West River Shoreline Trail/Niagara River Shoreline & Aquatic Habitat Restoration

Great Lakes Coastal and Nearshore Habitat Engineering and Design Project

Prepared for:
Coastal States Organization

February 28, 2023

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Funding for this project provided by Great Lakes Restoration Initiative (GLRI)

Project plan developed in partnership with:

- Project Partners
    - Coastal States Organization
    - New York State Office of Parks, Recreation and Historic Restoration
    - Buffalo Niagara Waterkeeper
    - National Oceanic and Atmospheric Administration (NOAA)
        - NOAA Office for Coastal Management
        - NOAA Restoration Center
    - New York State Department of Environmental Conservation
        - Division of Fish and Wildlife
        - Great Lakes Watershed Program
    - New York State Department of State
- Design Team
    - LimnoTech
    - GZA

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1 Introduction

The Niagara River lies between New York State, United States and Ontario, Canada. The river flows from Lake Erie in the south to Lake Ontario in the north. Grand Island lies within the Niagara River, approximately five miles south of Niagara Falls and five miles north of Black Rock Canal in the City of Buffalo, New York. The West River Shoreline Trail/Niagara River Shoreline & Aquatic Habitat Restoration project focuses on three sites on the west shoreline of Grand Island, within the west channel of the Niagara River. The sites are owned and actively managed by the New York State Office of Parks, Recreation, and Historical Preservation (NYSOPRHP). The project goal for all three sites is to restore shoreline function and habitat by reducing bank erosion and sediment wash into the river. Ancillary benefits of the project will introduce native plants to benefit migratory birds and structures for spawning fish in the river.

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

The following report includes 60% design for shoreline habitat enhancement, existing near shore habitat improvement and restoration along the west side of Grand Island NY and the Niagara River. This report also contains a regulatory review and a project plan that addresses pre- and post-construction monitoring, maintenance, and public outreach.

2 Background

2.1 Site Overview and Project Motivation

The west channel of the Niagara River lies between Grand Island NY and Ontario Canada. Along the western shoreline of Grand Island, riverbank erosion is occurring due to significant river flows along with waves created naturally and by boater recreation in the area. The shoreline erosion has been problematic in the loss of aquatic and shoreline habitats. The erosion is also threatening infrastructure on the island. A few possible reasons for the existing erosion are over mowing, high waves produced from recreational boating, and overgrowth of vegetation shading the herbaceous land cover. The project was developed to stabilize the shoreline and improve habitat at three sites along the west side of Grand Island. The three sites have been identified as No. 83, No. 85/86, and No. 91. See Figure 1 for project site locations. In all, the three sites account for a proposed restoration of 3200'. Restoration of both near shore and shoreline habitat would reduce erosion and sediment wash into the river while introducing native plants and spawning structures for fish and other wildlife. Migratory birds will benefit from the more productive and robust habitat for small fish.

Project objectives to meet the workshop goal include:

- Proposed bioengineering solutions along the west side of Grand Island to provide bank stabilization and ancillary benefits to fish and wildlife

To achieve the project goals, 60% designs detail techniques to stabilize the shoreline, reduce sedimentation into the Niagara River, protect critical infrastructure, and provide habitat for fish and wildlife. Target fish and wildlife species include muskellunge, larval fish, and herps.

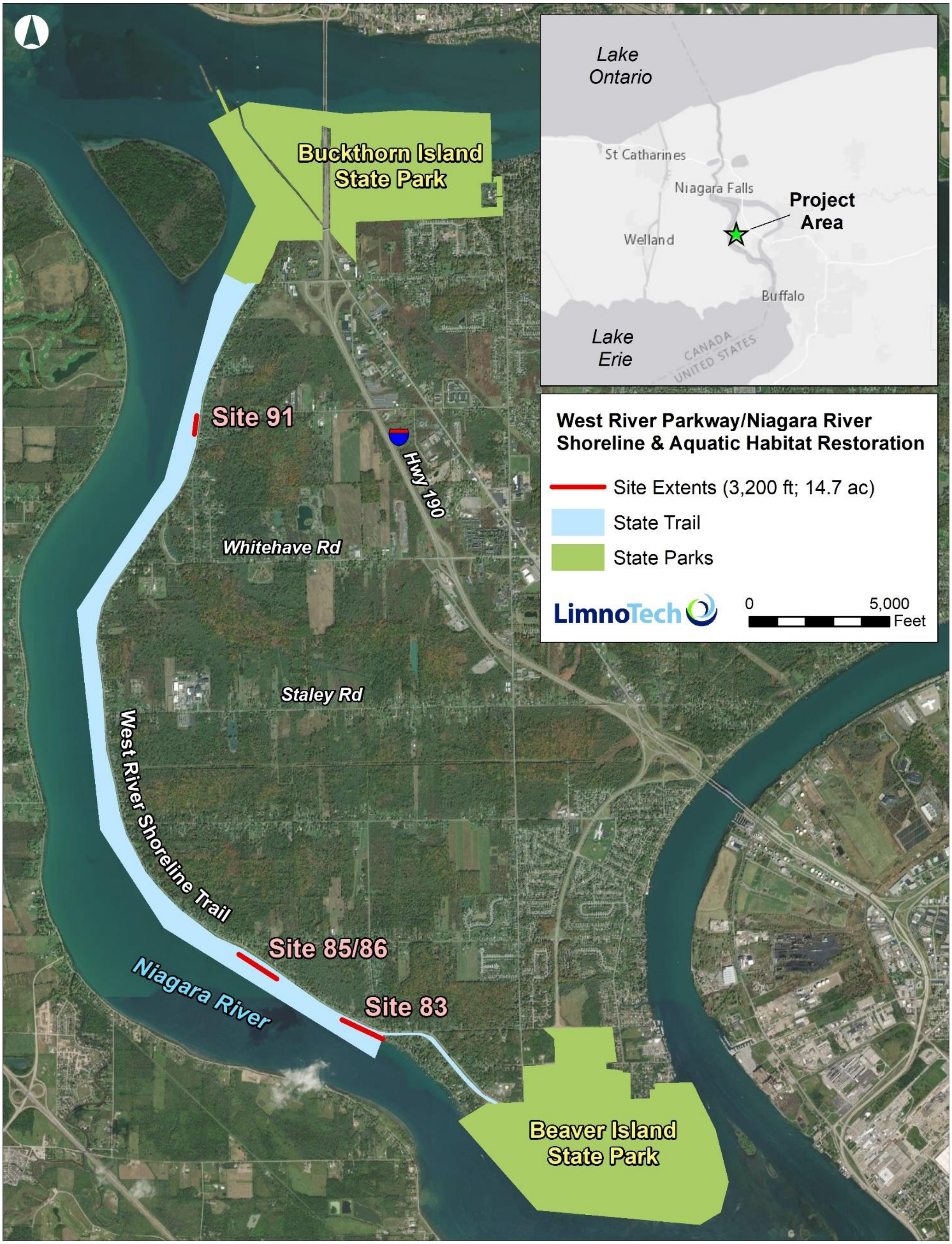


Figure 1. Niagara River Shoreline Sitemap

2.2 Existing Conditions

2.2.1 Background Data

The three separate project sites are located along the west side of Grand Island, on the west channel of the Niagara River. West River Shoreline Trail, a popular walking and bicycle trail runs along the top of the riverbank along the entire western side of the island. The existing site is heavily vegetated with shrubs and small trees, which shade out the smaller herbaceous vegetation leaving opportunities for erosion. The area is also populated by local landowners that are heavily invested in maintaining the viewshed and are not interested in large tree canopies.

The three sites were chosen as the riverbanks have been impacted by erosion and have been showing signs of slope instability. Existing mapping has shown submerged aquatic vegetation (SAV) in the area of all three sites. Visual inspection of the areas prior to design was completed showing the SAVs to be much more spares than mapping suggests. A new SAV survey will be necessary in the next phase of design.

Site No 83 consists of approximately 1200 ft of shoreline with a steep, vegetated slope up to a grassy area near the trail. Rip rap lines the shoreline at the water's edge, but it appears it may be undersized and has allowed for the degradation of the shoreline.

Figure 2. Photo of undersized rip rap, Site 83

Site No 85/86 has approximately 1400ft of shoreline, also with a steep vegetated slope with no rip rap toe protection. The riverbanks are showing signs of erosion and slope instability.

Figure 3. Photo of slope failure along the shoreline, Site 85/86

Site No 91 has approximately 600ft of shoreline, also with a steep vegetated slope. Site No 91 has intermittent rip rap along the toe of the slope. Failure of the rip rap is likely due to the lack of interlocking properties of the stone.

Figure 4. Photo of rip rap along shoreline, Site 91

2.3 Land Research

We would like to respectfully acknowledge the Seneca People who have stewarded this land for generations.

The Seneca are also known as the "Keeper of the Western Door," for the Seneca are the westernmost of the Six Nations of the Iroquois League. The Seneca People relied heavily on agriculture for food, growing the Three Sisters: corn, beans, and squash, which were known as Deohako,(pronounced: Jo- hay- ko) "the life supporters." In addition to raising crops, the early Seneca were also subsistence hunters and fishers.

Notes from the land history research are provided in Appendix C.

3 Analysis

GZA conducted a geotechnical site investigation. They identified mostly silty clay soils, and their preliminary design level analysis recommended slopes of not greater than 3H:1V. Their full geotechnical report is available in Appendix A.

GZA prepared a hydraulics report for this reach of the river. The full report is available in Appendix B. The major findings are as follows:

1. The long-term average water levels were estimated using available gage data, and the results are provided in Table 1.

Table 1 Long-term average water levels

Site	Average (ft NAVD88)
83	565.35
85/86	565.0
91	563.0

Notes: ft NAVD88 = feet(ft), North American Vertical Datum of 1988.

2. Boat waves are likely the controlling wave condition, and the peak wave height is about 3 ft, with typical wave heights closer to 2.1 ft.
3. No significant ice jams or ice accumulations along the shoreline are anticipated.

4 Engineering and Design

This section is a basis of design that will discuss the design criteria, design development, a summary of work to be completed in future design phases, and an opinion of construction costs. Plan sheets are available in Attachment A.

4.1 Design Criteria

The project objectives for meeting the restoration goal of restoring 300 acres of degraded habitat in this region of New York are:

- Stabilize eroding bank using bioengineering practices;
- Provide erosion protection with nearshore rock reefs to provide energy dissipation and create habitat for spawning and refuge targeting key aquatic species;
- Introduce native plants to benefit migratory birds;
- Consider climate change and water level fluctuations

Project partners also suggested the following potential reference conditions:

- Buckhorn Island State Park
- East River Marsh
- Beaver Island
- Strawberry Island

4.2 Preferred Design Alternatives

Plan sheets included with this Basis of Design report depict an overview layout of the preferred design alternatives to be utilized at each of the three sites. Site conditions will dictate the extent each practice is implemented.

GZA's geotechnical analysis found that preliminary designs should target a 3H:1V side slope when grading back eroded bank to provide a stable slope condition. We propose each site be graded at this maximum 3H:1V side slope for all terrestrial work. Using the maximum slope reduces the amount of disturbed area and earthwork necessary for completion of the project. A native seed mix should be used to establish vegetated cover and where possible, plant trees at the top of slope to provide ample understory cover and habitat for migratory birds. A list of native plants has been added to the plans for review. These will be updated as we receive additional information from sources such as the Seneca Nation and NYSOPRHP's biologist and landscape architect. Mowing delineators, such as signage and no-mow rocks, are to be incorporated into the plans.

Instream preferred design alternatives are detailed in the following sections. A typical cross section that implements the preferred design alternatives is shown in Figure 5.

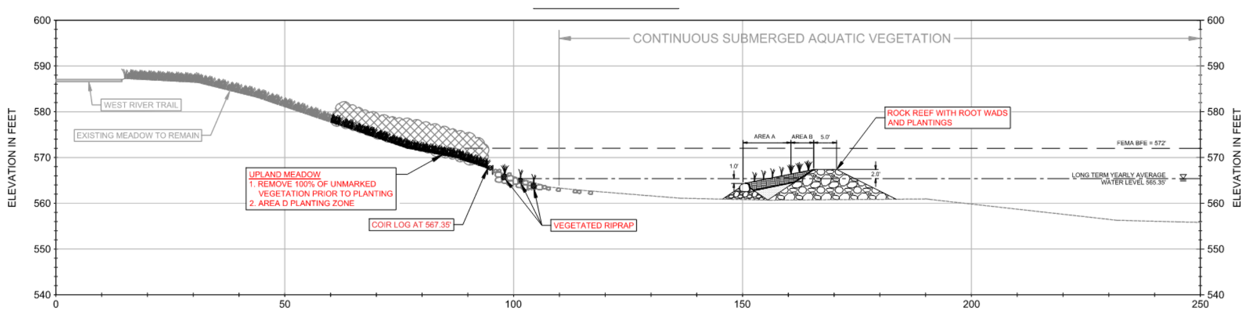


Figure 5. Typical cross section of the proposed site condition implementing various preferred design alternatives.

4.2.1 Rock Reef w/Rootwad (nearshore habitat protection)

A major design element across all three sites and as part of the preferred design is using nearshore rock reef structures (Figure 6), borrowed from a similar pilot approach that was successful in Illinois Beach State Park employing the use of rubble ridges. The function of these structures is two-fold. First, to provide protection against wave driven shoreline erosion by acting as energy dissipators: Setting the crest elevation of these structures will be important to maximize their protection. A wind/wave hydrodynamic model can be used to inform this elevation. And second, the rocks augmented with sand provide both habitat and desirable spawning substrate for key aquatic species such as crayfish, muskellunge, and various panfish.

Another feature of this design includes rootwads. Rootwads are tree trunks with the root ball still intact and are generally harvested onsite, either from slopes that are being regraded or from recently felled trees. They can also be sourced off-site, preferably from other active construction projects that involve tree clearing. The submerged root ball mass provides both additional energy dissipation from waves and river flows and provides unique habitat/refuge for aquatic species. The rootwad will be oriented towards shore and mostly submerged to extend the lifespan of the wood. A portion may protrude from the water during periods of low water levels.

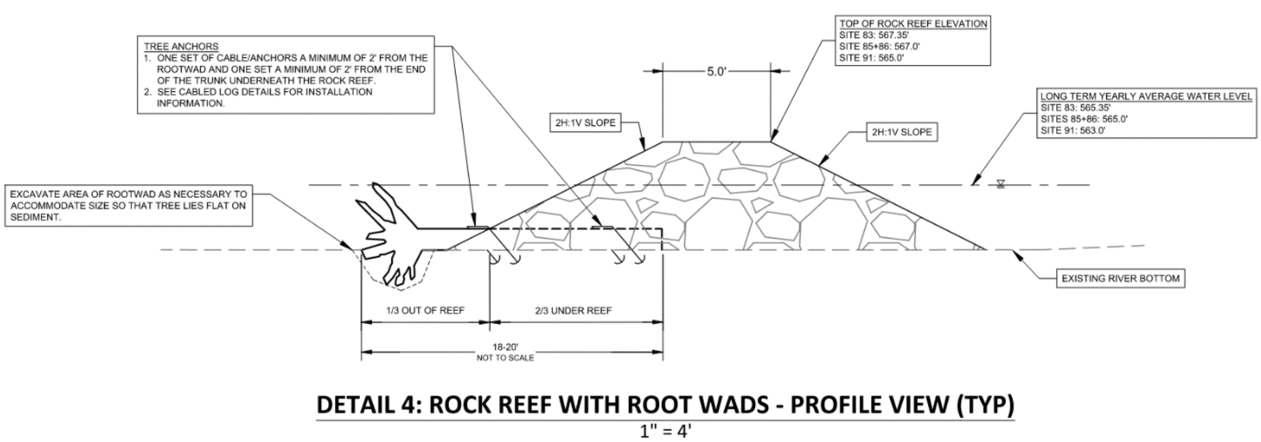


Figure 6. Typical schematic of a rock reef structure with rootwad.

On the protected side of the rock reef structure, calmer waters are expected, and the design can incorporate additional elements in these areas. Two possible options we propose are:

- Aquatic Vegetation
- Sand Spawning Beds

4.2.2 Aquatic Vegetation

Aquatic vegetation can be emergent and submerged. We propose a mix of species to improve flora diversity leading to a healthy ecosystem. Emergent vegetation is proposed on the rock reef structures, which will serve dual function of 1) stabilizing the side slope and helping to trap sediments and 2) providing habitat. Emergent species such as hardstem bulrush, wild rice, and water smartweed are options for the site, while submerged species could include American eelgrass and long-leaf pondweed. Submerged aquatic vegetation is a vital habitat element for the target fish species of this project for both spawning and refuge during early development. A complete list of emergent and submerged vegetation species for both rock reefs and vegetated rip rap are provided in the plans with this Basis of Design report.

Several reference sites with rock reefs have been addressed in the prior workshops. A previous project at East River Marsh utilized rock reef structures with crests above water. The reefs have been overtaken by the invasive black alder; the reefs were not planted at the time of construction. The rock reefs at both Strawberry and Frog Islands were constructed well above expected water surface elevations, but have been planted; to date, native species on the reef structures are dominant. To inhibit the spread of invasives, the rock reef elevations have been raised two feet above the long term average water surface elevation and will be planted with live stakes. Live stakes are typically used as a toe stabilization practice in river systems as dense root growth helps to lock the substrate material together. Live stakes can establish a population of preferred species and provide habitat for migratory birds. Once planted, live stakes need very little maintenance. Stakes may produce leaves during the first growing season, but a lack of leaves does not necessarily indicate mortality. Gently tugging on the stakes will help determine if there has been root development. If two or three growing seasons pass without signs of growth, new stakes can be planted to replace stakes that did not survive. Based on previous experience, a 50% mortality rate can be expected for the first round of live staking. The mortality rate is not necessarily based on site conditions, as the quality of the live stake prior to planting is unknown.

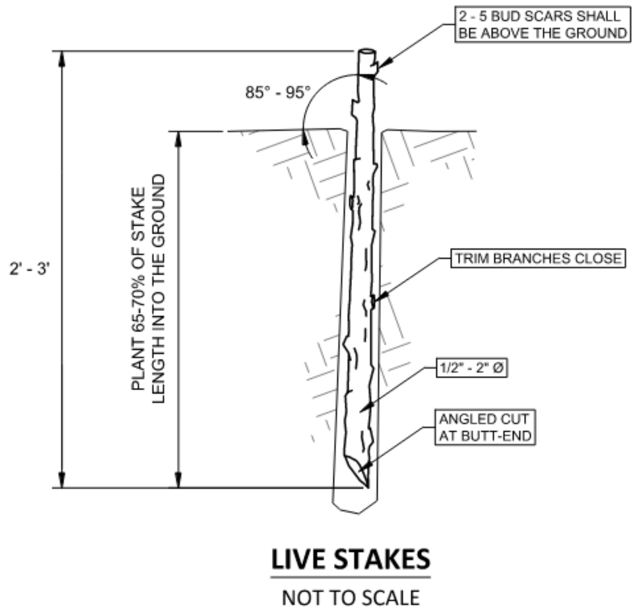


Figure 7. Live stake detail.

