Stream Crossing Survey of the Scarborough Marsh Watershed

Prepared for

Friends of Scarborough Marsh (FOSM)
Scarborough, Maine

Prepared by

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NOTE: Report designed for online viewing using a PDF file reader such as *Adobe Reader*. Please use the program's ***Zoom*** feature to enhance viewing of figures and some tables

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1.0 INTRODUCTION

At roughly 3,000 acres, Scarborough Marsh is the largest salt marsh in Maine. Most of the Marsh is owned by the State of Maine and managed by the Maine Department of Inland Fisheries and Wildlife (IFW). State and federal environmental laws further protect it from development and other forms of human encroachment. The health of its saltmarsh ecosystem also depends on the influx of water and nutrients from the feeder rivers and streams that flow in from the upland regions of the Scarborough Marsh Watershed. Increase in land development and an extensive system of roads threaten both the quality and quantity of these waters.

Previous studies (discussed in Section 4.0) have documented how tidal drainage barriers associated with the transportation network have degraded the saltmarsh ecology and allowed invasive plants to proliferate along the Marsh fringe.

In November 2015 and March 2016, a group of natural resource managers, FOSM board members and Scarborough municipal officials met to discuss the problem and extent of drainage barriers on the marsh ecosystem. These meetings revealed that, while substantial resources have been expended to study and mitigate drainage barriers within the Marsh footprint, relatively little effort has focused on the upland areas of the watershed.

FOSM initiated a stream-crossing survey in November 2016 to fill this gap. Steve Pinette, FOSM board member conducted the field work, evaluated the survey data, compiled the information from past studies and wrote this report. The goals of the study were to:

1) Compile and assess information from past studies related to drainage barriers in the Scarborough Marsh Watershed (Watershed);
2) Create an inventory of stream/river *crossings* (i.e., locations where roads and railroads cross streams and rivers) in the Watershed; and
3) Develop a preliminary assessment of whether these crossings adversely affect
    a. Water quality and quantity, and sediment flowing into the marsh, and
    b. Migration of anadromous fish

The final products of the survey consist of this report, associated graphics, and an electronic spreadsheet summary of the site survey data. FOSM will use these data and the findings to help guide future efforts related to safeguarding and improving the ecologic health of the Marsh.

2.0 PHYSICAL SETTING OF THE WATERSHED

According to Normandeau and Dewan (2002), approximately 54% of the 38,000-acre Scarborough Marsh Watershed is forested; the Marsh occupies roughly 8% of the area watershed area; pasture and agricultural lands cover 24%; residential and business properties cover about 7%.

An extensive network of local streets and country roads weaves through the watershed. Three major transportation corridors and a relic railroad bed cross the watershed, running roughly southwest to northeast. From north to south, these include the Maine Turnpike (I-95), Route 1, Eastern Road/Trail

and the Pan AM Railroad line. The watershed includes a major drainage (Nonesuch River) as well as several significant tributaries. Development is most dense along the seacoast, along Route 1 and on the eastern side of the watershed. Land elevations range from subtidal in the Marsh to 215 ft. above mean sea level (MSL) near the headwaters of Nonesuch River in the northwest region of the watershed. Blue Point Hill (elevation 120+ ft.) and Scottow Hill (elevation 150 ft.) dominate the local relief within a mile of the marsh edge.

Scarborough Marsh is classified as a back-barrier salt marsh formed behind the protective barrier beach at Pine Point and the Prouts Neck headland (Maine Audubon, 1999). It includes a subtidal river, intertidal mud flats and saltmarsh vegetation. State and federal agencies view these as part of a high-quality estuary where commercial shellfish harvesting, aquaculture and recreational fishing occur.

3.0 HUMAN HISTORY

Alterations to the Scarborough Marsh hydrology have occurred over a period of centuries.

- Early settlers and farmers excavated drainage ditches and built roads on the marsh to harvest marsh hay for livestock. This continued well into the 1900s.
- In the 1840s, the Portland, Saco & Portsmouth Railroad Company constructed a railroad bed, now called Eastern Road, which extends about 2.5 miles across the Marsh (Normandeau and Dewan, 2002); it crosses the Dunstan River.
- It's replacement to the south, the Boston & Maine Railroad, was constructed in 1871 and runs approximately 3 miles across the marsh (Normandeau and Dewan, 2002); it crosses the Scarborough and Nonesuch Rivers.
- Route 1 was constructed in its present location in by 1875.
- Pine Point Road reached Pine Point by 1877 (Kelley and Brothers, 2009).
- Natural sedimentation led to closure of Little River and partial isolation of the Jones Creek lobe of the Marsh by 1875 (Farrell, 1972, *referenced* in Kelley and others, 1995, and Kelley and Brothers, 2009). Prior to this, Pine Point was a barrier island, the only one in Maine.
- In 1987 a tidal gate was installed on the western end of Eastern Road in the old Dunstan River channel (a granite box culvert currently exists there) to promote diking and drainage in the Upper Marsh to the north for pasture and hay (Normandeau and Dewan, 2002).
- In more recent time, the State of Maine and the Town of Scarborough have constructed additional roads and streets to accommodate local and regional land development and commerce.

4.0 PREVIOUS STUDIES

Previous studies of impacts to the Scarborough Marsh hydrology and ecology have focused on the tidal rivers and creeks, and the historically intertidal marsh plain (i.e., low-marsh and high-marsh regions that are inundated with salt water several times each month).

4.1 Maine Audubon Society, 1999 – Scarborough Marsh: Historical Impacts, Current Conditions, and Restoration Potential.

This report identified 12 drainage restrictions in the Marsh with measurable impacts on the saltmarsh ecosystem. Table 1 excerpted from the Audubon report presents key data on these restrictions. Brief discussion of the four most severe restrictions follows.

- **Jones Creek** – The major restriction documented is at Pine Point Road where Jones Creek flows through a concrete box culvert. A narrow (7 ft.) box culvert constricts a channel that has a natural width of approximately 34 ft. (east side of Pine Point Road). More recent tidal water-level information (2016 unpublished data, The Nature Conservancy) has also confirmed constrictions upstream at the Pan Am Railroad crossing and at a dam installed near the Bayley's Campground in the mid-1980s.
- **Dunstan River at Eastern Road** – The natural river channel width in this area is about 125 ft., but the rip-rap armored channel under the bridge is 100 ft. wide. Audubon noted evidence of channel erosion upstream and downstream of this constriction. It is noteworthy that the historical Dunstan River channel crossed the Eastern Road to the west, just east of the existing Eastern Trail parking area, where a portion of the tidal flow now passes through a granite box culvert. A tidal gate at this location operated until 1953 when a large storm caused the river to cut a new channel and break through the Eastern Road in the current channel location. One of Audubon's report findings is that the high marsh surface located inland of the Eastern Road subsided on the order of six inches, presumably, because of tidal restrictions imposed by the Eastern Road causeway and tide gate.
- **Cascade Brook at Blue Point Road** – This restriction is located near the upper tide limit on Cascade Brook, immediately upstream from a bridge on Old Blue Point Road. While the bridge spans 91% of the tidal creek, a low steel dam (station 5-CB of this study) just upstream blocks tidal flow on all but the highest tides. Maine IFW reportedly installed this gate to create a freshwater habitat for waterfowl, while still allowing some fish passage.
- **Libby River at Black Point Road** – Prior to 2006, tidal waters in this 30-ft. wide section of the Libby River flowed through one undersized 60-inch diameter culvert. Maine DOT partially mitigated this constriction in 2006 by installing two 72-inch diameter culverts to supplement the existing culvert. In the first-year post-construction monitoring study for the project, Normandeau Associates (2008) reported a 21% improvement in Libby River tidal range (difference between high and low tide levels) northeast (upstream) of Black Point Road compared to pre-construction conditions. It is important to note that the post-construction high-tide level increased on the order of 0.7 ft. immediately upstream from Black Point road and 0.1 ft. in the mid-marsh area further upstream.

Table 1. Table 1 in Audubon, 1999, report. Results of Tidal Restriction Inventory and Assessment, Scarborough Marsh, 1998. *Phase 1 Classification* refers to the 'Inventory of Tidal Restrictions' phase, which was the first element of Audubon's three-part study.

		Field Measurements			Phase 1 Classification[1]			
Restriction #	Location	Restriction Width (ft)	Stream/ River Width(ft.)	Restriction Width as % of Total	Evidence of Restriction/ Erosion	Culvert/ Channel Ratio	Vegetation Difference Up-Down	Overall Rating
1	Jones Creek, Pine Point Road	7	34	21	4	4	4	12
2	Dunstan Canal, Pine Point Road	3	13	23	1	4	2	7
3	Cascade Brook, Blue Point Road[2]	20	22	91	3	5	4	12
4	Phillips Brook, Route 1	10	10	100	3	2	1	6
5	Dunstan River, Route 1	28	53	53	2	3	3	8
7	Dunstan River Tributary, Payne Road	3	5	60	1	3	2	6
8	Finnerd Brook, Payne Road	8	10	80	1	3	3	7
11	Nonesuch River, Black Point Road	30	50	60	3.5	2	1	6.5
12	Libby River, Black Point Road	5.5	30	18	3.5	5	1	9.5
13	Nonesuch River, Railroad tracks	130	150	87	1	3	1	5
14	Boston and Maine Railroad	500	750	67	1	3	1	5
15	Eastern Road	100	125	80	3	3	4	10
16	Dunstan Landing East	7	17	41	1	4	1	6
17	Dunstan Canal Tributary	3	2.5	100+	3	1	3	7

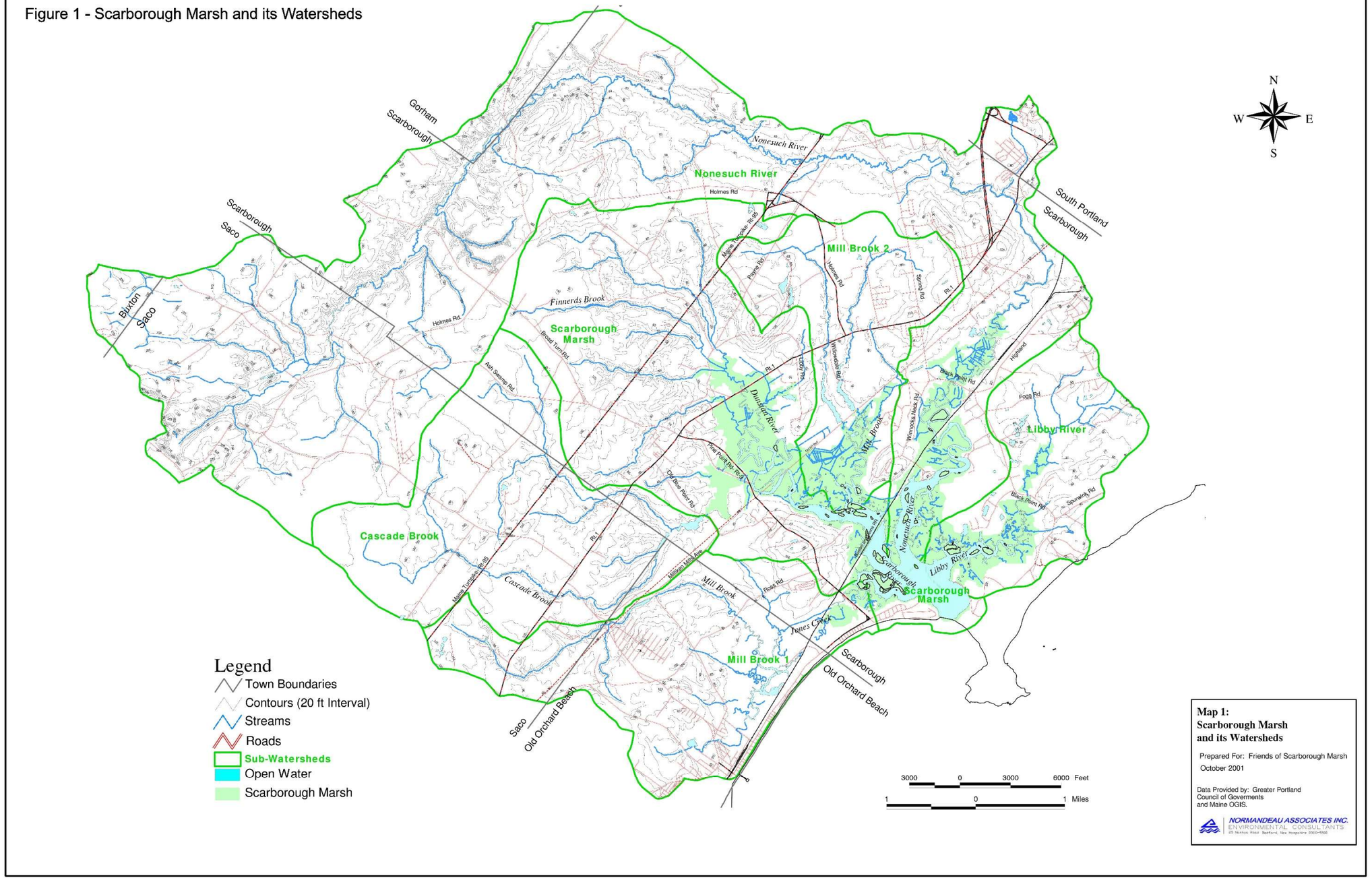
1. Classification based on Purinton and Mountain, 1997. 1 = Best Condition (nearest to natural); 5 = Worst Condition. See Appendix B for details.
2. Classification for culvert/channel ratio based on low steel dam located just upstream of Blue Point Road.

