Mill Pond Salt Marsh Restoration Alternatives Assessment Technical Memorandum

Town of Truro
Truro, MA

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Executive Summary

Currently, the Mill Pond Road culvert restricts tidal flow into Mill Pond from Pamet Harbor and, ultimately, Cape Cod Bay. The purpose of this project is to replace the damaged and undersized culvert at the Mill Pond Road dike with a larger structure or alternative breach design.

Structural, geotechnical analyses, and this technical memorandum were developed by Fuss & O'Neill, Inc. (F&O) in conjunction hydrologic/hydraulic analyses performed by Woods Hole Group (WHG). These analyses were completed to assess conditions and support development of 30% conceptual design drawings for the proposed alternatives to replace the of the existing 36-inch corrugated polyethylene pipe culvert on Mill Pond Road. A total of four alternatives were considered in the development of this report including two larger open bottom precast culverts and two embankment breach formations.

To assess the severity of the restriction and the potential for ecological restoration, the anticipated effects of replacing the undersized culvert with a larger culvert structure or open channel entailing abandonment of the road were evaluated. Woods Hole Group, Inc. (WHG) assessed the current and proposed alternative culvert and breach scenarios and provided recommendations for channel bed scour [protection measures for respective alternatives.

- Culvert Alternative No. 1: Single 8'-0"W x 8'-6"H Three-Sided Precast Concrete Box Culvert
- Culvert Alternative No. 2: Single 10'-0"W x 8'-6"H Three-Sided Precast Concrete Box Culvert
- Breach Alternative No. 1: 15' Bottom Width with Uniform Channel Banks
- Breach Alternative No. 2: 10' Bottom Width with Adjacent 15' Elevated Benches

An assessment of the above alternatives was completed, entailing consideration of construction costs, operation and maintenance costs and consideration of other evaluation criteria. Upon completing this assessment, it was determined that a breach channel with a 65-foot top width is the preferred alternative for subsequent design and implementation, subject to review and discussion with the Truro Selectboard and receipt of public input from ongoing outreach efforts

1 Project Description and Purpose

1.1 General Site Description and Project Purpose

The Project Site (Site) is located on Mill Pond Road (MPR) where the roadway crosses over a tidal creek referred to as the Mill Pond Channel stemming from Pamet Harbor to Mill Pond in Truro, Massachusetts. The Mill Pond Channel conjoins with the Pamet River and subsequently forms Pamet Harbor.

The earthen causeway supporting Mill Pond Road (MPR) effectively functions as a dike restricting tidal flows to, and drainage flows from, the Mill Pond impoundment. A 36-inch corrugated polyethylene pipe (CPP) conveys drainage from Mill Pond to the Pamet River (Figure 1).

Mill Pond has an extensive usage history dating back to the Revolutionary War Period. During the mid-19th century, Truro and other Cape Cod towns enjoyed economic success as major producers of salt from its shoreline waters. Mill Pond was regularly used as one of the largest salt works in New England. In 1869, a railroad bed was constructed across Pamet Harbor, which restricted Tidal Flows to Mill Pond, converting the impoundment to a freshwater marsh.

Figure 1 — Mill Pond Road Culvert Location

The freshwater condition remained until large storm events in 1978 and 1991 completely breached the former railroad embankment. The existing 36-inch CPP pipe was installed after the 1991 storm as a temporary measure, with the intent to subsequently install a larger timber bridge as a permanent structure. The bridge was never constructed and the 36-inch CPP remains today.

The roadway embankment covering over the culvert is subject to wave and roadway runoff erosion, resulting in a narrowing of the roadway shoulders over the culvert, and requiring regular repair and replenishment of stone armor scour protection.

The purpose of this project is to replace the undersized culvert that tidally restricts Mill Pond with a larger structure or channel breach alternative that will allow increased tidal flushing to restore degraded salt march resources, provide water quality improvements, and improve drainage runoff flows from the impounded system under both normal and storm flow conditions.

Woods Hole Group (WHG) is currently completing refined hydraulic modeling of alternative culvert sizes and configurations, in conjunction and collaboration with the structural and civil layout assessments described in this technical memorandum. The results of WHG's analyses and recommendations are contained in a separate technical memorandum to be provided to the Town of Truro in support of this project.

1.2 Existing Conditions

Conditions observed at the project site in May and June 2021 are described in the following sections. An existing conditions survey with current tidal elevations is provided as Attachment A.

1.2.1 Culvert and Downstream Channel/ Riverbank

The existing 36-inch diameter CPP below MPR has a total length of approximately 54 feet and is sloped from east to west at approximately 0.7 percent, having invert elevations of -2.03 and -1.6 (NAVD88) at its downstream (west) and upstream (east) ends, respectively. The downstream end of the culvert emerges from the causeway into a stone armored channel that discharges to the downgradient connecting to Pamet River.

Figure 2 — Downstream Culvert Outlet and Stone Armor Slope Protection (Facing North)

The areas surrounding the Mill Pond Channel are dominated by tidal conditions and supports a saltwater environment exhibited by the channel being surrounding by salt marsh vegetation and marsh flats farther downstream. The downstream channel is bounded by the Pamet Harbor Yacht Club to the north and Mill Pond Road/Post Drive to the south.

Approximately 1,600 feet downstream of the CPP, a breached former railroad embankment conveys tidal flow from Mill Pond to Pamet Harbor. The former railroad embankment appears to consist of sand with former railroad abutments of cut stone exposed in places at the breach..

The downstream face of the embankment is currently in poor condition as exhibited by displaced slope protection and debris build up around the culvert discharge point. The Town of Truro completes maintenance on the embankment annually to restore displaced riprap and repair areas of erosion. In addition, a scour hole is positioned at the discharge area at the beginning of the Mill Pond Channel.

1.2.2 Upstream Channel and Impoundment

The Mill Pond tidal impoundment upstream of the culvert receives water from upland areas via groundwater and overland runoff. The impoundment is bounded by salt marsh and other intertidal habitat around its perimeter, with forested residential properties bording the wetlands to the south, east and north, with a portion of the impoundment northern bank formed by the embankment slope supporting Depot Road.

The upstream end of the CPP projects from the earthen causeway supporting MPR, which is partially covered by stone armor protection over and adjacent to the culvert. Indications of a tidal restriction near the culvert's end include a scour hole with an intertidal island formed by shoaled

Figure 3 — Upstream Culvert Outlet, Scour hole and Shoaled Sediment (facing east)

Figure 4 — Downstream Tidal Channel and Abutting Salt Marsh (facing west)

Figure 5 — Upstream Culvert Outlet and Stone Armor Slope Protection (facing south)

sediment, a significant tidal lag and muting, poor drainage during inland precipitation events, and bank erosion adjacent to the culvert.