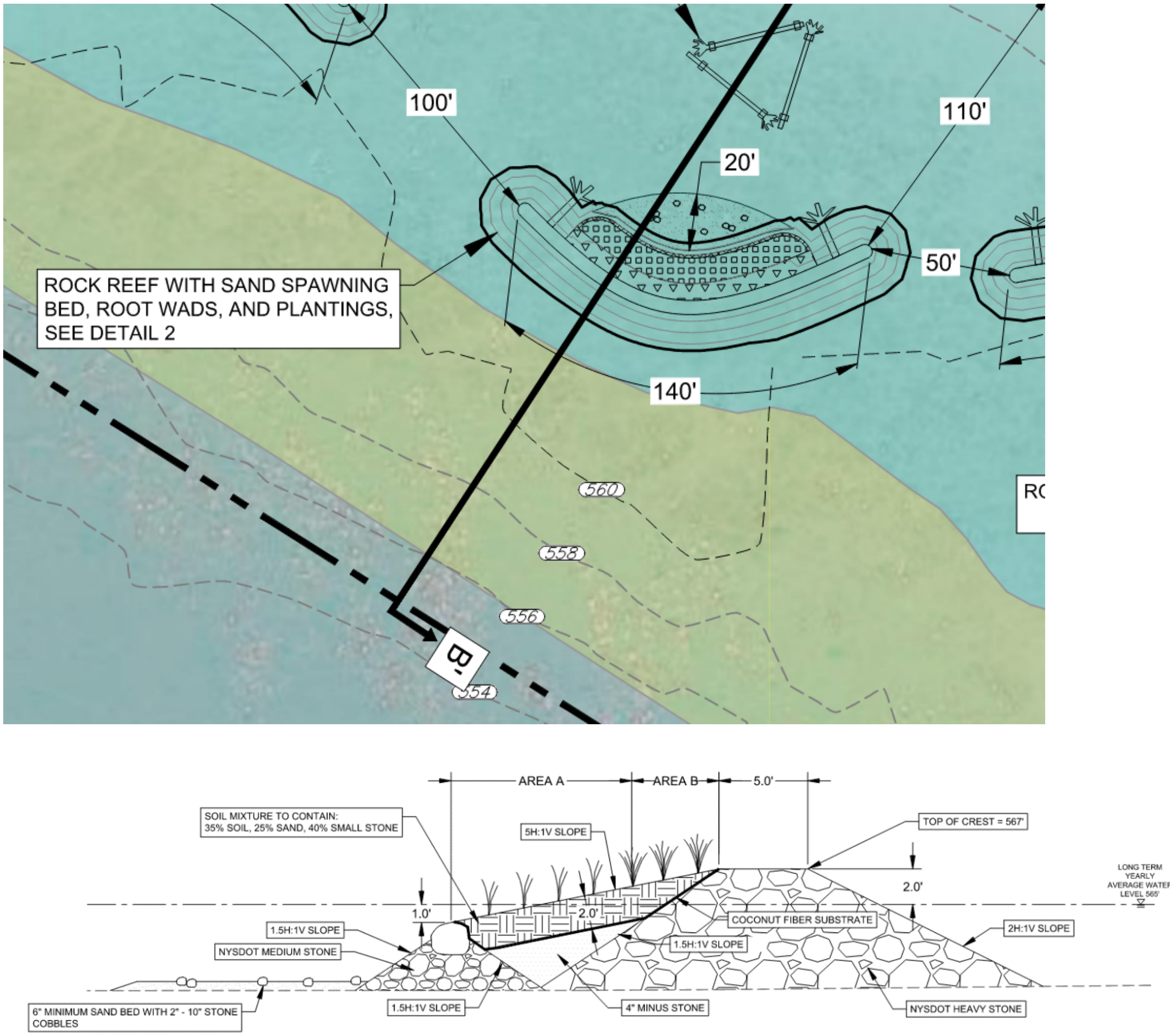
4.2.3 Spawning Beds

Spawning beds can be included on the inside curve of the reef structures. The target species for these beds is muskellunge due to limited known spawning grounds in the area. While muskellunge spawning sites have been relatively well studied, the construction of a muskellunge spawning reef in this area should be considered experimental.

Overall, muskellunge favor spawning at sites with sandy or organic substrate, with little to no submerged or emergent aquatic vegetation (Nohner & Diana, 2015; Dombeck, 1979). Spawning sites are often adjacent to riparian woody wetlands, if present in the system, and have moderate slopes, small flats, and concave shorelines (Nohner & Diana, 2015).

Muskellunge have also been known to spawn over a soft calcareous substrate, with *Chara* spp. as the dominant vegetation (Strand 1986).

Per conversations with the Wisconsin DNR muskellunge hatchery and stocking team, it is also believed that muskellunge prefer to spawn in shaded areas, and egg mortality due to oxygen deprivation and mold is a common risk. Given this, orienting portions of the reef perpendicular to the flow may help egg survival. The theory is that river flows can push though the reef and up though the spawning beds, thereby aerating the eggs. Planting woody live stakes along the ridge of the breakwaters may also provide some shade and attract spawning muskellunge.



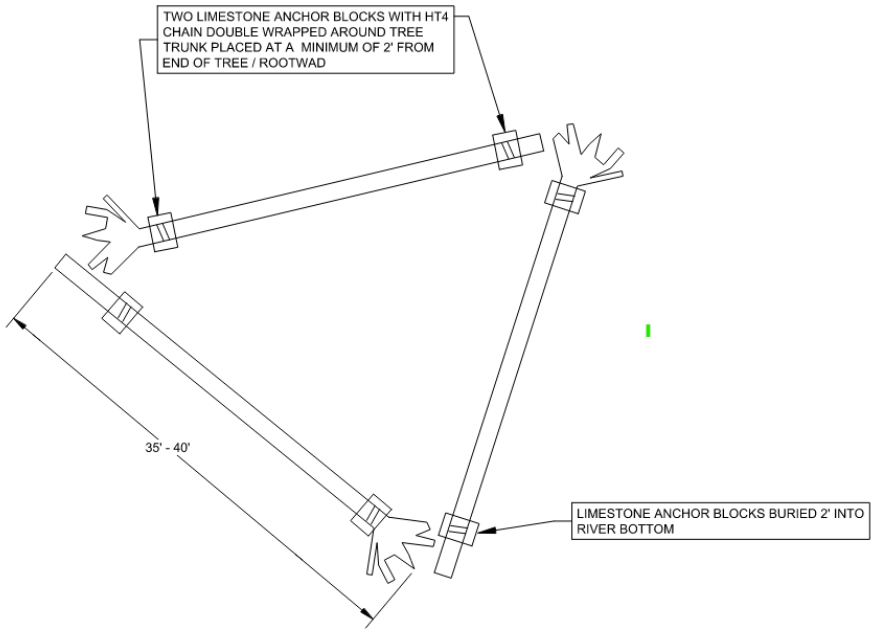
SECTION B-B': ROCK REEF WITH SAND SPAWNING BED AND PLANTINGS DETAIL
SCALE: 1" = 5'

Figure 8. Concept layout of a rock reef structure with a spawning sand bed on the protected side.

4.2.4 Submerged Woody Clusters (habitat features)

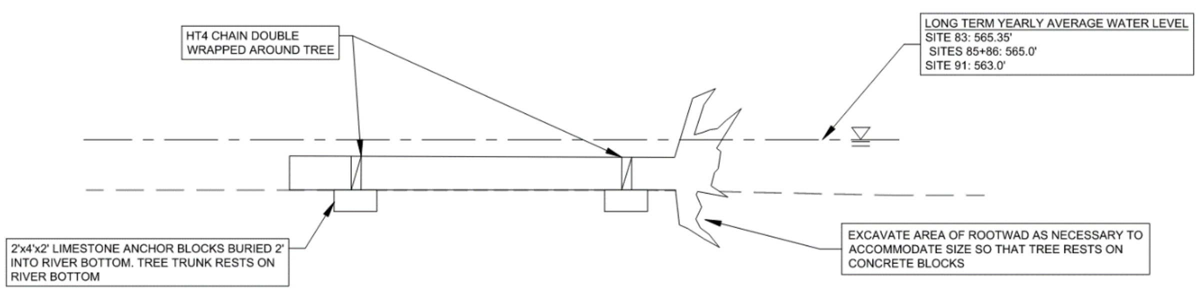
Submerged woody clusters offer excellent refuge for aquatic species and are an extremely affordable solution to creating aquatic habitat. The type of submerged habitat feature to consider is the log triangle fish crib configuration (Figure 9).

- The wood should be from suitable hardwood species.
- The log triangle design may need to be altered to a single row.
- Ballast will be provided by limestone anchor blocks, as depicted in Figure 9.



DETAIL 5: ANCHORED TREES - PLAN VIEW (TYP)

SCALE: 1" = 10'



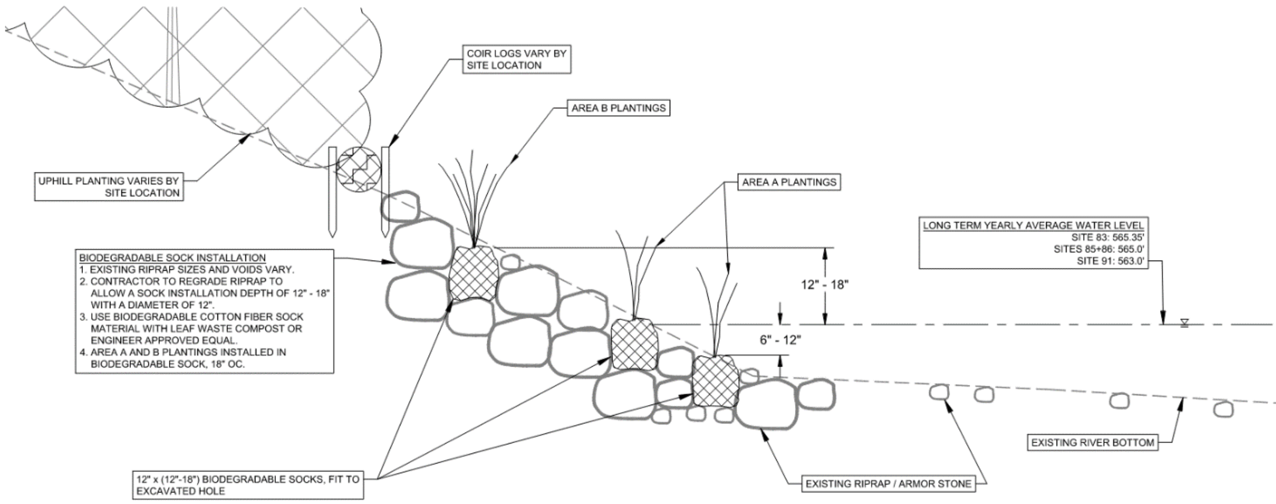
DETAIL 5: ANCHORED TREES - CROSS-SECTION VIEW (TYP)

SCALE: 1" = 10'

Figure 9. Example log triangle detail.

4.2.5 Vegetated Rip Rap

Vegetated rip rap will be incorporated at each site. Individual stones from the existing rip rap toe protection will be pulled at various locations. A biodegradable sock can then be installed into the void and filled with compost or other approved material for planting either emergent or riparian vegetation, depending on the elevation relative to the Long Term Yearly Average Water Level and shown in Figure 11. Over time, the root system provides structure to the rip rap, offering toe protection with a softened shoreline feel. See plan set drawing #3 for a list of plant A and B species.



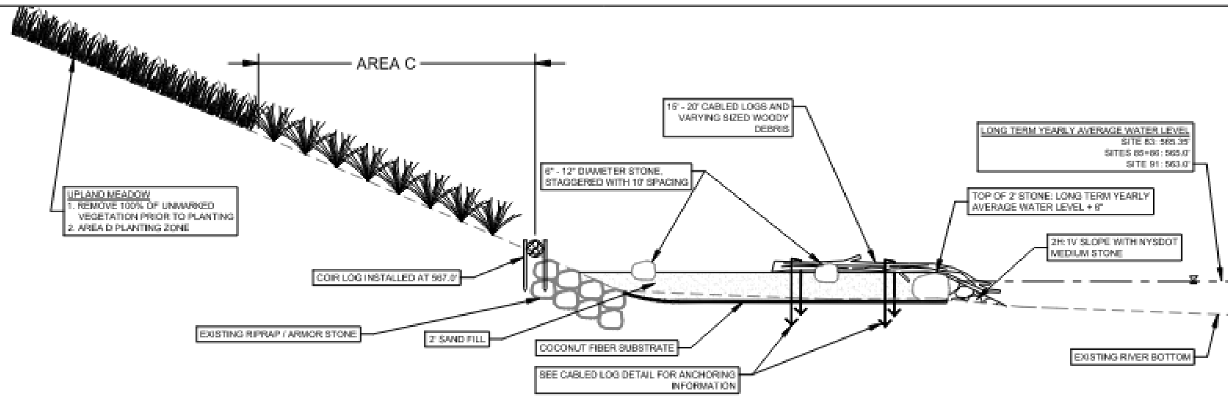
DETAIL 7: VEGETATED RIPRAP - CROSS SECTION (TYP)

SCALE: 1" = 2'

Figure 10. Example of vegetated rip rap detail

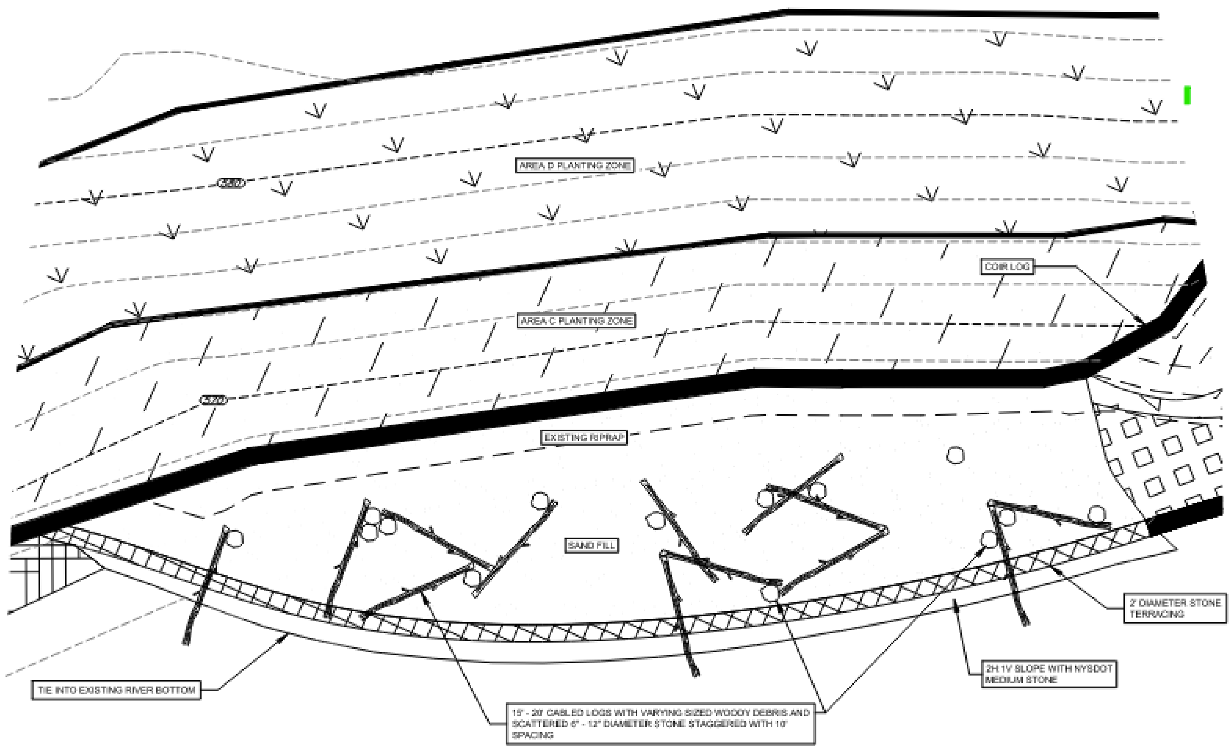
Sandy Shoreline Habitat with Cabled Logs

A sandy shoreline was added to site 83. The fill will be placed above the long-term average water surface elevation. Cabled log and woody debris will be added to the structure to enhance turtle habitat. See Figure 11.



DETAIL 6: SHORELINE HABITAT - CROSS SECTION (TYP)

SCALE: 1" = 5'



DETAIL 6: SHORELINE HABITAT - PLAN VIEW (TYP)

SCALE: 1" = 10'

Figure 11. Example of Sandy Shoreline Habitat.

4.2.6 Culturally Valued Plantings

In conversations with the Seneca Nation, they identified native plant species that provide not only habitat diversity but are also highly valued by the people of the Seneca Nation as food, medicine, and cultural resources (Table 2). During the review of the provided list, it was determined that several of the larger plants and trees may block views of the river and provide excess shading hindering the growth of the proposed native plantings. Of the plants in this list, the site appropriate ones have been added to the planting plan (See Attachment A).

Table 2. Seneca Nation Culturally Valued Plant List

Seneca Name	Common Name	Latin Name	Usage
Deyagony' Ta:s	Choke Cherry	Prunus Virginiana	Treat consumption, blood purifier, antidiarrheal, antihemorrhagic,
Osehda'	Red Osier Dogwood	Cornus sericea	Analgesic, cold remedy, pulmonary aid, eye medicine, Treat consumption
Gahno' Ga:'	Cottonwood	Populus deltoides	Anthelmintic, cold remedy, veterinary aid for horses
Jitgwa:e:' Niyaweodeh	Wrinkle leaf goldenrod	Solidago rugosa	Liver aid, heart medicine, used to treat dizziness, weakness and sunstroke
She'dewaweode'	Spotted Joe-pye weed	Eupatorium maculatum	Antidiarrheal, Gastrointestinal aid, Venereal aid, Tuberculosis remedy
Otgo da'	American Elder berry	Sambucus canadensis	Analgesic, Dermatological aid, Laxative, Pediatric aid, Febrifuge (berries used for fever)
Osdisda:ne'	Eastern Bottle Brush	Elymus hystrix	Kidney aid compound, Ceremonial medicine used to treat seed corn
Oeohgwa'	Sweet Flag	Acorus americana	Cold remedy, Anthelmintic, Gastrointestinal aid, Toothache remedy, Heart medicine
O'eohdo:t	Broad Leaf Cattail	Typha latifolia	Dermatological aid, orthopedic aid, Burn dressing, Venereal aid, food source
	Watercress	Rorippa nasturtium-aquaticum	Analgesic, Liver aid, food source, belly aches
	Broadleaf arrowhead	Sagittoria latifolia	Antirheumatic, Dermatological aid, Laxative, used as fertilizer to start corn

Seneca Name	Common Name	Latin Name	Usage
	American white-water lily	Nymphaea odorata	Cough medicine, toothache remedy, food source
	Northern watermilfoil	Myriophyllum sibiricum	Blood medicine, emetic, Pediatric aid

4.3 Alternatives Analysis

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

- Description
- Benefit
- Limitation
- Reason to exclude

4.3.1 Do Nothing Alternative

4.3.1.a Description

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

4.3.1.b Benefit

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

4.3.1.c Limitation

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

4.3.1.d Reason to exclude

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

4.3.2 Grading Alternative

4.3.2.a Description

This alternative would involve grading back the slope to create a more gradual swash and wave runup zones.

4.3.2.b Benefit

This alternative would produce a longer wave dissipation zone in which vegetation and shoreline/beach materials can attenuate wave energy.

4.3.2.c Limitation

There is limited space between the existing trail and the shoreline. This alternative requires additional land disturbance and earthwork that will need to be removed from the sites.

