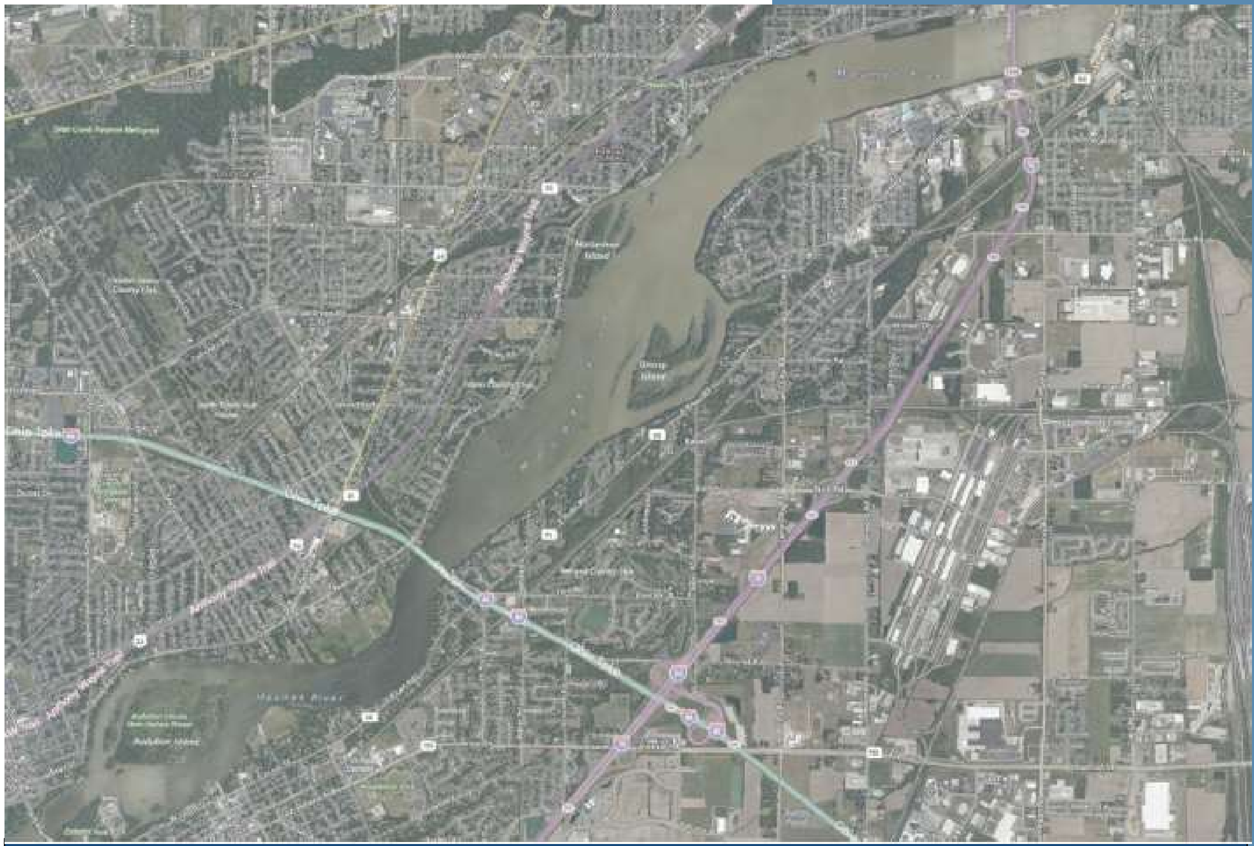

Hydraulic Analysis of Maumee Area of Concern Riverine Habitat Restoration Concepts

Prepared for:
United States Army Corps of Engineers Buffalo District under Contract No. W912P4-16-D-0003, Delivery Order W912P421F0035

Date: January 11, 2022

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January 2022

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Executive Summary

Project concepts for restoring habitat within the Maumee River lacustuary have been developed by a group of local scientists and engineers from federal government, academia, and the private sector. These concepts were identified after a significant field study which helped to identify opportune locations for habitat improvement. Concepts were further adapted following recent discussions with the public regarding their use and enjoyment of the river near project sites. Next, these concepts were evaluated for how they would impact the Maumee River.

Under contract to and direction from U.S. Army Corps of Engineers (USACE) Buffalo District, LimnoTech conducted the hydraulic analysis, building off recent hydraulic analysis LimnoTech has conducted within the Maumee River lacustuary. This report describes a conceptual level hydraulic analysis of the project concepts and their impact on the river. A numerical modeling tool, HEC-RAS2D, was applied to compare pre- to hypothetical post-project conditions. The model simulated a wide range of flow and water level conditions on the Maumee River. Based on this analysis, some conclusions were drawn about the viability of the project concepts, potential for secondary negative consequences, potential improvements to the concepts, and future analyses that would further help improve these initial designs.

Design concepts are briefly summarized as follows:

- At Audubon Islands, several near-bank features consisting of rock, root wads, trees, and other natural elements have been conceptualized to provide near-bank habitat and reduce bank erosion.
- At Audubon Islands and the Delaware/Horseshoe Island Complex, three shallow, relatively protected cove areas have been identified for potential establishment of submerged aquatic vegetation. With this concept, these areas would be dredged and natural features would be introduced to enhance habitat and heterogeneity.
- At Marengo Island, a protective vegetated rock structure would be constructed upstream of the island protect the island from fast-moving river currents, and potentially accumulate sediments to further build up the island and increase habitat area.
- Downstream of the Delaware/Horseshoe Complex in a relatively protected zone, a rock reef or islands would be constructed to either increase the shallow, protected cove area, or increase heterogeneity of habitat area.

Major findings associated with each of the above design concepts are summarized as follows:

- Near-bank features at Audubon Islands would help to reduce near-bank velocities which would help reduce bank erosion. The secondary effects of these hypothetical projects are not expected to significantly impact other nearby areas.
- Cove areas, which have been identified as potential locations for establishment of submerged aquatic vegetation, are expected to experience mean suspended solids concentrations ranging from 5 to 20 mg/L and sediment accumulation rates of 2.0 to 6.0 cm/year. These conditions should be considered with regard to their ability to support the establishment and sustenance of healthy SAV.
- Four versions of a Marengo Island protective structure were simulated, and they varied appreciably in their protection of the island. One of the simulations was particularly effective, and it demonstrated the viability of protecting the island using such a structure. We recommend additional simulations during detailed design to further refine the structure's size, orientation, and dimensions.
- Both project concepts evaluated for the area downstream of the Delaware/Horseshoe Complex—a rock reef or a set of islands—appear to be viable with regard to their impact on local hydraulics.

1 Introduction

1.1 Maumee River Area of Concern Habitat Beneficial Use Impairment

From the scope of work document for this project, adapted from Lower Maumee River Restoration Design Concepts Report (2021):

The Maumee River has the largest watershed of all the Laurentian Great Lakes tributaries and drains into western Lake Erie. The river is a vital resource for a variety of agricultural, industrial, and recreational uses in northwestern Ohio, and maintains biological value for a variety of aquatic organisms. Unfortunately, the lower Maumee River has undergone a variety of geologic, hydrologic, and biological changes since agricultural and industrial development began in the region in the 1800s. The region, which was once part of the “Great Black Swamp” on the western end of Lake Erie, has experienced extensive wetland habitat loss as a result of this development. The watershed is currently subject to excessive non-point source sediment and nutrient loads, among other anthropogenic forces that have led to aquatic habitat and biodiversity decline. As a result of these issues and other impairments, the downstream portion of the Maumee River and many surrounding waterways in the greater Toledo area were established as one of 43 Areas of Concern (AOC) in the U.S. and Canada in the 1987 Great Lakes Water Quality Agreement. Of the 14 beneficial use impairments (BUIs) defined for Great Lakes AOCs, the Maumee AOC, led by Ohio EPA and coordinated locally through the Maumee AOC Advisory Committee, is working through the process to restore water quality and habitat resources to remove nine BUIs.

Due to the extensive agricultural and urban development within and beyond the boundaries of the Maumee AOC, regeneration of the formerly expansive wetland network is prohibitive. Therefore, identifying main-channel fluvial habitats that support or could be enhanced to support river biota is essential to provide realistic and feasible recommendations for removing impairments to aquatic habitat and fish and invertebrate communities of the Maumee AOC. To accomplish this, during the summer of 2019, researchers from the University of Toledo (UT) and Bowling Green State University (BGSU) studied a stretch of the Lower Maumee River from Perrysburg (~river mile [RM] 15) downstream to I-75 (~RM 7) to identify potential in-channel projects to implement and address the BUIs in the Maumee AOC. This study reach contained several river island complexes that were thought to have high restoration potential (Hintz, et al., 2019). The BUIs to be targeted by this sampling and the resulting recommendations are 3a.) Degradation of fish populations, 6.) Degradation of benthos, and 14a.) Loss of fish habitat.

To identify the project sites where the most benefit may be achieved through restoration efforts, UT and BGSU performed sampling activities that included fish sampling with electrofishing and bottom trawling and invertebrate sampling with Ponar grab samples and Hester Dendy samplers (Hintz et al., 2019). The fish sampling was used to evaluate fish populations at the sampling sites through fish species richness, fish abundance, and Index of Biological Integrity (IBI). The invertebrate sampling was used to evaluate the benthos in these areas through taxa richness; total abundance; and percent Ephemeroptera, Plecoptera, and Trichoptera taxa abundance (%EPT).

1.2 Potential Restoration Project Sites and Desired Outcomes

Original project sites and site concepts were identified by project partners and documented in Lower Maumee River Design Concepts (2021). Since then, project partners have toured the sites, met with residents and stakeholders, and proposed some modifications to these concepts. Current concepts are briefly described below.

1.2.1 Audubon Islands Near-bank Habitat

Project concepts within the Audubon Islands (which includes both Ewing Island and Grape Island) are intended to introduce a greater diversity of in-water habitat and protect island banks from further eroding. These projects, which are summarized in Figure 1, may include rock reefs with woody debris and/or root wads to divert flows away from the banks. Modeling for this site will help identify the forces of water acting on the proposed features and how hydraulics in the vicinity of the project may change as a result of the project. Near the proposed project is a riverbed area designated as high-quality spawning ground, and this work will analyze potential impacts to this area.

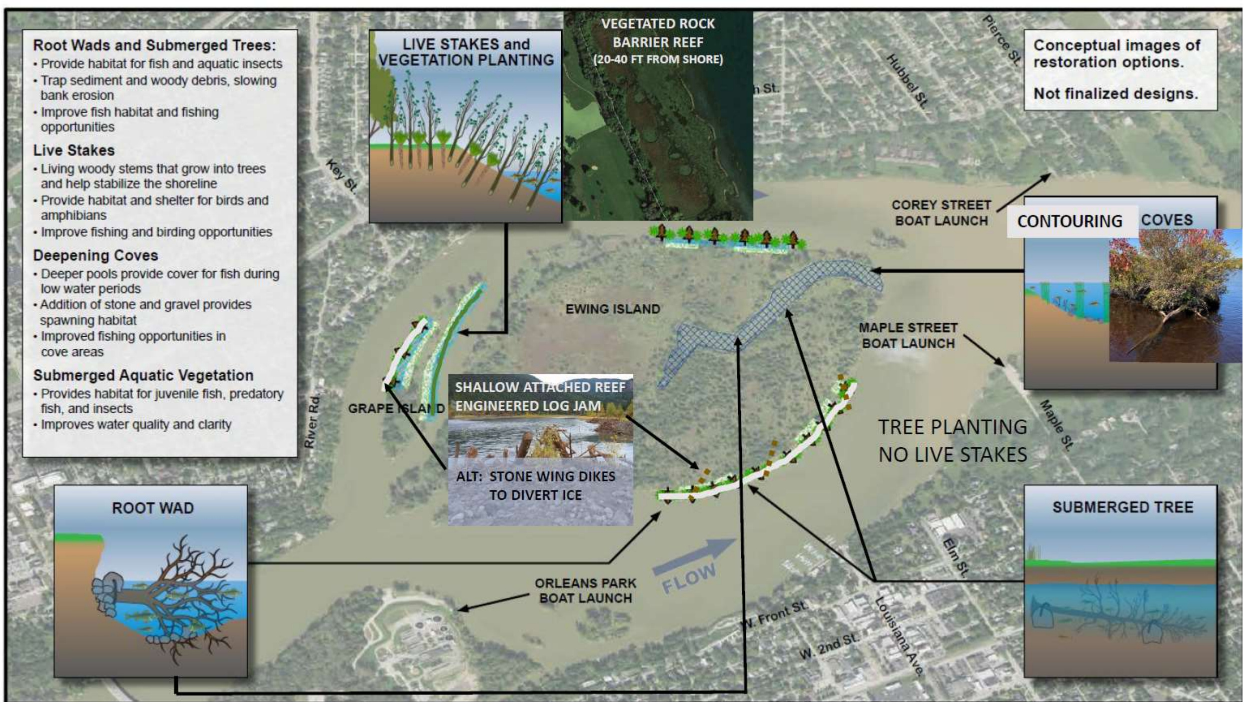

Figure 1. Current Design Concepts at Audubon Islands

1.2.2 Ewing and Delaware Island Coves

Another project concept is to attempt to establish submerged aquatic vegetation within some island coves. One of these coves is at Ewing Island and two are at Delaware Island. Soft sediment has accumulated in these areas and limits the degree to which vegetation can establish. As part of these projects, soft sediment in the coves would be excavated and submerged aquatic vegetation would be planted. Other vegetated features like woody debris that would provide a more diverse habitat may also be introduced. Modeling for this site will help identify the forces of water acting on the proposed features, and also will identify typical suspended sediment concentrations expected to occur within the cove. High turbidity caused by suspended sediment can limit or prohibit the establishment of aquatic vegetation (UMRCC, 2003). One of the Delaware coves is open at the upstream end, and for this cove the closure of this upstream end is being evaluated with the model. The Delaware Island cove is identified in Figure 3.

1.2.3 Marengo Island Protective Structure and Archipelago

Marengo Island has eroded significantly from its pre-development footprint which has reduced available habitat area. A project concept here, as shown in Figure 2, is to construct a structure upstream of the island that would protect the island from strong river currents and perhaps increase island area by enabling accumulation of coarse river sediments. Publicly owned property extends to about 100 feet upstream of the island. Modeling for the site will be used to identify what minimum size and what orientation of such a structure would help protect the island. Modeling will also be used to evaluate whether changes in river hydraulics due to a hypothetical structure would not be problematic for adjacent properties. Small islands may also be constructed on the downstream side of Marengo Island to further increase habitat area.

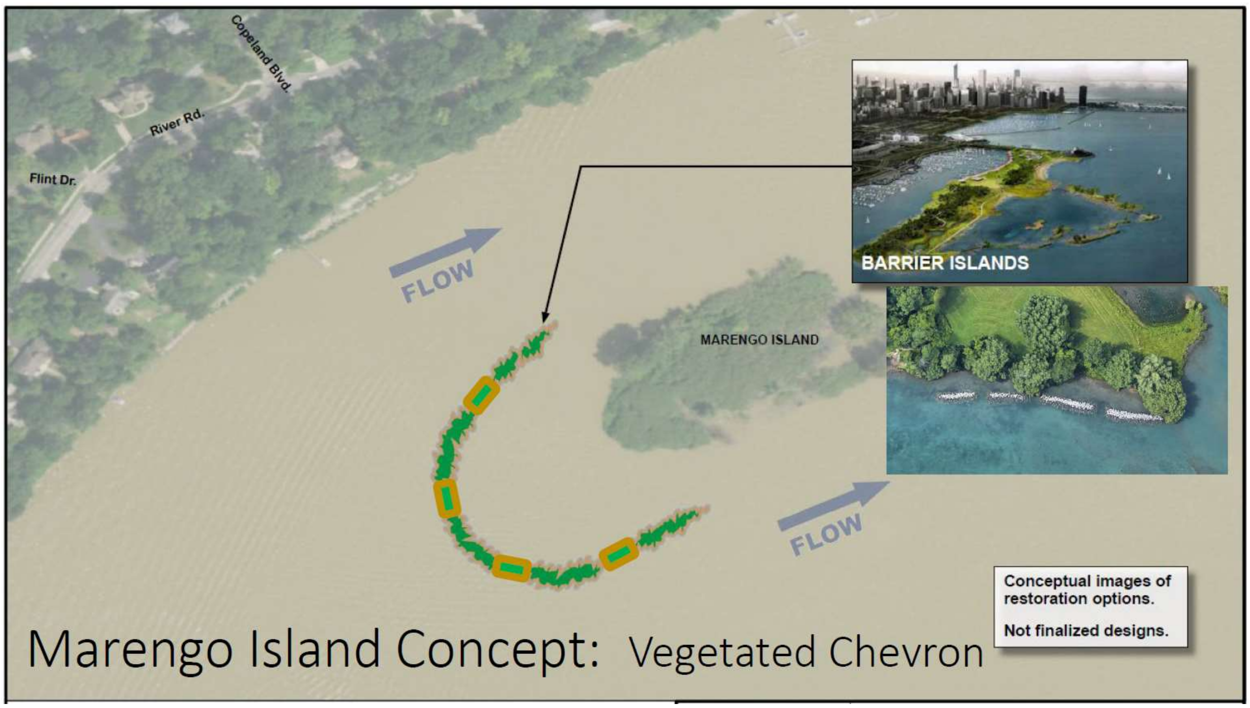

Figure 2. Current Design Concept at Marengo Island

1.2.4 Delaware/Horseshoe Complex Reef or Archipelago

Two other features are being considered at the downstream end of Delaware/Horseshoe Complex, as shown in Figure 3: a rock reef which could help limit turbidity in the coves, and a set of small islands which would increase habitat area. Again, the modeling will be used to help evaluate effects of these features on nearby hydraulics and to further inform their design.

