

Casco Bay Frontal Drainage

Watershed Management Plan

April 2026 | DRAFT

Prepared by
FB Environmental Associates

With assistance from Acorn Engineering, Inc and Field Geology Services

CASCO BAY FRONTAL DRAINAGE
WATERSHED MANAGEMENT PLAN

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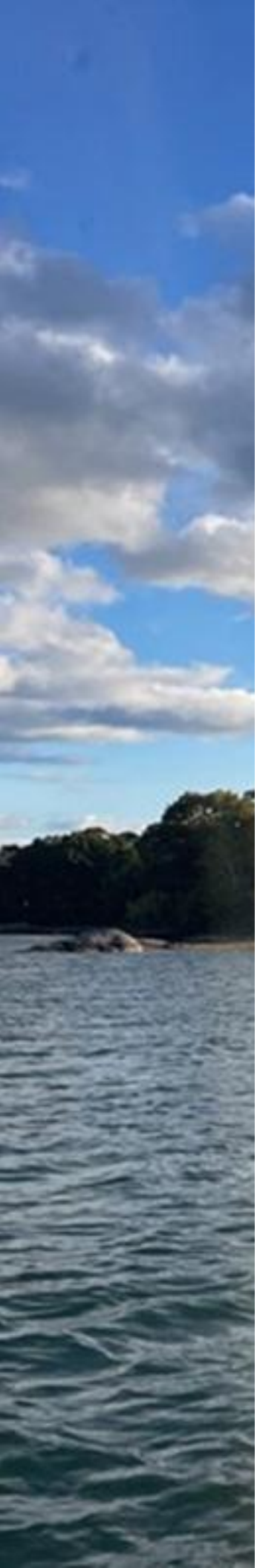
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For the Town of Falmouth

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ABBREVIATIONS

ACRONYM	DEFINITION
BMP	Best management practice
CAG	Community Action Grants
CBEP	Casco Bay Estuary Partnership
CCG	Coastal Communities Grant
CCSWCD	Cumberland County Soil and Water Conservation District
CWSRF	Clean Water State Revolving Fund
DEP	Department of Environmental Protection
DMR	Department of Marine Resources
DOT	Department of Transportation
EPA	United States Environmental Protection Agency
FBE	FB Environmental Associates
FPF	Fields Pond Foundation
L4C	Land for Communities
LMFP	Land for Maine's Future Program
LWCF	Land and Water Conservation Fund
MCM	Minimum control measures
MIAF	Maine Infrastructure Adaptation Fund
MNRCP	Maine Natural Resource Conservation Program
MOHF	Maine Outdoor Heritage Fund
MPN/100mL	most probable number per 100 milliliters
MS4	Municipal Separate Storm Sewer System
MSC	Municipal Stream Crossing Program
NAWCA	North American Wetlands Conservation Act
NEFRG	New England Forest and River Grant
NFWF	National Fish and Wildlife Foundation
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
ORLP	Outdoor Recreation Legacy Program
SCG	Small Community Grant program
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
WMP	Watershed-Based Management Plan
µS/cm	microsiemens per centimeter

DEFINITIONS

Adaptive management approach recognizes that the entire watershed cannot be restored with a single restoration action or within a short time frame. The approach provides an iterative process to evaluate restoration successes and challenges to inform the next set of restoration actions.

Best management practices (BMPs) are conservation practices designed to minimize discharge of nonpoint source pollution from developed land to lakes and streams. Management plans should include both non-structural (non-engineered) and structural (engineered) BMPs for existing and new development to ensure long-term restoration success.

Clean Water Act requires states to establish water quality standards and conduct assessments to ensure that surface waters are clean enough to support human and ecological needs.

Dissolved oxygen is a measure of the amount of oxygen dissolved in water. Low oxygen can directly kill or stress organisms and stimulate release phosphorus from bottom sediments.

Impervious cover refer to any surface that will not allow water to soak into the ground. Examples include paved roads, driveways, parking lots, and roofs.

Low impact development is an alternative approach to conventional site planning, design, and development that reduces the impacts of stormwater by working with natural hydrology and minimizing land disturbance by treating stormwater close to the source, and preserving natural drainage systems and open space, among other techniques.

Nonpoint source pollution comes from diffuse sources throughout a watershed, such as stormwater runoff, seepage from septic systems, and gravel road erosion. One of the major constituents of nonpoint source pollution is sediment, which contains a mixture of nutrients (like phosphorus) and inorganic and organic material that stimulate plant and algae growth.

Non-structural BMPs, which do not require extensive engineering or construction efforts, can help reduce stormwater runoff and associated pollutants through operational actions, such as land use planning strategies, municipal maintenance practices, and targeted education and training.

pH is the standard measure of the acidity or alkalinity of a solution on a scale of 0 (acidic) to 14 (basic).

Riparian refers to wildlife habitat found along the banks of a lake, river, or stream. Not only are these areas ecologically diverse, but they are also critical to protecting water quality by preventing erosion and filtering polluted stormwater runoff.

Structural BMPs, or engineered Best management practices, are often at the forefront of most watershed restoration projects and help reduce stormwater runoff and associated pollutants.

Total phosphorus is one of the major nutrients needed for plant growth. It is generally present in small amounts (measured in parts per billion) and limits plant growth in freshwater. In general, as the amount of total phosphorus increases, the number of algae also increases.

EXECUTIVE SUMMARY

The challenges facing the Casco Bay Frontal Drainage area and how we can work towards fixing them together.



The Casco Bay Frontal Drainages comprise several small watersheds and streams in Falmouth and Cumberland, Maine - Norton Brook, Webes Creek, Mill Creek, Chenery Brook, and Skitterygusset Creek. The first four of these streams drain to Mussel Cove, while Skitterygusset Creek drains to the Presumpscot River. Together these streams have a significant impact on the health of Casco Bay, an important natural, recreational, and economic resource for the watershed towns and beyond. The Bay's long-term health depends on how communities manage land use, development, and climate change impacts.

THE PROBLEM

Casco Bay faces increasing water quality threats from increasing watershed development and climate change. Concern over the inputs from the tributary streams in the Casco Bay Frontal Drainage watershed began with a 2021 Strategic Watershed Plan for the Town of Falmouth and a 2022 Maine Department of Environmental Protection Streams Stressor Report. These efforts began collecting water quality data on the streams, identifying stressors, and recommendation action items. Additional data were collected as part of the development of this watershed management plan in order to identify primary stressors, sources of pollution and habitat degradation, and action items for restoration and protection of water quality.

Key stressors to the Casco Bay Frontal Drainage include:

- High impervious cover and dense residential and commercial development contributing high volumes of stormwater runoff and associated pollutants (chloride, phosphorus, nitrogen, bacteria, etc.).
- Flow impacts from low baseflow, artificial channel straightening, and undersized stream crossings.
- Lack of in-stream wood and flow complexity.

Surveys identified opportunities for stormwater management practice installation, habitat improvement, and shoreline restoration to address the stream stressors.

THE GOAL

To protect water quality and recreation in Casco Bay, the Casco Bay Frontal Drainage Watershed Management Plan sets a 10-year goal for each of its tributary streams (Webes Creek, Skitterygusset Creek, Mill Creek, Chenery Brook, and Norton Brook) to attain all designated uses for Class B waterbodies in Maine. This goal is to be accomplished through the following objectives:

OBJECTIVE 1: Install structural best management practices to treat stormwater runoff in key areas of the watershed, particularly the Webes Creek and Norton Brook subwatersheds.

OBJECTIVE 2: Perform stream restoration practices to improve habitat in key segments of the five Casco Bay Frontal Drainage subwatersheds.

OBJECTIVE 3: Implement non-structural structural best management practices to reduce key pollutants identified as contributing to water quality criteria exceedances.



THE SOLUTION

The WMP includes an action plan developed by project partners that incorporates:

- **Structural Best Management Practices:** stormwater controls, in-stream habitat improvements, shoreline buffers, and erosion stabilization.
- **Monitoring:** continue and expand long-term monitoring to further understand pollutant inputs.
- **Education & Outreach:** strengthen community education on stormwater, vegetative buffers, septic system care, pet waste management, pesticide and fertilizer use, and shoreline protection.
- **Policy & Land Use Tools:** promote low impact development, revise ordinances, improve road and sewer maintenance, conserve land, and support resilient development standards.

Implementation is estimated at **$10.6-$16.8 million** over 10+ years, funded through state/federal grants, municipal commitments, and private support.



THE KEY TO SUCCESS

The success of this plan will depend on strong coordination among a dedicated stakeholder committee, active engagement from shoreline landowners, and sustained financial and volunteer support. Because pollutant reductions are complex and influenced by many factors, adaptive management will be essential to track progress and adjust strategies over time. With collaboration, commitment, and long-term investment, the community can protect Casco Bay and ensure a healthy future for this valuable resource.

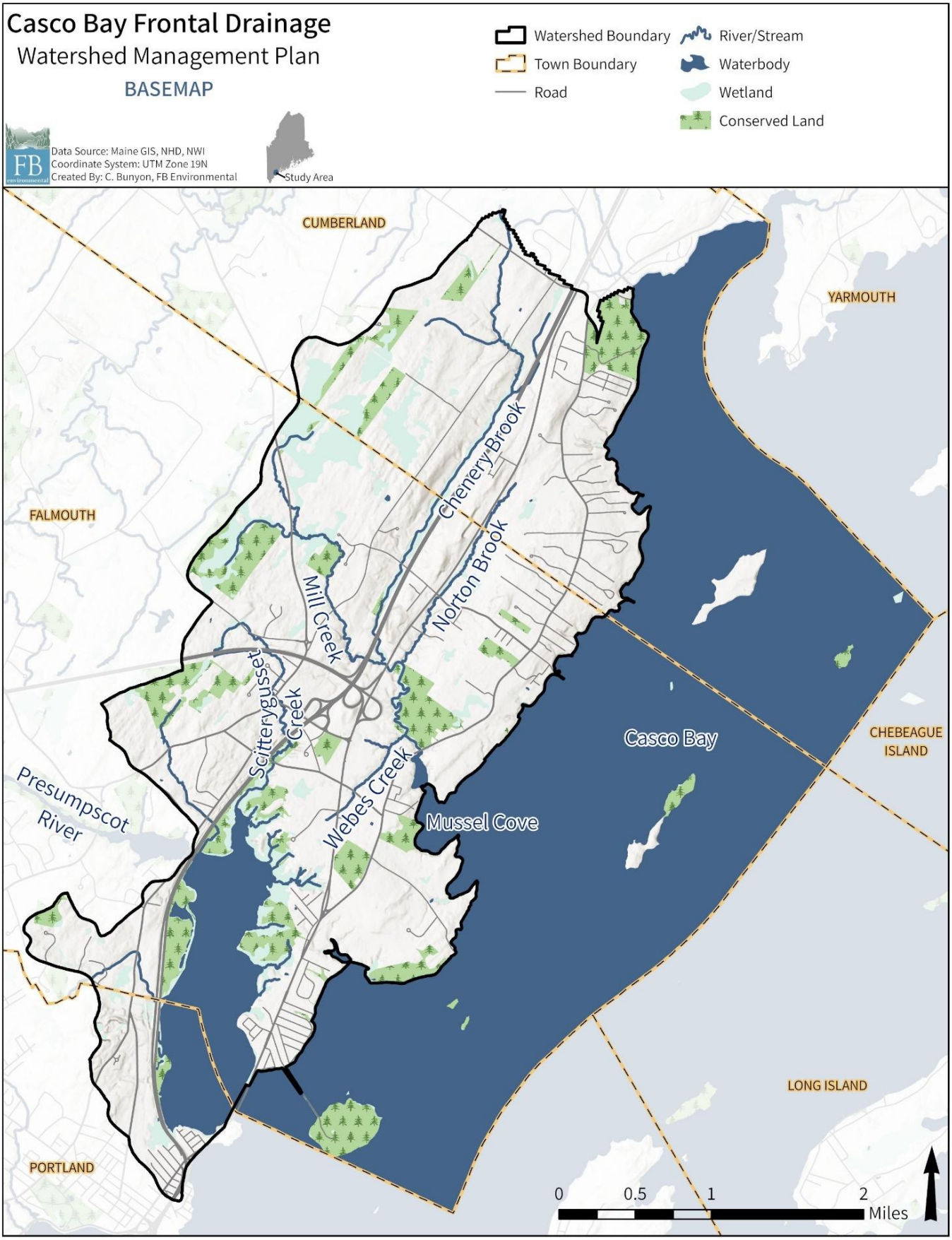


Figure 1. Casco Bay Frontal Drainage watershed basemap.

1 INTRODUCTION

1.1 WATERBODY DESCRIPTION AND LOCATION

Watershed Overview & Hydrology

The Casco Bay Frontal Drainages comprise several small watersheds and streams – Norton Brook, Webes Creek, Mill Creek, Chenery Brook, and Skitterygusset Creek (Figure 1). Four of these streams (Norton Brook, Webes Creek, Chenery Brook, and Mill Creek) drain to Mussel Cove, while Skitterygusset Creek drains to the Presumpscot River. Two watersheds, Skitterygusset Creek and Webes Creek, lie entirely within Falmouth, whereas the remaining three extend into the Town of Cumberland at their headwaters. The watershed areas of the four Mussel Cove tributaries are as follows: Mill Creek (3,485 acres), Chenery Brook (1,300 acres), Norton Brook (510 acres), and Webes Creek (337 acres) (Maine DEP, 2022a).

Norton Brook is a 2.0-mile Class B stream flowing from west of Route 1 in Cumberland to its confluence with Mill Creek east of Route 1. The watershed is predominantly forested, with an estimated 15.8% impervious cover. Most impervious cover occurs along Route 1, associated with commercial, office, light industrial, and multifamily residential land uses. Additional impervious cover comes from residential development along Johnson Road and Casco Bay Drive. The watershed has experienced approximately a 40% increase in impervious cover over the past 15 years (Maine DEP, 2022).

Webes Creek is a 0.71-mile stream flowing northeast between Route 1 and Foreside Road. The watershed extends from the Interstate 295 ramp south to the Volkswagen dealership and Foreside Estates. It has the highest impervious cover in Falmouth at 35% (Maine DEP, 2022), and is dominated by commercial and transportation uses along the Route 1 corridor. Stormwater from these developed areas enters Webes Creek via two stormwater outfalls and one tributary.

Chenery Brook is a 4.0-mile stream with headwaters in Cumberland. The watershed is heavily forested with only 7% impervious cover (Maine DEP, 2022), one-third of which is attributed to Interstate 295. The remaining impervious cover primarily consists of single-family residential development.

Mill Creek is a 3.7-mile Class B stream with headwaters in a mix of forested uplands and wetlands northeast of the Falmouth–Cumberland boundary. As of 2022, impervious cover accounts for 6% of the watershed (Maine DEP, 2022), with roughly 25% of this associated with I-295. Mussel Cove, the receiving waterbody, is a 55-acre intertidal embayment with a 0.5-mile-long channel extending from Foreside Road to the cove mouth.

Skitterygusset Creek is a 1.8-mile stream originating near the Falmouth Spur (Toll Road) and flowing south parallel to I-295 before discharging to the Presumpscot River near Tidewater Farm.



Soils and Topography

The Casco Bay Frontal Drainage watershed features a mix of well-drained upland soils and poorly drained coastal and lowland soils that influence runoff and erosion potential. Most of the landscape consists of gently sloping terrain (0-4%), with steeper slopes occurring near the coastline and along I-295. Areas with gentle slopes generally have low erosion risk, while steeper and more developed areas are more susceptible to soil loss and sediment transport, particularly near coastal inlets and major roadways. (Figure 2)



Land Cover

The Casco Bay Frontal Drainage watershed is dominated by forested land cover, with Upland Forest, Upland Herbaceous, and Scrub/Shrub habitats accounting for approximately 65% of the total area. Wetlands are also abundant, particularly Palustrine Forested Wetlands located northwest of the watershed behind I-295. Along the main inlet between Falmouth and Portland lies a large area of Unconsolidated Shore and Estuarine Aquatic Bed. Further inland, wetlands are primarily Estuarine Emergent and Palustrine Emergent types.

Developed impervious areas comprise about 18% of the land cover, concentrated along Route 1 in Falmouth, downtown Cumberland, and portions of the shoreline. Urban development is scattered throughout the towns, with the densest areas along the Route 1 corridor. (Figure 3)



Climate

The Casco Bay Frontal Drainage area experiences mildly cool summers, cold winters, and significant year-round precipitation influenced by proximity to the Atlantic Ocean. Coastal conditions contribute to periodic heavy snowfall and intense precipitation events associated with nor'easters and other coastal storms. Temperature variability is highest in winter and lowest in spring and fall. Annual precipitation typically ranges from 40–50 inches but can vary substantially from year to year.



Wildlife Habitat

The Casco Bay Frontal Drainage watershed supports diverse and high-value wildlife habitats. The mouth of the Presumpscot River between Portland and Falmouth is designated as a Maine shorebird area (10% of watershed), high-value tidal waterfowl and wading bird habitat (8%), and an exemplary salt-hay saltmarsh natural community. This area also supports habitats for state-listed species, including the least bittern and peregrine falcon. (Figure 4)

Conserved lands are distributed throughout the watershed, providing essential ecological protection. Much of the shoreline supports extensive eelgrass beds. Offshore islands include several critical habitat areas, such as tidal waterfowl and wading bird habitats, eelgrass beds, Maine Roseate Tern essential habitat, conserved lands, and designated Maine seabird nesting islands.

Riparian conditions vary among streams:

- **Norton Brook:** Dominated by mature upland mixed forest, with floodplain wetlands of red maple, alder, and both native and invasive shrubs in low-gradient areas.
- **Webes Creek:** Mixed forest on surrounding slopes and floodplain vegetation of invasive plants, alders, and shrubs; tidally influenced reaches support salt-tolerant grasses.
- **Chenery Brook:** Primarily natural riparian vegetation, with minor residential encroachment in Cumberland. Narrow valley sections are forested, while broader sections support shrub-scrub or meadow wetlands.
- **Mill Creek:** Natural wetland vegetation dominates the tidal reach, transitioning to forested riparian cover upstream.
- **Skitterygusset Creek:** Predominantly forested riparian corridors, especially in upper reaches, but with variable conditions due to past land clearing and development; some segments lack mature buffers and in-stream wood. Lower and more developed areas include constrained or altered buffers with lawns, fill, and infrastructure, contributing to localized erosion and reduced habitat complexity.



Figure 2. Topography in the Casco Bay Frontal Drainage watershed.

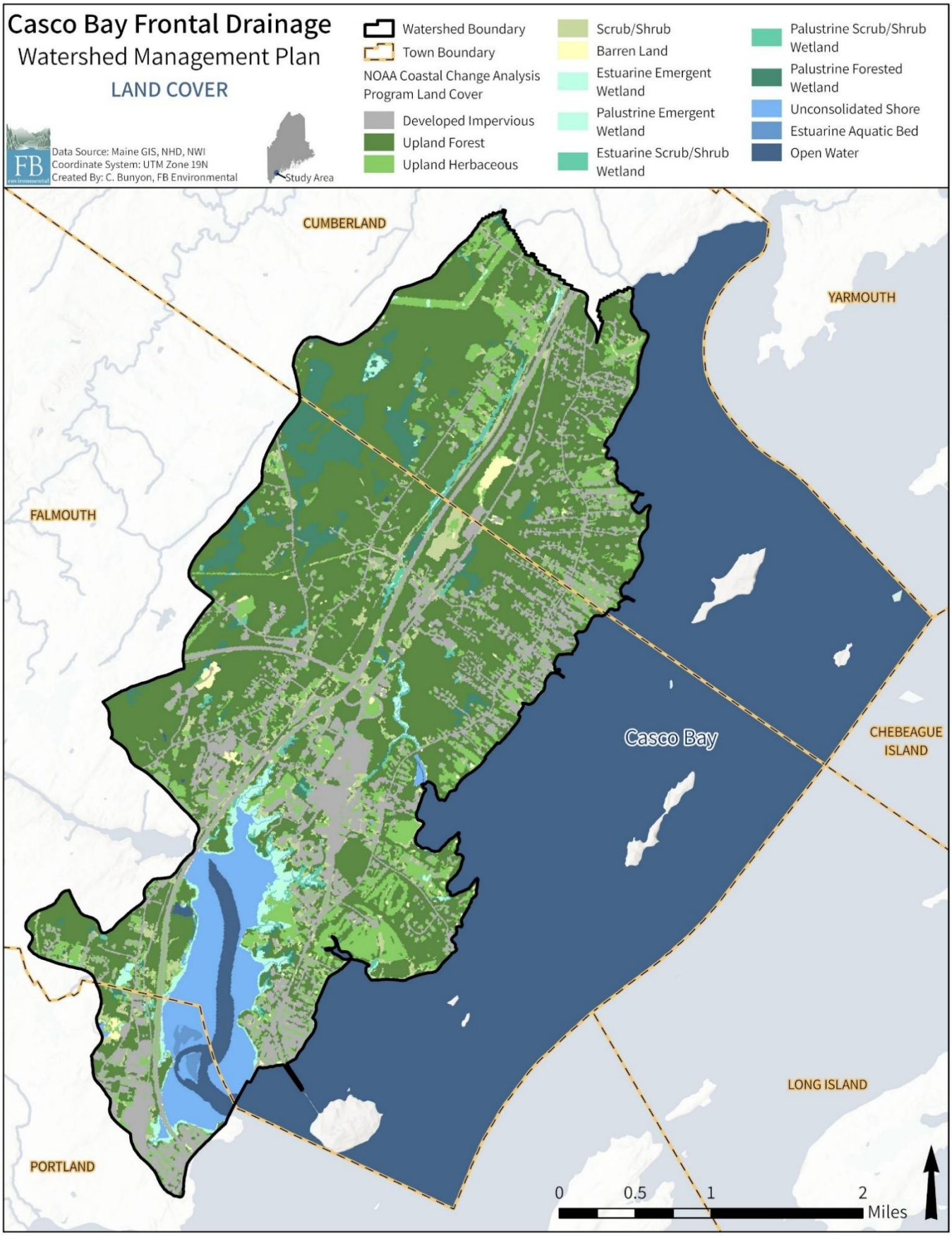


Figure 3. Land cover in the Casco Bay Frontal Drainage watershed.

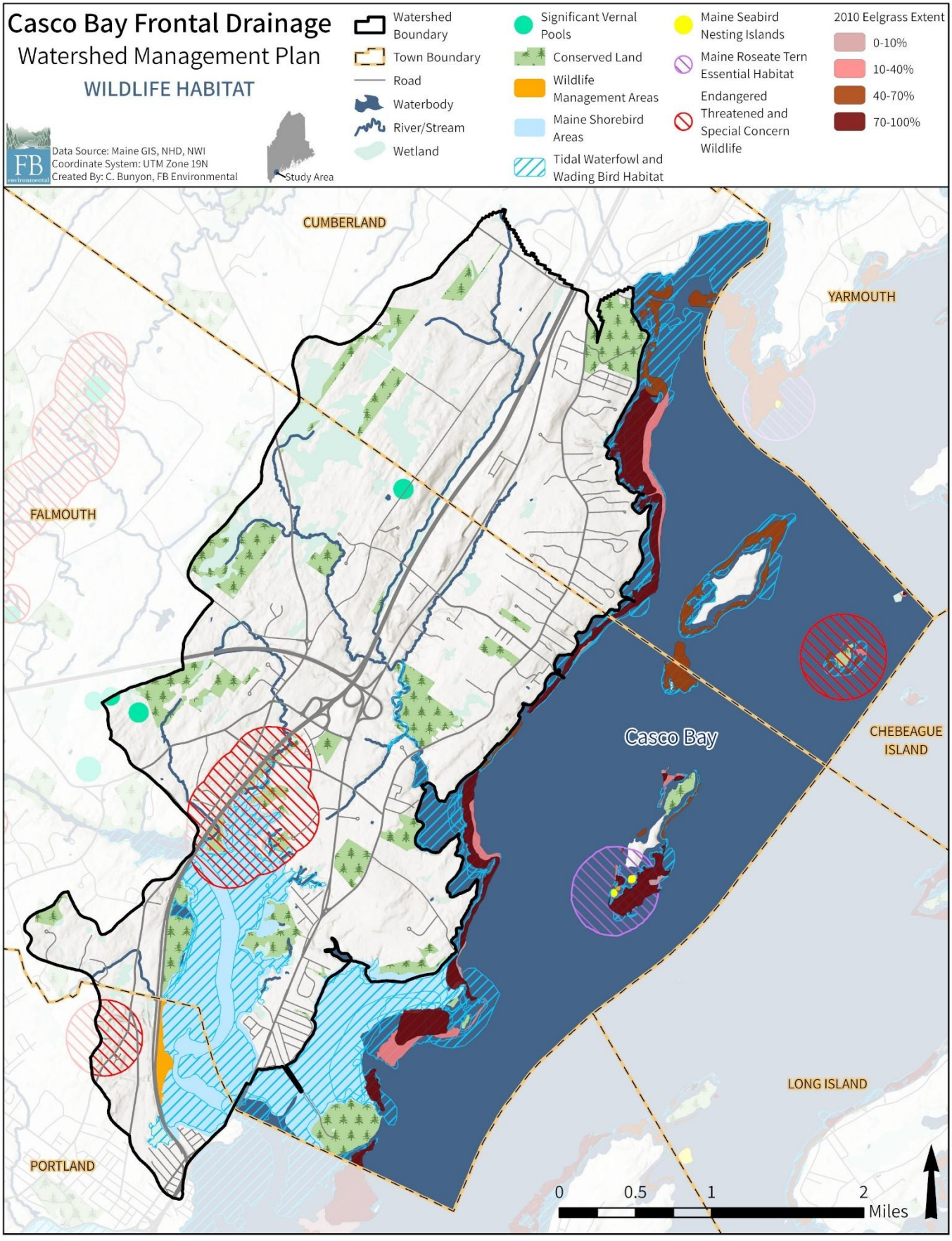


Figure 4. Wildlife habitat in the Casco Bay Frontal Drainage watershed.

1.2 WATERSHED PROTECTION GROUPS

The **Cumberland County Soil & Water Conservation District** (CCSWCD) is an organization in Cumberland County that "*focuses on educational programs and technical services that address the region's soil and water conservation needs, including stormwater, agriculture, soil health, watershed management, and invasive species*."

The **Casco Bay Estuary Partnership** (CBEP) is a collaborative effort of people and organizations dedicated to restoring and protecting the Casco Bay watershed; areas including the Casco Bay Frontal Drainage . CBEP performs habitat protection and restoration, pollution tracking, education and outreach, modeling, monitoring, and more for the entire Casco Bay watershed.

The **Friends of Casco Bay** is a non-profit organization based in Portland whose mission is to "*improve and protect the environmental health of Casco Bay.*" The group focuses on conducting scientific monitoring in the Bay, advocating for pollution reduction and climate change solutions in the watershed, and engaging with communities. Friends of Casco Bay is comprised of paid staff, a Board of Directors, and volunteers.

The **Maine Department of Environmental Protection** (DEP) works with local organizations to improve water quality in Maine at the watershed level. Maine DEP works with communities to identify water resource goals and to develop and implement watershed-based plans. This work is achieved by providing financial and technical assistance to local watershed management organizations and by investigating actual and potential water contamination problems, among other activities.

The **Falmouth Land Trust** has a mission "*to preserve and care for natural and agricultural lands in perpetuity, to enhance habitat for plants and wildlife, to advance the quality of life for all in our community, and to educate the public on the history and stewardship of protected lands."* They were founded in 1981 and have since conserved more than 2,700 acres in Falmouth.

The **Maine Coast Heritage Trust** has a mission "*to advance the conservation of lands and waters in Maine to ensure ecological wellbeing and foster thriving communities.*" Formed in 1970, they work statewide to conserve more than 180,000 acres, primarily along the coast. Their properties in the watershed include Clapboard Island East

Maine Audubon "*works to conserve Maine wildlife and wildlife habitat by engaging people in education, conservation, and action.*" Founded in 1843, it is Maine's oldest and largest conservation organization. They provide a variety of educational programs for all ages, monitor endangered species including the piping plover and least tern, and advocate for policies that protect wildlife and their critical habitats. Gilsland Farm Audubon Center in Falmouth is one of their eight centers throughout the state; its 65 acres provide trails and a setting for educational programming.

1.3 PURPOSE AND SCOPE

The purpose and overarching goal of the Casco Bay Watershed Management Plan (WMP) is to guide implementation efforts for the foreseeable future to maintain and improve the water quality of the Casco Bay Frontal Drainage such that each tributary meets Maine Water Quality Standards – Class B Freshwater criteria.

As part of the development of this plan, water quality monitoring was performed from May 2024 through September 2025 at five streams located in the Casco Bay Frontal Drainage's high growth coastal area: Chenery Brook, Mill Creek, Norton Brook, Webes Creek, and Skitterygusset Creek by FB Environmental Associates staff. Acorn Engineering performed a watershed best management practice (BMP) reconnaissance in the spring of 2025 and Field Geology Services completed a geomorphic assessment of Skitterygusset Creek in the spring of 2024. These field efforts were completed to assess each stream's current conditions. Results from these analyses were used to establish water quality goals and objectives, determine recommended management strategies, and implement BMPs to reach and maintain Maine Water Quality Standards Class B Freshwaters criteria. This plan meets the nine elements required by the United States Environmental Protection Agency (EPA) so that communities become eligible for federal watershed assistance grants.

1.4 COMMUNITY INVOLVEMENT AND PLANNING

This plan was developed over the course of 2024 and 2025 through active collaboration among FB Environmental Associates (FBE), Acorn Engineering Inc, Field Geology Services, the Town of Falmouth, Maine DEP, and Falmouth Land Trust.

1.4.1 Plan Development Meetings

Several meetings were held over the duration of the plan development by the project Steering Committee and Technical Advisory Committee.

February 8, 2024	Project kick-off meeting facilitated by FBE. Determined key project components including identifying Technical Advisory Committee and reviewing schedule.
April 30, 2024	First Technical Advisory Committee meeting to review water quality data gap analysis, monitoring plan details, and project timeline.
December 4, 2024	Second Technical Advisory Committee meeting to review results of the 2024 monitoring season and shoreline survey.
November 25, 2025	Third Technical Advisory Committee meeting to review results of the 2025 monitoring season, the Skitterygusset geomorphic assessment, and the Watershed Reconnaissance.
April XX, 2026	Presentation to the Falmouth Planning Board.

1.4.2 Draft WMP Public Presentation and Review Period

Description of Planning Board presentation here.

1.5 INCORPORATING EPA'S NINE ELEMENTS

EPA guidance lists nine components that are required within a WMP to restore waters impaired or likely to be impaired by **nonpoint source pollution**. These guidelines highlight important steps in restoring and protecting water quality for any waterbody affected by human activities.

The nine elements are as follows:

A. IDENTIFY CAUSES AND SOURCES OF POLLUTION

Sections 2 and 3 highlight pollution sources and stressors to Casco Bay Frontal Drainage and describe the results of assessments conducted in the watershed. These sources of pollutants must be addressed to continue achieving the water quality targets outlined in this plan.

B. ESTIMATE POLLUTANT LOADING INTO THE WATERSHED AND THE EXPECTED LOAD REDUCTIONS

Section 2 quantifies the magnitude of pollutant loading in the Casco Bay Frontal Drainages by using impervious cover as a proxy for the complex array of pollutants carried in stormwater. Section 5 outlines the pollutant load reductions that would be achieved through various management strategies.

C. DESCRIPTION OF MANAGEMENT MEASURES

Sections 4 and 5 identify ways to improve water quality conditions and in-stream habitat to achieve the appropriate water quality targets. The Action Plan focuses on several major topic areas that address nonpoint source pollution. Management options in the Action Plan focus on non-structural BMPs integral to the implementation of structural BMPs.

D. ESTIMATE OF TECHNICAL AND FINANCIAL ASSISTANCE AND RELEVANT AUTHORITIES

Sections 5 and 6 include descriptions of the associated costs, sources of funding, and primary authorities responsible for implementation. Sources of funding need to be diverse and should

include local, state, and federal granting agencies, local groups, private donations, and landowner contributions for implementation of the Action Plan.

E. EDUCATION & OUTREACH

Section 4 describes how the educational component of the plan is already being or will be implemented to enhance public understanding of the project.

F. DEVELOP A PROJECT SCHEDULE

Section 5 provides a list of action items and recommendations to improve water quality conditions and in-stream habitat within the Casco Bay Frontal Drainages. Each item has a set schedule that defines when the action should begin and/or end or run through (if an ongoing activity). The schedule should be adjusted by the Town of Falmouth on an annual basis (see Section 4 on Adaptive Management).

G. DESCRIPTION OF INTERIM MEASURABLE MILESTONES

Section 6 outlines indicators along with milestones of implementation success that should be tracked annually.

H. IDENTIFY INDICATORS TO MEASURE PROGRESS

Sections 2 and 6 can be used to determine whether water quality targets are being achieved over time and if substantial progress is being made towards achieving the water quality goal. If progress is not satisfactory, criteria outlined in these sections can guide the decision on whether revisions to the plan are necessary.

I. MONITORING COMPONENT

Section 6 describes the long-term water quality monitoring strategy for the Casco Bay Frontal Drainages, the results of which can be used to evaluate the effectiveness of implementation efforts over time as measured against the criteria in item (8) above. The success of this plan cannot be evaluated without ongoing monitoring and careful tracking of water quality improvements following successful BMP implementation projects.

2 ASSESSMENT OF WATER QUALITY

This section provides an overview of the past, current, and predicted future state of water quality in the Casco Bay Frontal Drainages based on available data and past assessments which identified pollutants of concern and informed the established water quality goal and objectives.

2.1 WATER QUALITY SUMMARY

Water quality standards and data can be complex. Here are the key points to know about the Casco Bay Frontal Drainages:

- **The Casco Bay Frontal Drainages are all Class B waterbodies.**

  Class B waters are considered lower class streams and are more susceptible to degradation due to their surrounding environment and potential stressors. These streams therefore have a lower expectation to achieve natural conditions. The most pertinent water quality criteria are those associated with the designated uses of aquatic life use support and recreation in and on the water

- **Norton Brook, Chenery Brook, Skitterygusset Creek, and Mill Creek are "threatened."**

  These streams are included in the 2022 Maine DEP Nonpoint Source Priority Watershed List as "Threatened." These streams are also identified as having "highway access-related development threats", indicating a high risk for future watershed development due to their proximity to highway exits along Interstate 295.

- **Webes Creek and Skitterygusset Creek had the greatest water quality exceedances in the 2024-2025 monitoring season.**

  Total phosphorus criterion exceeded in both streams. Total nitrogen criterion exceeded in all samples in Webes Creek, and 50% in Skitterygusset Creek. 25-50% of dissolved oxygen saturation, specific conductance, and *E.coli* measurements in both streams exceeded state criteria. The chronic chloride threshold was also exceeded in one sample on Webes Creek. *E.coli* in Webes Creek was especially high during wet weather sampling. Norton Brook, Chenery Brook, and Mill Creek had scattered but less consistent exceedances of all parameters, except in total nitrogen.

2.1.1 Water Quality Standards & Impairment Status

2.1.1.1 Designated Uses & Water Quality Criteria

Every other year, Maine DEP produces an Integrated Report that summarizes water quality data from surface waters across the state – this is required of the state under the Clean Water Act. This report lists impaired waterbodies that fail to attain one or more of their designated uses, and which impaired waters require a Total Maximum Daily Load (TMDL).

For surface waters in Maine, the five designated uses are as follows, and those applicable to the Casco Bay Frontal Drainages are **bolded**:

1. **Aquatic life use support** (i.e. support and maintenance of community of organisms having species composition, diversity, and functional organization)
2. **Recreation in and on the water:** primary recreation (swimming) and secondary contact recreation (boating, fishing)
3. Fish consumption
4. Navigation, hydropower, and agriculture / industrial supply
5. Drinking water supply after disinfection / treatment

> ***What is a TMDL?***
>
> A TMDL, or *Total Maximum Daily Load*, is a limit on how much pollution a water body (like a river, lake, or stream) can safely handle each day without becoming unhealthy. Think of it like a "pollution budget" that sets a maximum amount of pollutants – in this case bacteria – that can be released into the water while keeping it safe for uses like drinking, swimming, and supporting wildlife.

To determine if a waterbody is attaining these designated uses, Maine DEP reviews available water quality data and compares it to established water quality criteria to makes their assessment. For the Integrated Reports, these waterbody assessments are characterized into the five distinct categories, outlined below (Maine DEP, 2024):

Category 1 *Attaining all designated uses and water quality standards, and no use is threatened.*

Category 2 *Attains some of the designated uses; no use is threatened; and insufficient data or no data and information is available to determine if the remaining uses are attained or threatened (with presumption that all uses are attained).*

Category 3 *Insufficient data and information to determine if designated uses are attained (with presumption that one or more uses may be impaired).*

Category 4 *Impaired or threatened for one or more designated uses but does not require development of a TMDL.*

Category 5 *Waters impaired or threatened for one or more designated uses by a pollutant(s), and a TMDL report is required.*

Additionally, Maine DEP has four classes for freshwater rivers: AA, A, B, C. Each classification serves more as a scale of risk as opposed to quality, and there are only a few differences between each class in terms of their standards and uses. Higher class streams (AA and A) are more natural and have fewer human impacts, and as a result water quality degradation is unlikely and the expectation to achieve natural conditions is higher. Lower class streams (B and C) on the other hand are more susceptible to degradation due to their surrounding environment and potential stressors and therefore have a lower expectation to achieve natural conditions (Maine DEP, 2024). All five streams that make up the Casco Bay Frontal Drainages have been identified as Class B waterbodies by Maine DEP and as such are subject to the water quality criteria associated with that class. Due to the nature of the Casco Bay Frontal Drainages, the most pertinent water quality criteria are those associated with the designated uses of aquatic life use support and recreation in and on the water. A summary of the Class B criteria in Maine for these designated uses is provided in Table 1 below.

Table 1. Water quality criteria for Class B waterbodies in the State of Maine for designated uses relevant to the Casco Bay Frontal Drainages (Title 39, Chapter 3, Subchapter 1, Article 4-A, §465 of the Maine Legislature). MPN = most probable number. mg/L = milligrams per liter.

Designated Use	Parameter/Activity	Criteria
Aquatic life use support	Habitat suitability	Of sufficient quality to support all species of fish indigenous to those waters and to maintain the structure and function of the resident biological community [38 M.R.S. § 465(4)]
	Benthic macroinvertebrate bioassessments	Numeric biocriteria [Maine DEP Rule Chapter 579]
	Algae bioassessments	Narrative aquatic life use criteria and expert judgment evaluation of structure and function of the resident biological community [38 M.R.S. § 465]
	Dissolved oxygen	≥ 7.0 mg/L or ≥ 75% saturation (whichever is higher)
	Wetted habitat	Minimum flow necessary to maintain water quality standards. This flow will be based upon achieving the assigned classification, criteria and protection of the uses of the stream. [Maine DEP Rule Chapter 581]
Recreation in and on the water ***(i.e. primary and secondary contact recreation)***	*E. coli*	From 4/15 – 10/31, geometric mean ≤ 64 MPN/100mL over a 90-day interval and at least 90% of samples ≤ 236 MPN/100mL over a 90-day interval [38 M.R.S. § 465(4)]

ǂCriteria are pH, temperature, and salinity dependent; values shown reflect toxicity at pH = 7 and temperature = 25°C

Maine also has three marine classes – SA, SB, and SC. These classes follow similar patterns to freshwater classes in that lower classes (SB and SC) are more likely to be impacted by human degradation and have less stringent water quality standards. The majority of the Casco Bay frontal drainage is Class SB, except for the discharge from the Presumpscot River, which is Class SC.

Maine recently passed official nutrient criteria for Class AA, A, B, and C freshwater bodies that became effective on June 11, 2025 (Chapter 583). The EPA requires all states to report their progress toward establishing criteria for nitrogen and phosphorus in surface waters.

Maine DEP's rule evaluates nutrient conditions using two measures: **nutrient concentrations** and **environmental response indicators** (such as algae growth or water clarity). This combined approach reduces the risk of false results that can occur when relying only on concentration data. By incorporating environmental responses, the DEP aims to create a more complete picture of water quality and better protect aquatic ecosystems.

In the nutrient criteria, Class B waters are required to maintain the thresholds listed in Table 2. These criteria should guide future monitoring efforts in the Casco Bay Frontal Drainage watershed.

Table 2. Maine DEP nutrient criteria for Class B, Class SB, and Class SC waterbodies in the State of Maine. The Class B indicators presented here apply only to wadable stream and river segments with rocky substrate. Impoundments and other surface waters are subject to different secondary indicators.

Statutory Class	B	SB	SC
Total Phosphorus	From 6/1 – 9/30, geometric mean of total phosphorus in a season ≤30.0 micrograms per liter (or parts per billion)	N/A	N/A
Nuisance Algal Cover	≤ 24.0 %	N/A	N/A
Sewage Fungus	No visible patches of sewage fungus	N/A	N/A
Ecoregion XIV Total Nitrogen 304(a) Criteria	0.71 milligrams per liter (or parts per million)	N/A	N/A
DEP Proposed Total Nitrogen Criteria for Casco Bay	N/A	5/1-10/1 seasonal mean <0.45 milligrams per liter for estuarine waters and <0.32 milligrams per liter for open marine waters	5/1-10/1 seasonal mean <0.45 milligrams per liter for estuarine waters and <0.32 milligrams per liter for open marine waters

2.1.1.2 Waterbody Impairment Status

Norton Brook is currently listed by Maine DEP under Category 3: "Rivers and Streams with Insufficient Data or Information to Determine if Designated Uses are Attained (One or More Uses may be Impaired)." The creek was first listed as impaired for aquatic life use in 2004 because of a habitat assessment (Maine DEP, 2024). At that time, it was placed in Category 5-A, indicating an impairment caused by pollutants not covered under other subcategories (5-B through 5-D). In the 2006 Integrated Report, the listing was changed to Category 3 after conflicting data were discovered due to an administrative error. As of the 2024 Integrated Report, Norton Brook did not meet Class B macroinvertebrate standards based on 2017 sampling results, prompting the need for additional sampling to confirm whether the impairment

remains. None of the other tributaries within the Casco Bay Frontal Drainage watershed are listed as impaired in the 2024 Integrated Report.

Norton Brook, Chenery Brook, Skitterygusset Creek, and Mill Creek are all included in the 2022 Maine DEP Nonpoint Source Priority Watershed List as "Threatened." Webes Creek is not included on this list. Listing details are summarized in Table 3.

All listed Casco Bay Frontal Drainages were identified as having "highway access-related development threats", indicating a high risk for future watershed development due to their proximity to highway exits along Interstate 295. Additionally, Norton Brook is on the "watch list" because of its Category 3 listing in the Integrated Report. Mill Creek is also designated as a Municipal Separate Storm Sewer System (MS4) priority water, as identified in Falmouth's Stormwater Management Plan (2022) as one of the watersheds most at risk for water quality degradation, along with Casco Bay.

Table 3. Casco Bay Frontal Drainages Nonpoint Source Priority Watershed List listing reasons.

Stream	Listing Reason
Chenery Brook	Highway access-related development threat
Mill Creek	Highway access-related development threat, MS4 priority water
Norton Brook	Watch list, highway access-related development threat
Skitterygusset Creek	Highway access-related development threat

2.1.2 Water Quality Data Collection

Water quality monitoring in the Casco Bay Frontal Drainage watershed has been conducted by several organizations, including the Maine DEP, FBE, the University of Maine, and the Maine Department of Marine Resources (DMR).

- **Maine DEP** has conducted biological monitoring at Chenery Brook and Mill Creek, with some data also collected at Skitterygussett Creek. These datasets are publicly accessible through the Maine DEP Environmental and Geographic Analysis Database.
- **FBE** has completed additional monitoring and analyses, including stream geomorphic assessments, logger and grab sample data not available in the Environmental and Geographic Analysis Database, and chloride assessments conducted in 2023.
- **Maine DMR** has conducted monthly fecal coliform monitoring from March through November within coastal shellfish growing areas, which are classified as approved, conditionally approved, restricted, conditionally restricted, or prohibited. Maine DMR data also include salinity and temperature measurements.
- **University of Maine School of Marine Sciences – Orono Lab** has maintained long-term monitoring at Clapboard Island, providing continuous data on estuarine conditions.

Overall, 16 monitoring stations have been identified within the watershed, capturing a range of parameters, including algae, macroinvertebrates, stream flow, continuous logger data, and grab samples in both stream and estuarine environments (Figure 5).

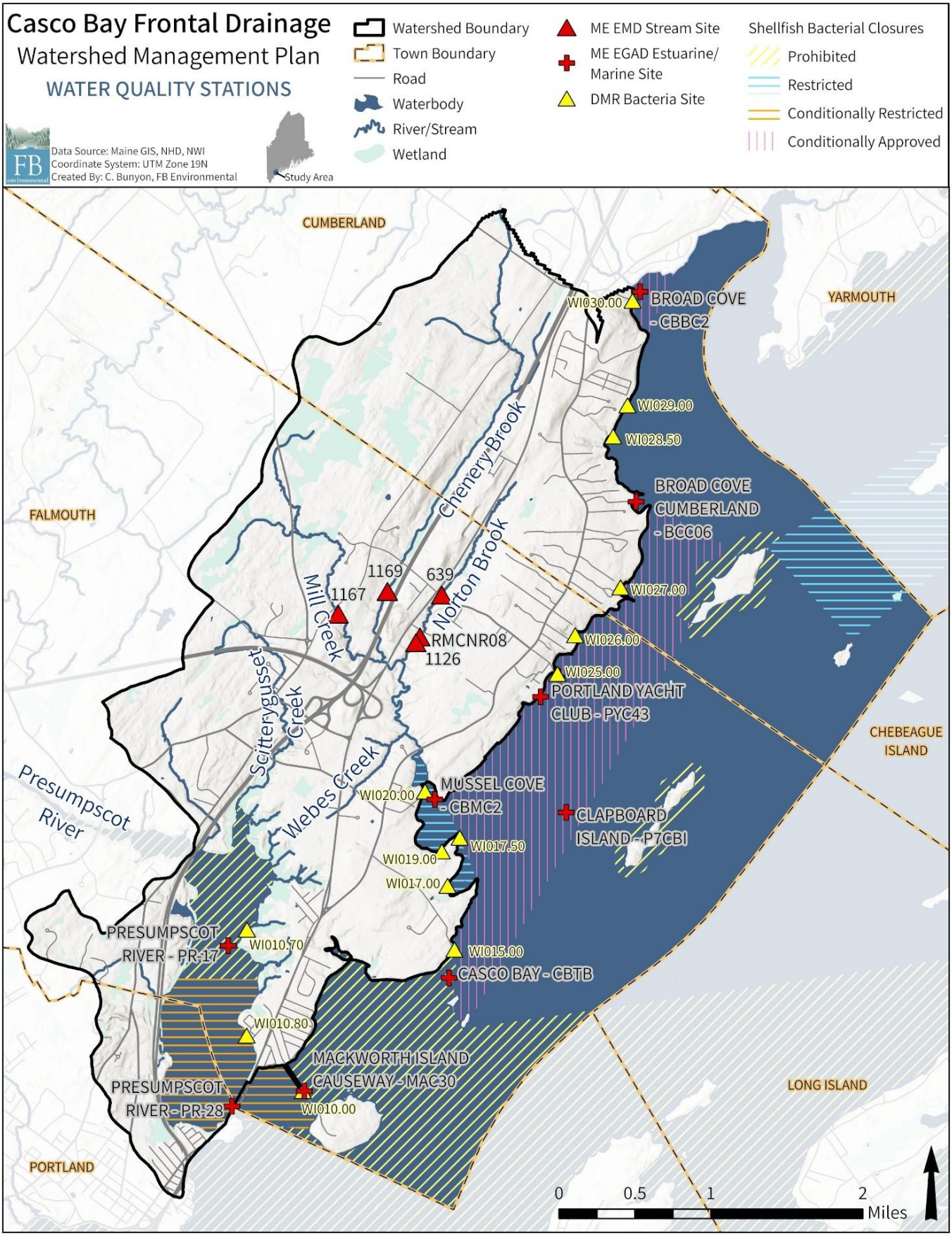


Figure 5. Water quality monitoring stations within the Casco Bay Frontal Drainage watershed.

2.1.3 Benthic Macroinvertebrates

The Maine DEP Biomonitoring Unit sampled for macroinvertebrates in Chenery Brook and Mill Creek in 2019 and in Norton Brook in 2017 and 2002. Sampling methodology consists of deploying an artificial substrate (rocks within baskets/bags or cones) submerged in the stream for 24-32 days between July and September. After the substrate is retrieved, all individuals are identified to genus or species, if possible (Davies, 2002). Compared to fish, macroinvertebrates are less mobile throughout their life stage in water, making it more difficult for them to avoid the impacts of pollutants. Each species has a varying ability to withstand pollutant levels, with some able to exist in the most severely polluted areas, and some only able to exist in near perfect conditions. These attributes make macroinvertebrates an easy target for sampling as they are exceptional indicators of the environment around them. Table 4 displays each macroinvertebrate sampling location in Casco Bay Frontal Drainage watershed and corresponding attainment for each year sampled as well as the most dominant taxa found that year.

Each of the four stations had different dominant taxa. At Norton Brook in 2017, the most dominant taxa was *Prodiamesa*, at Norton Brook in 2002 the most dominant was *Auldrilus*. During the 2019 sampling,the dominant taxa was *Microtendipes* at Mill Creek and at Chenery Brook it was *Dubiraphia*. There was no observed trend in dominant species between the sites and years. None of the four stations met Class B attainment during these sampling events, and only S-1167 on Mill Creek met a Class C determination.

Table 4. Maine DEP macroinvertebrate sampling sites and corresponding attainment for each year sampled.

Station	Year Sampled	Location	Final Determination	Most Dominant Taxa
S-1126	2017	Norton Brook	Non-Attainment	*Prodiamesa*
S-639	2002	Norton Brook	Non-Attainment	*Auldrilus*
S-1167	2019	Mill Creek	C	*Microtendipes*
S-1169	2019	Chenery Brook	Non-Attainment	*Dubiraphia*

2.1.4 Algae

Due to their short life cycle, algal communities react quickly to changes in their environment and thus serve as an indicator of environmental stressors and pollutants. In particular, nutrient pollution causes dramatic shifts in algal community composition and abundance. Data collected on algal types and densities are used to determine attainment of classifications for streams and rivers. As of 2025, Maine DEP does not have any algae sampling stations within the Casco Bay Frontal Drainage watershed.

2.1.5 Nutrients

Nutrient enrichment in waterbodies can cause a multitude of adverse effects that create an environment not conducive to aquatic life use support. These effects include nuisance algal blooms, low dissolved oxygen, and changes in food web dynamics. For freshwater streams, phosphorus is typically the limiting nutrient for algae growth and is therefore the one of primary interest. In Maine, the nutrient criterion for total phosphorus in Class B waters is ≤30 micrograms per liter. The nutrient criteria rule includes a decision framework that determines if a waterbody is attaining nutrient criteria based on seasonal

geometric means of total phosphorus and values for site-specific non-total phosphorus nutrients (Maine DEP, 2025). Site-specific nutrient criteria for total phosphorus or other nutrients must be developed with the Maine DEP and entered into Chapter 583 through Maine's formal rulemaking process.

Nitrogen is typically the limiting nutrient in marine waters and is therefore also a high priority input to be addressed for the Casco Bay Frontal Drainage watershed.

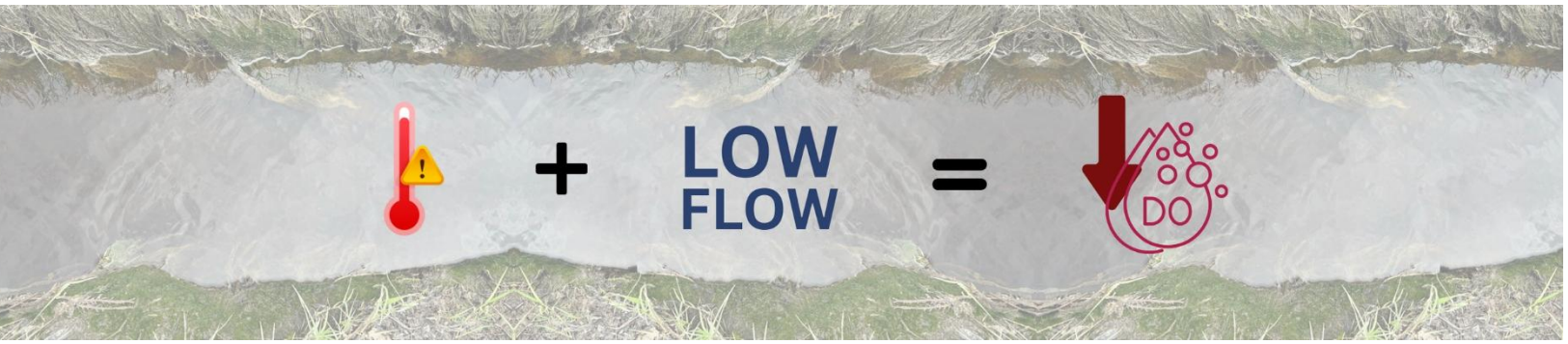
Nutrient data are very limited in the Casco Bay Frontal Drainage watershed. In 2024 and 2025, a total of four dry weather sampling events were conducted at five sites within the watershed (one on each main tributary). Ammonia, total nitrogen, nitrate-nitrite, and total phosphorus were collected during each sampling event. An additional wet weather sampling event was also conducted at Webes Creek in 2025, where four samples were collected over the rise and peak of the storm.

Across all four dry weather events and all sites, neither the acute nor chronic ammonia thresholds were exceeded. Total nitrogen was exceeded for all four samples at sites on Webes Creek and Mill Creek (WC-1 and Station 1167), three out of four samples at Chenery Brook (Station 1169), and two out of four samples at Skitterygusset Creek and Norton Brook (SC-1 and Station 1126). Wet weather sampling at Webes Creek resulted in all total nitrogen values exceeding the threshold. The total phosphorus geomean (essentially an average) also exceeded the threshold. Note that geomeans are intended to be calculated across a sampling season, but it is calculated for the singular wet weather event for comparison. Using the geomean total phosphorus criteria of 30 micrograms per liter to evaluate single grab sample events, Webes Creek exceeded the value for 7/8 samples, Skitterygusset Creek, Norton Brook, and Chenery Brook exceeded for 2/4 samples, and Mill Creek exceeded for 1/4 samples. Taking the geomean across the sampling season results in only Webes Creek, Skitterygusset Creek, and Norton Brook exceeding the total phosphorus criterion.

Though more sampling is needed to determine nutrient trends and sources, this preliminary sampling study suggests that both nitrogen and phosphorus levels may be high in the watershed. Potential sources or causes of high nitrogen levels include high impervious cover, fertilizer, pet waste, sewer system leaks, failing septic systems, or nearby remediation sites. Potential sources of causes of high phosphorus levels include the conditions noted above as well as suspended clay-sized apatite crystals which are a natural source of phosphorus.

2.1.6 Dissolved Oxygen

Dissolved oxygen has been measured sporadically at various sites in the Casco Bay Frontal Drainages since 2002, typically in bursts as part of seasonal studies as compared to annual monitoring programs. Many streams and rivers suffer from depleted dissolved oxygen throughout the summer months due to higher temperatures (warmer waters can hold less oxygen) and lower flows, creating an oxygen depleted environment. Human disturbances in the watershed (especially nutrient pollution causing eutrophication) are the primary cause of low oxygen. Dissolved oxygen concentration levels below 5 milligrams per liter (60%) in both freshwater and estuarine waters can stress and reduce habitat for sensitive aquatic organisms, including fish. It is important to keep tracking the extent and duration of low dissolved oxygen to watch for worsening trends due to additional human disturbance in the watershed. To meet Class B criteria, the Casco Bay Frontal Drainages must meet an instantaneous dissolved oxygen concentration of at least 7 milligrams per liter, or 75%.



The Casco Bay Frontal Drainages frequently suffer from low levels of dissolved oxygen, with about 33% of measurements showing a failure to meet Maine water quality criteria.

Table 5 shows dissolved oxygen data in the Casco Bay Frontal Drainage watershed. Excluding the sites from Norton Brook and Chenery Brook, which have met state criteria from all grab samples, the average rises to 45% of samples failing to meet dissolved oxygen standards. The most failures were observed within the Webes Creek subwatershed, which did not meet standards for 5 out of 8 samples across both wet and dry weather sampling events. However, it is important to note that grab samples are limited for all sites across all five streams.

33% of samples fail to meet dissolved oxygen standards, on average.

Table 5. Dissolved oxygen values compared to state criteria for all Casco Bay Frontal Drainage freshwater sites. The state criterion for Class B free-flowing rivers is >7 milligrams per liter or 75% saturation. Data reflect either concentration (milligrams per liter) or saturation (%), whichever is lower.

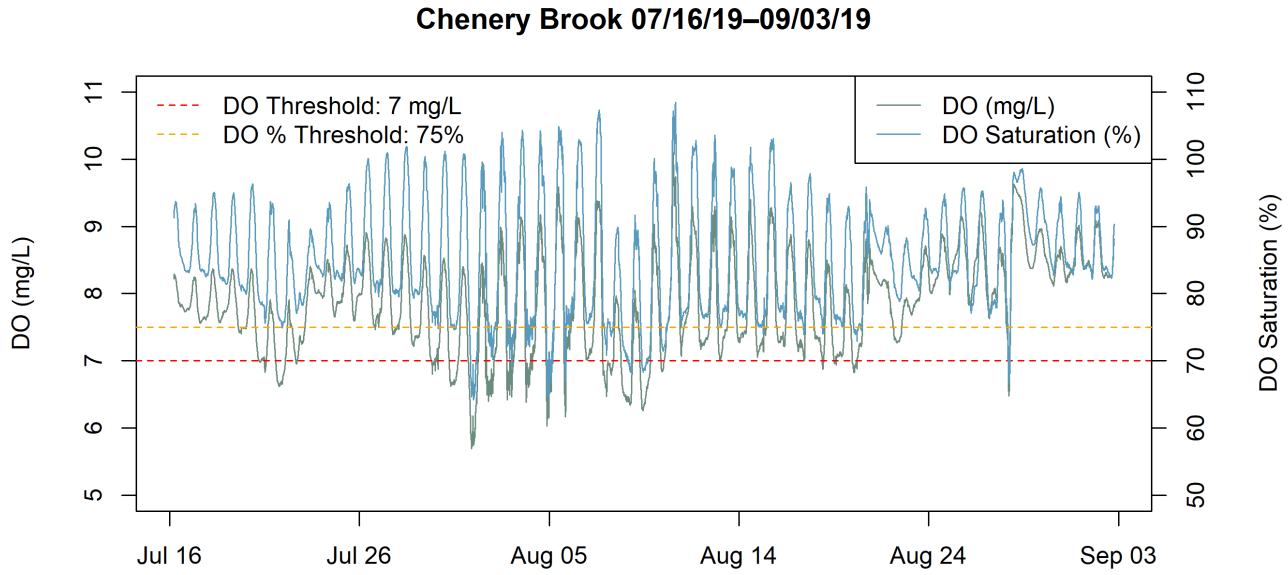
Site Name	Years Sampled	No. Data Points	No. Data Points Meeting State Criteria	% Data Points Meeting Standard	FAILURE RATE
WC-1	2024-2025	8	3	38%	**62%**
SC-1	2024-2025	4	3	75%	**25%**
Station 1167	2019, 2024-2025	6	4	67%	**33%**
Station 1169	2019, 2024-2025	5	5	100%	**0%**
Station 1126	2017, 2024-2025	6	6	100%	**0%**
Station 639	2002	1	1	100%	**0%**
RMCNR08	2006	5	5	100%	**0%**

Continuous data loggers for dissolved oxygen have been deployed for varying timeframes within all Casco Bay Frontal Drainage streams except Norton Brook (Figure 6). The results from the loggers indicate:

- Skitterygusset Creek had continuous data loggers deployed from June 10 through December 3, 2024, and again from April 9 through October 7, 2025. The site did not meet the dissolved oxygen criteria for 15% of both saturation and concentration measurements across the 2024 and 2025 sampling seasons. Average dissolved oxygen concentrations were 8.6 mg/L in 2024 and 9.0 milligrams per liter in 2025. Around September 2024 there was a large dip in dissolved oxygen

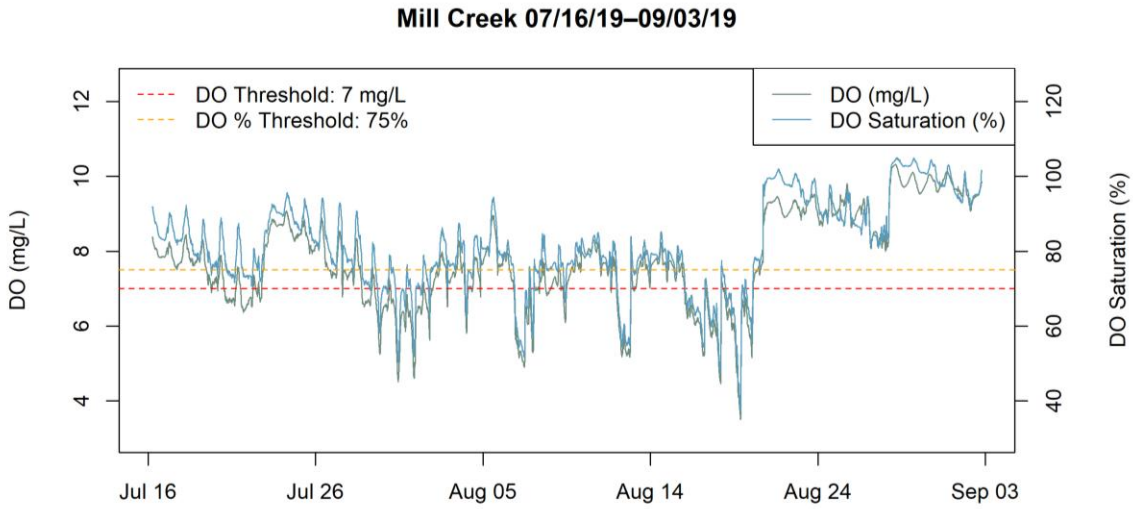
which may be associated with the extremely low precipitation experienced during that time. The recurring periods of low dissolved oxygen at SC-1 may also reflect elevated nutrient or organic matter inputs to Skitterygusset Creek. Excess nutrients can stimulate rapid algal and aquatic plant growth, followed by decomposition as biomass breaks down. These processes reduce dissolved oxygen levels and can create stressful conditions for aquatic life.

- Mill Creek had continuous data loggers deployed from July 16 through September 3 of 2019. Dissolved oxygen concentrations fell below the Class B threshold of 7 parts per million approximately 26% of the time, with the lowest concentrations occurring after extended dry periods in the early mornings (lowest flows and longest period since daytime photosynthesis).
- Chenery Brook had continuous data loggers deployed from July 16 through September 3 of 2019. Nighttime dissolved oxygen often dropped below the 7 parts per million Class B threshold and rose again during the day – likely a result of algal respiration. Dissolved oxygen concentrations did not meet the Class B threshold approximately 12% of the time.
- Webes Creek had continuous data loggers deployed from July 16 through September 3 of 2019. Dissolved oxygen levels remained above the Class B threshold the majority of the deployment period, failing to meet the standard approximately 2% of the time.

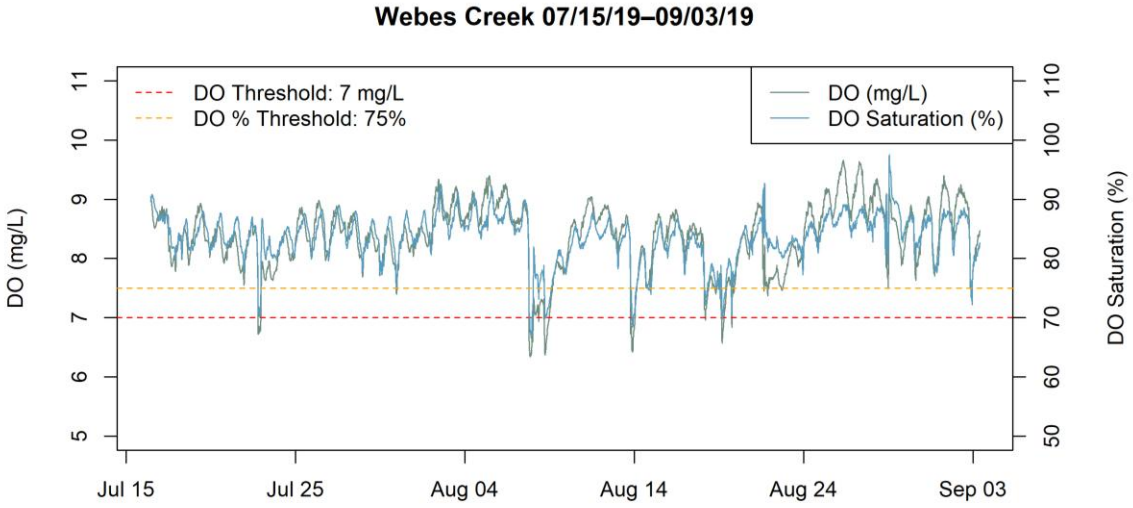


a.

b.



c.



d.

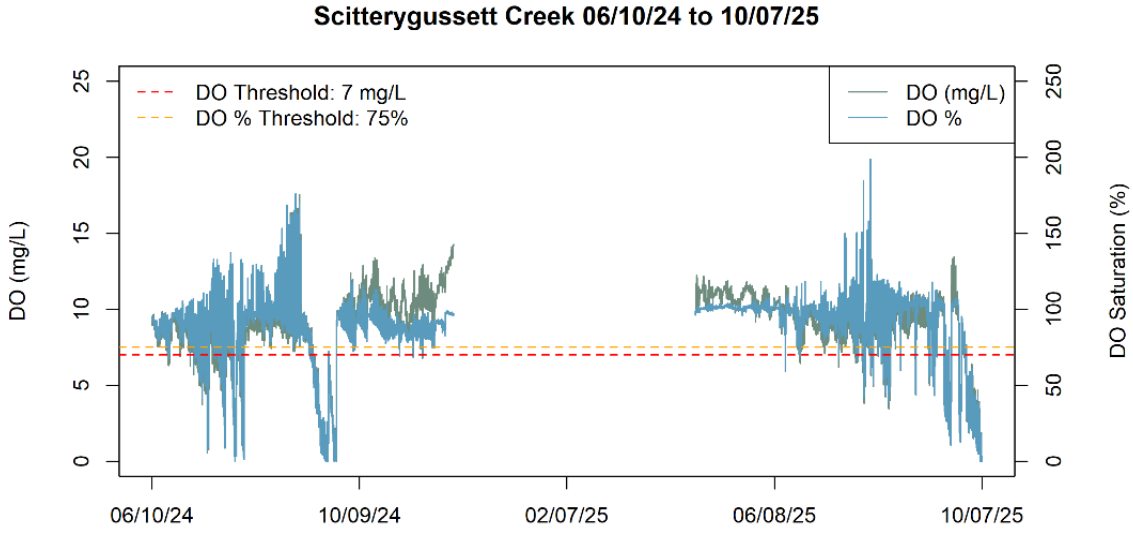
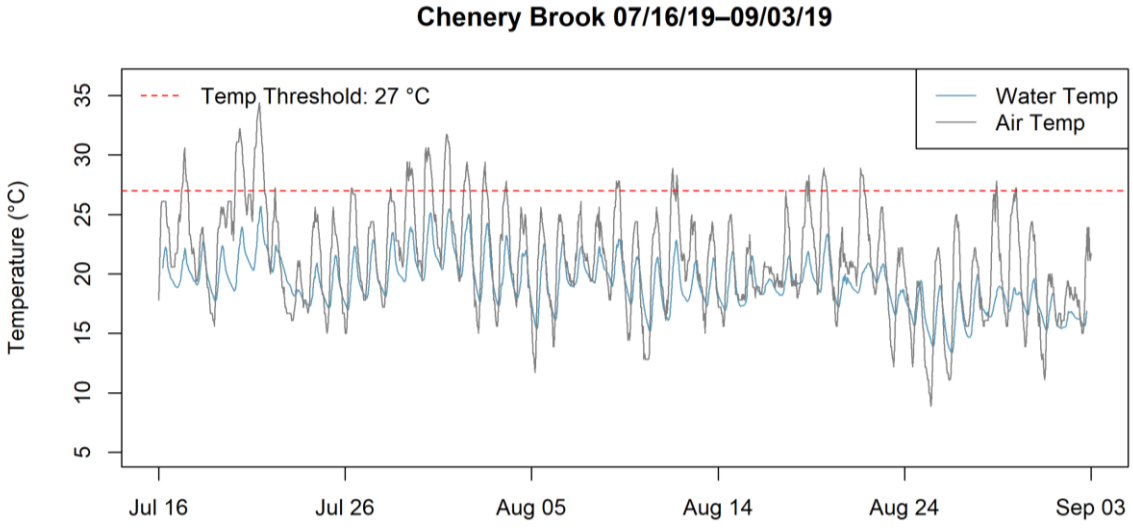


Figure 6. Continuous logger data for dissolved oxygen collected in Chenery Brook (2019, a), Mill Creek (2019, b), Webes Creek (2019, c), and Skitterygusset Creek (2024-2025, d). mg/L = milligrams per liter.

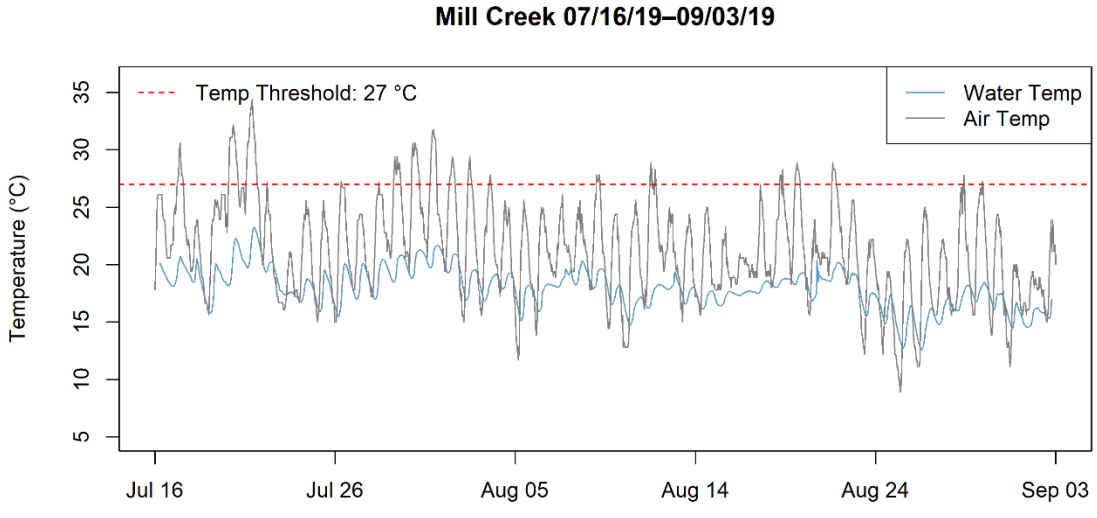
2.1.7 Water Temperature

As stated above, high water temperatures can cause environmental degradation as these waters hold lower levels of dissolved oxygen. Higher water temperatures can also facilitate the proliferation of aquatic plant or algae growth, potentially leading to harmful cyanobacteria blooms. Additionally, many of Maine's aquatic species are adapted to cold water temperatures.

Continuous data loggers for temperature have been deployed for varying timeframes within all Casco Bay Frontal Drainage streams (Figure 7). Water temperatures have never exceeded the Class B maximum temperature criteria of 28°C during logger deployments except for briefly on August 12 and 13, 2025 on Skitterygusset Creek. These exceedances may have been caused by extremely low water levels due to the drought experienced in the summer of 2025. Chenery Brook was also observed to have frequently elevated daytime water temperatures above 20°C during logger deployment in 2019, suggesting that high temperatures may be a stressor.



a.



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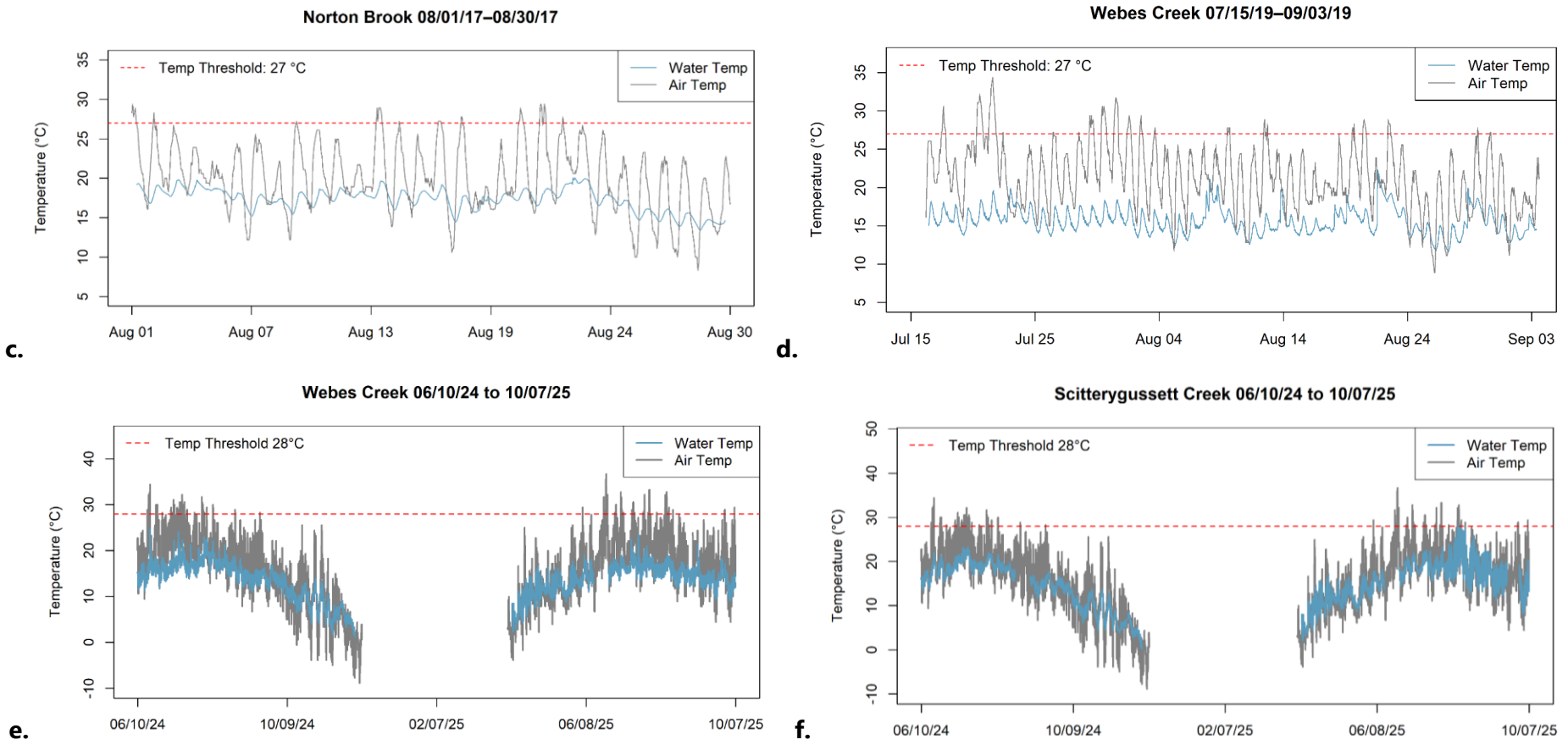


Figure 7. Continuous logger data for temperature collected in Chenery Brook (2019, a), Mill Creek (2019, b), Norton Brook (2017, c), Webes Creek (2019, d; 2024-2025, e), and Skitterygusset Creek (2024-2025, f).

2.1.8 Bacteria

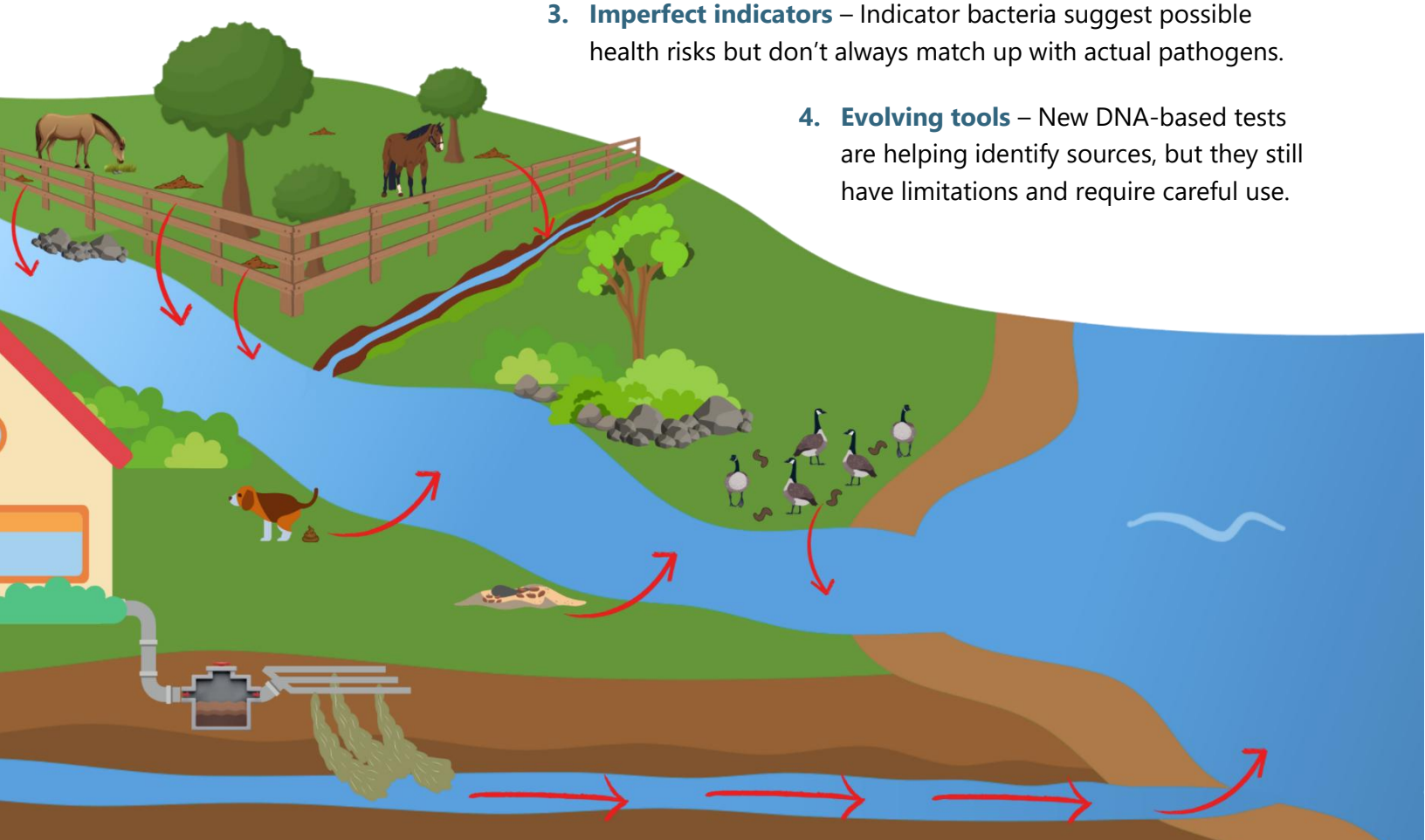
Certain types of bacteria, such as *E. coli*, Enterococci, and fecal coliform, are commonly used as indicators of fecal contamination in water. These bacteria don't usually cause disease themselves, but their presence suggests that other harmful germs (like viruses or disease-causing bacteria) from human or animal waste might be in the water. Testing directly for every possible pathogen would be too expensive and time-consuming, so these indicator organisms are used as a practical alternative.

High levels of these bacteria in rivers and coastal waters usually point to fecal pollution and an increased risk of illness for people who swim, fish, or come into contact with the water. These indicators are widely used to assess water quality for many purposes, including shellfish harvesting, drinking water safety, wastewater discharge, and recreational activities.

However, while indicator bacteria have been used for decades, they aren't perfect. They don't tell us where the contamination is coming from, only that it's likely present. And because fecal pollution can come from many places (e.g., leaky septic systems, pet waste, livestock, or wildlife) it's often hard to pinpoint and fix the source. This makes managing and cleaning up pathogen-impaired waters particularly challenging.

Here are four key reasons why fecal contamination is so difficult to address:

1. **Many sources** – Fecal bacteria can come from people, pets, livestock, or wildlife, making it hard to find the exact source.
2. **Fluctuating levels** – Bacteria levels change quickly, so a single test doesn't always reflect overall water quality.
3. **Imperfect indicators** – Indicator bacteria suggest possible health risks but don't always match up with actual pathogens.
4. **Evolving tools** – New DNA-based tests are helping identify sources, but they still have limitations and require careful use.



No historic bacteria sampling has occurred in the Casco Bay Frontal Drainage watershed. In 2024 and 2025, FBE sampled one site per each of the five Casco Bay tributaries; four times in dry weather as well as one wet weather sampling event on Webes Creek in 2025. Across the four dry weather events, the Maine DEP threshold of ≤ 236 most probable number per 100 milliliters (MPN/100mL) for *E. coli* was exceeded for 50% of samples at WC-1, 25% of samples at each SC-1, Station 1167, and Station 1169, and 0% of samples at Station 1126. The *E. coli* geometric mean criteria of ≤ 64 MPN/100mL was exceeded for WC-1, Station 1169, and Station 1126. These data are a loose comparison to the criteria since they were taken over the span of two years instead of 90 days, as the criteria sets.

Though these limited data are not sufficient to draw definitive conclusions, they suggest that elevated bacteria levels are likely within the Webes Creek watershed. Given the elevated results from the wet weather sampling, and the high impervious cover of approximately 50%, it is likely that stormwater runoff plays a large role in transporting excess bacteria to Webes Creek. Sources may include fertilizers, pet waste, and wildlife. Old sewer infrastructure may also contribute to elevated bacteria levels.

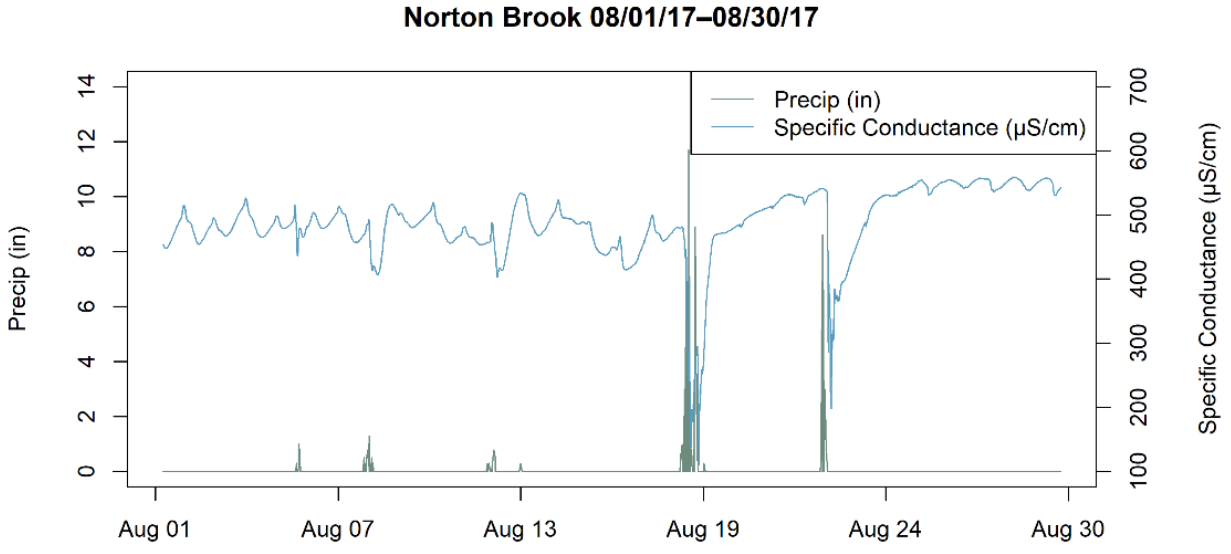
Additional monitoring is recommended to determine the extent and potential sources of bacteria throughout the Casco Bay Frontal Drainage watershed.

2.1.9 Chloride and Specific Conductivity

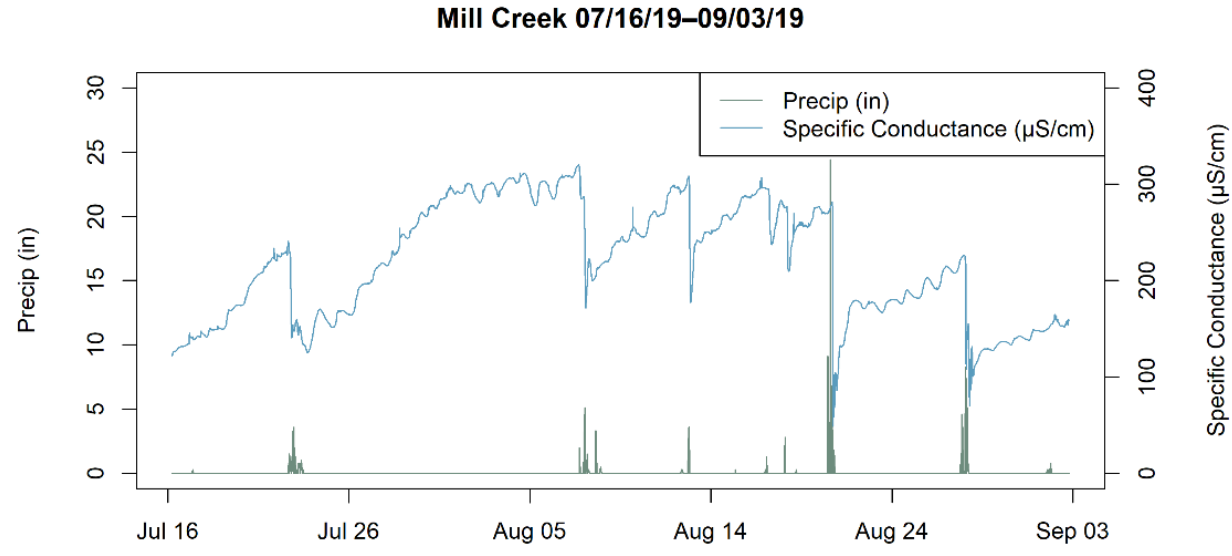
Continuous logger monitoring on all five streams included specific conductance across various timeframes as follows:

- Norton Brook had continuous data loggers deployed in August of 2017. Data logger specific conductance values ranged from 110 to 558 microsiemens per centimeter (µs/cm). The monitoring period consisted of low baseflows and low precipitation. The lowest specific conductance readings occurred following the little precipitation that occurred (Figure 8a).
- Mill Creek had continuous data loggers deployed from July 16 through September 3 of 2019. Specific conductance in Mill Creek decreased following precipitation events. The highest specific conductance concentration was 320 µs/cm during a dry period (Figure 8b).
- Chenery Brook had continuous data loggers deployed from July 16 through September 3 of 2019. Specific conductance ranged from 400 to 500 µs/cm. Specific conductance decreased following large rain events, indicating chloride contribution from groundwater sources more than stormwater runoff (Figure 8c).
- Webes Creek had continuous data loggers deployed from July 16 through September 3 of 2019. Specific conductivity values were above the Class B threshold of 899 µs/cm approximately 30% of the time. Loggers were also deployed June 10 - December 3, 2024, and again from April 9 - October 7, 2025. 25% of specific conductance measurements during this period were above established thresholds, suggesting occasional salt loading, potentially from road and parking lot de-icing activities (Figure 8d-e).
- Skitterygusset Creek had continuous data loggers deployed from June 10 through December 3, 2024, and again from April 9 through October 7, 2025. Logger data indicated that 20% of specific conductance measurements surpassed the threshold, suggesting some influence from road salts or other anthropogenic inputs. The Skitterygusset Creek subwatershed has approximately 24%

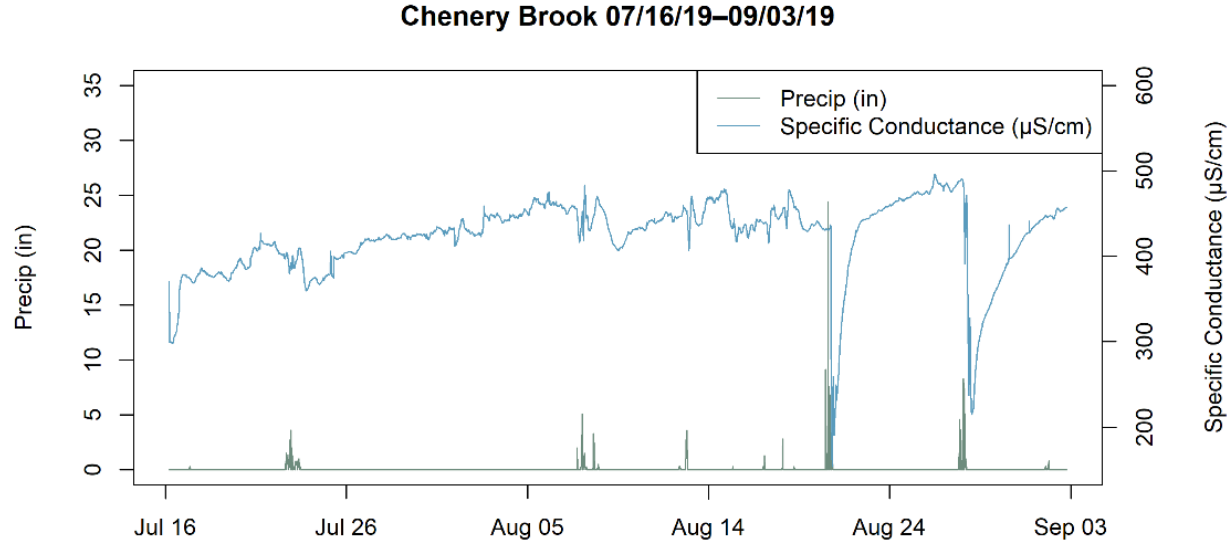
impervious cover, which is the second highest of all subwatersheds, following Webes Creek (Figure 8f).



a.

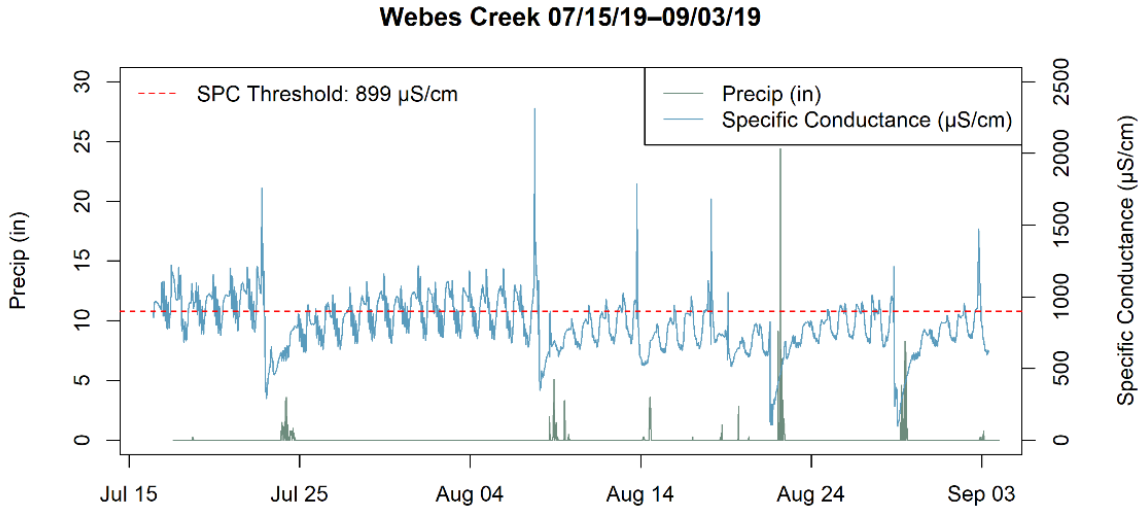


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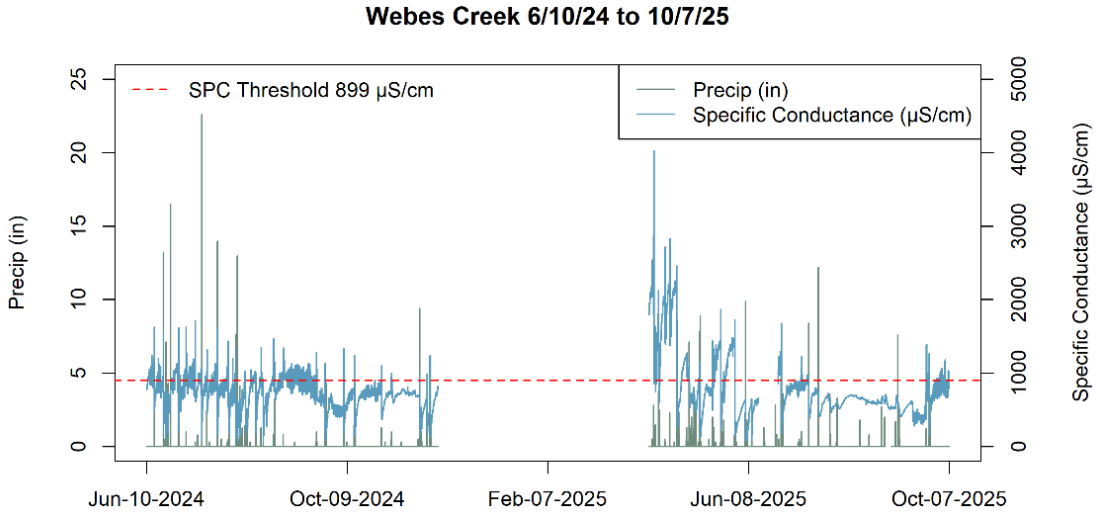


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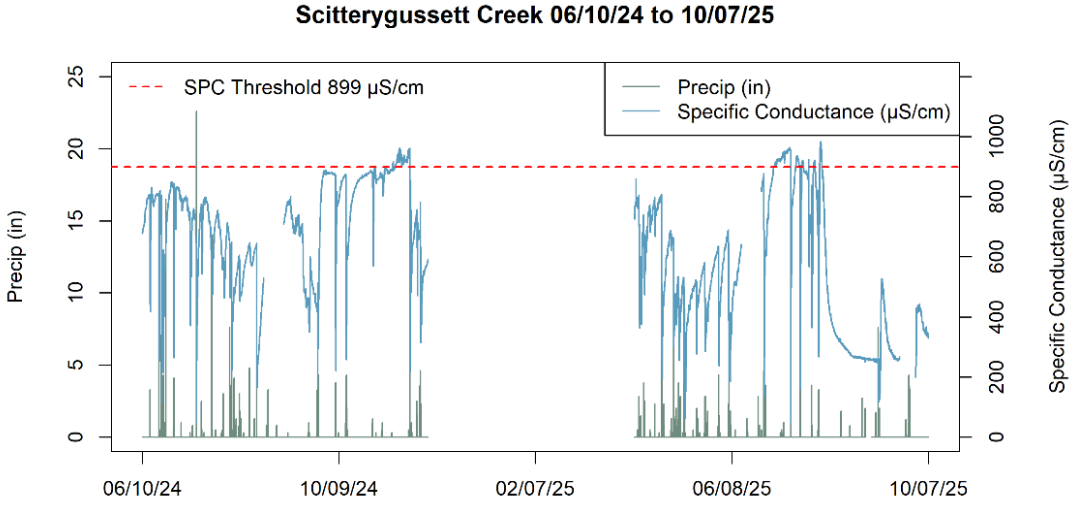


Figure 8. Continuous logger data for specific conductance at Norton Brook (2017, a), Mill Creek (2019, b), Chenery Brook (2019, c), Webes Creek (2019, d; 2024-2025, e), and Skitterygusset Creek (2024-2025, f). Precipitation data, shown in gray, are from the NOAA weather station located at the Portland International Jetport (PORTLAND JETPORT, ME US). in = inches. µs/cm = microsiemens per centimeter.

Specific conductance has also been measured via in-situ measurements, though data are limited. Grab samples have never exceeded Class B standards for sites on Mill Creek, Chenery Brook, and Norton Brook. From sampling during the 2024 and 2025 season, Skitterygusset failed to meet state criteria 25% of the time (1/4 samples) and Webes Creek failed 50% of the time (4/8 samples). Webes Creek failures were primarily during the wet weather sampling event.

Chloride samples were also taken during the 2024-2025 monitoring season. The chronic chloride threshold (230 milligrams per liter) was not exceeded by any streams except Webes Creek, which exceeded the standard in one of four dry weather samples, and two of four wet weather samples. No sites exceeded Maine's acute chloride criterion of 860 milligrams per liter.

Together these data suggest significant chloride inputs to the Webes Creek and Skitterygusset Creek subwatersheds. Increasing specific conductance values in Webes Creek with the first flush of a wet weather event suggests that stormwater runoff likely carries chloride from nearby development to the stream. Other subwatersheds have shown decreasing specific conductivity values during precipitation events, suggesting there could be groundwater chloride inputs.

3 POLLUTANT SOURCE IDENTIFICATION

In urban watersheds, the main stressor is often stormwater runoff from impervious cover. Runoff from roads, rooftops, parking lots, and other hard surfaces carries a wide variety of pollutants into streams, including road sand, salt, heavy metals, nutrients, bacteria, trash, oils, and grease.

Impervious surfaces not only transport pollutants but also alter stream hydrology. High impervious cover can create a "flashy" hydrologic response during storm events, producing rapid surges of water that increase erosion and sedimentation. The sediment and pollutants associated with these surges can smother aquatic organisms, destroy habitat features, and mobilize additional pollutants to the stream. Other contributors to urban stream pollution include illicit sewer discharge, residential yard runoff, pet waste, wildlife waste, and various commercial/industrial point sources (e.g., storage tanks, automobile salvage yards, hazardous waste sites, remediation sites, etc.)

Together, these stressors can degrade water quality, disrupt stream ecology, and threaten both aquatic life and downstream estuarine systems.

3.1 FLUVIAL GEOMORPHIC ASSESSMENT

Field Geology Services conducted a rapid geomorphic assessment of five streams in the Casco Bay Frontal Drainage watershed to evaluate their geomorphic condition and identify potential restoration options to support aquatic life use. The assessment included Skitterygusset Creek and five additional streams (Chenery Brook, Hobbs Brook, Norton Brook, Mill Creek, and Webes Creek) which were divided into 40 geomorphic reaches. Each reach represents a relatively homogeneous section of stream channel, often defined by abrupt changes in valley or channel characteristics, such as undersized stream crossings that disrupt natural processes. See Appendix B and Appendix C for maps of all stream segment locations.

The assessment evaluated the impacts of human activities, including historic land clearance, channel straightening, floodplain fill, old dams, and increased runoff from developed areas. These activities have degraded stream habitats, leading to inadequate amounts of woody debris in the streams, eroding banks, excess fine sediment deposition, and impounded flow areas. While many riparian zones remain well forested, nearly 60% of the Skitterygusset Creek watershed and long stretches of the other watersheds lack mature in-stream wood, which may take decades to recover naturally.

Restoration recommendations focused on:

- Removing constraints to natural channel adjustment, such as undersized culverts, floodplain fill, and old dams;

- Increasing in-stream wood through techniques such as "chop and drop" or anchored wood additions to enhance habitat complexity and connectivity.

Additionally, "like reaches" were identified so that findings and restoration techniques from one reach could be applied to similar reaches elsewhere in the watershed. The assessment concluded that strategically implemented restoration actions can accelerate natural recovery and help prevent these streams from being listed as urban-impaired by Maine DEP.

3.1.1 Positive Geomorphic Conditions

Of the 37 assessed reaches, 26 are considered "in regime", indicating that they are considered geomorphically stable and thought to represent the natural state of the channel in absence of human impacts (Field, 2023). At the subwatershed level this equates to:

- 8/10 reaches on Skitterygusset Creek
- 4/7 reaches on Chenery Brook
- 9/11 reaches on Mill Creek
- 1/4 reaches on Norton Brook
- 4/5 reaches on Webes Creek

Floodplain Access

Floodplains are a critical component of stream ecosystems. They provide habitat for riparian species, act as natural buffers against watershed runoff, and absorb excess water during storm events, helping reduce downstream flooding risk. Floodplains also support groundwater recharge, biodiversity, and the input of allochthonous material (such as leaves and woody debris) into streams. A stream's access to its floodplain provides critical flood storage. The condition of floodplains in each reach was evaluated as part of the geomorphic assessment.

Across the Casco Bay Frontal Drainage watershed, floodplain size and condition vary widely. Many reaches have little to no functional floodplain, or floodplains that are heavily altered due to artificial fill, channel constraints, and lawn clearing up to the stream edge (see Section 3.1.3 for details).

A few reaches, including C1, C3, C6, C7, W1, and S1 were noted to have good access to floodplains that provide important habitat and ecological services. These areas generally have lower levels of development, allowing space for continued natural floodplain processes. Restoration efforts to improve floodplain function should focus on:

- Removing artificial fill to reconnect the floodplain with the stream
- Adding in-stream wood to enhance habitat complexity
- Resizing culverts to restore natural floodplain dynamics, reduce flow velocities, and improve habitat quality

These actions can help restore natural hydrology, enhance ecological function, and support resilient stream ecosystems.

Woody Debris

Woody debris plays a vital role in stream ecosystems by providing habitat for fish, insects, and amphibians, creating diverse flow patterns that improve water quality, and helping to prevent erosion. It also traps sediment, facilitates nutrient cycling, and stabilizes stream channels, supporting overall riparian ecosystem health and resilience.

Across Chenery Brook, Norton Brook, Mill Creek, Webes Creek, and Skitterygusset Creek, there is generally a lack of woody debris, even in the most forested areas. This deficit is largely due to historic land clearing and ongoing constraints such as undersized culverts, channel straightening, and floodplain fill. Although many watersheds remain well forested, natural wood recruitment takes decades, so current woody debris levels remain well below those found in pristine streams.

Streams with long-forested watersheds, such as Chenery Brook, Mill Creek, and Norton Brook, generally have more woody debris than streams that were heavily cleared or only recently reforested, such as Webes Creek. In Skitterygusset Creek, even forested reaches often lack woody debris, contributing to eroding banks and sediment-starved channels. Segments with noted positive attributes of woody debris include C1, C3, C4, C7, M1, M6, M7, M10, N1, N4, W3, S3, S6, and S9.

Restoration strategies should focus on:

- Adding in-stream wood through “chop and drop” techniques or anchored structures such as log sills and jams
- Removing constraints such as undersized culverts, old dams, and floodplain fill to restore natural wood recruitment

These efforts will increase habitat complexity, trap sediment, and improve overall stream health and resilience.

Forested Buffers and Canopies

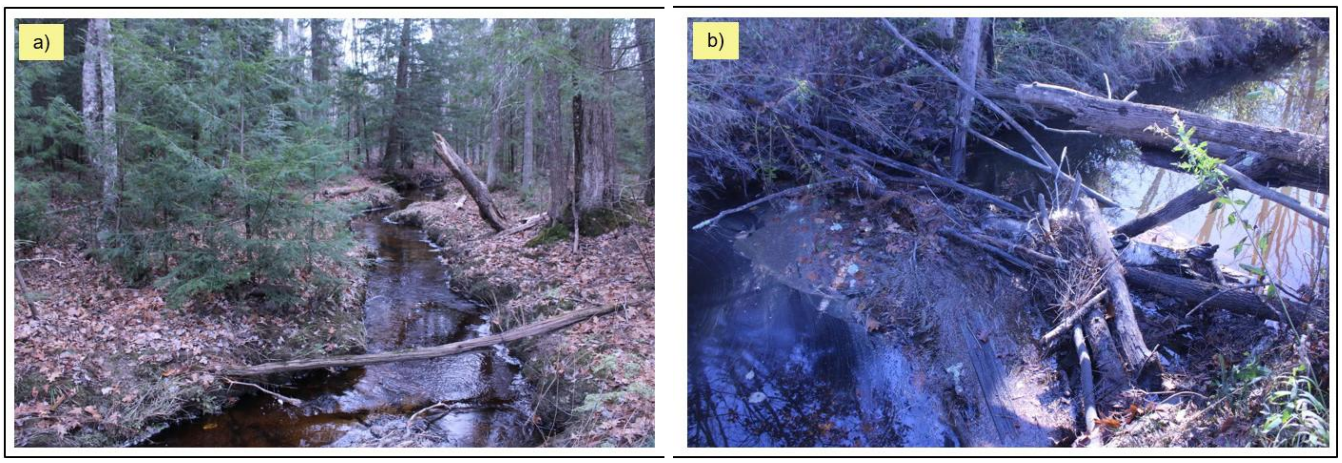
Well-vegetated riparian buffers provide critical habitat, filter excess nutrients and pollutants, stabilize streambanks, and provide flood buffering. In addition, forested canopies provide critical stream shading, keeping water temperatures cool in the summer. Cooler water temperatures support a broader range of aquatic organisms and allow the water to retain higher levels of dissolved oxygen.

In the Casco Bay Frontal Drainage watershed, human development has led to clearing of riparian buffers in more developed areas, though the majority of most subwatersheds remain forested. Reaches that were documented to have good riparian buffers or canopy include C1, C5, C7, M1, M3, M4, M5, M6, M7, M8, N1, N4, W3, and S1.

Restoration recommendations include:

- Adding or enhancing riparian buffers with native vegetation
- Reducing lawn coverage and replacing with shrubs or trees in the riparian zone

These actions will improve habitat and water quality and enhance overall watershed resilience.



Reach M4 has a well-forested buffer (left). Woody debris forming log jams and good flow complexity at reach C-3 (right). Photos by Field Geology Services.

3.1.2 Stream Stressors

Fill Encroachment

Fill encroachment is a significant stressor to streams because it alters natural channel morphology and hydrology. Encroachment restricts channel movement, disrupts sediment transport, and reduces floodplain connectivity, leading to decreased habitat diversity and stream stability. It can also exacerbate erosion and sedimentation, degrade water quality, and impair ecological functions essential for stream health and biodiversity.

Fill encroachment is a common issue in Skitterygusset Creek, Norton Brook, and Mill Creek, contributing to habitat degradation and channel instability. Specific reaches with observable fill include M3, N1, N2, N4, W1, S3, S4, and S8 where the channel is constrained by adjacent buildings, berms, or other fill types. Fill can block entire floodplains or drainages, preventing the development of a natural, well-defined channel.

While addressing fill encroachment can be challenging, removal or modification of artificial fill is critical for restoring stream habitat, channel function, and overall ecological integrity in these affected reaches.

Artificial Straightening

Artificial straightening of streams disrupts natural flow patterns and aquatic habitats, creating multiple ecological stressors. Straightened channels often have increased water velocity, which accelerates bank erosion and reduces habitat diversity. They also lack natural meanders and pools, leading to decreased biodiversity and disruption of the balance in aquatic ecosystems.

Evidence of artificial straightening is observed in several reaches throughout the Casco Bay Frontal Drainage watershed, including C2, C4, C6, C7, M2, M3, M11, N1, N2, W2, W3, W4, W5, and S5. These sections are characterized by deep, narrow, straightened channels, abrupt directional changes, single-thread channels through marshes, or sections that become sinuous downstream.

Potential restoration actions include:

- Removing landscape clippings and other debris from areas near surface waters, including flood plains.

- Adding in-stream woody debris to improve habitat complexity and flow dynamics

These observations highlight the importance of considering historical stream alterations when planning restoration efforts to improve habitat conditions and restore natural stream functions.

Obstructions (Dams and Culverts)

Obstructions such as dams and poorly designed culverts disrupt the natural flow of streams, creating a cascade of ecological impacts. Dams fragment habitats, block fish migration, and alter sediment transport, affecting both aquatic and riparian ecosystems. Similarly, undersized or poorly placed culverts can increase erosion, cause streambed scouring, and fragment habitats, compromising overall stream health and resilience.

Many culverts in the watershed are undersized or misaligned, contributing to unnaturally high downstream velocities, channel incision, upstream deposition, flow impoundment, and severe scouring downstream. Culverts in need of repair or replacement were observed at reaches C1, M1, M2, M3, M4, M8, N3, N4, W1, W3, and in all reaches except 6 and 7 on Skitterygusset Creek. These obstructions alter sediment transport and flow dynamics, further degrading stream habitat.

Potential restoration measures include:

- Resizing culverts to match or exceed bank-full channel width and/or realigning culverts to better match the stream channel and eliminating perched culverts
- Adding relief culverts to prevent impoundments from forming behind existing undersized culverts
- Implementing erosion control measures to restore natural flow patterns and stabilize channels

Addressing these obstructions is critical for restoring connectivity, habitat quality, and stream resilience across the watershed.



An artificially straightened section of Skitterygusset Creek at reach S-7 (left). Reach S-3 is confined by armored fill at the Department of Public Works facility, leading to channel incision and bank erosion (right). Photos by Field Geology Services.

3.1.3 Stream Restoration Recommendations

Restoration and management recommendations for the five assessed streams focus on enhancing habitat quality, restoring natural channel processes, and mitigating the impacts of past and present human alterations. Key strategies include:

- Adding woody debris to improve habitat complexity and flow diversity using cost-effective techniques such as "chop and drop", as well as marginal or channel-spanning log jams, log crib walls, and log sills to address bank erosion and encourage meander redevelopment.
- Replacing undersized or failing culverts with appropriately sized and geomorphically compatible structures. Priority culverts include the Bucknam Road culvert on Skitterygusset Creek and the Northbrook Drive culvert on Norton Brook.
- Removing artificial floodplain fill and legacy structures, such as old dams on Mill Creek, to restore floodplain connectivity and reduce constraints on natural channel adjustment.
- Adding or enhancing riparian buffers in areas where they are sparse or absent to promote streambank stability, stream shading, and pollutant filtration.

Collectively, these restoration strategies are designed to accelerate habitat improvements, reconnect isolated reaches, and reestablish natural geomorphic conditions throughout the watersheds.

3.2 SHORELINE SURVEY

FBE was contracted by the Town of Falmouth, to conduct a shoreline survey of Mussel Cove as part of the WMP. The shoreline survey was performed on October 10, 2024, by FBE staff. FBE documented the condition of the shoreline for each parcel using a scoring system that evaluates vegetated buffer, presence of bare soil, extent of shoreline erosion, distance of structures to the ocean, and slope. These scores were summed to generate an overall "Shoreline Disturbance Score" (scores ranging from 3-12) and "Shoreline Vulnerability Score" (scores ranging from 1-6) for each parcel. High scores indicate poor or vulnerable shoreline conditions. Photos were taken at each parcel and were cataloged by tax map-lot number. These photos will provide project stakeholders with a valuable tool for assessing shoreline conditions over time. The survey consisted of 54 parcels located along Mussel Cove and the adjacent shoreline.

The overall condition of the Mussel Cove and surrounding shoreline is considered moderately healthy, with an average disturbance score of 6.67 out of 12. This falls just below the threshold (score of 7) where impacts to marine water quality become more likely. However, over half the parcels (52%) scored 7 or higher, meaning that in general there is a need for improvement such as improved buffers or erosion control measures to more adequately protect the shoreline and water quality. Ten parcels had especially high disturbance scores (9+), largely due to inadequate buffers, bare soil, and visible erosion.

The average vulnerability score (slope and setback distance) was 3.76 out of 6, with more than half of parcels (55%) scoring 5 or greater, indicating susceptibility to erosion, especially on steep slopes or with structures near the water. FBE used EPA's Pollutant Load Estimation Tool model to estimate that parcels with higher disturbance scores contribute roughly 33.75 pounds of nitrogen annually to Mussel Cove; implementing BMPs at 50% efficiency could reduce this by about 16.9 pounds. Regular shoreline

assessments, recommended every five to ten years, will be important for tracking conditions and guiding targeted restoration efforts.

3.3 BMP RECONNAISSANCE

Between 2024 and 2025, Acorn Engineering conducted a number of reconnaissance surveys aimed at evaluating the feasibility of implementing stormwater BMPs. This assessment prioritized the Webes Creek and Norton Brook watersheds, which exhibit elevated levels of nutrient loading and toxic pollutants that could be mitigated through targeted BMP retrofits.

The field-based reconnaissance involved multiple site visits to evaluate existing development, stormwater infrastructure, land use conditions, and potential BMP retrofit or installation opportunities. Evaluation of aerial imagery mapping and Google Earth® street view was used for the assessment of existing drainage conditions. The goal was to identify locations where either new BMPs could be established, or existing systems could be improved to enhance stormwater management and water quality outcomes.

Acorn's proposed BMP implementation strategy is structured in two phases:

- **Phase 1** prioritizes addressing the most critical water quality challenges by focusing on high priority watersheds and pollutants identified through FBE's comprehensive water quality testing data. By strategically targeting these areas, Phase 1 aims to maximize the effectiveness through the development solutions with the highest potential for measurable impact. The overarching goal is to achieve measurable improvements in water quality by the year 2030. Webes Creek and Norton Brook have been prioritized for Phase I implementation of recommended BMPs.
    - This phase targets BMP implementation within the most impaired watersheds, through retrofits and new infrastructure, to achieve the greatest improvements in water quality and quantity.
    - The Town should continue to require that existing lots served by subsurface wastewater disposal systems, but are adjacent to the public sewer system, shall provide certificates every two years demonstrating the system is functioning properly.
    - The Town should implement a focused strategy requiring annual post-construction stormwater system inspection and maintenance reporting as a Planning Board condition of approval. The goal of this strategy would be to ensure MS4 compliance and long-term stormwater system performance.
    - When performing infrastructure upgrades to Town-owned stream crossing or crossculvert drainage infrastructure, the Town should incorporate design and installation practices which improve habitat connectivity and reduce the potential for erosion and associated sediment-related pollution.
- **Phase 2** serves as a follow-up initiative to address remaining or lower-priority pollutants and secondary stressors. This phase will extend BMP implementation into areas with less severe but still impactful sources of impairment. Phase 2 is designed to ensure that no source of impairment

is overlooked, reinforcing long-term resilience and ecological integrity across the subwatersheds. Chenery Brook, Mill Creek, and Skitterygusset Creek are proposed for Phase II improvements.

Primary BMP strategies identified throughout all subwatersheds include:

- Rain gardens/bioretention systems
- Vegetated buffer strips or swales with check dams
- FocalPoint systems
- Ditch turnouts
- Infiltration trenches
- Tree filters

The full BMP plan is provided as Appendix A, more information about proposed strategies can be found in Section 4.1.2.

3.4 NONPOINT SOURCE POLLUTION

Nonpoint source pollution originates from many diffuse sources across the landscape and is generally more difficult to identify and manage than point source pollution. Nonpoint source pollutants can enter surface waters through overland runoff (e.g., from agricultural, suburban, or rural areas), groundwater flow, or direct deposition.

In urban and developed watersheds, nonpoint source pollution most commonly results from runoff which transports pollutants to surface waters from erosion of soils, impervious surfaces, fertilizers and pesticides, agriculture practices, and pet and wildlife waste. Understanding these sources is essential for targeting stormwater management strategies and protecting water quality.

3.4.1 Development and Impervious Cover

Understanding population growth and demographics is essential for watershed management, as changes in population directly influence land use, development pressure, and stormwater impacts on stream water quality. Urbanization and shifts in community characteristics affect runoff volume and quality, wastewater infrastructure demands, and recreational use of waterways. Analyzing these trends helps watershed managers anticipate future land use changes and implement strategies to protect water resources.

To assess population dynamics within the Casco Bay Frontal Drainage watershed, data from seven U.S. Census tracts overlapping the watershed (Tracts 22, 23, 25.02, 25.01, 25.04, 42.01, and 42.02; Figure 9) were analyzed. Census tracts represent relatively homogeneous neighborhoods, providing insight into localized demographic and socioeconomic trends. **Between 2010 and 2020, the combined population across these tracts increased by 2,904 residents, from 27,285 residents to 30,189 residents**, reflecting steady growth in the area. Although some additional growth is expected, the watershed's high level of existing development suggests future population increases will likely be modest.

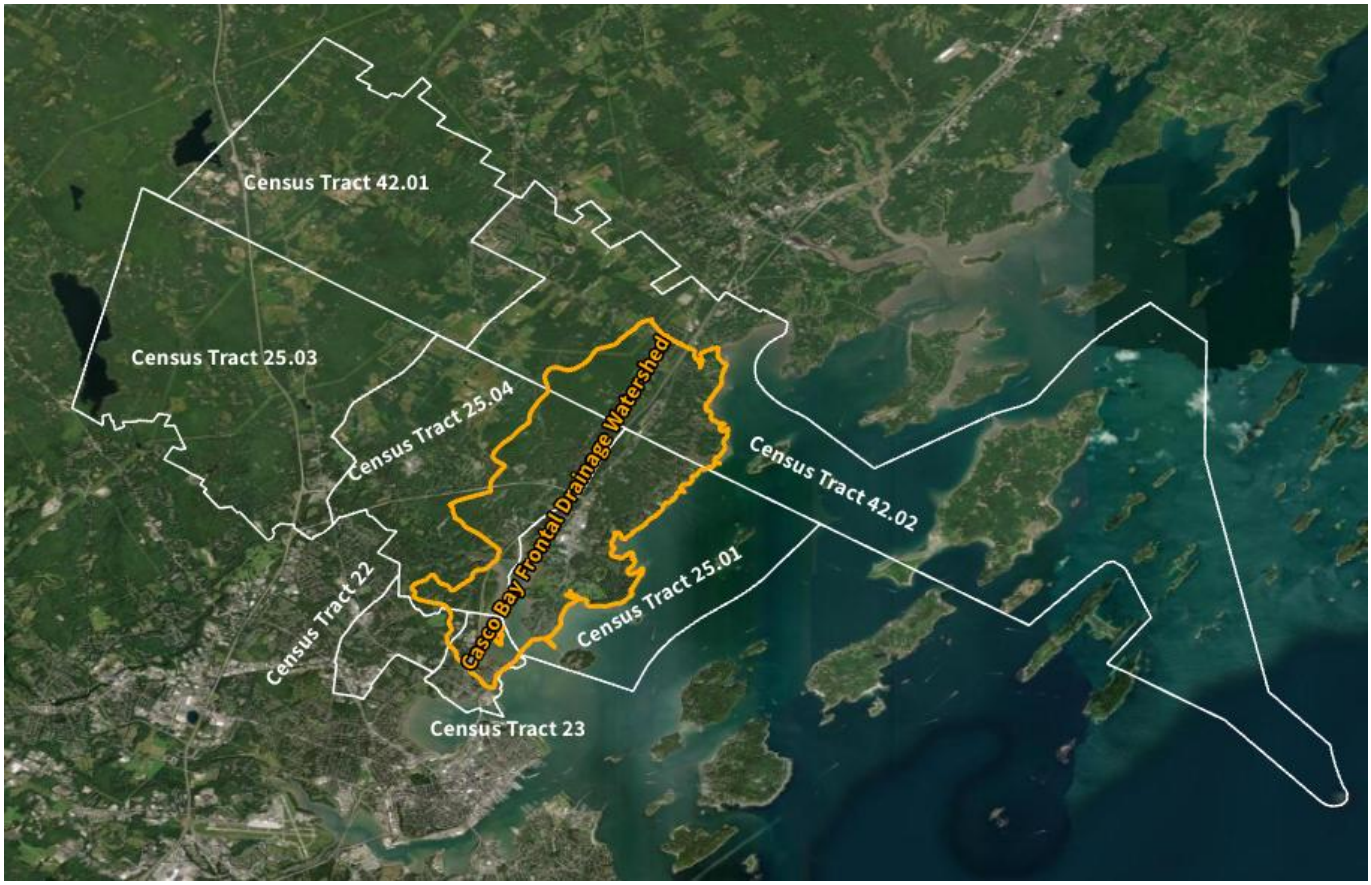


Figure 9. 2020 U.S. Census tracts and the Casco Bay Frontal Drainage watershed (Census Tracts 25.03 and 42.01 were group in to other tracts in the 2010 Census report, so these Tracts are included to keep consistency within data) (data sources: watersheds and census tracts, Maine Geographic Information Systems; aerial photo, Bing).

As populations have increased within the watershed, increases in associated development has led to the addition of more impervious cover as new homes, roads, sidewalks, commercial developments, and parking lots are installed. This development has not occurred equally throughout the watershed. Water quality monitoring in the 2024 and 2025 seasons suggests that inputs from stormwater runoff are likely causing water quality impairments, particularly in the highest covered watersheds of Webes Creek, Skitterygusset Creek, and Norton Brook.

The Maine Impervious Cover TMDL Assessment for Impaired Streams sets a target of 9% impervious cover or less for watersheds to meet Class B standards (Maine DEP, 2012). In 2018, three of the Casco Bay Frontal Drainage subwatersheds met this target: Chenery Brook (8%), Mill Creek (6%), and the Presumpscot Estuary (5%) (Table 6; Figure 10). By 2025, increases in impervious cover surged such that only the Mill Creek subwatershed continues to meet this target (8%). Although the Casco Bay Frontal Drainage streams are not subject to this TMDL, these benchmarks provide suitable targets for these watersheds. Reducing the effective impervious cover in these subwatersheds by installing stormwater management practices to capture, treat, and infiltrate stormwater will improve water quality. In the most developed areas, BMPs should be lined to prevent chloride from infiltrating into the groundwater, and should also emphasize infiltrating clean roof runoff.

Table 6. Impervious cover from 2018-2025 by subwatershed. IC = impervious cover.

Subbasin	Total Area *(acres)*	2025 IC *(acres)*	2025 Percent IC	2018 Percent IC	Change in Percent IC
Chenery Brook	1531.90	165.01	11	8	+3%
Direct Drainage	1569.55	349.81	22	14*	+8%†
Mill Creek	1278.17	107.34	8	6	+2%
Norton Brook	505.94	111.25	22	16	+6%
Presumpscot Estuary	2006.58	370.26	18	5*	+13%†
Skitterygusset Creek	551.74	134.40	24	15	+9%
Webes Creek	299.87	151.11	50	35	+15%

* Value taken from 2021 data instead of 2018 data.
† Value calculated with 2021 data instead of 2018 data

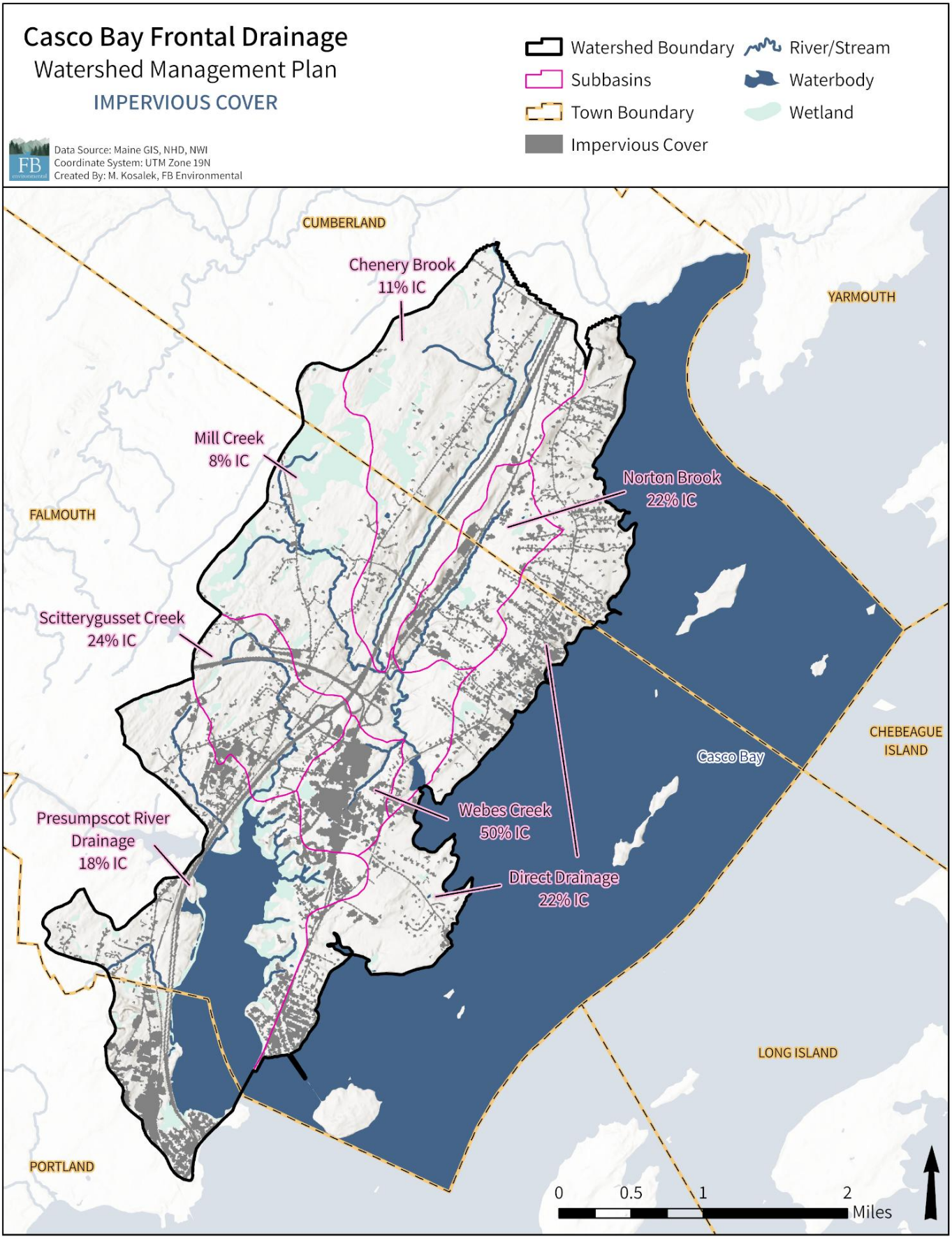


Figure 10. 2025 impervious cover by subwatershed in the Casco Bay Frontal Drainage watershed.

3.4.2 Pet Waste

Fecal matter from pets can be a significant contributor of bacteria and nutrients to surface waters.



Dogs are estimated to produce 200 grams of feces per day each, which contain concentrated amounts of bacteria estimated at 4.6 billion fecal coliform bacteria (Van der Wel, 1995). Phosphorus comprises an estimated 3.2% of dog waste by weight.



Cats can also contaminate surface waters. A 2007 study detected cat-sourced *E. coli* in stormwater (Ram, et al., 2007). Phosphorus comprises an estimated 2.0% of cat waste by weight.

If pet feces are not properly disposed of, these bacteria and nutrients can be washed off the land and transported to surface waters by stormwater runoff. Pet feces can also enter surface waters by direct deposition of fecal matter from pets standing or swimming in surface waters. Dumping cat litter next to surface waters has also been discovered in a nearby watershed, with rRNA tests confirming the presence of bacteria from cats in the stream water (Whiting-Grant, Dillon, & Dalton, 2003).

The Town of Falmouth has a carry-in/carry-out ordinance for all waste and therefore no trash receptacles are provided at public parks or trailheads. The Falmouth Land Trust reinforces this policy by posting reminders on trailhead kiosks, social media, and additional signage at some locations encouraging dog waste pickup. Popular dog-walking areas within the watershed include the Falmouth Nature Preserve/Mill Creek Preserve, Falmouth Community Park, Pine Grove Preserve, Tidewater Farm Preserve, Underwood Springs Forest Preserve, and Woodman Preserve. According to the Falmouth Land Trust and the Town of Falmouth Parks and Community Programs, residents are generally diligent about bagging and removing pet waste.

3.4.3 Wildlife



Nuisance wildlife, such as raccoons, birds, and rodents, can contribute to surface water pollution in urban and suburban areas where human activity overlaps with natural habitats. Fecal matter from these animals often contains pathogens, bacteria, and parasites that can be washed into storm drains and surface waters during rain events. Wildlife scavenging for food can also disperse trash and litter, while digging and foraging may disturb soil and vegetation, increasing erosion and sedimentation. These activities collectively degrade water quality and aquatic habitats.

Fecal matter from wildlife such as geese, gulls, ducks, and beavers may also be a significant source of nutrients, especially where human activities encourage congregation through feeding or habitat modification (CWP, 1999). Geese and gulls are of particular concern because they frequently deposit

waste near or directly into surface waters. High-risk areas include large, mowed fields and parking lots adjacent to rivers and streams, as well as bridge undersides where pigeons and other birds roost.

Studies have shown that geese in riparian areas can increase soil nitrogen availability (Choi, et al., 2020), while gulls along shorelines increase phosphorus concentrations in beach sand pore water, which can later enter surface waters through groundwater or wave action (Staley, He, Shum, Vender, & Edge, 2018). Droppings from geese and gulls rapidly release nitrogen and phosphorus when submerged, contributing to eutrophication in freshwater ecosystems (Mariash, Rautio, Mallory, & Smith, 2019). On a global scale, seabirds are estimated to release 591,000 metric tons of nitrogen and 99,000 metric tons of phosphorus annually, with the highest fluxes in arctic and southern coastal regions (Otero, De La Pena-Lastra, Perez-Alberti, Osorio Ferreira, & Huerta-Diaz, 2018).

Effective management strategies, such as habitat modification, waste management improvements, and public education, are important to mitigate the impacts of nuisance wildlife on surface water quality and ecosystem health.

3.4.4 Fertilizers

When lawn and garden fertilizers are applied in excessive amounts, in the wrong season, or just before heavy precipitation, they can be transported by rain or snowmelt runoff to lakes and other surface waters where they can promote cultural eutrophication and impair the recreational and aquatic life uses of streams. Many states and local communities are beginning to set restrictions on the use of fertilizers by prohibiting their use altogether or requiring soil tests to demonstrate a need for any phosphate application to lawns.

The Town of Falmouth's Pesticide and Fertilizer Regulation Ordinance aims to safeguard waterways, residents, pets, and natural ecosystems by limiting the use of synthetic fertilizers and pesticides on both public and private properties, with few exceptions. It will become effective April 1, 2026. Synthetic pesticides and fertilizers are known to harm pollinators, native species, and human health, with runoff exacerbating water pollution, promoting algae blooms, and jeopardizing marine life and local fisheries. Organic lawn care reduces chemical exposure risks for families and pets, promoting community health and environmental resilience. Prohibited products all neonictinoids and all synthetic pesticides unless specifically allowed on the National List. Additionally, all fertilizers and pesticides (both organic and synthetic) are prohibited within 75 feet of a waterbody and 20 feet of a storm drain. Only non-water soluble fertilizer, compost, or composted manure may be applied between 75 and 250 feet of any water body. Fertilizer containing nitrogen and phosphorus can be applied on lawns and natural turf in Falmouth as follows: A maximum of two pounds of nitrogen per 1,000 square feet per year on established turf and new development. A maximum of one pound of phosphorus per 1,000 square feet per year for new lawns or with a soil test that states phosphorus is needed. Application is limited to two times per year. Certain exemptions include commercial agriculture and horticulture, golf courses, rights-of-way, applications to treat invasive pests and plants, and town/school athletic fields (see the ordinance for the full list of exemptions).

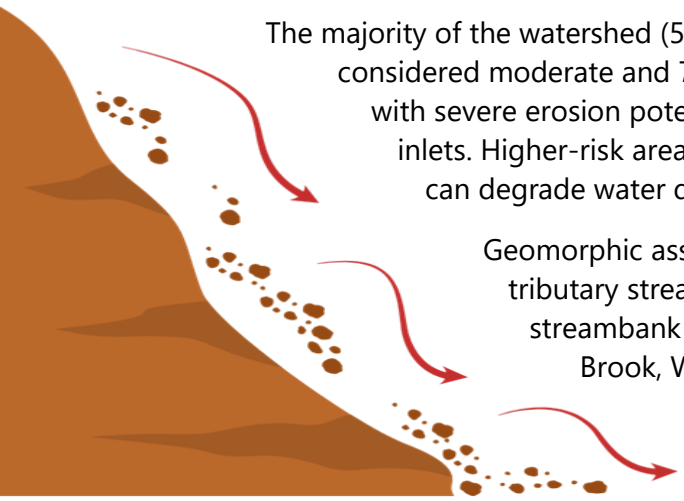
Water quality data from 2024-2025 show high levels of phosphorus at sampling sites on Webes Creek, Skitterygusset Creek, and Norton Brook, and high levels of nitrogen at all sites. This is a potential sign of fertilizer use within the watershed, though these high levels could also be accredited to erosion, sewer or septic failures, or other stormwater sources.

3.4.5 Soil & Streambank Erosion

The Casco Bay Frontal Drainage watershed contains a diverse range of soil types (Figure 11). The most prevalent is the Lyman–Abram complex, which accounts for approximately 19% of the watershed and is primarily located in inland areas. Other common soil types include the Lyman–Tunbridge complex (17%), Scantic silt loam (13%), Windsor loamy sand (9%), and Suffield silt loam (8%). The remaining 42% of the watershed consists of other soil types. Suffield silt loam is particularly prominent along portions of the shoreline, while the rest of the coastal areas consist of a mix of the remaining soil types.

Topography throughout the Casco Bay Frontal Drainage watershed is relatively consistent, with most areas characterized by gentle slopes of 0–2% and 3–4%. Steeper slopes, ranging from 11–30%, occur more frequently along the coastline and in inland areas surrounding I-295. Although areas with gentle slopes typically experience slower surface runoff and reduced erosion potential, steeper slopes can contribute to faster runoff and an increased risk of erosion.

Erosion can occur when ground is disturbed by digging, construction, plowing, foot or vehicle traffic, or wildlife. Rain and stormwater runoff then carry the loosened soil into streams. Once in surface waters, nutrients from the soil release and fuel algal growth, contributing to "cultural eutrophication," which degrades water quality. In areas of high impervious cover, excessive runoff gains speed and erosive force, leading to increased erosion along stream banks and channels The erosive power of runoff can scour streambeds, destabilize banks, and carry sediment downstream, degrading habitat and impairing water quality. Downstream, the increased sedimentation can smother aquatic habitats, disrupt aquatic ecosystems, and harm aquatic species.



The majority of the watershed (56%) is classified as having a slight erosion hazard, while 27% is considered moderate and 7% severe, with the remaining 10% unranked (Figure 12). Areas with severe erosion potential are primarily located around I-295 and near some coastal inlets. Higher-risk areas are more prone to soil loss and sediment transport, which can degrade water quality and increase flood potential.

Geomorphic assessments conducted for the Casco Bay Frontal Drainage tributary streams identified several areas of significant erosion. Evidence of streambank erosion was observed at Chenery Brook, Mill Creek, Norton Brook, Webes Creek, and Skitterygusset Creek. Each stream exhibited erosion in at least one location, with Webes Creek showing signs of streambank instability at the majority of sites evaluated.

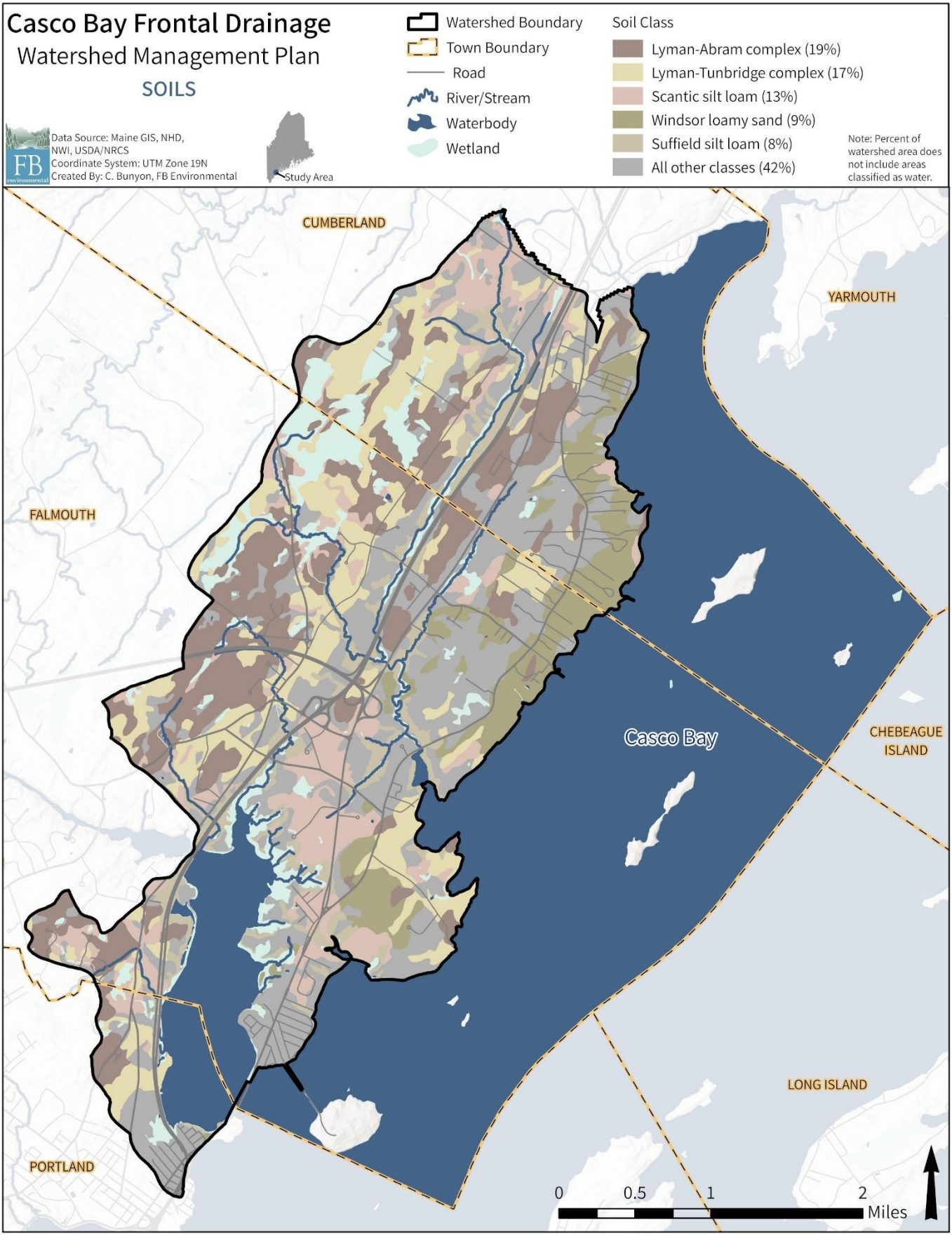


Figure 11. Soils in the Casco Bay Frontal Drainage watershed.

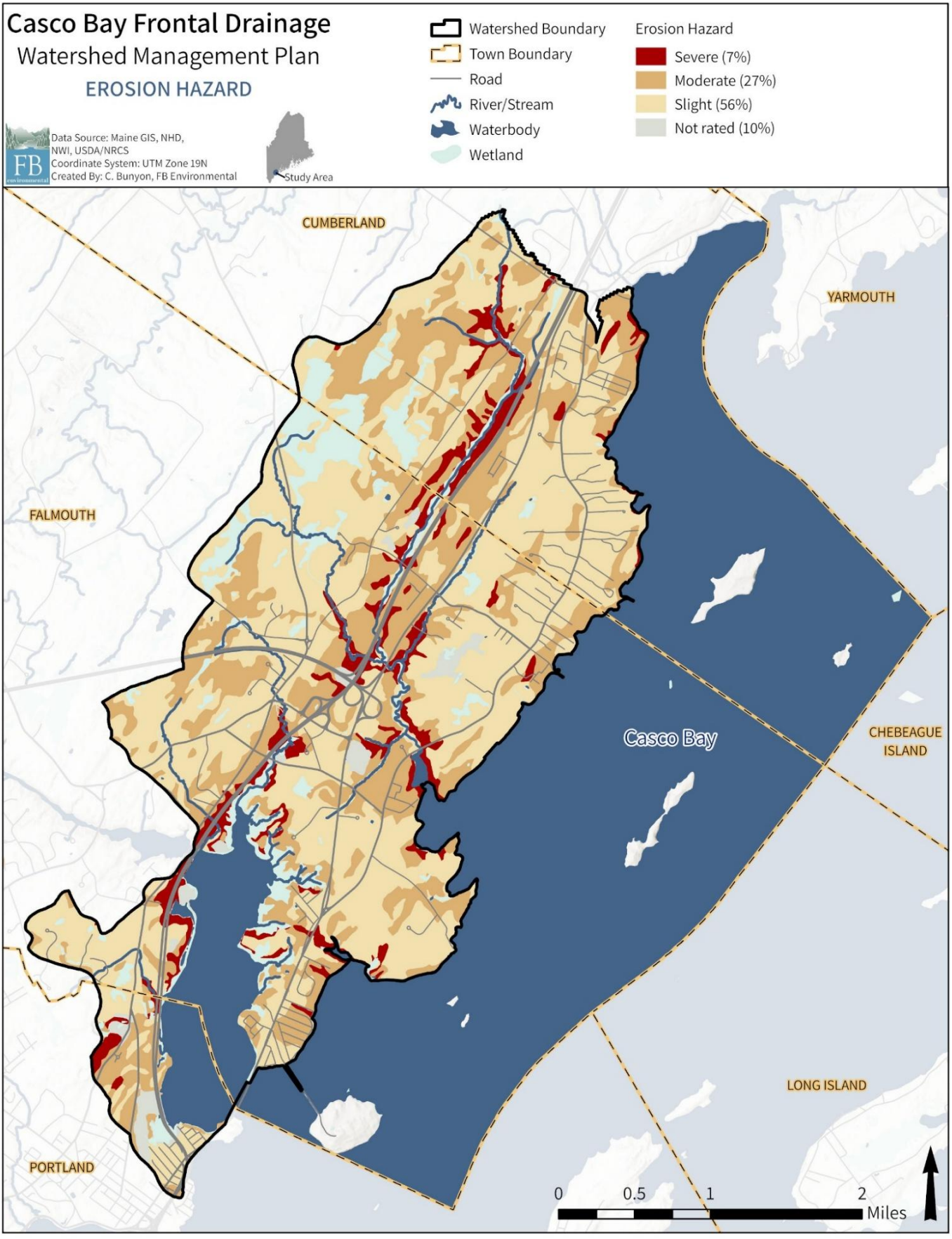
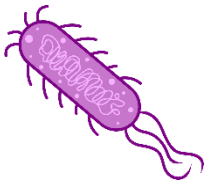


Figure 12. Soil erosion hazard in the Casco Bay Frontal Drainage watershed.

3.4.6 Wastewater

3.4.6.1 Septic Systems

Within the Casco Bay Frontal Drainage watershed, septic systems are most prevalent in the Mill Creek, Chenery Brook, and Norton Brook subwatersheds. Septic systems take wastewater from the house, filter out the solids in the septic tank, then discharge the effluent through the leachfield for natural filtration of pollutants such as pathogens, nitrogen, and phosphorus in the soil. When properly designed, installed, operated, and maintained, septic systems reduce pollutants to varying degrees of effectiveness.



Pathogens in wastewater include bacteria, viruses, protozoa, and parasites. Their presence is most often determined by measuring fecal indicator bacteria (Enterococcus), though viruses and other types of bacteria can persist for longer in soil. Pathogens are treated in the leachfield primarily through adsorption to soil particles; poor pathogen treatment can occur in systems shallow to groundwater or coarse soils with preferential flow pathways such as macropores or fractured bedrock.



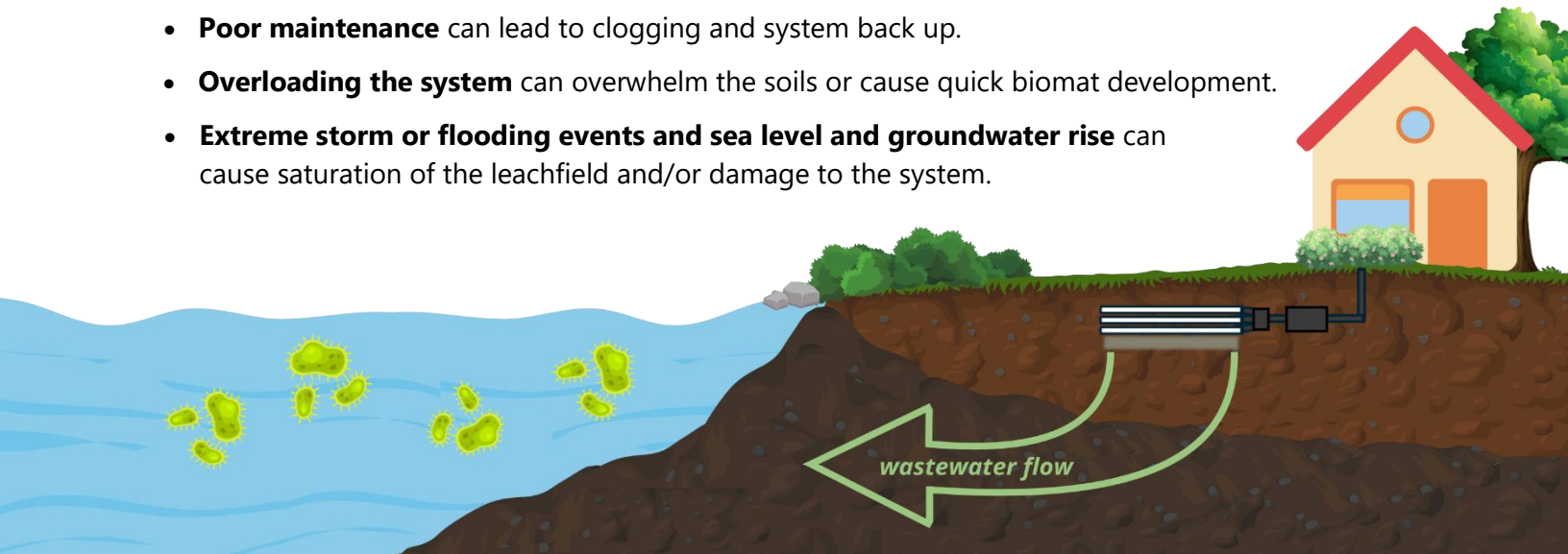
Nitrogen in wastewater can be removed into gaseous form through denitrification. Native soils beneath the leachfield are not effective at removing nitrogen (typically <40% removal), though additional denitrification can occur in groundwater, especially if anoxic conditions exist. Advanced septic systems technologies exist to remove nitrogen before wastewater enters the leachfield.



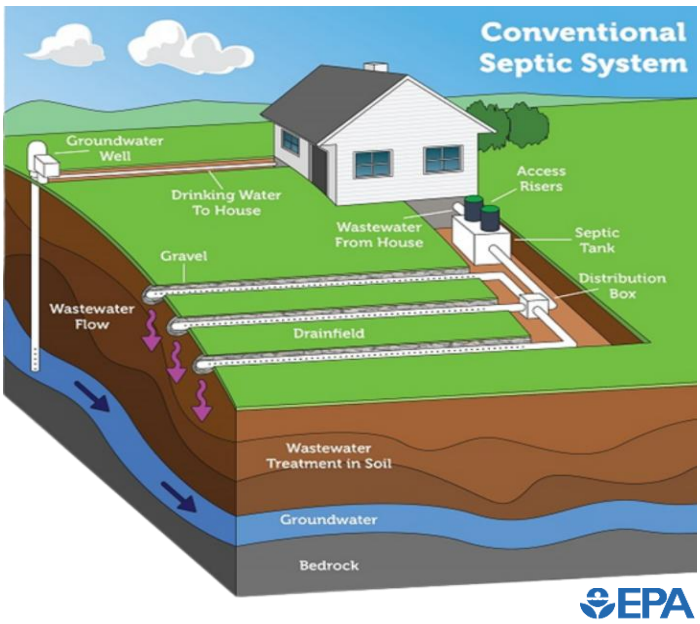
Phosphorus in wastewater can be almost entirely retained (>90% removal) in suitable soil conditions by adsorbing to soil particles or forming solid compounds with iron, aluminum, and calcium. Retention can be poor in systems shallow to groundwater or bedrock, soils with preferential flow pathways such as fractured bedrock, and high alkalinity soils low in iron and aluminum.

Failing or malfunctioning septic systems can release pollutants directly to surface waters. When a septic system fails, it may break out onto the leachfield surface (ponding), which can run off the property via a flow channel or during storms. Septic system failure can occur from:

- **Old age** can cause the biomat, a layer of organic material that forms beneath the leach field, to become too thick and cause wastewater to pond on the surface.
- **Poor maintenance** can lead to clogging and system back up.
- **Overloading the system** can overwhelm the soils or cause quick biomat development.
- **Extreme storm or flooding events and sea level and groundwater rise** can cause saturation of the leachfield and/or damage to the system.



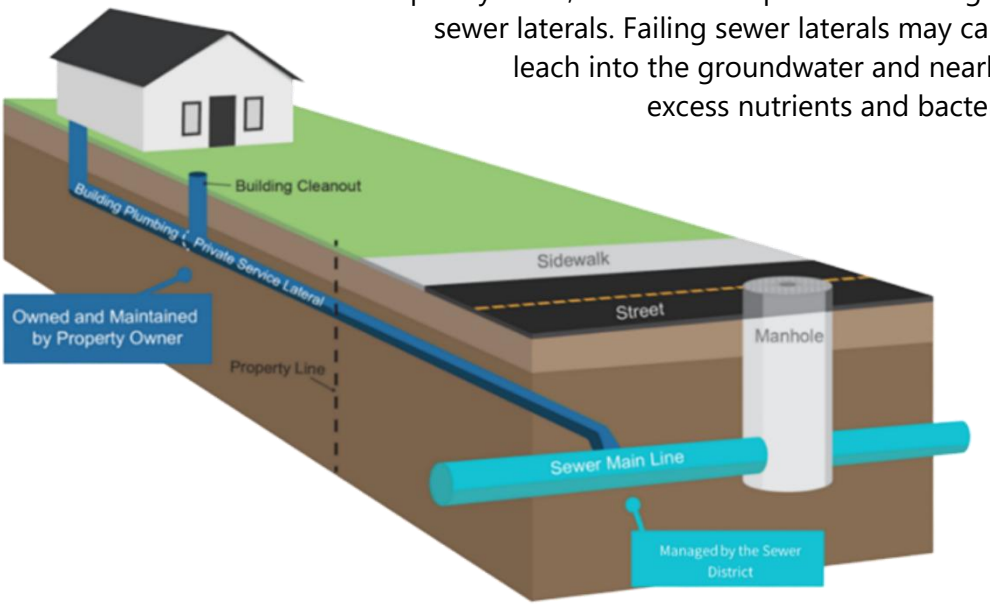
Regular septic tank pumping is essential for maintaining system functionality and protecting the surrounding environment. Components like distribution boxes and lateral lines should also be regularly inspected and maintained as needed. Over time, solid waste accumulates, increasing the risk of blockages, backups, and system failure. Sludge and scum buildup can hinder waste breakdown, leading to odors and potential contamination of soil and groundwater. Distribution boxes may clog or become unlevel, causing localized overloading of the leach field. Routine maintenance helps prevent costly repairs, extends system lifespan, and ensures effective wastewater management while safeguarding public health and the environment. The Town of Falmouth requires that septic systems are inspected every two years.



3.4.6.2 Sewer System

The Falmouth Wastewater Department is responsible for the operation and maintenance of the wastewater infrastructure within the Town (Figure 13). The collection and treatment system consists of approximately 58 miles of gravity sewer and force mains, 33 pump stations, and a 1.56 million gallons per day wastewater treatment facility located on Clearwater Drive. The Falmouth wastewater treatment facility also treats wastewater collected in the Town of Cumberland. Treated wastewater is discharged to the Presumpscot River Estuary and eventually Casco Bay.

The Town of Falmouth requires connection to the public sewer system for all properties in proximity to the Town's sewer infrastructure. Private sewer laterals that connect to the public sewer system are required to be inspected by the sewer superintendent during installation. Unlike septic systems, there is no requirement for regular inspection of private sewer laterals. Failing sewer laterals may cause untreated wastewater to leach into the groundwater and nearby waterbodies, contributing excess nutrients and bacteria.



Schematic of private sewer lateral line connection to the main sewer line.

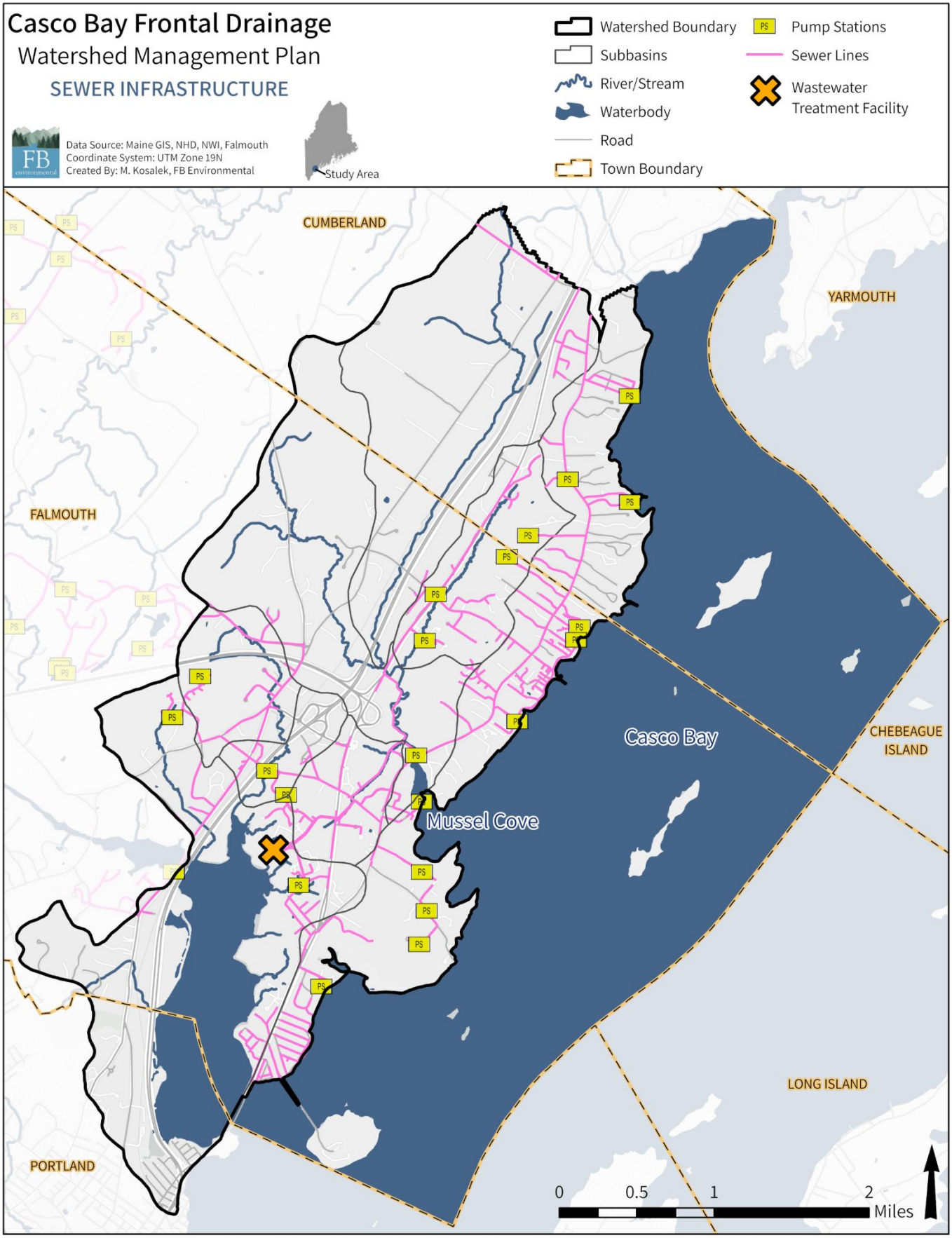


Figure 13. Sewer infrastructure in the Casco Bay Frontal Drainage watershed.

3.4.7 Agriculture



Stormwater runoff can pick up farm animal waste from sources such as manure and silage storage facilities and livestock grazing and barnyard areas and carry its bacteria and nutrients to waterways. Farm activities like plowing, livestock grazing, vegetation clearing, and vehicle traffic can also result in soil erosion and associated nutrient pollution through direct or indirect contact with surface waters. Nonpoint pollution from agriculture, particularly surface runoff from farms, is a leading cause of water impairment in watersheds across the U.S. (Adler, 2013).

Excessive or ill-timed fertilizer application or poor storage increases the potential for these nutrients and bacteria to wash away with precipitation, reducing both water quality and crop benefits. The key to fertilizer application is to apply the right type and amount at the right time. When used appropriately, synthetic fertilizers or animal manure can fertilize crops, restore nutrients to the land, and minimize bacteria pollution. When improperly managed, pollutants can easily enter waterways. Agriculture is not a major land use in the Casco Bay Frontal Drainage watershed; this activity is limited mainly to small household or hobby farms.

3.5 POINT SOURCE POLLUTION

Point source pollution originates from a specific source, such as a discharge pipe from an industrial facility, municipal treatment plant, permitted stormwater outfall, or a regulated animal feeding operation, making it relatively easy to identify. Section 402 of the Clean Water Act requires these discharges to be regulated under the National Pollutant Discharge Elimination System (NPDES) program, which controls pollutant types and quantity. NPDES permits establish monitoring, reporting, and compliance requirements under Sections 307, 318, 402, and 405 of the Clean Water Act.

Maine DEP manages the Environmental and Geographic Analysis Database which stores data on potential contamination sources across Maine. Identifying source types and locations within the watershed can help identify sources of pollution and target areas for restoration efforts.

Based on this database, potential point source pollution sources in the watershed include illicit sewer discharges, combined sewer overflows, closed municipal landfills, National Pollutant Discharge Elimination sites and outfalls, and remediation sites (Figure 14).

3.5.1 Illicit Sewer Discharges

Illicit discharges from sewers refer to any unauthorized or illegal releases of pollutants into the sewer system, which ultimately find their way into natural waterbodies such as rivers, lakes, and oceans. These discharges can originate from various sources, including industrial facilities, commercial establishments, and residential areas. The pollutants discharged can range from chemicals and heavy metals to oils, grease, and pathogens. These substances pose significant risks to aquatic ecosystems and public health.

They can contaminate water sources, harm aquatic life, degrade water quality, and compromise recreational activities. Additionally, illicit discharges rich in nutrients (e.g., sewage, some detergents) can exacerbate issues such as eutrophication and algal blooms, leading to further ecological imbalances. Effective management and enforcement strategies are crucial to prevent and mitigate the adverse impacts of illicit discharges on the environment.

The Illicit Discharge Detection and Elimination Program in the Town of Falmouth is a comprehensive initiative aimed at identifying and eliminating unauthorized releases of pollutants into the sewer system and waterbodies. The program operates as one of the six minimum control measures of Maine's MS4 permit, of which the Town of Falmouth is a permittee (see Section 3.5.2 on MS4). Some of the actions carried out as part of the Illicit Discharge Detection and Elimination Program include:

- Revising and refining a storm sewer system infrastructure map
- Maintaining the non-stormwater discharge ordinance
- Continuing the Illicit Discharge Detection and Elimination Program for the MS4
- Performing an open ditch illicit discharge and septic system assessment

As a part of continuing the Illicit Discharge Detection and Elimination Program for the MS4, the Town of Falmouth has conducted outfall inspections and dry weather sampling to identify potential illicit discharges as outlined in their MS4 annual reports produced every year. In the current permit cycle (7/1/2022 – 6/30/2027), one potential illicit discharge was identified in Permit Year 1, with a possible source identified as a residential compost bin or natural runoff. The Town worked with the property owner to relocate the bin away from a nearby catch basin.

3.5.2 Closed Municipal Landfills

Maine DEP oversees post-closure care at closed municipal landfills to prevent environmental contamination and ensure long-term compliance with state and federal standards. By monitoring groundwater, landfill gas, caps, and leachate controls, the Department verifies that containment systems function as designed and that nearby communities and ecosystems remain protected. This oversight helps prioritize maintenance and corrective actions, supports municipalities in meeting permit conditions, and ensures timely responses if monitoring indicates emerging risks.

There is one closed municipal landfill within the watershed located on Woods Road in Falmouth. This is a four-acre landfill that has been closed since 1990, as required by the Maine DEP landfill closure and remediation program. The closure of this landfill was completed consistent with the closure program.

3.5.3 National Pollutant Discharge Elimination System

Facility Sites

The NPDES oversees various facilities and activities across the United States that discharge pollutants into waterbodies. Under the administration of the EPA, NPDES regulates point sources such as industrial facilities, municipal wastewater treatment plants, stormwater systems, concentrated animal feeding operations, and MS4 areas (see Section 3.5.3). These facilities are required to obtain NPDES permits, which establish limits on pollutant discharges to safeguard water quality and human health. Through

monitoring, reporting, and compliance measures, NPDES works to mitigate water pollution and promote environmental stewardship nationwide.

There is one NPDES site (not including MS4 areas) in the Casco Bay Frontal Drainage watershed (Figure 14). This NPDES site is the Falmouth Wastewater Treatment Facility on Clearwater Drive (accessed via NPDES data on ArcGIS Hub). The Falmouth Wastewater Treatment Facility has an active permit.

Outfall Sites

Maine DEP oversees a program for monitoring and regulating NPDES outfall sites to protect water quality across the state. These sites, which discharge treated wastewater or stormwater into surface waters, are subject to strict state and federal permitting requirements. Facilities must routinely monitor and report on the volume and quality of their discharges, ensuring compliance with permit limits that safeguard aquatic life and public health. Maine DEP uses this data to track environmental performance, identify potential risks, and guide enforcement and pollution prevention efforts. This regulatory framework promotes transparency and helps maintain the integrity of Maine's waterways.

There is one outfall site in the watershed, the Falmouth Wastewater Treatment Facility. This site is closely monitored by Maine DEP to ensure compliance with strict state and federal discharge standards. Routine inspections, monitoring, and reporting requirements help Maine DEP track the quality and quantity of discharges, identify potential environmental risks, and protect the health of the watershed.

3.5.4 Remediation sites

A remediation site is a location where environmental contamination has been identified and is being investigated, managed, or cleaned up to protect human health and the environment. Maine DEP employs a systematic approach to identify and address remediation sites across the state. Beginning with thorough site assessments, Maine DEP experts analyze historical records and conduct field investigations to pinpoint areas potentially contaminated or posing environmental risks. Through rigorous testing of soil and water samples, they identify the presence and extent of contaminants, followed by a comprehensive risk assessment to evaluate potential hazards to human health and the environment. Prioritizing sites based on severity of contamination and proximity to sensitive receptors, Maine DEP develops tailored remediation plans encompassing strategies such as excavation, containment, or natural attenuation. Overseeing implementation in collaboration with stakeholders and regulatory partners, Maine DEP ensures adherence to cleanup standards and conducts ongoing monitoring to verify the effectiveness of remediation efforts.

Of the 17 remediation sites present within the Casco Bay Frontal Drainage watershed, three are in the remediation stage, nine are closed, four are classified as compliant investigated, and one is in the investigation stage (Figure 14, (Maine DEP, 2025)). Eight of the closed remediation sites are currently undertaking post-closure obligations, while the three remediation-stage sites are awaiting resources. The compliant investigated sites are reviewing site information. One of the closed sites has no contamination left on the property, and one of the compliant investigated sites was found to be unsubstantiated. Seven sites are actively meeting post-closure obligations. The remaining site, Walmart on US Route 1 in Falmouth, is currently in the investigation stage.

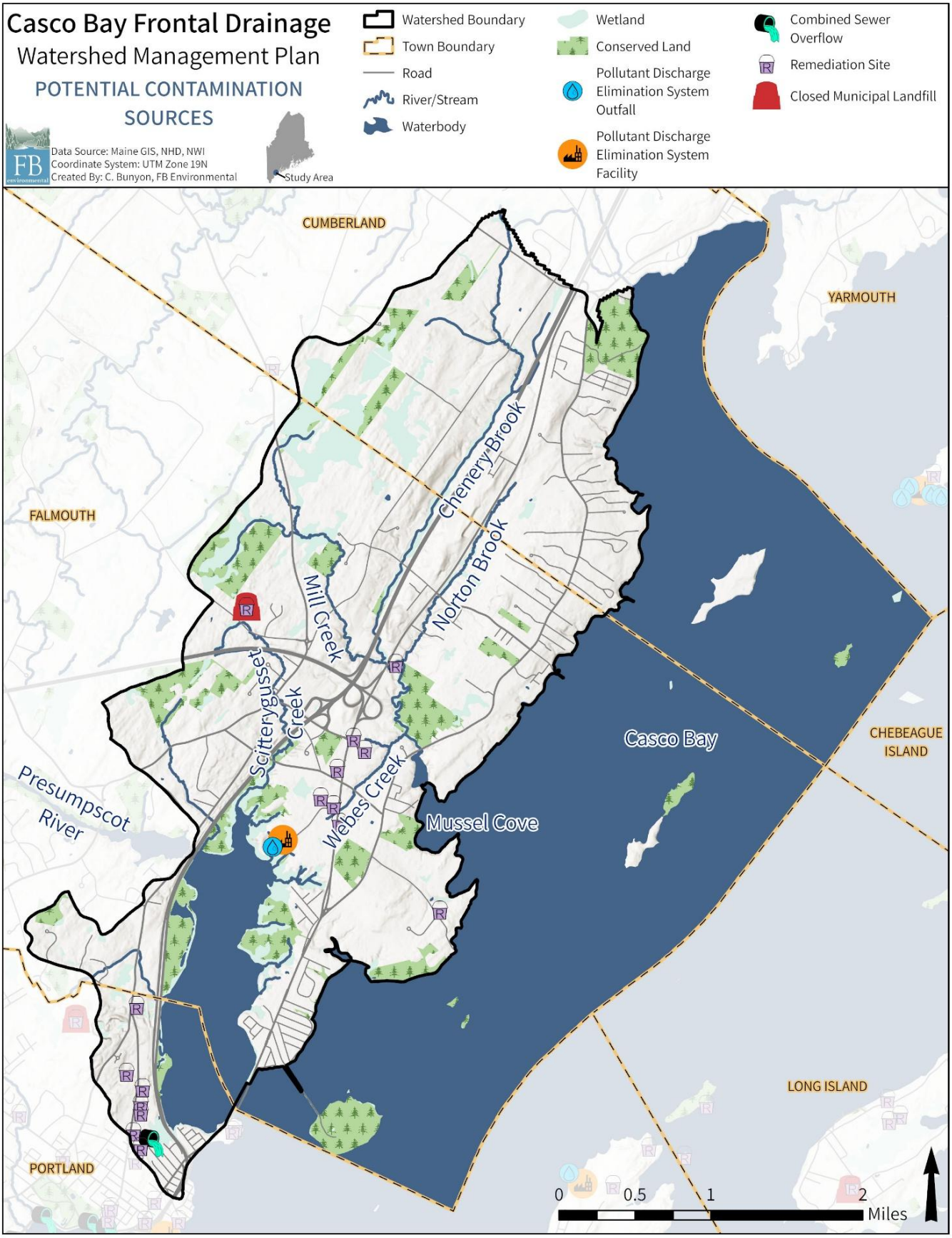


Figure 14. Point source pollution sites in the Casco Bay Frontal Drainage watershed as identified by Maine DEP's Environmental and Geographic Analysis Database.

3.6 CLIMATE VARIABILITY

Climate variability is already affecting water quality in New England and must be considered and incorporated into WMPs. Over the last century, New England has already experienced significant changes in precipitation, streamflow, and air temperature. Since the 1950s, the Northeastern U.S. has experienced a 60% increase in total precipitation during the most extreme events (top 1% of heaviest precipitation events; (Marvel, 2023). Of 28 rural streamflow stations in the region, 25 show increased flows, likely due to more frequent extreme precipitation events and higher annual rainfall. In the Oyster River at Durham, NH, three of the four largest recorded floods in 79 years occurred in the past decade (Ballestero, Houle, Puls, & Barbu, 2017). According to the 2021 International Panel on Climate Change Sixth Assessment Report, global surface temperature has increased by about 1.1 °C since 1850, with greater warming over land areas (approximately 1.6 °C) and the most pronounced increases occurring during the winter months in northern regions such as New England (IPCC, 2023). Increasing storm frequencies will flush more nutrients to surface waters for algae to feed on and flourish under warmer air temperatures.

These trends will likely continue to impact both water quality and quantity. Climate change models predict a 10-40% increase in stormwater runoff by 2050, particularly in winter and spring and an increase in both flood and drought periods as seasonal precipitation patterns shift. More intense storms can increase the already high erosive forces in the watershed due to extensive impervious cover and may also lead to the failure of current stormwater infrastructure that was designed to accommodate smaller volumes of stormwater. Figure 15 displays average yearly temperature at the Portland Jetport from 1940 to 2023. A consistent rise in temperature has occurred over these years, amounting to, on average, a 1.7°C increase since 1940. Since we know the temperature of Casco Bay closely mimics changes in air temperature, as evidenced by Figure 7, it is likely that the average temperature of Casco Bay has also increased a similar amount. Currently, warmer waters are not an issue in Casco Bay, but with air temperatures expected to continue increasing, it may become a problem in the future.

Maine Geologic Survey mapping does not predict direct flooding from sea level rise in the watershed up to the maximum sea level rise/storm surge scenario currently published (Highest Astronomical Tide Plus 10.9 feet, source maine.gov); however, groundwater rise can extend inland much further than sea level rise. A groundwater modeling study in Portsmouth, New Hampshire, predicted groundwater rise up to several miles inland from the coast, and cited effects such as reduced service life of pavement, infiltration of wastewater collection systems, and expanded wetland areas (Knott, 2019), all factors which may impact areas of the watershed in the future.

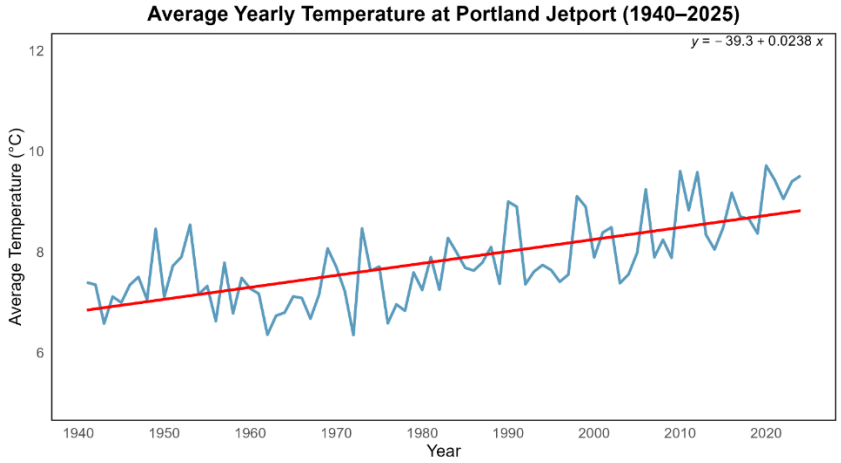


Figure 15. Average yearly temperature at Portland Jetport from 1940-2025.

3.7 WATER QUALITY GOAL & OBJECTIVES

The overall water quality goal for the Casco Bay Frontal Drainage watershed is for each of its tributary streams (Webes Creek, Skitterygusset Creek, Mill Creek, Chenery Brook, and Norton Brook) to attain all designated uses for Class B waterbodies in Maine. Though none of the streams are currently listed as impaired, bioassessments indicate that aquatic life uses may be impaired on Norton Brook, Chenery Brook, Mill Creek, and Webes Creek (Table 7). Additionally, water quality monitoring has suggested potential impairments due to elevated temperature on Chenery Brook; low dissolved oxygen on Chenery Brook, Mill Creek, Skitterygusset Creek, and Webes Creek; high specific conductance in Webes Creek, Skitterygusset Creek, and Norton Brook; and elevated *E.coli* levels in Webes Creek, Skitterygusset Creek, Mill Creek, and Chenery Brook. To mitigate the threat of future impairments because of these exceedances, watershed restoration efforts should aim to reduce the specific pollutants associated with the exceedances and improve habitat conditions so that all water quality criteria for aquatic life use are attained.

Table 7. Primary stressors and potential sources for each of the five Casco Bay Frontal Drainage subwatersheds.

Subwatershed	Primary Stressors	Potential Sources
Norton Brook	• Unstable substrate • Some high specific conductance values • High phosphorus and nitrogen • Very low baseflow	• Frequent disturbance of substrate • Floodplain fill • Undersized stream crossings • High impervious cover/stormwater runoff • Commercial development along Route 1
Chenery Brook	• Diurnal dissolved oxygen swings • High temperatures • High nitrogen • Lack of habitat and flow variation	• Interstate 295 • Erosion from development (Route 1, railroad culvert)
Mill Creek	• Periodic low dissolved oxygen • Some elevated bacteria • High nitrogen levels • Very low baseflow	• Fill encroachment • Channel straightening • Undersized stream crossings • Residential development (fertilizers, pet waste, septic systems)
Skitterygusset Creek	• Periodic low dissolved oxygen • High specific conductivity • High phosphorus and nitrogen • High temperatures • Some elevated bacteria	• Undersized stream crossings • Artificial fill • Channel straightening • Increased biological oxygen demand from nutrient or organic inputs • Suspended apatite crystals • High impervious cover/stormwater runoff • Closed municipal landfill

	• Lack of in-stream wood • Eroding streambanks	• Residential development (fertilizers, pet waste, septic systems)
Webes Creek	• Very low baseflow • Periodic low dissolved oxygen • High specific conductivity and chloride • High phosphorus and nitrogen • High bacteria counts • Unstable substrate • Lack of in-stream wood	• High impervious cover/stormwater runoff • Frequent disturbance of substrate • Channel straightening and constraints • Undersized stream crossings • Nearby remediation sites • Leaky sewers • Residential development (fertilizers, pet waste, septic systems)

To achieve this overall water quality goal, the following management objectives will be set (Table 8). Specific details for how these management objectives will be achieved will be outlined through action items presented in the Action Plan (Section 5). Due to limited monitoring data in the watershed, quantitative pollutant reduction goals will not be set for individual stressors. Instead, management practices will target the stressors as identified by this and past studies in order to improve habitat and water quality conditions.

Management Objectives:

a. Install structural BMPs to treat stormwater runoff in key areas of the watershed, particularly the Webes Creek and Norton Brook subwatersheds. This should follow the phased approach proposed by Acorn Engineering (see Section 4.1.2) where the most impaired subwatersheds are addressed in Phase I and less severe impairments or lower-priority stressors are addressed in Phase II.

b. Perform stream restoration practices to improve habitat in key segments of the five Casco Bay Frontal Drainage subwatersheds. See Section 4.1.1 for more information on specific habitat improvement recommendations within each stretch of the five streams.

c. Implement non-structural BMPs to reduce key pollutants identified as contributing to water quality criteria exceedances. As outlined in Table 7, pollutants and stressors vary by subwatershed but include:

    - Dissolved oxygen
    - Specific conductivity and chloride
    - Phosphorus
    - Nitrogen
    - *E. coli* bacteria
    - Temperature

Table 8. Summary of water quality objectives for the Casco Bay Frontal Drainage watershed. Interim goals/benchmarks are cumulative.

Interim Goals / Benchmarks	2028	2031	2036
Objective 1 Install structural BMPs to treat stormwater runoff in key areas of the watershed.	Complete installation of BMPs at 4 of 8 Phase I locations.	Complete installation of BMPs at all 8 Phase I locations. Begin Phase II implementation as funds allow.	Complete installation of BMPs at all 8 Phase II locations.
Objective 2 Perform stream restoration practices to improve habitat in key segments of the five Casco Bay Frontal Drainage subwatersheds.	Complete high priority habitat recommendations.	Complete moderate priority habitat recommendations.	Complete low priority habitat recommendations.
Objective 3 Implement non-structural BMPs to reduce key pollutants identified as contributing to water quality criteria exceedances.	Complete 2 non-structural practice recommendations (ordinance/policy updates, education and outreach, trainings, plans, etc.)	Complete 10 non-structural practice recommendations (ordinance/policy updates, education and outreach, trainings, plans, etc.)	Complete 20 non-structural practice recommendations (ordinance/policy updates, education and outreach, trainings, plans, etc.)

4 MANAGEMENT STRATEGIES

The following section details management strategies for achieving the water quality goal and objectives using a combination of structural and non-structural restoration techniques, as well as outreach and education and an adaptive management approach. A key component of these strategies is the idea that existing and future development can be remediated or conducted in a manner that sustains environmental values. All stakeholder groups have the capacity to be responsible watershed stewards, including citizens, businesses, the government, and others. Specific action items are provided in the Action Plan (Section 5).

4.1 STRUCTURAL NONPOINT SOURCE RESTORATION

Structural nonpoint source restoration techniques are engineered infrastructure designed to intercept stormwater runoff, often allowing it to soak into the ground, be taken up by plants, harvested for reuse, or released slowly over time to minimize flooding and downstream erosion. These BMPs often incorporate some mechanism for pollutant removal, such as sediment settling basins, oil separators, filtration, or microbial breakdown. They can also consist of removing or disconnecting impervious surfaces, which in turn reduces the volume of polluted runoff generated, minimizing adverse impacts to receiving waters.

4.1.1 Stream Restoration

In accordance with the water quality objective, the focus of this WMP is to emphasize stream restoration efforts at the streams found throughout the watershed. Skitterygusset Creek, Webes Creek, Chenery Brook, Norton Brook, and Mill Creek all have reaches that need restoration. Primary recommended restoration actions include the following:

- Wood additions (via chop and drop or addition of log sills, crib walls, and/or log jams).
- Riparian buffer establishment and enhancement.
- Riprap removal along stream banks, riparian areas, and flood plains.
- Dam removal.
- Artificial fill removal.
- Removal, resizing, addition, and replacement of culverts.
- Land conservation surrounding stream areas and throughout the watershed.

Wood Additions

Woody debris is crucial in stream ecosystems as it offers habitat for aquatic life like fish, insects, and amphibians. It also diversifies flow patterns, benefiting water quality and erosion prevention. Furthermore, it traps sediment, aids nutrient cycling, and boosts stream stability, thus promoting the well-being and resilience of riparian environments. This strategy is recommended as high priority due to the low cost and high natural benefits it provides.

Various strategies exist for enhancing the wood content of the streams in the Casco Bay Frontal Drainage. In sections with reduced flow, a mix of loose wood pieces of different sizes can be introduced through methods such as chop and drop or by transporting them in when local sources in the reach are insufficient. Alternatively, in areas requiring a more structured approach, anchoring wood is essential. This technique ensures prolonged stability, moderating flow speed and enabling the river to naturally and gradually heal from erosion.

The proposed solutions for wood additions to reaches where necessary are below.

Chenery Brook

- Chop and drop in reaches C1, C2, C5, C6, and C7.
- Log sills, crib walls, and/or log jams in reach C2.
- Wood additions in the small gully in reach C7.

Mill Creek

- Chop and drop in reaches M1, M3, M4, M6, M9, and M10.
- Chop and drop in low gradient area of reach M5.
- Chop and drop with log strainer in reach M8.
- Low log sills in reach M2.
- Log jams to encourage meandering growth in reach M11.

Norton Brook

- Chop and drop in reaches N1 and N4.
- Anchored chop and drop in reach N3.
- Log sills and jams in reach N2.
- Log cribbing to replace riprap in reach N3.

Webes Creek

- Log jams in reaches W1, W2 and W3.
- Log sills to trap sediment over clay in reaches W1 and W2.
- Log cribbing for bank protection in reach W2.

Skitterygusset Creek

- Wood additions in reaches 2, 4, 5, 9, and 10.



Chop and drop in a Vermont stream. Photo by Trout Unlimited.

Establish and Enhance Riparian Buffers

Planting riparian buffers along waterways offers a multitude of benefits for both aquatic ecosystems and surrounding landscapes. These vegetated strips of land act as a natural barrier, filtering pollutants from runoff before they enter the water, thereby improving water quality. Riparian buffers also stabilize

streambanks, reducing erosion and sedimentation, which helps to maintain the integrity of the stream channel and protect adjacent land from degradation. Moreover, the dense vegetation of riparian buffers provides habitat and food sources for a diverse array of wildlife, including birds, insects, and amphibians, enhancing biodiversity and promoting ecological resilience. Additionally, riparian buffers can mitigate the impacts of flooding by absorbing excess water and slowing down its movement, thereby reducing the risk of downstream flooding events. Overall, planting riparian buffers represents a cost-effective and environmentally sustainable approach to conserving water resources, preserving natural habitats, and enhancing overall ecosystem health.

The following sites are recommended for establishing and enhancing riparian buffer habitats. Several locations are along residential yards, thus requiring discussions with landowners to encourage buffer plantings. Planting additional buffer should always be considered when performing culvert removals or other projects that may disturb and displace existing buffers. The enhancement of riparian buffers is recommended as a high priority strategy due to the relatively low cost involved and the potential for significant rewards in terms of ecosystem health and resilience.

Chenery Brook

- Stabilize the streambank in reach C4.

Mill Creek

- Implement logs for bank protection near sewer line in reach M11.

Webes Creek

- Implement buffer plantings along the edges of lawns in reach W4.

Skitterygusset Creek

- Add riparian buffers in reaches 6, 7, 8, and 9.
- Implement natural bank stabilization in reach 8.



Riparian buffer planting. Photo by Stroud Water Research Center.

Riprap Removal

Riprap is an anthropogenic addition that provides stream bank stabilization; however, its use challenges the establishment and maintenance of natural fluvial processes. Immediate riprap removal would jeopardize bank stability, water quality, and associated aquatic life integrity, hindering progress toward achieving Class B stream standards. Given this, the recommendations for wood additions, above, should be implemented as the highest priority to begin rehabilitating and expanding the current macroinvertebrate communities. Only after assessing whether the added wood provides sufficient habitat for macroinvertebrates should riprap removal be considered for the upper watershed.

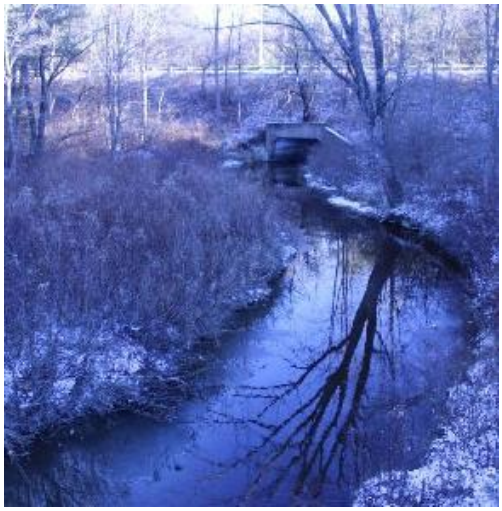
Conversely, in the lower watershed, the removal of rip rap is advised owing to the absence of macroinvertebrate populations and the significant adverse effects it imposes on stream geomorphology. The following areas are recommended for riprap removal.

Mill Creek

- Remove boulders in reach M9.
- Pull back riprap to alleviate constriction in reach M10.

Skitterygusset Creek

- Remove boulder armoring in reach 2.
- Remove Department of Public Works fill and armoring in reach 3.
- Remove armoring and replace with log crib wall in reaches 6 and 7.
- Replace armoring with natural bank stabilization in reach 8.
- Remove mill fill in reach 9.



