Lake Superior Shoreline Restoration

Preliminary Design Report

April 15, 2021 | 13290.102.R2.Rev0

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Lake Superior Shoreline Restoration

Preliminary Design Report

Prepared for:

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Revision	Date	Status	Comments	Prepared	Reviewed	Approved
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0	Apr 15, 2021	Final		MJC	CDA/MD/RBN	MJC

Executive Summary

The City of Marquette, Michigan (City) and the Superior Watershed Partnership (SWP) are undertaking the Lake Superior Shoreline Restoration project along 4,000 ft of waterfront in Marquette, roughly centered on the former Cliffs-Dow industrial site. The overall objectives of the project include stabilizing the shoreline, protecting infrastructure, providing habitat restoration, and improving public access to and along the City's waterfront.

The project location is shown Figure ES.1.1 below. The work is being executed in two phases:

1. Phase 1 – This phase involves relocating Lakeshore Boulevard inland of its current position. Design and construction of the Phase 1 work was undertaken by the City, and the roadway opened in October 2020.
2. Phase 2 – This phase involves shoreline restoration, including stabilization, habitat features, and public access to the waterfront. Engineering, design, and construction of this phase is being undertaken on behalf of the City by SWP.

For Phase 2, project funding is being provided by various sources, including the National Fish and Wildlife Foundation (NFWF), Michigan Coastal Management Plan (MCMP), and the City of Marquette. The NFWF metrics are related to restoration include upland areas, aquatic habitat, beaches, and coastal wetlands.

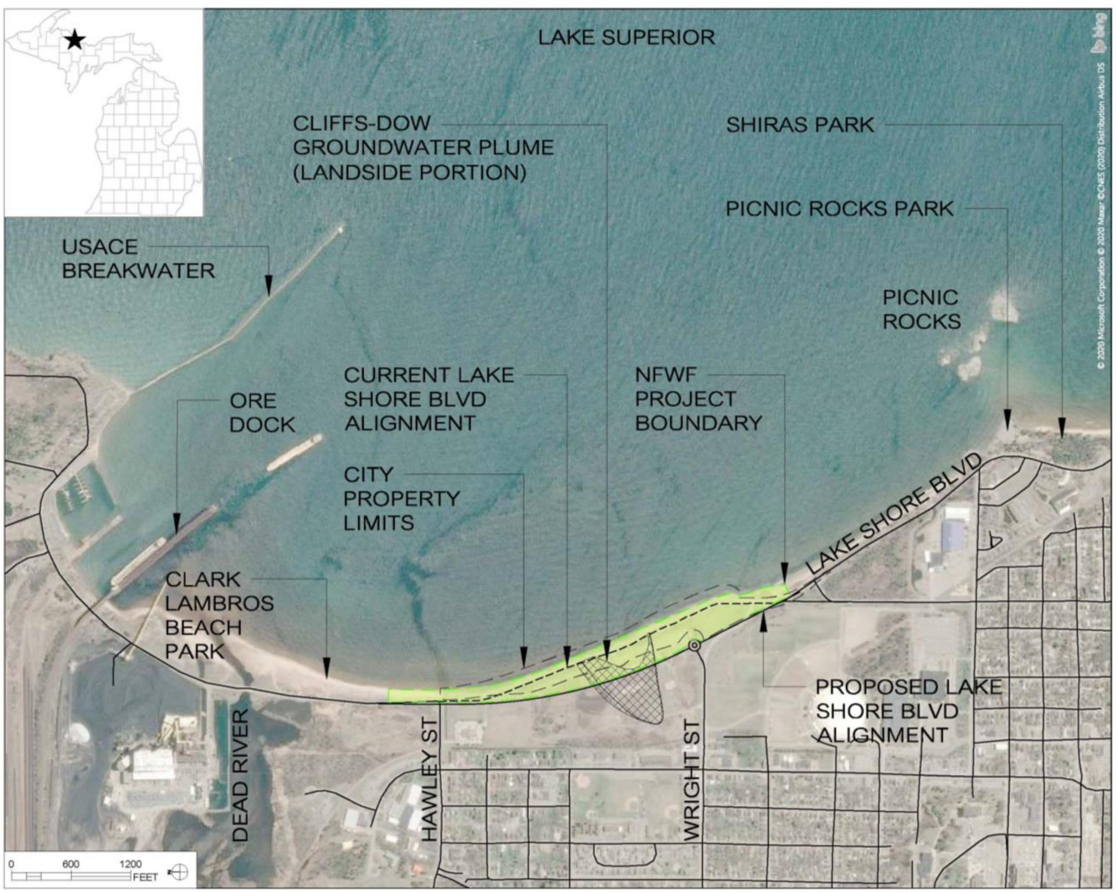

Figure ES.1.1: Project Location

W.F. Baird & Associates Ltd. (Baird) has been commissioned by SWP to undertake fieldwork, engineering, design, and permitting for Phase 2. The Baird team is comprised of Baird as team lead, with Foth LLC and Applied Ecological Services (AES) providing specialist technical input on civil engineering, structural engineering, permitting, environmental engineering, landscape architecture, and ecosystem restoration.

The scope of work for the Baird team involves producing Concept Designs to identify a preferred solution followed by a more detailed Preliminary Design, which involves further engineering, scientific analysis, and design development.

Stage 1 - Concept Design – The activities for this stage entailed data review, field data collection, assessment of Cliffs-Dow site remediation status, and determining existing coastal conditions. The work also involved preparation and evaluation of numerous alternative concepts, meeting with regulatory agencies to obtain feedback, and finalizing concepts. The result of this process concluded that the most prudent way to balance the habitat restoration and shoreline stabilization requirements is to create a Living Revetment, composed of cobble sized material placed at a shallow slope. The layout was well received by regulatory agencies the Michigan Department of Environment, Great Lakes, and Energy (EGLE) and the U.S. Army Corps of Engineers (USACE).

Stage 2 - Preliminary Design – The tasks that were undertaken during the preliminary design stage focused on further development of the shoreline restoration features associated with the Concept Design. The proposed solution is presented in Figure ES.1.2 and will provide approximately 4,000 ft of waterfront improvements and approximately 16 acres of parkland, as described below.

Sta 0+00 to Stat 10+00 – This portion of the project includes improvements that are on City and Northern Michigan University (NMU) property. The improvements in this area will include restoring the dune crest in three areas that have been lowered due to trampling by pedestrians. Additionally, a former dune on NMU property will be rebuilt and vegetated. On the landside, a wetland will be created at the far south end. Immediately north of this area, the improvements will involve constructing another wetland and grading to drain water away from the road and towards Lake Superior.

Sta 10+00 to Sta 41+66 – This portion of the project will feature shoreline protection in the form of a Living Revetment. The structure is comprised of quarried cobble sized stone that is placed at a slope of 6:1 and has a crest level ranging from +608 ft to 609 ft IGLD 1985. It provides a means to stabilize the shoreline and encourage habitat restoration, with specific elements as follows:

- Shoreline – The Living Revetment will provide approximately 3,000 ft of shoreline comprised of quarried cobble sized stone allowing for underwater habitat and public access to the water. This type of feature occurs naturally throughout the Lake Superior region.
- Wetlands - On the north side of the site, controlled breaches in the Living Revetment allow a hydraulic connection to be formed between Lake Superior and a wetland complex.
- Dune/Swale - In the middle and southern portions of the site, a dune/swale system will be created to mimic natural systems in the Marquette area.
- Overlook and Trails – these are provided for accessing the parkland, public recreation, and enjoying views of Lake Superior.
- Pocket Beach - A pocket beach is located near the south end of the project site to form a protected aquatic habitat and a sheltered area for public recreation. The pocket beach incorporates an armor stone wall, using stone salvaged from the existing revetment to create an arc around the landward perimeter of the pocket beach.

Regulatory agencies informed the team that, for the permitting process to be completed, an assessment of anticipated impacts to 1) adjacent properties; and 2) navigation is required. This task was undertaken and concluded that the project will not impact property owners to the north or south of the project. Also, it is anticipated that navigation will not experience any impact due to the project.

As the project is innovative and involves new construction, monitoring is required to understand its performance. The recommended actions involve:

1. **Site visits, observations, and surveys -** These are straightforward and can be done inexpensively by walking the site to record observations and surveys using drones.
2. **Stone monitoring** – monitoring of a select group of stones will be necessary to track the dynamic nature of the Living Revetment.
3. **Sta 0+00 to Sta 10+00 -** Based on the results of the monitoring efforts, there will be a need to maintain the area between Sta 0+00 and Sta 10+00. The work will likely involve occasional placing of sand/stone mix to replenish the dune.

A draft Project Construction Manual has been prepared comprising the request for bid language, general requirements, contract terms and conditions, specifications, and supplementary information. Preliminary design drawings have also been prepared to provide a full project layout and descriptions of major details.

The final step in the Preliminary Design Stage is to prepare a permit application for review by the regulatory authorities. It will include documentation confirming bottom lands have been conveyed to the City as well as supporting documentation that justifies the purpose and need for the project as well as investigating impacts on navigation and adjacent properties.

Stage 3 – Should the City and SWP elect to proceed with the project, Stage 3 would include Final Design and Bidding. The following activities are anticipated in Stage 3:

- Design adjustments – revising the design of the proposed solution to comply with comments from the regulatory authorities that come out the permit application review process.
- Final design – completing all remaining design details to fully define the scope of construction work for all project components.
- Bid Documents – preparation of bid documents, including drawings, specifications, contracts, bid notice.
- Pre-Bid Meeting – meeting with all interested contractors to review the bid package and answer questions.
- Bid Adjudication – review/assessment of bids and making recommendations for award of contract.

Schedule - A tentative schedule for the remainder of the project is shown below. It is based on securing the project permit by August 2021 and obtaining sufficient project funding. Should either of these items be delayed, then the schedule will be pushed back, and the project completion date will be later than that indicated below.

- Late February 2021 – completion of Preliminary Design
- Late March 2021 – prepare and submit permit application for construction to EGLE/USACE
- April – May 2021 – complete final design
- June 2021 – project bidding
- August 2021 – receive project permit from EGLE/USACE
- September 2021 – commence construction
- August 2022 - complete construction

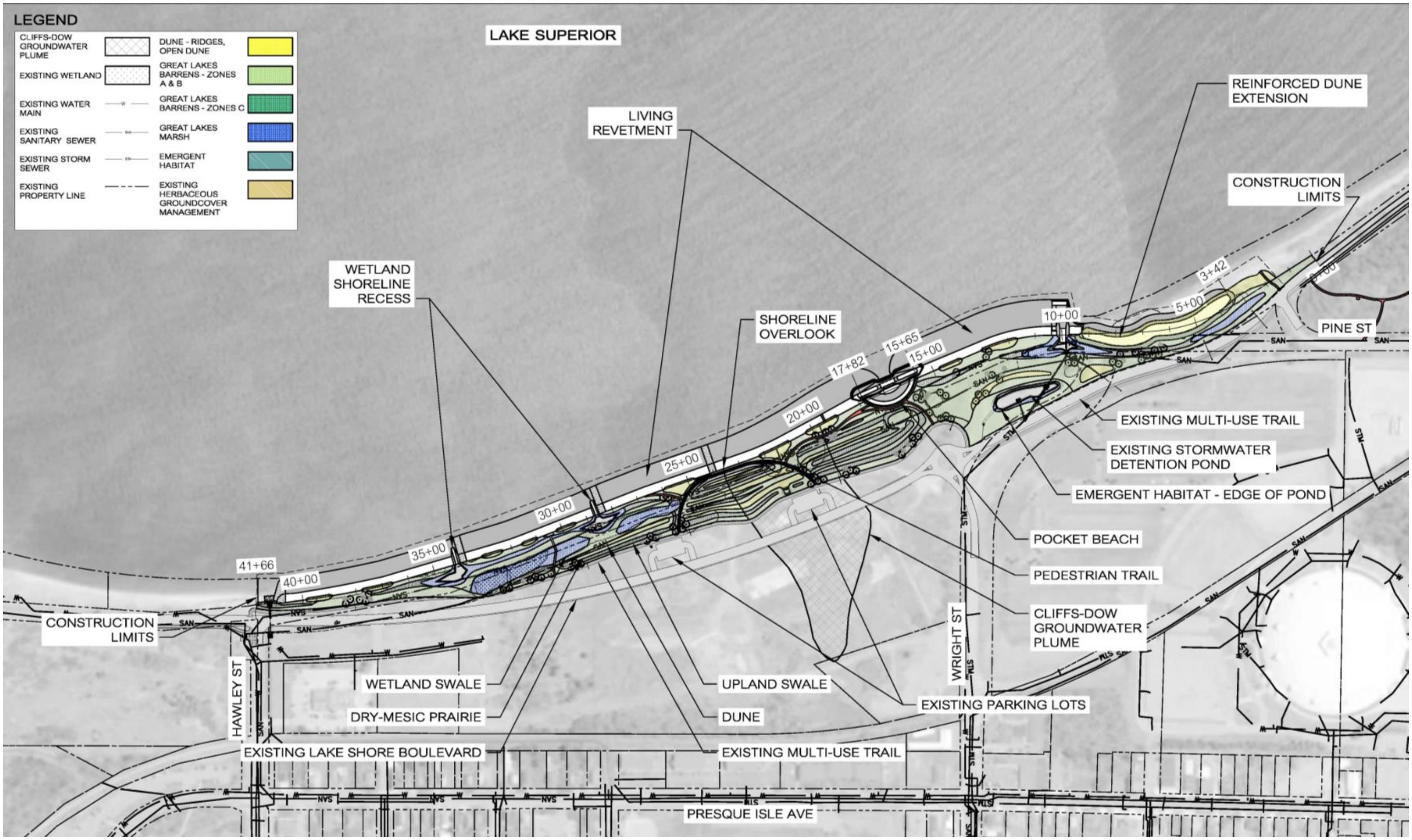

Figure ES.1.2: Project Layout - Living Revetment Solution

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1. Introduction

The City of Marquette, Michigan (City) and the Superior Watershed Partnership (SWP) are combining efforts to undertake the Lake Superior Shoreline Restoration project, which involves protecting infrastructure, habitat restoration, and public waterfront access.

The project location, shown in Figure 1.1 below, was the home of major industry for more than 70 years and is known as the former Cliffs-Dow site.

The project has two phases:

1. Phase 1 – This phase involves relocating Lakeshore Boulevard inland of its current position, which is adjacent to the shoreline. The roadway realignment is necessary to reduce risk of frequent damage due to wave overtopping during coastal storms. Design and construction of Phase 1 work was undertaken by the City, and the roadway opened in October 2020.
2. Phase 2 – This phase involves shoreline restoration involving stabilization, habitat features, and public access to the waterfront. Engineering, design, and construction of this phase is being undertaken on behalf of the City by SWP.

W.F. Baird & Associates Ltd. (Baird) has been commissioned by SWP to undertake fieldwork, engineering, design, and permitting for Phase 2. The Baird team is comprised of Baird as team lead, with Foth LLC and Applied Ecological Services (AES) providing specialist technical input on civil engineering, structural engineering, permitting, environmental engineering, landscape architecture, and ecosystem restoration.

Project funding for Phase 2 is partially provided by a grant from the National Fish and Wildlife Foundation (NFWF). The grant agreement indicates the habitat goals are as shown below. Meeting the exact acreage for each of the categories below is not required but is to be used as a guide in the development of the project layout.

- Beach area – 3 acres
- Aquatic habitat – 1.6 acres
- Wetlands – 3 acres
- Uplands – 16 acres

The remainder of this report is dedicated to documenting the process and results associated with understanding existing conditions, developing the preferred alternative design, defining the project elements, investigations related to regulatory impacts, and recommendations on subsequent tasks.

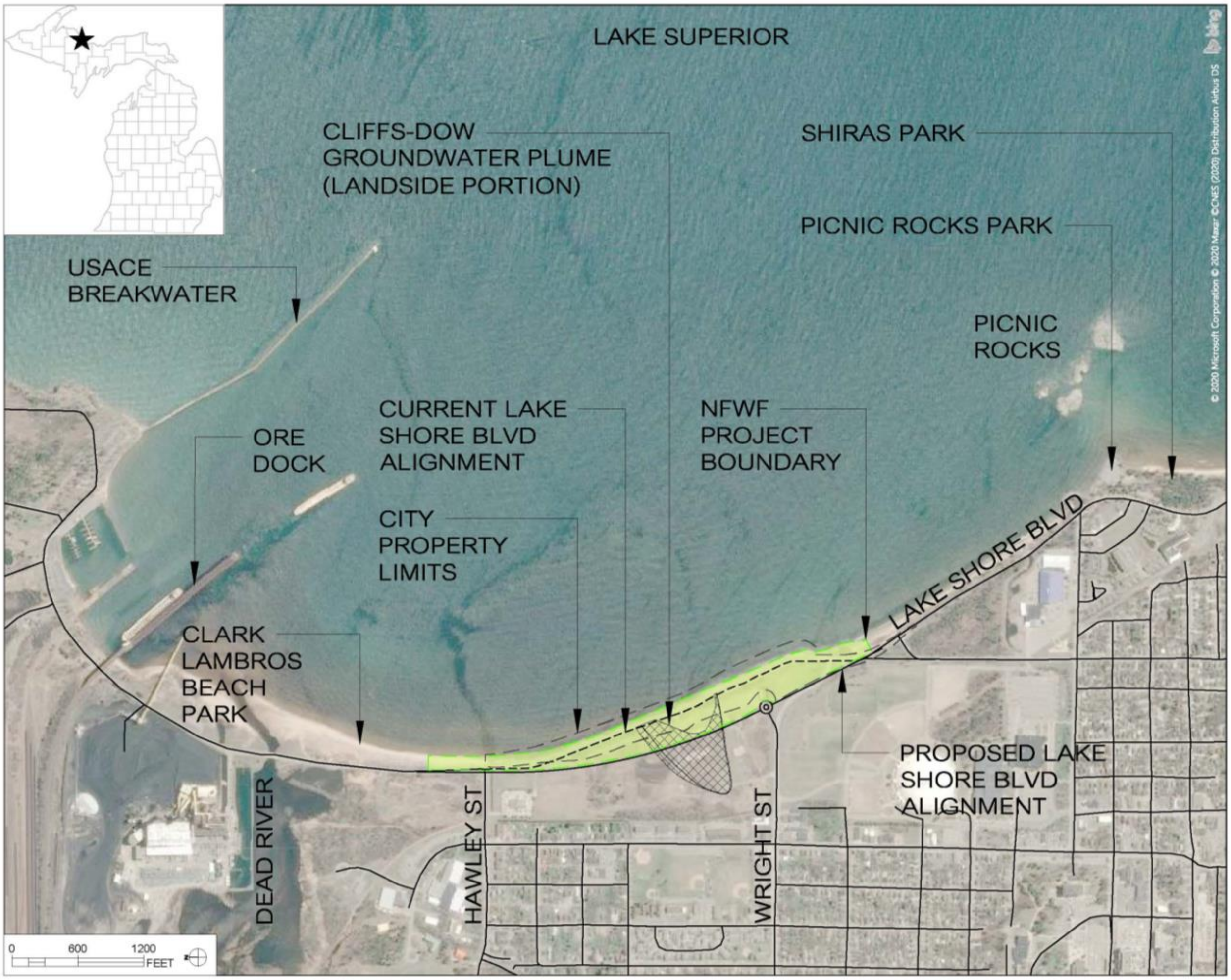


Figure 1.1: Project Location

2. Existing Conditions

2.1 Site Status

Site visits were conducted in June and August of 2020 for the purposes of observing conditions firsthand, taking photographs, and recording observations (Ref App A). A sampling of photographs taken during the site visits is shown in Figure 2.1. Key findings from the site visits, and conversations with SWP and the City, indicate:

- Overall – Most of the 4,000 ft shoreline is a public eyesore, a serious public safety hazard, offers no waterfront pedestrian access, and does not contribute to the surrounding ecosystem. In some portions of the site, the area adjacent to the shoreline will remain vulnerable to flooding unless protection is upgraded.
- Property Lines – Starting at Hawley Street and continuing south for 3,000 ft, the first line of defense against erosion and flooding (the existing revetment) is on City property. Further south, for the remainder of the project length (1,000 ft), the first line of defense is the dune, which is owned by Northern Michigan University (NMU).
- Topography – The site is partially vegetated and has limited relief, with elevations ranging from 605 ft to 610 ft (IGLD 1965), with higher grades at the north end.
- Bathymetry – Existing lakebed elevations, relative to Low Water Datum (601.1 ft IGLD 1985), range from -3 ft at the north end up to -9 ft at the south end of the site. This is expected as the north end is more protected and likely experiences less erosion.
- Structure – The existing revetment is a non-engineered structure comprised of randomly placed stone with estimated sizes ranging 0.25 ft to 3.9 ft (approx. 10 lbs to 5 tons). It provides marginal shoreline protection.
- Flooding – From discussions with the City and SWP, flooding at the north end is very rare and has not occurred in many years. However, the flood risk is much higher at the south end of the project where the existing grades are lower than the north end, and the shoreline is more exposed to wave action.
- Contamination – To observe existing contaminant concentrations below ground, approximately 15 monitoring wells have been established in the project footprint by the City. Some are still being used while others are abandoned. The Cliffs-Dow contaminant plume is shown on Figure 1.1.
- Wetland – There is a delineated wetland, 0.36 acres in area, in the northern portion of the site about 1,000 ft south of Hawley Street. From discussions with SWP, the wetland is considered by the USACE to be of low value.
- Legacy Materials - Remnants from the site's previous industrial operations include slag, a former dock wall, rubble from concrete foundations, abandoned outfalls, and other structures.
- Former Roadway - Immediately landward of the existing revetment and adjacent to the shoreline are the asphalt remnants of the former Lakeshore Boulevard, which has been damaged by ongoing erosion and wave overtopping. Damage is most severe in the southern reach of the project site and moderate along the northern portion of the site.
- Dunes – On the south end of the site, sand dunes are present on the NMU property and form part of the flood defense for Lakeshore Boulevard. The NMU dunes and beach are heavily used by pedestrians. As a result, the dunes have been breached in three areas where a path has been trampled over the crest.
- Outfalls – There are two existing stormwater outfalls, one at Hawley Street on the north side and one on the south side near Wright Street. Both outfalls are operable and will require integration into the design of the shoreline solution.

Figure 2.1: Shoreline Conditions

2.2 Cliffs-Dow Site

The Cliffs-Dow Site encompasses much of the project footprint and extends well beyond the project limits. Previous industrial chemical operations occurred at the Cliffs-Dow site began in 1902 and continued to 1969, reflecting a history of various processing, including:

- manufacturing of pig iron
- production of wood charcoal
- chemical refining of wood distillates

During the subsequent 28 years, ownership changed several times, and select demolition of structures and facilities occurred. In 1997, the City purchased the property.

Historical processing operations produced several waste streams, including unusable tar and soluble tar. Wastes were either stockpiled onsite or disposed of by standard industrial practices of the time. These practices reportedly included discharging of wastes into ditches which then emptied directly into Lake Superior (Barr, 1998). Two waste discharge ditches were identified. One discharged directly to the east from the plant area. The second discharge ditch traveled north along the western boundary of the site before heading east to Lake Superior. It discharged approximately where the present-day storm sewer discharges at the intersection of Lakeshore Boulevard and Hawley Street.

Since the cessation of plant operations, several investigations and remedial actions have taken place to identify and remove source contamination from the site. Several different parties have undertaken these actions, with the most recent efforts being undertaken by the City of Marquette and EGLE. Current efforts include the monitoring of site groundwater and the contaminant migration toward and into Lake Superior. EGLE and the City of Marquette have provided the Baird design team with available data sets from the mid-1990s to the present groundwater monitoring data.

2.2.1 Nearshore Impacts

Impacts to the shoreline and nearshore sediments are expected due to the sustained disposal of waste materials into Lake Superior through nearly 70 years of plant operations at the site.

In early June 2020, a shoreline reconnaissance was completed and identified the following features which may impact the design of the project:

- Large remnant steel outfall with the observed presence of tar like substance, which may be the direct discharge identified in the 1998 Barr report (Figure 2.2).
- Large amounts of scrap pig iron and slag located along the shoreline and between the existing revetment and former road.
- Six-inch (6”) steel pipe with observed tar residue inside.
- Building materials from historical upland operations.

Figure 2.2: Possible Historical Retort Discharge Pipe from Cliffs-Dow Site

In 2016, 2017, and 2018, EGLE conducted sediment borings to identify impacts within the upper layers of the sediment. These investigations found evidence of wastes from the historical industrial activities, including coal fragments and "campfire like" odors. A nearshore sediment coring investigation was undertaken to further identify the general nature of impacts. The sediment coring investigation was completed in May 2020 and observed coal-like material and the presence of odors within the sediments. The locations at which these were found are indicated on Figure 2.3 and are compared with the previous findings by EGLE (Ref Appendix B).

For the findings that represent individual locations, GPS coordinates were collected from locations identified during the Baird team's site reconnaissance. The scrap pig iron and slag deposits were consistent across the majority of the nearshore area; this suggests the materials may have been placed there as fill. In addition, a wooden pile wall was observed, which appeared to extend along the entire length from Wright Street to Hawley Street. Recent erosion in this area has exposed the piles, the steel tieback wires, and deadman anchors.

In August of 2020, test pits were dug at locations where excavation is planned during project construction. The purpose of this exercise was to understand if there were potential pitfalls related to handling and disposing of excavated material. There were three sites, with results as follows:

- Test Pit No. 1 (north of the existing wetland, lakeside) – results indicated material was mostly brown to dark brown sand with no evidence of volatile organic compounds or odors.
- Test Pit No. 2 (south of the existing wetland, lakeside) – results indicated material was topsoil underlain by dark brown sand with debris material from the former Cliffs-Dow plant operations. No odor was detected nor visible sheen.
- Test Pit No. 3 (near the area where the proposed pocket beach will be located) – results indicated material was a mixture of sand, pieces of shore protection fragments, and some organic material. No odor was detected nor visible sheen.

2.2.2 Considerations for Design and Construction

Based on discussion with the City of Marquette and EGLE, it is not anticipated that the planned excavation carried out during Phase 2 construction will be problematic in terms of environmental contamination. However, it is acknowledged that the character and quantity of such excavated materials are unknown at this time and will remain unknown at the time of bidding unless more investigations/studies are done. Additionally, NFWF funds do not allow for site remediation, which has been recognized by the City of Marquette. Therefore, various means to address this issue will be incorporated into the bidding and construction process, including:

- Excavation – excavation is, in general, minimal throughout the site and will be avoided in the area that lies above the plume footprint shown on Figure 1.1.
- Process – the specifications will include a section dedicated to a Response Action Plan, indicating what the contractor must do when encountering odors and visible contaminants. The plan should include contacting the State of Michigan EGLE response team.
- Line item – providing a line item in the bid form for waste (cu. yd or ton) that must be characterized, handled, and disposed of at a licensed landfill off-site. This item will be paid by the City of Marquette.

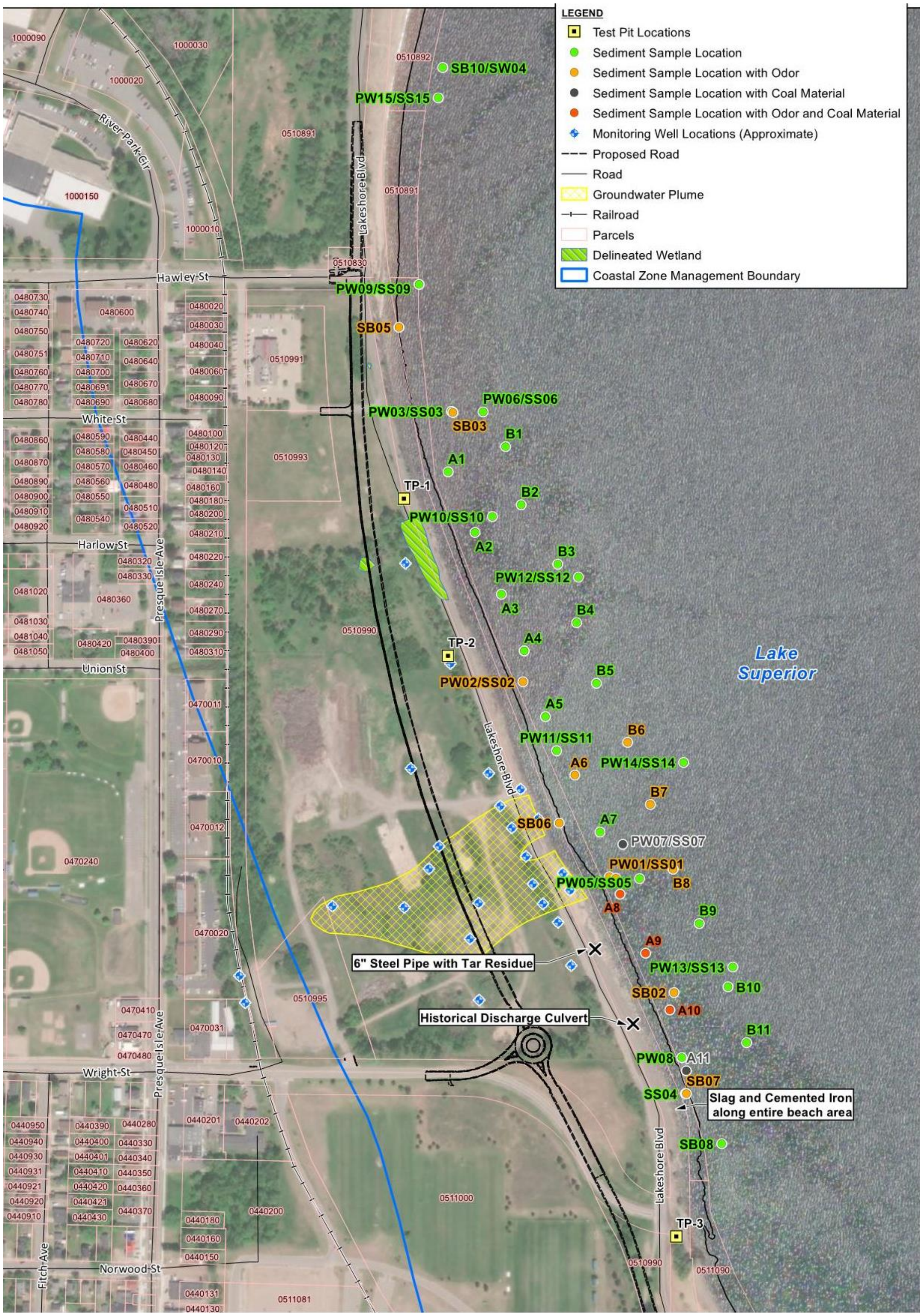


Figure 2.3: Cliffs-Dow Areas of Environmental Interest

2.3 Vegetation Assessment

Two sites were visited to understand the types of vegetation that could be applied to the Phase 2 site. These include an area referred to as the “Triangle Tract” and Tourist Park, the locations of which are presented in Figure 2.4.

Dune/Swale - The Triangle Tract comprises 10.5 acres of wooded dune and swale wetland located between Pine Street and Lakeshore Boulevard, north of the YMCA. It is one of the last remnants of the historic swamp that once covered northern Marquette. This area was visited during January 2020 and June 2020 to confirm observations documented in a 2002 report (Site Observations, Development Options, and Property Recommendations for the Longyear, Shiras and Triangle Land Tracts) by Ronald Sundell et al. It was confirmed that the physiognomic and ecological character of the Triangle Tract is consistent with what is described by Sundell et al (2002). Short dunes are present, vegetated by white pine, red maple, and white birch. Low swales separate the dunes and are vegetated by tag alder, red osier dogwood, black spruce, tamarack, and royal and sensitive ferns. Invasive glossy buckthorn is also present. Individual species and species assemblages observed and documented at the Triangle Tract will inform wooded and shrub communities proposed for the project area restoration.

Available 1-foot LIDAR data from the Triangle Tract (USGS 2015) was used to understand the physiognomic character of a remnant dune and swale system. The dunes and swales run parallel to the shoreline with the elevations of both features increasing with distance inland from the lake. The width of the features (e.g., from dune ridge to the next dune ridge) also generally increases with distance from the lake, in increments of approximately 20 ft ranging up to 80 ft, with frequent “breaks” between dune ridges connecting the swale features.

Beachgrass **–** In field establishment and elevation of beachgrass persisting along Lakeshore Boulevard was observed. This data provides insight as to how well beachgrass persists given the existing wave climate and will be used to inform the selection of locations restoring beachgrass along the shoreline in the project area. Since most of the remnant beachgrass occurs north of the project area and behind the shadow of the USACE breakwater, the existing elevations of the beachgrass do not directly correlate with the wave climate to the south of the project area.

Wetland Vegetation - Wetland and nearshore vegetation were monitored over several days at Tourist Park during June 2020. While the Dead River impoundment at Tourist Park lacks the coastal dynamics of the project area, the sandy substrate, vegetation, and proximity of the park is comparable to the project area. Furthermore, MDNR staff helped develop the plant and seed mix for Tourist Park and recommended that the design team use the same list for the restoration of the project area. A very good understanding has been developed as to what species from the original seed and plant lists thrived or failed to become established at Tourist Park. This data will be used in conjunction with the availability of native plant and seed material to develop an improved species list for the Lakeshore Boulevard project area.

Figure 2.4: Vegetation Assessment Areas

3. Wave and Water Level Conditions

3.1 Wave Conditions

Offshore Wave Climate – Information on the offshore wave environment is available through the Wave Information Studies (WIS) conducted by the USACE. The data set provides hindcast waves for the 1979-2014 period (i.e., 36 years) for a series of locations throughout the Great Lakes. Data from WIS Station 95077 (46.56° Lat and -87.32° Lon) located in approximately 44 m (144 ft) of water depth offshore of Marquette was used for this analysis.

The corresponding offshore/deep water wave rose is shown in Figure 3.1 and indicates the following:

- Offshore waves arrive from the northeast (NE) to northwest (NW) window approximately 60% of the time. Significant wave heights greater than 20 ft may occur during extreme storms from north-northeast (NNE) direction.
- Offshore waves arriving from the northeast (NE) to southeast (SE) window (i.e., easterly waves) occur approximately 10% of the time, with wave heights reaching 10 to 12 ft.
- Wave heights are less than 2 ft (i.e., relatively calm conditions) approximately 70% of the time. Wave heights are greater than 5 ft approximately 5% of the time. Wave periods range between 2 to 12 seconds.

Of note, the site is generally exposed to south easterly (SE) and east waves. However, the Federal breakwater provides a progressive increase in sheltering to the site from NE, north, and NW waves, as discussed below.

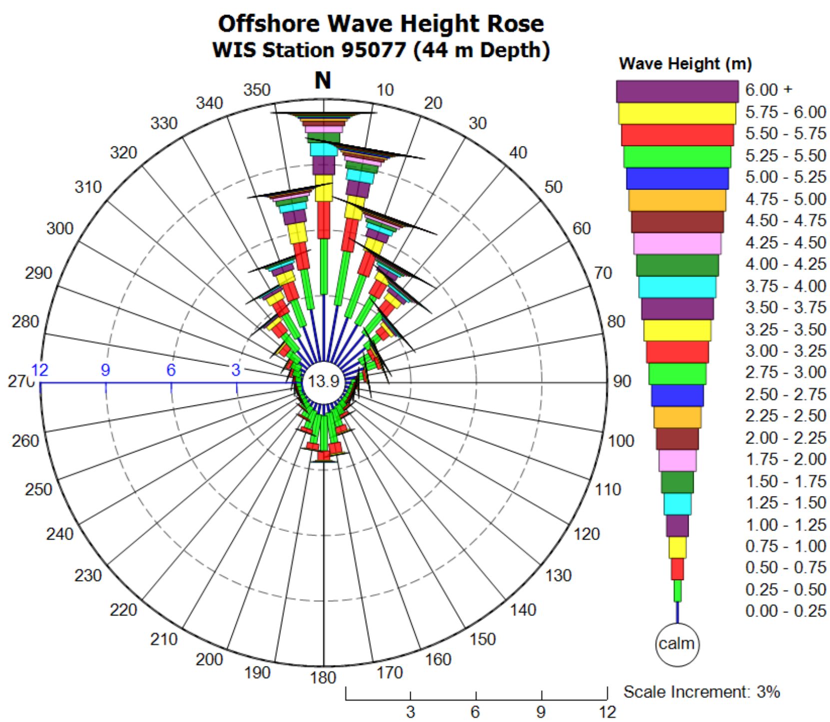


Figure 3.1: Offshore wave height rose at Marquette

Nearshore Wave Climate - To understand the nearshore wave climate, the offshore waves were transformed to various nearshore locations along the project shoreline using the Danish Hydraulic Institute (DHI) MIKE21 Spectral Wave (SW) model. Offshore wave conditions were defined at the model boundaries using the WIS data, and nearshore bathymetry was obtained from the USACE 2011 LiDAR data. Wave transformation calculations were performed for average lake level conditions (i.e., ~ 601.8 ft IGLD'85).

Examples of wave height patterns under a strong northeasterly (NE) event, as well as an easterly event (E), are displayed in Figure 3.2. The color shading in this figure represents the significant wave height Hs, and the arrows indicate the wave propagation direction. The model results illustrate how waves undergo refraction as they approach the project site. The results also indicate that the Federal breakwater has a significant impact on the nearshore waves in front of the shoreline, resulting in progressive reduction in wave height as one moves north into the shadow zone of the Federal structure. The sheltering effect progressively increases as the wave direction turns from east through NE to north and beyond.

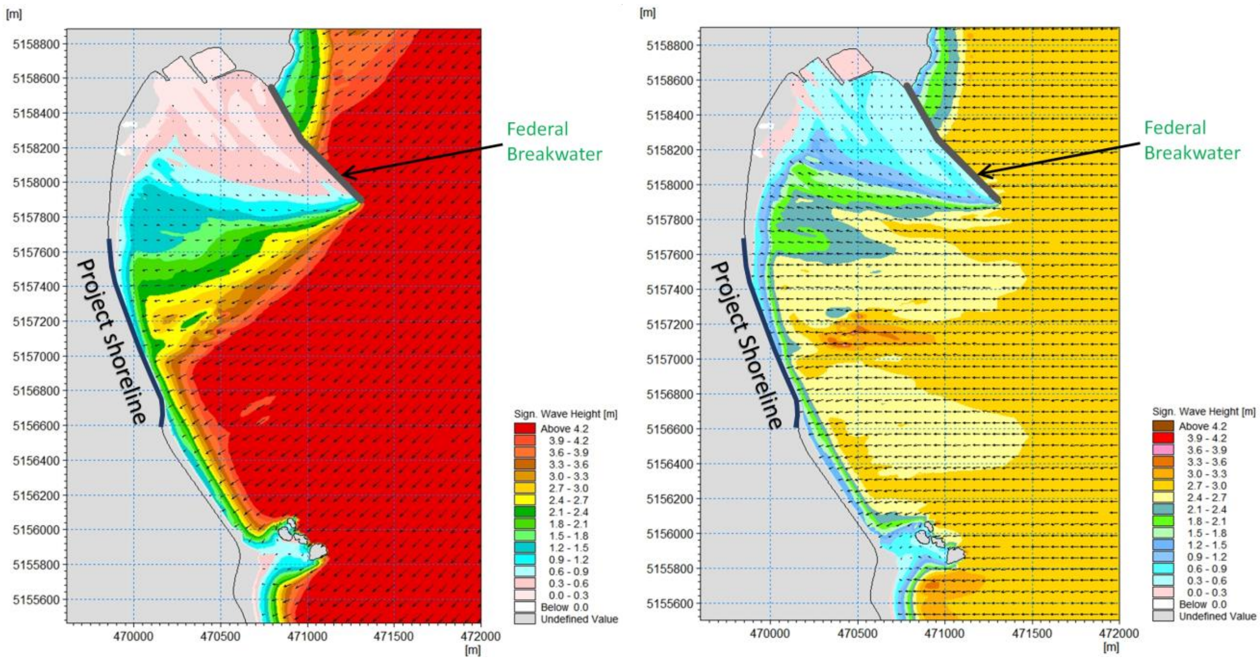


Figure 3.2: Model results (waves from NE direction on left, waves from E direction on right)

Extreme Wave Heights - Using the SW model, the entire offshore wave hindcast time series was transformed to a total of 15 locations along the project shoreline at various lakebed elevations 3 ft, 10 ft, and 16 ft (1m, 3m, 5m). Peak over threshold (POT) extreme value analyses (EVA) were subsequently performed on the transformed waves to determine extreme events with various return periods at locations shown in Figure 3.3; the results of the POT EVA are shown in Table 3.1. The results illustrate that the extreme wave height at the north end is reduced by more than 40% when compared to wave heights at the south end due to the sheltering effect of the Federal breakwater.

Of note, the extreme nearshore wave heights are depth-limited; hence, the water level and lakebed elevation are controlling variables, with larger wave heights occurring during periods of high lake levels and as one moves lakeward from the existing shoreline.

