Agenda Report

Subject: **Willow Road Stormwater Tunnel Project: Feasibility Report**

Prepared By: Steven M. Saunders, Director of Public Works/Village Engineer

Date: September 5, 2012

Background and Project Description

As a result of severe flooding events in 2007 and 2008, the Village engaged the services of Christopher B. Burke Engineering, Ltd. (CBBEL) to evaluate two larger areas of southwestern Winnetka that suffered significant flood damage, and to develop flood risk reduction improvements to provide protection against a 10-year flood event. After receipt and discussion of that report, the Village Council extended CBBEL's engagement to evaluate and develop improvements for 6 additional areas throughout Winnetka. This second study was completed and presented to the Village Council at the July 12, 2011 Study Session – 10 days before a devastating flood event. In the aftermath of the July flooding event, the Village directed CBBEL to evaluate the proposed 10-year flood reduction improvements against the actual rainfall received July 22-23, 2012. Predictably, this analysis indicated that the proposed improvements would have provided little benefit in the face of such a large event. The Council then directed CBBEL to extend and expand their analysis to provide flood risk reduction against a much larger set of storms with 25-year, 50-year, and 100-year return periods. This analysis was completed and presented to the Village Council in October, 2011.

CBBEL's recommendations also identified an additional project, consisting of a new storm sewer beneath Willow Road that would convey water from a roughly 900-acre drainage area on the west side of the Village eastward, towards Lake Michigan. This project, known as the Willow Road Tunnel project, would combine improvements for 5 of CBBEL's 8 study areas into a single project with a cost estimate of $32.5 million. This is not an additional study area, but rather a combined one, with a proposed improvement that benefits the North (including Provident Avenue) and South of Willow Road, Cherry Street Outlet and the Underpass Study areas for the 100-year design storm event. The benefits realized in each of the study areas included with this improvement are equal to the benefits realized for the recommendations in each itemized study area. This proposed improvement consists of a an 8-foot diameter storm sewer underneath Willow Road running from approximately Glendale Avenue to Lake Michigan, a distance of some 7,900 feet. Approximately 3,800 feet would be constructed by tunneling, the remainder by open cut methods. The project includes construction of additional storm sewer connected to the tunnel to provide relief to 5 drainage basins affected by frequent and/or severe stormwater flooding, construction of a structure to address water quality, and construction of an outlet structure to control water velocity and prevent erosion. The proposed project is graphically depicted in Attachment #1.

Understanding of Assignment/Purpose of Report

While a number of potential challenges and impediments are identified with this project, it has the advantage of being less costly than constructing all of the previously identified western improvements. It is also a simpler project from the perspective that there are no pumping facilities required, and the project would not require land acquisition from the many agencies that own available open space for detention. As a result, the Council directed staff to further delve into the feasibility of the proposed Tunnel project, to determine if the project can realistically be constructed for the associated cost estimate. This report responds to that Council direction.

Soil Boring Analysis

When the tunnel project was first conceived, a significant unknown possible expense involved potential construction through rock, at a cost of $56.8 million, as opposed to construction through clay at a cost of $32.5 million. To resolve this uncertainty, and to verify that soils were suitable for construction via tunneling, the Village obtained soil borings at critical locations along the length of the proposed tunnel route. Four borings were advanced to a depth 5 feet below the proposed tunnel depth. No rock was encountered in these borings, and the soils encountered were of suitable quality to permit tunneling construction. While this investigation will need to be supplemented with detailed soil borings along the entire construction route, it can be concluded that no rock will be encountered, and the clay soils are suitable for tunneling construction. The soil boring reports are shown in Attachment #2.

Outfall Structure Evaluation

A key component of the Willow Road Stormwater Tunnel is the design of the outlet structure to Lake Michigan. This structure must be designed with multiple factors in mind. It must reduce outlet velocity to safe levels; it must control erosion and prevent pollution; it must not contribute to beach degradation; it must withstand wave and ice action; it must not interfere with navigation or other uses of the Lake; and it must be aesthetically acceptable. Given that this is a significant challenge, in the unique setting of a coastal environment, the Village contracted with Baird and Associates, from the specialized discipline of coastal engineering, to provide conceptual designs and cost estimates for this structure. Baird and Associates (Baird) undertook a detailed design study focused on this outfall structure, with the following scope of work:

- Summary of coastal conditions, based on compilation/review of existing data (bathymetric survey, navigational charts, soil borings, beach soil sampling, water levels, wave climate, ice conditions, sediment transport and qualitative shoreline change analysis);
- Development of conceptual outfall alternatives;
- Preparation of probable construction costs;
- Evaluation of alternatives and identification of the preferred option.

This process was primarily based on the following criteria:

- Anticipated impacts on sediment transport processes and the shoreline (accretion/erosion);
- Outfall sedimentation (and possible blockage);
- Risk of structure damage by waves/ice;
- Qualitative assessment of water mixing efficiency;
- Regulatory agency input; and
- Constructability and estimated costs.

After determining key design parameters and criteria, Baird identified 8 potential outfall structure designs for consideration. Baird evaluated each of these 8 alternatives against critical design criteria and determined that 5 alternatives merited further consideration for the project. These 5 alternatives are listed below, and are more fully described in Section III of Baird's report. The following table provides a description of each alternative, a summary of the advantages and drawbacks of each, and the estimated probable cost for each.

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Alternative/ Short Description	Advantages	Disadvantages	Estimated Cost
1. Open Channel – CIP concrete Provide a trapezoidal cast-in-place concrete channel (30' long) with armor stone flanking and scour, discharge on the beach	• Easy to implement, land-based construction • Cost • Reduced impacts to sediment transport • Does not require a baffle system to reduce flow velocity • Self-flushing capability • Structure footprint below OHWM – no anticipated permit mitigation for less than 0.1 acres	• Large channel width and flow area • Aesthetics • Potential safety issue to beach users due to high discharge water velocity • Water mixing in the nearshore zone	$140,000
2. Pipe or culvert discharge on beach Provide a pipe or culvert (30' long) with stone protection structures and scour stone, discharge on the beach or to the water's edge (LWD)	• Easy to implement, land based construction • Reduced impacts to sediment transport • Self-flushing capability • Cost • Structure footprint below OHWM-no anticipated permit mitigation for less than 0.1 acres	• Pipe or culvert stability • Aesthetics • Safety issue for beach users due to high discharge water velocity to Lake Michigan • Water mixing in the nearshore zone • Might require a baffle system to reduce flow velocity	$160,000
3. Pipe or culvert discharge offshore Provide a pipe or culvert (140' long) with stone protection structures and scour stone, discharge offshore	• Does not require a baffle system to reduce flow velocity • Self-flushing capability • Water mixing in deeper water • Public access and beach enhancement opportunities	• Pipe or culvert stability • Structure footprint below OHWM-possible permit mitigation • Impacts the sediment transport, beach pre-fill needed • Cost • Aesthetics/Lake Michigan views	$550,000
4. Pipe on lake bottom Provide a pipe (185' long) with supporting piles above the lakebed with an offshore discharge	• Does not require a baffle system to reduce flow velocity • Self-flushing capability • Water mixing in deeper water • Public access and beach enhancement opportunities	• Pipe or culvert stability • Cost • Significant ice and wave uplift forces • Structure footprint below OHWM-possible permit mitigation • Impacts the sediment transport, beach pre-fill needed • Aesthetics/Lake Michigan views	$1,050,000
5. Buried Pipe Provide a buried pipe (215' long) with an offshore discharge structure	• Does not require a baffle system to reduce velocity • No permit mitigation • Water mixing in deeper water • Does not impact the sediment transport • Aesthetics	• Cost	$1,400,000

Based on the information shown above, two alternatives stand out for ultimate consideration – the outfall open channel (Alternative #1) and the Buried Pipe with

Offshore Discharge Structure (Alternative #5). At this time staff is recommending that, of the two, Alternative #1 be considered as the preferred alternative, based primarily on its significantly lower initial capital cost ($140,000 vs $1,400,000).

Baird's final report is attached as Attachment #3.

Regulatory Agency Evaluation

The proposed project involves diverting significant subwatershed of the Skokie River east, through a drainage divide and into Lake Michigan, via a new stormwater discharge system to the Lake. The project will therefore require permitting and cooperation with several regulatory agencies, including the Illinois Environmental Protection Agency, the US Army Corps of Engineers, the Illinois Department of Natural Resources, the North Cook County Soil and Water Conservation District, and the Metropolitan Water Reclamation District of Greater Chicago. Staff has engaged these regulatory agencies in multiple meetings to discuss the project, and the following describes staff's understanding of the current regulatory environment and approach of each agency.

Illinois Environmental Protection Agency (IEPA). The IEPA is one of three agencies that exercise jurisdiction over discharges to Lake Michigan via a "joint permit" process. The IEPA's regulatory interest in this project is derived from the Clean Water Act, and they will therefore evaluate this project from a water quality and resource protection perspective. The project will be processed through Section 401 of the Clean Water Act, which requires that a permit applicant assure the following:

- Applicable water quality standards will not be exceeded;
- All existing uses of the Lake will be fully protected;
- Incorporate all technically and economically reasonable measures to avoid or minimize increase in pollutant loading;
- If an activity results in an increased pollutant loading, that activity must benefit the community at large.

Unfortunately, the means to demonstrate these assurances are very project-specific, so the IEPA was unable to evaluate or determine the likelihood of the Village obtaining a project permit. IEPA did, however, provide guidance on the most important factors to be considered in their evaluation of the project. The Village will need obtain and provide chemical sampling data sufficient to demonstrate the water quality in the Village's existing storm sewer system. This work is included in the water quality assessment being performed by Baxter & Woodman under the Stormwater Master Plan contract. The data developed from this assessment will provide the Village and the IEPA with information necessary to develop a water quality protection plan to be incorporated into the formal permit application.

During staff's meetings with IEPA, we discussed the possibility of managing water quality at distributed points throughout the project reach, as opposed to a single, "end of pipe" treatment structure. This approach would consist of managing for sediments,

floatables, oils and grease, nutrients, and other common stormwater contaminants at intermediate intake points rather than the outlet point. Another key point in this approach is the possibility of designing the project such that approximately the first inch of rainfall, which contains most contaminants, would be directed via the existing stormwater system to the Skokie River, rather than the Lake. Without committing to approval, the IEPA expressed that this approach is sensible and worth pursuing.

US Army Corps of Engineers (USACE). USACE is the second of the three major regulatory agencies involved in the "joint permit" application process. The USACE project manager assigned to the tunnel project was very forthcoming with comments about the feasibility of the project. USACE is primarily concerned with physical aspects of the project associated directly with the discharge structure, including erosion and sediment control, impacts on navigation and safety, potential impacts on natural Lake Michigan near-shore processes (sediment transport) and adjacent properties, maintenance of public accessibility and aesthetic appearance. USACE reviewed each of the 5 potential discharge structures under consideration with staff, CBBEL, and Baird, and did not express extreme concerns with any of them. USACE indicated that the amount of effort involved in permitting the outfall structures would vary with the amount of disturbance below the Ordinary High Water Mark caused by the outfall structure. Alternate #1, consisting of a fairly simple discharge structure outletting directly to the Lake, produces the fewest potential impacts and would be the least difficult to permit. The remaining outlet structures create more construction disturbance and extend further into the Lake, causing greater potential impacts on natural near-shore processes and navigation.

Illinois Department of Natural Resources (IDNR). IDNR is the third agency involved in the "joint permit" process. During our meetings, IDNR expressed that they would likely permit the project provided that the other two agencies in the joint permit process were satisfied. IDNR's primary concern with this project centered on ascertaining that the project would result in increased quantities of stormwater being delivered to the Lake from the Skokie River watershed, partially reversing a 100-year-old diversion of stormwater from the Chicago River system away from the Lake. A monitoring plan will have to be implemented for the preferred alternative. This plan relies on annual survey information and analyzing the nearshore morphological changes. The goal is to demonstrate the project does not produce any significant impacts on near-shore processes (sediment transport) and adjacent properties.

North Cook County Soil and Water Conservation District (NCCSWCD). NCCSWCD's interest in this project pertains to sedimentation and erosion control, which are aspects more associated with construction of the project rather than the design or permitting. The Village will have to develop a very robust erosion and sedimentation control plan for the contractors to implement and follow, however this does not appear to be a significant hurdle for the project.

Metropolitan Water Reclamation District of Greater Chicago (MWRDGC). The MWRDGC has stormwater permitting authority in Cook County, and thus the Village would need to obtain a permit for the new outfall structure from the MWRDGC. During meetings with MWRDCG staff, including the Executive Director, the Village was

informed that MWRDGC would likely issue a permit for the project if the three "joint permitting" regulatory agencies approved the project.

Summary. The proposed project is being considered in a very complex regulatory environment. Based on meetings thus far, it does not appear that there are insurmountable hurdles or impediments to the project from regulatory agencies. The IEPA appears to be the agency that will require the most effort and consideration during project design, however they seem to have a clear process to follow, and they have been open to favorably consider the Village's initial conceptual plan to address their concerns. The next steps involved with fully understanding IEPA's requirements is to complete the water quality evaluation.

One uncertainty resulting from the complex permitting environment is the effect on the timeline and project schedule. It would not be unreasonable to expect the total elapsed time for the permitting phase of this project to run 12 – 14 months from the initial permit submittal to final regulatory approval.

One other factor to consider, which was raised by each regulatory agency, is the necessity for early and effective communication and involvement with various stakeholders. Lake Michigan is a critical resource to a wide variety of stakeholder groups, and the earlier and more effectively the Village engages these groups, the more likely that their input to the permitting process will be informed, thoughtful, and beneficial to the project as a whole.

Railroad Evaluation

The proposed project routing traverses beneath the Union Pacific Railroad (UPRR) at Willow Road. Staff has contacted Union Pacific and learned that they have pre-existing standards and requirements in place for utilities traversing beneath their facilities. These requirements include a minimum depth beneath the trackbed of 4.5 feet (the proposed tunnel will be approximately 18 feet below the trackbed), and the inclusion of a casing pipe beneath the railroad trackbed. Tunneling is a permitted method for installation of utilities beneath railroad facilities. Because of the size and depth of the proposed tunnel, the proposed project will require approval from the office of the Chief Structural Engineer. However, discussions with UPRR staff indicate that the project should be considered as feasible subject to these permitting requirements.

The application form also contains other requirements common to railroad construction (protective liability insurance, use of railroad flaggers during contractor operations, etc.), which pose no special or unique concerns for this project. Based on this information, it appears that there are no significant difficulties or unanticipated expenditures associated with construction beneath the Union Pacific Railroad Right-of-Way.

Utility Evaluation

The proposed tunnel project is a significant construction project, and there is a high likelihood that the project will come into conflict with existing utility infrastructure at various points. At this time, it should be considered a given that minor utility structures such as sewer, water gas, cable, and electric services will be in conflict with aspects of the proposed construction. This occurs with just about every utility construction project,

and even street repair projects, and is typically handled as part of the construction planning process. What could be much more problematic, however, would be the presence of a major utility conflict with a regional fiber optic line, high pressure gas lines, MWRDGC intercepting sewers, or other critical infrastructure. While the Village ultimately has the authority to require relocation of utilities located in its rights-of-way to allow implementation of Village projects, relocations are often technically difficult, time consuming, and can result in increased project costs. Staff has obtained the locations of key water, gas, electric, and communications infrastructure from various public and private utilities and there are some points of conflict that will need to be addressed. Among these are the presence of an ATT duct bank underneath Hibbard Road, a fiber optic cable along Ash Street and Willow Road towards the very west end of the project, and some Village sanitary sewers and water mains.

Cost Evaluation

When the tunnel project was initially proposed, CBBEL provided general per-foot cost estimates for the tunneled portion of the work, based on information they derived from previous tunneling projects they had designed. In order to more fully understand the costs of the tunneling portion of the project staff and CBBEL worked with a local tunneling contractor, Kenny Construction, to further refine and detail tunneling cost estimates.. Kenny Construction is a large contractor based in Northbrook with experience in constructing tunnels throughout the United States. After discussing the project and reviewing the details, Kenny Construction prepared a more detailed cost breakdown using the preliminary designs prepared by CBBEL. Whereas CBBEL's initial cost estimate was based on cost-per-foot for previous projects, Kenny's cost breakdown was prepared using unit costs, estimates of time required for the project, estimates of materials to be hauled out, mobilization costs, and other details. Kenny Construction has estimated the tunneling portion of the project to cost $9.541 million, compared to CBBEL's initial estimate of $8.25 million.

At the time of preliminary engineering, CBBEL included $50,000 for an erosion control structure at the Lake Michigan outfall. This cost has been increased to $140,000, representing the least costly preferred alternative provided by Baird Associates for the outfall structure.

A side-by side cost estimate for the project is shown below, comparing CBBEL's initial costs and the current, all-in cost estimate including Kenny Construction's modified tunnel costs, the revised outfall cost estimate as prepared by Baird Associates, and additional project related costs such as project management and material testing.

