Trip B-2

EASTERN LAKE ONTARIO DUNE-WETLAND COMPLEX FROM THE PLEISTOCENE TO TODAY: LAURENTIDE ICE SHEET DEGLACIATION, SHORELINE EVOLUTION AND MODEN GEOECOLOGY

ROY L. WIDRIG
New York Sea Grant, State University of New York at Oswego, Oswego, New York 13126

INTRODUCTION

The Eastern Lake Ontario Dune Complex and associated landforms, coastal morphology and wetlands have survived through constant change since the Late Pleistocene. While the general location of the Lake Ontario shoreline is the result of deglaciation of the Laurentide Ice Sheet (16,000-12,000 YBP) and drainage of Glacial Lake Iroquois, the natural processes acting upon the 27 km stretch of dunes is modified further by complexities of human interaction with the landscape since European settlement post-colonization. Today, natural processes such as longshore transport of sediment, climatic influence on lake level, erosion at the headwaters of Lake Ontario tributaries, and human intervention such as lake level controls and shoreline erosion management are in discordance with one another. The natural climatic and geologic processes in the context of human settlement along the lake creates a balancing act in which human settlements attempt to remain resilient while conserving and protecting delicate coastal ecosystems.

GEOLOGIC SETTING AND CHRONOLOGY

Glacial Lake Iroquois – Modern Lake Ontario

The previous stages of Glacial Lake Iroquois (proto-Lake Ontario, 16,000-13,000 cal YBP), sourced by glacial meltwater, exceeded the modern elevation of today's lakes by 60-75m (Bird and Kozlowski, 2016). The multitude of shoreline elevation changes in the late Quaternary have been attributed to repeated glacial lake meltwater events, periodically draining these lakes through the Iro-Mohawk River system (14.8 +/- 1.3 ka, Porecca, et. al 2018). Potholes from turbulent meltwater flow along Moss Island in Central New York have been attributed to these drainage events.

With additional northward retreat and a subsequent drop in the level of Glacial Lake Iroquois to that of modern Lake Ontario, a lower-elevation opening of the St. Lawrence Seaway eliminated the Iro-Mohawk River drainage, re-routing instead to the Northern Atlantic through the St. Lawrence River, which has continued into the present interglacial period.

Figure 1. *Map view with North oriented right of Eastern Lake Ontario Dune Complex, showing the entire Eastern Lake Ontario Dune Complex and field trip stops (orange.)*

Development of Dunes

As Glacial Lake Iroquois transitioned to modern Lake Ontario (13,000-present), remnant lakeshores remained across the New York and Ontario landscape, with similar processes and timing taking place for Glacial Lake Warren (Young et al., 2021). Woody debris found in situ along these remnant shorelines or buried in ice-contact lakes, coupled with lake cores depicting mineralogical/organic transitions have been used in constraining the ages of these events (Lewis and Anderson, 2020; Young et al., 2021). With the significant drop in elevation from the glacial lakes to the modern lakes, sand and silt composing the lake bottoms was exposed to the prevailing winds and dry conditions of the Late Pleistocene and Early Holocene in New York, resulting in the aeolian deposition of sand along the eastern Lake Ontario shoreline. The resulting complex includes young foredunes (beach-adjacent), interior dunes (middle aged, vegetated with young shrubs and trees) and older backdunes (capable of supporting large trees such as red oak and large cottonwood.) Additional dating of these sand dunes through OSL (optically-stimulated luminescence) could aid in determining the ages and lifecycles of these dunes along Eastern Lake Ontario. Additional geochronology could be pursued by constraining the mineralogical-biologic transition of Lake Ontario-adjacent wetlands and ponds.

Figure 2. *Young cottonwoods mixed in with dune grass populate the interior dune at Black Pond WMA.*

Sediments Sources

In addition to offshore sand bars in Lake Ontario, the shoreline of the lake and upland areas contribute to the sediments sources for Lake Ontario's eastern shore dunes. The southern shoreline tributaries of the Genesee and Oswego Rivers drain thousands of acres of farmland in New York State alone, adding to the sediment sources within the lakes, although much of this sediment is captured in shallow-basin bays along southern and eastern Lake Ontario, often protected from longshore currents by barrier bars. With the added erosion of drumlins (elongated, often teardrop-shaped subglacial landforms), there remains a constant sediment source for maintaining the eastern Lake Ontario dune complex, as well as the coastal features (barrier bars and spits) notorious throughout Wayne County and the spit complex at North Sandy Pond in Oswego County. More detailed studies on these processes are being proposed and are underway.

