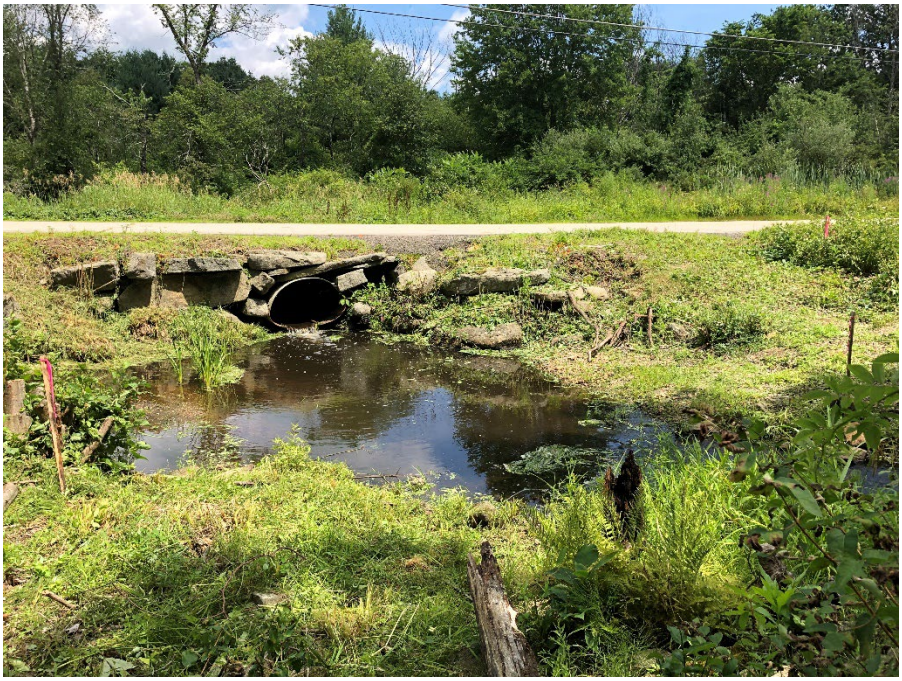
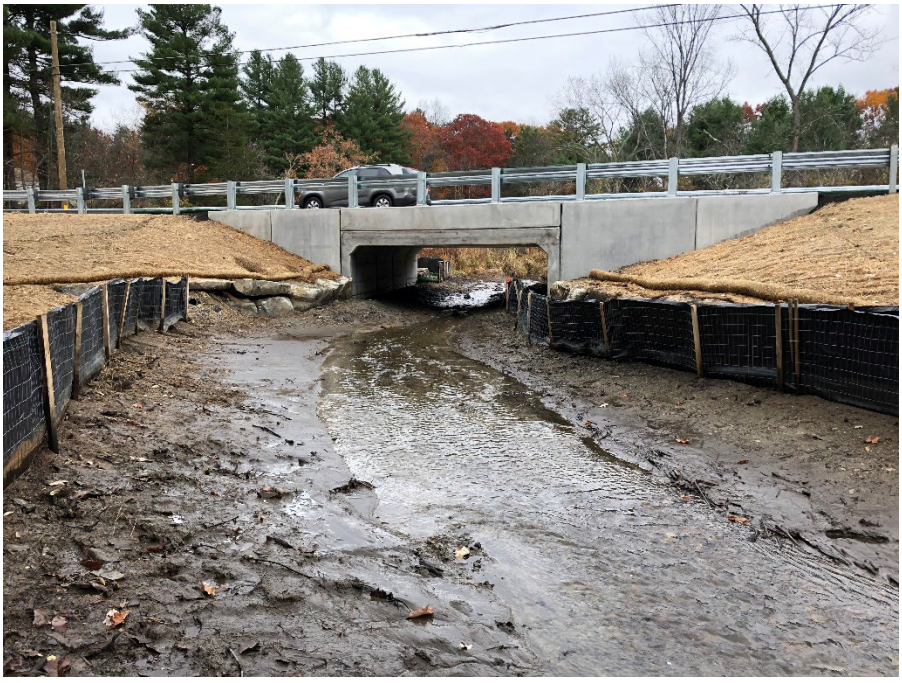
NEW HAMPSHIRE RESILIENT TIDAL CROSSINGS PROJECT

