Motion 15693 Attachment A

Kenmore Interceptor Report

March 2020

King County

I. Contents

II. Executive Summary

Ordinance 18835, Section 108, Proviso P2 identified four areas of concern relative to the placement and presence of the Kenmore Interceptor Section 2 along the bed of Lake Washington. The Kenmore Interceptor Section 2 is a 48-inch pipeline that conveys wastewater from the Kenmore area to the Matthews Beach Pump Station and the West Point Treatment Plant. The concerns identified in the proviso relate to the interceptor's impact on sediment accumulation and, subsequently, water fauna in Lake Washington, particularly on species of fish that migrate from the ocean to rivers or streams known as "anadromous"[1] species. Lake Washington is an important habitat for a number of species of migrating salmon and trout.

To address the areas of concern identified in the proviso, the Wastewater Treatment Division (WTD) of the Department of Natural Resources and Parks retained Environmental Science Associates (ESA) to analyze sedimentation and impacts to fish populations in the vicinity of the pipeline. The study area for the analysis encompassed the area between approximately Tracy Owen Station Park and Ballinger Way. The analysis included a comprehensive review of the 2011 *Kenmore Lake Line Lakebed Sedimentation Analysis* conducted by SoundEarth Strategies, Inc., and Lally Consulting LLC (Appendix B) in response to similar concerns raised in the past. Appendix A presents ESA's complete 2020 report, *Kenmore Interceptor Proviso P2 Support: Sediment and Fish Population Study*.

ESA's report concluded that the Kenmore Interceptor, which is buried throughout most of the Lyon and McAleer creek deltas, does not play a significant role in sedimentation patterns in the study area. The analysis concluded that the Kenmore Interceptor is currently 80 percent buried in the study area, with 20 percent of the interceptor casement exposed by no more than 10 inches above the lakebed. No measurable differences in sediment accumulation were observed along near-shore and off-shore sides of the interceptor, with the exception of one area of approximately 500 square feet where localized effects of minor accumulation on the shore side have occurred in an area 10 to 20 feet wide.

Additionally, ESA's report determined the dominant physical processes that have influenced sediment accumulation in the study area and enhanced accretion[2] under and around docks, contributing to a perceived shallowing of recreational mooring areas, include the following:

- Deposition of sediment by McAleer and Lyon creeks
- The presence of dense stands of Eurasian watermilfoil[3]
- Nearshore erosion caused by wind and wave action

Lastly, although Lake Washington continues to provide important habitat for many species of fish, the quality and quantity of fish habitat in the study area have been degraded over the years by several factors that are generally present on a lake-wide basis. The extent of shoreline armoring[4] and overwater structures, or docks, around Lake Washington has effectively limited the natural erosion processes

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[1] Anadromous fish are born in fresh water, spend most of their life in the sea, and then return to fresh water to spawn. Salmon are a type of anadromous fish.

[2] *Accretion* means a gradual buildup of sediment.

[3] Eurasian watermilfoil is an aquatic plant that can form thick mats in shallow areas of lakes and rivers.

[4] Armoring is the practice of using physical structures to protect shorelines from coastal erosion, such as a seawall.

leading to sediment transport, thereby altering out-migrating salmon behavior and introducing cover for salmon predators. ESA's report further determined that the resulting composition of most shoreline substrates does not contain habitat suitable to most salmonids.[5] However, the Kenmore Interceptor neither affects the processes that limit salmonid survival and migration nor contributes in a measurable way to other limiting factors to salmonids in Lake Washington.

III. Proviso Text

Of this appropriation, $250,000 shall not be expended or encumbered until the executive transmits a report on the Kenmore interceptor impacts to fish populations and a motion that acknowledges receipt of the report and the motion is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section and proviso number in both the title and body of the motion.

The report shall include, but not be limited to: (1) a discussion of the design and placement of Section 2 of the Kenmore interceptor, with particular attention to the placement of the interceptor section and efforts to avoid the accumulation of silt and accommodate the movement of water fauna; (2) a characterization of the silt accumulation beneath and around the Interceptor in the intervening years since its construction; (3) an analysis of the impacts of the silt accumulation on water fauna, with particular attention to the ability of the fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species; (4) an analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor Section 2. The report shall additionally address the impacts on the nearshore environment of effectively creating a barrier resulting in functionally separated lake areas. The report shall discuss options to remedy identified impacts as well as associated costs, and recommend appropriate subsequent steps.[6]

IV. Background

Department Overview: The King County Department of Natural Resources and Parks (DNRP) works in support of sustainable and livable communities and a clean and healthy natural environment. Its mission is to foster environmental stewardship and strengthen communities by providing regional parks; protecting the region's water, air, land, and natural habitats; and reducing, safely disposing of, and creating resources from wastewater and solid waste. The Wastewater Treatment Division (WTD) of DNRP protects public health and enhances the environment by collecting and treating wastewater while recycling valuable resources for the Puget Sound region.

Current and Historical Context: Wastewater from the Bothell, North Creek, and Kenmore areas is conveyed by local sewer pipelines to the Kenmore Interceptor. The Kenmore Interceptor consists of five sections, for a total pipeline length of 16,031 linear feet. The 48-inch diameter Kenmore Interceptor Section 2 (also referred to as the "lake line") is the subject of Proviso P2. This section of the interceptor (traveling from north to south) begins at maintenance hole W11-39, entering Lake Washington at the

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[5] *Salmonids* refers to fish of the salmon family (Salmonidae), including salmon, trout, chars, freshwater whitefishes, and graylings.

[6] Ordinance 18835, Section 108, Proviso P2

western end of Tracy Owen Station Park south of Bothell Way, and continues south to the Matthews Beach Pump Station at maintenance hole W11-01 (Appendix A, Figure 1). The pipeline transitions from Lake Washington to land at this location. From Matthews Beach, wastewater is pumped to West Point Treatment Plant in Magnolia.

Construction of the Kenmore Interceptor began in the early 1960s. Designed to convey 26 million gallons of wastewater per day, this pipeline was a critical piece of King County's new regional wastewater treatment system designed to keep wastewater out of Lake Washington. Design of the interceptor was per uniform building codes in effect at that time, and called for placement of the 48-inch pipe within a precast concrete rectangular casement set on piles driven into the lake bed. The entire casement was placed within a trench excavated along the lakebed, between 75 and 200 feet offshore. Backfill at the time of construction may have occurred through either mechanical means or natural processes. Today, the Kenmore Interceptor continues to function as a critical piece of the wastewater system in north King County. Recent inspections confirm the pipe is in good condition and will be able to remain in service for many years to come.

Residents in the Lake Forest Park area previously raised concerns about the placement of the interceptor as related to sediment deposition in the nearshore area of Lake Washington between Log Boom Park and the vicinity of Ballinger Way Northeast and Bothell Way Northeast. In 2011, WTD retained SoundEarth Strategies, Inc., and Lally Consulting LLC to conduct an inspection and analysis of the lakebed in the area referenced above. The 2011 report (Appendix B) concluded that there were no obvious indications that the interceptor was contributing, or had contributed, to sedimentation patterns in the study area. A review of the previous study was included in the scope of work for the current sedimentation and fish population study performed by ESA.

WTD staff visited the City of Lake Forest Park (City) in August 2019 to request information related to the proviso and current concerns by the City relative to the presence of the Kenmore Interceptor. The City described concerns that recently had been expressed by owners of the Lake Forest Park Community Center, where the boat launch requires dredging on a frequent basis to maintain a depth adequate for boat access.

Report Methodology: To address the concerns of Proviso P2, WTD retained ESA in September 2019. The analysis conducted by ESA focused on sedimentation and fish populations in the vicinity of the Kenmore Interceptor Section 2, in addition to a review of the 2011 study methods and conclusions. ESA compiled and reviewed recent public works projects in the City of Lake Forest Park relevant to sediment transport in the watershed, assessed the constructed conditions of the lake line, and reviewed the physical processes affecting sediment transport in the study area. ESA also conducted an assessment of shoreline and bathymetric[7] change over time using aerial orthophotos,[8] recent video inspection of the lakebed, and bathymetry from the National Oceanic and Atmospheric Administration (1902, 1975 and 2008), SoundEarth Strategies, and Gravity Marine. This report is attached as Appendix A.

[7] *Bathymetric or Bathymetry* refers to the measurement of the depth of water in oceans, seas, or lakes.
[8] Orthophotos are aerial photographs that have been geometrically corrected so that their scale is uniform and can be used in the same manner as a map.

V. Report Requirements

A. Discussion of the design and placement of Section 2 of the Kenmore Interceptor

Available information related to the design of the interceptor is limited to the engineer's approved design drawings dated August 1964 (Appendix A, Figures 5 and 6). No discussion or documents related to the placement of the interceptor to avoid the accumulation of silt or accommodate the movement of water fauna were discovered during background research efforts. Additionally, no documentation or historical photographs were discovered demonstrating the method of installation and backfill for the interceptor sections.

The design drawings specify three methods of installation that were allowed for interceptor placement on the lakebed, and it is reasonable to conclude that one or more of these methods was used by the construction contractor. The construction methods specified for the type of underwater topography in the study area would have likely been the method that completely buried or backfilled the pipe casement into an excavated trench or that partially buried the pipe casement into an excavated trench. Finally, given the design standards of the era, little consideration would likely have been given to the potential accumulation of silt or the movement of water fauna during design of the interceptor.

B. Characterization of the silt accumulation beneath and around the interceptor since its construction

Both the 2011 analysis (Appendix B) and the current analysis by ESA (Appendix A) showed that the interceptor is located in a net sediment depositional area. ESA determined that over the past 120 years, the nearshore within the study area has accumulated between one and four feet of sediment. Much of that occurred in the late 1800s and early 1900s, when logging around the lake and development activities resulted in increased runoff and uncontrolled erosion. The analysis concludes that continued accumulation in the nearshore area has been primarily caused by physical processes, such as sediment transport by Lyon and McAleer creeks, nearshore erosion caused by wind waves and boat propeller wash, and the trapping of sediment by dense stands of rooted aquatic vegetation, including Eurasian watermilfoil.

The most recent analysis by ESA included a review of the 2011 diving inspection of the interceptor, an October 2019 remotely operated vehicle (ROV) survey, and a January 2020 bathymetric survey using diving transects and single-beam sonar scans to characterize sediment accumulation nearby the interceptor in the study area. As of 2019, roughly 80 percent of the pipeline is covered in sediment within the study area. The remaining 20 percent includes areas where the casement is partially exposed to a maximum height of approximately 10 inches above the lakebed. Accumulation of sediment, as confirmed by recent ROV and bathymetric surveys, is similar on both sides of the interceptor, with the exception of one 500-foot section of pipeline where exposed casement appears to have had a minor influence on the downslope transport of sediment within 10 to 20 feet of the pipe (Appendix A, Figure 15). The section of the pipeline within the study area—even in locations where the pipe casing is exposed by up to 10 inches—is not acting as a sediment-trapping barrier.

C. Analysis of the impacts of silt accumulation on water fauna, including the ability of fauna to freely access the lake environment on both sides of the interceptor and potential Impacts on the migration of anadromous species

A variety of fish species inhabits Lake Washington, including several species of native salmon and trout. Species migrating through the Ship Canal and Lake Washington migratory corridor include Chinook, Sockeye, Chum, Coho, and Steelhead as well as Bulltrout and Cutthroat trout.

According to ESA's recent analysis, primary limiting factors to the successful growth and migration of salmonids in Lake Washington include shoreline armoring and development, lack of suitable lakeside vegetation, the presence of macrophytes[9] (especially non-native Eurasian watermilfoil), and water quality concerns from stormwater runoff. The Kenmore Interceptor is buried by sediment along 80 percent of the study area and, in the remaining 20 percent, is elevated from the lakebed by no more than 10 inches. Analysis conducted for this report finds that the presence of the interceptor in the study area is not a limiting factor to the successful survival or migration of salmonids. Based on its location primarily below the substrate and adequate depth of water over even exposed portions of the interceptor casement, ESA concluded that the Kenmore Interceptor does not play a significant role in local sediment dynamics and does not represent a migration barrier to fish as they can easily swim over and across it without stress.

D. Analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor, including impacts on the nearshore environment of creating a barrier, resulting in separated lake areas

The attached ESA report identifies areas of the shoreline in the vicinity of Lyon and McAleer creeks where the shoreline appears to be dynamically filling and eroding, affecting sedimentation rates in the immediate area. Bathymetric survey data from lake-wide surveying efforts in 1902, 1975, and 2008 overlap with the study area. As described previously, and verified by a comparison of the survey data, there was substantial accumulation of sediment in the lake between 1902 and 1975. A comparison of 1975 and 2008 elevations show that accumulation of plus/minus one foot of additional accumulation has occurred. Between 2008 and 2011, when sediment sampling occurred as part of the SoundEarth Strategies and Lally Consulting study, additional minor amounts of accumulation occurred. Based on the review of the data, the report concludes that the position of the lake line does not appear to influence a trend in accumulation or erosion. Accumulation of sediment during both time periods has occurred on both sides of the interceptor.

E. Options to remedy identified impacts as well as associated costs, and recommend appropriate subsequent steps

The proviso requested options and subsequent steps to remedy identified impacts. Because the analysis finds that the Kenmore Interceptor is not causing negative impacts to sediment and water fauna in Lake Washington, no actions nor further steps are necessary at this time. However, WTD will continue to monitor the health and impact of the interceptor and address any identified impacts in the future.

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[9] Macrophytes are aquatic plants growing in or near water.

VI. Conclusion

Ordinance 18835, Section 108, Proviso P2 identified four areas of concern relative to the Kenmore Interceptor's potential impact on sediment accumulation and migrating fish species and populations in Lake Washington. Lake Washington is an important habitat for many anadromous species of fish, including a number of species of migrating salmon and trout. To address the concerns identified in the proviso, WTD retained an environmental consultant, ESA, to analyze the design and placement of the interceptor in the study area, located between approximately Tracy Owen Station Park and Ballinger Way (Appendix A). ESA's analysis included a comprehensive review of the 2011 *Kenmore Lake Line Lakebed Sedimentation Analysis* (Appendix B) conducted by SoundEarth Strategies and Lally Consulting in response to similar concerns.

In its 2020 study and subsequent report, ESA compiled and reviewed recent public works projects in the City of Lake Forest Park relevant to sediment transport in the watershed, assessed the constructed conditions of the lake line, and reviewed the physical processes affecting sediment transport in the study area. ESA also conducted an assessment of shoreline and bathymetric change over time using aerial orthophotos, recent video inspection of the lakebed, and bathymetry from the National Oceanic and Atmospheric Administration (1902, 1975, and 2008), SoundEarth Strategies, and Gravity Marine.

ESA's analysis concluded that the Kenmore Interceptor is currently 80 percent buried in the study area, with 20 percent of the interceptor casement exposed by no more than 10 inches above the lakebed. No measurable differences in sediment accumulation were observed along near-shore and off-shore sides of the interceptor, with the exception of one area of approximately 500 square feet where localized effects of minor accumulation on the shore side have occurred in an area approximately 10 to 20 feet wide. Additionally, the dominant physical processes that have influenced sediment accumulation in the study area include the deposition of sediment by McAleer and Lyon creeks and the presence of dense stands of Eurasian watermilfoil. The Kenmore Interceptor, which is buried throughout most of the Lyon Creek and McAleer Creek deltas, does not play a significant role in how these processes affect sedimentation patterns in the study area.

The quality and quantity of fish habitat in the study area have been degraded over the years by several factors, which are generally present on a lake-wide basis. The extent of shoreline armoring and overwater structures around Lake Washington has effectively limited natural erosion processes, leading to sediment transport, and has altered out-migrating salmon behavior and introduced cover for salmon predators. The resulting composition of most shoreline substrates does not contain habitat suitable to most salmonids. The Kenmore Interceptor neither affects the processes that limit salmonid survival and migration nor contributes in a measurable way to other limiting factors to salmonids in Lake Washington. Finally, the nearly completely buried pipeline does not present a barrier to fish migration or passage in Lake Washington.

VII. Appendices

Appendix A: *Kenmore Interceptor Proviso P2 Support: Sediment and Fish Population Study*
Appendix B: *Kenmore Lake Line Lakebed Sedimentation Analysis (2011)*

Appendix A

KENMORE INTERCEPTOR PROVISO P2 SUPPORT

Sediment and Fish Population Study

Prepared for
King County
Wastewater Treatment Division

February 2020

Appendix A

Appendix A

KENMORE INTERCEPTOR PROVISO P2 SUPPORT

Sediment and Fish Population Study

Prepared for
King County
Wastewater Treatment Division

Contract No. P0019P16 WO39

February 2020

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Appendix A

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Acronyms and Abbreviations

cfs	cubic feet per second
Corps of Engineers	U.S. Army Corps of Engineers
DPS	distinct population segment
Ecology	Washington Department of Ecology
ESA	Environmental Science Associates, Inc.
ESU	evolutionarily significant unit
GPS	global positioning system
hp	horsepower
KCWTD	King County Wastewater Treatment Division
kg/m^3	Kilograms per square meter
NAVD	North American Vertical Datum
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
RM	river mile
ROV	remotely operated vehicle
TSS	Total Suspended Solids
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife

Glossary

Accretion (n) or Accrete (v)	The accumulation of sediment material over time.
Allocthonous	Materials that originated or formed in locations away from where the materials are currently found.
Aquatic Macrophytes	A water-dwelling plant. Algae are not macrophytes.
Cyanobacteria	A type of aquatic photosynthetic bacteria. Also known as blue-green algae.
Downdrift	In the direction of alongshore transport of sediment.
Eutrophication (n) or Eutrophy (v)	The state of excessive nutrients in aquatic environments, often resulting in poor water quality.
Fluvial	Related to or from rivers.
Forcings	Phenomena that cause effects or act to generate an outcome.

Appendix A

1 EXECUTIVE SUMMARY

Environmental Science Associates, Inc. (ESA) was contracted by the King County Wastewater Treatment Division (KCWTD) to analyze the sedimentation and fish populations in the vicinity of the Kenmore Interceptor Section 2 lake line. The Kenmore Interceptor lake line is a 48-inch pipeline that conveys wastewater flows from the Kenmore area south to the Matthews Beach Pump Station and is the target of concern in the KCWTD Budget Proviso P2. The Proviso objectives included, but were not limited to, four areas of discussion, including aspects of design relating to silt accumulation and potential effects to in-water habitat. The Proviso in its entirety is included in Section 2. The study methods and topics of analysis are briefly summarized below.

1.1 Study Methods

The analysis described in this document did not include a site investigation, data collection, or numerical modeling by ESA. ESA relied on existing studies, available data, and expert judgement to conduct the work. ESA reviewed the *Kenmore Lake Line Lakebed Sedimentation Analysis* conducted in 2011 by SoundEarth Strategies and Lally Consulting and found the report to be a reasonably thorough summary of the physical processes occurring near the lake line. Standard data collection procedures and analysis were performed. ESA concurs with the overall findings of the 2011 report.

Recent public work projects in the City of Lake Forest Park relevant to sediment transport in the watershed were compiled and reviewed by ESA. Several significant flood control projects in Lyon and McAleer Creeks have removed anthropogenic barriers to the natural transport of coarse sediment from the upper watershed to the nearshore areas of Lake Washington.

ESA assessed the constructed conditions of the lake line to the extent possible using available pre- and post-construction information, and explained the uncertainties associated with installation options shown on the as-built construction drawings.

ESA conducted an assessment of shoreline and bathymetric change over time using publicly available aerial orthophotos, as-built construction drawings for the lake line, a video inspection of the lakebed from 2019 (King County 2019), and bathymetry from the National Oceanic and Atmospheric Administration (NOAA) (1902, 1975, and 2008), SoundEarth and Lally (2011), and Global Diving & Salvage, Inc. Gravity Marine Consulting (2020).

ESA reviewed the physical processes affecting sediment transport in the nearshore of the study area, including precipitation, streamflow, climate change, wind waves, boat wakes and propeller wash, lake circulation, downslope transport, and rooted aquatic vegetation.

1.2 Proviso P2 Topics

ESA's report focuses on the four main areas of discussion outline in Proviso P2, as summarized below.

Discussion of the design and placement of Section 2 of the Kenmore interceptor, with particular attention to the placement of the interceptor section and efforts to avoid the accumulation of silt and accommodate the movement of water fauna.

The Kenmore Interceptor lake line was constructed in 1964 and has been in operation since that time. Section 2 of the pipeline is pile supported and was constructed beneath the lakebed of Lake Washington between 75 and 200 feet offshore. The pipeline conduit is installed inside a rectangular concrete casement that is approximately 5 feet wide.

Based on inspection of 1964 design documents, the pipeline appears to have been installed well below the existing lakebed surface south of Lyon Creek, with the exception of a segment of elevated or trenched area south of McAleer Creek where the pipeline is farthest from shore. From Lyon Creek north, the pipeline is near, at, or slightly above the surface of the lakebed.

Final construction grades above and on either side of the lake line are not provided in the 1964 plans, nor are the method of installation and backfill recorded for each segment along the pipeline. The 1964 plans generally specify three allowable cases for how the pipeline may be constructed and backfilled, depending on the slope of the shoreline and the elevation of the existing lakebed relative to the design pipeline invert. However, the locations where each of the cases were utilized during construction are not provided. Because natural shorelines in the study area are quite flat, it is likely that a type Case II installation, which specifies backfilling the pipeline flat to existing grades, was used. This means that in some areas where the designed top of casement elevations exceeded existing grade, the concrete casement would have remained exposed on the lakebed. Steeper portions along the study area may have utilized a Case I installation, which specifies backfilling above the top of the pipeline casement. Because final installation grades to either side of the line were not provided, it is not possible to determine how the installed casement elevations relate to post-construction sediment elevations on either side of the line. This hinders the ability to assess changes in lakebed elevations on either side of the line in the years following construction.

In areas where the pipeline was fully buried below existing grade, there would be no anticipated impacts whatsoever to the movement of water fauna and sediment transport processes. Portions of the pipeline where the casement was installed partially exposed likely had little effect on sediment processes and negligible effect on the movement of water fauna, since the amount of exposed casing is small and located in already-degraded habitat.

Characterization of the silt accumulation beneath and around the Interceptor in the intervening years since its construction.

As of 2019, roughly 80 percent of the pipeline is covered in sediment within the study area. The remaining 20 percent includes areas where the casement is partially exposed to a maximum height of approximately 10 inches above the lakebed. As-built drawings indicate that one 500-foot stretch of the pipeline may have been elevated across a trench or depression, although recent surveys do not show the pipeline casement exposed in this area. This elevated or cantilever portion occurs in the far south end of the study area where typical water depths exceed 10 feet. It may have been partially backfilled following construction or has partially filled with sediment in the years following pipeline installation.

The assessment found that the lake line is located in an area of net sediment accumulation. Over the past nearly 120 years, the nearshore within the study area has accreted between 1 and 4 feet. This accretion has occurred on both sides of the current lake line. Areas under and around residential docks throughout the study area have likely experienced accretion since residential development began in the mid-1900s, especially in areas near Lyon and McAleer Creeks, although elevation data under docks are not available.

In its current state, the mostly buried lake line does not play a significant role in how these processes affect sedimentation patterns in the study area. The lake line is entirely buried along more than 80 percent of the study area. Exposed casement areas may have had minor, localized effects on sediment transport and accumulation on either side of the pipeline; however, historical data in this area are limited in coverage. It is not possible to determine specifically how bed elevations have changed in the immediate vicinity of the lake line because of limited as-built construction information. However, ESA estimates that the length of shoreline where minor localized effects may have occurred is approximately 500 feet, and the width over which effects could have occurred is on the order of 10 to 20 feet.

Analysis of the impacts of the silt accumulation of water fauna, with particular attention to the ability of fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species.

The presence of the Kenmore Interceptor lake line does not play a significant role in influencing aquatic flora or fish migration in and through the area. Fish habitat has been degraded over the years by several factors including shoreline armoring and overwater structures, changes to shoreline vegetation, stormwater inputs and historical industrial uses in the basin, and most notably the abundance of invasive Eurasian watermilfoil in much of the lake’s littoral zone, where it often forms a floating canopy that shades native aquatic plants and reduces their growth. The presence of Eurasian watermilfoil can affect the distribution of and habitat use by salmonids, pushing salmonids into deeper water along with prey fish. The presence of the Kenmore Interceptor lake line does not have an effect on the amount or distribution of watermilfoil in the area, as watermilfoil in Lake Washington can grow up to depths of 30 feet (Seattle Public Utilities n.d.) on both sides of the lake line.

Similarly, the installation and operation of the lake line have not significantly changed the quality or quantity of habitat for aquatic organisms, specifically salmonids. Although nearshore habitat conditions for salmonids in the area are substantially degraded from pre-contact conditions, the literature indicates that the degradation is a result of shoreline armoring and development, impacts on lake water quality, and the introduction of Eurasian watermilfoil into the lake. Several of these factors, as well as the presence of two stream deltas, directly contribute to the sediment dynamics of the site, while the lake line does not significantly alter sediment dynamics or other processes that create and maintain salmonid habitat.

The presence of the exposed casement along limited portions of the study area is not a barrier to fish migration, as fish can easily swim over and across the short distance of casement.

Analysis of the interruption of natural upland soil distribution processes from area streams discharging into the lake in the area of the interceptor Section 2.

Dominant physical processes affecting sediment transport in the nearshore include the deposition of fluvial material by McAleer and Lyon Creeks and sediment trapping and building by rooted aquatic vegetation. The mostly buried lake line does not play a significant role in how these processes affect sedimentation patterns in the study area. Exposed casement areas may have a minor influence on the downslope transport of sediment by physically obstructing moving offshore along steep slopes and possibly exacerbated wave scour for a limited distance offshore of the pipeline. However, much of the study area is relatively flat, such that downslope transport is not a dominant physical process and large waves are infrequent. Portions of the exposed casement are sufficiently deep such that only large waves may reflect or interact with the exposed casement. Offshore processes are limited in the study area, given the relatively flat slopes and dense colonization of rooted aquatic vegetation that inhibits the downslope transport of material into deeper areas.

The deposition of coarse and fine materials from nearby creeks does not appear to be impeded by the lake line, which is buried throughout most of the Lyon Creek and McAleer Creek deltas. The creeks are likely the dominant factor driving sediment accumulation on both sides of the lake line.

2 PROVISO TEXT

The section of King County Wastewater Treatment Division's Budget Proviso P2 related to the Interceptor reads:

> *"Of this appropriation, $250,000 shall not be expended or encumbered until the executive transmits a report on the Kenmore interceptor impacts to fish populations and a motion that acknowledges receipt of the report and the motion is passed by the council. The motion should reference the subject matter, the proviso's ordinance, ordinance section and proviso number in both the title and body of the motion.*
>
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>
> (Ordinance 18835, Section 108, Wastewater Treatment Division, P2)

3 BACKGROUND

The purpose of this report is to address concerns identified in the King County Wastewater Treatment Division's Budget Proviso P2 related to the placement of the Kenmore Interceptor Section 2 lake line ("lake line" or "interceptor") on fish populations and sedimentation around the pipeline.

The Kenmore Interceptor lake line is a 48-inch pipeline that conveys wastewater flows from the Kenmore area south to the Matthews Beach Pump Station (Figure 1). The pipeline was constructed in 1964 and has been in operation since that time. Section 2 of the pipeline is pile supported and was constructed beneath the lakebed of Lake Washington between 75 and 200 feet offshore. Environmental Science Associates, Inc. (ESA) was contracted by King County Wastewater Treatment Division (KCWTD) to analyze the sedimentation and fish populations in the vicinity of the pipeline.

In 2011, SoundEarth Strategies and Lally Consulting prepared the *Kenmore Lake Line Lakebed Sediment Analysis* for this same segment of pipeline. ESA performed a technical peer-review of the 2011 report for technical completeness and accuracy, as well as conducted further review of existing documents and information available as of December 2019. No field data collection, such as aquatic wildlife surveys, sediment sampling, or bathymetry collection, has been performed by ESA as part of this effort. Updated bathymetric data in the study area were collected by Global Diving & Salvage, Inc. and Gravity Marine Consulting as part of a separate contract with King County in January 2020. The recent bathymetric data are presented herein, and a copy of the bathymetry report is included in Appendix A.

The target of this assessment was to further consider if the location and condition of the Kenmore Interceptor lake line could have potential impacts on aquatic organisms that use the nearshore of Lake Washington, including direct impacts on habitat, feeding, migration, and predation. The report also includes a qualitative analysis characterizing sediment accumulation trends over time in the vicinity of the interceptor and identifies the driving factors behind the trends.

SOURCE: King County, USGS

Kenmore Interceptor Proviso P2 Support

Figure 1
Study Area

3.1 Technical Review of 2011 Analysis

A *Sediment Analysis Report for the Kenmore Lake Line Lakebed* was prepared in 2011 by SoundEarth Strategies, Inc. and Lally Consulting LLC. That study conducted an investigation of the sediment transport mechanisms and depositional environment along the lake line to evaluate whether its position has influenced the accumulation of sediment in the study area. Dive observations conducted in 2011 indicated that the study area appeared to be a depositional environment. The surface sediments appeared to result from numerous potential sources including shoaling deposits from adjacent creek outlets; beach erosion; and organics/detritus from dense stands of Eurasian watermilfoil, overhanging trees, and potentially historic or current mill and plywood operations. Visual inspections of areas proximal to and beneath several docks were performed, with no significant accretion or erosion noted. Erosion was noted in several areas along the shoreline, particularly adjacent to shore landings or dock structures and along the downdrift side of armored beaches. No significant differences were noted in the surface sediment composition or vegetation density on either side of the lake line. The 2011study concluded that there were no obvious indications that the lake line was contributing to or had contributed to the sedimentation patterns in the study area, other than localized effects in one 10-foot section near a manhole (Manhole 37) where the lakeward bed elevation dropped approximately 0.5-foot relative to the top of the lake line. The lakebed was flush with the top of this conduit section in 2011.

ESA concluded that SoundEarth and Lally used standard practices throughout their assessment. The 2011 summary of nearshore sedimentation processes is technically accurate and reasonably thorough. Data collection methods for sediment sampling and depth measurements were standard, although, as the 2011 report discusses, the sampling was significantly limited in scope and spatial extent. The 2011 data and technical analyses are valuable for this current investigation and have been included and cited throughout this report.

As part of this renewed investigation, ESA has identified additional publically available data relevant to nearshore sedimentation processes that supplement the 2011 data. ESA has also provided a more detailed analysis of certain processes that were only briefly mentioned in the 2011 study, as well as a habitat impact assessment for the pipeline. However, this current study reaches the same overall conclusion as the 2011 effort; the area through which the interceptor passes is an area of net sediment accumulation regardless of the presence of the pipeline and that any effects on sediment transport are localized.