Table 3.1: Extreme Nearshore Significant Wave Heights (Hs, ft)*

Return Period	A			B			C			D			E		
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	E3
5-yr	4.1	7.4	8.1	2.3	6.8	7.6	3.4	5.6	5.5	2.2	4.0	4.1	2.4	3.6	3.8
10-yr	4.2	7.8	8.7	2.4	7.3	8.3	3.5	6.1	6.1	2.3	4.4	4.5	2.5	4.0	4.2
20-yr	4.2	8.1	9.3	2.5	7.7	9.0	3.6	6.5	6.6	2.4	4.7	4.9	2.6	4.3	4.6
50-yr	4.3	8.6	10.0	2.5	8.2	9.7	3.7	7.1	7.3	2.4	5.2	5.4	2.8	4.7	5.0
100-yr	4.3	8.9	10.5	2.6	8.5	10.3	3.8	7.5	7.7	2.5	5.5	5.8	2.8	5.0	5.4

Wave Transect Location (columns A–E)

*e.g. A1 indicates transect A at -3 ft LWD lakebed elevation. A2 and A3 are at lakebed elevations -10 ft and -16 ft LWD, respectively. LWD is 601.1 ft IGLD 85 on Lake Superior.

Figure 3.3: Wave Transects in the Project Area

3.2 Water Levels

Introduction - Water levels on the Great Lakes, including Lake Superior, vary on several different time scales in response to different climatic processes. At the longest time scale, measured in years, water levels vary on multi-year cycles based on changing precipitation and evaporation patterns over the Great Lakes drainage basin. It is noted that periods of below average lake levels tend to persist for several years, as do periods of above average lake levels. This is generally due to the large storage capacity of the lake relative to its outflow.

Seasonal variations in lake level also occur in response to seasonal weather patterns; the seasonal variation on Lake Superior is typically in the order of one foot, with low lake levels generally occurring in March/April and high lake levels generally occurring in August/September.

Finally, localized short-term fluctuations in water level occur in response to the passage of individual storm systems over the lake. These “storm surges” may be either positive or negative.

Extreme high and extreme low water levels are an important consideration in the design of shoreline protection systems as they are a controlling factor in nearshore wave heights and the severity of wave overtopping. Typical lake levels are important in the assessment of coastal processes, such as nearshore hydrodynamics and sediment transport, and also in the planning and design of features that are hydraulically connected to the lake, such as wetlands.

Lake Levels – Historical and seasonal variations in lake level on Lake Superior have been assessed through a review of monthly mean water level data published by the USACE Detroit District. Figure 3.4 presents a graphical summary of the historical fluctuation in monthly mean water levels on Lake Superior. The extreme range in monthly mean lake level (record high to record low) is approximately 4 ft, while the typical annual fluctuation is approximately 1 ft. The long-term average water level is 601.7 ft IGLD 1985, which is 0.6 ft above Chart Datum (CD), also referred to as Low Water Datum (LWD). The lake level on Lake Superior approached near record levels in 2019 and remains well above average at this time (refer to Figure 3.4).

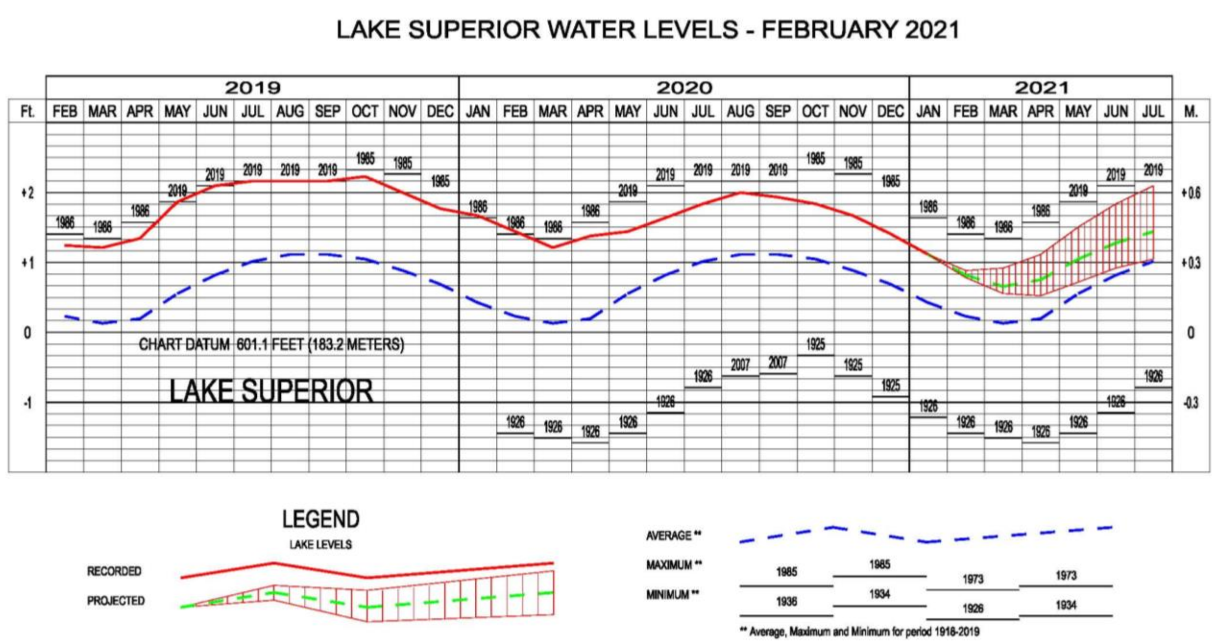


Figure 3.4: Average Water Levels on Lake Superior (blue dash)

Storm Surges – Local water levels may vary significantly on a short-term basis (i.e., over a period of hours to days) due to storm surge resulting from meteorological effects associated with individual storm events, including wind stress and barometric pressure. The magnitude of storm surge calculated for NOAA Station 9099018 in Marquette is approximately +/- 1 ft (positive/setup or negative/setdown). While storm surge varies depending on site location and local geomorphology, the NOAA Station in Marquette is located in close proximity to the project site and considered to be adequately representative of the project site conditions for design purposes. It should also be noted that surge occurs independent of the long-term and seasonal lake level fluctuations. However, there is a tendency for more severe surges to occur during the stormy winter period when lake levels tend to be lower.

Extreme Design Water Levels – The definition of extreme high and low water levels on Lake Superior must consider the combined effect of lake levels and storm surges. For the purposes of this Preliminary Design study, extreme water levels have been estimated through review of previous study reports and additional analysis, as described below:

- USACE (1993) - This report, "Design Water Level Determination on The Great Lakes", was developed by the USACE to provide guidance on design water levels for coastal engineering projects throughout the Great Lakes. The report presents design high water levels for various return periods based on statistical analyses of historical water level records from NOAA water level gauges around each of the Great Lakes.
- Baird (2004) – Baird performed an independent analysis of historical water level data recorded at Marquette (NOAA Station 9099018) to verify the 1993 USACE analysis and also define extreme low water levels by return period. The methodology utilized a joint probability analysis of monthly mean lake levels and storm surge.
- Baird (2020) - Baird carried out detailed statistical analysis of 40 years of recorded water level data at Marquette (hourly data from 1980 through 2020) to develop an updated estimate of extreme high-water levels by return period. Similar to the Baird (2004) study, this study utilized a joint probability analysis of monthly mean lake levels and storm surge.

Table 3.2 provides a comparison of the results for extreme high-water levels from each of the analyses described above. These water levels are presented relative to Lake Superior LWD, which is +601.1 ft IGLD 1985.

Table 3.2: Estimates of Extreme High-Water Levels

Return Period (Years)	USACE 1993 (ft LWD)	Baird 2004 (ft LWD)	Baird 2020 (ft LWD)
2	-	+2.0	+1.8
5	-	+2.4	+2.3
10	+3.1	+2.6	+2.6
20	+3.2	+2.7	+2.8
25	+3.3	+2.8	+2.9
50	+3.6	+2.9	+3.1
100	+3.8	+3.0	+3.2

The differences between the three sets of estimates are generally due to the use of different time periods and analysis methods. While both of the Baird analyses show lower extreme high-water levels than the USACE (1993) results, the more conservative USACE (1993) values have been adopted for the Preliminary Design.

The extreme low water levels estimated by Baird (2004) are summarized in Table 3.3 and have been considered in the Preliminary Design.

Table 3.3: Estimates of Extreme Low Water Levels

Return Period (Years)	Baird 2004 (ft LWD)
2	-0.4
5	-0.8
10	-1.0
25	-1.3
50	-1.5
100	-1.6

3.3 Climate Change

The following discussion provides a summary of the anticipated impacts of climate change on the design wave and water level conditions for the project.

Waves - The WIS hindcast considers the effect of ice cover, with no waves occurring when there is significant ice cover on the lake. The Environmental Law & Policy Center (2019) published a report indicating that ice cover is expected to decrease through the remainder of the 21st century but did not quantify the reduction. The Fourth National Climate Assessment (2018) indicates that average ice coverage on Lake Superior reduced by 71% between 1973 and 2010. Of note, ice coverage was high during the severe winters of 2014 and 2015, but a decreasing trend is expected in the future. Although some shore ice was observed at the site during the winter of 2019, based on the discussion above, no reduction in waves due to the presence of shore ice will be factored into the nearshore wave climate or analysis of coastal processes.

Water Levels - Climate change impacts to date are reflected in the water level data used in the current analyses. Looking ahead, the impact of climate change on water levels on the Great Lakes is uncertain; this is underscored by recent scientific research:

- A study by the International Joint Commission (2012) for the Upper Great Lakes notes that future water levels will continue to fluctuate as they have historically, with the potential for lake levels that are both higher and lower than the historical range.
- A study by the Environmental Law & Policy Center (2019) on the impacts of climate change on the Great Lakes indicates small reductions in water levels overall during the 21st century as opposed to previous research indicating larger decreases.

Given the uncertainty in this matter, the designs presented in this report consider extreme water levels based on analyses of historical water level record and do not consider any long-term increase or decrease in water levels that might result from climate change. We consider this approach to be reasonable as the predicted water levels are within the range of the historic record.

4. Concept Design - Project Layout

The current project layout is based on work undertaken during the Concept Design Study, which occurred from March to August of 2020 and is described in the Concept Design Report (Baird 2020). Below is a brief narrative of the process and results.

The Concept Design Study involved two main tasks:

Existing Conditions – compiling existing information, undertaking field data collection, and carrying out numerical analysis to help define the current conditions at the site. This data is needed for designing a solution that addresses site constraints.

Alternatives Evaluation – this task involved preparing and evaluating various alternative layouts that would address the site constraints, which included:

- Coastal conditions – aggressive marine conditions involving waves and water levels.
- Habitat – create habitat for terrestrial, aquatic, and wetland areas.
- Cliffs-Dow Site – understand and incorporate issues with the Cliffs-Dow Site into our design.
- Lakeshore Boulevard – provide flood protection to Lakeshore Boulevard.
- Shoreline – stabilize the shoreline and provide safe waterfront access.
- Stakeholder – incorporate the needs of project stakeholders.

There were three iterations of alternatives prepared for the project. Each round of alternatives was reviewed by SWP, the City, and regulatory agencies - EGLE and USACE.

Initial Concepts – A total of six initial concepts were created to provide shoreline stabilization, protect roadway infrastructure, and create habitat. The limits extended from Picnic Rocks to the Dead River. The concepts were prepared by Baird and subsequently reviewed by SWP and the City. The conclusion from this exercise is to confine the focus area to the NFWF boundaries, per previous public presentations. Habitat amenities could be added, but the main requirement is to provide erosion protection for the shoreline.

Pre-final Concepts – Based on the work involving the initial concepts and subsequent review feedback, three advanced options were prepared, each of which included armoring the shoreline with a stone revetment. These are presented in Figure 4.1 and described as follows:

- <u>Option 1</u> – The Option 1 concept involves armoring the shoreline with a conventional revetment extending for the length of the entire NFWF project shoreline. It includes a conventional stone structure with armor as well as stepped terraces located intermittently along the shoreline to provide waterfront access. The landward portion of the site includes a dune/swale system, stormwater detention wetland, and improvement to an existing wetland between the revetment and the relocated Lakeshore Boulevard. Trails between the new bike path and revetment walking path are also included.
- <u>Option 2</u> – The Option 2 concept includes the shoreline revetment in Option 1 plus a groin and beach system, created by placing sand at the north end of the site. The groin is a quarried stone structure and extends from the shoreline into the lake by about 450 ft. Its purpose is to prevent sand from migrating further to the north.
- <u>Option 3</u> – The Option 3 concept includes the shoreline revetment in Option 1 and a reef and beach system created by placing sand at the north end of the site. The reef is sited lakeward of the shoreline by 300-400 ft, varies in plan width (100-150 ft), and has a crest elevation of approximately 0.0 ft LWD (+601.1 ft IGLD 1985).

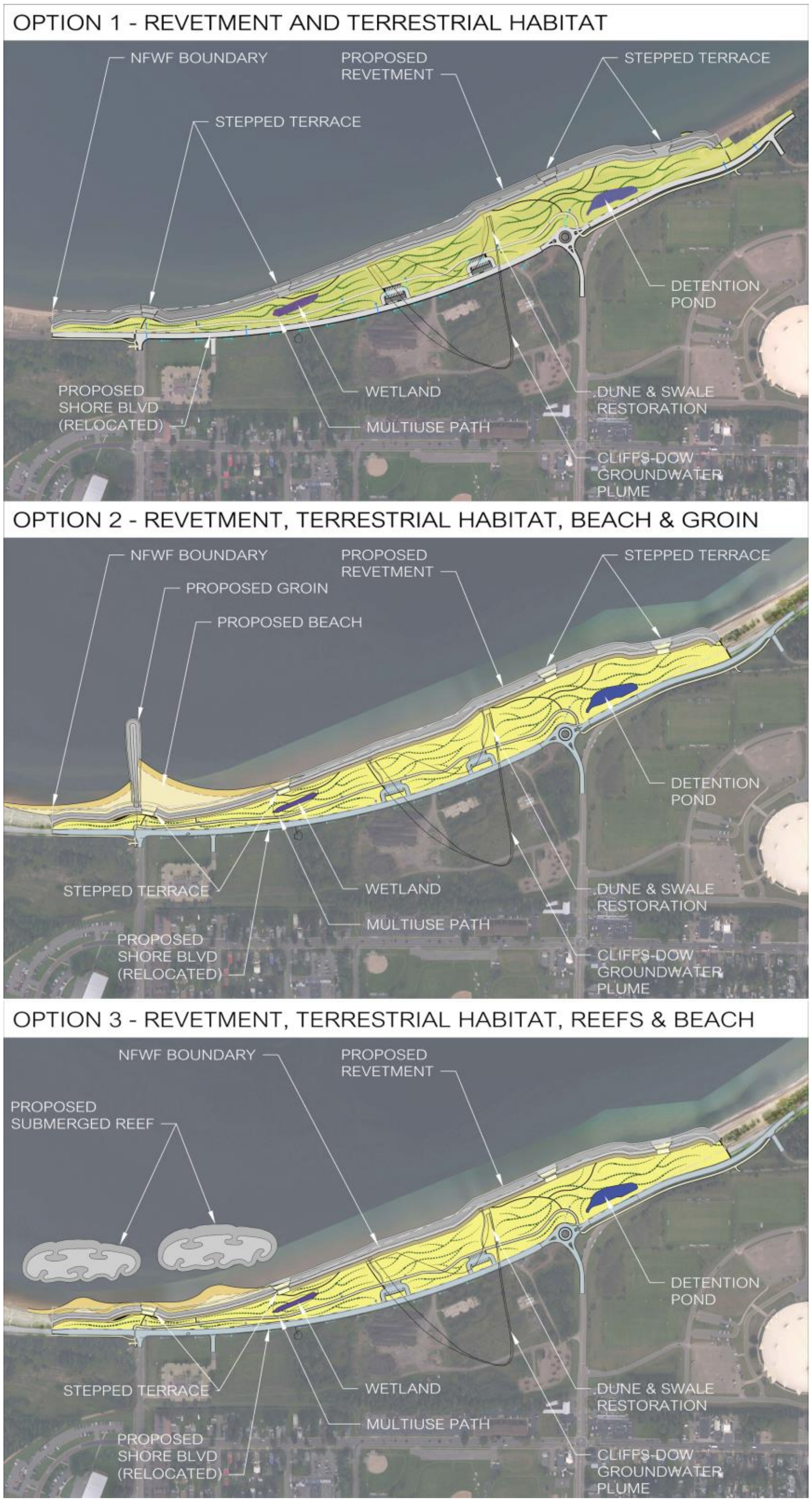


Figure 4.1: Pre-Final Concepts

Each of the pre-final concepts were presented to regulatory professionals during a pre-application meeting in late June 2020. The main take away from the discussion was that Option 1 presents the clearest path to obtaining a construction permit. Options 2 and 3 could initiate complexities in the regulatory approval process due to the amount of lakebed that would need to be conveyed to the City.

Based on the results of the pre-application meeting with the regulators, the final concept layout will be based on an alternative that does not contain offshore structures. The alternative that comes closest to meeting this criterion is Option 1, which involves shoreline armoring with a stone revetment.

Final Concept - To improve the balance between shore protection and habitat restoration, the Baird team developed a refinement to Option 1 that naturalized the shoreline and still achieved the requirement of creating a more resilient coastline.

Based on Baird's waterfront design experience and analysis of the wave climate, it was determined that a viable improvement to the conventional armor stone revetment would involve a Living Revetment (Option 1a) as the shore protection solution. Figure 4.2 presents an overall plan of this refinement to Option 1. The benefits to the project include:

Infrastructure and Use:

- Infrastructure Protection – will reduce overtopping compared to existing conditions and protect Lakeshore Boulevard from flooding.
- Shoreline Stabilization – reduces risk of shoreline erosion, allowing room for recreational use and enjoying the Lake Superior view.
- Waterfront Access – provides waterfront access along the entire length of shoreline.
- Aesthetic Improvement – an upgrade to shoreline aesthetics compared to the existing degraded condition.

Habitat creation:

- Structure - stone used for the Living Revetment would be 4-8 inches in size, placed at a 6:1 slope, thereby creating a large underwater surface area with interstices for small aquatic life. The stone materials would encourage plankton colonization that is needed for establishing algae growth.
- Wetlands - wetlands at the north end of the site will be created by forming controlled breaches in the revetment that allow hydraulic connection to Lake Superior.
- Dune/swale - in the area of the plume footprint, the dune/swale system will be continuous and merge into the Living Revetment, creating a seamless transition.
- Pocket Beach - south of the plume, a pocket beach would provide a sheltered area, essentially creating a habitat different than wetlands or the living revetment, focused primarily on shore birds and invertebrates.

A follow-up meeting was held in early Sept 2020 to update EGLE and USACE regarding the Living Revetment. In general, the regulatory agencies were in favor of this concept and did not have any significant comments that would result in major changes to the concept.

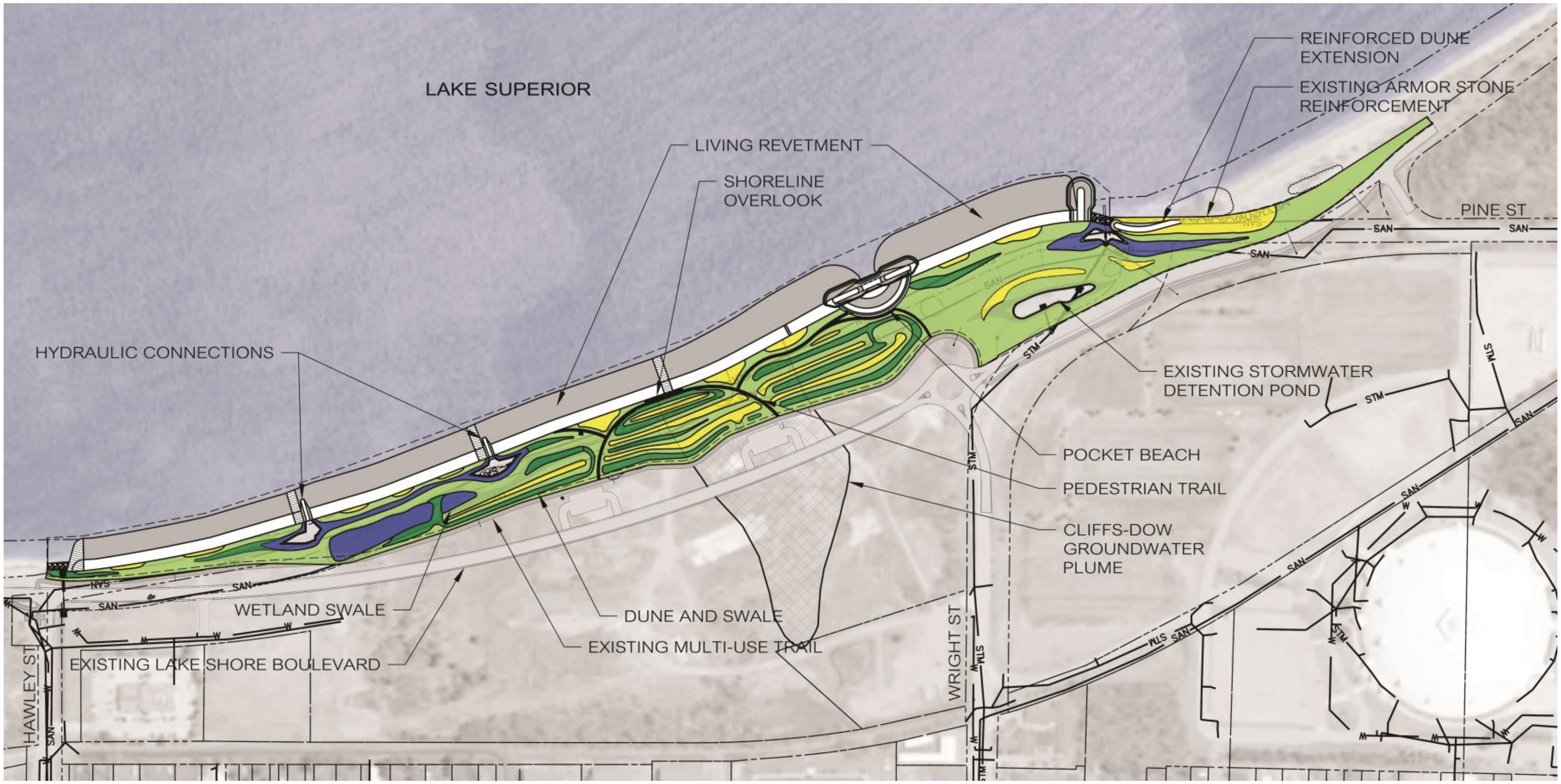


Figure 4.2: Final Concept

5. Preliminary Design

With the final concept design alternative established, the work in the Preliminary Design stage involved data collection, further engineering, and detailing. This section focusses on the major components associated with this stage of the project.

5.1 Dune Repair and Rebuilding (City/NMU Property)

Improvements in this area will take place in the southern most portion of the project, on contiguous properties belonging to the City and NMU (ref Figure 5.1). The site here is closer to Lakeshore Boulevard than the rest of the project footprint and is therefore somewhat confined.

NMU Property – The existing NMU property is mostly a gravel/sand beach and a parallel sand dune that is vegetated. The work on the NMU property involves two aspects:

- Dune Repair – the NMU sand dune has three low spots, essentially breaches. These are walking paths created by pedestrians trampling over the vegetation. The gaps will be filled with dune sand and revegetated for the purpose of closing off the pathways of water associated with wave overtopping during storms, providing a natural way of lowering the risk of coastal flooding. The improved gap closest to the Pine Street crosswalk will include the installation of a wooden slat dune crossing to provide a formal well-defined path to the beach.
- Dune Rebuilding – in the area from Sta 6 to Sta 10 approximately, the beach has a very low crest (less than 605 ft IGLD 1985). In this area the dune will be rebuilt and vegetated with a dune crest elevation of +610 ft IGLD 1985, which is considered appropriate for the expected conditions in this area. Immediately south of the southern drainage outlet, the area will be protected by stone.

City Property – the improvements on the City property in this area will involve:

- Dune Rebuilding – this involves the rebuilding the portion of the dune, from Sta 5 to Sta 10, that is on City property. The stone dike that was placed during Phase 1 will be reconfigured and covered with sand material.
- Wetland – two wetlands will be created. The first is a wetland close to Pine Street, landward of the dune repair that occurs on NMU property. The second wetland is near the southern drainage outlet and includes grading to convey water away from Lakeshore Boulevard toward the lake.

It is understood by the City and SWP that the NMU property will need to be monitored by undertaking regular surveys. Based on the results of the surveys, the City will undertake beach renourishment to maintain the beach and dune system.

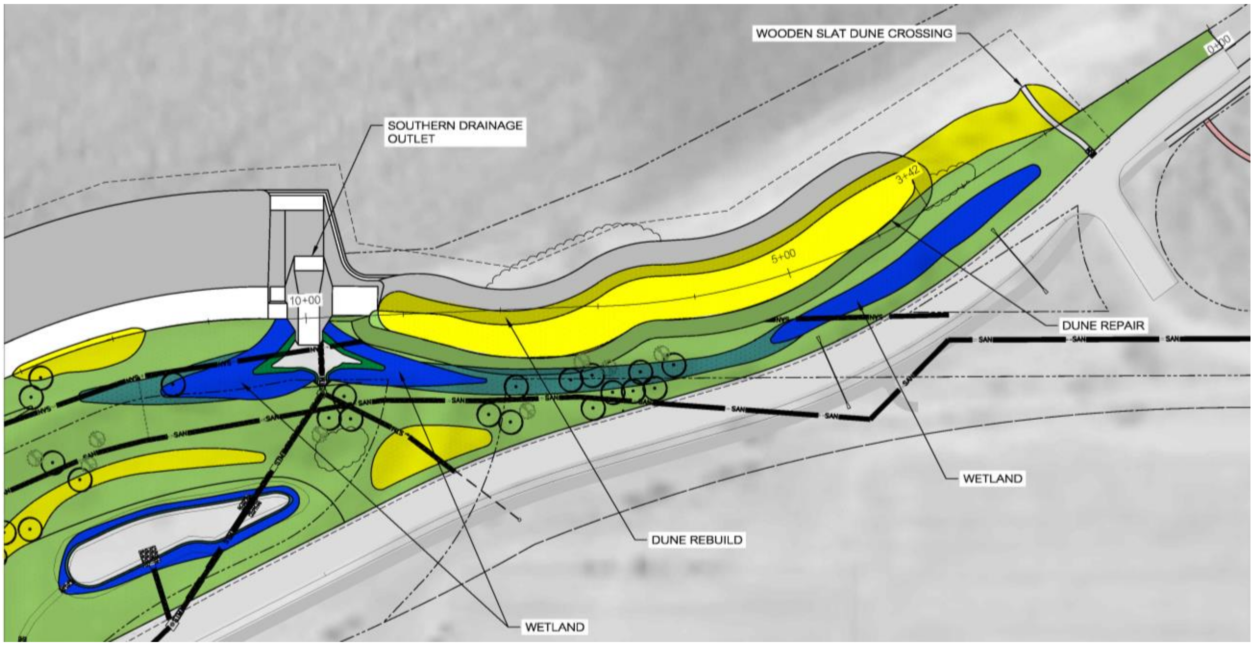


Figure 5.1: South End Improvements

5.2 Living Revetment

The purpose of the Living Revetment is three-fold:

- Provide shoreline stabilization – decrease the risk of shoreline erosion by implementing an engineered solution that does not require significant excavation landward of the existing shoreline.
- Reduce flood risk from wave overtopping – establish a crest elevation, crest width, and slope that will limit overtopping from waves to a manageable level.
- Restoration of shoreline – provide a feature with ample aquatic structure that also allows integration with the landward components of the proposed solution, such as the wetlands and pocket beach, and is inspired by existing natural Lake Superior shorelines.

To meet the purpose of the Living Revetment, the design intent focuses on creating a beach made of cobble-sized stone extending approximately 3,000 ft along the City owned shoreline, from Hawley Street to south of Wright Street. Overall, the configuration of the Living Revetment is relatively straightforward. It is comprised of two stone gradations, each of which is readily available and can be placed with construction equipment that is available in the Upper Peninsula region.

Natural beaches with cobble-sized material are a very frequent feature of the Lake Superior region. However, the design procedure for constructing these features for shore protection purposes is based more on experience than on a well-established engineering process. A cross-section of the proposed Living Revetment is provided in Figure 5.2.

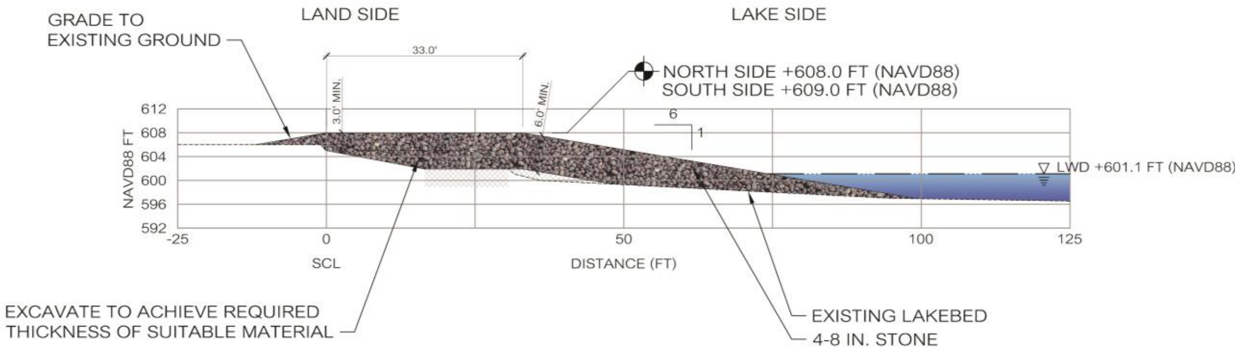


Figure 5.2: Living Revetment Cross-Section

Detailed analysis of the Living Revetment structure is described in Section 6 and Appendix C of this report. Key factors which needed to be determined for the configuration of the revetment cross-section are as follows:

<u>Slope</u> – the slope of the beach was selected based on the historical wave and water level conditions at the site as well as slopes that are found in natural cobble beaches around the Great Lakes. Through review of the scientific literature, a survey of in-house data and records, and prior experience, a slope of 6(H):1(V) was selected for the Living Revetment. This slope was used for numerical analysis of wave overtopping and storm profile evolution. It should be noted that, although the Living Revetment is designed with a slope of 6:1, the structure is intended to dynamically respond to the prevailing wave conditions and the actual slope of the structure will vary in the long term.

<u>Crest Width and Elevation</u> – the crest width and elevation of the Living Revetment should be wide enough to accommodate the formation of a storm berm and high enough to limit wave overtopping of the structure to acceptable levels. However, the crest width and elevation should both be minimized to the extent feasible in order to limit impacts on sightlines to Lake Superior, limit the amount of material needed, and achieve and efficient construction cost.

Based on observations of cobble beach widths on Lake Superior, the results of cross-shore profile modeling with XBeach-G, and Baird's experience, a crest width of 30 ft was specified for the design. This width will allow for the formation of a cobble storm berm without revetment material significantly impacting the upland improvements. It will also provide sufficient area for water from overtopping waves to infiltrate into the structure and flow back to the lake.

A design crest elevation of 609 ft IGLD 85 was found to effectively reduce wave overtopping rates for the southern 1,100 ft of the project shoreline. For the northern 1,900 ft of shoreline, shallower nearshore water depths along with sheltering provided by the Federal breakwater indicate that a crest elevation of 608 ft IGLD 85 is sufficient to provide comparable overtopping protection for this portion of the project site.

<u>Stone Size</u> – the specified stone size used in the Living Revetment is inherently a compromise. The stone should be large enough to reduce longshore transport and stabilize the shoreline, while still being small enough for the cross-shore profile to dynamically respond to changing wave and water level conditions during a storm event as well as throughout the life of the structure.

Through a combination of alongshore sediment transport modeling (COSMOS model, see section 6.4.1) and cross-shore transport modeling (XBeach-G model, see section 6.4.2), a stone size of 3-4 inches was found to be stable under expected extreme storm events. Additionally, a literature review of cobble beaches in various parts of the world concluded that those with a stone size of 8 inches and greater are usually stable, regardless of wave conditions. Therefore, although the model results show that a 3-4-inch gradation would be satisfactory, a gradation of 4-8 inches has been adopted for the cobble beach at the project site. This is expected to provide a conservative design and also allows for some deterioration/breakage of the stone that is expected to occur over the structure's lifetime without compromising its stability.

Control Structures – given the total length of the Living Revetment structure (3,000 ft) as well as its dynamic nature, control structures have been added to the design. While modeling suggests these structures may not be needed, they are being incorporated to help ensure the long-term stability of the Living Revetment. These features will be spaced at 500 ft intervals along the length of the Living Revetment as well as at the northern and southern terminals. With the exception of the southernmost structure, these will be simply comprised of stone that has a larger gradation (8-12 inches) than the regular cobble-sized materials (4-8 inches), providing an additional feature to ensure stability. The southernmost structure will include 1-2-ton armor stone, have a porous core, will extend about 60 ft from the existing shoreline. It will prevent migration of cobble sized material to the south of the project shoreline.

Thickness of Stone Layers – given the dynamic nature of the Living Revetment, the thickness of the permeable cobble-sized stone layers needs to be designed to allow for the natural evolution of the cross-shore profile in response to storm conditions while also maintaining drainage of overtopping through the structure. Through a combination of modeling (i.e., XBeach-G) and experience, a minimum stone layer thickness of 6 ft has been specified for the slope and lakeward edge of the crest of the Living Revetment. A minimum stone layer thickness of 3 ft has been specified for the landward edge of the structure crest; this provides a reduction in quantity while still allowing for infiltration of water from overtopping waves into the structure.

Overall, the configuration of the Living Revetment is relatively straightforward. It is comprised of two stone gradations, each of which is readily available and can be placed with construction equipment that is common in the Upper Peninsula region.

5.3 Pocket Beach

The inclusion of a pocket beach into the Living Revetment offers a variation in shoreline habitat with a locale that is more protected than the predominant cobble beach shoreline. With a length of about 250 ft and total area slightly greater than 0.5 acres, it will provide a stable environment for aquatic invertebrates. The pocket beach will also provide an area for overtopping water to drain during extreme storms, thereby reducing the risk of upland flooding. Finally, it is a destination for pedestrians using the trails and upland areas.

Design Plan – In general, the plan of the pocket beach simulates the smaller scalloped beaches that exist on the north side of Presque Isle Park. The pocket is formed by two quarried stone control structures that are parallel to the shoreline and have a 70 ft gap between them. Figure 5.3 provides a plan of the pocket beach.

The opening between the control structures forms a hydraulic connection to Lake Superior. It is anticipated that portions of the pocket beach near the gap will always be wet, while areas further up the slope will experience moisture during periods of high water and aggressive wave conditions.

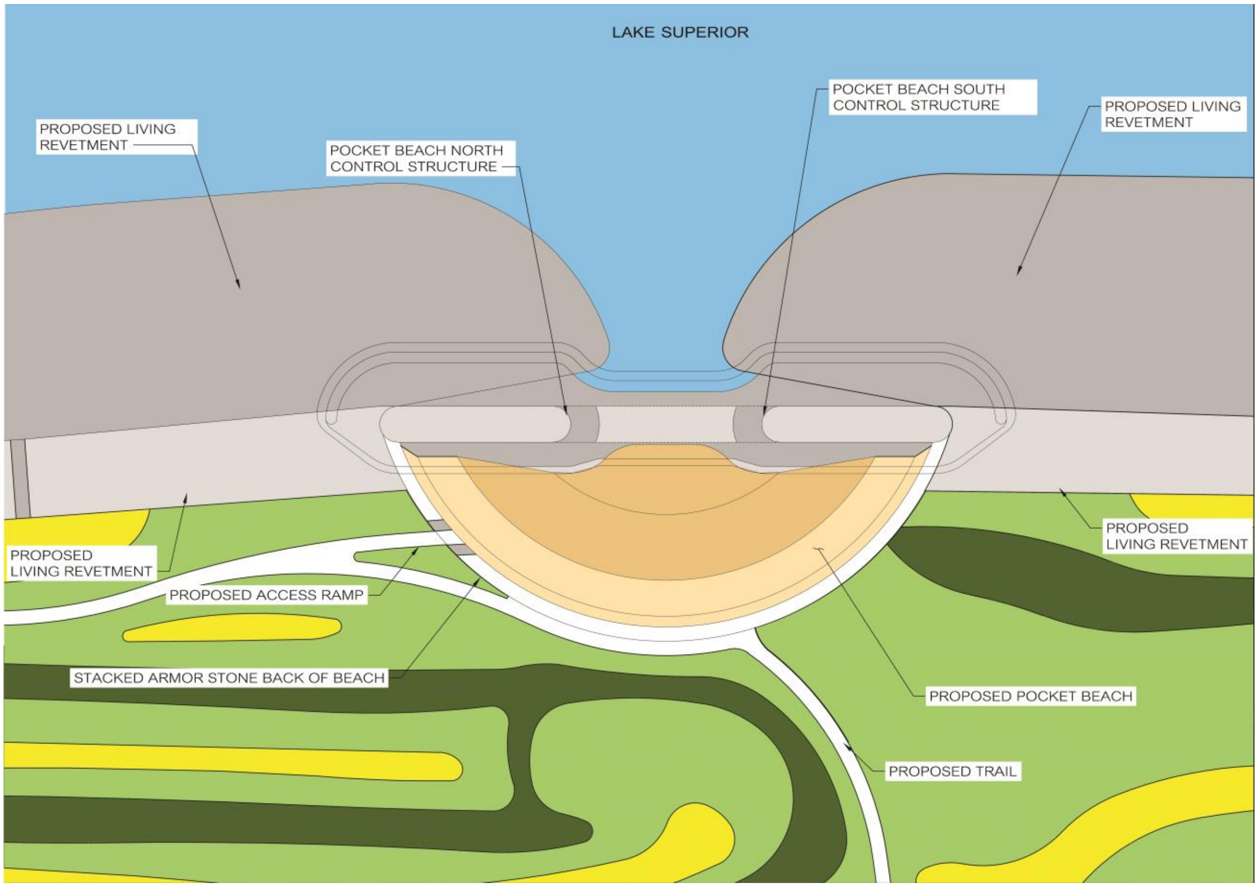


Figure 5.3: Plan Layout of Pocket Beach

Design Cross-Section – The beach extends from an elevation of 601.1 ft IGLD 85 (LWD) at the gap and then slopes upward at 6:1. It is comprised of two layers of smaller cobble-sized material, 2-4-inch layer on top of a 4-8-inch layer. Sand will be placed on the beach, near the landward side, in the upper portions of the beach. Figure 5.4 provides a cross-section of the pocket beach.

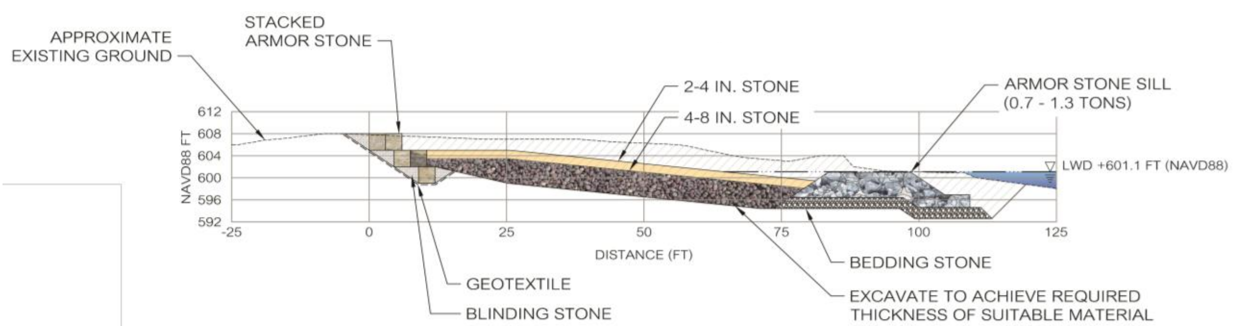


Figure 5.4: Cross-section of Pocket Beach

5.4 Trails and Overlook Structure

Providing opportunities for the public to interact with the shoreline area and Lake Superior is a key objective of this project. The preliminary design includes a series of walkways and an overlook structure. Paved trails are ADA compliant and accommodate wheelchair access. These are designed to be connected to the existing multi-use trail that was constructed during Phase 1.

Trails – As shown in Figure 5.5, the network of trails provides access to unique ecological features and views throughout the shoreline restoration. The trails are 6 ft wide and sited to encourage circulation through the site and connection to the overlook and pocket beach. Most of the trail length is made of crushed gravel. Gravel has simple maintenance requirements involving an annual walkover and occasional placement of gravel fill, grading, and compaction. A section of porous pavement is planned for a short length of trail, as described below. Seating areas are distributed along the trails, some capturing views of the lake, others are protected by existing trees, all with a unique view and landscape.

