TOWN OF WATERFORD
Application for Inland Wetland / Watercourse Permit

Type of Application:

Permitted Use, Section 4.1 ________

Unregulated Activities, Section 4.2 ________

Regulated Activities, Section 6 ✓ Fee: ✓

Agency Use:

Date Received: ________

Received By: ________

Application Number: C-26-02

1. Applicant: Connecticut College Arboretum	**Phone:** [redacted]
Address: [redacted] **State:** CT	**Zip:** [redacted]
Fax:	**E-Mail:** [redacted]
2. Owner: Connecticut College	**Phone:**
Address: [redacted] **State:** CT	**Zip:** [redacted]
Fax:	**E-Mail:**
3. Agent: GreenVest, LLC c/o Graham Boardman	**Phone:** [redacted]
Address: [redacted] **State:** MD	**Zip:** [redacted]
Fax:	**E-Mail:** [redacted]

4. Property Address: 435 Mohegan Ave Pkwy

5. Abutting Property Owners – Complete Attached Form Attached

6. Activity to be Reviewed and / or Licensed (attach sheet if necessary): Stream stabilization, Stream restoration; Non-native, invasive species management (see attached cover letter and design report.)

7. Description of Proposed Activity (attach sheet if necessary): See attached cover letter and design report

8. Purpose of Activity (attach sheet if necessary): See attached cover letter and design report

9a. Acreage of Property: 54.10 **9b. Acreage of Wetlands:** 3.07 (2.25 tidal; 0.82 inland)

10. Acreage of Wetlands Altered: 0.70

11. Wetland Mitigation Proposed: 0.75

12. Section 7 and sections 8.1 & 8.2 of the Town of Waterford "Inland Wetlands and Watercourse Regulations" have been complied with: (Review attached check list) **Yes:** X **No:**

The applicant / owner hereby gives the Commission, its agent and consultants the right of free access to any part of the property under consideration. The undersigned warrants the truth of all statements contained herein and in all supporting documents according to the best of his / her knowledge, information and belief.

Applicant: Maggie Reffer	**Date:**	2/12/26
Owner: Carey Cunych	**Date:**	2/13/26
Agent: Signed by: Brian Cramer	**Date:**	2/16/2026

RECEIVED

FEB 24 2026

Planning & Development
Town of Waterford, CT

Conservation Commission
Permit Application Attachment

Properties Adjacent to: 435 Mohegan Ave Pkwy

Owner	Parcel ID#		Property Address	Mailing Address
BLAHUN, GEORGE JR	393500		7 MAMACOKE ROAD	7 MAMACOKE ROAD
			QUAKER HILL, CT 06374	QUAKER HILL, CT 06374
	393900		5 MAMACOKE ROAD	451 MOHEGAN AVENUE PARKWAY
			QUAKER HILL, CT 06374	QUAKER HILL, CT 06374
CLEIN, ROBERT H	437500		449 MOHEGAN AVE PKWY	449 MOHEGAN AVE PKWY
			QUAKER HILL, CT 06374	QUAKER HILL, CT 06374
CONNECTICUT COLLEGE	393800		14 MAMACOKE ROAD	270 MOHEGAN AVE
			QUAKER HILL, CT 06374	NEW LONDON, CT 06320
CONNECTICUT COLLEGE	436800		435 MOHEGAN AVE PKWY	270 MOHEGAN AVE
			QUAKER HILL, CT 06374	NEW LONDON, CT 06320
PINKOWITZ, BARRY M &	24400		30 BENHAM AVENUE	30 BENHAM AVENUE
SHELBURN, JEANNE L			QUAKER HILL, CT 06374	QUAKER HILL, CT 06374
SHELBURN, JEANNE LEE	436500		417 MOHEGAN AVE PKWY	30 BENHAM AVENUE
			QUAKER HILL, CT 06374	QUAKER HILL, CT 06374
TREDWAY, LORAINE &	24800		34 BENHAM AVENUE	34 BENHAM AVENUE
KAPLAN, MICHAEL W			QUAKER HILL, CT 06374	QUAKER HILL, CT 06374

TOWN OF WATERFORD
Instruction Guide for Inland Wetland / Watercourse Permit

Application Fees: All Application fees include **$60.00** for the State of Connecticut.

Residential Improvements, Additions & New Structures: **$110.00**
Residential Subdivision, 3 or more Lots: **$160.00**
Commercial/Industrial Development: **$160.00**
Major or Significant Impact Activity: **$360.00**
Public Hearing Fee: **$400.00**

Permit Extension/Modification: **$ 110.00**
Permitted Use: **No Fee**
Unregulated Activity: **No Fee**

All applications shall include a <u>completed original application and 14 copies</u> to be submitted to the Conservation Commission office. The wetlands application checklist is for your convenience, it is <u>not</u> necessary to submit this document with your application. Incomplete applications will not be completed by staff, they will be returned.

1.	Applicant	Include the full name, address, zip code and telephone number of the applicant(s).
2.	Owner	Include the name(s) of the owner(s) of record as it appears on the land records (deed) of the Town of Waterford. The owners' complete address, zip code and telephone number are required.
3.	Agent	Include the full name, address, zip code, and telephone number of the agent. An agent prepares the application for submission or will represent the owner / applicant at a meeting.
4.	Address	Provide street name and number of subject property.
5.	List of Abutters	Complete the attached form with the name, address, and assessor's map and parcel numbers for all adjacent properties.
6.	Activity to Be Reviewed	Briefly describe the type or nature of permit requested. Attach additional sheet(s) if necessary.
7.	Description of Proposed Activity	Describe in detail all proposed work. Scope of all work shall be included. Attach additional sheet(s) if necessary.
8.	Purpose of Activity	Describe in detail the purpose of the permit request. Attach additional sheet(s) if necessary.
9a.	Acreage of Property	Provide the size of the subject parcel and the area of all wetlands on site. [Note: one acre = 43,560 square feet.]
9b.	Area of Wetlands and Watercourses	Provide the area of all wetlands on the site in acres. [Note: one acre = 43,560 square feet.]
10.	Wetlands Altered	Indicate the area of the wetlands to be altered by proposed activity.
11.	Wetland Mitigation	Describe measures incorporated in the plan to mitigate the wetland impacts associated with the proposed activity, including restoration, enhancement or creation of wetland area.
12.	Regulations	Indicate you have reviewed the "Waterford Inland Wetlands and Watercourses Regulations" and have complied with the application requirements.

Biohabitats
NORTHEAST HIGHLANDS & COASTAL BIOREGION

[redacted]
Biohabitats.com

February 17, 2026

Waterford Conservation Commission
c/o Maureen FitzGerald
15 Rope Ferry Road
Waterford, CT 06385

Re.: Mamacoke Brook Outfall Channel Stabilization & Restoration

Dear Ms. FitzGerald:

Connecticut College received grant funding to stabilize and restore Mamacoke Brook, a coastal lowland stream located on Connecticut College Arboretum property between Mohegan Avenue (Route 32) and the Thames River, north of Benham Avenue. The principal investigator at Connecticut College is Ms. Maria Rosa, with technical support from Dr. Doug Thompson, Connecticut College and Ms. Maggie Redfern, the Director of Connecticut College Arboretum. For the design team, GreenVest, LLC is the College's implementation partner for the broader Mamacoke Island Aquatic Habitat Resilience (MIAHR) initiative and Biohabitats is the project ecological and engineering lead

The project site, located at 435 Mohegan Avenue Parkway, is 54.10 wooded acres and contains approximately 0.82 acres of inland wetlands and watercourses and 2.25 acres of tidal wetlands. The proposed project intends to restore 0.27 acres of wetland and watercourse and enhance 0.47 acres of wetlands and watercourse.

A detailed assessment of the project site and Mamacoke Brook is discussed in the attached design report. This includes assessments of watershed characteristics, geology, soil, wetlands and watercourses, hydrology, vegetation and ecological communities, listed species, and cultural resources. These existing condition are accounted for in the design approach discussed in the report as well as depicted in the design plans. Below is a summary of design report and plans, specifically the project need, objectives and approach.

Mamacoke Brook currently exhibits substantial instability, including bank erosion and channel incision, producing excessive sediment that is transported downstream into Mamacoke Cove and ultimately the Thames River. Primary drivers include concentrated stormwater outfalls, a steep flow path, and reduced riparian vegetation in portions of the corridor. To reduce erosion and improve hydrologic and ecosystem function, the Mamacoke Brook restoration projected intends to:

1. Improve geomorphic function to promote long-term bed and bank stability
2. Reduce sediment transport downstream
3. Attenuate stormwater flows from concentrated sources by increasing infiltration/groundwater recharge where feasible, and reduce nonpoint source pollutants (e.g., roadway contaminants and fertilizers)
4. Enhance ecological functions and stream habitat quality
5. Maximize reuse of onsite native rock and wood in restoration features
6. Control invasive species and improve riparian vegetation conditions through treatment and native plantings

The design prioritizes long-term stability, floodplain reconnection, and water quality improvement while accommodating constraints such as steep terrain, limited construction access in forested reaches, and avoidance of significant impacts on Connecticut Department of Transportation (CTDOT) right-of-way. The project is divided into three segments based on field conditions and the related the design approach.

1. **Upstream Restoration Reach** - Although a reinforced plunge pool and outfall energy dissipation could reduce erosive power, this approach is not feasible under current constraints (e.g., pipe elevations, access limitations, and CTDOT right-of-way impacts). Instead, restoration in the upstream reach focuses on limited, low-impact measures to increase sediment trapping and habitat complexity. This approach uses wood augmentation, including Post-Assisted Log Structures (PALS) where feasible and/or strategic use of existing fallen trees. This is expected to provide modest functional uplift given the high-gradient environment and limited upstream wood recruitment potential (culvert constraints).

2. **Middle Restoration Reach** - The middle reach is identified as the most actively enlarging and degrading portion of the system. The proposed design will restore stability in a steep intermittent channel (~8–10% slope) using a series of cascade grade control structures spaced roughly every 70–100 feet, over a total length of approximately 560 feet to the more stable downstream reach.

   Key elements of the proposed design include:
   - Cascade structures that provide ~3–4 feet of vertical drop over short distances using large subangular boulders sized for stability during the 100-year storm, with plunge pools for energy dissipation.

- Between cascades, the restored channel bed is set higher (within ~1–2 feet of top-of-bank) and designed at ~5% slope to support riffle/pool formation and wood retention.
- Two complementary restoration techniques are incorporated to encourage geomorphic/habitat diversity and support adaptive learning:
    - Regenerative Stormwater Conveyance (RSC) riffle/pool step-pool approach, with riffles sized to convey approximately the 5-year storm (10 ft wide by 1 ft deep), plus shallow pools enhanced with woody material for roughness and habitat.
    - Dynamic boulder cluster / woody streambed approach to partially fill incised sections and promote a roughened bed surface that may evolve toward multi-threaded flow patterns (with performance standards acknowledging material sorting and wood decay over time).
- Because there are known sensitive archaeological resources within the project area, specific steps have been taken to avoid or limit ground disturbance that is otherwise not necessary or associated with the restoration of the stream channel through this reach.

3. **Downstream Restoration Reach** - Downstream, where the stream slope softens, the valley widens, and stability is greater, a Stage 0, full-valley restoration concept is proposed to maximize floodplain reconnection, wetland function, and water quality benefits. In this reach, design intent is to restore the wetland/valley complex with multiple anabranching flow paths, high habitat diversity, and enhanced sediment/nutrient retention across the floodplain.

   Because this downstream reach includes dense stands of *Phragmites australis*, an integrated management approach (i.e., timed chemical treatment combined with biomass removal) will be coordinated with the Arboretum's policies and long-term stewardship capacity. Additionally, because there are known sensitive archaeological resources within the project area, specific steps have been taken to avoid or limit ground disturbance that is otherwise not necessary or associated with the enhancement through this reach.

When implemented as designed, the project is expected to:

- Reduce active erosion and sediment delivery to the salt pond and Thames River through grade control, raised bed profiles, and floodplain reconnection

- *Improve stormwater attenuation, infiltration opportunities, and pollutant* processing by re-establishing floodplain and wetland function—especially within the Stage 0 restoration area
- Increase habitat complexity and ecological function through wood structures, dynamic bed features, invasive species management, and native plant community restoration
- Avoid and minimize impacts, to the greatest extent practicable, to trees along the restoration reach
- Protect known and potential areas of archaeological resources
- Preserve and avoid potential areas of state-listed species.
- Provide a high-value, long-term teaching and research opportunities for Connecticut College students, staff and partners

While the proposed project will result in 0.74 acres of direct wetland impacts, we believe that this restoration activity is not a significant impact.