Figure 3. *Looking southeast towards the Southern Spit at North Sandy Pond, December 2020. Constant sand transport towards eastern Lake Ontario results in seasonal deposition within the only active inlet to the pond, which is dredged annually by the Town of Sandy Creek and other entities. Dredged material is used to re-nourish breaches within the spit and in dune restoration projects.*

Dunes along eastern Lake Ontario remain in a constant state of change while balancing lake levels, sediment sources, environmental and climatic changes while under the influence of human populations. During recent flooding events in 2017 and 2019, many of these delicate dunes were significantly eroded, while the spit at North Sandy Pond experienced multiple dune blowouts and breaches, with other coastal formations such as the Blind Sodus Bay barrier bar completely eroding away, opening previously-closed bays to the forces of Lake Ontario and further, significant erosion and flooding of inland shorelines.

While growth and destruction of incipient foredunes is common and expected, destruction and rebuilding of backdunes is not. When erosion of these backdunes occurs, whether through deforestation, blowouts or other processes, the dune is often lost for good as the sediment supply is cut off or too far for Aeolian transport to remain viable. Subsequent stabilization of the dunes is possible through the return of vegetation to the system and dune fencing.

Dune-building Processes on Eastern Lake Ontario

With the available sand source from Glacial Lake Iroquois and the offshore sand bars in the newly-established Lake Ontario, winds across the basin transport sand and silt to the shoreline, while waves move more sediment to the nearshore and beaches. These sediments, when exposed along the shoreline, dry and become entrained with the wind and begin traveling up the shoreline to begin the dune forming process. When encountering an object such as vegetation, woody debris or rocks, the winds slow down and lose their capacity to carry sediment, and sand grains are deposited. Primary dune vegetation such as Champlain Beach Grass and creepers begin the stabilization process by trapping sediment and sending roots into it, forming the *incipient dune* or *foredune.* Secondary vegetation in the form of fast-growing shrubs and trees (sand cherry, dune willow, shrub willows, cottonwood) begin to thrive in the *foredune* environment. As these trees and shrubs enter mid-life and later, the *hind dune* or *backdune* is fully stabilized, beginning the creation of shallow forest soils and growth of larger trees and a more diverse (oak species, maple, etc.) forest. Storm surge, lake levels and wind events will often erode the fronting beach dunes, leaving the face of the dune eroded to the angle of repose (with slight influence based on vegetation). This erosion will continue until the dune face has stabilized or wind-blown sediment is returned to the system, often in the form of a drop in lake level or artificial nourishment.

Figure 3. *Dune grass and fencing at Southwick Beach State Park, part of a dune restoration project.*

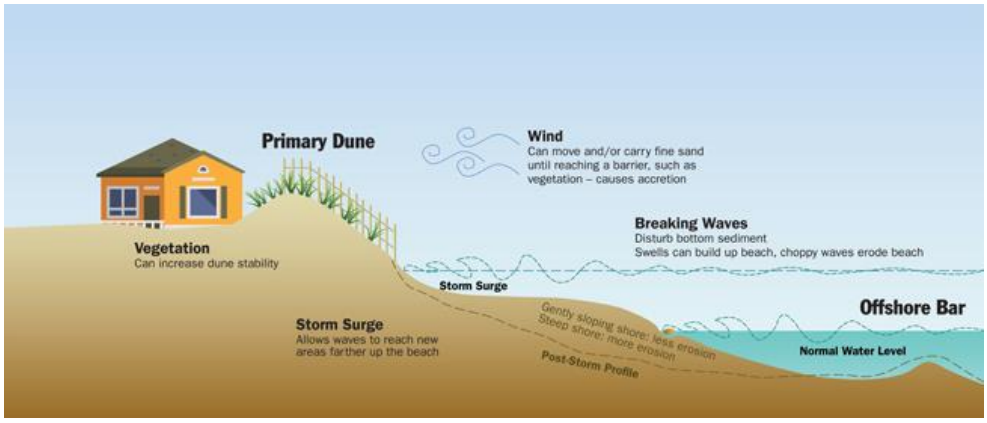


Figure 4. *Basic Dune-forming processes adapted from Long Island (from Fallon, 2022.)*

