

Foddering Farm Causeway Concept Study



Town of Narragansett Narragansett, RI

December 2021



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Attachments

- A Conceptual Plans
- B 2019 Tidal Level Monitoring Report
- C STORMTOOLS Output
- D Order of Magnitude Opinion of Cost

End of Report



1 Project Overview

This project, funded primarily by the Federal Emergency Management Agency Pre-disaster Mitigation Program (FEMA PDM) with additional in-kind services and financial support from the Town of Narragansett, friends of Harbour Island, and Salt Ponds Coalition, addresses the coastal resiliency of one of Narragansett's most vulnerable low-lying roadways. Foddering Farm Road provides the only access/egress for approximately 325 properties located on Harbour Island.

As stated on the PDM scope of work, Harbour Island residents have long-been aware of periodic flooding of the causeway. In 2018, during the Town's Hazard Mitigation Plan update, the residents reached out to staff to seek assistance on finding a long-term solution. At the same time, the Town had identified this location as a vulnerable area, because the recurring flooding may potentially isolate Harbour Island during a major storm event that could prevent egress for residents and threaten access for fire protection and emergency services should the roadway become impassable.

The Foddering Farm Road causeway is approximately 1000 feet in length and traverses point Judith Pond. The causeway is shown to be the only access point to the island in aerial images as far back as 1939, although at that time the access was a dirt road only accessible at low tide.

The goal of this project was to assess the vulnerability to future flood risks from sea level rise (SLR) and coastal storms and develop a set of alternatives to manage risks and improve the long-term resilience of the Foddering Farm causeway.



Figure 1: Water adjacent to Foddering Farm Road Causeway under high tide (October 8, 2021, Photo credit: Rick Black)

The major elements of this project were:

- Utilize Coastal Resources Management Council (CRMC) STORMTOOLS to assess the present day and long-term coastal storm flood risk and vulnerability to sea level rise (SLR).
- Assess alternatives to better manage flood risks based on roadway elevation enhancements. These alternatives will be compared against flood risk probability to allow the Town to better understand risk and investment and select an alternative that provides the best balances both for the Town and the residents of Harbour Island.
- Develop implementation plan that allows the Town to appropriately budget and plan actions required to implement the recommended plan. Alternatives will also be developed to allow adaptive management to address future flooding. For example, an approach where the investment can be phased and allow a less expensive investment to be made earlier that will allow a greater investment in the future as coastal conditions continue to worsen.



Figure 2: Flooding on Brush Hill, approximately 300 yards to the north of where it intersects Foddering Farm Road (November 5, 2021, Photo credit: Rick Black)

2 Data Collection

2.1 Base Mapping

Fuss & O'Neill compiled base mapping utilizing existing publicly available data. The following digital information was available to Fuss & O'Neill to develop the base map:

- LiDAR
- Aerial Imagery
- Parcel boundaries
- FEMA floodplain boundaries

In addition to the data above, Fuss & O'Neill field measured the existing roadway width at various points along the causeway. The purpose of this overall base mapping effort was to support the development of the conceptual alternatives. A more detailed field survey will be required in a future proposal for design and permitting.

The following was noted during the compilation of the base mapping as it pertains to the current evaluation:

- According to the Town of Narragansett MapGeo website, property on the north side of the causeway is owned by the Town. There are several private owners for properties on the south side of the causeway.
- The Town reports that there is a buried waterline in Foddering Farm Road.

2.2 Tidal Level Monitoring

In 2019, the Harbour Island Improvement Association (HIIA) and the Salt Pond Coalition (SPC) contracted with Fuss & O'Neill, and sub-consultant Woods Hole Group, to install three water level stations for a tidal gauge study. The study was undertaken to assess potential flood mitigation and water quality improvements by providing a culvert at Foddering Farm causeway. This study was not performed as part of the current evaluation.

The report, dated October 22, 2019, is provided in Attachment B. The instrumentation was deployed on either side of the causeway for 34 days. A third tidal gauge was provided in Galilee on the south side of Point Judith Pond. The tide gauge locations are depicted in Figure 3. The instrumentation measured salinity, water level, and temperature.

In summary, the evaluation did not provide clear evidence that a culvert would provide flood mitigation benefits. The gauges did not show a significant tidal change between Long Cove and Champlin Cove. However, the study was conducted during a dry period in August and early

September and that more impactful results may occur during the spring months. The study did not assess the circulation and focused solely on tidal range, phase, and salinity.

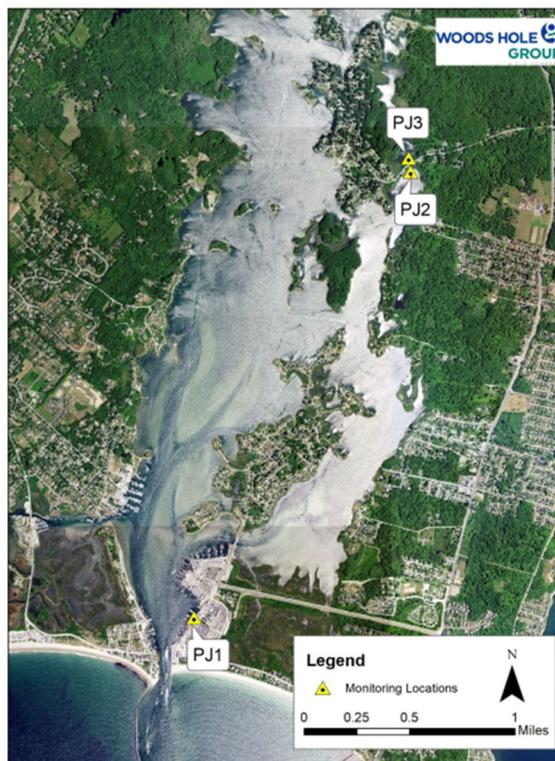


Figure 3: Monitoring Stations in Point Judith and Long Cove (2019)

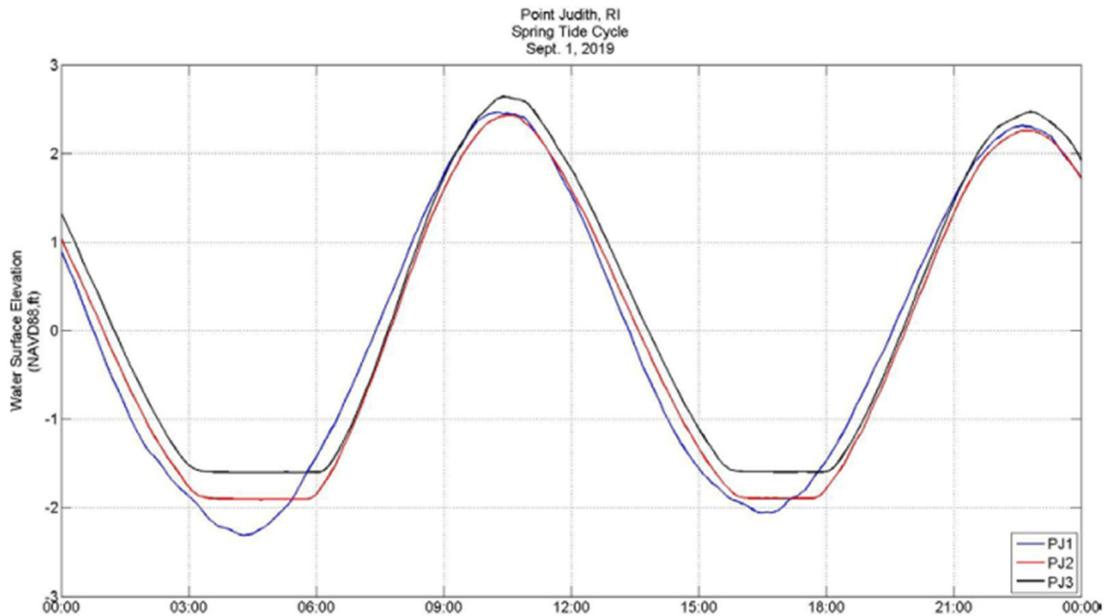


Figure 4: Tidal data showing water surface elevation measured during a single spring tide cycle. High and low tides appeared to occur at approximately the same time with minimal phase shift.

3 Vulnerability Assessment

3.1 Coastal Flood Risk Assessment

STORMTOOLS was utilized to assess daily, sunny day flooding due to SLR and flooding during nuisance and extreme coastal storms at various annual exceedance probabilities under present day Mean Higher High Water (MHHW) levels and superimposed with projected SLR levels for the planning horizons. Using the existing tool is beneficial to the Town since much of the upfront work and cost in developing the flood risk assessment is completed compared to a site specific, dynamic probabilistic model.

To quantify the maximum inundation depth for SLR and coastal storm flooding, two low points along the causeway were identified based on inspection of the publicly available LIDAR data. The lowest point was identified near the middle of the causeway and a second low point is located west of the intersection of Brush Hill Road and Foddering Farm Road. The low points at the center of causeway and west of Brush Hill Road are estimated to have approximate elevations of 4.0 feet \pm and 4.5 \pm , respectively. These elevations are visually interpolated from publicly available LIDAR data and actual elevations may vary. The approximate low areas are shown in Figure 5.



Figure 5: Overview of low points in study area



Figure 6: Causeway at Foddering Farm Road (lowest point in study area)



Figure 7: Low point west of Foddering Farm at Brush Hill Road

3.2 Sea Level Rise Projections

For the current analysis, “present day” high water levels along Foddering Farm Road were assumed to be approximately equal to the SLR projections provided by NOAA and presented in the CRMC Shoreline Change Special Area Management Plan (SAMP). Projected increases in SLR are shown in Table 1 with the corresponding STORMTOOLS map layer that was used to predict the potential SLR flooding. The changes represent the increase above the MHHW level at Foddering Farm Road.

The “present day” conditions for 2020 includes an increase of 1-foot of SLR. As indicated in the SAMP, the projections are based on data collected between 1983 through 2001 to estimate the daily high tide. The additional 1-foot of SLR considered for “present day” conditions in the table below accounts for SLR observed since that time in Rhode Island and other uncertainties. \$\$

Table 1: Estimated increase in the current MHHW due to SLR (ft.)

	Present Day	2050	2070
SLR Projection ¹	1.05	3.25	5.35
STORMTOOLS map layer to predict flooding due to SLR	+1	+3	+5

3.3 Sea Level Rise Flooding

The figures below focus on SLR scenarios for Foddering Farm Road Causeway. The SLR figures (Figures 8 through 10) illustrate the changes in daily higher high tides along the roadway. The figures depict the depth of flooding in feet in impacted areas relative to the daily higher high tide for the present day, 2050, and 2070 horizons. The figures below identify the approximate depth of flooding that was assessed using STORMTOOLS. The depth of flooding is approximated relative to the lowest point on the road estimated based on 2011 Northeast LIDAR data utilized in STORMTOOLS and not based on site specific elevation measurements, which may vary from the coarser resolution of the LIDAR data. The figures below are focused on daily tidal conditions and do not account for coastal storm-driven flooding.

As seen in the figures below, Foddering Farm Road will be flooded daily during high tide by 2050. Approximately 1,200 linear feet of Foddering Farm Road will be flooded daily during high tide by 2070.



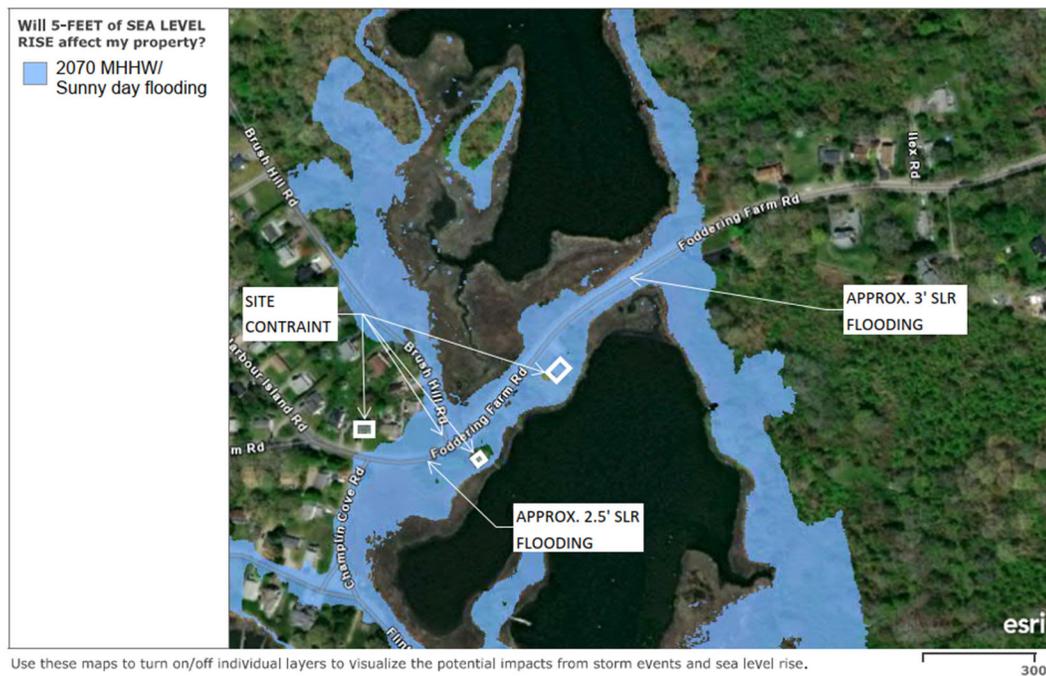
Figure 8: SLR Inundation Mapping for Present Day

¹ NOAA 2017 Relative Sea Level Change Scenario curve for Newport, RI, high curve.



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Figure 9: SLR Flood Depth (2050).



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Figure 10: SLR flood depth (2070).



3.4 Coastal Storm Flooding

STORMTOOLS was used to estimate the depth of water at Foddering Farm Road during a 1% annual exceedance probability (AEP) coastal storm event. STORMTOOLS output describes the likelihood of coastal storm events based on return periods. A 100-year storm describes an event that has a 1% chance of being met or exceeded in any given year. Annual exceedance probabilities are utilized in this report to describe storms in terms of probability instead of a return period, which may unintentionally imply that two severe events can't be experienced consecutively, but it is possible for example, to experience 100-year storms back-to-back. Corresponding return periods are provided in brackets. Figures were developed for the coastal storm with no SLR, and coastal storms with SLR associated with the 2050 and 2070 planning horizons.

Figures 11 through 13 indicate significant (10.0' +) depths of inundation along Foddering Farm Road during a 1% (100 year) storm. The flood depth is generally expressed on the figures below as the depth of water relative to the low point on the road at the center of the causeway.

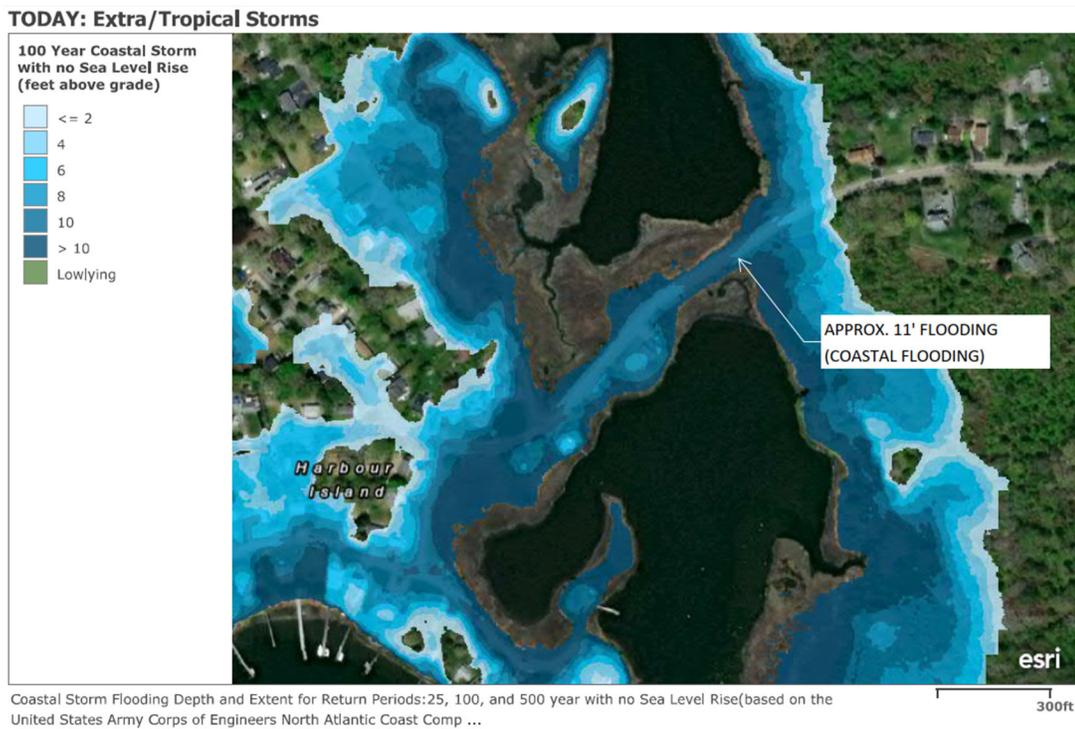


Figure 11: Depth of inundation during 1% (100 year) storm event, with no SLR

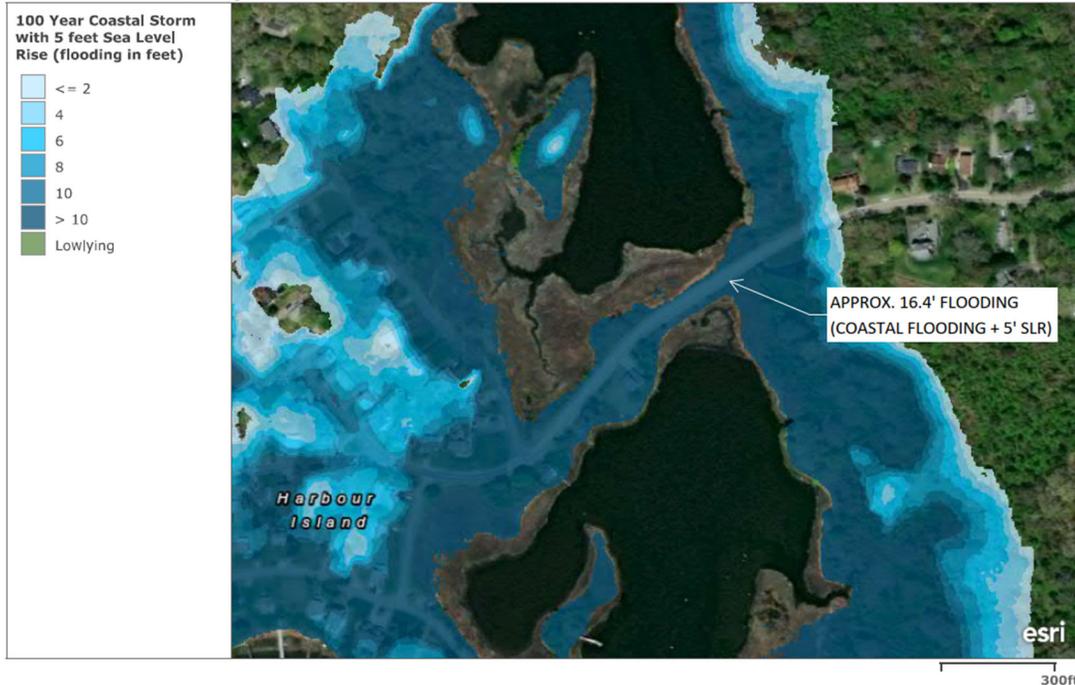
3 FEET SLR: Extra/Tropical Storms.



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Figure 12: Depth of inundation during 1% storm (100 year) event plus 3' SLR (2050)

5 FEET SLR: Extra/Tropical Storms.



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Figure 13: Depth of inundation during 1% storm (100 year) event plus 5' SLR (2070)



The figures above indicate 11 feet of flooding during a 1% AEP coastal storm and the flood depth is expected to increase to 16.4 feet for a 1% AEP coastal storm including SLR projected in 2070. Adapting to 1% storm conditions is complex due to the significant water inundation depth. Figures illustrating depths relative to the 2% (50-year), 10% (10-year), 25% (4-year), 50% (2-year), and 100% (annual) storm events for the present day, 2050, and 2070 coastal storm and SLR planning horizons to establish more realistic adaptation goals and objectives for the roadway are provided in *Attachment C*. The 10% (10-year) storm event with no SLR, and the 10% storm with SLR for 2050 and 2070 are shown below in Figure 14 to 16.

TODAY: Nuisance Storms

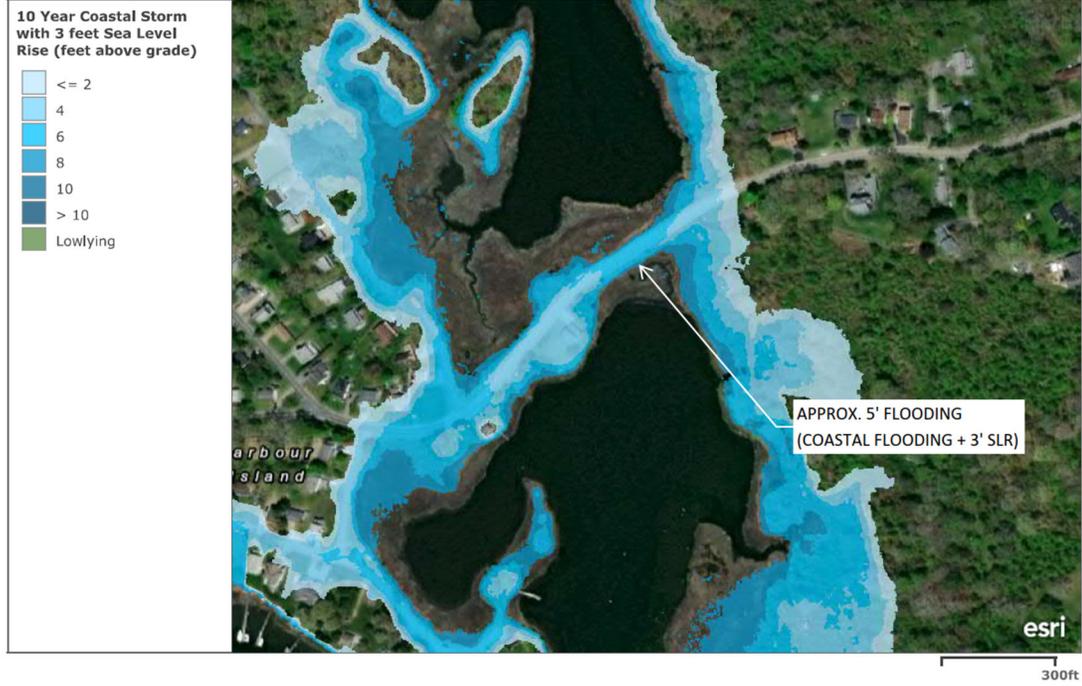


Coastal Storm Flooding Depth and Extent for Return Periods:1, 3, 5, and 10 year with no Sea Level Rise(based on the United States Army Corps of Engineers North Atlantic Coast Compr ...