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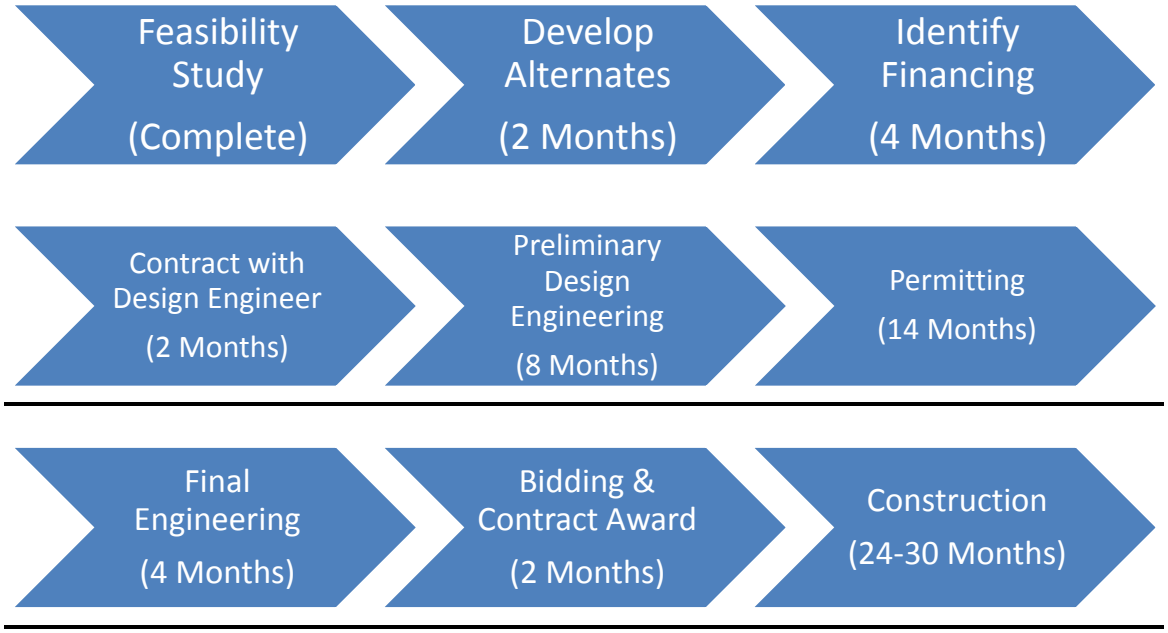
Item	Original Cost Estimate	Current Cost Estimate	Comments
Seeding/Erosion Control Blanket	$15,000	$15,000	
Topsoil Furnish and Place	$20,000	$20,000	
Remove Storm Sewer & Structure	$230,000	$230,000	
Storm Sewer, RCP (24" to 96")	$6,635,000	$6,635,000	Combines several diameters of storm sewer
Storm Sewer, RCP 96", Tunneled	$8,250,000	$9,540,870	Used Kenny Construction Detailed Estimate, see Attachment #4
Box Culvert 5'X8'	$1,125,000	$1,125,000	
Storm Structures, 5' Dia., 7' Dia, 10' Dia.	$965,000	$965,000	
Junction Chamber	$100,000	$100,000	
Riprap with Filter Fabric	$5,000	$5,000	
Class D Pavement Patches, 12 "	$2,649,975	$2,649,975	
Trench Backfill, Special	$2,981,250	$2,981,250	
Energy Dissipater	$50,000	$140,000	Used Baird Associates estimate for outlet Alternate #1
Water Quality Structure	$94,000	$94,000	
Traffic Control	$1,000,000	$1,000,000	
Construction Layout	$500,000	$500,000	
Utility Relocations	$-	$200,000	Conceptual Estimate
Subtotal Construction	$24,620,225	$26,201,095	
Contingency (20%)	$4,924,045	$4,763,176	Contingency reduced to 15% (from 20%) on tunneling item based on additional detail
Construction Total	$29,544,270	30,964,271	
Design Engineering (4.5%)	$1,329,492	$1,393,392	Percentage of construction costs
Construction Observation (4.5%)	$1,329,492	$1,393,392	Percentage of construction costs
Permitting (1.0%)	$295,443	$309,643	Percentage of construction costs
Feasibility Studies	$-	$37,750	Completed
Material Testing	$-	$35,000	Estimate
Project Management (1.5%)	$-	$464,464	Estimate
Total Estimated Project Cost	***$32,498,697***	***$34,597,912***	

It can be seen that the more detailed cost estimate for the tunneling work and the outlet structure has resulted in an increased cost, from approximately $32.5 million to approximately $34.6 million.

Project Timeline and Decision Points

The following is a simplified flow chart that outlines the major work tasks that remain on this project. At the end of each of these steps is an opportunity for the Council to make a decision on whether or not to continue advancing the project. The total elapsed time on this project, from today to the end of construction, is estimated at approximately 60 to 66 months. Therefore, if the Village were to begin contracting with a design engineer in April of 2013, Construction would be complete in the spring of 2018.



Potential Alternate Routes and Methods

During discussions with Kenny Construction, some potential project modifications were identified that could reduce the overall cost of the project. These modifications involve relocating most of the large diameter storm sewer, including the tunneled portion, from Willow Road one block north to Ash Street. The proposed storm sewer would still have an outlet to Lake Michigan at Willow Road, since that is where the public access point is located. However, relocating the storm sewer to Ash Street eliminates some of the connecting pipe runs necessary and will reduce the project cost somewhat. Relocating the pipe run to Ash Street would also potentially allow construction to proceed using a different tunneling method known as direct jacking. This method would require additional shafts to be constructed that would not be possible on Willow Road because of the attendant traffic disruption. However, Kenny Construction has suggested that this approach could reduce the overall construction cost.

At this time it is not known the extent to which the construction cost could be reduced with this project change, however this information could be obtained with a further iteration of the preliminary project design, and further design/construction input from Kenny Construction. This will be further discussed in the "Recommendations" section below.

Conclusion and Recommendations

At this time, information points to the following conclusions:

1. The project appears to be feasible from a technical and regulatory perspective. While the proposed project is not without challenges, none of the challenges appear insurmountable at this time.

2. The project timeline is estimated at an elapsed time of 30 months from authorization to proceed with detailed engineering and permitting until construction begins, with an additional 24 – 30 months of construction anticipated.
3. The estimated project cost, including all expenses related to connecting the five drainage areas to the tunnel, is $34.6 million, with the possibility of reduction using an alternate route (Ash Street) and alternate construction methods.

While there are several decisions that need to be made before advancing with detailed engineering and permitting for the project, the first next step on this project is to engage CBBEL and Kenny Construction with two small contracts, with no promise of future work, to develop and evaluate the cost of a possible alternate project route using Ash Street, and using the direct jacking method of construction. It is estimated that the total value of these two contracts will be less than $15,000.

Recommendation:

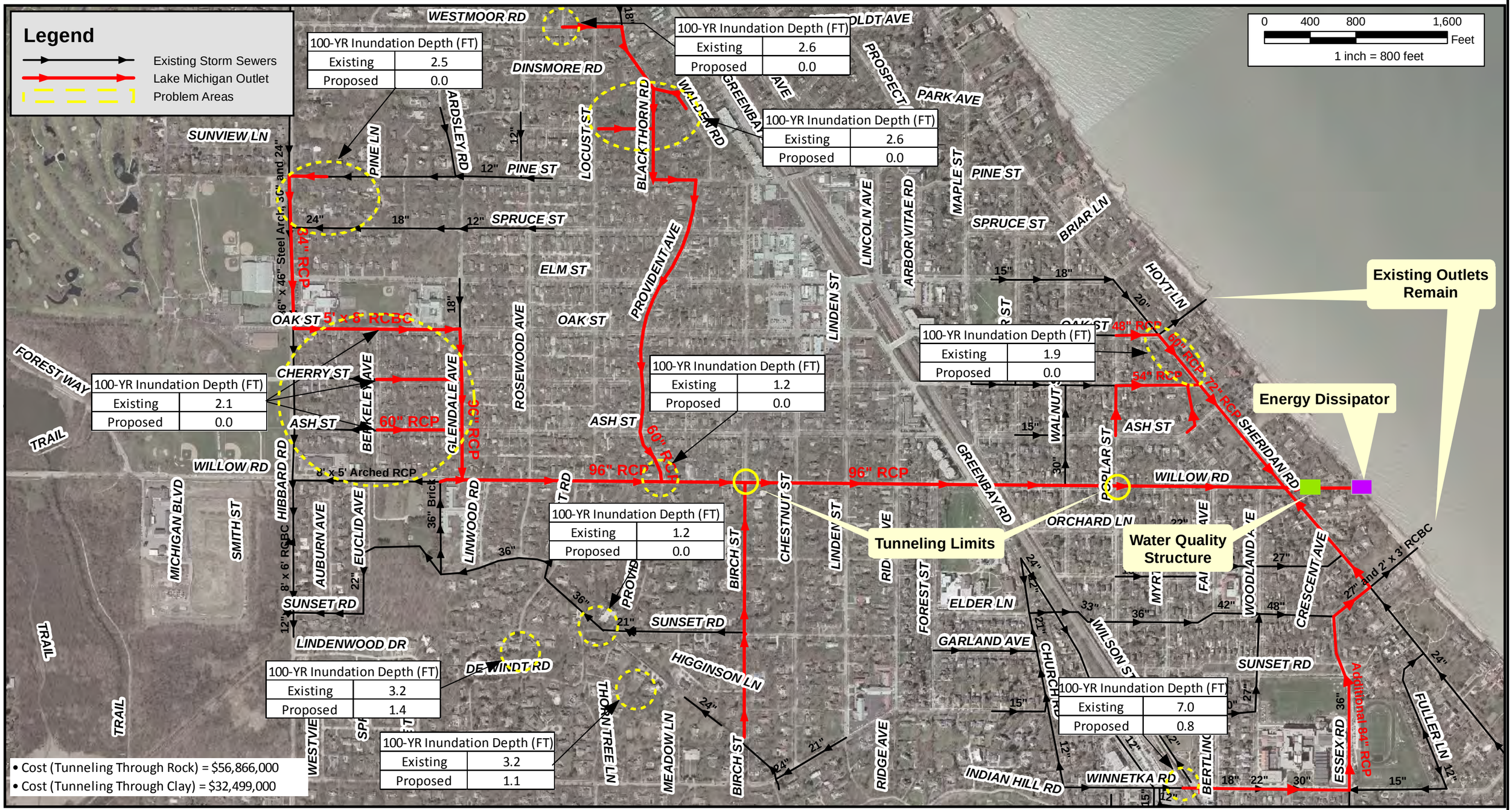
Consider directing staff to obtain contractual pricing from Christopher B. Burke Engineering, Ltd., and Kenny Construction to develop preliminary conceptual plans and cost estimates for an alternate project route using Ash Street, and using the direct jacking process for construction.

Attachments:

1. Preliminary Project Map
2. Soil Boring Report
3. Baird Report
4. Tunneling Cost Estimate

ATTACHMENT #1

PROJECT MAP



DSGN.	MJB	CHKD.	

Christopher B. Burke Engineering, Ltd.
9575 West Higgins Road, Suite 600
Rosemont, IL 60018
(847) 823-0500 / FAX (847) 823-0520

CLIENT	Village of Winnetka	PROJECT NO.	08-0671
TITLE	Lake Michigan Outlet - 100 Year Protection	DATE	9/20/11
			EXHIBIT 10

ATTACHMENT #2

SOIL BORING REPORTS

Local Office
December 12, 2011

TESTING SERVICE CORPORATION

Local Office:
457 E. Gundersen Drive, Carol Stream, IL 60188-2492
630.653.3920 • Fax 630.653.2726

Corporate Office:
360 S. Main Place, Carol Stream, IL 60188-2404
630.462.2600 • Fax 630.653.2988

Mr. Steven M. Saunders
Village of Winnetka
1390 Willow Road
Winnetka, Illinois 60093

RE: L-77,832
Willow Road Storm Sewer
Lake Michigan Outlet
Winnetka, Illinois

Dear Mr. Saunders:

This report presents results of a preliminary soils exploration performed in connection with the proposed construction of a storm sewer under Willow Road in Winnetka, Illinois. These geotechnical services have been provided in accordance with TSC Proposal No. 47,968 dated October 28, 2011, and the attached General Conditions, incorporated herein by reference.

The proposed project consists of improvements to the storm water drainage system in areas of the Village of Winnetka. This will include construction of an 8-foot diameter storm sewer to be constructed by open-trench and tunneling methods, connecting portions of western Winnetka to Lake Michigan.

Field Investigation and Laboratory Testing

Four (4) soil borings were drilled along Willow Road to assist in determining the feasibility of constructing the 8-foot storm water management tunnel (to be constructed by open-cut methods in some areas) from western Winnetka to Lake Michigan. The borings were laid out in the field by TSC at the approximate locations selected by others. Reference is made to the enclosed Boring Location Plan for the drilling layout, ground surface elevations at the borings also being shown. The elevations were provided to us by the Client.

The borings were drilled to depths ranging from 20 to 40 feet below existing grade, or approximately 5 to 8 feet below the proposed invert elevation of the sewer. They were drilled and samples taken in accordance with currently recommended American Society for Testing and Materials specifications. Soil sampling was performed at 2½ to 5-foot intervals. The samples were taken in conjunction with the Standard Penetration Test (SPT), for which driving resistance to a 2" split-spoon sampler (N value in blows per foot) provides an indication of the relative density of granular materials and consistency of cohesive soils. Water level observations were made during and following completion of drilling operations.

Soil samples were examined in the laboratory to verify field descriptions and to classify them in accordance with the Unified Soil Classification System. Laboratory testing included water content determinations for all cohesive soil types. An estimate of unconfined compressive strength was obtained for all cohesive soils using a calibrated pocket penetrometer, with actual measurements of unconfined compressive strength performed on representative samples of native clay soils. Dry unit weight tests were also run on specimens of cohesive fill.

Reference is made to the enclosed boring logs which indicate subsurface stratigraphy and soil descriptions, results of field and laboratory tests, as well as water level observations. Definitions of

Providing a Full Range of Geotechnical Engineering, Environmental Services, and Construction Materials Engineering & Testing

descriptive terminology are also included. While strata changes are shown as a definite line on the boring logs, the actual transition between soil layers will probably be more gradual.

Discussion of Test Data

All of the borings were drilled on the existing pavement of Willow Road. Borings 1 and 2 drilled to the west of Green Bay Road encountered approximately 8 to 9 inches P.C. concrete at the surface, underlain by about 4 inches granular base materials. Borings 3 and 4 drilled to the east of Green Bay Road encountered approximately 4 to 5 inches bituminous concrete at the surface, underlain by about 7 to 11 inches crushed stone base materials. The pavement thicknesses were estimated from the disturbed sides of the augered holes and should be considered approximate. Pavement cores should be taken if more accurate thicknesses are required.

Fill materials were encountered underlying the pavement section in Borings 1 - 3, extending to depths of about 3 to 4 feet below existing grade. The fill consisted primarily of silty clay in Boring 1, silty clay and medium to fine sand layers in Boring 2, and clayey sand in B-3. The pavement section in Boring 4 was underlain by a firm medium to fine sand deposit (possible fill) that extended to a depth of 5½ feet. This granular soil type exhibited SPT N values of 14 to 16 blows per foot.

Native soils below the above described fill and firm medium to fine sand materials consisted of stiff to hard silty clays that extended to the bottom of the boreholes. These low to medium plasticity cohesive soils exhibited unconfined compressive strengths ranging from 0.8 to 4.5+ tons per square foot (tsf), typically exceeding 1.5 tsf, at water contents between 14 and 24 percent.

The majority of the borings were "dry" both during and upon completion of drilling operations. The only exception was Boring 4 where free water was first encountered at a depth of 18 feet, the water level remaining at the same approximate depth upon completion of field operations (i.e. after auger removal and prior to backfilling the hole).

Analysis and Preliminary Recommendations

A previously discussed, the proposed drainage improvements include an 8-foot (96-inch) diameter storm sewer to be constructed by open-trench and tunneling methods, connecting portions of western Winnetka to Lake Michigan. Four (4) soil borings were drilled along Willow Road to assist in determining the feasibility of constructing this structure. The following table summarizes the boring locations, ground surface elevations, and proposed invert elevation and depth below existing grade at each boring.

Boring Number	General Location	Approximate Ground Surface Elevation	Proposed Sewer Invert	
			Depth (Feet)	Elevation
1	Near Willow Road & Birch Street	633.0	22.3	610.7
2	Near Willow Road & Green Bay Road	638.0	33.0	605.0
3	Near Willow Road & Walnut Road	619.0	15.8	603.2
4	Near Willow Road & Sheridan Road	613.0	15.0	598.0

Based on the proposed invert depths/elevations, the proposed sewer/tunnel will be located within native clays soils in all of the borings. The clay soils were typically in a very tough to hard condition, the exception being Boring 2 where they were in a stiff (medium) to tough condition within and above the tunneling zone. Free water was not encountered for the full depth of Borings 1 - 3, with free water being only found in Boring 4 at a depth of about 3 feet below the proposed invert depth / elevation.

The soil borings have revealed the presence of native clay soil basically from the ground surface to the proposed tunnel invert that are conducive for tunneling. Based on the results of the borings, groundwater is also not expected to be a problem due to both the practically impervious nature of the clay soils as well as water observations made in the borings. While serious groundwater problems are not expected at the boring locations, it should be noted that the borings were spaced up to approximately 2000 feet apart. Therefore, it is possible that different soil and groundwater conditions may be encountered between these locations. In this regard, the cohesive glacial till soils as encountered by the borings often contained sand seams/layers that may produce significant amounts of water.

In regards to tunneling, the relatively high unconfined compressive strengths revealed by the borings which generally exceeded 1.5 tsf (i.e. undrained shear strengths, Su, in excess of 1.5 ksf) indicate a firm ground condition in which heading may be advanced without initial support. However, tunnel face stability should be carefully evaluated in the area of Boring 2 due to the presence of marginal strength clay soils below a depth of about 17 feet below existing grade (approximate Elevation 621), i.e. within and above the tunneling zone. In this regard, it should be noted that it is the responsibility of the tunneling contractor to evaluate tunneling means and methods.

In regards to open-cut methods, the very tough to hard cohesive soils which predominate at the boring locations will generally stand, at least temporarily, on relative steep slopes. However, this represents a short-term condition, and blocks of soil will frequently fall into apparently stable excavations. To the extent that laborers will work in the excavation, protection against cave-ins must be provided. Protective measures should include the use of safety trench boxes, sheeting and bracing, or other appropriate methods. In this regard, the contractor must be responsible for meeting OSHA requirements, local regulations and/or project specifications with the respect to the safety of his work force.

The soils at the proposed pipe invert levels consisted of tough to very tough native silty clay at the boring locations. These cohesive soils will provide a stable/firm base for pipe installation and backfill support as well as an adequate factor of safety against basal heave.

