Pennsylvania Fish Spawning Habitat Construction & Restoration Pennsylvania Prime Fish Spawning Habitat

Prepared for:
Coastal States Organization
February 28, 2023

Pennsylvania Fish Spawning Habitat Construction & Restoration Great Lakes Coastal and Nearshore Habitat Engineering and Design Project

Prepared for:
Coastal States Organization

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Prepared at:
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Project plan developed in partnership with:

- Project Partners
  - Coastal States Organization
  - National Oceanic and Atmospheric Administration (NOAA)
  - Pennsylvania Department of Environmental Protection, Coastal Resources Management Program (PA CRMP)
  - Electric Power Research Institute (EPRI)
- Design Team
  - LimnoTech
  - Drummond Carpenter

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1 Introduction

The Lake Erie nearshore zone east of Pennsylvania's Presque Isle peninsula attracts lake trout and is a prime spawning ground. The goal of this project is to collaborate with project partners to develop designs for spawning habitat improvements of about 10 acres. In additional to the target species, lake trout, additional benefits are anticipated for walleye, perch, and other native species that use shoals, reefs, and other nearshore habitats in the project area.

This opportunity for habitat restoration was identified during a state-specific habitat restoration workshop series developed by National Oceanic and Atmospheric Administration (NOAA), the Coastal States Organization (CSO), and all eight Great Lakes Coastal Management Programs and designed to complement ongoing work under the Great Lakes Restoration Initiative (GLRI) nearshore framework. During state-specific workshops hosted in 2019 and 2020, local experts and partners worked together to identify and numerically rank habitat restoration projects that align with the restoration goals identified by the GLRI Focus Area 4—Species and Habitat in the GLRI Action Plan III (USEPA, 2019). The workshop series ultimately identified a list of 31 prioritized coastal and nearshore habitat restoration projects across the eight Great Lakes states. From that list, state partners, NOAA, and CSO identified a subset of projects that were deemed ready to proceed with engineering and design.

The following report includes a 60% design for lake trout spawning reefs along the Lake Erie shoreline east of Presque Isle. This report also contains a regulatory review and a project plan that addresses pre- and post-construction monitoring, maintenance, and public outreach.

2 Background

2.1 Site Overview and Project Motivation

The Pennsylvania construction and restoration of prime spawning habitat project will focus on improving fish spawning habitat near Presque Isle along the southern shoreline of Lake Erie. This project will restore and enhance prime spawning habitat over an approximate 10-acre area.   The components of the project presented in this 60% design document were developed over a series of workshops with project partners.

Project objectives to meet the workshop goal include:

- Improvement of 10-acre area of fish spawning habitat
- Deterrence of invasive species, such as Cladophora algae and Dreissenid mussels

To achieve the project goals the 60% designs were developed for several main components:

- Provide new reef habitat to optimize potential for lake trout spawning and other native species.
- Enhance habitat to be naturally scouring.
- Outline a monitoring plan to assess success.

The project is expected to enhance and restore spawning habitat for lake trout and other native species.

Figure 1. Pennsylvania Prime Spawning Habitat Location.

2.2 Existing Conditions

2.2.1 Background Data

The site chosen for habitat enhancement lies approximately 2500ft off the southern Lake Erie shoreline, about 8 miles northeast of Presque Isle, PA. The 10+acre site was chosen due to the proximity of suspected lake trout spawning areas. Lake trout activity has previously been recorded by telemetry tags in the area. As shown in Figure 8 Draft substrate mapping provided by PA DEP (Note: substrate has not been ground-truthed), the proposed site consists of fractured and stepped bedrock surrounded by boulders. Research presented in prior workshops indicates lake trout may prefer shallow water near shore in approximately 5-10m water depths (Gorman, 2010). This information would coincide with the telemetry tags as shown in Figure 2.

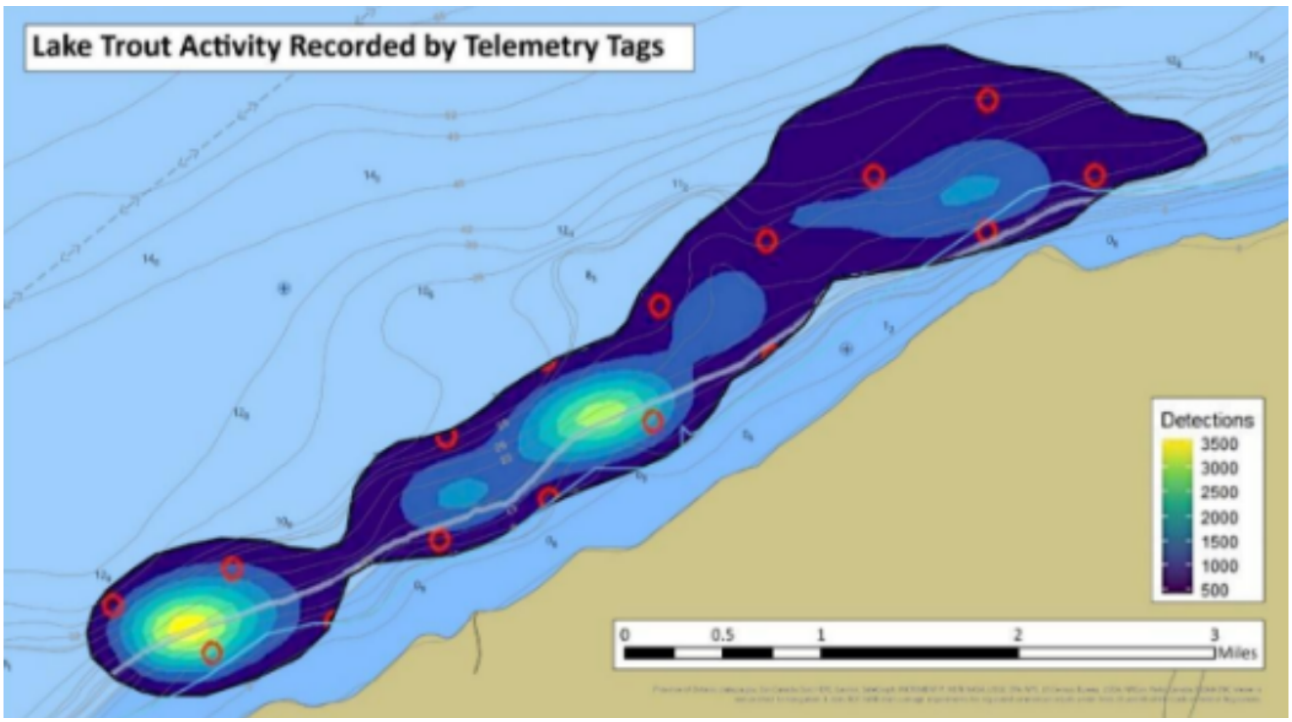


Figure 2 Recorded Lake Trout Activity by Telemetry Tags. [Image provided by PA DEP in the project RFP.]

Lake Erie is the shallowest of the Great Lakes, with high wave energy. The State of the Great Lakes 2022 Report, published by the U.S. Environmental Protection Agency and Environment and Climate Change Canada, evaluated Lake Erie as in poor, unchanging condition (SGLR, 2022). Despite the poor conditions, Lake Erie still supports the largest self-sustaining walleye population in the world, and zooplankton populations are in good condition to help support abundant prey and predator fish (SGLR, 2022).

2.2.2 Invasive and Target Species

Lake trout are the target species for the site, with walleye and perch also expected to benefit from the reef construction. During spawning, lake trout deposit their eggs into interstitial spaces, with substrate size, depth, distribution and the availability of interstitial space being important factors in egg survival at the spawning beds. The site is known to have invasive and nuisance species that may negatively affect the survival of lake trout eggs after spawning. The round goby is an invasive predator that appears to prey on trout eggs that are deposited in interstitial spaces, and the rusty crayfish is another predator known to prey on trout eggs (Farha, 2018 and Calabro, 2016). Taking the actions of these predators into consideration during reef design is important to help protect trout eggs and give them a better chance for survival.

Dreissenid mussels (zebra and quagga mussels) are also invasive species at the site, and they are known to biofoul hard surfaces, such as reefs, in the Great Lakes. Mussel growth can block interstitial spaces, which can limit oxygenation of the spaces and also prevent eggs from settling beyond the reach of invasive predators (Strayer, et al., 2019). It's important to consider ways to decrease the number of dreissenid mussels on the constructed reefs in order to increase the likelihood of spawning success.

3 Modeling

A hydraulic model was initially developed to identify current patterns and shear stresses throughout the project area. As the project developed, key design factors were dictated by other site constraints and the necessity of the model diminished. For example, it was originally envisioned that the model results could help identify zone of higher shear stress which could scour detritus out of the project site; however, updated near shore LiDAR data indicated that the bathymetry did not contain the shelf structures desired to facilitate scour events. Consequently, the site was selected based on recent substrate data and concerns over sheltering near Presque Isle.

Given the reduced value, the model development was halted and archived after the second iteration. For the purposes of record keeping, this section will discuss model development & refinement as well as the key takeaways.

3.1 Modeling Platform

The Finite Volume Community Ocean Model (FVCOM) is a three-dimensional fully coupled ice-ocean-wave-sediment-ecosystem model that operates on an unstructured grid. The model was originally developed, and is widely used, to simulate hydrodynamics in coastal ocean regions; however, it has recently gained popularity for use in large lakes, such as the Great Lakes Coastal Forecasting System. Because the model was developed for coastal ocean regions where tidal fluctuations are significant, FVCOM is capable of simulating wetting and drying of areas that are not continuously under water, an important feature for simulating changing coastlines. This ability allows for the model to include proposed reefs, islands and other habitat structures by altering the model bathymetry to represent them and allowing variable water levels to interact in both flooding and drying conditions. The source code was developed by researchers at the University of Massachusetts-Dartmouth and the Woods Hole Oceanographic Institute (Chen et al. 2003).