3.2 Study Area Characteristics

This section presents an overview of the study area and geographic context for the sedimentation and habitat concerns around the Kenmore Interceptor lake line in Lake Washington. Figure 1 outlines the study area in relation to the Kenmore Interceptor lake line, other King County Wastewater facilities, and Lyon and McAleer Creeks. Also shown on Figure 1 is the approximate extent of property owners that reportedly expressed sedimentation concerns, leading up the 2011 sedimentation study (Sound Earth Strategies, Lally Consulting 2011).

3.2.1 Lake Washington

Lake Washington is the second largest natural lake in the state of Washington with 80 miles of shoreline. The lake is approximately 20 miles long with a mean width of approximately 1.5 miles, has a circumference of 50 miles, covers 22,138 surface acres, has a mean depth of approximately 100 feet, and has a maximum depth of approximately 200 feet (Jones and Stokes 2005). Construction of the Lake Washington Ship Canal lowered the level of Lake Washington to its current elevation, and development has significantly altered the natural configuration of the lakeshore. Much of the shoreline adjacent to the lake has been developed with water-dependent industries, houses, bulkheads, docks, boat launches, and landscaped lawns.

3.2.1.1 History and Hydrology

The Lake Washington watershed has been dramatically altered from its pre-settlement conditions, primarily due to removal of the surrounding forest and urban development, as well as lowering of the lake elevation and rerouting of the outlet through the Ship Canal. As a result, the Cedar River is now the major source of freshwater to Lake Washington, providing about 50 percent (663 cubic feet per second [cfs]) of the mean annual flow entering the lake (NMFS 2008). The Cedar River drainage area is approximately 184 square miles, which represents about 30 percent of the Lake Washington watershed area. The Lake Sammamish basin is also a substantial freshwater source, providing about 25 percent (307 cfs) of the mean freshwater flow into Lake Washington.

The remainder of freshwater flow into Lake Washington originates from a variety of small creeks located primarily along the northern and eastern shores, including McAleer and Lyon Creeks. Within Lake Washington, the natural hydrologic cycle has been altered. Historically, lake elevations peaked in winter and declined in summer. Operation of the Government Locks now produces peak elevations throughout most of the summer.

The U.S. Army Corps of Engineers (Corps of Engineers) is mandated by Congress (Public Law 74-409, August 30, 1935) to maintain the level of Lake Washington between 20 and 22 feet Corps of Engineers datum or 16.75 to 18.75 feet NAVD88 datum, as measured at the Government Locks. The Corps of Engineers operates this facility to systematically manage the water level in Lake Washington over four distinct management periods, using various forecasts of water availability and use.

The four management periods are:

- **Spring Refill:** Lake level increases between February 15 and May 1 to 22 feet (Corps of Engineers datum).
- **Summer Conservation:** Lake level maintained at about 22 feet for as long as possible, with involuntary drawdown typically beginning in late June or early July.

- **Fall Drawdown:** Lake level decreases to about 20 feet from the onset of the fall rains until December 1.

- **Winter Holding:** Lake level maintained at 20 feet between December 1 and February 15.

Operation of the Government Locks and other habitat changes throughout the Lake Washington basin have substantially altered the frequency and magnitude of flood events in Lake Washington and its tributary rivers and streams. Historically, Lake Washington surface elevation was nearly 9 feet higher than it is today, and the seasonal fluctuations further increased that elevation by an additional 7 feet annually (Williams 2000). In 1903, the average lake elevation was recorded at approximately 32 feet (Corps of Engineers Datum) (NMFS 2008).

Development and urbanization have altered base flow in many of the tributary systems (Horner et al. 1997). Increases in impervious and semi-impervious surfaces increase runoff during storm events and reduce infiltration and groundwater discharge into streams and rivers. A substantial amount of surface water and groundwater is also diverted into the City of Seattle and King County wastewater treatment system and eventually discharged to Puget Sound.

Although the frequency and magnitude of flooding in the lake and the lower reaches of tributary streams have declined due to the operation of the Government Locks, flooding has generally increased in the upstream reaches of tributary rivers and streams. This change is largely because of the extensive development that has occurred within the basin over the last several decades (Moscrip and Montgomery 1997).

3.2.1.2 Shoreline Habitat

Lowering the lake elevation after completion of the Ship Canal transformed about 1,334 acres of shallow water habitat into upland areas, reducing the lake surface area by 7 percent, and decreasing the shoreline length by about 13 percent (10.5 miles) (Chrzastowski 1981). The most extensive changes occurred in the sloughs, tributary delta areas, and shallow portions of the lake. The area of freshwater marshes decreased about 93 percent, from about 1,136 acres, to about 74 acres (Chrzastowski 1981). Essentially all of the existing wetlands and riparian zone habitat were developed after the lake elevation was lowered. Currently, this habitat occurs primarily in Union Bay, Portage Bay, Juanita Bay, and Mercer Slough (Dillon et al. 2000).

Lake level regulation by the Corps of Engineers has eliminated the seasonal inundation of the shoreline that historically shaped the structure of the riparian vegetation community. This, together with urban development, has replaced much of the hardstem bulrush- and willow-dominated community with developed shorelines and landscaped yards. The current lake level regulation affects the growth of many species of native terrestrial and emergent vegetation. This hydrograph indirectly buffers the shorelines from potential wave impacts from winter storms. The loss of natural shoreline has also reduced the historic complex shoreline features such as overhanging and emergent vegetation, woody debris (especially fallen trees with branches and/or rootwads intact), and gravel/cobble beaches. The loss of native shoreline vegetation and wetlands has reduced the input of terrestrial detritus and insects to support the aquatic food web.

In addition to the loss of native shoreline due to lowering of the lake elevation, the remaining natural shoreline features have been largely replaced with armored banks, piers and floats, and limited riparian vegetation. A survey of 1991 aerial photos estimated that 4 percent of the shallow-water habitat within 100 feet of the shore was covered by residential piers (ignoring coverage by commercial structures and vessels) (USFWS 2008). Later studies report about 2,700 docks in Lake Washington and approximately 71 to 81 percent of the shoreline armored (Warner and Fresh 1999; City of Seattle 2000; Toft 2001).

3.2.1.3 Sedimentation Rates

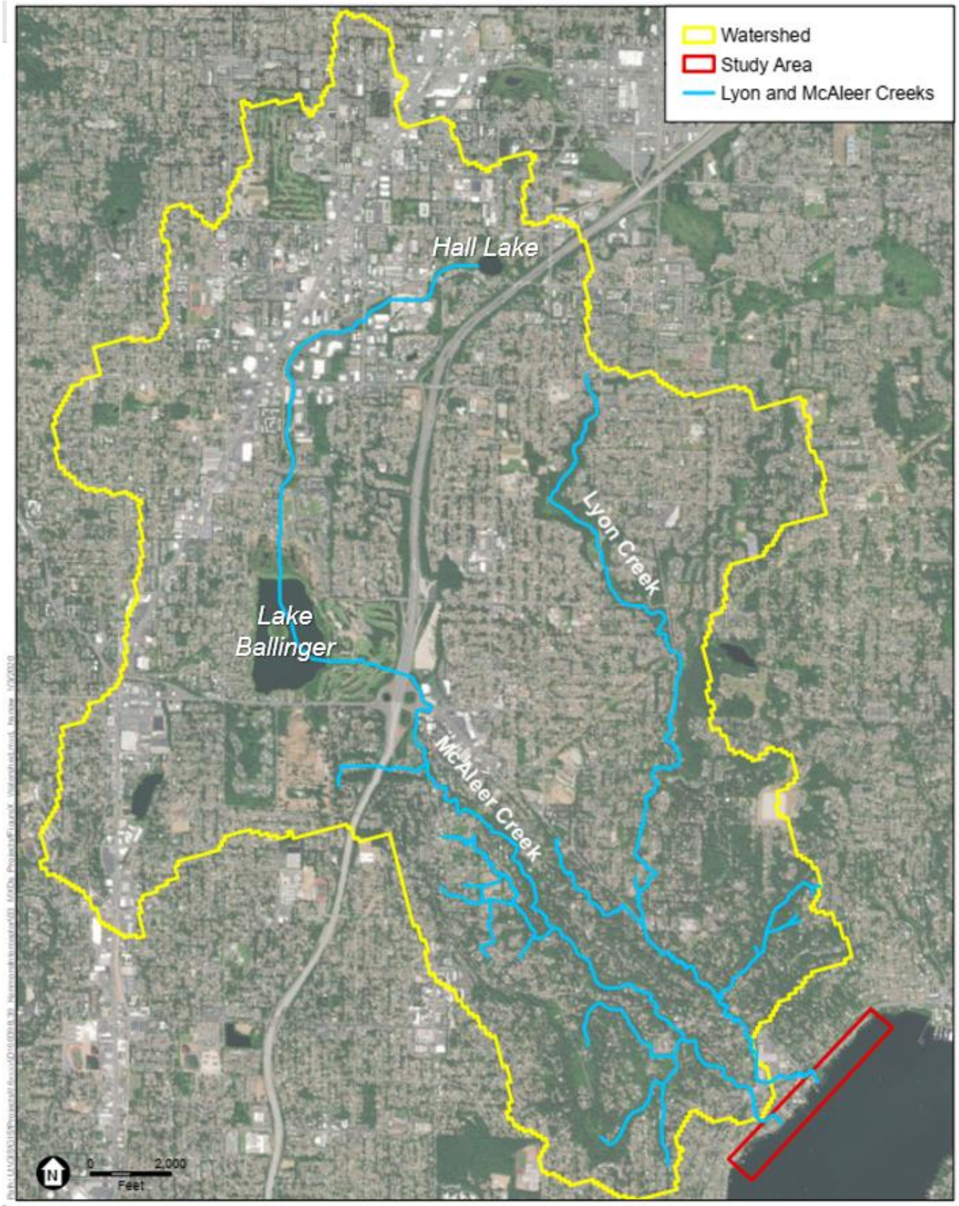
Rates of sedimentation in Lake Washington reflect the changing land uses in the watershed over time. Before the arrival of European settlers, Lake Washington was surrounded by dense stands of mixed coniferous forests and likely received little sediment and nutrient inputs. Pre-settlement sedimentation rates have been estimated between 0.73 and 1 mm/year (Birch et al. 1980, Wakeham et al. 2004). As the forests around the lake were logged in the late 1800s and early 1900s, the rates of sediment transport to the lake increased due to runoff from uncontrolled erosion. Sediment accumulation rates during this period were estimated to be between 4 and 5 mm/year (Birch et al. 1980).

In the early to mid-1900s, residential development near the lake grew considerably. During this time, secondary-treated sewage from nearby residences was discharged directly into the lake, delivering very high levels of nutrients. By 1922, sewage from 50,000 people was reaching the lake. Excessive nutrient delivery began to eutrophy the lake. Population growth continued, and by the 1950s, eutrophication in the lake was severe. Toxic cyanobacteria blooms and other nuisance algae growth seriously degraded both water quality and lake aesthetics. Periodic die-off of algal blooms contributed to increased sedimentation in the lake. During this highly eutrophic period, sedimentation rates were estimated between 2.2 and 5mm/year (Birch et al. 1980, Wakeham et al. 2004).

Efforts to restore the lake began in the early 1960s. Sewer trunk lines such as the Kenmore Interceptor lake line were installed to collect and reroute sewer discharges to the lake, and by 1968 all effluent was diverted. With these restoration efforts, the lake recovered rapidly. Sedimentation rates in the 1970s were between 2.5 and 3.1 mm/year. Today, the lake likely receives less sediment following the control on eutrophication, although little specific data on modern sedimentation rates are available (Ecology 2017).

3.2.2 Lyon Creek and McAleer Creek Watershed

Two major urban streams, Lyon and McAleer Creeks, flow through the City of Lake Forest Park and discharge directly to Lake Washington in the study area, near the north end of the lake (Figure 2). Both creeks naturally deliver sediment from the watershed into the nearshore areas of Lake Washington. Sediment deltas are found at the mouth of each stream where it enters Lake Washington.



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 2
Lyon and McAleer Watershed

3.2.2.1 Lyon Creek

The headwaters of Lyon Creek begin in wetlands in south Snohomish County and flow 3.8 miles through Lake Forest Park before draining into the northwest corner of Lake Washington. The drainage basin is approximately 2,600 acres in size, one of the smallest of the Lake Washington tributary systems. Land use in the basin is predominantly developed (86 percent) as much of the land was developed in the late 1970s (Kerwin 2001). Forest land cover represents only 13 percent of the basin, while wetlands represent less than 1 percent (King County 2020).

Based on aerial photo interpretation of the lake deltas, Otak et al. (2009) indicates that Lyon Creek may have more severe erosion and sedimentation issues than McAleer Creek, which has also experienced flooding and erosion, but appears to benefit from the management of Lake Ballinger as an effective detention basin for the upper reaches of this subwatershed. Details on sediment deposition from Lyon Creek are provided in Section 5.1.1.1.

According to WDFW (2020), Lyon Creek has documented coho use to the Snohomish-King County line and sockeye salmon spawning and winter steelhead presence upstream to approximately SR 504, as well as cutthroat trout in the lower reaches. However, no use by Chinook salmon has been documented. From 2000 to 2015, volunteers with the King County Salmon Watcher Program recorded salmon observations at river mile (RM) 0.1 (King County 2020). Several sockeye and coho salmon were observed in the lower reaches of Lyon Creek although coho sightings were very rare. The suitability of Lyon Creek as salmonid habitat has been impacted by high storm flows, which have resulted in degraded substrate and lack of spawning habitat.

3.2.2.2 McAleer Creek

The McAleer Creek drainage basin is approximately 5,700 acres in size and includes portions of Mountlake Terrace, Shoreline, and Lake Forest Park. McAleer Creek originates at Lake Ballinger and flows roughly 6 miles before draining into the northwest corner of Lake Washington just south of Lyon Creek. Land use in the basin is predominantly developed (92 percent), and forest land cover represents only 6 percent of the basin, while wetlands represent less than 1 percent (King County 2020).

The middle portion of the drainage basin consists primarily of low-density residential land use with deep ravines and eroded soils, while the lower basin flattens and fans into a floodplain across what is now the Lake Forest Park Mall and Bothell Way. Building density increases and encroaches into the stream corridor.

WDFW (2020) reports both Chinook and steelhead presence upstream to near I-5, and coho salmon distribution extends upstream of I-5. Cutthroat trout and sockeye spawning occur in the lower 1.7 miles of McAleer Creek. Several tributaries to McAleer Creek, including Brookside and Whisper Creeks, are also known to support salmonids (Lake Forest Park Stewardship Foundation 2001). From 1997 to 2015, volunteers with the King County Salmon Watcher Program recorded salmon observations in McAleer Creek (King County 2020). Volunteers consistently saw Chinook, coho, and sockeye in the creek. No kokanee salmon or cutthroat trout were seen.

Details on sediment deposition from McAleer Creek are provided in Section 5.1.1.1.

3.2.2.3 Restoration and Flood Control Projects

Both Lyon and McAleer Creeks have been subject to flooding over the years, and a number of projects have been undertaken in the drainage basin to alleviate localized flooding. Because these projects were implemented within the streams, they have the potential to influence sediment transport to the lake. The following tables focus on projects undertaken to reduce flooding and improve streamflows.

Table 1 summarizes two projects that have been undertaken on Lyon Creek since 2015. Both of these projects included replacing undersized culverts that were contributing to flooding, and/or were fish barriers. Replacement of these culverts allowed for improved water flow during high-flow events and allowed fish to migrate up the creek past the former culvert site. Replacing the former undersized culverts also removed anthropogenic barriers to the natural transport of coarse sediments from the watershed to Lake Washington, thus restoring or partially restoring the natural sediment processes within the lower reaches of the creeks. Evaluating the extent to which the former culverts blocked or trapped sediment transport was not within the scope of this study.

Table 2 summarizes seven projects that have occurred along McAleer Creek since 2012, with one project dating back to 1994. These projects were undertaken to reduce downstream flooding, replace deficient culverts, and stabilize eroding areas.

Table 3 summarizes a variety of projects that have occurred along the shoreline within the study area. These projects included multiple minor installations and repairs of lakeside structures, and a dredging project near the mouth of Lyon Creek.

Table 1
PROJECTS ON LYON CREEK & TRIBUTARIES

Project Name	Project Years	Project Location (Creek Miles)	Project Description	Likely Effects on Nearshore Sediment Processes
Lyon Creek Town Center Flood Mitigation Project	2015	0.05	Replaced the three private culverts and one public culvert on Lyon Creek under SR 522 to address repeated flooding of Lyon Creek near the Lake Forest Park Town Center. Culverts are 20-foot-wide four-sided box culverts with 100-yr storm capacity. Work included over 1,100 feet of stream channel widening and large woody debris placement.	Increase in downstream transport of coarse sediment, previously trapped by undersized culverts. Possible reduction in transport from periodic overbank flooding and subsequent erosion.
Lyon Creek L60 Culvert Replacement	2019	0.6	Replaced and upgraded a structurally deficient and partial fish barrier culvert with a 70-foot-long concrete box culvert. Located at the Lyon Creek crossing of NE 178th Street & 44th Avenue NE.	Increase in downstream transport of coarse sediment, previous trapped by undersized culvert.

Table 2
PROJECTS ON MCALEER CREEK & TRIBUTARIES

Project Name	Project Years	Project Location (Creek Miles)	Project Description	Likely Effects on Nearshore Sediment Processes
McAleer Creek Bypass	1994	0.1	Installation of 48" bypass pipe to divert flood flows in McAleer Creek in response to flooding of Sheridan Beach neighborhood. Pipe inlet is between the Burke Gilman Trail and discharges under the Shore Drive NE bridge.	Redirection of flood flows likely reduces scour and downstream transport of material in lower reach of creek.
McAleer Creek Bypass Retrofit	2012	0.1	Retrofit of McAleer Bypass System to optimize flood reduction benefits. Work included adjusting inlet control, smoothing pipe, and enhancing maintenance facilities.	See McAleer Creek Bypass.
McAleer Creek Culvert Replacement at 178th Street	2015	0.75	Replaced undersized/structurally deficient culvert on McAleer Creek at NE 178th Street. New culvert is 21-foot-wide box culvert that allows for natural stream channel. Project included channel restoration upstream and downstream of culvert.	Increase in downstream transport of coarse sediment, previously trapped by undersized culvert.
McAleer Creek Emergency Stream Bank Protection	2016	1.5	Installed bank protection rock along approx. 30 feet of McAleer Creek to protect public/private safety and infrastructure. A 15-foot vertical bank had eroded during a storm event along NE Perkins Way, threatening the road. Work included bank protection, relocation of large woody material, and restoration planting.	Reduction in sediment supply from eroding back; possible decrease in downstream transport.
McAleer Creek Culvert Replacements	2014	3.25	Replaced undersized culverts along McAleer Creek between Lake Ballinger and I-5 to reduce flooding of lakefront property.	Possible increase in downstream transport of coarse sediment previously trapped by undersized culverts.
Hillside Creek Stream Regrading south of Brookside Elementary	2015	On Hillside Creek, tributary to McAleer with confluence at creek mile 0.75	Regrading of 330 LF of stream channel along Hillside Creek, including removal of accumulated sediment and woody debris, and cleaning/inspection of nearby culverts. Large sediment deposits had shifted base flows from primary stream channel to a high flow bypass pipe, creating fish stranding/barrier concerns	Grading likely increased sediment storage capacity, possibly reducing downstream transport.
Hillside Creek Bank Stabilization near 2800 Blk of 178th Street	2014	On Hillside Creek, tributary to McAleer with confluence at creek mile 0.75.	Stabilization of two erosion areas (approx. 30-feet-long) and enhancement of 80 LF streambank along Hillside Creek. Work included bioengineered streambank stabilization, sediment removal, and a native planting plan.	Reduction in sediment supply from eroding back; possible decrease in downstream transport.

Table 3
PROJECTS ON MCALEER CREEK & TRIBUTARIES

Project Name	Project Years	Project Location	Project Description	Likely Effects on Nearshore Sediment Processes
Lyon Creek Waterfront Preserve Buoy Project	2015	17337 Beach Dr, NE, Lake Forest Park, WA 98155	Installed a navigational buoy attached to a 1½-inch galvanized steel pipe to demarcate the location of the Lyon Creek Waterfront Preserve and prohibit watercraft from entering the area adjacent to the site and dock.	Minor bed disturbance during installation. Preventing of vessels from accessing the area reduces propeller-wash & wake effects in Lyon Creek delta depositional area.
Lake Forest Park Civic Club Boat Ramp Dredging	2016-2019	17301 Beach Dr NE, Lake Forest Park, WA 98155	Removed fine sediment that had accumulated near the Lake Forest Park Civic Club boat ramp. Approximately 20 cubic yards of material removed from 770-square-foot area. Work included lakeside native planting.	Reduced lakebed elevations within dredging area. Possible disruption and redistribution of nearshore sediments within the surrounding area outside of dredging limits.
Various projects constructed on private residential properties	2014-2019	Shoreline properties: 16524 and 16560 Shore Dr NE, 17767, 17350, 17356, 17417, 17733, 17759, 17763, and 17767 Beach Dr NE	Various minor projects consisting of the repair and replacement of piles, piers, boatlifts, and bulkheads. One project was corrective action for unauthorized hydraulic work along the shoreline of Lake Washington.	Minor localized bed disturbances during construction activities.

3.2.3 Sheridan Beach and Beach Drive NE

The Sheridan Beach neighborhood was platted in 1927 and 1930. Although property development was slow in the 1930s, following World War II shoreline development boomed (City of Lake Forest Park n.d.). Inspection of aerial photos from the U.S. Geological Survey (USGS) and Google Earth shows that as of 1936, very few docks and other shoreline modifications (such as groins or bulkheads) existed along the shore of the study area. By 1954, more docks were present, although only a relatively small percentage of the platted properties included docks. In the subsequent 12 years, aerial photos show that many docks and shoreline developments were implemented such that in 1964, most properties along the shore had docks and in 1968, shoreline build-out was similar to current conditions.

Today, shoreline conditions along Sheridan Beach and Beach Drive NE generally consist of managed grass lawns, few to no trees or other overhanging vegetation, docks (which vary in length from 50 feet to 375 feet), and small overwater structures such as boat houses. Nearly every property adjacent to the shore has a private dock. In total, 56 docks span the 4,700 feet of shoreline in the study area, which corresponds to a dock density of one structure per 80 feet. The shoreline is also heavily armored by revetments and bulkhead walls, occasionally punctuated by managed sandy pocket beaches. Figure 3 shows the typical shoreline conditions along Beach Drive NE.

SOURCE: WA Ecology

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Figure 3
Study Area Typical Shoreline Condition

3.3 Constructed Conditions of the Lake Line

The Kenmore Interceptor lake line is a 48-inch concrete conduit pipeline that conveys wastewater flows from the Kenmore area south to the Matthews Beach Pump Station (Figure 1). The Section 2 lake line is connected to the Kenmore Interceptor land section via a connection line near Log

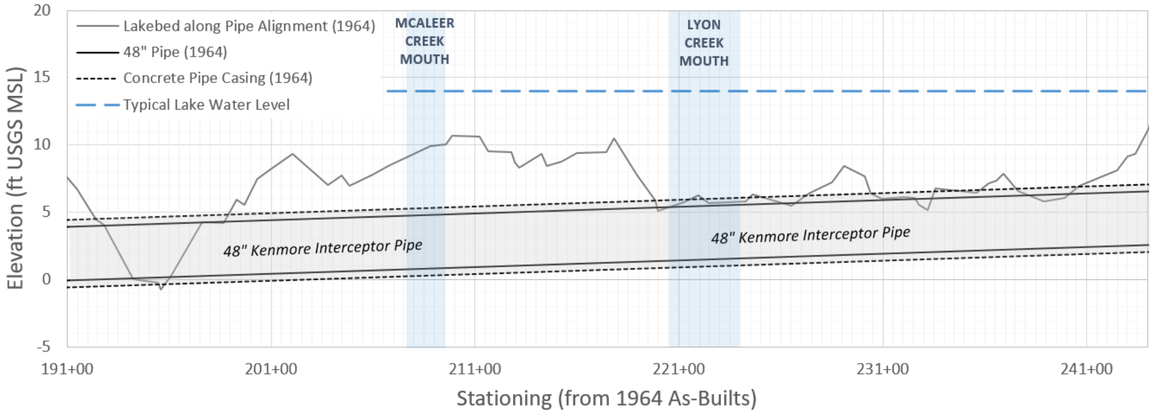
Boom Park in Kenmore. Within the lake, the pipeline is pile supported and was constructed beneath the lakebed of Lake Washington between 75 and 200 feet offshore. The typical depth of installation of the pipeline is 8–12 feet below the lake water level, which varies up to 2 feet seasonally.

Elevations for lake line are provided in the 1964 engineering drawings for the Kenmore Interceptor Section 2 Contract (Municipality of Metropolitan Seattle 1964) and are reproduced in Figure 4, which shows the 48-inch pipeline and concrete casing in profile view. The casing extends 6 inches above the crown and below the invert of the pipeline. The existing grade along the alignment from the 1964 plans is also shown. The existing grade is assumed to be the elevation of the lakebed along the pipe centerline prior to installation, as it is not marked as a finished elevation. South of Lyon Creek, the pipeline appears to have been installed well below the existing lakebed surface. From Lyon Creek north, the pipeline is near, at, or slightly above the surface of the lakebed.

It is not clear if the 1964 drawings represent the as-built condition of the pipeline, which would reflect any changes or conditions observed in the field, or are a copy of the permitted design set. Some minor discrepancies appear to exist between the installed conduit section geometry observed in a 2019 video inspection of the lake line and the 1964 drawings. It is possible that design geometry changes were made following the permit drawings that are not reflected in the plans. See Section 4.2.2 for more details on the visual observations. Additional construction notes or specifications were not available beyond those provided in the 1964 drawings. For the purposes of this study, ESA assumes that the elevations and sections shown in the drawings reflect the 1964 conditions, as-installed.

Final construction grades above and on either side of the lake line are not provided in the 1964 plans; however, Figure 5 provides a typical cross-section detail from the 1964 plans showing three typical installation grading cases. Within the study area, Case I or Case II installation likely occurred, with Case I installation intended for more steeply sloping banks, and Case II installation intended for relatively flat slopes. The 1964 plans do not specify where along the alignment Case I or Case II installation occurred or was anticipated to occur, nor is the anticipated limit of excavation specified. Natural shoreline slopes in the study area range from nearly flat to slopes up to 13 percent (see Section 4.2.1). In nearly flat areas of the shoreline, Case I installation likely occurred, and is evident in some areas from the 2019 visual inspection (see Section 4.2.2). In the steeper areas of the shoreline, natural slopes fall between the schematic Case I and Case II installation cases, as shown schematically on Figure 6. Thus, it is not possible to determine specifically where Case II installation occurred within the lake, or if some condition between Case I and Case II was implemented in 1964.

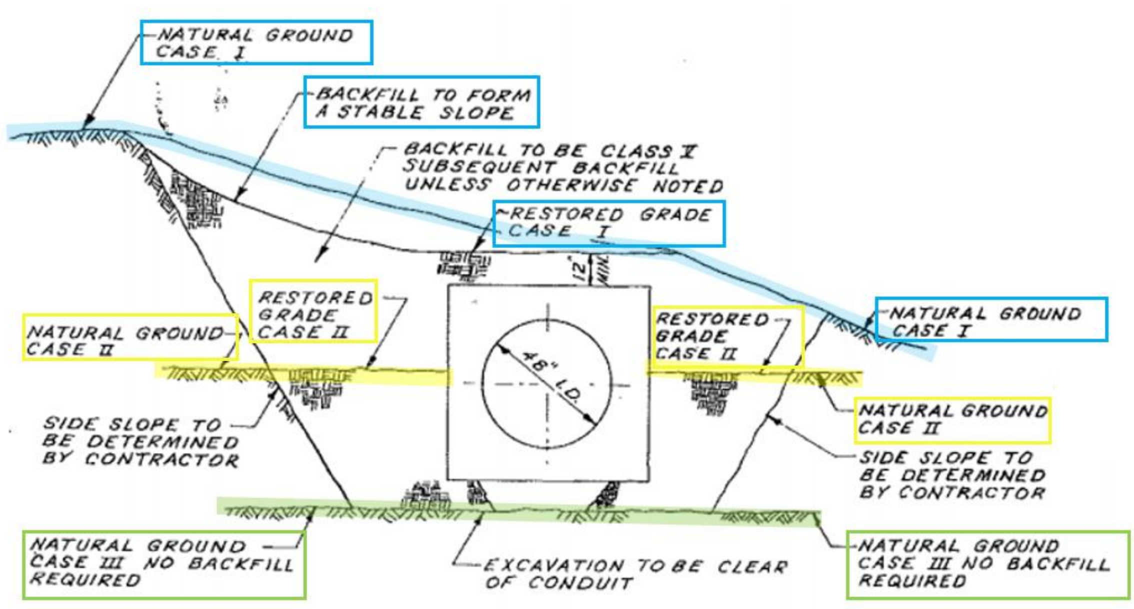
The 1964 plans indicate that a stretch of the pipeline at the southern end of the study area appears to be installed in a depression or trench. It is unclear if the pipe was backfilled following installation in this low area. This stretch is about 500 feet in length and is located in deeper water where the pipeline is farthest from shore.



