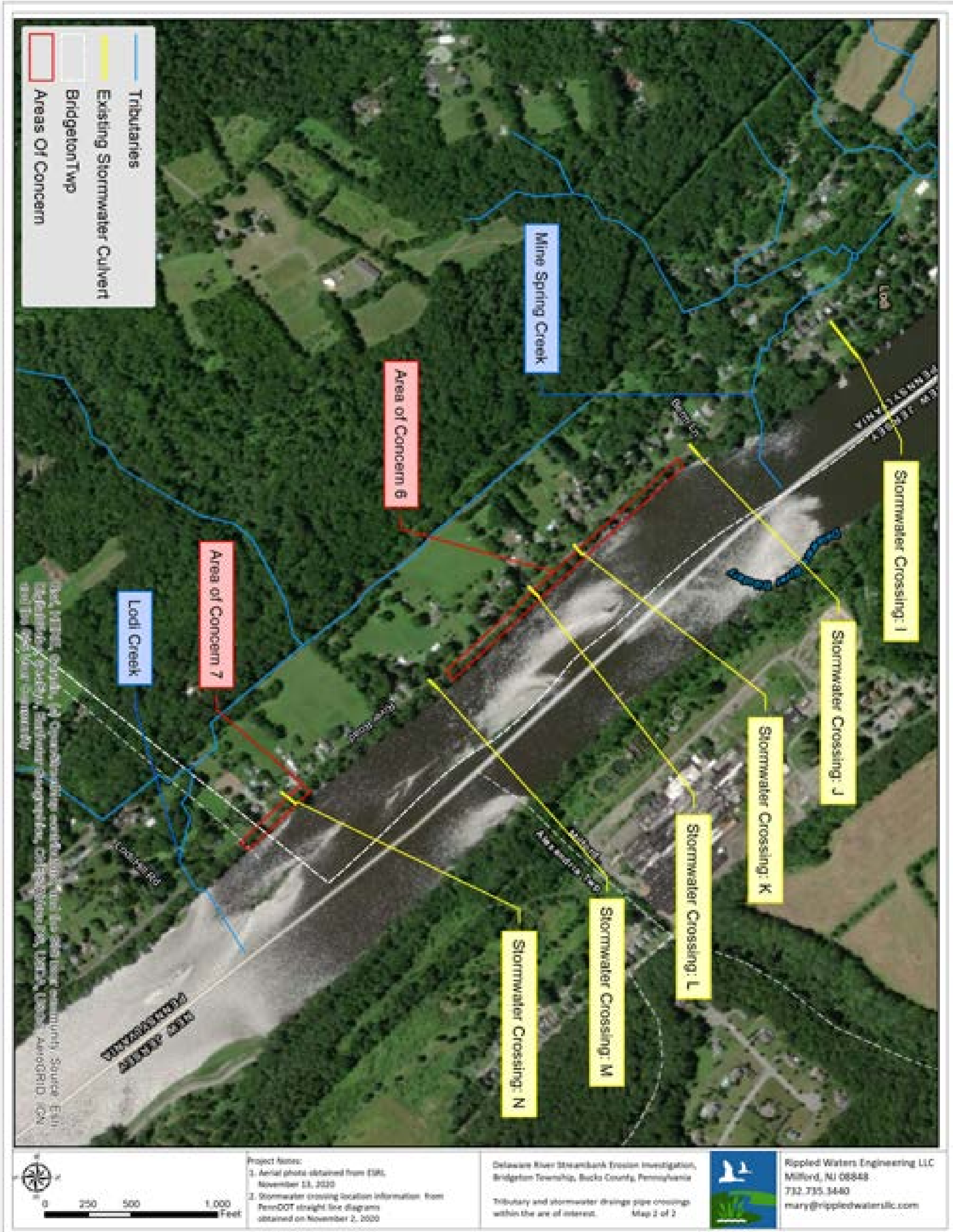
Tributaries
Existing Stormwater Culvert
BridgetonTwp
Areas Of Concern
Mine Spring Creek
Lodi Creek
Area of Concern 6
Area of Concern 7
Stormwater Crossing: I
Stormwater Crossing: J
Stormwater Crossing: K
Stormwater Crossing: L
Stormwater Crossing: M
Stormwater Crossing: N
0 250 500 1,000 Feet
Project Notes:
1. Aerial photo obtained from ESRI, November 13, 2020
2. Stormwater crossing location information from PennDOT straight line diagrams obtained on November 2, 2020
Delaware River Streambank Erosion Investigation, Bridgeton Township, Bucks County, Pennsylvania
Tributary and stormwater drainage pipe crossings within the are of interest. Map 2 of 2
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Appendix B

Soil Information

AlA—Alton gravelly loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: l7n6
Elevation: 0 to 910 feet
Mean annual precipitation: 28 to 50 inches
Mean annual air temperature: 45 to 57 degrees F
Frost-free period: 120 to 210 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Alton, gravelly loam, and similar soils: 90 percent
Minor components: 6 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alton, Gravelly Loam

Setting

Landform: Terraces, alluvial fans
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Parent material: Sandy and gravelly outwash and alluvium derived from sedimentary and metamorphic rock

Typical profile

Ap - 0 to 7 inches: gravelly loam
Bw - 7 to 41 inches: very gravelly coarse sandy loam
2C - 41 to 62 inches: extremely gravelly coarse sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: 60 to 99 inches to lithic bedrock
Drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Available water capacity: Low (about 4.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2s
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Udorthents, gravelly

Percent of map unit: 2 percent
Hydric soil rating: No

Udorthents, sandy

Percent of map unit: 2 percent
Hydric soil rating: No

Matapeake

Percent of map unit: 1 percent
Landform: Hillslopes
Landform position (two-dimensional): Summit, shoulder
Landform position (three-dimensional): Interfluve, side slope
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Conotton

Percent of map unit: 1 percent
Landform: Outwash terraces
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Bo—Bowmansville-Knauers silt loams

Map Unit Setting

National map unit symbol: l7nk
Elevation: 150 to 900 feet
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 45 to 57 degrees F
Frost-free period: 150 to 210 days
Farmland classification: Not prime farmland

Map Unit Composition

Bowmansville and similar soils: 41 percent
Knauers and similar soils: 39 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Bowmansville

Setting

Landform: Flood plains
Landform position (two-dimensional): Footslope, toeslope
Landform position (three-dimensional): Head slope
Down-slope shape: Concave, linear
Across-slope shape: Linear, concave
Parent material: Recent alluvial deposits weathered from sandstone and siltstone