3.2 Model Domain and Computational Mesh

NOAA's Great Lakes Environmental Research Laboratory (NOAA-GLERL) maintains an operational FVCOM model for Lake Erie (Lake Erie Operational Forecasting System, LEOFS), which continuously simulates the hydrodynamic transport for all of Lake Erie (Figure 3) in short term forecasts of up to five days. LimnoTech has recently adapted this model framework for hindcasting to simulate hydrodynamics and water quality based on observed meteorological and hydrology forcings on an annual basis.

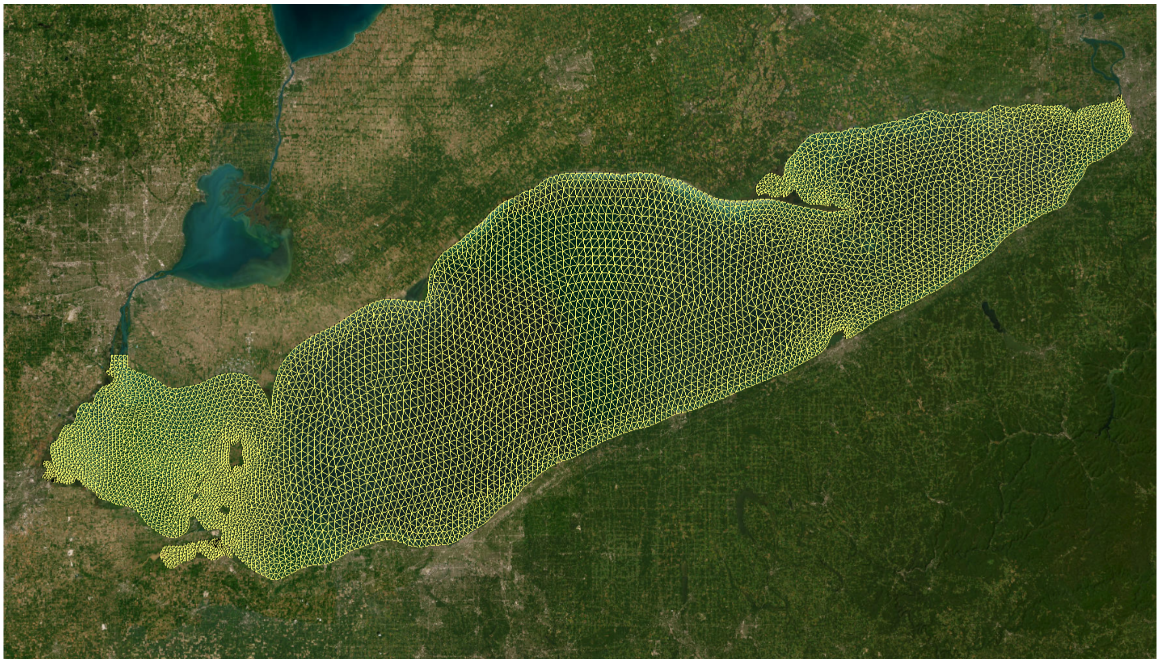


Figure 3 LEOFS-based FVCOM model domain and mesh for Lake Erie.

The LEOFS model mesh is relatively fine scale near shore, but does not provide a spatial resolution that is fine enough for assessment of habitat or spawning improvements in local site-specific areas. Because LimnoTech has adapted a version of LEOFS for hindcast purposes, we are able to use the whole lake LEOFS-based model to drive nested fine scale sub-domains within specific regions of Lake Erie. This process consists of developing a smaller model mesh at relevant project sites, with a common model boundary that matches the LEOFS mesh. The common boundary is used to provide transport boundary conditions from the larger whole lake model to the smaller fine scale nested model. Figure 4 shows the nested model domain near Presque Isle in Lake Erie. The blue triangular mesh represents the site-specific model mesh, with the outermost “ring” of cells being common to the whole lake mesh.

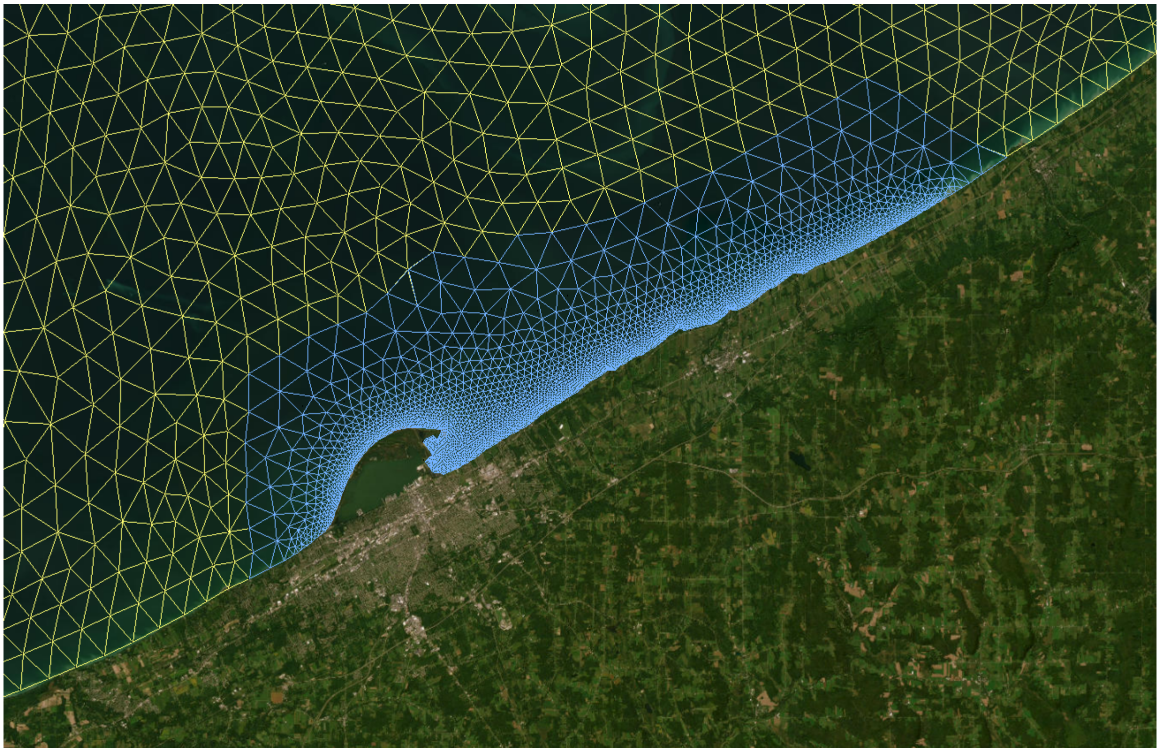


Figure 4 Nested model sub-domain to improve spatial resolution near Presque Isle.

3.3 Model Inputs and Forcings

FVCOM requires a number of inputs and forcings to represent the physical environment that is being modeled. LEOFS, as developed by NOAA-GLERL requires mesh geometry, tributary flow rates and temperature, bathymetry, and atmospheric conditions. The following sections describe the inputs for both the whole lake and sub domain models.

3.3.1 Mesh Geometry

FVCOM computes velocities and water surface elevations on an unstructured mesh that the user defines. The mesh defines how each triangular element is constructed by specifying the three vertices (nodes) that create it. The horizontal and vertical location of each node is defined in the FVCOM mesh input files, and the model computes the area and orientation of the elements. For this application, the horizontal and vertical locations are defined as longitude and latitude values, as opposed to using a geographic projection. Additionally, to be consistent with LEOFS, the vertical resolution in the whole lake domain uses twenty layers of uniform thickness. This scale of resolution is not required in the near shore area near Presque Isle, therefore, the vertical layering is collapsed to four layers in the sub domain mesh. The collapsing approach evenly weights the twenty layers in groups of five to generate four vertical layers.

3.3.2 Tributary Inputs

Inflow and the associated temperature input from river and creek tributaries are specified at nodes (vertices) in the FVCOM model meshes. The whole lake FVCOM model includes 80 such tributary boundary conditions, of which, three (Sixteenmile Creek [PA], Twentymile Creek [PA], and Chautauqua Creek [NY]) tributaries fall within the boundary of the Presque Isle model subdomain (Figure 4).. Data defining the inputs for all 80 tributaries in the model were obtained from USGS and Environment and Climate Change Canada. Temperature data are generally less abundant than flow data, particularly for smaller tributaries. In the whole lake model, where tributaries lacked temperature data or included gaps of missing data, temperature values were specified corresponding to the nearest data-rich tributary. While there are no major tributaries entering the site, the temperatures were modeled for the whole lake model because they influence global circulation. For the drainage area around Presque Isle, long-term daily temperature data were most abundant from the USGS station near Walnut Creek (USGS Site 04213152).

3.3.3 Bathymetry

Bathymetry for both model domains was based largely on standard NOAA bathymetric data (NOAA 1999). However, the bathymetry for the Presque Isle sub domain model was augmented with site specific bathymetric data provided by NOAA's geospatial data coordinator. FVCOM operates on a depth basis, where the water depth is specified at each node (vertex) of the model mesh relative to the low water datum of Lake Erie (173.5m IGLD 1985).

3.3.4 Atmospheric Forcings

FVCOM also requires inputs describing the time-variable meteorological conditions above the water surface. These inputs define the thermal and wind energy at the air-water interface, which drive the simulation of mixing and current regimes within the lake. FVCOM allows the user to choose from three separate heat flux sub-models to simulate the heat balance. To be as consistent as possible with the LEOFS model, the SOLAR heating module was used in this application. The SOLAR module requires the following inputs to calculate the heat balance: air temperature (°C), short wave radiation (Watts/m2), cloud cover (fraction), and dew point (°C).

The inputs to the heat flux module are all defined on a nodal basis in FVCOM. Data for these inputs were obtained from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Version 2 (CFSv2; Saha et al., 2011). The data from CFSv2 is available on an hourly basis, and the spatial resolution for thermal inputs is 0.2 degrees horizontally. Each node in the FVCOM mesh was assigned the values corresponding to the closest CFSv2 grid node.