SOURCE: Municipality of Metro Seattle (1964)

Kenmore Interceptor Proviso P2 Support

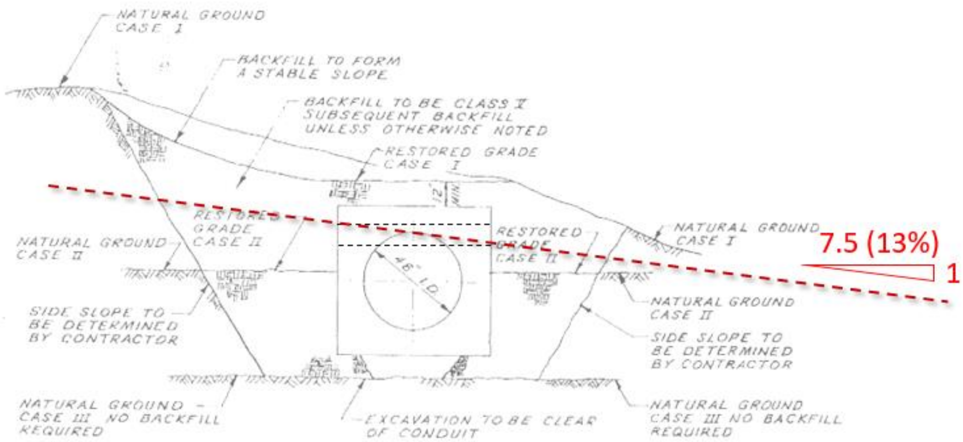
Figure 4
Typical Section of Kenmore Interceptor Lake Line



SOURCE: Municipality of Metro Seattle (1964)

Kenmore Interceptor Proviso P2 Support

Figure 5
Typical Section of Kenmore Interceptor Lake Line
Case II Highlighted in Yellow



SOURCE: Municipality of Metro Seattle (1964)

Kenmore Interceptor Proviso P2 Support

Figure 6
Schematic 13% Slope on Typical Section Detail

4 BATHYMETRIC ANALYSIS

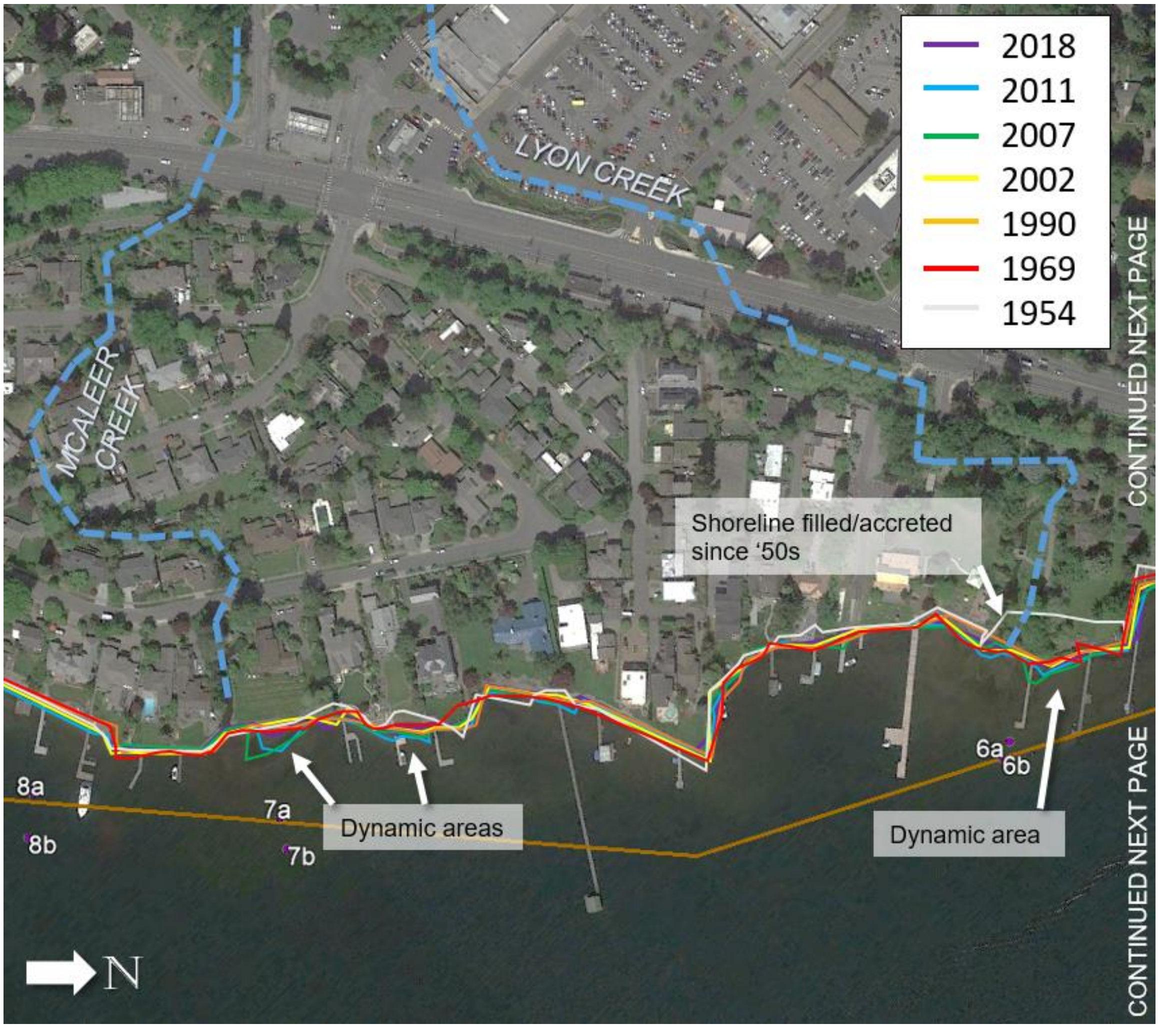
This section analyzes changes to the shoreline position and nearshore elevations over time with respect to the installation of the Kenmore Interceptor lake line.

4.1 Shoreline Analysis

Aerial images of the study area were analyzed from 1954 to 2018 to determine changes in the position of the shore-water interface over time. Image sources include Google Earth and USGS. Figure 7 compiles the traced historical shorelines from a selection of years onto one image (2018 Google Earth imagery).

The aerial images show several areas that appear to be dynamically filling and eroding. Most of these areas occur downdrift of the mouths of McAleer and Lyon Creeks (sediment drift is south to north in this stretch of shoreline; see Section 5.1.1.2 for more details). Because fluvial sediment transport occurs periodically and unevenly, observing variability over time along a downdrift shoreline is common. Another dynamic area is observed farther north of Lyon Creek. The shoreline structures and armoring in this area appear to have been manipulated several times since the early 2000s, resulting in a variable shoreline.

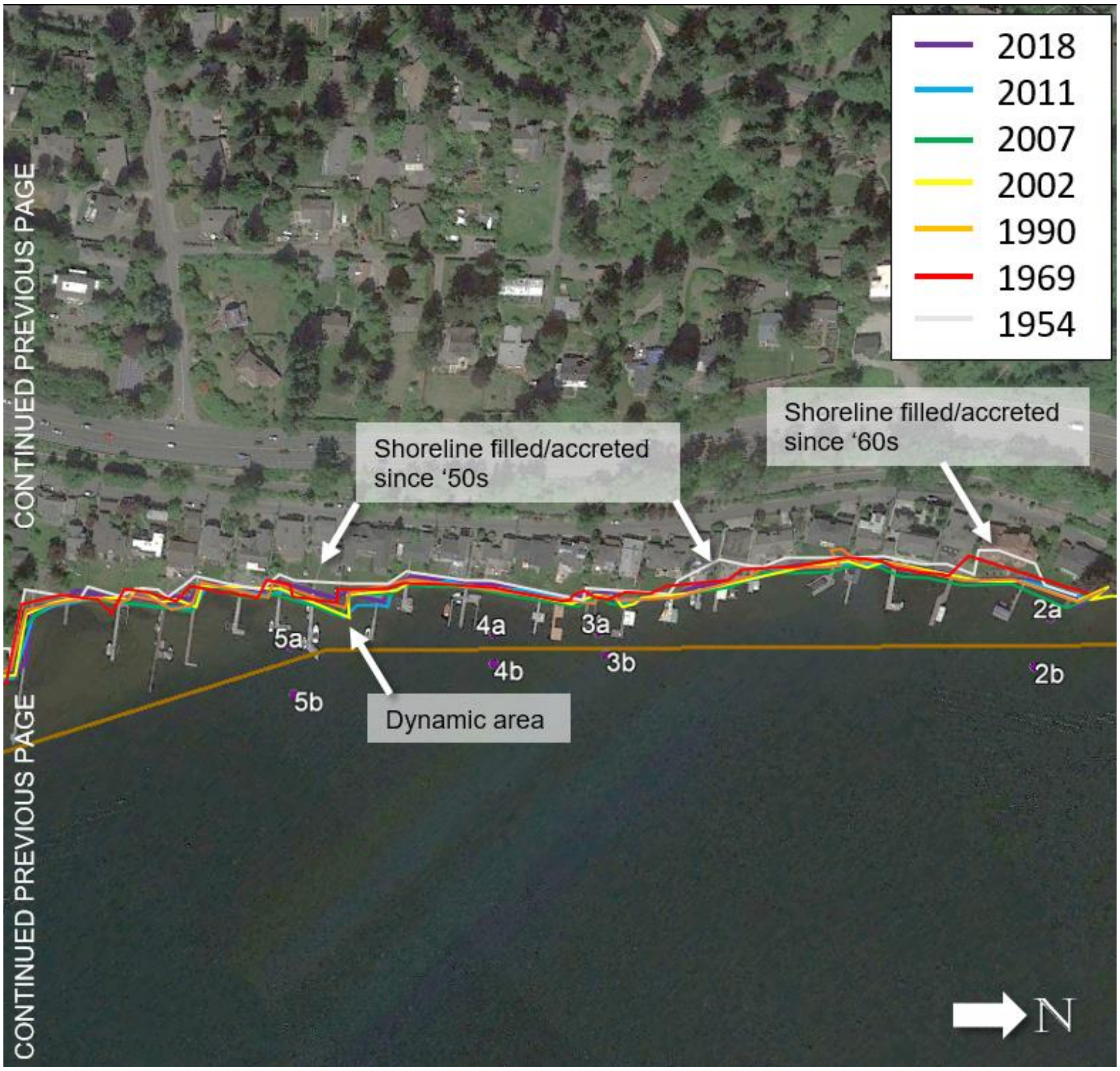
A few areas appear to have been filled since the 1950s or 1960s. The area near the mouth of Lyon Creek may have naturally accreted, or human modifications may be responsible for fill in the areas indicated. Slight variability between years, especially in armored stretches, is likely attributed to changes in water level between photos and variability in aerial photo rectification.



SOURCE: Google Earth, USGS

Kenmore Interceptor Proviso P2 Support

Figure 7a
Shoreline Trends
1954–2018



SOURCE: Google Earth, USGS

Kenmore Interceptor Proviso P2 Support

Figure 7b
Shoreline Trends
1954–2018

4.2 Existing Bathymetric Data

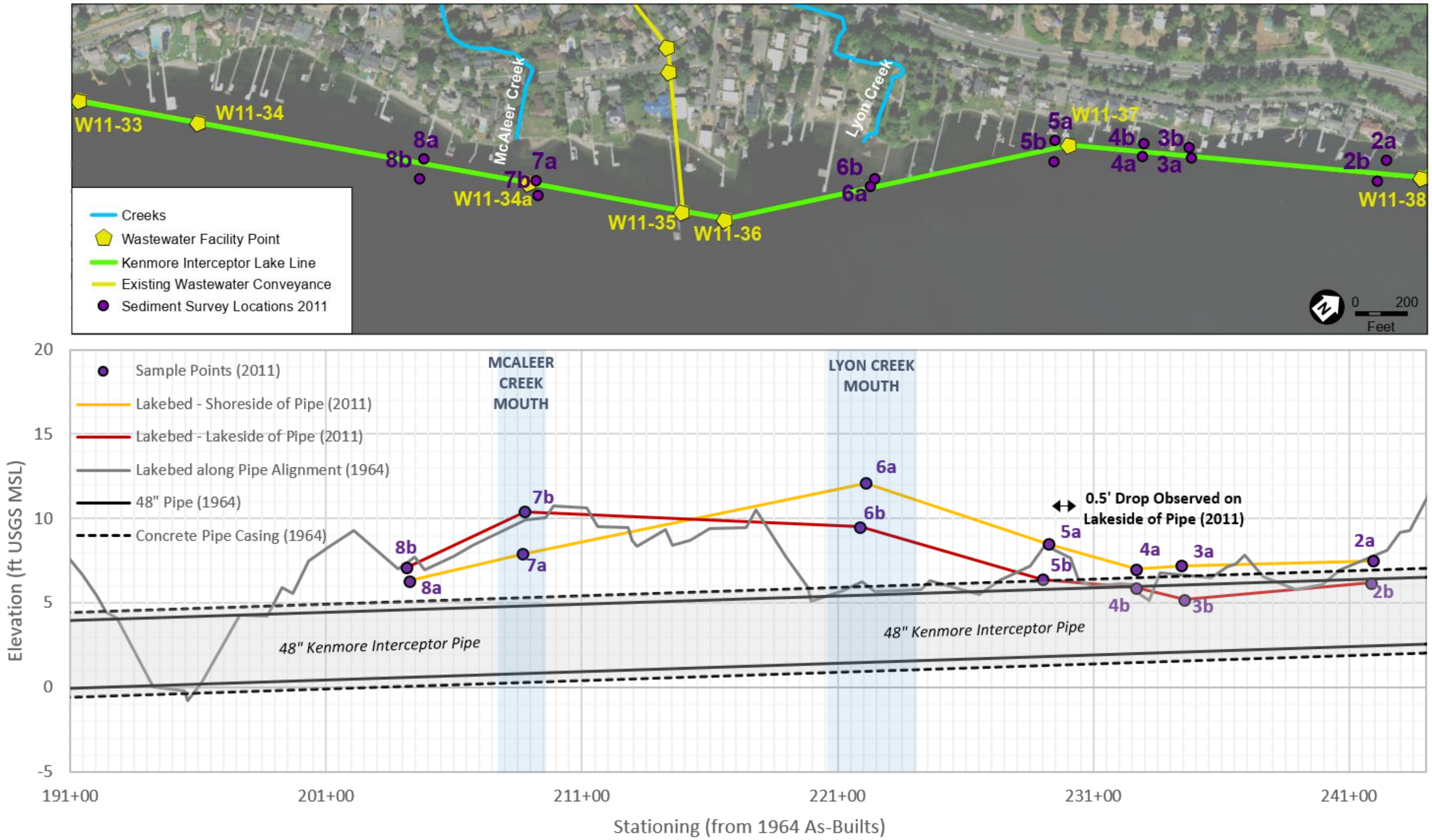
Available bathymetric data for the study area are limited. As of January 2020, datasets specifically related to pipeline elevations include the 1964 plan set elevations, the 2011 diving survey performed by Sound Earth Strategies and Lally Consulting, and the 2019 remotely operated vehicle (ROV) video images. Bathymetric points collected by NOAA during lakewide surveying operations in 1902, 1975, and 2008 also overlap with the study area and were included in this assessment.

4.2.1 Diving Survey, 2011

In June 2011, Sound Earth Strategies and Lally staff conducted a diving inspection of the lake line to support their sedimentation analysis. The inspection included depth and sediment sampling on either side of the Kenmore Interceptor lake line at eight different points along the alignment. Additional details on the diving methodology and observations are provided in Sound Earth Strategies and Lally (2011).

Figure 8 plots the results of the 2011 diving elevation measurements at paired points 2 through 8 along the alignment with the 1964 elevation data from Figure 4. Sample points were not taken directly over the top of the pipeline alignment, and instead are located between 10 and 40 feet offset from the centerline, thus capturing changes in elevations associated with natural cross-shore slopes. Figure 9 illustrates the approximate nearshore lakebed slopes, calculated between the shoreline and the "a" sample points. Slopes are generally flat, consistent with the 2011 diving observations (Sound Earth Strategies and Lally 2011). Sample sites 2, 3, and 4 were the steepest and are located where the pipeline is closest to the shore. Given the downward slopes, the "a" sample elevations would be expected to be higher than the "b" elevations. Refer to Figure 4 for a schematic example of how slopes may influence elevations in the vicinity of the lake line.

Direct comparison between the 2011 and 1964 elevations is not possible because of the uncertainty in installation grading conditions (Case I vs. Case II) and the inconsistent measurement locations (directly along the pipe centerline vs. horizontal offset of 10 to 40 feet). In areas where 2011 measurements are dramatically different than the 1964 existing grade, accretion or erosion has likely occurred over time. Near the mouth of Lyon Creek, accretion is clearly present on both sides of the lake line. However, in areas where the depth points are similar to the original existing grade (such as near sample sites 2, 3, 4, and 5), it is not possible to make a conclusion on accretion or erosion trends because of the uncertainty associated with comparing measurements at inconsistent locations. Also, individual spot measurements of elevation do not capture the natural variability within a localized area, making comparisons of small differences (less than 1 foot) difficult. In addition to the depth measurements, the 2011 diving survey indicated that a 10-foot-long stretch of the pipeline exhibited a 6-inch change in elevation between the shoreside and lakeside of the pipe. The report authors concluded that the lake line may have had localized effects on sediment accumulation in this isolated area. While this is possible, it is also difficult to determine based on the uncertainty of the originally constructed backfill grades on either side of the lake line.



SOURCE: Municipality of Metro Seattle (1964); Sound Earth Strategies and Lally (2011)

Kenmore Interceptor Proviso P2 Support

Figure 8
Change in Lakebed Elevation 1964–2011

SOURCE: SoundEarth and Lally 2011

Kenmore Interceptor Proviso P2 Support

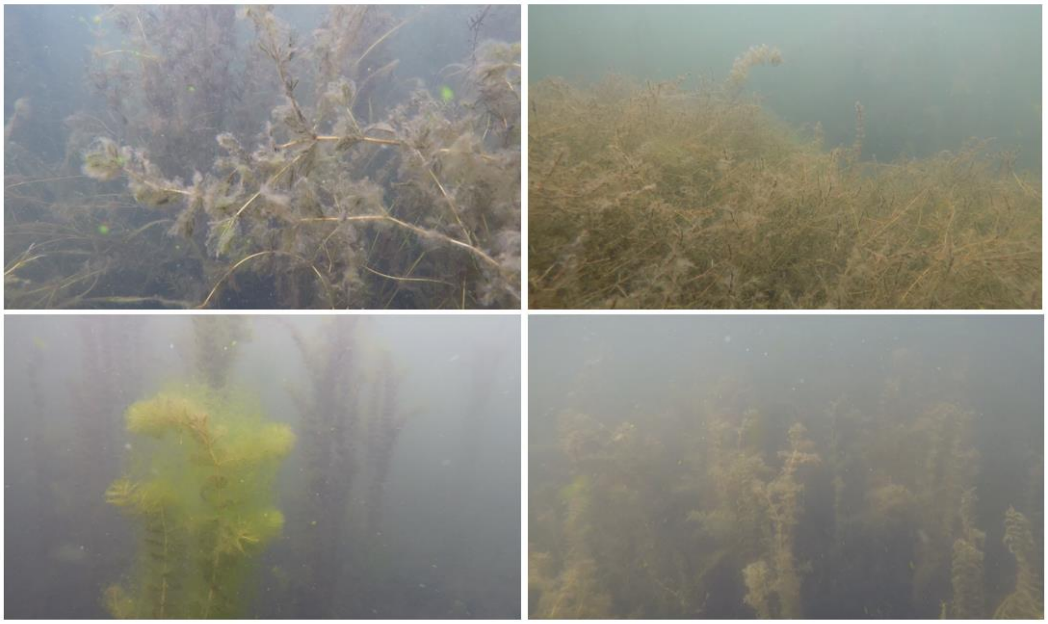
Figure 9
Nearshore Bed Slopes
Shoreward of Pipe Centerline

4.2.2 ROV Inspection, October 2019

On October 2, 2019, the King County Environmental Lab performed a remotely operated vehicle (ROV) survey of the lake line from near manhole W11-38 to W11-34a. Video from the ROV along with survey notes were provided to ESA.

Visual observation along much of the lake line is obscured by thick vegetation, high turbidity, propeller wash, and the uneven flight path of the ROV. ESA determined approximate location of the ROV based on nearby landmarks and properties shown when the ROV periodically surfaced. Figures 10 through 14 illustrate typical images from the ROV inspection along various segments of the survey.

Rooted aquatic vegetation occurs along most of the survey on both sides of the lake line. Figure 10 shows typical vegetation conditions, which is dominated by invasive European watermilfoil. The bed appears to be silty with organic debris where sediment is visible. In many locations, the vegetation completely obscures the lakebed and makes determination of bottom conditions impossible. Near the mouth of McAleer Creek, ROV images show a shallow, sandy lakebed with sand waves and limited aquatic vegetation (Figure 11). The creek mouths are more dynamic regions along the shore, with coarse bed materials and higher rates of sediment transport that likely inhibit vegetation establishment.



SOURCE: King County 2019

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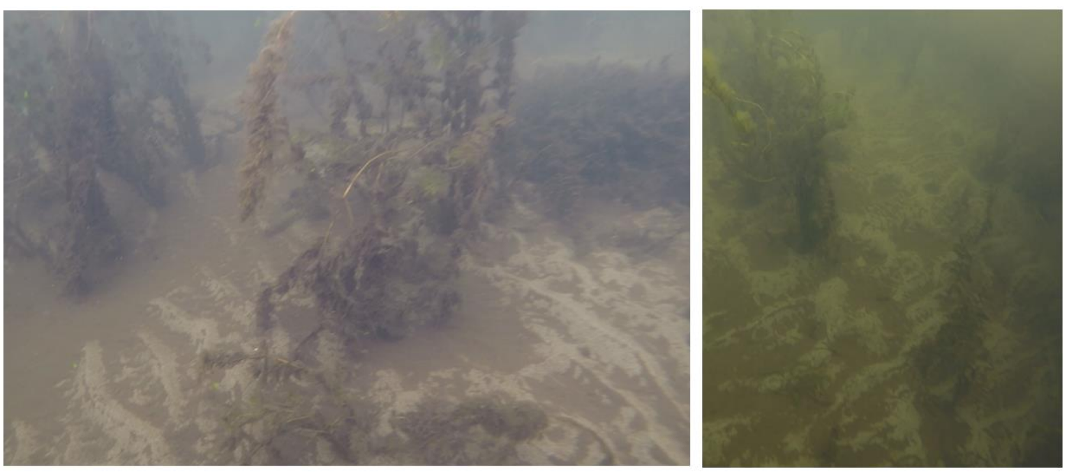
Figure 10
Dense Vegetation along Pipeline



SOURCE: King County 2019

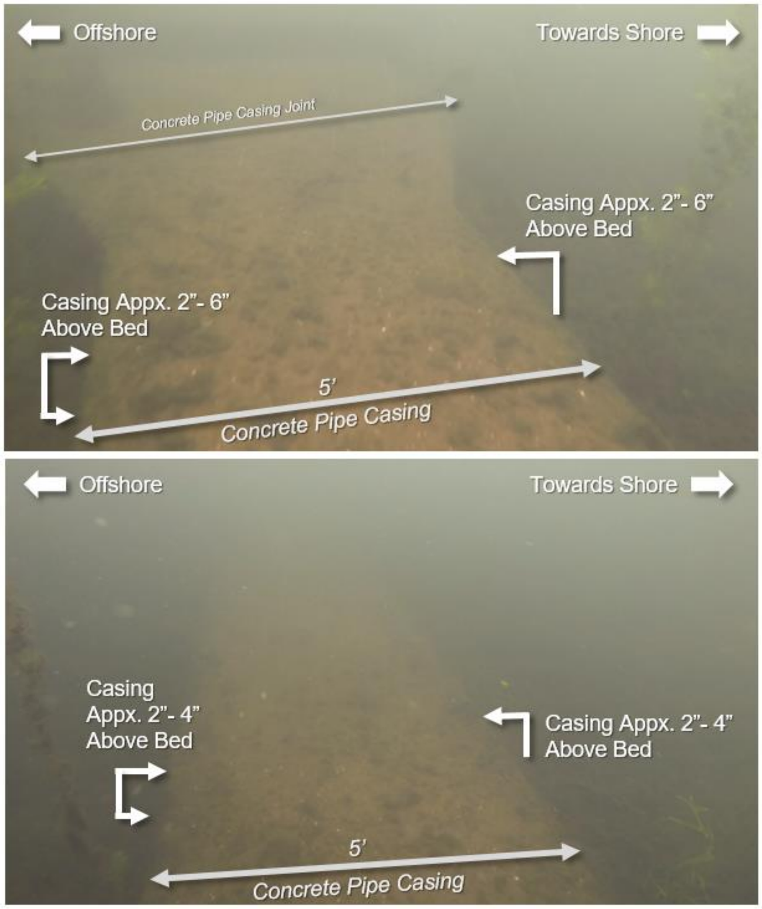
Kenmore Interceptor Proviso P2 Support

Figure 11
Sandy Bed near McAleer Creek Mouth

Figure 12 shows manhole W11-38 at the north end of the study area. Moving south from W11-38, Figure 13 shows the top of the lake line's 5-foot-wide concrete casing emerging from the sediment. The casing appears to stick up from the lakebed sediments several inches on both sides of the line. Farther south, Figure 14 shows images of the casing, which is partially covered by sediment on the shoreside of the pipeline and exposed up to an estimated 10 inches on the offshore side of the line. Video images and survey notes indicate that the casing is entirely covered in sediment south of approximately 17700 Beach Drive NW.

SOURCE: King County 2019 Kenmore Interceptor Proviso P2 Support

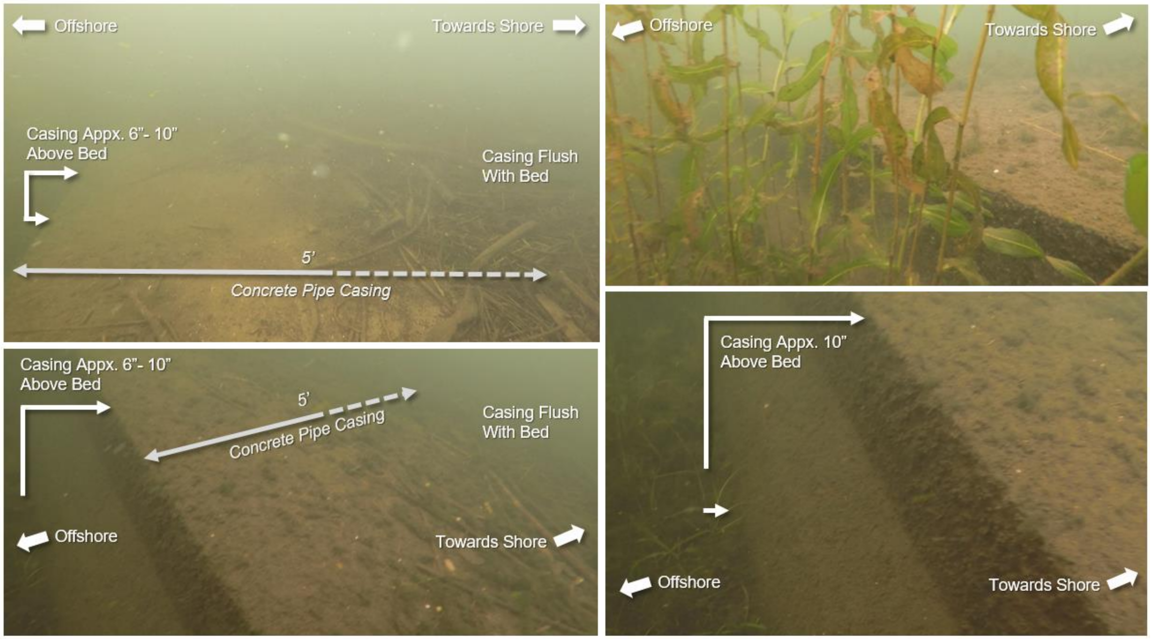
Figure 12
Manhole W11-38



SOURCE: King County 2019 Kenmore Interceptor Proviso P2 Support

Figure 13
Pipe Casing Near 17762 Beach Dr N
ROV Inspection – Oct. 2, 2019

The bottom panels of Figure 14 show what appears to be a beveled edge along some stretches of the lake line casing on the offshore side. This extends for some distance along the line, although it is difficult to estimate given the unknown speed of the ROV.



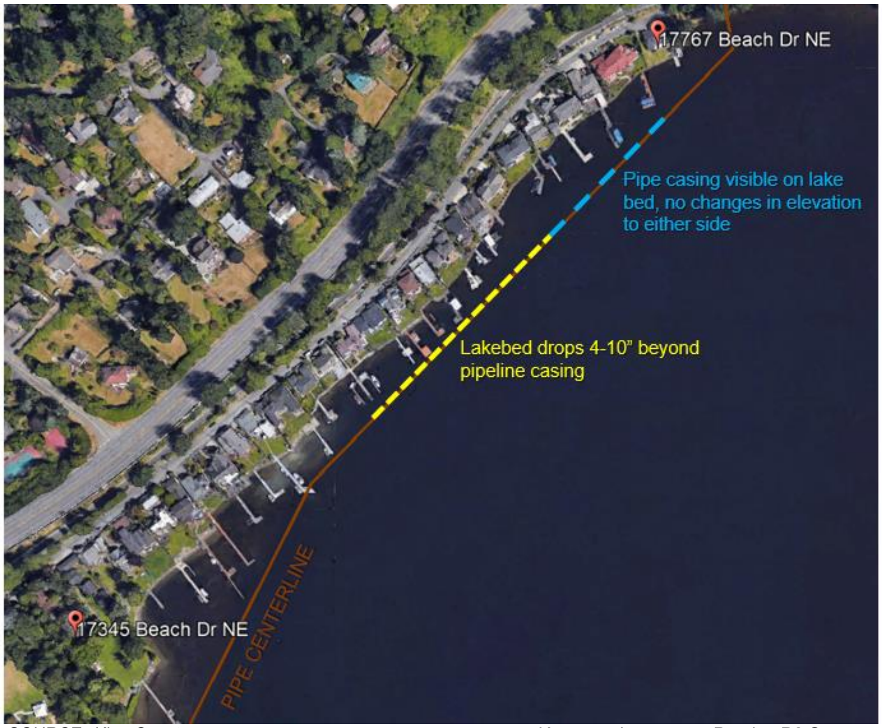
SOURCE: King County 2019

Kenmore Interceptor Proviso P2 Support

Figure 14
Pipe Casing Near 17718 Beach Dr N
ROV Inspection – Oct. 2, 2019

Figure 15 summarizes observations of the pipeline casing in the north end of the study area. The regions shown in Figure 15 are approximate based on sparse visual references from the ROV footage and survey.

The conditions observed during the ROV survey are somewhat different than the previous observations from 2011. While the 2011 survey observed an approximate 10-foot stretch of pipeline with a drop to the offshore side, the 2019 ROV inspection appears to show a roughly 500-foot stretch with some visible drop on the offshore side.



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 15
ROV Inspection Observations
King County Environmental Lab – Oct. 2, 2019

4.2.3 Hydrographic Survey, January 2020

On January 15, 2020, Global Diving LLC and Gravity Marine Consulting performed a bathymetry survey in the study area. The survey consisted of diving transects and single-beam sonar scans. The approximately 1-mile-long study area was mapped from the outermost extent of docks within the study area to approximately 600 feet offshore. The full technical memorandum describing the hydrography methods and results is included in Appendix A. Also included in Appendix A are figures showing the spatial extent of data collection and elevations of the survey points (Appendix A Figures 3 and 4). Bed elevations along the pipeline range from approximately 9 feet NAVD88 to 12 feet NAVD88. Elevations near the Lyon and McAleer Creek deltas are generally higher than in other areas. In the south end of the site, elevations are deeper closer to shore.