4.2 Normandeau Associates and Terrance Dewan & Associates, 2002 – Strategic Plan for Restoration and Enhancement of Important Habitats in Scarborough Marsh and Its Watershed.

In 2001 FOSM commissioned Normandeau Associates and Terrance Dewan Associates to identify degraded areas of the marsh and prioritize these for restoration and enhancement. Figure 1 presents a map from their report showing the Scarborough Marsh Watershed study area divided into the following sub-watersheds:

- Cascade Brook
- Nonesuch River
- Mill Brook 1 (***changed to Mill Brook *west* for this study)
- Mill Brook 2 (***changed to Mill Brook *east* for this study)
- Libby River
- Scarborough Marsh

Figure 1 - Scarborough Marsh and its Watersheds



The report identified 38 priority degradation/restoration areas within the marsh. These sites ranged from marsh-plain drainage ditches, hay roads and *Phragmites australis* (Phragmites) colonies, to in-stream drainage barriers documented by Audubon. Thirteen of these sites were categorized with tidal flow restrictions. A copy of Table 1 in the Normandeau and Dewan report is presented as Appendix A. For ease of reference, the 13 tidally restricted sites are presented in in Table 2 below. Note that subsequent Maine Department of Transportation (MDOT) highway rehabilitation projects improved the restrictive conditions described for Sites 5, 7 and 33.

Table 2. Sites with tidal restriction identified in Normandeau and Dewan (2002)

Map/Site ID (Normandeau)	Station ID (this study)	Project Name	Problem	Enhancement Action
1	1-DR	Enhance flows under Payne Rd.	Tidal flows to brackish marsh area restricted	Evaluate culvert sizing and invert
5	3-DR	Dunstan Marsh Restoration Project	Large Phragmites invasion (*note: the major problem here is constriction and tidal dampening imposed by Route 1*)	Site is currently being studied for restoration. Will probably include culvert enhancement, new pannes and perimeter ditching (Note: MDOT enhanced this crossing)
7	3-PB	Enhance flows at Phillips Brook	Tidal flows under Rt. 1 may be restricted	Evaluate need to enlarge culvert (Note: MDOT enhanced this crossing)
15	11-NR	RR bridge over Nonesuch River	May restrict tidal flows on river	Evaluate and determine adequacy of bridge (project assumes widening it)
16	CW-5	Restore connection to Cascade Brook at Route 9	Historic channel is blocked by Route 9, limiting flows behind	Add culvert under Route 9, and possibly deepen old channel
20	Section of Cascade Brk upstream of Pine Point Rd.	Enhance flows at Dunstan Landing Rd.	Area east of road has limited tidal exchange	Widen existing ford in old road and add others to enhance sheet flow; evaluate deepening primary ditch connection
21	6-CB	Remove dam on Cascade Brook	Tidal amplitude and salinities low because of impoundment	Lower coffer dam or remove some dam panels
22(a)	7A-DR	Enhance Eastern Rd. connection through box culvert	Tidal restriction caused by Eastern Road	Enlarge box culvert and lower invert
22(b)	7B-DR	Enhance Eastern Rd. connection through main channel	Tidal restriction caused by Eastern Road; dangerous currents, scouring	Widen channel and stabilize banks
25	approx. CW-4	Add culvert under railroad at Winnocks Neck	Tidal exchange is limited by railroad	Enhance exchange with culvert under railroad
29	2-SR	Tidal restriction at railroad bridge over Scarborough River	May form primary restriction to upstream marsh	Evaluate and determine adequate size (project assumes widening the bridge)
33	3-LR	Libby River Project	Tidal flow restriction under Black Point Road	Enlarge culvert/change invert as needed (Note: MDOT added two 72-inch dia. culverts in 2006)
37a & 37b	3-JC	Enhance flows through culvert on Jones Creek	Tidal flows to brackish marsh are restricted.	Remove tidal gate façade; add second culvert under Route 9; add ditching

4.3 NORMANDEAU ASSOCIATES & WOODS HOLE GROUP, 2002 – DUNSTAN MARSH RESTORATION PROJECT: PRE-RESTORATION MONITORING REPORT, SCARBOROUGH MARSH, MAINE.

The Julie N Oil Spill Natural Resource Trustees, led by the Maine Department of Inland Fisheries and Wildlife, NOAA, USFWS, and USACE-NED contracted with Normandeau Associates and their sub-consultant, Woods Hole Group (WHG) to conduct a study of the Dunstan Marsh area of Scarborough Marsh to assess options for restoring it to a natural saltmarsh ecosystem. The focus of the work was to evaluate man-made constrictions on tidal flushing and develop conceptual restoration designs to enhance salinity and tidal elevations within the upper Dunstan Marsh, north of Route 1. The over-arching goal of the project was to reduce invasive plants (e.g., *Phragmites australis*) coverage, and encourage colonization by more desirable saltmarsh plants (e.g., *Typha* and *Spartina alterniflora*). The consultants modeled tidal flow in the Dunstan and Scarborough Rivers from the Pan Am railroad bridge north to the upper reaches of the Scarborough Marsh, including Dunstan, Finnerd and Beaver Brooks. They relied on time-series measurements of water surface elevation, salinity, and temperature at nine sites to document existing tidal flushing and flooding conditions in this area.

Tide monitoring data and model results showed the following:

- The tidal range in the study area is reduced by a series of narrow constrictions: Pan Am railroad bridge, Eastern Road causeway, and Route 1 culverts. These constrictions are responsible for <u>less than 16% of tidal dampening</u> in the Upper Marsh. Frictional losses imposed by sediment texture, channel morphology (e.g., uneven bottom, river meanders, slumps), and in-channel structures (e.g., weirs and rock piles) are causing the rest of tidal dampening.
- One day of tidal gauge data for the marsh (for October 20, 2000), showed that there is an apparent ponding in the Dunstan River between Route 1 and Eastern Road for the three hours on either side of low tide, suggesting that a “dam” effect is occurring in Dunstan River. WHG’s analyses of aerial photographs identified extensive shoaling in the marsh creeks between Eastern Road and Route 1, and this may be responsible for some of the ponding. The importance of the dam effect is that freshwater retained at low tide appears to dilute the salinity of the incoming ebb-tide waters. The resultant brackish water flooding the high marsh would induce conditions that tend to favor invasive plants such as Phragmites.
- The monitoring and model data further indicate that the period of time (duration) that certain regions of the marsh are wetted with saltwater (i.e., the *hydroperiod*) during the tidal cycle affects whether they are susceptible to invasive plants. WHG determined that average hydroperiods of 2 – 3 hours are necessary to grow native salt marsh vegetation and ward off invasive plants. Moreover, hydroperiod is inversely correlated to marsh surface elevation, where higher elevations have a shorter hydroperiod. WHG noted that an average hydroperiod of 2 – 3 hours corresponds to a marsh plain elevation of around 3.5 ft. mean sea level (MSL).

4.4 Normandeau Associates and Woods Hole Group, 2003 - Alternatives Analyses: Dunstan Marsh Restoration Project, Scarborough Marsh, Maine.

Based on data and analysis from their earlier study, Normandeau and WHG presented several alternatives for restoring Dunstan Marsh north of Routes 1 to native saltmarsh vegetation and ecology. The proposed

alternatives range from *No Action* (Alternative 1a) and ditching to promote tidal flooding of the Phragmites areas (Alternatives 2 & 3), to dredging (skimming) and ditching to lower the marsh surface elevation to less than 4.5 ft. MSL to allow overbank flooding of the marsh surface at least 3- 4 times per month (Alternatives 4). Alternative 5 added shallow pools to Alterative 4 to create habitats for waterfowl and fish. Figure 2 presents Figure 10 from Normandeau and Woods Hole Group (2003) report showing the distribution of plant species within the Dunstan Marsh and the restoration areas for Alternative 5. None of these restoration alternatives has been implemented.

4.5 Statewide Stream Crossing Survey

In 2012, the U.S. Fish & Wildlife Service (FWS) launched the Maine Stream Crossing Survey. Coordinated amongst several State and federal agencies and non-profit organizations, this multi-year survey assesses stream and river crossings around the State to document their physical condition and whether they pose potential barriers to fish and terrestrial species. Thirty-four stream-crossing sites in the Scarborough Marsh Watershed were surveyed in 2012. FOSM launched the current study in fall 2016 to survey the missing sites. FWS released additional survey data for the Watershed in April 2017. Consequently, numerous stream-crossing sites in the Watershed were surveyed twice. FOSM used FWS data to augment its survey information where appropriate. The FWS statewide data can be accessed via the Maine Habitat Stream Viewer website: https://webapps2.cgis-solutions.com/MaineStreamViewer/.

5.0 DESCRIPTION OF THE STUDY AREA

As discussed elsewhere, the Scarborough Marsh Watershed study area comprises of six sub-watersheds that cover an area of approximately 38,000 acres. The Old Orchard Beach 7.5-minute USGS topographic quadrangle map covers the western portion of the study area and the Prouts Neck quadrangle map covers the eastern region. As noted, the survey focused on the intersections of streams/rivers depicted on these two quadrangle maps with roads, streets and railroads. We did not survey several small streams/drainages in the upland portions of the watershed that are not displayed on the USGS maps and have only local significance. Although technically in the Marsh Watershed, the northern drainages of the Nonesuch River sub-watershed (located in the northwestern portion of Prouts Neck quadrangle and southern portion of Gorham quadrangle) were not included in this survey. Table 3 presents a list of streams and river included in the study.

6.0 METHODOLOGY

6.1 Site Identification

Site identifiers use the stream/river name preceded by a number representing the site's order on the water course. Typically, site numbering order begins with the most upstream site. For example, if Cascade Brook intersects six roads/streets, the most upstream stream crossing site would be designate ***1-CB*** and the last downstream site would be ***6-CB***. Note that some sites deviate from this upstream-downstream nomenclature (notably for Dunstan River); several sites have an "A" or a "B" suffix to address "fill-in" sites.