- Deposition and/or removal of material will have substantial long-term benefits to the watercourse and overwhelm any potential negative short-term effects related to construction. Construction will include an erosion and sediment *control plan consistent with CTDEEP guidelines that will minimize impacts to* downstream wetlands and watercourses.
- The natural channel has been greatly impacted by erosion associated with increased runoff from Mohegan Avenue Parkway. Natural dynamics of the watercourse will be reintroduced through the construction of a natural channel to the extent practicable based on current climatic and land use conditions.
- The project will not diminish but rather enhance the watercourses' ability to: support aquatic life and wildlife; reduce flooding in established areas by reconnecting existing floodplains; promote improved water quality; and enhance recreational opportunities and safety at the site.
- Water quality will be further improved by reestablishing a riparian buffer within the upland review area and improving groundwater connections. Reducing erosion also decreases water turbidity and establishing a canopy will address increased water temperature relative to solar energy input.
- The project will be conducted during a period of low-flow when the Mamacoke Brook is typically dry. Turbidity, siltation, and sedimentation will be addressed during construction by using established erosion and sediment control techniques. Over the long-term, the proposed restoration will reduce turbidity, siltation, and sedimentation.

- The proposed restoration includes educational and scientific benefits by allowing students and faculty of Connecticut College to support the assessment and design process, observe construction, and complete monitoring to document project outcomes along with adaptive management if needed.

A detailed assessment of the project site and Mamacoke Brook and the resultant design are discussed in the attached design report and depicted in the attached design plans. It is anticipated that the project will begin during the low-flow period (summer) and take approximately 3 months to complete. Plantings will be installed immediately following construction, but no later than October 31.

Should you have any questions about the proposed project, please do not hesitate to contact me directly at 860.968.2738 or jwilson@biohabitats.com.

Sincerely,
Biohabitats, Inc.

Joshua H. Wilson, PWS
Sr. Ecologist

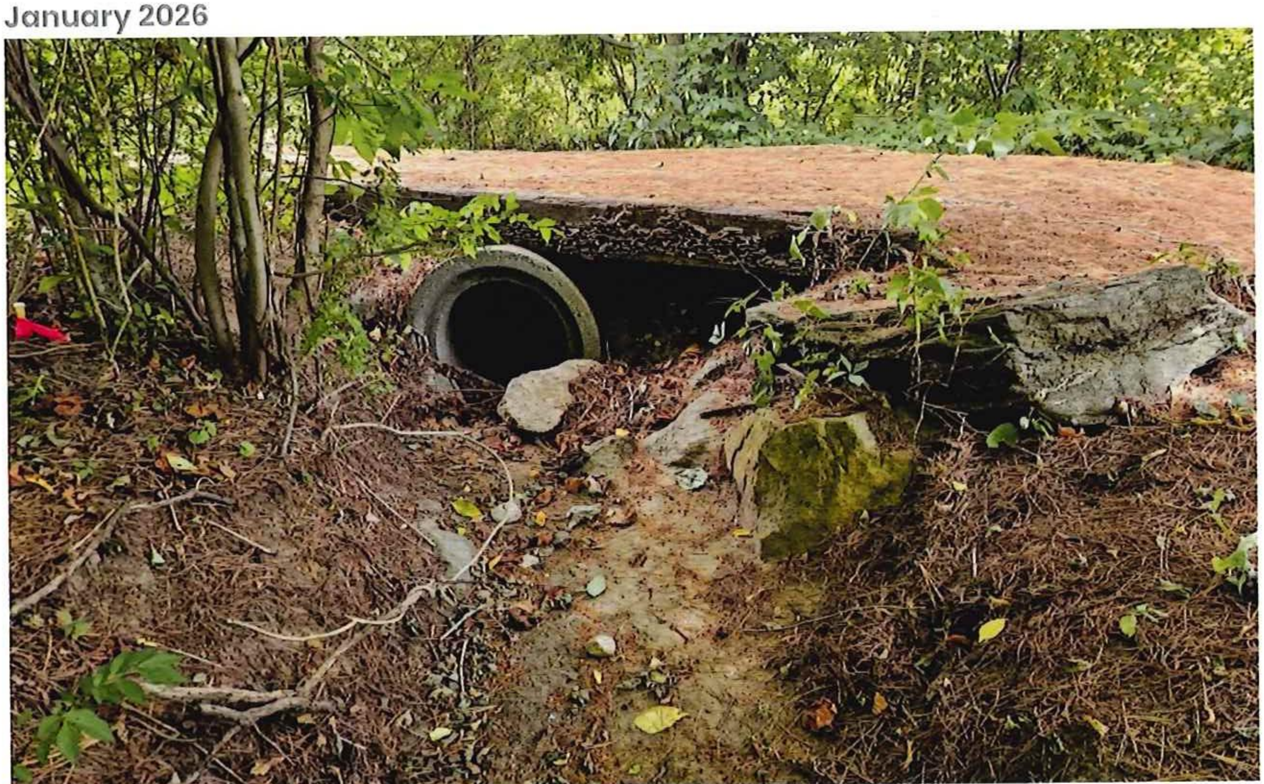
Enclosures

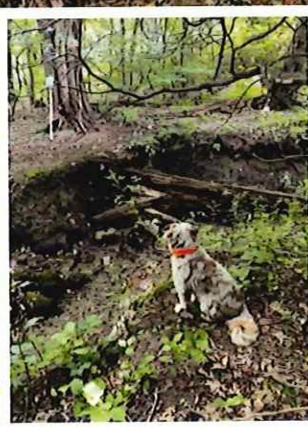
Mamacoke Brook Outfall Channel Stabilization and Restoration Project

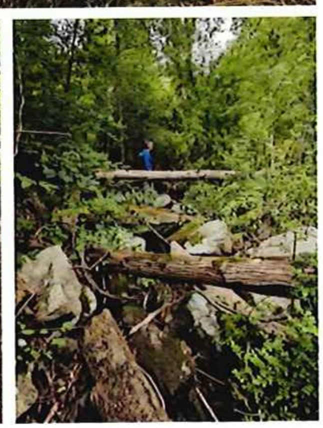
Mamacoke Island Aquatic Habitat Resilience Project
New London County – Thames River Watershed

Design Report

January 2026







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CONNECTICUT COLLEGE

Table of Contents

1 Introduction

1.1 Project Area and Background

Connecticut College received grant funding for the stabilization and restoration of the Mamacoke Brook, which is located on Connecticut College Arboretum property between Route 32 and the Thames River. GreenVest (GV) is the College's implementation partner. The Brook will be stabilized and restored as part of the Mamacoke Island Aquatic Habitat Resilience (MIAHR) Project, which also includes tidal marsh restoration along the Thames River. The Brook is laterally and vertically unstable, with eroded banks 4-6 feet in height and deep channel incision along portions of its approximate 1,500-foot length. This instability is likely caused by concentrated stormwater flow contributions, a steeply sloped flow path, and a reduction in vegetation along portions of the channel. Consequently, this has resulted in channel enlargement and excessive sediment generation due to bank erosion. The proposed stream restoration will stabilize the flowpath, enhance the overall health and stability of the stream system, and reduce pollutant loading into the Thames River.

Key Partners and Stakeholders involved in the project include Connecticut College as landowner, and who will act as the Administrator, Community Engagement Lead and provide technical assistance. GreenVest, Connecticut College's resiliency implementation partner, is managing the full delivery of the MIAHR project, including design, permitting, and eventual construction. Community stakeholders include the City of New London, Town of Waterford, and the Mohegan Tribe.

Connecticut College is committed to leveraging the MIAHR as a significant educational asset. The Project will serve as an instructional platform for students from high school to undergraduate and, through collaborations with regional universities, for graduate scholars as well.

The Mamacoke Stream restoration project area included in this report and associated design drawings are shown in Figure 1 below.

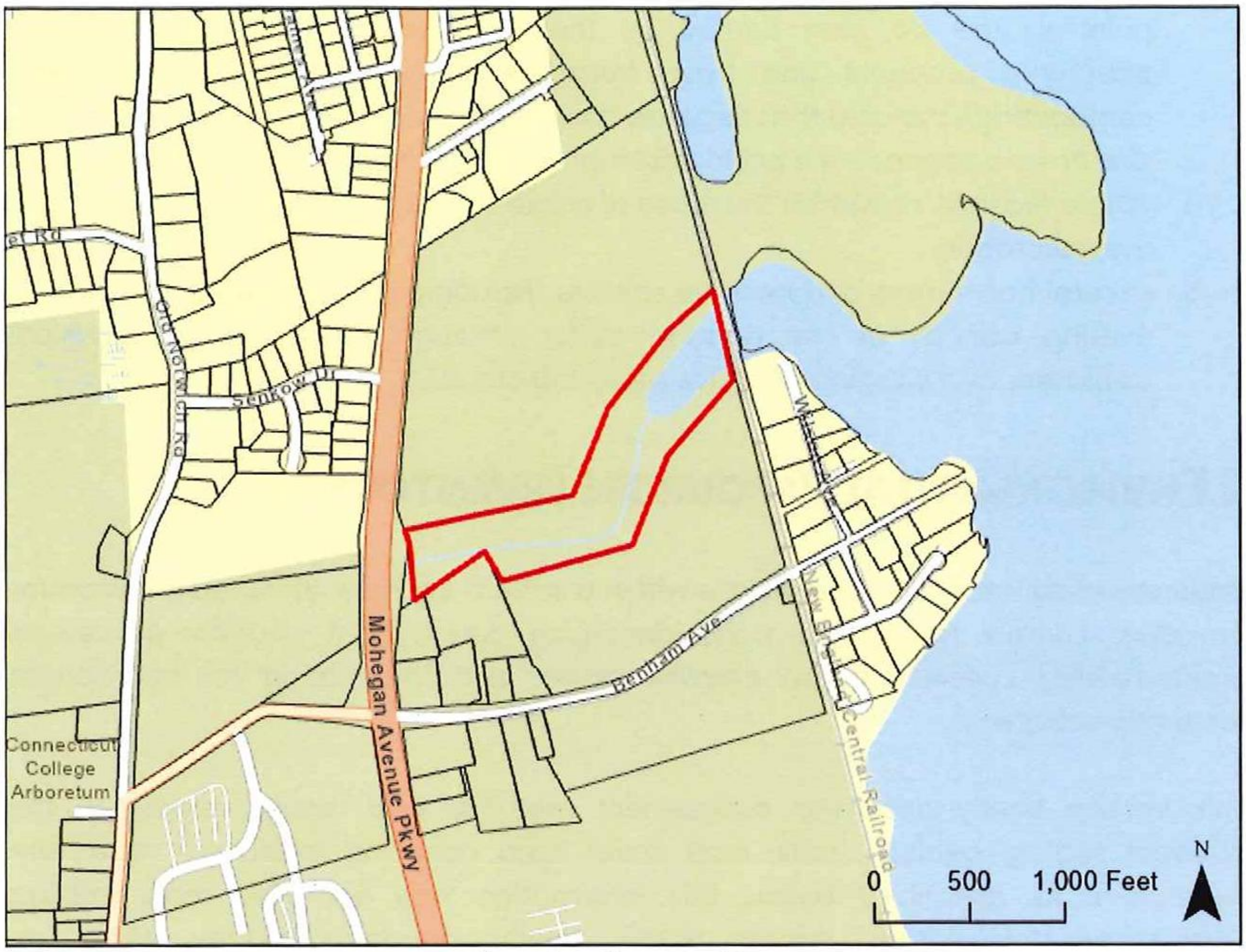

Figure 1: Project Area Map

1.2 Project Goals and Objectives

The Mamacoke Stream Restoration project (the Project) entails an environmental resource inventory, field surveys, schematic and final design, permitting, and construction implementation. The overall project goals for the Project are to improve the overall stability and habitat condition/diversity of the coastal lowland stream. Specific goals include:

1. Improve geomorphic function of the stream channel to promote long-term bed and bank stability. This will reduce sediment transport into Mamacoke Cove and the Thames River, improving water quality and habitat in the downstream restoration areas.
2. Attenuate/slow the delivery of stormwater flows originating from the concentrated flow sources at the upstream limit of the project to the salt pond and cove at the downstream limit of the project. Maximize the conversion of surface water to groundwater, assisting with the improvement in physicochemical functions and water quality. This will also decrease the non-

point source pollution carried by the stormwater discharges (such as petroleum products and trash from the roadway, and fertilizers from contributing land use) that degrade downstream water quality.
3. Create and enhance the ecological functions of existing stream habitats.
4. Where feasible, maximize the reuse of onsite native rock and wood throughout the restoration.
5. Control non-native and invasive species, including the vines pulling down the existing canopy in the riparian buffer, through chemical and physical treatment and planting of native trees and shrubs.