- Trails 1 and 2 - These trails extend from the parking lot to the shoreline overlook area and have a paved surface.
- Shoreline Overlook – This feature is a paved area adjacent to the shoreline and can be reached using Trails 1 and 2.
- Trail 3 – This is a spur trail that heads north and provides access to the Living Revetment. The trail is comprised of porous pavement, which will require an annual walkover and occasional hosing with water to make sure the pores are clear.
- Trail 4 - The south trail meanders between dunes and the crest of the Living Revetment, then connects to the pocket beach.
- Trail 5 – This trail connects the Phase 1 multi-use trail near the round-about to the proposed pocket beach.

Wetland Boardwalk and Overlook – The boardwalk provides a path into the wetland area for visitors to observe the scenery. An overlook structure is provided at the lakeward end of the boardwalk. The boardwalk and overlook are accessible to wheelchairs. Space for bench seating is provided at two positions on the overlook decking. The proposed material is composite decking, which blends wood and plastic to form a very durable surface.

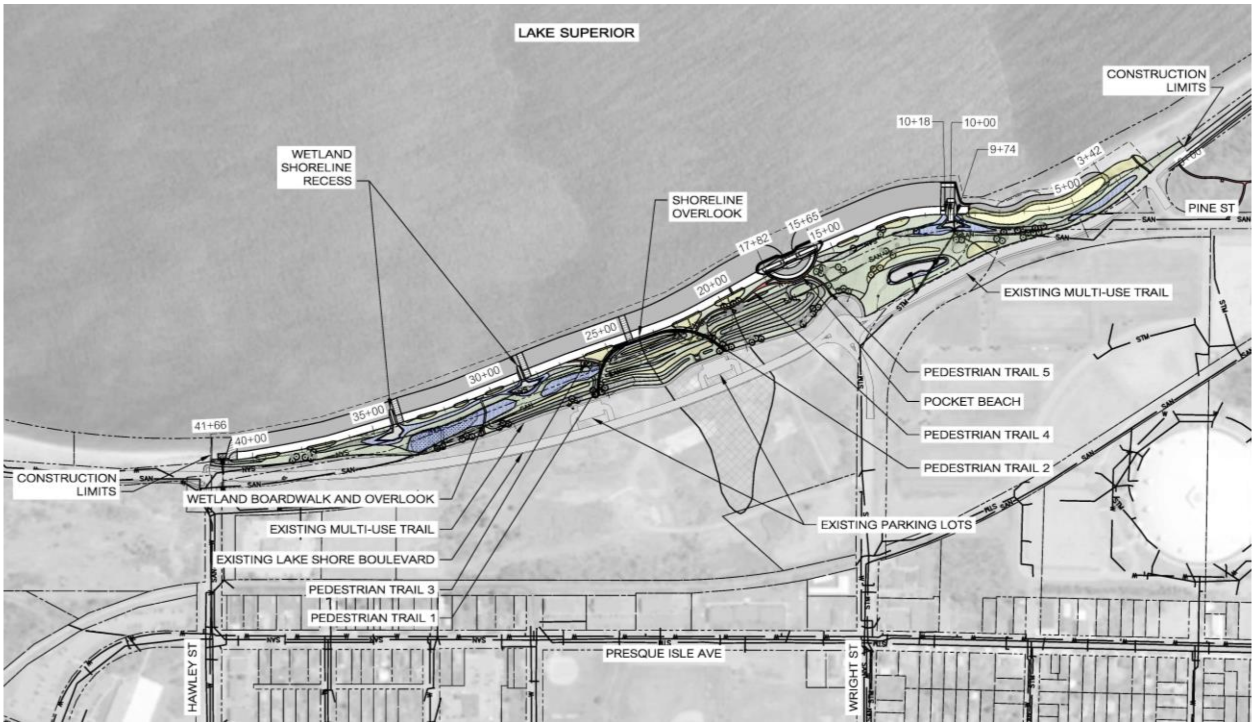


Figure 5.5: Layout of trails and overlooks

5.5 Upland Restoration

The upland restoration mimics historic regional dune and swale landforms and reintroduces native plant communities, habitat, and stability. The swales help to infiltrate and filter stormwater while dunes support native dune grasses and forbs and create variation in landform. Much of the natural dune and swale topography and landscape of the area has been lost to development over the years, and this project site is no different. As the dune and swale topography ripples away from the shoreline, the transect of vegetation varies by microclimate. While natural dune and swale landscapes were shaped by Lake Superior, the Living Revetment will protect the proposed landforms so they will be a stable feature.

The terrestrial features for the dune and swale system extend east of Lakeshore Boulevard and comprise planted dunes and swales, as shown in the plan (Figure 5.6) and cross-sections (Figure 5.7).

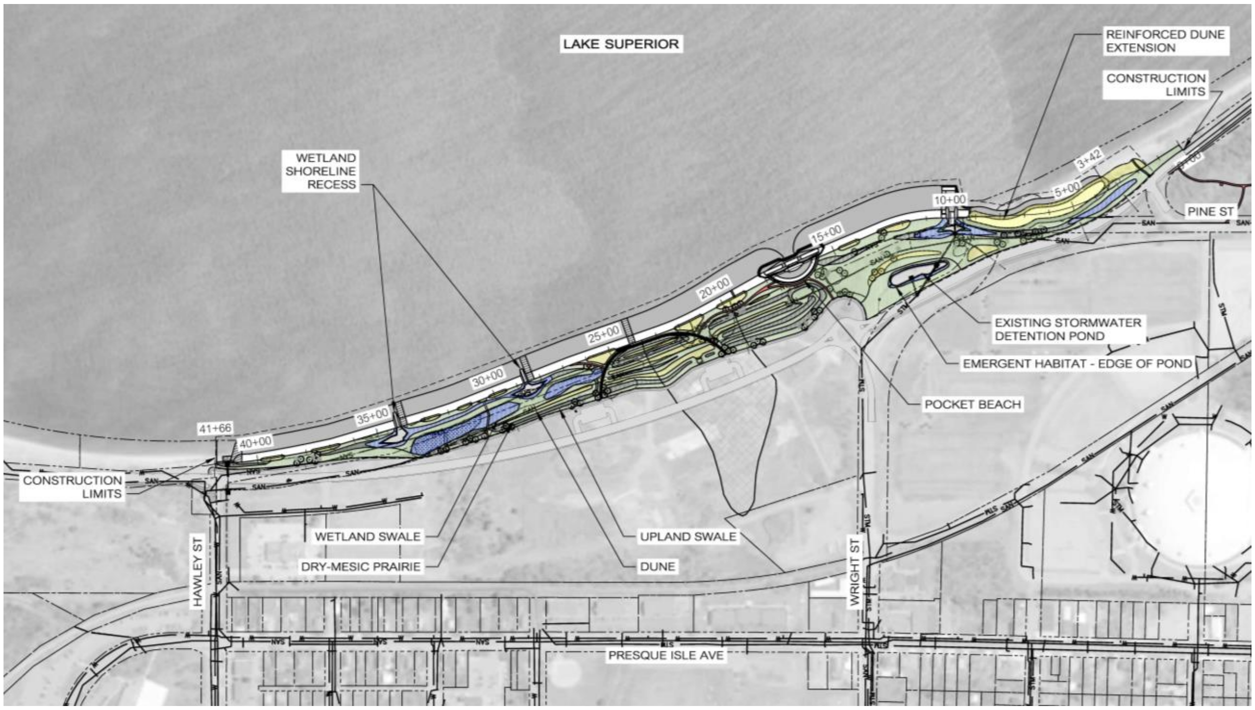


Figure 5.6: Upland Features Layout

Grading

Dune heights and the distance between dunes was determined based on data collected from the fieldwork undertaken in January and June 2020 of regional landforms, including the Triangle Parcel, which is a protected landscape on the south end of the project site. Dune slopes are maintained at 6:1 with dune heights ranging from three to six feet. Along the length of the Living Revetment, sandy dunes interface with the top of the cobble to create a varying edge to the landscape and revetment. Existing grades were maintained around the existing wetland and existing trees intended for preservation.

Four new wetland areas are proposed along the shoreline: two north of the parking lots adjacent to the existing wetland and two near the NMU beach at the south end of the Living Revetment. All should have some area of open water or wet soil, surrounded by emergent and wet prairie vegetation. The two north wetlands are located at depressions in the Living Revetment, which will allow hydraulic connectivity to the lake while maintaining protection from most wave activity. The largest southern wetland is connected to a piped overflow from the adjacent detention basin. It is protected by the Living Revetment to the north and an armor reinforced dune to the south.

Existing Wetland

The existing wetland will remain intact with no disturbance aside from the grading that took place to install the multi-use trail. Ground plane vegetation is a matrix of bluejoint grass (Calamagrostis canadensis) and other mostly native plants. We recommend removing any non-native invasive vegetation to promote the spread of established native species.

Soils

For the soil profiles of the dune and swale complexes, previous soil sampling field work from dune and swale systems in the Great Lakes as well as publications such as the 1999 Michigan Natural Features Inventory (Natural community abstract for wooded dune and swale complex) by Albert and Comer were used. Due to historical industrial land uses and its impact on the soils, excavation was minimized in the design of upland restoration measures across the site. Most dune and swale landforms will be created with imported soil. Dunes are to be topped with sand, swales will have one foot of topsoil, and side slopes will have a transition from one foot of topsoil at the base to four inches of topsoil at the top of the slope and limits of dune sand.

Vegetation

All native vegetation is proposed for this upland restoration. A wet prairie, dry prairie, and dry-mesic pollinator prairie mix were used across the site depending on topography and expected soil moisture.

- Dunes are seeded with the dry prairie seed mix and planted with dune grass stolons.
- Wetland swales are seeded with the wet prairie seed mix and planted with wet prairie plugs and wetland shrubs.
- Upland swales are seeded with the wet prairie and dry-mesic pollinator seed mixes to account for variations in soil moisture. They are also planted with mesic shrubs.
- Upland areas along trails are seeded with the dry prairie seed mix due to its short stature and planted with dry prairie plant plugs and shrubs. Using live plant material along the trails is also used to create a sudden impact in the most visible areas.
- Upland side slopes away from the trail are seeded with the dry-mesic pollinator seed mix to create interest with a diversity of forbs and provide habitat for pollinators.

Trees are grouped along trails to provide shade, shelter from the wind, and create an experience of moving through the north woods. Proposed trees are shown in-line with existing trees to be preserved or areas of high elevation so as to not create more areas of blocked water views.

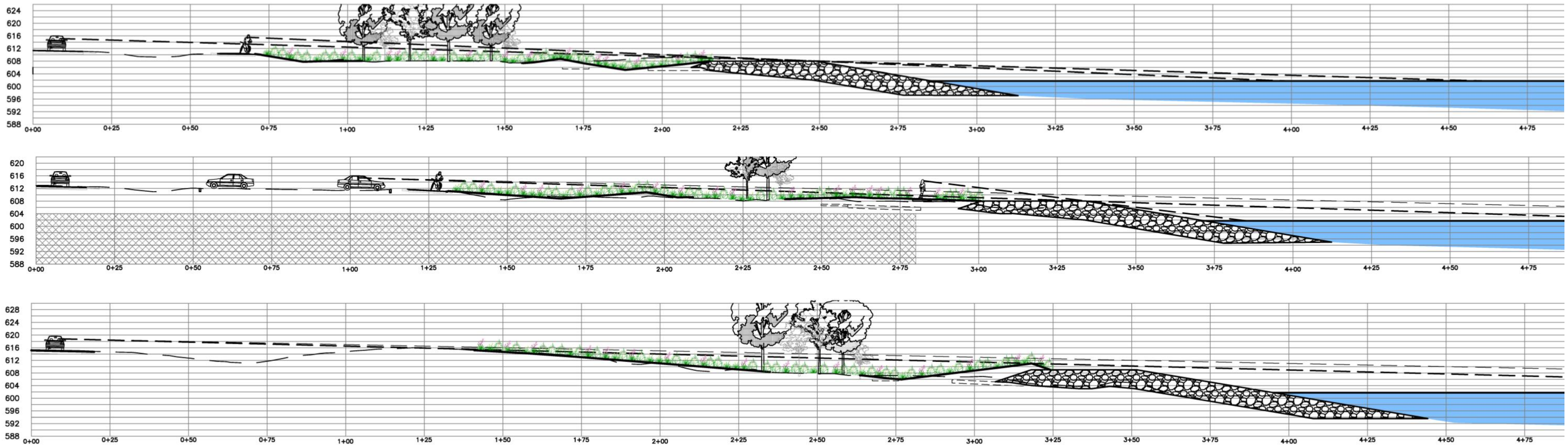


Figure 5.7: Cross-section Layouts

6. Sediment Transport and Impact Analyses

The shoreline improvements associated with the Living Revetment will be reviewed by regulatory authorities (EGLE and USACE Detroit) during the permit application period. It is our understanding that the USACE will require an analysis to determine how the project might, if at all, impact the following:

- Adjacent properties - properties adjacent to the project site, north of the property line at Hawley Street and the south side at the NMU property.
- Navigation – navigation is related to the ore dock berth and navigation channel north of the Clark Lambros Park. It is also related to recreational boaters that may be using this part of the shoreline.

The remainder of this section is dedicated to describing the sediment transport processes at the site and also provides an impact analysis for adjacent properties and navigation.

6.1 Morphological Background

The federally constructed improvements in Presque Isle Harbor (Figure 6.1) were authorized by the River and Harbor Acts approved 3 June 1896, 13 June 1902, 30 August 1935, and 14 July 1960.

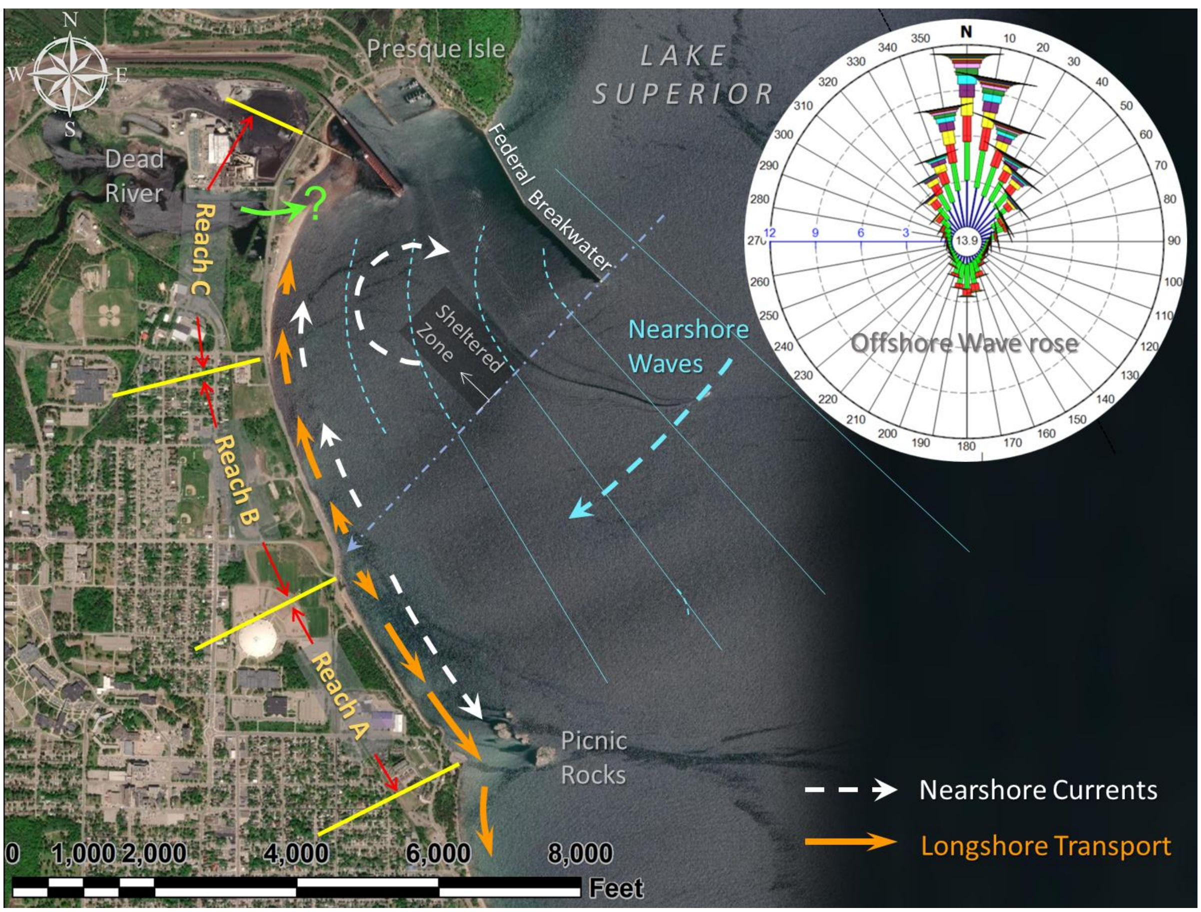


Figure 6.1: Schematics of predominant coastal processes along the project shoreline

The 1896 Act authorized construction of a 1,000-ft breakwater to provide a harbor-of-refuge at Presque Isle. This first breakwater was of stone-filled timber crib construction and extended on a bearing of 149.75° from the southern tip of Presque Isle. A 216-ft extension of the breakwater was authorized by the 1902 Act and completed in 1903. In 1926, the crib superstructure of the breakwater was rebuilt of concrete with riprap along its east side. The 1935 Act authorized a 1,600-ft extension of the breakwater with a navigational light at its outer end and dredging of the harbor to depths of 26 and 28 ft. This rubblemound extension was constructed on a bearing of 135° into 40 ft of water and was completed in 1939 creating a 2,816 ft long structure. The 1960 Act authorized additional dredging to depths of 28 ft in the inner harbor and 30 ft in the approach channel. Dredging to these depths was initiated in 1961 and completed in 1964 (USACE Section 111 DPR, June 1976).

The Federal breakwater was last extended in 1939. Predominant post-extension littoral processes at Marquette are shown in Figure 6.1. While predominant offshore waves are from the north, they undergo refraction and approach the project shoreline approximately from a northeasterly (NE) direction. The Federal breakwater blocks some of the waves, creating a sheltered (or wave diffraction) zone behind the structure.

In Figure 6.1, the shoreline of the study area is divided into three sections (following the 1976 Section 111 study). The shoreline immediately north of Picnic Rocks (Reach A) features a beach and dune system that is directly exposed to waves and is not protected by the Federal breakwater. Most of the Reach B shoreline is located in the shadow zone of the breakwater (relative to predominant waves). As a result of this sheltering effect, net longshore transport is towards the north along Reach B but towards the south along Reach A, creating a transport divergence zone roughly around the boundary between Reach A and Reach B that limits the transport of sediment from Reach A to Reach B and vice versa. Reach C is completely sheltered by the Federal breakwater. Longshore transport is towards the north and progressively decreases as it gets closer to the harbor, resulting in sediment accretion along Reach C, particularly around the mouth of the Dead River.

To the best of our knowledge, studies on sediment discharge levels (green arrow in Figure 6.1) from the Dead River have not been undertaken. In 2004, Baird undertook field reconnaissance of the watershed following the 2003 flood due to fuse plug failure in the upland reservoir. Baird's observations indicate the watershed is relatively small and heavily forested, providing a relatively small sediment yield. Also, a significant portion of the sediment is likely trapped by the dams and in the lower reaches of the river (e.g., in the new channel created by the 2003 flood) before reaching the shoreline. Examination of historic aerial photos and Google Earth imagery does not provide evidence of any significant sediment delivery from this river. The USACE Detroit District dredge records indicate that Presque Isle Harbor has been dredged in 1971 (20,100 cy), 1972 (29,200 cy), 1984 (8,308 cy), and 2017 (35,972 cy, higher volume possibly due to discharge from the 2003 dam failure event). Infrequent dredging and limited dredging volumes at the harbor, along with the above-mentioned observations, lead to the conclusion that the Dead River has not been, and likely will not be, a major sediment contributing factor for Reach C.

Figure 6.2 shows a typical nearshore profile along the southern half of Reach B. The nearshore lakebed in front of the existing stone revetment is relatively deep, with more than 8 ft of water under mean water level (MWL) conditions. Lakebed deepening is a common issue along many armored shorelines on the Great Lakes. This is believed to be the result of ongoing (slow but steady) removal of sediment cover from the lakebed by waves and longshore currents while the shoreline has been kept in place by the shore armoring. Eventually, the lakebed reaches a depth where non-storm waves are unable to generate typical nearshore processes such as wave breaking and longshore currents. As such, the transport of lakebed sediment only happens under severe storm events and even that may be at small levels. Lakebed borings using a check-valve sampler completed for this study indicate that the sediment thickness on the lakebed in this area is limited to 1 to 3 ft (Figure 2.3 and Appendix B).

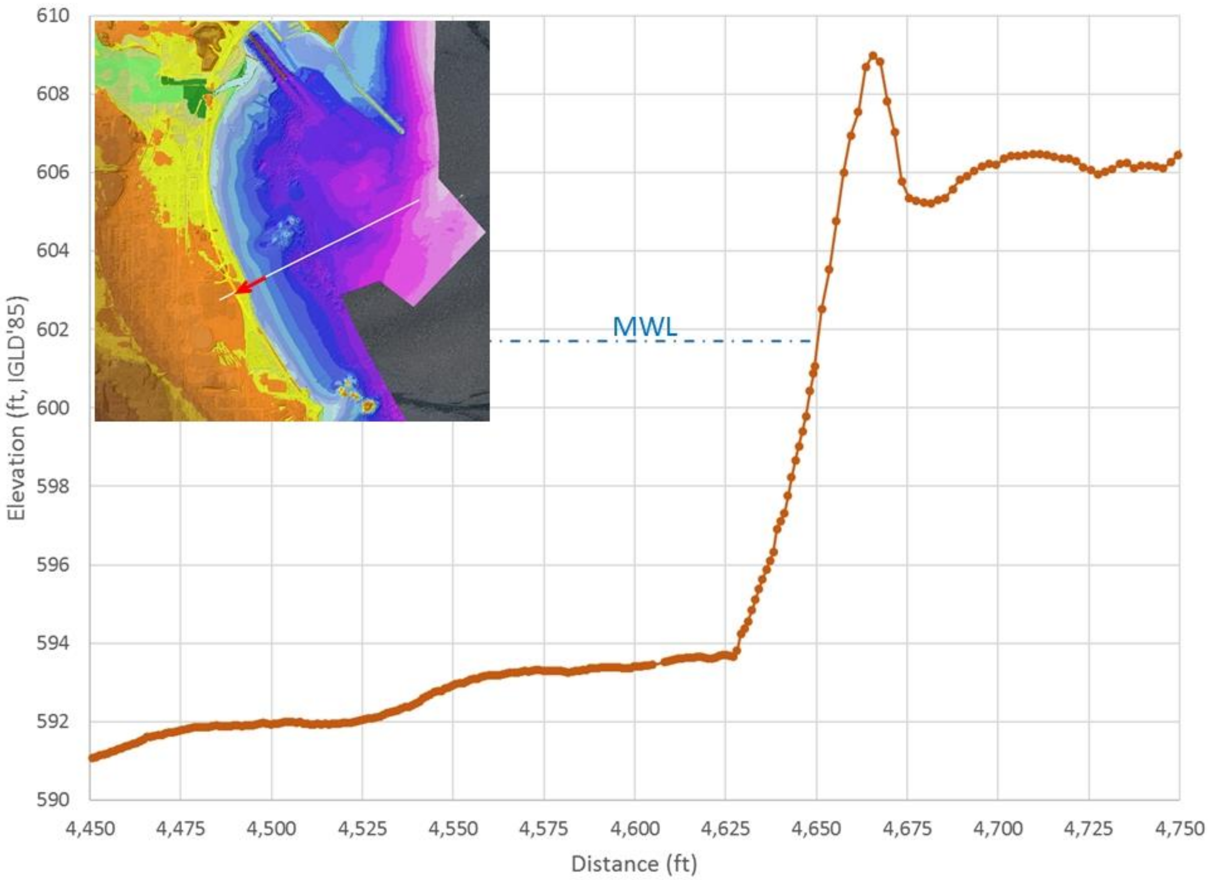


Figure 6.2: Typical nearshore profile along the southern half of Reach B (2020 survey)

6.2 Shoreline Comparisons

Shoreline evolution in the study area since the extension of the Federal breakwater in 1939 was investigated through examination of selected historic and recent aerial imagery from 1939, 1951, 1970, 2008, and 2020 in a GIS environment. Given the relatively small range in variation in Lake Superior water levels (~601.7±1.5 ft, IGLD'85), shoreline positions were not corrected for the effect of lake levels in this analysis. This may result in maximum shoreline position errors of approximately ±7 ft along Reach A, ±5 ft along Reach B, and ±10 ft along Reach C.

Figure 6.3 shows the corresponding shorelines along Reach B plotted on both the 1939 (left panel) and the 2020 (right panel) images. The shoreline in the southern half of Reach B shows almost no change over the comparison period.

Figure 6.3: Shoreline comparison at Reach B

This section of the shoreline has been protected since before 1939. Further to the north, the shoreline was not protected and experienced erosion between 1939 and 1951 as a result of northward longshore transport. By 1951, the entire Reach B shoreline was armored to protect the industrial facility. The Reach B shoreline has experienced little to almost no change since 1951. However, while the shoreline was kept in place by shore protection, alongshore currents continued to remove sediment from the nearshore lakebed along Reach B, resulting in deepening of the nearshore in front of the steeply sloping stone structure, as shown in Figure 6.2.

Historic and recent shorelines for Reach A are shown in Figure 6.4 on both the 1939 (left panel) and the 2020 (right panel) images. The shoreline in Reach A experienced significant erosion between 1939 and 1970 as a result of net southward longshore transport. The rate of shoreline erosion has slowed down since 1970. This is likely due to the construction of shore protection structures at both north and south ends of this shoreline as well as ad hoc stone placement efforts near the shoreline (as visible in the 2020 image).

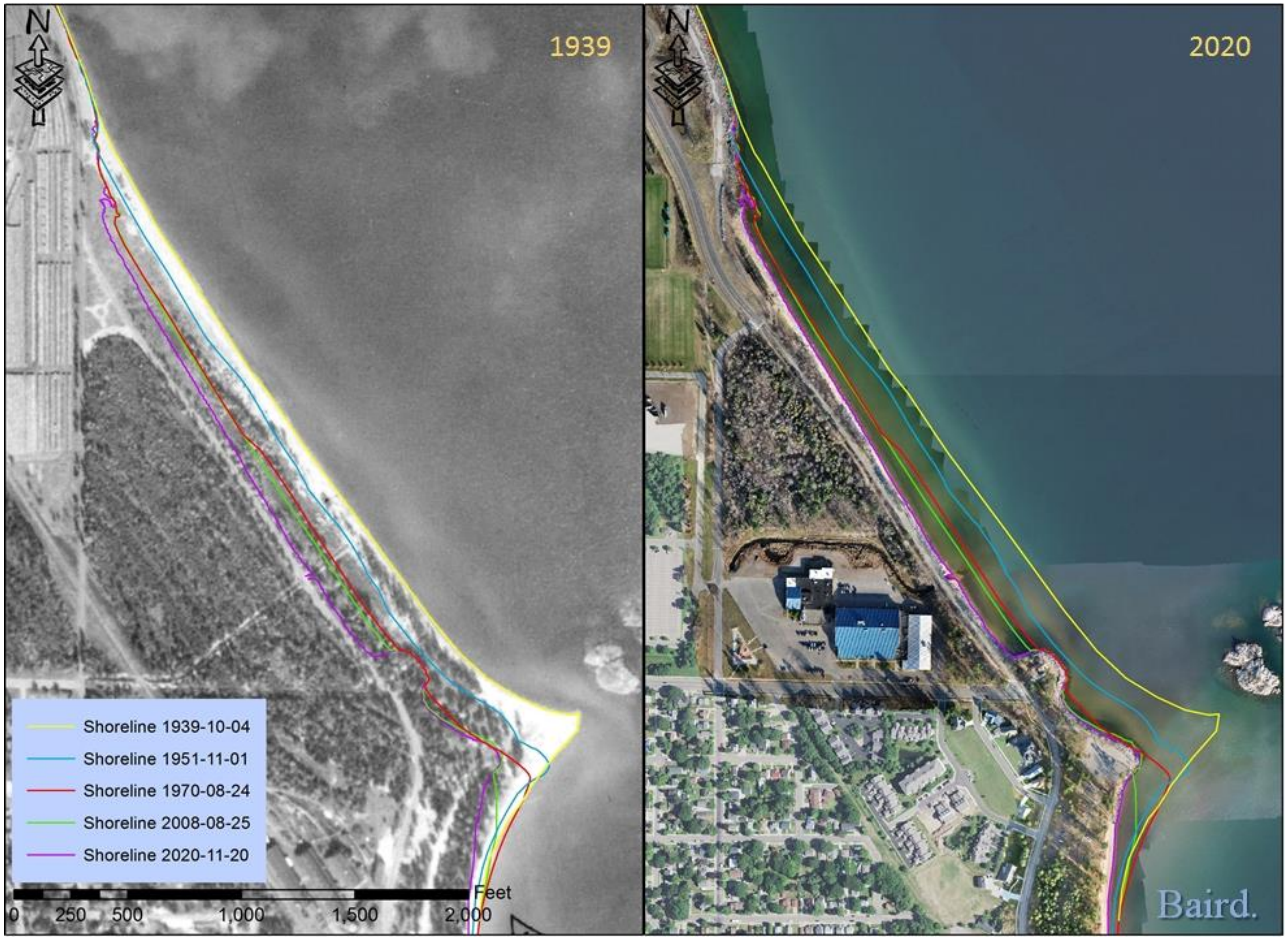


Figure 6.4: Shoreline comparison at Reach A

Figure 6.5 indicates that shoreline accretion was predominant along Reach C shoreline between 1939 and 2008. The accretion pattern around the Dead River mouth and against the pier near the north end confirms the northward direction of longshore transport along this reach. The shoreline at the south end of Reach C shows erosion between 2008 and 2020. This is likely due to a reduction in supply from the south, possibly as a result of nearshore lakebed deepening along Reach B. Figure 6.2 indicates that the nearshore area in front of the stone revetment in Reach B is more than 8 ft, deep making it difficult for non-storm waves to mobilize the bottom sediment. In addition, and as noted earlier, lakebed borings completed for the present study indicate that the sediment thickness on the lakebed in the nearshore area of Reach B is limited.

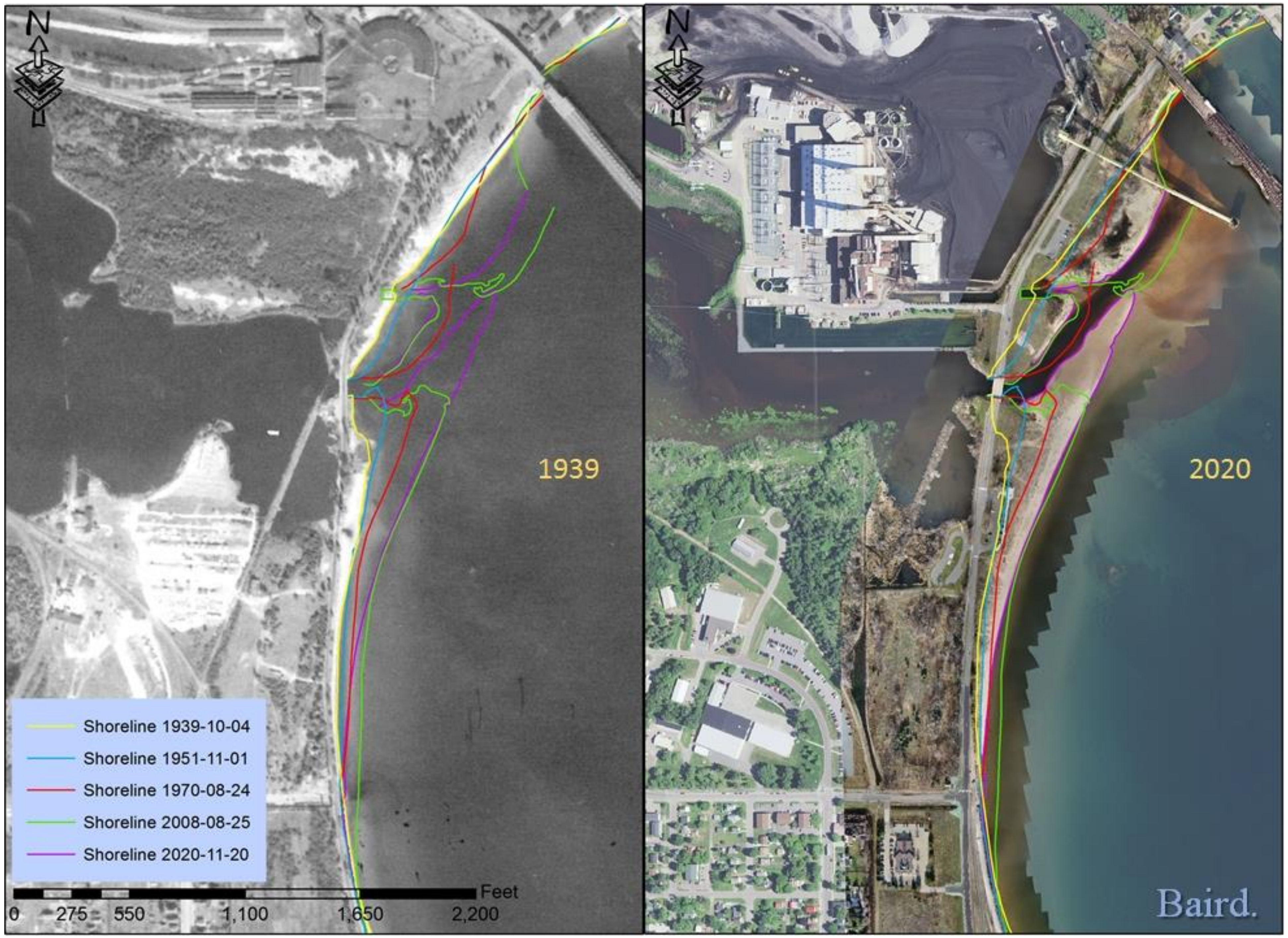


Figure 6.5: Shoreline comparison at Reach C

6.3 Impact Determination – Adjacent Shorelines

The proposed Living Revetment will replace the existing shore protection along Reach B with a larger footprint. Presently, the Reach B shoreline is featured by a relatively deep nearshore in front of an existing steep riprap structure (Figure 6.2). The nearshore is too deep for non-storm waves to be able to generate fully developed longshore currents induced by wave breaking. Lakebed borings have indicated there is little sediment left on the lakebed in this area. While the potential alongshore sediment transport along Reach B is towards the north, it is expected that currently there is no significant alongshore sediment supply from Reach B to Reach C. On the other hand, the proposed Living Revetment has a beach face slope of approximately 1V:6H. This will reduce wave reflection and will help re-establish a more natural beach condition compared to existing conditions, including promotion of breaking-induced processes and alongshore transport. The proposed design, therefore, will not interrupt (and will likely improve) the alongshore flow of sediment compared to existing conditions.

It is noted that while the Reach A shoreline has been historically eroding, net longshore transport along Reach A is towards the south. As such, erosion of the Reach A shoreline does not supply sediment to either Reach B or Reach C. Based on the above, it is concluded that the proposed Living Revetment will not have any negative impacts on littoral transport processes in the study area.

6.4 Living Revetment Stability

The proposed Living Revetment is comprised of angular quarried stone that is cobble sized. The structure is expected to be dynamic in nature. Specifically, the cobble-sized rocks will move and respond to the hydrodynamic forces while dissipating wave energy, absorbing wave runup, and protecting the backshore/upland area. Cobble beaches tend to become steeper and higher in response to storms when cobbles are transported onshore, creating a storm berm that protects the backshore/upland area. Loss of cobbles offshore is normally negligible, and nearshore lakebed erosion is tolerated by the flexibility of the design. In the alongshore direction, however, there could be some transport of cobbles along the shoreline, resulting in erosion of material from some areas and accretion in other areas. Typically, a program of periodic maintenance is included in cobble beach design. This may include redistribution of stones transported along/out of the project area or periodically placing additional material as the cobble volume decreases.

For the present project, the alongshore movement of the cobble-size stone has been addressed in two ways: 1) using a stone size that is relatively stable; and 2) embedding sections of larger stones every 500 ft along the revetment to control the rate of alongshore transport.

6.4.1 COSMOS Modeling

Longshore transport of the cobble-size stone was assessed with the COSMOS model. COSMOS is a detailed 1D processes-based cross-shore profile model that estimates wave transformation, wave-induced currents, and sediment transport across a user-specified nearshore profile. It uses bathymetry, sediment grain size, and wave and water level as input to predict transport rates. The COSMOS model has been extensively used, tested, and verified by Baird in numerous projects around the world involving sandy beaches. COSMOS can be applied to gravel/cobble beaches and was used to reasonably predict the likelihood of significant alongshore movement of cobble sized material.

Using the offshore hindcast wave data, COSMOS was run for extended periods of storm activity covering 1987, 2012, 2013, and 2017 (i.e., the four most energetic years in the hindcast) for different stone sizes. The model predicted zero longshore transport for stone sizes greater than 3" (~75 mm). It was, therefore, decided to use 4-8-inch stone for the proposed Living Revetment (D_{50}=6", W_{50}=17 lb).

6.4.2 XBeach-G Modeling

XBeach-G is a state-of-the-art processes-based numerical model that can predict storm impacts on gravel beaches and barriers. The model was used to simulate the storm response of the design cobble beach for multiple return period wave conditions. The 2, 5, 20, and 100-year storms were examined at two project locations, Profile B and Profile D, near the south and north ends of the proposed Living Revetment, respectively (see Figure 3.3). While Profile B near the south end is directly exposed to Lake Superior waves, Profile D on the north side is sheltered by the Federal breakwater. Note that XBeach-G does not predict longshore transport of cobbles. However, we have inferred the potential for alongshore transport of cobbles by looking at the profile response to storm wave conditions.

Figure 6.6 shows model prediction results at the more exposed (south) section of the Living Revetment (Profile B). The model predicts erosion of the lower slope and accretion of the upper slope, including the development of a moderate storm berm under 5-year and greater wave conditions. It is not possible to predict if this would translate to significant alongshore movement of the stones and if so, what would the rate of transport be. It does indicate that periodic maintenance, including returning of displaced stones (or adding new stone), may be required every five years on average.

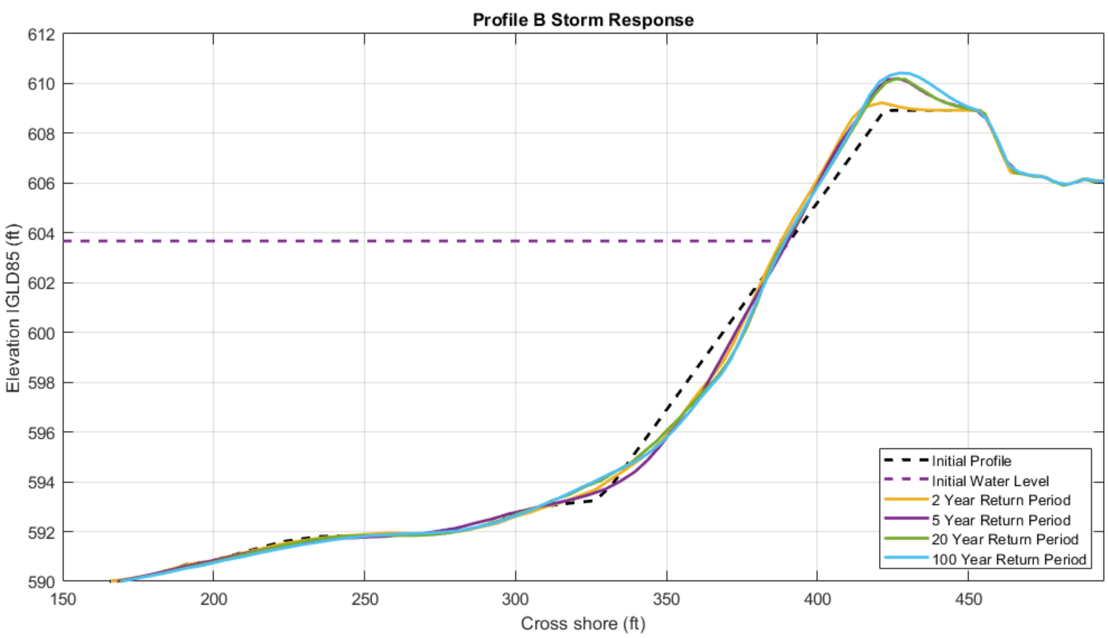


Figure 6.6: XBeach-G model predictions for the exposed profile near the south end

Figure 6.7 shows model prediction results at the sheltered (north) section of the proposed Living Revetment (Profile D). The model predicts onshore transport of lakebed material and a corresponding accumulation on the upper slope of the Living Revetment. This is attributed to a limitation of the XBeach-G model where it assumes that the sediment size across the entire profile is the same (i.e., the model can handle only one type of bed material, thus assuming that the lakebed is also covered with the same cobble-size stones as the Living Revetment). However, the lakebed is covered by sand, and the significant onshore transport predicted by the model is not expected. Overall, model results at Profile D suggest little movement of the cobble-size (6-inch) stone at this location; therefore, alongshore transport of 6-inch cobbles at this location is expected to be negligible.