Extensive aquatic vegetation in the survey area affected the quality of some data points, despite the hydrographers use of state-of-the-art technology to penetrate the vegetation. Some of the sonar beams are reflected off of the dense vegetation before reaching the lake bed surface, producing final elevations that are higher than the anticipated actual bed surface. The cross-shore transects were affected more than the alongshore transects because of the motion of the surveying vessel (Gravity Marine, pers. Communication, 2020). These issues are described further in Section 4.2.4.

4.2.4 NOAA Surveys from 1902, 1975, and 2008

Bathymetric data from lakewide surveying efforts in 1902, 1975, and 2008 overlap with the study area. The 1902 and 1975 surveys captured a limited number of individual depth points near the lake line, while the 2008 single-beam bathymetry survey provided high resolution coverage across the study area. Original survey data were provided as points in meters, Lake Washington Low Water Datum. ESA converted these datasets to feet, NAVD88 and, when the density of points was sufficient (2008 survey), converted the points into an interpolated elevation surface. The 2008 survey is used as a comparison surface for the other surveys because it is the highest resolution and NOAA performed an extensive quality control assessment for the survey.

Figure 16 shows the lakebed elevations in 2008. Visible in this chart area is the substantial delta landforms around Lyon and McAleer Creeks. The shoreline toward the north end of the study area is narrower than in areas within the deltas and farther south. South of McAleer Creek, a trench is visible in the bathymetry overlapping with the location of the lake line. This depression is not clearly apparent in the 2020 survey (Appendix A, Figure 4), although the density of points in this portion of the survey is low. Other than this feature, there is no observable spatial trend associated with the position of the lake line in 2008.

4.2.5 Hydrographic Survey Comparison

This section compares the results of hydrographic surveys from 1902 to 2020 collected by NOAA and Global Diving & Gravity Marine (2020).

Figure 17 shows the change in bed elevations between the 2008 survey, and the 1902 or 1975 survey, respectively. Warm colors indicate an increase between 1902 and 1975, respectively, and 2008, while cool colors indicate a decrease. The top panel of Figure 17 indicates that between 1902 and 2008, substantial accretion throughout the nearshore area has occurred on both sides of the lake line. This figure is representative of relatively long-term processes at the site. Erosion is observed in a few limited spots, but the general trend is accumulation, especially in the delta areas of Lyon and McAleer Creeks.

The lower panel of Figure 17 shows the difference between 1975 elevations and 2008 elevations. No identifiable spatial trend is present. Most 2008 elevations are within +/- 1 foot of their 1975 elevations. The position of the lake line does not appear to influence a trend in accumulation or erosion. The delta area near Lyon Creek appears to have experienced the most variability between 1975 and 2008.

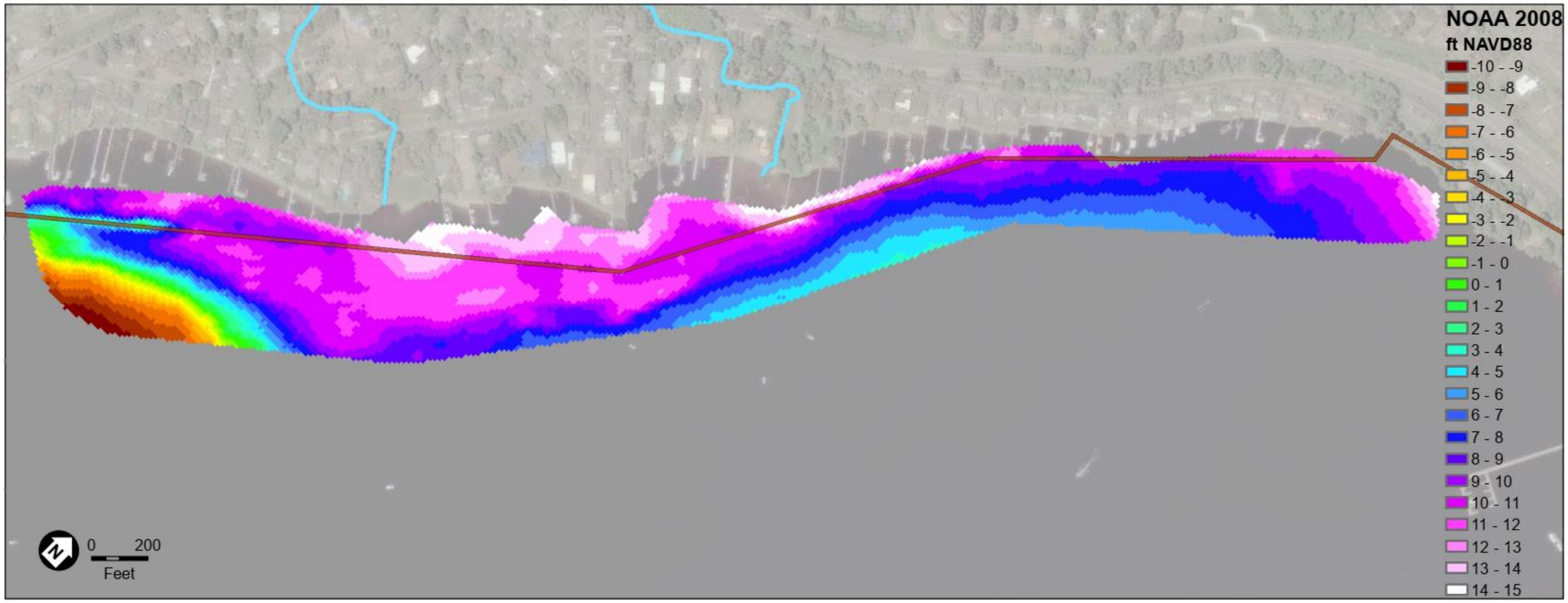
Figure 18 shows how the 2008 survey compares with the 2020 survey. Warm colors indicate an increase between 2008 and 2020, while cool colors indicate a decrease. These surveys, spaced 12 years apart, show some change in the bed elevations along the pipe centerline and to either side of the pipe. Most differences are +/- 1 foot, which is within the limit of accuracy for the surveys (Section 4.3). However, accretion greater than 1 foot is apparent on both sides of the pipeline, as is erosion. There are not clear spatial trends in erosion or accretion relative to the pipe centerline.

As described previously, the cross-shore transects for the 2020 survey were affected by dense vegetation, which skews reported elevations high (Gravity Marine, pers. communication, 2020). A typical transect that experienced vegetation effects is noted in Figure 18. These transects show a notable increase in elevation between 2008 and 2020. However, this apparent increase is likely exaggerated because of the effects of vegetation.

Erosion is seen along and shoreward of the pipe centerline near the north end of the site. This is consistent with the fact that the pipe casement was not observed exposed on the lakebed in 2011 in this area, but was observed in 2019 inspections. In the Lyon Creek delta, there are patches of localized erosion and accretion, which likely reflects the dynamic nature of the delta landforms, which change over time.

In the south end of the site, patterns of erosion and deposition are apparent near the trench-like feature observed in the 2008 survey. The feature appears to be mostly filled-in as of 2020. The densities of points in this area in 2020 are low and potentially affected by vegetation. It is difficult to assess what is happening in this region between 2008 and 2020, especially as it was not captured in the 2019 ROV survey. However, most of the change appears to occur in water deeper than 10 feet.

Figure 19 reproduces Figure 8 and includes elevations from the NOAA 1902, 1975, and 2008 surveys and the 2020 survey at locations similar to the 2011 sediment sample locations. Not all of the datasets had points near the 2011 sampling locations. In general, elevations from 1964, 1975, 2008, 2011, and 2020 are similar, except in the dynamic areas near the creek mouths. In some places, there appears to have been accretion on both sides of the lake line between 2008 and 2011 (e.g., sample sites 4, 5, and 8), where at other sites the bed elevations are nearly identical (e.g., sample site 2). At sites 4 and 5, there appears to be minor accretion (around 0.5 foot) between 2008 and 2011 on both sites of the line, but by 2020 elevations at these sites had returned to values similar to 2008. Data from 1975 to 2020 are similar, although fluctuations up and down are seen across all sites. At and south of McAleer Creek, there has been substantial accretion from 1902 to 1964. The most variability is seen near the creek mouths.



SOURCE: NOAA, 2008

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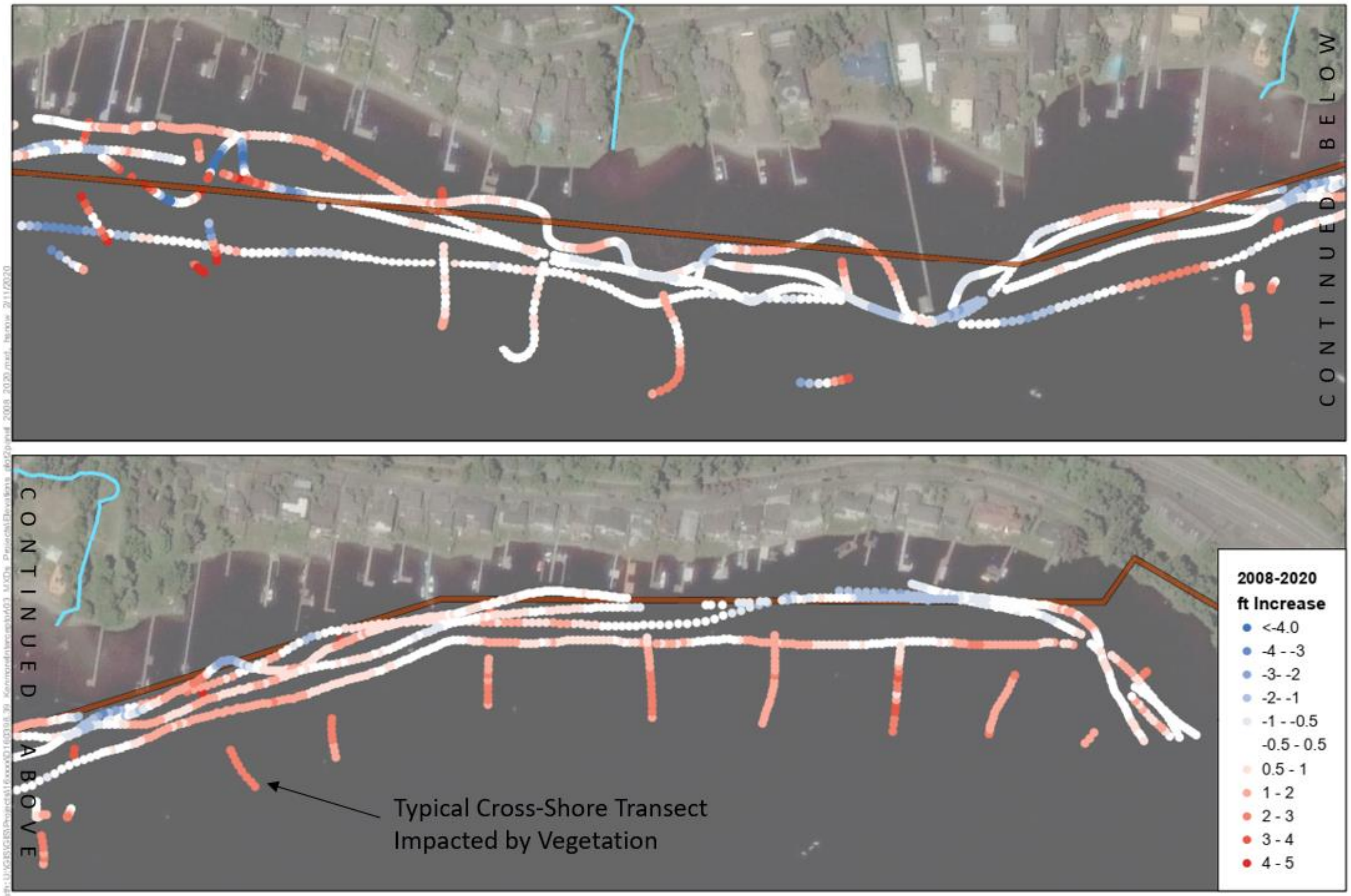
Figure 16
2008 NOAA Survey

SOURCE: NOAA 1902, 1975

Kenmore Interceptor Proviso P2 Support

Figure 17

Change in Lakebed Elevation from 1902 to 2008 (top) and from 1975 to 2008 (bottom)



SOURCE: Global Diving & Gravity Marine (2020)

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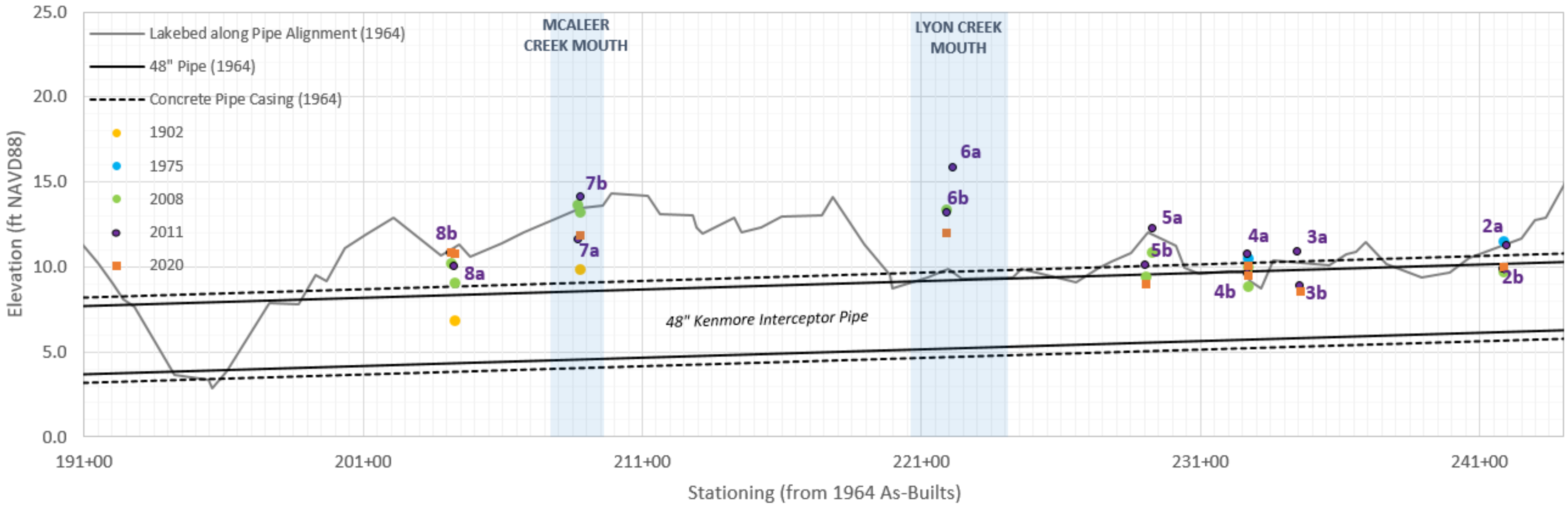
Figure 18
2020 Global Diving & Gravity Marine Survey versus 2008 NOAA Survey



SOURCE: Municipality of Metro Seattle 1964; NOAA, 1902, 1975 & 2008; SoundEarth and Lally 2011, Global Diving & Gravity Marine (2020)

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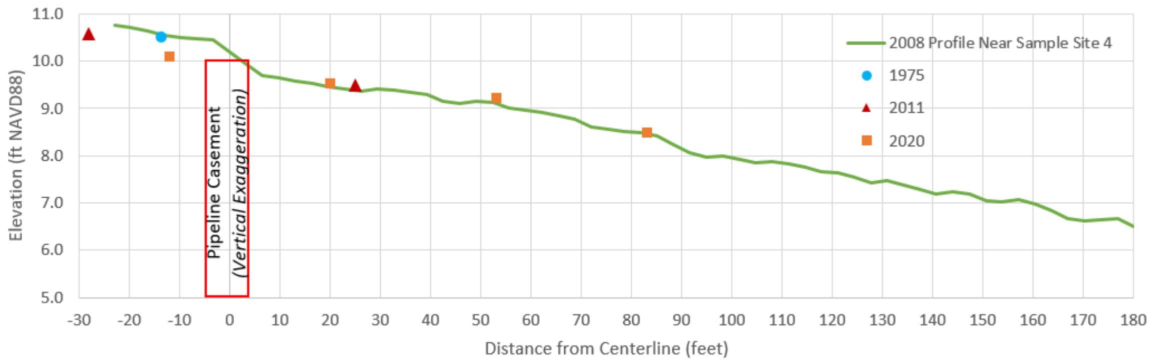
Figure 19
Data Points Near Interceptor Lake Line

Figure 20 plots an example profile near Profile 4 where a change in elevation across the pipeline is evident from the high resolution 2008 survey. The elevations of the pipeline casement are approximate and are shown vertically exaggerated on Figure 20. Elevations shoreside of the lake line have been relatively consistent since 1975 (within the range of uncertainty described in Section 4.3). A small step down occurs to the offshore side of the casement in the 2008 profile. Note that most of the profiles across the study area in 2008 show no grade breaks near the pipeline.



SOURCE: NOAA 2008; King County; SoundEarth and Lally 2011, Global Diving & Gravity Marine (2020)

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Figure 20
Example Profile near Sample Site 4
Lakebed Elevation Relative to Pipeline
Casement Elevations Approximate

4.3 Uncertainty

The process of surveying precise elevations underwater is challenging, making the comparison of small-scale accumulation and erosion difficult. Bathymetric data are often noisy and contain many sources of uncertainty. Sources of error within the bathymetry measurements described in this section include but are not limited to:

- Inconsistent measurement methods (e.g., sonar, diver, lead line).
- Inconsistent datums and conversions from historical datums.
- Seasonal lake water level corrections.
- Dense vegetation that reflects sonar and inconsistent surveying seasons resulting in variable density of vegetation.
- Variations in post-processing or correction for vegetation by surveyors.
- Soft sediments that allow for variable penetration by divers and lead lines.
- Inconsistent spatial location of measurements.
- Limited number of data points collected per survey.
- Limited number of total surveys.

- Inherent uncertainty with sonar, global positioning system (GPS), and other surveying methods.
- Disturbance of sediments by surveying vessel or divers causing temporary sediment redistribution and poor visibility.

This study did not include a quantitative uncertainty analysis. However, personal communication with dive teams, review of datum conversions, and professional experience with various surveying methods indicate that bed elevations reported in this section likely contain at least +/- 4 inches of uncertainty at a minimum. Reported variability for certain surveying methods is closer to +/- 1 foot. When comparing changes in elevation between the various surveys described in this section, this uncertainty should be considered.

4.4 Summary of Bathymetric Changes

Within the Lyon Creek delta area and extending across sample sites 6 and 5, sediment has apparently accumulated on both sides of the pipeline since its installation. Near the mouth of Lyon Creek, this accumulation has been significant on both sites of the pipeline (upwards of 4 feet) since installation of the lake line. Some accumulation (around 6 inches) appears to have occurred on both sides of the pipeline near site 4 and 5 between 2008 and 2011, although by 2020 the elevations had returned to similar to 2008 conditions. As described in Section 4.3, small-scale changes on the order of inches cannot be reported with confidence due to the uncertainty with bathymetry surveys in the study area. At sites 2 through 6, data points since 1975 fluctuated slightly up and down, generally staying +/- 1.5 feet. Historically since 1902, McAleer and Lyon Creek deltas have experienced significant accretion (greater than 4 feet of accretion).

In areas where visual observations indicate a differential drop-off on the offshore side of the pipeline, the presence of the lake line casing may have had localized effects on sediment trapping by obstructing downslope transport within several feet closest to the pipeline, or by exacerbating the effects of wave- or vessel wake-driven erosion immediately offshore of the pipeline within a distance of about 15 feet. This is apparent near site 4. Near the south end of the site, an apparent trench may be associated with the construction of the lake line, although reported existing grades in 1964 are also low. As of 2020, the trench feature was not clearly evident in the survey.

It is not possible to make a clear determination on how much, if any, the grades have changed since 1964 on either side of the lake line due to uncertainty in original construction conditions and lack of high-resolution historical bathymetry data during and prior to construction of the lake line.

5 SEDIMENT PROCESSES

Because of the limited availability of historical bathymetric data, it is not possible to determine specifically how the lakebed has changed over time. However, one can draw conclusions on likely changes based on measured or observed changes in the main physical factors that influence both deposition and erosion. This section describes the mechanisms and effects of various nearshore sediment processes in lakes and compares the relative magnitude of these processes in the study area.

5.1 Lacustrine Sediment Processes

After its formation, a lake accumulates inorganic and organic materials throughout its geological lifespan. These materials arrive at or are formed in the lake via a variety of mechanisms, and are distributed within different regions of the lake. Sources of sediments transported into lakes include:

- Inflowing water from the catchment watershed in the form of sediment-laden streams and urban runoff.
- Erosion from lake shorelines caused by wind wave or boat wake action, landslides, and human activities that may disrupt shoreline banks.
- Wind-blown dust.

Some sediments are also generated within the water column of the lake itself. These include:

- Organic material from the decay of algae and aquatic vegetation.
- Chemical precipitates.

Fine sediment generally accumulates in the deep, offshore region of lakes, called the profundal zone. Most measurements of sediment accumulation rates in lakes are calculated by corings from deep-water accumulation regions. Sediment also accumulates in flat (less than 15 percent slope) regions of the shoreline littoral zone that are colonized by aquatic macrophytes. These still, lower energy areas are ideal for settlement of even extremely fine class particles.

High-energy, shallow regions along beaches and near the mouths of rivers experience higher rates of sediment mobility and transport. At the shore-water interface, breaking waves and boat wakes erode materials from the shoreline. Near river mouths, sediment-laden flows deposit and rework material in their deltas. These regions are typically dominated by coarse sediments such as gravel and sand, although near river mouths, interrupted patterns of fine and coarse deposition may be observed.

5.1.1 Physical Processes

This section describes the physical processes by which sediment arrives at and moves within Lake Washington.

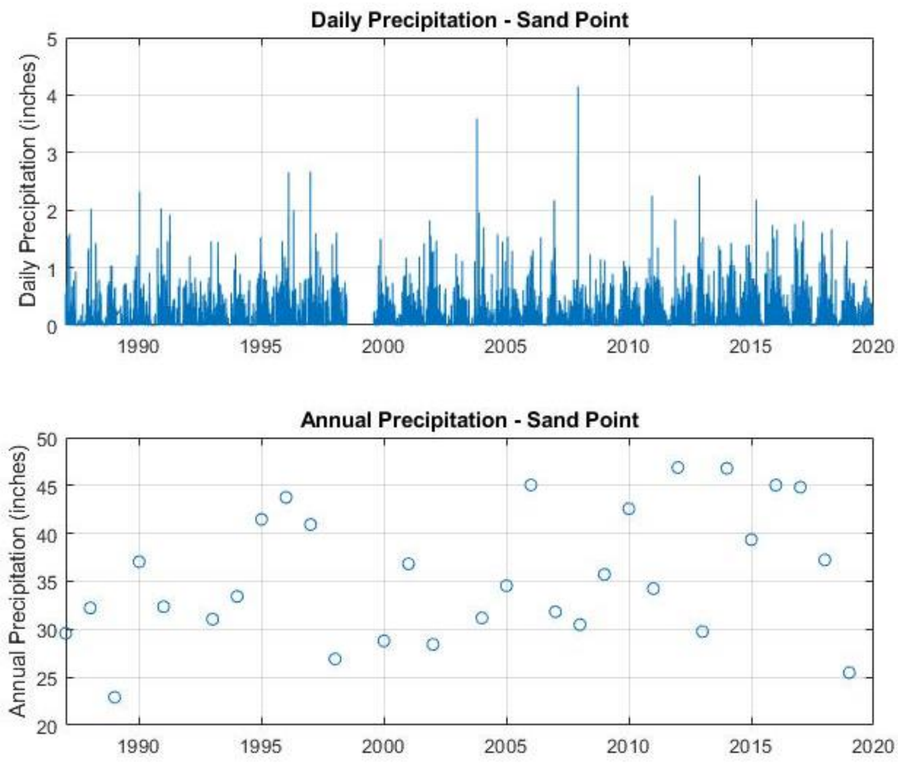
5.1.1.1 Precipitation and Streamflow

In the lowland areas of western Washington, small stream systems such as McAleer Creek and Lyon Creek are rain-fed. The water carried by these streams erodes sediment and transports it downstream. The main source of sediment to Lake Washington is material delivered by inflowing rivers (the Sammamish and Cedar) and smaller streams.

Precipitation

Precipitation data from 1987 to the present are available from the National Climate Data Center weather station at Sand Point on Lake Washington. The station is approximately 5 miles south of the study area. Precipitation data prior to 1987 are not available at Sand Point.

Figure 21 plots daily precipitation (top) and annual total precipitation (bottom) at Sand Point. No clear trends in precipitation occur from 1987 to 2020. The mid 2010s experienced several years of very high precipitation; however, interannual variability is high throughout the time period observed. Years of high precipitation may be correlated with increased streamflows and urban runoff directly into the lake from nearshore areas.



SOURCE: NOAA 2020

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Figure 21
Precipitation 1987–2019
Sand Point

Streamflows in McAleer Creek and Lyon Creek

Streamflow and water quality parameters are monitored by the USGS and King County at stream gauges on Lyon and McAleer Creeks (Figure 22). A record of 15-minute streamflow is available for both creeks and is shown for each creek's respective length of record in Figure 23. Figure 24 summarizes the peak annual discharge in each stream.

SOURCE: King County

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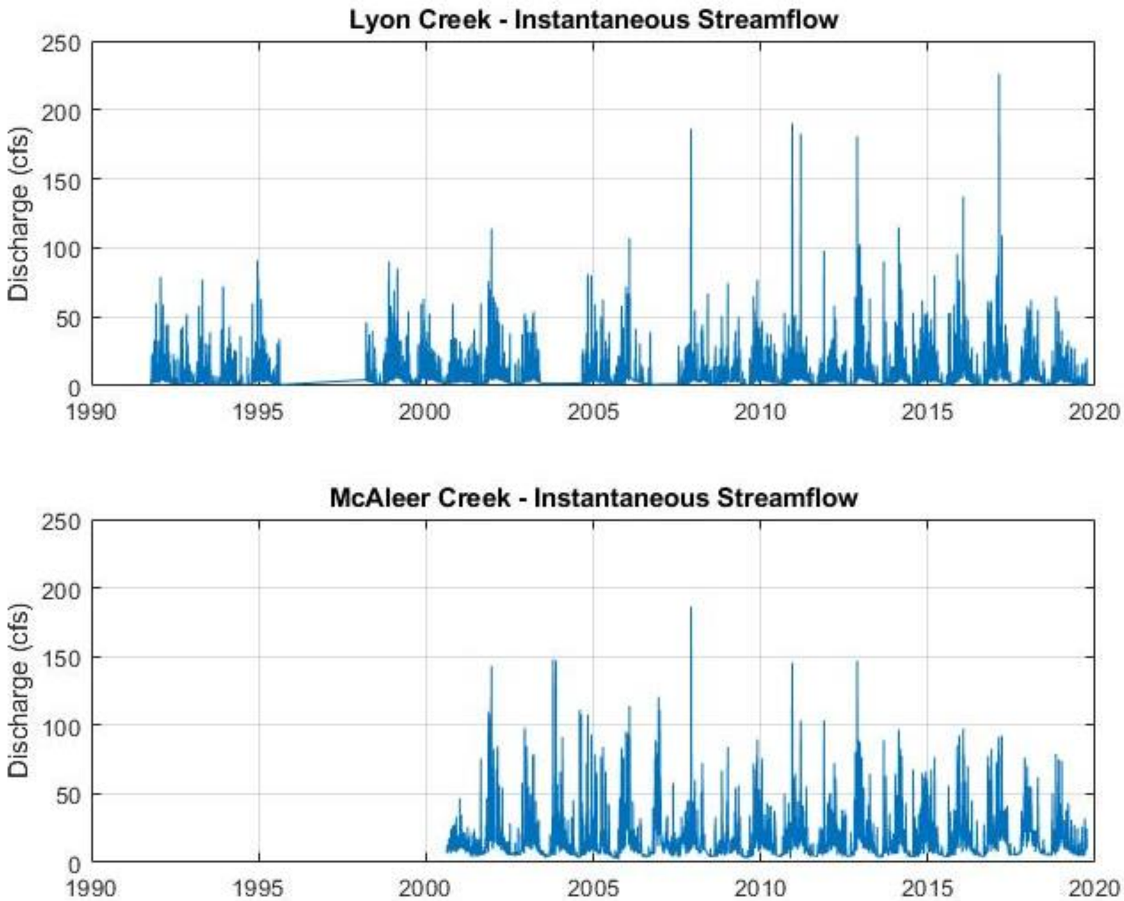
Figure 22
Stream Gauge Locations