4.3.2.d Reason to exclude

Space limitations. Additional land disturbance will require the removal of earth and vegetation that is currently helping the stabilization of the existing shoreline.

4.3.3 Concrete Wave Attenuation Structures Alternative

4.3.3.a Description

There are several proprietary concrete wave attenuation systems which have been proven effective at dampening wave energy and protecting shorelines. An example of such a system is provided in **Error! Reference source not found.**.

Figure 12. Concrete ring wave attenuation system (Image from Wayfarer Environmental Technologies

4.3.3.b Benefit

These systems have a long history of success in other river systems. While obstructive, they do not completely cover the bed materials as riprap would. The ring shape provided a protected bed that still allows vegetation to grow up through the rings. The use of pervious concrete also mimics a gradual bed and increases oxygen transport.

4.3.3.c Limitation

These types of products typically have an unnatural aesthetic. The placement of concrete fill is a regulatory challenge. They can colonize zebra mussels.

4.3.3.d Reason to exclude

At this site, rock reefs can yield similar benefits with fewer challenges.

4.4 Remaining Scope of Work to Complete Design and Permitting

- Additional detailed hydrodynamic modelling analysis to confirm the placement of rock reefs.
- Mussel survey will be necessary. This can have impacts to the construction schedule.
- Finalize drawings and plan sheets
  - Design details
- Complete technical specifications
  - Draft custom specs for sections related to habitat restoration.
  - Finalize general specifications.
- Permitting
  - See section 6 Regulatory and Environmental Compliance review of expected permitting.
  - Completion of federal, and state.
- Preparation of bidding and contract documents
  - Including scope of work, construction phasing, budget

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

4.5 Construction Cost Estimate

Estimated costs for each site are included in Figures 13,14 and 15. Material and labor costs can vary as it is unknown when construction of this project will proceed.

CSO Niagara River					
Itemized Statement of Probable Engineering Construction Costs					
Site 83					Date: 2023-2-27
Item Description	**Unit**	**Quantity**	**Unit Cost**	**Extension**	**Sub Total**
Mobilization/Demobilization	Allow	1	$30,000	$30,000	$30,000
Site Preparation/Grading	Allow	1	$30,000	$30,000	$30,000
Temporary Facilites	Allow	1	$50,000	$50,000	$50,000
Select Tree Removal	Allow	1	$20,000	$20,000	$20,000
Chemical Treatment Invasive Shrubs	Acre	0.27	$1,500	$405	$405
Foliar Chemical Treatment Invasives	Acre	0.27	$1,500	$405	$405
Rock Reefs					
NYSDOT Heavy Stone	CYDS	3,284	$80	$262,720	$262,720
NYSDOT Medium Stone	CYDS	145	$75	$10,875	$10,875
4 inch Minus Stone Fill	CYD	228	$50	$11,400	$11,400
Soil Mix Fill	CYD	524	$40	$20,960	$20,960
Plantings	EA	2,901	$20	$58,020	$58,020
Rootwads w/Anchoring	EA	10	$5,000	$50,000	$50,000
Coconut Fiber Mat	SQFT	11,095	$3	$33,285	$33,285
Select Medium NYSDOT Medium Toe Stone	CYDS	97	$80	$7,760	$7,760
Shoreline Habitat					
Sand Fill	CYDS	680	$30	$20,400	$20,400
Cabled Logs w/Anchoring	EA	2	$3,500	$7,000	$7,000
Woody Debris	EA	1	$5,000	$5,000	$5,000
Select Medium NYSDOT Medium Toe Stone	CYDS	60	$75	$4,500	$4,500
Stormwater Treatment Wetland					
Slope Regrading	EA	1	$5,000	$5,000	$5,000
NSDOT Medium Stone	CYDS	40	$50	$2,000	$2,000
Soil Mixture	CYDS	735	$40	$29,400	$29,400
Wetland Plants	EA	806	$5	$4,030	$4,030
Vegetated Rip-Rap					
Bags w/Plants	EA	1,935	$18	$34,830	$34,830
Coir Logs	EA	137	$100	$13,700	$13,700
Signage	Allow	1	$5,000	$5,000	$5,000
Area A					
Live Stakes	EA	220	$18	$3,960	$3,960
Emergent Plugs	EA	75	$15	$1,125	$1,125
Area B					
Emergent Plugs	EA	575	$15	$8,625	$8,625
Container Plants	EA	10	$40	$400	$400
Area C					
Plugs	EA	1,600	$12	$19,200	$19,200
Area D					
Seed Mix	SFT	39,710	$2	$59,565	$59,565
Restoration of Project Disturbed Areas	EA	1	$10,000	$10,000	$10,000
				Sub Total	$819,565
				10% Contingency	$81,957
				Total	$901,522

Figure 13. Site 83 Cost Estimate

CSO Niagara River					
Itemized Statement of Probable Engineering Construction Costs					
Site 85/86					Date: 2023-2-27
Item Description	Unit	Quantity	Unit Cost	Extension	Sub Total
Mobilization/Demobilization	Allow	1	$30,000	$30,000	$30,000
Site Preparation/Grading	Allow	1	$30,000	$30,000	$30,000
Temporary Facilites	Allow	1	$50,000	$50,000	$50,000
Select Tree Removal	Allow	1	$20,000	$20,000	$20,000
Chemical Treatment Invasive Shrubs	Acre	0.15	$1,500	$225	$225
Foliar Chemical Treatment Invasives	Acre	0.15	$1,500	$225	$225
Rock Reefs					
NYSDOT Heavy Stone	CYDS	3,329	$80	$266,320	$266,320
NYSDOT Medium Stone	CYDS	157	$75	$11,775	$11,775
4 inch Minus Stone Fill	CYD	154	$50	$7,700	$7,700
Soil Mix Fill	CYD	294	$40	$11,760	$11,760
Plantings	EA	1,557	$20	$31,140	$31,140
Rootwads w/Anchoring	EA	14	$5,000	$70,000	$70,000
Coconut Fiber Mat	SQFT	5,775	$3	$17,325	$17,325
Toe Stone	CYDS	50	$80	$4,000	$4,000
Sand Fill	CYDS	16	$30	$480	$480
Shoreline Habitat					
Sand Fill	CYDS	120	$30	$3,600	$3,600
Cabled Logs w/Anchoring	EA	2	$3,500	$7,000	$7,000
Woody Debris	EA	1	$5,000	$5,000	$5,000
Toe Stone	CYDS	21	$80	$1,680	$1,680
Select Medium NYSDOT Medium Stone	CYDS	9	$75	$675	$675
Stormwater Treatment Wetland					
Slope Regrading	EA	1	$5,000	$5,000	$5,000
NSDOT Medium Stone	CYDS	28	$50	$1,400	$1,400
Soil Mixture	CYDS	42	$40	$1,680	$1,680
Wetland Plants	EA	1	$5	$5	$5
Vegetated Rip-Rap					
Bags w/Plants	EA	1,350	$18	$24,300	$24,300
Signage	Allow	1	$5,000	$5,000	$5,000
Area A					
Live Stakes	EA	110	$18	$1,980	$1,980
Area D					
Seed Mix	SFT	26,770	$2	$40,155	$40,155
Restoration of Disturbed Areas	EA	1	$10,000	$10,000	$10,000
				Sub Total	$658,425
				10% Contingency	$65,843
				Total	$724,268

Figure 14. Site 85/86 Cost Estimate

CSO Niagara River					
Itemized Statement of Probable Engineering Construction Costs					
Site 91					Date: 2023-2-27
Item Description	**Unit**	**Quantity**	**Unit Cost**	**Extension**	**Sub Total**
Mobilization/Demobilization	Allow	1	$30,000	$30,000	$30,000
Site Preparation/Grading	Allow	1	$10,000	$10,000	$10,000
Temporary Facilites	Allow	1	$40,000	$40,000	$40,000
Select Tree Removal	Allow	1	$40,000	$40,000	$40,000
Chemical Treatment Invasive Shrubs	Acre	0.36	$1,500	$540	$540
Foliar Chemical Treatment Invasives	Acre	0.36	$1,500	$540	$540
Rock Reefs					
NYSDOT Heavy Stone	CYDS	832	$80	$66,560	$66,560
4 inch Minus Stone Fill	CYD	24	$50	$1,200	$1,200
Soil Mix Fill	CYD	118	$40	$4,720	$4,720
Plantings	EA	589	$20	$11,780	$11,780
Rootwads w/Anchoring	EA	10	$5,000	$50,000	$50,000
Coconut Fiber Mat	SQFT	2,505	$3	$7,515	$7,515
Toe Stone	CYDS	10	$80	$800	$800
Vegetated Rip-Rap					
Bags w/Plants	EA	1,275	$18	$22,950	$22,950
Signage	Allow	1	$5,000	$5,000	$5,000
Restoration of Disturbed Areas	EA	1	$10,000	$10,000	$10,000
				Sub Total	$301,605
				10% Contingency	$30,161
				Total	$331,766

Figure 15. Site 91 Cost Estimate

4.6 Items for Consideration under the 100% Design

The following list are key comments that should be considered under the 100% design phase:

1. The State Botanist should be consulted before state-threatened or state-endangered species are included in this planting plan, especially if a regional seed source has not been identified. This applies to watercress and prairie dropseed.
2. Discuss the merits of herbaceous vs woody plantings in the reefs.
    a. The reviewers are currently split on this topic.
        i. Some feel herbaceous will be harder to establish.
        ii. Some feel that woody material could destabilize the reef when it is blown over by wind or ice.

4.7 Risk Register

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

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

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

Table 3 Risk Register for Habitat Enhancement Projects at Tifft Nature Preserve and Potential Management Strategies

Risk	Minimize Risk	Mitigate Risk	Accept
Low- or high- water levels causing plant mortality during the establishment period.	Not applicable, controlling water levels to prevent plant mortality is beyond our ability to manipulate.	Require a one year warranty of all plant material. Plant emergent and wet meadow species across a range of elevations	Replant any vegetation as needed.
Proliferation of invasive species	Use best practices for native plantings also include appropriate herbicides to reduce risk of emergence	Include a 5-year maintenance/warranty agreement	Fund West River Shoreline Trail to coordinate the maintenance via separate contractors.
Potential failure of cables securing buoyant material	Use best practices and marine chain, minimum 1/2" alloy steel w/15,000lb load limit to secure root wads to stone	Include a 5-year maintenance/warranty agreement	Fund West River Shoreline Trail to coordinate the maintenance via separate contractors
Structural failure due to constant wave energy or extreme events with high wave energy	Use best practices and properly sized angular stone to resist mobilization of structures	Include a 5-year maintenance/warranty agreement	Fund West River Shoreline Trail to coordinate the maintenance via separate contractors
The construction contractor defaults on their warranty agreement.	Hire a reputable contractor with a positive history of upholding their warranty agreements.	Require a warranty bond to complete the warranty work via a separate contractor.	Fund West River Shoreline Trail to coordinate the maintenance via separate contractors.
Low water leading to more exposed wood and premature decay of root wad structure.	Not applicable; variations in water levels are beyond our ability to manipulate.	Include some fast-growing, short-life trees in the planting plan.	Wood Decay is a natural process and an acceptable risk

Risk	Minimize Risk	Mitigate Risk	Accept
Construction activities could impact public recreational access to the shoreline.	Contractor to prioritize public access points early in construction	Contractor to clearly mark access points to keep the public away from construction areas and heavy machinery	Install signage and provide public outreach when access will be available
Mowing will impact the natural accumulation of native species after planting	Use best practices for native plantings	Clearly delineate mowing areas from non-mowing areas with signage and other structures such as rocks	Fund West River Shoreline Trail to coordinate the maintenance via separate contractors.
Rock reefs provide a navigational hazard	Reef structure height to be 2'ft above the water surface and planted with live stakes	Signage to be added notifying boaters of the reef the structures	Install signage and provide public outreach at local marinas and boat launches. Provide for the maintenance of the reef vegetation.

5 Project Plan

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

5.1 Pre- and Post-Construction Monitoring Plan

5.1.1 Background and Purpose

This monitoring plan will serve as a guiding document to ensure the long-term success of the West River Shoreline Trail/Niagara River Shoreline & Aquatic Habitat Restoration project. Monitoring activities will include a mix of qualitative and quantitative assessments. All observations, measurements, and data downloads should be carefully documented by the field crew. This monitoring approach was adapted from the monitoring plan developed for the rubble ridges at Illinois Beach State Park.

5.1.2 General Schedule and Logistics

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

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

5.1.3 Dissolved Oxygen

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

5.1.4 Bank Cover Quantification

Vegetation monitoring along the bank through the project extent will use quantitative methods to evaluate long term success. Field staff will visually inspect the bank in its entirety and estimate the percentage (%) of bank covered in woody vegetation. This may be done on the entire length of bank or evaluated in sections. If evaluated in sections, the section length must be noted and similarly used in future monitoring.

If the mortality of the woody vegetation exceeds 70%, maintenance activities should be ordered to place additional live stakes.

In addition to bank cover quantification, field crews should also inspect rootwads for signs of rot and disturbance to the surrounding soil or changes to the angle of the root wads relative to the flow. Root wads are installed on the outside bend with a slight orientation facing upstream and should be submerged. Any visible signs that differ from expected conditions should be captured with detailed notes, photos, and location.

5.1.5 Debris Accumulation

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

5.1.6 Photos & Aerial Survey

To document changes to the project over time, photos should be taken during each site visit. For general site photos, these should be taken from the same location and orientation on each visit to best capture temporal changes. More detailed photos may be required depending on site conditions. These detailed photos should capture the preceding monitoring categories. If any maintenance is performed in the field, all activities will need to be documented in a field notebook or tablet, and photos should be taken to show before and after conditions.

In addition to site photos, an aerial drone survey should be flown along the site corridor, capturing the project extents at a minimum. This survey must be flown in the same direction each year.

5.1.7 Bed and Bank Stability

Bed and bank boulders will be inspected to identify material that has been displaced. Displaced material should be identified and photographed. If displaced material, or the voids left by displaced material, constitute a potential threat to the channel stability, maintenance activities should be ordered to address the issue. Indicators of a potential threat include:

- Exposed filter fabric
- Exposed anchoring material
- Bulk soil sluffing from the banks
- A hydraulic jump/standing wave in an unprotected portion of the bed
- Under-cutting and sluffing of the bank stones
- Total dislodging of the root wads

5.1.8 Erosion

Visual identification of bank and floodplain erosion should be conducted for each site. The most problematic erosion includes drainage outfalls and large rill/gully erosion on the upper banks. If erosion is identified, it should be located, and photo documented. Maintenance needs for erosion will be determined on a case-by-case basis.

5.1.9 Vegetation Monitoring and Maintenance

Plantings at the site will include woody and herbaceous plants in upland and floodplain areas, emergent vegetation, and submerged aquatic plantings. Vegetation monitoring through the project extent will use quantitative methods as a means of evaluating long term success. New submerged and emergent plantings may need protection from rough fish and other herbivores using a wire enclosure. Wave breaking devices may also be needed to protect submerged plantings. Temporary fencing can also be used to protect upland plantings from human or animal damage.

Monitoring is recommended for at least five years. Most plantings are expected to take two years to establish. During the first year after planting, upland plants should be watered regularly to keep soil moist. After the first year, regular watering is not needed unless there has been a lack of rainfall. Other establishment activities should include regular weeding and removal of invasive species within the planting area, fertilizing (if needed), and litter and debris removal.

Vegetative cover should be quantified annually. For upland and bank vegetation, field staff will visually inspect the bank in its entirety and estimate the percentage (%) of bank covered in vegetation. This may be done on the entire length of bank/reef or evaluated in sections. If evaluated in sections, the section length must be noted and similarly used in future monitoring. A similar approach should be taken for the rock reef, where the reef is visually inspected in its entirety and the percentage of cover by submerged and emergent vegetation is estimated. Emergent vegetation will also be planted in rip rap void spaces, which will serve as convenient sampling locations. For each area, field staff should record all herbaceous and non-vascular plant species present. Genera, family, or broader classifications are acceptable for some groups. Record percent cover of each species that is rooted within the plot. Field staff should count only foliage from individual plants rooted within the plot.

Restoration involves natural systems with many variables that can trigger unintended consequences; as such, adaptive management can help address the vegetation maintenance plan as new information becomes available. Replanting is not recommended in the first two years as vegetation is getting established. After that, it is generally recommended that if the mortality of the vegetation exceeds 70%, replanting activities should be ordered. If certain plant species are exhibiting higher mortality rates than others, it is not recommended to replant with these same species. On the other hand, if a certain species establishes well in the project area, this plant could be used to replace those with higher mortality rates.

5.1.10 Invasive Species Management

Invasive plant species can drastically impact an ecosystem by dominating the area and choking out growth of native species. Aggressive species such as Phragmites and buckthorn are common in the area. Prevention of these species from overtaking the project area will require routine monitoring to ensure populations are not found, and if they are, proper maintenance techniques applied. Ultimately, prevention is the most effective management strategy for any invasive species. Identifying mother colony sources and preventing their seed and vegetative spread into the site is imperative to prevent the spread of Phragmites, buckthorn, and other invasive species into the site. Prevention measures are the front line of invasive species management and should be implemented with all management activities and uses into and within the site. Seed sources, vegetation sources, and bare ground should be carefully managed and monitored to prevent spread.

Monitoring

Field staff should establish monitoring transects along the length of the project that can be followed with each visit. Visual inspections will be made and any areas where invasives are found should be documented with photos and GPS coordinates. This information should be made available to invasive species managers in order to develop an appropriate response to treatment. Recolonization can occur from remnant and neighboring populations and the existing seed bank in soil. Minimizing the impact from neighboring populations may not be possible, in which case annual monitoring and early detection becomes even more imperative. Following detection of resprout or recolonization, initial herbicide treatment should be implemented as quickly as possible along with any follow up treatment deemed necessary.

Maintenance

There are several maintenance and control methods for various invasive species. Field staff and invasive species managers will need to determine which control method is best suited to the particular species while also considering the extent to which treatment is required. A few examples of control methods are:

- Herbicide (first approach in most cases and should be done prior to any mechanical removal)
- Prescribed fire
- Mowing
- Hand cutting
- Drill and Fill Injection

5.2 Post-Project Public Outreach Plan

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

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

- Awareness of project-specific habitat restoration benefits
- Education about the importance of habitat restoration to maintaining wildlife
- Education about the eco-culturally valued species identified by the Seneca Nation.

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

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

Target Audience	Activity Type	Communication Method	Timing	Example
Public	Online	Social media engagement	Opportunistic	Publish Twitter and Facebook posts documenting post-construction monitoring or advertising press releases on NYSOPRHP and/or county websites.
Public	Online	Press release	After project completion	Develop a press release for the restoration project (LimnoTech

Target Audience	Activity Type	Communication Method	Timing	Example
				would be happy to write a web-article about the project).
Public	Print	Interpretive signage	After project completion	Engage with the Seneca Nation to develop signage that highlights the value of incorporating traditional knowledge into restoration projects.
Professional	In-person	Conference presentation	Annual conference	Engineering with Nature(EWN) Conference
Professional	Online	Web article	During Design	Web article on CSO or DEC website to highlight the value of these types of projects and the opportunities they present.