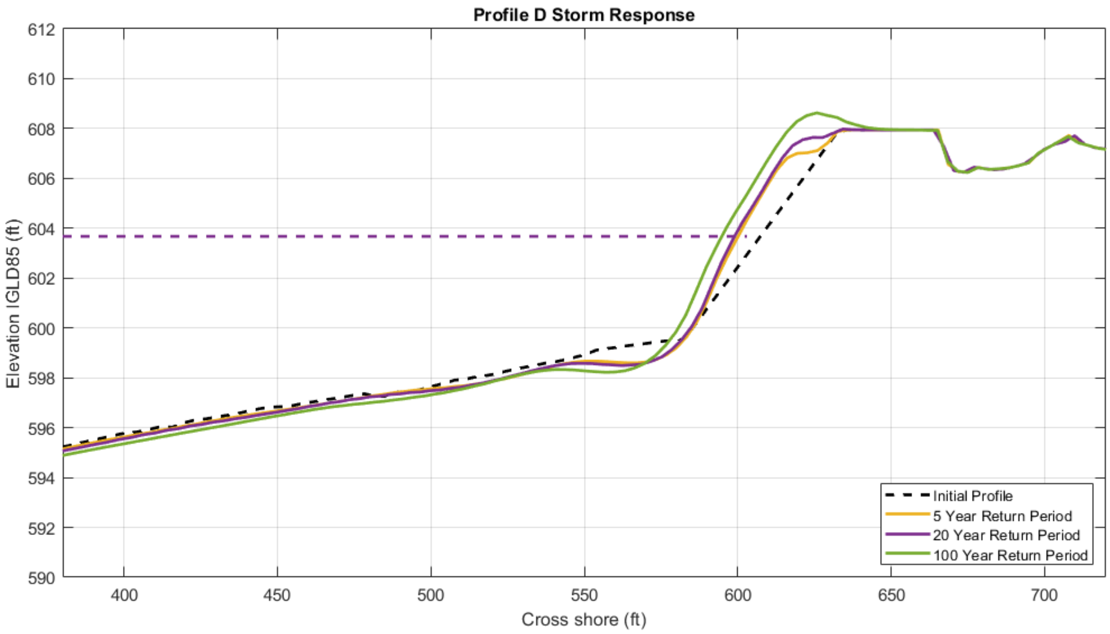


Figure 6.7: XBeach-G model predictions for the sheltered profile near the north end

6.4.3 Example: North Cove, Washington

Baird has extensive experience with the design of cobble beaches in Great Lakes environment. We have designed and monitored several cobble beaches on Lake Ontario over the past 25 years (with similar cobble size to what we are proposing for Marquette), thus allowing us to better understand cobble beach behavior and have confidence in our design.

The wave climate along selected portions of unprotected western US coastlines tends to be more energetic than Great Lakes coastlines. However, cobble beaches have worked in these highly dynamic environments as well. In the following, we have reviewed an example of a cobble beach constructed in an exposed ocean coast environment in Washington State.

A dynamic revetment, spanning over one mile of shoreline, was constructed at North Cove, Washington in December 2018. This structured is exposed to the open coast of the Pacific Ocean, where the wave climate is more aggressive than the project site at Marquette. The shoreline of North Cove had experienced significant erosion, at a rate of up to 145 ft/year, for decades. Hundreds of homes had fallen into the ocean as a result, and State Route (SR)-105 had to be relocated. To prevent further loss of the North Cove community, quarry spalls ranging in size from pea gravel to small boulders were placed on the upper beach to protect the uplands from attack by ocean waves. The rocks were expected to fracture and round over time due to wave action. The dynamic revetment simulates a natural cobble berm that absorbs wave energy and helps to stabilize the beach from further lowering and retreat.

Construction of the dynamic revetment at North Cove prior to the onset of winter storms prevented significant loss of the uplands from December 2018 to March 2019. Topographic surveys showed the revetment was remarkably resilient to storm waves and high-water levels, with little to no landward retreat. As part of their monitoring program, a total of 344 rocks were tagged by the Washington State Department of Ecology during

January and February 2019 so their movement could be tracked. It was found that some rocks weighing less than 10 kg (22 lb.), which roughly equates to an 8-inch size, migrated about 30 ft along the shoreline, and those that were heavier generally moved less (Figure 6.8). However, over the three months of rock tracking, most rocks stayed within 3 ft of their initial placement location.

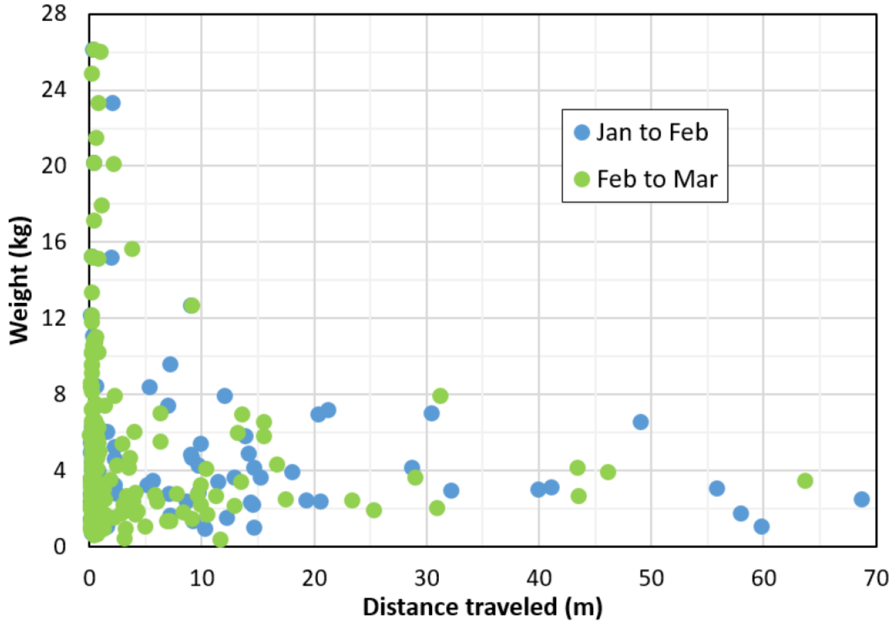


Figure 6.8: Rock alongshore transport distance by weight measured between January and March 2019 at North Cove, Washington

Rocks that weighed between 1 kg and 10 kg (2.2 and 22 lb.) have an estimated size of about 4 to 8 inches. In an environment as dynamic as North Cove, Figure 6.8 suggests that, over time, the stones within this range could migrate 100-230 ft along the shoreline. However, this dynamic revetment is still functioning well and has limited overall movement.

For the Living Revetment at Marquette, movement of the stone material has been investigated through numerical modeling and engineering judgement. The results suggest that a 3-inch stone will experience little movement. As a conservative measure, a stone size range of 4-8 inches, with a D50 of 6 inches, has been adopted for the preliminary design. Additionally, the design includes for control sections every 500 ft as described in Section 4.3. Further, the North Cove project provides an example of a successful application using 4-8-inch stone size at a site that has a wave environment that is 8-10 times more energetic than Marquette. Therefore, it is concluded that the proposed stone size of 4-8 inches will experience limited movement and will be stable for the Living Revetment structure.

6.4.4 Impact Determination - Navigation

Commercial Vessels. The only commercial vessel facility that is near the project site is the ore dock at Presque Isle Harbor, which is utilized by bulk freighters that arrive/depart via a Federal navigation channel. The ship berth and navigation channel are about 3,000 ft north of the Phase 2 site and are in the sheltered area created by the Federal breakwater (ref Figure 1.1).

As indicated in Figure 3.2 and Figure 3.3, the proposed Living Revetment is exposed to different degrees of wave energy, which decreases substantially from south to north. At the south end of the site, cobble sized material is expected to experience only limited movement. Moving northward along the shoreline, the area becomes much more sheltered, and movement of cobble sized stone is expected to be minimal. At the north end of the project, the revetment is still more than 3,000 ft away from the ore dock, which is located in an even more protected area. As a result, it is concluded that movement of cobble-sized stones anywhere near the navigation channel is highly unlikely since the required energy is not available to move the material. As part of the adaptive management of the shoreline, a monitoring program will be established to confirm these conclusions.

Recreational Boating - Recreational boating occurs in and out of Marquette's marinas and yacht club. These facilities are 1-2 miles away, north and south from the project site. Motor and sailboat traffic occurs offshore and does not ply the shallow nearshore waters near the project site. The Dead River kayak launch is 1,300 ft from the northern terminus of the revetment. If kayaks ply the water near the project shoreline, they will not draft enough to be impacted by the revetment.

Based on the above, it is concluded that the project will not adversely impact navigation.

Reference:

Weiner, H.M., Kaminsky, G.M., Hacking, A., and McCandless, D., 2019. North Cove Dynamic Revetment Monitoring: Winter 2018-2019. Shorelands and Environmental Assistance Program, Washington State Department of Ecology, Olympia, WA. Publication #19-06-008 https://fortress.wa.gov/ecy/publications/summarypages/1906008.html

7. Monitoring Overview

7.1 Shore Protection Monitoring

Implementation of the 4,000 ft project shoreline protection project will result in an improved level of erosion protection and flood risk reduction. As the improvements will be comprised of new construction and upgrades to existing natural features, it is important to establish a record of performance. Therefore, it is recommended that regular monitoring is performed, as follows:

- Drone Surveys (1 year initially) – Undertake a drone survey of the entire Living Revetment, Pocket Beach, and NMU shoreline every three months for the first year of the post construction period. At the end of each survey, data from all available surveys, including the post-construction as-built survey, should be compared to determine trends and understand overall performance of the shore protection. Decisions can then be made regarding frequency of further surveys. As mentioned in Section 5.1, maintenance will involve occasional placement of beach sand/gravel mix on the southern side of the project at the NMU property.
- Stone tracking (2 years) – at the end of construction, a select group of stones from the Living Revetment should be painted and have a number chiseled into one side. This should occur every 500 ft along the Living Revetment. At the beginning and each 500 ft increment, a total of 75 stones should be painted with marine grade paint and numbered (total of about 525 stones), and position noted in GPS coordinates. At 12-month intervals, each stone should be located, GPS position noted, and then compared with the previous position to determine the amount of movement. The same stones should then be repainted for the next inspection, 12 months later. This work can be done inexpensively under the guidance of a field technician.

7.2 Upland Monitoring

7.2.1 Trails and Overlooks

The five trails and shoreline overlook are configured for maintenance that is generally straightforward and does not require specialist input. These features will need to be inspected as follows:

- Gravel Trails – the trails should be observed twice a year (Spring and Fall) to review and note their condition (settlement, rutting, and compaction). Additional material and re-compaction or grading should be undertaken based on inspection results.
- Porous Pavement – Porous pavement should be observed twice a year (Spring and Fall) to review and note its condition (settlement, cracking, and pore clogging). Per vendors instructions, allow for cleaning of porous pavement with a power washer; this is needed maintain pavement porosity.
- Wetland Boardwalk and Overlook – the shoreline overlook should be visited once per year (late Spring) to observe the condition of the structure decking, railing, and substructure. Additionally, the ramps will need to be inspected to confirm the gap between the path and ramp can be easily negotiated in a wheelchair.

7.2.2 Restoration Monitoring

The proposed project solution, as shown in Figure ES.1.2, reflects a very positive trend in site restoration, with metrics as follows:

- Aquatic habitat – 2.5 acres (area of Living Revetment below Low Water Datum)
- Beaches – 4.2 acres (area of Living Revetment above Low Water Datum and Pocket Beach)

- Coastal Wetlands – 2.1 acres (four wetland areas in the current project plan)
- Dune/Swale/Uplands – 15.3 acres (does not include improvement for Ph 1)

SWP will monitor restored ecological communities as per NFWF's National Coastal Resilience Fund Monitoring protocol (Appendix D). In general, this protocol establishes methods for measuring key metrics for Marsh, Living Shoreline, and Beach and/or Dune restorations.

Some of the features of NFWF document that are relevant to this project include:

- Biomass by Species –
  - Uplands – plant coverage in dune swale and wetlands
  - Living revetment – underwater colonization of the stone matrix for the Living Revetment
- Elevation –
  - Uplands – elevation monitoring of dune/sale system and wetland area
  - Living Revetment – elevation monitoring of the slope and crest of the Living Revetment
- Shoreline Position –
  - Living Revetment – back of crest position
  - Dune Restoration - measurement of beach width, dune position and configuration, and grain size
- Water Level
  - Living Revetment – use the NOAA gage in Marquette (readings every 6 mins)

In addition, the project specifications will include performance standards related to the first year of vegetation establishment. These standards will include:

- 100% survivability of woody plant material
- 80% survivability of herbaceous plant material
- 80% cover of seeded areas

Appendix A

Site Visits

Baird.

W.F. Baird & Associates Ltd.

Office | 2924 Marketplace Drive, Suite 200, Madison, WI 53719, USA
Phone | +1 608 273 0592 Email | madison@baird.com

Memorandum

Reference # 13290.101.M2.Rev0

Status: Final

11 June 2020

Attention:	**Carl Lindquist**
CC:	
From:	Matthew Clark

Lake Superior Shoreline Restoration – Site Visit

Introduction

This memo provides a summary of findings made on a recent visit to the Lake Superior Shoreline Restoration project site in Marquette, Michigan.

Summary

On June 11, 2020, the Baird team visited the Lake Superior Shoreline Restoration project site in Marquette. Two team members from Baird, Matt Clark and Jared Dorvinen, along with one from Foth, Tim Wagner, participated in the site visit. This site visit was performed in addition to quarry visits, which took place over the three days from June 10 to 12.

The Baird team members arrived at the project site at 2:45 PM EDT, signed in with a Phase 1 contractor on-site representative, and were met by two representatives from the City of Marquette's City Engineering Department, Mik Kilpela and Jim Compton.

The group of five total individuals walked the entire project site along the shoreline from the NMU beach at Pine Street to just north of Hawley Street. Notes, photos, and select measurements were taken, and site conditions were discussed by the City's representatives and the Baird team. The site visit concluded at approximately 5:00 PM EDT.

Key findings from the site visit include:

- An extensive cemented iron-slag-cobble conglomerate was found along the shoreline at the project site. Appears to be extensive over the southern 1/3 of the project site but may extend further north.
- Remnants from a derelict timber pile bulkhead with steel cable tie-back was found buried in the existing stone revetment. This appears to have spanned the entire Cliffs-Dow site shoreline.
- A 6” iron pipe, a square riveted iron culvert, and other debris was found along the shoreline. Evidence of tar was found near the pipe and culvert.

- Slag, iron, timber, tar, and concrete post-industrial debris and waste was found at the surface along most of the project site.

One Baird team member, Jared Dorvinen, also visited Shiras Park and Clark Lambros Beach Park on June 12 and took photos to document the site conditions in these locations. These photos provide additional context for the shoreline conditions seen at the project site.

Locations of site photos are seen in Figure 1 on the following page. Appendix 1 includes Field Notes and pictures documenting the site visit.

Figure 1. Numbered photo locations from Baird site visit on June 11 and June 12, 2020

Attachment 1

Project Site Visit

Client:	Project No:	Report By:
Superior Watershed Partnership	13290.101	JID

Purpose: Project Site Investigation

Time Begin: 2:45 PM EDT **Time End:** 5:00 PM EDT

Date: June 11, 2020 **Day:** Thursday

WEATHER	
TEMPERATURE	68 to 55 °F
CONDITIONS	Mostly Cloudy to Cloudy, windy.
Impact Event:	none

ATTENDEES

	Total	
City of Marquette	2	Jim Compton (JC), Mik Kilpela (MK)
Baird	2	Matt Clark (MC), Jared Dorvinen (JID)
Foth	1	Tim Wagner (TW)

Total On-Site: 5

SUMMARY OF ACTIVITIES

1.0 Walked project site from south to north, observing shoreline and revetment condition.

2.0 Documented findings with photos, notes, and select geolocations.

3.0 Discussed findings with City of Marquette personel.

Select Photos

008 - Storm water detention basin being constructed. Location 9.

009 - Storm water detention basin being constructed. Location 9.

010 - Storm water detention basin being constructed. Location 9.

014 - Armor purchased by the city for temporary protection of the roadway. Location 4.

015 - Looking south at the NMU beach south of the project site. Note the eroding dune on the right and accumulation of gravel at the waterline. Location 2.

016 - Looking north from the NMU beach south of the project site. Location 2.

022 - Newly exposed concrete foundation on the NMU beach. Near Location 3.

023 - Gravel accumulated on the beach near the waterline. Near Location 3.

026 - Gravel accumulated on the beach near the waterline. Near Location 3.

038 - Eroding dune at north end of NMU beach. Location 3.

037 - Eroding dune at north end of NMU beach. Location 3.

039 - Eroding dune at north end of NMU beach. Location 3.

031 - Eroding dune at north end of NMU beach. Scarp is approximately 2' to 2.5' high. Location 3.

053 - South end of project site, looking south. Location 5.

051 - South end of project site, looking south. Location 5.

049 - South end of project site, looking south. Location 5.

040 - Stone at south end of project site. Location 5.

042 - Stone at south end of project site. Location 5.

056 - Stormwater outfall at Location 6.

061 - Successful ad-hoc protection of stormwater outfall. Location 6.

075 - Cemented iron-sand-cobble-slag conglomerate found along shoreline of project site. Location 8.

079 - Cemented iron-sand-cobble-slag conglomerate found along shoreline of project site. Location 8.

093 - Concrete pipe found on project site. Location 10.

086 - Looking sourth along shoreline, just south of Location 10.

085 - Looking north along shoreline, just south of Location 10.

096 - Concrete rubble and rebar in revetment near Location 11.

097 - Exposed iron-slag-cobble conglomerate along the project shoreline. Between Locations 11 and 12.

104 - Newly discovered riveted iron box culvert with evidence of tar. Location 11.

102 - Tar ball on discovered near Location 11.

105 - Exposed timber pile bulkhead with tie-back remants, near Location 11.

113 - 6" iron pipe with tar residue. Locaiton 12.

123 - Looking south along shoreline near Location 12.

124 - Looking north along shoreline near Location 12.

139 - Timber pile in revetment near Location 13.

134 - Woody debris in revetment near Location 13.

143 - Looking south old Lakeshore Boulevard near Location 14.

144 - Looking north old Lakeshore Boulevard near Location 14.

145 - Largest piece of existing wetland on project site, fenced off during roadway construction. Near Location 14.

149 - Looking south along old Lakeshore Boulevard, near Location 15.

150 - Looking north along old Lakeshore Boulevard, near Location 15.

153 - Looking south along old Lakeshore Boulevard, near Location 16.

154 - Looking north along old Lakeshore Boulevard, near Location 16.

156 - Looking south along lakeshore from Location 18.

159 - Newer revetment extension at Hawley Street intersection, geotextile is exposed. Location 17.

163 - Exposed geotextile. Location 17.

- End of Report -

Project Site Visit - Adjacent Shoreline

Client:	Project No:	Report By:
Superior Watershed Partnership	13290.101	JID

Purpose: Visit and document shoreline condition adjacent to the project site.

Time Begin: 12:00 PM EDT **Time End:** 1:00 PM EDT

Date: June 12, 2020 **Day:** Friday

WEATHER	
TEMPERATURE	50 °F
CONDITIONS	Partly cloudy, cold wind about 10mph from NE.
Impact Event:	none

ATTENDEES

	Total	
City of Marquette	0	
Baird	1	Jared Dorvinen (JID)
Foth	0	

Total On-Site: 1

SUMMARY OF ACTIVITIES

1.0 Visited Shiras Park and took photographs to document shoreline condition.

2.0 Visited Clark Lambros Beach Park and took photographs to document shoreline condition.

3.0 Took GPS coordinates of end of sand spit at mouth of the Dead River.

Select Photos

009 - Looking south along the shoreline at Shiras Park. Relatively new armoring indicates ongoing erosion. Location 1.

002 - Looking at Picnic Rocks from Shiras Park. Note the remenant SSP groyne on the left. Location 1.

014 - Looking north along the shoreline from Shiras Pake Not ad-hoc armoring and colapsing asphalt. Location 1.

008 - Eroding shoreline and colapsing asphalt from the parking lot at Shiras Park. Location 1.

005 - Sign advising swimmers against dangerous currents and water conditions has toppled due to chronic erosion. Location 1.

016 - Despite cold wind and degraded shoreline, about 12 cars were in the parking lot of Shiras Park.

018 - Looking south along the lakeshore at Clark Lambros Beach Park. A similar shoreline was once characteristic of the NMU Beach and Shiras Park. Location 19.

019 - Looking south along the lakeshore at Clark Lambros Beach Park. A similar shoreline was once characteristic of the NMU Beach and Shiras Park. Location 19.

020 - Looking north onto the sand spit at the mouth of the Dead River. Between Locations 19 and 20.

023 - Looking north at the LS&I railroad ore dock from the north end of the sand spit at the mouth of the Dead River. Location 20.

024 - Looking north at the LS&I railroad ore dock from the north end of the sand spit at the mouth of the Dead River. Water depths less than 2' extend out to the harbor's dredged berth. Location 20.

027 - Looking south from the end of the sand spit at the mouth of the Dead River. Lake Superior on the left, Dead River on the right. Location 20.

- End of Report -

Appendix B

Shoreline Borings

Foth Infrastructure & Environment, LLC
Eagle Point II • 8550 Hudson Blvd. North, Suite 105
Lake Elmo, MN 55042
(651) 288-8550 • Fax: (651) 288-8551
www.foth.com

June 4, 2020

TO: Matthew Clark - Baird

CC: Michael Raimonde - Foth

FR: Timothy Wagner P.E. - Foth

RE: Superior Watershed Partnership - LS Shoreline Restoration Nearshore Sediment Sampling Results

Mr. Clark,

Foth has completed the nearshore sediment sampling work as described in the previously submitted "Sediment Sampling Work Plan" (Foth 2020). The work completed includes the following tasks:

- Sediment poling to determine potential for "push" type sampling
- Completion of borings at twenty-two (22) locations using a check-valve sampler
- Collection of samples from the upper one foot of each sediment core for sieve analysis per your direction.

The purpose of these near shore sediment borings is to gather sediment data that will create a shallow sediment profile of the near shore Project Area. This sediment profile will contain visual contaminant observations and sediment data that will assist in determining the extent of apparently impacted materials within the near shore sediments of the Project Area.

Sediment Sample Collection

Foth mobilized to Marquette the week of May 11, 2020 to perform the field work. Field sampling was completed at the 22 locations shown in Figure 1 (Attachment 1). The initial poling data informed the final locations of the sampling which vary slightly from the locations proposed in the work plan. At each location the following process was utilized:

- Obtain location coordinates using GPS

- Perform sediment poling and record poling measurements
- Sample sediments using a check valve sampler
- Collect sediment from upper 1 foot of core for purposes of sieve analysis. Note: one additional analysis was conducted on a sample collected from A-9.

Logs for each sample location were created and are attached to this memorandum in Attachment 2.

All sediment samples collected were submitted to Soil Engineering Testing, in Minneapolis, MN, for sieve analysis using sieve sizes, #4, #10, #16, #20, #30, #40, #50, #60, #70, #100, #120, #140, #170, and #200. The sieve analysis results are included in Attachment 3.

Sampling Results

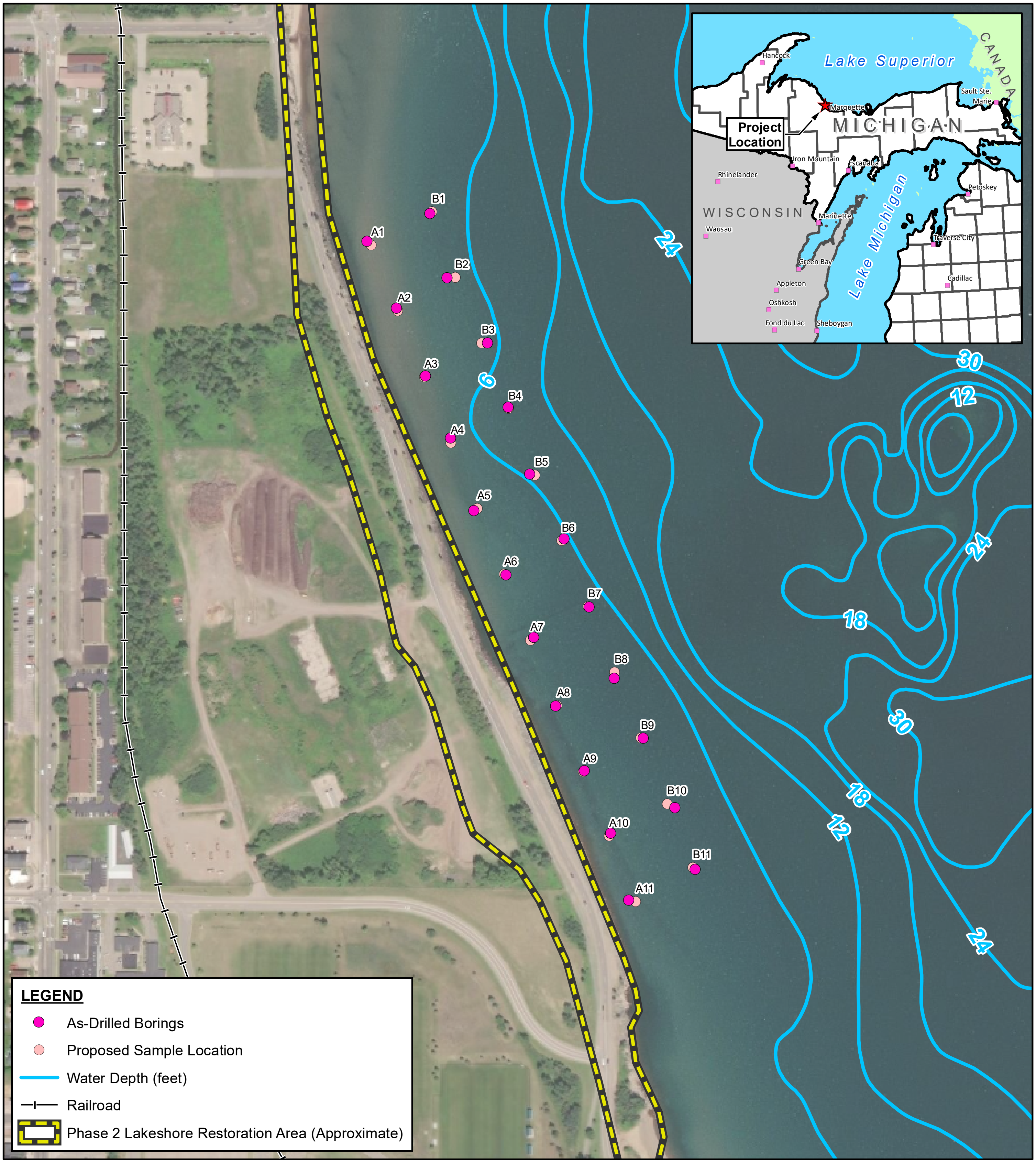
Samples collected were found to be predominately fine- to medium-grained sand. There were several locations with odors present and the presence of coal- or slag-like material. These locations include:

- A-6 : “burnt” odor
- A-8 : “burnt” odor and coal-like material present
- A-9 : “burnt” odor and coal-like material present
- A-10 : “burnt” odor and coal-like material present
- A-11 : coal-like material present
- B-6 : “burnt” odor
- B-7 : “burnt” odor
- B-8 : “burnt” odor

The findings are consistent with the known field observations previously presented by the Michigan Department of Environment, Great Lakes & Energy (EGLE). These results will be used in developing shoreline restoration designs.

Attachments:
Attachment 1. Figure 1
Attachment 2. Boring Logs
Attachment 3. Sieve Analysis Lab Results

Attachment 1. Figure 1



NOTES:

1. Basemap from esri.com, courtesy of the Microsoft Corporation and its data suppliers.
2. Water depth information taken from NOAA Navigational Chart 14970. (https://charts.noaa.gov/PDFs/14970.pdf)

Foth

N

This drawing is neither a legally recorded map nor a survey and is not intended to be used as one. This drawing is a compilation of records, information and data used for reference purposes only.

0 200 400 Feet

WF BAIRD ASSOCIATES

FIGURE 1

AS-DRILLED SAMPLE LOCATION MAP
CITY OF MARQUETTE,
MARQUETTE COUNTY, MICHIGAN

Date: JUNE 2020	Revision Date:

Drawn By: JRS1	Checked By: TSW1	Scope: 20B001

Path: Q:\Baird WF\20B001\GIS\mxd\Figure X - As-Drilled Sample Location Map.mxd Date: 6/1/2020

Attachment 2. Boring Logs

BORING NUMBER A1

CLIENT Baird

PROJECT NAME Nearshore Sediment Collection

PROJECT NUMBER 20B001

PROJECT LOCATION Lake Superior, Marquette, Michigan

DATE STARTED 5/12/20 **COMPLETED** 5/12/20

GROUND ELEVATION

HOLE SIZE 2.16 inches

DRILLING CONTRACTOR Foth

NORTH: 5157401.06 **EAST:** 469938.65

DRILLING METHOD Check Valve Sampler

LOGGED BY JRK3 **CHECKED BY** NMG1

NOTES Water Depth = 5.4 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.9 feet
1				
2			2.7	

Refusal at 3.0 feet.
Bottom of borehole at 2.7 feet.

BORING NUMBER A2

CLIENT Baird

PROJECT NAME Nearshore Sediment Collection

PROJECT NUMBER 20B001

PROJECT LOCATION Lake Superior, Marquette, Michigan

DATE STARTED 5/12/20 **COMPLETED** 5/12/20

GROUND ELEVATION **HOLE SIZE** 2.16 inches

DRILLING CONTRACTOR Foth

NORTH: 5157339.34 **EAST:** 469966.08

DRILLING METHOD Check Valve Sampler

LOGGED BY JRK3 **CHECKED BY** NMG1

NOTES Water Depth = 6.0 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND WITH GRAVEL, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.8 feet
1				
2				
3			3.0	

Refusal at 3.0 feet.
Bottom of borehole at 3.0 feet.

BORING NUMBER A3

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/12/20 **COMPLETED** 5/12/20
GROUND ELEVATION
HOLE SIZE 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5157276.6 **EAST:** 469992.95
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 6.9 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, little gravel, overall poling depth = 0.5 feet
1				
2			2.0	

Refusal at 2.0 feet.
Bottom of borehole at 2.0 feet.

BORING NUMBER A4

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/13/20 **COMPLETED** 5/13/20
GROUND ELEVATION **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5157219.24 **EAST:** 470015.94
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 7.8 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, trace gravel, overall poling depth = 0.6 feet
1				
			1.3	

Refusal at 1.5 feet.
Bottom of borehole at 1.3 feet.

BORING NUMBER A5

Foth

CLIENT Baird	**PROJECT NAME** Nearshore Sediment Collection
PROJECT NUMBER 20B001	**PROJECT LOCATION** Lake Superior, Marquette, Michigan
DATE STARTED 5/13/20 **COMPLETED** 5/13/20	**GROUND ELEVATION** **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth	**NORTH:** 5157152.3 **EAST:** 470037.67
DRILLING METHOD Check Valve Sampler	**LOGGED BY** JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 8.0 feet	

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.6 feet
1				
2			2.3	

Refusal at 2.3 feet.
Bottom of borehole at 2.3 feet.

BORING NUMBER A6

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/13/20 **COMPLETED** 5/13/20
GROUND ELEVATION
HOLE SIZE 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5157092.95 **EAST:** 470067.47
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 8.6 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0 – 2.7		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, little gravel, slight organic "burnt" odor, overall poling depth = 0.7 feet
2.7				Refusal at 2.7 feet. Bottom of borehole at 2.7 feet.

BORING NUMBER A7

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/13/20 **COMPLETED** 5/13/20
GROUND ELEVATION
HOLE SIZE 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5157035.03 **EAST:** 470093.02
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 10.4 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.5 feet
1				
2			2.3	

Refusal at 2.5 feet.
Bottom of borehole at 2.3 feet.

BORING NUMBER A8

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/13/20 **COMPLETED** 5/13/20
GROUND ELEVATION
HOLE SIZE 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5156971.91 **EAST:** 470113.39
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 10.5 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, slight to moderate organic "burnt" odor, coal-like material present, overall poling depth = 0.5 feet
1			1.4	

Refusal at 1.4 feet.
Bottom of borehole at 1.4 feet.

BORING NUMBER A9

Foth

CLIENT Baird	**PROJECT NAME** Nearshore Sediment Collection
PROJECT NUMBER 20B001	**PROJECT LOCATION** Lake Superior, Marquette, Michigan
DATE STARTED 5/13/20 **COMPLETED** 5/13/20	**GROUND ELEVATION** **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth	**NORTH:** 5156911.97 **EAST:** 470139.5
DRILLING METHOD Check Valve Sampler	**LOGGED BY** JRK3 **CHECKED BY** NMG1

NOTES Water Depth = 10.4 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0 – 2.7		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, moderate organic "burnt" odor, coal-like material present, overall poling depth = 0.5 feet
2.7				

Refusal at 3.3 feet.
Bottom of borehole at 2.7 feet.

BORING NUMBER A10

CLIENT Baird

PROJECT NAME Nearshore Sediment Collection

PROJECT NUMBER 20B001

PROJECT LOCATION Lake Superior, Marquette, Michigan

DATE STARTED 5/13/20 **COMPLETED** 5/13/20

GROUND ELEVATION **HOLE SIZE** 2.16 inches

DRILLING CONTRACTOR Foth

NORTH: 5156854.25 **EAST:** 470164.13

DRILLING METHOD Check Valve Sampler

LOGGED BY JRK3 **CHECKED BY** NMG1

NOTES Water Depth = 9.4 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0				
0–2.0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, moderate organic "burnt" odor, coal-like material present, overall poling depth = 0.5 feet
1				
2			2.0	

Refusal at 2.0 feet.
Bottom of borehole at 2.0 feet.

BORING NUMBER A11

Foth

CLIENT	Baird	**PROJECT NAME**	Nearshore Sediment Collection
PROJECT NUMBER	20B001	**PROJECT LOCATION**	Lake Superior, Marquette, Michigan
DATE STARTED	5/13/20 **COMPLETED** 5/13/20	**GROUND ELEVATION**	**HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR	Foth	**NORTH:**	5156792.56 **EAST:** 470180.95
DRILLING METHOD	Check Valve Sampler	**LOGGED BY**	JRK3 **CHECKED BY** NMG1
NOTES	Water Depth = 9.0 feet		

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0 – 2.6		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, coal-like material present, overall poling depth = 1.1 feet
2.6				

Refusal at 2.6 feet.
Bottom of borehole at 2.6 feet.

BORING NUMBER B1

Foth

CLIENT Baird		**PROJECT NAME** Nearshore Sediment Collection	
PROJECT NUMBER 20B001		**PROJECT LOCATION** Lake Superior, Marquette, Michigan	
DATE STARTED 5/12/20	**COMPLETED** 5/12/20	**GROUND ELEVATION**	**HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth		**NORTH:** 5157426.65	**EAST:** 469997.17
DRILLING METHOD Check Valve Sampler		**LOGGED BY** JRK3	**CHECKED BY** NMG1
NOTES Water Depth = 9.6 feet			

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, trace gravel, overall poling depth = 0.8 feet
1				
2			2.6	

Refusal at 3.0 feet.
Bottom of borehole at 2.6 feet.

BORING NUMBER B2

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/14/20 **COMPLETED** 5/14/20
GROUND ELEVATION
HOLE SIZE 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5157367.36
EAST: 470012.99
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3
CHECKED BY NMG1
NOTES Water Depth = 10.0 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, little gravel, overall poling depth = 0.6 feet
1			1.3	

Refusal at 1.5 feet.
Bottom of borehole at 1.3 feet.

BORING NUMBER B3

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/14/20 **COMPLETED** 5/14/20
GROUND ELEVATION **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5157307.06 **EAST:** 470050.1
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 12.2 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, little gravel, overall poling depth = 0.5 feet
1				
			1.4	Refusal at 1.4 feet. Bottom of borehole at 1.4 feet.

BORING NUMBER B4

CLIENT	Baird	**PROJECT NAME**	Nearshore Sediment Collection
PROJECT NUMBER	20B001	**PROJECT LOCATION**	Lake Superior, Marquette, Michigan
DATE STARTED	5/14/20 **COMPLETED** 5/14/20	**GROUND ELEVATION**	**HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR	Foth	**NORTH:**	5157247.88 **EAST:** 470069.41
DRILLING METHOD	Check Valve Sampler	**LOGGED BY**	JRK3 **CHECKED BY** NMG1
NOTES	Water Depth = 12.7 feet		

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, little gravel, overall poling depth = 0.5 feet
1				
			1.4	

Refusal at 1.4 feet.
Bottom of borehole at 1.4 feet.

BORING NUMBER B5

CLIENT	Baird	**PROJECT NAME**	Nearshore Sediment Collection
PROJECT NUMBER	20B001	**PROJECT LOCATION**	Lake Superior, Marquette, Michigan
DATE STARTED	5/14/20 **COMPLETED** 5/14/20	**GROUND ELEVATION**	**HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR	Foth	**NORTH:**	5157186.05 **EAST:** 470089.34
DRILLING METHOD	Check Valve Sampler	**LOGGED BY**	JRK3 **CHECKED BY** NMG1
NOTES	Water Depth = 13.6 feet		

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, trace gravel, overal poling depth = 0.3 feet
1				
			1.7	

Refusal at 1.8 feet.
Bottom of borehole at 1.7 feet.

BORING NUMBER B6

Foth

CLIENT Baird

PROJECT NAME Nearshore Sediment Collection

PROJECT NUMBER 20B001

PROJECT LOCATION Lake Superior, Marquette, Michigan

DATE STARTED 5/14/20 **COMPLETED** 5/14/20

GROUND ELEVATION **HOLE SIZE** 2.16 inches

DRILLING CONTRACTOR Foth

NORTH: 5157126.07 **EAST:** 470121.03

DRILLING METHOD Check Valve Sampler

LOGGED BY JRK3 **CHECKED BY** NMG1

NOTES Water Depth = 13.6 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, slight to moderate organic "burnt" odor, overall poling depth = 0.3 feet
1				
			1.5	

Refusal at 1.6 feet.
Bottom of borehole at 1.5 feet.

BORING NUMBER B7

CLIENT Baird

PROJECT NAME Nearshore Sediment Collection

PROJECT NUMBER 20B001

PROJECT LOCATION Lake Superior, Marquette, Michigan

DATE STARTED 5/14/20 **COMPLETED** 5/14/20

GROUND ELEVATION **HOLE SIZE** 2.16 inches

DRILLING CONTRACTOR Foth

NORTH: 5157063.08 **EAST:** 470144.3

DRILLING METHOD Check Valve Sampler

LOGGED BY JRK3 **CHECKED BY** NMG1

NOTES Water Depth = 17.0 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, trace to slight organic "burnt" odor, overall poling depth = 0.6 feet
1			1.0	

Refusal at 1.0 feet.
Bottom of borehole at 1.0 feet.

BORING NUMBER B8

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/14/20 **COMPLETED** 5/14/20
GROUND ELEVATION **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5156997.31 **EAST:** 470167.28
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 17.0 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0 – 1.6		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, slight organic "burnt" odor, overall poling depth = 0.3 feet
1.6				

Refusal at 1.7 feet.
Bottom of borehole at 1.6 feet.

BORING NUMBER B9

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/14/20 **COMPLETED** 5/14/20
GROUND ELEVATION **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5156942.02 **EAST:** 470194.01
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 16.5 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.6 feet
1				
			1.3	

Refusal at 1.4 feet.
Bottom of borehole at 1.3 feet.

BORING NUMBER B10

Foth

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/14/20 **COMPLETED** 5/14/20
GROUND ELEVATION **HOLE SIZE** 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5156877.8 **EAST:** 470223.34
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3 **CHECKED BY** NMG1
NOTES Water Depth = 14.6 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.5
1				
			1.5	

Refusal at 1.6 feet.
Bottom of borehole at 1.5 feet.