In addition to the heat flux inputs, FVCOM also requires wind speed (m/s) and direction input time series. Data describing the hourly wind fields were also obtained from the CFSv2 model. While thermal inputs are assigned to nodes in FVCOM, wind velocities are assigned at the element level. Wind data were assigned to each element in FVCOM, corresponding to the closest CFSv2 reporting location.

3.4 Model Scenarios

The FVCOM model was used to simulate circulation patterns for the period of April 1 – May 31, 2020. Time variable observed tributary flows and temperatures were used from this period, as well as CFSv2 generated atmospheric forcings. The whole lake model was run first to generate the boundary forcings for the Presque Isle subdomain model, which was subsequently run for the same period.

3.5 Model Results

During the two-month (April -May 2020) simulation period, the dominant flow direction is from west to east with transport closely following the shoreline. An example point-in-time map of the velocity fields is shown in Figure . Note that during times with the prevailing west to east winds the current velocities regularly exceed 0.4 m/s (1.3 ft/s).

The influence of the wind forcings can have a significant impact on the circulation patterns along the shore. An additional circulation map is shown for a few days after that shown in Figure , where winds reverse direction and transport is thus moving from east to west along the shore. Additionally, it should be noted that on the eastern most end of the sub model domain, the influence of the Chautauqua Creek inflow can be seen, where dynamic eddies can result in complex transport patterns. When longshore velocities within the lake are relatively low, the influence of tributaries as they enter the lake can be significant with regard to affecting local circulation patterns, as seen with Chautauqua Creek in Figure 6.

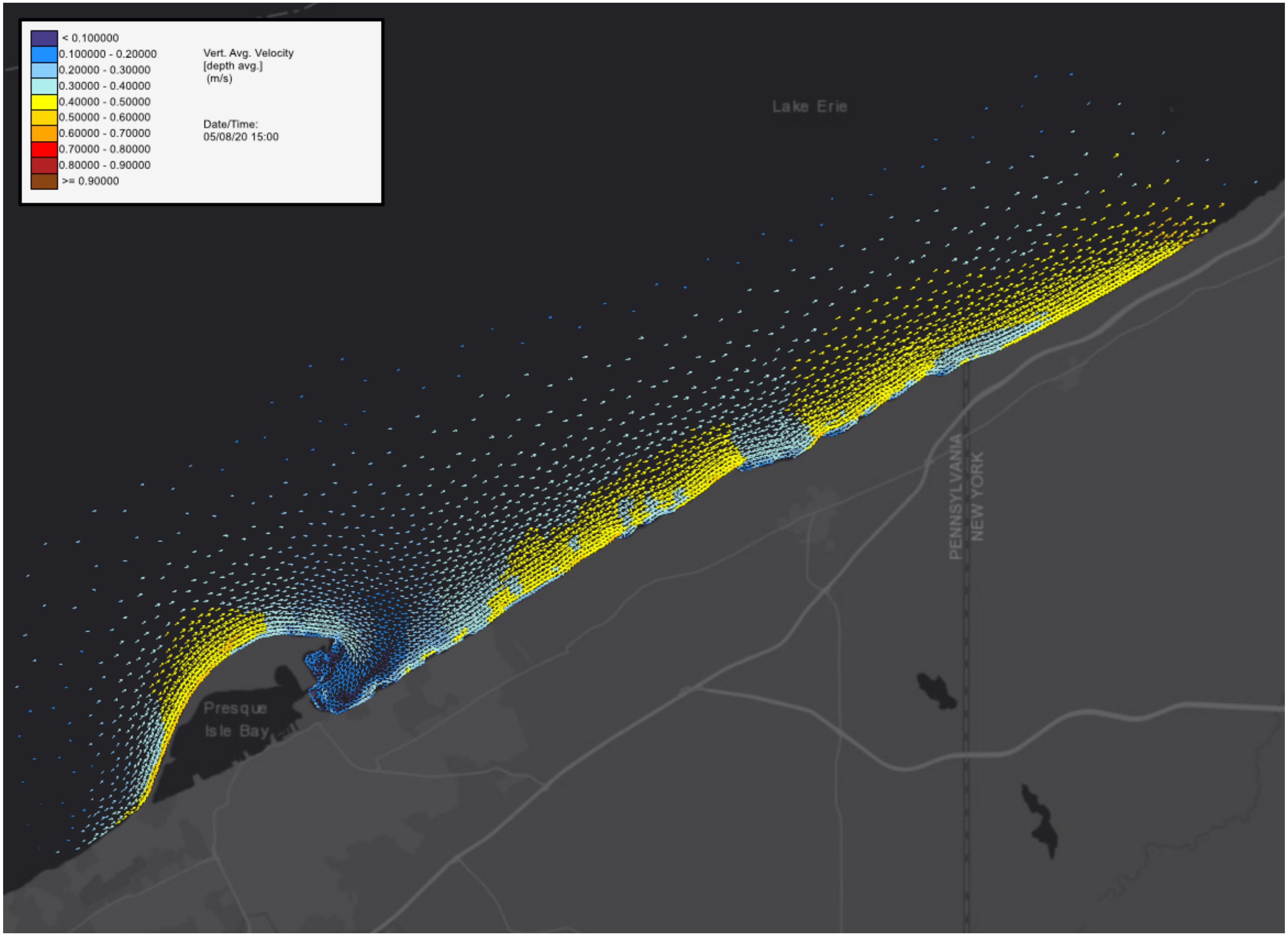


Figure 5 Example circulation field. Model output for May 8, 2020, shown as example of typical flow direction near Presque Isle.

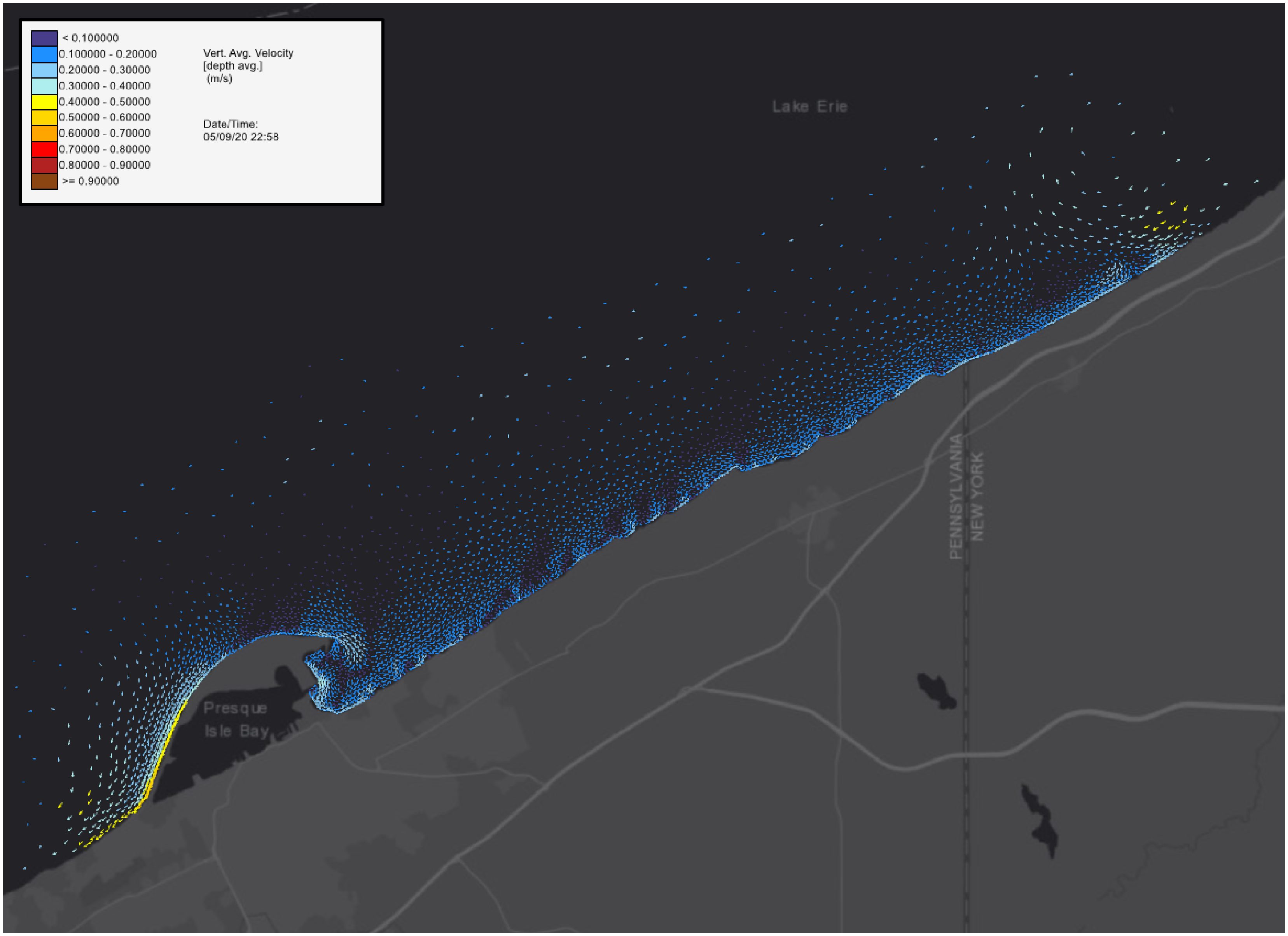


Figure 6 Example circulation field. Model output for May 8, 20201. shown as example of typical flow direction near Presque Isle.

4 Field Data Collection

Field data were collected by the PA CRMP, National Oceanic and Atmospheric Administration (NOAA), and LimnoTech. The data collected provided critical site information that facilitated the design.

PA DEP collected side-scan sonar over a targeted area of the site extents included within the FVCOM model domain (Figure 4) and near known areas of lake trout activity (Figure). The side-scan sonar revealed that much of the site consists of boulders, cobble, sand, and other granular material with sections of exposed bedrock. PA DEP used the sonar data to develop a draft substate map (Figure), which was utilized to identify a zone of predominantly fractured bedrock and stepped bedrock with a depth range 6-9 meters (grey rhombus outline in Figure).