6 Regulatory and Environmental Compliance Review

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

6.1 Federal

- Nation Wide Permit 27
    - Construction of open water areas and activities related to the re-establishment of native plant communities and the removal of non-native species.
    - Typically this type of project would require a pre-construction notification/Joint permit application submitted to USACE. Through the review process of the joint permit, coverage by completing NWP 27 would be confirmed. The Pre-Construction Notification (PCN) process can take time and must be taken into account for planning purposes.
- Endangered Species Act and the National Historic Preservation Act (Section 106)

6.2 State

- State Environmental Quality Review (SEQR)
    - The projects identified in this report are likely to meet the Type I action criteria because the impact area is greater than 2.5 acres in a park
    - NYSOPRHP will be the lead agency.
    - NYSDEC Water Quality Certifications (WQCs) are always required when a federal permit is required. This may be included with an NWP, however considering the presence of mussels at site 85/86 means a blanket WQC without a Joint Permit Application is unlikely.

Table 5 Summary of State Level Permitting and Environmental Review

Agency	Permits and Reviews	Details
NYSDEC	Article 15 – Protection of Waters Permit	This project would be exempt from this permit
NYSDEC	Article 24 – Freshwater Wetlands Permit	No regulated wetlands present but may change in January 2025

Agency	Permits and Reviews	Details
NYSDEC	Section 401 Water Quality Certification	Likely Required
NYSDEC	Part 182 – Endangered and Threatened Species of Fish and Wildlife; Species of Special Concern; Incidental Take Permits	Site 85/86 has found mussel shells. (Survey likely needed, but we don't anticipate impacts) Black chin shiners were found at several of the sites.
NY Natural Heritage Program (NYNHP)	Screening for rare species and significant natural communities	Parks to review.
NYS State Historic Preservation Office (NYSHPO)	Review for sites of historical significance	Reviewed in parallel to Parks review of NYNHP.

6.3 Local

Since this site is on state property, local permits are not anticipated.

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Appendix A: GZA Geotechnical Report

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MEMORANDUM

Date: October 12, 2022

To: Mr. Craig Taylor, P.E., Project Manager, Limnotech

From: Todd Bown, P.G., GZA GeoEnvironmental of New York
Jesse D. Graham P.E., GZA GeoEnvironmental of New York
Dan Veriotti P.E., GZA GeoEnvironmental of New York

File No.: 20.0157847.00 Task 0002

Re: Site No. 83, 85+86, and 91 Niagara River Shoreline Stabilization
Erie County
Grand Island, New York

cc: Vidya Balasubramanyam, Program Director, Coastal States Organization

GZA GeoEnvironmental of New York (GZA) is pleased to provide the findings of our subsurface exploration activities at three locations along the western shoreline of the Niagara River, commonly referred to as West River Parkway, and located in Grand Island, Erie County, New York (collectively, the "Sites"). The three sites have been previously identified as No. 83, No. 85+86, and No. 91, and increase in number designation from the south to the north along West River Parkway. The locations of the three sites and subsurface exploration boring locations are provided on **Figures 1, 2 and 3**. The work was conducted in general accordance with our February 28, 2022, Proposal, File No. 20.P0000639.22. This Memorandum provides our methodology, findings, and recommendations for follow-up activities. This Memorandum and the information presented herein are subject to the Limitations provided in **Attachment 1.**

BACKGROUND AND SITE CONDITIONS

The Sites are located along the western shoreline of Grand Island on the Niagara River on property that is managed by the New York State Parks, Recreation and Historical Preservation (NYSPRHP). At one time West River Parkway was a seasonal use road, but now has been converted to public bicycle and walking path. The three sites have been impacted erosion from the river, and each have been exhibiting signs of slope stability.

Site No. 83 has approximately 1,200 feet of shoreline length starting just north of a private drive round- about. The slope at the site is steep. The crest of the sites slope is approximately 50-feet east of the water's edge, and the slope is covered with heavy vegetative brush from the shoreline to the middle of the slope, beyond the middle of the slope is open lawn maintained by NYSPRHP. Riprap is present along the shoreline at the water's edge.

Site No. 85+86 has approximately 1,400 feet of shoreline length, which is unprotected. The slope at the site is steep, and narrow gravel beach is exposed along the shoreline. The crest of the sites slope is approximately 50-feet east of the water's edge, and the slope is covered with vegetative brush from the shoreline to the crest of the slope, beyond the crest is open lawn maintained by NYSPRHP. Directly beneath the slopes crest is a scarp face indicative of previous slope failures, as well as several tension cracks orientated parallel to the shoreline.

Site No. 91 has approximately 600 feet of shoreline. The slope at the site is steep. The crest of the sites slope is less than 30-feet east of the water's edge, and the slope is covered with heavy vegetative brush from the shoreline to the crest. Riprap and armor stone randomly placed is present along the shoreline at the water's edge.

Topographic and bathymetric survey data of the sites were obtained by GZA's subcontractor, KHEOPS Architecture, Engineering, and Survey, DPC (KHEOPS). Photographs of sites are provided in **Attachment 2**. We understand that "nature-based" methods for stabilizing the shorelines are being considered and are preferred for the project.

EXPLORATION ACTIVITIES

GZA contracted with Earth Dimensions, Inc. EDI) of Elma, New York to complete geotechnical drilling of two borings (B-1 and B-2) at Site No. 83. Access to the other sites were limited. Borings were located using a handheld GPS unit with a horizontal accuracy of about 1 foot. Prior to drilling, EDI called in an underground utility locate (UDIGNY Hotline) to identify and locate potential subsurface utilities. EDI used a track-mounted Diedrich D50 drill rig and 4.25-inch inside diameter, hollow-stem augers to advance the soil borings to depths of up to 40 feet below ground surface (bgs) and recover soil samples. Standard Penetration Test (SPT) and classification of soil samples was performed continuously at 2-foot intervals in the upper 16 feet and at 5-foot intervals thereafter, in general accordance with American Society for Testing and Materials (ASTM) D1586, *Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils*. SPT samples were used to estimate relative hardness of cohesive soils and retain samples for additional laboratory testing. At B-2, two undisturbed Shelby tube samples were collected for performing laboratory tests on relatively undisturbed soil samples. Groundwater was not encountered during drilling not at completion of test borings. Test borings were backfilled with drilling A GZA engineer logged the soil samples. The boring logs are provided in **Attachment 3**.

Soils at both borings generally consisted of a brown, Sand to Clayey SAND, and little to some root's fibers present within the first foot. Fine-grained, Silty CLAY was encountered till target depth at both boring locations until target completion depth.

GZA performed dynamic cone penetrometer (DCP) testing at each Site to further delineate the Silty CLAY encountered at the test borings performed near the crest of the slope at Site No. 83 and the other two sites. DCP is an in-situ field test using a handheld device used to provide an indication of relative degree of compaction. Originally developed for pavement design but has been adapted for geotechnical purposes based on published references providing correlations for SPT N-values. GZA performed an initial correlation adjacent to the test bore location of B-1 with the DCP by hand auguring to a depth of 2-feet below grade then performing the DCP test. GZA performed two DCP tests along the shoreline of at Site No. 83, one test at along the shoreline at Site No. 85+86 and Site No. 91. DCP test sheets are provided in **Attachment 4**. In addition, GZA completed one hand soil auger to a depth of 7-feet below at the shoreline of Site 85+86 to confirm the presence of Silty CLAY soils.

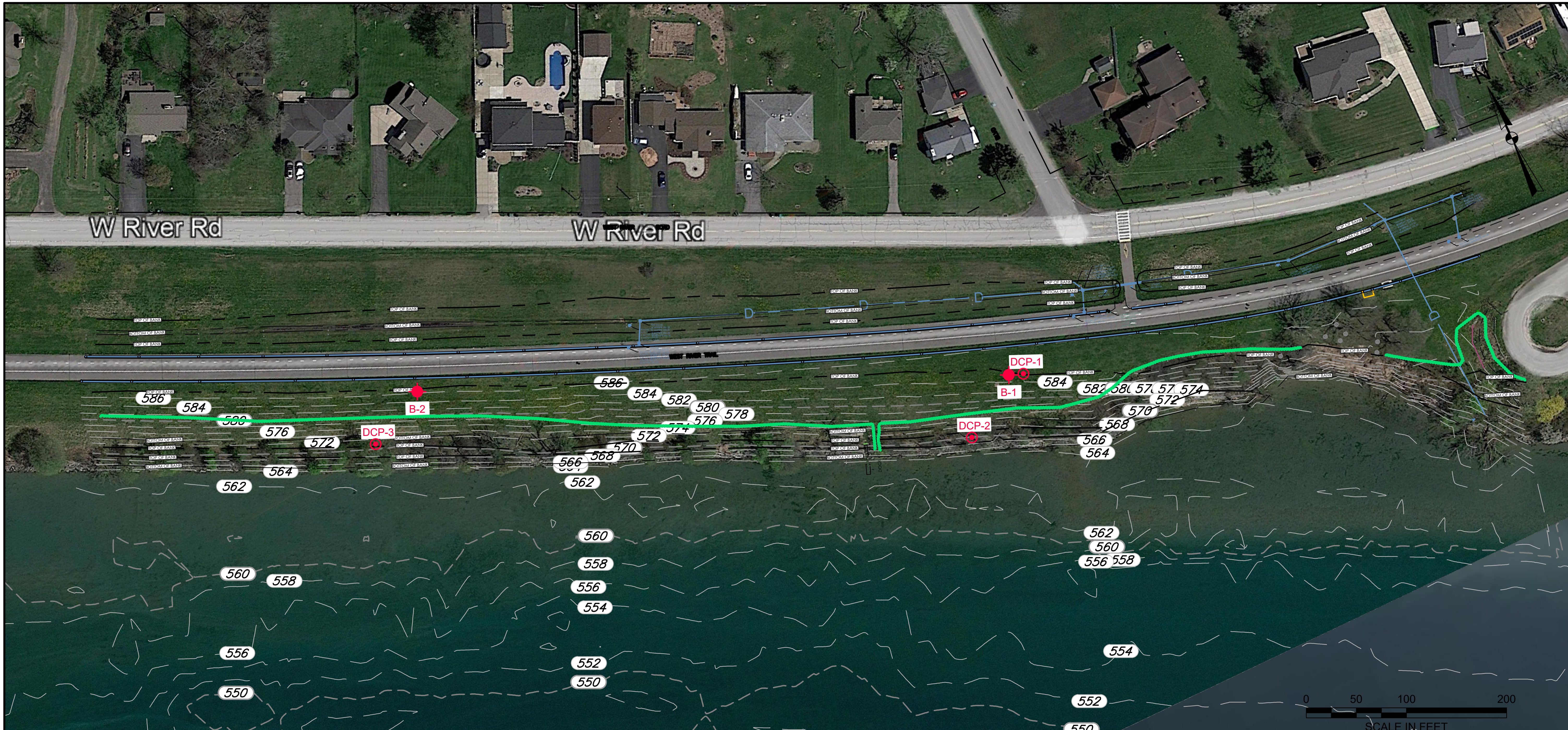
GEOTECHNICAL LABORATORY TESTING

GZA collected samples, which have been retained but due to budgetary constraints, no geotechnical analysis was performed.

CONCLUSIONS AND RECOMMENDATIONS

Based on the limited geotechnical data collected and our observations, GZA concludes that the encountered Silty CLAY is laterally continuous across all three sites. GZA also concludes that the field data measurements collected at each DCP locations has correlated been correlated with and estimated SPT value for the provided elevation (depth). For preliminary design we recommend that a slope of not greater than 3H:1V be utilized for regrading at each Site. Shallow slopes may be required based on the risk tolerance of the design team and are a function, in part, of the shoreline protection methodology chosen. GZA recommends additional borings be completed to fully delineate Site No. 85+86 and 91, along with task authorizations for geotechnic index and strength testing, and slope stability modeling.

FIGURES



LEGEND

580	CONTOUR (MAJOR)
581	CONTOUR (MINOR)
	PROPERTY LOT LINE (APPROX)
	ROW (APPROX)
BOTTOM OF SLOPE	SLOPE - BOTTOM
TOP OF SLOPE	SLOPE - TOP
	WOOD LINE
B-1	BORING LOCATION
DCP-2	DYNAMIC CONE PENETROMETER (DCP) TEST LOCATION
HA-1	HAND AUGER TEST HOLE LOCATION

REFERENCES

EXISTING SITE PLAN DEVELOPED FROM THE FOLLOWING:

1. DRAWING PROVIDED BY KHEOPS ARCHITECTURE, ENGINEERING & SURVEY, DPC. (KHEOPS) TITLED "CONTROL TIES, LEGENDS AND NOTES," OFFICE DATED AUGUST 30, 2022, FIELD DATED AUGUST 25, 2022, ORIGINAL SCALE 1"=20', SHEET 1 OF 1.
2. HORIZONTAL DATUM IS BASED ON NAD 1983 FROM DRAWING PROVIDED BY KHEOPS TITLED "CONTROL TIES, LEGENDS AND NOTES". COORDINATES SHOWN ON THIS SURVEY ARE BASED ON THE NEW YORK STATE PLANE COORDINATE SYSTEM - WESTERN ZONE.
3. VERTICAL DATUM IS BASED ON NAVD '88 FROM DRAWING PROVIDED BY KHEOPS TITLED "CONTROL TIES, LEGENDS AND NOTES".
4. LOCATION OF UTILITIES DEVELOPED FROM ELECTRONIC DRAWING TITLED "CONTROL TIES, LEGENDS AND NOTES", CREATED BY KHEOPS, DATED AUGUST 30, 2022, ORIGINAL SCALE 1"=20'.
5. AERIAL IMAGE FROM GOOGLE EARTH PRO.

NO.	ISSUE/DESCRIPTION	BY	DATE

UNLESS SPECIFICALLY STATED BY WRITTEN AGREEMENT, THIS DRAWING IS THE SOLE PROPERTY OF GZA GEOENVIRONMENTAL, INC. (GZA). THE INFORMATION SHOWN ON THE DRAWING IS SOLELY FOR USE BY GZA'S CLIENT OR THE CLIENT'S DESIGNATED REPRESENTATIVE FOR THE SPECIFIC PROJECT AND LOCATION IDENTIFIED ON THE DRAWING. THE DRAWING SHALL NOT BE TRANSFERRED, REUSED, COPIED, OR ALTERED IN ANY MANNER FOR USE AT ANY OTHER LOCATION OR FOR ANY OTHER PURPOSE WITHOUT THE PRIOR WRITTEN CONSENT OF GZA. ANY TRANSFER, REUSE, OR MODIFICATION TO THE DRAWING BY THE CLIENT OR OTHERS, WITHOUT THE PRIOR WRITTEN EXPRESS CONSENT OF GZA, WILL BE AT THE USER'S SOLE RISK AND WITHOUT ANY RISK OR LIABILITY TO GZA.

GRAND ISLAND SHORELINE STABILIZATION PROJECT
GRAND ISLAND, NEW YORK

BORING AND DCP TEST LOCATION PLAN
SITE 83

PREPARED BY: GZA GeoEnvironmental of NY, Engineers and Scientists, www.gza.com

PREPARED FOR: LIMNOTECH

PROJ MGR: DV	REVIEWED BY: BK	CHECKED BY: TGB	FIGURE
DESIGNED BY:	DRAWN BY: MDK	SCALE: AS SHOWN	1
DATE: SEPTEMBER, 2022	PROJECT NO. 20.0157847.00	REVISION NO.	

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LEGEND

580	CONTOUR (MAJOR)
581	CONTOUR (MINOR)
	PROPERTY LOT LINE (APPROX)
	ROW (APPROX)
BOTTOM OF SLOPE	SLOPE - BOTTOM
TOP OF SLOPE	SLOPE - TOP
	WOOD LINE
B-1	BORING LOCATION
DCP-2	DYNAMIC CONE PENETROMETER (DCP) TEST LOCATION
HA-1	HAND AUGER TEST HOLE LOCATION

REFERENCES

EXISTING SITE PLAN DEVELOPED FROM THE FOLLOWING:

1. DRAWING PROVIDED BY KHEOPS ARCHITECTURE, ENGINEERING & SURVEY, DPC. (KHEOPS) TITLED “CONTROL TIES, LEGENDS AND NOTES,” OFFICE DATED AUGUST 30, 2022, FIELD DATED AUGUST 25, 2022, ORIGINAL SCALE 1"=20', SHEET 1 OF 1.
2. HORIZONTAL DATUM IS BASED ON NAD 1983 FROM DRAWING PROVIDED BY KHEOPS TITLED “CONTROL TIES, LEGENDS AND NOTES". COORDINATES SHOWN ON THIS SURVEY ARE BASED ON THE NEW YORK STATE PLANE COORDINATE SYSTEM - WESTERN ZONE.
3. VERTICAL DATUM IS BASED ON NAVD '88 FROM DRAWING PROVIDED BY KHEOPS TITLED “CONTROL TIES, LEGENDS AND NOTES".
4. LOCATION OF UTILITIES DEVELOPED FROM ELECTRONIC DRAWING TITLED "CONTROL TIES, LEGENDS AND NOTES", CREATED BY KHEOPS, DATED AUGUST 30, 2022, ORIGINAL SCALE 1"=20'.
5. AERIAL IMAGE FROM GOOGLE EARTH PRO.

NO.	ISSUE/DESCRIPTION	BY	DATE

UNLESS SPECIFICALLY STATED BY WRITTEN AGREEMENT, THIS DRAWING IS THE SOLE PROPERTY OF GZA GEOENVIRONMENTAL, INC. (GZA). THE INFORMATION SHOWN ON THE DRAWING IS SOLELY FOR USE BY GZA'S CLIENT OR THE CLIENT'S DESIGNATED REPRESENTATIVE FOR THE SPECIFIC PROJECT AND LOCATION IDENTIFIED ON THE DRAWING. THE DRAWING SHALL NOT BE TRANSFERRED, REUSED, COPIED, OR ALTERED IN ANY MANNER FOR USE AT ANY OTHER LOCATION OR FOR ANY OTHER PURPOSE WITHOUT THE PRIOR WRITTEN CONSENT OF GZA. ANY TRANSFER, REUSE, OR MODIFICATION TO THE DRAWING BY THE CLIENT OR OTHERS, WITHOUT THE PRIOR WRITTEN EXPRESS CONSENT OF GZA, WILL BE AT THE USER'S SOLE RISK AND WITHOUT ANY RISK OR LIABILITY TO GZA.

GRAND ISLAND SHORELINE STABILIZATION PROJECT
GRAND ISLAND, NEW YORK

BORING AND DCP TEST LOCATION PLAN
SITE 85+86

PREPARED BY:
GZA GeoEnvironmental of NY
Engineers and Scientists
www.gza.com

PREPARED FOR:
LIMNOTECH

PROJ MGR: DV	REVIEWED BY: BK	CHECKED BY: TGB	FIGURE
DESIGNED BY:	DRAWN BY: MDK	SCALE: AS SHOWN	2
DATE: SEPTEMBER, 2022	PROJECT NO. 20.0157847.00	REVISION NO.	