Advancing high priority tidal culvert replacements through Tier 4 Tidal Stream Crossing Rules





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Advancing high priority tidal culvert replacements through Tier 4 Tidal Stream Crossing Rules

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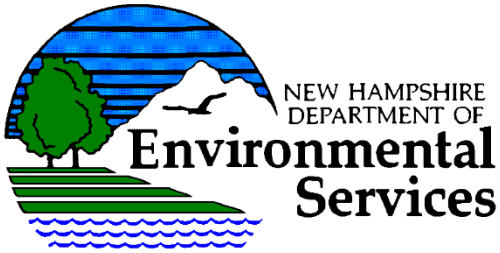

Acknowledgements:

The New Hampshire Resilient Tidal Crossing Project is a multi-year partnership between the New Hampshire Department of Environmental Services -Coastal Program and The Nature Conservancy that improved the practice of tidal stream crossing management in New Hampshire through the creation and implementation of a comprehensive field assessment protocol; creation of new regulatory policies; and the proactive advancement of design, permitting, and replacement of high priority tidal crossings. This project wouldn't have been possible without participation from tidal culvert owners, including the New Hampshire Department of Transportation and the Towns of Newmarket and Seabrook. Engineering services that contributed to the success of this project were provided by: Wright Pierce Engineers, CMA Engineers, Streamworks and Horsley Witten Group. Peter Steckler, Principal at Northeast Conservation Services, assisted in the drafting of the permitting guidance below.

This phase of the project was made possible with funding from NOAA's Office for Coastal Management under the Coastal Zone Management Act in collaboration with the New Hampshire Department of Environmental Services and The Nature Conservancy

Cover Photos:

Top Photo: Undersized and perched tidal culvert at Bay Road and Lubberland Creek in 2014 (credit: TNC). Bottom Photo: New restilient tidal culvert installed at Bay Road and Lubberland Creek in 2019 (credit: TNC)

INTRODUCTION

There are approximately 120 tidal stream crossings in New Hampshire. For the purposes of this project, a tidal crossing is a culvert, bridge, or tide gate associated with a road or other form of crossing infrastructure that conveys the flow of tidal water. There are relatively few tidal crossings in New Hampshire when compared to the approximate 21,000 freshwater stream crossings in the state, but they play a critical role for the ecological integrity of aquatic systems at both the estuary and watershed scales. For example, tidal crossings often restrict tidal flows (referred to as tidal restrictions) thus altering hydrology, sediment movement, salinity, and plant species composition of tidal wetlands. Tidal restrictions ultimately limit the ability for salt marsh systems to build in elevation and migrate upstream with rising sea levels. Tidal restrictions also block migratory fish from accessing critical upstream habitats. From a transportation connectivity perspective, tidal crossings are necessary to safely and reliably convey people, goods and services throughout coastal communities; however, this infrastructure is increasingly at risk from flooding and erosion with rising sea levels and more frequent and intense storm events. Designing resilient tidal crossing replacement projects requires balancing many considerations, which if done properly, can lead to ecological, infrastructure and flood risk mitigation improvements.

This document describes the process undertaken by the New Hampshire Department of Environmental Services (NHDES) and its partners to assess tidal crossings in New Hampshire and advance the highest priority tidal crossings through design, engineering and permitting in accordance with Tier 4 Stream Crossing Rules (Env-Wt 904.06), as well as New Hampshire Coastal Flood Risk Guidance (Env-Wt 603.05). The purpose of this publication is to give stakeholders (e.g., municipal employees and committees, consulting engineers, transportation managers, and habitat restoration practitioners) a simple overview of the NHDES permitting process for tidal crossing replacement as well as to provide case studies of recent proactive tidal crossing replacement projects in New Hampshire's Coastal Zone.