Groundwater problems are not anticipated due to in large part to the cohesive nature of the soils encountered by the borings. However, the accumulation of run-off water or seepage at the base of excavations should still be expected to occur during trench excavation and site work. The Contractor should be prepared to remove these accumulations by pumping from strategically placed sumps.

Closure

The analyses and preliminary recommendations submitted in this report are based upon the data obtained from the four (4) soil borings performed at the location shown on the Boring Location Plan. This report does not reflect and variations which may occur between this boring and the project site, the nature and extent of which may not become evident until during the course of construction. If

variations are then identified, recommendations contained in this report should be re-evaluated after performing on-site observations.

Please call if there are any questions in regard to this matter or if we may be of further service.

Respectfully submitted,

TESTING SERVICE CORPORATION

Alfredo J. Bermudez
Registered Professional Engineer
Illinois No. 062-046608

Charles R. DuBose, P.E.
Vice President

AJB:CRD:ab
Enc.

GENERAL CONDITIONS

Geotechnical and Construction Services

TESTING SERVICE CORPORATION

1. PARTIES AND SCOPE OF WORK: If Client is ordering the services on behalf of another, Client represents and warrants that Client is the duly authorized agent of said party for the purpose of ordering and directing said services, and in such case the term "Client" shall also include the principal for whom the services are being performed. Prices quoted and charged by TSC for its services are predicated on the conditions and the allocations of risks and obligations expressed in these General Conditions. Unless otherwise stated in writing, Client assumes sole responsibility for determining whether the quantity and the nature of the services ordered by Client are adequate and sufficient for Client's intended purpose. Unless otherwise expressly assumed in writing, TSC's services are provided exclusively for client. TSC shall have no duty or obligation other than those duties and obligations expressly set forth in this Agreement. TSC shall have no duty to any third party. Client shall communicate these General Conditions to each and every party to whom the Client transmits any report prepared by TSC. Ordering services from TSC shall constitute acceptance of TSC's proposal and these General Conditions.

2. SCHEDULING OF SERVICES: The services set forth in this Agreement will be accomplished in a timely and workmanlike manner. If TSC is required to delay any part of its services to accommodate the requests or requirements of Client, regulatory agencies, or third parties, or due to any cause beyond its reasonable control, Client agrees to pay such additional charges, if any, as may be applicable.

3. ACCESS TO SITE: TSC shall take reasonable measures and precautions to minimize damage to the site and any improvements located thereon as a result of its services or the use of its equipment; however, TSC has not included in its fee the cost of restoration of damage which may occur. If Client desires or requires TSC to restore the site to its former condition, TSC will, upon written request, perform such additional work as is necessary to do so and Client agrees to pay to TSC the cost thereof plus TSC's normal markup for overhead and profit.

4. CLIENT'S DUTY TO NOTIFY ENGINEER: Client represents and warrants that Client has advised TSC of any known or suspected hazardous materials, utility lines and underground structures at any site at which TSC is to perform services under this agreement.

5. DISCOVERY OF POLLUTANTS: TSC's services shall not include investigation for hazardous materials as defined by the Resource Conservation Recovery Act, 42 U.S.C.§ 6901, et, seq., as amended ("RCRA") or by any state or Federal statute or regulation. In the event that hazardous materials are discovered and identified by TSC, TSC's sole duty shall be to notify Client.

6. MONITORING: If this Agreement includes testing construction materials or observing any aspect of construction of improvements, Client's construction personnel will verify that the pad is properly located and sized to meet Client's projected building loads. Client shall cause all tests and inspections of the site, materials and work to be timely and properly performed in accordance with the plans, specifications, contract documents, and TSC's recommendations. No claims for loss, damage or injury shall be brought against TSC unless all tests and inspections have been so performed and unless TSC's recommendations have been followed.

TSC's services shall not include determining or implementing the means, methods, techniques or procedures of work done by the contractor(s) being monitored or whose work is being tested. TSC's services shall not include the authority to accept or reject work or to in any manner supervise the work of any contractor. TSC's services or failure to perform same shall not in any way operate or excuse any contractor from the performance of its work in accordance with its contract. "Contractor" as used herein shall include subcontractors, suppliers, architects, engineers and construction managers.

Information obtained from borings, observations and analyses of sample materials shall be reported in formats considered appropriate by TSC unless directed otherwise by Client. Such information is considered evidence, but any inference or conclusion based thereon is, necessarily, an opinion also based on engineering judgment and shall not be construed as a representation of fact. Subsurface conditions may not be uniform throughout an entire site and ground water levels may fluctuate due to climatic and other variations. Construction materials may vary from the samples taken. Unless otherwise agreed in writing, the procedures employed by TSC are not designed to detect intentional concealment or misrepresentation of facts by others.

7. DOCUMENTS AND SAMPLES: Client is granted an exclusive license to use findings and reports prepared and issued by TSC and any sub-consultants pursuant to this Agreement for the purpose set forth in TSC's proposal provided that TSC has received payment in full for its services. TSC and, if applicable, its sub-consultant, retain all copyright and ownership interests in the reports, boring logs, maps, field data, field notes, laboratory test data and similar documents, and the ownership and freedom to use all data generated by it for any purpose. Unless otherwise agreed in writing, test specimens or samples will be disposed immediately upon completion of the test. All drilling samples or specimens will be disposed sixty (60) days after submission of TSC's report.

8. TERMINATION: TSC's obligation to provide services may be terminated by either party upon (7) seven days prior written notice. In the event of termination of TSC's services, TSC shall be compensated by Client for all services performed up to and including the termination date, including reimbursable expenses. The terms and conditions of these General Conditions shall survive the termination of TSC's obligation to provide services.

9. PAYMENT: Client shall be invoiced periodically for services performed. Client agrees to pay each invoice within thirty (30) days of its receipt. Client further agrees to pay interest on all amounts invoiced and not paid or objected to in writing for valid cause within sixty (60) days at the rate of twelve (12%) per annum (or the maximum interest rate permitted by applicable law, whichever is the lesser) until paid and TSC's costs of collection of such accounts, including court costs and reasonable attorney's fees.

10. WARRANTY: TSC's professional services will be performed, its findings obtained and its reports prepared in accordance with these General Conditions and with generally accepted principles and practices. In performing its professional services, TSC will use that degree of care and skill ordinarily exercised under similar circumstances by members of its profession. In performing physical work in pursuit of its professional services, TSC will use that degree of care and skill ordinarily used under similar circumstances. This warranty is in lieu of all other warranties or representations, either express or implied. Statements made in TSC reports are opinions based upon engineering judgment and are not to be construed as representations of fact.

Should TSC or any of its employees be found to have been negligent in performing professional services or to have made and breached any express or implied warranty, representation or contract, Client, all parties claiming through Client and all parties claiming to have in any way relied upon TSC's services or work agree that the maximum aggregate amount of damages for which TSC, its officers, employees and agents shall be liable is limited to $50,000 or the total amount of the fee paid to TSC for its services performed with respect to the project, whichever amount is greater.

In the event Client is unwilling or unable to limit the damages for which TSC may be liable in accordance with the provisions set forth in the preceding paragraph, upon written request of Client received within five days of Client's acceptance of TSC's proposal together with payment of an additional fee in the amount of 5% of TSC's estimated cost for its services (to be adjusted to 5% of the amount actually billed by TSC for its services on the project at time of completion), the limit on damages shall be increased to $500,000 or the amount of TSC's fee, whichever is the greater. This charge is not to be construed as being a charge for insurance of any type, but is increased consideration for the exposure to an award of greater damages.

11. INDEMNITY: Subject to the provisions set forth herein, TSC and Client hereby agree to indemnify and hold harmless each other and their respective shareholders, directors, officers, partners, employees, agents, subsidiaries and division (and each of their heirs, successors, and assigns) from any and all claims, demands, liabilities, suits, causes of action, judgments, costs and expenses, including reasonable attorneys' fees, arising, or allegedly arising, from personal injury, including death, property damage, including loss of use thereof, due in any manner to the negligence of either of them or their agents or employees or independent contractors. In the event both TSC and Client are found to be negligent or at fault, then any liability shall be apportioned between them pursuant to their pro rata share of negligence or fault. TSC and Client further agree that their liability to any third party shall, to the extent permitted by law, be several and not joint. The liability of TSC under this provision shall not exceed the policy limits of insurance carried by TSC. Neither TSC nor Client shall be bound under this indemnity agreement to liability determined in a proceeding in which it did not participate represented by its own independent counsel. The indemnities provided hereunder shall not terminate upon the termination or expiration of this Agreement, but may be modified to the extent of any waiver of subrogation agreed to by TSC and paid for by Client.

12. SUBPOENAS: TSC's employees shall not be retained as expert witnesses except by separate, written agreement. Client agrees to pay TSC pursuant to TSC's then current fee schedule for any TSC employee(s) subpoenaed by any party as an occurrence witness as a result of TSC's services.

13. OTHER AGREEMENTS: TSC shall not be bound by any provision or agreement (i) requiring or providing for arbitration of disputes or controversies arising out of this Agreement or its performance, (ii) wherein TSC waives any rights to a mechanics lien or surety bond claim; (iii) that conditions TSC's right to receive payment for its services upon payment to Client by any third party or (iv) that requires TSC to indemnify any party beyond its own negligence These General Conditions are notice, where required, that TSC shall file a lien whenever necessary to collect past due amounts. This Agreement contains the entire understanding between the parties. Unless expressly accepted by TSC in writing prior to delivery of TSC's services, Client shall not add any conditions or impose conditions which are in conflict with those contained herein, and no such additional or conflicting terms shall be binding upon TSC. The unenforceability or invalidity of any provision or provisions shall not render any other provision or provisions unenforceable or invalid. This Agreement shall be construed and enforced in accordance with the laws of the State of Illinois. In the event of a dispute arising out of or relating to the performance of this Agreement, the breach thereof or TSC's services, the parties agree to try in good faith to settle the dispute by mediation under the Construction Industry Mediation Rules of the American Arbitration Association as a condition precedent to filing any demand for arbitration, or any petition or complaint with any court. Paragraph headings are for convenience only and shall not be construed as limiting the meaning of the provisions contained in these General Conditions.

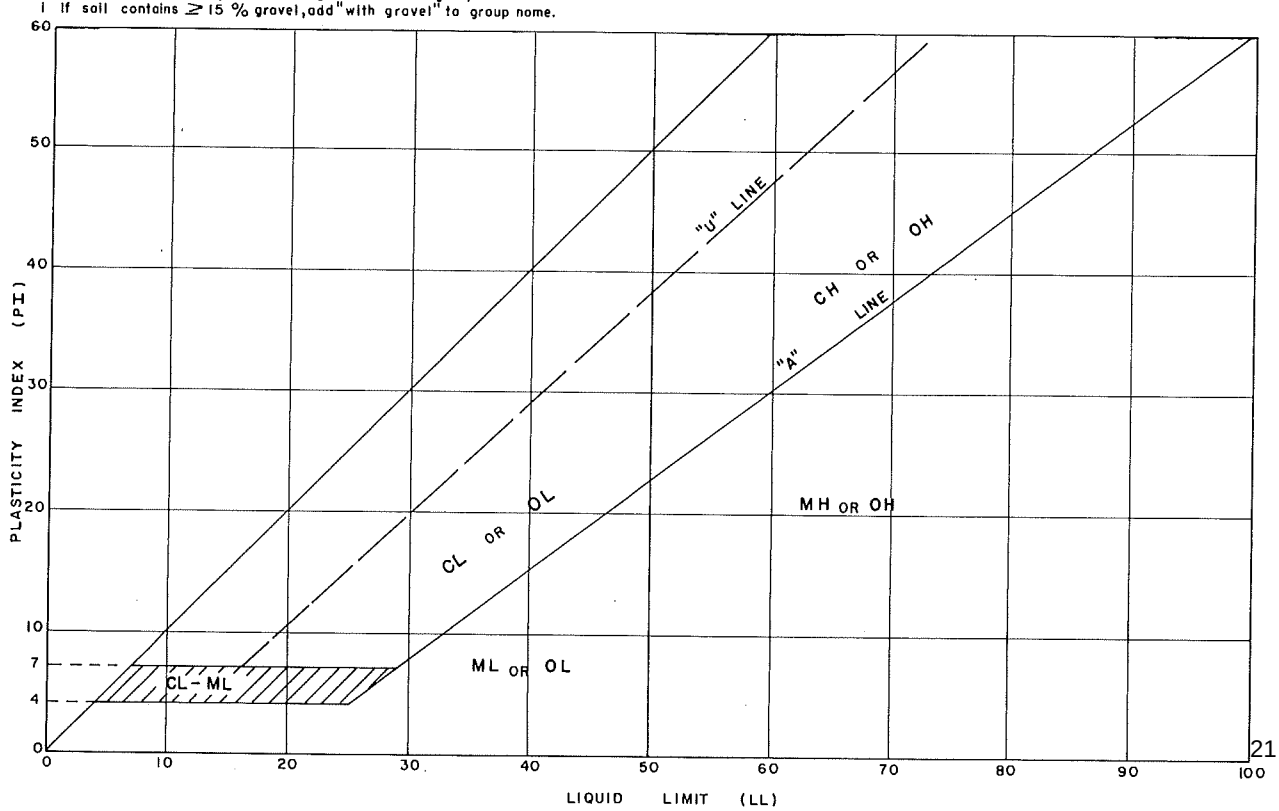
REV 02/08

TESTING SERVICE CORPORATION

UNIFIED CLASSIFICATION CHART

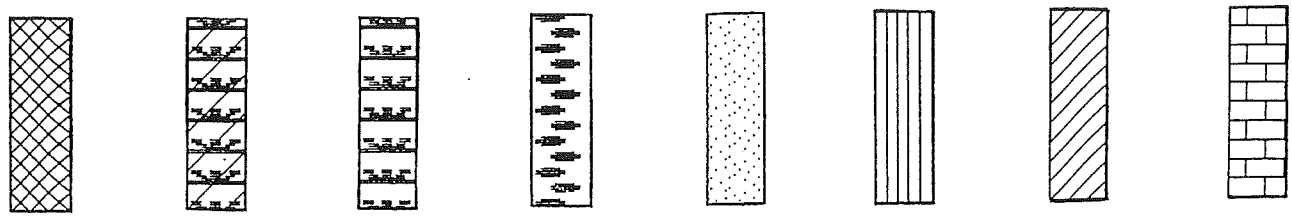
CRITERIA FOR ASSIGNING GROUP SYMBOLS AND GROUP NAMES USING LABORATORY TESTS [a]				SOIL CLASSIFICATION	
				GROUP SYMBOL	GROUP NAME [b]
COARSE-GRAINED SOILS more than 50 % retained on No. 200 sieve	GRAVELS More than 50 % of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS Less than 5 % fines [c]	$C_u \geq 4$ and $1 \leq C_c \leq 3$ [e]	GW	Well graded gravel [f]
			$C_u < 4$ and/or $1 > C_c > 3$ [e]	GP	Poorly graded gravel [f]
		GRAVELS WITH FINES More than 12 % fines [c]	Fines classify as ML or MH	GM	Silty gravel f,g,h
			Fines classify as CL or CH	GC	Clayey gravel f,g,h
	SANDS 50 % or more of coarse fraction passes No. 4 sieve	CLEAN SANDS Less than 5 % fines [d]	$C_u \geq 6$ and $1 \leq C_c \leq 3$ [e]	SW	Well-graded sand [i]
			$C_u < 6$ and/or $1 > C_c > 3$ [e]	SP	Poorly graded sand [i]
		SANDS WITH FINES More than 12 % fines [d]	Fines classify as ML or MH	SM	Silty sand g,h,f
			Fines classify as CL or CH	SC	Clayey sand g,h,f
FINE-GRAINED SOILS 50 % or more passed the No. 200 sieve	SILTS & CLAYS Liquid limit less than 50 %	Inorganic	PI > 7 and plots on or above "A" line j	CL	Lean clay k,l,m
			PI < 4 or plots below "A" line j	ML	Silt k,l,m
		Organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic clay k,l,m,n Organic silt k,l,m,o
	SILTS & CLAYS Liquid limit 50 % or more	Inorganic	PI plots on or above "A" line	CH	Fat clay k,l,m
			PI plots below "A" line	MH	Elastic silt k,l,m
		Organic	$\frac{\text{Liquid limit - oven dried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic clay k,l,m,p Organic silt k,l,m,q
Highly organic soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

a. Based on the material passing the 3-in (75-mm) sieve.
b. If field sample contained cobbles and/or boulders, add "with cobbles and/or boulders" to group name.
c. Gravels with 5 to 12 % fines require dual symbols
GW-GM well graded gravel with silt
GW-GC well graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay
d. Sands with 5 % to 12 % fines require dual symbols
SW-SM well graded sand with silt
SW-SC well graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay
e.
$$C_u = D_{60}/D_{10} \qquad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$
f. If soil contains ≥ 15 % sand, add "with sand" to group name.
g. If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.
h. If fines are organic, add "with organic fines" to group name.
i. If soil contains ≥ 15 % gravel, add "with gravel" to group name.
j. If Atterberg Limits plot in hatched area, soil is a CL-ML, silty clay.
k. If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel" whichever is predominant.
l. If soil contains ≥ 30 % plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains ≥ 30 % plus No. 200, predominantly gravel, add "gravelly" to group name.
n. PI ≥ 4 and plots on or above "A" line.
o. PI ≥ 4 or plots below "A" line.
p. PI plots on or above "A" line.
q. PI plots below "A" line.