LiDAR with nearshore bathymetry was provide by NOAA’s geospatial coordinator.

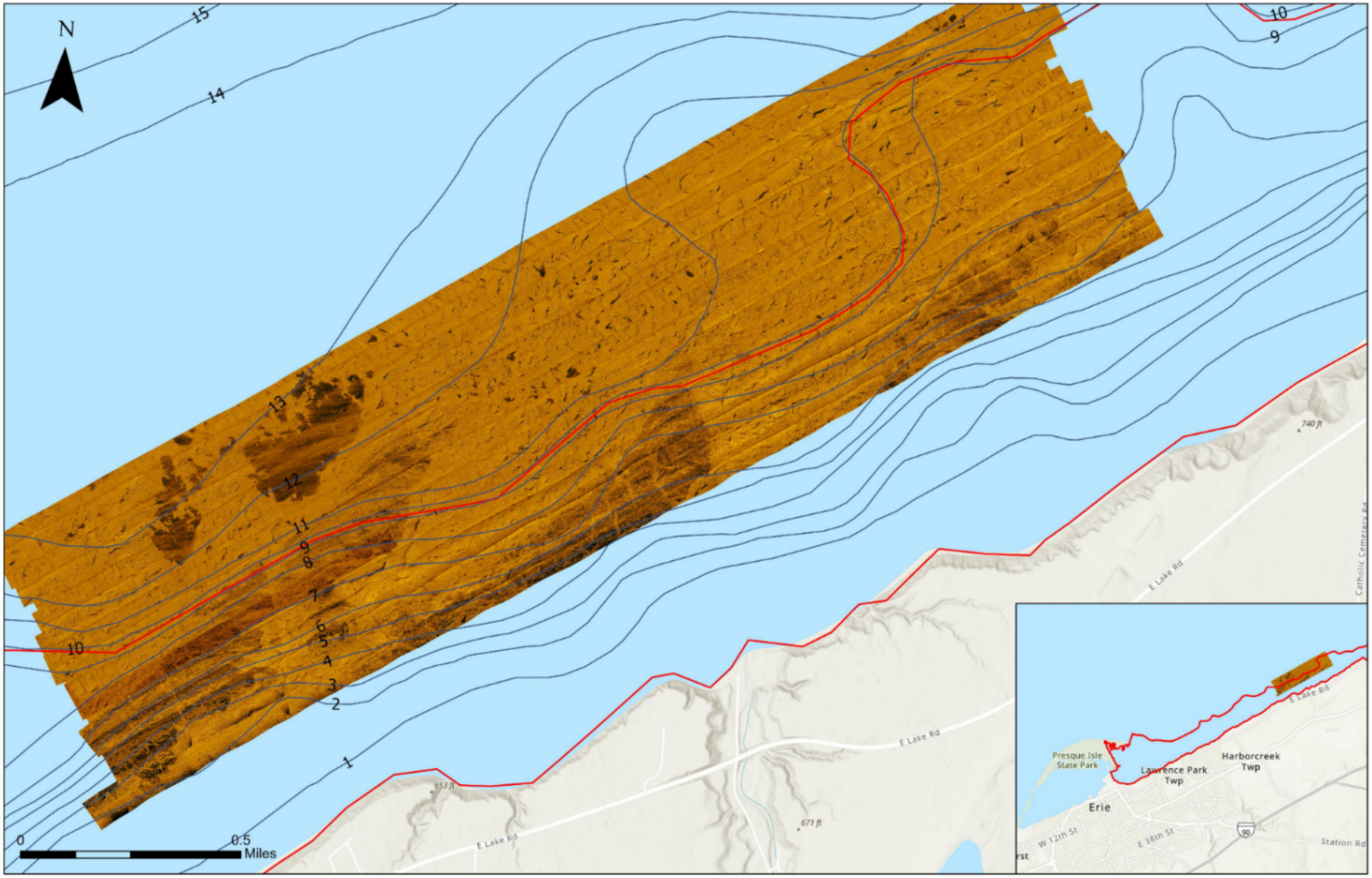


Figure 7 Side-scan sonar data collected by PA DEP (summer 2022).

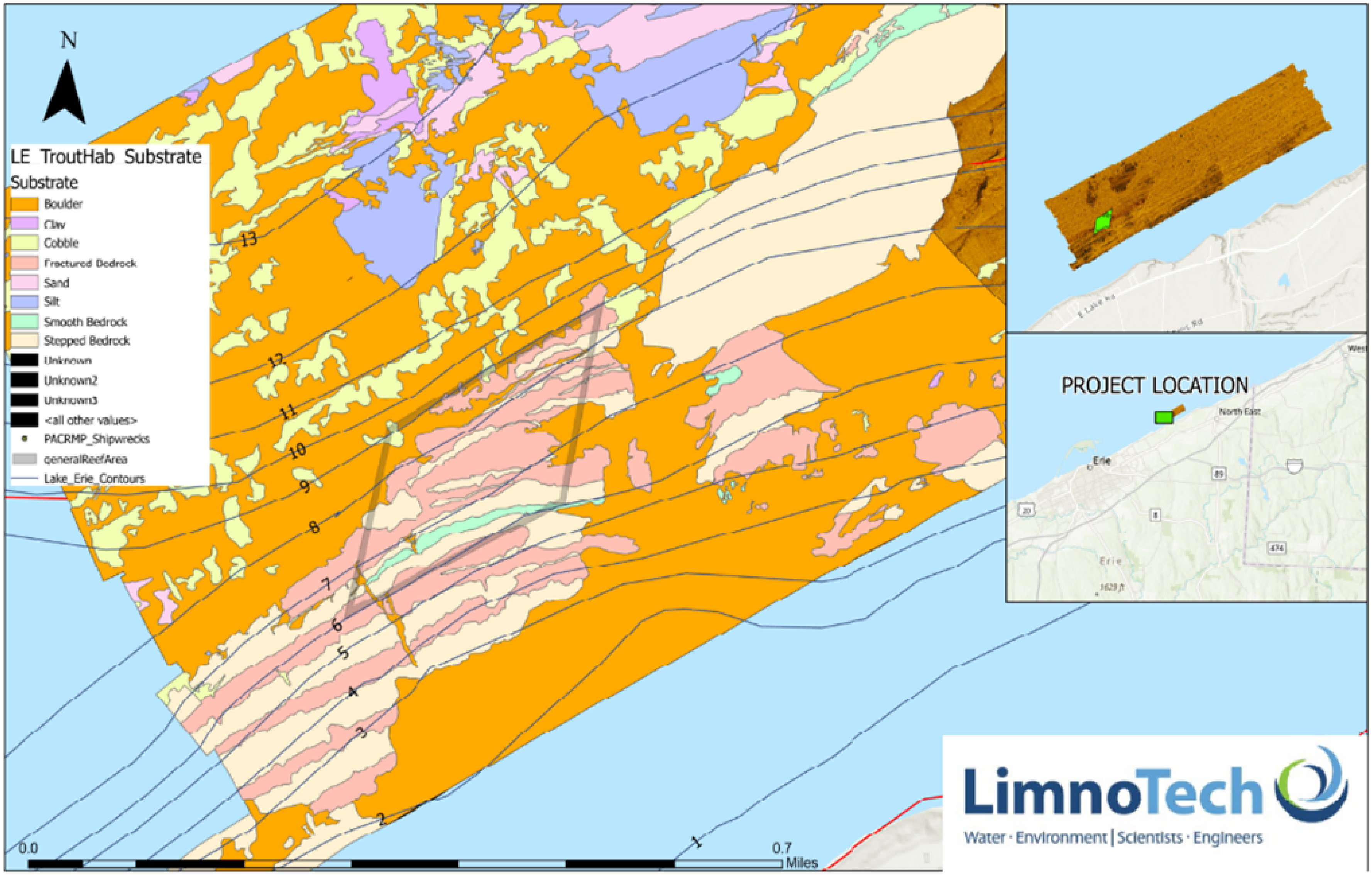


Figure 8 Draft substrate mapping provided by PA DEP (Note: substrate has not been ground-truthed).

With assistance from PA CRMP, LimnoTech collected Acoustic Doppler Current Profiler (ADCP) data at five locations within the project area during August 2022. The locations of these data are shown in Figure . The ADCP was deployed from an anchored watercraft for approximately 15 minutes at each location, measuring depth-variable current speed and direction.

The measured velocity magnitude and direction were relatively consistent at locations B, C, and D, while they differed at the ends of the measurement area (locations A and E, Table 1). In each location, the velocity measurements were relatively slow, with the maximum observed (location D) being ~0.1 m/s.

Note that locations B and C are most representative of the target area identified in Figure , and the current directions are consistent with the dominant current patterns observed in the FVCOM model (Figure).

Figure 9 Locations (shown as red dots) of ADCP current data measurements.

Table 1 Velocity Measurements at ADCP Sampled Locations.

ID	Lon	Lat	Vel East (m/s)	Vel North (m/s)	Speed (m/s)	Direction	Direction
A	-80.02	42.18	0.048	0.043	0.069	50.7	↗
B	-79.93	42.21	0.075	0.009	0.081	92.1	→
C	-79.90	42.22	0.083	0.008	0.089	82.4	→
D	-79.82	42.25	0.094	0.014	0.106	85.0	→
E	-79.78	42.27	0.006	-0.005	0.032	160.1	↓

NOAA collected and provided nearshore bathymetric LiDAR data. Because the existing bathymetric contours are in relatively close agreement with the LiDAR, the LiDAR was used as the basis for FVCOM model bathymetry.