BACKGROUND

The Nature Conservancy (TNC) and the NHDES Coastal Program (NHCP) began partnering on the subject of tidal crossings in 2014 when NHCP awarded Coastal Resilience Grant funding to TNC to support the design of New Hampshire's first truly resilient tidal crossing replacement at Lubberland Creek in Newmarket (see Case Study below) as well as the development of New Hampshire's Tidal Crossing Assessment Protocol. Published by TNC in 2017, the New Hampshire Tidal Crossing Assessment Protocol established methods and criteria to evaluate tidal crossings based on the following coastal resilience-focused attributes: structure condition; degree of flood risk to the roadway; degree of flood risk to the crossing structure; crossing effect on aquatic organism passage; crossing effect on salt marsh vegetation; crossing restriction of tidal flow in and out of the salt marsh; potential for the salt marsh to migrate inland with sea level rise; and potential adverse upstream impacts of restoring full tidal flow. NHCP used the protocol to assess all of New Hampshire's tidal crossings in 2018, which resulted in the publication of Resilient Tidal Crossings – An Assessment and Prioritization to Address New Hampshire's Tidal Crossing Infrastructure for Coastal Resilience and subsequently led to the identification of five tidal crossing replacement and restoration projects that TNC, NHCP and other partners advanced through design and engineering between 2020 and 2023. A few of these projects are highlighted in the Case Study and Appendices of this document to demonstrate approaches to developing resilient and ecologically compatible designs for tidal crossing replacement.

PLANNING AND DESIGN CONSIDERATIONS FOR REGULATORY COMPLIANCE

Projects involving dredge or fill or the placement of structures on or within the banks or bed of surface waters are subject to authorization by the NHDES Wetlands Bureau in accordance with RSA 482-A (Fill and Dredge in Wetlands) and the New Hampshire Code of Administrative Rules at Env-Wt 100-900. The NHDES Wetlands Permit Application can be downloaded from the NH Online Forms website.

The purpose of Chapter Env-Wt 900 is to "enhance public safety by establishing standards for stream crossings that are designed to lessen the risk of blockages and wash-outs of culverts and bridges, and the associated flooding, which can jeopardize property and human lives upstream and downstream of such crossings." The purpose is also to "preserve and enhance the functions and values of existing streams, support the restoration of impacted streams to their natural state, and improve aquatic organism passage and sediment transport." Therefore, the goal of NHDES Wetlands Bureau permitting is to design stream crossings that are compatible with the hydrology, geomorphology and passage of aquatic organisms in the stream.

Culvert replacement projects in New Hampshire are regulated by the NHDES Wetlands Bureau based on a hierarchy (Tiers) of increasing due diligence and engineering requirements and a corresponding increase of contributing watershed size and complexity of ecological setting. NHDES adopted "Tier 4" stream crossing rules (Env-Wt 904.06) in 2019, which created new regulatory design criteria for the replacement/repair of culverts and bridges affected by tidal flow. Tier 4 stream crossings require similar engineering and environmental due diligence as Tier 3 sites, except with a particular focus on the suitability of stream crossing infrastructure with tidal conditions. The following are regulatory design criteria for Tier 4 stream crossings, with guidance provided in *italic*:

- ***Env-Wt 904.01 (a) (3):*** All stream crossings, whether tidal or non-tidal, shall be constructed to not obstruct or substantially disrupt to movement of aquatic organisms.

  ✓ *Therefore, the design process must determine the aquatic organisms indigenous to the waterbody and incorporate their swimming capacities and/or passage needs into the design.*

- ***Env-Wt 904.06 (b)***: A tier 4 stream crossing shall be a span structure or a culvert specifically designed for the geomorphic and habitat conditions of the tidal environment.