Figure 2. ***Figure 10*** **from Normandeau and Woods Hole Group (2003) report showing the distribution of invasive and native plant species within the Dunstan Marsh, and the restoration areas for Alternative 5 (skimming and pools)**

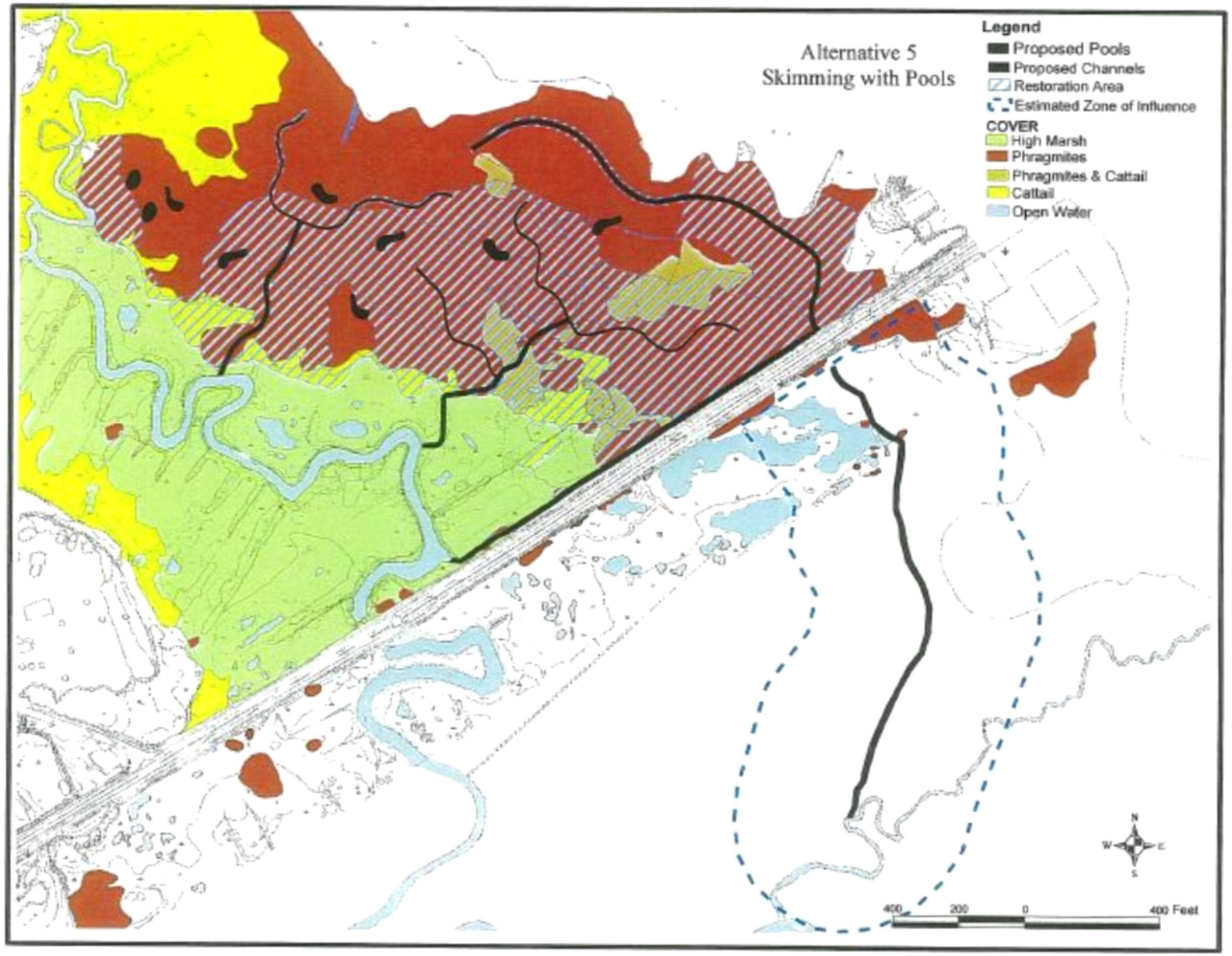


Table 3. List of Streams/Rivers included in this study

(* designates study-derived names for unnamed streams)

Streams/Rivers	Station ID for Stream/River Crossings Surveyed
Beaver Brook	(n = 5) 2-BvB through 5-BvB
Beech Ridge Brook *	(n = 1) 1-BRB
Bessey School Stream *	(n = 3) 1-BS through 3-BS
Boynton Brook	(n = 2) 1-BB and 2-BB
Carter Brook	(n = 1) 1-CartB
Cascade Brook	(n = 6) 1-CB through 6-CB
Cascade Brook Tributaries *	(n = 2) 1-CBtrib and 2-CBtrib
Diamond Drive Stream *	(n = 1) 1-DDS
Dresser Brook *	(n = 1) 1-DresserB
Dunstan River	(n = 8) 1-DR through 6-DR, 7A-DR and 7B-DR
Finnerd Brook	(n = 2) 2-FB and 4-FB
Grant Brook	(n = 2) 1-GB and 2-GB
Harmon Brook	(n = 1) 1-HB
Hearne Stream *	(n = 1) 1-HearnS
Hunnewell Stream *	(n = 2) 2-HS and 3-HS
Jones Creek	(n = 4) 1-JC through 4-JC
Jones Creek Tributaries *	(n = 1) 1-JC trib
Libby River	(n = 3) 1-LR through 3-LR
Manson-Libby Stream*	(n = 2) 1-MLS and 2-MLS
Merrill Brook	(n = 4) 1-MerB through 4-MerB
Mill Brook-east	(n = 6) 1A-MB-east and 1B-MB-east, and 2-MB-east through 5-MB-east
Mill Brook-west	(n = 8) 1-MB-west through 8-MB-west
Milliken Pond Stream *	(n = 2) 3-MPS and 4-MPS
Mill Brook-west Tributary *	(n = 1) 1-MB-west trib
Mitchell Hill Brook *	(n = 1) 2-MHS
Nonesuch Brook	(n = 2) 1-NB and 3-NB
Nonesuch River	(n = 11) 1-NR through 11-NR
Nonesuch River Tributary *	(n = 1) 1-NRT
Phillips Brook	(n = 3) 1-PB through 3-PB, and 100-PB
Ricker Brook	(n = 3) 1-RB through 3-RB
Scarborough River	(n = 1) 2-SR
Silky Brook	(n = 2) 1-SlkB and 2-SklB
Stuart Brook	(n = 5) 1-SB, 2-SB, 3a-SB, 3b-SB, 4-SB, 100-SB, 101-SB, 102-SB
Willowdale Stream	(n = 4) 1-WS, 2A-WS, 2B-WS, 4-WS and 5-WS
Winnocks Neck Stream *	(n = 1) 3-WNS

We identified 116 stream/river crossing sites within the Scarborough Marsh Watershed, as annotated on the USGS topographic maps presented in Appendix B. We surveyed 96 sites and relied on FWS statewide survey data for 14 of the remaining sites. Six upland sites (Beaver Brook: 1-BvB and 2-BvB; Carter Brook: 1-CartB; Beech Ridge Brook: 2-BRB and 3-BRB; and 1-HS) were not surveyed due to winter access and study timing constraints. We identified five additional sites along Pine Point Road, Eastern Trail and Pan Am Railroad where the constructed causeways appear to restrict natural flow of local marsh creeks, and included these in the discussions that follow.

The field work occurred in October 2016 through January 2017. Snowy winter conditions prevailed in December and January, and most streams and rivers had partial ice cover during this period.

6.2 Parameters Recorded

We evaluated five main site characteristics to assess whether potential water flow and fish-passage restrictions exist at a site. These and ancillary site data are presented below.

- Stream/river name
- Site identifier (e.g., 1-CB)
- Flow/fish-passage condition: number indicating category of flow restriction and fish-passage barrier.

    1 – No flow restriction or fish-passage barrier
    2 – Fish-passage barrier from elevated or perched culvert (typically the outlet end of the culvert)
    3 – Natural fish-passage barrier (e.g., waterfall, steep cascade)
    4 - Potential natural barrier for fish passage (e.g., cascade or small ledge drop)
    5 – Man-made flow restriction, such as an under-sized bridge which causes upstream or downstream erosion next to flow structure, or a dam

- Description of location (e.g., a*t railroad crossing northwest of Snow's Canning*)
- Crossing type and crossing dimensions (e.g., 70-inch diameter, corrugated metal pipe culvert)
- Inlet/outlet elevation relative to stream bed: this provides information on whether the bottoms of the culvert pipe at the inlet and outlet ends are at the same elevations (grades) as the stream/river bed.
- Outlet water depth: measure of the water depth in the culvert at the outlet (generally within six inches upstream from the outlet end of the pipe).

Appendix C presents a tabular summary of this information.

We typically used a steel carpenter's tape to measure water depth, structure vertical cross-section dimensions (excludes length) and culvert/streambed separation.

We examined several sites along the Maine Turnpike from only one side of the highway because of access restrictions. In addition, ice formation in the water channel or inside the culverts prohibited water-level measurements at numerous sites. Where available, we used available FWS Statewide Survey information to augment our data.

7.0 DATA COMPILATION

7.1 Streams and Rivers

7.1.1 General

The drainage structures at the crossing sites include pipe culverts, box culverts, arch culverts and bridges. Brief discussion of these structures follows. Note that several small concrete structures (e.g., 5-CB over Cascade Brook: **Photo 1**) are classified as *bridges*, but designation as large *box culverts* may also be appropriate.

Pipe Culverts. Pipe culverts are constructed of

- corrugated metal (e.g., 4-MB-west in Mill Brook-west: **Photo 2**);
- plastic (high-density polyethylene), both corrugated (**Photo 3**) and smooth (**Photo 4**); or
- concrete (e.g., 4-MPS in Milliken Pond Stream, **Photo 5**).

Pipe culvert diameters range between 20 and 82 inches. Several sites have two and three pipe culverts installed side-by-side; one site (5-BvB: Beaver Brook at Scottow Hill Road) has five culverts.

Box Culverts. The majority of box culverts are three-sided (top panel and two vertical side panels) with an *open* bottom; these are designated *open* box culverts. Typically, the sides consist of reinforced concrete, but some box culverts are constructed with granite blocks. Two box culverts are four-sided (e.g., 3-MPS on Milliken Pond Stream, **Photo 6**) and classified as *closed* box culverts. Several of the larger bridges/open-box culverts, notably over the Nonesuch River (e.g., 9-NR. **Photo 7**), have concrete wing-walls to armor the adjacent highway embankments against erosion.

Arch Culverts. Arch culverts consisted of two types: concrete arch and corrugated metal arch with concrete footwalls. Both types have natural stream sediments at their base. Site 5-NR (**Photo 8**) over the Nonesuch River is an example of a concrete arch culvert. Site 2-NR (**Photo 9**), also over Nonesuch River, is an example of latter.

Bridges. Pile-supported railroad bridges span Scarborough River at site 2-SR (**Photo 10**) and Nonesuch River at site 11-NR (**Photo 11**). A single-span steel bridge over the Dunstan River at site 7B-DR (**Photo 12**) accommodates pedestrian traffic and a gas utility line. Several small concrete bridges occur elsewhere in the watershed.

Flow Restriction and Fish-passage Data. Man-made water-conveyance structures, such as culverts, may by nature create friction that slows (restricts) mass-movement of water compared to natural sections of rivers and streams. For the purposes of this report, flow-conveyance structures that appear to be performing as designed and do not impede fish passage are designated ‘unrestricted’ (Restriction = ‘1’ in Appendix C).

Photo 1 (5-CB: small concrete bridge)	**Photo 2 (4-MB west: corrugated metal pipe culvert)**
	
Photo 3 (1-JC Trib: corrugated plastic culvert)	**Photo 4 (3-PB: smooth plastic culvert_FWS photo)**
	

Photo 5 (4-MPS: multiple concrete pipe culverts)

Photo 6 (3-MPS: closed-box culvert)

Photo 7 (9-NR: open-box culvert)

Photo 8 (5-NR: concrete arch culvert)

Photo 9 (2-NR: corrugated metal arch culvert)

Photo 10 (2-SR: pile-supported railroad bridge)

Photo 11 (11-NR: pile-supported railroad bridge)

Photo 12 (7B-DR: single-span steel bridge)

Sites where the bottom of the culvert outlet is perched above the streambed or the downstream water surface (i.e., invert elevation above the plunge-pool surface) are designated as fish-passage-restricted under low-flow conditions (Restriction = '2' in Appendix C). In some cases where the culvert invert is a few inches above the streambed, determining whether the site is fish-passage-limited is subjective. For this survey, a culvert elevated more than six inches above the stream bed is classified as fish-passage restricted. Ideally, this assessment would be made during dry summer conditions where the river or stream is in a *low-flow* (i.e., low water level) condition. Cases where the culvert invert is several inches above the downstream plunge pool (e.g., 3-ft. drop at site 4-DR on the Dunstan River) are more clear-cut.