Typical profile

Ap - 0 to 7 inches: silt loam
Bg - 7 to 26 inches: silty clay loam
Cg - 26 to 43 inches: fine sandy loam
2Cg - 43 to 65 inches: stratified gravel to sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: 72 to 99 inches to lithic bedrock
Drainage class: Somewhat poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 0 to 18 inches
Frequency of flooding: OccasionalNone
Frequency of ponding: None
Available water capacity: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: C/D
Hydric soil rating: No

Description of Knauers

Setting

Landform: Flood plains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Recent alluvium derived from sandstone and shale

Typical profile

A - 0 to 8 inches: silt loam
Bg1 - 8 to 17 inches: silt loam
Bg2 - 17 to 24 inches: gravelly sandy loam
2Cg - 24 to 60 inches: stratified sand to gravelly sandy loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: 72 to 99 inches to lithic bedrock
Drainage class: Poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: OccasionalNone
Frequency of ponding: Frequent
Available water capacity: Low (about 5.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: C/D
Hydric soil rating: Yes

Minor Components

Rowland

Percent of map unit: 20 percent
Landform: Flood plains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Head slope, base slope
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Hydric soil rating: No

DaA—Delaware fine sandy loam, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: l7p8
Elevation: 0 to 910 feet
Mean annual precipitation: 28 to 50 inches
Mean annual air temperature: 45 to 57 degrees F
Frost-free period: 110 to 210 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Delaware and similar soils: 90 percent
Minor components: 9 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Delaware

Setting

Landform: Terraces
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Postglacial alluvium derived from sandstone and shale

Typical profile

Ap - 0 to 10 inches: fine sandy loam
Bw - 10 to 40 inches: very fine sandy loam
C - 40 to 87 inches: loamy fine sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: 72 to 99 inches to lithic bedrock
Drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Available water capacity: Moderate (about 7.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 1
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Alton

Percent of map unit: 5 percent
Landform: Alluvial fans, terraces
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Hydric soil rating: No

Conotton

Percent of map unit: 2 percent
Landform: Stream terraces
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread, riser
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

Hatboro

Percent of map unit: 1 percent
Landform: Flood plains
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Nanticoke

Percent of map unit: 1 percent
Landform: Tidal flats
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: Yes

HbA—Hatboro-Codorus complex, 0 to 3 percent slopes, frequently flooded

Map Unit Setting

National map unit symbol: 2w06g
Elevation: 90 to 680 feet
Mean annual precipitation: 47 to 51 inches
Mean annual air temperature: 48 to 57 degrees F
Frost-free period: 180 to 210 days
Farmland classification: Not prime farmland

Map Unit Composition

Hatboro, frequently, and similar soils: 60 percent
Codorus, occasional, and similar soils: 35 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Hatboro, Frequently

Setting

Landform: Flood plains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Loamy alluvium derived from greenstone and/or phyllite and/or quartzite and/or schist

Typical profile

A - 0 to 11 inches: silt loam
Bg1 - 11 to 18 inches: silt loam
Bg2 - 18 to 29 inches: silt loam
BCg - 29 to 44 inches: silt loam
Cg1 - 44 to 55 inches: silty clay loam
Cg2 - 55 to 80 inches: sandy loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: FrequentNone
Frequency of ponding: Frequent
Available water capacity: High (about 9.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B/D
Hydric soil rating: Yes

Description of Codorus, Occasional

Setting

Landform: Flood plains
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Loamy alluvium derived from phyllite and/or mica schist and/or greenstone and/or old loamy alluvium derived from phyllite and/or mica schist and/or greenstone

Typical profile

Ap - 0 to 11 inches: silt loam
Bw1 - 11 to 18 inches: silt loam
Bw2 - 18 to 40 inches: gravelly silt loam
2C - 40 to 80 inches: very gravelly silt loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: NoneOccasional
Frequency of ponding: None
Available water capacity: Moderate (about 7.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: C
Hydric soil rating: No

Minor Components

Delanco

Percent of map unit: 5 percent
Landform: Stream terraces
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Convex
Hydric soil rating: No

Pr—Pits, quarry

Map Unit Setting

National map unit symbol: l7ry
Mean annual precipitation: 40 to 46 inches
Mean annual air temperature: 48 to 57 degrees F
Frost-free period: 161 to 215 days
Farmland classification: Not prime farmland

Map Unit Composition

Pits, quarries: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pits, Quarries

Setting

Landform: Hills
Down-slope shape: Linear, convex
Across-slope shape: Convex, linear
Parent material: Pits

Minor Components

Waste areas

Percent of map unit: 10 percent
Hydric soil rating: No

W—Water

Map Unit Setting

National map unit symbol: l7th
Mean annual precipitation: 36 to 50 inches
Mean annual air temperature: 46 to 59 degrees F
Frost-free period: 120 to 214 days
Farmland classification: Not prime farmland

Map Unit Composition

Water: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Water

Setting

Parent material: Rivers streams ponds

Properties and qualities

Runoff class: Negligible
Frequency of ponding: Frequent

Data Source Information

Soil Survey Area:	Bucks County, Pennsylvania
Survey Area Data:	Version 17, Jun 4, 2020