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Figure 14: Depth of inundation during 10% (10 year) storm event, no SLR

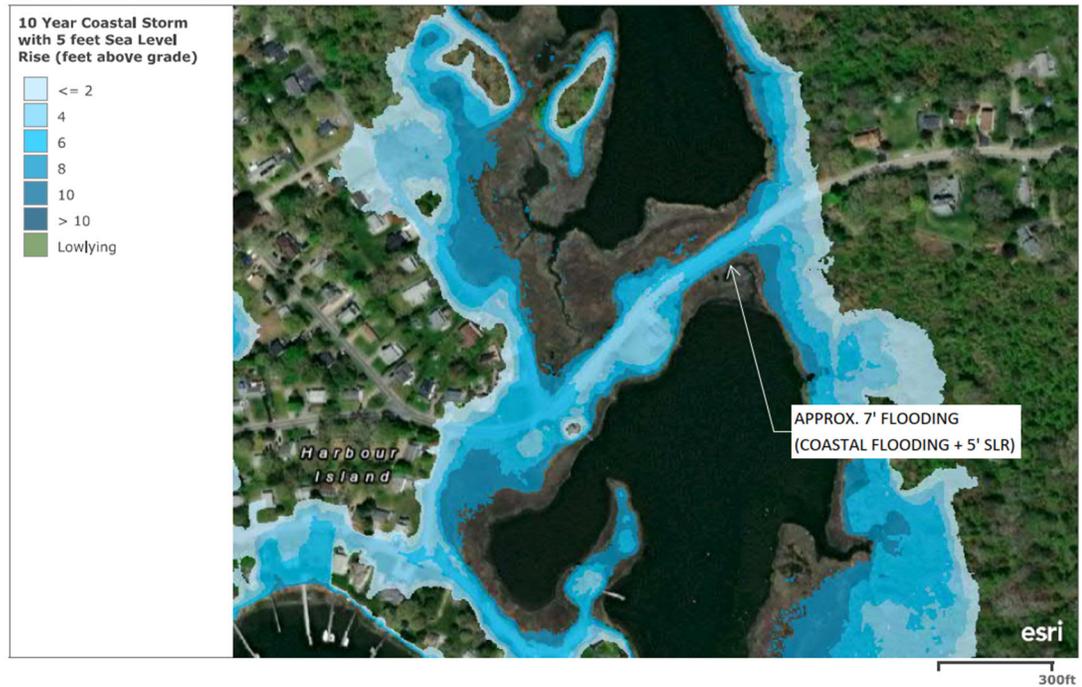
3 FEET SLR: Nuisance Storms.



Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, IPC

Figure 15: Depth of inundation during 10% storm (10 year) event plus 3' SLR (2050)

5 FEET SLR: Nuisance Storms.



Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, IPC

Figure 16: Depth of inundation during 10% storm (10 year) event plus 5' SLR (2070)



3.5 Vulnerability Assessment Summary

The SLR, Coastal flood annual exceedance probability and depth of inundation figures illustrate the expected changes in flood depths at Foddering Farm Road, identifies site-specific tipping points, appropriate timelines for adaptation, and specific sections of roadway to enhance. Based on the information presented above:

- **Sea Level Rise Scenarios** – Foddering Farm Road remains resilient to sunny-day, SLR flooding through 2030, with a tipping point between 2030-2050, when flooding begins to occur daily.
- **Probability and Depth of Inundation** – Foddering Farm Road may experience nominal flooding during the present day annual coastal flood (100% probability storm). Under present day conditions, up to 1.3 feet of flooding is anticipated during the 20% probability coastal storm (5-year storm) and the road will be impassible by passenger vehicles. The depth of flooding increases when coastal flooding combined with SLR is considered for planning horizons through 2070.

It *is possible* to plan for and adapt to SLR flooding through 2070 with some ancillary benefits expected for the range of 10% to 5% storm events.

4 Alternatives Analysis

4.1 Causeway Alternatives

Planning for sea level rise (SLR) along Foddering Farm Road is possible, however, it will be an exceedingly difficult roadway to build out of high intensity coastal storm flooding. The benefits to planning for SLR are maintaining daily access into the future by avoiding nuisance flooding associated with daily tidal activity and reducing the vulnerability to higher frequency storm flooding.

As noted in the Vulnerability Assessment Section (Section 3) of this report, under present day conditions, Foddering Farm Road is already at risk of inundation during coastal storms that would make the road impassable.

In developing alternatives, we sought a broad range of possible roadway enhancements that would reduce the probability and depth of inundation through the planning horizons. This would improve long-term resilience of the roadway infrastructure, reduce the frequency of roadway closures, and improve access and safety for residents and emergency vehicles. The scope of this project is to review possible adaptations to elevate the lowest portions of the existing Foddering Farm Road and stabilize the side slopes to improve the resilience of the causeway.

When exploring the potential for raising Foddering Farm Road, three alternatives were considered for the length of the roadway between Harbour Island Road to the west and Ilex Road to the east. The first alternative is to raise the road from its low point elevation of approximately 4.0 feet to a minimum

elevation of 7.0 feet (+3 feet maximum grade change); the second is to raise the road to a minimum elevation of 9.0 feet (+5 feet maximum grade change), and the third alternative is to raise the road to a minimum elevation of 11.0 feet (+7 feet maximum grade change). In addition to these alternatives, other measures can be simultaneously taken to enhance resiliency, such as improving the current vegetation treatment along the side slopes of the roadway and implementing an early warning system to communicate coastal storm flood risk events to residents.

A conceptual layout of the work proposed for each alternative is provided as *Attachment A*. Additionally, order of magnitude costs was developed for each of these three alternatives and are further detailed in the following section, as well as within *Attachment D*.

The wetlands at the site have not been delineated and references to wetland boundaries are conceptual in nature. Wetland delineation should be completed in a future phase to advance preliminary design. One design objective should be to minimize fill in the wetlands, if possible. Filling wetlands results in a loss of the natural resource.

4.1.1 Alternative 1 – Raise Roadway to El. 7.0 ft.

The first alternative includes raising Foddering Farm Road to by a maximum of 3 feet to a minimum elevation of 7.0 feet, based on the North American Vertical Datum of 1988 (NAVD88). An elevation of 7.0 feet was selected based on the projected maximum daily high tide, or mean higher high water (MHHW) level, for 2070. As shown in Figure 17, raising the roadway by three feet reduces the potential for the roadway to be inundated and potentially become impassable by the MHHW level associated with SLR through 2070. Figure 20 in Section 4.1.4 depicts the relative flood levels for various coastal storms and each road level enhancement. Under Alternative 1, the roadway will be above the present day 10% storm flood level and is expected to be inundated by less than one foot of water under the 5% (20-year) storm².

Raising the roadway to this elevation impacts approximately 1,160 linear feet of Foddering Farm Road between Harbour Island Road and Ilex Road.

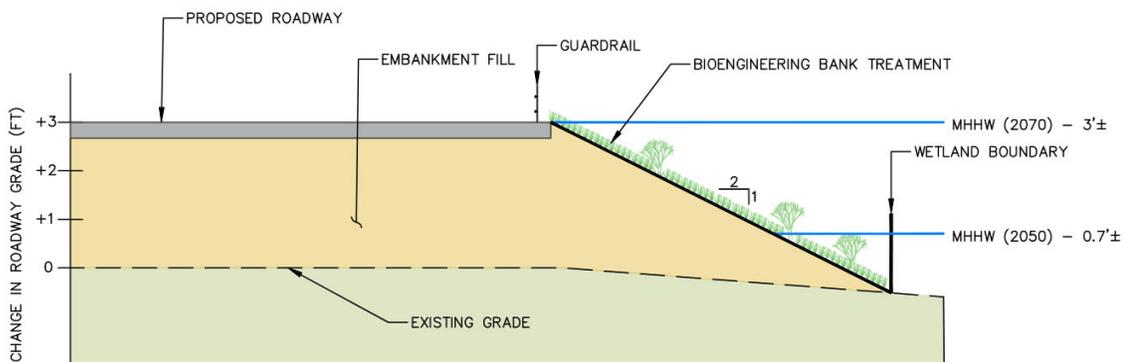


Figure 17: Representative cross section of Alternative 1: Raising the Road to Elevation 7.0

² Based on interpolation between the 10% and 2% storm from Figure 20.

Raising the roadway to an elevation 7.0 feet would require sections of the road to be raised a maximum of three feet at the assumed low point of the roadway, based on the LiDAR data collected for this area. Raising the road involves grading the roadway embankments on a slope to tie into existing grades. A 2H:1V slope would be implemented to minimize impacts to the surrounding salt marsh. The limits of this reconstruction as well as a conceptual layout of the work associated with this alternative are depicted in *Attachment A*. One possible bank restoration treatment involves using an erosion control blanket and native salt tolerant seed mix.

4.1.2 Alternative 2 – Raise Roadway to El. 9.0 ft.

The second alternative that has been investigated includes raising portions of the roadway to an elevation of 9.0 feet, based on NAVD88, as shown in Figure 18. This elevation was selected based on the projected maximum MHHW level through the year 2070. With this elevation being two feet higher than the MHHW, this alternative provides a greater reduction for the potential for the roadway to be inundated by sunny day flooding projections through 2070 with more coastal flood risk reduction compared to Alternative 1. Under this alternative, Figure 20 indicates that the roadway will be equal to the 10% coastal storm with 3-feet of SLR associated with the 2050 planning horizon.

The lowest portion of Foddering Farm Road would need to be raised a maximum of five feet. To safely transition the raised portion of the road to the adjacent side streets, a level landing space would be provided to approach vehicles on side streets and the standard maximum grade to tie in the new and existing portions of the roadway would six percent. This grade would need to extend approximately 62 feet from the level landing to meet the existing grade in this area. A standard level landing, according to the American Association of State Highway and Transportation Officials (AASHTO), is approximately 30 feet, or enough space for one passenger vehicles to approach the intersection. Therefore, to raise Foddering Farm Road to an elevation of 9.0 feet, Brush Hill Road would require approximately 100 feet of additional reconstruction to tie into the new elevation.

Given the site constraints of residential driveways, landscape, hardscape, etc. this grade could be steepened to as much as 8-12 percent, which would reduce the limits of construction to approximately 40-65 feet. As part of the data collection efforts for this project, it was noted that a few driveways are shorter than this required distance and/or are not paved structures in their existing condition. These driveways would need to be rerouted and coordination with the property owner is recommended to determine the best suitable option for both the Town and the owner.

Raising the road involves grading the roadway embankment on a slope to tie into the existing vegetated areas. Like Alternative 1, a 2H:1V slope would be implemented to minimize impacts to the surrounding salt marsh. This slope would be stabilized using an erosion control blanket and native salt tolerant seed mix, as well as a boulder toe slope. The fortified toe of slope would provide additional reinforcement given the height of the embankment and be placed outside of the wetland boundary to the maximum extent practicable. The limits of this reconstruction as well as a conceptual layout of the work associated with this alternative are depicted in *Attachment A*.

For this alternative, approximately 1,240 feet of Foddering Farm Road would need to be raised. The limits of this reconstruction, as well as a conceptual layout of the work associated with this alternative

are depicted in *Attachment A*. Portions of the road that are already above elevation 9.0 feet will not be impacted.

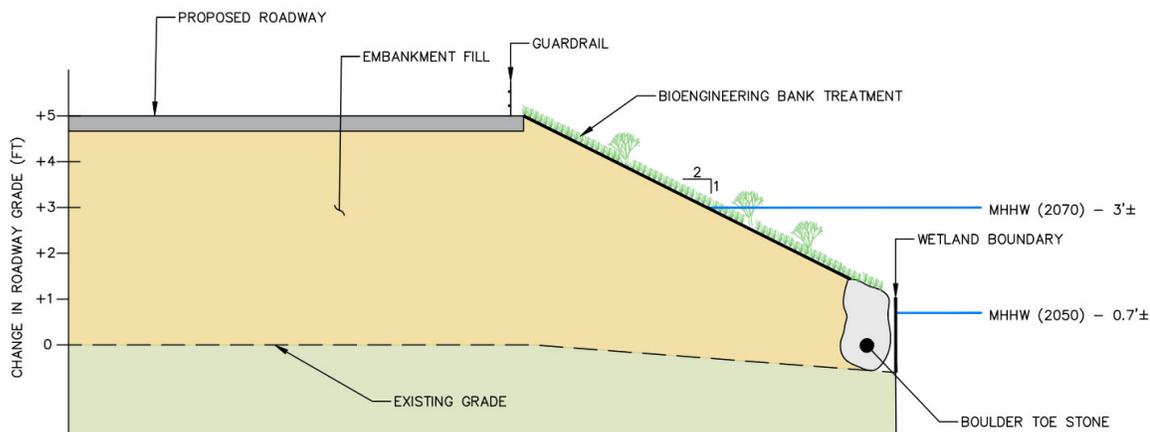


Figure 18: Representative cross section of Alternative 2: Raising the Road to Elevation 9.0

4.1.3 Alternative 3 – Raise Roadway to El. 11.0 ft.

The final alternative that has been investigated includes raising portions of the roadway to an elevation of 11.0 feet, based on NAVD88, as shown in Figure 19. This elevation was selected based on the existing roadway grading at the edges of the site, this alternative is considered the maximum that the road can be raised to tie into the natural, higher grade outside the limits of the causeway.

Under this alternative, Figure 20 indicates that the roadway will be above the present day 2.5% (40-year) storm flood level³ and is equal to the 10% coastal storm with 5-feet of SLR (approximately associated with the 2070 planning horizon). The roadway under Alternative 3 would be above the projected SLR flood levels through 2070. This alternative provides the highest reduction in coastal flood risk.

³ Based on interpolation between the 10% and 2% storm from Figure 20.

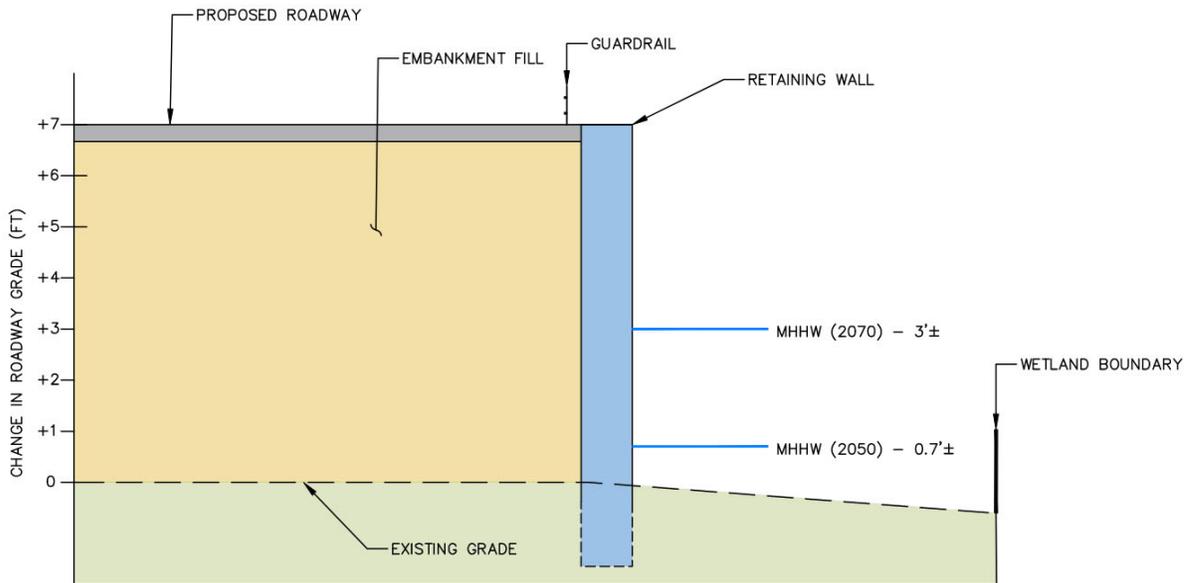


Figure 19: Representative cross section of Alternative 3: Raising the Road to Elevation 11.0

For this alternative, the lowest portion of Foddering Farm Road would need to be raised a maximum of seven feet. Like Alternative 2, to safely transition the raised portion of the road to the adjacent side streets, a level landing space would be provided to approach vehicles on side streets and the standard maximum grade to tie in the new and existing portions of the roadway would six percent. Therefore, to raise Foddering Farm Road to an elevation of 11.0 feet, Brush Hill Road would require approximately 140 feet of additional reconstruction to tie into the new elevation.

Raising the road a maximum of seven feet would have significant impacts to the existing vegetated areas that surround the area if a similar sloped embankment were to be implemented as proposed in Alternatives 1 and 2. Therefore, a retaining wall structure would be proposed for some segments of the road being raised in order to minimize the impact to the surrounding marsh area as well as the residences. While a retaining wall is anticipated to be a feature of Alternative 3, the increase in grade is not uniform across the impacted road section, therefore a combination of stabilization practices is anticipated under this alternative. During the preliminary design, the road stabilization would be designed to only provide a retaining wall where necessary, to minimize the height of the wall, and provide a sloped embankment transition to surrounding grades, if possible. Depending on the location of site constraints relative to the wall, the wall height can be further reduced in a future design phase by providing either a sloped embankment at the top or bottom of the wall, or a raised marsh platform at the bottom of the wall, if adjacent to the salt marsh.

Given the site constraints of residential driveways, landscape, hardscape, etc. this grade could be steepened to as much as 8-12 percent, which would reduce the limits of construction to approximately 60-90 feet. Driveways to be considered for additional coordination efforts with owners for Alternative 2 would require a similar level of coordination here. Raising the road by this amount could also warrant additional retaining walls on private property to balance the integrity of the side slopes of the roadway

with the grading impacts to private property, especially for those with homes within 100 feet of the proposed roadway.

The areas of Foddering Farm Road to be raised along residential properties, excluding the driveway areas, will be sloped more gradually, and restored to the maximum extent practicable. Instead of native, salt tolerant vegetation, these areas will be restored using loam and a residential seed mix along with existing landscaping.

4.1.4 Impacts Summary

The impacts to the built environment associated with each alternative to raise Foddering Farm Road are summarized below.

Alternative 1 – Raise Roadway to El. 7.0 ft

- The tie into Brush Hill Road would be approximately 50 feet long, areas of Brush Hill Road would remain susceptible to flooding
- Minor impacts at Champlin Cove Road
- Impacted driveways (addresses on Foddering Farm Road):
 - Minor impacts to driveways at 170 and 229 Foddering Farm Road
 - Regrading will be required within the existing driveway footprints to meet the proposed roadway grade at 198, 214, and 221 Foddering Farm Road

Alternative 2 – Raise Roadway to El. 9.0 ft

- Tie into Brush Hill Road and Champlin Cove Road. The tie into Brush Hill Road would be approximately 100 feet long.
- Impacted driveways:
 - Minor impacts to the driveway at 235 Foddering Farm Road
 - Regrading will be required within the existing driveway footprints to meet the proposed roadway grade at 170, 214, 221, and 229 Foddering Farm Road
 - The driveway will be required to be rerouted to meet the proposed road grade at 198 Foddering Farm Road

Alternative 3 – Raise Roadway to El. 11.0 ft

- Tie into Brush Hill Road and Champlin Cove Road at 6% grade. The tie into Brush Hill Road would be approximately 140 feet long.
- Retaining wall support likely required in some segments of the raised road to avoid existing structures or wetlands.
- Impacted driveways:
 - Regrading will be required within the existing driveway footprints to meet the proposed roadway grade at 170, 221, and 235 Foddering Farm Road
 - The driveway will be required to be rerouted to meet the proposed road grade at 214 Foddering Farm Road (currently grassed, no formal parking area)
 - The driveway at 229 Foddering Farm Road will be significantly impacted/steeped within existing footprint (10% grade)
- 198 Foddering Farm Road will be significantly impacted under this alternative. There are three sub-options for managing the impacts associated with raising the road under this alternative:
 - **Sub-option 1:** Provide a retaining wall to support Foddering Farm adjacent to the property and re-route the driveway.
 - **Sub-option 2:** Elevate the structure and provide a regraded driveway.
 - **Sub-option 3:** Purchase and demolish the structure.

4.2 Causeway Adaptations and Flood Mitigation Benefits

Figure 20 was developed utilizing the depths of inundation for various coastal storms to illustrate the probability that coastal storms would flood Foddering Farm Road. Various storm scenarios for storms with not SLR, and with SLR through 2070 and corresponding flood levels are depicted on this figure to compare the risk for coastal storm-induced flooding at Foddering Farm Road and assess the relative flood mitigation benefits of each causeway raising alternative.

The horizontal purple, green, and blue lines represent the raise in grade above the low point on the existing road (approximately El. 4) for each alternative described above.