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LEGEND

580	CONTOUR (MAJOR)
581	CONTOUR (MINOR)
	PROPERTY LOT LINE (APPROX)
	ROW (APPROX)
BOTTOM OF SLOPE	SLOPE - BOTTOM
TOP OF SLOPE	SLOPE - TOP
	WOOD LINE
B-1	BORING LOCATION
DCP-2	DYNAMIC CONE PENETROMETER (DCP) TEST LOCATION
HA-1	HAND AUGER TEST HOLE LOCATION

REFERENCES

EXISTING SITE PLAN DEVELOPED FROM THE FOLLOWING:

1. DRAWING PROVIDED BY KHEOPS ARCHITECTURE, ENGINEERING & SURVEY, DPC. (KHEOPS) TITLED “CONTROL TIES, LEGENDS AND NOTES,” OFFICE DATED AUGUST 30, 2022, FIELD DATED AUGUST 25, 2022, ORIGINAL SCALE 1"=20', SHEET 1 OF 1.
2. HORIZONTAL DATUM IS BASED ON NAD 1983 FROM DRAWING PROVIDED BY KHEOPS TITLED “CONTROL TIES, LEGENDS AND NOTES”. COORDINATES SHOWN ON THIS SURVEY ARE BASED ON THE NEW YORK STATE PLANE COORDINATE SYSTEM - WESTERN ZONE.
3. VERTICAL DATUM IS BASED ON NAVD '88 FROM DRAWING PROVIDED BY KHEOPS TITLED “CONTROL TIES, LEGENDS AND NOTES”.
4. LOCATION OF UTILITIES DEVELOPED FROM ELECTRONIC DRAWING TITLED "CONTROL TIES, LEGENDS AND NOTES", CREATED BY KHEOPS, DATED AUGUST 30, 2022, ORIGINAL SCALE 1"=20'.
5. AERIAL IMAGE FROM GOOGLE EARTH PRO.

NO.	ISSUE/DESCRIPTION	BY	DATE

UNLESS SPECIFICALLY STATED BY WRITTEN AGREEMENT, THIS DRAWING IS THE SOLE PROPERTY OF GZA GEOENVIRONMENTAL, INC. (GZA). THE INFORMATION SHOWN ON THE DRAWING IS SOLELY FOR USE BY GZA'S CLIENT OR THE CLIENT'S DESIGNATED REPRESENTATIVE FOR THE SPECIFIC PROJECT AND LOCATION IDENTIFIED ON THE DRAWING. THE DRAWING SHALL NOT BE TRANSFERRED, REUSED, COPIED, OR ALTERED IN ANY MANNER FOR USE AT ANY OTHER LOCATION OR FOR ANY OTHER PURPOSE WITHOUT THE PRIOR WRITTEN CONSENT OF GZA. ANY TRANSFER, REUSE, OR MODIFICATION TO THE DRAWING BY THE CLIENT OR OTHERS, WITHOUT THE PRIOR WRITTEN EXPRESS CONSENT OF GZA, WILL BE AT THE USER'S SOLE RISK AND WITHOUT ANY RISK OR LIABILITY TO GZA.

GRAND ISLAND SHORELINE STABILIZATION PROJECT
GRAND ISLAND, NEW YORK

BORING AND DCP TEST LOCATION PLAN
SITE 91

PREPARED BY:	PREPARED FOR:
GZA GeoEnvironmental of NY Engineers and Scientists www.gza.com	LIMNOTECH

PROJ MGR: DV	REVIEWED BY: BK	CHECKED BY: TGB	FIGURE
DESIGNED BY:	DRAWN BY: MDK	SCALE: AS SHOWN	3
DATE: SEPTEMBER, 2022	PROJECT NO. 20.0157847.00	REVISION NO.	

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ATTACHMENT 1

Limitations

LIMITATIONS

USE OF MEMO

1. GZA GeoEnvironmental, Inc. (GZA) prepared this Memo on behalf of, and for the exclusive use of our Client for the stated purpose(s) and location(s) identified in the Proposal for Services and/or Memo. Use of this Memo, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not expressly identified in the contract documents, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

STANDARD OF CARE

2. GZA's findings and conclusions are based on the work conducted as part of the Scope of Services set forth in Proposal for Services and/or Memo, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. If conditions other than those described in this Memo are found at the subject location(s), or the design has been altered in any way, GZA shall be so notified and afforded the opportunity to revise the Memo, as appropriate, to reflect the unanticipated changed conditions.

3. GZA's services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services, at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.

4. In conducting our work, GZA relied upon certain information made available by public agencies, Client and/or others. GZA did not attempt to independently verify the accuracy or completeness of that information. Inconsistencies in this information which we have noted, if any, are discussed in the Memo.

SUBSURFACE CONDITIONS

5. The generalized soil profile(s) provided in our Memo are based on widely-spaced subsurface explorations and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs. The nature and extent of variations between these explorations may not become evident until further exploration or construction. If variations or other latent conditions then become evident, it will be necessary to reevaluate the conclusions and recommendations of this Memo.

6. In preparing this Memo, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein which were made available to GZA at the time of our evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

7. Water level readings have been made in test holes (as described in this Memo) and monitoring wells at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Memo. Fluctuations in the level of the groundwater however occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The water table encountered in the course of the work may differ from that indicated in the Memo.

8. GZA's services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently, we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.

9. Recommendations for foundation drainage, waterproofing, and moisture control address the conventional geotechnical engineering aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

COMPLIANCE WITH CODES AND REGULATIONS

10. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

ADDITIONAL SERVICES

11. GZA recommends that we be retained to provide services during any future: site observations, design, implementation activities, construction and/or property development/redevelopment. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

ATTACHMENT 2

Photographic Log

Site Visit Photographs

Great Lakes CSO - Niagara River

September-22

Photo 1 - Drill rig set up near crest of slope at Site No. 83. Photograph view toward south taken from NYSPRHP dock site permit 41.

Photo 2 - Subcontracted drillers retrieving undisturbed (Shelby) tube sample from B-2 at Site No. 83.

Site Visit Photographs
Great Lakes CSO - Niagara River
September-22

Photo 3 - Recovered split spoon sample from test boring, showing recovered core sample of Silty CLAY.

Photo 4 - Tension cracks observed in clay soil slope at Site No. 85+86.

Photo 5 - GZA Engineer collecting hand auger soil samples near shoreline at Site No. 85+86.

Photo 6 - Recovered soil sample from hand augering near shoreline at Site No. 85+86. Confirmation of Silty CLAY soils up to a depth of 7-feet below ground surface.

Photo 7 - View to the south at Site No. 91. Note Vegetative scrub-like brush at crest of slope.

Photo 8 - Note exposed clay along slope at Site No. 91.

Photo 9 - Performing Dynamic Cone Penetrometer (DCP) test at Site No. 91. Note armor stone along shoreline.

ATTACHMENT 3

Soil Boring Logs and Summary Sheet

TEST BORING LOG

GZA GeoEnvironmental, Inc. *Engineers and Scientists*	Limnotech Great Lakes CSO - Niagara River Grand Island New York	**EXPLORATION NO.:** B-1 **SHEET:** 1 of 2 **PROJECT NO:** 20.015787.00 Task 0002 **REVIEWED BY:** T. Bown

Logged By: M. Kress
Drilling Co.: Earth Dimensions, Inc.
Foreman: P. Bence

Type of Rig: Track
Rig Model: Diedrich D50
Drilling Method: HSA

Boring Location: See Plan
Ground Surface Elev. (ft.): 584
Final Boring Depth (ft.): 40
Date Start - Finish: 9/21/2022 -

H. Datum: NAD83
V. Datum: NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4.25

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size:

Groundwater Depth (ft.)

Date	Time	Stab. Time	Water	Casing
Not Measured				

Depth (ft)	Casing Blows/ (Core Rate)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description (Modified Burmister Classification)	Remark	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
		S1	0.0-2.0	24	19	6 8 9 9	17	S1: (Top 2-in) Brown, SAND, some roots, moist. (Bottom 17-in) Brown, Silty CLAY, trace fine to coarse Sand, trace fine Gravel (angular), moist. PP > 4.5tsf.		0.5	TOPSOIL	583.5
		S2	2.0-4.0	24	14	7 8 9 9	17	S2: Brown, Silty CLAY, trace fine to coarse Sand, trace fine Gravel (angular), moist. PP > 4.5tsf.	1			
5		S3	4.0-6.0	24	18	5 6 7 7	13	S3: Brown, Silty CLAY, trace fine to coarse Sand, moist. PP > 4.5tsf.				
		S4	6.0-8.0	24	24	4 4 6 8	10	S4: Brown, Silty CLAY, moist. PP = 3.0tsf.				
		S5	8.0-10.0	24	24	3 5 7 9	12	S5: Similar as to sample (S4) above. PP = 3.5tsf.				
10		S6	10.0-12.0	24	21	3 5 7 9	12	S6: Similar as to sample (S4) above. PP = 3.0tsf.				
		S7	12.0-14.0	24	22	3 4 7 9	11	S7: Similar as to sample (S4) above. PP = 3.0tsf.				
15		S8	14.0-16.0	24	24	4 4 5 6	9	S8: Similar as to sample (S4) above. PP = 1.0tsf.			SILTY CLAY	
		S9	18.0-20.0	24	24	2 4 5 5	9	S9: Similar as to sample (S4) above. PP = 1.5tsf.				
20												
		S10	23.0-25.0	24	20	2 3 5 5	8	S10: Similar as to sample (S4) above. PP = 3.5tsf.				
25												
		S11	28.0-30.0	24	22	2 2 3 3	5	S11: Similar as to sample (S4) above. PP = 0.75tsf.				
30												

REMARKS

1 - PP = Field Pocket Penetrometer Readings reported in tons per square foot (tsf).

See Log Key for exploration of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: B-1

GZA TEMPLATE TEST BORING - GZA GINT DATA TEMPLATE 10-27-20.GDT - 10/7/22 13:19 - J:\21\GINT PROJECT DATABASES\TEST 2022.GPJ

TEST BORING LOG

GZA GeoEnvironmental, Inc. *Engineers and Scientists*	Limnotech Great Lakes CSO - Niagara River Grand Island New York	**EXPLORATION NO.:** B-1 **SHEET:** 2 of 2 **PROJECT NO:** 20.015787.00 Task 0002 **REVIEWED BY:** T. Bown

Logged By: M. Kress **Drilling Co.:** Earth Dimensions, Inc. **Foreman:** P. Bence	**Type of Rig:** Track **Rig Model:** Diedrich D50 **Drilling Method:** HSA	**Boring Location:** See Plan **Ground Surface Elev. (ft.):** 584 **Final Boring Depth (ft.):** 40 **Date Start - Finish:** 9/21/2022 -	**H. Datum:** NAD83 **V. Datum:** NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4.25

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size:

Groundwater Depth (ft.)				
Date	**Time**	**Stab. Time**	**Water**	**Casing**
Not Measured				

Depth (ft)	Casing Blows/ (Core Rate)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description (Modified Burmister Classification)	Remark	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
		S12	33.0-35.0	24	24	1 1 2 2	3	S12: Similar as to sample (S4) above. PP = 0.25tsf.				
35											SILTY CLAY	
		S13	38.0-40.0	24	24	1 1 2 3	3	S13: Similar as to sample (S4) above. PP = 0.25tsf.				
40								End of exploration at 40 feet		40		544.0
45												
50												
55												
60												

REMARKS

See Log Key for exploration of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: B-1

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

Limnotech
Great Lakes CSO - Niagara River
Grand Island
New York

EXPLORATION NO.: B-2
SHEET: 1 of 2
PROJECT NO: 20.015787.00 Task 0002
REVIEWED BY: T. Bown

Logged By: M. Kress
Drilling Co.: Earth Dimensions, Inc.
Foreman: P. Bence

Type of Rig: Track
Rig Model: Diedrich D50
Drilling Method: HSA

Boring Location: See Plan
Ground Surface Elev. (ft.): 586
Final Boring Depth (ft.): 40
Date Start - Finish: 9/21/2022 -

H. Datum: NAD83
V. Datum: NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4.25

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size:

Groundwater Depth (ft.)				
Date	Time	Stab. Time	Water	Casing
Not Measured				

Depth (ft)	Casing Blows/ (Core Rate)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description (Modified Burmister Classification)	Remark	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
		S1	0.0-2.0	24	12	3 4 6 5	10	S1: (Top 4-in) Brown, Clayey SAND, little roots, mosit. (Bottom 8-in) Brown, Silty CLAY, trace fine to coarse Sand, trace fine Gravel, moist. PP > 4.5tsf.		0.5	TOPSOIL	585.5
		S2	2.0-4.0	24	14	6 6 7 7	13	S2: Brown, Silty CLAY, trace fine to coarse Sand, moist. PP > 4.5tsf.	1			
5		S3	4.0-6.0	24	20	5 7 8 9	15	S3: Brown, Silty CLAY, trace fine to coarse Sand, moist. PP > 4.5tsf.				
		S4	6.0-8.0	24	24	5 6 8 10	14	S4: Brown, Silty CLAY, moist. PP > 4.5tsf.				
		S5	8.0-10.0	24	20	3 4 6 6	10	S5: Similar as to sample (S4) above. PP > 4.5tsf.				
10		S6	10.0-12.0	24	24	4 5 7 9	12	S6: Similar as to sample (S4) above. PP = 3.5tsf.				
		S7	12.0-14.0	24	24	3 4 5 6	9	S7: Brown, Silty CLAY, trace fine to coarse Sand, moist. PP = 2.8tsf.				
15		S8	14.0-16.0	24	24	2 3 5 6	8	S8: Similar as to sample (S7) above. PP = 2.8tsf.			SILTY CLAY	
		S9	18.0-20.0	24	24	2 3 4 6	7	S9: Similar as to sample (S7) above. PP = 2.5tsf.				
20												
		S10	23.0-25.0	24	24	1 3 4 3	7	S10: Similar as to sample (S7) above. PP = 0.8tsf.				
25		T1	25.0-27.0	24	20	PUSH		T1: Collected undisturbed tube sample.				
		S11	28.0-30.0	24	14	2 2 4 4	6	S11: Brown, Silty CLAY, moist.				
30												

REMARKS

1 - PP = Field Pocket Penetrometer Readings reported in tons per square foot (tsf).

See Log Key for exploration of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: B-2

GZA TEMPLATE TEST BORING - GZA GINT DATA TEMPLATE 10-27-20.GDT - 10/7/22 13:20 - J:\21\GINT PROJECT DATABASES\TEST 2022.GPJ

TEST BORING LOG

GZA GeoEnvironmental, Inc. *Engineers and Scientists*	Limnotech Great Lakes CSO - Niagara River Grand Island New York	**EXPLORATION NO.:** B-2 **SHEET:** 2 of 2 **PROJECT NO:** 20.015787.00 Task 0002 **REVIEWED BY:** T. Bown

Logged By: M. Kress **Drilling Co.:** Earth Dimensions, Inc. **Foreman:** P. Bence	**Type of Rig:** Track **Rig Model:** Diedrich D50 **Drilling Method:** HSA	**Boring Location:** See Plan **Ground Surface Elev. (ft.):** 586 **Final Boring Depth (ft.):** 40 **Date Start - Finish:** 9/21/2022 -	**H. Datum:** NAD83 **V. Datum:** NAVD88

Hammer Type: Automatic Hammer **Hammer Weight (lb.):** 140 **Hammer Fall (in.):** 30 **Auger or Casing O.D./I.D Dia (in.):** 4.25	**Sampler Type:** SS **Sampler O.D. (in.):** 2.0 **Sampler Length (in.):** 24 **Rock Core Size:**

Groundwater Depth (ft.)

Date	Time	Stab. Time	Water	Casing
Not Measured				

Depth (ft)	Casing Blows/ (Core Rate)	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows (per 6 in.)	SPT Value	Sample Description (Modified Burmister Classification)	Remark	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
		T2	30.0-32.0	24	24	PUSH		T2: Collected undisturbed tube sample.				
		S12	33.0-35.0	24	24	WOR WOH 1 1	1	S12: Brown, Silty CLAY, moist.	2			
35											SILTY CLAY	
		S13	38.0-40.0	24	14	1 3 10 11	13	S13: Gray-Brown, Silty CLAY, little fine to coarse Sand, little fine Gravel (rounded), moist.				
40								End of exploration at 40 feet		40		546.0
45												
50												
55												
60												

REMARKS

2 - WOR = Weight of Rods; WOH = Weight of Hammer

See Log Key for exploration of sample description and identification procedures. Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: B-2

GZA TEMPLATE TEST BORING - GZA GINT DATA TEMPLATE 10-27-20.GDT - 10/7/22 13:21 - J:\21\GINT PROJECT DATABASES\TEST 2022.GPJ

HAND AUGER LOG

GZA GeoEnvironmental of NY

Client:	LiminoTech	EXPLORATION NO.	HA-1
Project:	Great Lakes CSO - Niagara River	SHEET	1 of 1
Address	Site no. 85+86	GZA PROJECT NO.	20.015787.00 Task 0002
City, State:	Grand Island, New York	REVIEWED BY	T. Bown

LOGGED BY:	Kress/Bown	RIG TYPE:	NA	BORING LOCATION	See Plan	H. DATUM: NAD83	
DRILLING CO:	NA	MODEL:	NA	GROUND SURFACE EL.(FT)	569.00	V. DATUM: NAVD88	
FOREMAN:	NA	METHOD:	HAND AUGER	FINAL BORING DEPTH (FT)	7	DATE START/FINISH	

HAMMER TYPE:
HAMMER WEIGHT: SAMPLER:
HAMMER FALL: SAMPLER O.D.:
AUGER OR CASING O.D./I.D.: LENGTH:
CASING SIZE:

GROUNDWATER READINGS

DATE	TIME	WATER	CASING	STABILIZATION TIME

DEPTH feet	SAMPLE NO	SAMPLE DEPTH (feet)	PEN / REC (in)	RECOVERY (in)	BLOWS per 6" RQD (%)	SPT Value	SAMPLE DESCRIPTION AND IDENTIFICATION (MODIFIED BURMISTER PROCEDURE)	REMARK	STRATUM DESCRIPTION Depth (ft.) / Elev (ft.)
							Brown, fine to coarse **SAND**, moist		**TOP SOIL**
									2 / 567
2.5							Brown, **Silty CLAY**, moist.		**Silty CLAY**
									3.5 / 565.5
5							Brown, **Silty CLAY**, trace fine to coarse Sand laminae/partings, moist.		**Silty CLAY**
7.5							Bottom of Hand Exploration		
10									
12.5									
15									

REMARKS

EXPLORATION NO. HA-1

ATTACHMENT 4

Dynamic Cone Penetrometer Sheets

DCP NO.	DCP-1
SHEET 1 OF	1
FILE NO.	20.0157847.00
SURFACE ELEV.	585.0
DATUM	NAVD 88
ENGINEER	TGB/MDK

DYNAMIC CONE PENETRATION LOG

PROJECT: CSO Great Lakes Project - Niagara River, Grand Island, NY

LOCATION: Site 83 (See Figure1)

NOTES: Adjacent to completed Boring B-1, Hand augered to 2' then began test.

Length of rods: 4.50 feet

Length of extension rods: N/A feet

Depth from Surface Reference El.: 2.00 feet

Total Length of Rods (ft)	Measured Stickup (ft)	Depth from Grade (ft)	Depth from Surface El. (ft)	Test El. (Ft)	Interval Length (ft)	Blows Per Interval	Total Blows	PI (in/bl)	**SPT N-value (bpf)**	Remarks
4.5	2.5	0.0	2.0	583.0	0.0	0	0	0.0		Start of Test
4.5	2.3	0.3	2.3	582.8	0.3	3	3	1.0	19	
4.5	2.0	0.5	2.5	582.5	0.3	6	9	0.5	26	
4.5	1.8	0.8	2.8	582.3	0.3	7	16	0.4	29	
4.5	1.5	1.0	3.0	582.0	0.3	7	23	0.4	29	
4.5	1.3	1.3	3.3	581.8	0.3	6	29	0.5	26	
4.5	1.0	1.5	3.5	581.5	0.3	5	34	0.6	24	
4.5	0.8	1.8	3.8	581.3	0.3	6	40	0.5	26	
4.5	0.5	2.0	4.0	581.0	0.3	5	45	0.6	24	
										Test complete at
										depth of 4.0 feet
										relative to ground
										surface.