1.2.3 Roadway Approaches

The existing paved surface of MPR consists of two travel lanes (one lane in each direction) with a total width of approximately 18 feet. Metal beam guardrails are located on both sides of the roadway at its crossing over the culvert, with approximately 12-inches of clearance from the guardrail face to the edge of pavement (little to no shoulder).

Embankment slopes behind the guardrails exhibit signs of erosion and steepening, providing inadequate lateral support to the guardrail system, as indicated by leaning posts supporting the horizontal rail on the roadway's southbound (western) travel lane. Concrete posts are positioned beyond the ends of the metal beam guardrails in both directions at an approximate 8 foot spacing.

Figure 6 — Mill Pond Roadway Approach to Culvert (facing north)

Survey measurements along the roadway's centerline profile on both sides of the culvert indicate low points approximately 80 feet north and 115 feet south of the culvert (0.1 feet and 0.65 feet lower, respectively, than the roadway elevation at the culvert). The roadway is pitched to the upstream (east) slope in proximity to the culvert, with a small section south of the culvert nearly flat.

1.2.4 Roadway Stormwater Drainage

Stormwater runoff north of the culvert generally flows along the roadway's curb at the edge of pavement, with a leaching catch basin on the southbound (west) lane approximately 420 feet north of the culvert providing partial drainage. Runoff continuing past this drainage structure generally is generally conveyed as sheet flow to the shoulder and adjacent land along the northbound (east) lane, with the majority of runoff discharging from the road at the low point immediately north of the culvert and adjacent to a secondary residential driveway and sandy pull-out area.

Runoff arriving at the culvert from the north continues to the low point south of the culvert, where it generally is conveyed as sheet flow to Mill Pond as along the northbound shoulder and slope. A leaching catch basin is located on the northbound shoulder approximately 160 feet south of the culvert.

1.2.5 Flood Zones

Federal Emergency Management Agency (FEMA) Flood Map No. 25001C0227J for Barnstable County (with an effective date of July 16, 2014) depicts the project site as being located within a 'Zone AE' special flood hazard area with a 1% annual chance base flood elevation of 12 feet (NAVD88). The downstream tidal channel west of MPR is designated as a 'Zone AE' special flood hazard area with a 1% annual chance base flood elevation of El 13 feet (NAVD88). FEMA Flood Zone boundaries are depicted on the Existing Conditions Plan provided as Attachment A.

1.2.6 Contaminated/Hazardous Materials

There are no known or expected hazardous materials or contaminants located within the roadway and in off-roadway areas within the Project Site that would need to be managed during construction associated with the replacement of the existing culvert or excavation of an open channel alternative. Supplemental investigations of the environmental quality of soils comprising the causeway embankment are recommended in the subsequent project phase to confirm the above understanding.

1.3 Scope of Report

The primary scope of this report is to present findings of preliminary geotechnical and structural analyses completed to date and provide conceptual layouts for replacement culvert and open channel alternatives following removal of the Mill Pond Road culvert to improve tidal flows to Mill Pond and restore deteriorated salt marsh areas.

2 Geotechnical Investigation and Design Evaluation

The following sections summarize findings from a geotechnical investigation and preliminary design analysis completed in support of the replacement of the existing culvert. The contents of this section are subject to the limitations provided as Attachment B.

2.1 Program Objective

The objectives of the subsurface investigation was to assess subsurface conditions at the Mill Pond Road culvert (Site). To achieve these objectives, Fuss & O'Neill completed the following field investigation:

- Conduct two (2) geotechnical boreholes (B-1 and B-2) at the Site and collect soil samples
- Visually classify soil samples
- Complete three (3) gradation analyses on selected representative soil samples

Prior to conducting this investigation, the Natural Resources Conservation Service (NRCS) soil report for the Site, provided as Attachment C, was reviewed. The results of the subsurface investigation and laboratory testing, and preliminary design assessments, are presented below.

2.2 Subsurface Exploration Program

The subsurface exploration program consisted of two (2) boreholes (B-1 and B-2) completed by Soil X, Corp of Leominster, Massachusetts under subcontract to Fuss & O'Neill, Inc. Boreholes were completed on June 1 and 2, 2021 utilizing a truck-mounted drill rig. Hollow-stem augers were used to set the casing at each borehole. Boreholes were advanced using 4-inch inner-diameter flush wall casing and tricone roller bit. The approximate locations of the borings are depicted in Figure 7. All borings were observed and logged by a Fuss & O'Neill engineer. Boring logs are provided as Attachment D.

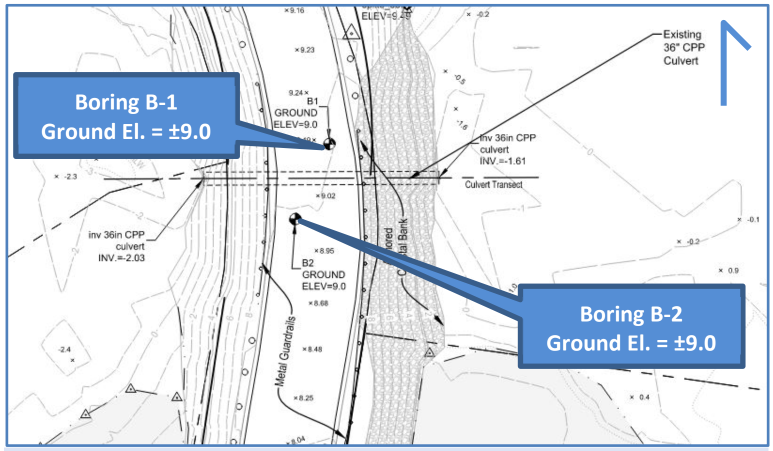

Figure 7 — Subsurface Boring Locations

Borings were advanced to depths ranging from 51 feet to 80 feet below the existing ground surface. Split spoon soil samples were obtained continuously to about 21 feet and then at intervals of 5 feet thereafter using the Standard Penetration Test (SPT) per ASTM D-1586 at each borehole location. The SPT consists of driving a 2-inch outside-diameter split spoon sampler 24 inches with a 140-pound hammer free-falling 30 inches. The number of blows required to drive the sampler from 6 to 18 inches is the Standard Penetration Resistance, also known as the SPT N-value, which is a relative indicator of the *in-situ* soil relative density or consistency. Boreholes were backfilled with tamped soil cuttings upon completion covered with cold patch asphalt prior to leaving the site.

During explorations, subsurface soils were visually classified utilizing the Burmister Classification System. This system describes soil composition based upon the percentage of soil particle size present in the sample with the major soil particle size listed first following other soil components described as "and" (indicating 35-50% by weight), "some" (indicating 20-35% by weight), "little" (indicating 10-20% by weight), or "trace" (indicating 0-10% by weight). Descriptions of each soil strata encountered during the investigations are provided in the Subsurface Profile section below.