TESTING SERVICE CORPORATION

LEGEND FOR BORING LOGS



FILL TOPSOIL PEAT GRAVEL SAND SILT CLAY DOLOMITE

SAMPLE TYPE:

SS = Split Spoon
ST = Thin-Walled Tube
A = Auger

FIELD AND LABORATORY TEST DATA:

N = Standard Penetration Resistance in Blows per Foot
Wc = In-Situ Water Content
Qu = Unconfined Compressive Strength in Tons per Square Foot
* Pocket Penetrometer Measurement; Maximum Reading = 4.5 tsf
γD = Dry Unit Weight in Pounds per Cubic Foot

WATER LEVELS:

▼ While Drilling
▽ End of Boring
▼ 24 Hours

SOIL DESCRIPTION:

MATERIAL	PARTICLE SIZE RANGE
BOULDER	Over 12 inches
COBBLE	12 inches to 3 inches
Coarse GRAVEL	3 inches to ¾ inch
Small GRAVEL	¾ inch to No. 4 Sieve
Coarse SAND	No. 4 Sieve to No. 10 Sieve
Medium SAND	No. 10 Sieve to No. 40 Sieve
Fine SAND	No. 40 Sieve to No. 200 Sieve
SILT and CLAY	Passing No. 200 Sieve

COHESIVE SOILS

CONSISTENCY	Qu
Very Soft	Less than 0.3
Soft	0.3 to 0.6
Stiff	0.6 to 1.0
Tough	1.0 to 2.0
Very Tough	2.0 to 4.0
Hard	4.0 and over

COHESIONLESS SOILS

RELATIVE DENSITY	N
Very Loose	0 - 4
Loose	4 - 10
Firm	10 - 30
Dense	30 - 50
Very Dense	50 and over

MODIFYING TERM	PERCENT BY WEIGHT
Trace	1 - 10
Little	10 - 20
Some	20 - 35

PROJECT **Willow Road Storm Sewer, Lake Michigan Outlet, Winnetka, Illinois**

CLIENT **Village of Winnetka, Winnetka, Illinois**

BORING **1** DATE STARTED **12-5-11** DATE COMPLETED **12-5-11** JOB **L-77,832**

ELEVATIONS

GROUND SURFACE **633.0**

END OF BORING **603.0**

WATER LEVEL OBSERVATIONS

WHILE DRILLING **Dry**

AT END OF BORING **Dry**

24 HOURS

SAMPLE NO.	SAMPLE TYPE	N	WC	Qu	γ DRY	DEPTH	ELEV.	SOIL DESCRIPTIONS
						0.7	632.3	8" P.C. Concrete **
						1.0	632.0	4" Crushed Stone **
1	SS	12	11.0	2.25*	119.1			FILL - Gray silty CLAY, little sand and gravel, trace crushed stone, moist (CL)
						3.0	630.0	
2	SS	22	14.1	7.10 4.5+*				Hard brown and gray silty CLAY, little sand and gravel, moist (CL)
3	SS	23	17.7	8.68 4.5+*				
4	SS	20	17.2	4.5+*				
5	SS	14	17.9	4.08 4.25*				
						18.0	615.0	
6	SS	13	18.2	3.75*				Very tough brown silty CLAY, little sand and gravel, moist (CL)
						23.0	610.0	
7	SS	10	18.3	2.77 2.5*				Very tough gray silty CLAY, little sand and gravel, moist (CL)
8	SS	12	19.8	2.0*				

DISTANCE BELOW SURFACE IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40

End of Boring at 30.0'

* Approximate unconfined compressive strength based on measurements with a calibrated pocket penetrometer.

** Approximate thicknesses determined by flight auger methods

SPT Hammer = CME Automatic

DRILL RIG NO. **315**

Division lines between deposits represent approximate boundaries between soil types; in-situ, the transition may be gradual.

TSC 77832.GPJ TSC_ALL.GDT 12 7 11

PROJECT **Willow Road Storm Sewer, Lake Michigan Outlet, Winnetka, Illinois**

CLIENT **Village of Winnetka, Winnetka, Illinois**

BORING **2** DATE STARTED **12-5-11** DATE COMPLETED **12-5-11** JOB **L-77,832**

ELEVATIONS

GROUND SURFACE **638.0**

END OF BORING **598.0**

WATER LEVEL OBSERVATIONS

WHILE DRILLING **Dry**

AT END OF BORING **Dry**

24 HOURS

SAMPLE NO.	SAMPLE TYPE	N	WC	Qu	γ_{DRY}	DEPTH	ELEV.	SOIL DESCRIPTIONS
						0.8	637.2	9" P.C. Concrete **
						1.1	636.9	4" Crushed Stone **
1	SS	21	12.5	1.75*	117.5			FILL - Brown and gray silty CLAY, little sand and gravel, moist (CL)
						3.0	635.0	
A			16.5			4.0	634.0	FILL - Brown medium to fine SAND, trace gravel, moist (SP)
2	SS	6						
B			23.7	2.25*				Very tough gray silty CLAY, trace sand and gravel, trace organic, moist (CL)
						5.5	632.5	
3	SS	18	16.4	6.73 4.50+*				
4	SS	15	17.7	3.75*				
								Hard to very tough brownish-gray silty CLAY, little sand, trace gravel, moist (CL)
5	SS	13	18.1	4.08 3.75*				
						17.0	621.0	
6	SS	7	22.2	0.75*				
								Stiff brownish-gray to gray silty CLAY, little sand, trace gravel, very moist (CL)
7	SS	6	22.3	0.89 0.75*				
						27.0	611.0	
8	SS	12	19.3	1.75*				Tough gray silty CLAY, little sand, trace gravel, moist (CL)
9	SS	8	17.0	1.91 1.5*				
10	SS	10	19.6	1.5*				

DISTANCE BELOW SURFACE IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40

LENGTH RECOVERY

* Approximate unconfined compressive strength based on measurements with a calibrated pocket penetrometer.

** Approximate thicknesses determined by flight auger methods

SPT Hammer = CME Automatic

DRILL RIG NO. **315**

Division lines between deposits represent approximate boundaries between soil types; in-situ, the transition may be gradual.

End of Boring at 40.0'

TSC 77832.GPJ TSC_ALL.GDT 12 7 11

PROJECT **Willow Road Storm Sewer, Lake Michigan Outlet, Winnetka, Illinois**

CLIENT **Village of Winnetka, Winnetka, Illinois**

BORING **3** DATE STARTED **12-2-11** DATE COMPLETED **12-2-11** JOB **L-77,832**

ELEVATIONS

GROUND SURFACE **619.0**

END OF BORING **599.0**

WATER LEVEL OBSERVATIONS

WHILE DRILLING **Dry**

AT END OF BORING **Dry**

24 HOURS

SAMPLE NO.	SAMPLE TYPE	N	WC	Qu	γ_{DRY}	DEPTH	ELEV.	SOIL DESCRIPTIONS
						0.4	618.6	5" Bituminous Concrete **
						1.3	617.7	11" Crushed Stone **
1	SS	11	15.8					FILL - Brown clayey SAND, trace gravel, moist (SC)
						3.0	616.0	
2	SS	10	16.0	4.92 4.5+*				Hard brownish-gray silty CLAY, little sand and gravel, moist (CL)
3	SS	16	16.2	4.59 4.5+*				
						8.0	611.0	
4	SS	23	15.8	4.5+*				Hard to very tough gray silty CLAY, little sand and gravel, moist (CL)
5	SS	12	16.4	3.21 3.0*				
6	SS	10	16.4	2.75*				

DISTANCE BELOW SURFACE IN FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40

End of Boring at 20.0'

* Approximate unconfined compressive strength based on measurements with a calibrated pocket penetrometer.

** Approximate thicknesses determined by flight auger methods

SPT Hammer = CME Automatic

DRILL RIG NO. **256**

Division lines between deposits represent approximate boundaries between soil types; in-situ, the transition may be gradual.

TSC 77832.GPJ TSC_ALL.GDT 12 9 11

PROJECT **Willow Road Storm Sewer, Lake Michigan Outlet, Winnetka, Illinois**

CLIENT **Village of Winnetka, Winnetka, Illinois**

BORING **4** DATE STARTED **12-2-11** DATE COMPLETED **12-2-11** JOB **L-77,832**

ELEVATIONS

GROUND SURFACE **613.0**

END OF BORING **593.0**

WATER LEVEL OBSERVATIONS

WHILE DRILLING **18.0 '**

AT END OF BORING **18.0 '**

24 HOURS

SAMPLE NO.	SAMPLE TYPE	N	WC	Qu	γ_{DRY}	DEPTH	ELEV.	SOIL DESCRIPTIONS
						0.3	612.7	4" Bituminous Concrete **
						0.9	612.1	7" Crushed Stone **
1	SS	16	8.8					Firm brownish-gray medium to fine SAND, moist (SP) [Possible Fill]
2	SS	14	14.3					
						5.5	607.5	
3	SS	15	15.9	3.67 4.25*				Hard to very tough gray silty CLAY, little sand and gravel, moist (CL)
4	SS	16	16.0	4.79 4.5+*				
5	SS	12	16.9	3.25*				
6	SS	9	19.1	2.76 3.0*				

End of Boring at 20.0'

* Approximate unconfined compressive strength based on measurements with a calibrated pocket penetrometer.

** Approximate thicknesses determined by flight auger methods

SPT Hammer = CME Automatic

DISTANCE BELOW SURFACE IN FEET

0, 5, 10, 15, 20, 25, 30, 35, 40

DRILL RIG NO. **256**

Division lines between deposits represent approximate boundaries between soil types; in-situ, the transition may be gradual.

TSC 77832.GPJ TSC_ALL.GDT 121211

ATTACHMENT #3

BAIRD FINAL REPORT

Baird

oceans

engineering

lakes

design

rivers

science

watersheds

construction

Village Of Winnetka, Illinois

Stormwater Relief Tunnel-Outfall Feasibility Study

Final Report

June 25, 2012

11962.100

Village Of Winnetka, Illinois

Stormwater Relief Tunnel-Outfall Feasibility Study

Final Report

Prepared for

Village of Winnetka, Illinois

Prepared by

W.F. Baird & Associates Ltd.

For further information please contact
Dan Veriotti, P.E. at (312) 893-5442

11962.100

This report was prepared by W.F. Baird & Associates Ltd. for Village of Winnetka. The material in it reflects the judgment of Baird & Associates in light of the information available to them at the time of preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, are the responsibility of such Third Parties. Baird & Associates accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

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EXECUTIVE SUMMARY

W. F. Baird & Associates Ltd. (Baird) was commissioned by the Village of Winnetka, Illinois to conduct an assessment of potential alternatives for a proposed stormwater outfall to Lake Michigan, for the Stormwater Relief Tunnel at the eastern end of the Willow Road location.

This report presents the methodology and preliminary results of Baird's feasibility study, which included the following key tasks:

- Summary of coastal conditions, based on compilation/review of existing data (bathymetric survey, navigational charts, soil borings, beach soil sampling, water levels, wave climate, ice conditions, sediment transport and qualitative shoreline change analysis);
- Development of conceptual outfall alternatives;
- Preparation of probable construction costs;
- Evaluation of alternatives and identification of the preferred option. This process was primarily based on the following criteria:
    - Anticipated impacts on sediment transport processes and the shoreline (accretion/erosion);
    - Outfall sedimentation (and possible blockage);
    - Risk of structure damage by waves/ice ;
    - Qualitative assessment of water mixing efficiency;
    - Regulatory agency input; and
    - Constructability and estimated costs.

The project findings were presented and discussed during a meeting with the regulatory agencies on May 10, 2012. The input provided was valuable for alternative final screening and refinement.

It is noted that effluent dispersion and pipe hydraulics have not been considered in the present study; it is understood that these issues will be addressed during the detailed design phase.

In addition, it is noted that there is an existing outfall in the vicinity of the proposed outfall; however, no information is available regarding the existing outfall. It may be possible to reroute the discharge from the existing outfall and incorporate it into the new outfall. This option has not been considered in the present study, but could be assessed during the detailed design phase.

The main goal of the study is to identify a preferred conceptual design for the outfall structure that will be the starting point for permitting and detailed design development. It is suggested that the detailed design phase also include the assessment and development of designs for bluff toe protection and slope restoration at the project site.

1.0 INTRODUCTION

The Village of Winnetka, Illinois (the Village) is planning a stormwater relief project that would allow for the construction of an eight-foot diameter storm sewer pipe underneath Willow Road, from Glendale Avenue to Lake Michigan. The storm sewer is intended to convey the excess stormwater to Lake Michigan via an outfall, to be designed for a 100-year event flow of 920 cubic feet per second (cfs). Under this flow condition, the peak velocity in the pipe will be approximately 20 feet per second (fps).

The project site is located on the Lake Michigan shoreline, approximately 18 miles north of Chicago. Locally, the shoreline is heavily altered and armored by structures, predominately steel sheet pile groynes and armor stone revetments.

A site visit was performed on March 7, 2012. The existing site consists of a narrow sandy beach. There is a 110 ft long concrete pier (partially open) to the north, with a dumped stone revetment north of the pier. A groyne field is located to the south; the groynes appear to be effective in maintaining a stable beach at present (during low water levels). Based on visual observations, the beach consists of medium sand with gravel and cobbles. There is also an existing 24'' diameter cast iron pipe with supporting steel "H" piles that extends into the lake and terminates with a steel framed outfall structure. Village records indicate that this appears to be an outfall from the railroad cut drainage system, but no flow information is available. The beach and existing discharge pipe are shown in Figure 1.

The existing bluff slopes steeply to a height of approximately 35 feet, with concrete stairs at the site, as shown in Figure 2. A portion of the bluff toe and slope are protected by dumped-in-place concrete rubble and stone. These works appear to be ineffective in maintaining a stable bluff, as noted by the off-vertical trees. In general, the shore protection on the property is ad-hoc in nature, and does not appear to have been well engineered. It appears to have shifted (failed) due to storm runoff from the bluff (from the cul-de-sac at the east end of Willow Road) and wave action (scour and bluff toe erosion), the latter of which would be more severe during periods of high lake levels. It is expected that the bluff slope will continue to deteriorate in the future unless bluff stabilization measures are implemented.

Figure 1: Existing Conditions - Beach and Discharge Pipe

Figure 2: Existing Conditions - Bluff Slope and Stairs

2.0 BACKGROUND INFORMATION

A summary of the existing conditions is presented below. This information provides the basis for understanding the site constraints and opportunities, and directly assists in the process of formulating conceptual design alternatives.

The existing conditions at the site are influenced by the regional/geomorphic shoreline characteristics, environmental conditions (i.e. winds, waves, lake levels and ice – often termed metocean conditions) which drive coastal processes (i.e. circulation and sediment transport), and man-made changes to the shoreline that alter these conditions and processes.

2.1 Regional/Geomorphic Shoreline Characteristics

Throughout the Lake Michigan shoreline, from Waukegan in the north to Wilmette in the south, the shoreline consists largely of bluffs, with heights ranging from 20 to 60 feet. The composition of the bluff and underlying nearshore material is cohesive glacial till with sand cover. Historically, the sand cover has provided some protection to the underlying cohesive material and reduced bluff erosion. However, the construction of the Waukegan Harbor, beginning in the 1880's, and the Great Lakes Naval Training Center Harbor in 1923, both north of the project site, resulted in a near total interruption of the supply of sand to the study reach for a considerable period of time (Chrzastowski and Trask, 1995).

Furthermore, the installation of extensive coastal protection structures along the shoreline to the north of the project site has reduced the quantity of sand released into the nearshore by bluff erosion. The presence of the updrift harbors and continued armoring of the shoreline has caused a significant reduction in the volume of sand remaining along the shoreline and nearshore profile in this region. This has allowed wave action to act on the underlying cohesive glacial till, causing irreversible erosion, termed lakebed downcutting. Lakebed downcutting is a process where the nearshore is progressively deepened, resulting in larger and more energetic waves reaching the bluff toe and shore protection, and causing accelerated erosion and/or damage to shore protection structures and the infrastructure they protect.

Lakebed downcutting rates are best calculated with the aid of fixed erosion monitoring profiles measured over a period of years and decades. Survey data from profile stations at Highland Park (near Ravine Drive, seven miles north of site) and Kenilworth Waterworks (0.6 miles south of site), with data going back to 1975, were reviewed. The nearshore downcutting rates at these locations have been previously estimated to be in the order of 1.6 and 5 mm per year (Baird, 2000). More recent profile measurements made by Baird in 2010 for the US Army Corps of Engineers (USACE) confirm that lakebed downcutting is still active in the area (Baird, open file). Based on this information, and assuming a proposed 50-year project life, it is expected that the total nearshore downcutting will be in the order of three to ten inches over the project life.

It is noted that the project design life, extreme design event and acceptable risk of damage have not been defined at this time. These criteria will be discussed/defined during the detailed design phase. Regardless of the design concept selected for implementation, lakebed downcutting will be an important consideration in the detailed design of the proposed outfall structure.

2.2 Local Beach and Nearshore Sediments

The properties of the beach sediment and sediment depths are important to the local response of the shoreline. At this time, no sediment samples have been collected from the project site. However, Baird has collected sediment samples at another project site located 1.8 miles to the north. These data are summarized below, as they are relevant given the proximity and generally similar shoreline conditions of the two sites.

A series of core samples collected on the beach and in the nearshore at the other project site indicate approximately three feet of sand over at least 27 feet of very stiff and silty clay (the clay extended below the limit of the borehole). The overlying sand on the beach consisted of fine to medium sand with a median grain size (D50) of approximately 0.3 mm. Progressing lakeward into the nearshore zone, some winnowed gravel (with a D50 of approximately 10-20 mm) over clay was observed. Similar findings are common on cohesive shorelines with thin sand cover around the Great Lakes, in areas with limited sand supply.

It is worth noting that these conditions were recorded in July 2011; Lake Michigan is currently in a period of low water. During periods of high water, the sand would move further offshore in response to storm events.

2.3 Topography and Bathymetry

Note: unless otherwise noted, all elevations in this report are referenced to Chart Datum (CD) or Low Water Datum (LWD) for Lake Michigan. 0 CD = 0 LWD = 577.5 ft above International Great Lakes Datum.

No site specific topographic or bathymetric surveys have been undertaken at this time. In addition, regional bathymetry datasets, such as the Lidar dataset (NOAA, 2008), do not include data in the immediate nearshore area. Nearshore bathymetry was recently collected by Baird in 2010 (Baird, open file) for another project located 1.8 miles to the north. These data were merged with available landside data (NOAA, 2008) in order to develop a representative beach and nearshore profile, as shown in Figure 3.