  ✓ *Therefore, the structure width should at least match the width of the reference tidal stream channel.*

- ***Env-Wt 904.06 (d)*** Compensatory mitigation shall be required for any new tier 4 stream crossing unless the replaced structure meets certain requirements, such as adhering to the General Design Considerations described in 904.01 and improving aquatic organism passage, connectivity, and hydraulics.

  ✓ *Therefore, incorporating resilience and restoration principals into tidal crossing design can achieve multiple benefits, including avoiding mitigation payment by ensuring compliance with required standards.*

- ***Env-Wt* 904.07 (c) (2):** Shall be designed of sufficient size to accommodate the 100-year 24-hour storm

  ✓ *Therefore, hydrologic analysis of the watershed needs to be performed to determine the 100 year discharge and the results need to be incorporated into the design.*

- ***Env-Wt 904.07 (d) (1)***: Based on a hydraulic analysis that accounts for daily fluctuating tides, bidirectional flows, tidal inundation, and coastal storm surge.

  ✓ *Therefore, hydrologic and hydraulic (H&H) modeling must be performed and should incorporate onsite upstream and downstream water level measurements to maximize compatibility of the proposed structure with normal tidal conditions and coastal storms. The type of hydraulic modeling will vary based on complexity of the tidal environment.*

- ***Env-Wt 904.07 (d) (2)***: To prevent creating a restriction on tidal flows.

  ✓ *Therefore, up and downstream surface water elevations are synchronized across all tidal stages. The proposed structure avoids an increase in water velocities through the structure that could result in channel scour and/or impacts to fish passage.*

- ***Env-Wt 904.07 (d) (3)***: To account for tidal channel morphology and potential impacts due to sea level rise.

  ✓ *Therefore, in addition to sizing the structure to match the existing stream channel size and shape, consider the height of the structure and road surface in relation to sea level rise at the site.*

Per Env-Wt 603.05, Tier 4 stream crossing replacement projects must also prepare a vulnerability assessment in accordance with the step-by-step process described in the "New Hampshire Coastal Flood Risk, Part II Guidance for Using Scientific Projections." By considering the New Hampshire Coastal Flood Risk Guidance early in the planning process, project proponents will incorporate coastal resilience principals into the design by identifying project goal(s), the design life of the project, the project's tolerance to flood risk from increases in sea level, coastal storms and extreme precipitation.

A Wetlands Functional Assessment Worksheet needs to be completed for each Tier 4 stream crossing replacement or restoration, which also requires the completion of a Coastal Area Worksheet. In addition, Env-Wt 603.04 requires the completion of a Coastal Functional Assessment (CFA) report as part of the Coastal Area Worksheet. Per Env-Wt 603.04 (b)(2)(b), which allows for alternative scientifically supported CFA methods, proponents of Tier 4 stream crossing replacement projects may use the results of New Hampshire's Tidal Crossing Assessment Protocol, including the Summary Sheets, which are available on the New Hampshire Coastal Viewer (under the "Layers" tab, see Environment and Conservation » Tidal Stream Crossings » Tidal Crossing Attributes » Summary Sheets).

CASE STUDIES

Funding from the National Oceanic and Atmospheric Administration's (NOAA) Office for Coastal Management has enabled NHCP to work with TNC and other partners to advance design and permitting at high priority tidal crossing sites. The local case studies described below demonstrate design processes and decisions for achieving resilient and ecologically compatible tidal crossing designs that are compliant with Tier 4 stream crossing rules.