Borehole B-1 was terminated without refusal at a depth of approximately 80 feet below the ground surface. The casing was driven to a depth of 74 feet below the ground surface and the split spoon sampler was advanced to the termination depth. Borehole B-2 was terminated without refusal at a depth of approximately 51 feet below the ground surface. The casing was driven to a depth of 49 feet below the ground surface and the split spoon sampler was advanced to the termination depth.

2.3 Subsurface Profile

Generalized subsurface conditions at the Site are described below, based on the results of the explorations and observations at the time of drilling.

- **General Description:** Brown sandy fill over brown to reddish brown native sand.
- **Fill:** Very loose to medium dense, brown, fine to medium sand with varying amounts of fine gravel and trace amounts of silt. One sample within the fill material contained trace amounts of woody fibrous material. Approximately seven (7) feet of sandy fill material was encountered in borings B-1 and B-2.
- **Native Sand:** Loose to medium dense, brown to reddish brown, fine to coarse sand with varying amounts of fine to coarse gravel and trace amounts of silt. At the transition point between the fill material and the native sand two samples had a main constituent of fine gravel with some fine to coarse sand and trace silt. The native sand layer was encountered beneath the fill in both borings and extended to the termination of each boring.

2.4 Laboratory Testing

Laboratory testing consisted of three (3) grain size analyses (per ASTM D6913) performed by Thielsch Engineering of Cranston, Rhode Island. Testing was performed to confirm visual classification of soils in the field. The results of the sieve analyses are included as Attachment E and are summarized below in Table 1.

Table 1
Summary of Laboratory Test Results

Sample No.	Identification Test		
	Sieve Analysis (ASTM D6913)		
	% Gravel	% Sand	% Silt
B-1 / S-2	0.0	97.7	2.3
B-2 / S-5	5.9	93.1	1.0
B-2 / S-12	6.8	92.0	1.2

2.5 Groundwater Conditions

Surveyed ground surface elevations at borings B-1 and B-2 are reported by Woods Hole Group at EL. 9.03 and 8.97 (NAVD88), respectively. Due to the tidal influence present at Mill Pond and the Pamet Harbor, groundwater elevations may fluctuate due to the tidal cycle, in additional to seasonally and due to storm- or drought-related events.

Groundwater was observed at the time of the subsurface investigation in each boring at depth of 7 feet below the ground surface. Since the borings were advanced utilizing cased borehole techniques involving water being poured into the boreholes during the driving process, natural groundwater levels are expected to vary from the measured values. Groundwater observation wells were not installed at the site.

A summary of groundwater elevations measured within the boreholes is provided in Table 2.

Table 2
Summary of Boring Groundwater Elevations

Boring No.	Date	Groundwater	
		Depth Below Ground (ft)	Approx. Elev. (ft, NAVD88)
1	6/1/2021	7	2.03
2	6/2/2021	7	1.97

2.6 Geotechnical Design Evaluations and Recommendations

Geotechnical design evaluations and recommendations presented below were developed by RMA GeoEnvironmental (RMA) under subcontract to Fuss & O'Neill. RMA was provided the geotechnical data report developed as part of the initial subsurface investigation as well as preliminary conceptual drawings for the culvert alternatives under consideration, in support of their preliminary design evaluations and foundation recommendations.

2.6.1 Seismic Design Parameters and Liquefaction Potential

Lower zones within the subsurface profile appear to have the potential for liquefaction under potential future seismic events and should be evaluated further under future design analyses. Depending on the results of those future analyses, alternative ground improvement methods should be considered and identified for potential implementation during the project's construction phase, as described in Section 2.6.2 below.

2.6.2 Recommended Foundation

A preliminary bearing capacity analysis was completed by RMA utilizing the subsurface investigation information and conceptual design drawings provided by Fuss & O'Neill. The analysis was completed using three independent bearing capacity equations (Bowles, Terzaghi, and Vesic) in accordance with established engineer practice and accepted principles of soil mechanics. These methodologies rely on weighted average of the N-values obtained during the subsurface investigation for footing influence depths that are corrected for field conditions, overburden, and groundwater table condition along with strength parameters (unit weight, friction angle, etc.) correlated from boring information.

Based on the results of the analysis, allowing for one-inch of total long-term settlement, the wingwalls and strip footings depicted on the conceptual drawings will provide adequate support for the proposed culvert structure, provided that the footings bear on a minimum of 12 inches of compacted crushed stone wrapped in non-woven geotextile fabric, as shown. This evaluation assumes a bearing pressure of 3,500 pounds per square foot (psf) for the culvert structures under consideration; as shown on the conceptual drawings, recommended footings should be designed with a width of 4 feet and be embedded below the scour depth determined from WHG's scour analyses.

Due to the loose lower zones observed within the boring's soil profile, a ground improvement method such as rammed aggregate piers should be considered to reduce the potential for settlement under a potential future seismic event. The scope of future investigations should consider the identified preferred alternative from the current evaluation; ground improvement methods would only be warranted for an alternative to construct a replacement culvert, and would not be required under either breach scenario.

Rammed aggregate piers (RAPs) consists of vertical columns of aggregate installed on a grid within the footprint of the construction. Piers are installed by placing and mechanically tamping lifts of aggregate through a bottom-fed pipe. The pipe is driven to the bottom of the pier depth and subsequently withdrawn and tamped downward during installation of the aggregate, forming bulbs along the length of the pier. Aggregate piers improve conditions at the site by displacing, and thereby, densifying the surrounding soil at each column and transferring loads from the spread footings to the underlying suitable soil.

Spread footings at the wingwalls and along the length of the alternative culvert walls and wingwalls will be constructed over the improved area following implementation of the rammed aggregate piers. As there is no dewatering required and the installation process does not generate any spoils during construction, this soil improvement approach is typically used to reduce the potential for long-term settlement where liquifiable conditions are identified under potential future seismic events.

2.6.3 Embankment Considerations

Within the limits of proposed excavation, sections of the embankment that are disturbed as part of activities to construct the replacement structure will be reconstructed to provide vertical and lateral support for both the new structures and the overlying roadway. This will be achieved by placement of an appropriate structural backfill (e.g., gravel borrow) and ensuring placement of this material under controlled conditions to achieve the required compaction and in-place density stated in the project's technical specifications.

For any construction during freezing weather, soil bearing surfaces in exposed culvert footing excavations should be protected from frost by use of insulated blankets, ground heaters or other acceptable methods. Specifications for protection and placement of materials would be developed under future phases of design entailing a replacement culvert structure, and would not apply for either alternative open channel configuration.