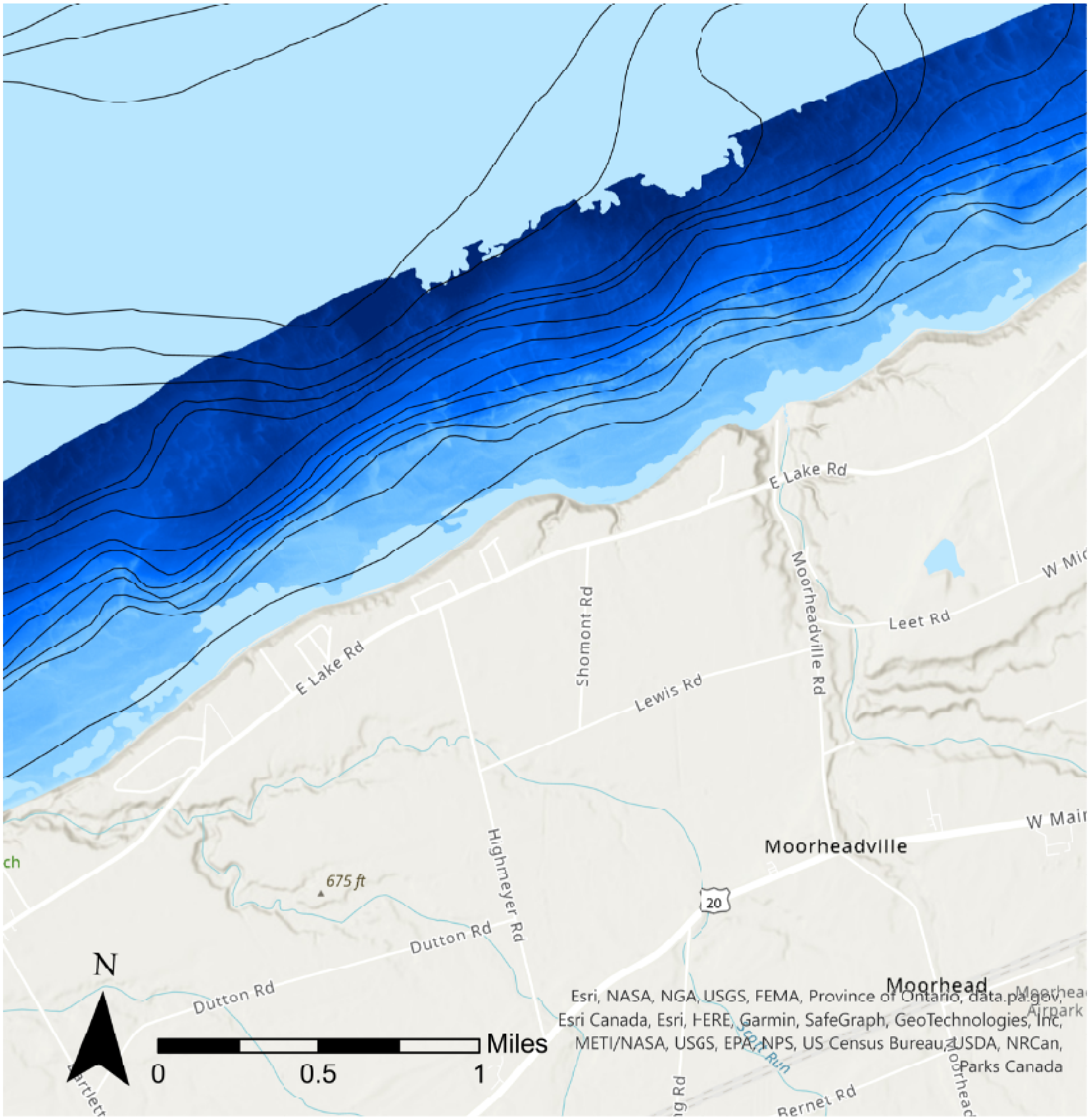


Figure 10 NOAA nearshore LiDAR plotted with bathymetry contours.

5 Engineering and Design

This section describes the basis of design, including the following design criteria: alternatives analysis, reef design, summary of work to be completed in future design phases, an opinion of construction costs, and a risk register. Plan sheets are available in Attachment A.

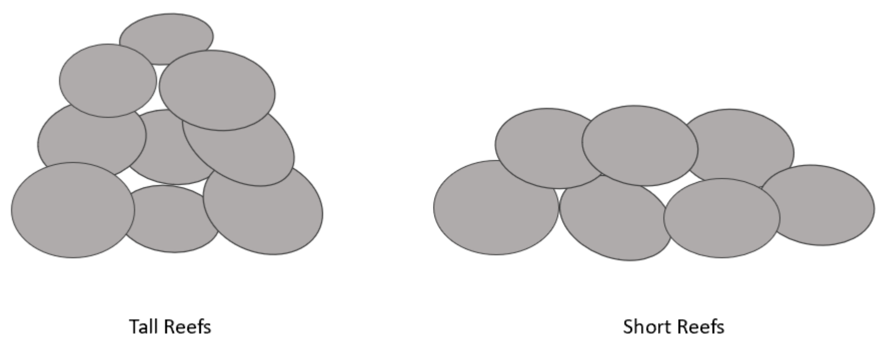
5.1 Design Criteria

As noted in section 2.1, the project objective for meeting the goal of establishing 10 acres of prime spawning habitat in this region of Pennsylvania is as follows:

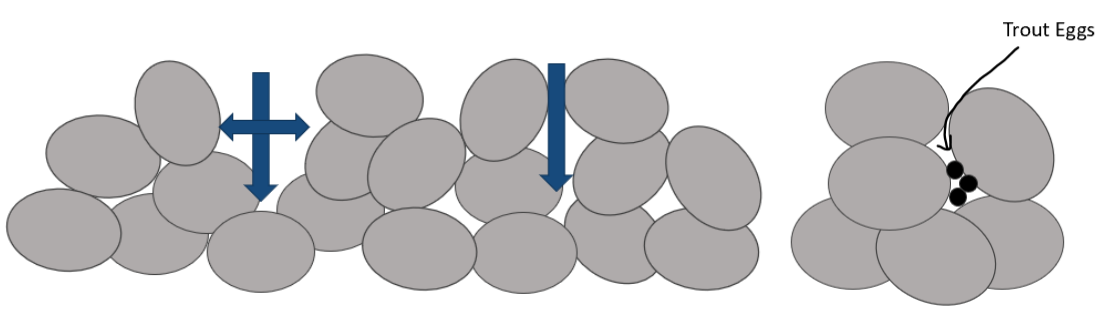
- Provide new, clean material reefs for the enhancement of spawning habitat.

In addition to the above objective, several additional design criteria were developed in conversation with project partners and regulators, as per lake trout spawning bed reef characteristics:

- Reef substrate should be course, loose, rounded or angular rubble, cobble and boulder that is 5-50 cm in diameter. New substrate, free of silt or organic debris in the interstices, is preferred.
- Reefs should be tall, with deep and open interstitial spaces to deposit eggs. Vertically piled rubble may increase spawning success.

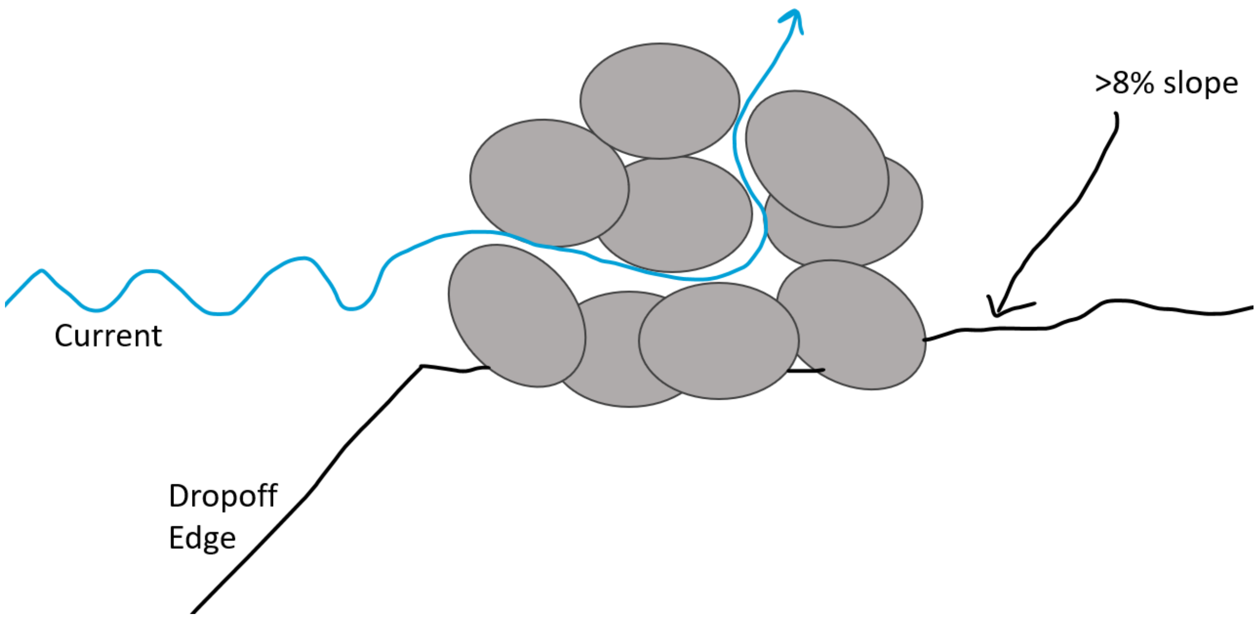


- In order to allow enough oxygen flow for egg/fry development and provide a wave buffer for protection, it is important to create deep interstitial spaces that range from 20-30 cm in depth (Gorman et al., 2010).