Dune Blowouts

Across the dune complex, dune blowouts may occur. Blowouts are depressed features within previously-vegetated dunes, where wind erosion has become accelerated and cuts into the dune perpendicular to the shore. In many cases this process is naturally occurring, a result of funneled winds along the shoreline. However, in Oswego County in particular, human activity along the dunes (walking over and destroying dune grasses, motorized vehicle transport, or the erection of buildings along the shoreline) has caused significant blowout events. Overuse of all-terrain vehicles in the 1980s resulted in significant dune blowouts, necessitating the formation of the Eastern Lake Ontario Dune Coalition to attempt to control human destruction of the dunes and to begin conservation programs locally. Remnants of the blowouts, both natural and unnatural, are still visible today and can be seen at Stops 1 and 3 (Black Pond WMA, Sandy Island Beach State Park.) In order to reduce the erosion of sand dunes through dune blowouts, multiple public and private projects have been executed to construct boardwalks or dune overwalks throughout the region, allowing dune grass to live while also securing human access to coastal areas. Additionally, dune fencing is used to slow the transport of sand grains along the shoreline. When coupled with planting of dune grass, dune fencing can help re-establish dunes within 2-5 years.

Figure 5: *Recent dune blowout at Black Pond WMA.*

DEVELOPMENT OF WETLAND COMMUNITIES AND MODERN COASTAL MORPHOLOGY

While dune complexes drain exceptionally well, wetlands are often associated with areas such as Eastern Lake Ontario as a result of multiple geological and hydrological processes. These processes have been fluctuating with climate trends since the last glacial maximum (LGM), and are further complicated by ecological processes and human intervention.

In most cases along eastern Lake Ontario, these wetland complexes have formed in areas where drainages meet an elevation impediment near the lakeshore, often the dunes themselves. This is starkly visible at Deer Creek Marsh Wildlife Management Area (WMA, Stop 2.) Deer Creek has headwaters just south of the Winona State Forest in Sandy Creek, but drains a significant portion of Oswego County before entering the WMA, a 1771 acre marsh, nestled between NYS-3 and shoreline dunes. The creek itself bends southward once meeting the dunes, and travels south for around 1 km before reaching Lake Ontario, where the creek only seldom drains into the lake directly. Reworked lake sediments often form a complex transitional area at Brennan Beach (private) impounding the creek.

With limited drainage and flushing of these coastal tributaries into Lake Ontario, wetland communities abound in the inland reaches behind back dunes. Cattail marshes are common, as well as forest and early successional grassland and shrublands. The dunes shelter these wetland areas, and frequent deposition of wind-blown sand creates new areas for pioneer species such as Champlain beach grass (*Ammophila brevigulata ssp. champlainensis),* before being populated by dune cherry (*Prunus pumila*), dune willow (*Salix cordata),* paper birch, (*Betula papyrifera*) eastern cottonwood (*Populus deltoides*), and eventually red oak (*Quercus rubra*).

Figure 6. *Open water and swamp at Deer Creek Marsh Wildlife Management Area as seen from lookout deck.*

Inland from the dunes are deep emergent and shallow emergent marshes, as well as deep water ponds and swamps (North Sandy Pond, South Pond, Lakeview Pond). In shallow emergent marshes (3”-6’ in depth), grasses and grass-like sedges dominate, along with tall wildflowers such as Joe Pye Weed and shrubs, including red osier dogwood, shrub willows and alder (Figure 7.) In the deeper emergent wetlands, cattails and pickerelweed are common, while larger fauna such as muskrats, wood ducks and other migratory waterfowl can be seen.

Coastal Fens

Fens are rare plant communities living above layers of peat. Composed of sedges and shrubs, fens are sometimes floating masses, and feature unique plants and animals not found in other biomes. Within the Eastern Lake Ontario Dune Complex, there are locally- and globally-rare species, including the bog buckbean (*Menyanthes trifoliate)* and the endangered bog buckmoth, (*Hemileuca spp.)* which form a symbiotic relationship. Of the ten known colonies of bog buckmoth throughout the world, six occur in Oswego County (Bonnano, 1997.) Also found within the fens of Oswego County are the insect-eating plants sundew (*Drosera sp.)* and pitcher plant (*Sarracenia purpurea)*.