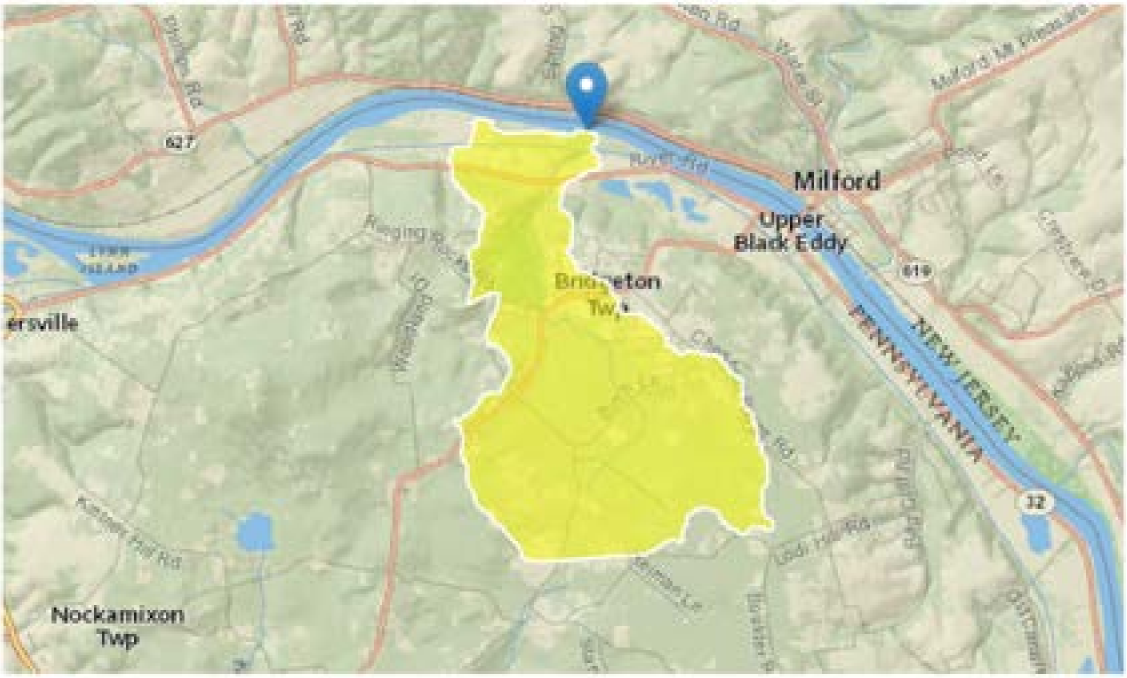
Appendix C

Stream Information

High Falls Creek`

StreamStats Report

Region ID: PA
Workspace ID: PA20201115212855510000
Clicked Point (Latitude, Longitude): 40.57309, -75.12050
Time: 2020-11-15 16:29:11 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRN	Drainage quality index from STATSGO	3.7	dimensionless
DRNAREA	Area that drains to a point on a stream	2.32	square miles
CARBON	Percentage of area of carbonate rock	0	percent
BSLOPD	Mean basin slope measured in degrees	2.5615	degrees
ROCKDEP	Depth to rock	4.5	feet
URBAN	Percentage of basin with urban development	1.3906	percent
ELEV	Mean Basin Elevation	499	feet

Parameter Code	Parameter Description	Value	Unit
PRECIP	Mean Annual Precipitation	46	inches
FOREST	Percentage of area covered by forest	86.2389	percent

Peak-Flow Statistics Parameters[Peak Flow Region 4 SIR 2019 5094]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.32	square miles	1.2	512
CARBON	Percent Carbonate	0	percent	0	68.5

Peak-Flow Statistics Flow Report[Peak Flow Region 4 SIR 2019 5094]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
2 Year Peak Flood	413	ft^3/s	40.4
5 Year Peak Flood	717	ft^3/s	33.1
10 Year Peak Flood	969	ft^3/s	30.9
25 Year Peak Flood	1340	ft^3/s	29.8
50 Year Peak Flood	1650	ft^3/s	30.4
100 Year Peak Flood	1990	ft^3/s	31.5
200 Year Peak Flood	2360	ft^3/s	32.7
500 Year Peak Flood	2910	ft^3/s	35.4

Peak-Flow Statistics Citations

Roland, M.A., and Stuckey, M.H.,2019, Development of regression equations for the estimation of flood flows at ungaged streams in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2019–5094, 36 p. (https:// doi.org/10.3133/sir20195094)

Low-Flow Statistics Parameters[Low Flow Region 1]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.32	square miles	4.78	1150

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
BSLOPD	Mean Basin Slope degrees	2.5615	degrees	1.7	6.4
ROCKDEP	Depth to Rock	4.5	feet	4.13	5.21
URBAN	Percent Urban	1.3906	percent	0	89

Low-Flow Statistics Disclaimers[Low Flow Region 1]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report[Low Flow Region 1]

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.175	ft^3/s
30 Day 2 Year Low Flow	0.269	ft^3/s
7 Day 10 Year Low Flow	0.0585	ft^3/s
30 Day 10 Year Low Flow	0.0956	ft^3/s
90 Day 10 Year Low Flow	0.211	ft^3/s

Low-Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Annual Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.32	square miles	2.26	1720
ELEV	Mean Basin Elevation	499	feet	130	2700
PRECIP	Mean Annual Precipitation	46	inches	33.1	50.4
FOREST	Percent Forest	86.2389	percent	5.1	100
URBAN	Percent Urban	1.3906	percent	0	89
CARBON	Percent Carbonate	0	percent	0	99

Annual Flow Statistics Flow Report[Statewide Mean and Base Flow]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SE	SEp
Mean Annual Flow	3.77	ft^3/s	12	12
Harmonic Mean Streamflow	1.02	ft^3/s	38	38

Annual Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Base Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.32	square miles	2.26	1720
PRECIP	Mean Annual Precipitation	46	inches	33.1	50.4
CARBON	Percent Carbonate	0	percent	0	99
FOREST	Percent Forest	86.2389	percent	5.1	100
URBAN	Percent Urban	1.3906	percent	0	89

Base Flow Statistics Flow Report[Statewide Mean and Base Flow]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SE	SEp
Base Flow 10 Year Recurrence Interval	1.88	ft^3/s	21	21
Base Flow 25 Year Recurrence Interval	1.68	ft^3/s	21	21
Base Flow 50 Year Recurrence Interval	1.57	ft^3/s	23	23

Base Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Bankfull Statistics Parameters[Statewide Bankfull Noncarbonate 2018 5066]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.32	square miles	2.62	207
CARBON	Percent Carbonate	0	percent		

Bankfull Statistics Disclaimers[Statewide Bankfull Noncarbonate 2018 5066]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Bankfull Statistics Flow Report[Statewide Bankfull Noncarbonate 2018 5066]

Statistic	Value	Unit
Bankfull Area	24.1	ft^2
Bankfull Streamflow	96.5	ft^3/s
Bankfull Width	21	ft
Bankfull Depth	1.19	ft

Bankfull Statistics Citations

Clune, J.W., Chaplin, J.J., and White, K.E.,2018, Comparison of regression relations of bankfull discharge and channel geometry for the glaciated and nonglaciated settings of Pennsylvania and southern New York: U.S. Geological Survey Scientific Investigations Report 2018–5066, 20 p. (https://doi.org/10.3133/sir20185066)

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Application Version: 4.4.0

Unnamed Tributary

StreamStats Report

Region ID: PA
Workspace ID: PA20201115215154833000
Clicked Point (Latitude, Longitude): 40.56875, -75.10632
Time: 2020-11-15 16:52:11 -0500

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.6	square miles
CARBON	Percentage of area of carbonate rock	0	percent
BSLOPD	Mean basin slope measured in degrees	6.8524	degrees
ROCKDEP	Depth to rock	3	feet
URBAN	Percentage of basin with urban development	14.7113	percent
ELEV	Mean Basin Elevation	315	feet
PRECIP	Mean Annual Precipitation	47	inches