Riprap in the stream channel at M10. Photo by Field Geology Services.

Dam Removal

Dams pose a number of negative impacts on both water quality and aquatic habitat. These barriers block the passage of fish and other aquatic organisms and disrupt sediment and nutrient cycling, leading to a build-up of sediment in the impoundment upstream of the dam and often starving downstream reaches of sediment crucial to aquatic habitats. Additionally, the water in impoundments is often degraded as it is warmer and lower in dissolved oxygen than free-flowing rivers. Removing dams or adding fish passage can restore streams and improve ecosystem-wide connectivity.

It is recommended to remove dams in the Chenery Brook C3 reach and the Mill Creek M6 reach.

Remove Artificial Fill

Removal of artificial fill would allow for floodplain restoration by reducing flow velocities and improving riparian vegetation, habitat, and associated processes. In addition to the below sites, there will likely be removal of artificial fill that naturally happens with culvert removal and replacement projects.

Norton Brook

- Remove fill in reach N2
- Remove fill crossing floodplain at old quarry access in reach N4.

Webes Creek

- Remove fill to protect manhole in reach W1.

Skitterygusset Creek

- Remove Department of Public Works fill in reach 3.
- Remove mill fill in reach 9.

Removal, Resizing, Addition, and Replacement of Culverts

The removal or resizing of culverts in streams offers a multitude of benefits to both aquatic ecosystems and surrounding communities. Culverts, when improperly sized or positioned, can obstruct the natural flow of water, impeding the movement of fish and other aquatic organisms. By removing or resizing culverts to align with natural stream channels, barriers to migration are eliminated, allowing for improved access to essential habitats for spawning, feeding, and refuge. Additionally, properly sized culverts help maintain natural flow regimes, reducing the risk of flooding and erosion while enhancing water quality by minimizing sediment accumulation. Moreover, restoring stream connectivity through culvert modification promotes biodiversity, supports healthy fish populations, and enhances overall ecosystem resilience in the face of environmental challenges. Overall, the removal or resizing of culverts represents a crucial step toward restoring the ecological integrity and functionality of streams, fostering sustainable water management practices, and ensuring the long-term health of aquatic ecosystems.

The following reaches contain culverts that are recommended for modifications:

Chenery Brook

- Replace the undersized culvert at the downstream end of reach C1.

Mill Creek

- Replace both undersized culverts in reach M1.
- Realign and resize culverts in reaches M2, M3 (Long Creek Way), M4 (driveway), and M8.
- Add relief culvert in reach M2.

Norton Brook

- Repair and resize the Northwood Drive culvert in reach N3.
- Add relief culverts at Johnson Road in reach N2.

Webes Creek

- Resize the Depot Road culvert in reach W1.

Skitterygusset Creek

- Enlarge and realign the downstream culvert in reach 2.
- Enlarge culverts in reaches 3 and 4
- Add relief culverts in reaches 1, 3, 5, and 10.
- Enlarge culvert in reach 4.
- Resize culverts in reaches 6, 7 and 9.

A summary of all recommendations is provided in Table 9. See Appendix B and C for a full detailed description of restoration recommendations.

Table 9. Matrix of stream restoration recommendations for five streams within the Casco Bay Frontal Drainage watershed. C= Chenery Brook, M = Mill Creek, N = Norton Brook, S = Skitterygusset Creek, W = Webes Creek.

Reach	Perform chop and drop	Add log sills, crib walls, and/or log jams	Conserve land	Stabilize bank and add riparian buffer	Reactivate abandoned channel	Replace, resize, or realign culvert	Add floodplain relief culverts	Remove dam	Remove boulders, rock wall, fill, or armoring	Stabilize Road	Build a pedestrian crossing above the channel
C1	✓					✓					
C2	✓	✓									
C3								✓			
C4			✓	✓							
C5	✓		✓								
C6	✓										
C7	✓	✓			✓						
M1	✓					✓					
M2		✓			✓	✓					
M3	✓					✓					
M4	✓		✓			✓					
M5	✓										
M6	✓							✓			
M7			✓								
M8	✓					✓					
M9	✓								✓		
M10	✓								✓		
M11		✓		✓							
N1	✓										
N2		✓					✓		✓		
N3	✓	✓				✓					

Reach	Perform chop and drop	Add log sills, crib walls, and/or log jams	Conserve land	Stabilize bank and add riparian buffer	Reactivate abandoned channel	Replace, resize, or realign culvert	Add floodplain relief culverts	Remove dam	Remove boulders, rock wall, fill, or armoring	Stabilize Road	Build a pedestrian crossing above the channel
N4	✓								✓		
S1							✓		✓		✓
S2	✓	✓				✓			✓		
S3						✓	✓		✓	✓	
S4	✓	✓				✓					
S5	✓	✓				✓					
S6		✓		✓		✓			✓		
S7		✓		✓		✓			✓		
S8				✓	✓				✓		
S9	✓	✓		✓		✓			✓		✓
S10	✓	✓					✓				
W1		✓				✓			✓		
W2		✓		✓	✓						
W3				✓							
W4				✓							
W5									✓		
Total	**21/37**	**15/37**	**4/37**	**9/37**	**4/37**	**15/37**	**4/37**	**2/37**	**13/37**	**1/37**	**2/37**

4.1.2 Structural Stormwater BMPs

Acorn Engineering completed a BMP reconnaissance survey in the Casco Bay Frontal Drainage watershed, as summarized in Section 3.3. The outcome of this assessment was recommendations for new BMPs and BMP retrofits that could be implemented in each of the five subwatersheds. The specific retrofit recommendations for each site are detailed in Table 10. Implementation of BMPs is proposed to occur in two phases with Phase I focusing on the highly impervious Webes Creek and Norton Brook subwatersheds, and Phase II focusing on Mill Creek, Chenery Brook, and Skitterygusset subwatersheds. See Appendix A: Acorn Engineering Water Quality Improvement Plan for the full BMP report.

Results from the BMP Reconnaissance highlight a few key practices for implementation:

a. Rain Gardens / Bioretention: Rain gardens are shallow depressions planted with native vegetation that capture and treat stormwater runoff through infiltration and evapotranspiration. Under Maine DEP guidelines, bioretention cells must include engineered soil media, underdrains (if needed), and overflow structures. They are effective at removing nutrients, metals, and sediments, and are particularly useful in residential and small commercial settings.
b. Tree Filters: Tree filters are compact, vegetated filtration systems that integrate trees with engineered soil media to treat stormwater runoff. These systems are particularly effective in highly impervious urban areas and are designed to capture and treat the first flush of runoff. Tree filters remove suspended solids, nutrients, and hydrocarbons while providing aesthetic and ecological benefits. They are typically installed in sidewalk cutouts or parking lot islands and conform to DEP standards for filtration BMPs.
c. Vegetated Filter Strips / Swales: Vegetated Filter Strips are gently sloped, vegetated areas that are designed to intercept and treat stormwater runoff. These strips are planted with grasses, shrubs, or other dense vegetation to promote a reduced runoff velocity and allow sediment, nutrients, and pollutants to be trapped and filtered through plant media and soil. Vegetated Filter Strips improve water quality before runoff enters nearby streams or stormwater systems.
d. Check Dams: Check dams are small structure placed across drainage swales or ditches to slow stormwater runoff. They can be constructed from a variety of materials including stones, log, earth, or manufactured materials. Check dams help prevent erosion, trap sediment, and encourage infiltration by reducing flow velocity.
e. Infiltration Trenches: Infiltration trenches are trenches filled with coarse aggregate designed to capture, store, and infiltrate stormwater runoff into the surrounding soil. Infiltration trenches are commonly used to manage surface water by reducing runoff volume and improving water quality. As water is drained through the aggregate, suspended solids, such as sediment and pollutants, are removed.
f. FocalPoint Systems: Maine DEP allows the use of proprietary stormwater treatment systems, such as FocalPoint biofiltration systems, provided they meet performance criteria for pollutant removal and temperature reduction. These systems are often used in constrained urban environments where space or site conditions limit the use of traditional BMPs.

Table 10. Stormwater retrofit recommendations for sites identified within the Casco Bay Frontal Drainage watershed, broken up by subwatershed. * = Locations with opportunity for large pollutant removal due to existing infrastructure connections.

WEBES CREEK – PHASE I

BMP Location	BMP	Location & Accessibility	Site Constraints	Stormwater Management Benefit	Construction Costs	Long-Term Costs
206 US Route 1 - Walmart Parking Lot*	Gravel Wetland	High – adjacent to road access and next to large parking lot area	Abutting parcel cooperation needed	High – good pollutant removal and volume control	High	Low – minimal upkeep once established
	Tree Filters	High – installed in curbside or landscaped areas near impervious areas	Cooperation needed with landowner	High – good pollutant removal; effective for small drainage areas	Moderate	Moderate – requires periodic maintenance
US Route 1 Storm Inlet*	Infiltration Basin	High – adjacent to road access	Limited space, abutting parcel cooperation needed, existing stormwater infrastructure elevations	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
	Rain Garden (Bioretention Cell)	High – adjacent to road access	Limited space, abutting parcel cooperation needed	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
Catchment 5	Tree Filters	High – installed in curbside or landscaped areas near impervious areas	Cooperation needed with landowner	High – good pollutant removal; effective for small drainage areas	Moderate	Moderate – requires periodic maintenance

BMP Location	BMP	Location & Accessibility	Site Constraints	Stormwater Management Benefit	Construction Costs	Long-Term Costs
Depot Road	Tree Filters	High – installed in curbside or landscaped areas near impervious areas	Requires adequate curbside space	High – good pollutant removal; effective for small drainage areas	Moderate	Moderate – requires periodic maintenance
	Focal Point	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection
Falmouth Little League Complex	Infiltration Trench	High – adjacent to road access	Requires permeable soils for infiltration	High – good pollutant removal and volume control	Moderate	Moderate – requires periodic sediment removal
	Vegetated Swales	High – adjacent to road access, parking lots, or open channels	Requires adequate space and permeable soils	Moderate to High – slows runoff, promotes infiltration, reduces peak flows	Low to Moderate	Low – routine maintenance for vegetation and sediment removal
	Vegetated Buffer Strip	High - adjacent to road access and parking lot	Requires adequate space for vegetation	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation

NORTON BROOK – PHASE I

BMP Location	BMP	Location & Accessibility	Site Constraints	Stormwater Management Benefit	Construction Costs	Long-Term Costs
US Route 1 - Roadway	Vegetated Swales with Check Dam	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils, road right-of-way not located in Town of Falmouth, right-of-way (Maine DOT)	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed, road right-of-way not located in Town of Falmouth, right-of-way (Maine DOT)	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
US Route 1 – Adjacent to Norton Brook	Vegetated Buffer Strips	High - adjacent to road access and parking lot	Requires adequate space for vegetation, road right-of-way not located in Town of Falmouth, right-of-way (Maine DOT)	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation
	Stabilize Storage Areas	Moderate - adjacent to Mill Creek, east of Route One corridor	Landowner cooperation required; road right-of-way not located in Town of Falmouth, right-of-way (Maine DOT)	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of storage
Northbrook Drive	Vegetated Swales with Check Dams	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils, road right-of-way not located in Town of Falmouth	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance

	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection

CHENERY BROOK – PHASE II

BMP Location	BMP	Location & Accessibility	Site Constraints	Stormwater Management Benefit	Construction Costs	Long-Term Costs
Middle Road	Vegetated Swales with Check Dam	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils, road right-of-way not located in Town of Falmouth	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance, road right-of-way not located in Town of Falmouth	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection
	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed, road right-of-way not located in Town of Falmouth	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
Interstate 295 (I-295)	Ditch Turnouts	High – Installed along roadside ditches	Requires available area along roadside, right-of-way (Maine DOT)	Moderate – Reduces runoff velocity and filters sediments	Low	Low – Occasional maintenance to clear debris, vegetation management
St. Lawrence and Atlantic Railroad	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed, portion not located in Town of Falmouth, privately owned	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established

	Check Dams in Drainage Channels	Moderate – adjacent to railroad access	Requires slope and permeable soils, portion not located in Town of Falmouth, privately owned	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic check dam maintenance
	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance, portion not located in Town of Falmouth, privately owned	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection

MILL CREEK – PHASE II

BMP Location	BMP	Location & Accessibility	Site Constraints	Stormwater Management Benefit	Construction Costs	Long-Term Costs
ME Route 9 - Longwoods Road	Vegetated Swales with Check Dam	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
US Route 1 - South Corridor	Vegetated Buffer Strips	High - adjacent to road access and parking lot	Requires adequate space for vegetation, right-of-way (Maine DOT)	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation
	Stabilize Storage Areas	Moderate - adjacent to Mill Creek, east of Route One corridor	Landowner cooperation required	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of storage

SKITTERYGUSSET CREEK – PHASE II

BMP Location	BMP	Location & Accessibility	Site Constraints	Stormwater Management Benefit	Construction Costs	Long-Term Costs
Highway Site Development – I-295 & Falmouth Spur Toll Road	Ditch Turnouts	High – Installed along roadside ditches	Requires available area along roadside, right-of-way (Maine DOT)	Moderate – Reduces runoff velocity and filters sediments	Low	Low – Occasional maintenance to clear debris, vegetation management
Roadway Site Development – Woods Road, Lunt Road, Depot Road, Bucknam Road, & Middle Road	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance, cooperation with landowners and privately owned right-of-way	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection
Town Facilities – Public Works and Falmouth Transfer Station	Vegetated Buffer Strip	High - adjacent to road access and parking lot	Requires adequate space for vegetation	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation
	Rain Garden (Bioretention Cell)	High – adjacent to road access	Limited space, abutting parcel cooperation needed	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established

4.2 NON-STRUCTURAL NONPOINT SOURCE RESTORATION

Non-structural watershed restoration techniques refer to a broad range of behavioral practices, activities, and operational measures that contribute to pollutant prevention and reduction. The following section highlights important restoration techniques applicable to urban impaired watersheds like the Casco Bay Frontal Drainage watershed, including pollutant reduction best practices, stream restoration, zoning and ordinance updates, land conservation, septic system regulation, fertilizer use prohibition, proper agricultural practices, pet waste management, and nuisance wildlife controls.

4.2.1 Stormwater Management Best Practices

4.2.1.1 Municipal Separate Storm Sewer System

Maine's MS4 program covers municipally owned pipes, ditches, channels, or conveyances of any kind within designated urban areas designed to collect stormwater runoff. The MS4 program has been developed by EPA in phases as part of the NPDES program. Phase I covered large cities beginning in the 1990's, and beginning in 1999, Phase II began to apply to smaller municipalities in U.S. Census Bureau defined urbanized areas and other entities such as state departments of transportation. For an overview, see EPA's introduction to the MS4 program. The entire Casco Bay Frontal Drainage watershed is a regulated MS4 area.

EPA has delegated MS4 administration to many states including Maine. The urbanized area of Falmouth has been covered by Maine DEP's General Permit for the Discharge of Stormwater from Small MS4 since 2003. Additional state / federal MS4 areas within the Casco Bay Frontal Drainage watershed are governed by the General Permit for the Discharge of Stormwater From Maine DOT and Maine Turnpike Authority MS4 Facilities. See an overview Maine's MS4 program, and maps and documents for specific MS4s (including Falmouth and Maine DOT).

Falmouth's MS4 general permit was revised in 2022. The MS4 program has a comprehensive set of stormwater and water quality requirements. An outline of the main requirements follows:



STORMWATER MANAGEMENT PLAN

Six Minimum Control Measures (MCM)

MCM 1- Education/Outreach Program



MCM 2- Public Involvement and Participation



MCM 3- Illicit Discharge Detection and Elimination Program



MCM 4- Construction Site Stormwater Runoff Control



MCM 5- Post Construction Stormwater Management in New Development and Redevelopment



MCM 6- Pollution Prevention/Good Housekeeping for Municipal Operations





Annual Report

Maine DOT related MS4 documents, including annual reports, are published on Maine's website under the Maine DOT Stormwater section. MS4 annual reports are sources of detailed information on municipal management within the Casco Bay Frontal Drainage watershed.

4.2.1.2 Municipal Stormwater Practices

The Town of Falmouth follows a Stormwater Management Plan which was last updated in 2022. The Stormwater Management Plan outlines goals including education and outreach, public involvement and participation, Illicit Discharge Detection and Elimination Program, construction and post-construction stormwater management, and municipal facilities and operations. Within the Stormwater Management Plan, Falmouth identifies the Mill Creek and Casco Bay watersheds as priority watersheds. In these watersheds and throughout the town, Falmouth has implemented a multifaceted strategy for stormwater management. Policy changes such as a stormwater discharge ordinance and enhanced standards for stormwater management have been enacted. Pollution prevention efforts involve ongoing street sweeping and catch basin cleaning programs, along with required construction site inspections. Education and outreach initiatives engage the community and schools, with the support of the Cumberland County Soil and Water Conservation District.

Further recommendations include:

- Implement the BMP suggestions from this WMP that are on municipal properties or rights-of-way.
- Prioritize streets in the Casco Bay Frontal Drainage watershed for street sweeping after snowmelt. Consider increasing the frequency that these streets are swept, such as conducting opportunistic sweeping of major watershed roads ahead of major rainfall events.
- Develop public-private agreements to sweep large commercial parking lots in priority watersheds.

Falmouth's Stormwater Discharge Ordinance

"Except as allowed or exempted herein, no person shall create, initiate, originate or maintain a non-stormwater discharge to the storm drainage system. Such non-stormwater discharges are prohibited notwithstanding the fact that the municipality may have approved the connections, drains or conveyances by which a person discharges unallowed non-stormwater discharges to the storm drainage system."

Allowable discharges: Exempt and allowable discharges include landscape irrigation, air conditioning condensate, lawn watering runoff, hydrant flushing, and individual residential car washing. The full list of exemptions is available in Section 20-6.b of the ordinance.

Enforcement: The ordinance permits the town to conduct monitoring or construct physical barriers to restrict access to the storm drainage system for violations of the ordinances. Violation penalties include notices, disconnection from system, fines, penalties, or injunctive relief.

The 2021 Strategic Watershed Management Plan recommended that the Town consider a salt management program as a moderate/low priority item for Norton Brook, Webes Creek, Chenery Brook, and Mill Creek watersheds. Baseflow chloride toxicity was identified as a current stressor to Webes Creek and potential future stressor to the other four as part of Maine DEP's Streams Stressor Report, finalized in 2022.

The Town maintains a public sand pile at the Public Works Facility. The public pile is stored outside of the municipal sand/salt shed and is not located under cover. Residents are allowed to take up to two five-gallon buckets at a time.

Recommendations to improve low-impact winter road maintenance are as follows:

- Store the public sand pile under cover to prevent wash out.
- Implement educational tactics to teach residents proper techniques which achieve deicing goals while reducing overall salt usage.
- Conduct outreach to commercial contractors responsible for winter management in privately-owned portions of the watershed to better understand current chloride practices. If needed, develop recommendations for reducing chloride outputs to improve water quality while maintaining safety.
- Consider creating or supporting a Green SnowPro Certification, modeled after the New Hampshire program, to certify that commercial salt applicators are following proper salt reduction practices.
- Consider implementing brine applications on roads to reduce the amount of rock salt that is required.
- Discuss with Maine DOT designating the portion of I-295 in the Casco Bay watershed a reduced salt area.
- Encourage structural practices such as impervious surface reduction, covered parking, or heated sidewalks, that reduce the area requiring deicing treatment.
- Consider reduction of public sand distribution limits and enforcement of current limits.

NH Green SnowPro Program

To protect New Hampshire waters from increased chloride concentrations, the New Hampshire Green SnowPro Program offers snow and ice management professionals training and certification in state of the art salt reduction practices that prioritize public safety while mitigating salt usage.

In return for their efforts, commercial salt applicators certified by New Hampshire Green SnowPro and property owners or managers who hire them, are granted liability protection against damages arising from snow and ice conditions.



Maine DOT truck applying salt brine. Photo by Kennebec Journal.

4.2.1.3 State Stormwater Practices

Maine DOT also has a Stormwater Management Plan. It includes strategies for managing stormwater including outfall inspections, catch basin cleaning, street sweeping, salt application, and construction stormwater controls, among other items.

Maine DOT has specialized chloride controls for managing impervious cover in the watersheds of urban impaired streams, but as the Casco Bay Frontal Drainage streams are not listed as urban impaired streams by Maine DEP, the controls are not applicable. Considering the high specific conductivity and

chloride levels in parts of the Casco Bay Frontal Drainage watershed, particularly in the Webes Creek and Skitterygusset Creek subwatersheds, Maine DOT should apply these same chloride controls to all impervious cover it manages in the watershed.

4.2.2 Zoning and Ordinance Updates

Municipal zoning, ordinances, and health regulations, including low impact development strategies, are just as crucial as structural BMPs for preventing polluted runoff from new and redeveloped areas. In many watersheds, local land use planning and zoning regulations are among the most effective tools for protecting water quality.

The Town of Falmouth has a Solid Waste ordinance that declares dumping in any areas besides permitted facilities illegal and subject to a minimum fine of $250. Household and electronic waste dumping have been noted on several open space properties, which are removed by the Falmouth Land Trust and Town staff. There have not been major issues with dumping within Town rights-of-way, though occasional yard waste and other debris are encountered during outfall inspections. Enforcement has been challenging with the perpetrators unknown.

- Perform annual inspection of areas where dumping has frequently occurred to track it and attempt to identify the source.
- Expand existing watershed signage that dumping is illegal at problem locations. Consider the temporary installation of trail cameras to further enforce if additional action is necessary.

Falmouth zoning ordinances (Figure 16) are outlined through the Zoning and Floodplain Management within Chapter II-19 of the Town Charter and Code of Ordinances. This code contains four Shoreland Districts, all of which are represented within the Casco Bay Frontal Drainage watershed.

Suggested improvements to the Zoning and Floodplain Management Ordinance to better protect Casco Bay include:

- Extend the Shoreland Zone to fully cover all Casco Bay tributary streams. Consider applying Stream Protection or Resource Protection District status wherever possible for maximum protection.
- Consider expanding resource protection zoning to wetlands smaller than 10 acres.
- Require stormwater management plans for all development, particularly within the Shoreland Zone.
- Consider defining explicit setbacks for fill within the Shoreland Zone (e.g., 50 feet) similar to buildings and parking. Despite protections within the Shoreland Zone, some riparian areas within the tributary streams still exhibit fill encroachment. Setting explicit setbacks for fill will prevent construction plans that endanger the geomorphology of floodplains from slipping through site plan reviews while simultaneously protecting the proposed construction from potential erosion issues in the future.
- Consider possible incentives (e.g., reduced permitting fees) to any project that restores vegetated stream buffers in areas that currently lack it.

The full ordinance review and recommendations is provided in Table 11.

Table 11. Ordinance review of regulatory and non-regulatory tools for natural resource protection in the Town of Falmouth.



Regulatory Tools

STRATEGY	Existing Status	Recommendation
Zoning districts addressing environmental protection.	Accounted for in Shoreland Zone (especially Stream Protection and Resource Protection Districts) and the Resource Conservation Zoning Overlay District.	Periodically review environmental protections and strengthen where appropriate. Consider weaving in environmental protections into other zones and overlays.
Shoreland zoning.	Shoreland Zone Overlay extends 250 feet from great ponds, rivers, coastal wetlands, and freshwater wetlands ≥10 acres, and 100 feet from streams. Four districts make up the Shoreland Zone: Resource Protection, Limited Residential, Limited Commercial, and Stream Protection. Each district regulates clearing, fill, structures, soil disturbance, etc., to protect water quality and habitat. A list of land use permitted within districts of the shoreland zone are listed in Table 1 of Sec. 19-100. Portions of Mill Creek, Chenery Brook, Webes Creek, and Norton Brook fall within the Stream Protection District. Where the streams converge, they are under Resource Protection, surrounded by sections of Limited Commercial and Limited Residential. Skitterygusset Creek is not protected under the Stream Protection District, but the mouth of the stream contains sections of Resource Protection, Limited Commercial, and Limited Residential.	Ensure that the entirety of Mill Creek, Chenery Brook, Webes Creek, Norton Brook, and Skitterygusset Creek are within the Shoreland Zone. Apply Stream Protection or Resource Protection District status where feasible. Ensure enforcement of riparian buffer standards and consider incentives for restoring buffers that are currently missing. Consider requiring stormwater management plans for all development.
Cluster development and/or open space provisions for subdivisions.	Mixed Use Cluster District. The Resource Conservation Zoning Overlay District, which covers most of the Town, includes standards for Conservation Subdivisions (which requires a significant portion of the site as common open space that is permanently protected) and identifies it as the preferred form of development. Much of the Norton Brook, Chenery Brook, and Webes Creek watersheds are not covered by the Resource Conservation Zoning Overlay District.	Consider incentivizing conservation subdivisions.

STRATEGY	Existing Status	Recommendation
Protection of wetlands.	Wetlands 10 acres or larger are protected through the Shoreland Zone overlay. The Subdivision Ordinance also contains wetland setback requirements.	Consider expanding protections to wetlands smaller than 10 acres.
Protection of groundwater.	No separate groundwater protection overlay. Well Exclusion Zones under the Subdivision Ordinance restrict placement of wells based on proximity to septic systems and exceedances of nitrate levels.	Create a groundwater protection overlay with restricted land uses for groundwater protection surrounding aquifers and public well resources.
Protection of steep slopes.	Within the shoreland zone, in areas of two or more contiguous acres with sustained slopes of 20% or greater, the boundary of the Resource Protection District shall extend a distance of 50 feet beyond the top of slope moving away from the water body. Small areas of slopes less than 20% may be included where there is a consistent and well defined top of bank, or where such areas are completely surrounded by steeper slopes.	Consider further restricting development on steep slopes beyond the Shoreland Zone, particularly on slopes greater than 25%.
Septic pump-out ordinance or regulation of septic and sewer systems.	No town-wide pump-out ordinance. Single-family residences with availability to the public sewer system but electing to remain on a septic system for up to 10 years must provide an inspection or pump-out their system every two years. Article II-18-2 regulates the Town's sewer system.	Require septic pump outs & inspections throughout town, or within an overlay district (such as the shoreland zone). Require inspections at point of sale or home expansion, Require certain design criteria (such as advanced systems for enhanced nutrient removal) in sensitive areas.
Nutrient loading analysis required for fresh waterbodies.	None identified.	Require stormwater management plans or phosphorus control plans to quantify nutrient loading from planned developments and the estimated load reductions from BMPs and low impact development techniques.
Low impact development requirements and standards.	Falmouth has prepared a Model Low Impact Development Ordinance as part of MS4 permit compliance; this draft outlines potential low impact development measures for adoption into local standards. The draft is dated 2022. Low impact development standards are also included in Chapter 3 of the Stormwater Management Manual.	Implement the draft Low Impact Development Ordinance.

STRATEGY	Existing Status	Recommendation
Fertilizer and/or pesticide ordinances.	Pesticide and fertilizer Regulation (Ch. 11-21). Requires annual registration and reporting of pesticide/fertilizer applicators, bans outdoor application between December 1 and March 31, bans application of specific materials, and exempts some land including commercial agriculture and commercial horticulture. An update to the ordinance was passed in February of 2025, banning pesticide and fertilizer applications within 75 feet of any body of water and within 20 feet of a storm drain.	Continue providing education, outreach, and enforcement surrounding the fertilizer/pesticide ordinance.
Environmental Ordinances (e.g. green building codes, green infrastructure, tree preservation, limits on impervious cover)	Municipal Green Building Ordinance (Ch II-24) establishes performance requirements for constructing and renovating town buildings and facilities to maximize energy performance, minimize adverse environmental impacts, provide healthy workplaces, conserve natural resources, promote sustainable development, and achieve portfolio-wide zero emissions in government operations by 2040 to mitigate the impacts of climate change. This is done by seeking LEED certification for all relevant projects, prioritizing proven energy efficiency strategies, providing EV infrastructure, and eliminating the use of non-emergency fossil fuel systems and appliances.	Consider incentivizing green building and green infrastructure practices in private development. Implement impervious cover limits, particularly within the Shoreland Zone. Consider other environmental policies such as tree preservation and require the use of native species in landscaping.
Implement and enforce a Stormwater Management Plan.	Falmouth's Stormwater Management Plan aligns with the Maine DEP MS4 General Permit (2022–2027), requiring stormwater controls, BMP implementation, illicit discharge detection/elimination, and annual reporting. The town has a Stormwater Management page describing implementation, ordinances to prohibit non-stormwater discharges, and how stormwater controls apply to new development.	Continue implementing the approved Stormwater Management Plan.

Conservation Funding Strategies

STRATEGY	Existing Status	Recommendation
Development transfer overlay district.	None identified.	Create a Development Transfer Overlay District encompassing infrastructure-dense areas and growth areas. This overlay district may allow a developer to build at additional density within these areas upon payment of a fee, which is then used to purchase conservation land in areas rich in natural resources or prioritized for conservation.
Conservation impact fees.	None. The 2018 Open Space Plan recommends to: "implement a fee for development impacts within natural resources and buffers, with the funds dedicated to protecting natural resources and buffers in other parts of the town."	Implement conservation impact fee.
Stormwater utility district or fee.	None identified.	Conduct a feasibility study for implementation of a stormwater utility fee. Stormwater utility fees can generate funds for stormwater infrastructure maintenance, replacement, green infrastructure, and more to prevent or mitigate localized flooding, combined sewer overflows, or infrastructure failure. Consult with other municipalities that have stormwater utilities, such as Portland, Lewiston, Bangor, and Augusta, for advice and examples of how a utility could be designed for Falmouth.
Open space or non-lapsing conservation fund.	The 2018 Open Space Plan says that the Town will help fund new open space acquisitions. In 2007, voters approved $5,000,000 over the next 10 years to fund the acquisition of open space.	Establish an open space or non-lapsing conservation fund.
Participate or collaborate with a local watershed association.	Casco Bay Estuary Partnership (CBEP).	Continue partnering with CBEP. Consider supporting the establishment of a local watershed group or groups for the Falmouth Casco Bay Frontal Drainage Streams.

STRATEGY	Existing Status	Recommendation
Participate or collaborate with a local land trust.	Local land trusts include: Falmouth Land Trust, Chebeague and Cumberland Land Trust, Maine Audubon, and the Maine Coast Heritage Trust.	Continue collaborating with local land trusts to conserve land.



Non-regulatory Strategies

STRATEGY	Existing Status	Recommendation
Open space plan.	Yes, 2018 Open Space Plan.	Implement the Open Space Plan recommendations.
Comprehensive plan addresses natural resources and environmental protection.	Yes, Comprehensive Plan was updated in 2025. The first pillar of the plan is: "continue to pursue environmental protection and sustainable practices." This includes protecting and maintaining existing open spaces, enhance environmental health, strengthen Falmouth as a green and sustainable community, and promote improvements and initiatives that enhance climate resiliency. Chapters on Water Resources, Natural Resources, Agriculture and Forestry, Marine Resources, and Sustainability highlight environmental protections.	Implement the Comprehensive Plan and other actions that support the goals of the Comprehensive Plan.
A town-wide natural resources inventory.	None identified.	Create a town-wide Natural Resources Inventory.
Stormwater system mapping	In progress with the Town's Open Gov asset management platform. These layers are not available on the Town's Public Vision Geographic Information Systems map.	Continue mapping stormwater infrastructure.
Consistent Public Outreach and Engagement / Public education programs	Education and outreach is one of the MCMs of Falmouth's MS4 permit. Outreach is led by the Cumberland County Soil and Water Conservation District (CCSWCD). The Town also has a webpage dedicated to stormwater management.	Continue supporting CCSWCD's outreach efforts. Continue to share information on the Town's website. Post the WMP to the website when finalized.

STRATEGY	Existing Status	Recommendation
Incentive-based programs for voluntary low impact development implementation.	None currently exist, but incentives are recommended in the Climate Action Plan for using electricity over fossil fuels, renewable energy sources, and tree cover/green space construction for new and existing infrastructure.	Consider incentive based programs that encourage low-impact development.
Incentive-based programs for stormwater reduction efforts.	None identified.	Consider incentive-based programs for stormwater reduction efforts, such as retrofits or other BMPs.
Have established conservation commission.	Yes.	Continue doing great work with the conservation commission!
Encourage property owners to put land into farmland/tree growth programs.	None identified.	Encourage landowners to take advantage of state agricultural and forestry programs.

Local land use planning and zoning ordinances should consider incorporating environmental variability resiliency strategies for protecting water quality and improving stormwater infrastructure based on temperature changes, precipitation, water levels, wind loads, storm surges, wave heights, soil moisture, and groundwater levels (Ballestero, Houle, Puls, & Barbu, 2017). There are nine strategies which can aid in minimizing the adverse effects associated with environmental variability and include the following (McCormick & Dorworth, 2019).



- ***Installing Green Infrastructure and Nature-Based Solutions***
  Creating a network of interconnected natural areas and open spaces needed for groundwater recharge, pollution mitigation, reduced runoff and erosion, and improved air quality. Examples of green infrastructure and nature-based solutions include forest, wetlands, natural areas, riparian (banks of a water course) buffers, and floodplains; all of which already exist to various extents in the watershed and have minimized the damage created by intense storms. Other examples of engineered green infrastructure that apply concepts from nature to treat stormwater include Regenerative Stormwater Conveyance, bioswales, and infiltration tree trenches. As future development occurs, these natural barriers must be maintained or even increased to reduce runoff of pollutants into freshwater. See also Section 4.2.3: Land Conservation.

- ***Using Low Impact Development Strategies***
  Replacing traditional approaches to stormwater management using curbs, pipes, storm drains, gutters, and retention ponds with innovative approaches such as bioretention, vegetated swales, and permeable paving.

- ***Minimizing Impervious Cover***
  Impervious cover such as roads, buildings, and parking lots should be minimized by creating new ordinances and building construction design requirements which reduce the imperviousness of new development. Property owners can increase the permeability of their lots by incorporating permeable driveways and walkways. In some cases, reducing mandatory minimum parking spaces for development may help achieve this goal.

- ***Encouraging Riparian Buffers and Maintaining Floodplains***
  Municipal ordinances should forbid construction in floodplains, and in some instances, floodplains should be expanded to increase the land area to accommodate larger rainfall events. Vegetated riparian buffers and filter strips along waterways should be preserved and/or created to slow runoff and filter pollutants.

- ***Protecting and Re-establishing Wetlands***
  Wetlands hold water, reduce flooding, recharge groundwater, and mitigate water pollution, making them very important to preserve.



- ***Encouraging Tree Planting***
  Trees help manage stormwater by reducing runoff and mitigating erosion along surface waters. They also provide critical shading and cooling to streams and land surfaces.
- ***Promoting Sustainable Landscaping Using Native Vegetation***
  Landowners should promote the use of native vegetation in landscaping, and landscapers should become familiar with techniques which minimize runoff and the discharge of nutrients into waterbodies (Chase-Rowell, Davis, Hartnett, & Wyzga, 2012).
- ***Slowing Down the Flow of Stormwater***
  To slow and infiltrate stormwater runoff, roadside ditches can be armored or vegetated and equipped with turnouts, settling basins, check dams, or infiltration catch basins. Rain gardens can retain stormwater, while water bars can divert water into vegetated areas for infiltration. Water running off roofs can be channeled into infiltration fields and drainage trenches.
- ***Coordinating Infrastructure, Housing, and Transportation Planning***
  Coordinate planning for infrastructure, housing, and transportation to minimize impacts on natural resources. Critical resources, including groundwater, must be conserved and remain free of pollutants especially as future droughts may deplete groundwater supplies.

4.2.3 Land Conservation

Land conservation is essential to the health of a region, particularly for the protection of water resources, enhancement of recreation opportunities, vitality of local economies, and preservation of wildlife habitat. Land conservation is one of many tools for protecting water quality for future generations.

Throughout the watershed, there are numerous small parcels of conserved land, many of which are owned and managed by the Falmouth Land Trust (Figure 17). Notable examples include the Falmouth Nature Preserve, Tidewater Farm Preserve, and Pine Grove Preserve. Other significant conserved properties include Mackworth Island, which spans 100 acres and is jointly owned by the State of Maine and the Maine Educational Center for the Deaf and Hard of Hearing and the Maine Audubon's Gilsland Farm. The Falmouth Nature Preserve is the largest conserved area in the watershed, covering approximately 110 acres. Just to the north in Cumberland, the Broad Cove Reserve is another major conserved property. This 104-acre site includes both town-owned land and conservation easements held by the Chebeague & Cumberland Land Trust.

Conserving additional land in the future can help to protect water quality and habitat in the Casco Bay Frontal Drainage watershed by maintaining more acres as undeveloped land and providing vegetated buffers to capture and filter stormwater runoff.

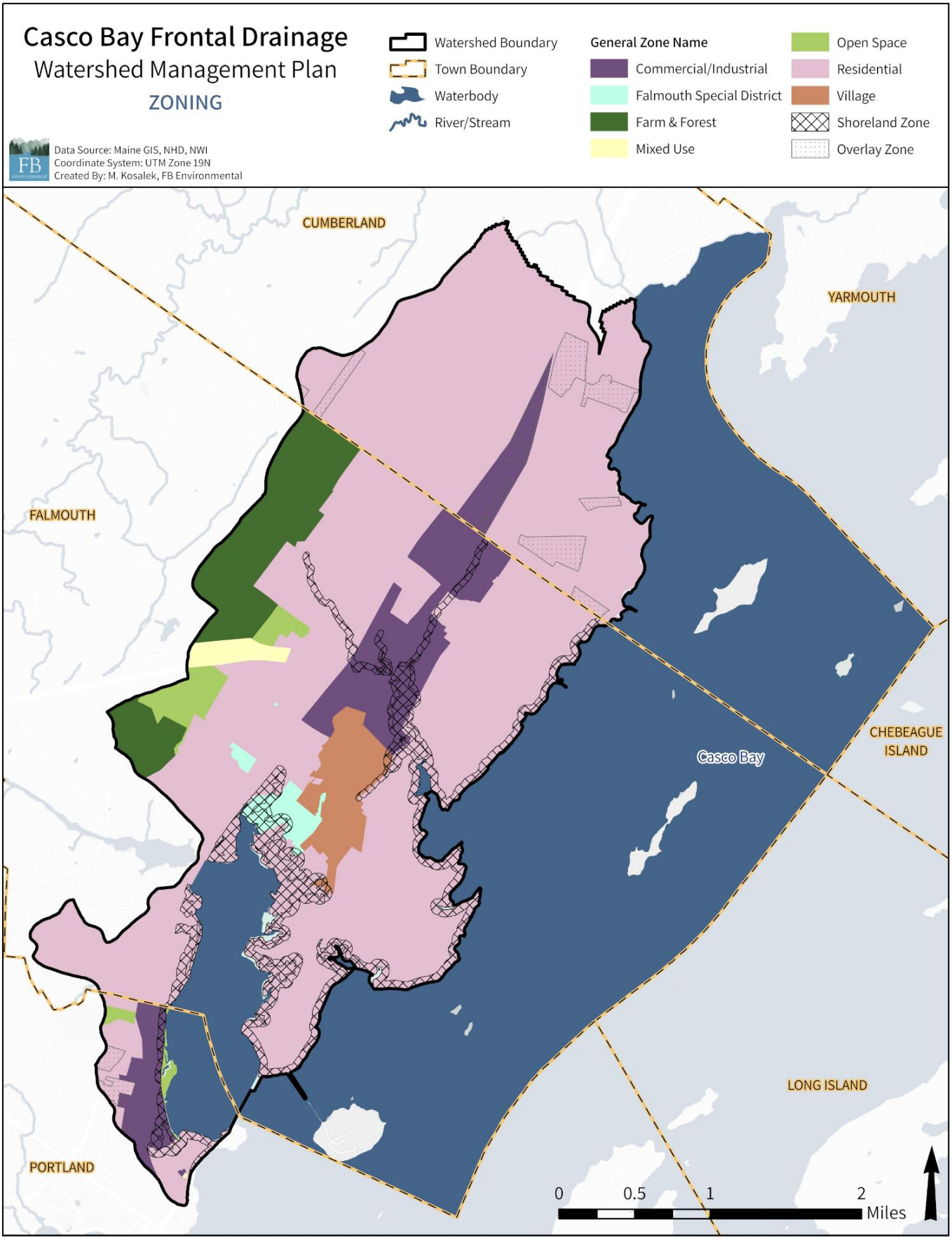


Figure 16. Casco Bay Frontal Drainage watershed zoning map.

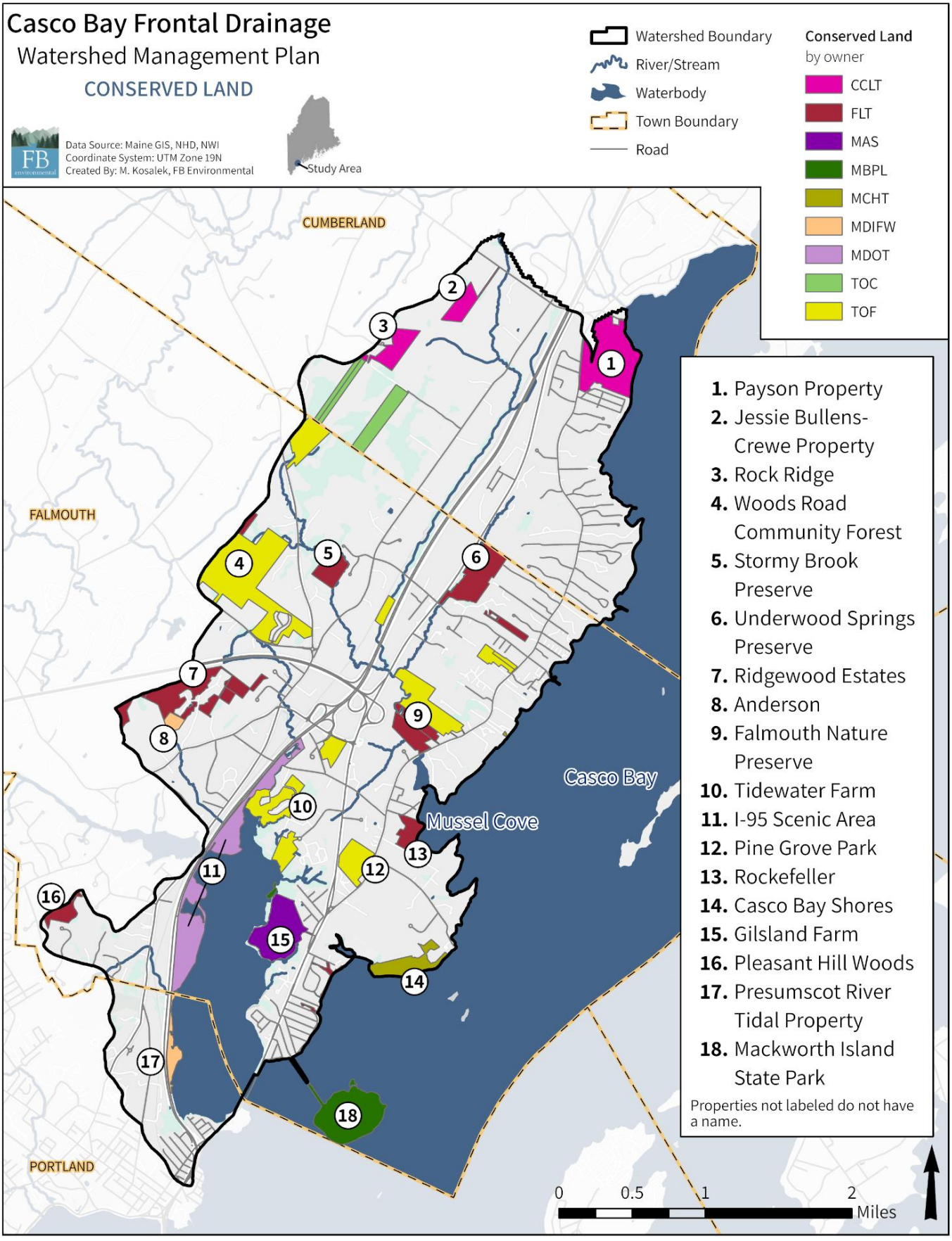


Figure 17. Map of conserved and municipally-owned land in the Casco Bay Frontal Drainage watershed.

4.2.4 Septic System Regulation

When properly designed, installed, operated, and maintained, septic systems can treat residential wastewater and reduce the impact of excess pollutants in ground and surface waters. It is important to note, however, that traditional septic systems are designed for pathogen removal from wastewater and not specifically for other pollutants such as nutrients. The phosphorus in wastewater is "removed" only by binding with soil particles or recycled in plant growth but is not removed entirely from the watershed system. Nutrient removal can only be achieved through more expensive, alternative septic systems. Proper design, installation, operation, maintenance, and replacement considerations include:

A. Proper **design** includes adequate evaluation of soil conditions, seasonal high groundwater or impermeable materials, proximity of sensitive resources (e.g., drinking water wells, surface waters, wetlands, etc.);

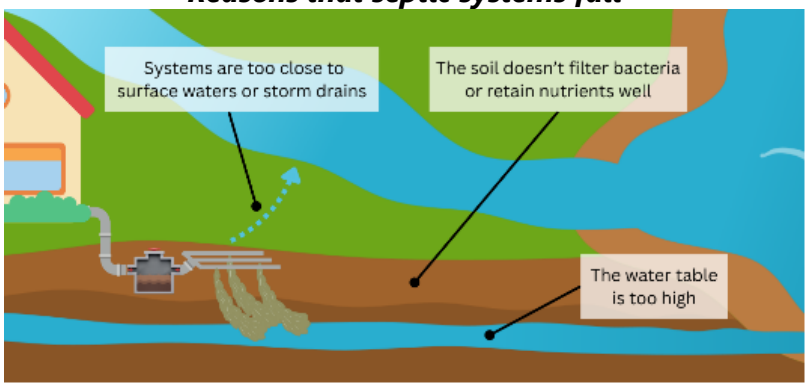
B. Proper siting and **installation** mean that the system is installed in conformance with the approved design and siting requirements (e.g., setbacks from waterways);

C. Proper **operation** includes how the property owner uses the system. While most systems excel at treating normal domestic sewage, disposing of some materials, such as toxic chemicals, paints, personal hygiene products, oils and grease in large volumes, and garbage, can adversely affect the function and design life of the system, resulting in treatment failure and potential health threats; proper operation also includes how the property owner protects the system; allowing vegetation with extensive roots to grow above the system will clog the system; driving large vehicles over the system may crush or compact piping or leaching structures;

D. Proper **maintenance** means having the septic tank pumped at regular intervals to eliminate accumulations of solids and grease in the tank; it may also mean regular cleaning of effluent filters, if installed. The frequency of septic pumping depends on the use and total volume entering the system. A typical 3-bedroom, 1,000-gallon tank should be pumped every 3-4 years;

E. Proper **replacement** of failed systems, which may include programs or regulations to encourage upgrades of conventional systems (or cesspools and holding tanks) to more innovative alternative technologies.

Reasons that septic systems fail



Management strategies for reducing water quality impacts from septic systems (as well as cesspools and holding tanks) start with education and outreach to property owners so that they are better informed to properly operate and maintain their systems. Other management strategies include setting local regulations for enforcing proper maintenance and inspection of septic systems and establishing funding mechanisms to support replacement of failing systems (with priority for cesspools and holding tanks).

4.2.5 Fertilizer and Pesticide Use Prohibition

The Town of Falmouth has a Pesticide and Fertilizer ordinance in place (effective 4/1/26) that aims to protect waterways and natural resources by curtailing the use of synthetic pesticides and fertilizers, and to further restrict the use of all pesticides and fertilizers within 75 feet of waterbodies and 20 feet of storm drains.

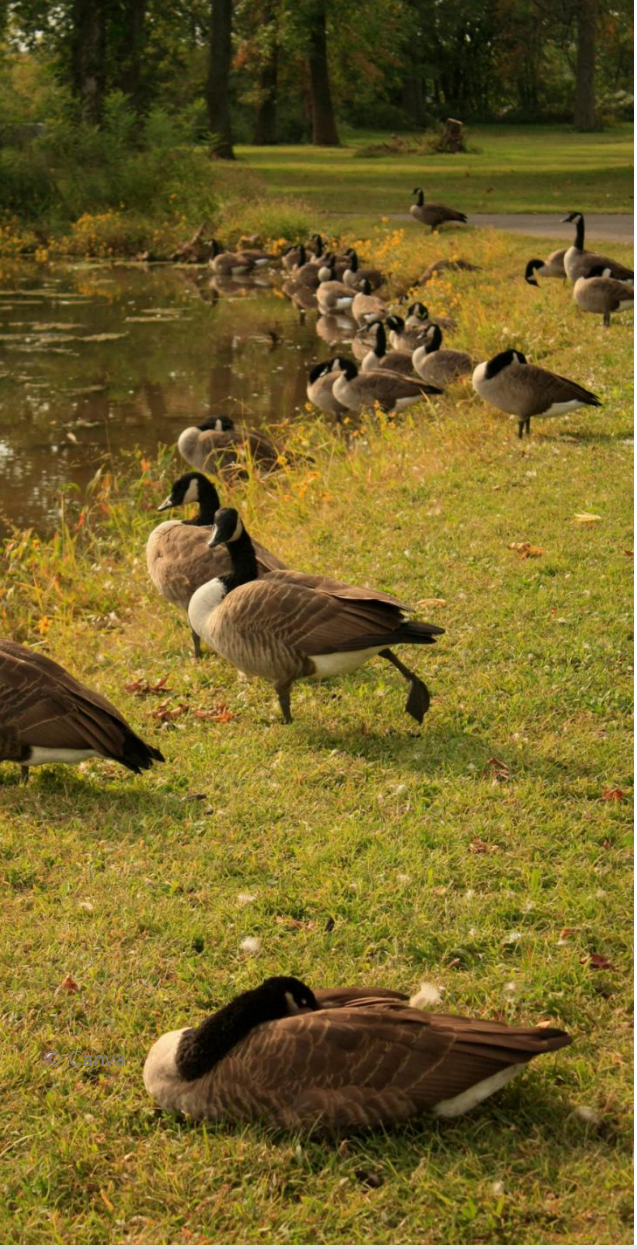
For pesticides, the ordinance permits organic pest management and the use of certain synthetic substances listed by the United States Department of Agriculture (USDA). It prohibits the use of all pesticides within 75 feet of waterbodies and 20 feet of storm drains. Certain activities and materials are exempt, including those related to commercial agriculture, golf courses, rights-of-way, town and school athletic fields, invasive plant and insect management, pet supplies, disinfectants, insect repellents, rat and rodent control supplies, swimming pool supplies, and general use paints and sealants. Specific applications, such as health and safety applications and treatments for invasive species, are also exempt.

The ordinance also imposes prohibitions and regulations on fertilizer applications. Prohibited actions include applying fertilizer within 75 feet of waterbodies or 20 feet of storm drains, outdoor applications between December 1 and March 31, and outdoor application of sludge and biosolids. It also restricts the use of fertilizers and compost within 75 and 250 feet of waterbodies, except for non-water soluble products. Nitrogen and phosphorus containing fertilizers on lawns and natural turf are restricted to a maximum of two pounds of nitrogen per 1,000 square feet per year on established turf and new development and a maximum of one pound of phosphorus per 1,000 square feet on new lawns or with a soil test that states phosphorus is needed. Applications are limited to twice a year.

As the new ordinance becomes law, the Town should ensure that there is sufficient outreach on and enforcement of these regulations within the Casco Bay Frontal Drainage watershed. Given the high density of both residential and commercial development in the watershed (with associated lawns), fertilizer and pesticide usage are important factors in the health of Casco Bay and its tributaries.

4.2.6 Pet Waste Management

Pet waste collection as a pollutant source control involves a combination of educational outreach and enforcement to encourage residents to clean up after their pets. Public education programs for pet waste management are often incorporated into a larger message of reducing pollutants to improve water quality. Signs, posters, brochures, and newsletters describing the proper techniques to dispose of pet waste can be used to educate the public and create a cause-and-effect link between pet waste and water quality (EPA, 2005). Adopting simple habits, such as carrying a plastic bag on walks and properly disposing of pet waste in dumpsters or other refuse containers, can make a difference. It is recommended that pet owners do not put dog and cat feces in a compost pile because it may contain parasites, bacteria, pathogens, and viruses that are harmful to humans and may or may not be destroyed by composting. "Pooper-scooper" ordinances are often used to regulate pet waste disposal. These ordinances generally require the removal of pet waste from public areas, other people's properties, and occasionally from personal property, before leaving the area. Fines are typically the enforcement method used to encourage compliance with these ordinances.



4.2.7 Nuisance Wildlife Controls

Human development has altered the natural habitat of many wildlife species, restricting wildlife access to surface waters in some areas and promoting access in others. Minimizing the impact of wildlife on water quality generally requires either reducing the concentration of wildlife in an area or reducing their proximity to a waterbody. There are a couple of options for combatting this:

Prohibit Feeding – Leverage educational outreach to discourage feeding of waterfowl or other wildlife. Consider developing an ordinance that prohibits the feeding of these animals.

Wildlife Repellent – Use scarecrows, kites, a daily human presence, or modification of habitat through plantings to reduce attractiveness of an at-risk area. Providing closed trash cans near waterbodies, as well as discouraging wildlife from entering surface waters by installing fences, pruning trees, or making other changes to landscaping, can reduce water quality impacts.



4.3 OUTREACH & EDUCATION

Awareness through education and outreach is a critical tool for protecting and restoring water quality. Most people want to be responsible watershed stewards and not cause harm to water quality, but many are unaware of best practices to reduce or eliminate contaminants from entering surface waters.

The following efforts are recommended:







Outreach Events

Catch basin stenciling: perform catch basin stenciling biannually. Consider creating public catch basin stenciling events or competitions to promote artistic, eye-catching, and impactful messages.

Watershed cleanups: hold clean ups for the watershed area and particularly along streams.

Socials: hold socials to raise awareness and teach homeowners about water quality, sewer lateral line maintenance, sustainable landscaping, fertilizer and pesticide use, pet waste disposal, waterfowl feeding, shoreline buffer improvements, and stormwater runoff controls.

Educational Campaigns and Materials

Educational campaigns should include raising awareness of water quality, sewer lateral maintenance, fertilizer and pesticide use, pet waste disposal, waterfowl feeding, invasive aquatic species, streambank buffer improvements, dumping in the stream, and stormwater runoff controls. Provide educational materials to existing and new property owners, as well as renters, by distributing them at various locations and through a variety of means, such as websites, newsletters, social media, community events, and community gathering locations.

Collaboration

Engage with local stakeholders such as land trusts, municipalities, conservation commissions, businesses (particularly landscapers), and landowners. Engage local students to teach them about their environment and involve them in volunteer work.

4.4 ADAPTIVE MANAGEMENT APPROACH

Establishing a formal committee to coordinate an adaptive management approach is strongly recommended. This approach enables stakeholders to implement restoration actions in phases, using the best available information. Ongoing watershed and water quality monitoring help assess effectiveness of actions, allowing for strategy adjustments before the next restoration phase. Adaptive management ensures efficient resource use through BMP performance testing and monitoring while maintaining a continuous program with adequate funding, stakeholder guidance, and coordination to track long-term restoration progress. The adaptive management components for implementation efforts should include:



Maintaining an Organizational Structure

A diverse stakeholder group, including agencies, municipalities, businesses, and landowners, should coordinate watershed management actions, with a formal structure and clear communication.

Refer to Section 6.1 for more information on plan oversight.



Establishing a Funding Mechanism

A mix of grants, private donations, and municipal funding should be used to support implementation and management actions.

Refer to Section 6.3 for a list of potential funding sources.



Determining Management Actions

This plan provides a menu of restoration options which serve as a foundation for grant proposals. Once a funding mechanism is established, priority restoration projects can be designed and scheduled for implementation.

Refer to Section 5.1 for detailed management actions.



Continuing and Expanding the Community Participation Process

Plan development has actively involved a diverse group of stakeholders, and successful implementation will require their continued participation, along with expanded support, gathered through ongoing public awareness campaigns.

Refer to Section 4.3 and 5.1 for outreach recommendations.



Continuing the Long-Term Monitoring Program

A water quality monitoring program is necessary to track water quality and measure effectiveness of management practices.

Refer to Section 6.4 for monitoring options.



Establishing Measurable Milestones

A restoration schedule with milestones for actions and monitoring is essential for the plan's success. Environmental, social, and programmatic indicators have also been identified to track progress.

Refer to Section 6.5 for measurable milestones

5 ACTION PLAN

5.1 ACTION PLAN

The Action Plan (Table 12) outlines responsible parties, approximate costs, an implementation schedule, and potential funding sources for each recommendation within the following major categories: (1) Watershed & Shoreline BMPs; (2) Municipal Operations; (3) Municipal Land Use Planning & Zoning; (4) Land Conservation; (5) Wastewater Management; (6) Education and Outreach; (7) Water Quality Monitoring; and (8) Implement Plan and Monitor Plan Efficacy. The plan is designed to be implemented from 2026-2036 and is flexible to allow for new priorities throughout the 10-year implementation period as additional data are acquired. Cost estimates are broad planning level estimates that will need to be adjusted based on further research and site design considerations.

Table 12. Action Plan for the Casco Bay Frontal Drainage watershed.

Action Item 1: Watershed and Shoreline BMPs

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
1a	Complete design and construction of stormwater BMPs at the eight Phase I locations within the Webes Creek and Norton Brook subwatersheds.	Towns, private landowners	$398K-$1.05M 2026-2030	CWSRF, Grants (319, CAG, MIAF, MSC, CCG, NFWF 5-Star), Municipalities, private landowners
1b	Complete design and construction of stormwater BMPs at the eight Phase II locations within the Skitterygusset Creek, Mill Creek, and Chenery Brook subwatersheds.	Towns, private landowners	$176.5K-$600K 2030-2036	CWSRF, Grants (319, CAG, MIAF, MSC, CCG, NFWF 5-Star), Municipalities, private landowners

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
1c	Complete design and construction of the 36 high priority geomorphic restoration projects.	Towns, private landowners	$5.5M-$8.3M 2026-2030	Grants (319, CBEP, CAG, MIAF, MSC, CCG, MNRCP, MOHF, NFWF NEFRG, NAWCA), Municipalities, private landowners
1d	Complete design and construction of the moderate priority geomorphic restoration projects.	Towns, private landowners	$2.5M-$3.8M 2030-2036	Grants (319, CBEP, CAG, MIAF, MSC, CCG, MNRCP, MOHF, NFWF NEFRG, NAWCA), Municipalities, private landowners
1e	Complete design and construction of the low priority geomorphic restoration projects as time and budgets allow.	Towns, private landowners	$1.8M-$2.7M 2026-2036	Grants (319, CBEP, CAG, MIAF, MSC, CCG, MNRCP, MOHF, NFWF NEFRG, NAWCA), Municipalities, private landowners
1f	Provide technical assistance and/or implementation cost sharing to watershed/shoreline property owners to install stormwater and/or erosion controls such as rain gardens and buffer plantings. Prioritize high impact properties (scores 9+) identified during the shoreline survey. Cost assumes technical assistance and implementation cost sharing provided to the 10 high impact shoreline properties.	Private landowners, CCSWCD, Towns	$40K-60K 2026-2030	Grants (319, CBEP, CAG, CCG), private landowners
1g	Provide technical assistance and/or implementation cost sharing to watershed/shoreline property owners to install stormwater and/or erosion controls such as rain gardens and buffer plantings on the medium impact properties (scores 7-9) identified during the shoreline survey. Cost assumes technical assistance and implementation cost sharing provided to the 18 medium impact shoreline properties.	Private landowners, CCSWCD, Towns	$72K-$96K 2030-2036	Grants (319, CBEP, CAG, CCG), private landowners

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
1h	Repeat the shoreline and watershed surveys in 5-10 years when updating the WMP. Use the results to target education and technical assistance for high impact sites. Cost assumes hired consultant for survey and summation of shoreline survey results.	Towns, consultant	$7K 2031, 2036	Municipalities, Grants (604b, CCG, CBEP), CWSRF

Action Item 2: Municipal Operations

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
2a	Provide education and training to contractors and municipal staff on protocols for road maintenance best practices. Assumes two workshops. Consider holding joint workshops with other municipalities or groups for cost sharing savings.	Towns, CCSWCD	$15K 2027, 2031	Municipalities, Grants (CBEP, 319)
2b	Contact the Maine DOT regarding decreasing their road salt usage on state roads within the watershed due to current trends in water quality and discuss reduced salt areas and low-salt approaches.	Towns, Maine DOT	N/A 2026-28	N/A
2c	Expand the street sweeping program to prioritize more frequent sweeping in highly impervious watersheds such as Webes Creek, Skitterygusset Creek, and Norton Brook subwatersheds. Consider opportunistically sweeping prior to large storm events to prevent debris from being washed into waterways.	Towns	TBD 2026-2036	Municipalities
2d	Review and update winter operations procedures to be consistent with Green SnowPro BMPs for winter road, parking lot, and sidewalk maintenance. Continue practicing low salt application practices in the watershed.	Towns	N/A 2026	N/A

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
2e	Review current protocols for catch basin cleaning. Prioritize and consider increasing the frequency of cleaning for priority problem areas (such as the Webes Creek subwatershed).	Towns	N/A 2026-2028	N/A
2f	Continue to comply with Maine DEP's General Permit for discharge of stormwater from MS4. Adjust the Towns' next round of minimum control measures to address priority issues identified in this plan.	Towns, CCSWCD	N/A 2026-2036	N/A
2g	Create a funding mechanism to fund stormwater and stream improvements (e.g., stormwater utility fee).	Towns	N/A 2028-2032	N/A
2h	Develop a public-private partnership program to incentivize BMP implementation through cost sharing and planning and labor support. Discuss parameters of the program including, but not limited to, how the program will be funded (e.g., stormwater utility), minimum and maximum project size, eligibility (i.e., homeowners, commercial properties, etc.), etc.	Towns	N/A 2030-2036	N/A



Action Item 3: Municipal Land Use Planning and Zoning

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
3a	Incorporate WMP recommendations into municipal master plans and encourage regular review of the WMP action plan.	Municipalities	N/A 2025-29	Municipalities
3b	Adopt/strengthen zoning ordinance provisions and enforcement mechanisms in the Town of Falmouth. See below for key recommendations and full recommendations in Table 11.	Town of Falmouth	TBD 2027-2036	Town of Falmouth

	1) promote or require low impact development practices through ordinances, incentives, and/or education 2) extend shoreland zoning protections to all Casco Bay tributary streams 3) require stormwater management plans for all development 4) create a groundwater protection overlay district 5) impose limits on impervious areas, particularly within the Shoreland Zone			
3c	Conduct an ordinance review for the Town of Cumberland. Amend the WMP with recommendations to protect water quality and habitat.	Town of Cumberland	$3k-$5k 2026-2027	Town of Cumberland
3d	Conduct a feasibility study for implementation of a stormwater utility in Falmouth.	Town of Falmouth	$40k-$60k 2028-2030	Town of Falmouth, CWSRF
3e	Increase municipal staff capacity through code enforcers/ building inspectors for inspections and enforcement of stormwater and other environmental regulations.	Municipalities	TBD 2026-34	Municipalities

Action Item 4: Land Conservation

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
4a	Complete a Natural Resources Inventory for the Towns of Falmouth and Cumberland.	Towns, Conservation Commissions	$25K-$35K per municipality 2028-30	Municipalities, Grants (CAG, MOHF)
4b	Create a priority list of watershed areas that need protection based on NRIs. Refer to Section 4.2.3 to understand current conservation lands	Towns, Conservation Commissions,	$4K-8K 2030-31	Municipalities, Grants (CAG, MOHF)

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
	and valuable habitats and wildlife in the watershed that can be used to help identify potential areas to target for conservation.	Falmouth Land Trust or other local land trusts		
4c	Identify potential conservation buyers and property owners interested in easements within the watershed. Use available funding mechanisms to provide conservation assistance to landowners.	Towns, Conservation Commissions, Falmouth Land Trust or other local land trusts	N/A 2028-33	Grants (FPF, MNRCP, MOHF, NAWCA, LWCF, ORLP, L4C, LMFP)
4d	Maximize conservation of intact forest and other ecologically important properties through education, zoning, and public or private conservation. Officially designate undeveloped Town-owned land in the watershed as conservation land.	Towns, Conservation Commissions, Falmouth Land Trust or other local land trusts	TBD 2029-36	Grants (FPF, MNRCP, MOHF, NAWCA, LWCF, ORLP, L4C, LMFP), Municipalities, private landowners
4e	Enhance community education regarding private land conservation easements. Host workshops educating landowners on the benefits. Cost variable depending on outreach methods and number of workshops.	Conservation Commissions, Falmouth Land Trust or other local land trusts	$5K - $15K 2026-31	Municipalities, private landowners, land trusts



Action Item 5: Wastewater Management

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
5a	Continue to regularly inspect sewer lines for leaks or other maintenance concerns. Prioritize repairs that are near receiving waterbodies.	Towns	TBD 2026-2036	Municipalities, CWSRF, USDA, EPA

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
5b	Create ordinance that requires the inspection of private sewer laterals for all property sales. Require upgrades if needed.	Towns	N/A 2028-2032	Municipalities
5c	Distribute educational materials to property owners about septic system function and maintenance.	Towns, Conservation Commissions	$2K-$8k 2026, 2030, 2035	Municipalities, Grants (319)
5d	Develop and maintain a town-wide septic inventory database base to facilitate code enforcement of any septic system ordinances.	Towns	$15k-$25k/town 2027-2028	Municipalities, CAG
5e	Evaluate locations of older and/or noncompliant septic systems (including cesspools or holding tanks) to identify clusters where conversion to sewer might be desirable or assist landowners in replacing failing septic systems.	Towns	$1k 2029	Municipalities, Grants (CAG, SCG)
5f	Conduct a septic system risk assessment to identify areas in town which may be more susceptible to septic system malfunction due to high groundwaters, soil filtering capacity, risk of flooding, age of infrastructure, and/or sea level rise and salt intrusion.	Towns	$15k-$20k 2029-30	Municipalities, CAG

Action Item 6: Education and Outreach

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
6a	Create a dedicated page on the Town of Falmouth website to share watershed information such as water quality data, plans, and educational materials. Periodically share information on town-wide emails, newsletters, or mailing lists.	Towns	TBD 2026	Town

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
6b	Educate private property owners on questions to ask hired landscaping companies to ensure they are complying with fertilizer and pesticide rules.	Conservation Commissions, Towns	N/A 2026-2028	N/A
6c	Coordinate with local organizations to establish a volunteer clean-up program in the Casco Bay Frontal Drainage watershed (or consider creating one for each of the five stream subwatersheds). Host annual volunteer clean ups.	Conservation Commissions, Towns	$3K-$6K 2026-2036	Municipalities, Grants (CBEP, 319)
6d	Educate contractors, planning board members, and municipal staff about erosion and sediment control practices required on plans. Ensure that there are sufficient resources to enforce permitting conditions.	Towns, Planning Boards	N/A 2026-2028	Municipalities, Grants (319, CBEP)
6e	Create flyers/brochures or other educational materials through printed or online mediums, regarding topics such as stormwater controls, buffer improvements, fertilizer and pesticide use, pet waste disposal, deicing, waterfowl feeding, and septic system maintenance.	Conservation Commissions, Towns, CCSWCD	$2K-$10K 2026-2030	Municipalities, Grants (319, CBEP)
6f	Install educational materials at public salt and sand piles to demonstrate proper use. Consider strict enforcement measures or limits to household allotments.	Towns	$500-$1K 2026	Municipalities
6g	Install pet waste signs and disposal stations in key areas of the watershed.	Towns, Falmouth Land Trust	$1K-$5K 2026-2028	Municipalities, Grants (319, CBEP)

Action Item 7: Water Quality Monitoring

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
7a	Conduct annual monitoring of Webes Creek, Skitterygusset Creek, Mill Creek, Norton Brook, and Chenery Brook, as well as the Bay. Consider enrolling through the Volunteer River Monitoring Program or hiring a consultant if town capacity is not sufficient to carry out the monitoring plans.	Towns	TBD 2025-34	Municipalities, Grants (CBEP, CCG)
7b	Conduct biomonitoring within all five stream watersheds every five years. Coordinate with Maine DEP to get the streams on the Biomonitoring Team's rotating schedule.	Maine DEP	N/A 2030, 2035	Maine DEP
7c	Periodically update water quality goals for each stream as needed based on monitoring results.	Towns, Maine DEP, Consultant	TBD 2030, 2035	N/A

Action Item 8: Implement Plan and Monitor Plan Efficacy

#	Sub-Item Description	Responsible Party	Estimated Cost / Schedule	Potential Funding Sources
8a	Host annual meetings to coordinate implementation efforts. Meetings should review action items, outline upcoming projects, delegate tasks, strategize potential funding opportunities, and assess implementation progress to determine if adaptive management measures are needed.	Towns	N/A 2026-2036	N/A
8b	Identify and apply for relevant grants to fund implementation efforts, particularly for structural recommendations and land conservation.	Towns	N/A 2026-2036	N/A
8c	Review WMP effectiveness and prepare for WMP update after 10 years.	Towns	N/A 2035-2036	N/A

6 IMPLEMENTATION & EVALUATION

The following section outlines the oversight structure, estimated implementation costs, and funding strategy for the recommended action items in the Action Plan (Section 5), along with the monitoring plan and performance indicators to track progress over time.

6.1 PLAN OVERSIGHT

The recommendations of this plan will be carried out largely by the Falmouth Department of Public Works with assistance from a diverse stakeholder group, including representatives from other Town departments (e.g., Planning, Planning Board, Conservation Commission, Town Council, etc.), the Town of Cumberland, state and federal agencies or organizations, nonprofits, schools and community groups, local business leaders, and landowners. The Action Plan (Section 5) will need to be updated periodically (typically every 2, 5, and 10 years) to ensure progress and to incorporate any changes in watershed activities. Measurable milestones (e.g., number of BMP sites, volunteers, funding received, etc.) should be tracked by Falmouth Department of Public Works.

The Action Plan (Section 5) identifies the stakeholder groups responsible for each action item. Generally, the following responsibilities are noted for each key stakeholder:

Roles and Responsibilities

Town of Falmouth	Lead plan oversight, address nonpoint source pollution, maintain roads using best practices, update ordinances to better protect water quality, coordinate implementation with other project partners, pursue funding opportunities, lead water quality monitoring, and conduct outreach.
Town of Cumberland	Address nonpoint source pollution, maintain roads using best practices, and consider adopting ordinances that protect water quality.
Conservation Commissions	Collaborate with municipal staff to help implement recommended actions, especially outreach.
Falmouth Land Trust	Continue to conserve land in the watershed, collaborate with municipal staff on outreach opportunities.
Maine DEP	Offer technical and financial assistance, including through 319 Nonpoint Source Watershed Implementation Grants.

Private Landowners	Increase awareness and adopt land management practices that minimize pollutant runoff. Address nonpoint source pollution.
Cumberland County Soil and Water Conservation District	Provide administrative and grant support for BMP implementation and education/outreach efforts. Continue supporting the MS4 program.

6.2 ESTIMATED COSTS

Achieving the water quality goals and objectives outlined in Section 3.7 will depend on available funding and labor resources. The strategy focuses on reducing pollutant loading through a combination of targeted actions, including BMP implementation, in-stream habitat improvements, continued water quality monitoring, and expanded education and outreach. Additional measures, though harder to quantify, such as revising local ordinances to require low impact development practices for new development, identifying and replacing failing septic systems, and conserving land, will also be critical (see Section 5: Action Plan for details).

With a dedicated stakeholder group in place and with the help of grant or local funding, it is possible to achieve the target water quality goals in the next 10 years. **Successful implementation is estimated to cost at least $10.6-$16.8 million over the next 10 or more years** (Table 13). These estimates will need to be refined as new information becomes available and do not include costs borne by private landowners.

Table 13. Estimated total and annual 10-year costs for implementation of the Action Plan to meet the water quality goal and objectives for Casco Bay Frontal Drainage.

Planning Action	Estimated Total Cost	Estimated Annual Cost
1. Watershed & Shoreline BMPs	$10,493,500 - $16,613,000	$1,049,350 - $1,661,300
2. Municipal Operations	$15,000	$1,500
3. Municipal Land Use Planning & Zoning	$43,000 - $65,000	$4,300 - $6,500
4. Land Conservation	$34,000 - $58,000	$3,400 - $5,800
5. Wastewater Management	$33,000 - $54,000	$3,300 - $5,400
6. Education & Outreach	$6,500 - $22,000	$650 - $2,200
7. Water Quality Monitoring	TBD	TBD
8. Implement Plan & Monitor Plan Efficacy	TBD	TBD
Total	**$10,625,000 - $16,827,000**	**$1,062,500-$1,682,700**

6.3 FUNDING STRATEGY

It is essential for the Town of Falmouth to establish a clear funding strategy to implement the recommendations outlined in the Action Plan (Section 5). Funding should rely on a mix of municipal budget allocations, state and federal grants, and private landowner contributions. The new Maine Community Funding Finder offers a helpful ongoing resource to find up to date information on upcoming state funding opportunities. The New England Environmental Finance Center can also provide free assistance to communities seeking funding with stormwater and wastewater projects.

Funding Options

- **Casco Bay Estuary Partnership Resilient Communities, Habitat, and Monitoring Grants** – These grants offer up to $25,000 in three categories prioritizing outreach and collaboration, habitat improvement, and expansion of water quality monitoring in the Casco Bay watershed.
- **Casco Bay Estuary Partnership Community Grants** – These grants offer $500 - $5,000 to support environmental education, stewardship, and community engagement projects focused on Casco Bay and its watershed.
- **Community Action Grants (CAG)** – Members of Maine's Community Resilient Partnership can apply for these grants to address actions on the List of Community Actions. No match is required if projects are on the list. Communities can request $75,000, or up to $175,000 if two or more communities apply together.
- **EPA/Maine DEP 319 Grants (Watershed Assistance Grants)** – This nonpoint source grant is designed to help communities make progress restoring or protecting waters named as Nonpoint Source Priority Watersheds (currently all Casco Bay Frontal Drainage tributaries except Webes Creek). 319 grants are available for the development and implementation of watershed-based plans and typically funded over the course of two years. The **604b** program funds watershed planning activities such as WMP development or updates.
- **Fields Pond Foundation (FPF)** – Provides $500 to $25,000 in funding to nonprofit organizations that address its priorities including trailmaking and other enhancements of public access to conservation lands, rivers, and coastlines, land acquisition for conservation, establishing stewardship as a component of a land protection project, and education programs and publications as components of a land protection project.
- **Maine DOT Infrastructure Adaptation Fund (MIAF)** – Established after a recommendation in the *Maine Won't Wait Climate Action Plan,* this grant provides up to $75,000 for scoping and design, or up to $3 million for construction projects. Eligible projects include stormwater systems upgrades, water system upgrades, and other interventions that support public infrastructure repair to reduce or eliminate climate impacts, such as coastal shoreline stabilization. A 5% local match is required.
- **Maine DOT Municipal Stream Crossing Program (MSC)** – Maine DOT provides this funding for the upgrade of municipal culverts at stream crossings, with the goal of creating infrastructure that is resilient to future climate conditions and that provides community, economic, and environmental benefits. This program requires local match.
- **Maine Coastal Community Grant Program (CCG)** – This competitive grant program provides funds to towns and regional organizations for projects in the areas of public access, water quality

improvement, storm hazard resiliency, and marine-related economic development. There is no match requirement for this grant.

- **Maine Clean Water State Revolving Fund (CWSRF)** – This program provides low interest loans to municipalities and quasi-municipal corporations (i.e. village corporations, sanitary, sewer & utility districts, etc.) for the construction of wastewater infrastructure projects. The primary purpose of the fund is to acquire, plan, design, construct, enlarge, repair and/or improve publicly-owned sewage collection systems, interceptor sewers, pumping stations, and wastewater treatment plants. In addition, the program also funds public and private nonpoint source water quality protection and improvement projects, such as landfill closures, sand/salt storage facilities, septic system repair and replacement, stormwater projects, agricultural BMPs, and specific silviculture equipment purchases.
- **Maine Natural Resource Conservation Program (MNRCP)** - Awards competitive grants each year to projects that restore and protect high priority aquatic resources in Maine. MNRCP was created to manage the allocation of funds collected through Maine's In Lieu Fee Compensation Program. This program does not require match.
- **Maine DOT Planning Partnership Initiative** – This initiative is intended to address time-sensitive locally-initiated planning and feasibility studies that occur outside Maine DOT's normal annual Work Plan cycle. An example project includes build-out analyses. Municipal match is required.
- **Maine Outdoor Heritage Fund (MOHF)** – Helps fund critical wildlife and conservation projects throughout Maine including conservation of fisheries, wildlife, and habitat, acquisition and management of public lands, parks, wildlife conservation areas, and public access and outdoor recreation sites, conservation of endangered and threatened species, and natural resources law enforcement and protection of public health. Must be submitted through an authorized Natural Resource Agency Representative. Awards are issued twice a year.
- **Maine Small Community Grant Program (SCG)** – This program provides grants to municipalities to help replace malfunctioning septic systems that are polluting a waterbody or causing a public nuisance. Grants can be used to fund from 25% to 100% of the design and construction costs, depending upon the property owners' income and the property's use.
- **New England Forest and River Grant (NFWF NEFRG)** – This grant awards $50,000 to $200,000 to projects that restore and sustain healthy forests and rivers through habitat restoration, fish barrier removal, and stream connectivity such as culvert upgrades.
- **Maine Forest Service Invasive Plant Management Program** – This program provides landowners (public or private ownerships 10 to 10,000 acres) with the resources to create and implement an Invasive Plant Control Plan, reimbursing up to half the cost of its preparation.
- **National Fish and Wildlife Federation (NFWF) Five Star and Urban Waters Restoration Grants (NFWF 5-Star)** – Grants seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. Eligible projects include wetland, riparian, in-stream and/or coastal habitat restoration; design and construction of green infrastructure BMPs; water quality monitoring/assessment; outreach and education.
- **North American Wetlands Conservation Act (NAWCA) Grants** – The U.S. Standard Grants Program is a competitive, matching grants program that supports PPPs carrying out projects in the United States that further the goals of the North American Wetlands Conservation Act

(NAWCA). These projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated uplands habitats for the benefit of all wetlands-associated migratory birds.

- **National Park Service - Land and Water Conservation Fund Grant Program (LWCF)** – Eligible projects include acquisition of parkland or conservation land; creation of new parks; renovations to existing parks; and development of trails. Municipalities must have an up-to-date Open Space and Recreation Plan. Trails constructed using grant funds must be ADA-compliant.
- **National Park Service – Outdoor Recreation Legacy Program (ORLP)** – a nationally competitive, dollar-for-dollar matching grant program created to aid disadvantaged, urban communities that lack access to close-by outdoor recreation. Funds can be used for the acquisition and/or development of, or substantial renovation of, public parks and other outdoor recreation spaces. Match is required.
- **Land for Communities (L4C)** – Provided by the Maine Community Fund, this program awards up to $50,000 for land acquisition support or up to $25,000 for land-based projects including infrastructure and stewardship. Eligible projects must focus on land return or land for food initiatives.
- **Land for Maine's Future Program (LMFP)** – the State of Maine's primary funding vehicle for conserving land for its natural, economic, and recreational value. The Program works to coordinate and finance acquisition of lands. Through the use of matching funds, the program encourages partnerships with local, regional, statewide, and federal conservation organizations.
- **USDA Water and Waste Disposal Loan and Grant Program**
  Supports drinking water, stormwater, and sewage systems in rural towns of <10,000 population.
- **US EPA Sewer Overflow and Stormwater Reuse Municipal Grants**
  Funds sewer and stormwater infrastructure upgrades, including inspection technologies.

6.4 MONITORING PLAN

A long-term water quality monitoring plan is critical to evaluate the effectiveness of implementation efforts over time. Given the limited availability of monitoring data, the following monitoring efforts are recommended to be conducted by the Town of Falmouth as feasible.

A. Continue annual monitoring for temperature, dissolved oxygen, and specific conductivity using a YSI or similar water meter once per month from May 15 through September 30 at SC-1, WC-1, Station 1126, Station 1167, and Station 1169 and in the Bay. Sampling events should contain a mix of wet and dry weather events.

B. Annually deploy temperature, dissolved oxygen, and conductivity loggers to better capture seasonal and daily fluctuations. Loggers purchased in 2024 can be rotated through the five streams. Loggers require at least monthly maintenance.

C. Include grab samples for total phosphorus, total nitrogen, chloride and *E.coli* in order to monitor key parameters of concern.

If additional funding is available, we also recommend the following to better track nonpoint source pollution:

- Establish additional monitoring stations on each stream to bracket sample around potential hotspots of nutrient or bacteria inputs.
- Consider using mtDNA, eDNA, or similar method to track bacteria sources. Understanding the inputs of bacteria will allow for better refinement of management techniques.

6.5 INDICATORS TO MEASURE PROGRESS

The following **environmental**, **programmatic**, and **social** indicators, along with their numeric targets (milestones), will track progress toward the Casco Bay Frontal Drainage watershed goals and objectives (Table 14). Milestones are set for short-term (2028), mid-term (2031), and long-term (2036) intervals, based on actions identified in the Action Plan (Section 5.1). These benchmarks support periodic plan updates, ensure ongoing relevance, and help the Town of Falmouth determine whether adjustments are needed if targets are not being met.

Environmental indicators directly measure conditions in the watershed and reflect the relationship between pollutant sources and water quality. They assume implementation of recommended actions from the Action Plan.

Programmatic indicators track watershed protection and restoration activities, showing whether planned actions are being carried out rather than directly measuring water quality.

Social indicators measure shifts in community practices and behaviors that support management measures and water quality improvement.

Table 14. Environmental, programmatic, and social indicators for the Casco Bay Frontal Drainage Watershed Management Plan. Milestones are cumulative, starting at year 1, 2026.

Environmental Indicators

Milestone	2028	2031	2036
Achieve Class B standards for aquatic life use based on Biomonitoring assessments on all five tributaries.	N/A	All meet at least Class C	All meet Class B
Achieve Class B standards for total phosphorus (≤30 µg/L) on all five tributaries.	<45 µg/L	<38 µg/L	<30 µg/L
Achieve Class B standards for dissolved oxygen (7 mg/L, or 75% saturation) on all five tributaries.	Failure rate <20%	Failure rate <10%	Failure rate <2%

Achieve Class B standards for bacteria (≤ 236 MPN/100mL instantaneous and ≤ 64 MPN/100mL geometric mean) for all five tributaries.	Failure rate <20%	Failure rate <10%	Failure rate <2%
Achieve Class B standards for specific conductivity and chloride, particularly for Webes Creek and Skitterygusset Creek.	Failure rate <20%	Failure rate <10%	Failure rate <2%
Improve in-stream geomorphic and habitat conditions by installing recommended improvements	Complete high priority recommendations.	Complete moderate priority recommendations.	Complete low priority recommendations.
Improve shoreline buffer and erosion scores by adding native plants and stormwater management practices to 28 high scoring shoreline properties (disturbance scores 7+)	9 properties addressed	18 properties addressed	28 properties addressed

Programmatic Indicators

Milestone	2028	2031	2036
Amount of funding secured	$4 million	$9 million	$13 million
Number of nonpoint source sites remediated (16 identified)	5	10	16
Number of workshops and trainings for stormwater improvements to residential properties	1	2	3
Number of updated or new ordinances that target water quality protection	1	3	5
Number of new municipal staff for inspections and enforcement of regulations	1	1	2
Number of informational workshops and/or trainings for landowners, municipal staff, and/or developers/landscapers on local ordinances, watershed goals, and/or best practices for road management and winter maintenance	2	4	8
Number of parcels with new conservation easements or number of parcels put into permanent conservation	1	2	5
Number of copies of watershed-based educational materials distributed or articles published	200	500	1,000
Number of meetings and/or presentations to municipal staff and/or boards related to the WMP	2	4	8
Number of new best practices for road management and winter maintenance implemented on public roads by the municipalities and Maine DOT	2	4	6

Social Indicators

Milestone	2028	2031	2036
Number of volunteers participating in annual cleanups	10	30	50
Number of public meeting or workshop attendees	15	40	75
Number of watershed private landowners installing stormwater practices on their properties (residential and commercial)	3	10	25
Number of municipal staff receiving training on winter management practices or erosion and sediment control practices	10	20	30



Mussel Cove. © FBE

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APPENDIX A: ACORN ENGINEERING WATER QUALITY IMPROVEMENT PLAN

Water Quality Improvement Plan

Casco Bay Frontal Drainage Watershed Management Plan

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Issued On:
January 19, 2026

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I. INTRODUCTION

Acorn Engineering, Inc. has been retained by FB Environmental Associates (FBE) to provide civil engineering services related to Task 3.5 - Watershed BMP Reconnaissance of the Casco Bay Frontal Drainage Watershed Management Plan (CBFD WMP). The CBFD WMP's goal is to outline strategies to improve water quality within five (5) watersheds draining to Mussel Cove and the Presumpscot River Estuary. The watershed basins collectively are identified as the Frontal Drainage Basin with land areas extending across the Towns of Falmouth and Cumberland. The location of these watersheds can be found in the Watershed Maps in **Appendix A**. The Watershed BMP Reconnaissance task involves identifying areas suitable for the implementation of best management practices (BMPs) to improve water quality and provide detention and treatment of runoff from developed areas. The five (5) watersheds include:

- Webes Creek
- Norton Brook
- Chenery Brook
- Mill Creek
- Scitterygusset Creek

Water sampling data and other watershed information collected by FBE's Environmental and Field Geology Services was used in the review of watershed areas which would benefit most from water quality and quantity improvements. An evaluation of available GIS data combined with field reconnaissance, potential sites within each watershed were evaluated and existing stormwater management practices were documented. BMP implementation for the Water Quality Improvement Plan is presented for selected sites, considering factors such as physical and technical site constraints, existing infrastructure, and accessibility for maintenance. The plan also outlines high-level cost projections and regulatory requirements.

II. EXISTING REPORTS

A. Route 1 Falmouth Commercial District, Stormwater Management Plan (2013)

The 2013 evaluation of stormwater management facilities report for the Town of Falmouth by Woodard and Curran focused on the area between Route 88 and the Turnpike Spur (**Appendix B**). The plan identified locations of existing stormwater systems within the project area and evaluated the types of systems in place and their effectiveness in managing both stormwater quantity and quality. The 2013 assessment relied on a review of aerial imagery and existing site plans to locate stormwater management facilities, which were mainly detention basins designed to manage peak runoff rates. In addition, newer systems aimed at both quantity and quality management were also considered. As part of the evaluation, field inspections of ten facilities were conducted, with a further two inspections taking place later in the year. These inspections focused on visually assessing the

performance of the facilities, using forms developed by the University of Minnesota for standardized evaluation.

The assessment included a qualitative approach to evaluating stormwater system performance, as comprehensive water quality and quantity monitoring would be required for a full evaluation. Key factors in the evaluation included the structural integrity of the facilities, their intended design, and the level of maintenance observed. While some stormwater management systems, such as filter systems, were noted for being particularly effective at managing both runoff quantity and quality when designed correctly, other systems, like dry detention basins, were less effective in terms of water quality but performed well in controlling peak runoff rates.

B. Catchment #5 Stormwater Evaluation Report (2025)

The Catchment #5 Stormwater Evaluation Report by Acorn Engineering for the Town of Falmouth, dated October 2025, assessed the stormwater infrastructure and management challenges in the Route 1 Commercial Area (Catchment 5), focusing on impacts to Webes Creek, the most developed catchment in the Frontal Drainage Basin (**Appendix C**). Through stakeholder engagement, hydraulic modeling, and analysis of three storage alternatives, the report explains that increasing inline stormwater storage, whether through public or private projects, can significantly reduce peak discharge rates and improve stream habitat. The study highlights the importance of strengthened local review, adherence to regulatory standards, and collaboration among property owners and agencies to ensure sustainable development and watershed health. Key recommendations included limiting waivers of the Flooding Standard, enhancing maintenance, and reporting requirements, and targeting specific runoff management strategies to balance commercial growth with environmental stewardship in the Webes Creek watershed.

C. Stream Crossing Resilience Survey

The Stream Crossing Resilience Survey Summary Report by Acorn Engineering for the Town of Falmouth, dated December 19, 2025, evaluated the hydraulic capacity and habitat connectivity at cross-culverts and road-stream crossings (assets) within the Town of Falmouth's roadway drainage network (**Appendix D**). The assessment included in-field inspections of 138 assets, identifying common issues and structural defects. Each asset was scored based on key performance indicators, including primary defects, habitat conditions, and water quality impacts. The study designated 18 assets as "high priority" based on Acorn's combined performance, structural integrity, and desktop analysis rankings, structure. Many of the existing assets are estimated to be undersized for conveyance of flow during larger rainfall events. As a result, they are likely contributing to water quality degradation within stream watersheds as documented in this report.

III. EXISTING CONDITIONS

The four (4) watersheds draining to Mussel Cove – Webes Creek, Norton Brook, Chenery Brook, and Mill Creek, along with the Scitterygusset Creek watershed draining to the Presumpscot River estuary – cover land areas within the Towns of Falmouth and Cumberland. Each watershed has distinct characteristics, hydrological patterns, and land use patterns, all of which are crucial to understand when identifying suitable locations for implementing BMPs to enhance water quality and implementation of flood control measures to address the increasing risk of flash flooding. Flash floods can lead to severe erosion, infrastructure damage, and degradation of natural habitats, posing a significant threat to both built and ecological resources. Below is a description of the existing conditions within each watershed, including current land uses and stormwater management practices.

A. Webes Creek Watershed: Located in southern Falmouth, the Webes Creek Watershed includes a mix of residential, commercial, and institutional land uses. Unlike other watersheds within the Frontal Drainage Basin, the development in this watershed consists largely of professional and commercial plaza areas with expansive areas of impervious surfaces. Stormwater runoff from these developed regions contributes to increased pollutant levels and flash flooding in the creek.

Maine Department of Environmental Protection (Maine DEP) and the Town of Falmouth have been monitoring water quality in Webes Creek since at least 2013, evaluating both water quality (e.g., dissolved oxygen, specific conductance, and temperature) as well as habitat quality (e.g., using "rock bags" to monitor and document the macroinvertebrate community present). Maine considers stream health to be a function of both water quality and the presence of complex and varied habitat that can support the macroinvertebrates that are indicators of good water quality. Of particular attention is the "Catchment 5" watershed, which includes downtown area properties on the west and east sides of US Route 1 between Bucknam Road and 241 US Route One. A portion of the Falmouth Fire Station and Grubb Field Recreation Complex (both owned by the town and accessed from Bucknam Road) parcels are also located within Catchment #5.

Historically, this area of Falmouth has been a center for commercial and institutional development, much of which predates the Maine Department of Environmental Protection (Maine DEP) Stormwater Management Law enacted in 2005. A review of Google Earth™ imagery and Maine DEP data layers indicates a number of residential and commercial developments have been approved under the State's Stormwater Management Law or the Site Location of Development ("Site Law") regulations, which typically require new projects to incorporate stormwater systems meeting water quality standards. In contrast, Acorn's site reconnaissance suggests that many developments established prior to 2005, particularly those with extensive impervious surfaces such as large parking areas, lack stormwater controls designed to manage water quality and quantity.

The headwaters of Webes Creek begin in urbanized areas, with the initial flow directed eastward across US Route One. The first 0.4 miles of the creek run alongside and beneath commercial development, where there is little vegetative buffer separating the creek from surrounding infrastructure. This lack of buffer limits the soil's ability to absorb runoff from impervious surfaces such as roads, parking lots, and lawns before it enters the creek. Furthermore, the absence of roadside vegetation reduces the natural cooling of runoff, allowing warmer, often polluted water to flow directly into the creek. In this area, stormwater systems frequently discharge close to the creek, exacerbating water quality issues. Much of the development in this portion of the watershed predates modern water quality standards, resulting in direct discharges from large impervious areas without sufficient treatment.

As Webes Creek continues to flow east past Depot Road, the landscape changes. The creek is bordered by residential development to the east and commercial development to the west. Along this stretch, the vegetative buffers along the creek improve, providing some natural filtration and mitigation for stormwater runoff. However, these buffers remain limited in some areas. A small unnamed tributary, originating from the commercial development along Bucknam Road and at the Bucknam Road/US Route One intersection, merges with Webes Creek just before it converges with Mill Creek. This additional tributary introduces more runoff, likely contributing further to the Creek's pollutant load.

The combination of urban runoff, minimal infiltration or detention, direct discharges, and minimal vegetative buffers along the creek makes it increasingly difficult for Webes Creek to maintain good water quality. Enhancing stormwater management practices, establishing vegetative buffers, and retrofitting existing infrastructure will be essential in improving the overall health of the creek and mitigating the impacts of urban development within the watershed.

B. Norton Brook Watershed: The Norton Brook watershed spans Falmouth and Cumberland, runs generally north-south along US Route One, and is characterized by a blend of forested areas, residential neighborhoods, and commercial zones. A significant portion of the land within the watershed remains undeveloped or is utilized for low-density residential purposes. Based on infrastructure maps published by the Town of Falmouth and Town of Cumberland a public sanitary sewer network currently serves a mix of the existing properties on the eastern side of I-295, providing treatment for those areas.

Over the past two decades, commercial and higher-density residential development along the US Route One corridor has led to an increase in impervious surfaces and flow channelization, contributing to elevated rates of runoff and potential water quality concerns. Norton Brook is listed as a threatened stream on the Maine DEP's Nonpoint Source Priority Watersheds List.

A review of Google Earth™ imagery and layers maintained by the Maine DEP indicates that many of the commercial and residential properties along this corridor were approved under Maine's Stormwater Management Law and the Site Location of Development ("Site Law") regulations. These laws typically require that new developments incorporate stormwater management systems that meet certain water quality standards, and Acorn has observed functioning BMPs at these newer developments.

There are several commercial and higher-density residential projects which are either under construction, approved, or proposed in the northern part of the watershed, particularly along the west side of US Route One. These projects' design will be subject to Local and State water quality and quantity standards. Nonetheless, careful monitoring and maintenance of erosion and sedimentation controls will be of utmost importance during construction to prevent sedimentation of the brook. As impervious surface percentage in the watershed increases, proper maintenance and monitoring of constructed stormwater BMPs must occur to preserve or enhance water quality and to avoid Norton Brook's placement on the impaired streams list.

Within the residential areas of the watershed, stormwater management practices are generally limited to traditional infrastructure, such as culverts and roadside ditches. While these systems serve basic drainage functions, they provide minimal treatment for water quality and offer little in terms of mitigating pollutants like nutrients, sediment, and contaminants commonly associated with urban runoff.

The brook itself flows southward, generally in close proximity to US Route One, where the development density increases. Along the brook's length, there are numerous culvert crossings beneath Town roads and other private crossings which constrict the natural bankfull width of the stream, are perched above the vertical profile of the stream, and contribute to erosion and habitat fragmentation. There is limited space available for establishing vegetative buffers or access to the natural floodplain along the west side of the brook, which reduces the potential for natural filtration and water quality benefits. The proximity of the road to the waterway, combined with the absence of sufficient buffering, means that stormwater runoff from the roadway and drainage systems is likely discharged directly to the brook without adequate treatment or cooling.

C. **Chenery Brook Watershed:** The 2.07 square mile Chenery Brook watershed spans Falmouth and Cumberland and runs generally north-south between Interstate 295/ railroad to the east and Middle Road to the west, with its headwaters located in Cumberland. Much of the land is wooded, but there are pockets of single-family residential development, primarily along Middle Road. **Chenery Brook is listed as a threatened stream on the Maine DEP's Nonpoint Source Priority Watersheds List, attributable to the highway and development.**

Chenery Brook flows southward, closely paralleling both the railroad and the four-lane section of Interstate 295 for about 2.1 miles, both of which are built up and reduce the available natural floodplain. Land slopes on both sides of the brook are generally moderate to steep. There are numerous culverts crossing under the Interstate and railroad conveying flow to the brook. The proximity of these infrastructure elements to the brook presents considerable challenges for managing water quality within the watershed. Stormwater from the highway, railroad, and eastern areas flows directly into the brook with minimal buffering or filtration. Much of this runoff is conveyed through culverts that appear undersized for larger storm events, resulting in higher flow velocities and increased erosion risk. The combination of untreated discharge, limited floodplain capacity, and moderate to steep slopes significantly contributes to water quality degradation.

In the residential areas of the Chenery Brook watershed, stormwater conveyance primarily relies on conventional infrastructure such as culverts, storm drains, and roadside ditches. While these drainage systems serve basic functions, they provide little to no treatment of runoff. These structures are not designed to filter or manage pollutants, so stormwater runoff from developed areas, flows directly into the brook or its tributaries without being treated. As single-family residential development continues in this area, stormwater buffers, level-lip spreaders, and culvert inlet and outlet stabilization should be encouraged to provide treatment and reduce risk of erosion.

There are several commercial and higher-density residential projects which are either under construction, approved, or proposed along the eastern part of the watershed, particularly east of I-295 along the ridge separating the Chenery and Norton Brook watersheds. These projects' designs will be subject to Local and State water quality and quantity standards. Nonetheless, careful monitoring and maintenance of erosion and sedimentation controls will be of utmost importance during construction to prevent sedimentation of the brook. As impervious surface percentage in the watershed increases, proper maintenance and monitoring of constructed stormwater BMPs must occur to preserve or enhance water quality and to avoid Chenery Brook's placement on the impaired streams list.

Infrastructure maps from the Towns of Falmouth and Cumberland indicate that most commercial and residential properties within the Chenery Brook watershed rely on individual septic systems for wastewater management. Malfunctioning or failing systems in this area may be contributing to increased pollutant loads downstream.

D. Mill Creek Watershed: The 2.01 square mile Mill Creek watershed spans Falmouth and Cumberland, with a small portion of upper headwaters located in Cumberland. Much of the land is wooded, but there are pockets of single-family residential development, primarily along Longwoods Road (ME Route 9). The watershed extends across both sides (east and west) of Interstate 295, with the creek running northwest to southeast. The creek is conveyed below Interstate 295 via a culvert immediately north of the spur interchange.

Residential development consists of mostly single-family residences with frontage along Longwoods Road or smaller scale subdivisions on both sides of the roadway, most of which predate the enactment of the Maine Department of Environmental Protection (Maine DEP) Stormwater Management Law in 2005. Stormwater conveyance primarily relies on conventional infrastructure such as culverts, storm drains, and roadside ditches. While these drainage systems serve basic functions, they provide little to no treatment of runoff before discharged into the creek. These structures are not designed to filter or manage pollutants, so stormwater runoff from developed areas, flows directly into the brook or its tributaries without being treated.

The majority of the watershed relies on individual septic systems for wastewater management. However, based on infrastructure maps published by the Town of Falmouth and Town of Cumberland a public sewer network currently serves a mix of commercial and residential properties on the eastern side of I-295, providing treatment for those areas.

E. Scitterygusset Creek: The 0.98 square mile watershed of Scitterygusset Creek is wholly located in Falmouth, with the headwaters to the north near the Falmouth Spur. The creek flows north to south. The majority of the land in the headwaters of the watershed is wooded, however portions of the Falmouth Public Works department, Woodlands Country Club, Falmouth Transfer Station, and capped landfill are located in the upper portion of the watershed. Southern areas of the watershed are largely developed for single-family and multi-family residential development. OceanView at Falmouth, a large multi-family development, is situated mostly within the watershed. The watershed also contains an approximate 5,150-foot stretch of Interstate 295, as well as an approximate 6,000-foot stretch of the Falmouth Spur. Residential development is primarily accessed from Middle Road. The creek passes beneath Interstate 295 through a culvert located south of the spur interchange.

Single-family dwellings along Middle Road and Falmouth Road predate the 2005 enactment of the Maine Department of Environmental Protection (Maine DEP) Stormwater Management Law. Larger multi-family developments, including Ocean View and Ridgewood, required approval under Site Location of Development Law which required water quality and quality improvements as part of the project. According to infrastructure maps published by the Town of Falmouth and Town of Cumberland, a large portion of development within this watershed is connected to a public sewer system, while some residential properties to the east continue to rely on individual septic systems for wastewater treatment.

In summary, the five watersheds vary significantly in terms of land use and current stormwater management practices. Webes Creek and Norton Brook are more heavily impacted by urbanization and require targeted BMP improvements to address water quality issues related to flow off impervious surfaces and from commercial development. The other watersheds, while more rural, still face water quality challenges from increased development, undersized stormwater conveyance

systems, and lack of vegetative buffers between development and natural drainageways. Understanding these conditions, as well as collected water sampling data, will guide the selection and design of BMPs that are both effective and appropriate for each watershed.

IV. WATER QUALITY DATA

FB Environmental (FBE) and Field Geology Services conducted an assessment of the stream watershed focusing on fluvial geomorphology and water quality. Field evaluations took place during two periods: June 10, 2024, to December 3, 2024 and April 9, 2025, to October 7, 2025. Findings from water quality sampling are summarized in Tables 5-7 of FBE's Casco Bay Frontal Drainage Water Quality Results Memorandum dated December 19, 2025.

The following parameters were monitored during each sampling event:

- Dissolved Oxygen
- Specific Conductance
- Nitrogen
- Phosphorus
- Chloride
- *E. coli*.

Webes Creek demonstrated threshold exceedances for all parameter, identifying it as a high priority watershed. Data collected were analyzed by Acorn Engineering to pinpoint priority areas for implementing best management practices (BMPs) aimed to improving water quality by reducing surface water runoff impacts.

V. BMP RECONNAISSANCE AND RECOMMENDATIONS

Between fall 2024 and fall 2025, Acorn Engineering conducted a number of reconnaissance surveys aimed at evaluating the feasibility of implementing stormwater Best Management Practices (BMPs). This assessment prioritized the Webes Creek and Norton Brook watersheds, which exhibit elevated levels of nutrient and toxic pollutants that could be mitigated through targeted BMP retrofits.

The field-based reconnaissance involved multiple site visits on April 19, 2024, November 25, 2024, August 11, 2025, and November 11, 2025, to evaluate existing development, stormwater infrastructure, land use conditions, and potential BMP retrofit or installation opportunities. Field-based reconnaissance did not involve evaluation of the Chenery Brook and Mill Creek watershed areas around the vicinity of Interstate 295 and railroad due to interstate traffic and minimal access points. Evaluation of aerial imagery mapping and Google Earth® street view was used for the

assessment of existing drainage conditions. The goal was to identify locations where either new BMPs could be established, or existing systems could be improved to enhance stormwater management and water quality outcomes.

Building on the findings of the 2013 Woodard and Curran and 2025 Acorn Engineering reports, new field data was integrated to develop a set of ranking criteria for BMP prioritization. These criteria considered factors such as:

- Watershed's influence on water quality
- Subwatershed size/ type of existing development
- BMP system type
- Location and accessibility for construction and maintenance
- Existing infrastructure and site constraints
- Stormwater Management benefit
- Opinion of Estimated construction costs
- Opinion of long-term costs

When reviewing water quality data, Acorn prioritized Nitrogen and Phosphorus threshold exceedances because of their strong correlation with stormwater runoff impacts. *E. coli* was also evaluated as its presence can indicate failing septic systems that may contribute to downstream water quality degradation.

Webes Creek was identified as top priority due to its significant role in overall water quality impairment, as demonstrated in FBE's water quality results referenced above. These results revealed notable exceedances for Nitrogen and Phosphorus, primarily linked to stormwater runoff originating from urbanized areas and heavily traveled roadways.
Other watersheds exhibited only mild to moderate exceedances for Nitrogen or Phosphorus. However, Chenery Brook and Mill Creek were also designated as key priorities because they are listed on Maine's Threatened Stream Priority List, underscoring their ecological importance and vulnerability.

Acorn's proposed BMP implementation for the Water Quality Improvement Plan is structured in two phases:

- **Phase 1** prioritizes addressing the most critical water quality challenges by focusing on high-priority watersheds and pollutants identified through FBE's comprehensive water quality testing data. By strategically targeting these areas, Phase 1 aims to maximize the effectiveness through the development solutions with the highest potential for measurable impact. The overarching goal is to achieve measurable improvements in water quality by the year 2030.

- This phase targets BMP implementation within the most impaired watersheds, through retrofits and new infrastructure, to achieve the greatest improvements in water quality and quantity.
- The Town should continue to require that existing lots served by subsurface wastewater disposal systems, but are adjacent to the public sewer system, shall provide certificates every two years demonstrating the system is functioning properly.
- The Town should implement a focused strategy requiring annual post-construction stormwater system inspection and maintenance reporting as a Planning Board condition of approval. The goal of this strategy would be to ensure MS4 compliance and long-term stormwater system performance.
- When performing infrastructure upgrades to Town-owned stream crossing or cross-culvert drainage infrastructure, the Town should incorporate design and installation practices. The Stream Crossing Resilience Survey Report (**Appendix D**) identifies high-priority cross-culverts and road-stream crossings that require replacement to improve hydraulic capacity, restore habitat connectivity, and enhance downstream water quality.

- **Phase 2** serves as a follow-up initiative to address remaining or lower-priority pollutants and secondary stressors. This phase will extend BMP implementation into areas with less severe but still impactful sources of impairment. Phase 2 is designed to ensure that no source of impairment is overlooked, reinforcing Falmouth's long-term resilience and ecological integrity across the watersheds.

The phased strategy ensures the efficient allocation of resources, balancing short-term improvements with long-term water quality goals. Proposed BMPs are scored using a ranking system to prioritize high-impact, cost-effective solutions in Phase I. Planning-level cost estimates were prepared for all proposed sites, with the understanding that these costs could be reduced using municipal labor and resources for design and construction. The phased implementation approach also supports the distribution of costs over time, helping municipalities budget appropriately and manage anticipated financial impacts.

The Water Quality Improvement Plan specifically targets areas with high nutrient and toxic pollutant loads originating from urban, residential, and commercial runoff. By reducing these pollutant inputs, the strategy aims to restore aquatic habitat quality, enhance ecological function, and safeguard water resources against future development pressures. Ultimately, the BMP implementation framework is designed to support a sustainable, adaptable approach to stormwater management across the Mussel Cove watershed.

VI. BMP RETROFIT LOCATIONS

Targeted areas within each watershed have been identified where stormwater retrofits would benefit water quality. As outlined earlier, reconnaissance surveys were conducted to pinpoint these high-priority locations. Based on this assessment, Webes Creek and Norton Brook are prioritized for Phase I implementation of recommended BMPs, while Chenery Brook, Mill Creek, and Scitterygusset Creek are proposed for Phase II improvements. **Appendix E** displays BMP retrofit locations, while **Appendix F** outlines the proposed Phase I and Phase II BMPs in each subwatershed. This phased approach ensures that more critical areas receive immediate attention while planning for long-term watershed health.

A. Webes Creek

Webes Creek was identified as a high-priority area due to the significant amount of developed impervious surfaces that contribute to declining water quality in Casco Bay. According to FBE's water quality sampling results, Webes Creek exceeds all thresholds for Nitrogen and Phosphorus. This watershed presents a significant challenge because the existing stormwater infrastructure is primarily subsurface, limiting opportunities for above-ground treatment. Much of this development predates the Maine Department of Environmental Protection (Maine DEP) Stormwater Management Law enacted in 2005, meaning it was not designed to meet current stormwater quality standards. To effectively capture pollutants such as Nitrogen and Phosphorus and prevent downstream impacts, stormwater must undergo treatment before entering the conveyance system, which poses a challenge with the current development. Within this watershed, several locations have been identified as candidates for potential implementation of BMPs with strategic collection points to help improve water quality in the Casco Bay region.

206 US Route One parking lot – adjacent Town owned parcel (Lot 8, Map U52):

Development at 206 US Route One (currently Walmart) includes an expansive parking lot (Lot 2, Tax Map U52), encompassing approximately 513,650 square feet of impervious surface. This large, paved area contributes significant runoff to the watershed. Stormwater generated across this site is collected through a network of basin inlets and conveyance systems, and is directly discharged to Webes Creek without water quality or quantity treatment. One outlet location is mapped as discharging north of the McDonald's parking lot across the Route One corridor via an existing stormwater outfall.

As mentioned in the Stormwater Management Plan completed in January 13 by Woodard & Curran (**Appendix B**), a Flow Control Structure also exists within the adjacent town owned parcel (Lot 8, Map U52) northeast of Lot 2, Tax Map U52. This area collects sheet flow from the expansive parking lot and runoff from three outfalls along Hat Trick Drive. This water flows into a naturalized channel that directs water to two large inlets within a densely

undeveloped area. These inlets connect and convey water into the Route One corridor toward the existing outfall location north of McDonald parking lot.

The large amount of traffic and lack of treatment within this area increases pollutant loads such as hydrocarbons, heavy metals, and nutrients such as phosphorus and nitrogen which exacerbate water quality concerns and stream health impacts. To reduce pollutant loads downstream, the following methods are recommended and should be designed to meet stormwater quality and quantity requirements:

- **Tree Filters**: The placement of tree filters along the curbside and landscaped areas of the US Route One corridor and expansive parking lots would provide a practical and aesthetically pleasing solution to improving water quality of runoff. Tree filters would capture runoff from adjacent impervious surfaces and filter it through an engineered soil layer to remove sediments and nutrients. The filtered water would then be infiltrated or conveyed through the existing drainage network to Webes Creek.
- **Gravel Wetland**: Constructing a gravel wetland within the Town-owned lot (Lot 8, Map U52) located northeast of the Walmart Plaza parking lot would offer a highly effective solution for treating stormwater runoff from abutting impervious areas and stormwater outfalls. This solution replicates natural wetland processes, enhancing stormwater treatment through sedimentation, filtration, and biological uptake of pollutants. As water moves through the vegetated media, sediments settle, nutrients are absorbed, and contaminants are filtered out. The treated water would then discharge through a controlled outlet structure to existing infrastructure that ultimately discharges into Webes Creek.

Storm Inlet – North of 227 US Route One

An existing stormwater inlet is located in a low-lying area off Route One, between the parking lots at 227 and 231 US Route One – identified as Critical Infrastructure Area 3 in Woodard & Curran's report (**Appendix B**). This inlet collects runoff from the large parking lot currently occupied by Walmart across Route One, adjacent lots, and storm inlets along the Route One corridor. The runoff is conveyed through a closed drainage system to an outfall that ultimately discharges into Webes Creek.

This location functions as a key junction within the subsurface conveyance system for a highly developed area, and also receiving surface runoff from two high-turnover restaurant establishments. Retrofitting this site offers a strategic opportunity to intercept and treat stormwater before it enters Webes Creek, while also improving the capacity of the closed drainage system. Implementing treatment measures here could reduce pollutants such as sediment, oils, and nutrients, enhance downstream water quality, and increase drainage capacity to minimize upstream flooding risk. The following BMPs are recommended to retrofit this location and decrease pollutant loads downstream.

- **Underdrained Soil Filter:** Retrofitting the low-lying area as an underdrained soil filter would significantly improve water quality by removing sediments, nutrients, and other pollutants from surface runoff before it reaches Webes Creek. Stormwater would enter the basin and pass through engineered filter media, where fine particles and contaminants are naturally captured. The placement of the filter media and underdrain system will need to be coordinated with the existing storm drain infrastructure. Relocating or upsizing the pipe to a more suitable location through the low-lying area should be considered. This adjustment would improve hydraulic efficiency, reduce the risk of upstream flooding, and enhance the overall resilience of the drainage network.
- **Rain Garden (Bioretention Cell)**: As an alternative, installing a bioretention cell within the existing stormwater infrastructure between the parking lots at 227 and 231 US Route One could provide both functional and aesthetic benefits in this highly visible area. A rain garden would prevent pollution and sediment from entering Webes Creek while creating a visually appealing landscape feature. The design would involve excavating the area to create a layered system of engineered soil media, mulch, and vegetation. Pollutants such as sediments and nutrients would be removed through filtration, adsorption, and biological processes. An underdrain would then convey treated water from the system to Webes Creek, ensuring effective pollutant reduction and controlled discharge.

Catchment 5 Area including Shaw's Plaza:

Catchment 5 is located within Webes Creek watershed and includes properties on the west and east sides of US Route One between Bucknam Road and 241 US Route One. This catchment area is primarily composed of commercial buildings and paved parking lots, served by a network of basin inlets and conveyance systems designed to collect and route stormwater. However, the existing infrastructure lacks sufficient capacity to manage peak flows during major storm events, increasing the risk of localized flooding and pollutant discharge. Ultimately, stormwater from this area is conveyed to and discharged untreated or unbuffered into an unnamed tributary that flows directly into Webes Creek. The Catchment #5 Stormwater Evaluation Report (**Appendix C**) describes the current limitations of the existing stormwater infrastructure for future development of the area and identifies opportunities to increase capacity and detain runoff.

To effectively reduce pollutant loads and support sustainable future development, the following BMPs are recommended to ensure compliance with stormwater quality and quantity requirements:

- **Tree Filters**: The placement of tree filters along the curbside and landscaped areas of the US Route One corridor and Catchment 5 would improve water quality of runoff by filtering stormwater. Tree filters would capture runoff from adjacent impervious surfaces and filter it through an engineered soil layer to remove sediments and nutrients. The filtered water would then be infiltrated or conveyed through the existing drainage network toward Webes Creek. Some suitable locations for tree filters would be near catch basins within the public right-of-way where runoff is directed into the closed drainage system as untreated. Tree filter installation would be suitable northwest of the Catchment 5 watershed at the intersection of US Route One and Bucknam Road, where pollutants from a high traffic zone could be mitigated.
- **Focal Point:** As an alternative to tree filters, custom Focal Point systems offer a small footprint and advanced media filtration to remove pollutants effectively. These systems are particularly suited for high-traffic areas where runoff contains elevated concentrations of contaminants such as oils and heavy metals. The Town has successfully implemented several Focal Point systems along US Route One, demonstrating their effectiveness and adaptability in similar settings.

Depot Road, between US Route One and Foreside Road:

A segment of Depot Road, on the eastern side of Webes Creek, contributes stormwater runoff to two stormwater outfalls. This roadway is characterized by continuous impervious pavement and limited vegetated buffers. Rainfall along this stretch is channeled through a series of storm inlets that discharge untreated runoff directly into Webes Creek. This runoff may often carry pollutants such as heavy metals and sediment from vehicular traffic, further impacting downstream water quality.

Existing development occupies a critical riparian zone directly on Webes Creek). While some of the existing developments along this road provide valuable green space, their operations - including irrigation, fertilizer application, and potential pesticide use - pose risk to water quality if not properly managed. Nutrient-rich runoff and chemical residues may enter Webes Creek during storm events, contributing to elevated nutrient loads and habitat degradation downstream. The following BMPs are recommended at these sites to reduce pollutant loads and protect ecological integrity and water quality of the creek corridor:

- **Tree Filter:** Tree filters are compact, vegetated systems designed to collect and treat stormwater runoff from impervious surfaces such as roads and parking lots. Installed adjacent to curb inlets along Depot Road, this system would utilize engineered soil media and vegetation to remove sediments, nutrients, hydrocarbons, and heavy metals from stormwater before it enters the existing subsurface conveyance network along the road. This BMP will be effective along this Depot Road due to the limited space provided and its ability to provide both water quality treatment and aesthetic

benefits. Their modular design also allows for retrofitting at existing inlet locations without major infrastructure changes.

- **Focal Point:** Similar to the Tree Filter in the proposed locations, a focal point would also be a great alternative due to its capacity to remove pollutants through advanced media filtration. These systems are ideal for high-traffic areas where runoff contains elevated concentrations of contaminants. Along Depot Road, this system could work by intercepting and treating stormwater at strategic locations such as the existing inlet basins connected to the subsurface storm pipes. Focal points in these locations will reduce pollutant loads while providing a compact footprint in the constrained urban environment.

Falmouth Little League Complex (Lot 5, Tax Map U52):

The Falmouth Little League Complex consists of four baseball and softball diamonds, as well as a playground and tennis courts. While the site itself does not have a dedicated stormwater conveyance system, runoff from the fields drains offsite, flowing toward inlet basins along Depot Road. Given that the maintenance of these sport fields often involves the use of fertilizers containing high levels of nitrogen and phosphorus and pesticides, it is crucial to proactively manage stormwater runoff before it enters the existing stormwater infrastructure, ultimately leading to Webes Creek. The following retrofitting techniques present effective management tactics to minimizing the risk of contaminants entering the waterway and ensuring the protection of the local ecosystem:

- **Buffer Strip:** A vegetated buffer strip, native or planted with native grasses, perennials, and shrubs, can be established in the grassed area at the south end of the parcel to act as a natural filter for the stormwater. A vegetated buffer strip would help filter out contaminants, such as excess nutrients from fertilizers and pesticides, while also reducing erosion and providing habitat for wildlife. The filters would reduce the amount of stormwater pollutants entering the existing stormwater conveyance system along Depot Road.
- **Vegetated Swales:** Vegetated swales around the edges of fields would manage runoff by slowing it down and allowing it to infiltrate into the soil before reaching the existing subsurface conveyance system along Depot Road. These shallow, landscaped channels would help filter pollutants like fertilizers and pesticides.
- **Infiltration Trenches**: Infiltration trenches strategically placed at this site would temporarily store stormwater runoff, allowing it to infiltrate into the underlying soil rather than enter the existing subsurface conveyance system that leads to Webes Creek. By slowing runoff and promoting infiltration, infiltration trenches would also reduce volume and peak flow into the storm sewer system, which helps further prevent downstream flooding and erosion.

An effective stormwater management plan for this area would likely involve the combination of these tactics. For example, a combination of buffer strips, vegetated swales, and infiltration trenches around the playing fields would both reduce runoff volume and filter out pollutants before reaching Webes Creek.

Non-point Source Pollution Risks

- **Fertilizer and Pesticide Use:** Fertilizer and pesticide use among residential and agricultural fields throughout the area contribute to large volumes of nitrogen and phosphorus in stormwater runoff. The Town of Falmouth's new fertilizer and pesticide ordinance includes a ban on neonicotinoid pesticides and restrictions on synthetic substances to decrease nutrient loads into the watershed. Further community engagement is encouraged to educate homeowners about the negative effects of fertilizer and pesticide use on water quality.

B. Norton Brook

US Route One – Roadway Site Development

Stormwater runoff from US Route One often carries elevated levels of sediment, hydrocarbons and deicing salts due to high traffic volumes and winter maintenance practices. Within the Norton Brook watershed, US Route One runs parallel to the Brook, with much of its runoff on the east side conveyed directly to the stream via shallow concentrated flow, and runoff on the west side conveyed through culverts to outfalls that discharge to Norton Brook. Much of the western side of Route One also contains several commercial buildings with minimal stormwater conveyance or treatment systems in place. The heavy traffic and proximity to the stream, increases the risk of pollutant loading. To mitigate these impacts, the following are recommended:

- **Vegetated Swales with Check Dams:** Along this stretch of US Route One, various grassed ditches currently convey water along the western edge and discharge into Norton Brook via culverts under the road. While these existing ditches appear to function adequately, replacing them with vegetated swales with check dams would enhance stormwater management and pollutant removal. As runoff enters the swale, dense vegetation slows the flow, allowing suspended sediments to settle, while check dams will further reduce peak flow, minimize erosion, and create temporary ponding areas that increase residence time. The root systems and organic matter in the soil trap fine particles and absorb nutrients from roadway waste. The gentle slope and porous soils in these locations would promote infiltration, reduce runoff volume and improving water quality before discharging to Norton Brook.

Infiltration Trenches: In addition to vegetated swales and check dams, installing infiltration trenches along the roadway edge could provide significant water quality and volume reduction. These trenches would intercept sheet flow from US Route One, providing pretreatment through sedimentation and filtration as water passes through the aggregate. This effective technique would capture runoff from parking lots and US Route One, reducing peak flows and pollutant loads before discharging to Norton Brook.

US Route One – Adjacent to Norton Brook

Existing and potential future developments located along the south corridor of US Route One abuts Norton Brook and may be contributing sediment and other nutrients, such as nitrogen and phosphorus, to the stream. Development along this stretch extend toward the creek create a potential pathway for contaminants. Parking lots and loose soil in these areas increase the risk of sediment and nutrient runoff directly entering Mill Creek. To mitigate these impacts and protect water quality, the following are recommended:

- **Vegetated Buffer**: Establishing a dense buffer of vegetation along the creek is recommended to reduce direct entry of sediment and contaminants into the Creek. A dense buffer in this area would intercept runoff, trap sediments, and absorb nutrients before reaching the Creek. Coordinate and cooperation with landowners would be required.
- **Stabilize Storage Areas**: Implementing erosion control measures throughout high traffic laydown areas – designated space on construction site where materials, equipment, and vehicles are temporarily stored - would reduce soil displacement into the Creek. Material management including storage of loose materials with a cover or on a stabilized surface would also minimize exposure to rainfall and reduce pollutant transport.

Northbrook Drive – Roadway development

Northbrook Drive includes several commercial and residential buildings with paved parking areas developed between 1990 and 2007. Stormwater runoff is collected by an existing closed drainage system that ultimately discharges into Norton Brook. Although three detention basins are present and help reduce peak flows, runoff from the roadway and portions of parking areas bypasses these basins and is discharged untreated into Norton Brook. This untreated runoff can transport sediments, nutrients, hydrocarbons, and other pollutants that degrade downstream water quality. To address these concerns and reduce pollutant and sediment loads entering Norton Brook, the following measures are recommended:

- **Vegetated Swale with Check Dams:** The section of Northbrook Drive that runs perpendicular to Norton Brook contains an existing grass-lined ditch along its eastern edge, which conveys stormwater to an inlet discharging into Norton Brook. To reduce pollutant loads from the adjacent parking lot and businesses that drain into this ditch, replacing it with a vegetated swale incorporating check dams would provide enhanced water quality treatment. A vegetated swale in this location would slow runoff and promote infiltration, while check dams interrupt flow along steeper slopes, creating temporary ponding areas that increase residence time. This extended contact with vegetation and soil improves sediment deposition, nutrient uptake, and pollutant filtration. Together these features would reduce peak flow, minimize erosion, and improve water quality before discharging into Norton Brook.

- **Focal Point:** Installing sediment and pollutant capture focal points at the four catch basins along the southern side of Northbrook Drive would provide important pretreatment before stormwater enters the existing subsurface conveyance network. These focal points are designed to intercept coarse sediments, as well as reduce nutrient and hydrocarbon loads that are common along roadways. Capturing these pollutants at the source will ultimately improve water quality downstream into Norton Brook.

- **Culvert Replacement:** Existing culvert stream crossings located at Northbrook Drive and Johnson Road need replacement. The current condition of the culverts at these locations may be contributing to erosion and habitat fragmentation. Although the pipes exhibited adequate capacity at the time of their inspections, they are likely undersized for storm flow conditions in Norton Brook. Additionally, the retaining walls at the crossing of Northbrook Drive are constructed of gabion baskets, which are currently stable but are beginning to show signs of wire failure, which would lead to eventual collapse of the walls at the crossing. The Town should consider replacing these crossing with appropriately sized spans.

Non-point Source Pollution Risks

- **Fertilizer and Pesticide Use:** Fertilize and Pesticide use among residential and agricultural fields throughout the area contribute to large volumes of nitrogen and phosphorus in stormwater runoff. The Town of Falmouth's new fertilizer and pesticide ordinance includes a ban on neonicotinoid pesticides and restrictions on synthetic substances to decrease nutrient loads into the watershed. Further community engagement is encouraged to educate homeowners about the negative effects of fertilizer and pesticide use on water quality.

C. Chenery Brook

Middle Road - Roadway Site Development:

Middle Road is one of the main roads that runs through the Chenery Brook watershed. The relative high traffic volume of this road produces untreated stormwater runoff that carries pollutants and sediments to Chenery Brook. The road is located approximately 0.25 miles West of Chenery Brook and consists of residential homes and woods on either side. The road has minimal existing subsurface stormwater conveyance in the Town of Falmouth and some subsurface conveyance in the Town of Cumberland. Many residential driveways contain culverts to connect grassed lined ditches in front of residential lots. Although runoff from this road travels through dense vegetation in various areas, the following efforts may further mitigate adverse downstream water quality effects of Chenery Brook:

- **Vegetated Swales with Check Dams:** Stretches of Middle Road include grassed ditches that currently convey runoff along the roadway edge. These existing ditches appear to function adequately, however, replacing them with vegetated swales with check dams would enhance stormwater management and pollutant removal. As runoff enters roadway pollutants and sediment will be reduced by absorption from vegetation, while check dams will create a temporary ponding area that reduces peak flows, increases sediment settlement and infiltration.

- **Infiltration Trenches:** Installing infiltration trenches along the roadway edge can enhance stormwater management by improving both water quality and reducing runoff volume. These trenches intercept sheet flow from the pavement, allowing water to undergo natural treatment processes such as sedimentation and filtration as it passes through the aggregate. This not only removes pollutants and suspended solids, but also reduces peak runoff rates.

- **Focal Point:** On sections of Middle Road in the Town of Cumberland, installing focal point systems at existing inlet basins would provide a critical parti in reducing pollutant and sediment runoff. These systems capture and treat runoff before it enters the subsurface conveyance network, where treatment becomes more challenging. By incorporating advanced media filtration, focal points would effectively remove pollutants and sediments, improving downstream water quality. Their compact design makes them ideal for high-traffic corridors where runoff contains large amounts of contaminants. Successful implementation will require coordination between the Towns of Cumberland and Falmouth.

Non-point Source Pollution Risks

Non-point source pollutant risks pose significant risk to water quality and ecosystems within the Chenery Brook watershed. Fertilizer and pesticide use, as well as failing septic systems

of residential areas within the watershed contribute pollutants that reduce water quality downstream.

- **Fertilizer and Pesticide Use:** Fertilize and Pesticide use among residential and agricultural fields throughout the area contribute to large volumes of nitrogen and phosphorus in stormwater runoff. The Town of Falmouth's new fertilizer and pesticide ordinance includes a ban on neonicotinoid pesticides and restrictions on synthetic substances to decrease nutrient loads into the watershed. Further community engagement is encouraged to educate homeowners about the negative effects of fertilizer and pesticide use on water quality.
- **Septic System Risk Analysis:** Conducting a comprehensive septic system risk analysis for all existing systems in the area is strongly recommended. Improper maintenance or failing installations can contribute significant non-point source pollutants to Chenery Brook, including nutrients and pathogens that degrade water quality. The risk analysis should include a detailed soil evaluation to determine whether current systems are functioning as intended or if short-circuiting is occurring – where highly permeable soils allow untreated wastewater to bypass natural filtration processes. Additional considerations should include system age, proximity to water resources, and hydraulic loading rates. Where vulnerabilities are identified, target mitigation strategies such as system upgrades or conversion to advanced treatment technologies should be explored to protect Chenery Brook and maintain compliance with environmental standards.

Interstate 295 (I-295) Roadway Site Development

I-295 runs across the Chenery Brook Watershed, parallel to Chenery Brook. Stormwater runoff from this section of Interstate flows directly into Chenery Brook from the roadway ditches along the western side of the highway. Several large culverts throughout this stretch convey water from northbound lanes toward Chenery Brook. Due to the high traffic volume, this runoff carries significant amounts of sediment and pollutants, which are discharged directly into the brook without treatment, reducing downstream water quality. To mitigate these impacts, the following are recommended to reduce pollutant and sediment loading into Chenery Brook:

- **Ditch Turnout Buffers:** Installing ditch turnouts that redirect stormwater from existing roadway ditches into adjacent wooded buffer areas would allow runoff to disperse as sheet flow. This approach promotes infiltration, sediment deposition, and pollutant removal through natural filtration processes before water reaches Chenery Brook. Benefits include improved downstream water quality, reduced erosion, and enhanced ecological resilience. Successful implementation will require coordination

between the Maine Turnpike Authority and the Towns of Falmouth and Cumberland to address design, land use, and maintenance considerations.

St. Lawrence and Atlantic Railroad

The St. Lawrence and Atlantic Railroad line runs through both the Town of Falmouth and Cumberland alongside Chenery Brook. This close proximity creates challenges for managing stormwater runoff, as sediment, erosion, and chemical pollutants from rail operations can easily enter the brook, degrading water quality. The successful implementation of BMPs adjacent to the railroad will require coordination between the railroad owner (State of Maine Department of Transportation) and the Towns of Falmouth and Cumberland. To address these concerns, the following are recommended to improve water quality of Chenery Brook:

- **Infiltration Trenches:** Where soil conditions allow, installing infiltration trenches parallel to the rail line would allow for sheet flow to be intercepted before it reaches Chenery Brook. These infiltration trenches would promote infiltration into the underlying soils, reducing pollutant loads and runoff volume.
- **Check Dams in Drainage Channels:** Natural drainage channels along the railroad provide direct entry of contaminants into Chenery Brook. To reduce pollutant loads, incorporating small check dams within these existing ditches would slow water velocity, encourage sedimentation, and minimize erosion.
- **Wooded/ Vegetative Buffers:** Protect and establish buffers between railroad embankments and Chenery Brook to enhance pollutant and sediment absorption. Native vegetation will intercept sheet flow, trap sediments, and filter pollutants before runoff reaches the brook.

D. Mill Creek

Longwoods Road - Roadway Site Development

Longwoods Road (Maine Route 9) serves as a primary transportation corridor through the Mill Creek watershed. For approximately half a mile, Mill Creek parallels the roadway and crosses it three times via large culverts. The high traffic volume along this stretch contributes to untreated stormwater runoff entering the creek, negatively impacting water quality throughout the watershed. Existing stormwater infrastructure includes roughly 11 roadway culverts and several additional driveway culverts that convey flow across and along the road. Land use in the watershed is characterized by residential development served by septic systems along Longwoods Road, interspersed with substantial forested areas. The successful implementation of BMPs adjacent to the State roadway will require coordination between the Town of Falmouth and Maine Department of Transportation. To reduce pollutant loads from roadway runoff and protect Mill Creek, the following strategies are recommended:

- **Vegetated Swales with Check Dams:** As the most heavily trafficked roadway within the Mill Creek watershed, Longwoods Road represents a significant source of stormwater pollutants that can impair water quality. While much of the roadside is bordered by dense vegetation, several sections could be enhanced by converting existing grass-lined ditches into vegetated swales. Incorporating native plants in these areas would improve pollutant retention, increase infiltration, and help moderate peak flows before they reach Mill Creek. Additionally, installing check dams within roadside ditches would slow water velocity, extend residence time, and promote sediment deposition and absorption, further reducing pollutant loads into Mill Creek.
- **Infiltration Trenches:** Installing infiltration trenches along Longwoods road would provide an effective strategy for improving both water quality and reducing runoff volumes. These trenches would intercept sheet flow from the roadway, allowing stormwater to infiltrate rather than discharge into Mill Creek. As water passes through the aggregate within the trenches, pollutants such as sediment and nutrients are filtered out, significantly lower risk of contamination. Infiltration trenches would also reduce peak flows and mitigate erosion.

Non-point Source Pollution Risks

Non-point source pollutant risks pose significant risk to water quality and ecosystems within the Mill Creek watershed. Fertilizer and pesticide use, as well as failing septic systems of residential areas within the watershed contribute pollutants that reduce water quality downstream.

- **Fertilizer and Pesticide Use:** Fertilize and Pesticide use among residential and agricultural fields throughout the area contribute to large volumes of nitrogen and phosphorus in stormwater runoff. The Town of Falmouth's new fertilizer and pesticide ordinance includes a ban on neonicotinoid pesticides and restrictions on synthetic substances to decrease nutrient loads into the watershed. Further community engagement is encouraged to educate homeowners about the negative effects of fertilizer and pesticide use on water quality.
- **Septic System Risk Analysis:** As previously mentioned, conducting a comprehensive septic system risk analysis for all existing systems in the Mill Creek watershed is strongly recommended. According to the Town of Falmouth and Cumberland's online utility mapping resources, majority of this watershed is on city sewer. A septic system risk analysis within this watershed is strongly recommended to evaluate performance and potential impacts of existing systems on downstream water quality. This assessment would help identify systems that may be contributing nutrients, pathogens, or other pollutants to Mill Creek. Additional considerations should include system age, proximity to water resources, and hydraulic loading rates.

Where vulnerabilities are identified, target mitigation strategies such as system upgrades or conversion to advanced treatment technologies should be explored to protect Mill Creek and maintain compliance with environmental standards.

US Route One - Developed Land adjacent to Mill Creek

Existing and potential future developments located along the south corridor of US Route One abuts Mill Creek and may be contributing sediment and other pollutants to the stream. Multiple developments along this stretch extend toward the creek, as close as 150 feet from the streambank in some areas, creating a potential pathway for contaminants. Parking lots and loose soil in these areas increase the risk of sediment and nutrient runoff directly entering Mill Creek. To mitigate these impacts and protect water quality, the following are recommended:

- **Wooded/Vegetative Buffers**: Establishing a dense buffer of vegetation along the creek is recommended to reduce direct entry of sediment and contaminants into the Creek. A dense buffer in this area would intercept runoff, trap sediments, and absorb nutrients before reaching the Creek. Coordination and cooperation with landowners would be required.
- **Stabilize Storage Areas**: Implementing erosion control measures throughout high traffic laydown areas – designated space on construction site where materials, equipment, and vehicles are temporarily stored - would reduce soil displacement into the Creek. Material management including storage of loose materials with a cover or on a stabilized surface would also minimize exposure to rainfall and reduce pollutant transport.

Non-point Source Pollution Risks

- **Fertilizer and Pesticide Use:** Fertilize and Pesticide use among residential and agricultural fields throughout the area contribute to large volumes of nitrogen and phosphorus in stormwater runoff. The Town of Falmouth's new fertilizer and pesticide ordinance includes a ban on neonicotinoid pesticides and restrictions on synthetic substances to decrease nutrient loads into the watershed. Further community engagement is encouraged to educate homeowners about the negative effects of fertilizer and pesticide use on water quality.
- **Septic System Risk Analysis:** As previously mentioned, conducting a comprehensive septic system risk analysis for all existing systems in the Mill Creek watershed is strongly recommended. According to the Town of Falmouth and Cumberland's online utility mapping resources, majority of this watershed is on city sewer. A septic system risk analysis within this watershed is strongly recommended to evaluate performance and potential impacts of existing systems on downstream

water quality. This assessment would help identify systems that may be contributing nutrients, pathogens, or other pollutants to Mill Creek. Additional considerations should include system age, proximity to water resources, and hydraulic loading rates. Where vulnerabilities are identified, target mitigation strategies such as system upgrades or conversion to advanced treatment technologies should be explored to protect Mill Creek and maintain compliance with environmental standards.

E. Scitterygusset Creek

Highway Site Development

I-295 and Falmouth Spur Toll Road run across the Scitterygusset Creek Watershed, with Scitterygusset Creek running along them and crossing at two points. Stormwater runoff from these sections of roadway flow directly into the Creek from the roadway ditches at certain points of the highway. Existing stormwater infrastructure including culverts and subsurface conveyance network direct stormwater to existing detention ponds or outfalls discharging directly into Scitterygusset Creek. Several large culverts throughout the I-295 corridor convey runoff across the Interstate towards the Creek. Runoff from these high-traffic roadways carries significant amounts of sediment and pollutants, which are discharged directly into the creek without treatment, reducing downstream water quality. To mitigate these impacts, the following are recommended to reduce pollutant and sediment loading into Scitterygusset Creek:

- **Wooded/ Vegetative Buffers/ Ditch Turnout Buffers:** Installing ditch turnouts along the I-295 and Falmouth Spur Toll Road corridor would help redirect stormwater from existing roadway ditches into adjacent vegetated areas. This approach promotes infiltration and sediment capture, reducing pollutant loads entering Scitterygusset Creek and improving downstream water quality. Successful implementation will require coordination between the Maine Turnpike Authority and the Town of Falmouth.

Roadway Site Development – Woods Road, Lunt Road, Depot Road, Bucknam Road, and Middle Road

Portions of Woods Road, Lunt Road, Depot Road, Bucknam Road, and Middle Road serve as moderately high-traffic corridors within the Scitterygusset Creek watershed. Existing stormwater infrastructure along these routes consists of inlet basins connected to subsurface conveyance systems that discharge to forested areas before ultimately reaching Scitterygusset Creek. While these systems provide basic conveyance, they offer limited treatment, allowing pollutants and sediments from roadway runoff to enter the watershed. To mitigate these impacts and protect water quality, the following strategies are recommended:

- **Focal Point:** Installing sediment and pollutant capture focal points at the existing basins inlets along these roadways would provide important pretreatment before stormwater enters the existing subsurface conveyance network. These focal points are designed to intercept coarse sediments, as well as reduce nutrient and hydrocarbon loads that are common along roadways. Capturing these pollutants at the source will ultimately improve water quality downstream into Scitteryguset Creek.

Town Facilities - Public Works and Falmouth Transfer Station

The Falmouth Public Works and Transfer Station may be contributing pollutants to stormwater runoff due to their operations and material handling. Common contaminants may include sediment and particulates, heavy metals, and oils and grease. Organic matter and nutrients from yard waste also contributes to degraded water quality. It is recommended that the Town review their material handling procedures at these locations to ensure that excess pollutants and sediment is not contributing to the decline in water quality of the Scitterygusset watershed. The following BMPs may also be installed to further reduce pollutants and sediment from running off into the watershed.

- **Vegetated Buffer**: Establishing a dense buffer of vegetation downstream from material and waste stockpiles would intercept runoff, trap sediments, and absorb nutrients before reaching Scitterygusset Creek. Coordinate with the Town would be required.
- **Rain Garden (Bioretention Cell)**: The installation of a bioretention cell at these locatoins would prevent pollution and sediment from discharging into Webes Creek. The area would need to be excavated to create a layered system that consists of engineer soil media, mulch, and vegetation. Sediments and nutrients would be removed through filtration, adsorption, and biological processes. An underdrain would direct treated water out of the system into existing stormwater infrastructure or directly into Scitterygusset Creek.

Non-point Source Pollution Risks

- **Fertilizer and Pesticide Use:** Fertilize and Pesticide use among residential and agricultural fields throughout the area contribute to large volumes of nitrogen and phosphorus in stormwater runoff. The Town of Falmouth's new fertilizer and pesticide ordinance includes a ban on neonicotinoid pesticides and restrictions on synthetic substances to decrease nutrient loads into the watershed. Further community engagement is encouraged to educate homeowners about the negative effects of fertilizer and pesticide use on water quality.

VII. BMP OVERVIEW

BMP retrofits will be designed in general conformance with the latest state and local standards for water quality and quantity. The Maine Department of Environmental Protection (DEP) Stormwater Management Design Manual (Volume III) provides technical guidance for the selection and implementation of BMPs that meet pollutant removal, cooling, channel protection, and flood control objectives.

The following BMPs are anticipated for use within the watershed for water quality and quantity control:

A. Underdrained Soil Filters: These filtration BMPs consist of engineered soil media over a gravel drainage layer with perforated underdrain piping. They are designed to treat runoff through physical filtration and biological uptake. These systems are suitable for sites with limited infiltration capacity and can be integrated into landscaped areas. Maine DEP specifies sizing based on contributing impervious and landscaped areas, with a minimum ponding depth and detention time to ensure effective treatment. These systems require engineered soil media, underdrains, and structures, resulting in moderate construction and maintenance costs. Typical installation and material costs range from $25,000 - $80,000, excluding engineering and construction administration costs.

Advantages:

- Effective removal of sediments, nutrients, and metals.
- Promotes groundwater recharge with infiltration where sandy soils are present.
- Suitable for high groundwater or poorly infiltrating soils.
- Familiar design and installation process for contractors, aiding in cost predictability and construction efficiency.

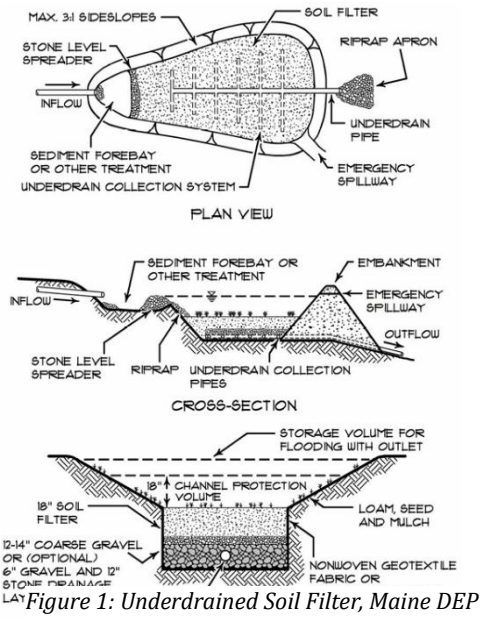


Figure 1: Underdrained Soil Filter, Maine DEP

Limitations:

- Requires a larger footprint, which can be challenging in space-constrained urban environments.
- Requires consistent maintenance to prevent clogging and ensure long-term performance.
- Installation costs may be higher compared to simpler BMPs due to excavation and material needs.

- May require a larger footprint, which can be challenging in space-constrained urban environments.

B. Rain Gardens (Bioretention Cells): Rain gardens are shallow depressions planted with native vegetation that capture and treat stormwater runoff through infiltration and evapotranspiration. Under Maine DEP guidelines, bioretention cells must include engineered soil media, underdrains (if needed), and overflow structures. They are effective at removing nutrients, metals, and sediments, and are particularly useful in residential and small commercial settings. Rain gardens are relatively simple landscaped practices with moderate excavation and planting costs, making them cost-effective for small drainage area. Typical installation and material costs range from $20,000 - $70,000, excluding engineering and construction administration costs.

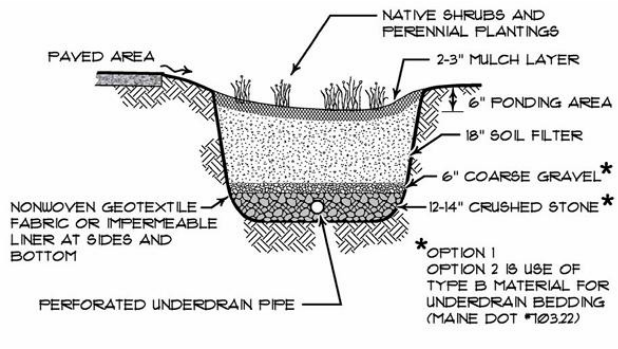


Figure 2: Rain Garden, Maine DEP



Figure 3: Rain Garden (Biorention Cell) installation

Advantages:

- Enhances site aesthetics and ecological value through native plantings, making it ideal for highly visible or public-facing areas.
- Provides high pollutant removal efficiency, particularly for nutrients and heavy metals.
- Supports groundwater recharge in areas with permeable soils, contributing to hydrologic balance.

Limitations:

- Limited capacity for managing large volumes of runoff, which may restrict use in high-flow areas.
- Sensitive to winter deicing chemicals and salt, which can affect plant health and soil function.
- Requires periodic replacement of vegetation and inspection of soil media and overflow structures.

C. Gravel Wetlands: Gravel wetlands are engineered systems that mimic natural wetland processes using saturated gravel beds and wetland vegetation. These systems provide both aerobic and anaerobic treatment zones, promoting denitrification and effective pollutant

removal. Maine DEP standards require gravel wetlands to include forebays for pretreatment, dual treatment cells, and underdrain systems to manage water quality volume and channel protection storage. Proper vegetation and soil composition are critical for long-term performance. These systems have the ability to handle runoff from larger watersheds. Due to gravel wetlands requiring significant excavation, liner or underdrain systems, and hydraulic controls, they are higher in cost, between $120,000 - $250,000. This price range reflects installation and material costs and excludes engineering and construction administration costs.

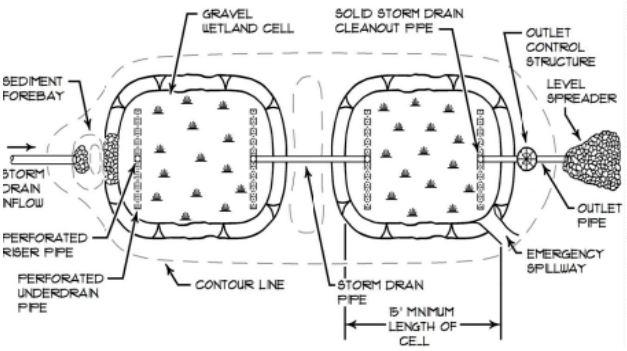


Figure 5: Gravel Wetlands – Plan View, Maine DEP

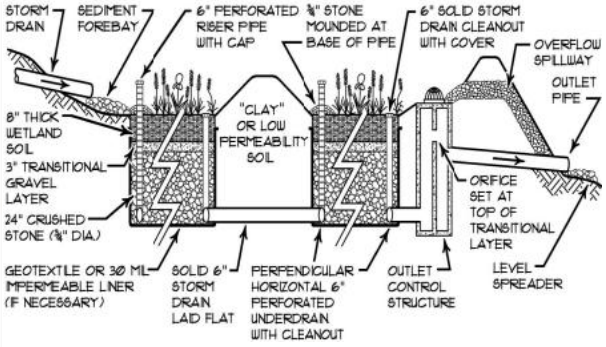


Figure 4: Gravel Wetlands –Cross Section, Maine DEP

Advantages:

- Highly effective at removing nutrients and bacteria, including nitrogen through denitrification.
- Provides ecological benefits such as wildlife habitat and enhanced landscape aesthetics.
- Performs well in cold climates due to subsurface flow, which maintains treatment during freezing conditions.

Limitations:

- Requires a larger footprint than many other BMPs, which may limit use in dense urban areas.
- Design and construction are more complex, often requiring specialized expertise.
- Vegetation must be carefully selected and maintained to ensure consistent treatment performance and system longevity.

D. Tree Filters: Tree filters are compact, vegetated filtration systems that integrate trees with engineered soil media to treat stormwater runoff. These systems are particularly effective in highly impervious urban areas and are designed to capture and treat the first flush of runoff. Tree filters remove suspended solids, nutrients, and hydrocarbons while providing aesthetic and ecological benefits. They are typically installed in sidewalk cutouts or parking lot islands and conform to DEP standards for filtration BMPs. Tree filter installation costs include

structural components, engineered soil, and vegetation, making them moderately priced at $40,000 - $70,000 including installation. Material costs alone can exceed $25,000 delivered to site. These costs do not include engineering and construction administration.



Figure 6 Tree Filter

Advantages:

- Space-efficient and visually appealing, making them ideal for dense urban settings.
- Effective at removing hydrocarbons, sediments, and nutrients from stormwater.
- Supports urban tree canopy expansion and helps mitigate heat island effects.

Limitations:

- Limited capacity for managing large volumes of runoff, restricting use to small drainage areas.
- Requires specialized design and installation to ensure proper function and tree health.
- Tree vitality may be compromised by poor water quality, compaction, or inadequate maintenance, potentially requiring replacement.

E. Wooded/Vegetative Buffers are natural or restored vegetated zones adjacent to streams that intercept and treat runoff before it enters waterbodies. They are designed to intercept and treat stormwater runoff. Where previously disturbed or cleared, these strips are can be restored grasses, shrubs, or other dense vegetation to promote a reduced runoff velocity and allow sediment, nutrients, and pollutants to be trapped and filtered through plant media and soil. These buffers provide an effective solution with low construction and long-term maintenance costs. Construction of a stone-bermed level spreader may be warranted to direct runoff through the buffer as sheet flow. Construction costs for the stone-bermed level spreader can range from $5,000 - $20,000 depending on size and location, excluding engineering and construction administration.

Ditch turn-out buffers can be constructed to direct runoff through a level spreader, dispersing flow as sheet flow across the buffer. These ditch turn-out buffers are particularly

effective along roadways where runoff is collected in swales. Ditch turn-outs involve minimal grading and stabilization to redirect flows into vegetated areas, keeping costs relatively low - generally under $15,000, excluding engineering and construction administration costs.

Advantages:

- Provides passive pollutant removal via filtration, uptake, and sediment deposition.
- Stabilizes streambanks and reduces erosion.
- Enhances wildlife habitat and ecological connectivity.
- Low-cost and low-maintenance once established. Buffers offer visual screening and aesthetic enhancement.

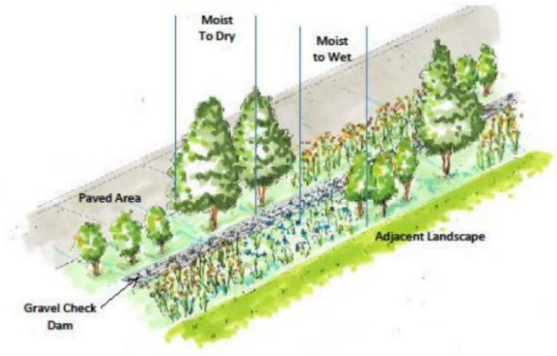


Figure 7: Vegetated Buffer

Limitations:

- Requires sufficient land area and protection from encroachment.
- Effectiveness depends on vegetation density, slope, and buffer geometry (length and width).
- May need invasive species management and periodic replanting.
- Most effective if flow remains as sheet flow.

F. Proprietary Focal Points: Maine DEP allows the use of proprietary stormwater treatment systems, such as FocalPoint biofiltration systems, provided they meet performance criteria for pollutant removal and temperature reduction. These systems are often used in constrained urban environments where space or site conditions limit the use of traditional BMPs. These systems have high upfront costs due to proprietary structures and installation.

Construction costs for a Focal Point system depend on whether subsurface detention is required, as specified in Maine DEP's approval letter. When detention is necessary, installation and material costs typically range from $60,000 - $75,000. If detention is not required, the expected cost is approximately $30,000 - $50,000. These cost ranges exclude engineering and construction administration costs.

Advantages:

- Compact and modular - ideal for space-limited or retrofit sites.
- Proven pollutant removal performance in urban settings.
- Often easier to maintain with manufacturer-provided design and support resources.

Limitations:

- Higher upfront costs due to proprietary components and specialized installation.
- May require long-term maintenance contracts or specialized training for upkeep.

- Limited flexibility in design and customization compared to non-proprietary systems.

G. Check Dams: Check dams are small structure placed across drainage swales or ditches to slow stormwater runoff. They can be constructed from a variety of materials including stones, log, earth, or manufactured materials and are inexpensive to install at small scales. Check dams help prevent erosion, trap sediment, and encourage infiltration by reducing flow velocity. Water quality benefits are provided through infiltration of runoff into underlying soils. Installation and material pricing is based on the number of check dams installed, with an anticipated range of $2,500 - $10,000. This price range does not include engineering and construction administration.

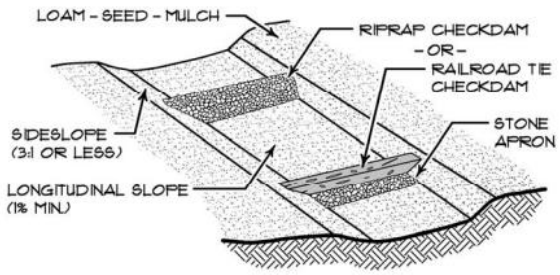


Figure 9: Check Dam, Maine DEP



Figure 8: Check Dam Installation

Advantages:

- Controls erosion and improves stability in swales and ditches.
- Cost effective solution that can be installed with locally available materials.
- Reduces flow and encourages sedimentation and ponding for nutrient uptake when used with vegetation.

Limitations:

- Requires periodic sediment cleanout to maintain effectiveness.
- Not a stand-alone treatment intended to fully detain stormwater.
- May obstruct maintenance equipment in swales and ditches.

H. Infiltration Trench: Infiltration trenches are trenches filled with coarse aggregate designed to capture, store, and infiltrate stormwater runoff into the surrounding soil. Infiltration trenches are commonly used to manage surface water by reducing runoff volume and improving water quality. As water is drained through the aggregate, suspended solids, such as sediment and pollutants, are removed. Infiltration trenches require excavation, stone, geotextile, and pretreatment measures, leading to moderate overall costs. Installation and material costs generally range from $15,000 - $35,000, excluding engineering and construction administration.

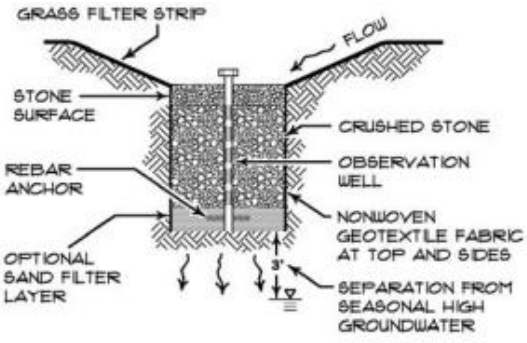


Figure 10: Infiltration Trench, Maine DEP



Figure 11: Infiltration Trench Installation

Advantages:

- Helps prevent flooding by reducing surface runoff.
- Filters pollutants through soil and aggregate.
- Easily integrated into existing landscapes with minimal space

Limitations:

- Sediment accumulation can reduce effectiveness, requires regular maintenance.
- Needs periodic inspection and cleaning to prevent failure.
- Effectiveness depends on soil permeability.

I. **Infiltration Basin:** Infiltration basins are designed to capture and temporarily store runoff, allowing it to infiltrate into the underlying soil. These basins mimic hydrologic processes by reducing runoff volume and filtering pollutants through soil and vegetation. They are commonly used in areas with permeable soils. Infiltration basins typically require excavation, pretreatment, and land area, driving moderate to higher construction costs. These systems have the ability to handle runoff from larger watersheds.

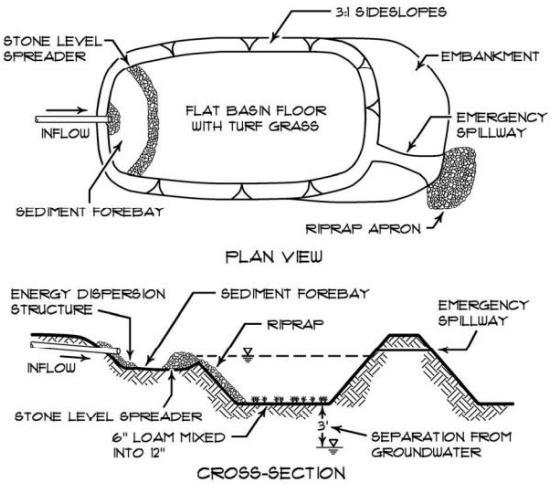


Figure 12: Infiltration Basin

Installation and material costs vary by size, ranging from approximately $30,000 for smaller systems to $100,000 for larger installations, excluding engineering and construction administration.

Advantages:

- Reduces stormwater runoff by promoting infiltration and groundwater recharge.
- Filters sediments, nutrients, and other contaminants through soil and plant uptake.
- Helps reduce peak flows during storm events.

Limitations:

- Ineffective in areas with clay soils or high groundwater tables
- Requires regular inspection for sediment buildup, vegetation health, and potential clogging.
- Infiltration rates may decline over time due to clogging.

All BMPs will be selected and designed to meet the specific hydrologic and pollutant loading conditions of each subwatershed. Maintenance plans will be developed to ensure long-term functionality and compliance with DEP's five-year recertification requirements. *Table 1* presents a summary of the stormwater best management practices (BMPs) proposed to support water-quality improvements in the Casco Bay Frontal Drainage Watershed.

Table 1: BMP Summary

Stormwater BMP	Typical Cost Range*	Planning-Level Description	Key Treatment Objectives
Check Dams	Very Low ($1,500–$10k)	Check dams are simple stone, log, or concrete structures and are inexpensive to construct at small scales.	Reduce flow velocity, promote sediment deposition, and provide channel stabilization in ditches and swales.
Ditch Turn-out Buffers	Low (<$15k)	Ditch turnouts require limited grading and stabilization to redirect flows into vegetated areas, keeping overall costs relatively low.	Disperse concentrated flows and enhance infiltration and filtering through existing vegetation.
Wooded / Vegetated Buffers	Very Low ($2k-$20k)	These practices primarily rely on land preservation or minimal planting and grading, resulting in very low construction and maintenance costs.	Filter pollutants, reduce runoff velocity, and provide nutrient and sediment uptake through natural vegetation.
Infiltration Trench	Moderate ($15k–$35k)	Infiltration trenches require excavation, stone media, geotextile, and pretreatment, resulting in moderate construction costs.	Infiltrate stormwater to reduce runoff volume and recharge groundwater while providing modest pollutant removal.

Rain Gardens	Moderate ($20k–$70k)	Rain gardens are relatively simple bioretention practices with moderate excavation and planting costs, making them cost-effective for small drainage areas.	Treat runoff through filtration and infiltration, reducing runoff volume and improving water quality for small sites.
Underdrained Soil Filters	Moderate ($25k–$80k)	These systems require engineered soil media, underdrains, and hydraulic structures, resulting in moderate construction and maintenance costs.	Provide high-level pollutant removal where infiltration is limited, especially for sediment and nutrients.
Tree Filters	Moderate ($40k–$70k)	Tree filters combine structural components, engineered soil, and vegetation, increasing installation costs compared to simpler bioretention systems.	Provide stormwater filtration and interception in highly constrained or urbanized areas.
Proprietary Focal Points	Moderate–High ($30k–$50k) - no detention; ($60k–$75k) - with detention	Proprietary devices have higher upfront costs for manufactured units and installation but require minimal land area.	Target specific pollutants (e.g., TSS, hydrocarbons, nutrients) in space-limited or retrofit applications.
Infiltration Basin	High ($30k–$100k)	Infiltration basins typically involve substantial excavation, pretreatment features, and land area, leading to higher overall costs.	Reduce runoff volume and peak flows through infiltration while providing water quality treatment.

* All costs ranges shown include installation and material costs and exclude engineering and construction administration.

VIII. CONCLUSION

The recommended BMP implementation strategy has been developed to align with the Town of Falmouth's stormwater management requirements and Maine DEP regulations, ensuring compliance with water quality and quantity standards. These measures are designed to address both immediate and long-term watershed health by mitigating pollutant loads, reducing peak runoff rates, and improving stream habitat conditions. By incorporating a mix of structural and non-structural BMPs, such as tree filters, gravel wetlands, vegetated buffers, and infiltration system, the plan provides effective treatment for stormwater before discharged into natural waterways. Each BMP has been selected based on site-specific constraints, accessibility, and anticipated performance, with the goal of exceeding regulatory treatment requirements while minimizing adverse impacts to erosion, drainage, and adjoining properties.

Beyond regulatory compliance, this phased approach supports sustainable watershed management and ecological resilience. Phase 1 prioritizes high-impact retrofits in the most impaired watersheds, while Phase 2 expands improvements to secondary areas, ensuring comprehensive coverage across the Casco Bay Frontal Drainage Basin. Together, these efforts will restore aquatic habitat, enhance pollutant removal, and safeguard water resources against future development pressures. The strategy also emphasizes cost efficiency through municipal resource utilization and long-term maintenance planning, enabling the Town to meet MS4 obligations and maintain BMP functionality over time. Ultimately, this plan represents a proactive investment in water quality, community health, and environmental stewardship, positioning Falmouth and Cumberland as leaders in sustainable stormwater management.

Appendix A: Watershed Maps

LEGEND

- WATERSHED BOUNDARY
- MUNICIPAL BOUNDARY
- STREAM | CREEK
- PUBLIC ROADWAY

NOTES:

1. WATERSHED BOUNDARIES SHOWN WERE DERIVED FROM THE USGS STREAMSTATS MAPPING APPLICATION ON APRIL 10, 2024.
2. ROADWAY, CULVERT, AND MUNICIPAL BOUNDARY LOCATIONS SHOWN WERE DERIVED FROM THE MAINE GEOLIBRARY DATA CATALOG ON APRIL 11, 2024.
3. STREAM AND CREEK DATA SHOWN WAS DERIVED FROM THE USGS NATIONAL HYDROGRAPHY DATASET ON APRIL 11, 2024.
4. ALL DATA PRESENTED WAS SOURCED FROM THE PUBLIC DATABASES INDICATED ABOVE AND ARE APPROXIMATE.

N

TOWN OF YARMOUTH
TOWN OF CUMBERLAND
I-295
BROAD COVE
TOWN OF CUMBERLAND
TOWN OF FALMOUTH
CHENERY BROOK WATERSHED
MILL CREEK WATERSHED
NORTON BROOK WATERSHED
I-95 FALMOUTH SPUR
SCITTERYGUSSET CREEK WATERSHED
WEBES CREEK WATERSHED
MUSSEL COVE
PRESUMPSCOT RIVER ESTUARY
CASCO BAY
ROUTE 1
TOWN OF FALMOUTH
CITY OF PORTLAND

1250 0 1250 2500

SCALE: 1" = 2500'

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SHEET NO.

CASCO BAY FRONTAL DRAINAGE STUDY WATERSHED

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 2500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME:

PROJECT NAME:
CASCO BAY FRONTAL DRAINAGE WMP

CLIENT:
TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

LEGEND

- WATERSHED BOUNDARY
- MUNICIPAL BOUNDARY
- STREAM | CREEK
- PUBLIC ROADWAY
- EXISTING CULVERT
- 150 MAJOR (50') CONTOUR
- MINOR (10') CONTOUR

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N

FALMOUTH SPUR INTERCHANGE.

CULVERT CROSSINGS AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

I-295

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

MILL CREEK

WEBES CREEK BASIN AREA: 0.54 MI²

CONFLUENCE WITH MILL CREEK

FALMOUTH LITTLE LEAGUE COMPLEX

BUCKNAM RD.

CATCHMENT 5

LUNT RD.

WEBES CREEK

SINGLE FAMILY DEVELOPMENT TYPICAL ALONG WEST SIDE OF FORESIDE RD.

206 ROUTE 1 - WALMART PLAZA

US RTE. 1

DEPOT RD.

US ROUTE 1 STORM INLET

COMMERCIAL DEVELOPMENT ALONG ROUTE 1 CORRIDOR TYPICAL OF WEBES CREEK WATERSHED

FORESIDE RD.

250 0 250 500

SCALE: 1" = 500'

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SHEET NO.

WEBES CREEK WATERSHED

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: WEBES CREEK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
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N

FORESIDE VILLAGE DEVELOPMENT

TOWN OF CUMBERLAND

TOWN OF FALMOUTH

MIDDLE RD.

US RTE. 1

NORTON BROOK BASIN AREA: 0.79 MI²

I-295

JOHNSON RD.

COMMERCIAL DEVELOPMENT TYPICAL ALONG WEST SIDE OF ROUTE 1

NORTON BROOK

SINGLE-FAMILY SUBDIVISION DEVELOPMENT TYPICAL OF EAST PORTION OF WATERSHED

CONFLUENCE WITH MILL CREEK

NORTHBROOK DRIVE DEVELOPMENT

FALMOUTH TOWN LANDING

MILL CREEK

FORESIDE RD.

CASCO BAY

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

CULVERT CROSSINGS AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

500 0 500 1000

SCALE: 1" = 1000'

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SHEET NO.

NORTON BROOK WATERSHED

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1000'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: NORTON BROOK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
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N

CHENERY BROOK BASIN AREA: 2.07 MI²

TUTTLE RD.

SINGLE FAMILY RESIDENTIAL DEVELOPMENT TYPICAL ALONG MIDDLE RD.

US RTE. 1

TOWN OF CUMBERLAND

TOWN OF FALMOUTH

MIDDLE RD.

CHENERY BROOK

ST. LAWRENCE AND ATLANTIC RAILROAD

I-295

MILL CREEK

JOHNSON RD.

US RTE. 1

CULVERT CROSSING AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

CONFLUENCE WITH MILL CREEK

CASCO BAY

750 0 750 1500

SCALE: 1" = 1500'

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SHEET NO.

CHENERY BROOK WATERSHED

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: CHENERY BROOK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

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N

MILL CREEK MAIN STEM
BASIN AREA: 2.01 MI²

MIDDLE RD.

TOWN OF CUMBERLAND

TOWN OF FALMOUTH

ME RTE. 9

SINGLE FAMILY RESIDENTIAL DEVELOPMENT TYPICAL ALONG RT. 9 & MIDDLE RD.

WOODS RD.

MILL CREEK

JOHNSON RD.

US RTE. 1

ME ROUTE 9 - LONGWOODS ROAD

I-295

CONFLUENCE OF CHENERY BROOK

CONFLUENCE OF NORTON BROOK

US ROUTE 1 - SOUTH CORRIDOR

I-95 FALMOUTH SPUR

MIDDLE RD.

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

CULVERT CROSSING AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

FORESIDE RD.

FALMOUTH RD.

US RTE. 1

CONFLUENCE OF WEBES CREEK

TIDAL OUTFALL OF MILL CREEK

MUSSEL COVE

750 0 750 1500

SCALE: 1" = 1500'

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SHEET NO.

MILL CREEK WATERSHED

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME:

PROJECT NAME:
CASCO BAY FRONTAL DRAINAGE WMP

CLIENT:
TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY DATE
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N

FALMOUTH TRANSFER STATION

FALMOUTH PUBLIC WORKS

MILL CREEK

WOODS RD.

SINGLE-FAMILY RESIDENTIAL DEVELOPMENT TYPICAL ALONG MIDDLE RD.

I-95 FALMOUTH SPUR

SCITTERYGUSSET CREEK BASIN AREA: 0.98 MI^2

MIDDLE RD.

BUCKNAM RD.

FALMOUTH RD.

DEPOT RD.

US RTE. 1

WEBES CREEK

TIDAL OUTFALL OF SCITTERYGUSSET CREEK

I-295

CULVERT CROSSING AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

PRESUMPSCOT RIVER ESTUARY

500 0 500 1000

SCALE: 1" = 1000'

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SHEET NO.

SCITTERYGUSSET CREEK WATERSHED

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1000'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

A C O R N ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: SCITTERYGUSSET CREEK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

Appendix B: Route 1 Falmouth Commercial District Stormwater Management Plan

Route 1 Falmouth Commercial District

Stormwater Management Plan



Town of Falmouth, ME

January 2013

This report was prepared for the Town of Falmouth under award NOAA CZM NA10NOS4190188 to the Maine Coastal Program from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

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EXECUTIVE SUMMARY

The Route 1 corridor in Falmouth is an important commercial center for the community. In 2011, the Town commissioned a Route 1 Infrastructure Plan for the area between Route 88 and the Turnpike Spur to coordinate future improvements in the public right-of-way. The Town of Falmouth envisions a denser pattern of development along the commercial Route 1 corridor with activities day and night. In order to further inform the redevelopment of this corridor, the Town acquired a National Oceanic and Atmospheric Administration - U.S. Department of Commerce grant through the Maine Coastal Program.

This study accomplished the following:

- identified the linkage of private and public stormwater runoff in the commercial Route 1 area;
- developed an integrated strategy that will complement the Route 1 Infrastructure Plan;
- provided a demonstration of the potential for integration of traditional infrastructure and Green Infrastructure management for a commercial district in Maine;
- began the process towards addressing polluted stormwater discharges into Mussel Cove, which is currently closed for shellfishing due to pollution; and
- identified an appropriate demonstration project from this plan in collaboration with MaineDOT along Bucknam Road.

Webes Creek is a small tributary of Mill Creek which discharges into Mussel Cove and Casco Bay. A large portion of the Route 1 commercial district is within the 341-acre Webes Creek watershed. This small watershed area contains over 112 acres of impervious surfaces (i.e. roadways, rooftop, pavements, etc.), or approximately 33% of the watershed area, which makes the tributary likely to be impaired due to polluted stormwater runoff. Twelve commercially developed parcels within the watershed currently provide some form of stormwater management for peak rate of runoff and/or water quality. Many of these systems are outdated under current standards, but can be cost-effectively retrofitted to provide advanced stormwater management. Several other areas within the Webes Creek watershed were identified as priorities for future stormwater management retrofitting, particularly for runoff from Route 1 itself. Stormwater drainage infrastructure was mapped and field verified as a part of this project and several critical pieces of drainage infrastructure along Route 1 were identified as having "sensitive" hydraulic capacity. These locations were recommended for improvements during future upgrades to Route 1 in order to alleviate upstream flooding problems and to maximize the potential for additional growth in the corridor.

Additionally, recommendations were made to evaluate and modify local codes and ordinances to maximize the potential for enhanced management of stormwater of future redevelopment projects in order to offset existing impacts and to accommodate future growth. Alternatives to addressing existing untreated stormwater discharges through redevelopment may include public-private partnerships for strategic retrofitting. Total cost for identified retrofits may range between $2 and $5 MM. Further evaluation of these retrofits was recommended to determine implementation feasibility and priority. Recommendations for financing retrofits included user fee implementation, use of Tax Increment Financing (TIF) funds, or special assessment districts.

1. INTRODUCTION

1.1 PROJECT BACKGROUND

Most of the commercially developed corridor along Route 1 in Falmouth is located within the Mill Creek watershed. The Mill Creek watershed is identified as a "priority watershed" by the Town of Falmouth in its municipal stormwater discharge permit program plan which obligates special attention by the Town to addressing polluted stormwater runoff.

Webes Creek is a small tributary of Mill Creek, which accepts the majority of stormwater runoff from the commercial corridor along Route 1. Mill Creek discharges into the Casco Bay at Mussel Cove, which lies within what the Maine Department of Marine Resources (DMR) calls "Growing Area 13", which is currently closed for shellfishing due to pollution. Mussel Cove is also a part of a coastal area (DMR 14-A) identified in the Statewide Bacteria Total Maximum Daily Load (TMDL) (approved September 2009) as "impaired" for bacteria. A Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. Due to increasing levels of development within the area, the Mill Creek watershed is thought to be susceptible to becoming an "Urban Impaired Stream" in the future.

Urban Impaired Streams are designations under State of Maine Stormwater Management Law, as a subset of impaired waters, and which are thought to be impaired due to stormwater runoff. Urban Impaired waterbodies have negative consequences environmentally, economically, and financially. The Town has been working proactively towards preventing this impairment from occurring.

In 2011, the Town commissioned a Route 1 Infrastructure Plan for the area between Route 88 and the Turnpike Spur to coordinate future improvements in the public right-of-way. This plan examines traffic, utilities, drainage, and streetscape. It is one component of an overall redevelopment plan for the Route 1 area. This infrastructure planning effort is being conducted in parallel with the development of recommended zoning ordinance amendments for this section of Route 1. The Town of Falmouth envisions a denser pattern of development along the commercial Route 1 corridor with activities day and night, and an emphasis on pedestrians and sidewalks with attractive landscaping which appeals to businesses and shoppers.

Well-managed stormwater runoff is imperative to good redevelopment planning. While it is known that stormwater runoff from private lands discharge into the public drainage system along Route 1, it is not well understood how the private lands impact stormwater volumes, or stormwater quality, which is then conveyed via the public drainage system into Webes Creek and eventually into Mill Creek and Casco Bay. A more detailed understanding of the interaction between private runoff and the public drainage system will enhance the Route 1 Infrastructure Plan both in terms of capacity for growth and also for a greater understanding of the need for public-private partnerships (such as shared stormwater treatment facilities, rather than parcel by parcel treatment) that can improve stormwater quality entering the public drainage system.

The Town identified the following key issues as the basis for this project:

- The Town lacks a good perspective on the contributions of private and public stormwater runoff to the overall drainage system;
- The Town lacks a good measure of the impervious surface area and build-out capacity for development in the project watershed;
- Just as the Town understands the linkage between the zoning for private properties and improvements to public right-of-way infrastructure, it wants to develop a similar understanding of the linkage of private and public stormwater runoff;

- The Town desires to build on, and not duplicate, past study efforts and use a comprehensive, holistic approach to redevelopment planning;
- The Town seeks to balance planning efforts with actual implementation and evaluation;
- The Town desires to update its stormwater regulations to the current best management practices for new treatment systems; and
- The Town desires to explore innovative public-private partnerships and funding mechanisms to enhance stormwater quality entering Webes Creek, to reduce peak flows to ensure the capacity required for growth, and to make an efficient and effective use of private and public funds.

This project was funded under award NOAA CZM NA10NOS4190188 to the Maine Coastal Program from the National Oceanic and Atmospheric Administration - U.S. Department of Commerce. It should be noted that the statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the National Oceanic and Atmospheric Administration or the Department of Commerce.

1.2 PROJECT GOALS

The project goals are to:

- examine the linkage of private and public stormwater runoff in the commercial Route 1 area;
- develop an integrated green infrastructure strategy that will complement the Route 1 Infrastructure Plan;
- provide a demonstration of the potential for integration of traditional infrastructure and Green Infrastructure management for a commercial district in Maine;
- begin the process towards addressing polluted discharges into Mussel Cove, which is currently closed for shellfishing due to pollution; and
- commit to implementing an appropriate demonstration project from this plan in collaboration with MaineDOT.

1.3 REPORT OBJECTIVES

Consistent with the Project Scope of Work, to be completed by December 31, 2012, the objectives of this Report are to:

- Document the methods utilized to execute the Route 1 Falmouth Commercial District Stormwater Management Plan Tasks;
- Define the Webes Creek subwatershed boundary (i.e. project boundary), which includes:
    - Enhanced drainage infrastructure mapping.
- Provide evaluations of the private stormwater management facilities, which includes:
    - Confirmation of the presence of such facilities;
    - Any noticeable deviations or defects from the original design intent;
    - A general performance rating of the system; and
    - Noting potential locations to consider in future retrofitting efforts.
- Conduct a Build-Out Analysis, which includes:

- Projected increases in project area impervious surface coverage;
- Projected capacities of the Town's drainage infrastructure under future build-out; and
- Recommendations for management enhancements.

- Conduct a Stormwater Retrofit Analysis based on results from the private stormwater management evaluations and the build-out analysis, which includes:
  - Suggested modifications to existing stormwater management facilities;
  - Proposed new stormwater quality treatment systems for enhanced stormwater quality or reduced peak flow rates; and
  - Planning-Level Opinion of Costs.
- Provide suggestions for adjustments to Town Ordinance or Rule Changes to enhance Stormwater Management.

2. MAPPING THE WEBES CREEK SUBWATERSHED

2.1 METHODS

Multiple steps were taken to define the Webes Creek subwatershed boundary, which also defines the limits of this study. The first step towards defining the drainage boundary consisted of an evaluation of Falmouth's Geographic Information System (GIS) including topographic contours, existing stormwater drainage system, parcel boundaries and other relevant geographic information. Next, a more in-depth analysis of the drainage area was conducted utilizing site plans provided by the Town of Falmouth (Town) for certain developments within the subwatershed. These site plan sheets provided information on the site-specific storm drain piping networks necessary to refine the previous draft of the subwatershed boundary by incorporating missing storm drain data. Additionally, site plans were used to identify stormwater management facilities (i.e. detention basins, treatment units, etc.) for incorporation into the Town's GIS and as a basis for facility evaluation discussed in Section 3.

Site plans were obtained for the following facilities:

- CDC, Parcel ID U24-007 (no detail sheets included in plan set)
- Bangor Savings, Parcel ID U11-035A (no detail sheets included in plan set)
- Falmouth Inn, Parcel ID U11-035 (no detail sheets included in plan set)
- Gorham Savings, Parcel ID U52-004
- Maine Med, Parcel ID U58-010
- Morong Service Center, Parcel ID U52-001B
- Norway Savings, Parcel ID U58-010-A1
- Rite Aid, Parcel ID U12-011
- Wal-Mart, Parcel ID U52-002 (no detail sheets included in plan set)
- Key Bank, Parcel ID U58-006
- Falmouth Shopping Center, Parcel ID U12-002
- Family Ice, Parcel ID U52-005 (no detail sheets included in plan set)
- Foreside Assoc., Parcel ID U11-026 (no detail sheets included in plan set)
- Fundy Circle, Parcel ID U11-035C
- Shops at Falmouth Village, Parcel ID U24-005
- Tidewater Development, Parcel ID R04-028 (no detail sheets included in plan set)
- Athletic Fields, Parcel ID U58-004 (no detail sheets included in plan set)

The final step in refining the subwatershed boundary was to field verify locations where drainage flow direction was not clear based on pipe networks or contour data. A site visit was conducted on August 6, 2012. After observing the physical drainage features and localized topography in the field, the subwatershed boundary was finalized and is shown in Figure 2-1.

2.2 CLARIFICATIONS

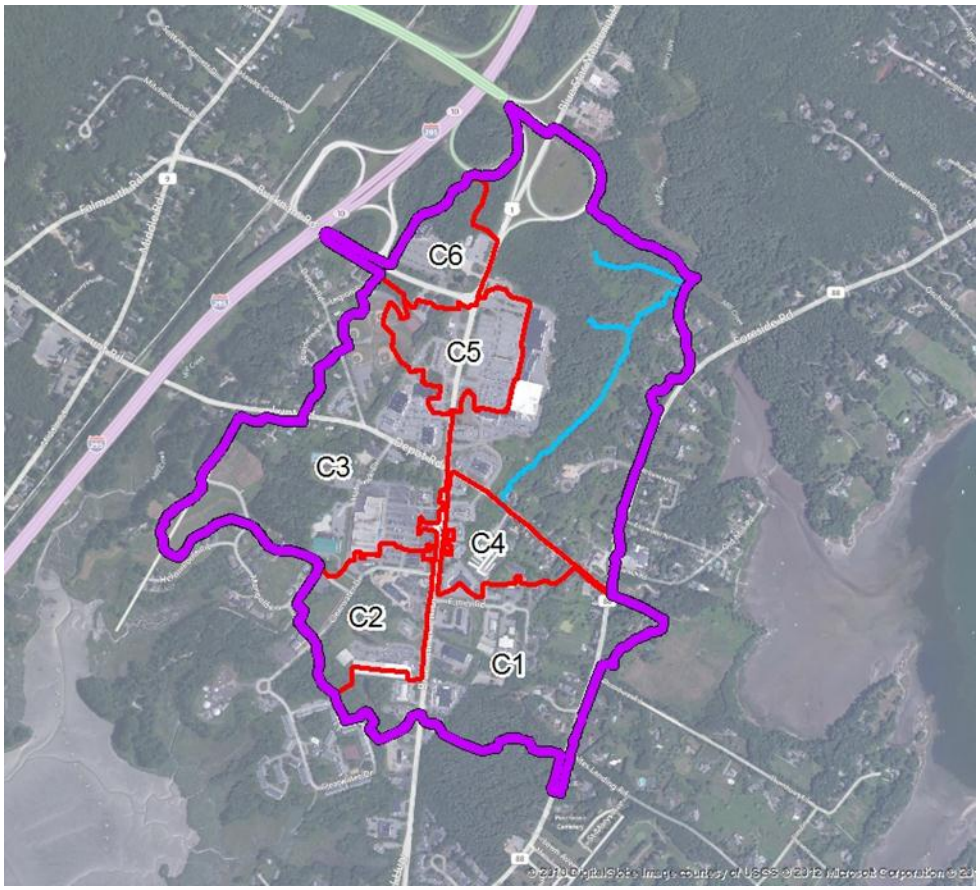
The following is a list of the key assumptions utilized in the development of this task:

- The site plans/details provided by the Town are the most up-to-date records available; and
- Existing data layers within GIS for the Town of Falmouth (drainage, contours, parcels, etc.) are accurate.

2.3 FINDINGS

The figure below shows the final Webes Creek Subwatershed Boundary, as it has been delineated utilizing the methods discussed above. It encompasses an area of approximately 341 acres, and consists of several important commercial properties along the Route 1 corridor in addition to residential properties primarily on the eastern side of the subwatershed. Through impervious cover mapping evaluation (discussed in Section 4), it was determined that the subwatershed contains approximately 112 acres of impervious surfaces. These surfaces, such as rooftop, roadway and parking area, restrict infiltration of precipitation and increase runoff. Numerous studies in a variety of geographies and climates indicate that small urban streams with watersheds that have greater than 10% of their land area covered by impervious surfaces are generally impaired from pollution associated with stormwater runoff. Currently, the Webes Creek subwatershed area is approximately 33% impervious cover. It is our understanding that Webes Creek has not been assessed for impairment and therefore is not currently classified as an impaired water despite its high percentage of impervious surface. The subwatershed has been further subdivided into smaller hydrologic units (catchments) in order to conduct hydrology evaluations for the build-out analysis, as discussed in Section 4 of this Report. These catchment areas were selected for delineation in order to assess the influence of these areas on critical drainage infrastructure within the overall project area and they do not constitute the entirety of the Webes Creek subwatershed. The Webes Creek subwatershed boundary is the basis for all further evaluation in this Report and is considered to be the "project area".

Figure 2-1: Webes Creek Subwatershed Boundary



Key:

Purple = Webes Creek Subwatershed Boundary
Red = Catchment Areas
Light Blue = Webes Creek

3. EVALUATING PRIVATE STORMWATER MANAGEMENT FACILITIES

3.1 BACKGROUND AND METHODS

The objectives of this task of the project is primarily to 1) identify where designed stormwater management (quality or quantity) is occurring within the subwatershed, 2) identify what types of systems are within the project area for consideration of future upgrade or improved management, and 3) provide a qualitative assessment of the systems' effectiveness for both stormwater quality and quantity management. Stormwater management facility locations were identified from review of aerial photography and from site plans obtained and discussed in the previous Report section.

Stormwater management facilities, as identified in this project area, typically consist of detention basins designed to manage stormwater quantity (i.e. peak flow rates) or newer systems designed to manage both stormwater peak runoff rates and also improve stormwater quality. Performance inspections of ten above-grade stormwater management facilities were conducted in the field on August 6, 2012, and the remaining two (Gorham Savings Bank and Fundy Road Pond) were conducted on October 30, 2012. Each inspection consisted of an initial visual evaluation of the site against site plans and other available documentation, and included photographs, measurements, and notes on the inspection forms. Performance inspections were largely based on visual inspection forms developed by The University of Minnesota. Copies of the inspection forms completed during the site visits conducted on August 6, 2012, as well as photographs taken of the site, are included as Appendix B of this Report.

The "Stormwater Treatment: Assessment and Maintenance" forms primarily focus on facility structural condition which is one of the four components of our evaluation for stormwater management system effectiveness. The performance rankings provided in this section are not quantitative, but are instead a qualitative evaluation based on best professional judgment and the following characteristics of each facility: structural condition, design intent, system type, and apparent level of maintenance

It is important to note that without comprehensive water quality and quantity sampling/monitoring it is not possible to fully evaluate the effectiveness of a stormwater system to provide water quality or quantity benefit.

For reference, the following table summarizes the typical pollutant removal efficiency up to the 1-inch storm event, as reported in the Stormwater Best Management Practices Performance Analysis prepared by Tetra Tech, Inc. on behalf of the USEPA and dated March 2010, for the types of stormwater management facilities identified within the project area. Stormwater filters are generally the most effective system for both water quantity and quality management if designed and constructed correctly. Dry detention basins are the least effective for quality control, but can be very effective for peak runoff rate attenuation (i.e. quantity control).

Table 3-1: Stormwater Management Facility Typical Performance Summary

System Category	Metals Removal Efficiency[1]	Nutrient Removal Efficiency[2]	TSS Removal Efficiency[3]
Filter System (includes all proprietary and non-proprietary systems with aerobic filter components	70-99%	30-80%	65-99%
Dry Detention Basin	50-70%	5-15%	20-45%
Wet Pond	60-90%	5-20%	30-80%

[1] Zinc used as representative "metal"; Zinc is the primarily detectable metal in non-industrial stormwater.
[2] Varying filter media components will influence nutrient removal efficiency in filtration systems.
[3] TSS = Total Suspended Solids

3.2 CLARIFICATIONS

The following is a list of the key assumptions utilized in the development of this section of the Report:

- Detention Basins that did not have a specified permanent pool elevation on project site plans were assumed to be Dry Detention Basins, even if standing water was visible within the system;
- Performance evaluations conducted via visual inspection provide minimal evidence of a system's overall effectiveness. For detailed analysis of effectiveness, comprehensive monitoring is necessary; and
- Due to access limitations, below-grade stormwater management facilities, such as the one located at the Shops at Falmouth Village (Parcel ID U24-005) and Norway Savings Bank (Parcel ID U58 010-A1), were not evaluated. Additionally, there are two below-grade stormwater management facilities that have been proposed and approved at the Wal-Mart site (Parcel ID U52-002) that have not been constructed at this time;

3.3 FINDINGS

A qualitative ranking system of Poor, Fair, Good, and Excellent was used to identify the effectiveness of each system to provide BOTH quality and quantity treatment.