Other Coastal Geologic Features of Eastern Lake Ontario

The Eastern Lake Ontario Dune Complex is defined by a 27 km stretch of coastal dunes and wetlands, but also features the North Sandy Pond Spit, a barrier complex with a pair of recurved spits (Mattheus, et al., 2016) and dynamic inlet/outlet changes well-documented throughout written history in the region (Figure 3.) Here, the ample sediment supply in eastern Lake Ontario provides sand to the eastern shore, with occasional breaches through the narrower stretches of the ~10-300m wide barrier bar. The main inlet has been kept remarkably consistent since the 1950s, and dredging of the inlet and sand shoal has maintained this inlet in recent years. Since 1950 multiple breaches have occurred which either self-healed or were repaired by means of artificial sand nourishment along the shoreline.

Further north at Black Pond-El Dorado, the dune complex is abruptly truncated by the mouth of Black Pond outlet. Here is one of the few locations along Lake Ontario where bedrock (Chaumont Limestone, Black River Group, middle Ordovician) is exposed at the surface. The outcrop, accessible from Stop 1 at Black Pond WMA, is believed to act as a dam, keeping the dunes constrained to the south of the feature.

Shoreline Management

With increasing development pressure in the region and the transition from seasonal to full-time residency along the shoreline, the dunes along with eastern shore of Lake Ontario are subjected to a myriad of shoreline management strategies, some of which have detrimental effects of the coastal processes and ecology of the region. Prior to European settlement, this was not the case. Greene Point, located within North Sandy Pond, remains one of the first known European settlements in the area, being founded in 1803, and began the cycles of deforestation and the building of permanent structures before recreation and tourism became a dominant industry by the 1870s.

Figure 7. *Limestone rip-rap and dune revegetation on display along the south spit, October 2021.*

In the human need of controlling the environment, shoreline stabilization was inevitable. The dune complex remains highly active and at times unpredictable, and stabilization of inlets and shorelines to match property boundaries was deemed necessary to maintain erosion-resilient communities along the Lake Ontario shoreline. However, due to their dynamic nature, dunes and sandy shorelines are notoriously difficult to control in a geomorphic context. Since cottage development in the 1950s, shoreline residents have attempted many solutions to solving the shifting sands: wooden plank cribbing, gabion baskets (metal mesh containers filled with stones), rock rip-rap (large boulders parallel to the shore) and nature-based restoration (mimicking the natural environment to stabilize erosion, Figure 8) remain the most common approaches, while physical movement of structures away from coastal erosion hazard areas has been discussed extensively, yet remains unviable in many situations and unpalatable to residents in others. Shoreline residents are not encouraged to move away from the shoreline, as in many cases, these residents provide a significant portion of the tax bases for many Great Lakes counties, towns and villages.

While heavily engineered solutions to shoreline erosion exist throughout the dune complex, longshore sand transport remains efficient along the eastern shore. However, further hardening of the shoreline may endanger these processes. In many situations, these hard structures along the shoreline act in opposition to the coastal processes needed to maintain the dunes and barrier spit morphology. Hard shorelines often cause scouring at the base of structures, moving sand off the shoreline and out into the lake where it becomes inaccessible to waves, failing to bring the much-needed sediment to the shoreline. Additionally, these walls have been shown to accelerate erosion along adjacent shorelines (Figure 9) and act as a deterrent to beneficial native wildlife (Gittman et al., 2015) and an attractant to nuisance species such as Canadian geese and cormorants.

Figure 8. *Headland created by artificial shoreline stabilization techniques, South Spit of Sandy Pond. Here, waves have been deflected away from the shoreline and into unprotected shoreline areas, resulting in additional, accelerated erosion along the flanks of the rip-rap wall.*

Shoreline Restoration

In recent years a trend has occurred in which shoreline restoration, rather than manipulation through shoreline hardening, has become an emergent shoreline management technique. This is evident throughout the dune complex, but is highlighted by natural resiliency projects at Southwick Beach State Park and along both private and public-owned land at the North Spit of Sandy Pond, part of Sandy Island Beach State Park.

At Southwick Beach, significant shoreline dunes were lost in the flooding and erosion as a result of historically-high lake levels in both 2017 and 2019. In order to restore these shorelines to a status worthy of presenting in a New York State park, dune fencing and significant planting of dune grass occurred between 2019-2021, with more plantings planned in the future. This minimalist approach has led to a nearly complete restoration of the previous shorelines. Additional funding and planning has also implemented stormwater basins, grassed waterways and raingardens in and around parking areas in the park to mitigate flooding events in the future.

