Lake Erie Shore Erosion Management Plan

Bratenahl to Grand River: Reach 05

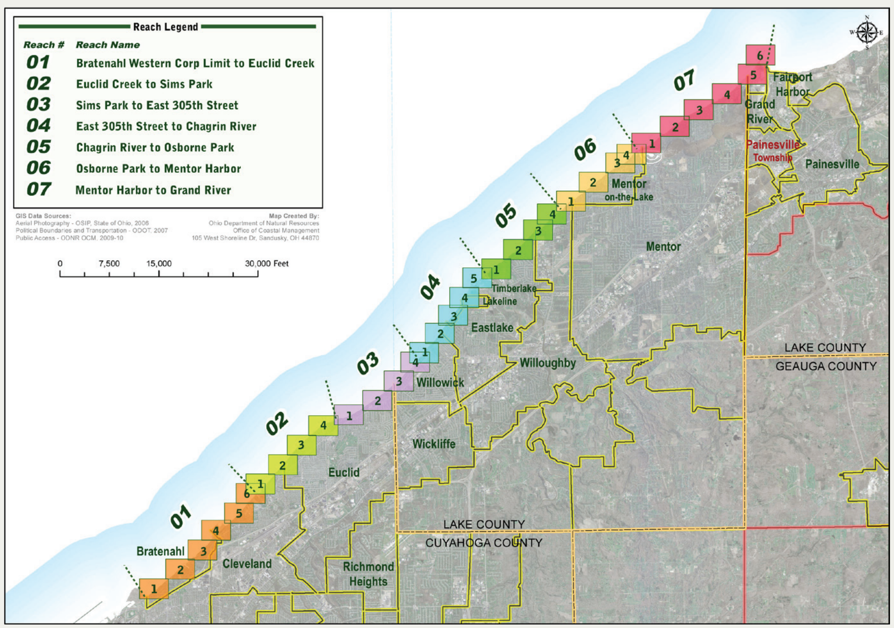
LESEMP

About the Program

In an on-going effort to assist property owners along Ohio's Lake Erie coast by providing free technical assistance, the *Lake Erie Shore Erosion Management Plan* (*LESEMP*) is being developed by the Ohio Department of Natural Resources through a partnership between the Office of Coastal Management, Division of Wildlife and Division of Geological Survey.

The *LESEMP* identifies the causes of erosion in specific areas called reaches which are stretches of shore with similar site conditions. The *LESEMP* then outlines the most likely means of successful erosion control based on reach-specific erosion issues, geology and habitat. The objective of the reach-based approach to erosion control is to simplify the decision process while enhancing the effectiveness of solutions to erosion related issues.

The *LESEMP* does not contain any regulatory oversight provisions.



The LESEMP is being developed by the project partners, Ohio Department of Natural Resources Office of Coastal Management, Division of Geological Survey and Division of Wildlife. Federal grant funding for this project is provided by the National Oceanic and Atmospheric Administration.

Description

The LESEMP Bratenahl to Grand River Region Reach 05 extends from the mouth of the Chagrin River to the east end of Osborne Park. This reach contains approximately 16,000 feet of shoreline near the western end of Lake County including the lakefront residential communities within the east end of Eastlake and the west portion of Willoughby. Most of Reach 05's lakeshore is privately owned with the exception of Willowbeach Park, Sunset Park, Osborne Park and a series of three scenic overlooks along Beachview Road in Willoughby.

The shore of Reach 05 is oriented from southwest to northeast along Lake Erie's Central Basin. The angle of the shoreline is fairly consistent with the exception of a broad headland near the Eastlake/Willoughby municipal boundary. On a large scale, the shore is fairly uniform; but on a more local scale, man-made structures have caused small irregularities in the shore form. The shore is generally characterized by 10-foot high banks to 40-foot high bluffs as the relief of the upland gradually increases from the Chagrin River floodplain to the east end of the reach. The banks/bluffs are composed of glacial till covered with laminated clay and sand. The shore in this reach is heavily armored with protective structures and occasionally fronted by narrow, transient beaches. The net direction of littoral transport is from west to east. The largest beaches in this reach are near the mouth of the Chagrin River due to sediment discharge from the river. Wider beaches are also present in the shallow embayment caused by the broad headland at the west end of Willoughby.

The nearshore in Reach 05 is composed of till covered with a 3 to 6-foot thick layer of sand along the shore. Sand deposits in the area are variable but generally increase from west to east. The reduced sand supply at the west end of the reach is due sand accumulation updrift of the breakwaters at the Eastlake Power Plant that are near the east end of Reach 04. Nearshore slopes are greatest within the first 50 to 100 feet from shore and gradually flatten to approximately 1 degree farther offshore. Nearshore slopes become more variable in the eastern portions of the reach due to the occasional formation of sand bars.

The east jetty at the mouth of the Chagrin River extends approximately 150 feet into the lake at the west end of the reach. The first 500 feet of shore to the east is a barrier beach protecting the Chagrin Lagoons area near the mouth of the river. The next 1,400 feet of shore to the east is protected with a continuous revetment along Galalina Boulevard. This revetment was constructed under the flood protection authority by the U.S. Army Corps of Engineers in the 1970s. Although maintenance work was completed on the revetment in 1986 the structure has been released to the city of Eastlake and is not eligible for federal funds. The relief of the upland increases from just a few feet along the barrier beach to the west to about 10 feet along Galalina Boulevard.

To the east, the shore is primarily protected with concrete rubble along a shallow embayment. The embayment is formed between small artificial headlands created by the shore structures near Forest Drive and Wrenwood Drive. Narrow beaches occasionally form in the shallow embayment. The next 300 feet of shore to the east is protected by an armor stone revetment fronted by a moderate beach. The beach is trapped in an embayment between shore structures near the ends of Wrenwood Drive and North Parkway Drive.

East of North Parkway Drive bluff heights quickly increase to about 30 feet near a storm sewer outfall along the shore. The sewer outfall is protected by shore-perpendicular steel sheet pile extending approximately 75 feet into the lake. The structures at the sewer outfall help support narrow beaches in the area lakeward of North Parkway Drive.

