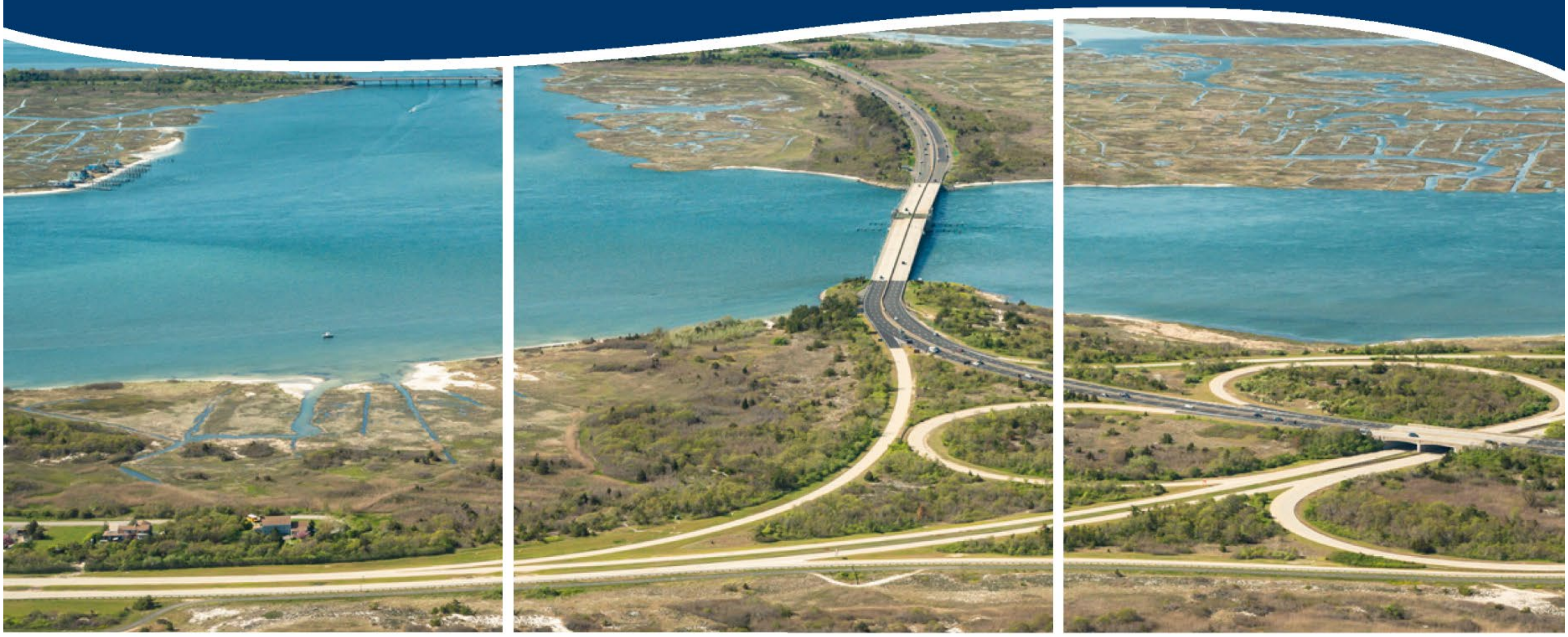
Tidal Restriction Prioritization Protocol for the Restoration of Tidal Wetlands

New York, New Jersey, Puerto Rico, and the U.S. Virgin Islands



United States Environmental Protection Agency

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This Protocol was largely developed through feedback received during a stakeholder workshop (see attendees in Appendix A) in November 2022. We are indebted to the attendees for their valuable insights and recommendations. The Protocol also benefitted greatly from review and comments from stakeholders and external reviewers, including: Eric Ham (Maine Department of Transportation), Kat Hoenke (Southeast Aquatic Resources Partnership), Scott Jackson (Northeast Atlantic Aquatic Connectivity Collaborative), Joshua LaFountain (The Nature Conservancy), Richard Mitchell (EPA), Jamie Onge (New York City Parks and Recreation Department), Michael Setering (NJ FHWA), Isabelle Stinnette (NY/NJ Hudson Estuary Partnership), and Brittney Wilburn (NJ Department of Environmental Protection).

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PURPOSE

The *Tidal Restriction Prioritization Protocol for the Restoration of Tidal Wetlands* (*Protocol*) was developed to evaluate tidal restrictions and identify/prioritize those which could be removed or replaced to meet multiple management objectives, including those that aid in the restoration of tidal wetland habitats and functions for the states and territories of New York, New Jersey, Puerto Rico, and the U.S. Virgin Islands. In addition, as tidal restrictions are often the result of transportation infrastructure, the *Protocol* also includes objectives relating to transportation structures and their uses. The management objectives or "categories" addressed in the *Protocol* include ecological enhancement, climate/ecological resilience, transportation network resilience, and infrastructure condition. Importantly, the *Protocol* is adapted from existing tools that assess and prioritize tidal restrictions, for removal/remediation as well as those used for aquatic organism passage. It is designed as a screening tool for resource managers to help focus resources on achievable projects that rehabilitate/replace tidally restrictive structures and provide restorative benefits to tidally influenced wetlands and built infrastructure.

PART 1: BACKGROUND

I. Introduction

Tidal restrictions are built structures or landforms that limit or prevent tidal exchange between upstream and downstream habitats. Common examples of tidal restrictions include undersized bridges or culverts; road causeways; and water control structures such as tide gates, weirs, levees, dikes, berms, and dams. Alteration of tidal exchange can lead to direct loss of tidal wetlands or their function. Hydrologic and salinity changes associated with tidal restrictions can result in adverse effects on wetlands and other coastal habitats, water quality, wildlife, and coastal communities. In addition to effects on the natural environment, restrictions may also create maintenance issues for transportation infrastructure by increasing forces of erosion, scour, and flooding.

In 2020, the U.S. Environmental Protection Agency (EPA) published the *Tidal Restriction Synthesis Review (Review)*, an analysis of U.S. tidal restrictions and opportunities for their avoidance and removal. The *Review* noted/indicated that location and severity of tidal restrictions data in the U.S. are limited, and the data that are available often focus on the passage of aquatic organisms rather than wetland habitat, resilience, or other related objectives. To address this gap, the *Review* recommended to "use and adapt existing tidal crossing field evaluation methods to confirm the existence of restrictions, determine their severity, and prioritize them for removal."

In 2021, EPA partnered with the Federal Highway Administration (FHWA) to help implement this recommendation from the *Review* by initiating the development of a regional tidal restriction prioritization protocol for New York (NY), New Jersey (NJ), Puerto Rico (PR), and the U.S. Virgin Islands (USVI) (which comprise EPA Region 2). This multi-year effort was conducted with contractor support from Ecosystem Planning and Restoration, Inc. and included a virtual meeting and in-person workshop with regional stakeholders to solicit input and guide protocol development, mainly through discussion of existing protocols, related efforts in the region, protocol management objectives and measurements/observations to include (i.e., metrics), level of field effort, and implementation strategies (see Summary in Appendix A).

This *Protocol* was completed in 2024. It consists of a single integrated protocol that provides a generally consistent approach across the region but also accounts for geographic variability where needed, largely due to differences in current data availability.

In order for the *Protoco*l to be used and integrated with existing efforts related to aquatic organism passage, we anticipate significant coordination and leveraging of existing online data platforms. We also expect to identify opportunities to pilot the *Protocol* within the geographic area of focus, which may help inform improvement or updates in the future. Ideally, the *Protocol* for NY, NJ, PR, and USVI could be transferred to similar protocols in other areas. We are interested to hear from stakeholders to both incorporate feedback on the *Protocol* as well as opportunities for implementing the protocol.

A. Existing Protocols

The following existing protocols were reviewed for this effort. All of these existing protocols are designed to assess tidal restrictions and/or aquatic organism barriers associated with transportation crossings (e.g., bridges and culverts).

- Tidal Crossing Handbook; Purinton and Mountain, 1998 (Purinton and Mountain protocol).
    - Largely field-based and assesses tidal restriction severity through metrics and direct field measurement of the tidal range over one 12-hour tidal cycle.
- New Hampshire Tidal Crossing Assessment Protocol; Steckler et al., 2017 (NH protocol).
    - Field- and desktop-based metrics that are designed to both identify severely restricted crossings and prioritize them for removal. Most of the NH protocol desktop metrics rely on results from a Sea Level Affecting Marshes Model (SLAMM) that was run for the state.
- North Atlantic Aquatic Connectivity Collaborative Tidal Stream Crossing Protocol for Aquatic Passability Assessments; Jackson, 2019 (NAACC tidal protocol).
    - Field-based metrics that assess whether a crossing presents a barrier to aquatic organism passage, as well as its severity. While the NAACC protocol is designed to assess aquatic organism passage, it still has significant field metric overlap with the NH protocol. The NAACC organization geographically overlaps both NY and NJ; however, at the time of this document's publication, the NAACC tidal protocol has been applied to a limited extent in NY.

- The Nature Conservancy Road-Stream and Tidal Crossing Prioritization Tool; The Nature Conservancy, 2021 (TNC tool).
    - Developed for use in Suffolk County, NY and has been applied to those crossings where field measurements and observations taken from the NH and NAACC protocols were collected previously. The TNC tool also includes desktop metrics developed or adapted for the tool. As with the NH protocol, some of the desktop metrics in the TNC tool are reliant on results from SLAMM products and model results that are only available for certain geographic areas.

II. Protocol Structure and Use

<u>Structure</u>

The overall structure of the *Protocol* is modified from the TNC tool developed for Suffolk County, NY (described above). The TNC tool was used as a model because: 1) many of the metrics aligned with those identified by regional stakeholders as important; 2) it could be used with field data collected using the NAACC tidal protocol, which is already being deployed by some regional stakeholders; 3) field data collection time was manageable; and 4) the scoring is relatively straightforward and customizable based on project goals.