2 Environmental Resources Inventory

Understanding the existing conditions within a stream and its watershed is critical for providing context for project work, identifying determinant physical processes, characterizing specific stream stability issues, and formulating an appropriate restoration strategy.

This section briefly describes assessment methods and results related to the physical setting, geology, soils, land cover, land use, and hydrology within the watershed. As described below, this information was compiled from existing Geographic Information System (GIS) layers, orthophotography, field run topographic survey, and field observations.

Prior to the development within the watershed, this channel likely did not receive concentrated storm flows and was a likely a wider, shallower vegetated flowpath. The Mamacoke Brook watershed and the surrounding area have undergone land use changes following the establishment of Connecticut College in the early 1900s. Review of historical maps and aerial imagery show that the roadway (Route 32) and railroad that serve as the bounding limits for the project were in place in the 1890s. The 1950s saw the construction of a residential neighborhood at the upper limits of the watershed. This watershed development resulted in increased impervious surfaces and installation of storm drain conveyance systems that increased the volume and rate of stormwater being delivered to the steeply sloped channel. Site history reviewed for this project confirms that a portion of the land surrounding the channel was converted from forest to meadow in 2005. These land use changes throughout the watershed, as well as increases in rainfall intensity and frequency of storm events driven by climate change, are causing impacts to the stream network within the project area. Stream conditions throughout the project area are variable and described on a reach-by-reach basis later in this report.

2.1 Overview of Assessment Methods

Desktop analyses primarily used orthophotography, existing geographic information system (GIS), and other watershed data available from various sources. GIS data for the full watershed area including natural watershed boundaries, hydrography, geology, roads, land cover, and LiDAR-derived topography, were downloaded online from the University of Connecticut Center for Land Use Education and Research (CLEAR) and the Connecticut Department of Energy and Environmental Protect (CTDEEP). Local utility data, notably stormwater infrastructure, was downloaded from the Town of Waterford and the Connecticut Department of Transportation (ConnDOT). Soils data were obtained from the Natural Resource Conservation Service's (NRCS) Web Soil Survey available online.

Base mapping for the project area was created for the immediate stream corridor using dedicated LiDAR-derived topography collected by Whiteout Solutions in October 2024. Field run topographic survey was conducted in the Summer of 2025 by Martinez Couch & Associates, LLC. Additional data was added by Biohabitats from follow-up field survey efforts. GIS data was used for basemapping purposes outside of the stream valley.

Field investigations were conducted by Biohabitats staff during the summer and fall of 2025. Investigations within the project area included a general reconnaissance, a limited geomorphic channel assessment, and characterization of bank conditions, wetland delineation, and a vegetative inventory. Wetland boundary locations were collected by Biohabitats.

Each assessment is discussed and summarized in the sections that follow. Mapping showing existing conditions through the project area is included in the Schematic Design plans, with more detailed information about the mapped features included throughout this report.

2.2 Watershed Characterization

The Project originates at a confluence of stormwater pipes at Mohegan Avenue Parkway (Route 32) and flows east through Connecticut College Arboretum property (the George S. Avery Tract and the Katherine Matthies Tract) to its terminus at a small pond ("Salt Pond") which is bounded to the east by an elevated private railroad. The Salt Pond is connected by a box culvert to the South Cove of Mamacoke Island, a tidal bay along the Thames River.

The project drainage area is in Waterford, New London County and a drainage area map is included in Section 2.5 below. The drainage area is generally of steep topographic relief that slopes east, rapidly becoming lowland terrain near the confluence with the Salt Pond. The upstream portion of the watershed consists of residential properties, Route 32 runoff, and undeveloped wooded areas which drain towards the wooded upland College Arboretum before continuing downstream where the valley widens to a maintained meadow area with scattered trees.

2.3 Geology and Soil

Geology within the project area consists of the Mamacoke Formation (Zwm). This formation consists of interlayered light- to dark-gray, medium-grained gneiss from the Neoproterozoic geologic age (USGS).

A soil survey using the Natural Resource Conservation Service (NRCS) soil web map was completed to evaluate the major soil components within the project area. The soil resource report equips field investigators and designers with information about soil properties and land classifications that supports a better understanding of the behavioral characteristics of a proposed project. "The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans." (NRCS).

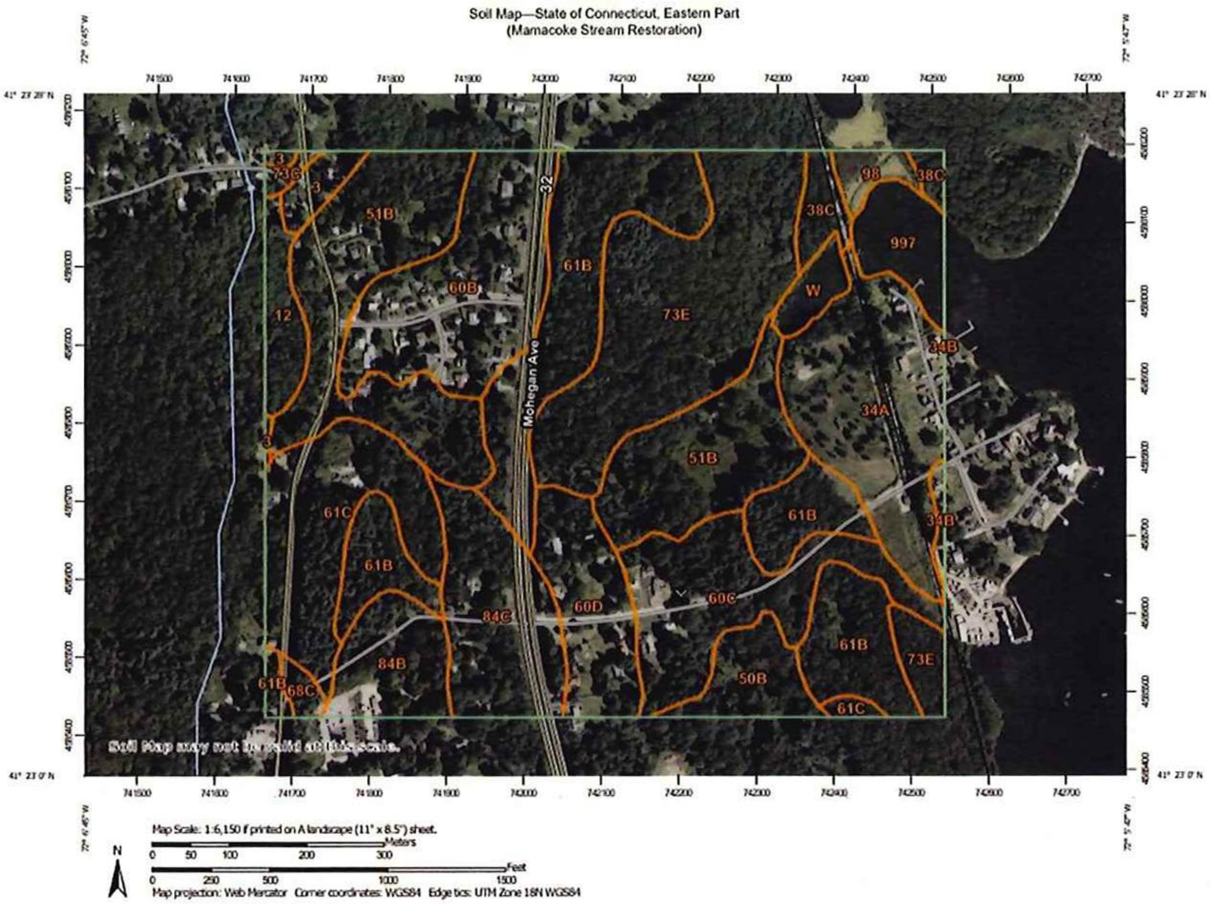

Figure 2: NRCS Soil Resource Report Soil Map

The upstream limits of the project area are classified as Canton and Charlton soils (60D), a steep-sloped, well-drained soil. The majority of soils within the project area are classified as Sutton fine sandy loams (50B), which is a moderately well-drained soil typically found on hillslopes and classified as having high runoff potential. The northern side and downstream limits of the project area are Charlton-Chatfield complex (73E), a very rocky, well-drained soil found on 15 to 45 percent slopes. All of these soil classes are derived from granite, gneiss, and/or schist.

2.4 Wetlands and Surface Waters

A wetland delineation was completed by Biohabitats staff in September 2025. The Project is located on a 54.1 acres parcel, which contains 3.07 acres of wetlands – 2.25 acres tidal, 0.82 acres inland. An inland scrub-shrub wetland totaling 0.48 acres was identified within the project area along with 0.34 acres of inland watercourse. The majority of the 1,500 linear feet of inland watercourse channel within the project area was determined to be intermittent, approximately 1,200 linear feet originating from the Rt 32 culvert. There is short section of perennial channel below the confluence with spring fed tributary near the downstream end, approximately 300 linear feet. The channels and wetlands are depicted on the design plan sheets, below is a summary of methodology.

2.4.1 Federal Jurisdictional Wetlands

In support of the Project, the wetland and waters of the U.S. (WUS) boundaries were identified, flagged and survey located. Biohabitats identified, delineated, and documented nontidal wetlands and WUS within the project limits in compliance with applicable State and Federal regulations. The delineation was performed using the three parameter approach – wetland hydrology, hydrophytic vegetation, and hydric soils – in accordance with the 1987 Corps of Engineers Wetlands Delineation Manual - Technical Report 87-1 (USACE, 1987) and the Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region - Version 2.0 (USACE, 2012). The existing hydrology was evaluated at each sample location by documenting the presence of primary and secondary hydrologic indicators, which provide evidence as to whether a site has a continual wetland hydrologic regime. For the hydrophytic vegetation determination, the abundance of each species within five strata – tree stratum, sapling stratum, shrub stratum, herb stratum, and woody vines – was sampled. The vegetative sample plots had a 26.3-ft radius, according to standard USDA forest inventory methods. A wetland indicator status was applied to each identified plant species per the 2014 National Wetland Plant List (NWPL) (Lichvar et. al., 2014). To determine if hydric soils were present, the soil profile at each sample location was characterized, focusing on the presence/absence of redoximorphic features to a depth of 12 to 18 inches using an auger and/or spade. Upon assessment of the three parameters, wetland area boundaries were flagged and plotted with sequentially numbered flagging. In depth discussion of the findings of the wetland delineation can be found in the wetland delineation memo (Appendix A).

2.4.2 Connecticut Jurisdictional Wetlands

Inland, non-tidal wetlands are regulated under the Connecticut Inland Wetland and Watercourses Act. In general, wetlands are defined as a soil that is saturated to within 20 inches of the surface during a portion of the growing season. These soils have redoximorphic features, a deficiency of oxygen near the surface, and/or ponded water during the growing season. They are poorly drained, very poorly drained, alluvial, or fluvial as specified by the USDA Natural Resource Conservation Service (NRCS). Depth to seasonal high water table is determined by low-chroma mottling or wetness indicators.

Inland, non-tidal watercourses are also regulated under the Connecticut Inland Wetland and Watercourses Act. Watercourses are rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water including natural or artificial, vernal or intermittent, public or private. A defined permanent channel and bank, and the occurrence of two or more of the following characteristics delineate intermittent watercourses:

- Evidence of scour or deposits of recent alluvium or detritus
- Presence of standing or flowing water for a duration longer than a particular storm incident
- Presence of hydrophytic vegetation

2.5 Hydrology

Biohabitats identified and evaluated two delineation points and three sub-watersheds for hydrologic analysis throughout the project reach. The overall drainage area includes portions of the Connecticut College Arboretum, residential neighborhoods and College properties west of Route 32, an undeveloped portion of the watershed immediately west of Route 32, and a segment of Route 32 itself. A drainage area map showing the three sub-watersheds is shown below in Figure 3. The watershed contains 14.2% impervious surfaces.

