Branch Ave Park Stream Restoration
Erie Street SE & Branch Avenue SE

Final Design Report

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Prepared for:

Department of Energy and Environment, District of Columbia Government, Watershed Protection Division
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Revision History Table

Version	Date	Notes
1.0	3/8/2019	Concept report submitted to DOEE
1.1	5/24/2019	Semi-final report submitted to DOEE
1.2	8/7/2019	Final report submitted to DOEE

Table of Contents

List of Tables

List of Figures

List of Photos

Appendices

List of Acronyms

Acronym	Definition
BANCS	Bank Assessment for Non-point source Consequences of Sediment
BEHI	Bank Erosion Hazard Index
cfs	Cubic Feet per Second
DB Team	Design/Build Team
DBH	Diameter at Breast Height
DGS	Department of General Services
DOEE	Department of Energy and Environment
DPR	Department of Parks and Recreation
ft	Feet
HSG	Hydrologic Soils Group
lb.	Pound
N	Nitrogen
NBS	Near Bank Stress
NRCS	Natural Resources Conservation Service
P	Phosphorous
psf	Pounds per Square Foot
RSC	Regenerative Stream Conveyance
SPSC	Step Pool Stormwater Conveyance
sf	Square Feet
Sq Mi	Square Mile
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

1. Project Description and Background

The District Department of the Energy and Environment (DOEE) procured the Design/Build (DB) team of Actaeon LLC (Actaeon) and Straughan Environmental Inc. (Straughan) to design and construct a stream restoration project in Branch Avenue Park, Southeast Washington, D.C. Straughan prepared this semi-final design report to describe the current geomorphology of the site and provide a description and design computations for the chosen design.

1.1. Project Goals

DOEE's goal is to restore natural stream flows through Branch Avenue park to reduce erosion and stormwater pollution and provide enhanced wildlife habitat. Additionally, DOEE wants to provide safe public access to the park. The DB Team will design both the stream restoration and a walking trail through the park. The specific goals for the project are:

1. Improve control of stormwater into the park to reduce bank erosion and provide more habitat
2. Uplift the hydrologic, hydraulic, geomorphic and physicochemical, processes of the stream
3. Provide a safe walking trail for the community to access the park

1.2. Site Description

Branch Avenue Park is a small triangular wooded parcel bounded by Branch Avenue to the west, Erie Street to the northeast and Southern Avenue to the southeast. The park has a stream that flows from northwest to southeast. The stream enters the park from an enclosed storm drain system under Branch Avenue and leaves the park into another enclosed storm drain system under Southern Avenue. The downstream storm drain system crosses Southern Avenue into Prince George's County, Maryland and discharges into Oxon Run.

Photo 1 – Above ground sewer line running in a concrete encasement from Branch Avenue to Erie Street.

Several existing site characteristics constrain a potential restoration design. The largest constraint is the existing above ground sewer line between Branch Avenue and Erie Street north of the storm drain inflow. Per DOEE instruction, the proposed design must avoid disturbing the concrete structure and its foundations. The design will also need to consider impacts to the forested character of the site. Currently the stream is surrounded by several large 24 to 40-inch diameter trees that are not only of an important ecological value but also a community asset providing screening from the busy intersection. DOEE has noted that both they and the community value forested cover.

2. Desktop Analysis

2.1. Drainage Area

Branch Avenue Park has a 43-acre watershed stretching from Southern Ave SE north to Alabama Ave SE, and from Branch Ave SE west to 32nd Street. The watershed is developed with single family homes and is 35% impervious. DC Water has a separate storm drain system that brings most of the watershed to the 36-inch pipe under Branch Ave SE. One and a half acres of single-family houses along Gainesville Street drain to the project site through a separate 18 -inch pipe under Branch Ave. Erie Street collects drainage from another 2 acres of single-family houses along the northeastern edge of the project and drains to the stream through an incised gully in the park. To the northeast of Erie Street and at the top of a steep hill, Denver Street and the alley between Erie and Denver Streets drain to a storm drain system between the houses that runs under Erie Street to Southern Avenue, where it turns southwest and joins the project site's outfall. The inlets on Denver Street and the alley both overflow into a small channel between the homes that enters Erie Street on the surface and goes to the gully in the park. Most small storms likely bypass the project site through the storm drain, but large events that overwhelm the inlets will join the other drainage from Erie Street and add to the water eroding the gully.

Straughan delineated the drainage area using digital elevation maps acquired from Maryland's iMap service and GIS storm drain networks provided by DOEE. See Appendix B for the drainage area map.

2.2. Hydrologic Analysis

Straughan used the United States Department of Agriculture's (USDA) WinTR-55 program to develop storm flows based on the delineated drainage areas (United States Department of Agriculture, 1986). Table 1 provides a summary of the flow rates. Appendix B contains the preliminary drainage area map and hydrologic calculations.

Drainage Area	Area (Acres)	% Impervious	2-Year Storm (CFS)	5-Year Storm (CFS)	10-Year Storm (CFS)	50-Year Storm (CFS)	100-Year Storm (CFS)
Upstream Storm Drain	39.1	35%	33	50	66	112	136
Gainesville Street	1.5	40%	3	5	6	10	12
Erie Street	5.4	36%	12	17	21	34	41
Downstream (Peak)	45.9	36%	37	55	72	121	148

Table 1 – Summary of Storm Flows.

2.3. Soils

Straughan obtained a Web Soil Survey report for the drainage area and project site on January 2, 2019 from the USDA Natural Resources Conservation Service (NRCS). The project site has

Muirkirk variant complex soils. Muirkirk soils are considered well drained (Hydrologic Soil Group (HSG) C) with layers of loamy sand and sandy loam overlying a layer of clay at 31 to 60 inches deep. During field visits, Straughan observed a soil profile consistent with this description in the exposed stream banks.

The drainage area is mostly Beltsville and Chillum Urban land complexes with slopes ranging from 0 to 40 percent. Beltsville soils are a moderately well drained silt loam classified as HSG C. Chillum soils are a well-drained gravel loam with HSG C. However, in the areas of Chillum soil with slopes greater than 15%, NRCS did not give an HSG rating. Straughan assumed a rating of D since rainfall is unlikely to infiltrate quickly into steep slopes. The NRCS mapped the soils at a scale of 1-inch equals 1,000 feet. Straughan used the mapping for hydrology and preliminary design purposes.

Straughan engaged ECS Capitol Services, PLLC to complete a hand-auger geotechnical analysis at two boring locations in February 2019. Both boring locations were located 30-40 feet into the left overbank area to a depth of 5-6 feet (hand auger refusal depth). Both borings generally found sandy clay to a depth of approximately three feet, underlain by gravels. Groundwater was not observed in either boring location, indicating groundwater resides greater than 6 feet beneath the floodplain terrace.

The results generally agreed with visual observation of the soil profile from the stream bank. Straughan observed the stream bottom had cut through a layer of consolidated clay. Above the clay is a layer of cobble and gravel, mixed with silty sand. The remaining soil up to the floodplain was clayey/silty sand. This indicates that some of the soil will be suitable for re-use as part of mass grading. Areas of channel fill near the bottom of the channel would be appropriate where the existing soil profile has a high clay content. This will also help support surface flow where the channel is raised. However, the top three feet of channel fill will likely need to be imported from off site to have a higher sand content, supporting improved infiltration and hyporheic exchange.

See Appendix J for detailed soil data.

3. Field Verification

3.1. Drainage Area Walk

Straughan walked the drainage area on December 13th, 2018. The field crew visually confirmed highpoints and opened manholes to confirm the GIS data provided by DOEE. After the field walk, Straughan corrected the preliminary drainage area and land use to match field observations.