Parameter Code	Parameter Description	Value	Unit
FOREST	Percentage of area covered by forest	67.6555	percent
DRN	Drainage quality index from STATSGO	3	dimensionless

Peak-Flow Statistics Parameters[Peak Flow Region 4 SIR 2019 5094]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.6	square miles	1.2	512
CARBON	Percent Carbonate	0	percent	0	68.5

Peak-Flow Statistics Disclaimers[Peak Flow Region 4 SIR 2019 5094]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Peak-Flow Statistics Flow Report[Peak Flow Region 4 SIR 2019 5094]

Statistic	Value	Unit
2 Year Peak Flood	160	ft^3/s
5 Year Peak Flood	289	ft^3/s
10 Year Peak Flood	398	ft^3/s
25 Year Peak Flood	560	ft^3/s
50 Year Peak Flood	698	ft^3/s
100 Year Peak Flood	849	ft^3/s
200 Year Peak Flood	1010	ft^3/s
500 Year Peak Flood	1260	ft^3/s

Peak-Flow Statistics Citations

Roland, M.A., and Stuckey, M.H.,2019, Development of regression equations for the estimation of flood flows at ungaged streams in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2019–5094, 36 p. (https:// doi.org/10.3133/sir20195094)

Low-Flow Statistics Parameters[Low Flow Region 1]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.6	square miles	4.78	1150
BSLOPD	Mean Basin Slope degrees	6.8524	degrees	1.7	6.4
ROCKDEP	Depth to Rock	3	feet	4.13	5.21
URBAN	Percent Urban	14.7113	percent	0	89

Low-Flow Statistics Disclaimers[Low Flow Region 1]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report[Low Flow Region 1]

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.0351	ft^3/s
30 Day 2 Year Low Flow	0.0558	ft^3/s
7 Day 10 Year Low Flow	0.0115	ft^3/s
30 Day 10 Year Low Flow	0.0202	ft^3/s
90 Day 10 Year Low Flow	0.0369	ft^3/s

Low-Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Annual Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.6	square miles	2.26	1720
ELEV	Mean Basin Elevation	315	feet	130	2700
PRECIP	Mean Annual Precipitation	47	inches	33.1	50.4
FOREST	Percent Forest	67.6555	percent	5.1	100
URBAN	Percent Urban	14.7113	percent	0	89
CARBON	Percent Carbonate	0	percent	0	99

Annual Flow Statistics Disclaimers[Statewide Mean and Base Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report[Statewide Mean and Base Flow]

Statistic	Value	Unit
Mean Annual Flow	0.953	ft^3/s
Harmonic Mean Streamflow	0.276	ft^3/s

Annual Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Base Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.6	square miles	2.26	1720
PRECIP	Mean Annual Precipitation	47	inches	33.1	50.4
CARBON	Percent Carbonate	0	percent	0	99
FOREST	Percent Forest	67.6555	percent	5.1	100
URBAN	Percent Urban	14.7113	percent	0	89

Base Flow Statistics Disclaimers[Statewide Mean and Base Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Base Flow Statistics Flow Report[Statewide Mean and Base Flow]

Statistic	Value	Unit
Base Flow 10 Year Recurrence Interval	0.47	ft^3/s
Base Flow 25 Year Recurrence Interval	0.422	ft^3/s
Base Flow 50 Year Recurrence Interval	0.395	ft^3/s

Base Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Bankfull Statistics Parameters[Statewide Bankfull Noncarbonate 2018 5066]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.6	square miles	2.62	207
CARBON	Percent Carbonate	0	percent		

Bankfull Statistics Disclaimers[Statewide Bankfull Noncarbonate 2018 5066]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Bankfull Statistics Flow Report[Statewide Bankfull Noncarbonate 2018 5066]

Statistic	Value	Unit
Bankfull Area	8.24	ft^2
Bankfull Streamflow	30.4	ft^3/s
Bankfull Width	11.3	ft
Bankfull Depth	0.772	ft

Bankfull Statistics Citations

Clune, J.W., Chaplin, J.J., and White, K.E.,2018, Comparison of regression relations of bankfull discharge and channel geometry for the glaciated and nonglaciated settings of Pennsylvania and southern New York: U.S. Geological Survey Scientific Investigations Report 2018–5066, 20 p. (https://doi.org/10.3133/sir20185066)

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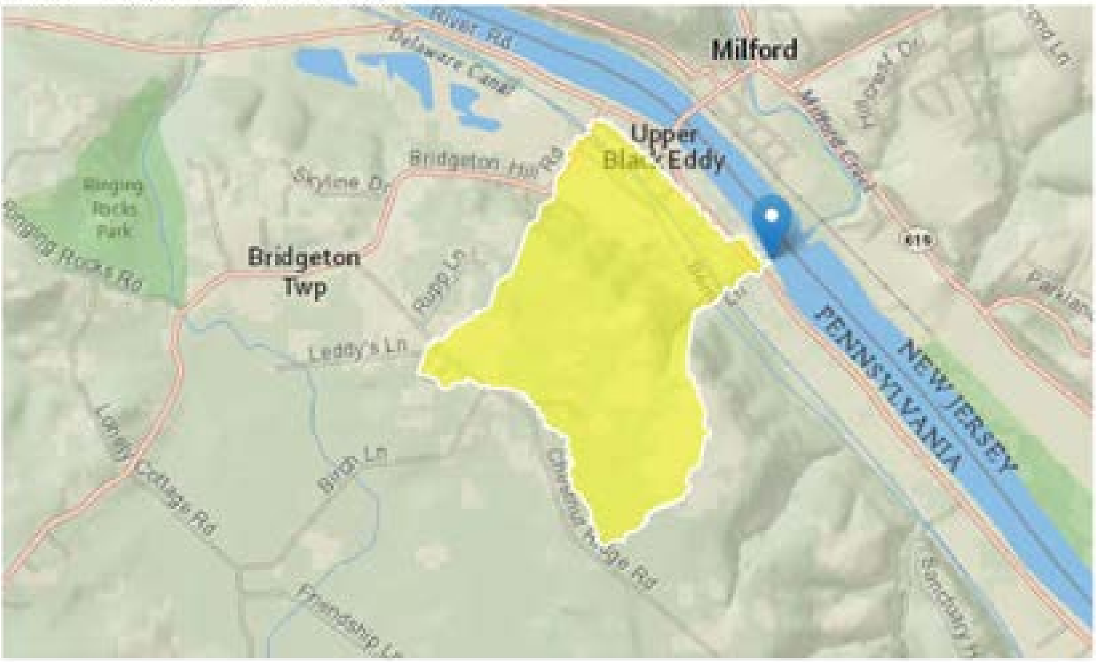
Application Version: 4.4.0