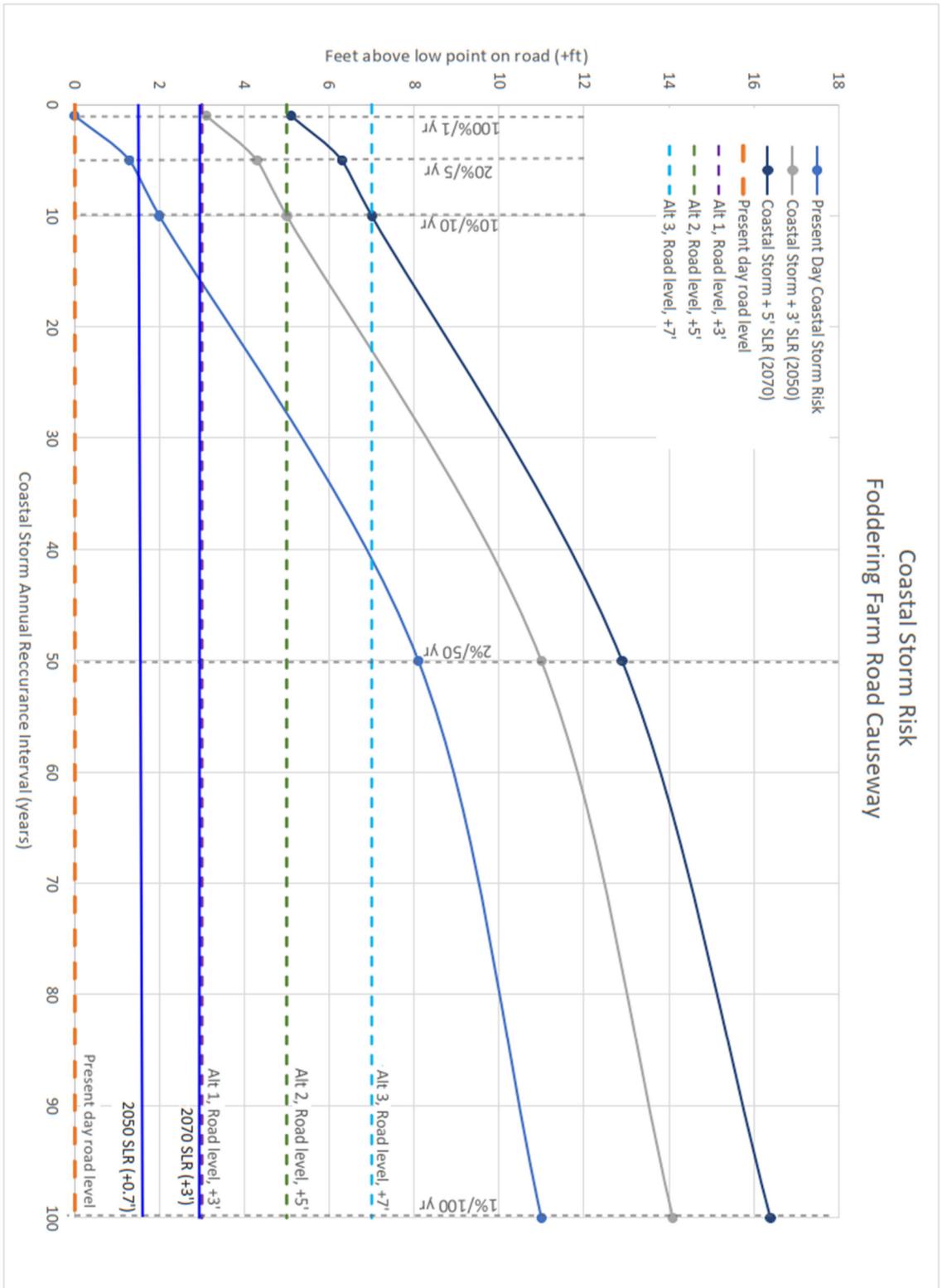


Figure 20: Coastal Storm Flooding and Projected SLR at Foddering Farm Road for present day, 2050, and 2070 planning horizons.

4.3 Additional Considerations for Future Implementation

4.3.1 Culverting Foddering Farm Road

The Town, HHA, and SPC have expressed interest in providing a new culvert at the Foddering Farm Causeway. Potential benefits of providing a culvert may include enhanced water quality and potential ancillary flood risk reduction for nuisance coastal storm events. We recommend that the following steps be implemented to better understand the potential risks and benefits of providing a culvert.

- Quantitatively assess how existing and future hydrologic conditions will impact marsh quality. This study should be developed by a biologist with direct experience addressing these questions. The previous study found that there was no lag between the tidal cycles on either side of the causeway and therefore it's not apparent that the current tidal range is impairing the marsh, however the existing study did not account for potential benefits due to improved circulation.
- Review findings with potential project partners and funders such as the CRMC or National Fish and Wildlife Federation and National Oceanic and Atmospheric Administration (NOAA) to confirm interest in funding a project to achieve expected restoration objectives.
- Retain a consultant that specializes in coastal modeling to assess culvert size alternatives and their impacts on marsh hydrology. This would include addressing the questions below:
 - What is the flood reduction benefit of providing a new culvert?
 - What culvert size is required to meet the project objectives? Models can be established to assess changes in both hydrology and other parameters such as salinity that will impact marsh health.
 - Will increased flow cause erosion problems?
 - How will future sea level rise impact flooding in the marsh?

A new culvert at Foddering Farm Road would be compatible with any of the road raising alternatives considered in this report. Mid-term and long-term adaptations that may be implemented during the service life of the culvert should be considered in the design of the culvert. The culvert foundations and end walls should be configured to accommodate potential, future adaptations.

4.3.2 Slope Treatments

The slope treatments will be determined in a future phase of work. The potential treatments may consist of green, living-shorelines approaches, hybrid bio-engineered alternatives, and grey-hardened solutions to improve the resilience of the roadway side slopes.

Given the range of potential road raising levels under consideration and types of abutting site constraints (build environment versus salt marsh), it is likely that a combination of alternatives (rather than a single, preferred alternative) will be necessary to help reduce risk and improve resilience along the raised causeway embankments.

Segments of grey hardened solutions are more likely to be required for alternatives that involved raising the road to a higher level. Sections of retaining wall will very likely be required for Alternative 3 and may be required for Alternative 2.

Reconstructed roadway embankments would be seeded with a native coastal salt tolerant grass seed mix and blanketed with 100% biodegradable erosion control matting and overlain with weight coir matting, planted with a combination of native woody and perennial coastal salt tolerant species.

Hybrid solutions may involve toe protection at the slope or the use of natural or structural materials to reinforce a soil embankment slope. Some examples may include utilizing a natural boulder toe stone or a short structural sheet pile sill at the toe of the slope to support the slope and avoid wetland impacts. Another approach may involve construction of a salt marsh platform at the base of the slope. The lift would be backfilled with engineered, salt marsh compatible soil and planted with salt marsh vegetation. The salt marsh lift approach would have a larger footprint and therefore a greater impact on the adjacent coastal resource areas than the other alternatives. However, it would provide a higher marsh platform and ideally, would help to facilitate salt marsh migration.



Figure 21: Toe stone at an approximately 2H:1V slope with vegetated erosion control matting



Figure 22: Concrete capped sheetpile sill wall and coir log at an embankment slope with vegetated erosion control matting

Structural retaining walls (“grey” solutions) are anticipated to support the raised roadway when side slopes are infeasible due to adjacent site constraints. Retaining walls are likely required to support sections of the roadway in Alternative 3. Walls may be required to support isolated sections of the roadway if a sloped embankment is infeasible due to conflicts with adjacent structures and natural resource areas.

4.3.3 Water Quality

Surface water quality from samples obtained in Point Judith Pond were reviewed as a cursory assessment on potential benefits of a new culvert under the Foddering Farm Road causeway to connect Long Cove and Champlin’s Cove.

Fuss & O’Neill reviewed data from samples collected by the SPC which were analyzed by the University of Rhode Island. The sampling data included several monitoring events in 2020. For this review, the data analysis is limited to dissolved oxygen (DO), enterococci, and fecal coliform. The review included surface water quality data at Long Cove, Champlin’s Cove, and other monitoring points within the Point Judith Pond. The data was compared to determine whether surface water quality varied between Long and Champlin’s Coves. Data was available for the following monitoring locations:

- Point Judith Pond – East Pond
- Point Judith Pond – Central
- Point Judith Pond – Gardiner Island
- Point Judith Pond – Champlin's Cove
- Point Judith Pond – Ram Point
- Point Judith Pond – Long Cove
- Saugatucket River – Caleb's Dock
- Point Judith Pond – Billington Cove

The analytical data was compared to applicable Rhode Island Department of Environmental Management (RIDEM) Water Quality Standards. These standards are:

- Fecal coliform standard for shell fishing criteria is not to exceed a geometric mean value of 14 most probable number (MPN) per 100 millimeters (ml) and the primary contact recreational / swimming criteria is not to exceed a geometric mean of 50 MPN per 100 ml. Shellfishing criteria also requires that not more than either 10% of the estimated 90th percentile of the samples shall exceed an MPN value of 49 per 100 ml for a three-tube decimal dilution or 31 cfu per 100 ml for MF (mTEC). Primary contact recreational criteria also requires that not more than 10% of the total samples taken shall exceed 400 MPN/100 ml.
- Enterococci primary contact recreational / swimming criteria is a geometric mean density of 35 colonies per 100 ml and the single sample maximum is 104 colonies per 100 ml.
- DO standard is that for surface waters above a seasonal pycnocline is to not be less an instantaneous value 4.8 milligrams per liter (mg/l) more than once every three years, except as naturally occurs.

The major observations based on this data include:

- DO was detected at concentrations below the RIDEM standard of 4.8 mg/l at four locations during July and August of 2020. Long Cove and Champlin's Cove each had DO levels at multiple sampling locations below 4.8 mg/l between July and August in 2020.
- Three locations, Ram Point (375 MPN/100), Saugatucket River – Caleb's Dock (52 MPN/100), and Long Cove (139 MPN/100) had fecal coliform concentrations (geometric mean of all samples collected) at concentrations greater than both the shell fishing and primary contact standards. No other locations exceeded either applicable standard.
- Enterococci concentrations at the Ram Point and Saugatucket River – Caleb's Dock locations had the highest individual and geometric mean concentrations and exceeded the RIDEM standards. Long Cove exceeded the individual and geometric mean RIDEM standards, but were well below the Saugatucket River location concentrations

Based on the 2020 sampling results, water quality in Long Cove generally has higher fecal coliform and Enterococci concentrations and lower DO concentrations than most of the other sampling stations in the pond. Ram Point and Saugatucket River – Caleb's Dock had the highest concentrations of fecal coliform and enterococci. The Saugatucket River is a significant source of water quality impacts being observed in the pond, but it is unclear how other sources may be influencing water quality in the Pond and Long Cove.

Given the water quality impacts that are being observed in Long Cove, additional investigation would be required to better define the sources of these impacts and thereby define potential solutions. These solutions could include a culvert under Foddering Farm Road to improve circulation of water in the cove. This investigation should include modeling that could assess how a culvert could improve water quality in that cove.

4.3.4 Early Warning System

In addition to the alternatives noted herein, an early warning communication system should be considered to provide an opportunity for residents to be notified in advance of coastal storms that are forecast to inundate the egress from Harbour Island. This type of system may include the Town's existing automated phone and cable television communication channels. The early warning system (EWS) should be developed with local and state emergency response officials in accordance with FEMA guidance. An action plan should be developed to define what level of coastal flood will trigger the early warning system, identify decision makers, emergency response personnel, and notification protocols. Incorporate a local tide gauge in this recommendation to monitor SLR and storm water levels, use algorithms to develop local tide predictions, and provide situational/operational awareness and link to warning system. The EWS and action plan should be updated and exercised periodically. There is no design or permitting associated with the development of an early warning system and action plan.

4.4 Order-of-Magnitude Opinion of Construction Costs

Order-of-magnitude opinion of construction costs were prepared for the alternatives discussed herein. Further breakdown of the costs is included in *Attachment D*. These costs were developed based on a combination of recent project experience, current Rhode Island Department of Transportation Weighted-Average Unit Prices, and RSMMeans construction cost data. The opinion of cost includes a 25 percent contingency and is presented as a range of minus 15 to plus 30 percent to reflect the variability of the competitive bidding environment when construction occurs. The costs reflect 2021 pricing, state prevailing wage labor rates, and do not account for inflation. The opinion of cost includes assumed costs for detailed design, permitting, and procurement.

The road raising costs do include the work required to tie into adjacent driveways and side streets. The costs do not include the costs for land access agreements, easements, property acquisitions, elevating residential structures, relocating buried or overhead utilities, or retaining wall construction under Alternative 3 as more design information is required.

Costs are based on a single construction phase for the culvert construction and a single phase for the road raising alternatives. The project may be implemented in more phases, but additional cost savings may be realized if the culvert and road raising work is completed concurrently.

Table 4: Order of Magnitude Opinion of Construction Cost Range – Road Raising Alternatives

Road Raising Alternative	Cost Range
Alt 1: Raise Road to El. 7.0 feet	\$1,710,000 - \$2,600,000
Alt 2: Raise Road to El. 9.0 feet	\$2,350,000 - \$3,560,000
Alt 3: Raise Road to El. 11.0 feet	\$2,990,000 - \$4,540,000

Planning-level opinion of costs were developed for a conceptual open bottom culvert. This order of magnitude costs was developed based on the existing roadway geometry (width and embankment height) and did not involve a well-defined culvert configuration. The costs associated with constructing a new culvert may vary widely depending on the culvert sizing, the amount of sediment dredging required, and the culvert foundation configuration.

Table 3: Order of Magnitude Opinion of Construction Cost Range - Culvert Replacement

Culvert Concept	Cost Range
New open bottom culvert at Foddering Farm Road	\$610,000 - \$1,140,000

5 Considerations and Recommendations

5.1 Considerations

The following considerations apply to the next steps to implementing the adaptations:

- The Town should implement the road raising adaptation in conjunction with future capital improvements at the roadway, such as buried utility projects or pavement repair, if possible. The Town indicated that there were no near term planned capital improvements planned for Foddering Farm Road.
- The existing buried waterline and overhead wires will require relocation for any of the potential road raising alternatives.
- The Town indicated that a buried gas line may be installed in the future on Foddering Farm Road. There is no schedule or definitive plans established for the work. Consider incorporating an empty sleeve to receive a future gas line should the road be raised to limit the disturbance to the pavement should a gas line later be installed on Foddering Farm Road.
- There is a low point on Brush Hill Road approximately 500 feet north of the intersection of Brush Hill Road and Foddering Farm Road. Based on STORMTOOLS output, this segment of Brush Hill Road is likely to flood before Foddering Farm Road, however, alternate exit routes are possible to Foddering Farm Road via Harbour Island Road. Therefore, the consequences of flooding on Brush Hill Road are less severe than the consequences of flooding on Foddering

Farm Road. There maybe ancillary flood reduction benefits to low lying areas of Brush Hill Road should Foddering Farm Road be adapted for resiliency.

- During the roadway and culvert construction it will be critical to always maintain ingress/egress to Harbour Island. As Foddering Farm Road is a two-way road, one possible approach to maintain access involves multi-phased construction to raise the road one lane at a time. A phased approach is anticipated but should the culvert work be completed concurrent to the roadway raising project, it will be critical to coordinate the roadway construction and the culvert construction schedules to ensure that the respective phasing is compatible. The duration of the roadway raising project will be longer than the culvert construction. Traffic control, such as portable traffic signal lights, will be required 24 hours a day to manage vehicles approaching and departing the single open travel lane through the work area, particularly for the road raising project. If the culvert construction is performed as a separate phase, traffic maybe managed outside of peak travel hours utilizing a message board directing drivers to stop and alternate passage through the work area. The traffic control should be developed with input from the Department of Public Works.

Another potential alternative may involve shifting the proposed roadway alignment slightly to the north (to the landward side) of the existing causeway to maintain an open lane of traffic in a phased approach. Additional field data, such as wetland boundaries and topographic survey, will be required to confirm that this approach is feasible. However, the vegetated shoulder on the north side of the causeway appeared significantly wider than the south shoulder and a slight shift in the causeway may provide a benefit if a shifted alignment reduces natural resource impacts and facilitates traffic control during phased construction.

- The Town owns the property on the north side of the causeway and the property on the south side of the causeway are owned by several private property owners.
- Temporary water control, such as driven sheet piles, is anticipated to isolate the work area from the tidal range so that the culvert can be constructed under dry conditions.
- The recreational use of Foddering Farm Road will likely be disrupted to cyclists and pedestrians as they should not be traversing an active construction site due to safety concerns. Access to cyclists and pedestrians will not be restricted in the bypass travel lane, but that may present conflicts with vehicular traffic.
- Information regarding construction schedules with respect to disruptions to vehicular traffic, cyclists, and pedestrians and changes in traffic patterns should be communicated to the public.

5.2 Recommendations

We recommend that Alternatives 2 and 3 be selected for further study prior to selecting a preferred alternative. Begin with a scoping study to collect additional data to support future decision making. The study is recommended to include the following elements:

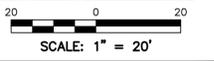
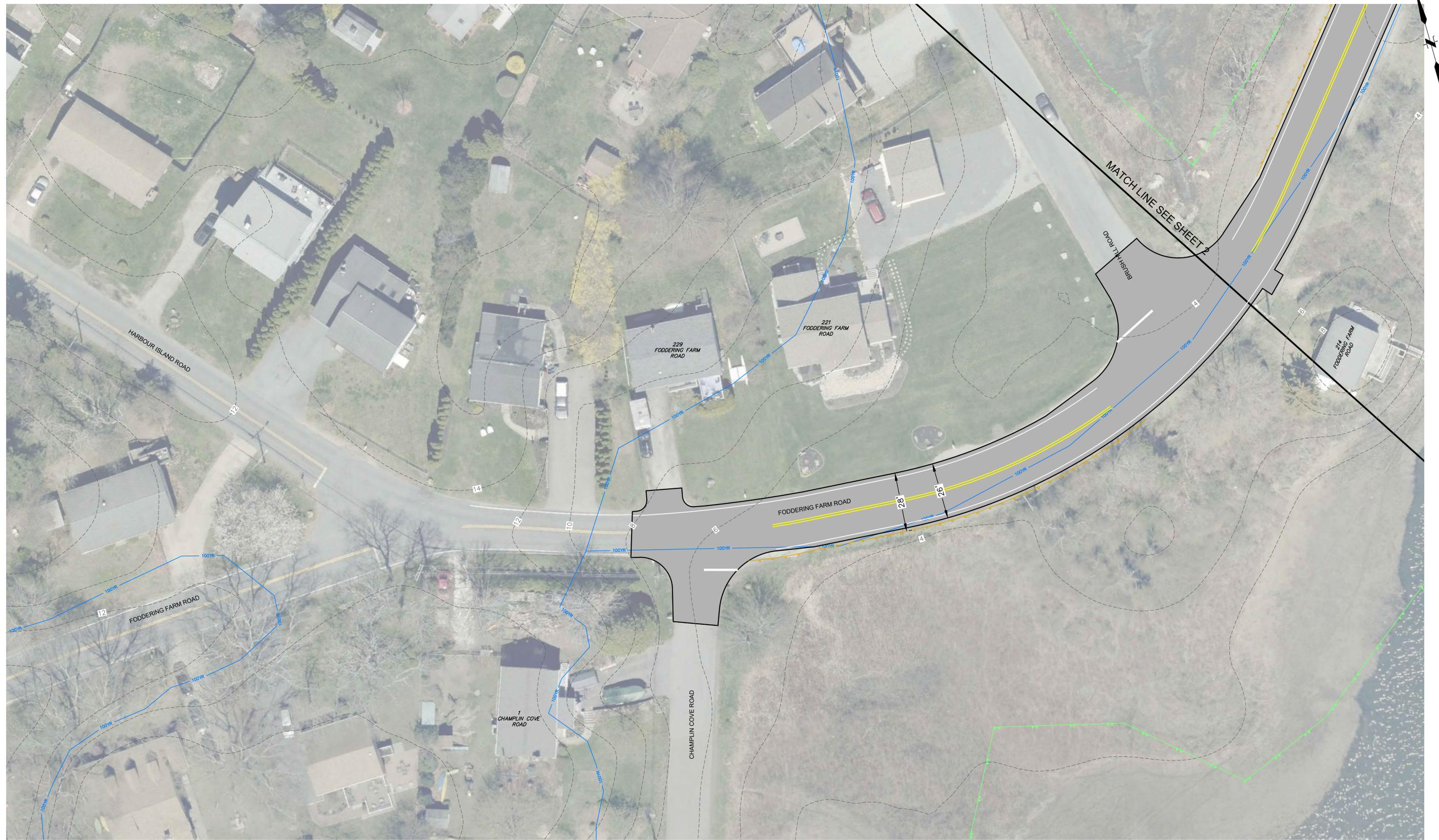
- Collect site specific field data, including wetland resource delineation, topographic, and boundary survey. The wetland delineation and topographic/boundary survey should extend past the footprint associated with Alternative 3 and include potentially impacted areas of Brush Hill Road, Champlin Cove Road. Supplemental topographic/boundary survey and wetland delineation may be required in a future design phase once schematic layout of the culvert is finalized.
- Complete a limited, due-diligence geotechnical subsurface investigation on the causeway. A secondary or supplemental geotechnical investigation may be required in a future design phase once the schematic layout of the culvert is finalized and the need for structural retaining walls is confirmed.
- Develop a hydrodynamic model to assess and size a culvert at Foddering Farm Road. The study should address questions raised in Section 4.3.1 of this report. The study should quantify flood reduction and water quality improvement benefits at Foddering Farm Road. Develop a schematic layout for the culvert. Consider including more detailed storm modelling as part of the study to confirm flood risk reduction for the two potential road raising scenarios.
- Update the schematic layout for Alternatives 2 and 3, identify bank treatments, hybrid slope support, and structural retaining wall locations, if necessary. Identify properties where easements will be required to perform the work.
- Update the planning level, order of magnitude costs for Alternatives 2 and 3 developed under the current evaluation. Include planning level costs to relocate utilities, obtain easements, or obtain property, if necessary.
- Prepare a Benefit Cost Analysis (BCA) for each of the two causeway alternatives and the potential culvert connection at Foddering Farm Road.
- Once a preferred alternative is identified, consult with local, state, and regulatory officials, including the CRMC, RIDEM, and US Army Corps of Engineers (USACE), to confirm the environmental compliance pathway to implement the preferred alternative, including possible culverting and bank treatments.