The ten stormwater management facilities and their assumed performance ranking are summarized in the table below, and described in more detail in the following sections. A location map of these facilities has been provided in Figure 1 Appendix A of this Report.

Table 3-2: Private Stormwater Management Facility Performance Rankings

Parcel ID	Facility Name	Type of System	Performance Ranking
U11-035-C	Fundy Circle (Basin 1)	Dry Detention Basin	Poor
U11-035-C	Fundy Circle (Basin 2)	Dry Detention Basin	Fair
U11-035-D	Fundy Road (Basin 3)	Dry Detention Basin	Fair
U58-010	Maine Medical Center	Dry Detention Basin	Good
U52-001-B	Morong Service Center	Dry Detention Basin	Good
U12-002	Falmouth Shopping Center	Dry Detention Basin	Good
U58-006	Key Bank (SF 1)	Soil Filter	Excellent
U58-006	Key Bank (SF 2)	Soil Filter	Excellent
U52-004-ON	Gorham Savings Bank	Soil Filter	Excellent
U12-011	Rite Aid	Wet Pond	Excellent
U24-001 & U24-005	Shops at Falmouth Village	Below-Grade Storage	Not Evaluated
U58 010-A1	Norway Savings Bank	Below-Grade Filter	Not Evaluated

3.3.1 Fundy Circle (Dry Detention Basin 1) Parcel ID: U11-035C

The stormwater management facility at Fundy Circle consists of two Dry Detention Basins located on the eastern end of the Fundy Circle parking lot. Detention Basin 1 has one inlet, which discharges from a catch basin within the parking lot and which is almost completely clogged with sediment and vegetation. The standing water in both the catch basin and the pond (a.k.a. detention basin) was noted as having

visible surface sheen, which may be indicative of oil contamination from the adjacent parking lot. In addition to having sheen, the water in this pond had evidence of suspended solids and algal blooms. It should be noted that no sampling was conducted on the standing water, so the pollutants resulting in the sheen remain unknown.

The pond has about 80% vegetation cover and is overrun by cattails. There is an estimated 1.5 feet of standing water, and close to one foot of sediment deposition. All of the flow from this pond ultimately discharges into Fundy Circle Pond 2 (see below). A local employee of Normandeau Associates (whose office is adjacent to these ponds) stated that these ponds had been dredged twice since their construction, and that local residents of Fundy Circle had complained that they did not want the cattails removed.

Based on the condition of the pond's water, its historic issue with sediment, and the excessive vegetation and standing water (which are not components of properly constructed Dry Detention Basin), this facility was evaluated as Poor.

3.3.2 Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C

The second of the two Dry Detention Basins located in series at Fundy Circle (as noted above) is located slightly north of the walking path between the two ponds. It accepts discharge from two outlets, one from Pond 1 and the other from a catch basin in a more northern part of the lot. The pond has an outlet control structure. The outlet of the pond consists of a catch basin with overflow pipe, a trash rack, and an emergency spillway. The low-flow inlet from the pond to the outlet structure could not be located in the field; it may be submerged and potentially clogged. Both inlets into the pond have much less sedimentation than Detention Basin 1, but still have excessive vegetation growth in front of the culvert. Just as in Pond 1, there was approximately 1-foot of sediment deposit, about 1.5-feet of standing water, and approximately 90% vegetated cover consisting largely of cattails. In addition to having an oily sheen, the water in this pond had evidence of suspended solids and algal blooms.

Based on the condition of the pond's water (which appeared slightly better than Detention Basin 1), its historic issue with sediment, and the excessive vegetation and standing water (which are not components of properly constructed Dry Detention Basin), this pond was evaluated as Fair.

3.3.3 Fundy Road (Dry Detention Basin 3) Parcel ID: U11-035D

This stormwater management facility located off of Fundy Road is a Dry Detention Basin, just east of the Falmouth Inn. There is one riprap lined inlet to the pond, which accepts runoff via surface flow from the parking lot to the south and east. The pond has an outlet control structure consisting of a grated concrete structure with a partially clogged V-notch weir and three 15-inch diameter Corrugated Metal Pipe (CMP) outlets. There did not appear to be a designed emergency spillway and erosion, due to the high flow bypass of the system, was occurring across the detention basin impoundment. There is excessive vegetation growth in the pond consisting largely of cattails.

Based on the presence of excessive vegetation and standing water (which are not components of properly constructed Dry Detention Basin), this pond was evaluated as Fair.

3.3.4 Maine Medical Center (Dry Detention Basin) Parcel ID: U58-010

The stormwater management facility at the Maine Medical Center is a Dry Detention Basin located on the eastern side of the entrance to the Center, and has a security fence around the perimeter of the basin. There is one inlet to the pond, which is located at the end nearest to the parking lot and appeared clear of obstructions. On the opposite end of the pond, there are three outlets, which vary in elevation (the smallest pipe being at the lowest elevation). The lowest outlet was completely submerged and appeared to be mostly clogged, despite flow discharging at the outlet.

There were no visible signs of major erosion within the pond, but there were several animal burrow holes, as well as trees along the slopes, both of which can jeopardize the embankment's stability. The standing water in the pond appeared to have evidence of suspended solids and had approximately 50% vegetative cover consisting largely of cattails.

Based on the condition of the pond's water and embankments, and the presence of vegetation and standing water (which are not components of properly constructed Dry Detention Basin), this pond was evaluated as Good.

3.3.5 Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B

This stormwater management facility is a Dry Detention Basin located at the northwest end of the parking lot. It has two inlets to the pond, one of which has a Downstream Defender, a subsurface proprietary sediment pretreatment unit, upstream of the detention basin discharge. The outlet of the pond is abutted by an emergency spillway with a wooden berm/weir. The outlet control structure, a catch basin with a flow control panel, was enclosed in a concrete structure and therefore could not be inspected. There was a tree growing on top of one of the inlets, which restricts maintenance access and threatens stability. The length to width ratio of the pond slightly hinders its functionality, as the west end of the system only sees flow during high storm events. The standing water in the pond appeared to have evidence of suspended solids and sediment deposition, and had approximately 60% vegetative cover consisting largely of cattails.

Based on the condition of the pond's water, and the shape of the pond, the presence of vegetation and standing water (which are not components of properly constructed Dry Detention Basin), this pond was evaluated as Good.

3.3.6 Falmouth Shopping Center (Dry Detention Basin) Parcel ID: U12-002

The stormwater management facility for the Shaw's Shopping Plaza is a Dry Detention Basin. It is located to the south of the parking lot. The provided site plan indicated that a sediment pretreatment unit was located upstream of the pond's inlet, but this device could not be located.

There were no signs of erosion and the one inlet to the pond had very minor evidence of sedimentation. The Dry Detention Basin had extensive vegetative growth and very little standing water, but was covered by cattails. This system also has a buffer between its outlet and the nearby Webes Creek. For its intended purpose, the pond seemed to have effective flow control, evidenced by its still-functioning V-notch weir, which had unobstructed flow discharging from the system.

Based on the field evaluation of Dry Detention Basins, this pond was evaluated as Good.

3.3.7 Key Bank (Soil Filter 1) Parcel ID: U58-006

The stormwater management facility at Key Bank is comprised of two Underdrained Soil Filters (USF). USF 1 is the smaller of the two and has one inlet and one outlet with an outlet control structure located in the southern end of the basin. There is very minor sedimentation at the inlet pipe. The outlet control structure which this soil filter discharges to was found to have two unknown connections; these connections could not be identified on the plans and should be investigated, as it is unclear as to whether the site plans are out-of-date, or if the systems have adequate capacity to accept these additional flows. There was also evidence of minor sediment deposition at the discharge point of the outlet structure.

Based on the field evaluation of the USF, this facility was evaluated as Excellent.

3.3.8 Key Bank (Soil Filter 2) Parcel ID: U58-006

The second of the two USFs at Key Bank has two inlets located on either end of the system. Overflow control consists of an existing catch basin, the inlet of which was raised for the soil filter's construction, and ties into the Route 1 drainage system. There is very good vegetation growth throughout the system. There was also evidence of minor sediment deposition at the discharge point of the outlet structure.

Based on the field evaluation of the USF, this facility was evaluated as Excellent.

3.3.9 Gorham Savings Bank (Soil Filter) Parcel ID: U52-004-ON

The stormwater management facility for Gorham Savings Bank is located in the center of the parking lot. Review of the site plans proved inconclusive in determining what type of system this was intended to be, given a lack of details, unknown subsurface conditions, and the at-grade overflow control structure, so this system was assumed to be a soil filter for evaluation purposes. The outlet control consists of a catch basin, which according to the site plan, includes a "bio-skirt" and snout oil and debris separator, and sits approximately at-grade within the soil filter, and ties into the Route 1 drainage system. The outlet control structure accepts stormwater runoff via surface flow from the surrounding parking lot, and from nearby catch basins. There is very good vegetation growth throughout the system.

It should be noted that there was evidence of standing water in the system, and it is unclear as to whether this is due to the recent storm event, clogging of the filter media, or if the design intent was for the system to provide detention prior to discharging to the outlet control structure.

Based on the field evaluation of the USF, this facility was evaluated as Excellent.

3.3.10 Rite Aid (Wet Pond) Parcel ID: U12-011

The stormwater management facility for Rite Aid is a wet pond located downslope of the parking lot in the woods. It has a security fence around its perimeter, and one riprap lined inlet. It also has an emergency spillway close to the outlet control structure. This wet pond appeared to be functioning well at the time of the site visit, as it had evidence of ponded water being retained, its trash rack was free of debris, and its outlet control structure had very minor sediment deposition. Being a fairly new stormwater control system (installed in 2007), it also has an underdrained gravel trench per current MaineDEP guidance, designed to reduce stormwater effluent temperature. There were minimal signs of erosion and only some spotty cattail growth throughout. The quality of the standing water appeared to be good, and the pond had approximately 60% vegetative cover.

Based on the field evaluation of this Wet Pond, this facility was evaluated as Excellent.

It should be noted that this facility is adjacent to an open area with a downstream buffer before discharging to Webes Creek.

3.3.11 The Shops at Falmouth Village (Below-Grade Stormwater Management Facility) Parcel ID: U24-001 & U24-005, and Norway Savings Bank (Below-Grade Stormwater Management Facility) Parcel ID: U58-010-A1

As previously noted, due to access limitations, the below-grade stormwater management facilities located at the Shops at Falmouth Village and Norway Savings Bank were not evaluated. It is assumed that both systems provide at least peak flow attenuation and perhaps other stormwater management benefits.

3.4 CONCLUSION

As noted above, stormwater management system effectiveness can only be understood through comprehensive monitoring. Stormwater management systems can vary in their ability to treat common

stormwater pollutants and effectiveness can even vary amongst the same systems depending upon design details, storm event duration, intensity and seasonality. If a system has been poorly constructed or maintained, it may be achieving very little of its potential for peak flow attenuation and/or pollutant removal.

Despite the shortcomings of a qualitative evaluation, the value of the facility evaluation component of this project is primarily to 1) identify where stormwater management (quality or quantity) is occurring within the project area and 2) identify what types of systems are within the project area for future upgrade or management considerations. Modifications through retrofitting an older type of treatment system (i.e. Dry Detention Basins) could be implemented to maximize the effectiveness of the existing systems. Potential retrofits are discussed further in Section 5 of this Report.

4. BUILD-OUT ANALYSIS

4.1 BACKGROUND AND METHODS

A build-out analysis of the Webes Creek Subwatershed was conducted to determine the available hydraulic capacity of critical drainage infrastructure under existing and future conditions. This analysis can be used by the Town as a means of determining the potential impact of future development on stormwater contribution to the Town's drainage infrastructure, and therefore inform the Town on drainage improvements that may be necessary to accommodate future development.

The first step in this evaluation was to identify critical infrastructure. The Town's drainage infrastructure was evaluated to determine what areas contained critical infrastructure that may be impacted by existing and future development. From our analysis of the subwatershed hydrology, it appears that there are six key locations within the project area that convey upstream stormwater drainage, and which may be most impacted by future development.

After identifying the critical pieces of the Town's drainage infrastructure, appropriate catchments were delineated for the areas draining to each of these locations, for a total of six catchments. As this part of the study focused on critical infrastructure, other portions of the subwatershed that do not drain to major Town or private drainage infrastructure were not included in the analysis associated with peak flow impacts under build-out conditions. The remainder of the subwatershed was included in Table 4-1 given the potential of several parcels to be developed within these areas.

The catchments were delineated utilizing the same methods executed in defining the Webes Creek subwatershed boundary; much of the data compiled during that phase of the project helped to guide the development of the catchments. However, additional data on the impervious surface cover of the subwatershed was utilized for input into the hydrologic model, which was in-turn utilized to determine the peak flows of each catchment. Kappa Mapping, Inc. was subcontracted to conduct an impervious surface cover analysis of the area. GIS was employed to provide an analysis of the impervious surface cover data by each catchment area as shown in Table 4-1.

Based on feedback from a meeting with Town staff on October 1, 2012, the following parcels were identified as having potential for future development:

- R02-011 in Catchment 1;
- U52-001 in Catchment 2;
- U52-006 in Catchment 2;
- U52-005 in Catchment 3;
- U52-008 in Catchment 3;
- U24-006 in Catchment 3; and
- U24-007 in Catchment 3.

Of the six catchments, three (Catchments C1, C2 & C3) contained parcels identified as potential future development sites. The potential impervious area on each developable parcel was determined based on the average impervious coverage on adjacent parcels, excluding residential or undeveloped parcels. The approximate increase in impervious surface coverage for those parcels was then added to the catchment's overall impervious surface cover; this data, summarized in the table below, was then used as the basis for the hydrologic analysis. An average of 50% build-out of an average commercial parcel was used in the remainder of the subwatershed to account for possible development of U12-007-A, U13-002-B, and U12-006-A.

Table 4-1: Impervious Cover Projections by Catchment

Catchment	Total Catchment Area (acres)	Existing Impervious Cover (acres)	Projected Impervious Cover (acres)
C1	64.82	22.39	25.79
C2	25.98	10.68	13.68
C3	76.63	27.60	37.50
C4	17.34	6.67	6.67
C5	22.45	14.02	14.02
C6	17.76	7.06	7.06
Remainder of Subwatershed	115.82	23.88	38.27
Total	340.8	112.30	142.99

Peak runoff rates (cubic feet per second) were determined using the Rational Method. The main inputs for determining peak runoff rates via the Rational Method are drainage areas, impervious surface cover, and rainfall intensity. The size of the drainage areas was determined using GIS measurements of the delineated catchments, and the percentage of impervious surface cover was determined utilizing the GIS analysis described above. Rainfall intensity is based on geographic and storm-type-sensitive coefficients and the Time of Concentration (TC) for the catchment's stormwater runoff. Consistent with the Town's ordinance requirements for flood control, coefficients for the 2, 10, and 100-year storm events were taken from Table 12-2.4 of the *State of Maine Urban & Arterial Highway Design Guide*, dated January 2005, and the TC was defined using catchment topography. The HydroCAD Stormwater Modeling System by Applied Microcomputer Systems was then used to compute the TC time calculations using sheet flow, shallow concentrated flow, pipe flow, pond flow, and channel flow. It should be noted that the TC for Catchments C2 and C6 bypass the stormwater management facilities in these catchments, and therefore do not account for the impact the ponds may have on the TC. Refer to Figure 2-Appendix A of this Report for the Webes Creek Drainage Map, which shows parcels, catchments, existing stormwater management facilities, TC, and the critical infrastructure areas evaluated.

Once the projected peak runoff rate discharging to the Town's critical drainage infrastructure was determined, it was compared to the available capacity of the existing storm drain system. The capacity of these pipes was determined utilizing Manning's Equation, which uses pipe size, material, and slope to determine the maximum flow rates the system can accommodate. The size, material, and slope of the six pieces of critical drainage infrastructure were determined from the available site plans obtained from the Town as part of previous tasks. In areas where site plans were unavailable and GIS data was incomplete, field verifications were conducted on October 30, 2012. On this site visit, pipe sizes and materials were noted, and depth measurements of catch basin inverts were recorded and compared to GIS topography to approximate pipe slopes. The specific sources of pipe data is noted in the Build-Out calculations included as Appendix C of this Report, which consist of the Rational Method spreadsheet and the TC HydroCAD Calculations.

It should be noted that the objective of this assessment was to identify possible hydraulic capacity issues at priority drainage infrastructure and not to identify pollutant loads under build-out conditions. As stated in previous report sections, the Webes Creek watershed area is already beyond the "10% impervious cover threshold" that is linked to water quality impairment and any new impervious surface will continue to create challenges for management of runoff quality or quantity.

4.2 FINDINGS

Table 4-2 is a summary of the projected flow rates in each catchment, and the drainage system's available capacity. It should be noted that, in some cases, multiple catchments may impact a single piece of the Town's drainage infrastructure. Figure 4-1 shows a drainage diagram of the subwatershed.

Figure 4-1: Webes Creek Subwatershed Drainage Diagram

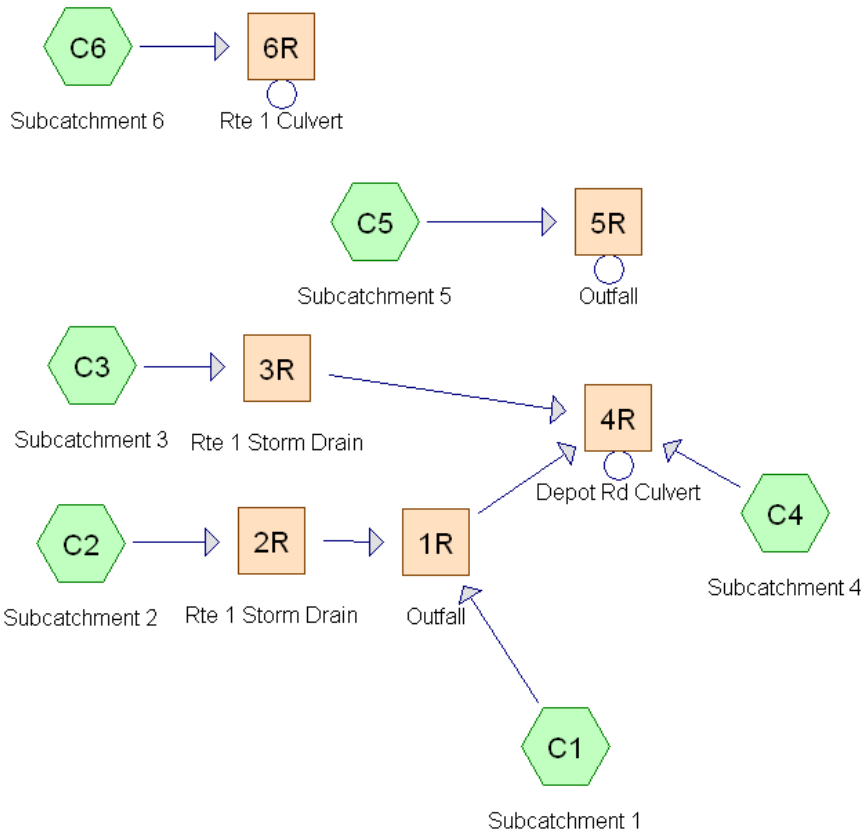


Table 4-2: Impact of Build-Out Conditions on Stormwater Contribution to Town's Drainage Infrastructure

Critical Infrastructure Area[1]	Catchments Draining to Infrastructure	Existing Infrastructure Diameter (inches)	2-Year Storm Flow (CFS)	10-Year Storm Flow (CFS)	100-Year Storm Flow (CFS)	Approximate System Capacity (CFS)
1 (1R Outfall)	C1, C2	36	59	87	124	31
2 (2R Rte 1 Storm Drain)	C2	36	14	21	31	74
3 (3R Rte 1 Storm Drain)	C3	42	46	70	101	80
4 (4R Depot Rd Culvert)	C1, C2, C3, C4	Two 40	123	181	260	172[2]
5 (5R Outfall)	C5	36	27	39	55	147
6 (6R Route 1 Culvert)	C6	18	14	20	28	9

[1] Refer to Figure 2-Appendix A of this Report for the Webes Creek Drainage Map, which shows parcels, catchments, existing stormwater management facilities, TC, and the critical infrastructure areas evaluated.

[2] Critical Infrastructure Area 4 consists of two 40-inch diameter culverts.

4.3 RESULTS AND CONCLUSIONS

Based on the results summarized above, it appears that critical infrastructure areas 1, 3, 4, and 6 may currently be experiencing storm drain capacity issues during the 100-year storm event, and that areas 1 and 6 may be experiencing storm drain capacity issues during the 2 and 10-year storm events as well. These infrastructure areas are sensitive to upstream development and may need to be evaluated and/or improved to accommodate additional development. Critical infrastructure areas 2 and 5 appear to have ample available hydraulic capacity and may be able to adequately accommodate future developments. As noted above, Catchments C1, C2, and C3 have been identified as areas most likely to experience future development which would impact areas 1, 2, 3, and 4. A summary of this discussion has been provided in the following table.

Table 4-3: Build-Out Potential of the Webes Creek Subwatershed Area

Critical Infrastructure Area	Catchments Draining to Infrastructure	Parcels with Future Development Potential? (Y/N)	Infrastructure Capacity
1	C1, C2	Y	Sensitive Storm Drain Capacity
2	C2	Y	Available Capacity
3	C3	Y	Sensitive Storm Drain Capacity
4	C1, C2, C3, C4	Y	Sensitive Storm Drain Capacity
5	C5	N	Available Capacity
6	C6	N	Sensitive Storm Drain Capacity

We would recommend that the critical infrastructure areas 1, 3, and 4 be further evaluated and potentially improved as part of the Town's current/ongoing Route 1 Planning Study or as a part of future developments in Catchment C1, C2, and C3. Even though Catchment C6 was not identified as a potential site for future development, the improvement of the critical infrastructure in this area may still be beneficial to improve the existing condition.

The excel spreadsheet describing the Build-Out calculations has been included as Appendix C for reference. Please note that, due to access issues and a lack of project records for the Route 1 drainage infrastructure, this model is considered preliminary, and the pipe slope can have a significant influence on culvert hydraulics. Further evaluation will be needed before this model is used in determining the acceptability of future development applications.

5. STORMWATER RETROFIT ANALYSIS

5.1 BACKGROUND AND METHODS

In general, the intent of a structural stormwater retrofit inventory is to identify specific locations within a watershed area that may allow the construction of updated stormwater management infrastructure. For the purposes of this project, the term retrofit is used to describe any engineered modification to existing infrastructure or land area(s) to improve stormwater quality or reduce peak runoff rates from impervious and developed areas.

Stormwater management retrofits can be implemented as modifications to existing stormwater management facilities or as new stormwater management facilities to be incorporated into an existing storm drain system or built area. Retrofit opportunity areas for this project were selected based on one or more of the following criteria:

- Available undeveloped or underdeveloped area to provide stormwater management;
- Impervious area without an engineered treatment system to addresses stormwater quality; or
- Developed area that discharges to one of the critical infrastructure locations identified as having "sensitive storm drain capacity".

There are three primary management goals considered for stormwater management retrofit facilities. These include:

- Stormwater quantity control (i.e. reducing peak rate of runoff) to prevent flooding using systems typically designed to manage 2, 10, or 100-year recurrence storm events;
- Stormwater quality or Water Quality Volume (WQV) treatment typically associated with the 1-inch, 24 hour storm event; and
- Peak runoff rate attenuation for the Channel Protection Volume (CPV) typically associated with the 1-year recurrence storm event. The CPV helps to minimize erosion and other such impacts to downstream natural stream systems.

The following represent the types of systems considered for retrofits within the project area and a brief description of the system.

Below-Grade Storage with Below-Grade Filter: Below-grade storage with below-grade filter refers to a combination system designed to detain a particular volume of flow and provide filtration for that storage volume. These systems are well suited to areas where surface land-use limits the development of a surface storage system and/or if stormwater is already routed via below-grade drainage infrastructure. The system considered for this analysis is a Stormtech™ chamber storage and "isolator row" filtration system. This system has the potential to attenuate peak flows and provide pollutant removal; in appropriate locations, it can provide volume reductions via infiltration.

Filter Box: Esplanade filter boxes refer to at-grade, vertical flow media filtration systems. These systems are well-suited to roadways or other developed areas were surface constraints limit installation of a soil filter. The Filterra™ tree box filters are used as model systems in this analysis; they range in footprint from 24 to 91 square feet of surface area. The filter has the potential to provide pollutant removal, but does not provide peak flow attenuation or volume reduction. These systems must be placed just upstream of existing catch basins (which will then act as overflow devices) and are connected via storm piping to the existing catch basins. Overflows from the box filters are collected at grade via the existing catch basins.

Soil Filter (aka Rain Garden, Bioretention or Filter Swale): Soil filter systems are vertical flow media filters that are typically vegetated with grass and/or landscape plantings. Often, these systems require an underdrain in poorly draining subsoils, but can provide some volumetric reduction via evapotranspiration and can be designed to promote infiltration below the underdrain if appropriate. Soil filter systems have the potential to reduce overall stormwater volumes and peak flows and have been shown to be effective in generally reducing loads of certain pollutants, including bacteria. Dry Swales are a subset of soil filters, but are developed as a linear filter and conveyance system for roadways. Rain gardens are a subset of soil filters that rely primarily on simple modified soil media and infiltration for treatment. Costs for soil filter systems can vary significantly depending on design complexity and site conditions.

Gravel Wetland: Gravel wetlands are horizontal flow retention and filter systems. The Gravel Wetland utilizes temporary storage and solids settling and soil media filtration as the primary mechanisms for pollutant removal. These systems can also provide peak flow attenuation and, through evapotranspiration, can reduce stormwater volumes. These systems are especially well-suited on poorly draining soils or in locations with limited hydraulic head. This is one of the University of New Hampshire Stormwater Center's most successful systems for overall pollutant removal.

Flow Control Structure: Flow control structures as retrofits are modifications to an existing culvert or storm drain inlet that is designed to control outflow into "downstream" stormwater management or conveyance structures. A flow control structure can take a variety of forms such as a weir, orifice, or a combination of the two. Flow control structures will not significantly reduce the total volume of runoff, but will redistribute the rate of runoff over a period of time by providing temporary storage of a certain amount of stormwater upstream of the control structure. The purpose is to reduce downstream flooding, peak rates of runoff and/or erosion problems.

Temperature Control Structure (Underdrained Gravel Trench): Temperature control structures are modifications to the outlet control structure of wet or dry ponds in order to reduce effluent temperature. In Maine, this is called the Underdrained Gravel Trench and extends horizontally from an existing or new outlet control structure along the edge of a wet pond. These are relatively inexpensive retrofits, are the current design standard for wet ponds in Maine and can also provide additional water quality or quantity management. The water quality volume is discharged solely through the underdrained gravel trench.

The following table provides a general summary of typical pollutant removal efficiency up to the 1-inch storm event, as reported in the Stormwater Best Management Practices Performance Analysis prepared by Tetra Tech, Inc. on behalf of the USEPA and dated March 2010, and average unit costs of several typical types of stormwater management systems considered in the project for retrofits. Each of the following systems can be designed for peak rate flooding or channel protection.

Table 5-1: Stormwater Retrofit Performance Summary

System Category	Metals Removal Efficiency	Nutrient Removal Efficiency	TSS Removal Efficiency
Filter System (includes all proprietary and non-proprietary systems with aerobic filter components)	70-99%	20-80%	45-99%
Gravel Wetland	60-90%	20-60%	50-99%
Flow/Temperature Control Structure Modification	N/A	N/A	N/A

As previously discussed, potential areas for stormwater retrofits were identified during the evaluations of private stormwater management facilities, and with consideration of the results of the build-out analysis. To summarize, the private stormwater management facility evaluation determined that the only stormwater management facilities considered to be in excellent condition were the soil filters located at Key Bank and Gorham Savings Bank, and the wet pond located at Rite Aid. The remaining facilities, which included low performing and outdated dry detention basins, all were evaluated as being in less than excellent condition and have room for improvement. Furthermore, the build-out analysis determined that critical infrastructure areas 1, 3, 4, and 6 have sensitive storm drain capacities; so, catchment areas C1, C2, C3, and C6, which discharge to these infrastructure areas, were evaluated for retrofit opportunities to improve the existing hydraulic condition and to accommodate future development.

5.2 CLARIFICATIONS

The following is a list of the key assumptions utilized in the development of this section of the Report:

- Unit costs utilized in the budget-level opinion of costs for the stormwater retrofits are derived from retrofit estimates developed for theoretical systems managing a unit of impervious area in order to develop an installation cost per unit; and
- Stormwater Quality Retrofits are sized based on available space for budgetary purposes, and should be evaluated in regards to MaineDEP stormwater management system design intent prior to implementation.

5.3 FINDINGS

The following subsections of this Report outline the priority areas for stormwater quality or quantity management identified throughout the course of this project, and the recommended potential retrofits associated with each site. The proposed modifications to existing stormwater management features will help to enhance water quality or quantity performance.

The following is a list of the stormwater retrofit opportunity areas, which have been identified for both quantity and quality, in reference to the numbered areas shown in the Webes Creek Retrofit Site Location Map (see Figure 3 - Appendix A of this Report). The list is not in order of priority.

<u>The Falmouth Shopping Center Dry Detention Basin Retrofit</u>

The Falmouth Shopping Center Dry Detention Basin (adjacent to Shaws) was reviewed as part of the evaluation of private stormwater management facilities. Existing infrastructure at this facility consists of an 18-inch HDPE pipe discharging into a dry detention basin approximately 5,000 Square-Feet (SF) in size, with a single outlet consisting of a V-notch weir. As was previously discussed in Section 3 of this Report, based on the field evaluation of this Dry Detention Basin, this system was evaluated as Good. However, a Dry Detention Basin is an outdated stormwater management system; so, this facility was noted as a good location for a potential stormwater retrofit opportunity.

An appropriate stormwater quality retrofit for this facility would be a gravel wetland retrofit, which would provide better quality treatment.

<u>The Falmouth Shopping Center Plaza Quality Enhancements</u>

The Falmouth Shopping Center contains a large amount of impervious surface consisting of buildings and a parking lot;. Portions of this development discharge untreated stormwater runoff directly to Webes Creek. Existing infrastructure in the developed area consists of a storm drain network comprised of manholes, catch basins, and HDPE piping ranging from 15 to 36-inches beneath the plaza parking lot. This discharges to a 36-inch RCP outfall in a densely vegetated, undeveloped area at the bottom of a steep slope behind the Falmouth Shopping Center, ultimately forming channelized flow to Webes Creek.

However, within Catchment C5, stormwater quality treatment is provided via the underdrained soil filters, located at Key Bank, upstream of the untreated area. In order to maximize the benefits associated with the upstream treatment provided by the underdrained soil filters located at Key Bank, which were found to be in excellent condition as discussed in Section 3 of this Report, stormwater quality and quantity retrofits should be considered for this area.

Systems that may function within existing parking areas, such as below-grade filter systems, can be expensive upgrades. A gravel wetland system in the undeveloped area at the outfall may be an appropriate alternative.

Clearwater Drive Flow Control

There is a large undeveloped forested wetland area behind the Morong Service Center, which discharges to a 24-inch PVC inlet south of the Foreside Place. Parcel U52-001 was identified by the Town during the build-out analysis as an area that is anticipated to undergo future development, and is also part of a catchment that has sensitive storm drain capacity. This undeveloped location is a good stormwater quality retrofit opportunity for a proposed flow control structure at the existing 24-inch PVC inlet. These can be highly cost effective to install for channel protection or flood control, but evaluation of upstream flooding is a crucial consideration. This type of retrofit may compromise future development of the parcel, and will therefore need to be evaluated as part of future land development plans. This retrofit option could be presented to prospective commercial developers to implement as part of future private site improvement projects.

The Fundy Circle Pond Retrofits

Fundy Circle, as discussed in Section 3 of this Report, currently has two ponds in series. Existing infrastructure consists of a 24-inch HDPE pipe discharging into two dry detention basins in series, which total approximately 8,000 SF in size, with a single outlet control structure that discharges to the Fundy Road storm drain system comprised of 24-inch HDPE piping, 15-inch PVC culverts, and roadside ditches. In their current state, these ponds are operating as poorly functioning stormwater management facilities, as noted in Section 3 of this Report, and could benefit from additional stormwater quality retrofits.

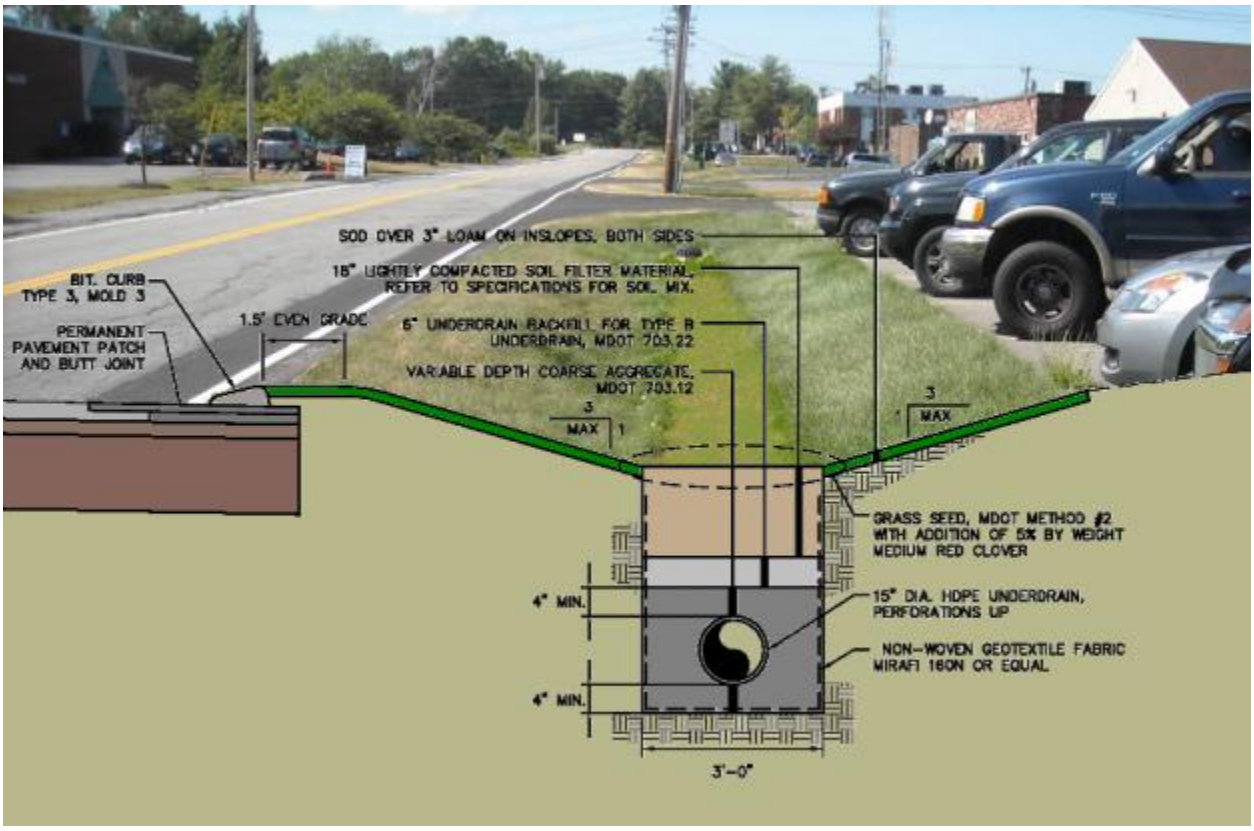
An appropriate stormwater quality retrofit for this facility would be a gravel wetland retrofit, which would provide improved stormwater quality treatment and channel protection.

Fundy Roadside Retrofit

There is an existing ditch that runs along Fundy Road which drains toward Route 1. The ditch collects runoff from surrounding developments and the Fundy Circle ponds. The ditch has two culvert inlets and discharges to a storm drain network consisting of 30-inch RCP piping, which ultimately discharges to a nearby 36-inch CMP outfall. This space within the roadway Right-of-Way could be better utilized to add to the area's aesthetic and safety, and provide stormwater quality treatment through a roadside filter retrofit. The installation of a filtration swale would not only provide stormwater quality treatment for Fundy road, but would also eliminate the need to have a deep and unattractive roadside ditch with the inclusion of a below grade conveyance pipe to accommodate upstream drainage.

The following figure demonstrates what a filtration swale may look like and is also applicable to the Bucknam Road Gateway retrofit concept.

Figure 5-1: Example Filtration Swale



The Falmouth Inn Greenspace Retrofit

East of the Falmouth Inn is a large, open, undeveloped vegetated area which straddles two parcels. The Fundy Road Dry Detention Basin #3 discharges to this area. Existing infrastructure consists of three, 15-inch CMP outlets from the existing dry detention basin into a well-vegetated, undeveloped, channelized area populated by cattails, which conveys stormwater runoff to the Fundy Road storm drain network of culverts.

This location would provide a good opportunity for additional stormwater quality treatment and channel protection volume discharge control, and would not disrupt existing uses, as it already functions as a wetland area. A viable retrofit for this area would be a gravel wetland.

The Greenway Waterlane

The Town has expressed interest in developing a Veteran's Memorial Park in the undeveloped space just north of the intersection of Depot Road and Lunt Road. This area is currently known as "The Lane" and collects runoff from the nearby Town baseball fields. This location would provide an excellent opportunity to incorporate a stormwater quality treatment system into an aesthetically pleasing memorial park, in place of the existing site, which has suffered in the past from severe erosion (as shown in the photograph below), where runoff bypassed the existing storm drain system completely. This erosion has recently been repaired by the Town. The existing infrastructure consists of a single catch basin structure, which ties into the depot road storm drain system. A viable retrofit for this area would be a gravel wetland.

Figure 5-2: Recent Conditions at The Lane Prior to Erosion Repair



Hat Trick Drive Flow Control Structure

There is a large, undeveloped area on Town-owned land, which discharges to two inlets, an 18-inch and a 24-inch CMP, at the Wal-Mart plaza off of Hat Trick Drive. Existing infrastructure consists of the two inlets located in a densely vegetated undeveloped area northeast of Wal-Mart, which conveys stormwater runoff from a natural channelized area to another channel north of the Wal-Mart parking lot, before discharging to the Route 1 storm drain system.

This area was identified by the Town during the build-out analysis as an area that is anticipated to undergo future development and is also part of a catchment that has sensitive storm drain capacity. This is a potential location for a flow control structure retrofit to reduce peak rates of runoff at downstream critical infrastructure areas. These can be highly cost effective retrofits to install for channel protection or flood control, but the extent of upstream flooding that can be accommodated is a crucial consideration.

The Morong Service Center Pond Outlet Modification

The Morong Service Center, as discussed in Section 3 of this Report, currently has a large dry detention basin, which was evaluated as being in relatively good condition. Furthermore, it is located in a catchment that has sensitive storm drain capacity. Existing infrastructure consists of two inlets, an 8-inch PCV and an 18-inch HDPE pipe, discharging into a dry detention basin approximately 16,500 SF in size, with a single outlet control structure, which discharges to a large, densely vegetated, undeveloped area.

An appropriate stormwater quality retrofit for this facility would be a Temperature Control Structure, or a more extensive gravel wetland retrofit, which would provide enhanced quality treatment, but would be more costly to implement. For the purposes of this Report, a simple modification of the outlet control system to provide temperature control is recommended for this location.

Bucknam Road Gateway Retrofit

There is an existing ditch on both sides of Bucknam Road, near the intersection of Route 1, which collects runoff from surrounding developments, existing culverts, and the Maine Med Pond, which was found to be in good condition, as discussed in Section 3 of this Report. The existing ditch collects runoff from Bucknam Road and the three Maine Med Dry Detention Basin outlets. The outlet ultimately discharges to an 18-inch RCP culvert outfall across Route 1. This space is part of a developed area that could be better utilized, and add to the area's aesthetic and safety through a stormwater quality retrofit, such as a roadside filtration swale. Furthermore, it is located in a catchment that has sensitive storm drain capacity.

The installation of a filtration swale would not only provide stormwater quality treatment, but would also eliminate the need to have a deep and unattractive roadside ditch.

An additional level of design concept and opinion of cost has been developed for this retrofit based on a potential collaborative project between the Town and MaineDOT. This concept and cost estimates are contained in Appendix E.

Route 1 Roadway

There is a large network of catch basins within the Route 1 Right-of-Way, which ultimately discharges untreated stormwater runoff to several outfalls. There are several different kinds of proprietary and non-proprietary structures, such as catch basin inserts, filter boxes, or green stormwater planters, which could be installed along the Route 1 roadway depending on available funds and redevelopment plans. The existing infrastructure consists of a large network of catch basins and associated storm drain piping, which present opportunities for placement of these stormwater treatment structures. This retrofit recommendation reflects what we understand is being considered as part of the Route 1 Infrastructure Plan redevelopment and does not constitute a separate retrofit project.

The Wal-Mart Plaza Quality Retrofits

The Wal-Mart plaza contains a large amount of impervious surface consisting of buildings and a parking lot, which discharges untreated stormwater runoff directly to Webes Creek via a culvert across Route 1. Existing infrastructure in the developed area consists of two storm drain networks comprised of manholes, catch basins, and 15-inch HDPE piping beneath the plaza parking lot, both of which discharge to a densely vegetated, undeveloped area north of the parking lot, which ultimately forms channelized flow to a 42-inch RCP inlet to the Route 1 storm drain system.

Extensive stormwater quality retrofits could be installed in this area, such as a below-grade filter treatment system in the developed lot and/or a modified rain garden system along the northern edge of the lot, which currently produces sheet flow to the vegetated area north of the parking lot. It should be noted that stormwater management improvements are planned for portions of this parking area as part of an approved redevelopment plan.

5.4 OPINION OF COST

It should be noted that these proposed stormwater retrofit sites have been preliminarily sized based on available space and anticipated water quality volumes for planning purposes only, and will require additional survey and engineering prior to implementation. It is important that appropriate retrofits be selected and designed, so that they can adequately accommodate stormwater quantity, channel protection volume and stormwater quality requirements. A planning-level opinion of costs for the proposed stormwater retrofits follows.

A planning-level opinion of cost for design, permitting, and construction has been developed for the proposed retrofit opportunity areas, so that they can be considered as part of future municipal capital improvement projects or presented to commercial property owners for consideration as part of future

private site improvement projects. The stormwater management systems utilized to develop the cost estimate were selected to provide a range of anticipated costs, depending on a variety of design options. Before selecting specific retrofits, a more detailed analysis of each site should be conducted; it should be noted that proper modifications to an existing system can produce good performance for a significantly lower construction cost relative to a newly constructed retrofit.

The typical unit costs for each type of proposed stormwater management system used in this opinion of costs have been developed by Woodard & Curran during retrofit studies using specific site constraints, as noted in the calculations contained in Appendix D of this Report. These costs are being used for planning purposes only based on the size of the system anticipated to be installed, or the volume of stormwater anticipated to be treated, and should be re-evaluated upon determining appropriate retrofits for each specific site. The total cost for all identified retrofits range between $2.5 and $5.0 Million. The following table is a summary of the anticipated range of budgetary costs associated with each proposed retrofit site.

Table 5-2: Summary of Opinion of Costs Associated with the Retrofit Opportunity Area

Stormwater Retrofit Opportunity Area	Stormwater Management Benefit	System Type considered for this Location	Opinion of Cost (+/-)	Unit Used as Cost Basis	Quantity of Unit
1. The Falmouth Shopping Center Dry Detention Basin Retrofit	Quality	Gravel Wetland Retrofit	$135,000	Per SF of Available Space	6,910 SF
2. The Falmouth Shopping Center Plaza Quality Enhancements	Quality & Quantity	Gravel Wetland/Below-Grade Filter System	$795,000/$1,315,000	Per CF of WQV	36,400 CF
3. Clearwater Drive Flow Control	Quantity	Flow Control	$30,000	Per Each unit	1
4. The Fundy Circle Pond Retrofits	Quality	Gravel Wetland Retrofit	$230,000	Per SF of Available Space	11,520 SF
5. Fundy Roadside Retrofit	Quality	Filtration Swale/Soil Filter	$105,000/$130,000	Per SF of Available Space	7,260 SF
6. The Falmouth Inn Greenspace Retrofit	Quality	Gravel Wetland	$220,000	Per SF of Available Space	10,970 SF
7. The Greenway Waterlane	Quality	Gravel Wetland	$715,000	Per SF of Available Space	36,100 SF
8. Hat Trick Drive Flow Control Structure	Quantity	Flow Control	$30,000	Per Each unit	1
9. The Morong Service Center Pond Outlet Modification	Quality	Outlet Temperature Control/Gravel Wetland Retrofit	$60,000/$535,000	Per SF of Available Space	26,900 SF
10. Bucknam Road Gateway Retrofit	Quantity & Quality	Filtration Swale/Soil Filter	$210,000/$260,000	Per SF of Available Space	14,790 SF
11. Route 1 Roadway	Quality	Catch Basin Insert/Filter Box	$35,000/$45,000[1]	Per Each Unit	1
12. The Wal-Mart Plaza Quality Retrofits	Quality	Raingarden/ Below-Grade Filter System	$90,000/$1,305,000	Per CF of WQV	36,100 CF

1 The costs associated with Route 1 Roadway Retrofits reflect the costs associated with a single unit; the Town may elect to install multiple units along the Route 1 Roadway, which is not reflected in this estimate.

5.5 RETROFIT CONSIDERATIONS

The previously discussed retrofit inventory and recommended opportunity areas provide a preliminary assessment of locations within the Webes Creek watershed that will provide water quality, channel protection and/or peak runoff rate control. In any retrofitting scenario, there are numerous possibilities depending on a community's priorities and long-term management interest. As retrofitting existing built areas is expensive and will likely require extensive public/private dialogue and legal agreements, it is important to acknowledge that prioritization is an important next step.

This study now provides the fundamental information that can be utilized for stormwater management prioritization. Ideally a prioritization process would include engagement of a technical advisory committee made up of community leaders, property owner representatives, experts and Town staff. Prioritization matrices for stormwater management retrofitting may include, but not be limited to, the following:

- water quality benefit;
- peak runoff attenuation;
- available space;
- overlap with a planned project;
- landowner acceptance;
- community engagement potential; and
- community aesthetic improvement, and others.

Water quality benefit can be difficult to quantify and at a minimum will require additional investigation of specific retrofit locations, site survey and water quality modeling. The relative weighting of each of these criteria should be developed through collaborative committee process.

This study can be considered a first step in the process of more active management of stormwater discharges in this district, but the preliminary nature of the evaluation should not preclude consideration of a few selected retrofits. Given the extensive consideration for re-visioning and reconstruction of Route 1 and the potential for addressing a significant untreated impervious area in the district, the Route 1 roadway retrofits would likely end up as a high priority retrofit. Additionally, the Bucknam Road Gateway Retrofit would extend the benefits of the Route 1 corridor improvements and address aesthetic and water quality benefits through a "gateway" improvement at a main entry into the Commercial District of Falmouth. The cooperation of the Maine Department of Transportation both financially and technically makes this an attractive retrofit for short-term consideration as a green infrastructure demonstration project.

6. ORDINANCE REVIEW AND FUTURE CONSIDERATIONS

6.1 BACKGROUND

Land use, which is largely directed by local zoning, influences the distribution of stormwater discharges and the magnitude of pollutant loads. The National Stormwater Quality Database uses land use types (e.g. residential, commercial, industrial) as a basis for classifying the predicted "typical" level of pollutant concentrations in stormwater runoff. As such, consideration of land use regulatory tools for the Webes Creek subwatershed, including water quality-related performance standards and/or an overlay zone with provisions intended to mitigate stormwater pollutants, can become important considerations within the overall strategy for effective watershed management. Additionally, maximum impervious surface cover ratios and other such dimensional requirements dictated by zoning can help anticipate future build out scenarios.

The implementation of local and regional planning policies may be one of the most economical and effective long-term strategies for stormwater pollution mitigation in urban water bodies.

- The American Rivers publication, Local Water Policy Innovation – A Road Map for Community Based Stormwater Solutions[1,] indicates that "local environmental protection ultimately relies on local solutions… Regardless of federal laws, our local and regional water quality will not be protected unless we take action at home." The report goes on to identify why local policy is important to stormwater management, including:
    - Local governments have the experience and authority to regulate land use,
    - Zoning and development review regulations are ideal processes for stormwater regulations,
    - Local governments can remove barriers to Low Impact Development (LID),
    - Local action is vital to the federal Clean Water Act permitting system, and
    - Individuals have great power to create change on a local level.
- The Center for Watershed Protection contends that requiring stormwater retrofits during redevelopment is the most effective method to achieve maximum water quality improvements over time in impaired water bodies.

The Town of Falmouth has identified water quality protection and conserving natural resources as some of the key goals and objectives in its Comprehensive Plan. The objective of this task was to review Town zoning ordinances and stormwater standards to identify possible changes that will help enhance future stormwater quality or quantity management and provide enhanced flexibility for developers and landowners.

6.2 ORDINANCE REVIEW METHODS

The Town conducted a review of its zoning ordinance in regards to identifying impediments to green infrastructure concepts and low impact development principles. Town staff reviewed and utilized a Code and Ordinance Worksheet created by the Center for Watershed Protection to assist communities to identify sections of code that may be revised to accommodate current stormwater management design

[1] Brent, Denzin, 2008. *Local Water Policy Innovation – A Road Map for Community Based Stormwater Solutions.* American Rivers.

practices both for stormwater treatment systems and to minimize the impact of development on receiving water bodies and infrastructure.

The Town's stormwater standards were then reviewed to determine if modifications to the standards may be beneficial to provide improvements for stormwater management in the project area. The Town's stormwater standards must, at a minimum, meet or exceed state and federal regulatory guidance but should provide maximum flexibility for cost-effective and science-based management.

The Town anticipates reviewing recommendations in concept form with the Planning Board and the Town Council to get their feedback prior to preparing actual proposed zoning language. It is anticipated that some of the proposed amendments, such as reducing parking requirements to reduce impervious surfaces and stormwater runoff, will be incorporated in a comprehensive zoning package that is currently being developed by Town staff for the Route 1 commercial district. The Route 1 zoning package is expected to be finalized by mid-2013. The remaining recommended zoning amendments are expected to be completed prior to the end of 2013.

6.3 SUMMARY OF FALMOUTH'S EXISTING STORMWATER MANAGEMENT STANDARDS

The Town of Falmouth's Land Subdivision Ordinance (Chapter 701) includes an Appendix section specific to "Stormwater Management" (Appendix 7). In addition to Subdivisions, projects that are subject to "Site Plan Review" must also comply with the "Stormwater Management" section (by reference). Although not specifically noted in the standard, any project that meets or exceeds the applicability requirements for State Stormwater Law must comply with both the State standards and the Town standards. A summary of Town and State Stormwater Standards has been developed in a Table format and included as Table 6.1 and Table 6.2.

Table 6-1: Town of Falmouth Stormwater Standards (Chapter 701 Land Subdivision Ordinance; Appendix 7)

Applicability	**A Stormwater Management Plan is required for** Subdivision and Site Plan Applications for projects which will expose more than 60,000 sq ft of soil at one time or which will produce more than 10,000 sq ft of additional impervious surface (unless direct discharge to Presumpscot River or Atlantic Ocean)
Performance Standards	**Quantity:** Peak discharge for developed site shall not exceed the peak discharge for the undeveloped site for the 2, 10 and 100 year storm events **Quality:** Sediments and other pollutants shall be limited, through appropriate management practices, to prevent adverse downstream water quality impacts (no quantitative criteria or prescriptive water quality measures required)

Table 6-2: State of Maine Stormwater Management Law (Chapter 500)

	Requirements of the Standards	***Applicability Under MaineDEP Chapter 500***
Basic Standards	• Erosion and Sediment Control • Inspection and Maintenance • Housekeeping • ***Submit:*** Plan(s) that address each	Disturbances of 1 acre or more

General Standards	• Water quality volume treatment utilizing:
	  ○ Wet pond
	  ○ Filter
	  ○ Infiltration
	  ○ Buffer
	  ○ MaineDEP approved alternative device
	• ***Submit:*** Narrative, Plans, Calculations, Details
		Disturbances of 1 acre or more AND
		Creation of 1 or more acres of impervious area, 20,000 SF impervious in UIS watershed, or 5 acres or more of developed area

Flooding Standard	• Detain, retain, or infiltrate stormwater from the 2, 10 & 25 year, 24-hr storm event • Post-development peak flowrates cannot exceed pre-development peak flowrates • ***Submit:*** Stormwater subcatchment plans with flow paths and hydrology computations (model) of pre- & post-development conditions	Creation of 3 acres or more of impervious area, or 20 acres or more of developed area

Urban Impaired Stream (UIS) Standard	• Mitigate project impacts by treating, reducing, or eliminating an off-site or on-site predevelopment impervious stormwater source; or, • Pay a compensation fee in-lieu of treatment, reduction, or elimination of impervious stormwater source • ***Submit:*** Calculations showing compliance, and compensation fee, as applicable	Creation of 3 acres or more of impervious area, or 20 acres or more of developed area in UIS watershed listed in Chapter 502

Falmouth's Stormwater Management requirements (Appendix 7 of the Subdivision Standards) are broken out into six sections:

- Intent
- Stormwater Management Plan Required
- Performance Standards
- Design Standards
- Storm Drainage Construction Standards
- General Construction Requirements

The standards are clearly written, flow smoothly from section to section, and appear to provide a sufficient level of information for a design professional to develop a plan that incorporates and addresses the Town's requirements.

The Stormwater Management Section (Appendix 7) is primarily stand-alone, with little cross reference to other sections of the Town's Ordinances. The exception being cross references to the Town's Erosion and Sediment requirements (Zoning and Site Plan Review Ordinance, Section 5.39), Post-Construction Monitoring Requirements (Zoning and Site Plan Review Ordinance, Section 5.39A), and Section 3 (Guidelines) of the Land Subdivision Ordinance. This allows for ease of use and limits the likelihood of misinterpretation or misunderstanding by Applicants. A design engineer can determine applicability, design criteria, and the materials required for construction in this one section of the code.

Applicability requirements are as follow: Projects that expose more than 60,000 square feet of soil at one time or produce 10,000 square feet or more of new impervious surface are required to evaluate runoff through the development of a Stormwater Management Plan. Exceptions are provided for projects with direct discharge to the Presumpscot River or the Atlantic Ocean, as discharge to these resources poses little flooding risk to Town or adjacent private infrastructure. Projects that meet or exceed the State criteria for Stormwater Management Law must prepare a plan that addresses both the State and Town stormwater management standards.

For projects that require a Stormwater Management Plan, the Town's code is primarily focused on keeping the stormwater discharge rate from a site at or below the pre-development condition. These are generally known as "flooding" standards and engineering design associated with these standards may not specifically address runoff quality. The code requires that the applicant evaluate the 2, 10 and 100 year storm events. Reference is made to the rainfall records for the City of Portland. The 2, 10 and 100 year, 24-hour storm events provided in MaineDEP guidance for southeast Cumberland County are 3.0, 4.7 and 6.7 inches, respectively. These storm events are often considered to be the design storm events for sizing conveyance systems to limit flooding impact on properties and adjacent or downstream infrastructure.

Under the Town's Performance Standards, projects that require a Stormwater Management Plan must limit sediments and other pollutants through appropriate management practices to prevent adverse downstream water quality impacts. The language utilized in the Performance Standards is not prescriptive of a stormwater treatment methodology, a water quality treatment goal (percentage of area treated) or a water quality storm event (which allows a design professional to calculate the runoff quantity that must be managed). The reference to "sediment" is in-line with older State of MaineDEP water quality guidance, which primarily focused on reduction of suspended solids in stormwater. Recent State guidelines broaden water quality treatment goals beyond a focus on suspended solids to a broad range of pollutants, including suspended solids, metals, nutrients, bacteria and temperature control.

6.4 POLICY CONSIDERATIONS

The intent behind the following recommendations is to allow for smart growth and redevelopment of the project area, preserving and enhancing the economic viability of the area while limiting, and ultimately reducing the water quality impacts that the Commercial District has on the receiving waterbodies such as Webes Creek, Mill Creek, Mussel Cove and Casco Bay. Fundamentally, the value of a stormwater master plan allows greater flexibility within the management area that focuses regulations via redevelopment where it is most needed and makes the most sense. A "one-size-fits-all" stormwater management standard(s) works well without a master plan but can obligate property owners to increased development/redevelopment costs for limited environmental or runoff management benefit.

The current local standards, as written, do not focus on water quality, and can be costly and difficult to implement, particularly related to the detention of large quantities of stormwater under 10 and 25-yr storm events. Managing stormwater by focusing on detaining large storm events provides limited water quality benefit, and can take up valuable real estate that may serve a better purpose for economic development. "Flooding" standards are meant to reduce the impact of a facility on downstream infrastructure and can be important in particular areas. Under a stormwater management plan, as described herein, more informed decisions can be made about the relative benefit of requiring flooding standards for specific parcels versus focusing primarily on smaller storm event filtration and retention.

In the context of the specific development patterns within the Webes Creek watershed area, recommended modifications to the Town's Stormwater Management Ordinance may be best applied by way of a stand-alone overlay district ordinance that encompasses the Webes Creek watershed area. The Webes Creek watershed is largely commercial with somewhat unique development in comparison to the rest of the community. This area also is largely "built-out" where modifications to code that focus on new development may be less applicable than a focus on redevelopment.

As identified in Section 4 of this report, the project study area is largely built-out at this time, and anticipated impervious surfaces associated with new commercial development is limited to approximately 16 acres, or 5% of the overall watershed. Water quality improvement within Webes Creek and Mussel Cove will not be realized if the Town's water quality standards primarily focus on new development. To improve water quality within the Town's drainage system and waterways, redevelopment projects should incorporate stormwater quality treatment measures as practicable. As existing commercial sites are redeveloped over time, drainage of the untreated commercial areas will become treated. Setting stormwater quality treatment requirements for redevelopment projects will result in enhancement to overall water quality over time, but clearly come with a cost. Any increased requirements for quality treatment should be balanced by reduced requirements for large storm detention (as discussed below) where appropriate in order to offset increased costs associated with quality treatment. However, this can only be allowable for projects that are not subject to meeting State stormwater flooding standards.

The Town's ordinance, as currently written, requires water quality treatment for redevelopment projects having 60,000 sq ft of soil exposed "at one time". We recommend identifying a new threshold to define the applicability of redevelopment projects that require water quality treatment. This value should be small enough to require treatment for redevelopment of the majority of the commercial lots within the watershed. An example of this would be "Water Quality Treatment is required for a redevelopment area of 10,000 square feet or more". To ensure that the standards apply to situations where a large percentage of a small lot is being redeveloped, a percentage standard could also be included; "Water Quality Treatment is required for a redevelopment area equal to 25% or more of a total lot area" (note that these numbers are for example purposes and have not been specifically evaluated for suitability). The term "Redevelopment" will need to be defined within the standard. The Town may also want to include lower applicability thresholds for sites that result in particularly high pollutant loads, such as gas stations or busy parking areas with high vehicle turnover.

The standards should identify the percentage of the new development or redevelopment area that should be treated by means of a water quality treatment measure, keeping in mind that full treatment (100%) of a site is often difficult to achieve, especially the entry areas or linear areas of projects. Providing the option to treat an existing, equivalent surface area and surface type on the site (for redevelopment projects) may provide more flexibility for applicants to meet the design standards and water quality goals.

Where applicable (e.g. facilities where capacity is available in downstream infrastructure), we recommend moving local standards away from requiring onsite detention for managing large storm events (2, 10, 100 year, 24 hour events), and focus on the smaller, more frequent storm events such as the water quality storm event (1" in 24 hours) and the 1-year channel protection event (2.5" in 24 hours). These storms are likely to be more manageable onsite, potentially by means of treatment systems incorporated into the landscaping of the site (i.e. treatment in landscaped areas versus stand-alone wet detention ponds). Applicants should still be required to ensure the storm drain collection and conveyance system on the site is sized to limit the potential for flooding conditions, typically sized to handle the 25 year event (5.5" in 24 hours). This report provides a basis for identifying critical upstream and downstream hydrology and infrastructure that could be utilized by applicants during design of their stormwater management systems.

As noted in Section 4 of the Report, there are several areas within the watershed where critical drainage infrastructure may be undersized to fully convey larger storm events. Drainage infrastructure renewal investment via general fund, TIF or other financing to maximize capacity in priority sections of drainage infrastructure would reduce management requirements for large storm detention. If investments are not made to "priority" drainage infrastructure, we recommend maintaining language in the standard that requires the applicant to ensure that the impact of their project does not adversely affect upstream drainage conveyance across their site or downstream public or private drainage capacity, but does not automatically obligate them to meet "flooding" standards (unless required under State Stormwater Management Law).

The Town's ordinance currently includes a general requirement for limiting "sediment and other pollutants" from impacting downstream resources. We recommend referencing more prescriptive water quality treatment measures, whether identified by the MaineDEP in their Stormwater Best Management Practices Manual or potentially from other local communities (i.e. South Portland Small Sites Stormwater Solutions web-based manual). Sizing requirements for these stormwater management systems are often included within the manual or system summary sheet.

This stormwater management plan may allow the Town and State to grant exemptions to State Stormwater Management Law Standards (Section 9 - Chapter 500), so long as an overall plan is approved by the MaineDEP and actively implemented. Shared stormwater management responsibilities between the Town and landowners can provide for an environmentally friendly and economically viable approach to smart growth planning but will require some level of investment for implementation of shared management facilities. It is recommended that the Town of Falmouth discuss this document as basis for a stormwater management plan as described in Section 9.

Additional recommendations are as follows and refer to Appendix 7 Stormwater Management of Chapter 701 Land Subdivision Ordinance of the Town of Falmouth:

- (A) Intent: Provide a reference to the MaineDEP Stormwater Management Law, stating that projects that qualify for a Stormwater Management Law or Site Location of Development Law permit are required to meet both State and Town Stormwater Management Standards.
- (C) Performance Standards & (D) Design Standards: For storm event data, reference MaineDEP BMP Technical Design Manual, Chapter 2 Stormwater Hydrology, Table 2-1 "24 Hour Duration

Rainfalls for Various Return Periods Natural Resources Conservation Service County Rainfall Data"; Cumberland County SE.

- (D) Design Standards: Standard number 9 should state "All pipe shall be designed to flow at a minimum velocity of two feet per section when flowing ¼ full."

The Stormwater Management ordinance references Section 5.39A of the Zoning and Site Plan Review Ordinance. Section 5.39A provides the requirements for Post-Construction Stormwater Management following MaineDEP standards for compliance with the Town's stormwater NPDES permit. The applicability requirement for Post-Construction Stormwater management is listed as projects encompassing 43,560 sq ft (1 acre). We recommend matching the project area covered under this standard to coincide with the applicability requirements for the treatment standards that will be defined within the Stormwater Management Ordinance (note that the applicability for this standard cannot be increased above the number prescribed by MaineDEP; 1 acre).

6.5 LID STRATEGIES WITHIN CODE

To evaluate whether the Town's Ordinances are environmentally friendly, or whether they are prohibitive to Low Impact Development (LID) design, the Town of Falmouth Planning Department reviewed their Code against the Massachusetts Low Impact Development Toolkit (a production of the Metropolitan Area Planning Council, in coordination with the I-495 MetroWest Corridor Partnership, with financial support from the US EPA). Planners use this Toolkit to review their local codes for consistency with LID principles. A copy of the Town's evaluation of their code is contained in Appendix G.

We identified the following "Improvement Methods" from the Toolbox as items that should be encouraged in a potential overlay district for the Webes Creek Watershed. The Town has acknowledged that many of these items are allowed or acceptable under their Code, we foresee further encouraging these items as part of development within the Webes Creek Watershed:

- Dimensional Requirements
    - Permit the location of bioretention areas, rain gardens, filter strips, swales, and constructed wetlands in required setback areas and in buffer strips.
- Open Space Developments
    - Permit construction of LID stormwater management techniques (bioretention, swales, filter strips) on land held in common.
- Site Plan Requirements
    - Allow bioretention areas, filter strips, swales, and constructed wetlands to count towards to fulfillment of site landscaping/open space requirements.
- Street Cross Sections
    - Establish criteria for the design of roadside swales to ensure adequate stormwater treatment and conveyance capacity.
- Site Work
    - Require contractors to reestablish permeability of soils that have been compacted by construction vehicles. For example, contractor can rototill lawn areas prior to seeding to re-establish void space (hence permeability and infiltration) of the soils.

- Wetlands Bylaw and Regulations
    - Permit the use of low impact stormwater structures (such as bioretention areas, infiltration trenches, or grass swales) within the buffer zone of (state or local jurisdictional) wetland resource areas, provided the location of these structures is not in conflict with any other setback criteria required by NRPA
- Department of Public Works / Building Inspector
    - Local plumbing codes should permit the use of harvested rainwater for interior non-potable uses such as toilet flushing.

6.6 FUNDING CONSIDERATIONS

There are a limited number of alternatives available to fund the development of the proposed stormwater management activities. The revenue alternatives generally fall into three different categories: user based, infrastructure/economic development/grants/loans, and general fund based. As is typical with other municipal infrastructure projects, a combination of these categories could be used to fund the Webes Creek Stormwater Management Plan. This Plan section focuses on the Town of Falmouth for financing alternatives. However, the responsibility for water quality improvements in Webes Creek should be a joint effort between regulated dischargers in the watershed including the Town, private property owners, and the Maine Department of Transportation.

Within Maine, our understanding of the most common mechanism for financing stormwater and stream restoration efforts is through the use of grants. The following are other common mechanisms for funding infrastructure and natural resource management and improvement programs.

- User based revenue is generated from the use of the stormwater drainage, water or sanitary wastewater system through user fees. User fees are generated from residential, commercial, industrial, public sector, and other users. The Town of Falmouth maintains an existing user based revenue source that provides funding for sanitary wastewater management services.
- Infrastructure/economic/grant based revenue are generated by grants and low interest loans obtained from the federal or state government agencies, used to reduce the debt load generally associated with the capital requirements of projects.
- General fund revenue is taxation based, given the universal public benefit and economic and community development components of infrastructure and restoration projects.

6.6.1 User Based

Utility Districts/User Fee

Revenues generated from the use of the stormwater drainage, water or sanitary wastewater systems are typically the means of paying for capital operations and maintenance of the system, with a depreciation account to fund repairs and infrastructure replacement once its service life is reached, and debt service incurred to construct the structural components of the management system.

User fees based on “equivalent users” for stormwater, ensures that each user pays proportionally for the stormwater they generate; properties that generate more stormwater will pay more in user fees than properties that generate less. This creates an equitable and legal fee structure. Typically, the amount of impervious cover on a property is used as the means of estimating stormwater infrastructure usage.

Special Assessment Districts

Several methods can be used to recover the carrying costs on large municipal capital projects. Special Assessment Districts (aka Betterments) represent one of the methods that a municipality can use. A Special Assessment District (SAD) is a special property tax or fee that is assessed to a property due to the benefit the property receives as a result of a construction project. SADs are assessed upon the property in proportion to the amount of such benefit. A municipality may formally adopt an ordinance which describes the area to be improved by the construction project and states the special assessment that will be levied for the improvement(s). There are several methods for estimating the special assessment. SADs can be assessed using a uniform unit method. The uniform unit method calculates assessment costs by dividing the project cost by the total number of "units" contributing to the project in this manner.

6.6.2 Infrastructure/Economic Development Grant and Loans

Grant programs are available from various state and federal agencies such as the MaineDEP, the Department of Economic and Community Development (DECD), and often through Congressional earmarks for worthy projects. Each funding agency has its own unique requirements but they often collaborate to fund projects.

Maine Department of Environmental Protection

The MaineDEP offers grant/loan packages for towns to improve their wastewater and stormwater management systems. In addition, loan money is available through the Clean Water State Revolving Loan Fund (SRF) at 2-percent below the market interest rates for terms up to 20-years. Recent changes in the State Revolving Load Fund program provide for principle forgiveness on up to 50% of the loan. The amount of principle forgiveness is based on specific economic criteria and environmental worthiness. Grant eligibility is determined by comparing user rates to the users' or municipality's Median Household Income (MHI). A town will be classified as disadvantaged, and therefore grant eligible if rates exceed a certain percentage of the MHI. Applications to the SRF program are accepted throughout the year with bond sales generally occurring twice per year in April and October to coincide with the Maine Municipal Bond Bank (MMBB) schedule of bond sales. The MMBB assists the DEP in the administration of the SRF program. Twenty percent of the federal capitalization grants are set-aside for funding "green" projects. Green projects include: a.) green infrastructure, projects that mimic natural biological systems, rain gardens, swales; b.) water and energy conservation, reduced use; and c.) environmentally innovative activities, including planning studies that integrate resources in a more sustainable manner, utility sustainability, greenhouse gas inventory, LEED buildings, etc. These projects are eligible for principle forgiveness.

Additionally, the MaineDEP maintains the Nonpoint Source Grant Program which is administered by the MaineDEP in consultation with the U. S. Environmental Protection Agency (EPA). The grant program provides funding for nonpoint source implementation projects once an approved watershed management plan exists. The development of the Webes Creek Stormwater Management Plan provides the basis for grant funding, or development of a more comprehensive Mill Creek Watershed Management Plan may open more opportunities for grant funds. The MaineDEP states that the implementation project must be designed to substantially contribute to protection or improvement of a waterbody. MaineDEP accepts applications for funding annually in the spring of each year. These are generally highly competitive grants.

It should be noted that the financing of implementation projects cannot be for projects that "undertake, complete or maintain erosion or stormwater control work otherwise required by existing permits or orders" (examples: Maine Pollutant Discharge Elimination System Stormwater Permit, Site Location of Development Permit or Stormwater Law permit).

U.S. EPA STAG

U.S. EPA's State and Tribal Assistance Grant (STAG) grants are requested by Congress, i.e. Maine delegation, as an allocation to address a specific project within a State. STAG applications are available through the delegation's local offices.

Other Grants

The following grants were identified as possible funding opportunities which appear to be well suited to actions identified in the Webes Creek Stormwater Management Plan.

Watershed Protection and Flood Prevention - USDA/NRCS

The Wetlands Protection and Flood Prevention program funds projects related to watershed protection, flood mitigation, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, agricultural water conservation, and public recreation are eligible for assistance. Technical and financial assistance is also available for planning new watershed surveys.

Five Star Restoration Program – US EPA/US Fish and Wildlife

EPA supports the Five-Star Restoration Program by providing funds to the National Fish and Wildlife Foundation and its partners, the National Association of Counties, NOAA's Community-based Restoration Program and the Wildlife Habitat Council. These groups then make subgrants to support community-based wetland and riparian restoration projects. Competitive projects will have a strong on-the-ground habitat restoration component that provides long-term ecological, educational, and/or socioeconomic benefits to the people and their community. Preference is given to projects that are part of a larger watershed or community stewardship effort and include a description of long-term management activities. Projects must involve contributions from multiple and diverse partners, including citizen volunteer organizations, corporations, private landowners, local conservation organizations, youth groups, charitable foundations, and other federal, state, and tribal agencies and local governments.

6.6.3 General Fund Revenues

Revenues generated from taxation have been a method that municipalities typically use for stormwater drainage infrastructure capital projects, operations and compliance. The intent behind the use of the general fund is to distribute the cost among the broader beneficiaries of the project, extending beyond the direct drainage system users. This funding source is particularly appropriate in watershed pollution issues where pollution sources are a contributor to water quality impairment in important community resources such as Mussel Cove.

Tax Increment Financing

Tax increment financing (TIF) is a tax incentive program that is used to help communities finance public investments, including infrastructure improvement projects. A TIF provides a municipality a mechanism to use some of the general fund property taxes that result from investment projects within a designated area, commonly referred to as "district", for a variety of improvements. The equalized assessed value of the taxable property can be frozen for up to 30 years in the designated district. The incremental equalized assessed value is used to pay for the project costs. One benefit of a TIF is that the incremental equalized assessed value is sheltered from the computation of adjustments and state education subsidies based on its total municipal valuation. The municipality may use the taxes to retire bonds issued to finance the project or pay for project costs. Portions of the Webes Creek subwatershed are within the existing Route One North and Route One South TIF districts.

7. PUBLIC OUTREACH

7.1 BACKGROUND

Two public meetings were conducted for the project. The Town and Woodard & Curran presented the background to the study, along with the approach and outcomes of the work performed to date. These meetings were organized by the Town of Falmouth, and held on July 25 and December 13, 2012 at the Town's Public Library. 22 attendees on July 25, 2012 and 17 attendees on December 13, 2012. Woodard & Curran prepared a PowerPoint presentation for each, and presented the study to members of the public, which included residents and commercial property owners. Formal meeting minutes were not produced for the meetings; however, an open forum discussion was held both during and after each meeting.

Copies of the meeting presentations are included in Appendix F of this report.

General discussion topics with members of the public are as follows:

- Community members identified several areas in the watershed where flooding or high water has been previously noted;
- Discussed importance of non-structural stormwater quality controls (sweeping / ice application)
- What are the overall benefits of this study; how will the Town, businesses and residents benefit from implementing water quality improvements?
- Careful consideration should be made for any "detention" or hydrologic modifications of infrastructure as part of stormwater management;
- Infrastructure design and standards should consider climate change; specifically storm frequency & size;
- General discussion of viable stormwater quality/quantity retrofits; and
- Project next steps.

APPENDIX A: GIS FIGURES

Legend

Stormwater System Structures

- Catchbasin
- Manhole
- Open System Inlet
- Open System Outlet
- Outfall
- Inlet
- Outlet
- Overflow
- Tee
- Stormwater Treatment
- Pipe
- Culvert
- Stormwater Management Facility
- Webes Creek Subwatershed
- Watershed Parcels

Natural Drainage

- Channel
- Water

Norway Savings Bank Below-Grade Stormwater Management Facility

Maine Med Dry Detention Basin

Key Bank Soil Filter 2

Key Bank Soil Filter 1

Falmouth Shopping Center Dry Detention Basin

The Shops At Falmouth Village Below-Grade Stormwater Management Facility

Rite Aid Wet Pond

Approved Below-Grade Stormwater Management Facilities (Not Yet Constructed)

Gorham Savings Bank Soil Filter

Fundy Road Dry Detention Basin 3

Fundy Circle Dry Detention Basin 2

Morong Service Center Dry Detention Basin

Fundy Circle Dry Detention Basin 1

0 100 200 400 Feet

bing

Stormwater Management Plan

WEBES CREEK EXISTING STORMWATER MANAGEMENT FACILITY LOCATION MAP

Figure 1

WOODARD &CURRAN

DATE: November 2012	SCALE: 1 "=200 '
DRAWN BY: JS	DOC: WebesCreek_Facilities.MXD

Basemap Source:
© 2010 DigitalGlobe Image courtesy of USGS © 2012 Microsoft Corporation

Legend

Stormwater System Structures

- Catchbasin
- Manhole
- Open System Inlet
- Open System Outlet
- Outfall
- Inlet
- Outlet
- Overflow
- Tee
- Stormwater Treatment
- Pipe
- Culvert
- Tc Lines
- Stormwater Management Facility
- Webes Creek Catchments
- Webes Creek Subwatershed

Natural Drainage

- Channel
- Water

N

C6

C5

C4

C3

C2

C1

Critical Infrastructure Area 6

Critical Infrastructure Area 5

Critical Infrastructure Area 4

Critical Infrastructure Area 3

Critical Infrastructure Area 1

Critical Infrastructure Area 2

0 100 200 400 Feet

bing

Stormwater Management Plan

WEBES CREEK DRAINAGE MAP AND HYDROLOGIC ANALYSIS

Figure 2

WOODARD &CURRAN

DATE: November 2012	SCALE: 1 "=200 '
DRAWN BY: JS	DOC: WebesCreek_Drainage.MXD

Basemap Source:
© 2010 DigitalGlobe Image courtesy of USGS © 2012 Microsoft Corporation

Legend

Stormwater System Structures

- Catchbasin
- Manhole
- Open System Inlet
- Open System Outlet
- Outfall
- Inlet
- Outlet
- Overflow
- Tee
- Stormwater Treatment
- Pipe
- Culvert
- Stormwater Management Facility
- Webes Creek Catchments
- Webes Creek Subwatershed
- Watershed Parcels

Natural Drainage

- Channel
- Water

C1
C2
C3
C4
C5
C6

1 2 3 4 5 6 7 8 9 10 11 12

0 100 200 400 Feet

bing

Stormwater Management Plan

WEBES CREEK RETROFIT SITE LOCATION MAP

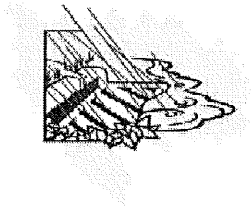
Figure 3

WOODARD &CURRAN

DATE: November 2012	SCALE: 1 "=200 '
DRAWN BY: JS	DOC: WebesCreek_Retrofit.MXD

Basemap Source:
© 2010 DigitalGlobe Image courtesy of USGS © 2012 Microsoft Corporation

APPENDIX B: PRIVATE STORMWATER MANAGEMENT FACILITY INSPECTION FORMS & PHOTOGRAPHS



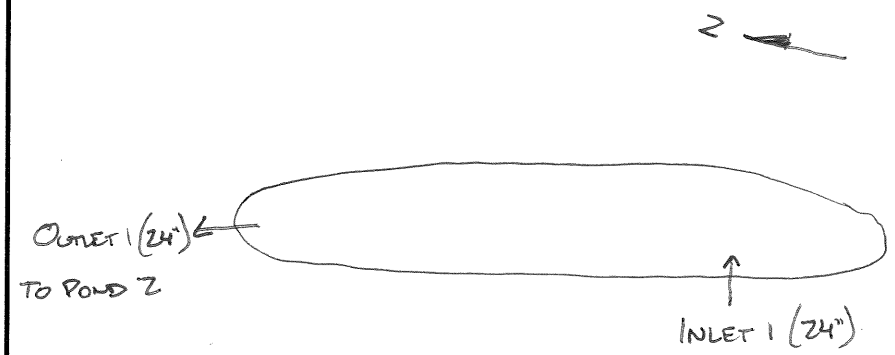
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Dry Ponds

Inspector's Name(s): Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the wet pond: Fundy Circle Pond 1
Address or Intersection: Fundy Rd.
Latititude, Longitude: 43.717327, -70.230140
Date the wet pond began operation: 2002
Wet pond dimensions. Depth (ft.): 1/3'
Area (ft. x ft.) 150' x 30'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location:

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date:
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Access
   3. a) Access to the dry pond is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   3. c) Access to the upstream and downstream drainage is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments
Vegetation cover 80% Good Length to width ratio; inlet perpendicular to pond flow

Sedimentation Practices

University of Minnesota

4. Inlet Structures

4. a) How many inlet structures are present? ☐ 0 ☑ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #: 1	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely	Sediment				
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason					

5. Is there standing water in the dry pond? ☑ Yes ☐ No

5. a) If yes, does the water have:

☑ Surface sheen (from oils or gasoline)
☑ Murky color (from suspended solids)
☑ Green color (from algae or other biological activity)
☐ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?

☐ Yes ☐ No ☑ I don't know (if yes, describe in comment box)

7. Are there indications of any of the following in the dry pond? (If yes, mark on site sketch)

☑ Sediment deposition
☐ Erosion or channelization
☑ Excessive or undesirable vegetation (that needs mowing or removal)
☐ Bare soil or lack of healthy vegetation significantly different from the original design
☐ Litter or debris
☐ Other
☐ No

7. a) If sediment deposition is evident, what is the source?

☐ Erosion or channelization inside the dry pond
☐ Erosion or channelization outside the dry pond
☐ Construction site erosion
☐ Other
☑ Unknown

Comments

Water in parking lot CB leading to Pond 1 had oily sheen

Major cattail growth within pond

About 1' of deposited sediment in pond

Inlet to Pond 1 almost completely plugged with sediment and plant growth

Spoke with local who stated that residents of Fundy Rd. "don't want to get rid of cattails."

Local (an employee of Normandeau Associates) also informed that the ponds had been dredged twice since construction.

Sedimentation Practices

University of Minnesota

8. Are there indications of any of the following on the banks of the dry pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - ☑ Trees on constructed slopes

9. Are any outlet or overflow structures clogged? ☑ No □ Partially □ Completely □ NA

   9. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

   9. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

10. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments

Fundy Circle (Dry Detention Basin 1) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 1) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 1) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 1) Parcel ID: U11-035C



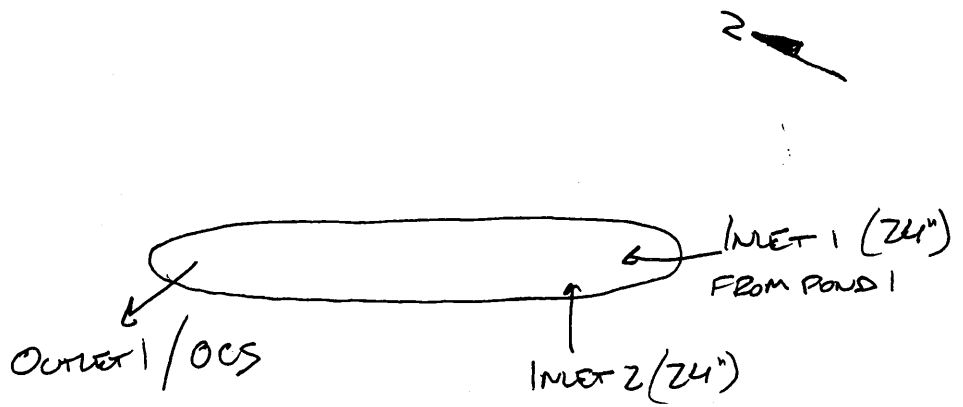
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Dry Ponds

Inspector's Name(s): Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the wet pond: Fundy Circle Pond 2
Address or Intersection: Fundy Rd.
Latititude, Longitude: 43.717658, -70.230104
Date the wet pond began operation: 2002
Wet pond dimensions. Depth (ft.): 1/3'
Area (ft. x ft.) 110' x 25'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location:

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date:
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Access
   3. a) Access to the dry pond is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   3. c) Access to the upstream and downstream drainage is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments

Vegetation cover 90%

Two Inlets, one from parking lot CB and the other from Pond 1

Good Length to Width ratio; inlet 2 perpendicular to pond flow

Sedimentation Practices

University of Minnesota

4. Inlet Structures

4. a) How many inlet structures are present? ☐ 0 ☐ 1 ☑ 2 ☐ 3 ☐ 4 ☐ 5 ☐ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #: 1	Inlet #: 2	Inlet #:	Inlet #:	Inlet #:
Partially	Sediment	Sediment			
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason					

5. Is there standing water in the dry pond? ☑ Yes ☐ No

5. a) If yes, does the water have:

☑ Surface sheen (from oils or gasoline)
☑ Murky color (from suspended solids)
☑ Green color (from algae or other biological activity)
☐ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?

☐ Yes ☐ No ☑ I don't know (if yes, describe in comment box)

7. Are there indications of any of the following in the dry pond? (If yes, mark on site sketch)

☑ Sediment deposition
☐ Erosion or channelization
☑ Excessive or undesirable vegetation (that needs mowing or removal)
☐ Bare soil or lack of healthy vegetation significantly different from the original design
☐ Litter or debris
☐ Other
☐ No

7. a) If sediment deposition is evident, what is the source?

☐ Erosion or channelization inside the dry pond
☐ Erosion or channelization outside the dry pond
☐ Construction site erosion
☐ Other
☑ Unknown

Comments

Both inlets are mostly open for flow, partial sedimentation

Major cattail growth within pond

About 1' of deposited sediment in pond

Outlet overflow trash rack free of debris

Spoke with local who stated that residents of Fundy Rd. "don't want to get rid of cattails."

Local also stated that Pond 2 had "been dredged a couple of times"

Local was employee of neighboring Normandeau Associates office.

8. Are there indications of any of the following on the banks of the dry pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - ☑ Trees on constructed slopes

9. Are any outlet or overflow structures clogged? ☑ No □ Partially □ Completely □ NA

   9. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

   9. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

10. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments

Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C

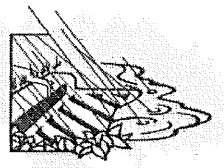


Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C



Fundy Circle (Dry Detention Basin 2) Parcel ID: U11-035C





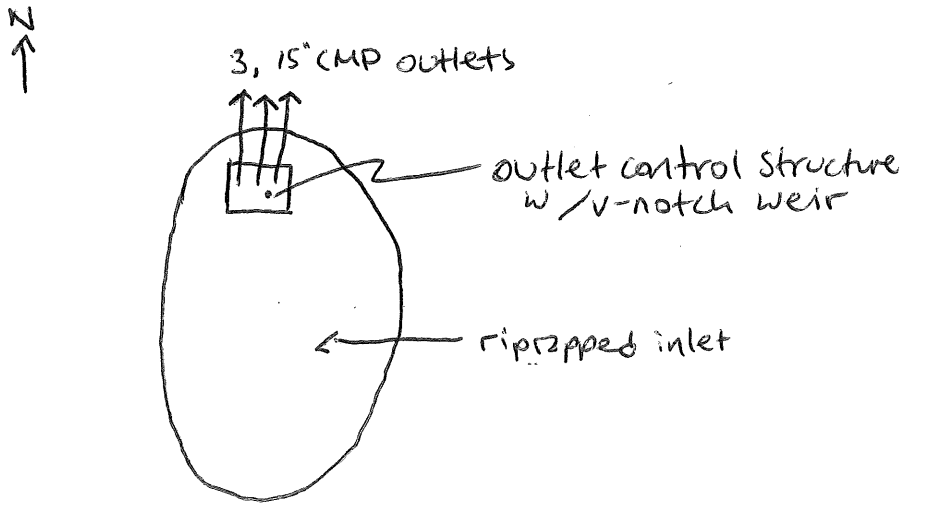
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Dry Ponds

Inspector's Name(s): Ashley Auger & Zach Henderson
Date of Inspection: 10/30/2012
Location of the wet pond: Off of Fundy Road, next to USF&W
Address or Intersection: Fundy Rd.
Latititude, Longitude: 43.717664, -70.231494
Date the wet pond began operation: Unknown
Wet pond dimensions. Depth (ft.): Unknown
Area (ft. x ft.) 1300 SF
Time since last rainfall (hr): 1
Quantity of last rainfall (in): 0.81"
Rainfall Measurement Location: _____

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? □ Yes □ No ☑ I don't know
   1. a) If yes, enter date: _____
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   □ Yes □ No ☑ I don't know (If yes, describe actions in comments box)
2. Has it rained within the last 48 hours at this location? ☑ Yes □ No □ I don't know
3. Access
   3. a) Access to the dry pond is:
   ☑ Clear □ Partially obstructed □ Mostly obstructed □ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
   □ temporary **and** □ no action needed **or** □ action needed
   □ permanent **and** □ before or during installation **or** □ new since installation
   3. c) Access to the upstream and downstream drainage is:
   ☑ Clear □ Partially obstructed □ Mostly obstructed □ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
   □ temporary **and** □ no action needed **or** □ action needed
   □ permanent **and** □ before or during installation **or** □ new since installation

Comments

Vegetation Cover 80%

Good Length to Width Ration; inlet perpendicular to pond flow

4. Inlet Structures

4. a) How many inlet structures are present? □ 0 ☑ 1 □ 2 □ 3 □ 4 □ 5 □ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason					

5. Is there standing water in the dry pond? ☑ Yes □ No

5. a) If yes, does the water have:

□ Surface sheen (from oils or gasoline)
□ Murky color (from suspended solids)
□ Green color (from algae or other biological activity)
□ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?

□ Yes ☑ No □ I don't know (if yes, describe in comment box)

7. Are there indications of any of the following in the dry pond? (If yes, mark on site sketch)

□ Sediment deposition
□ Erosion or channelization
☑ Excessive or undesirable vegetation (that needs mowing or removal)
□ Bare soil or lack of healthy vegetation significantly different from the original design
□ Litter or debris
□ Other
□ No

7. a) If sediment deposition is evident, what is the source?

□ Erosion or channelization inside the dry pond
□ Erosion or channelization outside the dry pond
□ Construction site erosion
□ Other
□ Unknown

Comments

8. Are there indications of any of the following on the banks of the dry pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - □ Trees on constructed slopes

9. Are any outlet or overflow structures clogged? □ No ☑ Partially □ Completely □ NA

   9. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

   9. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

10. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - ☑ Within a year or two
    - □ No sign that any is required

Comments
The V-notch weir is partially clogged with sediment The outlet control structure should be cleaned

Fundy Road (Dry Detention Basin 3) Parcel ID: U11-035D



Fundy Road (Dry Detention Basin 3) Parcel ID: U11-035D



Fundy Road (Dry Detention Basin 3) Parcel ID: U11-035D



Fundy Road (Dry Detention Basin 3) Parcel ID: U11-035D



Fundy Road (Dry Detention Basin 3) Parcel ID: U11-035D



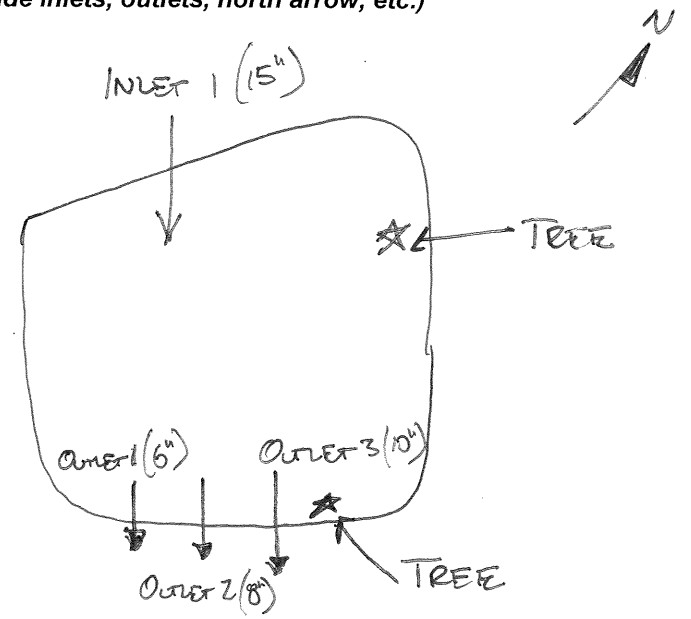
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Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Dry Ponds

Inspector's Name(s): Zach Henderson, Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the wet pond: Maine Med, located near entrance
Address or Intersection: 5 Bucknam Rd
Latitude, Longitude: 43.726382, -70.232801
Date the wet pond began operation: 1995
Wet pond dimensions. Depth (ft.): 1-1.5'
Area (ft. x ft.) 80 x 160
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location:

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date:
   1. b) Based on previous visual inspections, have any corrective actions been taken?
      ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)
2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know
3. Access
   3. a) Access to the dry pond is:
      ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
      ☐ temporary **and** ☐ no action needed **or** ☐ action needed
      ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   3. c) Access to the upstream and downstream drainage is:
      ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
      ☐ temporary **and** ☐ no action needed **or** ☐ action needed
      ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments

Vegetation cover 50%

No major sediment desposited at inlet

Good vegetation growth

No visible signs of erosion

Security fence with gate around perimeter of pond

1-1.5' water depth

Sedimentation Practices

University of Minnesota

4. Inlet Structures

4. a) How many inlet structures are present? ☐ 0 ☑ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #: 1	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason					

5. Is there standing water in the dry pond? ☑ Yes ☐ No

5. a) If yes, does the water have:

- ☐ Surface sheen (from oils or gasoline)
- ☑ Murky color (from suspended solids)
- ☐ Green color (from algae or other biological activity)
- ☐ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?

☐ Yes ☑ No ☐ I don't know (if yes, describe in comment box)

7. Are there indications of any of the following in the dry pond? (If yes, mark on site sketch)

- ☐ Sediment deposition
- ☐ Erosion or channelization
- ☑ Excessive or undesirable vegetation (that needs mowing or removal)
- ☐ Bare soil or lack of healthy vegetation significantly different from the original design
- ☐ Litter or debris
- ☐ Other
- ☑ No

7. a) If sediment deposition is evident, what is the source?

- ☐ Erosion or channelization inside the dry pond
- ☐ Erosion or channelization outside the dry pond
- ☐ Construction site erosion
- ☐ Other
- ☑ Unknown

Comments
Major cattail growth within pond No mowing seems to have taken place Landscaping waste had been disposed of within the discharge area, which could be contributing nutrients to the stormwater

Sedimentation Practices

University of Minnesota

8. Are there indications of any of the following on the banks of the dry pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - ☑ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - ☑ Trees on constructed slopes

9. Are any outlet or overflow structures clogged? □ No ☑ Partially □ Completely □ NA

   9. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:1	Outlet #:	Outlet #:
Material	See Note		
Partial or Comp.			

   9. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

10. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments
Lowest outlet (6" INV. 48.00) submereged, appears to be somewhat clogged. Small flow coming out at the end of the pipe No emergency spillway Numerous animal burrows throughout pond berm

Maine Med (Dry Detention Basin) Parcel ID: U58-010



Maine Med (Dry Detention Basin) Parcel ID: U58-010



Maine Med (Dry Detention Basin) Parcel ID: U58-010



Maine Med (Dry Detention Basin) Parcel ID: U58-010



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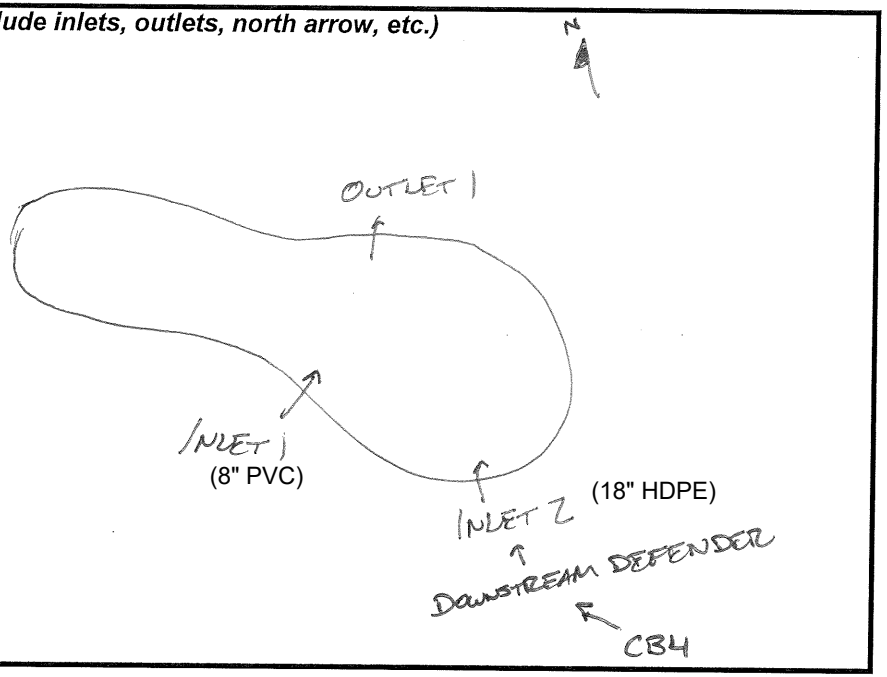
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Dry Ponds

Inspector's Name(s): Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the wet pond: Morong, NW End of Parking Lot
Address or Intersection: Route 1
Latititude, Longitude: 43.717528, -70.235145
Date the wet pond began operation: 2006
Wet pond dimensions. Depth (ft.): 2/3'
Area (ft. x ft.) 290' x 80'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location:

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date:
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Access
   3. a) Access to the dry pond is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   3. c) Access to the upstream and downstream drainage is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments

Vegetation cover 60%

Downstream Defender in place prior to discharge from CB4

Grassed Maintenance access to outlet

Poor length to width ratio

Sedimentation Practices

University of Minnesota

4. Inlet Structures

4. a) How many inlet structures are present? □ 0 □ 1 ☑ 2 □ 3 □ 4 □ 5 □ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #: 1	Inlet #: 2	Inlet #:	Inlet #:	Inlet #:
Partially	Sediment				
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #: 2	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason	See Note				

5. Is there standing water in the dry pond? ☑ Yes □ No

5. a) If yes, does the water have:

□ Surface sheen (from oils or gasoline)
☑ Murky color (from suspended solids)
□ Green color (from algae or other biological activity)
□ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?

□ Yes ☑ No □ I don't know (if yes, describe in comment box)

7. Are there indications of any of the following in the dry pond? (If yes, mark on site sketch)

☑ Sediment deposition
□ Erosion or channelization
☑ Excessive or undesirable vegetation (that needs mowing or removal)
□ Bare soil or lack of healthy vegetation significantly different from the original design
□ Litter or debris
□ Other
□ No

7. a) If sediment deposition is evident, what is the source?

□ Erosion or channelization inside the dry pond
□ Erosion or channelization outside the dry pond
□ Construction site erosion
□ Other
☑ Unknown

Comments
Inlet 2 from CB4 has a tree growing on top of it. Makes access limited for maintenance Major cattail growth within pond Approx. 6" of sediment buildup in pond

Sedimentation Practices

University of Minnesota

8. Are there indications of any of the following on the banks of the dry pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - □ Trees on constructed slopes

9. Are any outlet or overflow structures clogged? □ No □ Partially □ Completely □ NA

   9. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

   9. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

10. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments
1 Outlet Control Structure. View inside the structure was inaccessible, appears to be unobstructed. 1 Emergency Spillway with wooden berm/weir.

Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B



Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B



Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B



Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B



Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B



Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B

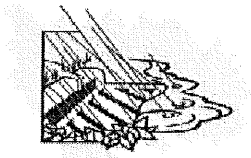


Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B



Morong Service Center (Dry Detention Basin) Parcel ID: U52-001B





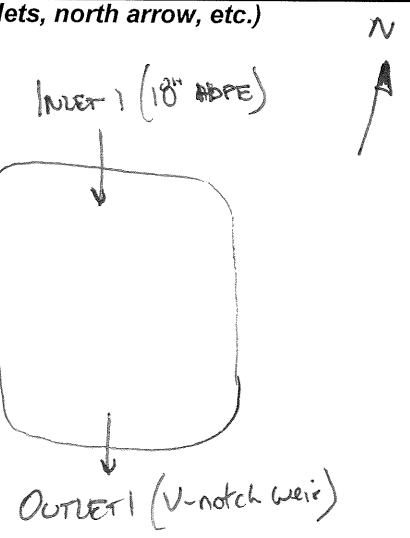
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Dry Ponds

Inspector's Name(s): Zach Henderson, Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the wet pond: Shopping Center (Shaws)
Address or Intersection: Route 1
Latititude, Longitude: 43.722217 -70.229980
Date the wet pond began operation: 2005
Wet pond dimensions. Depth (ft.): 1/3'
Area (ft. x ft.) 60' x 90'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location:

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date:
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Access
   3. a) Access to the dry pond is:
   ☐ Clear ☐ Partially obstructed ☑ Mostly obstructed ☐ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☑ permanent **and** ☐ before or during installation **or** ☑ new since installation
   3. c) Access to the upstream and downstream drainage is:
   ☐ Clear ☑ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☑ permanent **and** ☐ before or during installation **or** ☑ new since installation

Comments

Vegetation cover 95%

Good vegetation growth

No signs of erosion; riprapped inlet w/metal header

One inlet, 18" HDPE

Access to pond was difficult. No signs of mowing or maintenance

Access was inhibited by excessive vegetation (thorn bushes)

*Note presence of bees

No security fence

Sedimentation Practices

University of Minnesota

4. Inlet Structures

4. a) How many inlet structures are present? □ 0 ☑ 1 □ 2 □ 3 □ 4 □ 5 □ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #: 1	Inlet #: 2	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #: 1	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason	See Note				

5. Is there standing water in the dry pond? ☑ Yes □ No

5. a) If yes, does the water have:
- □ Surface sheen (from oils or gasoline)
- □ Murky color (from suspended solids)
- □ Green color (from algae or other biological activity)
- □ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?
□ Yes ☑ No □ I don't know (if yes, describe in comment box)

7. Are there indications of any of the following in the dry pond? (If yes, mark on site sketch)
- □ Sediment deposition
- □ Erosion or channelization
- ☑ Excessive or undesirable vegetation (that needs mowing or removal)
- □ Bare soil or lack of healthy vegetation significantly different from the original design
- □ Litter or debris
- □ Other
- □ No

7. a) If sediment deposition is evident, what is the source?
- □ Erosion or channelization inside the dry pond
- □ Erosion or channelization outside the dry pond
- □ Construction site erosion
- □ Other
- □ Unknown

Comments
Could not locate Downstream Defender. No evidence of maintenance or access location Major cattail growth within pond Some standing water within detention pond

Sedimentation Practices

University of Minnesota

8. Are there indications of any of the following on the banks of the dry pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - □ Trees on constructed slopes

9. Are any outlet or overflow structures clogged? ☑ No □ Partially □ Completely □ NA

   9. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

   9. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

10. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments
1 Outlet Control Structure (V-notch weir). Good flow out, unobstructed

Falmouth Shopping Center (Dry Detention Basin) Parcel ID: U12-002

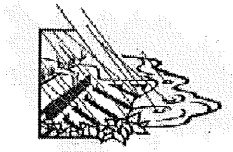


Falmouth Shopping Center (Dry Detention Basin) Parcel ID: U12-002



Falmouth Shopping Center (Dry Detention Basin) Parcel ID: U12-002





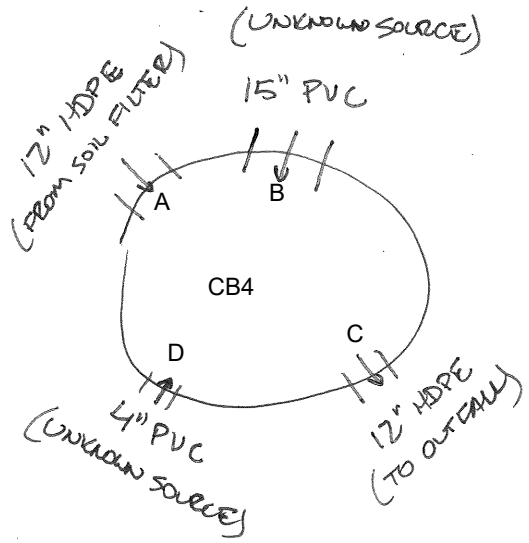
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection Filtration Practices

Inspector's Name(s): Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the filtration practice: Key Bank (Soil Filter 1)
Address or Intersection: Route 1
Latitude, Longitude: 43.724471, -70.233235
Date the filtration practice began operation: 2006
Filter Size (ft. x ft.): 40' x 40'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location:

Site Sketch (include inlets, outlets, etc.)



Depths to invert
A= 4'-8"
B= 4'-8"
C= 5'-1"
D= 3'-9"

Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date:
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Does this filtration practice untilize pretreatment practices upstream?
   ☐ Yes ☑ No ☐ I don't know (If yes, describe pretreatment practices in comment box)

4. Access
   4. a) Access to the filtration practice is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   4. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   4. c) Access to the upstream and downstream drainage is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   4. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments

5. Inlet Structures

5. a) How many inlet structures are present? □ 0 ☑ 1 □ 2 □ 3 □ 4 □ 5 □ > 5

5. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

5. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Yes					
No					

6. Is there standing water in the filtration practice? □ Yes ☑ No

6. a) If yes, does the water have:
- □ Surface sheen (from oils or gasoline)
- □ Murky color (from suspended solids)
- □ Green color (from algae or other biological activity)
- □ Other (describe In comment box)

7. Is there evidence of illicit storm sewer discharges?
☑ Yes □ No □ I don't know (if yes, describe in comment box)

8. What is the approximate percentage of vegetation coverage in the practice? 100 %

9. Are there indications of any of the following in the filtration practice? (If yes, mark on site sketch)
- □ Sediment deposition
- □ Erosion or channelization
- □ Excessive or undesirable vegetation (that needs mowing or removal)
- □ Bare soil or lack of healthy vegetation significantly different from the original design
- □ Litter or debris
- □ Other
- ☑ No

9. a) If sediment deposition is evident, what is the source?
- □ Erosion or channelization inside the filtration practice
- □ Erosion or channelization outside the filtration practice
- □ Construction site erosion
- □ Other
- □ Unknown

Comments
Minor sedimentation at inlet and outlet pipe See above sketch for possible illicit tie-in Soil Filter not connected to nearby wetland

10. Are there indications of any of the following on the banks of the filtration practice:
    - □ Erosion or channelization
    - □ Soil slides or bulges
    - □ Excessive animal burrows
    - □ Seeps and wet spots
    - □ Poorly vegetated areas
    - □ Trees on constructed slopes

11. Is the bottom of the filtration practice covered with a layer of silts and/or clays?
    - □ Yes ☑ No

12. Are any outlet structures or the emergency spillway clogged? □ No ☑ Partially □ Completely □ NA

    12. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:1	Outlet #:	Outlet #:
Material	Sediment		

    12. b) Are any of the outlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

13. Is there any evidence of any of the following downstream of the outlet structure?
    ☑ Sediment deposition □ Erosion or channelization □ Other □ No

    13. a) If sediment deposition is evident, what is the source?
    - ☑ Erosion or channelization inside the filtration practice
    - □ Erosion or channelization outside the filtration practice
    - □ Construction site erosion
    - □ Other, Specify_____
    - ☑ Unknown

14. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments

Key Bank (Soil Filter 1) Parcel ID: U58-006



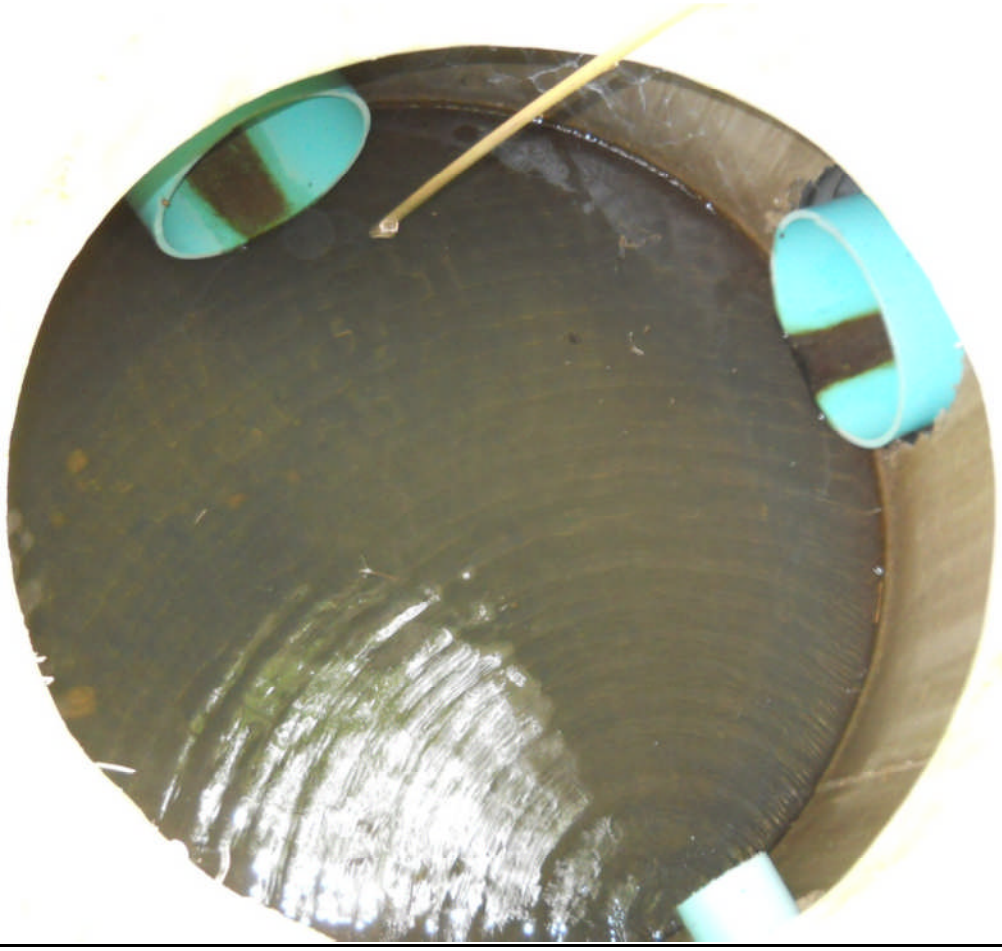
Key Bank (Soil Filter 1) Parcel ID: U58-006



Key Bank (Soil Filter 1) Parcel ID: U58-006



Key Bank (Soil Filter 1) Parcel ID: U58-006



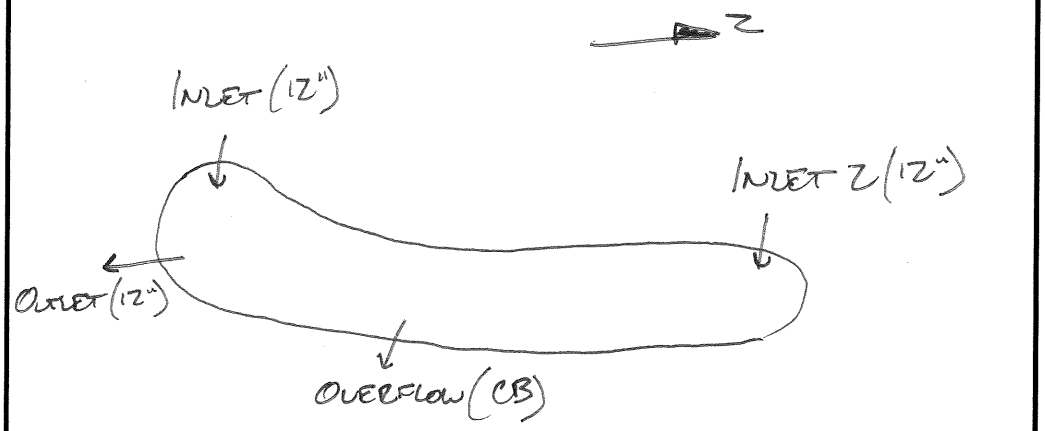
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Filtration Practices

Inspector's Name(s): Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the filtration practice: Key Bank (Soil Filter 2)
Address or Intersection: Route 1
Latititude, Longitude: 43.724471, -70.233235
Date the filtration practice began operation: 2006
Filter Size (ft. x ft.): 200' x 40'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location: _____

Site Sketch (include inlets, outlets, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date: _____
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Does this filtration practice untilize pretreatment practices upstream?
   ☐ Yes ☑ No ☐ I don't know (If yes, describe pretreatment practices in comment box)

4. Access
   4. a) Access to the filtration practice is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   4. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   4. c) Access to the upstream and downstream drainage is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   4. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments

University of Minnesota

5. Inlet Structures

5. a) How many inlet structures are present? □ 0 □ 1 ☑ 2 □ 3 □ 4 □ 5 □ > 5

5. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

5. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Yes					
No					

6. Is there standing water in the filtration practice? □ Yes ☑ No

6. a) If yes, does the water have:
- □ Surface sheen (from oils or gasoline)
- □ Murky color (from suspended solids)
- □ Green color (from algae or other biological activity)
- □ Other (describe In comment box)

7. Is there evidence of illicit storm sewer discharges?
□ Yes □ No ☑ I don't know (if yes, describe in comment box)

8. What is the approximate percentage of vegetation coverage in the practice? 100 %

9. Are there indications of any of the following in the filtration practice? (If yes, mark on site sketch)
- □ Sediment deposition
- □ Erosion or channelization
- □ Excessive or undesirable vegetation (that needs mowing or removal)
- □ Bare soil or lack of healthy vegetation significantly different from the original design
- □ Litter or debris
- □ Other

☑ No

9. a) If sediment deposition is evident, what is the source?
- □ Erosion or channelization inside the filtration practice
- □ Erosion or channelization outside the filtration practice
- □ Construction site erosion
- □ Other
- □ Unknown

Comments
Soil Filter not connected to nearby wetland

10. Are there indications of any of the following on the banks of the filtration practice:
    - □ Erosion or channelization
    - □ Soil slides or bulges
    - □ Excessive animal burrows
    - □ Seeps and wet spots
    - □ Poorly vegetated areas
    - □ Trees on constructed slopes

11. Is the bottom of the filtration practice covered with a layer of silts and/or clays?
    - □ Yes ☑ No

12. Are any outlet structures or the emergency spillway clogged? □ No ☑ Partially □ Completely □ NA

    12. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:1	Outlet #:	Outlet #:
Material	Sediment		

    12. b) Are any of the outlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

13. Is there any evidence of any of the following downstream of the outlet structure?
    ☑ Sediment deposition □ Erosion or channelization □ Other □ No

    13. a) If sediment deposition is evident, what is the source?
        - □ Erosion or channelization inside the filtration practice
        - □ Erosion or channelization outside the filtration practice
        - □ Construction site erosion
        - □ Other, Specify_____
        - ☑ Unknown

14. Inspector's Recommendations. When is maintenance needed?
    - □ Before the next rainfall
    - □ Before the next rainy season
    - □ Within a year or two
    - □ No sign that any is required

Comments

Key Bank (Soil Filter 2) Parcel ID: U58-006



Key Bank (Soil Filter 2) Parcel ID: U58-006



Key Bank (Soil Filter 2) Parcel ID: U58-006

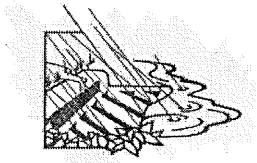


Key Bank (Soil Filter 2) Parcel ID: U58-006



Key Bank (Soil Filter 2) Parcel ID: U58-006





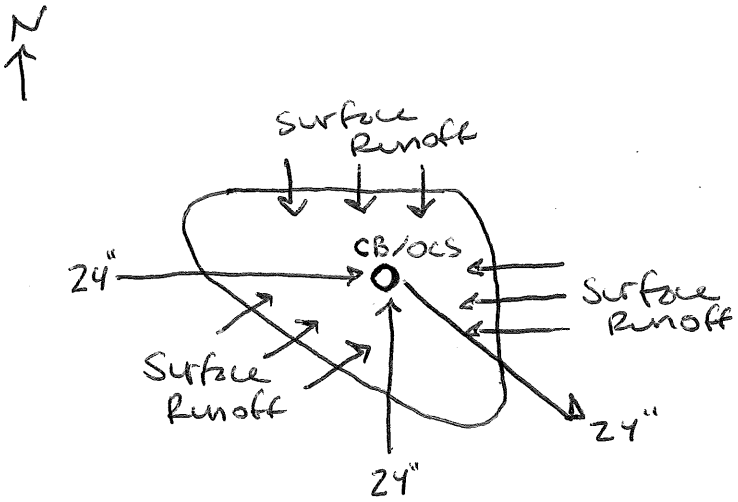
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Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Filtration Practices

Inspector's Name(s): Ashley Auger & Zach Henderson
Date of Inspection: 10/30/2012
Location of the filtration practice: Gorham Savings Bank
Address or Intersection: 202 US Route 1, Falmouth, ME
Latititude, Longitude: 43.718992, -70.233681
Date the filtration practice began operation: 2010
Filter Size (ft. x ft.): 950 SF
Time since last rainfall (hr): 1
Quantity of last rainfall (in): 0.81"
Rainfall Measurement Location: _____

Site Sketch (include inlets, outlets, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? ☐ Yes ☐ No ☑ I don't know
   1. a) If yes, enter date: _____
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   ☐ Yes ☐ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes ☐ No ☐ I don't know

3. Does this filtration practice untilize pretreatment practices upstream?
   ☐ Yes ☑ No ☐ I don't know (If yes, describe pretreatment practices in comment box)

4. Access
   4. a) Access to the filtration practice is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   4. b) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation
   4. c) Access to the upstream and downstream drainage is:
   ☑ Clear ☐ Partially obstructed ☐ Mostly obstructed ☐ Inaccessible
   4. d) If obstructed, the obstruction is (choose and provide comments) :
   ☐ temporary **and** ☐ no action needed **or** ☐ action needed
   ☐ permanent **and** ☐ before or during installation **or** ☐ new since installation

Comments

5. Inlet Structures

5. a) How many inlet structures are present? □ 0 ☑ 1 □ 2 □ 3 □ 4 □ 5 □ > 5

5. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

5. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Yes					
No					

6. Is there standing water in the filtration practice? ☑ Yes □ No

6. a) If yes, does the water have:

□ Surface sheen (from oils or gasoline)
□ Murky color (from suspended solids)
□ Green color (from algae or other biological activity)
□ Other (describe In comment box)

7. Is there evidence of illicit storm sewer discharges?

□ Yes □ No ☑ I don't know (if yes, describe in comment box)

8. What is the approximate percentage of vegetation coverage in the practice? 100 %

9. Are there indications of any of the following in the filtration practice? (If yes, mark on site sketch)

□ Sediment deposition
□ Erosion or channelization
□ Excessive or undesirable vegetation (that needs mowing or removal)
□ Bare soil or lack of healthy vegetation significantly different from the original design
□ Litter or debris
□ Other
☑ No

9. a) If sediment deposition is evident, what is the source?

□ Erosion or channelization inside the filtration practice
□ Erosion or channelization outside the filtration practice
□ Construction site erosion
□ Other
□ Unknown

Comments

10. Are there indications of any of the following on the banks of the filtration practice:
- □ Erosion or channelization
- □ Soil slides or bulges
- □ Excessive animal burrows
- □ Seeps and wet spots
- □ Poorly vegetated areas
- □ Trees on constructed slopes

11. Is the bottom of the filtration practice covered with a layer of silts and/or clays?
- □ Yes ☑ No

12. Are any outlet structures or the emergency spillway clogged? ☑ No □ Partially □ Completely □ NA

12. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			

12. b) Are any of the outlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

13. Is there any evidence of any of the following downstream of the outlet structure?
- □ Sediment deposition □ Erosion or channelization □ Other ☑ No

13. a) If sediment deposition is evident, what is the source?
- □ Erosion or channelization inside the filtration practice
- □ Erosion or channelization outside the filtration practice
- □ Construction site erosion
- □ Other, Specify_____
- □ Unknown

14. Inspector's Recommendations. When is maintenance needed?
- □ Before the next rainfall
- □ Before the next rainy season
- □ Within a year or two
- ☑ No sign that any is required

Comments

Gorham Savings Bank (Soil Filter) Parcel ID: U52-004-ON



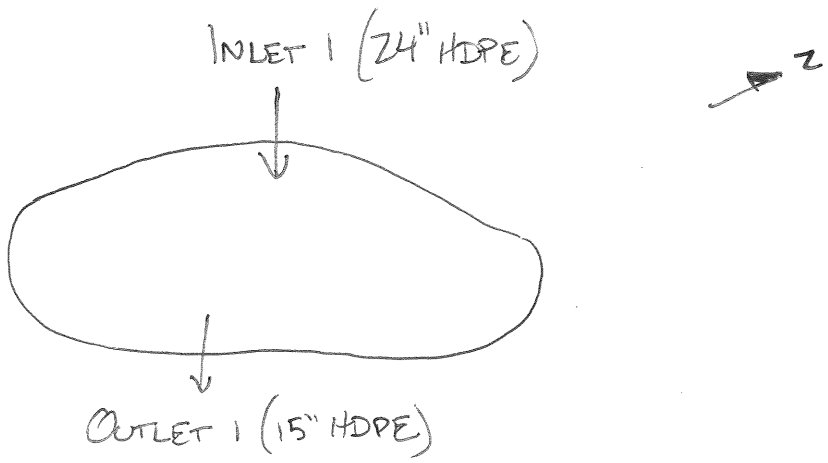
UNIVERSITY OF MINNESOTA

Stormwater Treatment: Assessment and Maintenance

Field Data Sheet for Level 1 Assessment: Visual Inspection
Wet Ponds

Inspector's Name(s): Zach Henderson, Ashley Auger & Mat Hardison
Date of Inspection: 8/6/2012
Location of the wet pond: Rite Aid
Address or Intersection: Route 1
Latititude, Longitude: 43.722081, -70.230512
Date the wet pond began operation: 2007
Wet pond dimensions. Depth (ft.): 8'
Area (ft. x ft.) 80' x 60'
Time since last rainfall (hr): 6
Quantity of last rainfall (in): 0.2"
Rainfall Measurement Location: _____

Site Sketch (include inlets, outlets, north arrow, etc.)



Based on visual assessment of the site, answer the following questions and make photographic or video-graphic documentation:

1. Has visual inspection been conducted at this location before? □ Yes □ No ☑ I don't know
   1. a) If yes, enter date: _____
   1. b) Based on previous visual inspections, have any corrective actions been taken?
   □ Yes □ No ☑ I don't know (If yes, describe actions in comments box)

2. Has it rained within the last 48 hours at this location? ☑ Yes □ No □ I don't know

3. Access
   3. a) Access to the wet pond is:
   □ Clear ☑ Partially obstructed □ Mostly obstructed □ Inaccessible
   3. b) If obstructed, the obstruction is (choose and provide comments) :
   □ temporary **and** □ no action needed **or** □ action needed
   ☑ permanent **and** □ before or during installation **or** ☑ new since installation
   3. c) Access to the upstream and downstream drainage is:
   □ Clear ☑ Partially obstructed □ Mostly obstructed □ Inaccessible
   3. d) If obstructed, the obstruction is (choose and provide comments) :
   □ temporary **and** □ no action needed **or** □ action needed
   ☑ permanent **and** □ before or during installation **or** ☑ new since installation

Comments

Inlet and outlet both relatively clear and free of sediment

Good vegetation growth, no signs of erosion

60% vegetation

Riprapped inlet with 24" HDPE

Security fence with gate around perimeter of pond
Pond is located at the bottom of a steep slope and surrounded by dense vegetation

Poor Length to Width ratio

Sedimentation Practices

University of Minnesota

4. Inlet Structures

4. a) How many inlet structures are present? □ 0 ☑ 1 □ 2 □ 3 □ 4 □ 5 □ > 5

4. b) Are any of the inlet structures clogged? (If yes, mark location on site sketch above and fill in boxes below with items causing clogging (ie. debris, sediment, vegetation, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Partially					
Completely					
Not Applicable					

4. c) Are any of the inlet structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Inlet #:	Inlet #:	Inlet #:	Inlet #:	Inlet #:
Reason					

5. How many cells are in the wet pond system? 1

5. a) Does the water in the pond have:
- □ Surface sheen (from oils or gasoline)
- □ Murky color (from suspended solids)
- □ Green color (from algae or other biological activity)
- □ Other (describe In comment box)

6. Is there evidence of illicit storm sewer discharges?
□ Yes ☑ No □ I don't know (if yes, describe in comment box)

7. Does the wet pond smell like gasoline or oil? □ Yes ☑ No

8. Are there indications of any of the following in the wet pond? (If yes, mark on site sketch)
- □ Sediment deposition in excess of 50% of the sediment storage capacity
- □ Erosion or channelization
- ☑ Excessive or undesirable vegetation (that needs mowing or removal)
- □ Bare soil or lack of healthy vegetation significantly different from the original design
- □ Litter or debris
- □ Other
- □ No

8. a) If sediment deposition is evident, what is the source?
- □ Erosion or channelization inside the wet pond
- □ Erosion or channelization outside the wet pond
- □ Construction site erosion
- □ Other
- □ Unknown

Comments
Trash rack was free of debris and litter

Sedimentation Practices

University of Minnesota

9. Are there indications of any of the following on the banks of the wet pond:
   - □ Erosion or channelization
   - □ Soil slides or bulges
   - □ Excessive animal burrows
   - □ Seeps and wet spots
   - □ Poorly vegetated areas
   - □ Trees on constructed slopes

10. Are any outlet or overflow structures clogged? ☑No □ Partially □ Completely □ NA

10. a) If yes, specify the clogging material (i.e. debris, sediment, vegetation, etc.) in the box below.

	Outlet #:	Outlet #:	Outlet #:
Material			
Partial or Comp.			

10. b) Are any of the outlet or overflow structures askew or misaligned from the original design or otherwise in need of maintenance? (if yes, write in reason: frost heave, vandalism, unknown, etc.)

	Outlet #:	Outlet #:	Outlet #:
Reason			

11. Is there any evidence of any of the following downstream of the outlet structure?
   - □ Sediment deposition □ Erosion or channelization □ Other ☑No

11. a) If sediment deposition is evident, what is the source?
   - □ Erosion or channelization inside the filtration practice
   - □ Erosion or channelization outside the filtration practice
   - □ Construction site erosion
   - □ Other, Specify_____
   - □ Unknown

12. Inspector's Recommendations. When is maintenance needed?
   - □ Before the next rainfall
   - □ Before the next rainy season
   - □ Within a year or two
   - □ No sign that any is required

Comments
System has underdrained gravel trench, but no flow control orifice

Rite Aid (Wet Pond) Parcel ID: U12-011



Rite Aid (Wet Pond) Parcel ID: U12-011



Rite Aid (Wet Pond) Parcel ID: U12-011



Rite Aid (Wet Pond) Parcel ID: U12-011



Rite Aid (Wet Pond) Parcel ID: U12-011



Norway Savings Bank (Below-Grade Stormwater Management Facility) Parcel ID: U58-010-A1



Norway Savings Bank (Below-Grade Stormwater Management Facility) Parcel ID: U58-010-A1



APPENDIX C: BUILD-OUT MODEL

Rational Method - Peak Runoff Determination:

Key:

Input

Output

Q=uCiA

u=	1	*Constant Unit conversion factor			
C=	0.5265	*Runoff coefficient = %impervious	%impervious =	0.5265	*From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	69.9	*Time of Concentration from AutoCAD
A (ac) =	25.98	*Watershed Area			
Q (CFS) =	CALCULATED BELOW	*Peak Runoff			

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.698
c =	7.141	8.133	9.921
I (in/hr) =	1.008	1.551	2.238
Q (CFS) =	13.788	21.221	30.611

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	6,692	0.010	0.865	0.601	0.020	0.012	-0.98	-1.37046	0.40067
2	29,860	0.046	1.369	0.851	0.040	0.034	-0.96	-1.287	0.567588
3	71,436	0.110	1.788	1.044	0.059	0.062	-0.94	-1.22263	0.696332
4	132,404	0.205	2.159	1.208	0.079	0.095	-0.92	-1.16808	0.805432
5	213,371	0.330	2.498	1.353	0.098	0.132	-0.9	-1.11977	0.902054
10	927,659	1.435	3.900	1.931	0.191	0.368	-0.8	-0.9273	1.287002
15	2,159,847	3.341	5.024	2.386	0.279	0.665	-0.7	-0.7754	1.590798
20	3,891,035	6.018	5.980	2.782	0.362	1.006	-0.6	-0.6435	1.85459
25	6,086,479	9.414	6.812	3.142	0.440	1.382	-0.5	-0.5236	2.094395
30	8,701,319	13.458	7.546	3.478	0.513	1.784	-0.4	-0.41152	2.318559
35	11,683,141	18.070	8.196	3.798	0.580	2.205	-0.3	-0.30469	2.532207
40	14,973,294	23.158	8.771	4.108	0.643	2.640	-0.2	-0.20136	2.738877
45	18,507,556	28.625	9.279	4.412	0.699	3.085	-0.1	-0.10017	2.941258
50	22,216,376	34.361	9.722	4.712	0.750	3.534	0	0	3.141593
55	26,024,748	40.251	10.104	5.013	0.795	3.984	0.1	0.100167	3.341927
60	29,851,709	46.170	10.426	5.316	0.833	4.428	0.2	0.201358	3.544308
65	33,609,308	51.982	10.688	5.626	0.864	4.864	0.3	0.304693	3.750978
70	37,200,773	57.536	10.887	5.947	0.889	5.285	0.4	0.411517	3.964626
75	40,517,235	62.666	11.020	6.283	0.905	5.687	0.5	0.523599	4.18879
80	43,431,544	67.173	11.081	6.643	0.913	6.062	0.6	0.643501	4.428595
85	45,785,304	70.814	11.058	7.039	0.910	6.404	0.7	0.775397	4.692388
90	47,356,309	73.243	10.931	7.494	0.894	6.701	0.8	0.927295	4.996183
95	47,743,639	73.843	10.646	8.072	0.859	6.936	0.9	1.11977	5.381132
100	44,432,812	68.722	9.722	9.425	0.750	7.069	1	1.57079	6.283173

Diam. (in)	36	*From Site Plans
Manning n	0.011	*From Site Plans
Slope(ft/ft)	0.00756	*Estimate from GIS Topography & Field Measurements

Rational Method - Peak Runoff Determination:

Key:

Input

Output

Q=uCiA

u=	1	*Constant Unit conversion factor			
C=	0.3978	*Runoff coefficient = %impervious	%impervious =	0.3978	*From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	29.9	*Time of Concentration from AutoCAD
A (ac) =	64.82	*Watershed Area			
Q total(CFS) =	CALCULATED BELOW	*Peak Runoff from Catchments 1 & 2			

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.698
c =	7.141	8.133	9.921
I (in/hr) =	1.741	2.540	3.636
Q total(CFS) =	58.671	86.717	124.369

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	2,833	0.004	0.366	0.601	0.020	0.012	-0.98	-1.37046	0.40067
2	12,642	0.020	0.580	0.851	0.040	0.034	-0.96	-1.287	0.567588
3	30,245	0.047	0.757	1.044	0.059	0.062	-0.94	-1.22263	0.696332
4	56,058	0.087	0.914	1.208	0.079	0.095	-0.92	-1.16808	0.805432
5	90,339	0.140	1.057	1.353	0.098	0.132	-0.9	-1.11977	0.902054
10	392,762	0.607	1.651	1.931	0.191	0.368	-0.8	-0.9273	1.287002
15	914,458	1.414	2.127	2.386	0.279	0.665	-0.7	-0.7754	1.590798
20	1,647,426	2.548	2.532	2.782	0.362	1.006	-0.6	-0.6435	1.85459
25	2,576,955	3.986	2.884	3.142	0.440	1.382	-0.5	-0.5236	2.094395
30	3,684,053	5.698	3.195	3.478	0.513	1.784	-0.4	-0.41152	2.318559
35	4,946,527	7.651	3.470	3.798	0.580	2.205	-0.3	-0.30469	2.532207
40	6,339,546	9.805	3.714	4.108	0.643	2.640	-0.2	-0.20136	2.738877
45	7,835,918	12.119	3.928	4.412	0.699	3.085	-0.1	-0.10017	2.941258
50	9,406,196	14.548	4.116	4.712	0.750	3.534	0	0	3.141593
55	11,018,623	17.042	4.278	5.013	0.795	3.984	0.1	0.100167	3.341927
60	12,638,921	19.548	4.414	5.316	0.833	4.428	0.2	0.201358	3.544308
65	14,229,852	22.009	4.525	5.626	0.864	4.864	0.3	0.304693	3.750978
70	15,750,443	24.360	4.609	5.947	0.889	5.285	0.4	0.411517	3.964626
75	17,154,600	26.532	4.666	6.283	0.905	5.687	0.5	0.523599	4.18879
80	18,388,490	28.441	4.691	6.643	0.913	6.062	0.6	0.643501	4.428595
85	19,385,049	29.982	4.682	7.039	0.910	6.404	0.7	0.775397	4.692388
90	20,050,197	31.011	4.628	7.494	0.894	6.701	0.8	0.927295	4.996183
95	20,214,189	31.264	4.507	8.072	0.859	6.936	0.9	1.11977	5.381132
100	18,812,417	29.096	4.116	9.425	0.750	7.069	1	1.57079	6.283173

Diam. (in)	36	*Field Verified (Site Plans Specified 48")
Manning n	0.025	*Field Verified (Site Plans Specified RCP - .011)
Slope(ft/ft)	0.007	*From Site Plans

Rational Method - Peak Runoff Determination:

Key:

Input

Output

Q=uCiA

u=	1	*Constant Unit conversion factor			
C=	0.4893	*Runoff coefficient = %impervious	%impervious =	0.4893	*From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	51.5	*Time of Concentration from AutoCAD
A (ac) =	76.63	*Watershed Area			
Q (CFS) =	CALCULATED BELOW	*Peak Runoff			

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.698
c =	7.141	8.133	9.921
I (in/hr) =	1.236	1.866	2.687
Q (CFS) =	46.328	69.956	100.750

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	7,278	0.011	0.691	0.701	0.023	0.016	-0.98	-1.37046	0.40067
2	32,475	0.050	1.094	0.993	0.046	0.046	-0.96	-1.287	0.567588
3	77,692	0.120	1.429	1.219	0.069	0.084	-0.94	-1.22263	0.696332
4	143,999	0.223	1.725	1.410	0.092	0.129	-0.92	-1.16808	0.805432
5	232,057	0.359	1.996	1.579	0.114	0.180	-0.9	-1.11977	0.902054
10	1,008,901	1.560	3.116	2.252	0.222	0.501	-0.8	-0.9273	1.287002
15	2,349,001	3.633	4.015	2.784	0.325	0.905	-0.7	-0.7754	1.590798
20	4,231,801	6.545	4.778	3.246	0.422	1.370	-0.6	-0.6435	1.85459
25	6,619,516	10.238	5.443	3.665	0.513	1.881	-0.5	-0.5236	2.094395
30	9,463,357	14.636	6.029	4.057	0.598	2.428	-0.4	-0.41152	2.318559
35	12,706,319	19.652	6.549	4.431	0.677	3.001	-0.3	-0.30469	2.532207
40	16,284,615	25.187	7.008	4.793	0.750	3.594	-0.2	-0.20136	2.738877
45	20,128,399	31.132	7.414	5.147	0.816	4.199	-0.1	-0.10017	2.941258
50	24,162,027	37.370	7.768	5.498	0.875	4.811	0	0	3.141593
55	28,303,927	43.776	8.074	5.848	0.927	5.422	0.1	0.100167	3.341927
60	32,466,042	50.214	8.331	6.203	0.972	6.027	0.2	0.201358	3.544308
65	36,552,722	56.534	8.540	6.564	1.009	6.620	0.3	0.304693	3.750978
70	40,458,718	62.575	8.699	6.938	1.037	7.194	0.4	0.411517	3.964626
75	44,065,627	68.154	8.805	7.330	1.056	7.740	0.5	0.523599	4.18879
80	47,235,163	73.056	8.854	7.750	1.065	8.251	0.6	0.643501	4.428595
85	49,795,059	77.015	8.836	8.212	1.061	8.716	0.7	0.775397	4.692388
90	51,503,649	79.658	8.734	8.743	1.043	9.120	0.8	0.927295	4.996183
95	51,924,899	80.309	8.506	9.417	1.003	9.441	0.9	1.11977	5.381132
100	48,324,119	74.740	7.768	10.996	0.875	9.621	1	1.57079	6.283173

Diam. (in)	42	*From Site Plans
Manning n	0.011	*From Site Plans
Slope(ft/ft)	0.00393	*Estimate from GIS Topography & Field Measurements

Rational Method - Peak Runoff Determination:

Key:

Input

Output

Q=uCiA

u=	1	*Constant Unit conversion factor			
C=	0.3847	*Runoff coefficient = %impervious	%impervious =	0.3847	*From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	13.7	*Time of Concentration from AutoCAD
A (ac) =	17.34	*Watershed Area			
Q total(CFS) =	CALCULATED BELOW	*Peak Runoff from Catchments 4 & 1+2,3			

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.698
c =	7.141	8.133	9.921
I (in/hr) =	2.673	3.717	5.235
Q total(CFS) =	122.831	181.468	260.043

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	7,768	0.012	0.813	0.668	0.022	0.015	-0.98	-1.37046	0.40067
2	34,662	0.054	1.287	0.946	0.044	0.042	-0.96	-1.287	0.567588
3	82,926	0.128	1.681	1.161	0.066	0.076	-0.94	-1.22263	0.696332
4	153,699	0.238	2.030	1.342	0.087	0.117	-0.92	-1.16808	0.805432
5	247,689	0.383	2.348	1.503	0.109	0.163	-0.9	-1.11977	0.902054
10	1,076,864	1.666	3.667	2.145	0.212	0.454	-0.8	-0.9273	1.287002
15	2,507,237	3.878	4.724	2.651	0.310	0.821	-0.7	-0.7754	1.590798
20	4,516,869	6.986	5.623	3.091	0.402	1.242	-0.6	-0.6435	1.85459
25	7,065,428	10.928	6.405	3.491	0.489	1.706	-0.5	-0.5236	2.094395
30	10,100,839	15.622	7.095	3.864	0.570	2.202	-0.4	-0.41152	2.318559
35	13,562,258	20.976	7.706	4.220	0.645	2.722	-0.3	-0.30469	2.532207
40	17,381,599	26.883	8.247	4.565	0.714	3.260	-0.2	-0.20136	2.738877
45	21,484,313	33.229	8.724	4.902	0.777	3.809	-0.1	-0.10017	2.941258
50	25,789,659	39.887	9.142	5.236	0.833	4.363	0	0	3.141593
55	30,210,570	46.725	9.501	5.570	0.883	4.918	0.1	0.100167	3.341927
60	34,653,059	53.596	9.804	5.907	0.925	5.467	0.2	0.201358	3.544308
65	39,015,031	60.342	10.049	6.252	0.960	6.005	0.3	0.304693	3.750978
70	43,184,147	66.791	10.236	6.608	0.987	6.525	0.4	0.411517	3.964626
75	47,034,029	72.745	10.362	6.981	1.006	7.021	0.5	0.523599	4.18879
80	50,417,075	77.977	10.419	7.381	1.014	7.484	0.6	0.643501	4.428595
85	53,149,414	82.203	10.398	7.821	1.011	7.906	0.7	0.775397	4.692388
90	54,973,100	85.024	10.278	8.327	0.993	8.272	0.8	0.927295	4.996183
95	55,422,727	85.719	10.010	8.969	0.955	8.564	0.9	1.11977	5.381132
100	51,579,387	79.775	9.142	10.472	0.833	8.727	1	1.57079	6.283173

Diam. (in)	40	*Field Verified
Manning n	0.025	*Field Verified
Slope(ft/ft)	0.03	*From GIS Topography

Rational Method - Peak Runoff Determination:

Key:

Input

Output

Q=uCiA

u=	1	*Constant Unit conversion factor			
C=	0.6247	*Runoff coefficient = %impervious	%impervious =	0.6247	*From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	25.8	*Time of Concentration from AutoCAD
A (ac) =	22.45	*Watershed Area			
Q (CFS) =	CALCULATED BELOW	*Peak Runoff			

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.698
c =	7.141	8.133	9.921
I (in/hr) =	1.900	2.747	3.923
Q (CFS) =	26.644	38.522	55.013

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	13,330	0.021	1.723	0.601	0.020	0.012	-0.98	-1.37046	0.40067
2	59,482	0.092	2.727	0.851	0.040	0.034	-0.96	-1.287	0.567588
3	142,304	0.220	3.562	1.044	0.059	0.062	-0.94	-1.22263	0.696332
4	263,754	0.408	4.301	1.208	0.079	0.095	-0.92	-1.16808	0.805432
5	425,044	0.657	4.975	1.353	0.098	0.132	-0.9	-1.11977	0.902054
10	1,847,941	2.858	7.769	1.931	0.191	0.368	-0.8	-0.9273	1.287002
15	4,302,518	6.654	10.009	2.386	0.279	0.665	-0.7	-0.7754	1.590798
20	7,751,126	11.988	11.912	2.782	0.362	1.006	-0.6	-0.6435	1.85459
25	12,124,555	18.752	13.570	3.142	0.440	1.382	-0.5	-0.5236	2.094395
30	17,333,442	26.809	15.031	3.478	0.513	1.784	-0.4	-0.41152	2.318559
35	23,273,374	35.996	16.326	3.798	0.580	2.205	-0.3	-0.30469	2.532207
40	29,827,515	46.133	17.472	4.108	0.643	2.640	-0.2	-0.20136	2.738877
45	36,867,935	57.022	18.483	4.412	0.699	3.085	-0.1	-0.10017	2.941258
50	44,256,080	68.449	19.367	4.712	0.750	3.534	0	0	3.141593
55	51,842,540	80.182	20.128	5.013	0.795	3.984	0.1	0.100167	3.341927
60	59,466,028	91.973	20.770	5.316	0.833	4.428	0.2	0.201358	3.544308
65	66,951,344	103.550	21.290	5.626	0.864	4.864	0.3	0.304693	3.750978
70	74,105,714	114.615	21.687	5.947	0.889	5.285	0.4	0.411517	3.964626
75	80,712,264	124.833	21.952	6.283	0.905	5.687	0.5	0.523599	4.18879
80	86,517,706	133.812	22.073	6.643	0.913	6.062	0.6	0.643501	4.428595
85	91,206,509	141.064	22.029	7.039	0.910	6.404	0.7	0.775397	4.692388
90	94,336,026	145.905	21.774	7.494	0.894	6.701	0.8	0.927295	4.996183
95	95,107,605	147.098	21.207	8.072	0.859	6.936	0.9	1.11977	5.381132
100	88,512,280	136.897	19.367	9.425	0.750	7.069	1	1.57079	6.283173

Diam. (in)	36	*From Site Plans
Manning n	0.011	*From Site Plans
Slope(ft/ft)	0.03	*From Site Plans

Rational Method - Peak Runoff Determination:

Key:

Input

Output

Q=uCiA

u=	1	*Constant Unit conversion factor			
C=	0.3973	*Runoff coefficient = %impervious	%impervious =	0.3973	*From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	24.9	*Time of Concentration from AutoCAD
A (ac) =	17.76	*Watershed Area			
Q (CFS) =	CALCULATED BELOW	*Peak Runoff			

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.698
c =	7.141	8.133	9.921

I (in/hr) =	1.939	2.798	3.993
Q (CFS) =	13.685	19.742	28.176

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	848	0.001	0.439	0.301	0.010	0.003	-0.98	-1.37046	0.40067
2	3,786	0.006	0.694	0.426	0.020	0.008	-0.96	-1.287	0.567588
3	9,057	0.014	0.907	0.522	0.030	0.015	-0.94	-1.22263	0.696332
4	16,788	0.026	1.095	0.604	0.039	0.024	-0.92	-1.16808	0.805432
5	27,054	0.042	1.267	0.677	0.049	0.033	-0.9	-1.11977	0.902054
10	117,619	0.182	1.978	0.965	0.095	0.092	-0.8	-0.9273	1.287002
15	273,850	0.424	2.548	1.193	0.139	0.166	-0.7	-0.7754	1.590798
20	493,351	0.763	3.033	1.391	0.181	0.252	-0.6	-0.6435	1.85459
25	771,714	1.194	3.455	1.571	0.220	0.345	-0.5	-0.5236	2.094395
30	1,103,254	1.706	3.827	1.739	0.256	0.446	-0.4	-0.41152	2.318559
35	1,481,324	2.291	4.156	1.899	0.290	0.551	-0.3	-0.30469	2.532207
40	1,898,488	2.936	4.448	2.054	0.321	0.660	-0.2	-0.20136	2.738877
45	2,346,603	3.629	4.706	2.206	0.350	0.771	-0.1	-0.10017	2.941258
50	2,816,850	4.357	4.931	2.356	0.375	0.884	0	0	3.141593
55	3,299,720	5.104	5.125	2.506	0.397	0.996	0.1	0.100167	3.341927
60	3,784,946	5.854	5.288	2.658	0.416	1.107	0.2	0.201358	3.544308
65	4,261,378	6.591	5.420	2.813	0.432	1.216	0.3	0.304693	3.750978
70	4,716,746	7.295	5.521	2.973	0.444	1.321	0.4	0.411517	3.964626
75	5,137,245	7.946	5.589	3.142	0.453	1.422	0.5	0.523599	4.18879
80	5,506,755	8.517	5.620	3.321	0.456	1.516	0.6	0.643501	4.428595
85	5,805,192	8.979	5.608	3.519	0.455	1.601	0.7	0.775397	4.692388
90	6,004,382	9.287	5.544	3.747	0.447	1.675	0.8	0.927295	4.996183
95	6,053,492	9.363	5.399	4.036	0.430	1.734	0.9	1.11977	5.381132
100	5,633,707	8.713	4.931	4.712	0.375	1.767	1	1.57079	6.283173

Diam. (in)	18	*From Site Plans
Manning n	0.011	*From Site Plans
Slope(ft/ft)	0.0049	*From Site Plans

Summary for Subcatchment C1: Subcatchment 1

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Rainfall not specified

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.2	100	0.1500	0.10		**Sheet Flow, A-B** Woods: Dense underbrush n= 0.800 P2= 3.00"
8.8	696	0.0690	1.31		**Shallow Concentrated Flow, B-C** Woodland Kv= 5.0 fps
0.2	63	0.0500	4.54		**Shallow Concentrated Flow, C-D** Paved Kv= 20.3 fps
0.3	54	0.0040	3.33	4.09	**Circular Channel (pipe), D-E** Diam= 15.0" Area= 1.2 sf Perim= 3.9' r= 0.31' n= 0.013 Corrugated PE, smooth interior
0.3	97		5.67		**Lake or Reservoir, E-F** Mean Depth= 1.00'
0.1	40	0.0063	5.72	17.96	**Circular Channel (pipe), F-G** Diam= 24.0" Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
0.2	71		5.67		**Lake or Reservoir, G-H** Mean Depth= 1.00'
2.0	544	0.0040	4.55	14.31	**Circular Channel (pipe), H-I** Diam= 24.0" Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Corrugated PE, smooth interior
0.2	63	0.0050	4.84	5.94	**Circular Channel (pipe), I-J** Diam= 15.0" Area= 1.2 sf Perim= 3.9' r= 0.31' n= 0.010 PVC, smooth interior
0.4	225	0.0200	8.44	219.52	**Trap/Vee/Rect Channel Flow, J-K** Bot.W=7.00' D=2.00' Z= 3.0 '/' Top.W=19.00' n= 0.030 Short grass
0.2	63	0.0050	6.98	34.28	**Circular Channel (pipe), K-L** Diam= 30.0" Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.011 Concrete pipe, straight & clean
29.9	2,016	Total			

Summary for Subcatchment C2: Subcatchment 2

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Rainfall not specified

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
18.9	100	0.0300	0.09		**Sheet Flow, A-B**
					Woods: Light underbrush n= 0.400 P2= 3.00"
50.3	1,169	0.0060	0.39		**Shallow Concentrated Flow, B-C**
					Woodland Kv= 5.0 fps
0.7	329	0.0070	7.83	24.61	**Circular Channel (pipe), C-D**
					Diam= 24.0" Area= 3.1 sf Perim= 6.3' r= 0.50'
					n= 0.010 PVC, smooth interior
69.9	1,598	Total			

Summary for Subcatchment C3: Subcatchment 3

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Rainfall not specified

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	100	0.0300	0.19		**Sheet Flow, A-B**
					Grass: Short n= 0.150 P2= 3.00"
21.6	628	0.0048	0.48		**Shallow Concentrated Flow, B-C**
					Short Grass Pasture Kv= 7.0 fps
0.3	37	0.0022	2.13	1.67	**Circular Channel (pipe), C-D**
					Diam= 12.0" Area= 0.8 sf Perim= 3.1' r= 0.25'
					n= 0.013 Corrugated PE, smooth interior
12.2	1,095	0.0100	1.50		**Shallow Concentrated Flow, D-E**
					Grassed Waterway Kv= 15.0 fps
4.4	281	0.0008	1.06	3.33	**Circular Channel (pipe), E-F**
					Diam= 24.0" Area= 3.1 sf Perim= 6.3' r= 0.50'
					n= 0.025 Corrugated metal
4.1	457	0.0153	1.86		**Shallow Concentrated Flow, F-G**
					Grassed Waterway Kv= 15.0 fps
0.3	214	0.0100	12.36	118.90	**Circular Channel (pipe), G-H**
					Diam= 42.0" Area= 9.6 sf Perim= 11.0' r= 0.88'
					n= 0.011 Concrete pipe, straight & clean
51.5	2,812	Total			

Summary for Subcatchment C4: Subcatchment 4

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Rainfall not specified

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	100	0.0600	0.26		**Sheet Flow, A-B** Grass: Short n= 0.150 P2= 3.00"
5.1	408	0.0368	1.34		**Shallow Concentrated Flow, B-C** Short Grass Pasture Kv= 7.0 fps
0.8	220	0.0500	4.54		**Shallow Concentrated Flow, C-D** Paved Kv= 20.3 fps
0.8	78	0.0600	1.71		**Shallow Concentrated Flow, D-E** Short Grass Pasture Kv= 7.0 fps
0.5	223	0.0090	7.49	299.49	**Trap/Vee/Rect Channel Flow, E-F** Bot.W=2.00' D=4.00' Z= 2.0 '/' Top.W=18.00' n= 0.030 Earth, grassed & winding
13.7	1,029	Total			

Summary for Subcatchment C5: Subcatchment 5

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Rainfall not specified

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.3	100	0.0250	0.18		**Sheet Flow, A-B** Grass: Short n= 0.150 P2= 3.00"
2.8	111	0.0090	0.66		**Shallow Concentrated Flow, B-C** Short Grass Pasture Kv= 7.0 fps
5.2	219	0.0200	0.71		**Shallow Concentrated Flow, C-D** Woodland Kv= 5.0 fps
0.7	119	0.0200	2.87		**Shallow Concentrated Flow, D-E** Paved Kv= 20.3 fps
0.1	20	0.0250	2.37		**Shallow Concentrated Flow, E-F** Grassed Waterway Kv= 15.0 fps
0.2	45	0.0050	3.21	2.52	**Circular Channel (pipe), F-G** Diam= 12.0" Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
2.5	214	0.0090	1.42		**Shallow Concentrated Flow, G-H** Grassed Waterway Kv= 15.0 fps
0.5	88	0.0050	3.21	2.52	**Circular Channel (pipe), H-I** Diam= 12.0" Area= 0.8 sf Perim= 3.1' r= 0.25' n= 0.013 Corrugated PE, smooth interior
0.0	5		5.67		**Lake or Reservoir, I-J** Mean Depth= 1.00'
0.5	114	0.0040	3.76	6.64	**Circular Channel (pipe), J-K** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.013 Corrugated PE, smooth interior
2.0	128	0.0008	1.06	3.33	**Circular Channel (pipe), K-L** Diam= 24.0" Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.025 Corrugated metal
1.0	449	0.0100	7.20	22.62	**Circular Channel (pipe), L-M** Diam= 24.0" Area= 3.1 sf Perim= 6.3' r= 0.50' n= 0.013 Concrete pipe, bends & connections
0.5	244	0.0100	8.36	41.02	**Circular Channel (pipe), M-N** Diam= 30.0" Area= 4.9 sf Perim= 7.9' r= 0.63' n= 0.013 Corrugated PE, smooth interior
0.5	277	0.0090	8.95	63.28	**Circular Channel (pipe), N-O** Diam= 36.0" Area= 7.1 sf Perim= 9.4' r= 0.75' n= 0.013 Corrugated PE, smooth interior
25.8	2,133	Total			

Summary for Subcatchment C6: Subcatchment 6

Runoff = 0.00 cfs @ 5.00 hrs, Volume= 0.000 af, Depth= 0.00"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Rainfall not specified

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.0	100	0.1800	0.10		**Sheet Flow, A-B** Woods: Dense underbrush n= 0.800 P2= 3.00"
7.0	513	0.0600	1.22		**Shallow Concentrated Flow, B-C** Woodland Kv= 5.0 fps
1.3	194	0.0150	2.49		**Shallow Concentrated Flow, C-D** Paved Kv= 20.3 fps
0.6	128	0.0137	3.62	6.39	**Circular Channel (pipe), D-E** Diam= 18.0" Area= 1.8 sf Perim= 4.7' r= 0.38' n= 0.025 Corrugated metal
24.9	935	Total			

APPENDIX D: STORMWATER RETROFIT COST ESTIMATE

COMMITMENT & INTEGRITY DRIVE RESULTS
WOODARD & CURRAN
41 HUTCHINS DRIVE
PORTLAND, MAINE 04102
TEL.(207)774-2112

CLIENT	TYLin		
PROJECT	Route 1 Falmouth Commercial District Stormwater Management Plan		
DESIGNED BY	ZLH & AEA	DATE	10/30/2012
COST BY	AEA	DATE	11/8/2012
CHECKED BY	ZLH	DATE	
PROJECT NO.	225740.00	SHEET NO.	1 of 2

Stormwater Retrofits - Opinion of Probable Cost

Assumptions: Unit costs are derived from retrofit estimates developed for theoretical systems managing a unit of impervious area in order to develop an installation cost per unit. Flow through proprietary systems were sized for a given contributing area and time of concentration assumed to be typical for the study area setting. Raw materials including crushed stone, asphalt, gravel, and pavement demolition costs were based on a "bulk rate"--approximately 10 units of each BMP type installed. Costs are for delivered and in place materials unless otherwise noted. The ENR Construction Cost Index for this estimate is 9290 as of April 2012.

Pond Retrofits - Temperature Control	Quantity	Unit	Unit Cost	Price	Total	Notes
The following system was sized for an existing pond						***Pond Area = 27000 sf***
Excavation & Disposal	280	CY	$ 30.00	$ 8,400.00		Excavate to 8' wide berm and for gravel placement
Gravel Trench						
Gravel Trench (3' depth)	100	CY	$ 30.00	$ 3,000.00		Trench area
Geotextile	260	SY	$ 2.25	$ 585.00		Sides and bottom of gravel trench
6" Underdrain	230	LF	$ 25.00	$ 5,750.00		Gravel trench drain line and connection to overflow, including pipe only
Overflow Structure (4' diameter)	1	EA	$ 3,500.00	$ 3,500.00		New structure or modify existing
12" Diameter PVC Pipe	50	LF	$ 85.00	$ 4,250.00		Outlet pipe, including excavation, pipe, bedding, backfill
Loam and Seed (bench and slope)	1770	SY	$ 6.00	$ 10,620.00		Bench and slope areas around gravel
Erosion & Sedimentation Control	1	LS	$ 2,500.00	$ 2,500.00		
				Construction Subtotal:	*$ 38,605.00*	
				Mobilization & Administration (5%):	*$ 1,940.00*	
				Contingency (25%):	*$ 9,660.00*	
				Total Construction:	***$ 50,210.00***	
				Engineering, Permitting, & Survey (20%):	*$ 10,050.00*	(Minimum $10,000, includes survey, evaluation of drainage area, system volume, and water quality requirements)
				Total System Cost:	***$ 60,260.00***	
				Total Cost per Square Foot :	***$ 2.23***	

New Retrofits	Quantity	Unit	Unit Cost	Price	Total	Notes
The following systems were sized for a .5 acre impervious drainage area and 1-inch 24-hour precipitation event						***Water Quality Volume = 1815 cf***
Gravel Wetland Sample (installation in unpaved setting)						*Includes: Pretreatment Basin and 2 Cells*
Excavation & Disposal	400	CY	$ 30.00	$ 12,000.00		*Assume: Design based on UNH Stormwater Center Draft Design Criteria*
Wetland Soil (8")	200	SY	$ 10.00	$ 2,000.00		*Assumed Excavated Area - 2,000 sf*
3/4" Crushed Stone (24")	150	CY	$ 40.00	$ 6,000.00		
Riprap (5")	2	CY	$ 65.00	$ 130.00		
Underdrain (6")	91	LF	$ 25.00	$ 2,275.00		
3' Diameter Perforated Riser	1	EA	$ 650.00	$ 650.00		
6" Diameter Galvanized Riser	1	EA	$ 500.00	$ 500.00		
Loam	150	SY	$ 4.00	$ 600.00		
Seed	150	SY	$ 2.00	$ 300.00		
				Construction Cost per Unit:	***$ 24,455.00***	
				Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ 8,559.25***	
				Contingency (20%):	***$ 6,602.85***	
				Total Cost per System:	***$ 39,617.10***	
				Total Cost per Cubic Foot :	***$ 21.83***	
				Total Cost (System & Connection) per SF :	***$ 19.81***	
Soil Filter (installation in unpaved setting)						*Assumed Dimension: 1210 SF surface area with 1.5' storage over media*
Excavation & Disposal	180	CY	$ 30.00	$ 5,400.00		*Assumed Excavated Area - 1600 sf*
Riprap Inlet	1	CY	$ 65.00	$ 65.00		*Assumed Dimension: 3' W x 6'L x 1.5' D*
Soil Filter (18")	68	CY	$ 80.00	$ 5,440.00		
Coarse Gravel (12")	45	CY	$ 35.00	$ 1,575.00		
Geotextile Fabric	175	SY	$ 2.25	$ 393.75		
Underdrain (6" Diameter)	150	LF	$ 25.00	$ 3,750.00		
Loam	135	SY	$ 4.00	$ 540.00		
Seed	135	SY	$ 2.00	$ 270.00		
				Construction Cost per Unit:	***$ 17,433.75***	
				Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ 6,101.81***	
				Contingency (20%):	***$ 4,707.11***	
				Total Cost per System:	***$ 28,242.68***	
				Total Cost per Cubic Foot :	***$ 15.56***	
				Total Cost (System & Connection) per SF :	***$ 17.65***	
Raingarden (installation in unpaved setting)						*Assumed Dimensions: 3' D x 605 SF*
Excavation & Disposal	68	CY	$ 30.00	$ 2,040.00		*Assumed require organic soil amendments.*
Organic Soil Modification	4	CY	$ 65.00	$ 260.00		*Assumed outlet conveyance is existing*
Loam	70	SY	$ 4.00	$ 280.00		*Assumed Excavated Area - 605 sf*
Seed	70	SY	$ 2.00	$ 140.00		
				Construction Cost per Unit:	***$ 2,720.00***	
				Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ 952.00***	
				Contingency (20%):	***$ 734.40***	
				Total Cost per System:	***$ 4,406.40***	
				Total Cost per Cubic Foot :	***$ 2.43***	
				Total Cost per SF :	***$ 7.28***	

Below Grade Filter (installation in paved setting)							*Assumed Area: Controlled by width - 13.82'(W) x 115.57'(L) (1600 sf)*
							Controlled by length - 10.49'(W) x 158.27'(H) (1660 sf)
Pavement Demolition	70	SY	$	10.00	$ 700.00		*Area can range depending on chamber arrangement: assume 1600 sf - 2000 sf*
Sawcut	60	LF	$	3.00	$ 180.00		*Assumed Excavated Area - 2,500 sf*
Excavation & Disposal	180	CY	$	30.00	$ 5,400.00		
Stormwater Chamber (SC-310)	60	EA	$	160.00	$ 9,600.00		*Assume storage chamber located in impervious surface*
3/4" Angular Stone	137	TON	$	40.00	$ 5,480.00		
Geotextile Fabric	30	SY	$	2.25	$ 67.50		
Hot Mix Asphalt (4")	17	TON	$	100.00	$ 1,700.00		
Aggregate Base (3")	6	CY	$	30.00	$ 180.00		
Aggregate Subbase (18")	35	CY	$	30.00	$ 1,050.00		
Gravel	24	CY	$	35.00	$ 840.00		
Filter Sand	35	CY	$	50.00	$ 1,750.00		
6" Underdrain	100	LF	$	25.00	$ 2,500.00		
Police Detail	2	DAYS	$	300.00	$ 600.00		
					Estimated Cost for Storage Chambers	***$ 30,047.50***	
					Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ 10,516.63***	
					Contingency (20%):	***$ 8,112.83***	***Notes: Costs are given for delivery and installation of Stormtech Chambers with Isolator Row. Design is based on manufacturer recommendations plus 18" sand filter for bacteria reduction as described in Maine BMP manual.***
					Total Cost per System:	***$ 48,676.95***	
For connection with existing system. Assume one connection per unit.							
Pavement Demolition	25	SY	$	10.00	$ 250.00		
Sawcut	50	LF	$	3.00	$ 150.00		
Excavation & Disposal	45	CY	$	30.00	$ 1,350.00		
Manhole (4')	2	EA	$	3,500.00	$ 7,000.00		
12" Piping	20	LF	$	85.00	$ 1,700.00		
					Estimated Cost for Connection	***$ 10,450.00***	
					Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ 3,657.50***	
					Contingency (20%):	***$ 2,821.50***	
					Total Cost per Connection to System:	***$ 16,929.00***	
					Total Cost (System & Connection) :	***$ 65,605.95***	
					Total Cost (System & Connection) per Cubic Foot :	***$ 36.15***	
					Total Cost (System & Connection) per SF :	***$ 26.24***	*Design assumes removal and replacement of pavement.*
The following systems are on a per unit basis.							
Catchbasin Insert							*Unit Costs based on HydroInternational Up-Flo Filter*
6 module system	1	EA	$	30,000.00	$ 30,000.00		*Dimensions based on design peak flow, 6 module system treats only 0.27 cfs*
					Construction Cost per Unit:	***$ 30,000.00***	
					Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ -***	
					Contingency (20%):	***$ 6,000.00***	
					Total Cost per System:	***$ 36,000.00***	
Esplanade Filter Box (installation in unpaved setting)							*Assumed Dimension: 6' x 12' Box*
Sawcut	60	LF	$	3.00	$ 180.00		*Treats up to 0.81 acres for residential where C=0.50 & up to 0.48 acres for commercial*
Pavement Demolition	35	SY	$	10.00	$ 350.00		
Excavation & Disposal	4	CY	$	30.00	$ 120.00		
Bacterra Unit w/ tree grate	1	EA	$	22,300.00	$ 22,300.00		
Crushed Stone (12")	1	CY	$	40.00	$ 40.00		
4" Connection Pipe	50	LF	$	30.00	$ 1,500.00		
Coring	1	EA	$	1,000.00	$ 1,000.00		
Police Detail	2	DAYS	$	300.00	$ 600.00		
					Construction Cost per Unit:	***$ 26,090.00***	
					Engineering (15%), Survey (10%) and Construction Bonds, Insurance, etc. (10%):	***$ 9,131.50***	
					Contingency (20%)	***$ 7,044.30***	
					Total Cost per System:	***$ 42,265.80***	
The following system was sized for an existing swale or drainage ditch.							***Example Swale Area = 3750 sf***
Filtration Swale Sample							
Excavation & Disposal	220	CY	$	30.00	$ 6,600.00		Excavate for filter media and forebay construction
Soil Filter Media:							
Soil Filter (18" depth)	70	CY	$	80.00	$ 5,600.00		Filter area
Coarse Gravel (12" depth)	50	CY	$	35.00	$ 1,750.00		Filter area
6" Underdrain	200	LF	$	25.00	$ 5,000.00		Single run, length of filter, including pipe only
Overflow Structure (4' diameter)	1	EA	$	3,500.00	$ 3,500.00		New structure
12" Diameter PVC Pipe	10	LF	$	85.00	$ 850.00		Tie overflow structure into existing culvert, including excavation, pipe, bedding & backfill
Loam and Seed	900	SY	$	6.00	$ 5,400.00		Filter area, side slopes, and forebay
Landscaping	1	LS	$	2,000.00	$ 2,000.00		Additional landscaping around filter
Erosion & Sedimentation Control	1	LS	$	2,500.00	$ 2,500.00		
					Construction Subtotal:	*$ 33,200.00*	
					Mobilization & Administration (5%):	*$ 1,660.00*	
					Contingency (25%):	*$ 8,300.00*	
					Total Construction:	***$ 43,160.00***	
					Engineering, Permitting, & Survey (20%):	*$ 10,000.00*	(Minimum $10,000, includes survey, evaluation of drainage area, system volume, and water quality requirements)
					Total Cost per SF :	***$ 14.18***	

COMMITMENT & INTEGRITY
DRIVE RESULTS
WOODARD & CURRAN
41 HUTCHINS DRIVE
PORTLAND, MAINE 04102
TEL.(207)774-2112

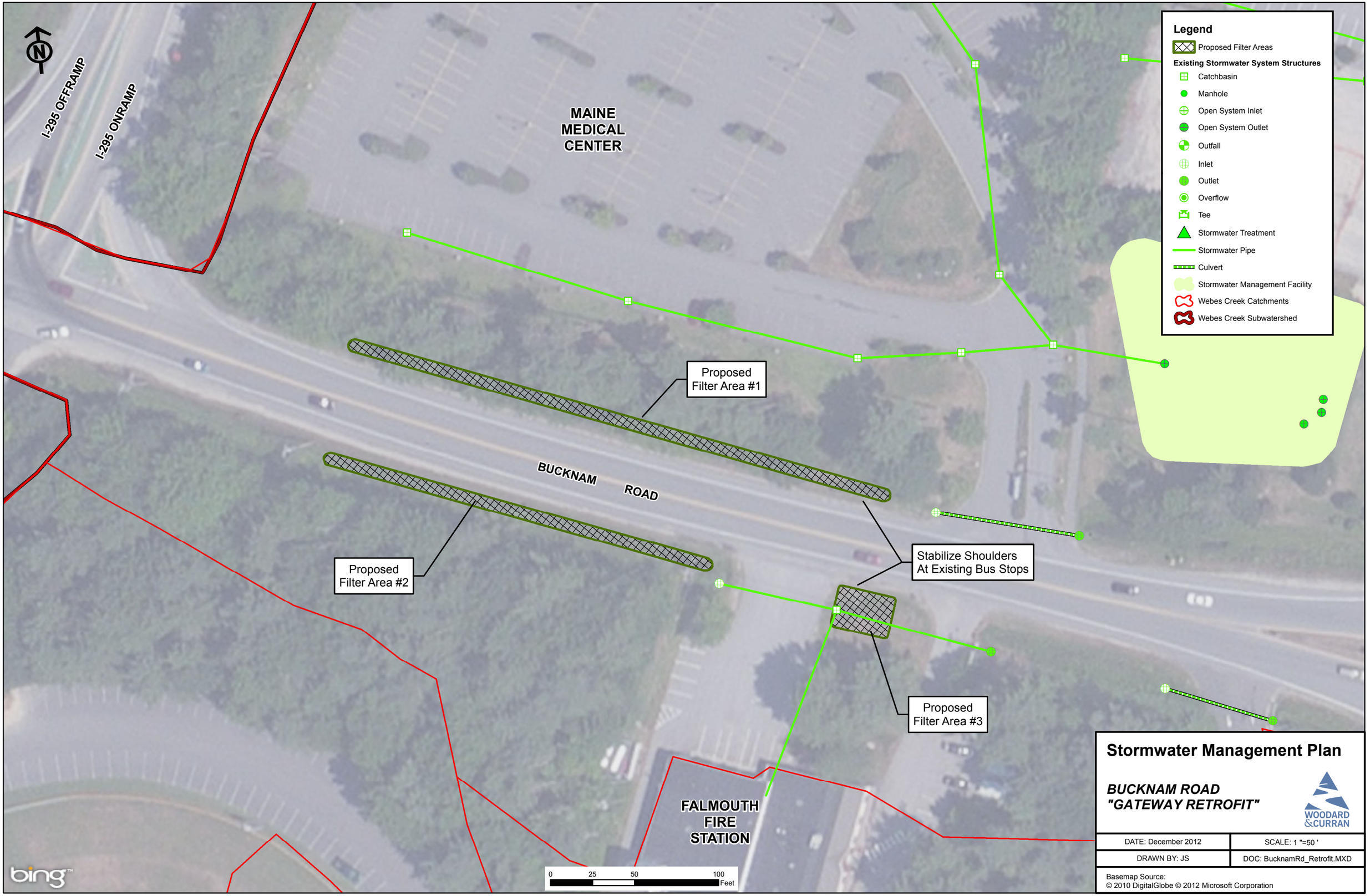
CLIENT	TYLin		
PROJECT	Route 1 Falmouth Commercial District Stormwater Management Plan		
DESIGNED BY	ZLH & AEA	**DATE**	10/30/2012
COST BY	AEA	**DATE**	11/8/2012
CHECKED BY	ZLH	**DATE**	
PROJECT NO.	225740.00	**SHEET NO.**	2 of 2

Stormwater Retrofits - Opinion of Probable Cost

Assumptions:

Retrofits - Flood Control	Quantity	Unit	Unit Cost	Price	Total	Notes
Excavation & Disposal	84	CY	$ 30.00	$ 2,520.00		Excavate for 4' diameter structure
Overflow Structure (4' diameter)	1	EA	$ 3,500.00	$ 3,500.00		New structure or modify existing
12" Diameter PVC Pipe	50	LF	$ 85.00	$ 4,250.00		Outlet pipe, including excavation, pipe, bedding, backfill
Erosion & Sedimentation Control	1	LS	$ 2,500.00	$ 2,500.00		
				Construction Subtotal:	$ *12,770.00*	
				Mobilization & Administration (5%):	$ *640.00*	
				Contingency (25%):	$ *3,200.00*	
				Total Construction:	***$ 16,610.00***	
				Engineering, Permitting, & Survey (20%):	$ *10,000.00*	(Minimum $10,000, includes survey, evaluation of drainage area, system volume, and water quality requirements)
				Total System Cost:	***$ 26,610.00***	

APPENDIX E: BUCKNAM ROAD GATEWAY RETROFIT CONCEPT


I-295 OFFRAMP
I-295 ONRAMP
MAINE MEDICAL CENTER
Proposed Filter Area #1
BUCKNAM ROAD
Proposed Filter Area #2
Stabilize Shoulders At Existing Bus Stops
Proposed Filter Area #3
FALMOUTH FIRE STATION
0 25 50 100 Feet
bing
Legend
Proposed Filter Areas
Existing Stormwater System Structures
Catchbasin
Manhole
Open System Inlet
Open System Outlet
Outfall
Inlet
Outlet
Overflow
Tee
Stormwater Treatment
Stormwater Pipe
Culvert
Stormwater Management Facility
Webes Creek Catchments
Webes Creek Subwatershed
Stormwater Management Plan
BUCKNAM ROAD "GATEWAY RETROFIT"
WOODARD &CURRAN
DATE: December 2012
SCALE: 1 "=50 '
DRAWN BY: JS
DOC: BucknamRd_Retrofit.MXD
Basemap Source:
© 2010 DigitalGlobe © 2012 Microsoft Corporation

WOODARD &CURRAN
41 HUTCHINS DRIVE
PORTLAND, MAINE 04102
TEL. (207) 774-2112
FAX (207) 774-6635

CLIENT TYLin
PROJECT Falmouth Rte 1 SW Plan
DESIGNED BY AEA DATE 12-12-12
CHECKED BY _____ DATE _____
PROJECT NO. 225740 SHEET NO. 1 OF 2

Bucknam Road Conveyance - Water Quality Sizing & Cost

(Note: These estimates are preliminary)

* Area 1:

Watershed = 47,713 SF = 27,648 SF Pervious
20,065 SF Impervious

Water Quality Volume (WQV) = (0.5" x Impervious)

→ $WQV = \left[\left(\frac{0.5"}{12"/1'}\right)(20{,}065\ SF)\right]$

= 836 CF

Assuming 4" deep swales,

→ $A_{req'd} = \frac{WQV}{4"} = \frac{836\ CF}{4"/12"/1'} = 2{,}508\ SF$

Available Space = 3,135 SF ✓ OK

Approximate Cost per SF of Filtration Swale = $15/SF

*Note: Unit cost from Stormwater Retrofit Cost estimate - Appendix D of Route 1 Falmouth Commercial District Stormwater Management Plan

∴ Cost = $\frac{\$15}{SF} \times 2{,}508\ SF = \$37{,}620$

*Area 2:

Watershed = 61,328 SF = 46,994 SF Pervious
14,334 SF Impervious

→ $WQV = \left[\left(\frac{0.5"}{12"/1'}\right)(14{,}334\ SF)\right]$

= 597 CF

→ $A_{req'd} = \frac{597\ CF}{4"/12"/1'} = 1{,}791\ SF$

Available Space = 12,685 SF ✓ Ok

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PORTLAND, MAINE 04102
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FAX (207) 774-6635

CLIENT TY Lin
PROJECT Falmouth Rte 1 SW Plan
DESIGNED BY AEA DATE 12-12-12
CHECKED BY _____ DATE _____
PROJECT NO. 225740 SHEET NO. 2 OF 2

Buckman Road Conveyance - Water Quality Sizing & Cost

*Area 2 Cont'd...

Cost = $\frac{\$15}{SF}$ × 1,791 SF = $ 26,865

*Area 3:

Watershed = 13,401 SF = 6,597 SF Pervious
6,804 SF Impervious

→ WQV = [(0.5"/12") (6,804 SF)]
= 284 CF

→ A_{reqd} = $\frac{284\ CF}{4"/12"/1}$ = 852 SF

Available Space = 2,245 SF ✓ OK

Cost = $\frac{\$15}{SF}$ × 852 SF = $ 12,780

Total Cost = $ 37,620
$ 26,865
$ 12,780
$ 77,265

APPENDIX F: MEETING PRESENTATIONS



Route 1 Falmouth Commercial District

Stormwater Planning for Long-Term Sustainable Growth

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Introductions

Theo Holtwijk, Director of Long Range Planning
Mel Dickenson, Conservation Commission

Zach Henderson, Woodard & Curran
Curtis Bohlen, Casco Bay Estuary Partnership



Meeting Goals

To provide overview of Stormwater Management Plan project.

To get your input.

Town officials have made no decisions on any matters that will be discussed here.



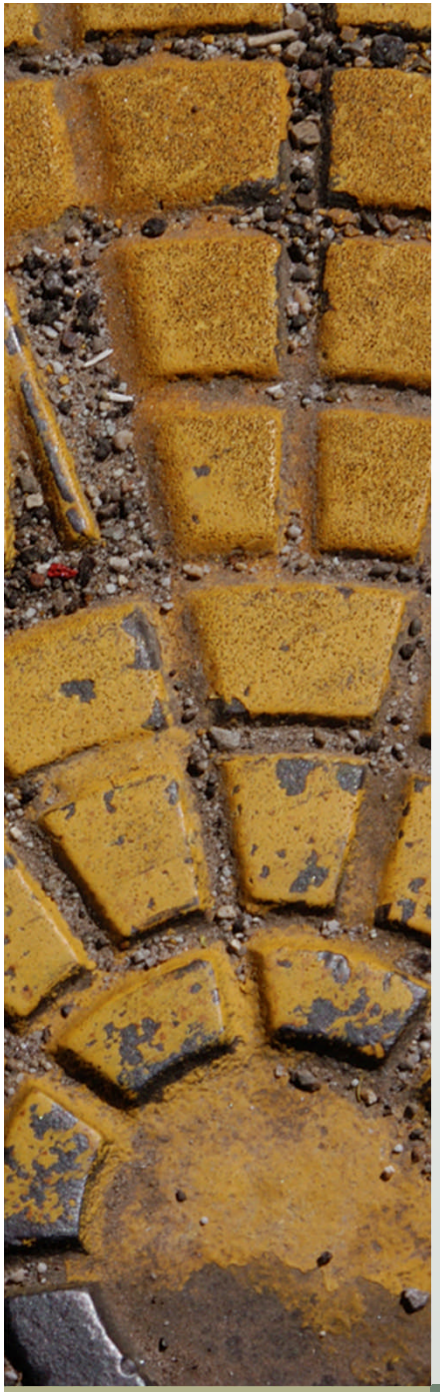
How did this Project come about?

The future of Route 1 has been discussed since 2002.

Current work has two components:

- Zoning - Town land use rules
- Infrastructure -Town financial investment
  - Traffic
  - Utilities, incl. stormwater
  - Streetscape/Landscaping

February 2012: Maine Competitive Coastal Grant Program



Project Goals

Our project hopes to accomplish the following through a collaborative partnership between state, town and private property owners:

1. Identification of opportunities for shared runoff management versus conventional approach where each property owner manages stormwater runoff on their own property.

2. Evaluation of the potential cost savings and reduced permitting requirements for managing stormwater runoff in the project area.

3. Enhanced capacity for future commercial growth.

4. A roadmap to better water quality in Mill Creek, Mussel Cove and Casco Bay.



What About Drainage?

- Drainage is not the sewer we often think of, but it *is* an underground system of pipes that maintains our urban built environment.
- Drainage systems convey fallen rainwater, called *stormwater*, from paved streets, parking lots, our lawns and basements (via sump pump) to prevent pooling and flooding.





Drainage Prevents Damage

Stormwater is drained away to prevent expensive damage to our infrastructure.

basements → **cracking**

streets → **flooding**

beneath roadways → **heaving**







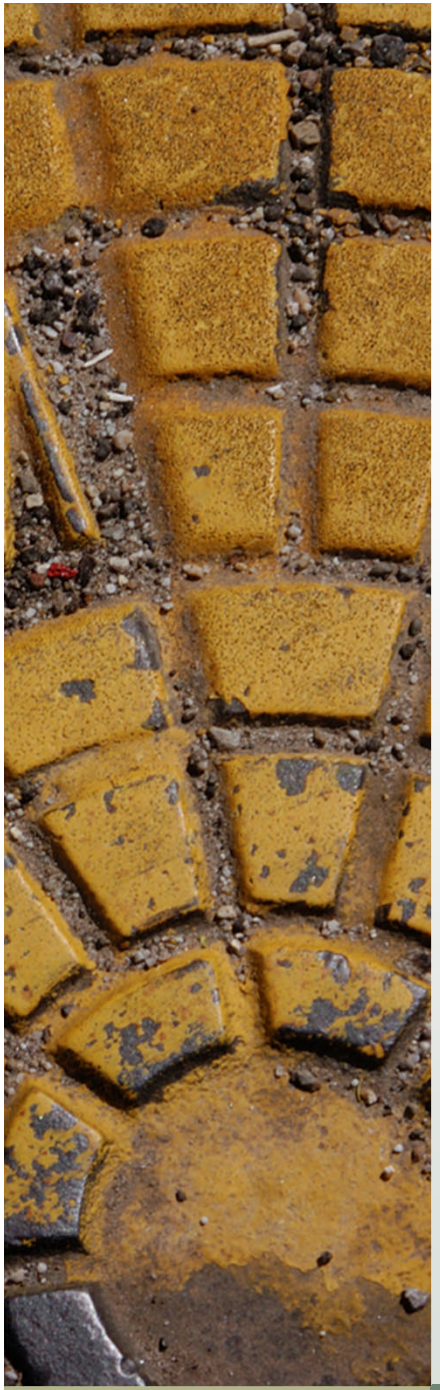


Polluted Stormwater

- Unfortunately, our drainage systems also carry pollutants like oil, fertilizers, sediment and trash.
- Rainwater that falls on paved streets, lawns, parking lots and sidewalks becomes polluted stormwater.







Stormwater & Maine Water Pollution

So, polluted stormwater from our neighborhoods runs directly to streams and water bodies, including the Casco Bay.

- **Did You Know:** polluted stormwater runoff is the largest source of water quality problems for Maine's waters?

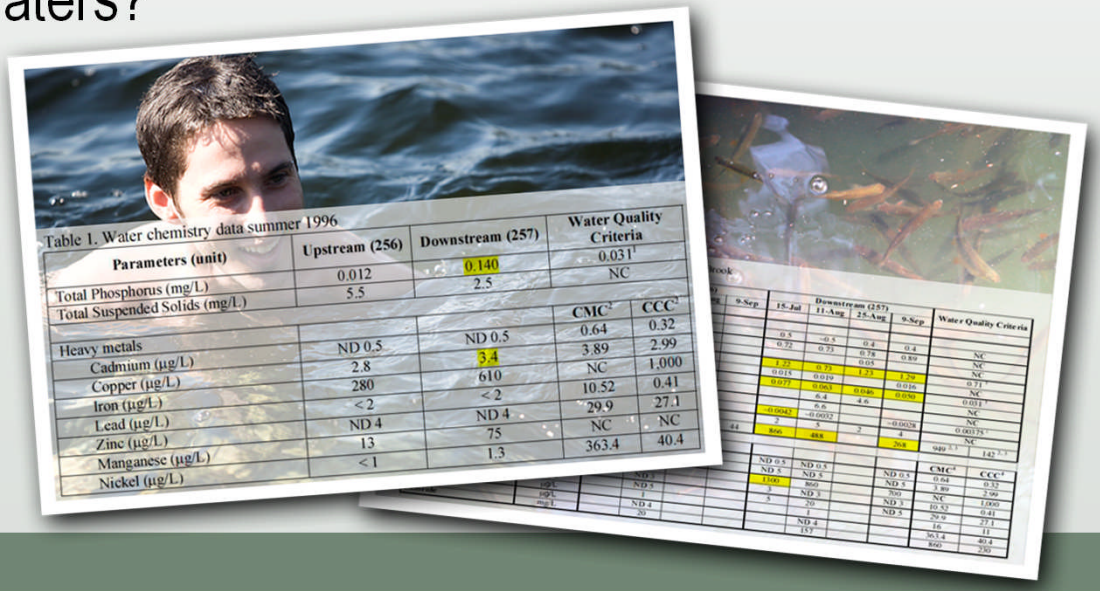


Table 1. Water chemistry data summer 1996

Parameters (unit)	Upstream (256)	Downstream (257)	Water Quality Criteria	
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Cadmium (µg/L)	ND 0.5	ND 0.5	0.64	0.32
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Iron (µg/L)	280	610	NC	1,000
Lead (µg/L)	<2	<2	10.52	0.41
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Manganese (µg/L)	13	75	NC	NC
Nickel (µg/L)	<1	1.3	363.4	40.4



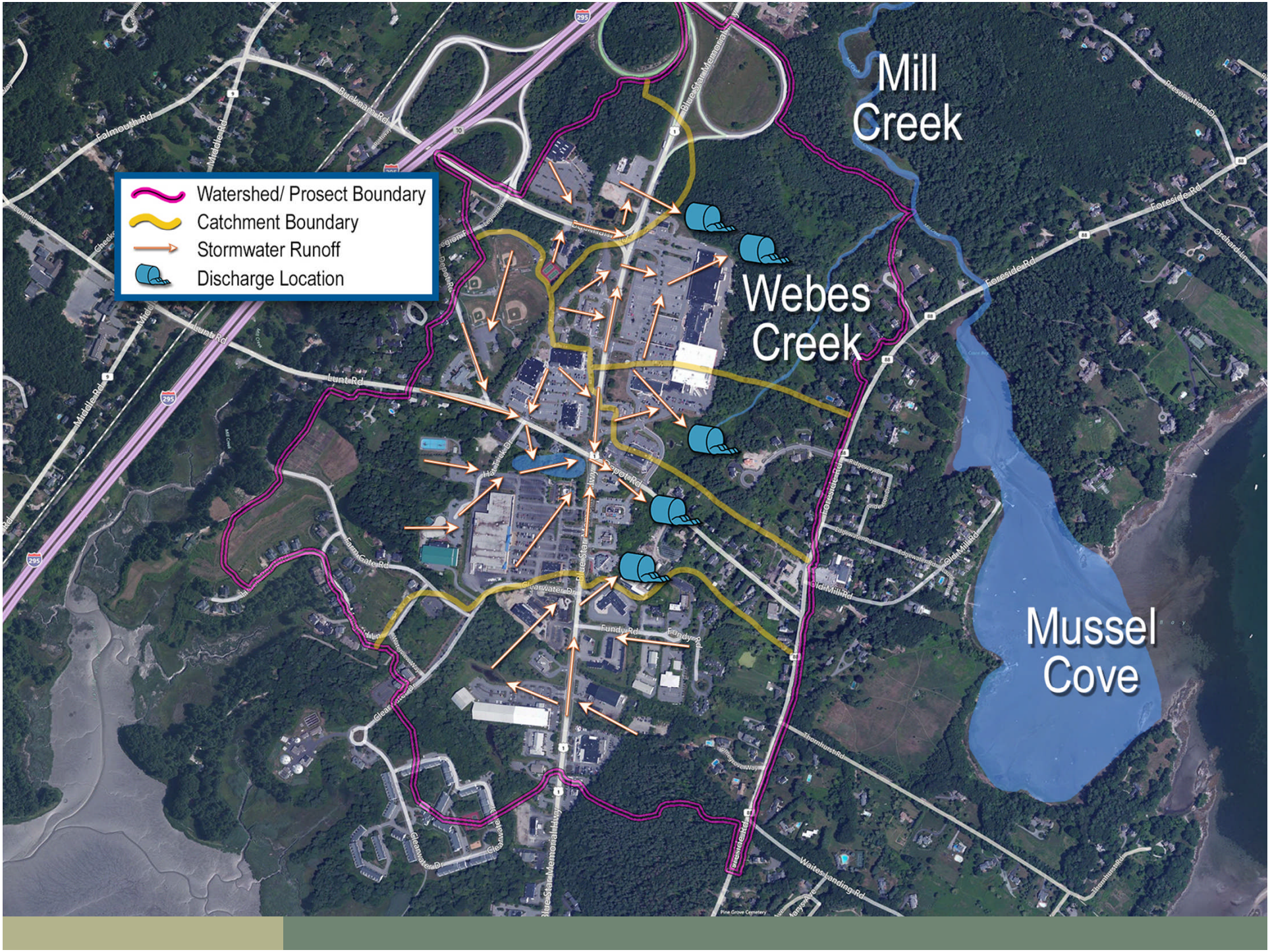
That Storm Drain does NOT lead to the Sewer

Water from your toilet and sink
sewer and on to the treatme



Polluted stormwater enters the
through the storm drains, which
vers and streams. Stormwater is




Watershed/ Prosect Boundary
Catchment Boundary
Stormwater Runoff
Discharge Location
Mill Creek
Webes Creek
Mussel Cove
Falmouth Rd
Middle Rd
Blue Star Memorial Hwy
Lunts Rd
Foreside Rd
Depot Rd
Fundy Rd
Old Mill Rd
Thornhurst Rd
Waites Landing Rd
Clearwater Dr
Farm Gate Rd
Pine Grove Cemetery



How is Stormwater Regulated?