<u>Measurement</u>

Like the TNC tool, the *Protocol* has both field and desktop metrics. Most of the field metrics are taken straight from the TNC tool. However, measurement methods are those employed by the NAACC tidal protocol (where applicable), while the scoring criteria are largely adapted from both the TNC tool and the NH protocol. For the *Protocol*'s desktop metrics, some were taken directly from the TNC tool and did not require any modification (e.g., heavy rainfall flood risk in the watershed). Others were either adapted to use different data sources or were dropped altogether since they used SLAMM results not publicly available for the entire region or were modified to include all tidal wetlands rather than just salt marsh, which is the focus of the TNC tool.

Use

The *Protocol* is best applied to transportation crossings or similar structures, which can include bridges, culverts, and pipes, in all wetland areas influenced by the tide, including saline, brackish, and freshwater tidal environments.

IMPORTANT: the Protocol is a screening tool only, and **DOES NOT**:

- Directly measure tidal hydrology,
- Quantitatively determine structure condition,
- Determine functional uplift associated with tidal restriction removal for mitigation crediting purposes, or
- Determine flooding risk to nearby built structures if a restriction is removed.

A. Management Categories and Metrics

The *Protocol* focuses on four management categories[1] that broadly reflect potential management objectives for removing a tidal restriction: ecological enhancement (e.g., wetland restoration), climate/ecological resilience, transportation network resilience, and infrastructure condition. For example, management objectives to re-establish full aquatic organism passage and upstream salt marsh communities would fall under the ecological enhancement category.

Due to a difference in data availability for one of the desktop metrics, the *Protocol* for PR and the USVI is slightly different from NY and NJ, as shown in Table 1. Metric scoring is described in Section VI Protocol Scoring and Crossing Prioritization.

[1] Adapted from the TNC tool.

Table 1. Protocol management categories and associated metrics. If a data source is greyed out, the metric is not used in that state or territory. An 'F' indicates that the metric requires data from the field; a 'D' indicates that the metric requires desktop data to complete. The use of both indicates a mixture of field and desktop data are required to calculate the metric. Metrics where data collected during a NAACC tidal protocol assessment can be used are bolded.

Category	Metric	Data Source(s)/ Protocol			
Ecological Enhancement		NY	NJ	PR	USVI
E1	Tidal Wetland Complex Size (D)	National Wetland Inventory			
E2	**Restriction Severity (F)**	Measurement field methods from the NAACC tidal protocol			
E3	**Vegetation Comparison (F)**	Visual field assessment (like NAACC tidal and NH protocols)			
Climate/Ecological Resilience		NY	NJ	PR	USVI
R1	Heavy Rainfall Flood Risk (D)	National Land Cover Dataset			
R2	Risk of Sea-Level Rise Inundation of Crossing (D)	NOAA SLR Viewer			
R3	Unvegetated Marsh Vulnerability (F, D)[1]	UVVR + visual observation			
R4	Tidal Wetland Migration Potential (D)	NOAA SLR Viewer Marsh Migration Tool			
Transportation Network Resilience		NY	NJ	PR	USVI
T1	Road Functional Classification (D)	NY DOT	NJ DOT	PR JP	None; Apply standard[2]
T2	Evacuation Route (D)	Nassau & Suffolk Counties; Apply standard[2] all others	Ready NJ	PR Seismic Network	VITEMA
Infrastructure Condition		NY	NJ	PR	USVI
C1	**Crossing Structural Condition (F)**	Visual field assessment (like NAACC tidal and NH protocols)			
C2	**Current Inundation Risk and Lack of Clearance (F)**	Measurement field methods from the NAACC tidal protocol			
C3	Scour Severity (F)[1]	Visual assessment			

[1] This metric was specifically developed for the *Protocol* and assessments for such a metric are not included in the TNC tool or NAACC tidal protocol; however, the armoring measurement from NAACC may indicate greater scour.
[2] Standard score is specific to this *Protocol*. See Protocol Scoring and Crossing Prioritization section.

PART 2: USING THE PROTOCOL

III. Site Identification and Training

As stated above, the *Protocol* applies to crossings in the tidal zone that can include salt, brackish, and freshwater tidal wetlands. To determine the extent of the tidal zone in a given location for site identification and survey planning, desktop tools can be used in lieu of direct observations. To identify the head of tide on larger inland rivers (e.g., the Hudson River), the National Oceanic and Atmospheric Administration's (NOAA) Tide Predictions website[2] or other reputable tide charts can provide an indication of this point. For smaller tributaries and associated tidal wetlands, using the extent of wetlands classified as tidal by the National Wetlands Inventory[3] (NWI) is an acceptable method. Applicable wetland types, using the Cowardin classification system employed by the NWI, are shown in Table 3 under the Tidal Wetland Complex Size metric. In NY and NJ, a model is available that identifies potential tidal restrictions (by severity) based on an estimate of the historic loss of mapped, upstream salt marshes in areas where they should occur given elevation and tidal regime[4]. Depending on the age of the imagery, wetlands that were once tidal may no longer be classified as such in the NWI. However, these same wetland areas may be included in the model as tidal, as they may have been so historically. Areas predicted to be tidal by the model should be evaluated, even if the NWI does not currently classify them as an applicable wetland type.

To identify potential crossing sites to survey in the tidal zone, consult recent, high quality aerial photos, recent and older topographic maps, as well as local trail maps, which, as available, can each provide indication of crossing locations. Working with regional partners such as NAACC (for NY and NJ) and the Southeast Aquatic Resources Partnership[5] (SARP; for PR and USVI) on site identification and survey prioritization is advised.

There is currently no independent training framework proposed for the *Protocol*; because many of the field metrics are also used in the NAACC tidal protocol, it is suggested that users in NY and NJ complete the trainings conducted by NAACC[6]. For PR and USVI, SARP has trainers who are familiar with the NAACC tidal protocol and may be able to coordinate

[2] https://tidesandcurrents.noaa.gov/tide_predictions.html
[3] https://fwsprimary.wim.usgs.gov/wetlands/apps/wetlands-mapper/
[4] https://nalcc.databasin.org/datasets/67eb4b83b1d141a388ed66debe820ea2/
[5] https://southeastaquatics.net/sarps-programs/aquatic-connectivity-program-act
[6] https://streamcontinuity.org/naacc/states/new-jersey; https://streamcontinuity.org/naacc/states/new-york

and/or provide training. For the vegetation comparison metric, it is recommended that at least one member of the field crew has knowledge of regional natural vegetative communities and plant species identification skills.

IV. Conducting an Assessment

This *Protocol* is a stand-alone assessment method that can also utilize field data collected as part of a NAACC tidal protocol evaluation for certain metrics, where available. Table 2 shows a crosswalk between shared metrics in the *Protocol* and the NAACC and how measurements and observations taken as part of a NAACC assessment are applied in the *Protocol*.

Table 2. Metric crosswalk with the NAACC tidal protocol.

Protocol Metric or Sub-Metric	NAACC Metric(s)	Application of NAACC Data to Protocol
Tidal Range Ratio (Degree of Restriction Sub-Metric 1)	Tidal Constriction and Outlet Perch at High Tide	Direct measurements of upstream/ downstream (US/DS) tidal range taken during a NAACC assessment can be used to score this *Protocol* sub-metric, in conjunction with NAACC observation and quantification of high tide perching.
Crossing Ratio (Degree of Restriction Sub-Metric 2)	Constriction Ratio	Direct measurements of structure and channel width taken during a NAACC assessment can be used to score this *Protocol* sub-metric.
Erosion Classification (Degree of Restriction Sub-Metric 3)	Upstream/Downstream Scour	Direct measurements of US/DS pool width and channel width taken during a NAACC assessment can be used to score this *Protocol* sub-metric.
Presence and Type of Tide Gate (used in Degree of Restriction overall score)	Tide Gate Barrier Severity	Observations of tide gate presence and characterization of barrier degree made in a NAACC assessment can be used to score the *Protocol* degree of restriction metric.

Protocol Metric or Sub-Metric	NAACC Metric(s)	Application of NAACC Data to Protocol
Vegetation Comparison Metric	Vegetation Change	Visual assessment of differences between vegetation US and DS made during a NAACC assessment can be used to score this *Protocol* metric. **The NAACC scoring categories are slightly different, so some level of professional judgement will apply when using NAACC data to determine a score using *Protocol* criteria.**
Crossing Structural Condition Metric	None (not used in scoring)	While the NAACC does not use crossing structural condition in scoring, data on condition is collected as part of a NAACC assessment. **Condition categories in the NAACC are slightly different, so some level of professional judgement will apply when using NAACC data to determine a score using *Protocol* criteria.**
Current Inundation Risk and Lack of Clearance	None (not used in scoring)	While the NAACC does not use current structure inundation risk in scoring, needed data to determine whether the road is inundated at high tide (e.g., road fill height, structure height, and high tide water depth) is collected as part of a NAACC assessment.

It is important to note that Section V Data Collection in this document includes all measurement instructions (even for those adapted from the NAACC tidal protocol) and scoring criteria for each metric in the *Protocol*. The *Protocol* has both desktop and field metrics—the desktop analysis may be completed at any point before or after the field evaluation and does not necessarily have to be completed by the field observers. The field survey portion of the *Protocol* is designed to be conducted at low tide (or just before or after low tide, generally within an hour before or after); for freshwater tidal crossings, assessments should be conducted at low tide and during low flow periods, particularly summer and early fall. Field assessments should take about 30 minutes per crossing (not including desktop analyses)[7].

[7] Based on survey methods in the NAACC tidal protocol and stakeholder input.

A. Equipment, Safety, and Environmental Considerations[8]

The following equipment is required to complete a field assessment:

- Data Forms (best printed on waterproof paper)
- Clipboard, pencils, and erasers
- Reel tape (100 ft.); 6 ft. pocket tape (or "pocket rod") for smaller lengths
- Stadia rod (also called a leveling rod)
- Hand level (or surveyor's level with tripod)
- Rangefinder (optional)
- Safety vest (brightly colored and reflective)
- Waders or hip boots
- Sun protection and insect repellent
- First aid kit
- GPS receiver
- Digital camera

Safety is an important component of the *Protocol*, especially as field data collection is likely to involve work around roads and in environments with slippery marine clays, mucky substrates, and modifications that may produce tripping or falling hazards (e.g., ditches, rip-rap). Following is a partial list of recommendations and precautions that should be taken to mitigate known safety risks[9].