Photo 2 – Typical view of single-family neighborhoods in the drainage area.

3.2. Field Survey

The DB Team engaged Mercado Consultants Inc. to survey the project site and surrounding storm and sanitary sewer systems. Mercado performed the field work in December 2018. This work includes locating the existing stream, stream banks, outfall structures, edge of water, pipe structures, trees larger than 12” diameter at breast height (DBH), berms, spillways, fences, all above ground utilities, top and toe of banks, any man-made features, and all terrain breaks and spot elevations to create an accurate surface model. The survey also included collecting the storm drain and sewer systems along Erie St., Southern Ave, and Branch Ave.

3.3. Utility Designation

The DB Team contracted Accumark Inc. to designate underground utilities in the project area in compliance with Quality Level B and A, respectively as defined in CI/ASCE 38-02, *Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data.* This includes the entire park area and the utilities along Erie Street. Accumark performed field work for the designations in early January 2019. Accumark found gas, water, sewer, electrical and an unknown 16-inch pipe under Erie Street. They did not locate any utilities inside the project area.

3.4. Geotechnical Investigation

The DB Team engaged ECS Capitol Services, PLLC to perform a geotechnical investigation of the project site. ECS performed two hand augured bore holes. Both holes stopped at around 5 feet deep because of refusal (likely from tree roots/consolidated soil). ECS classified the soils found and performed a constant head infiltration test. Both borings had a 2-3-foot-deep layer of sandy clay fill material over a one-foot layer of clayey gravel. Under the clayey gravel is more sandy clay. The saturated infiltration rate for western boring is 2.3 inches per hour and the eastern boring is 2.4 inches per hour. See Appendix I for the full geotechnical report.

3.5. Wetland Delineation

Straughan performed a wetland delineation field investigation on January 2nd and 17th, 2019 following the *Army Corps of Engineers Wetland Delineation Manual 1987*. The field investigation identified one palustrine emergent wetland and a perennial waterway (the stream) and an ephemeral waterway (the gully from Erie Street). The report advises that impacts to either the wetland or waterways may require a permit from the United States Army Corps of Engineers.

Straughan also completed specimen tree assessment and identified 87 trees. Eight of trees are considered heritage trees with a diameter of over 31.8 inches.

See Appendix D for the full wetland delineation report.

4. Geomorphic Analysis

4.1. Geomorphic Assessment

Straughan performed a geomorphic survey which included a longitudinal profile, three cross sections, a pebble count, Bank Erosion Hazard Index (BEHI) assessments, and an assessment of stream function on December 11th and 13th, 2018

Photo 3 –Cross Section 1.

4.1.1. Survey

Straughan collected a longitudinal profile and three cross sections along the subject reach on December 11th, 2018. The channel has an average slope of 5.7%.

See Appendix C for the profile and cross sections.

4.1.2. Bankfull Depth and Stream Type

The field team observed a floodplain bench that is a potential bankfull indicator at the downstream cross section 3. The remaining sections of stream did not display any identifiable bankfull indicators due to extreme entrenchment and instability.

Straughan compared the one-year discharge to the bankfull discharges developed by the USFWS for the coastal plain province on the western side of the Chesapeake Bay (McCandless, 2003). The USFWS curves estimate a bankfull discharge of 4.6 cubic feet per second (cfs) (Table 2), while our hydrology model estimated the one-year discharge to be 24 cfs. We chose to discard the regional curves values in favor of our site-specific hydrology because our watershed is dissimilar to the ones studied by USFWS. The USFWS curves are not representative because this watershed is too small (the smallest watershed in the study was 192 acres instead of 46 acres for Branch Avenue Park) and too impervious (the maximum imperviousness in the USFWS study is 17%, our watershed is 34% impervious). Also, the enclosed storm drains of our watershed decrease the travel time of concentration compared to the watershed in the study. The cumulative effect of these differences would be higher flows at the bankfull recurrence interval, which is consistent with our calculated hydrology.

Based on the selected bankfull discharge of 32 cfs from cross section 3, the stream is a Rosgen Type G in the upstream reach at cross section 2 where the stream is fully entrenched not accessing the floodplain. The downstream reach is transitioning to a Rosgen Type B stream where bank and erosion and overbank deposition are beginning to develop a new floodplain.

Figure 1 – Location of the geomorphic cross sections, where bank pins and BEHI assessments were performed

Method	Bankfull Discharge (cfs)	Bankfull Cross Section Area (sf)	Bankfull Top Width (ft)	Bankfull Depth (ft)
1-year Storm	24			
Potential Bankfull Indicator (Cross Section 3)	31.98	7.43	5.6	1.44
USFWS Regional Regression Curves	4.6	1.6	3.8	0.4

Table 2 – USFWS Regional Regression Equation Bankfull Parameters

4.1.3. Pebble Count

The field team performed a pebble count in the downstream section where the bed is sand and gravel. The pebble count included 100 particles and found a D50 of 11.8 millimeters.

See Appendix C for the pebble count data.

4.2. Bank Pins

Straughan installed three sets of four rebar bank pins on December 11, 2018. The bank pins are installed at the locations of the Bank Erosion Hazard Index (BEHI) assessments and the geomorphologic survey cross sections. See Figure 1 for the location of the bank pins. Each set has two two-foot long pins made from rebar on each bank. One pin is set a foot above ordinary high water, as determined by field observations, and the second pin is set another foot above the first. A field crew member hammered the pins into the bank until only six inches protruded from the bank.

During subsequent field visits, we noted that the site is experiencing types erosion that will not be well captured by the bank pins alone. On a March 27, 2018 field visit, Straughan identified a recent "mass wasting" bank failure near cross section 2, in which the full bank slope failed near its top and sloughed into the stream (over the bank pins). Straughan recommends that the bank pin data be supplemented with field-informed assumptions on any slope failures that may interfere with the estimates. Straughan will return to periodically check the pins over the next year until construction starts.

4.3. Function-Based Assessment

Straughan completed a function-based assessment on December 13, 2018 following the Function-Based Rapid Stream Assessment Methodology published by the United States Fish and Wildlife Service (USFWS) Chesapeake Field office in May 2015 (Starr, Harman, & Davis, 2015). See Table 3 for a summary of the assessment

Photo 4 – Bank pins on the right bank at Cross Section 2. Driven into the clay bank.

4.3.1. Hydrology

The stream's hydrology is not functioning because the entire watershed is fully developed without stormwater management. Most of the upstream flow path is in enclosed storm drains creating a flashy flow regime. The headwaters of this stream are piped. Perennial flow emerges from the upstream storm drain, indicating that the storm drain intercepts groundwater.

4.3.2. Hydraulics

The stream's hydraulics are not functioning. Most of the channel is very entrenched with banks that are almost 16 feet high and nearly vertical. The disconnected floodplain does not provide any retention of incoming storm flow because most of the water enters directly through two enclosed storm pipes and a deep gully that cuts through the floodplain and flows through the incised stream channel at a high velocity.

4.3.3. Geomorphology

The stream's geomorphology is not functioning because of a lack of stable habitat and variety in the planform. The upper two hundred feet of the channel has a clay bottom that does not provide any support for habitat features like gravel or woody debris. The lower half of the reach has a gravel bottom but no variety in flow depth or features.

4.3.4. Physicochemistry

The stream's physicochemistry is not functioning because the water quality is poor. The field crew observed the water was grey and smelled of sewage during the field visits on December 11th and 13th, 2018. The water also developed a white foam on the surface around pools. The field team observed the adjacent above ground sewer was leaking slightly on the 11th. The project manager reported the leak to DC Water and DC Water lined the sewer on December 13th, 2018.