Clean Water Act

- **Maine Pollution Discharge Elimination System (MEPDES)**
  - Maine is a delegated state and issues permits
  - Establishes required discharge limits and testing requirements.
- **Municipal Separate Storm Sewer System Discharges**
  - Five year general permit – 6 management measures
  - Progress required to clean up urban impaired streams
- **Residual Designation Authority (Long Creek)**

Maine Law

- State Stormwater Management Law (Chapter 500)
- Urban Impaired Streams
- Provision for waiver where local program addresses stormwater



Components of Maine Law

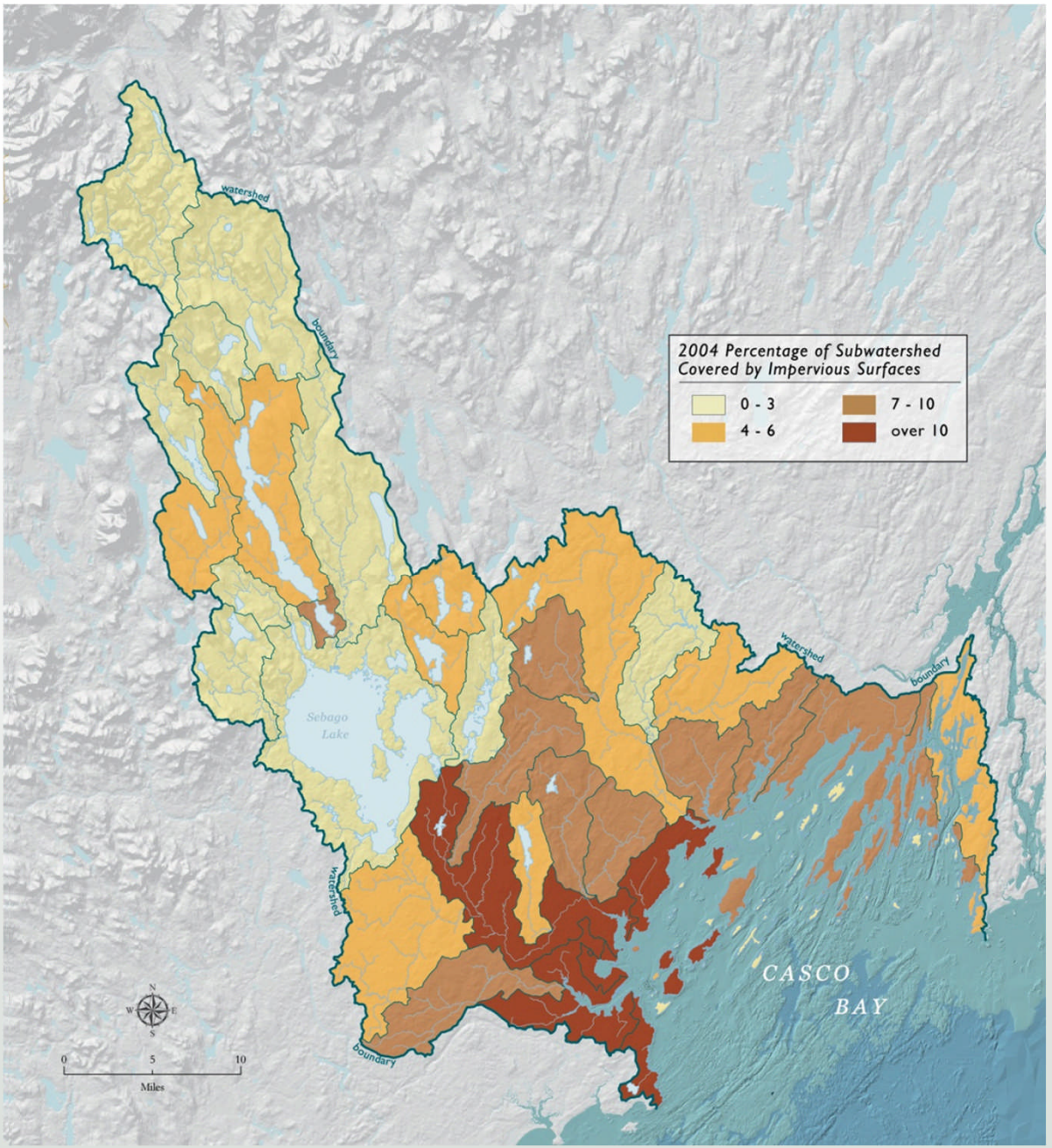
- Basic Standards – Erosion and Sediment Control
- General Standards – Storing and treating the first inch of runoff
- Flooding Standards – Storing and slowly releasing the runoff associated with the 2, 10 and 25 year events
- Urban Impaired Waters



Casco Bay Impaired Waters Are Suburban

A close relationship between impaired waters and stormwater derived from roads and rooftops



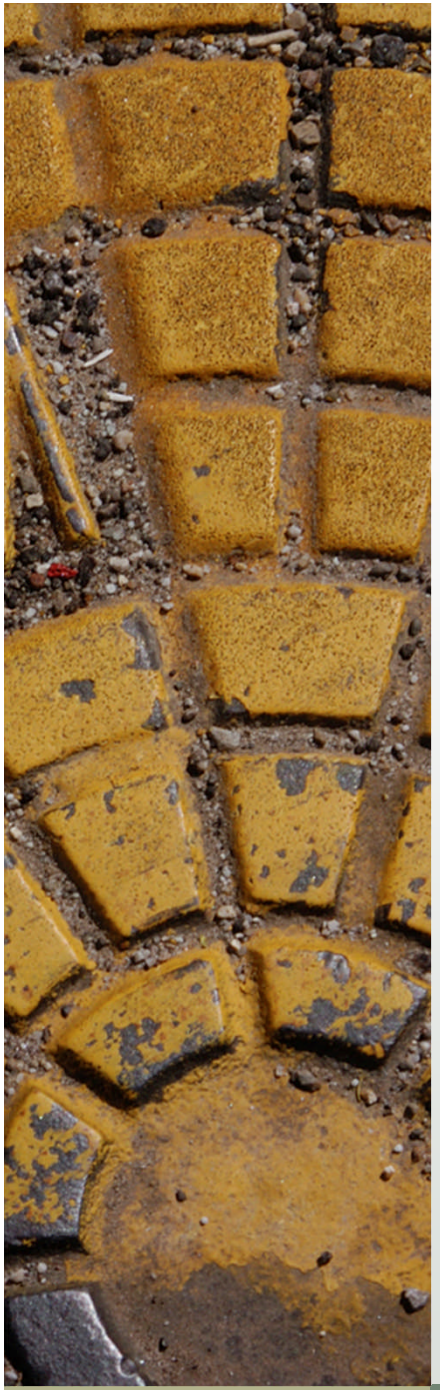

2004 Percentage of Subwatershed Covered by Impervious Surfaces
0 - 3
4 - 6
7 - 10
over 10
watershed boundary
watershed boundary
watershed boundary
Sebago Lake
CASCO BAY
N
W
E
S
0
5
10
Miles



Our cities and towns can be hard on Casco Bay

- Developed land pollutants degrade coastal water quality
  - High bacteria counts can close clam flats, swimming beaches
  - Nutrients in runoff affect coastal water quality
    - algae blooms
    - low DO
    - potential fish kills
  - Toxic chemicals accumulate in sediments and marine organisms, especially top predators like Osprey
- (Sub) urbanization triggers loss and reduction in quality of habitat





Status of Casco Bay Clam Flats

- DMR has mapped nearly 11,000 acres of softshell clam habitat and close to 1,300 acres of quahog habitat in Casco Bay
- Slightly less than 2/3 of Casco Bay Flats are usually open for harvest
- Nearly ¼ are permanently closed to harvest





Status of Mussel Cove

- DMR divides Mussel Cove into Inner and Outer portions, managed differently
- Harvesting clams is prohibited in Inner Mussel Cove
  - No single source of bacteria has been identified but the site has a history of high levels
  - Water samples from near Route 1 have shown high bacteria levels
- Outer Mussel Cove is closed seasonally





Project Tasks

- Identification of opportunities for shared runoff management and cost savings.
  - Mapping
  - Evaluation of private and public stormwater management



Project Tasks

- Integration with Route 1 Infrastructure Study
  - Build out Analysis
  - Zoning modifications



Project Tasks

- Enhanced capacity for future commercial growth.
  - Stormwater management on cooperative basis, particularly for flooding criteria.
  - Ordinance and Rule Changes



Project Tasks

- A Roadmap to better water quality in Mill Creek, Mussel Cove and Casco Bay.
  - MDOT Demonstration project


Questions
&
Discussion



Route 1 Falmouth Commercial District

Stormwater Planning for Long-Term Sustainable Growth

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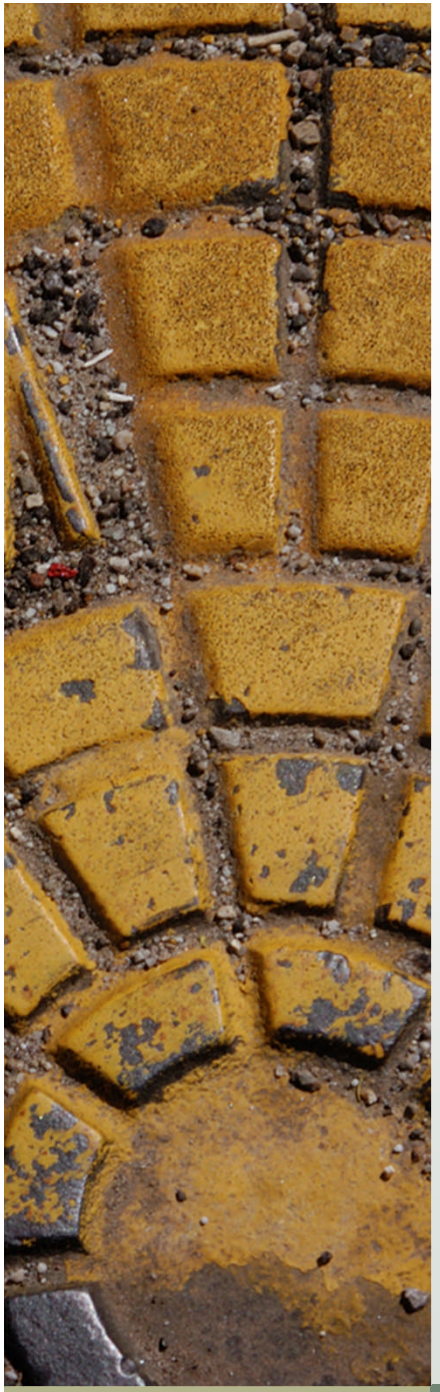
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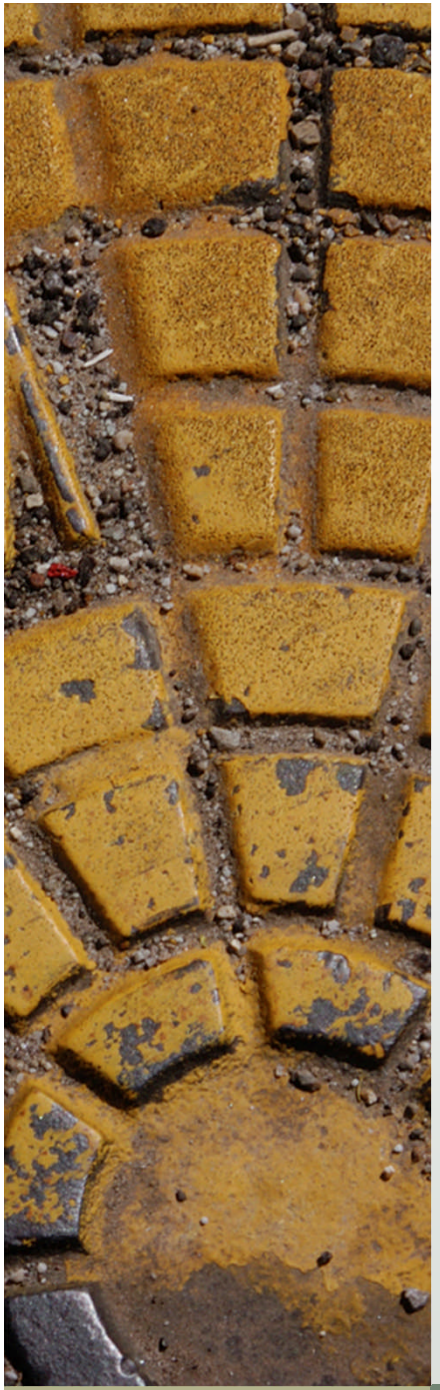


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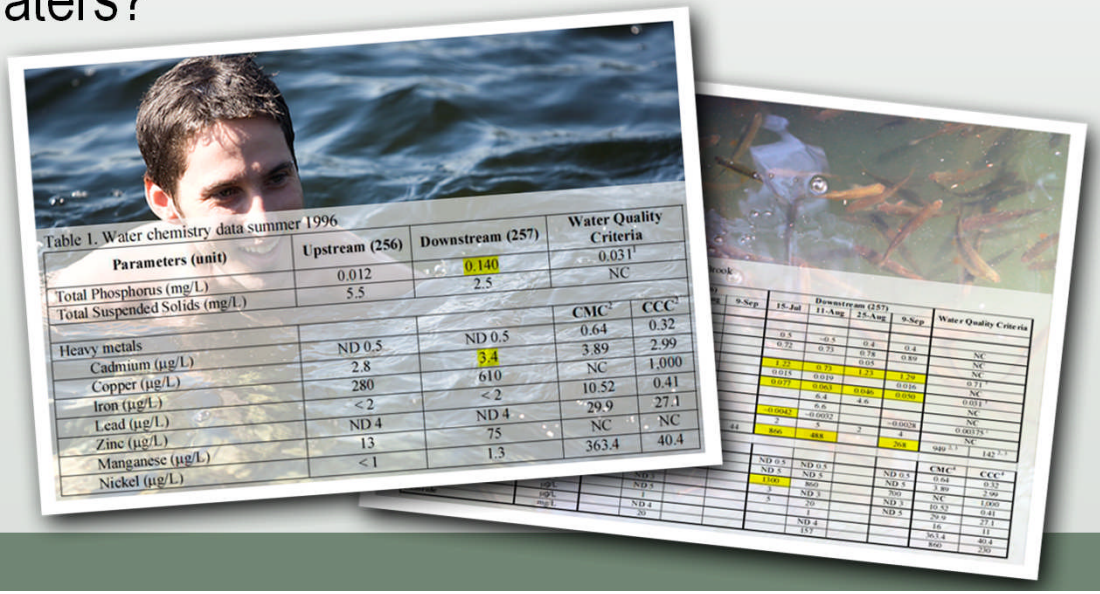


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That Storm Drain does NOT lead to the Sewer

Water from your toilet and sink flows to the sanitary sewer and on to the treatment plant.

Polluted stormwater enters the drainage system through the storm drains, which drain directly to nearby ponds, rivers and streams. Stormwater is not treated.





Our cities and towns can be hard on Casco Bay

- Developed land pollutants degrade coastal water quality
  - High bacteria counts can close clam flats, swimming beaches
  - Nutrients in runoff affect coastal water quality
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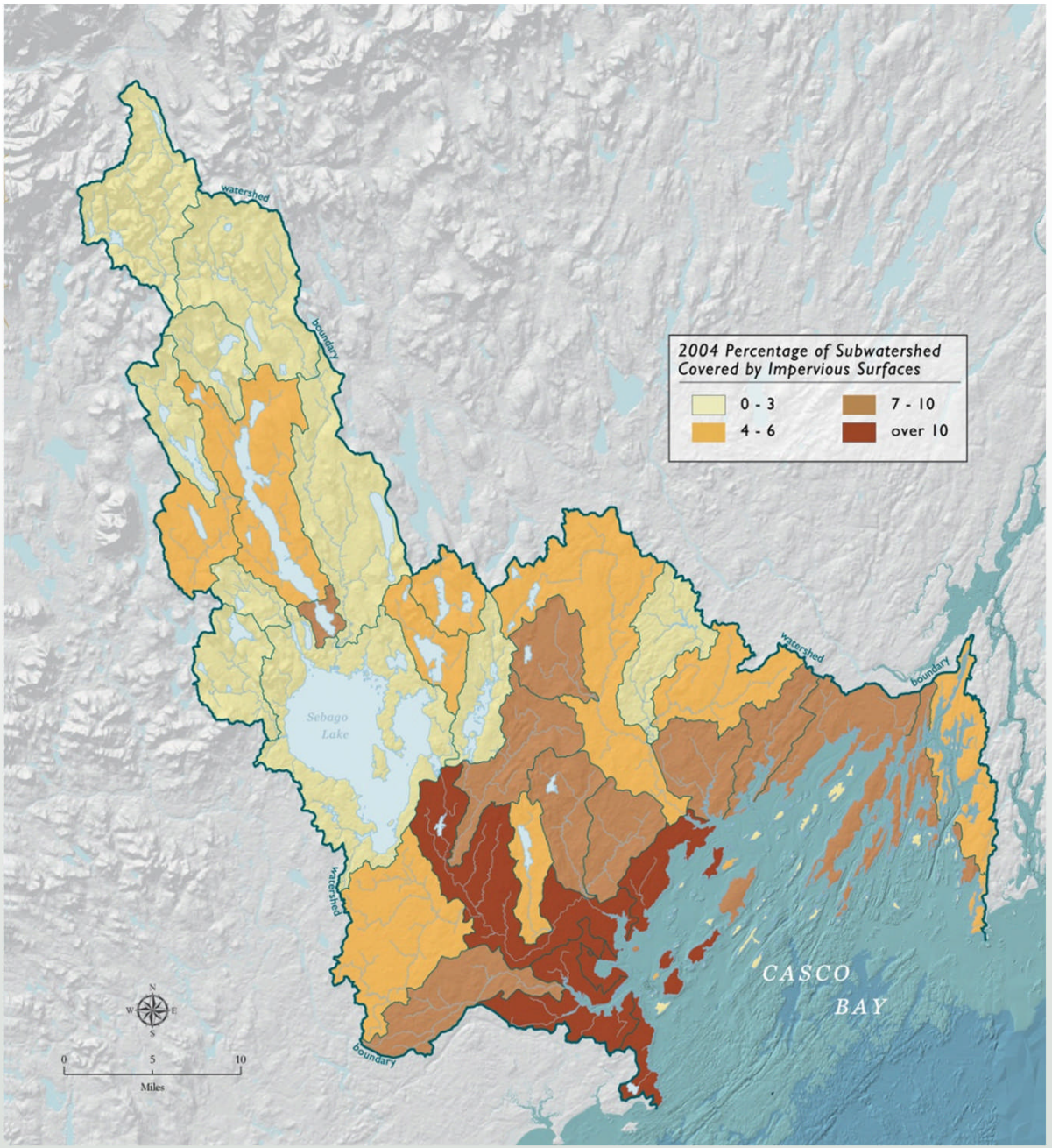




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A close relationship between impaired waters and stormwater derived from roads, parking areas and rooftops

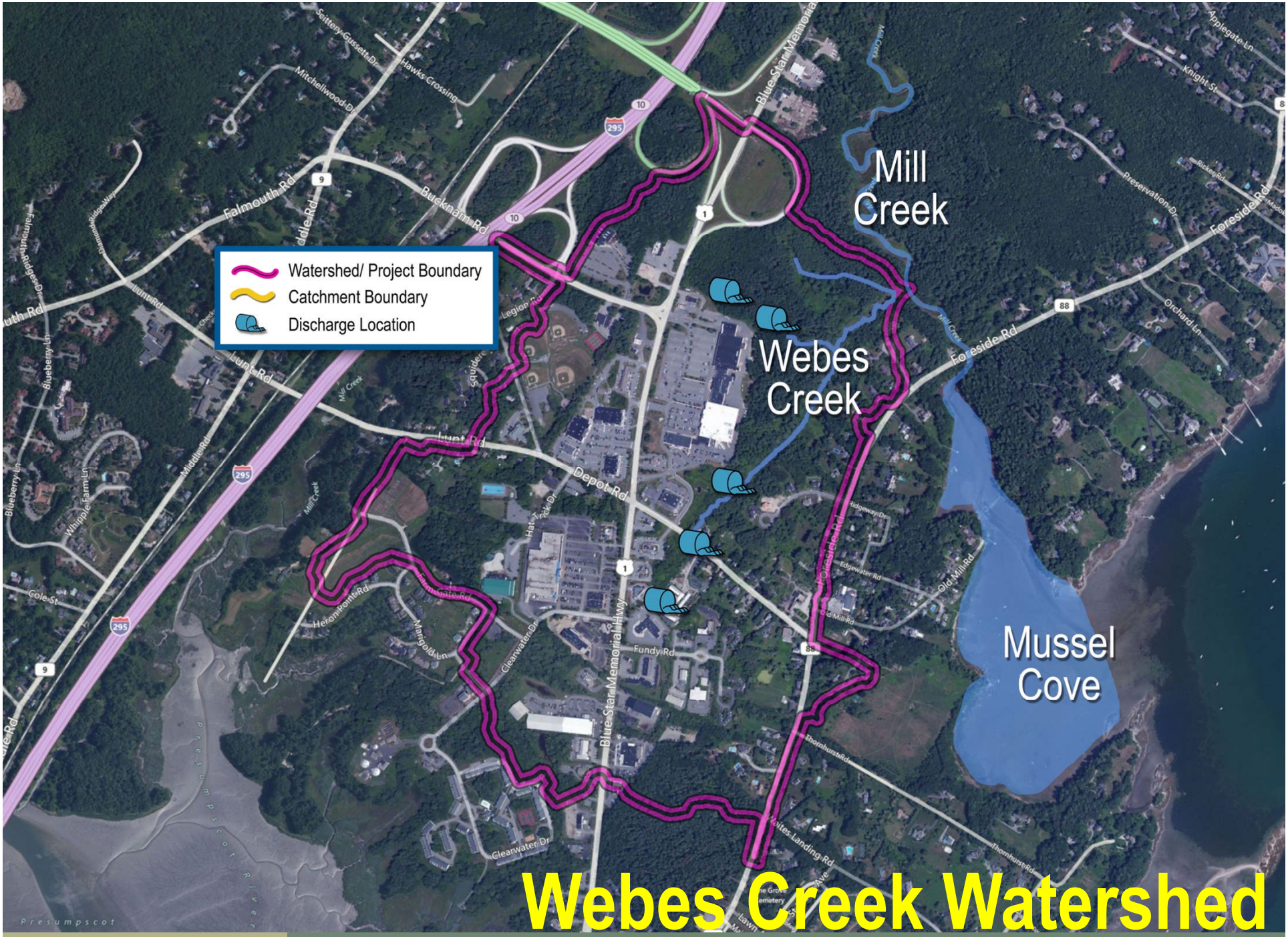


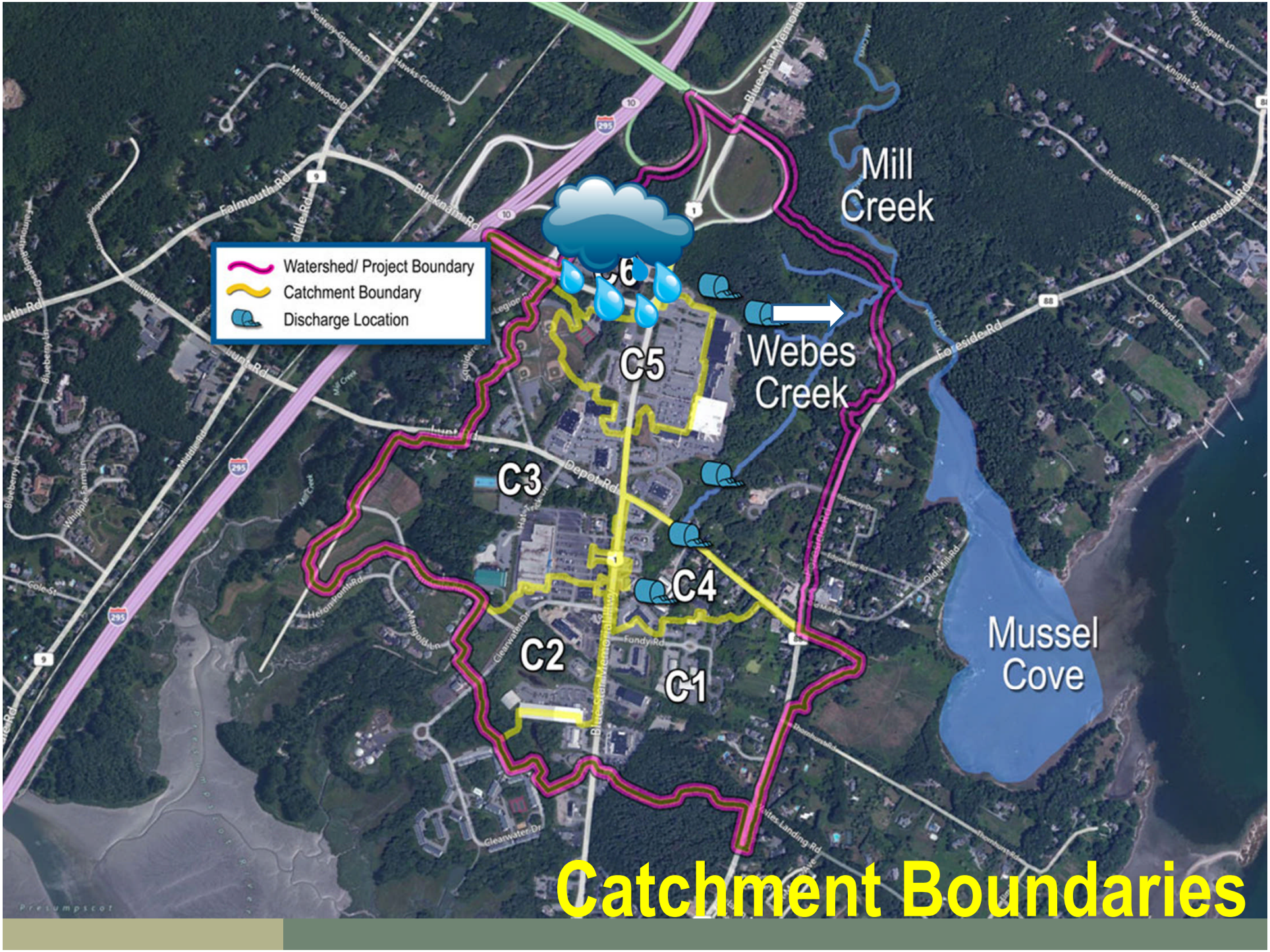

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Watershed/ Project Boundary
Catchment Boundary
Discharge Location
Mill Creek
Webes Creek
Mussel Cove
Webes Creek Watershed



Catchment Boundaries


Watershed/ Project Boundary
Catchment Boundary
Discharge Location
Mill Creek
Webes Creek
Mussel Cove
Existing SW Management



Rite Aid Wetpond



Key Bank Soil Filter



Maine Med Detention Basin

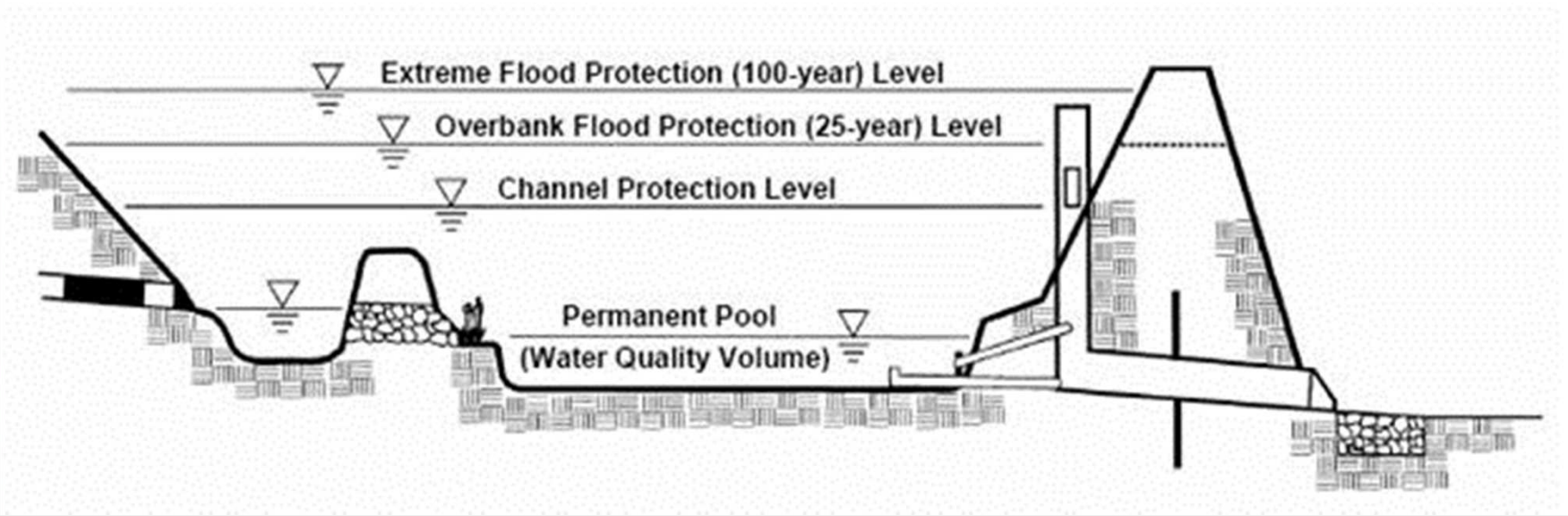


Falmouth Shopping Center Detention Basin



Norway Savings Below-Grade Stormwater Management Facility

What Do These Systems Do?



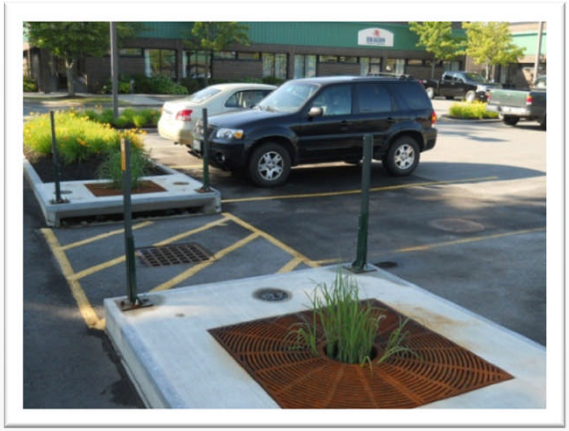
- Water Quality Volume = 1” Rainfall x Area Producing Runoff
- Channel Protection Volume = 2.5” in 24 hrs
- Flooding Protection = 5.5”- 6.7” in 24 hrs



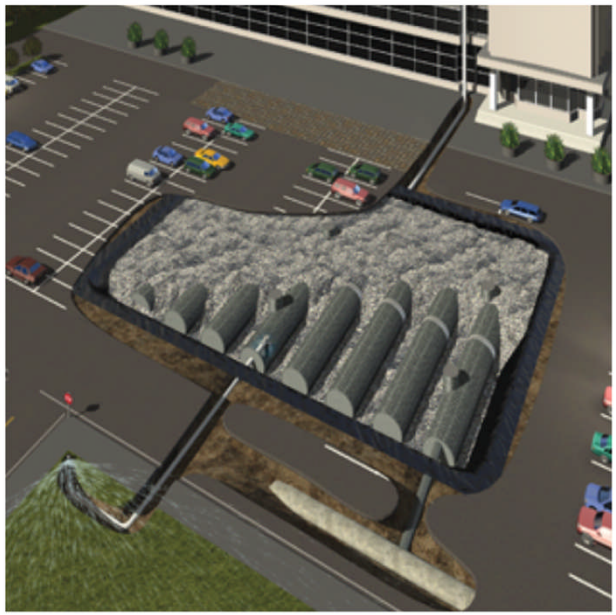
Soil Filter - South Portland



Streetscape Esplanade Filter



Tree Box Filter - South Portland



Rainwater Harvesting



Sidewalk Tree Filters - Portland

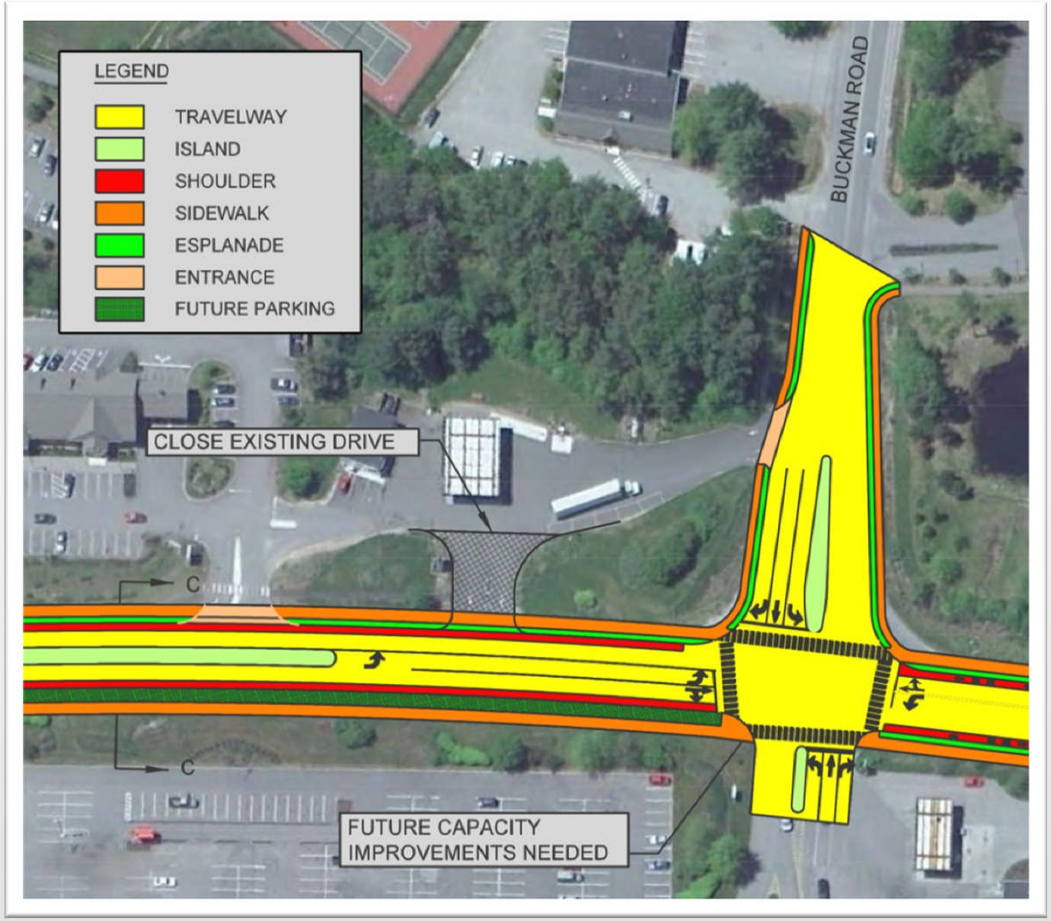
The Future of SW Management Infrastructure



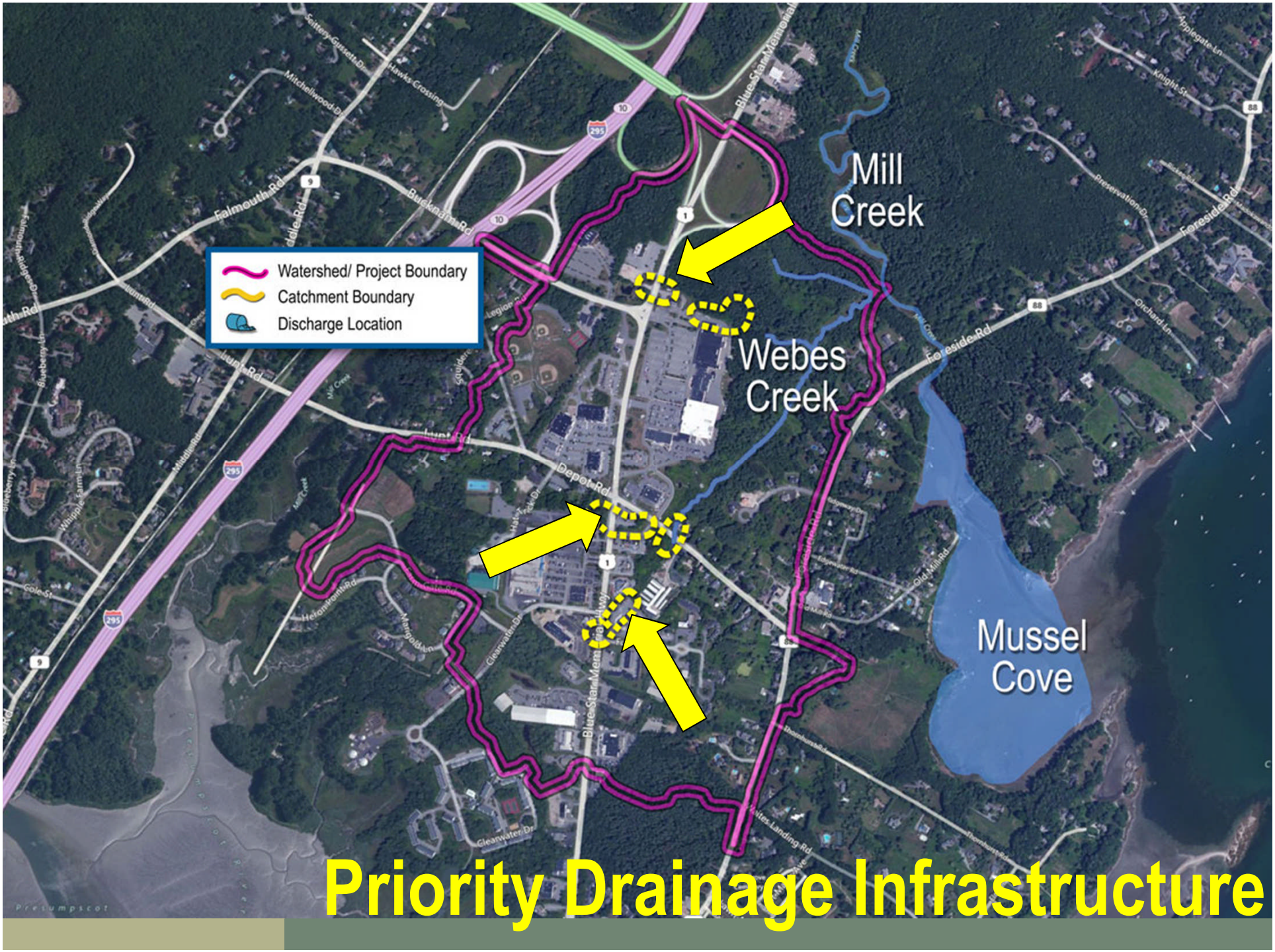
The Future is Expensive….

Stormwater Retrofit Opportunity Area	Possible Stormwater Management Retrofit	Total Construction Cost (+/-)
1. The Falmouth Shopping Center Dry Detention Basin Retrofit	Gravel Wetland Retrofit	**$135,000**
2. The Falmouth Shopping Center Plaza Quality Enhancements	Gravel Wetland/Below-Grade Filter System	**$795,000-$1,315,000**
3. Clearwater Drive Flow Control	Flow Control	**$30,000**
6. The Falmouth Inn Greenspace Retrofit	Gravel Wetland	**$220,000**
10. Bucknam Road Gateway Retrofit	Filtration Swale/Soil Filter	**$210,000-$260,000**
11. Route 1 Roadway Per Unit	Catch Basin Insert/Filter Box	**$35,000-$45,000**[1]
12. The Wal-Mart Plaza Quality Retrofits	Raingarden/ Below-Grade Filter System	**$90,000-$1,305,000**

Integration With Route 1 Study



- Where is the priority drainage infrastructure?
- What are the possible impacts from Build-Out?

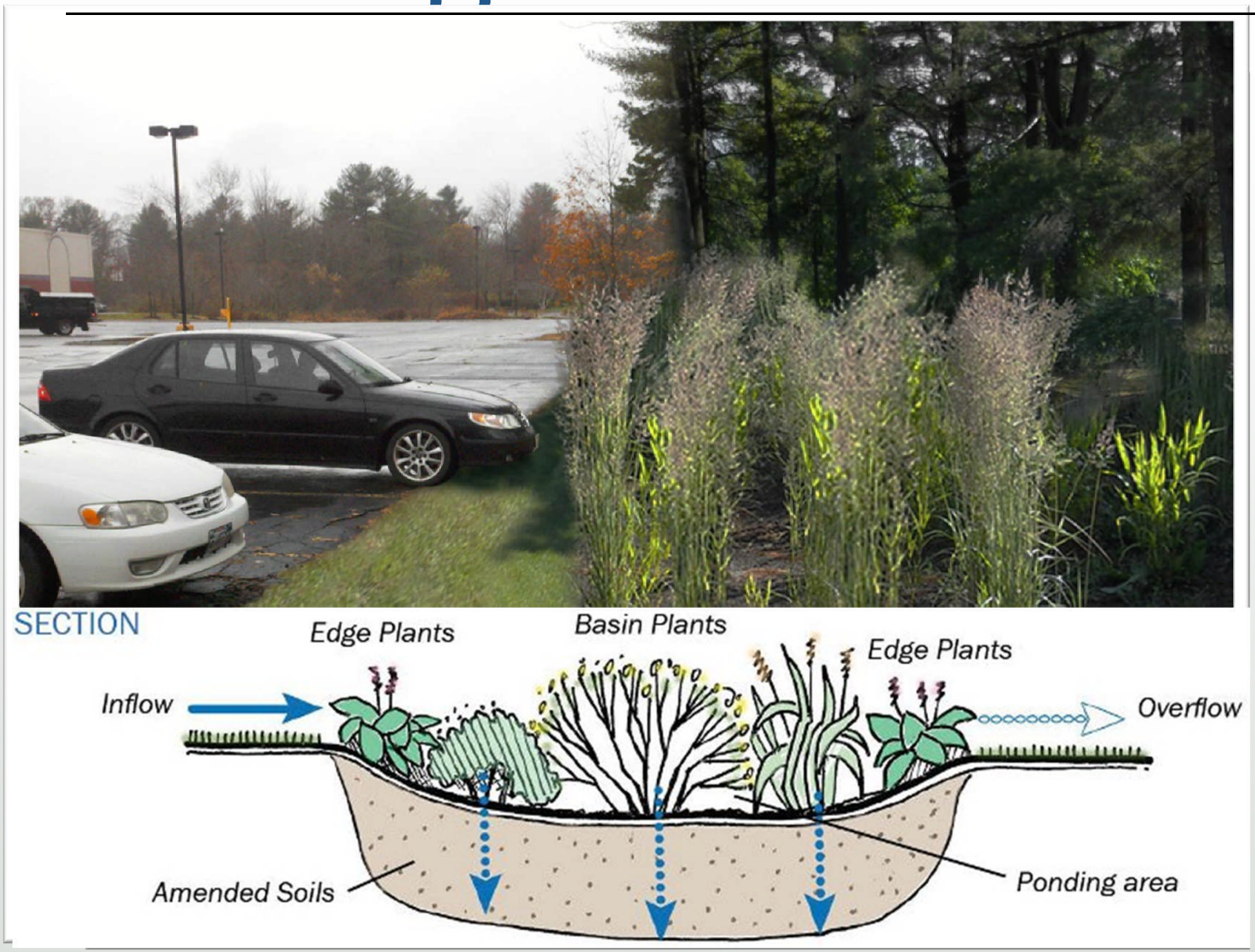


Priority Drainage Infrastructure



SW Mngt. & Treatment Opportunities

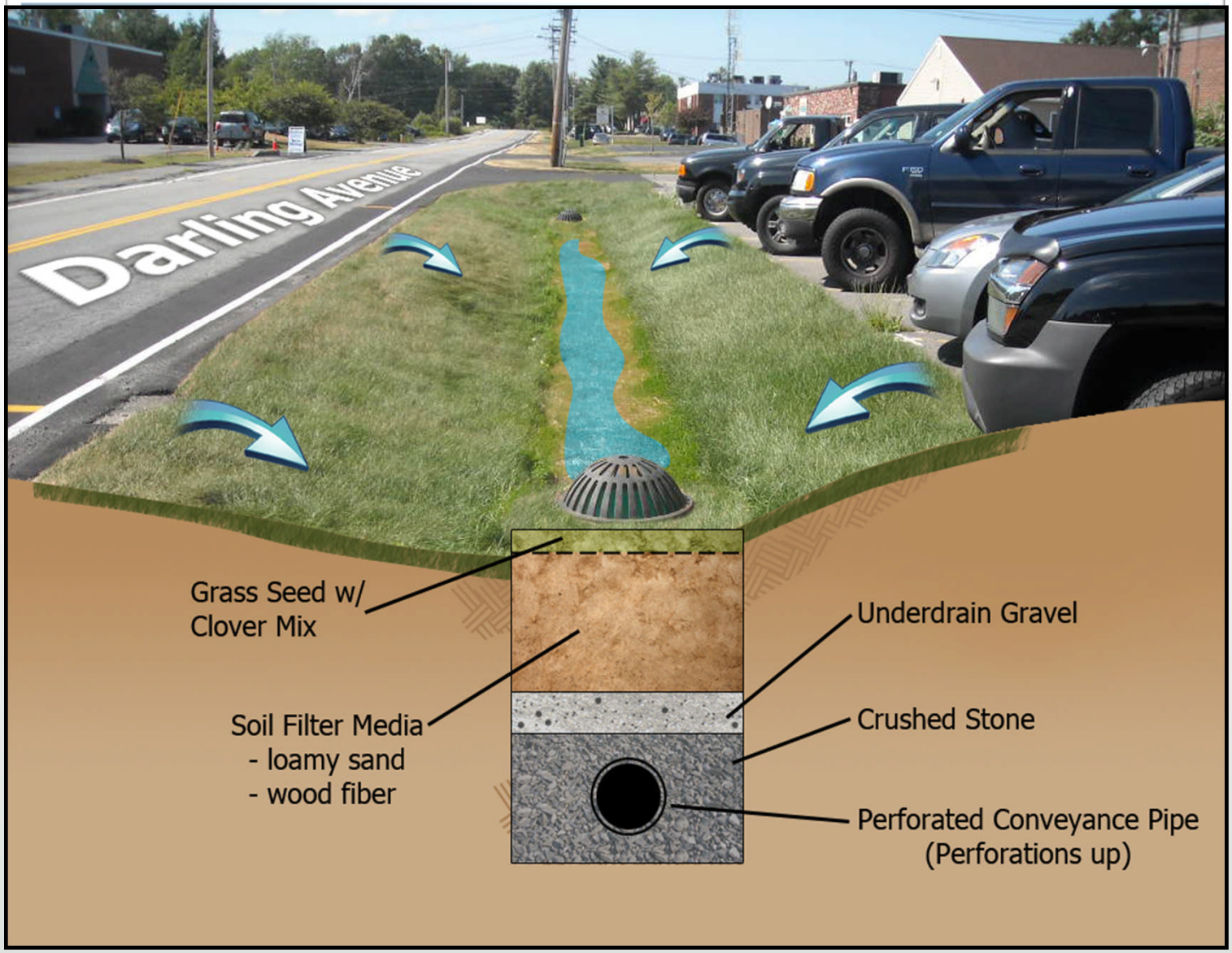
Retrofit Opportunities



Wal Mart Plaza Raingarden



Hat Trick Drive Flow Control



Bucknam Road Gateway



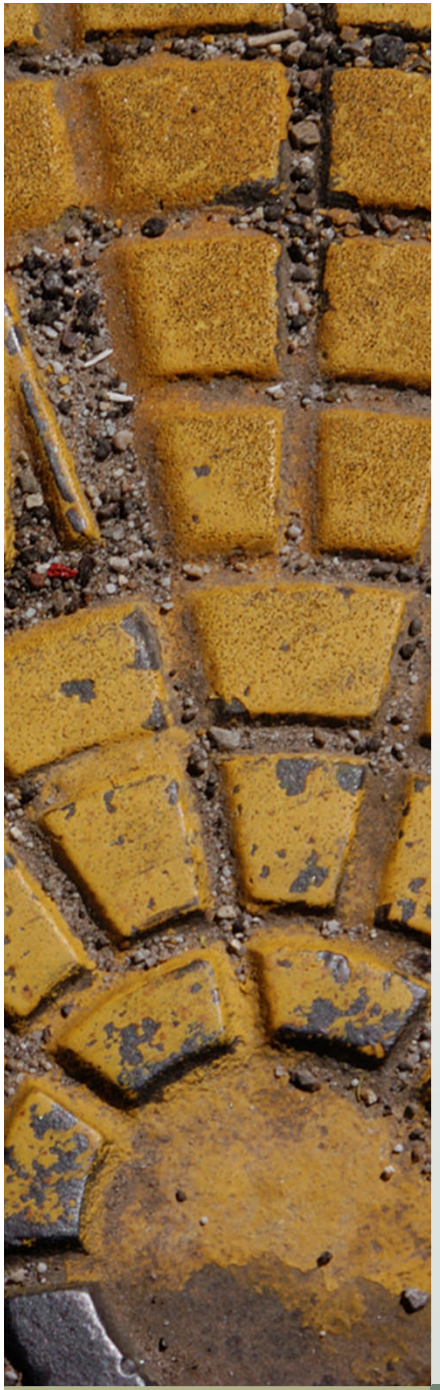
Ordinance Considerations

- Reduce Impediments to Low Impact Development Design and Construction
  - Use of Setbacks for Treatment Zones
  - Flexible Off-Street Parking Requirements
- Overlay District
- Reduced Individual Site Requirements Under A Managed Plan



Funding Considerations

- Special Assessment Districts (TIF)
- Grants and Loans
- General Fund Revenues
- User Fees



Future Opportunities

- Ahead of Regulatory Requirements
- Re-Visioning of Route 1
- Shared Opportunities Often Less Expensive than Site-by-Site
- Shared Private Property Management (Landscaping, Winter Operations, Sweeping)


Questions
&
Discussion

APPENDIX G: TOWN ORDINANCE REVIEW

Improvement Method	Development Friendly	Residential Commercial Universal	Level of Difficulty	Planned for in Route One Zoning for SB1
Zoning Bylaw and Site Plan Review Standards				
Dimensional Requirements				
Permit the location of bioretention areas, rain gardens, filter strips, swales, and constructed wetlands in required setback areas and in buffer strips.	X	u	1	x
Minimize setback distances in residential districts in order to increase flexibility with regard to house location.	X	r	1	na
Permit reduction in frontage (and corresponding road length/paved area) where appropriate, such as in open space residential developments, at the outside sideline of curved streets, and around cul-de-sacs.	X – in current Sec 3.13 could be easier	r	1	na
Establish limits on the extent of lawn area on residential lots, either area or percentage of lot.		r	1	na
Bylaw should establish regulatory controls over tree clearance and removal of mature trees/forest stands.		u	1	??
Open Space Developments				
Permit open space residential developments (cluster development or conservation subdivision design) as a "by right" form of development (no special permit required.) Permit flexible site design criteria such as reduced setbacks and smaller lot sizes.	3.13 already in place, need to adopt amendments as already drafted and allow smaller lots	r		na
Permit construction of LID stormwater management techniques (bioretention, swales, filter strips) on land held in common.	x	U	1	
Parking Requirements				
Permit use of permeable paving for parking stalls and spillover parking areas.	x	C	1	x
Do not require more than 3 off-street parking spaces per 1000 square feet of gross floor area in professional office buildings.	x	C	2	x
Do not require more than 4.5 off-street parking spaces per 1000 square feet gross floor area of shopping centers.	x	C	2	x
Do not require more than 2 off-street parking spaces per single family home.	x	C	2	x

Improvement Method	Development Friendly	Residential Commercial Universal	Level of Difficulty	Planned for in Route One Zoning for SB1
Establish parking maximums.	?	U		?
Establish formulas for the utilization of shared parking for uses with different peak demand periods (e.g., office peak demand period 9am – 5pm; housing peak demand period 6pm – 8am.) Allow reduction of parking requirements if shared parking is proposed. Provide model shared parking agreements that can be included as deed restrictions or permit requirements.	x	C	2	x
Permit stall width of 9 feet or less for a standard parking space.	current	U	1	x
Permit stall length of 18 feet or less for a standard parking space.	x	U	1	x
Recommend or require smaller stalls for compact cars, up to 30% of total number of parking spaces.	Current up to 50%	C	1	x
Establish landscaping requirements for parking areas that include vegetated islands with bioretention functions.		C		
Common Driveways				
Permit the use of common driveways to serve up to four houses, including lots that do not meet standard dimensional requirements.	x	R	1	na
Site Plan Requirements				
Allow bioretention areas, filter strips, swales, and constructed wetlands to count towards to fulfillment of site landscaping/open space requirements.	x	U	1	x
Require driveway width no more than 9 feet.	x	U	2	
Permit use of pervious material for single family driveways (porous pavers, paving stones, pervious asphalt or concrete), and/or use of 'two-track' design for residential driveways.	x	R	1	na
Allow discharge of uncontaminated rooftop runoff to lawn areas and buffers, with level spreader or other velocity reduction mechanism.	x	U	2	
Allow temporary (72-hour) ponding of stormwater prior to infiltration.	x	U	1	
Require development of a stormwater management and erosion control plan for construction activities.	existing	U	2	Need to design new standards
Subdivision Rules and Regulations/Roadway Design Standards				

Improvement Method	Development Friendly	Residential Commercial Universal	Level of Difficulty	Planned for in Route One Zoning for SB1
Street Location				
Considerations for street layout should include reducing street length and minimizing total paved area (including cul-de-sacs), with the goal of protecting site hydrology. Identify the need to reduce cut and fill, do not run streets across steep hillsides, route streets along ridgelines, protect important natural features.		R	2	na
Street Cross Sections				
Permit a minimum pavement width of 18-22 feet on low-traffic local streets in residential neighborhoods. Allow narrower pavement widths along sections of roadway where there are no houses, buildings, or intersections, and where on-street parking is not anticipated.	x	R	1	na
Permit the use of "open section" roadways with roadside swales. Do not require the use of conventional curbs for the full length of all streets in residential neighborhoods. Where curbs are deemed necessary to protect the roadway edge, allow the use of perforated curbs (that allow runoff to flow into swales) or "invisible curbs" (flush with the road surface.)	existing			
Establish criteria for the design of roadside swales to ensure adequate stormwater treatment and conveyance capacity.		R		na
Permit placement of utilities under the paved section of the right of way or immediately adjacent to the road edge (so that the land adjacent to the roadway can be used for swales.)	??	U	2	
Permit use of permeable paving for road shoulders/parking lanes in residential neighborhoods, with use of conventional paving for travel lanes only.		R	1	na
Permit the use of permeable paving for sidewalks.		U	1	??
Permit sidewalk placement on one side of the street only in low-density residential neighborhoods.				
Provide flexibility with sidewalk layout; e.g., alternative pedestrian circulation layout that uses common areas, rather than street rights of way.	x	R		

Improvement Method	Development Friendly	Residential Commercial Universal	Level of Difficulty	Planned for in Route One Zoning for SB1
Sidewalks should be designed so that the runoff is disconnected from the stormwater system. e.g, place a green strip			??	
Site Work				
Encourage developer to limit clearing within the right-of-way to the minimum necessary to construct roadway, drainage, sidewalk, and utilities, and to maintain site lines; do not require clearing and grubbing of entire right-of-way.	X	U	1	??
Require contractors to reestablish permeability of soils hat have been compacted by construction vehicles. For example, contractor can rototill lawn areas prior to seeding to re-establish void space (hence permeability and infiltration) of the soils.		U	1	??
Dead Ends				
Minimize the required radii for cul-de-sacs. A radius of 35 feet is optimal, depending on emergency vehicles.		U	2	??
Allow the creation of landscaped island (and bioretention cells) within cul-de-sacs.	x	U	1	
Permit use of one-way loop streets to eliminate turnarounds.	x	U	1	
Permit "hammerhead" turnarounds instead of cul-de-sacs.	x	U	1	
Wetlands Bylaw and Regulations				
Permit the use of low impact stormwater structures (such as bioretention areas, infiltration trenches, or grass swales) within the buffer zone of (state or local jurisdictional) wetland resource areas, provided the location of these structures is not in conflict with any other setback criteria required by NRPA.	??	U	1	
Department of Building Inspector				
Local plumbing codes should permit the use of harvested rainwater for interior non-potable uses such as toilet flushing.	x	U	2	???

Appendix C: Catchment #5 Stormwater Evaluation Report

ACORN ENGINEERING, INC.

CATCHMENT #5 STORMWATER EVALUTION REPORT

Prepared For:

Town of Falmouth, Maine
271 Falmouth Road
Falmouth, Maine 04105

Prepared By:

Acorn Engineering, Inc.
16 Middle Street, Suite 302
Portland, Maine 04103



October 2025

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ATTACHMENTS

A Maine DEP Webes Creek Water Quality Report January 2022
B Acorn Presentation at the September 14, 2022 Stakeholder Meeting
C Minutes from the September 14, 2022 Stakeholder Meeting
D Sources of Data Used in this Evaluation

A. INTRODUCTION

1. Purpose

In August 2022, the Town of Falmouth hired Acorn Engineering, Inc., (Acorn) to evaluate options to improve the function of a portion of its Route 1 Commercial area referred to as "Catchment #5". The Town's goal was to determine how this popular commercial area could continue to grow while safeguarding water quality and preserving the habitat of downstream drainage ways.

As part of this project with the town, Acorn was prepared do the following:

- Facilitate a series of stakeholder meetings with owners of property located within Catchment #5;
- Compile information about stormwater infrastructure (conveyance, treatment, and/or storage) located in Catchment #5;
- Update maps and models to reflect parcels within the catchment that had recently been developed (or redeveloped);
- Build a hydraulic model to understand capacity limitations of existing stormwater infrastructure;
- Develop conceptual options that could be implemented to mitigate or improve capacity issues;
- Design funding approaches that could equitably distribute the cost of any proposed improvements to stakeholders; and
- Present potential improvements and approaches to stakeholders.

The outcome of the first stakeholder meeting (September 14, 2022) altered the project's approach, as will be discussed in Section B.1. This Evaluation will summarize the actual work performed by Acorn, and the useful information from that work.

2. Description of Catchment #5

The boundary of the area known as Catchment #5 –the focus of this evaluation – is bounded in red on ***Figure 1***, and generally includes properties on the west and east sides of US Route 1 between Bucknam Road and 241 US Route 1. A portion of the Falmouth Fire Station and Grubb Field Recreation Complex (both owned by the town and accessed from Bucknam Road) parcels are also located within Catchment #5.

Runoff from the area within Catchment #5 is conveyed through an engineered stormwater system and discharges to a tributary of Webes Creek.

3. Importance of Webes Creek

Webes Creek is a 0.71-mile Class B stream that flows northeast in a valley between Route 1 and Foreside Road. ***Figure 2*** shows the location of Webes Creek (blue) as well as a tributary to the creek (shown in orange) to which Catchment #5 discharges. The point of discharge to this tributary is from catch basin CB-4554 in the northeast corner of the Falmouth Center, LLC property (Map U12 Lot 002). Other upstream catchments in the Town of Falmouth discharge directly to Webes Creek. The

lower portion of the creek (approximately 1,600 linear feet) is tidally-influenced and has brackish water, but the rest of the creek is free-flowing freshwater.

4. Current Maine DEP Assessment

Maine DEP has been monitoring water quality in Webes Creek since at least 2013, evaluating both water quality (e.g., dissolved oxygen, specific conductance, and temperature) as well as habitat quality (e.g., using "rock bags" to monitor and document the macroinvertebrate community present). Maine considers stream health to be a function of both water quality and the presence of complex and varied habitat that can support the macroinvertebrates that are indicators of good water quality.

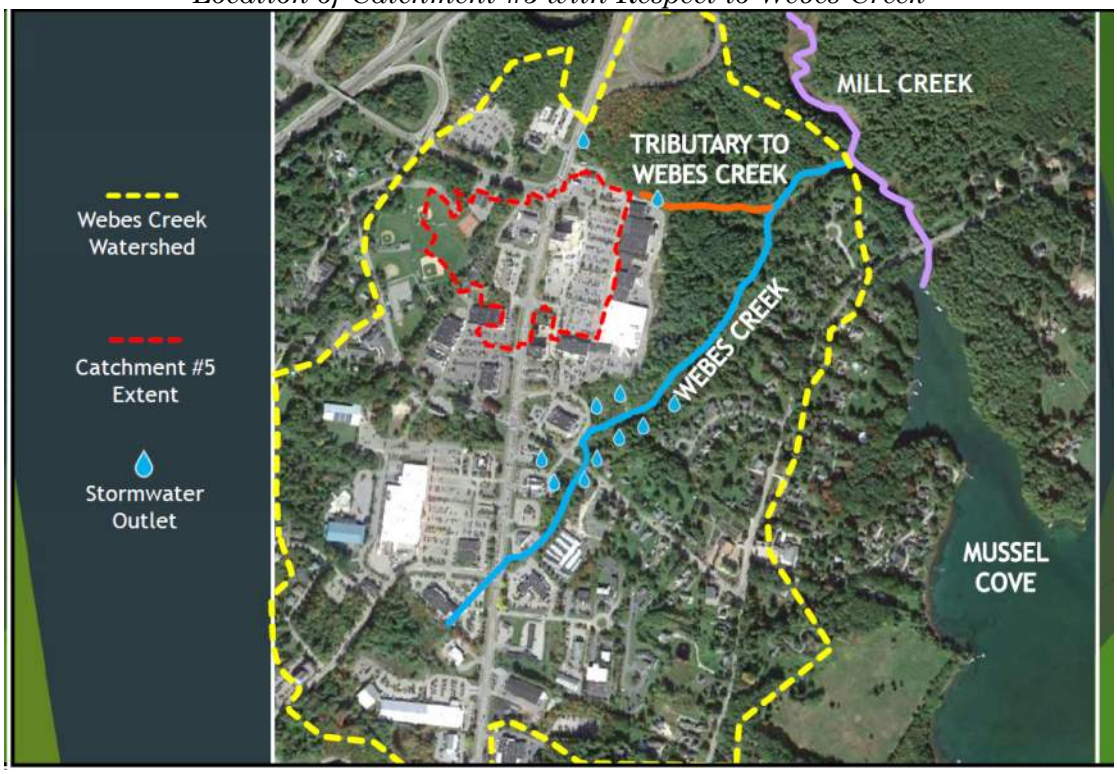
The most recent Maine DEP water quality report for Webes Creek was published in January 2022 and reflects data collected in 2017, 2018, and 2019 (see ***Attachment A***). The findings in the 2022 report are as follows:

1. Water quality (other than specific conductivity) is generally moderate to good;
2. There is little baseflow in the stream during dry weather periods;
3. High chloride concentrations were detected during low baseflow conditions (not surprisingly, based on the amount of roadway in the drainage area); and
4. Storm events have a significant and adverse impact on habitat (some sections were observed in June 2019 to have been scoured to native hard clay).

Impact of storm events on the stream was highlighted by Maine DEP as one of the most significant challenges to habitat: in fact, the rock bags deployed were fully buried by six inches of sand (and therefore unusable) during two relatively minor storm events during the four-week monitoring period. The straight, flat geometry of the creek means that stream flow is fast, and the scoured channel means that rising water cannot access the historical floodplain.

The Town acknowledged in February 2022 (when sharing a draft of a Strategic Watershed Plan for Town Council's review) that "Watershed health is becoming [an] increasingly important indicator for a community's health". In the Webes Creek watershed, the key issue was water quantity, not water quality.

Figure 2
Location of Catchment #5 with Respect to Webes Creek



Studies performed by and for the Town of Falmouth and by specific landowners in Catchment #5 suggested that there were physical limitations within the stormwater system that would limit future development if not improved.

B. STAKEHOLDER MEETINGS

The scope proposed a series of Stakeholder Meetings to present the challenges of Webes Creek to property owners in Catchment #5, demonstrate that capacity restrictions would impact development, to lay out options for improving the stormwater system (including a managed program similar to the Long Creek Watershed Management District [LCWMD]), provide options for improvements, and develop an equitable way to fund those improvements.

1. Stakeholder Meeting #1

The first stakeholder meeting was held on September 14, 2022 and was attended by representatives of most of the property owners in Catchment #5. In the first part of the meeting, Acorn staff provided a summary of water quality data, including Maine DEP's most recent assessments (discussed in Section A.4 of this report). A key finding presented to participants was that the rate at which water was discharged to the tributary of Webes Creek (shown in orange on Figure 2) was the most significant challenge. Again, water quality within the water body – while not excellent – would still allow for healthy macroinvertebrate populations to exist if their habitat were not damaged by sediment scour and deposition.

Attachment B includes the material presented by Acorn at this Stakeholder Meeting, and ***Attachment C*** includes a summary of the group's discussion about the Town's objectives for this Evaluation.

The participants of Stakeholder Meeting #1 responded positively to this information, and generally agreed to cooperate with the Town (and Acorn) on the next step, which was to develop a detailed Existing Condition Assessment. The next step would be for Acorn to follow up with property owners and request as-built plans and inspection and maintenance reports and records for their stormwater systems, update the Town's existing GIS map (if needed) to reflect recent development, and use inspection and maintenance records to understand how stormwater BMPs on each property were functioning.

During Stakeholder Meeting #1, participants discussed how certain properties are more directly affected by the flow of stormwater runoff through the existing closed drainage system. The conversation highlighted concerns about how proposed improvements might impact these properties, particularly in terms of financial responsibility and logistical burden. Commercial properties were noted as potentially facing greater challenges, including disruptions to tenants and their customers or clients, as well as the need to relocate existing utilities to accommodate infrastructure upgrades. These concerns underscored the importance of ensuring that any cost-sharing approach adopted for the project is equitable and considers the varying degrees of impact across properties.

2. Influence of Other Projects on the Existing Condition Assessment

In November 2022, while Acorn was in the process of gathering records and plans, it became aware that the Maine Department of Environmental Protection (DEP) was also conducting assessments within Catchment #5. Fluvial geomorphologist John Field was evaluating segments of Webes Creek located in both Catchment #5 and Catchment #4. His work primarily took place within the stream

corridor, classified as a Water of the State, and did not involve direct access to private property. However, as a courtesy, Mr. Field sent notification letters to adjacent property owners informing them of his planned activities.

On November 28, 2022, Town Manager Nathan Poore formally notified Acorn that consultants working on behalf of the Town, including Acorn, were restricted from accessing certain identified properties to collect information related to infrastructure or stream conditions. This limitation affected Acorn's ability to verify key infrastructure details—such as location, diameter, depth, and pipe inverts—on one of the more critical properties within the catchment. As a result, the restriction posed challenges to the completeness and accuracy of the assessment in that area.

3. Revised Stakeholder Engagement Approach

The outcome of Stakeholder Meeting #1 had a significant impact on the original proposed scope of work. With a critical landowner removed from the discussion, there was little value in scheduling additional meetings with other property owners. The Town and Acorn decided that Acorn would move forward to perform an Existing Condition Assessment and create a hydraulic model that reflects the existing system, calibrated to represent how the current system performs. To understand options for the Town and other property owners to move forward, Acorn will "plug" a few in-line storage alternatives into the hydraulic model to see what impact they had on the rate at which water discharged to the tributary to Webes Creek on Map U12 Lot 002.

Acorn continued to engage with the other Catchment #5 property owners and with the Town's GIS consultant (Judy Colby-George of Viewshed [formerly Spatial Alternatives]) to collect information that would be used to develop the Existing Condition Assessment. ***Table 1*** shows the result of this information-gathering. As-built plans were not available for the stormwater system on most properties- the exception being the FocalPoint BMPs installed by the Town in 2014 along Route 1 - and some properties had development under construction. For properties approved by the Planning Board but not yet constructed, Acorn used design plans as the foundation for mapping the stormwater system, field-verifying it as much as possible on properties that allowed access.

Acorn supplemented the information provided by property owners with information about Maine DEP permits that had been issued for work on the property, as well as the level of treatment provided. Many properties in Catchment #5 had upgrades or improvements that were designed to comply with Maine DEP Rule Chapter 500. At least three properties met the Flooding Standard, either because the project triggered Maine DEP Site Location of Development (SLODA, or "Site Law") or because it was required by local ordinance. Some projects *should* have triggered the local Flooding Standard but requested – and were granted – a waiver by the Town.

Acorn observed that the largest property in Catchment #5 was essentially providing no treatment or storage of stormwater, since it had been developed before Maine DEP required water quality to be addressed in stormwater design. Two redevelopment projects had been designed and constructed (or were under construction) on this property but they were not providing Chapter 500-level treatment for the impervious area. Another development project immediately adjacent to this large property, and sharing infrastructure with it, was currently under review. This project would also discharge to the tributary to Webes Creek. Maine DEP had ruled that the work didn't trigger Site

Law; as a result, storage wasn't required, meaning that peak flow rates of stormwater into the tributary of Webes Creek would not be mitigated. Acorn will discuss the implications of this in Section D.4.

4. Additional Stakeholder Involvement

The owner of one critical Catchment #5 property had expressed little interest in participating in the project and had prohibited Acorn from gathering information about infrastructure on his property. Without the willingness of this property owner to engage in discussion, additional Stakeholder meetings would have been of little value, and no more were held.

C. EXISTING CONDITIONS ASSESSMENT

1. Performing an Existing Condition Assessment

a. Resources

Acorn drew upon numerous references and resources to gain an understanding of infrastructure located within Catchment #5. Sources of information (general, as well as detailed documents we reviewed for each parcel) are listed in ***Attachment D.***

b. Current Understanding of Catchment #5 Capacity

Acorn's first step was to try to understand why existing estimates of Catchment #5 stormwater capacity did not match observations.

In its January 2013 *Route 1 Falmouth Commercial District Stormwater Management Plan* ("the 2013 Plan")[1], Woodard & Curran included a table showing the potential impact of "build-out" in six (6) subcatchments that discharge to Webes Creek on the capacity of the stormwater system in those catchments.

This build-out analysis captured future development in Catchments 1, 2, and 3 that would increase the amount of impervious area in those areas. However, the build-out analysis assumed that impervious cover in Catchment #5 would remain about 62% (14.02 acres of impervious area 22.45 acres). Based on this assumption, the report projected that the approximate capacity of Catchment #5 stormwater system (with the 36-inch outlet pipe 95% full) would be 147 cubic feet per second (CFS; see ***Table 2)***

The system capacity in Table 4-2 in the 2013 Plan did not appear to be consistent with observed flooding in Catchment #5. For example, if system capacity was 147 CFS, flooding would not be observed even during/after a 100-year storm; in reality, flooding of the Falmouth Center property occurs quite frequently.

[1] The 2013 Woodard & Curran Plan is available at: www.falmouthme.org/DocumentCenter/View/1142/Report-Text-Only-48-Pages-PDF?bidId=

Table 2
Estimated Capacity of Catchment #5
per Woodard & Curran (January 2013)

Table 4-2: Impact of Build-Out Conditions on Stormwater Contribution to Town's Drainage Infrastructure

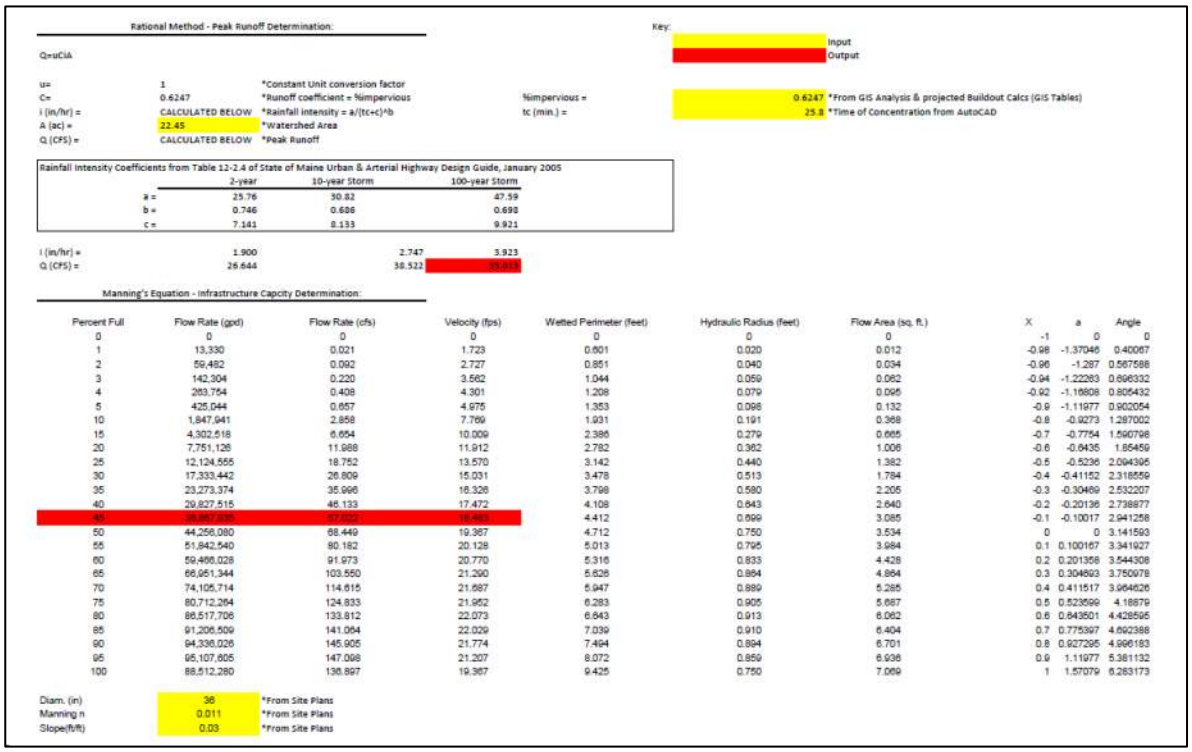
Critical Infrastructure Area[1]	Catchments Draining to Infrastructure	Existing Infrastructure Diameter (inches)	2-Year Storm Flow (CFS)	10-Year Storm Flow (CFS)	100-Year Storm Flow (CFS)	Approximate System Capacity (CFS)
1 (1R Outfall)	C1, C2	36	59	87	124	31
2 (2R Rte 1 Storm Drain)	C2	36	14	21	31	74
3 (3R Rte 1 Storm Drain)	C3	42	46	70	101	80
4 (4R Depot Rd Culvert)	C1, C2, C3, C4	Two 40	123	181	260	172[2]
5 (5R Outfall)	C5	36	27	39	55	147
6 (6R Route 1 Culvert)	C6	18	14	20	28	9

[1] Refer to Figure 2-Appendix A of this Report for the Webes Creek Drainage Map, which shows parcels, catchments, existing stormwater management facilities, TC, and the critical infrastructure areas evaluated.

[2] Critical Infrastructure Area 4 consists of two 40-inch diameter culverts.

To determine how the approximate system capacity had been developed, Acorn reviewed attachments in the 2013 Plan that showed how the capacity had been calculated. Upon review, Acorn recognized that the Rational Method had been used to estimate system capacity. ***Figure 3*** below shows the calculation for Catchment #5 for a 100-year storm event. This approach is appropriate for very small areas, but makes assumptions that do not account for multiple pipe diameters and slopes (including flat sections) within the catchment or storage that is provided within the system. As a result, it overestimates capacity.

Figure 3
Woodard & Curran 2013 Rational Method Calculation for Catchment #5



Rational Method - Peak Runoff Determination:

Q=uCIA

Key: Input / Output

u=	1	*Constant Unit conversion factor		
C=	0.6247	*Runoff coefficient = %impervious	%impervious =	0.6247 *From GIS Analysis & projected Buildout Calcs (GIS Tables)
i (in/hr) =	CALCULATED BELOW	*Rainfall intensity = a/(tc+c)^b	tc (min.) =	25.8 *Time of Concentration from AutoCAD
A (ac) =	22.45	*Watershed Area		
Q (CFS) =	CALCULATED BELOW	*Peak Runoff		

Rainfall Intensity Coefficients from Table 12-2.4 of State of Maine Urban & Arterial Highway Design Guide, January 2005

	2-year	10-year Storm	100-year Storm
a =	25.76	30.82	47.59
b =	0.746	0.686	0.693
c =	7.141	8.133	9.921
I (in/hr) =	1.900	2.747	3.923
Q (CFS) =	26.644	38.522	55.013

Manning's Equation - Infrastructure Capcity Determination:

Percent Full	Flow Rate (gpd)	Flow Rate (cfs)	Velocity (fps)	Wetted Perimeter (feet)	Hydraulic Radius (feet)	Flow Area (sq. ft.)	X	a	Angle
0	0	0	0	0	0	0	-1	0	0
1	13,330	0.021	1.723	0.601	0.020	0.012	-0.98	-1.37046	0.40067
2	59,482	0.092	2.727	0.851	0.040	0.034	-0.96	-1.287	0.567588
3	142,304	0.220	3.562	1.044	0.059	0.062	-0.94	-1.22283	0.696332
4	263,754	0.408	4.301	1.208	0.079	0.095	-0.92	-1.16808	0.806432
5	425,044	0.657	4.975	1.353	0.098	0.132	-0.9	-1.11977	0.902054
10	1,847,941	2.858	7.769	1.931	0.191	0.368	-0.8	-0.9273	1.287002
15	4,302,518	6.654	10.009	2.386	0.279	0.665	-0.7	-0.7754	1.590798
20	7,751,126	11.988	11.912	2.782	0.362	1.006	-0.6	-0.6435	1.85459
25	12,124,555	18.752	13.570	3.142	0.440	1.382	-0.5	-0.5236	2.094395
30	17,333,442	26.809	15.031	3.478	0.513	1.784	-0.4	-0.41152	2.318559
35	23,273,374	35.996	16.326	3.798	0.580	2.205	-0.3	-0.30469	2.532207
40	29,827,515	46.133	17.472	4.108	0.643	2.640	-0.2	-0.20136	2.738877
45	36,867,936	57.021	18.493	4.412	0.699	3.085	-0.1	-0.10017	2.941258
50	44,256,080	68.449	19.367	4.712	0.750	3.534	0	0	3.141593
55	51,842,540	80.182	20.128	5.013	0.795	3.984	0.1	0.100167	3.341927
60	59,466,028	91.973	20.770	5.316	0.833	4.428	0.2	0.201358	3.544308
65	66,951,344	103.550	21.290	5.626	0.864	4.864	0.3	0.304693	3.750978
70	74,105,714	114.615	21.687	5.947	0.889	5.285	0.4	0.411517	3.964626
75	80,712,264	124.833	21.952	6.283	0.905	5.687	0.5	0.523599	4.18879
80	86,517,706	133.812	22.073	6.643	0.913	6.062	0.6	0.643501	4.428595
85	91,206,509	141.064	22.029	7.039	0.910	6.404	0.7	0.775397	4.692388
90	94,336,026	145.905	21.774	7.494	0.894	6.701	0.8	0.927295	4.996183
95	95,107,605	147.098	21.207	8.072	0.859	6.936	0.9	1.11977	5.381132
100	88,512,280	136.897	19.367	9.425	0.750	7.069	1	1.57079	6.283173

Diam. (in)	36	*From Site Plans
Manning n	0.011	*From Site Plans
Slope(ft/ft)	0.03	*From Site Plans

Acorn understood it would be necessary to develop a better way to understand how runoff moved within Catchment #5, supporting the inclusion of a hydraulic model in the revised scope of work.

2. Building a Hydraulic Model of Catchment #5

a. Model Selection

Acorn decided to use HydroCAD to model the Catchment #5 stormwater system, since it is the standard for land use development, and because the catchment is relatively small and straightforward.

b. Design Storm Selection

One of the key objectives of this Evaluation is to better understand limitations of the system that contribute to flooding observed in the parking lot of the Falmouth Center property (Map U12 Lot 002). During the period of Acorn's work, a storm event occurred that resulted in substantial flooding of the Falmouth Center parking lot as well as the point where runoff from this property discharged to the tributary to Webes Creek. This event occurred on August 22, 2022, and resulted in 2.19 inches of rain falling over a 3.75 hour period.

Using photos taken during a site visit immediately after this storm event (see *Figure 4*), Acorn documented the extent of flooding caused by the storm and overlaid the flooding extent over site

maps. This visual representation of the flooding extent was used to calibrate the HydroCAD model to reflect existing conditions. This storm event is referred to as the "design storm", and the alternatives discussed in Section C were run using this rainfall. (*Note: this site visit occurred before Acorn staff were prohibited from accessing the property)*

Figure 4
Photos of Falmouth Center, LLC Parking Lot After August 22, 2022 Storm Event



3. Model Development

To develop a HydroCAD model for Catchment #5, Acorn drew upon as-built plans (where available), design plans, Town GIS, and notes from inspection reports were used to create nodes to reflect existing stormwater structures, including catch basins, drain manholes, and stormwater BMPs.

The starting point for the system was the Town's stormwater GIS layer, which was provided by the Town's GIS consultant (Judy Colby-George of Viewshed [formerly Spatial Alternatives]). The Town's stormwater infrastructure layer, as of September 2022, is shown in ***Figure 5***.

a. Reflecting Recent Projects

Upon reviewing the Town's stormwater GIS in September 2022, Acorn recognized that it did not reflect recent redevelopment or improvement of several parcels, including:

1. Building A at 251 US Route 1 in 2022 (Sicilian Table) on Map U12 Lot 002
2. Building B at 241 US Route 1 in 2021 (Chase Bank) on Map U12 Lot 002

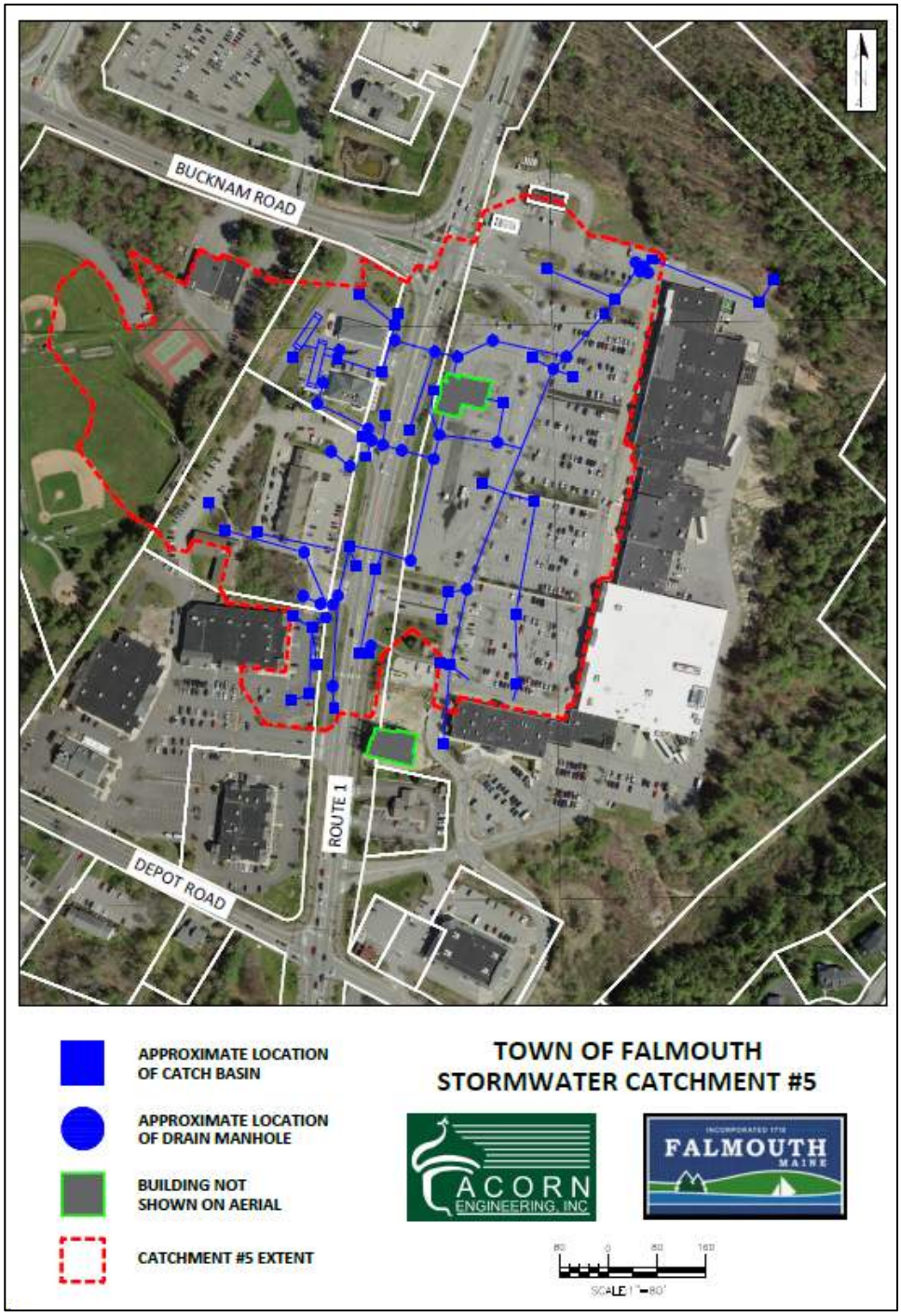
The Town GIS did reflect the 2018 retrofit at Irving Oil Properties on Map U58 Lot 007.

b. Confirming Post-Construction Stormwater BMPs

Acorn reviewed the post-construction stormwater BMPs inspection and maintenance (I&M) reports provided by two landowners, Irving Oil Properties, LLC (Map U58 Lot 007) and JB Brown & Sons (Map U58 Lot 006). No other property owners provided this information. These I&M reports were used to confirm the number, location, and type of treatment and storage structures on private property. Acorn assumed that the Town has maintained its FocalPoint BMPs, located on Route 1 within Catchment #5.

Using inspection reports prepared by Walsh Engineering Associates, Acorn was able to determine that the stormwater BMP known as Key Bank Soil Filter 1, located on Map U58 Lot 006, is actually an infiltration basin, not an underdrained soil filter.

Figure 5
Starting Point for Modeling Stormwater Infrastructure in Catchment #5
(per ViewShed, Town GIS Contractor; September 2022)



c. Updating Catchment Boundaries

Acorn reviewed the boundary of Catchment #5 as shown in the 2013 Plan and updated the boundary to account for grading associated with development and redevelopment projects. Acorn also modeled unique subcatchments within the watershed of Catchment #5. ***Figure 6*** shows the extent of Catchment #5 and the subcatchments modeled by Acorn.

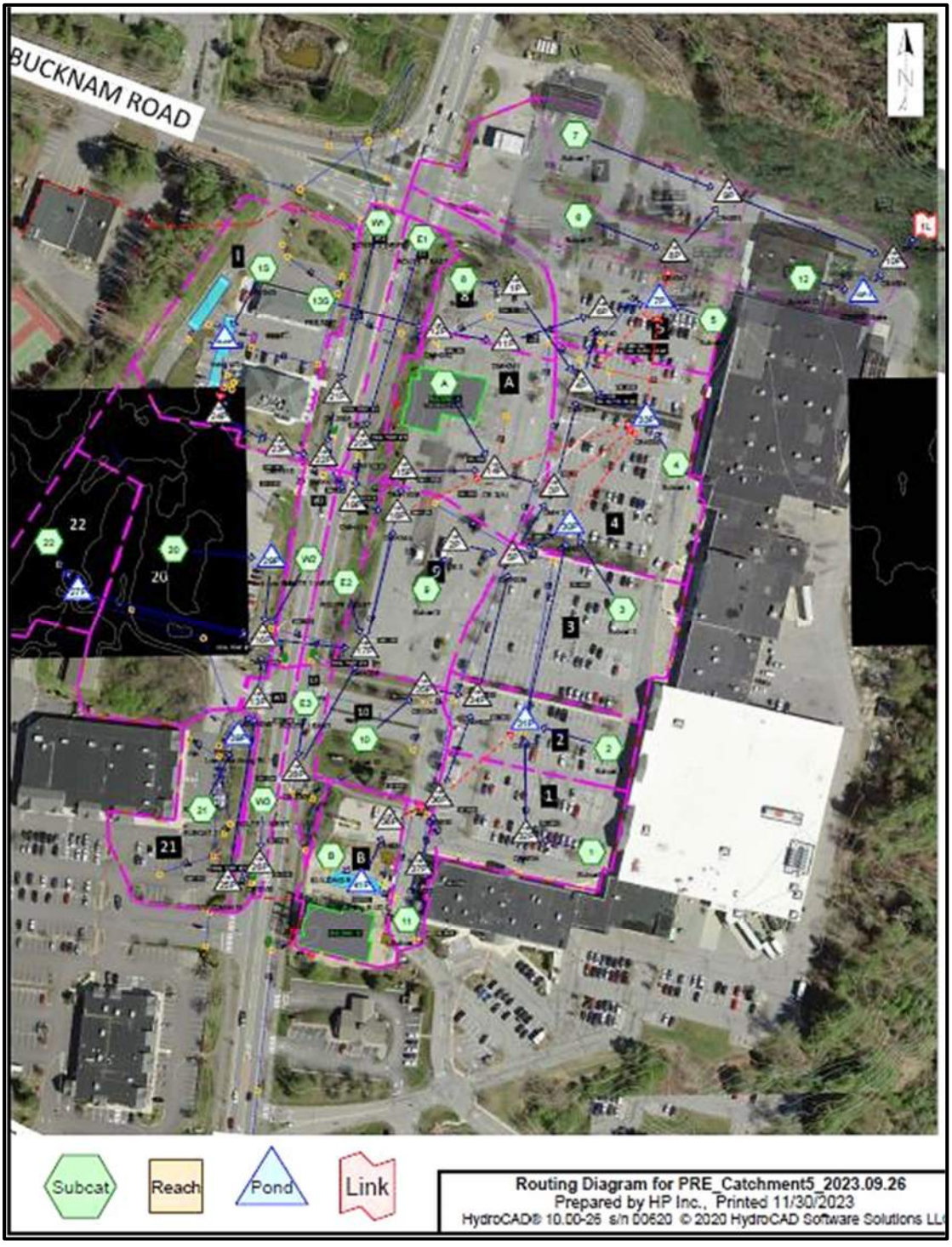
Figure 6
Subcatchments Defined in HydroCAD Model of Existing Conditions
Catchment #5



The routing diagram of the HydroCAD model of Existing Conditions at Catchment #5 is included as ***Figure 7***.

Existing stormwater BMPs were modeled as ponds in HydroCAD; the key to these BMPs is in ***Table 3***.

Figure 7
Routing Diagram for HydroCAD Model of Existing Conditions
Catchment #5



To calibrate HydroCAD to replicate the real-world impacts of the design storm, Acorn set the flood elevation of catch basins in the parking lot of Falmouth Center (Map U12 Lot 002) to six inches above the flood elevation. This mimics the ponding seen during the August 22, 2022 storm. Since Acorn was, by this point, prohibited from accessing Map U12 Lot 002 to verify elevations, the elevations used in HydroCAD for rims of these catch basins were taken from the March 30, 2005 "Overall Existing Conditions Plan for Falmouth Shopping Center" prepared by Appledore Engineering.

For Building B (Chase Bank) in the Falmouth Center Parking lot, Acorn, modeled each Filterra (FC01, FC02, and FC03) with an outlet control structure and a one-inch diameter orifice, using the draft March 22, 2022 as-built plans provided by Gorrill-Palmer, which were not verified.

For Building A (Sicilian Table, etc.) in the Falmouth Center parking lot, Acorn did not specify individual BMPs because the March 21, 2021 plans prepared by Gorrill Palmer indicated that the site would connect to the existing closed drainage system.

Table 3
Key to Existing Catchment #5 BMPs as Modeled in HydroCAD

BMP Name	BMP Type	Property	HydroCAD Pond
Key Bank Soil Filter 1 (SF 1)	Infiltration basin*	U58 Lot 006	Pond 29P
Key Bank Soil Filter 2 (SF 2)	Underdrained soil filter	U58 Lot 006	Pond 27P
Irving Storage	Subsurface storage	U58 Lot 007	Pond 42-43P
Falmouth Village Storage	Infiltration/storage	U24 Lot 005	Pond 39P
Town FP-12	Focal Point	US Route 1 West	Pond 26P
Town RT-12	R-Tank for FP-12	US Route 1 West	CB5155
Town FP-13	Focal Point	US Route 1 West	Pond 43P
	R-Tank for FP-13		DMH-412
Town FP-14	Focal Point	US Route 1 East	Pond 45P
	R-Tank for FP-14		DMH-336
Town FP-15	Focal Point	US Route 1 East	Pond 20P
Town RT-15	R-Tank for FP-15	US Route 1 East	CB81
Town FP-16	Focal Point	US Route 1 West	Pond 21P
Town RT-16	R-Tank for FP-16	US Route 1 West	CB3508
Chase Bank Filterra-FCO1	4' by 4' Filterra tree box filter	U12 Lot 002	CB4630
Chase Bank Filterra-FCO2	4' by 4' Filterra tree box filter	U12 Lot 002	CB4631
Chase Bank Filterra-FCO3	6' by 6' Filterra tree box filter	U12 Lot 002	CB4632
Detention-FC01	Subsurface storage	U12 Lot 002	Pond 41P

*- This BMP was thought to be an underdrained soil filter. Acorn believes it does not have an underdrain and modeled it as an infiltration basin.

4. Alternatives Modeled

Acorn modeled three in-line storage options for Catchment #5.

- Alternative #1: Large subsurface storage at Falmouth Center, LLC (Map U12 Lot 002)
- Alternative #2: Add R-Tank Chambers to FocalPoint BMPs to Increase Storage
- Alternative #3: Provide Storage Under Vegetated Island between US Route 1 and Falmouth Center, LLC

a. Alternative #1: Large subsurface storage at Falmouth Center, LLC

Description

Acorn modeled 34,971 cubic feet (CF) of storage to be provided by a StormTech chamber under the Falmouth Center (Map U12 Lot 002) parking lot, as Pond 40P. The approximate extent of the Alternative #1 BMP is shown in ***Figure 8***.

- 19,846 CF of storage would be provided by 432 separate StormTech SC-740 chambers placed in 18 rows.
- 13,572 CF of storage would be provided by six inches of stone bedding (40% void space) under the StormTech chambers.
- 1,553 CF of storage would be provided in four inches of sand bedding (30% void space) under the stone.

Figure 8



Advantages

- Installation of this BMP would mitigate flooding that makes this part of the parking lot unusable. (The images in Figure 4 were taken at this location after the August 22, 2022 design storm).
- Subsurface storage chambers are relatively easy to maintain and don't require expensive landscaping.

Disadvantages

- A large portion of the parking lot would be removed from service during construction, disrupting the flow of customers/clients to businesses located in the plaza.
- The cost of the project would be significant, and even if an equitable funding program were developed, there may be opposition to using town funding for work on private property.

b. Alternative #2: Add R-Tank Chambers to FocalPoint BMPs to Increase Storage

Description

Acorn revised the existing conditions model to provide additional subsurface storage by adding R-Tank subsurface storage tanks to five (5) Focal Point BMPs owned by the Town and located within the right-of-way.

Additional storage is provided within three (3) inches of stone bedding (40% void space) located under the R-Tank chambers. Total storage that would be provided by this alternative is 8,465 CF, as shown in ***Table 4***.

Table 4
Total Storage Provided by Alternative #2
(Adding R-Tank Chambers to Existing Focal Point BMPs)

Focal Point ID	Modeled Node	# of R-Tank Chambers (in 10 rows)	Storage in R-Tanks (CF)	Storage in Stone Bedding (CF)	Total Storage (CF)
15	20P/ CB81	160	1,013	573	1,586
16	21P/ CB3508	160	1,013	545	1,558
13	43P/ DMH-412	160	1,013	573	1,586
14	45P /DMH-336	160	1,013	573	1,586
12	26P/ CB5155	180	1,485	664	2,149
				Total Storage=	**8,465**

Advantages

1. Proposed work is for Town-owned infrastructure, making use of town funding straightforward.
2. Based on design plans, there appears to be adequate elevation to modify discharge

configuration to add R-Tanks.
3. Proposed work is within the Town right-of-way, so no construction easement will be required.
4. R-Tanks are proprietary and the Town may be able to use the procurement process to purchase them directly from the vendor (instead of having an earthwork contractor purchase them), saving time and money.

Disadvantages
1. Proposed work is within Town right-of-way and may result in traffic impacts on Route 1.
2. The Town would not likely be able to maintain R-Tanks using its own equipment, requiring use of a third-party contractor. This will increase maintenance costs and add to staff responsibilities.

c. Alternative #3: Provide Subsurface Storage under Vegetated Island between US Route 1 and Falmouth Center, LLC

Description
Total storage that would be provided by this alternative is 10,500 CF. The approximate extent of the Alternative #3 BMP is shown in ***Figure 9***.

Figure 9



Advantages
1. Some of the proposed work is for Town-owned infrastructure, making use of town funding

straightforward.
2. Location of the proposed work would not impact traffic on Map U12 Lot 002.

Disadvantages
1. Involves potential disruption to the nearby row of parking on private property.

5. Impact of Modeled Alternatives

***Table 5* shows the peak flow** rate at Point 1L, which is the 36-inch diameter pipe outlet that discharges to the tributary of Webes Creek. Under current conditions, modeled with 2.19 inches of rain, peak flow is 73.2 cubic feet per second (cfs).

The HydroCAD model demonstrates that implementing any of the three proposed alternatives will reduce peak flow rates during the design storm and slow the timing of discharge, thereby mitigating downstream impacts. As expected, **Alternative #1**, which involves a large subsurface chamber, yields the most significant reduction in peak flow. However, even **Alternative #3**, which adds subsurface storage to the Town's existing FocalPoint BMPs along Route 1, shows measurable improvements in flow attenuation.

The effectiveness of each alternative is influenced by site-specific constraints, particularly the available area for subsurface storage. While Alternatives #2 and #3 offer more modest reductions compared to Alternative #1, further investigation may reveal opportunities to expand storage capacity within the identified site areas, leading to a greater reduction in peak rates of runoff.

Overall, the modeling results support the conclusion that each alternative contributes to improved stormwater management, and that optimizing available space for storage will be key to maximizing long-term benefits.

Table 5
Impact on Modeled Alternatives on Peak Flow Rate to Webes Creek Tributary

	Existing Conditions	Alternative 1	Alternative 2	Alternative 3
Peak cfs at 1L	73.20	34.91	67.68	62.38
Time	1.94 hours	1.97	1.95	1.95
Volume (acre feet)	2.489	2.386	2.555	2.493

D. RESULTS

1. Adding Additional Inline Storage Capacity Will Benefit Webes Creek

Prior to modeling the catchment, it was not known whether a project would need to be very large to have a meaningful impact on reducing the peak flow rate of stormwater discharged to the tributary to Webes Creek.

HydroCAD results for all three alternatives demonstrate that even moderate inline storage will result in improvement.

In this Catchment #5 Evaluation, Acorn has demonstrated that even incremental increases in stormwater storage capacity within this catchment can have a measurable impact on reducing the peak discharge rate to the tributary to Webes Creek.

Additional inline storage can also be provided by private projects, consistent with Town ordinances. Appendix 7-7 (Stormwater Management) to the Town's Code of Ordinances Chapter II-7[2] (Land Subdivision) includes a requirement that "*…peak discharge for the developed site shall not exceed the peak discharge for the undeveloped site for the 2-, 10-, and 100-year storm*". This is hereafter referred to as the Flooding Standard.

The Planning Board is authorized to approve waivers of the Flooding Standard, and has done so in recent projects within Catchment #5 (i.e., Building B [241 US Route 1] on the Falmouth Center, LLC property, Tax Map U12 Lot 002). For these projects, the developer stated that there was adequate storage capacity in the pipe system; approval of the requested waiver meant that the project was not required to provide additional independent storage.

For this reason, Acorn recommends that the Planning Board limit the approval of requested waivers of the Flooding Standard in Catchment #5.

2. Strengthening Local Review Will Benefit Webes Creek

Having reviewed many technical reports that focus on the specific impervious area within Catchment #5 and the specific challenges facing Webes Creek, Acorn has identified additional actions or practices that would reduce the impact of stormwater discharge to the creek.

a. Be Vigilant for Projects that May Trigger Site Law

The Maine DEP Site Location of Development Act ("Site Law") is triggered when a project will result in three acres (or more) of impervious area or 20 acres (or more) of developed area. This bar seems very straightforward, but there are several criteria that can be overlooked when interpreting what counts toward the trigger. A few key interpretation pointers are presented below:

[2] Appendix 7-7 (Stormwater Management): https://online.encodeplus.com/regs/falmouth/doc-viewer.aspx?secid=93#secid-93

1. Terminology: Some applications will describe their project as "creating less than three acres of impervious area." However, the language in Chapter 500 is "…will result in", which means that the applicant must also address existing impervious area on the lot and whether that counts toward the three acres (or justify why existing impervious area is exempt).

2. Redevelopment / Change of Use: Some applications will describe a redevelopment project as "not creating any new impervious area." However, changing the function of existing impervious area – even if it was created before Chapter 500 was in effect – can invalidate previous exemptions. For example,
   a. If an existing farm access road is to be redesigned to serve as the access road for a new subdivision, the use will change from agricultural to residential, and the area of the existing road must be included in the total that "will result" from the project.
   b. If an existing parking lot is to be converted into a new building, the purpose of the impervious area changes, and the impervious area to be redeveloped must be included in the total that "will result" from the project.

3. Change in Vegetation Type: Maine DEP considers change in vegetation type (from forested to grassed, for example) to be developed area, *even if* the disturbed area is revegetated within one calendar year of being disturbed. This is because the area is not returned to the "…*condition that existed prior to the disturbance.*[3]" Some applications may not include these areas in the total of developed area, underrepresenting the area subject to regulation and review.

4. Maintenance: Maine DEP exempts some paving or re-paving of impervious areas as "maintenance"[4] of the existing surface, limiting the exemption to cases where existing elevations do not change significantly and the roughness of the surface remains the same. The nature of surfaces described as "maintenance" in applications should be scrutinized to determine whether the proposed change is more substantial.

5. Common Ownership, Financing, Management, or Operation: The definition of "Common Scheme of Development"[5] in Maine DEP's Rule Chapter 371 ("Definitions of Terms Used in Site Location of Development Law and Regulations") includes several conditions that could be used to consider two projects to be separate parts of the same project. These conditions include: ownership, management, or supervision; sharing of common equipment or labor (which would apply to maintenance of stormwater infrastructure); and common financing.

6. Non-Contiguous Parcels: The definition of "Common Scheme of Development" in Maine DEP's Rule Chapter 371 is not limited solely to parcels that are immediately next to the

[3] Definition of "Developed area" in Maine DEP Rule Chapter 500, www.maine.gov/sos/cec/rules/06/096/096c500.docx
[4] Definition of "Maintenance" in Maine DEP Rule Chapter 500, www.maine.gov/sos/cec/rules/06/096/096c500.docx
[5] Maine DEP Rule Chapter 371: https://www.maine.gov/sos/cec/rules/06/096/096c371.doc

subject project ("contiguous")- it includes properties that are across a road or street or are otherwise "in the same immediate vicinity", describing them as "non-contiguous". Some applications will downplay or otherwise misrepresent development on nearby parcels that is owned, managed, operated (etc) by the same party, obscuring the fact that "Common Scheme of Development" has been satisfied.

7. Title, Right, or Interest Agreements not Executed: Maine DEP's Rule Chapter 2[6] ("Rules Concerning the Processing of Applications and Other Administrative Matters") allows documents such as the option for Party A to purchase (or lease) a property from Party B to satisfy "title, right, or interest" (TRI) for the purposes of an application to the Department. However, these options do not always result in the actual sale of the property to Party B (or execution of a lease between the parties). In the case where option documentation submitted to the Department is not executed, Party A effectively retains TRI. If Party A also has TRI over other adjacent parcels, "Common Scheme of Development" is satisfied, and the impervious and developed area on all of the parcels counts toward the Site Law trigger. Maine DEP does not have a mechanism to verify that the submitted option was executed, with the exception of a Special Condition (which is not often used). In this way, projects that satisfy "Common Scheme of Development" can be difficult to identify.

8. Consider standardizing a more robust outlet protection measure than a riprap apron. Riprap aprons are adequate for small storms, but a series of step pools will absorb more energy during larger storm events, reducing scour in the receiving water.

b. Consider Implementing Additional Conditions of Approval

1. Proof of Property Transfer: Some projects approved through local review were dependent on a property transfer occurring. For example, the reason Maine DEP considered Map U13 Lot 002B to not be "common scheme of development" with Map U12 Lot 002 is that the property was to be sold by Rawhide, LLC (which has the same owner as Map U12 Lot 002) to a new LLC called The Shops at Falmouth Center, LLC, because a Purchase & Sale Agreement was part of the application to Maine DEP. However, based on the Town of Falmouth's current tax map, this property transfer has not occurred. Since the parcels (Falmouth Center, LLC and Rawhide, LLC) still have common ownership, the development of Map U13 Lot 002B should have triggered Site Law, which would have pulled Map U12 Lot 002 into Site Law and required it to meet current requirements for stormwater treatment and storage. Adding a local condition of approval to prove that property was transferred prior to scheduling a Pre-Construction meeting or issuing a Building Permit will help prevent projects like this from slipping through the cracks.

2. Stormwater Maintenance Agreement in Owner Name: Applications to the Town often include a Maintenance Agreement in the name of the current owner of the property. If a project is

[6] Maine DEP Rule Chapter 2: https://www.maine.gov/sos/cec/rules/06/096/096c002.docx

truly unrelated to the adjacent property and will be sold to a new owner, the original owner will not be involved in maintenance. The Maintenance Agreement should be in the name of the new owner. Adding a local Condition of Approval to provide an executed Maintenance Agreement prior to issuing a Certificate of Occupancy will help prevent projects like this from slipping through the cracks.

3. As-Built Plans: Many projects reviewed by Acorn did not provide as-built plans to the Town (or at least these were not available), so we used elevations on design plans to build the HydroCAD model. Recommend including a Condition of Approval that final Performance Guarantee will not be released until As-Built plans are provided to the Town.

4. Post-Construction Inspection & Maintenance Records: A few property owners, such as Irving Oil Properties, LLC (Map U58 Lot 007) and JB Brown & Sons (Map U58 Lot 006)—voluntarily provided post-construction inspection and maintenance (I&M) reports to Acorn. However, the majority of properties within Catchment #5 did not have records available for review. Some of these sites are subject to Maine DEP Stormwater Law permits and are located within the Town's Municipal Separate Storm Sewer System (MS4) area. To improve compliance and record-keeping for future developments, it is recommended that a Condition of Approval be included in project permitting that explicitly requires submission of annual post-construction I&M reports. This will help ensure long-term functionality of stormwater infrastructure and support the Town's efforts to meet MS4 and DEP regulatory obligations.

c. Increase the Channel Protection Storage Volume

In its 2022 Stream Stressor Individual Watershed Report, Maine DEP recommended that channel protection volume be provided for 1.5 inch of runoff from parking, driveway, and sidewalk areas, instead of the 1.0 inch recommended in Volume III of the Maine DEP Stormwater Management Design Manual[7]. This would increase the volume of storage provided for any individual project, further decreasing the peak discharge rate into the tributary to Webes Creek.

Implementing this change would require revision to Sections 19-72 and 19-72A of the Town's Code of Ordinances Chapter II-19 ("Zoning and Floodplain Management") which otherwise adopt the standards in Maine DEP Rule Chapter 500 and related guidance documents.

Acorn recommends that the Town consider implementing recommendations from the 2022 Stream Stressor Individual Watershed Report for additional protection volume.

d. Avoid Infiltrating Runoff from Paved Surface to Groundwater

In its 2022 Stream Stressor Individual Watershed Report, Maine DEP recommended limiting infiltration of runoff that contains high concentrations of salt to avoid introducing more chloride into the stream during low-flow conditions. This constant salt loading contributes to chronic exceedances.

[7] Maine DEP Stormwater Management Design Manual. Volume III: Technical Design Manual https://www.maine.gov/dep/land/stormwater/stormwaterbmps/vol3/volume%20III%20May%202016.pdf

Impervious areas that receive high loadings of salt should continue to discharge directly to the stream, since macroinvertebrates are generally able to handle acute exceedances.

e. Identify Opportunities to Infiltrate Roof Runoff

In its 2022 Stream Stressor Individual Watershed Report, Maine DEP recommended maximizing opportunities to infiltrate roof runoff – which would not have salt – into groundwater. There are many opportunities within Catchment #5 to do this, including properties that will likely need to meet current Chapter 500 Stormwater standards. Acorn recommends that intended approach for roof runoff be discussed at Pre-Application meetings.

CLOSURE

The evaluation of Catchment #5 demonstrates the importance of proactive stormwater management to support sustainable development in Falmouth's Route 1 Commercial Area. Through stakeholder engagement, hydraulic modeling, and the assessment of multiple storage alternatives, the project identified both challenges and actionable solutions for improving water quality and habitat in Webes Creek. The findings underscore the need for increased storage capacity, strengthened local review processes, and careful consideration of regulatory requirements to ensure long-term watershed health.

Moving forward, collaboration among property owners, the Town, and regulatory agencies will be essential to implement recommended improvements and maintain compliance with evolving standards. By adopting the proposed strategies and remaining vigilant in project review and maintenance, the community can balance growth with environmental stewardship, safeguarding the vitality of Webes Creek and the surrounding area for years to come.

Thank you for giving us the opportunity to assist you on this project. Please do not hesitate to contact Acorn Engineering if you have any comments or questions.

Sincerely,

Craig Burgess

Craig Burgess, P.E.
Senior Project Manager
Acorn Engineering, Inc.

ATTACHMENT A: Maine DEP Webes Creek Water Quality Report January 2022

Falmouth Study Streams Stressor Report

Individual Watershed Reports

January 2022

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Background

During the field seasons of 2017, 2018 and 2019 the Maine Department of Environmental Protection's (DEP) Watershed Unit conducted a special study of several streams in Falmouth, Maine – Norton Brook, Webes Creek, Mill Creek, Chenery Brook, Scitterygusset Creek and Hobbs Brook. The special study was in support of the "Falmouth Proactive Watershed Management" Coastal Community Grant Project awarded to the Greater Portland Council of Governments. Four of the study streams drain to Mussel Cove – Norton Brook, Webes Creek, Chenery Brook and Mill Creek. These stream watersheds are in Falmouth's high growth coastal area and were chosen for additional study due to their location in an area with continuing development pressure, and the likelihood of threat to stream health. Hobbs Brook was chosen for study due its water quality impairment. Scitterygusset Creek is a coastal stream that drains to the Presumpscot River and underwent preliminary study, but an individual watershed report has not been completed. Mussel Cove did not undergo additional study as a part of this project, but the DEP Marine Unit provided an analysis of the embayment for this report.

Following is detailed information of the surveying, monitoring and assessment methods and findings of this special study of Mussel Cove tributaries and Hobbs Brook, along with a discussion of known data on Mussel Cove. The information in this report is summarized in the *Falmouth Stream Stressor Report Summary (January 2022)*. The *Summary Report* and this *Individual Watershed Report* were finalized in January 2022, with the only substantive change from the drafts released in early 2020 being the

addition of some information about Scitterygusset Creek in the Summary Report and the addition of the Hobbs Brook Watershed Report to this report.

Figure 1. Coastal Area Study Stream Map: Watersheds and Surveying and Monitoring Locations.

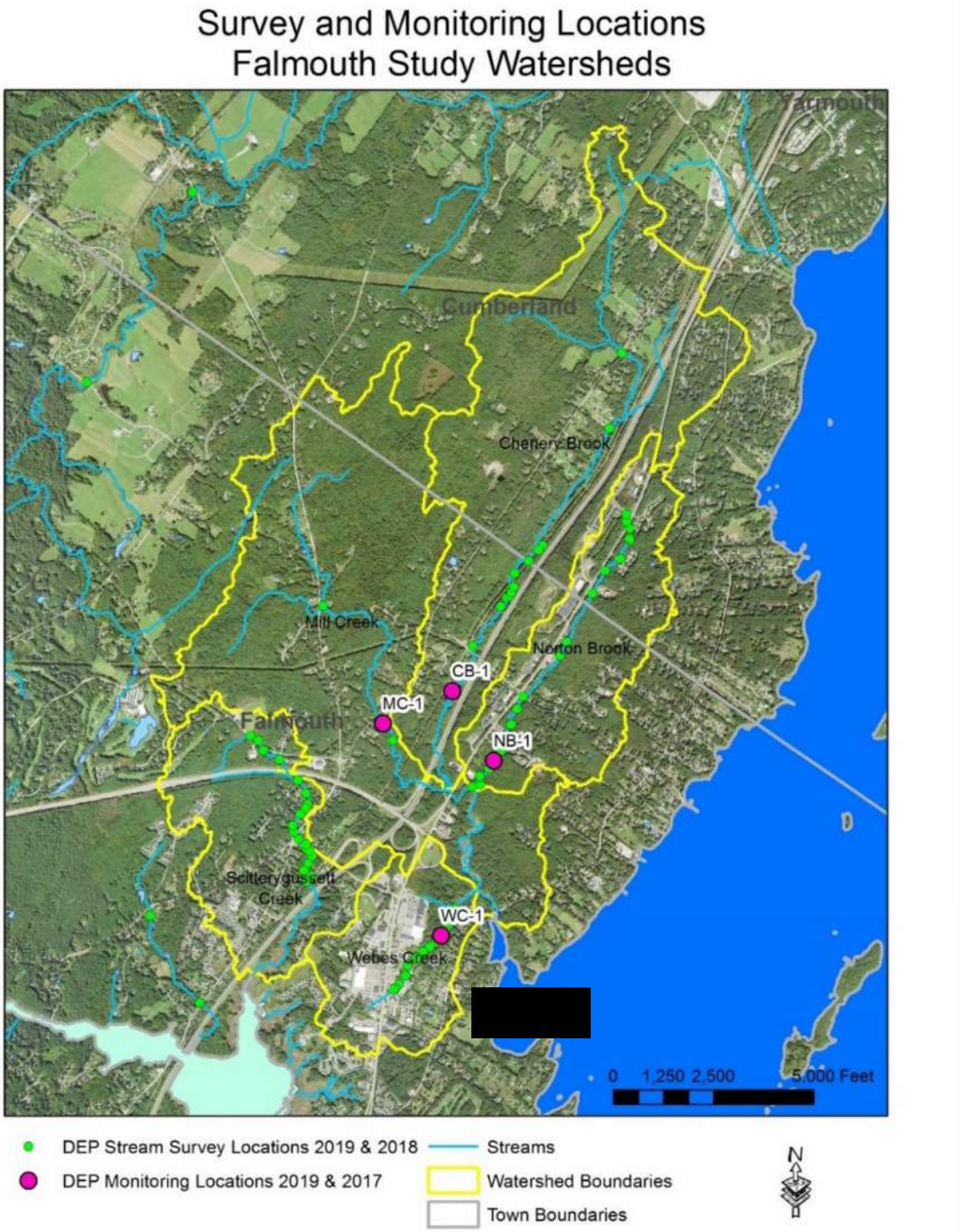
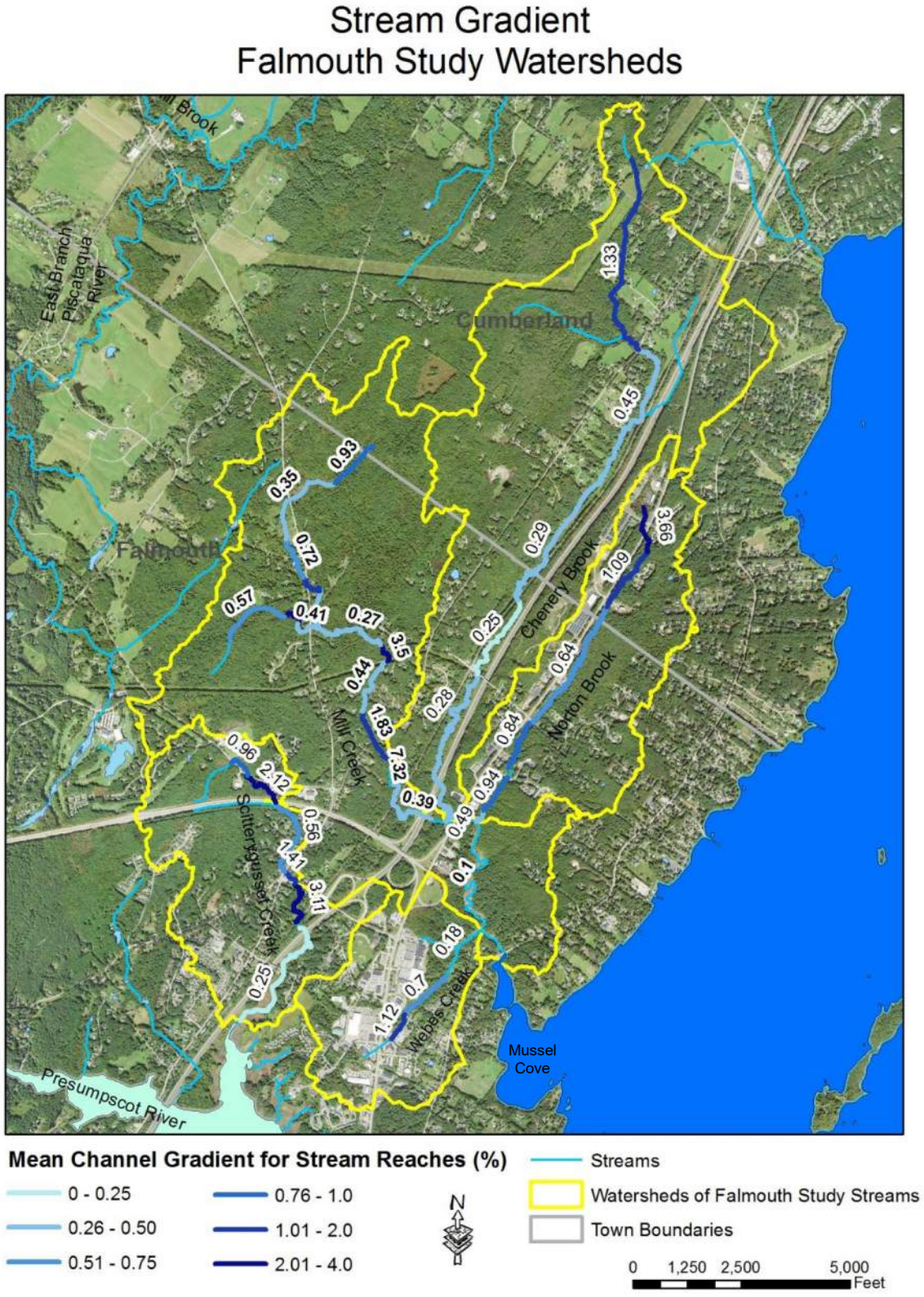


Figure 2. Coastal Area Study Streams Gradient Map.



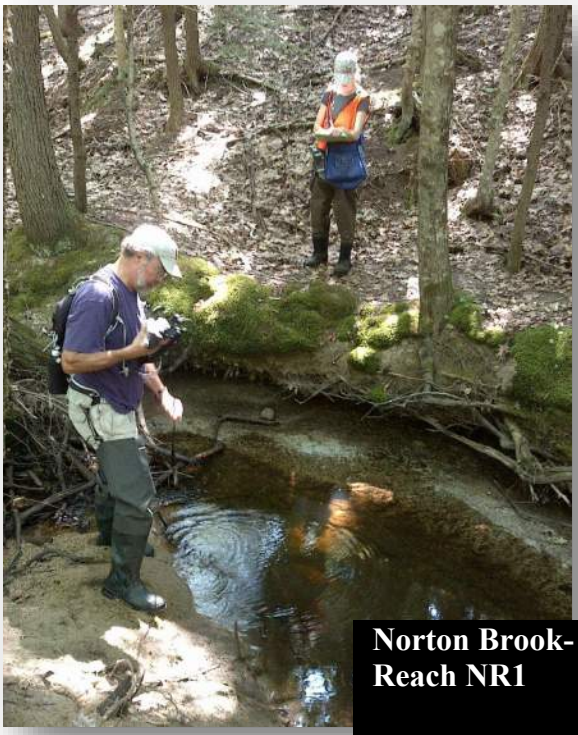
Norton Brook

Norton Brook is a 2.0 mile long stream that drains south from a forested wetland behind the Seafax property on the west side of Route 1 in Cumberland. It crosses to the east side of Route 1 just south of Casco Bay Drive, and parallels Route 1 as it flows south to its junction with Mill Creek behind the Protection Professionals property in Falmouth. It is a free-flowing freshwater stream except for the last 500 feet which are at times brackish due to tidal influences.

Watershed Characterization

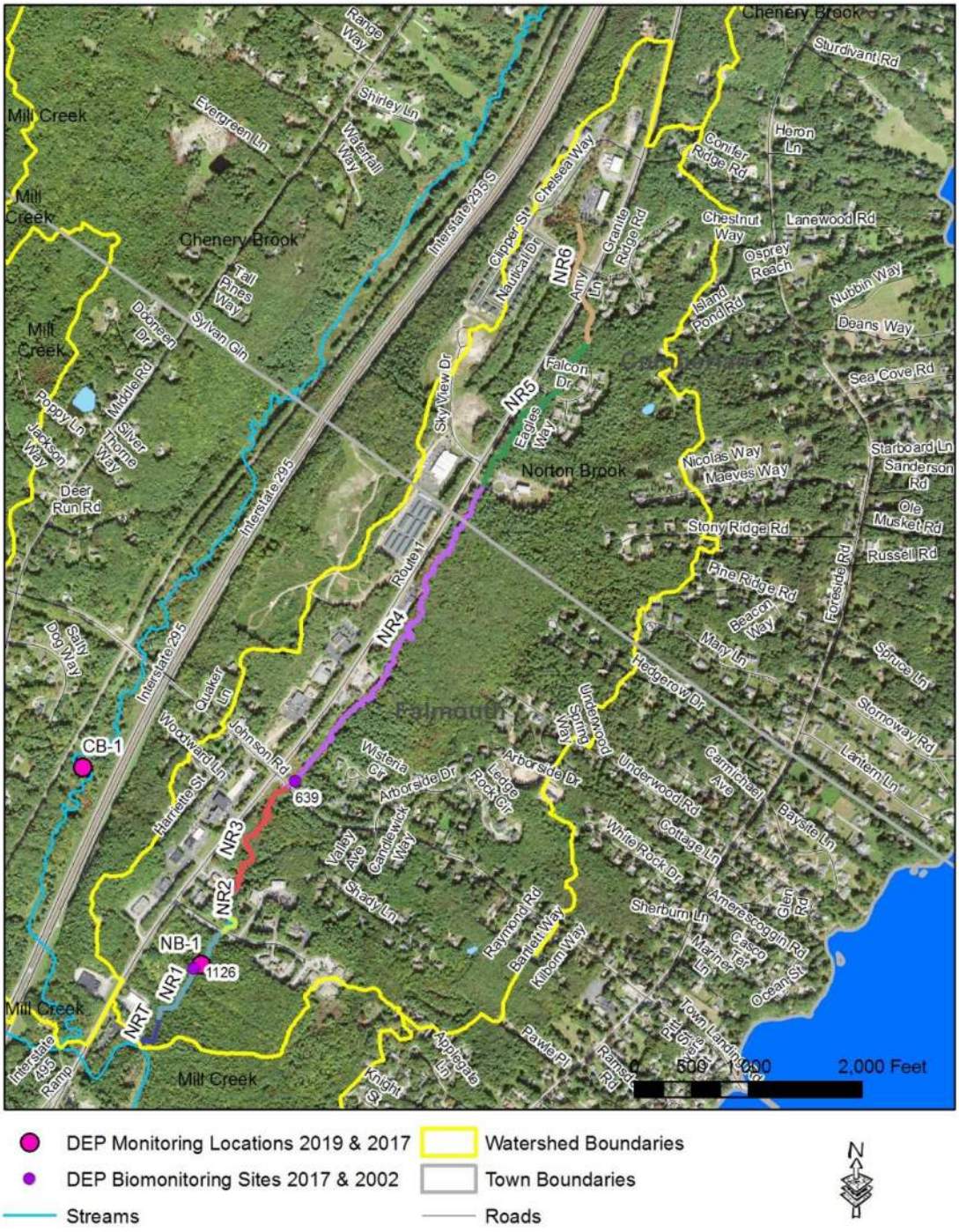
The Norton Brook watershed is split between the towns of Cumberland and Falmouth, with the upper third of the 510-acre watershed area in Cumberland and the remainder in Falmouth. Since the western boundary of the watershed is a ridge line between interstate 295 and Route 1, the area west of Route 1 accounts for only 25% of the watershed. The majority of the watershed drains the west side of the hills between Route 1 and Route 88.

The watershed is mostly forested but contains 80 acres of impervious cover (15.8% IC, 2018 estimation) as well as the landscaped areas associated with the impervious cover. Much of the impervious cover is associated with commercial, office, storage, light industrial and multifamily residential land use along the Route 1 corridor and in the Northbrook Drive Business Park. The remaining impervious cover is single family residential development along and off of Johnson Road and Casco Bay Drive, as well as the western portions of some subdivision development accessed from Foreside Road. In 2004 the impervious cover in the watershed was only 47.6 acres (9.3% IC), so about 40% of the impervious cover was constructed within the last 15 years.



Norton Brook-Reach NR1

Study Watershed Reach Names
Norton Brook



Geologic and Topographic Setting

Bedrock Geology, Surficial Geology and Soils. The valley in which Norton Brook lies is bounded by two metamorphic bedrock ridges, the Richmond Corner Formation on the west and the Torrey Hill Formation on the east. The bedrock base of the valley is the more easily eroded metamorphic rocks of the Hutchins Corner Formation. The western ridge is covered with a thin layer of glacial till, and the east ridge and the most northern portion of the valley are covered with reworked terminal moraine deposits of sand and silt which are shallow to bedrock on the top of the ridge. The southern portion of the valley is overlain with marine clay sediments of the Presumpscot Formation. The soils reflect the surficial geology with shallow till soils on the western slope, sandy soils on the eastern slope, silt loam soils in much of the stream corridor and, on the lower portion of the eastern slope, coarse loamy soils overlying silt loam soils.

Stream Gradient and Substrate. With the exceptions of a short ledge drop just upstream of Northbrook Drive and the most upstream reach from the Casco Bay Drive crossing to just below the Route 1 crossing, Norton Brook is a low gradient stream with channel slopes ranging from 0.6% to 1.1%. This is not surprising given that much of the channel sits on Presumpscot Formation marine clay covered with varying amounts of alluvial sands and silty sands. In the upper reaches, where the stream runs through coarser soils the substrate is a combination of sands, silty sands, gravel and some cobbles, particularly in the headwater reach.

Riparian Condition

Despite Norton Brook's proximity to Route 1 and the concentration of commercial development to the south, nearly the entire riparian corridor of the stream is forested. South of Johnson Road and north of the Friends School of Portland, the vegetation is relatively mature upland mixed growth forest. Along the lowest gradient stretches from just downstream of Johnson Road up to the Friends School the brook flows in and out of riparian floodplain wetlands of red maple, alder and both native and invasive shrubs. Except near the five stream crossings (Northbrook Drive, Johnson Road, the Friends School entrance, Falcon Drive and Route 1), the forest on the east side of the stream extends uninterrupted 300 to 1,000 feet up the slope. On the west side the width of the forest cover can drop to 50 feet or less adjacent to the commercial and business development along Route 1.

Habitat

Reach NRT. Starting at the confluence with Mill Creek, the first 400 feet or so of Norton Brook is tidal. The substrate is principally silty sand on marine clay. The channel is somewhat incised as is typical in tidal reaches. There is some woody debris, but no debris dams.


Norton Brook - Reach NR1

Reach NR1. This low gradient reach extends from head of tide about 1000 feet upstream to Northbrook Drive. The substrate is sand or silty sand with many meander bars and sand deltas at the outlets of two intermittent tributaries that drain gullies on the east side of the watershed. There is a large debris dam near the lower end of the reach which provides some habitat complexity both in substrate and velocity. In the stretch between the two tributaries a large abandoned culvert that provided the stream crossing for a discontinued road lies parallel to the stream in the stream channel. This restriction and the likely heavy stormflows from the upstream tributaries that drain most of the Northbrook Business Park has resulted in severe erosion of the western bank of Norton Brook, thus contributing more sand to the downstream deltas and bars. The DEP macroinvertebrate monitoring station is located just downstream of this tributary. It is apparent that the sand substrate in this reach is not stable and is likely altered during large runoff events.

Reach NR2. This very high gradient 330 foot reach extends from Northbrook Drive to the top of the ledge drop cascade. The substrate just upstream of the road crossing is a mixture of sand, gravel and cobble. The substrate in the cascade is ledge and boulders with some cobbles and gravel.

Reach NR3. Reach 3 extends from the top of the ledge drop 1550 feet upstream to the Johnson Road Crossing. It is mostly a low gradient reach with a substrate of sand and silty sand and some woody debris. A large intermittent tributary draining residential development along and accessed from Johnson Road enters about a third of the way up the reach.

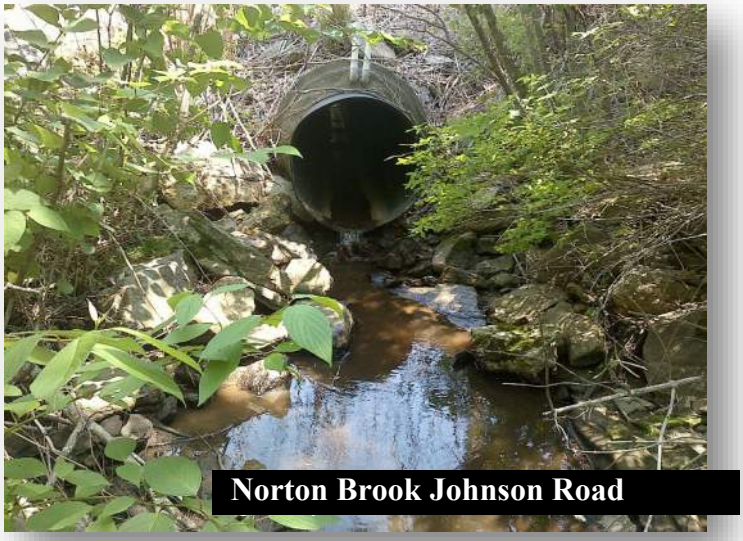
Reach NR4. This meandering, very low gradient 4,000 foot reach extends from Johnson Road to the Friends School. The substrate is sand and silty sand. Woody debris provides limited habitat and flow diversity. Because of the low gradient, baseflow velocity in the long runs is very low in this reach.

Reach NR5. Reach 5 extends 2,000 feet from the Friends School upstream past Falcon Drive to a relatively new double culvert crossing 300 feet downstream of Route 1. The reach has moderately low gradient with substrate of sand and gravel with some cobbles. The channel is slightly incised with undercut banks in some places. The volume of baseflow is very limited because of the small contributing drainage area.

Reach NR6. This high gradient 1,150 foot reach extends from the top of Reach 5 under Route 1 upstream to Casco Bay Drive. Substrate in the steepest parts of this reach is boulder and cobble, with a mixture of cobble, gravel and sand in lower gradient sections.

All reaches. All reaches except 2 and 6 showed at least some indication of unstable substrate, particularly Reach 1. Observations of Norton Brook during periods of little precipitation indicate that the volume, and in runs and pools the velocity, is very low, thus limiting both the amount and quality of available habitat.

Stream Crossings/Culverts. Three of the six road crossings (Johnson Road, Friends School and the double culvert downstream of Route 1) are hanging culverts that likely prevent upstream migration of fish except during very high flows. While the culvert under Falcon Drive is not hanging, flow of water over the broad concrete apron is so shallow during low to moderate flow that upstream passage is unlikely. Except in very low flow conditions, upstream passage is possible for the two remaining crossings – Northbrook Drive and Route 1.


Norton Brook Johnson Road

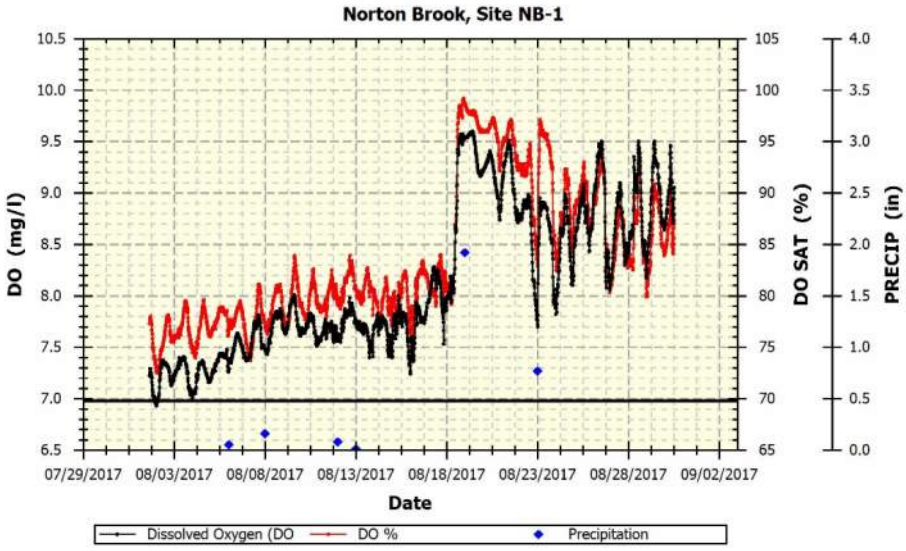
Water Quality

Temperature. Temperature was measured at Site NB-1 with a continuous data logger at the biomonitoring station August 1, 2017 to August 30, 2017, coincident with the period of deployment rock bag artificial substrates to monitor the macroinvertebrate community. The logger took measurements every 15 minutes. Temperature ranged from 13.1° C to 19.9° C with an average of 17.0° C.

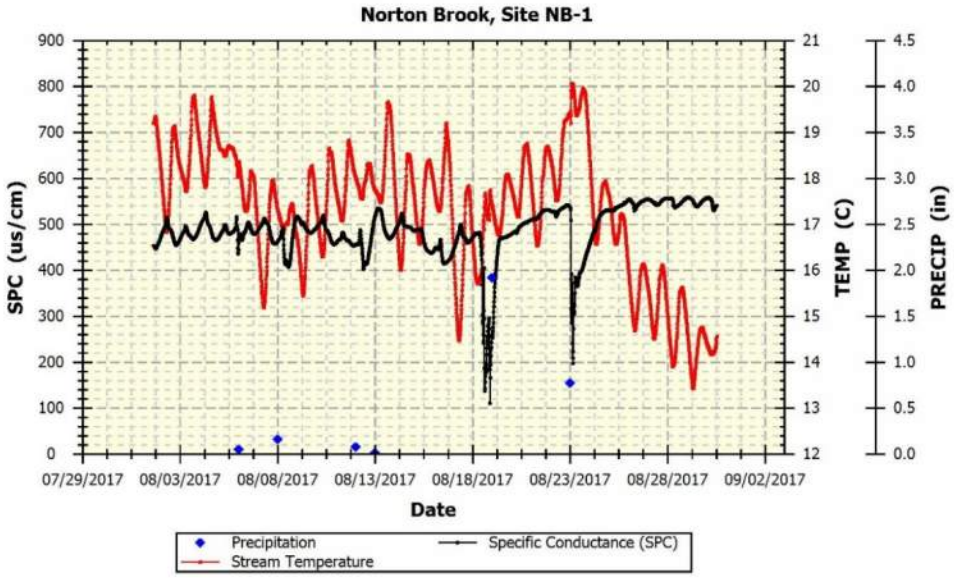
Dissolved Oxygen. Dissolved oxygen (DO) was measured at Site NB-1 with a continuous data logger at the biomonitoring station August 1, 2017 to August 30, 2017, coincident with the period of deployment rock bag artificial substrates to monitor the macroinvertebrate community. The logger took measurements every 15 minutes. During this period DO concentration averaged 8.13 ppm with a minimum of 6.93 ppm. Percent saturation averaged 83.8% with a minimum of 72.5%. The diurnal variation in DO concentration was minimal, suggesting there was very little loss of oxygen due to algal respiration in this reach of the stream. This could be due to the fact that the stream is shaded by intact riparian cover, to a lack of sufficient nutrients to support significant algal production or to a combination of these factors. The period of time, only 0.6%, when DO

concentration was below the 7.0 ppm standard for Class B streams was limited to the first night after deployment, and it only dropped to 6.93 ppm.

Daytime DO readings taken at 26 points in the stream during the July 11, 2018 stream walk with very low stream flow showed only 4 instances of concentrations less than 7.0, with the lowest readings being just downstream of the wetland source of the stream above Casco Bay Drive and in the tidal reach just above the confluence with Mill Creek.



Specific Conductance. Specific conductance (SPC) was measured at Site NB-1 with a continuous data logger at the 2017 biomonitoring station August 1, 2017 to August 30, 2017, coincident with the period of deployment rock bag artificial substrates to monitor the macroinvertebrate community. The logger took measurements every 15 minutes. During this period SPC ranged from 110 µs to 558 µs, with an average of 486 µs and a median value of 488 µs. During this period, there was very little precipitation and the stream was at low baseflow most of the time. Nearly all of the lowest readings (<300 µs) occurred during and shortly after a half inch rain event on August 18. This pattern of higher conductivity during baseflow than during storms indicates that many of the ions contributing to the conductivity are in the groundwater. In urban and urbanizing streams, the most likely culprit is chloride because of the high amounts of deicing salts that are applied in the watershed and the fact that, unlike most other ions, chloride is not attenuated in the soil.



Specific conductance was also measured at 26 sites during the 2018 stream walk. At this time the stream was at a very low baseflow, with most of the flow derived from groundwater. Starting in the headwaters at Casco Bay Drive the SPC is 900+ µs, reflecting significant chloride contamination of the groundwater from adjacent parking lots and dense residential development. Just downstream of Route 1 SPC jumps to 1250 µs due, no doubt, to the influence of deicing salts on the groundwater adjacent to the highway. Approximately 300 feet downstream of Route 1 a tributary draining the more lightly developed east side of the upper watershed joins the mainstem. SPC in the mainstem above the confluence is still very high at 1170 µs, but below it drops to 750 µs, reflecting dilution of the Route 1 impact by low chloride tributary water. SPC remains in this range for 3000+ feet despite the fact that the stream is at times very close to Route 1. This is probably due to the fact that tributaries and springs from the lightly developed and comparatively large east side of the watershed are continuing to provide dilution of the Route 1 salt impact. At the point where the Route 1 culvert draining the Scir `x Pharmacy development and the west side of Route 1 discharges into Norton Brook the SPC jumps to 830 µs and stays in the 800s downstream to Northbrook Drive. The higher conductance in this stretch is likely due to the density of commercial development along Route 1 as well as residential development along Johnson Road. Downstream of Northbrook Drive SPC drops to +/- 600 and stays there until head of tide where it rises dramatically near the confluence with Mill Creek.

Biological Condition

The macroinvertebrate community in Norton Brook has been sampled using rock bags on two occasions. The first was in August of 2002 at a site just upstream of Johnson Road (Site 639). The second was in August of 2017 at a site approximately 450 feet downstream of Northbrook Drive (Site 1126). In Maine's statutory Water Classification Program (38MRSA§465) Norton Brook is classified as a Class B stream. Evaluation of the composition and structure of the community collected in both sampling events indicated that the community failed to meet the narrative biological criteria for Class C streams, let alone for Class B. Additional evaluation of the taxa present in these two events gives some indication of the reasons for the impairment.
While neither the 2002 nor the 2017 community met minimum biological criteria, the 2002 sample contained more individuals and a higher diversity of taxa than the 2017 sample. The 2002 Johnson Road sample suggested a community with habitat limitations, particularly low baseflow velocity with little water exchange, but did not suggest that the habitat was unstable. The 2017 sample below Northbrook Drive had considerably fewer taxa, and the taxa present suggested the habitat/substrate was unstable and subject to frequent physical alteration. This was confirmed by the fact that one of the rock bags was completely covered with sand. Under these conditions taxa that have very short life cycles make up a large portion of the community. The composition of the community also suggested that low baseflow velocity was a likely issue. Neither sample showed signs of toxicity or low dissolved oxygen stress, as both contained taxa that are not usually present under those conditions.

Likely Stressors to the Biological Community

Both the continuous monitoring data and discrete measurements collected during the stream walk for temperature and dissolved oxygen indicate that neither are likely to be stressors to the biota in Norton Brook. The cool water (maximum temperature of 19.9 degrees C) and dissolved oxygen that only rarely dropped below 7 ppm suggest good conditions for both the macroinvertebrate and fish communities.

Current Stressors

- *Frequent disturbance of the substrate.* Both the habitat assessment during the 2018 stream walk and the composition of the macroinvertebrate community point to frequent disturbance of the sandy substrate as the most important current stressor to the biota in Norton Brook. When substrate sediment is relocated in every large storm event, it is difficult for the taxa living in and on the sediment to avoid being washed downstream. As a result, the taxa that are most abundant in the remaining community are ones with short life cycles that can re-establish themselves quickly after a significant runoff event. Taxa with annual life cycles (only one generation per year) like mayflies, stoneflies and caddisflies have a hard time maintaining themselves in these conditions.

  The fact that imperviousness in the watershed has increased dramatically in the last two decades, and that much of the runoff from impervious areas is delivered very efficiently to the stream with no or limited detention may explain why this stressor appears to be dominant in Norton Brook.
- *Very low baseflow.* Norton Brook has a very small ground watershed, so during the extended periods of little or no precipitation that have been typical of the last five summers, and also of the summers of 2001, 2002, and 2003 the flow in the stream gets very low. This is no doubt exacerbated by the sandy composition of much of the stream's substrate, which allows significant hyporheic flow (flow through the substrate) thus further reducing surface flow over the substrate. In summers without long periods of droughty weather, the biological community may fare better than it has in the relatively dry summers of 2002 and 2017.

Future Stressors

- *Baseflow chloride toxicity.* The specific conductance measurements below Northbrook Drive (450 to 600 µs) where the 2018 macroinvertebrate samples were collected do not suggest that baseflow chloride toxicity was a significant stressor on that community. Generally speaking, when SPC exceeds 900 µs it is likely the threshold of chronic toxicity for chloride (230 mg/l) has been exceeded. Between Northbrook Drive and Falcon Drive, SPC ranges from 750 to 850, dangerously close to the threshold. Above and below the Route 1 crossing SPC is between 900 and 1250, suggesting that baseflow chloride toxicity may be currently impairing the macroinvertebrate community in that reach. *At the very least, there is a high risk that baseflow chloride toxicity could become a significant stressor if future development of the watershed does not address groundwater contamination with deicing salts.*

Stressors associated with downstream watersheds – Mussel Cove

- *Nitrogen.* Norton Brook is a tributary to Mill Creek which in turn drains to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. Addition of any of the following land uses to the Norton Brook watershed has the potential to exacerbate the impairments to the stream's biota:

- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage.
- Any new impervious area that has deicing salts regularly applied to it, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Low density, single family residential development will have significantly less potential impact because it is not likely to discharge as much runoff or use as much salt as the above listed uses.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Norton Brook watershed:

Commercial, Institutional, Office, Multi-family Residential

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.

- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
    - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Resource Protection and Restoration.

- *Shoreland Zoning.* One thing that Norton Brook has working for it is its relatively intact stream corridor. With the exception of some encroachment from development adjacent to Route 1, most of the immediate riparian area is covered with natural, though not necessarily native, vegetation and, for most of its length it is well shaded. Maintaining this natural corridor is essential to prevent any further impairment of the biological community and to allow recovery of the stream from its current stressors. Shoreland zoning currently prevents structures within 100 feet of the stream, but only provides for a 25 foot buffer where natural vegetation is maintained. This buffer should be expanded to prevent significant disturbance of the vegetation within no less than 100 feet of the stream. Ideally this standard would also be applied to the tributaries, particularly the ones that have at least some flow in the summer. A further shoreland zone (i.e. 250 feet) which would allow some development but would maintain an essentially forested character would provide a significant wildlife corridor and, at least as important, reproductive habitat for the adult insects that lay their eggs in the stream (e.g. mayflies, stoneflies, caddisflies) and could be considered for the east side of the stream.

- *Instream habitat enhancement.* In addition to attenuation of high stormflow discharges from intensely developed areas, it will likely be necessary to take measures to increase substrate and habitat stability in the stream channel. Strategic placement of structures such as log bars, root wads, and K dams can help the most vulnerable sections of the stream retain its sediment and enhance habitat by providing diversity of both substrate and flow velocity. Any work in the stream corridor should include removal of the abandoned culvert in Reach NR1.

Further assessment needs.

- *Fluvial geomorphological assessment.* Effective instream enhancement measures will require a detailed assessment of the stream channel by a qualified fluvial geomorphologist. The

assessment would include recommendations on the location and design of any instream structures.

- *Culvert evaluation.* The four culverts with upstream passage issues should evaluated for potential mitigation.
- *Assessment of functionality of existing stormwater infrastructure.* Approximately one third of the non-residential developments along Route 1 have either stormwater detention basins or vegetated under-drained soil filters, both of which should provide some level of stormwater detention and, in the case of the filters, some removal of traditional pollutants (not chloride). Initial observation of these suggests that some, if not the majority, are not functioning as their design intended and that nearly all could be modified or enhances to provide more effective detention of stormwater. Evaluation of the potential of these systems for upgrades or modifications would be an important first step towards reducing flashy stormwater discharges to Norton Brook.
- *Additional monitoring.*
    - Biological monitoring. Collection and evaluation of macroinvertebrate samples in future years would help assess the recovery potential of the stream and document the effectiveness of any restoration efforts. Particularly, it would be beneficial to collect this information for some less droughty summers than 2002 and 2017. A wetter summer with shorter dry periods might increase the level of the primary current stressor (frequent disturbance of the substrate), but would increase baseflow velocity, habitat availability and dilution of chloride laden groundwater. Understanding how the community responded to such different conditions could provide additional guidance for protection and restoration efforts.
    - Specific conductance. Repetition of conductivity screening in various stream reaches and, if possible, continuous monitoring with data loggers will help evaluate if baseflow chloride toxicity is becoming a more or less important stressor.

Webes Creek

Webes Creek, also known as Webes Brook, is a 0.71 mile Class B stream that flows northeast in a valley between Route 1 and Foreside Road. It begins in a stormwater outfall in the northern corner of the Ace Hardware Parking lot off Route 1 and outlets into Mill Creek, about 750 feet upstream of the Foreside Road crossing. The lower 40% of the stream is subject to at least some tidal influence, including intermittently brackish water. The remainder is a free flowing, freshwater stream.

Watershed Characterization


Webes Creek - Reach WR1

The Webes Creek watershed is bounded on the east by Foreside Road and the west by a low ridge that separates it from the Scitterygussett watershed. It extends from the Interstate 495 ramp south to the Volkswagen dealership and the northern edge of Foreside Estates. With 35% of its 337 acres covered by impervious surfaces it is the most densely developed watershed in Falmouth and one of the most densely developed watersheds in Maine. The large majority of this impervious area is found in the commercial, business and transportation land use along the Route 1 corridor. Residential land use along Depot Road and Foreside Road account for the remainder. Most of the non-residential development drains to the stream via one of three major outfalls: (1) a tributary that discharges to Webes Creek in its tidal reach and drains the most northern part of the Route 1 corridor, including the Bucknam Road intersection and most of the Shaw's Shopping Center parking lot; (2) a stormwater outfall/ditch draining the mid-portion of the Route 1 corridor that discharges into to Webes Creek just upstream of Depot Road; and (3) the stormwater outfall at which the stream originates that drains the southern portion of the Route 1 corridor.

Geologic and Topographic Setting

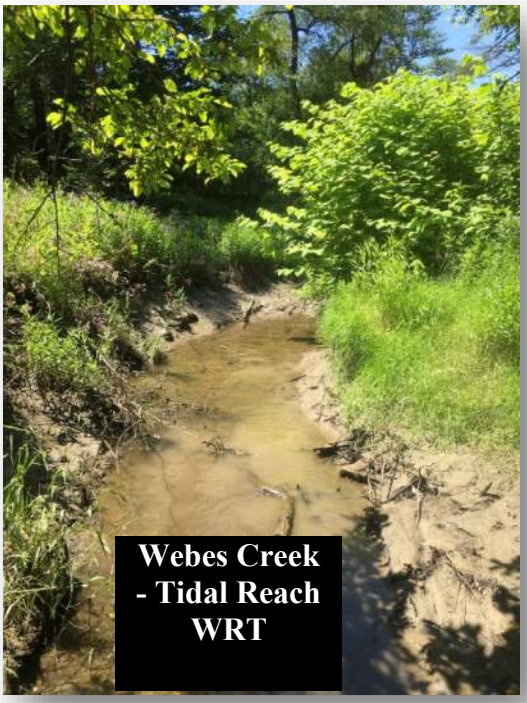
Bedrock Geology, Surficial Geology and Soils. The Webes Creek valley is bounded by metamorphic bedrock ridges on the east and the west. With the exception of some coarse marine deposits overlying glacial till on the top of the eastern ridge, the watershed is overlain with Presumpscot Formation marine sediments. As a result, the soils in the watershed are dominated by low permeability silt loams, with some small areas of very fine sandy loams.

Study Watershed Reach Names
Webes Creek



Stream Gradient and Substrate. The portion of the stream that appears to be subject to at least some tidal influence extends roughly 1600 feet (based on local observations) upstream from Webes Creek's confluence with Mill Creek. The amount of tidal influence varies dramatically within this reach, with the greatest and most frequent influence nearest the outlet to Mill Creek and only slight and infrequent influence (spring and/or king tides) in the most upstream portion. Stream gradient in this reach is very low, with a mean channel slope of 0.18 %. The substrate of the stream bottom in this reach ranges from gravelly sand over hard clay to silty sand over hard clay.

While the entire length of Webes Creek is low gradient, the mean channel slope of 0.70 % in the reach between "head of tide" and Depot Road is somewhat higher than the tidal reach. The substrate includes varied depths of gravel, gravelly sand, sand and silty sand over the underlying marine clay. There are a few places where the underlying hard clay is exposed.



Mean channel slope is slightly higher at 1.12 % in the uppermost reach of the stream between its stormwater outfall start and Depot Road. In the flattest part of this reach, just upstream of Depot Road, the substrate is a deep, soft mixture of sand, silt and clay. Gradient increases as one moves upstream where the substrate is gravel on hard clay.

Riparian Condition

The riparian corridor of Webes Creek consists principally of a shrub/scrub floodplain ranging in width from 40 feet to 100 feet. The floodplain is bounded by slopes that are covered in mixed forest except where development encroaches. With the exception of many invasive plants in the floodplain, the vegetation is natural except for:

- A stretch extending 500 feet upstream from a point 1250 feet upstream of the confluence with Mill Creek, in which landscaping from residential development along Foreside Road encroaches on the floodplain and the eastern slope
- A stretch extending 500 feet downstream of Depot Road and upstream to the headwater stormwater outfall where the corridor is altered by commercial development and, on the east side downstream of Depot Road, residential landscaping

Alders and other shrubs provide reasonable shade for much of the stream's length except in a few places where the stream channel is particularly wide, where landscaping extends to the channel itself, and in the most downstream half of the tidal reach where the floodplain is dominated by salt tolerant grasses.

Habitat

DEP staff conducted a stream walk on Webes Creek on June 28, 2019. Much of the following is a result of observations during that walk up the stream channel.

The habitat of Webes Creek has been altered in many ways. According to a person who has lived and worked adjacent to the stream all his life, the stream was channelized with a bulldozer in the 1950's. This is reflected in the non-tidal portions of the stream by the relative straightness of the channel for such a low gradient system, with limited meanders, usually in response to current or recent debris dams. The historic, and in part current, sewer line adjacent to the north side of the stream may also be confining channel movement. This results in a system with low habitat diversity. The substrate in the wetted channel ranges from silty sand, to sand, to gravely sand to gravel. Most if not all of this material is underlain by hard marine clay. The principal source of the deposited sand and gravel is likely from erosion of the stream's banks and the stream channel, though some of the sand may come from soil erosion in the watershed. While the sand and gravel could provide reasonable habitat for many of the macroinvertebrates (insects, crustaceans, mollusks) that would be expected in a free flowing freshwater stream, the quality and utility of this habitat is severely compromised by the high storm flows that the stream receives from its highly impervious watershed.

The sand and gravel substrate is in a state of frequent flux. This is evident from the nature of the sand bars in the channel as well as indirect observation. In August of 2019 the DEP deployed bags of rocks in the stream in order to evaluate the macroinvertebrates that would colonize the introduced substrate. When the bags were retrieved after a four week deployment, they were buried in sand and therefore useless for evaluation, indicating that sand is moving freely in the system and the habitat it provides is not stable. During the period of deployment there were two significant, but not exceptionally large storm events (1.8 and 1.4 inches, Portland Jet Port). Storms of this magnitude are not infrequent, and the amount of sand movement evident during the deployment period suggests that organisms trying to live in or on the substrate could be washed downstream with the sediment.

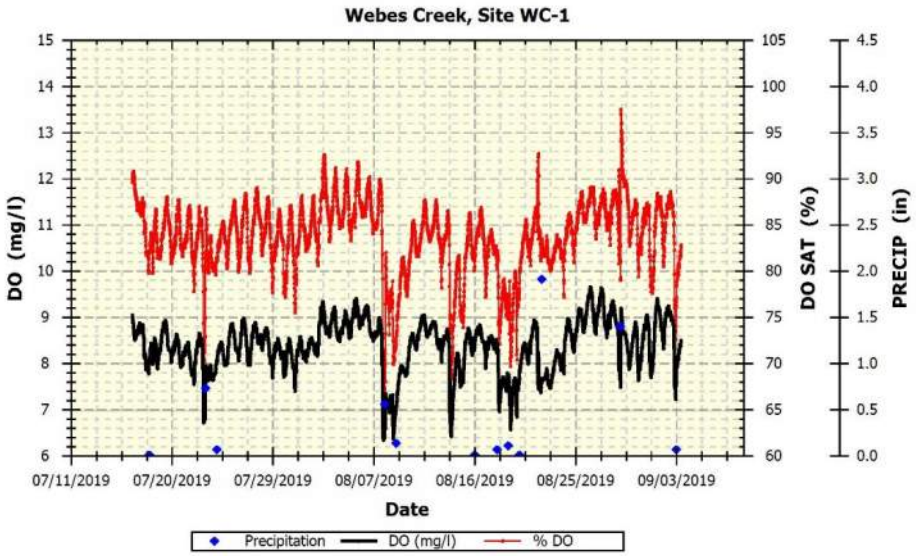
In addition to the physical alterations of the channel discussed above, habitat is compromised by extremely low baseflow during periods of extended dry weather, and a general lack of diversity in baseflow velocity in some stretches. The watershed is small and highly impervious, so low baseflow is to be expected, especially given the frequency of relatively dry summers in recent years.

Water Quality

Temperature, dissolved oxygen and specific conductance were monitored during the June 28th stream walk and with continuous data loggers at Site WC-1 that recorded measurements every 15 minutes from August 6, 2019 to September 3, 2019, while the data loggers were deployed.

Temperature. During the June 28, 2019 stream walk water temperature ranged from 16˚C to 20˚C, with the warmest temperature just downstream and upstream of Depot Road where shade is limited. The continuous logger data in August generally indicated daytime high temperatures between 15˚C and 18˚C, with early morning temps 3 to 4 degrees lower. During storm events temperature spiked to 20˚C or higher, usually dropping to 18˚C or cooler within a day or less.

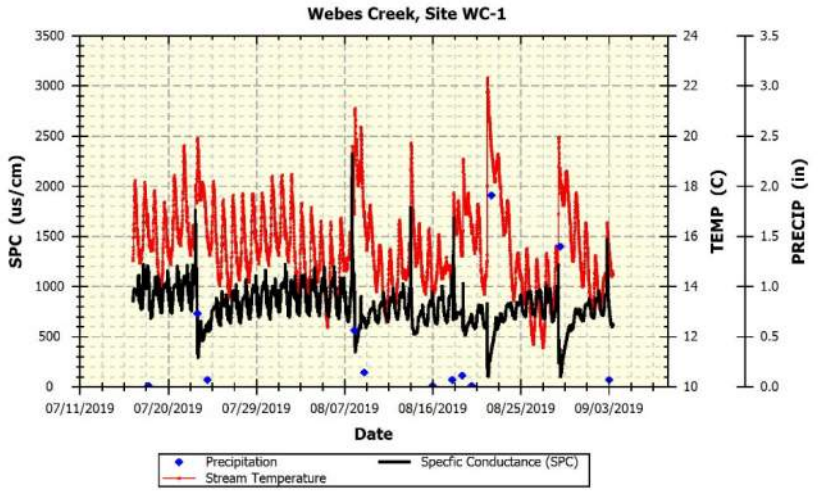
Dissolved Oxygen. Daytime DO measurements collected during the stream walk were above the Class B standard of 7 ppm except for two readings taken upstream of Depot Road that were 6.3 ppm and 6.8 ppm. DO concentrations from the August logger data generally ranged from 7.5 to 9.5 ppm with diurnal swings of only 0.5 to 1.5 ppm, suggesting only minimal oxygen loss due to algal respiration. DO drops slightly below 7.0 ppm for short periods during storm events. This may be a function of flushing of lower DO water from upstream wetlands and detention basins or it may simply be associated with the warmer temperature of the stormwater runoff.



Specific Conductance/Chloride.

In urban and urbanizing streams, the most likely cause of elevated baseflow specific conductance (SPC) is chloride because of the high amounts of deicing salts that are applied in the watershed and the fact that, unlike most other ions, chloride is not attenuated in the soil. The chronic toxicity threshold for chloride is 230 mg/l according to EPA's Water Quality Criteria. Correlation of SPC and chloride measurements from other urban stream watersheds indicate that this threshold is likely to be exceeded if SPC is greater than 900 µs.

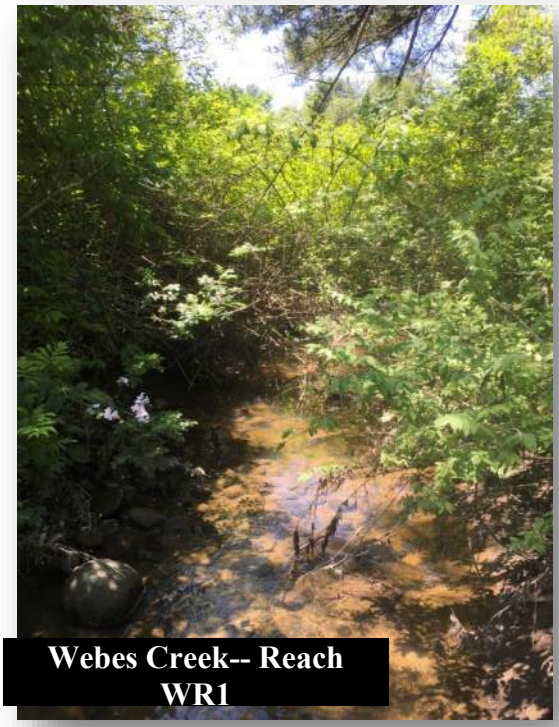
The SPC continuous logger measurements for Webes Creek taken at at Site WC-1 illustrate several interesting phenomena that support this assertion. To put the following discussion in perspective, the SPC typical of natural streams is +/- 100 µs. During periods of dry weather and low baseflow SPC exhibits daily diurnal swings between 700 µs and 1200 µs. The highest values occur in the evening, peaking around 10:30 PM, the lowest around 6:00 AM. This suggests that high conductivity groundwater from the upper developed part of the watershed is being diluted by lower conductivity groundwater from less developed areas downstream. During the day evapotranspiration by flood plain vegetation is reducing the amount of dilution provided, so



conductance rises. Overnight, the groundwater flow into the stream from the floodplain recovers, dilution increases and conductance drops.

When a storm event occurs there is an initial, very short-term spike in conductance to as high as 2,600 µs. This spike is immediately followed by a precipitous drop to very low SPC, around 200 µs and a less steep rise over a period of two to three days to the baseflow equilibrium diurnal swing SPC. The initial spike in conductance indicates that, during the period between storms, high conductance groundwater has seeped into the stormwater infrastructure in the upper watershed. It is immediately flushed out of the stormwater system with the first runoff, after which it is followed by low conductivity stormwater. The magnitude of the spike correlates with the time period between storms – the longer the period the more high conductivity groundwater can seep into the storm sewer system and the higher the SPC spike. During the days after the storm the stream gradually returns to a groundwater dominated system.

Specific conductance was measured at 12 sites during the June 28, 2019 stream walk at a time between storm events when the stream was at a low baseflow. SPC measurements during the stream walk ranged from 733 µs above head of tide near the logger station at Site WC-1 to 1047 µs about 400 feet downstream of Depot Road and all measurements upstream of the logger station exceeding 900 µs. These readings were taken between 10:00 AM and 2:00 PM near the midpoint of the logger data's diurnal swing, so the peak values for the day were probably 200 to 300 µs higher.



Webes Creek-- Reach WR1

Nutrients, Metals and Hydrocarbons. No data has been collected on these typical stormwater pollutants. However, given the large amount of road surface and parking in the watershed, there is no doubt that the concentrations of phosphorus, nitrogen, heavy metals and some hydrocarbons are at least somewhat elevated during the first flush of intense storms.

Biological Condition

Rock bags were deployed to collect a sample of the macroinvertebrate community in Webes Creek at station WC1 for four weeks in August 2019. Unfortunately, during the deployment the bags were buried in the sandy substrate and were not able to be used as valid samples. While there is no direct data on which to base an evaluation of the biota in the stream, the fact that at the end of the deployment period the bags were buried in approximately six inches of sand suggests that the community is likely impaired. It is likely that this is a result of a combination of (1) erosion of sediment beneath and around the bags that allowed them to sink into the substrate during a period

of high storm flow and (2) deposition of sand, probably later in the storm event, that covered the bags and the eroded area. This combination of erosion and sedimentation indicates that a substantial amount of substrate is being disturbed and washed downstream, where it is later deposited. This disturbance is also likely to wash the biota living in the substrate downstream as well. During the period of deployment there were two storms events that exceed 1.0 inch (1.8 in and 1.4 in) at the Portland Jetport. Storms of this magnitude occur frequently. In the 12 month period from September 2018 thru August 2019 there were 18 storms with ≥ 1.0 inch of rain, 8 with ≥ 1.5 inches and 3 with ≥ 2.0 inches recorded at the Jetport. Such frequent disturbances of the substrate make it difficult for macroinvertebrates with annual life cycles (e.g. mayflies, stoneflies and caddisflies) to survive. The very high amount of impervious area (35%) in the watershed results in dramatically higher stormflows for any given storm event than the stream channel would otherwise receive.

Likely Stressors to the Biological Community

Current Stressors. The habitat, water quality and biological information discussed above strongly suggest that (1) neither temperature or low dissolved oxygen are significant stressors to the biological community and (2) at least three stressors – frequent disturbance of habitat, baseflow chloride toxicity and low baseflow velocity – are currently impacting the biota of Webes Creek.

- *Frequent disturbance of the substrate.* Evidence from both the habitat assessment during the stream walk and the buried rock bags indicate that the predominantly sandy substrate of Webes Creek is being disturbed and transported during moderate and frequent storm events. This type of unstable habitat greatly limits the composition and diversity of the macroinvertebrate community as well as the quality and abundance of food available for resident fish.

- *Baseflow chloride toxicity.* Both the stream walk and logger SPC data suggest that during extended low baseflow the chloride concentration in Webes Creek, for half, if not most of the day exceeds the 230 mg/l threshold for chronic toxicity. It is likely that this is having an impact on biota in the stream that are sensitive, which includes a lot of the macroinvertebrates that normally inhabit freshwater streams.

- *Very low baseflow.* The very low baseflow discussed in the Habitat section reduces the velocity of flow to the point where many of the insects that rely on stream flow to deliver food to their nets or pass oxygen over their gills cannot be supported. During wetter summers than 2015 to 2019, this stressor may not have much effect on the community, but in dry summers it probably at least exacerbates the effect of other stressors. Some of this low baseflow is natural because the watershed is small and much of it is underlain with marine clay which has only limited groundwater storage potential. This natural limitation is exacerbated by the addition of large impervious areas which prevent any significant infiltration of rainfall.

- *Other likely stressors.* Conventional pollutants associated with stormwater from highly impervious urban areas include nutrients, heavy metals and hydrocarbons. Though these have not been monitored in Webes Creek, it is likely that the runoff from the watershed's parking lots has relatively high concentrations of these.

  Observation of the stream and the fact the there is only a slight diurnal swing in dissolved oxygen concentrations suggest that growth of algae in the stream is not an issue, but this may be a function of effective shade over much of the channel and not of low nutrient levels. Loss of shade might result in sufficient algal production to reduce night time DO to that point that it becomes a stressor.

  Though many of the metals and hydrocarbons will be quickly transported to Mussel Cove during significant storm events, some may accumulate in the silty sand sediments found in the lowest gradient sections of the stream. These could have a toxic effect on sensitive insects trying to live in the substrate.

Potential Future Stressors. Given the fact that the watershed of Webes Creek is already quite urban, most of the stressors associated with urban watersheds are already in play. While there are no obvious new stressors that are of concern, it is likely that the watershed will continue to develop, and additional impervious area and the increased storm intensity associated with climate change could substantially increase the impact on the biological community from the two most important current stressors (frequent disturbance of substrate and baseflow chloride toxicity) unless the new development incorporates, to the greatest extent possible, measures to minimize these stressors.

Stressors associated with downstream watersheds – Mussel Cove

- *Nitrogen.* Webes Creek is a tributary to Mill Creek which in turn drains to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. Addition of any of the following land uses to the Webes Creek watershed has the potential to exacerbate the impairments to the stream's biota:

- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage.
- Any new impervious area that has deicing salts regularly applied to it, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Low density, single family residential development will have significantly less potential impact because it is not likely to discharge as much runoff or use as much salt as the above listed uses.
Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Webes Creek watershed:

Commercial, Institutional, Office, Multi-family Residential

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
    - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Resource Protection and Restoration.

- *Shoreland Zoning.* Below Depot Road, most of immediate riparian area adjacent to Webes Creek is covered with natural, though not necessarily native, vegetation and, for most of its length it is well shaded. Maintaining this natural corridor is essential to prevent any further impairment of the biological community and to allow recovery of the stream from its current stressors. Webes Creek is not currently designated for protection under the Falmouth shoreland zoning ordinance. It should be zoned to prevent new development and

significant disturbance of the vegetation within no less than 100 feet of the stream. Ideally this standard would also be applied to the tributaries, particularly the ones that have at least some flow in the summer.

- *Instream habitat enhancement.* In addition to attenuation of high stormflow discharges from intensely developed areas, it will likely be necessary to take measures to increase substrate and habitat stability in the stream channel. Strategic placement of simple structures such as log bars, root wads, and K dams can help the most vulnerable sections of the stream retain its sediment and enhance habitat by providing diversity of both substrate and flow velocity. The potential for enhancement will likely be limited by restrictions to access and low stream gradient.

Further assessment needs.

- *Fluvial geomorphological assessment.* Effective instream enhancement measures will require a detailed assessment of the stream channel by a qualified fluvial geomorphologist. The assessment would include recommendations on the location and design of any instream structures.
- *Assessment of functionality of existing stormwater infrastructure.* Some of the more recent developments in the Webes Creek watershed incorporate stormwater management practices, particularly stormwater detention. Evaluation of the potential of these systems for upgrades or modifications would be an important first step towards reducing flashy stormwater discharges to Webes Creek.
- *Additional monitoring.*
    - Biological monitoring. Some evaluation of macroinvertebrate community in future years would help assess the recovery potential of the stream and document the effectiveness of any restoration efforts. It may be necessary to use a different sampling method than the rock bag deployment given the apparent magnitude of sand movement in the stream. It would be beneficial to collect this information for at least one future droughty summer and one wetter summer. A wetter summer with shorter dry periods might increase the level of the primary current stressor (frequent disturbance of the substrate), but would increase baseflow velocity, habitat availability and dilution of chloride laden groundwater. Understanding how the community responded to such different conditions could provide additional guidance for protection and restoration efforts.
    - Specific conductance. Repetition of conductivity screening in various stream reaches and, if possible, continuous monitoring with data loggers will help evaluate if baseflow chloride toxicity is becoming a more or less important stressor.

Chenery Brook

Chenery Brook is a 4.0 mile long stream that starts in the town of Cumberland as an intermittent swale in the power line just north of Tuttle Road. After crossing Tuttle Road it drains south through forest passing the western end of the Butterworth Farm Road before turning southeast and crossing Middle Road. A short distance downstream of Middle Road it turns south-southwest and parrallels the railroad track until, just downstream of the Falmouth town line it turns southeast and passes under the tracks. It then flows southwest in the confined valley between the railroad and Interstate 295, crossing Johnson Road and the interstate just upstream of its confluence with Mill Creek. Approximately 40% of the stream's length and 25% of its watershed are in town of Falmouth, with the remainder in Cumberland.

Watershed Characterization


Chenery Brook – Reach CR2

Chenery Brook's approximately 1300 acre watershed is mostly forested with relatively light single family residential land use. Only 7% of the watershed is covered with impervious surfaces and approximately one third of that is Interstate 295. The interstate and the railroad are both prominent features that confine the valley in which much of the stream flows.

Geologic and Topographic Setting

Bedrock Geology, Surficial Geology and Soils. The Chenery Brook watershed is underlain by metamorphic rocks of the Hutchins Corner Formation. The stream valley is overlain by Presumpscot formation marine clay. It is bounded on the east by a ridge that separates the Chenery and Norton Brook watersheds and on the west by the ridge that separates the Chenery and Mill Creek watersheds. Both ridges are covered with a thin layer of glacial till. The marine clay that underlies the stream channel is mostly covered by alluvial sands, silts and rarely gravel. The soils in the watershed generally reflect the underlying parent material with silt loams and very fine sandy loams in the valley and coarser sandy loams and loamy sands on the ridges.

Figure 5. Chenery Brook Watershed and Study Reaches.



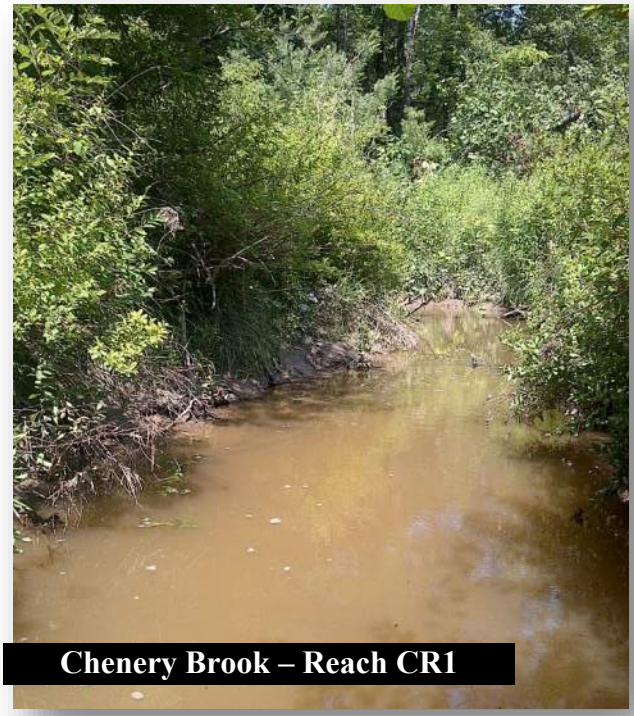
Stream Gradient and Substrate. For most of its length between Middle Road and head of tide at the I 295 crossing, Chenery Brook is a very low gradient stream with mean channel slopes of 0.2% except in three short drops – downstream of Middle Road, downstream of the railroad crossing and just upstream of Johnson Road. The drop at Johnson Road is enhanced by a man-made boulder and cobble dam which impounds a deep, very slow run for approximately 1,000 feet upstream. Substrate in the channel ranges from bare marine clay in some riffles to silty sand and sand in the slower reaches which account for the majority of the stream, to gravel and some cobble in the somewhat steeper sections.

Riparian Condition

With the exception of some fields in the headwater reach and a few spots where residential landscaping encroaches in Cumberland, the entire length of the Chenery Brook is bounded by natural riparian vegetation. Where the bottom of the valley floor is narrow the riparian cover is dominated by forest. In places where the valley is broad riparian cover includes more shrub-scrub or meadow floodplain wetland. This is the case for most Reach CR3, which extends about 4,000 feet upstream from the railroad crossing, and is partially located in a power line corridor where large woody vegetation is discouraged.

Habitat

This habitat assessment is not as detailed as the Norton Brook and Webes Creek assessments because a walk of the entire stream channel was was not performed. The assessment is based on observations at a number of key sites along the stream corridor.



Chenery Brook – Reach CR1

Reach CRT. This tidal reach extends from the confluence with Mill Creek up to the I 295 culvert. The substrate is principally silty sand on marine clay. The channel is somewhat incised as is typical in tidal reaches.

Reach CR1. This is a very low gradient reach between the I 295 crossing and Johnson Road. It meanders through forest and flood scrub wetlands that provide much but not complete shade to the channel. The stream is incised in places with high banks, particularly on the outside of meanders, so access to the floodplain is not always available. It has typically long, slow runs with relatively rare riffles. The substrate is a mixture of sand bars and silty sand over clay, with the hard clay exposed in many of the riffles. Some diversity in habitat and velocity is provided by woody debris, which is present but not abundant.

Reach CR2. Most of Reach CR2 is very low gradient except immediately upstream of its beginning at Johnson Road and immediately downstream of its upstream terminus at the railroad crossing. The man-made dam upsream of Johnson Road impounds a long, relatively deep run, depriving the stream of habitat and flow diversity for for nearly 1,000 feet. The valley between the interstate and railroad is narrow and fairly steep in this reach so riparian cover is mostly forest and the stream is well shaded. The stream meanders less in this reach and the floodplain is limited because of the steep valey slopes. Substrate in the long, slow run is silty sand on clay with little habitat diversity except that created by woody debris. Substrate above the run is a mix of sand, sand bars and some gravel in the riffles with much greater habitat and flow diversity.

Reach CR3. Most of this reach, which extends upstream from the railroad crossing to a foot bridge adjacent to residential development on Shirley Lane, consists of a low gradient stream that meanders through a broad, 75 to 150 foot wide shrub-scrub and meadow wetland. Stream banks are steep and sometimes quite high where the outside of the meanders meet the steep slope of the valley on the west or the wooded slope created by fill for the railroad on the east. Shade is limited due to the nature of the flooplain vegetation and, for some of the reach, by the control of woody vegetation resulting from managment of the power line corridor. The bottom substrate appears to be mostly sand on marine clay with typical meander bar formation and hard clay exposed in higher velocity stretches on the outside of the some meanders.



Chenery Brook – Reach CR3

Reach CR4. For much of Reach CR4, which extends from the footbridge to the Middle Road Crossing, habitat is similar to Reach CR3, with the stream channel meandering in a broad, mostly shrub-scrub valley except where landscaping encroaches on the east. In a stretch extending 1,000 feet downstream from Middle Road the valley narrows and the gradient steepens. In this section substrate is coarser, with gravel, sand, and some cobbles; shade is consistent because of the forest riparian cover; and both habitat and flow diversity increase.

Reach CR5. No direct observations were made of habitat in this reach. Habitat is likely very similar to uppermost section of Reach CR4, but due to the very small watershed, the stream likely has little or no flow during extended dry periods.

All non-tidal reaches. Though the Chenery Brook watershed is not that small (about 2 square miles) observation of the stream during a very dry period in 2018 showed very little flow, particularly in the upper reaches. This limits both the velocity of flow and the availability of wetted substrate. These particularly low flows are likely due to the shallow to bedrock till and silty marine clay soils that

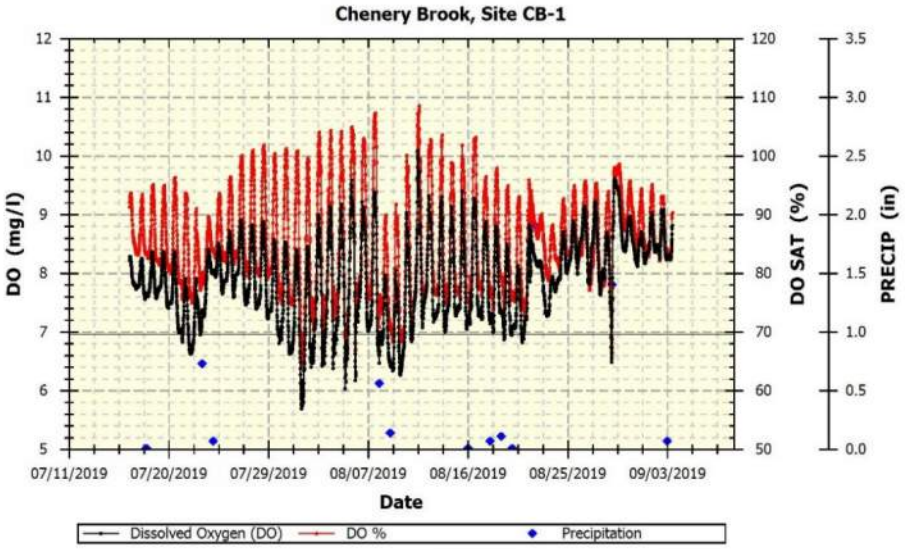
cover the watershed, neither of which have the ability to store much groundwater, thus limiting the volume of baseflow in extended dry periods.

Water Quality

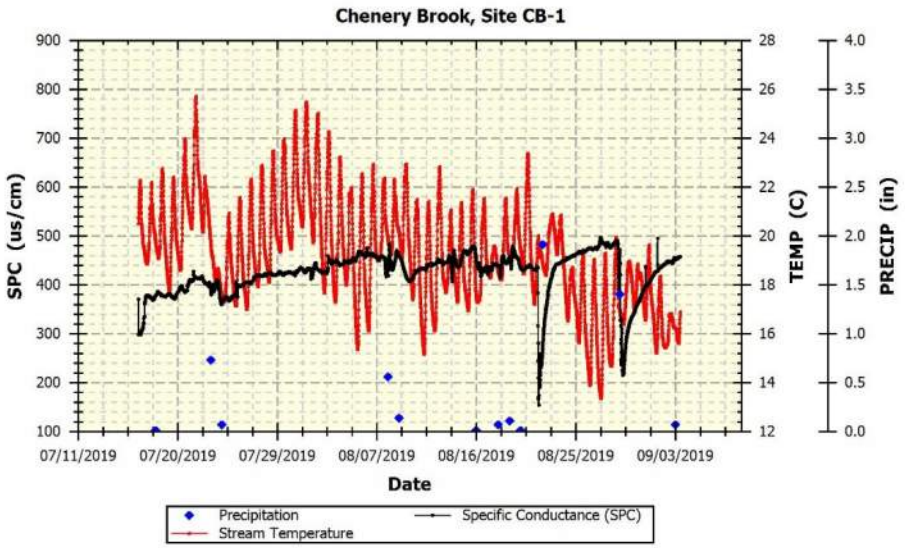
Data loggers were deployed at a site approximately 1,500 feet downstrem of Johnson Road from July 16, 2019 to September 3, 2019. The loggers recorded temperature, dissolved oxygen and specific conductance at 15 minute intervals over that period.

Temperature. For much of the time that the data loggers were deployed, daytime temperatures in Chenery Brook exceeded 20˚C, and rose to over 24˚C on several days in late July and early August. These high temperatures are likely due to 1) the fact that shade is limited in many places upstream of the site due to the shrub/scrub/meadow, as opposed to forest, vegetation on the floodplain; and 2) the low velocity of baseflow in these low gradient reaches allows a long period of exposure in unshaded areas.

Dissolved Oxygen. From July 30 to August 11 night time dissolved oxygen concentrations dropped below the 7.0 ppm Class B water quality standard. This coincided with large diurnal swings of 2.0 to 3.5 ppm, indicating that the low nightime DO was a result of periphytic algal respiration. Some growth, though not excessive growth of filamentous algae was observed upstream of the site. This suggests that nutrient levels in the brook are high enough to support significant algal production under optimal conditions and that shade is insufficient to limit that production.



Specific Conductance. During logger deployment, specific condutance at the logger station ranged between 400 µs and 500 µs, except dutring and immediately after the two largest rain events, when it dropped to around 200 µs. While these values do not suggest chloride levels that are high enough to be problematic by themselves, the fact that conductance decreases when baseflow is diluted by stormwater runoff indicates that most of the conductivity, and likely chloride, in the stream is from groundwater sources. The biggest source of chloride in the watershed is deicing salt applications on I 295, and infiltration of meltwater on the inslopes and swales that drain the road surface may explain why conductance is significantly higher than would be expected in a more natural watershed.



Biological Condition

During August of 2019 rock bags were deployed near the logger station to sample the macroinvertebrates (insects, crustaceans, worms and mollusks) living in Chenery Brook. Unfortunately, the taxonomic evaluation of these samples is not yet completed, so there is little known about the health of the stream's biological community at this point. When data becomes available this report will be updated.