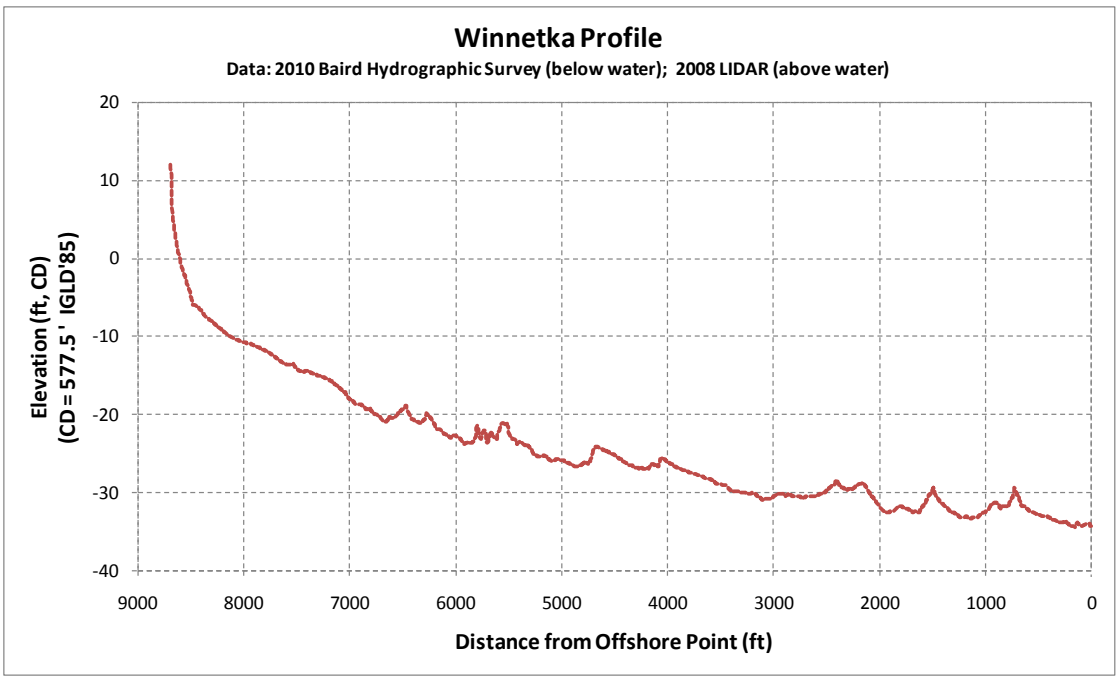


Figure 3: Winnetka Offshore Profile

As can be seen from the plot, the profile exhibits a concave shape, with a progressively flatter slope as one moves offshore. This profile shape is typical of eroding cohesive shorelines on the Great Lakes.

A preliminary project basemap has been developed using the available survey data. The 2008 SHOALS Lidar data coverage is presented in Appendix A. These data have adequate coverage within 100 feet of the water's edge, but there is a significant data gap shoreward of -10 ft LWD. This is likely due to the data collection difficulties in the surf zone, where wave action impedes accurate readings. These data have been supplemented with information presented in Chart 14905 (NOAA, 2007) in order to generate 1-foot bathymetric contours. The combined database is overlain on a 2008 aerial photograph and is presented in Appendix B.

2.4 Historic Shoreline Changes

The long term average bluff retreat rates along this section of shoreline (Waukegan to Wilmette) have ranged from 0 to 1 m/year (0 to 3.3 ft/year) over the period from 1937 to 1987 (Jibson, Odum and Staube, 1994). Based on a previous study by Baird in the Winnetka area (Whitebridge Lane, 2012), the bluff in the project area appears to have been relatively stable since at least the 1950s, likely owing in large part to the installation of shore protection. However, there have been significant variations in the beach width over this time, likely caused by a combination of varying lake levels, the impact of varying lake levels on coastal processes, and changes in shoreline protection.

As noted earlier, nearshore lakebed downcutting is an ongoing process. Should the current shore protection not be maintained, eventually the shoreline and bluffs will erode to "catch up" with the downcutting of the nearshore lakebed.

2.5 Water Levels

Water levels on Lake Michigan vary in response to long-term and seasonal climatic fluctuations (predominantly precipitation and evaporation) over the Great Lakes drainage basin and over the short-term as a result of individual weather systems (storm surge). Long-term monthly mean lake levels were obtained from the USACE, Detroit District. The historic data extending from 1918 to 2011 is summarized in Figure 4.

Since 1918, the average monthly lake level on Lake Michigan has varied from a high of 582.35 feet IGLD 1985 (+4.85 feet CD) in October 1986 to a low of 576.05 feet IGLD 1985 (-1.45 feet CD) in March 1964. The long-term annual average level is 578.9 feet IGLD 1985 (+1.4 feet CD).

The seasonal variation on Lake Michigan is typically in the order of one foot, with the annual high occurring in the summer (June-July) and the annual low occurring in the winter (January-February). Localized, short-term storm surges of up to three feet (positive/setup or negative/setdown) may also occur in response to the passage of individual storm events. The extreme high and low monthly water levels on record at Calumet Harbor are +4.02 (August 1952) and -1.55 (February 1964) ft LWD, respectively.

Lake levels are a significant factor when considering coastal processes and the design of coastal structures. Higher lake levels allow larger waves to impact the shoreline and coastal structures. Lower lake levels increase the potential for local scour and nearshore downcutting. In addition, wave action at varying lake levels may redistribute the sand cover across the nearshore profile.

Considering the present study, high water levels will be a critical consideration in the design of any proposed outfall structure due to wave loads, while low water levels will be a critical consideration with respect to potential sedimentation (blocking) of the outfall. It is important to note that periods of high (or low) lake levels tend to persist for several years. For example, referring to Figure 4, lake levels have been below average for the past ten years.

Based on the historical data, as well as extensive experience in the planning, design and construction of coastal structures in this region, it is recommended that the design of the storm sewer outfall consider an extreme water level range of -1.5 to +6 ft LWD.

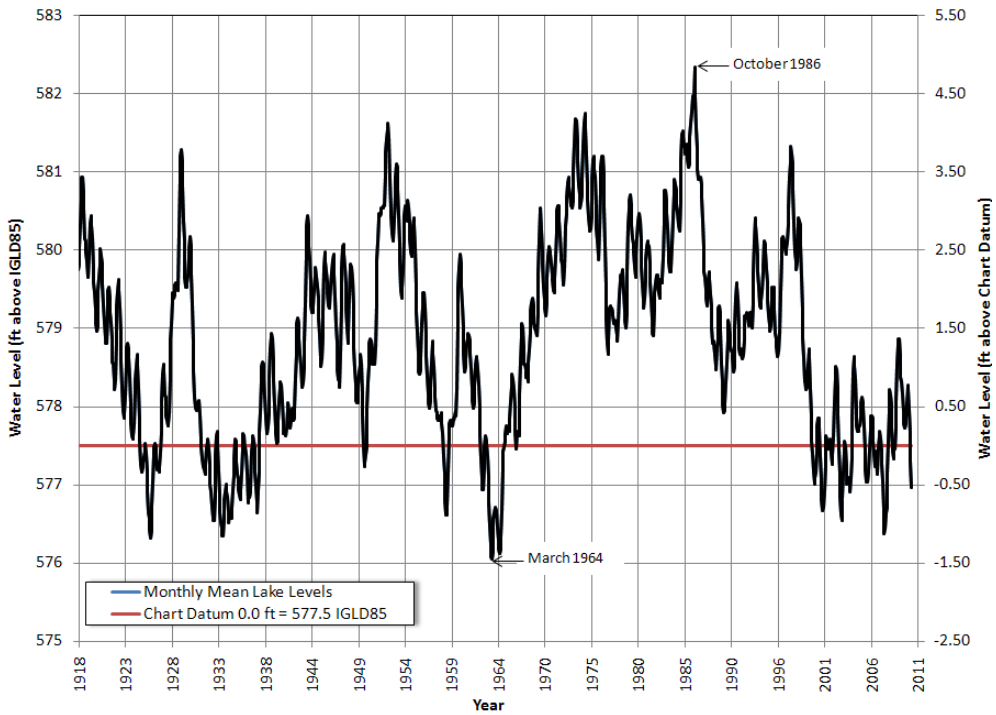


Figure 4: Monthly Mean Lake Levels on Lake Michigan (1918-2011)

2.5.1 Lake Levels

As noted earlier, fluctuations in lake level occur over seasonal and annual scales as well as decadal scales. Monthly mean lake levels are published by the USACE each month and archived online. The historical data for Lake Michigan are presented in Figure 4. The more recent data (1965-2011) have been analyzed to provide three representative lake levels for consideration in this study. Specifically, Table 1 presents estimates of a "typical" high water level (80th percentile of the annual maximum of the monthly means), the average lake level (median of the annual maximum of the monthly means) and a "typical" low-water level (20th percentile of the annual maximum of the monthly means). These lake levels do not include storm surge (refer to Section 2.5.2).

Table 1: Summary of Representative Lake Levels

Condition	Lake Level (ft LWD)
Typical Low Water (20%)	+0.5
Average Lake Level	+2.6
Typical High Water (80%)	+4.0

It is important to note that Lake Michigan is currently at a relatively low level (+0.1 ft LWD). Higher water levels will likely occur at some point in the future.

2.5.2 Storm Surge

Storm surge is a short-term increase or decrease in the water level associated with the passage of a storm event. In particular, wind stress on the water surface will cause an increase (setup) in the water level along the downwind shoreline, and a decrease (setdown) in the water level along the "upwind" shoreline.

The short-term water level variations at the Calumet Gage (NOAA 9087044) were determined by extracting surge from the hourly water level time series for the period 1970-2011. A peak over threshold (POT) analysis was performed on the positive surge data (i.e. setup) to determine extreme events in the dataset, and an extreme value analysis (EVA) was completed, as summarized in Table 2. The magnitude of negative surges (i.e. setdown) may be similar to that of the positive storm surges.

Table 2: Extreme Storm Surges

Return Period (years)	Positive Surge (ft)
1.5	1.8
2	1.9
5	2.2
10	2.4
20	2.7
25	2.7
50	3.0
100	3.2

2.6 Waves

Waves are one of the controlling factors in the design of coastal structures and sediment transport processes. Severe wave events on Lake Michigan result from the passage of storms, with the magnitude of the wave conditions controlled by wind speed, fetch (distance on the lake over which the wind propagates) and water depth. In general, wave measurements are insufficient to define design conditions for coastal engineering projects, so "hindcast" methods are utilized, where wave conditions are estimated based on historical wind records. For this study, the wave climate has been estimated using a long-term hindcast available from another study in this region (Baird, 2000).

A wave rose and exceedance plot summarizing the hindcast wave conditions (in deep water) are presented in Figure 5. The largest and most common waves approach from the north and northeast, with a maximum wave height of approximately 15 feet. The wave height is less than four feet approximately 90% of the time. An extreme value analysis was completed, with the 100-year deep water wave height estimated to be 18.7 feet.

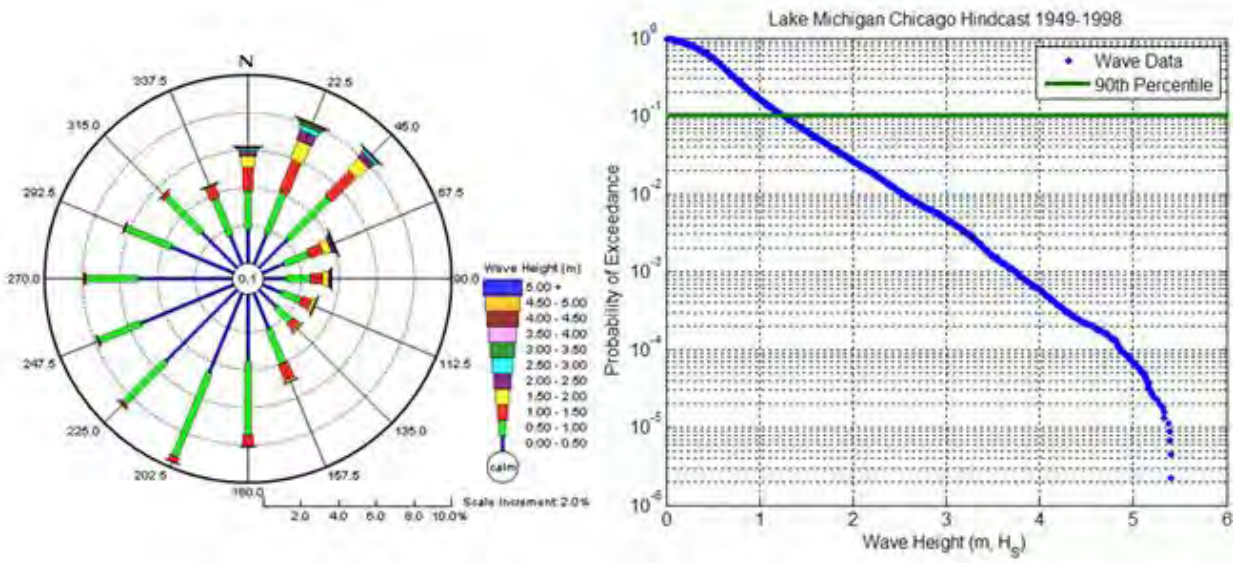


Figure 5: Wave Height Rose and Exceedance Plot - Chicago Hindcast (1959-1998)

These deep water wave conditions are subject to various shallow water transformations as they propagate towards the shoreline. In particular, the wave heights at the project site will be controlled by breaking, with the wave height limited to approximately 70% of the water depth. For example, assuming a lakebed elevation of -1 ft LWD and a design high water level of +6 ft LWD, the wave height would be approximately five feet. More detailed analyses of nearshore wave conditions will be required to support detailed design development.

2.7 Ice

Ice cover on Lake Michigan varies significantly from year to year. The historic ice record was provided by NOAA's Great Lakes Environmental Research Laboratory (GLERL) and spans from 1973 - 1998. Ice data was extracted from a point on the lake adjacent to the reach area to provide a local dataset (Reach 1022). A summary of the probability of ice cover in the project area is provided in Table 3. The ice cover may extend from December through March, with ice cover being most common in February (present 63% of the time).

Ice conditions, including ice thicknesses, strength and mobility, may also vary considerably. Regarding the proposed storm sewer outfall, various ice processes may cause structural damage (large forces on vertical faces, displacement of armor stones, jacking/uplift of piles). Additional investigations should be undertaken during detailed design to assess ice conditions, and to develop an outfall structure design that minimizes the risk of damage by ice.

Table 3: Summary of Ice Cover Probability - GLERL Reach 1022 (1973-1998)

Month	Day with Ice	Total Days	Ice Frequency
December	34	744	5%
January	321	744	43%
February	427	679	63%
March	111	744	15%

2.8 Sediment Transport

Longshore sediment transport (LST) refers to the transport of sediment in the littoral zone along the shoreline as a result of obliquely approaching waves. Over time, waves can move significant volumes of sediment along the shoreline. Coastal structures such as groynes and jetties can significantly impact this process by trapping the sediment that is being transported along the shoreline.

The following represents a summary of the findings using data from a Baird study (2011) for a site located 1.8 miles north of the project study area:

- Based on the shoreline orientation and the long north and northeast fetches, the net sediment transport is from north to south. As such, the construction of a solid structure extending into the lake is likely to cause accretion on the north side of the structure (characterized by the development of a fillet beach) and erosion (due to reduced sediment supply) along the shoreline to the south. Analyses indicated that the long term annual average *potential* LST rate is approximately 400,000 yd^3/yr. However, this potential transport rate is not realized, as the sediment supply to this shoreline is limited (i.e. it is a "supply starved" environment).

- Previous studies indicate *actual* LST rates, from north to south, in the order of 60,000 yds^3/year (Chrzastowski and Trask, 1995). Earlier studies generally cite much higher numbers; however, Baird's review of these studies (open file) suggests they likely used incompatible datasets or flawed methods.

- Groynes will limit or block sand transport until the groyne is filled to capacity and bypassing can occur. Depending on the design concept, a storm sewer outfall projecting into the lake may act as a groyne.

- In order to limit the downdrift impacts of a sediment trapping structure, it will be necessary to pre-fill the updrift shoreline to capacity, and also to develop a bypassing shoal with the ability to bypass sand at the *actual* LST rate (~60,000 yd^3/yr).

- The most reliable method to predict stable shoreline azimuths along a given stretch of shoreline is to observe beach azimuths at nearby fillet beaches. Five shorelines (1999-2010) for Winnetka properties were digitized in GIS. The stable shoreline orientation for those beaches was calculated to be approximately 140 degrees, with a shore-perpendicular azimuth equal to approximately 50 degrees. This information is presented as a planning guideline only, for beach sand pre-fill (permitting requirement) for outfall alternatives that might interrupt the natural sediment transport.

3.0 DEVELOPMENT OF ALTERNATIVES

This section summarizes the site opportunities and planning constraints in the study area, and the alternative formulation and evaluation.

3.1 Site Opportunities and Planning Constraints

Site planning opportunities and constraints are items of consideration that are used in the formulation and evaluation of possible conceptual design solutions.

3.1.1 Site Opportunities

A groyne field located south of the project site is effective in maintaining a stable beach at lower water levels; it is anticipated that at higher water levels, the usable beach is drastically reduced, and the toe of the bluff needs protection against wave action. The existing bluff slope at the eastern end of Willow Road is deteriorated; there is an opportunity to stabilize and enhance the beach and bluff protection with the design and construction of the outfall phases.

The north pier provides partial wave sheltering from a north storm for an outfall located on the beach. The existing site allows contractor access, material and equipment delivery by trucks, and land-based construction.

There is an important opportunity to combine the existing stormwater outfall (that may be approaching the end of its useful life) with the new proposed outfall.