Sites with potential natural fish-migration barriers nearby, such as waterfalls, ledge-drops or steep cascades, are assigned Restriction = '3' in Appendix C. Cascade Brook site 2-CB (2-ft. ledge drop directly upstream and Stuart Brook site 4-SB (waterfall downstream) are in this category.

Sites with other features (e.g., cobble/gravel mound or rip-rap piles, upstream or downstream) that *may* restrict fish passage under low-flow conditions are assigned Restriction = '4' in Appendix C. Sites on Cascade Brook (3-CB, 4-CB, 1-CB-trib **[Photo 13]**), Dunstan River (1-DR, 4-DR), Finnerd Brook (4-FB) and Mill Brook-west (4-MB-west) are in this category.

Sites with visible bank erosion or channel-widening immediately downstream or upstream, e.g., 5-CB: **Photo 14,** of the flow structure (i.e., indicates under-sized structure) and those with dams are designated as flow-restricted (Restriction = '5' in Appendix C). Undersized structures appear to have caused channel erosion on Jones Creek at site 2-JC and Dunstan River at sites 7A-DR and 7B-DR. A sheet-pile dam on Cascade Brook (5-CB) upstream from Old Blue Point Road appears to restrict ebb tide drainage and fish passage. A concrete dam inside a box culvert in Mill Brook-west (site 7-MB-west, **Photo 15**) creates an impoundment upstream, traps sediment and limits fish passage. Based on tidal water-level monitoring by others, a dam installed in the mid-1980s on Jones Creek (site 4-JC, see **Photo 16**) appears to limit tidal flushing west (upstream) of the dam.

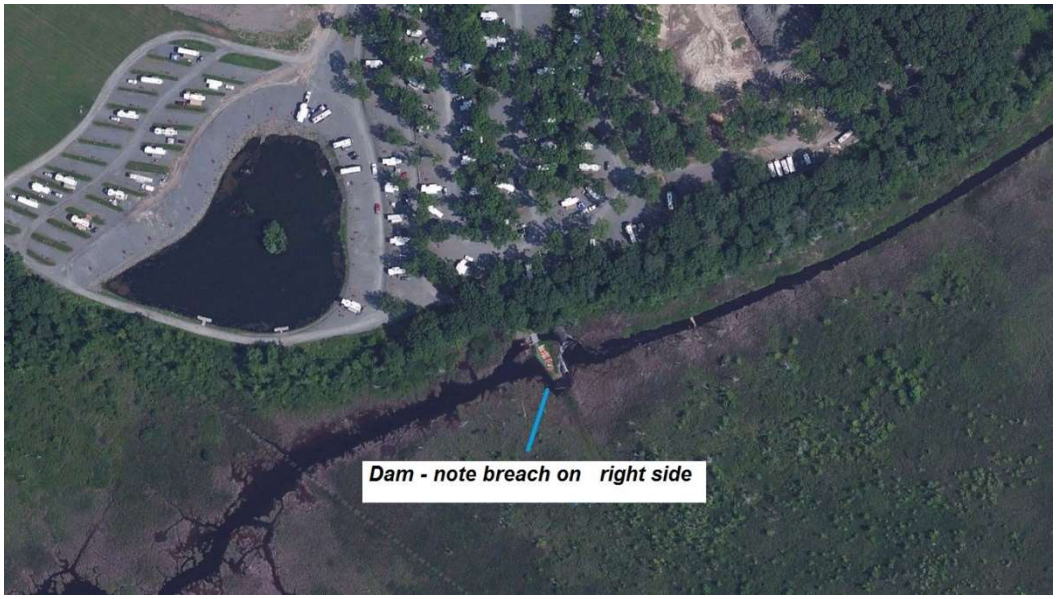
It is important to note that many of the sites identified as limiting (Restriction Categories '2' and '3') or potentially limiting ('4') to fish passage should be visited by a fisheries expert to confirm our notion of their *restriction* classification.

Photo 13 (1-CB trib: cobble mound [potential low-flow fish restriction] at outlet)

Photo 14 (5-CB: channel-widening upstream from culvert inlet; view from inlet)

Photo 15 (7-MB west: concrete dam inside box culvert)

Photo 16 (4-JC: aerial view of dam on Jones Creek)



7.1.2 Survey Results

Approximately 84% of the stream/river crossings in the Scarborough Marsh Watershed have no water flow restrictions; 5% have dams that restrict both water flow and fish passage; and, 4% have tidal flow restrictions based on the results of modeling and tide monitoring studies by others (i.e., Normandeau and WHG, 2002; 2016, unpublished data, TNC). Seven percent of the crossing sites in the Watershed were not surveyed.

Twenty-five percent of the sites present barriers to fish passage: 18% have perched culverts, 2% (2-CB and 4-SB) have waterfalls or ledge drops upstream or downstream, and 5% have dams.

A substantial portion of sites (10%) have features which we interpret as potential barriers to fish passage under moderate to low-flow conditions. These include steep cascades immediately upstream or downstream (e.g., 3-CB, 4-CB, 1-PB) and flow through cobble/rip-rap mounds (e.g., 1-DR, 4-FB, 2A-MB east).

Table 4 summarizes the flow and fish restriction data from the field survey. Table 5 presents the crossing sites in restriction categories 2 - 5. Note that Nonesuch River, the longest water course in the Watershed, has no crossings that appear to restrict water flow and fish passage. Eleven local brooks and streams are similarly unrestricted.

Table 4. Summary of data for Restriction category in Appendix C

Restriction Category	Number in Category
Unrestricted ('1') [for both water flow and fish passage	63 (54.3%)
Man-made restrictions for fish passage ('2')	21 (18.1%)
Natural restrictions for fish passage ('3')	2 (1.7%)
Potential natural restrictions for fish passage ('4')	11 (9.5%)
Flow-restricted ('5'; includes dams and ***modeled*** restrictions)	11 (9.5%)
No Data	8 (6.9%)
Total	116 (100%)

Table 5. Crossing Sites in Restriction Categories 2 – 5

Stream/River	Number of Restrictions	Restriction Category			
		'2' fish: *man-made*	**'3' fish: *natural***	**'4' fish: *potential***	**'5' flow: *man-made***
Beaver Brook	**0**				
Beech Ridge Brook	**1**	**1-BRB**			
Bessey School Stream	**2**	**1-BS**		**2-BS**	
Boynton Brook	**1**	**1-BB**			
Cascade Brook	**5**	**6-CB**	**2-CB**	**3-CB, 4-CB**	**5-CB**
Cascade Brook Tributaries	**1**			**1-CB Trib**	
Diamond Drive Stream	**1**				**1-DDS**
Dresser Brook	**0**				
Dunstan River	**5**	**4-DR**		**1-DR, 5-DR**	**7A-DR, 7B-DR**
Finnerd Brook	**1**			**4-FB**	
Grant Brook	**1**	**2-GS**			
Harmon Brook	**0**				
Hearne Stream	**0**				
Hunnewell Stream	**1**	**2-HS**			
Jones Creek	**4**	**1-JC**			**2-JC, 3-JC, 4-JC**
Jones Creek Tributaries	**0**				
Libby River	**1**	**2-LR**			
Manson-Libby Stream	**0**				
Merrill Brook	**0**				
Mill Brook-east	**3**	**3-MB east**		**2A-MB east**	**5-MB east**
Mill Brook-west	**3**	**1-MB west**		**4-MB west**	**7-MB west**
Mill Brook-west tributary	**1**	**1-MB west Trib**			
Milliken Pond Stream	**1**	**3-MPS**			
Mitchell Hill Stream	**0**				
Nonesuch Brook	**1**	**3-NB**			
Nonesuch River	**0**				
Nonesuch River Tributary	**1**	**1-NR Trib**			
Phillips Brook	**1**			**1-PB**	
Ricker Brook	**0**				
Ross Road Stream	**0**				
Scarborough River	**1**				**2-SR**
Silky Brook	**2**	**1-SlkB, 2-SklB**			
Stuart Brook	**4**	**3A-SB, 102-SB**	**4-SB**	**1-SB**	
Willowdale Stream	**3**	**2B-WS, 4-WS**			**5-WS**
Winnocks Neck Stream	**0**				

7.2 Marsh Plain – Impact of Pine Point Road, Eastern Road and Pan Am Railroad Causeways

A system of small creeks drains tidal and storm water from the marsh plain to the major rivers[1] in the Marsh. Although we did not conduct extensive geomorphic mapping of the Marsh, our limited field work and subsequent examination of aerial photos revealed five sites where earthen embankments have altered the Marsh hydrology. These sites include one area along Eastern Road causeway and three areas along the Pan Am Railroad causeway where local creek flow has been altered or redirected by the associated causeway embankment. In addition, Normandeau and Dewan (2002) identified one location (their site 16) where Pine Point Road interrupts a historical segment of the Cascade Brook channel.

Area CW-1 along the north side of Eastern Road – **Photo 17** presents an aerial view of a local creek (unnamed) which flows southwesterly toward Dunstan River along the Eastern Road causeway, rather than south toward a more proximal creek.

Area CW-2 along the north side of Pan Am Railroad, west of Scarborough River – **Photo 18** presents an aerial view of a local creek which flows northeasterly along the railroad causeway, rather than southerly toward the nearest reach of the Scarborough River.

Area CW-3 along the north side of Pan Am Railroad, south of High Point Road – **Photo 19** presents an aerial view of two small creeks that merge into one. This collector creek flows southwesterly along the railroad toward Scarborough River, rather than toward the nearest reach of the Nonesuch river, immediately south of the railroad.

Area CW-4 along the north side of Pan Am Railroad, east of Winnocks Neck Road – **Photo 20a** presents an aerial view of several small creeks that drain southerly to a northeast-flowing collector creek along the base of the railroad causeway, rather than flowing toward the nearest reach of the Nonesuch River immediately south of the railroad. **Photo 20b** shows a ground-level perspective of this feature (view toward the northeast).

Area CW-5 on Pine Point Road – **Photo 21** presents an aerial view showing where Pine Point Road crosses an abandoned reach of Cascade Brook (note swath with greener vegetation on right/east side of road). Normandeau and Dewan (2002) recommended establishing a hydrologic connection between both segments of this abandoned channel.

Note, we present these sites only to document their hydrologic impacts, not to propose hydrologic mitigation.

[1] Dunstan River, Libby River, Nonesuch River, Scarborough River and Jones Creek