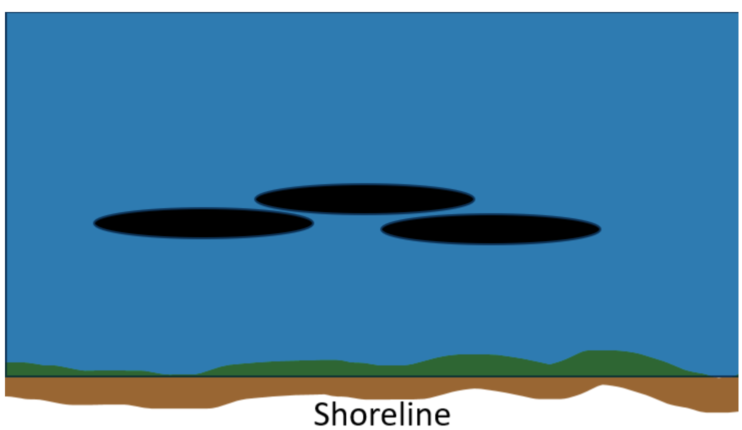


- Incorporating stratified rock sizes in the reef design and creating a variety of interstitial spaces may also provide additional protection from predators by keeping eggs out of reach (Roseman et al., 2011, Edsell et al., 1992, and Calabro, 2016).

- Reefs should be placed adjacent to steep drop-off areas to reduce sedimentation via the Venturi-effect (Marsden, 1995, 2005).



- Consider nearshore higher energy environments for moderate wave activity to remove fine sediments and reduce dreissenid density.
- Reefs should be placed in shallower (5-22 m depth) nearshore areas where natural light illumination reaches the lakebed (Gorman et al., 2010; Edsell et al., 2010).
- Clustered reefs that are larger are more likely to be found and used by lake trout.



- Reef height should be 1 – 1.5 meters, with steep walls.

5.2 Alternatives Analysis

Multiple alternatives have been identified for this project. Each alternative will be presented below, and for each, we will provide the following:

- Description
- Benefit

- Limitation
- Recommendation (include or exclude)

5.2.1 Do Nothing Alternative

5.2.1.a Description

The do-nothing alternative must always be considered and is the baseline condition against which all other alternatives are evaluated.

5.2.1.b Benefit

There are relatively limited benefits of this alternative beyond cost savings; however, even cost savings should be considered a limited benefit.

5.2.1.c Limitation

This alternative would allow the existing spawning habitat to continue to degrade.

5.2.1.d Recommendation

Exclude this alternative. During the previous site selection project, this site was already identified as a priority for restoration.

5.2.1 Stone reef Alternative (Preferred Alternative)

5.2.1.a Description

Stone reefs are cobble and boulder deposits along the lakebed, which is the preferred spawning substrate for lake trout.

5.2.1.b Benefit

Stone reefs provide spawning habitat for lake trout. Similar rock reef projects around the Great Lakes have been found to be effective.

5.2.1.c Limitation

Stone reefs can be prone to fouling.

5.2.1.d Recommendation

This is the preferred alternative. Design details will be discussed in the reef design section.

5.2.1 Reef balls and woody reefs Alternative

5.2.1.a Description

Reef ball and wood reefs both provide unique habitat types that cater to a wide range of species and sizes of fish.

Reef balls are essentially perforated concrete domes. They are a popular reef growth media in saltwater and brackish water coasts and are gaining popularity along urban water fronts. Reef ball reefs are typically placed in rows and are designed to maximize the surface area for growing attached organisms.

Figure 11 Reef ball image (from reefballfoundation.org)

Wood reefs typically consist of partial or whole trees interconnected and secured to the lakebed by mechanical means. Wood reefs are most commonly found in shoreline areas.

5.2.1.b Benefit

These options provide a diverse range of habitat types. With the increased clarity in the Great Lakes over the past few decades, organic habitat & substrates are becoming more common.

Reef balls have been shown to be effective at attenuating wave energy.

5.2.1.c Limitation

The reef balls are known to be rapidly colonized by dreissenids. Neither reef ball nor wood reefs provide spawning habitat for lake trout.

5.2.1.d Recommendation

Exclude this alternative because it does not provide spawning habitat.

5.2.2 Maintenance Alternative – Portable Jetting (Preferred Alternative)

5.2.2.a Description

Portable jetting, i.e., a boat mounted muck blower, is essentially an underwater fan that can be towed behind a boat and pointed at the bottom. The velocities from the jet will stir up the accumulated detritus deposited in the reef.

5.2.2.b Benefit

The alternative can be designed to remove detritus and dislodge dreissenids. It is also portable and can be applied to adjacent fouled reefs.

5.2.2.c Limitation

Requires specialized or custom equipment.

5.2.2.d Recommendation

This is the preferred option due to its portability and adaptability. PA CRMP would be responsible for ongoing maintenance, either in-house or through contracting. As a case study, we recommend delineating portions of the reef with differing cleaning intervals. This will help identify the required cleaning frequency.

5.2.1 Maintenance Alternative – Tarping

5.2.1.a Description

This alternative consists of placing large tarps over the reefs to smother dreissenids and other attached growth.

5.2.1.b Benefit

This is a relatively affordable and conceptually simple technique. It is effective.

5.2.1.c Limitation

Does not remove organic matter from interstitial spaces, and consequently, does not remove existing fouling or prevent the resulting detritus from accumulating within and on the reef.

5.2.1.d Recommendation

Exclude this alternative because it does not clean out interstitial spaces.

5.2.2 Maintenance Alternative – Back Flushing System

5.2.2.a Description

A back flushing system would consist of placing a network of perforated pipe under the reef. During the maintenance season (non-spawning season), water would be pumped into the lines to jet water out of the perforations and up through the void spaces. The jetting water would displace accumulated material in the interstitial spaces and scour off attached dreissenids.

Figure 12 shows a concept layout of the perforated pipe in a one-acre back flushing system. Such a system would have the following design characteristics:

- Reef Information
    - Reef area – 1 acre
    - Effective treatment area = 1000-2000 ft^2
- Pump and Manifold

- Pump Discharge Pipe Size = 16" Ø
- Manifold pipe diameter range = 8"-16" Ø
- Pump Discharge Requirements = 9500gpm at 50TDH

- Pipe
    - Pipe type = DR-26 Perforated Pipe
    - Perforated pipe dimensions = 6" x 100' branches
    - Pipe perforation dimensions = ½" Ø spaced at 3ft
    - Required orifice velocities = ~1fps for mussel removal
    - Pump Discharge Requirements = 9500gpm at 50TDH

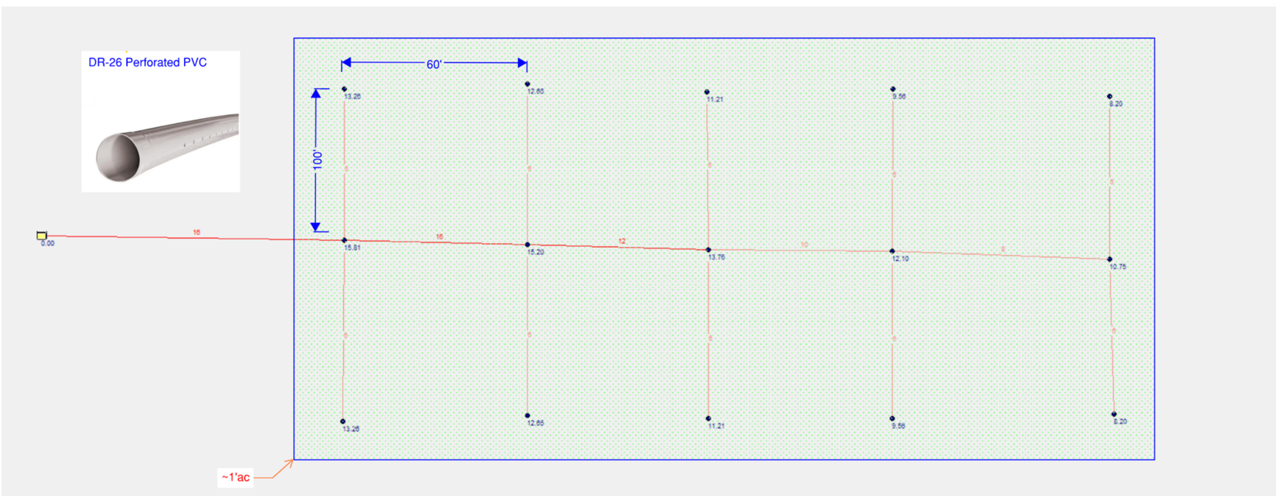


Figure 12 Sample back flushing system layout for a one-acre reef.

5.2.2.b Benefit

Backflushing has the potential to scour off dreissenids and clear out interstitial spaces in the reef.

5.2.2.c Limitation

The effective treatment area is relatively small, and the pumping requirements, and corresponding costs, are relatively high.

5.2.2.d Recommendation

Exclude this alternative due to limited return on investment.

5.2.3 Maintenance Alternative – Chemical Molluscicide Treatment

5.2.3.a Description

Chemical molluscicide, such as Zequanox®, has been found effective at killing dreissenids. Chemical treatment could be achieved by dosing the reef in situ as part of a regular maintenance regimen, or by pre-treating the reef stone prior to placement.

5.2.3.b Benefit

Proven effective at killing dreissenids.

5.2.3.c Limitation

Unknown secondary impacts to lake trout eggs.

5.2.3.d Recommendation

Exclude this alternative due to unknown secondary impacts to lake trout eggs.

5.3 Reef Design

The design criteria were incorporated into the reef design and adapted as seen fit for the site specifics. Other projects with similar designs were studied and the concepts were replicated, especially the Illinois Beach State Park rubble ridge project, which is the only other fully established constructed offshore reef at the time of this report.