Stressors to the Biological Community

Current Stressors. The water quality data and habitat analysis suggest that two stressors are currently impacting Chenery Brook's biota. These are likely to be most significant in the slower reaches without forest riparian cover and include lack of diversity in habitat and flow, and low baseflow velocities.

- *Lack of habitat and flow diversity.* The low gradient of much of Chenery Brook results in many long runs with uniformly sandy substrate on hard clay. In these runs the only variation in flow and substrate is provided by large woody debris and debris dams. The non-forested nature of the flooplain riparian cover in many of these runs limits the amount of woody debris that is deposited in the channel and its associated habitat diversity. Though we do not yet have data to confirm this, it is likely that this lack of variation in habitat in turn results in

macroinvertebrate and fish communities that are limited to taxa that do well in low velocity and sand/silty sand substrates.

- *Low baseflow velocities.* As discussed in the habitat section, baseflow in Chenery Brook during extended periods of dry weather can get very low. The resultant extremely low velocity in runs and very limited wetted bottom in riffles renders much of the stream uninhabitable by many of the taxa native to Maine free-flowing streams. As a result of climate change, droughty summers are becoming more frequent so this stressor, which is otherwise a function of natural stream coniditions, is likely to become even more limiting.

Potential Future Stressors.

- *Diurnally depressed dissolved oxygen.* The amount of periphytic algae in streams is limited by the avalability of light and nutrients. The relatively large swing in durnal DO discussed in the water quality section indicates that both light and nutrients are currently sufficient to support significant algal production in Chenery Brook. At this point the dirunal depression of DO does not drop low enough to be a serious stressor on the stream's biota. However, if either nutrient levels increased or shading of the stream channel decreased in the future, dirunal depletion of DO might result in loss of many taxa from the community.
- *Baseflow chloride toxicity.* With the exception of the interstate and the railroad, land use in the Chenery Brook watershed is mostly relatively sparse single family residential and forest, neither of which result in high levels of contamination of the groundwater with chloride. As long as this land use pattern continues it is unlikely that baseflow chloride concentration will rise to a level that is problimatic, but if land use were to shift toward commercial, institutional or office development the apparently small volume aquifer that feeds baseflow could become contaminated and salt intolerant stream biota could be lost.


Chenery Brook – Reach CR2

- *Frequent disturbance of the substrate.* Because of the relatively low impervious cover in the Chenery Brook watershed, the current storm flow regime in Chenery Brook is close enough to natural that movement of the sand substrate in the stream, while more frequent than in streams with coarser, less erodible substrates, is likely not preventing maintenance of a healthy macroinvertebrate community. If highly impervious watershed development in concert with the more intense and frequent precipitation associated with climate change resulted in substantially higher and flashier

stormflows, the frequency of disturbance of the sandy substrate could result in impairment of the stream's macroinvertebrate community. Specifically, it would likely shift the biota from taxa with annual life cycles (e.g. stoneflies, mayflies and caddisflies) to taxa with much shorter life cycles (e.g. midges, crustaceans).

Stressors assciated with downstream waters.

- *Nitrogen.* Chenery Brook is a tributary to Mill Creek which in turn drains to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. Substantial addition of any of the following land uses to the Chenery Brook watershed has the potential to degrade the stream's biota:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to dramatically increase nutrient levels in the stream, resulting enhanced algal production and lower night time dissolved oxygen.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could also elevate stream nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of the stream channel.
- Large impervious areas that have deicing salts regularly applied to them, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Falmouth's current zoning in the watershed prevents some of these land uses. The exception is the land between I 295 and the railroad, which is zoned as Business and Professional. This area is the stream corridor for much of Chenery Brook in Falmouth, and, because of steep slopes and/or floodplain, is largely unsuitable for this type of development. Rezoning of this area to more compatible land uses should be considered.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Chenery Brook watershed:

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:

  - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
  - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Agriculture. Although it is unlikely that significant commercial agriculture will be established in the Chenery Brook watershed, the following practices should be required to minimize export of nutrients to the stream if such land use is proposed:

- Commercial livestock or horse operations
  - incorporate conservative manure management practices
  - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
  - incorporate practices which minimize soil loss from cultivated fields
  - distribute runoff from cultivated areas into adjacent natural buffers

Commercial, Institutional, Office, Multi-family Residential. If zoning in the watershed is altered to allow significant development of this type, the following practices should be required, or at least encouraged.

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Resource Protection and Restoration.

- *Shoreland Zoning.* Maintaining this natural corridor of Chenery Brook is essential to preventing impairment of the stream's biota. Chenery Brook is not currently designated for protection under the Falmouth shoreland zoning ordinance. Its corridor should be zoned as stream protection to prevent significant disturbance of the vegetation shade and terrestrial habitat adjacent to the stream.
- *Instream habitat enhancement.* The lack of habitat and flow diversity in the lower gradient reaches of Chenery Brook could be addressed by strategic additions of large wood in the stream channel. These could both provide additional substrate for colonization by macroinvertebrates and improve the diversity of flow velocity in the long runs. The potential for enhancement may be limited by restrictions to access and low stream gradient.

Further Assessment Needs. The results, when available, of the macroinvertebrate samples collected in 2109 may point to a need for additional assessment of the stream and its corridor. If the macroinvertebrate community appears to be already under significant stress, more data may be needed to characterize the source and scope of the stressor(s) that are indicated. As conditions in the watershed change due to new development, monitoring should be repeated to see if the stream or its biota have been altered.

Mill Creek

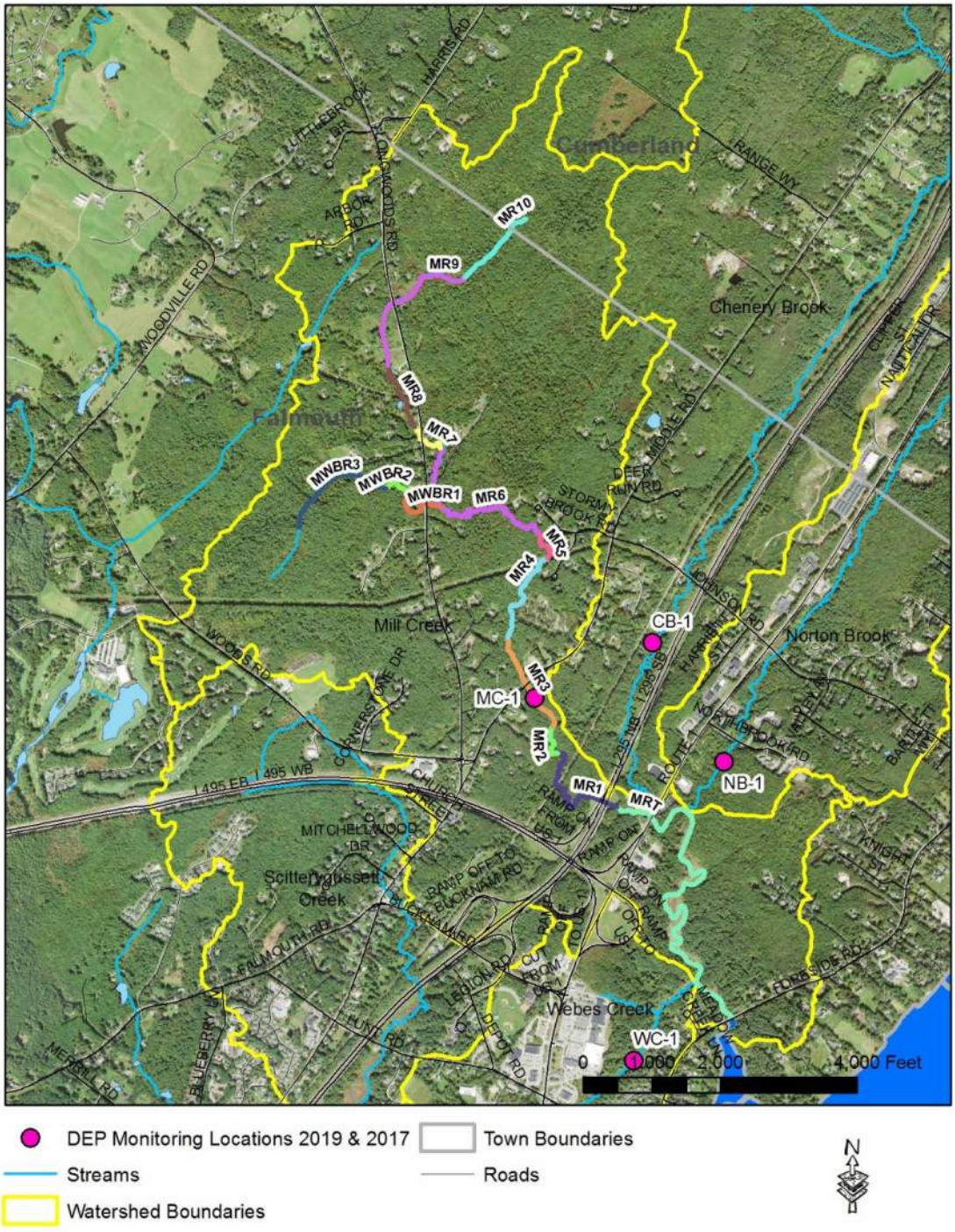
Mill Creek is a 3.7 mile long Class B stream with its headwaters in a mix of forested uplands and wetlands just northeast of the Falmouth/Cumberland boundary and roughly 2000 feet east of the junction of Longwoods Road and Arbor Road. It flows west southwest until it crosses Longwoods Road where it turns south for approximately 2000 ft before re-crossing Longwoods Road near Paddington Way. The stream continues south along the east side of Longwoods Road until it is joined by the smaller west branch just downstream of Thomas Way, at which point it drains east and then south through the forest between Longwoods and Middle Roads. It crosses Middle Road approximately 0.5 miles south of the Johnson Road intersection and continues in a southerly direction until it turns east and crosses first the railroad and then I 295, at which point it becomes tidal. It is joined by Chenery Brook just upstream of its Route 1 crossing, and then by Norton Brook 700 feet downstream of the crossing. It then meanders in a southerly direction until it is joined by Webes Creek 750 feet upstream of the Foreside Road bridge. Just downstream of the bridge Mill Creek drains into the upper mudflats of Mussel Cove.


Mill Creek - Reach MR2

Watershed Characterization

The total watershed area of Mill Creek in 3,485 acres (approximately 5.5 square miles). If the sub-watersheds of Norton Brook, Chenery Brook and Webes Creek are discounted, the remaining watershed area (its direct watershed), including portions that drain to the tidal sections upstream of the Foreside Road Bridge, is 1,345 acres. Land cover in the direct watershed is mostly forest with moderately dense single family residential development associated with Longwoods Road and Middle Road, as well as a section of I 495 and portions of the 495 and Bucknam Road interchanges. Only 6.0% of the direct watershed is covered with impervious surfaces, 25% of which are associated with the interstates and their interchanges. While the % impervious area in the direct watershed remains fairly low – it is the lowest of the four Mussel Cove tributary streams – imperviousness has increased from 4.7% to 6.0% in the period between 2004 and 2018, and virtually all of this growth was associated with residential development (including associated roads and driveways), reflecting an increase of at least 30% during that timeframe in residential land use.

Study Watershed Reach Names
Mill Creek



Geologic and Topographic Setting

Bedrock Geology, Surficial Geology and Soils. With the exception of a small area in the vicinity of Route 1, the direct watershed of Mill Creek is underlain by metamorphic rocks of the Hutchins Corner Formation. The tidal portion of the stream valley is covered by the marine clay of the Presumpscot Formation. It is bounded on the east by a ridge of reworked terminal moraine deposits of sand and silt and on the west by the Webes Creek sub-watershed. Nearly all of the portion of the watershed that drains to the free flowing stream upstream of I 295 is overlain with a thin layer of glacial till. The exception to this is a finger of marine clay deposits that extend up the relatively confined stream valley to the vicinity of Chandler Drive and Stormy Brook Road. Soils in the upper watershed are mostly shallow to bedrock till soils.
Stream Gradient and Substrate. Unlike the other Mussel Cove tributaries, the gradient of Mill Creek's channel is highly varied, with several fairly steep drops. Going upstream from the Foreside Road Bridge the tidal portion of the channel is very low gradient with a mean slope of 0.1%. Above the interstate the slope increases slightly to 0.3% as the stream passes under the railroad. It remains low gradient for roughly 600 feet upstream of the railroad crossing, where the channel suddenly steepens in a series of bedrock and boulder cascades in which it gains 30 feet of elevation in 200+ feet. Upstream of the cascade gradient moderates, ranging from 0.5 to 2.0% with variably frequent riffles as the stream crosses Middle Road and continues up to the vicinity of Stormy Brook Road, where gradient increases to 3.5% in a series of short ledge drops. Upstream of this the gradient of the main stem is quite low to the headwaters, ranging between 0.25% and 0.95%, with the exception of a short, somewhat steeper section just downstream of the Longwoods Road crossing. The channel slope of the West Branch is also fairly low, around 0.5%, except for a steep section 600 to 1000 feet upstream of Longwoods Road.

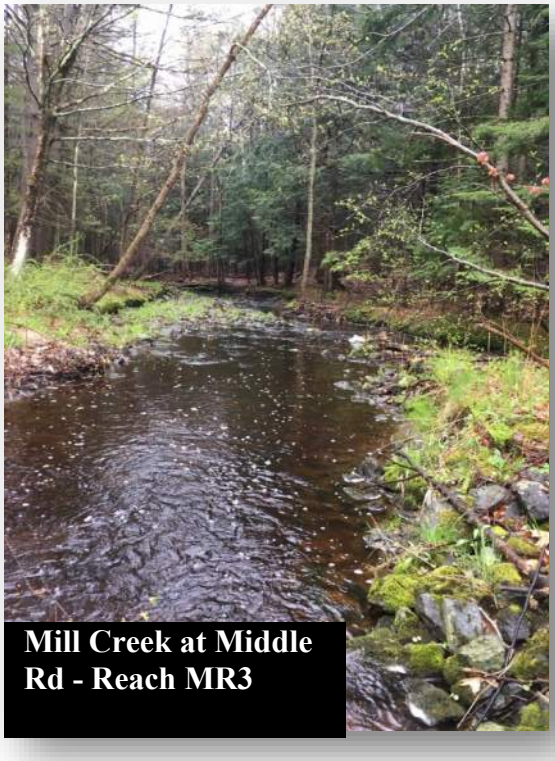
Riparian Condition

Within the tidal reach much of Mill Creek passes through tidal wetlands, and in these areas riparian cover is natural wetland vegetation. In the upper portion of this reach and in the remaining free flowing reaches of the stream the riparian cover is natural forest except in the immediate vicinity of the road and interstate crossings and in the reaches where the stream parallels Longwoods Road where some of the residential yards extend into the riparian area.

Habitat

This habitat assessment is not as detailed as the Norton Brook and Webes Creek assessments because a walk of the entire stream channel was was not performed. The assessment is based on observations at a number of key sites along the stream corridor. While no comprehensive assessment of the in-stream habitat in Mill Creek has been performed, it appears that, with the exception of the road, interstate and railroad crossings, the condition of the habitat is mostly natural. In the tidal reach the substrate in the channel is mostly sand and silty sand on marine clay. In the remainder or the stream, substrate varies with gradient and underlying surficial geology, with the steepest reaches (MR2 and MR5) principally cascade/pool habitat with bedrock, boulders and cobbles. The moderate gradient reaches (MR3, MR7 and MWBR2) have mostly riffle/run habitat with an occasional pool, and with cobbles and some boulders in the riffles and a mixture of sand, gravel and cobbles in the runs. The lower gradient reaches (MR1, MR4, MR6, MR8, MR9, MR10, MWBR1 and MWBR3) have riffle/run habitat with the length of run between riffles increasing and

the coarseness (sand and gravel, sand, silty sand) of the substrate decreasing as channel slope decreases.


Mill Creek at Middle Rd - Reach MR3

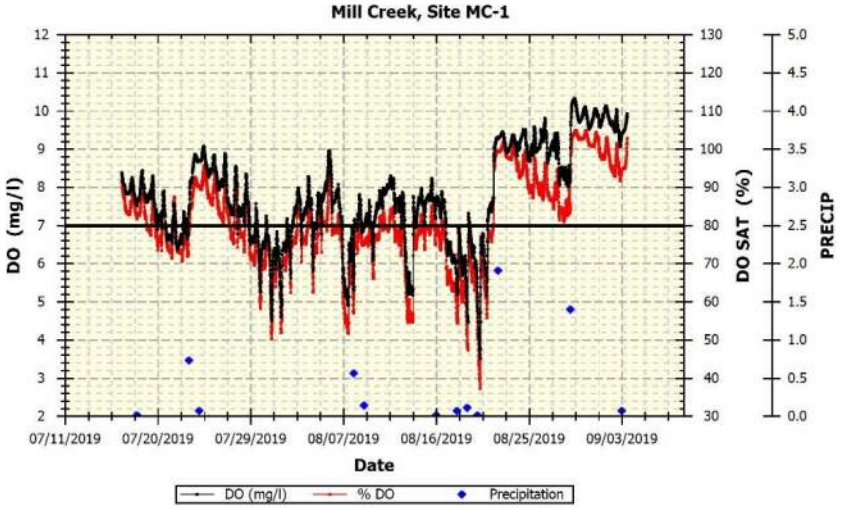
While the physical condition of most of Mill Creek appears to be natural with little evidence of instability or anthropogenic alteration, the baseflow hydrology may limit the biological community. The summer of 2018 was droughty with very infrequent precipitation. This was also true, though to a lesser degree in the late summer of 2019, and in the summers from 2014 to 2017. In early September of 2018 the sand and gravel reach in the main stem east of Longwoods Road just upstream of the confluence with the West Branch was observed to be so dry that, while there was some water in the pools, runs between the pools were completely dry with only some subsurface (hyporheic) flow. In the pool/riffle/run reach downstream of Middle Road there was only a trickle of surface flow between the pools. In August of 2019, conditions at these sites were similar to 2018, though not quite as extreme. In both years, the available habitat for the inhabitants of the stream that require flowing water was virtually non-existent, at least in these two reaches. While the watershed above the upstream site is fairly small (0.6 square miles), it is surprising that the flows drop so low at the lower Middle Road site which drains nearly 1.5 square miles. Some of this is probably natural given the limited groundwater storage in the shallow to bedrock soils that cover most of the watershed. However, the recent increase in the frequency and duration of summer droughty periods which may be associated with climate change contributes significantly to the problem and may exacerbate it in the future.

Water Quality

Data loggers were deployed at a site approximately 200 feet downstrem of Middle Road from July 16, 2019 to September 3, 2019. The loggers recorded temperature, dissolved oxygen and specific conductance at 15 minute intervals over that period.

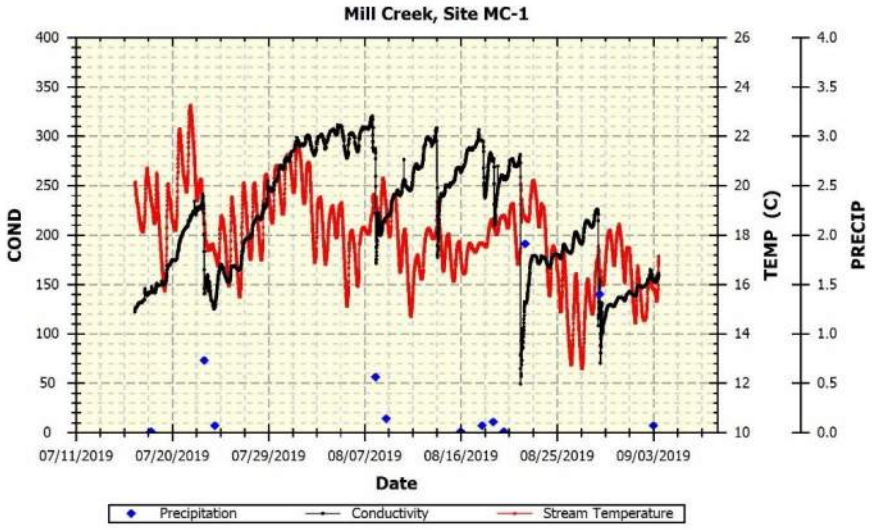
Temperature. Water temperature over the period ranged from 13˚C to 23˚C and fluctuated within this range mostly as a function of air temperature. The 23˚C reading occurred on a day when air temperature reached 94˚F and the 13˚C during a period when daytime air temperature highs were in the high 60s or low 70s. Streams such as Mill Creek are often quite cool during baseflow regardless of air temperature because their flow is mostly derived from cold groundwater, but, as discussed in the habitat section above, surface flows were so low in Mill Creek in late July and August that the

residence time of water in pools was long enough for high air temperatures to cause substantial warming.



Dissolved Oxygen. At times during the deployment dissolved oxygen concentrations (DO) at the monitoring station was lower than expected given the land use and riparian cover in the Mill Creek watershed. During the period from late July through mid-August DO frequently dropped below the Class B standard of 7.0 ppm. On several occasions DO dropped diurnally below the Class C 5.0 ppm standard, with one instance as low as 3.5 ppm. The periods of lowest early morning DO depression occur after long periods without significant rainfall and likely correlate with the lowest flows in the stream. It may be that at these lowest flows the residence time of water in pools is sufficiently long to allow bacterial digestion of benthic organic matter to deplete oxygen more than it usually would. This effect would also be enhanced by relatively limited reaeration in downstream riffles due to decreased turbulence. These oxygen concentrations are likely low enough to be problematic for sensitive organisms, but the condition is likely "natural", except that the high frequency and extended duration of periods of droughty weather that give rise to these extreme low flows may be a result of climate change.

Specific Conductance. Specific conductance (SPC) rises during the dry periods between storm events to as high as 320 µs when the stream flow is derived from groundwater. As soon as low conductivity stormwater runoff reaches the stream, SPC drops precipitously reflecting dilution of the groundwater by the runoff. The magnitude of the decrease appears to be a function of the amount of precipitation. Following the biggest rainfall (1.9 inches) of the monitored period SPC dropped from 282 µs to 49 µs, the lowest value recorded during the deployment. Since SPCs in totally natural settings range from 50 µs to 100 µs, it is likely that the groundwater that



contributes to baseflow in Mill Creek is contaminated with chloride from deicing salts applied, in this instance, to Middle Road, but the contamination is likely not high enough to be a significant stressor on the biological community.

Biological Condition

During August of 2019 rock bags were deployed near the logger station to sample the macroinvertebrates (insects, crustaceans, worms and mollusks) living in Mill Creek. Unfortunately, the taxonomic evaluation of these samples is not yet completed, so there is little known about the health of the stream's biological community at this point. When data becomes available this report will be updated.

Stressors to the Biological Community

Current Stressors. The water quality data and habitat analysis suggest that two stressors are currently impacting Mill Creek biota – extremely low baseflow during droughty periods and diurnally low dissolved oxygen concentrations extreme low flows.

- *Low baseflow*. The very low baseflow conditions discussed in the habitat and water quality sections above impact the macroinvertebrate and fish communities of Mill Creek in several ways. During these periods, most of the water in the stream is in the pools and runs, and the velocity of flow in these areas is so low as to be immeasurable. The very small amount of flow in the riffles – often just a trickle – is so shallow and narrow that it provides little if any viable habitat for organisms adapted to living in a free flowing stream. These include many of the mayfly, stonefly and caddisfly taxa. The wetted area in pools and runs is also greatly reduced, thus limiting the habitat availabe for other taxa that do not require moving water. As discussed above, this condition is partly natural and has probably been a stressor in Mill Creek during particularly dry summers in the past, but the apparent increase in the frequency of droughty periods in recent years may be increasing the effect of this stressor. The magnitude of the impact of this stressor on the macroinvertebrate community will be better understood after analysis of the taxonomic data from the 2019 macroinvertebbrate sampling is completed.
- *Diurnally low dissolved oxygen*. Early morning DO concentrations in Mill Creek drop to very low levels during periods of extreme low flow. As discussed in the water quality section above, these low DO concentrations are likely a function of the very low flows in the stream and not attributable to excessive algal production and associated nutrient inputs. The concentrations are low enough to affect the viability of particularly sensitive organsms (e.g. mayflies, stoneflies and brook trout) if the condition persists for a period of time, but the impact on these organisms when exposure is for a relatively short duration during relatively infrequent events is less well understood. As with the low flow stressor, the magnitude of the the impact of these low DO events on the macroinvertebrate community will become evident when analysis of the 2019 taxonomic data is completed.

Potential Future Stressors

- *Baseflow chloride toxicity.* The Mill Creek watershed is mostly relatively sparse single family residential and forest land use, neither of which result in high levels of contamination of the groundwater with chloride. As long as this land use pattern continues it is unlikely that baseflow chloride concentration will rise to a level that is problematic, but if land use were to shift toward commercial, institutional or office development the apparently small volume aquifer that feeds baseflow could become contaminated and salt intolerant stream biota could be lost.

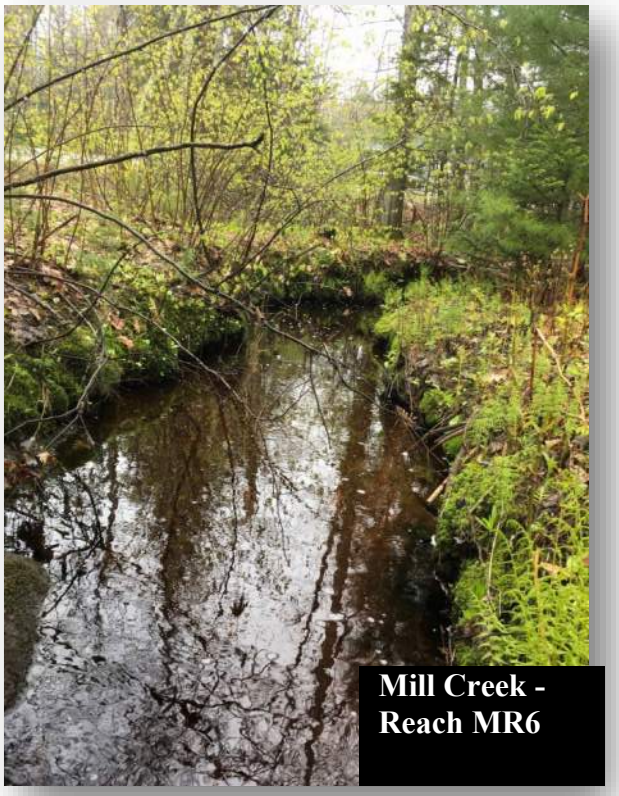
Stressors Associated with Downstream Waters

- *Nitrogen.* Mill Creek and its tributaries drain to Mussel Cove. As discussed in the stressor report for Mussel cove, nitrogen is the limiting nutrient for algal production in the Cove and there is abundant habitat in the Cove for macroalgae. While limited nitrogen data does not currently indicate elevated levels in the Cove, periodic high levels of fecal bacteria suggest the types of stormwater sources that would also discharge nitrogen are draining to the cove. There is the potential, given the available habitat, for eutrophication of the cove, including depressed oxygen levels.

Management Implications

Future Land Use. While the topographical and geological setting and the relatively low density of development in the watershed may make it more resilient than its tributary streams, substantial addition of any of the following land uses to the Mill Creek direct watershed has the potential to degrade the stream's biota:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to dramatically increase nutrient levels in the stream, resulting enhanced algal production and lower night time dissolved oxygen even in moderate flow conditions.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could also elevate stream nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater



Mill Creek - Reach MR6

runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of the stream channel.

- Large impervious areas that have deicing salts regularly applied to them, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Falmouth's current zoning in the watershed prevents some of these land uses, but if significant zoning changes are proposed the above should be considered.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Mill Creek direct watershed:

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
    - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Agriculture. Although it is unlikely that significant commercial agriculture will be established in the Mill Creek watershed, the following practices should be required to minimize export of nutrients to the stream if such land use is proposed:

- Commercial livestock or horse operations
    - incorporate conservative manure management practices
    - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
    - incorporate practices which minimize soil loss from cultivated fields
    - distribute runoff from cultivated areas into adjacent natural buffers

Commercial, Institutional, Office, Multi-family Residential. If zoning in the watershed is altered to allow significant development of this type, the following practices should be required, or at least encouraged.

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms) unless their location in the watershed indicates that peak flows in the stream would be lessened by an early release. To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of

groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.

- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Resource Protection and Restoration.

- *Shoreland Zoning.* Maintaining the natural corridor of Mill Creek is essential to preventing impairment of the stream's biota. Most of its corridor is currently zoned as stream protection. This should be expanded to include the West Branch and the portion of the main stem upstream of the confluence with the West Branch to prevent significant disturbance of the vegetation shade and terrestrial habitat adjacent to the stream.

Further Assessment Needs. The results, when available, of the macroinvertebrate samples collected in 2109 may point to a need for additional assessment of the stream and its corridor. If the macroinvertebrate community appears to be already under significant stress, more data may be needed to characterize the source and scope of the stressor(s) that are indicated. As conditions in the watershed change due to new development, monitoring should be repeated to see if the stream or its biota have been altered.

Mussel Cove

Mussel Cove is an approximately 0.1 square mile (~55 acres), intertidal embayment characterized by a narrow, 0.5 mile long channel extending from the Rt. 88 (Foreside Rd.) crossing to the Cove mouth. Mussel Cove begins at its intersection with Mill Creek, remains constricted through a shallow sill approximately 0.25 mile from the Rt. 88 overpass, and then broadens before opening to the inner Casco Bay.

Habitat

Mussel Cove is composed mostly of intertidal silt and sand flats, with some scattered boulders and ledge in the upper intertidal and at the Cove mouth. The Cove is bounded by segments of narrow, fringing salt marsh around its upper intertidal perimeter, and a dense, fringing bed of eelgrass (*Zostera marina*) at its mouth. The eelgrass bed ranges from 300-500 ft in width, and has been present since prior to 1993. The upland boundary is characterized by fringing to more extensive tree cover, behind which are residential lawns and/or fields. No more than approximately a dozen ramps and floats extend from the upland over the intertidal shoreline.

Figure 7. Mussel Cove Map.



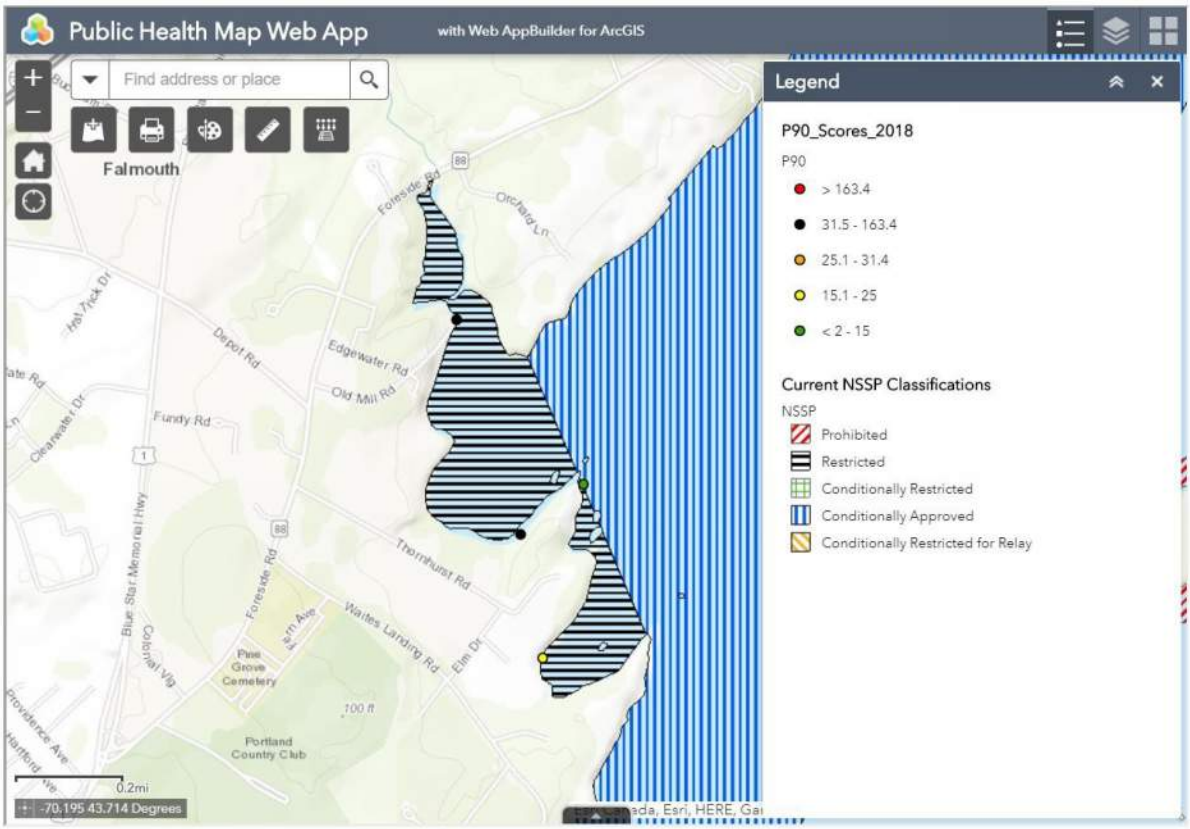
Water Quality

Known studies of Mussel Cove water quality occurred during spring-summer 2006-2008[1] and on four dates in summer-fall 2013 (Maine DEP unpublished data). While a sparse data set and representative mostly of Mussel Cove mouth conditions, available information demonstrates a marine-dominated embayment with temperature and salinity ranging from approximately 6°C to 19°C, and 24 ppt to 31 ppt (April to November), respectively. Available observations indicate low turbidity (mean 2.49 NTU), low dissolved inorganic nitrogen (<0.01 mg/L to 0.12 mg/L) and phosphorus (<0.01 mg/L to 0.21 mg/L) concentrations, and the potential for bacterial and/or algal productivity to influence dissolved oxygen and pH conditions. Total nitrogen concentrations from the 2013 survey reflect levels typical for inner Casco Bay's marine-dominated embayments (0.15

[1] Libby, S., Anderson, D. and B. Keafer. 2010. Red Tides in Inshore and Offshore Casco Bay and Their Relationship to Local and Gulf of Maine Physical and Biological Conditions: Final Report to the Casco Bay Estuary Partnership. October 2010.

mg/L to 0.31 mg/L; mean = 0.25 mg/L (n=6)). Libby, Anderson and Keafer (2010)[1] demonstrated influence at the mouth of Mussel Cove from Portland Harbor-area freshwater sources including the Presumpscot River, whose influence was observed most notably during spring (April, May) monitoring dates. The influence of Mill Creek on quality of the upper, constricted portion of Mussel Cove is not known, though localized freshening and eutrophication immediately following storm events could be reasonably expected. Similarly, the influence of surface flow off residential land during heavy rainfall could affect the water quality character overlying tidal flats and within pore water close to shore.

Mussel Cove (Area No. 13[2]) is currently "restricted" to the harvest of clams, quahogs, oysters and mussels due to elevated scores of fecal indicator bacteria, as monitored year round by the Maine Department of Marine Resources (ME DMR). Two survey sites located within Mussel Cove demonstrated geometric mean values and 90th percentile scores of 6.30 CFU/100 mL and 44 CFU/100 mL, respectively (inner site) and 5.80 CFU/100 mL and 48 CFU/100 mL, respectively (outer site) during 2018. Additional fecal coliform scores are available for 2015-2017 through ME DMR's Public Health Map Web App[3], and generally demonstrate higher scores for the inner embayment site.



[2]https://www.maine.gov/dmr/shellfish-sanitation-management/closures/documents/13.pdf
[3] https://www.maine.gov/dmr/shellfish-sanitation-management/maps/index.html

Biological Condition

No studies of the biological community are known from Mussel Cove, although the community is anticipated to consist of those benthic organisms typical of small grain size, intertidal and shallow subtidal habitats (polychaetes, bivalves, and small crustaceans). Larger crustaceans such as crabs are likely, and finfish like winter flounder and striped bass as well as marine mammals such as seals may also occupy Mussel Cove in search of food resources during tidal inundation. The persistent and dense eelgrass present at the mouth of the Cove may locally increase biological diversity and abundance of some species known to inhabit this habitat type for refuge or forage.

Stressors to the Biological Community

Sufficient water quality data gaps exist that inhibit robust assessments of biological stressors. The well documented, elevated levels of fecal indicator bacteria keep the intertidal and shallow subtidal flats restricted to harvest due to potential human health impacts, which may help to protect the natural abundance and distribution of shellfish within Mussel Cove. The periodic high levels of fecal bacteria, however, may reflect localized eutrophication of Mussel Cove. Nutrient sources to the Cove likely include wildlife contributions introduced from Mill Creek and the intertidal shoreline, runoff from urban and residential land, and human discharges from vessels operating or moored within or just outside the mouth of Mussel Cove. While the sparse nitrogen data available do not demonstrate elevated concentrations of nitrogen, the potential for increased vulnerability exists if nitrogen levels increase or loading becomes more persistent through storm events. The architecture of Mussel Cove offers quality habitat for nuisance macroalgae and accumulation of organic matter, both of which would fuel increased productivity and corresponding extremes of dissolved oxygen and pH. Additionally, eutrophication of Mussel Cove could lead to deterioration of the eelgrass resource, thereby reducing valuable subtidal habitat and water quality benefits.

Management Implications

Future Land Use. Addition of any of the following land uses to the Mussel Cove watershed, including its direct watershed and tributaries, has the potential to degrade the cove's habitat, result in nuisance macroalgae and exacerbate the events of elevated fecal bacteria:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to dramatically increase nutrient and bacteria levels in the cove.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could elevate cove nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of tributary stream channels and result in increased loading of sediment and nitrogen to the cove.

Falmouth's current zoning in the watershed prevents some of these land uses in the direct watershed, but rezoning in areas.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the Mussel Cove watershed:

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:
    - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
- Minimize the use of fertilizers and pick up pet waste.

Agriculture. Although it is unlikely that significant commercial agriculture will be established in the Chenery Brook watershed, the following practices should be required to minimize export of nutrients to the stream if such land use is proposed:

- Commercial livestock or horse operations
    - incorporate conservative manure management practices
    - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
    - incorporate practices which minimize soil loss from cultivated fields
    - distribute runoff from cultivated areas into adjacent natural buffers

Commercial, Institutional, Office, Multi-family Residential

- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

Resource Protection and Restoration.

- *Eelgrass protection.*
    - Encourage recreational vessel operators to avoid anchoring or dragging fishing gear within eelgrass beds and adjacent habitat.
    - Provide resources to recreational vessel operators about available pump out vessels and shore-side locations to avoid dumping of human waste.
- Protect fringing marsh habitat by keeping people and their belongings off the marsh surface.
- Avoid direct impacts on marine habitat by shoreline structures, and minimize indirect impacts, like shading, of intertidal and subtidal vegetation.

Further assessment needs.

- *Identification of sources of fecal bacteria.* Conduct bacteria monitoring to identify and bracket any bacterial hotspots, including tributary streams. Investigate potential sources through shoreline surveys and watershed surveys. Consider any potential sources, including leaking sewer lines and connections, malfunctioning septic systems, pet waste, wildlife and hobby farms.

- *Additional monitoring.*
    - Report any evidence of widespread, dense and/or persistent green macroalgal cover in the intertidal zone to the Friends of Casco Bay.
    - Monitor the health of the eelgrass bed at the mouth of the Cove by observing fouling (generally trailing, fluffy brown growth) on the conspicuous ends of shoots during low tides. Compare the appearance of the shoots and degree of fouling to eelgrass along the shoreline to the north and south of the Cove to determine qualitative differences in water quality that may affect the eelgrass health.

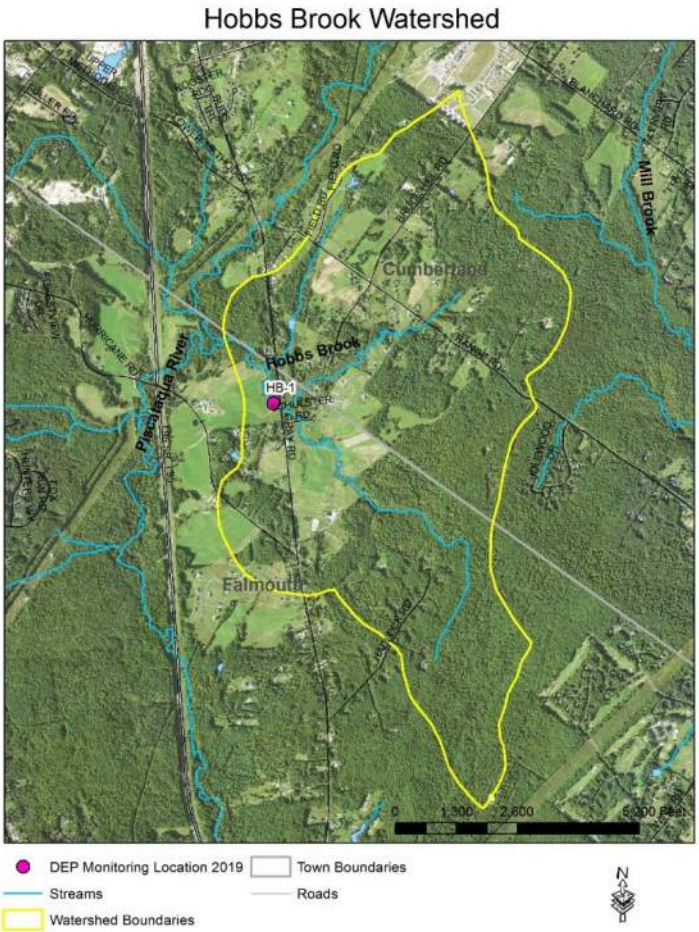
Hobbs Brook

Hobbs Brook is a 1.5 mile long stream that starts just north of Range Road in the town of Cumberland. The brook is joined by a tributary from Falmouth just prior to crossing Gray Road, and another tributary from Cumberland soon after. The brook feeds into the Pisacataqua River about half a mile upstream of the river's crossing of I-95 at Hurricane Road. Hobbs Brook is a Class B stream and does not meet water quality standards for dissolved oxygen and E. coli. Summary information about the stream and its watershed is available in Appendix 6-18 of the Maine Statewide TMDL for NPS Pollution (2016).

Watershed Characterization

Hobbs Brook's watershed is approximately 1447 acres (2.26 sq miles). Landuse consists of forested (60.3%), agriculture (34.5%), developed (4.4%) and wetland (0.8%). (Maine NPS TMDL, 2016)

Figure 8. Hobbs Brook Watershed & Monitoring Site

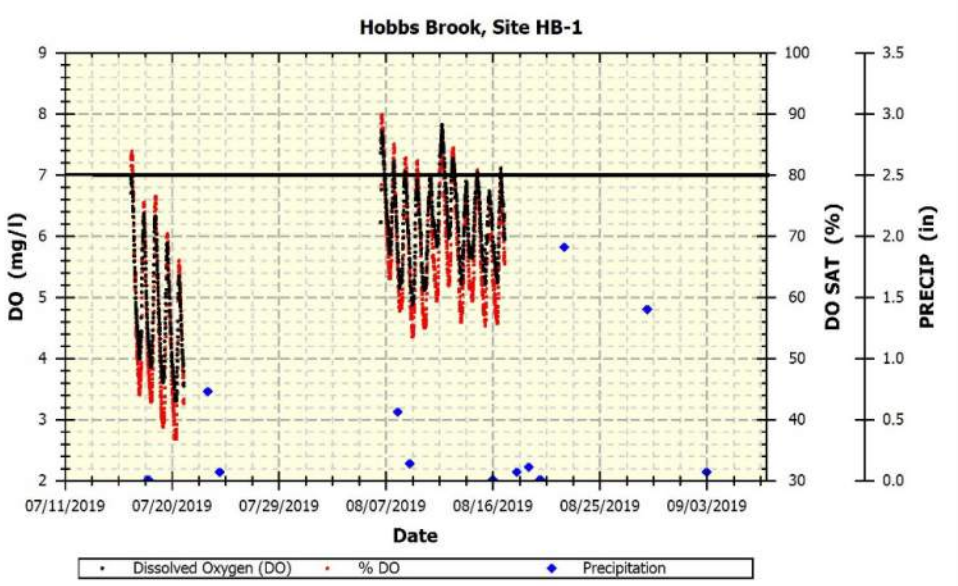


Water Quality

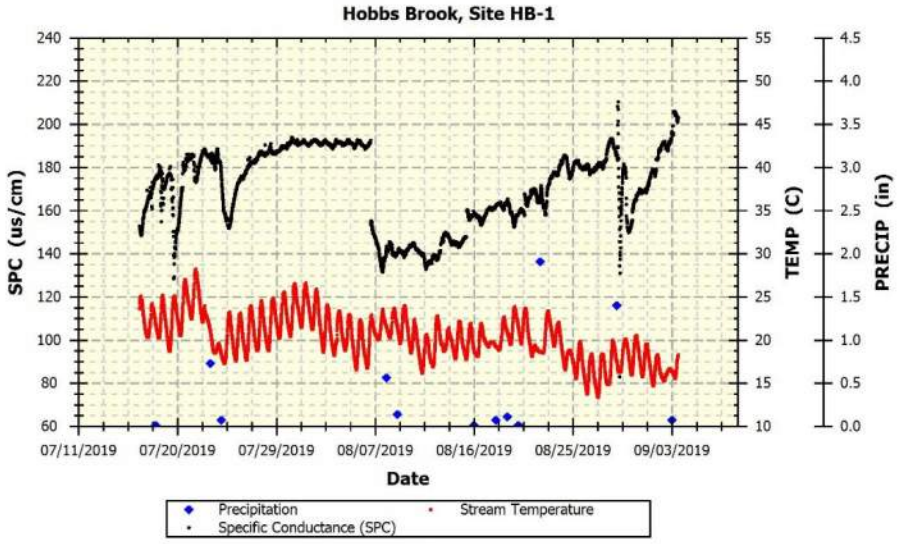
Data loggers were deployed (Site HB-1) approximately 200 feet downstream of Gray Road, alongside a hayfield from July 16, 2019 to September 3, 2019. The data loggers recorded temperature, dissolved oxygen and specific conductance at 15 minute intervals over that time period. The dissolved oxygen logger was partially buried when checked mid-deployment and at retrieval. Data was removed from analysis for those periods the logger appeared buried.

Temperature. Water temperature over the period ranged from 13˚C to 28˚C, with a mean value of 20˚C. Maine's regulations relating to temperature (06-096 CMR Chapter 582) require that discharge of pollutants not raise the temperature of any river and stream above the EPA criteria for indigenous species (23 °C maximum and 19 °C weekly average). While there are no licensed discharges on the brook, the EPA criteria indicate that during the deployment period, Hobbs Brook likely does not meet the temperature needed for indigenous species.

Dissolved Oxygen. The dissolved oxygen logger was partially buried in sediment when checked mid-deployment and at retrieval. Data was removed for the periods it appeared to have been buried. Dissolved oxygen was predominantly below the Class B standard of 7.0 ppm, with values from 3.3 ppm to 7.8 ppm, and a mean value of 5.8 ppm for the period recorded. The diurnal swing was regularly around 2 ppm, with a maximum of 3 ppm, indicating that the low nighttime dissolved oxygen was a result of periphytic algal respiration. This suggests that nutrient levels in the brook are high enough to support significant algal production under optimal conditions and that shade is insufficient to limit that production. The overall low dissolved oxygen levels indicate increased bacterial respiration as well.



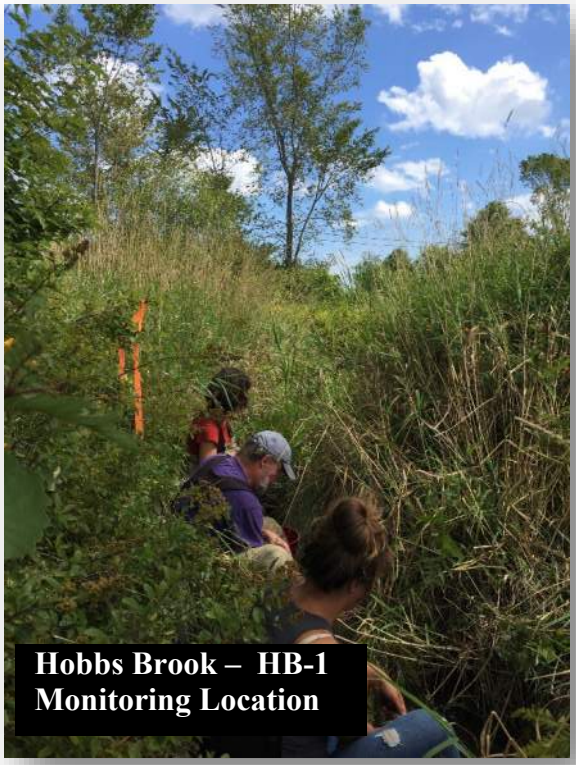
Specific Conductance. During logger deployment, specific conductance ranged between 83 µs and 210 µs, with a mean value of 170 µs. These values do not suggest chloride levels that are problematic. While not problematic to stream biota at current levels, baseflow specific conductance decreased with rainfall, suggesting slight chloride contamination of the groundwater at that location which was approximately 200 feet downstream of Gray Road.



Biological Condition

During August of 2019 rock bags were deployed near the logger station to sample the macroinvertebrates (insects, crustaceans, worms and mollusks) living in Hobbs Brook. Unfortunately, the taxonomic evaluation of these samples is not yet completed. The results will be made available when the evaluation is complete.

Stressors to the Biological Community


Hobbs Brook – HB-1 Monitoring Location

Current Stressors. The water quality data and watershed analysis suggest that two stressors are currently impacting Hobbs Brook's biota. These are likely to be most significant in the slower reaches without forest riparian cover.

- *Depressed dissolved oxygen.* The amount of periphytic algae in streams is limited by the avalability of light and nutrients. The relatively large swing in diurnal DO indicates that both light and nutrients are currently sufficient to support significant algal production in Hobbs Brook and likely results in loss of many taxa from the community. The overall low DO levels indicate increased bacterial respiration as well, possibly from manure sources given the watershed landuse.
- *Lack of habitat diversity.* The lack of forested riparian cover in many areas limits the amount of woody debris that is deposited in the channel and its associated habitat diversity. It is likely that this lack of variation in habitat in turn results in macroinvertebrate and fish communities that are limited to taxa that do well in low velocity and sand/silty sand substrates.

Stressors associated with downstream waters.

- *Phosphorus and Nitrogen.* Hobbs Brook is a tributary to the Piscataqua River which in turn drains to the Presumpscot River, then drains to Casco Bay. Phosphorus is the limiting nutrient for algal production in the freshwater Piscataqua and Presumpscot Rivers and nitrogen is the limiting nutrient in the saltwater bay. While an analysis of the Piscataqua River and Presumpscot River was not completed as a part of this study, the input of nutrients from tributaries, including Hobbs Brook should be included in such an analysis.

Management Implications


Hobbs Brook – upstream from Gray Rd crossing

Future Land Use. Substantial addition of any of the following land uses to the Hobbs Brook watershed has the potential to further degrade the stream's biota:

- Active agriculture (e.g. cattle farms, row crop truck farming or horse boarding facilities) have the potential to increase nutrient levels in the stream, resulting in enhanced algal production and lower night time dissolved oxygen.
- High densities of residential development that do not incorporate stormwater management BMPs that infiltrate runoff into vegetated areas could also elevate stream nutrient levels.
- Concentrated impervious areas (i.e. commercial, business, institutional, multiunit residential) where stormwater runoff is not distributed, intentionally or otherwise, over adjacent pervious buffer areas or otherwise attenuated by effective, well maintained channel protection detention storage could cause destabilization of the stream channel.
- Large impervious areas that have deicing salts regularly applied to them, particularly parking lots, especially if the meltwater runoff is allowed to infiltrate into the groundwater.

Stormwater Management. The following types of stormwater management practices should be required for any new regulated development and prioritized for retrofit of existing development in the watershed:

Agriculture. The following practices should be required to minimize export of nutrients to the stream:

- Commercial livestock or horse operations
  - incorporate conservative manure management practices
  - isolate clean runoff (e.g. roof) from high use areas
  - distribute runoff from pasture or holding areas into adjacent natural buffers
- Commercial row crop operations (e.g. vegetable farming)
  - incorporate practices which minimize soil loss from cultivated fields
  - distribute runoff from cultivated areas into adjacent natural buffers

Single Family Residential

- Require the initial site planning for subdivisions be laid out so that:

  - runoff from developed areas, including roads, will drain, to the greatest extent possible given the site's topography, in unconcentrated flow to protected natural buffer areas.
  - natural drainageways and intermittent channels are protected and are not diverted by road ditches but are passed under the road via culverts that discharge into the downstream continuation of the natural drainage.
- Minimize the use of fertilizers.

Commercial, Institutional, Office, Multi-family Residential. If zoning in the watershed allows significant development of this type, the following practices should be required, or at least encouraged.

- Provide secure (no infiltration potential) channel protection storage of at least the first 1.5 inches of runoff from parking, driveways and sidewalks where deicing salts are applied, such that the volume stored is discharged over a period of no less than 24 hours and no more than 72 hours. Provide additional storage for very large, low frequency events (i.e. 2, 10 and 25 year storms). To the greatest extent possible discharge this storage, at least from meltwater events, directly to the stream in order to avoid contamination of groundwater with chloride. Requiring this type of flow mitigation on new development is essential to preventing further degradation of the stream's habitat. Retrofitting it into existing development where feasible will reduce the stream's primary current stressor (frequent disturbance of substrate) and allow some recovery of the biological community.
- Encourage practices and design principles that minimize the use of deicing salts such as roofed or under-business parking, heated sidewalks and driveways, and compact parking schemes.
- Infiltrate as much salt-free roof runoff as possible.
- For new development, implement BMPs that provide effective nitrogen removal, particularly if they are treating landscaped and high traffic areas.
- Minimize the use of fertilizers on landscaped areas.

<u>Resource Protection and Restoration.</u>

- *Riparian Buffer Restoration.* Allowing woody vegetation to grow along the impacted riparian corridors is essential to restoring the stream's biota. Larger, woody vegetation would allow for the natural addition of large wood to the stream, increasing habitat diversity. Larger vegetation would also provide shading of the stream, cooling it down and decreasing growth of algae.
- *Shoreland Zoning.* Maintaining areas of natural corridor of Hobbs Brook are also essential to restoring the stream's biota. Hobbs Brook is not currently designated for protection under the Falmouth shoreland zoning ordinance. Its corridor should be zoned as stream protection to prevent further disturbance of the vegetation shade and terrestrial habitat adjacent to the stream.

- *Instream habitat enhancement.* The lack of habitat and flow diversity in the brook could be addressed by strategic additions of large wood in the stream channel. These could both provide additional substrate for colonization by macroinvertebrates and improve dissolved oxygen due to increased velocity.

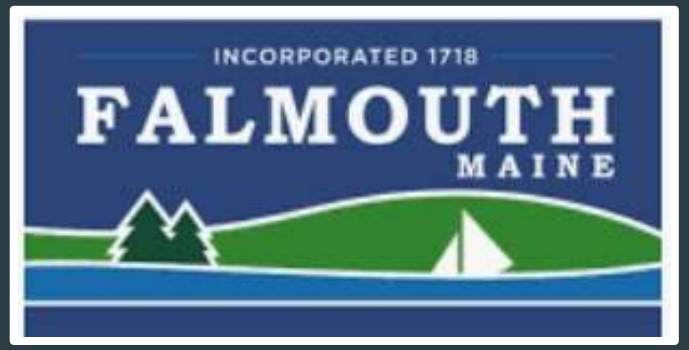
Further Assessment Needs. The results, when available, of the macroinvertebrate samples collected in 2109 may point to a need for additional assessment of the stream and its corridor. If the macroinvertebrate community appears to be under significant stress, more data may be needed to characterize the source and scope of the stressor(s) that are indicated. As conditions in the watershed change due to new development, monitoring should be repeated to see if the stream or its biota have been altered.

ATTACHMENT B: September Stakeholder Meeting Presentation

Route 1 Stormwater Initiative

Stakeholder Meeting #1

September 14, 2022





Proposed Project Goals

- Avoid Webes Creek being designated as an “urban impaired stream” by Maine DEP.

- Explore a voluntary public-private partnership that:
  - creates innovative stormwater management solutions,
  - meets regulatory requirements for current development and planned expansions, and
  - is equitable and cost-effective.



Webes Creek Watershed

Catchment #5 Extent

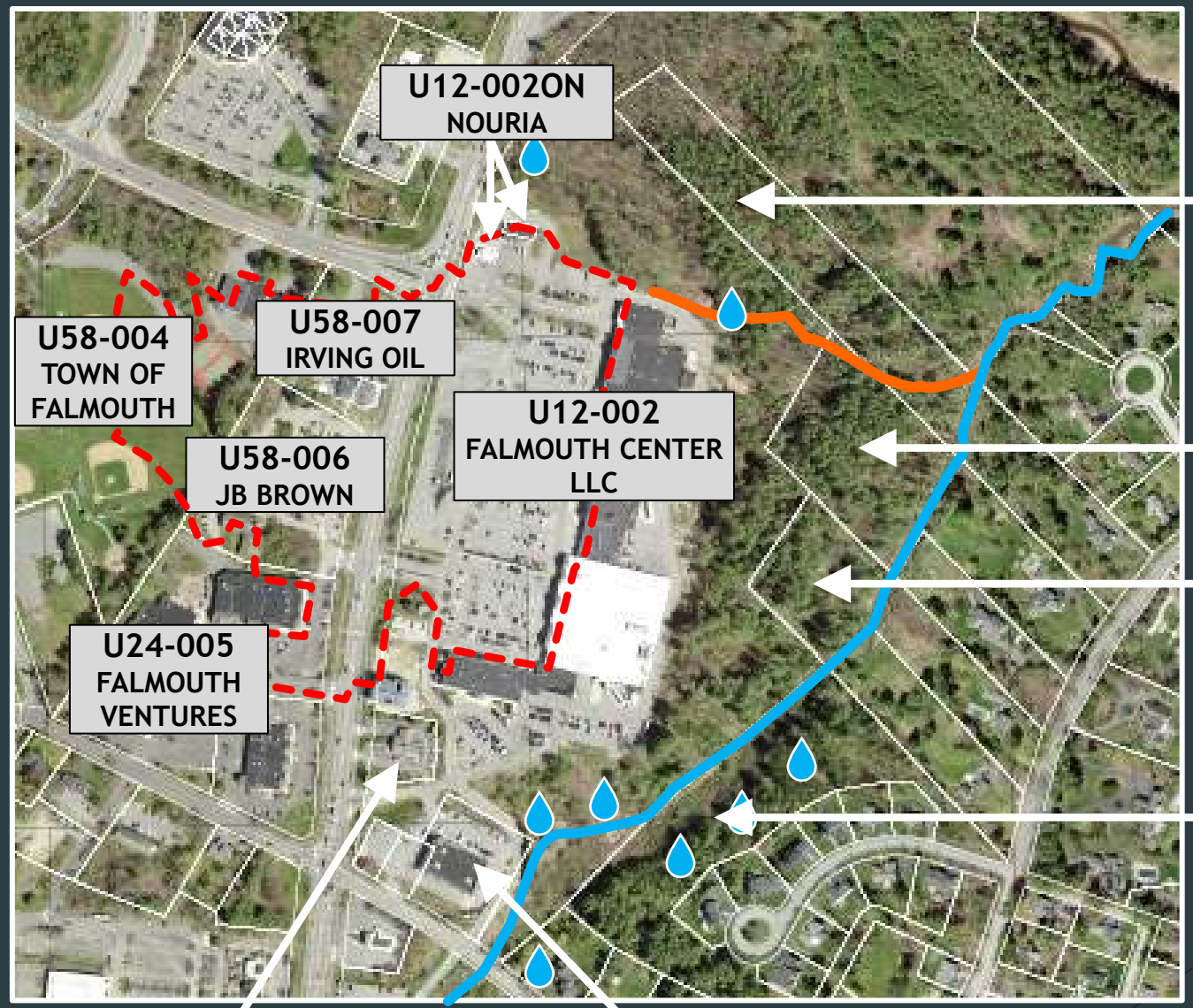
Stormwater Outlet

Catchment #5 Extent

Webes Creek

Tributary to Webes Creek

Stormwater Outlet



GOALS FOR THIS MEETING

We plan to:

- Introduce stakeholders in (and adjacent to) Catchment #5
- Describe challenges that could limit additional growth within Catchment #5.
- Discuss regulatory programs that have a “say” in Catchment #5 development
- Provide an overview of the proposed stakeholder process.
- Solicit input from stakeholders on willingness to participate in the process.
- Use feedback from stakeholders to develop next steps.

TERMINOLOGY

Stormwater

Water that runs off a surface during a rain event.

Impervious

Hard surfaces that can't absorb water.

BMP: Best Management Practice

A system that provides treatment or storage of stormwater.

Capacity

How much space is available in a pipe or section of pipe to accommodate additional runoff.

Discharge

Where water in the stormwater system enters a surface water body.

Watershed

Area of land that all drains to the same point



TREE BOX FILTER

Source: Contech Engineered Solutions



RAIN GARDEN

Source: City of South Portland

WATER QUALITY: WATER BUREAU

- Webes Creek → Mill Creek → Mussel Cove
- Class B
  - Fishing, agriculture, recreation
  - Support native aquatic species without changing the community.
- Monitoring by Water Bureau since 2013
  - Rain events (intensity and total)
  - Dissolved oxygen, specific conductance, temperature
  - Macroinvertebrates

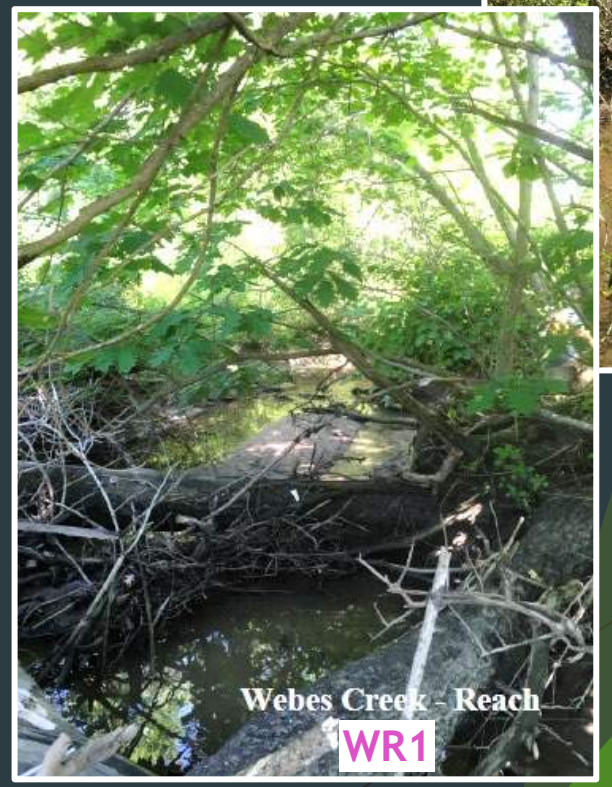


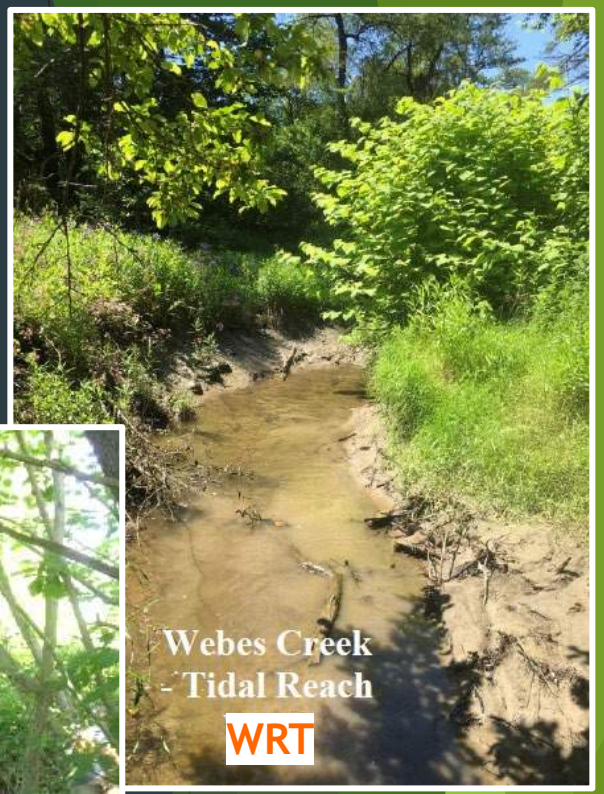
WEBES CREEK WATERSHED REACHES

Source: Maine DEP Water Bureau

WATER QUALITY: WATER BUREAU

- Findings from August 2019 Report:
  - Some good water quality
  - Low baseflow conditions
  - High chloride concentrations
  - Storm events impact habitat
- Recommendations
  - Increase stormwater storage
  - Improve stream habitat
  - Increase baseflow
  - Require BMPs that address nitrogen
  - Reduce use of salt
  - Limit development in the watershed





WEBES CREEK MONITORING AREAS

Source: Maine DEP Water Bureau

WATER QUALITY: LAND BUREAU

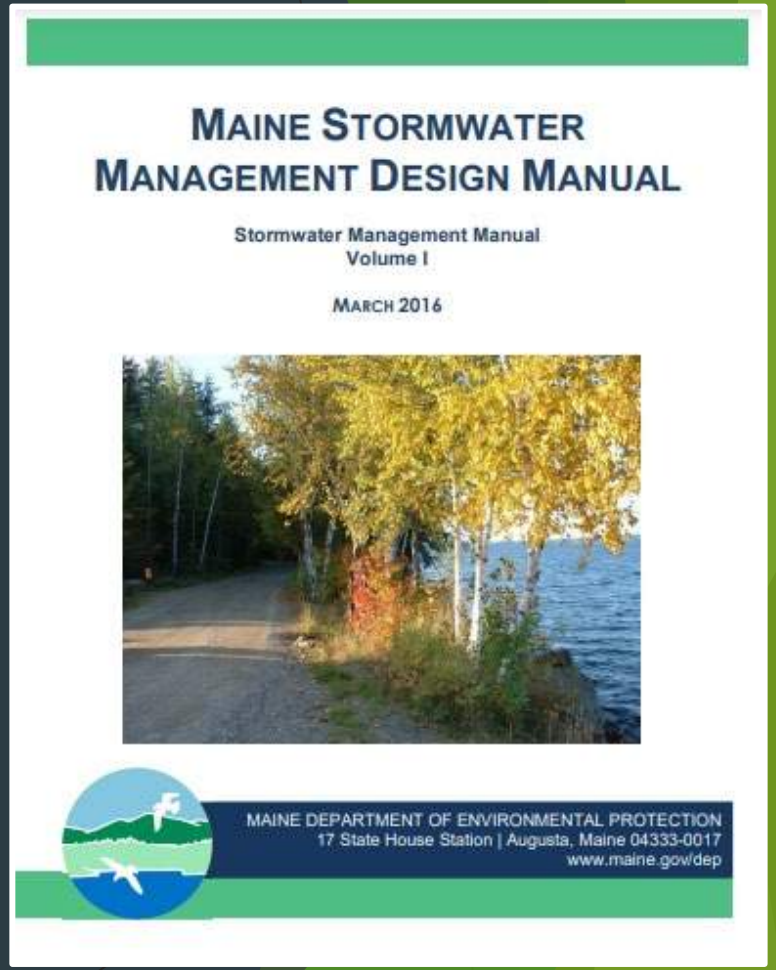
- Stormwater permitting
  - Treatment of runoff from developed areas
  - Storage of treated runoff
- Natural Resources Protection Act
  - Protect natural resources adjacent to development
- Other tools available now
  - Deny requested waivers
  - Require increased and/or nutrient treatment
  - Require treatment of more than 1” of rain
  - Even more attention, based on third party input.



SUBSURFACE SAND FILTER
Source: Acorn Engineering

CATCHMENT #5 SUMMARY

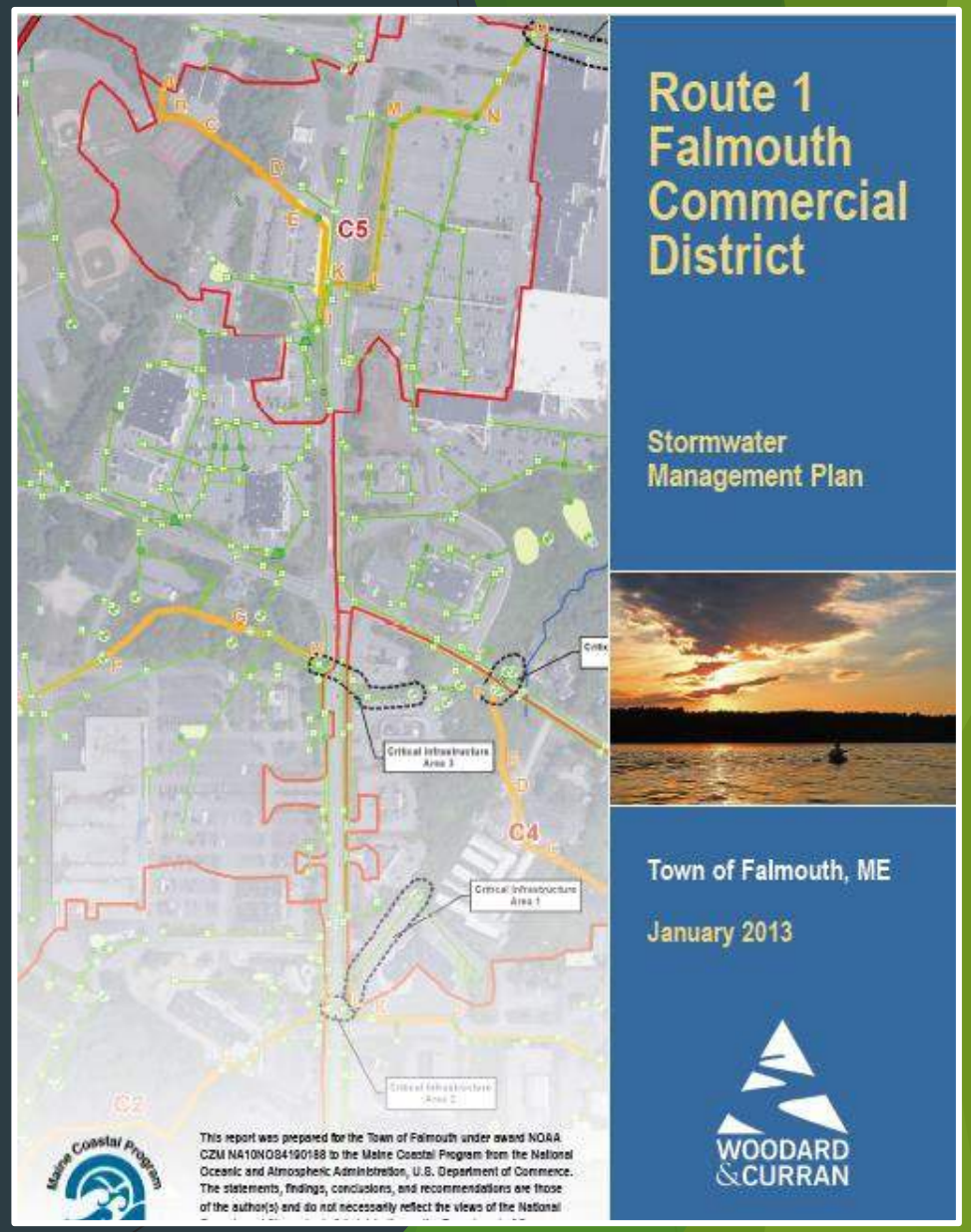
- Further degradation of Webes Creek may result in:
  - Zoning that prohibits more development
  - Higher level of treatment and/or storage
  - Stream restoration/ habitat improvement
  - Creation of a Long Creek-type watershed plan
- Costly and difficult requirements are not in the best interest of landowners or the Town.
- Town prefers to take a more proactive approach: collaborate with stakeholders in this area.



PREFERRED APPROACH

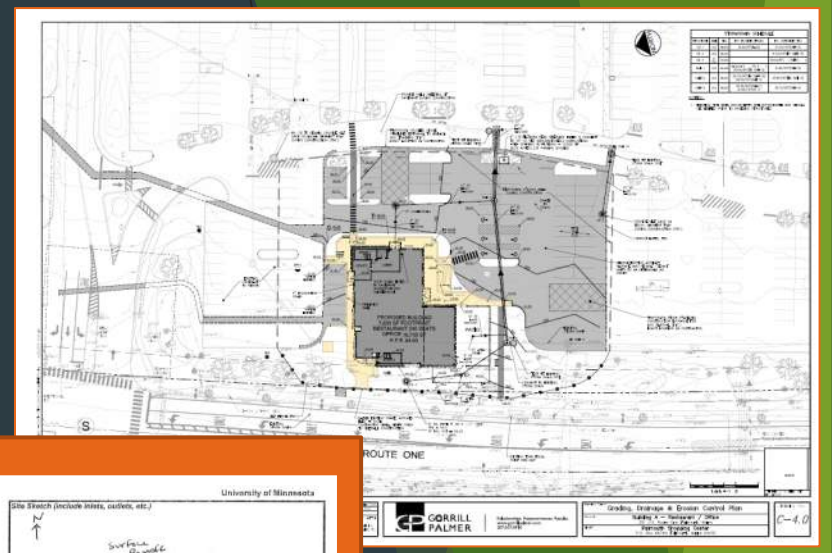
- Woodard & Curran prepared Stormwater Management Plan for the "Route 1 Falmouth Commercial District"
- Major elements:
  - Looked at the condition of private stormwater BMPs
  - Considered potential build-out
  - Assessed places stormwater retrofit was possible

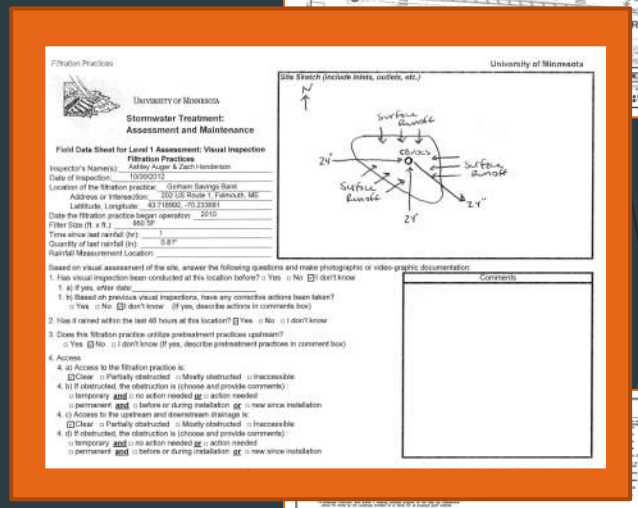
OBJECTIVE: build on the 2013 study by updating it to current conditions.

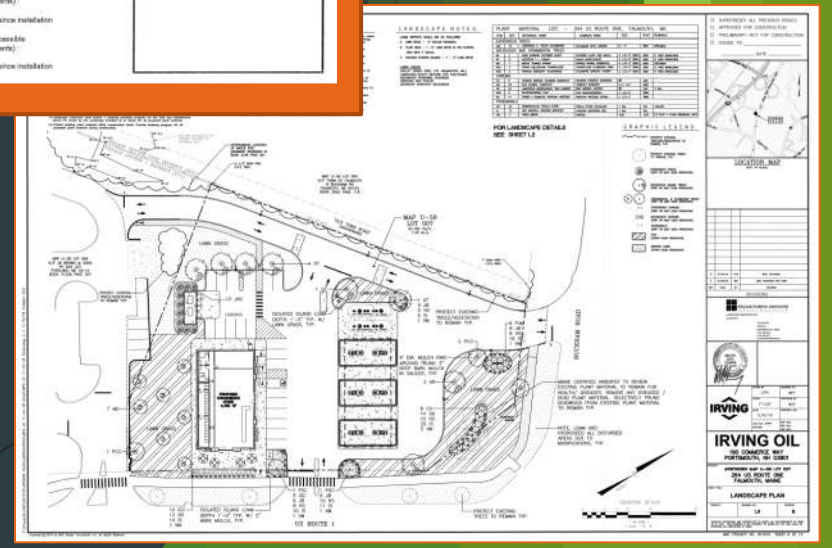


PROPOSED NEXT STEP

- Develop Existing Conditions within Catchment 5
  - Add projects constructed since 2013
  - Update condition of stormwater BMPs
  - Evaluate pipe capacity
- What's required?
  - Stakeholder willingness to participate
  - Permission to access properties
  - Land-owners share inspection & maintenance records
  - Outreach to engineers to get as-built plans
- Report back to stakeholder group with findings.







DISCUSSION

ATTACHMENT C: Minutes from September Stakeholder Meeting

Town of Falmouth, Maine
Route 1 Commercial District Stormwater Initiative: Catchment #5

Follow-Up from Stakeholder Meeting #1 (September 14, 2022)
Location: Falmouth Town Hall, 271 Falmouth Road Second Floor Conference Room
Zoom Link: https://us02web.zoom.us/j/81554983821
Meeting ID: 815 5498 3821
Passcode: 772836

Meeting Participants

- Town of Falmouth
  - Theo Holtwijk (Planning Director, retiring)
  - Theresa Galvin (Sustainability Coordinator
  - Justin Early, PE (Town Engineer)
  - Adam Causey (Planning Director, pending)
  - Nathan Poore (Town Manager)
- Acorn Engineering, Inc. (consultant to the Town)
  - Aubrey Strause, PE (in person)
  - Danielle McGowan (in person)
  - Will Savage, PE (via Zoom)
- Irving Oil Properties LLC (U58_007)
  - Brian Cyr (in person)
  - Jennifer Daigle, P.Eng. (via Zoom)
- J.B. Brown & Sons (U58_006)
  - Vin Veroneau (in person)
- Falmouth Center LLC (U12_002) and the Shops at Falmouth Center (U12-007A)
  - Jonathan Cohen (in person)
  - Kaleb Bourassa, PE (Gorrill Palmer; in person)

Not in attendance:

- A representative from Falmouth Ventures LLC (U24_005)
- A representative from Nouria Energy (U12_002ON)

Summary of the Meeting

The meeting began with a 20-minute presentation by Acorn Engineering (see ***Attachment A***) that:

- showed participants the location of Webes Creek (and its watershed) and the extent of Catchment #5;
- described challenges that could limit additional growth in Catchment #5;
- described the roles of the Maine DEP Water Bureau and Land Bureau in managing water quality;
- provided an overview of the Town's goals for this Initiative

This presentation was followed by a 40-minute discussion between Town representatives and landowners in Catchment #5, who are all stakeholders in this initiative.

The participant discussion from Stakeholder Meeting #1 has been organized into nine (9) questions, presented below with feedback provided during the course of the meeting. These questions and answers are presented *in lieu of* formal minutes and capture the nature of the conversation.

1. **Other parts of the Route 1 Commercial District discharge to Webes Creek. Why is the Town focusing on Catchment #5 for this Initiative?**
   Stormwater enters Webes Creek and the tributary to Webes Creek from multiple properties in the Route 1 Commercial District through multiple outfalls. Woodard & Curran delineated six catchments in the 2013 "Route 1 Commercial District Stormwater Management Plan" it prepared for the Town[1].

   Of these six catchments, Catchment #5 has experienced significant development (and redevelopment) since 2013, with additional growth currently under consideration. In 2013, it had by far the highest percentage of impervious area (62.45%) of any of the six catchments evaluated- a position it likely still holds.

   Some projects proposed in recent years would have been located in Catchment #5, but did not move forward because of uncertainty about their potential impact to Webes Creek and the tributary to Webes Creek.

   The outfall from Catchment #5 to the tributary to Webes Creek is located immediately upstream of the area in which Maine DEP identified habitat challenges in its January 2022 "Falmouth Study Streams Stressor Report".

   Finally, Catchment #5 has a limited number of landowners, making it possible for the Town to engage in meaningful dialogue and identify workable solutions. The lessons learned during this Initiative would inform a similar approach to other catchments.

2. **Why is DEP so focused on the habitat provided in Webes Creek?**
   Webes Creek is designated by Maine DEP as a Class B fresh surface water body. To maintain this classification, the water body needs to have certain water quality and must be able to support aquatic species that would be indigenous within it[2]. This means that certain numbers and species of macroinvertebrates should be present in biomonitoring samples[3].

   Water quality monitoring data from Maine DEP's 2019 study (see ***Attachment B*** for the Maine DEP Water Bureau January 2022 "Falmouth Study Streams Stressor Report" that summarized the portions of the 2019 study that were in Webes Creek) showed acceptable values for dissolved oxygen and temperature, and variable values for specific conductance.

[1] Available at: https://www.falmouthme.org/community-development-committee/pages/january-2013-report-materials
[2] See 38 MRSA §465: https://legislature.maine.gov/statutes/38/title38sec465.html
[3] See Maine DEP's Biomonitoring website for more information: www.maine.gov/dep/water/monitoring/biomonitoring/sampling/index.html

However:

- Maine DEP was unable to collect biomonitoring samples during the 2019 study because the sample bags were buried and/or covered with sediment.
- Maine DEP observed eroded stream banks and channel during field visits.
- Maine DEP correlated observed erosion and sedimentation with storm events that occurred during the same period.
- Maine DEP concluded in the report from this study that the macroinvertebrate community "is likely impaired."

Maine DEP has the power to classify Webes Creek as an "impaired stream" if conditions - including the quality of habitat - continue to fall short of the requirements of a Class B water. Placement of Webes Creek on an impaired stream list would have adverse implications for both the Town and private landowners.

3. Is all stormwater that discharges to Webes Creek fully treated?

No, not all stormwater discharging to Webes Creek receives treatment.

Several properties in Catchment #5 have stormwater management systems that meet current Maine DEP treatment requirements, and some recently-proposed projects will also require installation of stormwater BMPs that meet current requirements. However, other properties in Catchment #5 were originally constructed in the 1950's and 1960's, and stormwater treatment from those lots doesn't - and isn't required to - meet current requirements. These older properties would be required to upgrade stormwater BMPs to current standards if they propose work that would result in a certain amount of impervious area. When Acorn has completed the Existing Conditions Assessment, we will be able to say what percentage of impervious area in Catchment #5 is being treated.

The same statement is true for other catchments in the Route 1 Commercial District: some properties do not provide stormwater treatment that meets current standards and are not currently required to.

Stormwater that discharges to Webes Creek from catch basins in the roadway (like Depot Road) is also not treated.

4. My property has stormwater Best Management Practice (BMPs). Isn't that enough?

Stormwater BMPs can have different purposes:

- Some provide treatment of stormwater;
- Some provide storage of stormwater (treated or untreated); and
- Some provide both treatment and storage.

Not all Catchment #5 properties are required to provide treatment and storage on-site.

However, regardless of whether stormwater is treated or untreated, if it is discharged quickly to a water body like Webes Creek, the energy of the water can cause erosion. This erosion can wash out the sediments and debris that provide the habitat the stream is required to provide, like Maine DEP observed in August 2019.

The goal of the Catchment #5 Initiative is to update records on what BMPs currently exist within Catchment #5, evaluate the condition of each, and determine storage capacity.

Potential recommendations may include but are not limited to: adding new BMPs (or retrofitting existing ones) to provide more storage; restoring the natural floodplain of Webes Creek to increase resiliency during storms and thereby improve habitat; and/or infiltrating clean runoff from rooftops into groundwater.

5. **How much water discharges to Webes Creek from the town vs. from the state vs. private properties?**

   As of now, we don't know exactly how much water discharges from each type of property to Webes Creek, but the 2013 "Route 1 Commercial District Stormwater Management Plan" developed estimates of how much discharges from each of the six catchments in this area.

   We propose to update the 2013 plan, starting with Catchment #5, to get a better understanding of current conditions. Ideally, the result of the Catchment #5 initiative will suggest what catchment(s) should be the next priority for a similar review by the Town.

6. **Does participation by a Catchment #5 landowner in this initiative substitute for site-specific permitting?**

   No, participation in this initiative is not a substitute for any landowner's obligation for applying for (and receiving) any required Town or Maine DEP stormwater permitting and/or for maintaining any existing stormwater BMPs on their property.

   The objective of this Initiative is to identify projects:
   - That do <u>not</u> already have a specific regulatory driver;
   - That would address cumulative impacts to Webes Creek and its tributary;
   - That would benefit all Catchment #5 landowners by restoring habitat and thereby prevent having Webes Creek formally listed as "impaired" by Maine DEP.

7. **No landowner in the Route One Commercial District wants a version of the Long Creek Watershed Management Project to be forced on us. How do we prevent it?**

   Maine DEP determined that Long Creek was impaired because it didn't provide adequate habitat to support the types of aquatic species that should be present.

   The Long Creek WMP formed after USEPA and Maine DEP determined that regulation of stormwater from municipal and state properties was not enough to restore the desired habitat: regulation of stormwater from private property was also required.

   The goal of the Catchment #5 Initiative – and similar evaluations of other catchments – is to improve water quality and/or conditions in Webes Creek before a similar determination is made. These improvements may be in the form of additional stormwater treatment or storage, floodplain restoration efforts, or other projects.

8. How committed is the town to working with Private landowners?

The Town has demonstrated through its participation in projects in the Route 1 Commercial District that it is very committed to doing what it can to restore Webes Creek and allow for development of the Route 1 Commercial District.

One example of this commitment includes the FocalPoint® stormwater BMPs the Town installed along Route One, using dedicated funding from its Route One Tax Increment Financing (TIF) Districts.

A second example of the commitment is the Town's financial contribution (as part of a public/private partnership) to install additional stormwater treatment BMPs on Hat Trick Drive during a private project to add additional parking for the Family Ice Center.

In the Catchment #5 Initiative, the Town's role may include adding new BMPs on property it owns to provide more storage, contributing to a floodplain restoration project in Webes Creek, or participating in a way that has not yet been envisioned.

9. What do you need from the participating landowners now?

The Town has four requests of property owners in Catchment #5 to allow Acorn to perform an Existing Conditions Assessment:

1. Provide as-built plans (record drawings) from any projects constructed on your property since 2012.
2. Share the most recent inspection report or maintenance record (for example, cleanout of the Isolator Row of subsurface stormwater chambers) for all stormwater treatment and/or storage BMPs on your property.
3. Share the summary, logs, and/or videos of the most recent closed-circuit television (CCTV) inspection of the drainage system on your property.
4. Grant permission for the Town's team (including Acorn) to access your property to verify the location of stormwater BMPs and to perform inspections of the stormwater system and parts of Webes Creek.

Together, this information will allow Acorn to field-verify structures, evaluate system capacity, and determine the condition of existing treatment and storage BMPs.

Acorn will follow up separately on these four requests.

Attachments

A: Acorn Stakeholder Meeting #1 Presentation
B: Maine DEP Water Bureau January 2022 "Falmouth Study Streams Stressor Report"

ATTACHMENT D: Sources of Data Used in this Evaluation

References

Numerous references or resources were used by Acorn Engineering to get an understanding of stormwater infrastructure in Catchment #5. These are listed chronologically by newest to oldest.

1. 2023, January 16. USDA Natural Resources Conservation Service (NRCS) Soil Report for the Catchment #5 area.

2. 2022, January. *Falmouth Study Streams Stressor Report: Individual Watershed Reports*, prepared by Maine DEP's Watershed Unit.

3. 2021, September 30 (Final). *Strategic Watershed Plan*, prepared by ATTAINING: Sustainable Solutions, LLC for the Town of Falmouth.

4. Google Earth aerial images (all available)

5. 2021 and 2022. Town of Falmouth Tax Map #240 (www.cumberlandcountyme.gov/Departments/Regional%20Assessing/Falmouth/Tax%20Maps%202022/TaxMaps_11x17_240.pdf)

6. 2013, January. *Route 1 Falmouth Commercial District Stormwater Management Plan*, prepared by Woodard & Curran, Inc., for the Town of Falmouth.

Related to Building A (261 US Route 1) at Falmouth Center, LLC (U-12 Lot 002)

As-Built Plans

- 2022, March 22. VHB Sheet Sv-1 with markups with as-built elevations for Building A (261 US Route 1) and Building B (241 US Route 1) utilities. Provided by Gorrill Palmer on November 21, 2022.

Proposed Plans

- 2021, April 20. Sheet C-4.0, Grading and Drainage Plan for Building A (261 US Route 1), revised and submitted per Town Engineer Comments.
- 2021, March 9. Plans (18 sheets) other than Sheet C-4.0. Final May 2021 Site Plan Application, prepared by Gorrill Palmer.

Applications for Local Review

- 2021, April 4: Stormwater Memo for Amended Site Plan Application, prepared by Gorrill Palmer

Other Plans

- *None*

Inspection Reports

- *None*

Related to Building B (241 US Route 1) at Falmouth Center, LLC (U-12 Lot 002)

As-Built Plans

- 2022, March 22. VHB Sheet Sv-1 with markups with as-built elevations for Building A (261 US Route 1) and Building B (241 US Route 1) utilities. Provided by Gorrill Palmer on November 21, 2022.

Proposed Plans

- 2020, November 10. Plan Set (19 sheets) for February 2021 Final Site Plan Review Application.

Applications for Local Review

- 2020, November 10. February 2021 Site Plan Review Application for Building B at Falmouth Shopping Plaza (Falmouth Center, LLC), 74 pages, prepared by Gorrill Palmer. This included a Stormwater Memo (6 pages) as Attachment F, but no site plans.

Other Plans

Inspection Reports

Related to Falmouth Center, LLC, 251 US Route 1 (U-12 Lot 002)

As-Built Plans

Proposed Plans

Applications for Local Review

Other Plans

- 2005, March 30. Sheet C-1: Overall Existing Conditions Plan for Falmouth Shopping Center (Falmouth Center, LLC), prepared by Appledore Engineering, Inc. Provided by Gorrill Palmer on November 21, 2022.

Inspection Reports

- 2021, May 4. Pipe inspection report prepared by EJ Prescott/Plastic Pipe Fabrication for Commercial Properties Management, 251 US Route 1 (Falmouth Center, LLC). 131 pages.

Related to Nouria Energy Retail Maine, Inc. (U-12 Lot 00-ON2)

As-Built Plans

- *None*

Proposed Plans

- *None*

Applications for Local Review

- *None*

Other Plans

- *None*

Inspection Reports

- None

Related to The Shops at Falmouth Center (U-12 Lot 007A)
As-Built Plans

Proposed Plans

Applications for Local Review

Other Plans

Inspection Reports

Related to Falmouth Ventures, LLC c/o Scion Management LLC (U-24 Lot 005)
As-Built Plans

Proposed Plans

Applications for Local Review

Other Plans

Inspection Reports

Related to Town of Falmouth Infrastructure in US Route 1 (U-58 Lot 004)

As-Built Plans

- 2022, September 13. GIS data of the stormwater system in Catchment #5, provided by Judy Colby-George of Viewshed (formerly Spatial Alternatives), who managed stormwater GIS for the Town of Falmouth.

Proposed Plans

- 2014, May 12. Route 1 Infrastructure Project Sheets, prepared by Fay, Spofford & Thorndike (FST) for the Town of Falmouth. Provided by Gorrill Palmer on November 21, 2022, as follows:
  - Sheet 38 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 10+00
  - Sheet 38A of 113: Grading, Drainage and Erosion Control Plan for Depot Road from Route 1 to exit from Falmouth Shopping Center.
  - Sheet 39 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 312+25 to 315+00 (240 US Route 1)
  - Sheet 40 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 315+00 to 317+75 (Falmouth Ventures, LLC at 240 US Route 1; 251 US Route 1)
  - Sheet 41 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 317+75 to 320+50 (256 US Route 1 and 251 US Route 1)
  - Sheet 42 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 320+50 to 323+25 (264 US Route 1)
  - Sheet 43 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 323+25 to 326+00 (264 US Route 1)
  - Sheet 43A of 113: Grading, Drainage and Erosion Control Plan for Bucknam Road Station 1+00 to 3+50.
  - Sheet 44 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 326+00 to 328+75 (265 US Route 1 and 266 US Route 1)
  - Sheet 45 of 113: Grading, Drainage and Erosion Control Plan for Route 1 Station 328+75 to 331+50 (270 US Route 1)

Applications for Local Review

Other Plans

- 2013, January 25. Existing Conditions Plans for US Route 1, prepared by Northeast Civil Solutions for the Town of Falmouth. Provided by Gorrill Palmer on November 21, 2022, as follows:
  - Sheet 6 of 8 (Intersection with Depot Road)
  - Sheet 7 of 8 (Irving/ Key Bank/ Starbucks)
  - Sheet 8 of 8 (Intersection with Bucknam Road)

Inspection Reports

Related to JB Brown & Sons (U-58 Lot 006)

As-Built Plans

Proposed Plans

Applications for Local Review

Other Plans

Inspection Reports

Related to Irving Oil Properties (U-58 Lot 007)

As-Built Plans

Proposed Plans

- 2018, May 7. "Stormwater Management, Drainage Calculations & Best Management Practices", May U-58 Lot 007, 91 pages. Prepared by MHF Design Consultants, Inc., for Irving Oil Marketing, Inc. (264 US Route 1) Includes Pre- and Post-Development HydroCAD model results and Drainage Plans.

Applications for Local Review

Other Plans

Inspection Reports

Appendix D: Stream Crossing Resilience Survey

STREAM CROSSING RESILIENCE SURVEY SUMMARY REPORT

Prepared for the Town of Falmouth, Maine



Culvert inlet and headwall on Twin Ponds Drive



Perched, sliplined culvert outlet on Eastern Avenue

Prepared by:

Acorn Engineering, Inc.
16 Middle St., Suite 302
Portland, ME 04101

FB Environmental Associates
97A Exchange St., Suite 305
Portland, ME 04101

Field assessments conducted:
May - October, 2025

Issued on:
December 19, 2025

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- Culvert assessment data – Microsoft Excel supplemental files

A. INTRODUCTION

Justin Early, PE
Assistant Public Works Director/ Town Engineer, Town of Falmouth
101 Woods Road, Falmouth, Maine 04105

December 19th, 2025

Subject: Stream Crossing Resilience Survey Report

Mr. Early:

Acorn Engineering and FB Environmental (the Project Team) are pleased to provide the Town of Falmouth (the Town) with the following Report, which presents an analysis of 138 Town-owned cross culvert and stream crossing assets inspected in May through October 2025. Through the RFP issued by the Town for this project, and through discussion with Town staff, the Project Team understands that the Town's drainage infrastructure has been subject to increasing pressure and damage in recent years due to high intensity storms, and that prioritized repairs to high-risk, vulnerable, and ecologically degraded culverts and road-stream crossings would increase the safety, resilience, and sustainability of the Town's transportation network and water resources. The scope of work included in this assessment report was partially funded by a Clean Water State Revolving Fund (CWSRF) loan awarded to the Town in 2024. The CWSRF low-interest loan program is a partnership between the Maine Municipal Bond Bank and Maine DEP.

The goal of this field assessment and Report is to inform future maintenance and planning efforts. It is our aim that this Report will assist the Town in planning for regular cross culvert and stream crossing maintenance, inform decision-making strategy for infrastructure replacements, support potential road-stream crossing grant applications, and, once implemented, improve the overall condition and resiliency of the Town's drainage network.

Organization of this Report

An Executive Summary has been provided at the head of the report to summarize notable conclusions and recommendations discussed further in the body of the report.

The main body of this report has been organized to present the project chronologically from initiation phase to completion of the report.

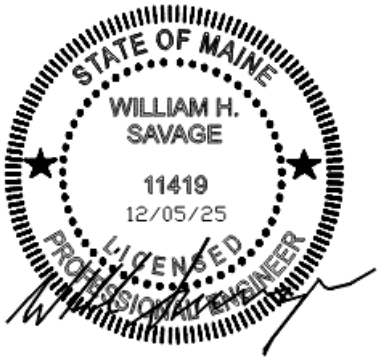
- The body of the report begins by discussing project initiation, establishment of scope of work and establishment of inspection and assessment criteria.
- We then move into a presentation of methodologies for field work, data processing, scoring, and prioritization.
- Finally, we provide a discussion of general trends across the 138 assessed assets, briefly discuss priority crossings, and recommend actions to improve resiliency, performance, and habitat throughout the network.
- Included in the Conclusions section is a brief presentation of potential funding opportunities which may be leveraged by the Town to complete upgrades to their infrastructure.

Sincerely,

Finn Bondeson, PE
Associate Project Manager



William Savage, PE
Principal



Craig Burgess, PE
Senior Project Manager



EXECUTIVE SUMMARY

The analysis and results presented in the following report reveal that there is a need to increase hydraulic capacity and habitat connectivity at cross-culverts and road-stream crossings (assets) throughout Falmouth's roadway drainage network. This executive summary has been prepared to highlight common, overarching issues and defects observed during in-field inspections of the 138 assets included in the assessment and the subsequent desktop study. Discussion is continued in further depth in the body of the Report.

Structural Condition, Performance, and Desktop Study Criteria

Many of the evaluated assets exhibited one or more indicators of an underperforming crossing. Perched outlets (14% of assets), constriction of flow width by the crossing (17%), and presence of downstream erosion or a scour pool (10%) are a few notable examples. Sediment accumulation and sliplining, each of which further reduce hydraulic capacity, were observed at 42% and 22% of the assets, respectively. In addition, many of the study's assets failed to provide habitat connectivity for either aquatic or terrestrial organisms. Perched outlets, scour pools, lack of mineral streambed, and undersized, smooth-bore pipes, which were observed throughout the network, significantly encumber fish and terrestrial animal passage beneath the road. Of the 48 assets depicted as a blue line on USGS topographic maps, 73% are identified as potential barriers to aquatic organism passage on the Maine Stream Habitat Viewer, which is managed by Maine Department of Inland Fisheries and Wildlife.

After conducting a scoring and ranking exercise, Acorn identified 18 "high priority" assets which were deficient in multiple condition, public safety, and performance criteria. A table presenting characteristics of the 18 priority assets is included in this Executive Summary. Thirteen (13) of these assets could be hydraulically modeled using data sourced from the USGS StreamStats database, and Acorn's hydraulic analysis revealed that only one (1) of the thirteen (13) crossings is sized to freely pass discharge from a 100-year storm event. Undersized crossings impound water against the roadbed, increasing the potential for road failure through overtopping or erosion of the road base material. Pavement degradation at the crossing was observed at 13% of the assets at the time of inspection, likely from the effects of road base saturation, flow along the culvert/structure walls, or shallow cover at the crossing. For crossings that lie beneath dead-end or high-volume roadways, failure would present risks to life safety and normal flows of traffic.

When replacing cross culverts and stream crossings, design to StreamSmart guidelines is recommended, including spanning 1.2x the bankfull width of the stream or channel, providing 1.2x freeboard during the 100-year storm event, and providing natural substrate at the channel bottom. More details on StreamSmart design can be found in MDOT's StreamSmart Guidebook. It is understood that budgetary constraints may not allow for such robust design at cross culvert replacements not within jurisdictional streams. Nonetheless, Acorn encourages the Town to increase hydraulic capacity when replacing cross culverts to increase storm resiliency across the network.

Habitat and Water Quality

The most common habitat and water quality issue observed throughout the assessment was the presence of invasive, non-native plant species, which occurred at 94 of the 138 assessed crossings (68%). Invasive species are the second greatest global threat to biodiversity after habitat loss, often spreading quickly and overtaking native vegetation. All other habitat and water quality indicators were observed at a much lower frequency, occurring at 0-17 assessed crossings. Of these, foam, algae, poor riparian buffers and road shoulder erosion were the most commonly observed issues. Overall, FBE documented 11 high-priority culverts based on environmental indicators. Recommendations include regular water quality monitoring to better understand potential water quality issues, invasive species management and native plantings to improve riparian buffers, and installation of erosion control practices to mitigate nonpoint source pollution.

Below is a table summarizing notable characteristics of the 18 assets identified as "high priority" assets in Acorn's performance, structure, and desktop study rankings. Further information on ranking and prioritization can be found in report Sections C & D of this report, as well as the spreadsheets provided as an Appendix.

Falmouth Stream Crossing Resilience Survey Summary Table - Priority Assets Based Upon Structure & Desktop Rankings											
Asset	Structure & Desktop Study (Acorn) Score	Habitat & Water Quality (FBE) Score	Total Score	Street	USGS Stream	MDOT AADT	Dead End Road	Diameter (in.)	Material	Estimated Replacement Cost	Primary Defects
0656	**23**	3	26	Hillside Ave	No	180	Yes	18	CMP	$ 50,000 - $190,000	Collapse, corrosion, debris accumulation, upstream and downstream erosion, perched outlet, constriction
0403	**16**	5	21	US Route 1	No	15186	No	36	RCP/HDPE	$ 260,000 - $320,000	Cracking, corrosion, debris accumulation, upstream and downstream erosion, sliplined
0303	**14**	4	18	Bucknam Rd	Yes	13227	No	36	CMP	$ 330,000 - $480,000	Corrosion, misalignment with stream channel, invert degradation, debris accumulation (paired with 0987)
0724	**14**	1	15	US Route 1	No	11893	No	36	RCP/HDPE	$ 260,000 - $320,000	Debris accumulation, upstream erosion, flow constriction, surface deformation at median, sliplined
0987	**14**	4	18	Bucknam Rd	Yes	13227	No	36	CMP	$ 330,000 - $480,000	Corrosion, misalignment with stream channel, invert degradation, debris accumulation (paired with 0303)
0188	**13**	2	15	Woodville Rd	No	1260	No	20	HDPE	$ 50,000 - $190,000	Pavement and road surface degradation, shallow cover, collapse, cracking, perched outlet
0859	**11**	0	11	Winn Rd	No	3067	No	24	RCP	$ 200,000 - $250,000	Pavement and road surface degradation, flow constriction, erosion upstream and downstream, scour pool, perched outlet
0384	**10**	4	14	Johnson Rd	Yes	2800	No	40	RCP/HDPE	$ 490,000+	Flow constriction, erosion upstream and downstream, perched outlet, sliplined
0664	**10**	3	13	Eastern Ave	Yes	151	Yes	48	CMP/HDPE	$ 490,000+	Flow constriction, perched outlet, location in FEMA floodplain, sliplined
0772	**10**	1	11	Northbrook Dr	Yes	257	Yes	48	RCP	$ 490,000+	Flow constriction, degradation of gabion retaining walls
0201	**9**	4	13	Winding River Ln	No	243	Yes	20	PVC	$ 50,000 - $190,000	Downstream erosion, perched outlet
0343	**9**	1	10	Route 1	No	8232	No	18	CMP	$ 50,000 - $190,000	Collapse, corrosion, debris accumulation
0415	**9**	0	9	Hurricane Rd	No	432	No	20	CMP	$ 50,000 - $190,000	Pavement and road surface degradation, corrosion, debris accumulation
0553	**9**	1	10	Grist Mill Dr	No	212	No	18	CMP	$ 260,000 - $320,000	Corrosion, invert degradation, debris accumulation
0653	**9**	1	10	Hillside Ave	No	180	Yes	15	CMP	$ 50,000 - $190,000	Collapse, corrosion, debris accumulation, downstream erosion, perched outlet
0723	**9**	1	10	Route 1	No	11893	No	36	RCP/HDPE	$ 260,000 - $320,000	Surface deformation at median, downstream erosion, sliplined
0766	**9**	2	11	Woodville Rd	Yes	1768	No	30	RCP	$ 490,000+	Corrosion, perched outlet
1191	**9**	2	11	Schuster Rd	Yes	118	Yes	48	CMP	$ 490,000+	Corrosion, failed invert, flow constriction, debris accumulation

B. FIELD ASSESSMENT

The following section describes the inspection and assessment of select Town-owned culvert and stream crossing assets throughout Falmouth. Preliminary inspections were conducted by the Project Team during June 2025. Data were reviewed by the Project Team and preliminary results were discussed with the Town in August 2025. After Subsequent follow-up field visits to add additional photographic data and confirm and cross-check preliminary inspection criteria were performed in August and October 2025.

B.1 Scope of work and inspection criteria

During a project kickoff meeting at the Town's Public Works facility in March 2025, the Project Team and Town staff discussed the proposed assessment scope of work and reviewed potential inspection criteria of interest to the Town. Town staff established that they would review the existing infrastructure records housed in their geospatial asset management software, OpenGov, and compile a list of approximately 150 town-owned cross-culverts and road-stream crossings to be assessed by the Project Team. Scope would be limited to assets passing beneath Town roadways, and no driveway culverts would be included.

Additionally, the Project Team and Town discussed buildout of the culvert and crossing inspection form to be used to collect data on the in-scope crossings. The form was to be housed within OpenGov, with back-end setup to be completed by Town Staff. The Project Team proposed various inspection criteria valuable to improving the Town's understanding of their infrastructure, and to support potential future stream crossing grant applications, to be included in the inspection form.

Subsequent to the meeting, the Project Team compiled the inspection criteria in a Microsoft Word document and provided the document to the Town to assist in back-end inspection form setup in OpenGov. After brief discussion of inspection criteria between the Town and Project Team to set the final criteria, the inspection form was set up in OpenGov by Town staff. In general, inspection criteria were to inform a handful of overarching categories: verification of parent asset data, condition/performance of the crossing, potential habitat impacts, and potential water quality impacts.

A brief summary of inspection criteria is provided below. The full list of inspection criteria can be viewed in the supplemental data provided with this Report, and in the inspection results saved in OpenGov.

Parent Asset Data

- Structure type
    - Parent asset data was reviewed and modified where necessary to indicate what type of structure the crossing was, e.g. pipe, box, arch, etc…
- Material type
    - Parent asset data was reviewed and modified where necessary to indicate what material the crossing structure was made of, e.g. HDPE, PVC, RCP, CMP, etc…
- Structure diameter
    - Parent asset data was reviewed and modified where necessary to accurately capture structure diameter or span. Measurements were taken with a tape measure.

- Structure length
    - Parent asset data was reviewed and modified to the nearest 5-feet where necessary to verify approximate length of the crossing structure. Note that this variable was modified for very few crossings, in cases where parent asset data varied significantly from field conditions, an approach confirmed by the Town.
- Lining method
    - Where the asset had been lined, the lining method was recorded; e.g. sliplining, segmented, smooth bore
- Structure slope
    - Slope of the structure was recorded using a 4-foot smart level to the nearest tenth of a percent. Smart level measurements were taken at the inside top wall of the structure, where safe access was available.
- Conveyance type
    - The type of channel conveyance passing through the structure was recorded; e.g. stream, vegetated swale.
- Upstream and downstream channel material
    - The material of the upstream and downstream channel bottom was recorded; e.g. riprap, mineral streambed, woody vegetation, grass vegetation

Structure Condition and Performance

- Road surface condition (e.g. pavement degradation at crossing, heaving, etc…)
    - The road surface immediate to the crossing was inspected, and a box was checked if there was pavement degradation, deformation in the pavement surface, or erosion in the traveled way in the culvert vicinity. Localized road surface degradation may be related to failure or improper installation of the culvert (e.g. shallow cover leading to heaving).
- Structure condition
    - The structure was inspected for signs of degradation, and a box was checked if defects in the pipe or span were observed; e.g. collapse, corrosion, degraded invert, cracking, joint separation, fluid bypass along the outside wall of the structure, spalling
- Structure alignment to flow of water
    - The orientation of the structure to the flow of water was assessed and given a score of adequate, fair/moderate, poor, or critical. In general, culverts aligned parallel to the flow of water more easily convey flow and are less susceptible to causing erosive or constricting conditions than culverts skewed 45 degrees or greater to the flow of water.
- Stream width
    - At crossings with perennial flow, the stream width upstream and downstream of the crossing was measured with a tape measure and recorded.

- Sediment and debris accumulation
    - The structure was inspected for presence of debris and sediment accumulation, and the degree of blockage was recorded in the following categories: None, 0-25%, 25-50%, >50%, or clogged. Culverts with significant debris and sediment accumulation are more likely to constrict flow and contribute to poor drainage conditions.
- Erosion at road embankment/shoulder
    - The road embankment and shoulder local to the structure were inspected for signs of erosion. Erosion was recorded on a presence/absence basis both upstream and downstream of the structure.
- Erosion at culvert/structure invert/stream channel
    - The streambed or channel/ditch local to the structure was inspected for signs of erosion. Erosion was recorded on a presence/absence basis both upstream and downstream of the structure, with an option to record a scour pool. Scour pools may indicate severe constriction of flow and are most often observed at perched culverts where water exiting the culvert is flowing at a high energy, erosive state.
- Erosion at stream banks
    - At stream-type crossings, the streambanks local to the structure were inspected for signs of erosion. Erosion was recorded on a presence/absence basis both upstream and downstream of the structure.
- Perched culvert/structure inlets
    - The structure inverts were inspected for a perched condition, where the structure is elevated above the surrounding streambed or channel bottom. Especially at the downstream ends of culverts, a perched condition can hasten erosion as water falls out of the culvert at a high energy, erosive state. Additionally, many aquatic organisms cannot access the structure to pass beneath the road when culverts are perched, resulting in habitat fragmentation.

Habitat and Water Quality Impacts

- Rain within 24 hours
    - To provide context for the survey responses, this box was checked for each survey if rain was received within Falmouth in the previous 24 hours. Weather Underground precipitation history for the nearest station (Portland International Jetport) was used to determine precipitation history.
- Water clarity
    - If water was present during the inspection, this parameter was categorized as clear or turbid water. If there was no flow during the inspection, the response was left blank. Turbid water can occur naturally but may also indicate a source of upstream erosion that may be contributing excess sediment or pollutants.
- Potential pollution indicators
    - FBE assessed each crossing for a variety of potential water quality pollutant indicators which included odor, algae, foam, iron oxidation, and sheen. Presence or absence of each of these indicators was documented. These indicators may occur naturally and may not indicate poor water quality, but further follow-up is recommended in order to determine the cause.

- Riparian buffer status
    - FBE assessed the quality of the riparian buffer around each crossing. The buffer was categorized as dense, sparse, or none. A dense buffer indicated that there was primarily forest or wetland around the crossing with a robust buffer of trees and shrubs. A sparse buffer includes some vegetation around the crossing and stream but may also include sections of lawn or other bare land uses. No buffer indicates that the surrounding buffer is entirely lawn or bare soil that provides little to no habitat or water quality benefits.
- Invasive species
    - Presence or absence of non-native, invasive plant species was documented at each crossing. Invasive plants threaten the biodiversity of native plant species and do not provide sufficient benefits to native wildlife.
- Macroinvertebrates
    - At stream crossings, FBE assessed for the presence or absence of macroinvertebrates by turning over rocks, leaves, and/or woody debris within the stream channel. This indicator was marked as not assessed for crossings with no flow during the inspection or stormwater drainage systems not tied to a stream. The indicator may have been marked not assessed for select stream crossings that could not be safely accessed to assess macroinvertebrate presence. Macroinvertebrates are a key component of the aquatic food chain. Certain species are more tolerant of pollution while others are very sensitive to pollution. Species identification of macroinvertebrates was outside of the scope of this project.
- Beavers
    - The presence or absence of beavers was assessed at each crossing by looking for signs of recent beaver activity such as gnawed trees or the presence of beaver dams or lodges.
- Erosion
    - FBE assessed for the presence of nearby sources of erosion that could pose water quality threats to adjacent streams or drainage channels. When erosion was observed, FBE documented if it came from one or more of the following sources: adjacent land use, ditch, invert, active construction, road shoulder, or streambank.
- Land use
    - At each crossing, FBE documented the adjacent land use types into one or more of the following categories: agriculture, commercial, forest, industrial, dense residential, rural residential, and wetland. Agriculture, commercial, industrial, and dense residential land uses are likely to have a negative impact on water quality unless appropriate stormwater management practices are in place to filter pollutants prior to discharge into the stormwater system or stream.

The inspection form contained a “notes” section, in which the Project Team could record notable characteristics of the crossing or add context to the observed conditions. Additionally, the form allowed the Project Team to indicate if they were unable to locate or inspect the crossing.

After compiling the list of in-scope culverts and building out the inspection form in OpenGov, the Town set up a work order to assist the Project Team in systematically collecting data within the software. A total of 142 crossings were included in the preliminary Scope of Work, and the Town gave the Project Team permissions to review, edit, and attribute data to these crossings in OpenGov.

B.2 Inspection and data collection methodology

During June, August, and October 2025, the Project Team mobilized to the 142 assets throughout Town to conduct the assessment. Using the OpenGov smartphone application, the Project Team was able to navigate through the Work Order and fill the inspection form criteria in real time in the field. Dependent on the criteria being assessed, data were recorded as a picklist value, checkbox, or typed entry field. Additionally, photographs of conditions observed at each asset, and surrounding habitat at the crossing, were captured and attributed to the inspection form and parent asset. Any data captured in areas of limited network connectivity were saved within the app for upload when the Team moved into an area with adequate service.

Throughout the assessment, Acorn staff collected or verified parent asset data, as well as filling in the structure condition and performance sections of the inspection form. FBE staff collected data on habitat and water quality impact criteria. The majority of the inspection criteria were assessed through visual observation, and a smart level or tape measure were used to assess dimensional criteria such as the structure slope, diameter, and stream width.

After preliminary assessment was completed in June 2025, the Project Team met with the Town to discuss preliminary results and review potential data gaps. In August and October 2025, the Project Team remobilized to several crossing locations to confirm data, capture additional photos, and complete inspections at crossings which were inaccessible earlier in the season due to dense and thorny vegetation. During remobilization, the Project Team also confirmed presence or absence of a few assets which did not appear to exist. Two crossings, assets 0441 & 1050, could not be located and were presumed to not exist. One crossing, asset 1192, could not be located and likely exists but appeared completely buried. Due to its status as a State-owned bridge, one crossing on Hurricane Road was removed from the scope. Additionally, two assets on Twin Ponds drive functioning as a single, linear culvert were combined to form as single asset. In total, 138 crossings were assessed in the final scope. The complete list can be viewed on the OpenGov database under this project's Work Order.

C. RANKING & PRIORITIZATION

The following section describes the methods used to rank and prioritize the 138 assessed crossings.

C.1 Data Organization

After the field assessment was complete, Town staff assisted the Project Team with exporting data from OpenGov for use in Microsoft Excel. Once the export was complete, the Project Team utilized Microsoft Excel to divide the data between Acorn and FBE for analysis relevant to each consultant's expertise. Each asset/crossing was given a row in the spreadsheet, with inspection criteria being in columnar format. Extraneous or irrelevant columns contained in the export file were hidden or deleted from analysis. Data were spot-checked between individual inspection records in OpenGov and the spreadsheet to confirm the export and post-processing preserved proper data organization.

Addition of Desktop Study Data

To add context to the field data, several desktop study-level criteria were added to the assessment by Acorn. To help assess potential vulnerability and flood risk, and to provide information relevant to municipal stream crossing grant applications, the following desktop study criteria were assessed for each asset:

- Indication of if each asset is on a dead end roadway.
- Estimate of Average Annual Daily Traffic (AADT) at each asset location.
    - AADT is a measure of estimated vehicle trips per day at a certain point along a road; this data was sourced from the MaineDOT Public Map Viewer for all 138 crossing locations. For scoring, AADT values were assigned a score of 0, 1, 2, or 3, generally based upon Federal Highway Administration recommendations for categorizing roadways as "Local", "Minor Collector", "Major Collector", and "Minor Arterial".
- Indication of whether each asset may be constricting flow (upstream stream width > downstream)
    - For assets at stream crossings, measured stream widths upstream and downstream of the culvert were compared. All culverts with wider stream widths upstream than downstream were earmarked as potential constrictions to flow.
- Status of each asset's presence in a FEMA-mapped floodplain.
- Status of each asset's presence in a tidally-influenced area.
- Status of each asset's presence within critical plant or animal habitat on the Maine Department of Inland Fish & Wildlife's Beginning with Habitat map viewer.
    - Assets located within critical habitat often score higher in stream crossing replacement grant applications.
- Status of each asset as being located on a "blue line" perennial stream on USGS topographic maps.
    - Each of the 138 asset locations was compared against USGS topographic maps to proxy whether the crossing would be defined as a "stream" by most regulatory jurisdictions. Where applicable, the parent asset data was updated to indicate "stream crossing", as opposed to "cross culvert". Crossings defined as streams often score higher in stream crossing replacement grant applications.
- Status of each asset as a "potential barrier" or "barrier" to aquatic organisms on the Maine Stream Habitat Viewer.

- Each of the 48 assets at stream crossings was compared against the data in the Maine Stream Habitat Viewer to identify whether the crossing has previously been identified as a barrier or potential barrier to aquatic organisms by the Maine Stream Connectivity Work Group. Crossings identified as barriers or potential barriers often score higher in stream crossing replacement grant applications.

C.2 Ranking and Scoring

Once the inspection data was compiled and organized in Excel, the Project Team assigned each inspection criterion a ranking based upon the presence, absence, or severity of defect, habitat indicator, or desktop review category. Data in each column, for each criterion, was converted into a numerical score based on the type of data in that category. Yes/No categories were converted into a binary score of 1 or 0. Ranked categories and AADT were converted into an integer (e.g. 0,1,2,3,4) based upon severity of defect or number of trips.

The numerical scores for certain structure, performance, and desktop study categories were multiplied, or weighted, by a factor of 2 prior to raise the relative importance of those categories in the final, summed score. Categories to be weighed were based on Acorn staff's prior experience with identifying important indicators for assessing crossing integrity and potential habitat impacts, and a comparison of the rankings with photos from site visits.

Weighted categories included the following:

- Potential to serve as a barrier to aquatic organisms
  - This criteria is a key scoring factor in many grant applications.
- Evidence of collapse or failure of the structure
  - This condition is a key indicator of potential failure of the crossing, which may lead to delayed emergency response, road closure, or threats to life safety.
- Deformation of the pavement surface at the crossing (e.g. heaving or collapse)
  - This condition is a potential indicator of crossing structure degradation. Failure of the crossing may lead to delayed emergency response, road closure, or threats to life safety.
- Degradation or failure of the culvert invert
  - This condition is a key indicator of potential failure of the crossing, which may lead to delayed emergency response, road closure, or threats to life safety. Additionally, invert failure, especially in corrugated metal culverts, produces hazardous conditions and barriers for aquatic organisms.
- Evidence of flow constriction (upstream width > downstream)
  - This condition indicates that the culvert may not adequately convey flow beneath the roadway during storm events. This increases the likelihood of roadway overtopping during storm events, leading to delayed emergency response, road closure, or threats to life safety.
- Evidence of roadway embankment erosion or erosion at the culvert invert.
  - This condition indicates that the culvert may be exacerbating erosion during storm events. Persistent erosion increases the likelihood of roadway or culvert/structure failure during storm events, leading to delayed emergency response, road closure, or threats to life safety.
- Perched condition at the culvert invert

- This condition indicates that the culvert may be undermined at its outlet, and is at higher risk of failure during storm events. Additionally, perched culverts most always serve as barriers to aquatic organisms.

The scores for each ranking criterion were then summed for each asset to calculate a score for structure, performance, and desktop study criteria (by Acorn), a score for environmental criteria (by FBE), and a total score. A higher score in either ranking system indicated that the asset should be considered a higher priority for future repairs. Scores for each of Acorn's and FBE's analyses were summed to rank the assets in order of highest priority of replacement to lowest. A map depicting the summed score of each asset is presented in Figure 3 below. For further information on ranking and scoring, please reference the spreadsheets provided with this report as an Appendix.

In general, we found the combined score to be non-impactful to the study discussion, as there was significant overlap between priority assets identified in the combined score and the priority assets identified by Acorn and FBE individually. Additionally, the Acorn score was the primary driver of total score due to the higher number of ranking criteria contributing to Acorn's scoring matrix. Due to these factors, we have separated discussion of priority assets between the structure, performance, and desktop study criteria, and the environmental criteria. These discussions are presented in Sections D.3 and D.4 of this report.

For the structure, performance, and desktop study criteria assessed by Acorn, the top 18 assets (having a score of 9 or greater) were flagged as high priority for potential action by the Town. For Acorn's criteria, the maximum possible score was 58, and the highest-ranking (worst-performing) asset had a ranking of 23. Most of the assets (121 of 138) scored 6 or lower; the distribution of structure, performance, and desktop study scores is shown in Figure 1. Further discussion of general results of structure, performance, and desktop study criteria is given in Section D.1 of this report, and specific discussion of the 18 high-priority culverts is included in Section D.3.

Stream Crossing Capacity Analysis

Forty-eight (48) of the study's assets were located on USGS "blue-line" streams. To contextualize existing capacity of the stream crossings, Acorn utilized the USGS StreamStats web application to estimate the bankfull width and 1% AEP (100-year) discharge of the watercourse at each crossing. Bankfull width is defined as the distance across a stream channel at the top of the banks and is commonly understood as the width a stream exhibits immediately prior to overflowing into its natural floodplain. Bankfull width and discharge (flow) are commonly observed during a 1-to-2-yr storm event. For each of the 48 assets at stream crossings, bankfull width estimated by StreamStats was compared with the existing dimensions of the crossings to provide a high-level estimate of existing capacity at each crossing. Note that in general, bankfull widths generated by StreamStats modeling are theoretical in nature, may misrepresent field conditions, and should always be confirmed by field study if to be used for design. However, our comparison of estimated bankfull widths to existing crossings dimensions was conducted to provide a high-level overview of trends across the 48 assets at stream crossings. General discussion of the capacity of stream crossings across the study network is included in Section D.1.

At each of the thirteen (13) high-priority assets for which StreamStats data was available, hydraulic capacity of the existing culvert(s) or structure was compared with 100-year storm discharge using the Federal Highway Administration's culvert modeling software, HY8, to assess existing capacity. In cases where the existing crossing is undersized, HY-8 was used to model potential designs capable of conveying 100-year storm discharge. Note that this high-level, preliminary sizing is not comprehensive, and did not consider embankment/roadway elevation,

characteristics of any upstream impoundments, specific channel geometry immediate to the crossing, and other levels of detail requiring further study if the crossing were chosen for replacement. Specific discussion of the high priority crossings modeled in this way is provided in Section D.3.

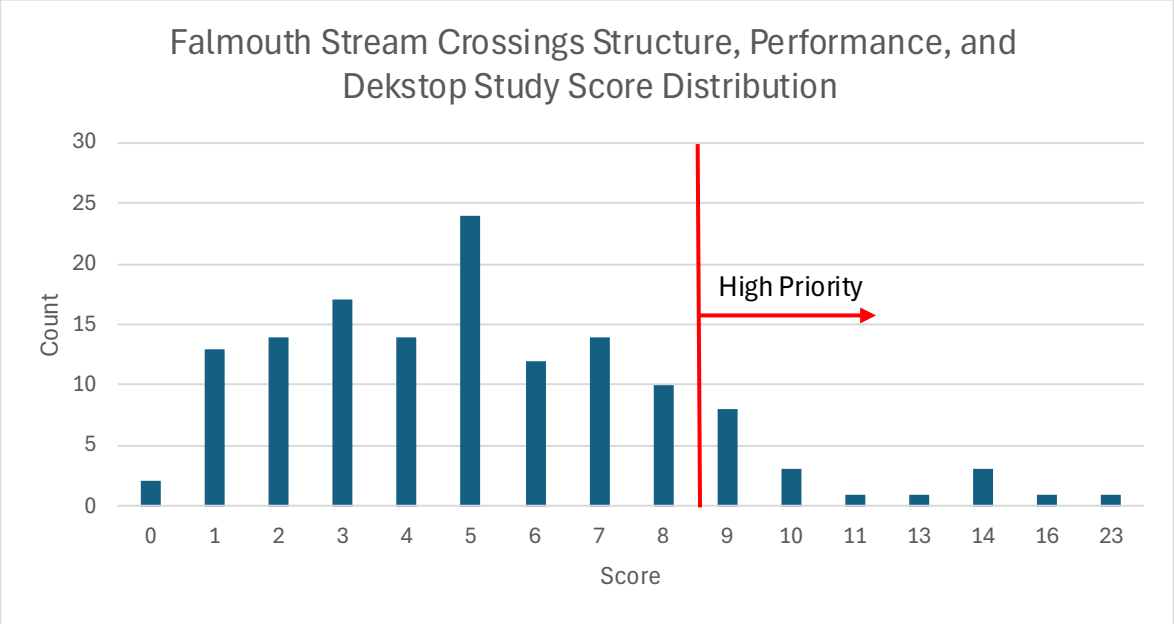


Figure 1: Structure, Performance, and Desktop Study Score Distribution

FBE performed a similar ranking based on their analysis of potential environmental and/or water quality impacts. A binomial scoring system was used to assess the habitat and water quality parameters of each asset. The presence of algae, foam, iron oxidation, odor, sheen, or turbid water clarity each scored a one. Absence or blank responses (in the case of water clarity) scored a zero. These parameters were tallied to form the water quality score for each crossing.

To assess habitat parameters, an asset scored a one for each source of erosion identified (adjacent land use, road shoulder, ditch, invert, and/or streambank), and a zero if erosion was not identified at the sources. Presence of invasive species at the crossing scored a one, absence a zero. Finally, the riparian buffer density was scored such that a dense buffer received a zero, sparse a one, and none a two. These parameter scores were tallied to form the total habitat score. Finally, the water quality and habitat scores were summed to give the total environmental score for each asset.

Following the ranking, values for the assessed assets ranged from 0-5 for the total environmental score, of a maximum possible score of 14. The distribution of environmental scores can be seen in Figure 2. Only one asset scored the highest score of 5.

Presence and absence of beavers and macroinvertebrates were not factored into the environmental scoring matrix, as the presence or absence of either would not contribute to poor water quality conditions. Additionally, macroinvertebrates were not assessed at non-stream cross assets and would therefore lack data for a significant portion of the study.

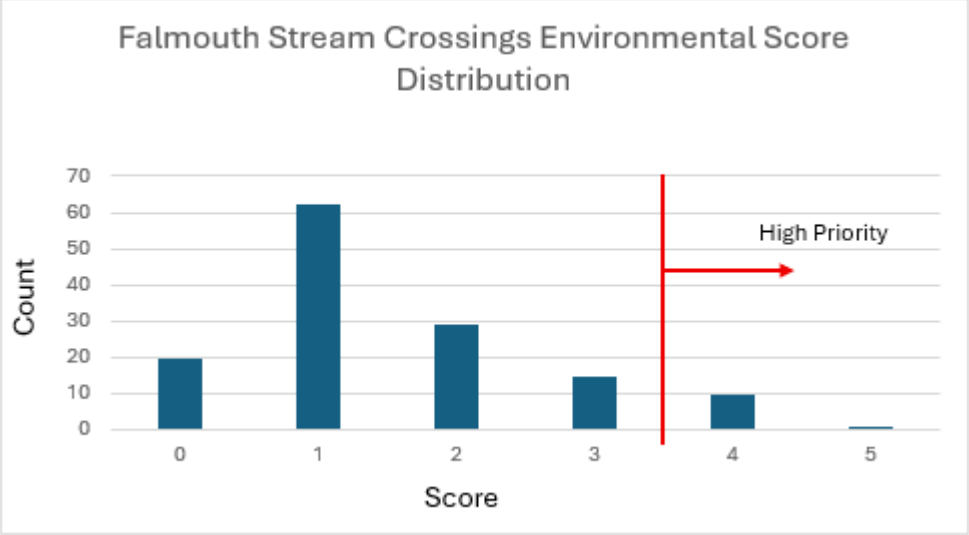


Figure 2: Environmental Score Distribution

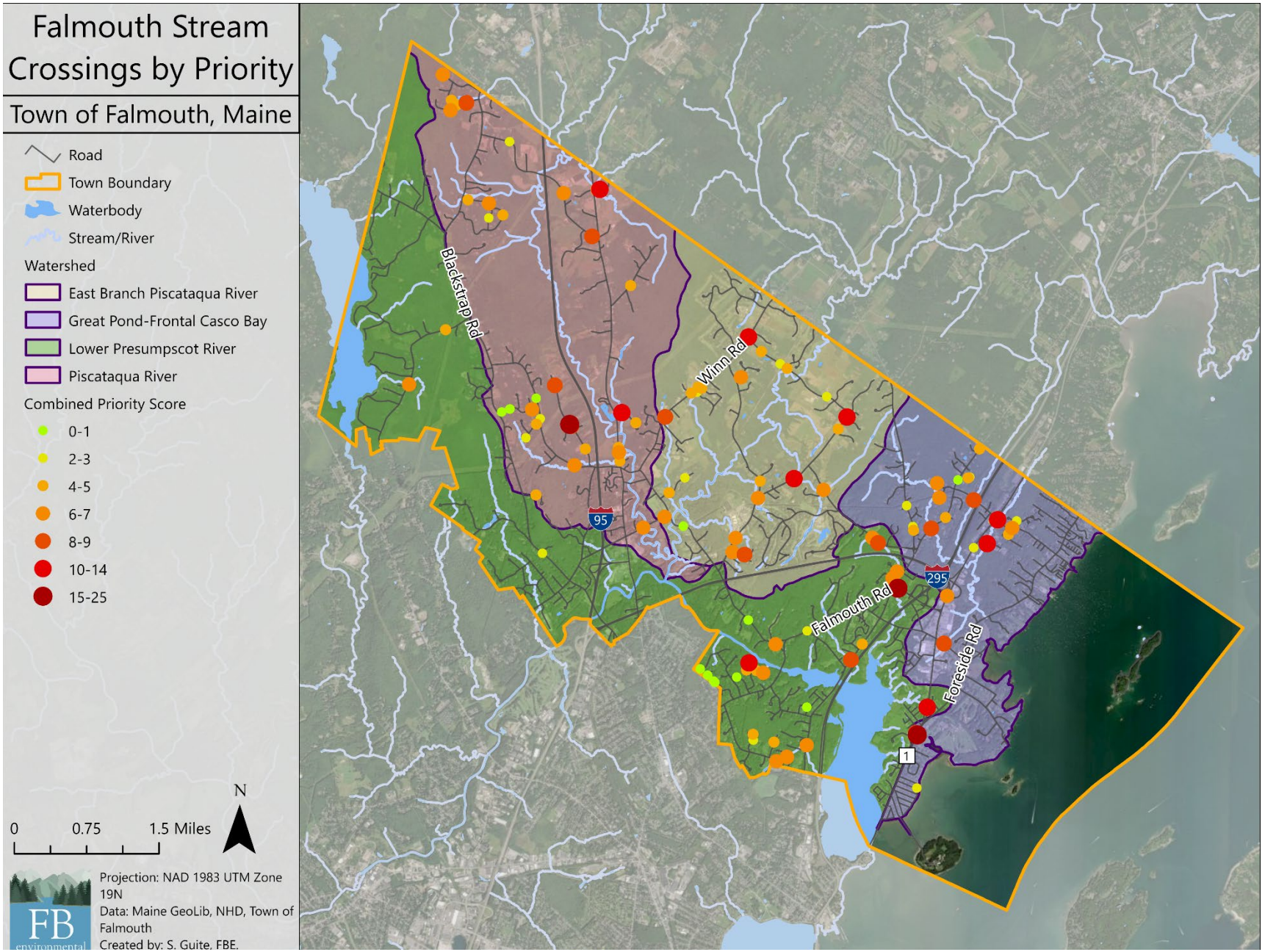


Figure 3: Falmouth Assets by Total Score

D. DISCUSSION & RECOMMENDATIONS

D.1 General trends – structural, performance, and desktop study criteria (by Acorn)

The most common structural or performance criterion observed throughout the assessment was the accumulation of sediment and debris within crossings/culverts, which was observed at 58 of the 138 assessed assets (42%). This finding illustrates that there is a need across the network to maintain infrastructure to restore its ability to pass storm flows. Allowing free passage of drainage is critical to preserving the integrity of the road network and reducing the likelihood that roadways are damaged due to saturated, softened roadbeds or overtopping.

Although percentages of various defects observed during the study were relatively low, the most common defects observed were perching at the downstream end of the crossing (20 count or 14%), pavement degradation at the crossing (18 count or 13%), erosion of the channel downstream of the crossing (14 count or 10%), and corrosion of the pipe (12 count or 9%). In many cases, several of these defects occurred at the same crossing, as discussed in Section D.3.

Through our comparison of stream widths upstream and downstream of the crossings, we found that 23 assets, or 17% of the total scope of work, presents a potential constriction to stream flow. Often, artificial widening of the watercourse upstream of a crossing can indicate that the crossing is undersized, constricting flow, and undersized.

Additionally, in our desktop review of the Maine Stream Habitat viewer, 35 of the assessed assets had been identified by the Maine Stream Connectivity Work Group as a potential barrier to aquatic organisms. This represents 25% of the 138 assets assessed, but more importantly, 73% of the 48 assets located along USGS streams.

Of the 48 assets located along USGS streams, only 9, or 20%, are sized with spans or diameters >1.2x the bankfull width provided by StreamStats, and only 3 assets (845, 1039, and 1069) contain a natural streambed material. Providing a span or diameter of at least 1.2 bankfull width *and* providing a natural streambed material within the crossing are two of the core principles of StreamSmart design. Overall, the findings presented herein illustrate that there is a high need across the network to improve hydraulic and habitat connectivity at road-stream crossings.

Of the 13 "high priority" crossing locations for which 100-year discharge data was available in StreamStats, only one (1) – asset 0403 - was sufficiently sized to freely convey the 100-year discharge. However, all 13 existing assets failed to meet StreamSmart requirements in other ways, such as not having natural channel bottoms, not spanning the stream channel, or having a perched outlet. See discussion in Section D.3 for additional detail.

Distribution of structure, performance, and desktop study scores can be viewed in Figure 4. Note that Figure 4 has been simplified for visual purposes to remove criteria with low or zero totals. For example, zero crossings exhibited perching at the upstream end. For further information on ranking and scoring, please reference the spreadsheets provided with this report as an Appendix.

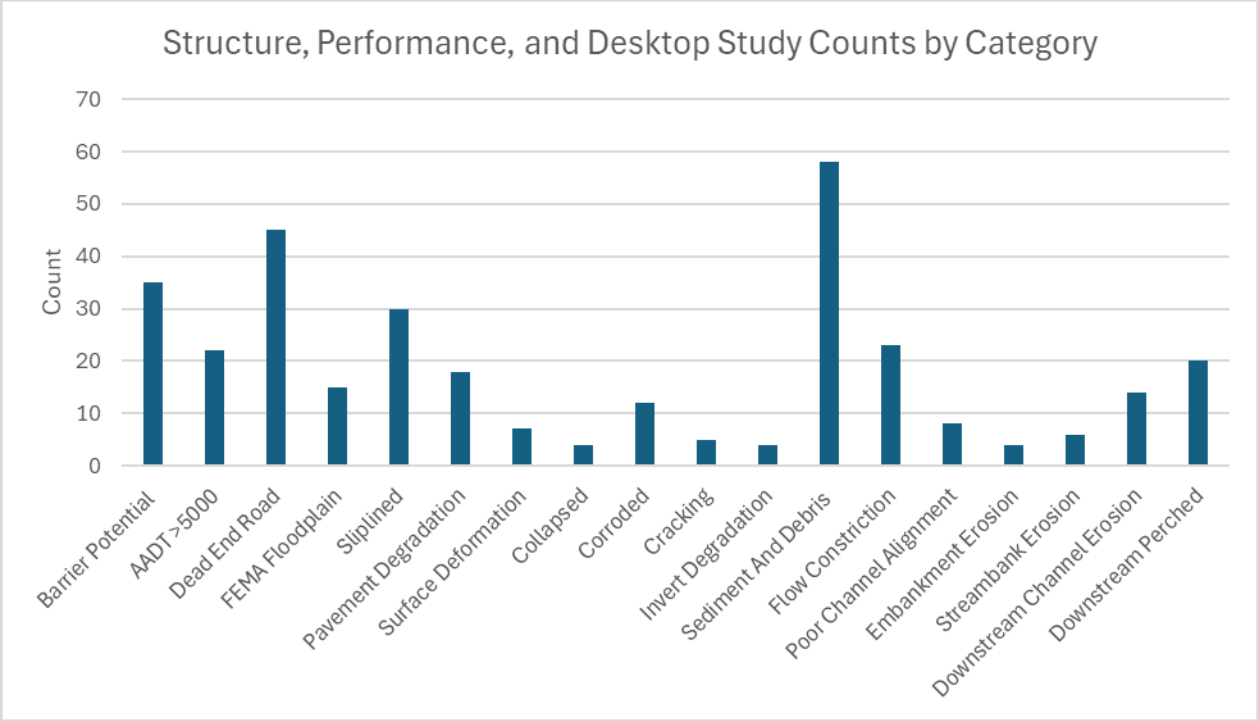


Figure 4: Structure, Performance, and Desktop Study Counts by Category

D.2 General trends – habitat criteria (by FBE)

The most common habitat and water quality issue observed throughout the assessment was the presence of invasive, non-native plant species, which occurred at 94 of the 138 assessed crossings (68%). Invasive species are the second greatest global threat to biodiversity after habitat loss. They are easily spread via transportation and road corridors, and in fill used for construction. These species have many adaptations such as growing leaves earlier or later in the season, emitting chemicals inhibiting growth of other species, or ability to spread through both rhizomes and seeds that allow them to colonize an area quickly, overtaking native species and often forming dense monocultures. These traits allow invasive species to be highly competitive for resources or physically alter habitats and soil geochemistry, displacing native species and reducing diversity. These impacts can also have a domino effect through the food web. For example, herbivores may selectively browse native species over invasive ones, predation pressure which when combined with enhanced resource competition from invasive species can cause further declines in native species. Invasive species typically require a multi-year effort to manage or eradicate.

All other habitat and water quality indicators were observed at a much lower frequency, occurring at 0-17 assessed crossings. Of these, foam, algae, poor riparian buffers and road shoulder erosion were the most commonly observed issues. Adjacent land use, inverts, and active construction were the least common sources of erosion observed. Distribution of scores by category can be viewed in Figure 5. All categories were rated on a 0-1 scale for absence or presence with the exception of “Riparian Buffer Status” which was rated on a scale of 0-2 (0 = dense buffer, 1 = sparse buffer, 2 = no buffer); thus the count of the Riparian Buffer Status shown in Figure 5 does not indicate the number of crossings with poor riparian buffers, but the total score of sparse or no buffers.

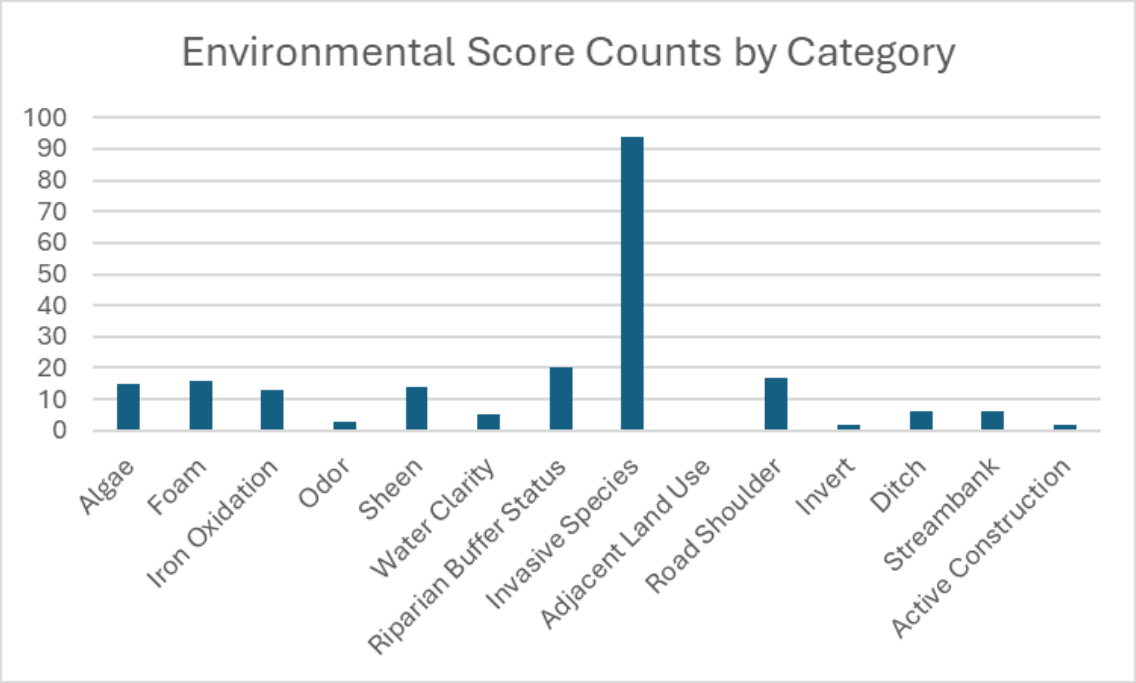


Figure 5: Environmental Score Counts by Category

D.3 High-priority locations – structure, performance, and desktop study criteria

Acorn identified 18 high-priority crossings based on the structure, performance, and desktop study data collected. This section briefly discusses existing conditions at each of these crossings and provides potential maintenance or replacement strategies in alignment with StreamSmart standards. Even for crossings not located at regulated or jurisdictional streams, Acorn recommends that the Town implement StreamSmart design to the greatest extent allowable by the Town's budget. Acorn acknowledges that budgetary constraints will not always allow the most robust design to be implemented, and it is expected that the Town will replace defective cross culverts at their discretion. However, providing capacity for a 100-year discharge event is a driving characteristic of StreamSmart design and providing this capacity, or at least a level of storm capacity satisfactory to the Town, is our primary recommendation to improve resiliency, no matter of stream jurisdiction. Additionally, providing minimum 6" culvert embedment with natural streambed substrate within the culvert, even at crossings with intermittent flow, has potential to improve habitat connectivity in headwater reaches for both aquatic and terrestrial organisms, and is a USACE design requirement for spans between wetlands.

For the thirteen (13) of these eighteen (18) crossing locations which could be modeled in StreamStats, we present and discuss the results of the high-level hydraulic analysis conducted using HY8. For these crossings, we provide a table containing the existing dimensions, the 100-year discharge, and a culvert or structure size which would safely pass the 100-year discharge and meet StreamSmart embedment, span, and headspace standards. Note that the proposed estimated replacement structures do not comprehensively consider all StreamSmart design requirements or the surrounding roadway elevation and geometry; this would need to be studied further as part of a site-specific design if the crossing is chosen for replacement.

Asset ID 0656. Hillside Ave. – Acorn score: 23; Combined Priority Score: 26

This 18-inch corrugated metal cross pipe in a steep, hilly watershed in West Falmouth is nearly buried at each end and appears to be clogged at an undetermined point beneath the roadway. The pipe is located on a dead-end street, Hillside Avenue, and crossing failure would pose a life safety risk to residents of approximately 14 homes at the end of Hillside Drive. Local residents who approached the Project Team during inspection communicated that the road is frequently overtopped in this area after storm events. Acorn's hydraulic analysis confirmed that the existing culvert is incapable of freely conveying a 100-year discharge. The existing paved roadway is in good condition in this area.

Although this cross pipe does not convey a USGS blue-line stream, Acorn recommends that this culvert be replaced with a larger cross pipe or span meeting StreamSmart standards as much as practicable to prevent roadway overtopping and to provide a natural channel bottom. If such a design is not financially practicable, a replacement crossing should at least provide an appropriate increase in hydraulic capacity. Local hydrology and the interaction between this culvert and nearby Asset 0653 (also a critical crossing, see more details later in this section) should be considered during replacement. The table below presents a comparison of existing conditions at the crossing against 100-year discharge and provides potential replacement design alternatives.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structures to Convey 100-Year Discharge
18	27	4' span x 3.5' tall box or 4'⌀ culvert, embedded 12"





Asset ID 0403. U.S. Route 1 – Acorn score: 16; Combined Priority Score: 21

This 36" sliplined concrete pipe cross pipe passes beneath Route 1 just north of the intersection with Gilsland Farm Road. Route 1 is considered a Major Collector at this location per MDOT. The culvert is over 50% full of sediment and some erosion was observed locally to the inlet and outlet of the structure, and along the roadway embankments above the structure. Some degradation of the original concrete culvert was observed, but the sliplined portion appeared sound. Although this cross culvert is performing poorly, it may have a low probability of overtopping the roadway because the structure is far beneath the roadbed.

The existing clogged crossing impounds water against the roadbed and creates the potential for erosion around the edge of the culvert. Acorn's modeling showed that if the sediment currently clogging the crossing is removed, the crossing would be hydraulicly capable of passing the 100 year flows. However, the crossing still would not supply the extra headspace capacity and habitat connectivity requirements consistent with StreamSmart standards.

If replacement is not determined to be feasible, maintenance should be conducted to restore the pipe's hydraulic capacity and remove sediment. The road is in excellent condition at location of the crossing.

Additionally, this cross pipe is associated with Asset 1192, just upstream of Asset 0403 beneath Old Route 1. Asset 1192 could not be located during the Assessment and is assumed to exist but was fully buried/ presumed clogged at the time of inspection, with road embankment erosion observed where the inlet and outlet of 1192 were presumed to be.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structures to Convey 100-Year Discharge
36	31	4' span x 3.5' tall box or 4'⌀ culvert, embedded 12"





Asset IDs 0303 & 0987. Bucknam Road – Acorn score: 14/14; Combined Priority Score: 18/18

These twin 36" corrugated metal pipes (CMP) convey Skitterygusset Creek beneath Bucknam Road just east of the Bucknam/Falmouth/Middle Road intersection. Bucknam Road is classified as a Minor Arterial at this location by MDOT. Acorn's modeling showed that a 100-yr discharge cannot be freely passed by these culverts, leading to impounded water against the roadbed and a higher risk of overtopping or potentially undermining the subsurface of the road. Additionally, the inlets of these CMPs are showing early signs of rust/corrosion degradation, and the crossing is poorly aligned with the stream channel, especially at the outlet, potentially leading to erosion downstream of the crossing. Habitat connectivity is poor, and aquatic organisms cannot easily pass beneath Bucknam Road at the crossing.

Twin culverts are generally not recommended StreamSmart structures. This is due to the risk of degradation and failure from fluid bypass outside the culvert walls if material is inadequately compacted during installation, poor habitat connectivity at low flows, and risk of trapping floating debris. Acorn recommends replacing these paired culverts with a span, as recommended in the table below.

Also note that due to the local importance of Bucknam Road, consequence of failure, the age and material of the crossing, potential to restrict habitat connectivity, and potential to restrict flow, this crossing may score well in a Municipal Stream Crossing Grant application.

Existing Diameters (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
36, 36	159	10' span x 6' tall box, embedded 24"





Asset IDs 0724 and 0723. U.S. Route 1 – Acorn score: 14/9; Combined Priority Score: 15/10

These 36" sliplined concrete cross pipes pass beneath US Route 1 at the large, grassed median just north of the intersection with Foreside Road. Route 1 is considered a Major Collector by MDOT at this location. These crossings were not able to be modeled in StreamStats because hydraulic flow information is not available at the crossing location. Similarly to asset 0403, these culverts were observed with significant sediment deposits and should be cleaned if the Town wishes to restore full capacity to the crossings. Culvert 0724 in particular was completely submerged at the inlet, as pictured below. Additionally, significant ground surface deformation (sinkhole) was observed at a nearby catch basin within the grassed median. The Project Team did not investigate the source of erosion further, but it is believed this catch basin flows into either Asset 0723 or 0724. This issue should be investigated, and the source of erosion corrected, to reduce risk of a sinkhole in this area. Although these cross culverts are performing poorly, they may have low failure probability due to being far beneath the road bed. Nonetheless, maintenance should be conducted to restore hydraulic capacity. The road is in excellent condition at the crossing locations.





Asset ID 0188. Woodville Road – Acorn score: 13; Combined Priority Score: 15

This 20" HDPE cross pipe has limited cover over the pipe at the road surface, which has caused heaving and transverse cracking at the crossing. Woodville Road is considered a Local Road at this location per MDOT. The pipe exhibits signs of buckling and damage to the inlet and outlet. Acorn's hydraulic analysis showed the existing culvert is incapable of freely conveying a 100-year discharge. At a 100-year discharge, water would be impounded at the roadbed and this condition is likely to lead to roadway overtopping and possible crossing failure.

Acorn recommends replacing this culvert when conducting maintenance on Woodville Road and setting the structure at a lower elevation if possible, in combination with localized re-ditching. Replacement with a StreamSmart design including embedment is recommended, however due to the crossing's position near the upper portion of the watershed, inconsistent perennial flow, and relative cost, a StreamSmart design may not be deemed feasible by the Town. Regardless, the replacement culvert should increase the hydraulic capacity and provide a minimum of 24" of cover above the top of the structure to protect the road surface, with >3-feet of cover recommended. The table below provides potential replacement options that meet StreamSmart standards.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structures to Convey 100-Year Discharge
20	25	4' ⌀ pipe or 3.5' span x 3.5' tall box, embedded 12"





Asset ID 0859. Winn Road – Acorn score: 11; Combined Priority Score: 14

This 24" concrete pipe cross pipe passing beneath Winn Road just north of the Woodville Road intersection is perched at the outlet and is displaying erosion at the road shoulder and a scour pool at the pipe outlet. Minor longitudinal cracking and rutting is observed at the road at the crossing, possibly connected to settlement of the road shoulder in this area. Winn Road is considered a Minor Collector at this location per MDOT. Although the crossing was mostly dry at the time of inspection, Acorn's modeling revealed the crossing is undersized to freely pass the modeled 100-year storm discharge. The perched condition at the outlet prevents aquatic and terrestrial organism movement through the culvert.

The crossing is not on a USGS stream, but observations of the area around the crossing during inspection suggest that this pipe conveys significant flow during storm events, conveys a defined intermittent channel, and is a good candidate for replacement with a StreamSmart compatible span or embedded culvert with natural streambed substrate if funds are available. See the table below for a potential replacement structure.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
24"	23	4' ⌀ pipe or 3.5' span x 3.5' tall box, embedded 12"





Asset ID 0384. Johnson Road – Acorn score: 10; Combined Priority Score: 14

This 40" sliplined concrete pipe stream crossing conveys Norton Brook beneath Johnson Road and has a perched outlet with erosion at the outlet observed (scour pool). Johnson Road is considered a Major Collector in this location by MDOT. Sliplining of the original pipe has further constricted Norton Brook's flow over time and currently prevents organism passage through the crossing. Although the pipe exhibited adequate capacity at the time of inspection, Acorn's analysis showed that the existing crossing cannot freely convey the modeled 100-year storm discharge. During large storm events, water would be impounded against the roadbed, potentially leading to road overtopping or erosion of the road subsurface.

Due to the local importance of Johnson Road, consequence of failure, potential to improve aquatic organism passage, and potential to reduce flood vulnerability at this location, Acorn recommends replacing this crossing with a span or embedded box meeting StreamSmart standards. A replacement crossing should provide a riprap stabilized fill slope and/or cast in place concrete walls at the road embankments.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
40"	168	9' span x 6.5' tall box, embedded 18"





Asset ID 0664. Eastern Ave – Acorn score: 10; Combined Priority Score: 13

This 48" sliplined corrugated metal pipe conveys an unnamed stream beneath Eastern Avenue, an MDOT Local, dead-end street. The road acts as a dam in this location, and the pipe outlet is severely perched. Acorn's hydraulic analysis showed the existing culvert is incapable of freely conveying a 100-year discharge at this location and would lead to impoundment behind the culvert and likely overtopping. The current roadside slopes appeared to be fairly stable at the time of inspection, but the road displays signs of deformation and/or heaving and is potentially susceptible to overtopping and failure if dammed water begins leaching through the roadbed or begins to bypass around the outside of the structure. Failure of this crossing would pose a life safety risk to residents at the end of Eastern Ave.

Although requiring potentially complex permitting due to impacts to the wetland impounded by the crossing, the Town should consider replacing this crossing with a span meeting StreamSmart standards and restoring the natural run of the stream to enhance the resiliency and habitat potential of this crossing, which is just upstream of the Piscataqua River. The table below compares the existing conditions to 100-year flows and recommends a StreamSmart compatible replacement structure.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
48"	217	11' span x 6.5' tall box, embedded 18"





Asset ID 0772. Northbrook Drive – Acorn score: 10; Combined Priority Score: 11

This 48" concrete pipe stream crossing conveys Norton Brook beneath Northbrook Drive, a dead-end, Local Road with an elderly care center and numerous other commercial spaces beyond the crossing. Although the pipe exhibited adequate capacity at the time of inspection, Acorn's analysis showed that the existing crossing cannot freely convey the modeled 100-year storm discharge. During large storm events, water would be impounded by the roadbed, potentially leading to road overtopping or erosion of the road subsurface. Additionally, the retaining walls at the crossing are constructed of gabion baskets, which are currently stable but are beginning to show signs of wire failure, which could eventually lead to catastrophic failure of the walls at the crossing. Failure of this crossing would pose a significant life safety risk to residents and employees of the elderly care center and other businesses at the end of Northbrook Drive.

The Town should consider replacing this crossing with a span meeting StreamSmart standards and provide a riprap stabilized fill slope and/or cast-in-place concrete walls to stabilize the road embankments. The table below compares the existing conditions to 100-yr flows and provides a replacement option that would meet StreamSmart standards.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
48"	238	13.5' span x 6.5' tall box, embedded 18"





Asset ID 0201. Winding River Lane – Acorn score: 9; Combined Priority Score: 13

This cross pipe has severe erosion at the bank below the structure's outlet and the inlet is blocked by thick, thorny vegetation. Erosion had not begun to affect the road at the time of inspection, but may begin to in the future if bank erosion continues. The cross pipe is near the end of Winding River Lane, a dead end Local Road. One (1) home lies beyond the crossing. This crossing was not modeled in StreamStats because hydraulic information was not available at the crossing location. Acorn recommends replacing the pipe with a larger structure when capital improvements to this road are planned, and stabilizing the slope below the outlet.





Asset ID 0343. Route 1 – Acorn score: 9; Combined Priority Score: 10

This 18" CMP cross pipe runs beneath Route 1 just south of the Falmouth Spur intersection. The existing pipe is severely corroded/collapsed clogged, and likely undersized based on in-field observation. Hydraulic modeling was not performed because hydraulic flow information was not available on StreamStats for this location. Route 1 is considered a Major Collector at this location according to MDOT, and the road is in excellent condition at the crossing. The cross pipe should be cleaned to restore hydraulic capacity. If work is planned on Route 1 in this location, Acorn recommends replacing the existing, dilapidated structure with a replacement that has greater hydraulic capacity.





Asset ID 0415. Hurricane Road – Acorn score: 9; Combined Priority Score: 9

This 20" corrugated metal cross pipe has a failed invert, is beyond its design life, and may constrict high-intensity flow. Minor surface cracking and heaving were observed on the road surface, likely due to shallow cover over the pipe and collapse of the invert. Acorn recommends replacing this with a new, larger cross culvert at a deeper depth and providing at least 24" of cover above the culvert, if possible. This crossing was not able to be modeled in StreamStats. Hurricane is considered a Local Road at this location per MDOT.





Asset ID 0553. Grist Mill Road – Acorn score: 9; Combined Priority Score: 10

Asset 0503 and paired 0504 are twin 18" corrugated metal cross pipes that convey an unnamed stream beneath Grist Mill Road and do not provide natural channel substrate at the crossing, posing a potential barrier to aquatic organism passage. Grist Mill Road is a local road according to MDOT in this location. Both culverts have rusted and degraded inverts and are poorly aligned with upstream and downstream flow. Modeled 100-year storm discharge cannot be freely conveyed by the pipes; this condition impounds water against the roadbed and puts the road at risk of overtopping or failure. Acorn recommends replacing the two pipes with larger structure meeting StreamSmart and aligning the structure to the direction of flow.

Existing Diameters (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
18", 18"	45	5' span x 4' tall box, embedded 12"





Asset ID 0653. Hillside Drive – Acorn score: 9; Combined Priority Score: 10

This culvert conveys an unnamed intermittent stream beneath Hillside Drive. The existing culvert has corroded inlets and a perched outlet, and there is no natural channel substrate at the crossing. Acorn's hydraulic analysis shows that the culvert cannot freely pass the modeled 100-year storm discharge, and that large flows impound water against the roadbed and put the road at risk of overtopping or failure. Similar to cross pipe 0656 discussed above, the pipe drains a steep, hilly watershed on a dead-end road in West Falmouth serving approzimately 14 homes, and should be upsized when replaced, ideally to StreamSmart standards if budget allows, to increase both hydraulic capacity and habitat connectivity. Crossing failure would pose a life safety risk to residents of approximately 14 homes at the end of Hillside Drive. See Asset 0656 for additional recommendations.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structures to Convey 100-Year Discharge
15"	28	4' span x 3.5' tall box or 4'⌀ culvert, embedded 12"





Asset ID 0766. Woodville Road – Acorn score: 9; Combined Priority Score: 11

This 30" concrete pipe stream crossing has a perched outlet, and is paired with Asset 0767, a 42" diameter HDPE pipe in better condition. The pipes pass beneath Woodville Road just south of the intersection with Woods Road. Woodville Road is considered a Local Road in this location per MDOT. These twin pipes' combined diameters are undersized to freely convey the modeled 100-year storm discharge; this condition impounds water against the roadbed and puts the road at risk of overtopping or failure. Dual culverts are not recommended due to the potential for water to leach around the culverts and undermine the roadbed, as well as their inability to convey aquatic organism passage at low flows, and risk of trapping floating debris.

Acorn recommends replacing these pipes with a span or embedded box culvert meeting StreamSmart standards to improve hydraulic performance and enhance habitat connectivity. The table below compares existing conditions to the 100 year discharge and provides an estimated StreamSmart compatible design.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
30"	119	10' span x 5' tall box, embedded 18"





Asset ID 1191. Schuster Rd – Acorn score: 9; Combined Priority Score: 11

This 48" corrugated metal pipe (CMP) stream crossing conveys an unnamed tributary of Hobbs Brook beneath Schuster Road, a dead-end Local Road. The existing pipe is severely undersized, has a completely failed invert, and is within the FEMA floodplain. Hydraulic modeling of the existing crossing shows considerable impoundment is likely during a 100-year storm event as the existing crossing is incapable of freely conveying discharge. During large storm events, this impoundment poses a risk of roadway overtopping. Failure of this crossing would pose a life safety risk to residents at the end of Schuster Road.

The Town should consider replacing this crossing with a span meeting StreamSmart standards. The table below compares the existing conditions to 100-yr flows and provides a replacement option that would meet StreamSmart standards.

Existing Diameter (in)	100-year Discharge (CFS)	Estimated Replacement Structure to Convey 100-Year Discharge
48"	293	12' span x 7.5' tall box, embedded 24"





D.3.1 Structure, performance, and desktop study recommendations

To improve the performance and resiliency of road-stream crossings and cross-culverts in Falmouth, the following actions are recommended:

- Maintain crossings to remove accumulated debris and sediment. Culverts with significant debris and sediment accumulation are more likely to constrict flow and contribute to poor drainage conditions. Allowing free passage of drainage is critical to preserving the integrity of the road network and reducing the likelihood that roadways are damaged due to saturated, softened roadbeds or overtopping.
- Replace compromised and degraded metal culverts with HDPE culverts, which are less susceptible to environmental degradation.
- When replacing cross culverts or small stream crossings, install large, angular riprap (D50 >8") at the culvert inlets and outlets, and along the roadway shoulder and embankment as necessary, to protect the crossing from erosion. Woven geotextile fabric should be installed beneath the riprap and keyed into the surrounding subgrade.
- At any crossing identified for replacement, properly set the culvert or structure elevation to achieve a minimum of 2-feet of cover above the top of the pipe or span, with >3-feet of cover recommended. Providing adequate cover over the crossing, as well as providing compacted, well-drained, and stable base material below the culvert, reduces the probability of movement and heaving during freeze-thaw cycles. In areas with known poor or wet soils, woven geotextile fabric should be installed and keyed into the surrounding subgrade prior to placing base material.
- At any crossing identified for replacement, properly align the crossing to be parallel with the direction of flow as practicable. In some cases, this may require skewing the structure at an angle across the roadway. Aligning the crossing to the direction of flow reduces the likelihood of erosion at the inlet and outlet of the structure, as water does not need to turn to access the crossing.
- At any crossing identified for replacement, and especially at stream crossings, properly set the elevation and slope of the culvert or span to seamlessly align with the vertical profile of the channel it conveys. Culverts should not be installed in a "perched" condition. At larger spans or streams, it is recommended that a hydraulic analysis and engineered design be conducted to properly size the structure and set the culvert elevation and slope.
- As funds allow, replace culverts at road-stream crossings with appropriately-sized spans or embedded large culverts (>6' diameter) to convey storm flows and create natural streambed conditions to support habitat connectivity.
- As funds allow, replace lined culverts to restore (or increase) the intended hydraulic capacity of the original culvert. In many cases, lining has significantly reduced the hydraulic capacity of the original culvert via reducing the diameter of the opening.

D.4 High-priority locations – habitat criteria

FBE identified 11 high-priority crossings based on the environmental data collected. This section describes additional details on each of those crossings, followed by general recommendations for improving habitat and water quality.

Asset ID 0403. Route 1 – FBE score: 5 ; Combined Priority Score: 21

This cross culvert received the highest (i.e., poorest) environmental score among all those surveyed. The elevated score resulted from both poor habitat and water quality indicators. For the water quality, the water at the culvert had an odor, visible iron oxidation, and a surface sheen on the water. Habitat degradation was also observed in the form of streambank erosion. Dense Japanese knotweed was also present at this crossing, a non-native, invasive species known for its ability to create dense colonies and spread from small segments of both roots and shoots.





Asset ID 0005. Gray Road – FBE score: 4 ; Combined Priority Score: 9

This cross culvert received a high overall score due to a combination of water quality and habitat concerns. The notable water quality factor was that algae growth was observed within and around the small stream at the culvert. Several additional habitat issues were also documented, including the presence of invasive plant species, noticeable ditch erosion, and a sparse vegetative buffer along the streambanks. The ditch erosion was particularly severe and is highlighted in the images below. Collectively, these factors indicate reduced habitat quality and limited stabilization of the surrounding area.





Asset ID 0201. Winding River Lane – FBE score: 4 ; Combined Priority Score: 13

This cross culvert received an elevated score mostly due to its habitat issues. There were no noted water quality issues, but also there was no observed flowing water. For the surrounding habitat, there was a thick population of invasive species including Japanese knotweed and multiflora rose. There was also a sparse riparian buffer which contributed to the low score. Streambank erosion and invert erosion were both present, particularly at the outlet, as seen in the images below.





Asset ID 0252. Middle Road – FBE score: 4 ; Combined Priority Score: 7

This cross culvert, which conveys an intermittent channel, received a low score due to both water quality and habitat issues. For water quality, there was presence of both iron oxidization and a sheen in the small region of surrounding water at the culvert. Road shoulder erosion was observed near the culvert and the presence of invasive species such as honeysuckle and Asiatic bittersweet surrounding the culvert. It should also be noted that there was construction occurring adjacent to the culvert outlet at the time of the survey and there were no sediment controls.





Asset ID 0384. Johnson Road – FBE score: 4 ; Combined Priority Score: 14

Multiple potential water quality issues were observed at this stream crossing, including iron oxidization and a sheen present in the water. Dense invasive species were also present, such as Japanese knotweed. There was also streambank erosion that was noted downstream of the culvert.





Asset ID 0439. Terison Drive – FBE score: 4 ; Combined Priority Score: 7

Water quality issues that were observed at this cross culvert, which conveys an intermittent channel, included scattered patches of algae presence and poor water clarity. Invasive species were present in the riparian area and streambank erosion was observed, depositing additional sediment in the stream.





Asset IDs 0798 and 0799. Middle Road – FBE score: 4 ; Combined Priority Scores: 10 / 8

This location contains a double culvert stream crossing, both of which rank high primarily due to observed water quality indicators. Green algae, a sheen, and a noticeable odor were all documented at the culvert inlets. The primary habitat issue noted was the presence of invasive species in the area surrounding the culvert. Mowing and vegetation clearing upstream of the culverts also provides poor stream shading, pollutant filtration, and flood buffering.



Asset ID 0979. Stormy Brook Road – FBE score: 4 ; Combined Priority Score: 7

Though flow was low at the time of the survey at this cross culvert which conveys an intermittent defined channel, a sheen and small foam patches were observed. There was also a sparse buffer at the site, limiting shading and habitat benefits for the stream channel. Invasive species were also observed at the site, further degrading the quality of the riparian buffer.





Asset IDs 0987 and 0303. Bucknam Road – FBE score: 4 ; Combined Priority Scores: 18 / 18

These double stream crossing culverts ranked high primarily for observed habitat issues. Road shoulder erosion was observed near the culverts, carrying sediment to the stream from adjacent Bucknam Road. In addition to the erosion, there was also a poor riparian buffer. Invasive species were documented in the buffer, further degrading its quality. Additionally, small patches of brown algae were observed in the low flow of water present during the survey.







D.4.1 habitat and water quality recommendations

To improve the commonly observed habitat and water quality issues at culvert crossings in Falmouth, the following actions are recommended:

- Water quality testing at sites with potentially poor water quality indicators (turbid water, foam, sheen, odor, iron oxidation, or algae growth). Water quality monitoring should take place between June and September and include testing for nutrients (phosphorus and nitrogen), bacteria, chloride, dissolved oxygen, and temperature at a minimum. Creating long-term monitoring programs for each prominent stream is recommended to determine significant trends over time, as results can be highly variable over one season of monitoring. The goals of monitoring should be to determine if the waterbody is meeting state water quality standards, and to determine if there are any sources of pollution entering the waterbody. If signs of pollution are observed, bracket sampling at multiple locations along the stream may assist in locating the source. This work should build on the Town's ongoing efforts to develop a Watershed Management Plan for the Casco Bay Frontal Drainage watershed, which has identified multiple sources of pollution within five stream subwatersheds (Mill Creek, Chenery Brook, Norton Brook, Webes Creek, and Scitterygusset Creek).
- Invasive species management is recommended to improve habitat conditions. Commonly observed invasive species at Falmouth's culverts include Japanese knotweed, multiflora rose, Morrow's honeysuckle, Asiatic bittersweet, purple loosestrife, Japanese barberry, glossy false buckthorn, and Norway maple. Species-specific management strategies can be found on the Maine Natural Areas Program invasive species fact sheets. In general, removal via hand tools or mechanical means is recommended due to the location of these species adjacent to water bodies or drainage channels. Chemical management via pesticides must comply with applicable state and municipal regulations and may require the use of a licensed applicator. Invasive species management could occur opportunistically during structural repairs of crossings, though follow up work will be required to ensure long-term management or eradication. Native plant species should immediately replace invasive species to discourage reestablishment. Many resources for native plant guides are available to provide recommendations for planting including the Maine Buffer Handbook Planting List and the New Hampshire Native Shoreland/Riparian Buffer Plants list.
    - Education on invasive species identification and management is also critical to the success of town-wide improvement. These resources should be shared with private and commercial landowners as well as municipal Public Works staff.
- Erosion control is critical to mitigating nonpoint source pollution that may carry excess nutrients and other pollutants into waterbodies. Sites with identified erosion issues should be evaluated by an engineer or other qualified professional to recommend techniques for stabilization. Road shoulder, ditch, or construction sources of erosion can be addressed via the Best Management Practices (BMPs) recommended in Maine's Stormwater Best Management Practices Manual. Streambank erosion can be addressed via live staking, using cuts of suitable native plant species to stabilize the eroding bank and provide other habitat co-benefits. Hardscaping, such as riprap, to address streambank erosion should be considered only in extreme cases or in combination with native plantings.

E. COST & FUNDING DISCUSSION

The following section presents a high-level overview of estimated costs for various scales of crossing replacement, as well as a list of funding opportunities which the Town could potentially leverage to support crossing replacement projects.

High-Level Cost Projections:

The following list of order-of-magnitude costs has been compiled from recent MDOT bid tabs to assist the Town with high-level budgeting for crossing replacements. Fifteen (15) bid tabs which included the replacement of a cross culvert, large culvert, or stream crossing were sourced from MDOT's website. The winning bid price for the replacement of the culvert or structure itself (not including ancillary line items contained in the bid package, which varied significantly across bid packages) was extracted from each bid - these were compiled in Microsoft Excel. Note that most projects were bid "per culvert/structure replacement" and did not typically include linear foot cost. Thus, costs presented are assumed to be "per crossing". The group of bids assembled was for projects throughout the State bid in 2024 and 2025 and included installation of HDPE and precast culverts and precast arches, spans, and boxes. It is our opinion that the group of bids is representative for the purposes of capital improvement planning purposes

Costs to replace the culvert or structure were grouped by diameter/size, as indicated below. To estimate the entire cost of crossing replacement, Acorn supplemented the grouped structure replacement costs with an estimated cost to complete the road work associated with replacement, and an estimate of traffic control cost. Road work was estimated at 2x – 2.5x the structure installation cost, and traffic control was estimated at 10% of the sum of structure installation and road work costs. These subtotals were then summed for each structure size grouping to provide a high-level range of replacement cost for various crossings. These ranges are presented below.

Structure Size (Culvert, Box, or Span)	Estimated Cost of Crossing Replacement
≤24"	$ 50,000 - $190,000
25"-48"	$ 200,000 - $250,000
49"-72"	$ 260,000 - $320,000
73"-96"	$ 330,000 - $480,000
97"+	$ 490,000+

Funding Opportunities:

The Project Team has additionally prepared the list of grant opportunities below to assist the Town in funding future culvert improvements.

- **EPA/MEDEP 319 Grants (Watershed Assistance Grants)** – This NPS grant is designed to help communities make progress restoring or protecting waters named as NPS Priority Watersheds. 319 grants are available for the development and implementation of watershed-based plans and typically funded over the course of two years. Must have an approved watershed management plan to apply.
- **Maine Forest Service Invasive Plant Management Program** – This program provides landowners (public or private ownerships 10 to 10,000 acres) with the resources to create and implement an Invasive Plant Control Plan, reimbursing up to half the cost of its preparation. As of the time of this report, applications are currently closed with no announced date of anticipated future funding.
- **Maine Natural Resource Conservation Program** (MNRCP)- Awards competitive grants each year to projects that restore and protect high priority aquatic resources in Maine. MNRCP was created to manage the allocation of funds collected through Maine's In Lieu Fee Compensation Program. This program does not require match. The next funding round will open in spring 2026.
- **Maine DOT Municipal Stream Crossing Program** – Maine DOT administers this funding for the upgrade of municipal culverts at stream crossings, with the goal of creating infrastructure that is resilient to future climate conditions and that provides community, economic, and environmental benefits. This program requires local match. As of the writing of this report, an invitation for applications for FY 2026 funding has not been announced.
- **Maine Coastal Community Grant Program** – This competitive grant program provides funds to towns and regional organizations for projects in the areas of public access, water quality improvement, storm hazard resiliency, and marine-related economic development. There is no match requirement for this grant. Applications are currently open and due January 5, 2026.
- **Maine Clean Water State Revolving Fund** – This program provides low interest loans to municipalities and quasi-municipal corporations (i.e. village corporations, sanitary, sewer & utility districts, etc.) for the construction of wastewater infrastructure projects. The primary purpose of the fund is to acquire, plan, design, construct, enlarge, repair and/or improve publicly-owned sewage collection systems, interceptor sewers, pumping stations, and wastewater treatment plants. In addition, the program also funds public and private NPS water quality protection and improvement projects, such as landfill closures, sand/salt storage facilities, septic system repair and replacement, storm water projects, agricultural BMPs, and specific silviculture equipment purchases. Funding for 2026 has not yet been announced, but applications are typically due in April.
- **New England Forest and River Grant (NFWF NEFRG)** – This grant awards $50,000 to $200,000 to projects that restore and sustain healthy forests and rivers through habitat restoration, fish barrier removal, and stream connectivity such as culvert upgrades. Funding for 2026 has not yet been announced, but applications are typically due in June.
- **North American Wetlands Conservation Act (NAWCA) Grants** – The U.S. Standard Grants Program is a competitive, matching grants program that supports PPPs carrying out projects in the United States that further the goals of the North American Wetlands Conservation Act (NAWCA). These projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated uplands habitats for the benefit of all wetlands-associated migratory birds. Funding for 2026 has not yet been announced, but applications are typically due in July.

- **Community Action Grants (CAG) –** Funds actions from the Maine Won't Wait List of Community Actions with no match requirements, or other projects that support capacity building, planning, and implementation. The municipality must be registered as part of the Community Resilience Partnership to be eligible. The next funding round has not yet been announced.
- **Restoring Fish Passage through Barrier Removal Grants –** This program, administered by NOAA, supports projects that reopen migratory pathways and restore access to healthy habitat for fish, particularly threatened and endangered species. Awards range from $750,000 to $8 million. As of the writing of this report, an invitation for applications for FY 2026 funding has not been announced

F. CONCLUSION

The Project Team has been pleased to assist the Town of Falmouth with this cross-culvert and stream crossing assessment. We understand the importance of properly performing drainage infrastructure to the Town's transportation security and ecological health and are proud to have partnered with the Town as they work to sustain this network for generations to come.

Through the study and creation of this report, our goal has been to provide the Town with a valuable document to inform capital improvement planning, vulnerability assessment, and habitat improvement. Please do not hesitate to contact Acorn and FBE if further assistance is needed to complete funding applications, design, permitting, or construction administration for stream crossing and cross culvert replacements throughout Falmouth. The Project Team stands ready to assist the Town with these efforts in any way we can.

Appendix E: BMP Location Maps

LEGEND

- WATERSHED BOUNDARY
- MUNICIPAL BOUNDARY
- STREAM | CREEK
- PUBLIC ROADWAY
- EXISTING CULVERT
- 150 MAJOR (50') CONTOUR
- MINOR (10') CONTOUR
- PROPOSED BMP LOCATION
- PRIORITY LOCATION

NOTES:

1. WATERSHED BOUNDARIES SHOWN WERE DERIVED FROM THE USGS STREAMSTATS MAPPING APPLICATION ON APRIL 10, 2024.
2. ROADWAY, CULVERT, AND MUNICIPAL BOUNDARY LOCATIONS SHOWN WERE DERIVED FROM THE MAINE GEOLIBRARY DATA CATALOG ON APRIL 11, 2024.
3. STREAM AND CREEK DATA SHOWN WAS DERIVED FROM THE USGS NATIONAL HYDROGRAPHY DATASET ON APRIL 11, 2024.
4. CONTOURS SHOWN WERE SOURCED FROM THE NOAA DATA ACCESS VIEWER ON APRIL 11, 2024.
5. ALL DATA PRESENTED WERE SOURCED FROM THE PUBLIC DATABASES INDICATED ABOVE AND ARE APPROXIMATE.

N

I-295

MILL CREEK

WEBES CREEK BASIN
AREA: 0.54 MI²

FALMOUTH LITTLE LEAGUE COMPLEX

BUCKNAM RD.

CONFLUENCE WITH MILL CREEK

CATCHMENT 5

LUNT RD.

WEBES CREEK

206 ROUTE 1 - WALMART PLAZA

US RTE. 1

DEPOT RD.

US ROUTE 1 STORM INLET

FORESIDE RD.

250 0 250 500

SCALE: 1" = 500'

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SHEET NO.

WEBES CREEK WATERSHED BMP LOCATIONS

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: WEBES CREEK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

LEGEND

- WATERSHED BOUNDARY
- MUNICIPAL BOUNDARY
- STREAM | CREEK
- PUBLIC ROADWAY
- EXISTING CULVERT
- MAJOR (50') CONTOUR (150)
- MINOR (10') CONTOUR
- PROPOSED BMP LOCATION
- PRIORITY LOCATION

NOTES:

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N

FORESIDE VILLAGE DEVELOPMENT

TOWN OF CUMBERLAND

TOWN OF FALMOUTH

MIDDLE RD.

US RTE. 1

I-295

JOHNSON RD.

NORTON BROOK

NORTON BROOK BASIN AREA: 0.79 MI²

COMMERCIAL DEVELOPMENT TYPICAL ALONG WEST SIDE OF ROUTE 1

SINGLE-FAMILY SUBDIVISION DEVELOPMENT TYPICAL OF EAST PORTION OF WATERSHED

CONFLUENCE WITH MILL CREEK

NORTHBROOK DRIVE DEVELOPMENT

FALMOUTH TOWN LANDING

MILL CREEK

FORESIDE RD.

CASCO BAY

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

CULVERT CROSSINGS AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

500 0 500 1000

SCALE: 1" = 1000'

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SHEET NO.

NORTON BROOK WATERSHED BMP LOCATIONS

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1000'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: NORTON BROOK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

LEGEND

- WATERSHED BOUNDARY
- MUNICIPAL BOUNDARY
- STREAM | CREEK
- PUBLIC ROADWAY
- EXISTING CULVERT
- MAJOR (50') CONTOUR
- MINOR (10') CONTOUR
- PROPOSED BMP LOCATION
- PRIORITY LOCATION

NOTES:

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N

CHENERY BROOK BASIN AREA: 2.07 MI²

TUTTLE RD.

SINGLE FAMILY RESIDENTIAL DEVELOPMENT TYPICAL ALONG MIDDLE RD.

US RTE. 1

TOWN OF CUMBERLAND

TOWN OF FALMOUTH

MIDDLE RD.

CHENERY BROOK

ST. LAWRENCE AND ATLANTIC RAILROAD

I-295

MILL CREEK

JOHNSON RD.

US RTE. 1

CULVERT CROSSING AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

CONFLUENCE WITH MILL CREEK

CASCO BAY

750 0 750 1500

SCALE: 1" = 1500'

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SHEET NO.

CHENERY BROOK WATERSHED BMP LOCATIONS

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: CHENERY BROOK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

LEGEND

- WATERSHED BOUNDARY
- MUNICIPAL BOUNDARY
- STREAM | CREEK
- PUBLIC ROADWAY
- EXISTING CULVERT
- 150 MAJOR (50') CONTOUR
- MINOR (10') CONTOUR
- PROPOSED BMP LOCATION
- PRIORITY LOCATION

NOTES:

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N

MILL CREEK MAIN STEM
BASIN AREA: 2.01 MI²

SINGLE FAMILY RESIDENTIAL DEVELOPMENT TYPICAL ALONG RT. 9 & MIDDLE RD.

ME ROUTE 9 - LONGWOODS ROAD

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

CULVERT CROSSING AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

CONFLUENCE OF CHENERY BROOK

CONFLUENCE OF NORTON BROOK

US ROUTE 1 - SOUTH CORRIDOR

CONFLUENCE OF WEBES CREEK

TIDAL OUTFALL OF MILL CREEK

MUSSEL COVE

ME RTE. 9

MILL CREEK

WOODS RD.

FALMOUTH RD.

I-95 FALMOUTH SPUR

MIDDLE RD.

JOHNSON RD.

I-295

US RTE. 1

TOWN OF CUMBERLAND

TOWN OF FALMOUTH

FORESIDE RD.

750 0 750 1500

SCALE: 1" = 1500'

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SHEET NO.

MILL CREEK WATERSHED BMP LOCATIONS

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1500'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME:

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

LEGEND

- WATERSHED BOUNDARY
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- STREAM | CREEK
- PUBLIC ROADWAY
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N

FALMOUTH TRANSFER STATION

FALMOUTH PUBLIC WORKS

MILL CREEK

WOODS RD.

SINGLE-FAMILY RESIDENTIAL DEVELOPMENT TYPICAL ALONG MIDDLE RD.

I-95 FALMOUTH SPUR

SCITTERYGUSSET CREEK BASIN AREA: 0.98 MI^2

MIDDLE RD.

BUCKNAM RD.

FALMOUTH RD.

DEPOT RD.

US RTE. 1

WEBES CREEK

TIDAL OUTFALL OF SCITTERYGUSSET CREEK

I-295

CULVERT CROSSING AS IDENTIFIED ON TOWN OF FALMOUTH DATABASE, TYP.

CULVERT CROSSING AS IDENTIFIED ON MAINE DOT CULVERT DATABASE, TYP.

PRESUMPSCOT RIVER ESTUARY

500 0 500 1000

SCALE: 1" = 1000'

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SHEET NO.

SCITTERYGUSSET CREEK WATERSHED BMP LOCATIONS

FILE:	1223_CIVIL.DWG
JN:	1223
SCALE:	1" = 1000'
DESIGN BY:	N/A
DRAWN BY:	FAB/ARC
CHECKED BY:	CAB

ACORN ENGINEERING, INC.