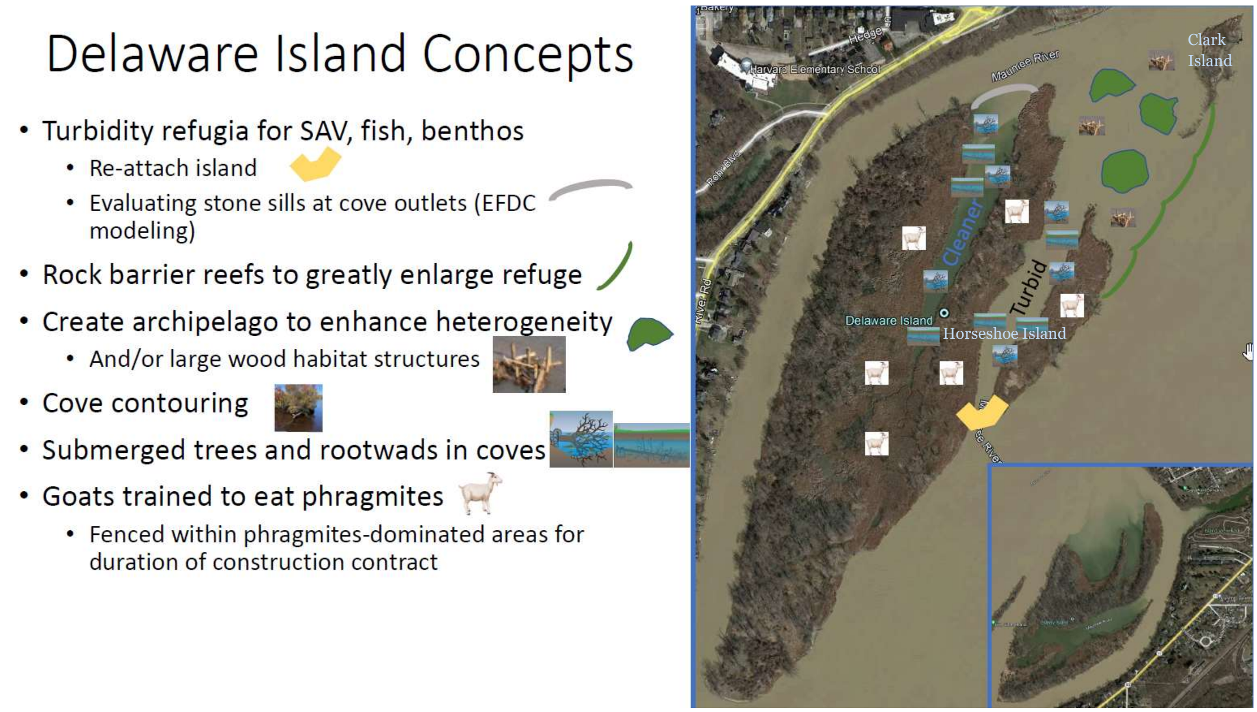

Figure 3. Current Design Concepts at Delaware/Horseshoe Complex

2 Modeling Approach, Results, and Findings

This section describes development and performance evaluation of the computational model of the project area (2.1), application of the model to evaluate restoration concepts (2.2), and limitations, uncertainties, and future recommendations for increasing certainty in results and refining the design concepts (2.3).

2.1 Model Development and Performance Evaluation

A HEC-RAS 2D model was developed based on information and lessons learned from past modeling of the Lower Maumee River by LimnoTech (2013). RAS2D was chosen for this project largely because of its support for flexible meshes. These meshes enable variation in element shape (i.e., other than near-rectangular elements) which allows for larger variation in element sizes, fewer total elements, and faster simulation times. The model extends for approximately 14 miles from the I-475 bridge crossing just upstream of Audubon Islands to the Maumee River confluence with Toledo Harbor. Element sizes range from 10 to 50 feet. The smaller element sizes were necessary for representation of relatively small-scale restoration features and the hydraulic variations around these features.

2.1.1 Model Input Development

Inputs to the model included elevation data (bathymetry and topography), bottom roughness (in the form of Manning's N coefficient), and upstream inflow and downstream water surface elevation. Inflow time series were developed from data at the U.S. Geological Survey (USGS) Maumee River at Waterville OH site (#04193500). Downstream water level time series were developed from data at the National Oceanic and Atmospheric Administration (NOAA) site #9063085 at Toledo, OH.

2.1.1.a Digital Elevation Model

A digital elevation model of bathymetry and topography was developed from the following data sources:

- University of Toledo (UT) 2019 bathymetric point data (Shane *et al.*, 2021)
- USGS 2019 bathymetric point data (Jackson, P.R. and Vonins, B.L., 2022)
- USGS 2016 LiDAR data (OCM Partners, 2022)
- FEMA 1% chance flood extent (FEMA, 2016)

Data were processed as follows:

- The UT 2019 bathymetric data were reported as depths. These were converted to bed elevations by estimating a water surface elevation for the surveyed reach and subtracting the reported depths. Data were collected between May 2019, 2019 and June 7, 2019 when the Maumee River flow was between 10,000 and 30,000 cfs and Lake Erie water levels were between 574.1 and 575.1 feet NAVD88. The mean water surface elevation for this period was estimated by adding the UT depths to nearby points of known sediment bed elevation from the USGS 2019 bathymetric dataset. The resulting estimated water surface elevations were mostly in the range 575.5 to 576.5 feet. The mean water surface elevation was computed as the arithmetic mean of the distribution, which was 575.9 feet.
- Next, bathymetric contours were manually drawn at as low as a 0.25-meter interval using the UT and USGS datasets.
- Next, some shoreline contour data were generated by digitization of an aerial photograph. The shoreline was then offset into the river at a 3:1 slope to generate a relatively steep bank profile that was internally consistent with adjacent bathymetric data.

- A digital elevation model in the form of a triangulated irregular network (TIN) was generated using all data sources described above, including the 2016 Lower Maumee LiDAR data, which were processed to only include ground points and last returns. The TIN extent was set to the full extent of FEMA's 1% chance flood extent, which was downloaded from FEMA's map service center (FEMA, 2016).
- A raster dataset (*.tif) was generated from the TIN at a 5-foot horizontal resolution.

2.1.1.b Bottom Roughness

The roughness coefficient Manning's N was set consistently with the hydraulic modeling conducted for FEMA as part of their Flood Insurance Study of the Lower Maumee River. This coefficient was set to 0.03 in the channel and to 0.08 in the floodplain.

2.1.2 Model-Data Comparisons

The model was run for a wide range of flow and seiche conditions then compared with FEMA's model results and observed data to confirm adequate model performance.

First, the model was run for the rising limb of a 100-year flood event (i.e., 1% annual chance event) for comparison with FEMA's model results. The maximum water level and velocity were sampled from this simulated event. Then water levels and velocities were mapped, and cross-sectional average velocities were computed. Comparisons of these results with FEMA's model results are shown below in Figure 4. Predicted water depths and velocities are consistent within 10% between the two models. There is more variability in the water surface prediction from RAS2D compared to FEMA because of the greater detail of the RAS2D calculations.

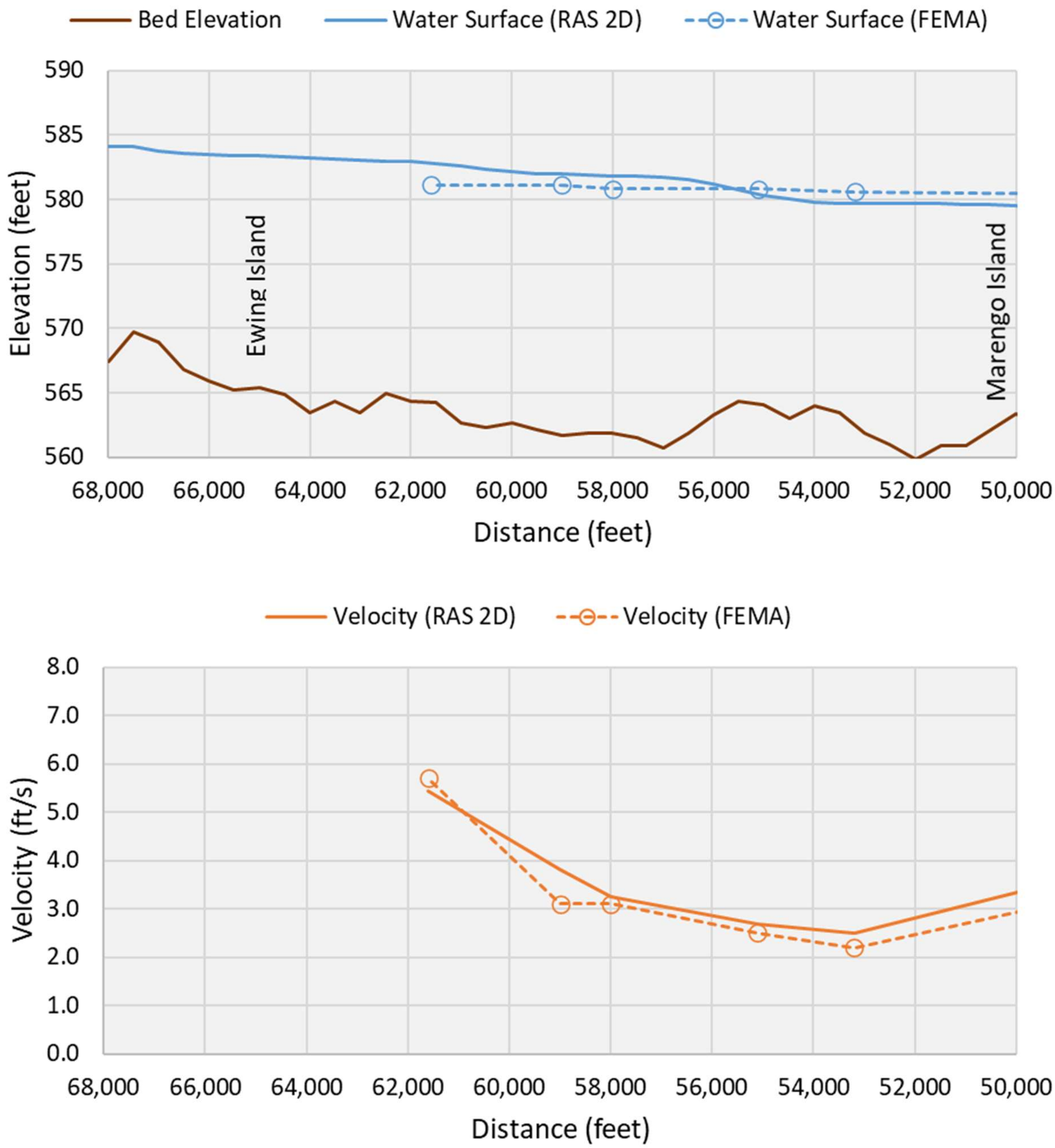

Figure 4. Comparison of FEMA and Project Model Results for 100-year event

Results of the 100-year flood event were also compared with data at NOAA's current meter, which is located near the upstream end of the Toledo Harbor Navigation Channel (Site GL0201). The basis for this comparison was a scatter plot of Maumee River flow and observed current velocity as shown in Figure 5. The model results, shown as red dots, fall along a single trajectory while the data occur in a swath, showing more variability. This is due in part to the fact that the model result was generated using a single, constant value of the Lake Erie water level as a downstream boundary condition, whereas the data occur over a wide range of Lake Erie water levels and seiche conditions. Also, the model result represents the rising limb of the flow hydrograph, which tends to produce higher velocities than the falling limb. Another difference between model and data is that the model represents a vertically-averaged current velocity but the data represents a smaller mid-depth segment of the water. Considering these caveats, the model result shows good consistency with the range and pattern in these observed data.

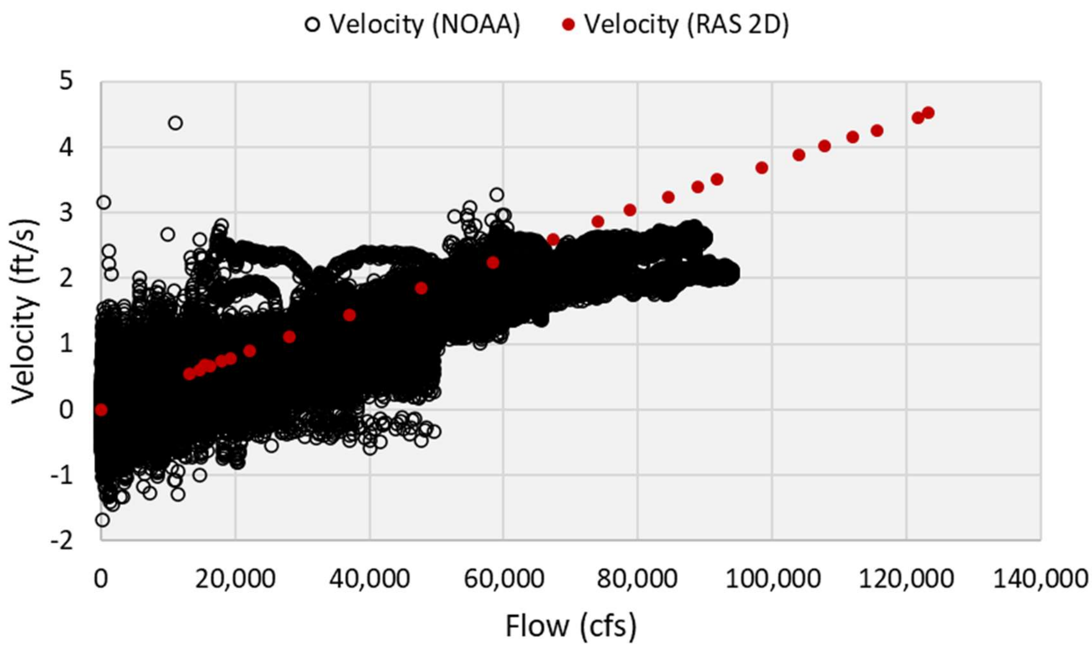

Figure 5. Comparison of NOAA Observed Velocities and Modeled (RAS 2D) Velocities

Second, the model was run for a month-long period in 2009, September 26 through October 16 with significant seiche activity and few data gaps at the NOAA current meter. Modeled velocities were visually compared with observed velocities in time series format, included here as Figure 6 through Figure 8. During most of the month, the model compares suitably well with the observed data. However, during some of the strongest seiche conditions the model underpredicts the amplitude of the seiches effect on current velocities in the lower river. This is especially apparent on October 23 and 24. This bias has the potential to influence the sediment deposition calculations within the coves, as discussed subsequently in section 2.2.3. In Section 2.2 we describe the implications of this bias with regard to the model application. Potential ways to reduce this bias could be to expand the modeled region and/or adjust model parameters related to turbulent mixing or the model solution scheme. For the purposes of this project, however, which is to evaluate project concepts, we consider this degree of model bias to be acceptable.