Along the North Spit (Figure 10), significant breaches occurred in 2017 and 2019, occurring close to residential properties in the north. Local communities and organizations were mobilized to action, and received grants from the State of New York to begin a dredge-and-place project along the shoreline to repair the breaches in the barrier, install dune fencing to catch wind-blown sediment, and provide numerous spring and fall dune grass plantings with community volunteers. Dredge material is sourced from the nearby North Sandy Pond inlet, where a navigation channel is maintained (visible in Figure 3.)

Through three phases in 2020 a total of 40,000 yd^3 of dredged material was placed along the shoreline to repair the breaches. The sediment was almost immediately mobilized by the cross-lake winds, recovering the beach and barrier bar to greater widths than observed in previous years (Figure 10). The barrier is continuously monitored by a dedicated group of volunteers and organizations associated with the Eastern Lake Ontario Dune Coalition and the project is used as a demonstration project for beneficial use of dredged materials and restoration of Great Lakes shorelines through natural and nature-based methods.

Figure 9. *Aerial view of beach nourishment project, north spit of Sandy Pond, Summer 2021. Here, sand dredged from the channel (background, far left) and placed along the shorelines (in front of dune fencing) and*

allowed to blow across the narrow spit, depositing in incipient dunes and overwash deposits. Prior to 2019, the spit was wooded along its length, but was washed out completely from storm events in 2017 and 2019.

In other attempts at shoreline restoration and projection in the Oswego County, there has been less success. At Sandy Island Beach State Park (Stop 3), a combination of heavily-engineered and nature-based features were used to restore the dunes at this location. Similar to the North Spit, the shoreline here was eroded heavily in 2017. However, to maintain local infrastructure including park buildings, an access road to South Pond, and a parking lot, an engineered solution was deemed necessary. This included the installation of trap bags (geotextile bags filled with sand), toe protection through limestone rip-rap, and fill brought in from an upland source. Unfortunately in 2019, water levels exceeded previous highs witnessed in 2017, and the rip-rap was quickly overtopped by waves, eroding the filled material up to the installed trap bags, resulting in a significant loss of land (Figure 11.) Additionally, the upland sediment source used as fill was not suitable for dune-building, and was unable to be entrained within the winds enough to contribute to the success of the dune grass plantings, which have struggled. This location is now being studied extensively to develop new solutions to the local erosion issues while maintaining a resilient shoreline for the local infrastructure.

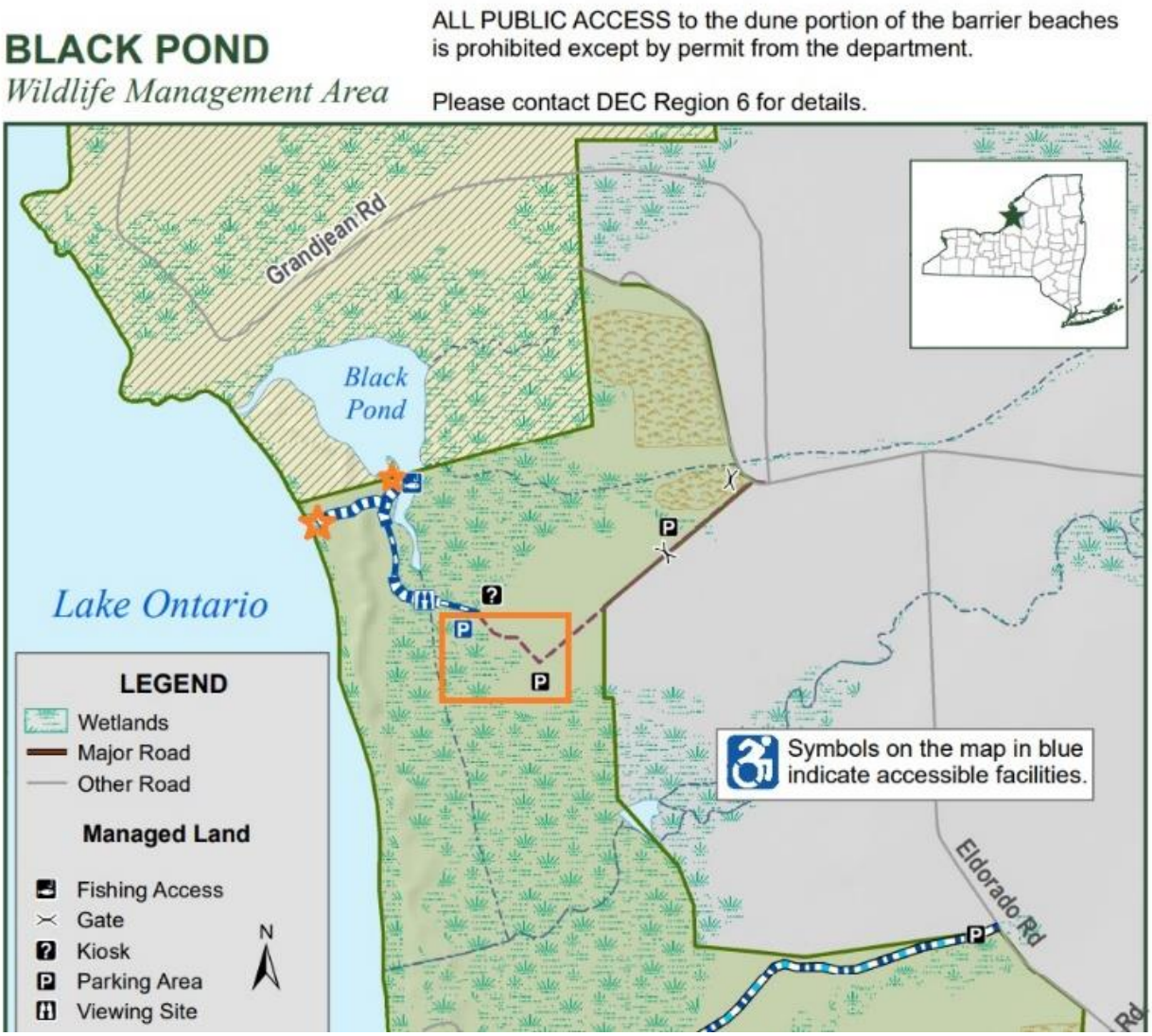
Figure 10. *Failed stabilization attempt at Sandy Island Beach, 2019. Here, large, coarse rip-rap was introduced to reduce erosion of an eroding dune face, but deflected and intensified erosion-causing waves into the inadequate upland sediment (not suitable for dune material) resulting in an immediate and excessive loss of shoreline material.*