- Have a float plan or field plan for each field day with destination, route, expected timing, names of persons in field crew, description of vehicle or boat, and contact information. Make sure that a third party who is not going in the field is aware of the plan and confirms the field crew's safe return.
- A safety plan for field crew members should also be available and brought on-site, including potential risks (e.g., heat, insects), nearest hospitals, emergency contact information, and any forms needed for reporting work injuries or near misses.
- Field surveys are best undertaken by teams of at least two people. This facilitates measurements and decision-making in challenging situations and improves safety outcomes.

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[8] Adapted from the NH protocol.

[9] See NAACC tidal protocol for a more thorough discussion at: https://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/NAACC_Instructions%20for%20Tidal%20Crossings%208-23-19_0.pdf

- Always wear brightly colored reflective vests along roads and other transportation corridors. Avoid walking on railroad tracks. Take care when parking and exiting vehicles and crossing busy roads.
- Avoid wading into streams of all sizes at high flows and entering pools of unknown depth. If direct measurements cannot be taken safely, make best estimates instead.
- When using a telescoping stadia or leveling rod, be aware of and avoid contact with overhead utility lines.
- Follow wader safety guidelines, such as:
    - Wear a personal flotation device.
    - Use a wading belt when wearing chest waders.
    - Always maintain two points of contact as you move—you may use the leveling rod as a point of support. Test water depths and substrate softness with the leveling rod to avoid overtopping your waders and/or sinking into the substrate.
- Use caution when entering a stream crossing structure. Never enter a structure without another person watching for your safety.
- Be prepared for exposed conditions with limited shading, as well as biting insects and poison ivy. Have access to sunscreen, ample water, and insect repellent, and consider wearing long-sleeves and a hat. Check for ticks after each field day.

Users of this *Protocol* should follow best management practices to avoid inadvertently contributing to the spread of aquatic invasive species, including non-native plants, animals, and microorganisms (including microscopic life stages of larger animals) that damage ecosystems or threaten commercial, agricultural, and recreational activities (e.g., European green crab, zebra mussel, Brazilian waterweed, *Melaleuca quinquenervia*, etc.). These can include species adapted for saline or freshwater environments and those that may not have been documented in the region but have been found in states neighboring NY and NJ. A partial list of best management practices to avoid the spread of invasive species is below[10].

[10] See NAACC tidal protocol for a more thorough discussion at: https://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/NAACC_Instructions%20for%20Tidal%20Crossings%208-23-19_0.pdf.

- Conduct surveys within one HUC12[11] watershed per day if evaluating multiple crossings, beginning surveys at the upstream end of a HUC12 and progressing downstream, if possible.
- Do not use waders with felt soles (also helps with safety).
- Before leaving a site, clean, drain, and dry (or treat) equipment. Inspect personal (boots, waders) and survey equipment and remove/dispose of any attached mud, debris, and plants.
- Completely dry (at least 48 hours) or treat personal equipment after each survey day, or when moving between HUC12 watersheds.

V. Data Collection

This section outlines all field and desktop data that must be collected as part of the *Protocol*, including descriptions and measurement methods for each management category metric (see Table 1). Required information is also found on the data collection form (Appendix B), including data for both field and desktop metrics. Scoring criteria are outlined in Section VI Protocol Scoring and Crossing Prioritization.

A. General Crossing Information

The following information prompts are found in the field data collection portion of the data form (Appendix B) and provide contextual site information not used to score metrics. The information needed for each metric is found in the management category sections below.

- Date Observed/Time – date, start and end time.
- Observers – names of survey team.
- Municipality/County – specify city/town or township, as appropriate.
- Stream/river name – if unnamed, find nearest named stream and input "unnamed tributary to [nearest named stream]".
- GPS coordinates – in decimal degrees. Include a narrative description as well if there is any doubt someone could find this crossing again or may mistake it for another.

[11] Smallest classification level (sub-watershed) of the hierarchical system dividing the U.S. into hydrologic units. Each hydrologic unit is assigned a 2- to 12-digit Hydrologic Unit Code (HUC) that uniquely identifies each of the six levels of classification within six two-digit fields, where the 2-digit code is the largest in area, and the 12-digit code is the smallest. HUC maps are available at: https://water.usgs.gov/GIS/huc.html.

- Crossing name – for roads, include any route numbers. For driveways, trails, or railroads lacking known names, input "unnamed".
- Crossing type:
  - Public or private road.
  - Driveway: serving only one or two houses or businesses.
  - Trail: can include paved recreational paths (e.g., greenways) and railroad beds without tracks.
  - Railroad: with tracks, whether currently used or not.
  - Other: any other crossing type not already described.
- Road type (if applicable):
  - Multilane (> 2 lanes, including divided highways).
  - 1-2 Lanes.
  - N/A (not a road).
- Crossing surface type:
  - Paved (any type—concrete, asphalt, etc.).
  - Gravel/stone.
  - Dirt.
- Crossing structure type – choose only one:
  - Bridge.
  - Single culvert or pipe.
  - Multiple culverts or pipes.
  - Other; describe type in comments.
- Bridge or Culvert type (see Steckler et al. 2017 for type descriptions)
  - Culverts: round, elliptical, or pipe arch (embedded or not), box, and open bottom arch.
  - Bridges: with abutments, side slopes, or both.
- Tide stage – low slack tide, low ebb tide (outgoing), or low flood tide (incoming), or unknown if unsure.
- Tide prediction – input time of nearest low tide and the data source used to determine this information. Users can consult NOAA's Tide Predictions website[12] or other reputable tide charts for the site area to help determine tide stage. As a reminder, assessments should only be conducted at (or within one hour of) low tide.

[12] https://tidesandcurrents.noaa.gov/tide_predictions.html

- Flow condition – based on freshwater inputs to the system. Users can consult the Antecedent Precipitation Tool[13] to determine whether precipitation at the site has been in a "normal" range.
    - Dewatered: No water is flowing in the channel.
    - Unusually low: conditions that are unusually low, even for the driest times of a normal year.
    - Typical low: most commonly used and expected value for surveys completed during summer low flows.
    - Moderate: water levels have climbed at or above the level of herbaceous streambank vegetation.
    - High: flows are very high relative to streambanks, making surveys difficult or impossible. Avoid surveying crossings during high flows for safety reasons and because accurate data will be difficult to obtain.
- Adjacent land uses and historic land use (if known)
- Collect photos – at a minimum, the following photos should be taken:
    - Photos facing upstream and downstream from the structure, and
    - Inlet and outlet structure photos taken from adjacent streambanks or other nearby vantage point.

B. Field Data and Metrics

Degree of Restriction (E2)

Geography: All

This metric involves the combination of four field measurements/observations for an overall rating. Three sub-metrics, tidal range ratio, crossing ratio, and erosion classification, combine for a single overall score that indicates whether a restriction is likely present. This score is then combined with observations of upstream tidal flow control mechanisms (e.g., tide gates) at the crossing to determine restriction severity. Because highly restricted crossings can cause high velocity flows and/or lack of tidal exchange, they also act as barriers to aquatic organism passage up and downstream, especially when combined with mechanisms meant to impede tidal flooding. The overall Degree of Restriction evaluation score is shown below, following the sub-metric descriptions and associated scores.

[13] https://www.epa.gov/wotus/antecedent-precipitation-tool-apt

Tidal Range Ratio (Sub-metric 1)

The tidal range ratio compares the tidal range (elevation difference between high tide and low tide) on the upstream side of the crossing to the tidal range on the downstream side. Because assessments occur at or close to low tide, the high tide elevation is estimated based on a "High-Water Indicator" (or HWI), such as water stains on nearby structures or vegetation (preferred method), wrack lines, or sediment deposition on vegetation. Users should be mindful of recent rainfall events and high flows (e.g., bankfull or greater) when locating the high-water indicator, especially upstream of a potential restriction where freshwater inflows occur, so that recent evidence of high flows is not mistaken for the high tide elevation in these cases.

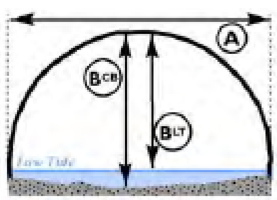
To measure, find the difference between the high-water indicator and the water surface elevation in decimal feet on either side of the crossing. Depending on where the high-water indicator is located and the crossing size, users may find the difference using a reel tape, pocket rod, or stadia rod, the latter of which may be paired with a hand level to find the relative elevation difference, if practicable. When paired with a hand level, one person will hold the stadia rod at the desired feature (water surface or high-water indicator) and the other will sight the elevation on the stadia rod. To enable reading the stadia rod from the same location for all feature measurements, the person using the hand level should be situated at or higher than the highest feature being sighted. Because elevations for the top of the structure and the crossing surface relative to the high-water indicator are also needed for the Current Inundation Risk and Lack of Clearance metric, it is recommended that the person with the hand level set up at the elevation of the crossing surface and take all measurements at once from this location. To find accurate feature height differences with this method, it is imperative that the person with the hand level stay in the same location for all measurements. If users have an available tripod and survey level, these can be used in lieu of a hand level; however, as above, this set-up must also stay at the same location for all measurements.

For culverts, also note whether downstream invert(s) are perched (i.e., the outlet is elevated above the channel bed or water surface) at low (direct observation) or high (using high-water indicator) tide (i.e., the high-water indicator is below the culvert outlet).

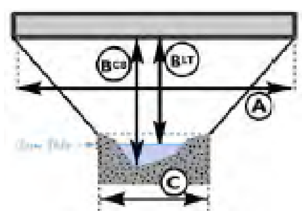
Crossing Ratio (Sub-metric 2)

The crossing ratio compares the width of the crossing opening to the channel width. The crossing opening width of most structures will be measured at the widest interior point that is not embedded in the substrate; though measurement location(s) can vary based on structure type (see Figure 1). In all cases, the width should be measured for both the upstream (inlet) and downstream (outlet) ends of the structure.