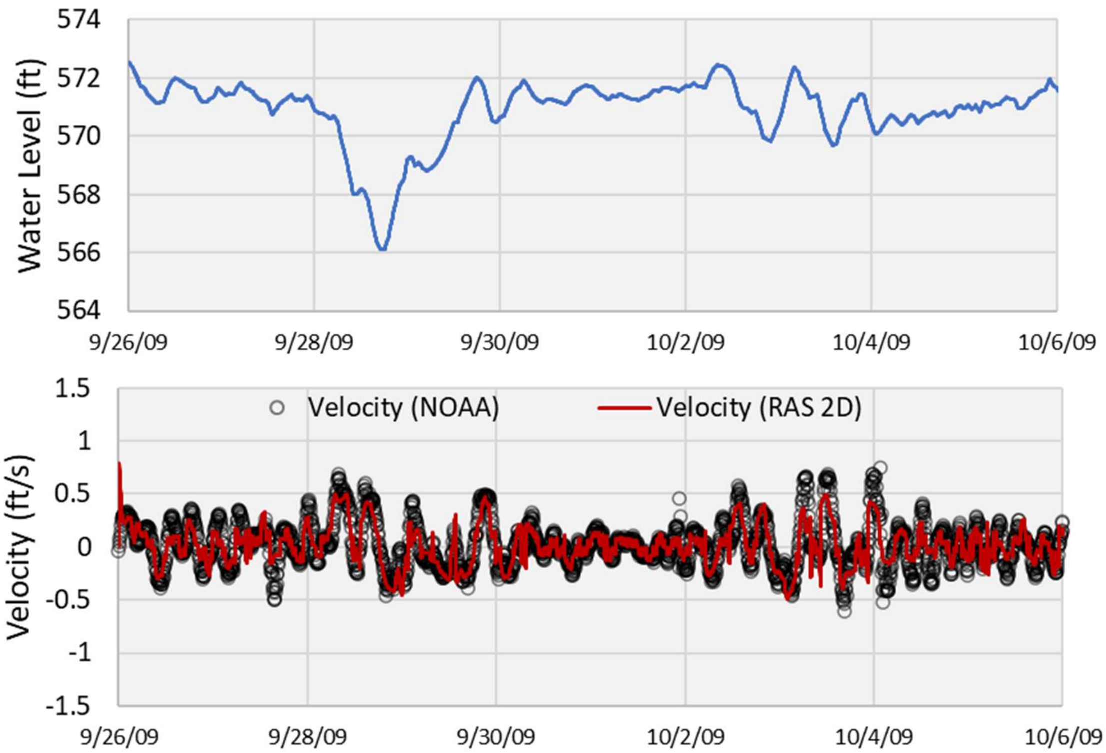

Figure 6. Time Series Comparison of NOAA Observed Velocities and Modeled (RAS 2D) Velocities: Period 1

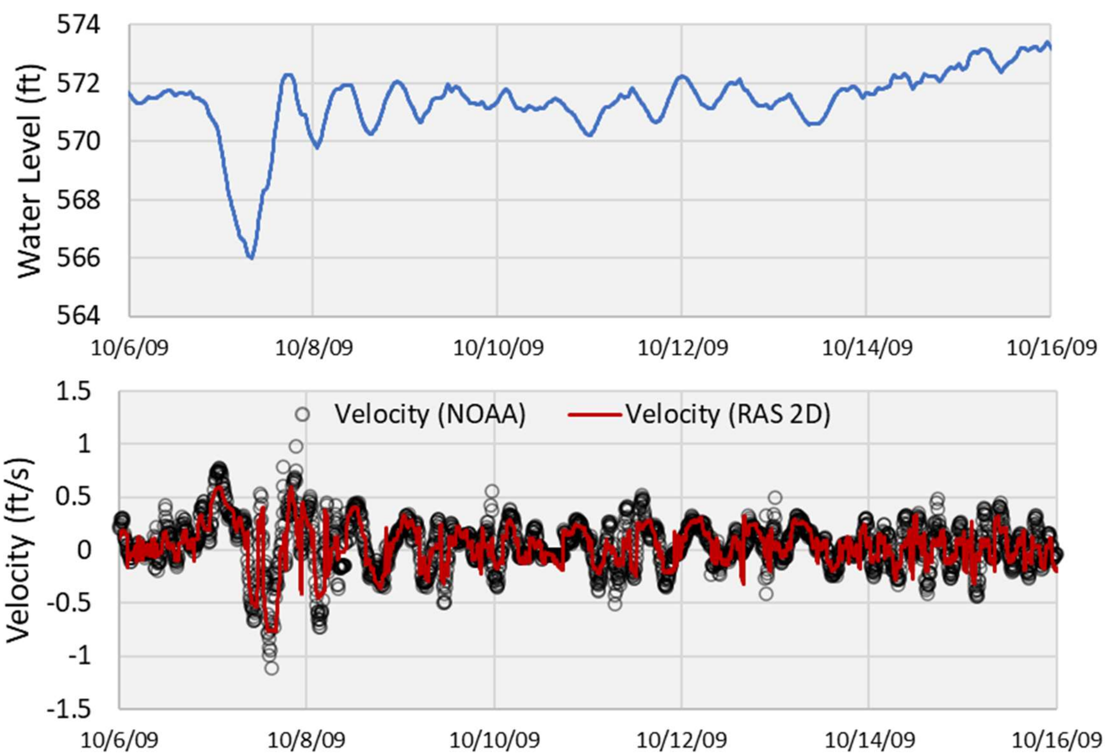

Figure 7. Time Series Comparison of NOAA Observed Velocities and Modeled (RAS 2D) Velocities: Period 2

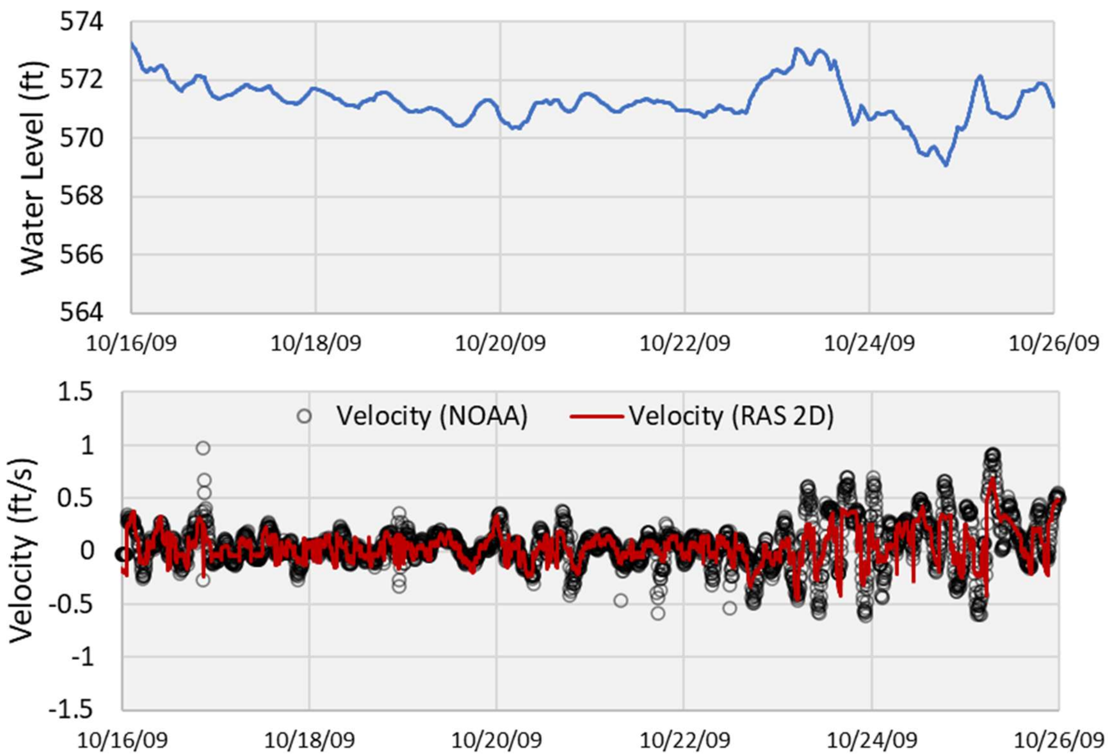

Figure 8. Time Series Comparison of NOAA Observed Velocities and Modeled (RAS 2D) Velocities: Period 3

The conclusion from the model evaluations described above was that the RAS 2D model predictions were adequately similar to observed data and to the FEMA model to confirm the model's usefulness for evaluating design concepts.

2.2 Restoration Concepts Analysis and Design Recommendations

2.2.1 Simulated River Conditions

Two types of model simulations were conducted to support the hydraulics analysis of design concepts:

1. Simulation of the 1%-annual chance event (120,000 cfs) for representing extreme velocities and shear stress;
2. Simulation of low to moderately high flow conditions as steady-state conditions to evaluate the change in river hydraulics with and without conceptual design features.

2.2.2 Audubon Islands Near-bank Habitat

Project partners have recommended the evaluation of placement of root wads, submerged trees, and vegetated reefs at four locations within the Audubon Islands. These features are intended to help stabilize river banks and introduce more heterogeneous near-bank conditions, which is in turn expected to enhance existing habitat. Modeling objectives for this site are to

1. estimate velocities, shear stresses, and depths, with and without project features, both at the site and upstream where there is habitat designated as a high-quality spawning area (Schmidt et al 2020) and
2. assess the likelihood that the existing bank would be disturbed by proposed project features.

Simulations of river hydraulics and review of substrate data under existing conditions support a conceptual understanding of how water and sediments move near the island. This conceptual understanding in turn supports the potential for stable and effective design features at Audubon Islands:

- Audubon Islands is at the upstream end of the lacustuary where there is a rapid transition from faster to slower moving river currents. Project features have generally been located where there are slower moving currents in this relatively energetic reach. However, the main channel habitat feature would likely be better protected by shifting it slightly to the northeast where current velocities and shear stresses are lower.
- Audubon Islands is inundated at a flow of approximately 10-year recurrence (82,000 cfs). Bottom shear stresses in the cove are low, even for the 100-year event (124,000 cfs). This indicates that the coves may be a suitable low-turbidity location for establishment of submerged aquatic vegetation.

This conceptual understanding is illustrated in Figure 9 using model results. Potential project features are outlined in white. Model results are for the 25-year peak flow conditions (about 97,000 cfs).

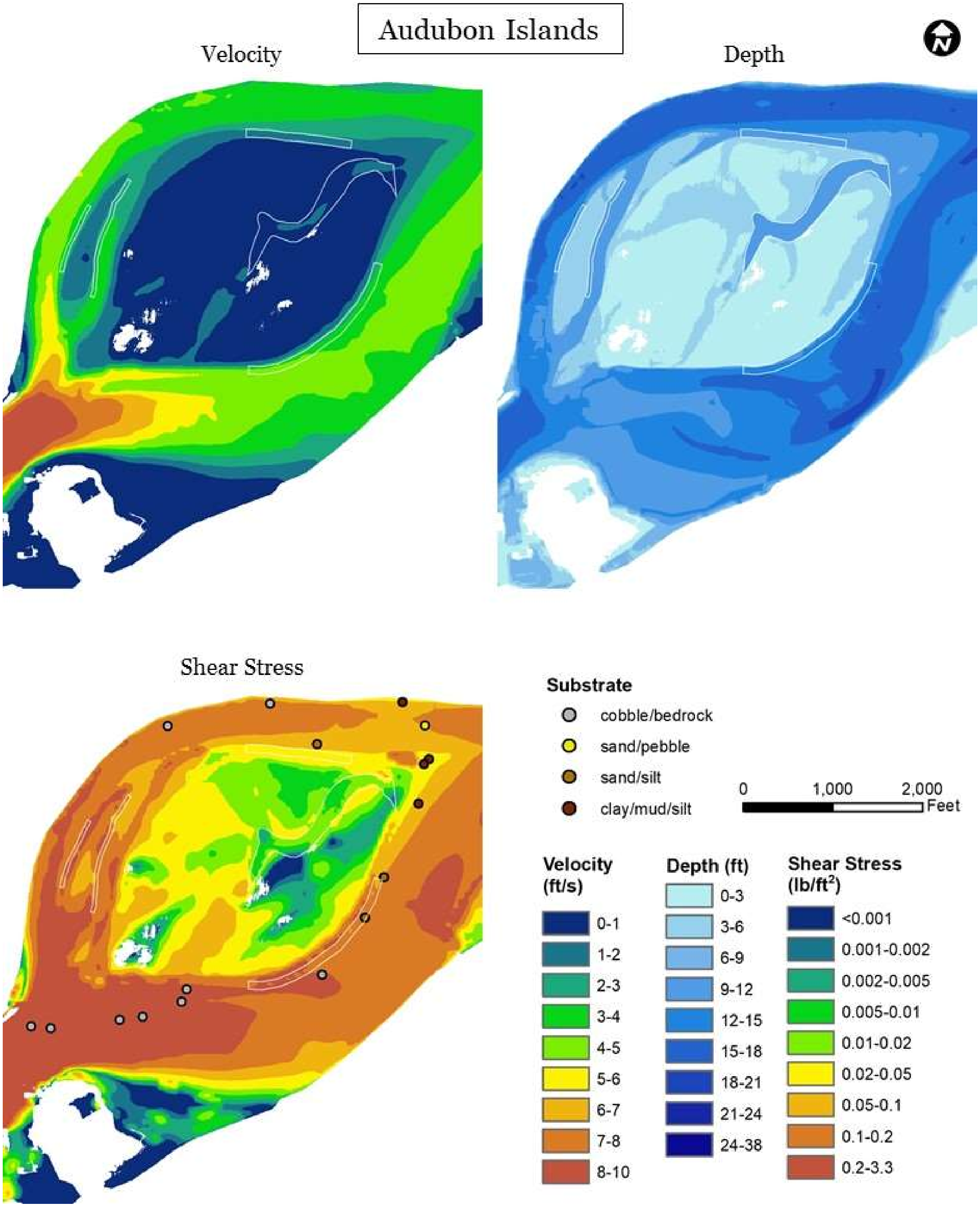

Figure 9. Conceptual Understanding of River Hydraulics near Audubon Islands Pertaining to Habitat Restoration Concepts, 25-year flood event

Restoration features were represented in the model as changes in bottom roughness and Manning's N was set to 0.08 for these features.

Figures below illustrate the impacts of these features on stream hydraulics for four flow conditions: median flows, and the 1-year, 25-year, and 100-year flows. Predicted total shear stresses for all four flow conditions are shown in Figure 10. Velocities, and the change in velocity relative to existing conditions, are shown in Figure 11 for median and 1-year flows. Figure 12 shows velocities, and changes relative to existing conditions, for the 25-year and 100-year flow. Effects of these features on hydraulics and sediment transport are predicted to be as follows:

- Maximum predicted shear stresses near the banks of Audubon Islands are as high as about 0.4 pounds per square feet, which approach thresholds for permissible shear stresses of bioengineering features (National Engineering Handbook, 2007). This island area experiences higher shear stresses than others in the lacustuary and habitat features should be designed carefully for long term durability. Increases in shear stress within the project feature footprints, which are outlined in pink below, are primarily due to the increase in Manning's N from 0.03 to 0.08.
- Habitat features will increase flows and velocities in the main channel and outer side channel to the north of Ewing Island and reduce flows and velocities over the island which would reduce bank erosion potential along the islands. Increases in velocities within the main channel are marginal at (i.e., < 10%) and not expected to produce an appreciable change in sediment transport there.
- Changes in hydraulic conditions in nearby areas designated as high-quality spawning habitat (Schmidt, et al 2020) are predicted to be nominal (<0.25 feet per second).