DYNAMIC CONE PENETRATION LOG

DCP NO.	DCP-2
SHEET 1 OF	1
FILE NO.	20.0157847.00
SURFACE ELEV.	566.0
DATUM	NAVD 88
ENGINEER	TGB/MDK

PROJECT: CSO Great Lakes Project - Niagara River, Grand Island, NY
LOCATION: Site 83 (See Figure 1)
NOTES: Downslope of completed Boring B-1, 8 ft. from waterline. Hand augered to 21 in. then began test.

Length of rods: 4.50 feet
Length of extension rods: N/A feet
Depth from Surface Reference El.: 1.75 feet

Total Length of Rods (ft)	Measured Stickup (ft)	Depth from Grade (ft)	Depth from Surface El. (ft)	Test El. (Ft)	Interval Length (ft)	Blows Per Interval	Total Blows	PI (in/bl)	SPT N-value (bpf)	Remarks
4.5	2.8	0.0	1.8	564.3	0.0	0	0	0.0		Start of Test
4.5	2.5	0.3	2.0	564.0	0.25	3	3	1.0	19	
4.5	2.3	0.5	2.3	563.8	0.25	2	5	1.5	15	
4.5	2.0	0.8	2.5	563.5	0.25	1	6	3.0	11	
4.5	1.8	1.0	2.8	563.3	0.25	1	7	3.0	11	
4.5	1.5	1.3	3.0	563.0	0.25	1	8	3.0	11	
4.5	1.3	1.5	3.3	562.8	0.25	1	9	3.0	11	
4.5	1.0	1.8	3.5	562.5	0.25	1	10	3.0	11	
4.5	0.8	2.0	3.8	562.3	0.25	2	12	1.5	15	
4.5	0.5	2.3	4.0	562.0	0.25	3	15	1.0	19	
4.5	0.3	2.5	4.3	561.8	0.25	4	19	0.8	22	
4.5	0.0	2.8	4.5	561.5	0.25	3	22	1.0	19	
4.5	-0.3	3.0	4.8	561.3	0.25	5	27	0.6	24	
4.5	-0.5	3.3	5.0	561.0	0.25	5	32	0.6	24	
4.5	-0.8	3.5	5.3	560.8	0.25	6	38	0.5	26	
4.5	-1.0	3.8	5.5	560.5	0.25	6	44	0.5	26	
										Test complete at depth of 5.75 feet relative to ground surface.

DCP NO.	DCP-3
SHEET 1 OF	1
FILE NO.	20.0157847.00
SURFACE ELEV.	568.0
DATUM	NAVD 88
ENGINEER	TGB/MDK

DYNAMIC CONE PENETRATION LOG

PROJECT: CSO Great Lakes Project - Niagara River, Grand Island, NY

LOCATION: Site 83 (See Figure 1)

NOTES: 8 ft. from waterline. Hand augered to 11 in. then began test.

Length of rods: 4.50 feet

Length of extension rods: N/A feet

Depth from Surface Reference El.: 0.90 feet

Total Length of Rods (ft)	Measured Stickup (ft)	Depth from Grade (ft)	Depth from Surface El. (ft)	Test El. (Ft)	Interval Length (ft)	Blows Per Interval	Total Blows	PI (in/bl)	**SPT N-value (bpf)**	Remarks
4.5	3.6	0.0	0.9	567.1	0.0	0	0	0.0		Start of Test
4.5	3.4	0.3	1.2	566.9	0.3	5	5	0.6	24	
4.5	3.1	0.5	1.4	566.6	0.3	11	16	0.3	36	
4.5	2.9	0.8	1.7	566.4	0.3	6	22	0.5	26	
4.5	2.6	1.0	1.9	566.1	0.3	5	27	0.6	24	
4.5	2.4	1.3	2.2	565.9	0.3	6	33	0.5	26	
4.5	2.1	1.5	2.4	565.6	0.3	8	41	0.4	31	
4.5	1.9	1.8	2.7	565.4	0.3	5	46	0.6	24	
4.5	1.6	2.0	2.9	565.1	0.3	5	51	0.6	24	
4.5	1.4	2.3	3.2	564.9	0.3	5	56	0.6	24	
4.5	1.1	2.5	3.4	564.6	0.3	6	62	0.5	26	
4.5	0.9	2.8	3.7	564.4	0.3	5	67	0.6	24	
4.5	0.6	3.0	3.9	564.1	0.3	4	71	0.8	22	
4.5	0.4	3.3	4.2	563.9	0.3	5	76	0.6	24	
4.5	0.1	3.5	4.4	563.6	0.3	7	83	0.4	29	
4.5	-0.2	3.8	4.7	563.4	0.3	5	88	0.6	24	
4.5	-0.4	4.0	4.9	563.1	0.3	5	93	0.6	24	
4.5	-0.7	4.3	5.2	562.9	0.3	4	97	0.8	22	
4.5	-0.9	4.5	5.4	562.6	0.3	4	101	0.8	22	
										Test complete at
										depth of 4.9 feet
										relative to ground
										surface.

DYNAMIC CONE PENETRATION LOG

DCP NO.	DCP-4
SHEET 1 OF	1
FILE NO.	20.0157847.00
SURFACE ELEV.	566.0
DATUM	NAVD 88
ENGINEER	TGB/MDK

PROJECT: CSO Great Lakes Project - Niagara River, Grand Island, NY

LOCATION: Site 85+86 (See Figure 2)

NOTES: Adjacent to hand auger test hole HA-1 (refusal at 7 ft. bgs). 6 ft. from waterline. Test initiated at ground surface

Length of rods: 6.50 feet

Length of extension rods: N/A feet

Depth from Surface Reference El.: 0.00 feet

Total Length of Rods (ft)	Measured Stickup (ft)	Depth from Grade (ft)	Depth from Surface El. (ft)	Test El. (Ft)	Interval Length (ft)	Blows Per Interval	Total Blows	PI (in/bl)	SPT N-value (bpf)	Remarks
6.5	6.5	0.0	0.0	566.0	0.0	0	0	0.0		Start of Test
6.5	6.3	0.3	0.3	565.8	0.3	1	1	3.0	11	
6.5	6.0	0.5	0.5	565.5	0.3	2	3	1.5	15	
6.5	5.8	0.8	0.8	565.3	0.3	2	5	1.5	15	
6.5	5.5	1.0	1.0	565.0	0.3	1	6	3.0	11	
6.5	5.3	1.3	1.3	564.8	0.3	2	8	1.5	15	
6.5	5.0	1.5	1.5	564.5	0.3	1	9	3.0	11	
6.5	4.8	1.8	1.8	564.3	0.3	2	11	1.5	15	
6.5	4.5	2.0	2.0	564.0	0.3	1	12	3.0	11	
6.5	4.3	2.3	2.3	563.8	0.3	2	14	1.5	15	
6.5	4.0	2.5	2.5	563.5	0.3	1	15	3.0	11	
6.5	3.8	2.8	2.8	563.3	0.3	1	16	3.0	11	
6.5	3.5	3.0	3.0	563.0	0.3	1	17	3.0	11	
6.5	3.3	3.3	3.3	562.8	0.3	2	19	1.5	15	
6.5	3.0	3.5	3.5	562.5	0.3	2	21	1.5	15	
6.5	2.8	3.8	3.8	562.3	0.3	3	24	1.0	19	
6.5	2.5	4.0	4.0	562.0	0.3	5	29	0.6	24	
6.5	2.3	4.3	4.3	561.8	0.3	6	35	0.5	26	
6.5	2.0	4.5	4.5	561.5	0.3	6	41	0.5	26	
6.5	1.8	4.8	4.8	561.3	0.3	8	49	0.4	31	
6.5	1.5	5.0	5.0	561.0	0.3	8	57	0.4	31	
6.5	1.3	5.3	5.3	560.8	0.3	8	65	0.4	31	
6.5	1.0	5.5	5.5	560.5	0.3	9	74	0.3	32	
6.5	0.8	5.8	5.8	560.3	0.3	9	83	0.3	32	
										Test complete at
										depth of 5.75 feet
										relative to ground
										surface.

DYNAMIC CONE PENETRATION LOG

DCP NO.	DCP-5
SHEET 1 OF	1
FILE NO.	20.0157847.00
SURFACE ELEV.	562.0
DATUM	NAVD 88
ENGINEER	TGB/MDK

PROJECT: CSO Great Lakes Project - Niagara River, Grand Island, NY

LOCATION: Site 91 (See Figure 3)

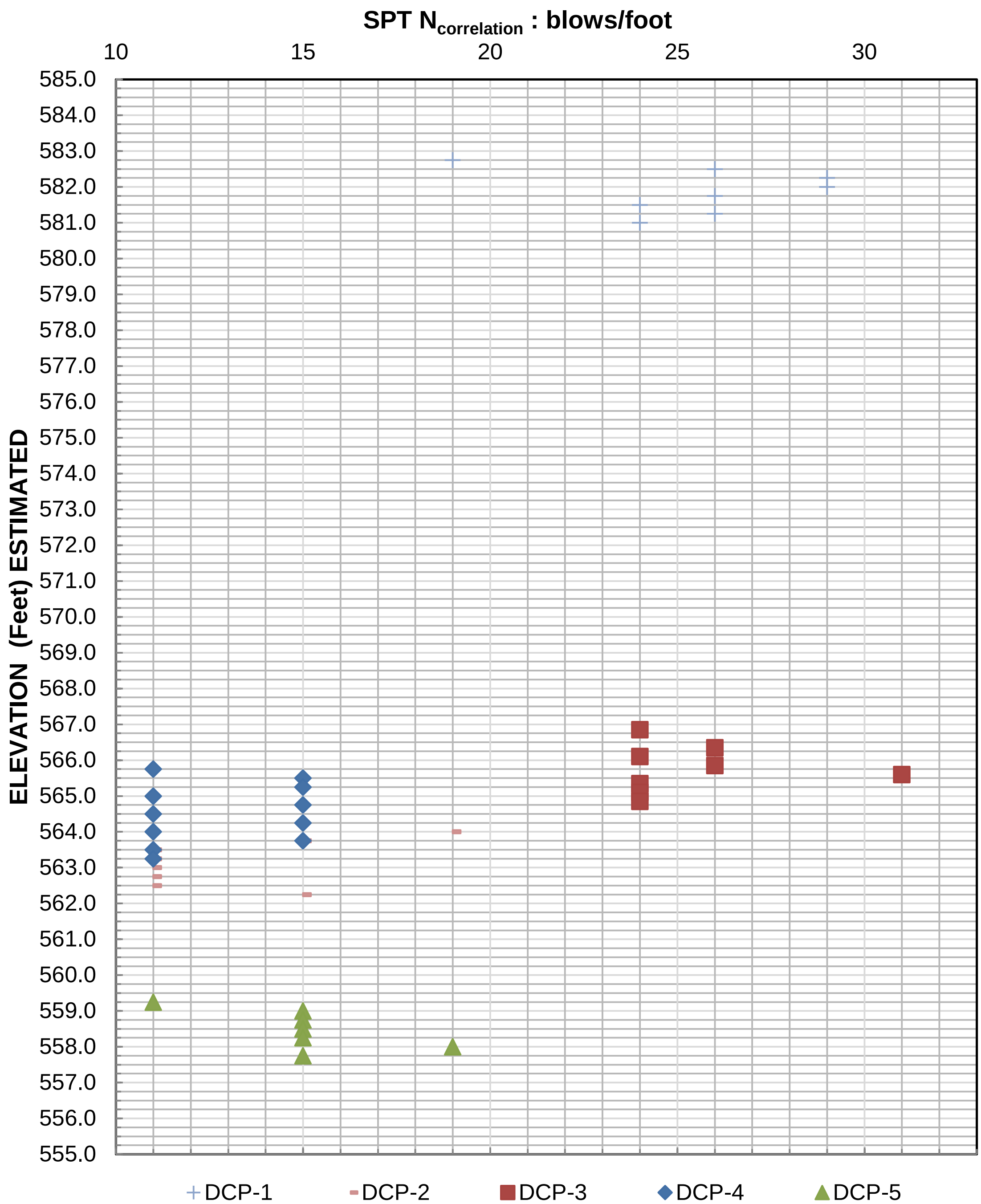
NOTES: Within Niagara River. 1 ft. from shoreline. Start of test at mudline. Water depth 0.8 ft. Weight of rods embedded point 1.7 ft. into strata, then began test.

Length of rods: 6.50 feet

Length of extension rods: N/A feet

Depth from Surface Reference El.: 2.50 feet **See Notes

Total Length of Rods (ft)	Measured Stickup (ft)	Depth from Grade (ft)	Depth from Surface El. (ft)	Test El. (Ft)	Interval Length (ft)	Blows Per Interval	Total Blows	PI (in/bl)	SPT N-value (bpf)	Remarks
6.5	4.0	0.0	2.5	559.5	0.0	0	0	0.0		Start of Test **
6.5	3.8	0.3	2.8	559.3	0.3	1	1	3.0	11	
6.5	3.5	0.5	3.0	559.0	0.3	2	3	1.5	15	
6.5	3.3	0.8	3.3	558.8	0.3	2	5	1.5	15	
6.5	3.0	1.0	3.5	558.5	0.3	2	7	1.5	15	
6.5	2.8	1.3	3.8	558.3	0.3	2	9	1.5	15	
6.5	2.5	1.5	4.0	558.0	0.3	3	12	1.0	19	
6.5	2.3	1.8	4.3	557.8	0.3	2	14	1.5	15	
6.5	2.0	2.0	4.5	557.5	0.3	1	15	3.0	11	
6.5	1.8	2.3	4.8	557.3	0.3	1	16	3.0	11	
6.5	1.5	2.5	5.0	557.0	0.3	2	18	1.5	15	
6.5	1.3	2.8	5.3	556.8	0.3	3	21	1.0	19	
6.5	1.0	3.0	5.5	556.5	0.3	4	25	0.8	22	
6.5	0.8	3.3	5.8	556.3	0.3	3	28	1.0	19	
6.5	0.5	3.5	6.0	556.0	0.3	3	31	1.0	19	
6.5	0.3	3.8	6.3	555.8	0.3	4	35	0.8	22	
										Test complete at
										depth of 3.3 feet
										relative to ground
										surface.



***NOTES*:**

1. SPT $N_{correlation}$ is the Standard Penetration Test N-value based on the Relationship Between DCP Penetration Index (DPI) and Standard Penetration Test Results (Ishai, I. and Livneh, M., 1988).
2. SPT $N_{correlation}$ is based on Dynamic Cone Penetration Tests performed in the field. Refer to the Dynamic Cone Penetration Log for field obtained data.

CSO Great Lakes Project GRAND ISLAND, NEW YORK		DYNAMIC CONE PENETRATION SUMMARY PLOT	
SHEET NO. 1 OF 1	Project 20.0157847.00	September 2022	FIGURE NO. 3

J:\21\Other Offices\20 Projects - Waukesha, WI\20.0157847.00 CSO Great Lakes Projects - Niagara River\Geotech Report\[DCP Data - Niagara River.xlsx]DCP-1

Appendix B: GZA Hydrologic Analysis Report

MEMORANDUM

Date: December 5, 2022

To: Craig Taylor, P.E., Project Manager, Limnotech

cc: Vidya Balasubramanyam, Program Director, Coastal States Organization

From: Dan Veriotti P.E., GZA GeoEnvironmental

File No.: 20.0157847.00 Task 4

Re: Niagara River Hydrology Summary
Erie County
Grand Island, New York

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F: 716.248.1472
www.gza.com

GZA GeoEnvironmental of New York (GZA) is pleased to provide a summary of the Niagara River hydrology and hydraulics, and the expected wind waves and boat wakes for the project sites, as part of the project's Basis of Design.

BACKGROUND AND SITE CONDITIONS

The project sites (83, 85+86, 91) are located along the west shoreline of Grand Island on the Niagara River on property that is managed by the New York State Parks, Recreation, and Historical Preservation (NYSPRHP). The West River Parkway was a seasonal use road, which was converted to a public bicycle and walking path. The three sites were impacted by shoreline erosion due to river velocities and waves.

Site No. 83 has approximately 1,200 feet of shoreline length starting just north of a private drive roundabout. The slope at the site is steep. The crest of the site's slope is approximately 50 feet from the water's edge and the slope is covered with heavy vegetative brush from the shoreline to the middle of the slope. Beyond the middle of the slope is an open lawn maintained by the NYSPRHP. Heavy riprap is present along the shoreline at the water's edge, along the majority of the property length.

Site No. 85+86 has approximately 1,400 feet of shoreline length, which is mostly unprotected. The side slope at the site is steep and a narrow, gravel beach is exposed along the shoreline. The crest of the site's slope is approximately 50 feet from the water's edge and the slope is covered with vegetative brush from the shoreline to the crest of the slope. Beyond the crest is an open lawn maintained by the NYSPRHP. Directly beneath the slope's crest, a scarp face was observed, indicative of previous slope failures, as well as several tension cracks oriented parallel to the shoreline.

Site No. 91 has approximately 600 feet of shoreline. The side slope at the site is steep. The crest of the site's slope is less than 30 feet from the water's edge and the slope is covered with heavy vegetative brush from the shoreline to the crest. Randomly placed riprap and armor stone (without good stone interlocking) are present along the shoreline at the water's edge.

Topographic and bathymetric survey data of the sites were obtained by GZA's subcontractor, KHEOPS Architecture, Engineering, and Survey, DPC (KHEOPS).

DOCUMENTS REVIEWED

The following data and documents were obtained and reviewed:

- West River Parkway Conceptual Design Addendum, Ecology and Environment, 2016;
- Water level gauges (National Oceanic and Atmospheric Administration [NOAA]: 9063012, United States Geological Survey [USGS]: 04216220);
- 2010-2011 Operating of the Lake Erie-Niagara River Ice Boom, International Niagara Working Committee, 2011;
- Buffalo and Niagara Rivers Habitat Assessment and Conservation Framework, Buffalo Niagara Waterkeeper, 2008;
- Niagara River Water Level and Flow Fluctuation Study, URS, 2003;
- Effect of Water Level and Flow Fluctuations on Aquatic and Terrestrial Habitat, URS, 2004;
- Submerged Aquatic Vegetation Mapping in the Niagara River, O'Brien and Gere, 2015; and
- Predicting Boat Generated Wave Heights, US Naval Academy, 2012.

The following is a summary of the documents reviewed, our analysis and findings.

RIVER HYDROLOGY AND HYDRAULICS

The Niagara River's annual average flow is approximately 220,000 cubic feet per second (cfs). The Lake Erie outflow into the river is immediately past Buffalo, New York. The river channel is relatively narrow (1,500 feet) with an average depth of 17 feet when it reaches a shallow rock ledge, which naturally controls its outflow. This constricted channel is spanned by Peace Bridge, with three piers that further restrict the channel.

The water levels are dynamic and variable based on project locations. The man-made influences include hydroelectric withdrawals and regulation on the Niagara Falls flow, while natural factors include the Great Lakes precipitation cycle, Lake Erie outflow, storm surge, and seiche events. The Lake Erie levels control the Niagara River levels (i.e., the river is under the backwater influence of the lake).