FIELD GUIDE AND ROAD LOG

STOP 1 / Meeting Location: Black Pond Wildlife Management Area (43.802162, -76.224055)

Directions (55 minutes): From SUNY Oswego, take NY-104 E to NYS-104B E (10 miles) to the junction with NY-3 E (left-hand turn at 6 miles). Once on NY-3 E, follow for 22.4 miles to Bolton Rd (left). Follow Bolton Rd to Black Pond WMA Access Rd after about 1 mile. Take access road about .5 mile to parking lot. *Less than a mile walk over boardwalk and trail to shoreline.*

Discussion: Eastern Lake Ontario Dune Complex – Dune Formation and Modern Habitats



STOP 2
Deer Creek Marsh Wildlife Management Area - North (43.600754, -76.197299)

Directions (30 minutes): From Black Pond WMA, take access road and Bolton Rd. back to NY-3 W. After right on to NY-3 W, take for 15 miles to Rainbow Shores Rd (right.) Follow Rainbow Shores Rd. for 1.8 miles to Rainbow Shores Rd. South (left). After about .5 mile, road will diverge – take left for another .3 mile to the parking lot at Deer Creek marsh WMA. *Walking over sand and boardwalk for about 1-2 miles, depending on stops.*

Discussion: Sand dune and wetland management, dune system hydrology.