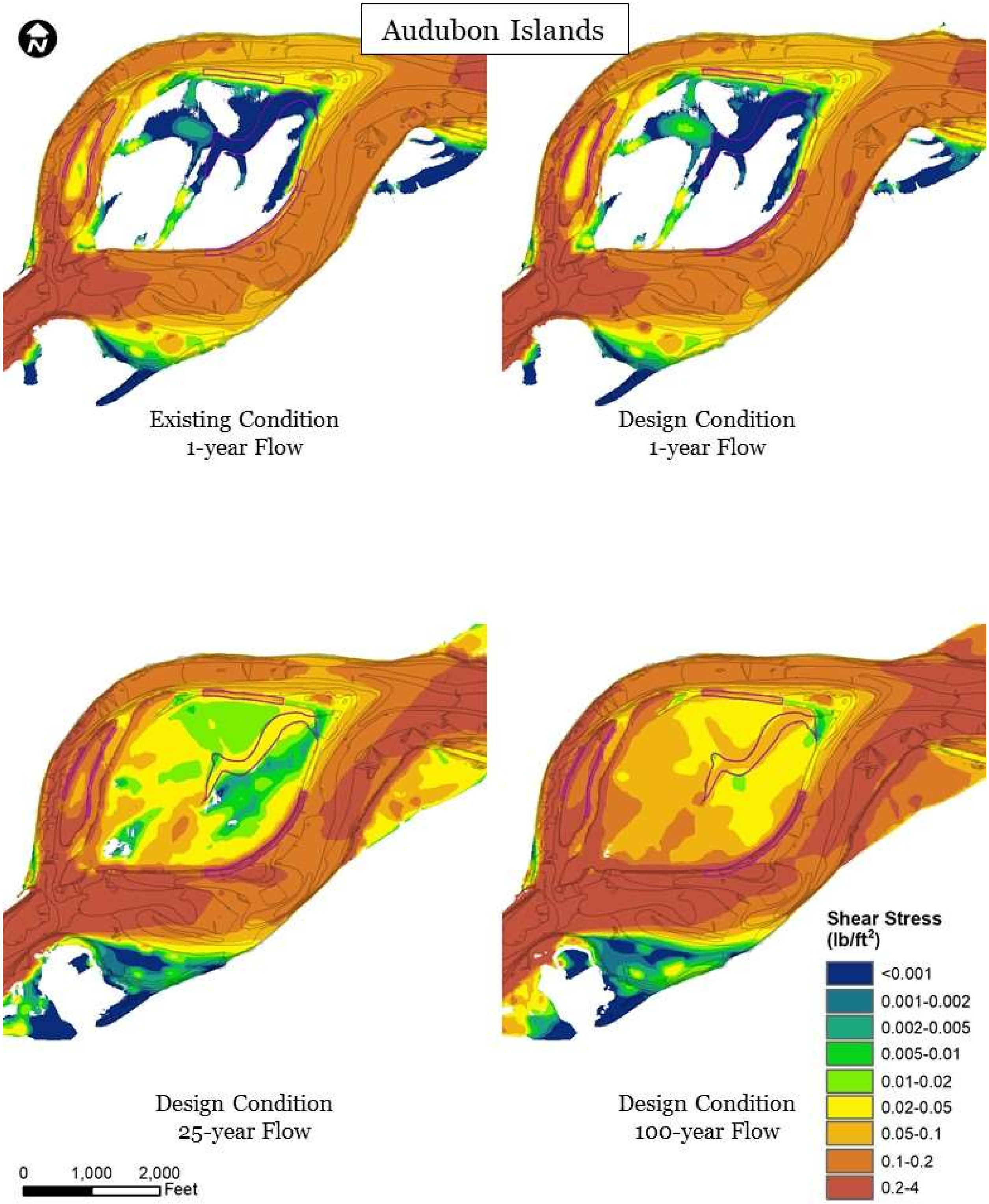

Figure 10. Predicted Audubon Islands Total Shear Stresses

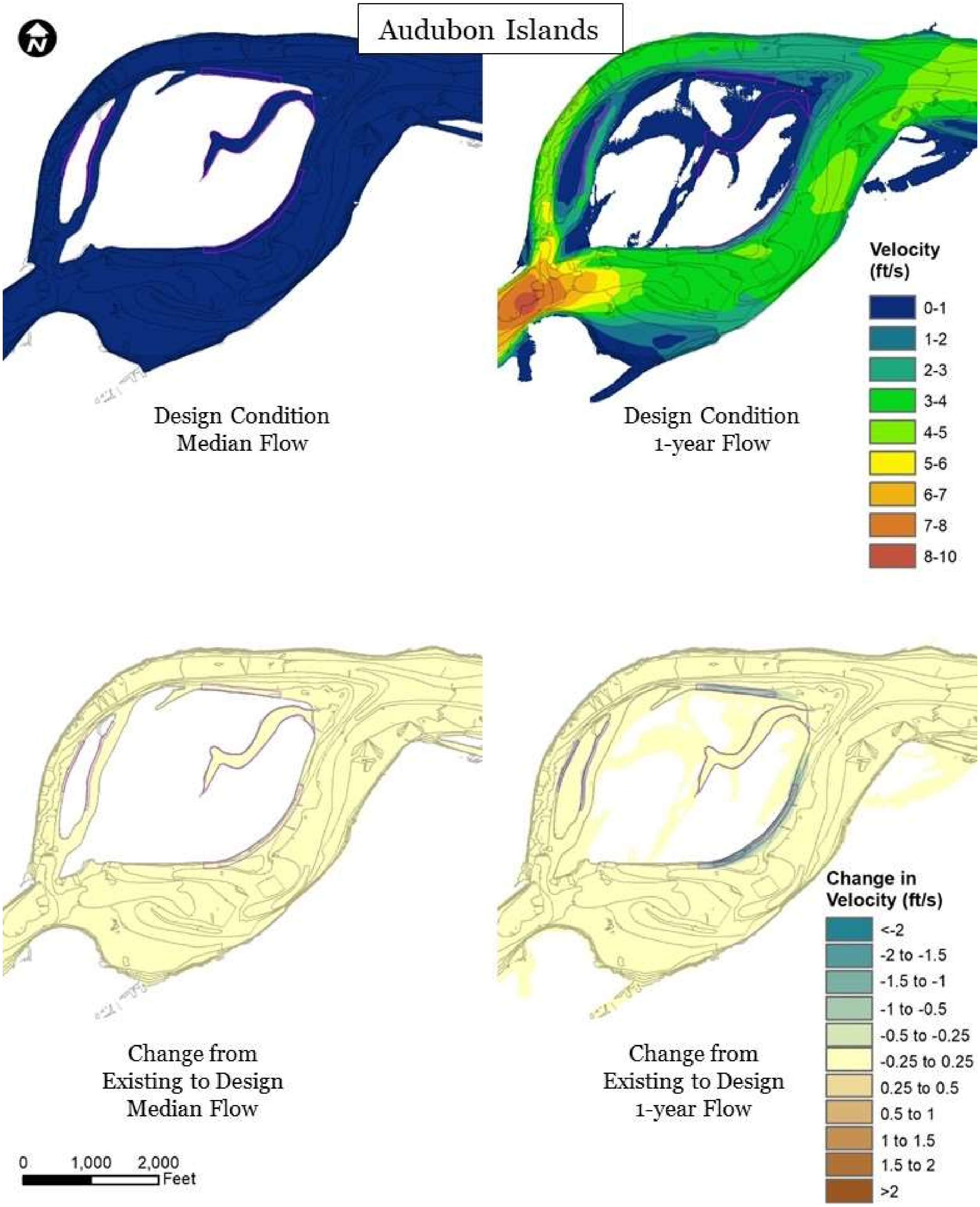

Figure 11. Predicted change in Audubon Islands Velocities due to Proposed Habitat Features (Lower 2 simulated flow conditions)

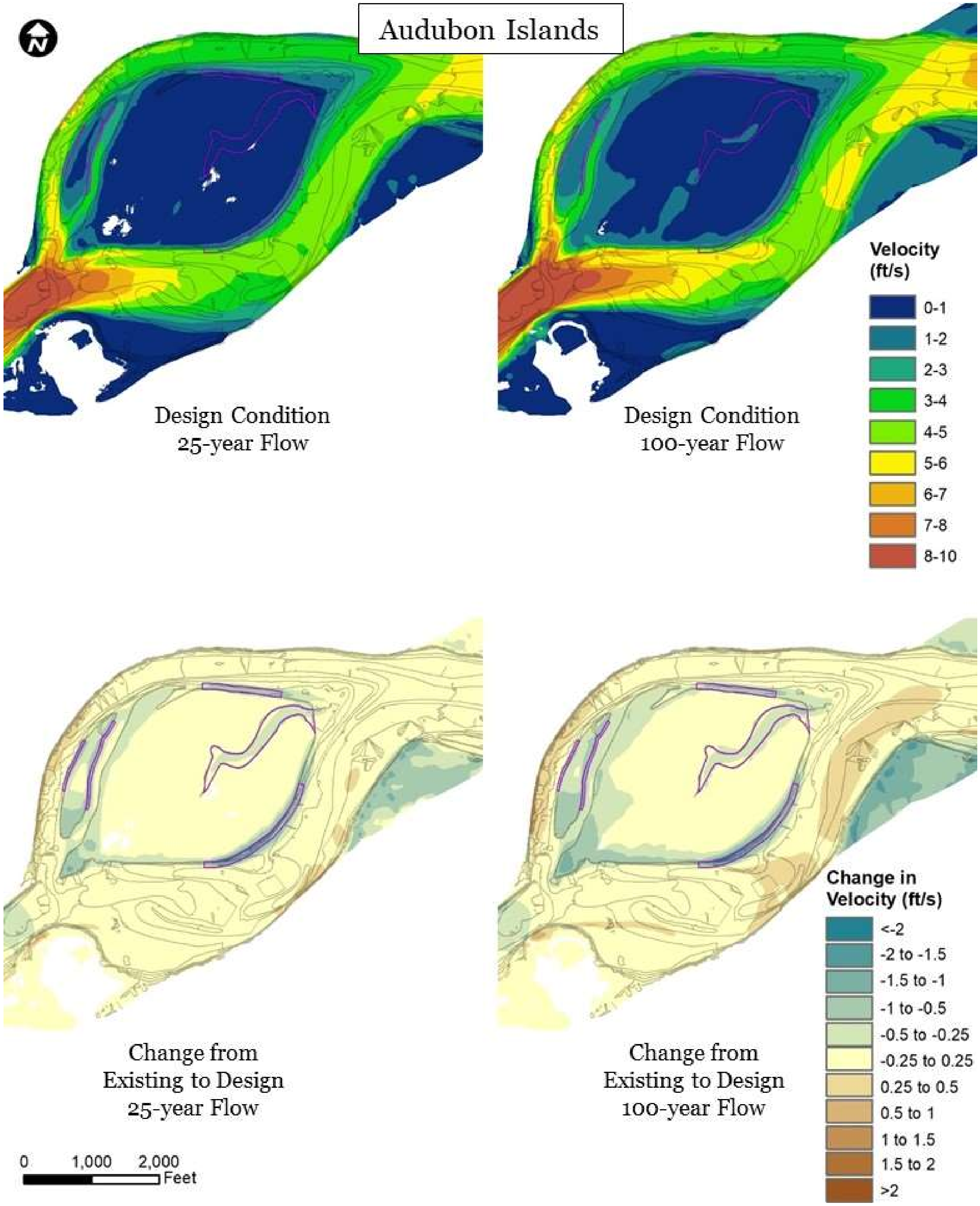

Figure 12. Predicted change in Audubon Islands Velocities due to Proposed Habitat Features (Higher 2 simulated flow conditions)

2.2.3 Submerged Aquatic Vegetation in Coves at Ewing and Delaware Islands

At three locations, one at Audubon Islands and two at Delaware Island, project partners have recommended the evaluation of dredging of soft sediment from cove areas to help establish submerged aquatic vegetation. Modeling objectives for these sites are to evaluate whether long-term suspended sediment concentrations and/or sedimentation rates would limit the potential for SAV establishment in the coves.

Drivers of sediment transport in the coves are the Lake Erie seiche, which can move large quantities of water and sediments through the lacustuary, and high river flows, which can overtop the islands and move water and sediments into the coves.

Suspended sediment concentrations and sedimentation rates in the coves were estimated using a combination of observed data and model results. Total suspended solids (TSS) data from Heidelberg University were used as estimates of suspended sediment concentrations in the lacustuary. Water level data from NOAA were used in combination with HEC-RAS2D modeled water levels to estimate surge- and seiche-induced upstream water and sediment movement into the coves. Downstream flows into the coves during high river flows were estimated using the model. Sedimentation rates were predicted using a simple mass balance approach (Chapra and Reckhow, 1983), which considered residence time of water and typical settling rates for fine-grained particles.

Sedimentation rates and suspended solids concentrations were calculated for a 17-year period from August 2002 through September 2019. This period was selected based on the overall completeness of the six-minute water level data; there were also about 8,500 TSS measurements from the Heidelberg data set over this same period. The calculations were performed using a wide range of settling velocities, and for a range of project excavation depths from existing conditions (bottom elevation of 571) to four feet of excavation. The total mass settled was converted to a sediment depth using an assumed bulk density of 0.6 g/cm^3, intended to be representative of soft sediments.

The sedimentation rate calculation results are shown in Figure 13. Existing rates are estimated to be around 2.0 cm/year, increasing by up to 25% for excavation depth of four feet. The rates do not increase significantly at the higher end of the range of settling velocities, suggesting that the process is limited by available mass.

Average TSS concentrations for a growing season defined as April through October are shown in Figure 14. The concentrations stay below a threshold value of 25 mg/L (UMRCC, 2003) for the full range of settling velocities, with negligible increases predicted for the excavated conditions.

High flows that inundate the islands are expected to also contribute to sedimentation in the coves. A conservative estimate of the mass of sediment delivered in this fashion was made using a combination of data and HEC-RAS model results, following this methodology:

1. A RAS model with ramped flow was used to find a threshold above which the islands were inundated, and to determine the fraction of the total flow that passes across the cove areas;
2. Starting with daily flow data from the USGS gauge at Waterville for the same 17-year period as the seiche-driven calculations, days where inundation occurred were determined along with the volume of flow across each island;
3. Mass sediment loads were calculated using Heidelberg TSS data and the flows obtained in step 2;
4. Total depths of accumulated sediment were calculated assuming that all the load settled, converting to volume using the same bulk density of 0.6 g/cm^3 used for the seiche-driven calculations.

The resulting sedimentation rates are summarized in Table 1, along with the total number of days of inundation through the 17-year period. In combination with the seiche-driven rates, the totals range from around 2.0 to 6.0 cm/year. The higher end may be undesirably high for establishment of SAV, but it is noted that the calculated rates are conservatively high, based on the assumption of complete settling for inundated conditions as well as the relatively low bulk density of 0.6 g/cm^3.