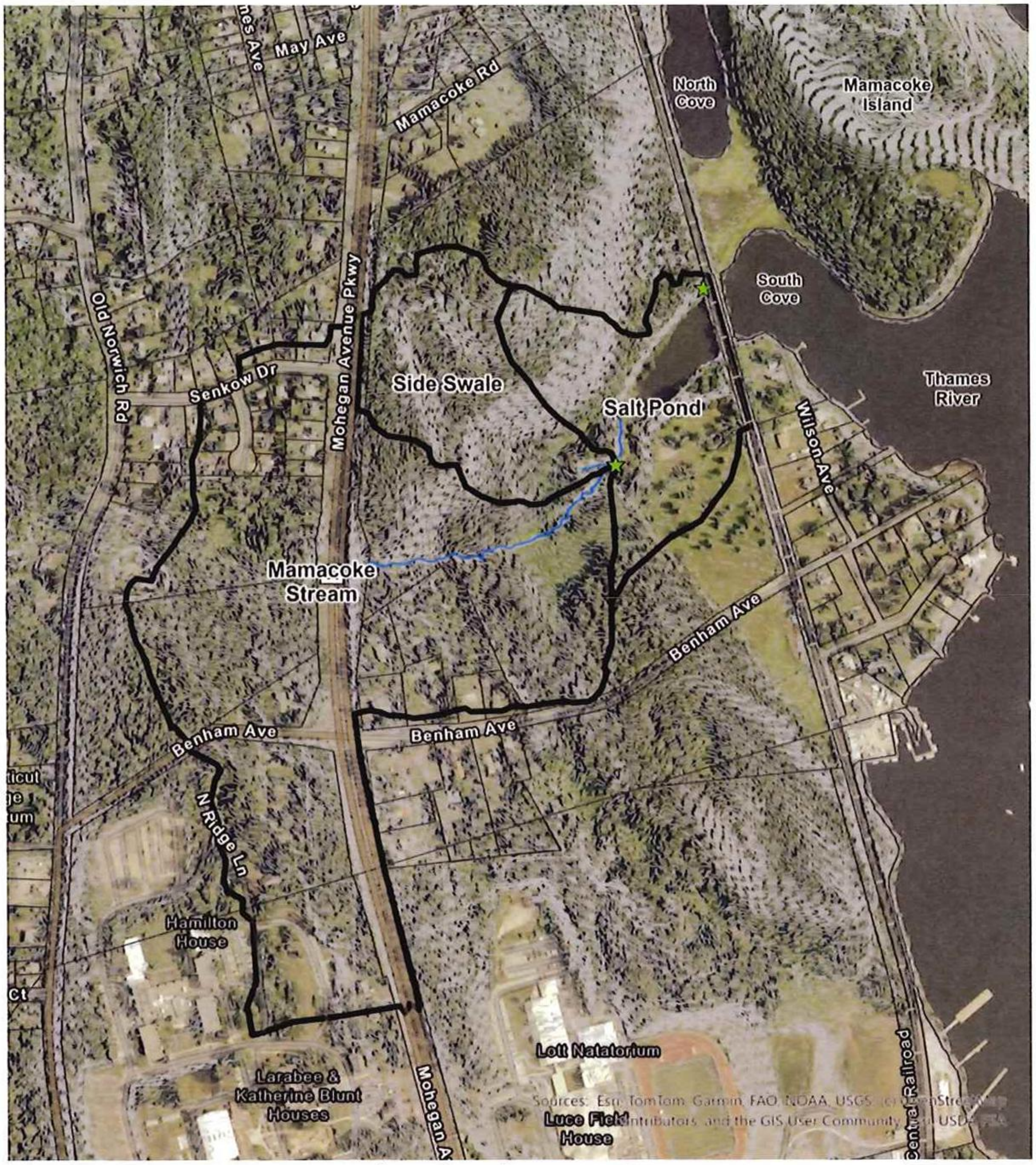

Figure 3: Drainage Area Map

Biohabitats collected inputs from available LiDAR and GIS data from New London County, Connecticut and site-specific LiDAR. The available GIS data was utilized to determine time of concentration paths and weighted curve numbers for the overall project drainage area. Weighted curve numbers are based on hydrologic soil group (NRCS Web Soil Survey) as well as land use (NOAA) to reflect current existing conditions. Maps showing the drainage area's soil and land use are shown below in Figures 4 and 5.

The County's zoning indicates that the entire drainage area could be developed as medium density residential (R-20), however given the fact that the majority (approximately 70%) of the watershed is within the arboretum, it is assumed this area is protected from future development and will not be developed.

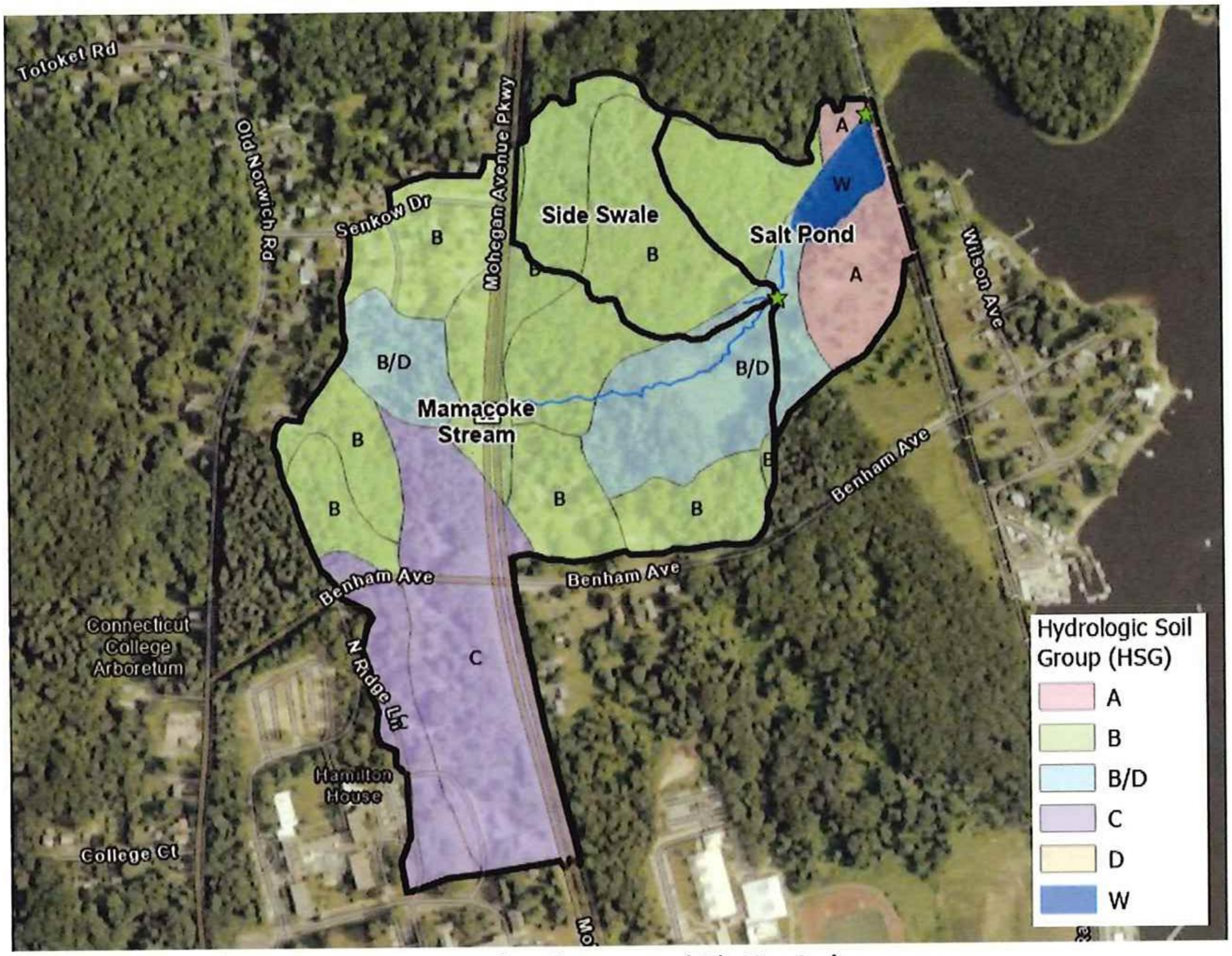

Figure 4: Hydrologic Soil Groups within the drainage area

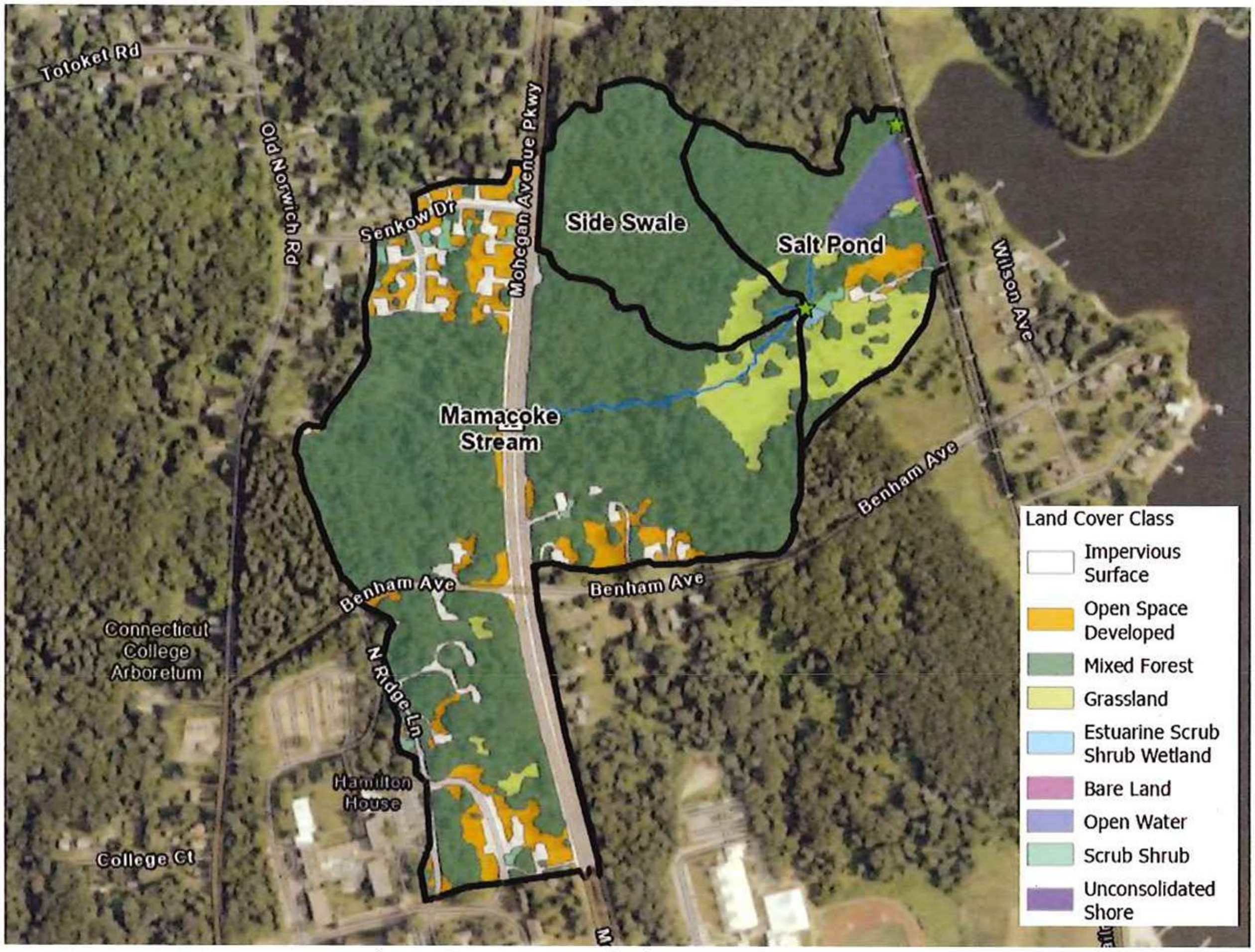

Figure 5: Land Use within the drainage area

NRCS hydrologic modeling was performed in HydroCAD Version 10.00, a hydrologic modeling software, to calculate the peak discharges for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events. For this analysis, the runoff method was SCS TR-20, rainfall distribution was 24-hour NOAA D and rainfall depths were pulled from NOAA Atlas 14, Volume 10, Version 3. All hydrologic modeling for this project was performed in accordance with the Connecticut Stormwater Quality Manual. The full hydrologic modeling results can be found attached in Appendix B. Summaries of the hydrologic analysis are shown in Tables 1 through 4 below.