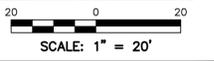
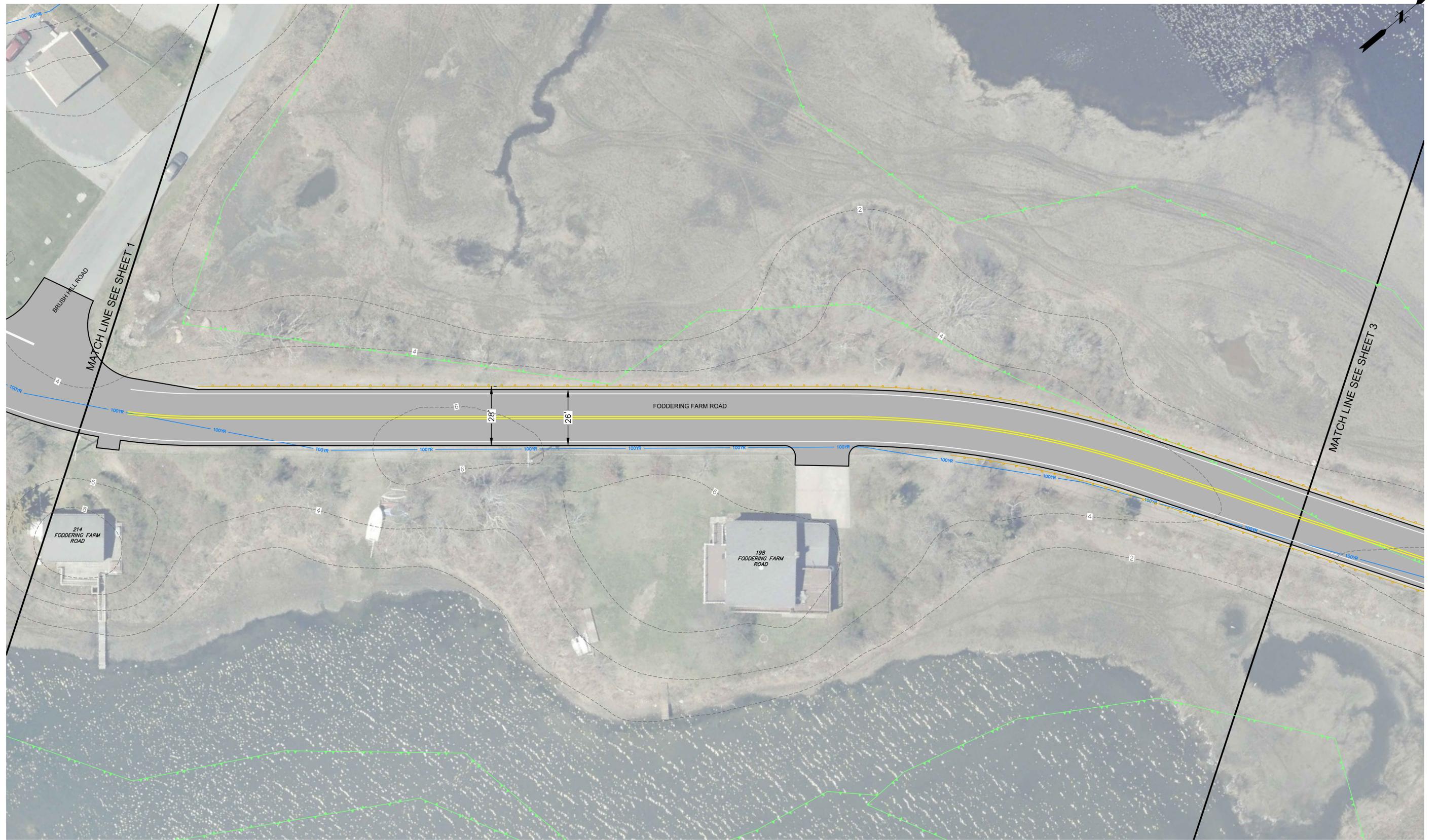
The next phase (Phase II) should focus on quantifying the mitigation benefits and costs of the two preferred alternatives and the culvert based on site specific data. The objective of the next phase is to identify one preferred road raising alternative, to confirm the benefits of a culvert connection at the

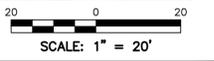
causeway, determine the culvert sizing, if applicable, and to obtain funding for the subsequent phase (Phase III). The subsequent phase (Phase III) is anticipated to involve detailed design and permitting of the selected project elements and may entail supplemental field data collection.

Attachment A

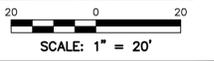
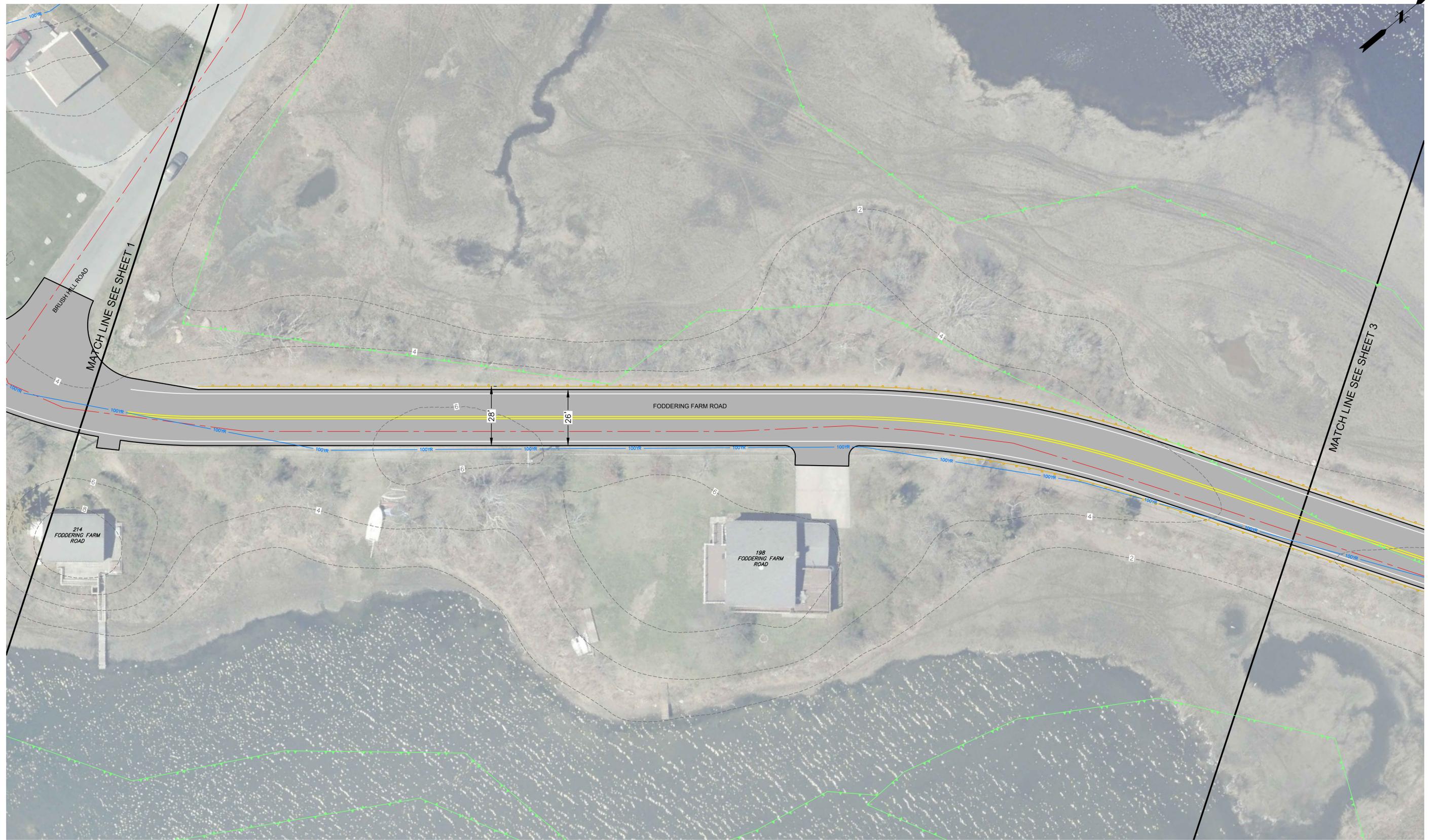
Conceptual Plans



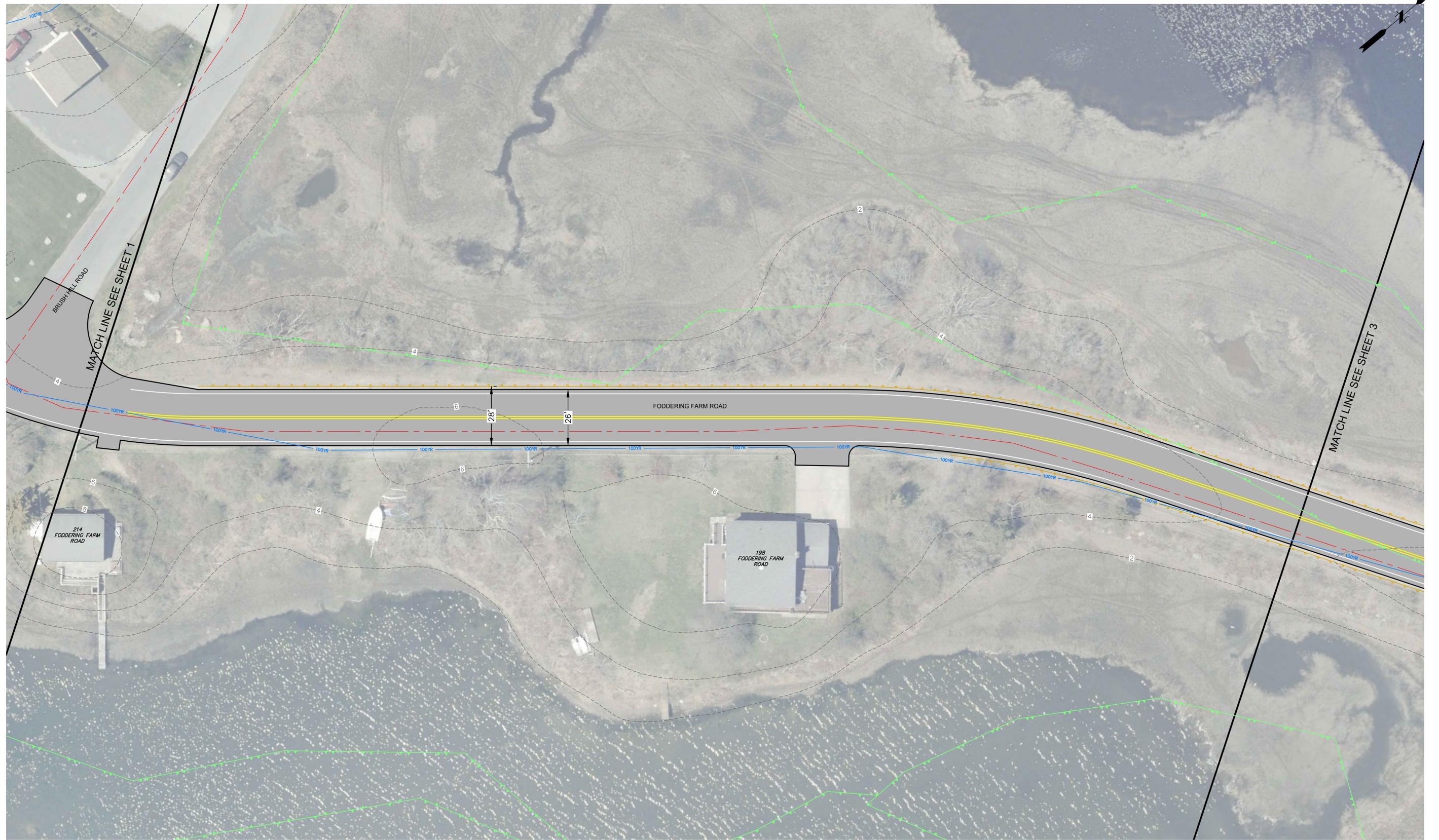












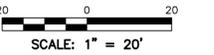
SCALE: 1" = 20'



MATCH LINE SEE SHEET 2

FODDERING FARM ROAD

170 FODDERING FARM ROAD



SCALE: 1" = 20'

Attachment B

STORMTOOLS Output



MEMORANDUM

DATE October 22, 2019

TO Dean Audet, Senior Vice President, Fuss and O’Neil, Inc.

FROM Zac Duval, Coastal Scientist, Woods Hole Group
 Direct Phone: (508) 495-6211
 dduval@woodsholegroup.com

Hydrologic Monitoring of Point Judith Pond and Long Cove for Culvert Feasibility Study, RI

Introduction

The Woods Hole Group was contracted to install three water level stations in Point Judith Pond and Long Cove by Fuss and O’Neil, Inc for a feasibility study of a proposed culvert under Foddering Farm Road to connect Long Cove and Point Judith Pond. The three monitoring stations were deployed at locations agreed upon by WHG and Fuss and O’Neil on August 8, 2019 (Table 1). Station PJ1 was deployed on a piling in Galilee, with the permission of Daniel Costa of the RI Department of Environmental Management (Figure 1). Stations PJ2 and PJ3 were deployed on pipe anchors south and north (respectively) of Foddering Farm Road, the southern boundary between Long Cove and Point Judith Pond, and target for the proposed culvert (Figure 2). Stations were recovered on September 11, 2019 for a total of 34 deployment days.

Table 1. Monitoring station locations and pressure sensor elevations.

Station	Latitude	Longitude	Elevation (NAVD88, ft)
PJ1	41.378985	71.511070	-4.7
PJ2	41.409602	71.491315	-1.9
PJ3	41.410549	71.491488	-1.6

At each station an In-Situ AquaTroll 200 was deployed to measure temperature, conductivity, and pressure. All instruments were surveyed upon installation and recovery with a Trimble R10 or R8 RTK GPS to provide a sensor elevation relative to the vertical datum NAVD88, which was used to render the pressure data to water level. Meteorological data was obtained from Newport, RI including atmospheric pressure, to convert the absolute pressure of the instruments to water pressure, and precipitation.



Figure 1. Monitoring stations in Point Judith Pond and Long Cove, RI.

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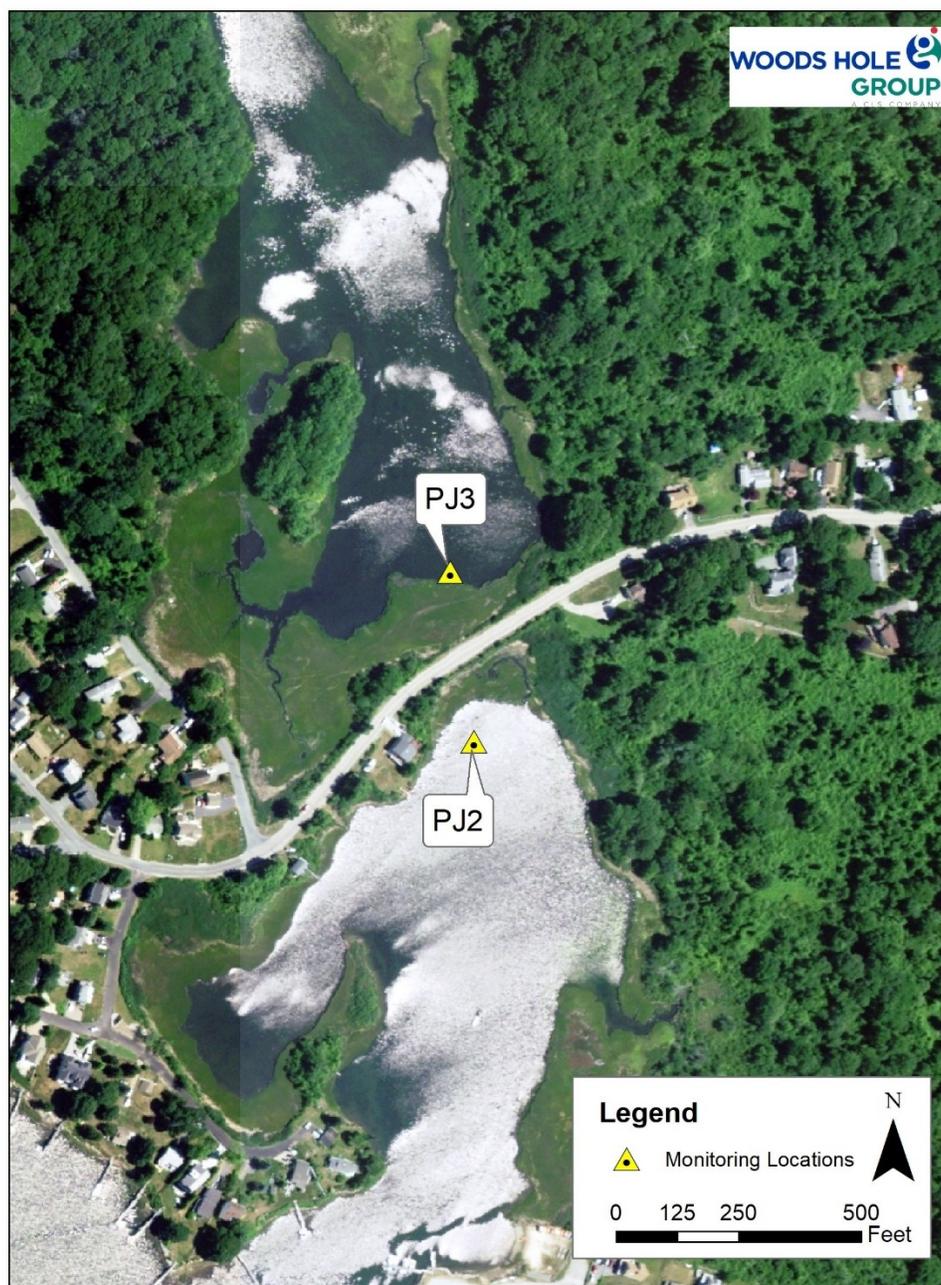


Figure 2. Monitoring stations JP2 and JP3.

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Results

Instruments were deployed from August 8th to September 11th, 2019 for a total of 34 deployment days. During the recovery, it was noted that stations PJ2 and PJ3 went dry during spring low tides, as can be seen in the data (Figure 3). Precipitation does not appear to have a significant impact on the system, though the largest two-day rain event was less than an inch of rain on August 28th and 29th. Therefore, precipitation may result in some additional influences on water levels, especially in the upstream estuary locations (PJ2 and PJ3). For all three stations, high and low tides occurred at approximately the same time, with minimal to no phase shift, and with roughly the same amplitude.

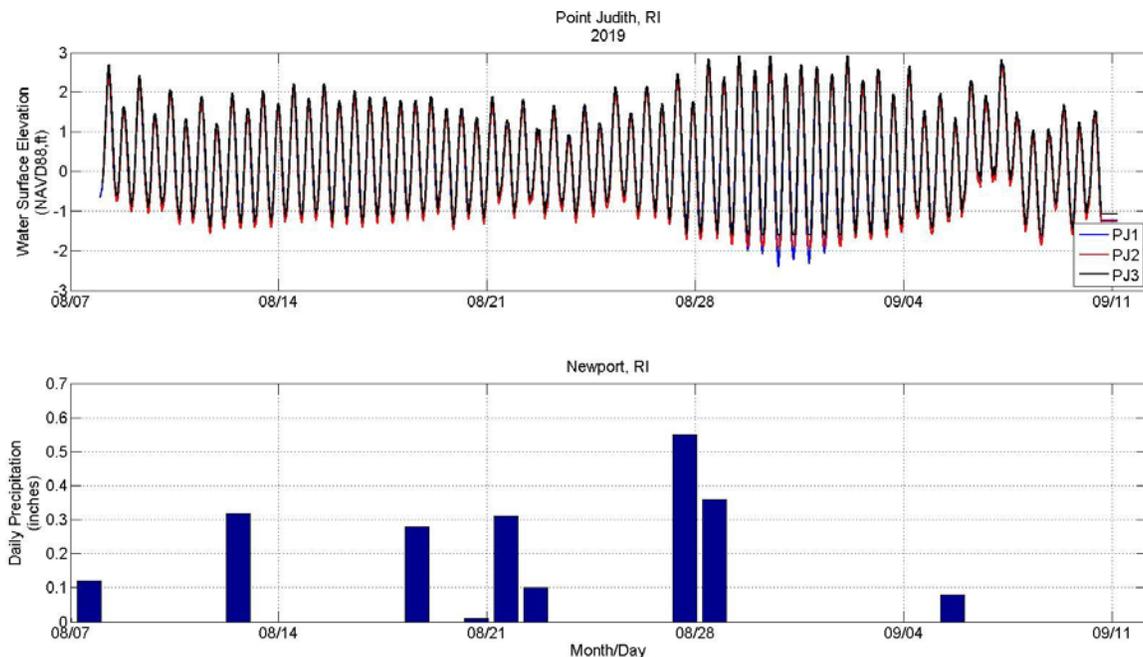


Figure 3. Time-series of water surface elevation (NAVD88, feet) at all stations (top) and daily precipitation (inches) at Newport, RI (bottom).

Figures 4 through 7 show neap and spring tide variability in tide range, from roughly 3 feet during neap tide to 5 feet during spring tide. As can be seen in the full deployment (Figure 3) and individual tides (Figures 4 and 5), the three stations experience essentially the same tidal response at all locations. As such, there is nothing in the data to suggest that the data missing from PJ2 and PJ3 were different from what was observed at PJ1 during the spring low tides. Figures 6 and 7 show the time series of water surface elevations for approximately a day on August 18, 2019. Again, there is minimal difference in the amplitude and phase of the tide. This indicates that there is minimal tidal attenuation that occurs between the entrance to Point Judith Pond and Long Cove. Therefore, evaluation of the water surface elevation alone indicates there would be minor tidally-driven exchange and flow between the local water bodies north and south of Foddering Farm Road.