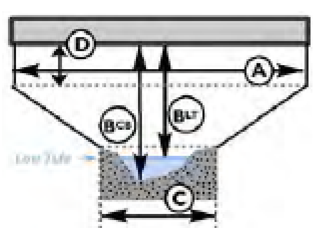
Channel width can be measured in the field with a reel tape or rangefinder if conditions allow for it to be done safely (e.g., for smaller channels). If measuring in the field, use the normal high tide channel width (the channel can often be demarcated by a lack of terrestrial vegetation). Otherwise, channel width can be estimated from aerial imagery if the imagery scale is known. Channel width should be estimated both upstream and downstream of the crossing, using the average of 3 measurements in each case, generally within 300 feet of the crossing (Figure 2). Avoid measurements at sharp channel bends, scour features immediately up- or downstream of the crossing itself, split or divided channels, and above or below a confluence. For example, if there is a confluence with another stream 100 feet downstream of the crossing, limit width measurements to within 100 feet downstream. If either up- or downstream is significantly braided, take the width measurement across the main channel carrying flow.



Open Bottom Arch Culvert; 'A' dimension = crossing width



Bridge with Side Slopes (no abutments); Average of 'A' and 'C' dimension = crossing width



Bridge with Side Slopes and Abutments; Average of 'A' and 'C' dimensions = crossing width

Figure 1. Examples of structures with atypical interior width measurements (Steckler et al. 2017).Illustrations and photos of other structure types can be found in Steckler et al. (2017) and Jackson (2019).

Erosion Classification (Sub-metric 3)

The erosion classification metric compares the width of scour pools up- and downstream of a crossing to the channel width, as measured for the crossing ratio. Erosion or scour pools are indicators that a structure is undersized for the stream system, which is also a sign of tidal restriction. In this case, maximum pool width is a surrogate for determining the degree of erosion (see example in Figure 2).

Figure 2. Maximum pool width vs. channel width. In this example, the upstream max pool is wider than the upstream channel width, while downstream they are about the same.

Presence and Type of Tide Gate

Tide gates are doors or flaps mounted on the downstream ends of culverts that generally allow upstream waters to drain while preventing inflows from tidal surges or flood events. Traditional tide gates open when hydrologic head on the upstream side is greater than the downstream side, usually at low or ebb tide, resulting in high velocity outflows and a default closed position (Souder et al. 2018). These types of gates (e.g., flap gates) can be assumed to block most tidal flow upstream. Self-regulating tide gates allow tidal flow upstream during normal conditions but restrict high flows to prevent upstream flooding. See Jackson (2019) or Giannico and Souder (2005) for descriptions and illustrations of common tide gate types.

Vegetation Comparison (E3)

Geography: All

Native tidal wetland plant communities are comprised of species adapted to the range of flooding and salinity changes associated with the local tidal regime. For instance, in NY and NJ, "low salt marsh" is found in areas of lower elevation (e.g., along banks of tidal creeks and depressions on the marsh surface) and is regularly flooded by high tide. Alternatively, "high salt marsh" is found between mean high tide and the upland edge, generally experiencing lower levels of flooding and salinity than low salt marsh. Because each vegetative community reflects different flooding and salinity levels, comparing plant communities up- and downstream of a tidal crossing can provide a field indicator of potential restriction that limits natural tidal flooding upstream. Tidal wetland vegetation differs greatly across NY, NJ, PR, and USVI; a brief discussion of the types found in NY and NJ vs. PR and USVI follows. The scoring criteria for this metric (see Section VI Protocol Scoring and Crossing Prioritization) rely on vegetative community type, structure, and presence of invasive species; therefore, having some knowledge of regional wetland community types and identification of species (native and invasive) typical of these communities is recommended.

New York and New Jersey

Tidal wetlands in NY and NJ are usually dominated by emergent (i.e., marsh) or low-growing scrub-shrub vegetation. As mentioned above, the most common emergent vegetation in highly saline environments is often termed "low salt marsh," which is often a monoculture of smooth cordgrass (*Spartina alterniflora;* tall form). Vegetation in slightly less saline environments (often behind the low marsh) is often termed "high salt marsh," which is dominated by smooth cordgrass (short form), saltmeadow cordgrass (*S. patens*), spike grass (*Distichlis spicata*), and black needle rush (*Juncus gerardii*). Brackish marsh is generally characterized by high marsh species as well as those that are less salt tolerant (including more woody species), whereas freshwater tidal marsh is characterized by species adapted to inundation but intolerant to saline conditions. Freshwater tidal marshes typically develop far enough upstream that the salts in sea water fully deposit out of the water column, producing freshwater conditions. Upstream from a highly restricted crossings, more salt intolerant species will likely occur, including invasives that may out-compete native species. "Invasive species" in this context are those that are non-native or naturalized and may include, but are not limited to, common reed

(*Phragmites australis var. australis*), narrowleaf cattail (*Typha angustifolia*), purple loosestrife (*Lythrum salicaria*), and Japanese knotweed (*Fallopia japonica*).

Puerto Rico and the U.S. Virgin Islands

In PR and the USVI, forested mangrove swamps are more common than salt marsh, characterized by four low-growing tree species with similar growth habits and tolerance of saltwater: red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia racemosa*) mangrove, and to a lesser extent buttonwood (*Conocarpus erectus*). Emergent tidal marsh, where it occurs, is usually found in more irregularly flooded areas upland of the mangrove forests; in the USVI, it may be uncommon or absent entirely. In PR, tidal marsh is generally characterized by two different types based on salinity level and soils. Tidal marsh dominated by dense stands of leatherleaf fern (*Acrostichum* spp.) is generally found in brackish environments on organic soils. Sometimes, these marshes will grade into freshwater marsh dominated by southern cattail (*Typha domingensis*) and common reed. Tidal marsh dominated by succulent species such as saltwort (*Batis maritima*) and sea purslane (*Sesuvium portulacastrum*) are found on hypersaline soils with little organic matter, usually in more arid regions of PR. Areas of lower salinity in these environments can be dominated by seaside rush (*Sporobolus virginicus*).

Crossing Structural Condition (C1)

Geography: All

Removal of a restriction may best be paired with replacement and/or maintenance of failing infrastructure; therefore, a structure in bad condition will receive a higher score. This metric evaluates the overall condition of the structure, including the structure itself and any wingwalls, headwalls, abutments, footers, etc., depending on structure type. The score is based on all structures (if multiple), especially those that are the largest or carrying the most flow. Focus on the condition of structure materials and whether the conveyance is functioning as intended. For culverts, a good resource for determining condition is the NAACC culvert condition assessment manual[14].

General condition ratings[15] are used as part of the National Bridge Inspection Standards to rate the condition of bridges and culverts that carry traffic and have an opening of more

[14] https://streamcontinuity.org/sites/streamcontinuity.org/files/pdf-doc-ppt/CulvertManual_2019_082919.pdf
[15] https://www.penndot.pa.gov/ProjectAndPrograms/Bridges/Pages/Bridge-Inspection-Terminology.aspx

than 20 feet. If current (generally within 2 years) general condition ratings[16] (scored from 0-9, where 9 is excellent and 0 is failed) for a particular bridge or culvert are available to the user, these can be used to inform the structural condition score.

Current Inundation Risk and Lack of Clearance (C2)

Geography: All

Restrictions may cause ponding up- or downstream, leading to greater flooding probability, especially with low-lying transportation infrastructure. This metric estimates current flooding risk to the structure by comparing the relative elevation of the high-water indicator to the top of the structure or the crossing surface elevation (e.g., road; may be approximately the same if the structure is a bridge). Depending on the location of the high-water indicator and the crossing size, these measurements can be done with a reel tape, pocket rod, or a stadia rod, the latter of which may be paired with a hand level to find the relative elevation difference, if practicable. For instructions on how to use a stadia rod and hand level, please see the Tidal Range Ratio sub-metric under Degree of Restriction. Keep in mind that the elevation difference between the high-water indicator and the top of structure and the crossing surface will often be a negative number and should be written as such on the data form (e.g., the high-water indicator is at a lower elevation than these features). If historic aerial photos (available through Google Earth) from the past ten years show flooding of the crossing, this can also be used to indicate that inundation risk is greater.

Scour Severity (C3)

Geography: All

Scour at the structure may be an indication that the crossing is undersized for the stream, much like the Erosion Classification sub-metric under Degree of Restriction. However, this metric captures the degree to which scour is undermining the structure and/or causing ongoing maintenance issues. Evidence of scour can include: armoring at the inlet or outlet to try and halt further erosion; perching, water visibly flowing under or to the side of a culvert; structure materials sloughing into the channel; or the exposure of structure areas typically covered by stream bed material (e.g., bridge footings).

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[16] https://www.penndot.pa.gov/ProjectAndPrograms/Bridges/Pages/Bridge-Inspection-Terminology.aspx

C. Desktop Data and Metrics

Tidal Wetland Complex Size (E1)

Geography: All

This metric evaluates the acreage of tidal wetlands that may be hydraulically re-connected to each other through restoration of tidal flow if a restriction is removed, where greater acreage receives a higher score. It uses the NWI[17] to estimate the tidal wetland complex size at the area being assessed. To calculate, determine the acreage of tidally influenced wetlands hydrologically connected to the tidal crossing area, which can be upstream and/or downstream (see examples in Figures 3 and 4.). The NWI uses the Cowardin wetland classification system[18]; wetland types applicable for this metric are shown in Table 3. The NWI Mapper[19] allows users to visualize NWI polygons and provides Cowardin classification of each, as well as acreages. If custom measurements are needed, there is an area measurement tool available to users in the mapper itself.

Table 3. Applicable Cowardin wetland types for the tidal wetland complex size metric.