Oxon Run, the downstream receiving water, is not listed for section 303(d) impairments by the Maryland Department of the Environment because of insufficient data (Maryland Department of the Environment, 2019).

We observed detritus on the surface of the streambed and excess sediment did not bury the smaller sticks and leaves. The field crew did not observe fine organic sediment deposits within the channel or signs of anaerobic decomposition in the channel, despite clear evidence of fine sediment input from wasting of the stream banks This indicates that any fine sediment input to the channel is being transported downstream.

4.3.5. Biology

The biology of the stream is not functioning. The field team did not observe any fish or benthic macroinvertebrates in the stream during the field assessments. Team members checked rocks in the gravel bed section of the stream at the downstream end and did not see any evidence of invertebrate activity.

Functional Pyramid Level	Existing Conditions
Hydrology	Not Functioning
Hydraulics	Not Functioning
Geomorphology	Not Functioning
Physicochemical	Not Functioning
Biology	Not Functioning

Table 3 – Summary of Function-based assessment for existing conditions.

5. Design Alternative Analysis

Straughan prepared two design alternatives for DOEE to consider prior to the Concept design phase. The alternatives for the stream incorporated elements of valley restoration/legacy sediment removal and regenerative stream conveyance (RSC). Additionally, we presented DOEE two different alternatives for SPSCs from Erie Street and for the walking trails.

Valley restoration/legacy sediment removal is excavating a new floodplain above the existing channel bottom. Valley restoration reduces bank erosion by allowing storm flows to overtop the stream bank and spread out on to the floodplain for most storm events. Reconnection of the floodplain meets the design goals by improving hydraulic function of the stream with less entrenchment and improving geomorphology with native plants in the riparian buffer and creating a variety of riffles and pools in the base flow channel. The wetland plants and reconnected floodplain also meet the physicochemical uplift goal by filtering nutrients to improve water quality.

RSC is a valley wide step pool and weir stream restoration method focused on maintaining vertical stability while encouraging infiltration and filtration of water in the floodplain. RSC stabilizes the stream vertically and horizontally with weirs and cascades of boulders and large rocks designer's size to be immobile during the design storm event. Between the weirs large valley wide pools dissipate the water's energy after cascades and weirs. While the weirs and channel are not as wide as typical valley restoration projects, the floodplain is wide enough to improve connectivity and uplift the hydraulic function of the stream. Native upland and wetland plants along the stream improve riparian vegetation. The sequence of weirs, pools, and cascades improve the bedform diversity. Step pools increase groundwater/surface water interaction and provide pollution retention and treatment within the reach.

For this report, we define SPSCs as a type of dry channel RSC that use sand filter beds to treat ephemeral outfalls across steep slopes.

DOEE selected their preferred restoration methods and alignments for the stream SPSC, and the walking trail.

5.1. No Action Alternative

The first alternative considered by Straughan was the no action alternative. If no work is done, the stream's head cuts would continue upstream, and possibly undermine the storm drain and sanitary sewer under Branch Ave. The steep channel banks would continue to erode, threatening the forest along the top of the banks and releasing sediment into the stream, blocking downstream storm drains and adding sediment and nutrients to the Oxon Run, the Potomac River and the Chesapeake Bay. The park would remain unsafe and poorly accessible to the public. Invasive plants would continue to spread throughout the forest and displace native species. Although the no action alternative incurred no immediate cost, the lack of maintenance on failing storm drain infrastructure would push additional maintenance and repair costs into the future.

5.2. Design Alternative 1

Straughan developed a hybrid approach using valley restoration in the upper 200 feet of the stream and an RSC design for the lower 230 feet. The approach was originally proposed by the Actaeon team in the procurement phase of this project.

Preliminary survey data indicated that design alternative 1 may have a significant impact on large trees in the upstream half of the site. Survey data also indicated that the stream itself is steeper than the DB Team assumed, which made achieving a low enough slope to spread flows across the valley more challenging.

5.3. Design Alternative 2

Straughan extended the RSC through the entire site to further minimize construction impacts and reduce the volume of material moved in the second design alternative. The upper segment floodplain was too far above the existing channel to allow valley restoration in the upper reach without an additional forty feet of excavation width to reach existing ground. The extra excavation required the removal of several large specimen trees directly adjacent to the existing banks. The design required fifteen riffle weirs with a one-foot drop and three boulder cascades with three-foot drops. In the less forested downstream segment, Straughan proposed localized excavation to maximize floodplain area and create better habitat and water quality treatment.

The second alternative emphasized limiting the impact to existing high-quality resources and minimizing the earthwork. The drawback of the approach was less floodplain area and a more entrenched proposed stream. Also, the increase in RSC structures requires importing more rocks and boulders to the site.

5.4. Construction Entrance and Stormwater Capture Opportunities/Alternatives

Straughan proposed two locations along Erie St SE for the construction entrance. The first location was 390 feet from Branch Ave SE and the road ran near the above ground sewer line between Frankford St SE and Erie St SE. The second location was 480 feet from Branch Ave SE and the road ran along the existing gully to the stream. Construction would enter from the chosen entrance and drive through the site to exit on Southern Ave SE heading southwest.

Straughan proposed a SPSC for each construction entrance option. The first option, close to the above ground sewer, allowed a longer flow path for a proposed SPSC. The first SPSC and the first access roads would be built in tandem and would consist of a series of weirs and boulder cascades. Unfortunately, opening the curb at Erie Street at the first location did not maximize stormwater inflow as a large volume of surface channel flow appears to reach the curb east of the proposed entrance.

Straughan proposed the second construction entrance and SPSC option at failed curb where the gully starts. The option included filling the gully for the access road, which the DB Team would later construct the SPSC on top of. The location of the failed curb matched the low point along Erie Street where runoff leaves the street. The proposed SPSC here would help solve standing water and safety problems. The second entrance required building a more significant haul road near the top of slope to allow vehicles to navigate the very steep drop off in the first 40 feet. Also, the length of the proposed SPSC was much shorter, which resulted in a steeper profile and the need to rely predominantly on cascades. The result was a higher cost for boulders and stabilization material.

5.5. Trail Alternatives

The alternative designs included proposed trails to allow the community to access the site. Straughan proposed several trail alternatives, which could be accepted or rejected in combination. For efficiency, the Actaeon team intended to re-use part of the selected alignment of the construction access road between Erie St SE and Southern Ave SE as the primary trail. Straughan proposed an optional leg that crosses the stream and switch backs up to Branch Ave SE at Gainesville St SE. Straughan did not proposed access to Branch Ave SE at Erie St SE because the above ground sewer blocks foot traffic.