There are two regulatory constraints on flow and water level fluctuations - the Niagara River Water Diversion Treaty of 1950 and the 1993 Directive of the International Niagara Board of Control (INBC).

For purposes of generating electricity from the Niagara River, two different seasons are recognized, tourist season and non-tourist season. The tourist season (April through October) coincides with the months in which tourist hours are in effect. By adopted treaty, at least 100,000 cfs must be allowed to flow over Niagara Falls during tourist hours (April 1st to October 31st), and at least 50,000 cfs during other times.

Based on the requirements of the 1993 Directive of the INBC, water level fluctuations in the Chippawa-Grass Island Pool (in the upper Niagara River, including our project locations) are limited to 1.5 feet per day. The daily fluctuation is allowed within a 3-foot range for normal conditions. For extreme conditions (i.e., high flow, low flow, ice, etc.), the allowable range of Chippawa-Grass Island Pool water levels is extended to 4 feet and the 1.5 feet daily fluctuation tolerance can be waived.

At Grand Island, the Niagara River flow divides into two channels, the Chippawa Channel west of the island and the Tonawanda Channel to the east. Both channels are navigable. The Chippawa Channel has minimum depths of 10 feet below Chart Datum and is estimated to convey approximately 58% of the river flow.

The Chippawa Channel velocities are reported to be 2 to 3 feet per second (ft/sec). They were estimated by URS and the United States Army Corps of Engineers (USACE) from limited field measurements. It is noted that these are average velocities along transects perpendicular to the shoreline and that in the near-shore area, they are expected to be less significant. GZA conducted limited measurements at the project sites on June 6, 2022, with a floating object. In the near-shore area, approximately 20 feet form the shoreline, the surface river velocities were up to 1 ft/sec (Site 91) and up to 0.5 ft/sec at Sites 83 and 85/86.

The project sites are located between the downstream NOAA NYPA Intake (Station 9063012) and upstream USGS Black Rock Lock (Station 04216220) (see Figure 1).

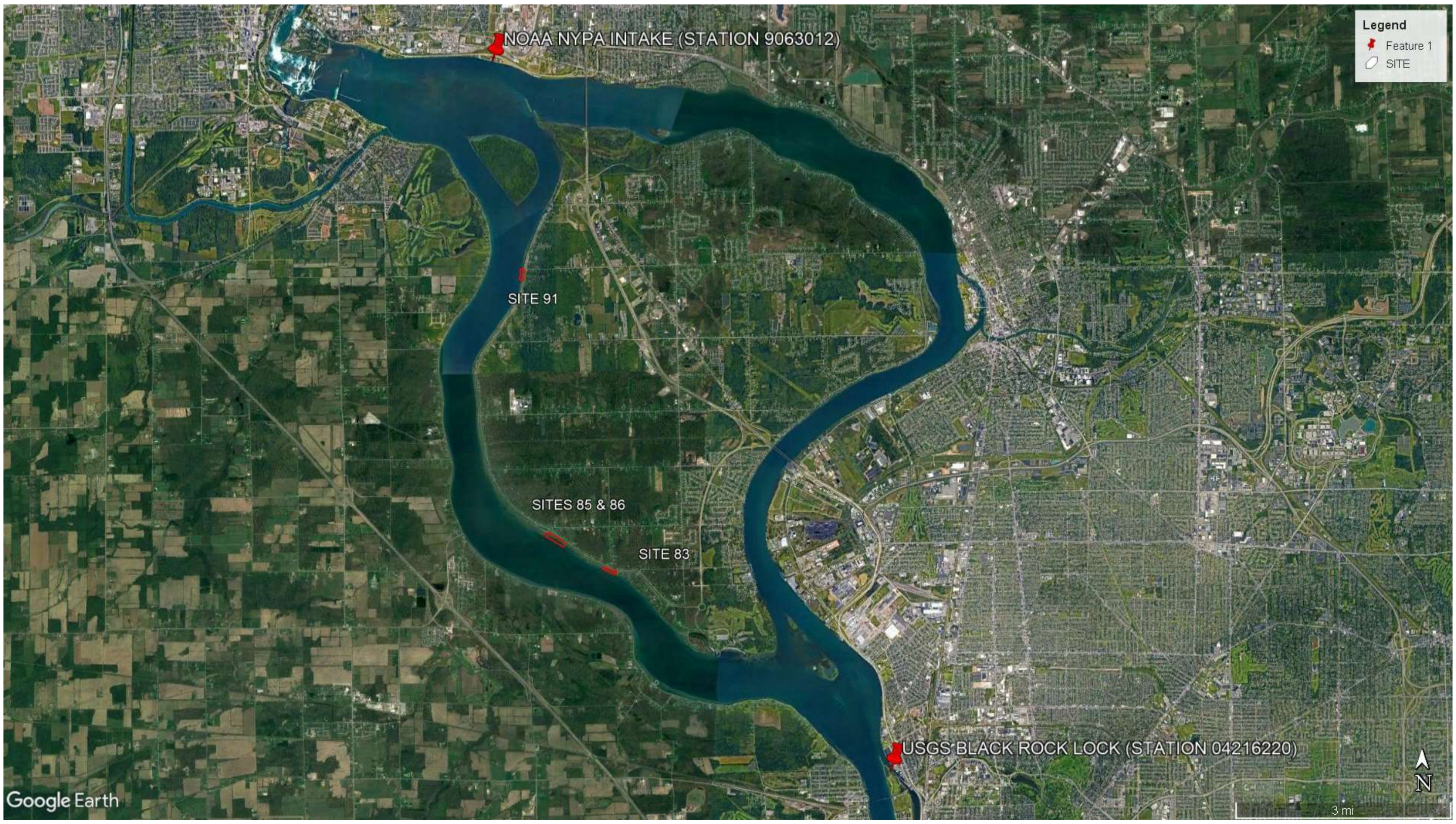

Figure 1. Project Location Map and Water Level Gauges

The historic recorded daily minimum and maximum are presented in Table 1.

Table 1. Daily Minimum and Maximum at the NOAA 9063012 and USGS 04216220 Stations

Station	Minimum (ft IGLD 85)	Maximum (ft IGLD 85)
USGS 04216220	561.92 (Jan. 14, 1999)	571.05 (Dec. 2, 1985)
NOAA 9063012	560.11 (Jan. 26, 2019)	564.65 (Nov. 1, 2019)

Notes:

1. ft IGLD 85 = feet, International Great Lakes Datum of 1985.

From the table, the largest recorded daily value was on December 2, 1985, by the USGS gauge and was due to a Lake Erie seiche that raised the water level in Buffalo by 6.6 feet, 2.9 feet at the Lock, and 2.4 feet at the Intake location.

It is noted that these are extreme recorded instantaneous daily values; as median daily averages, they are typically expected to vary only between 0.5- and 0.6-foot in the project area, respectively. Figure 2 shows data from the tourist versus non-tourist seasons. The more significant tourist season variances are recorded due to the more river diversions to meet the flow regulations during summer, and also due to the higher Lake Erie outflow from the natural cycle in the summer months.

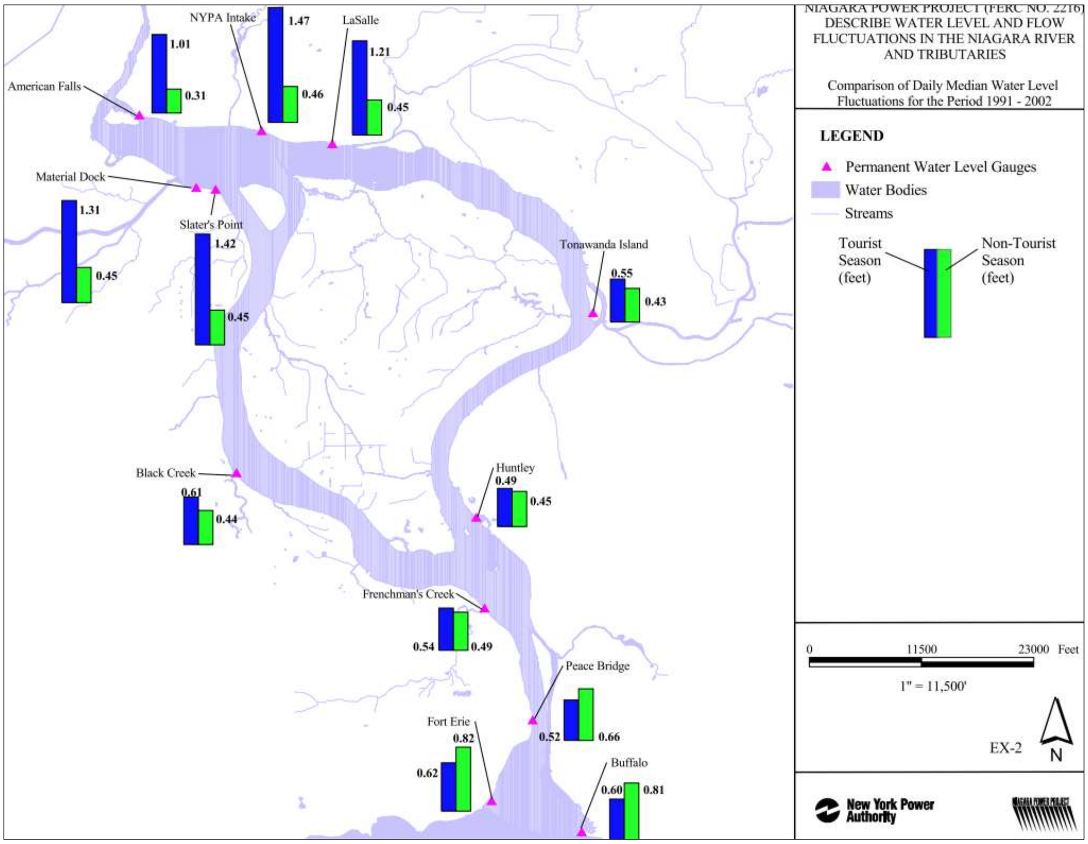

Figure 2. Daily Water Level Fluctuations (URS, 2003)

Based on calculations performed by URS at the Black Creek location (located across Grand Island on the Canadian side), Figure 3 shows the maximum daily fluctuations and the cause (Lake Erie surge/seiche), with a maximum daily variation between 1.73 feet and 3.36 feet, and a typical range of 2.0 to 3.0 feet due to Lake Erie surge/seiche influence.

Rank	Difference (ft) between Daily Max. & Min. Elev	Date of Event	Special Event (if applicable)
1	3.36	02/01/02	High Flow (surge at Ft. Erie)
2	3.34	12/03/91	Low to High Flow (surge at Ft. Erie)
3	3.32	10/30/96	High Flow (surge at Ft. Erie)
4	3.08	12/14/91	High Flow (surge at Ft. Erie)
5	2.97	03/10/02	High to Low Flow (surge at Ft. Erie)
6	2.92	03/09/02	High Flow (surge at Ft. Erie)
7	2.88	11/28/95	High Flow (surge at Ft. Erie)
8	2.77	01/27/96	High Flow (surge at Ft. Erie)
9	2.69	10/27/97	High Flow (surge at Ft. Erie)
10	2.68	12/17/00	High Flow (surge at Ft. Erie)
11 thru 20	2.60 - 2.14 feet		38 events were surges at Ft. Erie 2 events were fluctuations related to operations
21 thru 30	2.13 - 1.93 feet		
31 thru 40	1.93 - 1.85 feet		
41 thru 50	1.84 - 1.73 feet		

Figure 3. Daily Maximum Elevation Fluctuations at Black Creek (URS, 2003)

The river stage is highest in the summer months (June, July, and August) and lowest in the winter months (December, January, and February). Based on long-term monthly averages, the water level varies between 0.7-foot upstream of Grand Island (USGS gauge) and 0.5-foot downstream (NOAA gauge), as shown in Table 2.

Table 2. Long-Term Monthly Water Level Averages

Station	Long-Term Average Monthly (ft IGLD85)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
USGS 04216220	565.31	565.34	565.24	565.54	565.65	565.81	565.87	565.88	565.70	565.52	565.20	565.20
NOAA 9063012	561.80	561.70	561.75	562.05	562.07	562.15	562.17	562.10	562.03	561.97	561.77	561.81

Our computed monthly average differences are well in agreement with the daily computed averages (URS, 2003) at Black Creek (see Figure 4).

BLACK CREEK : 1991 - 2002

Year	Jan Min	Max	Ave	Feb Min	Max	Ave	Mar Min	Max	Ave	Apr Min	Max	Ave
1991	565.10	567.27	565.87	565.06	566.83	565.57	564.60	568.25	565.54	564.57	566.91	565.59
1992	564.38	567.15	565.42	564.74	566.40	565.37	564.45	566.75	565.34	564.48	566.12	565.41
1993	564.65	567.96	565.95	564.42	567.11	565.78	564.21	566.60	565.69	565.09	566.63	565.94
1994	564.22	566.87	565.31	563.84	566.18	565.05	564.70	565.92	565.34	564.86	566.48	565.62
1995	564.48	566.43	565.38	564.14	566.93	565.26	564.29	565.80	565.11	564.56	566.33	565.42
1996	563.53	567.26	565.08	564.41	566.19	564.91	563.93	566.92	564.97	564.29	565.98	565.22
1997	564.85	567.83	566.11	565.31	567.01	565.75	565.27	567.41	566.08	565.54	567.47	566.21
1998	565.15	567.49	565.88	565.03	566.42	565.77	564.69	567.80	565.97	564.92	566.84	566.01
1999	563.17	566.42	564.97	564.16	565.98	564.94	563.78	566.18	565.04	563.91	565.89	565.11
2000	563.80	566.09	564.60	563.85	565.91	564.47	564.01	565.25	564.54	563.79	565.66	564.77
2001	564.07	565.63	564.49	563.81	566.02	564.61	563.91	565.38	564.64	564.39	565.51	564.94
2002	563.43	565.87	564.72	564.32	567.80	564.89	564.02	568.58	564.87	564.46	565.85	565.17

Year	May Min	Max	Ave	Jun Min	Max	Ave	Jul Min	Max	Ave	Aug Min	Max	Ave
1991	564.64	566.56	565.60	564.51	566.12	565.41	564.57	565.92	565.30	564.49	565.77	565.17
1992	564.88	566.08	565.43	564.76	566.07	565.43	564.52	566.32	565.54	564.98	566.78	565.69
1993	565.30	566.29	565.84	565.11	566.37	565.76	565.16	566.38	565.79	564.83	566.25	565.65
1994	565.03	566.69	565.83	565.04	566.59	565.69	565.14	566.19	565.68	565.27	566.69	565.72
1995	564.80	565.98	565.44	564.60	565.78	565.27	564.90	566.19	565.51	564.89	565.96	565.48
1996	564.85	566.28	565.57	565.21	566.16	565.69	565.21	566.36	565.73	565.11	566.19	565.72
1997	565.57	567.77	566.11	565.47	566.92	566.27	565.77	567.05	566.18	565.60	567.05	566.05
1998	565.32	566.70	566.01	565.31	566.54	565.99	565.55	566.93	566.12	565.31	566.70	565.93
1999	564.49	566.39	565.29	564.59	565.86	565.29	565.02	565.85	565.42	564.61	566.17	565.34
2000	564.04	566.10	564.96	564.27	565.97	565.28	564.94	565.84	565.38	564.93	566.25	565.51
2001	564.43	565.56	564.96	564.69	565.77	565.21	564.29	565.70	565.01	564.32	565.87	565.00
2002	564.46	566.05	565.34	564.84	566.04	565.34	564.59	565.80	565.23	564.78	565.73	565.25

Year	Sep Min	Max	Ave	Oct Min	Max	Ave	Nov Min	Max	Ave	Dec Min	Max	Ave	Year Min	Max	Ave
1991	564.28	565.58	565.09	564.29	565.70	564.87	564.25	566.62	565.03	563.54	567.74	565.02	563.54	568.25	565.37
1992	565.11	566.48	565.75	564.89	567.44	565.63	564.48	568.76	565.88	564.94	567.89	565.83	564.38	568.76	565.58
1993	564.91	567.66	565.64	564.85	566.92	565.54	564.38	566.76	565.28	564.53	566.78	565.32	564.21	567.96	565.69
1994	564.81	566.38	565.48	564.49	566.31	565.28	564.46	567.10	565.32	564.19	566.18	565.08	563.84	567.10	565.44
1995	564.56	566.03	565.31	563.59	566.64	565.37	564.51	567.58	565.25	564.02	567.08	565.16	563.59	567.58	565.32
1996	565.01	567.11	565.84	565.11	568.56	565.85	565.01	566.65	565.64	564.55	567.11	565.78	563.53	568.56	565.49
1997	565.64	567.37	566.21	564.75	567.90	565.82	564.45	567.05	565.79	564.65	566.65	565.75	564.45	567.90	566.02
1998	565.21	566.53	565.77	564.87	566.43	565.49	564.53	566.51	565.17	564.59	566.50	565.10	564.53	567.80	565.78
1999	564.60	566.12	565.30	564.21	566.11	565.21	564.38	566.33	565.04	563.49	566.56	564.83	563.17	566.56	565.15
2000	565.07	565.59	565.35	564.61	565.50	565.13	564.32	566.50	565.05	563.88	567.09	564.82	563.79	567.09	564.96
2001	564.25	566.02	564.90	564.21	566.65	565.01	564.04	565.46	564.60	563.50	565.83	564.82	563.50	566.65	564.87
2002	564.75	565.77	565.19	564.06	566.42	565.01	563.27	565.83	564.56	563.67	566.00	564.59	563.27	568.58	565.01

Figure 4. Monthly Water Level Fluctuations at Black Creek (URS, 2003)

Based on the water level duration analysis by URS at Black Creek, Figure 5 shows the percent exceedance for water surface elevations during the tourist and non-tourist seasons.