System	Subsystem, Class, and Modifiers
Estuarine (E)	All Intertidal (2) wetlands in the Emergent (EM), Shrub-Scrub (SS), and Forested (FO) classes
Palustrine (P)	EM, SS, and FO classes with S, R, T, or V water regime modifiers

Depending on the age of the imagery used to derive the NWI layer, users may need to adjust wetland acreage to account for development or other changes taking place in the intervening years by using more recent aerial imagery, additional data sources[20], and/or field observations. It is possible that, where a restriction is in place for a long period of time, NWI mapping developed using more recent imagery may show the conversion of tidal wetlands to non-tidal wetlands or even uplands. Therefore, this metric may be adjusted based on desktop (e.g., elevation data) and/or field observations of whether existing topography and lack of development constraints may indicate that restriction removal has the potential to restore tidal wetlands upstream. The estimated restoration area can then be counted towards the overall wetland complex size. In NY and NJ, there is a model available that identifies potential tidal restrictions (by severity) based on an

[17] https://www.fws.gov/program/national-wetlands-inventory/wetlands-mapper
[18] https://www.fws.gov/sites/default/files/documents/wetlands-and-deepwater-map-code-diagram.pdf.
[19] https://fwsprimary.wim.usgs.gov/wetlands/apps/wetlands-mapper/
[20] For example, the New Jersey Land Use/Cover map layer includes tidal wetlands and may be more accurate than the NWI: https://www.nj.gov/dep/landuse/eservices/webmappingtool.html.

estimate of the historic loss of mapped, upstream salt marshes in areas where they should occur given elevation and tidal regime[21], which may also help in this analysis.

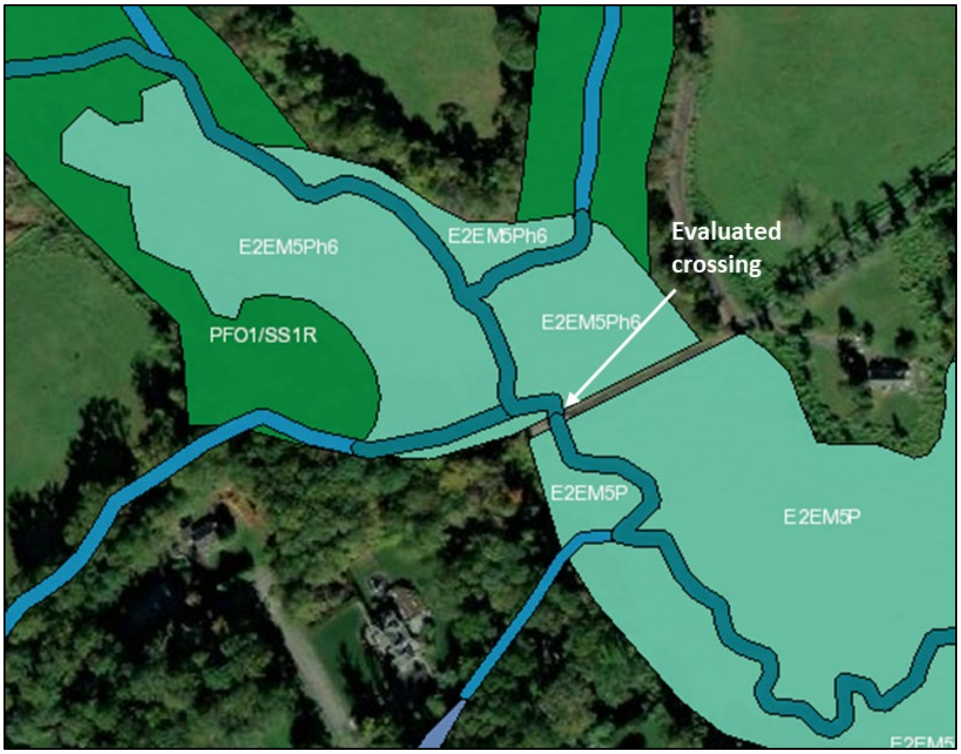

Figure 3. Tidal wetland complex example 1.
For the evaluated crossing, all wetlands shown are applicable to this metric (NWImapper).

[21] https://nalcc.databasin.org/datasets/67eb4b83b1d141a388ed66debe820ea2/

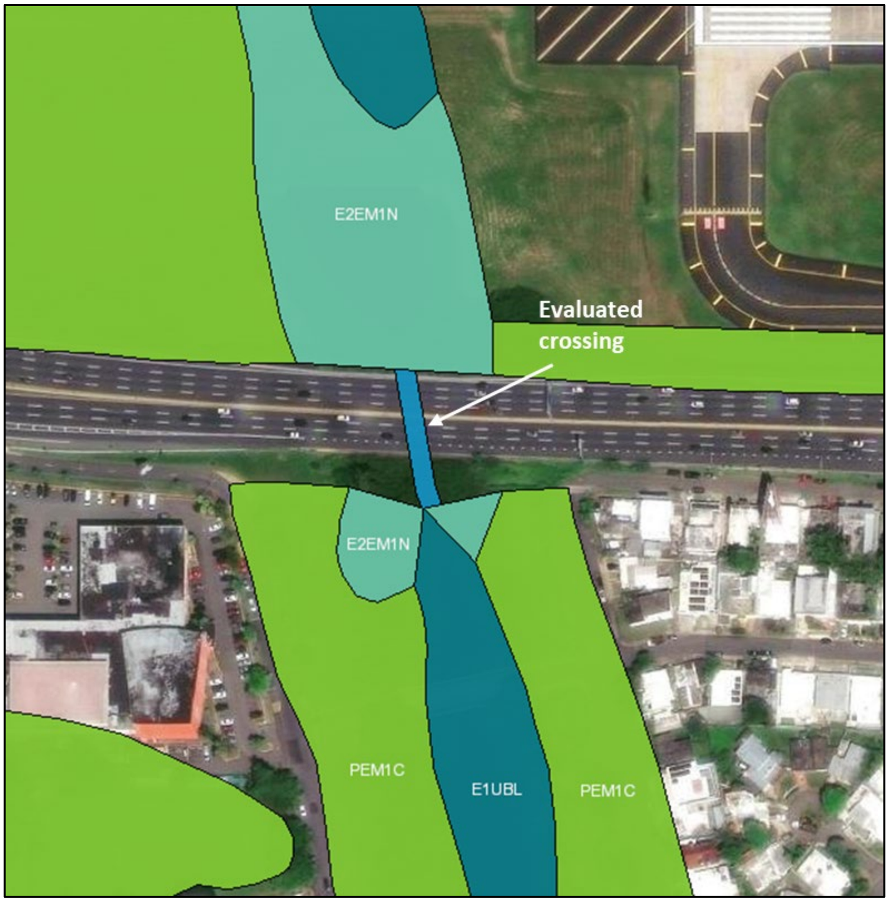

Figure 4. Tidal wetland complex example 2. For the evaluated crossing, only the E2EM wetlands would count for this metric, as the PEM wetlands do not have tidal water regime modifiers (NWImapper).

Heavy Rainfall Flood Risk within the Watershed (R1)

Geography: All

Climate change is super-charging the hydrological cycle as warmer oceans increase the amount of water evaporating into the air, leading to more intense precipitation events and associated flooding. The intensity of precipitation events and resultant flooding are exacerbated by large amounts of impervious surfaces, which increase surface runoff rates. This metric approximates the flood risk to a crossing using the estimated amount of impervious surface in the immediate upstream watershed (or catchment) as a proxy. The National Land Cover Dataset[22] (NLCD; Dewitz and USGS 2021) provides a "developed" layer class that can be used to estimate impervious surface in the upstream watershed

[22] https://www.mrlc.gov/

(class categories 21-24[23]). Though not always advised for use in tidal areas, StreamStats[24] may be used to produce the upstream catchment area if needed.

Risk of Sea Level Rise Inundation of Road/Crossing (R2)

Geography: All

As the climate warms, sea level rise (SLR) has the potential to flood crossings in the current tidal zone. Those crossings more likely to be flooded under lower levels of SLR are less resilient to climate change and may benefit from replacement or retrofitting while also removing a restriction. This metric uses the SLR tool at the Sea Level Rise Viewer developed by NOAA[25] to estimate crossing flood risk (i.e., inundation) under different SLR scenarios. Data can be viewed online or downloaded.

Unvegetated Tidal Marsh Vulnerability (R3)

Geography: NY and NJ

This metric gages how vulnerable existing tidal marsh is to open water conversion upstream of a potential restriction. This is important because removing restricted crossings with higher unvegetated tidal marsh vulnerability may result in more ponding or "drowning" of the upstream marsh unless there are ecological interventions conducted in concert with the removal. Tidal marshes that have experienced decreased tidal flushing for long periods of time due to restriction may experience a reduction in sediment supply from tidal sources. Less sediment availability can lead to greater conversion of the marsh plain to unvegetated, open water, because the sediment required to sustain vegetation is not replenished. Loss of vegetated surface may also be compounded by past land use practices that caused soil compaction (e.g., salt hay farming). Ponding on the marsh plain can result in an acceleration of marsh loss since unvegetated areas have greater erosion potential.

The Unvegetated to Vegetated Marsh Ratio dataset[26] (UVVR; Couvillion et al., 2021) can be used for screening purposes—this dataset displays a ratio of unvegetated to vegetated area at each pixel (approximately 30x30 meter rectangles) calculated from Landsat 8 satellite imagery (2014-2018) for the contiguous U.S. The dataset includes salt, brackish, and freshwater emergent tidal marsh. Because the resolution of the UVVR is relatively

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[23] https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description
[24] https://streamstats.usgs.gov/ss/
[25] https://coast.noaa.gov/digitalcoast/tools/slr.html
[26] https://marine.usgs.gov/coastalchangehazardsportal/ui/item/JoDCAjXG#; not available for PR or the USVI

broad, the score for this metric should be confirmed in the field and/or using more recent imagery, if available. Unvegetated areas can include open water (with or without floating or submersed vegetation), mud flats, and ditches, but not the tidal stream channel itself if present.