The next 550 feet to the east is primarily protected with concrete Great Lakes Erosion Control (GLEC) modules or cylindrical concrete modules at the toe of the bluff. The bluffs are re-graded along the western 300 feet of this area. The eastern portion has natural bluffs fronted by a 50-foot wide perched beach landward of the GLEC modules. The next 800 feet of shore to the east is relies on concrete rubble placed at the toe of the bluff for shore protection. The concrete rubble extends to the top of the bluff face along several properties in this area.

The shore to the east protrudes approximately 50 feet lakeward and is protected by a steel sheet pile bulkhead that extends along about 300 feet of shore. The headland continues along the next 220 feet of shore to the east. The shore in this area is protected by a seawall and a row of GLEC modules.

The east jetty at the mouth of the Chagrin River extends approximately 150 into the lake at the west end of the reach.

To the east the shore retreats back about 60 feet landward along a steel sheet pile retaining wall. The next 550 feet of shore to the east is protected with concrete rubble placed along the bluff face and at the toe of the bluff. This area is occasionally fronted by narrow, transient beaches that accumulate updrift of a row of GLEC modules placed about 50 feet from the toe of the bluff to the east. The GLEC modules continue along approximately 300 feet of shore. A portion of this area is also protected by an armor stone revetment at the toe of a re-graded bluff.

The next 550 feet of shore leading up to the storm sewer outfall near the end of Shelton Road is mainly protected with concrete rubble placed along the bluff face and at the toe of the bluff. A few properties also have large concrete structures placed in the nearshore or at the toe of the bluff. Narrow beaches occasionally form updrift of the shore-perpendicular steel sheet pile jetties protecting the sewer outfall but sand accumulation is often prevented by a slight headland about 150 feet to the west.

The next 2,000 feet of shore along Lake Shore Boulevard (State Route 283) contains a variety of interspersed shore protection structures but is mostly unprotected. Most sites in this area have a natural bluff with very little protection. In some areas, concrete modules or groins are placed lakeward of unarmored bluffs. Narrow beaches occasionally form at the toe of the bluff but quickly erode during periods of high water, leaving the bluff vulnerable to erosion from wave action. Other properties rely on concrete rubble or earth fill dumped from the top of the bluff for shore protection. This material is quickly eroded by wave action and often causes increased erosion at the top of the bluff by adding significant weight to an unstable slope. The shore of this area also experiences erosion due the geology of the bluff. Ground water seeping between the till and layers of clay and sand exposed along the bluff face can cause slumping or mass wasting. Erosion concerns in this area are increased due to the close proximity of several upland structures to the edge of the bluff.

The next 650 feet of shore to the east is protected by concrete modules placed at the toe of the bluff or in the nearshore. The western 200 feet of this area is protected by a row of GLEC modules placed approximately 30 feet from the toe of a re-graded and vegetated bluff. To the east about 200 feet of shore is protected with Campbell Modules placed in the nearshore. The eastern portion of this area also has a row of GLEC modules protecting the

Great Lakes Erosion Control (GLEC) modules are common throughout the reach. Although GLEC modules have helped stabilize the shore in some areas, their functionality is often limited due to issues with uneven settling, cracking and excessive splashing and overspray.

toe of the bluff. An additional 200 feet of shore to the east is protected with a row of GLEC modules. The eastern 50 feet of this area is protected with a row of large concrete blocks placed updrift of a concrete groin extending approximately 50 feet lakeward from the toe of the bluff.

To the east, approximately 200 feet of shore consists of sand beach, cobble and concrete rubble near the mouth of a small creek. The next 300 feet of shore is protected with a steel sheet pile bulkhead. The bulkhead gradually angles lakeward leading up to about 250 feet of armor stone revetment along the broad headland near the Eastlake/Willoughby municipal boundary. A variety of concrete modules and a series of concrete groins protect about 200 feet of shore along the downdrift side of the headland. Approximately 1,400 feet of shore to the east is fronted by a narrow beach in the shallow embayment downdrift of the headland. Concrete rubble has been placed along the toe of the bluff in some areas of the beach, particularly at the east and west ends. Approximately 250 feet of GLEC modules also protect the toe of the bluff just west of the Sandcrest Apartments. The beach gradually narrows along about 250 feet of shore just west of Sunset Park. The shore in this area is protected with a series of concrete structures and GLEC modules. A large amount of concrete rubble and earth fill has also been placed along the bluff face in this area.

The next 600 feet of shore to the east is protected by the steel sheet pile bulkhead at Sunset Park along North Beachview Road in Willoughby. The bulkhead angles approximately 40 feet lakeward for about 100 feet near the east end. There are a few concrete modules visible in the nearshore lakeward of the bulkhead. The bluff above the bulkhead has been re-graded to a stable slope and is vegetated. East of Sunset Park, approximately 450 feet of shore is covered with concrete rubble leading up to a concrete seawall and crib pier near the end of Windermere Drive. This area also includes a few concrete groins or other concrete modules in the nearshore. The next 1,650 feet of shore along North Beachview Road is generally protected by concrete rubble at the toe of the bluff. This area includes a series of three scenic overlooks with public access along North Beachview Road. Along a few sites, the concrete rubble extends up the bluff face adding significant weight to the bluff. This often causes slumping along unstable slopes. The shoreline in this area is wavelike in when viewed from above and narrow beaches often accumulate in shallow embayments along the shore. In some areas the beaches are stabilized by concrete groins, particularly near the east end of North Beachview Road.

At the east end of the reach, approximately 1,450 feet of shore at Osborne Park is protected with a series of seawalls constructed with Great Lakes Erosion Control Modules. The GLEC modules curve to the east to create a

Erosion of the shore along Lake Shore Boulevard is due to both wave action at the toe of the bluff and slumping of the upper portion of the bluff (left). Dumping concrete rubble or other material along the shore can increase erosion by adding significant weight to the bluff face. A large amount of concrete rubble and earth fill has been placed along the bluff in the area just west of Sunset Park in Willoughby (right .

slight embayment east of the groin structures at the end of North Beachview Road. Several rows of GLEC modules are also offset along the shore allowing narrow beaches to accumulate during periods of lower water levels. The bluff above the GLEC modules has been re-graded to a series of stable slopes and is vegetated for recreational use at the park. The GLEC modules continue along the shore lakeward of Orchard Road and into Reach 6.

Recession/Erosion

The ODNR Division of Geological Survey has evaluated the recession of Ohio's Lake Erie shore over three time periods: 1876 to 1973, 1973 to 1990 and 1990 to 2004. Changes in the rates measured during each of the time periods are generally attributed to development along the coast and natural factors such as lake level changes.