It is understood that potential increases of the embankment's crest (roadway) elevation may be evaluated as potential variants of the culvert alternatives assessment presented in the sections below. Considerations relative to either raising or not raising the embankment crest include the following:

- Not raising the embankment crest will result in more frequent and severe future inundation/overtopping conditions under sea level rise projections outlined by Woods Hole Group's June 2022 Hydraulic Analysis Report. These overtopping events will impact usability of MPR for normal and emergency response uses. In addition, overtopping events will result in increased maintenance and repair of the road and slopes due to scour erosion.
- Raising the embankment crest will reduce, and possibly avoid depending on the magnitude of the increase, the impacts noted above however will require supplemental field investigations and analyses to evaluate horizontal layout and structural considerations in designing a higher embankment configuration that would be structurally adequate to support a public road.
    - Horizontal considerations include potential impacts to adjacent wetland resources by the increased base with of the embankment's cross-section that would be entailed with slopes remaining at their current configuration (i.e., not increasing the proposed slopes, which would increase stability concerns).
        - Such impacts to adjacent wetlands may be prohibitive considering the length of road that would need to be raised (approximately 1,600 feet). In addition, soils adjacent to the existing embankment may not be structurally suitable to support the weight of soils placed as to laterally expand the embankment, and thus would need to be excavated and replaced with suitable soil or augmented by geosynthetics or other ground improvement methods.
    - Structural considerations include potentially incorporating retaining walls along the top and/or bottom of the embankment to provide lateral support for soils placed to increase the embankment crest in order to avoid or minimize the extent of encroachment into adjacent wetlands (that would otherwise result from a widening of the embankment's base, as described above).
        - A number of wall structure types and configurations could be evaluated. Supplemental subsurface investigations would be required to evaluate soil properties along the length of the embankment in support of subsequent design analyses. If unsuitable soil conditions are identified, improvement methods and/or deeper wall configurations would likely be required.

2.7 Geotechnical Construction Considerations

2.7.1 Surface and Groundwater Management

As noted above, water elevations within the boreholes were measured at El. 1.91 – 2.03 feet (NAVD88) during subsurface exploration. These observed elevations are in the vicinity to the Mean High-Water elevation (El. 2.75 feet, NAVD88) immediately upstream of MPR. Water levels are expected to fluctuate moderately with the varying tidal elevations and seasonal conditions during construction.

Based on the proposed culvert invert elevation (El. -1.6, NAVD88) and conceptual culvert/foundation system developed from preliminary foundation design evaluations to date, it is expected that excavations may be required to El. -9.6 or lower, which is approximately 12-feet below observed groundwater levels within the causeway. Temporary seepage cutoff (e.g., steel sheeting) and groundwater dewatering systems will need to be designed and implemented by the contractor to maintain adequately dewatered conditions for construction of the foundation elements.

As part of these measures, surface water flowing within the channel will need to be maintained throughout the period of construction. It is expected that flow will be maintained through the existing culvert during the period of construction of the proposed culvert or open channel. Upon completion of construction of the replacement culvert, or partial construction of the alternative breach channel, the existing culvert will be abandoned in place or removed and replaced with compacted backfill.

2.7.2 Excavations

It is expected that approximately 19 vertical feet of embankment fill material will need to be excavated below the roadway surface to remove embankment (fill) soil supporting MPR and underlying native soil to allow placement of proposed foundation elements and culvert/wall structures on a suitable subgrade surface.

Temporary excavation slopes will range between a maximum of 1.5H:1V to 2H:1V for culvert alternatives, unless otherwise reinforced or shored, to allow construction equipment to safely reach the deepest/interior work areas. Consideration of the type of equipment expected for construction will affect the configuration of shoring systems and platforms for position of equipment required to construct culvert structures, if selected. It is expected that embankment breach alternatives can be constructed without any temporary shoring systems.

While other cutoff and shoring systems may also provide suitable conditions for mobilization of materials and equipment in support of construction operations, it is expected that steel sheeting would be most cost effective given the limited area and depth of excavation required below expected groundwater elevations, as well as this type of system being most widely used by contractors in the region.

2.7.3 Obstructions

Based on our observations at the site and review of available reports and records, it does not appear that structures or other objects that would obstruct excavation work associated with the alternative culvert structure or channel configurations under consideration. If such structures or objects are encountered and are determined to be abandoned or remnant structures, it is expected that they will be partially or completely removed as required to allow placement of proposed materials and structures in accordance with the developed drawings and specifications.

2.7.4 Protection of Adjacent Structures

Adjacent structures include the paved roadway beyond the proposed work limits depicted on the conceptual alternative drawings and the leaching catch basin to the south of the MPR culvert. It is expected that proposed construction activities will be conducted in a manner avoiding interruption to, or temporary relocation of, this structure. Temporary steel sheeting is expected to be installed if a culvert alternative is selected, to limit the extent of impacts resulting from excavation to the depths required for construction of the proposed structure.

It is also noted that existing steel guardrails in the immediate vicinity of the culvert will be removed and replaced with steel-backed timber guardrails if either replacement culvert alternative is selected.

2.7.5 Additional Earthwork Considerations

The following controls or methods should be employed during construction of either culvert alternative to ensure that the structures are not compromised by inadequate structural fill or improper construction techniques.

- Fill used as gravel borrow for bridge/footing foundations or for embankment fill should meet the gradation requirements of MassDOT Item No. M1.03.0 Type b and should be free of organic material, construction debris, ice, snow, and other deleterious material. The on-site fill may be selectively reused as bedding and backfill materials adjacent to the culvert structure, subject to inspection and testing to verify gradation requirements are met in other excavation areas. The existing native soils are not suitable for reuse for these applications.
- Crushed Stone may be used for wet subgrades, as a replacement for fill used below foundation level. This material is to be a crusher-run stone quarry product, should meet the gradation requirements of MassDOT Item M2.01.4 (minus ¾-inch crushed stone), and should be wrapped in a geotextile separation fabric.
- Fill placed above footings should be placed in loose lifts not to exceed 12 inches in thickness and should be compacted to 95 percent of maximum dry density as determined by ASTM 1557, Method C.

Excavation, fill placement, and footing construction for cul;vert alternatives should be conducted under dry conditions. Excavation shoring and side slopes, where used, should be in accordance with Occupational Safety and Health Administration (OSHA) standards. This will require that methods be developed and implemented to bypass tidal and storm flows at the site through temporary structures while the replacement structure is being constructed. It will also require the cutoff and drawdown of groundwater within the excavated areas until constructed features are backfilled to a high enough elevation that structures and materials are not potentially compromised by natural high surface water and/or groundwater conditions (e.g., floods, seasonal high tides, storm surges, etc.).

Dewatering within excavated areas would likely be most effectively completed by installing and operating appropriately sized and spaced conventional groundwater dewatering sumps. These sumps should be employed in concert with positive cutoff methods provided by driven cofferdam/shoring sheets in order to maintain water levels sufficiently below the ground surface to allow placement of soil materials and structures under controlled conditions. The contractor will be responsible for design of these provisions, which will subsequently be reviewed for acceptance by the design engineer.