- The reefs will be placed perpendicular to the predominant current direction – west to east (Figure 13 Concept reef layout.). This will reduce the stresses on the reefs in the middle of the formation and promote scour of fine sediments on the east side of the reef.
- The reefs will be placed on mainly fractured and stepped bedrock to increase the stability of the reef materials.
- The reefs will be allowed to be extended over boulder beds because the boulder bed is already fouled and is therefore a less suitable trout spawning habitat.
- The reefs will be 2 m high in the middle. This height and regular spacing will help create a rougher surface that results in more water plunging between the reefs, pushing water through the stones, and both oxygenating the interstitial spaces and scouring fine sediments out of the reef. (Figure 14 Typical reef sections)
- The slopes are uniform throughout the site (from 2% to 3% slope).
- Fish in the site area are most often found on the southeast facing slopes of the natural reefs, so constructed reefs will be stepped east to have the preferred and more gradual slopes facing SE.
- The reefs will have a maximum height of 2 meters. While the literature suggests that 1-1.5-meter reefs are most effective, we have set our maximum reef height to 2 meters for the following reasons:
    - Some of the reef material will be sporadically mobile, especially during high energy events, so the additional height will allow the reef material to shift and settle to an overall height closer to 1.5 meters.
    - A taller reef will have deeper interstitial spaces to accumulate detritus without completely fouling the reef.
    - Given the triangular cross-section of the reef, only the apex of the reef is 2 meters high, while the rest of the reef is shorter.
- The reefs will be constructed in water that is at least 6 m deep to accommodate the 2 m reef structure and allow for 4 m of water for a recreational vessel to clear the reef.
- Where the reef extends over a bedrock step, efforts will be made to step the reef as well to maintain a 2-meter maximum thickness; however, we can expect there to be variability in the reef thickness due to the challenges of placing stone at this depth.

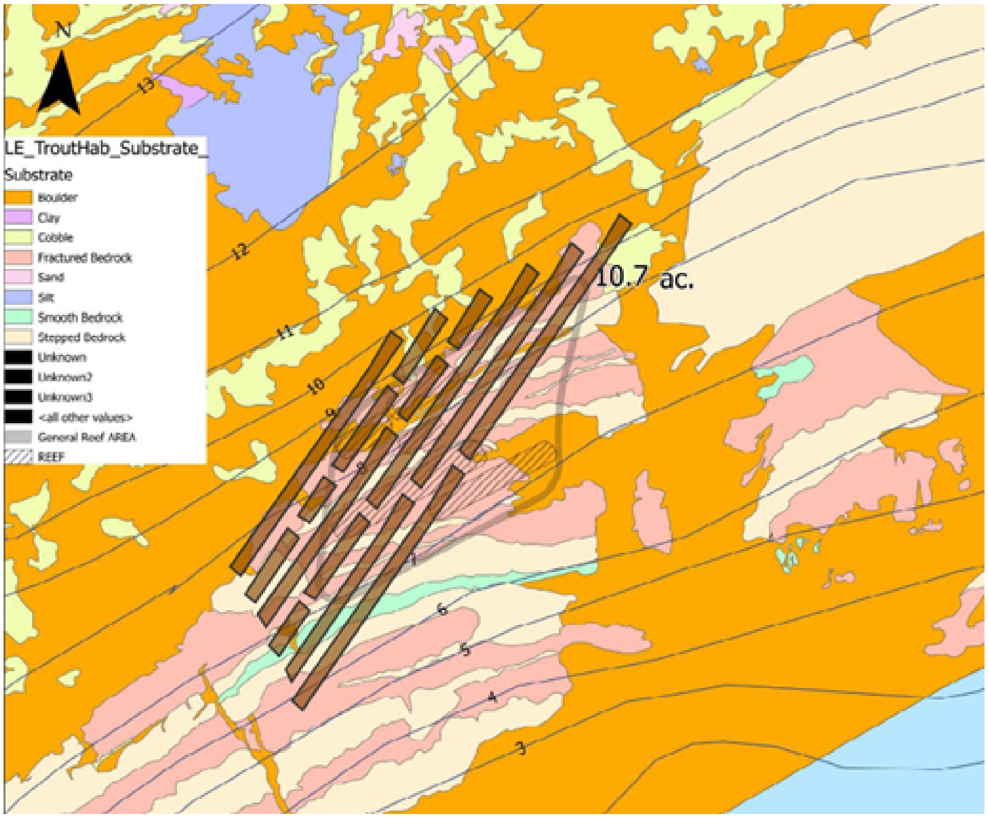


Figure 13 Concept reef layout.

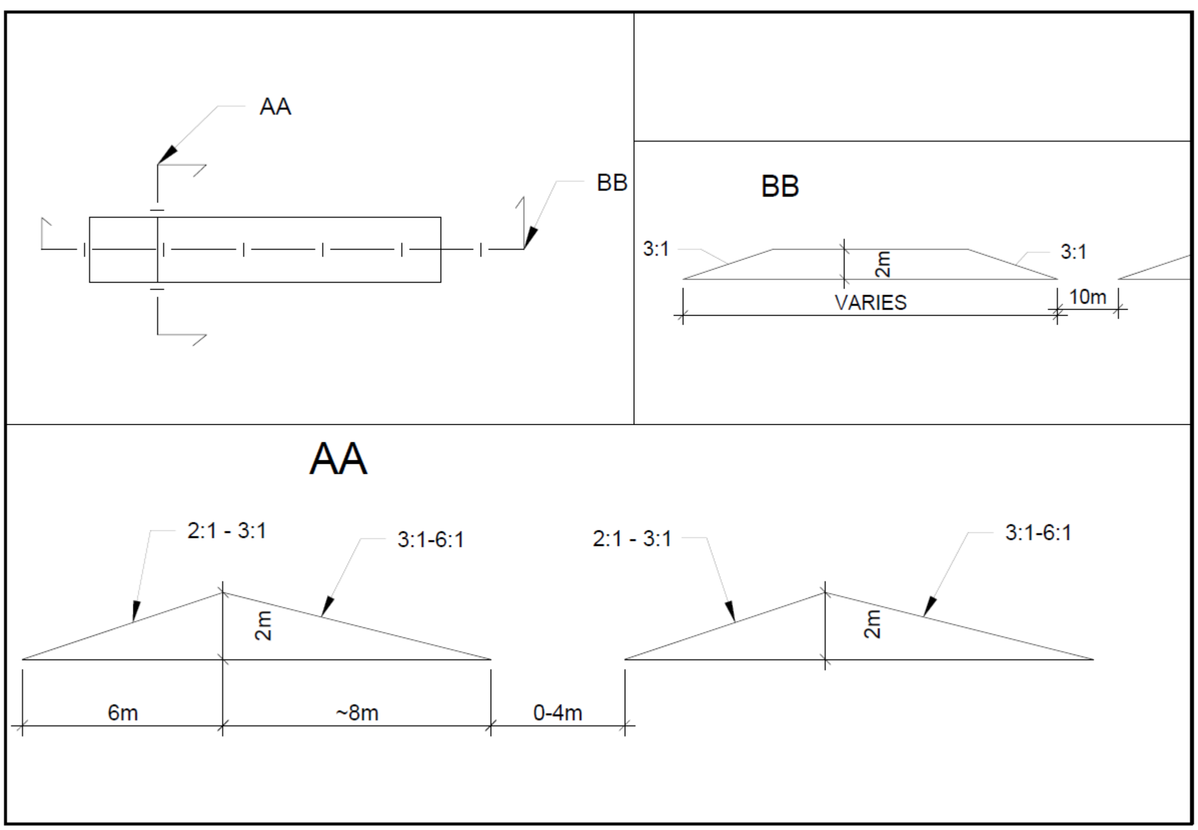


Figure 14 Typical reef sections.

Full design drawings are provided in Attachment A.

5.4 Remaining Scope of Work to Complete Design and Permitting

- Finalize drawings and plan sheets.
    - Design details
- Complete technical specifications
    - Finalize general specifications.
- Permitting
    - See section 6 Regulatory and Environmental Compliance review of expected permitting.
    - Completion of federal, and state.
- Preparation of bidding and contract documents
    - Including scope of work, construction phasing, budget

Basis of design report will be updated as needed prior to permitting to document major design decisions over the final 60% of the design completion.

5.5 Construction Cost Estimate

Estimated costs for the site are included in Table 2. Material and labor costs can vary as it is unknown when construction of this project will proceed. Project size and material quantities can be scaled to correspond with project funding.

Table 2. Construction Cost Estimate

PA Spawning Itemized Statement of Probable Engineering Construction Costs 2/27/2023					
		1. FULL PROJECT			
Item	**Description**	**Qty**	**Unit**	**Unit Price**	**Cost**
1	Mobilization	1	LS	$ 50,000	$ 50,000
2	Construction Area Control Points	1	LS	$ 10,000	$ 10,000
5	Permits	1	LS	$ 5,000	$ 5,000
6	As-Built Topobathy	1	LS	$ 20,000	$ 20,000
7	Staging Area	1	LS	$ 50,000	$ 50,000
8	Shoreline Access	1,500	LF	$ 100	$ 150,000
9	Rock Reefs	50,000	Ton	$ 180	$ 9,000,000
			Sub Total		$ 9,285,000
			15% Contingency		$ 10,677,750

5.6 Risk Register

In every restoration project there are unknown conditions that create unique design challenges. These unknowns introduce risk to potential projects that could impact cost or design efficacy. This risk register identifies potential design and construction risks and recommends possible strategies for managing these risks. Risk management strategies presented in Table 8 fall into three categories:

- Minimize – Deploy strategies to reduce the likelihood that the risk event occurs.
- Mitigate – Deploy a strategy to reduce the consequences to the site and design if the risk event occurs.
- Accept – Acknowledge risk and formulate a strategy to respond should the risk event occur.

For each of the risks identified, the risk register suggests a recommended method for managing the risk.