During the time period from 1876 to 1973 this reach experienced average recession rates ranging from less than 1-foot per year to 3-5 feet per year. Moderate recession was most common early in the time period in the unarmored areas downdrift of the headland near the Eastlake/Willoughby border. Recession rates generally decreased as the shore was progressively developed and protected with shore structures. Overall recession was typically greatest in unarmored areas downdrift of shore-perpendicular structures.

In the time period from 1973 to 1990 most of this reach experienced slow to moderate recession, although a few areas experienced rapid recession. Average recession rates ranged from 0 feet per year to 9.6 feet per year. Recession was greatest along the shore of Osborne Park (prior to the installation of the GLEC modules). Average recession rates also reached 6.3 feet per year along the beach just east of the headland near the Eastlake/Willoughby border. Average recession rates also reached 4.4 feet per year in the shallow embayment between the headlands created by the shore structures near the ends of Wrenwood Drive and just east of Pinehurst Boulevard. Average recession rates throughout the rest of the reach were generally between 0 and 2 feet per year. Overall, recession was typically greatest in areas without shore structures and areas relying on concrete rubble for shore protection.

From 1990 to 2004 average recession rates ranged from 0 feet per year to 2.6 feet per year but most of the reach experienced little to no recession. Recession was greatest in the areas without shore protection or relying on concrete rubble for shore protection along Lake Shore Boulevard (State Route 283) near the east end of Eastlake. Average recession rates

The shore of Sunset Park in Willoughby is protected with a steel sheet pile bulkhead at the base of a re-graded, vegetated bluff as viewed from the top of the bluff looking east (top) and from atop the steel sheet pile looking west (bottom).

also reached 1.8 feet per year along the shore near the east end of North Lakehurst Drive. Average recession rates were otherwise less than 1-foot per year throughout the reach. Average recession rates were considerably reduced at Osborne Park and along the east end of North Beachview Road due to the construction of shore structures in the area.

Beaches/Sand Supply

There is sand available in the littoral system throughout the reach from the Chagrin River to Osborne Park. A 3 to 6-foot thick layer of sand covers the nearshore zone along most of the reach, however man-made influences have caused a gradual decrease in sand resources. Lakebed down cutting and wave reflection as a result of shore structures has caused a general increase in water depths, increasing the wave energy in the area resulting in the gradual migration of beach sand from the shore to the nearshore. The construction of groins to stabilize eroding beaches in the area has also helped divert the littoral drift farther offshore (around the structures). This has contributed to the migration of sand resources offshore by preventing sand from reaching the shore in many areas.

In 1876 a narrow beach fronted the entire reach. As the shore was developed, a wide variety of structures were constructed to prevent erosion and protect upland property. The large-scale hardening of Lake Erie's shores has prevented sand from entering the littoral system and from eroding the bluffs, resulting in an overall reduction of beach material.

The construction of the breakwaters at the Eastlake Power Plant in the early 1950s has caused a gradual accumulation of sand updrift of the structures. This has significantly decreased sand resources in the western portion of this reach. By 1973, beaches fronted about 70 percent of the reach, but were quite narrow west of the headland near the Eastlake/Willoughby municipal boundary. In the eastern portion of the reach, beaches were often supported by small groins, many of which are still visible in the nearshore.

Today sand resources generally increase from west to east as sand supply at the west end of the reach is still restricted by the breakwaters at the Eastlake Power Plant. Even though sediment discharge from the Chagrin River does provide some sand to the western portion of the reach beaches in the area are primarily present updrift of shore-perpendicular structures or in shallow embayments between structures. Narrow, transient beaches commonly form at the toe of the bluff throughout the reach.

The shore of Osborne Park is protected with several rows of Great Lakes Erosion Control (GLEC) modules as viewed on Nov 14, 2009, from atop the modules looking west (left) and looking east (right)

Use of Shore Structures

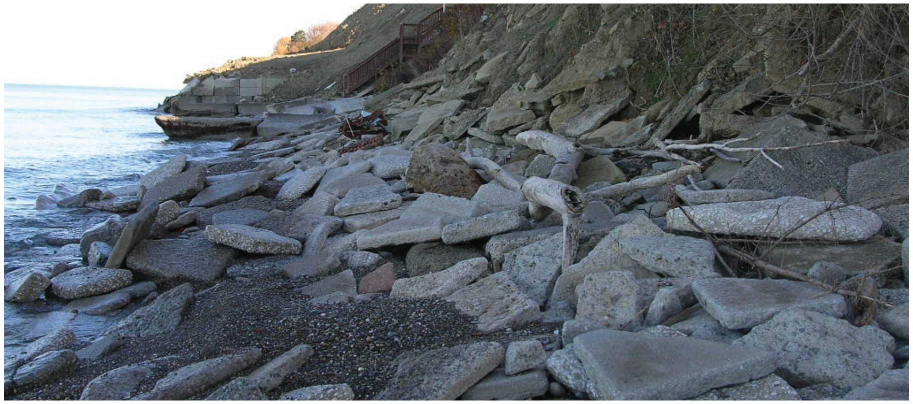
Much of the shore from the Chagrin River to Osborne Park is protected by some form of shore structure. Most of this reach is residential property with each property owner responsible for their own shore protection. This has led to a wide variety of shore structures, ranging from well-constructed seawalls and revetments to less effective measures, such as dumping concrete rubble along the shore.

Although ineffective, the most common shore structure in this reach is concrete rubble placed along the bluff face or at the toe of the bluff. Concrete rubble is primarily relied on for shore protection along most of Lake Shore Boulevard near the east end of Eastlake. In many cases the concrete rubble has also been displaced by wave action and is dispersed throughout the nearshore. The placement of pre-cast concrete modules, particularly Great Lakes Erosion Control Modules, at the toe of the bluff or in the nearshore is also common.