BORING NUMBER B11

CLIENT Baird
PROJECT NAME Nearshore Sediment Collection
PROJECT NUMBER 20B001
PROJECT LOCATION Lake Superior, Marquette, Michigan
DATE STARTED 5/14/20 **COMPLETED** 5/14/20
GROUND ELEVATION
HOLE SIZE 2.16 inches
DRILLING CONTRACTOR Foth
NORTH: 5156821.02
EAST: 470241.98
DRILLING METHOD Check Valve Sampler
LOGGED BY JRK3
CHECKED BY NMG1
NOTES Water Depth = 14.0 feet

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SP		POORLY GRADED SAND, (SP) brown, poorly graded, fine grained, moist, overall poling depth = 0.4 feet
1				
			1.9	

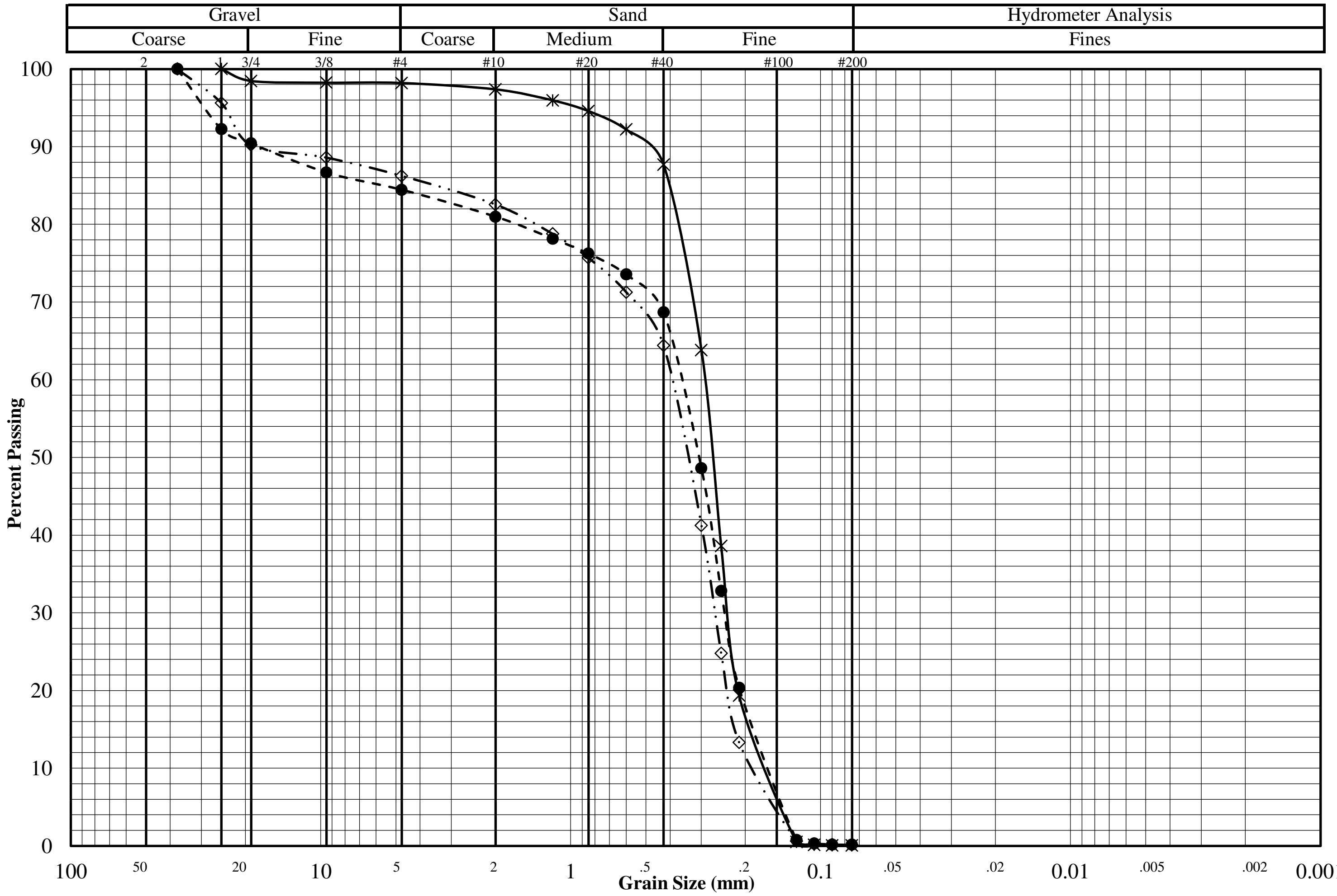
Refusal at 2.0 feet.
Bottom of borehole at 1.9 feet.

Attachment 3. Sieve Analysis Lab Results

Grain Size Distribution ASTM D6913

Project:	Marquette - LS Shoreline Restoration	Job No. :	**12548**
		Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	A-1	1	0-1	Bag	Sand, fine grained (SP)
●	A-2	1	0-1	Bag	Sand w/gravel, fine grained (SP)
◇	A-3	1	0-1	Bag	Sand w/a little gravel, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1279.8	1462.0	1382.4
3"			
2"			
1.5"		100.0	
1"	100.0	92.3	100.0
3/4"	98.5	90.4	90.2
3/8"	98.3	86.7	88.6
#4	98.2	84.5	86.3

Percent Passing (Fine Sieves)

	*	●	◇
#10	97.4	81.0	82.6
#16	96.0	78.2	78.8
#20	94.6	76.2	75.7
#30	92.2	73.6	71.3
#40	87.7	68.7	64.4
#50	63.8	48.6	41.2
#60	38.6	32.8	24.8
#70	19.3	20.4	13.3
#120	0.5	0.8	0.6
#140	0.1	0.3	0.3
#170	0.1	0.2	0.2
#200	0.0	0.2	0.1

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

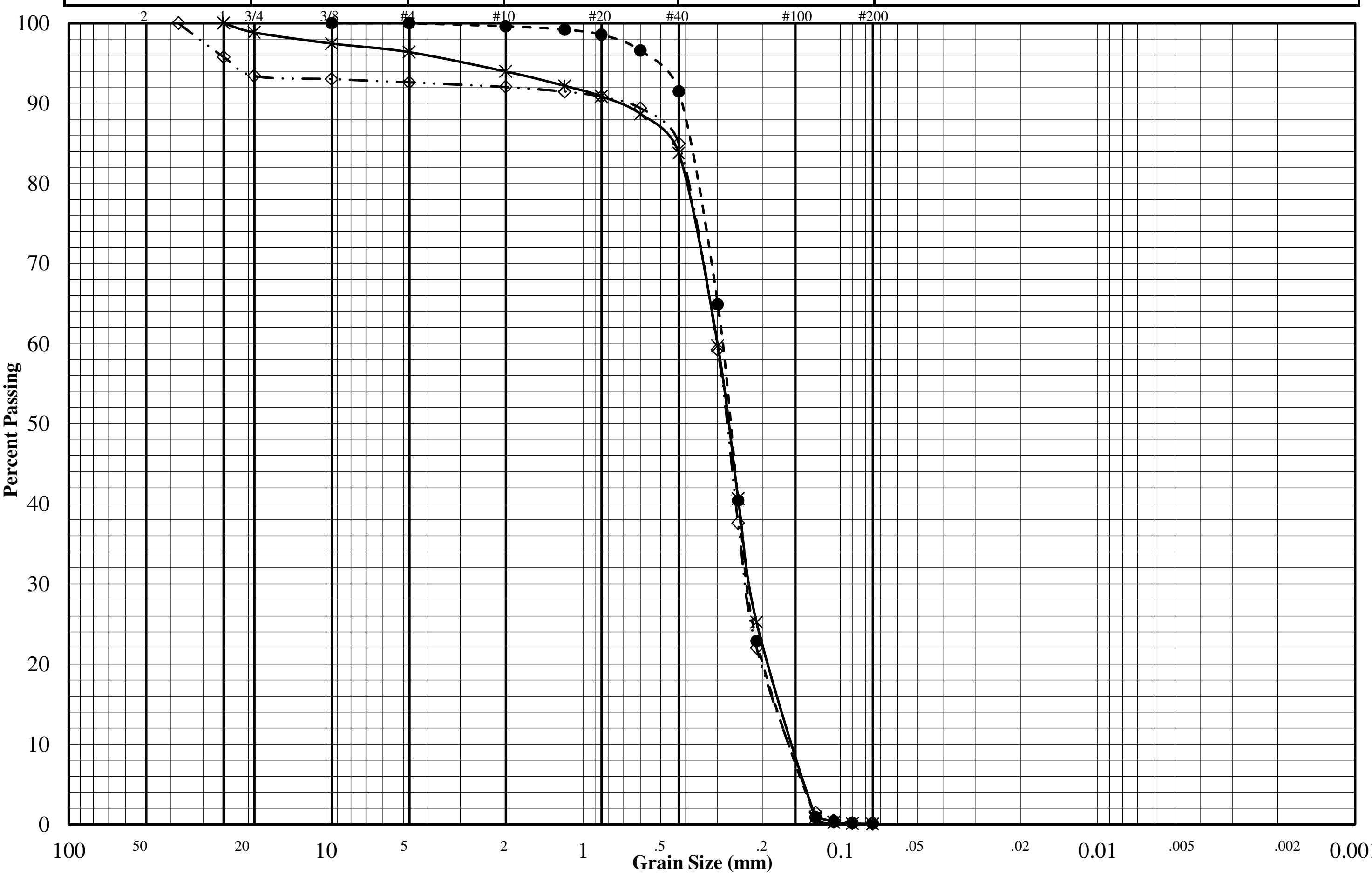
(* = assumed)

Grain Size Distribution ASTM D6913

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

Job No. : **12548**

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	A-4	1	0-1.1	Bag	Sand w/a trace of gravel, fine grained (SP)
●	A-5	1	0-1.1	Bag	Sand, fine grained (SP)
◇	A-6	1	0-1.1	Bag	Sand w/a little gravel, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1452.2	1418.9	1351.6
3"			
2"			
1.5"			
1"	100.0		100.0
3/4"	98.8		93.4
3/8"	97.5	100.0	93.0
#4	96.4	100.0	92.6

Percent Passing (Fine Sieves)

	*	●	◇
#10	94.0	99.6	92.0
#16	92.2	99.2	91.5
#20	90.9	98.6	90.8
#30	88.7	96.6	89.4
#40	83.8	91.5	85.0
#50	59.7	64.9	59.2
#60	40.7	40.4	37.6
#70	25.2	22.9	22.0
#120	0.9	0.9	1.5
#140	0.2	0.4	0.5
#170	0.1	0.2	0.1
#200	0.1	0.1	0.1

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

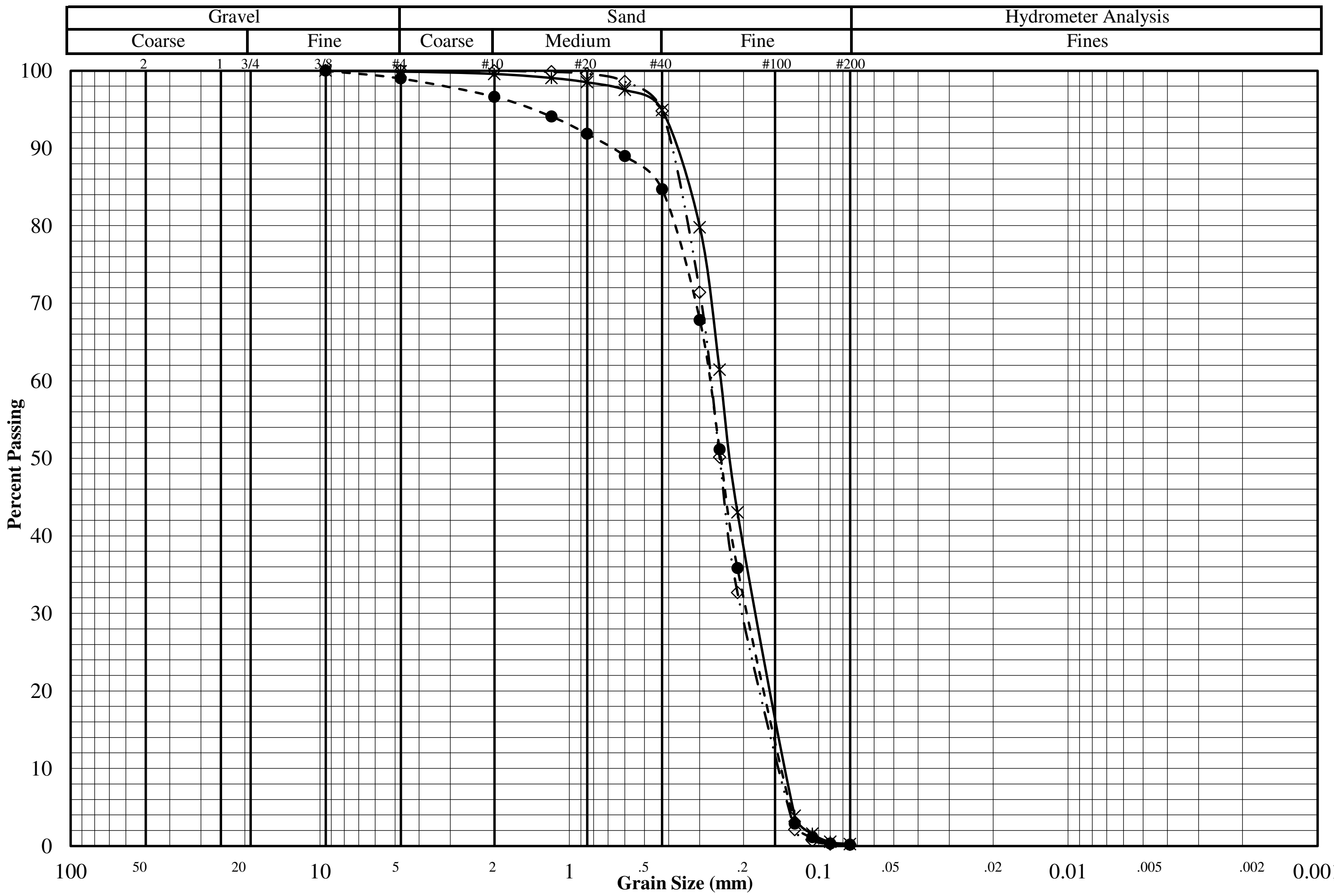
(* = assumed)

Grain Size Distribution ASTM D6913

Job No. : **12548**

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	A-7	1	0-1.1	Bag	Sand, fine grained (SP)
●	A-8	1	0-1.1	Bag	Sand, fine grained (SP)
◇	A-9	1	0-1.1	Bag	Sand, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1352.0	1477.3	1485.3
3"			
2"			
1.5"			
1"			
3/4"			
3/8"	100.0	100.0	100.0
#4	99.9	99.0	100.0

Percent Passing (Fine Sieves)

	*	●	◇
#10	99.6	96.6	100.0
#16	99.1	94.1	99.9
#20	98.5	91.8	99.6
#30	97.5	89.0	98.6
#40	94.9	84.7	94.8
#50	79.8	67.8	71.4
#60	61.4	51.2	50.2
#70	43.0	35.8	32.7
#120	3.9	2.9	2.1
#140	1.6	1.1	0.7
#170	0.5	0.3	0.3
#200	0.3	0.2	0.2

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

(* = assumed)

9530 James Ave South

SOIL ENGINEERING TESTING, INC.

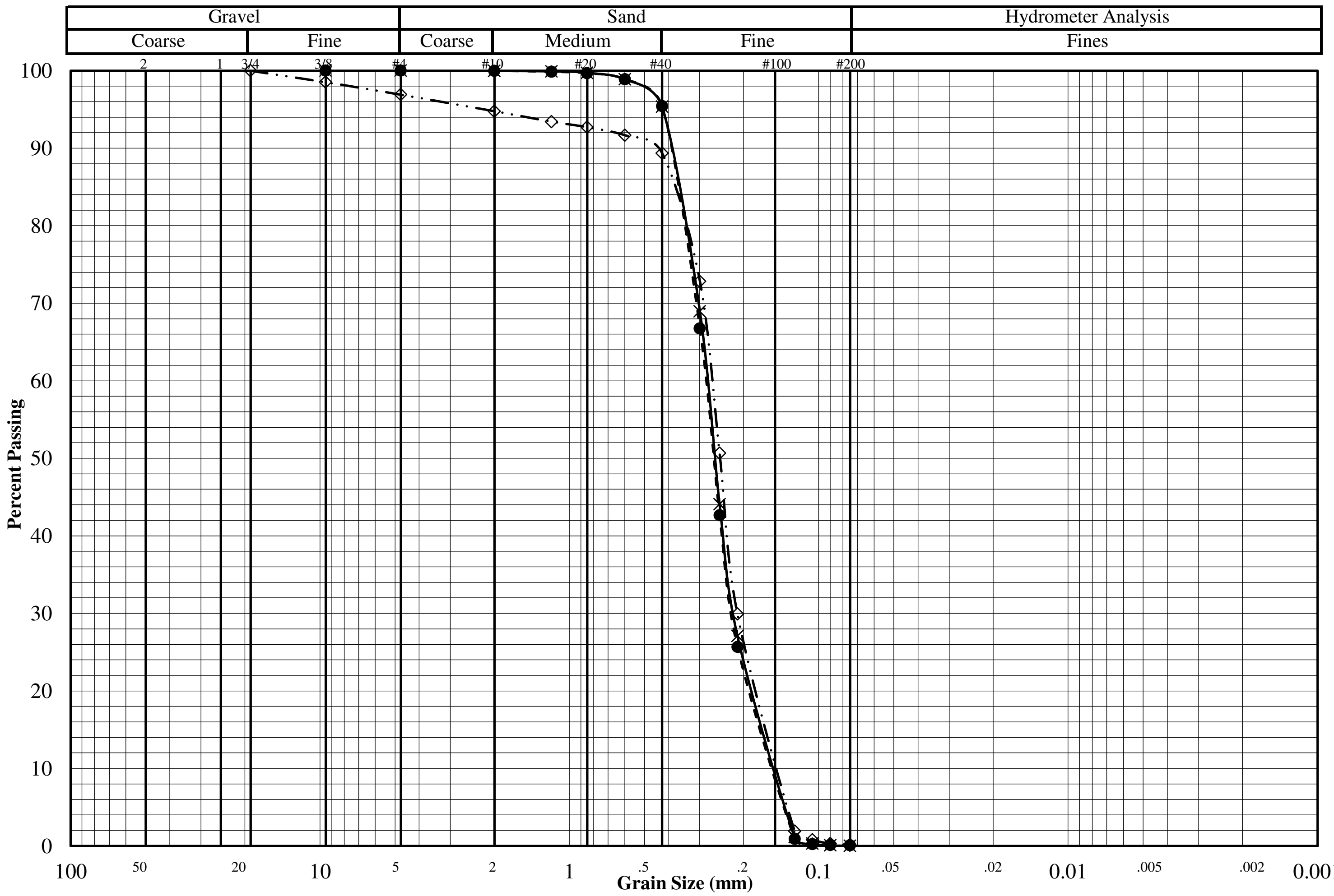
Bloomington, MN 55431

Grain Size Distribution ASTM D6913

Job No. : **12548**

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	A-10	1	0-1.1	Bag	Sand, fine grained (SP)
●	A-11	1	0-1.1	Bag	Sand, fine grained (SP)
◇	B-1	1	0-1	Bag	Sand w/a trace of gravel, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1393.5	1332.7	758.8
3"			
2"			
1.5"			
1"			
3/4"			100.0
3/8"	100.0	100.0	98.5
#4	100.0	100.0	96.9

Percent Passing (Fine Sieves)

	*	●	◇
#10	100.0	100.0	94.8
#16	99.9	99.9	93.4
#20	99.7	99.7	92.7
#30	98.9	98.9	91.7
#40	95.3	95.4	89.4
#50	68.9	66.8	72.8
#60	44.1	42.7	50.7
#70	27.1	25.7	29.9
#120	1.1	0.9	1.9
#140	0.3	0.3	0.8
#170	0.1	0.1	0.3
#200	0.0	0.1	0.2

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

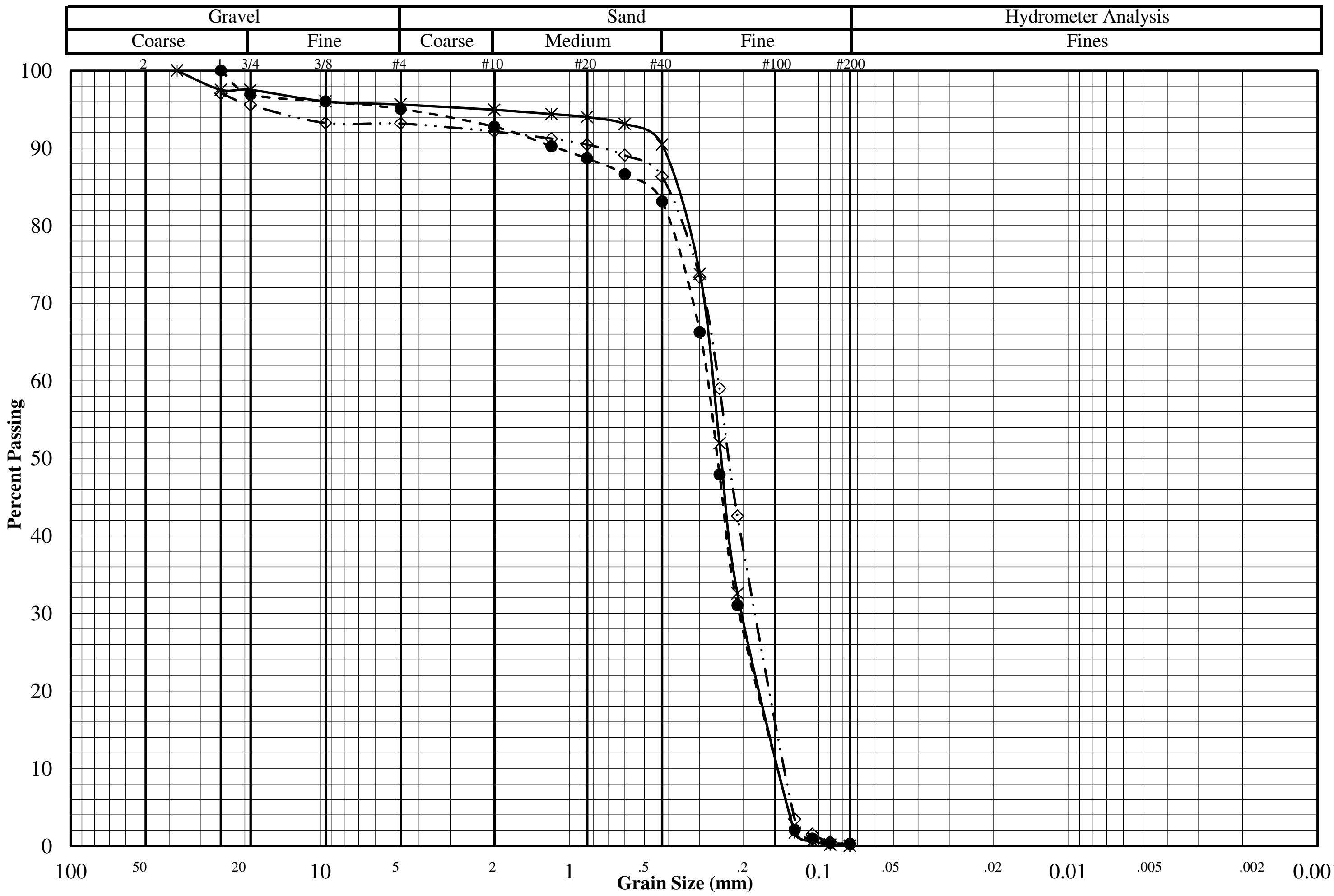
(* = assumed)

Grain Size Distribution ASTM D6913

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

Job No. : **12548**

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-2	1	0-1.2	Bag	Sand w/a little gravel, fine grained (SP)
●	B-3	1	0-1.3	Bag	Sand w/a little gravel, fine grained (SP)
◇	B-4	1	0-1.4	Bag	Sand w/a little gravel, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1276.4	1839.8	1775.2
3"			
2"			
1.5"	100.0		
1"	97.5	100.0	
3/4"	97.5	97.0	95.6
3/8"	96.0	96.0	93.3
#4	95.6	95.1	93.2

Percent Passing (Fine Sieves)

	*	●	◇
#10	95.0	92.8	92.1
#16	94.4	90.3	91.2
#20	94.0	88.7	90.5
#30	93.1	86.7	89.1
#40	90.5	83.1	86.3
#50	73.8	66.3	73.3
#60	51.9	47.9	59.0
#70	32.6	31.0	42.5
#120	1.7	2.1	3.5
#140	0.7	1.0	1.5
#170	0.2	0.4	0.6
#200	0.0	0.3	0.3

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

(* = assumed)

9530 James Ave South

SOIL ENGINEERING TESTING, INC.

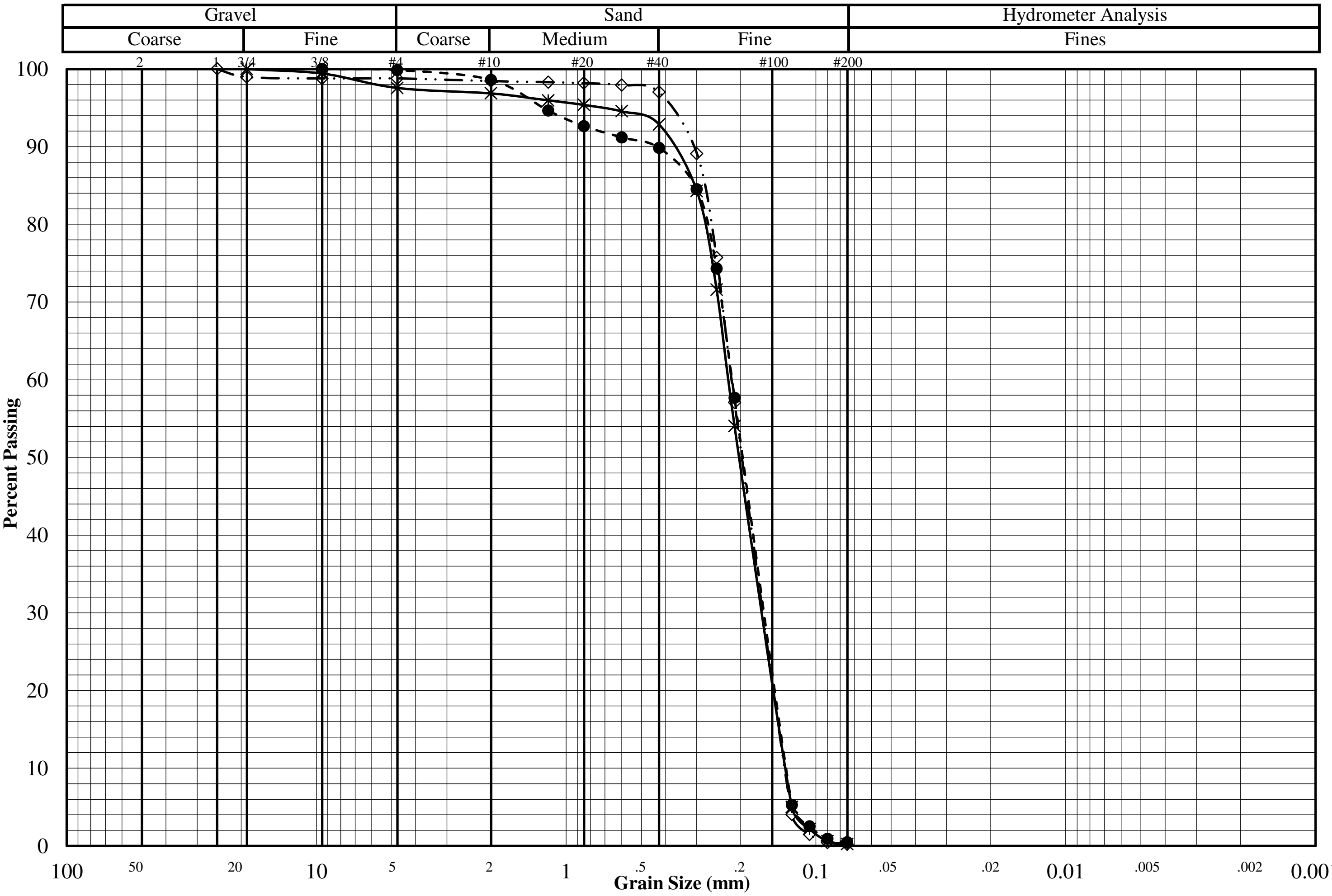
Bloomington, MN 55431

Grain Size Distribution ASTM D6913

Job No. : **12548**

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-5	1	0-1.1	Bag	Sand w/a trace of gravel, fine grained (SP)
●	B-6	1	0-1.1	Bag	Sand, fine grained (SP)
◇	B-7	1	0-1	Bag	Sand, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1396.3	1394.4	1290.0
3"			
2"			
1.5"			
1"			
3/4"	100.0		99.0
3/8"	99.4	100.0	98.8
#4	97.6	99.9	98.8

Percent Passing (Fine Sieves)

	*	●	◇
#10	96.9	98.6	98.5
#16	96.0	94.7	98.3
#20	95.4	92.6	98.2
#30	94.6	91.2	97.9
#40	92.9	89.8	97.0
#50	84.3	84.5	89.1
#60	71.6	74.3	75.7
#70	54.1	57.7	57.1
#120	5.0	5.3	4.0
#140	2.2	2.5	1.5
#170	0.6	0.9	0.4
#200	0.2	0.5	0.2

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

(* = assumed)

9530 James Ave South

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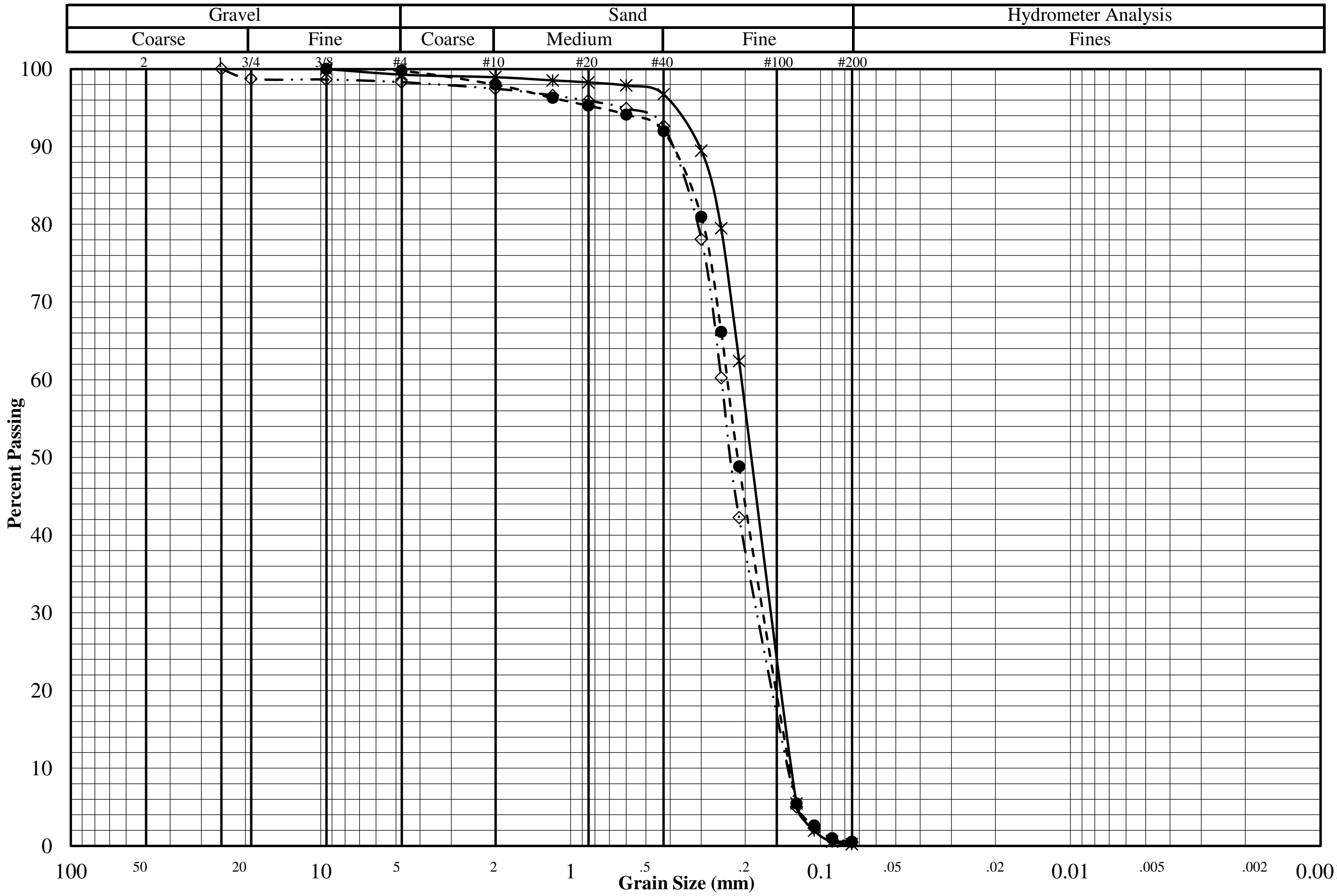
Bloomington, MN 55431

Grain Size Distribution ASTM D6913

Job No. : **12548**

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-8	1	0-1.1	Bag	Sand, fine grained (SP)
●	B-9	1	0-1.3	Bag	Sand, fine grained (SP)
◇	B-10	1	0-1.1	Bag	Sand, fine grained (SP)



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1386.5	1495.6	1444.7
3"			
2"			
1.5"			
1"			
3/4"			98.7
3/8"	100.0	100.0	98.6
#4	99.3	99.8	98.3

Percent Passing (Fine Sieves)

	*	●	◇
#10	99.0	98.0	97.5
#16	98.5	96.3	96.6
#20	98.3	95.3	95.9
#30	97.9	94.1	94.9
#40	96.8	92.0	92.7
#50	89.5	81.0	78.1
#60	79.5	66.2	60.2
#70	62.4	48.8	42.3
#120	5.5	5.4	5.0
#140	2.0	2.6	2.3
#170	0.5	1.0	0.8
#200	0.2	0.5	0.4

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

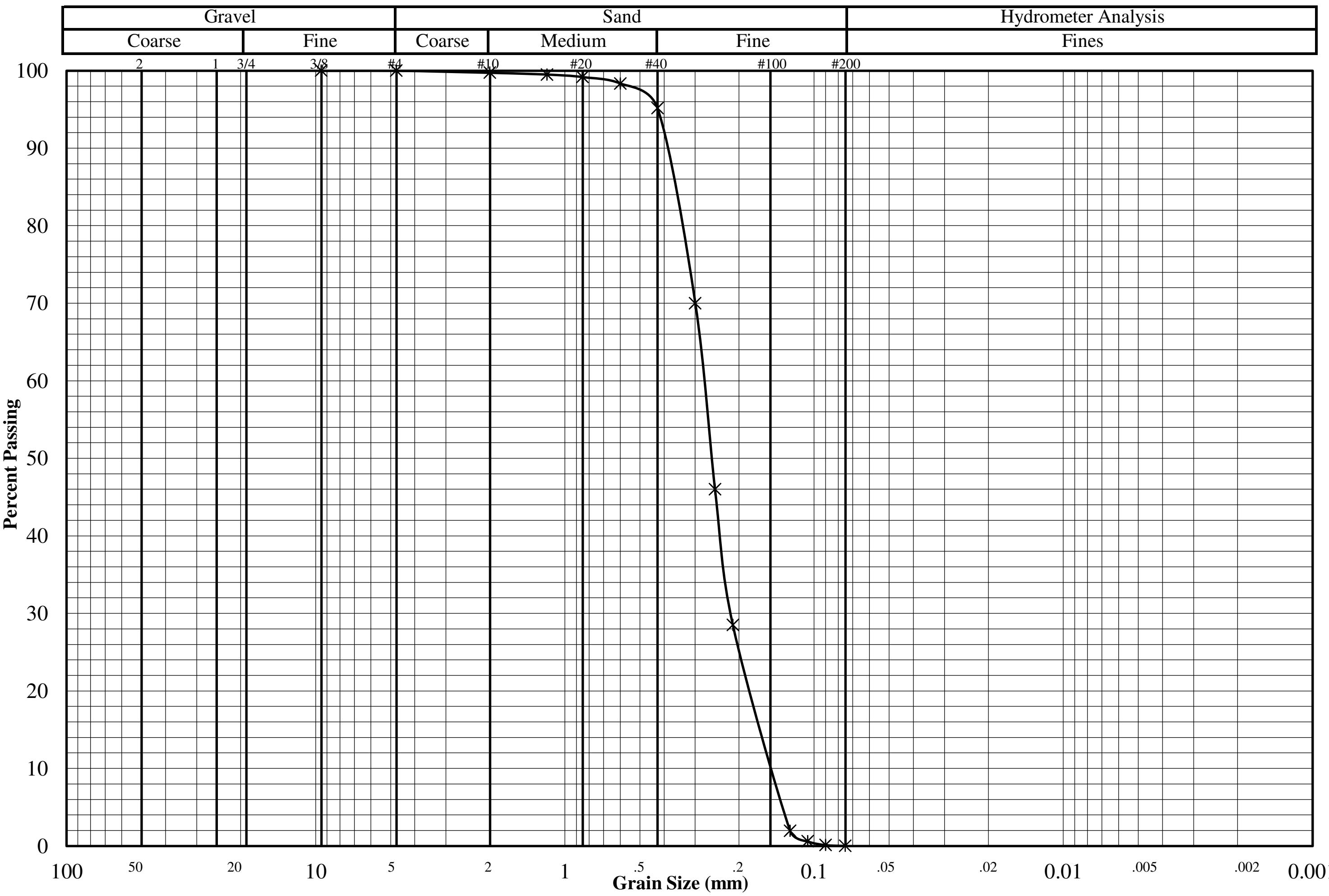
(* = assumed)

Grain Size Distribution ASTM D6913

Job No. : **12548**

Project:	Marquette - LS Shoreline Restoration	Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-11	1	0-1.1	Bag	Sand, fine grained (SP)
●					
◇					



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1427.7		
3"			
2"			
1.5"			
1"			
3/4"			
3/8"	100.0		
#4	100.0		

Percent Passing (Fine Sieves)

	*	●	◇
#10	99.7		
#16	99.5		
#20	99.2		
#30	98.3		
#40	95.2		
#50	70.0		
#60	46.0		
#70	28.5		
#120	2.0		
#140	0.6		
#170	0.1		
#200	0.0		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

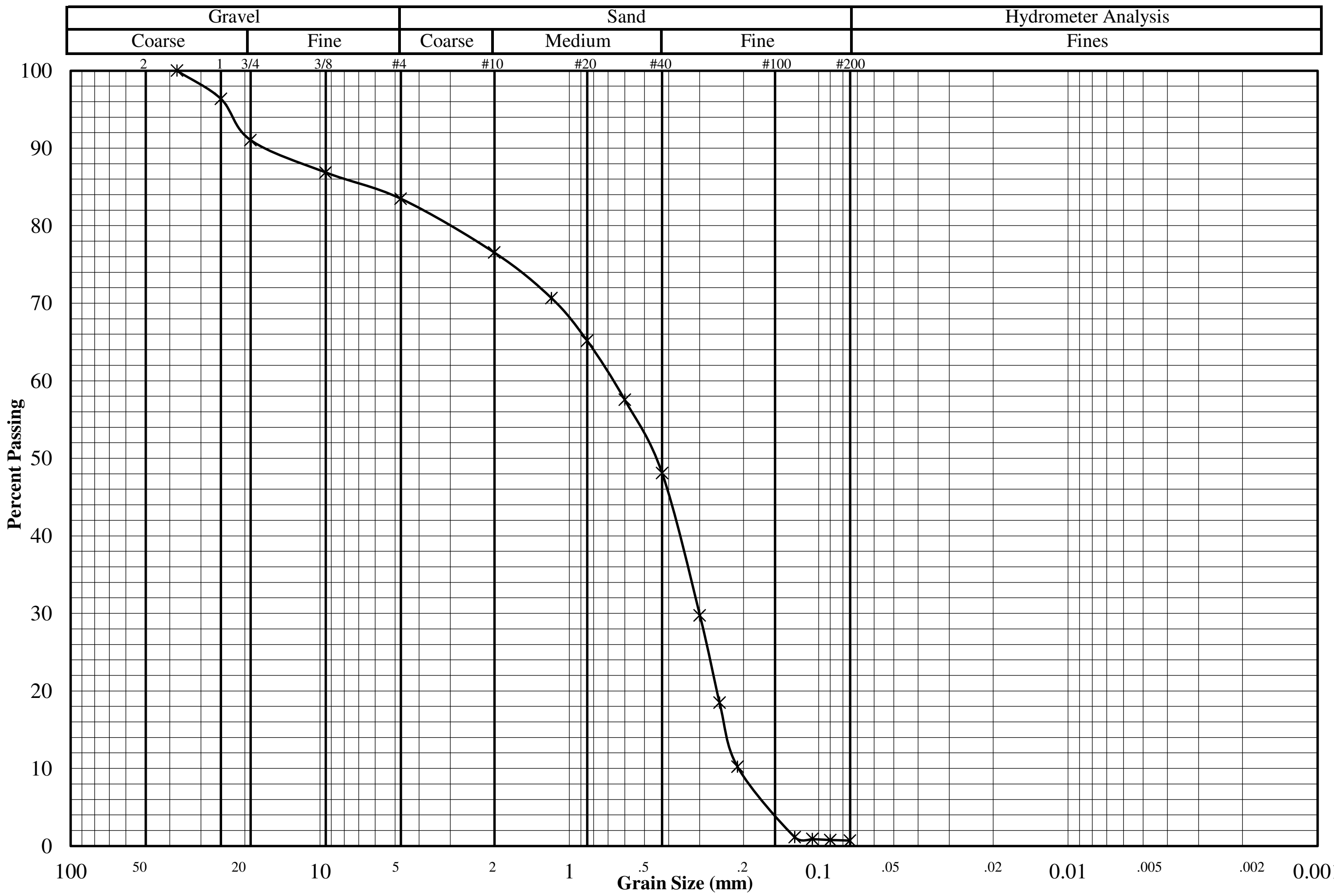
Remarks:

(* = assumed)

Grain Size Distribution ASTM D6913

Project:	Marquette - LS Shoreline Restoration	Job No. :	**12548**
		Test Date:	5/20/20
Reported To:	Foth Infrastructure & Environment, LLC	Report Date:	5/22/20

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	A-9	2	1.5-2.7	Bag	Sand w/gravel, medium to fine grained (SP)
●					
◇					



Percent Passing (Coarse Sieves)

	*	●	◇
Sample Mass (g)	1348.4		
3"			
2"			
1.5"	100.0		
1"	96.4		
3/4"	91.1		
3/8"	86.9		
#4	83.5		

Percent Passing (Fine Sieves)

	*	●	◇
#10	76.5		
#16	70.7		
#20	65.2		
#30	57.6		
#40	48.1		
#50	29.8		
#60	18.5		
#70	10.2		
#120	1.2		
#140	0.9		
#170	0.8		
#200	0.7		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

(* = assumed)

9530 James Ave South

SOIL ENGINEERING TESTING, INC.