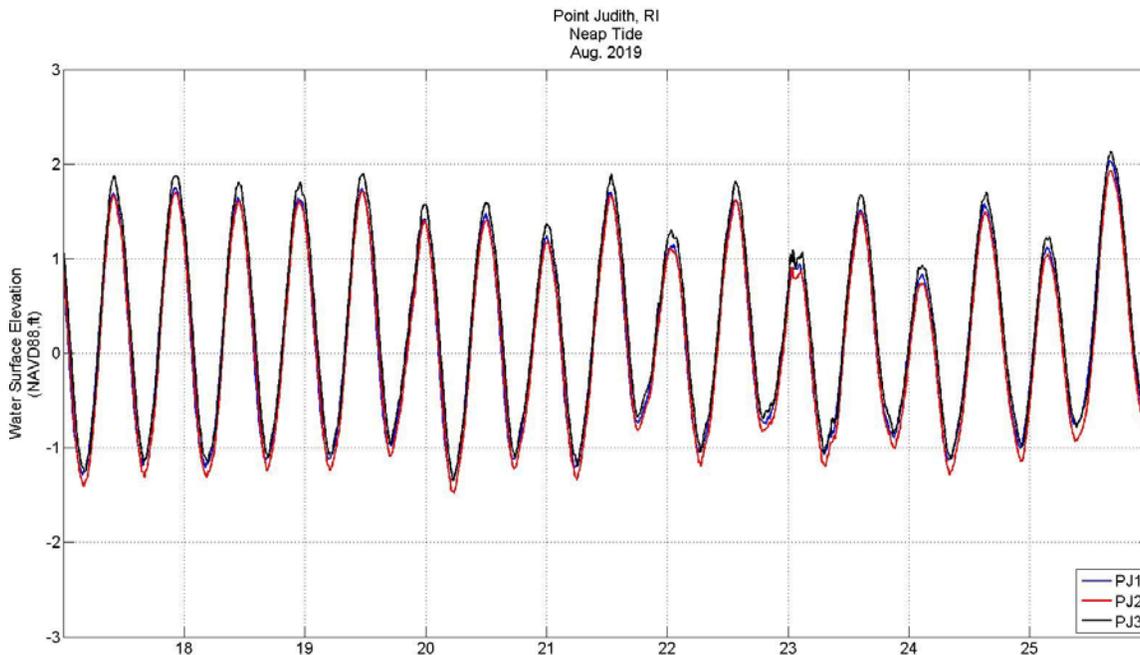


Figure 4. Time-series of water surface elevation (NAVD88, feet) of stations PJ1 (blue), PJ2 (red), and PJ3 (black) during a neap tide.

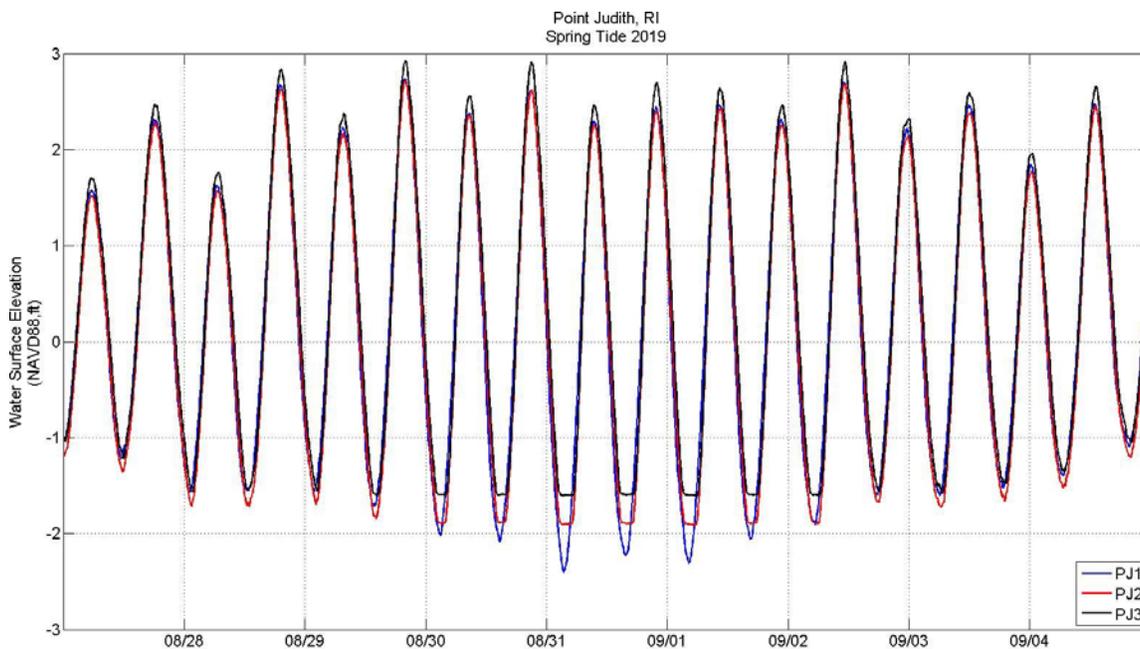


Figure 5. Time-series of water surface elevation (NAVD88, feet) of stations PJ1 (blue), PJ2 (red), and PJ3 (black) during a spring tide.

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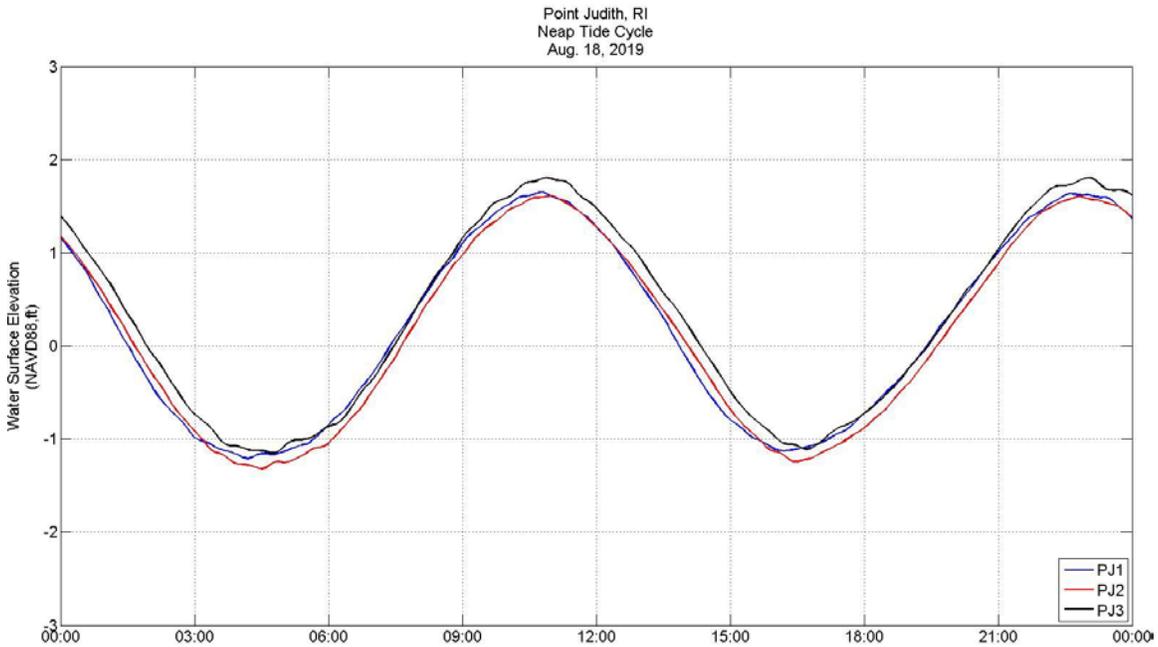


Figure 6. Time-series of water surface elevation (NAVD88, feet) of stations PJ1 (blue), PJ2 (red), and PJ3 (black) during a single neap tide cycle.

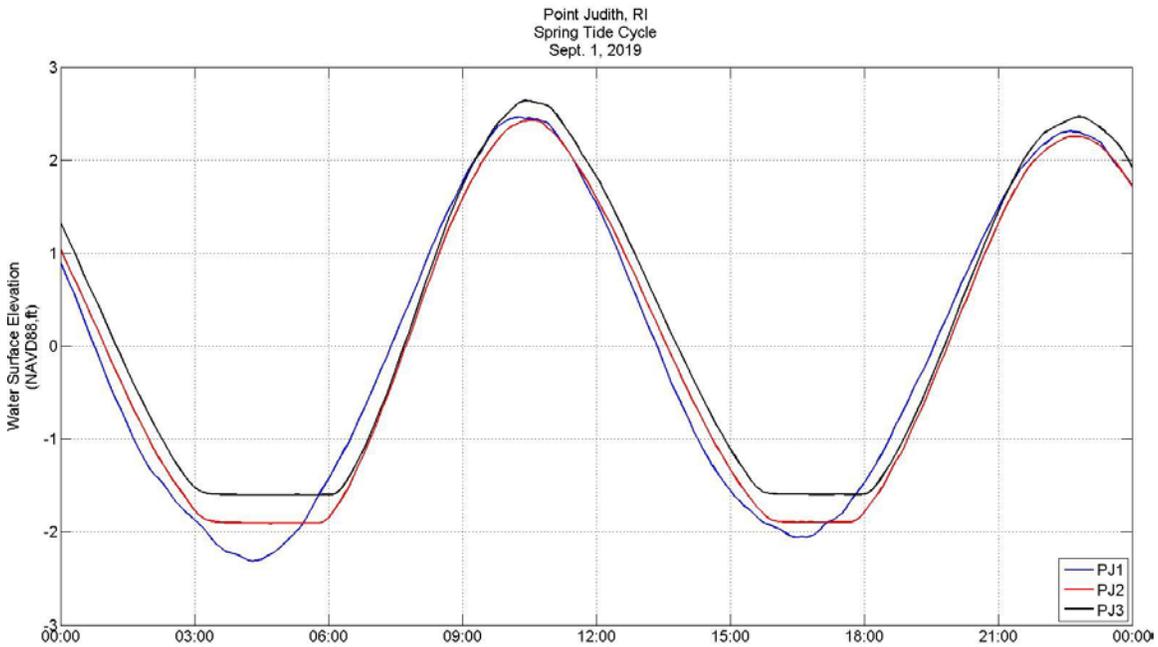


Figure 7. Time-series of water surface elevation (NAVD88, feet) of stations PJ1 (blue), PJ2 (red), and PJ3 (black) during a single spring tide cycle.

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Comparison to Previous Data

To confirm the lack of tidal attenuation that was observed in the data collected in the vicinity of Long Cove during August 2019, additional data collected within Point Judith Pond in 2010 was also evaluated. Woods Hole Group had previously collected water surface elevation in Point Judith Pond over the course of an entire year (2010). In that study, two water level stations were deployed in the system, one at the entrance to Point Judith Pond in Galilee, RI and the second deployed in Upper Pond, at the Ram Point Marina. Figure 8 shows the water surface elevation at the two stations during a portion of that deployment (fall of 2010). As with the 2019 data, there was insignificant tidal attenuation as the amplitude or phase was nearly the same at the entrance and Upper Cove. This confirms the lack of attenuation observed within Long Cove, and indicates that even in the upper reaches of the system the tidal variations are approximately the same. Therefore, the Point Judith Pond system has minimal tidal restrictions (natural or anthropogenic) that would limit tidal exchange and flushing, and a potential connection at Foddering Farm Road will not create a significant tidally forced improvement in water exchange.

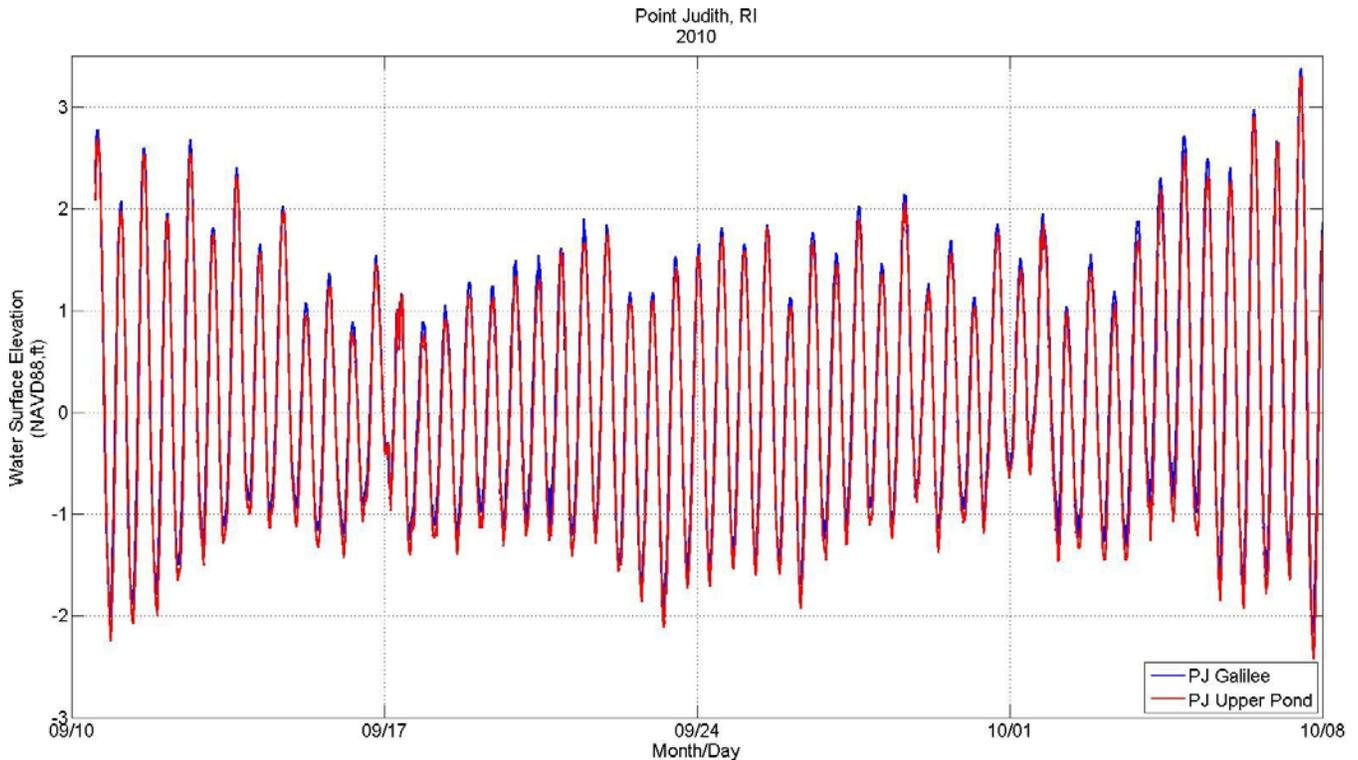


Figure 8. Time series of water surface elevation (NAVD88, feet) of stations PJ Galilee and PJ Upper Pond from 2010.

Temperature and Salinity

While the water surface elevation remains approximately (amplitude and phase) on either side of Foddering Farm Road, the potential variations in water temperature and specific conductivity (salinity) were also evaluated. Figure 9 shows the temperature observed over the deployment periods. While the temperature is slightly colder at the inlet to the Pond, the water temperature on either side of the causeway is similar. Therefore, there would be no temperature driven circulation differences that would be expected at this location.

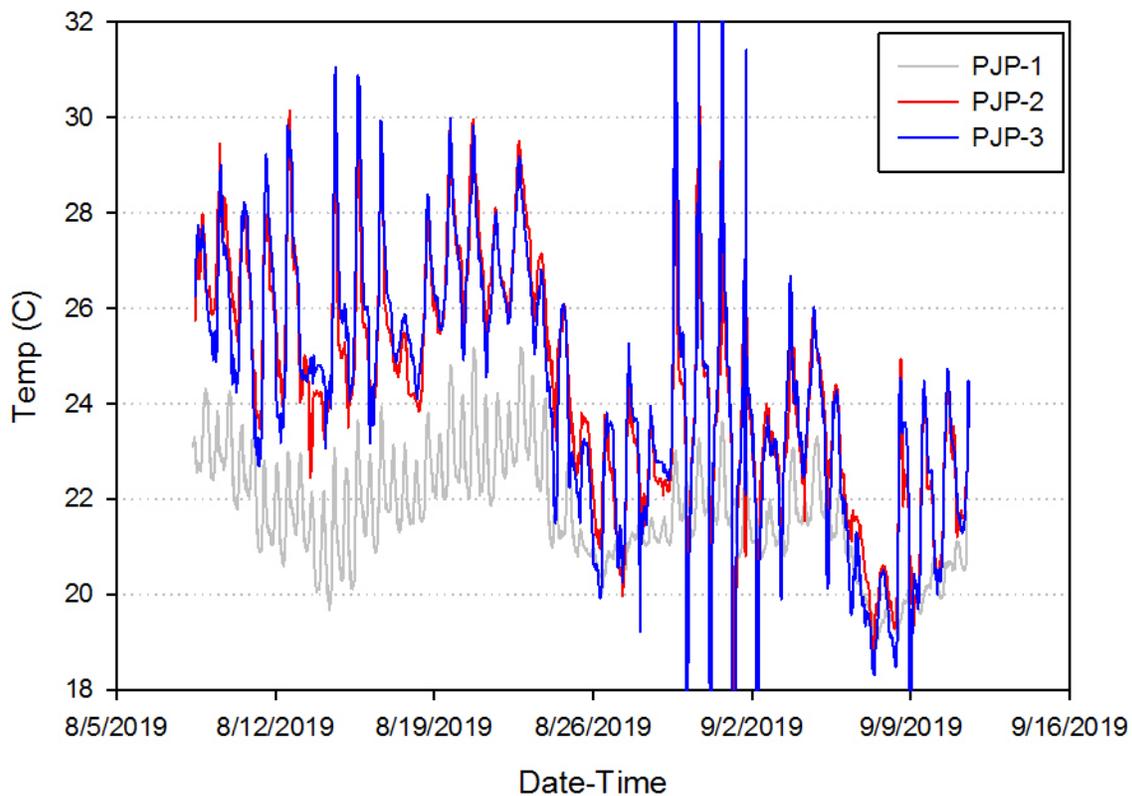


Figure 9. Time series of temperature (degrees C) at the three observation locations in 2019.

Similarly, Figure 10 shows time series of the salinity data (shown as specific conductivity) observed over the deployment period. These data show a difference in the salinity levels between the north side and south side of the Foddering Farm Road causeway. The water on the south side of the causeway is more saline, while the water on the north side of the causeway is slightly fresher, likely due to freshwater input from the upstream areas and the overall watershed. This indicates that there may be some density driven exchange that could be expected to occur via a connection under the causeway based on salinity difference between the north and south side of the causeway.

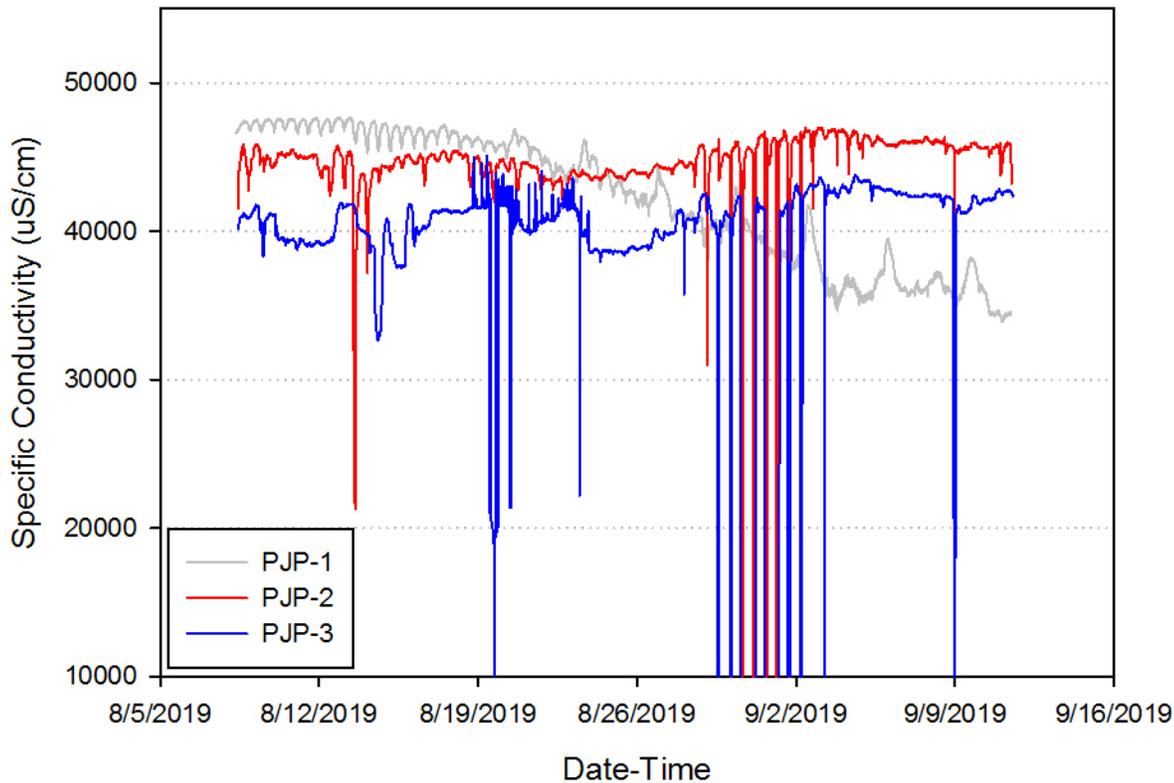


Figure 10. Time series of specific conductivity at the three observation locations in 2019.