Photo 17 – Location of Site CW-1 on Map B-2

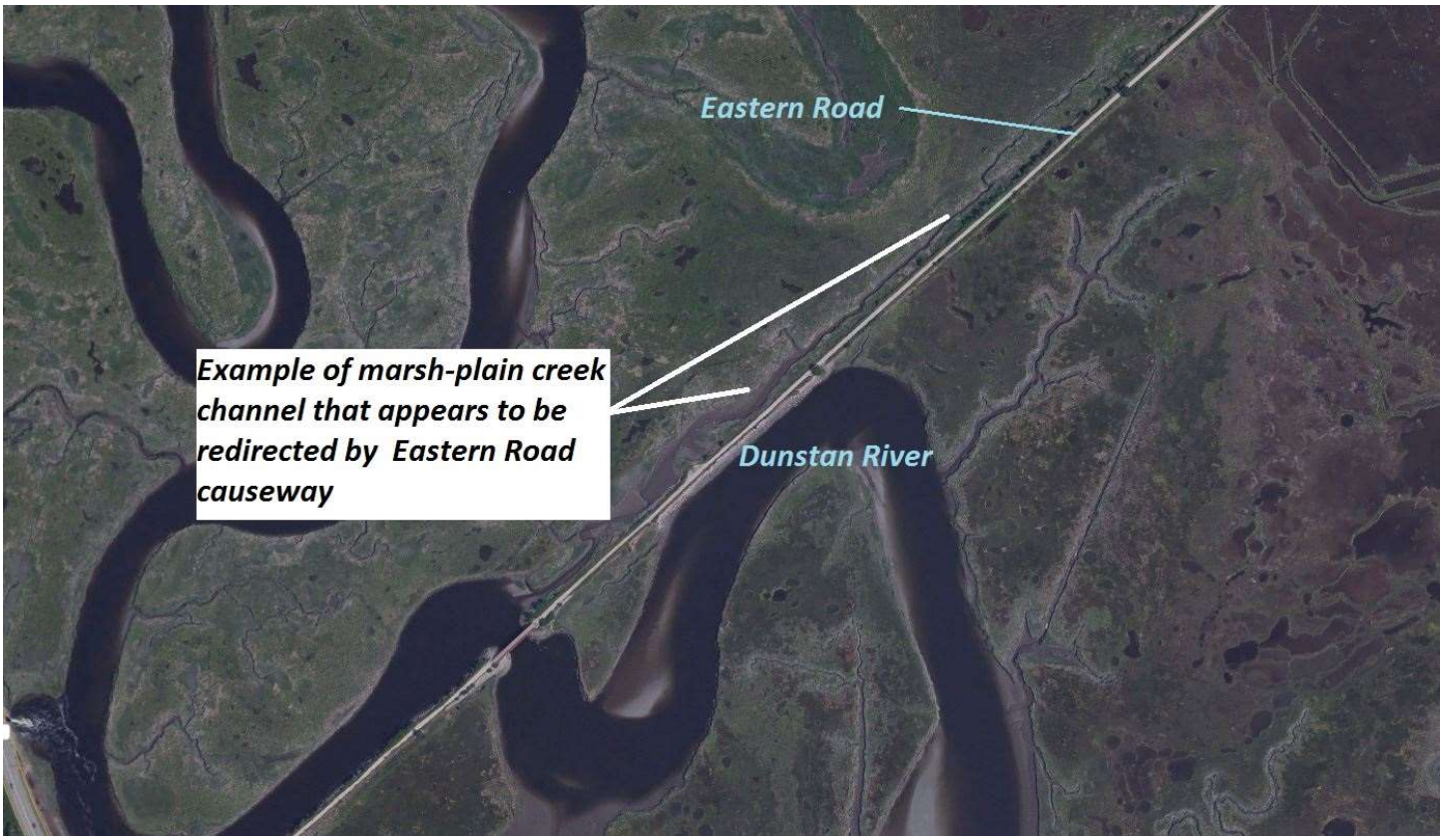


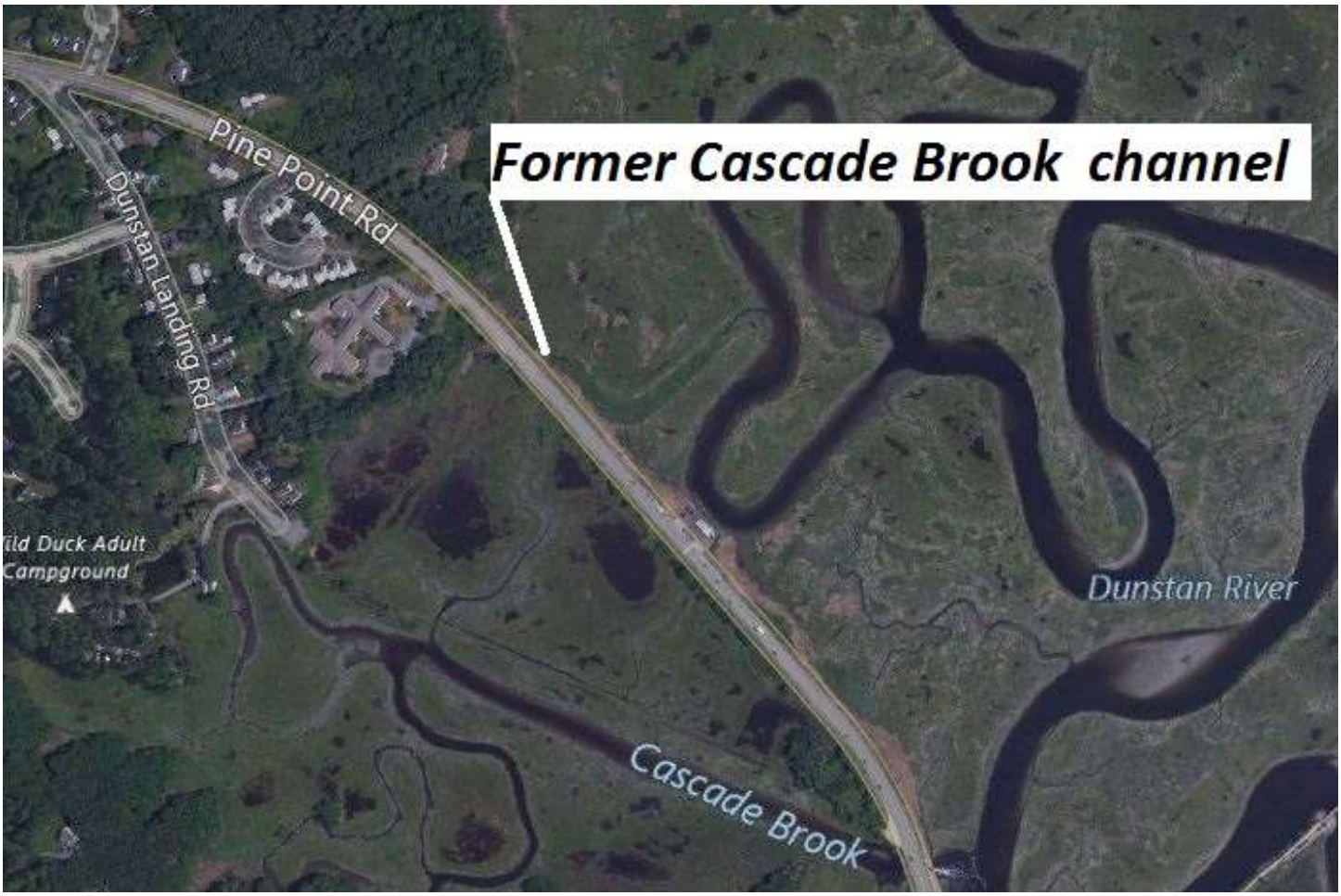
Photo 18 – Location of Site CW-2 on Map B-2

Photo 19 – Location of Site CW-3 on Map B-2

Photo 20a – Location of Site CW-4 on Map B-2

Photo 20b – Ground-level photo of CW-4 site; view is toward the northeast

Photo 21 – Location of CW-5 on Map B-1



8.0 SUMMARY AND RECOMMENDATIONS

Previous work by others (Maine Audubon, 1999; Normandeau and Dewan, 2002; Normandeau and WHG, 2003; TNC, unpublished data, 2016) identified several locations in the Scarborough Marsh where roads and railroad causeways restrict tidal flow and cause degradation of the saltmarsh ecology. The principal motivation for the current stream-crossing survey project is to provide FOSM's Board with additional data to assess where roads crossing streams and rivers in the upland regions of the Marsh Watershed (i.e., areas not addressed by previous studies) are impacting the Marsh's ecology.

The survey data indicate that most of the upland drainage *restrictions* identified affect fish-passage, not the quality or quantity of water flowing to the Marsh. Mitigation of fish-passage issues in these upland freshwater reaches of rivers and streams likely falls within the domain of Maine's Department of Inland Fisheries and Wildlife (IFW) and the responsible state and municipal transportation managers with management oversight for the affected road crossings. We do not recommend that FOSM insert itself as a stakeholder in the effort to solve this problem. FOSM should provide its survey data to IFW, and to USFWS to augment the Maine Stream Crossing database.

We recommend that FOSM focus its limited resources toward mitigating the impacts tidal restrictions and diminished tidal hydroperiod are having on the entire marsh, especially in the Jones Creek Marsh and Dunstan Marsh areas. A steering committee chaired by the Conservation Law Foundation is currently exploring options for restoring Jones Creek Marsh to a saltmarsh habitat. FOSM should continue its involvement on this steering committee and its derivative committees.

FOSM should assemble a separate working group to focus on corrective measures to stem the proliferation of invasive plant species—starting with the Dunstan Marsh. Mapping the current extent of invasive plants on the entire Marsh should be one of the group's first tasks. The working group should explore non-pesticide options for eradicating invasive plants such as Phragmites, since the current herbicides practice does not appear to be an effective and sustainable long-term solution. The working group should evaluate a range of mitigation measures, including local modification of the high-marsh elevation to increase tidal hydroperiod and storm water control in highly developed neighborhoods along the Marsh fringe.

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Normandeau Associates and Woods Hole Group, 2003, Alternatives Analysis: Dunstan Marsh Restoration Project, Scarborough Marsh, Maine (for U.S. Army Corps of Engineers).

Normandeau Associates and Woods Hole Group, 2002, Dunstan Marsh Pre-Restoration Monitoring Report, Scarborough Marsh, Maine (for Julie N Spill Natural Resource Trustees).

The Nature Conservancy, 2016, Unpublished October-November 2016 tidal water-level data for Jones Creek, Scarborough Marsh, Maine (Data presented to the Jones Creek Saltmarsh Restoration Project Steering Committee on March 21, 2017)

APPENDIX A

Table 3-1 from Normandeau and Dewan, 2002, listing 38 degradation/restoration sites

Table 3-1. Summary of project sites, type of degradation and anticipated enhancement action. Projects are listed in order of approximate location from north to south on map.

Map Numbers	Project Type	Project Name	Problem	Enhancement Action
1	Future	Enhance flows under Payne Rd.	Tidal flows to brackish marsh area restricted.	Evaluate culvert sizing and invert.
2	Marsh Surface	Plug ditches on Nonesuch above road	Ditches drain marsh excessively.	Selectively plug ditches and add pools.
3	Marsh Surface	Remove roads and plug ditches on Nonesuch	Sheet flow at high tide is impeded.	Selectively breach hay roads and plug ditches.
4	Future	Remove weir on Nonesuch	Remnants of low bridge/weir impede flow at low tide.	Evaluate benefits of removal.
5	Active	Dunstan Marsh Restoration Project	Large Phragmites invasion.	Site is currently being studied for restoration. Will probably include culvert enhancement, new pannes and perimeter ditching.
6	Marsh Surface	Plug ditches and remove Phragmites SW of Rt 1	Marsh appears waterlogged and brackish; invasives expanding.	Enhance ditching and pools.
7	Tidal Restriction	Enhance flows at Phillips Brook	Tidal flows under Rt 1 maybe restricted.	Evaluate need to enlarge culvert.
8	Marsh Surface	Plug ditches on Nonesuch below road	Ditches drain marsh excessively.	Selectively plug ditches and add pools.
9	Marsh Surface	Deepen large pools by Route 1	Shallow pools by Route 1 go dry and are at risk for invasive plant colonization.	Deepen some pools to enhance habitat diversity.
10	Marsh Surface	Plug ditches west of industrial park	Marsh appears waterlogged and brackish; invasives expanding.	Enhance ditching and pools; remove hay road.
11	Future	Assess restoring tides to 2 impoundments	Impoundments are currently freshwater with no tidal exchange.	Evaluate habitat benefits of restoring tidal flows.
12	Marsh Surface	Plug ditches and restore large pool below impoundments	"T" ditch drains marsh excessively.	Plug ditch and add pool.

Map Numbers	Project Type	Project Name	Problem	Enhancement Action
13	Marsh Surface	Breach hay road and plug ditches near Mill Creek	"C" shaped hay road impedes sheetflow.	Breach road in several locations.
14	Future	Enhance drainage southeast of Rt 1	Marsh appears waterlogged and brackish; ripe for invasives.	Enhance ditching and pools.
15	Tidal Restriction	RR bridge over Nonesuch River	May restrict tidal flows on river.	Evaluate and determine adequacy of bridge (project assumes widening it).
16	Tidal Restriction	Restore connection to Cascade Brook at Route 9	Historic channel is blocked by Route 9, limiting flows behind .	Add culvert under Route 9, and possibly deepen old channel.
17	Marsh Surface	Breach road and plug ditches below Willowdale	Sheet flow at high tide impeded by hay roads; ditches failed.	Selectively breach hay roads and plug ditches to enhance tidal exchange.
18	Marsh Surface	Plug ditches along Mill Creek	Ditches drain marsh excessively.	Selectively plug ditches and add pools.
19	Marsh Surface	Enhance flows behind railroad on Nonesuch River	Marsh behind railroad is waterlogged and brackish; ripe for invasives.	Improve tidal exchange, probably by ditch north of railroad.
20	Tidal Restriction	Enhance flows at Dunstan Landing Rd.	Area east of road has limited tidal exchange.	Widen existing ford in old road and add others to enhance sheet flow; evaluate deepening primary ditch connection.
21	Tidal Restriction	Remove dam on Cascade Brook	Tidal amplitude and salinities low because of impoundment.	Lower coffer dam or remove some dam panels.
22	Tidal Restriction	Enhance Eastern Rd. connection through box culvert.	Tidal restriction caused by Eastern Rd.	Enlarge box culvert and lower invert.
22	Tidal Restriction	Enhance Eastern Rd. connection through main channel	Tidal restriction caused by Eastern Road; dangerous currents, scouring.	Widen channel and stabilize banks.
23	Future	Enhance pools and pannes below Eastern Rd	Area has no pools and pannes and is very uniform high marsh.	Enhance site diversity by adding pools.