Table 1. Calculated Sedimentation Rates from Island Inundation

Location	Average Sedimentation Rate (cm/yr)	Days of Inundation over 17-Year Period
Ewing	1.52	13
Delaware East	3.68	36
Delaware West	1.69	17

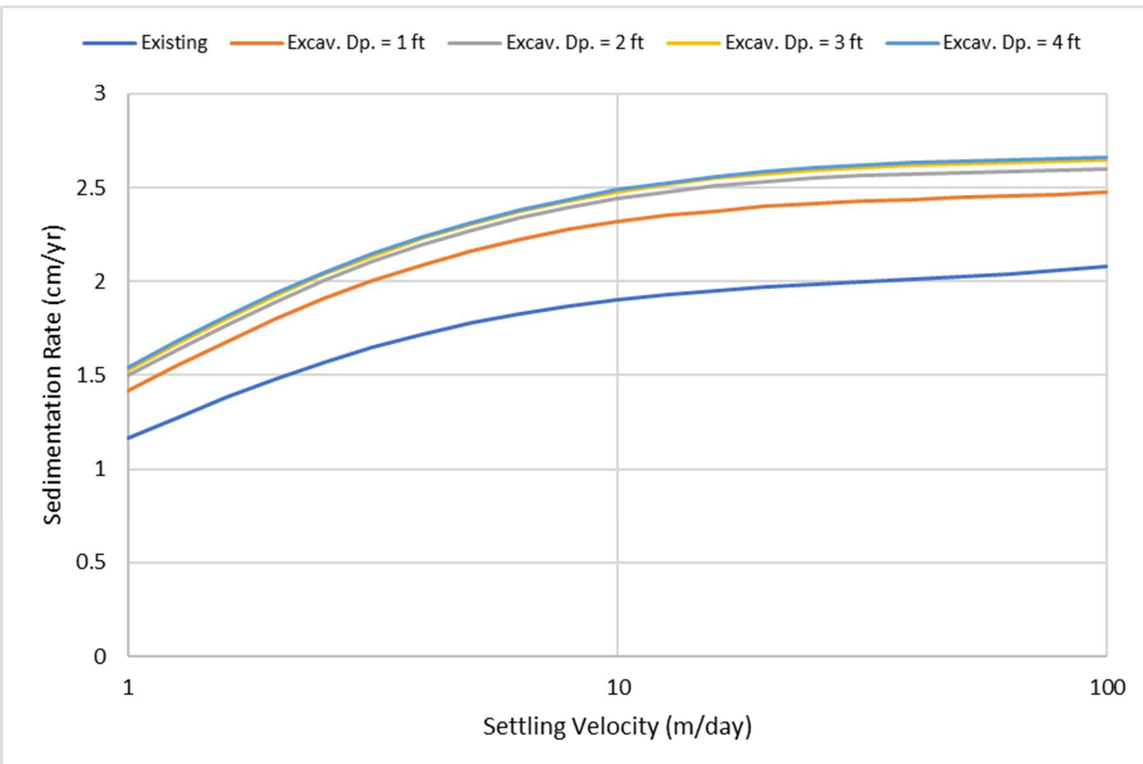

Figure 13. Sedimentation Rates for Seiche-Driven Solids Loading into Coves: Existing Conditions and Project Excavation Rates from 1 to 4 feet

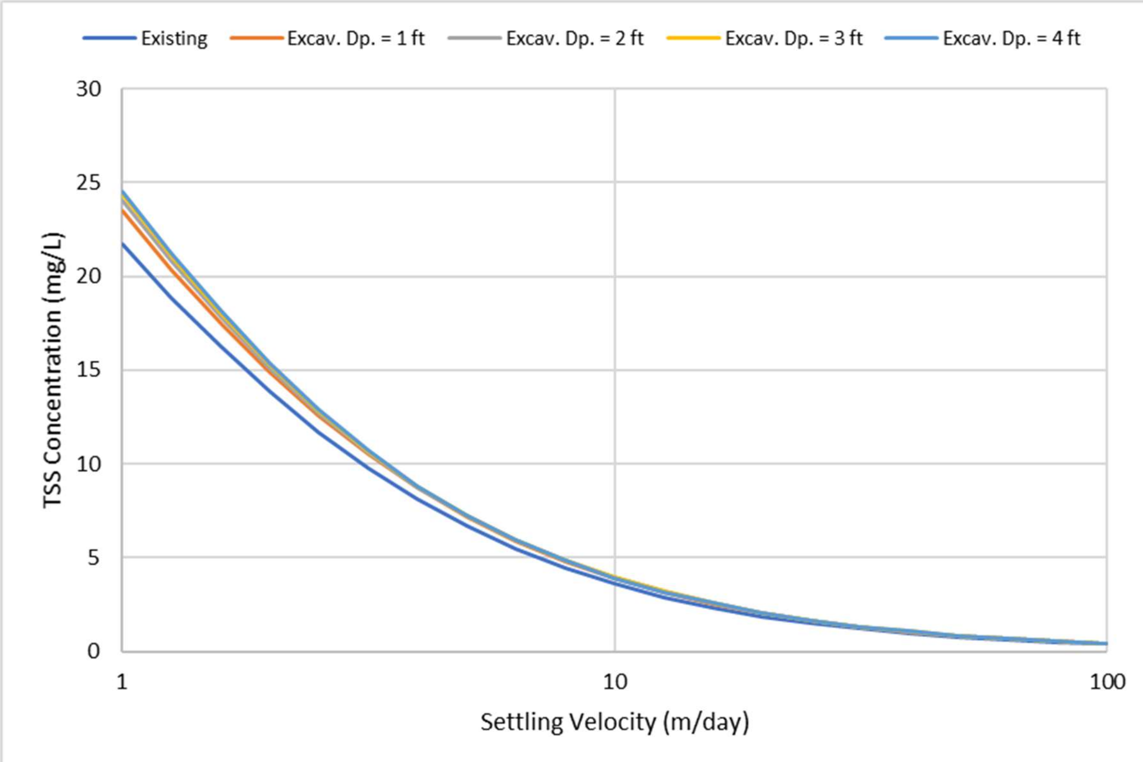

Figure 14. Average TSS Concentration in Coves from Seiche-Driven Solids Loading (April-October): Existing Conditions and Project Excavation Rates from 1 to 4 feet

2.2.4 Marengo Island Structural Protection

At Marengo Island, project partners have recommended the evaluation of construction of a chevron dike or similar structure to force water around the island and promote sediment accretion downstream of the structure and along the island. Also under consideration is the construction of small habitat islands on the downstream side of Marengo Island where there is protection from stronger river currents to some degree by the island. Modeling objectives for this site are as follows:

1. To identify the best location, shape, and length of the structure to protect the island and potentially accrete sediment; and
2. To evaluate whether the upstream areas of the structure is expected to become suitable over time for fish spawning habitat.

Simulations of river hydraulics and review of substrate data near Marengo Island under existing conditions support a conceptual understanding of how water and sediments move near the island. This conceptual understanding in turn supports the potential for effective design features at Marengo Island:

- Marengo Island is at a widening section of the Maumee River. In the center of the channel, south of Marengo Island, currents are faster moving and substrate is sandier. North of the island currents are somewhat slower and substrate is siltier. This indicates that transport rates of sand are lower to the north of the island, and a protective structure would be more likely to accrete sediments on the southern side of the island.
- Marengo Island is inundated at a flow of approximately 1-year recurrence (57,000 cfs). Bottom shear stresses are highest along the upstream edge of the island and increase with flow rate up to about 0.5 pound per square foot for the 100-year event (124,000 cfs).

This conceptual understanding is illustrated in Figure 15 using model results for the 25-year peak flow conditions (about 97,000 cfs).

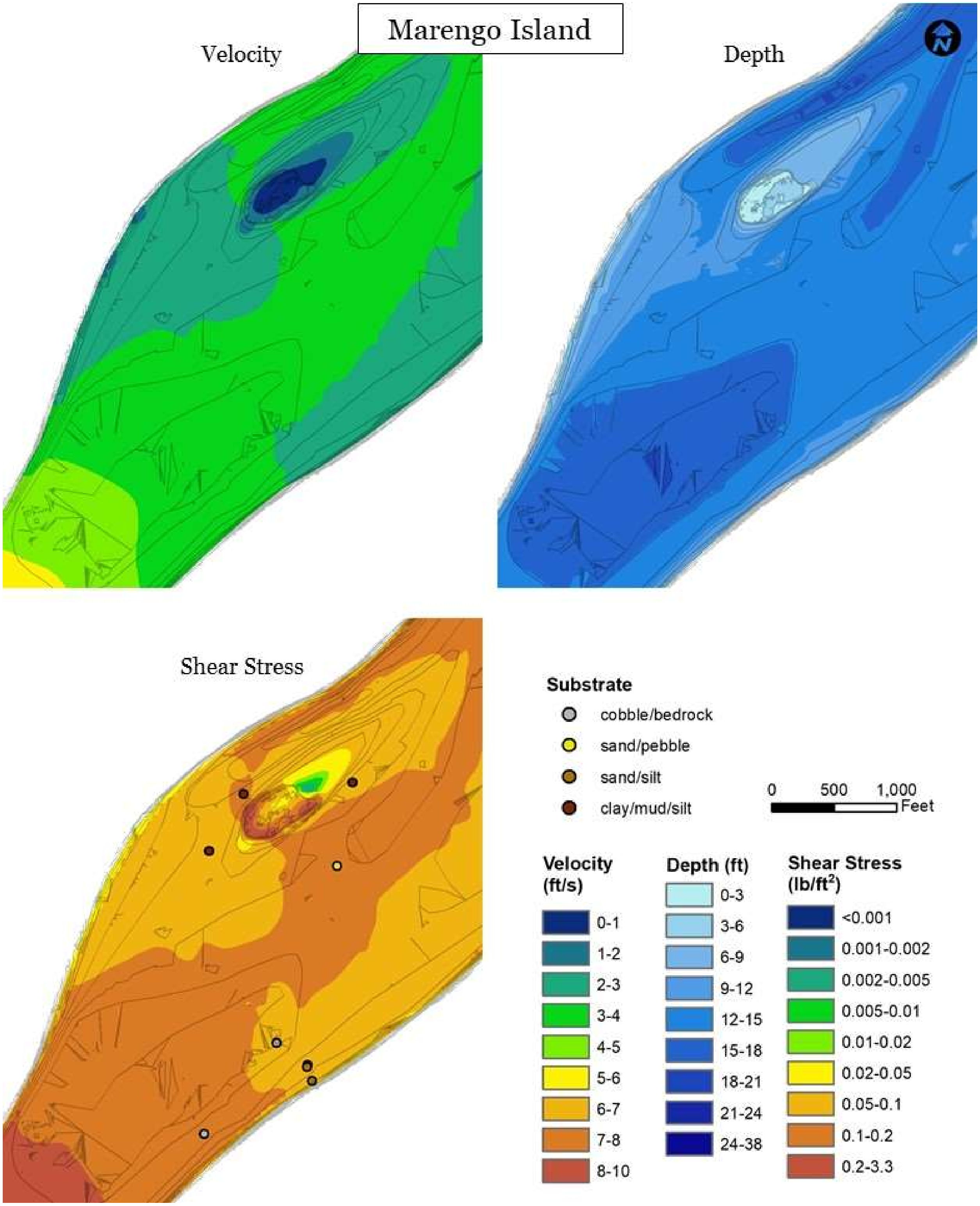

Figure 15. Conceptual Understanding of River Hydraulics near Marengo Island Pertaining to Habitat Restoration Concepts, 25-year flood event

Modeled shear stresses at Marengo Island increase with flow rate as shown in Figure 16. Shear stresses are highest on the upstream face of the island and the southern side of the island.

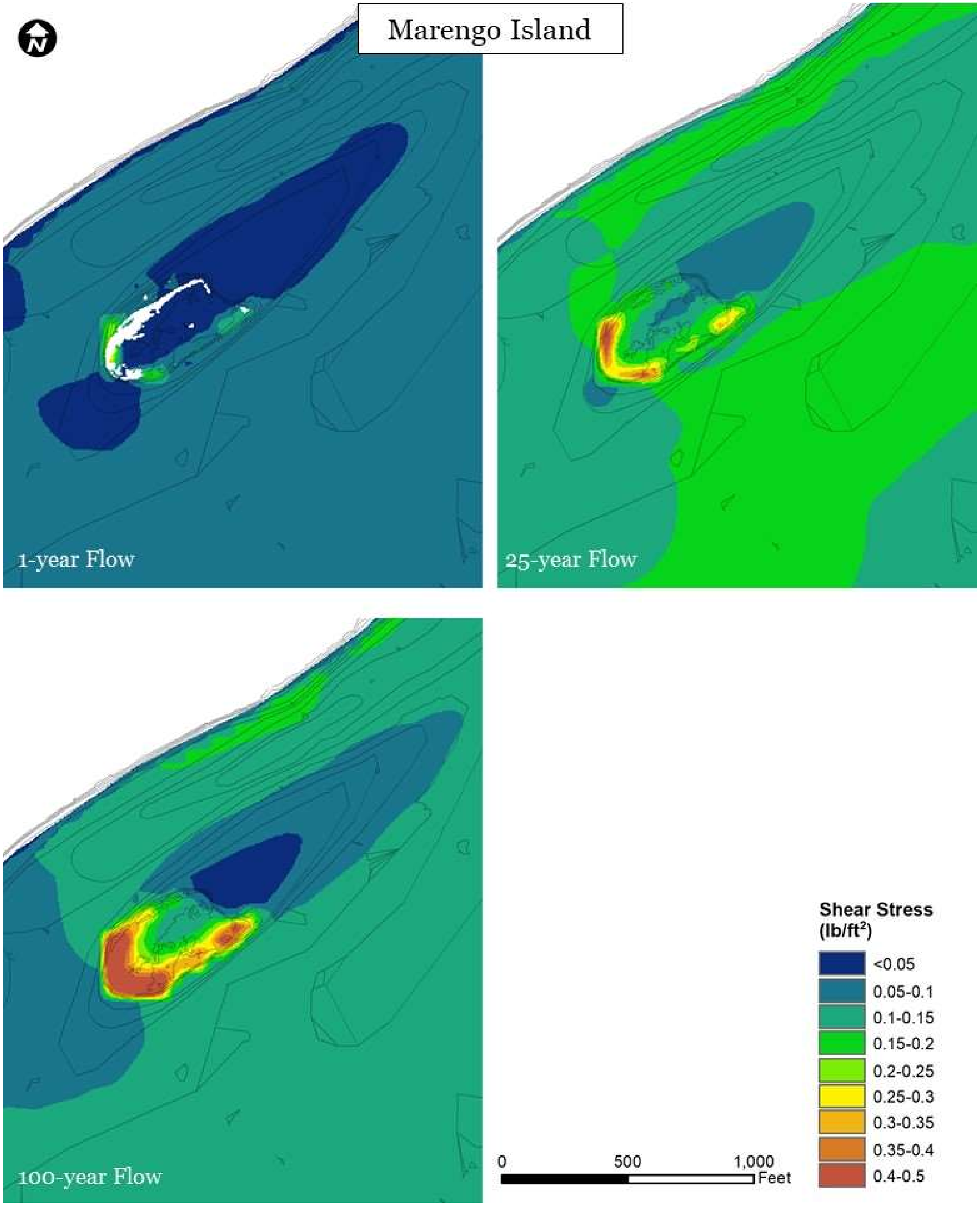

Figure 16. Predicted Marengo Island Shear Stresses: Existing Conditions

A study evaluating the effect of structural dimensions on sediment accretion (Roy et al, 2021) was reviewed for its applicability and principles related to Marengo Island. Principles from the study are informative for design of a dike for Marengo Island. For example, the study identifies different scour morphologies and looks for relationships among various dimensionless parameters that may indicate a tendency for the formation of one morphology over another. Given that a specific morphology is preferred in this case, the study results may provide some guidance in the dike design, in particular the height of the structure. However, the Maumee River at Marengo Island is notably different dimensionally from the flume that was studied. For example, the Maumee River near Marengo Island has much finer substrate ($D50 < 75$ microns in the Maumee River, $D50 = 1{,}000$ microns in the flume). In addition, the island is offset farther from the center of the channel than any of the flume experiments, so the effect on scour morphology cannot be inferred to the same extent. As such, the analysis described below mainly relies on interpretation of model results, data, and principles from the study and not specific quantitative results from the study.

Four configurations of the structure were simulated to illustrate their effect on the island and surrounding bed area. These configurations include two smaller structures that fit within the Marengo Island property lines and two larger structures that extend upstream of the property line. Each of these structure sizes were tested for two structure orientations: one that is aligned with Marengo Island and one that is skewed into the main channel, which was evaluated for its potential to capture more sediment accretion on the south side of the island. Findings from this analysis were that:

- Structure orientation and size are critical factors in designing a structure that will protect the island. There is some risk in designing a structure that would increase shear stresses on the downstream side of the island.
- All but one of the four design conditions (#1 of 4) increased shear stresses on the northern edge of the island. The condition that was more protective of the island extended farther north than the other three and was longer than two of the other three.
- All simulations produced somewhat significant increases in velocities (i.e., > 25%), especially north of the structure where substrate is currently fine-grained (clay / silt). If this concept moves forward, detailed design should include some evaluation of whether significant morphologic change would occur (i.e., scour and deposition), and what effect this would have on the function of the structure.
- Sediment accretion downstream of the structure is expected to be fairly limited in spatial extent relative to the island footprint, and would mostly occur between the structure and the upstream end of the island where shear stresses would rarely exceed typical thresholds for suspension of coarse sands (~0.05 lbs/ft^2).
- Along the upstream edge of the structure, there will be some area where velocities increase and some areas where velocities decrease, which may provide opportunities for additional habitat.
- Additional simulations may be conducted to evaluate whether design adjustments may produce a more effective design and/or a design that could be effective and limited in extent within the island property.