ACORN ENGINEERING, INC. P.O. BOX 3372 PORTLAND, MAINE 04104 (207) 775-2655

DRAWING NAME: SCITTERYGUSSET CREEK

PROJECT NAME: CASCO BAY FRONTAL DRAINAGE WMP

CLIENT: TOWN OF FALMOUTH, MAINE

ISSUED FOR	BY / DATE
BMP SCOPE	CAB 4/12/24
DRAFT REPORT	CAB 11/21/25
FINAL REPORT	CAB 1/16/26

Appendix F: BMP Matrix

TABLE C-1: WEBES CREEK - PHASE I BMP IMPLEMENTATION

WEBES CREEK – PHASE I						
BMP Location	**BMP**	**Location & Accessibility**	**Site Constraints**	**Stormwater Management Benefit**	**Construction Costs**	**Long-Term Costs**
206 US Route 1 - Walmart Parking Lot *	Gravel Wetland	High – adjacent to road access and next to large parking lot area	Abutting parcel cooperation needed	High – good pollutant removal and volume control	High	Low – minimal upkeep once established
	Tree Filters	High – installed in curbside or landscaped areas near impervious areas	Cooperation needed with landowner	High – good pollutant removal; effective for small drainage areas	Moderate	Moderate – requires periodic maintenance
US Route 1 Storm Inlet *	Infiltration Basin	High – adjacent to road access	Limited space, abutting parcel cooperation needed, existing stormwater infrastructure elevations	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
	Rain Garden (Bioretention Cell)	High – adjacent to road access	Limited space, abutting parcel cooperation needed	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
Catchment 5	Tree Filters	High – installed in curbside or landscaped areas near impervious areas	Cooperation needed with landowner	High – good pollutant removal; effective for small drainage areas	Moderate	Moderate – requires periodic maintenance

Depot Road	Tree Filters	High – installed in curbside or landscaped areas near impervious areas	Requires adequate curbside space	High – good pollutant removal; effective for small drainage areas	Moderate	Moderate – requires periodic maintenance
	Focal Point	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection
Falmouth Little League Complex	Infiltration Trench	High – adjacent to road access	Requires permeable soils for infiltration	High – good pollutant removal and volume control	Moderate	Moderate – requires periodic sediment removal
	Vegetated Swales	High – adjacent to road access, parking lots, or open channels	Requires adequate space and permeable soils	Moderate to High – slows runoff, promotes infiltration, reduces peak flows	Low to Moderate	Low – routine maintenance for vegetation and sediment removal
	Vegetated Buffer Strip	High - adjacent to road access and parking lot	Requires adequate space for vegetation	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation

***** - Locations with opportunity for large pollutant removal due to existing infrastructure connections.

TABLE C-2: NORTON BROOK - PHASE I BMP IMPLEMENTATION

NORTON BROOK – PHASE II						
BMP Location	**BMP**	**Location & Accessibility**	**Site Constraints**	**Stormwater Management Benefit**	**Construction Costs**	**Long-Term Costs**
US Route 1 - Roadway	Vegetated Swales with Check Dam	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils, Road ROW not located in Town of Falmouth, ROW privately owned (MEDOT)	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed, Road ROW not located in Town of Falmouth, ROW privately owned (MEDOT)	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
US Route 1 – Adjacent to Norton Brook	Vegetated Buffer Strips	High - adjacent to road access and parking lot	Requires adequate space for vegetation, Road ROW not located in Town of Falmouth, ROW privately owned (MEDOT)	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation
	Stabilize Storage Areas	Moderate - adjacent to Mill Creek, east of Route One corridor	Landowner cooperation required; Road ROW not located in Town of Falmouth, ROW privately owned (MEDOT)	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of storage

Northbrook Drive	Vegetated Swales with Check Dams	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils, Road ROW not located in Town of Falmouth	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection

TABLE C-3: CHENERY BROOK - PHASE II BMP IMPLEMENTATION

CHENERY BROOK – PHASE II						
BMP Location	**BMP**	**Location & Accessibility**	**Site Constraints**	**Stormwater Management Benefit**	**Construction Costs**	**Long-Term Costs**
Middle Road	Vegetated Swales with Check Dam	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils, Road ROW not located in Town of Falmouth	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance, Road ROW not located in Town of Falmouth	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection
	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed, Road ROW not located in Town of Falmouth	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
Interstate 295 (I-295)	Ditch Turnouts	High – Installed along roadside ditches	Requires available area along roadside, ROW privately owned (MEDOT)	Moderate – Reduces runoff velocity and filters sediments	Low	Low – Occasional maintenance to clear debris, vegetation management
St. Lawrence and Atlantic Railroad	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed, portion not located in Town of Falmouth, privately owned	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established

	Check Dams in Drainage Channels	Moderate – adjacent to raiload access	Requires slope and permeable soils, portion not located in Town of Falmouth, privately owned	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic check dam maintenance
St. Lawrence and Atlantic Railroad	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance, portion not located in Town of Falmouth, privately owned	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection

TABLE C-4: MILL CREEK - PHASE II BMP IMPLEMENTATION

MILL CREEK – PHASE II						
BMP Location	**BMP**	**Location & Accessibility**	**Site Constraints**	**Stormwater Management Benefit**	**Construction Costs**	**Long-Term Costs**
ME Route 9 - Longwoods Road	Vegetated Swales with Check Dam	High – adjacent to road access, parking lots, or open channels	Requires slope and permeable soils	High – slows runoff, promotes infiltration, and removes pollutants	Moderate	Low to Moderate – Requires periodic vegetation and check dam maintenance
	Infiltration Trench	High – adjacent to road access	Limited space, abutting parcel cooperation needed	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established
US Route 1 - South Corridor	Vegetated Buffer Strips	High - adjacent to road access and parking lot	Requires adequate space for vegetation, ROW privately owned (MEDOT)	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation
	Stabilize Storage Areas	Moderate - adjacent to Mill Creek, east of Route One corridor	Landowner cooperation required	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of storage

TABLE C-5: SCITTERYGUSSET CREEK - PHASE II BMP IMPLEMENTATION

SCITTERYGUSSET CREEK – PHASE II						
BMP Location	**BMP**	**Location & Accessibility**	**Site Constraints**	**Stormwater Management Benefit**	**Construction Costs**	**Long-Term Costs**
Highway Site Development – I-295 & Falmouth Spur Toll Road	Ditch Turnouts	High – Installed along roadside ditches	Requires available area along roadside, ROW privately owned (MEDOT)	Moderate – Reduces runoff velocity and filters sediments	Low	Low – Occasional maintenance to clear debris, vegetation management
Roadway Site Development – Woods Road, Lunt Road, Depot Road, Bucknam Road, & Middle Road	FocalPoint	Moderate – Installed adjacent to storm inlets and junction points	Requires connection to existing subsurface conveyance, cooperation with landowners and privately owned ROW	High – good pollutant removal through advanced media filtration	High	Moderate – Requires periodic maintenance for sediment removal and inspection
Town Facilities – Public Works and Falmouth Transfer Station	Vegetated Buffer Strip	High - adjacent to road access and parking lot	Requires adequate space for vegetation	Moderate to High – slows runoff, promotes infiltration, reduces pollutant loads	Low to Moderate	Low – routine maintenance of vegetation
	Rain Garden (Bioretention Cell)	High – adjacent to road access	Limited space, abutting parcel cooperation needed	High – good pollutant removal and volume control	Moderate	Low – minimal upkeep once established

APPENDIX B: FIELD GEOLOGY SERVICES 2023 GEOMORPHIC ASSESSMENT FOR FIVE CASCO BAY FRONTAL DRAINAGE WATERSHED STREAMS

Geomorphic Assessment and Restoration Recommendations for Five Streams in Falmouth, Maine

Prepared for

Town of Falmouth (Maine)



Norton Brook in Falmouth, ME

Prepared by

Dr. John Field
Field Geology Services
Portland, ME

June 2023

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EXECUTIVE SUMMARY

A fluvial geomorphic assessment was completed of five streams in Falmouth, Maine: Chenery Brook, Hobbs Brook, Norton Brook, Mill Creek, and Webes Creek. The assessment was completed to determine what restoration actions might be taken to remove Hobbs Creek from Maine's impaired streams list and ensure the other four streams are not listed as urban-impaired streams by the Maine Department of Environmental Protection. The findings were used to identify the impacts of urbanization on channel morphology and physical aquatic habitat in order to develop conceptual restoration options that will address the identified underlying causes for stream degradation. In total, 30 distinct geomorphic reaches of uneven lengths were delineated on the five streams with breaks between reaches occurring where the character of the valley or channel changes abruptly. Many of the reach breaks are at stream crossings where undersized culverts often disrupt the continuity of geomorphic, hydraulic, and ecological processes.

Human activities in the watershed have impacted the five assessed streams to varying degrees and extents. In-stream wood is an important element of high-quality physical aquatic habitat on streams in temperate climates. While the riparian zones on the five streams are well forested in most areas, long sections of even the most densely forested reaches are devoid of wood and may reflect past land clearance activities from decades ago. Streams that have had predominately forested watersheds for decades, such as Chenery Brook, Mill Creek, and Norton Brook, have more wood in the channel than watersheds that have become less forested through time (e.g., Webes Creek) or have only recently become reforested (e.g., Hobbs Brook). Forests take time to mature sufficiently for trees to begin decaying and naturally falling into the stream channel. In-stream wood levels in even the most forested of the five assessed streams are still below levels in pristine watersheds and will take decades to noticeably improve naturally. Therefore, the associated habitat benefits of in-stream wood could be more rapidly restored through "chop and drop" wood addition projects in remote areas or anchored wood additions using log sills, isolated logs, and log jams near stream crossings and other developments.

Multiple undersized stream crossings are present along the five assessed streams with at least one such crossing on each stream. Undersized crossings are unable to convey large flow discharges without impounding flow, upsetting the natural hydrological, geomorphological, and ecological continuity of the stream. Large wetland complexes dominated by low growing alders have formed upstream of undersized crossings on all five streams (e.g., upstream of Johnson Road on Norton Brook), although natural wetlands may have existed in some of these areas prior to the crossings' presence. Since the backwatering upstream of a culvert leads to deposition, flows exiting the culvert outlet are sediment starved and scour downstream of the undersized culverts is sometimes severe, exposing a hardpan clay on the stream bottom and eroding banks. The most dramatic scouring is present downstream of the railroad culvert on Chenery Brook, although the highest priority for a culvert replacement is at the Northbrook Drive culvert on Norton Brook where the headwall is damaged and the road could potentially be overtopped by severe backwatering during a large storm. The best restoration measure to

address the impact of the undersized crossings is to replace them with geomorphically compatible structures that have a width at least equivalent to the stream channel and also provide for relief culverts where wide floodplains are present. Larger structures may take years to replace given the high cost, so log crib walls and log sills could be used in the interim to address the impacts of bank and bed scour, respectively, at the undersized culvert outlets.

Past direct human activities on or near the stream channel continue, at least locally, to constrain the stream's adjustment and impact channel morphology. An old dam on Mill Creek blocks the sinuous natural flow path with the stream now flowing through a deep eroding gully around the dam's flank. Artificial fill on the floodplain at two or more locations on Norton Brook constrains channel migration and the development of a more natural sinuous planform. On the most upstream reach of Webes Creek, channel constraints by fill has caused erosion of the opposite bank and exposure of a manhole along the sewer line paralleling the length of the stream. Portions of the five streams were likely straightened in the past and the resulting higher flow velocities tend to be associated with the exposure of a habitat-poor hardpan clay on the stream bottom. Ideally, these various constraints to channel adjustment can be removed as part of restoration efforts (e.g., fill removal), so natural conditions can develop and be sustained over time. Elsewhere, log jams and other restoration structures could be constructed to more immediately improve aquatic habitat and encourage meander redevelopment along straightened reaches.

Human development within the watersheds of the five streams has increased over time, particularly in the Webes Creek watershed. Little evidence was seen on the five streams that excess runoff from impervious surfaces or concentration of runoff was having a direct impact on the stream channels. However, concentration of runoff along Route 1 has resulted in the erosion of a small gully that has led to deposition of a delta into Chenery Brook at the mouth of the gully. The excess runoff from development could, however, be indirectly contributing to erosion of the bed and banks more directly related to other human activities (e.g., undersized crossings). In-stream efforts to address these issues could include reclamation of the floodplain through the removal of artificial fill and the addition of in-stream wood, both of which should reduce flood flow velocities potentially enhanced from excess (and the concentration) of runoff.

Despite the human influences on the five streams, natural conditions still exert a strong influence. A great length of all five streams flow through stiff fine-grained glaciomarine clays and silts (i.e., hardpan), leading to channels with a low width:depth ratio (i.e., relatively deep and narrow) and high sinuosity with sometimes very tight meanders developing. Wood in the channel is typically associated with positive habitat attributes such as cover, flow complexity, and the deposition of sediment above the hardpan clay. These natural conditions indicate that restoration efforts focused on removing constraints to natural processes and increasing wood loading in the stream channels will lead to sustainable habitat improvements that will keep the streams from being listed as urban impaired by the State of Maine.

1.0 INTRODUCTION

The following report presents the findings and recommendations resulting from a fluvial geomorphic assessment of five streams in Falmouth, Maine (listed in alphabetical order): Chenery Brook, Hobbs Brook, Mill Creek, Norton Brook, and Webes Creek (Figure 1). Hobbs Brook is in a separate watershed in a rural setting that drains to the Piscataqua River, whereas Chenery Brook, Norton Brook, and Webes Creek are tributaries to Mill Creek that drains directly into Mussel Cove. The watersheds of Hobbs Brook, Chenery Brook, and Norton Brook extend into the neighboring Town of Cumberland but the geomorphic assessment was restricted to Falmouth alone.

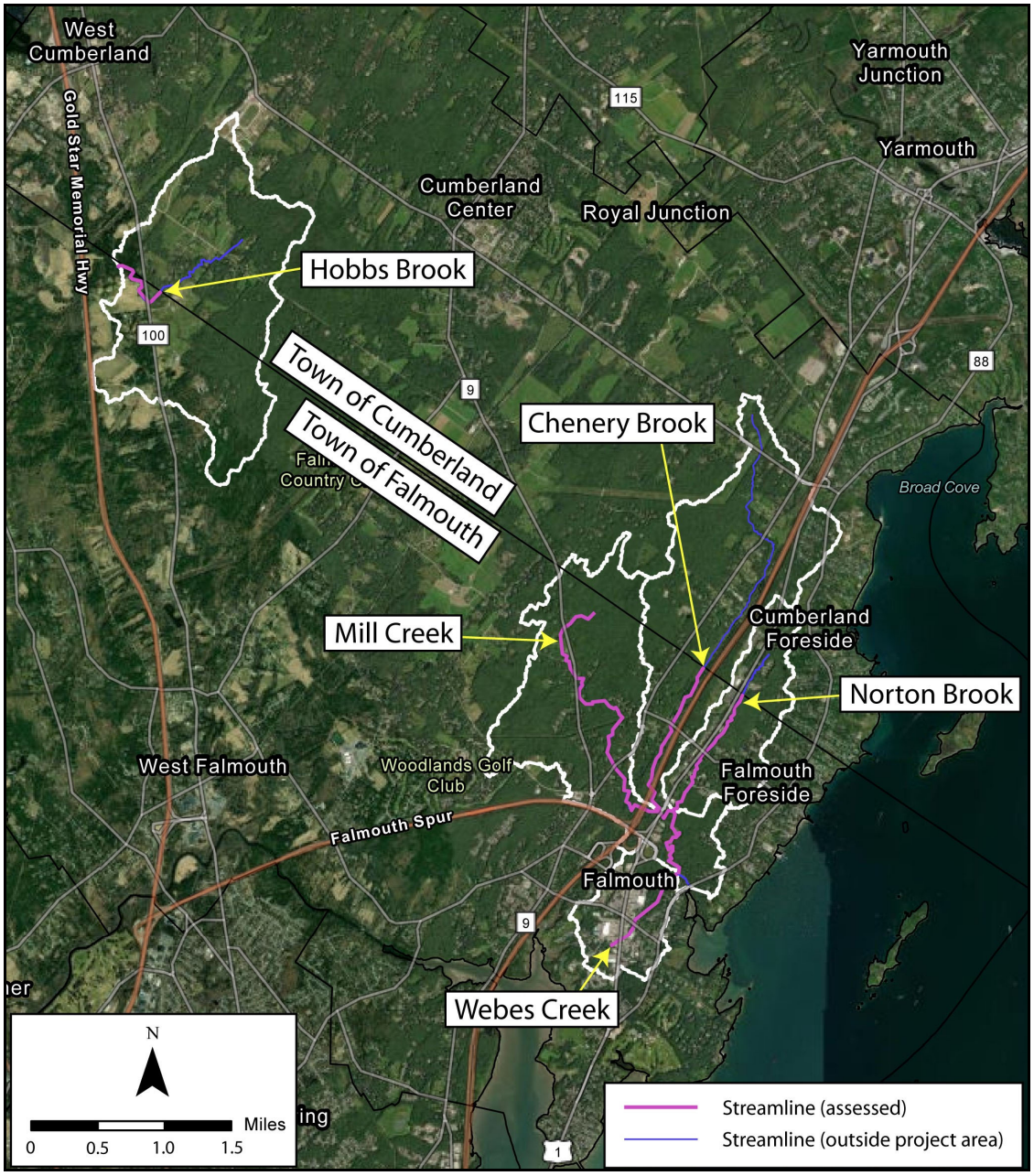


Figure 1. Map showing the location of the five assessed streams and their surrounding watersheds.

The five assessed streams are either impaired (Hobbs Brook) or could potentially be listed as urban impaired by the Maine Department of Environmental Protection (DEP), and, as a result of a listing, the streams would face stricter stormwater discharge requirements (Web citation 1). The geomorphic assessment of each stream was completed to: 1) establish the current condition of the streams and the natural and human factors, past and present, influencing those conditions; 2) determine whether excess stormwater and sediment runoff from development in the surrounding watersheds and other human activities are causing habitat and water quality degradation in the streams; and 3) identify and develop conceptual restoration projects that will sustainably enhance aquatic habitat, macroinvertebrate assemblages, and fish populations. The conceptual restoration projects are intended to ensure that the streams meet DEP's designated stream class and, as a result, either prevent the stream's from being listed as urban impaired or remove the existing impaired listing on Hobbs Brook.

The geomorphic assessment consisted of five technical tasks: 1) review of background materials including previous reports, soils maps, and surficial geology maps; 2) historic assessment of channel and watershed changes using topographic maps and aerial photographs; 3) a rapid geomorphic assessment of the stream channels; 4) a detailed assessment including mapping of channel features and topographic surveying of channel dimensions; and 5) development of conceptual restoration designs. Each component of the assessment was similarly completed on all five streams. The results for each of these technical tasks are discussed below.

2.0 BACKGROUND REVIEW

The background review of existing materials consisted of an evaluation of previous reports, topographic maps, and surficial geology maps relevant to understanding the natural conditions and human activities influencing conditions on the five assessed streams. The most significant findings resulting from the background review include:

- Timber was an important part of Falmouth's economy in the 1700s (Web citation 2). Lumber mills operated on the Presumpscot and Piscataqua Rivers as well as Mussel Cove. In addition, Falmouth was an important supplier of white pine for use as masts by the British navy. While no mention of the five assessed streams is mentioned in the History of Falmouth Maine (Web citation 2), logs in the 1700s were moved along streams, so log drives on the five streams could very well have occurred to supply timber for the lumber mills and British ships. Mill Creek, given its name and size, might have had mills and associated dams even upstream of its confluence at Mussel Cove known to have mills;

- Interstate 295 was completed through Falmouth in 1961 (Web citation 3) with construction presumably beginning in the 1950s. I-295 crosses both Mill Creek and Chenery Brook and, for some distance, closely approaches and parallels Chenery Brook. As a result, I-295 may be causing an impact on portions of Mill Creek and Chenery Brook;

- The first railroad came through Falmouth in 1848 (Web citation 4). Since two rail lines pass through Falmouth, some uncertainty remains as to whether the line that crosses Chenery Brook and Mill Creek was operational in 1848 or sometime after but before 1889 as the railroad appears on a topographic map surveyed that year (Web citation 5). The rail line crossings and proximity of the rail grade to the stream in other locations has likely locally impacted both streams for more than a century;

- The level of riparian zone disturbance (within the Town of Falmouth) varies between the five streams with: a) 26 percent disturbance along Chenery Brook, b) six percent along Hobbs Brook, c) 15 percent along Mill Creek, d) 12 percent along Norton Brook, and e) 44 percent along Webes Creek (Web citation 1). The amount of wood in the five assessed stream channels may be, at least partially, related to the levels of disturbance within the associated riparian zones. Streams with wood in the channel generally have higher fish populations (Flebbe, 1999), a greater abundance and richness of macroinvertebrates (Bond et al., 2006), and more complex physical habitat (Benke and Wallace, 2003);

- Topographic maps available for download and use in Google Earth (Web citation 6) reveal features useful in anticipating stream conditions and controls. Chenery Brook and Norton Brook are separated by an elevated narrow linear ridge, all three of which parallel each other. The ridge is likely composed of bedrock and suggests that ledge might be exposed along these two streams as well as Mill Creek that crosses the southern nose of the ridge near the confluence of Chenery Brook. Ledge is less likely to be found on Webes Creek and Norton Brook. The lower end of Mill Creek is highly sinuous and flows through a tidal marsh before reaching Mussel Cove downstream of Route 1. Given that Norton Brook and Webes Creek enter Mill Creek downstream of Route 1, tides may influence the lower ends of these two streams as well;

- Surficial geology maps show that large portions of Chenery Brook, Norton Brook, and Webes Creek flow through the Presumpscot Formation, a gray to bluish-gray marine silt and clay (Web citation 7 – Portland East Quadrangle), suggesting that a compacted, or hardpan, silt and clay may be occasionally exposed on the bed and banks of these streams (referred to as a hardpan clay throughout the report). Similar conditions likely exist on Mill Creek from a short distance upstream of the Chenery Brook confluence down to the Norton Brook confluence, although the Presumpscot Formation is mapped as just a thin veneer over bedrock upstream of the Chenery Brook confluence, so ledge is also likely present along the channel in this area. Glacial till, an admixture of clay, silt, sand, gravel, and even boulders, is mapped along the upper portion of Mill Creek and is also found as a thin veneer over bedrock in upland areas along the edges of Chenery Brook and Norton Brook, so a gravel or coarser substrate derived from the till or bedrock is possible on these three streams. A coarse substrate on Webes Creek is less likely to be found as the entire length of the stream is within the Presumpscot

Formation. Like Mill Creek, Hobbs Brook is entirely within the Presumpscot Formation (Web citation 7 – Cumberland Center Quadrangle), so a coarse substrate is unlikely but hardpan clay on the bed or banks should be expected.

3.0 HISTORICAL ASSESSMENT

The historical assessment of the five streams consisted of: a) a visual inspection of historical aerial photographs and topographic maps to identify changes in channel position and b) a GIS analysis of land use changes in each watershed.

3.1 Channel changes

Topographic maps of the five streams are available back to maps surveyed in 1889 (and published in the early 1890s) and can be compared with other historical topographic maps from 1916, 1941, and 1956 (Web citation 8) as well as the most recent topographic map from the 1980s available for viewing in Google Earth (Web citation 6). The resolution of the 1890s topographic maps is poor, so uncertainty remains as to whether the minor changes discussed below are actually on-the-ground changes or merely artifacts of comparing maps of different resolution. Two examples are the apparent a) development of high amplitude meanders in the tidal marshes of lower Mill Creek and b) shift at the confluence of Norton Brook shown on the 1890s maps as first joining Chenery Brook before entering Mill Creek. If these changes really did occur, they would have happened prior to 1916 but they are more likely only artifacts of different mapping methods and resolution rather than actual changes. If Norton Brook did flow into Chenery Brook in the past, then the construction of Route 1 with a high road grade between the two streams would be the most plausible explanation for the change. However, Route 1 wasn't constructed in Maine until 1926 (Web citation 9) and, therefore, after the apparent change in position of the Norton Brook confluence. The only more definitive change observed is that the position of upper Mill Creek on the 1980s topographic map differs from its current position in the large flat wooded area downstream of Long Creek Way; whether the channel was rerouted or whether the map shows Mill Creek following a preexisting tributary rather than what is now defined as Mill Creek is uncertain. Other minor changes have possibly occurred but the resolution of the maps are insufficient to identify such changes on these relatively small streams.

Aerial photographs of the five streams are available on Google Earth back to 1996 and Earth Explorer back to 1940 (Web citation 10). Unfortunately, the streams are too small, the banks generally well forested, and the resolution of the aerial photographs frequently too poor to discern channel changes over time. The aerial photographs do show the riparian zones of the Mill Creek watershed have largely remained forested through the photographic record despite increasing development in the watershed. The aerial photographs were also useful in identifying land use changes in the watersheds (see Section 3.2 below).

3.2 Watershed land use changes

Watershed land use changes can cause impacts to the channel by altering the amount of runoff and sediment delivered to the channel during storm events. A rapid decline in biotic diversity occurs on urban streams where more than 10 percent of the watershed is covered with impervious surfaces (Klein, 1979). Urbanization also impacts the physical characteristics of streams in several ways including increases in channel size, greater bed and bank erosion, and more simplified channel morphology (e.g., loss of pools, less in-stream wood) (McBride and Booth, 2005).

How the amount of forested, open land, and, in particular, developed land has changed through time was determined by hand digitizing the limits of each land use type within the watersheds of the five assessed streams on aerial photographs from 1940, 1960, 1975, 2006, and 2022 (Appendix 1). While the field assessments of the streams themselves included only those portions of the streams within the Falmouth town limits, the land use mapping included the entire area of the watersheds, even those portions of Chenery Brook, Hobbs Brook, and Norton Brook (and as a consequence Mill Creek as well) that extend into the Town of Cumberland. Maps are provided only for the Hobbs Brook and Mill Creek watersheds with the watershed limits of Chenery Brook, Norton Brook, and Webes Creek clearly demarcated on the Mill Creek watershed maps. The data on land use changes displayed in Figure 2 and Table 1 separate out the results for these three subwatersheds, while the data for Mill Creek includes both the data for these three subwatersheds and the additional areas outside the limits of those subwatersheds.

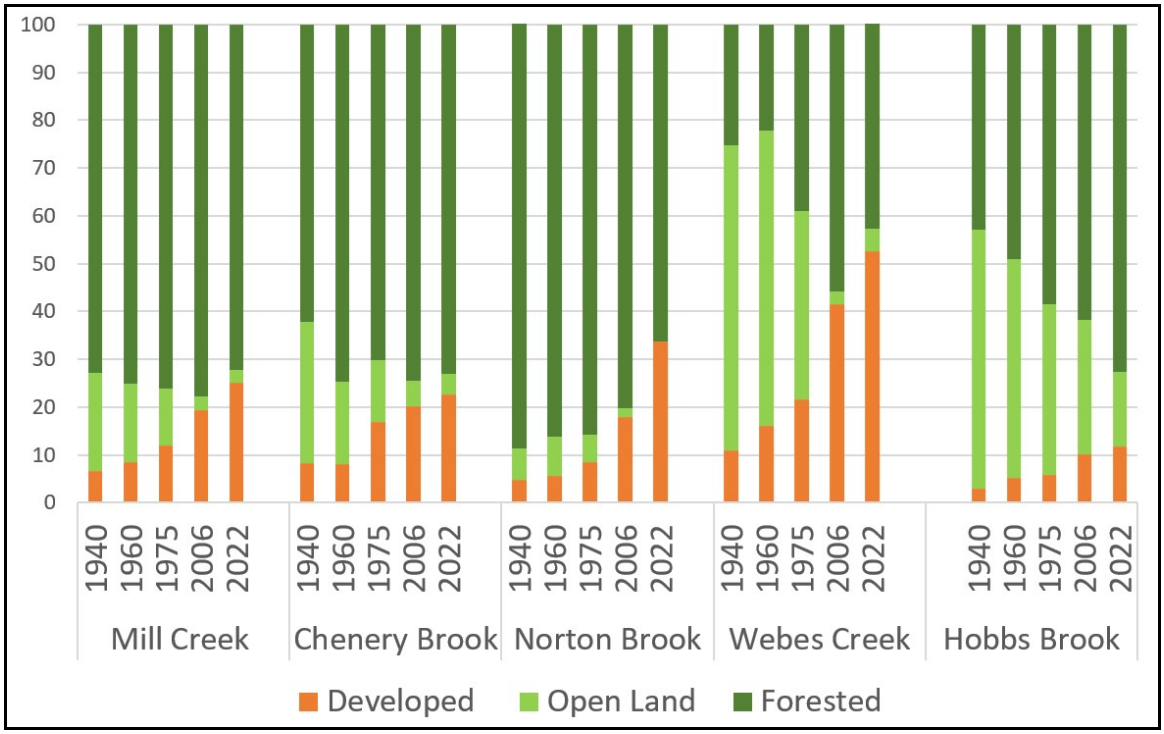


Figure 2. Land use changes through time by percentage of watershed area on the five assessed streams.

Stream/Land use	Drainage area (mi^2)	Percent of watershed (year) 1940	1960	1975	2006	2022	Total change (%) 1940-2022	Period of Greatest Change
Chenery Brook*	2.0648							
Forest		62.1	74.8	70.2	74.6	73	17.6	1940-1960
Open lands		29.6	17.2	13	5.2	4.4	-85.1	1975-2006
Developed		8.3	8	16.8	20.2	22.6	172.3	1960-1975
Hobbs Brook	2.3498							
Forest		42.9	49	58.4	61.7	72.7	69.5	1975-2006
Open lands		54.1	45.8	35.7	28	15.6	-71.2	1975-2006
Developed		3	5.2	5.9	10.2	11.7	290.0	1975-2006
Mill Creek	5.3234							
Forest		72.7	75.1	76.2	77.6	72.2	-0.7	2006-2022
Open lands		20.6	17.4	11.8	3	2.7	-86.9	1975-2006
Developed		6.6	8.5	12	19.3	25.1	280.3	1975-2006
Norton Brook*	0.7863							
Forest		88.8	86.3	85.8	80.2	66.3	-25.3	1975-2006
Open lands		6.6	8.1	5.8	1.8	0	-100.0	1975-2006
Developed		4.7	5.6	8.4	18	33.7	617.0	1975-2006
Webes Creek*	0.5419							
Forest		25.3	22.1	39.1	55.9	42.9	69.6	1960-1975
Open lands		63.7	61.8	39.2	2.5	4.7	-92.6	1975-2006
Developed		11	16.1	21.7	41.6	52.5	377.3	1975-2006

* These streams are smaller subwatersheds within the Mill Creek watershed

Table 1. Land use changes through time on the five assessed streams.

Three land use categories were mapped: forested lands, open lands, and developed lands. Forested lands are those areas of large contiguous tree growth. Open lands include agricultural areas, open fields that may or may not be in agricultural production, and wetland/marsh areas. Developed lands are those areas where homes, commercial developments, and roadways are concentrated. While changes in the amount of developed lands serve as a proxy for changes in the amount of impervious surface area, the total percentage of impervious surface area is likely much less than the percentage of developed lands that also includes small patches of open space, trees, etc. Further refinement of the land use mapping, such as carefully mapping impervious surface areas, was not possible given the resolution and clarity of the older aerial photographs.

With only minor exceptions, the amount of agricultural land (including open fields and marsh land that might not be in production) has decreased over time in each of the five watersheds, while the amount of developed land has increased (Figure 2 and Table 1). The percentage increase in developed land has been significant in the Mill Creek watershed with most of the increase occurring after 1975 (Table 1). The increases in development have been most significant in the Webes Creek subwatershed, particularly in the upper watershed (Appendix 1). As a result, a greater percentage of the watershed in the upper portion of Webes Creek will be covered with impervious surfaces and, therefore, the channel is more likely to be impacted by excess runoff. Development in the other watersheds is not only less significant overall but also less concentrated, so is less likely to cause an impact. However, development activities directly on the streams, regardless of the overall percentage of imperviousness in the watersheds, could impact the streams (e.g., road crossings).

Mill Creek, Chenery Brook, and Norton Brook have remained well forested since 1940 (Figure 2 and Table 1). Despite recent losses in forest cover to development, that

development has largely avoided the riparian zone (Appendix 1), so considerable in-stream wood might be present in these stream channels. In contrast, while Hobbs Brook has seen the greatest increase in forest cover since 1940, less in-stream wood may be present because the forest is less mature and fewer trees dying and falling into the stream channel as would be expected in an older forest stand.

4.0 RAPID GEOMORPHIC ASSESSMENT

As part of the Rapid Geomorphic Assessment completed in Fall 2023, each of the five streams were subdivided into reaches of uneven length. Each reach is a relatively homogeneous length of stream channel that has a character distinct from adjacent reaches or is separated from an adjacent reach by a structure (e.g., culvert) or land feature (e.g., tributary confluence) that significantly alters the channel morphology upstream and/or downstream. The reaches on each stream are numbered sequentially from the upstream end and given a prefix letter to identify the stream (the first letter of the stream's name) such that Reach N1 is the most upstream reach on Norton Brook. See Appendix 2 for maps of all of the reach locations on the five streams. Some of the streams extend into the neighboring town of Cumberland, but the assessments and the reach numbering are restricted to Falmouth. Delineating the reaches and characterizing the morphological conditions present in each reach are critical for identifying the natural and human factors potentially responsible for observed channel instabilities and degraded aquatic habitat.

Reaches that share similar traits are referred to as "like-reaches" and an understanding of channel response or effective restoration techniques gained in one reach may apply to other "like-reaches". See Table 2 (placed at the end of the report) for details on the location, length, and characteristics of each reach. The breaks between reaches occur at observable changes resulting from various natural and human conditions such as a change in channel confinement, channel gradient, or human alteration of the channel such as at a culvert. Typically, these reach breaks, whether at natural or human features, represent grade controls whereby channel adjustments in adjacent reaches cannot migrate upstream or downstream due to constraints at the reach breaks themselves. Consequently, the most dramatic channel adjustments often occur immediately adjacent to the reach breaks.

The rapid geomorphic assessment was conducted on all of the delineated reaches on the five streams using an adaptation of EPA's *Streamwalk* protocol developed by Maine Inland Fisheries and Wildlife (Appendix 3). The rapid geomorphic assessment uses visible physical characteristics of the stream to identify whether the stream is undergoing morphological adjustments associated with aggradation (e.g., presence of bars, siltation in pools), degradation (e.g., headcuts, elevated tree roots), widening (e.g., leaning trees, erosion on both sides of channel), or planform changes (e.g., cut-off channels, formation of islands). Depending on the total number of features observed that are indicative of these adjustments, the stream is characterized as either "in adjustment" (i.e., numerous observed features), "transitional/stressed" (i.e., some observed features), or "in regime" (i.e., very few or no observed features) (Appendix 3).

Reaches "in regime" are considered geomorphically stable (i.e., in equilibrium) and are taken to represent the natural state of the channel that would emerge in the absence of human impacts. In contrast, reaches categorized as "stressed" or "in adjustment" are considered to be responding to varying degrees to human influences (e.g., channel straightening) or natural events (e.g., floods). However, the scores are based on the presence or absence of certain features and not how well developed those features are. Consequently, a clearly degrading reach evidenced by dramatic increases in bank height may still classify as "in regime" if none of the other characteristic features of degradation are present. Furthermore, some unaltered stream reaches are naturally dynamic and the resulting complexity is important for ecosystem health, so the presence of some of the assessed features does not necessarily imply unstable or undesirable conditions. Consequently, the results of the rapid geomorphic assessment are best corroborated by a qualified professional (i.e., fluvial geomorphologist) and/or more detailed assessments.

Of the 30 total assessed reaches on all five streams, only one, on Norton Brook, rates as "in adjustment", eight are classified as "transitional/stressed", and 21 are considered "in regime" (Appendix 1). These results accurately reflect the overall good and intact morphological condition of all five streams and suggest current conditions do not represent a great departure from what might be expected naturally. While human alterations of the channel are causing localized impacts, systemic channel responses extending across multiple reaches or even the full length of individual reaches are not present. Consequently, stream restoration efforts on the five streams addressing the localized impacts observed are likely to have a greater chance of success.

The overall reach conditions recorded on the rapid geomorphic assessment forms (Appendix 3) do not accurately capture all of the localized channel adjustments occurring on the streams, Consequently, a brief description of each reach from upstream to downstream on all five streams (presented in alphabetical order) is provided below with ideas for potential restoration projects where appropriate. Table 2 provides a summary of the conditions and potential restoration options for each reach. A priority rating is given to provide a sense as to how important the project is to complete for improving geomorphic and habitat function, and a complexity rating is given to indicate how difficult the project will be to complete in terms of access and perceived landowner willingness among other considerations (although likely costs are indicated in a separate column. A priority/complexity rating of high/low is ideal as great benefit can accrue relatively easily, whereas a low/high rating would require great effort with little benefit.

4.1 Chenery Brook

Reach C1 – Cumberland town line to railroad culvert

Much of the reach is likely impacted during large storms by flow impoundment upstream of the undersized railroad culvert at the downstream end that may also enhance development of the high amplitude meanders, relatively deep and narrow channel morphology (i.e., low width:depth ratio), and fine-grained substrate (i.e., sand and silt)

that characterize the low-gradient reach. Bank erosion and undermined trees are present where the meander apices impinge on the higher slopes of clay along the valley's edge with narrow sandy point bars observed on the inside bends of the tight meanders Figure 3a). Numerous small logs in the channel create flow complexity where present (Figure 3b). More and larger wood would likely be in the channel if the riparian vegetation consisted of larger trees rather than the shrubs and grasses present under the power line under which the stream flows for most of the reach.

Given the limited access to the reach, "chop and drop" wood additions (i.e., directionally felling standing trees into the steam) could increase wood loading and flow complexity in those areas where the stream moves away from the power line and tall mature trees are present.

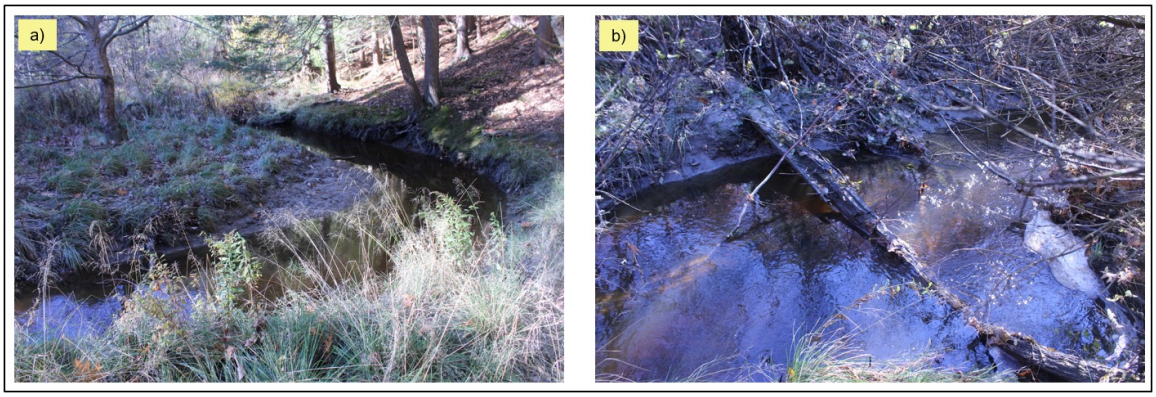


Figure 3. Reach C1 exhibits a) bank erosion where meander apices impinge on higher banks and b) flow complexity where wood is present in the channel.

Reach C2 – Railroad culvert to widened floodplain with sinuous channel

Severe scour of the banks is evident at the outlet of the railroad culvert (Figure 4a) with the bed substrate stripped away to hardpan clay and a large cobble bar formed downstream that has infilled the channel, forcing the channel to shift into an eroding bank. Beyond the scour area, the channel has been artificially straightened against the I-295 road grade, perhaps resulting in the cutting off of a now abandoned meander that is located just upstream of a constricting ridge of higher ground on the right bank floodplain (looking downstream). The straightened channel has a sandy substrate for most of its length and minimal wood, pools, and flow complexity are present (Figure 4b). The high road grade of Interstate 295 is composed of large boulders at its base, but the right bank floodplain is quite wide in most areas. The floodplain is forested with mature trees, providing a good canopy despite only a few mature trees on the I-295 road grade.

Given the limited access to the reach, "chop and drop" wood additions could increase wood loading and flow complexity along the straightened channel that comprises nearly the entire length of the reach. Wood additions are likely to immediately improve flow complexity and pool depths where the substrate is sandy. The leaning trees downstream of the railroad culvert (Figure 4a) indicate scour is ongoing and could be treated, if access routes are identified, with log cribbing to reduce erosion and fine sediment inputs into the

channel. Low log sills could be placed on the channel bed to redirect flow away from the scoured banks and trap sediment to provide a substrate above the hardpan clay. Larger marginal log jams could be built along the straightened channel to encourage meander development.

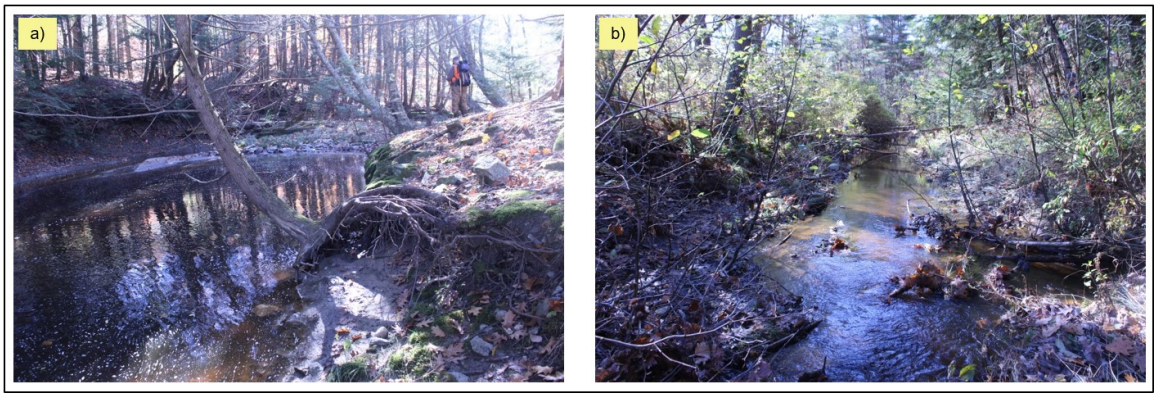


Figure 4. Reach C2 a) exhibits severe scour downstream of the railroad culvert and beyond the scour b) is artificially straightened with minimal wood, pools, and flow complexity in the channel.

Reach C3 – From start of widened floodplain with sinuous channel to Johnson Road

As the channel moves away from the I-295 road grade and the straightened portion of the channel ends, a more sinuous channel emerges with the meanders sometimes impinging on natural higher ground along the left bank (Figure 5a). Numerous tall standing dead trees are present on the floodplain, many of which have fallen into the channel to form log jams and good flow complexity (Figure 5b). Beaver activity was observed in the reach and is partially responsible for the abundance of wood in the channel. The dead standing trees suggest the area was previously impounded, but such ponding likely ended approximately five years ago based on the size of new saplings now growing on the floodplain. A small dam and upstream pond is present just upstream of Johnson Road near a residential property, although another unknown reason (perhaps beaver activity) is considered responsible for impounding the entire reach. The Johnson Road culvert is nearly as wide as the channel and no deposition is present upstream that would suggest backwatering is occurring upstream of the culvert.

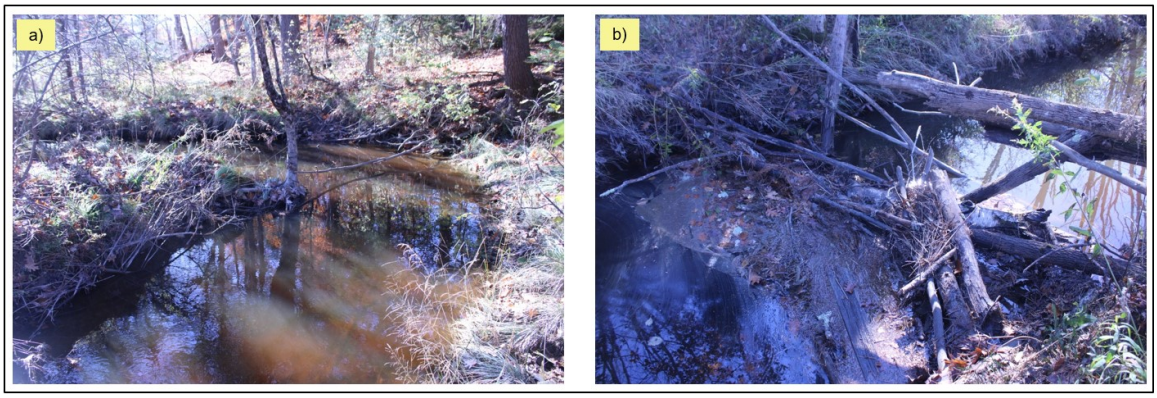


Figure 5. Reach C3 is a) more sinuous than Reach C2 and b) loaded with large fallen wood that forms log jams and good flow complexity.

Stream conditions are good through most of the reach, but removal of the dam and associated rock work is recommended, assuming permission is granted by the landowners who do not seem to currently occupy or use the property.

Reach C4 – Johnson Road to area of increasing confinement

An 8-inch diameter gas line crosses the stream just downstream of the Johnson Road, but no significant scour is present at the culvert outlet that would threaten the pipeline. The high left bank just downstream of the gas pipeline is unstable (Figure 6a). A gravel substrate is present near the gas pipeline, perhaps associated with the pipeline or erosion from the high bank. The stream quickly transitions to a sinuous channel downstream with a low width:depth ratio and clay banks. Abundant small wood has created multiple log jams and beaver dams (Figure 6b), creating good flow complexity; a side channel has been carved into the wide floodplain where impounded flow behind one log jam overtopped the bank. The presence of two adjacent sharp right angle bends in the channel may indicate the reach was channelized in the past. The floodplain is well vegetated with shrubs dense enough to provide a good canopy over the narrow stream. The absence of tall mature trees suggest the floodplain is inundated for extended periods.

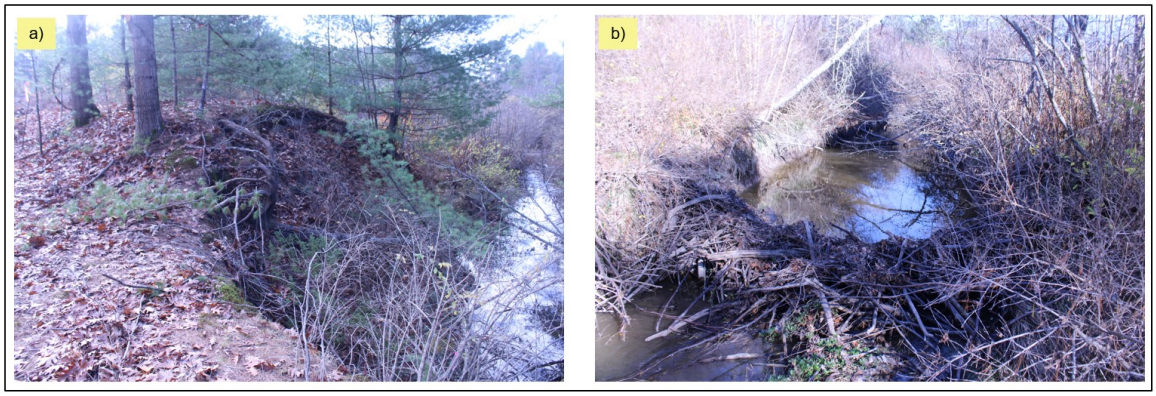


Figure 6. Just downstream of the gas pipeline a) the high bank is eroding, while further downstream b) numerous log jams and beaver dams are present in the channel.

Given the good condition of the stream, poor access, and lack of tall mature trees for chop and drop, restoration is not critical nor practical for much of the reach. Outreach to the landowner is recommended to discuss conservation, so the reach can remain undisturbed. Bank stabilization of the high bank just downstream of the gas pipeline could be completed with log cribbing but is not considered essential as the pipeline is not considered threatened by the erosion (Figure 6a).

Reach C5 – From area of increasing confinement to I-295 culvert

Although Reach C5 maintains a sinuous channel in parts, the floodplain narrows considerably as higher ground approaches closer to the channel from both sides (Figure 7a) with some erosion along the higher banks. A cobble substrate is present where the channel impinges on the high ground. A cobble substrate is present for 150ft upstream of the I-295 culvert and suggests no backwatering is occurring upstream of the appropriately

sized culvert. A large beaver dam is impounding much of the reach with abundant leaves floating on the stagnant water in the channel (Figure 7b) with a second smaller beaver dam just downstream. Additional logs and branches that have fallen into the channel also improve flow complexity. Tall trees are present on the high ground and provide some canopy over the channel (Figure 7b) with lower shrubs still dominating the floodplain vegetation (Figure 7a) as in Reach C4.

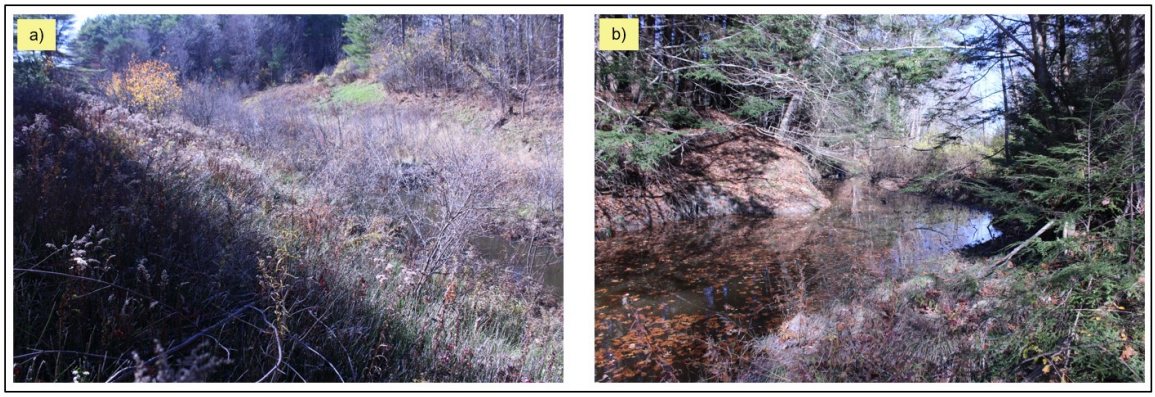


Figure 7. Reach C5 has a) a narrower floodplain as high ground on both sides converge and b) a lengthy impounded area upstream of a large beaver dam.

Given the good condition of the stream and poor access, restoration is not critical nor practical for much of the reach. Outreach to the landowner is recommended to discuss conservation, so the reach can remain undisturbed. With tall trees on the high ground in close proximity to the channel (Figure 7b), chop and drop could be performed along portions of the reach to further improve flow complexity.

Reach C6 – I-295 culvert to sharp bend on high right bank

Immediately downstream of the I-295 culvert, Chenery Brook is narrowly confined by 8-foot high banks on both sides of the channel (Figure 8a). Ledge extends high up the left bank near the culvert, but is found only at the base of the bank further downstream with clay of the Presumpscot Formation above. The high right bank is largely composed of the glaciomarine clay with some sloughing close to the culvert. However, severe scour is not observed, because the culvert is nearly as wide as the channel. The right bank remains confining throughout the reach but a floodplain emerges on the left bank near the downstream end of the reach with a vegetated overflow channel present. Within the channel, a cobble substrate is present through the confined reach and becomes finer downstream with sand bars along the channel margins, including on the inside of the sharp bend at the downstream end of the reach (Figure 8b). The sand bar formation coincides with the emergence of the left bank floodplain and backwatering upstream of the sharp bend. A beaver dam and other wood are present in the channel but the wood is not abundant. A few mature trees are growing on both banks and provide some canopy over the stream channel.

Chop and drop wood additions could increase flow complexity in this short reach, but is a low priority given the existing in-stream wood and beaver dam.

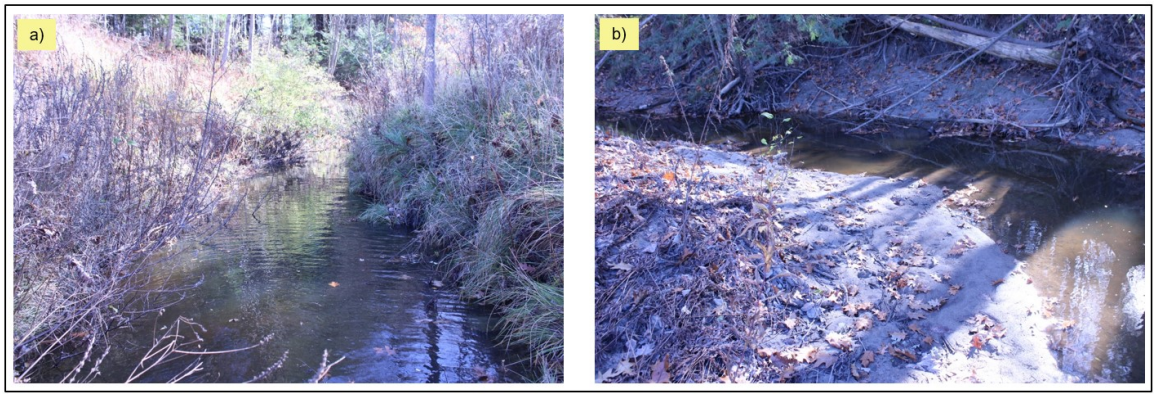


Figure 8. C6 is a) confined at the upstream end with b) sand bars present further downstream where at a sharp bend at the downstream end of the reach.

Reach C7 – Sharp bend on high right bank to Mill Creek confluence

Reach C7 is highly sinuous with a sandy substrate and eroding banks on the outside bend of meanders (Figure 9a). A wide floodplain is present but the channel occasionally impinges on the high banks along the back edge of the floodplain. A former channel is present on the floodplain at the upstream end of the reach and along with two close by sharp right angle bends in the channel suggest the channel's position may have been altered in the past by humans. The presence of wide sand bars, leaning trees along undermined and eroding banks, and abundant wood in the channel indicate the channel is dynamic and the meanders actively migrating. While the channel has a low width:depth ratio in places as a result of the meander migration and bar deposition, flow complexity is good, pools are formed around logs in the stream, and a well developed canopy covers nearly the entire reach due to the mature forested floodplain. A cobble bar has formed at the mouth of a small tributary (Figure 9b) that is actively eroding from runoff concentrated along Route 1.

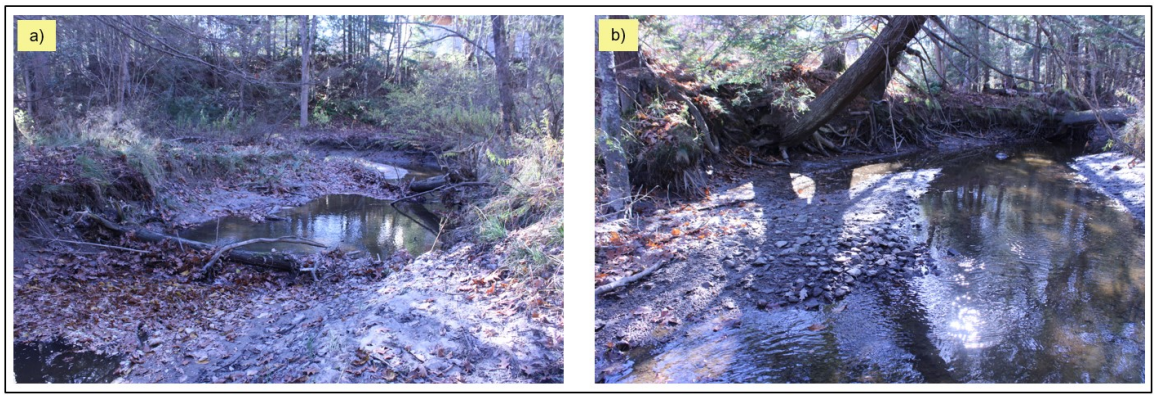


Figure 9. Reach C7 has a) a sinuous channel with abundant wood, bars, and undermined and eroding banks and b) a cobble bar formed at the mouth of an eroding gully off of Route 1.

Reach C7 is currently in good condition, so restoration in the channel is a low priority, although chop and drop and reactivating the abandoned channel could increase flow complexity and reduce sediment inputs from the high banks, respectively. A higher

restoration priority would be to add wood to the eroding gully off of Route 1 to reduce the erosion and trap sediment before reaching Chenery Brook.

4.2 Hobbs Brook

Reach H1 – Cumberland town line to Gray Road

Reach H1 is characterized by a sinuous sand-bed channel with a low width:depth ratio flowing through an alder and cattail dominated wetland (Figure X). Flow in the channel was stagnant at the time of the assessment during low-flow conditions. Backwatering upstream of the Gray Road culvert may enhance the wetland conditions that would likely persist even in the absence of the culvert. A gas pipeline crosses the channel and wetland immediately upstream of the culvert. Few mature trees are growing along the channel nor was wood observed in the channel, although the channel was closely inspected only at its downstream end at Gray Road.

Restoration is not recommended for Reach H1 given the persistent wetland conditions and no perceived threat to the gas pipeline, Gray Road, or other nearby infrastructure (e.g., adjacent residential homes).



Figure 10. Reach H1 has a low width:depth ratio as it flows through a wetland.

Reach H2 – Gray Road to high confining left bank

A scour pool lined with cattails is present at the outlet of the 10-foot wide and 4-foot high Gray Road culvert (Figure 11a); the culvert closely matches the channel's dimensions but does block floodplain/wetland conveyance, so has a scouring effect at high flows. The banks throughout the reach are composed of the Presumpscot Formation with the clay forming a hardpan substrate on the channel bottom where not covered by a thin bed of gravel along riffles or soft fine sediment and organics in areas of more stagnant flow. A few isolated boulders are seen throughout the upper half of the reach and may be associated with past farming activities. A low discontinuous floodplain is inset within a

higher continuous floodplain, suggesting channel incision occurred in the reach. The sinuous channel with a low width:depth ratio has little in-stream wood with only a few mature trees growing along the channel that passes through open fields (Figure 11b).

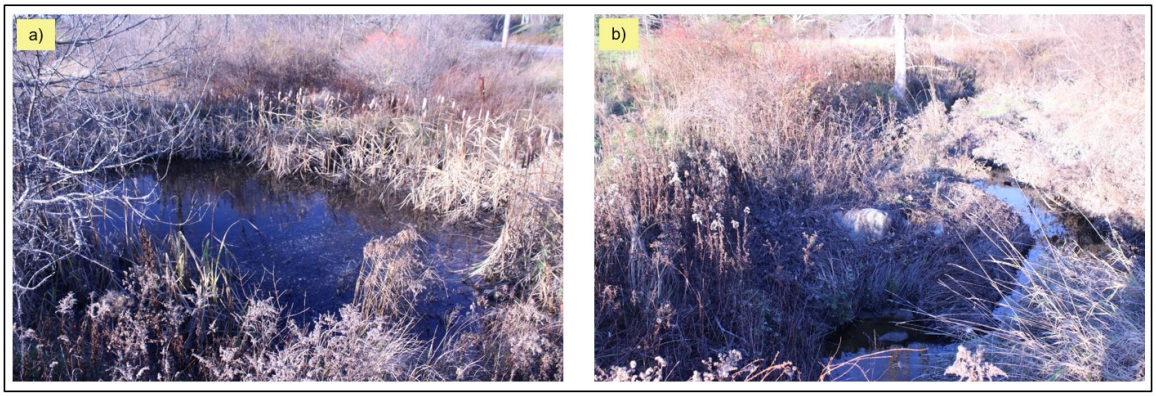


Figure 11. Reach H2 has a) scour pool at the outlet of the Gray Road culvert, but further downstream is b) a sinuous channel with little in-stream wood.

Flow complexity could be increased and sediment deposition enhanced above the exposed hardpan clay substrate through wood additions such as low log sills. Chop and drop could be used in the lower third of the reach where the approaches uplands with mature trees. Any restoration activities would first require the permission of the landowner.

Reach H3 – From high confining left bank to Piscataqua River confluence

Reach H3 is a relatively straight channel that flows along a high surface on the left bank with only a narrow floodplain before encountering higher ground on the right bank as well (Figure 12a). The channel has a soft substrate and very low banks perhaps due to infilling by fine sediments associated with past ponding caused by a fallen large tree crossing the channel downstream that was further jammed up by small branches emplaced, in part, by beaver (Figure 12b). The highwater mark of the impoundment is demarcated along the high left bank by a color change on the ground (marked by red arrows on Figure 12a) with a thin gray film of fine silt draping the lower slope and right bank floodplain. The impoundment has since drained as the channel has migrated around the fallen tree. One small tree has fallen across the channel within the formerly impounded area (at red arrow furthest to right in Figure 12a) and may act as a log sill to improve flow complexity within this upper portion of the reach with otherwise little wood. The channel is better defined with higher banks downstream of the formerly impounded area. While few mature trees are found on the narrow floodplain, particularly in the impounded area, forest growth on the higher adjacent surfaces provides a good canopy over the entire channel (Figure 12).

Given the relatively undisturbed condition of the stream, restoration is not critical for much of the reach. Outreach to the landowner is recommended to discuss conservation, so the reach can remain in a fairly pristine condition. With landowner permission, Reach H3 would be an excellent candidate for chop and drop given the large stand of mature

trees growing on the high ground near the channel and the upper portion of the reach that is largely devoid of in-stream wood (Figure 12a).

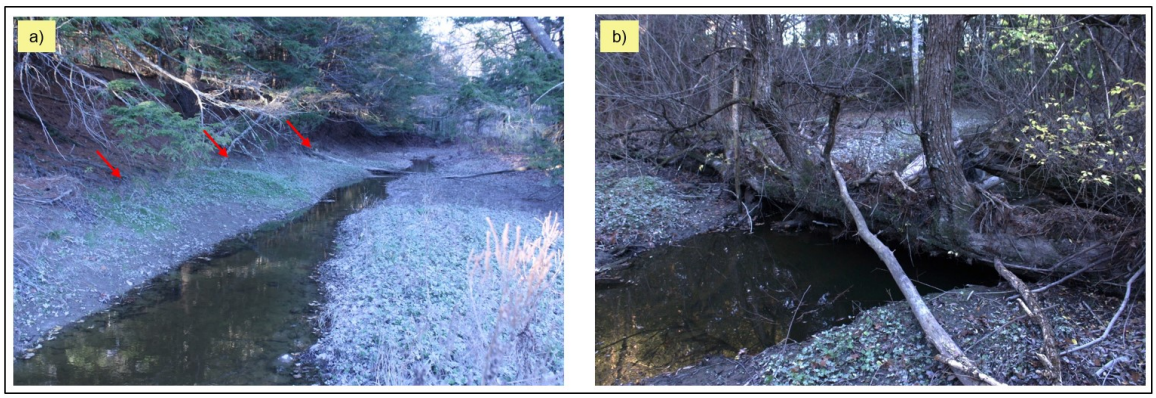


Figure 12. The upper portion of Reach H3 was a) impounded by b) a fallen large tree jammed with smaller branches further downstream.

4.3 Mill Creek

Reach M1 – Route 9 to Olde Blackwood Way

Immediately below Route 9, Reach M1 flows in a well defined sinuous channel (Figure 13a) with a substrate of clean pea-sized gravel. Within 250 ft of Route 9, the channel quickly transitions into a wetland with a poorly defined channel that comprises most of the reach's length. The impounded flow condition is enhanced by a small culvert passing under a private driveway but wetland conditions are present on both sides of the culvert. A well defined channel reemerges as the channel becomes increasingly confined by higher ground. The channel, behind a residential home, appears to have been altered by human activity with a large meander cutoff and the channel now straight. At the downstream end, a sharp right angle bend is present (Figure 13b) at the edge of Olde Blackwood Way as part of a realignment of the channel to flow through the culvert. In-stream wood is creating good flow complexity at the downstream end of the reach with jams forming as leaves and smaller branches are trapped behind larger fallen trees. A mature forested buffer is growing at the upstream and downstream ends of the reach (Figure 13). The channel through the wetland area is bordered by low growing alders.

The private driveway culvert could be enlarged to reduce backwatering in the wetland area. The culvert under Olde Blackwood Way could be repositioned to better align with the preexisting flow path and, thus, eliminate the sharp bend (Figure 13b) that could create erosion problems by the road during a large storm. Chop and drop or wood additions could be used to increase flow complexity at the upstream and downstream ends of the reach, but will require landowner permission.

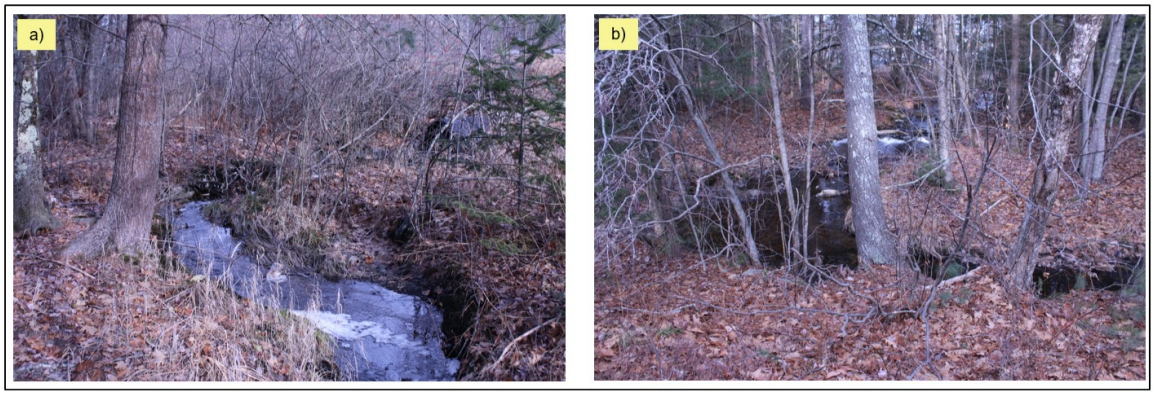


Figure 13. The upper part of Reach M1 has a) a well defined sinuous channel while the end of the reach has b) a sharp bend indicating the channel was realigned to pass through the culvert.

Reach M2 – Olde Blackwood Way to Route 9

Minor bank scour has occurred at the outlet of the undersized double culvert under Olde Blackwood Way. The straightened channel behind the home and barn in the upper reach has a high width:depth ratio with little in-stream wood. An abandoned meander is present on the right bank (Figure 14a) that extends upstream to Olde Blackwood Way and aligns with the sharp bend in Reach M1 (Figure 13b from reach M1), suggesting the main flow path was moved as part of road construction or prior human activity. Downstream of a small culvert under a field road, the stream transitions into a wetland area dominated by cattails and alders with the straightened channel eventually approaching and then flowing along Route 9 at the end of the reach (Figure 14b). The stream passes through a culvert under Paddington Way before taking a sharp left turn into the culvert under Route 9 that is set a bit low (but does not appear to be problematic). A large tributary enters the stream immediately upstream of the Route 9 culvert. Given the fields behind the home and barn in the upper reach and low shrubs in the wetland, very few large mature trees are present along the channel to provide canopy cover or a long-term source for wood recruitment into the stream for improved habitat and flow complexity.

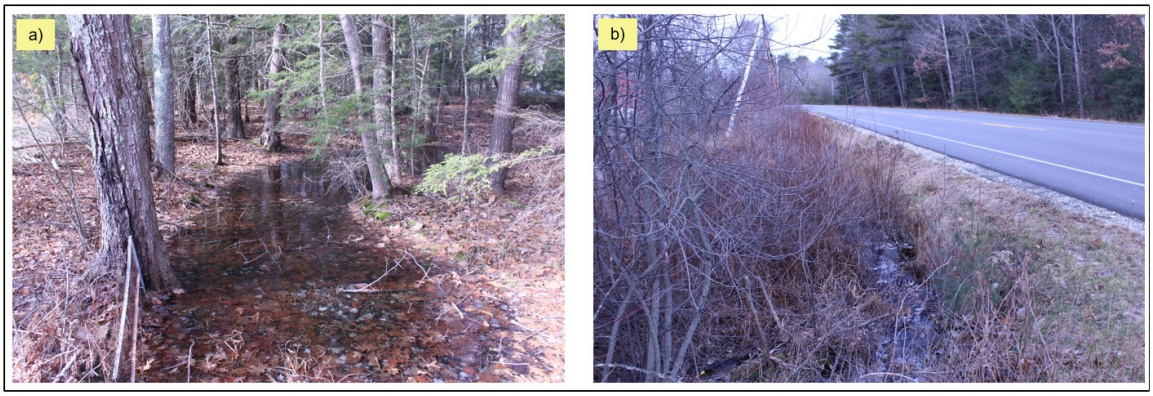


Figure 14. Reach M2 a) has an abandoned meander in the upper reach and b) flows along Route 9 at the downstream end of the reach.

Restoration opportunities include replacing the field road with a larger culvert or ford and realigning the stream to avoid a sharp bend entering the Route 9 culvert. The channel

could be realigned to reestablish flow in the old meander and eliminate the hard bend in Reach M1 (Figure 13b from Reach M1), but this would require moving the culvert under Olde Blackwood Way. If this proves insurmountable, then another option would be to place a relief culvert under the road at the sharp bend, so flood flows can pass into the old meander and reduce some of the erosive force on the road grade. Wood could be added to the channel in the form of low log sills to improve flow complexity without increasing flooding, so could be palatable to the landowner who would need to provide permission for the project.

Reach M3 – Route 9 to Long Creek Way

The Route 9 culvert outlets at a sharp bend and flows directly into a left bank composed of ledge and, given the sharp bends at both the inlet and outlet of the culvert, suggests significant modifications to the channel alignment occurred during the construction of Route 9. An overflow chute has formed on the left bank floodplain just beyond the ledge outcrop. The channel flows across a wide floodplain that is slightly constrained by artificial fill on the right bank on which homes have been built along Route 9. The channel has a high width:depth ratio and the upper part of the reach may have been artificially straightened in the past, but three high amplitude meanders have formed in the lower reach (Figure 15a), likely due to a combination of flow impoundment downstream and clay bank materials. The channel substrate contains pea gravel at the upstream end but is predominately sand before reaching the downstream end with occasional small sand bars present along the margins of the channel. For short lengths, in-stream wood is creating good flow complexity with minor flow impoundment upstream, cascading flow over logs, and overflow onto the floodplain (Figure 15b). However, in general, the amount of wood in the channel is minimal despite the forested floodplain with numerous tall mature trees providing a full canopy over the channel. The undersized culvert at the downstream end is paired with an additional small culvert set at the floodplain elevation.

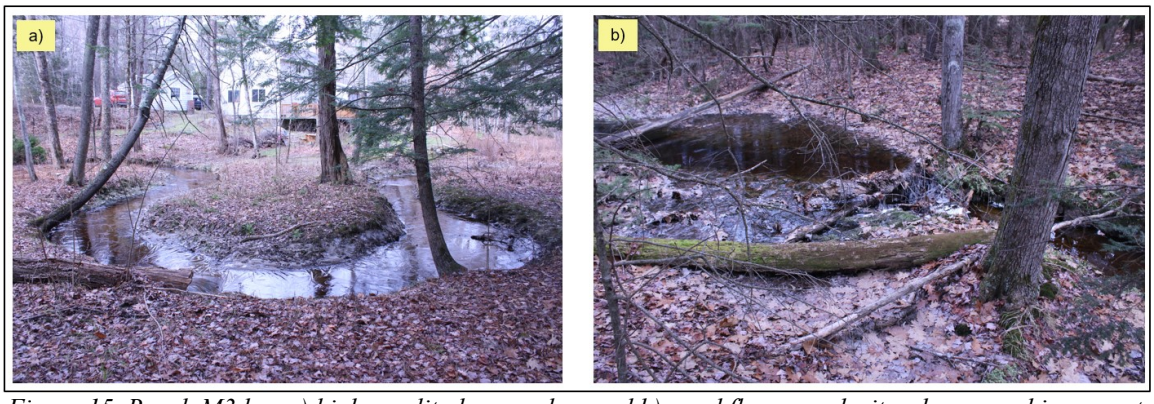


Figure 15. Reach M3 has a) high amplitude meanders and b) good flow complexity where wood is present.

Resizing the Long Creek Way culvert will be simpler than realigning the Route 9 culvert given the size of the roadways. Naturally, wood loading in the forested channel will increase slowly as the forest ages, but a chop and drop project will lead to immediate aquatic habitat improvements. The artificial fill on which several homes and yards are situated is not a severe channel constraint so need not be removed.

Reach M4 – Long Creek Way to the bedrock falls

Reach M4 has a sinuous channel with a substrate ranging in size from pea gravel to sand. The upper reach has a low width:depth ratio and relatively high banks due to minor incision, in part associated with scour at undersized culverts at Long Creek Way and a private driveway, that transitions to a channel with a higher width:depth ratio, lower banks, evidence of abandoned meanders on the floodplain, and greater sinuosity. High amplitude meanders, similar to Reach M3 (Figure 15a for Reach M3), become more frequent downstream as the stream becomes backwatered upstream of the bedrock falls. A few small sand bars have formed along the margins of the channel. While wood is largely absent from the channel despite a well forested buffer with several tall mature trees (Figure 16a), wood that is present, even very small pieces, help to trap sand and fine gravel (Figure 16b) and create good flow complexity.

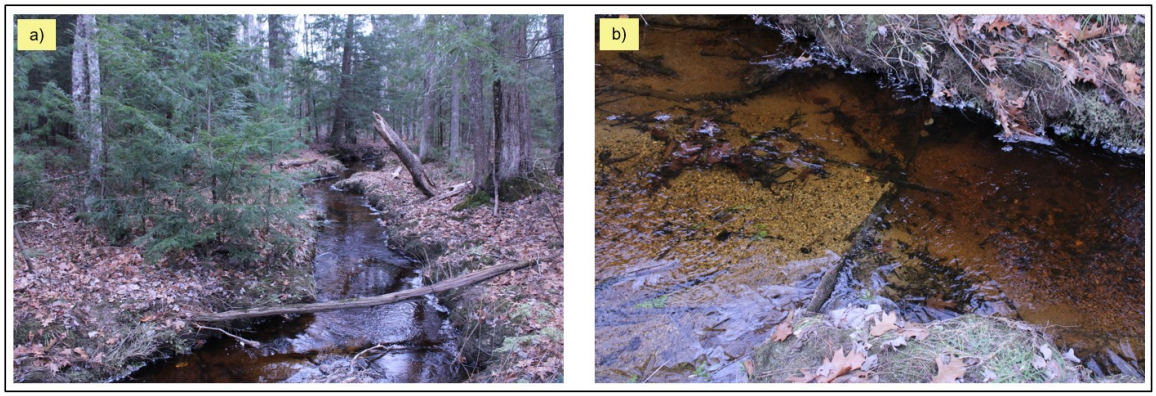


Figure 16. Wood is a) largely absent from Reach M4 despite a well forested buffer but, where present, b) even small pieces of wood help trap sediment.

Replacing the two undersized culverts at the upstream end of the reach will improve sediment transport continuity and reduce scour. One is under a small road and the other a private driveway. These projects are likely feasible but they are not creating major problems so are considered a low priority. Greater improvements reach wide would be achieved by completing chop and drop wood additions that would immediately improve aquatic habitat. This is a long wooded reach that should be a high priority for land conservation as conditions will improve over time if no actions are taken.

Reach M5 – From the bedrock falls to the transmission line

Reach M5 is characterized by a channel confined by high banks and a series of small bedrock waterfalls (Figure 17a) separated by steep sections with large boulders and, in places, bifurcated flow around islands. At the base of one falls, a side channel has formed where flow escapes the main channel at high flow. The channel widens dramatically for a short distance where the high banks recede away from the channel, leading to a wide low-gradient area backwatered behind additional bedrock falls downstream. A large sand delta has formed where a small tributary enters this ponded section (Figure 17b). Minimal wood is in the channel that is likely difficult to retain in

the steeper confined sections dominating the reach. A well forested buffer with tall trees provides a full canopy throughout the reach.

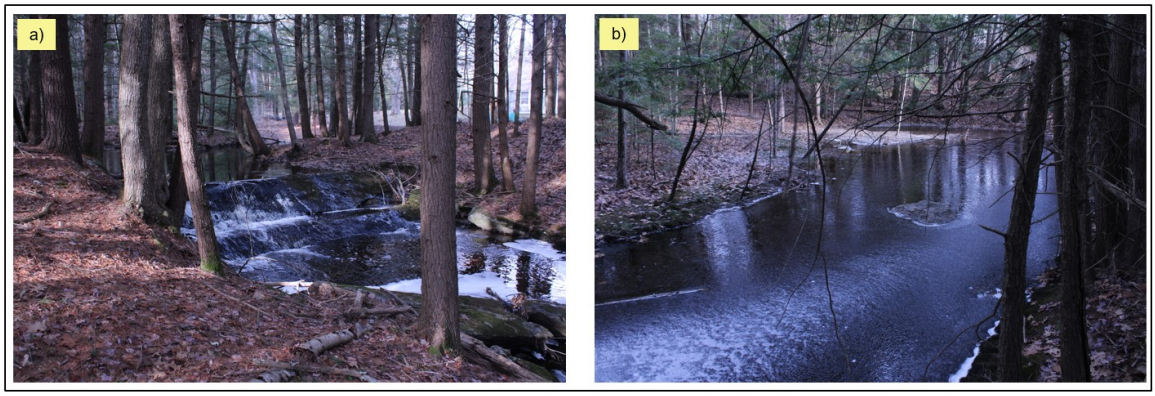


Figure 17. Reach M5 has a series of a) bedrock falls with an intervening b) a wide low-gradient backwatered area with a sand delta at a tributary confluence.

Reach M5 is in excellent condition with limited need for restoration. Chop and drop could be completed in the short wider section where wood is more likely to be retained without anchoring but is considered a low priority.

Reach M6 – From the transmission line to Middle Road

Reach M6 is largely a sinuous channel with a high width:depth ratio, eroding banks, and, in most locations, a wide floodplain. The channel occasionally bifurcates around islands. A hardpan clay outcrops on the stream bottom in many places while in others a cobble and gravel substrate is present with bedrock occasionally observed. In some areas, the gravel particles are actually composed of clay derived from the hardpan (referred to as rip-up clasts of clay). Small bedrock steps are present at the lower end of the reach. An old remnant dam occurs within the reach (Figure 18a) with the stream having carved a deep gully through high banks of clay around the flanks of the dam with trees falling and/or slowly sliding into the channel from the top of the gully walls (Figure 18b). The gully is straight but the original sinuous channel is still present downstream of the dam. Numerous log jams fully or partially cross the channel, although long sections are devoid of wood despite the forested floodplain that provides a full canopy over the channel along the entire reach. The elliptical-shaped culvert at the downstream end of the reach spans the entire width of the channel, so no signs of backwatering (i.e., excessive deposition of fine sediment) are present.

In addition to chop and drop through the entire reach to supplement the existing in-stream wood and enhance aquatic habitat, the remnant dam (Figure 18a) could be removed and the channel realigned into the former sinuous channel to prevent further fine sediment from eroding from the clay banks through the deep gully (Figure 18b). A lot of wood could be placed in the gully to prevent further erosion but could remain as an overflow channel during large floods. The gully could be Given that the Middle Road culvert already closely matches the channel's width, no action needs to be taken.

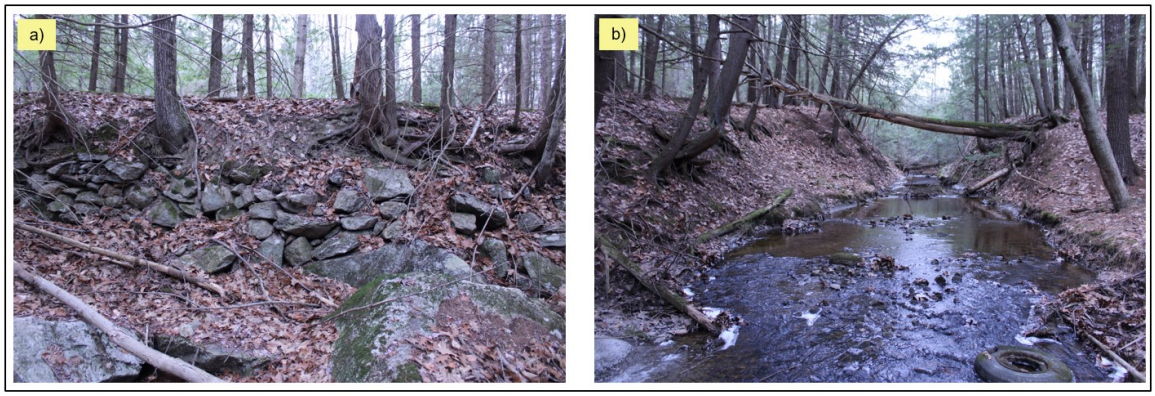


Figure 18. Reach M6 has a) an old dam with b) a gully carved through clay around the dam's flank.

Reach M7 – Middle Road to downstream end of the bedrock gorge

No scour is present downstream of the Middle Road culvert outlet, but a large gravel bar has formed just downstream (Figure 19a) that is more likely the result of backwatering upstream of some bedrock falls (Figure 19b) than due to impacts associated with the culvert. Most of the reach flows through a confined bedrock gorge with periodic low bedrock falls. A rocky channel with a high width:depth ratio is present in lower gradient sections in between the falls. An old remnant dam is at the top of one of the falls. Wood is abundant in the channel with several log jams present (Figure 19b) with a well forested buffer present providing a full canopy over the channel throughout the reach.

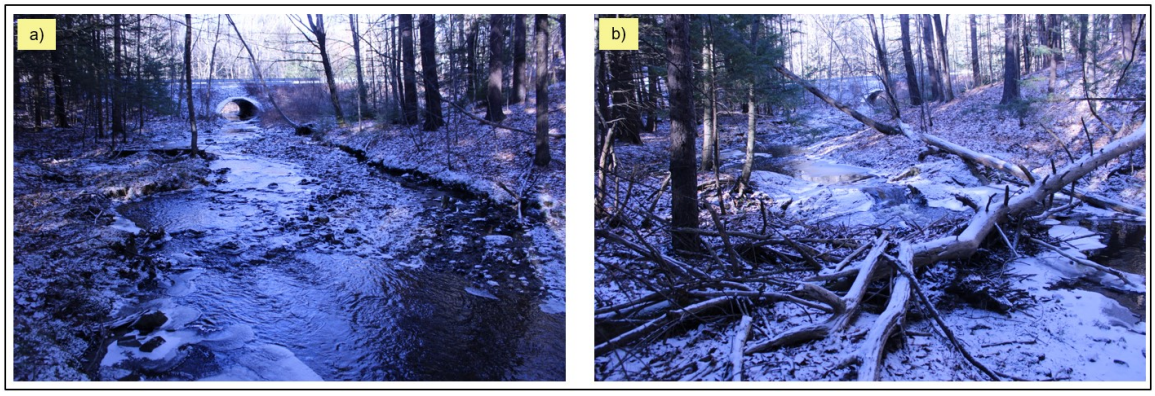


Figure 19. At the outlet of the Middle Road culvert a) a large gravel bar has formed but is more likely related to b) the bedrock falls just downstream.

Reach M7 is in excellent condition with no need for restoration. The old remnant dam is having no morphological impact and can remain in place. Abundant wood is already in the channel, so chop and drop would provide little added benefit. Attempting to conserve the land around the channel through the reach would prevent future development that might threaten the stream's excellent condition. Discussions with the landowner at the upstream end of the reach indicated his interest in conserving his parcel, so outreach to him might prove beneficial.

Reach M8 – From downstream end of the bedrock gorge to the railroad crossing

As the channel becomes less confined at the downstream end of the bedrock gorge, the expansion of flow has created a bifurcated channel with one of the channels creating a large meander (Figure 20a). Further downstream, a single wide channel forms with minimal in-stream wood (Figure 20b). The left bank of the channel at the downstream end flows against the railroad grade and approaches the railroad culvert at a right angle, although no observable impact is associated with this sharp approach angle. A forested buffer provides a canopy over the entire reach, including along the railroad grade.

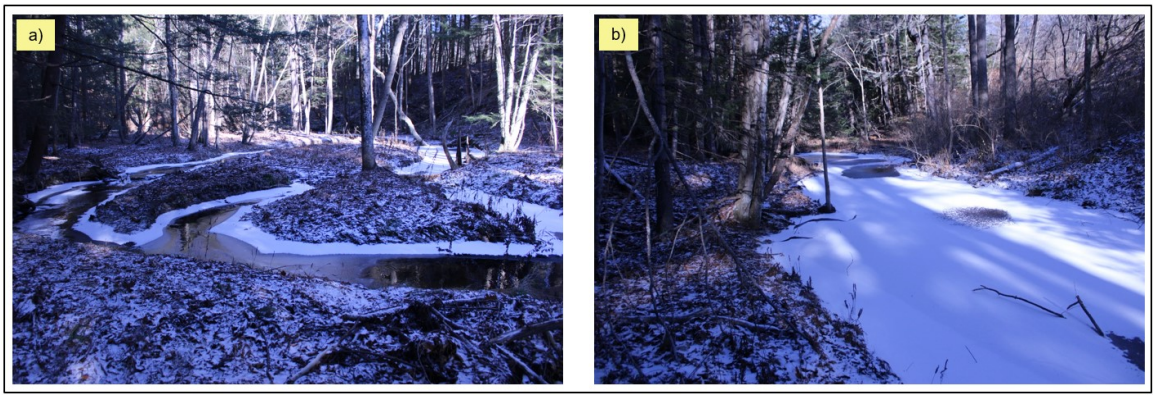


Figure 20. a) The stream bifurcates around an island at the upstream end of Reach M8 but becomes b) a wide single-thread channel at the downstream end (railroad grade on right side of photo).

Chop and drop is recommended along the reach to immediately improve wood loading and aquatic habitat. Given the railroad culvert just downstream, a log strainer should be built to catch any mobile wood to prevent blockage at the inlet of the culvert. While better realigning the railroad culvert with the stream would restore full geomorphic function, implementation would likely be cost prohibitive and no significant negative impacts resulting from the poor alignment are evident.

Reach M9 – Railroad crossing to I-295

Significant scour is present at the outlet of the railroad culvert with erosion leaving boulders in the channel that formerly lined the bank for protection (Figure 21a). The reach is characterized by high-amplitude meanders where scour on the outside bends of meanders is relatively minor. Near the downstream end of the reach, the channel takes a sharp bend and becomes straighter where approaching and then flowing against a high bank. At the end of the high bank, the channel takes another sharp bend (against more high ground opposite the high bank) that is severely scoured (Figure 21b) and then encounters a jumble of large boulders that partially block the channel before entering the I-295 culvert. The origin of the boulders is uncertain and could be natural or placed by humans (either part of a remnant dam or the result of I-295 construction). The double culvert under I-295 appears well sized and no evidence of backwatering was observed. Aside from the boulders at the downstream and upstream (Figure 21a) ends, the substrate is largely composed of sand. Limited wood is found in the channel and large trees are found only on the higher slopes with smaller trees and shrubs present on the floodplain.

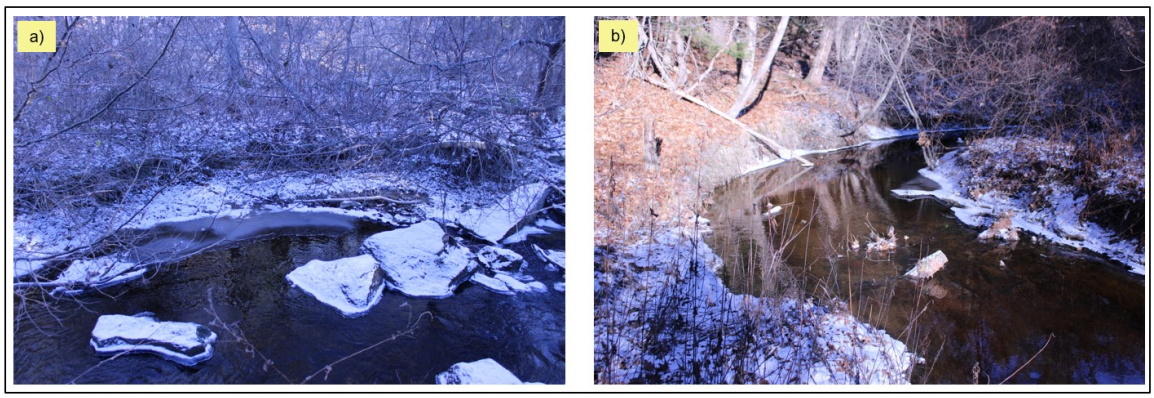


Figure 21. Scour in Reach M9 is most severe a) at the outlet of the railroad culvert and b) at a sharp bend against a high bank.

Access to this reach between the railroad and I-295 would be difficult, so the only practical restoration alternative would be to conduct limited chop and drop where sufficient tall trees are available. If access were available, removal of the boulders partially blocking the channel upstream of the I-295 culvert is recommended if they are determined to be unnatural. Scour at the railroad culvert outlet is likely to continue unless the culvert can be resized, a likely cost-prohibitive endeavor.

Reach M10 – I-295 to Route 1

No scour is evident at the outlet of the double culverts passing under I-295 that, together, closely match the width of the channel. No signs of fine sediment deposition are seen upstream of the Route 1 box culvert at the downstream end of the reach, a structure that also closely matches the width of the channel. The sinuous channel between the culverts, flows across a narrow floodplain and occasionally impinges on the high banks on the back edge of the floodplain. A channel-spanning bridge crosses the stream where a private driveway passes over the channel, but the rock armor protecting the bridge abutments constricts the channel slightly (Figure 22a). In-stream wood includes a log sill crossing the channel that is trapping pea-gravel upstream and creating flow complexity as water passes over the log (Figure 22b). Elsewhere, a fallen tree spanning the channel at the floodplain level has caught wood underneath to create a log jam blocking the entire channel. Only a partial canopy shades the channel as only a few large trees are present on the floodplain dominated by low growing shrubs.

Some chop and drop could be completed in the reach but the number of available trees is limited and considerable in-stream wood is already present. While the bridge (Figure 22a) fully spans the channel, pulling back some of the armor to reduce or eliminate the constriction of the channel is recommended if approval is given by the landowner. The culverts at the upstream and downstream end closely match the channel width and show no signs of morphological adjustment, so, while not ideal, are a low priority for replacement.

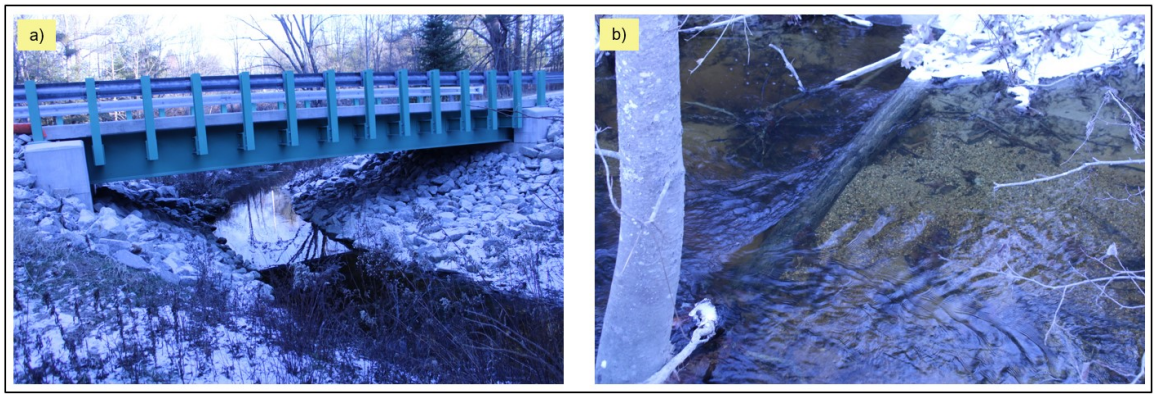


Figure 22. a) a bridge crossing the channel spans the channel but the rock armor partially constricts the channel and b) a log sill is trapping pea-gravel upstream and creating flow complexity.

Reach M11 – Route 1 to Foreside Road

The entire length of Reach M11 is tidally influenced. The reach is initially confined by high banks of clay but downstream of the Norton Brook confluence opens up onto a wide tidal marsh with broad high-amplitude meanders traversing nearly the entire width of the marsh (Figure 23a). The channel just below the Norton Brook confluence appears to have been artificially straightened with a low berm at the top of the right bank and higher ground along the left bank. Daily fluctuations of the water level leads to sapping erosion of the fine-grained bank material along the entire reach with erosion most severe on the outside bends of meanders but occurring nearly everywhere as evidenced by the unvegetated banks and materials slumping into the channel. A sewer line runs along the edge of the marsh for much of the reach's length on the right bank at the base of the uplands. While the sewer line is for the most part quite distant from the channel, at least one manhole has largely become exposed by erosion on the outside bend of a meander (Figure 23b) and others are close to the bank. Wood in the upper confined reach is fairly abundant due to erosion of the high slopes but is much more limited downstream where the channel occasionally impinges on the uplands. The substrate is fine-grained, often rippled, sand. A forested canopy is restricted to the upper reach and the few areas where the channel flows near the uplands.

The exposed manhole (Figure 23b) could be protected from further erosion by constructing a marginal log jam around it such that the structure would be in the center of the jam. A series of log jams should be constructed along the eroding meander bend to prevent outflanking of the manhole protection structure. Similarly, a series of log jams could be built along the left bank of the straightened section to encourage meander growth across the marsh. Berm removal should accompany this restoration effort. Additional log structures could be built for habitat enhancement where the channel approaches the uplands, but would not look particularly natural if built in the center of the marsh where wood is unlikely to naturally collect.

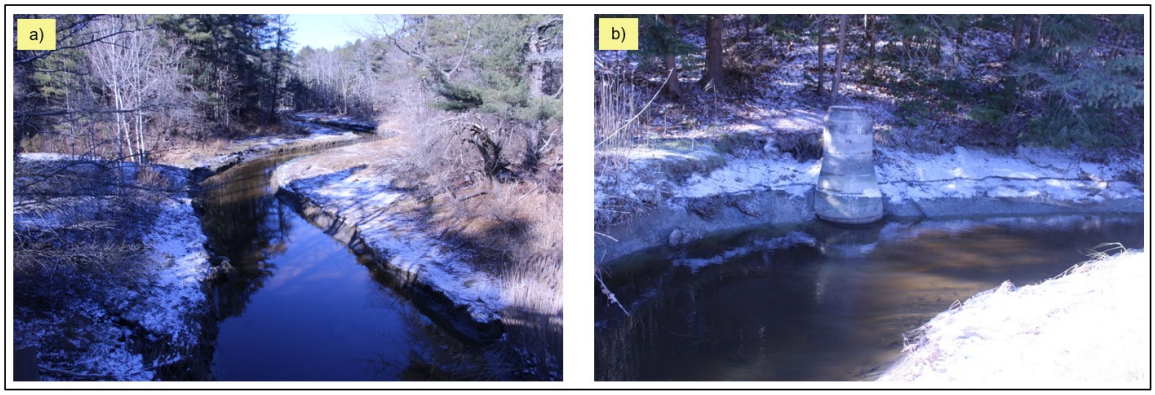


Figure 23 Reach M11 is characterized by a) broad meanders across the marsh that have b) exposed a manhole through bank erosion in at least one location.

4.4 Norton Brook

Reach N1 – Cumberland town line to behind Street Cycles store

The upstream end of the reach is slightly incised, and the channel's position appears to have recently shifted along a short section (e.g., tree root crossing over the channel, tree growing in center of channel, headcut on small tributary). Elsewhere, a shift in the channel's position is ongoing as flow is split around an island with one channel showing signs of abandonment (e.g., accumulating fine sediments and organics). These changes in channel position indicate the stream is dynamic. Throughout the reach the channel is sinuous (Figure 24a) and becomes less incised downstream. High-amplitude meanders are present, particularly at the downstream end of the reach where the floodplain is constricted by the placement of artificial fill at the Street Cycles building. Where the outside bends of meanders occasionally impinge on the uplands at the edge of the floodplain, mass failures can occur. A portion of the channel may have been straightened behind the Invisible Fence Building, although meanders are naturally reforming along this section. A sand substrate characterizes the entire reach with small point bars of sand on the inside bends of meanders and overbank sand deposits occasionally observed on the floodplain along the margins of the channel. Numerous log/stick jams and isolated wood is present in the channel and pools are carved in association with this wood. The channel flows through a well-forested floodplain providing a full canopy over the channel (Figure 24).

The reach is largely in excellent condition with dynamic changes, flow complexity, and plentiful wood to ensure numerous habitat types in close proximity. Additional wood could be added through chop and drop in areas with low wood loading but given the present condition, this is considered a low priority. Bank erosion (Figure 24b) is not prevalent and need not be treated as no infrastructure is threatened and contributes wood and sediment to the channel that sustain the dynamic nature of the stream. The stream, or at least the land on the left bank, is already conserved and under the control of a local land trust.

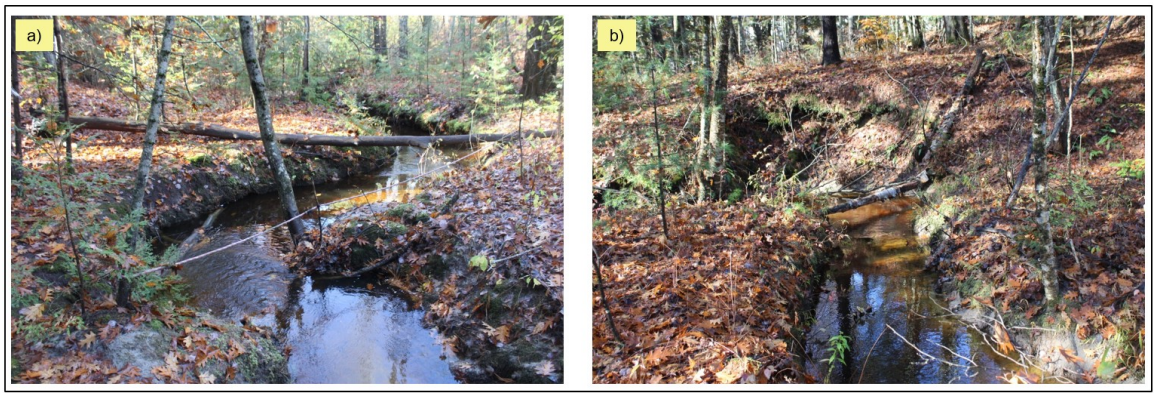


Figure 24. Reach N1 is a) a sinuous channel with b) erosion where channel impinges on uplands.

Reach N2 – From behind Street Cycles store to Johnson Road

Reach N2 is only slightly sinuous and may have been artificially straightened in the past, in part, and is now naturally reforming incipient meanders (Figure 25a). A portion of the straight channel flows against artificial fill extending 50 ft out onto the floodplain behind the Street Cycles building. Two steps in the stream profile occur along this section, one composed of broken asphalt pieces and the other of boulders presumably both derived from the fill. The artificial fill extends downstream to just upstream of the European Bakery and Tea Room where the floodplain widens out again. The substrate is sandy with some gravel, perhaps derived from the fill. Limited wood is found in the channel, because the floodplain is dominated by shrubs with few tall trees, providing a dense low canopy over the stream channel (Figure 25b). The density of the shrubs increases downstream, perhaps, in part, due to the backwatering effects upstream of the Johnson Road culvert that does not include any relief culverts across the wide floodplain.

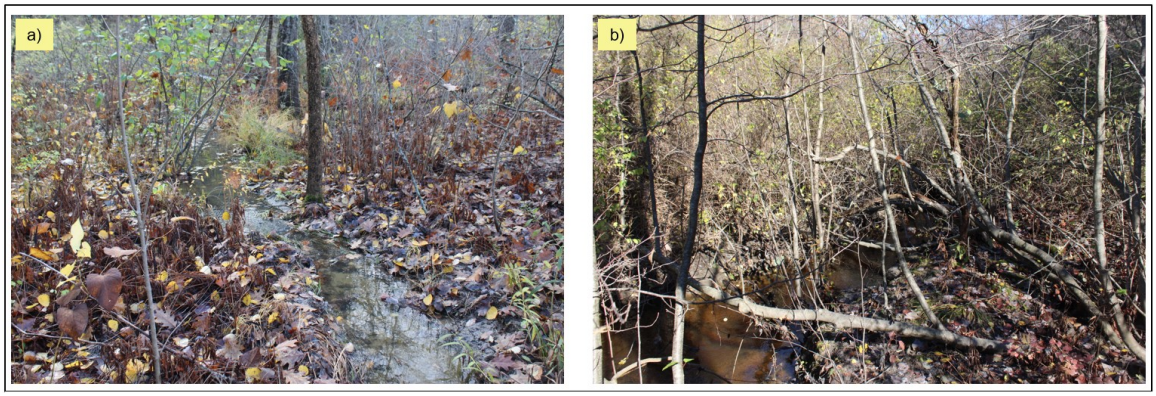


Figure 25. Reach N2 a) may have been artificially straightened with incipient meanders now naturally reforming and b) has a dense growth of shrubs providing a low canopy over the channel.

Wood additions in the channel could increase flow complexity and encourage further meander development, but access might be difficult given the dense vegetative growth. The artificial fill could be removed behind the Street Cycles store to restore the natural floodplain width, but would disrupt the existing business given the current use on the fill surface. While the Johnson Road culvert closely matches the width of the channel, floodplain relief culverts should be added under Johnson Road to reduce backwatering

during large storm events and allow for the growth of a forested floodplain that would, over decades, provide a supply of wood into the channel.

Reach N3 – Johnson Road to Northbrook Drive

Scour downstream of the undersized Johnson Road culvert has created a slight perching at the outlet, exposed the geotextile fabric placed under the riprap on the bank, and caused erosion downstream of the riprap. The first 200 ft of the reach are a dense thicket of shrubs across a wide floodplain similar to Reach N2 (Figure 25b from Reach N2) but quickly transitions downstream to a narrower floodplain confined by high forested bedrock-controlled uplands. Possible remnants of an old dam where placed rocks extend up the higher slopes is present near where the natural confinement begins. The channel is slightly incised with high amplitude meanders further downstream (Figure 26a) that have likely formed due to backwatering upstream of bedrock falls just downstream (Figure 26b). A mass failure is present on the high left bank at a sharp bend at the downstream end of the falls but does not threaten any infrastructure. While a rocky substrate is found through much of the reach, a hard-pan clay is exposed on the channel's bed and banks between the base of the falls and the Northbrook Drive culvert. The gabion headwall above the Northbrook Drive culvert at the downstream end of the reach is failing (i.e., leaning and sliding down the slope) and needs to be fixed to prevent the culvert from becoming blocked. In-stream wood is present in the reach but is not plentiful despite a well forested buffer with a full canopy through most of the reach (Figure 26).

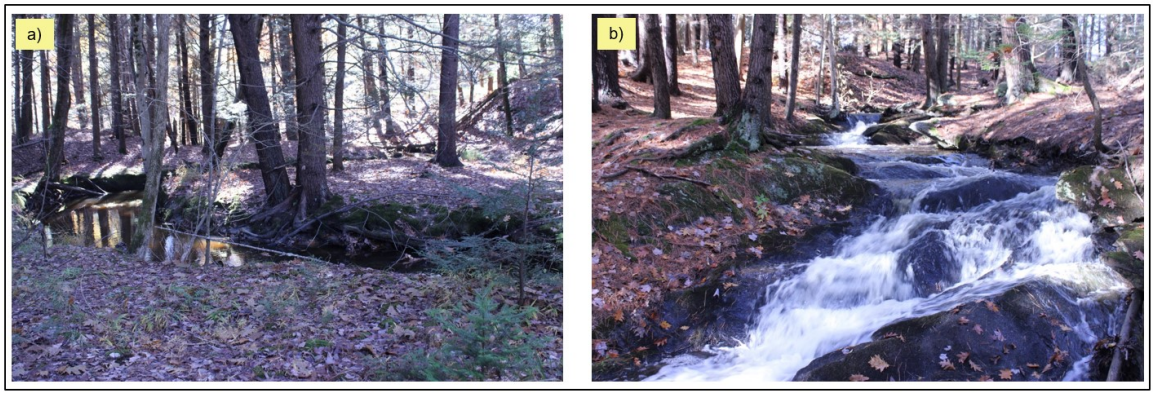


Figure 26. In Reach N3, a) high-amplitude meanders have formed b) upstream of bedrock falls.

The scour around the riprap downstream of the Johnson Road culvert could be replaced with log cribbing, but, as mentioned above for Reach N2, adding floodplain relief culverts is the best solution for reducing scour and restoring geomorphic function at the crossing. Wood additions through chop and drop would improve flow complexity and trap sediment and cover the exposed hardpan clay, but should be anchored in place given the proximity to the Northbrook Drive culvert. The headwall at the Northbrook Drive culvert needs to be repaired and the undersized structure enlarged to at least match the full width of the channel and perhaps also include floodplain relief culverts.

Reach N4 – Northbrook Drive to Mill Creek confluence

The headwall at the outlet of the Northbrook Drive culvert has similar, but not as severe, problems as the inlet as described above for Reach N3. A scour pool and eroding banks just downstream of the outlet are resulting from the undersized nature of the culvert. The channel through the reach is slightly incised with high-amplitude meanders (Figure 27a) that are most prevalent at possible backwatering sites such as upstream of the Mill Creek confluence (with tidal influence) and upstream of an apparent old crossing to the gravel pit where fill blocks the floodplain (with two old displaced culvert pipes remain in the stream nearby). Significant deposition is occurring locally even on the outside bend of a meander where a tributary enters and a large log helps trap the sediment (Figure 27b). Plenty of wood is in the channel, particularly where meanders impinge on higher slopes and cause mass failures. However, long stretches of stream have no wood (Figure 27a). A wide forested floodplain is present throughout the reach with a full canopy over the channel, although the floodplain is blocked at the inferred crossing to the gravel pit and constricted by artificial fill on which the Sullivan Tire store is built.

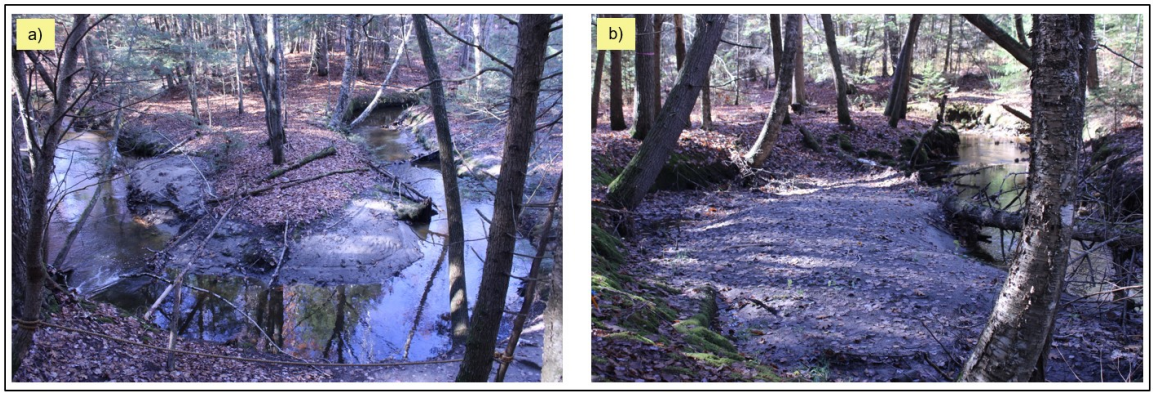


Figure 27. a) High-amplitude meanders and b) sand deposition (even on the outside bends of meanders) characterize Reach N4.

The simplest and most effective restoration approach is to complete chop and drop to improve flow complexity, although the stream condition is good throughout the reach so is a low priority. Repairs to the Northbrook Drive culvert and addition of floodplain culverts was already considered for Reach N3 (see above and Table 2d). The removal of floodplain fill and the culvert pipes at the old gravel pit crossing are a high priority but may be difficult to access.

4.5 Webes Creek

Reach W1 – Culvert by Ace Hardware store to Depot Road

Webes Creek drains the most heavily developed portion of Falmouth (Figure 2, Table 1, and Appendix 1). The upper portion of Reach W1 is straight and confined by high banks of natural clay and is further constrained on the right bank by brush, wood pallets, and concrete blocks discarded over the edge by the greenhouse operations situated on top of

the bank (Figure 28a). Bank erosion is located directly across from the area of greatest constriction where the channel has shifted towards the left bank, exposing the base of a manhole along the sewer line that parallels the length of Webes Creek (Figure 28b). A floodplain is present at the lower end of the reach and the channel becomes slightly sinuous. The double culvert under Depot Road is backwatering the channel upstream where the substrate becomes increasingly soft. Upstream in the confined area the substrate is rocky in places but much of the gravel component consists of rip-up clasts of clay derived from those areas where a hardpan substrate is exposed. Aside from small branches, no wood is present in the channel. The floodplain is dominated by shrub vegetation with few tall trees, so the canopy over the stream is limited.

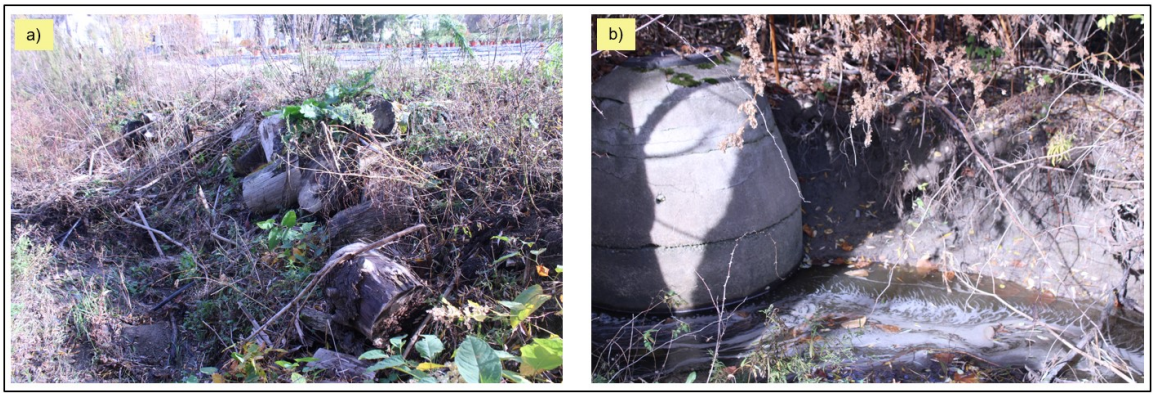


Figure 28. In Reach W1 a) stumps, branches, and other fill on the right bank have constricted the channel and shifted the channel towards the left bank where b) erosion around a manhole is occurring.

Removal of the largely organic fill on the right bank will reduce flow constriction and reclaim a narrow strip of floodplain in the confined upper reach. After fill removal, the channel could be rerouted away from the eroding manhole with marginal log jams built around the structure as well as upstream and downstream. Low log sills crossing the channel through the reach could trap more sediment and organics on the stream bottom and reduce the percentage of the bed that is either hardpan or clay rip-up clasts. Resizing the Depot Road culvert would reduce backwatering on the floodplain upstream and allow for a planting project to encourage the growth of taller trees that will ultimately provide a better canopy over the channel and supply wood to the channel over time.

Reach W2 – Depot Road to the end of the lawn

Reach W2 is a short reach running the length of a grassy lawn on a residential property downstream of Depot Road. The slightly sinuous channel flows against a higher bank of clay on the left bank and was likely artificially straightened in order to create a larger lawn. Natural incipient meanders are reforming along the straightened channel (Figure 29a). Scour at the outlet of the Depot Street has displaced riprap to form a large cobble bar (Figure 29b). Just downstream, a long narrow section of the lawn has slumped down the bank due to scour (Figure 29b). The erosion continues through the upper half of the reach. Downstream of the cobble bar, a hardpan clay is largely exposed on the stream bed with minimal substrate of fines and gravel. A 6-inch pipe crosses the channel and connects to the sewer line and rests on the channel bed causing a minor flow

impoundment and accumulation of organic material (i.e., leaves and small branches) upstream. With a lawn on the right bank and largely shrubs on the right bank, a canopy over the channel is largely absent and no large wood is present in the channel.

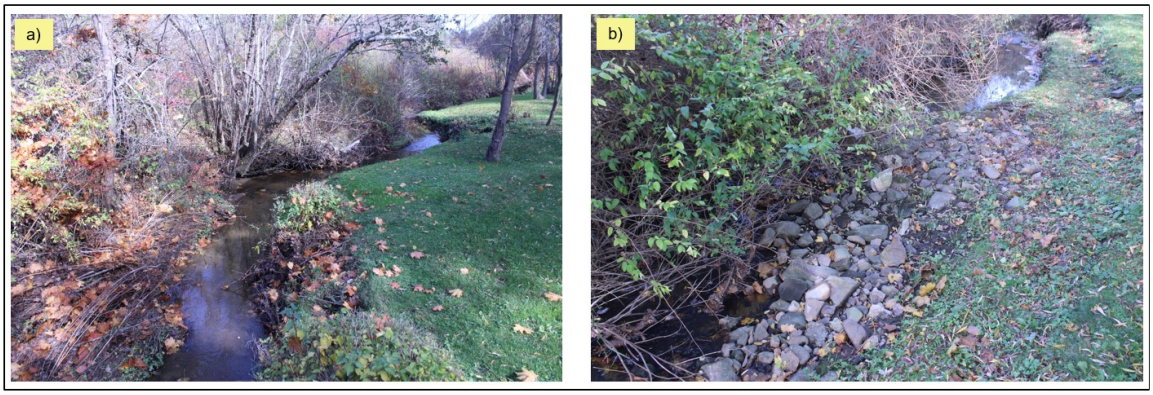


Figure 29. Reach W2 flows a) in a straightened channel now naturally reforming meanders along the edge of the lawn with b) a large cobble bar and eroding banks downstream of the Depot Road culvert.

Enlarging the Depot Road culvert would greatly reduce the scour and erosion observed in the upper portion of Reach W2. Log sills could be spaced throughout the reach to help trap sediment and cover the hardpan clay while increasing flow complexity. The eroding banks could be protected with log cribbing. The pipe crossing the channel needs to be either removed (if no longer in use) or protected with a full channel spanning log jam and log cribbing along the banks to prevent damage from the impact of rocks, wood, or debris carried by high flows. A more holistic approach to many of these problems might be to recreate the broader meanders across the lawn that were likely present naturally. All of these restoration options will require landowner permission to implement with recreating meanders requiring removal of part of the lawn, so unlikely to be supported.

Reach W3 – From the end of the lawn to the next lawn downstream on the right bank

The upper portion of Reach W3 is a sinuous unconfined channel with bank erosion on the outside bends of meanders, especially where they impinge on the higher uplands, and significant sand deposition on the inside bends (Figure 30a). The channel becomes straighter downstream despite a wide floodplain, so was perhaps artificially straightened in the past. A dense growth of shrubs overhangs the channel close to the water surface and supplies small branches to form numerous jams that divert flow into side channels and create small steps in the longitudinal profile (Figure 30b). The channel's banks are very low and poorly defined, especially upstream of jams. The sewer line runs along the reach on the left bank but does not directly impinge on the channel. The channel substrate consists of a clay hardpan that is sometimes covered by a thin layer of clay rip-up clasts or thick muck upstream of jams.

Access to the reach is poor, although an access path is maintained along the sewer line off the left bank. Clippings of shrubs were seen along the access path and could be bundled together with twine and placed in the stream to form additional steps like seen naturally (Figure 30b). At minimal cost, this could further enhance flow complexity and

trap sediment to cover the hardpan clay where exposed. Eroding banks at the upstream end of the reach are supplying the sediment that could provide this substrate above the hardpan, so bank stabilization is not recommended as no infrastructure is threatened.

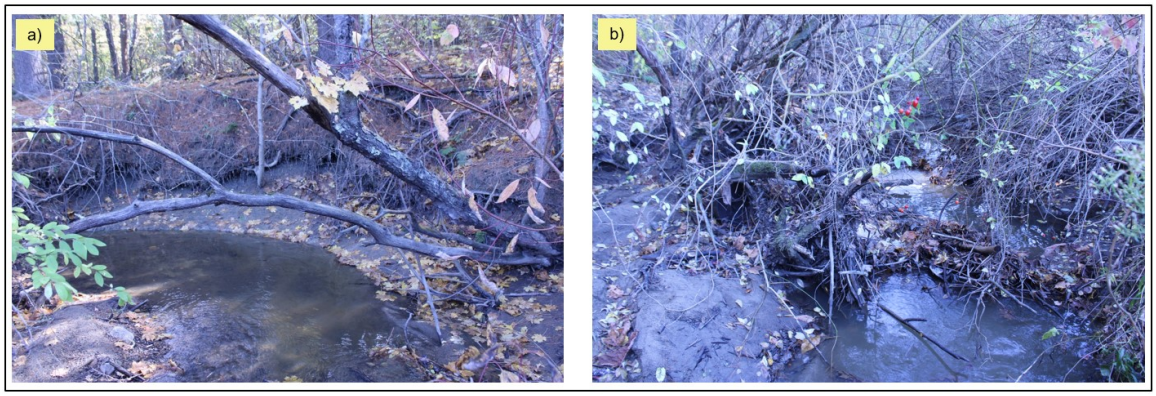


Figure 30. Reach W3 is a) sinuous with erosion on the outside bends of meanders and sand deposition on the inside bends in the upper part of the reach while b) flow complexity is maintained in the straighter downstream part of the reach by jams formed by small sticks.

Reach W4 – From the next lawn downstream on the right bank to open meadowy area

Reach W4 is a short straight reach where the channel banks become better defined as the large residential lawns on the right bank slope down to the channel from the uplands. The floodplain is considerably narrower on the left bank compared to Reach W3 upstream. Localized bank erosion is occurring and undermining trees (Figure 31a). Multiple large trees have fallen across the channel and are partially blocking flow (Figure 31b). Flow is stagnant through the reach due to either (or both) blockages by fallen trees or backwatering upstream of the Mill Creek confluence. Shrub vegetation and lawns dominate the top of the banks but some large trees provide a partial canopy over the channel.

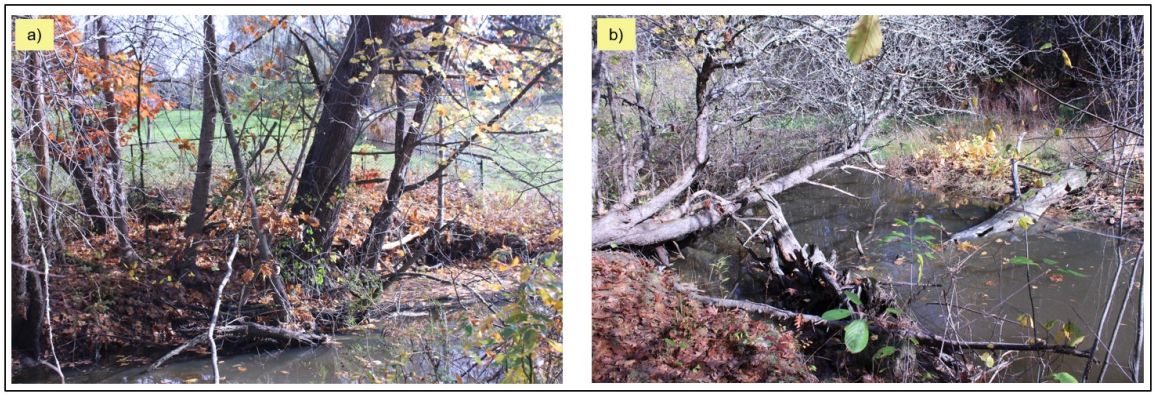


Figure 31. In Reach W4 a) localized erosion is undermining trees that ultimately b) causes large trees to fall across the channel.

No in-stream restoration recommendations are available. Residential property owners might be approached to discuss the environmental benefits of planting a buffer of trees

and/or shrubs along the edge of the channel where lawns now extend to the top of the right bank.

Reach W5 – From the open meadowy area to Mill Creek confluence

Reach W5 is a tidal marsh backwatered by tides moving up from Mill Creek. The high-sinuosity channel has a low width:depth ratio with the banks nearly submerged at high tide (Figure 32a). The sewer line runs along the edge of the marsh and the channel approaches a manhole at the outside bend of one meander but is not impacted by erosion. A broken concrete bridge crosses the channel (Figure 32b) in line with an access road coming down the slope from the uplands on the right bank, so might have been used for access to the sewer line. No adverse channel response is apparent due to the bridge blocking the channel with low velocity flows likely passing over the structure at higher tides and stream flows. No significant in-stream wood was observed in the reach. Large trees growing on the uplands bordering the marsh provide minimal canopy where the meanders approach the edge of the marsh as no shrubs or trees are growing in the marsh bordering the channel.

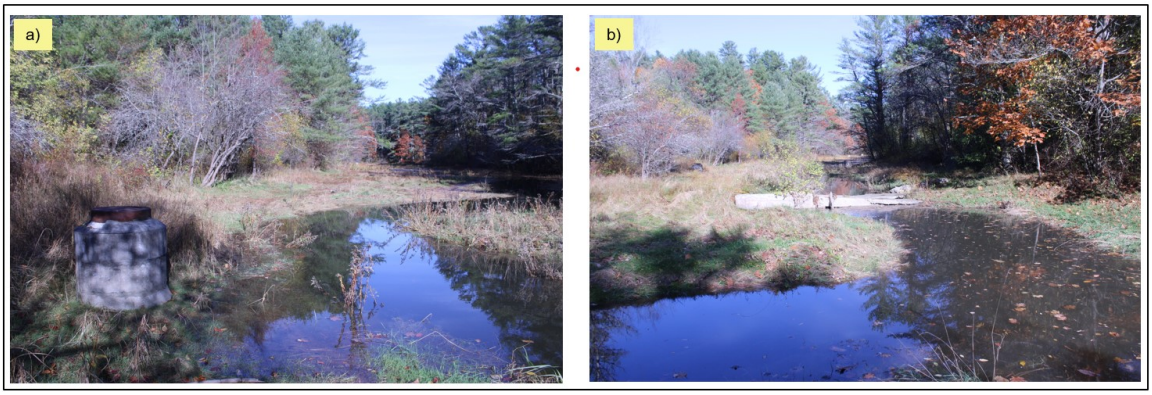


Figure 32. In Reach W5, a) meanders approach the sewer line at the edge of the marsh and b) a collapsed concrete bridge crosses the channel.

No restoration is needed in Reach W5, but the concrete bridge could be removed to improve the aesthetic and to fully restore geomorphic function in this tidally dominated reach. Monitoring should periodically be conducted to be sure erosion does not threaten the manholes near the channel on the left bank.

5.0 DETAILED GEOMORPHIC ASSESSMENT

A more detailed assessment of the five streams was completed by: 1) mapping important channel features observed while traversing the length of the streams and 2) surveying channel dimensions and conditions at 10 representative sites (generally two sites per stream). The results of the mapping and surveying are described below.

5.1 Channel features mapping

A number of channel features were mapped where observed along the streams including in-stream wood and areas of bank erosion. (In some areas with thick shrub vegetation, walking directly in the channel was sometimes difficult, so the mapping missed some features over short distances.) Table 3 provides a summary of these and other mapped features with the locations provided as ArcGIS shapefiles in the digital supplement to this report. Key features are described below individually. The GIS data could be queried further to determine if associations exist between features such as whether deep pools are associated with in-stream wood.

	Chenery Brook		Hobbs Brook		Mill Creek		Norton Brook		Webes Creek	
Mapped features	Total	Per mile	Total	Per mile	Total	Per mile	Total	Per mile	Total	Per mile
Instream habitat features										
Large wood (includes log jams)	169	129	19	30	244	64	164	123	26	30
Log jams	20	15	1	2	28	7	22	16	6	7
Deep pools	12	9	1	2	42	11	14	10	2	2
Beaver dams	4	3	0	0	0	0	0	0	0	0
Channel stability/Sediment loading										
Grade controls	0	0	0	0	15	4	3	2	0	0
Mass failures	1	1	0	0	1	0	3	2	0	0
Eroding banks	35	27	5	8	41	11	12	9	13	15
Sand/gravel bars	21	16	11	17	37	10	14	10	6	7
Migration features										
Avulsions	0	0	0	0	1	0	2	1	0	0
Flood chutes	12	9	0	0	9	2	8	6	1	1
Oxbows/cutoffs	2	2	0	0	1	0	3	2	0	0
Stream crossings (bridges/culverts)	3	2	2	3	14	4	2	1	2	2

Table 2. Summary of mapped channel features. The assessed length of Chenery Brook was 1.3 mi, Hobbs Brook was 0.6 mi, Mill Creek was 3.8 mi, Norton Brook was 1.3 mi, and Webes Creek was 0.9 mi.

Wood serves as a proxy for good aquatic habitat in streams given its association with higher fish populations (Flebbe, 1999), a greater abundance and richness of macroinvertebrates (Bond et al., 2006), pools (Montgomery et al., 1995), and more complex physical habitat in general (Benke and Wallace, 2003). All five streams have in-stream wood, including log jams that span the channel. Given the narrowness and small size of the streams, particularly at their upstream ends, these log jams are often formed by small branches and sticks derived from alders and other shrubs growing along its banks. Although perhaps not adequately reflected in the mapping data, the log jams and other in-stream wood tend to be closely associated with complex flow patterns, pools, and the accumulation of organic rich fine sediments (over a clay hardpan) that can serve as a food source for macroinvertebrates. Chenery Brook and Norton Brook have considerably more wood per stream mile compared to the other three streams (Table 3). However, the frequency of wood on Chenery Brook and Norton Brook is still well below the more than 200 pieces/mile targeted by fisheries biologists for even small New England streams (Kratzer and Warren, 2013). Therefore, the channel features mapping reveals a need for increased wood loading on the five assessed streams, even those in well forested areas with locally excellent habitat conditions such as Norton Brook.

Mass failures, and bank erosion in general, on the streams are not significant. While numerous areas of erosion are observed along the streams, they tend to be of short length

and are often associated with the outside bends of high-amplitude meanders where they impinge on higher banks of the uplands at the back edge of the streams' floodplains. Trees growing on the bank collapse into the streams at these locations, so the erosion serves as a source of wood inputs to the stream channels. Mass failures and severe bank scour were also observed at the outlet of several undersized culverts, most notably the railroad culvert on Chenery Brook and the Depot Street culvert on Webes Creek. The bank scour associated with undersized culverts is localized and does not extend far downstream. The erosion observed on the five streams is largely part of natural channel processes (e.g., outer bend of a meander) or is localized around undersized culverts. Long continuous areas of erosion associated with a major basin-wide disturbance, such as urbanization, are not observed. The short discontinuous mass failures and bank erosion revealed through the channel features mapping are largely consistent with a natural sinuous stream generating the periodic inputs of sediment and wood necessary to sustain a dynamic stream channel with good flow complexity and a channel substrate of sediment (rather than a hardpan clay stream bottom).

In contrast to the presence of in-stream wood, hardpan clay exposed on the stream bottom is a proxy for poor aquatic habitat quality (but was not mapped as part of the channel features mapping). All five streams have formed in valleys primarily, if not exclusively, floored by the Presumpscot Formation. Therefore, exposure of the hardpan on the bed of the channel is an indication that flow velocities in that area are too strong to retain and accumulate sediment. Without sediment and organic matter on the stream bottom, a substrate for macroinvertebrate colonization and feeding will be lacking. Even a thin layer of sediment, as is the case in many areas on the assessed streams, would represent greatly improved habitat compared to the bare hardpan. An exposed hardpan on the stream bed was observed in several locations on all five streams. Exposed hardpan tends to be located where stream velocities are high and/or where sediment is limited such as at the outlets of undersized culverts or downstream of bedrock falls. While short distances of hardpan may be exposed immediately downstream of log jams, this is balanced by longer sections upstream where sediment, sometimes considerable amounts, tends to accumulate.

5.2 Topographic surveying

Topographic surveying was completed along portions of ten reaches. Three surveys were conducted on Norton Brook (Reaches N1, N2, and N3), two each on Chenery Brook (two adjacent sites surveyed in Reach C2), Hobbs Brook (Reaches H2 and H3) and Mill Creek (Reaches M6 and M11), and only one on Webes Creek (Reach W1). The surveys were conducted to establish the channel's (bankfull) dimensions (i.e., width, depth, sinuosity, and slope) and allow for comparisons between sites to document how the dimensions vary between more natural conditions and various settings altered by human impacts (e.g., outlet of an undersized culvert). The survey data is summarized in Table 4 with plots of the planviews, cross sections, and longitudinal profiles of each site provided in Appendix 4. The survey data was also used to develop conceptual restoration designs, so

further details about the surveys are discussed along with the developed designs in Section 6.0 below.

Stream	Reach number	Cross section	Bankfull width (ft)	Mean depth (ft)	Max depth (ft)	Width/ depth	Channel gradient	Sinuosity
Chenery Brook	C2a	1	18.4	2.89	4.71	6.4	0.0048	1.107
	C2a	2	43.2	2.89	4.35	14.9	0.0048	1.107
	C2a	3	45.1	1.23	3.01	36.7	0.0048	1.107
	C2b	4	19.8	2.24	2.63	8.8	0.0025	1.044
	C2b	5	22.8	2.12	3.49	10.7	0.0025	1.044
	C2b	6*	26.1	0.95	1.25	27.5	0.0025	1.044
Hobbs Brook	H2	1	31.3	0.76	2.51	41.4	0.0014	1.230
	H2	2	16.1	0.69	2.13	23.4	0.0014	1.230
	H2	3	15.7	0.95	2.61	16.6	0.0014	1.230
	H3	4	32.3	0.64	1.82	50.5	0.0006	1.162
	H3	5	23.6	0.60	1.54	39.4	0.0006	1.162
	H3	6	16.6	0.79	1.90	21.1	0.0006	1.162
Mill Brook	M6	1	16.0	1.88	2.44	8.5	0.0042	1.051
	M6	2	21.9	1.50	1.68	14.6	0.0042	1.051
	M11	1	24.7	3.38	4.86	7.3	0.0004	1.097
	M11	2	22.5	3.74	5.86	6.0	0.0004	1.097
Norton Brook	N1	1	12.7	1.69	3.22	7.5	0.0041	1.357
	N1	2	17.2	1.52	3.09	11.3	0.0041	1.357
	N1	3	14.2	1.97	2.83	7.2	0.0041	1.357
	N2	1	10.5	1.24	2.08	8.5	0.0057	1.632
	N2	2	15.7	1.14	3.42	13.8	0.0057	1.632
	N2	3	7.9	1.56	2.87	5.0	0.0057	1.632
	N3	1	23.4	2.16	2.93	10.8	0.0499	1.122
	N3	2	16.1	2.24	2.92	7.2	0.0499	1.122
	N3	3	13.4	2.06	3.65	6.5	0.0499	1.122
Webes Creek	W1	1	15.6	1.73	2.73	9.0	0.0087	1.118
	W1	2	20.5	1.08	2.59	19.0	0.0087	1.118
	W1	3	9.1	1.45	1.97	6.3	0.0087	1.118

* Transect crosses abandoned meander/oxbow channel

Table 4. Summary of survey data.

6.0 CONCEPTUAL RESTORATION PLANS

All of the topographic survey sites (see Section 5.2 above) were also locations for which conceptual restoration designs were developed. The survey data provide the necessary detail on channel dimensions to develop viable conceptual restoration plans, although issues regarding machine access (that might be difficult though not insurmountable) in some instances are not addressed. The chosen survey/restoration sites were selected for their potential to: 1) restore natural fluvial processes, 2) address channel instability and habitat degradation, and, as a whole, 3) exemplify a range of restoration strategies that might be effective for "like-reaches" elsewhere on the five assessed streams. The restoration plans span a range of complexities from relatively simple and inexpensive

approaches that do not require heavy machinery to more complex and expensive strategies.

The ten conceptual restoration designs are described further below and presented in Appendix 4 with the associated survey data. Restoration ideas for other reaches for which concepts have not been developed (see Table 2) and are considered too expensive or complex to be completed for environmental purposes only (e.g., culvert replacements at major roads) should be placed on a "watch list" such that when funding becomes available for other purposes (e.g., improve safety of an aging culvert), these "watch list" restoration ideas can be presented to the project designers to ensure that the environmental concerns at these sites are simultaneously considered (for example, see Section 6.1 below).

6.1 Reach C2a: Log crib walls and log sills

Reach C2 on Chenery Brook begins at the outlet of the railroad culvert. A continuous two-part survey was completed from the railroad culvert outlet to an area where the channel becomes confined between natural uplands on the right bank and the I-295 road grade on the left bank (Appendix 4). The upper portion of the surveyed area (Reach C2a) documents the scour and deposition occurring at the outlet of the undersized railroad culvert, while the downstream end of the survey area (see Reach C2b below) characterizes an artificially straightened channel and the associated abandoned meander upstream of the valley constriction.

Severe scour at the outlet of the railroad culvert (Figure 4a) has more than doubled the channel width relative to unaffected areas (compare Cross Section 2 in Reach C2a with Cross Section 4 in Reach C2b in Table 4 and Appendix 4). The bed of the channel immediately downstream of the outlet has been stripped of sediment, exposing the hardpan clay underneath. The material scoured from the bed and banks of the channel have been redeposited downstream to form a large gravel bar that has caused a shift in the channel's position and further widening of the channel (Reach C2a Cross Section 3). Scouring of the right bank continues along the new channel. This scour, deposition, and channel migration is in response to a 67 percent constriction of the channel caused by the undersized railroad culvert (Appendix 4 – see Cross Section 1 in Reach C2a).

The only long-term sustainable manner of addressing the scour at the outlet of the railroad culvert is to replace the structure with a crossing that at least matches the width of the channel. However, a culvert replacement is not considered as part of the conceptual design here, because the project is considered a "watch list" project on Table 2 given the expected high cost, complexity, and long timeframe required to implement such a project along the rail line. A conceptual design of a culvert replacement is provided for Reach N3 at Northbrook Drive (see Section 6.9 below).

A more feasible short-term solution to address the environmental and geomorphic impacts of the scour at the outlet of the railroad culvert would be to construct log crib walls along the eroding banks to save the undermined trees along the edge of the bank

and to reduce the introduction of fine sediment to the channel (Appendix 4). Additionally, log sills could be placed on the bed of the channel to locally reduce flow velocities that will trap sediment above the hardpan clay, narrow the channel, and improve substrate conditions for macroinvertebrate colonization. Ideally, these log structures would be constructed with heavy machinery but given the difficulty in accessing the site and the forested nature of the site, the work could be completed with hand tools (e.g., grip hoists) with the trees sourced on site. The use of log crib walls and log sills would also be appropriate for similar "like reaches" where scour is occurring at the outlet of culverts such as Reach N3, Reach N4, and Reach W2. These same locations would also be appropriate for culvert replacements given that the cause of the scouring at these sites relates to the undersized nature of the stream crossing structures.

6.2 Reach C2b: Boulder-supported log jams

Reach C2b, just downstream of Reach C2a, is an artificially straightened channel flowing against the high I-295 road grade on the left bank with boulders at the base (Appendix 4). The straightened channel extends downstream for a long distance beyond the surveyed area. A floodplain is present on the right bank that pinches down to nothing at the downstream end of the surveyed area due to a spur of high ground that encroaches on the channel. An abandoned meander is present on the right bank floodplain that was likely originally formed as a result of backwatering upstream of the constricting spur (Appendix 4 – see planview and Cross Section 6) . Abandonment of the meander presumably occurred when the channel was artificially straightened, possibly at the time of I-295 construction. The bed of the meander is elevated above the bed of the active and straightened channel due to slight incision below the floodplain. As a consequence, only larger flows now enter the abandoned meander.

Although the width:depth ratio of the straightened channel is not as high as in Reach C2a (Table 4), straightened channels typically have poor habitat due to wide channels without confining bars at low flow. Consequently, summertime flow depths are low and flow complexity minimal. To restore more natural conditions, a series of boulder-supported log jams could be built along the margins of the artificially straightened channel (even beyond the surveyed area) to increase flow complexity, provide cover habitat, and promote sediment deposition to narrow the channel (Appendix 4). By alternating the bank on which the log jams are built, meanders could be encouraged to form by redirecting flow into the bank across from each jam. Ultimately, this would improve substrate particle size segregation (i.e., reduce embeddedness) and increase pool depths. If boulders from the base of the I-295 road grade could be repurposed, then the log jams could be constructed with hand tools only, given the difficulty of accessing the site with heavy machinery, but the use of heavy machinery would be preferable. Boulder-supported log jams could also be used on other artificially straightened reaches such as Reach N2 and Reach W2.

6.3 Reach H2: Riparian plantings and isolated wood additions

Reach H2 flows through an open field with a poor riparian canopy. Most of the reach has a relatively low width:depth (i.e., less than 25.0) (Table 4 – see Cross Sections 2 and 3) and may be slightly incised as a narrow discontinuous floodplain is inset below a wider more continuous flat surface (considered to be the historic floodplain). The channel has good sinuosity (Appendix 4 – see planview) but the lack of wood in the channel is limiting flow complexity and sediment accumulation on the stream bed, so hardpan clay is exposed in places.

With landowner agreement, perhaps assisted by NRCS programs to compensate the landowner for lost productivity, the planting of riparian zone trees to a minimum width of 35 ft from the top of the stream bank would improve the canopy and provide a source of wood over time (Appendix 4). For more immediate improvements (and perhaps more acceptable to the landowner), the placement of isolated wood buried in the channel with root wads exposed on the channel bed or in the form of low log sills running across the channel would both enhance flow complexity, provide cover habitat, and encourage sediment deposition to create a substrate over the hardpan clay for macroinvertebrate colonization. Boulders already in the channel could be repurposed to help anchor some of the structures. The implementation could be completed with hand tools, but access for heavy machinery would not be problematic with permission from the landowner. Riparian plantings would also be effective in those reaches without tall trees growing along the stream such as Reach M2 (with landowner permission) and Reach N2 (with resizing of the Johnson Road culvert).

6.4 Reach H3: Chop and drop wood additions

For most of Reach H3, the channel is largely infilled by fine sediment that was deposited in the channel and across the narrow floodplain when flow was impounded behind a fallen tree later plugged with smaller branches by beaver (Figure 12). As a result, the channel has minimal depth and a resulting high width:depth (Table 4 – see Cross Sections 1 and 2). Based on the deposition line at the back edge of the floodplain (Figure 12a), the depth of the impoundment above the floodplain level was 2.0 ft (Appendix 4 – see cross sections). Now that the impoundment has drained, conditions are slowly recovering with greater channel depth and lower width:depth ratios closer to the fallen tree. The lack of in-stream wood within the formerly impounded area may be slowing the rate of recovery.

Adding wood to the channel through the chop and drop method within the formerly impounded area (Appendix 4) will improve cover habitat where little is present now and generate flow complexity to help remove the built up fine sediment in the channel. The possibility exists the added wood could also impound flow. Although impounded flow is not considered an issue, the application of chop and drop could be at a lower density (one key log every 6 to 8 channel widths compared to a more typical wood loading of every 3 or 4 channel widths) to reduce the potential for impounding flow. The reach is in excellent condition currently and discussing with the landowner the potential for placing the land in conservation would ensure a long-term supply of wood reaches the channel

from the forested riparian zone. Chop and drop is a technique that could be applied to most forested reaches on all five of the assessed streams to supplement existing in-stream wood even where conditions are already excellent such as Reach M4 and Reach N1.

6.5 Reach M6: Dam removal and channel realignment

The topographic survey of Reach M6 was conducted in the vicinity of the old dam and includes both the existing channel and the old channel across which the dam was originally built (Appendix 4 – see planview). The stacked stone of the dam fills in a gap between ledge on both flanks of the structure. The dam was 10 ft high above the old channel bed that is still visible downstream of the dam. Upstream, the original channel is not present, perhaps due to infilling of the channel through sediment deposition. The current channel formed by eroding through Presumpscot Formation clay beyond the bedrock ledge on the right flank of the dam (looking downstream), perhaps at a low area that was overtopped during a large flood. The bankfull width of the narrow gully formed from the outflanking of the dam is less than the width of the former channel blocked by the dam (Appendix 4 – see cross sections) and remains confined by high banks of clay, whereas the former channel has access to a wide floodplain (Appendix 4 – compare Cross Sections 1 and 2). Without restoration, the channel through the gully area is likely to widen over time until matching the former channel's width with the high banks continuing to erode.

As self-stabilization of the high eroding banks through the gully may take decades, removal of the dam and realignment of the creek back into its former channel and wide floodplain (Appendix 4) would reduce flow energy in the immediate vicinity and reduce fine sediment loading to downstream areas. Large wood, potentially through chop and drop, could be placed in the gully (to be abandoned by realigning the channel) to prevent the channel from reoccupying the area but still providing an overflow channel during high flows to reduce flow energy in the reactivated channel. Access for heavy machinery would be relatively easy from the end of Chandler Drive as long as one of the residential homeowners agrees to having an excavator traverse the edge of their lawn. To avoid trucking off site, the rocks of the dam could be repurposed as boulder clusters or for anchoring logs placed in the realigned channel and/or set aside in an upland area. The old dam is rather unique for the five assessed streams, so no "like reaches" exist where dam removal and channel realignment could also be used. The only other possible remnant dams observed were in Reach M7 and N3, neither of which are causing issues necessitating removal.

6.6 Reach M11: Berm removal and marginal log jams

The surveyed area of Reach M11 includes the apparently straightened section of channel with a low berm along the right bank (Appendix 4 – see Cross Section 1). The straightened section begins near the confluence of Norton Brook and continues downstream to include part of a broad meander that is forming where the marsh widens. The difference in sinuosity between the broad meander and the straightened section is clear in planview (Appendix 4).

The natural morphology of the creek through the tidal marsh is a highly sinuous meandering form. The berm along a straightened section of channel where the survey was conducted suggests the straightening was completed by humans. To restore the more natural sinuous conditions, the berm could be removed and several marginal log jams constructed along the left bank to divert flow into the opposite bank to encourage meander growth along the straightened section (Appendix 4). To have the desired effect, the log jams would need to protrude out into the channel about 50 percent of its width, or approximately 12 ft with each log jam spaced about five times the protrusion distance or 60 ft. The log jams would ideally be anchored with vertical and horizontal log piles, but the exact method of securing the structures would occur in a later design phase. The log jams would look natural given that the left bank runs at the edge of the forested uplands. Smaller boulder-supported log jams were recommended for Reach C2b. Given the generally small size of the five assessed streams, the larger more robust marginal log jams suggested for Reach M11 are not considered appropriate elsewhere on the five streams.

6.7 Reach N1: Chop and drop

The sinuous channel (Appendix 4 – see planview) flowing on a forested floodplain in Reach N1 has a very low width:depth ratio of less than 12.0 (Table 4), both consistent with a stream flowing through hardpan clay that is exposed along the stream. The low width:depth ratio is also consistent with channel incision, although the presence of sand deposits along the edge of the channel at or near the floodplain level would indicate no, or only slight, incision has occurred. While numerous small log jams and isolated pieces of wood are found in the survey area and throughout the reach as a whole, long sections have no in-stream wood and the total loading is considered far below target levels (Kratzer and Warren, 2013).

Conditions are currently very good through much of Reach N1 and is largely free of human constraints (i.e., only minor amounts of fill at the back edge of the floodplain), so, in many respects, Reach N1 can be considered a reference reach for understanding how all five of the assessed streams may have appeared prior to human alterations of the channels and surrounding watersheds. That said, wood loading in the streams could be higher. Chop and drop wood additions could be completed to add wood to the channel (Appendix 4) where long sections of the stream currently do not have in-stream wood. The floodplain is well forested and wood will slowly be recruited to the channel as the forest matures. The chop and drop projects would more immediately improve flow complexity, cover habitat, and increase deposition in the channel to remedy the slight incision that may have occurred along the channel. Given the maturing forest, the benefits of the chop and drop project will be sustainable as future wood recruitment will replace the felled trees over a few decades. Many well forested reaches with low levels of in-stream wood are found on the five assessed streams, all of which would be good candidates for chop and drop projects such as portions of Reach N3 and Reach N4.

6.8 Reach N2: Fill removal

The survey of Reach N2 was conducted at the upstream end of the reach and includes a portion of Reach N1 in order to document the constriction of the floodplain by artificial fill and the change from a highly sinuous channel upstream in Reach N1 to the straighter configuration of N2 (Appendix 4 – see planview). The top of the fill on the right bank is more than 5.0 ft higher than the floodplain on the left bank (Appendix 4 – see Cross Section 3). The differences in channel dimensions between the sinuous channel upstream and the artificially straightened channel downstream are distinct (Table 4 – compare Cross Sections 1 and 3). The straightening and the constraint of the channel flowing against the elevated coarse artificial fill has resulted in a narrower channel with a lower width:depth ratio than the more natural conditions upstream. Straightened channels typically have a higher width:depth ratio than natural unaltered channels (Simon, 1989), so the opposite trend in this case suggests that the straightening occurred recently enough that the channel has yet to respond and/or the coarser fill material is inhibiting the widening into the right bank. Future widening, however, should be expected if no restoration occurs but may require a large flow event to be initiated.

The artificial fill on the right bank at the upstream end of Reach N2 has significantly narrowed the natural floodplain and its removal (Appendix 4) will restore the full floodplain width, eliminate constraints to channel adjustment, and reduce flood flow velocities in the channel. While full fill removal would be ideal, the presence of an active commercial property on the fill may preclude that; however, even partial removal would be helpful and is more likely to be considered by the landowner. In-stream restoration activities could be completed with fill removal or on its own if the landowner does not permit fill removal. Isolated logs could be placed in the channel to improve flow complexity and log placements on the restored floodplain (if the fill is removed) would prevent scour of the surface and serve as nurse logs for the growth of trees. Boulder-supported log jams could be used to encourage the growth of meanders along the straightened channel in a manner as described above for Reach C2b (see Appendix 4 and Section 6.2). Fill removal could also be used in Reaches N1 (although the fill does not constrict the floodplain as significantly) and N3 where fill for the old road to the gravel pit (see Section 4.4 above) appears to completely block the floodplain.

6.9 Reach N3: Culvert replacement

The overall slope of the surveyed portion of Reach N3 is quite high (0.05 – see longitudinal profile in Appendix 4) due to the bedrock ledges at the upstream end. Just upstream of the culvert, the gradient is much lower with only a narrow floodplain present before rising up to higher banks (Appendix 4 – Cross Section 3). As a result, backwater from the undersized culvert under Northbrook Drive could rise quite high given the limited space to store floodwaters between the high banks and bedrock ledges upstream. The culvert constricts the channel by 75 percent (Table 4 and Appendix 4 – see Cross Section 3). Detailed hydraulic modeling is needed to establish the potential risk of backwatering during a large runoff event overtopping the road.

The gabion headwall above and around the Northbrook Drive culvert is sliding and rotating down the slope above the culvert (Figure 33) and could potentially block portions of the inlet and greatly worsen the backwater effect. A culvert replacement with a larger structure spanning at least 1.2 times the bankfull width (or 16.1 ft based on a bankfull width of 13.4 ft – see Table 4) should be a high priority with additional relief culverts set at the floodplain level to eliminate the channel constriction and minimize backwatering during even the largest flows (Appendix 4). The gabion headwall should be replaced at the same time to prevent any threat of blocking the culvert inlet that would also be greatly minimized by the enlarged structure. A structure spanning the entire channel, ideally a bridge that also spans the entire narrow floodplain, will better pass sediment and wood, thereby reducing the geomorphic impact of the stream crossing. Replacing undersized culverts with wider crossings could also be completed at the downstream end of Reaches C1, M1, N2, and W1 among others.



Figure 33. Gabion baskets on the headwall of Northbrook Drive are sliding down slope above the culvert inlet.

6.10 Reach W1: Manhole protection and fill removal

Reach W1 is immediately downstream of extensive commercial development in the watershed and begins at a culvert draining this area. The upper portion of the reach is confined, to some degree by artificial fill on the left bank, and, as a result, the channel is wider and deeper than the unconfined lower portion of the reach (Table 4 and Appendix 4 – compare Cross Sections 2 and 3). The confining fill and resulting strong confined flows are responsible for stripping the substrate down to a hardpan clay and redirecting flow into the opposite bank where a sewer manhole has been exposed. The wide floodplain downstream prevents in-channel flow velocities from increasing beyond that of the bankfull flow and prevents channel widening and deepening.

While extensive earthen fill might be on the right bank of the channel, a considerable amount of brush and other material has more obviously been placed over the right bank and further constrained the channel. This fill should be removed to restore at least a

narrow portion of the floodplain (Appendix 4) and reduce flow velocities responsible for bank erosion and a hardpan clay substrate. These issues should also be more directly addressed with log sills placed along the channel to help trap sediment above the substrate and a log jam constructed around the manhole exposed by erosion to prevent damage and to encourage the channel back into its original path along the right bank. After removing fill from the right bank, the slope should be sloped back and treated with a bioengineering solution, such as fascine bundles and willow plantings, to encourage vegetative growth that over time will provide a canopy over the stream channel and a long-term source of in-stream wood as the trees mature.

7.0 CONCLUSIONS

Centuries of human activities in and around the five assessed streams in Falmouth, Maine have, at least locally, constrained natural processes and degraded habitat quality. In-stream and floodplain activities by humans include the construction of dams, placement of artificial fill on the floodplains, artificial straightening of the channels, and building of undersized stream crossings. Along with the indirect contribution of excess (and the concentration of) runoff from developed areas of the watershed (particularly Webes Creek), these various human activities have led to the degradation of aquatic habitat as reflected in low wood loadings in the streams, exposure of a hardpan clay on the stream bottom, eroding stream banks, and areas of impounded flow with wetland rather than fluvial characteristics. While most of the streams' length are largely stable, the generally short lengths of degraded habitat, in the immediate vicinity of an undersized culvert for example, lead to the isolation of larger areas of good habitat found along the five streams.

Conceptual restoration designs have been developed to address the human impacts observed on the five streams. In areas with low wood loadings and far from any infrastructure, the "chop and drop" approach of directionally felling trees into the stream channel represents the quickest, cheapest, and most effective approach to improve cover habitat, flow complexity, and retention of sediment on the stream bed (where hardpan clay is now exposed). Constructed marginal log jams or smaller boulder-supported log jams can be used to encourage meander growth along artificially straightened channels, while log crib walls are recommended for addressing bank scour at the outlet of undersized culverts. Where these larger wood structures are not practical, isolated logs and log sills can be utilized to improve habitat conditions with minimal impact to the existing channel morphology or nearby infrastructure. The various wood-based measures proposed will provide immediate habitat improvements. Sustaining those improvements, however, will depend on removing constraints to natural channel adjustment such as the resizing of culverts narrower than the stream channel (with the culvert at Northbrook Drive on Norton Brook being the highest priority), removal of the dam on Mill Creek, and artificial fill removal (with fill at the upstream end of Webes Creek being a high priority). Only through a continued effort over time, starting with the easiest and most inexpensive efforts first while the capacity is developed to address the larger projects, can the Town of Falmouth avoid the streams being listed as urban impaired by the Maine

Department of Environmental Protection. The natural conditions on the streams, particularly the bed and banks composed of the fine-grained silts and clays of the Presumpscot Formation, ensure the streams will respond rapidly and positively to the restoration efforts.

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TABLE 2

(Reach summary)

Table 2a. Summary of reach characteristics and restoration options for Chenery Brook.

a)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
C1	Cumberland town line to railroad culvert	1,075	- Floodplain access - Shrubs for canopy - Narrow channel - Small log jams - Fine substrate	- Undersized culvert - Partial forest buffer removal	1) Chop and drop 2) Replace undersized culvert at downstream end	1) Very low ($25k) 2) Watch list (> $1 million)	1) Mod./Low 2) High/High	
C2	Railroad culvert to widened floodplain with sinuous channel	854	- Severe scour at culvert outlet - Largely fine substrate - Minimal wood in channel	- Channel straightening - Flows along I-295 road grade	1) Chop and drop 2) Log sills, crib walls, and/or log jams	1) Very low ($25k) 2) Low ($100k)	1) Mod./Low 2) Mod./High	
C3	Widened floodplain wirh sinuous channel to Johnson Road	1,422	- Floodplain access with sinuous channel - Drowned dead trees - Beaver activity - Abundant wood in channel	- Small dam and associated pond - Johnson Rd culvert but sufficiently sized	1) Dam removal	1) Moderate ($120k)	1) Mod./Mod.	
C4	Johnson Road to area of increasing confinement	2,208	- Sinuous channel - Small log jams - Predominately fine substrate - Canopy of small shrubs	- Gas pipeline crossing - Straightening (?)	1) Land conservation 2) Bank stabilization	1) Very low ($50k) 2) Low ($100k)	1) Mod./Mod. 2) Low/Mod.	

Table 2a (continued). Summary of reach characteristics and restoration options for Chenery Brook.

a)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
C5	Area of increasing confinement to I-295 culvert	1,141	- Narrow floodplain - Cobble substrate in places - Beaver dam with large impoundment - Mature trees on nearby uplands	- I-295 culvert but no backwatering evident	1) Land conservation 2) Chop and drop	1) Very low ($50k) 2) Very low ($25k)	1) Mod./Mod. 2) Low/Low	
C6	I-295 culvert to sharp bend on high right bank	556	- Upper reach confined - Ledge outcropping on left bank - Sloughing right bank of clay - Floodplain and sand bars in lower reach	- Abandoned channel and sharp bend suggest straightening	1) Chop and drop	1) Very low ($25k)	1) Mod./Low	
C7	Sharp bend on high right bank to Mill Creek confluence	903	- Floodplain access - Good tree canopy - Abundant wood - Sinuous dynamic planform - Predominately sandy substrate	- Straightening (?) - Concentrated runoff in small gully from Route 1	1) Chop and drop 2) Reactivate abandoned channel 3) Wood additions in small gully	1) Very low ($25k) 2) Mod. ($150k) 3) Low ($50k)	1) Low/Low 2) Low/Mod. 3) High/Low	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2b. Summary of reach characteristics and restoration options for Hobbs Brook.

b)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
H1	Cumberland town line to Gray Road	601	- Marsh lands with dense shrubs - Low width:depth channel - Fine substrate	- Undersized culvert at downstream end - Gas pipeline crosses just upstream of culvert	1) Replace undersized culvert	1) Watch list ($300k)	1) Mod./Mod.	
H2	Gray Road to high confining left bank	1,593	- Scour at culvert outlet - Clay hardpan substrate - Minimal wood in channel - Sinuous low width:depth channel	- Straightening (?) - Clearance of riparian zone - Boulders in channel	1) Chop and drop 2) Log sills	1) Very low ($25k) 2) Very low ($45k)	1) High/Low 2) High/Low	
H3	High confining left bank to Piscataqua River confluence	1,121	- Narrow floodplain - Upper half imounded by fallen tree jammed with branches - Good forest canopy - Minimal wood in channel	- None evident directly in channel	1) Land conservation 2) Chop and drop	1) Very low ($50k) 2) Very low ($25k)	1) Mod./Mod. 2) Low/Low	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2c. Summary of reach characteristics and restoration options for Mill Creek.

c)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
M1	Route 9 to Olde Blackwood Way	1,599	- Sinuous channel at upstream and downstream ends - Alder wetland in middle of reach - Small log jams - Good canopy	- Undersized culverts - Channel realignment	1) Chop and drop 2) Replace both undersized culverts	1) Very low ($25k) 2) Moderate ($150k)	1) Mod./Low 2) Mod./Mod.	
M2	Olde Blackwood Way to Route 9	814	- Channel with high width:depth ratio - Abandoned meander on right bank - Little in-stream wood - Wetland at end of reach	- Channel straightening - Undersized and poorly aligned culverts	1) Provide relief culvert or reactivate meander 2) Realign and resize culverts 3) Low log sills	1) Moderate ($100k) or high ($200k) 2) High ($200k) 3) Low ($50k)	1) Mod./Mod. 2) Mod./High 3) Mod./Low	
M3	Route 9 to Long Creek Way	1,133	- High amplitude meanders downstream - Gravel/sand substrate - High width:depth channel - Minimal wood in channel despite forest	- Channel realigned at Route 9 - Fill blocks portion of floodplain - Straightening (?) at upstream end - Undersized culvert	1) Chop and drop 2) Resize Long Creek Way culvert	1) Very low ($25k) 2) Moderate ($100k)	1) Low/Low 2) Mod./Low	
M4	Long Creek Way to the bedrock falls	2,286	- High amplitude meanders downstream - Gravel/sand substrate - Low to high width:depth channel - Minimal wood in channel despite forest	- Undersized culvert under private driveway	1) Land conservation 2) Chop and drop 3) Resize driveway culvert	1) Low ($75k) 2) Low ($100k) 3) Low ($50k)	1) High/Mod. 2) Mod/Low 3) Low/Low	

Table 2c (continued). Summary of reach characteristics and restoration options for Mill Creek.

c)

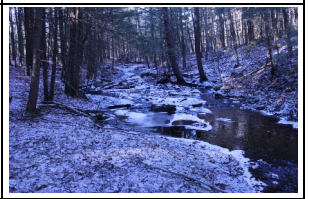
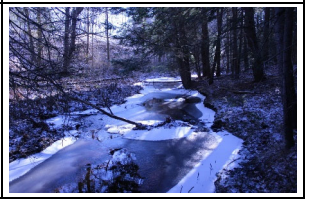
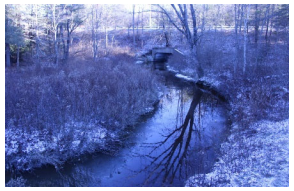
Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
M5	Bedrock falls to the transmission line	536	- Confined channel - Bedrock falls - Large sand bar in low gradient area - Well forested buffer	- None evident directly in channel	1) Chop and drop in low gradient area	1) Very low ($20k)	1) Low/Low	
M6	Transmission line to Middle Road	2,315	- Sinuous high width:depth channel - Hardpan clay substrate common - Well forested buffer - Numerous log jams - Narrow floodplain	- Remnant dam - Middle Road culvert (but not undersized)	1) Chop and drop 2) Remove dam and realign channel	1) Very low ($30k) 2) High ($250k)	1) Mod./Low 2) High/Mod.	
M7	Middle Road to downstream end of bedrock gorge	1,204	- Confined channel - Low bedrock falls - Cobble substrate and bars in low gradient areas - Abundant in-stream wood and good buffer	- Remnant dam - Middle Road culvert (but not undersized)	1) Land conservation	1) Very low ($40k)	1) High/Mod.	
M8	Downstream of bedrock gorge to railroad culvert	511	- Bifurcated channel where flow expands - High width:depth - Minimal in-stream wood - Good forested buffer	- Poorly aligned culvert - Flow along railroad grade	1) Chop and drop w/ log strainer 2) Resize and realign culvert	1) Very low ($30k) 2) Watch list (> $1 million)	1) Mod./Mod. 2) Low/High	

Table 2c (continued). Summary of reach characteristics and restoration options for Mill Creek.

c)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
M9	Railroad culvert to I-295 culvert	1,116	- Sinuous with high amplitude meanders - Sand substrate - Straight along high bank - Minimal wood & poor buffer on floodplain	- Riprap at railroad culvert outlet - Large boulders in channel upstream of I-295 culvert (see photo)	1) Chop and drop 2) Remove boulders	1) Very low ($25k) 2) Low ($60k)	1) High/Low 2) Low/High	
M10	I-295 culvert to Route 1 culvert	837	- Sinuous channel - Narrow floodplain - Significant in-stream wood -Low shrubs on floodplain	- Riprap under bridge constricts channel - Culverts at both ends but both match channel width	1) Chop and drop 2) Pull back riprap to alleviate constriction	1) Very low ($20k) 2) Very low ($20k)	1) Low/Low 2) Mod./Mod.	
M11	Route 1 culvert to Foreside Road bridge	5,537	- Tidally influenced - High amplitude meanders across marsh - Minimal wood - Fine substrate - Eroding banks	- Straightening and berming in short section - Sewer line at edge of floodplain w/ channel imipinging at one spot	1) Berm removal & log jams to encourage meander growth where straightened 2) Bank protection with logs where near sewer line	1) High ($250k) 2) Mod. ($200k)	1) Low/Mod. 2) High/Mod.	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2d. Summary of reach characteristics and restoration options for Norton Brook.

d)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
N1	Cumberland town line to behind Street Cycles store	1,868	- Dynamic sinuous channel - Low width:depth channel - Sand substrate - Multiple log jams w/ forested floodplain	- Straightening (?) - Floodplain partially constricted by fill	1) Chop and drop	1) Very low ($25k)	1) Low/Low	
N2	Behind Street Cycles store to Johnson Road culvert	1,316	- Channel flows against fill at upstream end - Wide marshy floodplain downstream - Minimal wood in channel - Low sinuosity	- Straightening (?) - Floodplain partially constricted by fill - Johnson Rd culvert	1) Log sills and jams 2) Remove fill 3) Add relief culverts at Johnson Road	1) Low ($100k) 2) Mod. ($200k) 3) High ($250k)	1) Mod./Mod. 2) Mod./High 3) High/High	
N3	Johnson Road culvert to Northbrook Drive culvert	1,541	- Rocky substrate above hardpan clay - Bedrock confinement - Minimal wood - Sinuous above falls - Headwall above culvert inlet collapsing	- Remnant dam (?) - Riprap at culverts - Johnson Rd culvert	1) Log cribbing to replace riprap 2) Repair and resize Northwood Dr culvert 3) Anchored chop and drop	1) Low ($100k) 2) High ($250k) 3) Very low ($40k)	1) High/Low 2) High/Mod. 3) Mod./Low	
N4	Northbrook Drive culvert to Mill Creek confluence	1,338	- Sinuous channel across wide floodplain - Sandy substrate and large sand bars - Good forest canopy - In-stream wood common	- Fill across floodplain at old crossing to quarry - Fill constricts floodplain at Sullivan Tire - Scour at culvert outlet	1) Chop and drop 2) Remove fill crossing floodplain at old quarry access	1) Very low ($25k) 2) High ($250k)	1) Low/Low 2) High/High	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2e. Summary of reach characteristics and restoration options for Webes Creek.

e)

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
W1	Culvert by Ace Hardware store to Depot Road	703	- Floodplain access at downstream end - Confined by clay and fill upstream - Limited wood and canopy - Hardpan clay on bed	- Undersized culverts - Fill constricts channel - Manhole exposed by erosion - Forest buffer removed	1) Remove fill and log jams to protect manhole 2) Log sills to trap sediment over clay 3) Resize Depot Rd culvert	1) High ($200k) 2) Low ($40k) 3) High ($250k)	1) High/Mod. 2) High/Mod. 3) High/High	
W2	Depot Road culvert to end of the lawn	257	- Severe scour at culvert outlet - Minor sinuosity - Hardpan clay on bed - Minimal buffer and in-stream wood	- Channel straightening - Pipe crosses channel - Severe scour at culvert outlet - Forest buffer rremoved	1) Log cribbing for bank protection 2) Log sills to trap sediment over clay 3) Remove pipe or protect w/ log jam 4) Recreate meanders	1) Very low ($40k) 2) Very low ($40k) 3) Moderate ($120k) 4) High ($300k)	1) High/Low 2) Mod./Mod. 3) High/Mod. 4) Mod./High	
W3	End of the lawn to the next lawn downstream on the right bank	1,211	- Upstream end sinuous - Low banks downstream - Hardpan clay exposed in areas - Jams w/ sticks derived from thick shrub buffer	- Straightening (?)	1) Bundle clippings to form jams	1) Very low ($10k)	1) Mod./Low	
W4	Next lawn downstream on the right bank to open meadowy area	391	- Straight channel with better defined banks - Bank erosion causing large trees to fall into channel - Stagnant flow - Poor canopy	- Straightening (?)	1) Buffer planting along edge of lawnss	1) Very low ($25k)	1) High/Mod.	
W5	Open meadowy area to Mill Creek confluence	983	- Tidally influenced - High amplitude meanders across marsh - Minimal wood and poor canopy - Fine substrate - Low width:depth	- Straightening (?) at upstream end - Concrete bridge collapsed in channel - Channel approaching sewerline	1) Remove collapsed bridge	1) Low ($75k)	1) Low/Mod.	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert). A best estimate of cost given in parentheses for each reach and includes design, permitting, and construction costs

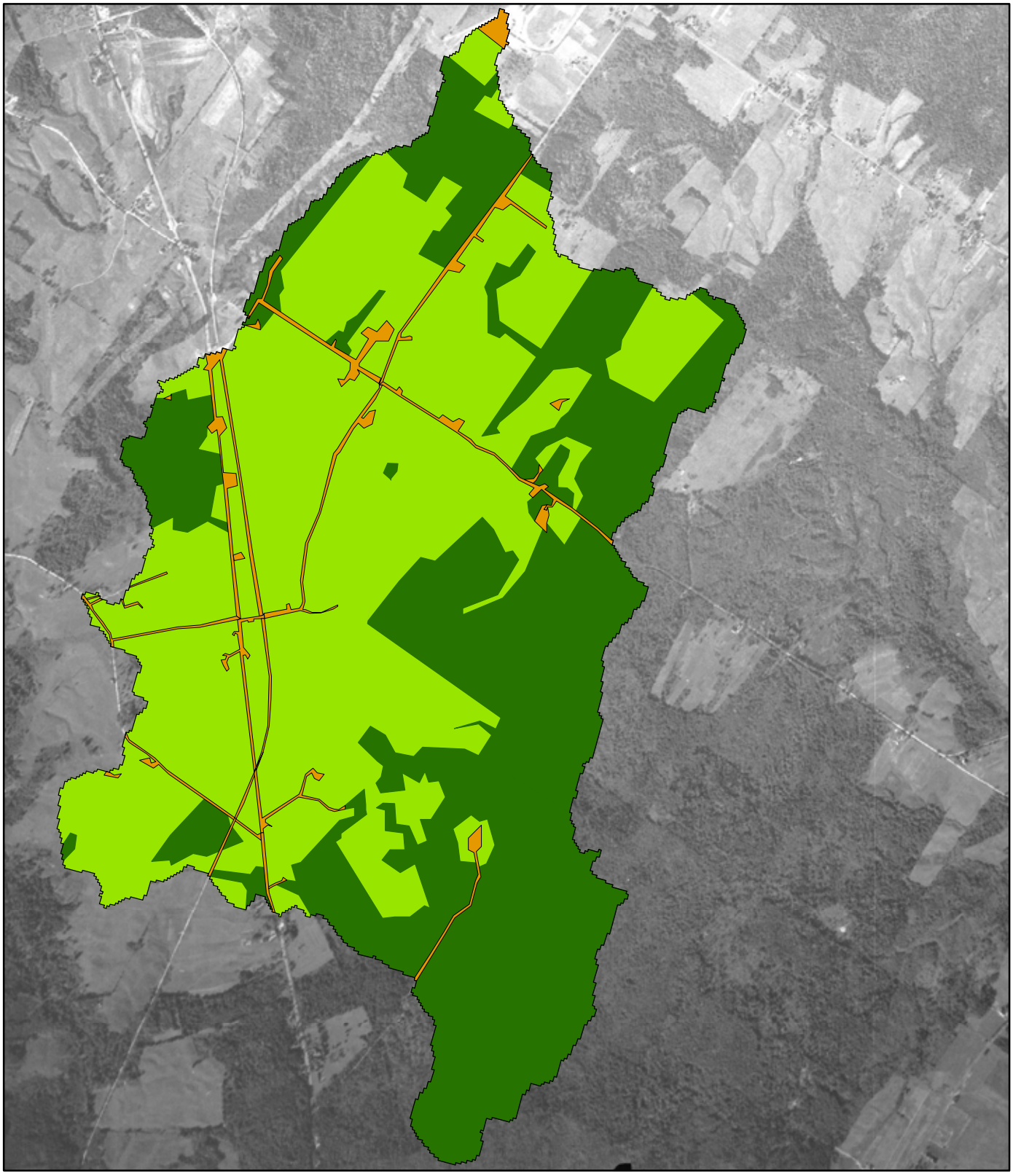
† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

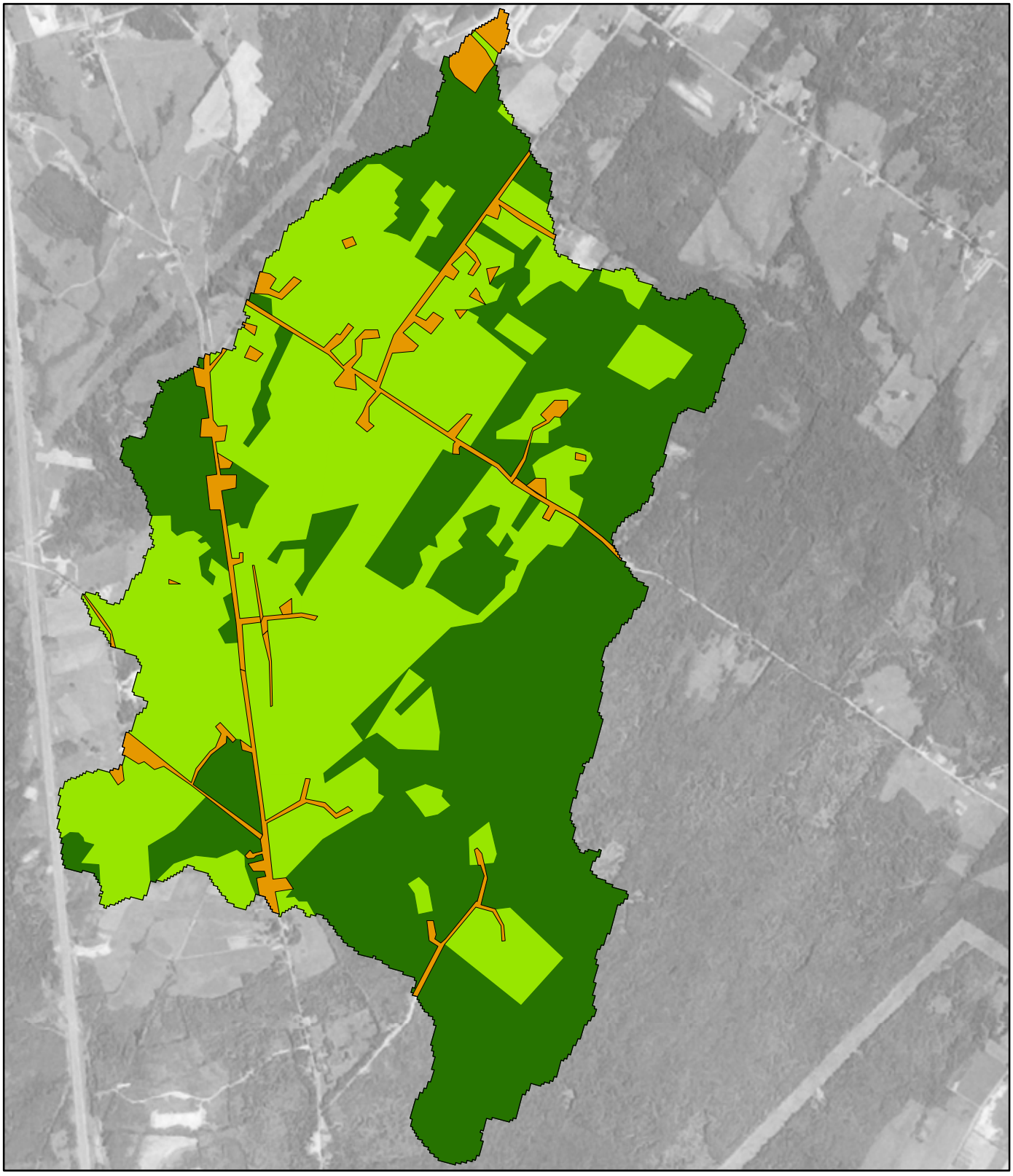
APPENDIX 1

(Land use maps)

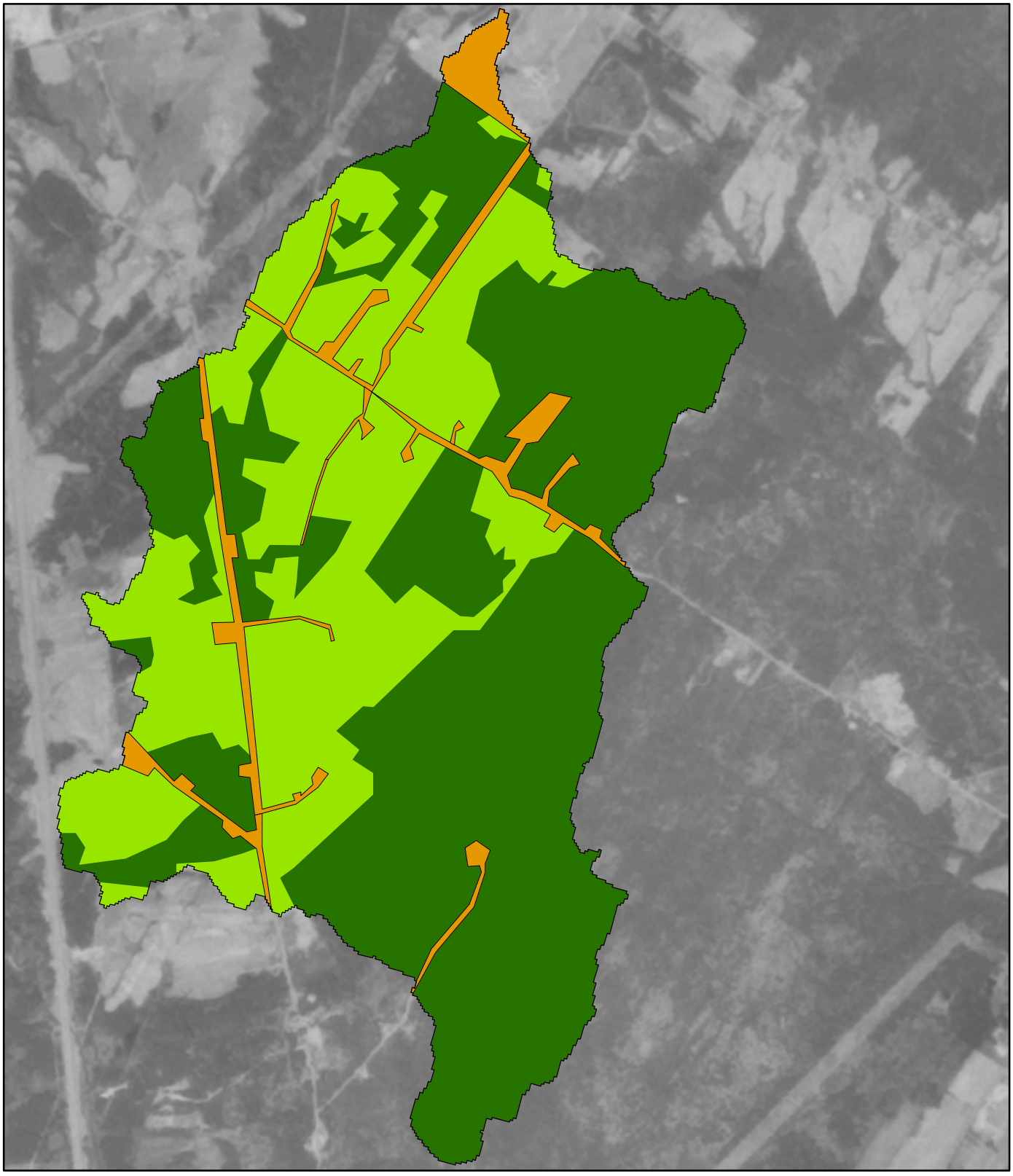
1940 Land Use for Hobbs Brook



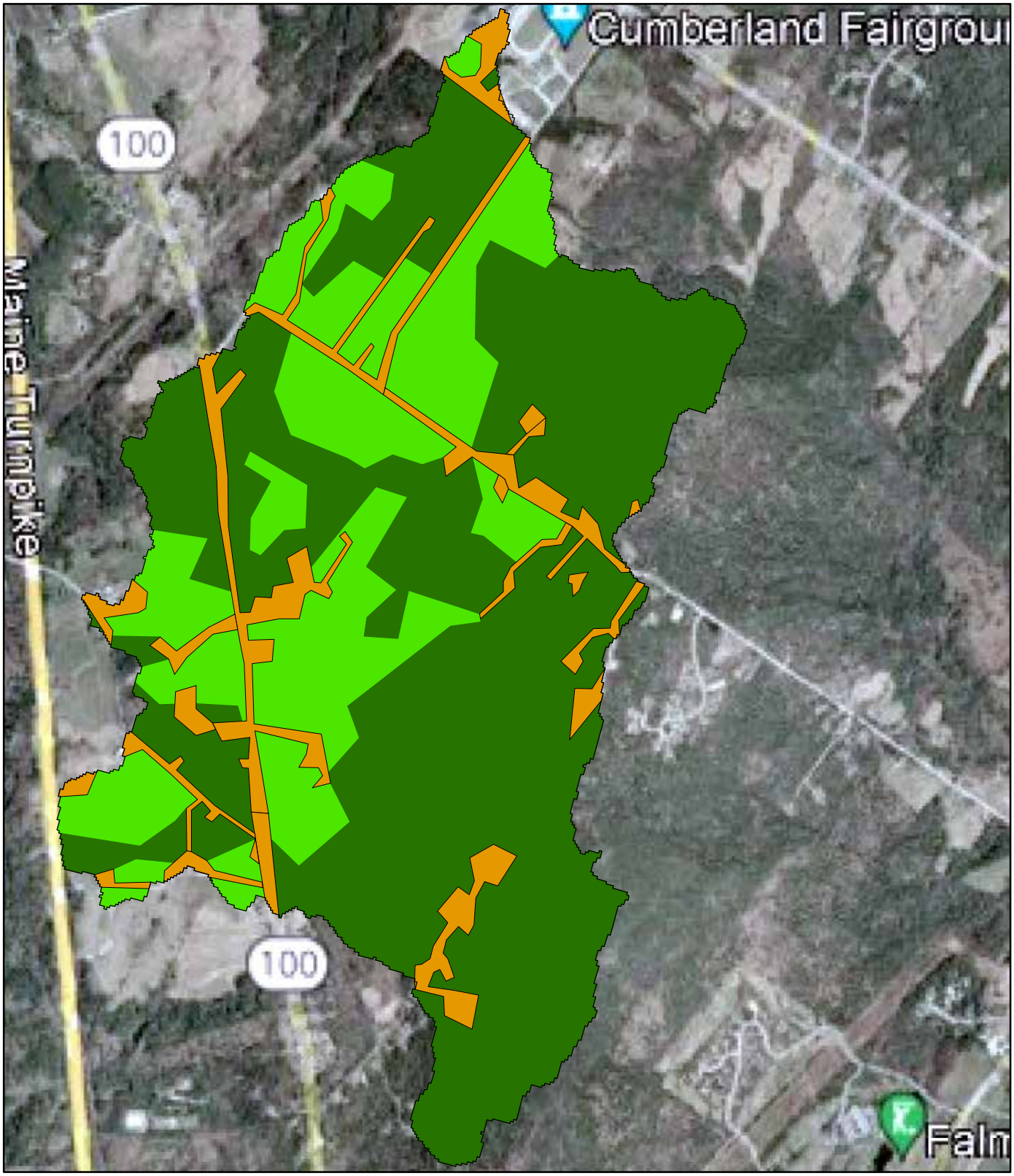
1960 Land Use for Hobbs Brook



1975 Land Use for Hobbs Brook



2006 Land Use for Hobbs Brook



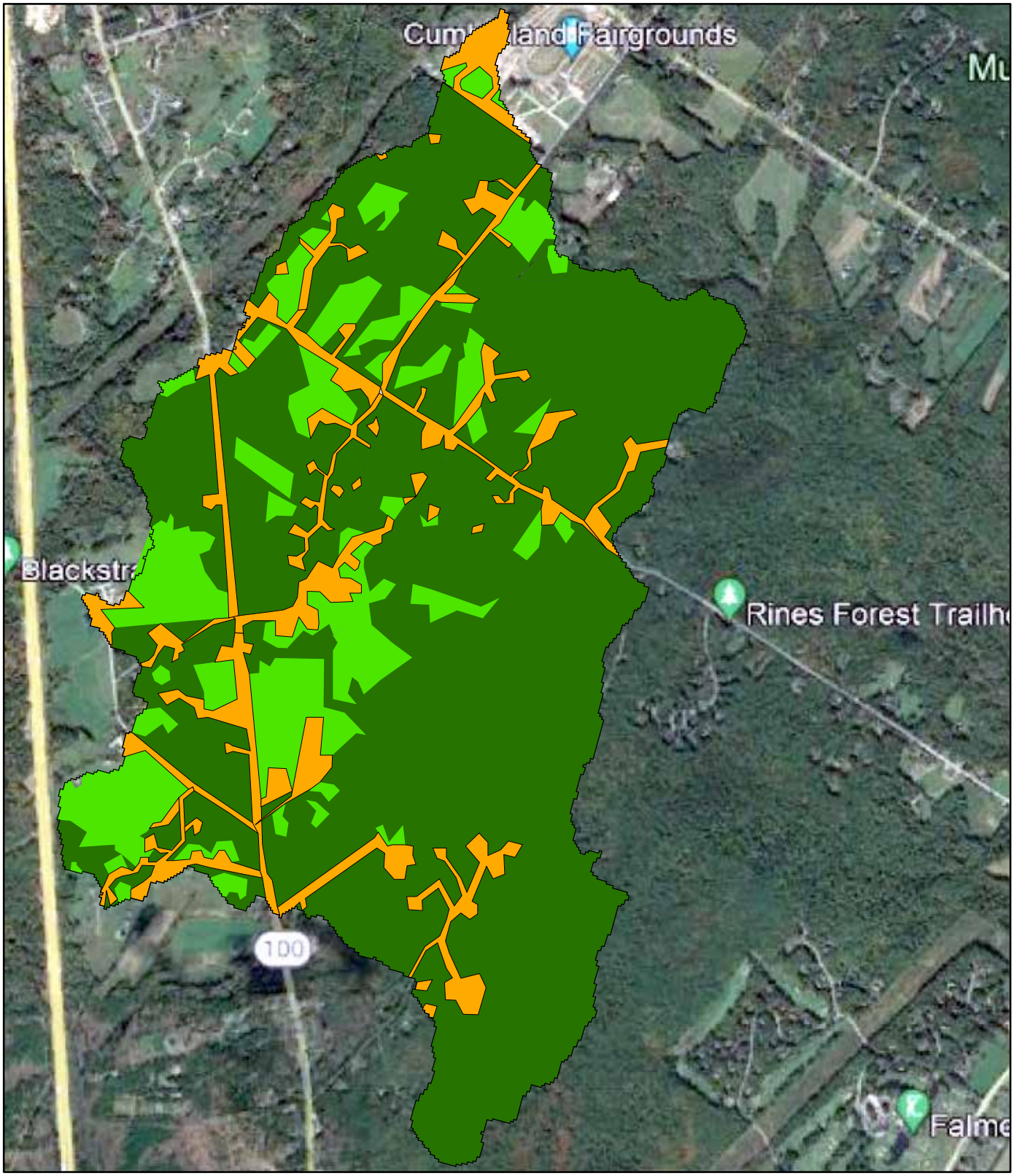
Legend

- Developed
- Forested
- Open Land

0 0.375 0.75 1.5 Miles

N

2022 Land Use for Hobbs Brook



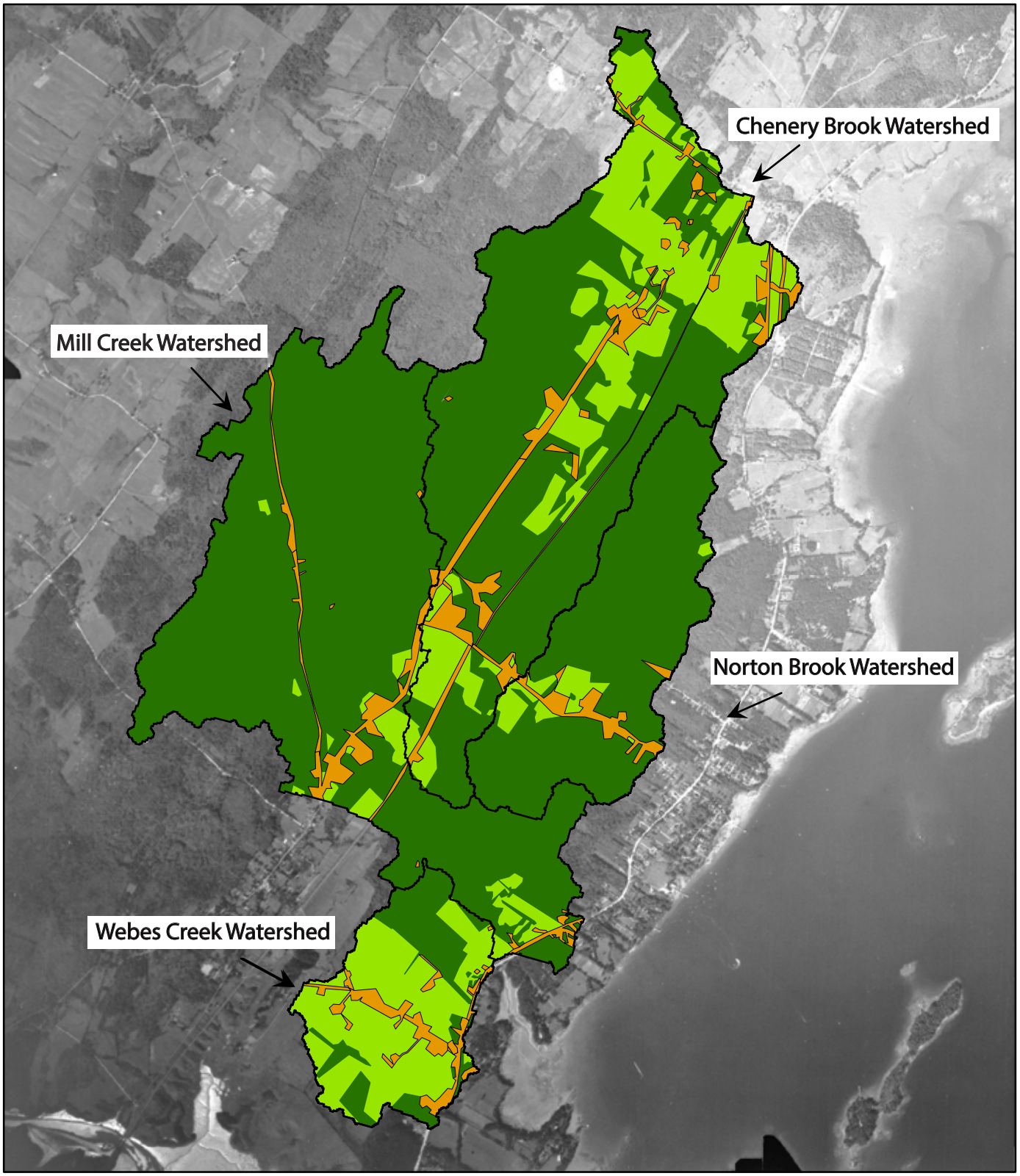
Legend

- Developed
- Forested
- Open Land

0 0.375 0.75 1.5 Miles

N

1940 Land Use for Mill Creek



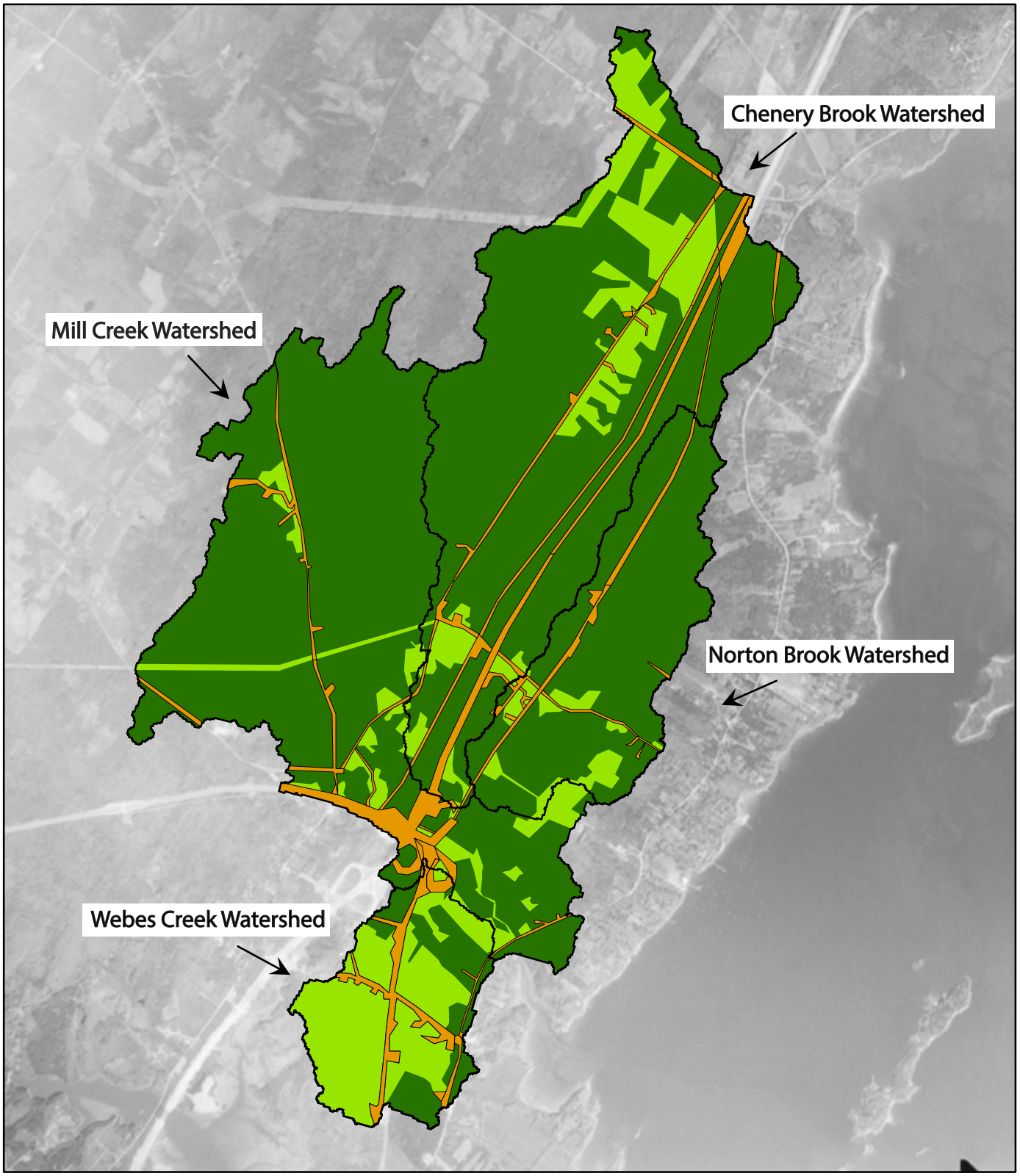
Legend

- Developed
- Forested
- Open Land

0 0.5 1 2 Miles

N

1960 Land Use for Mill Creek



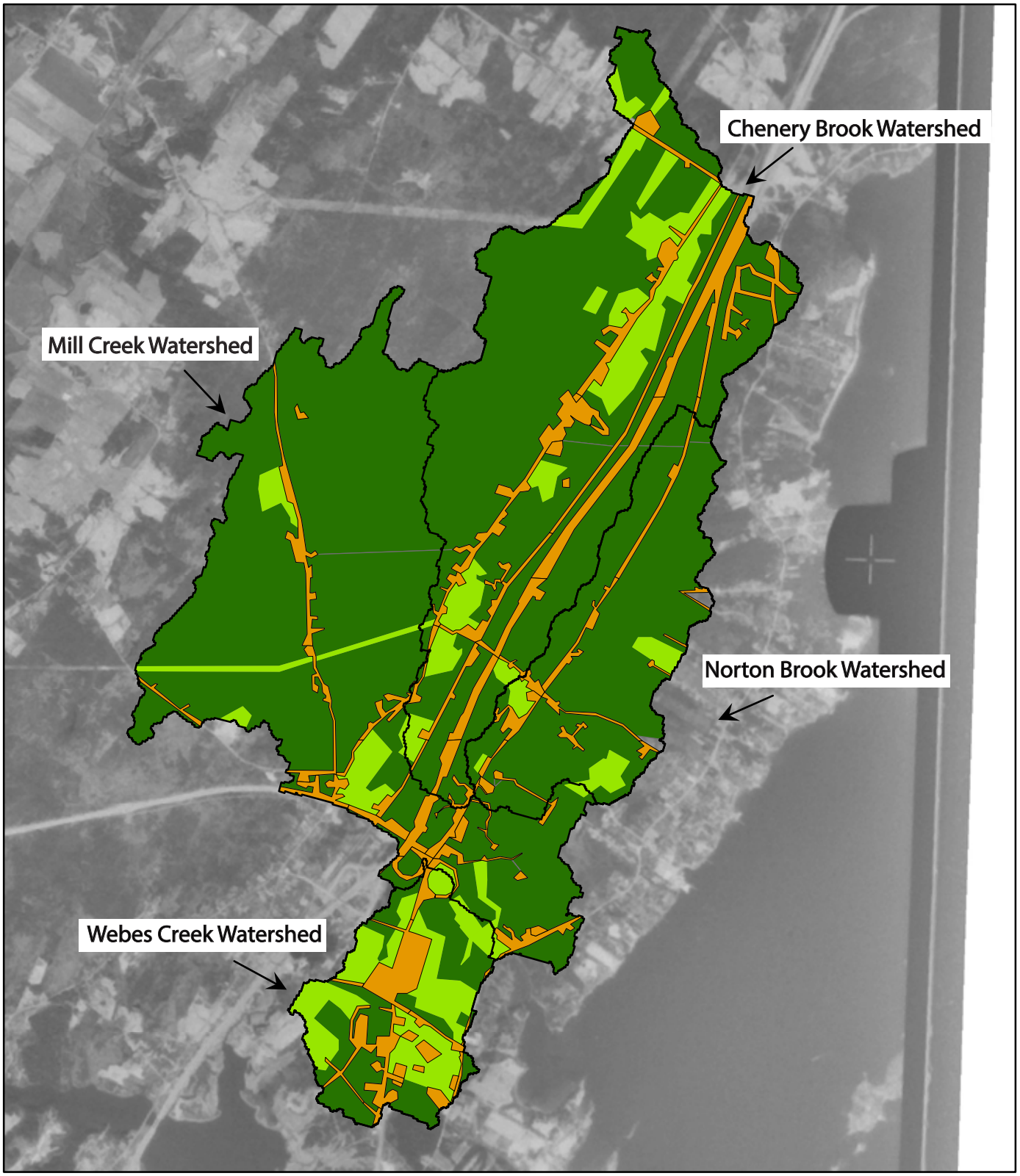
Legend

- Developed
- Forested
- Open Land

0 0.5 1 2 Miles

N

1975 Land Use for Mill Creek



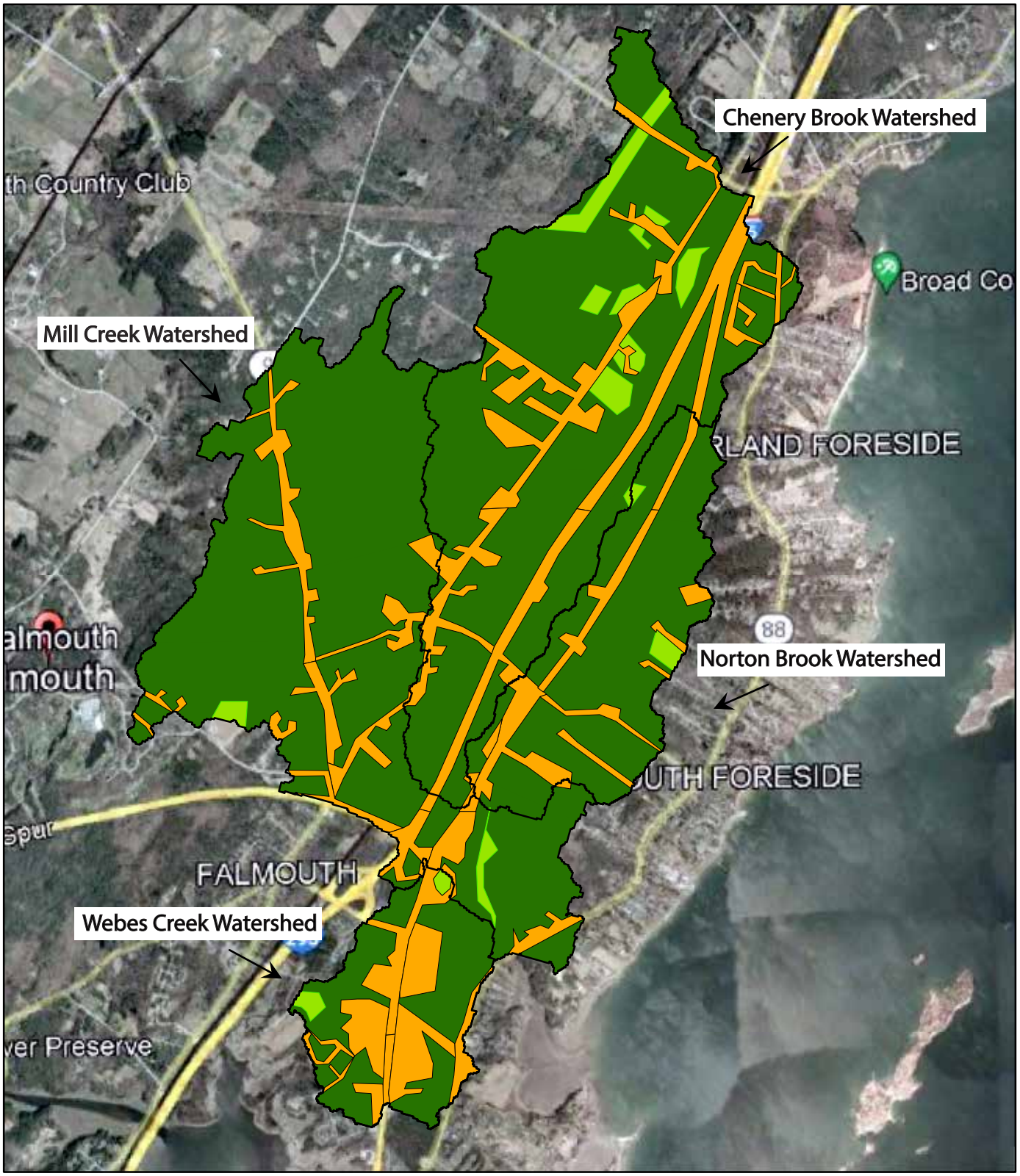
Legend

- Developed
- Forested
- Open Land

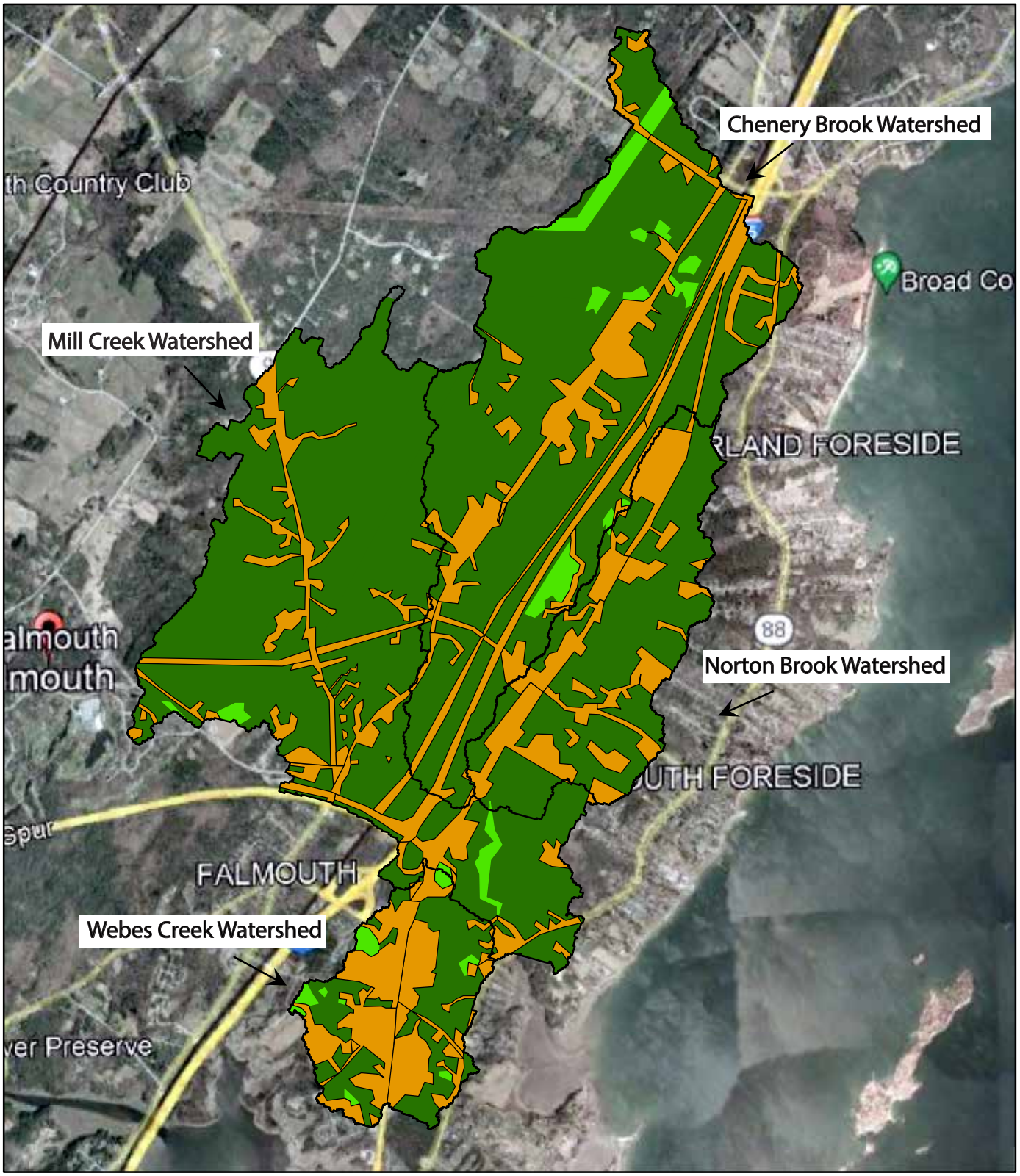
0 0.5 1 2 Miles

N

2006 Land Use for Mill Creek

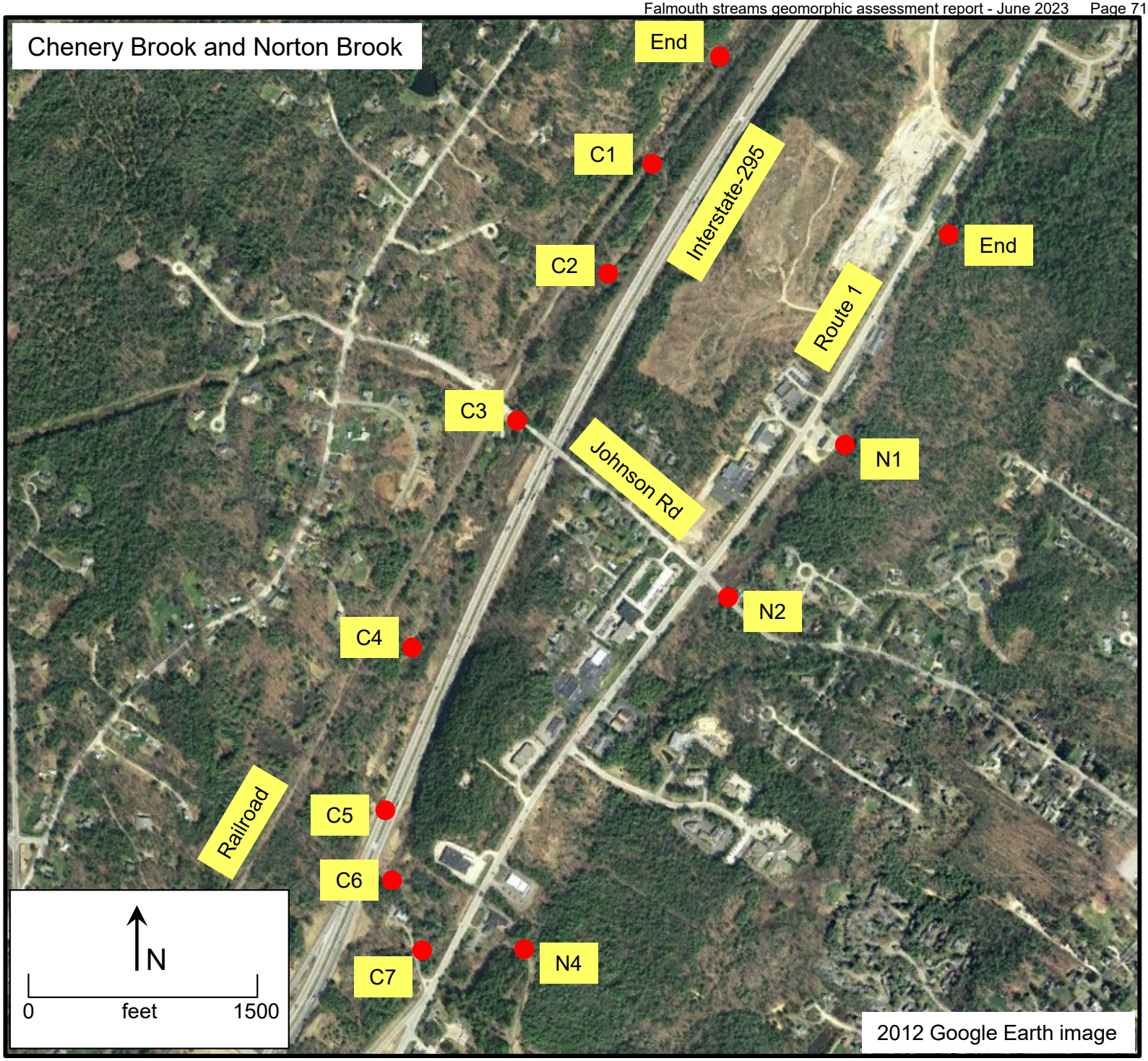


2022 Land Use for Mill Creek



APPENDIX 2

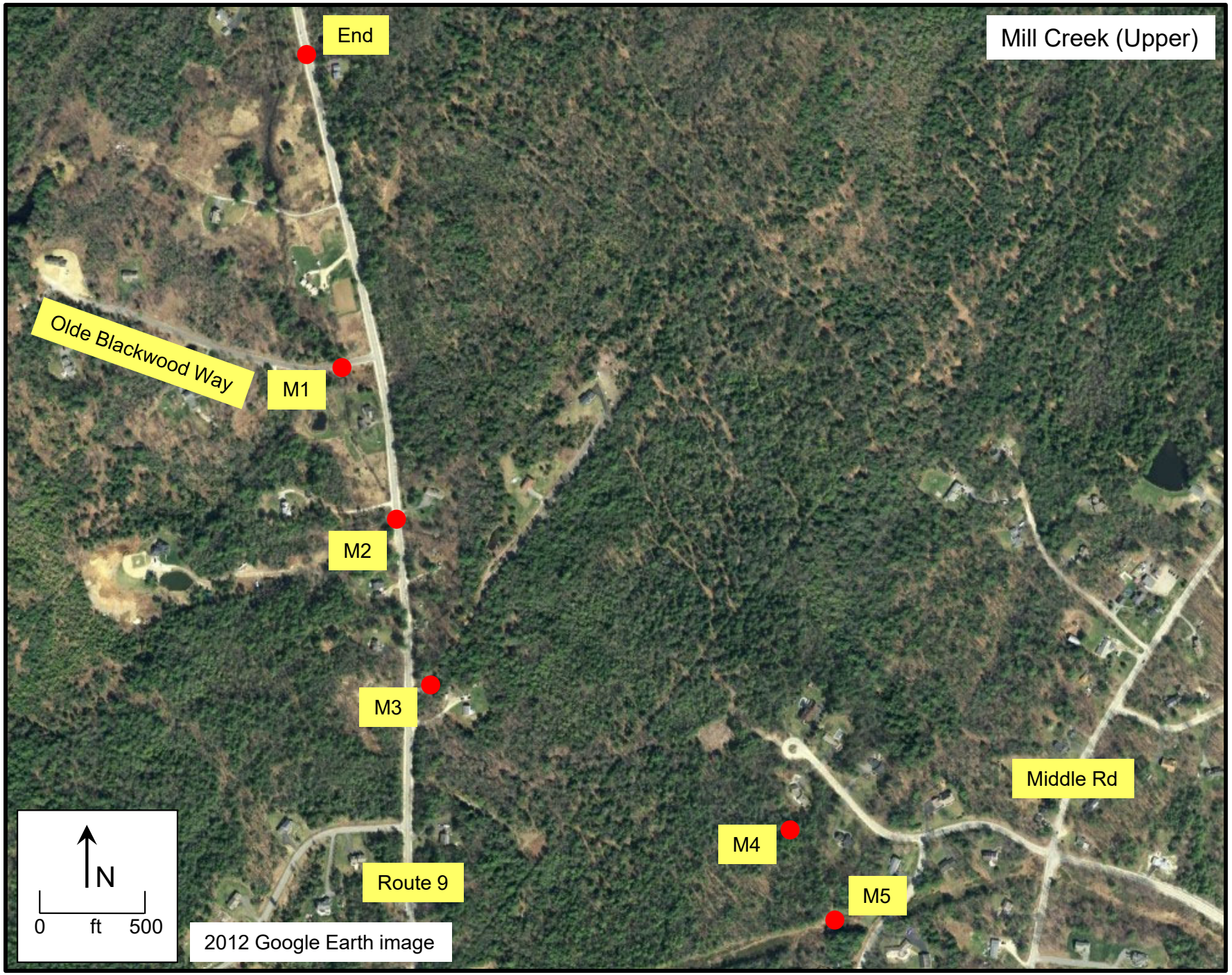
(Reach location maps)



Appendix 2. Reach location map for Chenery Brook and Norton Brook.