Bay Road at Lubberland Creek Salt Marsh - Newmarket, New Hampshire

Bay Road crosses Lubberland Creek at the upstream extent of tidal flooding, also known as the head-of-tide. The pre-existing 36 inch squashed corrugated metal pipe under the Town of Newmarket's Bay Road (class V) was perched at all tidal stages. As such, it was a complete barrier to aquatic organism passage and was incompatible with upstream and downstream stream channel geometries. In addition to the culvert being ecologically incompatible, Bay Road had a history of being overtopped by Lubberland Creek. Maintaining transportation connectivity on Bay Road during storm events was a priority for the Town of Newmarket due to other known road flooding elsewhere in Town.

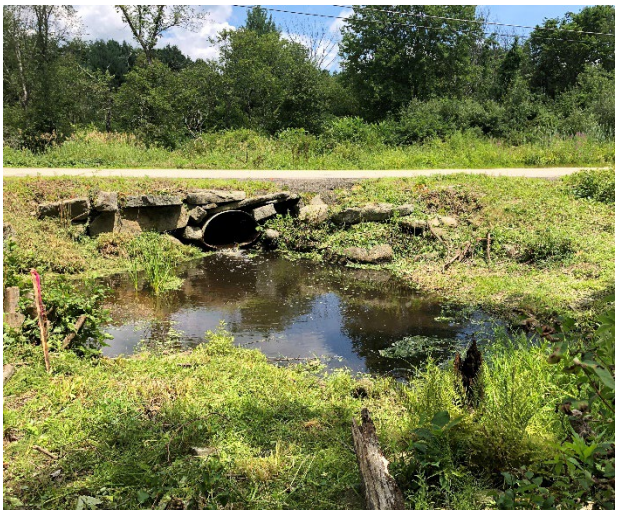

Figure 1. Culvert outlet at Bay Road and Lubberland Creek.

The table below details key design considerations that were incorporated into the 2015 project, prior to the availability of the "New Hampshire Coastal Flood Risk, Part II Guidance for Using Scientific Projection." Resilience is now bolstered at Bay Road because the 2015 culvert design assumed that a 100-year rain event would coincide with the highest tide of the year, while also planning for 3.74 feet of relative sea level rise (RSLR) occuring over the design life of the structure. While there is a low likelihood of a 100-year storm occurring during the highest tide of the year, the larger culvert design provides added resilience to the transportation network and improves conditions for fish and wildlife passage.

	Design Life	Flood Risk Tolerance**	RSLR Addressed**	Flood Resilient through Year	Reference Channel Width	Proposed Structure Width	H&H Modeling Approach	Eliminates Tidal Restriction
Bay Road*, Newmarket	75 years (~2100)	Low (emergency access)	3.74'	2115	10' to 12'	16-foot embedded Box	SCS TR-20 & 1D HEC-RAS v4.1.0	Yes

** The planning, design and engineering work for Lubberland Creek crossing replacement was completed prior to the adoption of the 2019 Tier 4 Stream Crossing Rules, but the planning process was driven by coastal resilience principles and therefore the constructed replacement (completed in summer 2019) is Tier 4 compliant.*

***Flood tolerance and RSLR projections for Bay Road were determined in 2015 in accordance with the U.S. Army Corps of Engineers' circular entitled "Incorporating Sea-level Change Considerations in Civil Works Programs."*

NH Route 1A at Rye Harbor - Rye, New Hampshire

NH Route 1A, or Ocean Boulevard, is a regionally significant north-south transportation corridor that runs adjacent to the Atlantic Ocean. In addition to its day-to-day service to local residents, Route 1A is the primary access to New Hampshire's most popular beaches, tourist amenities and active working waterfronts, and is a designated emergency access/evacuation route. In the vicinity of Rye Harbor, Route 1A is a low-lying causeway that bisects tidal creeks and salt marsh habitat. Flooding of the Route 1A causeway occurs during severe Nor'easters when tides are especially high. The subject granite and concrete culvert structure conveys tidal flows to and from the upper reaches of its watershed near Jenness Beach, where neighborhood flooding is becoming a more frequent issue from heavy precipitation events and Nor'easters that create coastal over-wash. The Rye Harbor culvert was identified by the NH Tidal Crossing Assessment Protocol as in extremely poor condition and in need of replacement for reliability and safety.