Table 1: 24-hour Rainfall Depths (inches)

1-year	2.89
2-year	3.45
5-year	4.36
10-year	5.11
25-year	6.15
50-year	6.93
100-year	7.76

Table 2: Hydrology Summary

Drainage Area (ac)	76.6
Impervious Area (ac)	10.9 (14.2%)
Weighted CN	70
1-year peak (cfs)	23.82
2-year peak (cfs)	37.92
5-year peak (cfs)	64.38
10-year peak (cfs)	88.39
25-year peak (cfs)	123.84
50-year peak (cfs)	151.59
100-year peak (cfs)	181.90

Table 3: Sub-Watershed Hydrologic Summary

Sub-Watershed ID	*Area [AC]*	*RCN*	*Tc [hr]*
Mamacoke Stream	53.26	73	0.577
Side Swale	10.99	61	0.525
Salt Pond	12.40	60	0.665

Table 4: Peak Flows by Sub-Watershed

Sub-Watershed ID	*Peak Flows [cfs]*						
	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Mamacoke Stream	21.95	33.37	53.89	72.09	98.53	118.98	141.12
Side Swale	1.17	2.60	5.69	8.70	13.37	17.14	21.35
Salt Pond	1.02	2.31	5.21	8.10	12.61	16.28	20.41

2.6 Vegetative Community Assessment & Tree Survey

A vegetation inventory was completed by Biohabitats staff in September 2025. Four main vegetative communities were identified on-site: Mature Mixed Deciduous-Coniferous Upland Forest, Deciduous Hedgerow, Scrub-shrub Wetland and Dry Meadow. Each of these communities contain a diverse mix of native species and non-native invasive vegetation including multiple stands of non-native *Phragmites* *australis* located within the identified wetland. These communities are mapped and included in the Schematic Design plans. Below is a brief summary of the vegetation communities identified within the project area.

Mature Mixed Deciduous-Coniferous Upland Forest is the primary forest type that surrounds the project area and occurs primarily on the hillslopes. The mature canopy of red/black and white oak, sweet birch, red maple, American beech and white pine that are over 18" in diameter at breast height (dbh) dominates over the 6"-12" dbh American beech, sweet birch, mockernut hickory and sugar/Norway maple of the sub canopy. The understory is dense within the project area containing primarily non-native shrub species including barberry, burning bush, multiflora rose, wineberry, Tartarian honeysuckle among the native maple-leaved viburnum, sassafras and arrowwood. The typical sparse groundcover layer of vegetation occurs in this forest which contains a mix of wintergreen, white wood aster, garlic mustard, burnweed, and woodland sedge with poison ivy, Japanese honeysuckle and Asiatic honeysuckle vines growing where canopy gaps have allowed for more sunlight.

The upstream 500' of the project area contains numerous dead standing trees and multiple blowdowns that have created gaps in the canopy allowing the growth of a large stand of tree of heaven and other non-native invasive species in this upland forest community along the stream channel.

Dry Meadow

The vegetation community within the large open areas along the lower half of the project site include a variety of native grasses and forbs with an occasional woody trees or shrub. Dominant herbaceous species present in this community include grass leaved goldenrod, showy goldenrod, wrinkleleaf goldenrod, spotted joe-pye weed, big bluestem, New England aster, hairy aster, butterfly weed, bracken fern, mugwort, common milkweed, and late boneset. Observed trees and shrubs include Eastern red cedar and winged sumac. The Dry Meadow area was forested until 2005, when the woody vegetation was cleared and converted into meadow habitat. This was done with the intent of creating early-successional habitat for floral and faunal species that depend on open canopies.

Deciduous Hedgerow is the dense vegetation community type that is in between the open dry meadow areas, relic agriculture fields and roadways within and surrounding the project area. This community is composed of a few tree species such as crabapple, young black oak, northern catalpa, black cherry, winged sumac and sassafras but generally dominated by shrub and vine species. These include autumn olive, multiflora rose, shrub honeysuckle, burning bush, barberry, privet, porcelainberry, Japanese honeysuckle, Asiatic bittersweet, poison ivy, greenbriar, and fox grape.

Scrub-shrub Wetland Two stands of common reed occupy a large portion of this vegetation community and porcelainberry is growing in from the periphery, but there are numerous native shrub and herbaceous species present between the non-native invasives. Shrubs are dominated by spicebush and gray alder with some privet present in lower numbers. Dominant herbaceous species include arrowhead, tickseed, water plantain, false nettle, greenbriar, clearweed, smartweed, skunk *cabbage, white snakeroot, soft rush, narrowleaf cattail, giant goldenrod and* jewelweed.

All trees greater than 6" in diameter at breast height (DBH) within the possible project limits of disturbance (LOD) were considered "significant" and identified to species and evaluated for their general condition (Good, Fair, Poor). Each tree was marked with a sequentially numbered round aluminum tag that was affixed to the tree using an aluminum nail at approximately eye level, generally located on the side of the trunk facing the stream channel. Pink survey flagging tape was also attached to the tag for improved visibility in locating each tag, and to keep track of the survey completion allowing the survey crew to remove as they survey trees. The DBH of each tree was estimated and occasionally measured using a DBH measuring tape as calibration to maintain accurate estimates. Trees with multiple trunks were treated *as a single tree for survey purposes but the DBH of each stem was recorded and a* composite DBH was calculated using the following root sum squared formula: $\sqrt{(dbh1^2+dbh2^2+\ldots+dbhn^2)}$. A total of 76 significant trees were located and tagged, 8 of which were specimen trees with greater than 24" DBH (Table 5). Located trees are included in the plan set basemapping and shown on the existing and proposed conditions sheets (Appendix F).

Table 5: Mamacoke Tree Survey – September 2025

Tree Number	Species	DBH (inches)	Condition	Notes
1	Red Oak	28"	Good	
2	Sweet Birch	18"	Good	Multistem 13, 13
3	Sweet Birch	17"	Good	
4	Sweet Birch	19"	Good	
5	Sweet Birch	14"	Good	
6	Hackberry	12"	Poor	
7	American Beech	7"	Poor	
8	Hackberry	6"	Poor	
9	American Beech	7"	Poor	
10	American Beech	28"	Poor	
11	Sweet Birch	19"	Poor	
12	Sweet Birch	11"	Good	
13	Sweet Birch	12"	Good	
14	Sweet Birch	7"	Good	
15	Sweet Birch	8"	Good	Multistem 6, 6
16	Black Cherry	8"	Good	
17	Sweet Birch	6"	Good	
18	Sweet Birch	12"	Good	
19	Red Oak	32"	Good	
20	Willow	14"	Good	Multistem 11, 8
21	White Pine	23"	Good	
22	Catalpa	10"	Good	Multistem 8, 6
23	Sweet Birch	7"	Good	
24	Unknown	12"	Dead	
25	Sweet Birch	15"	Good	undercut bank
26	Hickory	19"	Good	
27	Black Oak	18"	Fair	
28	Black Oak	31"	Good	
29	Black Oak	24"	Good	
30	Black Oak	24"	Good	
31	Ash	7"	Good	
32	Red Maple	6"	Fair	Poor Form
33	Red Maple	26"	Poor	
34	Red Maple	19"	Poor	
35	Norway Maple	12"		NNI
36	Unknown		Dead	8-ft snag & 15-ft snag
37	Unknown	36"	Dead	Multistem 18, 18, 18, 18
38	Tree Of Heaven	7"		NNI
39	Norway Maple	14"		NNI
40	Unknown	20"	Dead	40-ft snag
41	Elm	9"	Poor	
42	Hackberry	8"	Good	

Tree Number	Species	DBH (inches)	Condition	Notes
44	Unknown	23"	Dead	Multistem 16, 16; 15-ft snag & 40-ft snag
45	Norway Maple	7"		NNI
46	Norway Maple	9"		NNI
47	Unknown	18"	Dead	40-ft snag
48	Norway Maple	12"		NNI
49	Cherry	6"	Poor	
50	Red Maple	8"	Poor	
51	Black Oak	22"	Good	
52	Elm	6"	Good	
53	Elm	6"	Good	
54	Red Maple	12"	Good	
55	Red Maple	12"	Good	
56	Unknown	20"	Dead	20-ft snag
57	Black Oak	26"	Poor	Multistem 14, 22
58	Elm	7"	Good	
59	Red Maple	8"	Poor	
60	Unknown	20"	Dead	
61	Red Maple	6"	Good	
62	Unknown	20"	Dead	
63	Black Oak	23"	Poor	
64	Elm	11"	Good	
65	Norway Maple	8"		NNI
66	Elm	6"	Good	
67	Norway Maple	10"		NNI
68	Norway Maple	11"		NNI
69	Elm	11"	Poor	
70	Unknown	24"	Dead	50-ft snag
72	Norway Maple	12"		NNI
73	Norway Maple	6"		NNI
74	Norway Maple	16"		NNI
75	Red Maple	12"	Good	
76	Tree Of Heaven	10"		NNI

2.7 Listed Species

The proposed project limits are located within a designated Natural Diversity Data Base (NDDB) area. This would indicate that there is or historically has been observed instances of a state-listed endangered, threatened, or special concern species. Based on discussion with the College, there is one known instance of historical documentation of the special concern plant species *Bolboschoenus maritimus* ssp. *paludosus* (saltmarsh bulrush). This species, which was last documented in 2006, was observed in the tidal scrub-shrub wetland area where a significant stand of common reed is currently found.

An NDDB request was filed with the Connecticut Department of Energy and Environmental Protection (CTDEEP) and a response was received on December 5, 2025 (Appendix C). In accordance with the recommendation from CTDEEP, a botanical survey will be conducted to confirm and the presence or absence of this species in or near the project area. Alterations to the design plans or inclusion of best management practice will be incorporated based on the findings of the botanical survey and coordination with CTDEEP.

2.8 Cultural Resources

An archaeological and cultural resource inventory was performed by Dr. Anthony Graesch, Ph.D Associate Professor of Anthropology at Connecticut College. See Appendix D for full report. Recommendations from this report were considered when developing the proposed design and continued coordination will be required as the design progresses.

3 Site Constraints

3.1 Existing Utilities and Infrastructure

Based on site observations and survey, the following utility and infrastructure constraints have been identified within the project limits:

- Stormwater Infrastructure
    - Mohegan Avenue Parkway (Route 32)
        - A 48" RCP conveys the primary channel underneath Mohegan Ave, tied into concrete headwalls on both sides of the road.
        - Numerous drop culverts along the roadway convey water to the upstream limits of the project reach, there are 4 culvert pipes which discharge into multiple headwalls at the upstream limits of the project.
    - Stream Culvert
        - A 24" RCP is located in the middle of the project channel, timbers are placed to span this culvert. This culvert was recently damaged during a storm event and replaced in its current configuration as a temporary measure.
    - Railroad Culvert
        - An aging4' W x 2' H concrete box culvert that is likely nearing the end of its service life (visual observations noted possible

blockage or partial collapse within it) crosses underneath the railroad embankment at the downstream limit of the salt pond.

- Electrical Infrastructure
  - Overhead power lines run along Mohegan Avenue Parkway as well as Benham Avenue.
- Sewer Infrastructure
  - No sanitary sewer infrastructure was observed on site or anticipated based upon review of readily available sources.
- Rock walls, trails, bridges
  - Stacked stone walls and mowed grass or earthen trails are located throughout the entire project area.
  - A wooden pedestrian bridge is located mid-channel and spans the project reach.

There are several private properties and ConnDOT right-of-way (ROW) abutting the project area. No impacts to properties other than those owned by the College are anticipated. And no work is required on ConnDOT ROW or to infrastructure owned by ConnDOT. Above ground utilities were located as part of the topographic survey.

3.2 Property Ownership and Easements

The project area is located on property owned by Connecticut College and is used as the Connecticut College Arboretum. Privately-owned properties abut the project site but will not be impacted by the proposed restoration work. There are no known easements within the project area. Access to the project site will come off of Benham Avenue as shown in the schematic design plans. At this time, no new easements are assumed to be necessary.

3.3 Regulated Floodplain and Hydrologic Trespass

An existing FEMA floodplain Zone AE was identified within the project limits for the downstream Thames River. Zone AE is a FEMA zone indicating that base flood elevations have been determined. The estimated Zone AE base flood elevation within the project limits is 11 ft. A FEMA FIRMEtte (a smaller, printable version of a FEMA FIRM panel) is included in Figure 6 to indicate the extents of National Flood Hazard information. FEMA boundary limits are also shown on the Schematic Plans.