3 Culvert Structure Alternatives Assessment

The following sections summarize the results of assessments of alternative culvert structure configurations at the Project Site.

3.1 Culvert Structure Design Criteria

Alternative culvert structures evaluated would meet applicable requirements of the American Association of State Highway and Transportation Officials (AASHTO) Load Resistance and Factor Design (LRFD) Specifications and MassDOT's Bridge Manual and Highway Specifications. Primary conceptual design parameters are listed below.

Vehicle Loading:	HL-93
Vehicle Speed:	25 MPH
Overhead Clearance:	18" over MHW

There is no current or proposed marine traffic that affects the structure's layout. There is potential that this channel is, or will be, used by recreational paddlers and fish passage. Therefore, the height of the structure was set strictly based on hydraulic modeling recommendations, recreational access and fish passage as outlined by Woods Hole Group.

3.2 Alternative Culvert Structure Configurations

Two precast concrete open bottom culvert configurations were evaluated, both of which would meet the project's restoration objectives by increasing tidal volumes and elevations to/from Mill Pond while also improving drainage from Mill Pond following large storm events (dimensions indicated are hydraulic opening sizes):

- **Culvert Alternative No. 1:** Single 8'-0"W x 8'-6"H Three-Sided Precast Concrete Box Culvert
- **Culvert Alternative No. 2:** Single 10'-0"W x 8'-6"H Three-Sided Precast Concrete Box Culvert

Plan, profile and section views of these alternatives are provided on drawings Culvert Alt-1 and Culvert Alt-2 included in Attachment F. The following general considerations are noted for both culvert alternatives.

- The structure's configuration is compatible (i.e., construction- and cost-effective) with the geotechnical foundation recommendations outlined above.
- The structure's configuration supports placement of sediment within voids of stone armor scour protection to provide a natural channel substrate through the culvert.
- The alternative culvert opening sizes provide improved tidal volumes and ranges to support restoration of salt marsh areas within Mill Pond, and improve post-storm drainage conditions (i.e., allowing impounded water to drain out more quickly vs. existing conditions).

- A replacement culvert would maintain MPR as a local roadway for normal use and emergency response. The elevation of MPR could potentially be increased in the future in response to sea level rise conditions.
- Maintaining the culvert and embankment reduces energy within Mill Pond during coastal storm events, in comparison to breach channel alternatives being considered.

These and other considerations are further evaluated in relation to the two culvert configurations and breach alternatives in Section 6 below.

3.3 Culvert Structure Span and Foundation

The subsurface investigation observed unsuitable (non-structural) soil forming the embankment, with traces of organic material (timber) observed in one of the borings. This fill material would be excavated and removed/replaced with compacted structural backfill adjacent to/over the culvert structures.

As noted above, based on the findings of the subsurface investigation and preliminary geotechnical design analyses, the culverts and wingwalls can be placed on concrete spread footings with the potential need for supplemental ground improvement within the footprint of the footings depending on the results of future design analyses. Both culvert structure alternatives would have a span of approximately 32 feet based on conceptual layout analyses conducted to date. Other relevant design considerations include the following:

- The conceptual wingwall configuration will minimize impacts to adjacent wetlands by reducing the amount of fill that would otherwise be required to provide stable embankment slopes, and by reducing discharge velocities emerging from the culvert structure.
- Stone armor channel and slope protection will be placed along the beyond the limits of the culvert for additional scour protection and to protect embankment slopes during higher energy storm conditions.

Future design evaluations in the project's next phase will further assess scour countermeasures that would be required within and beyond the limits of the culvert and on embankment slopes (i.e., based on wave generation analyses, and stormwater drainage analyses for the roadway).

3.4 Culvert and Tidal Channel Alignment

The conceptual culverts alignments included in Attachment F position the proposed precast concrete culverts immediately south of the existing CPP and channel. Offsetting the proposed culverts would allow tidal and drainage flows to be maintained through the existing CPP during construction of the new culvert, at which point flow would be diverted through the new culvert to allow removal of the existing CPP (or removal/burial of the CPP ends and infilling the remaining central section with flowable fill).

Shifting the culverts south maintains general alignment with the existing tidal channel to Pamet Harbor and would direct flow within Mill Pond toward the shoaled area shown on Figure 5. Future layout analyses may entail adjusting the alignment further to discharge flows into Mill Pond north of the shoaled area, however that may result in a conflict with the existing culvert and/or reduce alignment with the tidal channel to Pamet Harbor. Future supplemental field investigations of sediment properties on both sides of MPR would also be considered in potential dredging and/or grading sediment to create continuous channels from the culvert's ends to existing channels in Mill Pond and leading to Pamet Harbor.

3.5 Channel and Bank Protection

The channel bottom within the culvert and immediately adjacent to the ends of the culvert (to the limits of the splayed wingwalls) will be stabilized with sediment-filled stone armor as scour protection upstream and downstream of the culverts. The dimensions of the scour aprons beyond ends of the culvert would be evaluated and updated in future design analyses. Embankment slopes immediately adjacent to the culvert openings (to the extent of excavation required for placement of the culver) would be protected by vegetated soil-filled stone armor and toe protection. Based on preliminary scour assessments by Woods Hole Group, it is expected that stone armor would be required to meet Federal Highway Administration (FHWA) Class IV sizing (D_{50} of 14 inches) and be placed in layer with a minimum thickness of 36" over a crushed stone bedding layer underlain by geotextile filter fabric. Embankment slopes would be seeded and covered with a biodegradable erosion control blanket to establish coastal grass vegetation for additional surface stabilization.

As shown on the drawings included in Attachment F, the open-bottom culvert would be configured with sediment-filled stone armor placed to provide a natural channel substrate. A concrete cutoff wall has been included in the conceptual layout drawings to provide additional protection against movement of armor stones within the culvert due to excessive scour velocities, however would be evaluated in future design phases to determine if it is required or other measures could be incorporated to provide improved protection against potential movement (e.g., increasing stone size, or grouting lower ¼ of stones before placing infilled sediment). It is expected that future design evaluations would also consider the cross-sectional configuration of the channel bottom within the culvert to improve channel conditions (e.g., water depths) for aquatic animals and/or paddlecraft passing through the structure.

3.6 Roadway Layout and Drainage

Mill Pond Road's cross-section over the embankment and culvert currently consists of two approximately 9-foot wide travel lanes (no outer stripes) with approximate 12-inch wide grassed shoulders inside the face of metal beam guardrails bordering the embankment over the tidal channel, as shown on Figure 8. The conceptual roadway section depicted on drawings included in Attachment F maintains existing travel lane widths within the limits of excavation required to construct the culvert, which conforms to the Town's requirements for a 'Type B' roadway (defined as a road serving 5-10 residential properties).