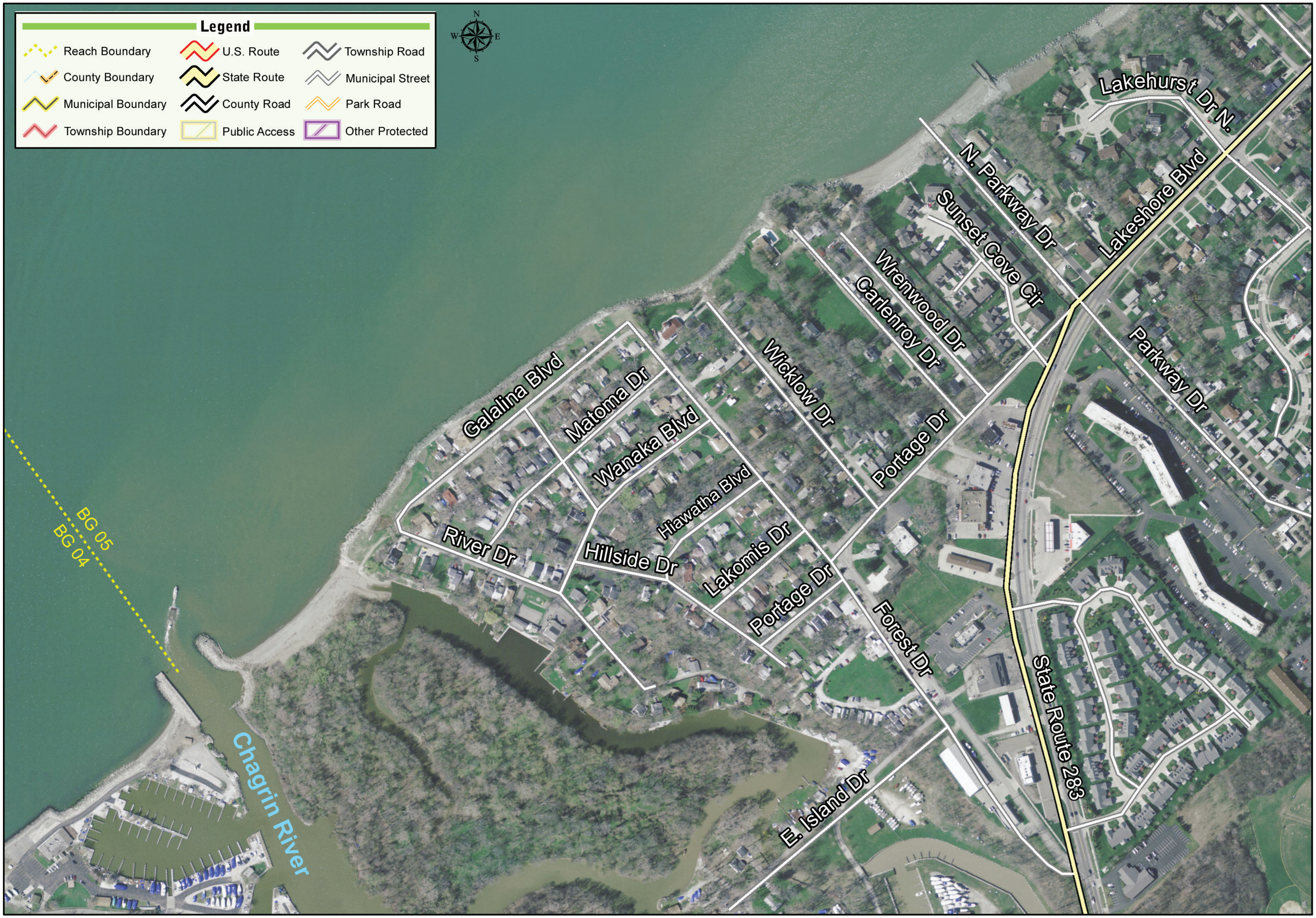
Several properties along Lake Shore Boulevard near the east end of Eastlake and the west end of Willoughby do not appear to be protected by any shore structures.

Summary

The reach from the mouth of the Chagrin River in Eastlake to Osborne Park in Willoughby primarily consists of residential development with the exception of Willowbeach Park, Sunset Park, Osborne Park and a series of scenic overlooks along Beachview Road in Willoughby. The relief of the upland is generally less than 10 to 15 feet near the Chagrin River but increases just east of North Parkway Drive in Eastlake. Bluff heights range from 30 to 40 feet throughout the rest of the reach. Sand resources generally increase from west to east in this reach due to the reduction of sand supply to the west end of the reach by the breakwaters at the Eastlake Power Plant. Much of the shore of this reach is armored with protective structures. Although ineffective as shore protection, concrete rubble is commonly placed along the shore of this reach. In some areas more effective structures such as revetments and seawalls are also present. Narrow beaches are present updrift of the small shore-perpendicular structures or in shallow embayments, particularly in the eastern half of the reach. This reach has historically experienced slow to moderate recession rates although more rapid recession has occurred downdrift of the small headlands in this reach, particularly on properties without shore structures or properties relying on concrete rubble for shore protection.



Narrow, transient beaches often form at the base of the bluff and lakeward of shore protection structures throughout this reach (top). Although ineffective as shore protection, concrete rubble is often dumped along the shore. Concrete rubble is easily fractured and displaced by wave action near the toe of the bluff and can cause slope failures by adding excessive weight to the bluff face (middle and bottom).



GIS Data Sources:
Aerial Photography - OSIP, State of Ohio, 2006
Political Boundaries - ODOT, 2007
Public Access - ODNR OCM, 2009-10
Transportation - LBRS, Erie County and State of Ohio, 2005-07