Mine Spring Creek

StreamStats Report

Region ID: PA
Workspace ID: PA20201115214353602000
Clicked Point (Latitude, Longitude): 40.56088, -75.09400
Time: 2020-11-15 16:44:08 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.52	square miles
CARBON	Percentage of area of carbonate rock	0	percent
BSLOPD	Mean basin slope measured in degrees	6.3072	degrees
ROCKDEP	Depth to rock	3.7	feet
URBAN	Percentage of basin with urban development	10.7842	percent
ELEV	Mean Basin Elevation	382	feet
PRECIP	Mean Annual Precipitation	47	inches

Parameter Code	Parameter Description	Value	Unit
FOREST	Percentage of area covered by forest	76.7289	percent
DRN	Drainage quality index from STATSGO	3.2	dimensionless

Peak-Flow Statistics Parameters[Peak Flow Region 4 SIR 2019 5094]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.52	square miles	1.2	512
CARBON	Percent Carbonate	0	percent	0	68.5

Peak-Flow Statistics Disclaimers[Peak Flow Region 4 SIR 2019 5094]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Peak-Flow Statistics Flow Report[Peak Flow Region 4 SIR 2019 5094]

Statistic	Value	Unit
2 Year Peak Flood	145	ft^3/s
5 Year Peak Flood	262	ft^3/s
10 Year Peak Flood	362	ft^3/s
25 Year Peak Flood	511	ft^3/s
50 Year Peak Flood	637	ft^3/s
100 Year Peak Flood	776	ft^3/s
200 Year Peak Flood	927	ft^3/s
500 Year Peak Flood	1150	ft^3/s

Peak-Flow Statistics Citations

Roland, M.A., and Stuckey, M.H.,2019, Development of regression equations for the estimation of flood flows at ungaged streams in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2019–5094, 36 p. (https:// doi.org/10.3133/sir20195094)

Low-Flow Statistics Parameters[Low Flow Region 1]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.52	square miles	4.78	1150
BSLOPD	Mean Basin Slope degrees	6.3072	degrees	1.7	6.4
ROCKDEP	Depth to Rock	3.7	feet	4.13	5.21
URBAN	Percent Urban	10.7842	percent	0	89

Low-Flow Statistics Disclaimers[Low Flow Region 1]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report[Low Flow Region 1]

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.0626	ft^3/s
30 Day 2 Year Low Flow	0.0896	ft^3/s
7 Day 10 Year Low Flow	0.0235	ft^3/s
30 Day 10 Year Low Flow	0.0365	ft^3/s
90 Day 10 Year Low Flow	0.0605	ft^3/s

Low-Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Annual Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.52	square miles	2.26	1720
ELEV	Mean Basin Elevation	382	feet	130	2700
PRECIP	Mean Annual Precipitation	47	inches	33.1	50.4
FOREST	Percent Forest	76.7289	percent	5.1	100
URBAN	Percent Urban	10.7842	percent	0	89
CARBON	Percent Carbonate	0	percent	0	99

Annual Flow Statistics Disclaimers[Statewide Mean and Base Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report[Statewide Mean and Base Flow]

Statistic	Value	Unit
Mean Annual Flow	0.852	ft^3/s
Harmonic Mean Streamflow	0.238	ft^3/s

Annual Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Base Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.52	square miles	2.26	1720
PRECIP	Mean Annual Precipitation	47	inches	33.1	50.4
CARBON	Percent Carbonate	0	percent	0	99
FOREST	Percent Forest	76.7289	percent	5.1	100
URBAN	Percent Urban	10.7842	percent	0	89

Base Flow Statistics Disclaimers[Statewide Mean and Base Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Base Flow Statistics Flow Report[Statewide Mean and Base Flow]

Statistic	Value	Unit
Base Flow 10 Year Recurrence Interval	0.431	ft^3/s
Base Flow 25 Year Recurrence Interval	0.388	ft^3/s
Base Flow 50 Year Recurrence Interval	0.363	ft^3/s

Base Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Bankfull Statistics Parameters [Statewide Bankfull Noncarbonate 2018 5066]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.52	square miles	2.62	207
CARBON	Percent Carbonate	0	percent		

Bankfull Statistics Disclaimers [Statewide Bankfull Noncarbonate 2018 5066]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Bankfull Statistics Flow Report [Statewide Bankfull Noncarbonate 2018 5066]

Statistic	Value	Unit
Bankfull Area	7.35	ft^2
Bankfull Streamflow	26.9	ft^3/s
Bankfull Width	10.6	ft
Bankfull Depth	0.738	ft

Bankfull Statistics Citations

Clune, J.W., Chaplin, J.J., and White, K.E.,2018, Comparison of regression relations of bankfull discharge and channel geometry for the glaciated and nonglaciated settings of Pennsylvania and southern New York: U.S. Geological Survey Scientific Investigations Report 2018–5066, 20 p. (https://doi.org/10.3133/sir20185066)

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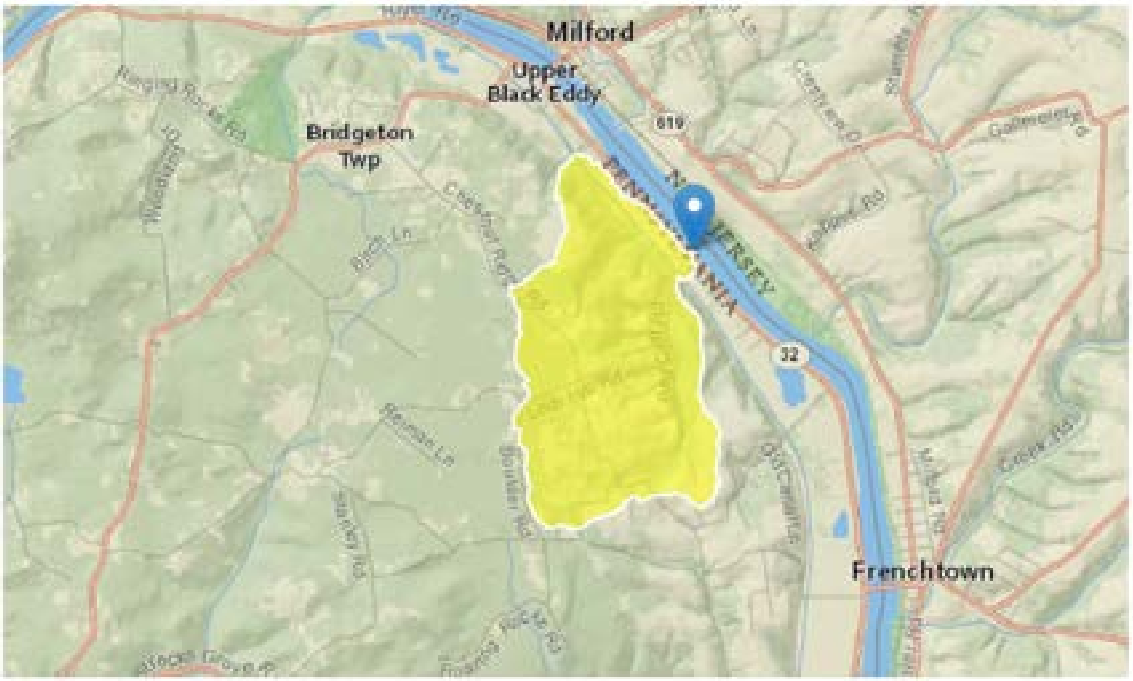
Application Version: 4.4.0