SOURCE: King County

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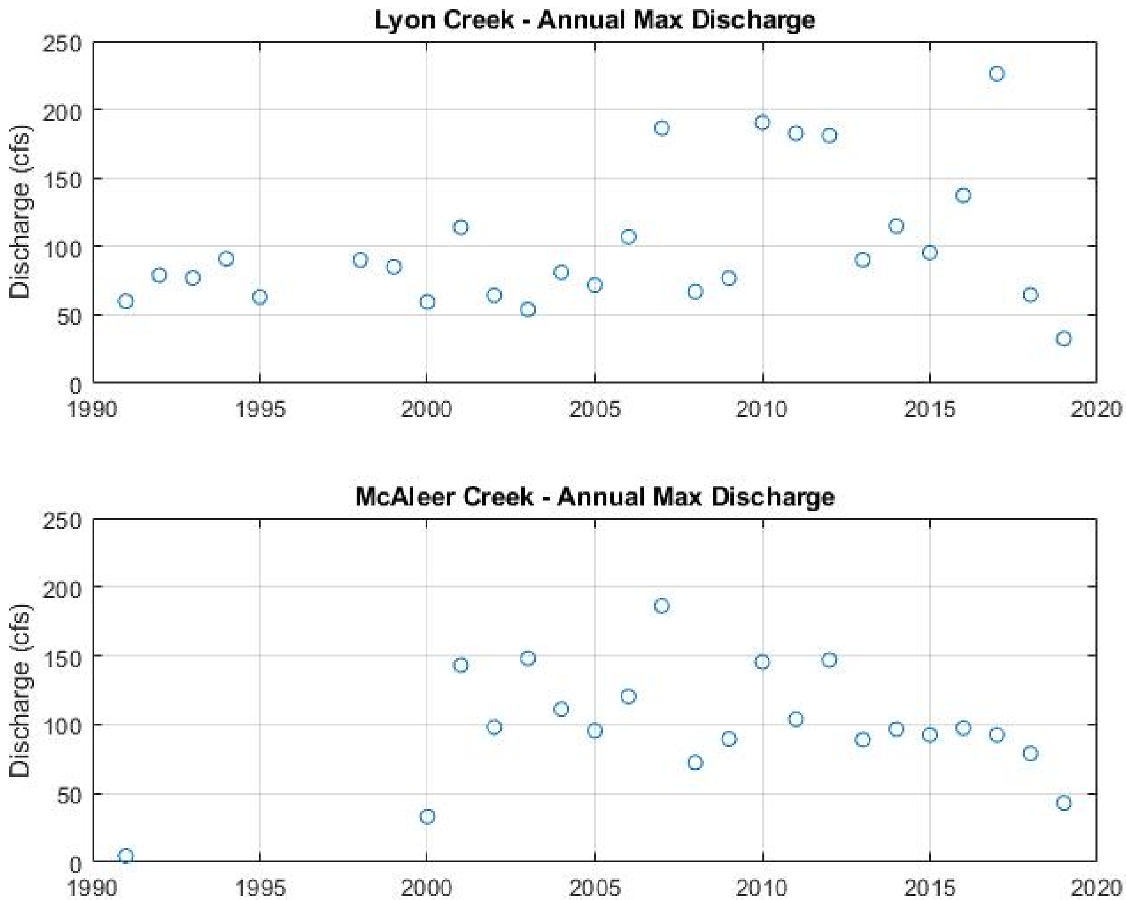
Figure 23
Instantaneous Streamflow 1990–2019
Lyon and McAleer Creeks



SOURCE: King County

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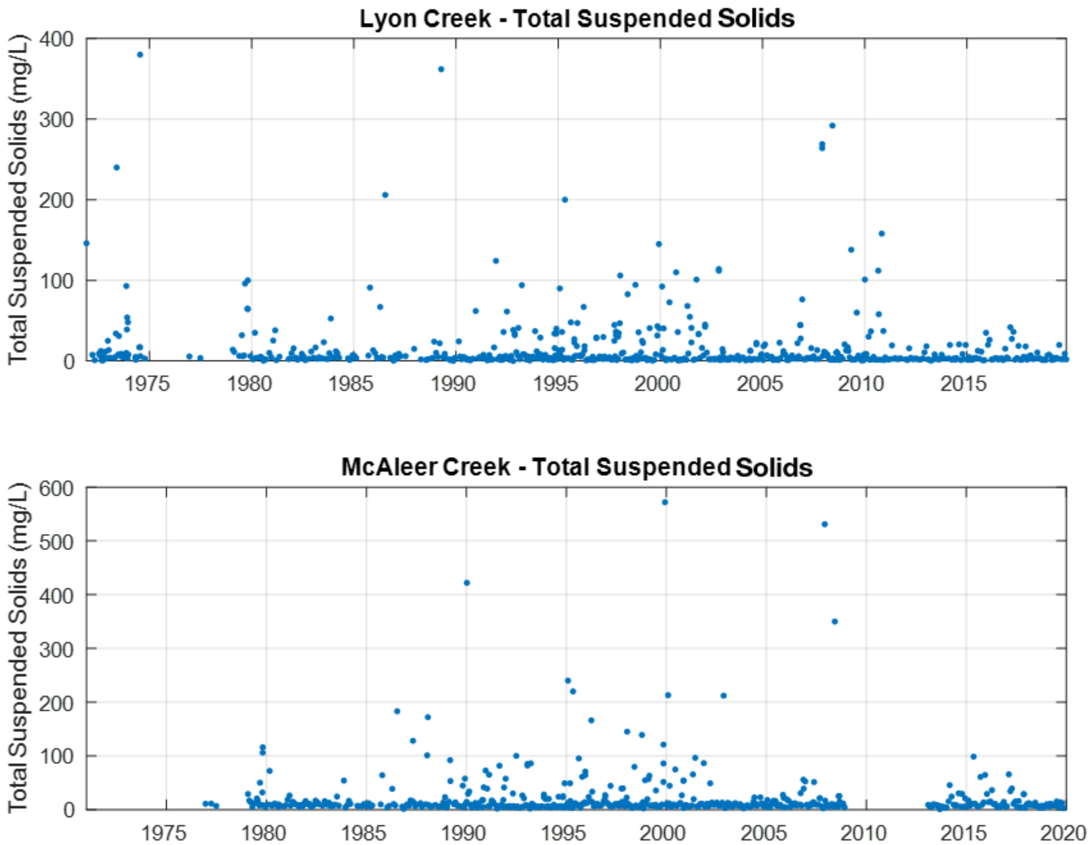
Figure 24
Annual Maximum Discharge 1990–2019
Lyon and McAleer Creeks

While the instantaneous rates are generally similar, McAleer Creek has higher baseflows year round when compared to Lyon Creek, which appears to be more variable. McAleer Creek may be less influenced by intense precipitation events because of the storage capacity of Lake Ballinger. Discharge from the lake also likely stabilizes base flows.

McAleer Creek exhibited the highest streamflows in the 2000s, while Lyon Creek had high flows in the 2010s. Since 2013, annual maximum discharges in McAleer Creek peaked at near 100 cfs.

High streamflows correspond to increased channel flow velocities, which can scour and mobilize sediment from the creek bed and bank areas. Mobilized sediment, transported as bedload or as suspended sediment, is deposited downstream, typically ending up in Lake Washington. Transported material generally settles in the delta area of each creek. Fine suspended sediments may remain suspended in the water column for longer, and may eventually settle in deeper areas.

Suspended sediment concentration is measured for water quality assessments as Total Suspended Solids (TSS). TSS provides an estimate of the rate of sediment transport in a stream, although it underestimates the actual transport amount by neglecting mobilized material that travels as bedload (non-suspended). Figure 25 plots TSS for Lyon and McAleer Creeks from the 1970s to the present.



SOURCE: King County

Kenmore Interceptor Proviso P2 Support

Figure 25
Total Suspended Solids 1971–2019
Lyon and McAleer Creeks

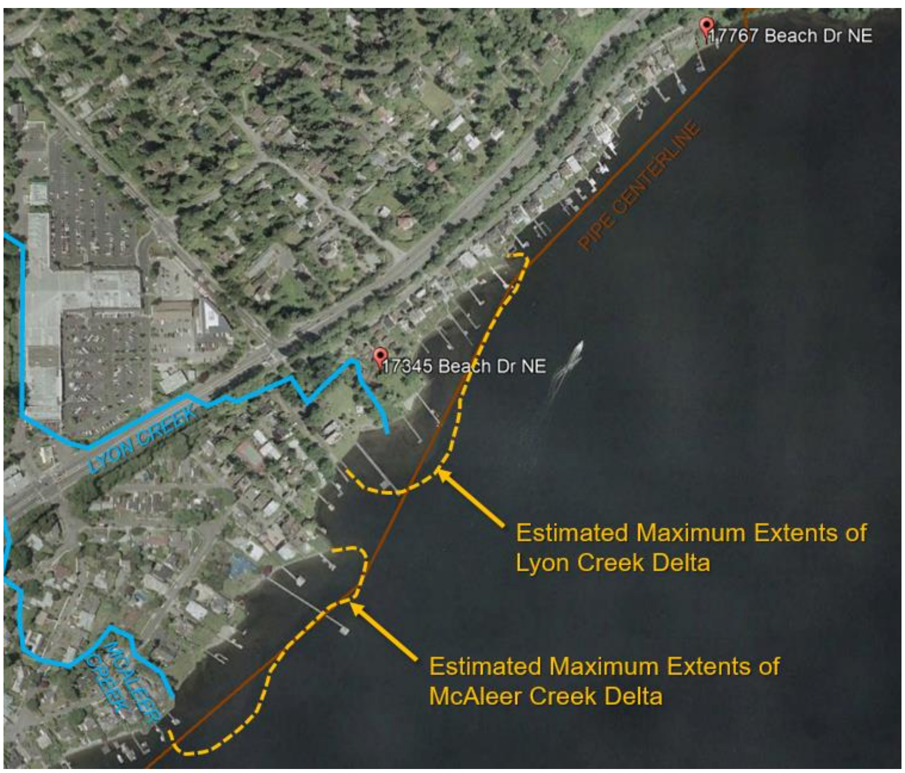
TSS measurements at the Lyon and McAleer Creek gauges are taken periodically (generally monthly) and provide only a snapshot of sediment transport rates at one instance in time, which may vary dramatically over the course of a storm event. It is difficult to determine trends from such infrequent sampling; however, since 2011, TSS concentrations have been low in both creeks.

The total rate of sediment delivery from each creek is estimated by summing the product of the TSS concentration and flow rate over time. The rate of sediment mass delivery per second is converted into a volume rate by assuming a typical bulk density for sand of 1,400 kg/m^3. As a rough approximation, suspended material delivered by the creek is assumed to deposit uniformly in a plane across the delta area of the creek. Review of aerial photos indicates the approximate extents of the deltas, which appear as areas of deposited coarse materials (sand) that are generally free of vegetation (Figures 26 and 27). Lyon Creek has a maximum delta extent of approximately 4 acres, while the McAleer Creek delta covers about 4.4 acres.

Using these assumptions, ESA calculated the rate of sediment accumulation over years when TSS and streamflow data were available for each creek. The estimated deposition rate in Lyon Creek varies from near zero to 0.5 inch/year (13mm/yr) with an average of 0.1 inch/year (3mm/year). Deposition rates in McAleer Creek were similar, ranging from near zero to 0.6 inch/year (15mm/year) with an average of 0.2 inch/year (5mm/year). No clear interannual trend was observed. This could lead to a deposition of up to 2.3 feet of fine sediment across the delta areas between 1964 and 2011.

Note that these estimates based on TSS do not capture coarse sediment transported along the streambed as non-suspended bedload. Observed changes of approximately 4 feet in the delta areas since 1964 likely consist of fine sediments and coarse sediments, which are not included in the deposition rates described above. In reality, accumulation of material does not occur uniformly across the delta in an even plane, and variability in accretion amounts are expected.

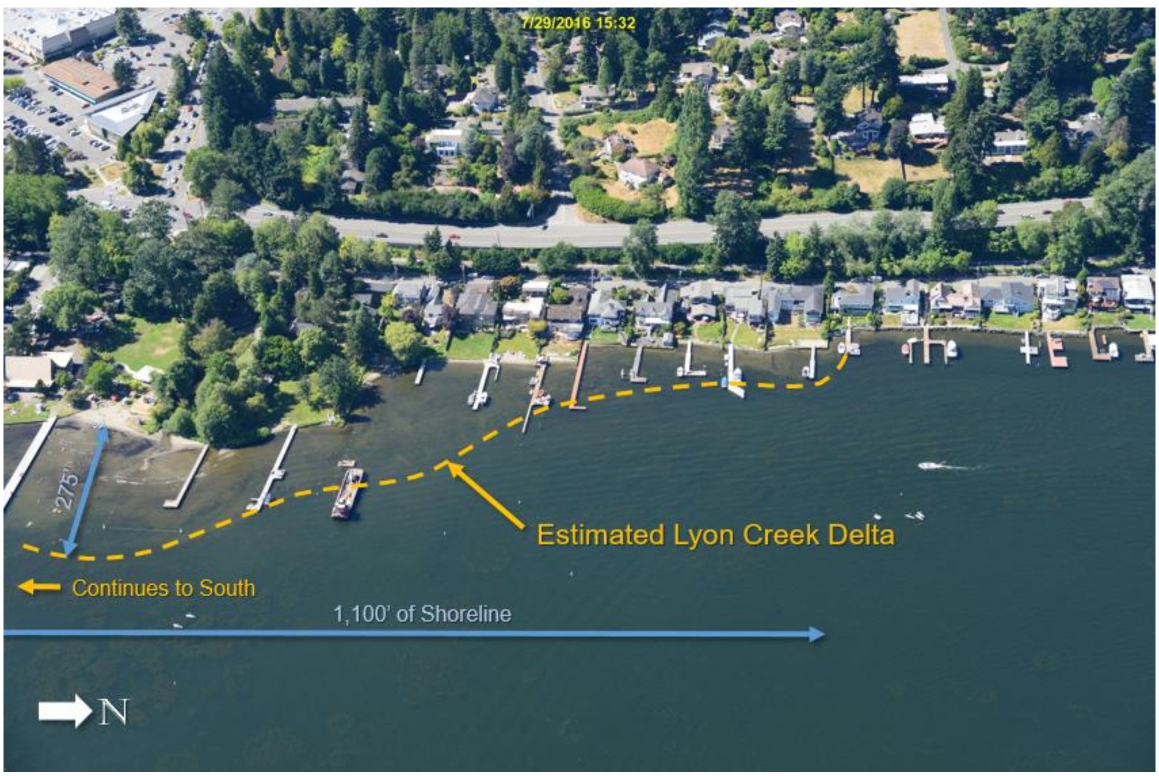
Culvert replacement projects described in Section 3.2.2.3 have likely further increased the amount of coarse material reaching the creek deltas in the years since the replacements, which occurred in 2014–2019.



SOURCE: Google Earth

Kenmore Interceptor Proviso P2 Support

Figure 26
Extents of Lyon and McAleer Creek Deltas Estimated from Aerial Images



SOURCE: WA Ecology

Kenmore Interceptor Proviso P2 Support

Figure 27
McAleer (top) & Lyon (bottom) Creeks Delta Extent
Estimated from 2016 Aerial Oblique Images

Sammamish River Flow

The Sammamish River, which drains Lake Sammamish, enters Lake Washington to the east of the study area (Figure 28). The Sammamish River represents 27 percent of the total flow input to Lake Washington, second only to the Cedar River contribution in the south of the lake (King County 2016). The mouth of the Sammamish River forms a bar-mouth type delta, comprised mainly of sand. The active area of deposition is approximately 2.3 acres, although it is heavily influenced by managed dredging activity. Sand deposits from the delta cover 30 acers of historically deposited materials, estimated to have been deposited at an average rate of 1.5 inches/year in the 1900s (Northwest Hydraulic Consultants Inc. and The Watershed Company 1991).

The western-most extent of the Sammamish River delta is about 0.5 mile east of the study area, most of which spans a deep-water area of the lake. Sediment delivered by the Sammamish River is not expected to reach the study area in any significant amounts.

SOURCE: Google Earth

Kenmore Interceptor Proviso P2 Support

Figure 28
Mouth of the Sammamish River

Climate Change

Global climate models for the Puget Sound region project an increase in the intensity of storms (Mauger, et al. 2015). Heavier, more intense rainfalls will increase the risk of urban flooding in small stream systems with limited storage capacity, such as the Lyon-McAleer Creek basin. Increased streamflows and overbank flooding will likely deposit additional sediment within the study area from bank and urban floodplain erosion. The University of Washington Climate Impact Group predicts that the rates of erosion and sediment transport will increase in fluvial systems, especially in the winter and spring (Mauger, et al. 2015), while summertime streamflows and subsequent sediment transport rates will decrease.

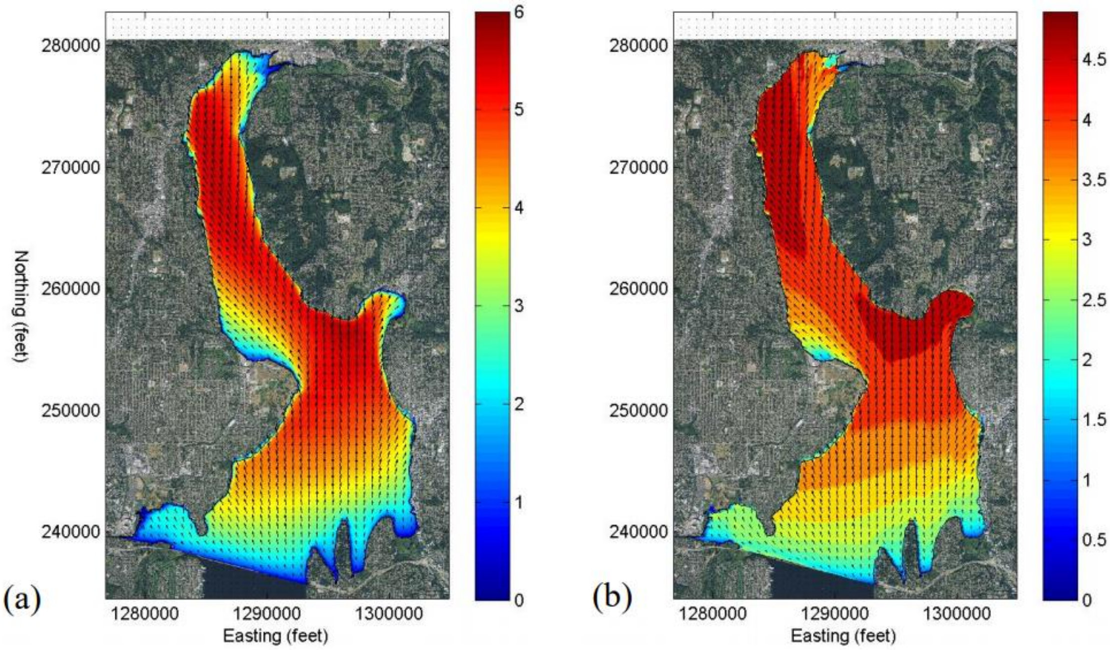
5.1.1.2 Waves and Propeller Wash

Wind waves, boat wakes, and propeller wash introduce turbulence to the nearshore environment and disturb sediments. The zone of influence of these forces is limited by the depth of water in which they occur, with shallow areas most affected by waves and propeller wash. The regular pattern of wind waves arriving at the study area causes a net transport in sediment along the shore from south to north. Propeller wash and boat wakes are periodic and irregular, causing the resuspension and scour of sediments depending on the location of passing vessels.

Wind Waves

SoundEarth and Lally (2011) assessed typical wind regimes in Lake Washington and found that the dominant wind direction along Lake Washington is from the southeast to northwest. This wind direction occurs approximately 45 percent of the time and is associated with strong winds. These winds generate waves that grow in wave height and period as they travel from the south to the north and reach the study area.

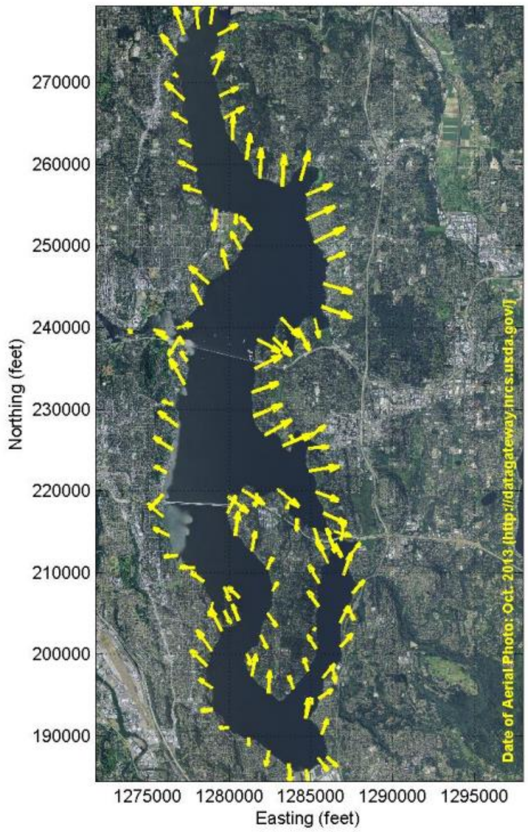
In addition to the information provided in SoundEarth and Lally (2011), Mott McDonald performed detailed wave modeling throughout Lake Washington on behalf of Washington Sea Grant and the City of Seattle in 2015. This work found that in the study area, a 100-year wind storm can generate waves with significant wave heights of approximately 5 feet and wave periods of 4.5 seconds (Figure 29, Mott McDonald 2015). Figure 30 shows the wave directions associated with the maximum nearshore wave heights over a series of model runs from the Mott McDonald report. Modeling confirms that in the study area, the nearshore wave directions associated with large waves from the south approach the shore in a northerly direction.



SOURCE: Mott McDonald, 2015

Kenmore Interceptor Proviso P2 Support

Figure 29
Reproduction of Figure10 from Mott McDonald (2015)
Wave Model Results for a 100-year Wind Storm from 170°
Significant Wave Height (right) and Wave Period (left)



SOURCE: Mott McDonald, 2015

Kenmore Interceptor Proviso P2 Support

Figure 30
Reproduction of Figure17 from Mott McDonald (2015)
Wave Direction Associated with the Maximum Wave Height
from Series of Model Runs

Waves arriving at an oblique angle to the shoreline generate a longshore transport of sediment from southwest to northeast along the study area. The shoreline orientation in the study area is approximately 215° (SoundEarth and Lally 2011) and the dominant wave direction is approximately 170° (Mott McDonald 2015). This means that the dominant waves arrive at approximately 45° to the shore. The lake line is oriented in line with the direction of sediment transport, and thus likely does not interrupt the longshore flow of wind-generated sediment transport. Most of this transport occurs shoreward of the lake line, in depths shallower than 6 feet for typical wave conditions (SoundEarth and Lally 2011). For a detailed discussion on the mechanisms of wave-driven sediment transport, see SoundEarth and Lally (2011).

Boat Wakes

Recreational vessels traveling along the shore near the study area and accessing docks within the area generate wakes that travel toward the shoreline. Wakes within the study area are likely around 1 to 2 feet in amplitude. When reaching shallow water, vessel wakes interact with bed sediments and cause the resuspension of fine materials.

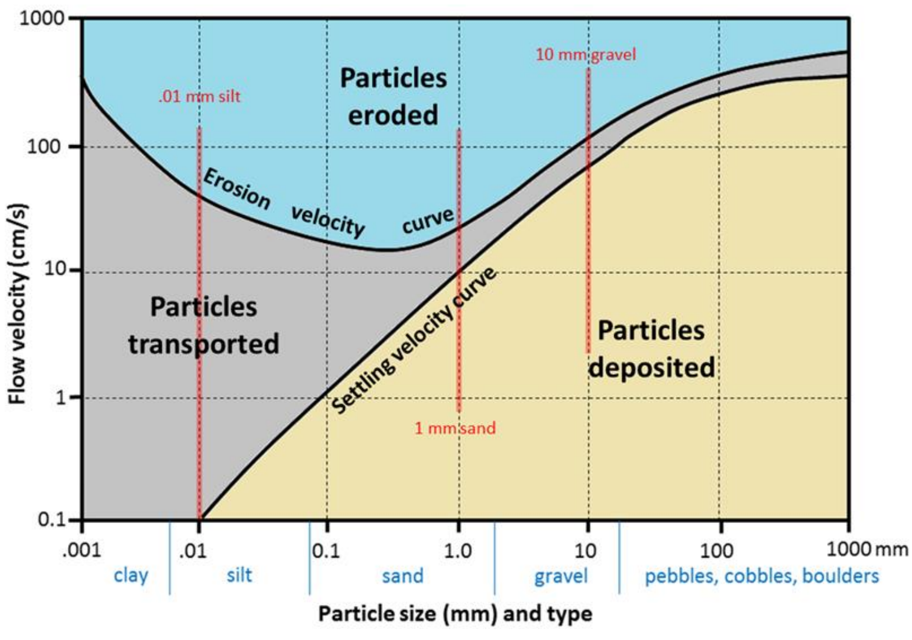
Unlike wind waves, wakes can arrive in the shallows at many angles, depending on the direction of travel of the passing vessels. Therefore, wakes in this area likely do not cause any alongshore trend in sediment transport. Instead, the periodic passing of vessels likely disrupts fine sediments in shallow parts of the lakebed in a chaotic manner and may erode sediment from beach or bank areas of the shoreline.

Propeller Wash

Use of propellers in shallow waters can erode and transport bottom sediments. The amount of transport depends on sediment grain size, the depth of water below the propeller, the size of the propeller and horsepower (hp) of the motor, and the length of time the propeller is operated.

Simplified estimates of propeller scour potential are given by Blaauw and van de Kaa (1978). To estimate typical scour potential, a typical small vessel berthed in the study area is assumed to have a 150-hp engine that is operated at 50 percent power when maneuvering nearshore. The vessel is assumed to have a 1-foot diameter non-ducted propeller. Using Blaauw and van de Kaa (1978), the lakebed would experience maximum velocities of 0.9 feet/sec (27 cm/sec) when the vessel is operated in 10 feet of water (below the propeller line). This velocity is sufficient to transport silts and sands, using a Hjulström-Sundborg diagram (Figure 31). The same vessel operated in 5 feet of water below the propeller can erode fine gravels.

Given the number of docks and the vessel traffic in the study area, propeller wash likely frequently disrupts and redistributes bottom sediments in shallow areas less than 15 feet-deep.



SOURCE: Earle (2019)

Kenmore Interceptor Proviso P2 Support

Figure 31
A Hjulström-Sundborg Diagram
Figure Reproduced from Earle (2019)

5.1.1.3 Lake Circulation

No public data are available on the horizontal circulation patterns in Lake Washington (Ecology 2017). Lake Washington does have documented seasonal patterns of vertical circulation and mixing typical of a deep, mid–high latitude lake; however, this vertical mixing likely has minimal effect on sediment in the littoral (near shore) zone as velocities are likely low and flows periodic.

5.1.1.4 Downslope Transport

The downslope transport of sediment from the shallow erosive zones of lakes to the deeper depositional areas of lakes is known as sediment focusing. Focusing is influenced by topographic controls (slopes) and hydraulic controls (waves and currents or changes in water levels). Turbulence near the bottom can resuspend particles in high-energy zones, which eventually deposit in low-energy zones, often in the deepest parts of lakes. Sediment can also move downslope in a thin, granular bed flow or in larger slumps (LaGarde 2018).

Sediment does not generally accumulate at angles greater than about 15 percent and is transported downslope. Slumping typically occurs on steeper slopes greater than 20 percent slope (Morales-Marin, et al. 2018).

Sediment can accumulate in areas <15 percent where erosive forces do not continually resuspend sediment. Because the study area is generally flat (0–13 percent) and heavily colonized by rooted vegetation, downslope transport does not likely occur at considerable rates. In steeper sections of the shoreline, sediment may have a stronger tendency to move downslope. Obstructions along the path of downslope transport could block transport occurring as granular bed flow or slumps.

Sediment focusing is a result of highly complex relationships between small-scale topography, wave dynamics, water level changes, and sediment properties. The use of sophisticated hydrodynamic models is needed to spatially predict sediment focusing.

5.1.1.5 Rooted Aquatic Vegetation

Rooted aquatic vegetation, also called rooted macrophytes, occurs in shallow areas of lake systems where sufficient light and nutrients are available. The root systems of such plants are anchored in the lakebed sediment, and the body of the plant extends upward toward the surface, in some instances reaching considerable length.

Macrophytes increase sedimentation rates in the littoral zone of lakes via two mechanisms: modifying the flow of water through the vegetation, which encourages settling and stabilization of fine sediments; and contributing organic material directly to the lakebed when vegetation senescences (dies).

Stands of rooted macrophytes decrease the flux of water through the vegetation and reduce turbulence in vegetated areas. The reduced water velocities in the vegetation beds subsequently enhance the trapping of fine sediment and inhibit sediment transport that might otherwise move sediment away from the beds into other areas of the lake (Carpenter and Lodge 1986). In lakes, shallow and mid-water zones are typically characterized as regions of sediment erosion, resuspension, and transport; however, this characterization does not reflect conditions where the littoral zone is colonized by vegetation (Rooney, Kalff and Habel 2003). When vegetation senescences, the organic detritus accumulates within the vegetation bed, eventually breaking down and contributing to organic materials in the sediment. Because water flow is restricted through the bed, these accumulated sediments are less likely to be transported away from the vegetation beds, contributing to an overall increase in sedimentation. Sediment accumulation within macrophyte beds in North American lakes is documented to have localized accumulation rates up to double the average rate in the lake (Rooney, Kalff and Habel 2003). In Lake Washington, this could mean localized accumulation rates near 0.08 inch/year (2 mm/year).

The 2019 ROV survey of the Kenmore Interceptor lake line captured many images of dense Eurasian watermilfoil along the pipeline alignment, as shown in Figures 10–14. Even in areas where macrophytes are less dense, which occurs in some areas along the pipeline, moderate plant density sufficiently reduces turbulence for permanent sedimentation of fine particles (Rooney, Kalff and Habel 2003). Sedimentation rates in the study area have likely increased significantly since the introduction of invasive Eurasian watermilfoil in 1970. Areas previously free of vegetation on both sides of the lake line may have accumulated several inches of sediment as a result of vegetation growth since the 1970s.

5.2 Summary

Most of the physical processes described in this section contribute to accretion in the nearshore zone, namely fluvial and vegetation processes. Some factors, such as wind waves and propeller wash, act to resuspend and transport sediment generally within the nearshore zone. Offshore processes are limited in the study area, given the relatively flat slopes and dense colonization of rooted aquatic vegetation that inhibit the downslope transport of material into deeper areas. Table 4 summarizes the sources and physical forcings associated with sediment transport within the study area.

The presence of the Kenmore Interceptor lake line does not play a significant role in influencing nearshore sediment processes. In areas where the pipe casing was partially exposed above the lakebed after installation, the casing may have partially obstructed the downslope transport along the steepest slopes. However, as described in this section, downslope transport is not a significant mechanism in gently sloped nearshore lacustrine areas, and thus the overall net effect of any obstruction is minimal. The nearshore area along the lake line appears to be a net depositional zone, with the primary drivers being fluvial sediment deposition and trapping within rooted vegetation beds.