Bloomington, MN 55431

Construction Observation Report

Location ______

WEATHER	Temp (° F)		Sky Cond.	Precip. (in.)			Site Conditions (describe)	
	Low	High			Rain	Snow	Dry	Muddy
	63	81	Clear Pt. Cldy Cloudy	None			X	

Contractors on site *(include no. of personnel per contractor)*

Wyatt Smith – Smith Construction

Other personnel on site:
Kellen Wessels-Marquette Engineering Department

Purpose:
Test pit clearance and coordination with Smith Constuction

Work observation report, comments:

Bob Meller and Kellen Wessels GPS located the three test pits using coordinates provided by Baird. Mr. Wessels was able to confirm that there were no buried utility issues near each test pit. Test Pits #1 and #3 were placed as proposed. Test Pit 2 was moved several feet west due to the presence of a dense growth of poplar trees. The nearest underground utility identified by Mr. Wessels was a sanitary sewer force main located west of Test Pit #2. All of the test pits were difficult to keep open long due to the loose nature of the sands encountered and the shallow water table. As such, photographs of the test pit walls were nearly impossible to obtain. Photos of the test pit locations and photos of potential interest are attached.

Test Pit #1 - 0930

Test Pit # 1 encountered thinly bedded beach sands with trace wood fragments from grade to approximately six feet. It was difficult to keep the excavation open due to the collapsing sand sidewalls. No field indications of volatile organic compound (VOC) or chemical type impacts were observed.

0' – 6' Brown to dark brown medium to fine sand, moist to wet at approximately four feet, with wood fragments and The beach sand consisted of dark reddish brown to brown medium to fine sand which was moist to wet at approximately 4'. An irregularly bedded organic layer (less than 2 inches to approximately four inches thick) consisting of organics and organic silt was noted at varying depths in the test pit. Water seepage was observed at approximately four and a half feet.

Test Pit #2 – 0950
Test Pit 2 actual coordinates are as follows:
46º34'04.1461"N
87º23'32.137" W

Construction Observation Report

Test Pit #2 encountered approximately two and a half feet of black stained fill overlying beach sand which extended to the test pit bottom at a depth of approximate five feet. No petroleum sheen was observed on the water entering the excavation. The fill had no obvious odor. The sand however, had a faint sweet organic odor.

0- 8" Topsoil layer consisting of organic matter, black stained medium to fine sand, coal ash, gravel sized pieces of brick and clinker's.
8" – 2' Fill – dark brown to black stained, moist, medium to fine grained sand with gravel sized pieces of brick and foundry clinkers. No visual evidence of residual tar was observed.
2' – 5' Brown to dark brown, silty, medium to fine sand, moist to wet at approximately four feet. Visible water seepage at approximately four feet.

Test Pit # 2 is approximate twenty feet north of a well nest consisting of one protop well and two flushmount wells. Based on broken off lathe near the well nest, these are GSI-100A, GSI-100B what could be GSI-100C. The third well name is no longer visible. This monitoring well nest appears to be one of several located west of the fence along the eastern side of the property. Additionally, it was noted that the City had several new monitoring well nests installed along the actual lakeshore to replace wells which were abandoned due to construction activities. Additionally, it should be noted that future excavation could encounter anything from steel railroad rails to foundry machinery parts as observed during the walk into Test Pit #2.

Test Pit #3 – 1015

Test Pit #3 encountered mixed beach sand and riprap material to a depth of approximately two feet, followed by an irregular layer of organic matter, and was terminated in beach sand from approximately four to six feet. Test pit continued to collapse. No odor observed emanating from any of the material and no rainbow sheen observed on the water surface.

0'- 2' Brown medium to fine sand with cobble to boulder sized pieces of riprap of varying composition from asphalt and concrete to bricks and native rock.
2'- 4' Dark brown moist organic layer with consistency of peat with fine organic debris scattered throughout. Thickest on south end of test pit at approximately one foot, thinning and rising to north where it was less than one inch thick.
4'- 5' Brown to dark brown moist to wet medium to fine sand. Water seepage was observed at a depth of approximately five feet.

Photographic Log

Client's Name:	Site Location:	Project No.
Baird-THRW Borings	Marquette, MI	020B001.00.4.8

Photo No. 1	**Date:** 8/24/20
Direction Photo Taken: Southeast	
Photo Taken By: Bob Meller	
Description: Note backfilled Test Pit #1 location to left of former walking trail and woods.	

Photo No. 2	**Date:** 8/24/20
Direction Photo Taken: West	
Photo Taken By: Bob Meller	
Description: Excavated Sands from Test Pit #1	

Photographic Log

Client's Name:	Site Location:	Project No.
Baird-THRW Borings	Marquette, MI	020B001.00.4.8

Photo No. 3	**Date:** 8/24/20
Direction Photo Taken: East	
Photo Taken By: Bob Meller	
Description: Looking east toward Test Pit #2 location in beneath young poplar trees. Note linear outline or railroad rail near edge of grass.	

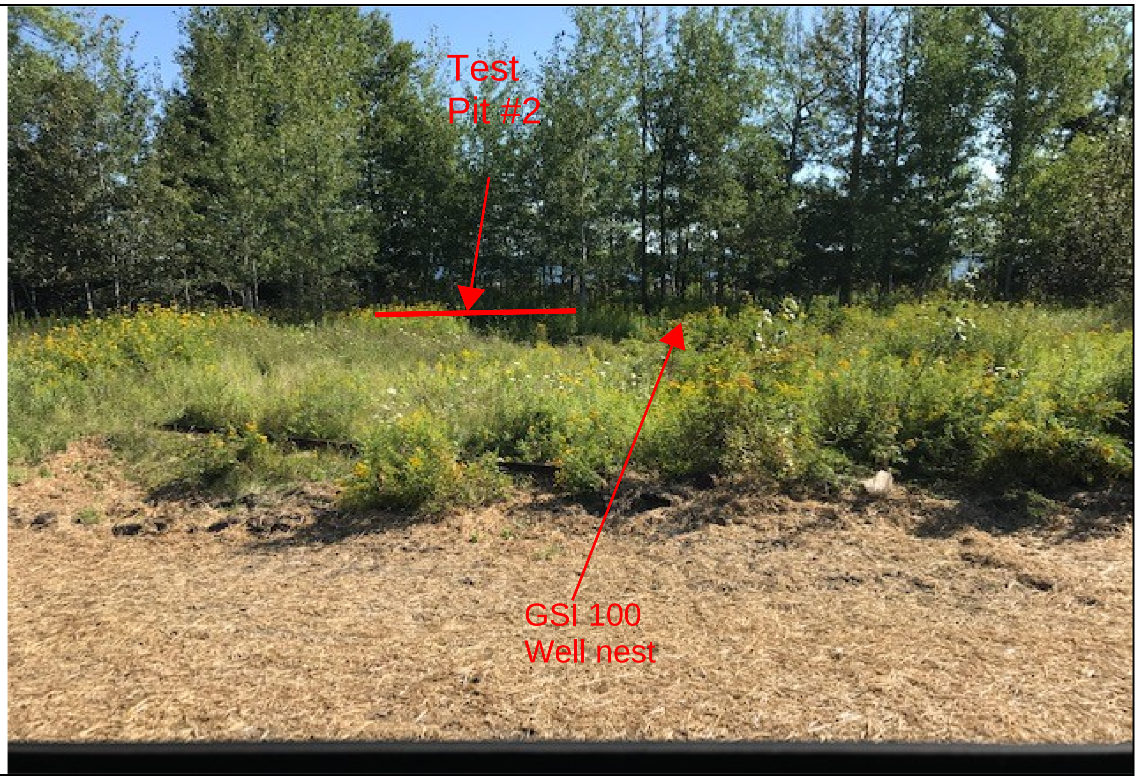


Photo No. 4	**Date:** 8/24/20
Direction Photo Taken: East	
Photo Taken By: Bob Meller	
Description: Test Pit #3 backfilled.	

Photographic Log

Client's Name:	Site Location:	Project No.
Baird-THRW Borings	Marquette, MI	020B001.00.4.8

Photo No.	Date:
5	8/24/20

Direction Photo Taken:
North

Photo Taken By:
Bob Meller

Description:

Top layer of Test Pit #3, beach sand and mixed riprap fill.

Photo No.	Date:
6	8/24/20

Direction Photo Taken:
East

Photo Taken By:
Bob Meller

Description:

Excavated organic material from TP-3.

Photographic Log

Client's Name:	Site Location:	Project No.
Baird-THRW Borings	Marquette, MI	020B001.00.4.8

Appendix C

Overtopping Analysis – Living Revetment

C.1 Living Revetment - Wave Overtopping

C.1.1 Introduction

Wave overtopping occurs when wave runup on a structure exceeds the crest of the structure, resulting in water flowing into/onto the area behind the structure (refer to Figure C.1). Wave overtopping is a complex three-dimensional process that varies significantly in both time and space. In general, wave overtopping increases with more severe wave conditions, higher water levels, and lower structure crest elevations. Under moderate conditions, spray and splash overtopping can create nuisance and/or dangerous conditions for pedestrians and vehicles. Wind may play a significant role, driving spray and splash a significant distance inland, and freezing temperatures may result in a significant accumulation of ice on structures. Under more severe conditions, “green water” overtopping may result in structural damage and site flooding.

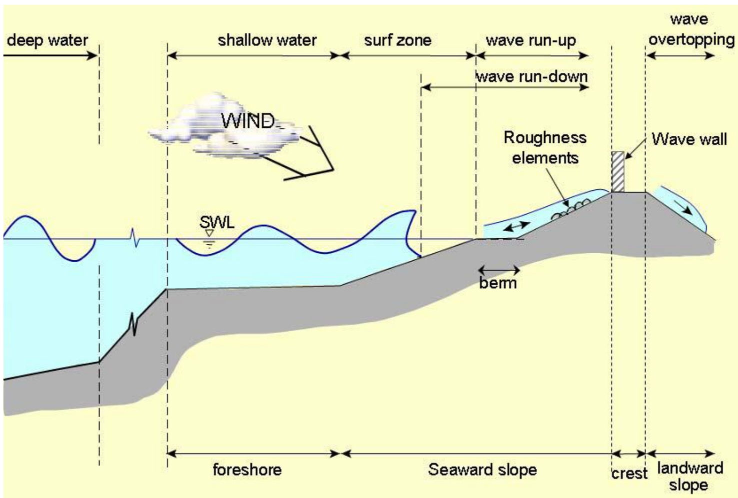


Figure C.1: Wave Overtopping - Schematic (left) and Example (right)

Both empirical and numerical methods are available to estimate the severity of wave overtopping of coastal structures, including mean overtopping rates (i.e., a temporal average over a period of minutes or hours) as well as volumes associated with individual waves (i.e., over a period of seconds). However, given the complexity of the wave-structure interaction processes, there is considerable uncertainty in the prediction of wave overtopping rates using these methods, and a conservative design approach is recommended.

C.1.2 Allowable Wave Overtopping Rates

The EurOtop Manual provides guidance on allowable wave overtopping rates. For example, Table C.1 summarizes wave overtopping rates that may damage shoreline protection structures. Considering the information presented in Table C.1, as well as prior Baird experience with similar projects, a mean wave overtopping rate of 50 liters per second per meter (l/m/s) was identified as the threshold overtopping rate for potential damage to the backshore areas behind the Living Revetment structure.

Table C.1: Allowable limits for wave overtopping for structure design (EurOtop 2007)

Hazard type and reason	Mean discharge q (l/s/m)
Embankment seawalls / sea dikes	
No damage if crest and rear slope are well protected	50-200
No damage to crest and rear face of grass covered embankment of clay	1-10
No damage to crest and rear face of embankment if not protected	0.1
Promenade or revetment seawalls	
Damage to paved or armoured promenade behind seawall	200
Damage to grassed or lightly protected promenade or reclamation cover	50

C.1.3 Selection of Method

The proposed Living Revetment will be composed of cobble-sized materials similar to a cobble beach. These structures do not have clearly published guidelines for calculating overtopping. However, upon completing a literature review it was decided to evaluate three methods for quantifying overtopping of the planned structure, including:

1. EurOtop (2018)
2. CSHORE
3. XBeach-G

Two of the methods, CSHORE and EurOtop, were compared to the results of previous physical modeling performed by Baird for a similar shoreline project (Cat Island Restoration in Green Bay, WI). When comparing these results to the physical modeling, it was seen that the EurOtop method typically gave the best agreement. The CSHORE model typically predicts wave OT rates that are less than the EurOtop method, usually by a factor of 1.5-2. This is relatively close for wave overtopping, where model test results typically show significant scatter. Overall, the XBeach-G model was found to provide the lowest overtopping predictions of the methods tested.

For the analysis of overtopping in this design, the EurOtop methodology was chosen. This was due to its role as the industry standard for evaluating overtopping on rubblemound structures, its ease of implementation, and its conservatism relative to the two alternative models evaluated.

C.1.4 Calibrating EurOtop for Cobble-Sized Material

The methods for estimating overtopping provided by the EurOtop manual are applicable to armored rubble slopes, mounds, and sloping dikes. However, specific guidance does not exist for applying this methodology to structures constructed of cobble-sized materials. In order to apply EurOtop to the Living Revetment design, there are two important parameters that needed to be calibrated in this methodology. The first is the slope roughness factor, gamma, which accounts for the roughness of the structure slope depending on the type of material used. This value has a maximum of 1, which is used for smooth impermeable surfaces and lower values for different types of armor. The second is a runup reduction factor. This is not explicitly accounted for in basic EurOtop methodology, which estimates overtopping values at the structure's crest but is simply a factor (less than or equal to 1) applied to the estimated overtopping volume to account for infiltration of a portion of the wave overtopping as it passes over a permeable crest.

C.1.5 Slope Roughness Factor

Slope roughness factors suggested by the EurOtop manual are seen in Table C.2. It is noted that currently, there is no established slope roughness factor, gamma, suggested for cobble-sized materials. Therefore, a slope roughness factor needed to be developed for this design.

When comparing the EurOtop results to those provide by CSHORE in test cases, a value of gamma = 1 provides the best agreement between the two methods. However, both are significantly higher than the results predicted by XBeach-G. Conversely, when comparing EurOtop to the results of XBeach-G test cases, a value of gamma = 0.63 produced the best fit. Finally, comparing EurOtop to the results of flume testing carried out at University of Delaware, reported by de los Santos and Kobayashi (2006), a value of gamma = 0.75 provides a reasonable match. So as not to over-estimate the effects of slope roughness while accounting for the results of the published research, a potentially conservative value of gamma = 0.8 was selected for evaluating overtopping in this design.

Table C.2: Suggested roughness factors (gamma) from the EurOtop manual (2018)

Type of armour layer	γ_f	Figure
Smooth impermeable surface	1.00	Figure 6.8
Rocks (1 layer, impermeable core)	0.60	
Rocks (1 layer, permeable core)	0.45	
Rocks (2 layers, impermeable core)	0.55	
Rocks (2 layers, permeable core)	0.40	Figure 6.8
Cubes (1 layer, flat positioning)	0.49	
Cubes (2 layers, random positioning)	0.47	Figure 6.8
Antifers	0.50	Figure 6.8
HARO's	0.47	Figure 6.9
Tetrapods	0.38	Figure 6.9
Dolosse	*0.43*	
Accropode™ I	0.46	Figure 6.9
Xbloc®; CORE-LOC®; Accropode™ II	0.44	Figure 6.9
Cubipods one layer	*0.49*	
Cubipods two layers	*0.47*	

C.1.6 Runup Reduction Factor

One shortcoming of the EurOtop methodology is that it does not directly account for overtopping reduction across the width of a porous berm crest, as is present in the proposed Living Revetment design. However, a runup reduction factor can be developed through runup and overtopping estimates developed with models such as XBeach-G.

When evaluating overtopping of the proposed design profile with XBeach-G, the calculated runup reduction factor from the top of slope to back of berm (10 m) varied from 0.2 to 0.45. This equates to a 55% to 80% reduction in overtopping volumes across the 10 m width of the porous crest of the Living Revetment. A conservative runup reduction factor of 0.5 was utilized for estimating overtopping values for the preliminary design.

C.1.7 Design Analysis

To capture the full effect of historical site conditions on the proposed design, an analysis of overtopping was performed using the entire available hindcast of combined wave and water level conditions, a 40-year record from 1980 through 2019. This was applied to three cross-sections, A, B, and D (originating at points A2, B2, and D2 shown in Figure 3.3) to capture the full range of conditions at the project site, from most exposed in the south (Transect A) to most sheltered in the north (Transect D). Wave hindcast data came from the USACE WIS study, while measured hourly water levels were taken from NOAA Station 9099018 in Marquette.

Once predicted hourly overtopping rates were calculated for the entire 40-year record, a peak over threshold extreme value analysis was performed to define wave overtopping rates as a function of return period. This process was conducted for a variety of crest elevations for each of the three cross-sections, including existing conditions. The relevant results of this analysis are summarized in Table C.3, which presents a summary of the storm conditions that would result in wave overtopping sufficient to damage well-protected backshore/upland areas under existing and proposed (design) conditions.

Table C.3: Estimated Recurrence Interval of Damaging Overtopping (>50 l/s/m)

	Return Period (yrs)	Crest Elev. (ft IGLD85)	EurOtop Factors		
			Slope	Roughness	Runup Reduction
Existing Conditions					
Transect A	2	608	8:1	1	1
Transect B	<1	606	5:1	0.61	1
Design Conditions					
Transect A	25	610	8:1	1	1
Transect B	>50	609	6:1	0.8	0.5
Transect D	>200	608	6:1	0.8	0.5

In order to facilitate the interpretation of these results, representative wave heights are presented with an approximate combined return period for occurrence simultaneously with a 2-year return period water level (i.e., +1.8’ LWD or +602.9’ IGLD85, see Table 3.2 in the main report). The presented wave heights in Table C.4 are representative for a depth of ~16 feet (5 meters) offshore with the labeled wave transect locations corresponding to those presented in Figure 3.3 in the main report.

For two independent events A and B with occurrence probabilities of X and Y, the probability of A and B occurring simultaneously is equal to X*Y. For example, the combined return period of a 2-year (P=0.5) Water Level and a 5-year (P=0.2) Wave Height is approximately equal to a 10-year event (P = 0.5*0.2 = 0.01). While the occurrence of extreme water levels and wave heights on Lake Superior are not statistically independent events (i.e., higher wave heights tend to be associated with higher water levels), they can be assumed independent for illustrative purposes.

Table C.4: Representative wave heights (in feet) listed by approximate combined return period for occurrence simultaneously with a 2-year water level (+1.8' LWD or +602.9' IGLD85).

	Wave Transect Location				
Combined Return Period (approx. years)	**A3**	**B3**	**C3**	**D3**	**E3**
10	8.1	7.6	5.5	4.1	3.8
20	8.7	8.3	6.1	4.5	4.2
40	9.3	9	6.6	4.9	4.6
100	10	9.7	7.3	5.4	5
200	10.5	10.3	7.7	5.8	5.4

C.1.8 Selected Crest Height

Sta 0+00 to Sta 10+00 (Transect A) - By restoring and extending the foredune in the southernmost reach of the project site (Transect A), the potential of damaging overtopping in this area will be significantly reduced. Currently, low spots and breaks in the dune allow for relatively frequent damage level overtopping (> 50 l/s/m), an approximately 2-year return period event. With a (typical) 2 ft increase in dune crest elevation to 610 ft IGLD 85, this is reduced to a 1 in 25-year return period event.

Sta 10+00 to Sta 21+00 (Transect B) - For the southern 1,100 ft of the Living Revetment (Transect B), a preliminary design crest elevation of 609 ft IGLD 85 was chosen. This is an increase of 3 ft from typical existing revetment crest elevations in the area. This increase is expected to reduce the occurrence of damaging overtopping from an annual or even more frequent event to in excess of a 50-year return period event.

Sta 21+00 to Sta 41+00 - For the northern approximately 1,900 ft of revetment (Transect D), which is sheltered by the Federal breakwater, a slightly lower crest elevation of 608 ft IGLD 85 was chosen. This will reduce the total quantity of material required while still reducing the occurrence of damaging overtopping to a greater than a 200-year return period event.

Appendix D

Restoration Monitoring

Marsh Restoration and/or Living Shorelines					
Metric (include units)	**Difference to Recommended Methods and Protocols (if any)**	**Spatial extent of metric monitoring**	**Baseline yr**	**Frequency/ Timing**	**Data Limitations/ Considerations**
Percent Cover of biomass by species or cover type (% ranging from 0-100)	No differences (Use transects and quadrants method. In each quadrant determine the % of canopy cover (e.g. aerial view looking down) for each plant species).	At each quadrant	2020	Annually around the time of peak marsh biomass (July-August). Pre- and post-construction.	
Elevation (cm)	No differences (Use benchmark method with a laser level, optical level, or an RTK GPS unit).	At each quadrant	2019	Bi-annually in the same seasons every year (spring and fall every year) and after storm events. Pre- and post- construction.	
Shoreline Position	No differences (When establishing your quadrants for the plant community monitoring, include permanent quadrant at the shoreline (e.g. at the edge of vegetation). Mark the edge landward and seaward).	Shoreline quadrant	2019	Annually during the same season every year (July/Aug). Pre- and post-construction.	
Water level	Manually measure water level at each quadrant each year (at the same time as percent cover of biomass monitoring – peak)	At each quadrant	2020	Annually at the same time every year (July/Aug)	Freshwater system, not tidal system. Wetland water levels are anticipated to be more heavily influenced by groundwater as opposed to surface water.
Oyster reef restored (acres)[if applicable]	Not applicable				

National Coastal Resilience Fund Monitoring

Purpose

NFWF seeks to better understand the impact of our National Coastal Resilience Fund (NCRF) grantmaking investments on human community and fish and wildlife resilience. The purpose of this document is to describe the NCRF monitoring approach, provide standard metrics and protocols for common restoration categories, and provide a template for grantees to share information on their metrics data collection.

Approach

Grantees, and potentially a third party, will collect data to answer questions to assess the success of the projects funded by NCRF grants, and provide insight into their impact on human community and fish and wildlife habitat resilience. To measure the success of restoration activities, NFWF is using a limited number of core metrics to ensure greater consistency of measurement across NFWF grants and will allow us to better compare and aggregate across resilience projects.

Standardization across metrics and data collection protocols is crucial to compare and aggregate across NCRF projects and NFWF resilience programs. Therefore, NFWF is requiring that each implementation grantee adopt a minimum set of core metrics according to their project type and provide detailed information on their monitoring plan. To this end, NFWF is providing a list of required metrics and guidance on monitoring protocols that will be suitable for each metric. In addition, NFWF will convene both implementation and design project grantees via a series of webinars targeted to the various activities to discuss monitoring and to foster cross-project learning.

Standardization and suggested metrics for collecting socio-economic data are still under development and will either be incorporated into projects over the life of the grant through a similar process or developed by a third-party through direct coordination with NFWF grantees.

Priority for ecological and socioeconomic monitoring is being placed on the NCRF implementation projects. Although design projects will not be required to provide monitoring data as part of project deliverables, it is NFWF's expectation that design projects requesting funds for implementation grants in the future will be required to provide baseline data on relevant core ecological and socioeconomic metrics (when available).

Core Ecological Metrics for each Priority Resilience Activity

Marsh Restoration (see Appendix A)

- Plant species metrics (e.g. percent cover by plant species)
- Water level (to calculate inundation)
- Elevation
- Shoreline position

Living Shoreline Restoration (see Appendix A)

- Plant species metrics (e.g. percent cover by plant species)
- Water level (to calculate inundation)
- Elevation
- Shoreline position
- Acres of oyster reef restored (if applicable)

Beach and/or Dune Restoration (see Appendix B)

- Shoreline position
- Beach width
- Elevation
- Volume
- Shoreface
- Backshore width
- Dune width
- Dune height
- Dune volume
- Grain size

National Coastal Resilience Fund: Project Monitoring Plan Template

Use the following tables to provide more detailed information on the monitoring requested by NFWF for the type of restoration work for which you have been funded, even if the monitoring will be funded by other sources than your NFWF grant. You MUST use the associated appendix table to help you fill out the tables for your project.

Goal of project: [*In one sentence, please describe the primary goal of the project].*

Monitoring approaches for Marsh Restoration and/or Living Shorelines
[You must use Appendix A to complete this table]

Marsh Restoration and/or Living Shorelines					
Metric (include units)	**Difference to Recommended Methods and Protocols (if any)**	**Spatial extent of metric monitoring**	**Baseline yr**	**Frequency/ Timing**	**Data Limitations/ Considerations**
Percent Cover of biomass by species or cover type (% ranging from 0-100)					
Elevation (cm)					
Shoreline Position					
Water level					
Oyster reef restored (acres)[if applicable]					

Monitoring approaches for Beach/Dune Restoration
[You must use Appendix B to complete this table]

Beach and Dune Restoration					
Metric (include units)	**Difference from Recommended Methods and Protocols (if any)**	**Spatial extent of metric monitoring**	**Baseline yr**	**Frequency/ Timing**	**Data Limitations/ Considerations**
Shoreline position (cm)					

Beach width (cm)					
Elevation (cm)					
Volume (cm^3)					
Shoreface (cm)					
Backshore width (cm)					
Dune width (cm)					
Dune height (cm)					
Dune volume (cm^3)					
Grain size (mm)					

Appendix A: Metrics and Methods for Monitoring Marsh/Living Shoreline Restoration

Monitoring Overview: Use permanent transects perpendicular from the shore line with quadrat plots to sample changes in plant community, water encroachment and changes in elevation over time.

General guidelines for using transects and quadrats method:

- These guidelines are relevant for the following metrics: Percent cover of biomass, Elevation, and Shoreline position.
- Initial placement of transects must be random and stratified, and then quadrats are placed along those transects. Be sure to capture the edge.
- Transects should capture the seaward edge of marsh vegetation, capture transition zones in elevation or vegetation, and continue through the upper marsh or approximate MHHW, different elevations, upper elevation, and different regions within the site.

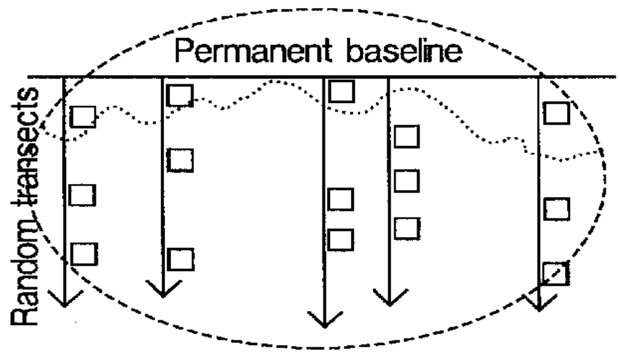


Figure 1: Sketch of random transects and quadrats

- Use 1 m^2 plots.
- Use ~25-50 plots, depending on the size of the project.
- Permanent plots are preferred, as they facilitate capturing change over time, and once established they reduce sampling time. However, but be careful when walking across the same areas over time as this can result in visible damage to the restoration. Be sure to avoid walking within the plot area itself.
- If there are unique vegetation zones (i.e. low marsh, high marsh, etc.) it may be valuable to use a stratified random design (where the strata are the vegetation/elevation zones) with randomization occurring within each strata. For example, if there are two zones of relatively equal size and 6 quadrats total, three would be placed at randomly determined locations (along the transect) within each zone. If zones are substantially different in width, it may be worth distributing the sample plots proportionally.

Guidelines for estimating Percent Cover of Biomass:

- Identify all plant species found in the quadrat. For each species, estimate and record the total percent cover by category (1-9 according to the NCVS vegetation categories outlined below; Peet et al. 1998[1]). Using the same coverage categories, identify and record the cover of live oyster, live mussels, and wrack.

Cover Range	NCVS category
Solitary/Few/Small	1
0.1-1%	2
1-2%	3

[1] See attached

2-5%	4
5-10%	5
10-25%	6
25-50%	7
50-75%	8
75-95%	9

- Materials needed: meter sticks, PVD quadrat, clipboards and datasheets

Figure 2: Estimating percent cover at permanent sampling location along transect. Take care to walk on opposite side of transect tape to avoid inadvertently standing in plot when setting up transect tape.

General guidelines for Benchmarking:

- These guidelines are relevant for the following metrics: Elevation and Water Level
- Establish a benchmark into a fixed location using materials that can withstand the saltwater environment. A steel rod driven >5' into the ground and encased in concrete is acceptable (see TGBM in figure 2 below). Establish ~1 benchmark for every acre of project.
- Follow the protocol laid out in SOP:3 (Lynch, J. C., P. Hensel, and D. R. Cahoon. 2015[2]). The surface elevation table and marker horizon technique: A protocol for monitoring wetland elevation dynamics.

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[2]https://irma.nps.gov/DataStore/Reference/Profile/2225005. This protocol describes the installation of a steel rod with a receiver for attachment of a SET arm. You will not need the receiver - follow the method for installing stainless rod and encasing it with cement – leaving the top of the rod several inches above the ground surface. This rod will provide the stationery reference point (benchmark) from which to reference marsh surface and water level elevations.

Figure 3: Rod installed into ground before installation of cement-filled PVC collar.

Figure 4: Rod with PVC "collar" filled with cement

Guidelines for Elevation monitoring:

- Laser or optical leveling techniques to determine difference in elevation (~cm of change) from a benchmark to each permanent plot.
- These techniques provide consistent results, and the ability to measure change over time, when reliant on a permanent reference benchmark. If none are available, one should be installed.
- Marsh surface elevation can also be obtained with RTK GPS units, which will also provide best results with a permanent benchmark.
- Place the leveling rod/rover pole in the center of the plot. If the ground is very soft, you may need to use a small item placed on the sediment surface to keep the leveling rod from sinking in the mud while you take your reading (the lid of a Tupperware container works well). If you do this, be sure to use it on all plots throughout the site.

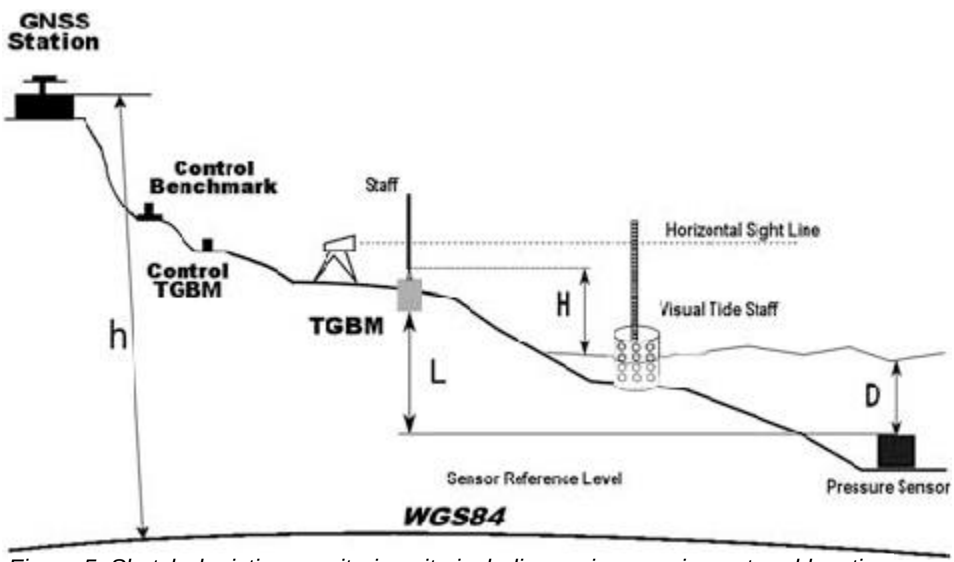


Figure 5: Sketch depicting monitoring site including various equipment and location of measurements within the site.

Guidelines for Water Level monitoring:

- A pressure sensor-style water level logger (Onset or similar, www.onsetcomp.com) should be installed on site. Be sure to select a model that is resistant to saltwater.
- The sensor should be attached to a stable fixed structure (piling or pier) if one is available. If not, attach the sensor to a PVC or rebar pole driven into the substrate far enough to ensure stability (several feet depending on how consolidated the substrate is).
- Sensors can be installed inside of a vented PVC pipe for added protection. The sensor should be attached firmly so that there is no movement in position of the reading lens over time.
- Ideally, to capture the full range of the tide, the sensor should be installed below MLW if at all possible.
- An additional barometric sensor should be installed nearby so that water levels may be corrected for changes in atmospheric pressure (per manufacturer instructions).
- Determine the elevation of the installed sensor relative to the benchmark so that water levels may be interpreted with respect to marsh surface elevation.

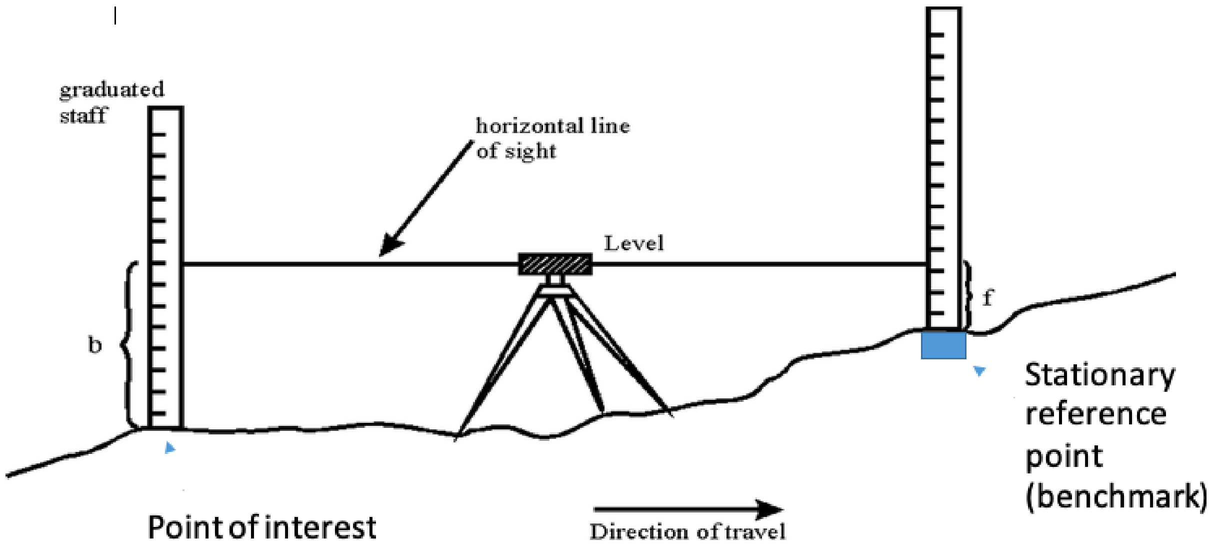


Figure 6: Sketch of leveling technique

Metrics and Protocols:

Metric Name (include units)	Recommended data collection protocols[3]	Spatial extent of metric monitoring	Frequency/ Timing	Use of metric
Percent Cover of biomass by species or cover type (% ranging from 0-100)	Use transects and quadrants method. In each quadrant determine the % of canopy cover (e.g. aerial view looking down) for each plant species.	At each quadrant	Annually around the time of peak marsh biomass (e.g. July-August). Pre- and post- construction.	Increased biomass can result in higher functioning of the marshland for resilience purposes.
Elevation (cm)	Use benchmark method with a laser level, optical level, or an RTK GPS unit.	At each quadrant	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	Provides range of elevation over which marsh species occur (useful for diagnosing plant failure or species shifts). Provides change in elevation (~ 1 cm resolution when tied to a permanent benchmark).
Shoreline position	When establishing your quadrants for the plant community monitoring, include permanent quadrant at the shoreline (e.g. at the edge of vegetation). Mark the edge landward and seaward.	Shoreline quadrant	Bi-annually in the same seasons every year (e.g. spring and fall every year). Pre- and post-construction.	This measurement will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)

[3] Grantees are welcome to use a method of monitoring any metric which exceeds the accuracy of the recommended monitoring method.

Water Level (the measure of time and/or water depths that tidal water is over the marsh surface)	Measure water level and marsh surface elevation to the same established benchmark reference point. Water level can be measured with loggers. Most projects will likely only require 1 logger, though large projects may need more.	Loggers should be installed in adjacent subtidal or low intertidal areas.	Water logger measured ideally at 6-minute or up to 15-minute intervals. At least a month of data is needed, and ideally a year of uninterrupted data.	This measurement is needed to calculate the amount of time that the water level is greater than the marsh surface level, e.g. inundation. The distribution of marsh plant species is determined by inundation and salinity. Although it is not a measure of restoration success, measures of inundation time that marsh is covered by tidal water provides valuable data on where the marsh is in the tidal frame. Ideally, this should be determined BEFORE the restoration.
Oyster reef restored (acres)	Only if applicable. Mark edge of restored oyster bed.	Entire reef	Bi-annually in the same seasons every year (e.g. spring and fall every year). Pre- and post-construction.	Document the change in restored oyster reef over time.

Additional Resources:
For more information on the installation of a steel rod with a receiver for attachment of a SET arm visit: https://irma.nps.gov/DataStore/Reference/Profile/2225005

For more information on installing a SET and standard operating procedures see *"NPS_SET_Protocol_InstallationSOP3.pdf"* (PDF attached)

For more information on the North Carolina Vegetation Survey (NCVS) protocols for recording vegetation percent cover see *"NCVS protocol.pdf"* (PDF attached)

Appendix B: Metrics and Methods for Monitoring Beach and Dune Restoration

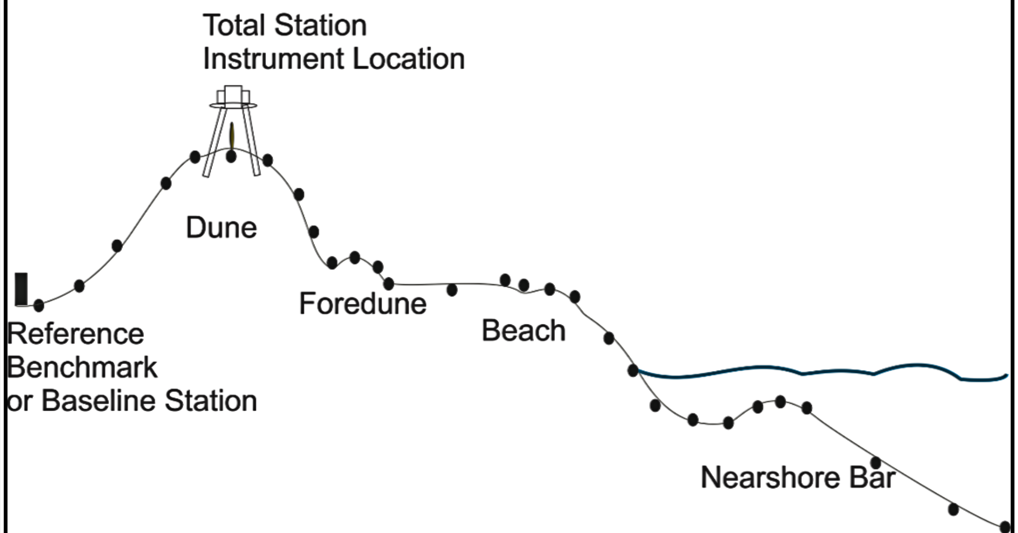
Monitoring Overview: Use permanent transects perpendicular from the shore line with quadrat plots to sample changes in plant community, water encroachment and changes in elevation over time. Use a sand gauge or core samples to monitoring sand grain size.