Figure 17 shows modeled shear stresses for existing condition and for each of the four dike configurations. Velocities, and the changes in speed relative to existing conditions, for the 25-year and 100-year events are shown in Figure 18 through Figure 21 for the four simulated design conditions.

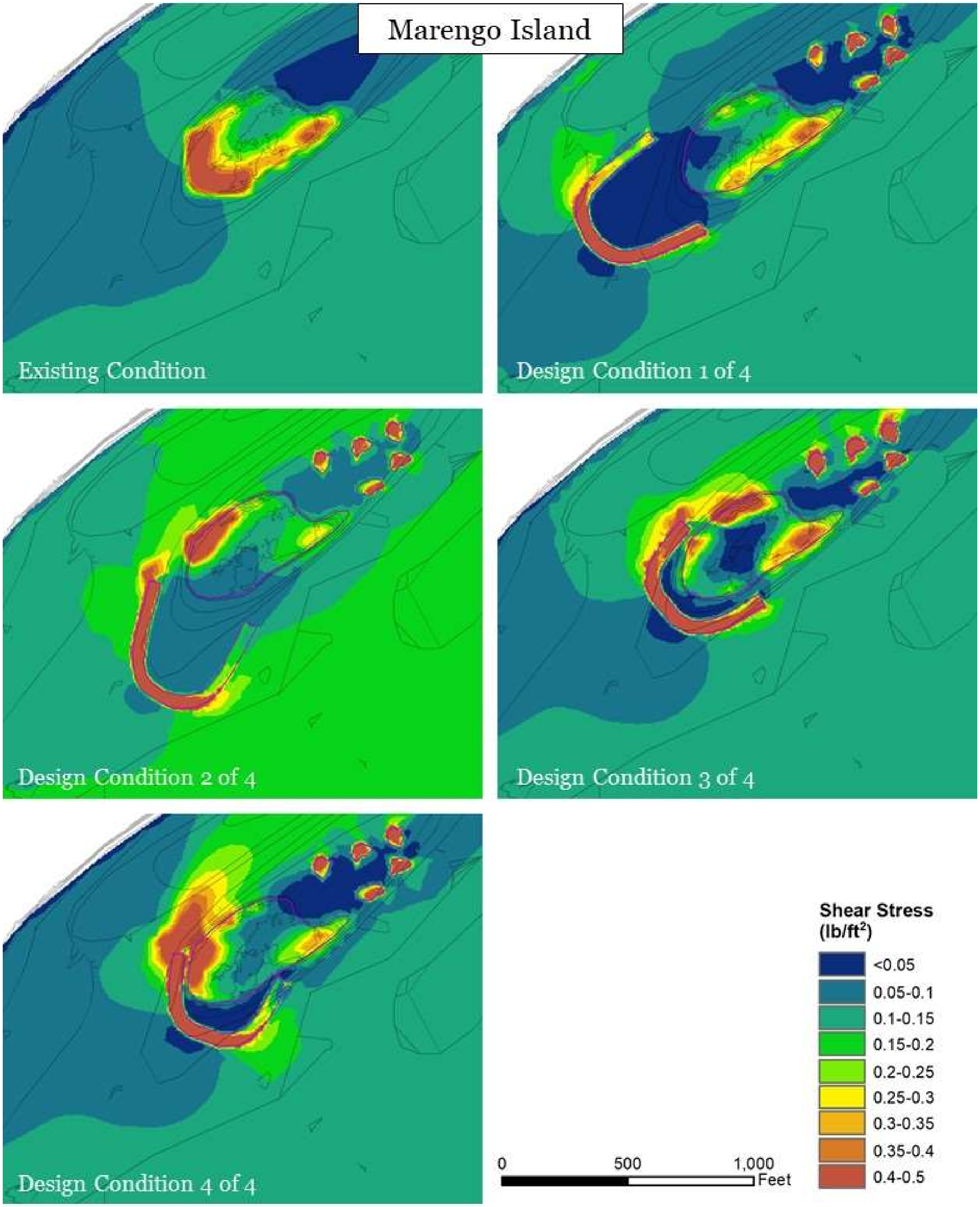

Figure 17. Predicted Marengo Island Shear Stresses: 100-year flow

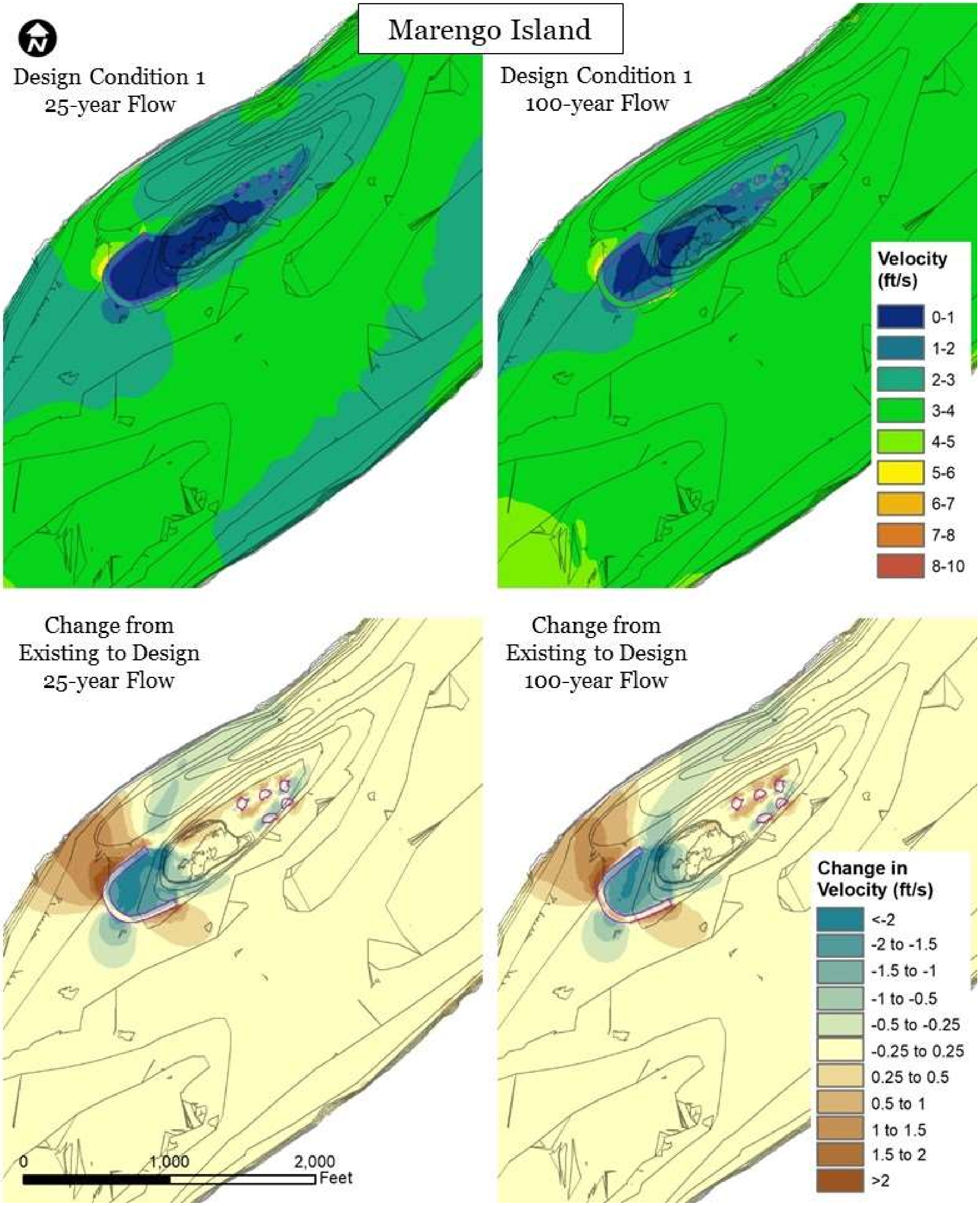

Figure 18. Predicted change in Marengo Island Current Velocities due to Proposed Protective Structure: Design Condition 1 of 4, 25- and 100-year flow conditions

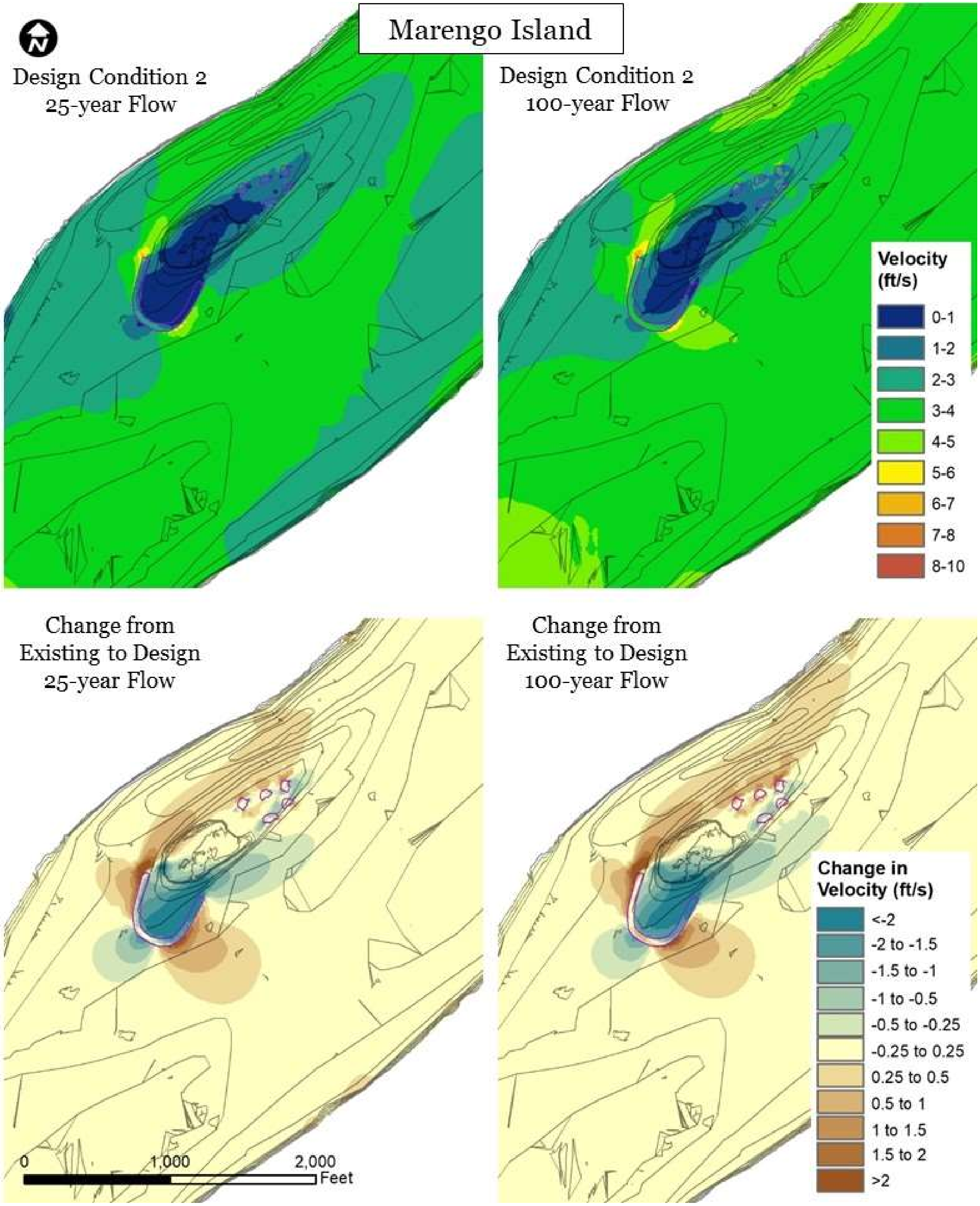

Figure 19. Predicted change in Marengo Island Current Velocities due to Proposed Protective Structure: Design Condition 2 of 4, 25- and 100-year flow conditions

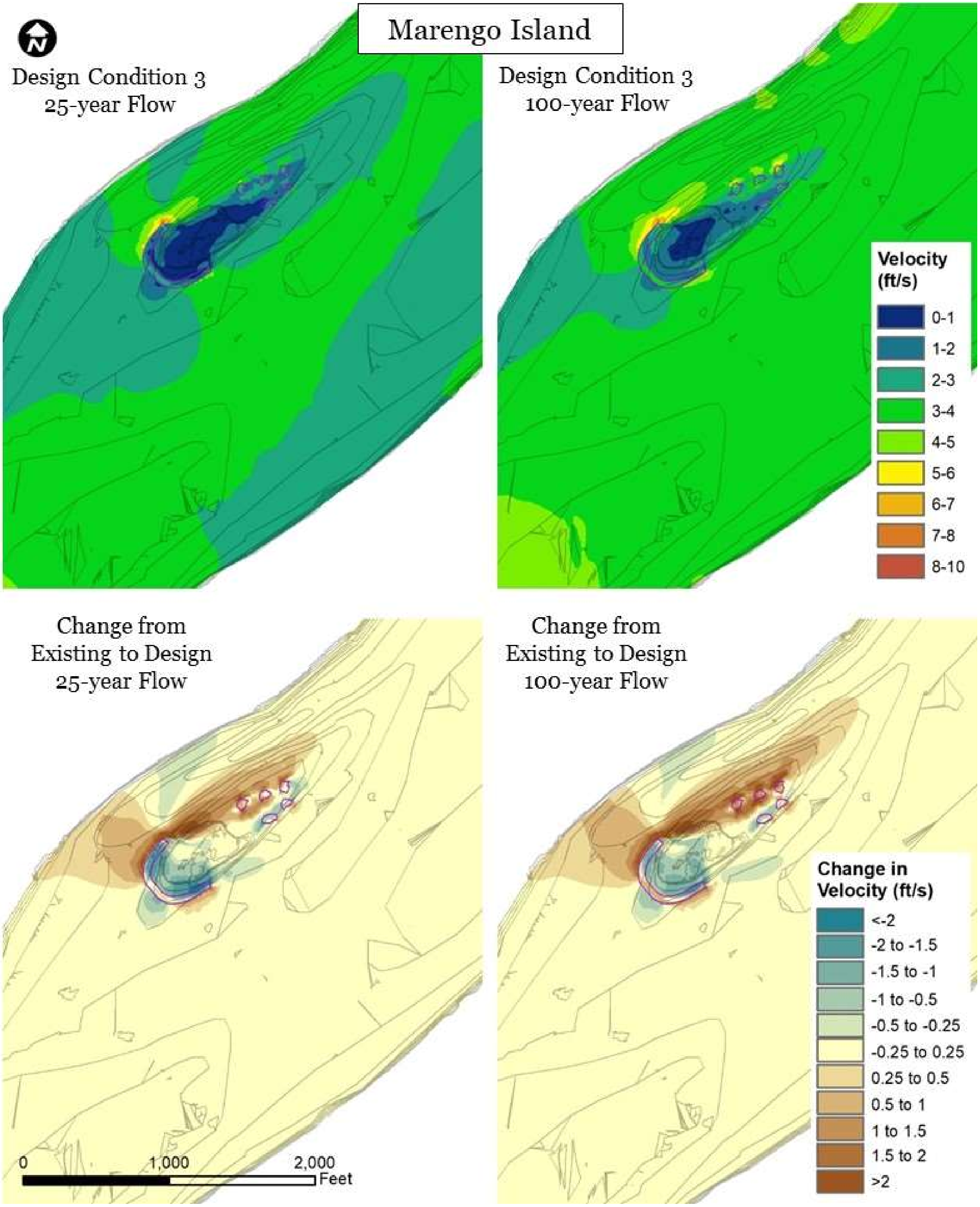

Figure 20. Predicted change in Marengo Island Current Velocities due to Proposed Protective Structure: Design Condition 3 of 4, 25- and 100-year flow conditions