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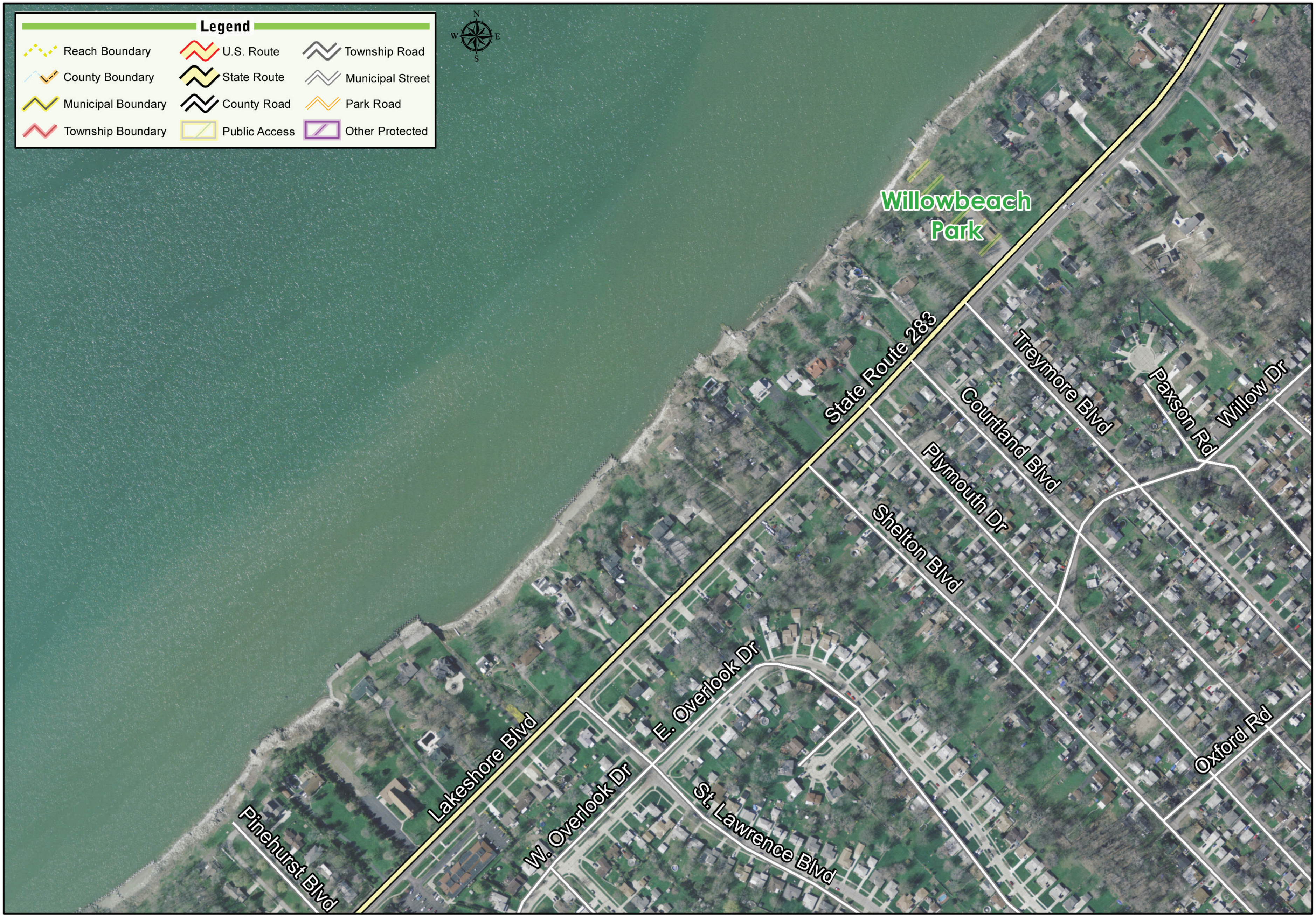

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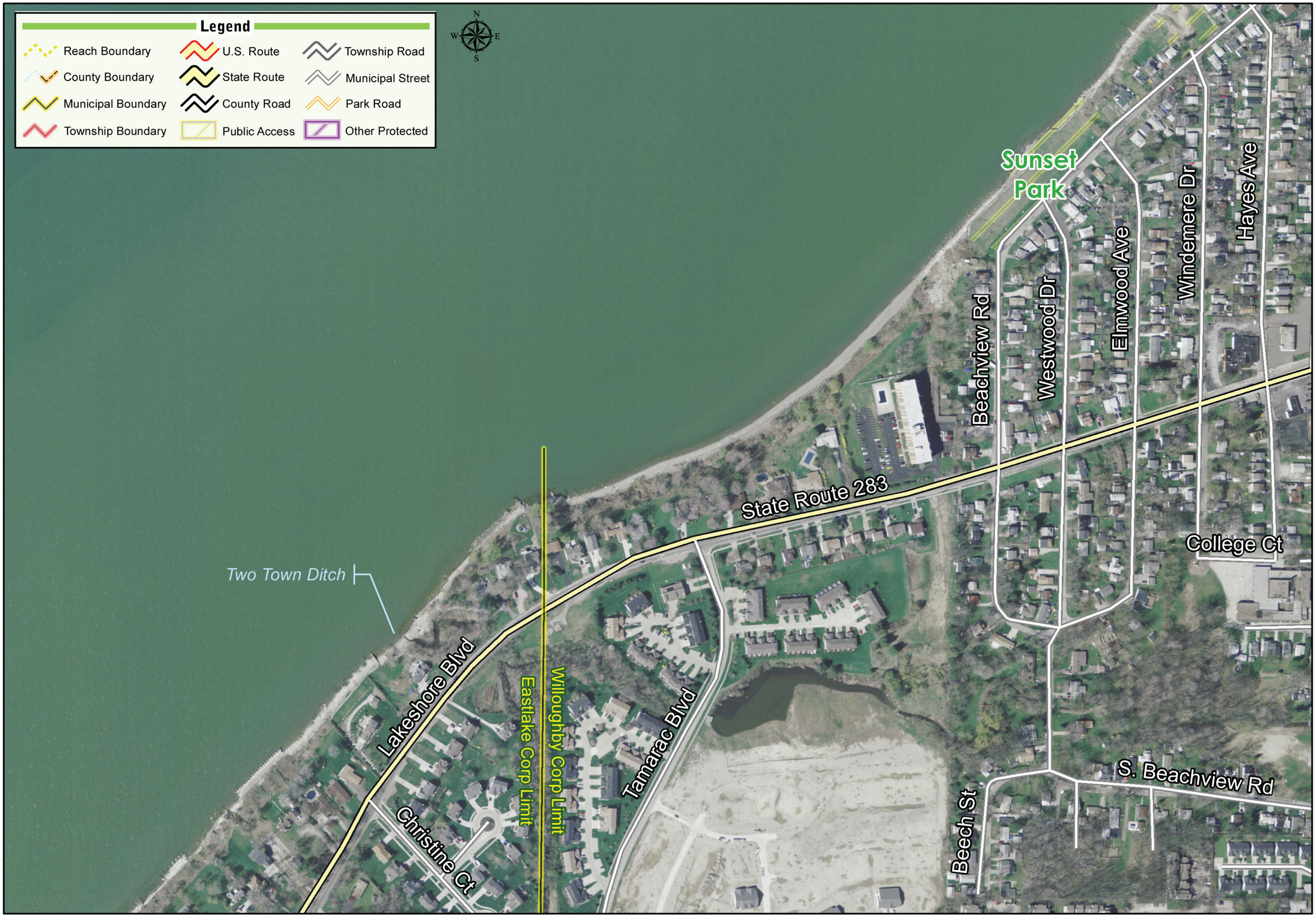