Figure 8 — Mill Pond Road Layout (facing south)

Steel-backed timber guardrails are conceptually proposed to replace the existing metal beam guardrails. Standard MassDOT guardrail section requirements including a minimum of 24-inches of compacted soil behind guardrails to provide lateral support for driven posts, as shown on Figure 9. Guardrails are conceptually depicted along both lanes within the limits of excavation associated with the culvert, and would be evaluated in future design phases to adjacent the extent required along both lanes to provide adequate protection to prevent errant vehicles from striking the bridge's wingwalls or entering the steeply sloped banks and open water.

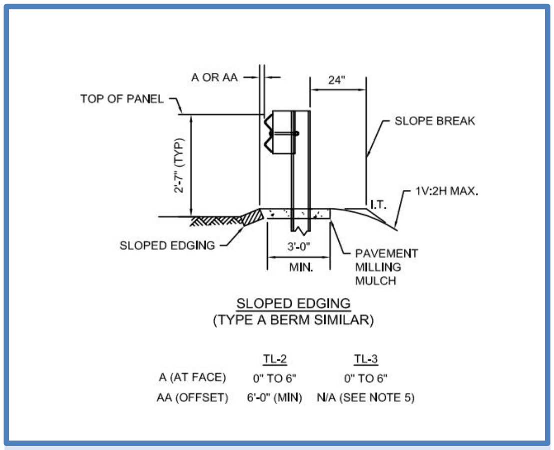

Figure 9 — Typical MassDOT Guardrail Section

The conceptual embankment/roadway section depict the faces of guardrails a minimum offset of 3-feet from the edges of pavement, providing an standard shoulder along both travel lanes and the 24-inch minimum width of level soil being the both guardrails. Future design phases would determine how respective segments of the roadway approaching the culvert and over the culvert would be crowned or pitched uniformly to provide positive drainage from the road to existing or additional drainage structures conveying runoff to adjacent wetlands and open water areas.

3.7 Operation and Maintenance

Operation and maintenance guidelines for respective elements associated with the culvert alternatives are outlined below. Specific and more detailed requirements, including inspection and recordkeeping frequencies, would be developed as part of an Operation and Maintenance Plan in support of future permitting activities.

- Concrete Culvert and Headwall/Wingwall Structures
  - Inspection and maintenance/repair of concrete surfaces for damage and deterioration (e.g., cracks, delamination, exposed reinforcing steel).
- Stone Armor Scour and Slope Protection
  - Inspection and maintenance/repair of stone armor if displaced or damaged from storm events, runoff or anthropogenic factors.
- Vegetative Stabilization
  - Inspection and maintenance to assure that embankment slopes and other areas subject to runoff erosion are stable.

4 Causeway Breach Alternatives Assessment

The following sections summarize the results of conceptual design evaluations of the proposed breach alternatives to remove the existing culvert and create an open channel through the causeway supporting MPR. These alternatives would result in elimination of Mill Pond Road as a pedestrian and vehicle travelway between Depot Road and Post Drive.

4.1 Breach Channel Design Criteria

Breach channel alternatives considered would provide increased tidal and drainage conveyance to/from Mill Pond in comparison to either culvert alternatives. Hydraulic modeling analyses by Woods Hole Group have evaluated upstream water levels and conditions affecting bordering properties and the embankment supporting Depot Road on Mill Pond's northern bank. Sizing of the channel alternatives have been developed to achieve restoration objectives without causing impacts to bordering upland properties.

Channel banks on both sides of alternative breach channels would incorporate stone armor slope protection on lower elevations and bioengineered bank stabilization on upper intertidal portions to protect the adjacent embankment soils from scour, wave and runoff erosion.

As noted above, any breach alternative would result the loss of pedestrian/vehicular traffic between Depot Road and Post Drive. Pavement would be maintained to the residential property south of the intersection with Depot Road through Mill Pond Road to maintain access to that residence. Remaining segments of the embankment would have pavement removed and be restored to a natural (soil or vegetated) surface. Considerations for emergency vehicle access and maneuvering on the resulting cul-de-sac roadway segments would need to be identified (if any) and evaluated to determine if additional layout modifications (e.g., to accommodate the turning radius of an emergency response vehicle) would need to be incorporated in a future design phase.

While it is not anticipated that the channel would be navigated by powered watercraft, it is likely that the channel would provide adequate widths and water depths for small boats to access Mill Pond.

4.2 Alternative Breach Channel Configurations

Two alternative breach configurations were evaluated and are described in the following sections, as depicted on drawings Breach Alt-1 and Breach Alt-2 included in Attachment F

- **Breach Alternative No. 1:** 15' Bottom Width with Uniform Channel Banks
- **Breach Alternative No. 2:** 10' Bottom Width with Adjacent 15' Elevated Benches

The following general considerations are noted for both breach alternatives.

- As noted above, both alternatives would allow increased inundation into Mill Pond during coastal storm events. Potential impacts to the Depot Road embankment and other adjacent properties, and potential protection/mitigation measures, would need to be evaluated in a future design phase.
- Public access accommodations including vehicle parking, pedestrian access and provisions for potential emergency response would need to be evaluated in a future design phase.

- Both breach configurations would significantly improve passage conditions for aquatic life and recreational paddlers.
- Embankment slopes bordering the breach channel would incorporate vegetated stabilization practices to provide wetland habitat bordering the waterway.

4.3 Channel Improvements

Both breach alternatives would improve tidal exchange and drainage from Mill Pond, and improve resiliency of the system to withstand future climate changes (both anticipated increased precipitation and sea level rise), in comparison to both existing conditions and both culvert alternatives.

The channel bed for both alternatives would be stabilized with native channel substrate incorporating natural cobbles sized to remain stable potential future storm events that would be evaluated in a future design phase. Similarly, armor protection for channel banks would be sized baased on future supplemental hydraulic and wave generation analyses by Woods Hole Group.

The increased width of both breach alternatives would provide improved connectivity for aquatic organisms and enhance natural processes including sediment transport and elevated salinity levels and lower low tides supportive of degrading salt marsh resources bordering Mill Pond.

As noted above, the channel opening would increase water levels and wave energy within the Mill Pond impoundment, both of which could potentially affecting the stability of the embankment slope supporting Depot Road. This potential concern would need to be investigated/evaluated in a future design phase.

4.4 Pavement Removal and Embankment Restoration

Figure 10 — Limit of Pavement Removal South of Mill Pond Road / Depot Road Intersection (facing south)

Both breach alternatives involve abandonment of Mill Pond Roadway due to the breach through the causeway, with the asphalt pavement to be removed and conceptually replaced with a gravel walking path bordered by grassed shoulders. As shown in Figure 10, pavement would be removed from the northern segment of Mill Pond approximately 150 feet south of the intersection of Mill Pond Road and Depot Road and continue to a location immediately north of the culvert, as shown in Figure 11. The limit of pavement removal will maintain access to a residential driveway at 40 Mill Pond Road, which is north of the limit of pavement removal shown in Figure 10.