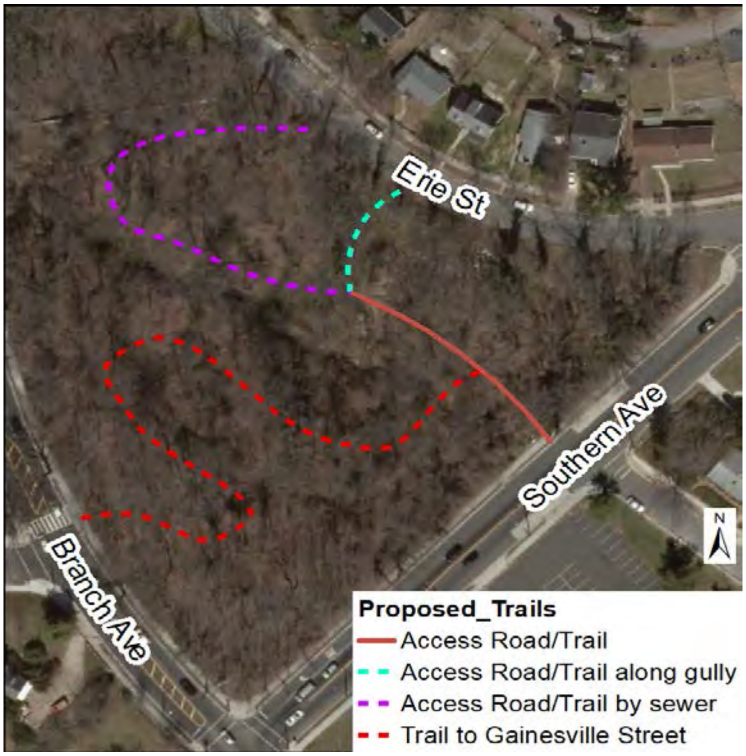

Figure 2 – Alternative Trail Alignments

We proposed the three entrances to the park to provide community access to pedestrians. Erie St SE had street parking during the day that more distant community members could use to see the park. Southern Ave SE had a bus stop near the trail end. The leg to Gainesville St SE started along a sidewalk at a crosswalk across Branch Ave SE. The trail to Gainesville St SE used a riffle to provide a shallow crossing over the stream near the downstream end.

The DB Team designed the trail to be a six-foot-wide mulch walking path. The trail crossed the SPSC and the stream riffles where hikers can cross on stepping-stones.

5.6. Selected Alternative

DOEE selected the second alternatives for both the stream and the SPSC. DOEE opted to proceed with a trail extending from the sewer entrance at Erie street to Southern Avenue. Other segments of trail, including an extension to Branch Avenue were eliminated.

5.7. Additional Alternative

During semi-final design, following discussions with Actaeon and DOEE, Straughan prepared an additional alternative design involving lifting the stream channel fully to the legacy fill terrace and modifying the storm drain outfall structure to raise its invert. This approach minimizes disturbance to adjacent forest and addresses channel incision along steep banks. Straughan presented a comparison of potential improvements to habitat and stream function against project cost. After review, DOEE opted not to proceed further with the design alternative due to the high cost of additional fill and stabilization material, compared to the amount authorized for this project.

6. Proposed Design

6.1. Changes During Final Design

During the final design phase, Straughan took steps to improve function, reduce impacts to forest, and reduce cost. The most significant changes are as follows:

- Revised the floodplain bench slopes in the upstream RSC section to be 2:1 (from 2%) to reduce the length of steep existing stream bank slopes to facilitate vegetative stabilization and improve access to the stream. The shallower slopes will also reduce the likelihood of failure because of erosion.
- Redesigned the stream-wetland complex riffles based on the results of two-dimensional modeling. The riffles are now 10 feet wide and use a D50 of 9 inches for the stones.
- Evaluated the TMDL credits based on Protocols 1, 2, 3, 4 and the proposed protocol 5.

6.2. Stream Restoration Design

Straughan proposes a hybrid approach to the project to maximize uplift within the given landscape constraints. The approach includes lifting the main stem channel bottom by an average of 6 feet throughout the length. In the upstream entrenched portion, Straughan proposes a series of valley-width weirs and cascades to safely filter and transfer flow. In the downstream section, where potential impacts to trees and steep slopes would be less significant, Straughan proposes two sections of wider floodplain with interconnected stream/wetland complexes. At the downstream end one last cascade will drop the stream into the existing storm drain under Southern Ave SE. The goal of the design is to minimize the number of trees removed and the grading, while maximizing the amount of high-quality stream and wetland habitat created.

The RSC in the existing 12 to 16-foot deep upstream section will take five riffle weirs with a one-foot drop, and two boulder cascades with 4.25-foot drops. The weirs and cascades are fifteen feet long and fifteen feet wide. Their width goes from edge of the existing channel to the other. The stones remain immobile during the 100-year storm event in the design.

In the less forested downstream segment, Straughan proposes widening the valley to create two floodplain wetlands. The first wetland is upstream of the gully from Erie Street SE and the 18” corrugate metal pipe outfall from Gainesville Street SE. The wetland will be approximately 25 feet wide and heavily vegetated with grasses to prevent erosion during floods. The wetland will include a combination of aquatic, emergent, and floodplain wetlands and will be separated into two cells by slightly elevated ground (6”) and riffles. The floodplain will end with a five-foot cascade to the next floodplain segment.

The downstream floodplain will be similar in width (25 feet wide). The downstream storm drain creates a backwater during storms greater than the 10-year event which creates ponding on the floodplain and reduces erosion. This stream-wetland complex will feature a single riffle. We anticipate that a portion of the excavated material from the new floodplain can be reused for fill within the project.

6.3. Step Pool Stormwater Conveyance

Currently stormwater leaves Erie Street SE at a low spot and has eroded a deep gully to the stream. The gully is now undermining and destroying the edge of Erie Street. Straughan proposes a SPSC system to stop the erosion and provide water quality treatment for the stormwater from Erie Street. The SPSC requires eight 10-feet wide and 10-feet long boulder cascades ranging from 5-6' in height depending on their landscape position. The SPSC enters the stream at the downstream end of the upper stream-wetland complex on the left bank at grade.

6.4. 18" Corrugated Metal Pipe Outfall

Currently a failed 18-Inch corrugated metal pipe discharges stormwater from the intersection of Branch Avenue and Gainesville Street SE into the stream channel. The pipe invert is four or five feet above the stream, and the end of the pipe is undermined and hanging almost vertically. Straughan proposes cutting the pipe back approximately 20 feet and daylighting the pipe into the stream-wetland complex. To improve outfall stability, we proposed sleeving and grouting the pipe with an HDPE pipe and stabilizing with a boulder endwall structure. This pipe will daylight at grade into the stream-wetland complex.

6.5. Anticipated Uplift of Stream Function

The restoration is anticipated to improve the stream hydraulics and geomorphology to functioning and the physicochemical processes to function at risk. The proposed design reduces the stream's entrenchment by raising invert and excavating a lower floodplain, which storm events will frequently access. Also, by using the stable rock structures future stream invert lowering will be prevented. The wider floodplain and stable channel will reduce lateral instability and the new floodplain sections will provide a diverse habitat of both fast and still water.

The new floodplains and reduced bank erosion are anticipated to improve the physicochemical processes in the stream by encouraging groundwater interactions that treat excess nutrient. The increased floodplain connection will also increase nutrient filtering and improve the water quality. Stabilizing the gully from Erie Street will reduce the inflow of sediment to the channel.

Because the project site is a small portion of the developed watershed, we do not anticipate any change to the hydrology coming to the project. However, the floodplain storage and step pools in the project may reduce the hydrograph leaving the project site. See Table 4 for a summary of the potential changes to stream function. Biology is generally difficult to improve without a physical connection to existing populations. The storm drain under Southern Avenue SE creates a physical barrier to aquatic animals trying to reach the site. However, with the improved habitat and water quality, some benthic insect species may colonize the stream.

Functional Pyramid Level	Existing Conditions	Proposed Design
Hydrology	Not Functioning	Not Functioning
Hydraulics	Not Functioning	Functioning
Geomorphology	Not Functioning	Functioning
Physicochemical	Not Functioning	Functioning at Risk
Biology	Not Functioning	Not Functioning

Table 4 – Summary of Function-based assessments for Proposed conditions.

6.6. Walking Trail

The design includes a proposed trail to allow the community to access the site. The trail will be a six-foot-wide mulch walking path. The stream crossing will be at boulders where hikers can cross on stepping stones.

7. Hydraulic, Velocity, and Sediment Transport Analyses

Straughan created one-dimensional hydraulic models of the existing and proposed conditions along with a preliminary two-dimensional model in HEC-RAS. The model does not include the Erie Street Gully. Detailed grade control structure sizing is included in Appendix G. Detailed HEC-RAS output, including both existing and proposed conditions, is included in Appendix H.