There may be opportunities to enhance the beach for public benefit and create public access, depending on the alternative selected.

3.1.2 Site Planning Constraints

Specific site planning constraints include:

- Avoid/minimize actions that result in downdrift erosion, reduced beach width, and compromised aesthetics. An outfall structure acting as a groyne has the potential to interrupt the LST, and create shoreline erosion to the south, especially if the structure extends a significant distance offshore. This can be mitigated by pre-filling to create a stable fillet beach on the updrift (north) side of the structure, thereby allowing natural sediment bypassing to occur.

- Risk of sedimentation and blockage. An outfall structure on the beach has the potential to experience significant sedimentation and possible outfall blockage. A longer structure, with

the outlet in deeper water, will reduce the sedimentation risk but will increase the cost, as well as the structure's impact on adjacent properties by interrupting sediment transport.

- Design for exposed lake conditions. Any proposed outfall needs to be robust to minimize the risk of damage by severe wave and ice action.

- Navigation safety. An offshore outfall discharge needs to avoid/minimize adverse impacts on recreational boating or other water-based recreational activity (e.g., swimming, beach usage).

- Outfall velocity. An outfall on the beach with a significant velocity has the potential to scour the beach and nearshore materials but needs to be self-flushing (ability to remove accumulated sediment at the outlet) to reduce the annual maintenance. The velocity might be a safety concern for the beach users, depending on the alternative selected.

- Aesthetics. The aesthetics of the outfall structure, total footprint, top elevation, etc., need to be carefully considered.

3.2 Alternative Formulation

Eight preliminary outfall alternatives were developed (independent of the existing storm outfall) and include the following:

1. Outfall open channel – steel sheet piling (SSP), with steel framing/bracing, with or without concrete cap. This option was discarded primarily due to estimated high cost.

2. Outfall open channel – cast-in-place concrete extending to the beach, or up to the current water's edge (Low Water Datum). This needs to be robust to resist wave and ice forces, and is provided with armor stone flanking, and scour stone at the outfall. This option was retained for further consideration

3. Outfall open channel – stone. This needs to be robust to resist wave and ice forces, and was discarded due to flow area needed (significant channel width), beach users safety concerns, and expected high maintenance needed.

4. Pipe or box culvert with containment/protective structures, extending to the beach, or up to the current water's edge (Low Water Datum). This option was retained for further consideration.

5. Pipe or box culvert with containment/protective structures, such as rubblemound, SSP, or "H" steel piles extending offshore. This option was retained for further consideration.

6. Pipe supported pipe/box culvert at some height above the lakebed to reduce impact on sediment transport. This option was dismissed due to significant expected wave and ice uplift forces and annual maintenance.

7. Pipe on the lake bottom with protective SSP or "H" steel piles extending offshore. This option was retained for further consideration.

8. Buried pipe with offshore discharge structure. This option was retained for further consideration.

Through the initial screening process, three alternatives were eliminated from further analysis due to various reasons, as outlined in Table 4; five alternatives were kept for further analysis. It is assumed that the preferred alternative will be well engineered, with reasonable annual maintenance requirements.

Table 4: Summary of Conceptual Alternatives

Alternative/ Short Description	Pros	Cons	Unknowns	Screening Decision/Notes
1. Open channel-SSP Provide a SSP channel with toe armor stone flanking and scour, discharge on the beach	• Reduced impacts to sediment transport • Does not require a baffle system to reduce flow velocity • Self-flushing capability • Structure footprint below OHWM-no anticipated permit mitigation for less than 0.1 acres	• Large channel width and flow area • Aesthetics • Safety issue for beach users due to high discharge water velocity to Lake Michigan • Water mixing in the nearshore • High cost comparing to other shore discharge alternatives • Land-based construction but needs specialized equipment	• Private property owners and public support • Impacts on nearshore circulation, outlet channel migration	**Dismissed** due to high cost, construction complexity
2. Open channel-concrete Provide a trapezoidal cast in place concrete channel with armor stone flanking and scour, discharge on the beach	• Easy to implement, land-based construction • Cost • Reduced impacts to sediment transport • Does not require a baffle system to reduce flow velocity • Self-flushing capability • Structure footprint below OHWM-no anticipated permit mitigation for less than 0.1 acres	• Large channel width and flow area • Aesthetics • Safety issue for beach users due to high discharge water velocity to Lake Michigan • Water mixing in the nearshore	• Private property owners and public support • Impacts on nearshore circulation, outlet channel migration	**Kept** for further analysis (Alternative 1)
3. Open channel-stone Provide a trapezoidal channel with armor stone flanking and scour, discharge on the beach or to the water's edge (LWD)	• Easy to implement, land-based construction • Cost • Reduced impacts to sediment transport • Does not require a baffle system to reduce flow velocity • Self-flushing capability • Structure footprint below OHWM-no anticipated permit mitigation for less than 0.1 acres	• Large channel width and flow area • Aesthetics • Safety issue for beach users due to high discharge water velocity to Lake Michigan • Water mixing in the nearshore	• Private property owners and public support. • Impacts on nearshore circulation, outlet channel migration	**Dismissed** due to expected high structure maintenance

Alternative/ Short Description	Pros	Cons	Unknowns	Screening Decision/Notes
4. Pipe or culvert discharge on beach Provide a pipe or culvert with stone protection structures and scour stone, discharge on the beach or to the water's edge (LWD)	• Easy to implement, land-based construction • Reduced impacts to sediment transport • Self-flushing capability • Cost • Structure footprint below OHWM-no anticipated permit mitigation for less than 0.1 acres	• Pipe or culvert stability • Aesthetics • Safety issue for beach users due to high discharge water velocity to Lake Michigan • Water mixing in the nearshore • Might require a baffle system to reduce flow velocity	• Private property owners and public support • Impacts on nearshore circulation, outlet channel migration	**Kept** for further analysis (Alternative 2)
5. Pipe or culvert discharge offshore Provide a pipe or culvert with stone protection structures and scour stone, discharge offshore	• Does not require a baffle system to reduce flow velocity • Self-flushing capability • Water mixing in deeper water • Public access and beach enhancement opportunities	• Pipe or culvert stability • Structure footprint below OHWM-possible permit mitigation • Impacts the sediment transport, beach pre-fill needed • Cost • Aesthetics/Lake Michigan views	• Private property owners and public support • Impacts on nearshore circulation, sediment transport	**Kept** for further analysis (Alternative 3)
6. Pipe or culvert, pile supported Provide a pipe or culvert with supporting piles above the lakebed with an offshore discharge	• Does not require a baffle system to reduce velocity • No permit mitigation • Self-flushing capability • Water mixing in deeper water • Does not impact the sediment transport	• Pipe stability • Significant ice and wave uplift forces • Construction-marine. • Aesthetics/Lake Michigan views • Cost	• Private property owners and public support • Impacts on nearshore circulation	**Dismissed** based on ice/wave upflift forces and annual maintenance
7. Pipe on lake bottom Provide a pipe with supporting piles above the lakebed with an offshore discharge	• Does not require a baffle system to reduce flow velocity • Self-flushing capability • Water mixing in deeper water • Public access and beach enhancement opportunities	• Pipe or culvert stability • Cost • Significant ice and wave uplift forces • Structure footprint below OHWM-possible permit mitigation • Impacts the sediment transport, beach pre-fill needed • Aesthetics/Lake Michigan views	• Private property owners and public support • Impacts on nearshore circulation and sediment transport	**Kept** for future analysis (Alternative 4)
8. Buried Pipe Provide a buried pipe with an offshore discharge structure	• Does not require a baffle system to reduce velocity • No permit mitigation • Water mixing in deeper water • Does not impact the sediment transport • Aesthetics	• Cost	• Private property owners and public support • Impacts on nearshore circulation and sediment transport	**Kept** for future analysis (Alternative 5)

As noted above, five pre-screened options have been "short-listed" for further consideration, as discussed in the following sections, which includes photographs of similar structures which have been constructed elsewhere on the Great Lakes. In addition, Appendix C presents plan views and cross-sections to depict the general intent of each design concept.

3.2.1 Alternative 1: Open Channel, Beach Discharge

This alternative includes an open channel discharging onto the beach, somewhere landward of the water's edge (Low Water Datum). The structure is provided with wing walls and/or armor stone to protect against flanking erosion, and the beach/lakebed around the outlet area is protected with scour stone. Figure 6 presents an example of a trapezoidal concrete open channel on Lake Ontario; this structure was designed for a similar discharge rate as the proposed Willow Road outfall, and has not required any maintenance over its 30+ year life.

Figure 6: Example of Open Channel with Beach Discharge (Lake Ontario)

3.2.2 Alternative 2: Pipe or Culvert, Beach Discharge

This alternative includes an eight foot diameter pipe (or box culvert of similar capacity) discharging onto the beach somewhere landward of the water's edge (Low Water Datum). The structure is provided with wing walls and/or armor stone to protect against flanking erosion, and the beach/lakebed around the outlet area is protected with scour stone. Figure 7 presents an example of a pipe discharging on a Lake Michigan beach.

Figure 7: Example of Pipe with Beach Discharge (Lake Michigan)

3.2.3 Alternative 3: Encased Pipe or Culvert, Nearshore Discharge

This alternative includes an eight foot diameter pipe (or box culvert of similar capacity) extending across the beach to a nearshore discharge, with the pipe or culvert encased in/protected by a rubblemound structure or steel sheet piling. Figure 8 presents an example of a stormwater outfall with an offshore discharge into Lake Ontario; this structure is encased by steel sheet pile walls and a concrete cap.

Figure 8: Example of Encased Culvert with Nearshore Discharge (Lake Ontario)

3.2.4 Alternative 4: Anchored Pipe or Culvert, Nearshore Discharge

This alternative includes an eight foot diameter pipe (or culvert) placed on/across the beach to a nearshore discharge, with the pipe held in place by some type of piled framing. For example, the existing outfall at the project site is held in place with H-piles (refer to Figure 1). Figure 9 shows another example of an outfall pipe which is held in place by a timber pile frame.

Figure 9: Pipe on Lake Bottom
(Source http://www.naplesnews.com/photos/2012/jan/18/371053)

3.2.5 Alternative 5: Buried Pipe, Nearshore Discharge

This alternative includes an eight foot diameter pipe buried under the nearshore lakebed, with a riser to a discharge structure above the lakebed at some distance offshore. It is anticipated that the pipe would be installed using a cut and cover operation. Due to the shallow water depths, it is likely that a temporary stone dike (causeway) would have to be constructed to provide access for equipment to excavate the trench, place the pipe sections and backfill. Figure 10 presents a photo showing the use of a temporary dike to place a marine pipeline.

Figure 10: Temporary Dike to Support Installation of Marine Pipeline (Source: http://www.ltlgroup.ca/article/projects-126.asp)

3.2.6 Summary of Alternative Concepts

Five outfall alternatives have been evaluated; three have a shore (beach) discharge, while two have in-water (nearshore) discharges. A summary of the alternatives is presented below and shown in Figure 11:

- Alternative 1: Open Channel, Beach Discharge - 30 foot long open concrete open channel, 20 foot bottom width, discharging onto the beach; provided with wing walls and/or armor stone to protect against flanking erosion, and scour stone at the outlet area.

- Alternative 2: Pipe or Culvert, Beach Discharge - Eight foot diameter pipe (or box culvert of similar capacity), 30 feet long, discharging onto the beach; provided with wing walls and/or armor stone to protect against flanking erosion, and scour stone at the outlet area.

- Alternative 3: Encased Pipe or Culvert, Nearshore Discharge - Eight foot diameter pipe (or box culvert of similar capacity), 140 feet long, extending across the beach to a nearshore discharge, with rubblemound structure or steel sheet piling.

- Alternative 4: Anchored Pipe or Culvert, Nearshore Discharge - Eight foot diameter pipe (or box culvert of similar capacity), 185 feet long, placed on/across the beach to a nearshore discharge, with piled framing.

- Alternative 5: Buried Pipe, Nearshore Discharge - Eight foot diameter pipe buried under the nearshore lakebed, 215 feet long with a riser to a discharge structure above the lakebed.

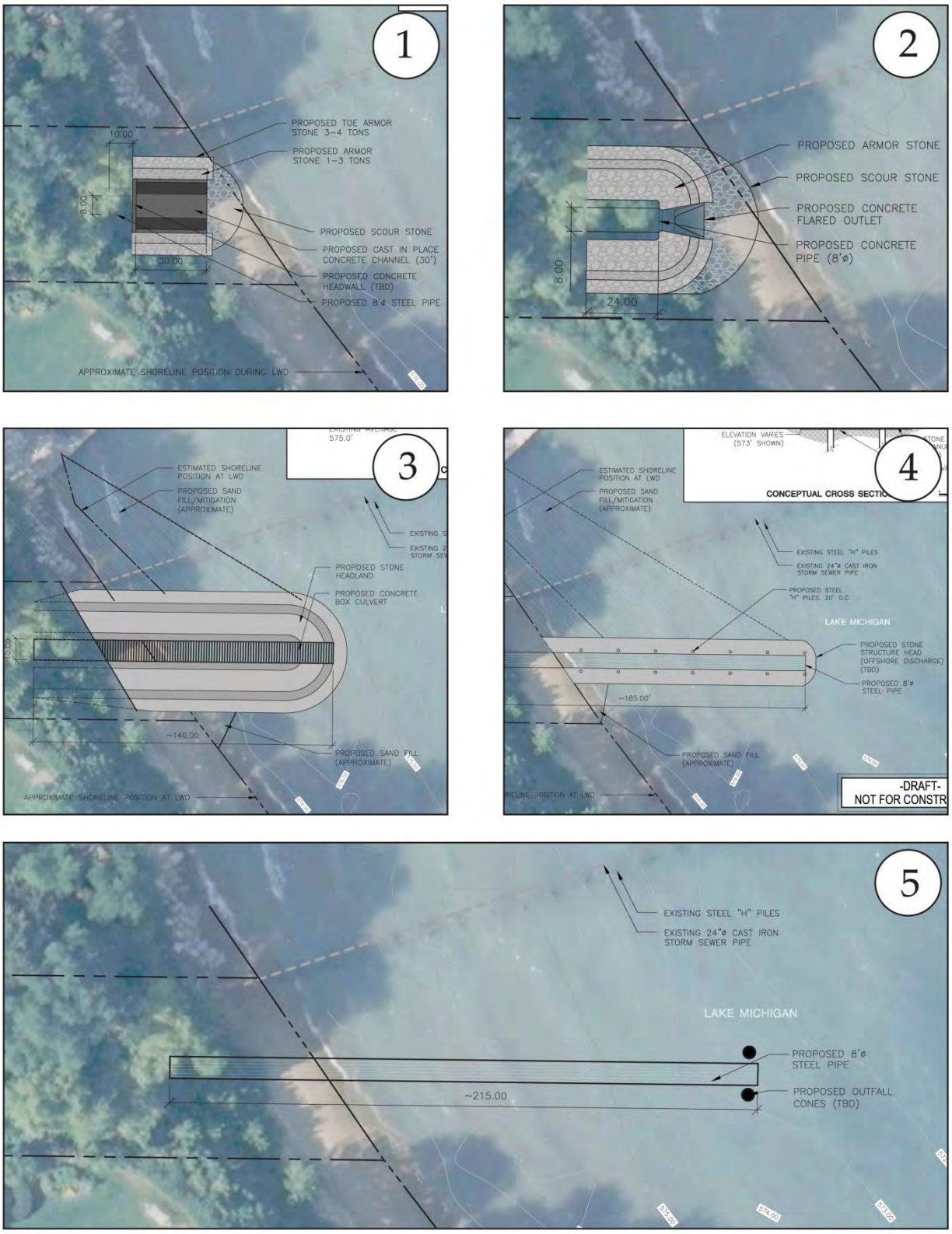


Figure 11: Summary of Alternatives (Not to Scale)

3.3 Preliminary Opinion of Probable Construction Costs

Anticipated unit costs for various structural elements that might be used in the proposed outfalls have been estimated based on a review of unit prices from recent bids for various projects in Illinois and Wisconsin, review of Baird's in-house cost database, and discussions with specialized marine contractors. The anticipated unit prices are presented in Table 5; these are "in place" unit prices, including supply, transport and placement.

Table 5: Estimated Unit Prices

Item	Unit Price (2012 USD)
Armor Stone 1 to 6 tons	$75/ton
Scour Stone	$65/ton
Bedding Stone	$55/ton
8′ Dia. Pipe-Shore	$1,000/lft
8′ Dia.Pipe, Lake Bottom	$3,500/lft
8′ Dia. Pipe, Buried	$4,600/lft
Pipe Outfall (Offshore Structure)	$100,000/ea
Sand Fill	$50/cyd
Concrete Flared Outlet	$20,000/ea
Concrete Headwall	$25,000/ea
Concrete Culvert, 8′ Dia.	$1,200/lft

Preliminary quantity and cost estimates have been developed for outfall concepts discussed above, with concept level drawings presented in Appendix C. The material quantities were estimated based on the conceptual design cross-sections presented in Appendix C and estimated topographic/bathymetric data along the proposed structure alignment. The unit prices for the buried pipe (Alternative 5) included the temporary construction of a stone dike to allow for excavation in shallow water, and the dike removal.

In general, the construction costs may vary significantly, depending on the following factors:

- Market conditions prevailing at the time of bidding.
- Material availability and cost, particularly for large diameter pipe.

In addition, the construction cost of the buried pipe concept (Alternative 5) is subject to additional uncertainty, due to the following factors:

- Depth of pipe below the lake bottom, location of sand/clay interface and characteristics of materials (excavation in sand will require flatter slopes and greater quantities; excavation in hard clay will be difficult and offshore or land disposal of clay materials might be required).

- Permitting requirements may modify/affect the construction method and sequence.

- Construction methodology and stone dike requirement.

Table 6 summarizes preliminary cost estimates for the five different concept-level alternatives, including mobilization/demobilization and contingency allowances of 10% and 25% respectively.