Tidal Wetland Migration Potential (R4)

Geography: All

Existing tidal wetlands are threatened by SLR, as it is likely that rapidly rising sea levels will outpace the rate at which tidal wetland habitats can build elevation and sustain themselves. As former tidal wetlands are converted to unconsolidated shore or open water, the ability for tidal wetlands to migrate upstream will be an important mechanism for maintaining this habitat type. This metric uses the Marsh Migration tool at the Sea Level Rise Viewer developed by NOAA[27] to estimate the potential for tidal wetlands to migrate above a crossing with SLR, given development and elevation constraints. In this case, "tidal wetlands" are categorized as either "salt marsh" or "brackish/transitional marsh," even if the actual wetland type is forested. For example, tidal mangrove forest in PR is termed "salt marsh" by the tool even though it is not an emergent wetland type. Scoring assumes low levels of sediment accretion under an intermediate-high SLR scenario, using 2080 as the planning horizon.

Road Functional Classification (T1)

Geography: NJ, NY, and PR

The FHWA categorizes road types by their functions, which are largely based on levels of mobility and access control. It is assumed for this metric that principal arterials, which have high levels of mobility and limited access control are more important from a network resilience perspective than minor arterials, and so on. For instance, a restriction can cause flooding issues that would be more problematic on a major vs. minor collector road; therefore, a major collector is given a higher score. Road functional classifications can be found for each state or territory, except for the USVI, at the following locations. See Section VI Protocol Scoring and Crossing Prioritization for information on how to treat the USVI for this metric.

New Jersey: https://www.state.nj.us/transportation/refdata/roadway/fcmaps.shtm.

[27] https://coast.noaa.gov/digitalcoast/tools/slr.html

New York: https://gis.dot.ny.gov/html5viewer/?viewer=FC

Puerto Rico: https://jp.pr.gov/mapas

Evacuation Route (T2)

Geography: NY (Suffolk and Nassau counties only), NJ, PR, and USVI

Similar to the road functional classification metric, it is assumed that flooding or any other road access issues related to a restriction would be more problematic on a hurricane or tsunami evacuation route. In NY, areas outside of Nassau and Suffolk counties do not have designated evacuation routes; scoring for crossings outside Long Island is addressed in Section VI Protocol Scoring and Crossing Prioritization. To determine if the crossing is an evacuation route, consult the following for each state or territory:

Suffolk County, NY: https://www.suffolkcountyny.gov/Portals/0/FormsDocs/fres/Forms/OEMDOCS/Suffolk%20CER.pdf

Nassau County, NY: https://nassau-county.maps.arcgis.com/apps/webappviewer/index.html?id=0bb83341f55f4df6842c957214890699

New Jersey: https://nj.gov/njoem/plan/pdf/maps/statecoastal_evac.pdf.

Puerto Rico: https://redsismica.uprm.edu/english/tsunami/evacuation_maps.php

U.S. Virgin Islands: https://vitema.vi.gov/plan-prepare/tsunamis

VI. Protocol Scoring and Crossing Prioritization

As described above, the *Protocol* is comprised of management categories with related sets of metrics. These metrics are rated on a 1 to 5 scale, where a lower number corresponds to a lower priority for replacement/rehabilitation of the tidal restriction. Metric scores are then averaged across each management category and added together for a total prioritization score between 4 (lowest priority) and 20 (highest priority). In addition, each management category may be scored separately or in different combinations to align with specific management objectives, if desired. For example, if a practitioner is more interested in benefits to tidal wetland communities and coastal resilience from restriction removal, they could use the ecological enhancement and climate/ecological resilience category scores only to determine an overall prioritization score using two categories instead of four (so, the total prioritization score would be between 2 and 10). Scoring criteria for each metric is shown below, by management category.

A. Ecological Enhancement Management Category

E1. Tidal Wetland Complex Size

Table 4. Tidal wetland complex size scores.

Scoring Criteria	Score
≥15 acres	5
<15 acres	3
Limited connectivity to marsh complex	1

E2. Degree of Restriction (overall)

Table 5. Degree of restriction (overall) scores.

Scoring Criteria	Score
Average of metric sub-scores is > 4 OR a tide gate is present that prevents most upstream flow (whether by design or because of maintenance issues).	5
Average of metric sub-scores is >3 but ≤4	4
Average of metric sub-scores is >2 but ≤3	3
Average of metric sub-scores is >1 but ≤2	2
Average of metric sub-scores is ≤1	1

E2 Sub-metric 1 (Tidal Range Ratio)
Upstream tidal range/downstream tidal range x 100: ________________%

Table 6. Tidal range ratio scores.

Scoring Criteria	Score
For culverts, downstream invert is perched at high tide OR tidal range upstream is less than 50 percent of downstream range	5
Tidal range upstream is between 50 and 70 percent of downstream range	4
Tidal range upstream is between 70 and 80 percent of downstream range	3
Tidal range upstream is between 80 and 90 percent of downstream range	2
Upstream tidal range is >90% of downstream tidal range AND there is no downstream invert perch at low tide (for culverts only)	1

E2 Sub-metric 2 (Crossing Ratio)

The crossing ratio is the channel width/crossing width (both downstream and upstream). The final score is the higher of the two sub-scores.

Table 7. Crossing ratio scores.

Scoring Criteria	Sub-scores *Upstream*	*Downstream*	Final Score
Channel width greater than 5 times crossing width	5	5	
Channel width 2 to 5 times crossing width	4	4	
Channel width up to 2 times crossing width	3	3	
Channel width = crossing width	2	2	
Channel width < crossing width	1	1	

E2 Sub-metric 3 (Erosion Classification)

The erosion classification is the maximum pool width/channel width (both downstream and upstream). The final score is the higher of the two sub-scores.

Table 8. Erosion classification scores.

Scoring Criteria	Sub-scores *Upstream*	*Downstream*	Final Score
Erosion class >2; pool width is more than twice as wide as channel	5	5	
Erosion class >1.5 but ≤2; pool width is between 50 and 100% wider than channel	4	4	
Erosion class >1.2 but ≤1.5; pool width is between 20 and 50% wider than channel	3	3	
Erosion class >1 but ≤1.2; pool width is up to 20% wider than channel	2	2	
Erosion classification ≤1; pool width is approximately the same as channel width	1	1	

E3. Vegetation Comparison

Use any natural vegetation to score this metric, even if the extent of natural vegetation is less on one side than the other. If there is no vegetation because of development on either side of the crossing, or the vegetation present is not indicative of natural vegetation (i.e., lawns, other planted vegetation) do not score this metric and leave out of the overall ecological enhancement score (do not use in averaging).

Table 9. Vegetation comparison scores.

Scoring Criteria[1]	Score[2]
Up- and downstream plant communities are ***very different*** wetland types, in vegetative structure (including non- or sparsely vegetated areas) and/or suite of plants. Invasive species may be prevalent across the marsh plain upstream, but are largely absent, or only concentrated near the crossing structure, downstream.	5
Up- and downstream plant communities are ***moderately different*** wetland types, or the same types are present but the proportion of each differs substantially on either side of the crossing (e.g., ratio of low marsh to high marsh). Invasive species may be present upstream but are not as common as native species or may only be concentrated near the crossing structure.	3
Up- and downstream plant communities are ***comparable*** wetland types and different types are present in similar proportions. Little to no invasive species are present in the upstream community.	1

[1] Comparison categories are not the same as those used for the vegetation change metric in the NAACC tidal protocol. Use best professional judgement and intermediary scores (see below), as needed to translate NAACC observations.

[2] Intermediary scores of 2 and 4 may be used if needed to better reflect a range of conditions.

Overall Ecological Enhancement Score: ____

B. Climate and Ecological Resilience Category

R1. Heavy Rainfall Flood Risk in Watershed

Table 10. Heavy rainfall flood risk within watershed scores.

Scoring Criteria	Score
40% or greater	5
30-40%	4
20-30%	3
10-20%	2
10% or less	1

R2. Risk of Sea Level Rise Inundation of Road/Crossing

Table 11. Risk of sea level rise inundation of road/crossing scores.

Scoring Criteria	Score
Crossing partially or totally inundated by 1 ft. of SLR	5
Crossing partially or totally inundated by 2 ft. of SLR	4
Crossing partially or totally inundated by 3 ft. of SLR	3
Crossing partially or totally inundated by 4 ft. of SLR	2
Crossing partially or totally inundated or not inundated by ≥5 ft. of SLR	1

R3. Unvegetated Marsh Vulnerability

Metric scoring differs for PEM wetlands with seasonally flooded-tidal (Cowardin modifier "R") and temporarily flooded-tidal (Cowardin modifier "S") regimes since these types of tidal regimes would naturally have been less significant sediment supply sources (Table 13). **Important: If tidal wetlands being evaluated are not classified as emergent, do not use this metric in scoring.**

Table 12. Unvegetated tidal marsh vulnerability scores for all E2EM wetlands and tidal PEM wetlands excluding R and S tidal regime modifiers.

Scoring Criteria	Score
UVVR shows majority of upstream marsh as having a vulnerability index ≤0.1 OR unvegetated areas comprise ≤10% of upstream marsh area (field observation and/or aerial interpretation)	5
UVVR shows upstream marsh vulnerability index as >0.1 OR unvegetated areas comprise >10% of upstream marsh area (field observation and/or aerial interpretation)	1

Table 13. Unvegetated tidal marsh vulnerability scores for PEM-R and PEM-S wetlands.

Scoring Criteria	Score
UVVR shows majority of upstream marsh as having a vulnerability index ≤0.3 OR unvegetated areas comprise ≤30% of upstream marsh area (field observation and/or aerial interpretation)	5
UVVR shows majority of upstream marsh as having a vulnerability index >0.3 OR unvegetated areas comprise >30% of upstream marsh area (field observation and/or aerial interpretation)	1

R4. Tidal Wetland Migration Potential

Table 14. Tidal wetland migration potential scores.

Scoring Criteria	Score
Increase in tidal wetlands above the crossing under an intermediate-high SLR scenario with low levels of accretion by 2080.	5
No increase in tidal wetlands above the crossing under an intermediate-high SLR scenario with low levels of accretion by 2080, OR only loss of tidal wetlands shown (converted to open water or unconsolidated shore) with no associated migration of tidal wetlands.	1

Overall Climate/Ecological Resilience Score: ____

C. Transportation Network Resilience Management Category

T1. Road Functional Classification

For all USVI crossings, this metric will be scored as a '3'.

Table 15. Road functional classification scores.