Summary and Recommendations

This deployment captured 34 days of observed water surface elevation. Based on current and previous data, there is no significant change in amplitude or phase through the system. Point Judith Pond experiences approximately the same tides at the same time, from the mouth at Galilee to Upper Pond in the north. Similar temperatures were also observed on either side of the Foddering Farm Road causeway. However, salinity did differ slightly, as there was more saline water on the south side of the causeway compared to the north side of the causeway. These observations were collected as a first phase in determining the potential benefit of connecting Long Cove on the south end via a culvert, bridge, or other connection at Foddering Farm Road. Specifically, these data were collected to provide an initial evaluation of the potential need to develop a hydrodynamic model of a proposed connection. These data would be required to develop a hydrodynamic model, and as such, this memorandum offers a reasonable stopping point and assess if the development of a hydrodynamic model is warranted. If there was some phase shift and or amplitude difference between the north and south side of the causeway, then it would be straightforward to recommend proceeding with the

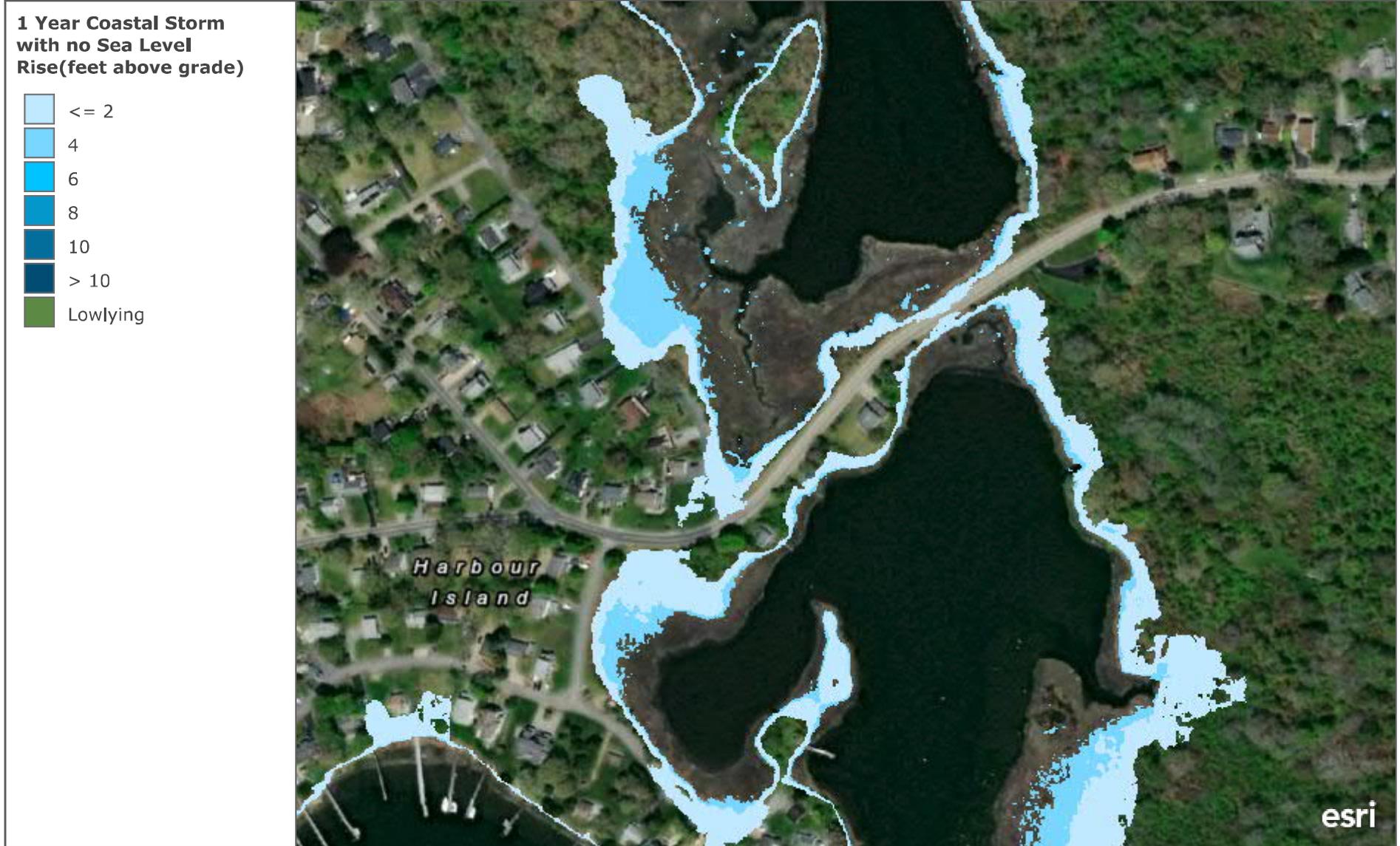
development of a hydrodynamic model. However, based on the result of the tidal observations alone, there is expected to be minimal change in tidal driven circulation within Long Cove via a connection through or under the Foddering Farm Road causeway. That does not mean; however, that a potential connection is unwarranted, as a connection under the causeway may have some local circulation improvements (due to wind, freshwater flow, and density-driven salinity difference, etc.). Additionally, the dilution of various water quality constituents may be impacted and improved due the inclusion of a connection. Unfortunately, no water quality data were collected as part of this initial phase of work, so it is unclear if a connection may improve water quality on one or both side of the causeway. Based on the data observations, the only way to potentially determine if a potential connection through or under the Foddering Farm Road causeway would be beneficial is to advance to development of a hydrodynamic model and identify if circulation and exchange of water is enhanced at some level. It is possible, given these observations, that the hydrodynamic model reveals that a connection only provides minor benefits.

Attachment C

2019 Tidal Level Monitoring Report



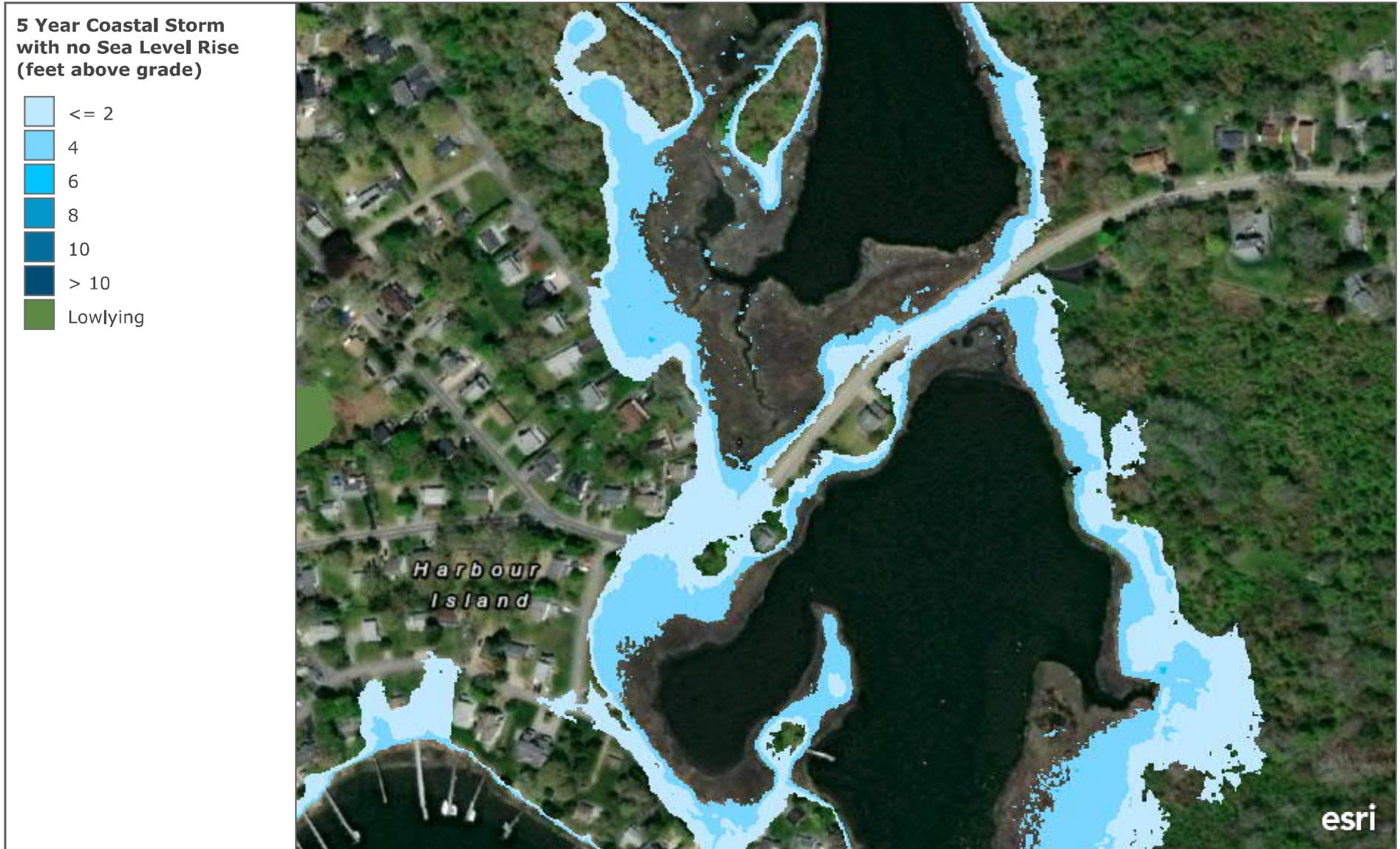
TODAY: Nuisance Storms



Coastal Storm Flooding Depth and Extent for Return Periods:1, 3, 5, and 10 year with no Sea Level Rise(based on the United States Army Corps of Engineers North Atlantic Coast Compr ...

Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

TODAY: Nuisance Storms



Coastal Storm Flooding Depth and Extent for Return Periods:1, 3, 5, and 10 year with no Sea Level Rise(based on the United States Army Corps of Engineers North Atlantic Coast Compr ...

300ft

Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

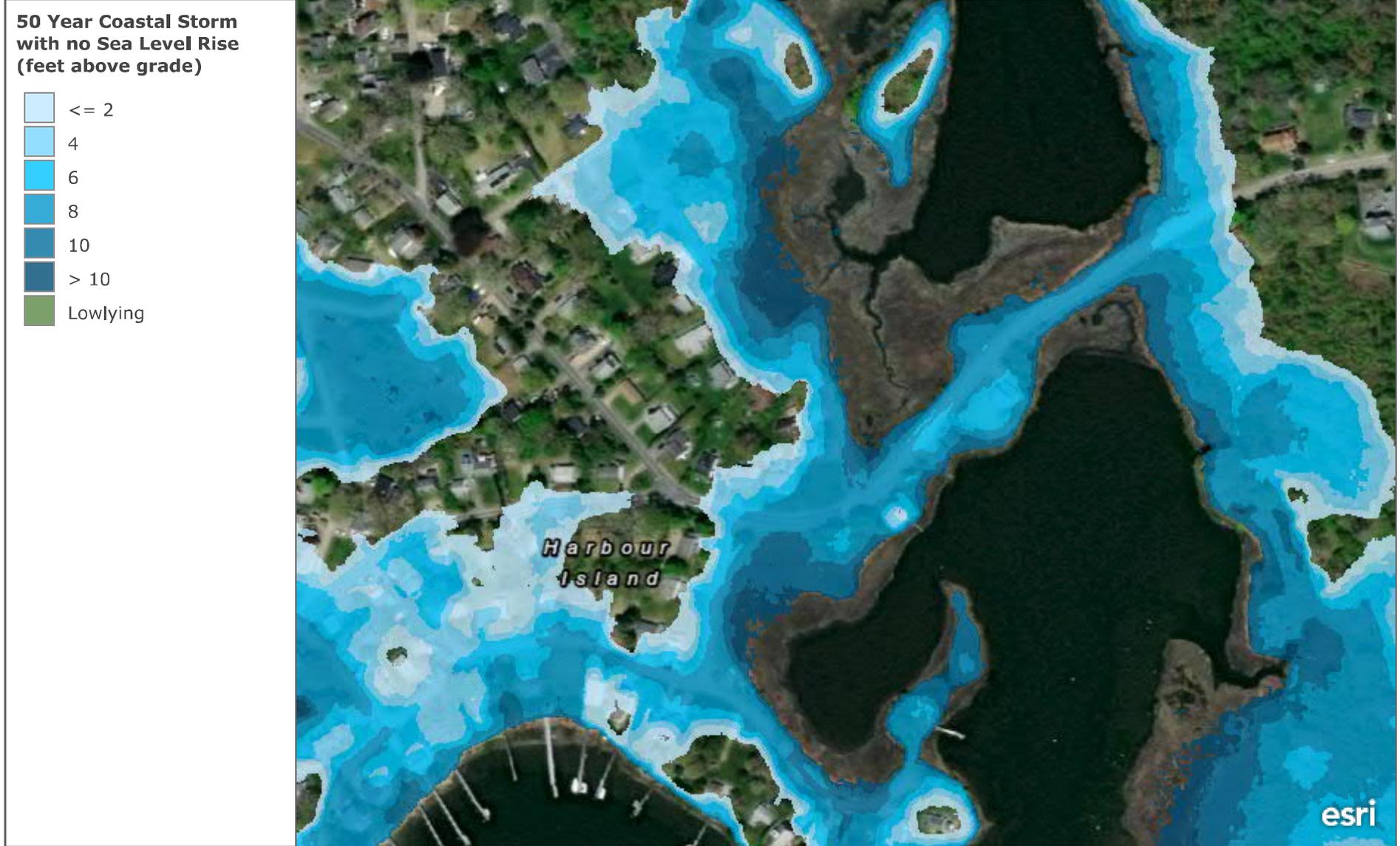
TODAY: Nuisance Storms



Coastal Storm Flooding Depth and Extent for Return Periods:1, 3, 5, and 10 year with no Sea Level Rise(based on the United States Army Corps of Engineers North Atlantic Coast Compr ...

Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

TODAY: Extra/Tropical Storms



Coastal Storm Flooding Depth and Extent for Return Periods:25, 100, and 500 year with no Sea Level Rise(based on the United States Army Corps of Engineers North Atlantic Coast Comp ...

Maxar | RI CRMC, URI OCE, URI EDC, URI CRC | RI CRMC, URI OCE, URI EDC, URI CRC | Esri, HERE, Garmin, iPC

TODAY: Extra/Tropical Storms

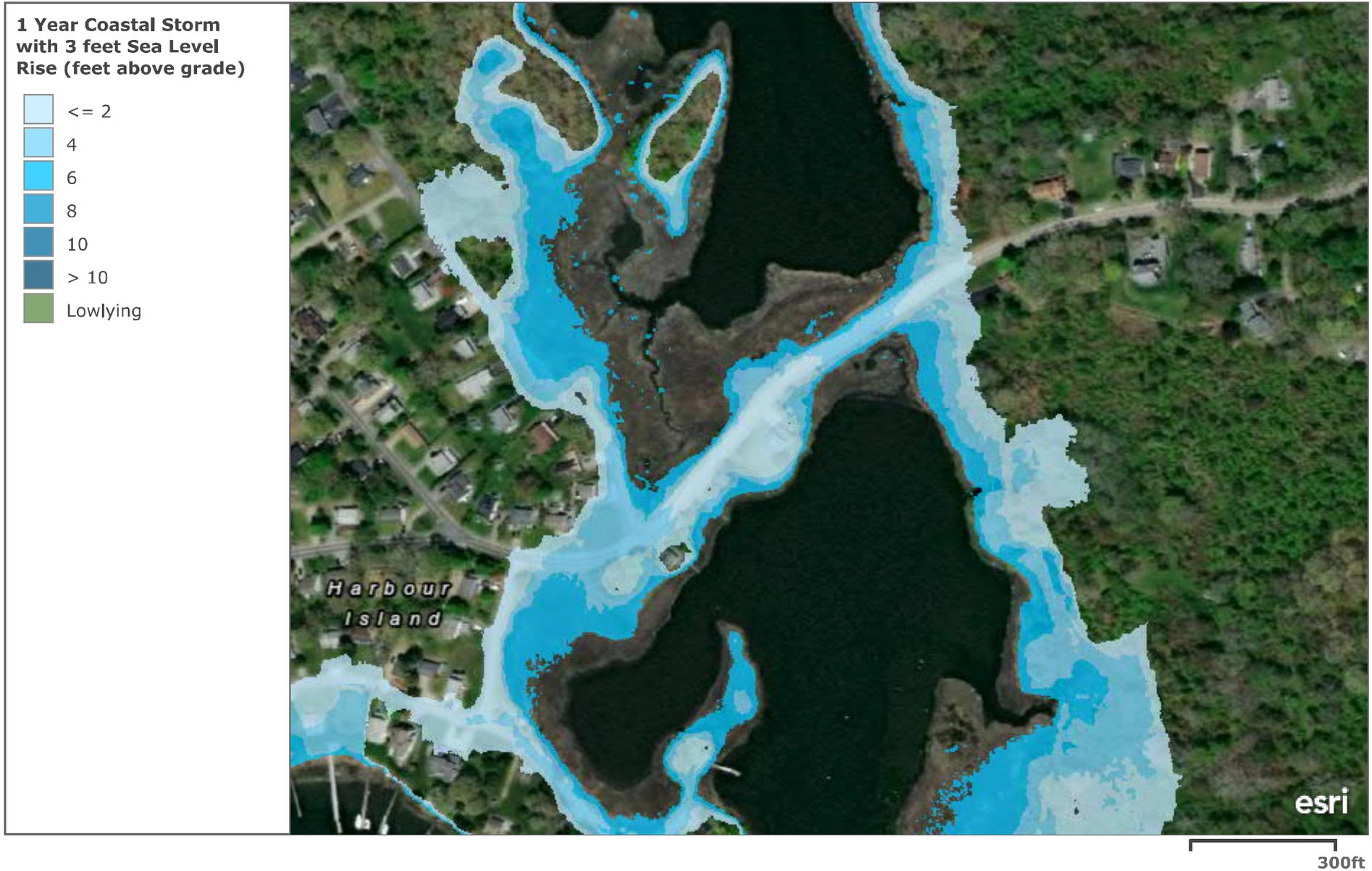


Coastal Storm Flooding Depth and Extent for Return Periods:25, 100, and 500 year with no Sea Level Rise(based on the United States Army Corps of Engineers North Atlantic Coast Comp ...

300ft

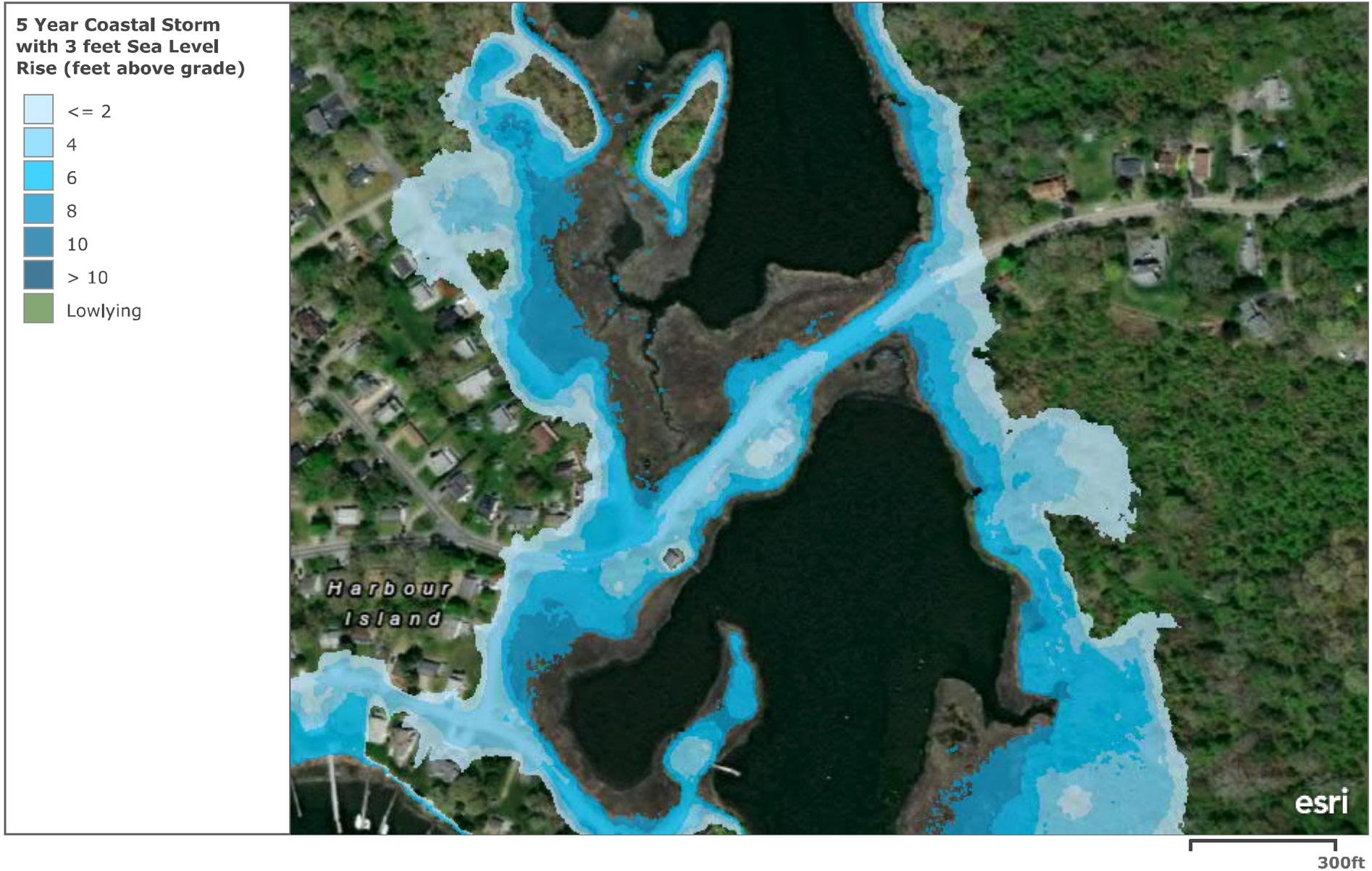
Maxar | RI CRMC, URI OCE, URI EDC, URI CRC | RI CRMC, URI OCE, URI EDC, URI CRC | Esri, HERE, Garmin, iPC