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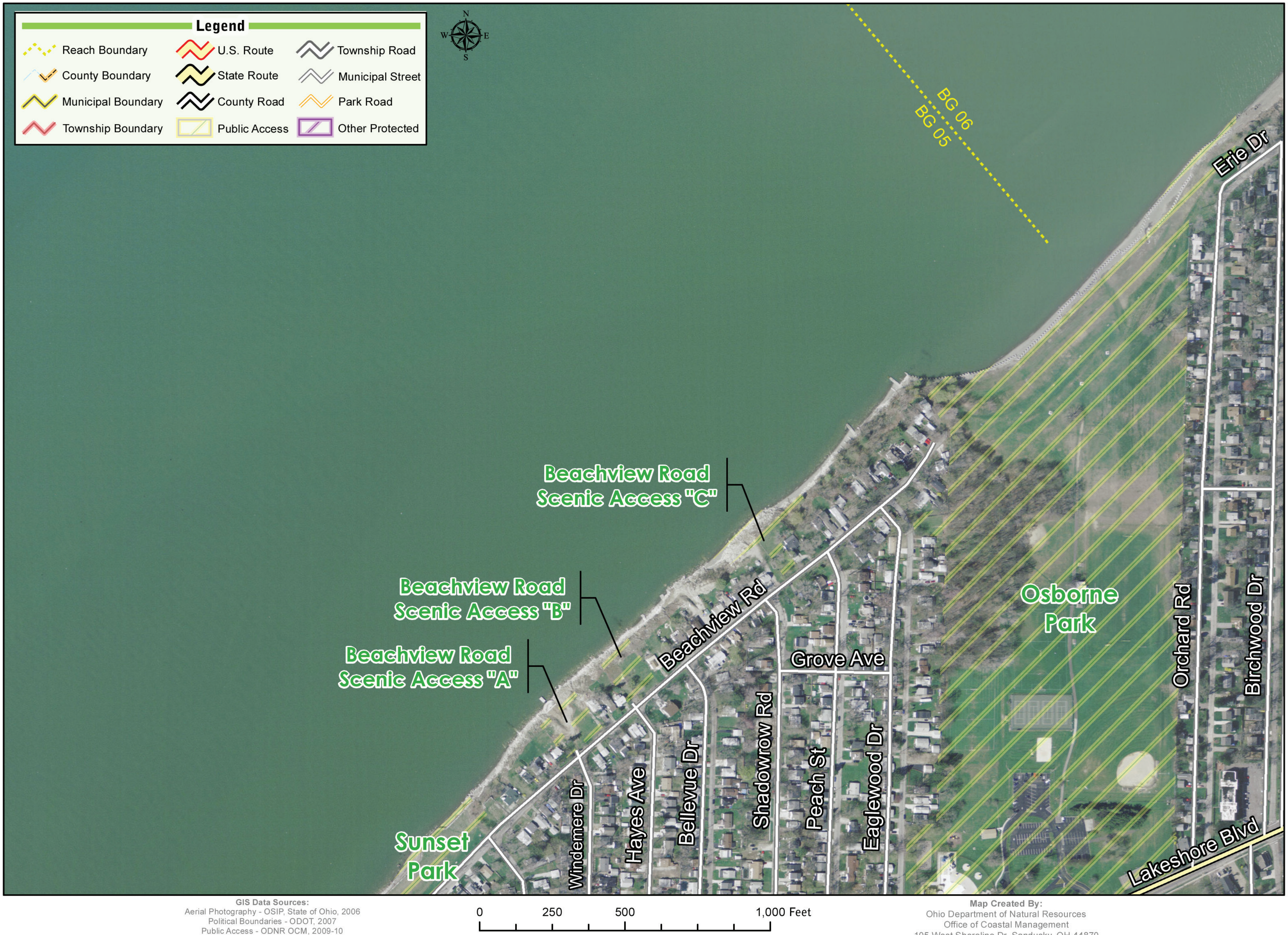

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Revetments along the toe of a bank will aid in protecting against wave-based erosion (top). Allowing native vegetation to grow on the natural bluff face or on the re-graded slope above seawalls, revetments and other shore structures helps stabilize the bluff by reducing excess surface and ground water (bottom).

Recommendations

The recommendations included below are options that may be applicable within this reach and should only be used for planning purposes. Based upon the physical characteristics of the reach, the following recommendations are suggested for the reach between the Chagrin River and Osborne Park. Each recommendation includes a brief overview of the solution prior to addressing areas within the reach where the recommendation is best suited. For more information on any of the items listed below, please refer to the Glossary and Erosion Control Methods Appendix.

In addition to the recommendations listed below, a "do nothing" alternative should also be considered. This may be a viable, and even favorable, alternative for much of Ohio's Lake Erie shore. Areas with existing shore structures and relatively low erosion rates, such as the shore of Osborne Park, may not require additional protection. In these areas attention should be focused on monitoring and maintaining the structures. In other areas, particularly those with a natural shoreline and relatively low erosion rates, the best option may be to hold development back from the shore and allow natural erosion/accretion processes to occur. This option should be considered on the unarmored beaches near the mouth of the Chagrin River.

Sand Management:

1. Conserve Sand Resources: Conserve sand resources within the shore and nearshore areas. Sand is a limited resource in constant fluctuation. Avoid removing sand from the system. Sand moved or excavated from along the shore during construction should be placed in the nearshore, not on the upland. The sand should also not be incorporated into the construction project.

While there is sand available in the littoral system, this recommendation should be considered throughout this reach. Several properties along Lake Shore Boulevard do not have shore protection and rely on narrow, transient beaches to dissipate wave energy. A decrease in sand resources could significantly increase erosion in this area.

Narrow, transient beaches often form lakeward of shore structures placed at the toe of the bluff throughout the reach. Sand accumulation lakeward of the structures and in the nearshore helps to reduce water depths and causes waves to break farther offshore. A reduction of sand in the littoral system would cause a corresponding increase of wave energy along the shore and reduce the effectiveness of many protective structures.