Scoring Criteria	Score
Principal Arterial (Interstate, Freeway/Expressway, Other)	5
Minor Arterial	4
Major Collector	3
Minor Collector	2
Local Roads, other crossings with no functional classification	1

T2. Evacuation Route

For all crossings in New York outside of Long Island, this metric will be scored as a '1'.

Table 16. Evacuation route scores.

Scoring Criteria	Score
Yes	5
No	1

Overall Transportation Network Resilience Score: ___________________________________

D. Infrastructure Condition Management Category

C1. Crossing Structural Condition

Table 17. Structural condition scores.

Structural Condition[1]	Score[2]
Poor or Failing: significant deterioration of structure, such as rotted metal (not just surface rust), spalling (cracking) concrete, or culvert joint separation leading to potential voids around the structure; extreme overall shape distortion (e.g., flattened culvert); and/or structures that are already collapsing or in danger of imminent failure.	5
Fair: some deterioration that does not indicate a risk of failure, such as surface rust, low to moderate cracking, or culvert joint separation with minor infiltration; localized distortion in shape; still functionally adequate	3
Good or New: like new, with little or no deterioration; consistent shape; joint misalignment, if present, is minor; structurally sound, and functionally adequate.	1

If general condition ratings are available, the rating might correspond to the full range of condition scores as shown in Table 18.

Table 18. Translating general condition ratings to a structural condition score.

General Condition Rating[1]	Structural Condition Score
0-2	5
3-4	4
5-6	3
7-8	2
9	1

[1] General condition ratings of 4 or less are generally considered 'structurally deficient'.

C2. Current Inundation Risk and Lack of Clearance

Table 19. Current inundation risk and lack of clearance scores.

Inundation Risk and Lack of Clearance	Score
High-water indicator (HWI) is at or above the crossing surface elevation or structure ceiling; OR structure is submerged at low tide; OR historic aerial photos (past ten years) show the crossing being totally or partially flooded at least once	5
HWI is less than 1′ below the structure's ceiling OR less than 1.5′ below the crossing surface elevation	4
HWI is less than 2′ below the structure's ceiling OR less than 3′ below the crossing surface elevation	3
HWI is less than 3′ below the structure's ceiling OR less than 6′ below the crossing surface elevation	2
HWI is greater than 6′ below the crossing surface elevation AND greater than 3′ below the structure ceiling	1

C3. Scour Severity

Table 20. Scour severity scores.

Scour Severity	Score[1]
Severe scour is present – jeopardizes structural integrity of crossing components or crossing structure as a whole. Immediate maintenance is required. Stabilization methods (e.g., armoring) are likely apparent.	5
Noticeable scour is observed – left unmaintained, scour will continue to undermine and jeopardize structure components. Armoring or other methods may have been used to stabilize structure.	3
Little to no scour is observed – where scour is present, it does not pose an immediate threat to the crossing structure.	1

[1] Intermediary scores of 2 and 4 may be used if needed to better reflect a range of conditions.

Overall Infrastructure Condition Score: ____

Overall Prioritization Score: ______________

VII. References

Couvillion, B.R., N.K. Ganju, and Z. Defne. 2021. An Unvegetated to Vegetated Ratio (UVVR) for coastal wetlands of the Conterminous United States (2014-2018): U.S. Geological Survey data release.

Dewitz, J., and U.S. Geological Survey (USGS). 2021. National Land Cover Database (NLCD) 2019 Products (ver. 2.0, June 2021): U.S. Geological Survey data release.

Giannico, G.R., and J.A. Souder. 2005. Tides Gates in the Pacific Northwest. Prepared for Oregon Sea Grant, Corvallis OR. Publication no. ORESU-T-05-001, 33 pp. Online at: https://seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/sgpubs/onlinepubs/t05001.pdf

Jackson, S.D. 2019. NAACC Tidal Stream Crossing Instruction Manual for Aquatic Passability Assessments. North Atlantic Aquatic Connectivity Collaborative (NAACC), University of Massachusetts Amherst. Online at: https://streamcontinuity.org/naacc/assessments/documents

Purinton, T.A., and D.C. Mountain. 1998. Tidal Crossing Handbook: a volunteer guide to assessing tidal restrictions. Parker River Clean Water Association, Byfield, MA. Online at: https://pie-rivers.org/documents/TidalCrossingHandbook_1996.pdf

Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018. Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis. Report to Oregon Watershed Enhancement Board. Institute for Natural Resources, Oregon State University. Corvallis, OR. 136 pp. Online at: https://www.oregon.gov/oweb/Documents/Tide-Gate-Ecological-Effects.pdf

Steckler, P., K. Lucey, D. Burdick, J. Glode, and S. Flanagan. 2017. New Hampshire's Tidal Crossing Assessment Protocol. The Nature Conservancy. Prepared for the New Hampshire Department of Environmental Services Coastal Program. Online at: https://www.nature.org/content/dam/tnc/nature/en/documents/nh-tidal-crossing-assessment-protocol.pdf

The Nature Conservancy. 2021. Road-Stream and Tidal Crossing Prioritization Tool. Online at: https://tnc.maps.arcgis.com/apps/webappviewer/index.html?id=db144f948c4d4512b3f2c4b3267d50a3.

U.S. Environmental Protection Agency. 2020. Tidal Restriction Synthesis Review: An Analysis of U.S. Tidal Restrictions and Opportunities for their Avoidance and Removal. Washington D.C., Document No. EPA-842-R-20001. Online at: https://www.epa.gov/sites/default/files/2020-12/documents/tidal_restrictions_synthesis_review_final_12.01.20.pdf

APPENDIX A

Virtual Meeting and In-Person Stakeholder Workshop Executive Summary

Tidal Restriction Protocol Project:
NY, NJ, PR and USVI (EPA Region 2)

Final
Meeting and Workshop Executive Summary




Virtual Meeting
October 4, 2022
&
In-Person Workshop (with Virtual Option)
November 1, 2022
Ted Weiss Federal Building, NY, NY

Report Date: February 2023

Executive Summary

In 2020, EPA released the Tidal Restriction Synthesis Review document, which aimed to summarize existing information on tidal restrictions in the coastal U.S., including common types, their abundance and distribution, adverse effects to tidal wetlands and species that depend on them, and existing policies, practices, or tools that could facilitate their avoidance and/or removal. In addition, the document presented a set of 11 recommendations for further eliminating tidal restrictions from the landscape, one of which was to "use and adapt existing tidal crossing field evaluation methods to confirm the existence of restrictions, determine their severity and prioritize them for removal". These existing protocols were developed outside Region 2 or have a greater focus on aquatic organism passage than tidal wetland restoration/rehabilitation.

The overall goal of this project is to develop a tidal restriction protocol for EPA Region 2 (New York, New Jersey, Puerto Rico, and the US Virgin Islands) that will serve as a screening tool to focus resources on achievable projects that rehabilitate/replace tidally restrictive structures and provide restorative benefits to tidally influenced natural habitats and built infrastructure. As part of this project, a virtual meeting and an in-person workshop with regional stakeholders were held in October and November 2022. This report is a summary of the material presented and discussions that occurred at each of those meetings. The meeting and workshop summaries are presented separately and are arranged by topic.

Some of the main take-aways from the discussions included:

- Six (6) management objectives, as derived from the New Hampshire Tidal Crossing Assessment Protocol, were found to be important to include in a Region 2 protocol. However, some may need further definition to fully encapsulate all management concerns (e.g., maintain and increase carbon sequestration).
- Fourteen (14) metrics derived from both the NH protocol and the North Atlantic Aquatic Connectivity Collaborative (NAACC) Tidal Stream Crossing Protocol that assesses aquatic organism passage, were deemed to be important to include in a Region 2 protocol. Metrics were selected by participants and from a "straw poll" conducted by EPA prior to the workshop, and included those measuring:
    - Crossing condition and inundation risk of structure and surrounding development
    - Tidal range and crossing ratios

    - Presence of barriers and their severity, including perching, tide gates, and other barriers (e.g., debris/sediment, fencing)
    - Vegetation comparison
    - Erosion/scour at crossing
    - Salt marsh migration potential
- This suite of metrics will need to be modified for use in sub-tropical portions of Region 2 (PR and the USVI) due to differences in habitat, natural tidal range, and availability of data.
- Existing field protocols only address transportation crossings, though other types of tidal restrictions exist (e.g., dikes/berms, dams). Participants determined that a separate protocol with modified or different metrics for these types of restrictions was not needed to evaluate them.
- A protocol where the field portion can be completed in 30 minutes or less is ideal.
- A protocol that allows end users to customize the outcome based on different prioritization factors is important.
- Regional efforts are already underway in NY and NJ to assess and prioritize tidal crossings with the NAACC protocol and the Nature Conservancy (TNC) Road-Stream and Tidal Crossing Prioritization Tool (Long Island only currently, with plans for expansion). The TNC protocol was not considered when discussing metrics and includes a few metrics (mostly desktop) not found in the NH and NAACC protocols. TNC has also developed a map that houses and visualizes the data for crossings assessed with the method. EPA plans to explore coordination with these stakeholders as the protocol is developed to avoid duplicative efforts in these states.
- PR is part of the Southeast Aquatic Resource Partnership (SARP), which maintains a database of aquatic barrier assessments, including those using the NAACC tidal protocol (used in the Southeast states, though not in PR). Given this existing framework, SARP is a potential data management partner for this effort.