3 FEET SLR: Nuisance Storms.



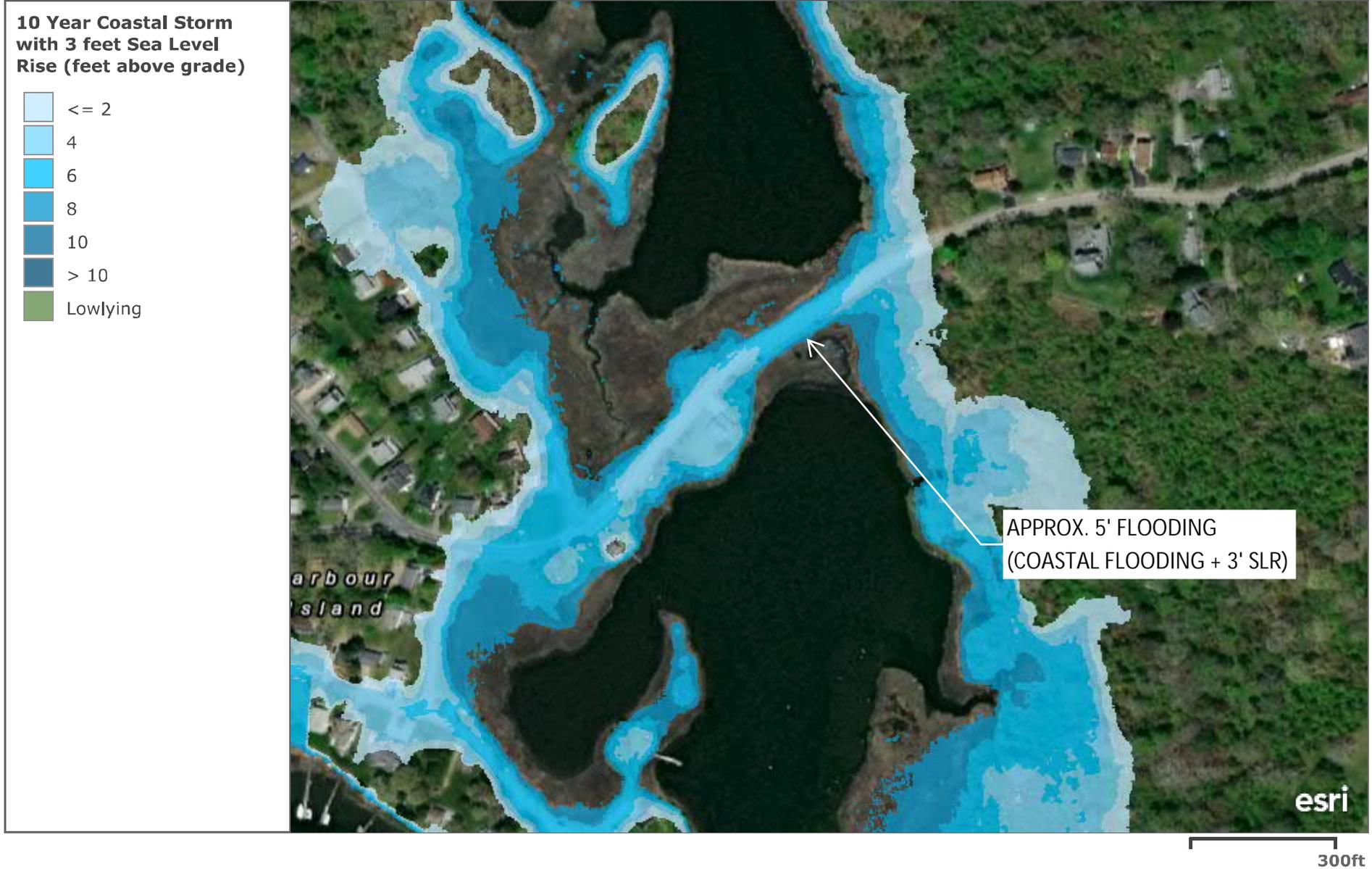
Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

3 FEET SLR: Nuisance Storms.



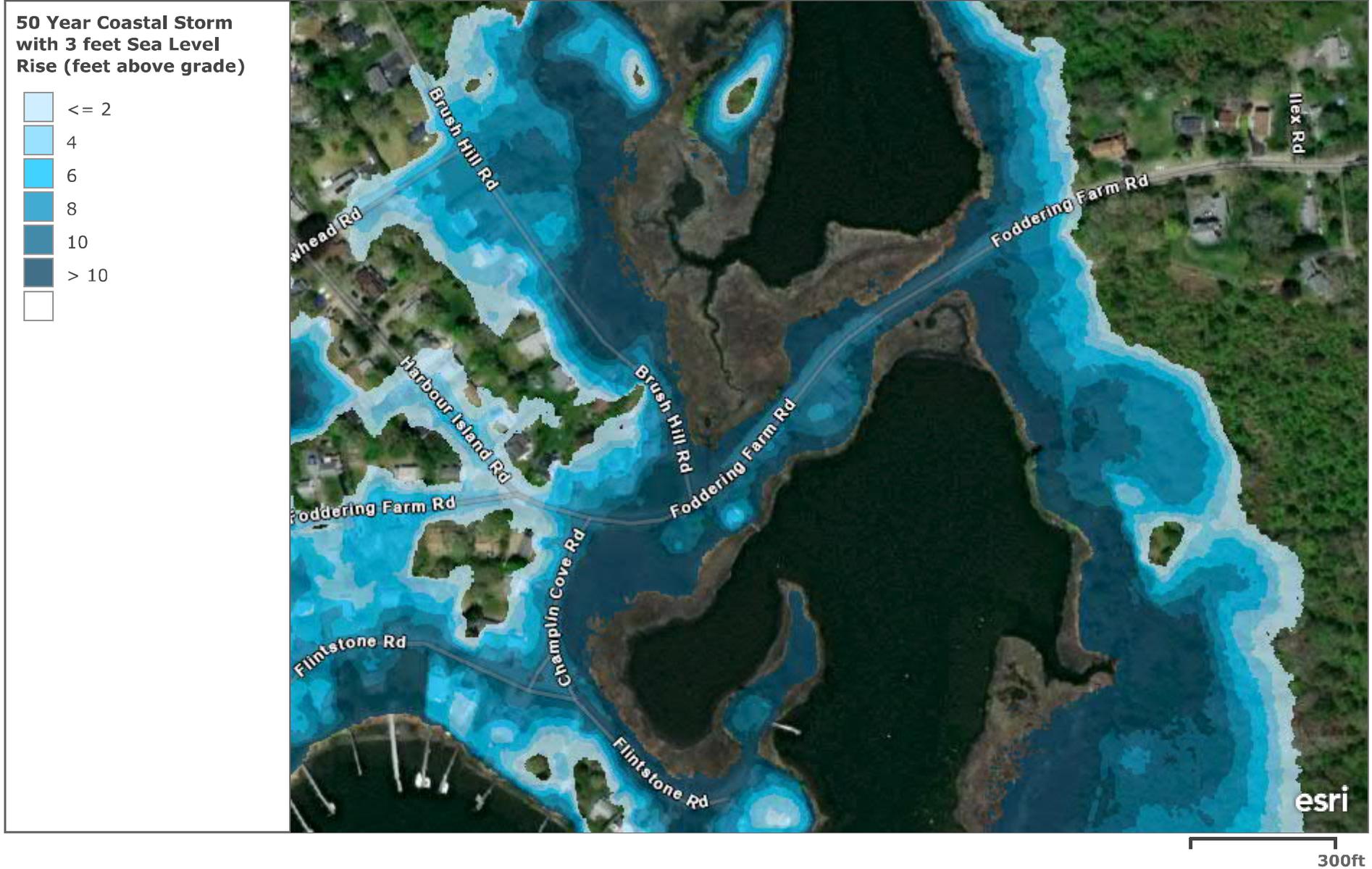
Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

3 FEET SLR: Nuisance Storms.



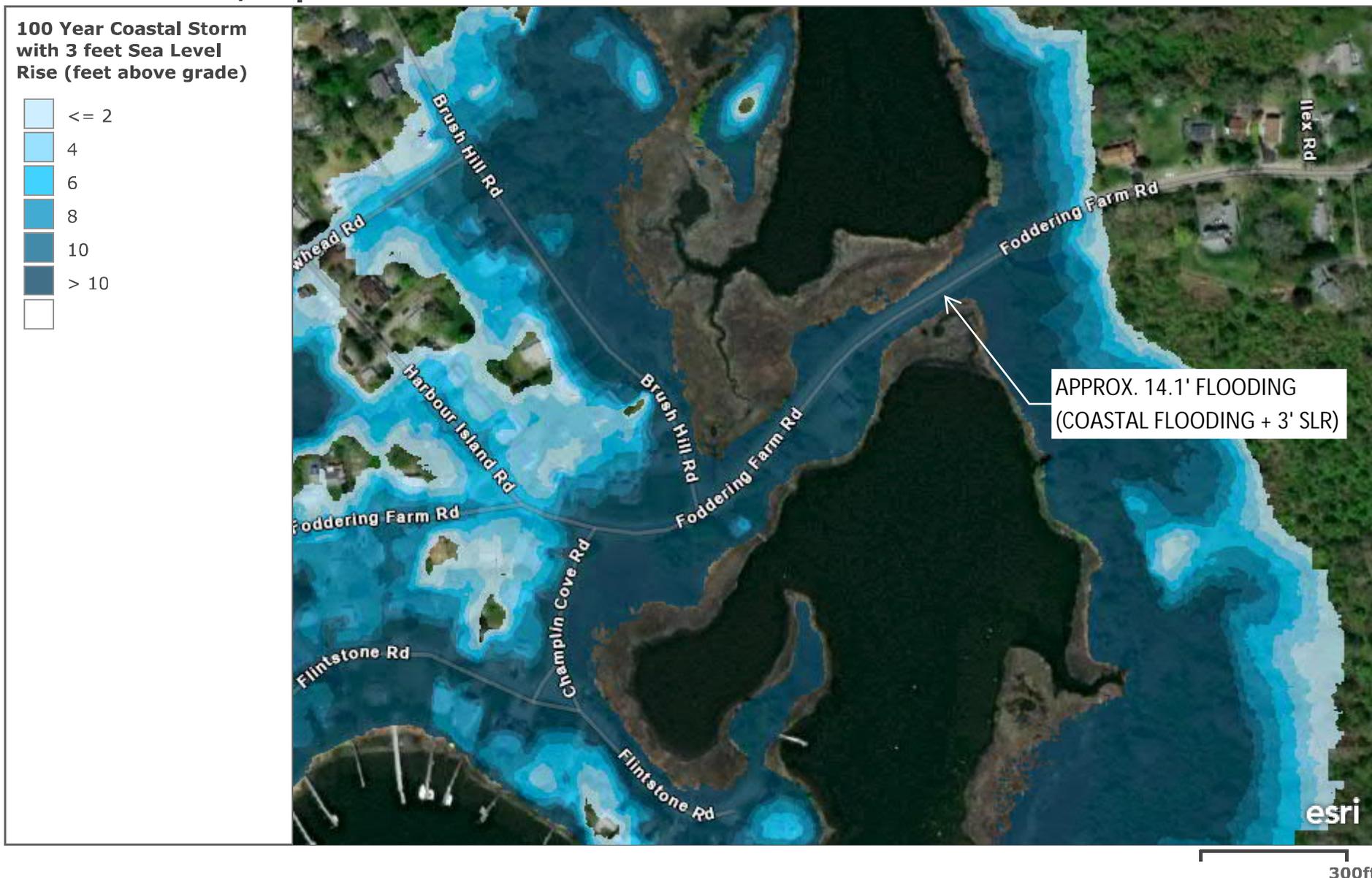
Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

3 FEET SLR: Extra/Tropical Storms.



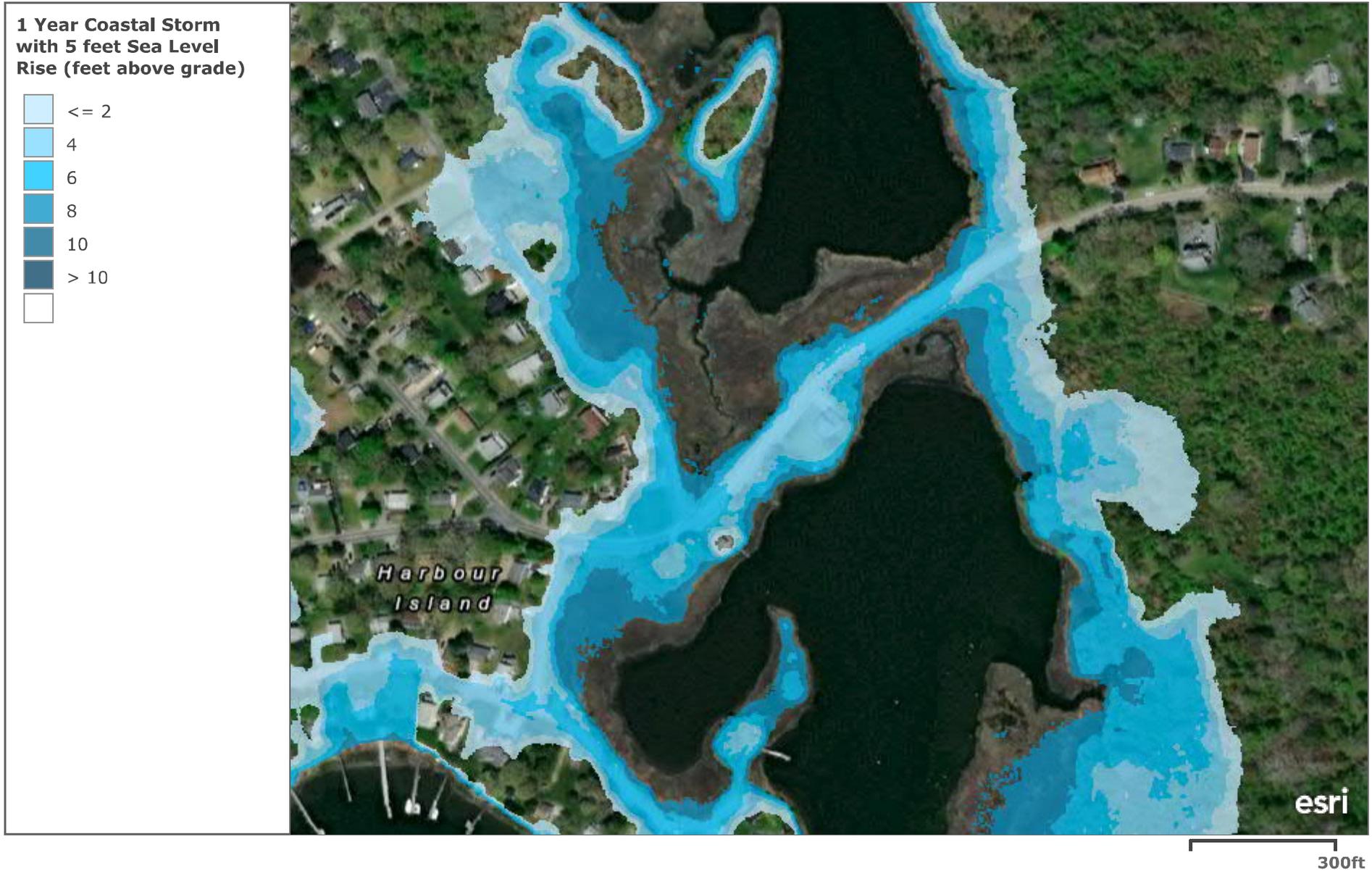
USACOE, NACCS, URI OCE, URI EDC | RI CRMC, URI OCE, URI EDC, URI CRC | RI CRMC, URI OCE, URI EDC, URI CRC | Maxar | Esri Community Maps Contributors, MassGIS, © OpenStreetMap, Microsoft, Esri, HERE, Garmin, SafeGraph, INCREMENT P, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA

3 FEET SLR: Extra/Tropical Storms.



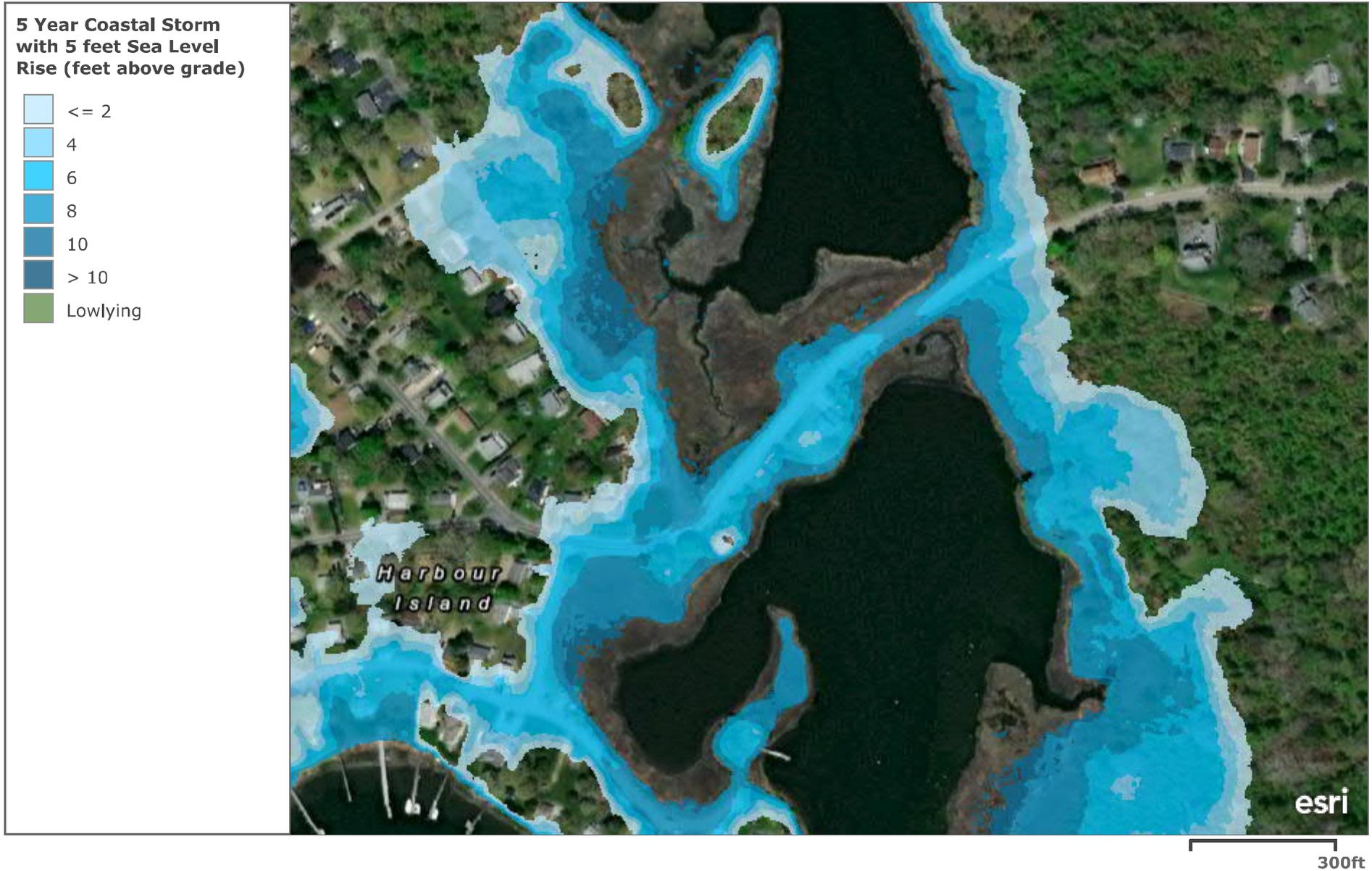
USACOE, NACCS, URI OCE, URI EDC | RI CRMC, URI OCE, URI EDC, URI CRC | RI CRMC, URI OCE, URI EDC, URI CRC | Maxar | Esri Community Maps Contributors, MassGIS, © OpenStreetMap, Microsoft, Esri, HERE, Garmin, SafeGraph, INCREMENT P, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA

5 FEET SLR: Nuisance Storms.



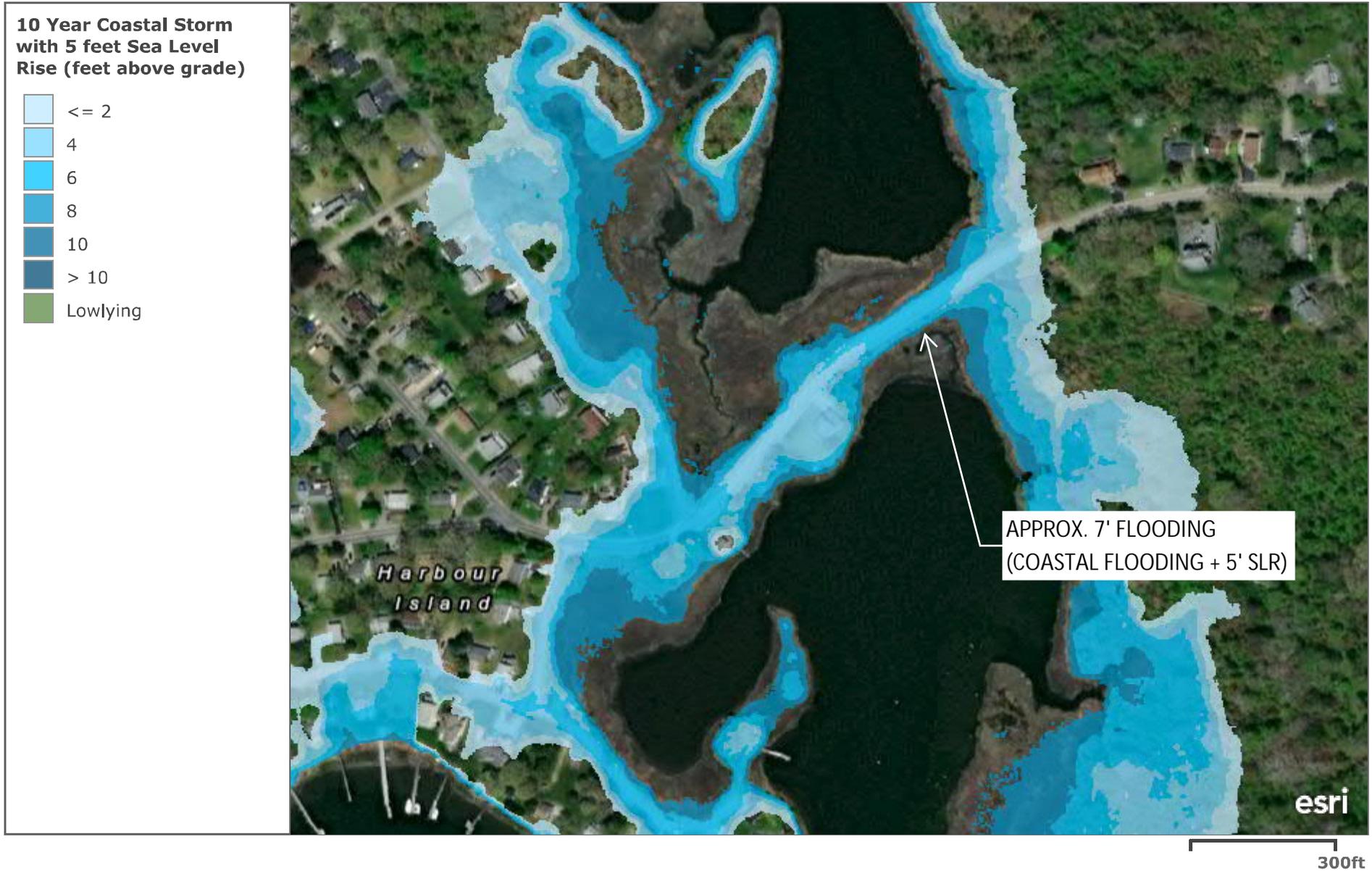
Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