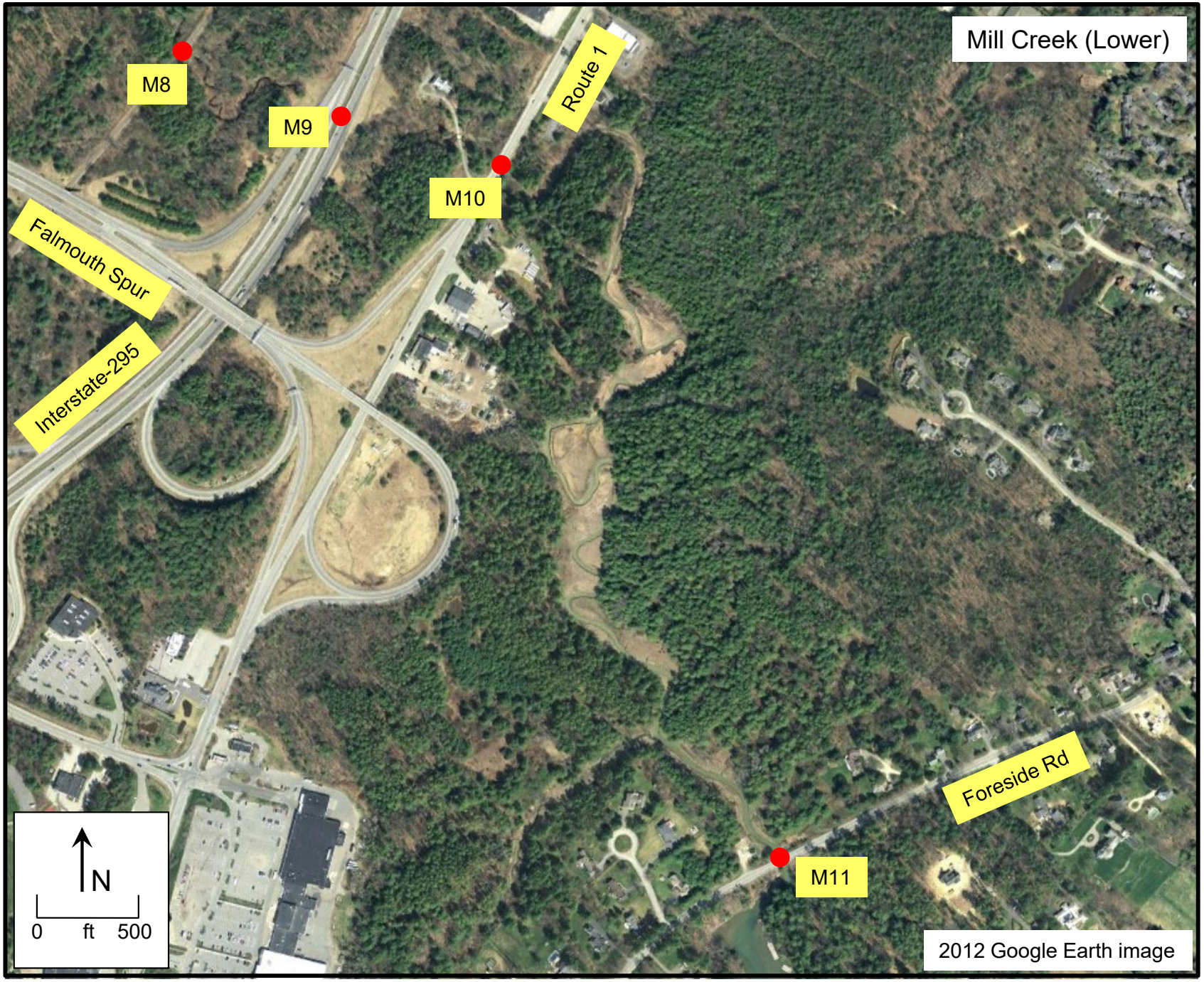
Appendix 2. Reach location map for Hobbs Brook.



Appendix 2. Reach location map for Mill Creek (Upper).



Appendix 2. Reach location map for Mill Creek (Middle).



Appendix 2. Reach location map for Mill Creek (Lower).



Appendix 2. Reach location map for Webes Creek.

APPENDIX 3

(Rapid Geomorphic Assessment forms)

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 1 ***Recorder:*** NickMiller, JohnField

Location: Cumberland town line to RR Xing ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	5	4	0.44
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.17

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 2 ***Recorder:*** NickMiller, JohnField

Location: Railroad culvert to widened floodplain with sinuous channel ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	4	5	0.56
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.28

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 3 ***Recorder:*** NickMiller, JohnField

Location: From start of widened floodplain with sinuous channel to Johnson Road ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	4	5	0.56
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.20

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 4 ***Recorder:*** NickMiller, JohnField

Location: Johnson Rd to area of increasing confinement ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded		x	
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone	x		
		Sum of Indices:	4	5	0.56
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.24

Condition: Transitional or stressed

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 5 ***Recorder:*** NickMiller, JohnField

Location: Area of increasing confinement to I-295 culvert ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.15

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 6 ***Recorder:*** NickMiller, JohnField

Location: I-295 culvert to Sharp bend at high RB ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	5	4	0.56
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.20

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Chenery Brook Reach 7 ***Recorder:*** NickMiller, JohnField

Location: Sharp bend at high RB to Mill Brook confluence ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	2	7	0.78
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.33

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 11/7/2022 ***Sample ID:*** Hobbs Brook Reach 1 ***Recorder:*** NickMiller, JohnField

Location: US of Gray Rd to Upstream Town Line ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 11/7/2022 ***Sample ID:*** Hobbs Brook Reach 2 ***Recorder:*** NickMiller, JohnField

Location: Gray Rd to High confining LB ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	6	9	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.08

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 11/7/2022 ***Sample ID:*** Hobbs Brook Reach 3 ***Recorder:*** NickMiller, JohnField

Location: High confining LB to Piscataqua River confluence ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	6	3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.15

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 1 ***Recorder:*** NickMiller, JohnField

Location: Route 9 to Olde Blackwood Way ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	Places
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.125
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel		x	some
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.094

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 2 ***Recorder:*** NickMiller, JohnField

Location: Olde Blackwood Way to Route 9 ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =

SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.028

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 3 ***Recorder:*** NickMiller, JohnField

Location: Route 9 to Long Creek Way ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.125
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.159

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 4 ***Recorder:*** NickMiller, JohnField

Location: Long Creek Way to the bedrock falls ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.0275

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 5 ***Recorder:*** NickMiller, JohnField

Location: From the bedrock falls to the transmission line ***Crew:***

Form/ Process	Num	Geomorphic Indicator: Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.10

Condition: In regime

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 6 ***Recorder:*** NickMiller, JohnField

Location: From the transmission line to Middle Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	6	3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases		x	
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	5	2	0.29
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	6	2	0.25
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.29

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 7 ***Recorder:*** NickMiller, JohnField

Location: Middle Rd to downstream end of bedrock gorge ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	3	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)		x	
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =

SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.19

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 8 ***Recorder:*** NickMiller, JohnField

Location: From downstream end of bedrock gorge to the railroad crossing ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)		x	
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	4	3	0.43

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.11

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 9 ***Recorder:*** NickMiller, JohnField

Location: RR crossing to I-295 ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)		x	
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.13

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 10 ***Recorder:*** NickMiller, JohnField

Location: I-295 to Rt 1 ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.125
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.03

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 6/1/2022 ***Sample ID:*** Mill Creek Reach 11 ***Recorder:*** NickMiller, JohnField

Location: Rt 1 to Foreside Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone	x		
		Sum of Indices:	5	4	0.44
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	6	1	0.14
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle		x	
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach		x	
	8	Fracture lines along top of bank	x		
		Sum of Indices:	4	4	0.50
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.27

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/25/2022 ***Sample ID:*** Norton Brook Reach 1 ***Recorder:*** NickMiller, JohnField

Location: Cumberland town line to behind Street Cycles store ***Crew:***

Form/ Process	Num	Geomorphic Indicator: Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone		x	
		Sum of Indices:	6	3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed		x	
	3	Bank height increases		x	
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	4	3	0.43
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	4	4	0.50
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel		x	
	3	Evolution of pool-riffle form to low bed relief form		x	
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form		x	
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	3	4	0.57

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.46

Condition: In adjustment

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/27/2022 ***Sample ID:*** Norton Brook Reach 2 ***Recorder:*** NickMiller, JohnField

Location: From behind Street Cycles store to Johnson Rd ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	7	2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	7	1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	4	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.12

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/27/2022 ***Sample ID:*** Norton Brook Reach 3 ***Recorder:*** NickMiller, JohnField

Location: Johnson Rd to Northbrook Dr ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars		x	
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone		x	
		Sum of Indices:	6	3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	6	1	0.14
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.25

Condition: Transitional or stressed

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/27/2022 ***Sample ID:*** Norton Brook Reach 4 ***Recorder:*** NickMiller, JohnField

Location: Northbrook Dr to Mill Creek confluence ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	5	4	0.44
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		x	
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	6	1	0.14
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		x	
	2	Occurrence of large organic debris		x	
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach		x	
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	5	3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)		x	
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	5	2	0.29

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.31

Condition: Transitional or stressed

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 1 ***Recorder:*** NickMiller, JohnField

Location: Culvert at Ace Hardware to Depot Rd ***Crew:***

Form/ Process	Num	Geomorphic Indicator Description	Present No	Present Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	8	1	0.11
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		x	
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	6	1	0.14

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.06

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 2 ***Recorder:*** NickMiller, JohnField

Location: Depot Rd to the end of the lawn ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded		x	
	3	Siltation in pools	x		
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	7	2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots		x	
	4	Basal scour on inside meander bends		x	
	5	Toe erosion on both sides of channel through riffle		x	
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach		x	
	8	Fracture lines along top of bank		x	
		Sum of Indices:	3	5	0.63
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.21

Condition: Transitional or stressed

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 3 ***Recorder:*** NickMiller, JohnField

Location: From end of the lawn to next lawn on RB DS ***Crew:***

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		x	
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools		x	
	4	Mid-channel bars	x		
	5	Deposition on point bars		x	
	6	Poor longitudinal sorting of bed materials		x	
	7	Soft, unconsolidated bed		x	
	8	Evidence of deposition in/around structures		x	
	9	Deposition in the overbank zone		x	
		Sum of Indices:	2	7	0.78
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0.20

Condition: In regime

Field Geology Services
Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 4 ***Recorder:*** NickMiller, JohnField

Location: 1st lawn DS to Open meadowy backwater area ***Crew:***

Form/ Process	Num	Geomorphic Indicator: Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools			
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed			
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0

Condition: In regime

Field Geology Services Fluvial Geomorphology

Appendix 2. Rapid geomorphic assessment data sheet.

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 10/28/2022 ***Sample ID:*** Webes Creek Reach 5 ***Recorder:*** NickMiller, JohnField

Location: Open meadowy backwater area to Mill Creek confluence ***Crew:***

1st

Form/ Process	Num	Geomorphic Indicator: Description	Present: No	Present: Yes	Score *
Evidence of Aggradation (AI)	1	Lateral bars	x		
	2	Coarse materials in riffles embedded	x		
	3	Siltation in pools			
	4	Mid-channel bars	x		
	5	Deposition on point bars	x		
	6	Poor longitudinal sorting of bed materials	x		
	7	Soft, unconsolidated bed	x		
	8	Evidence of deposition in/around structures	x		
	9	Deposition in the overbank zone	x		
		Sum of Indices:	9	0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock	x		
	2	Elevated tree roots/root fan above channel bed	x		
	3	Bank height increases	x		
	4	Absence of depositional features (no bars)	x		
	5	Cut face on bar forms	x		
	6	Head cutting due to knick point migration	x		
	7	Suspended armour layer visible in bank	x		
		Sum of Indices:	7	0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc	x		
	2	Occurrence of large organic debris	x		
	3	Exposed tree roots	x		
	4	Basal scour on inside meander bends	x		
	5	Toe erosion on both sides of channel through riffle	x		
	6	Steep bank angles through most of reach	x		
	7	Length of bank scour >50% through subject reach	x		
	8	Fracture lines along top of bank	x		
		Sum of Indices:	8	0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes	x		
	2	Single thread channel to multiple channel	x		
	3	Evolution of pool-riffle form to low bed relief form	x		
	4	Cut-off channel(s)	x		
	5	Formation of island(s)	x		
	6	Thalweg alignment out of phase meander form	x		
	7	Bar forms poorly formed / reworked / removed	x		
		Sum of Indices:	7	0	0

*** Score value = #YES / Total #**
STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4
CONDITION =
SI ≤ 0.20 = *in regime*
SI 0.21 – 0.40 = *transitional or stressed*
SI ≥ 0.41 = *in adjustment*

Stability Index: 0

Condition: In regime

Field Geology Services Fluvial Geomorphology

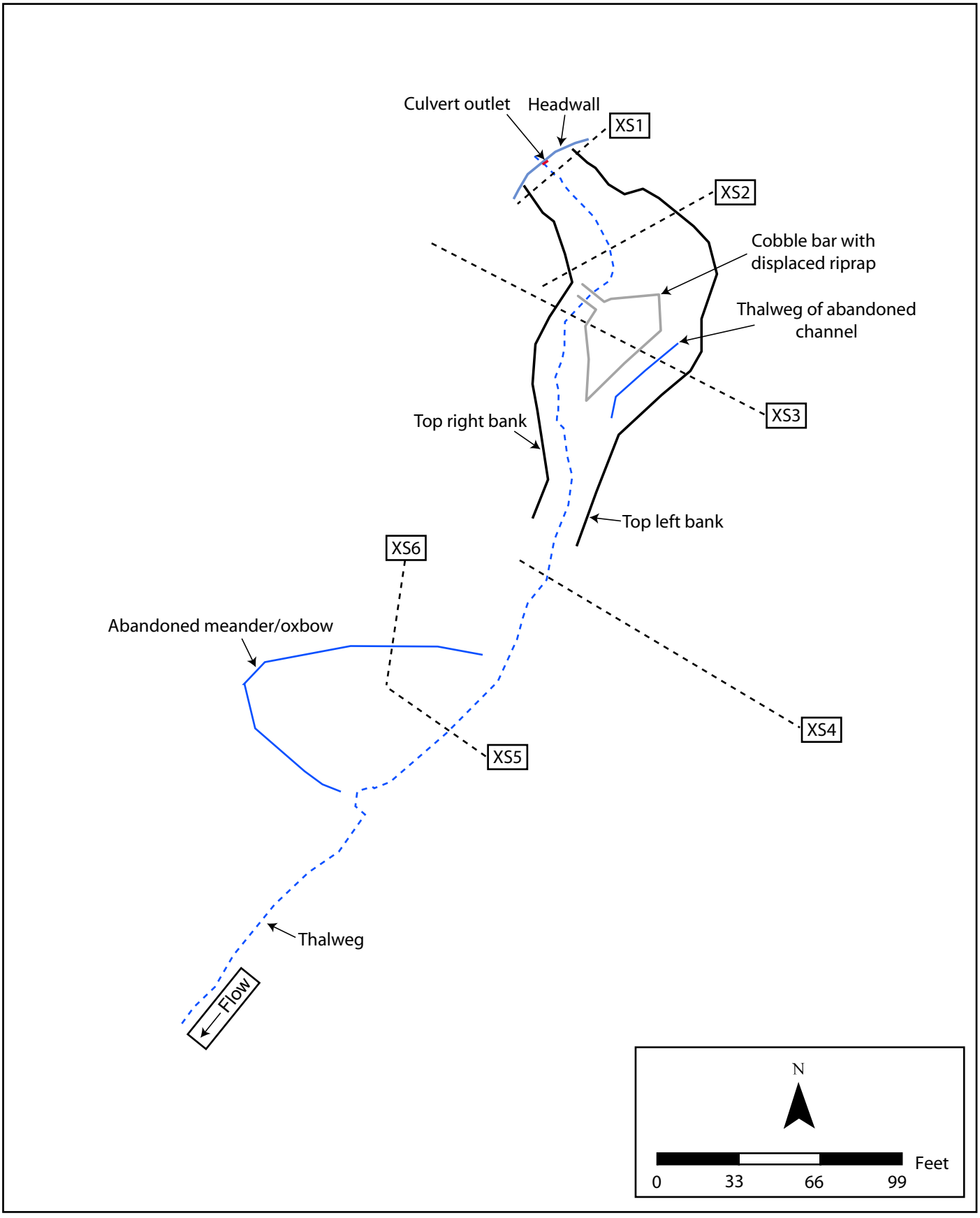
Appendix 2. Rapid geomorphic assessment data sheet.

APPENDIX 4

(Survey data and conceptual design packets)

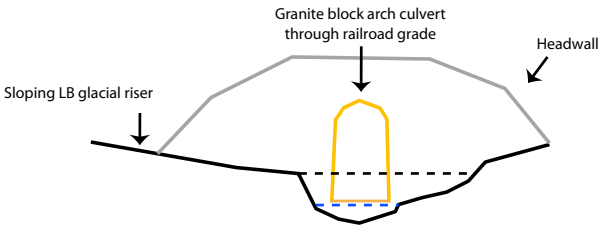
Chenery Brook – Reach C2a

Survey Data and Conceptual Restoration Design

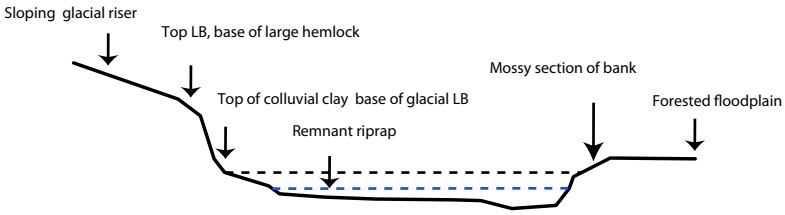


Chenery Brook - Surveyed plan view. Reaches C2a and C2b.

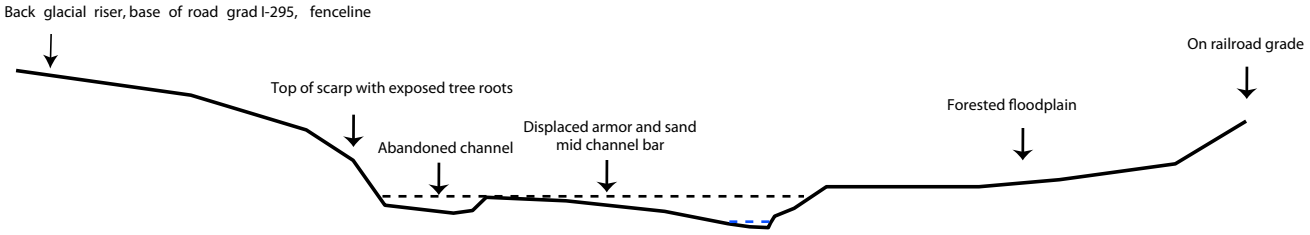
Cross Section 1 - Just downstream of railroad culvert outlet

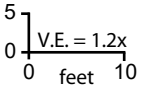


Cross Section 2 - Across wide scour pool from the right bank to the left bank



Cross Section 3 - Across wide mid channel bar

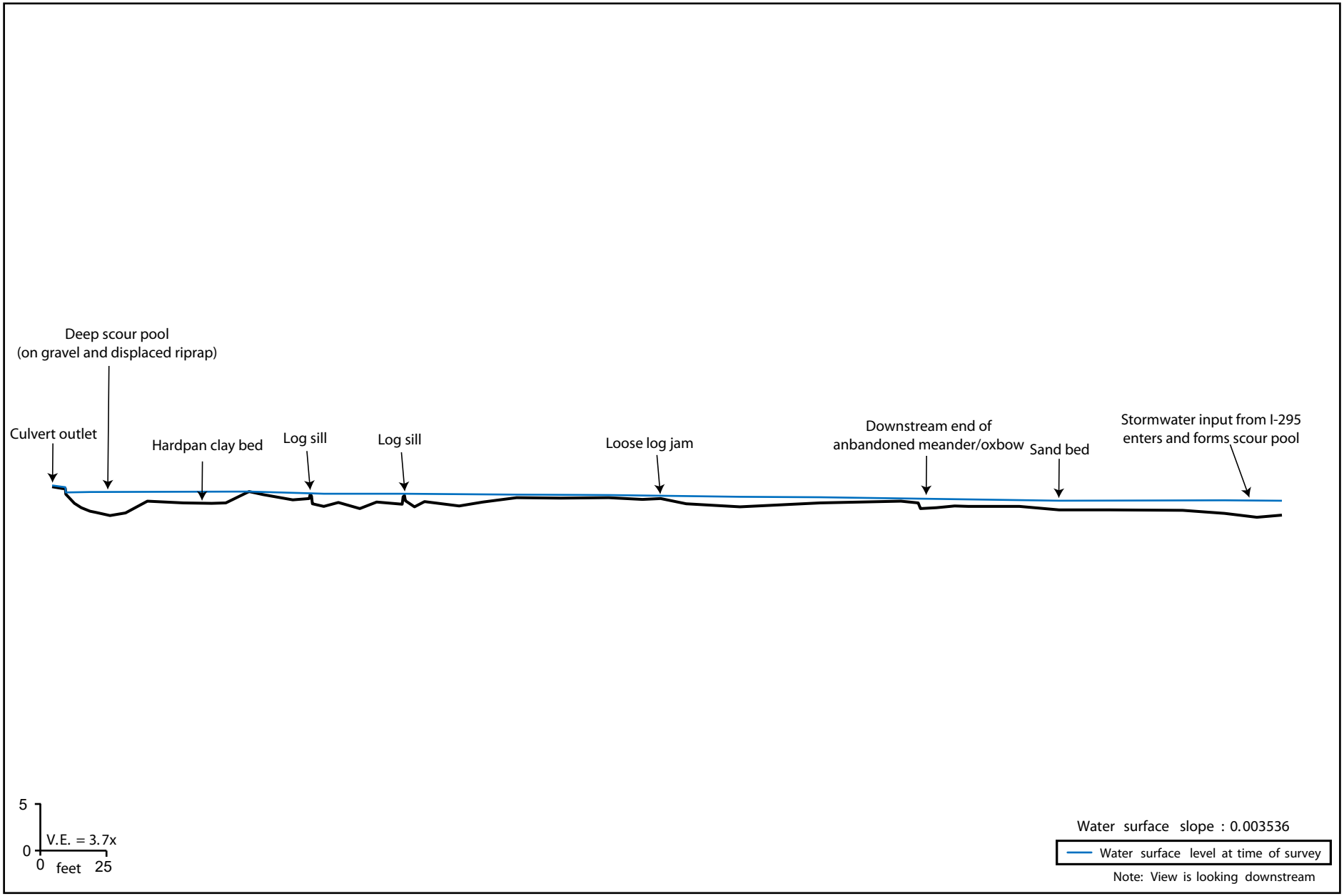




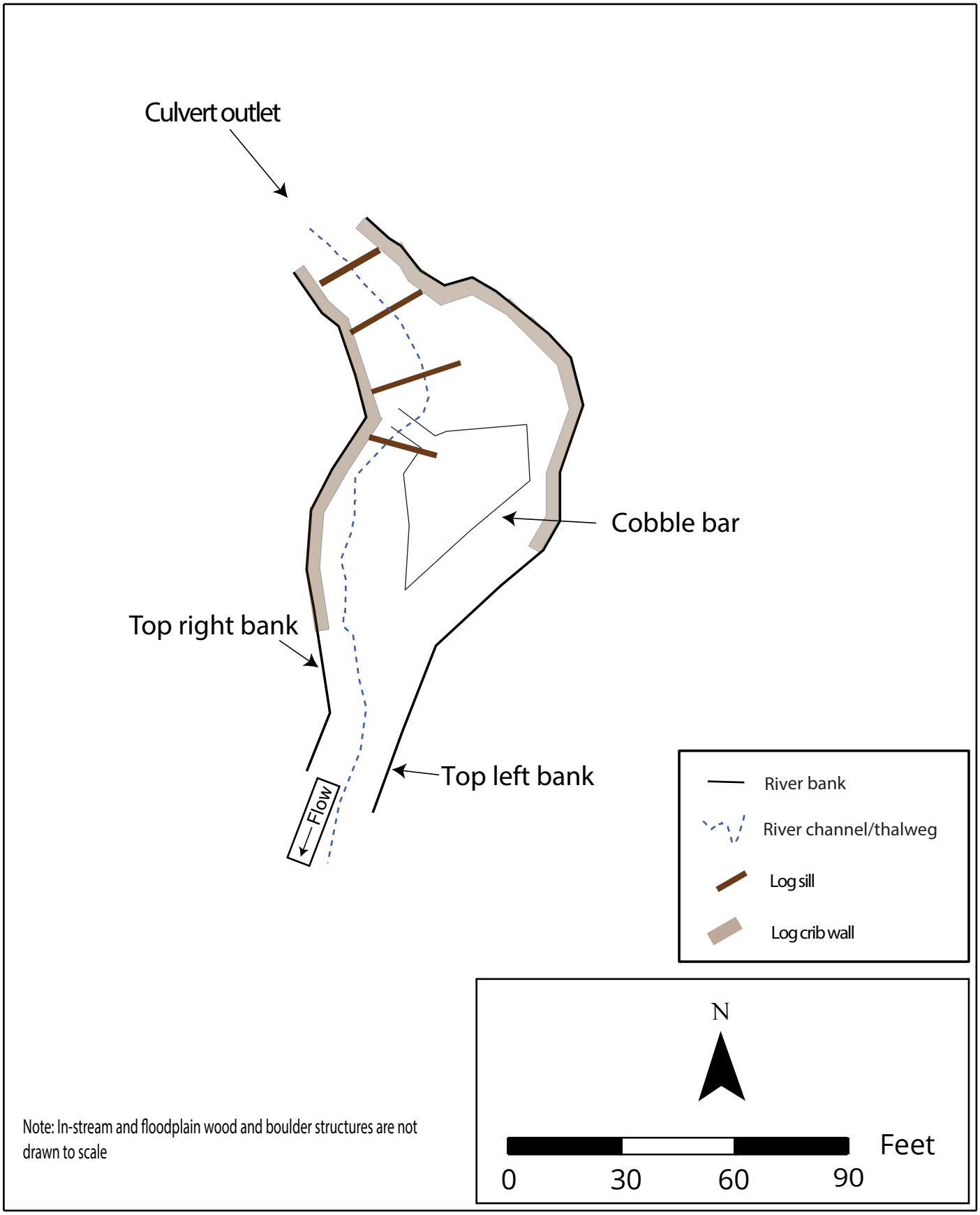
--- Bankfull elevation
--- Water surface at time of survey

Note: view looking downstream

Chenery Brook - Surveyed cross sections. Reach C2a.



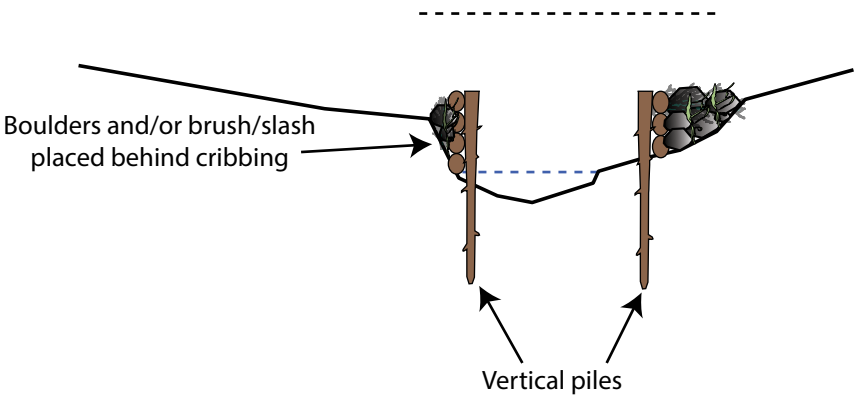
Chenery Brook - Longitudinal profile. Reaches C2a and C2b.

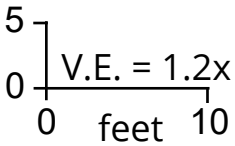


Note: In-stream and floodplain wood and boulder structures are not drawn to scale

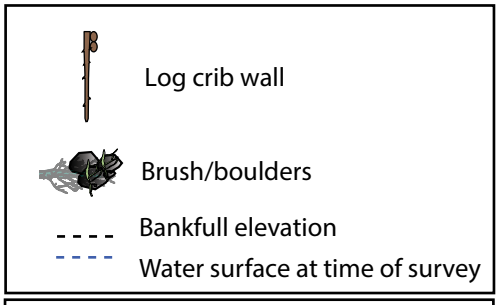
Chenery Brook - Proposed planview. Reach C2a.

Cross Section 1
Log Crib Wall





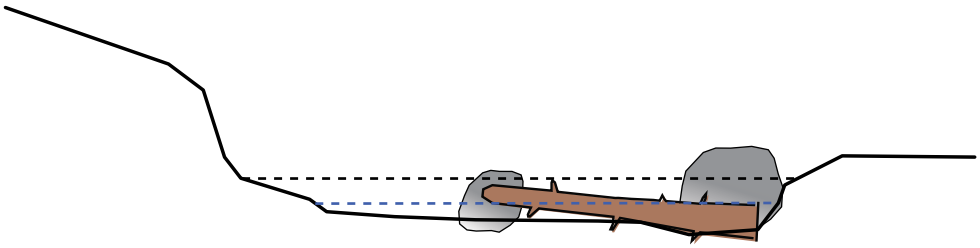

Example of crib wall on Sunday River, ME



Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chenery Brook - Proposed Condition for Cross Section 1. Reach C2a.

Cross Section 2
Log Sill



5
0 V.E. = 1.2x
0 feet 10



Natural log sill on Clesson Brook, MA

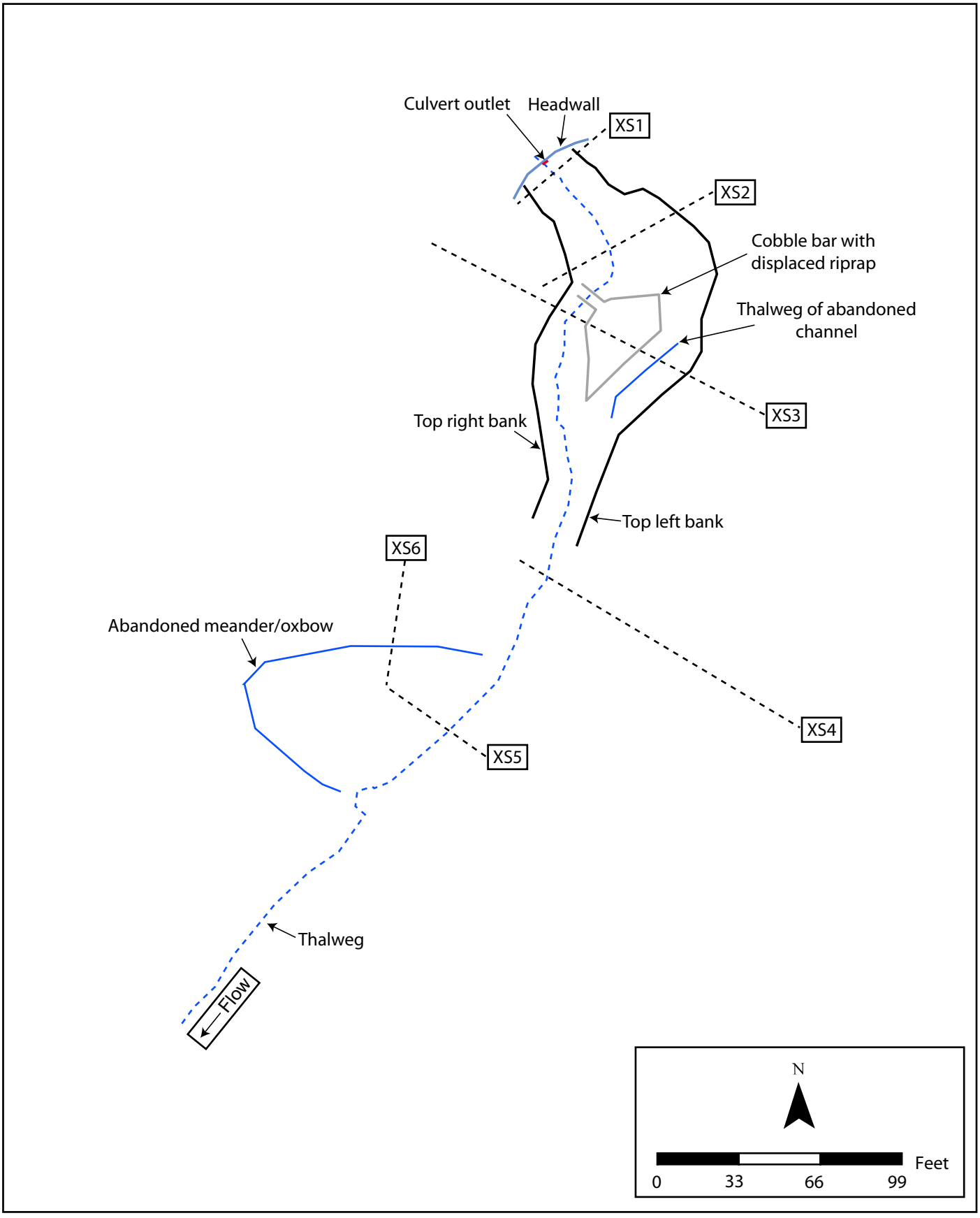
Boulder
Log
Bankfull elevation
Water surface at time of survey

Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chenery Brook - Proposed Conditions for Cross Section 2. Reach C2a.

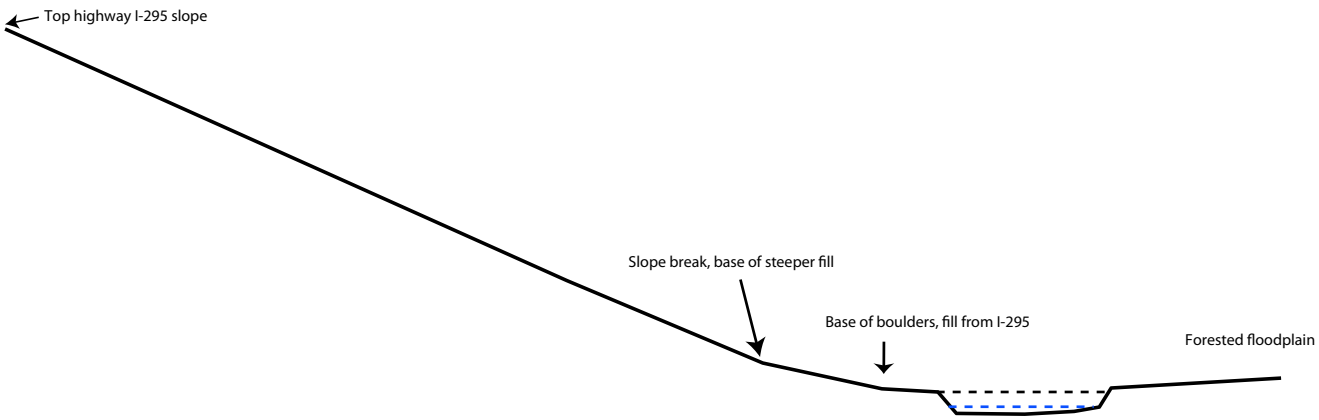
Chenery Brook – Reach C2b

Survey Data and Conceptual Restoration Design

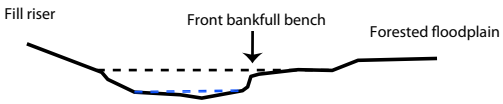


Chenery Brook - Surveyed plan view. Reaches C2a and C2b.

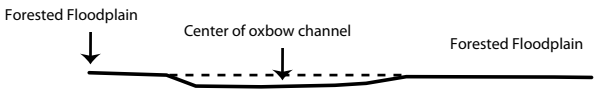
Cross Section 4 - Across riffle straightened channel

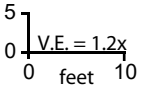


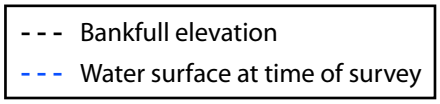
Cross Section 5 - Across straight channel onto floodplain



Cross Section 6 - Across oxbow meander

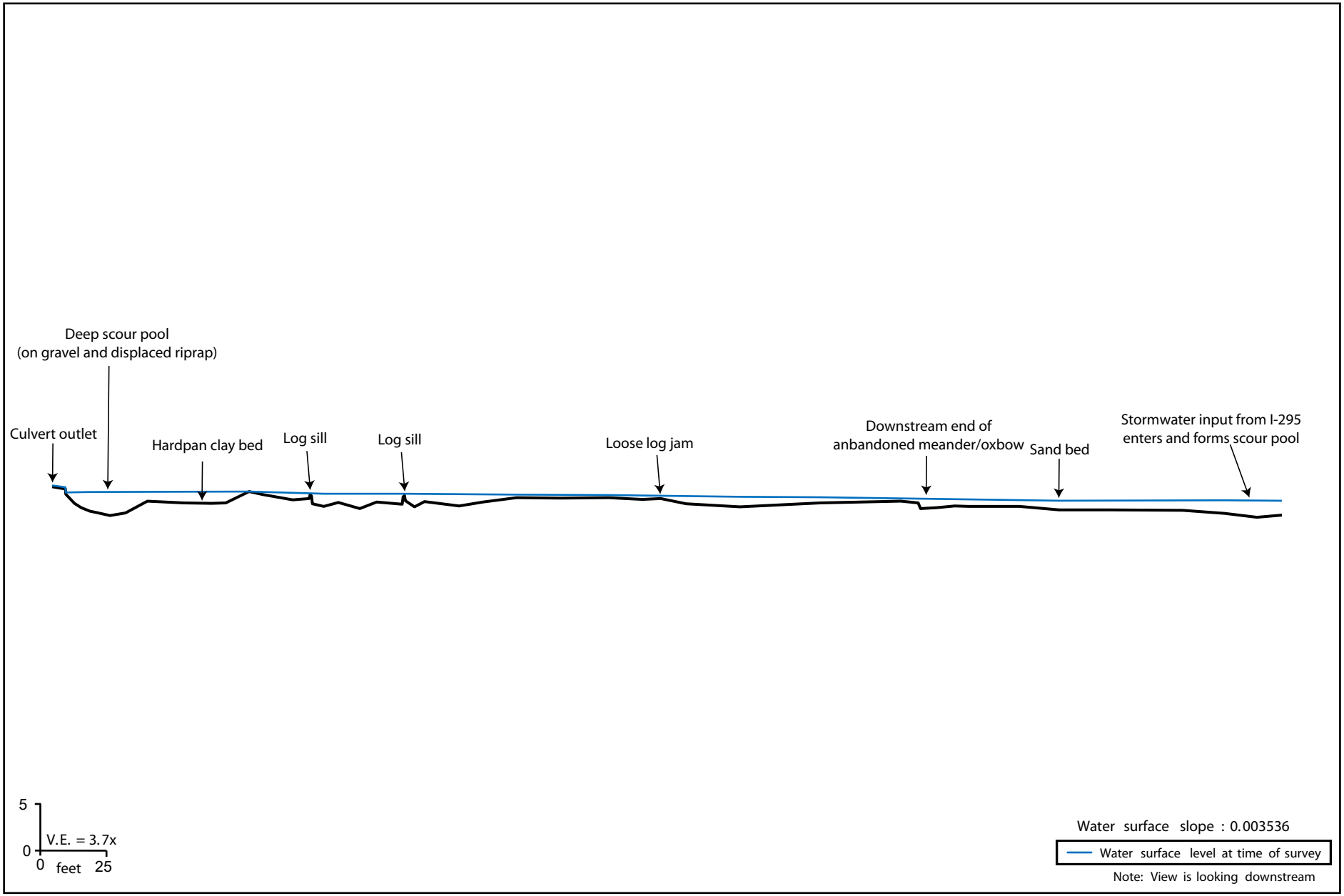




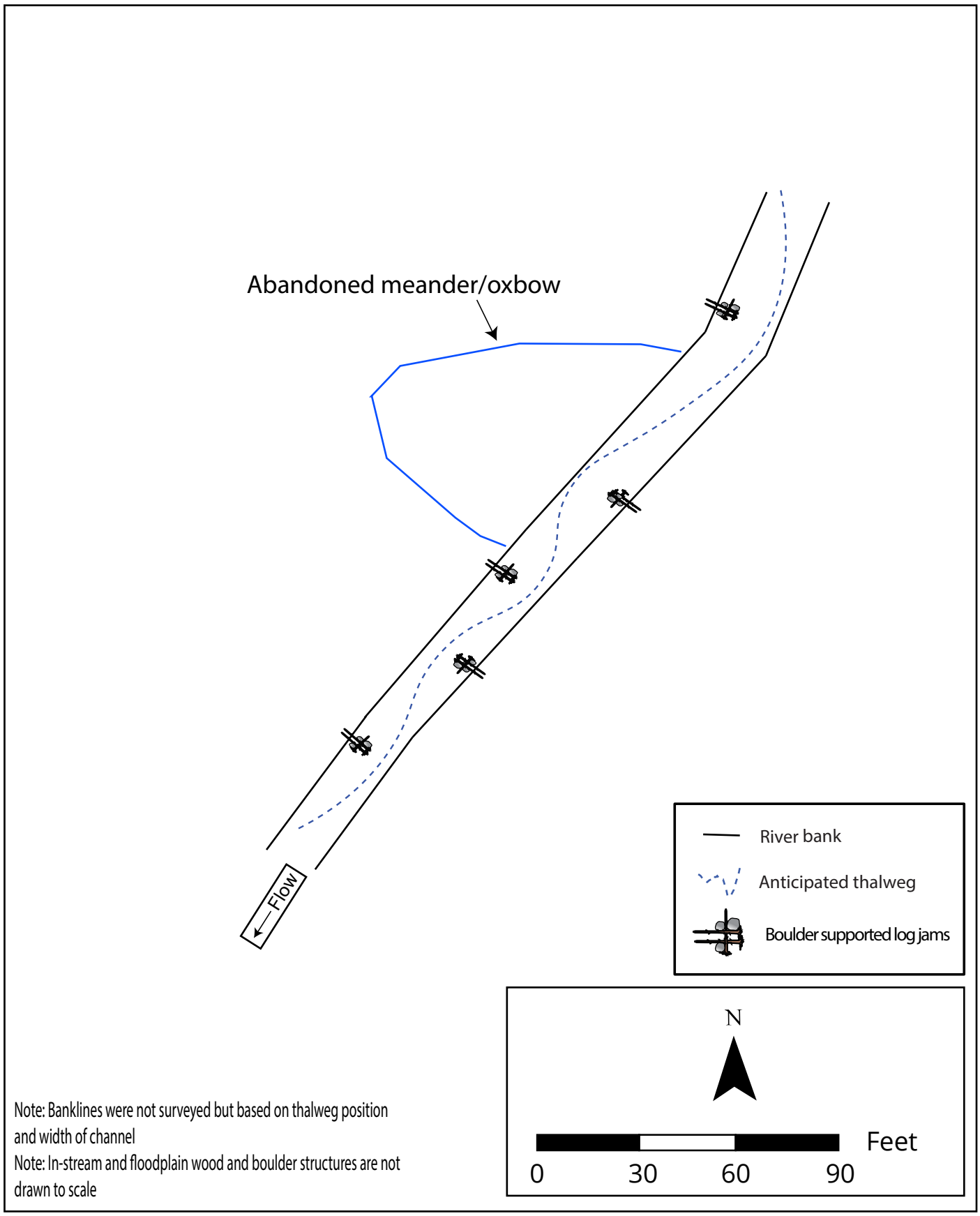


Note: view looking downstream

Chenery Brook - Surveyed cross sections. Reach C2b.



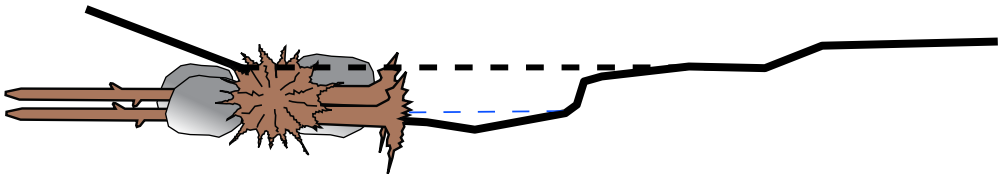
Chenery Brook - Longitudinal profile. Reaches C2a and C2b.

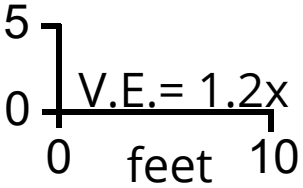


Note: Banklines were not surveyed but based on thalweg position and width of channel
Note: In-stream and floodplain wood and boulder structures are not drawn to scale

Chenery Brook - Proposed planview. Reach C2b.

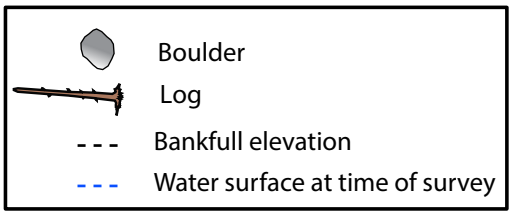
Cross Section 5
Boulder Supported Log Jam







Boulder supported log Jam in Houlton, ME

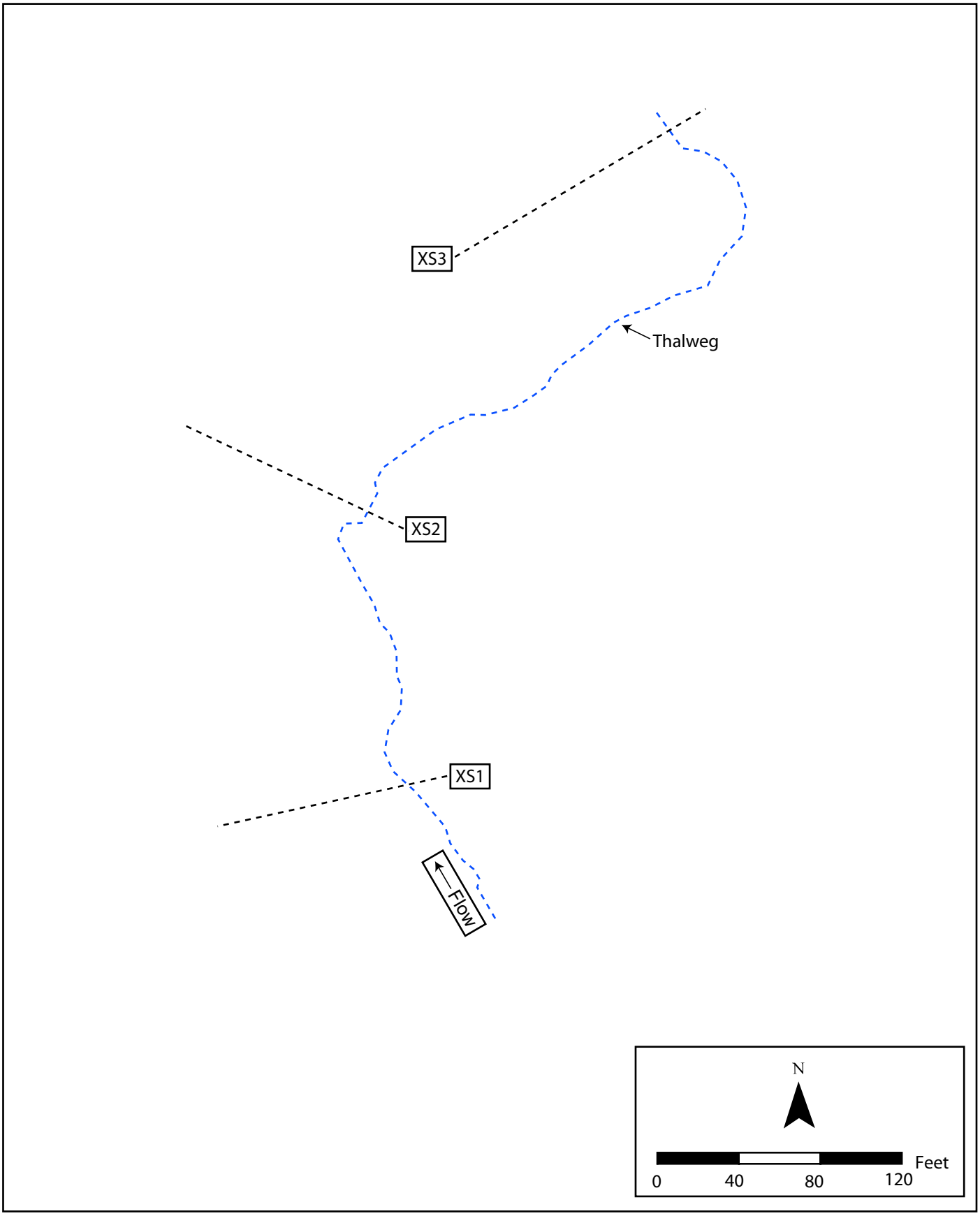


Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chenery Brook - Proposed conditions for Cross Section 5. Reach C2b.

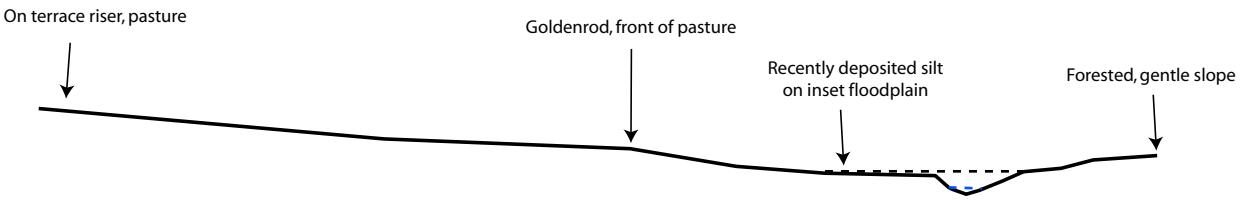
Hobbs Brook – Reach H2

Survey Data and Conceptual Restoration Design

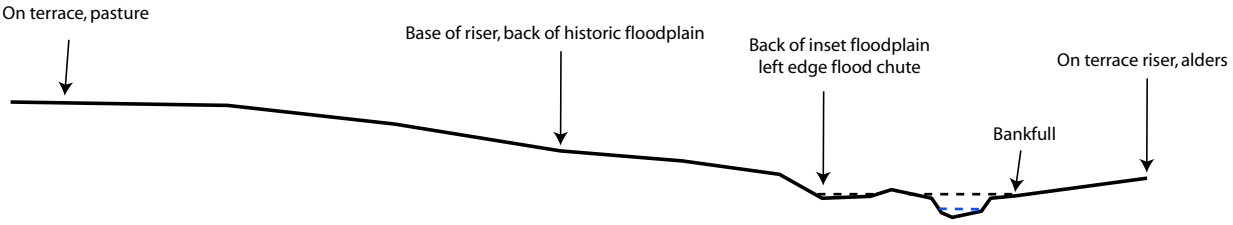


Hobbs Brook - Surveyed plan view. Reach H2.

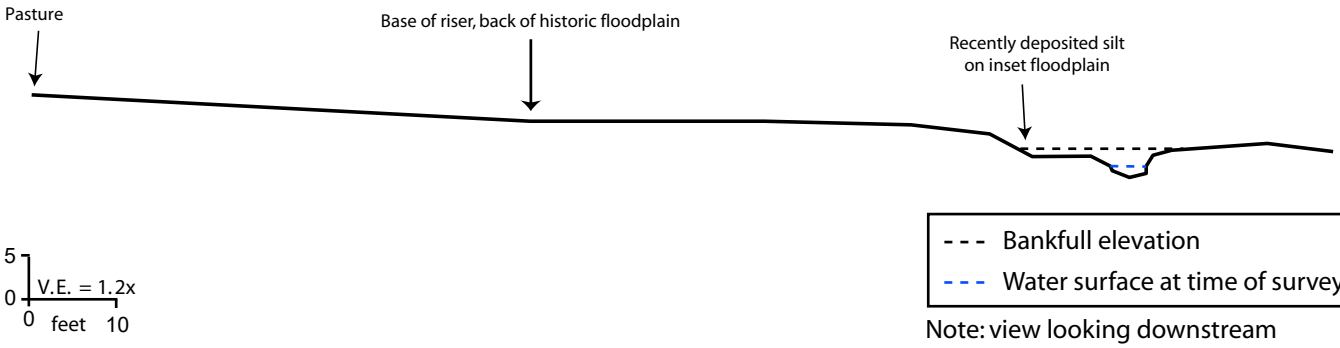
Cross Section 1 - Across straight channel



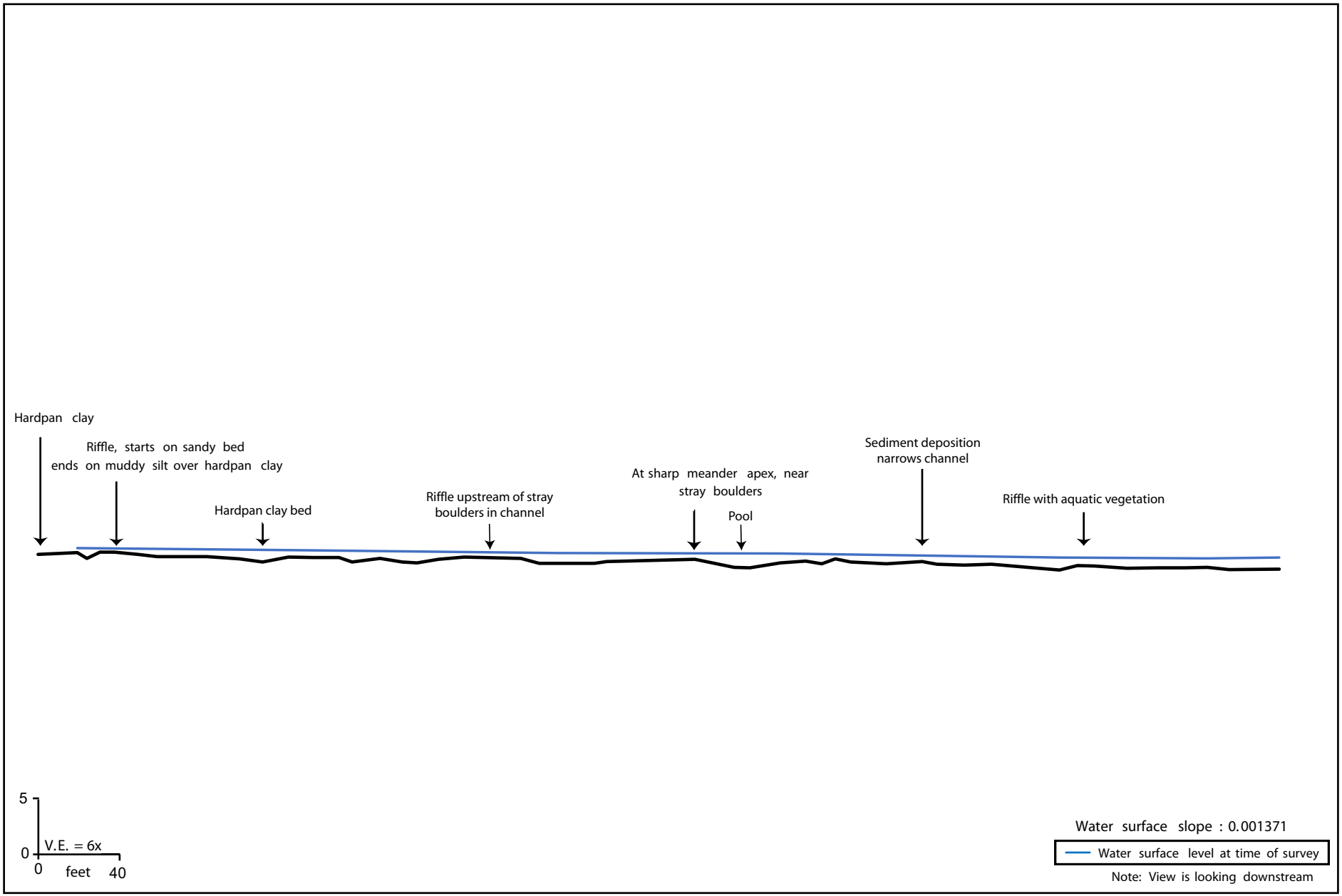
Cross Section 2 - Across meander



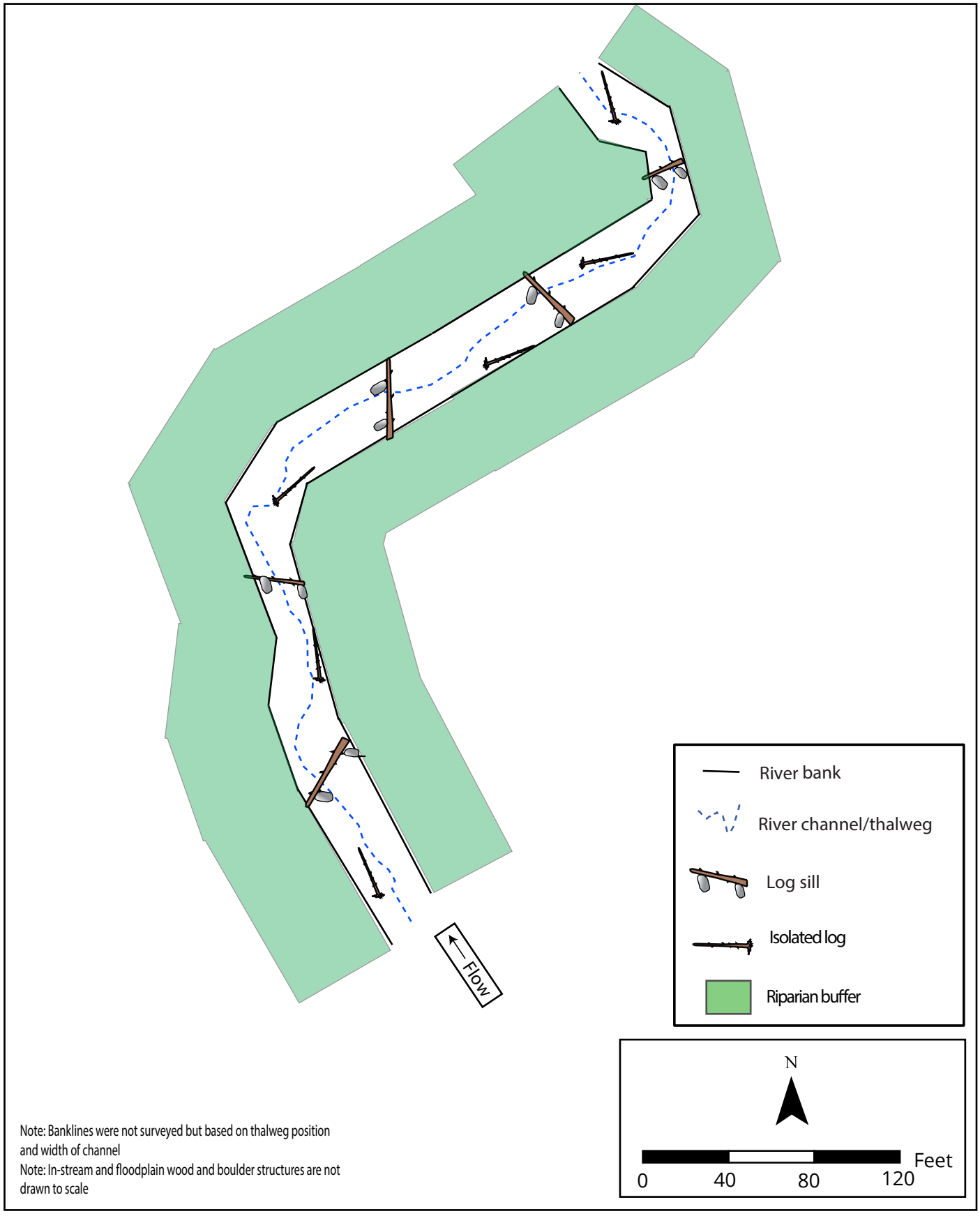
Cross Section 3 - Across straight channel and bankfull bench



Hobbs Brook - Surveyed cross sections. Reach H2.

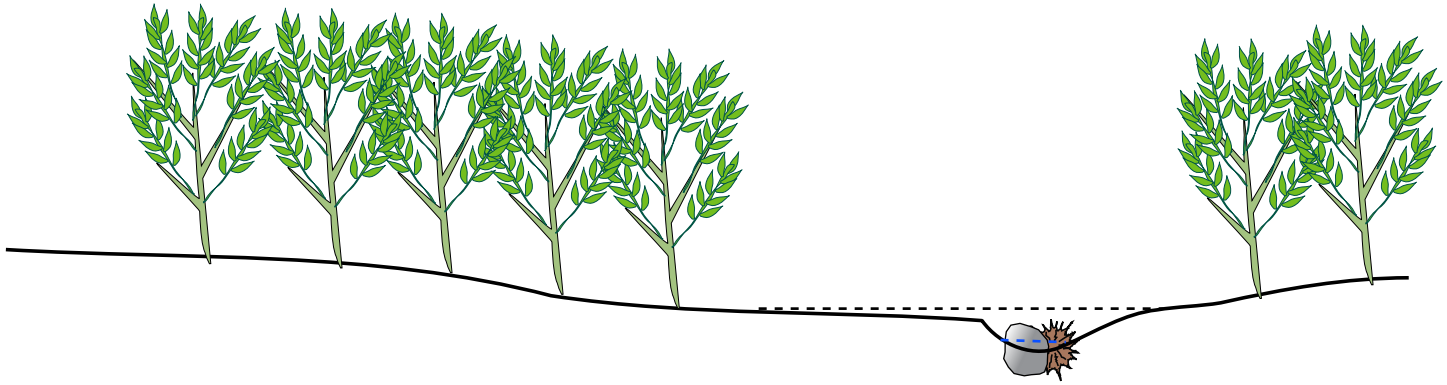


Hobbs Brook - Longitudinal profile. Reach H2.



Hobbs Brook - Proposed planview. Reach H2.

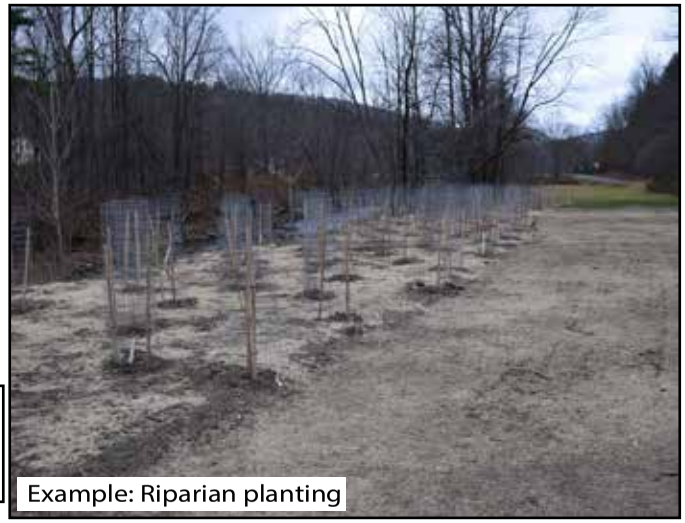
Cross Section 1
Isolated Log
Riparian Buffer Planting



5
0
V.E. = 1.2x
0 feet 10

- Boulder
- Log
- Willows (riparian buffer)
- --- Bankfull elevation
- --- Water surface at time of survey

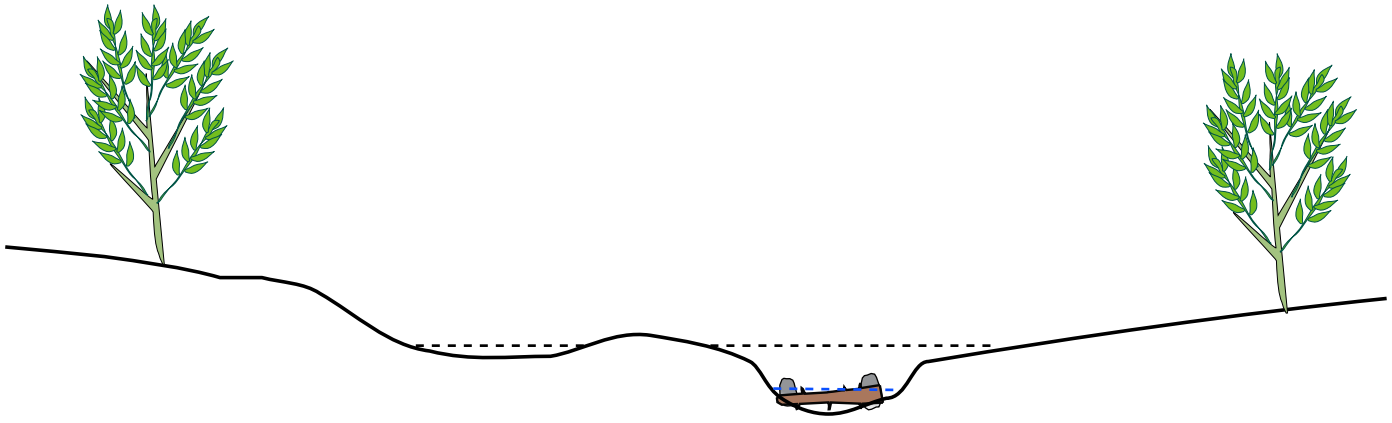
Note: view looking downstream
Note: Structural elements are schematic and not to scale

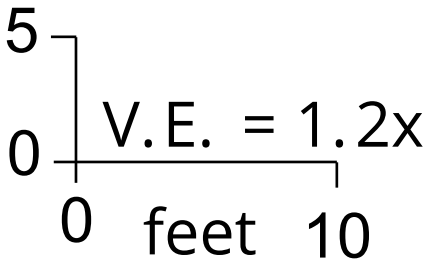

Example: Riparian planting


Example photo: Isolated log

Hobbs Brook - Proposed conditions for Cross Section 1. Reach H2.

Cross Section 2
Log Sill





- Boulder
- Log
- Willows (riparian buffer)
- Bankfull elevation
- Water surface at time of survey

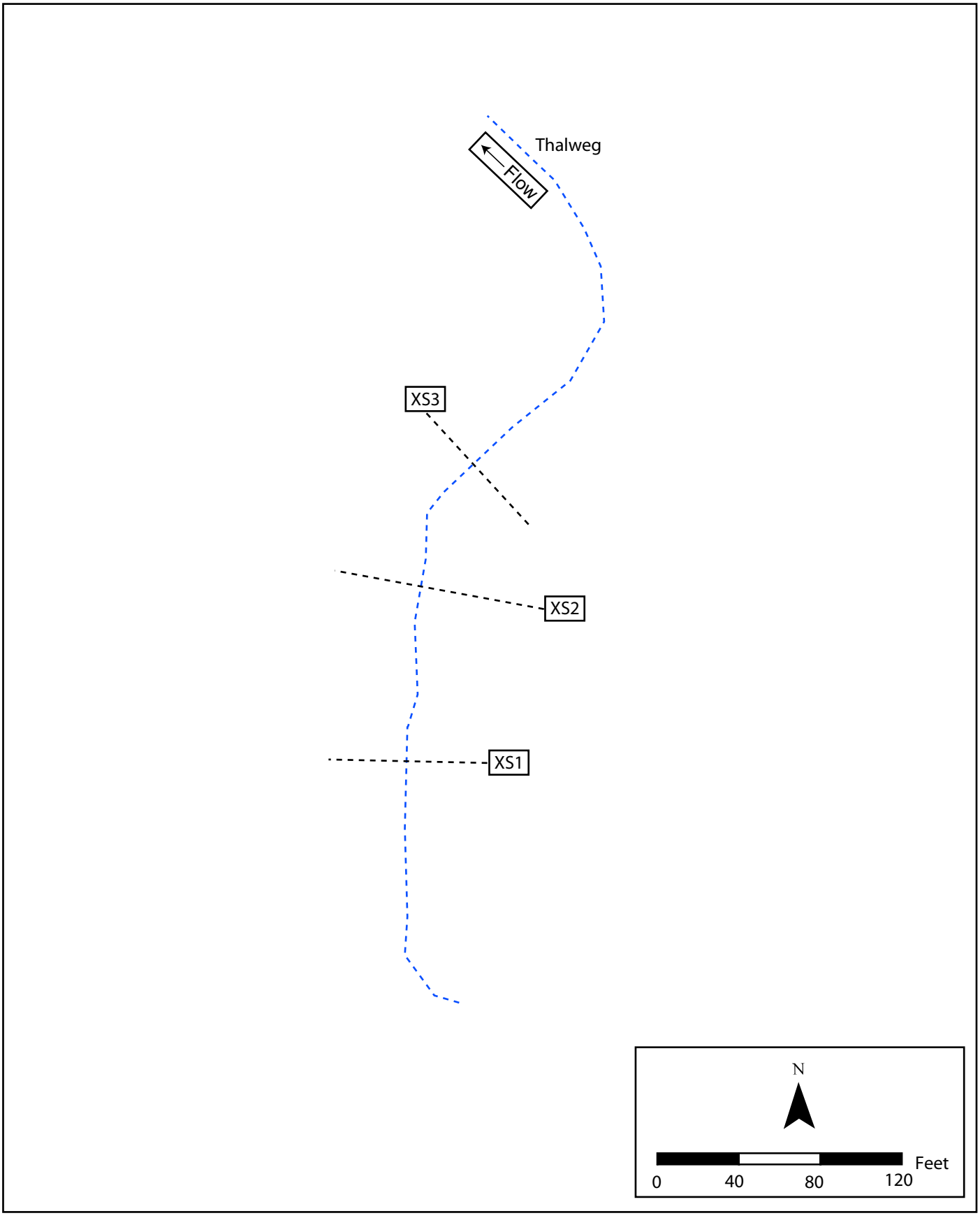
Note: view looking downstream
Note: Structural elements are schematic and not to scale


Natural log sill on Clesson Brook, MA

Hobbs Brook - Proposed conditions for Cross Section 2. Reach H2.

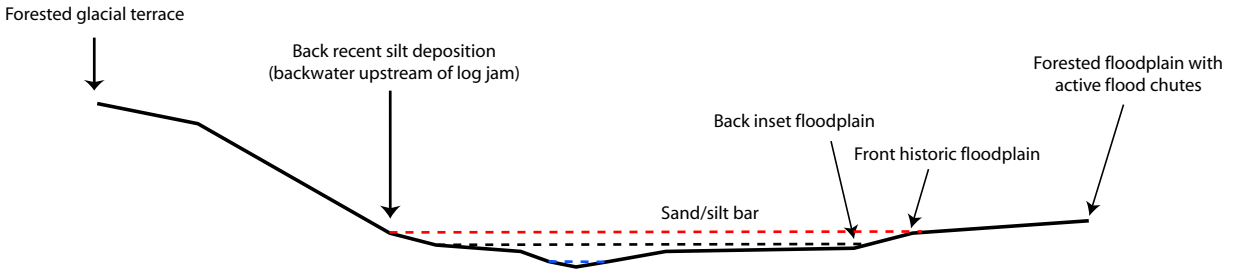
Hobbs Brook – Reach H3

Survey Data and Conceptual Restoration Design

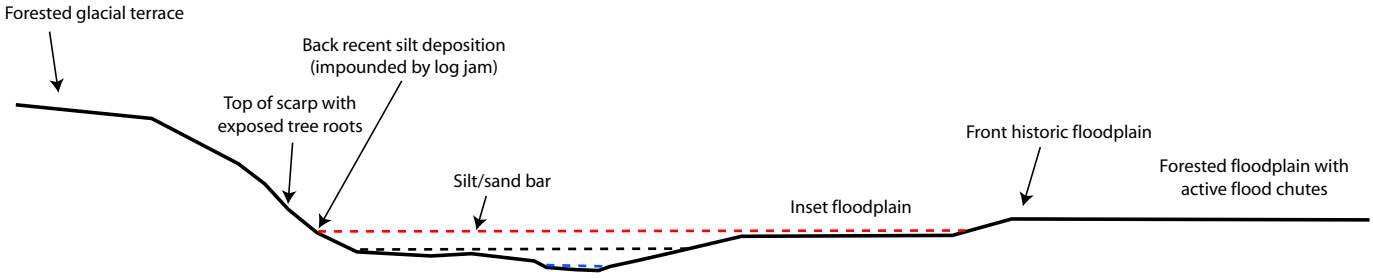


Hobbs Brook - Surveyed plan view. Reach H3.

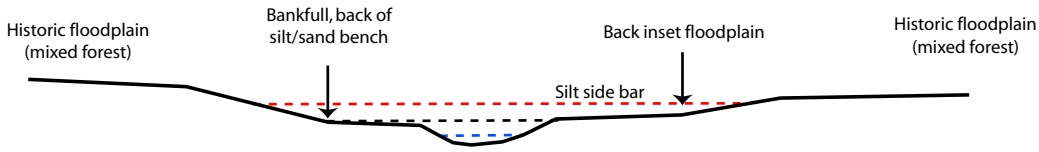
Cross Section 1 - Crosses wide side bars upstream of log sill

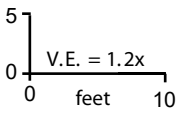


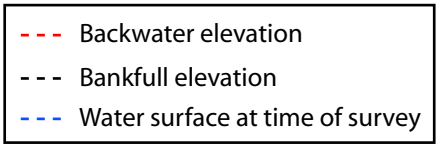
Cross Section 2 - Crosses straight channel with silt/sand bars



Cross Section 3 - Silt/sand deposition upstream of large log jam

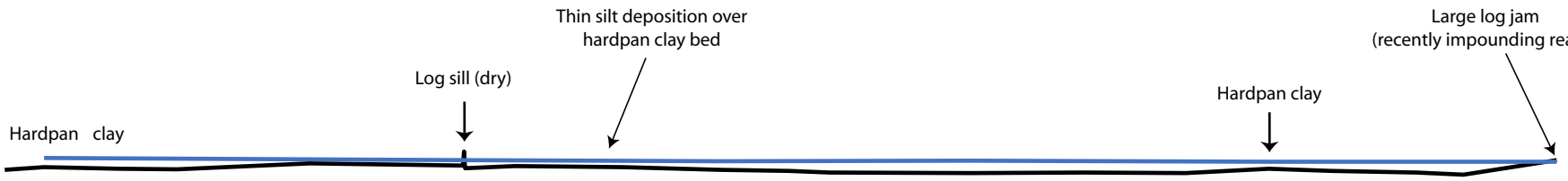






Note: view looking downstream

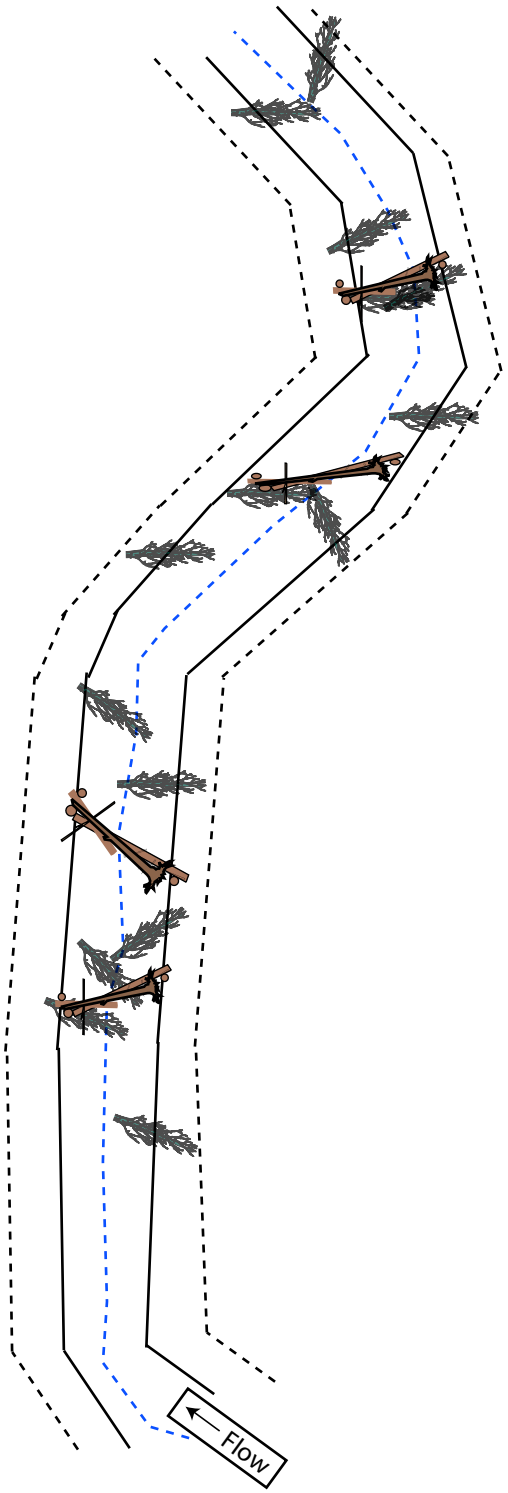
Hobbs Brook - Surveyed cross sections. Reach H3.



5
0
V.E. = 3.9x
0 feet 20

Water surface slope : 0.00064
Water surface level at time of survey
Note: View is looking downstream

Hobbs Brook - Longitudinal profile. Reach H3.



Back edge of floodplain

River bank

River channel/thalweg

Chop and drop trees

N

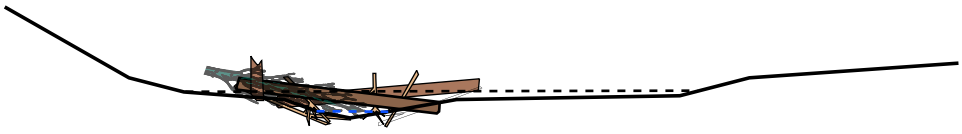
0 40 80 120 Feet

Note: Banklines were not surveyed but based on thalweg position and width of channel

Note: In-stream and floodplain wood and boulder structures are not drawn to scale

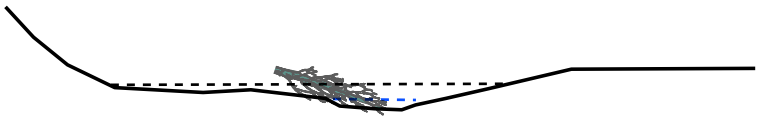
Hobbs Brook - Proposed planview. Reach H3.

Cross Section 1
Chop and Drop



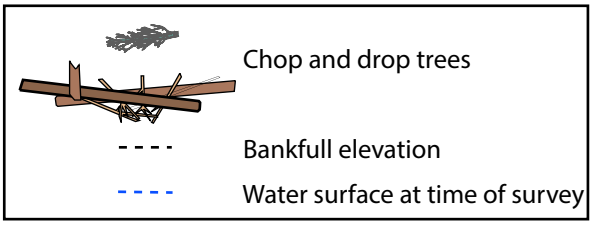


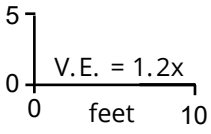
Cross Section 2



Cross Section 3





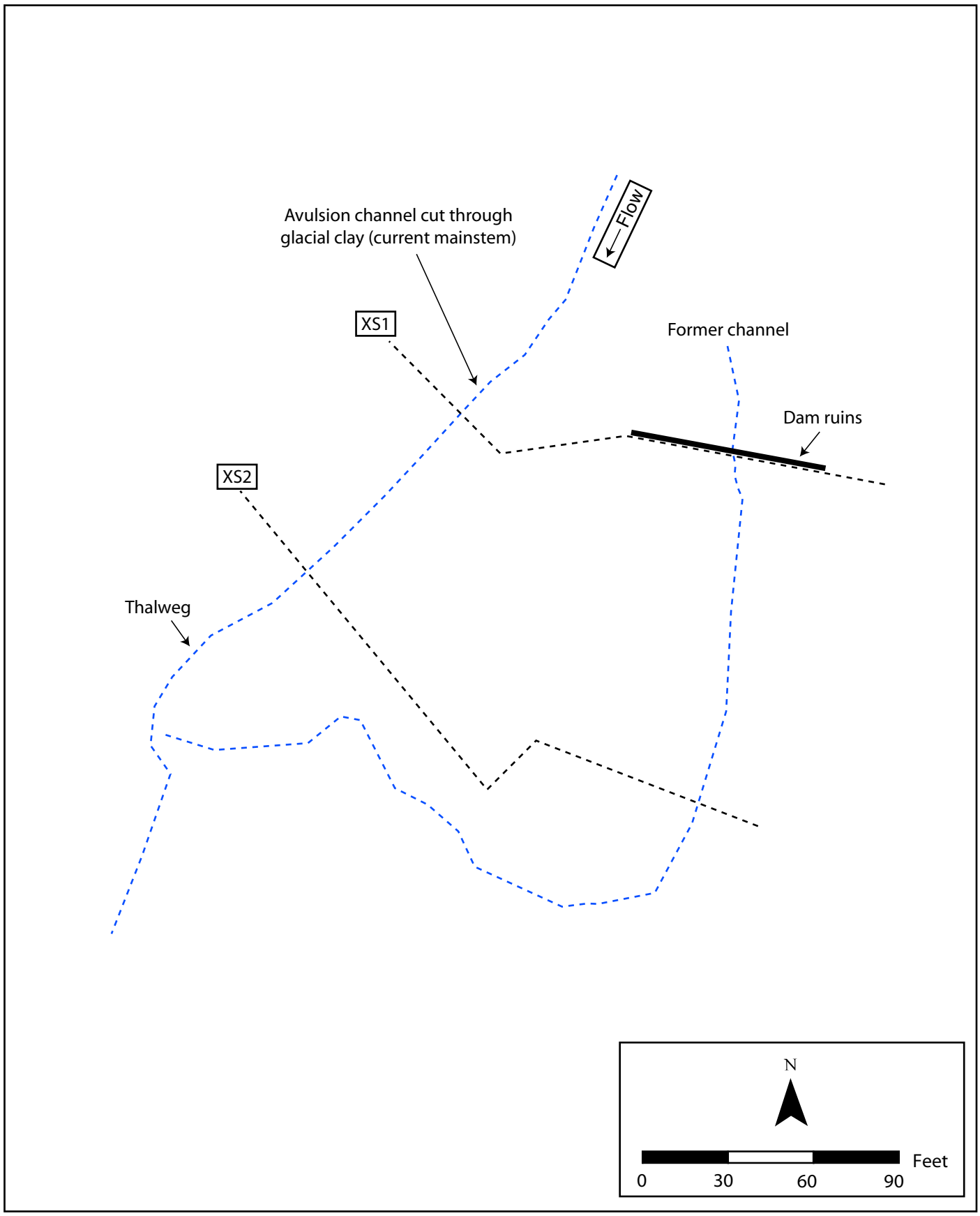


Note: view looking downstream
Note: Structural elements are schematic and not to scale

Hobbs Brook - Proposed conditions for cross sections. Reach H3.

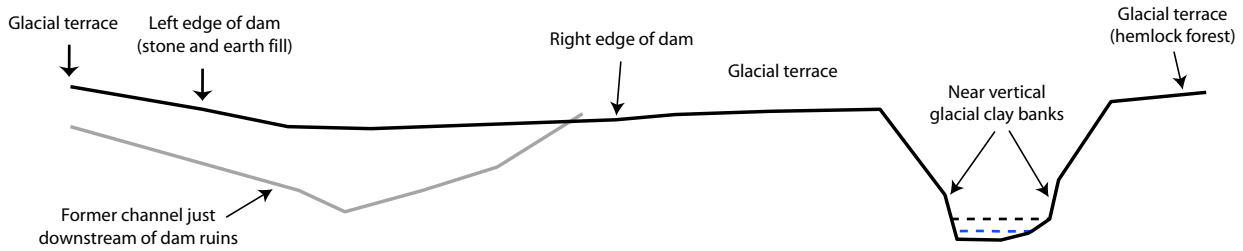
Mill Creek – Reach M6

Survey Data and Conceptual Restoration Design

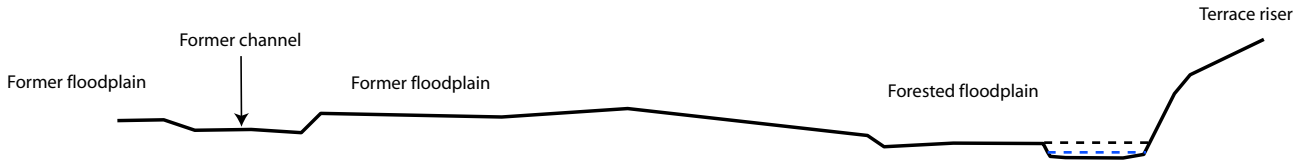


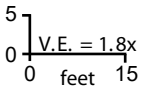
Mill Creek - Surveyed plan view. Reach M6.

Cross Section 1 - Across dam ruins and avulsion channel cut through glacial clay (current mainstem)



Cross Section 2 - Across former channel and current mainstem channel





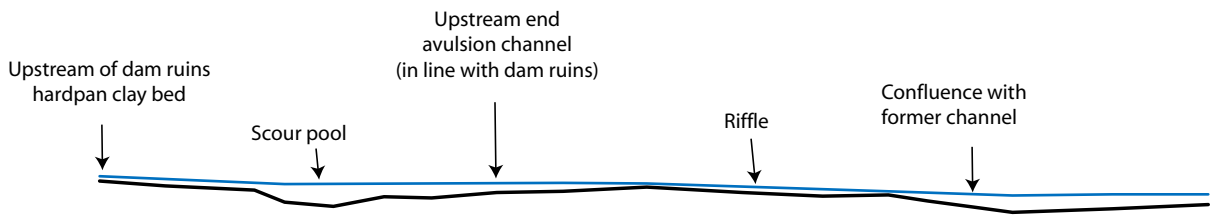
Bankfull elevation
Water surface at time of survey

Note: view looking downstream

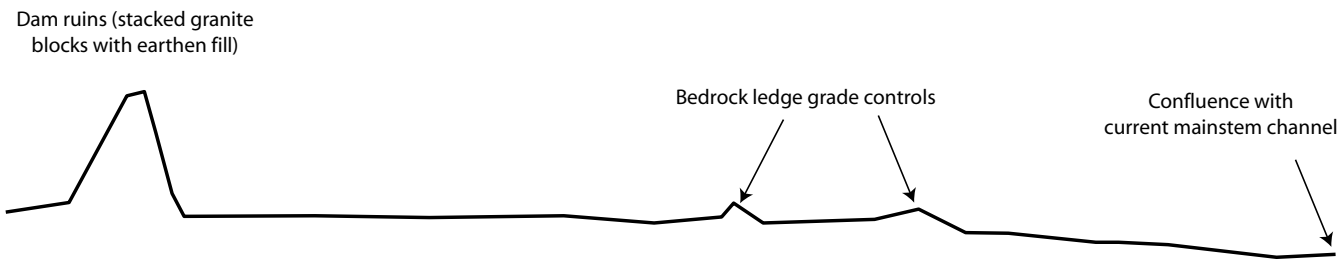
Mill Creek - Surveyed cross sections. Reach M6.

Field Geology Services
Fluvial Geomorphology

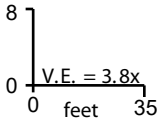
Longitudinal profile of current mainstem



Longitudinal profile of abandoned former channel



Note: reduced length of current avulsion channel has increased overall channel gradient (slope of reach)



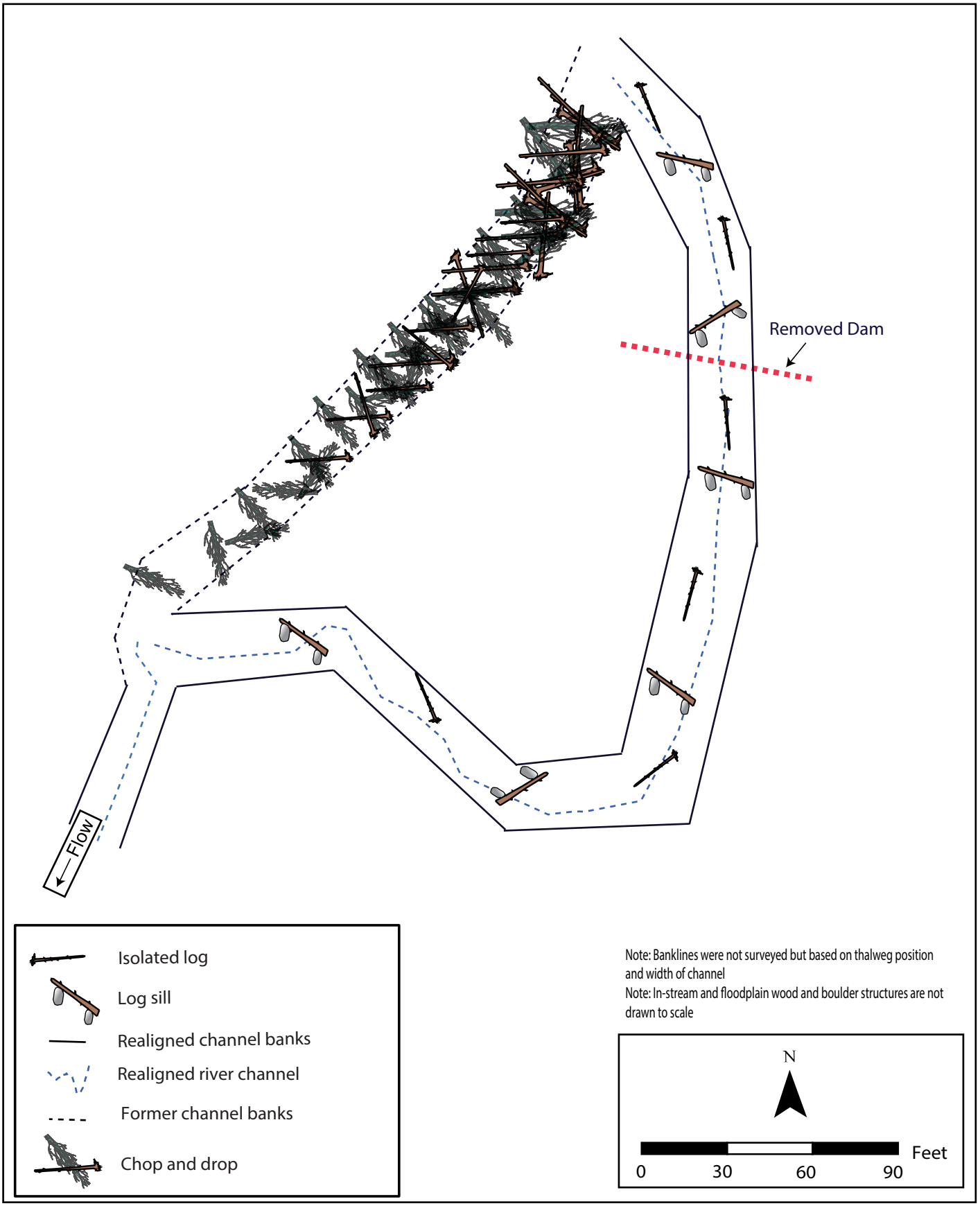
Water surface slope : 0.00426

Water surface level at time of survey

Note: View is looking downstream

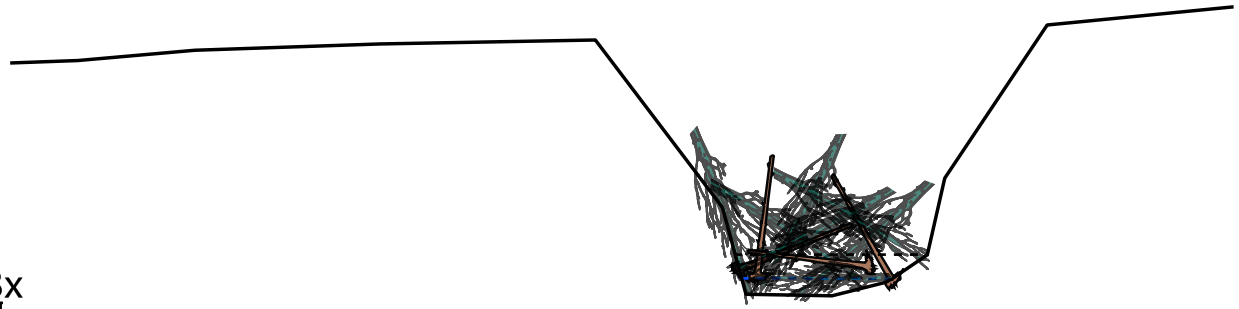
Mill Creek - Longitudinal profile. Reach M6.

Field Geology Services
Fluvial Geomorphology



Mill Creek - Proposed planview. Reach M6.

Cross Section 1
Chop and Drop for Channel Realignment



5
0
V.E. = 1.8x
0 feet 15





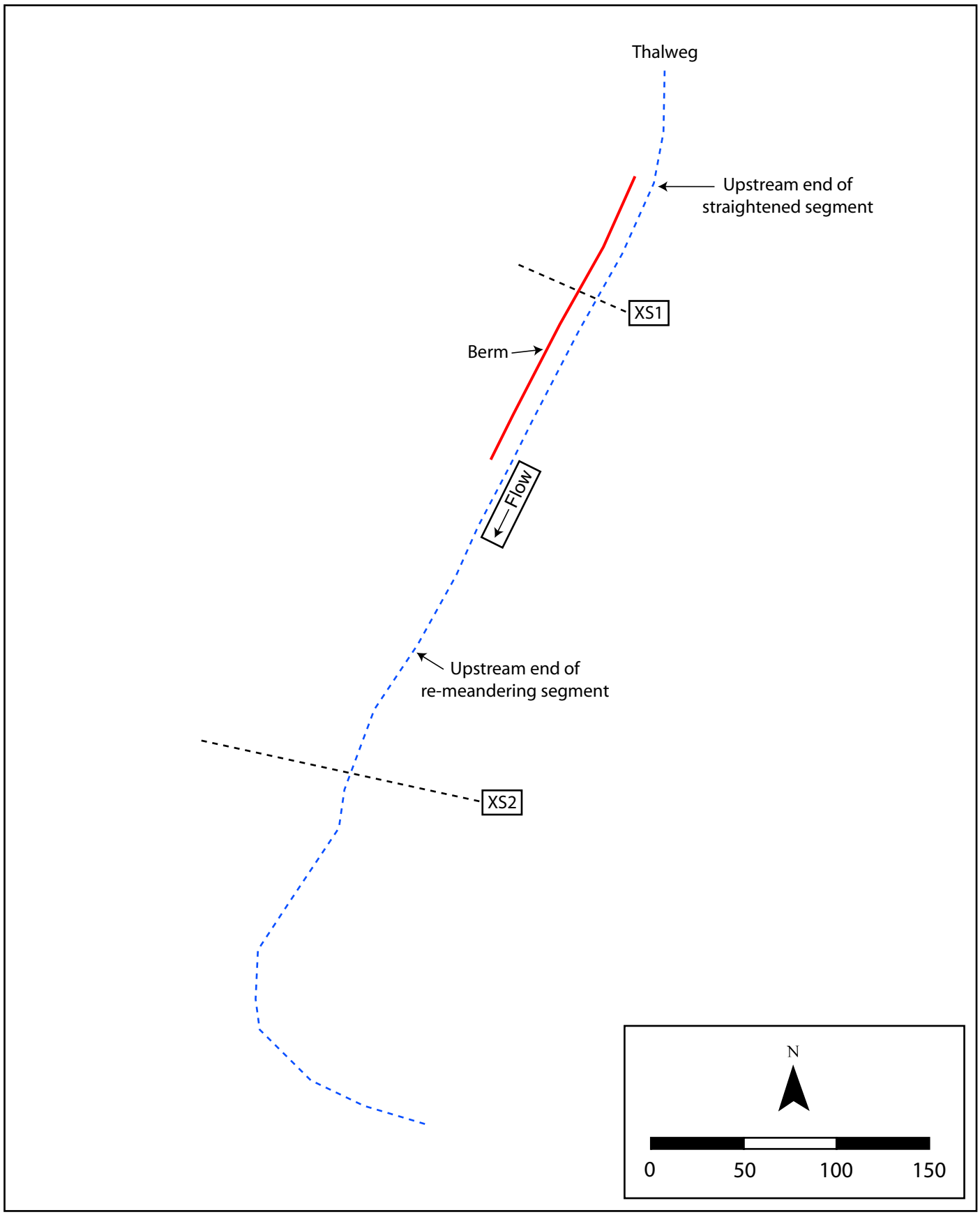
Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chop and drop
Bankfull elevation
Water surface at time of survey

Mill Creek - Proposed conditions for Cross Section 1. Reach M6.

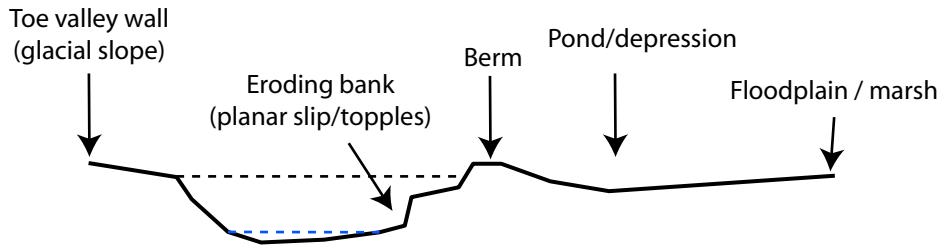
Mill Creek – Reach M11

Survey Data and Conceptual Restoration Design

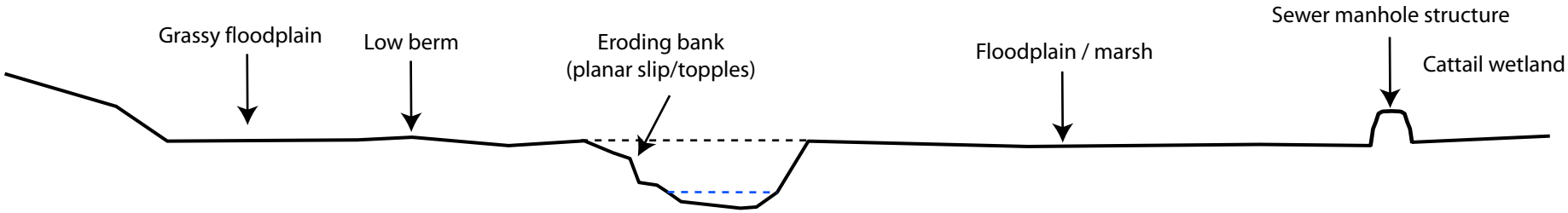


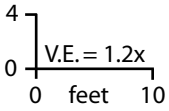
Mill Creek - Surveyed cross sections. Reach M11.

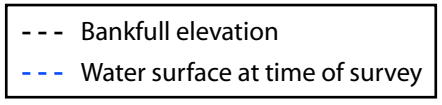
Cross Section 1 - Straight channel (artificially straightened)



Cross Section 2 - Re-meandering channel

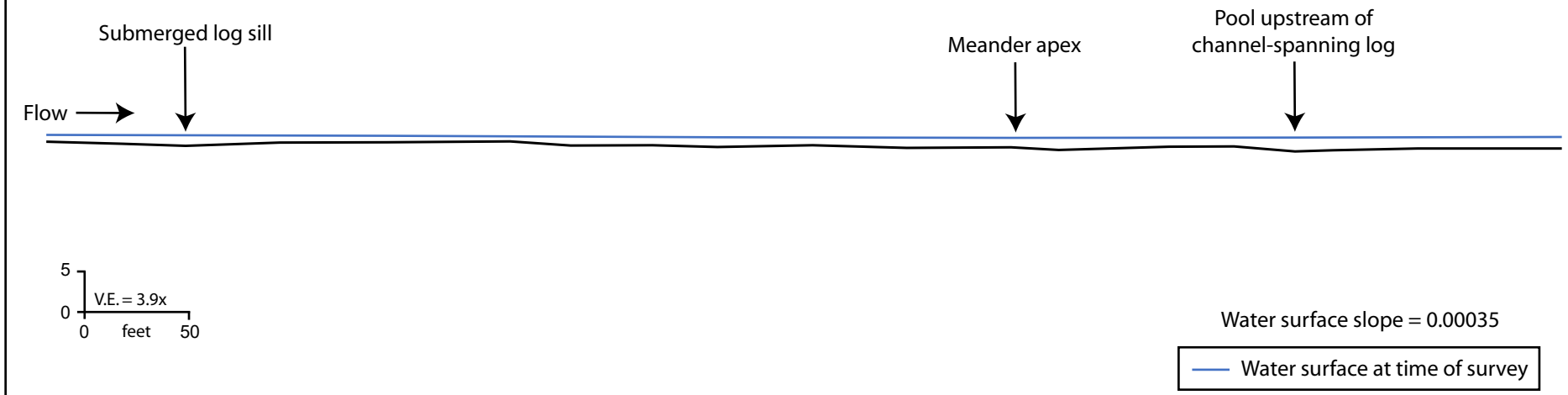




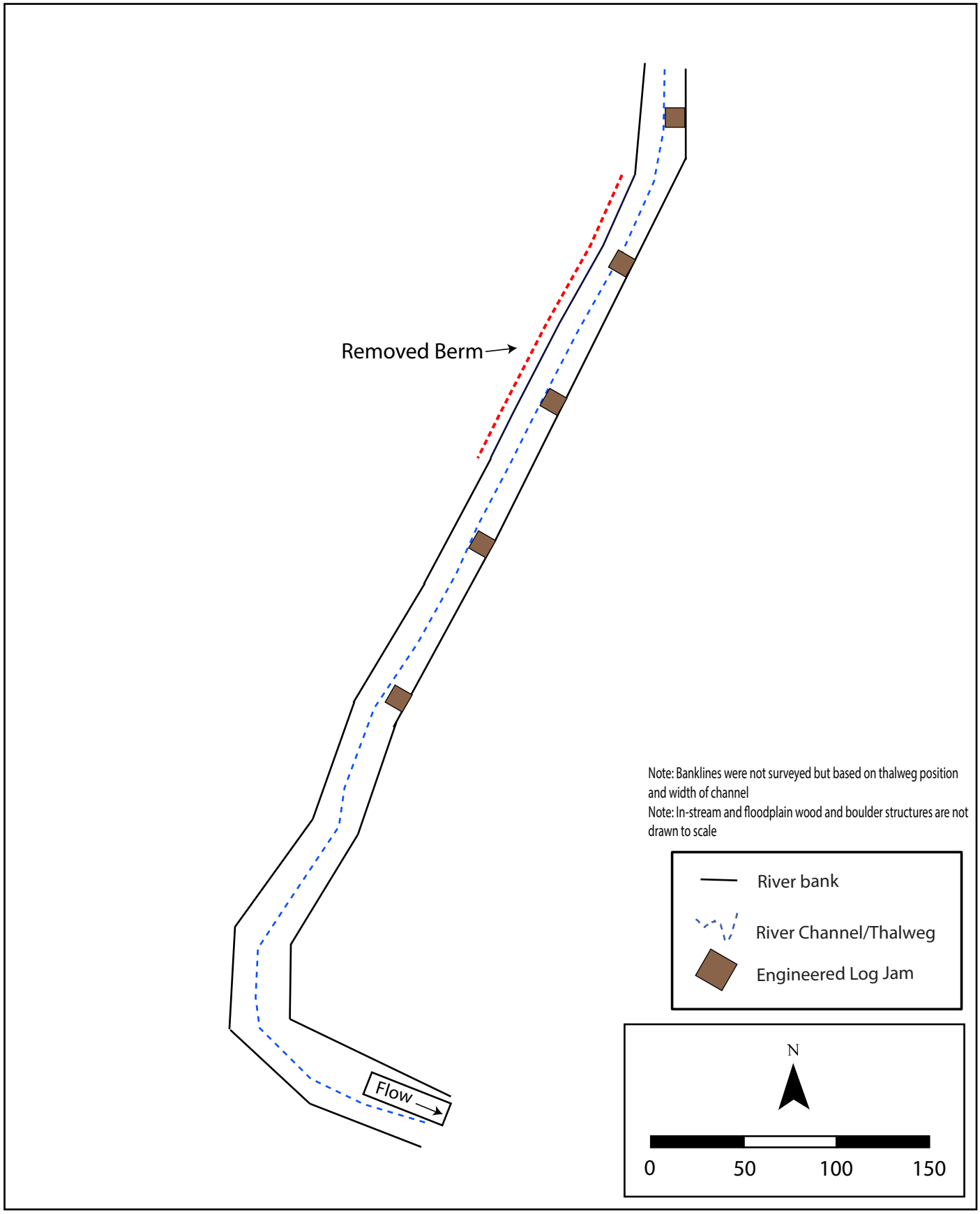


Note: view looking downstream

Mill Creek - Surveyed cross sections. Reach M11.

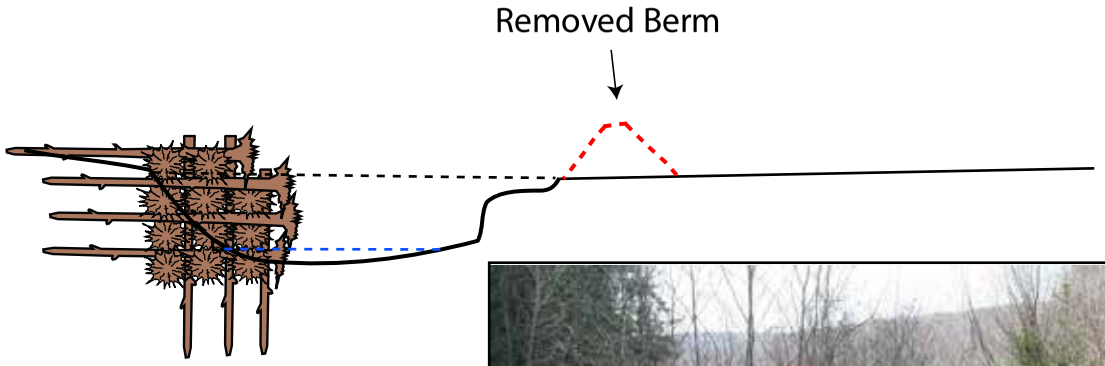


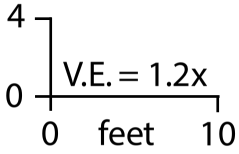
Mill Creek - Longitudinal profile. Reach M11.



Mill Creek - Proposed planview. Reach M11.

Cross Section 1
Engineered Log Jam






Example: Berm removal on Nash Stream, NH


Example: Marginal log jam in Stark, NH

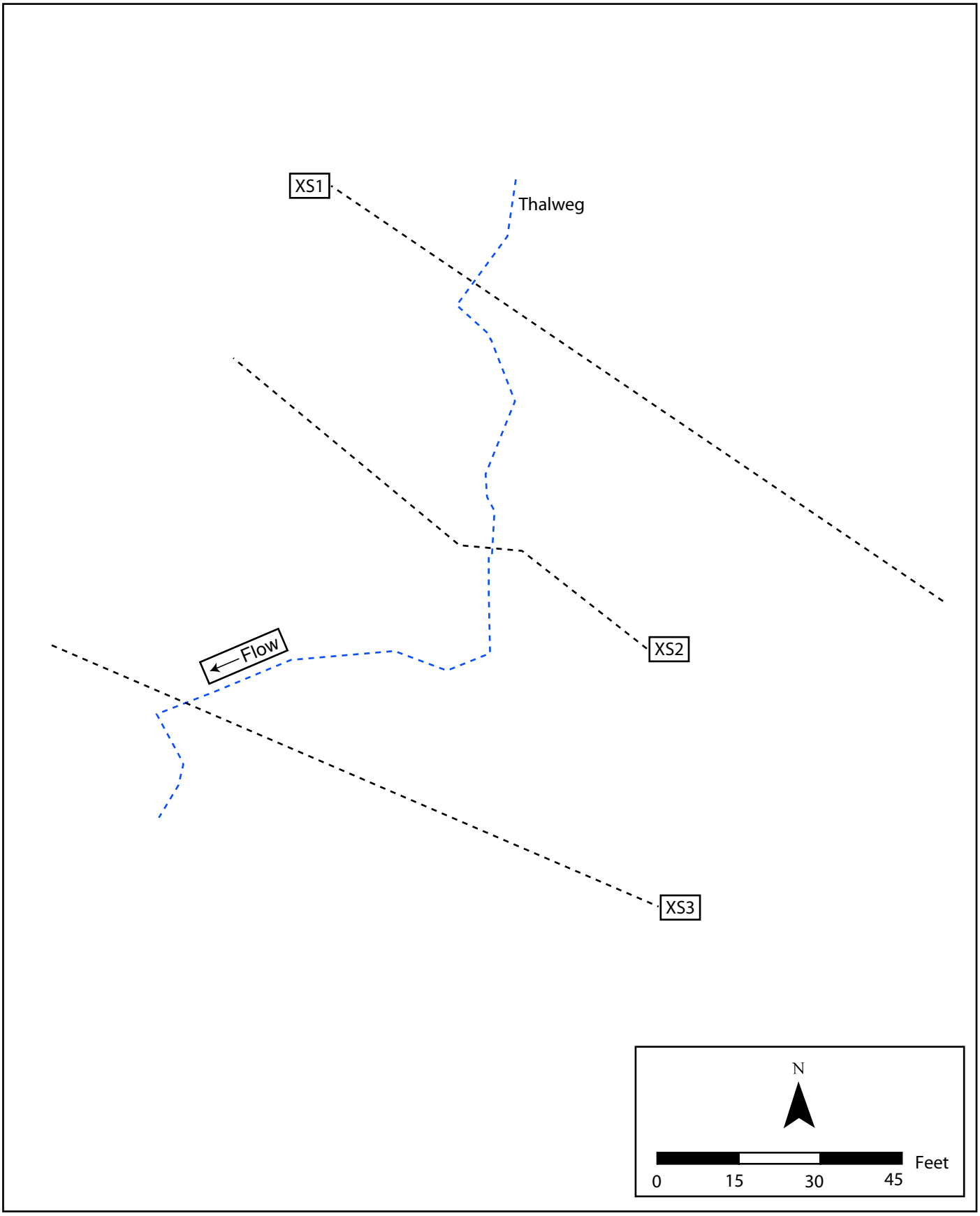
Note: view looking downstream
Note: Structural elements are schematic and not to scale

Root Wad
Bankfull elevation
Water surface at time of survey

Mill Creek - Proposed conditions for Cross Section 1. Reach M11.

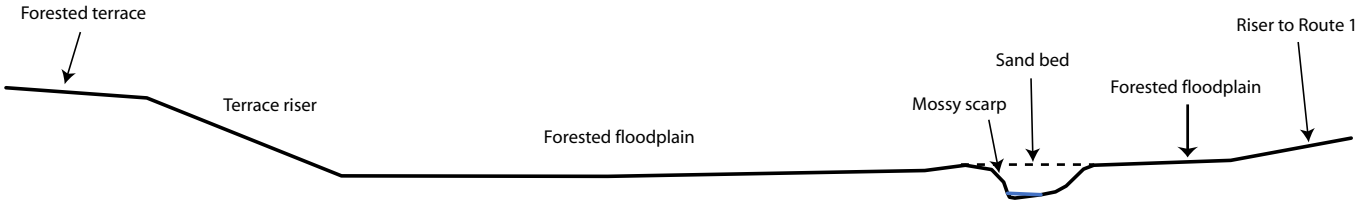
Norton Brook – Reach N1

Survey Data and Conceptual Restoration Design

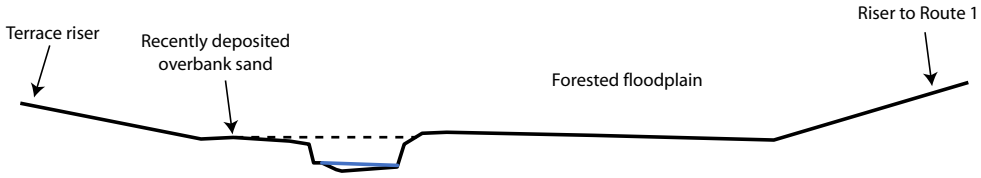


Norton Brook - Surveyed plan view. Reach N1.

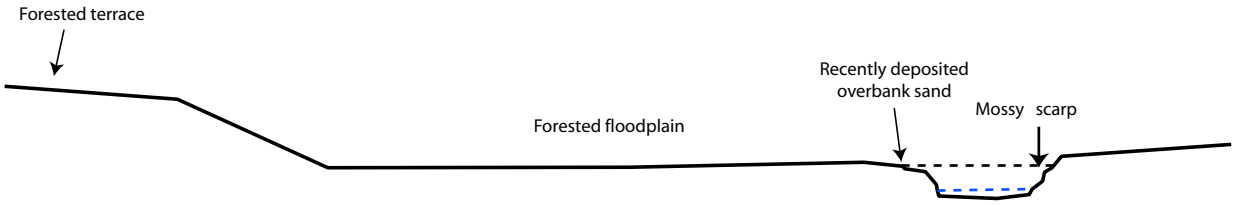
Cross Section 1 - Across wide floodplain and straight riffle

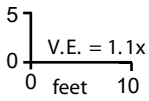


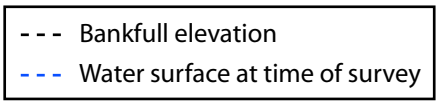
Cross Section 2 - Across sand bed channel with overbank sand deposition



Cross Section 3 - Crosses channel at meander apex

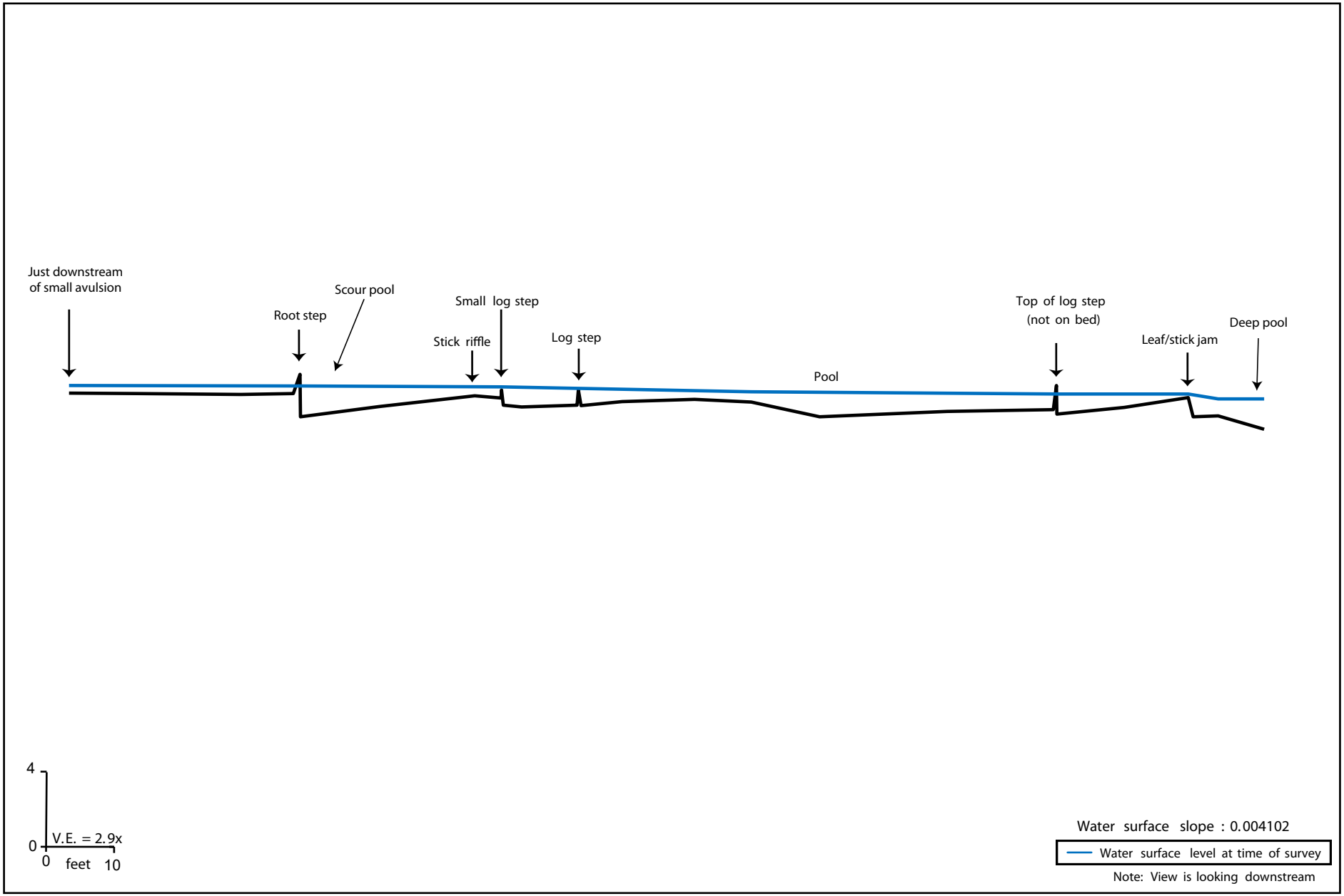




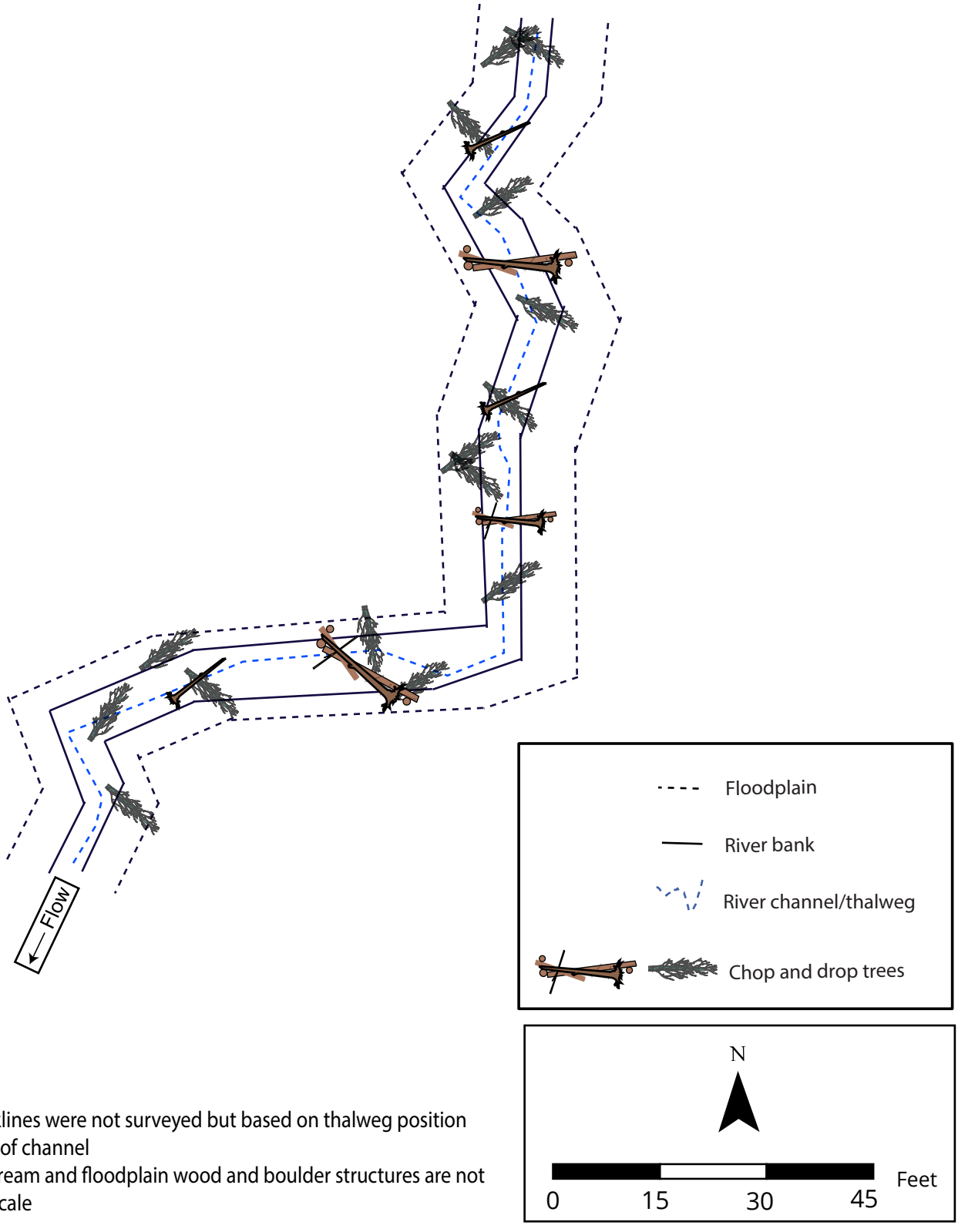


Note: view looking downstream

Norton Brook - Surveyed cross sections. Reach N1.



Norton Brook - Longitudinal profile. Reach N1.



Note: Banklines were not surveyed but based on thalweg position and width of channel
Note: In-stream and floodplain wood and boulder structures are not drawn to scale

Norton Brook - Proposed plan view. Reach N1.

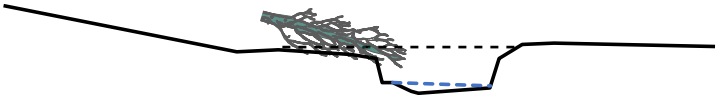
Chop and Drop

Cross Section 1

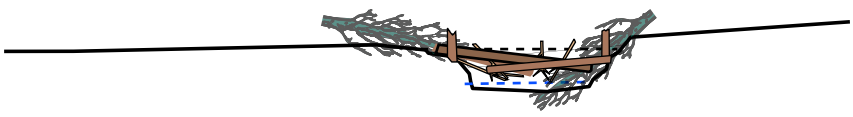




Cross Section 2



Cross Section 3



5
0 V.E. = 1.1x
0 feet 10

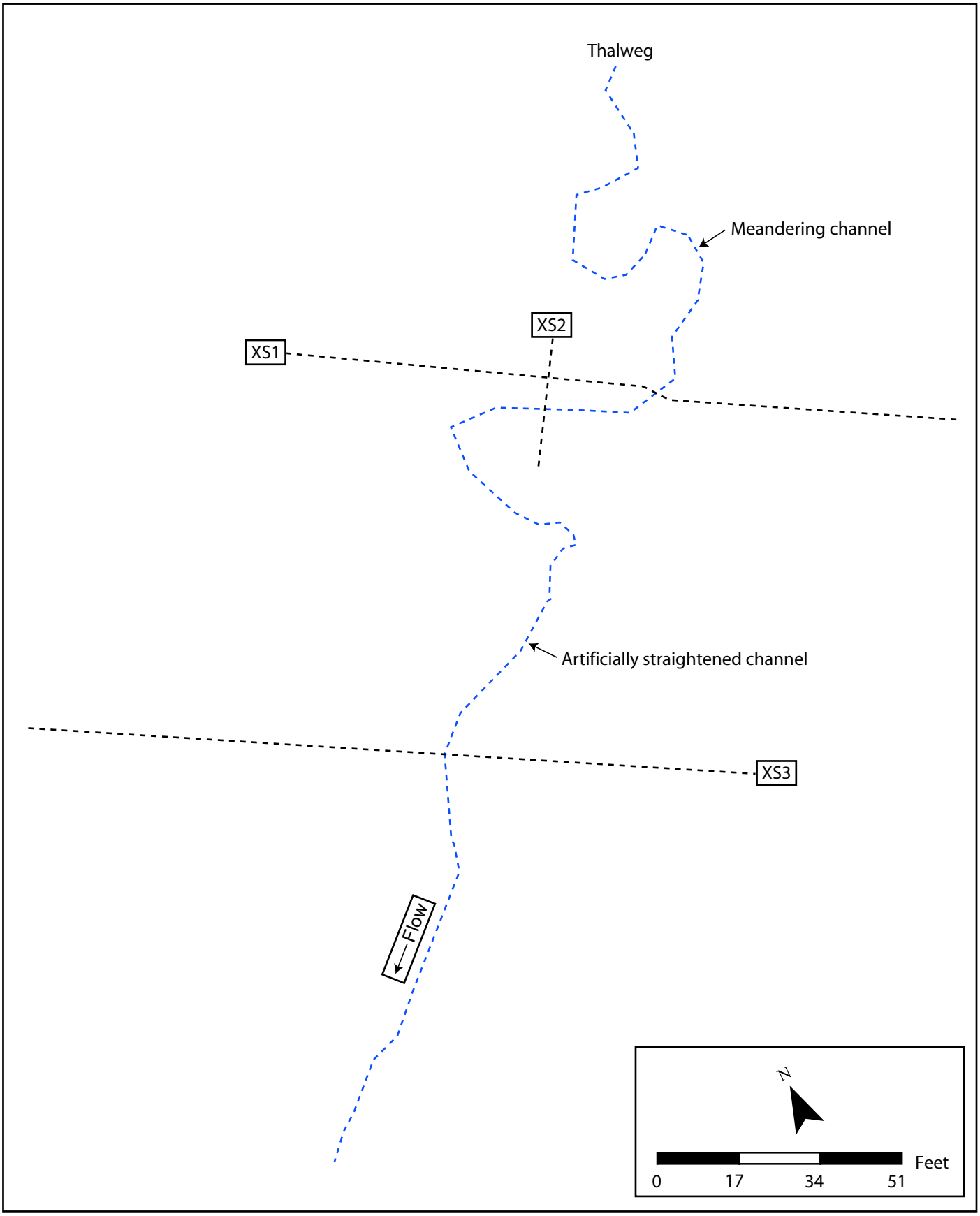
Note: view looking downstream
Note: Structural elements are schematic and not to scale

Chop and drop trees
Bankfull elevation
Water surface at time of survey

Norton Brook - Proposed conditions for cross sections 1-3. Reach N1.

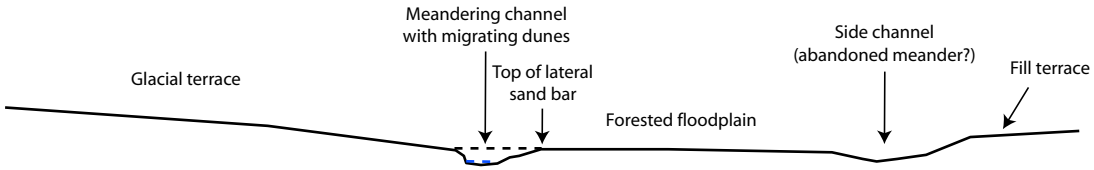
Norton Brook – Reach N2

Survey Data and Conceptual Restoration Design

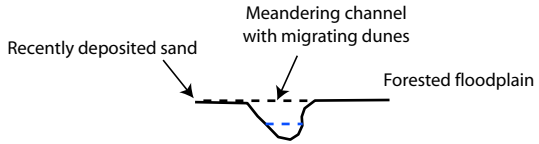


Norton Brook - Surveyed plan view. Reach N2.

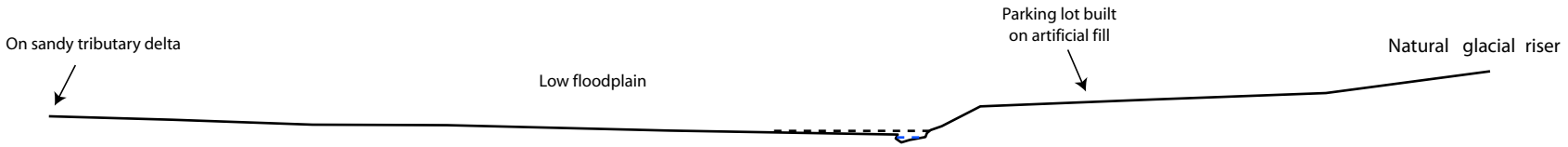
Cross Section 1 - Across meandering channel and forested floodplain

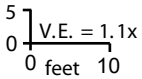


Cross Section 2 - Across riffle section of horseshoe meander with high sinuosity



Cross Section 3 - Crosses straightened channel and fill encroachment



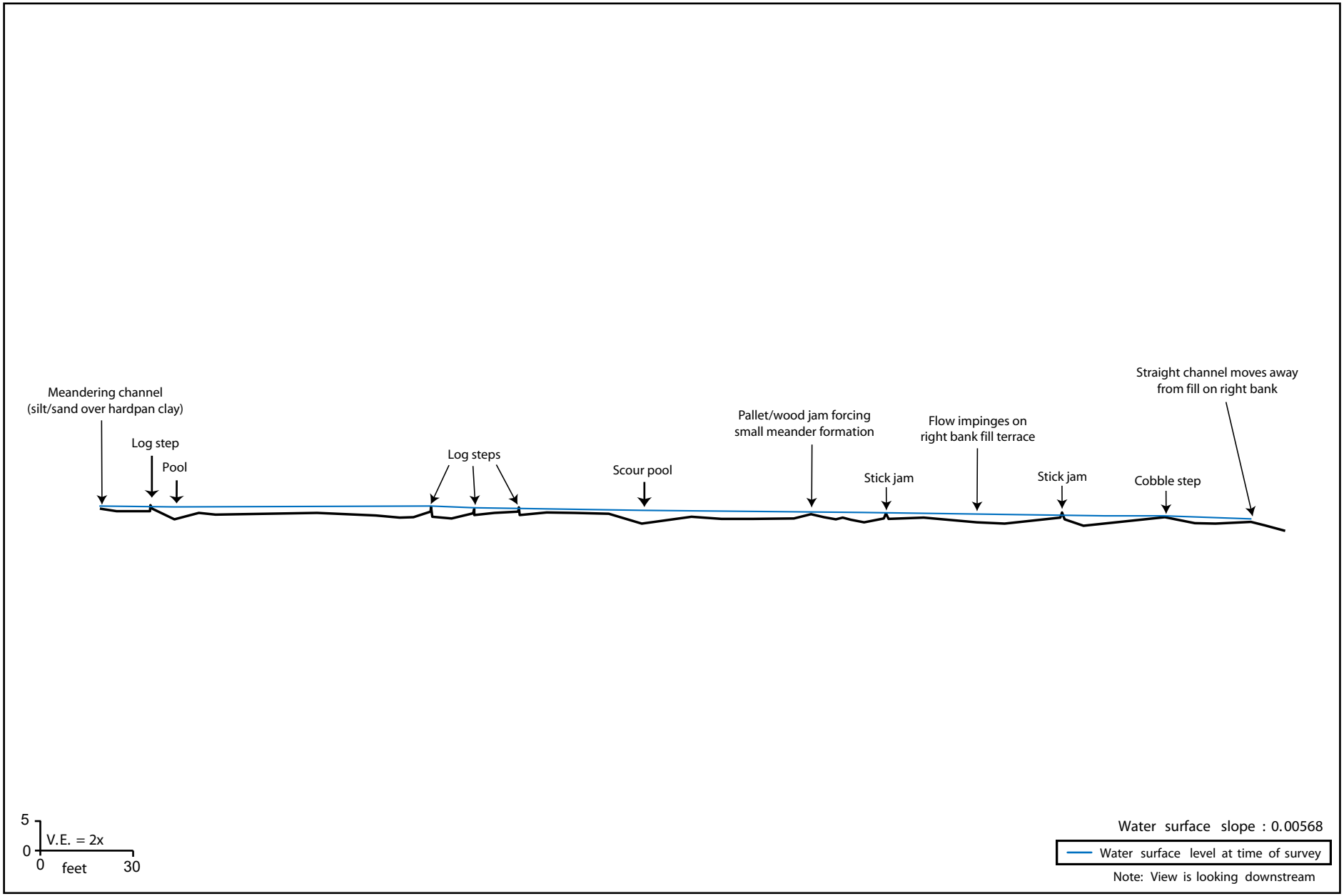


--- Bankfull elevation
--- Water surface at time of survey

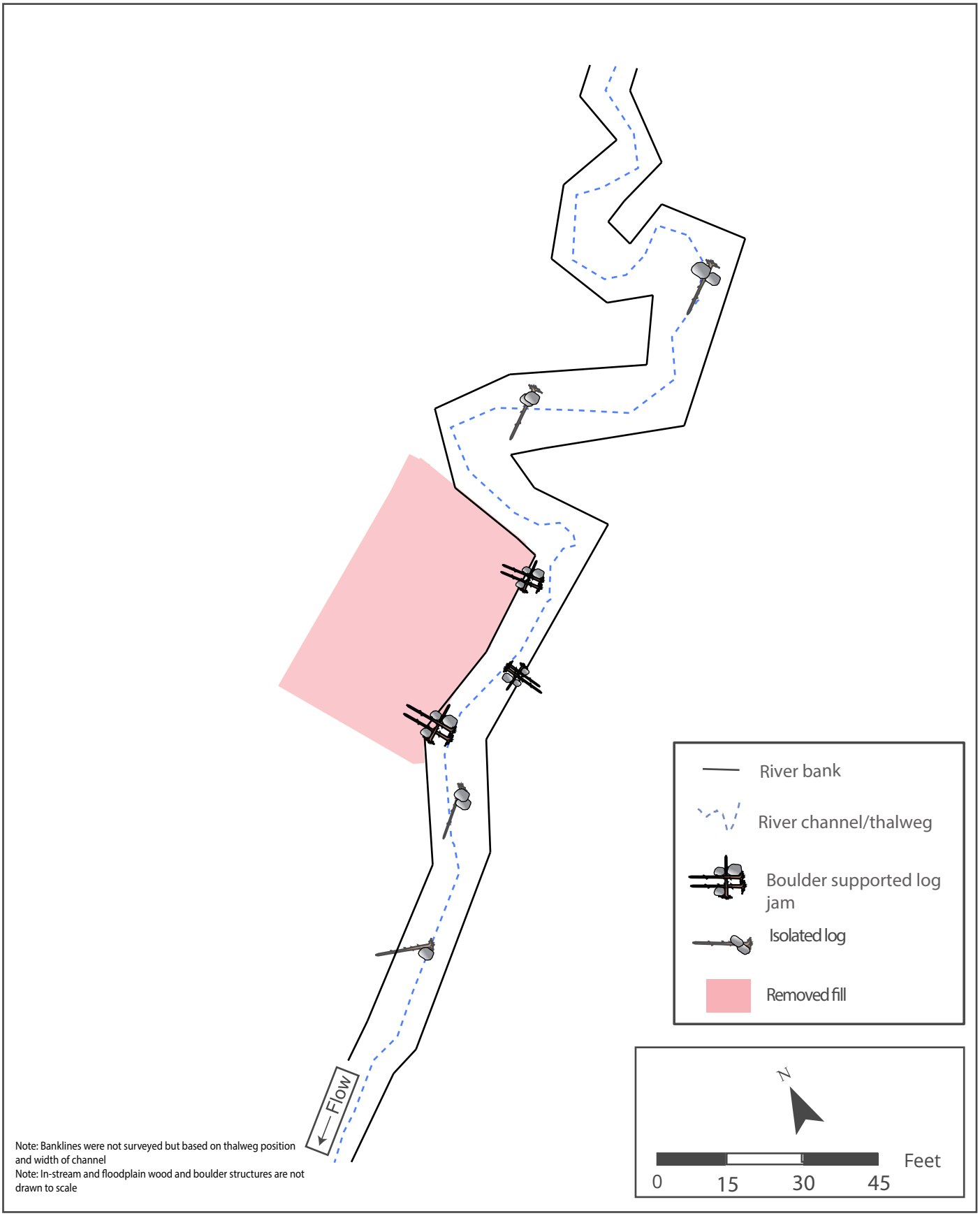
Note: view looking downstream

Norton Brook - Surveyed plan view. Reach N2.

Field Geology Services
Fluvial Geomorphology

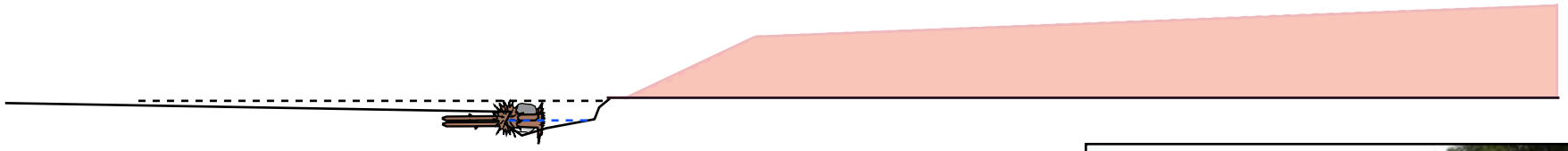


Norton Brook - Longitudinal profile. Reach N2.



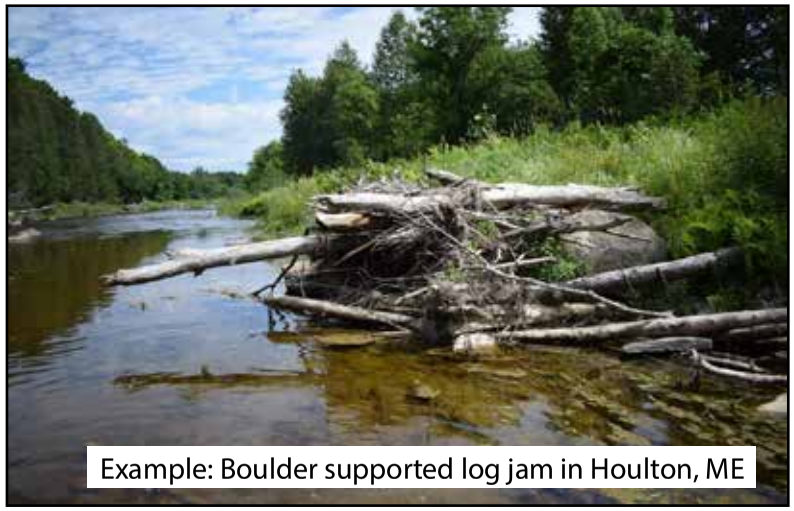
Norton Brook - Proposed plan view. Reach N2.

Cross Section 3
Boulder Supported Log Jams
Fill Removal





5
0
V.E. = 1.1x
0 feet 10



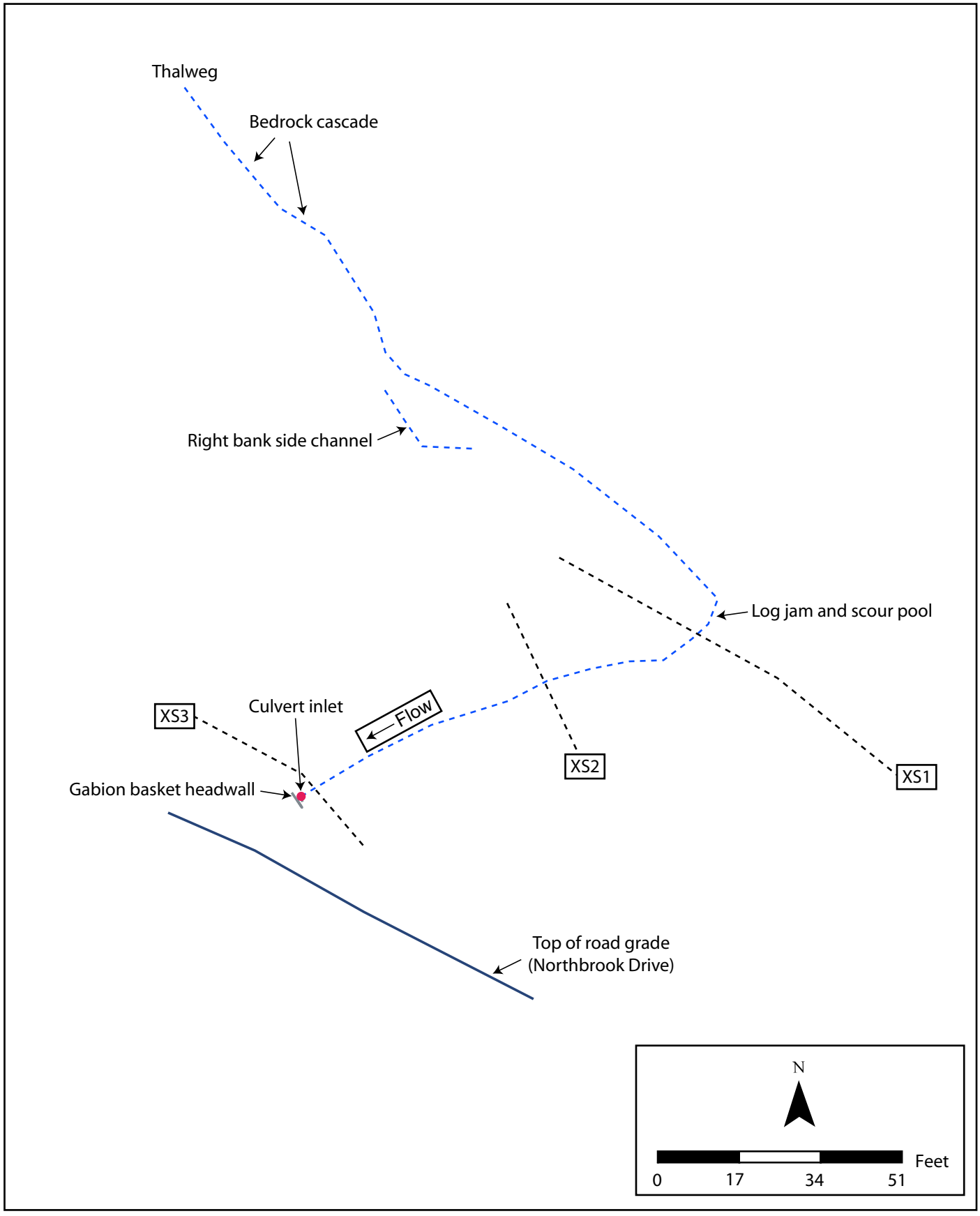
Boulder supported log jam
Removed fill
Bankfull elevation
Water surface at time of survey

Note: view looking downstream
Note: Structural elements are schematic and not to scale

Norton Brook - Proposed conditions for Cross Section 3. Reach N2.

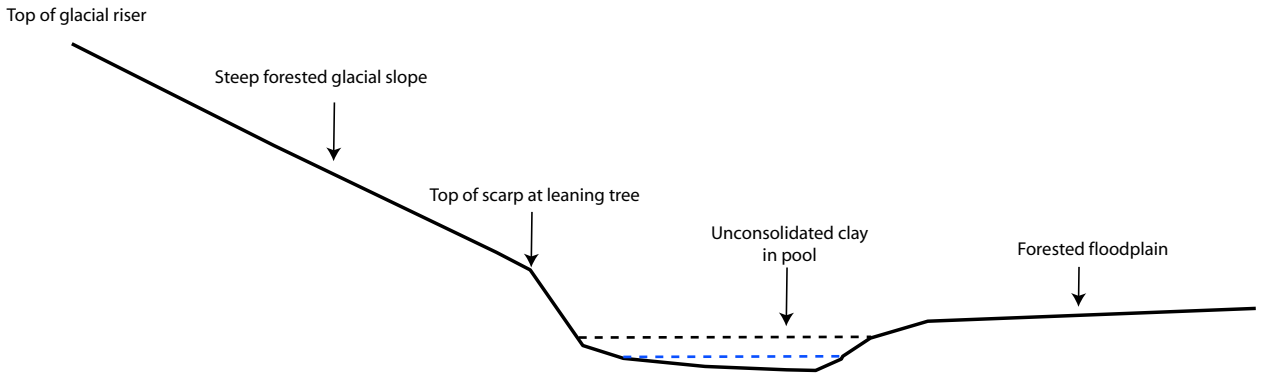
Norton Brook – Reach N3

Survey Data and Conceptual Restoration Design

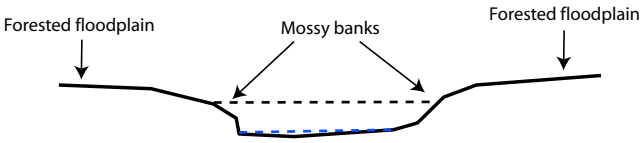


Norton Brook - Surveyed plan view. Reach N3.

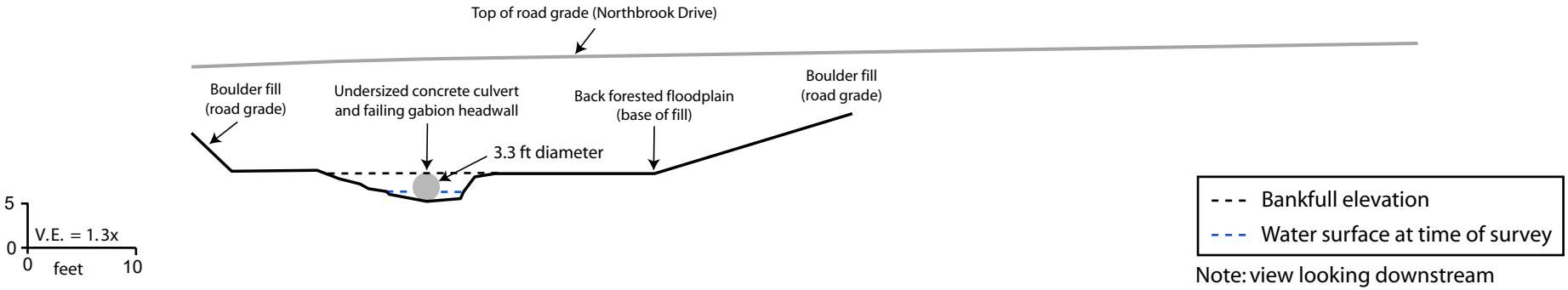
Cross Section 1 - Across tight meander and scour pool, just upstream of log jam



Cross Section 2 - Across straight cobble riffle



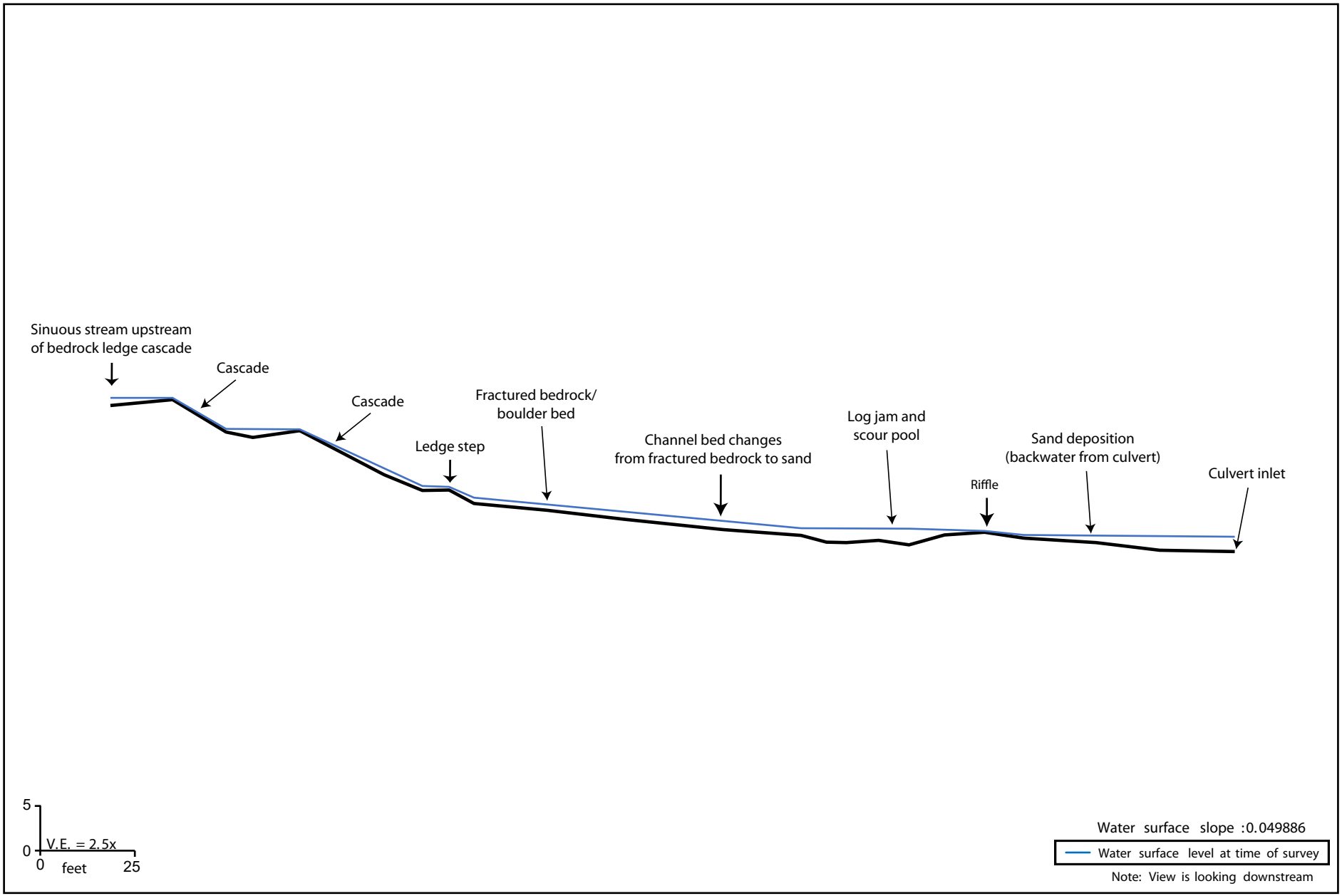
Cross Section 3 - Just upstream of Northbrook Drive culvert



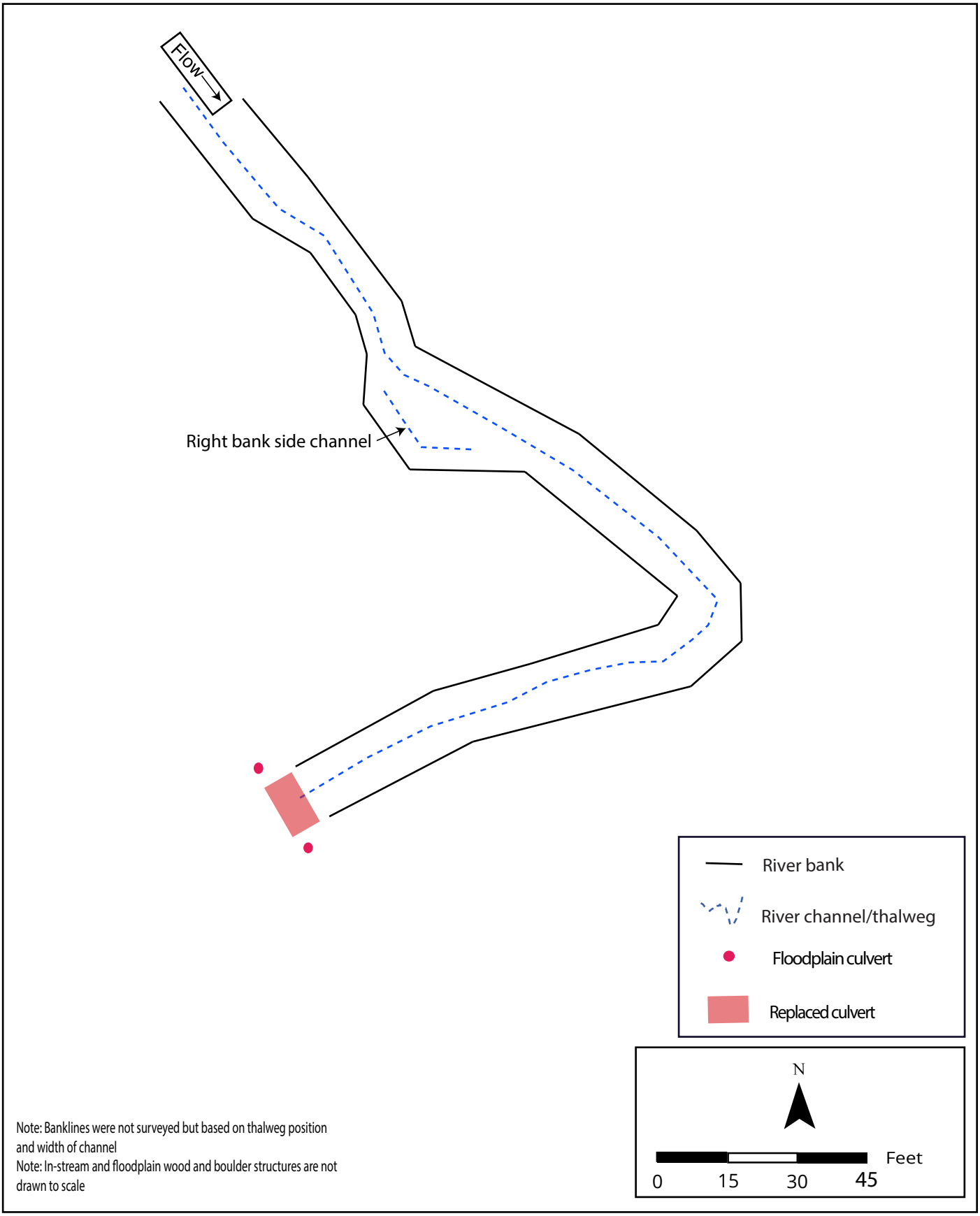
Note: view looking downstream

Norton Brook - Surveyed cross sections. Reach N3.

Field Geology Services
Fluvial Geomorphology

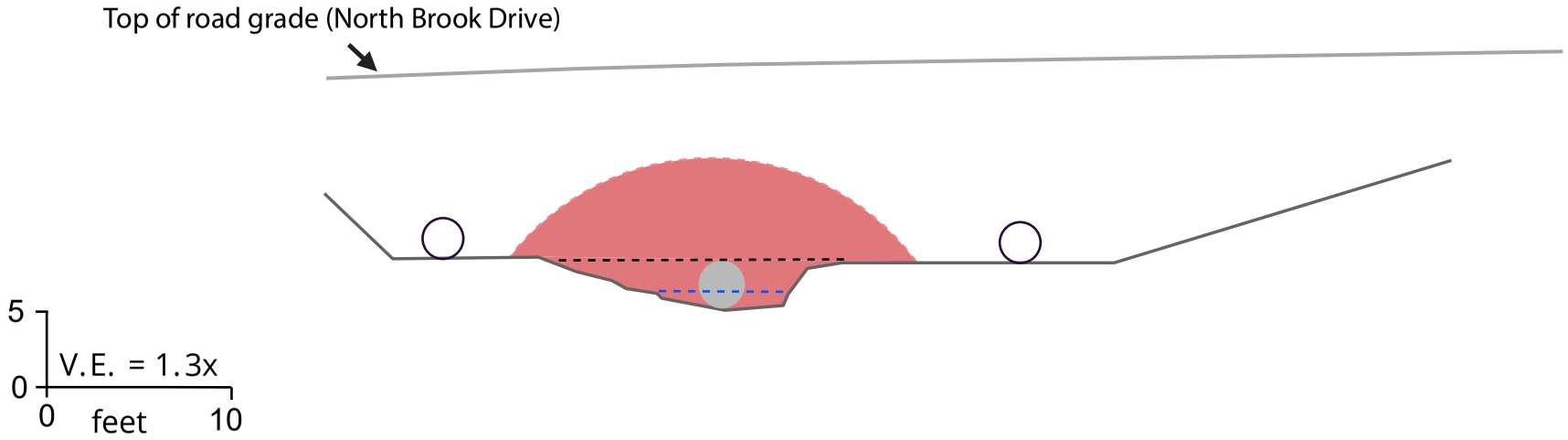


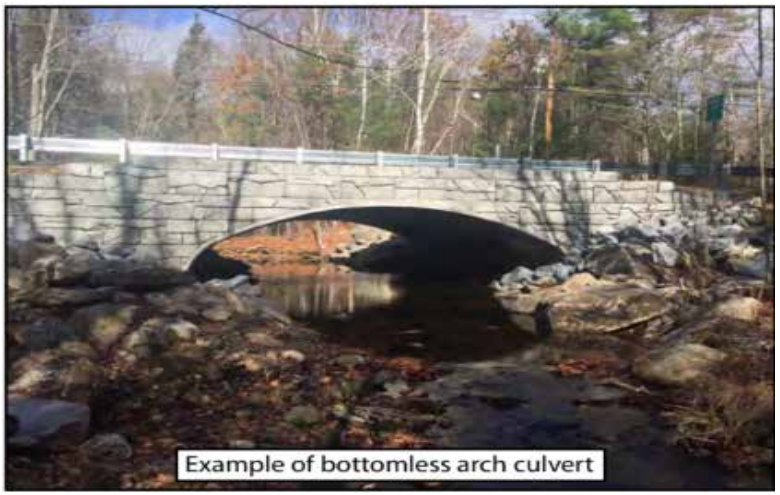
Norton Brook - Longitudinal profile. Reach N3.



Norton Brook - Proposed plan view. Reach N3.

Cross Section 3
Culvert and Headwall Replacement
Floodplain Culverts





Existing culvert diameter: 3.3 ft
Resized culvert diameter: 21ft
Bankful channel width: 17 ft
1.2x Bankful channel width: 20.4 ft

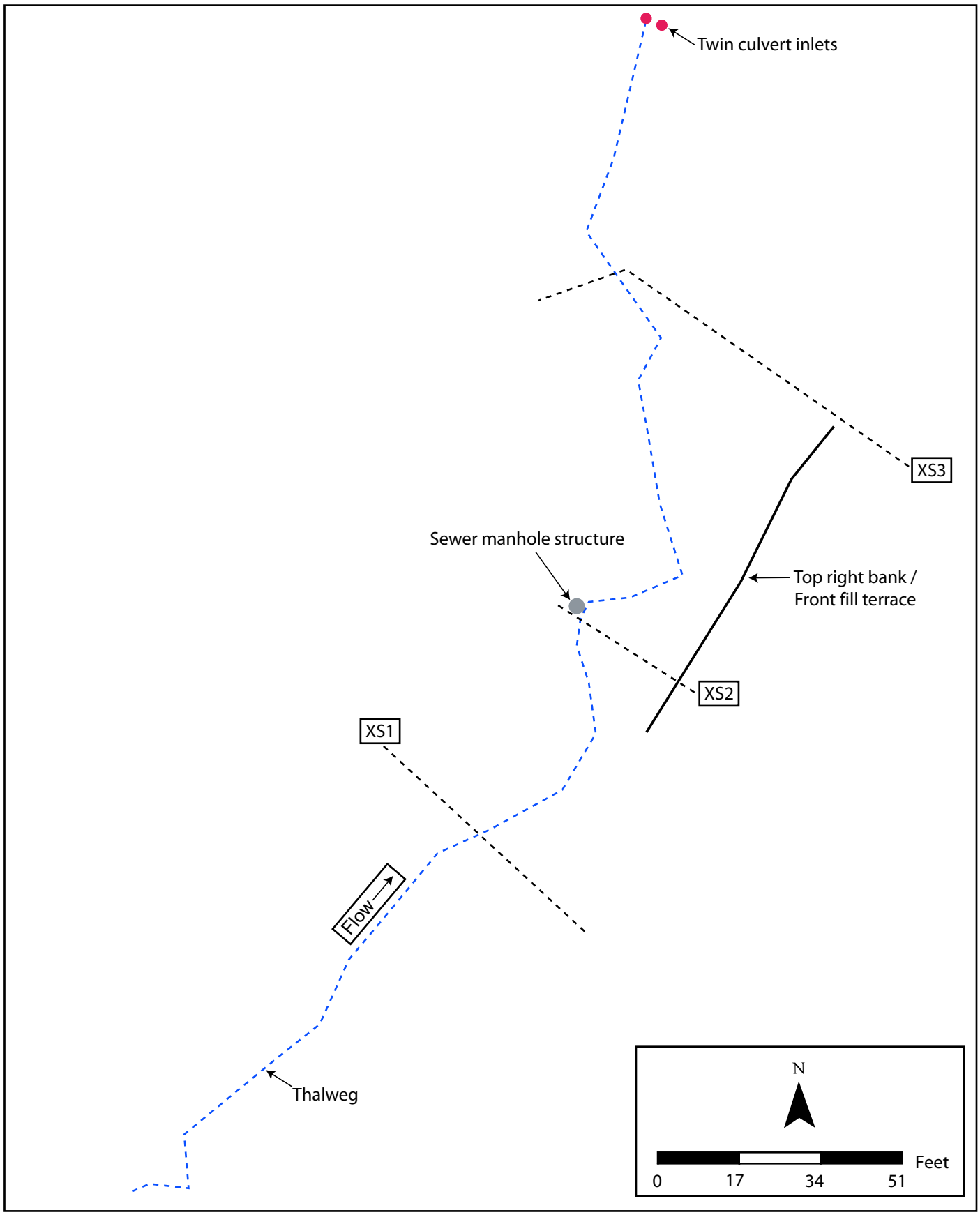
Note: view looking downstream
Note: Structural elements are schematic and not to scale

Floodplain culvert
Resized culvert
Existing culvert
Bankfull elevation
Water surface at time of survey

Norton Brook - Proposed condition for Cross Section 3. Reach N3.