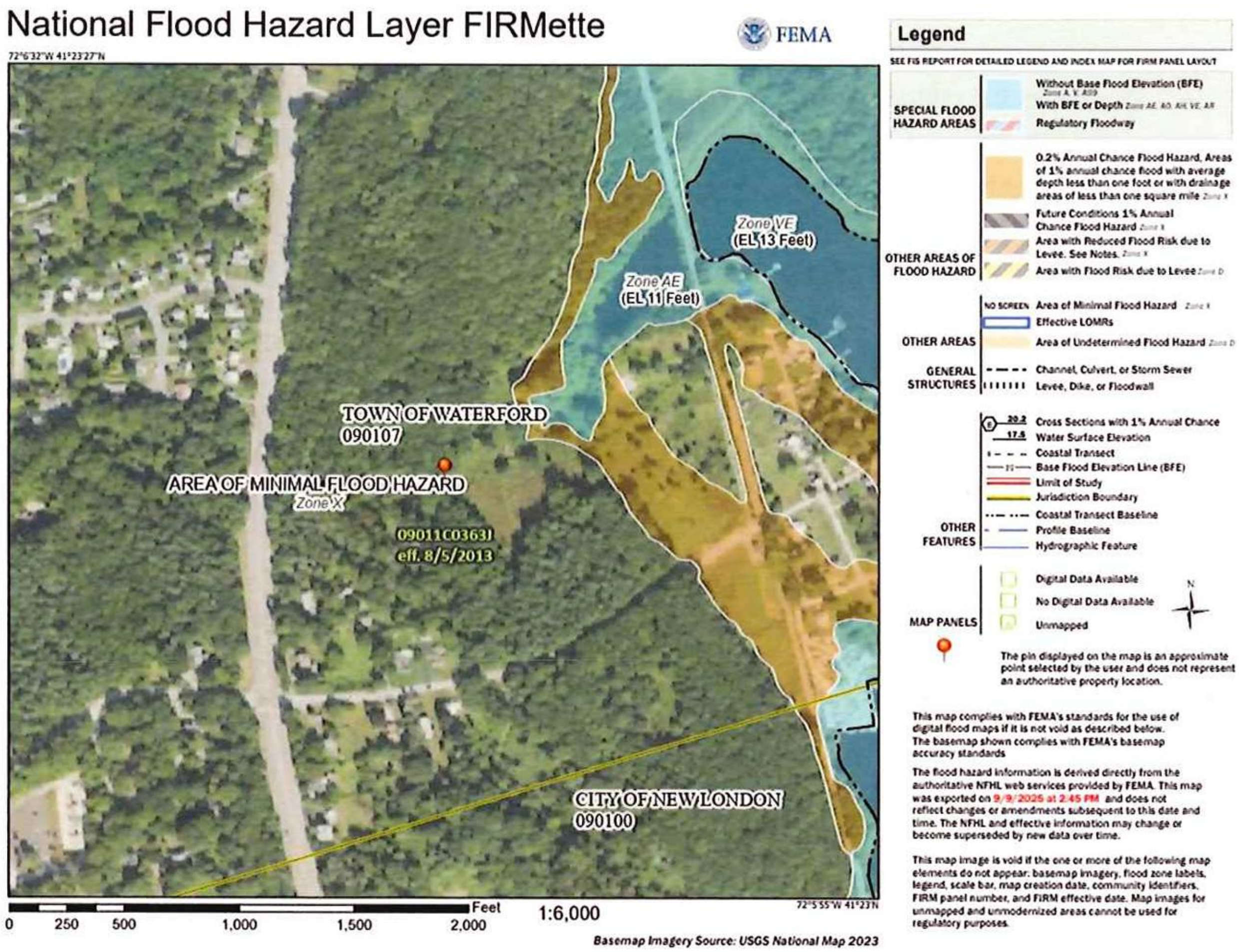

Figure 6. FEMA FIRMette

Changes to the regulated FEMA Zones are not anticipated as a result of this project, as the FEMA zones within the project area are related to backwater from the Thames River. This project is anticipated to result in a no-rise floodplain condition.

Above the FEMA Zone AE, we anticipate water surface elevation rises but none that would impact infrastructure or buildings. There are no known floodplain restrictions in this location. Coordination with the College will be required to ensure they are accepting of the proposed changes.

3.4 Stream and Wetland Impacts

This restoration project will result in unavoidable impacts to the state- and federal-regulated wetlands and watercourses (including WUS and adjacent wetlands). All impacts shall be permitted through the Town of Waterford, CTDEEP and USACE Connecticut General Permit process. Post restoration, all wetlands impacted shall be restored in-kind to the same or greater size with improved functional condition (no net loss).

3.5 Cultural Resource Impacts

The proposed restoration work will occur with zones of archaeological sensitivity identified by Dr. Graesch. The degree to which these impacts will adversely affect the cultural resources is actively being discussed with the College. However, these zones of archeological sensitivity have been avoided to the greatest extent possible by minimizing the construction footprint. Additionally, construction access and staging have been located outside the zones of archeological sensitivity. Lastly, best management practices such as the use of construction matting and limited ground disturbance have been identified in the design.

4 Existing Stream Conditions

4.1 Site Assessment

A site assessment was performed in August and September 2025 to identify distinct reaches, document existing channel conditions, document causes and extent of instabilities and qualitatively assess the potential to provide ecological uplift. This included the collection of site photos, the identification of stream channel geomorphic conditions, habitat assessment, and a bank stability analysis. A map of the existing channel condition is shown on the Design Plans.

4.2 Stream Geomorphology

Stream channel stability is often described as a long-term state of "dynamic equilibrium." In such a state, a channel's bed and banks maintain their dimensions, pattern, and profile indefinitely, through a sustained balance between aggradation and degradation processes, even while experiencing natural migration and adjustment.

The stream channel within the project limit is currently in a state of disequilibrium exhibiting high degrees of aggradation and degradation in various sections. Overall, the channel is unstable and continues to adjust its channel dimension. Much of the channel's length contains visible signs of high rates of adjustment, most notably including active headcutting, incision and channel enlargement. These adjustments have created conditions that have decreased groundwater elevations, decreased connection of flood flows to the floodplain, increased sediment and nutrient supplies via bank erosion, contribute to decreased downstream water quality, and increased downstream aggradation impacts. Alterations to the natural hydrology of the system and the human alteration of the stream channel are often the root cause of instability and can set into motion a series of major, sometimes rapid, channel adjustments that can be detrimental to a stream ecosystem.

Our assessment of the current geomorphic condition of the stream agrees with findings from the 2008 study of the channel, and subsequent resurveying of channel cross sections from 2008 to 2025, performed by students of Doug Thompson at Connecticut College, which primarily focused on the assessment of Reaches 2 and 3 as defined below. Though a direct comparison of the measures was not made, the conclusions of that report, and subsequent documentation of active channel cross section erosion, are consistent with the findings below. This includes characterizing the channel as deeply incised, with scattered large boulders, and is trending towards a step-pool morphology. The report assessed extent is transitioning from a stable Rosgen A channel at the upstream limits, to an unstable F/G channel, and the downstream portion is re-stabilizing as a Rosgen C/B. We agree with the conclusions of this assessment, and note that the unstable F/G portion appears to have migrated further upstream from the time of the initial assessment. Reach 1 and 4 would classify as Rosgen A and C, respectively. The unstable portions of the channel are capable of moving fairly large particles during small storm events. Locations of the college's cross section monuments found during our assessment work demonstrate the channel is not migrating horizontally but mostly downcutting vertically.

4.2.1 General Conditions

The project area is located within the New England physiographic province and the Southern New England Coastal Lowland region. During the field reconnaissance, crews noted steep to moderate channel slopes, streambed materials dominated by glacial-till boulders and silt to gravel-sized substrate, and a steep sloped valley rapidly transitioning into Thames River glaciofluvial terraces, which are consistent with this setting. The steep to moderate sloped channels are boulder run dominated with sporadic step/pool formations mostly due to wood debris jams or headcuts and associated scour pools. In some locations along the project area, the channel has downcut through the upper soil horizons and exposed bedrock and is incised. The stream reaches have low sinuosity associated with their steep, step pool configurations with minimal meander development, and the riparian corridor varies between a forest and meadow condition.

Observations along the channel network suggest the flow regime is primarily intermittent along the stream channel except for the most downstream limit, which is perennial. The upper stream is fed by stormwater runoff from Route 32 and seasonal flow. The downstream reach is fed by a springhead.

In general, conditions along the stream reaches are typical of degraded systems in suburban areas. Historical changes in land use activities and stream valley disturbances are potential factors that influence the planform of the channels. Many streams have been straightened to allow for farming, development, and other such activities.

4.2.2 Reach Measurements and Descriptions

Biohabitats walked the length of the stream and broke the project into four distinct geomorphic reaches, as denoted on the BEHI Map. In general, the location of reach breaks is based on visually appreciable changes in drainage area and other measurable changes in morphology including channel slope, substrate, incision, floodplain characteristics, valley condition, planform geometry, channel stability and manmade obstructions such as dams and road crossings. In general, identified reach lengths are at the scale of about 200 to 500 feet in length. The following sections describe the stream geomorphology in more detail.

During the field survey, bankfull elevations were observed from all available indicators including depositional features, changes in bank angle, vegetation patterns, and scour lines. Because the erosional reaches are mostly incised channels with vertical banks, few strong field indicators are present.

4.2.2.1 Reach 1

Reach 1 stream channel is a 14% gradient, high energy boulder dominated channel within a forested riparian buffer. The upstream limits of the reach begin at two headwalls located east of Route 32 where four stormwater pipes enter at the top of the system. Despite the initial flow concentrated condition, the channel is relatively stable given the presence of large immobile boulders (approximate D50 of boulders is greater than 4 feet) within the flowpath. There is significant woody material load within or overhanging the channel. There is often not a clear distinction between the channel bed and bank and no obvious bank erosion. Channel planform is very straight and down-valley, the channel was dry during the field survey.

Figure 7. Typical Reach 1 Stream Condition

4.2.2.2 Reach 2

Reach 2 is the most complex of the reaches and is experiencing active headcutting and upstream migration. The upstream limit of the reach begins where a stone wall, located on either side of the channel, once likely crossed the flowpath, near a 90 deg bend at the property line. The stone wall is no longer present within the crossing and has likely fallen into the channel. Similarly, to Reach 1, the upstream half of this reach remains relatively steep and boulder-dominated. However typical boulder size is smaller (approximate D50 of 2 feet) and the channel has downcut and widened around the boulder dominated channel bed, resulting in less consistent grade control provided by the boulders. There is a wooden pedestrian footbridge spanning the channel approximately halfway through this reach. Immediately upstream and downstream of the pedestrian bridge the channel exhibits significant erosion, including downcutting to bedrock exposure. Impacts of erosion are evident in the existence of the bridge itself, this crossing was previously a low water crossing and was replaced with the footbridge in recent years due to the need to span the incising channel. This location is the upstream extent of a knickpoint caused by active headcutting and channel enlargement. There are some gaps in canopy cover throughout this reach, and significantly less woody material load than Reach 1. Although the majority of the reach is within a forest, the downstream does extend into the meadow. The overall channel slope is 7% and the channel was dry during the field survey.

Figure 8. Typical Reach 2 Stream Condition

A geomorphic cross section (oriented in the downstream direction, perpendicular to stream flow) was surveyed in Reach 2, the reach which is experiencing the most active erosion. The cross section was surveyed at a location which represented typical channel condition, had a bankfull indicator and evidence of recent particle deposition. The longitudinal reach profile was obtained from the field-survey completed by MCA. A Wolman pebble count of the existing channel substrate was performed at the surveyed cross section. This data was processed and evaluated in the Reference Reach Spreadsheet (Mecklenburg 2006). The Mecklenburg spreadsheet uses the Manning equation for discharge given the bankfull elevation, local channel geometry, slope, and Manning's roughness coefficient. The Manning's roughness coefficient "n," was approximated using the results of the Wolman pebble count to account for bed material roughness, as well other factors that influence channel roughness observed in the field.

Results from the Mecklenburg spreadsheet bankfull discharge calculations are compared to the hydrological model results outlined in Section 2.5 above and are used to inform proposed channel sizing. Bankfull measurements were recorded as a width of 7.1 feet, mean depth of 0.8 feet and a cross-sectional area of 5.7 square feet. Average grain size from the pebble count was D50 of 8.8 mm (gravel). The bankfull discharge was calculated at 45.4 cfs, which falls between the 2 and 5-year storm hydrologic model results. While this bankfull discharge trends higher than typically anticipated bankfull recurrence intervals, it makes sense given the intermittent stream condition and relatively small drainage area.

Additional geomorphic ratios include the bank height ratio and entrenchment ratio, both of which can be used to quantitatively assess the vertical containment of a river. For the surveyed section location, the bank height ratio was calculated at 2.1 (deeply incised) and the entrenchment ratio was calculated at 1.1 (entrenched). See the Mecklenburg cross section spreadsheet in Appendix E.

Figure 9. Reach 2 Cross Section

Figure 10. Reach 2 Materials

4.2.2.3 Reach 3

Reach 3 generally is an incised channel due to past headcut migration through it, dominated by actively eroding streambank. A 24" reinforced concrete pipe and timber mat bridge cross partway through this reach. This culvert was recently damaged during a storm event and replaced in its current configuration as a temporary measure. Some portions of the stream banks downstream of the 24" RCP show signs of past failure and are beginning to re-stabilize and re-vegetate.