Table 6: Estimated Alternatives Construction Costs

Alternative	Unit Price (2012 USD)
I: Concrete Channel	$140,000
II: Pipe/Culvert-Beach	$160,000
III: Pipe/Culvert-Offshore	$550,000
IV: Pipe-Lake Bottom	$1,050,000
V: Buried Pipe	$1,400,000

It is noted that the estimated construction costs will vary depending on the final selected structure length of the preferred alternative outfall, to be revised in the design development phase.

3.3.1 Structure Maintenance Costs

Maintenance costs for marine and coastal structures are typically associated with repair/rehabilitation works undertaken in response to storm damage and/or the gradual deterioration of the structure over time. For project planning purposes, the annual maintenance cost may be estimated as a fraction of the initial construction cost. Baird (1993) undertook a literature review on this topic, and noted that annual maintenance allowances typically range from 0.3 - 3.0% for rubblemound structures (Baird 1993). The USACE typically assumes 2% for rubblemound structures.

It is noted that defining maintenance costs as a percentage of the initial construction cost is used as a planning guideline only. Annual maintenance work is generally not undertaken for rubblemound structures. Rather, maintenance and repair/rehabilitation works are typically carried out in a reactive fashion. An annual monitoring program is recommended to define the requirement for such works prior to the onset of significant damage to structures.

It is recommended that the Village of Winnetka consider an annual maintenance cost allowance of 2% for over the project life for planning and budgeting purposes. If either Alternative 4 or 5 is selected for implementation, a periodic underwater investigation program (diver inspection) is recommended to document the condition of the pipe and sedimentation.

3.4 Evaluation of Alternatives

All five screened alternatives have been conceptually designed to provide the design stormwater outfall flow. Permitting and approvals may be easier for some alternatives than others. For example, it may be more difficult to obtain permits and approvals for larger structures (Alternative 3) than those with minimal in-water work (Alternative 1 and 2). Also, although Alternative 5 disturbs a significant area of lake bottom, it will not result any significant changes to the nearshore environment upon its completion.

Intuitively, longer structures will provide better performance with respect to water mixing processes (i.e. dispersion of the discharge from the outfall), as deeper water mixing is more efficient than shallow water. However, longer structures are more expensive, and increase the potential to trap sediments. The latter issue can be mitigated by pre-filling the north side of the structure, and creating a fillet beach that will allow natural sediment bypassing to occur. The fillet beach will also serve as shoreline and bluff toe protection.

Table 7 presents a matrix comparison of the five alternative concepts. Specifically, the alternatives have been ranked relative to one another under various factors in order to facilitate the identification of a preferred alternative(s) for consideration by the Village. It is noted that no weighting factors have been applied at this time.

The evaluation criteria included:

- Estimated construction cost
- Anticipated impacts on sediment transport and adjacent properties
- Structure footprint/permitting - total footprint below the Ordinary High Water Mark, (OHWM = + 4 ft LWD) is a consideration in the permitting process
- Water mixing efficiency - discharge in deeper water provides better mixing
- Shoreline protection - ability of structure to contribute to protection of shoreline and bluff (separate project that can be implemented in the same time with the outfall structure)
- Aesthetics - visual impacts (i.e. unobstructed views of Lake Michigan are preferred)
- Public access - uninterrupted public access along the shoreline is preferred
- Beach improvements – opportunities provided by the structure

Table 7: Matrix Comparison of Alternatives

Evaluation Factor	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5
Capital Cost	E	G	S	P	VP
Sediment transport/neighbors impacts	G	G	S	S	E
Structure footprint/permitting	G	G	S	S	E
Water mixing efficiency	S	S	G	G	E
Shoreline/bluff protection	S	S	E	E	P
Aesthetics	G	G	S	S	E
Beach users safety	S	S	G	G	E
Shoreline access	G	G	S	S	E
Beach improvements	G	G	E	E	S
Total Rank	**2nd**	**3rd**	**3rd**	**4th**	**1st**

Note: E=Excellent, G=Good, S=Satisfactory, P=Poor, VP=Very Poor.

The results of this preliminary comparison suggest that Alternative 5 (buried pipe) provides the best overall combination of performance and cost, even though the capital construction cost is highest for this option. Alternative 1 (concrete channel) is second, followed by Alternatives 2 and 3. It is noted that the application of weighting factors (i.e. to give increased importance to certain factors) could change the results of our evaluation.

The alternatives developed were presented to the regulatory agencies on May 10, 2012; the meeting provided valuable input for screening, but the water quality mixing and criteria remain undefined.

This preliminary matrix analysis is presented as basis for review and further analysis by the Village; the evaluation method and criteria may be modified as required based on factors determined appropriate and important.

As an additional consideration, it may be feasible to incorporate the discharge from the existing outfall at the site, and two other Village outfalls, into the new outfall. This cannot be confirmed at this time, but could be assessed and addressed in the design development phase.

4.0 CONCLUSONS AND RECOMMENDATIONS

Five alternative outfall concepts have been developed to accommodate the design stormwater flow. A preliminary evaluation was undertaken in order to rank each alternative for a range of factors, including preliminary estimates of capital cost, and qualitative assessments/expert opinions regarding potential impacts on sediment transport, water mixing efficiency, ability to protect the bluff toe, aesthetics, beach user safety, shoreline access, and potential opportunities for beach enhancement.

This evaluation identified two alternatives that may warrant further consideration. Specifically, Alternatives 1 and 5 appear to provide the best overall combination of performance and cost. Although Alternative 5 has the highest capital cost (due to the high cost to provide a buried pipe under the lake bed), it does not interfere with the sediment transport, should not require permit mitigation, provides mixing in deeper water, does not obstruct the Lake Michigan views, and does not interfere with the beach users.

Input received from the regulatory agencies on May 10, 2012 has been incorporated into the alternative screening process. However, the water quality mixing and criteria remain undefined at this time, and no analyses of this issue have been undertaken.

Following the selection of an alternative by the Village, additional data collection and technical analyses will be required to support permitting and final engineering design, potentially including the following tasks:

- Pre-permit application meeting with the regulatory agencies to refine/detail the permitting requirements and supporting technical analysis.
- Bathymetric and topographic surveys (all alternatives).
- Geotechnical investigation (particularly for Alternative 5).
- Hydrodynamic and sediment transport modeling and analysis of potential impacts of project (particularly for Alternatives 3 and 4).
- Water sampling and analysis for stormwater detention basins (if required by IEPA).
- Water quality modeling/plume dispersion (if needed).
- Selection of project life and allowable risk of damage (through discussion with the Village).

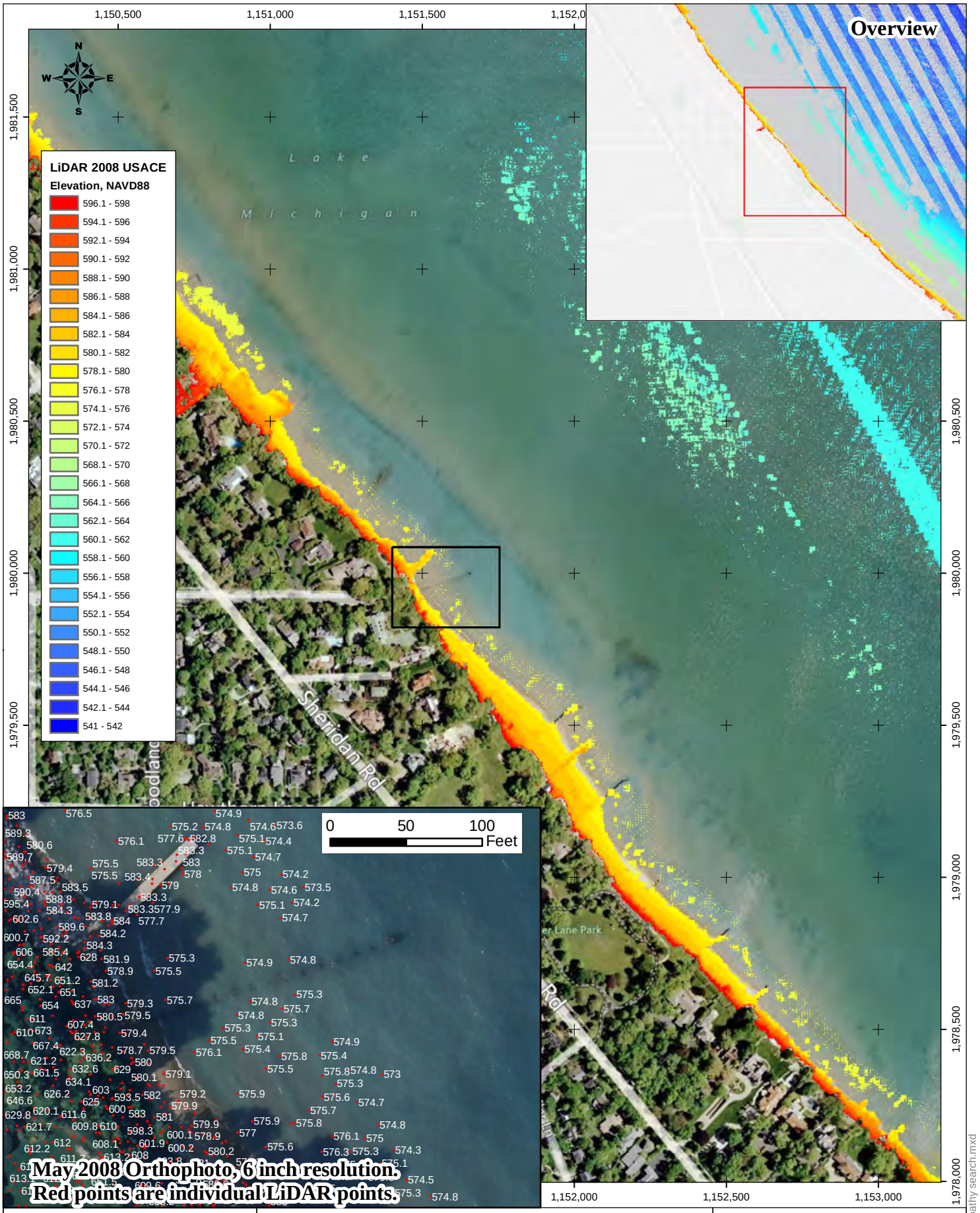
- Development of extreme design conditions for water levels, waves and ice.
- Detailed structure design development (layouts, cross-sections, details) for selected concept.
- Final designs, plans and specifications, and revised estimated construction cost and schedule.
- Bidding and construction.

In addition, the following issues may warrant consideration by the Village prior to beginning design development for the preferred outfall alternative:

- Expand project scope to include discharge from other outfalls with the Willow Road structure.
- Expand project scope to include bluff and shoreline improvements and protection.

APPENDIX A

SURVEY DATA



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0 250 500 ft

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2008 LiDAR, USACE

Colored Areas Match Survey Data Limits

LiDAR Bathy: CHARTS, 17-26 September 2008.
Grid Spacing: 500 feet.
Spatial Reference: State Plane, Illinois East.

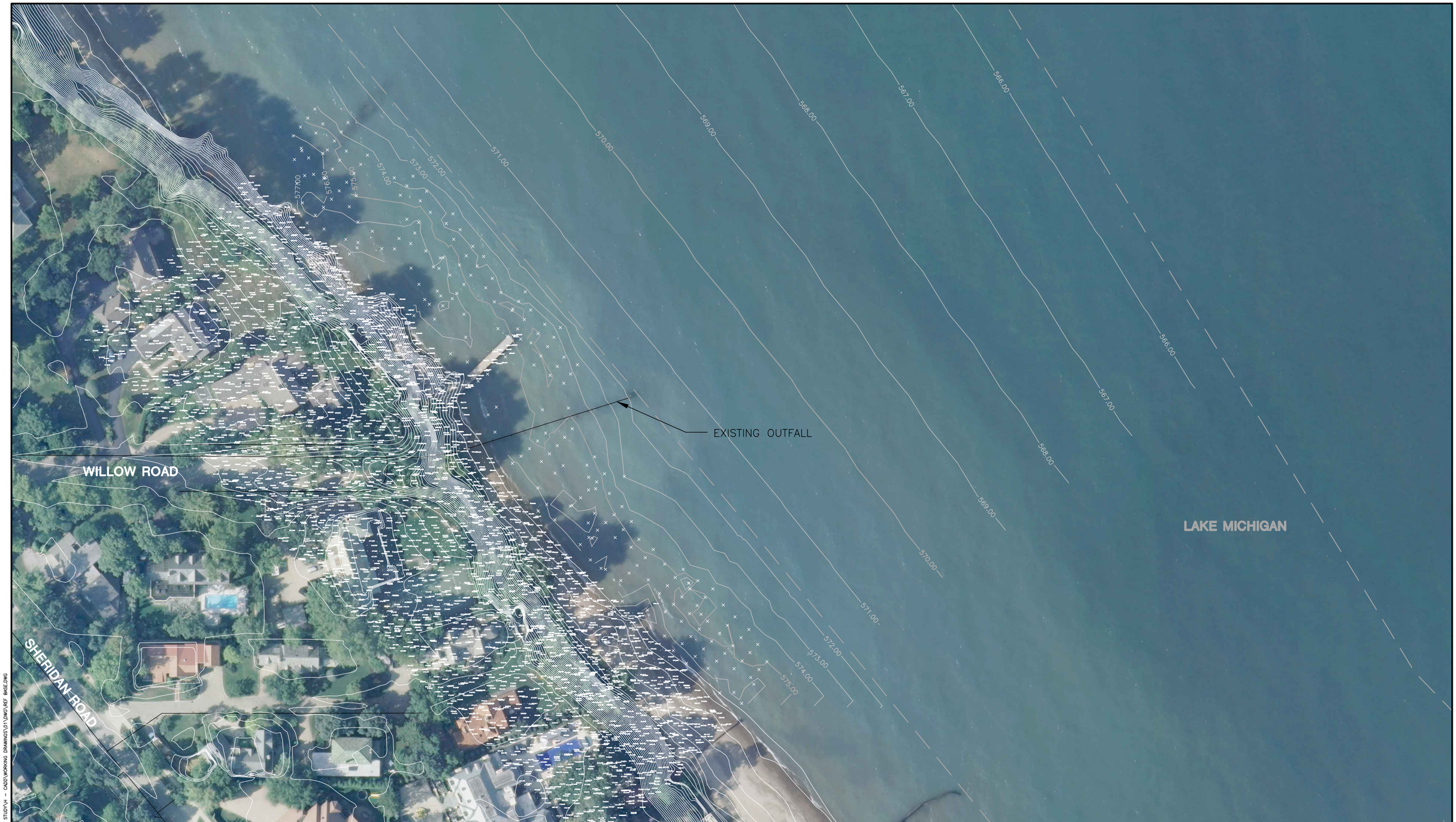
Baird

Map Published: 2012-04-16

11962 Winnetka bathy search.mxd

APPENDIX B

BASE MAP



GENERAL NOTES

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- Points: 2008 USACE LIDAR Below 577.5 NAVD88
- Bathy Contour From LIDAR Points
- Bathy Contour from NOAA Chart 14905
- Topo Contour From Winnetka

ELEVATIONS REFERENCE VERTICAL DATUM NAVD88/IGLD85 (LWD=577.5 FEET)

BATHYMETRY CONTOURS ARE APPROXIMATED BASED ON 2008 USACE LIDAR DATA TO AN ELEVATION OF 572.0 AND BASED ON NOAA CHART 14905 BELOW 572.0

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PREPARED FOR: VILLAGE OF WINNETKA ILLINOIS CORPORATE SEAL

PREPARED BY: Baird — W.F. Baird & Associates, Ltd.

Willow Road Stormwater Relief Tunnel

Existing Conditions

DRAWING: 11962.100 — 01 — 01 62 REV. 00

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APPENDIX C

CONCEPTUAL ALTERNATIVES

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PREPARED BY: Baird
W.F. Baird & Associates, Ltd.

Willow Road Stormwater Relief Tunnel

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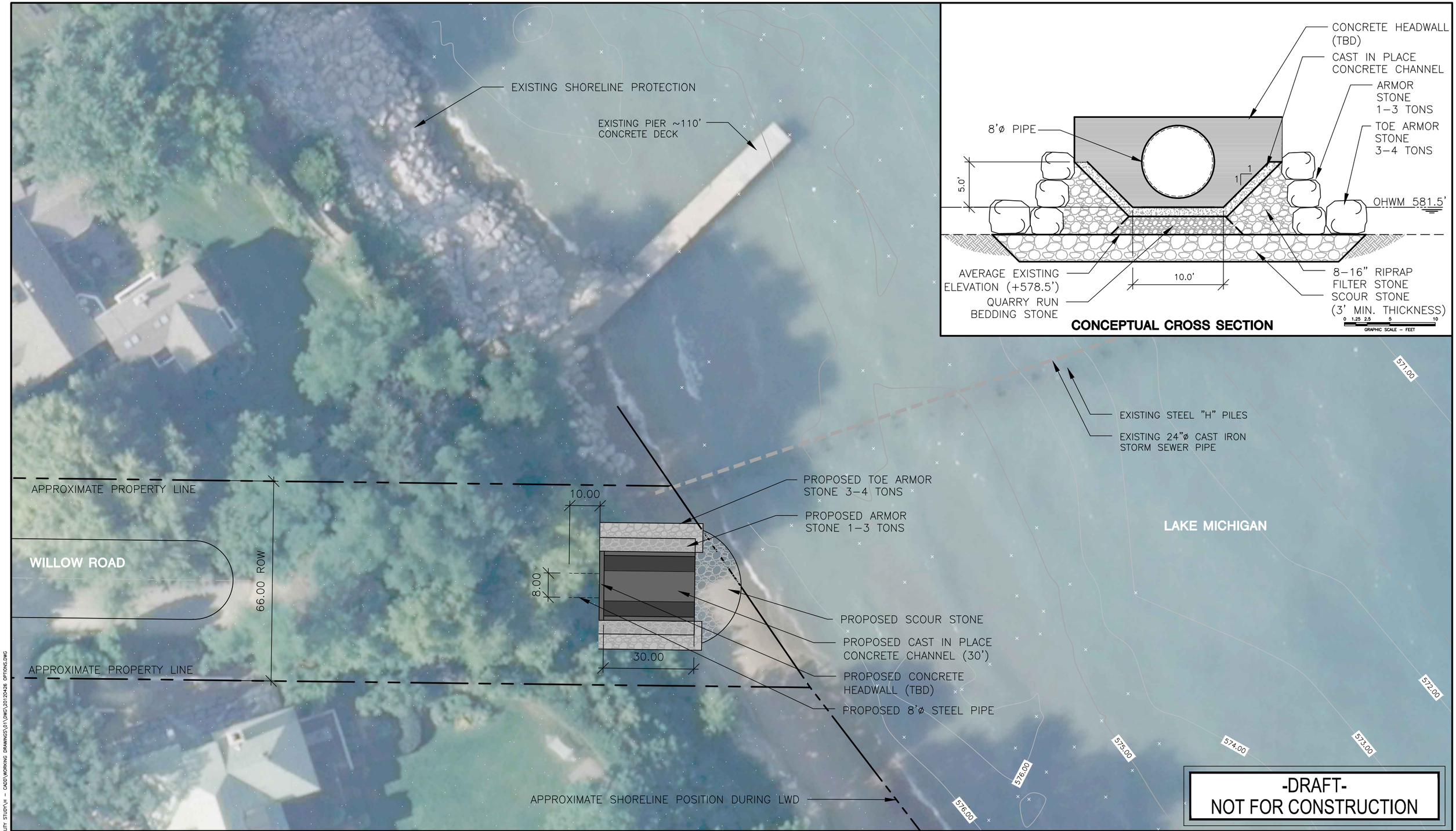

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PREPARED FOR: VILLAGE OF WINNETKA CORPORATE SEAL

PREPARED BY: Baird — W.F. Baird & Associates, Ltd.