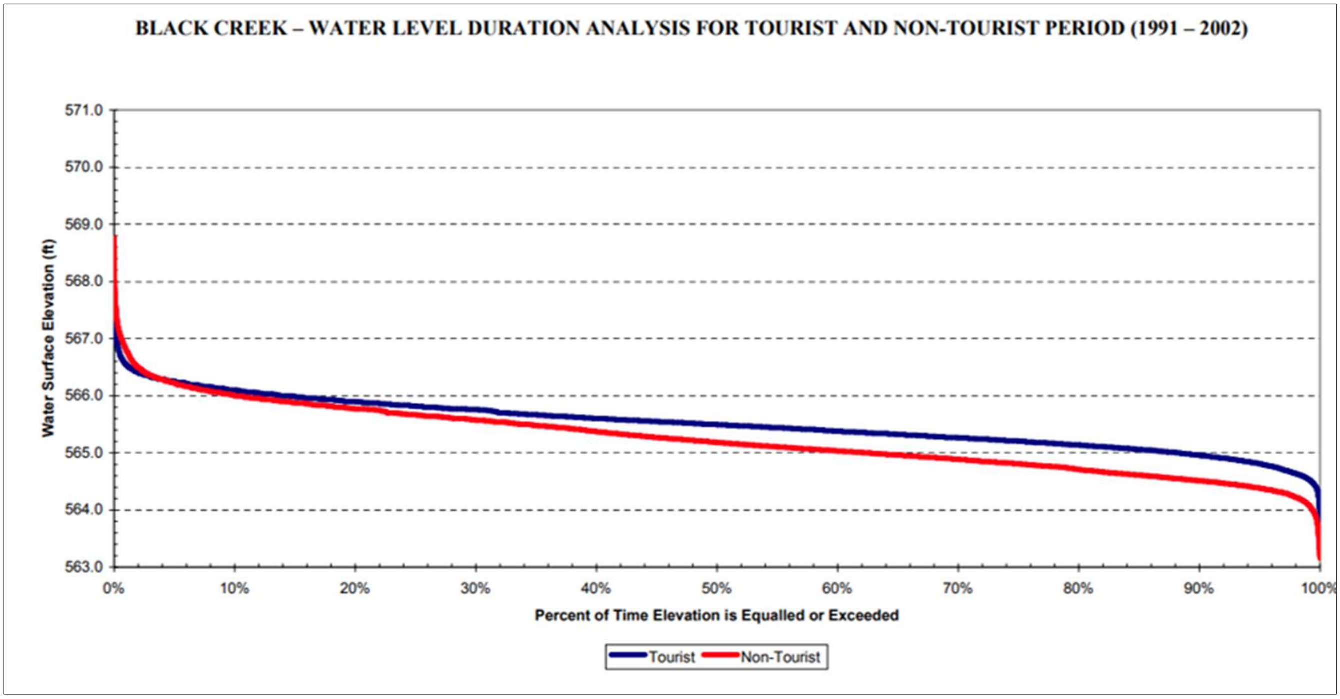

Figure 5. Water Level Duration Analysis at Black Creek (URS, 2003)

According to the chart, the water levels are 566.0 feet International Great Lakes Datum of 1985 (IGLD85) for 10% exceedance during both tourist and non-tourist timeframes. For 90% exceedance, the water levels are 565.0 feet (tourist) and 564.7 feet (non-tourist). During our Grand Island site survey on August 25, 2022, the water level was 565.05 feet.

Considering a typical range of 10% to 90%, the water levels at the project sites are expected to vary between 564.7 feet and 566.0 feet, based on the Black Creek data. Based on the data we have reviewed, the long-term annual average value for Site 83 is 565.35 feet. The listed annual average water level for the West Trail plans issued for construction (Ecology and Environment, March 2022) is 5652.5 feet. The West Trail project is located at the Grand Island north end. Based on the river's assumed bottom slope, the following averages were calculated for the project sites, as shown in Table 3.

Table 3. Estimated Long-Term Annual Average Water Levels

Site	Average **(ft NAVD88)**
83	565.35
85/86	565.0
91	563.0

Notes:

1. ft NAVD88 = feet, North American Vertical Datum of 1988.

A review of recorded seiches on Lake Erie indicates a typical water level increase of 5 to 7 feet in Buffalo, with as much as 9 to 10 feet, while the USGS and NOAA gauge locations show 2 to 3 feet. These are reflected in the daily recordings by the water level gauges. Figure 6 shows an example of a recorded significant seiche on January 30, 2008, that produced a water level increase of 9.4 feet at the Buffalo location and 2.5 feet at the Water Intake location.

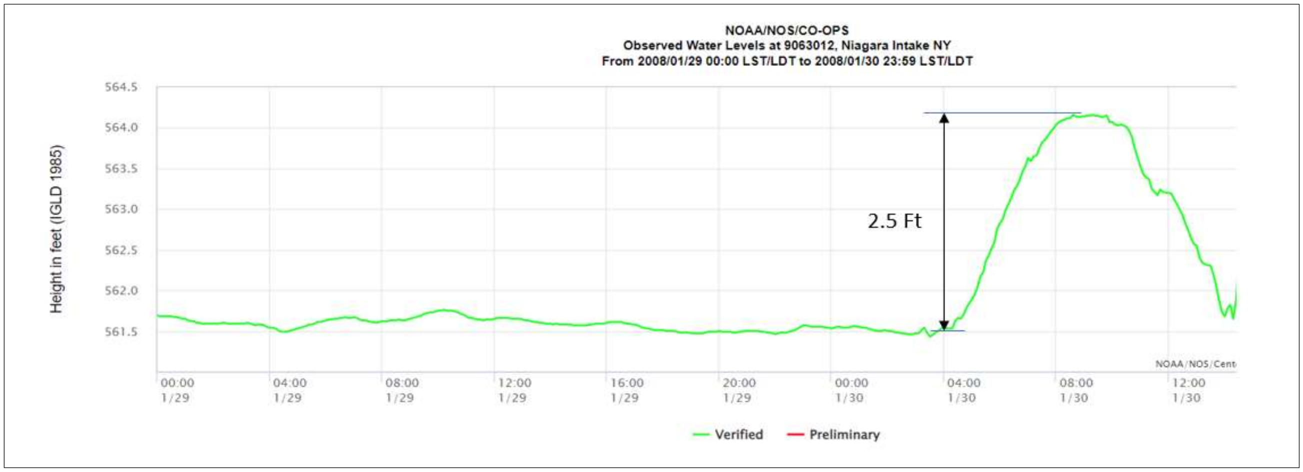

Figure 6. Lake Erie Induced Seiche at the Water Intake (NOAA Gauge 9063012)

The impacts of seiches, therefore, are attenuated downstream the river. Based on the data reviewed, the expected water level increases in the project areas due to Lake Erie seiches are in the range of 2 to 3 feet, well in agreement with previous studies.

WIND WAVES

Based on the Lake Erie long fetches (distances over the open lake) from the west and southwest, significant waves and storm surges are produced by storms at the Buffalo location. They will be limited downstream of the river at the Grass Island project locations. A wind rose was downloaded from the Wave Information Studies (USACE), as shown in Figure 7.

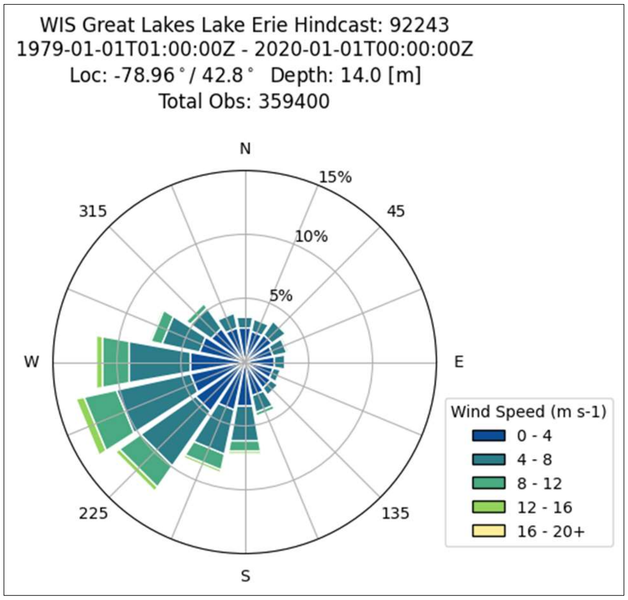

Figure 7. WIS Buffalo Station 92243 (USACE)

The predominant wind directions are from the southwest quadrant, with typical sustained wind speeds up to 45 miles per hour (mph). However, the river fetches for these directions are limited and will not produce significant waves at the project locations.

In order to be conservative, a sustained 25-mph wind speed was selected for the longest SE fetch of 3.6 miles (Sites 85+86). Using the USACE Shallow Water Formulas (USACE Coastal Protection Manual), the following was obtained considering an average water depth of 20 feet along the fetch:

- Significant wave height 1.7 feet, wave period of 2.7 seconds.

For a sustained wind from the west at 25 mph, the calculated wave is 1.0 foot with a wave period of 1.9 seconds. The USACE Coastal Engineering Manual Shallow Water Formulas were created for calculating the wave height and period for water bodies that are relatively shallow and when the fetch, wind speed, and water depth are known. The results were double-checked using the Saville Jr. et al. (1962) formulas that only account for the wind speed and fetch, not using the water depth. A 1.8-foot wave was calculated (the period is not provided in the formula) for the longest SE fetch and a 1.1-foot wave from the west. The results using the two methodologies are in agreement.

BOAT WAKES

Boat wakes depend on the vessel type, traveling speed, and water depth. It is noted that a vessel's mode of operation plays a crucial factor in determining its wave-making ability. Upon reaching a critical speed, some vessels transition to planing mode and the shape and size of the wakes change. As the vessel speed increases, the lift force on the vessel bottom pushes the bow upwards, a rise partially out of the water. This condition causes the largest wakes.

The boat waves are not measured, and, in most cases, surface observations are used to estimate the boat waves. We understand that there are posted recommended traveling speeds (5 mph), but the speeds are not mandatory in the project areas. There is anecdotal information from previous studies (URS) about boats speeding in the project areas and creating a 1.5-foot wake.

Empirical models have been developed to calculate the boat waves; however, the models assume that the vessel's individual characteristics are known (ship hull form, displaced water volume, boat speed, distance between boat and location of interest, etc.). As we do not have specific data on the boats traveling on the river, we have researched other empirical models that attempt to estimate boat wakes without considering the specific boat geometry, but primarily rely on the vessel length and traveling speed.

Of particular interest is the US Naval Academy report (*Predicting Boat-generated Wave Heights: A Quantitative Analysis through Video Observations of Vessel Wakes*, 2012). This study coupled the wave heights measured through an underwater acoustic wave profiler and surface video recordings on the Severn River in Annapolis, Maryland. A total of 471 vessels were tracked in the range of 16 to 74 feet length overall (LOA), which traveled at speeds between 11 and 33 mph.

In order to estimate the typical recreational boats traveling by the Niagara River project sites, the following local/regional marina slips were preliminarily reviewed, both on the United States side and the Canadian side:

- Blue Water Marina, slips up to 46 feet;
- Big Six Marina, slips up to 45 feet;
- Niagara Parks Marina, slips up to 41 feet;
- Greater Niagara Boating Club, slips up to 45 feet;
- Sandy Beach Yacht Club, slips up to 40 feet;
- La Salle Yacht Club, slips up to 47 feet; and
- Erie Basin Marina, slips up to 45 feet.

The longest recreational vessel at these marinas is 47 feet (14.3 meters). The typical vessel length ranges between 25 and 40 feet (7.6 to 12 meters). Both the largest vessel and the typical range were well represented in the US Naval Academy study (see Figure 8).

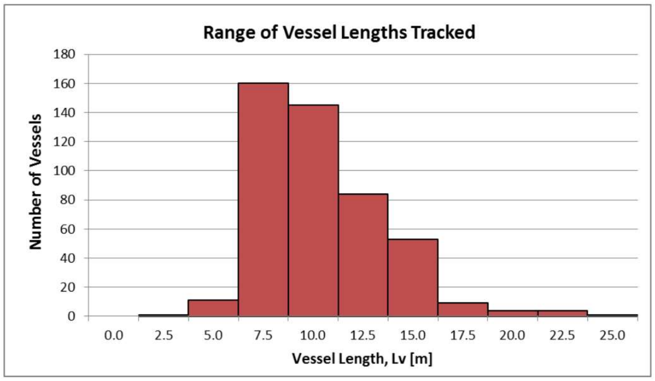

Figure 8. Lengths of Boats Studied (US Naval Academy Maryland, 2012)

Using the US Naval Academy's charts for the longest boat present in the regional marinas (47 feet, 14.3 meters) (see Figure 9), the recorded vessel traveling speeds varied between 2.5 meters per second (m/s) (5.6 mph) and 22.5 m/s (50.3 mph). As these are extreme minimum and maximum values recorded by only three out of 471 vessels, they were discarded from our analysis. The average speed of all vessels is 11 m/s (24.4 mph), with the recorded boat wakes values being as follows:

- Minimum = 0.4 meter (m) (1.3 feet);
- Maximum = 0.92 m (3.0 feet); and
- Average = 0.64 m (2.1 feet).

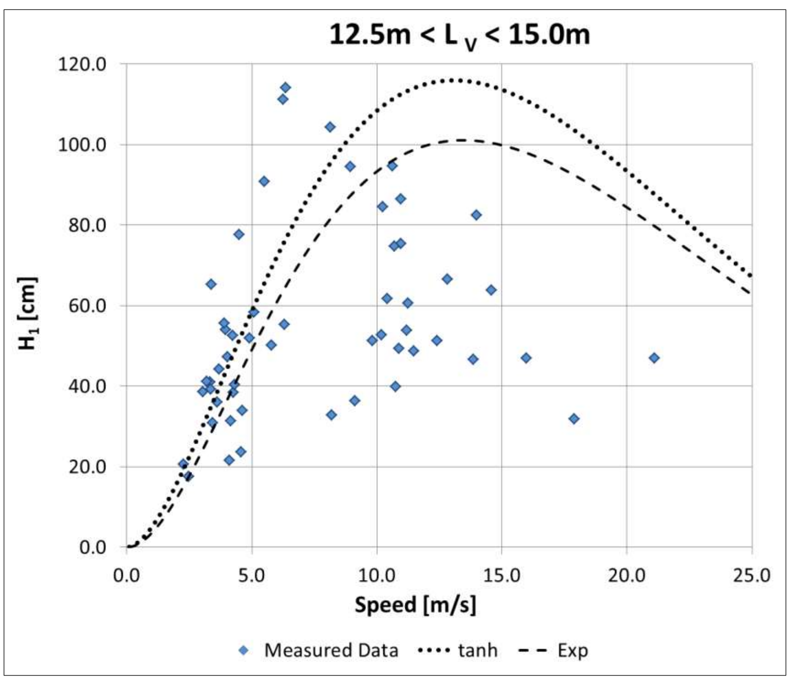

Figure 9. Boat Wake Plot (US Naval Academy Maryland, 2012)

ICE CONSIDERATIONS

Under normal conditions, the placement of the ice boom in the vicinity of Buffalo provides ice-free conditions on the Niagara River. Even when submerged due to high winds, the boom still attenuates the ice movement and runs on the river. USACE documents the river ice conditions immediately after removing the ice boom. Based on various video files reviewed, there are no ice jams on the river, but the movement of ice flows along the shoreline can still be significant for a few days, as shown in Figure 10 (April 10, 2022 at the Raymond Klimek Veterans Park).[1] No significant ice ride-up (ice accumulation on the riverbank slopes) was documented.

Figure 10. River Ice Movement (April 10, 2022, Raymond Klimek Veterans Park)

SUMMARY

The fluctuations of the Niagara River water levels are due to a combination of both natural conditions and made-made flow regulations. The expected water level variation is less than the regulated 1.5 feet per day. The water level variations for the project sites are expected to vary as follows:

- Between 564.7 feet and 566.0 feet, considering a typical range of 10% to 90% exceedance; the long-term estimated annual averages are: 565.35 feet for Site 83, 565.0 feet for Site 85/86, and 563.0 feet for Site 91;
- Lake Erie storm surges/seiches will produce a temporary 2.0 to 3.0 feet of water level increase for a few hours; and
- Between 0.5-foot and 0.6-foot between tourist and non-tourist timeframes.

The river velocities in the near-shore will be less that the estimated main channel velocities (2 to 3 ft/sec). Based on limited surface measurements on June 6, 2022, the estimated velocities were less than 1 ft/sec in the near-shore areas.

The predominant and highest winds are occurring from the west and southwest. However, the fetches from these directions are small. The longest fetch is from the southeast, but sustained high winds from this direction are rarely occurring. The calculated maximum wind waves are up to 1.8 feet at the sites.

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[1] https://www.youtube.com/watch?v=RSssN1bQkhM.

The boat waves are expected to be in the range of 1.3 feet to 3.0 feet, with an average of 2.1 feet for a vessel of 47 feet traveling at 24.4 mph.

Ice considerations are important immediately after removing the Lake Erie ice boom, but no significant ice ride-up was observed in the documents studied.

REFERENCES

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- Water level gauges:
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- Coastal Engineering Manual, USACE, https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/u43544q/636F617374616C20656E67696E656572696E67206D616E75616C/, 2002.
- 2010-2011 Operating of the Lake Erie-Niagara River Ice Boom, International Niagara Working Committee, 2011;
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- Submerged Aquatic Vegetation Mapping in the Niagara River, O'Brien and Gere, 2015; and
- Predicting Boat Generated Wave Heights: A Quantitative Analysis through Video Observation of Boat Waves, US Naval Academy: https://www.usna.edu/Hydromechanics/_files/documents/NAHL_Trident_Scholar_Reports/Tan_2012.pdf, 2012.

Appendix C: Notes from Land Research

Below are excerpts from resources we identified while researching the land history of the site.

https://nfexchange.ca/museum/discover-our-history/brief-history-of-niagara-falls/indigenous-history-a-brief-summary

The French soon realized the strategic importance of the Niagara River and convinced the Senecas in 1720 to let them build a "House of Peace," at the mouth of the Niagara River and the head of Lake Ontario. The building, which quickly grew into Fort Niagara, played a major role in the European contest for North America between the French and the British.

Colonization changed the look of the landscape and impacted Indigenous cultures as well. Manufactured goods began to replace the hand-made household goods of the past. Ceramic cooking vessels were replaced with metal kettles. Wood and stone tools were replaced by metals utensils and European-made weapons.

The local Indigenous peoples were often caught between the French and English, or later, between the Americans and the British. The river became both a geographic and political border between those opposing forces.

https://www.cachoeirasseguras.com/post/niagara-falls-indigenous-mythology-and-tourism

Throughout history, at a given moment, several ethnic groups or indigenous nations joined in a Confederation (Iroquois or Haudenossaunee) and they began to live democratically under a same government. They were the people Seneca, Cayuga, Onondaga, Oneida, Mohawk and Tuscarora. Benjamin Franklin even drew inspiration from the Iroquois Nation model to draft the Constitution of the United States of America.

These people lived from hunting and gathering, farming and fishing in the region's rivers, including the Niagara River. Their cosmologies include myths linked to these waters and especially to Niagara Falls, home of the Thunder God.

There is controversy over who would have been the first "white man" to see the Niagara Falls. It could have been Samuel de Champlain in 1604, or many others that followed in 1669, 1679, 1688 and 1721, men who left their amazement written about the strength and beauty of the Niagara River Waterfall. Those were years of conflict over territorial domination: the natives, the English and the French fought for hegemony in the region, and so we have the context to understand the manipulation that the European conquerors made of the image of the Native Americans they were conquering. They had to pass on the idea that they were savage, just savage people who did not deserve sympathy and thus spread a misrepresented version of the most famous myth connected to Niagara Falls, a myth that has been disseminated to the present day by active tourism agencies.

https://usfwsnortheast.wordpress.com/tag/seneca-indian-nation/

https://sni.org/about/

The Seneca Nation of Indians currently has a total enrolled population of nearly 8,000 citizens. The territories are generally rural, with several residential areas. Many Seneca citizens live off-territory, some are located across the country, as well as in other countries. Off-territory residents comprise nearly 1/2 of the citizenship.

The Seneca are also known as the "Keeper of the Western Door," for the Seneca are the westernmost of the Six Nations. At the time of the formation of the Iroquois League, the original five nations of the Iroquois League occupied large areas of land in the Northeast USA and Southeast Canada.

In the Seneca language we are known as O-non-dowa-gah, (pronounced: Oh-n'own-dough-wahgah) or "Great Hill People."

The historical Seneca occupied territory throughout the Finger Lakes area in Central New York, and in the Genesee Valley in Western New York, living in longhouses on the riversides. The villages were well fortified with wooden stake fences, just one of the many industrious undertakings.

The people relied heavily on agriculture for food, growing the Three Sisters: corn, beans, and squash, which were known as Deohako,(pronounced: Jo- hay- ko) "the life supporters." In addition to raising crops, the early Seneca were also subsistence hunters and fishers.