The reach lacks floodplain connection and consistent bed protection throughout, select embedded boulders as well as the 24" RCP pipe have maintained channel profile at discrete spot locations. The streambed is mainly composed of sediment deposition (silt, sand and gravel), small boulders, and cobble-sized material. The overall slope of Reach 3 is 7%, however the downstream-most 40 feet of this reach lessens in gradient and widens, thus improving the relative stability of the channel at this location. The majority of this reach runs through the meadow and has either a narrow, immature treed streamside buffer or no treed buffer at all. Reach 3 was dry during field survey.

Figure 11. Typical Reach 3 Stream Condition

4.2.2.4 Reach 4

Reach 4 is visually and morphologically different than the upstream three reaches. It is a perennial, low-sloped channel that feeds into, and is likely occasionally backwatered by, the Mamacoke Salt Pond. A stable, well-connected channel (banks less than 1 foot), the channel runs along the toe of slope on the west side of the valley. A side channel joins the flowpath here that originates from the west. The bed material consists of silt and sand. The floodplain is stable but dominated by phragmites. The entirety of reach 4 was delineated by a wetland.

Figure 12. Typical Reach 4 Stream Condition

4.3 Habitat Assessment

A Rapid Bioassessment of the stream channel was performed for each reach using the EPA Rapid Bioassessment Protocol for high and low gradient streams. The data sheets can be found in Appendix E. Tables 6 and 7 below summarize the results of each habitat assessment. Reach 1 scored as optimal, reaches 2 and 4 scored in the suboptimal range, and reach 3 scored as marginal.

Table 6: Habitat Assessment Results – High Gradient Ephemeral or Intermittent Stream

Parameter		Reach 1	Reach 2	Reach 3
Substrate Diversity		20	12	11
Embeddedness		16	15	10
Channel Alteration		20	15	9
Fine Sediment Deposition		16	13	10
Bank Stability	Left	10	7	2
	Right	10	5	2
Bank Vegetative Protection	Left	10	6	2
	Right	10	4	2
Width of Undisturbed Vegetative Zone	Left	10	10	3
	Right	10	10	3
Total		132	97	54

Table 7: Habitat Assessment Results – Low Gradient Perennial Stream

Parameter		Reach 4
Epifaunal Substrate /Available Cover		5
Pool Substrate Characterization		10
Pool Variability		4
Sediment Deposition		11
Channel Flow Status		8
Channel Alteration		14
Channel Sinuosity		15
Bank Stability	Left	7
	Right	8
Vegetative Protection	Left	5
	Right	5
Riparian Vegetative Zone Width	Left	7
	Right	6
Total		105

4.4 Bank Stability Analysis and Erosion Estimate

A bank stability analysis was conducted in the field to determine the potential quantity of bank erosion within the project area. The Bank Assessment for Non-Point Source Consequences of Sediment (BANCS) model (Rosgen, 2001, 2006) was conducted using the Bank Erosion Hazard Index (BEHI), and Near-Bank Stress (NBS) evaluations.

The inventory followed the Bank Assessment for Non-Point Source Consequences of Sediment (BANCS; Rosgen, 2006). The BANCS method estimates the rate of erosion and the volume of bank material delivered to the stream via bank erosion. It is a field-based visual assessment tool that, when combined with empirical studies, can be used to predict estimates of erosion rates.

The BANCS method integrates two erodibility tools to estimate erosion rates: 1) The Bank Erosion Hazard Index (BEHI), and 2) Near Bank Stress (NBS). The BEHI is a bank erodibility estimation tool that assesses streambank erosion condition and potential. To develop the BEHI rating at a location, the following physical parameters are assessed: 1) study bank height, 2) bankfull height, 3) root depth, 4) root density, 5) bank angle, and 6) surface protection. Field-measured variables are converted to risk ratings between 1 and 10 with corresponding adjective values of risk (e.g., very low to extreme).

The second assessment is Near Bank Stress (NBS). NBS variables are used to adjust the BEHI prediction based on the potential disproportionate energy distribution in the near-bank portion of the channel cross section. Along the Project Limits, NBS was assessed using the Level 1 rapid assessment diagram from the WARSSS protocol (Rosgen, 2006).

BEHI and NBS assessment was completed for both banks for the entire stream length. Table 8 below summarizes the lengths of stream banks in each erosion risk category, non-erosive banks are not included. More than 50% of the banks fall within the "high" or "very high" category. This is supported by Connecticut College cross section analysis conducted by Doug Thompson at ten locations in 2008 and repeated in 2025, which recorded bank depositional rates of up to 1.6 feet and incision of 7.1 feet. These findings document the channel degradation and support the need for restoration.

Table 8: Length of BEHI risk values in the project reach.

BEHI Risk Rating	Length (feet)
Low	137
Moderate	601
High	1,030
Very High	335
Total	**2,103**

5 Stream Restoration Design

5.1 Overall Restoration Approach

As stated in the Introduction, the overall project goals are to:

1. Improve geomorphic function of the stream channel to promote long-term bed and bank stability. This will reduce sediment transport into Mamacoke Cove and the Thames River, improving water quality and habitat in the downstream restoration areas.
2. Attenuate/slow the delivery of stormwater flows originating from the concentrated flow sources at the upstream limit of the project to the salt pond and cove at the downstream limit of the project. Maximize the conversion of surface water to groundwater, assisting with the improvement in physicochemical functions and water quality. This will also decrease the non-point source pollution carried by the stormwater discharges (such as petroleum products and trash from the roadway, and fertilizers from contributing land use) that degrade downstream water quality.
3. Create and enhance the ecological functions of existing stream habitats.
4. Where feasible, maximize the reuse of onsite native rock and wood throughout the restoration.
5. Mitigate non-native and invasive species, including the vines pulling down the existing canopy in the riparian buffer, through initial treatment/eradication and planting of native trees and shrubs.

Biohabitats identified a suite of restoration opportunities and approaches for the project area to accomplish the restoration goals while also accounting for site specific conditions and constraints of the project area. Restoration approaches are described in this section, supporting documentation can be found in Appendix F and design plans in Appendix G.

<u>Upstream Restoration Reach</u>

Several stormwater outfalls discharge directly to the receiving channel at the same location just below the Rt 32 crossing. Potential hydraulic improvement at the upstream is possible through the implementation of a reinforced plunge pool below the outfalls to dissipate concentrated storm flows before entering the steeply sloped channel. However, the potential amount of improvement is limited due to the height of pipes above the receiving channel. Due to site constraints on construction access (forested condition, steeply sloped) and location on ConnDOT ROW, outfall stabilization and energy dissipation is considered infeasible for this project without significant natural resource impacts. Therefore, it is not included in the project scope.

Starting at the College property line adjacent to ConnDOT ROW and continuing downstream to just above the first trail crossing of the channel, the upstream reach's intermittent channel is a laterally and vertically stable boulder dominated conveyance channel within a mature riparian forest area. Potential geomorphic improvements to this reach are limited to increasing the sediment trapping capacity through the augmentation of wood structures. Due to limited construction access to upper reach (forested condition, steeply sloped), the opportunity for improvements here is limited to placement of woody material within the spaces between boulders along the bed of the stream. This will include installation of Post-Assisted Log Structures (PALS), which are hand installed, low-tech, processed based restoration technique and/or dropping the fallen trees that are currently overhanging the channel. Given the high gradient slope of the channel here, functional uplift with this approach is anticipated to be minimal and we should anticipate wood mobilization to occur with limited potential for recruitment due to the presence of upstream culverts.

- PALS: Channel spanning PALS are composed of woody material of various sizes pinned together with untreated wooden posts driven into the substrate to mimic natural wood accumulations and influence hydraulics and geomorphic processes. PALS in these proposed locations are used to achieve a range of restoration outcomes including creating high flow refugia for aquatic species; increasing physical complexity by altering patterns of erosion and deposition; and promoting channel incision recovery by forcing channel widening and aggradation. Unsecured wood ("seeding") can also be added within groups of PALS to increase wood density but defer to the system where the wood will accumulate (Chapter 5: Shahverdian et al., 2019b). The orientation of structures (relative to flow) can be as varied as natural wood accumulations, but generally channel-spanning PALS are built angled upstream. PALS are generally built with woody material that can be moved and placed by one to four people (i.e., shrubs, branches, logs, and/or trees 1-1.5 ft (30-45 cm) diameter and 10-16 ft (3-5 m) long). Generally, a wide range of sizes are used; large pieces are positioned first and pinned in place with medium and small pieces used to fill in gaps and make the structure less porous. This simulates natural racking of small material on a natural log jam. PALS typically have a limited lifespan and are not intended to be permanent structures, as they will naturally decompose over time at this location. They are used to initiate natural processes of slowing the flow velocities, trapping sediment, detritus and wood to promote ecological diversity.

The riparian area is dominated by non-native invasive (NNI) species such as bush honeysuckle, Asiatic bittersweet, porcelainberry, barberry, privet, multiflora rose, Japanese honeysuckle, and tree of heaven. As part of the long-term maintenance and monitoring, non-native invasive species removal/control along the riparian corridor will be conducted in cooperation with the Arboretum..

The original concept plan developed for grant funding identified repairs to the southern storm drain outfall pipe wingwall. Given there is no construction access, and it is location within ConnDOT right-of-way, this is not being implemented for this project.

Middle Restoration Reach

Starting at the upstream limit of the actively enlarging channel, located approximately 130 linear feet upstream of the trail crossing the channel, restore horizontal and vertical stability of the degraded steeply sloped (approximately 8 to 10%) intermittent channel using a series of grade control structures placed on the channel at key locations, approximately every 70 to 100 ft. These cascade grade control structures are intended to mimic boulder cascades (similar to what is found in upstream reach) and provide long-term stability of the channel bed, protecting against headcutting and upstream migration, and allow for the proposed channel thalweg to be elevated above its current incised condition and closer to the top of bank elevation. This reach terminates approximately 625 feet downstream at a stable channel section located where the confined valley begins to open into a broader downstream reach.

- Cascades: The cascade structure will provide stable, vertical transition of approximately 3 to 4 feet over a relatively short distance. Each cascade cross section will be sized to convey close to the 100-year stormflow discharges in a generally parabolic shape to limit uncontrolled out of bank flows. This requires a 10 ft wide, 2 ft deep cross section. Large subangular bounders, sufficiently sized to remain immobile during the 100-year storm, will comprise most of the structure, placed in a natural configuration with a pool at the base of each to dissipate energy and mimic a steep step-pool system.

Between these cascade structures, the restored channel cross section will be set to a higher elevation within the enlarged channel, within a foot or two of the top of bank. Because the cascade structures account for a significant portion of the overall drop within the system, these reaches between cascades will be a lower sloped (approximately 5%) to create lower energy reaches and allow for the formation of a riffle/pool channel bed that supports natural stream processes, such as trapping and retaining wood within the flowpath. To accomplish this, two distinct techniques will be utilized to allow for variation and provide an opportunity to study the effectiveness of the techniques over time. The following two techniques will be considered:

- Regenerative Stormwater Conveyance (RSC) step pool design approach using riffle structures built on channel fill material and interrupted by shallow pools loaded with woody material to establish a stable plan and profile. Throughout the reach, onsite materials such as boulders, streambed material, and wood will be incorporated into the structures and pools to maximum extent feasible.
    - Riffle: Each riffle cross section will be sized to convey a small storm event (approximately the 2-year storm) in a generally parabolic shape but broken up by erratic boulders and wood elements. This requires a 10 ft wide, 1 ft deep cross section. The riffle substrate mix will be composed of a heterogeneous mix of subangular cobbles and gravels placed in a natural configuration to mimic a moderately steep step-pool system. The size class determination of the furnished bed material is based on the 10-year storm channel velocity as calculated in shear stress values derived from the structure sizing spreadsheets (Appendix F). The results indicate that furnished bed material needed to construct the riffles shall consist of an average grain size of 12.0 inches. Results from the proposed hydraulics model were used to validate the rock size selection. The existing streambed material will be salvaged and incorporated into the riffles to the maximum extent practicable. This structure is intended to maintain grade while also allowing for some natural migration of bed materials. Soil will be incorporated into the riffle substrate mix to promote near channel vegetation to establish and narrow the active flowpath.

    - Pool Wood/Boulder Cluster Treatment: within the shallow pool areas between riffle and cascade grade control structures, wood and boulder clusters will be installed along the pool bed and banks to increase roughness and provide habitat complexity. Wood material size will vary depending on what is available to salvage from the site or able to be procured for the project from off-site sources. The intent is for this larger course wood or smaller branches to be bundled and partially buried within the bed or banks, along with boulder clusters to anchor in place and over time act as an attachment point for additional wood recruitment.
- Dynamic Boulder Cluster / Woody Complex Streambed design approach using a combination of boulder clusters, wood material of varying sizes of branching material, and salvaged streambed material to partially fill the incised channel and create a highly roughened, diverse, and dynamic streambed that is anticipated to result in a multi-threaded flow path. Larger wood can be incorporated throughout the roughened surface, and the boulder clusters will provide attachment points for additional wood trapping/recruitment over time. Due to its dynamic nature, sorting of bed materials and wood decay is anticipated and must be taken into consideration when defining performance standards.