General guidelines for using cross-shore topographic profile method:

- These guidelines are relevant for the following metrics: Shoreline position, Beach width, Elevation, Volume, Shoreface, Backshore width, Dune width, Dune height, and Dune volume
- Beach profile monitoring uses survey transects running shore normal from the landward dune toe to the low water mark (MLW) or closure depth depending on project goals, beach type and location. The beach profile provides information used to assess whether a shoreline is eroding or accreting, changes to key features, along with elevation and sand volume changes at the selected site.
- Establish transects every 400-800 ft. for long-term monitoring for resilience projects. Shorter transect intervals provide greater data density that may be beneficial for analysis objectives depending on project goals. Establish the baseline relatively parallel to the shoreline and then create individual measuring stations for transects perpendicular to the shoreline. Be sure to establish transects at changes in topography. Survey an initial baseline pre-construction which will indicate where to start monitoring post-construction. Transects should be established in control areas beyond the project site. Control profiles should go beyond the project area, ~1,000 feet beyond any major structures or up to 1/2 mile for fairly long beaches without major features.
- Measure at a minimum to mean-high waterline using an RTK GPS or a total station electronic transit. Start survey on landward side of project, and move seaward taking regular interval data points include at all changes in slope, key features (dune toe, swales, berms, berm ponds, ridges, runnels, wrack and high water lines, etc.) and any significant changes in elevation as you cross over the transect site. The Maximum distance between points on the beach can be 20 ft., to verify no significant change in elevation. Surveys should move into the water's edge at low tide to maximize the extent of coverage area. Take sufficient measurements of elevation and distance along the profile that includes all changes in slope to accurately establish the profile cross section. The spacing between profiles and the frequency of surveying depends amongst other things on the type of beach, the reason for collecting the data and financial constraints.
- When surveying the profile, reference measurements to a survey benchmark with a known survey datum. Modern GPS systems using RTK station networks allow for virtual benchmark establishment.

Typical Beach Profile

The Profile is surveyed starting at the Reference landward of the dune. Survey continues across the dune, beach and into the water. Coordinate position and elevation data points are surveyed at key features along the profile such as changes in slope, dune toe and waterline, etc. or at regular intervals 20-30 feet apart.



Data points may be surveyed using either a total station and prism, shown above or using RTK GPS. Reference all measurements to a survey benchmark with a known survey datum. RTK GPS systems using RTK station networks allow for immediate corrected values.

LiDAR data provides denser data collection, use as needed for project analysis where greater resolution is required and as budgets allow.

Figure 7: Sketch of Beach Profile Method

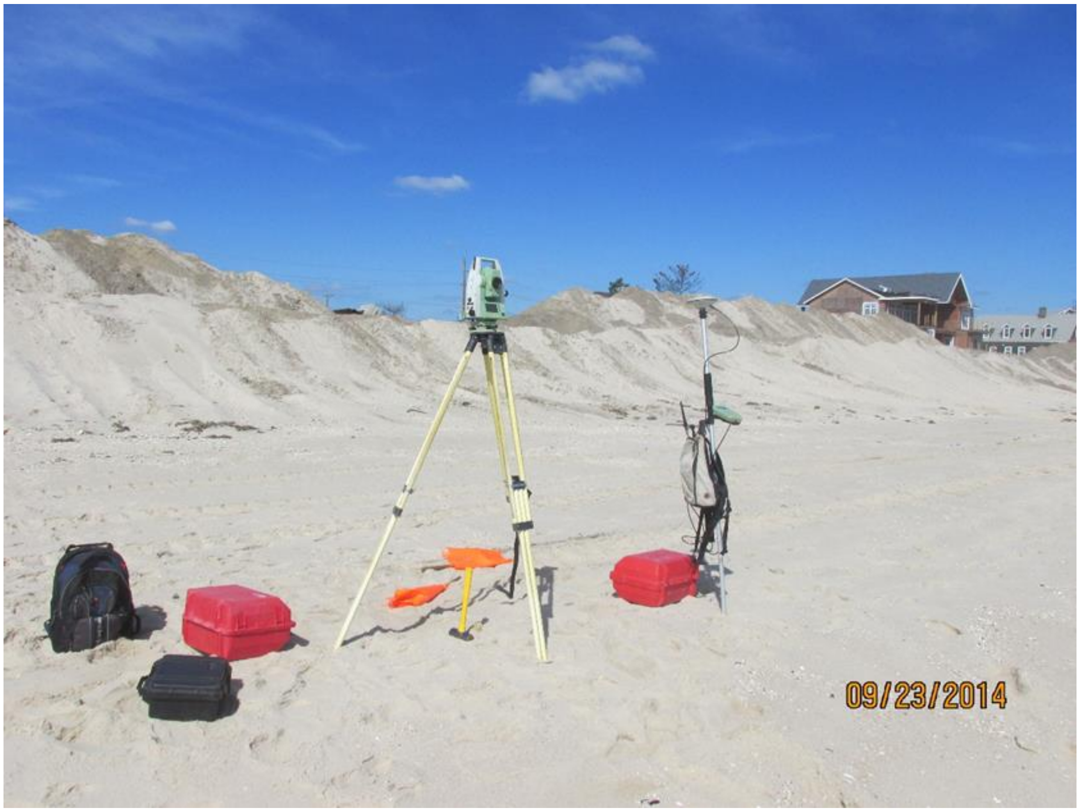


Figure 8: Image of traditional survey equipment used for Beach Profiles (Total Station and RTK GPS Rover)

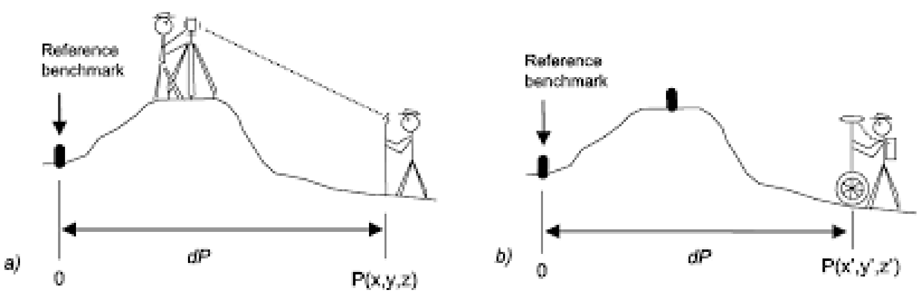


Figure 9: Character sketch of beach profiling using a) Total Station and b) RTK GPS

General guidelines for core samples:

- These guidelines relevant for the following metric: Grain size
- Recommend 20cm thick Core Samples. Taken from dune base to lower beachface slope to determine textural variability across the beach system. Processing method typically used sieving considered adequate, simple method for size determination of sand ranges.

General Guidelines for Sand Gauge:

- These guidelines relevant for the following metric: Grain size
- This is more low-tech than core samples. This method of measuring sand size can be conducted in the field. These are small, credit-card sized, plastic charts with calibrated samples of sieved sand mounted on the face. Allows use of a hand-lens and sand gauge chart, to compare beach samples with calibrated samples for an estimate of the grain size

Metrics and Protocols:

Metric Name (include units)	Recommended data collection protocols[4]	Spatial extent of metric monitoring	Frequency/ Timing	Use of metric
Shoreline position (cm)	Cross-shore topographic profile. RTK GPS following shoreline and beach berm	Statistically significant changes in shoreline position measurements along profile taken no greater than 20 feet onshore 30-40 feet offshore	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	This measurement (in combination with others) will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)
Beach width (cm)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	This measurement (in combination with others) will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)
Elevation (cm)	Cross-shore topographic profile	Statistically significant changes in elevation measurements along profile taken no greater than 20 feet onshore 30-40 feet offshore	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	This measurement (in combination with others) will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)
Volume (cm^3)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	Tells how the beach develops and performs in storms
Shoreface (cm)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	Tells how the beach develops and performs in storms.

[4] Grantees are welcome to use a method of monitoring any metric which exceeds the accuracy of the recommended monitoring method.

Backshore width (cm)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	This measurement (in combination with others) will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)
Dune width (cm)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	This measurement (in combination with others) will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)
Dune height (cm)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	This measurement (in combination with others) will give you an idea about the impacts to the shoreline (i.e. wave energy, erosion, design success, etc.)
Dune volume (cm^3)	Cross-shore topographic profile	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	Tells how the beach develops and performs in storms. Also relevant for FEMA interests.
Grain size (mm)	Core sample or Sand gauge chat	See general guidelines above	Bi-annually in the same seasons every year (e.g. spring and fall every year) and after storm events. Pre- and post-construction.	Can be an indication of change in slope and accretion. Helps to determine what kind of wave energy is needed to move sand around.

Additional resources:
For more information on conducting a Cross-Profile Topographic Profile visit:

- https://www.escp.org.uk/topographic-beach-survey
- https://www.niwa.co.nz/coasts-and-oceans/nz-coast/learn-about-coastal-environments/beach-types/beach-profile-monitoring-sites
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A Flexible, Multipurpose Method for Recording Vegetation Composition and Structure

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ABSTRACT

We present a flexible protocol for recording vegetation composition and structure that is appropriate for diverse applications, is scale transgressive, yields data compatible with those from commonly used methods, and is applicable across a broad range of terrestrial vegetation. The protocol is intended to be flexible in the intensity of use and commitment of time, and sufficiently open in architecture as to be adaptable to unanticipated applications.

The standard observation unit is a 10 × 10 m (0.01 ha) quadrat or "module." Where the extent of homogeneous vegetation is sufficient, multiple modules are combined to form a larger, more representative sample-unit. All vascular species are recorded by cover class and in intensively sampled modules as present or absent in sets of nested quadrats. For each module, tree stems are tallied by diameter class; species with exceptionally high or low stem density can be sub- or supersampled to allow efficient collection of data and assessment of population structure. The most common plot configuration consists of 10 modules arranged in a 2 × 5 array with four modules sampled intensively; this size is often necessary to capture the complexity of a forest community. For rapid reconnaissance or inventory purposes, fewer modules are typically employed, and less information is collected.

INTRODUCTION

The North Carolina Vegetation Survey (NCVS) is a collaborative research program with the general goal of characterizing the natural vegetation of North Carolina and adjacent states. Specific objectives include description, classification and inventory of vegetation, interpretation of vegetation-environment relationships, and long-term monitoring of ecosystem conditions. These objectives reflect the information needs of two important constituencies, the scientific community, which aspires to a better understanding of how vegetation varies through time and with respect to local conditions, and the conservation and natural resource management community, which requires information on the abundance, condition, and threats to conservation of natural ecosystems.

Vegetation type, the purpose and scale of a study, and financial resources all influence decisions on how to record vegetation (Kent and Coker 1992). We sought a core methodology sufficiently flexible as to be applicable in most circumstances and for most purposes. A review of existing methods for recording vegetation revealed none sufficiently flexible to provide consistent, useful information on vegetation composition and structure over the range of natural vegetation in southeastern North America. Moreover, existing methodologies are sufficiently divergent that data collection using one method often precluded inclusion of valuable datasets collected by workers who used other methods. To resolve these difficulties we have developed a methodology for recording vegetation that is sufficiently flexible to cover a broad range of applications and vegetation types, while retaining maximal compatibility with other existing methods. Application at nearly 3,000 sites over a ten-year period have verified the flexibility and efficiency of the resultant protocol. Here, we present an overview of the NCVS protocol for recording vegetation composition and structure. This overview is intended to serve as an expanded explanation of methods for readers of publications that use data collected following this protocol (e.g., Newell and Peet 1998). In addition, we hope our efforts will lead to greater standardization of field methods and thereby facilitate further collaborative research and more effective inventory and conservation of natural vegetation.

OBJECTIVES

The following design objectives guided development of the NCVS protocol.

1. *Appropriate for most types of vegetation.* Textbook recommendations for recording vegetation often include a decision tree based on physiognomy of the vegetation to be studied, with the result that data collected from divergent types such as forests and grasslands are not always directly comparable. We desired a method sufficiently general to provide comparable data from the full array of terrestrial vegetation types in the Southeast, including such divergent communities as grass- and forb-dominated savannas, dense shrub thickets, mesic cove forests, and sparsely vegetated rock outcrops.

2. *Appropriate for diverse applications.* Vegetation plot data provide a record of sampled sites long after the sites have disappeared. Consequently, there are many possible users of and uses for vegetation data beyond the initial study; old data often find uses entirely different from those the original field workers anticipated. Moreover, objectives can evolve during a study, and field data can lead to new insights and new objectives. Accordingly, we sought a set of methods that would accommodate as many of the diverse needs of data collectors and data users as possible.

3. *Flexible in intensity and time commitment.* Some applications require detailed data that are time-intensive to collect, whereas other applications call for extensive data to be collected with limited time and personnel. We required that the NCVS protocol incorporate considerable flexibility in the detail to be obtained at any one location, without sacrificing compatibility at certain fundamental levels.

4. *Scale transgressive.* Vegetation structure and composition can be viewed at many spatial scales, each providing a somewhat different perspective. Choice of scale in vegetation measurement is often based on observations of species-area relationships, which results in sample size variation between studies. Moreover, vegetation measurement is typically directed at "homogeneous" vegetation, but environment and disturbance generate different patterns in vegetation at different scales such that no one scale is ever fully satisfactory for observations. The dependence of species richness observations on scale of observation led Whittaker (1977, Whittaker et al. 1979, Shmida and Whittaker 1981, see Shmida 1984) to develop a recording method that includes several scales of observation. These same considerations led us to seek methods that provide information about species composition across a wide range of spatial scales.

5. *Appropriate for long-term studies.* Many of the data applications we envision require plots that can be resampled (permanent sample plots). Accordingly, vegetation plots should be configured in a manner that facilitates accurate relocation and remeasurement.

6. *Compatible with other methodologies.* Our scientific interests require collection of compositional data suitable for standard analytical procedures and that can be merged with datasets collected using other methods. Similarly, our conservation interests require data suitable for use by collaborating agencies and organizations interested in inventory and classification of natural communities at both the state and national level. For these reasons we required that standard measures such as basal area, tree density, cover, and species richness be obtained. We have also sought to maintain maximal compatibility with widely used methods, such as those of Braun-Blanquet (1964), Whittaker (1960; also Shmida 1984), Daubenmire (1968), and various agencies and organizations, such as the U.S.D.A. Forest Service and The Nature Conservancy.

7. *Easy to learn and use.* Flexibility is bought at the price of greater complexity of methodology and more subjective choices to be made by the practitioner. However, we recognize the need for methods to be moderately easy to use in the field so that only minimal training is

needed for field personnel. Cumbersome protocols are soon discarded as impractical, regardless of their specific merits.

8. Open architecture. To accommodate the many potential users who have their own particular needs, the protocol needs to be based on a fundamentally open architecture; the methods need to be open to adjustment and supplementation as needed for different, specialized applications, provided only that the core architecture that ensures compatibility with other forms of data is retained.

THE MODULE CONCEPT

Two fundamental problems that confront scientists wishing to characterize vegetation are that different vegetation processes are apparent at different spatial scales, and that vegetation typically exhibits strong spatial autocorrelation. Reed et al. (1993) have shown that correlations between vegetation and environment change dramatically with scale of observation. The spatial scale problem also can be seen in the fact that disturbance-caused vegetation patches range from the size of a small anthill to a landscape altered by a vast forest fire. Consequently, no one size (area) of observation will be optimal for all purposes, yet consistency in size is needed to ensure comparability between observations. The spatial autocorrelation problem is apparent in the common observation that plots with high perimeter to area ratios have higher species counts per unit area than circular or square plots (Bormann 1953, cf., Stohlgren et al. 1995), in part because they encompass more microvariation in habitat, and because more combinations of interacting plant species are encountered. Spatially distributed subplots will generally include more species and provide a more representative estimate of composition, but when summed they provide a biased estimate of species co-occurrence.

Our solution to the problems of scale and spatial autocorrelation is to adopt a modular approach to plot layout, wherein all measurements are made in plots comprised of one or more 10 × 10 m quadrats or "modules" (100 m^2 = 1 are = 0.01 hectare). The module size and shape were chosen to provide a convenient building block for larger plots, and because a body of data already exists for plots of some multiple of this size. The square shape is efficient to lay out, ensures the observation is typical for species interactions at that scale of observation, and avoids the biases built into methods with distributed quadrats or high perimeter-to-area ratios.

In effect, our methodology defines most spatial heterogeneity in vegetation at scales below 10 × 10 m as within-community pattern. Smaller-scale processes can be captured to some extent by nested subquadrats as described below, but are generally not well described with our methods. Vegetation that is patchy at a very small scale, such as certain glade and outcrop communities, or which is strongly zoned at the scale of one to a few meters, such as the narrow bands surrounding a depression wetland, will generally be homogenized by plot-based sampling methods.

The flexibility of the NCVS protocol stems primarily from flexibility as to the number of modules included in a plot and the information recorded for each. Numerous configurations are possible. A 2 × 5 module array (0.1 ha) is commonly used and often needed to capture for purposes of classification and description the complexity of a forest community. In contrast, in structurally simpler communities and for reconnaissance or inventory purposes, a small number of modules will often suffice. In situations where a standard plot configuration would not fit or would be inadequate or heterogeneous, investigators are encouraged to modify plot layout to obtain a representative portrayal of homogeneous vegetation. For example, a ridgeline might best be captured with a 1 × 5 array, and a rock outcrop might contain space for only 1 or 2 modules. Where site conditions dictate, it is even possible to change the shape of the module to ensure homogeneity, though this should normally be avoided for reasons related to the spatial autocorrelation of vegetation as stated above. In one particularly extreme case, we "stretched" a module to a 2 × 50 m shape to accommodate a narrow rockface along a steep riverbank.

SPECIES IMPORTANCE

Many attributes of vegetation have been proposed for use in the description of vegetation. We have chosen to include three of the simplest and most widely used forms of data: presence, cover, and woody stem sizes.

Presence

We define "presence" as the occurrence of a species (based on emergence of a stem or stems) within a quadrat, where the species must be "rooted" in the quadrat. Determination of the presence or absence of a species has the advantage that it is entirely objective, assuming careful searching techniques; a clean decision can be made as to whether aboveground parts of a plant are or are not present in a quadrat. It is also a parameter compatible across all growth forms. Many analytical procedures (e.g., ordination, classification) can accept presence/absence data, and presence is used in determination of the most fundamental diversity parameter, species richness.

Nested subquadrats are employed to obtain estimates of species number and co-occurrence at spatial scales less than that of the 100 m^2 module. Species presence is determined for a $\log_{10}$ series of nested subquadrats (e.g., 0.01, 0.1, 1.0, and 10 m^2) established in one or more corners of the module(s) (or in the center, allowing for as many as 5 sets of nested subquadrats that overlap only at the 100 m^2 scale; see Figure 1). The nested subquadrats in a single nest are square and share an outside corner to facilitate establishment and accurate relocation. The number of subquadrats in a nest is referred to as depth, where a depth of 1 indicates presence recorded only at the 100 m^2 or full-module scale, and a depth of 5 indicates presence recorded in a subquadrat of 0.01 m^2. For each nest, the smallest subquadrat is searched first and each species receives a number corresponding to the depth at which it is first encountered. Presence recorded for a particular depth implies presence at all lower-numbered depths as well, which allows the full nest of subquadrats to be recorded as a single column of single digits. A depth of 0 is used to indicate cover in the module contributed by a species that is not rooted in that module.

Depth of sampling and number of nests per module are generally determined by the individual researcher based on the objectives of the project and the time available. Use of nested subquadrats can add substantially to the time and effort required, but this is dependent on the number of nests per module, the depth to which they are recorded, and the attributes of the vegetation. Inclusion of nested quadrats has the advantage that it forces a particularly careful examination of the plants in a module. In practice, depth is almost always set either at 5 (when intensive data are desired) or 1 (when time is limited and a rapid, relevé-style observation is desired). We state that a recorded module is an "intensive" module when all vascular species are recorded by cover class and as present or absent in one or more sets of nested quadrats. In contrast, if species are recorded only at level 1, we refer to a "relevé" module. Although plots within a particular study can vary in sampling depth, it is helpful to be consistent in sampling depth to allow efficient use of the data collected.

Generally, between subquadrat variance increases as subquadrat size decreases, with the result that observation of only one or two nests is often viewed as inadequate for small subquadrats. When we choose to record only a single module at a site, we often include 4–5 nests. More commonly, we observe a set of (usually 10) contiguous modules, in which case two nests are observed for each of four modules that make up a central block of four (400 m^2; see Figure 1).

Cover

In the NCVS protocol, cover is the only quantitative vegetation parameter recorded across all plant growth forms. "Cover" is here defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface. No species may exceed 100% cover, though the sum of cover estimates across all species often exceeds 100%. In this case, the plant need not be rooted in the area under consideration.

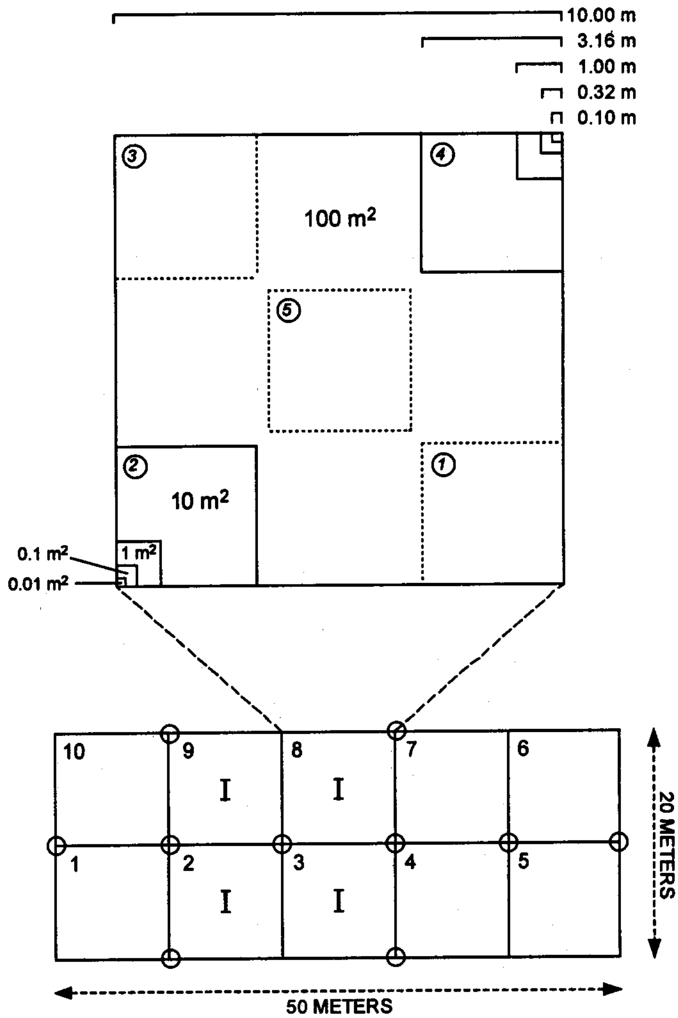

Figure 1. Typical layout of an intensive module, and a set of 10 modules as a 0.1 ha plot. Modules are numbered counter-clockwise. The five standard locations in a module for nested quadrats are indicated, although in the standard 0.1 ha configuration only two nests are recorded (solid lines rather than dashed) in each of the four intensive modules. Typically, these intensive modules are 2, 3, 8 and 9 as intensive modules (marked I), with nested quadrats in the eight corners indicated. The remaining six modules are recorded as an aggregate. Corners within a module are numbered clockwise, starting along the centerline and moving initially along the centerline in the direction that the modules are numbered, as indicated for module eight. Typically a 50 m tape is placed along the centerline and two 20 m tapes cross the main tape along the outside edges of the four focal modules. Permanent metal stakes (circles in the 0.1 ha configuration) are located at the 10 locations where a tape touches the corner of a module.

Percentage cover estimates provide data suitable for quantitative analyses and include all species encountered.

Cover is estimated visually by the researcher, usually at the level of the module (depth 1). Much has been written about the relative merits of cover-class scales versus direct estimation of cover (e.g., Schultz et al. 1961, Mueller-Dombois and Ellenberg 1974, Oksanen 1976, Sykes et al. 1983). We have found that use of cover classes results in more rapid data collection, greater ease of training, and greater agreement and satisfaction among observers as compared to direct estimation of percentage cover. Generally, the human mind perceives cover on a

Table 1. Comparison of Cover-Abundance scales used in different sampling methods

Cover Range	NC	BB	D	K	FS	H-S	NZ
Missing but nearby	.	()					
Solitary	1	r	1	+	T	+	1
Few	1	+	2	1	T	1	1
0–1%	2	1	2	2	T	1	1
1–2%	3	1	3	3	1	1	2
2–3%	4	1	3	3	1	1	2
3–5%	4	1	4	3	1	1	2
5–6.25%	5	2	4	4	2	1	3
6.25–10%	5	2	4	4	2	2	3
19–12.5%	6	2	5	5	2	2	3
12.5–25%	6	2	5	5	2	3	3
25–33%	7	3	6	6	3	4	4
33–50%	7	3	7	7	3	4	4
50–75%	8	4	8	8	4	5	5
75–90%	9	5	9	9	5	5	6
90–95%	9	5	10	9	5	5	6
95–99%	10	5	10	9	6	5	6
100%	10	5	10	10	6	5	6

NC = North Carolina Vegetation Survey; BB = Braun-Blanquet; D = Domin (1928); K = Domin *sensu* Krajina 1933; FS = US Forest Service–Western US (modified from Daubenmire 1968); H-S = Hult-Sernander (Hult 1881); NZ = New Zealand Reconnaissance Plot Sampling (Allen 1992, Hall 1992).r, +, and T = very uncommon with much less than 1% cover.

geometric scale rather than a linear one; our visual abilities are well attuned to doublings and we can much more easily see the difference between 1 and 2 % cover than that between 31 and 32%.

Numerous cover class schemes have been proposed and several of the more popular variants are presented in Table 1. For the NCVS protocol, we devised a ten-point scale consistent with rough doublings of cover (or lack of cover), with breaks placed to assure maximal ease of interconversion with other cover-class scales. Specifically, we use the following scale: 1 = trace, 2 = 0–1%, 3 = 1–2%, 4 = 2–5%, 5 = 5–10%, 6 = 10–25%, 7 = 25–50%, 8 = 50–75%, 9 = 75–95%, 10 = >95%. These cover classes represent classes that we have found to be generally repeatable to within one class when replicate plots recorded by the same or different investigators are compared. A convenient guide for estimating cover classes at the module scale is to recall that a 1 × 1 m block of leaf area corresponds to 1% cover.

One difficulty with use of cover classes has involved determination of means. To accomplish this, we average the percentages corresponding to cover-class mid-points (e.g., for class 5 = 5–10% we use 7.5%) followed by assignment of the average to the appropriate cover class. As noted by Bonham (1989), use of class midpoints presupposes a symmetrical dispersion of actual cover values within the class, an assumption that is probably incorrect but which introduces only a modest bias toward larger values for species. In contrast, Oksanen (1976) suggested that if cover classes make up a geometric series, the geometric mean of the class limits might be more appropriate for calculating mean cover, but we suspect that this procedure over corrects.

Woody Plant Diameters

Tree stem data are needed for computation of basal area and density, the two most commonly used importance measures for woody species (here including all trees, shrubs, and woody lianas that reach breast height). These measures may be used in various quantitative analyses and permit comparisons with a large body of data from forestry and vegetation science. In addition, tallies by size class allow inferences about population stability.

Woody stem data are collected as tallies of stems in diameter classes established for efficiency of data collection and for maximal compatibility with existing data (including those collected using English units). NCVS diameter classes are 0–1, 1–2.5, 2.5–5, 5–10, 10–15, 15–20, 20–25, 25–30, 30–35, and 35–40 cm. Stems with diameters greater than 40 cm are tallied individually to the nearest cm for efficiency of recording and because small differences in diameter at large sizes produce large differences in basal area. All diameters are measured at breast height (1.4 m). Multiple stems arising from a common root system are recorded separately if they branch below 0.5 m above ground level (stems branching above 0.5 m and below 1.4 m are measured at the narrowest point below the branch). Tallies are maintained by species and are recorded separately for each module (or sometimes as an aggregate for modules recorded after the first four intensive modules).

To increase flexibility and applicability to unusual vegetation, the area surveyed by stem count may be a specified percentage (subsample or supersample) of the module, such as 20% for dense shrublands or 200% for savannas. This is easily implemented in the field by adjusting the width of the module (for purposes of woody plant tallies only).

PLOT AND SITE CHARACTERISTICS

Site and plot characteristics are collected for all plots and include basic information necessary for interpretation of the plot data, documentation of plot location, and placement of the plot within the FGDC/TNC National Vegetation Classification (NVC; Federal Geographic Data Committee 1997). Additional site data for interpretation of the environmental context of a plot can be extremely valuable, but the details of variables needed and how they should be measured vary substantially between studies and regions. Consequently, standards for site characterization are not part of the NCVS protocol.

The following list includes the most basic information collected for all plots. General information must include plot identifier (usually plot number), date sampled, names of researchers, plot size in ares (0.01 hectare modules), identification numbers of intensive modules, depth of nesting for intensive modules and authority for botanical nomenclature. Plot description starts with physiognomic class of the NVC, physiognomic subclass of the NVC, hydrologic class of the NVC if applicable, and height in m and total cover in percent of the dominant (canopy) woody vegetation layer, the herbaceous layer (herbaceous species only) and the bryophyte layer (nonvascular species only). Location is required in the form of geocoordinates (UTM, or latitude and longitude) with a notation as to the method used to obtain the coordinates (e.g., GPS, map and compass, aerial photo). Site physical characteristics nearly always of value include elevation, slope, aspect, and topographic position. In addition, soils data should always be collected. Ideally, a complete profile should be described. In addition to examining the soil profile, we routinely collect soil samples consisting of the top 10 cm of mineral soil for nutrient and texture analysis. Samples are collected from each of the intensive modules, or a single sample is collected when no modules are intensive. B horizon samples are collected in studies where deemed potentially important.

PLOT CONFIGURATION OPTIONS

A NCVS plot may consist of any number of modules. A single module is possible and often appropriate for rapid assessment purposes, but is usually insufficient for obtaining an adequate representation of most woody vegetation. Mueller-Dombois and Ellenberg (1974) recommended an area of 200–500 m^2 for forest vegetation, and we have found that even this area is often too small for an adequate representation of composition in large-stature or species-rich forests. Numerous North American vegetation studies have employed 20×50 m plots (1,000 m^2 or 0.1 ha) similar in design to those first employed by Whittaker (1960). The widespread use of 20×50 m plots in a variety of forested vegetation types, and the consequent availability of substantial comparative vegetation data at this scale, led to the adoption of this plot size and shape as a standard NCVS configuration.

Within the 0.1 ha plot (2×5 array of modules), a prescribed 2×2 block of four intensive modules is selected for standard intensive measurement wherein species cover class values and woody stem tallies are recorded separately for each module. An aggregate count of woody stems is made in the remaining six modules, and this area (600 m^2) is searched for species not encountered in the four intensive modules measured previously. Percentage cover estimates are made for these additional species at the 0.1 ha level.

There will be situations where constraints posed by heterogeneity of vegetation and/or environment, researcher time available, or significance of the site makes the standard 0.1 ha configuration inappropriate or impractical. Numerous other configurations of modules are possible. Often, a single module is suitable for obtaining cover and presence determinations in a small patch of vegetation, especially when herbaceous and shrubby strata are of primary concern. However, stem counts for woody species within a single module may be inadequate for characterizing the woody vegetation, and cover estimations may be strongly influenced by the presence of one or more large canopy trees within the module.

Numerous other combinations of modules can be used for special circumstances. Where a full 0.1 ha plot will not fit, a block of four intensive modules (2 × 2 configuration) can be a good substitute. The resulting plot is 400 m^2 in area, within the size range recommended by Mueller-Dombois and Ellenberg (1974) for forest vegetation. Strips of two, three, four, or five modules can be used where homogeneity considerations limit the number of modules. However, it is desirable to increase the number of corners with nested subquadrats in each module when fewer than four intensive modules are measured.

SUPPLEMENTAL DATA COLLECTION

The NCVS protocol is intended to be sufficiently simple that supplemental measurements can be added to accommodate requirements for specific projects. A typical example might consist of mapping exact locations of woody stems to study spatial processes. Another might be incorporation of additional small quadrats of a size particularly appropriate for monitoring abundance of a specific rare species. For some applications, it is valuable to know the vertical distribution of cover by species. A common supplement to the regular 0.1 ha implementation of the NCVS protocol is to record additional cover values for specific vertical strata. A typical implementation of this addition is to record for each woody plant species in each of several vertical strata (e.g., 0–0.5 m, 0.5–2 m, 2–5 m, 5–15 m, 15–35 m, >35 m) the cover value of the species in that stratum averaged over the intensive modules. Details of several such supplements are described in an expanded manual available from the authors upon request.

IMPLEMENTATION

The effectiveness and efficiency of a vegetation measurement protocol such as presented here depends in large part on details of implementation. To facilitate efficient use of the protocol, we summarize procedures developed during 10 years of application, with emphasis on a typical 0.1 ha or 20 × 50 m configuration, but with guidelines for generalization to other configurations. This represents one of the more intensive and complex implementations of the protocol; reconnaissance or inventory plots are simpler as they generally include only a subset of the procedures described here.

Plots should be placed to minimize within-plot environmental heterogeneity, which implies that the long axis of the plot should encounter the least possible variation in these characteristics. A 50 m measuring tape is used to establish the plot midline, and permanent stakes are placed at 10 m intervals along the tape. Plot establishment is completed by centering two 20 m tapes on and perpendicular to the midline tape (Figure 1), typically one 10 m from the start of the 50 m tape and one at 30 m. Stakes are placed at the ends of the two 20 m tapes, thereby defining the outside corners of four intensive modules (2, 3, 8, and 9 when numbered in the standard counter-clockwise fashion). Intensive modules are centrally located to assure the contents are as representative as possible, and to reduce subjective bias associated with starting the tape in close proximity to these modules.

In the typical 0.1 ha configuration, two series of nested subquadrats are recorded for each of the four intensive modules, each series being located in a standard fashion that associates its common corner with a fixed stake (Figure 1). Use of the recommended corners distributes the nests and prevents nests from being adjacent. If disturbance or other unusual conditions suggest that a specific corner would be inappropriate, it is possible to switch corners. With other configurations, the number of nests of subquadrats per module can range from zero to five (Figure 1).

Plant taxa are recorded to as fine a level as possible in as much as subsequent lumping of taxa is always possible, but splitting would usually be impossible. Field names are later transcribed to standard codes, in our case 8-character acronyms consisting typically of the first four letters of the genus, the first three of the specific epithet and a single character for subspecies or variety; special rules apply for potential duplicates and synonymy. If no local list of codes is available, the U.S.D.A. PLANTS Database provides a helpful but less intuitive U.S. national list of species codes.

Data are collected and recorded in a standard fashion designed for efficiency of field recording and subsequent data transcription. Presence data are always recorded in the form of a couplet with the first column used for the depth at which a species is first recorded as present and the second for cover. Couplet headings (header line in example below) are module and corner numbers (e.g., 2–2, 2–3, etc.), except for (where applicable) an aggregate pair headed R-R (for "residual") that contains species first encountered in an aggregate of modules that supplement those sampled intensively.

Within a typical intensive module, presence data are recorded for two corners. The normal 8 corners for nests are 2–2, 2–4, 3–2, 3–3, 8–2, 8–4, 9–2 and 9–3 (Figure 1). Starting in the first corner (corner 2) of module 2 (2–2 in the 0.1 ha configuration), all species rooted in (having a stem or stems emerging in) a 0.1 × 0.1 m (0.01 m^2) subquadrat are listed and assigned a value of 5 in the left column of the pair of data columns for corner 2. A 0.32 × 0.32 m (0.1 m^2) subquadrat nested in the same corner is then surveyed for species not encountered in the previous subquadrat; these are listed and assigned a value of 4. A 1.0 × 1.0 m (1.0 m^2) subquadrat is then surveyed and new species encountered are assigned values of 3, followed by a 3.16 × 3.16 m (10 m^2) subquadrat with new species assigned values of 2 in the left column. As an illustration, consider the example in Figure 2. There the species DICHOVAA (*Dichanthelium ovale* var. *ovale*) occurred first in the 0.32 × 0.32 m subquadrat of corner 2–2, whereas LIQUSTY (*Liquidambar styraciflua*) occurred first in the 1 × 1 m subquadrat, and SMILGLA (*Smilax glauca*) occurred first in the 3.16 × 3.16 m subquadrat.

The presence survey is repeated in the second corner of the module (typically corner 4 in module 2). Presence values are again recorded in the left column of the pair for this corner at levels 5, 4, 3, and 2, with new species names added as needed. In our example, DICHOVAA first occurs at the 2 (3.1 × 3.1 m) level for this corner, whereas PANIVIR first occurs at the 3 level, and so on. The presence survey is completed by listing all species within the module that were not encountered in a set of nested subquadrats and assigning each of them a value of 1, which is recorded in the left column of the first corner surveyed (i.e., they occurred at level 1, which is the full 100 m^2, an area shared by all nests within the module). Species not present in the first (or "master") nest of subquadrats surveyed, but present in subsequent nests (XYRICAR in this example), are also assigned a value of 1 in the left data column for the first nest surveyed. In summary, all species with stems emerging anywhere within the focal module should be listed and each of these species should have a value ranging from 1–5 in the left column of the column pair for the first corner surveyed.

Cover data for the module are recorded next. When more than one column is available for recording cover in a module (which will be the case whenever more than one nest is recorded), only the first available column is used and the others are left blank. Cover is recorded after all nests in a module have been completed, thereby assuring a complete species list and maximizing time for familiarization with vegetation in the module.

As a final illustration, consider the species SMILGLA in the example above (Figure 2). For module 2, this species occurs first in corner 2 at depth 2, first at depth 4 in corner 4, and has a cover of 2 in the module. In module 9 this species occurs first at depth 3 in corner 2 and at depth 2 in corner 3 and again has a cover value of 2. By comparison, NYSSBIF is not found in any of the intensively sampled modules and is found only in the residual area where it has an overall cover of 2 (species in the residual can only have a depth of occurrence of 1).

Plot ______ Date ______ Total ares ______

Species Code	2	2	2	4	3	2	3	3	8	2	8	4	9	2	9	3	R	R
DICHOVAA	4	2	2	.	2	2	.	.	3	2	.	.	4	1	5	.	.	.
PANIVIR	3	5	3	.	3	5	.	.	4	6	3	.	1	6	2	.	.	.
LIQUSTY	3	5	3	.	2	5	3	.	2	4	3	.	1	6	2	.	.	.
SMILGLA	2	2	4	.	2	2	2	.	2	2	.	.	3	2	2	.	.	.
XYRICAR	1	2	2	.	.	.	.	.	1	2	.	.	2	2	.	.	.	.
XYRIAMB	1	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NYSSBIF	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2

Figure 2. Example of a portion of a datasheet for recording presence and cover in nested plots. Note that the header line contains couplets with the first number referring to the module and the second to the specific corner (see Figure 1). In the datalines, the first column of a couplet refers to the level in nested quadrats at which the species was first encountered as present, and the second refers to cover in the module. When more than one nested set of quadrats is recorded for a module, cover is recorded in association with presence for the first corner. Species codes are standard acronyms used for data coding (see text), though on real datasheets a field identification would be recorded in a separate column, and the official code would be added later.

Woody stem data are recorded on a separate data form. The basic line of data consists of module number, species code, and columns for tally counts of stem occurrences by set dbh classes, as described earlier. Columns are also provided for listing individually to the nearest centimeter stems larger than 40 cm. Stems are tallied separately for the intensive modules, but can be aggregated for residual modules (6 residual modules in the standard 0.1 ha configuration). Percentage sub- or supersamples used are recorded as needed. Total number of modules must also be recorded to allow interpretation of the area of the residual category.

Adaptability to unusual stem densities is achieved by allowing for designation of a percentage subsample for saplings and a percentage subsample for trees. These refer to the percentage of the module area sampled (or the sampled area of the aggregate of residual modules) surveyed for 0–2.5 cm dbh stems and >2.5 cm stems, respectively. Subsampling and supersampling are generally accomplished by adjusting the distance from the edge of the module adjacent to the midline of the plot by an appropriate percentage (for woody stems only). In a vine thicket a 20% (2 m wide) subsample might be appropriate, whereas in a savanna a 200% (20 m wide) supersample might be selected.

Some species have unusual densities and require, for efficiency of fieldwork, a sample size different from that used for the remainder of the species. For shrubs in a pocosin shrubland or bamboo in a canebreak, a subsample is often appropriate, but the scattered pines in these communities might well require supersample to adequately capture population structure. For this purpose columns are provided on dataforms for percentage subsamples for sapling and for trees on an individual species basis, which overrides the universal subsample designations described in the previous paragraph.

The time and personnel required for plot establishment varies considerably with the complexity of the vegetation and the experience and personalities of the field workers. In general, we have found that an experienced team of two, one of whom is intimately familiar with the flora, can finish from one to three 0.1 ha plots per field day. The floristically experienced team member records the presence and cover data while the assistant completes the tree tally. The first one to finish initiates collection of site information.