Pavement removal on Mill Pond Road's southern segment would begin approximately 150 feet east of the Post Drive/Mill Pond Road intersection and continue to the southern limit of the conceptual breach channel, as shown in Figures 12 and 13, respectively.

Boulders (or a lockable reflectorized swing gate) would be placed at the ends of pavement removal north and south of the breach channel to prevent vehicular access while still providing access for maintenance and emergency vehicles. Consultation would likely be required to determine access requirements to the secondary informal access to a residential property at 31 Mill Pond Road (shown in the background in Figure 10), which has its primary driveway at 62 Depot Road.

At each of limits of pavement removal, it is anticipated that a crushed stone apron would be constructed, and/or a stormwater biowswale or other infiltration practice constructed, to prevent erosion from precipitation runoff draining from upgradient paved areas.

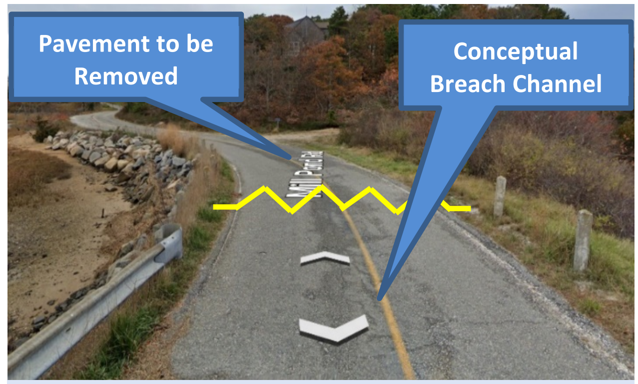

Figure 11— Approximate Limit of Pavement Removal and Channel Breach North of Mill Pond Culvert (facing north)

Figure 12 — Limit of Pavement Removal South of Mill Pond Road / Post Drive Intersection (facing north)

Figure 13 — Approximate Limit of Pavement Removal and Channel Breach South of Mill Pond Culvert (facing south)

4.5 Operation and Maintenance

Operation and maintenance guidelines for respective elements associated with the breach alternatives are outlined below. It is not anticipated that a formal Operation and Maintenance Plan would be required for a breach channel as it is expected to be resilient to current and future environmental conditions at the site.

- Stone Armor and Bioengineered Channel Bank and Embankment Slope Stabilization
  - Inspection and maintenance/repair to assure that channel banks subject to channel, runoff and/or wave erosion remain stable.
- Channel Bed Scour Protection
  - Inspection and maintenance/repair of channel bed if scour erosion undermines, or could potentially undermine, adjacent channel banks.
- Gravel Pathway and Vegetated Shoulders
  - Inspection and maintenance/repair of the gravel pathway and vegetated shoulders for signs of erosion from stormwater runoff from paved areas.

5 Construction Phase Issues Assessment

The following sections outline evaluations completed to address construction phase issues associated with construction of respective culvert and breach alternatives.

5.1 Sequence of Construction

5.1.1 Culvert Alternatives

The anticipated sequence of construction for both culvert alternatives is described below. It is noted that the contractor would be responsible for establishing and implementing its own construction sequence and phasing based on its selected means and methods of construction, which must be developed in compliance with future permit authorizations and performance requirements established in the (future) contract specifications.

<u>Phase 1</u>

1. Establish survey control, traffic controls, and staging areas.
2. Install erosion & sedimentation controls and perform any necessary clearing required to construct modifications and improvements.
3. Remove and dispose the existing pavement on Mill Pond Road within the limits of excavation necessary to construct the new culvert structure.
4. Install "Phase 1" temporary cofferdamming to enable excavation and installation of temporary shoring around the footprint of the proposed culvert structure. The existing 36-inch CPP culvert would remain in place to maintain tidal/drainage flows between Mill Pond and Pamet

Harbor until the new culvert is in place.

5. Dewater area as required within limits of the "Phase 1" cofferdam. Discharge from dewatering pumps shall be discharged into a dewatering basin prior to being released to the environment. Contractor's proposed methods shall be described in a water control plan submittal, submitted for engineer's review and acceptance.
6. Construct culvert, wingwalls and associated structures. Construct proposed in-river improvements including channel realignment, channel scour and slope protection practices and establish vegetation in disturbed areas.

Phase 2

1. Remove the "Phase 1" cofferdam around the new culvert to allow tidal/drainage flows through this structure.
2. Install "Phase 2" cofferdamming (if/as required) around the existing culvert to allow is removal (or abandonment in place by placement of flowable fill into the culvert and removal/burial of exposed ends).
3. Construct remaining embankment slope and toe protection.
4. Construct roadway and stormwater improvements including, curbing/berm, guardrails, the pavement surface course and roadway striping.
5. Place seed and install plantings along the roadway shoulders and restore all disturbed areas.
6. Remove perimeter erosion and sedimentation controls upon establishing stable vegetation.

5.1.2 Breach Alternatives

The anticipated sequence of construction activities for both breach alternatives is described below. As for the culvert alternatives, the contractor would be responsible for establishing and implementing its own construction sequence and phasing in compliance with permitting and contract specification requirements.

1. Establish survey control, traffic controls, and staging areas.
2. Install erosion & sedimentation controls and perform any necessary clearing that will be required to construct modifications and improvements.
3. Remove and dispose the existing pavement on Mill Pond Road from the upper limits of pavement removal to the limit of the excavation necessary to complete the desired breach formation.
4. Install "Phase 1" temporary cofferdamming around the portion of the breach section that does not obstruct flow through the existing culvert.
5. Complete channel bed grading, grade breach side slopes and construct stone armor bank protection and bioengineered bank stabilization in the "Phase 1" work area.
6. Remove temporary "Phase 1" cofferdamming and divert flows through the partially-constructed breach channel.
7. Install temporary "Phase 2" cofferdamming around the existing culvert and proposed breach

channel and banks.

8. Remove the existing culvert and embankment soils.
9. Complete channel bed grading, grade breach side slopes and construct stone armor bank protection and bioengineered bank stabilization in the "Phase 2" work area.
10. Remove temporary "Phase 2" cofferdamming and restore tidal flow through the complete breach channel.
11. Construct gravel pathway and install boulders/gates at pavement limits north and south of the breach channel.
12. Place seed and install plantings within the "Phase 2" work area, along the pathway shoulders and restore all disturbed areas.
13. Remove perimeter erosion and sedimentation controls upon establishing stable vegetation.

5.2 Temporary Traffic Detour and Management

Traffic would be detoured during construction of both culvert and breach alternatives as closure of MPR would be required. The closure would enable continued access to residential properties near Depot Road and at Post Drive. It is estimated the construction associated with both culvert alternatives would require approximately 4-5 months to complete.

The temporary detour, which would entail use of Depot Road and Old County Road, would need to be reviewed and approved by Truro Public Safety officials prior to construction.