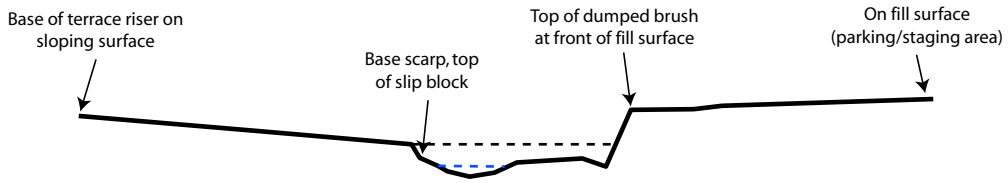
Webes Creek – Reach W1

Survey Data and Conceptual Restoration Design

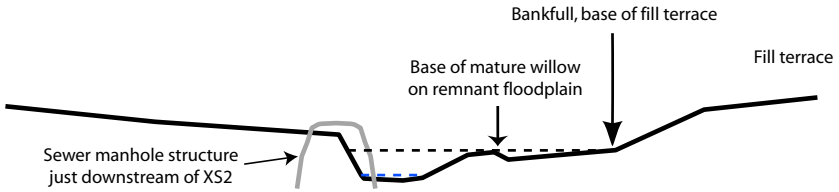


Webes Creek. Surveyed planview. Reach W1.

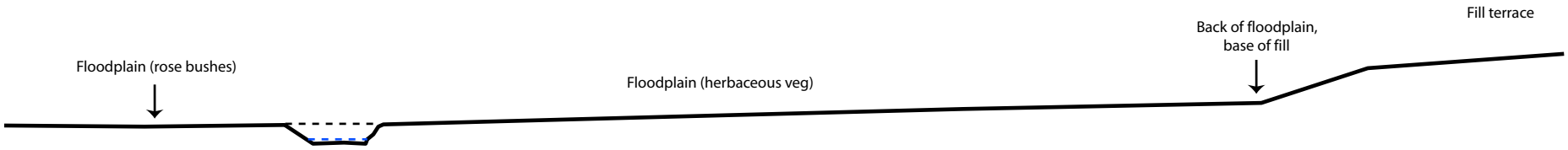
Cross Section 1 - Across straight channel with dumped brush encroaching into channel

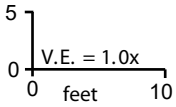


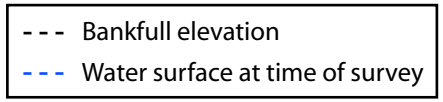
Cross Section 2 - Just upstream of sewer manhole structure



Cross Section 3 - Across wide floodplain upstream of Depot Rd culverts

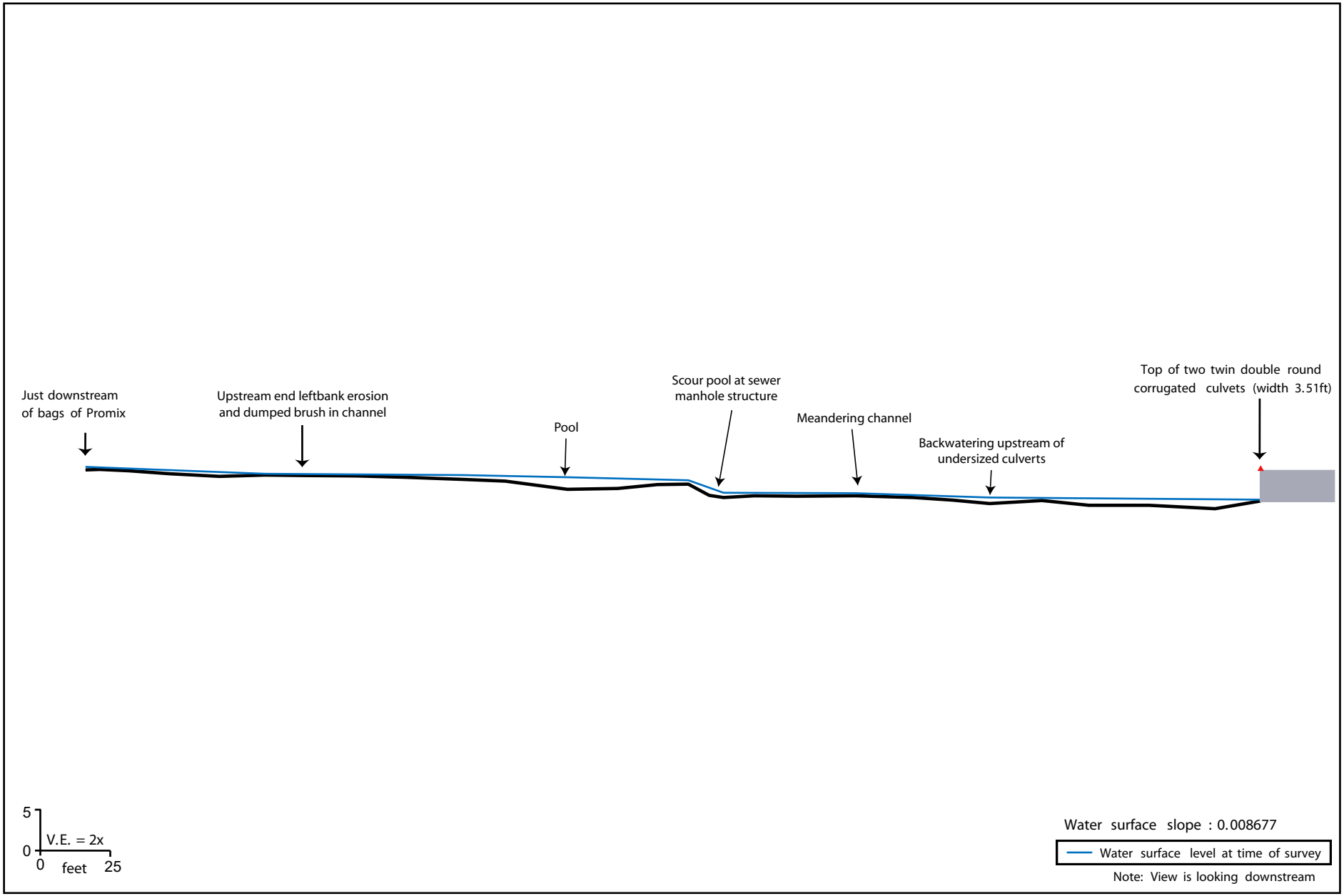




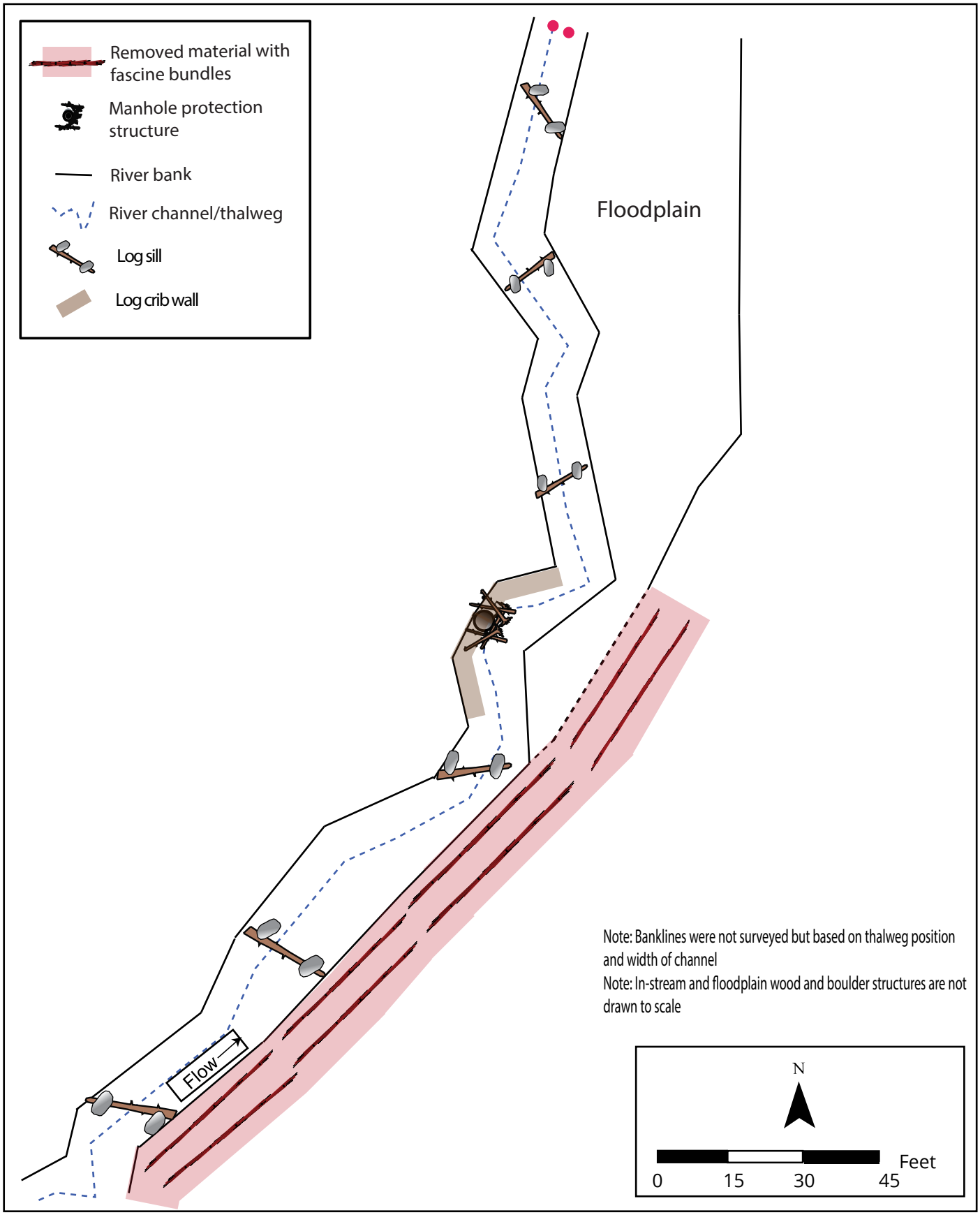


Note: view looking downstream

Webes Creek - Surveyed cross sections. Reach W1.

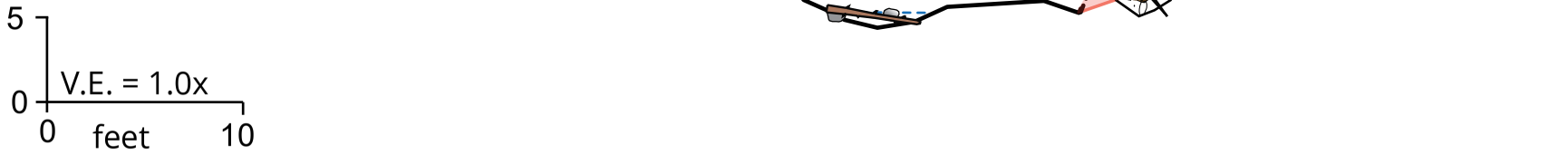


Webes Creek - Longitudinal profile. Reach W1.



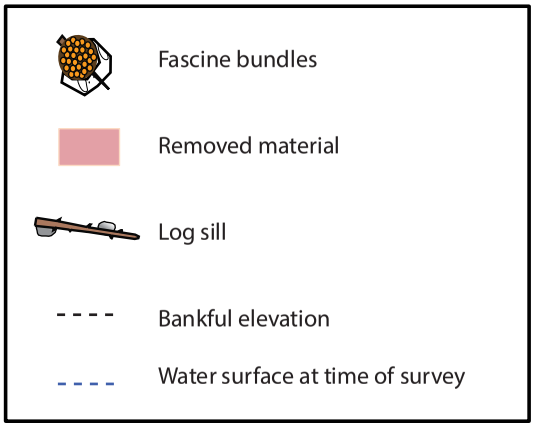
Webes Creek. Proposed Planview. Reach W1.

Cross Section 1
Removed dumped material/fill encroaching into channel
Log sills





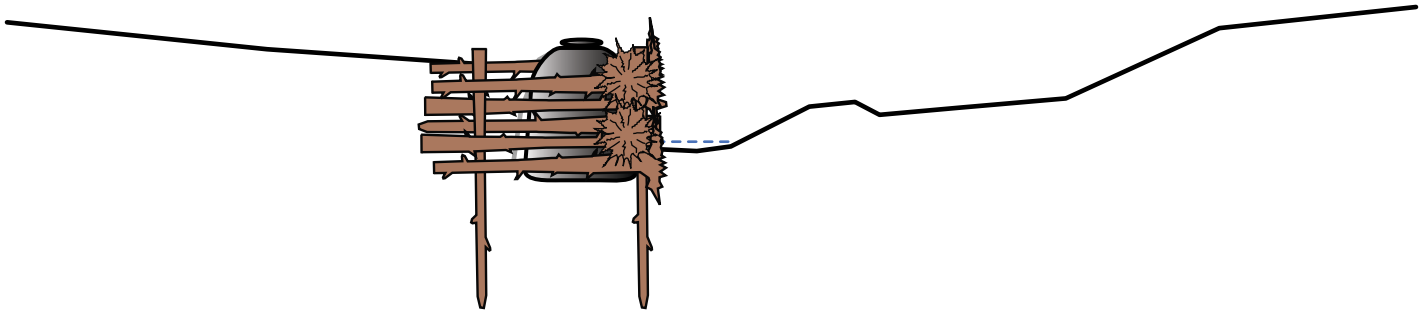




Note: Structural elements are schematic and not to scale
Note: View is looking downstream

Webes Creek - Proposed conditions at Cross Section 1. Reach W1.

Cross Section 2
Log jam protection for sewer manhole structure



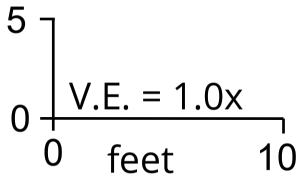



Photo of manhole structure on Webes Creek

Log

Sewer manhole structure

Bankfull elevation

Water surface at time of survey

Note: Fill removal on right bank is not shown but typical can be seen on Cross Section 1.
Note: Structural elements are schematic and not to scale
Note: View is looking downstream

Webes Creek - Proposed conditions at Cross Section 2. Reach W1.

APPENDIX C: FIELD GEOLOGY SERVICES 2025 GEOMORPHIC ASSESSMENT FOR SKITTERYGUSSET CREEK

Geomorphic Assessment and Restoration Recommendations for Skitterygusset Creek in Falmouth, Maine

Prepared for

Town of Falmouth (Maine)



Skitterygusset Creek in Falmouth, ME

Prepared by

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Field Geology Services
Portland, ME

July 2025

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EXECUTIVE SUMMARY

A fluvial geomorphic assessment was completed on Skitterygusset Creek in Falmouth, Maine to determine what restoration actions might be taken to prevent the stream from being listed as urban-impaired by the Maine Department of Environmental Protection. The findings were used to identify the impacts of urbanization on channel morphology and physical aquatic habitat in order to develop conceptual restoration options that will address the identified underlying causes for stream degradation. Ten distinct geomorphic reaches of uneven lengths were delineated on the stream with breaks between reaches occurring where the character of the valley or channel changes abruptly. All of the reach breaks are at undersized stream crossings that disrupt the continuity of geomorphic, hydraulic, and ecological processes critical for sustaining high-quality aquatic habitat.

Human activities in the watershed have impacted the stream to varying degrees and extents. In-stream wood is an important element of high-quality physical aquatic habitat on streams in temperate climates. While the riparian zones on the stream are well forested in most areas, long sections of even the most densely forested reaches are devoid of wood, reflecting past land clearance activities from decades ago. While the amount of forested land has declined over the past several decades, nearly 60 percent of the watershed remains forested. However, forests take time to mature sufficiently for trees to begin decaying and naturally falling into the stream channel. In-stream wood levels in even the most forested areas are still below levels in pristine watersheds and will take decades to noticeably improve naturally. Therefore, the associated habitat benefits of in-stream wood could be more rapidly restored through “chop and drop” wood addition projects in remote areas or anchored wood additions using log sills, isolated logs, and log jams near stream crossings and other developments.

Human activities in or adjacent to the stream have more direct impacts such as undersized stream crossings narrower than the channel’s width (e.g., upstream crossing under Woods Road), old dams (e.g., downstream of Bucknam Road), placement of artificial fill on the floodplain that constricts flood flows (e.g., Falmouth Department of Public Works facility), and past artificial channel straightening (e.g., downstream of Middle Road). These various human activities have led to the degradation of aquatic stream habitat as reflected in low wood loadings in the channel, eroding stream banks, and the excess deposition of fines in areas of impounded flow, creating areas with more wetland rather than fluvial characteristics. In addition, the indirect contribution of excess (as well as concentrated) runoff from developed areas of the watershed (particularly in the lower watershed) potentially exacerbates these issues.

While most of the stream can naturally recover on its own, because the stream can migrate and adjust its dimensions across a floodplain, short lengths of degraded habitat found in the immediate vicinity of undersized culverts or other constraints to channel adjustment (e.g., fill on the floodplain) leads to the isolation of those larger areas with much better geomorphic and habitat function. Wood in the channel is typically associated with positive habitat attributes such as cover, flow complexity, and sediment storage (as well as particle size segregation that reduces embedment). Restoration efforts focused on removing constraints to natural processes and increasing wood loading in the stream channel can accelerate the habitat improvements that will ultimately keep Skitterygusset Creek from being listed as urban impaired by the State of Maine.

1.0 INTRODUCTION

The following report presents the findings and restoration recommendations resulting from a fluvial geomorphic assessment of Skitterygusset Creek in Falmouth, Maine (Figure 1). Skitterygusset Creek has a total watershed area of 0.97 mi^2 and a mainstem stream length of 2.1 mi from the culvert outlet under the Falmouth Spur to the culvert inlet under Interstate-295. Downstream of I-295, the stream is tidally influenced. In the upper portion of the watershed, Skitterygusset Creek is a narrow channel flowing through a forested landscape. Downstream of Coles Village Road, a greater level of development impacts the stream.

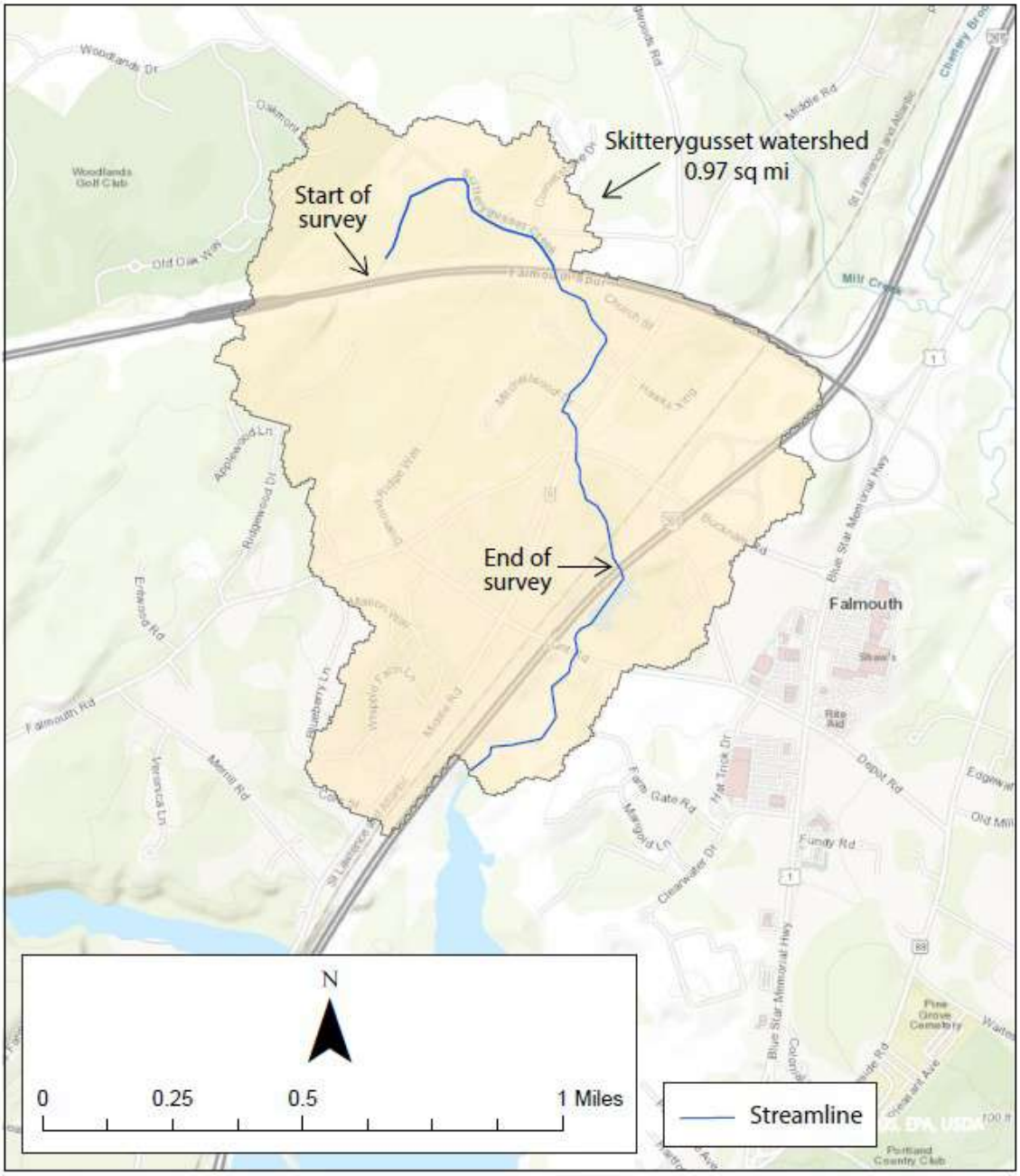


Figure 1. Map of Skitterygusset Creek and its surrounding watershed.

Field (2023) conducted a geomorphic assessment of five streams in Falmouth: Chenery Brook, Hobbs Brook, Mill Creek, Norton Brook, and Webes Creek. As was the case for those five streams, the geomorphic assessment of Skitterygusset Creek was completed to: 1) establish the current condition of the stream and the natural and human factors, past and present, influencing those conditions; 2) determine whether excess stormwater runoff and sediment loading from development in the surrounding watersheds and other human activities are causing habitat and water quality degradation in the stream; and 3) identify and develop conceptual restoration projects that will sustainably enhance aquatic habitat, macroinvertebrate assemblages, and fish populations. Skitterygusset Creek could potentially be listed as urban impaired by the Maine Department of Environmental Protection (DEP), and, as a result of a listing, the stream would face stricter stormwater discharge requirements (Web citation 1). The conceptual restoration projects are intended to ensure that Skitterygusset Creek meets DEP's designated stream class and, as a result, prevent the stream from being listed as urban impaired.

The geomorphic assessment consisted of five technical tasks: 1) review of background materials including previous reports and surficial geology maps; 2) historical assessment of channel and watershed changes using topographic maps and aerial photographs; 3) a rapid geomorphic assessment of the stream channel; 4) a detailed assessment including mapping of channel features and topographic surveying of channel dimensions; and 5) development of conceptual restoration designs. The results for each of these technical tasks are discussed below.

2.0 BACKGROUND REVIEW

The background review of existing materials consisted of an evaluation of previous reports and surficial geology maps relevant to understanding the natural conditions and human activities influencing conditions on Skitterygusset Creek. The most significant findings resulting from the background review include:

- Timber was an important part of Falmouth's economy in the 1700s (Web citation 2). Falmouth was an important supplier of white pine for use as masts by the British navy and numerous shipyards were established along the coast, including one at the mouth of Skitterygusset Creek. In the 1700s, logs were moved along streams to supply timber for lumber mills and British ships, so log drives could have occurred along Skitterygusset Creek despite its small size.

- By the end of the 1700s, the mast trade was replaced by farming in Falmouth, and the landscape transitioned from forested to open lands. Mills were built along streams that flowed close to roads, leading to population growth in Falmouth (Web citation 2). Skitterygusset Creek's proximity to early roads (Web citation 3) indicates that it would be an ideal site for a mill. Middle Road was one of the first principal roads connecting southern Maine to Brunswick with a crossing present over Skitterygusset Creek for more than 250 years (David Farnum, email communication, November 22, 2024).

- The first railroad began operations in Falmouth in 1848 (Web citation 4). An 1857 map of Cumberland County shows a rail line crossing and paralleling Skitterygusset Creek until just upstream of Lunt Road (Web citation 3), indicating the railroad grade has locally impacted the stream for over 150 years.

- The Falmouth Spur was constructed a few years after the Maine Turnpike opened in 1947 (Web citation 4). The Spur crosses Skitterygusset Creek twice in the upper portion of the watershed. The first crossing separated natural drainage paths in the headwaters from the stream and marks the beginning of the assessed portion of the stream (see Section 4.0 below).

- Interstate 295 was completed through Falmouth in 1961 (Web citation 5). Construction presumably began in the 1950s. I-295 runs between the railroad and tidal marsh in the lower portion of the Skitterygusset Creek watershed. The impacts of the interstate's construction are discussed further in Section 3.1 below.

- In the 2022 Strategic Watershed Plan conducted by the Town, the Skitterygusset Creek watershed was recorded as 46 percent forested cover (Web citation 6). The amount of wood in the stream channel may be, at least partially, related to the levels of forest cover and disturbance within the associated riparian zones. Streams with wood in the channel generally have higher fish populations (Flebbe, 1999), a greater abundance and richness of macroinvertebrates (Bond et al., 2006), and more complex physical habitat (Benke and Wallace, 2003). The results from the assessment of land use changes (see Section 3.2 below) suggest that Skitterygusset Creek may have abundant in-stream wood in the upper reaches with greater impacts downstream.

- The surficial geology map of the area shows that most of the Skitterygusset watershed upstream of the railroad flows through glacial till (i.e., a mixture of clay, silt, sand, gravel, and boulders (Web citation 7). From just north of the railroad to I-295, the stream flows through the Presumpscot Formation, a bluish-gray marine silt and clay, suggesting that a compacted, or hardpan, silt and clay may be occasionally exposed on the bed and banks of this portion of the channel. The channel south of I-295 is mapped as a wetland with grassland vegetation.

3.0 HISTORICAL ASSESSMENT

The historical assessment of Skitterygusset Creek, as discussed below, consisted of: a) a visual inspection of historical aerial photographs and topographic maps to identify changes in channel position and b) a GIS analysis of land use changes based on historical aerial photographs.

3.1 Channel changes

Early maps of Falmouth from 1630-1690 (Web citation 8) and 1828 (Web citation 9) depict only the lower portion of Skitterygusset Creek as a sinuous channel draining into the Presumpscot River. The earliest USGS topographic map of Skitterygusset Creek was surveyed in 1889 (but

published in 1891) and can be compared with historical topographic maps covering several years from 1916-2024, although most merely reuse maps from earlier years with few, if any, of the changes over time (especially in regards to the stream's position) recorded (Web citation 10-12). Historical aerial photographs more accurately reflect changes in land use (see Section 3.2), but their limited resolution make identifying channel changes difficult on small streams like Skitterygusset Creek, particularly when leaves are on the trees. That said, some changes were observed, primarily on the lower reaches of the stream, by comparting aerial photographs ranging from 1940-2024 (Web citation 13-14). Where topographic maps and aerial photographs provide conflicting information as to the timing of changes on the stream, highlighted below, the aerial photographs are considered more reliable.

- Both topographic maps and aerial photographs demonstrate that Skitterygusset Creek was historically straightened. Between 1941 and 1944, Skitterygusset Creek was straightened parallel to Middle Road with a sharp 90-degree bend created to flow under Middle Road (Figure 2a). Prior to 1956, Skitterygusset Creek was straightened around agricultural fields, buildings, and next to the railroad (Figure 2b).

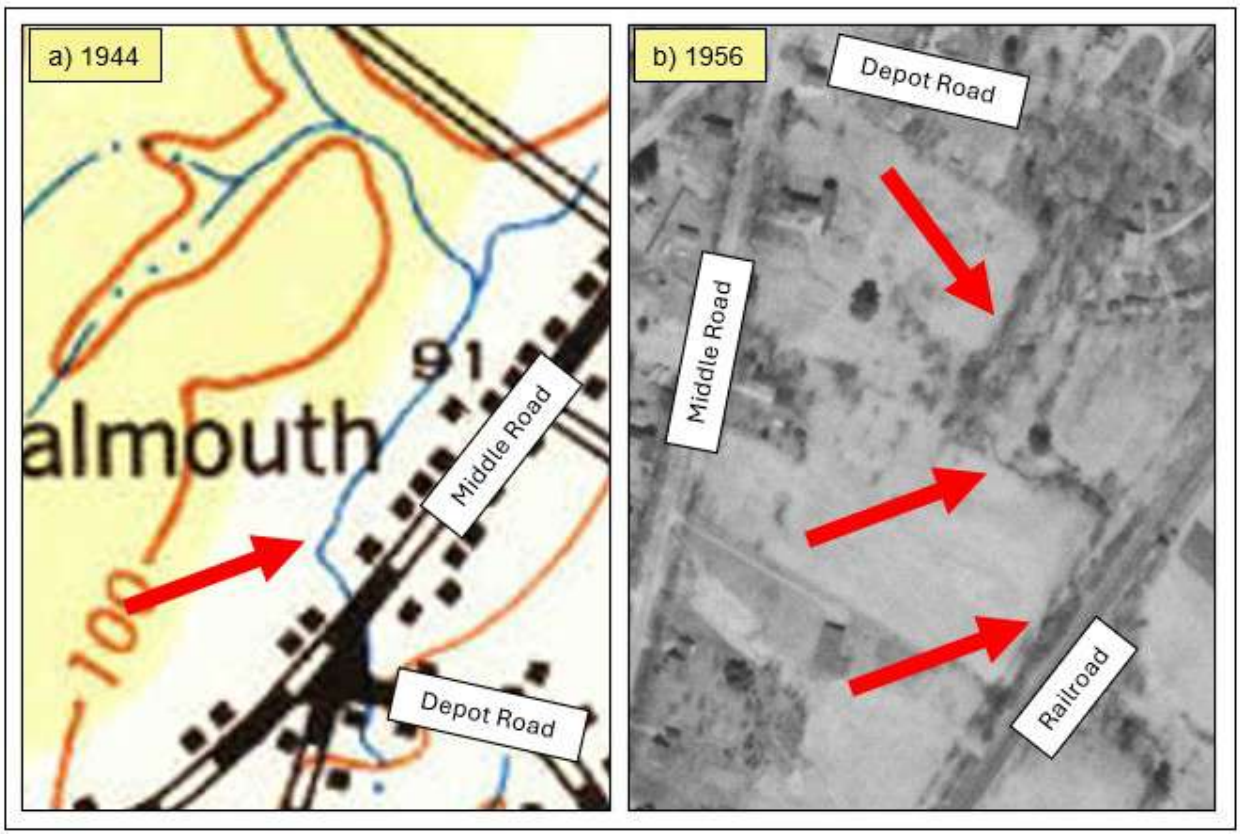


Figure 2. Skitterygusset Creek was historically straightened with a) the 1944 topographic map highlighting the channel paralleling Middle Road with a sharp turn (red arrow) before the crossing and b) the 1956 aerial photograph showing the channel straightened around agricultural fields and parallel to the railroad (red arrows). (Note: Depot Road was replaced by Bucknam Road when I-295 was constructed.)

- The position of Skitterygusset Creek at the Falmouth Corner intersection was changed at some point between the time the 1944 topographic map was surveyed in 1941 and the 1956 aerial photo (Figure 3).

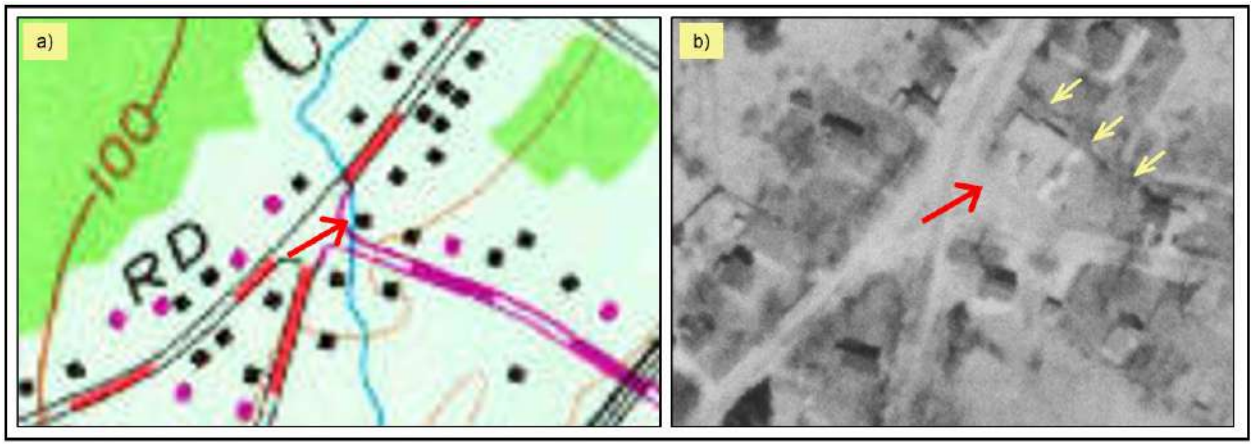


Figure 3. Skitterygusset Creek changes highlighted by comparing a) 1956 topo (although stream position is from survey of 1944 topo map) when the channel was to the west of the structure by the red arrow (where Bam Bam Bakery currently operates) and b) 1956 aerial photo when channel (highlighted with yellow arrows) is flowing east of the structure where the stream remains today.

- During I-295 construction, the 1960 aerial photograph showed (as better reflected on the 1970 topographic map) the channel was shifted to the east relative to the 1893 topo map, likely due to artificial fill used to build the highway, confining the floodplain east of the highway (Figure 4). At the I-295 culvert outlet close to the northerly extent of the old tidal marsh (Figure 4a), an ice-skating pond (Figure 4b) was built in 1947 (Falmouth Express, 1947). As part of this project, an old bridge was removed and a dam built with a sluice gate that prevented tidal water from reaching the pond. The pond is still visible on 2003 aerial photos but appears drained by 2006. The 2021 topo map (Figure 4c) captures the return of the stream to this, once again, tidally influenced area.

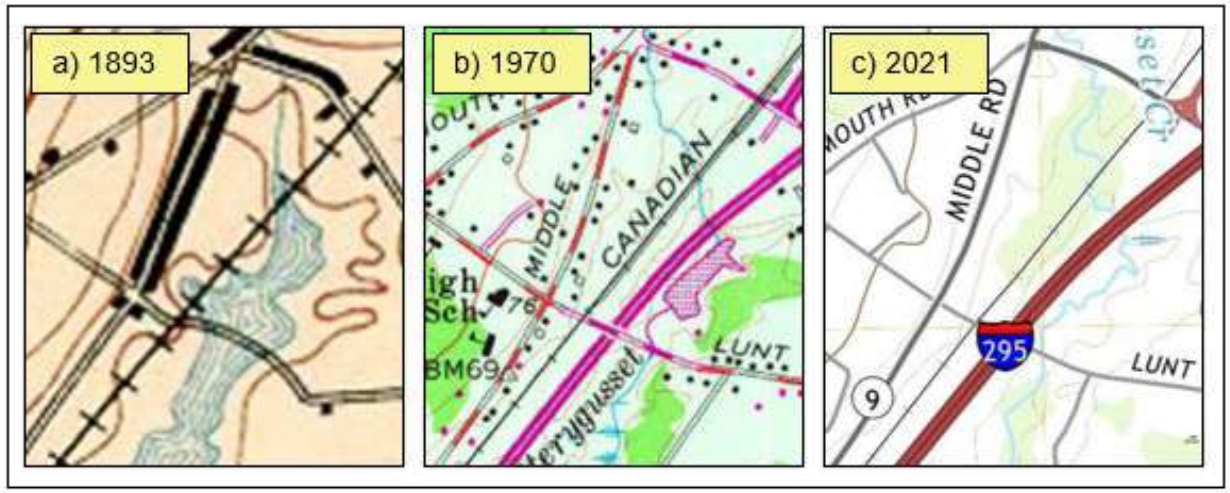


Figure 4. Topographic maps show the evolution of Skitterygusset Creek downstream of the railroad tracks from a) a tidal marsh in 1893 to b) an ice-skating pond in 1970 separated from tides to c) a tidally influenced stream in 2021.

- The number of roads, buildings, and stream crossings on Skitterygusset Creek have increased over time, likely impacting stream geomorphology. Aerial photos helped identify several notable changes:

    - Skitterygusset Creek was crossed to access a home on Coles Village Road before 1956;
    - The Town of Falmouth Department of Public Works building is shown on the 1970 topographic map and the fill area to the northwest along Skitterygusset Creek first appears on an aerial photograph in 1975;
    - Skitterygusset Drive and Mitchellwood Drive were built between 1987 and 1998 and are associated with the expanding residential areas north of Middle Road; and
    - A pedestrian bridge was built across Skitterygusset Creek just upstream of the railroad culvert by 2014.

3.2 Watershed land use changes

Watershed land use changes can impact the channel by altering runoff and sediment delivery to the stream. Biotic diversity declines rapidly where more than 10 percent of the watershed is covered with impervious surfaces (Klein, 1979). Urbanization also impacts several physical characteristics of streams, including increases in channel size, greater bed and bank erosion, and more simplified channel morphology (e.g., loss of pools, less in-stream wood) (McBride and Booth, 2005).

Changes in the amount of forested, open, and developed land around Skitterygusset Creek were determined by hand digitizing land use type within the watershed on five aerial photos from 1940 to 2022 (Appendix 1). Three land use categories were mapped: forested lands, open lands, and developed lands. Forested lands are those areas of large contiguous tree growth. Open lands include agricultural areas, open fields that may or may not be in agricultural production, and wetland/marsh areas. Developed lands are those areas where homes, commercial developments, and roadways are concentrated. While changes in developed lands serve as a proxy for changes in the amount of impervious surface area, the total percentage of impervious surface area is less than that of developed lands as the latter includes small patches of open space, lawns, trees, etc. Further refinement of the land use mapping, such as carefully mapping impervious surface areas, was not possible given the resolution and clarity of the older aerial photographs.

Developed land has steadily increased over time in the watershed with an almost 600 percent increase from 1940 to 2022 (Figure 5 and Table 1). Open land declined from 1940 to 1975, but has since remained largely steady. Forested land declined as well except for a short period from 1960 to 1975 as open land, including agricultural fields, transitioned to forested land. The upper watershed has historically been forested with most of the development expanding from Middle Road south. This suggests in-stream wood will be more abundant in the upper reaches compared to the lower reaches of the watershed. However, less in-stream wood is likely to be found where streamside forests are young and have not had enough time to mature to the point where trees are dying and falling into the channel. More development appears around the area of Middle Road after completion of the Falmouth Spur by 1956 and expanded to the north of the spur by 2006.

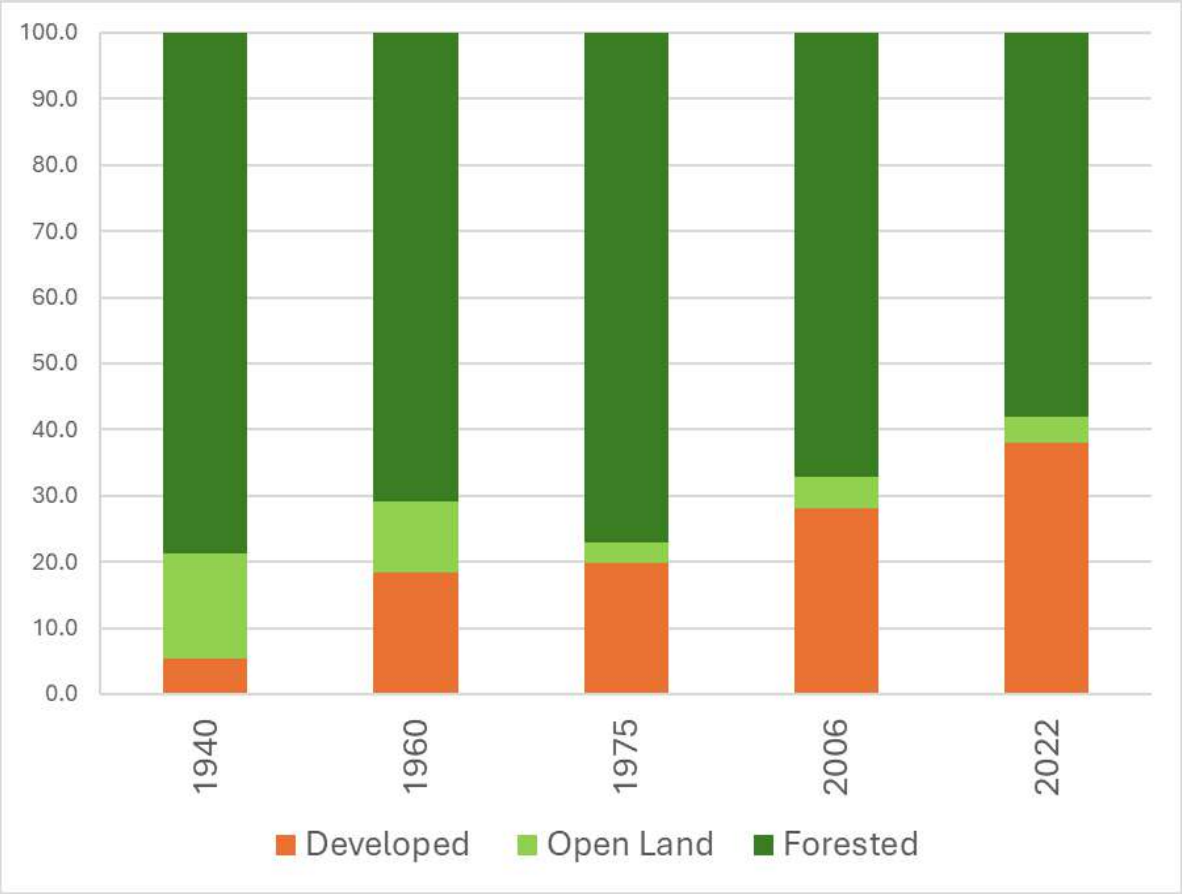


Figure 5. Land use changes through time in the Skitterygusset Creek watershed by a percentage of watershed area.

Land Use	Percent of watershed (year) 1940	1960	1975	2006	2022	Total change (%) 1940-2022	Period of Greatest Change
Forest	78.8	70.8	77.1	67.1	58.0	-26.3	1975-2006
Open Land	15.8	10.7	3.2	4.7	4.0	-74.5	1940-1960
Developed	5.4	18.5	19.7	28.2	37.9	597.4	1940-1960

Table 1. Land use changes through time on Skitterygusset Creek.

4.0 RAPID GEOMORPHIC ASSESSMENT

As part of the Rapid Geomorphic Assessment completed in May 2024, Skitterygusset Creek was subdivided into reaches of uneven lengths. Each reach is a relatively homogeneous length of stream channel that is distinct from adjacent reaches or is separated from an adjacent reach by a structure (e.g., culvert) that could significantly alter the channel morphology on either side of the crossing. All of the reach breaks separating the reaches on Skitterygusset Creek are at stream crossings. The reaches on the stream are numbered sequentially from the upstream end (Figure 6). Delineating the reaches and characterizing the morphological conditions present in each reach are critical for identifying the natural and human factors potentially responsible for channel instabilities and degraded aquatic habitat.

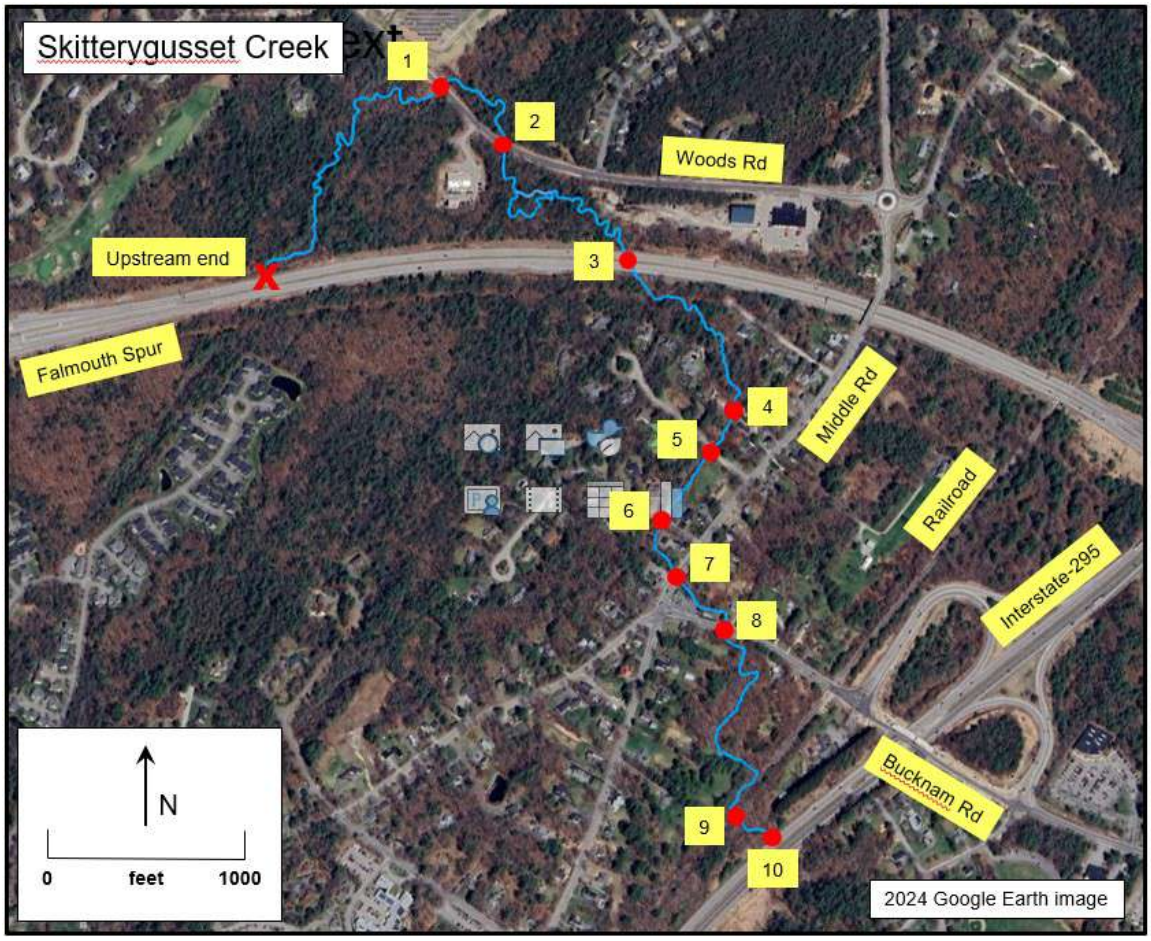


Figure 6. Reach location map for Skitterygusset Creek. Numbered reach breaks are at the downstream end of the given reach.

Reaches that share similar traits are referred to as "like-reaches" and an understanding of channel response or effective restoration techniques gained in one reach may apply to other "like-reaches." See Table 2 (placed at the end of the report) for details on the location, length, and characteristics of each reach. The breaks between reaches occur at observable changes resulting from various natural and human conditions such as a change in channel confinement, channel gradient, or human alteration of the channel such as at a culvert. Typically, these reach breaks, whether at natural or human features, represent grade controls whereby channel adjustments in adjacent reaches cannot migrate upstream or downstream due to constraints at the reach breaks themselves. Consequently, the most dramatic channel adjustments typically occur immediately adjacent to the reach breaks.

The rapid geomorphic assessment was conducted on all of the delineated reaches using an adaptation of EPA's *Streamwalk* protocol developed by Maine Inland Fisheries and Wildlife (Appendix 2). The rapid geomorphic assessment uses visible physical characteristics of the stream to identify whether the stream is undergoing morphological adjustments associated with aggradation (e.g., presence of bars, siltation in pools), degradation (e.g., headcuts, elevated tree roots), widening (e.g., leaning trees, erosion on both sides of channel), or planform changes (e.g., cut-off channels, formation of islands). Depending on the total number of features observed that

are indicative of these adjustments, the stream is characterized as either "in adjustment" (i.e., several observed features), "transitional or stressed" (i.e., some features noted), or "in regime" (i.e., very few or no observed features).

Reaches "in regime" are considered to be geomorphically stable (i.e., in equilibrium) and are thought to represent the natural state of the channel that would emerge in the absence of human impacts. In contrast, reaches categorized as "stressed" or "in adjustment" are considered to be responding to varying degrees to human influences (e.g., channel straightening) or natural events (e.g., floods). However, the scores are based on the presence or absence of certain features and not how well developed those features are. Consequently, a clearly degrading reach evidenced by dramatic increases in bank height may still classify as "in regime" if none of the other characteristic features of degradation are present. Furthermore, some unaltered stream reaches are naturally dynamic and the resulting complexity is important for ecosystem health, so the presence of some of the assessed features does not necessarily imply unstable or undesirable conditions. The rapid geomorphic assessment results, therefore, are best corroborated by a qualified professional (i.e., fluvial geomorphologist) and/or more detailed assessments.

Of the 10 total assessed reaches, eight are considered "in regime", only one rates as "in adjustment", and one is classified as "transitional or stressed" (Appendix 2). These results accurately reflect the overall good and intact morphological condition of most reaches and suggest current conditions do not represent a great departure from what might be expected naturally. While human alterations of the channel are causing localized impacts, systemic channel responses extending across multiple reaches or even the full length of individual reaches are not present. Consequently, stream restoration efforts addressing the localized impacts observed are likely to be successful.

The overall reach conditions recorded on the rapid geomorphic assessment forms (Appendix 2) do not accurately reflect the many localized impacts and channel adjustments occurring in each stream reach. Consequently, a brief description of each reach from upstream to downstream is provided below with ideas for potential restoration projects where appropriate. Table 2 provides a summary of the conditions and potential restoration options for each reach. A priority rating is given for each option to provide a sense as to how important the project is for improving geomorphic and habitat function. The complexity rating indicates how difficult the project will be to complete in terms of access and perceived landowner willingness among other factors. Estimated costs are indicated in a separate column and take into account the reach length being treated. A priority/complexity rating of high/low is ideal as great benefit can accrue relatively easily, whereas a low/high rating would require considerable effort without a significant benefit.

Reach 1 – Falmouth Spur to Woods Road

Skitterygusset Creek essentially begins at the outlet of the Falmouth Spur culvert as it flows through a marshy floodplain. The channel in the upper portion of the reach is a 3-foot wide, slow-moving stream within a broad, forested floodplain. The floodplain narrows as the banks steepen and converge on the stream. A rock wall extends across the channel leading to some backwatering that traps fine sediments, creating a sand and mud substrate (Figure 7a). The sediment is cobbly with exposed ledge on the left bank downstream of the rock wall, reflecting

minor erosion caused by a sediment deficit from the deposition upstream. A pedestrian crossing as part of a nature trail was built downstream of the rock wall and is also trapping sediment upstream. At another location, a single large boulder extends across most of the channel, leading to backwatering upstream and a scour pool downstream. While there is some wood that has fallen into the channel creating log jams with small sticks (i.e., stick jams) in places, wood loading in the reach as a whole is low. As the stream approaches Woods Road, the floodplain widens into a large cattail marsh (Figure 7b). The marsh extends approximately 500 ft upstream of Woods Road and abuts the road for the approximately 250- foot width of the floodplain. Two side-by-side 30-inch culverts drain the entire area, leading to the backwatering effects that help maintain the marsh hydrology.

Removing the rock wall and rock pedestrian crossing are the greatest restoration priorities for this reach. The rock wall is not currently in use so its removal is low cost for a high benefit for geomorphic and habitat function. A pedestrian crossing should be designed and installed that does not impinge on the natural flow paths. Additionally, several relief culverts should be installed along Woods Road to eliminate the backwatering effects and allow adequate drainage of the marsh at high flows.

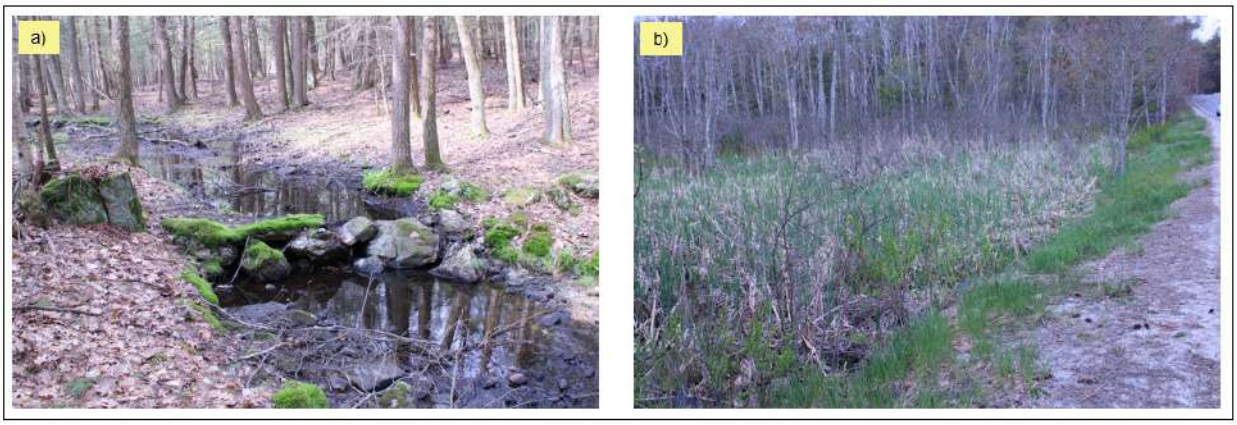


Figure 7. Reach 1 has a) a rock wall leading to backwatering upstream and b) an expansive cattail marsh at the inlet to the Woods Road culvert.

Reach 2 – Woods Road to Woods Road

At the culvert outlets under Woods Road, the road grade is armored with cobble and the bed is scoured before the channel quickly widens to a slow-moving pool. On the left bank, armored with large boulders, is a solar array built on top of a former landfill (Figure 8a). Discolored water, perhaps leaching from the landfill, covers a substrate of organic muck in an area of pooled water. The upper portion of the reach has low banks with some sinuosity and a low, wide, shrub-covered floodplain. This morphology and the pooling of water result from backwatering upstream of a steep bedrock gorge in the lower reach that has boulder steps confined by the high forested slopes (Figure 8b). A large tree has fallen across the channel creating a log jam, but flow is still able to pass under the logs. A single, 36-inch culvert under Woods Road is slightly undersized and is prone to being blocked and overtopping the road given the confinement upstream.

Restoration of Reach 2 should focus on improving the functionality of the culverts. The boulder armoring at the outlet should be rearranged to reduce scour. At the downstream end of the reach, the culvert should be enlarged to at least match the width of the channel. Adding wood to the upstream backwatered portion of the reach could increase flow complexity and improve habitat in this portion of the reach.



Figure 8. Reach 2 a) has large boulders armoring the bank (of a solar array) where the flow is pooled upstream of b) a steep, confined channel with boulder steps.

Reach 3 – Woods Road to the Falmouth Spur

Flowing out of the culvert under Woods Road, Reach 3 immediately bends sharply 90 degrees at a bedrock slope on the right bank (looking downstream), forming a scour pool at its base. The stream parallels the road for about 75 ft as it cascades over a series of small bedrock falls. The left bank along the road is unstable with the road's guardrail leaning in places. The channel migrates away from the road briefly as it forms a large meander and cobble point bar, but impinges on the road for another 60 ft with the road grade undercut at the apex of the next meander. As the channel moves away from Woods Road and flows across a wide forested floodplain, the channel becomes more sinuous with low banks. Two old meander loops may have been abandoned by past channel straightening, but also reflects the dynamic nature of the channel through this portion of the reach. Abundant wood in the channel has led to the deposition of sand bars that improve flow complexity (Figure 9a). Downstream, the floodplain abruptly narrows due to fill placed on the floodplain before 1975 (see Section 3.1 above) on which the Falmouth Department of Public Works (DPW) facilities rest (Figure 9b). The channel, confined by the fill with armored side slopes on the left bank (Figure 9b) and a high natural terrace on the right bank, is slightly incised with erosion along both banks. Where the floodplain reemerges downstream of the confining fill, the channel is backwatered by the undersized 3-foot diameter culvert under the Falmouth Spur.

Several restoration opportunities could be pursued in this complex reach, including: 1) building log crib walls to stabilize portions of the road grade at the upstream end of the reach; 2) adding wood to the channel to reconnect the abandoned meanders; 3) removing the fill at the DPW facilities to reestablish the floodplain; and 4) replacing the undersized culvert at the downstream end of the reach with a larger crossing and floodplain relief culverts. See Section 6.0 below for a conceptual restoration design further detailing some of these concepts.

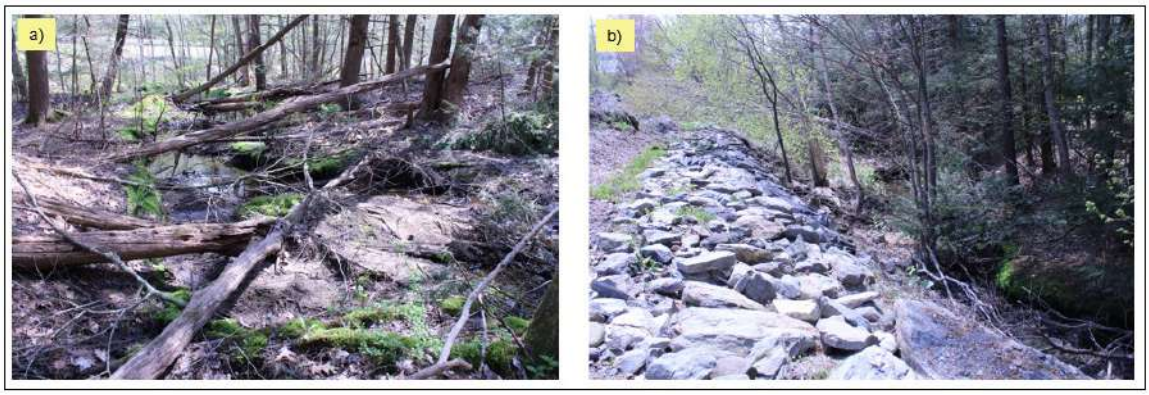


Figure 9. Reach 3 a) has abundant wood, in places, that traps fine sediments and b) elsewhere is confined by armored fill at the DPW facility that has led to channel incision and bank erosion.

Reach 4 – Falmouth Spur to Coles Village Road

A stick jam just downstream of the Falmouth Spur culvert traps sediment and prevents scour at the outlet. The channel is slightly incised with a sandy substrate covered by a layer of organics. The channel widens and shallows as it flows parallel to the Falmouth Spur and passes under a set of power lines; a downed wire is resting on the top of the low banks but is not considered live (Figure 10a). The narrow floodplain has a dense growth of shrubs (perhaps constricted by the Church Street road grade). Downstream from the power line, the floodplain widens and becomes forested with invasive Japanese Knotweed in places. The limited small wood in the channel forms several stick jams. Approaching Coles Village Road, the channel is backwatered and marshy due to the two undersized 30-inch culverts. Aquatic vegetation is growing in the channel (Figure 10b). The adjacent residential homes are likely built on fill and constrain the floodplain.

The habitat and geomorphology would benefit from wood additions throughout the reach. In the lower portion of the reach, chop and drop (i.e., directionally felling trees into the channel) of mature trees would help provide flow complexity to the stream. Larger trees would need to be brought in to the site and placed in the upper reach where shrubs dominate. The culvert under Coles Village Road should be replaced and resized to at least match the bankfull width of the channel to allow high flows to pass more easily and reduce the backwatering effect upstream. This would prevent fine-sediment deposition and the marshy conditions.

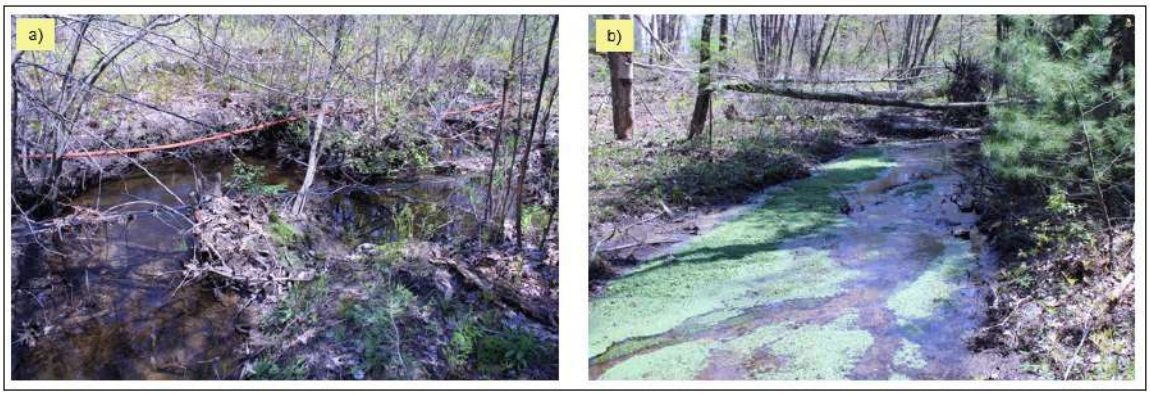


Figure 10. Reach 4 has a) a narrow, shrub dominated floodplain with downed power lines on the bank in the upper reach and b) backwatering upstream of the culvert inlet at the downstream end of the reach with aquatic vegetation.

Reach 5 – Coles Village Road to Skitterygusset Drive

Skitterygusset Creek appears straightened throughout the reach, supporting the topographic map evidence from 1944 that shows a straightened channel from just upstream of Coles Village Road to Mitchellwood Drive (Figure 2a). A floodplain, where present, is very narrow. The channel has a cobble substrate with limited wood present in the channel. Minor scouring is found at the culvert outlet under Coles Village Road. A small pedestrian bridge spanning the full width of the channel does not impact stream flow (Figure 11a). At the culvert inlet at the downstream end of the reach, a layer of mud is deposited on top of the cobbles due to backwatering upstream of the undersized 6-foot-wide culvert (Figure 11b).

This short reach would benefit from wood additions to encourage meander reformation and increase flow complexity. While costly, adding flood relief culverts under Skitterygusset Drive would remove the backwatering effect and prevent the deposition of mud that embeds the substrate.

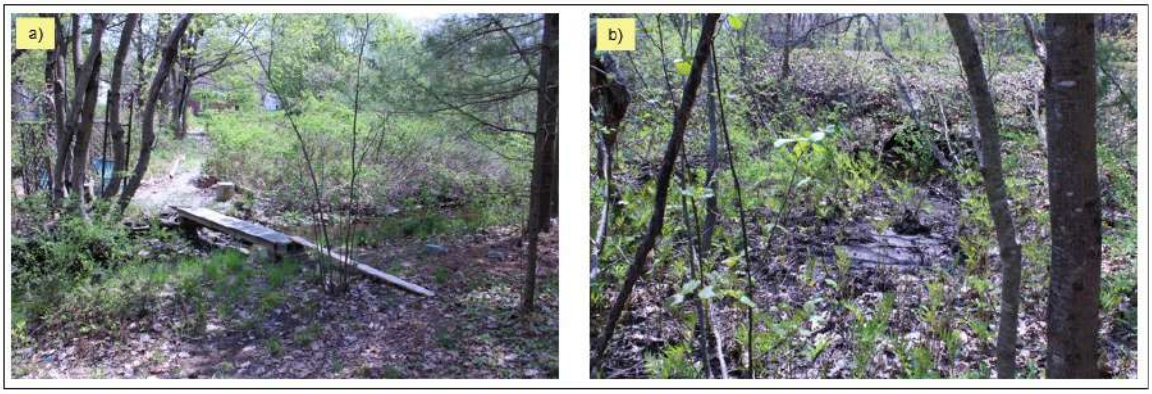


Figure 11. Reach C5 is a straightened channel with a) a pedestrian crossing that does not confine flow and b) a mud substrate at the culvert inlet due to backwatering.

Reach 6 – Skitterygusset Drive to Mitchellwood Drive

Reach 6 is slightly scoured at the culvert outlet before spreading out across a narrow floodplain. A channel-spanning log jam in the upper portion of the reach causes extensive backwatering and the accumulation of fine sediments (Figure 12a). On the left bank, a couple of grassy lawns extend to the edge of the channel without a forested buffer. The right bank floodplain has a mature forest buffer, supplying the abundant wood found in the channel. Downstream of the log jam, the left bank is armored to prevent erosion into a building. The erosion, prior to the placement of the armor, was perhaps a reflection of the incipient stages of meander reformation on the straightened stream. At the downstream end of the reach, the channel is narrow and confined (Figure 12b), making the twin undersized culverts susceptible to blockage and flooding across the road. Both banks upstream of the culvert are armored.

Planting riparian buffers on the left bank is a high priority for restoration to improve shading of the channel. The armor by the building and the inlet to the Mitchellwood Drive culvert could be replaced with log cribbing or other appropriate type of nature-based bank stabilization technique. Resizing the culvert inlet would reduce the risk of blockage and overtopping.

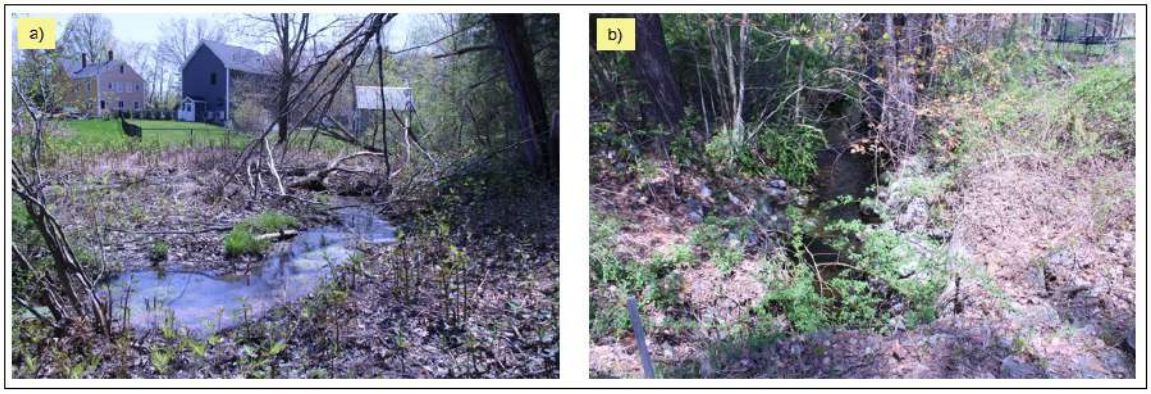


Figure 12. Reach 6 has a) a log jam that backwaters the upper portion of the reach (also note the lack of a forested buffer); and b) armoring at the undersized inlet culvert.

Reach 7 – Mitchellwood Drive to Middle Road

While the left bank is armored at the culvert outlet, minimal scour is present on the bed and right bank. The entire reach is wide and shallow with a sandy substrate and limited wood in the channel. The sharp 90-degree bend near the downstream end is armored and was created as part of the channel straightening that began just upstream of Coles Village Road (Figure 2a). The armoring at the bend is eroding at the downstream end with armor stones now in the center of the channel where the bank has receded (Figure 13a), leading to channel confinement and upstream backwatering where aquatic vegetation is growing. Downstream of the bend, the channel is more incised with a coarse substrate and flows next to a forested buffer on the right bank and a yard and driveway on the left bank. More sharp artificial bends direct the channel to three 30-inch culverts. A log blocks most of the culverts, making Middle Road susceptible to overtopping during high flows (Figure 13b). The culverts were replaced in 2022.

Reach 7 would benefit from reconnecting the floodplain with wood additions to allow meanders to reform along the straightened channel. This could be accomplished with chop and drop given the forested buffer, but, with the culvert downstream, constructed log jams anchored in place would be safer and could trap wood before reaching the culvert. As part of this process, the armoring on the sharp bend (Figure 13a) could be removed. The culverts are adequately sized at this location, but need to be monitored and cleared regularly to prevent blockages from forming.

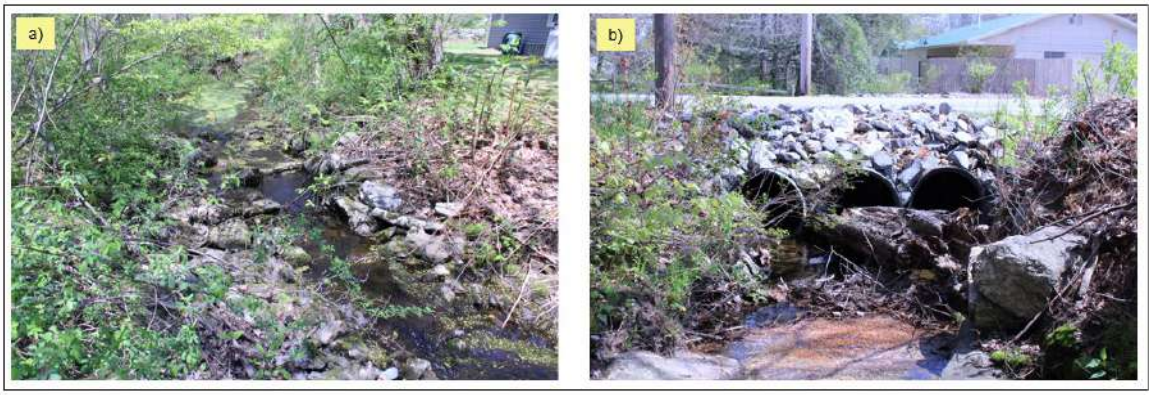


Figure 13. Reach 7 a) was straightened and armored at a 90-degree bend and b) has a log blocking the culverts under Middle Road, increasing the risk of high flows overtopping the road.

Reach 8 – Middle Road to Bucknam Road

Reach 8 is a historically straightened channel that is wide and shallow with bank erosion at the culvert outlet undermining trees that could fall onto the Bam Bam Bakery building. The channel was realigned into this location most likely in the 1940s or 1950s (Figure 3) with minor sinuosity reforming in the upper portion of the reach since that time (Figure 14a). The channel remains in a straightened configuration downstream due to confinement between elevated banks of fill that are armored in places (Figure 14b). The fill also blocks an abandoned meander (likely abandoned prior to the 1893 topo map) on the left bank with the existing channel taking a near right-angle bend towards the Bucknam Road culvert where the channel is armored along a grassy lawn on the left bank. Wood is absent from the channel throughout the reach. Ledge on the left bank extends partially into the channel and may be contributing to bank instability along the edge of the bakery's parking lot situated on the top of the right bank. Ledge is also present about 50 ft upstream of the Bucknam Road culvert and crosses the entire channel. The undersized culvert, if blocked, could overflow the road and redirect floodwaters into the steep roadside ditch along Bucknam Road. Although unlikely, this ditch could capture the stream's flow by taking a shorter path to the railroad grade and cut off Reaches 9 and 10 while incising a deep gully along and into Bucknam Road (unless ledge is present below the road surface to arrest the incision).

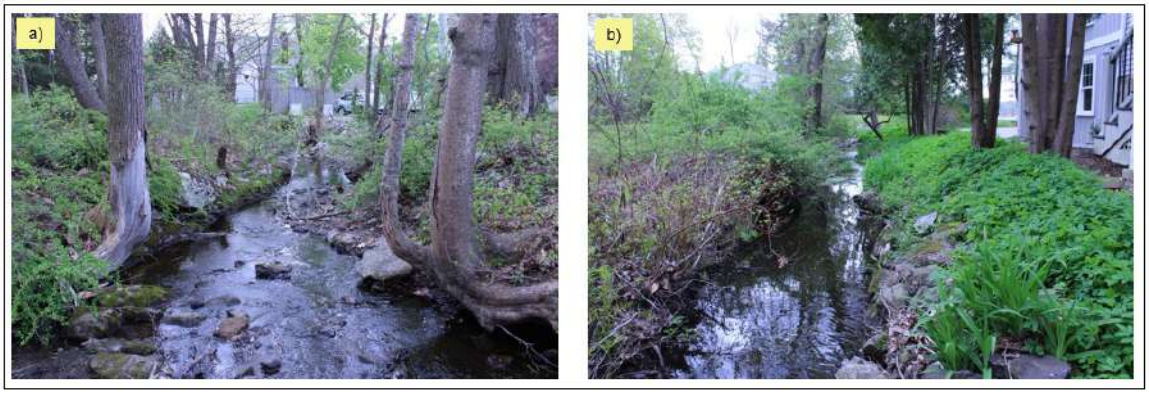


Figure 14. Reach 8 transitions from being a) a wide, shallow channel in the early stages of meander reformation to b) a narrow straightened channel confined by artificial fill downstream.

A restoration priority in Reach 8 is to replace the armoring protecting structures and property on the edge of the channel with natural bank stabilization techniques such as a log crib wall in order to improve stream habitat. The long-ago abandoned meander on the left bank could be reconnected and move the channel away from the parking lot and building currently threatened by erosion. A riparian buffer should be established on both banks just upstream of the Bucknam Road culverts if the landowners were willing. While the likelihood is very low that a blockage of the culvert inlet would lead to the roadside ditch capturing the stream's flow, the potentially severe consequences of such an event warrant monitoring of Reach 8 to ensure loose logs do not block the culvert during a large flood event.

Reach 9 – Bucknam Road to the Railroad culvert

The culvert outlet is misaligned with the channel; the older culvert (Figure 15a) that may have existed prior to the 1940/50's realignment of the channel (Figure 3) is better aligned with the

channel. The right bank is armored at the sharp bend where the newer double culvert outlets. In the upper reach, the channel cascades over ledge and the channel splits into two defined paths. The upstream end of the straighter path appears to be the location of an old mill dam with a tall pile of rock fill on the left bank and a flat millstone in the channel (Figure 15b). The second channel flowing to the right may be the old mill race with a gravel bar with glass and brick where the split channels reconnect.

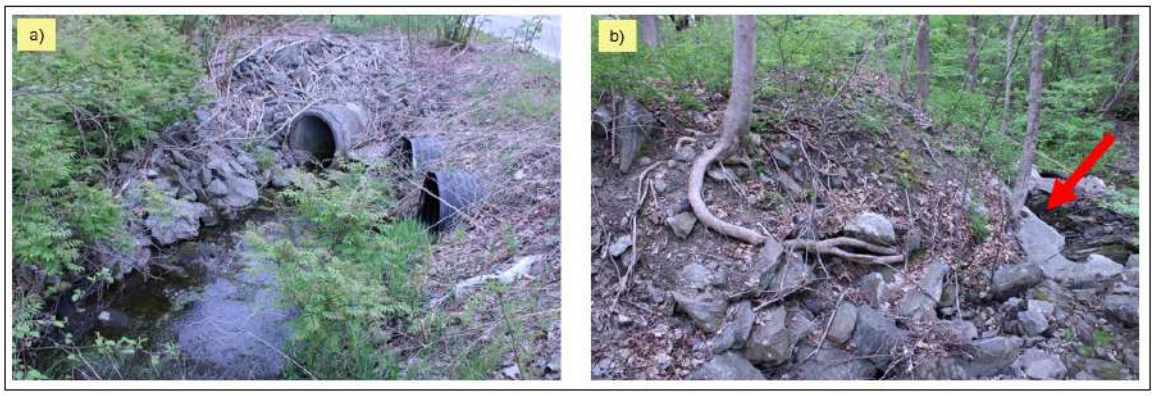


Figure 15. Reach 9 has a) two active culverts at the outlet that are misaligned with the channel and are next to the outlet of a single culvert possibly from prior to 1956 and b) a historic mill built on top of a steep bedrock cascade. The red arrow points to an old millstone.

As the slope of the channel declines downstream of the bedrock falls, the channel widens and a few large, downed trees span the channel. Meanders are reforming on the straightened channel with the deposition of sand and gravel bars that undercut the opposite bank (Figure 16a). Further downstream, the floodplain becomes a mowed lawn up to both banks with no forested buffer. The eroding right bank is forming a meander upstream of a constrictive pedestrian bridge (Figure 16b) with scoured abutments that are leaning at severe angles. The sediment in the banks through this wide flat grassy area are suggestive of impoundment sediments upstream of a dam with, indeed, evidence of another dam just downstream (i.e., boulders aligned across the channel) where a ledge-controlled channel reenters the forest. (A swale up the left bank valley side slope near this dam is rock lined and may be an old tail race connecting with the other dam upstream or even a canal used to transport goods closer to tidewater where ships could be loaded.)

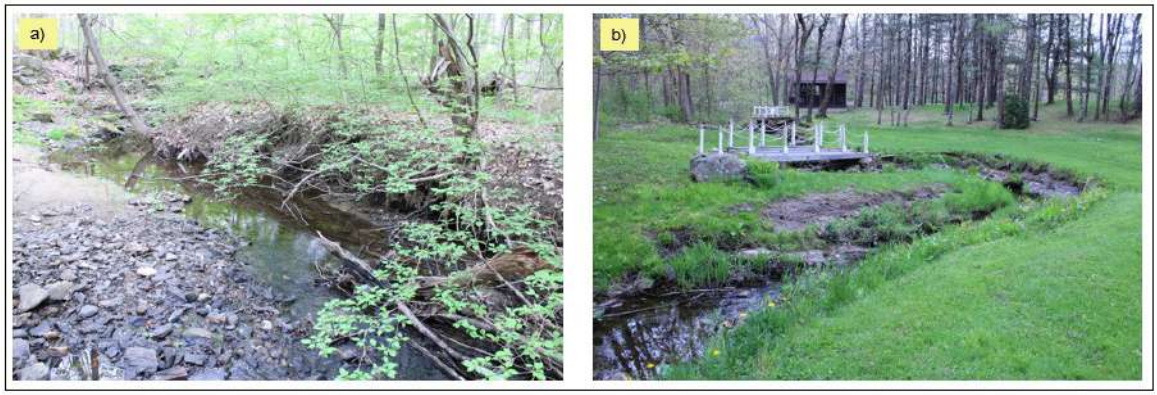


Figure 16. Reach 9 is a) starting to reform meanders along a previously straightened channel before exiting the forest to b) a grassy floodplain with a meandering channel that is eroding rapidly upstream of an unstable, constricting pedestrian bridge.

The bottom section of the reach takes a sharp bend to the right upon encountering the elevated railroad grade that is eroding at the bend (Figure 17a). The creek then flows against the railroad grade on the left bank with the channel slightly incised and both banks eroding but not as severely as at the sharp bend. The substrate is predominately cobble with ledge visible in places on the channel bed. An old telegraph line runs along the railroad with one pole in the center of the stream where further erosion has occurred. Log cribbing lines a short portion of the railroad grade and, at another location, the railroad grade has slumped into the stream. At the downstream end of the reach, the channel takes another sharp 90-degree turn to the left into the narrow box culvert under the railroad tracks (Figure 17b). Due to the significantly undersized culvert width, a small stick jam has formed at the inlet, leading to fine-sediment deposition upstream. The backwatering upstream of the culvert has prevented the right bank from eroding at the sharp bend.

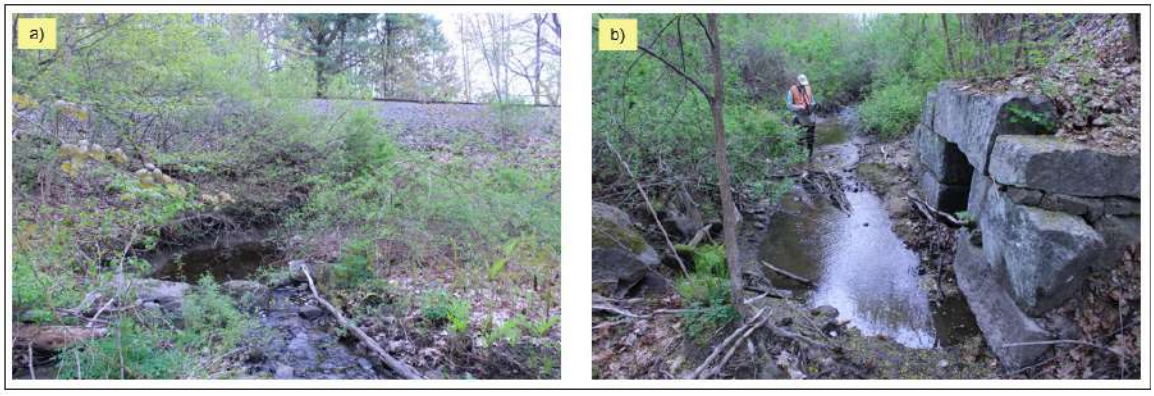


Figure 17. As Reach 9 reaches the railroad, the creek a) erodes into the railroad grade, and then flows parallel to the railroad before taking b) a sharp bend and flowing into an undersized box culvert passing under the railroad.

The entire reach would benefit from the addition of wood in the channel. Chop and drop would be an effective approach for those portions of the reach that run through forested areas with mature trees. While some large logs are resting on both banks, few were low enough in the channel to trap any branches to form jams. Removing the old rock rubble fill around the upper mill dam will make the channel less confined in this steep reach. The portion of the channel that runs through the lawn would benefit from a riparian buffer to provide shade and long-term bank stability if the landowner is interested. Natural bank stabilization techniques such as a log crib wall could be used to reduce erosion, but removal or rebuilding of the pedestrian bridge might be more effective for reducing the rate of meander growth and fine-sediment inputs into the stream.

Reach 10– Railroad culvert to I-295 culvert

The culvert under the railroad drops approximately 10-feet over steep bedrock steps from the inlet to the outlet. The channel drops another 4-feet at the outlet on a series of ledge and boulder steps (Figure 18a). The fill on the steep right bank of the railroad grade is scoured. The floodplain in the upper portion of the reach is forested though limited wood has fallen into the channel. As the channel gradient declines, the substrate transitions from cobble to sand. Historic backwatering and flow impoundment upstream of I-295 impact the lower half of this short reach. Where the channel is reforming a meander in the lower reach, scour on the outer bend exposes clay with a small pebble bar deposited on the inside bend. Wood is exposed in the bed and banks

as the channel incises through impoundment sediment possibly deposited during the construction of I-295 (Figure 18b). The floodplain in the lower portion of the reach is mostly shrubs and grasses with minimal canopy cover over the channel. A large tree has fallen into the channel, trapping twigs to form a small jam. The culvert under I-295 is approximately 4-feet wide by 5-feet tall and is slightly narrower than the width of the channel. Downstream of I-295, the stream becomes tidally influenced and was not included in the geomorphic assessment.

Restoration options are fairly limited in this reach, but wood additions could increase flow complexity. Adding relief culverts to I-295 would provide the greatest benefit by preventing backwatering effects, although such a project would be extremely expensive for limited habitat improvement.

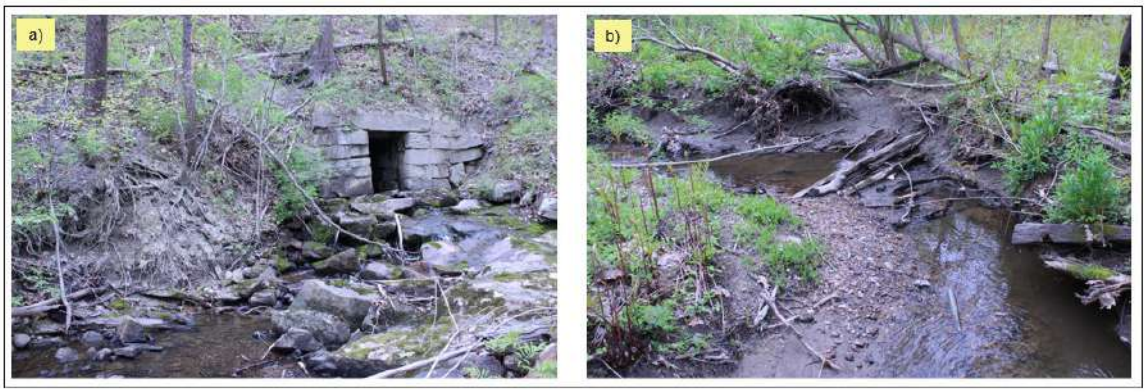


Figure 18. Reach 10 a) outlets out of a steep narrow culvert and scours the railroad grade and b) erodes into impoundment sediment deposited behind the I-295 culvert, exposing old logs and branches.

5.0 DETAILED GEOMORPHIC ASSESSMENT

A more detailed assessment of the stream was completed by: 1) mapping several important channel features observed while traversing the length of the stream and 2) topographic surveying of channel dimensions and conditions in two adjacent segments of Reach 3. The results of the mapping and surveying are described below.

5.1 Channel features mapping

Several channel features were mapped along the stream, including in-stream wood and bank erosion. (In some areas with dense shrub vegetation, walking directly in the channel was sometimes difficult, so the mapping missed some features over short distances.) Table 3 provides a summary of these and other mapped features with the locations provided as ArcGIS shapefiles in the digital supplement to this report. Key features are described below individually. The GIS data can be queried further to determine if associations exist between features such as whether deep pools are typically found at culvert outlets.

Mapped features	Skitterygusset Creek	
	Total	Per mile
Instream habitat features		
Large wood	214	103
Log jams	15	7
Beaver dams	0	0
Channel stability / sediment loading		
Grade controls	13	6
Mass failures	1	0
Eroding banks	45	22
Knickpoints	0	0
Channel bars	28	13
Migration features		
Side channels	1	0
Flood chutes	6	3
Oxbows/cutoffs	4	2
Stream crossings (bridges/culverts)	15	7

Table 3. Summary of mapped channel features. The assessed length of Skitterygusset Creek is 2.1 mi.

Wood serves as a proxy for good aquatic habitat in streams given its association with higher fish populations (Flebbe, 1999), a greater abundance and richness of macroinvertebrates (Bond et al., 2006), pools (Montgomery et al., 1995), and more complex physical habitat in general (Benke and Wallace, 2003). In-stream wood, including log jams that span the channel, was found on all reaches of the stream in varying abundance. Given the narrowness and small size of the stream, log jams are often composed of only small branches rather than large logs. Although perhaps not adequately reflected in the summary of the mapping data, the log jams and other in-stream wood tend to be closely associated with complex flow patterns, pools, and the accumulation of organic rich fine sediments that can serve as a food source for macroinvertebrates. The amount of wood in the stream as a whole is well below the more than 200 pieces/mile targeted by fisheries biologists for even small New England streams (Kratzer and Warren, 2013). Therefore, the channel features mapping reveals a need for increased wood loading on Skitterygusset Creek, even those reaches in well forested areas.

Several bridges and culverts cross the stream (Table 3), including at each of the ten reach breaks. Nearly all of the crossings are undersized (i.e., less than the channel's width) and, thus, impact geomorphic processes and habitat function. During bankfull flows and higher, flow backs up behind the culverts due to their constrictive nature and lead to the accumulation of fine sediment upstream and scour downstream as the sediment-starved waters jet out of the crossings at high velocities. Similar upstream responses are observed where the channel is naturally constricted by bedrock ledge such as in Reach 2 and Reach 9. Where stream crossings are undersized, replacing them with new structures that at least match the bankfull width of the channel and, where the floodplain is wide, include relief culverts will prevent the crossings from continuing to negatively impact geomorphic and habitat function.

The overall amount of bank erosion along the stream is not significant. While numerous areas of erosion are observed along the stream (Table 3), they tend to be of short length and are almost always associated with human disturbances such as: a) on the outside bends of meanders in backwater areas upstream of undersized crossings (Figure 16b), at artificially hard bends created by channel straightening (Figure 17a), where the channel is reforming meanders along straightened channels (Figure 16a), at culvert outlets (Figure 18a), or where the floodplain has been constricted by fill (Figure 9b). Rock armor (i.e., riprap) for bank stabilization also tends to be located in the same areas in order to address these erosion issues, although nature-based stabilization solutions should be considered in the future as needed. Where forested, trees are often undermined by the erosion (Figure 14a) and sometimes fall into the stream, so the erosion can serve as a source of wood inputs to the stream channel. The erosion observed on the stream largely reflects natural channel adjustments to past (e.g., straightening) or existing (e.g., culverts) human impacts to the channel. Long continuous areas of erosion associated with a major basin-wide disturbance, such as urbanization, are not observed. As channel adjustments continue in response to the human disturbances to the channel, the amount of erosion will subside and geomorphic and habitat function improve, in part, as a result of wood inputs caused by the erosion.

Abandoned meanders are cutoff from the stream in at least four places (Table 3) and are believed to be the result of past artificial straightening rather than natural processes. As wood is recruited in the channel over time, meanders will reform and the once higher natural sinuosity will be restored. This natural recovery will not be possible where artificial fill has elevated the surface of the floodplain and constrained the channel. In these areas, only restoration, including removal of the fill, will allow natural stream function to return.

5.2 Topographic surveying

Topographic surveying was completed along two adjacent sites on Reach 3 to compare more natural conditions where the floodplain is wide with an area constrained by artificial fill on the floodplain at the DPW facility. The surveys were conducted to measure the channel's bankfull dimensions (Table 4) and document how those dimensions vary between a more natural setting and the altered conditions. By selecting two adjacent sites, changes in the drainage area that might otherwise skew the results are minimal. Plots of the planview, longitudinal profile, and cross sections are provided in Appendix 3. A comparison of Cross Section 4 where the natural floodplain is relatively undisturbed and Cross Section 2 where the fill has been placed on the floodplain to a depth of about 8 ft shows that flood flows spread across the floodplain are constricted by more than 75 percent (i.e., [18/80]x100) by the fill (Figure 19), a significant constriction that has caused the stream to respond with channel incision and bank erosion as described in Section 4.0 above for Reach 3. The survey data were also used to develop conceptual restoration designs, so further details about the surveys are discussed with the developed designs in Section 6.0 below.

Cross section	Bankfull width (ft)	Max depth (ft)	Width/ depth	Channel gradient
1	8.5	1.66	5.1	0.0190
2	6.5	1.1	5.9	0.0022
3	25.0	1.09	22.9	0.0080
4	4.0	0.83	4.8	0.0220
5	7.4	1.15	6.4	0.0047

Table 4. Summary of topographic survey data from Reach 3.

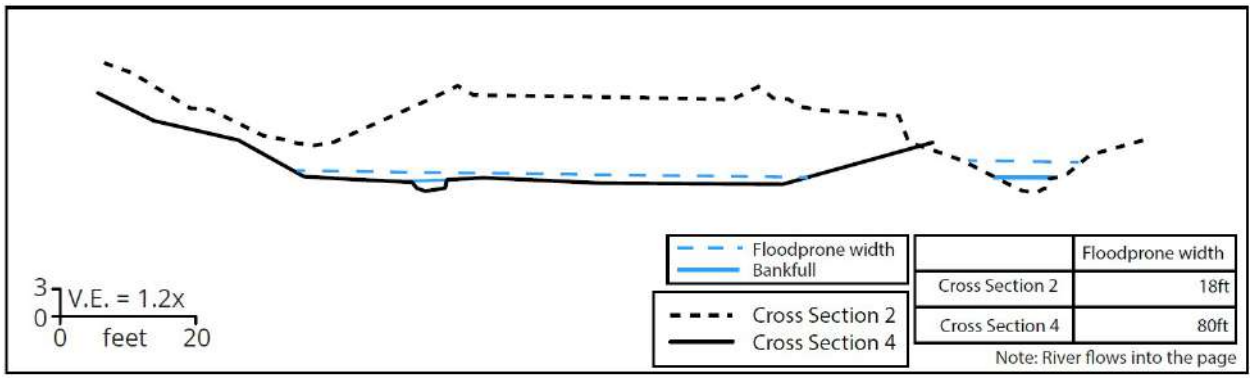


Figure 19. Comparison of Cross Sections 2 and 4 (see Appendix 3 for locations) showing extreme constriction of flood flows (>75 percent) caused by the placement of artificial fill on the floodplain at Cross Section 4. The floodprone width is measured at two times the bankfull depth.

6.0 CONCEPTUAL RESTORATION PLANS

The topographic survey site at Reach 3 (see Section 5.0 above) was also the location for which a conceptual restoration design was developed. The survey data provide the necessary detail on channel dimensions to develop a viable conceptual restoration plan, although issues regarding machine access (that might be difficult though not insurmountable) and other details are not addressed. Reach 3 was selected for the potential to: 1) restore natural processes, 2) address channel instability and habitat degradation, and, as a whole, 3) exemplify restoration strategies and in-stream structures that might be effective elsewhere on Skitterygusset Creek. The restoration plan represents a more complex and costly project with more simple and inexpensive approaches appropriate in other reaches listed in Table 2. The conceptual restoration design for Reach 3 is described below and presented in Appendix 3 with the associated survey data. Restoration ideas for other reaches where concepts were not developed (see Table 2) and are considered too expensive or complex to be completed for environmental purposes only (e.g., replacing culverts at major roads) should be placed on a "watch list" such that when funding becomes available for other purposes (e.g., improve safety of an aging culvert), these "watch list" restoration ideas can be presented to the project designers to ensure environmental concerns at these sites are considered simultaneously.

Reach 3 begins at the outlet of the Woods Road culvert near the Falmouth Police Station and is initially confined. The first site of the survey and concept design begins downstream where the

stream flows across a wide floodplain (Appendix 3). Although much of the channel through this unconfined area was artificially straightened and a large meander loop abandoned, meanders are beginning to reform as natural channel adjustments across the floodplain are possible. The second site of the survey is immediately downstream where artificial fill associated with the DPW facilities has constricted the floodplain by more than 75 percent (Figure 19) and has led to the most severe and extensive channel incision and bank erosion anywhere on Skitterygusset Creek.

The conceptual design includes restoration elements at both survey sites (Appendix 3). The unconfined area upstream has the ability to restore its original pre-straightening sinuosity but will require decades to do so naturally as in-stream wood loading will increase only as the floodplain forest slowly matures. To accelerate the natural recovery process, the conceptual design envisions adding wood into the channel with four types of log structures: 1) log sills, 2) isolated logs, 3) marginal log jams, and 4) a single channel-spanning log jam. The channel-spanning log jam will cross the full width of the existing channel just downstream of the entrance to the old cut-off meander in an attempt to reactivate the old meander. Two marginal log jams will be built just upstream to divert flow towards the entrance of the old meander. Isolated logs partially buried in the channel are proposed for the length of channel downstream of the channel-spanning log jam and the reentry point of the old meander. These isolated logs should create enough roughness in the existing channel to encourage the reactivation of the old meander. Sediment accumulated in the old meander could be excavated to further ensure its reactivation (not depicted in Appendix 3). Log sills, consisting of a single log protruding from the bank of the channel will redirect flow passing over them to help encourage the growth of incipient meanders already forming along the straightened channel. Increasing the channel's sinuosity with these restoration techniques will reduce stream velocities, retain more in-stream wood, store more sediment, improve flow complexity, and, as a result, lead to the faster recovery of habitat and geomorphic function in the reach and further downstream.

The site confined by artificial fill immediately downstream has had a significant impact on the channel's morphology and natural recovery is unlikely. The cross section with the greatest bankfull depth is in the confined area (i.e., Cross Section 1), reflective of the ongoing channel incision (Table 4). The highest bankfull width (i.e., Cross Section 3) is immediately upstream of the constricting fill where flows are backwatered, resulting in deposition of a mid-channel bar and formation of a flood chute (Appendix 3). However, the most telling impact of the artificial fill and resulting channel response is the degree to which flood flows are constricted (Figure 19). The conceptual restoration design for this downstream site envisions the removal of the fill and excavation of a new sinuous channel across the restored floodplain surface (Appendix 3). The final design phase will establish in greater detail the dimensions and sinuosity of the channel with the unconfined upstream site (including the cut-off meander) potentially serving as a reference reach despite the past straightening. The meanders developed in the newly excavated channel should not be armored but instead should include log sills (as well as the other log structures listed above) to encourage meander growth and future channel migration. Creating a dynamic, rather than a static, channel will be key to restoring geomorphic and habitat function in the currently constrained portion of the reach.

7.0 CONCLUSIONS

Human activities, past and present, on Skitterygusset Creek in Falmouth, Maine have, at least locally, constrained natural processes and degraded habitat quality. In-stream and floodplain activities by humans include the construction of dams, placement of artificial fill on the floodplain, artificial channel straightening, and construction of undersized stream crossings. Along with the indirect contribution of past land clearance (limiting forest age and wood recruitment) and the excess (and concentration of) runoff from impervious surfaces (particularly in the lower watershed), these various human activities have led to the degradation of aquatic stream habitat as reflected in low wood loadings in the stream, eroding stream banks, and the excess deposition of fines in areas of impounded flow that have wetland rather than fluvial characteristics. While most of the stream's length is largely stable, the generally short lengths of degraded habitat, often in the immediate vicinity of undersized culverts, lead to the isolation of larger areas of much better habitat elsewhere on the stream.

Restoration ideas were developed for each reach to address the human impacts observed (Table 2) with more detailed conceptual restoration designs developed for two adjacent segments on Reach 3 (Appendix 3). In areas with low wood loadings, far from any infrastructure and with a forested buffer, the "chop and drop" approach of directionally felling trees into the stream channel represents the quickest, cheapest, and most effective approach to improve cover habitat, flow complexity, and retention of sediment. Constructed marginal log jams or channel-spanning log jams can be used to encourage meander growth or reoccupation of abandoned meanders along artificially straightened channels, while log crib walls are recommended for addressing bank scour at the outlets of undersized culverts and other areas of bank erosion that threaten infrastructure. Where larger wood structures are not practical, isolated logs and log sills can be utilized to improve habitat conditions with minimal impact to the existing channel morphology or nearby infrastructure.

The various wood-based measures proposed will provide immediate habitat improvements on the stream. Sustaining those improvements, however, will depend on removing constraints to natural channel adjustment such as the resizing of culverts narrower than the stream channel (with the culvert at Bucknam being the highest priority given the low but extreme risk of stream capture along the steep roadside ditch) and artificial fill removal (with the fill at the DPW facility a high priority given the extent of ongoing channel incision and bank erosion). Only through a concerted effort over time, starting with the easiest and most inexpensive projects first while the capacity is developed to address the larger more complicated projects, can the Town of Falmouth prevent Skitterygusset Creek from being listed as an urban-impaired stream by the Maine Department of Environmental Protection. The natural conditions on the stream, particularly the presence of a floodplain and fine-grained bank sediments in most areas, ensure the stream will respond positively to the various restoration efforts proposed.

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TABLE 2

(Reach summary)

Table 2. Summary of reach characteristics and restoration options for Skitterygusset Creek. Note: Reach lengths measured from topo map and not based on field mapping.

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
1	Falmouth Spur to Woods Rd	1640	- Cobble substrate with ledge in places - Forested floodplain but limited wood in channel - Large cattail marsh upstream of Woods Rd	- Rock wall and rock pedestrian crossing - Undersized culverts lead to backwatering	1) Remove rock walls 2) Build a pedestrian crossing above the channel 3) Add floodplain relief culverts	1) Very low 2) Very low 3) Moderate	1) High/Low 2) High/Mod. 3) High/High	
2	Woods Rd to Woods Rd	667	- Pooled water at inlet - Transitions to steep, confined, boulder-step channel in the forest - No channel-spanning jams that alter flow	- Boulder armor next to solar field/landfill - Leachate on organic substrate - Undersized culvert	1) Remove boulder armoring 2) Enlarge and realign downstream culvert 3) Wood additions	1) Very low 2) Moderate 3) Very low	1) Low/Low 2) High/High 3) Low/Low	
3	Woods Rd to Falmouth Spur	1,734	- Small ledge falls - Abandoned meander cut-offs - Abundant wood in places	- Poorly aligned culvert - Road grade prevents sinuosity & is eroding - Fill of DPW impinges on floodplain - Undersized culvert	1) Stabilize road grade 2) Reconnect channel to old meanders 3) Remove DPW fill and armoring 4) Enlarge culvert/add relief culverts	1) Low 2) Low 3) High 4) Watch list	1) Mod./Mod. 2) Mod./Low 3) High/High 4) High/High	
4	Falmouth Spur to Coles Village Rd	1208	- Wide, shallow channel - Limited sinuosity - Small branch jams but no large wood	- Fill on floodplain - Powerline on bank - Undersized culverts - Excess nutrients lead to aquatic veg growth	1) Wood additions 2) Enlarge culvert	1) Very low 2) Low	1) Mod./Low 2) High/Mod.	
5	Coles Village Rd to Skitterygusset Dr	246	- Lack of floodplain - Cobble substrate - Limited wood	- Historically straightened channel - Undersized culvert	1) Wood additions 2) Add relief culverts	1) Very low 2) Moderate	1) Mod./Low 2) High/Mod.	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert. A best estimate given in parentheses for each reach and includes design, permitting, and construction costs

† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

Table 2 (continued). Summary of reach characteristics and restoration options for Skitterygusset Creek. Note: Reach lengths measured from topo map and not based on field mapping.

Reach #	Location	Length (ft)	Conditions	Human alterations	Restoration options	Anticipated cost*	Priority/Complexity†	Ground photo
6	Skitterygusset Dr to Mitchellwood Dr	458	- Backwatering from a channel-spanning jam - Narrow, confined channel - Abundant wood	- No riparian buffer next to yards - Bank armoring	1) Add riparian buffers 2) Remove armoring and replace with log crib wall 3) Resize culvert	1) Very low 2) Low 3) Moderate	1) High/Mod. 2) Low/Mod. 3) High/Mod.	
7	Mitchellwood Dr to Middle Rd	354	- Wide, shallow channel - Sandy substrate - Limited wood	- Armoring around culverts and on banks - Riparian buffer absent - Artificial bends - Vegetation growth from excess nutrients - Log blocking culvert	1) Add riparian buffers 2) Remove armoring and replace with log crib wall 3) Resize culvert	1) Very low 2) Low 3) Moderate	1) High/Mod. 2) Low/Mod. 3) High/Mod.	
8	Middle Rd to Bucknam Rd	410	- Sinuosity developing - Ledge on banks/ bed - Abandoned meander - Transitions to confined, deep channel - No wood	- Substantial bank armoring - Artificial fill on floodplain - Riparian buffer absent in places - Undersized culverts	1) Replace armoring with natural bank stabilization 2) Reconnect the abandoned meander 3) Add riparian buffer	1) Moderate 2) Moderate 3) Very low	1) High/Mod. 2) Low/High 3) High/Mod.	
9	Bucknam Rd to Railroad culvert	1,482	- Steep with ledge and boulder steps - Wood in places - Sinuosity developing downstream	- Misaligned culverts - Remnant features from mill dams - No riparian buffer along lawn - Eroding railroad grade - Undersized culvert	1) Wood additions 2) Remove mill fill 3) Add riparian buffer 4) Redesign/replace pedestrian bridge 5) Resize RR culvert	1) Low 2) Low 3) Very low 4) Very low 5) Watch list	1) High/Mod. 2) High/Mod. 3) High/Mod. 4) High/Mod. 5) High/High	
10	Railroad culvert to I-295 culvert	237	- Ledge and boulder steps - Limited wood - Cobble to sand substrate - Developing sinuosity	- Eroding railroad grade - Historic I-295 impoundment - Backwatering from undersized culvert	1) Wood additions 2) Add floodplain relief culverts	1) Low 2) Watch list	1) Mod./Mod. 2) Mod./High	

* - Categorized as very low (<$50k), low ($50k-$100k), moderate ($100-$200k), high ($>200k), watch list (cost likely too high to solely complete for restoration purposes so will need to wait for an additional reason to arise to complete work such as a rusted culvert. A best estimate given in parentheses for each reach and includes design, permitting, and construction costs

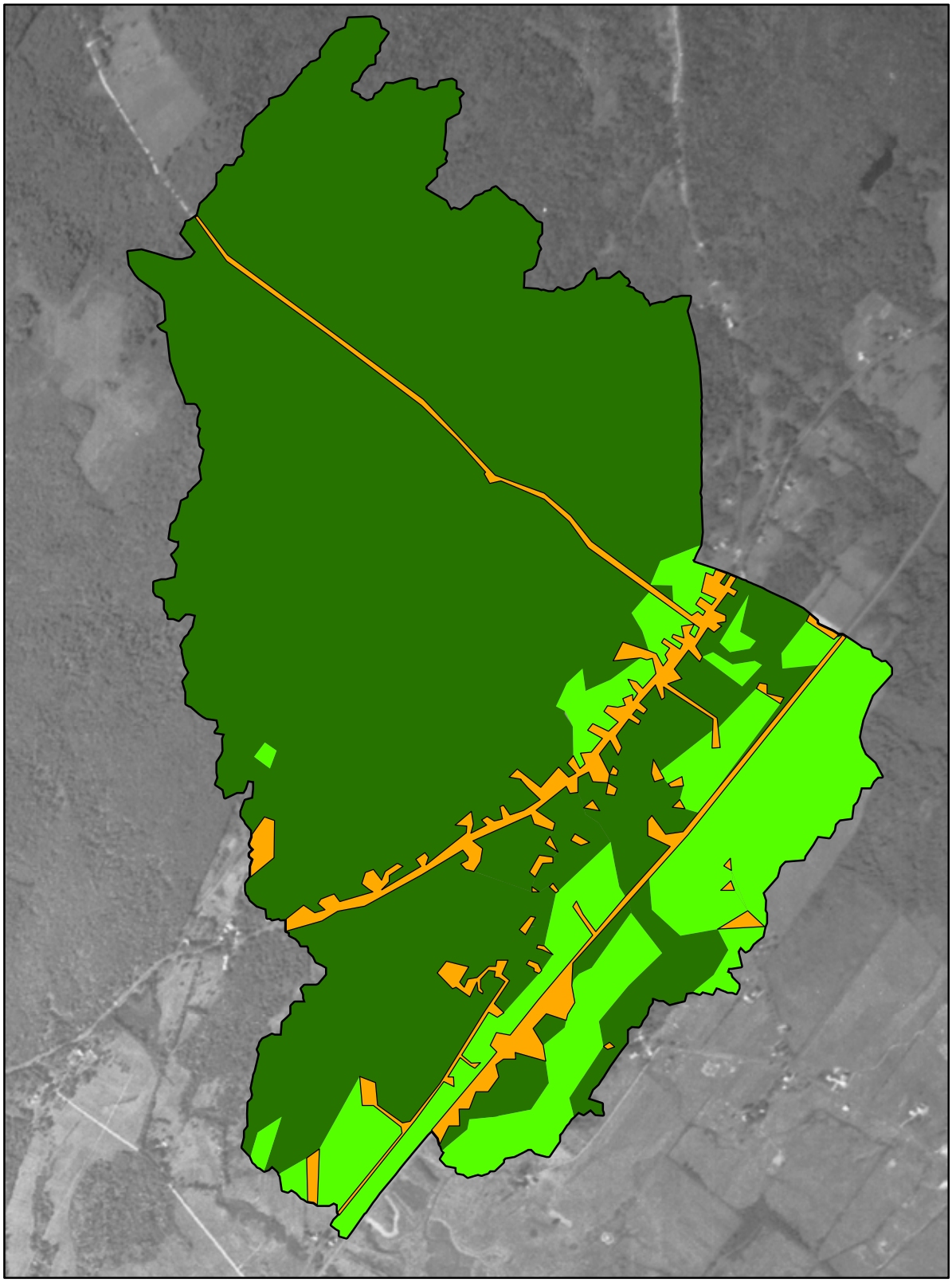
† - Categorized as low, moderate (mod.), or high for both priority and complexity. Complexity considers construction difficulties, potential landowner issues and coordination, and access to site

Note: Suggestions for stream crossing resizing are mentioned generally for only the reach upstream of the structure but typically will also benefit the downstream reach.

APPENDIX 1

(Land use maps)

1940 Land Use for Skitterygusset Creek

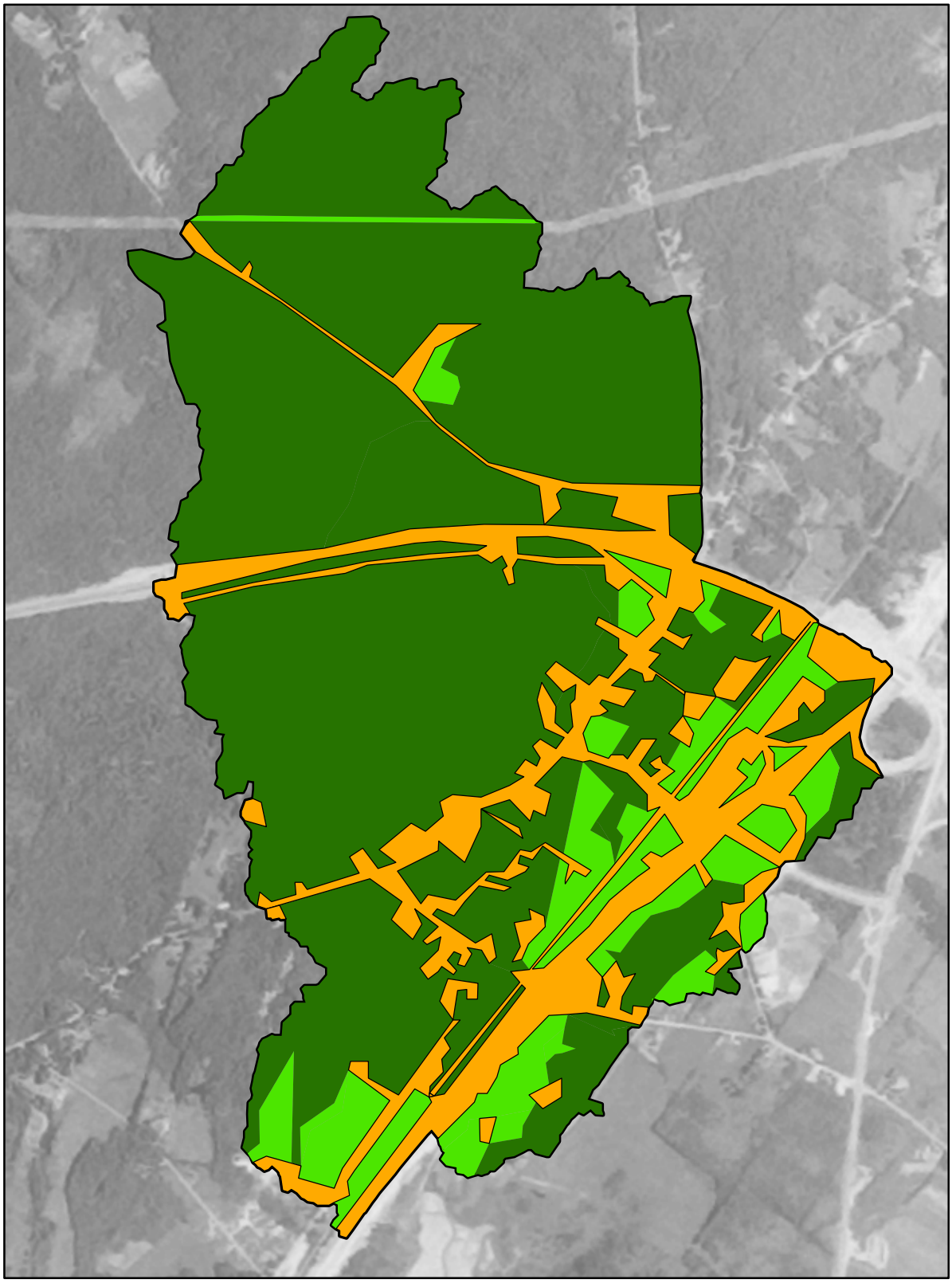


Legend

- Developed
- Forested
- Open Land

0 0.125 0.25 0.5 Miles

1960 Land Use for Skitterygusset Creek

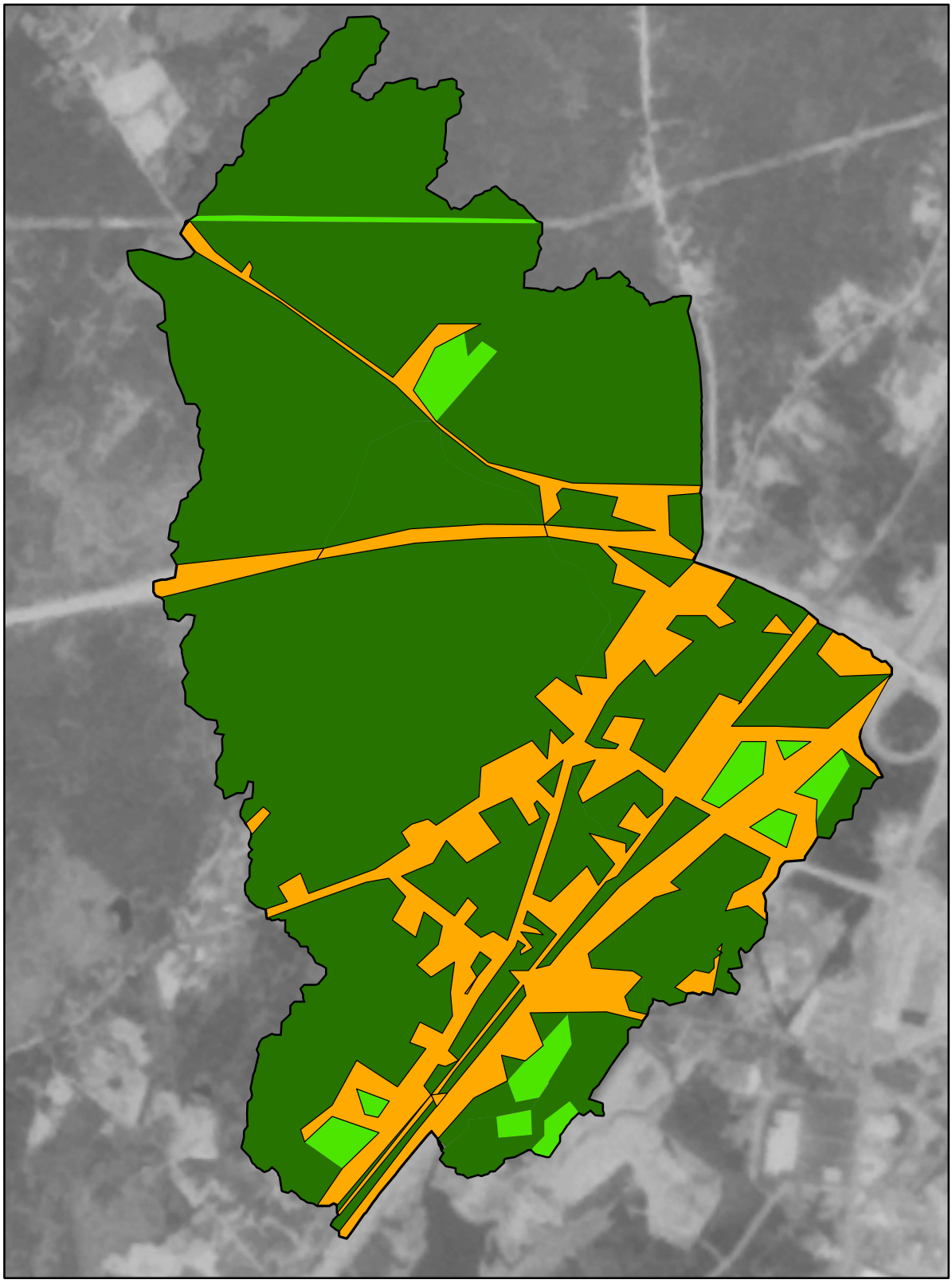


Legend

- Developed
- Forested
- Open Land

0 0.125 0.25 0.5 Miles

1975 Land Use for Skitterygusset Creek

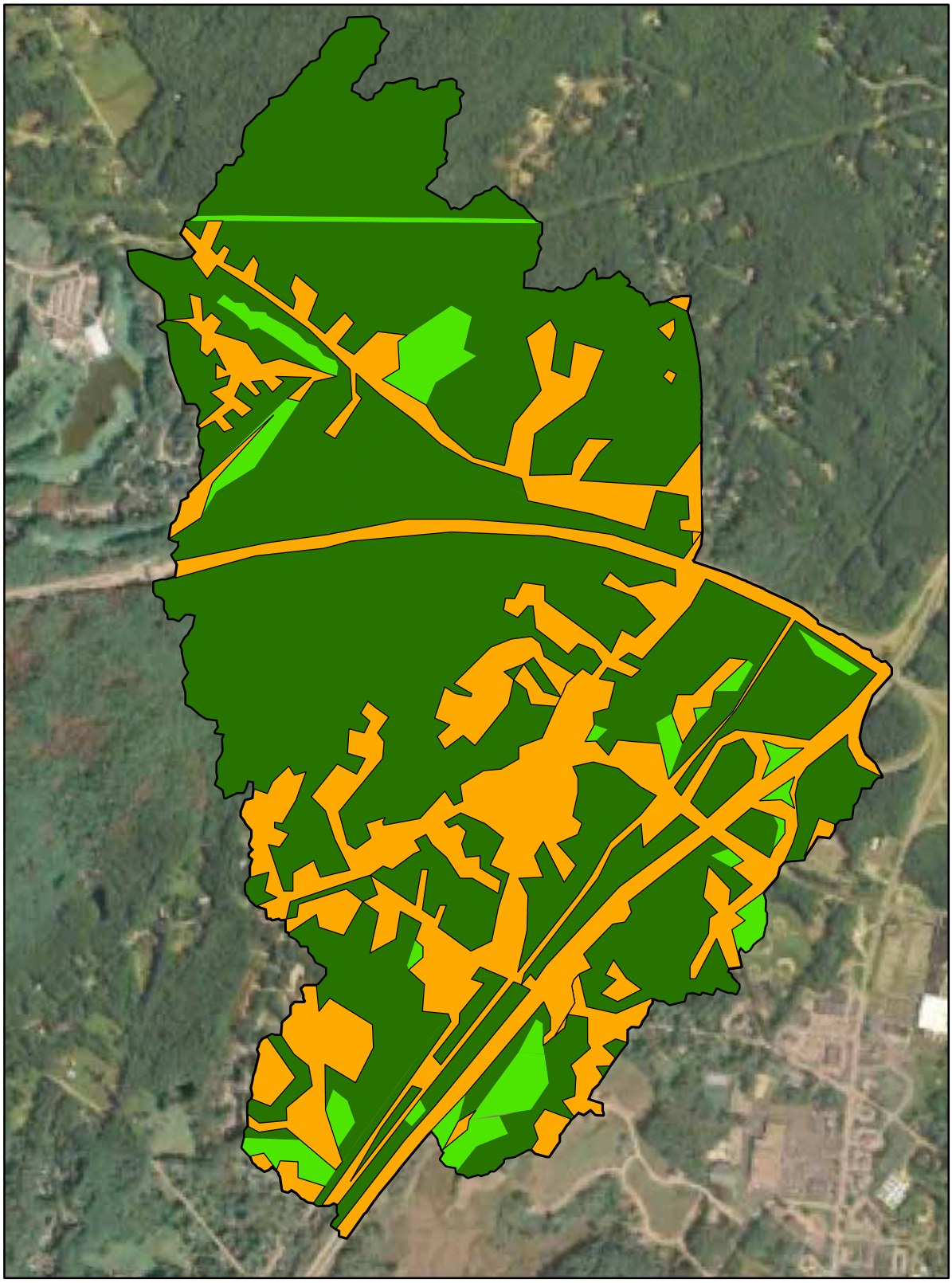


Legend

- Developed
- Forested
- Open Land

0 0.125 0.25 0.5 Miles

2006 Land Use for Skitterygusset Creek

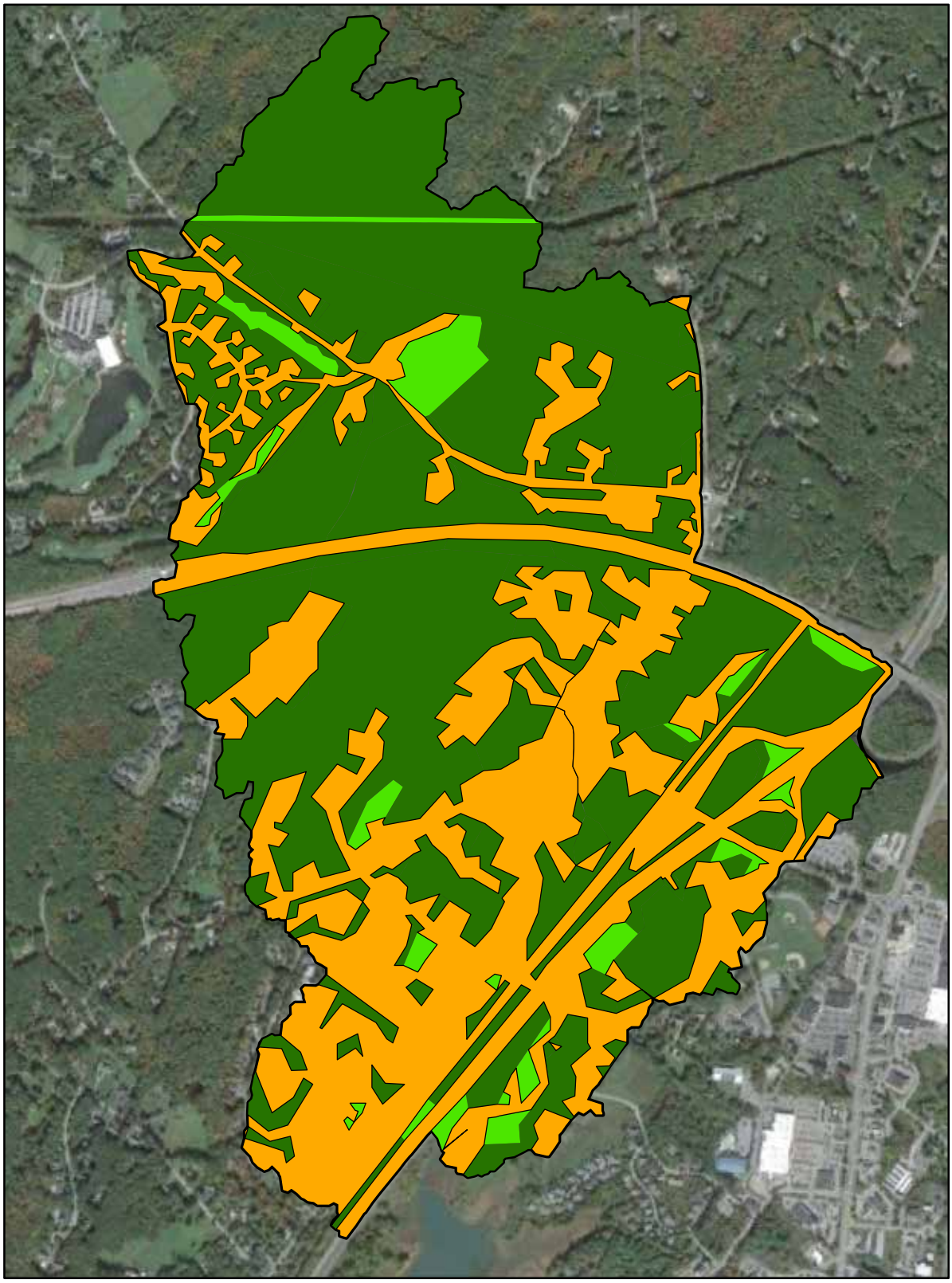


Legend

- Developed
- Forested
- Open Land

0 0.125 0.25 0.5 Miles

2022 Land Use for Skitterygusset Creek



Legend

- Developed
- Forested
- Open Land

0 0.125 0.25 0.5 Miles

APPENDIX 2

(Rapid Geomorphic Assessment forms)

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 1 ***Recorder:*** John Field

Location: Falmouth Spur to Woods Rd ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars		X	
	2	Coarse materials in riffles embedded			
	3	Siltation in pools		X	
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed			
	8	Evidence of deposition in/around structures			
	9	Deposition in the overbank zone			
		Sum of Indices:		2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock			
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases			
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc			
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		1	0.14

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.12

Condition: in regime

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 2 ***Recorder:*** John Field

Location: Woods Rd to Woods Rd ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed		X	
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		X	
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases		X	
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		2	0.29
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc			
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		X	
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		2	0.29

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.23

Condition: transitional or stressed

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 3 ***Recorder:*** John Field

Location: Woods Rd to Spur ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools		X	
	4	Mid-channel bars		X	
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed			
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		X	
	2	Elevated tree roots/root fan above channel bed		X	
	3	Bank height increases		X	
	4	Absence of depositional features (no bars)		X	
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		4	0.57
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		X	
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots		X	
	4	Basal scour on inside meander bends		X	
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach		X	
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		5	0.63
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		X	
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		2	0.29

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.46

Condition: in adjustment

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 4 ***Recorder:*** John Field

Location: Spur to Coles Village Rd ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed		X	
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		4	0.44
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock			
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases			
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc			
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.14

Condition: in regime

Boxes not marked are considered to be a "No"

Field Geology Services
Fluvial Geomorphology

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 5 ***Recorder:*** John Field

Location: Coles Village Rd to Skitterygusset Dr ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials		X	
	7	Soft, unconsolidated bed		X	
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		3	0.33
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock			
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases			
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc			
	2	Occurrence of large organic debris			
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.08

Condition: in regime

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 6 ***Recorder:*** John Field

Location: Skitterygusset Dr to Mitchellwood Dr ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed		X	
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		2	0.29
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock			
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases			
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc			
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = ***in regime***

SI 0.21 – 0.40 = ***transitional or stressed***

SI ≥ 0.41 = ***in adjustment***

Stability Index: 0.11

Condition: in regime

Boxes not marked are considered to be a "No"

Field Geology Services
Fluvial Geomorphology

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 7 ***Recorder:*** John Field

Location: Mitchellwood Dr to Middle Rd ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed		X	
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		2	0.29
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock			
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases		X	
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		1	0.14
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		X	
	2	Occurrence of large organic debris			
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.14

Condition: in regime

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 8 ***Recorder:*** John Field

Location: Middle Rd to Bucknam Rd ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed			
	8	Evidence of deposition in/around structures			
	9	Deposition in the overbank zone			
		Sum of Indices:		0	0
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		X	
	2	Elevated tree roots/root fan above channel bed		X	
	3	Bank height increases		X	
	4	Absence of depositional features (no bars)		X	
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		4	0.57
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		X	
	2	Occurrence of large organic debris			
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		1	0.13
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.18

Condition: in regime

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 9 ***Recorder:*** John Field

Location: Bucknam Rd to Railroad culvert ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars		X	
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed			
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		2	0.22
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock			
	2	Elevated tree roots/root fan above channel bed			
	3	Bank height increases			
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		0	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc		X	
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots		X	
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		3	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes		X	
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		1	0.14

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.19

Condition: in regime

Boxes not marked are considered to be a "No"

Section 2.3.1 **Data Collection Form – RGA**

Rapid Geomorphic Assessment (RGA)

(Part of the Stream Corridor Survey [Level 1])

Date: 5/14/24 ***Sample ID:*** Reach 10 ***Recorder:*** John Field

Location: Railroad culvert to I-295 culvert ***Crew:*** Nic Miller

Form/ Process	Geomorphic Indicator		Present		Score
	Num	*Description*	*No*	*Yes*	*
Evidence of Aggradation (AI)	1	Lateral bars			
	2	Coarse materials in riffles embedded			
	3	Siltation in pools			
	4	Mid-channel bars			
	5	Deposition on point bars			
	6	Poor longitudinal sorting of bed materials			
	7	Soft, unconsolidated bed			
	8	Evidence of deposition in/around structures		X	
	9	Deposition in the overbank zone			
		Sum of Indices:		1	0.11
Evidence of Degradation (DI)	1	Channel incision into undisturbed overburden / bedrock		X	
	2	Elevated tree roots/root fan above channel bed		X	
	3	Bank height increases			
	4	Absence of depositional features (no bars)			
	5	Cut face on bar forms			
	6	Head cutting due to knick point migration			
	7	Suspended armour layer visible in bank			
		Sum of Indices:		2	0.29
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc			
	2	Occurrence of large organic debris			
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Toe erosion on both sides of channel through riffle			
	6	Steep bank angles through most of reach			
	7	Length of bank scour >50% through subject reach			
	8	Fracture lines along top of bank			
		Sum of Indices:		0	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chutes			
	2	Single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cut-off channel(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase meander form			
	7	Bar forms poorly formed / reworked / removed			
		Sum of Indices:		0	0

*** Score value = #YES / Total #**

STABILITY INDEX (SI) = (AI + DI + WI + PI) / 4

CONDITION =

SI ≤ 0.20 = *in regime*

SI 0.21 – 0.40 = *transitional or stressed*

SI ≥ 0.41 = *in adjustment*

Stability Index: 0.1

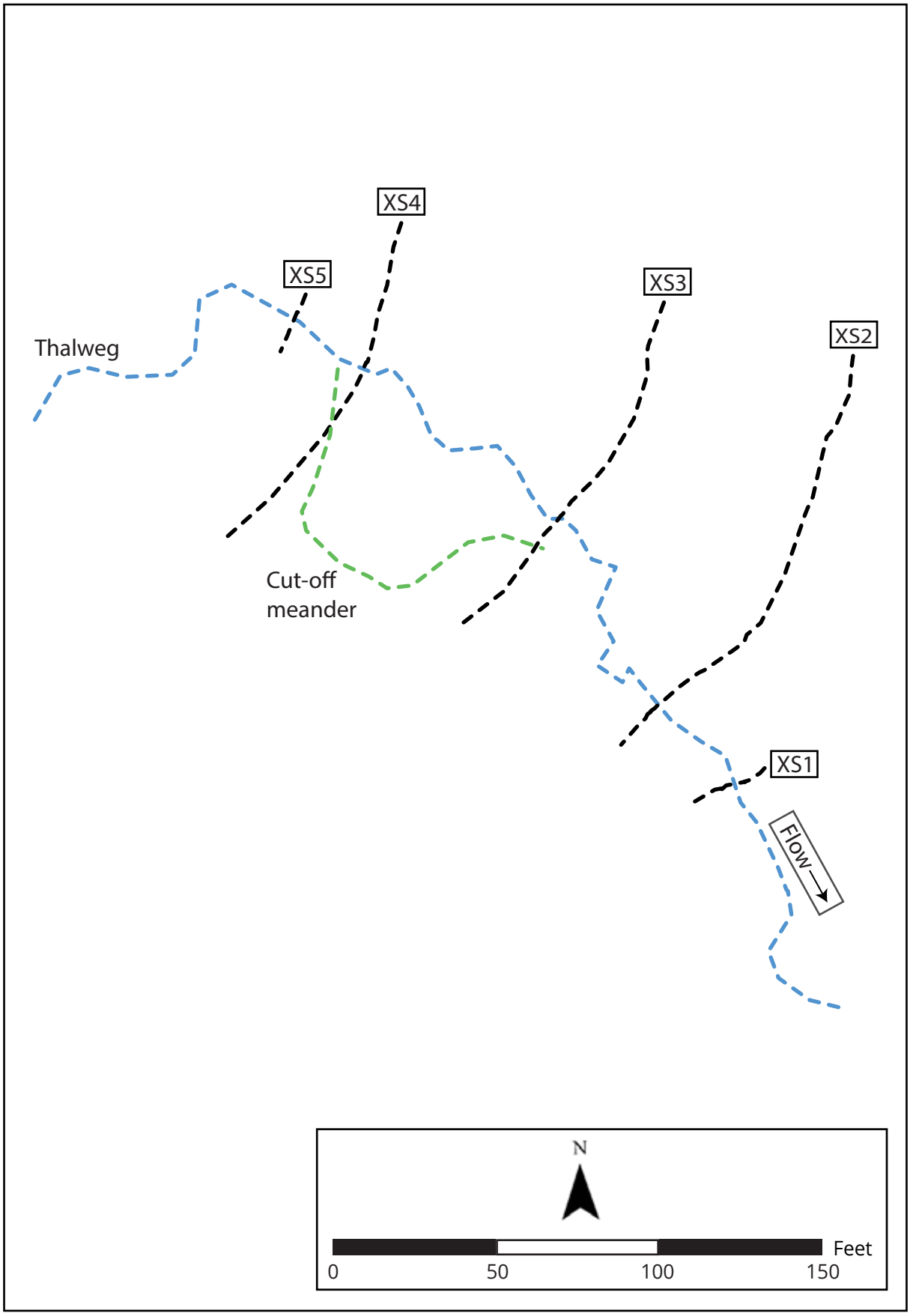
Condition: in regime

Boxes not marked are considered to be a "No"

Field Geology Services
Fluvial Geomorphology

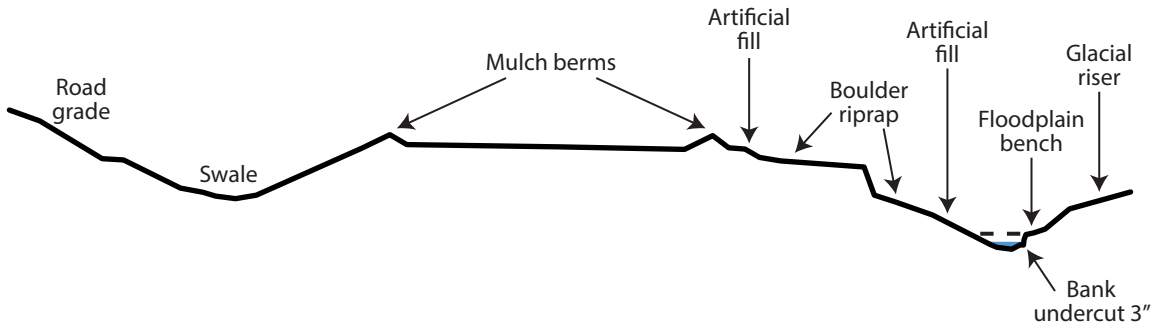
APPENDIX 3

(Survey data and conceptual restoration design)

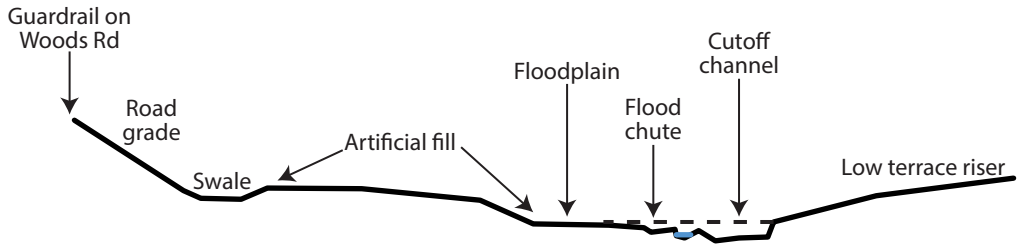


Appendix 3. Skitterygusset Creek - Surveyed planview.

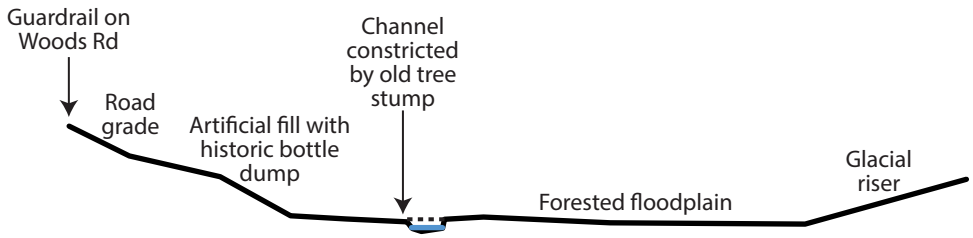
Cross Section 2 - Across Department of Public Works fill terrace

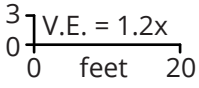


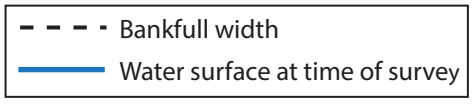
Cross Section 3 - Upstream of fill terrace



Cross Section 4 - Across floodplain



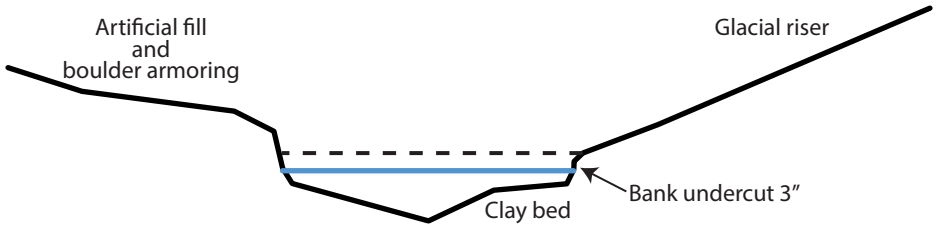




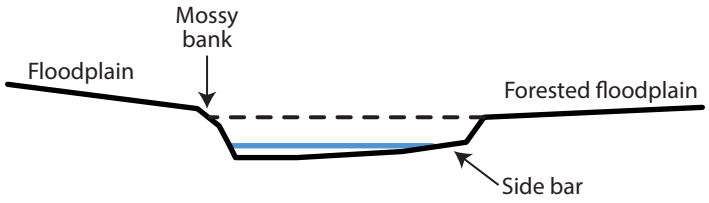
Note: River flows into the page

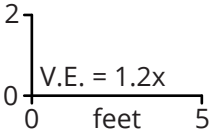
Appendix 3. Skitterygusset Creek - Surveyed cross sections.

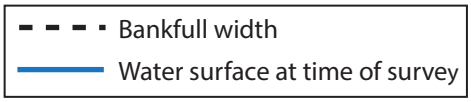
Cross Section 1



Cross Section 5 - Across a straight riffle segment

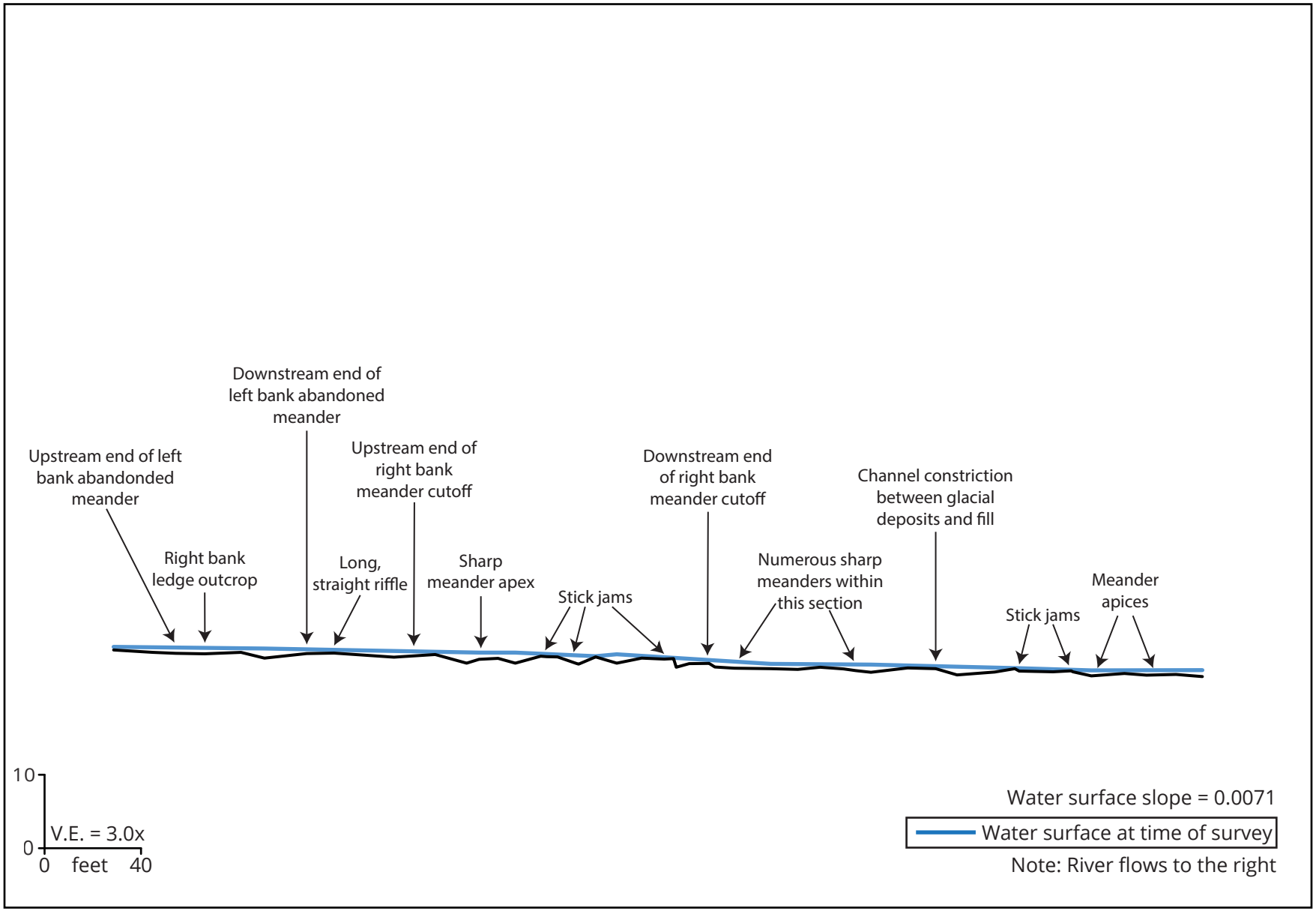




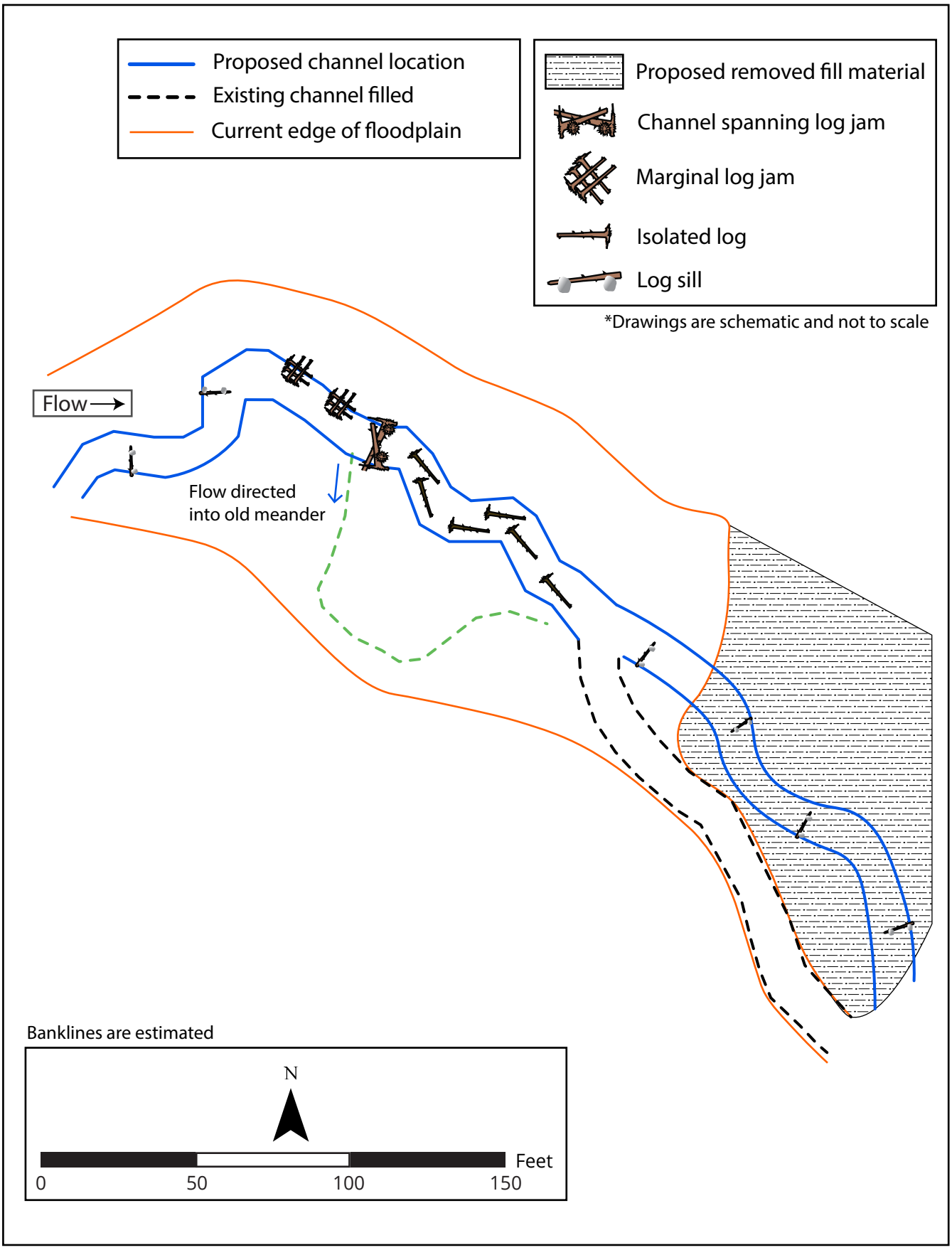


Note: River flows into the page

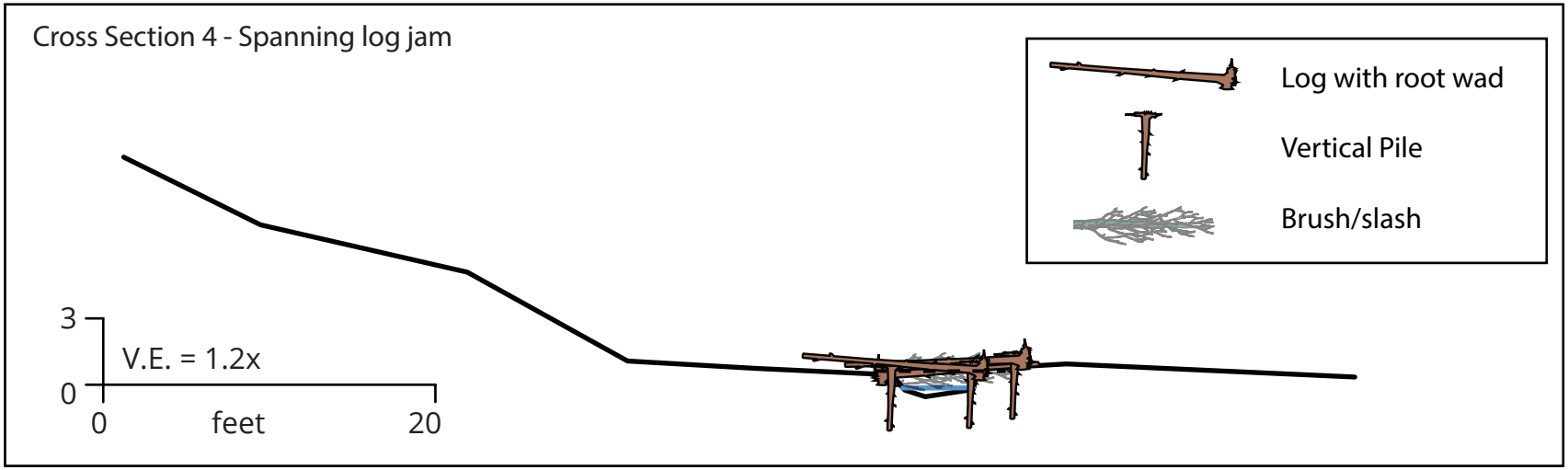
Appendix 3. Skitterygusset Creek - Surveyed mini cross sections of channel.

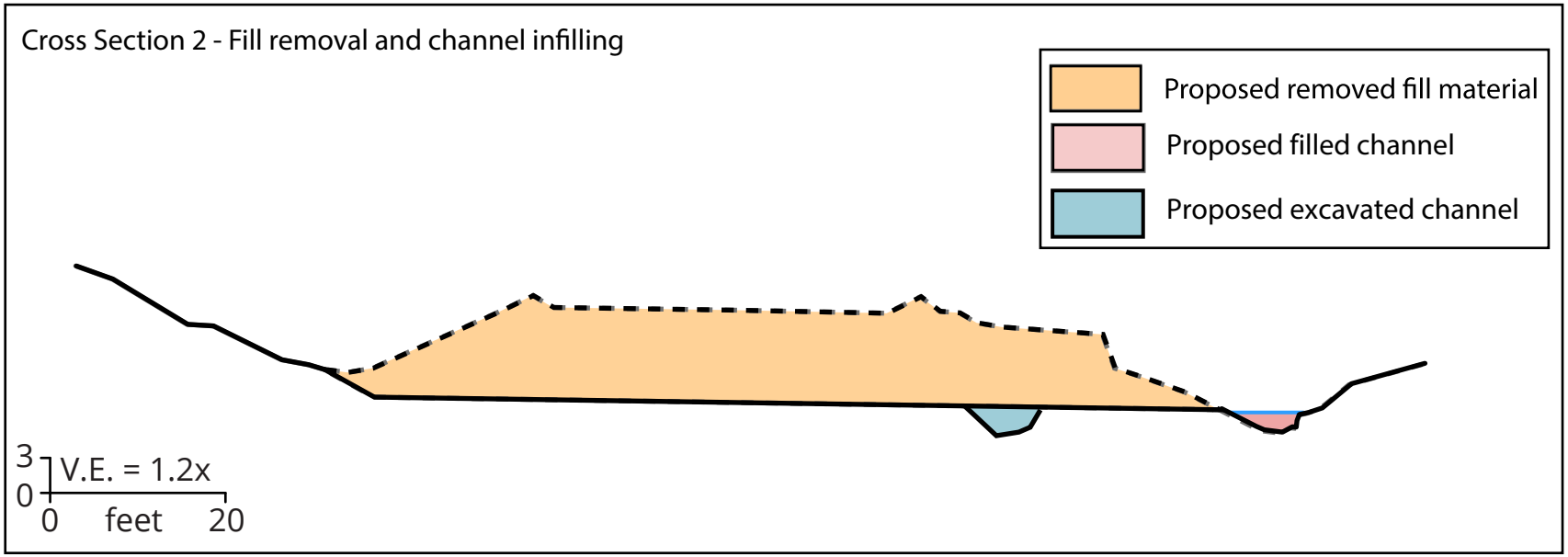


Appendix 3. Skitterygusset Creek - Longitudinal profile.



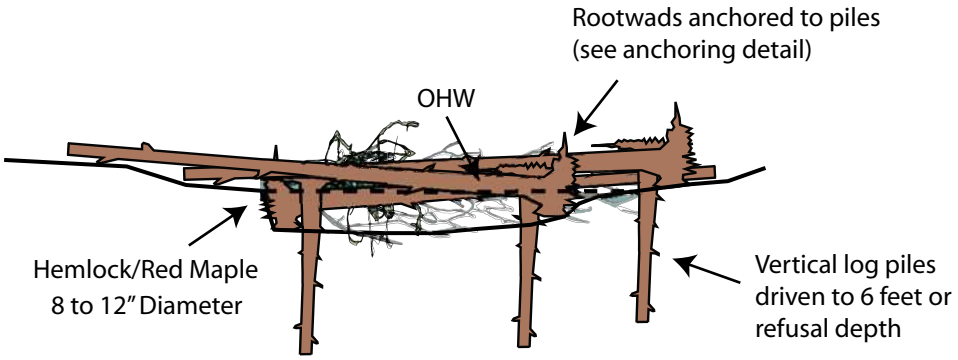
Appendix 3. Skitterygusset Creek - Conceptual restoration design planview.



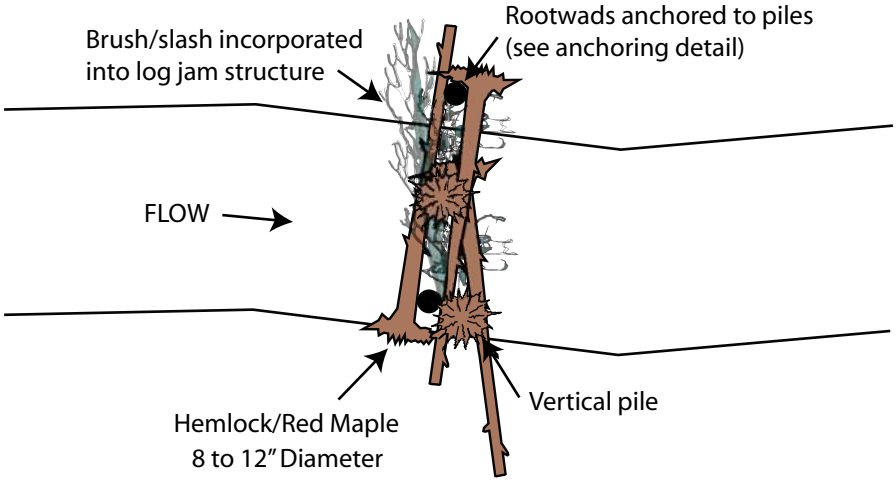


Appendix 3. Skitterygusset Creek - Conceptual restoration design cross sections.

CROSS SECTION VIEW



PLAN VIEW

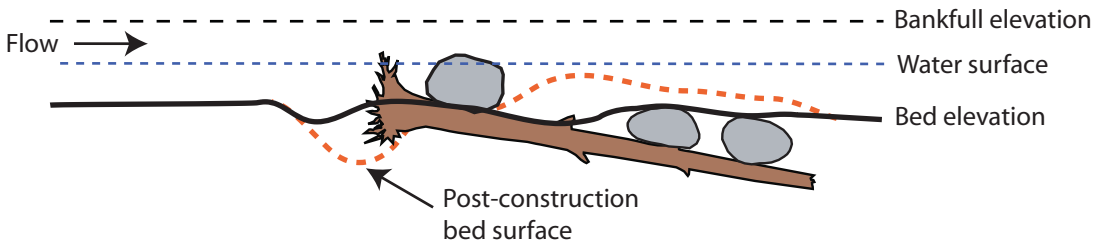




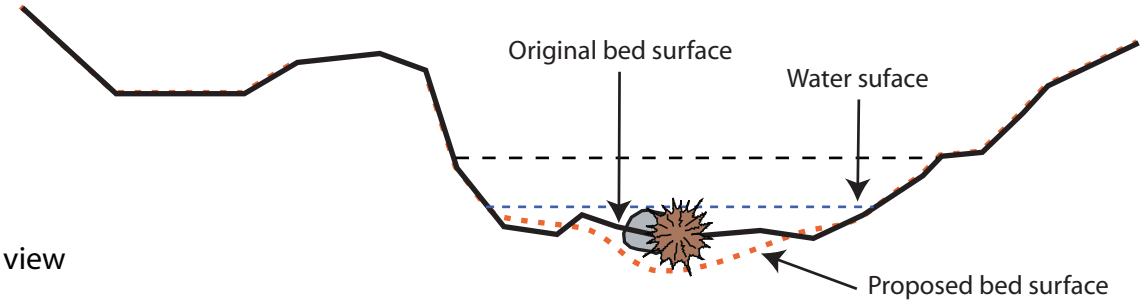
Example photo: Channel-spanning log jam
(Long Creek in S. Portland, ME)

Appendix 3. Channel-spanning log jam design typical.

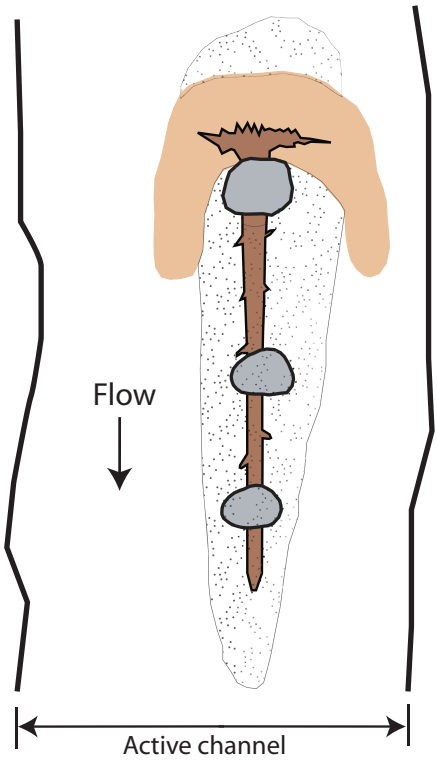
Longitudinal view



Cross section view



Plan view





Legend

Expected deposition

Expected scour

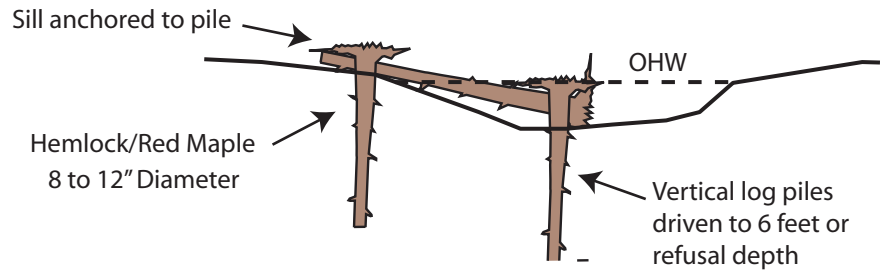
Treatment: Isolated logs

The isolated logs are a treatment where individual logs are added and naturally anchored within the low flow channel. The root wad of each log is faced upstream and remains above the channel bed while most of the attached log (at least 15 ft long) is placed in a trench excavated into the channel bed. The log is anchored when the trench is backfilled over the log with a couple of boulders added for extra stability. The isolated log treatment provides additional roughness and alters the flow velocities to create distinct zones of scour and deposition with pools generally forming upstream of the root wad face and sand/gravel bars downstream along the length of the buried portion of the log.

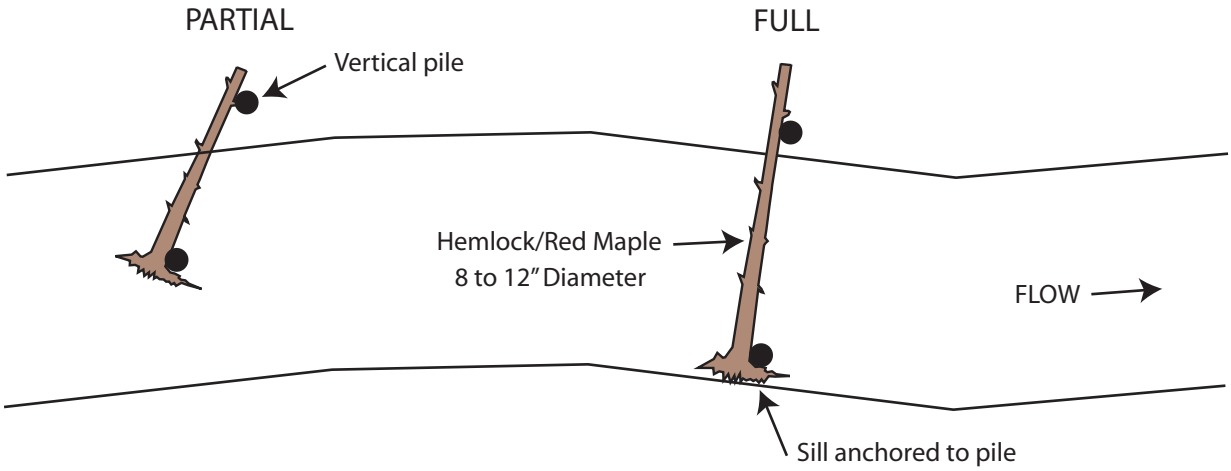
Note: Drawings are not to scale

Appendix 3. Isolated log design typical.

CROSS SECTION VIEW
Partial channel-spanning sill



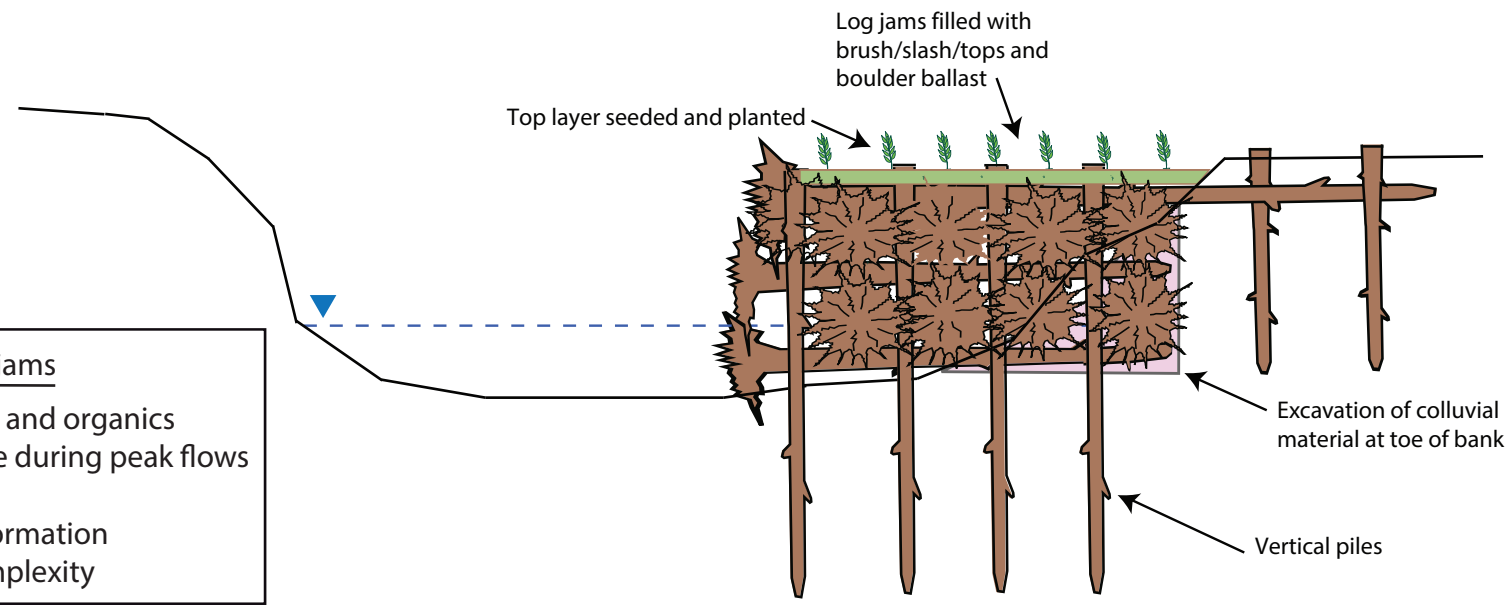
PLAN VIEW





Example photo: Log sill
(Long Creek in S. Portland, ME)

Appendix 3. Log sill design typical.



Goals of marginal log jams

- Trapping of sediments and organics
- Channel margin refuge during peak flows
- Additional roughness
- Encourage meander formation
- Increase planform complexity

Treatment Description

Marginal log jams are built against the channel's banks with multiple log layers stacked in an interlocking fashion and anchored to vertical log piles driven deep below the channel bed. Constructed log jams mimic natural wood accumulations in terms of their form, location and function. Log jams will provide additional roughness and flow complexity at all flow stages, thereby creating zones of deposition and scour in and around the structure.

Log jams shall be constructed during low flow conditions to minimize in-stream disturbances. The success of the structures can be monitored through repeat topographic cross sections, photographs, and biological surveys to identify pool formation, spawning gravel deposition, and increased aquatic organism usage.



Marginal log jam (Nash Stream (NH)

Appendix 3. Marginal log jam design typical.

APPENDIX D: FBE SHORELINE SURVEY REPORT

MUSSEL COVE SHORELINE SURVEY| MEMORANDUM

TO: Justin Early and Theresa Galvin, Town of Falmouth
FROM: Bina Skordas, FB Environmental Associates (FBE)
SUBJECT: Mussel Cove Survey Results
DATE: November 13, 2024

FB Environmental Associates (FBE) was contracted by the Town of Falmouth, to conduct a shoreline survey of Mussel Cove, as part of the development of a watershed-based management plan (WMP) for the Casco Bay Frontal Drainage watershed. The survey was completed on October 10th, 2024, by FBE Project Manager Luke Frankel and technical staff Zachary Ennis. Boating assistance for surveying parcels with ocean frontage was provided by the Town of Falmouth. FBE documented the condition of the shoreline for each parcel using a scoring system that evaluates vegetated buffer, presence of bare soil, extent of shoreline erosion, distance of structures to the ocean, and slope. These scores were summed to generate an overall "Shoreline Disturbance Score" (scores ranging from 3-12) and "Shoreline Vulnerability Score" (scores ranging from 1-6) for each parcel. High scores indicate poor or vulnerable shoreline conditions. Photos were taken at each parcel and were cataloged by tax map-lot number. These photos will provide project stakeholders with a valuable tool for assessing shoreline conditions over time. It is recommended that a shoreline survey be conducted in mid-summer every five years to evaluate changing conditions.

RESULTS

A total of 54 parcels were evaluated along the shoreline of Mussel Cove and the adjacent shoreline from Mussel Cove to Falmouth Town Landing. The average Shoreline Disturbance Score (buffer, bare soil, and shoreline erosion[1]) for the shoreline was 6.67 (Table 1). Twenty-six (26) parcels (48%) received relatively good Shoreline Disturbance Scores (scores 3-6). About 52% of the shoreline (28 parcels) scored **7 or greater** (Figure 1). A disturbance score of 7 or above indicates shoreline conditions that may be detrimental to marine water quality. Ten parcels (18.5%) recorded a Shoreline Disturbance Score of 9 or above with one priority parcel receiving a score of 12. These shoreline properties tended to have inadequate buffers, evidence of bare soil, and shoreline erosion. The average Shoreline Vulnerability Score (slope and setback distance) was 3.76 (Table 1). About 55% (30 parcels) scored a vulnerability score of 5 or greater (Figure 2). High vulnerability scores (5-6) are the most likely to experience erosion issues and indicate that the parcel may have a home less than 150 feet from the shoreline and a moderate or steep slope to the shoreline. Parcels with a vulnerability score of four or greater are also more prone to erosion issues whether or not adequate buffers and soil coverage are present. Two parcels received a maximum vulnerability score of 6 and 12 parcels received a vulnerability score of 5.

The overall shoreline condition of Mussel Cove and the adjacent shoreline from Mussel Cove to Falmouth Town Landing is good (average disturbance score below 7). Improvements can be made to 28 parcels (52%) that would address erosion issues impacting the nearshore environment. Mussel Cove and the surrounding shoreline are prone to erosion due to their location, withstanding both the associated tides and weather.

[1] Shoreline erosion can be from or exacerbated by natural phenomena or human-related activities. Natural phenomena typically include the orientation of the parcel to prevailing winds and subsequent greater wave action, composition of the shoreline bank (whether highly erodible soil material or hardened rocky or bedrock outcroppings), and winter ice damage. Human-related activities typically include motorboating (which generate wakes whose wave energy is dissipated by the shoreline) and shoreline development (which includes retaining walls, beaches, access points, etc.).

Note: When evaluating the shoreline condition of each parcel, we consider the entire length of each parcel's shoreline. Because of this approach, the same shorefront home would score better on a parcel with a long shoreline that was mostly natural buffer compared to on a parcel with a short shoreline that consisted mostly of the developed area. You will notice that a few parcels with long, protected shorelines received lower Shoreline Disturbance Scores because of a relatively small area of disturbance (refer to map).

FBE then used the EPA PLET model to estimate pollutant loadings based on Shoreline Disturbance Scores. Standardized model inputs were used to represent different scores, therefore loading results should be treated as gross estimates. The 28 parcels with elevated disturbance scores (greater than 7), are contributing an estimated **33.75 pounds of nitrogen annually**[2]. Remediation efforts on all properties using a 50% Best Management Practices (BMP) efficiency rate could result in an **annual reduction of 16.875 pounds of nitrogen**.

Table 1. Average scores for each evaluated condition criterion and the average Shoreline Disturbance Score and average Shoreline Vulnerability Score for Mussel Cove and the adjacent shoreline. Lower values indicate shoreline conditions that are effective at reducing erosion and keeping excess nutrients out of the cove. Note: the numbers in parentheses are the range of possible scores for that variable.

Evaluated Condition	Average Score	
Buffer (1-5)	2.96	Average Shoreline Disturbance Score (3-12) **6.67**
Bare Soil (1-4)	1.59	
Shoreline Erosion (1-3)	2.1	
Distance (0-3)	1.5	Average Shoreline Vulnerability Score (1-6) **3.76**
Slope (1-3)	2.26	

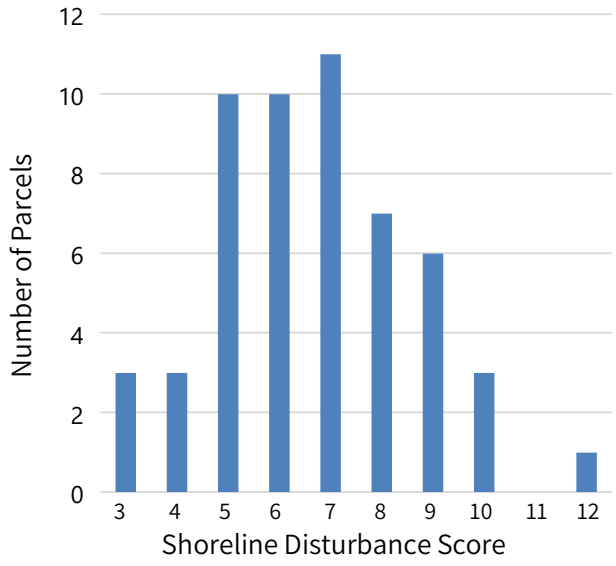


Figure 1. Histogram showing the number of parcels by Shoreline Disturbance Score. The possible range of Shoreline Disturbance Scores is 3-12.

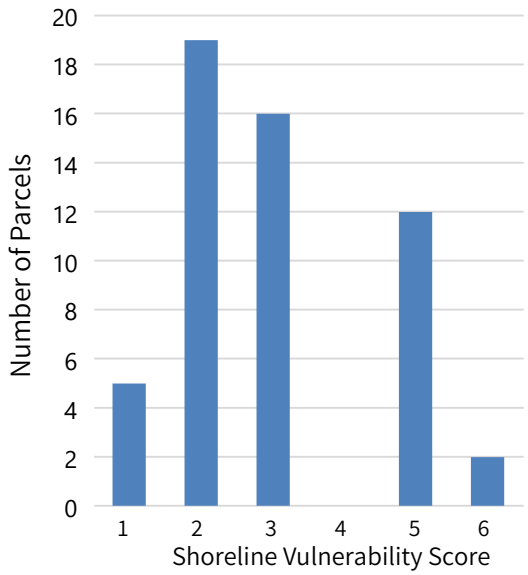


Figure 2. Histogram showing the number of parcels by Shoreline Vulnerability Score. The possible range of Shoreline Vulnerability Scores is 1-6.

[2] Based on PLET model bank stabilization estimate for fine sandy loams, using 50 ft or 100 ft or 200 ft (length) by 3 ft (height) and moderate lateral recession rate of 0.1 ft/yr.

NEXT STEPS

The information obtained from this survey will be used to plan next steps for improving Mussel Cove and the adjacent shoreline to further inform the Watershed Management Plan. The survey map and database highlight areas that are possibly contributing to polluted runoff, and the shoreline scores should be used to prioritize areas of the shoreline for remediation. Recommendations largely include improving shoreline vegetated buffers and reducing concentrated runoff pathways to the water. Encouraging landowners to plant and/or maintain vegetated buffers as a BMP along their shoreline, particularly in areas of bare soil, will help mitigate erosion and reduce sediment and nutrient loading to the cove.

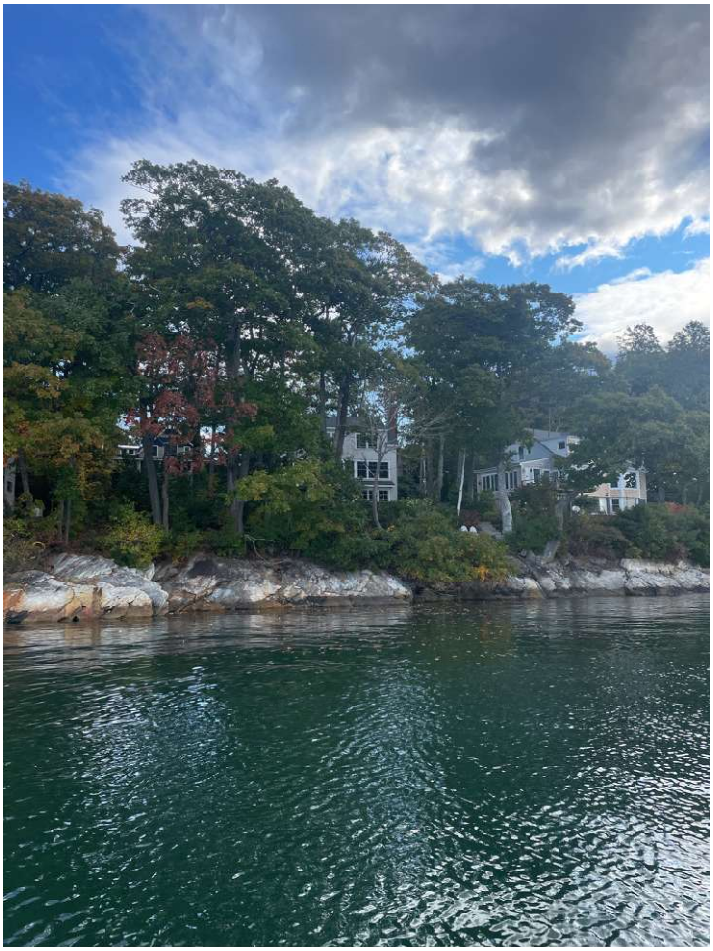
RECOMMENDATIONS

Generally, landowners should be encouraged to revegetate their shoreline buffers with native plants, avoid large grassy lawns, and increase mower blade heights to 4 inches. Woody vegetation with deep rooting structures stabilizes banks and intercepts water flow, allowing it to spread out, slow down, and be filtered by the soil.

- Implement BMPs with a focus on living shoreline solutions. Living shorelines help stabilize the shoreline, reduce erosion rates and storm damage, provide ecosystem services to fish and other aquatic species, and maintain connections between land and water ecosystems to enhance resilience.
    - Vegetation Only: Best for low wave energy environments. Use native plants to dissipate wave energy, slow inland water transfer, increase storm water infiltration, and have a minimal impact on natural ecosystem processes while maintaining an aquatic/terrestrial interface.
    - Edging: Suitable for most areas except for high wave energy environments. Edging uses native vegetation with material options (fencing, erosion control blankets, timber, living reef, etc.) to dissipate wave energy, slow inland water transfer, provide natural habitat, increase stormwater infiltration, and protect wetland edge loss.
    - Sills: Suitable for most areas except for high wave energy environments. Sills use native vegetation in junction with more aggressive material options (stone, sand breakwaters, living reef systems, rock gabion baskets) to provide habitat, dissipate wave energy, slow inland water transfer, increase natural stormwater infiltration, and create toe protection to help prevent wetland edge loss.
- Use survey results to target future implementation efforts on residential shoreline properties.
- Locate willing volunteers to “demonstrate” what an ideal shoreline buffer looks like and how it functions.
- Continue to monitor for bare soil, shoreline erosion, and slope conditions.
- Re-survey the shoreline in 5-10 years when updating the watershed plan.
- For future projects, site-specific recommendations should be made for each lot with engineered designs when needed.

Examples of adequate vegetated shoreline buffers:





Examples of shoreline properties with great vegetated buffers consisting of multi-story canopy (trees and shrubs) and no exposed soil).

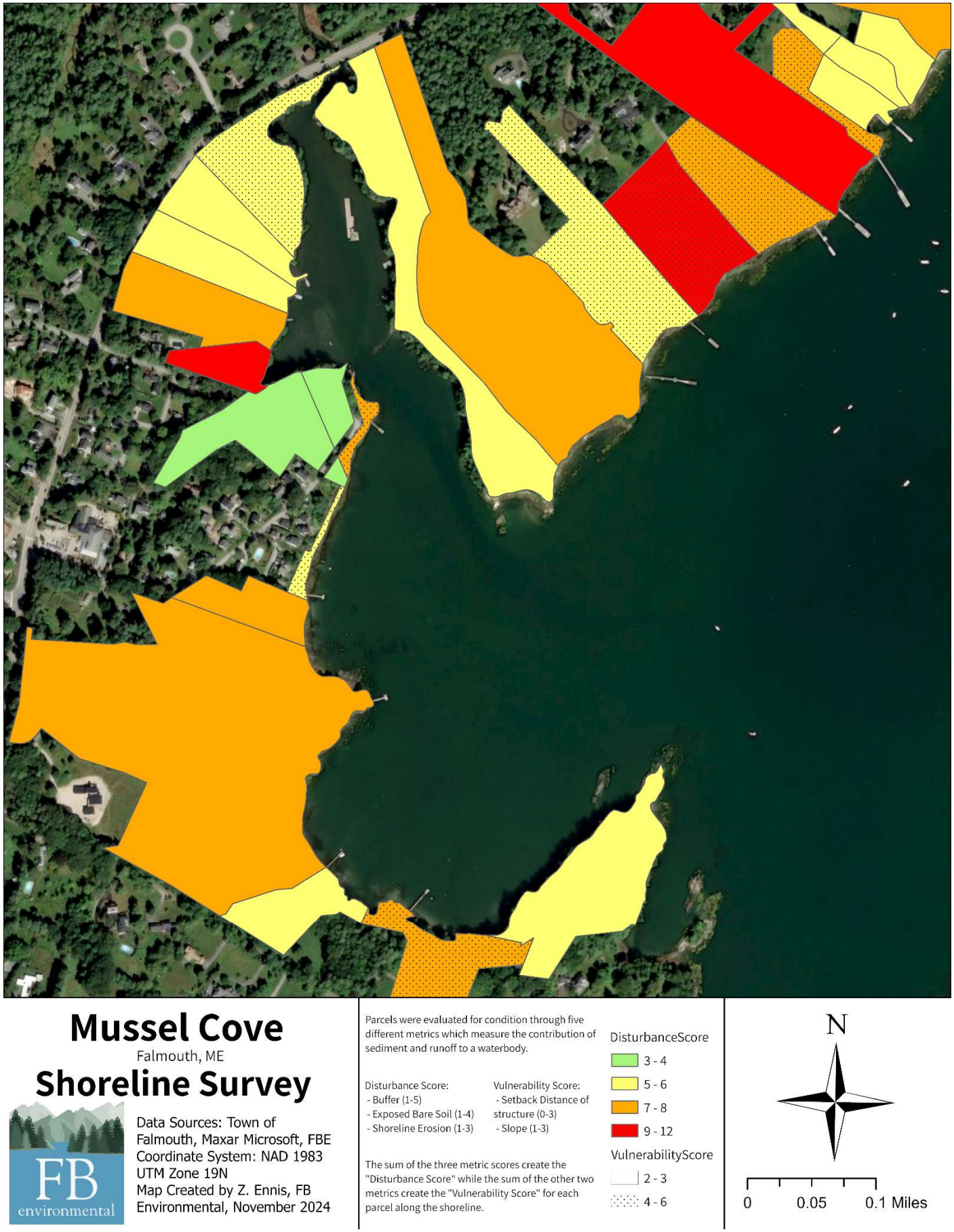


Figure 3. Map of the Mussel Cove adjacent shoreline and shoreline parcels. Scores indicated come from the shoreline survey.

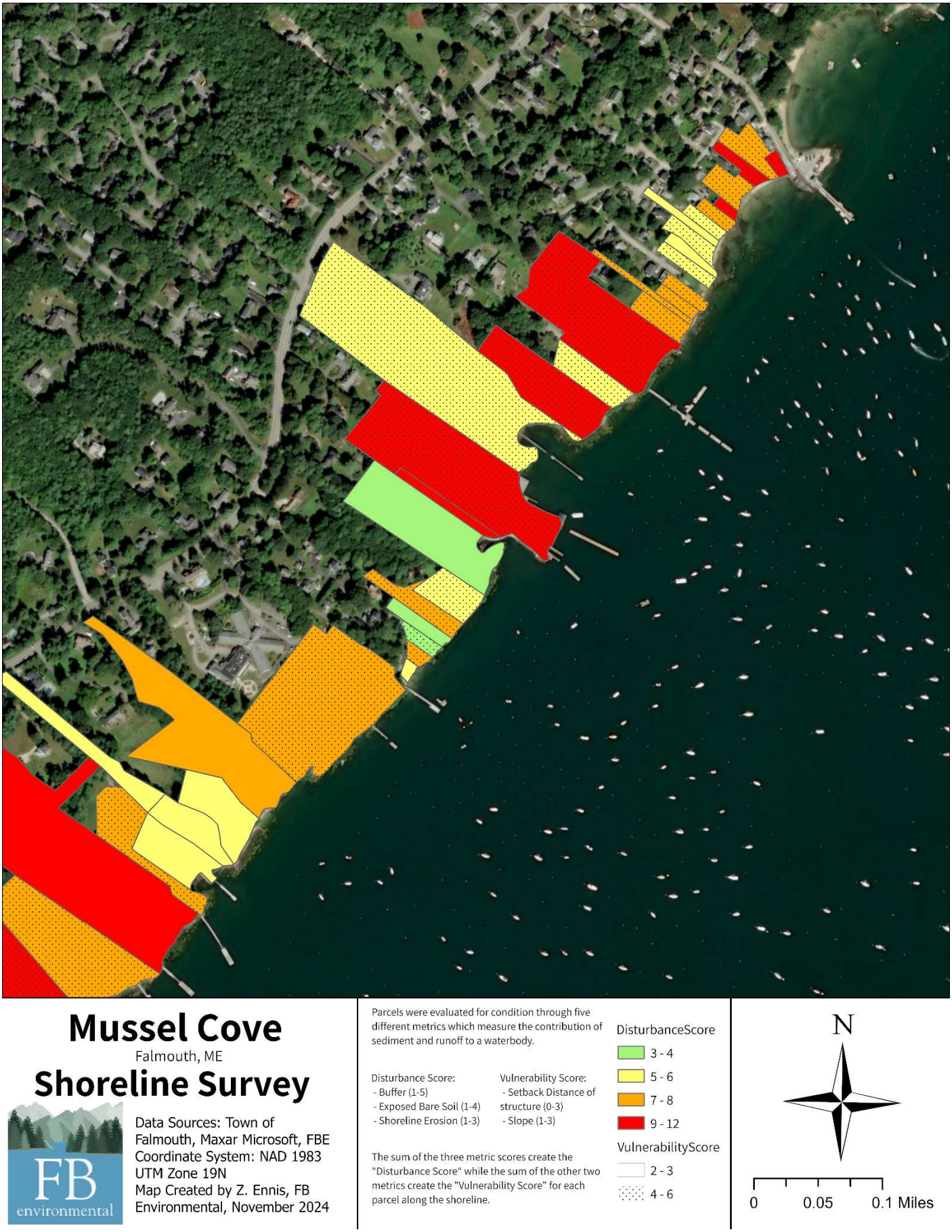


Figure 4. Map of the Mussel Cove shoreline parcels. Scores indicated come from the shoreline survey.