APPENDIX B

USGS Topographic Maps Showing Site Locations

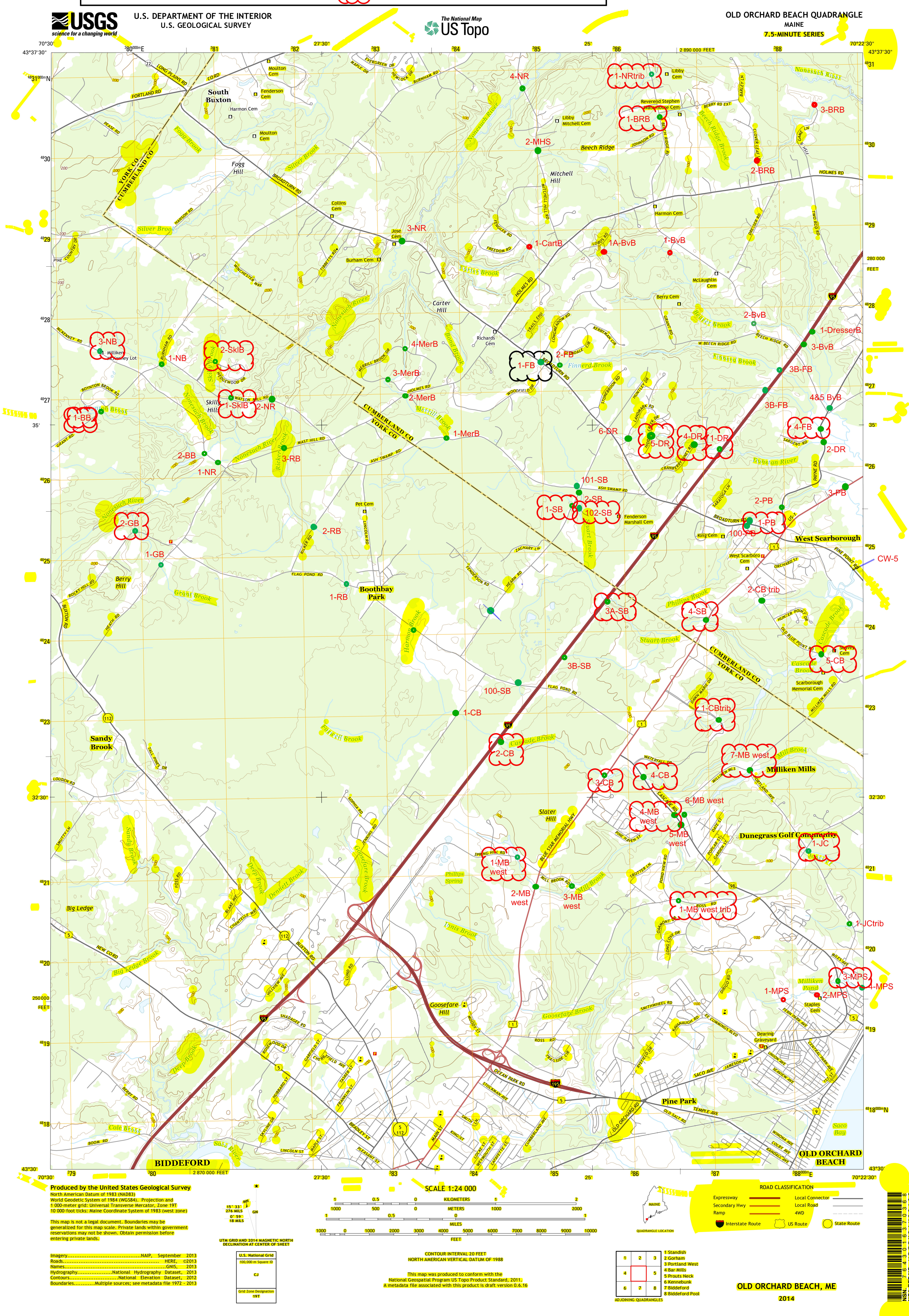
- Map B-1: Old Orchard Beach with stream crossing sites
- Map B-2: Prouts Neck Quad with stream crossing sites

(use the *Zoom* feature to enlarge the image)

Map B-1 Legend

- Stream crossing site surveyed
- Stream crossing site not surveyed
- Stream crossing site not found
- Site with water-flow or fish-passage restriction

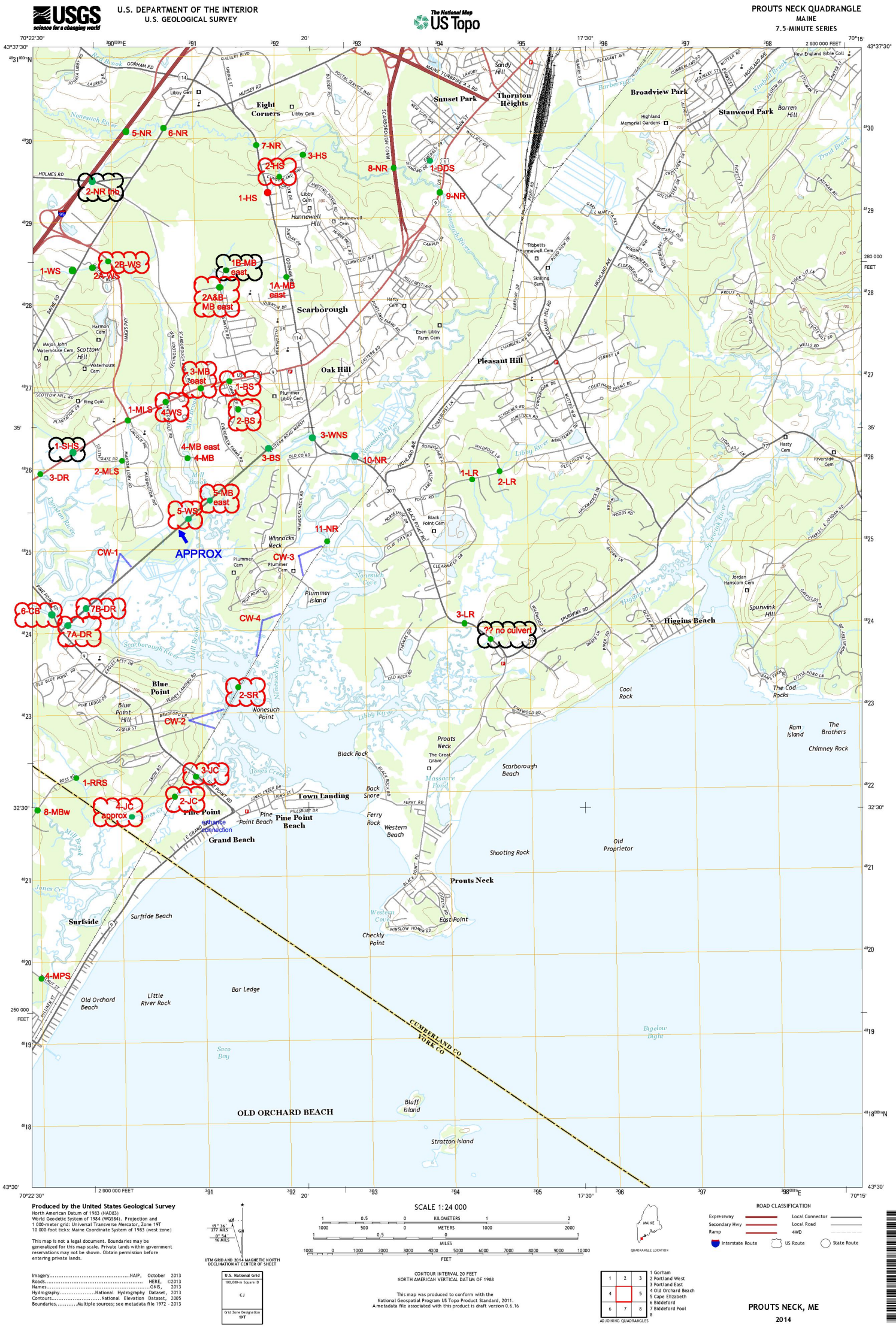
MAP B-1



Map B-2 Legend

- Stream crossing site surveyed
- Stream crossing site not surveyed
- Stream crossing site not found
- Site with water-flow or fish-passage restriction

MAP B-2



APPENDIX C

Stream Crossing Survey Spreadsheet

(use the *Zoom* feature to enlarge the image)