Lodi Creek

StreamStats Report

Region ID: PA
Workspace ID: PA20201115214805030000
Clicked Point (Latitude, Longitude): 40.55222, -75.08421
Time: 2020-11-15 16:48:21 -0500



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	1.55	square miles
CARBON	Percentage of area of carbonate rock	0	percent
BSLOPD	Mean basin slope measured in degrees	8.025	degrees
ROCKDEP	Depth to rock	4.3	feet
URBAN	Percentage of basin with urban development	4.9575	percent
ELEV	Mean Basin Elevation	405	feet
PRECIP	Mean Annual Precipitation	47	inches

Parameter Code	Parameter Description	Value	Unit
FOREST	Percentage of area covered by forest	78.7556	percent
DRN	Drainage quality index from STATSGO	3.6	dimensionless

Peak-Flow Statistics Parameters[Peak Flow Region 4 SIR 2019 5094]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.55	square miles	1.2	512
CARBON	Percent Carbonate	0	percent	0	68.5

Peak-Flow Statistics Flow Report[Peak Flow Region 4 SIR 2019 5094]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SEp
2 Year Peak Flood	311	ft^3/s	40.4
5 Year Peak Flood	546	ft^3/s	33.1
10 Year Peak Flood	743	ft^3/s	30.9
25 Year Peak Flood	1030	ft^3/s	29.8
50 Year Peak Flood	1280	ft^3/s	30.4
100 Year Peak Flood	1540	ft^3/s	31.5
200 Year Peak Flood	1840	ft^3/s	32.7
500 Year Peak Flood	2270	ft^3/s	35.4

Peak-Flow Statistics Citations

Roland, M.A., and Stuckey, M.H.,2019, Development of regression equations for the estimation of flood flows at ungaged streams in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2019–5094, 36 p. (https:// doi.org/10.3133/sir20195094)

Low-Flow Statistics Parameters[Low Flow Region 1]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.55	square miles	4.78	1150

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
BSLOPD	Mean Basin Slope degrees	8.025	degrees	1.7	6.4
ROCKDEP	Depth to Rock	4.3	feet	4.13	5.21
URBAN	Percent Urban	4.9575	percent	0	89

Low-Flow Statistics Disclaimers[Low Flow Region 1]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report[Low Flow Region 1]

Statistic	Value	Unit
7 Day 2 Year Low Flow	0.435	ft^3/s
30 Day 2 Year Low Flow	0.536	ft^3/s
7 Day 10 Year Low Flow	0.21	ft^3/s
30 Day 10 Year Low Flow	0.272	ft^3/s
90 Day 10 Year Low Flow	0.356	ft^3/s

Low-Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Annual Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.55	square miles	2.26	1720
ELEV	Mean Basin Elevation	405	feet	130	2700
PRECIP	Mean Annual Precipitation	47	inches	33.1	50.4
FOREST	Percent Forest	78.7556	percent	5.1	100
URBAN	Percent Urban	4.9575	percent	0	89
CARBON	Percent Carbonate	0	percent	0	99

Annual Flow Statistics Disclaimers[Statewide Mean and Base Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report[Statewide Mean and Base Flow]

Statistic	Value	Unit
Mean Annual Flow	2.54	ft^3/s
Harmonic Mean Streamflow	0.723	ft^3/s

Annual Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Base Flow Statistics Parameters[Statewide Mean and Base Flow]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.55	square miles	2.26	1720
PRECIP	Mean Annual Precipitation	47	inches	33.1	50.4
CARBON	Percent Carbonate	0	percent	0	99
FOREST	Percent Forest	78.7556	percent	5.1	100
URBAN	Percent Urban	4.9575	percent	0	89

Base Flow Statistics Disclaimers[Statewide Mean and Base Flow]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Base Flow Statistics Flow Report[Statewide Mean and Base Flow]

Statistic	Value	Unit
Base Flow 10 Year Recurrence Interval	1.27	ft^3/s
Base Flow 25 Year Recurrence Interval	1.14	ft^3/s
Base Flow 50 Year Recurrence Interval	1.07	ft^3/s

Base Flow Statistics Citations

Stuckey, M.H.,2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p. (http://pubs.usgs.gov/sir/2006/5130/)

Bankfull Statistics Parameters[Statewide Bankfull Noncarbonate 2018 5066]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1.55	square miles	2.62	207
CARBON	Percent Carbonate	0	percent		

Bankfull Statistics Disclaimers[Statewide Bankfull Noncarbonate 2018 5066]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Bankfull Statistics Flow Report[Statewide Bankfull Noncarbonate 2018 5066]

Statistic	Value	Unit
Bankfull Area	17.5	ft^2
Bankfull Streamflow	68.4	ft^3/s
Bankfull Width	17.5	ft
Bankfull Depth	1.05	ft

Bankfull Statistics Citations

Clune, J.W., Chaplin, J.J., and White, K.E.,2018, Comparison of regression relations of bankfull discharge and channel geometry for the glaciated and nonglaciated settings of Pennsylvania and southern New York: U.S. Geological Survey Scientific Investigations Report 2018–5066, 20 p. (https://doi.org/10.3133/sir20185066)

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Application Version: 4.4.0

Appendix D

PennDOT Straight Line Diagrams

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EXTRACT DATE: 12/18/2019     ROADWAY MANAGEMENT SYSTEM       PAGE NUMBER:    61
  PRINT DATE: 12/22/2019   SLD COUNTY/SR - ANNUAL PRINT    COUNTY: BUCKS

DIR: N             TOTAL LEN:   40.574 MI.          DIST: 06-1      SR:    32
LEFT MUN: BRIDGETON T                          RIGHT MUN: BRIDGETON T