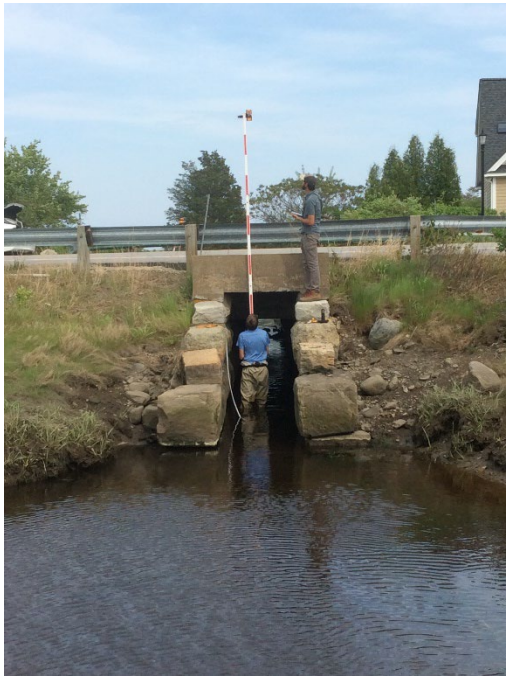

Figure 2. Culvert inlet at Route 1A and an unnamed tributary of the Awcomin Salt Marsh.

The table below details key design considerations in response to the Tier 4 stream crossing rules and the coastal vulnerability assessment for the Rye Harbor crossing. Due to the complexity of the tidal setting of Rye Harbor, a 2-dimensional hydraulic model was created to evaluate alternative culvert designs and flooding scenarios. The selected alternative at Rye Harbor will replace the existing 3.5 ft wide x 7 ft high granite block culvert with a 15 ft wide x 7 ft high, 3-sided concrete box on footings. Design goals for the project are to replace a poor condition crossing, enhance coastal resilience by addressing longer-term sea level rise and storm related flooding, eliminate tidal restriction, enable upstream marsh migration, and benefit organism passage and wildlife habitat. The design process determined that regardless of culvert size, road flooding will continue and potentially worsen in the future. Elevating Route 1A for flood resilience was considered but was determined to be well beyond the scope of the culvert re-design project. However, the proposed replacement structure is engineered to accommodate up to two additional feet of road elevation to adapt to sea level rise in the future*.

	Design Life	Flood Risk Tolerance*	RSLR Addressed	Flood Resilient through Year	Reference Channel Width	Proposed Structure Width	H&H Modeling Approach	Eliminates Tidal Restriction
Route 1A, Rye Harbor	75 years (~2100)	Medium	5.3'	Coastal storms will continue to cause road flooding	15'	15-foot three sided box	HEC-HMS v4.7.1, SMS v13.0.12 & SRH-2D	Yes

**Adaptively elevating the road surface by two feet in the future will accommodate the 2100 great diurnal tide without road flooding at the crossing. However, this additional road elevation is still subject to flooding from the 50 and 100-year storm surges in year 2100.*

Squamscott Road at Chapman's Landing Salt Marsh - Stratham, New Hampshire

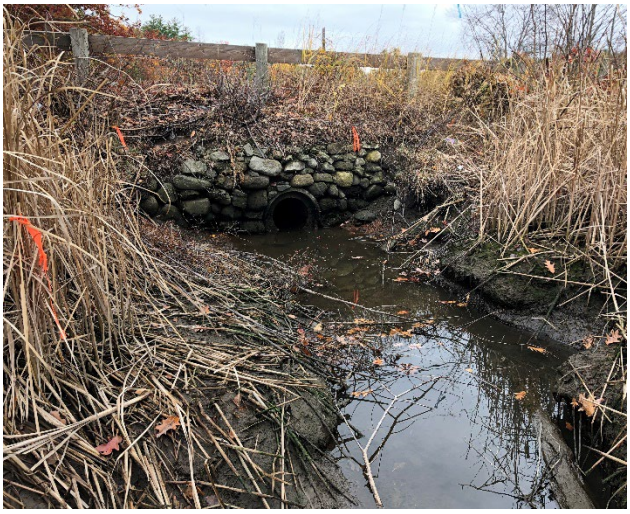

Figure 3. Culvert inlet at Squamscott Road and an unnamed tidal tributary of the Chapman's Landing Salt Marsh.