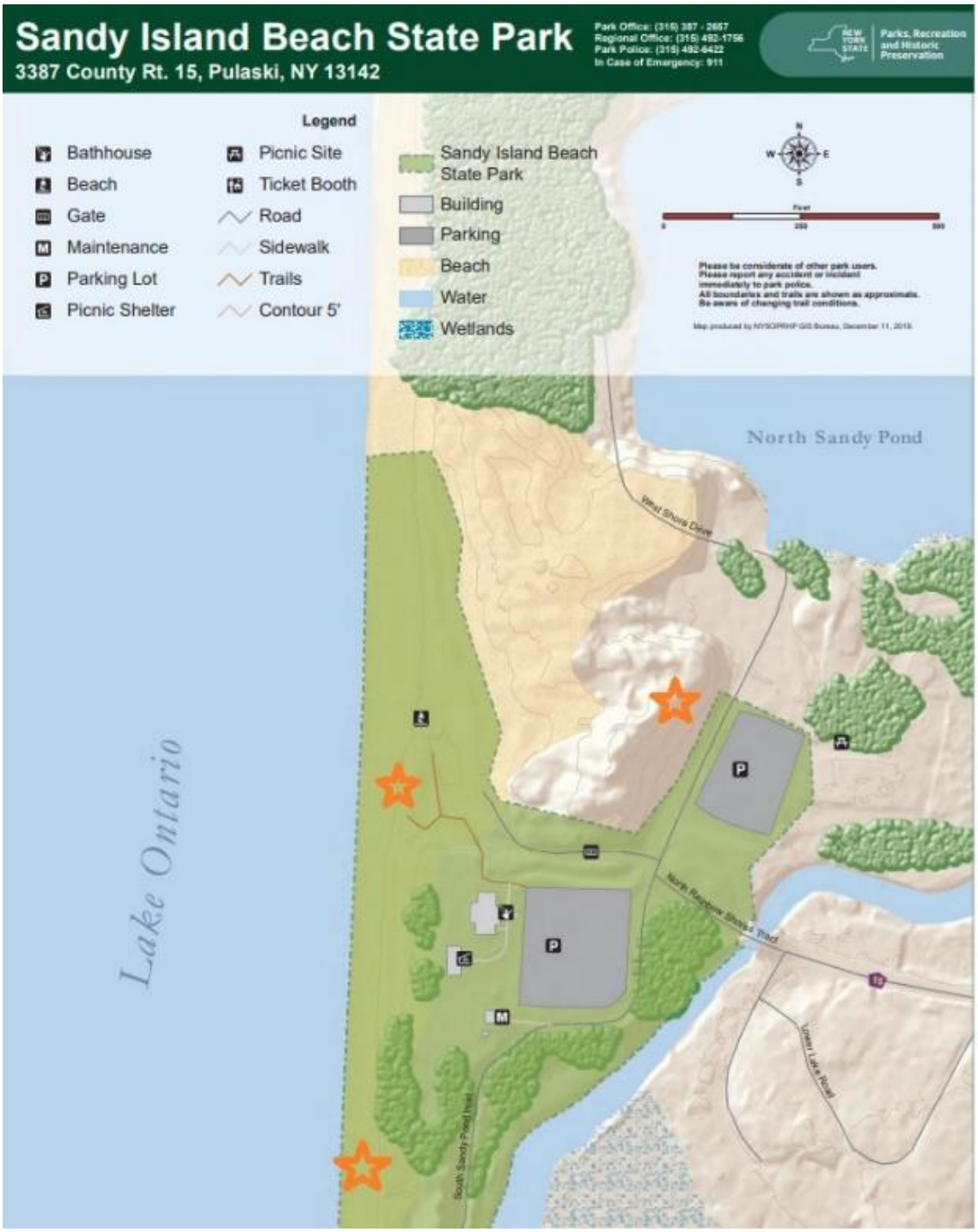
Eastern Lake Ontario Dune Complex – Coastal Geomorphology

STOP 3

Sandy Island Beach State Park – Main Parking Lot (43.630755, -76.195224)

Directions (12 minutes): From Rainbow Shores Rd., turn left on to Tryon Rd. after .7 miles. After 1.4 miles, turn left on to Ouderkirk Rd. Follow Ouderkirk Rd. to the T with County Route 15, and take a left. Sandy Island Beach State Park is .3 mile down this road, after crossing the bridge, use parking lot to the right.

Discussion: Human Intervention and Conservation in Dune Systems



STOP 4 (OPTIONAL/LIMITED PARKING)

Salmon River Bridge – DEC Launch Parking Lot

Directions (11 minutes): From Sandy Island Beach State Park, take County Route 15 to NY-3 W (2.3 miles). Take NY-3 W for 4.7 miles to fishing access/parking lot on the north side of the NY-3 Bridge over the Salmon River. NOTE: There is only space for nine vehicles here and NY-3 is very busy. This stop is optional.

Discussion: Dunes, recreation, politics and conservation.

ACKNOWLEDGEMENTS

Many thanks are due from the author to Nicolas DiFrancesco and David Valentino of SUNY Oswego and the New York State Geological Association for the humbling and generous invite to be a part of this meeting. The author would also like to thank P. Jay Fleischer and Leslie Hasbargen for nurturing their love of Quaternary geology and glaciology in the contest of the Great Lakes Region, as well as David G. White III for his tutelage and mentoring over the last five years with New York Sea Grant.

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