                                           018 "DIA  CIRC METAL
                                 0800/1307 LEN=0025  INSTALLED UNKN
                                           012 "DIA  CIRC CONCR
                                 0800/1065 LEN=0025  INSTALLED UNKN
                                           012 "DIA  CIRC CONCR
                                 0800/0835 LEN=0025  INSTALLED UNKN

                                 0800/0019 BMSEN 09/0032/0800/0000
        200492 FT                200888 FT 1 D 00326 0 01  2126+16
                                           FALLS CREEK
                                           BMSBG 09/0032/0800/0000
                                 0800/0000 LENGTH(AH  2426 BK 3170)
                                           012 "DIA  CIRC CONCR
                                 0790/3025 LEN=0033  INSTALLED UNKN

                                           015 "DIA  CIR PLASTIC
                                 0790/2368 LEN=0027  INSTALLED UNKN
                                           015 "DIA  CIRC METAL
                                 0790/1900 LEN=0027  INSTALLED UNKN

                                 0790/0020 BMSEN 09/0032/0790/0000
        197322 FT                197718 FT 1 D 00326 0 01  2094+38
                                           HIGH FALLS CREEK
                                           BMSBG 09/0032/0790/0000
                                 0790/0000 LENGTH(AH  3170 BK 3149)

                                           018 "DIA  CIRC METAL
                                 0780/0225 LEN=0038  INSTALLED UNKN
                                 0780/0051 BMSEN 09/0032/0780/0000
        194173 FT                194569 FT 1 D 00326 0 01  2062+96
                                           DELAWARE CANAL
                                           BMSBG 09/0032/0780/0000
                                 0780/0000 LENGTH(AH  3149 BK 3099)
                                           TRAILS END LN
                                 0770/2891 (PRDR)
                                           018 "DIA  CIRC CONCR
Stormwater Crossing: A           0770/2610 LEN=0026  INSTALLED UNKN
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EXTRACT DATE: 12/18/2019     ROADWAY MANAGEMENT SYSTEM          PAGE NUMBER:   60
  PRINT DATE: 12/22/2019   SLD COUNTY/SR - ANNUAL PRINT         COUNTY: BUCKS

DIR: N              TOTAL LEN:   40.574 MI.          DIST: 06-1       SR:   32
LEFT MUN: BRIDGETON T                         RIGHT MUN: BRIDGETON T

                 Stormwater Crossing: B               0770/1582  018 "DIA  CIR PLASTIC
                                                                 LEN=0030  INSTALLED UNKN
                 Stormwater Crossing: C               0770/1185  015 "DIA  CAST IRON
                                                                 LEN=0036  INSTALLED UNKN

1 0 00326 0 01 2031+84 191074 FT                      191470 FT
BRIDGETON HILL RD
(SR1017 SEG 0090/1514)  0770/0000                     0770/0000  LENGTH(AH 3099 BK 3288)
                 Stormwater Crossing: D               0760/3270  012 "DIA  CIRC METAL
                                                                 LEN=0025  INSTALLED UNKN
                 Stormwater Crossing: E               0760/3060  018 "DIA  CIR PLASTIC
                                                                 LEN=0025  INSTALLED UNKN
                 Stormwater Crossing: F               0760/2565  018 "DIA  CIRC CONCR
FIREHOUSE LN                                                     LEN=0030  INSTALLED UNKN
(T443)                  0760/2481
                 Stormwater Crossing: G               0760/2372  012 "DIA  CIRC CONCR
                                                                 LEN=0030  INSTALLED UNKN
                                                      0760/2302  INTERSTATE BRIDGE RD
BRIDGE LN                                                        (GOVT)
(T446)                  0760/2222
                 Stormwater Crossing: H               0760/2195  015 "DIA  CIRC CONCR
CANAL LN                                                         LEN=0025  INSTALLED UNKN
(T447)                  0760/1690

                 Stormwater Crossing: I               0760/0687  012 "DIA  CIRC CONCR
                                                                 LEN=0040  INSTALLED UNKN
1 0 00326 0 01 1970+17 187786 FT                      188182 FT
BERM LN
(T450)                  0760/0000                     0760/0000  LENGTH(AH 3288 BK 2044)
                 Stormwater Crossing: J               0750/1615  012 "DIA  CAST IRON
                                                                 LEN=0033  INSTALLED UNKN
                 Stormwater Crossing: K               0750/0735  018 "DIA  CIR PLASTIC
                                                                 LEN=0025  INSTALLED UNKN
            Stormwater Crossing: L 185742 FT          0750/0460  015 "DIA  CAST IRON
                                                                 LEN=0033  INSTALLED UNKN
                                                      186138 FT  0 0 00000 0 00 0000+00
                                                      0750/0000  LENGTH(AH 2044 BK 2272)
                 Stormwater Crossing:M                0740/2272  015 "DIA  CIRC METAL
                                                                 LEN=0030  INSTALLED UNKN

                 Stormwater Crossing:N                0740/1220  012 "DIA  CIRC METAL
                                                                 LEN=0033  INSTALLED UNKN
```

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EXTRACT DATE: 12/18/2019     ROADWAY MANAGEMENT SYSTEM        PAGE NUMBER:    59
  PRINT DATE: 12/22/2019   SLD COUNTY/SR - ANNUAL PRINT    COUNTY: BUCKS

DIR: N              TOTAL LEN:   40.574 MI.          DIST: 06-1       SR:    32
LEFT MUN: BRIDGETON T                          RIGHT MUN: BRIDGETON T

                                                     BRIDGETON
                                           0740/0480 TINICUM T
                   183470 FT               183866 FT 1 D 00326 0 01 1927+01
                                                     LODI CREEK
                                                     STRUCTURE LENGTH   14 FT
                                                     BMSID 09/0032/0740/0000
                                           0740/0000 LENGTH(AH 2272 BK 1688)
LODI HILL RD
(T451)              0730/1471
                                                     015 "DIA CIRC METAL
                                           0730/1140 LEN=0035 INSTALLED UNKN
                                                     015 "DIA CIRC METAL
                                           0730/0550 LEN=0035 INSTALLED UNKN
                   181782 FT               182178 FT 1 D 00326 0 01 1909+53
                                           0730/0000 LENGTH(AH 1688 BK 3657)
                                                     012 "DIA CAST IRON
                                           0720/3657 LEN=0026 INSTALLED UNKN

                                                     018 "DIA CIRC METAL
                                           0720/0115 LEN=0042 INSTALLED UNKN
1 0 00326 0 01 1873+19 178125 FT           178521 FT
JUGTOWN HILL RD
(T445)              0720/0000              0720/0000 LENGTH(AH 3657 BK 3259)
                                                     015 "DIA CIRC METAL
                                           0700/2869 LEN=0029 INSTALLED UNKN
                                                     018 "DIA CIRC METAL
                                           0700/2668 LEN=0032 INSTALLED UNKN

                   174866 FT               175262 FT 1 D 00326 0 01 1840+60
                                           0700/0000 LENGTH(AH 3259 BK 2822)
                                                     060"H 00"W MULT METAL
                                           0690/2805 LEN=0028 INSTALLED UNKN
                                                     018 "DIA CAST IRON
                                           0690/2323 LEN=0030 INSTALLED UNKN
```