Squamscott Road is a New Hampshire Department of Transportation (NHDOT) owned Class II "Local Connector." Within a 0.3 mile segment, Squamscott Road has three tidal crossings through the Chapman's Landing Salt Marsh, two of which (Stratham East #113 and Stratham West #114) are severely undersized and incompatible with their tidal systems. Both crossings are 18-inch round reinforced concrete pipes that restrict tidal flows, have important upstream salt marsh migration potential, and are at-risk infrastructure due to poor condition and flood hazards. Located at the head-of-tide, there currently is limited tidal flooding at Squamscott Road, therefore, addressing freshwater flooding was a primary consideration in the re-design of these crossings.

The table below details key design considerations in response to the Tier 4 stream crossing rules and the coastal vulnerability assessment for the Stratham crossings. The selected alternative at Stratham East and West will increase culvert size from 18-inch pipes to 8 feet wide x 7 feet high concrete box culverts with simulated stream bed through the structures. Design goals for Stratham East and Stratham West are to replace aging infrastructure with crossing structures that minimizes future flood risk, eliminate tidal restrictions, enable upstream marsh migration, and benefit organism passage and wildlife habitat.

	Design Life	Flood Risk Tolerance	RSLR Addressed	Flood Resilient through Year	Reference Channel Width	Proposed Structure Width	H&H Modeling Approach	Eliminates Tidal Restriction
Stratham East #113 Stratham West #114	75 years (2100)	Medium (local connector)	3.8'	2100	9.5' 6.5'	8-foot embedded Box	1D HEC-RAS v5.0.7	Yes

APPENDICES: CASE STUDY DETAILS

The project materials presented in Appendix A, B and C (below) were prepared for TNC over the duration of the New Hampshire Resilient Tidal Crossing partnership with NHCP (2015-2023).

The tidal stream crossing replacement projects at New Hampshire Route 1A at Rye Harbor (Appendix B) and Squamscott Road at Chapmans Landing (Appendix C) were funded, in part, by:

- NOAA's Office for Coastal Management under the Coastal Zone Management Act – Project of Special Merit (NA20NOS4190110).

- NFWF NCRF (EasygrantsID 62525) “Tidal Crossing Replacements for a Resilient Coastal NH- TNC.”

While the Bay Road at Lubberland Creek Project (Appendix A) did not receive grant funding from this phase of work, the Project is included in this document because it is an important example of a resilient tidal crossing design. The engineering design drawings presented in Appendix B and C are not final, have not been granted final regulatory approval and are insufficient for construction.

A. BAY ROAD at LUBBERLAND CREEK - NEWMARKET.

    1. Bay Road - Alternative Analysis and Design Memo.

    2. Bay Road - Final Engineering Design Plans.

B. NEW HAMPSHIRE ROUTE 1A at RYE HARBOR - RYE.

    1. Rye Harbor - Preliminary Design Summary Memo.

    2. Rye Harbor - Preliminary Engineering Design Plans.

C. SQUAMSCOTT ROAD at CHAPMAN’S LANDING SALT MARSH - STRATHAM.

    1. Squamscott Road - Alternative Analysis and Design Memo.

    2. Squamscott Road - Preliminary Engineering Design Plans.

NOTE: The information presented in the remaining pages of this document include a mix of technical memos, graphs, figures and engineering design plans that are not machine readable.