Excel file available upon request: stevepinette@outlook.com

Scarbourgh Marsh Watershed: Stream-Crossing Survey Data

Report date - October 2017

River or Stream	FOSM Crossing ID [a]	Statewide Stream Crossing Survey ID	Crossing Type	Crossing Description [b]	Restriction [c]	Cause of Restriction	Description of location	inlet elev. with respect to streambed (in.)	outlet elev. with respect to streambed (in.)	outlet water drop (ft.)	(e) OUTLET Water Depth (ft.)	Date of Survey [d]	Comments
Beaver Brook	1a-BvB	not surveyed		**NOT SURVEYED BY EITHER STUDY**	**NS**		off lobos Rd	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Beaver Brook	1b-BvB	not surveyed		**NOT SURVEYED BY EITHER STUDY**	**NS**		on side road on east side of Beech Ridge	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Beaver Brook	2-BvB	51676	round culvert	70" ID corrugated metal pipe culvert	1		at Beech Ridge Rd.	@grade	@grade		1.42	12/27/2016	
Beaver Brook	3-BvB	51675	box culvert	approx. 10-ft. long concrete open box culvert with wing walls	1		under Turnpike	na	na		nm	1/5/2017	
Beaver Brook	4-BvB	56183	round culverts	three 60" ID corrugated metal pipe culverts	1		intersection of Payne and Beech Ridge rd	@grade	@grade		0.50	12/21/2016	
Beaver Brook	5-BvB	56184	round culverts	four 50-55" ID corrugated metal pipe culverts	1		at Scottow Hill Road	@grade	@grade		0.58	12/21/2016	
Beech Ridge Brook	2-BRB	not surveyed		**NOT SURVEYED BY EITHER STUDY**	NS		at Clover Leaf Lane	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Beech Ridge Brook	3-BRB	not surveyed		**NOT SURVEYED BY EITHER STUDY**	**NS**		at end of Fish & Game Lane	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Beech Ridge Brook	1-BRB	not surveyed	round culvert	30" corrugated metal pipe culvert	2	perched outlet	at Beech Ridge Rd.	@grade	perched	0.41	1.92	12/27/2016	
Bessey School Stream	1-BS	not surveyed	round culvert	48" ID concrete pipe culvert	2	perched outlet	at Route 1	nm	perched	0.17	0.08	12/21/2016	
Bessey School Stream	2-BS	not surveyed	round culvert	48" ID plastic, corrugated pipe culvert	4	outlet +4" above stream bed	at Ballantine Drive off Commerce Drive	+5"	+4"		0.08	12/21/2016	
Bessey School Stream	3-BS	not surveyed	box culvert	granite-block, open-box culvert, 35" W x 40" H	1		at Eastern Trail	na	na		0.67	1/9/2017	
Boynton Brook	1-BB	11391	round culvert	48" ID plastic pipe culvert	2	perched outlet	at Grant Road	+9"	perched	nm	0.33	11/25/2016	outlet discharges into plunge pool, which flows into steep-gradient rocky channel
Boynton Brook	2-BB	11382	round culvert	58" ID corrugated metal pipe culvert	1		at McKenney Rd.	@grade	@grade		0.92 (at inlet)	11/25/2016	inlet on bedrock; outlet on sand/cobble substrate
Carter Brook	1-CartB	not surveyed		**NOT SURVEYED BY EITHER STUDY**	**NS**		at Fengler Rd.	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Cascade Brook	1-CB	11290	bridge/box culvert	12.5-ft. wide concrete, open-box culvert	1		at Jenkins Rd.	na	na		na	1/2/2017	
Cascade Brook	2-CB	11289	bridge/box culvert	double, open-box culvert w/ wing walls	3	2-ft. ledge drop directly upstream	under Turnpike	@grade	inaccessible		inaccessible	1/2/2017	2 ft. high ledge drop directly upstream may limit some fish migration
Cascade Brook	3-CB	11352	bridge/box culvert	8-9 ft. wide concrete open-box culvert	4	series of cascades downstream	at Route 1	na	na		na	1/5/2017	cascades downstream may restrict fish passage
Cascade Brook	4-CB	11353	bridge/box culvert	9-10 ft. wide concrete open-box culvert, cobble bottom	4	cascade upstream	at Route 98	na	na		na	1/5/2017	cascade upstream may restrict fish passage
Cascade Brook	5-CB	D1400	bridge/box culvert	concrete open-box culvert w/ wing walls; steel dam immediately upstream	5	Dam	at Old Blue Point Rd.	na	na		na	11/6/2016	Dam (81.8' L x 8.2' W; spillway = 4.3' L x 6.2' H)
Cascade Brook	6-CB	56119	round culvert	large ID corrugated metal pipe culvert; couldn't measure diameter	2	perched outlet	at Pine Point Rd.	@grade	perched	0.4	1.5	12/21/2016 (7/21/2015)	metal dam panels upstream are corroded and breached; affects flow dynamics
Cascade Brook Trib.	1-CB trib	not surveyed	box culvert	6 ft. wide concrete open-box culvert; 32" high	4	significant cascade immediately downstream	Waterfall Dr. extension to Donna Marie D	na	na		0.50	1/5/2017	cascades immediately downstream may restrict fish migration
Cascade Brook Trib.	2-CB trib	not surveyed	round culvert	29" ID black plastic pipe culvert, smooth interior	1		at Old Blue Point Rd.	@grade	@grade		1.08	1/5/2017	1
Diamond Drive Stream	1-DDS (a)	D1404	dam	Concrete Dam; 7.55' ht. x 98.8' long; spillway 7.22' ht. x 9.8' long	5	Dam	on Diamond Drive (near So.Po. Townline	na	na		na	6/7/2012	
Dresser Brook	1-DB	56174	box culvert	~12-15 ft. concrete open-box culvert	1		under Turnpike	na	na		na	12/31/2016	
Dunstan River	1-DR	60203	round culvert	82" ID concrete pipe culvert	4	upstream flow through raised cobble/talus pile	under Turnpike	@grade	inaccessible		0.5 (inlet)	1/2/2017	upstream flow through raised cobble/talus; may restrict fish passage at low water
Dunstan River	2-DR	60209	round culverts	two 42" ID corrugated metal pipe culverts	1		at Payne Rd.	@grade	@grade		0.25	12/21/2016	
Dunstan River	3-DR	56186	round culverts	four 78" ID thick-walled, smooth plastic pipe culverts	1		at Route 1	@grade	@grade		1.83	12/21/2016	
Dunstan River	4-DR	not surveyed	round culvert	48" ID concrete pipe culvert with ~3-ft. drop to water pool	2	perched outlet	at Cranberry Pines Rd.	@grade	perched	nm	nm	1/2/2017	
Dunstan River	5-DR	not surveyed	round culvert	~31" ID smooth pipe culvert (didn't record type: concrete or plastic)	4	1-ft. (elev change) 20 ft. downstream	at Hidden Creek Drive	@grade	+2"		0.33	1/6/2017	1+ ft. high cascade approx. 20 ft. downstream
Dunstan River	6-DR	not surveyed	round culverts	30" ID concrete pipe culvert (dry) and 20" ID conc. pipe culvert	1		at Landmark Drive	@grade (20"ID)	@grade (20"ID)		0.33	1/6/2017	invert of larger pipe ~ 2.5 ft. above stream substrate grade; cobble apron below 20" pipe potential fish restriction
Dunstan River	7A-DR	not surveyed	box culvert (closed	showing box culvert at western end of ET trail over Marsh	5	box culvert with visual evidence of flow volume restriction	Eastern Trail: west granite box culvert	na	na		na	1/9/2017	box culvert with visual evidence of flow volume restriction
Dunstan River	7B-DR	60484	bridge	bridge with armored rip-rap banks	5	evidence of constriction from aerial photo	at Eastern Trail	na	na		na	1/9/2017	evidence of constriction from aerial photo and modeling (Normandeau and WHO, 2002)
Finnerd Brook	2-FB	not surveyed	round culvert	24" ID corrugated metal pipe culvert	1		at Glendale Drive	inaccessible	@grade		0.67	1/6/2017	
Finnerd Brook	3a-FB (a)	56179	round culvert	concrete pipe culvert (Photo only--no measurments)	not noted	not noted	at Turnpike	not noted	not noted		not noted	10/1/2015	
Finnerd Brook	3b-FB (a)	60204	round culvert	concrete pipe culvert (Photo only--no measurments)	not noted	not noted	at Turnpike	not noted	not noted		not noted	10/1/2015	
Finnerd Brook	4-FB	56185	round culverts	two 60" ID corrugated metal pipe culverts	4	cobble raceway upstream	at Payne Rd.	@grade	@grade		0.33	12/21/2016	cobble raceway from upstream pond likely restricts fish passage; ***strong diesel/sewerage odor**
Grant Brook	1-GB (a)	11288	round culvert	73" ID corrugated metal pipe culvert	1		at Heath Road	@grade	@grade		0.59	5/18/2012	
Grant Brook	2-GB (a)	11350	round culvert	49" ID corrugated metal pipe culvert	2	perched outlet	at Rocky Hill Road	@grade	perched	0.98	2.30	5/18/2012	
Harmon Brook	1-HB	11348	round culvert	43" ID corrugated metal pipe culvert	1		at Flag Pond Rd.	@grade	@grade		1.08	1/6/2017	
Hearn Stream	1-HearnS	not surveyed	round culvert	24" ID corrugated metal pipe culvert	1		at Hearn Rd.	@grade	@grade		0.25	1/6/2017	this stream isn't shown on USGS topo map
Hunnewell Stream	1-HS	not surveyed		**NOT SURVEYED BY EITHER STUDY**	**NS**		at route 114	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Hunnewell Stream	2-HS	11447	round culvert	37" ID corrugated metal pipe culvert with metal 'spreader' structure at both ends	2	inlet and outlet would be "dry at low flow	at Cumberland Way	+5"	+11"		0.17	1/31/2017	
Hunnewell Stream	3-HS	not surveyed	round culverts	34" ID corrugated metal pipe culvert; and auxillary corrugated plastic pipe, 15" ID	1		at Woodspell Drive	@grade	@grade		0.58	1/31/2017	auxillary pipe is perched 18" above substrate (~14" above plunge pool)
Jones Creek	1-JC	not surveyed	round culvert	~25" ID corrugated metal pipe culvert	2	perched outlet	at Portland Rd.	nm	perched	0.33	0.17	1/5/2017	
Jones Creek	2-JC	56152	box culvert	Granite-block, open-box culvert, W ~ 60"	5	evidence of constriction from site visit and aerial photo	at railroad crossing SW of Snows Canning	na	na		3.08	12/29/2016	Tide-level monitoring (TNC, unpub. Data) indicates constricted flow
Jones Creek	3-JC	55028	box culvert	upstream: ~8' wide concrete, open-box culvert; downstream: granite-block, open-box culvert without flood gate	5	Previous flow modeling indicated constricted flow	at Pine Point Road	@grade	submerged		nm	12/21/2016	Tide-level monitoring (TNC, unpub. Data) indicates constricted flow
Jones Creek	4-JC	not surveyed	dam	Dam at Bayley Campground; data from 'Jones Creek Restoration Project' monitoring	5	Dam	dam adjacent to Bailey Campground	**NS**	**NS**	**NS**	**NS**	**NS**	
Jones Creek Trib.	1-JC trib	55330	round culvert	18" ID corrugated plastic pipe culvert	1		at Portland Ave.	@grade	@grade		0.13	1/6/2017	
Libby River	1-LR	not surveyed	round culvert	30" ID corrugated metal pipe culvert	1		at Fogg Rd.	@grade	@grade		0.92	12/27/2016	
Libby River	2-LR	not surveyed	round culverts	two 24" ID corrugated metal pipe culverts	2	perched outlet	at Fogg Rd.	nm	perched	0.33	0.42	12/27/2016	
Libby River	3-LR	not surveyed	round culverts	two 74" ID corrugated metal pipe culverts, plus one 54" ID corrugated metal pipe culvert	1		at Black Point Rd.	@grade	@grade		1.67	11/26/2016	
Manson-Libby Stream	1-MLS	not surveyed	round culvert	40" ID corrugated metal pipe culvert; outlet completely submerged	1		at Manson-Libby Rd. and Route 1	nm-iced	nm-flooded		nm-flooded	12/21/2016	outlet flooded
Manson-Libby Stream	2-MLS	56190	round culvert	30" ID corrugated metal pipe culvert	1		at Manson-Libby Rd.	@grade	@grade		1.50	12/21/2016	dense phragmites on both ends
Merrill Brook	1-MerB (a)	11274	round culvert	37" ID corrugated metal culvert	1	-	at Ash Swamp Road	@grade	@grade		0.98	5/29/2012	
Merrill Brook	2-MerB	11261	round culvert	36" ID corrugated metal pipe culvert	1		at Holmes Rd.	@grade	@grade		0.67	11/25/2016	
Merrill Brook	3-MerB	11496	round culvert	47" ID concrete pipe culvert	1		at Merrill Brook Drive	@grade	+5"		0.42	1/31/2017	
Merrill Brook	4-MerB	11499	round culvert	47" ID concrete pipe culvert	1		at Merrill Brook Drive	@grade	@grade		1.42	1/31/2017	
Mill Brook east	1a-MB-east	not surveyed	round culvert	54" corrugated metal pipe culvert; corroded at water line; 34" to substrate, therefore, embedded ~20"--unless it's an arch culvert??	1		at Route 114	embedded	embedded		0.25	11/26/2016	cmp corroded; pools downstream, possibly due to log across channel
Mill Brook east	2a-MB-east	not surveyed	round culvert	54" corrugated metal pipe culvert	4	rip-rap pile above inlet & below outlet	at Sawyer Road	@grade	@grade		0.50	11/26/2016	rip-rap piles above inlet and below outlet may restrict fish passage
Mill Brook east	2b-MB-east	not surveyed	round culvert	72" corrugated metal pipe culvert	1		at Sawyrass Drive	@grade	@grade		8"	11/26/2016	
Mill Brook east	3-MB-east	56172	round culvert	70" ID concrete pipe culvert	2	perched outlet	at Route 1 near Comfort Inn	embedded	perched	nm	0.33	12/21/2016	
Mill Brook east	4-MB-east	not surveyed	round culverts	two 50" ID corrugated metal pipe culverts	1		at Willowdale Rd.	nm	nm		1.58	12/21/2016	
Mill Brook east	5-MB-east	D3243	dam	concrete dam with flow structure	5	concrete dam/flow structure at inlet end w/ 2-ft. pool drop	at Eastern Trail	na	na	2	nm	1/9/2017	
Mill Brook west	1-MB-west	not surveyed	round culverts	Twin 48" ID concrete pipes culverts with downstr. 'flare' /spreader structure	2	perched outlet	at Industrial Park access rd.	na	perched	0.33	0.25	1/5/2017	outlet lip is ~4" above pool level; inlet is a concrete flow-control structure at Mill Pond
Mill Brook west	2-MBwest	55597	round culvert	40" corrugated metal pipe culvert	1		at Route 1	@grade	@grade		1.25	1/5/2017	
Mill Brook west	3-MB-west	not surveyed	round culvert	60" ID concrete pipe culvert	1		at Mill Brook Rd.	@grade	@grade		1.58	1/5/2017	
Mill Brook west	4-MB-west	56154	round culvert	72" corrugated metal pipe culvert	4	cascade 5-6 ft. upstream	at Route 98	@grade	@grade		1.67	1/5/2017	cascade 5-6 ft. upstream of culvert
Mill Brook west	5-MB-west	55013	round culvert	54" corrugated metal pipe culvert	1		at Route 98 near ET crossing	@grade	@grade		1.75	1/5/2017	
Mill Brook west	6-MB-west	not surveyed	box culvert	concrete open-box culvert; ~7 ft. wide	1		at Old Cascade Rd.	na	na		~3.0	1/5/2017	inlet has 6" high cascade ~ 5 ft. upsteam
Mill Brook west	7-MB west	D1403	box culvert (closed	Concrete closed-box culvert with concrete dam underneath	5	concrete dam under box culvert	at Milliken Mills/Portland Ave.	dam	na		nm	11/6/2016	
Mill Brook west	8-MB-west	55139	round culverts	Three 48" ID corrugated metal pipe culverts	1		at Ross Rd.	@grade	@grade		0.25	11/7/2016	
Mill Brook west trib.	1-MB-west trib.	56155	round culvert	24" ID corrugated metal pipe culvert	2	perched outlet	at Pond View Rd.	@grade	perched	0.50	0.25	1/5/2017	
Milliken Pond Stream	3-MPS	55713	box culvert (closed	concrete closed-box culvert: W = 5'1; H = 3'6"	2	perched outlet; top of base slap is 2-3" above pool surface	at Route 98	perched	perched	0.25	0.33	1/6/2017	top of base slab is 2-3" above pool surface;
Milliken Pond Stream	4-MPS	55554	round culverts	3 x 24" ID concrete pipe culverts	1		at Walnut St.	@grade	@grade		0.50	1/6/2017	water is ponded along a significant portion of upstream section of Walnut St.
Mitchell Hill Stream	2-MHS	11358	round culverts	two 30" corrugated metal pipe culverts; one outlet imbedded in sand substrate & other outlet 1-2" above substrate	1		at Mitchell Hill Rd.	@grade	@grade (~2")		0.10	11/25/2016	
Nonesuch Brook	1-NB	11380	round culvert	62" ID corrugated metal pipe culvert	1		at Burnham Rd.	+"8"	+4"		1.00	11/25/2016	
Nonesuch Brook	3-NB (a)	11378	round culvert	30" ID corrugated metal pipe culvert	2	perched outlet	at McKenny Rd. north of 1-NB	@grade	perched	2.03	0.16	5/18/2012	
Nonesuch River	10-NR	11335	bridge	single-span bridge	1		at Black Point Rd.	na	na		na	1/6/2017	
Nonesuch River	11-NR	not surveyed	bridge	wooden pile-supported railroad trestle	1		railroad trestle over Scarb. River in E. Mar	na	na		na	1/6/2017	channels formed along railroad embankment perpendicular to river axis
Nonesuch River	1-NR	11381	round culverts	three 36" ID corrugated metal pipe culverts	1		at McKennish Rd.	embedded	+2"		0.50	11/25/2016	pools above and below culvert
Nonesuch River	2-NR	11286	pipe-arch culvert	half-arch corrugated metal pipe with concrete footings/sidewalls; walls 10" ht. on upstream end	1		at Watson Mill Rd.	@grade	@grade		0.83 (at inlet)	11/25/2016	bedrock stream bed on both ends; ledge drop ~10" downstream of inlet may restrict some fish passage at low water levels
Nonesuch River	3-NR	11255	box culvert	concrete open-box culvert; has wing walls	1		at Broadturn Rd.	na	na		na	11/25/2016	
Nonesuch River	4b-NR	11357	box culvert	40' long concrete open-box culvert/bridge (no measurements)	1		at Beech Ridge Rd.	na	na		na	12/27/2016	
Nonesuch River	4-NR	11328	pipe-arch culvert	two +12' ID half-arch corrugated metal pipe culverts; could not see if there is a concrete footing on either side.	1		at Mitchell Hill Rd.	na	na		na	11/25/2016	
Nonesuch River	5-NR	11466	bridge	concrete arch culvert/bridge; ~20 ft. wide; viewed outside r.o.w.	1		under Turnpike	na	na		na	12/31/2016	downstream side is ponded; could indicate(?) some restriction to upstream flow if in tidal zone; viewed outlet only
Nonesuch River	6-NR	11359	bridge	20'+ concrete open-box arch culvert	1		at Payne Rd.	na	na		na	12/21/2016	
Nonesuch River	7-NR	11327	bridge	~19' long concrete open-box culvert/bridge	1		at Route 114	na	na		na	12/27/2016	
Nonesuch River	8-NR	11347	bridge	~20' long concrete open-box culvert/bridge	1		at Scarborough Connector	na	na		na	12/21/2016	
Nonesuch River	9-NR	11330	bridge	~22' long concrete open-box culvert/bridge	1		at Route 1	na	na		na	12/21/2016	
Nonesuch River Trib.	1-NRTrib	(a) 11356	round culvert	26"ID corrugated metal pipe	2	perched outlet	at Beech Ridge Rd.	@grade	perched	0.16	0.16	5/29/2012	
Phillips Brook	1-PB	56193	round culverts	38" ID and 32" ID smooth plastic pipe culverts	4	stream bed cascades into both inlets	at Broadturn Rd.	embbedded	@grade		1.50 & 0.33	1/6/2017	stream cascades into both inlets; the 32" pipe recieves the most flow (has the 18" outlet water level)
Phillips Brook	2-PB	56194	round culverts	two 60" ID plastic pipe culverts	1		at Payne Rd.	@grade	@grade		1.25	12/21/2016	
Phillips Brook	3-PB	56195	round culvert	70"+ ID smooth plastic pipe culvert	1		at Route 1	@grade	@grade		3.50	12/21/2016	
Phillips Brook	100-PB (a)	56192	round culvert	38" ID corrugated metal pipe culvert	1		at Martin's Ave.	@grade	@grade		0.1	7/17/2015	
Ricker Brook	1-RB (a)	11311	round culvert	concrete pipe culvert	1		at Flag Pond Rd.	@grade	@grade		0.70	5/29/2012	
Ricker Brook	2-RB (a)	11383	round culvert	47" ID corrugated metal pipe culvert	1		at Ricker Rd.	@grade	@grade		2.13	5/29/2012	
Ricker Brook	3-RB	11499	round culverts	two 18" ID corrugated metal pipe culverts	1		at Mast Hill Rd.	@grade	+2"		0.21	11/25/2016	
Ross Rd. Stream	1-RRS	55651	round culvert	32" ID corrugated metal pipe culvert	1		at Ross Rd.	@grade	+2"		0.50	1/6/2017	
Scarborough River	2-SR	not surveyed	bridge	wooden pile-supported railroad trestle	5	evidence of constriction from aerial photo	railroad trestle over Scarborough River	na	na		na	12/29/2016	evidence of constriction from aerial photo and modeling (Normandeau and WHO, 2002)
Skilly Brook	1-SkiB	11379	round culvert	42" ID corrugated metal pipe culvert; upstream end has concrete-tile flow structure	2	perched outlet	at Watson Mill Rd.	@grade	perched	0.83	0.13	11/25/2016	
Skilly Brook	2-SkiB (a)	11439	round culvert	39" ID corrugated metal pipe	2	perched outlet	at Wedgewood Drive	@grade	perched	nm	1.64	5/18/2012	
Stuart Brook	101-SB (a)	11278	round culvert	38" ID smooth concrete culvert, and corrugated metal pipe culvert (not measured)	1		at Ash Swamp Rd.	@grade	@grade		0.62	5/25/2012	
Stuart Brook	1-SB	11277	round culvert	56" ID corrugated metal pipe culvert	4	pool cascade into inlet with 6" drop	at Hearn Rd. near Frazier Acres access rd.	no(-6")	@grade		0.50	1/6/2017	pool above inlet cascades into culvert with ~6" drop;
Stuart Brook	2-SB	11273	round culvert	56" ID corrugated metal pipe culvert	1		at Hearn Rd.	@grade	@grade		0.58	1/6/2017	
Stuart Brook	3a-SB	11310	round culvert	10" ID concrete pipe culvert	2	perched outlet (viewed from outside r.o.w.)	under Turnpike	no access	perched		0.10	1/2/2017	viewed from ~40 ft. away outside right-of-way fence; viewed outlet only
Stuart Brook	3b-SB	not surveyed	round culvert	concrete pipe culvert, 12-16" ID, estimated	1		under Turnpike, trib. to Stuart Brook	nm	embedded		1.0+ in channel	1/2/2017	viewed from ~40 ft. away outside right-of-way fence;
Stuart Brook	4-SB	11344	arch culvert	5-6 ft. wide concrete open arch culvert	3	waterfall ~100 yards downstream	at Route 1	na	na		na	1/5/2017	theres's a significant waterfall ~100 yds. downstream
Stuart Brook	102-SB (a)	11448	round culvert	26" ID corrugated metal pipe culvert	2	perched outlet	at Frazier Road	@grade	perched	1.31	0.16	5/25/2012	primary culvert rusted out, forming a cascade
Stuart Brook	100-SB (a)	11396	round culvert	26" ID corrugated metal pipe	1		at Flag Pond Rd. north of TPk	@grade	@grade		1.05	5/29/2012	
Willow Stream	1-WS	not surveyed	round culvert	40" ID (type?) pipe culvert	1		at Payne Rd.	@grade	@grade		2.08	12/27/2016	
Willow Stream	2a-WS	not surveyed	round culverts	two 30" ID concrete pipe culverts; adjacent 14" ID plastic corrugate pipe culvert	1		at Gateway Blvd.	@grade	@grade		0.08	12/27/2016	
Willow Stream	2b-WS	not surveyed	round culverts	three 40" ID concrete pipe culverts	2	2 pipes are dry; wet pipe has perched outlet	at Haigis Parkway	see comments	perched	0.33	0.50	12/27/2017	2 of the pipes dry; pipe with flow has 6" of water level at pipe outlet, but plunges ~4" to lower pool surface
Willow Stream	4-WS	not surveyed	round culvert	70" ID concrete pipe culvert	2	perched outlet	at Route 1	embedded	perched	nm	0.83	12/21/2016	2
Willow Stream	5-WS	D3242	dam	inlet = concrete dam and flow struction; outlet = 8' wide granite-block open-box culvert	5	concrete dam/flow structure at inlet end w/ 2-ft. pool drop	at Eastern Trail	na	na	2	na	1/9/2017	
Winnocks Neck Stream	3-WNS	11265	round culvert	34" corrugated metal pipe culvert embedded in substrate 9-10"	1		at Black Point Rd.	embedded	embedded		1.17	11/26/2016	