7.1. Sources of Hydraulic Instability

In existing conditions, the stream is severely incised and entrenched. By lifting the stream channel, we provide space for both a wider channel and a wider flood-prone area. The greater width reduces both the depth of incision and the degree of entrenchment. In particular, the downstream stream/wetland complexes provide access to a wide floodplain. The channel changes reduce stress on banks during high flow events. For example, the one-dimensional model shows the average top width during the 10-year event increasing from 8.4 feet in existing conditions to 20.8 feet in the proposed design.

The design also relies on stone stabilization structures to provide both lateral and vertical grade control to withstand higher velocity and shear stress.

7.2. Sediment Transport, Channel and Grade Control Sizing

The Branch Ave Stream Restoration project is located at the stream headwaters and has no upstream bedload supply of sediment. The primary source of sediment within the existing channel is the eroding stream banks themselves. The proposed design will eliminate the cause of bank instability. Once the project is installed, the channel will have comparatively minimal supply of sediment.

7.2.1. Stability Thresholds for Grade Control Structures:

The proposed grade control structures are not designed to transport large sand, gravel, and cobble during design or bankfull events because there is no upstream supply to replace them. Therefore, all stone structures must be sized so as not to be moved during large floods. Straughan designed all structures to remain immobile up to and including the 100-year storm event.

Most of the flow to the Branch Avenue site comes from a storm drain network. The network was not designed to carry the 100-year event from the entire watershed. Therefore, the 100-year event is unlikely to be fully realized from top to bottom of the site as the network that feeds the project does not have adequate capacity. The 100-year event is a conservative choice for a threshold of bed movement.

7.2.2. Sizing of Parabolic Weir and Cascade Grade Control Structures

Straughan used the Isbash equation to size material by threshold velocity at a typical section, in accordance with Anne Arundel County's Regenerative Step Pool Storm Conveyance Design Guidelines from 2012. We then used a one-dimensional HEC-RAS model to validate the design velocities.

Along the main stem, riffle grade control weirs (1-foot drops) will have a width of 15 feet, a length of 15 feet, and a parabolic depth of 2 feet. These structures are be expected to withstand a velocity of approximately 7-8 ft/s, with a stone mix sized to D50 of 12 inches. The cascades (4 to 5-foot drops) will have a width of 15 feet, length of 15 to 18 feet, and a parabolic depth of 2 feet. These structures are expected to withstand a maximum velocity of approximately 13-14 ft/s, using large boulders with a minimum primary axis length of 30 inches.

Along the Erie Street SPSC, cascades (5 to 6-foot drops) will have a width of 10 feet, a length of 10 feet, and a parabolic depth of 2 feet. These structures are expected to withstand a maximum velocity of 13-14 ft/s, using large boulders with a minimum primary axis length of 30 inches.

7.2.3. Sizing of Stream/Wetland Complex Sequences

In the two stream-wetland complex areas, we designed our grade control structures to safely transfer base flow. A highly interconnected floodplain will transfer storm events through the stream/wetland sequence.

Straughan sized the floodplain slope to safely pass the 100-year design storm with shear stress less than 2.0 psf. The low slope ensures a maximize residence time of water within the wetland area. Straughan set the average floodplain slope at 0.011 ft/ft (1.1%).

At this slope, the 100-year flow rate (136 cfs) does not require a large belt width to remain stable. However, given the relative absence of wetland and floodplain on site, we opted to maximize floodplain width within our work area. Both stream-wetland complexes have a maximum width of approximately 25 feet. We tested this width at our design slope using the FHWA Hydraulic toolbox and found that this floodplain would carry the 100-year storm at a depth of 1.6 feet, at an average velocity of 3.3 ft/s, and a maximum shear stress of 1.1 psf.

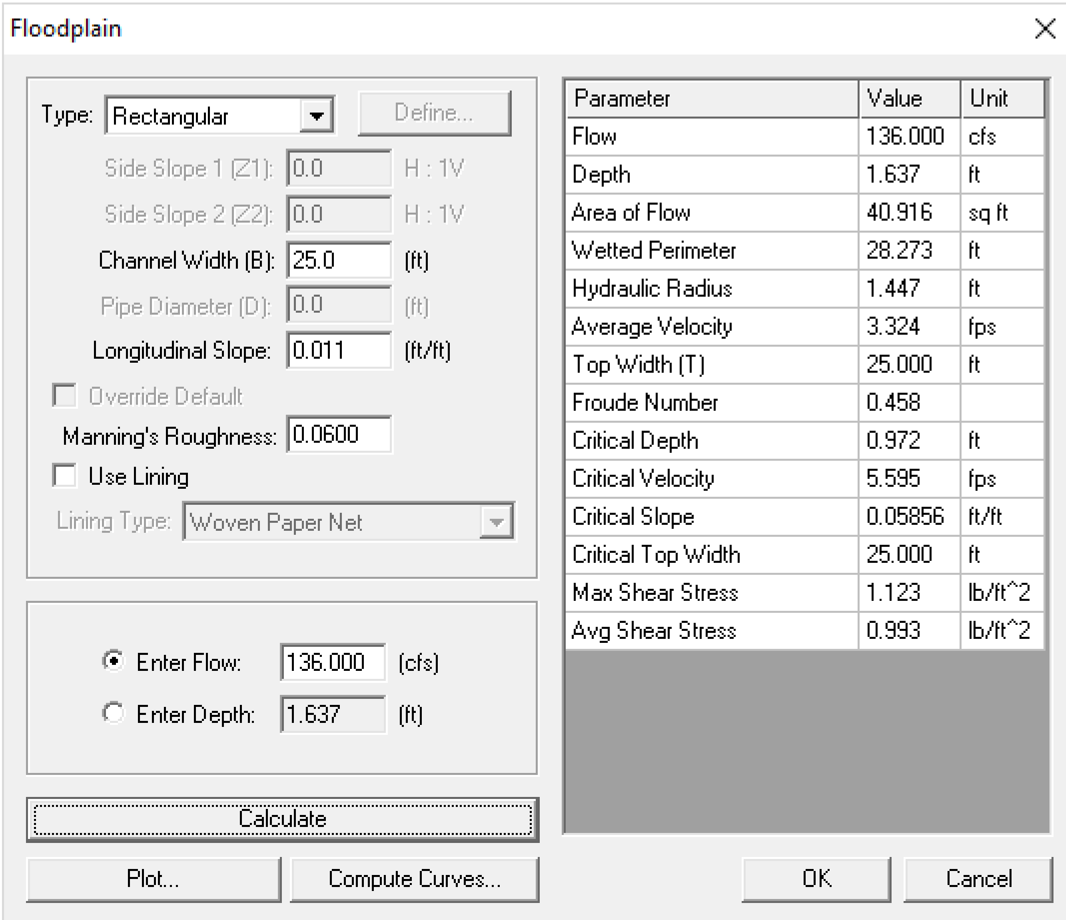

Figure 3: FHWA Hydraulic Toolbox Output

The floodplains will support wetland hydrology using very broad, shallow pools that will transition gradually to wetland throughout the area. The pools have a maximum depth of 18 inches, to support aquatic, emergent, and wetland species both within the pool and in the adjacent floodplain. The wetland pools are separated by a low profile (six-inch) area of higher ground. Riffle grade control structures transfer baseflow between the pools. During all storm events, the full floodplain is inundated.