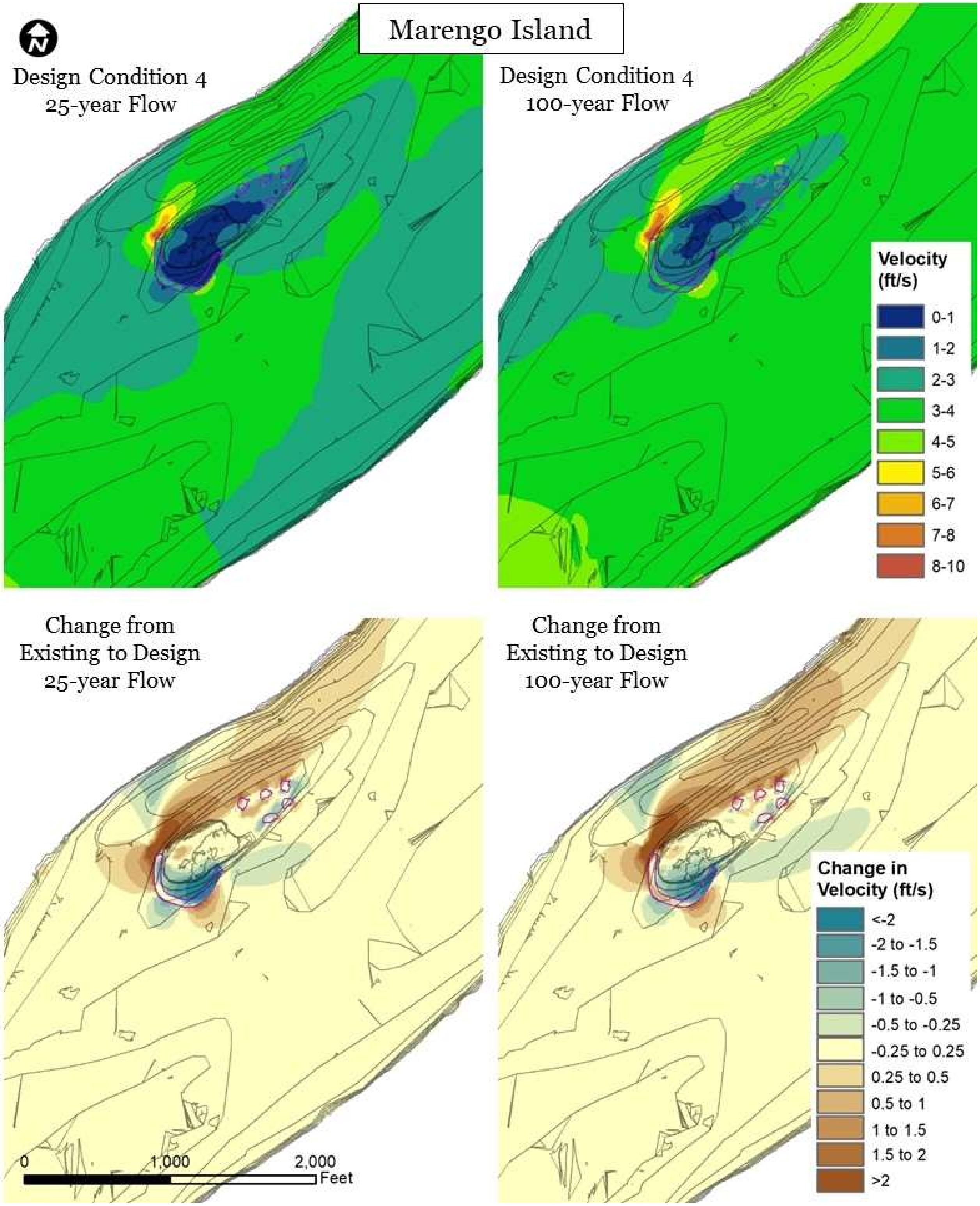

Figure 21. Predicted change in Marengo Island Current Velocities due to Proposed Protective Structure: Design Condition 4 of 4, 25- and 100-year flow conditions

2.2.5 Features near the Delaware/Horseshoe Complex

At Delaware/Horseshoe Complex, project partners are considering the construction of habitat features that would enhance heterogeneity of hydraulics, substrate, and habitat within the island complex. Features under consideration include 1) a long rock reef structure connecting Delaware Island and the small remnant of Horseshoe/Long Island that would effectively establish a much larger cove area, 2) a set of small built islands between Delaware/Horseshoe Complex and the Horseshoe/Long Island remnant, and 3) connection of the two islands at Delaware/Horseshoe Complex to create a cove area where there is currently a channel between the two islands.

Simulations of river hydraulics and review of substrate data near Delaware/Horseshoe Complex under existing conditions support a conceptual understanding of how water and sediments move near the island, as shown in Figure 22:

The Delaware/Horseshoe Complex is at a relatively wide and deep section of the Maumee River as it approaches the navigation channel. In the center of the channel, currents are faster moving and substrate is coarser. Near Delaware/Horseshoe Complex currents are somewhat slower and substrate is siltier. However, there are two locations along the island complex that experience relatively high shear stresses: 1) along the upstream end of the eastern section of Horseshoe Island which is now separated from the western part of Horseshoe Island by a narrow channel, and 2) the small remnant of Horseshoe/Long Island about 500 feet downstream.

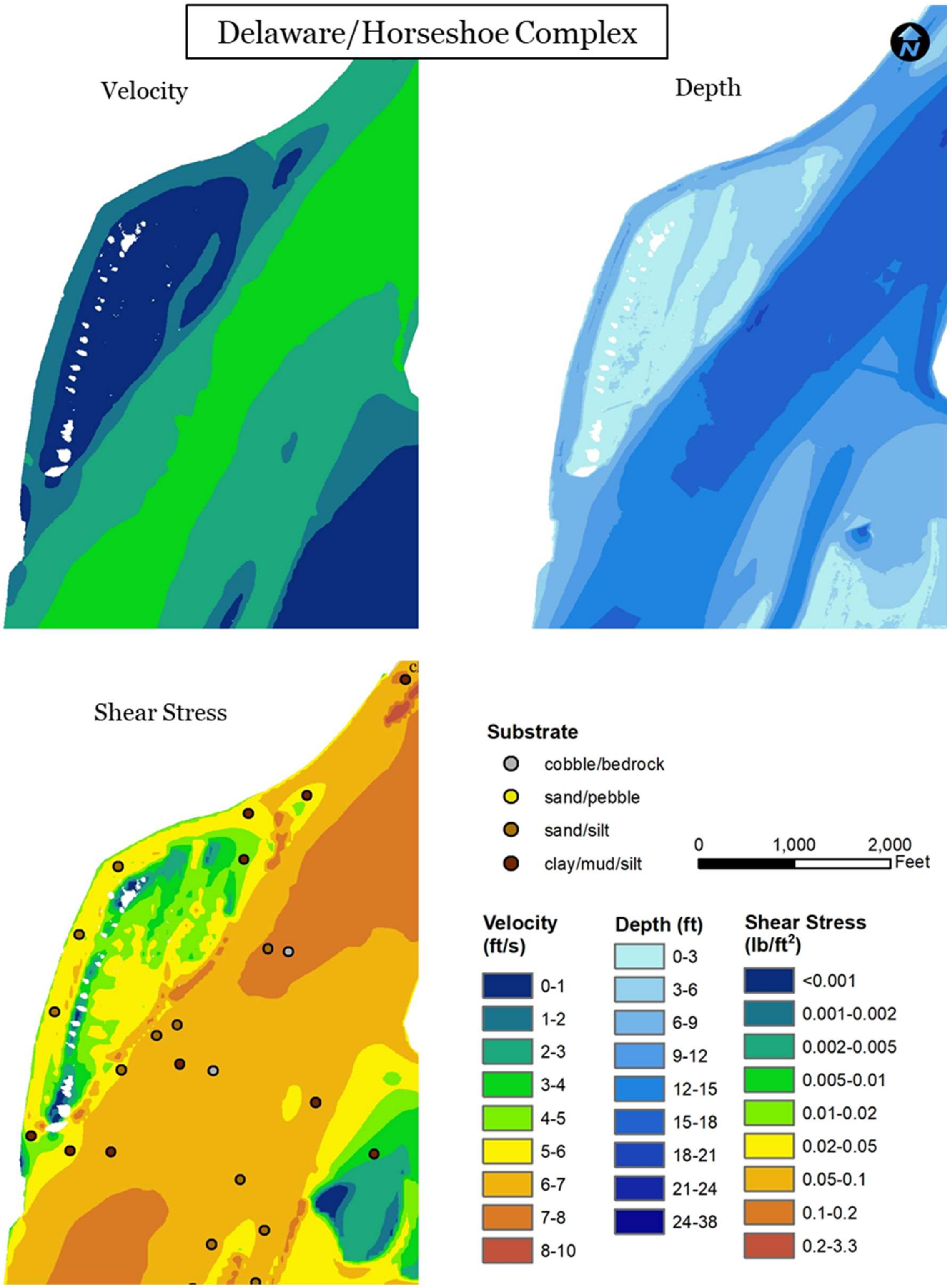

Figure 22. Conceptual Understanding of River Hydraulics near Delaware/Horseshoe Complex Pertaining to Habitat Restoration Concepts, 25-year flood event

Two configurations of the Delaware/Horseshoe Complex habitat concepts were simulated to illustrate their effect on the island and surrounding bed area. In both configurations, the two segments of Horseshoe Island are connected by a berm at the upstream end to close off the downstream cove area. In one configuration there is a rock reef structure connecting the downstream end of the eastern segment of Horseshoe Island to the Horseshoe/Long Island remnant. The crest elevation for this reef was assumed to be 574 feet which would make it most effective at lower lake level and lower river flow conditions. In the other configuration this reef is not present and instead there are three islands between Delaware Island and the Horseshoe/Long Island remnant. Findings from this analysis were that:

- A berm connecting the two segments of Horseshoe Island would be effective at reducing velocities and shear stresses in the cove area for potential establishment of submerged aquatic vegetation.
- A reef structure connecting Horseshoe Island and the Horseshoe/Long Island remnant would make for a much larger and mostly quiescent cove area downstream of Delaware Island, especially during frequently-occurring high flow conditions (i.e., the 1-year event).
- Alternatively, a series of smaller islands between Delaware Island and the Horseshoe/Long Island remnant would introduce greater variations in current velocities at this location which could promote a greater diversity of substrate and habitat conditions.
- Impacts of all of these features are predicted to be localized, largely because the river cross-section is relatively wide at Delaware Island.

Figure 23 shows model-predicted shear stresses around the Delaware island complex for existing conditions, and for the 1-year event the two design conditions. Figure 24through Figure 27 illustrate the simulated impacts of the Delaware/Horseshoe Complex concepts on current velocities for the median flow, 1-year, 25-year and 100-year events.

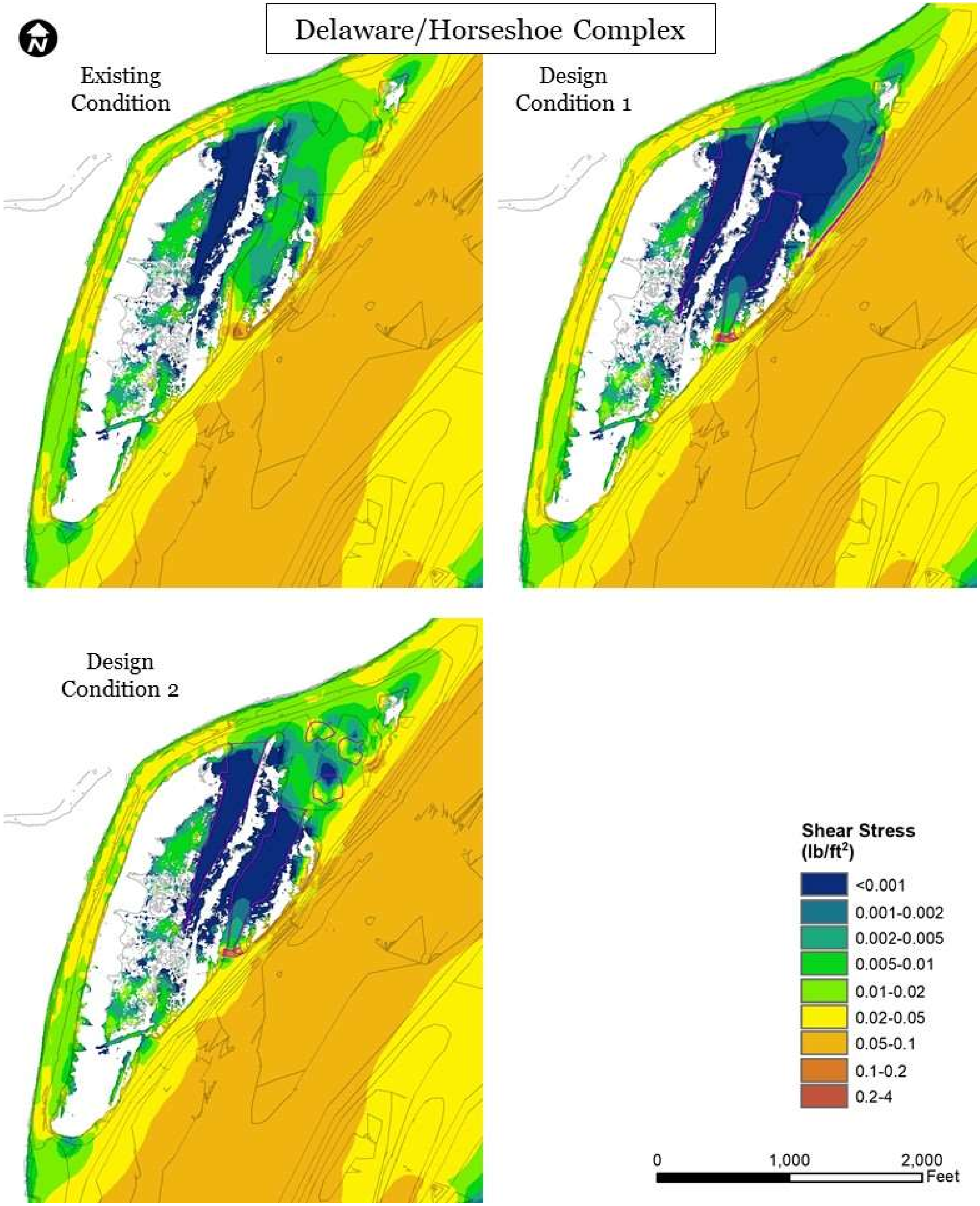

Figure 23. Predicted Delaware/Horseshoe Complex Total Shear Stresses, 1-year Flow Event

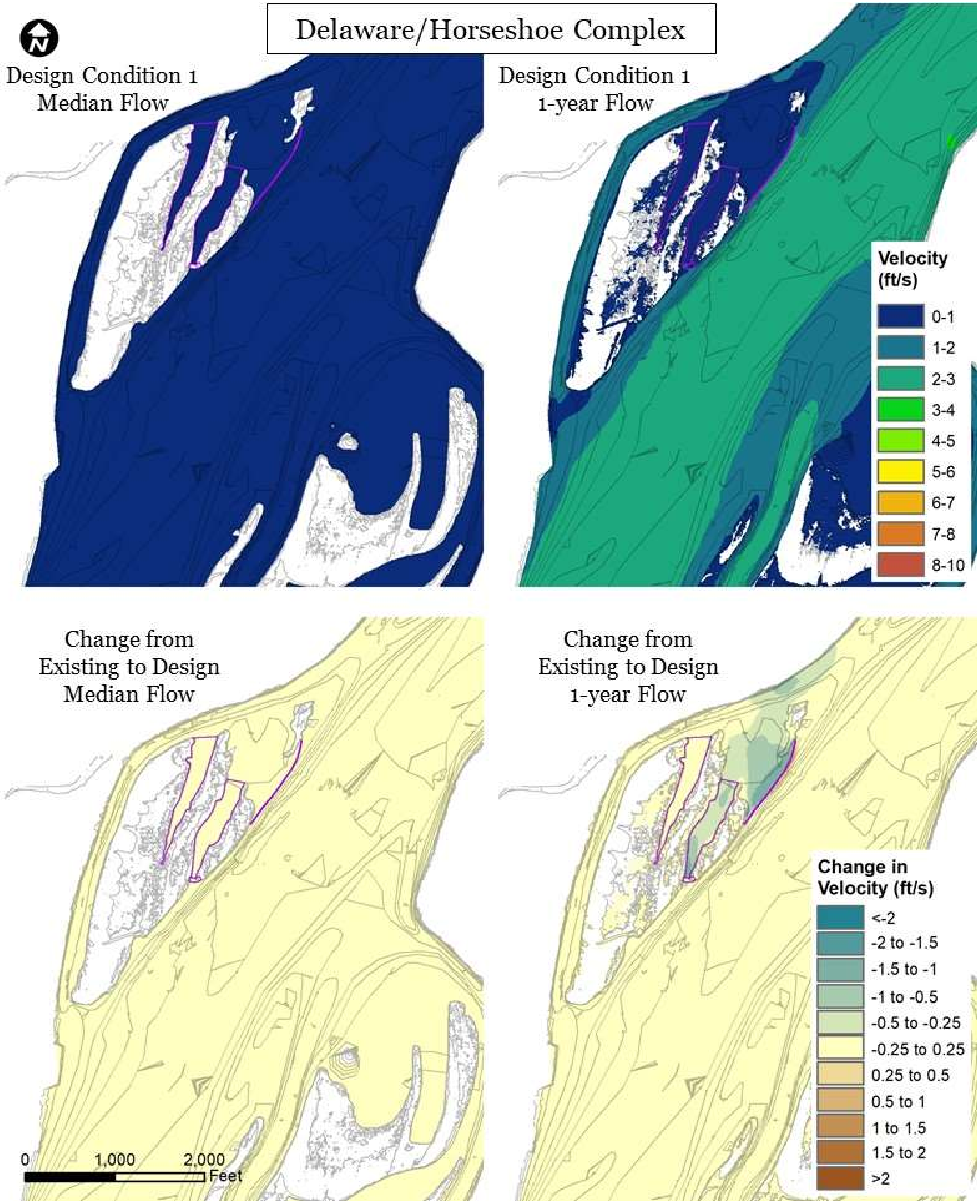

Figure 24. Predicted change in Delaware/Horseshoe Complex Velocities due to Proposed Habitat Features (Design 1, Lower 2 simulated flow conditions)