5 FEET SLR: Nuisance Storms.



Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

5 FEET SLR: Nuisance Storms.

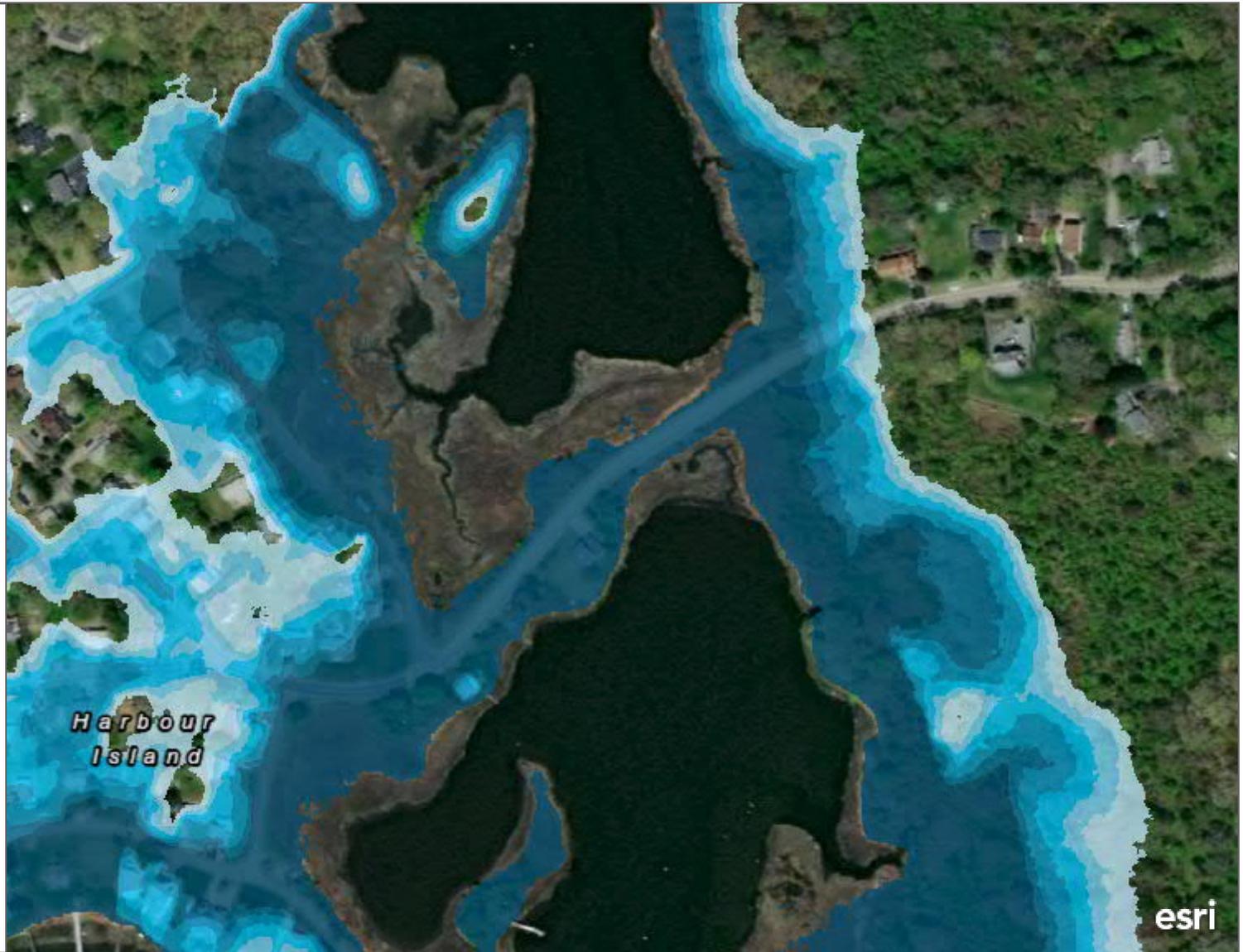


Maxar | URI OCE, URI EDC, URI CRC, RI CRMC, NACCS | URI EDC | RIGIS | RIGIS, University of Rhode Island Environmental Data Center | Esri, HERE, Garmin, iPC

5 FEET SLR: Extra/Tropical Storms.

50 Year Coastal Storm
with 5 feet Sea Level
Rise (feet above grade)

-  <= 2
-  4
-  6
-  8
-  10
-  > 10
-  Lowlying



300ft

Maxar | RI CRMC, URI OCE, URI EDC, URI CRC | RI CRMC, URI OCE, URI EDC, URI CRC | Esri, HERE, Garmin, iPC

5 FEET SLR: Extra/Tropical Storms.



Maxar | RI CRMC, URI OCE, URI EDC, URI CRC | RI CRMC, URI OCE, URI EDC, URI CRC | Esri, HERE, Garmin, iPC

Attachment D

Order of Magnitude Opinion of Costs



Foddering Farm Road Causeway Concept Study

Narragansett, Rhode Island

Conceptual Estimate

Alternative 1: Elev. 7.0

December xx, 2021

TOWN OF	Narragansett, RI
PROJECT NO.	20181137.A20
ESTIMATE BY	KAP
DATE	11/12/2021
REVISED	PT
CHECKED BY	11/16/2021

NO.	ITEM	UNIT	QUANTITY	PRICE	AMOUNT
201.0321	CLEARING AND GRUBBING	SY	4,000	\$30.00	\$120,000.00
201.0409	REMOVE AND DISPOSE FLEXIBLE PAVEMENT	SY	3,500	\$20.00	\$70,000.00
201.0610	REMOVE AND DISPOSE DIRECTIONAL, WARNING, REGULATORY, SERVICE AND STREET SIGNS	EA	5	\$50.00	\$250.00
204.0100	TRIMMING AND FINE GRADING	SY	3,500	\$7.00	\$24,500.00
206.0301	COMPOST FILTER SOCK	LF	2,500	\$5.00	\$12,500.00
209.0200	SACK INSERT CATCH BASIN INLET PROTECTION	EA	3	\$130.00	\$390.00
212.2000	CLEANING AND MAINTENANCE OF EROSION CONTROLS	LS	1	\$10,299.25	\$10,299.25
301.0200	GRAVEL BORROW BASE COURSE	CY	1,750	\$35.00	\$61,250.00
302.0100	GRAVEL BORROW SUBBASE COURSE	CY	11,875	\$38.00	\$451,250.00
401.1000	CLASS 19.0 HMA	TON	500	\$110.00	\$55,000.00
401.3000	CLASS 9.5 HMA	TON	400	\$185.00	\$74,000.00
403.0300	ASPHALT EMULSION TACK COAT	SY	3,500	\$0.50	\$1,750.00
707.2000	ADJUST FRAME AND GRATE TO GRADE	EA	2	\$400.00	\$800.00
714.8263	REMOVE AND RELOCATE POST TYPE HYDRANT	EA	2	\$3,000.00	\$6,000.00
902.9901	WOOD RAIL BARRIER	LF	1,250	\$100.00	\$125,000.00
907.0100	WATER FOR DUST CONTROL	MGAL	5	\$15.00	\$75.00
907.0200	CALCIUM CHLORIDE FOR DUST CONTROL (PROJECT WIDE)	TON	5	\$375.00	\$1,875.00
922.0100	TEMPORARY CONSTRUCTION SIGNS STANDARD 29.1.0 AND 27.1.1	SF	300	\$25.00	\$7,500.00
923.0105	DRUM BARRICADE STANDARD 26.2.0	BDAY	4,200	\$0.20	\$840.00
932.0200	FULL-DEPTH SAWCUT OF BITUMINOUS PAVEMENT	LF	150	\$1.50	\$225.00
936.0110	MOBILIZATION AND DEMOBILIZATION	LS	1	\$51,496.23	\$51,496.23
937.0200	MAINTENANCE AND MOVEMENT OF TRAFFIC PROTECTION	LS	1	\$102,992.45	\$102,992.45
L01.9901	SAND SOIL MIX 4 INCHES DEEP	SY	300	\$7.50	\$2,250.00
L02.9901	NEW ENGLAND COASTAL SALT TOLERANT GRASS MIX	SY	300	\$3.00	\$900.00
L05.0505	EROSION CONTROL BLANKET	SY	2,000	\$4.75	\$9,500.00
T20.2404	4 INCH WHITE FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	2,250	\$1.00	\$2,250.00
T20.2412	12 INCH WHITE FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	40	\$3.30	\$132.00
T20.2806	6 INCH YELLOW FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	2,250	\$0.75	\$1,687.50
-	UTILITY POLE RELOCATION	LS	1	\$55,000.00	\$55,000.00
-	CULVERT	LS	1		\$0.00

Subtotal \$1,249,712

Contingency (25%) \$312,428

Insurance & Bonds (5%) \$62,486

Subtotal \$1,624,626

Engineering and Procurement (15%) \$243,694

Construction Survey Layout and As-Built Mapping (2.5%) \$40,616

Ppolice Detail (5%) \$81,231

Subtotal \$1,990,167

Grand Total \$2,000,000

Total -15% to +30% (Rounded to the nearest \$10,000)

\$1,710,000

to

\$2,600,000

Foddering Farm Road Causeway Concept Study

Narragansett, Rhode Island

Conceptual Estimate

Alternative 2: Elev. 9.0

December xx, 2021

TOWN OF	Narragansett, RI
PROJECT NO.	20181137.A20
ESTIMATE BY	KAP
DATE	11/12/2021
REVISED	PT
CHECKED BY	11/16/2021

NO.	ITEM	UNIT	QUANTITY	PRICE	AMOUNT
201.0321	CLEARING AND GRUBBING	SY	4,250	\$30.00	\$127,500.00
201.0409	REMOVE AND DISPOSE FLEXIBLE PAVEMENT	SY	3,750	\$20.00	\$75,000.00
201.0610	REMOVE AND DISPOSE DIRECTIONAL, WARNING, REGULATORY, SERVICE AND STREET SIGNS	EA	5	\$50.00	\$250.00
204.0100	TRIMMING AND FINE GRADING	SY	3,750	\$7.00	\$26,250.00
206.0301	COMPOST FILTER SOCK	LF	2,500	\$5.00	\$12,500.00
209.0200	SACK INSERT CATCH BASIN INLET PROTECTION	EA	4	\$130.00	\$520.00
212.2000	CLEANING AND MAINTENANCE OF EROSION CONTROLS	LS	1	\$13,921.42	\$13,921.42
301.0200	GRAVEL BORROW BASE COURSE	CY	1,750	\$35.00	\$61,250.00
302.0100	GRAVEL BORROW SUBBASE COURSE	CY	20,625	\$38.00	\$783,750.00
401.1000	CLASS 19.0 HMA	TON	600	\$110.00	\$66,000.00
401.3000	CLASS 9.5 HMA	TON	400	\$185.00	\$74,000.00
403.0300	ASPHALT EMULSION TACK COAT	SY	3,750	\$0.50	\$1,875.00
707.2000	ADJUST FRAME AND GRATE TO GRADE	EA	3	\$400.00	\$1,200.00
714.8263	REMOVE AND RELOCATE POST TYPE HYDRANT	EA	2	\$3,000.00	\$6,000.00
902.9901	WOOD RAIL BARRIER	LF	1,250	\$100.00	\$125,000.00
907.0100	WATER FOR DUST CONTROL	MGAL	5	\$15.00	\$75.00
907.0200	CALCIUM CHLORIDE FOR DUST CONTROL (PROJECT WIDE)	TON	5	\$375.00	\$1,875.00
922.0100	TEMPORARY CONSTRUCTION SIGNS STANDARD 29.1.0 AND 27.1.1	SF	300	\$25.00	\$7,500.00
923.0105	DRUM BARRICADE STANDARD 26.2.0	BDAY	4,200	\$0.20	\$840.00
932.0200	FULL-DEPTH SAWCUT OF BITUMINOUS PAVEMENT	LF	150	\$1.50	\$225.00
936.0110	MOBILIZATION AND DEMOBILIZATION	LS	1	\$69,607.10	\$69,607.10
937.0200	MAINTENANCE AND MOVEMENT OF TRAFFIC PROTECTION	LS	1	\$139,214.20	\$139,214.20
L01.9901	SAND SOIL MIX 4 INCHES DEEP	SY	300	\$7.50	\$2,250.00
L02.9901	NEW ENGLAND COASTAL SALT TOLERANT GRASS MIX	SY	300	\$3.00	\$900.00
L05.0505	EROSION CONTROL BLANKET	SY	2,750	\$4.75	\$13,062.50
T20.2404	4 INCH WHITE FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	2,500	\$1.00	\$2,500.00
T20.2412	12 INCH WHITE FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	40	\$3.30	\$132.00
T20.2806	6 INCH YELLOW FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	2,250	\$0.75	\$1,687.50
-	UTILITY POLE RELOCATION	LS	1	\$60,000.00	\$60,000.00
-	CULVERT	LS	1		\$0.00

Subtotal \$1,674,885

Contingency (25%) \$418,721

Insurance & Bonds (5%) \$83,744

Subtotal \$2,177,350

Engineering and Procurement (15%) \$326,603

Construction Survey Layout and As-Built Mapping (2.5%) \$54,434

Ppolice Detail (5%) \$108,868

Subtotal \$2,667,254

Grand Total \$2,750,000

Total -15% to +30% (Rounded to the nearest \$10,000)

\$2,350,000

to

\$3,560,000

Foddering Farm Road Causeway Concept Study

Narragansett, Rhode Island

Conceptual Estimate

Alternative 3: Elev. 11.0

December xx, 2021

TOWN OF	Narragansett, RI
PROJECT NO.	20181137.A20
ESTIMATE BY	KAP
DATE	11/12/2021
REVISED	PT
CHECKED BY	11/16/2021

NO.	ITEM	UNIT	QUANTITY	PRICE	AMOUNT
201.0321	CLEARING AND GRUBBING	SY	4,500	\$30.00	\$135,000.00
201.0409	REMOVE AND DISPOSE FLEXIBLE PAVEMENT	SY	3,750	\$20.00	\$75,000.00
201.0610	REMOVE AND DISPOSE DIRECTIONAL, WARNING, REGULATORY, SERVICE AND STREET SIGNS	EA	5	\$50.00	\$250.00
204.0100	TRIMMING AND FINE GRADING	SY	4,000	\$7.00	\$28,000.00
206.0301	COMPOST FILTER SOCK	LF	3,000	\$5.00	\$15,000.00
209.0200	SACK INSERT CATCH BASIN INLET PROTECTION	EA	3	\$130.00	\$390.00
212.2000	CLEANING AND MAINTENANCE OF EROSION CONTROLS	LS	1	\$18,215.25	\$18,215.25
301.0200	GRAVEL BORROW BASE COURSE	CY	2,000	\$35.00	\$70,000.00
302.0100	GRAVEL BORROW SUBBASE COURSE	CY	31,250	\$38.00	\$1,187,500.00
401.1000	CLASS 19.0 HMA	TON	600	\$110.00	\$66,000.00
401.3000	CLASS 9.5 HMA	TON	400	\$185.00	\$74,000.00
403.0300	ASPHALT EMULSION TACK COAT	SY	4,000	\$0.50	\$2,000.00
707.2000	ADJUST FRAME AND GRATE TO GRADE	EA	3	\$400.00	\$1,200.00
714.8263	REMOVE AND RELOCATE POST TYPE HYDRANT	EA	2	\$3,000.00	\$6,000.00
902.9901	WOOD RAIL BARRIER	LF	1,250	\$100.00	\$125,000.00
907.0100	WATER FOR DUST CONTROL	MGAL	5	\$15.00	\$75.00
907.0200	CALCIUM CHLORIDE FOR DUST CONTROL (PROJECT WIDE)	TON	5	\$375.00	\$1,875.00
922.0100	TEMPORARY CONSTRUCTION SIGNS STANDARD 29.1.0 AND 27.1.1	SF	300	\$25.00	\$7,500.00
923.0105	DRUM BARRICADE STANDARD 26.2.0	BDAY	4,200	\$0.20	\$840.00
932.0200	FULL-DEPTH SAWCUT OF BITUMINOUS PAVEMENT	LF	150	\$1.50	\$225.00
936.0110	MOBILIZATION AND DEMOBILIZATION	LS	1	\$91,076.23	\$91,076.23
937.0200	MAINTENANCE AND MOVEMENT OF TRAFFIC PROTECTION	LS	1	\$182,152.45	\$182,152.45
L01.9901	SAND SOIL MIX 4 INCHES DEEP	SY	450	\$7.50	\$3,375.00
L02.9901	NEW ENGLAND COASTAL SALT TOLERANT GRASS MIX	SY	450	\$3.00	\$1,350.00
L05.0505	EROSION CONTROL BLANKET	SY	3,500	\$4.75	\$16,625.00
T20.2404	4 INCH WHITE FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	2,500	\$1.00	\$2,500.00
T20.2412	12 INCH WHITE FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	40	\$3.30	\$132.00
T20.2806	6 INCH YELLOW FINAL EPOXY RESIN PAVEMENT MARKINGS	LF	2,250	\$0.75	\$1,687.50
-	UTILITY POLE RELOCATION	LS	1	\$60,000.00	\$60,000.00
-	CULVERT	LS	1		\$0.00

Subtotal \$2,172,968

Contingency (25%) \$543,242

Insurance & Bonds (5%) \$108,648

Subtotal \$2,824,859

Engineering and Procurement (15%) \$423,729

Construction Survey Layout and As-Built Mapping (2.5%) \$70,621

Ppolice Detail (5%) \$141,243

Subtotal \$3,460,452

Grand Total \$3,500,000

Total -15% to +30% (Rounded to the nearest \$10,000)

\$2,990,000

to

\$4,540,000



FUSS & O'NEILL, INC.
317 Iron Horse Way, Suite 204
Providence, RI 02908

OPINION OF CONSTRUCTION COST		DATE PREPARED:		17-Nov-21	
Type:	Order of Magnitude				
PROJECT:	Foddering Farm Road Causeway	BASIS: Experience, RSMMeans, RIDOT WAUP 2020, Recent bid results for local projects, prevailing wage rates. Pricing reflects 2021 dollars and does not reflect potential for inflation.			
LOCATION:	Narragansett, RI				
DESCRIPTION:	Culvert - 6' wide, 4' high				
DRAWING NO.:	NA - Site geometry based on Plans	ESTIMATOR:	ACJ	CHECKED BY:	
<p>OPINION OF CONSTRUCTION COST - ORDER OF MAGNITUDE: An opinion of cost made without detailed engineering data. Costs may be estimated by comparison with similar projects. It is normally expected that an estimate of this type would be accurate within plus 50% or minus 30%. Since Fuss & O'Neill has no control over the cost of labor, materials, equipment or services furnished by others, or over the Contractor's methods of determining prices, or over competitive bidding or market conditions, Fuss & O'Neill's opinion of probable Total Project Costs and Construction Costs are made on the basis of Fuss & O'Neill's experience and qualifications and represent Fuss & O'Neill's best judgment as an experienced and qualified professional engineer, familiar with the construction industry; but Fuss & O'Neill cannot and does not guarantee that proposals, bids or actual Total Project or Construction Costs will not vary from opinions of probable cost prepared by Fuss & O'Neill. If prior to the bidding or negotiating Phase the Owner wishes greater assurance as to Total Project or Construction Costs, the Owner should employ an independent cost estimator.</p>					
ITEM NO.	ITEM	UNIT MEAS.	NO. UNITS	PER UNIT	TOTAL COST
1	Site Preparation				
	Site Access and Staging	LS	1	\$ 5,000.00	\$5,000
	Site Restoration	LS	1	\$ 5,000.00	\$5,000
	Site Preparation Subtotal				\$10,000
2	Erosion and Sediment Control				
	Erosion and Sediment Control	LS	1	\$ 10,000.00	\$10,000
	Erosion and Sediment Control Subtotal				\$10,000
3	Traffic Control - Completed with road raising				
	Traffic Control - cones, signage, barricades	LS	0	\$ 12,000.00	\$0
	Police Detail	DAY	0	\$ 450.00	\$0
	Traffic Control Subtotal				\$0
4	Control of Water				
	Dewatering	LS	1	\$ 30,000.00	\$30,000
	Temporary cofferdam/steel sheet pile (install)	LF	60	\$ 1,500.00	\$90,000
	Temporary cofferdam steel sheet pile (removal)	LF	60	\$ 300.00	\$18,000
	Control of Water Subtotal				\$138,000
5	Culvert				
	Earth Excavation (assume shored cut with vertical sides)	CY	450	\$ 25.00	\$11,250
	Dredging	CY	160	\$ 40.00	\$6,400
	Steel sheet pile shoring/support of excavation (install)	LF	100	\$ 1,500.00	\$150,000
	Steel sheet pile shoring/support of excavation (remove)	LF	100	\$ 300.00	\$30,000
	Cast in place concrete foundations	CY	40	\$ 2,000.00	\$80,000
	Soil Disposal	TON	560	\$ 30.00	\$16,800
	Fine Grading and Compacting	SY	56	\$ 10.00	\$560
	Concrete Culvert	LF	60	\$ 500.00	\$30,000
	Substrate placement in culvert bottom	CY	80	\$ 60.00	\$4,800
	Concrete cut-off	CY	10	\$ 2,000.00	\$20,000
	Embankment Fill Placement	CY	200	\$ 40.00	\$8,000
	Pre-cast end/headwalls	EA	2	\$ 8,000.00	\$16,000
	Culvert Subtotal				\$373,810
	CONSTRUCTION SUBTOTAL (NOT INCLUDING GENERAL CONDITIONS)				\$531,810
	General Conditions				
	Mobilization & Demobilization (5%)	LS	1	\$ 27,000.00	\$27,000
	Engineer Inspection/Construction Admin.	LS	1	\$ 50,000.00	\$50,000
	Construction Survey Layout and As-Built Mapping	LS	1	\$ 10,000.00	\$10,000
	Field and Laboratory Testing	LS	1	\$ 7,000.00	\$5,000
	Insurance and Bonds (5%)	LS	1	\$ 27,000.00	\$27,000
	CONSTRUCTION ADMINISTRATION SUBTOTAL				\$119,000
	OVERALL SUBTOTAL				\$650,810
	CONTINGENCY (25%)				\$162,703
	TOTAL (ROUNDED TO NEAREST \$10,000)				\$810,000
	TOTAL -30% TO +50% (ROUNDED TO NEAREST \$10,000)		\$610,000	TO	\$1,140,000



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