Willow Road Stormwater Relief Tunnel

Alternative I - Open Channel, Beach Discharge

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EXISTING SHORELINE PROTECTION

EXISTING PIER ~110'
CONCRETE DECK

APPROXIMATE PROPERTY LINE

WILLOW ROAD

66.00 ROW

APPROXIMATE PROPERTY LINE

PROPOSED ARMOR STONE

PROPOSED SCOUR STONE

PROPOSED CONCRETE
FLARED OUTLET

PROPOSED CONCRETE
PIPE (8'ø)

8.00

24.00

EXISTING STEEL "H" PILES

EXISTING 24"ø CAST IRON
STORM SEWER PIPE

LAKE MICHIGAN

571.00

572.00

573.00

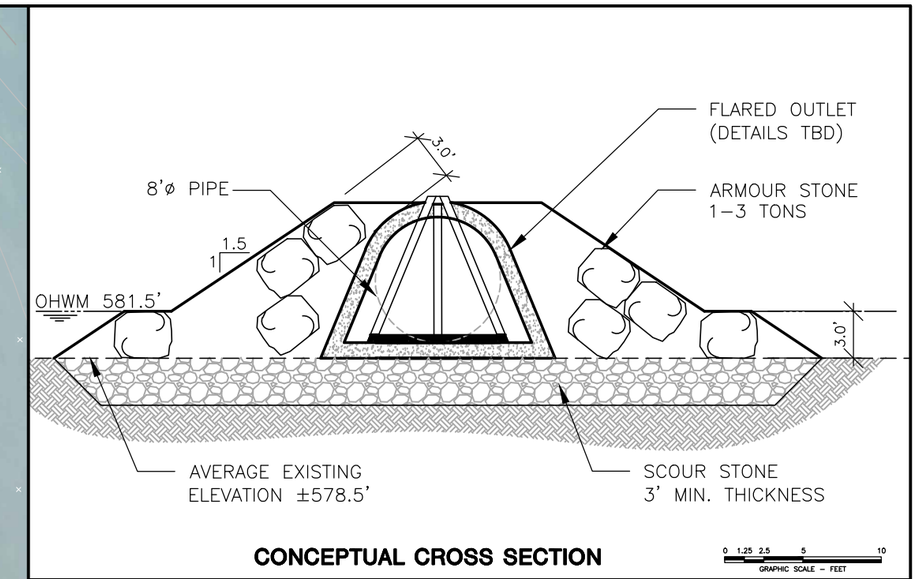
574.00

575.00

576.00

576.00

APPROXIMATE SHORELINE POSITION DURING LWD



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GENERAL NOTES

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PREPARED FOR: VILLAGE OF WINNETKA ILLINOIS INCORPORATED 1869

PREPARED BY: Baird — W.F. Baird & Associates, Ltd.

Willow Road Stormwater Relief Tunnel

Alternative 2: Pipe or Culvert, Beach Discharge

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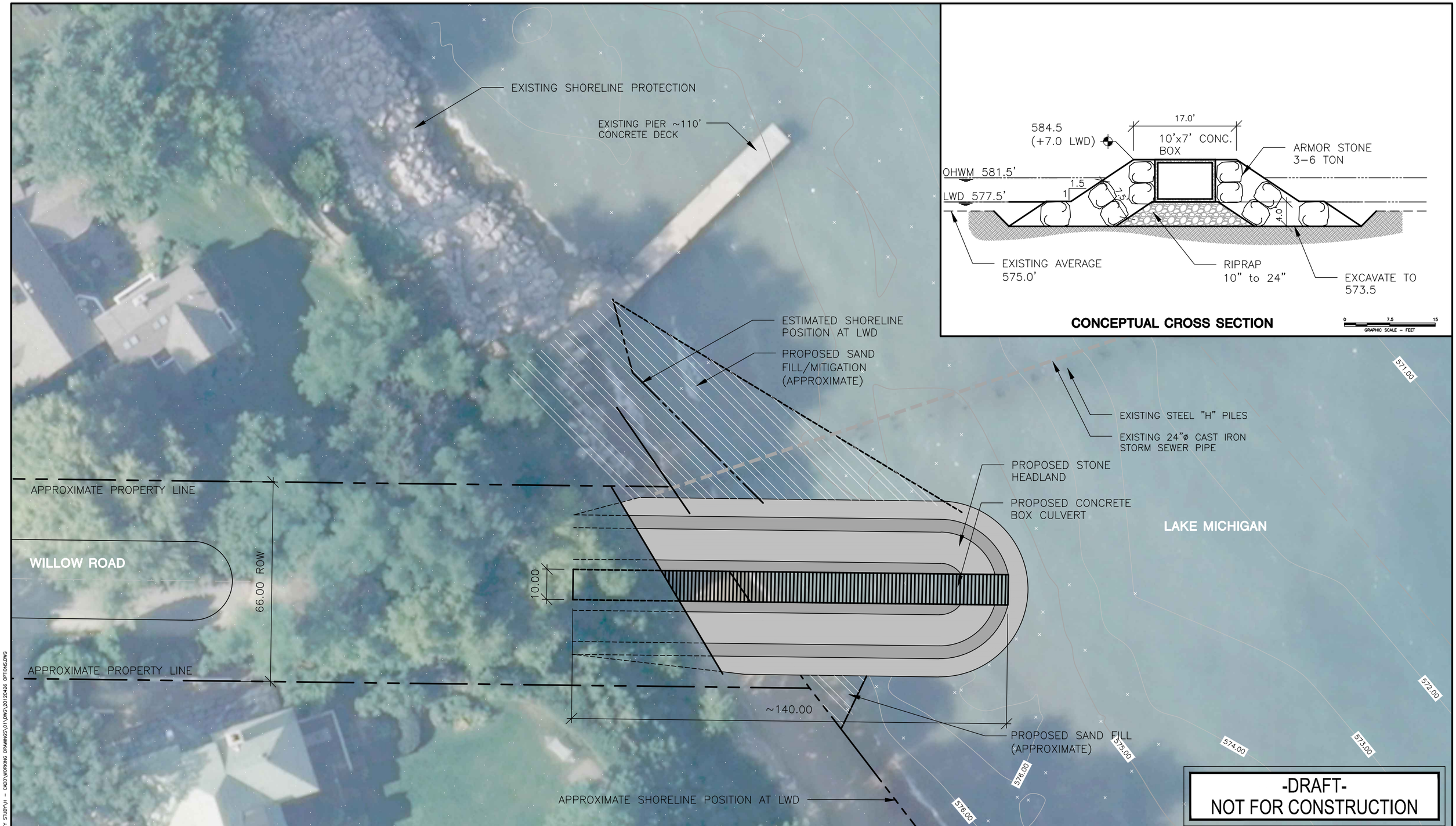

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PREPARED FOR: Village of Winnetka Corporate Seal

PREPARED BY: Baird — W.F. Baird & Associates, Ltd.

Willow Road Stormwater Relief Tunnel

Alternative 3: Encased Pipe or Culvert, Nearshore Discharge

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Date Plotted: 5/25/2012 11:20:10 AM

EXISTING SHORELINE PROTECTION

EXISTING PIER ~110' CONCRETE DECK

ESTIMATED SHORELINE POSITION AT LWD

PROPOSED SAND FILL/MITIGATION (APPROXIMATE)

EXISTING STEEL "H" PILES

EXISTING 24"ø CAST IRON STORM SEWER PIPE

PROPOSED STEEL "H" PILES, 20' O.C.

APPROXIMATE PROPERTY LINE

WILLOW ROAD

66.00 ROW

8.00

~185.00'

LAKE MICHIGAN

PROPOSED STONE STRUCTURE HEAD (OFFSHORE DISCHARGE) (TBD)

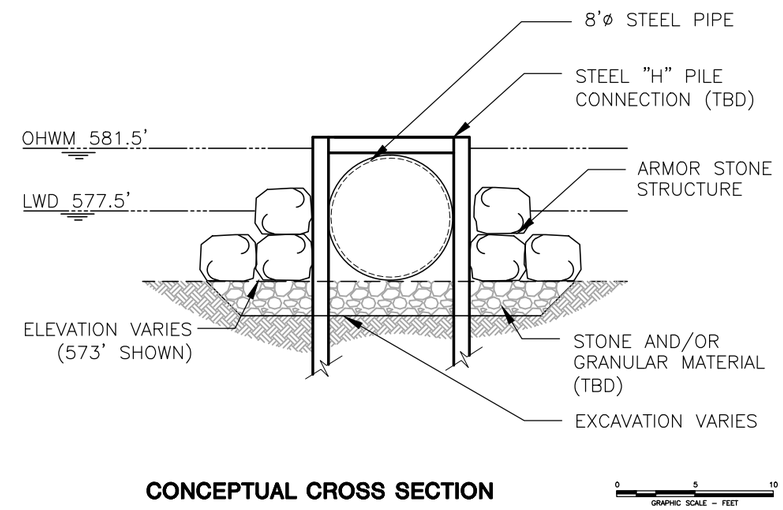
PROPOSED 8'ø STEEL PIPE

APPROXIMATE PROPERTY LINE

PROPOSED SAND FILL (APPROXIMATE)

APPROXIMATE SHORELINE POSITION AT LWD

571.00 572.00 573.00 574.00 575.00 576.00 576.00



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GRAPHIC SCALE – FEET

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Willow Road Stormwater Relief Tunnel

Alternative 4: Anchored Pipe or Culvert, Nearshore Discharge

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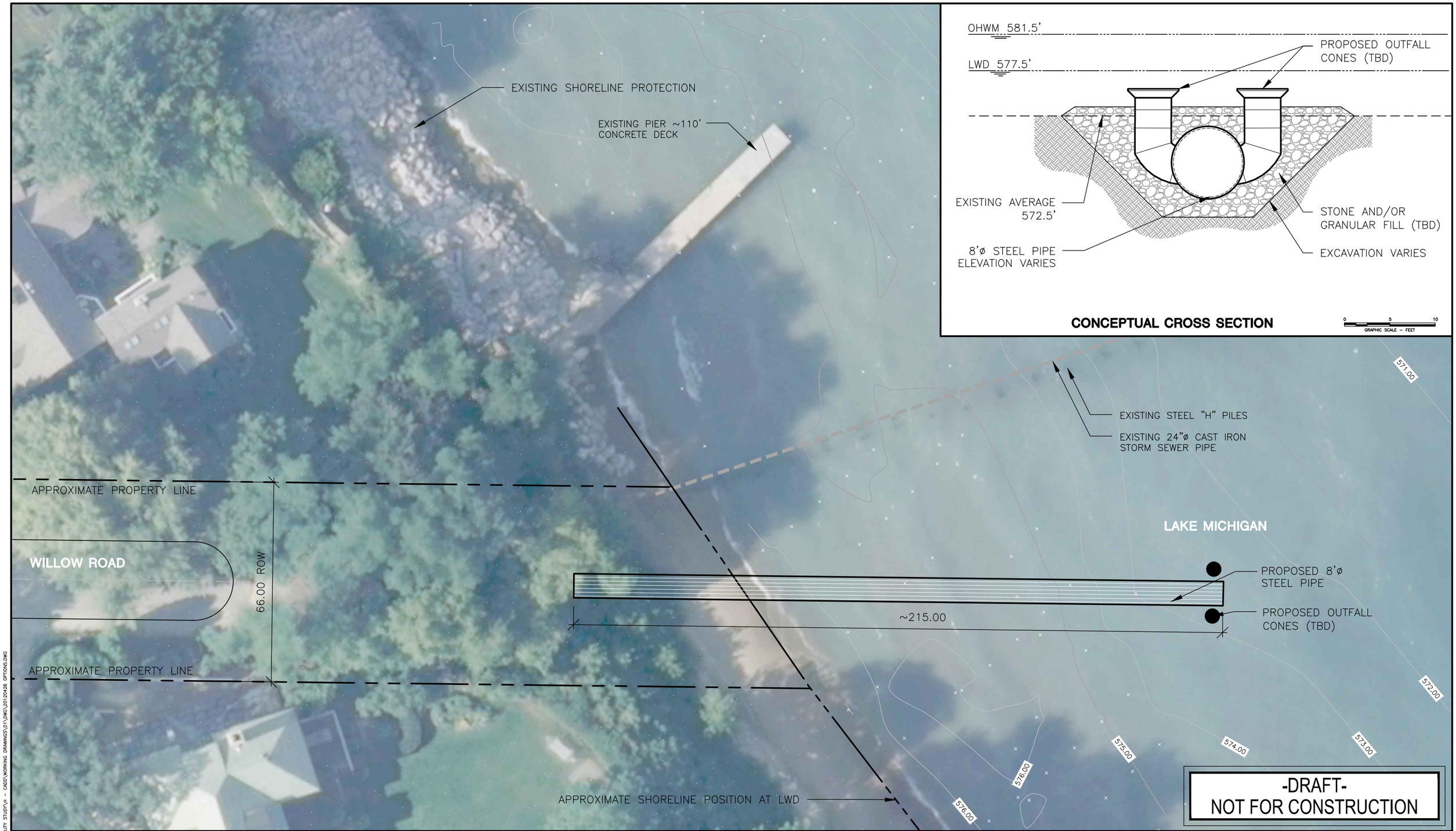

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GRAPHIC SCALE – FEET

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PREPARED BY: Baird W.F. Baird & Associates, Ltd.

Willow Road Stormwater Relief Tunnel

Alternative 5: Buried Pipe, Nearshore Discharge

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Date Plotted: 5/25/2012 1:47:56 PM

ATTACHMENT #4

TUNNELLING COST ESTIMATE

KENNY

Village of Winnetka
Willow Road Storm Tunnel

for Steve Saunders, Director of Public Works, Village Engineer
Directed by: Dr. Thomas Burke, Christopher B. Burke Engineering

Assumptions: 3,3300 lf of 96 inch internal diameter storm tunnel in Willow Road
Entry shaft at Willow & Walnut Street
Exit shaft at Willow & Birch

		Unit	UM	
Launch Shaft at Walnut				
	17 vf to invert, 20 vf to shaft bottom for launching shaft 30 ft long x 14 ft wide x 20 vf			
	Support of excavation	20	vf	
	Backfill & restore work area	1	ls	
	Mobilzation, Trucking, etc.	1	ls	
				$ 349,200
Retrieval Shaft at Birch				
	24 vf to invert, 27 vf to shaft bottom for removal shaft 24 ft long x 14 ft wide x 27 vf			
	Support of excavation	27	vf	
	Backfill & restore work area	1	ls	
	Mobilzation, Trucking, etc.	1	ls	
				$ 389,400
Tunnel Excavation				
	3,300 lf of 131 inch TBM bore with rib & lagging			
	Shaft utilities, launch frame, launch pad	1	ls	
	Assmble TBM	1	ls	
	Start TBM 300 ft at 20 fps	1	ls	
	Mine balance 3,000 lf at 48fps	3,000	ft	
	Support crews	68	sft	
	Generator for TBM	68	sft	
	Remove TBM	10	sft	
	Clean tunnel for pipe, place invert	3,300	lf	
	Materials rib & lagging	3,300	lf	
	Load & Trucking spoil	11,400	cy	
				$ 3,617,520
Pipe in Tunnel				
	Labor to set up & jack 3,300 lf	3,300	lf	
	Materials pipe & blocking	3,300	lf	
	Material annulus grout pumped	1,635	cy	
				$ 1,927,710

General & Supervision			
	PM, Supts. Survey, Admin, Safety	7 mos	
	Office, Plant, Mechanics, Electricians	7 mos	
	Insurance & bond w deductibles	1 ls	
	Consultants, traffic, safety, misc	1 ls	
			$ 1,845,000
Equipment			
	TBM, locomotives, pipe jack frame 96"	1 ls	
	Cranes (132 ton & 40 ton) & Loaders	7 mos	
	Supv vehicles	28 ls	
	Linear plant, rail, cable, vent pipe	3,300 lf	
	Freight, service boom truck	1 ls	
			$ 1,412,040
	Total Cost	3,300 lf	$ 9,540,870
	Cost per Foot		$ 2,891