Straughan tested the stream-wetland complex grade control structures using one-dimensional modeling. At this project location, the 10-year storm is the highest risk event, since the 100-year storm is influenced by receiving culvert backwater. The one-dimensional model indicated that the structures in the upstream stream-wetland complex would need to withstand an average maximum velocity of 4-5 ft/s (including all storm events).

Straughan also completed a two-dimensional analysis on the upstream stream-wetland complex. The two-dimensional model revealed the potential for instability as high flows pass through the grade control structures and transition into the receiving wetland pools. In final design, we tried many design iterations to ensure the stream-wetland complex riffles would be stable. Based on the two-dimensional and one-dimensional models, we determined the upstream most riffle was at the highest risk because the culvert's backwater reached the riffle last and it was exposed to the highest flows and the high velocity of the upstream cascade was the highest. Straughan investigated design option for the upstream pool length and depth and the riffle width and material. Straughan lengthened the upstream pool by 10 feet, increased the maximum depth to 4 foot, widened the riffle to 10 feet (from 5 feet) and increased the riffle D50 to 9 inches (from 6 inches).

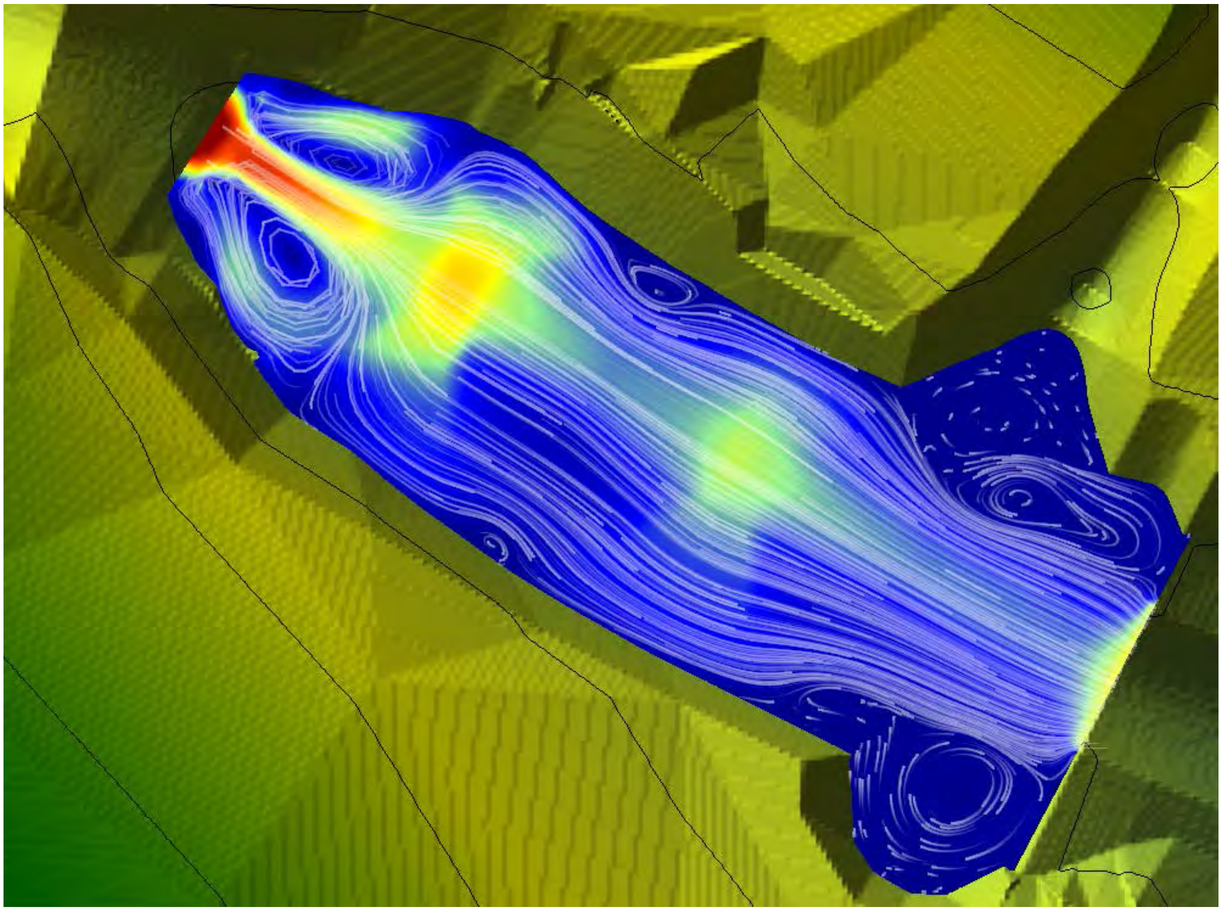

Figure 4: Two-dimensional velocity plot within stream/wetland complex (Peak Discharge through upstream riffle)

7.3. Comparison of Existing Conditions to Proposed Conditions Hydraulics

Comparing velocity and shear stress between existing and proposed conditions section by section does not adequately convey the performance of this stream project. In general, the existing conditions model is more uniform in profile than the proposed condition. The proposed condition includes engineered riffles and cascades, some of which are steep and high-energy structures. However, the proposed condition also has bed material designed to withstand this stream power. In exchange, the proposed condition provides access to extremely low energy and low velocity pools, shallow aquatic areas, and floodplain.

The existing stream bed and banks are not currently able to withstand the velocity and shear exerted on them. The bed and bank material are fine grained slit and clay. The existing conditions experiences shear stresses of up to 9 psf and velocities of 16 ft/s, which are eroding the stream channel. Detailed results from both the existing and proposed models are included in Appendix H.

7.4. FEMA modeling and mapping

Straughan prepared both existing conditions and proposed conditions 100-year floodplain mapping that matches our model. This mapping is provided in a geodatabase.

To be compliant with FEMA standards, Straughan modeled and mapped the design events using the "subcritical" setting in HEC-RAS. The subcritical setting does not allow supercritical flow, and instead defaults all potentially subcritical areas to critical depth. This provides a more conservative estimate of floodplain width and depth; however, it can also underestimate velocity and shear. When sizing our material, we used the "mixed-flow" setting to properly size material during both super- and sub-critical flow regimes.

8. Estimated TMDL Reductions

Straughan followed the recommendations of the Expert Panel to define removal rates for individual stream restoration projects to estimate the amount of sediment, nitrogen and phosphorus for which the project can receive credit (Schueler & Stack, 2014). The Panel defines four protocols for determining credit from stream restoration projects. Three protocols are for perennial streams and the fourth is for dry step pool systems.

- Protocol 1 evaluates the amount of sediment lost to bank erosion.
- Protocol 2 accounts for improvements in nutrient processing because of improved groundwater interactions.
- Protocol 3 evaluates improved nutrient filtering because of floodplain reconnection.
- Protocol 4 investigates volume storage from Dry Channel RSC/Step Pool Stormwater Conveyance.

At the time of this report, the Chesapeake Bay Program is evaluating the addition of a fifth protocol to credit projects for preventing headcut propagation in zero- and first-order streams. It is assumed that this guidance will be based on the Alternative Headwater Channel and Outfall Crediting Protocol drafted by the Maryland State Highway Administration (MDOT SHA, 2018).

- *Anticipated* Protocol 5 evaluates outfall/headcut stabilization

The protocols are evaluated separately for each project, and the credits can be added to determine for the total for an individual project.

8.1.1. Protocol 1: Prevented Sediment

Protocol 1 uses the bank erosion rate (feet/year) to estimate the total weight of soil that erodes from the unrestored stream. The eroded sediment is converted to a mass of pollutants per year based on conversion factors, provided by the Expert Panel recommendations (Schueler & Stack, 2014), which is used to estimate the amount of pollution prevented by the restoration project.