NOTES

[a] If annotated, indicates crossing information is based entirely on Maine Stream Crossing Survey (i.e., FOSM survey did not survey this site)

If underlined, indicates specific parameter is based on Maine Stream Crossing Survey information

[b] 3-sided (or 'open') box culvert/bridge = concrete culvert with two vertical sidewall and horizontal top panel, but with no bottom panel

3-sided arch culvert/bridge = concrete structure with two vertical sidewall panels and arched top panel

Closed box culvert =4-paneled concrete structure, with panels intersecting at right-angles

Arch culvert = typically, top half of a cmp culvert, resting on concrete sidewalls

cmp = corrugated metal pipe culvert (traditional culvert design)

concrete pipe culverts = as cmp, but concrete composition, instead of metal

plastic pipe culvert = as cmp, but with plastic composition, instead of metal; may be corrugated or smooth design

[c] Restrictions: 1 = none: neither flow or fish-passage restriction; 2 = fish-passage restriction (culvert); 3 = natural fish passage restriction (waterfall; natural barrier); 4 = Potential natural or man-made fish passage restriction; 5 = flow restriction/barrier);

[d] Outlet water depths measured in 2012 and 2015 are from Maine Stream Crossing Survey; indicates that icing or access problem prevented measurement during FOSM survey

na = not applicable (generally pertaining to bridge outlet and inlet data)

nm = not measured

NS = note surveyed by either study