2. Beach Nourishment: Supplement the current sand supply with beach nourishment, also known as beach fill or pre-fill. Beaches protected by groins and detached breakwaters will benefit from initial nourishment (pre-fill during or directly after construction) and periodic re-nourishment. The sand used in these projects should be acquired from an upland source.

The east end of this reach is often fronted by narrow beaches that would benefit from nourishment. The addition of beach nourishment would be especially beneficial if added to sites with existing structures to stabilize it or as part of new construction for detached breakwaters.

3. Vegetation: Encourage growth of native vegetation on the back beach. Beach vegetation encourages the formation of a dune system by holding sand in place and providing protection from wind. It is also possible to simply allow the natural succession of native plant species to grow along the beach.

This recommendation is most applicable on wider beaches near the mouth of the Chagrin River and in the shallow embayment between the headland at the Eastlake/Willoughby border and Sunset Park. Native vegetation on the narrow beaches helps encourage sand accumulation and dune formation at the toe of the bluff. Dunes provide a natural sand reserve to restore beaches during periods of erosion due to storms or high water. Native varieties of American beach grass, little bluestem, sand dropseed or beach pea are well suited for beach vegetation in this area.

4. Sand Bypassing: Move sand from areas of excess accretion, usually up-drift of a shore perpendicular structure, to areas downdrift. By redistributing sand within the nearshore system, the littoral drift in the area will be more evenly dispersed.

Sand bypassing would be beneficial around the breakwaters at the Eastlake Power Plant (in Reach 04). The shore-perpendicular breakwaters protecting the water intake at the power plant have impeded the flow of littoral material, trapping sand on updrift beaches and preventing material from reaching the shore downdrift. Bypassing future accretion to the area east of the Chagrin River jetties would be beneficial to reduce erosion along the western shores of this reach.

5. Dredging: Dredge marinas and harbors on as frequent a basis as possible to add sand into the littoral system. Dredging of navigation channels at harbors and marinas enhances navigation for boaters and provides sand for downdrift areas when then dredged material is placed along the shore. When dredged material is disposed of on the upland or in offshore areas, the material is no longer a benefit to the littoral system. In-lake placement of dredged material is preferred as long as the sand meets the grain size and total organic carbon criteria. Uncontaminated dredge material that is composed of sand and gravel should be placed in the nearshore through sidecasting or placing downdrift. In order to nourish downdrift beaches sand must be placed in water shallow enough to be influenced by littoral currents.

If maintenance dredging is required at the mouth of the Chagrin River or near the Eastlake Power Plant, the nearshore placement of dredge materials should be considered. If the dredge materials are suitable for the nearshore environment, nearshore placement would be beneficial to nourish the narrow beach just east of the Chagrin River jetties.

Toe Protection:

6. Revetments: Revetments along the toe of a bank will aid in protecting against wave-based erosion. In areas without beaches, a structural measure may be necessary to protect the toe of the bank. The low-relief banks within this reach have relatively gradual slopes, which are ideal for revetment development. In essence, the revetments form a stable bank slope providing protection to the soil underneath while breaking up wave attacks. Since material eroded off the bank is one source of beach-building sand, some regulatory agencies may require that one of the design components for a revetment be the inclusion of sand pre-filling in the amount equal to that which would have been added to the system over the life of the structure.

Where constructed, revetments have been effective at stabilizing the shore and minimizing erosion in the area. Revetments are intended to dissipate wave energy along the rough angular slope of the structure and should be constructed with armor stone large enough to be stable when impacted by significant wave forces. To provide long term shore protection, revetments are typically constructed with carefully placed limestone, sandstone or engineered concrete modules.

In many areas of this reach, randomly placed or dumped concrete rubble is relied on for shore protection. Reviewing the areas in this reach with moderate recession rates demonstrates that concrete rubble does not provide adequate protection from wave action. In general, areas in this reach relying on concrete rubble for shore protection have higher average recession rates than properties with well constructed revetments or seawalls. This is because concrete rubble is too light to withstand the wave forces along the shore and is easily displaced and transported by littoral currents. Rubble on the

Concrete rubble is too light to withstand wave forces along the shore and is easily transported by littoral currents. Fractured concrete rubble provides little protection and is a significant hazard (top and above).

The bluff at Osborne Park has been stabilized with toe protection, re-grading and vegetation.

upper bluff will frequently slide down to the toe and increase the continuing erosion of the bluff. Individual pieces of concrete typically weigh less than a few hundred pounds as compared to the several-ton armor stone used in revetment construction.

Concrete rubble also fractures much more easily than the solid stone armor units used in properly constructed revetments. Much of the concrete placed along the shore is in the form of slabs and broken pavement. Randomly placed concrete rubble often has large voids causing concrete slabs to be unevenly supported and easily fractured. When concrete cracks it also crumbles more easily than limestone or sandstone resulting in very small pieces that are easily moved by waves, providing little protection to the shore. In some cases, concrete rubble can be used in the base layers of a revetment if covered by suitably sized armor stone.

Bluff/Bank Modifications:

7. <u>Re-Grading/Terracing</u>: Re-grade or terrace less stable bluffs/banks to a more gradual slope. By creating a lower (flatter) slope angle or terracing the slope to a series of steps, instability caused by gravity's forces on the upper bluff/bank is decreased. Re-grading is a non-structural approach to stabilize the bluff that leaves the shore relatively unaltered. When re-grading, also review the toe of the bluff/bank to determine if a structural (revetment) or non-structural (beach nourishment) solution would be preferable.

This recommendation is applicable to the 30 to 40-foot bluffs along the shore east of North Parkway Drive in this reach. The bluffs from the Chagrin River to Osborne Park are primarily composed of till covered with layers of laminated clay and sand. These materials are highly susceptible to slumping if the toe of the bluff is eroded by wave action or if slope failures occur as a result of ground water seepage. In some areas, particularly along Lake Shore Boulevard in Eastlake, upland structures are very close to the edge of the bluff. In this case terracing of the bluff face may be considered.

Re-grading or terracing is typically done in conjunction with the construction of toe protection to provide a stable slope above the structure. A review of erosion rates before and after re-grading and installing toe protection at Osborne Park illustrates the effectiveness of this measure. Average recession rates from 1973 to 1990 (prior to construction) reached 9.6 feet per year. After construction (during the time period from 1990 to 2004) the bluff was stable with average recession rates of 0 feet per year.