Table 4
Sediment Transport Sources and Forcings In the Study Area

Sources	Description	Magnitude in the Study Area	Effect in the Study Area
Fluvial Deposition	Materials transported into the nearshore via rivers and streams. Coarse materials are generally deposited within the delta area.	High	Estimated 3–6 mm/year of fine sediment deposition in delta zone of Lyon and McAleer Creeks (Figures 26–27) and additional unestimated volume of coarse sediment deposition. Little effect beyond the deltas.
Shoreline Erosion	Erosion of bank and beach sediments, caused by some of the forcings below.	Low	Minor added material to the study area in the shallow areas. Shoreline is heavily armored, with minimal material available to erode.
Aquatic Vegetation Decomposition	Senescence and decomposition of algae and rooted macrophytes contribute organic material that is incorporated into lakebed sediments.	High	Accretion of sediment in areas colonized by Eurasian watermilfoil could be up to 2 mm/year.
Riparian Vegetation Litter Decomposition	Organic debris accumulation from overhanging vegetation.	Low	Minor added material to the study area in the shallow areas. Minimal overhanging vegetation is present on shoreline.
Wind-blown Dust	Deposition of dust transported from nearby areas.	Low	Minor added materials uniformly across the lake. Wind-blown dust volumes are generally low in western Washington, especially around imperious surfaces.
Transport Forcings	**Description**	**Magnitude in the Study Area**	**Effect in the Study Area**
Fluvial Currents	High water velocities caused by existing rivers and streams.	Low–High	Carries coarse and fine materials into delta from watershed. Resuspends and transports settled fine sediments in nearshore areas. Effect is large closer to stream delta and low elsewhere.
Fluvial Obstructions	Thick woody debris and undersized culverts may trap sediments and prevent downstream transport to the creek delta. Properly sized box culverts should not obstruct sediments.	Low–High	Replacement of undersized culverts in the 2010s has likely increased downstream sediment transport of coarse material to McAleer and Lyon Creek deltas. Undersized culverts have likely artificially suppressed coarse sediment transport since the development of the Lake Forest Park area. Effect is large closer to stream delta and low elsewhere.
Wind Wave and Vessel Wake	Transport of sediment caused by wave orbital velocities and breaking wave impact.	Medium	Wind waves cause net longshore transport from south to north in the study area. Wind waves and wakes resuspend fine sediments in shallow areas and may erode unarmored beaches and banks.
Propeller Wash	Resuspension of sediment from wave orbital velocities and breaking wave impact.	Medium	A typical vessel in the study area will resuspend silt and likely sand when departing and docking.

Transport Forcings	Description	Magnitude in the Study Area	Effect in the Study Area
Water Level Changes	Annual fluctuations in lake levels controlled by the Corps of Engineers.	Low	Likely minimal effect. Can influence depth at which waves and wakes affect the lakebed.
Lake Circulation	Lakewide currents generated by seasonal changes and large scale wind patterns.	Unknown, likely low	No data available. Assumed periodic, minor effect on sediment resuspension.
Downslope Transport	Downslope sediment migration from shallow areas to deep areas.	Low	Study area is <15% slope, so accumulation dominates downslope transport. Likely minor amounts of sediment transported in the offshore direction in the steepest portions of the study area.
Lakebed Obstructions	Topographic obstructions can intercept downslope transport.	Low	Downslope transport estimated to be low, so interception of downslope transport likely minimal.
Rooted Aquatic Vegetation	Rooted macrophytes inhibit turbulence and the transport of sediments through vegetation beds. Decay of plant litter contributes additional organic materials to the sediment.	High	Significantly increased sediment accumulation rates in macrophyte beds.

6 AQUATIC FLORA & FAUNA

The Proviso includes objectives pertaining to aquatic flora and fauna, and in particular the potential for sediment accumulation around the Kenmore Interceptor lake line to affect anadromous fish migration, as noted in provision 3:

> *(3) an analysis of the impacts of the silt accumulation of water fauna, with particular attention to the ability of fauna to freely access the lake environment on both sides of the interceptor, including any potential impacts on the migration of anadromous species;*

This section describes the fish species present in Lake Washington and several factors that limit salmonid habitat in the lake.

6.1 Fish Species in Lake Washington

A diverse group of fish species inhabit the Lake Washington watershed, including several species of native salmon and trout as well as introduced stocks. Most of these species likely occur at least occasionally in the study area. The more common of these species are listed in Table 5, which provides information on the general habitat used by the species of greatest concern within the watershed. Several other introduced (exotic) species also occur in Lake Washington, such as black crappie, carp, tench, and goldfish.

Table 5
Prevalent Fish Species in the Lake Washington Watershed and Their Ecological Roles

Species Scientific Name	Federal and State Status [a]	Native or Nonnative Species	Ecological Role and Population Characteristics
River lamprey *Lampetra ayresi*	FCo, SC	Native	Predator of salmonids observed in Lake Washington system. High predation rates measured for this species.
Bull trout *Salvelinus confluentus*	FT, SC	Native	Overlapping habitat with other salmonids, but very low numbers or nonexistent in most of watershed. Major fish predator.
Cutthroat trout *Oncorhynchus clarki* (formerly *Salmo clarki*)	None for Puget Sound ESU	Native	Young compete with other salmonids for prey. Adult cutthroat consume fish, including Chinook salmon and sockeye salmon. Population likely smaller than some other potential predators.
Steelhead/rainbow trout *O. mykiss* (resident and steelhead)	FT	Native	Overlapping habitat with other salmonids, consume similar prey. Some predation on young salmonids probable.
Chinook salmon *O. tshawytscha*	FT, SC	Native	Both wild and hatchery origin.

Species Scientific Name	Federal and State Status [a]	Native or Nonnative Species	Ecological Role and Population Characteristics
Coho salmon *O. kisutch*	FCo for Puget Sound	Native	Probably most abundant in north Lake Washington, primarily hatchery.
Sockeye salmon/ kokanee *O. nerka*	None for Lake Washington	Native [b]	Pelagic in open water areas.
Largemouth bass *Micropterus salmoides*	None	Nonnative	Major fish predator that occupies shoreline habitat. Young compete with young salmonids for some prey.
Smallmouth bass *Micropterus dolomieui*	None	Nonnative	Major fish predator that occupies salmonid fish habitat, resulting in some prey competition. Population size uncertain.
Brown bullhead *Ictalurus nebulosus*	None	Native	Competitor with young salmonids for some of same prey.
Longfin smelt *Spirinchus thaleichthys*	None	Native	Pelagic in open water areas. Little likelihood of salmonid prey competition.
Northern pikeminnow *Ptychocheilus oregonensis*	None	Native	Major fish predator that occupies salmonid fish habitat. Former common name was “northern squawfish.”
Peamouth chub *Mylochelius caurinus*	None	Native	Large numbers. Some occupy shallow benthic habitat, consume some of same prey as young salmonids.
Threespine stickleback *Gasterosteus aculeatus*	None	Native	Numerous, substrate-oriented, often near aquatic vegetation, provides prey for larger fish.
Pelagic sculpin *Cottus aleuticus*	None	Native	Also known as coast range sculpin. Pelagic in open water areas. Some overlap in prey with young salmonids. Sculpins represent 72 percent of Lake Washington biomass.
Prickly sculpin *Cottus asper*	None	Native	Benthic habitat from shorelines to deep water. Prey competition with young salmonids. Sculpins represent 72 percent of Lake Washington biomass. Larger sculpins prey on small fish.
Yellow perch *Perca flavescens*	None	Nonnative	Prey overlap with young salmonids. Abundant but substantially less than peamouth (introduced).

[a] FCo=Federal Species of Concern, FT=Federally Threatened, SC=State Candidate Species, ESU=evolutionarily significant unit.
[b] Introduced stock, uncertain whether there was originally a native stock inhabiting this watershed.
Source: Summarized from Wydoski and Whitney 2003

Lake Washington tributaries provide spawning and early rearing habitat for anadromous Chinook, coho, and sockeye salmon and steelhead trout. Cutthroat trout are also present in many of the tributaries and the lake. Rainbow trout were commonly planted in Lake Washington in the past and are still present in the lake.

Recent evidence for sockeye salmon indicates that spawners in the Cedar River and Issaquah Creek are likely descendants of introduced fish (Baker Lake stock), while those spawning in Bear Creek may be native fish (Hendry et al. 1996). All sockeye tend to have similar life-history patterns in the Lake Washington watershed, but the Cedar River sockeye tend to be larger and older than the Bear Creek spawners (Hendry and Quinn 1997). Chinook salmon naturally reproduce in many of the watershed streams and are supplemented by hatchery production of fish originally from the Green River (Weitkamp and Ruggerone 2000). Steelhead/rainbow trout are a mix of introduced hatchery and native stocks. Cutthroat trout are assumed to be native coastal cutthroat.

Lake Washington and the Ship Canal provide a migratory corridor and juvenile-rearing area for all salmonids produced in the Lake Washington watershed. Juvenile salmonids migrating and rearing in the study area include subyearling Chinook and chum salmon. Yearling sockeye, coho, and steelhead salmon, along with a few Chinook salmon, also migrate to Puget Sound through Lake Washington. Adults of each salmon species migrate upstream through the Ship Canal to Lake Washington tributaries. Subadult and adult bull trout and cutthroat trout also most likely migrate in both directions through the Ship Canal.

6.1.1 Endangered Species Act Listed Species

Salmonid species that are listed as threatened or endangered under the federal Endangered Species Act that potentially occur in Lake Washington include Chinook salmon, steelhead trout, and bull trout (Table 5). Lake Washington supports one or more life stages of Chinook salmon, steelhead, and bull trout, which are currently listed as threatened under the Endangered Species Act (NMFS 1999, 2007; USFWS 1999). Lake Washington Chinook salmon are a part of the Puget Sound evolutionarily significant unit (ESU). NOAA Fisheries has also designated critical habitat for the Puget Sound ESU of Chinook salmon (NMFS 2005). This critical habitat includes Lake Washington, as well as the Ship Canal and Lake Union between the Ballard Locks and Lake Washington. The designation identified Lake Washington as high conservation value habitat because of its connectivity with the high-value Cedar River watershed and its support of rearing and migration habitat for fish from all four watersheds in the subbasin (Lake Washington, Sammamish River, Lake Sammamish/Issaquah Creek, and the Cedar River). Chinook salmon fry tend to use shallow shoreline area with finer gravel and sand substrates. They use woody debris for cover during the day and tend to avoid armored shorelines. Juveniles avoid overwater structures and are attracted to non-natal tributaries, and larger Chinook fingerlings move into deeper water and avoid overwater structures. Adult Chinook returning to freshwater spend 2 to 5 days in Lake Washington before staging near the Cedar or Sammamish rivers.

Lake Washington steelhead are part of the Puget Sound distinct population segment (DPS), also listed by the National Marine Fisheries Service (NMFS) as threatened (NMFS 2007). The listing indicated that Lake Washington steelhead include spawning populations in the Cedar River, Issaquah Creek, and Bear Creek, with the Cedar River contributing most of the escapement (the number of adults that return to the spawning grounds). While the Lake Washington population also appears to include a substantial number of rainbow trout (the resident form of steelhead), there is insufficient information to evaluate whether, under what circumstances, and to what extent the resident form may contribute to the viability of steelhead over the long term (NMFS 2007). Critical habitat has not yet been designated for Puget Sound steelhead. Juvenile steelhead are found in both littoral and limnetic areas, and steelhead in limnetic areas consume zooplankton.

USFWS listed the Coastal-Puget Sound DPS of bull trout as federal threatened, which includes the population in the Lake Washington watershed (USFWS 1999). Distribution of bull trout in the

Lake Washington watershed is uncertain, but individuals have been occasionally observed in recent years at the Ballard Locks and at several other locations in the watershed. USFWS also designated bull trout critical habitat in Lake Washington, in the Ship Canal, and Lake Union (USFWS 2005). These areas provide foraging, migratory, and overwintering habitat for bull trout outside of currently delineated core areas in the Puget Sound Recovery Unit. No bull trout critical habitat is designated in any Lake Washington tributaries.

6.2 Salmonid Habitat Limiting Factors in Lake Washington

The City of Seattle (2010) characterized human-caused stressors on lake, marine, and estuarine watershed processes as a part of the Shoreline Characterization Report. Sediment delivery stressors include in-water structures such as jetties, breakwaters, groins, log booms and rafts, dredging, armoring fill and dikes, native vegetation removal, boat wakes and propeller wash, and boat launches and rails.

Because of the extent of shoreline armoring around Lake Washington, which as described above in Section 3.2.1 effectively limits the natural erosion processes leading to sediment transport, most shoreline substrates do not contain habitat suitable for most salmonids. The extensive armoring also results in a lack of habitat structure used for rearing and allocthonous inputs necessary to support foraging. Juvenile salmonids feed primarily on aquatic and terrestrial invertebrates. The lack of overhanging and emergent vegetation limits allocthonous input of both detritus and invertebrates.

Limiting factors identified in McAleer and Lyon Creeks include large volumes of stormwater runoff from development. Stormwater carries toxic substances from streets, homes, lawns, and other sources, and, in the volumes frequently occurring in the basin, causes physical damage to streambanks and beds. Low impact development measures are important ways to reduce runoff from developed sites into streams. Installing rain gardens and replacing hard surfaces with permeable surfaces are steps that residents can take to reduce stormwater runoff from their properties.

6.2.1 Eurasian Watermilfoil

As described above under *Rooted Aquatic Vegetation,* invasive species such as Eurasian watermilfoil are concerns in the littoral zone of Lake Washington, in addition to other concerns such as shoreline armoring, overwater structures, and lighting (City of Seattle and U.S. Army Corps of Engineers 2008).

Shoreline vegetation in Lake Washington has changed substantially from historic conditions. Vegetation was reported as a dense undergrowth of small trees, brush, and Tule grass, but is now primarily landscaped residential properties with bulkheads. Shallow-water habitats are dominated by Eurasian watermilfoil (*Myriophyllum spicatum*), a non-native invasive aquatic plant introduced into the lake in the 1970s. Despite reversing the eutrophication trend in the lake, the introduction of Eurasian watermilfoil to Lake Washington in the 1970s has caused additional water quality problems, as it has displaced native aquatic vegetation and changed substrate characteristics (Patmont et al. 1981).

Watermilfoil is present in much of the lake's littoral zone, where it often forms a floating canopy that shades native aquatic plants and reduces their growth (Frodge et al. 1995). Watermilfoil contributes to phosphorus loading in the lake sediments through its release of phosphorus during decomposition, decreasing the effectiveness of alum treatments. Dense communities can reduce dissolved oxygen to below 5 parts per million (less than the minimum requirements for salmonids) through oxygen consumption during respiration at night (WDFW 2001). In addition, the decomposition of dead plant material increases the biological oxygen demand, further reducing dissolved oxygen and pH levels. In summary, dense communities of aquatic vegetation, or floating mats of detached plants, can adversely affect localized water quality conditions. Under extreme conditions, these situations can become anoxic.

In addition, the excessive accumulation and decomposition of organic material has transformed areas of natural sand or gravel substrate to fine silt and mud. Substantial shoreline areas of Lake Washington, including the study area, have soft substrate, with substantial accumulations of organic material from the decomposition of watermilfoil and other aquatic vegetation. The dense vegetation reduces the currents and wave energy in these areas, encouraging the accumulation of fine sediment material. Accumulated material and dense stands of vegetation cause aesthetic, recreational, and navigational concerns. Section 5.1.1.5 provides additional discussion of the effects of rooted vegetation on sediment accumulation.

The presence of Eurasian watermilfoil can also affect the distribution of and habitat use by salmonids. Tabor et al. (2006) found that the presence of Eurasian watermilfoil in Lake Washington appeared to cause juvenile Chinook salmon to be farther offshore in deeper water. The top of the watermilfoil appeared to act as the bottom of the water column for Chinook salmon. At some piers with extensive watermilfoil growth, Chinook salmon were located on the outside edge of the pier and the pier had little effect on their behavior. For example, at locations where the top of the watermilfoil was close to the water surface along the entire length of the dock, few Chinook salmon were observed; in contrast, at sites where watermilfoil was close to the water surface along the length of the dock except at the offshore end of the pier, Chinook salmon were only seen at the end of the dock and did not appear to change their behavior in response to the pier.

Alterations in fish distribution also appear to affect fish that prey on juvenile salmonids. Most bass used docks and other artificial structures (Celedonia et al. 2008), but distribution shifts to the deeper littoral zones in later summer were theorized to reflect watermilfoil growth.

6.2.2 Water and Sediment Quality in Lake Washington

The water and sediment quality in the Lake Washington basin is degraded from a variety of current and historic sources of both point and non-point pollution. Historically, Lake Washington, Lake Union, and the Ship Canal were the receiving waters for municipal sewage, with numerous outfalls located along the shorelines that discharged untreated or only partially treated sewage directly into these waterways. Cleanup efforts in the 1960s and 1970s included expanding the area of wastewater treatment facilities (including the Kenmore Interceptor lake line), and eliminating most untreated effluent discharges into Lake Washington. However, some untreated discharges occasionally still enter these waterways during periods of high precipitation through discharge from combined sewer overflows (NMFS 2008).

In addition to point source pollution, a variety of non-point sources continue to contribute to the degradation of water and sediment quality. Non-point sources include stormwater and subsurface runoff containing pollutants from road runoff, failing septic systems, underground petroleum storage tanks, gravel pits/quarries, landfills and solid waste management facilities, sites with improper hazardous waste storage, and commercial and residential sites treated with fertilizers and pesticides.

Historical industrial uses in the basin, such as around Lake Union and the southern Lake Washington, Newcastle, Kirkland, and Kenmore areas, have contaminated sediments with persistent toxins, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and heavy metals (King County 1995). The expanding urbanization in the basin has also increased sediment input into the Lake Washington system water bodies.

Along with these physical changes to the basin, substantial biological changes have occurred. Non-native plant species such as Eurasian watermilfoil have been introduced into Lake Washington, and years of sewage discharge into the lake increased phosphorus concentrations and subsequently led to extensive eutrophication. Blue-green algae dominated the phytoplankton community and suppressed the production of zooplankton, which reduced the available prey for salmonids and other species. However, water quality improved dramatically in the mid-1960s as sewage was diverted from Lake Washington to Puget Sound, and the dominance by blue-green algae subsided and zooplankton populations rebounded.

The thermal stratification of Lake Washington and Lake Union can produce surface water temperatures in excess of 68° F for extended periods during the summer. In addition, there is a long-term trend of increasing summer and early fall water temperatures (Newell and Quinn 2005). From 1932 to 2000, there has been a significant increase in mean August water temperature at a depth of 15 feet from about 66° F to 70° F (Shared Strategy 2007). If this trend continues, surface water temperatures could exceed the lethal threshold for returning adult Chinook salmon in some years. However, steelhead and bull trout migrate through the lake in the spring and early summer, so they are less likely to be substantially affected by the increasing summer water temperatures.

6.3 Summary

Primary limiting factors to salmonids in Lake Washington include shoreline armoring and development, lack of suitable lakeside vegetation, the presence of aquatic macrophytes (especially non-native Eurasian watermilfoil), and water quality concerns from stormwater runoff. The presence of the Kenmore Interceptor lake line does not play a significant role as a limiting factor to salmonids and has minimal influence on aquatic flora or fish migration within and through the study area. As described above, the Kenmore Interceptor lake line does not play a significant role in local sediment dynamics and does not represent a migration barrier to fish, as the structure is buried along most of its length and, where exposed, extends an estimated 10 inches above the lakebed. Fish can easily swim over and across it without stress.

The quality and quantity of fish habitat in the study area have been degraded over the years by several factors, which are generally present on a lake-wide basis. The extent of shoreline armoring and overwater structures (docks) around Lake Washington has effectively limited the natural erosion processes leading to sediment transport and has altered outmigrating salmon behavior, as well as introducing cover for salmon predators. The resulting shoreline substrates do not contain habitat suitable for most salmonids. Historically, shoreline vegetation was reported as a dense undergrowth of small trees, brush, and Tule grass, but is now primarily landscaped residential properties with bulkheads. The lack of overhanging trees and vegetation limits the food sources (invertebrates) available to fish in the nearshore. Stormwater inputs carry toxic substances from streets, homes, lawns, and other sources, and, in the volumes frequently occurring in the basin, causes physical damage to streambanks and beds and degrades water quality. Historical industrial uses in the basin have contaminated sediments with persistent toxins, degrading fish habitat.

Invasive Eurasian watermilfoil is present in much of the lake’s littoral zone, where it often forms a floating canopy that shades native aquatic plants and reduces their growth. Watermilfoil contributes to phosphorus loading in the lake sediments through its release of phosphorus during decomposition, and dense communities can reduce dissolved oxygen to levels below the minimum requirements for salmonids. As described above, the decomposition of dead plant material increases the biological oxygen demand, further reducing dissolved oxygen and pH levels. Dense communities of aquatic vegetation, or floating mats of detached plants, can also adversely affect localized water quality conditions. The presence of Eurasian watermilfoil can also affect the distribution and habitat usage of salmonids, pushing salmonids into deeper water along with prey fish. The large amount and wide distribution of watermilfoil in the study area is a significant contributor to the increased rates of sedimentation in the study area, as are the alluvial fans from McAleer and Lyon Creeks. The Kenmore Interceptor lake line neither affects these processes, nor contributes in a measurable way to the other identified limiting factors to salmonids in Lake Washington.

7 CONCLUSIONS AND RECOMMENDATIONS

Physical sedimentation processes in the nearshore are not significantly affected by the presence of the Kenmore Interceptor Section 2 lake line, which is covered in sediment along more than 80 percent of its length in the study area.

The lake line is located in an area of net sediment accumulation, as is typical in the nearshore area of most lakes with gently sloping lakebeds. Over the past nearly 120 years, the nearshore within the study area has generally accreted between 1 and 4 feet. This accretion has occurred on both sides of the present lake line. Much of the accumulation likely occurred during periods of intensive logging and eutrophication in Lake Washington. The accumulation of 1 to 4 feet is consistent with 120 years of lakewide sediment accumulation ranging from 0.08 to 02 inch/year cited in literature and calculated creek deposition rates of 0.1 to 0.6 inch/year in the Lyon and McAleer Creek deltas. Areas under and around residential docks throughout the study area have likely experienced accretion since residential development began in the mid-1900s, especially in areas near Lyon and McAleer Creeks. The introduction and growth of invasive Eurasian watermilfoil since 1970 have likely enhanced accretion under and around docks and, in addition to causing actual increase in sedimentation rates, have likely contributed to a perceived shallowing of recreational mooring areas.

ESA did not observe significant changes to nearshore lakebed elevations that appear to be related to the lake line. Possible localized scour on the offshore side of the lake line and minor accumulation on the shore side of the line may have occurred in limited stretches. The length of shoreline where localized effects may have occurred is approximately 500 feet, and the width over which effects could have occurred is on the order of 10 to 20 feet. It is not possible to determine with certainty how bed elevations have changed immediately above and around the lake line following its installation because of limited as-built construction information.

Dominant physical processes affecting sediment transport in the nearshore include the deposition of fluvial material by both McAleer and Lyon Creeks and sediment trapping and building by rooted aquatic vegetation. The mostly buried lake line does not play a significant role in how these processes affect sedimentation patterns in the study area. Exposed casement areas may have had a minor influence on the downslope transport of sediment by physically obstructing movement offshore along steep slopes and possibly exacerbated wave scour for a limited distance offshore of the pipeline. However, much of the study area is relatively flat, such that downslope transport is not a dominant physical process. Portions of the exposed casement are sufficiently deep such that only extreme waves may reflect or interact with the exposed casement.

Based on the sediment analysis, there are no significant changes to the quality and quantity of habitat for aquatic organisms, specifically salmonids, that have resulted from installation or operation of the lake line. Although nearshore habitat conditions for salmonids in the area are substantially degraded from pre-contact conditions, the literature indicates that the degradation is a result of shoreline armoring and development, impacts on lake water quality, and the introduction of Eurasian watermilfoil into the lake. Several of these factors, as well as the presence of two stream deltas, directly contribute to the sediment dynamics of the site, while the lake line does not significantly alter sediment dynamics or other processes that create and maintain salmonid habitat. In areas where the pipeline casement is exposed, fish can easily swim over the low and relatively short obstruction.

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Appendix A

Appendix A

Kenmore Interceptor Bathymetry and Dive Inspection Technical Memorandum

To: King County Wastewater Division

From: Global Diving & Salvage, Inc.

Date: January 31, 2020

Subject: *C01298C18 – Work Order 02*

Project: Kenmore Interceptor Bathymetry and Dive Inspection

Overview

On January 15, 2020 Global Diving & Salvage, Inc. (Global) was issued Work Order 02 under contract C01298C18. The scope of work was to conduct a bathymetric survey and dive inspection of a section of the Kenmore Interceptor wastewater conveyance pipeline pathway in the northwestern portion of Lake Washington. Gravity Marine Consulting (Gravity) was subcontracted by Global to conduct the bathymetric survey and establish transect coordinates for detailed inspection by diver. This report details the survey methodology and findings for both phases of work.

Divers walked four transects perpendicular to the pipeline. The pipe was not exposed in any of these locations. Substrate was variable but consisted of mud and clay or hard packed sand. There was heavy milfoil growth in several locations.

SBES Hydrographic Survey

SURVEY METHODOLOGY

Survey Coverage

The SBES survey was conducted in the Northwestern extent of Lake Washington, near Kenmore, WA. The survey area was concentrated around an existing buried pipeline used by King County for wastewater conveyance. Pipeline and requested survey area are shown in Figure 1.

The survey area was concentrated within a hydrographic polygon supplied by King County representatives. The hydrographic survey area extended along a section of the pipeline, approximately one-mile long. The area was surveyed within the polygon as close to shore as possible given depth and obstruction limitations. Attention was also given to requested diver transects, so that sonar data could also be collected directly over these same locations.

Survey Vessel and Crew

The MBES survey was conducted on R/V Discovery, a 26-ft aluminum survey vessel owned and operated by Gravity Marine, LLC. Lead surveyor for the data acquisition was Gravity's Senior Engineer, Jeff Wilson MSc, with assistance from Gravity's USCG Captain and Sonar Technician, Edward Sloan

Survey Equipment

Acoustic surveys in moderate to heavy vegetated areas is a constant problem for reliable and accurate data acquisition. The aquatic vegetation tissue acts as an excellent reflector of acoustic energy, thus skewing the absorption and reflection of the sonar beam. Given that this location had a significant amount of aquatic vegetation, a special SBES specifically designed for aquatic vegetation was used for data acquisition.

The BioSonics MX sonar was used for this survey. It is a single beam sonar platform specifically designed for the mapping of aquatic vegetation and the seafloor beneath. Through a proprietary developed filtering algorithm, the BioSonics MX sonar is able to filter through the backscatter created by heavily vegetative area, and delineate both the top of vegetation, and the mudline beneath.

The BioSonics MX sonar was outfitted on a Gravity Survey vessel and attached to a custom designed survey pole. The sonar was used in unison with a Trimble R8 GNSS and GLONASS receiver. The GPS receiver sent accurate position data and information to the data acquisition platform to create precise position data for each sonar sounding.

Figure 1. Survey Transects and Pipeline

Accurate tidal data was measured using a Trimble R8 GNSS Rover. The R8 collects highly accurate elevation data using RTK positioning. RTK corrections were transmitted to the R8 from the Washington State Reference Network (WSRN) via an NTRIP communication configuration. The Puget Sound subnet (PRSN) was used for real-time RTK corrections. Each subnet is a combination of approximately 22 base stations collecting and transmitting position correction data real time. The combination of all these base stations allows for an extremely accurate position correction. The subnet was monitored real time to ensure stations were transmitting properly and in real time.

The following survey equipment was used to conduct the SBES survey;

- Echosounder
  - BioSonics MX Aquatic Habitat Echosounder
  - 204.8 kHz / 8.4-degree SBES
- GPS Receiver
  - Trimble R8 GNSS and GLONASS Receiver
  - Positioning Set to 20 Hz
  - Receiving Real Time Kinematics (RTK) Corrections
- Sound Velocity Profiler
  - YSI/Sontek Castaway CTD Sound Velocity Profiler

Data Acquisition

Survey data was acquired on two separate platforms during the survey. The sonar data was acquired using the BioSonics proprietary data acquisition software Visual Acquisition. The program receives the sonar data, and GPS navigation data and combines them to create a time synced and georeferenced position for each sonar sounding. The program saves all sonar and navigation data to a connected PC as ".dt4" files, a proprietary format developed by BioSonics.

Visual Acquisition also shows a full echogram and performs real-time filtering of the acoustic amplitudes for observation during survey acquisition. This helps the surveyor identify mudlines, presence of vegetation, and the sediment/vegetation interface.

Simultaneously, vessel navigation data was acquired through the survey software platform HYPACK SURVEY. This software is used for vessel navigation, allows the vessel to follow predetermined transect lines, and logs all raw GPS data. Files were recorded as ".RAW" files and saved to a connected PC.

SBES QA/QC

System Assessment

Prior to commencing SBES survey activities, a full system assessment was conducted to ensure all proper checks and procedures were in place to execute a successful SBES survey. This includes assessment of the following items;

- Confirm SBES system is powered and transmitting/receiving data
- Confirm GPS system is powered and transmitting/receiving position data, and position data seems reasonable given the geographic location
- Check survey acquisition software is running properly, and all sensors are communicating properly with software
- Check survey computer that it has sufficient hard drive space and memory to conduct survey and run current version of acquisition software.

SBES Bar Check

A bar check is conducted by placing a static object below the transducer at a specified depth, and recording the sonars measurement of the object's depth. This is done by placing a flat plate or solid lead weight below the transducer.

Both the depth of the object and the sonar draft are included in the depth calculations and should be confirmed during the bar check.

Sound Velocity Profiles

Sound velocity profiles are vital to acoustic data collection, and dictate the angles of acoustic beam transmission and return. Sound velocity data were used in final SBES processing to calculate accurate sounding data.

The BioSonics proprietary acquisition software Visual Acquisition was used for sonar data acquisition, and real time adjustments of sonar data with sound velocity. While other survey acquisition programs require a full depth sound velocity profile, Visual Acquisition only requires an average temperature and salinity to compute a bulk sound velocity value. Therefore, a salinity value of zero (freshwater), and a temperature of 7.8 Celsius was used.

Position Accuracy Verification

Horizontal and vertical positions were corrected via a Real-Time Kinematic (RTK) broadcast to the GPS receiver. The Trimble R8 receiver board receives the RTK corrections and processes position data in real time. With an RTK broadcast less than 30 km from the receiving antennas, the Trimble R8 specifications allow for a horizontal accuracy of approximately 1 cm, and a vertical accuracy of approximately 1.5 cm.

RTK corrections were transmitted to the INS via the Washington State Reference Network (WSRN) via an NTRIP communication configuration. The PRSN subnet was used for real-time RTK corrections. The PRSN is a combination of 22 base stations collecting and transmitting position correction data real time. The combination of all these base stations allows for an extremely accurate position correction. The subnet was monitored real time to ensure stations were transmitting properly and in real time.

SBES PROCESSING

Sonar data from the BioSonics MX sonar was processed in the manufacturers proprietary processing software Visual Habitat. In this software the raw .dt4 files are processed to extract the several available products from the dataset.