Straughan followed the Bank Assessment for Non-point source Consequences of Sediment (BANCS) method developed by Rosgen and the U.S. Environmental Protection Agency to create an initial estimate of the erosion rate (Rosgen, 2001). BANCS uses BEHI and Near Bank Stress

(NBS) assessments to estimate the erosion rate. Straughan performed BEHI assessments and estimated the NBS at the three geomorphic cross section locations on December 13, 2018.

The channel divides into three distinct reaches based on banks and bed material. The upstream reach is from the storm drain outfall for about 150-feet and is characterized by a series of clay bottom cascades and soil banks. The bank slope is about a half foot horizontal to one-foot vertical slope and are covered with English ivy growing down from the floodplain. The middle reach is about 470-feet long with a flatter clay bottom and clay banks that extend two to three feet from the base. Above the clay banks are nearly vertical soil walls which seep groundwater constantly into the channel. The banks in this reach are about eleven feet, with a maximum depth of 16 feet. The downstream 260 feet have a gravel and sand bed and two to three feet high vertical banks, which are slightly undercut. Straughan performed a BEHI assessment in each reach. See Figure 1 for the BEHI locations.

Both banks of the stream are uniform, so the reach length is doubled to represent the total length of bank along each reach. Straughan used RIVERMorph 5.1.8 to calculate the BEHI ratings and the annual erosion using the preliminary curve from North Carolina. The default rates for pounds of phosphorous and pounds of nitrogen per ton of sediment from the Expert Panel guidance, 1.05 pounds P/ton and 2.28 pounds N/ton, are used to calculate the nutrient loadings. The project is assumed to have a 50% efficiency rate at preventing nutrients from eroding, based on the Expert Panel’s guidance. Finally, Straughan applied the Expert Panel recommended Sediment Delivery Ratio of 0.061 for Coastal Plain streams. The erosion rates from the BANCS method will be reevaluated when data from the on-site bank pins is available. Straughan notes that the stream has now down-cut into consolidated clay layers. We hypothesize that this clay may be more laterally stable than the silty sand layers that eroded previously, and therefore the bank pins may not match estimates from BEHI/NBS. Also, historic soil loss appears to be episodic and related to soil sloughing from steep banks into the channel. See Appendix F for the BEHI, NBS, and nutrient credit calculations. Table 6 summarizes the nutrient reduction calculations.

Reach	Total Length (ft)	Bank Height (ft)	BEHI Rating	NBS Estimate	Predicated Erosion (Ton/year)
Reach 1	152	12.2	High	Moderate	14.3
Reach 2	472	11.2	High	Moderate	40.7
Reach 3	260	2.6	Very High	Moderate	23.8

Table 5 – Summary of BEHI and NBS Assessments

	Reach 1	Reach 2	Reach 3	Total
Predicated Erosion (Ton/year)	14.3	40.7	23.8	78.8
Total Phosphorous (lbs/year)	15.1	42.8	25.0	82.8
Total Nitrogen (lbs/year)	32.7	92.9	54.2	179.7
Estimated Phosphorous Prevented (lbs P/year)*	7.5	21.4	12.5	**41.4**
Estimated Nitrogen Prevented (lbs N/year)*	16.3	46.4	27.1	**89.9**
Estimated Sediment Prevented (tons/year)**	0.4	1.2	0.7	**2.4**

*Includes practice efficiency of 50%.

**Includes practice efficiency of 50% and SDR of 0.061 for Coastal Plain Stream

Table 6 – Summary of Estimated Nutrient Reductions

8.1.2. Protocol 2: Credit for In-Stream Riparian Nutrient Processing during Base Flow

Protocol 2 determines credit for projects which embrace features known to promote denitrification during base flow, as an enhancement above and beyond Protocol 1. The credit applies to the length of the stream reach where floodplain connectivity has improved, as indicated by a Bank Height Ration (BHR) of 1.0. Connected floodplains should be well vegetated to provide a long-term source of carbon availability to promote denitrification.

It is assumed that the denitrification takes place within a "hyporheic box" with a maximum depth of 5 feet beneath the stream invert, with a width that includes the base flow channel and 5 feet added on either side of the stream bank.

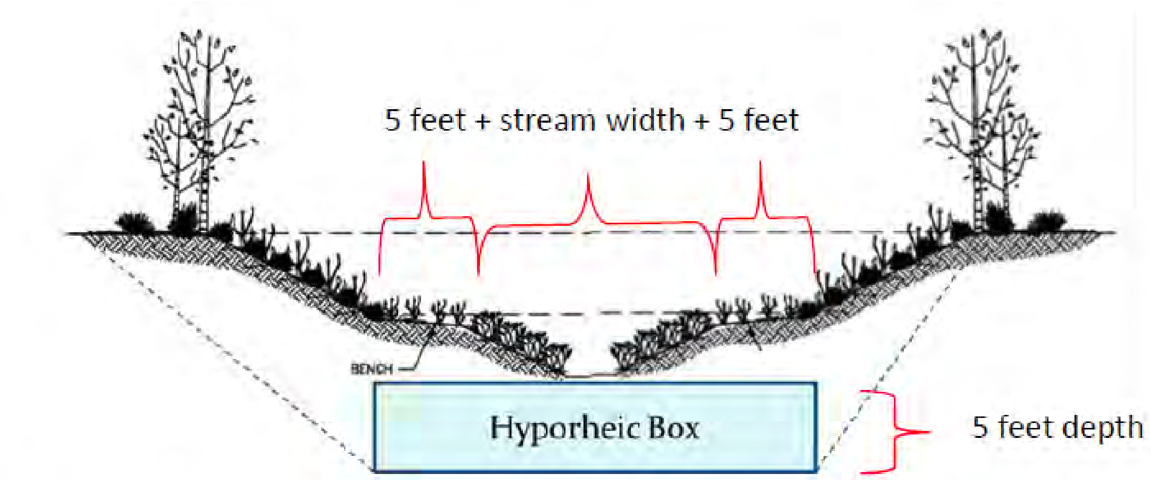

Figure 5: Typical cross section of hyporheic box (Berg, Burch, & et. al., 2014)

Areas of bedrock outcroppings or confining clay layers should be excluded, and the dimensions of the box adjusted accordingly. The Expert Panel caps this credit at 40% of the Chesapeake Bay Program land-river segment.

In the Branch Avenue Stream Restoration project, there are limited opportunities for floodplain reconnection and therefore hyporheic exchange credit. The RSC approach used throughout portions of the main stem addresses vertical and lateral stability, but the stream will remain entrenched due to the confined nature of the valley. The two proposed short segments of "stream-wetland complexes" will meet the intentions of the Expert Panel criteria. These segments include the establishment of a highly connected, well-vegetated floodplain controlled by structures with BHR ≤1.0. The two areas are noted in Figure 6 below.

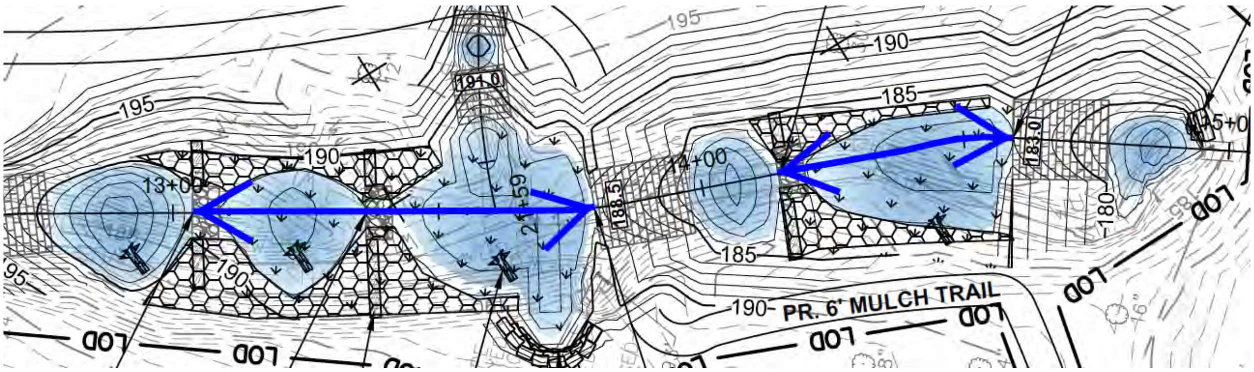

Figure 6: Areas likely to qualify for hyporheic exchange credit (shown in blue).