Both techniques are anticipated to improve water quality, raise the local groundwater elevation or the extent/duration of water retention to expand the wetted surface zone, and increase instream habitat diversity through the raising of the channel invert using a subsurface filter of porous fill material and coarse woodchips that maximize hyporheic connection between surface and groundwater. Instream channel habitat quality and diversity will be improved through the incorporation of salvaged or imported on-site woody material throughout the streambed to increase channel roughness that will provide the benefit of dissipating the energy of concentrated flows and reduce flow velocities. The use of wood throughout the channel also naturalizes the aesthetic of the restoration.

The riparian area is dominated by non-native invasive (NNI) species such as bush honeysuckle, Asiatic bittersweet, porcelainberry, barberry, privet, multiflora rose, Japanese honeysuckle, and tree of heaven. As part of the long-term maintenance and monitoring, non-native invasive species removal/control along the riparian corridor will be conducted in cooperation with the Arboretum.

NNI treatment will result in opportunity to perform supplemental native plantings within the treated areas to kickstart recovery. Coordination with the arboretum is required to define appropriate vegetative communities and specific plant palettes.

There are two locations where existing trails cross the stream channel at structures. The upstream crossing is currently a small pedestrian footbridge and the downstream crossing is a timber mat bridge with culvert pipe; both are limiting the restoration potential and impact channel conditions due to flow constrictions. Because of the proposed channel profile adjustments, both crossings are being proposed for removal and replacement with either stepping boulders or a low rock ford crossing integrated into the proposed restoration structures. The upstream crossing has been designed to facilitate pedestrians crossing the channel using stepping boulders, and the downstream crossing location has been designed to facilitate both pedestrians crossing the channel using stepping boulders as well as a riffle sufficiently wide to facilitate vehicular traffic crossing the channel.

Downstream Restoration Reach

The downstream reach is a perennial system that is laterally and vertically stable, lower sloped system, approximately 2 to 3%, with a primary flowpath located at the toe of slope along the west side of the valley that transitions from the confluence of the outfall channel and spring fed channel to the salt pond within a wide, densely vegetated valley bottom with several large phragmites stands. Although significant geomorphic uplift over existing conditions is limited within this reach due to its relative stability, it is critical to ensure base level controls remain intact given possible changes to the downstream railroad culvert and to provide resiliency to climatic changes over time. There is also significant uplift potential to the stream system's physicochemical and biological processes. Improvements include maximizing the stream and wetland habitat quality, extents, and diversity, through a full reconnection of the stream to its floodplain. This may be accomplished through the incorporation of valley-wide post and wattle structures and salvaged on-site woody material within the full width of the stream valley to maximize wetland function on material processing and associated water quality improvements. For the designs, a Stage 0 full valley restoration approach was selected to achieve the project goals.

- Stage 0: The Stage 0 restoration approach is proposed to restore the physical, chemical, and biological processes of a healthy, resilient stream ecosystem within this reach. The term "Stage 0" refers to the stages of a stream channel evolution model, as modified by Cluer and Thorne (2013). Stage 0 refers to a pre-channelization phase in which a stream valley is occupied by a forested wetland complex with many anabranching (interweaving) flowpaths and no defined single threaded channel. In the stream evolution model, channelization, or the development of a single threaded channel to transport water through the stream valley, occurs in Stage 1 and is a result of a change in water supply or concentration within the stream valley. This Stage 1 channel continues to progress through the remaining stages as it degrades, widens, and begins to readjust. The approach is founded on established principles of process-based stream restoration (Beechie et al. 2010, Roni and Beechie 2012) and focuses on addressing the historic root causes of channel and ecological degradation such as channel straightening and simplification to support past land use activities, which led to channel incision and disconnection of the stream from its floodplain.

The Stage 0 restoration approach is accomplished here by blocking of the active channels throughout the floodplain with woody brush mattress elements using in combination with post and wattle structures that span the width of the floodplain, and planting the restored valley bottom with native riparian and obligate wetland species. This approach looks beyond the channel to restore natural connectivity within the channel-wetland-floodplain system. The goal is to restore the floodplain-wide valley bottom, and allow natural erosion, deposition, and avulsion processes to create, maintain and support resilient instream, wetland, and floodplain habitats that support all life stages of target fish and wildlife species. In small, frequent storm events, and during periods of seasonally high groundwater, flows spread out across the floodplain and activate multiple flow paths. Benefits of a Stage 0 restoration approach include reducing the flow energy and increasing the system's ability to trap and deposit incoming sediment across the valley, thus preventing the transport of excess sediment and nutrient pollution. The topography of the restored stream valley bottom is highly variable, with many small mounds and depressions. With more frequent inundation of the valley bottom during storm events and due to increased near surface groundwater, the formation of natural high and low points during flow events will result in a dynamic, multi-channel system that provides refuge to many aquatic and terrestrial species.

The design of a Stage 0 system involves the proper sizing of the floodplain bottom width and energy slope to ensure shear stress values on the floodplain and flow velocities are low enough to remain stable during the 100-year storm event. For this, we target low shear stress values of up to 1 lb/sf to design a system without the need for valley-wide grade control reinforcement. If values between approximately 1 lb/sf and 2 lb/sf, valley wide grade controls are added to support vegetation in ensuring the necessary surficial protection is provided to resist scour. Preliminary computations to predict the shear stress based on a design flow of 140 cfs (10 0yr storm event) and energy slope of 2% resulted in less 1 lb/sf for a valley width of 67 ft. Because this stream valley bottom is approximately 100 ft width, this provides a high degree of confidence in the achieving a stable, multi-threaded stage 0 system along this lower reach.

Portions of the floodplain in this downstream reach are dominated by dense stands of *Phragmites australis*, a non-native invasive (NNI) species. *Phragmites* stands will be managed in accordance with Connecticut College Arboretum's policy and standards for management of non-native invasive species. Specifically, a regimen of herbicide treatment and above-ground biomass removal will be conducted to extirpate the *Phragmites* from this area. Additionally, supplemental plantings of wood vegetation will be incorporated when the stands of *Phragmites* are sufficiently reduced as to not adversely affect the planted species. As this area is located within a zone of archaeological sensitivity, no ground disturbance activities are proposed.

NNI treatment will result in opportunity to perform supplemental native plantings within the treated areas to kickstart recovery. Coordination with the arboretum is required to define appropriate vegetative communities and specific plant palettes.

5.2 Landscape Installation

A landscaping plan has been developed in coordination with the Connecticut College Arboretum based on the desired communities and species they are managing for. The species listed in the design set will be installed after construction and all areas not planted will be seeded and stabilized.

5.3 Construction Access and Erosion and Sediment Control

Construction access for equipment access and material transport is proposed to originate at an existing driveway opening along the north side of Benham Avenue and continue north along the existing path to the channel through arboretum property. This path was recommended in the Archaeological Consultation Report.

A staging and stockpile area is proposed east of this location, adjacent to the railroad and south of Benham Avenue. Per the Archaeological Consultation Report, this location was recommended by Connecticut College Arboretum Director. Because this location is disconnected from the work area, it provides an area for equipment storage but would not be advantageous for material storage.

A staging and stockpile area is proposed within the meadow just south of the stream channel, just off the construction access path to the site. This location is advantageous for material delivery, storage, and loading onto construction vehicles for placement due to its location along the construction access path and proximity to the work area. The Archaeological Consultation Report recommended no staging north of Benham Avenue due to evidence for Indigenous uses and an inadequately assessed archaeological record in those spaces. Because of this, it is proposed that this stockpile area be protected with hardwood mats to minimize disturbance to the ground surface and protect these resources. Along all construction access paths within the archaeological sensitive areas, either a thick layer of mulch or mulch with hardwood mats on top will be used.

Along the Upstream Restoration Reach, all proposed work is being performed by hand installed means, without the use of heavy construction equipment, to limit impacts to the natural resources. Material (woody debris, wood stakes) shall be delivered to the proposed locations using ATVs or hand carried, and materials installed using handheld tools (sledge, gas powered post drivers, etc).

Along the full length of the Middle Restoration Reach, which is primarily through the meadow, the construction access path is proposed on the area immediately adjacent to the right (south) channel bank.

Along the Downstream Restoration Reach, all proposed work is being performed by hand installed means, without the use of heavy construction equipment, to limit impacts on the natural and culturally significant resources. Material (wattles, woody debris, wood stakes) shall be delivered to the proposed locations using ATVs or hand carried, and materials installed using handheld tools (sledge, gas powered post drivers, etc).

Other than working during a low-flow period, we assume that there will not be any in-stream work restrictions for this site. This assumption will be confirmed during the permitting process. Any permit-related restrictions or requirements will be addressed as part of our response to permitting comments or as conditions of the permits issued. All erosion and sediment control measures and best practices shall follow local regulations and are anticipated to include perimeter controls around stockpile areas, stabilized construction entrance, and stabilization of disturbed areas with temporary seed and mulch.

5.4 Existing and Proposed Hydraulics

A one-dimensional steady-state model was created to evaluate the existing and proposed conditions for the project reach for the 1, 2, 5, 10, 25, 50 and 100-year storms. Modeling was completed using the U.S. Army Corp of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 6.6. The restoration reach alignment was utilized for the channel baseline, which closely follows the existing channel centerline. The upstream limit of analysis began at the outfall of Mohegan Avenue and the downstream limit of analysis is the Mamacoke Tidal Pond.

Cross sections extend upstream and downstream of the proposed restoration extents to include unaltered channel reaches for continuity. Cross sections were placed at the upstream controlling elevation of each proposed structure or intermediate distances of less than 150 feet. Cross sections were drawn from left bank to right bank (looking downstream) and perpendicular to the channel and floodplain contours. The same cross sections were used for both the existing and proposed model. Topographic data was compiled from the LiDAR-derived topography collected by Whiteout Solutions in October 2024. Proposed channel cross sections were modified to reflect the proposed restoration grading. The two existing elevated crossings (pedestrian bridge and timber mat footbridge) were removed from the proposed model, as they will be replaced with stepping-stone crossings.

Ineffective flow areas and expansion and contraction coefficients were adjusted based upon the restricted flow openings as recommended by the HEC-RAS Reference Manual. Manning's n-values were selected for the channel and overbank areas from the recommended values tabulated in Open-Channel Hydraulics (Chow, 1959). For the existing model, channel n-values ranged from 0.025 to 0.04 and overbank values ranged from 0.05 to 0.07. For the proposed model, channel n-values increased to 0.05 to 0.06 for restoration reaches, but remained the same as existing conditions in areas that would be unchanged. Overbank values similarly changed for areas that would be converted from meadow to forested condition but otherwise matched the existing conditions.

Flow rates for the modeled storms were pulled from the HydroCAD hydrology model (Section 2.5). During large storm events, the downstream end of the project will be backwatered by the New England Central Railroad bridge and Thames River. However, to isolate analysis on impacts of the Mamacoke Brook restoration, the HEC-RAS model was run in mixed flow regime with a downstream boundary condition set to the elevation of the typical low tide water surface elevation of the tidal pond and an upstream boundary condition of the typical channel slope. The existing and proposed conditions utilized the same flow data and boundary condition.

Comparison of existing to proposed conditions model results show an expected rise in proposed water surface elevation across all modeled storm events throughout the length of the restoration. For the upstream and middle restoration reaches, the existing channel water surface elevation is confined to within the stream banks during the modeled 10-year event, whereas the proposed channel throughout this length regularly gets out of bank for the smaller events.

The proposed model saw decreases in channel velocities and increases in overbank velocities (due to increased overbank wetting) when compared to the existing. Slight increases in shear stress values were seen across both the channel and overbanks. The most significant increase in overbank shear stress values was seen in the downstream restoration reach during the larger modeled storms. Further analysis determined that these shear stresses were not seen in a true backwater condition, which would be expected in a larger storm, due the tidal influence and the undersized railroad culvert, and were exasperated by using a low tide water surface elevation boundary condition, and therefore are not a concern. Another section that experienced high shear stress in both models is located at the transition point between the middle and downstream restoration reaches, where there is a significant change in both channel gradient and dimension.

Velocities and shear stress values were used to calculate proposed particle sizing (see Section 5.1) for the reinforced bed material. HECRAS cross sections and output tables are included in Appendix H.

6 REFERENCES

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