Data processing was conducting in a three-stage process. This process takes the data from its raw form to a processed state for analysis and creation of geospatial products. The data processing stages are as follows:

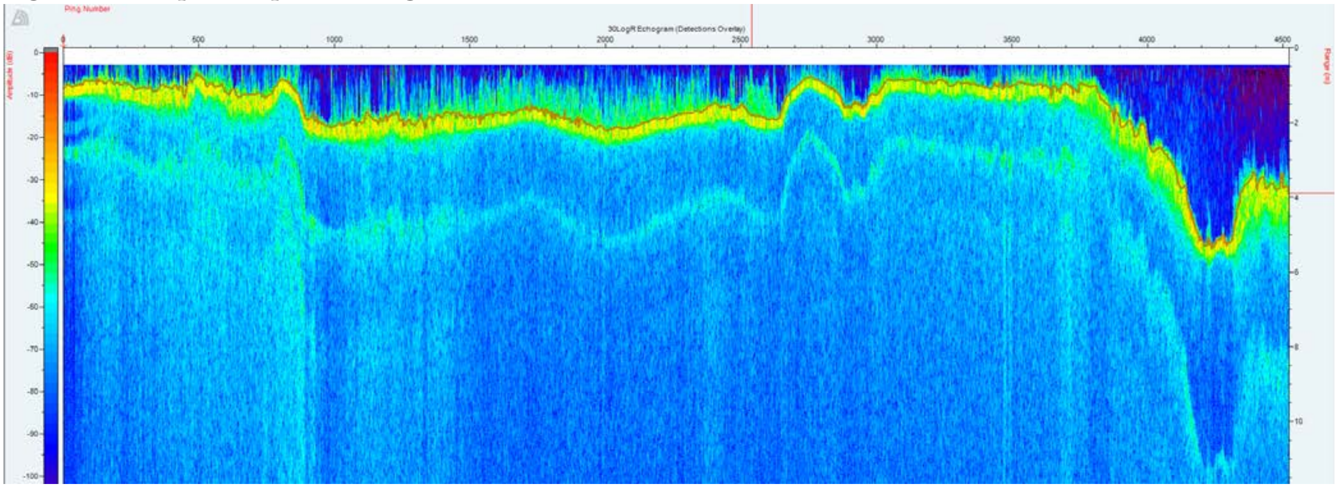
- Stage 1: Process all raw .dt4 files in Visual Habitat through auto filters for desired features extractions (i.e. Bottom detection, Plant detection, Feature Extraction, Bottom typing)
- Stage 2: Manually edit all transect lines to correct for any erroneous sonar soundings
- Stage 3: Export processed data matrix into ArcGIS for geospatial analysis and deliverable creation.

The raw data was initially processed in Visual Habitat for bottom detection only. This is because the actual mudline elevation of the survey area is of greatest interest compared to plant coverage and height of the area. Plant and bottom typing data is also possible to extract from the acoustic data if desired. Bottom detection was initially conducted through some auto filtering and processing tools created by BioSonics. These algorithms run through each sounding and attempt to delineate the interface between water, vegetation, and sediment for each echogram. The following criteria were used for Stage 1 processing;

- Domain: 30LogR
- Rising Edge Threshold: -40dB
- Rising Edge Length: 10 cm
- Rising Edge Search Window: 100 cm
- Reset Search Window: 5 ensembles
- Rising Edge Min Detection Range: 0 m
- Rising Edge Max Detection Range: 1000 m

Given the extensive coverage of aquatic vegetation, all survey lines underwent manually editing to correct for biases due to extensive acoustic backscatter. Each line was manually editing to position the mudline surface in the most appropriate position, based on visual assessments of the full echogram from each sounding. An example echogram can be seen in Figure 2.

Figure 2. Example interpreted echogram



The solid brown line in Figure 2 indicates the interpreted mudline of the lake bottom in contrast to the water column (dark blue) and aquatic vegetation (turquoise). This is done by contrasting the return amplitude of the acoustic beam received by the sonar system. Typically, the strongest return (yellow-red) is the area where the density gradient is the greatest, such as the interface between water and sediment.

Following the processing of each survey line in Visual Habitat, all sonar data was exported into a matrix which included a lake bottom depth, a GPS time stamp, and GPS latitude and longitude. This data was then paired with the RTK elevation data captured by the Trimble R8 to compute a real time elevation of the data referenced to NAVD88. This was done by pairing the GPS synced time stamp between both data sets to arrive at a final and single elevation data point for each sounding.

Referenced data was then imported into ESRI's ArcMap to plot and interpolate the data sets. The bathymetric data was used to create a digital elevation model (DEM) and bathymetric contours for the survey area. These data were plotted on aerial imagery for visual reference of the information with the surrounding area.

Diver Inspection Survey

The subsea inspection was completed utilizing a three (3) person dive team working off of the Dive Support Vessel (DSV) “Titan”. The diver used surface supplied shallow water air diving gear with full (2) way communications and a laptop computer with video recording software. A helmet mounted camera and light was used to view and document the dive inspection as well as capture the video for recording to hard disk.

Each transect was inspected between two referenced points measured with a GPS. Inspection points were spaced equally between start and stop reference points for each transect. Inspection continued as close to shore as possible until either the end of transect was reached or lack of water no longer allowed for a diver inspected point. The below table outlines each diver inspected location, a Northing and Easting location, converted mud line elevations from water depths, and inspection notes. Station identification numbers follow the format “transect number (##)-point number (##)”. For example, the seventh inspection point on transect 9 would have a station identification of 09-07.

The following conditions were found to exist:

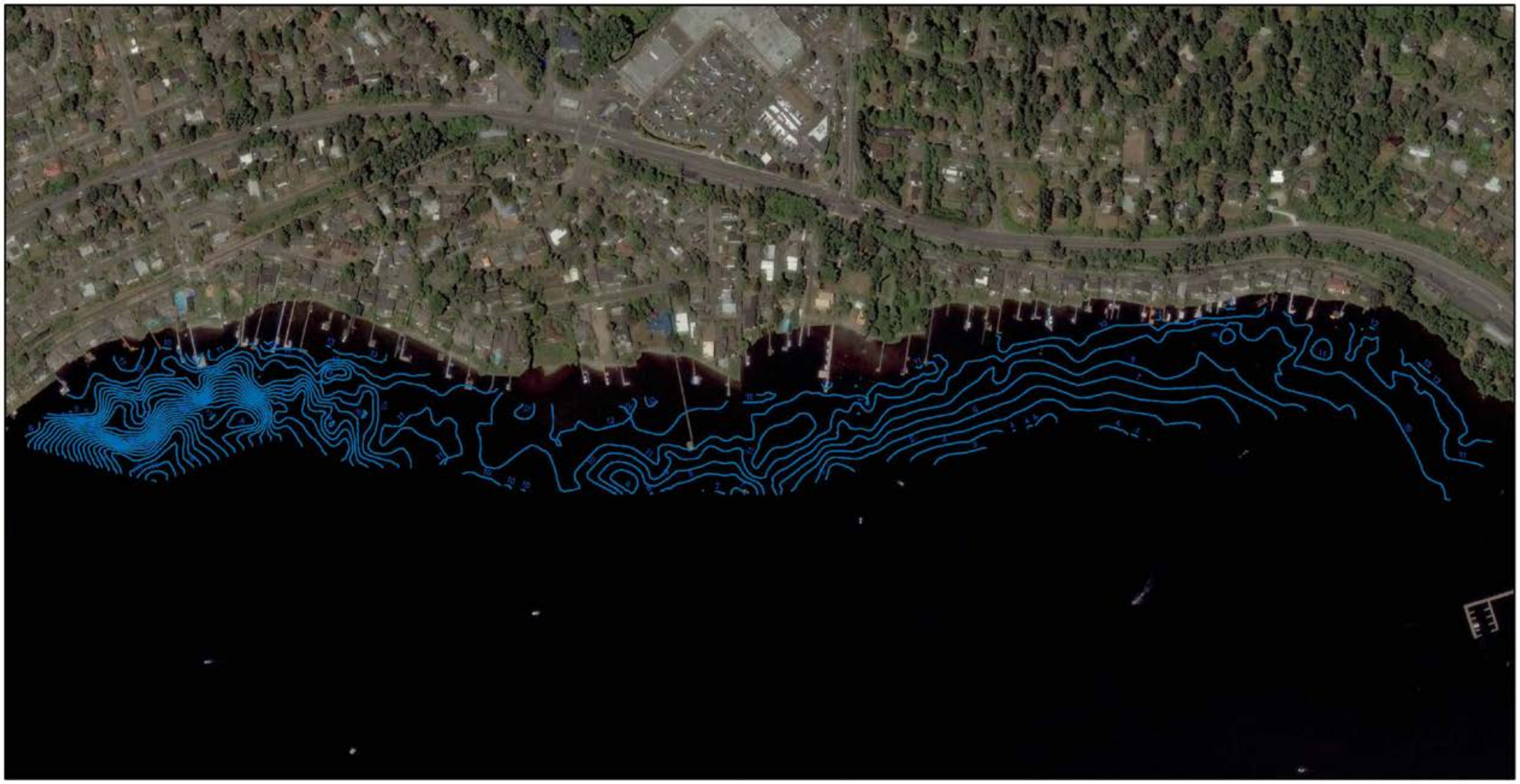
Table 1. Diver Inspection Notes

Station ID	X	Y	Elevation (NAVD88)	Notes
08-01	1286076.186	277688.063	7.15	clay/mud
08-02	1286064.983	277704.8231	7.15	clay/mud
08-03	1286053.935	277720.7821	7.15	clay/mud
08-04	1286042.886	277737.3549	9.15	clay/mud, slight slope, hard pack
08-05	1286031.838	277753.9277	9.15	clay/mud
08-06	1286019.868	277770.1936	11.15	clay/mud. flat, hard pack
08-07	1286009.434	277787.3803	13.15	clay/mud. flat, hard pack
08-08	1285998.078	277803.6462	16.15	1' or less depth, Hard Pack
08-09	1285986.853	277818.988	16.15	1' or less depth, Hard Pack
09-01	1285951.716	277336.588	12.15	hard pack sand, slight marine growth, flat
09-02	1285935.347	277347.5255	12.15	heavy grass, hard pack sand, slight slope to beach
09-03	1285918.406	277358.2057	12.15	no growth, hard back sand with mud, slight slope
09-04	1285901.833	277368.886	12.15	mud/clay mix. Flat surface, no growth
09-05	1285884.708	277379.3821	12.15	mud/clay mix. Flat surface, no growth
09-06	1285867.828	277390.1851	13.15	muddy, light growth, slight up hill to beach
09-07	1285851.378	277400.7426	14.15	muddy, 4" top. hard pack below. slight slope
09-08	1285833.455	277412.2822	14.15	hard pack mud, moderate growth. slight uphill slope
11-01	1285225.549	276734.946	10.15	hard pack sand with milfoil, flat bottom

Station ID	X	Y	Elevation (NAVD88)	Notes
11-02	1285211.238	276748.2647	11.15	hard pack sand with milfoil, flat bottom
11-03	1285195.77	276761.1547	12.15	slight sand, slight slope up, milfoil
11-04	1285180.349	276775.022	11.15	hard pack sand, sloped up to shore
11-05	1285165.386	276787.1188	12.15	hard pack sand with mud mixed. slight slope to beach
11-06	1285150.103	276800.1929	12.15	hard pack sand with mud mixed. slight slope to beach
11-07	1285135.187	276812.8987	12.15	hard pack sand with mud. Milfoil, slight slope to beach
12-01	1284926.251	276407.353	14.15	hard pack sand slight slope to beach
12-02	1284912.832	276422.1107	15.15	no marine growth, sand, slight slope to beach
12-03	1284898.356	276435.6863	15.15	hard pack sand, no growth, slight slope
12-04	1284884.464	276449.5782	15.15	hard pack sand, no growth, slight slope
12-05	1284870.009	276463.2823	15.15	hard pack sand, no growth, no slope
12-06	1284855.742	276477.9251	16.15	gravel and hard pack sand, slope
12-07	1284841.662	276491.6293	17.15	on shore
12-08	1284804.357	276526.462	15.15	>2' depth to the beach

SURVEY DRAWINGS

Figure 3. Bathymetric contours at 1-foot intervals



Geodetic Settings		Survey Equipment	
Horizontal Datum	NAD83 - State Plane	Sonar	BioSonics MX
Vertical Datum	NAVD88	Inertial Nav System	NA
Coordinate System	WA North FIPS 4601	RTK Corrections	WSRN PNSN via NTRIP
Horizontal Units	US Survey Feet	Speed of Sound	YSI CastAway CTD
Vertical Units	US Survey Feet	Survey Date	JAN 17 2020
Vertical Control	WSRN	Data Collection & Processing Software	Hypack 2018/ BioSonics VA
Horizontal Control	WSRN	Mapping and Production Software	ArcGIS 10.4

0 150 300 600 900 1,200 Feet

Notes:
1) Sonar data acquired in BioSonics proprietary software Visual Acquisition
2) Navigation Data acquired in Hypack Survey 2018
3) RTK elevation data acquired with Trimble R8 in Trimble Access
4) Depths reported in NAVD88

King Co Pipeline Survey
Lake Washington, WA, USA
Bathymetry - NAVD88
January 17th, 2020

Data Acquisition:	J.Wilson/E. Sloan
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GRAVITY

Figure 4. Digital Elevation Model (DEM)

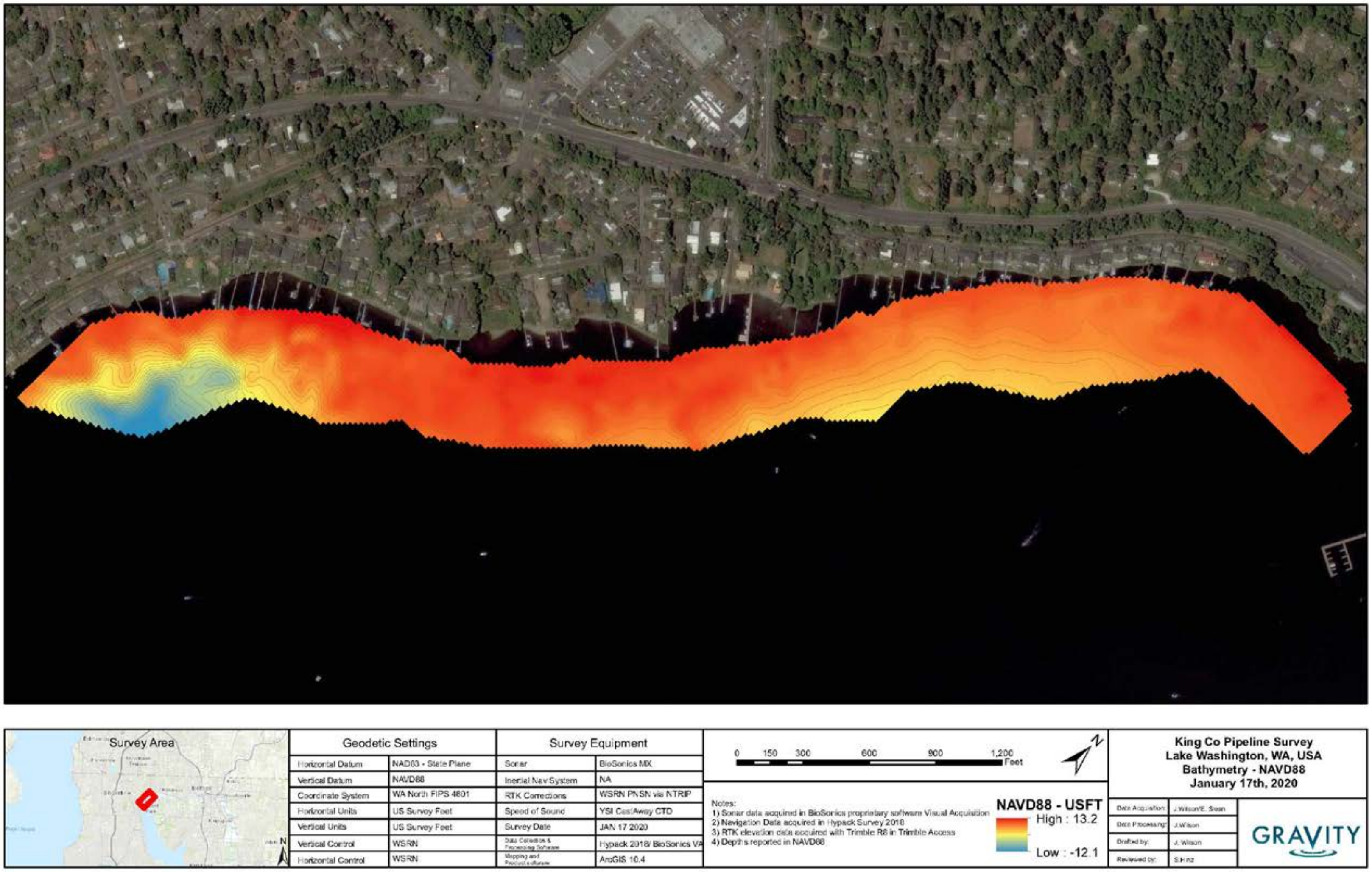
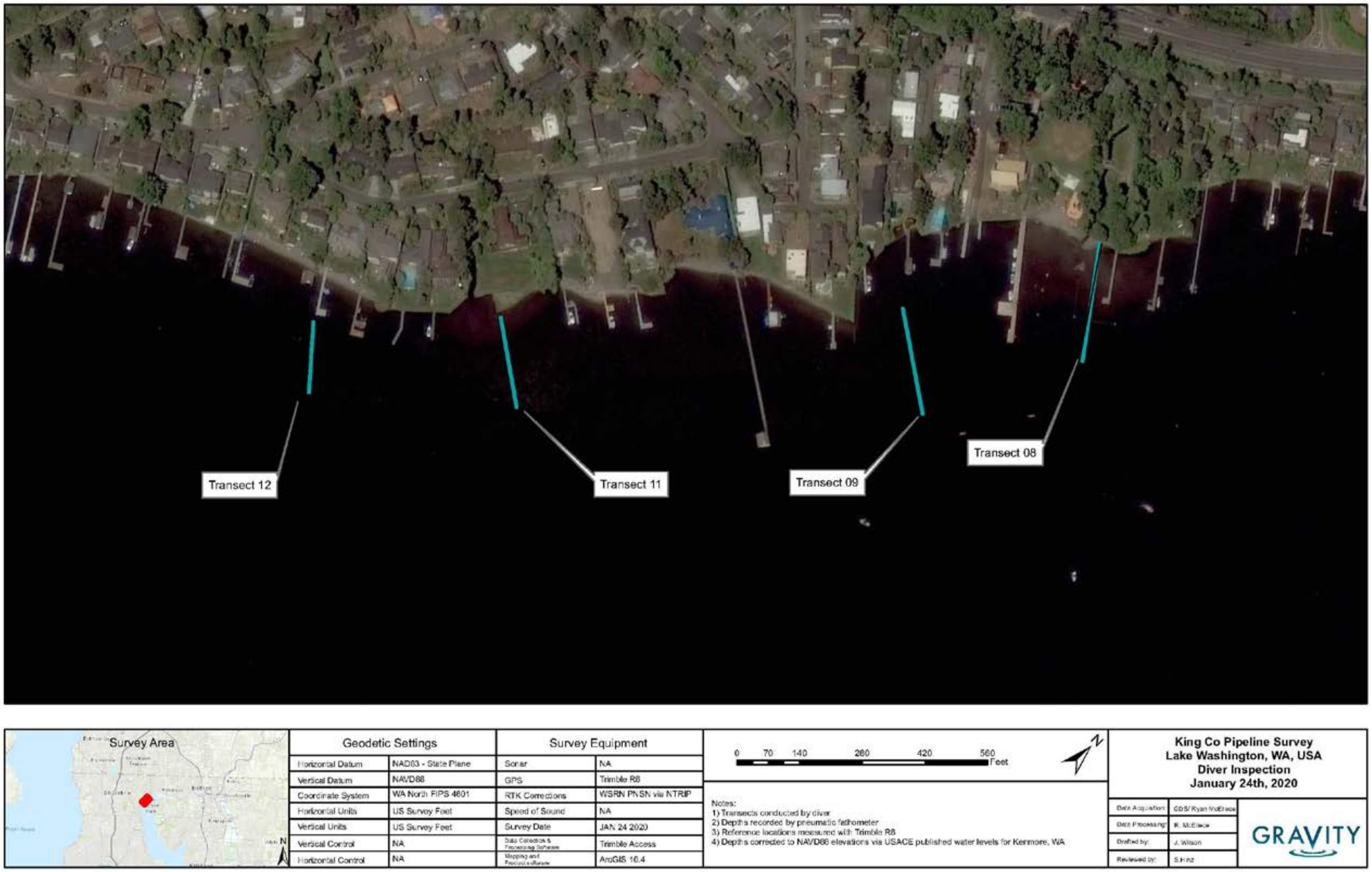


Figure 5. Diver Inspection Transects



KENMORE LAKE LINE LAKEBED SEDIMENTATION ANALYSIS

Property:
Kenmore Lake Line
Lakebed Sedimentation Analysis
Lake Washington
King County, Washington

Prepared for:
King County Wastewater Treatment Division
Department of Natural Resources and Parks
201 South Jackson Street
Seattle , Washington

Report Date:
October 6, 2011

Kenmore Lake Line Lakebed Sedimentation Analysis

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EXECUTIVE SUMMARY

SoundEarth Strategies, Inc., and Lally Consulting LLC have prepared this Sedimentation Analysis Report for the Kenmore Lake Line Lakebed on behalf of King County Wastewater Treatment Division, Department of Natural Resources and Parks. King County owns and operates the Kenmore Lake Line Interceptor sewer pipeline located along the lakebed ranging approximately 75 to 200 feet offshore of the north Lake Washington shoreline between Kenmore and Matthews Beach Park. Shoreline residents along the study reach, between 17345 and 17767 Beach Drive Northeast, have reportedly expressed concerns that sediment deposition has occurred on the lakebed fronting their properties and that the deposition may be caused by the position of the Lake Line.

At King County's request, SoundEarth Strategies, Inc., and Lally Consulting LLC performed an investigation of the sediment transport mechanisms and depositional environment along the Lake Line to evaluate whether the position of the Lake Line has influenced accumulation of sediments in the study area.

Field investigations were performed at the study area on June 15 and 16, 2011. Dive observations yielded the following initial findings regarding the erosional and depositional environment in the vicinity of study area:

- The areas investigated, within and immediately to the southwest of the study area, appeared to be depositional, based on the presence of compressible fine sands, silts, and organics at the lakebed surface.
- The surface sediments appeared to result from numerous potential sources, including shoaling deposits from adjacent creek outlets; beach erosion; and organics/detritus from dense stands of Eurasian watermilfoil, overhanging trees in a few locations, and perhaps anthropogenic influences from historical or current mill and plywood operations.
- The dense growth of Eurasian watermilfoil within the study area likely has an effect on sediment transport processes, as well as vessel navigation.
- Visual inspections of areas proximal to and beneath several docks were performed, with no significant accretion or erosion patterns noted by the pile alignments or moorings.
- Erosion was observed along several areas of the shoreline within the study area, particularly adjacent to shore landings for the dock structures and along the downdrift side of armored beaches. A close inspection of the shorelines was not within the scope of this investigation; however, it was observed that natural beaches and man-made beaches are present within and adjacent to the study area.
- No significant differences were noted in the surface sediment composition or vegetation density on either side of the Lake Line.
- There were no obvious indications that the Lake Line was contributing to or had contributed to the sedimentation patterns in the study area, other than localized effects within a few feet of the emergent section of the Lake Line southwest of Manhole 37. At this location, the lakeward bed elevation dropped approximately 0.5 feet relative to the top of the Lake Line along an approximately 10-foot section of the conduit. The lakebed elevation was flush with the top of the conduit along this section.

EXECUTIVE SUMMARY (CONTINUED)

Results of the sediment sampling activities indicate that in areas other than the Lyons Creek and McAleer Creek outlet shoals, surface sediment generally consisted of fine sand with silt and organics, overlying a thicker layer of finer sediments consisting of organics and silt with some sand. It was noted that both the surface layer and substrate were comprised of shoaling materials, with the surface layer appearing to consist of fine sands, likely originating from the adjacent creek outlets and/or shoreline erosion. The fine sands overlay a more organic-rich layer, perhaps from in-place decomposition of aquatic vegetation or deposition from other sources. Detailed analyses of the geotechnical composition of the samples were performed by a geotechnical laboratory.

Supplemental to the field investigations, lacustrine sedimentation analyses of samples collected from outside the study area at the north end of Lake Washington were undertaken by SoundEarth Strategies, Inc., and Lally Consulting LLC. Site geomorphological, lake level, wind and wave regime, and sediment transport processes were evaluated and characterized for the study area.

The findings from the field investigation and sedimentation processes evaluation suggest that the study area is located in a net depositional area, regardless of the Lake Line. The following primary conclusions were made:

- Submerged aquatic vegetation appears to play a role in limiting both the initiation of sediment movement and deposition patterns within the Lake Line study area. The aquatic vegetation is of a significant density and height to potentially impact vessel navigation and create a perceived shoaling condition.
- The sediment depositional patterns on both sides of the Lake Line are essentially the same and appear to have reached a state of dynamic equilibrium with respect to uniform deposition across the Lake Line.
- Lyons and McAleer creeks and erosion of shoreline areas within and outside the study area appear to be the primary sources of sediment. The in-place decomposition of aquatic vegetation may also be a source of shoaling material.
- The north end of Lake Washington is in a “downdrift” littoral cell with respect to lacustrine sediment transport processes, which results from the predominant wind, wave, and current directions in the lake.
- The dominant southerly wind-wave direction produces a net longshore current from southwest to northeast. This finding was supported by analysis of aerial photography and observations in the field.

SoundEarth Strategies, Inc., and Lally Consulting LLC conclude that the study area is in a net depositional littoral cell of Lake Washington and will therefore continue to experience accretion of sediments. It is also our opinion that the Lake Line sewer pipeline, where originally emergent, likely had some localized effect on the sedimentation immediately within the vicinity of its alignment. However, the sedimentation volumes are overwhelmingly more attributable to the location of the study area being at the north end of the lake and to natural sedimentation processes in the study area.

1.0 INTRODUCTION

According to information provided by the King County Wastewater Treatment Division, Department of Natural Resources and Parks (DNRP), King County owns and operates the Kenmore Lake Line Interceptor sewer pipeline (Lake Line) located along the lakebed ranging approximately 75 to 200 feet offshore of the north Lake Washington shoreline between Kenmore and Matthews Beach Park, as shown on Figure 1. The top of the 48-inch-diameter sewer line, which was installed in 1966, is situated at a depth of approximately 8 feet beneath the lake surface in a shallow trench that was either backfilled to the top of the sewer pipe following its installation or allowed to backfill naturally. The sewer pipe is encased in a 66-inch-square concrete conduit. The study area, shown on Figure 1, is approximately 4,000 feet long. As-built drawings (Appendix A) show the pipeline between stations 190+00 and 245+00 (a length of approximately 5,500 feet), buried as much as 6 feet and exposed as much as 4 feet, at the time of installation.

Shoreline residents along the study reach, between 17345 and 17767 Beach Drive Northeast, have reportedly expressed concerns that sediment deposition has occurred on the lakebed fronting their properties, and they suspect it may be related to the position of the Lake Line. The span of 29 properties where sedimentation concerns have been expressed by the residents is located in the City of Lake Forest Park between Logboom Park, near the intersection of Northeast Bothell Way and 61st Avenue Northeast, and the shore area in the vicinity of Ballinger Way Northeast and Bothell Way Northeast.

DNRP contracted with SoundEarth Strategies, Inc. (SoundEarth) to conduct an inspection and analysis of the lakebed in the vicinity of Lake Line. SoundEarth and Lally Consulting LLC (Lally) prepared this report, which summarizes the results of our field investigation and analyses and provides observations on the sediment transport mechanisms at work in the vicinity of the project area, including the extent to which the Lake Line shows evidence of having a role in sediment deposition in this location.

SoundEarth and Lally attended a pre-dive meeting with DNRP on March 2, 2011. The pre-dive meeting discussion topics included local community relations, the Lake Line easement and access agreement, the field work schedule and weather contingencies, sediment sampling scope of work and sampling techniques, and the reporting schedule. The number and location of sediment samples were also discussed, and it was concluded that in order to more accurately evaluate whether the Lake Line is affecting the sediment accumulation patterns, additional sediment sample locations outside of the study area were warranted. These additional sample locations were intended to provide a baseline for the study because the sediment in these areas would not be affected by the position of the Lake Line. DNRP tentatively approved the additional sample locations if the samples could be collected within the allotted time frame of a 2-day field event.

The following documents and data were provided by King County to SoundEarth and Lally in support of the sedimentation analyses:

- Kenmore Interceptor Section 2B – Construction Drawings, Cross Sections, Plans, and Details
- Kenmore Interceptor Manhole Locations
- Utility Easement – Volume 4515, Pages 222 and 223

2.0 FIELD INVESTIGATION

Field investigations were performed at the study area by SoundEarth and Lally personnel June 15 and 16, 2011. A 20-foot-long, aluminum diving support vessel was employed and mobilized to the site, along with dive equipment, a piston core sampler system, an underwater camera, a global positioning system (GPS) unit, a laser rangefinder, and ancillary equipment. The vessel was operated by Global Diving & Salvage, Inc., and skippered by personnel having knowledge of the locations of the Lake Line and manholes through prior work at the site.

2.1 DIVING OBSERVATIONS

On June 15, 2011, SoundEarth and Lally personnel visually inspected the lakebed of the study area using scuba equipment. Observations commenced in the vicinity of Manhole 37, near the northeast end of the study area. In total, approximately 2,500 linear feet were covered by the dive investigation including between 17360 and 17731 Beach Drive Northeast, where the Lake Line is situated closest to the shoreline; between the Lake Line and the outlets of Lyons Creek and McAleer Creek; and between approximately 16726 and 16740 Shore Drive Northeast, outside and southwest of the original study area.

Numerous dive transects were performed, both shore-perpendicular across and shore-parallel along the Lake Line alignment. Observations made by the diver over the course of the investigations were relayed to personnel aboard the survey vessel and recorded. Appendix B provides a field record of observations and positions, as well as photos taken during the dive and field investigation activities. A summary of findings from the dive survey are provided below.