5.3 Temporary Cofferdamming and Control of Water

Surface water control will be required for both culvert and breach channel alternatives, and groundwater control will be required for construction of both culvert alternatives due to the need for deeper excavations associated with construction of the culvert foundations and channel bed scour countermeasures. Surface water bypass flow diversion measures will be required to maintain tidal and drainage flows to/from Mill Pond during the entire period of construction for all alternatives.

While specific practices employed to bypass surface water around active construction areas will be determined by the contractor based upon its preferred means/methods and construction sequence, as noted above all measures would be required to comply with permit and contract specification performance requirements, and be reviewed and accepted by the engineer prior to implementation. Primary elements for control of water at the site for respective alternatives are outlined below.

- The existing culvert will be used to maintain tidal/drainage flows to/from Mill Pond during initial phases of construction.

- Large bulk sandbag cofferdams or steel sheeting will likely be used to temporarily prevent surface water and tidal flows from entering active work areas upstream and downstream of MPR.
- It is anticipated that a steel sheeting cofferdam would be utilized for culvert alternatives to provide groundwater cutoff for the lowered excavations association with construction of the culvert foundation. Groundwater dewatering would be employed to dewater the work area and allow culvert construction to occur in a controlled environment. Specific measures employed for groundwater dewatering will be determined by the contractor based on its proposed means and methods, where such practices would need to comply with permitting and contract specification performance requirements, respectively.

5.4 Preliminary Opinion of Probable Construction Cost

The budgetary opinion of construction cost associated with respective culvert and breach channel alternatives are summarized in Table 3 below. All conceptual alternative costs include a 20 percent contingency and are typically expected to be accurate within -30% to +50% (depending on market conditions and other factors at the time of construction), resulting in a stated construction cost range.

These costs do not include future costs for supplemental field investigations, engineering analyses, design development, permitting, and construction oversight. It should also be noted that the costs only include fees associated with the construction cost and do not include long-term operation and maintenance costs. Detailed opinions of cost are provided in Attachment G, based on assessments of material quantities corresponding to conceptual drawings included in Attachment F.

Table 3
Order-of-Magnitude Opinions of Probable Construction Cost for Conceptual Alternatives

Conceptual Alternative	Order of Magnitude Opinion of Cost	-30%	+50%
Culvert Alternative No. 1	$1.56M	$1.17M	$2.20M
Culvert Alternative No. 2	$1.71M	$1.49M	$2.42M
Breach Alternative No. 1	$795K	$596K	$1.13M
Breach Alternative No. 2	$1.05M	$785K	$1.48M

6 Salt Marsh Restoration Alternatives Assessment

An assessment of each alternative was performed under consideration of identified criteria including site compatibility/natural resources criteria, construction phase criteria and long-term operation and maintenance criteria.

The following sections provide brief descriptions of respective criteria considered for this assessment, followed by a review of assessment matrices developed to evaluate each alternative. A preliminary recommendation for the preferred alternative, subject to receipt and incorporation of input from project partners, property owners and other project stakeholders, is provided at the end of this section.

6.1 Evaluation Criteria

Respective criteria identified to assess relative advantages/disadvantages for each alternative are described in following sections.

6.1.1 Site Compatibility/Natural Resources Criteria

The following site compatibility and natural resources criteria were considered in assessing each alternative.

Environmental Impacts

- Minimize environmental impacts, requirements, regulatory barriers
- Minimize number of permit applications under consideration of the following programs:
    - Massachusetts Environmental Protection Agency Environmental Notification Form
    - Notice of Intent
    - MADEP Chapter 91 License
    - Army Corps of Engineers Section 404 Permit
    - MADEP Section 401 Water Quality Certification
    - MA Coastal Zone Management

Wave Action and Vulnerability

- Minimize the potential for wave action during coastal storm events to destabilize the slope supporting Depot Road and private properties bordering Mill Pond
- Minimize vulnerability of bordering private properties to increased tides

Ecological Restoration

- Maximize aquatic passage and ecological restoration
- Maximize potential sediment transport
- Increase tidal flushing and enhancement of bordering salt marsh areas
- Enhance shellfish habitat
- Improve water quality

Emergency Response

- Minimize impacts to emergency response vehicles for private properties on Mill Pond Road and public recreation within Mill Pond

Recreation

- Maximize recreational passage for paddlecraft and motorcraft users
- Maximize safety for recreational boating
- Maximize passive recreation opportunities (e.g., birdwatching, etc.)

6.1.2 Construction Phase Criteria

The following construction phase criteria were considered in assessing each alternative.

Minimize Construction Cost

- Minimize the overall cost for construction

Minimize Construction Duration

- Minimize the duration of construction

6.1.3 Long-Term Operation and Maintenance

The following long-term operations criteria were considered in assessing each alternative.

Minimize Operation/ Maintenance Costs

- Minimize repair or future replacement costs.
- Minimize the overall cost for future operation and maintenance

Maximize Resiliency to Climate Change

- Maximize adaptability to climate change and sea level rise

6.2 Alternatives Assessment and Recommended Alternative

Comparative criteria evaluation matrices have been developed addressing considerations, advantages and disadvantages for each alternative in relation to respective criterion, based on our project's team's assessments to date. Respective matrices reflect weighted and unweighted criteria based on initial evaluations by the engineering assessment, with weighted criteria subject to revision based upon input received from the Town and project partners.

Within each matrix, brief descriptions of assessment results and relative numeric scores are provided for each alternative/criterion. Scores as based on a scale of 1 to 5, with 5 being most advantageous and 1 being most disadvantageous, with respect to other alternatives. Scores for each alternative are aggregated across all criteria to identify an overall score representing relative rankings with respect to other alternatives.

It is noted that the matrices are intended as a decision-making tool to facilitate aggregation of multiple layers of information within a single document, thus providing a clearly documented and transparent mechanism to communicate assessment results within a project team. Its value is in providing a collaborative platform to inform decision-making where multiple, and sometimes conflicting considerations, present a complex environment from which to advance subsequent project development with the support of all interested parties.

The weighted and unweighted assessment matrices developed through project evaluations and consultations with project partners are included in Attachment H, and a summary of overall scores is provided below in Table 4.

Table 4
Overall Alternatives Assessment Matrix Scores

Conceptual Alternative	Unweighted Evaluation Matrix Score	Weighted Evaluation Matrix Score
Culvert Alternative No. 1	2.67	2.66
Culvert Alternative No. 2	2.67	2.69
Breach Alternative No. 1	3.78	3.80
Breach Alternative No. 2	3.67	3.74

Based on the results of above evaluations, Breach Alternative 1 has been identified as the preferred alternative. Further investigations, hydraulic modeling, and design evaluations, and consultations with the Town of Truro and project partners are recommended to confirm and refine this determination.