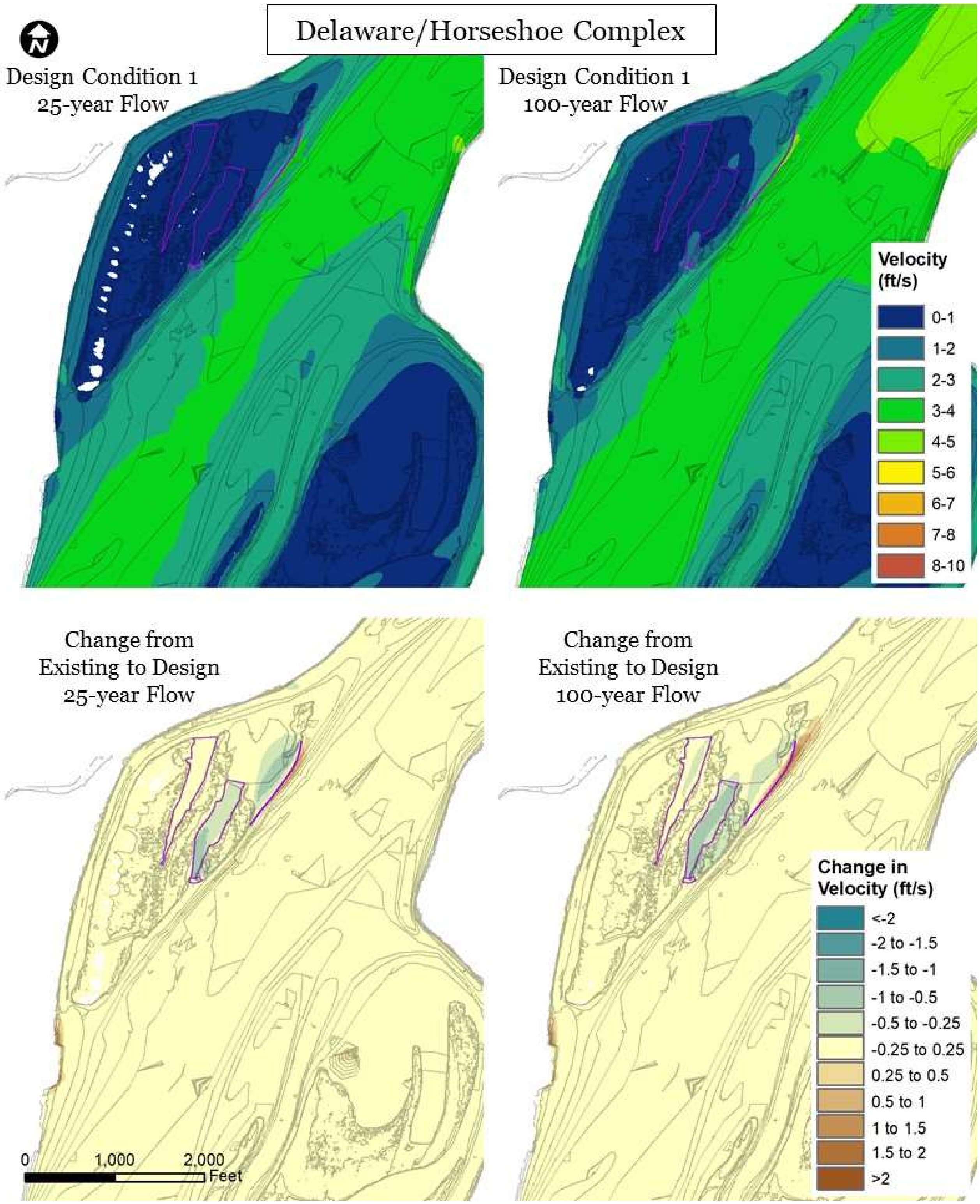

Figure 25. Predicted change in Delaware/Horseshoe Complex Velocities due to Proposed Habitat Features (Design 1, Higher 2 simulated flow conditions)

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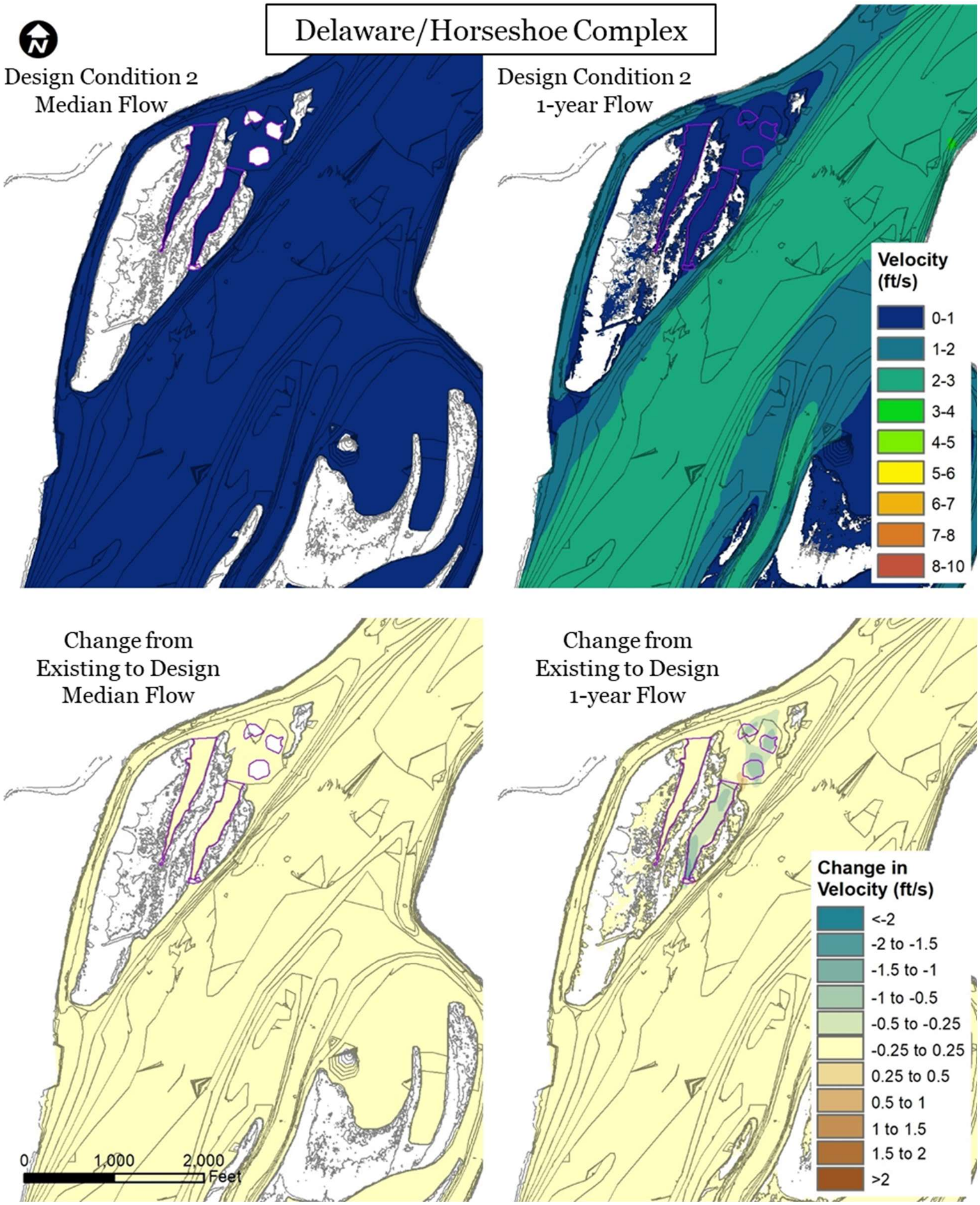

Figure 26. Predicted change in Delaware/Horseshoe Complex Velocities due to Proposed Habitat Features (Design 2, Lower 2 simulated flow conditions)

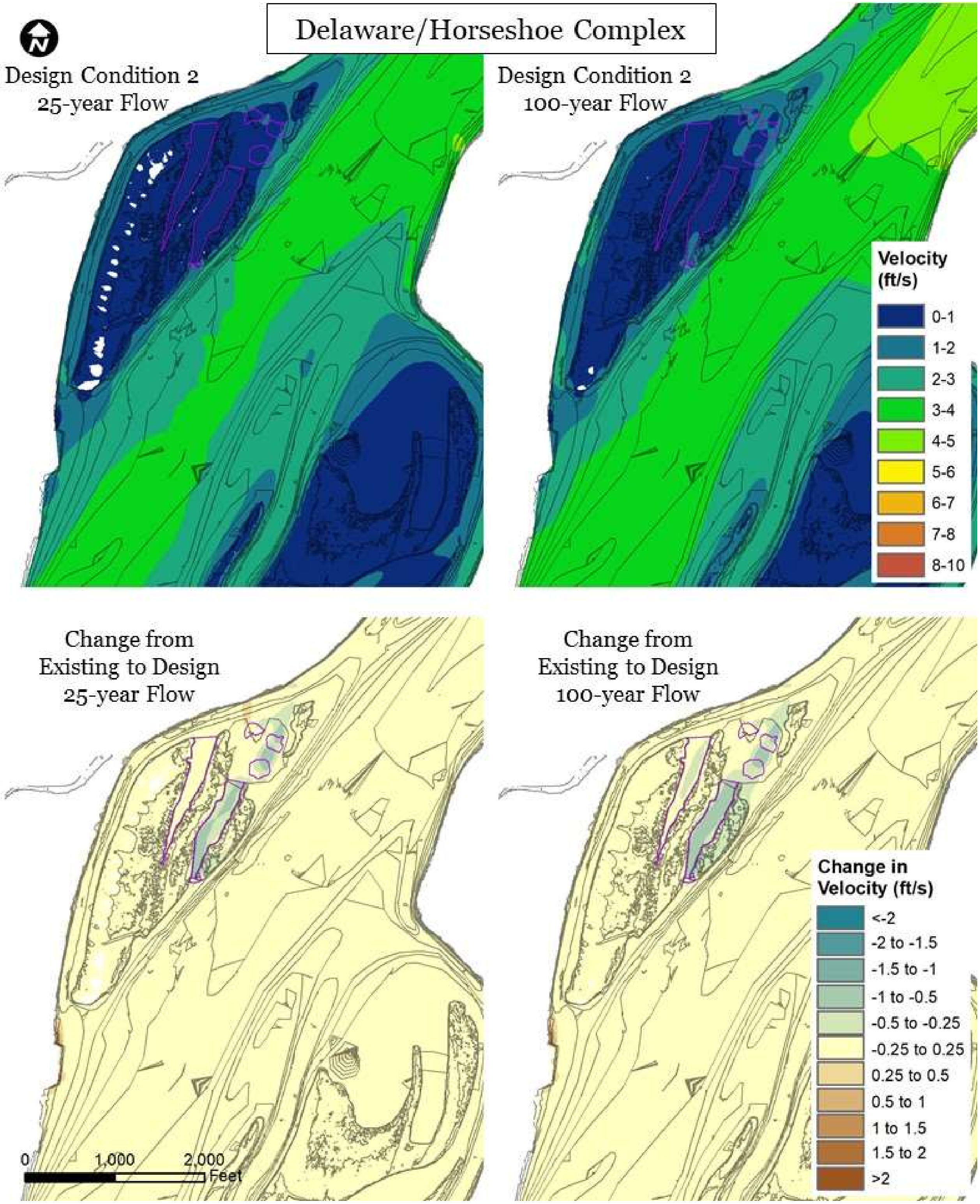

Figure 27. Predicted change in Delaware/Horseshoe Complex Velocities due to Proposed Habitat Features (Design 2, Higher 2 simulated flow conditions)

2.2.6 Ice Analysis

Ice break-up conditions can cause significant damage within the Maumee River floodplain, especially at locations of relatively sudden change in channel and/or floodplain width. For example, in 2015 at a location just downstream of a bridge crossing, sudden ice movement from channel to floodplain toppled headstones at Riverside Cemetery and deposited large ice chunks there.

The historical ice jam record (CRREL, 2021) was reviewed to identify flow conditions corresponding to ice off conditions. This was to evaluate whether potential design features within a certain elevation range would be more susceptible to ice damage than features within other elevation ranges. However, ice off conditions have been observed at a wide range of flow conditions on the Maumee River, ranging from 3,600 cubic feet per second to 80,000 cubic feet per second. Therefore, it was not possible to identify a specific range of elevations within which ice impacts would be either more or less likely to occur.

2.3 Analysis Limitations, Uncertainties, and Future Recommendations

The following sub-sections lists limitations and uncertainties and recommendations for future analysis for each site.

2.3.1 Audubon Islands Near-bank Habitat

The flow resistance introduced by near-bank habitat features has been represented in the model as a large increase in Manning's N. Depending on the characteristics of a potential future detailed design, the actual degree of roughness may be somewhat higher or lower. Future simulations could consider the sensitivity of project function to degree of roughness.

2.3.2 Submerged Aquatic Vegetation in Coves at Ewing and Delaware Islands

Estimated total suspended solids concentrations and estimated accretion rates are highly sensitive to the assumed gross settling velocities for particles that enter the coves, as well as the assumed bulk density of the sediment deposits. These settling velocities can vary over several orders of magnitude for fine-grained particles and for flocculated sediments. Some monitoring of turbidity within the coves would help to confirm the range of actual suspended solids concentrations within the coves.

2.3.3 Marengo Island Structural Protection

The predicted response in current velocities around the simulated protective structure designs is sensitive to the parameterization of the turbulent mixing scheme used by the model. Some monitoring of current velocities near the island would help to parameterize the model to better match existing hydraulics and more reliably inform future design.

During detailed design, additional configurations of a Marengo Island protective structure may be evaluated to optimize the design. Initial simulations during this project showed that shear stresses on Marengo Island can vary significantly with relatively small-scale changes to the structure's design. There is opportunity to refine the design considerably for effectiveness in protecting the island and accreting sediment downstream of the structure.

Lastly, predicted changes in current velocities due to a structure would be large enough to potentially cause morphologic change (i.e., scour and deposition) near the structure. Future simulations could be used to evaluate the impact of morphologic change on function of the structure.

2.3.4 Features near the Delaware/Horseshoe Complex

The flow resistance introduced by habitat features has been represented in the model as a large increase in Manning's N. Depending on the characteristics of a potential future detailed design, the actual degree of roughness may be somewhat higher or lower. Future simulations could consider the sensitivity of project function to degree of roughness.

During detailed design, additional configurations of the Delaware/Horseshoe Complex rock reef or islands may be evaluated to optimize the design with regard to changes in hydraulics.

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