Project Team

Jennifer Linn and Amanda Santoni (U.S. Environmental Protection Agency [EPA] Office of Wetlands, Oceans and Watersheds)
Jaclyn Woollard (EPA Region 2)
Mike Ruth and Richard Darden (Federal Highway Administration [FHWA])
Amy James and Paxton Ramsdell (Ecosystem Planning and Restoration [EPR]; contractor)

Participants

Name	Affiliation	Attendance	
		Virtual Meeting	In-Person Workshop
Jade Blennau	Peconic Estuary Partnership	✓	✓
Richard Bolton	NYS Department of Transportation (DOT)	✓	✓ (Virtual)
Jeremy Campbell	NY Department of State, Long Island South Shore Estuary Preserve	✓	✓
Terry Doss	NJ Sports and Exhibition Authority	✓	
Dr. Augustin Engman	University of Tennessee	✓	
Elizabeth Freiday	USFWS NJ Ecological Services	✓	
Piotr Gajewski	USVI Dept. Public Works	✓	
Heather Gierloff	NYS Department of Environmental Conservation (DEC)	✓	
Dr. Gregory Guannel	University of the Virgin Islands	✓	
LeeAnn Haaf	Partnership for the Delaware Estuary	✓	
Emily Hall	Seatuck Environmental Association	✓	✓
Heidi Hanlon	Cape May National Wildlife Refuge (USFWS)	✓	
Kat Hoenke	Southeastern Aquatic Resource Partnership (SARP)	✓	
David Hsu	Montclair University/Connecting Habitats Across New Jersey (CHANJ)	✓	✓
Scott Jackson*	University of Massachusetts; North Atlantic Aquatic Connectivity Collaborative (NAACC)		✓ (Virtual)
Gregg Kenney	NYS DEC		✓
Josh LaFountain	The Nature Conservancy (NY)	✓	✓ (Virtual)
Megan Lung	NYS DEC; Hudson River Estuary Program	✓	✓
Victoria O'Neill	NYS DEC	✓	✓ (Virtual)
Jamie Ong	NYC Department of Parks and Recreation	✓	
Dr. Concepcion Rodriguez-Fourquet	University of Puerto Rico Bayamon	✓	✓
Michael Setering	FHWA NJ	✓	✓ (Virtual)
Joseph Smith	Forsythe National Wildlife Refuge (USFWS)	✓	
Jose Soto	EPA Region 2 (Caribbean)	✓	
Isabelle Stinnette	NY/NJ Hudson River Estuary Partnership	✓	✓
Burton Suedel	USACE ERDC	✓	

Name	Affiliation	Attendance	
		Virtual Meeting	In-Person Workshop
Cayla Sullivan	EPA Region 2 (Long Island Sound Study)	✓	✓
Melissa Toni	FHWA NY	✓	
Barry Volson	NYS DEC / Peconic Estuary Partnership	✓	✓
Brittany Wilburn	NJ Department of Environmental Protection	✓	✓ (Virtual)
Gregg Williams	NYS DOT	✓	✓

*Present to provide context and input related to NAACC protocol

APPENDIX B

Field and Desktop Data Form

CROSSING DATA

Date Observed: ____________________ **Start Time:** __________ **End Time:** __________
Observers: ____________________
Municipality/County: ____________________ **Stream/River:** ____________________
GPS Coordinates (Decimal Degrees): ____________________
Location Description: ____________________

Crossing Name:
Crossing Type: ☐ Public Road ☐ Private Road ☐ Driveway ☐ Trail ☐ Railroad ☐ Other (Describe):

Culvert/Pipe Type: ☐ Round ☐ Elliptical ☐ Pipe Arch ☐ Box ☐ Open Bottom Arch No. of Culverts: __________
Embedded: ☐ Yes ☐ No

Road Type: ☐ > 2 Lanes (Multilane) ☐ 1-2 Lanes ☐ N/A
Crossing Surface Type: ☐ Paved ☐ Gravel/Stone ☐ Dirt
Crossing Structure Type: ☐ Bridge ☐ Culvert/Pipe ☐ Other (Describe)

Tide Stage: ☐ Low Slack ☐ Low Ebb ☐ Low Flood ☐ Unknown/Other (Describe): __________
Tide Prediction: Time of Nearest Low Tide
Data Source__________
Flow Condition: ☐ Dewatered ☐ Unusually Low ☐ Typical Low ☐ Moderate ☐ High

Bridge Type: ☐ Abutments ☐ Side Slopes ☐ Both
No. of Bridge Cells:

Adjacent Land Use (Current and Historic, if known): ____________________

____

[C2] Elevation Difference between the Road and the High-Water Indicator (HWI; ft.): __________
Is Road Susceptible to Flooding at High Tide (as indicated by measurement above)? ☐ Yes ☐ No
[E2] Downstream: Channel Width (ft.)__________Max Pool Width (ft.) __________Tidal Range (ft.) __________
[E2] Upstream: Channel Width (ft.) __________Max Pool Width (ft.) __________ Tidal Range (ft.) __________
[E2] Tide Gate: ☐ Yes ☐ No
[E2] Tide Gate Type: ☐ Traditional ☐ Self-regulating ☐ Other (Describe):__________
[E3] Vegetation Comparison Upstream/Downstream: ☐ Comparable ☐ Moderately Different ☐ Very Different
Vegetation Description (note typical species, including invasive species, if present): __________

____

____

[R3] Field Estimate of % Unvegetated Area Upstream (emergent tidal marsh only):__________
Structure Location (if more than one): __________

STRUCTURE 1

[C1] Structure Condition: ☐ Good or New ☐ Fair ☐ Poor or Failing
Structure Condition Description: ____________________

____

[C3] Scour Severity: ☐ Little to None ☐ Noticeable ☐ Severe
Scour Description (note extent of armoring, if present): ____________________

____

OUTLET

Outlet Information (ft.): [E2] Width __________ [C2] Elevation Difference Between the HWI and the: Top of Structure (can be a negative #) __________and the [E2] Water Surface __________
[E2] Outlet Perch Above Water Surface (ft.): High Tide (use HWI) __________ Low Tide __________ ☐ None

INLET

Inlet Information (ft.): [E2] Width __________ [C2] Elevation Difference Between the HWI and the: Top of Structure (can be a negative #) __________ and the [E2] Water Surface __________
[E2] Inlet Perch Above Water Surface (ft.): High Tide (use HWI) __________ Low Tide __________ ☐ None
For Additional Structures, See Additional Sheets Starting on Page 2

ADDITIONAL

Additional Crossing or Structure Notes: ____________________

____

____

Photo File Nos.: Outlet __________ **Inlet** __________ **Upstream** __________
Downstream __________
Other (Describe) ____________________

STRUCTURE 2

[C1] Structure Condition: ▢ Good or New ▢ Fair ▢ Poor or Failing

Structure Condition Description: ____

____

[C3] Scour Severity: ▢ Little to None ▢ Noticeable ▢ Severe

Scour Description (note extent of armoring, if present): ______________________________

____

OUTLET

Outlet Information (ft.): [E2] Width __________ [C2] Elevation Difference Between the HWI and the: Top of Structure (can be a negative #) __________and the [E2] Water Surface __________

[E2] Outlet Perch Above Water Surface (ft.): High Tide (use HWI) _________ Low Tide ___________ ▢ None

INLET

Inlet Information (ft.): [E2] Width ___________ [C2] Elevation Difference Between the HWI and the: Top of Structure (can be a negative #) __________ and the [E2] Water Surface ___________

[E2] Inlet Perch Above Water Surface (ft.): High Tide (use HWI) __________ Low Tide ____________ ▢ None

For Additional Structures, See Additional Sheets Starting on Page 2

ADDITIONAL

Additional Crossing or Structure Notes: ____

____

____

Photo File Nos.: Outlet ______________ **Inlet** ________________ **Upstream** ______________

Downstream ___________

Other (Describe) ____

STRUCTURE 3

[C1] Structure Condition: ▢ Good or New ▢ Fair ▢ Poor or Failing

Structure Condition Description: ____

____

[C3] Scour Severity: ▢ Little to None ▢ Noticeable ▢ Severe

Scour Description (note extent of armoring, if present): ______________________________

____

OUTLET

Outlet Information (ft.): [E2] Width __________ [C2] Elevation Difference Between the HWI and the: Top of Structure (can be a negative #) __________and the [E2] Water Surface __________

[E2] Outlet Perch Above Water Surface (ft.): High Tide (use HWI) _________ Low Tide ___________ ▢ None

INLET

Inlet Information (ft.): [E2] Width ___________ [C2] Elevation Difference Between the HWI and the: Top of Structure (can be a negative #) __________ and the [E2] Water Surface ___________

[E2] Inlet Perch Above Water Surface (ft.): High Tide (use HWI) __________ Low Tide ____________ ▢ None

For Additional Structures, See Additional Sheets Starting on Page 2

ADDITIONAL

Additional Crossing or Structure Notes: ____

____

____

Photo File Nos.: Outlet ______________ **Inlet** ________________ **Upstream** ______________

Downstream ___________

Other (Describe) ____

[1]Field Measurements or observations not included in the NAACC tidal protocol are indicated in orange. If completing this protocol as a supplement to the NAACC, data for these measurements or observations must be collected separately.
[2]Relevant metric numbers are indicated in brackets, as applicable.

DESKTOP DATA COLLECTION

Crossing/Stream Name: ______________________________

[E1] National Wetland Inventory (NWI) Cowardin Tidal Wetland Type:

Downstream (record all) ______________________________
Upstream (record all) ______________________________

[E1] Do the wetlands on-site approximately match the Cowardin wetland type:
☐ Yes ☐ No; if No, please describe

____

[E1] Approximate Area of NWI Tidal Wetlands (Acres): Downstream ______________
Upstream ______________

[E1] What sources were used to determine potential presence of upstream tidal wetlands (if any)?

____

[R1] Approximate Upstream Watershed Area (Acres): ______________

[R1] Percent Impervious of Upstream Watershed Area (NLCD values 21-24): ______________

[R2] Level of Sea Level Rise Likely to Inundate or Partially Inundate the Crossing: ______________

[R3] Ratio of Unvegetated to Vegetated Marsh Upstream of Crossing (UVVR):
☐ ≤10% ☐ >10% ☐ ≤30% ☐ >30% (PEM-R and –S wetlands only)

[R4] Tidal Wetland Migration Potential Upstream: ☐ Increase ☐ No Increase or Only Loss

[T1] Road Functional Classification: ☐ Principal Arterial ☐ Minor Arterial : ☐ Major Collector ☐ Minor Collector :
☐ Local Roads/No Functional Classification

[T2] Evacuation Route: ☐ Yes ☐ No

[1] As the NAACC tidal protocol does not use desktop metrics, all desktop information will need to be filled in independently of a NAACC tidal assessment.