The cumulative length of the qualifying segments is 120 feet. The "base flow channel" in this instance is controlled by riffle grade control structures with a 10-foot width.

Therefore, the hyporheic box dimensions are:

$$Qualifying\ Length, L = 120\ ft$$

$$Stream\ Width, W = 10\ ft$$

$$Box\ Area, B = (5 + W + 5) * 5 = (5 + 10 + 5) * 5 = 100\ ft^2$$

$$Box\ Volume = B * L = 100 * 120 = \ \ 12{,}000 ft^3$$

The denitrification is calculated by multiplying the hyporheic box volume by the unit denitrification rate (1.06 x 10^{-4} pounds/ton/day of soil). Straughan estimates a soil bulk density of 100 lbs/ft^3 based on the observed bank composition of sandy silt and sandy lean clay.

$$Denitrification = 12{,}000 ft^3 * \frac{100 lb}{ft^3} * \frac{1 ton}{2000 lb} * \left(\frac{1.06 * 10^{-4}\, \frac{lb}{ton}}{day} \right) = 0.0636\ lb/day$$

The estimated TN credit from Protocol 2 is 0.0636 lb/day or 23.2 lbs/year.

According to the Expert Panel guidance, the Chesapeake Bay Program Modeling Team should be contacted for the total nitrate loading to assure that the load reductions from this and other projects do not exceed the 40% cap for the subject land-river segment.

8.1.3. Protocol 3 Credit for Floodplain Reconnection Volume

This protocol offers credit for annual sediment and nutrient reduction attributed to floodplain uptake and processing. Per Expert Panel guidance, to ensure adequate detention time in the floodplain to support those factors, there should be a minimum watershed to floodplain surface area ratio of 1%. Projects that don't meet this criterion may secure a discounted credit.

The potential floodplain connection area is shown in Figure 7. This area totals approximately 3,820 square feet.

Figure 7: Qualifying floodplain connection area

The total drainage area for the project is 45.9 acres, or 1,999,404 square feet. Therefore, the available floodplain area compared to watershed area has a ratio of 0.2%. Any credit for floodplain reconnection volume would be reduced to an efficiency of 20%.

Given the comparatively small surface area available for storage, and the likelihood that volumetric storage will not be highly significant relative to total flow, Straughan did not pursue further analysis of Protocol 3.

8.1.4. Protocol 4 Dry Channel RSC as a Stormwater Retrofit

The gully from Erie Street will be retrofit with an SPSC (equivalent to a dry-channel RSC). The gully is located outside of the Waters of the US and would be classified as an upland stormwater retrofit. SPSCs combine both surface volumetric storage with an underground filter bed to support vertical infiltration and treatment of flood waters. Anne Arundel County maintains the most comprehensive guidelines on SPSC design standards (Anne Arundel County, 2012). Anne Arundel County's guidelines recommend that water quality credit should not be claimed for SPSC segments with a longitudinal profile slope that exceeds 5%. This is to prevent claim of storage for flow that will not reside above the filter bed long enough to infiltrate.

The proposed SPSC along Erie Street includes multiple cascade structures with an average slope greater than 5%, and flat (0%) pools. Therefore, no infiltration volume will be credited for this project. However, we will take credit for the water quality volume stored in the pools. The SPSC includes 8 pools, with an average volumetric storage of 52.5 cubic feet each. This totals 420 cubic feet of volumetric storage (0.0096 ac-ft).

Using the standard retrofit equation:

$$\frac{(RS)(12)}{IA} = x\ in$$

Where: RS = retrofit storage in acre-ft

12 = conversion from feet to inches

I = impervious cover percent expressed as a decimal

A= drainage area in acres

$$\frac{(0.0096\ ac - ft)(12in/ft)}{0.36 *\ 5.4\ ac} = 0.06\ in$$

A storage volume of 0.06 inches falls below the Adjustor curves for Phosphorus, Nitrogen, and Sediment removal, therefore, no credit will be awarded under protocol 4.

8.1.5. *Anticipated* Protocol 5 for Prevented Headcut Erosion

At the time of this report, the Chesapeake Bay Program is evaluating the addition of a fifth protocol to credit projects for preventing headcut propagation in zero- and first-order streams. It is assumed that this guidance will be based on the Alternative Headwater Channel and Outfall Crediting Protocol drafted by the Maryland State Highway Administration (MDOT SHA, 2018). Please note that this protocol is not yet approved, and it is unknown whether the CBP will accept the methodology and, if so, what potential credit caps, qualifications, or additional provisions will be considered. Straughan presents this estimate in Table 7 for informational purposes only.

Table 7: Summary of Protocol 5 Nutrient Reduction

Reach	Total Length (ft)	TN Reduction (lbs/yr)	TP reduction (lbs/yr)	TSS Reduction (tons/yr)
Reach 1	145	856.9	394.6	22.9

This estimate includes a practice efficiency factor of 56% and a sediment delivery ratio of 0.061. The potential nutrient and sediment removal from addressing the Erie Street headcut is very significant. Stabilization will be highly effective because, although the headcut is large, it has not propagated through most of the gully length.

8.1.6. Summary of Nutrient Removal

The nutrient reductions along the main stem are summarized in Table 8 below.

Table 8: Summary of Nutrient Removal (Main Stem)

Protocol	TN Reduction (lbs/yr)	TP reduction (lbs/yr)	TSS Reduction (tons/yr)
1	89.9	41.4	2.4
2	23.2	0	0
3	0	0	0
4	N/A	N/A	N/A
5*	N/A	N/A	N/A
Total	**113.1**	**41.4**	**2.4**

The nutrient reductions along the Erie Street SPSC are summarized in Table 9 below.

Table 9: Summary of Nutrient Removal (Erie St. SPSC)

Protocol	TN Reduction (lbs/yr)	TP reduction (lbs/yr)	TSS Reduction (tons/yr)
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	0	0	0
5*	856.9	394.6	22.9
Total	**856.9**	**394.6**	**22.9**

*Protocol 5 has not been formally adopted by the Chesapeake Bay Program, and this potential reduction is reported for informational purposes only.

9. Conclusion

The DB team presents this report to summarize the existing conditions and proposed design approach for stabilizing and uplifting the stream in Branch Avenue Park in Southeast D.C. and providing safe community access to the park. Currently, the stream is not classified as functioning on a hydrologic, hydraulic, geomorphologic, nor physicochemical level. The DB Team proposes a restoration project that will address the hydraulic and geomorphologic problems by creating a stable channel with functional geomorphologic features, which provide increased habitat and nutrient treatment. Additionally, the design provides regenerative stormwater management for part of the watershed to improve the hydrologic function of the watershed and provides more access to the floodplain improving the physicochemical processes in the stream. The project is completed with a natural surface walking trail allowing the community to safely use the park both for recreation and as a pathway between Erie Street, Branch Avenue and Southern Avenue.

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