Table 3 Risk Register and Potential Management Strategies

Risk	Minimize Risk	Mitigate Risk	Accept
Materials Sourcing	Specify material gradation that is both optimal spawning and is found in abondance locally	Work with local contractors prior to specifying materials to determine local availability	Instruct the contractors to bid accordingly
Weather Delays	Not applicable; variations in weather events are beyond our ability to manipulate.	Contractor to complete work during months with less historical variability in weather	Instruct the contractors to bid accordingly
Dynamic Water Levels – Bridge Clearance	Not applicable; variations in water surface elevations are beyond our ability to manipulate	Contractor to complete work during months with less historical variability in water surface elevations	Instruct the contractors to bid accordingly
Rapid Wind Changes	Not applicable; variations in weather events are beyond our ability to manipulate.	Contractor to complete work during months with less historical variability in weather	Instruct the contractors to bid accordingly
Navigation Hazards	Top of reefs are to be constructed at minimum depth of 4m	Request a navigational map revision to include the reef structures	Acceptable risk with structure location publicly available
Ice Impacts	Top of reefs are to be constructed at minimum depth of 4m	Reefs are to be monitored regularly record any possible damages from ice impacts	Acceptable risk, as reefs are not likely to be impacted by ice movement

Risk	Minimize Risk	Mitigate Risk	Accept
Maintenance & Monitoring Costs	Maintenance and Monitoring are necessary costs to aid in the success of the reef		Include funding for a 5yr minimum maintenance and monitoring plan

6 Project Plan

The project plan presented in this section consists of two elements: a pre- and post-construction monitoring plan, and a post-construction public outreach plan. The purpose of this plan is to provide a roadmap for project care that ensures continued success after initial construction. All plan and programs within this section are subject to change based on the finalization of 100% design and permitting requirements.

6.1 Pre- and Post-Construction Monitoring Plan

6.1.1 Background and Purpose

This monitoring plan will serve as a guiding document to ensure the long-term success of the Pennsylvania Fish Spawning Reefs. Monitoring activities will include a mix of qualitative and quantitative assessments. All observations, measurements, and data downloads should be carefully documented by the field crew.

6.1.2 General Schedule and Logistics

Pre-construction monitoring should be done once within 6 months prior to construction. Post-construction monitoring should be completed twice within the first 12 months and once per year during the second through fifth year after construction. Early summer is the target time frame for conducting monitoring activities, as this is after the spring spawning season. The exact timing will be determined by weather, site conditions, and staff availability; however, timing should be consistent from year to year.

Although recommendations for survey methods and sampling time periods are included in this monitoring plan, the health and safety associated with accessing the site will be left up to the discretion of the qualified field team. If one does not already exist, a Health and Safety Plan (HASP) should be prepared that outlines the safety issues of concern prior to the first site visit. Field crews should have the proper training necessary to ensure their safety and for the operation, maintenance, and calibration of field equipment. Any special permissions to access the site should be obtained prior to field mobilization.

6.1.3 Dissolved Oxygen

Dissolved oxygen levels need to remain suitable for fish survival and can be monitored through observable indicators when no dissolved oxygen sensor is available. While monitoring the site, field crews should look for signs of potential low dissolved oxygen levels in the water and note them if observed. Indicators of low dissolved oxygen levels include turbid water, foul-smelling water, water discoloration, areas of stagnant or low-flowing water, the presence of algal blooms or high algal growth in the water, high levels of organic debris, and aquatic life kills or fish gulping air. Any visible indicators or signs that differ from expected water conditions should be captured with detailed notes, photos, and location coordinates.

6.1.4 Fish Monitoring and Telemetry Survey

Fish monitoring will be an important way to determine the success of the spawning reefs. Fish count surveys can be done to compare the trout using the reef by comparing pre-project and post-project trout population sizes near the reef. Telemetry surveys, which include implanting tags into trout, would also help monitor fish movement and use of the reef with near real-time receivers. These receivers detect the presence of acoustic tags implanted in the fish. The tag detection data can provide information about the habits of trout around the constructed reefs. Tracking egg deposition, with egg bags or mats, could also be used to monitor trout spawning on the constructed reefs.

6.1.5 Reef Debris Accumulation

Field crews also need to evaluate debris accumulation in the reef. Field crews must first make visual identifications of all types of debris accumulation and document the findings along with photos and location coordinates. Next, the person(s) must estimate the percentage (%) of reef length impacted. If the longitudinal extent of debris accumulation is small, or localized to just a few sections, the field crew may also estimate the percentage (%) of the reef cross sectional area that is impacted.

6.1.6 Photos & Underwater Survey

To document changes to the project over time, photos should be taken during each site visit. Aerial or surface photos will only be of use during periods of extremely good water clarity, which is rare. Underwater video and photographic documentation should be used instead. PA CRMP possesses a VideoRay ROV and HD drop camera, which can be used for this documentation. General site photos should be taken from the same location and orientation on each visit to best capture temporal changes.

Side Scan can also be used for monitoring any spatial changes in the reef footprint or areas of debris accumulation. The Side Scans could be followed up with video surveys to target any anomalies that were detected acoustically. More detailed photos may be required depending on site conditions. If any maintenance is performed in the field, all activities will need to be documented in a field notebook or tablet, and photos should be taken to show before and after conditions.

6.1.7 Reef Bed Stability

Reef bed rubble will be inspected to identify material that has been displaced. Displaced rubble should be identified and photographed. If displaced material, or the voids left by displaced material, constitutes a potential threat to the reef stability, maintenance activities should be ordered to address the issue.

6.1.8 Erosion

Visual identification of reef and rubble erosion should be conducted for the entire site. If erosion is identified, it should be located, and photo documented. Maintenance needs for erosion needs to be determined on a case-by-case basis.

This monitoring plan was adapted from the Illinois Beach State Park Rubble Ridge monitoring plan, given the extensive history of pre and post site monitoring that took place at the project site.

6.2 Maintenance Plan

Based on discussion with the Illinois Beach State Park project team (Healthy Port Futures), David Fielder (Michigan Department of Natural Resources) Bretton Joldersma (Michigan Department of Environment, Great Lakes and Energy) Tomas Hook (Purdue University), and Anthony Arnold (USGS), who have experience with previous reef construction projects, it was recommended that a tow behind jetting system/sled be considered for maintaining the reef.

The MI jetting system is essentially a sled that can be dragged over the top of the reef with an underwater jet mounted to it. The MI jetting system was custom built for their needs. In PA DEC is interested in pilot testing a such a system they should reach out to David Fielder and Bretton Joldersma to discuss renting the MI jetting system. If a pilot test is successful, a long-term agreement could be may with MI or PA DEC may commission a similar sled.

6.3 Post-Project Public Outreach Plan

The recommended post-project public outreach plan has been developed to provide a path for communicating project results to target audiences after completion. It is designed to be thorough, but not onerous: targeting a wide audience across multiple communication methods and focusing public outreach activities that project partners may already participate in. Messaging should consider the audience, the goals of the outreach activity, and the timing of the communication. Partners should consider coordinating with their internal communications offices for assistance with materials development.

This post-project public outreach plan is intended to reach two audiences: the general public and other restoration-focused professionals (both internal and external to participating partner organizations). Public communication goals include the following:

- Awareness of project-specific habitat restoration benefits
- Education about the importance of habitat restoration to maintaining healthy fisheries and waterfronts

Public communication methods should include a variety of communication pathways—in-person, online, and in-print—to reach a wide audience. A summary of activities that could meet the above criteria is presented in Table 4.

Table 4. Summary of Potential Post-Project Public Outreach Strategies

Target Audience	Activity Type	Communication Method	Timing	Example
Public	Online	Social media engagement	Opportunistic	Twitter and Facebook posts documenting post-construction monitoring or advertising press releases regarding the new habitats.

Target Audience	Activity Type	Communication Method	Timing	Example
Public	Online, In-Person	Social media engagement, Informational Kiosk, Public Event	During project implementation, After project completion	Work with S.O.N.S.
Public	Online	Press release	After project completion	Develop a press release for reef construction on "Press Releases" section of the PA DEP website
Public	Print	Informational kiosk	After project completion	Develop an informational kiosk for display at the launch points near Presque Isle.
Professional	In-person	Conference presentation	Annual conference	Present projects at Great Lakes Fisheries Commission Annual Meeting.
Professional	In-person	Internships	After completion	Internships with PA DEP to train students how to execute monitoring plans.

There are several groups which could be engaged with as part of targeted public engagement. These include:

- Save Our Native Species (S.O.N.S. of Lake Erie)
    - S.O.N.S. is an not for profit organization dedicated to the improvement of fishing on Lake Erie and its Pennsylvania tributaries, and they are leaders in the push for free public access to the water.
    - The current president is: Jerry Skrypzak - sonslakeri@aol.com
- NAACP Pennsylvania
    - The NAACP has a brand dedicated to environmental and climate justice.
    - Conversations with the NAACP environment teams from other states have always been stimulating and productive. Opportunities for engagement have always been an organic outcome of the conversation.
    - The current PA representative is: Richard Wukich - **Environment@pastatenaacp.org**

- Pennsylvania Sea Grant
    - They offer graduate fellowships, K-12 learning opportunities, and stewardship opportunities.
    - The local college program office is located near the peninsula.

7 Regulatory and Environmental Compliance Review

The final phase of design before construction will require permitting and environmental compliance at the federal, state, and local level. The regulatory and environmental compliance review is intended to identify the appropriate permits and review at each level of government and to identify design or site constraints that should be carefully considered by regulatory partners.

7.1 Federal

A Nationwide Permit 27 (Aquatic Habitat Restoration, Enhancement, and Establishment Activities) is anticipated for this site. This site falls within the USACE Pittsburgh District. Information regarding this permit application can be found at:

https://www.swt.usace.army.mil/Portals/41/docs/missions/regulatory/NationwidePermits/Nationwide%20Permit%2027%20-%20Aquatic%20Habitat%20Restoration,%20Enhancement,%20and%20Establishment%20Activities.pdf?ver=2017-03-31-150708-350

This project is also anticipated to require a Nationwide Permit 1 (Aids to Navigation). This permit can also be applied for through the USACE Pittsburgh District office who will engage with the U.S. Coast Guard for approval. Additional information regarding this permit application can be found at:

https://saw-reg.usace.army.mil/NWP2021/NWP-1.pdf

7.2 State

Current state permit applications go through PA DEP Waterways and Wetlands Program. The current contact there is Karl Gross.

This project will likely need to be permitted under State Code Chapter 105 Dam Safety and Waterways Management as a general permit. Additional information regarding this permit can be found at:

http://www.pacodeandbulletin.gov/Display/pacode?file=/secure/pacode/data/025/chapter105/subchapLtoc.html&d=reduce

7.3 Local

Local permits are not anticipated to be required at this site.

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