DATA TRANSCRIPTION, REDUCTION AND SUMMARIZATION

The flexibility of the NCVS protocol is attained at the price of greater complexity of data reduction. Although data reduction is conceptually simple, there are sufficient options and complications that some researchers will require special software tools for data entry, quality control and extraction of critical summary information. To assist with these tasks we have collaborated with Dr. Richard Duncan of Lincoln University, New Zealand, to construct a series of SAS programs for use in data preparation and summarization. These are available from the authors upon request.

DISCUSSION

Comparison with Other Methods

Many design elements of the NCVS protocol derive from methods proposed and employed by R.H. Whittaker. The 0.1 ha measurement unit was originally proposed by Whittaker (1960), whose example was followed by many others (e.g., Glenn-Lewin 1977, Peet 1981, Wentworth 1981, Rice and Westoby 1983) with the result that a large number of such plots are now available for comparative studies. In the last years of his career, Whittaker became progressively more interested in patterns of species richness and the importance of scale for understanding vegetation, two interests we share with him and which have strongly influenced design of the NCVS sampling protocol. To investigate these issues, he devised a new plot design that he applied widely during his research excursions. This Whittaker diversity sample was an outgrowth of his original 1,000 m^2 plots, but with nested subplots over a range of scales so as to facilitate comparison with other studies and calculation of the slope of the species-area curve (10 1 × 1m plots, 2 1 × 5 plots, 1 10 × 10, and 1 20 × 50; see Naveh and Whittaker 1979, Whittaker et al. 1979, Shmida and Whittaker 1981, Shmida 1984).

The NCVS plot design retains the geometric sequence of subquadrats proposed by Whittaker, but includes a broader range of sizes and more subquadrats of most sizes to compensate for between subquadrat variation. As subquadrat size increases, there is less variance between subquadrats due to averaging out of within subquadrat variance, and a smaller element of chance in whether any one species will be present in a subquadrat (see Reed et al. 1993). A consequence is that the larger subquadrat sizes are well represented by our proposed methodology, but the smaller subquadrats (especially 1 m^2 and less) can be highly variable. This problem has been further articulated by Stohlgren et al. (1995) and Yorks and Dabydeen (1998) whose papers each present a modification of Whittaker's diversity plot, but with a broader spatial dispersion of the smaller subquadrats to more effectively represent variation present in the plot. Unfortunately, these authors aggregate the dispersed subquadrats to obtain estimates of richness at larger scales. Such richness estimates are biased because they ignore the intrinsic spatial autocorrelation of vegetation. In contrast, the NCVS protocol primarily uses averages of single square subquadrats so as to retain the spatial autocorrelation structure of the vegetation in richness estimates. In short, the 0.1 ha configuration of the NCVS protocol appears to provide a substantive improvement over the Whittaker diversity plots, while retaining compatibility with data collected using those methods.

The increased insight allowed by examination of species richness across subquadrats and modules spanning six orders of magnitude of size, as provided by the 0.1 ha configuration of the NCVS protocol, is illustrated in Table 2 by a few representative plots collected in the Nantahala Mountains of North Carolina. In these plots, species richness at 0.1 or 1 m^2 has little correlation with species number at 400 or 1,000 m^2. Vegetation types with many small plants, like meadows and barrens, have high species richness at small scales, but this provides little insight into species numbers at larger scales of observation. Cove forests, which are often suggested to have high species richness, tend to plateau in species richness early, with little increase after the first 100 m^2, largely because of competition for light among the dense herb layer plants, whereas dry oak forests, which have less dense herb layers, plateau much less

Table 2. Species richness values calculated using data from representative 0.1 ha configuration NCVS plots recorded in the Nantahala Mountains, North Carolina

Community Type	Plot size (m^2)						
	0.01	0.1	1.0	10	100	400	1,000
Canada hemlock forest	0.38	1.25	1.88	3.4	10.0	16	16
Rich alluvial forest	2.75	5.63	15.00	32.5	77.0	120	146
Carex-Scirpus meadow	2.25	4.38	8.25	13.4	20.7	33	38
Mafic white oak forest	0.38	3.88	14.25	38.9	73.0	109	115
Rich cove forest	1.50	4.25	11.50	23.7	42.5	60	65
Ultramafic barren	3.38	8.13	14.00	20.4	32.0	47	50
High-elevation red oak forest	1.25	2.38	4.25	9.5	21.0	40	50
Dry oak forest	0.75	2.13	5.88	18.6	48.2	85	96

quickly. Rich alluvial forests, where dynamics are driven more by a steady supply of propagules carried by flood waters and less by competition, show little evidence of a plateau even at 1,000 m.

The large, intensive plots advocated by Whittaker and the 0.1 ha NCVS configuration provide detailed information on vegetation structure, but at a significant cost in terms of time required per plot. Where a quick reconnaissance or inventory study is required, a set of simpler and faster plots can be more appropriate, with examples being the traditional *relevé* or *aufnahme* of European workers (e.g., Braun-Blanquet 1964), the "recce" plots used in New Zealand (Allen 1992, Hall 1992), and the reconnaissance plots proposed by Franklin et al. (1970) for use in the Pacific Northwest. For such purposes we recommend recording species presence only to depth 1, and, if necessary, reducing module number. The European relevé is similar in that the core dataset includes a list of species with cover class values. The recce plots of New Zealand ecologists are similar in the focus on rapid reconnaissance (Allen 1992); they also include a species list with cover values, but given by species by six height tiers (<0.3, 0.3–2, 2–5, 5–12, 12–25, and >25 m). The recce method does not use a fixed area because of the emphasis on speed, efficiency, and homogeneous vegetation, whereas the NCVS protocol can provide reconnaissance data with standardized plots that facilitate comparisons.

Some divergence in methodologies occurs in plot size. Mueller-Dombois and Ellenberg (1974) suggest 400 m^2 for forest understories, with smaller plots recommended for grassland and larger ones (1,000–2,500 m^2) for deserts and other arid zones. A major advantage of the NCVS protocol is that several standard plot sizes can be created by combining modules, thereby facilitating comparisons across many kinds of vegetation.

Ten years of experience applying the NCVS protocol has led us to appreciate the flexibility and transportability of the methods. Some variant of the protocol can be applied in nearly all situations and without loss of compatibility with other data collected using the protocol. Intensively sampled modules, and especially as used in the fully elaborated 0.1 ha configuration, provide detailed information on vegetation structure not available with other widely used methods. Consistency with standards applied in other methodologies facilitates data exchange and sharing, which should hasten efforts to describe, inventory and understand vegetation.

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SOP 3: Installing an RSET Mark

Version 1.00 (January 2015)

The following table lists all changes that have been made to this Standard Operating Procedure (SOP) since the original publication date. Any recommended or required changes added to the log must be complete and concise and promptly brought to the attention of the Project Leader. The Project Leader will review and incorporate all changes, officially complete the revision history log, and change the date and version number on the title page. For complete instructions, refer to SOP #10: Revising the Protocol or SOPs.

Revision History Log:

New Version #	Previous Version #	Revision Date	Author (full name, title, affiliation)	Location in Document and Description of Change	Reason for Change

Introduction

Once the study design and layout have been established for a particular project (SOP #1, SOP #2), the next step is the installation of the SET mark(s) at each sample station. A Rod SET (RSET) mark is designed to provide a vertical reference point from which elevation measurements can be collected for many years. Two types of marks can be used with the RSET instrument: deep and shallow, and both are designed to be stable for many years (Figure 3.1). Both mark types integrate processes occurring from the bottom of the mark to the wetland surface. A shallow mark integrates processes occurring near the surface since it is typically driven to a depth of less than 1 meter. A deep mark integrates over a greater depth of the soil profile since it is driven much deeper than a shallow mark. Processes occurring below the mark (i.e. deep subsidence) are not measured by the RSET. There are numerous options for driving the rods used in a deep mark; from a hand pounder to a gasoline powered hammer drill. The shallow mark design differs from the rod mark and has a different installation procedure. A shallow mark is commonly installed in conjunction with a deep mark. The measurement of both marks simultaneously can be used to determine where elevation change is occurring in the soil profile.

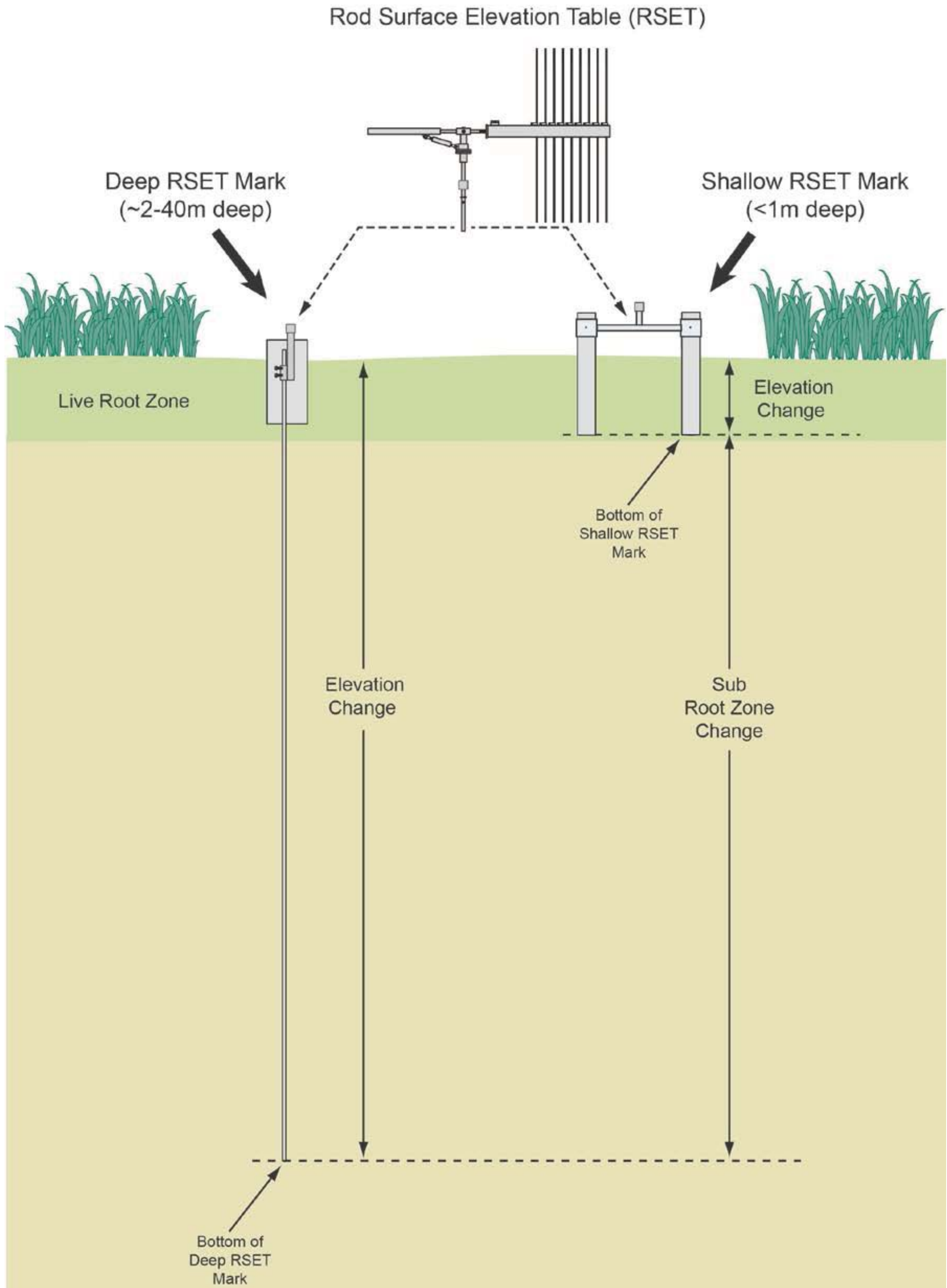

Figure 3.1. Cross section of a wetland showing the deep and shallow RSET marks commonly used for monitoring elevation change. The deep mark consists of 4 foot (1.2 m) sections of stainless steel rod threaded together.

Deep RSET Mark

A deep RSET mark is installed using stainless steel (SS) rods driven into the wetland sediment to a considerable depth. A custom built receiver, which couples with the SET instrument, is securely attached to the top of the deep mark.

The general procedure for installing a deep RSET mark is as follows:

1. Install a temporary or permanent platform to work on.
2. Dig a hole and drive multiple sections of stainless steel rod into the ground.
3. Cut the rod (if necessary).
4. Insert PVC collar.
5. Attach the receiver to the rod.
6. Fill PVC pipe with cement.

Supplies for Installing a Deep RSET Mark

Refer to Appendix A for a detailed list of supplies.

1. Sampling Platform – See SOP #2
2. Stainless Steel Rods – A deep mark consists of 15 mm (9/16th inch) diameter, 1.2 m (4 feet) long stainless steel rods that are threaded together (Figure 3.2). Costs per rod range from $15-$25. Prices can vary considerably from year to year. Rods are driven into the sediment to a depth ranging from 2m to over 40m (~6-130 ft.) depending on the particular conditions found at each wetland and the equipment used to install them. Driving points are short pieces of SS rod with a point on the end (Figure 3.2). These are placed on the leading edge of the first rod in a deep mark. So, only a single driving point is needed for each mark.

   Estimate the number of rods per deep mark and order them ahead of time. How many to order depends on:

   a. The depth of unconsolidated wetland sediments, geologic history of the sediment vertical profile, and the nature of the underlying geology.

   b. The equipment used to drive the rods.

   c. Budget.

   Since the rods are rather expensive, the budget for installation may impact the number of rods available for deep marks. In addition, the different tools used to install them could also affect the number of rods used. For example, the hammer drill can easily use 20 or more rods for each mark, whereas the hand pounder will commonly use less than 20 rods. A good estimate would be 15-20 rods per mark if NOT using the hammer drill and 20 or more if using one. In wetlands where one might expect to hit bedrock or limestone, fewer rods may be needed.

Figure 3.2. Stainless steel rod showing the driving point used on the first rod. Note the threaded studs used to couple sections of rod together.

3. Hammer or pounder for driving rods into the wetland sediment:

   There are three commonly used tools for driving the rod into the ground:

   a. Hand Pounder – Figure 3.3

   b. Demolition Hammer – Figure 3.4

   c. Hammer Drill – Figure 3.5

   Table 3.1 gives an overview of these three devices. Method B or C is recommended for the installation of a deep mark even though they are expensive. Consider renting or borrowing this equipment if it cannot be purchased.

Figure 3.3. Hand pounder (Waquoit Bay NERR, Massachusetts, USA).

Figure 3.4. Demolition hammer and generator (Cape Cod NS, Massachusetts, USA).

Figure 3.5. Gasoline powered hammer drill (Chesapeake Bay Environmental Center, MD, USA).

Table 3.1. Comparison of features in the equipment commonly used to install a deep RSET mark.

	Hand Pounder	**Demolition Hammer**	**Hammer Drill**
Manufacturer	Custom Built	Bosch 11316EVS	Cobra Combi
Weight of tool	~15 lbs.	~28 lbs.	~55 lbs.
Cost of tool (US $)	~$100-200	~$700-800	~$4500
Operation of tool	By hand	Electric. Need a generator	Gasoline powered
Minimum number of people to operate.	One	Two	Two
Typical depth of mark	0-60 feet	0-80 feet	0-130 feet
Pros	Very light and easy to handle.	Relatively light and easy to operate.	Generates the most power. Can drive rods the deepest.
Cons	May require considerable physical labor to drive in the rods. Doesn't usually get as deep as other techniques.	Requires a generator. Not as powerful as the hammer drill.	Expensive and Heavy. More involved to carry and operate.

1. Driving head - Attaches to the top-most stainless steel rod (Figure 3.10). It takes the blows from the hammer or pounder. The head protects the 4' sections of rod from getting deformed from the pounding. They can be ordered when purchasing rods or cut from a 4' rod to use for this purpose. It needs to have threads on one end so it can couple with each new rod added to the mark. The driving head is usually 4-12" in length. After a rod is pounded into the ground, the driving head is removed and a new rod attached. The driving head is attached to the new rod and this step is repeated until the driving stops.

2. Angle Grinder or Bolt Cutter - When the mark can no longer be driven into the ground, the rod may need to cut if it is not level with the surface (i.e., some of the rod protrudes above the wetland surface). An angle grinder is recommended to cut the rod at the wetland surface (Figure 3.15). It should be battery powered or electric (if a generator is available). A hydraulic bolt cutter can also be used to cut the rod (Figure 3.17) but is not recommended. A hacksaw will work with considerable effort and is also not recommended.

3. Narrow bladed "sharpshooter" shovel or post hole digger – To dig the shallow hole for the deep rod (Figure 3.7). The shovel is also used for mixing cement.

4. Receivers– Receivers are custom built out of stainless steel. They cost $125 - $175 each (US$). Receivers are designed to bolt onto the last section of rod and couple with the RSET instrument (Figure 3.6). The receiver allows for a fixed and repeatable coupling so the SET instrument is in the exact same position for each sampling. One receiver is needed for every deep mark.

5. Concrete – "redi-mix" concrete (with stones) or mortar (without stones) work fine. The depth of the hole (and PVC collar) will determine how much concrete is needed for a mark. It typically takes ½ - 1 bag of cement (60 lb.) for a single deep mark.

6. PVC Collar – 15cm (6") diameter PVC pipe (Schedule 40) - ~18-48" long. The PVC pipe goes into the hole after the rod is finished being driven (Figure 3.19). After the receiver is attached to the rod, the PVC pipe is filled with cement.

7. Tools/Gear: Vice Grips (2-3), box wrench (9/16"), small sledgehammer, bucket, paper towels, duct tape, hand pump, gloves, hearing protection, thread locker glue, dust mask.

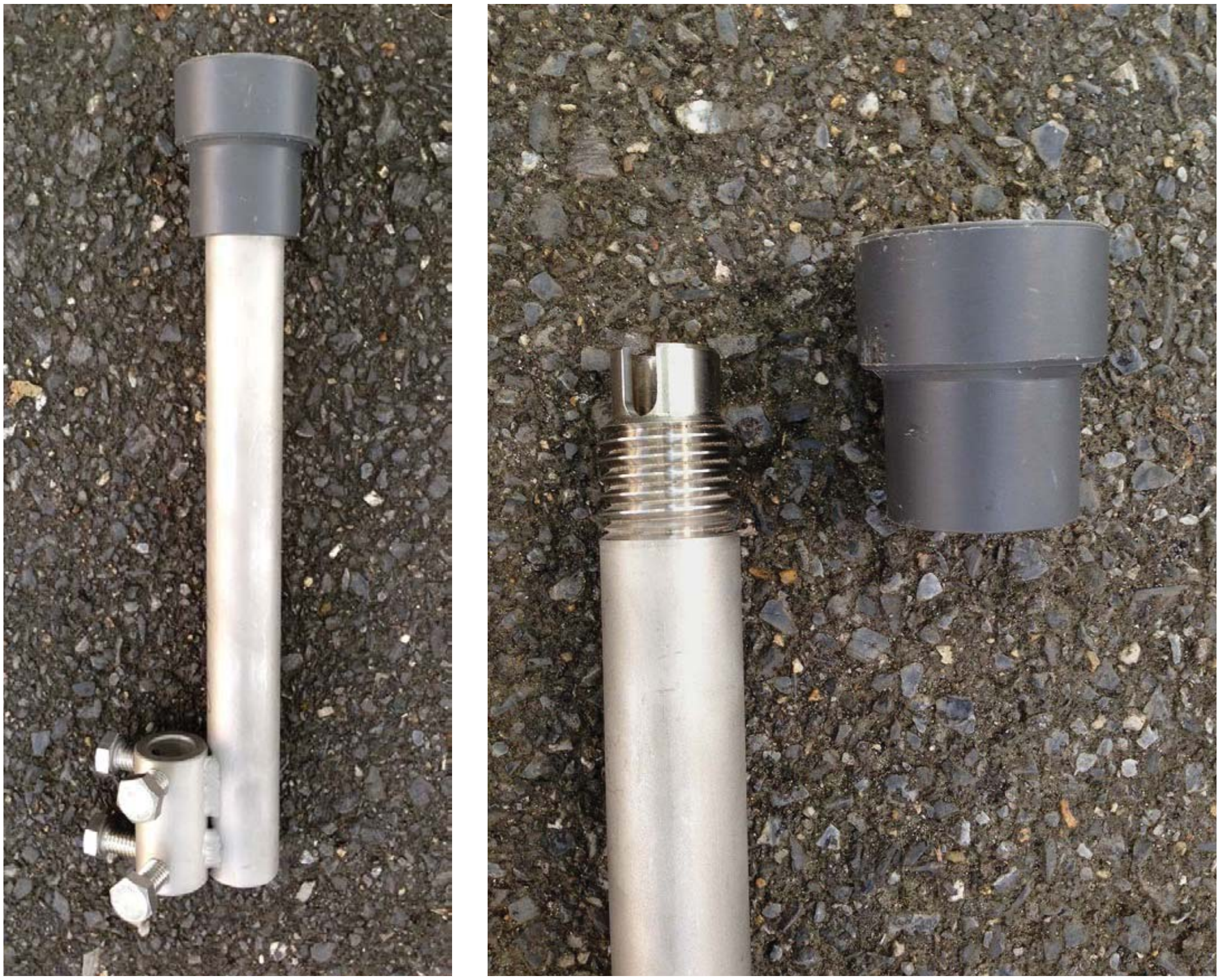

Figure 3.6. Receiver.

Deep Mark Installation Instructions

1. Use a temporary platform or build a permanent platform. Refer to SOP #2 for details.

2. Drive Rods into the wetland sediment.

    a. Dig a hole and drive the stainless steel rods into the ground: Determine the location of the deep mark. Using a post-hole digger and/or narrow blade shovel, dig a 6" diameter hole (the diameter of the PVC collar) to the appropriate depth (Figure 3.7). Note that the hole may have water in it (Figure 3.9). This is normal.

    b. The depth of the hole is determined by the length of the PVC Collar which may vary in length from 18”- 48”. Place the soil from the hole in a bucket and remove it from the immediate area of the sample station. The hole should be shallower than the length of the 6" PVC collar.

For example, if using a 24" length of 6" PVC for the collar, dig a hole about 6" wide about 12-15" deep (Figure 3.8). This ensures that the bottom of the PVC pipe will be driven into the underlying substrate when installed. This will help to anchor and stabilize the collar and mark. Note that this normally occurs AFTER the rods are driven into the ground.

Note, that it is also possible to dig the hole for the PVC pipe after installation of the rods and not before.

c. Screw together the first two sections of stainless steel rod. Apply thread locker to both sides of the threads on the stud (wear gloves). Install the driving point on the leading edge.

d. Make sure the rod is vertical and push it into the center of the hole in the ground. The first few rods can usually be pushed in by hand.

e. Attach the driving head which is a short piece of stainless steel rod that will take the blows from the pounder or hammer (Figure 3.10).

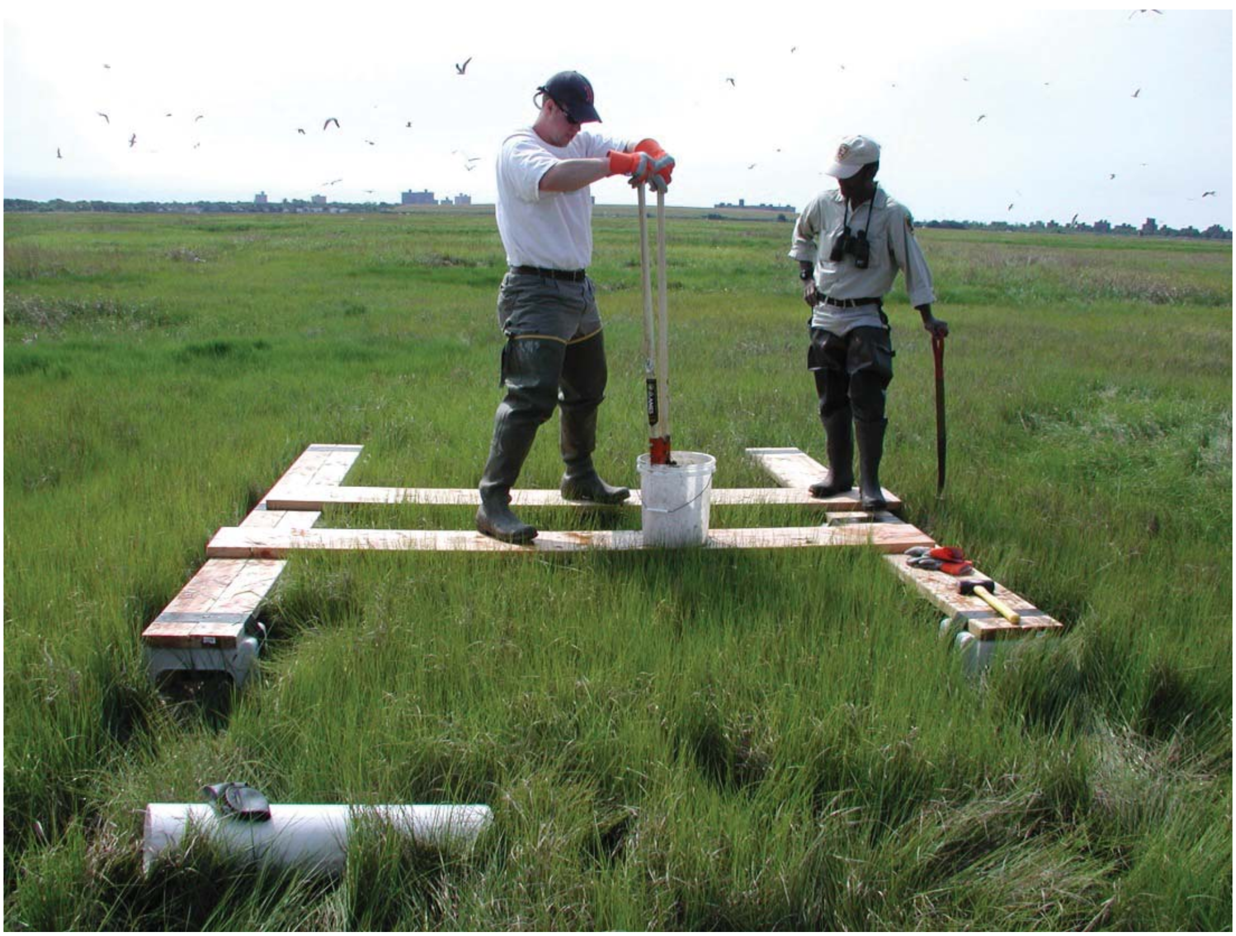

Figure 3.7. Digging the hole (Gateway NRA, New York, NY USA).

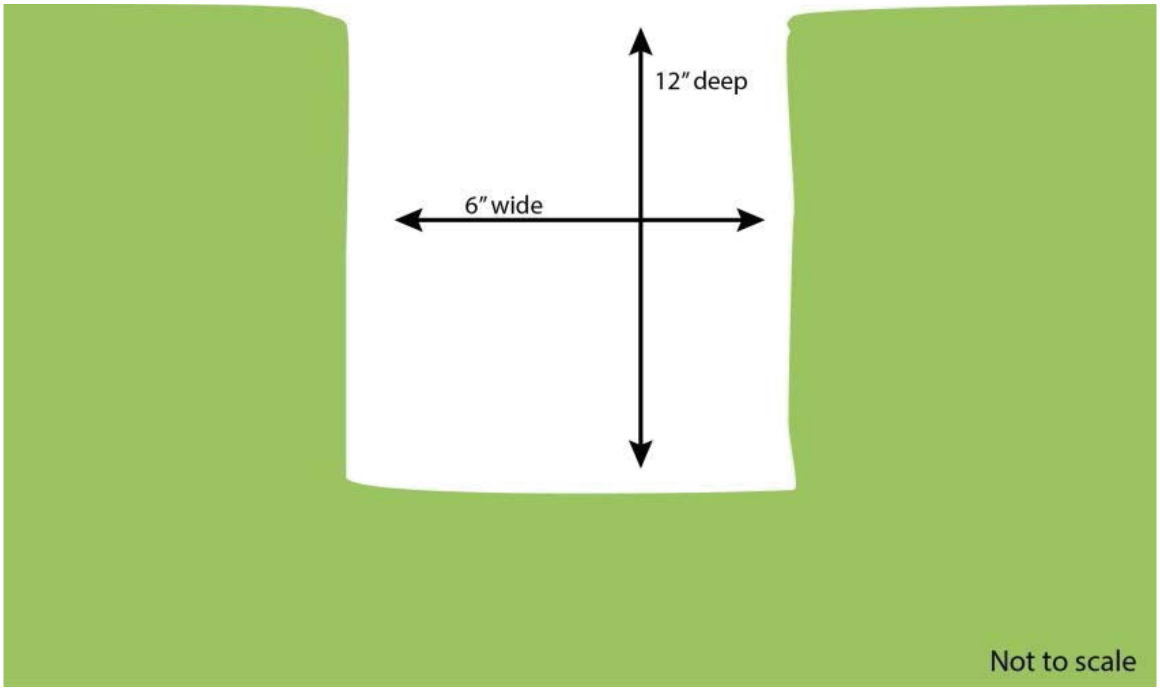

Figure 3.8. Approximate dimensions of the deep mark hole. Depth of the hole may vary.

Figure 3.9. It is common for the hole to have water in it.

Figure 3.10. Attaching the driving head (Waccamaw River, South Carolina, USA).

f. Start pounding the rods into the ground with the hand pounder, demolition hammer or hammer drill (Figure 3.3, 3.4, 3.5). Be sure to wear gloves, a hardhat, hearing and eye protection. Stop pounding each section when the driving head is about 6” above the wetland surface. Remove the driving head. Add a new rod (use thread locker glue), attach the driving head (Figure 3.10), tighten with vice grips (Figure 3.11) and resume pounding (Figure 3.12). Repeat this process until significant resistance is met or the rod hits limestone or bedrock. Refer to table 3.2 for guidance on when to stop pounding rods.

Deep RSET mark installation notes:

- The threaded connections between rods can get loose from the pounding. Especially the top most sections. When adding a new rod, use vice grips to screw the entire rod mark clockwise to keep all the rods snugly connected (Figure 3.11). Also use thread locker glue on the studs when adding a new rod. When only a few rods have been installed, the entire deep rod mark may spin when tightening with the vice grips. This will stop once the rods get deeper into the sediment.
- While pounding, the driving head will come loose. Be sure to keep the driving head screwed on snugly when actively pounding on the rods (wear gloves).

- Swap out the threaded stud (Figure 3.2) on the pounding head from time to time. The threaded stud takes a lot abuse and may break if used for too long. It is good to swap it out with a new stud every 5 rods or so.

- Number of Rods: VERY IMPORTANT: Keep an accurate count of rods used. It's very easy to get confused and lose track of how many rods that have been sunk into the ground. Start all installations with bundles of 10 rods to minimize the chances for error (Figure 3.12). In the data book, record the total number of rods used for the mark.

- Depth of the mark: The number of rods used for a deep mark will only give an approximation of the final depth of the mark since rods have been known to bend (i.e. curve) as they are driven into the substrate.

Figure 3.11. Tightening rods (Waquoit Bay NERR, MA USA).

Table 3.2. When to stop driving rods.

Unless the rod point hits bedrock or limestone (refusal), determining when to stop driving rods into the ground is not always a straightforward decision. In many coastal wetlands in the U.S., the first 1 to 5 rods (4 to 20 feet) may go into the ground easily. At deeper depths, driving the rods slows down and takes more time and energy. Every wetland substrate is different and how the installation proceeds will usually change as more rods are added to the deep SET mark. Keeping track of this change will help determine when to stop pounding.

The recommended procedure is to time the installation (in seconds) of each 4' rod. As the mark gets deeper and there is more resistance, it will take longer to drive in each rod. Pounding on the rod is stopped when "susbstantial resistance" is achieved. This occurs when the installation of a deep SET mark goes beyond some agreed upon time interval. For example, pounding stops when it takes 120 or more seconds (30 seconds/foot for a 4' rod) to drive fully a single rod into the ground with a demolition hammer. The National Geodetic Survey (NGS) has a rule of 240 seconds (60 seconds/foot for a 4' rod) when using a hammer drill to install geodetic marks.

Below is an example for a U.S. coastal wetland using a demolition hammer:

1) Rods 1-5 (0-20') – Rods go in easy. Very fast. (20-30 seconds per rod)
2) Rods 6-11 (24-44')- Rods go in moderately fast and easy. (45 seconds per rod)
3) Rods 12, 13 (44-52') – Rods go in slow, then very slow. (60-90 seconds per rod).
4) Rod 14 (52-56') - Very slow – (120 or more seconds per rod) .Stop pounding. Finished.

If it takes longer than 2 minutes to install a 4' rod with a power tool, the sediments are likely to be very firm.

There are some situations when the rods may not slow down to the point where pounding can stop. This may happen in some sandy soils like on a barrier island. In this case, the pounding may have to stop without achieving "significant resistance" and stopping at 20 rods (80') would be adequate. Realize that choosing when to stop is a decision based on the materials on hand, the equipment being used to drive the rods and the conditions present at the site.

Be aware that once pounding has stopped, a deep SET mark should freeze up quickly and provide a very stable mark for taking measurements with the SET instrument. The main point of the deep SET mark installation is to ensure the mark is deep enough to provide a vertically stable platform for many years of SET measurements.

Figure 3.12. Driving rods. Note the bundle of rods on the end of the platform (Acadia NP, ME USA).

1. Stop pounding and cut the rod (if necessary) – As the downward movement of the deep SET mark slows and the pounding is about to stop, the goal is to have the joint between rods close to the wetland surface or a few inches above it. Under these circumstances, the rod will not need to be cut (Figure 3.13, 3.14). Unscrew the top section of rod and tighten the last rod in the ground with a vice grip in case it has become loose from the pounding.

   If this is not possible and the rod needs to be cut, it is recommended to use an angle grinder with a 4 1/2" steel/stainless steel cutting wheel (battery powered or electric). This is a fast and safe way to cut a rod (wear eye protection and gloves, Figure 3.15 and 3.16). A hydraulic bolt cutter will also work but is not recommended. It is more difficult and potentially dangerous (Figure 3.17). If using a bolt cutter, have someone hold the top piece as it is cut. Otherwise, it may be launched into the air and could be a hazard.

2. When finished installing the deep mark, the final rod in the ground should be at the wetland surface or a few inches above it (Figure 3.14).

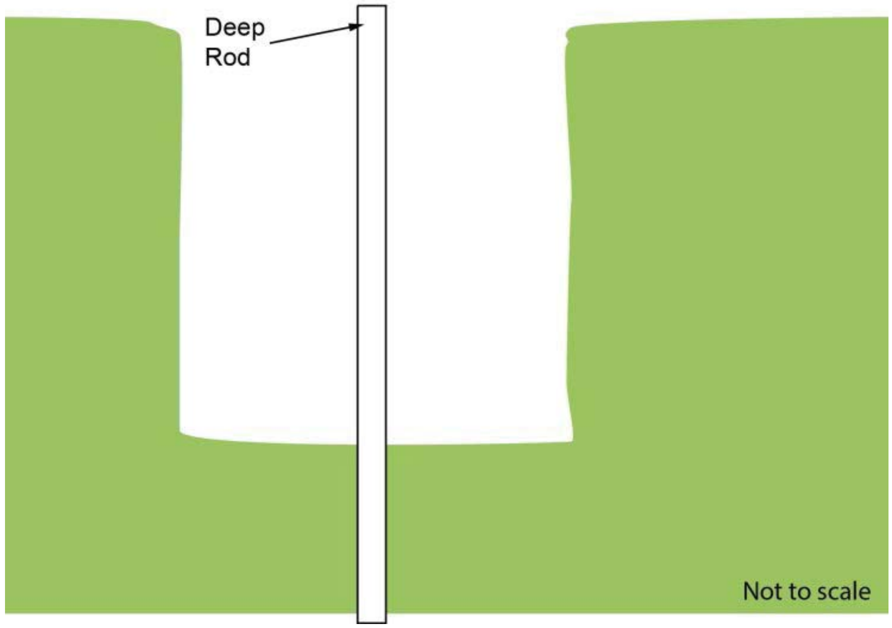

Figure 3.13. The top of the deep SET mark will be just above the wetland surface after installation is complete.

Figure 3.14. Deep SET mark in the hole after pounding has stopped. Note that pounding was stopped at a joint.

Figure 3.15. Electric angle grinder (Boston Harbor Islands NRA, MA, USA).

Figure 3.16. Cutting the rod with an angle grinder (Boston Harbor Islands NRA, MA, USA).

Figure 3.17. Hydraulic bolt cutter attached to the deep rod.

3. Install PVC Collar – Push the 6" PVC pipe into the hole around the rod (Figure 3.18, 3.19). Step on it and/or use a sledgehammer to knock it down to the appropriate depth (Figure 3.20). Try to get the bottom of the PVC pipe into the sediments below the bottom of the hole to improve stability. The top of the PVC pipe should stick up about 4-6" (10-15 cm) above the wetland surface. Be sure that the top of the stainless steel rod remains below the top of the PVC pipe. It is also very common to have water in the bottom of the hole. Remove excess water in the PVC pipe with a hand bilge pump or small plastic cup.

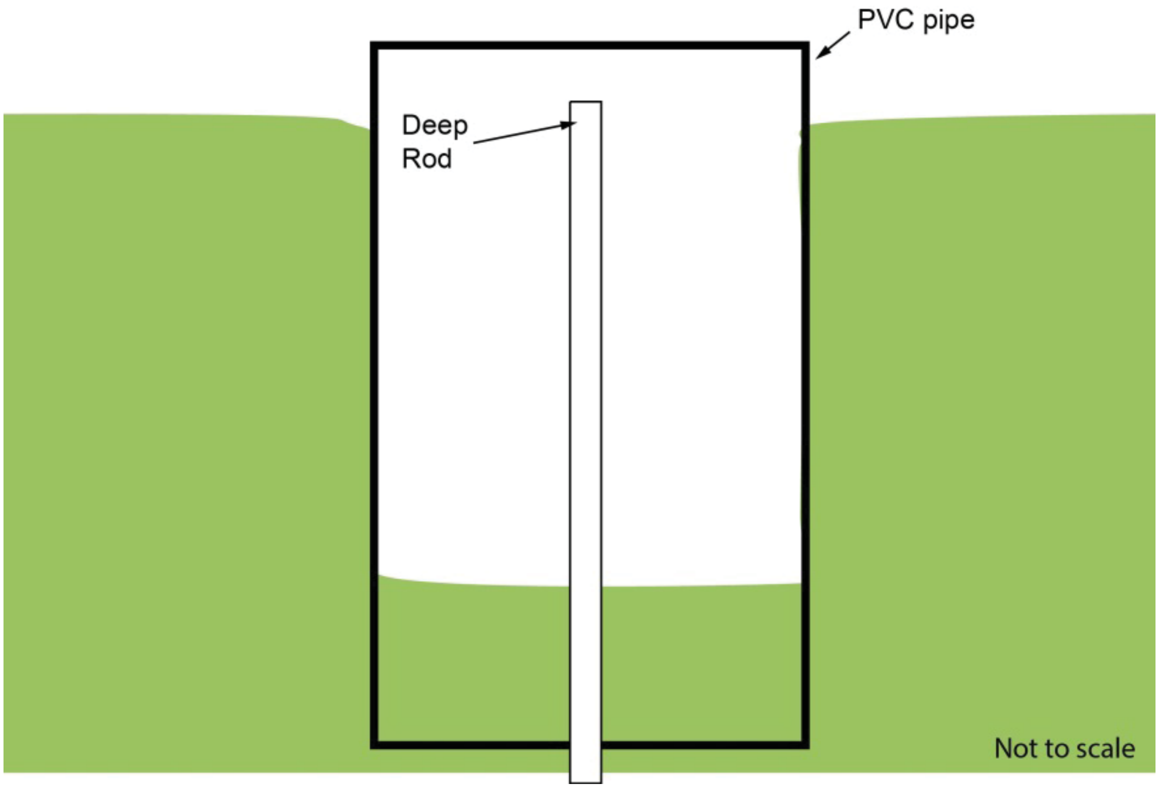

Figure 3.18. PVC collar in the ground.

Figure 3.19. PVC collar (Barn Island, CT USA).

Figure 3.20. Installing the PVC collar (Boston Harbor Islands NRA, MA USA).

4. Attach the receiver – Slide the stainless steel receiver over the rod and into the hole (Figure 3.21, 3.22, 3.23). Tighten the bolts on the receiver with a 9/16" wrench, thereby attaching it to the deep mark. Make sure the rods are snug and tight before attaching the receiver. Use the notch in the top of the receiver to align the receiver in the desired orientation for the SET measurements. Once the receiver is attached to the deep rod and encased in cement, the directions available for SET measurements will be fixed. It is important to be aware of the directions prior to attaching the receiver and adding cement to the PVC pipe.

Figure 3.21. Receiver (on wooden plank) prior to attachment to the deep SET mark.