Appendix E

FEMA Information

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
DELAWARE RIVER (continued)								
EA	856.47 / 162.21	1428 / 1093 / 1637	29492	9.4	117.6	117.6	118.0	0.4
EB	857.95 / 162.49	1032 / 818 / 1510	25458	10.9	118.3	118.3	118.8	0.5
EC	859.48 / 162.78	1208 / 772 / 2040[3]	27856	10.0	119.7	119.7	120.1	0.4
ED	860.96 / 163.06	1626 / 1238 / 2369	29684	9.4	120.7	120.7	121.1	0.4
EE	862.48 / 163.35	2949 / 2396 / 2424	43521	6.4	122.2	122.2	122.6	0.4
EF	864.02 / 163.64	2031 / 1584 / 2308[3]	32844	8.5	122.5	122.5	122.8	0.3
EG	865.28 / 163.88	1786 / 1131 / 2219[3]	27977	9.9	123.0	123.0	123.4	0.4
EH	867.35 / 164.27	1607 / 1103 / 1722[3]	30267	9.2	124.8	124.8	125.2	0.4
EI	869.99 / 164.77	2209 / 1679 / 1890	40518	8.4	126.4	126.4	126.7	0.3
EJ	871.48 / 165.05	2213 / 1847 / 1847	24175	11.5	126.7	126.7	127.0	0.3
EK	872.94 / 165.33	2147 / 1504 / 1940[3]	42301	8.8	128.9	128.9	129.1	0.2
EL	874.53 / 165.63	1691 / 1293 / 1578[3]	30237	10.1	129.4	129.4	129.6	0.2
EM	876.00 / 165.91	1430 / 789 / 1052[3]	27017	10.3	130.2	130.2	130.4	0.2
EN	877.48 / 166.19	1181 / 727 / 849[3]	25461	10.9	131.2	131.2	131.5	0.3
EO	878.91 / 166.46	981 / 522 / 522	26323	10.5	132.2	132.2	132.5	0.3
EP	880.44 / 166.75	929 / 546 / 562	26003	11.1	132.9	132.9	133.3	0.4

[1]Thousands of feet above mouth / Miles above mouth
[2]Width / Width within Bucks County / Width within Bucks County (0.2 ft encroachment)
[3]Cross section includes small lengths of high ground above the 0.2 ft encroachment floodway

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY

BUCKS COUNTY, PA (ALL JURISDICTIONS)

FLOODWAY DATA

DELAWARE RIVER

nt file (Ctrl+P)

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH[2] (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
DELAWARE RIVER (continued)								
EQ	881.92 / 167.03	1129 / 591 / 722	29588	9.8	134.3	134.3	134.6	0.3
ER	883.71 / 167.37	711 / 406 / 1059	22041	12.6	134.6	134.6	134.9	0.3
ES	885.30 / 167.67	893 / 452 / 982	26988	10.3	136.7	136.7	137.2	0.5
ET	886.46 / 167.89	905 / 449 / 747	26556	10.5	137.2	137.2	137.7	0.5
EU	887.94 / 168.17	751 / 422 / 643	25373	10.9	137.8	137.8	138.4	0.6
EV	889.52 / 168.47	701 / 451 / 729	23834	11.7	138.4	138.4	138.9	0.5
EW	891.00 / 168.75	904 / 602 / 613	27453	10.1	139.3	139.3	139.9	0.6
EX	892.48 / 169.03	982 / 665 / 864	28817	9.7	140.1	140.1	140.7	0.6
EY	894.01 / 169.32	1228 / 896 / 1021	28543	9.7	140.9	140.9	141.5	0.6
EZ	895.49 / 169.60	1848 / 1148 / 1284	32437	8.6	141.9	141.9	142.5	0.6
FA	896.97 / 169.88	1336 / 894 / 1230	33025	8.4	143.0	143.0	143.5	0.5
FB	898.50 / 170.17	984 / 593 / 787	26266	10.6	143.2	143.2	143.8	0.6
FC	899.96 / 170.45	655 / 310 / 389	22949	12.1	144.1	144.1	144.7	0.6
FD	901.51 / 170.74	667 / 419 / 419	21254	13.1	144.7	144.7	145.4	0.7
FE	902.93 / 171.01	659 / 372 / 394	21211	13.1	145.9	145.9	146.6	0.7
FF	904.46 / 171.30	914 / 562 / 632	29694	9.3	148.3	148.3	148.9	0.6
FG	906.00 / 171.59	1282 / 996 / 1011	33894	8.2	149.2	149.2	149.8	0.6

[1]Thousands of feet above mouth / Miles above mouth
[2]Width / Width within Bucks County / Width within Bucks County (0.2 ft encroachment)

TABLE 8

FEDERAL EMERGENCY MANAGEMENT AGENCY

BUCKS COUNTY, PA (ALL JURISDICTIONS)

FLOODWAY DATA

DELAWARE RIVER

TABLE 4- SUMMARY OF DISCHARGES (continued)

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cubic feet per second) 10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
DELAWARE RIVER					
At USGS Gage 01463500 at Trenton, NJ	6,780	169,000	245,000	280,000	372,000
Downstream of confluence of Tohickon Creek	6,588	168,150	243,301	277,451	366,053
At USGS Gage 01457500 at Riegelsville, PA	6,328	167,000	241,000	274,000	358,000
At Belvidere, NJ	4,535	118,000	190,000	230,000	350,000
At Port Jervis, NY	3,076	88,000	140,000	170,000	270,000

TABLE 6- MANNING'S "n" VALUES (continued)

Stream	Channel "n"	Overbank "n"
Cuttalossa Creek	*	*
Deep Run	0.035-0.045	0.030-0.700
Delaware River	0.020-0.100	0.035-0.100
East Branch Perkiomen Creek	0.04-0.05	0.045-0.13
Gallows Run	0.035-0.045	0.080-0.100