***8. Surface Water Management*: Route surface water away from the face of the bluff/bank. In areas where gullies or rills are forming, surface water is slowly eroding the face of the bluff/bank. Where possible, re-route water away from the bluff/bank. Sometimes this may involve changing gutter or driveway drainage. Terracing of the bluff/bank can also be used as a means of intercepting and diverting seeped ground water. Sources of surface water include, but are not limited to roof gutter downspouts, runoff from driveways and sidewalks, precipitation, and sprinkler systems.**

The re-routing of surface water should occur throughout the Chagrin River to Osborne Park reach. The till covered with laminated clay and sand that makes up the bluffs in this reach are highly erodible by surface water. Attention to the signs of surface water will allow for early action on limiting the affects of runoff.

***9. Ground Water Management*: Remove ground water from within the bank. Drainage should be installed in areas with excess water in the bank, visible as seeps or springs in the middle of the bank. A subsurface drainage system should remove water from an upper layer within the bank (often a sandy layer), and should exit at the lake level to limit lower bank erosion. Sources of ground water include, but are not limited to leaking septic systems, underground pipes or swimming pools.**

East of North Parkway Drive, where bluff heights range from 30 to 40 feet, ground water seepage can be a significant cause of erosion. The bluffs typically contain layers of sand and laminated clay. Ground water can cause slipping between the layers leading to slope failures. A subsurface drainage system should be considered for properties prone to rotational slumps or with visible signs of ground water seepage. Drainage systems are often installed as a component of a re-grading or terracing project to create a stable slope.

The addition of a drainage system can help reduce erosion due to surface and ground water. Any water collected should be drained as close to the toe of the bluff as possible.

***10. Vegetation*: Encourage growth of vegetation along the bank slope. Where possible plant vegetation, preferably native species, along the bank to remove excess ground water while retaining soil strength. It is also possible to simply allow the natural succession of native plant species to grow along the bank.**

This recommendation is applicable throughout the area from the mouth of the Chagrin River in Eastlake to Osborne Park in Willoughby. Allowing native vegetation to grow on the natural bluff face or on the re-graded slope above the seawalls, revetments and other shore structures in this reach would reduce excess ground water and help stabilize the bluffs and low banks. Well-rooted vegetation also helps hold soil in place to prevent erosion from runoff and can protect the bluff face from weathering.

The till and clay bluffs in this area are sloped, exposed to harsh weathering processes and are relatively low in nutrients. Native plants from a local source are best adapted to survive in these conditions. It is typically most effective to cultivate plants already growing along the shore or to survey established vegetation along nearby properties and plant similar varieties. In general, well-rooted grasses, shrubs and small trees are most effective as they remove surface and ground water without adding excessive weight to the bluff face. Native varieties of indian grass, big bluestem grass, mesic grapes, sumacs, gray dogwood, heartleaved willow, and cottonwood trees are well adapted to survive along the till and glaciolacustrine bluffs common in this area.

While beneficial along the bluff, vegetation growing on shore structures should be closely monitored. For example, vegetation growing on a rip-rap or armor stone revetment could damage the structure by causing stones to be broken or displaced.

Management and Monitoring:

***11. Bank-Top Management*: Keep heavy materials, equipment and/or structures well back from the edge of the bank-top. Any structure (concrete decks, stone walls) or heavy object (vehicles or construction equipment) placed near the bank edge will increase the stress within the soil and can lead to slope failure.**

This recommendation applies to the 30 to 40-foot bluffs throughout this reach. Care should be taken when accessing the top of the bluff with heavy materials or machinery while maintaining existing shore structures to prevent sliding failures. This recommendation should also be carefully considered when planning new structures on the upland or along the shore.

This recommendation also applies to the placement of debris or yard waste near or over the edge of the bluff. Leaves and grass clippings can become saturated with water and greatly increase the weight on the bank's slope, directly causing slumping. Concrete rubble and construction debris should never be placed along or near the slope of the bluff.

12. <u>Coordination of Projects</u>: Continuation of similar erosion control measures along a stretch of shore will often yield more effective protection than the installation of multiple types of structures adjacent to one another. Most erosion control measures function better when utilized over large areas of the shore.

This recommendation is applicable throughout the reach. In residential areas, shoreline property is often divided into parcels as small as 50 feet wide with each property owner responsible for their own shore protection. This is common throughout the reach from the Chagrin River to Osborne Park and has led to the construction of a mix of shore protection structures of varying designs, construction quality and condition. Complex interaction between structures in certain wave conditions often limits their effectiveness and at times can cause increased erosion at the site or on adjacent properties. This is best avoided by coordinating projects over a length of shore. In addition to creating more effective shore protection, coordinating projects limits the amount of time the littoral system is disturbed and can also allow some engineering and construction expenses to be spread over several properties.

When structures can not be continued across multiple properties, conditions at the ends of the structure should be carefully considered in the design. The structures should be designed to prevent intersections causing increased wave energy or gaps between structures where increased erosion is likely.

13. <u>Shore Structure Management/Monitoring</u>: Monitor and maintain shore structures. Routine monitoring of shore structures will allow for early detection of any potential failures. Smaller repairs performed more frequently will be less costly and can often increase how long the structure will be effective at controlling erosion. If removal of an aged or deteriorating structure is necessary, consider the above recommended items as potential future solutions.

Many of the structures in this reach were constructed more than 30 years ago. The condition of the structures should be closely monitored and repairs should be made when necessary. Periodic monitoring of existing structures should include a visual inspection for displaced armor stone, cracked armor stone or concrete, uneven settling of the structure, slumping or gullies in the upland or bluff face and flanking at the ends of structures. Inspections should also include a review of sand resources or beach widths in the area and should note conditions on adjacent properties. If the base of a structure is visible during periods of low water, inspections should also be made to check for scour and possible undermining of the structure.

If new erosion control measures are installed, the recommendations listed above should be considered. A combination of recommendations may be the most effective solution. For example, to effectively protect a steep bluff with concrete rubble placed at the toe, re-grading the bluff and constructing an armor stone revetment may be considered. In many cases the existing concrete rubble along the shore can be re-used in the base of the structure if covered with appropriately sized armor stone.

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