Visibility was less than approximately 5 feet, and submerged aquatic vegetation was very dense throughout the majority of the study area, making visual observations of the bottom conditions often difficult. Several underwater photos were taken; however, image quality was poor due to the poor visibility in the water column and vegetation density. Observations of bottom conditions were most often made by feel or, where vegetation was not overly dense, by viewing within inches of the lakebed. Care was taken to minimize fin movements to avoid resuspending bottom sediments, thereby further impairing visibility.

Although the Lake Line was not exposed throughout much of the study area, its position was established by identifying the locations of Manholes 35 and 36, which had been previously marked by buoys, and by using a mapping-grade GPS unit to identify the locations of Manholes 34A, 37, and 38, the coordinates of which had been provided by DNRP. The Lake Line was assumed to run in a direct line between the manhole locations, as depicted on the Lake Line as-built construction plans and drawing. Diving personnel were able to physically locate Manholes 35, 36, and 37, as well as a section of the Lake Line's concrete conduit that extends in a southerly direction from Manhole 37 throughout the study. Manholes 34A and 38, as well as the remaining sections of the concrete conduit, were covered by sediment and vegetation and were not physically identified in the course of the investigation.

Both shoreward and lakeward of the Lake Line, the lakebed surface sediments consisted predominantly of loose, silty, fine sand and/or sandy silt and organics. As noted and photographed during the dives, dense stands of Eurasian watermilfoil (*Myriophyllum spicatum L.*) were present within and outside of the study area, with the exceptions of areas with coarser sands and gravels in the nearshore to shoreline zones and outlets to McAleer and Lyons creeks.

The lakebed bathymetry was observed as gently sloping to flat, with no significant undulations along or across the Lake Line alignment or nearshore areas within the study area. Except in nearshore areas, generally shallower than 3 to 5 feet, the lakebed surface material was compressible and appeared to be shoaling material. At depths shallower than 3 to 5 feet, the lakebed was generally stiffer sands and gravels, with less vegetation.

Near the outlets of both Lyons and McAleer creeks, the lakebed consisted of fluvial deposits of coarser sands, and gravels approximately 2 inches in diameter and smaller. These materials were noted as visually similar to the sediments found in the creeks. The water depths over the creek offshore deposits were generally shallower than adjacent offshore areas. Deposits of coarser and stiffer sands appeared to extend approximately 100 to 300 feet on either side of the creek outlets, but generally trended in a net northeasterly direction within the study area.

Outside the original study area to the southwest, the materials also appeared to be coarser sands and gravels along the Lake Line alignment, as influenced by the McAleer Creek shoal, trending to more compressible, finer sands and organics within about 100 feet west of the creek outlet. In this area it was noted, by feel, that some form of geotextile fabric had been placed offshore of at least one property on the lakebed. The area of geotextile fabric placement was estimated to cover at least 1,000 square feet of the lakebed, and it was surmised that the fabric was installed for suppression of submerged vegetation.

The concrete conduit of the Lake Line was physically encountered offshore of the residence at 17364 Beach Drive Northeast. The Lake Line was covered with at least a 1-inch-thick layer of sediment in this area, but could be followed by running ones hands over the approximate 5-foot-wide concrete box conduit. About 200 feet south of Manhole 37, in front of 17360 Beach Drive Northeast, an approximately 10- to 15-degree southward turn was noted in the Lake Line concrete box conduit. In the vicinity of the turn, the lakebed was noted as dropping in elevation approximately 0.5 feet on the lakeward side of the Lake Line relative to the elevation of the sediment on top of the Lake Line conduit and the shoreward lakebed. The slight change in elevation extended a distance of approximately 10 feet; further south, the concrete box conduit was covered by sediment and could not be located by feel.

Manholes 35 and 36 were visually located since they had been previously marked with floats. The manholes were measured to be approximately 5 feet in diameter and had lifting eyes welded on the top plates. The manholes, like the Lake Line, were surrounded by dense Eurasian watermilfoil.

Dive observations yielded the following initial findings regarding the erosional and depositional environment in the vicinity of study area:

- The areas investigated, within and immediately to the southwest of the study area, appeared to be depositional, based on the presence of compressible fine sands, silts, and organics at the lakebed surface.
- The surface sediments appeared to result from numerous potential sources including shoaling deposits from adjacent creek outlets; beach erosion; and organics/detritus from dense stands of Eurasian watermilfoil, overhanging trees in a few locations, and perhaps anthropogenic influences from historical or current mill and plywood operations.
- The dense growth of Eurasian watermilfoil within the study area likely has an effect on sediment transport processes, as well as vessel navigation.

- Visual inspections of areas proximal to and beneath several docks were performed, with no significant accretion or erosion patterns noted by the pile alignments or moorings.
- Erosion was observed along several areas of the shoreline within the study area, particularly adjacent to shore landings for the dock structures and along the downdrift side of armored beaches. A close inspection of the shorelines was not within the scope of this investigation; however, it was observed that natural beaches and man-made beaches are present within and adjacent to the study area.
- No significant differences were noted in the surface sediment composition or vegetation density on either side of the Lake Line.
- There were no obvious indications that the Lake Line was contributing to or had contributed to the sedimentation patterns in the study area, other than localized effects within a few feet of the emergent section of the Lake Line southwest of Manhole 37. At this location, the lakeward bed elevation dropped approximately 0.5 feet relative to the top of the Lake Line along an approximately 10-foot section of the conduit. The lakebed elevation was flush with the top of the conduit along this section.

2.2 SEDIMENT SAMPLING

Additional investigations of lakebed sediments were conducted on June 16, 2011, by SoundEarth and Lally personnel from the sampling vessel. Sediment sampling was performed using a piston core system with a stainless steel, 1.5-inch-diameter, 6-foot core. Twelve samples at six paired stations were collected within the original study area (Stations 2 through 7), and an additional four samples were collected at two paired stations (Stations 1 and 8) located outside the study area to the northeast and southwest, respectively. Samples were collected in pairs along the Lake Line alignment both shoreward and lakeward of the Lake Line. Station 1 was located to the northeast of the point where the Lake Line intersects the shoreline; sediment samples from this station were collected at similar distances from the shore as those collected from the other stations. Sediment sample and station locations are depicted on Figures 2 and 3.

Refusal (i.e., the inability to further advance the sampler) was generally met within 3 feet of the lakebed surface. In the vicinity of Lyons Creek and McAleer Creek, the sampler met refusal at depths of less than 1 foot due to the presence of compacted sands and gravel in the surface layer. The core samples were extruded in a core tray on the deck of the survey vessel for preliminary analysis and cataloging. Several of the samples that exhibited distinct layers of sediment were partitioned. All samples were photographed and placed in individually labeled and sealed plastic bags for grain-size analysis at a geotechnical laboratory.

The depth to the sediment surface at each sample location was measured by lead line sounding and corrected to U.S. Army Corps of Engineering (Corps) datum. The lake elevation as measured at the Corps Kenmore gage was 22.13 feet on June 15, 2011, and 22.15 feet on June 16, 2011. Table 1 summarizes the sample locations and corrected depths for each sediment sample location.

The results of the sediment sampling activities indicate that in areas other than the Lyons Creek and McAleer Creek outlet shoals, surface sediment generally consisted of fine sand with silt and organics, overlying a thicker layer of finer sediments consisting of organics and silt with some sand. It was noted that both the surface layer and substrate were comprised of shoaling materials, with the surface layer appearing to consist of fine sands, likely originating from the adjacent creek outlets and/or shoreline erosion. The fine sands overlay a more organic-rich layer, perhaps from in-place decomposition of aquatic vegetation or deposition from other sources. More detailed analyses of the geotechnical composition of the samples are described below and in Appendix C.

2.2.1 Geotechnical Analyses

Sediment samples were delivered to the HWA Geosciences Inc. laboratory in Bothell, Washington, on June 16, 2011, for testing and grain-size analysis. Moisture contents of the samples were determined in accordance with American Society for Testing and Materials (ASTM) D2216, and grain-size distributions were determined in accordance with ASTM D422. Standard sieve analysis was employed for the grain-size analysis, as well as a hydrometer analysis when a significant fines fraction was present. Particle-size distribution reports were generated for each sample; the reports provide grain-size curves and other information, including the percentages of fines, sand, and coarser fractions, as well as the moisture content of the samples. The complete geotechnical testing report is provided as Appendix C.

A summary of the laboratory testing results, including sample location, depths, and geotechnical characteristics, is provided in Table 1.

2.3 DEPTH MEASUREMENTS

Depth measurements were collected at each sample location by lead line sounding. Table 1 summarizes the locations and corrected depths of the soundings.

Figure 3 plots the sample depths, corrected to Mean Sea Level datum, along with the 1966 as-built depth profile. Lack of adequate data density and limited or unknown horizontal and vertical positioning accuracy between the two survey methods prevent a reliable comparison between the surveys to be made. However, it can be observed from the sample location depth measurements and from stations 7 and 8 that the shallowest depths are located over the shoals of McAleer and Lyons creeks. In general, there appear to be no significant deposition patterns along the Lake Line alignment in other than the creek areas. Although the lakebed depth increased with distance from shore in most portions of the study area, the depth decreased with distance from shore in the vicinity of stations 7 and 8, which are the two southwesternmost stations. The cause of this irregularity was not apparent. To evaluate the sedimentation depths and patterns by depth measurement, with any level of useful accuracy, both the historical and current surveys would need to encompass a wider study area, on either side of the Lake Line, and similar data density and sounding methods would need to be employed for all comparative surveys.

3.0 SEDIMENTATION ANALYSES

Supplemental to the field investigations, additional lacustrine sedimentation analyses of the north end of Lake Washington were undertaken by SoundEarth and Lally in the effort to assess the sedimentation conditions and the relative contributions that the Lake Line and other factors may have made toward the reported decrease in lakebed depth in the study area.

3.1 SITE GEOMORPHOLOGY

The study area is located at the north end of Lake Washington, which is a long, narrow ribbon lake, excavated by advancing glaciers. As the Puget lobe of the Cordilleran Ice Sheet flowed southward near the end of the Late Pleistocene, it met bands of harder and softer rock. Erosion of the softer rock occurred more quickly than that of the harder rock and a linear depression was created in the flow direction. When the glacier melted, the lake filled with meltwater, which was retained by morainal deposits (Booth 1994).

Ribbon lakes such as Lake Washington commonly have rivers at each end; one river an inlet and one river an outlet. However, in the case of Lake Washington, both rivers (the Cedar River to the south and the Sammamish River to the north) are inlets. The outlet for Lake Washington is the Lake Washington Ship Canal, which empties into Puget Sound. There are also several creeks that feed Lake Washington. Two of the creeks, Lyons Creek and McAleer Creek, empty into and contribute sediment to the study area. The Sammamish River outlet is located approximately 4,000 feet to the east of the center of the study area and is likely not a significant source of sediment to the study area.

The shoreline of Lake Washington, including that of the study area, has been highly developed. Within and adjacent to the study area, large portions of the shoreline are hardened with vertical bulkheads of various composition, including large, keyed-in rock or sheet piles. Less frequently, the shoreline consists of native or man-made beach. Based on review of aerial photography of the study area, approximately 60 percent of the shoreline within the study area is hardened and 40 percent is soft native or beach shoreline. Approximately 35 of the 42 properties within the study area have docks. Docks vary in configuration and construction, but are generally built shore-perpendicular with timber piles and fixed pier decks. Based on review of historical aerial photographs, between 1963 and 2011, 15 or more docks appear to have been constructed within the study area.

A review of historical aerial photographs indicates that Lyons and McAleer creeks are significant sediment sources to the littoral system within the study area. As viewed during the field investigation and supported by analysis using aerial photography, the net longshore direction along the north shoreline of Lake Washington, including the study area, is to the northeast. This is evident based on the accretion of sediments on the updrift (southwest) side of structures and headlands, and erosion immediately downdrift (northeast).

3.2 SEDIMENTATION PROCESSES

The primary forces driving lacustrine sedimentation processes in nearshore areas are lake levels, winds, wind-waves, and currents. The following sections characterize these forces in the study area, based on prior work.

3.2.1 Lake Levels

Water surface elevations, or lake levels, control the depth or height to which sediment is eroded and transported along lake shorelines and nearshore zones. The water level of Lake Washington is controlled by the Corps at the dam adjacent to the Ballard Locks. The legislation authorizing the Corps to maintain the Lake Washington Ship Canal, established by Congress June 25, 1910, requires that the lake level in Lake Washington be maintained between 20.0 feet and 22.0 feet, Corps Locks datum.

To meet this requirement, the Corps starts each planned calendar year with the lake level at an elevation of 20.0 feet as part of the winter holding period. On or about February 15 of each year, the lake level is allowed to rise slowly during the spring refill period to elevation 22.0 feet on or about May 1. The lake is maintained at elevation 22.0 feet through the summer conservation period and then allowed to recede during the fall drawdown period starting on or about November 1. By December 1, the lake level has typically returned to elevation 20.0 feet (Corps 2004). The actual Lake Washington water level cycle can deviate from the standard operating schedule depending on the amount of rainfall received during the year and other factors.

The Corps maintains water level gages on the Lake Washington Ship Canal at the Ballard Locks and at the north end of Lake Washington in Kenmore. The Ballard Locks gage data is available for the period 1999–present and can be accessed online at <http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=id:LKW>. The Kenmore gage data is available for the period 2004–present and can be accessed at <http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=id:LWKW>. Both gages report water level data to the Corps datum.

Data from both Ballard Locks and Kenmore gages were compiled and analyzed for the period 1999 through 2009. A summary hydrograph for the period 2004 through 2009 comparing the two gage locations is presented in Diagram 1.

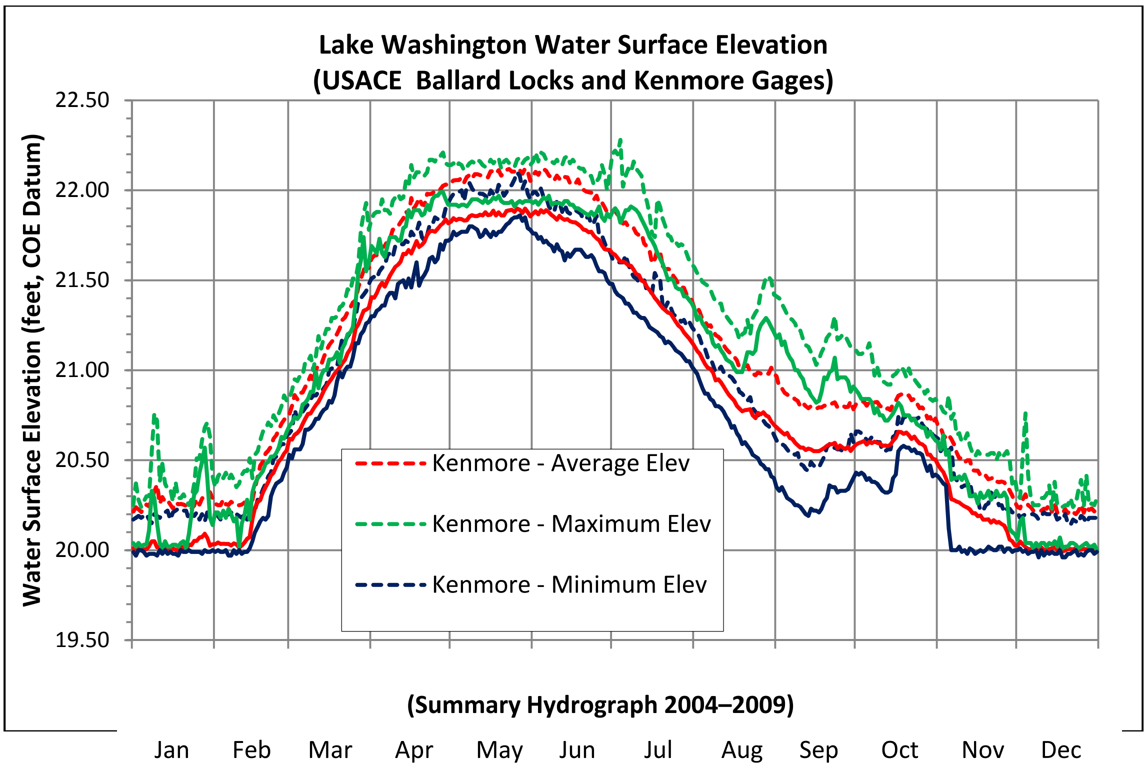

Diagram 1. Lake Washington Water Surface Elevation at Ballard Locks and Kenmore Gages, 2004–2009. (Lally 2010)

As shown in Diagram 1, the lake level at the Kenmore gage is consistently 0.15 feet to 0.30 feet above the elevation at the Ballard Locks gage. According to the Corps, this is at least in part attributable to water “stacking” at the north end of Lake Washington due to basin narrowing and the dominant southerly winds.

3.2.2 Wind Regime

The major axis of Lake Washington is approximately 23 miles long and lies in a north-south direction. The predominant weather systems of the Pacific Northwest from late fall to early spring generate winds from the southwest through the southeast. Northerly winds (from the north) accompany cold fronts that pass through occasionally during the winter. Light, northerly winds also occur during the summer season. The general meteorological conditions and site topography are not conducive to the formation of winds from either the west or east. The most severe storm winds over Lake Washington are southerly (from the south) and are associated with the strong, semipermanent low pressure system that exists over the Gulf of Alaska in winter (Glosten Associates 1993).

Wind analyses for Lake Washington were performed using Washington State Department of Transportation meteorological record files, including wind speed, direction, and frequency data, from the Evergreen Point Floating Bridge (SR-520) meteorological station (Lally 2010). The data generated from the SR-520 station, located approximately 45,000 feet south of Kenmore, appear to be the most representative of the wind conditions having an effect on the sedimentation processes in the study area.

The raw wind data, consisting of over 4,600 individual files and 8.1 million wind measurements, including date, time, and a number of wind speed and direction values, were statistically analyzed to develop 1-year and 10-year recurrence interval wind spectra as the basis for wave and sediment transport calculations. A wind rose was developed for the period 2000 through 2009 using the hourly wind data (Diagram 2). The wind rose illustrates how the wind speed and directions are typically distributed on Lake Washington.

As can be seen from Diagram 2, the wind spectra for the area are generally bimodal. The dominant mode is from the southeast through southwest (150 degrees [°] to 250° from north), a directional range that is also associated with the strongest winds. Winds in this directional range occur approximately 45 percent of the time. The second mode ranges northwest through northeast (330° to 40° from north) approximately 30 percent of the time. Winds in this range are more moderate than those from the south.

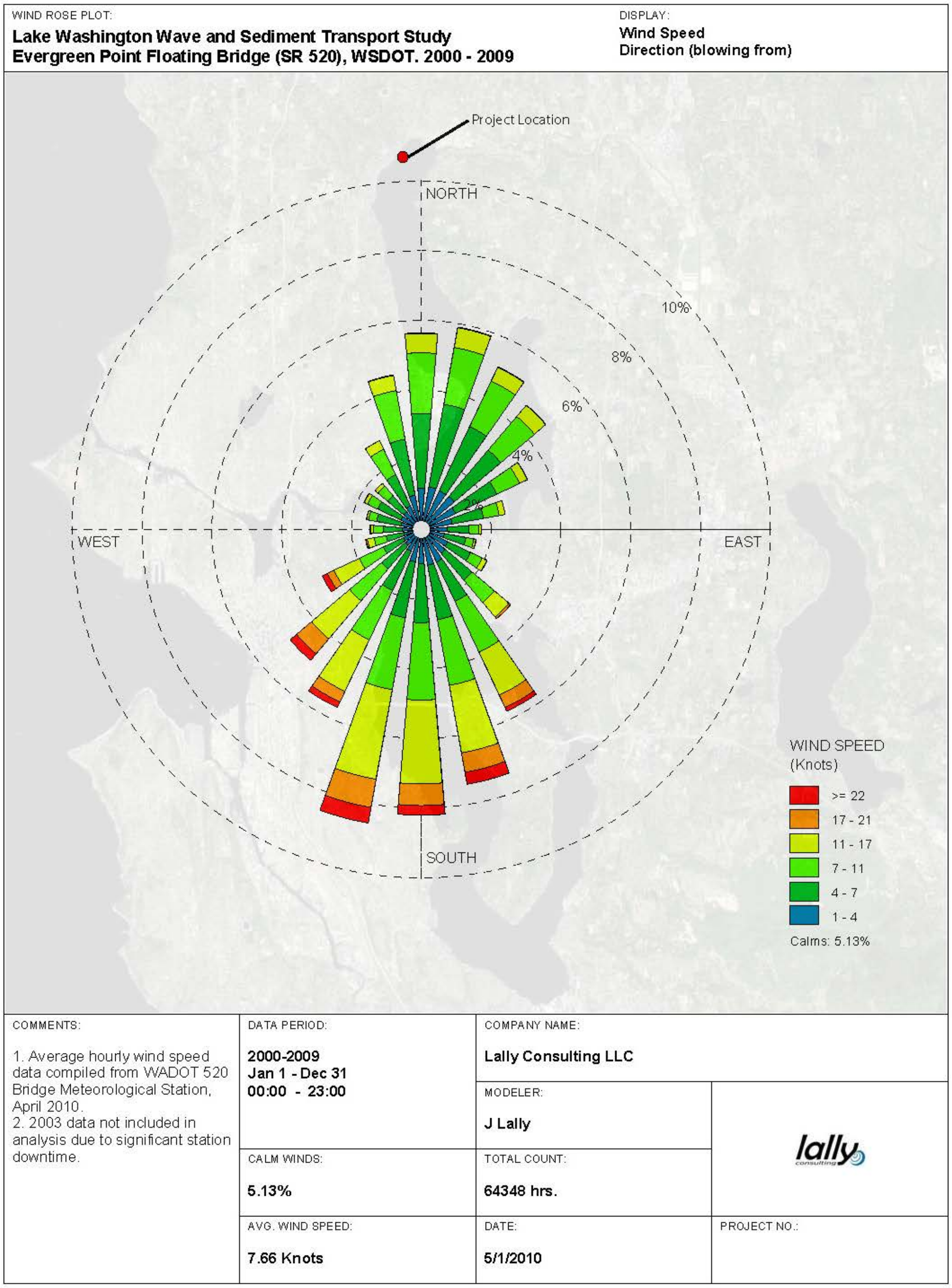

Diagram 2. Lake Washington Wind Rose 5-Min. Avg. Wind Speeds at SR-520 Bridge, 2000–2009.

A scatter plot for 1 year (Diagram 3) presents the directional distribution of winds, further showing that the strongest and most frequent winds are from the south. This characterization of the wind regime further suggests that the net longshore currents along Lake Washington shorelines and nearshore zones are generally toward the north.

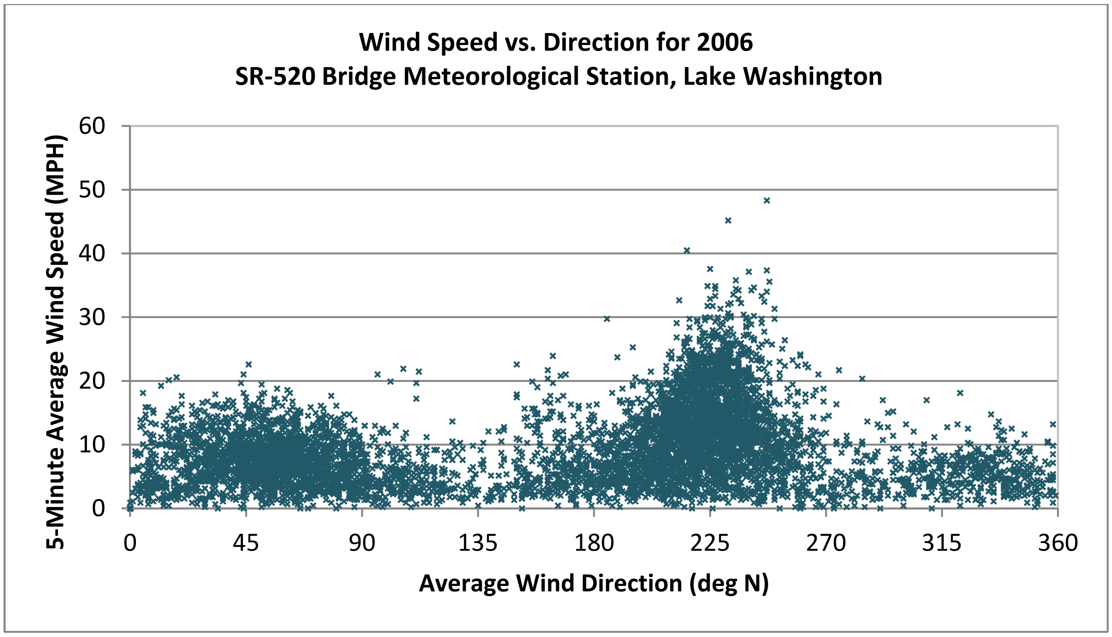

Diagram 3. Scatter Plot of Wind Speed vs. Wind Direction, SR-520 Bridge, 2006. (Lally 2010)

Considering the critical relationship between wind and wave generation, and the associated sediment transport regime in the Lake Line study area, it is important to recognize that the lake winds can be highly localized due to topography effects. Along the east and west shores of Lake Washington north of the SR-520 bridge, hills several hundred feet high exert a significant steering influence on the winds, in the case of southerly winds, to the northeast. The lake also narrows at its north end, which likely creates a Venturi effect and increases wind speed.

3.2.3 Wave Regime

When wind blows over water it exerts a stress on the surface, transferring some of its energy into the water and forming waves. As wind-waves travel across the water surface, orbital motions are created within the wave. In deep water, the motions approximate closed circular orbits. As the wave advances into intermediate water, the motions become more elliptic as the wave “feels” the bottom. In shallow water, the motions become a series of horizontal oscillatory movements capable of transporting sediment. A generalized wave orbital motion diagram is shown in Diagram 4.

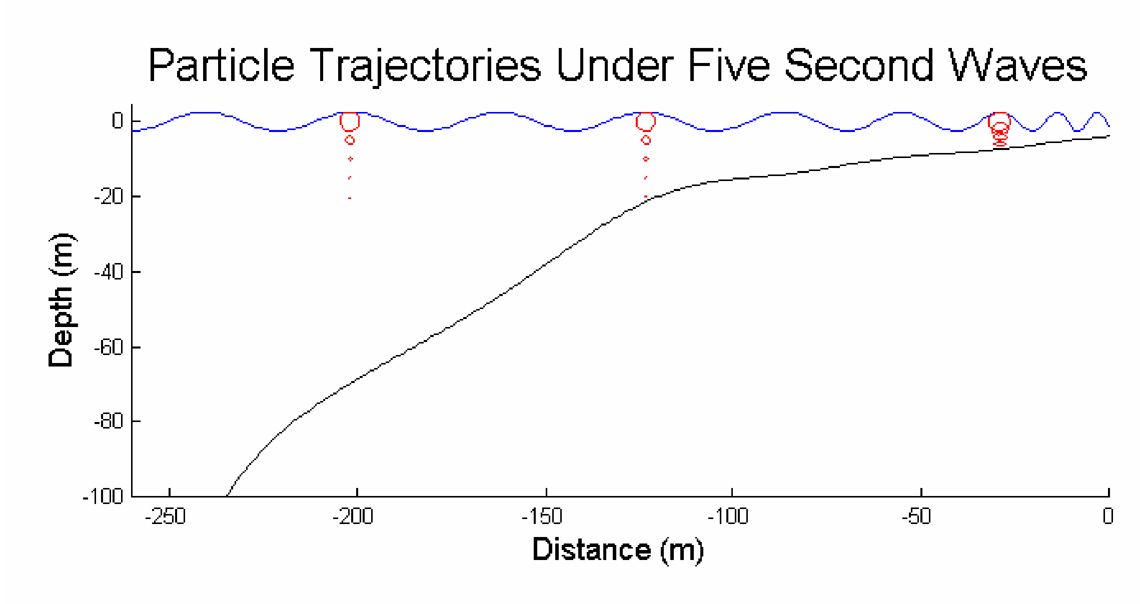

Diagram 4. Diagram of Water Orbital Motions under a Wave. (From TRDI 2006)

The wind-waves that are generated in Lake Washington are a function of the wind speed and duration, as well as the depth of the lake and the fetch (the distance the wind travels over the lake). The generation of wind-waves for a given wind speed is either limited by the duration of a storm event or by the fetch. Wave generation, therefore, is referred to as being either duration-limited or fetch-limited. For a smaller body of water, like Lake Washington, the generation of wind-waves is fetch-limited.

Due to the location of the Kenmore Lake Line project site on the north end of Lake Washington, only winds from approximately 110° (east-southeast) through 205° (southwest), can affect the formation of wind-waves incident to the site. The longest fetch for the study area is estimated at 7.3 nautical miles, or 8.4 statute miles, from 162° (south-southeast). This is a relatively long fetch for Lake Washington, which likely allows for the formation of some of the highest waves and shoreline currents on the lake.

3.2.4 Sediment Transport Processes

The two main littoral current systems that can develop in the nearshore forward of breaking waves are longshore currents and cross-shore currents. Longshore currents generally result from waves crests approaching the shoreline obliquely, while cross-shore currents form when waves approach with their crests approximately parallel to the shoreline. Both current types are capable of transporting large quantities of sediment within a nearshore shoreline system.

The major axis of the Kenmore Lake Line study area is oriented approximately 215° (N35°E), which suggests that, regardless of storm intensity, the angle of wave incidence along the study area is predominantly longshore, with likely a cross-shore component.

The sum of all the movements in longshore or cross-shore directions is known as the gross sediment transport rate. The term “littoral” accounts for movements in both longshore and cross-shore directions. The net littoral transport rate quantifies the sediment movement in a single direction.

From prior work, it has been estimated that net sediment transport rates within the nearshore zone with a more moderate wind regime in the central section of Lake Washington are 5 to 10 cubic yards per foot per year (Lally 2010). The nearshore zone extends from approximately the initiation of wave breaking, or approximately the 5- to 6-foot-depth contour in the case of Lake Washington, to the shoreline. Sediment transport rates can be affected by grain size, bathymetry, presence of structures, and other factors.

When current velocities reach a critical threshold, sediment is entrained (eroded) and transport is initiated. Once sediment is in motion it can generally be described as moving in one of two modes: bedload transport or suspended transport (Diagram 5). Bedload transport occurs when grains are in continual or frequent contact with the bed. Particles move by creeping or rolling in a zigzag pattern along the bed. Suspended transport occurs when particles leave the bed due to fluid turbulence and are predominantly transported in the water column. Particles settle out and deposit when current (settling) velocities fall beneath the critical transport threshold. Settling velocities of the particles will vary depending on their grain size.

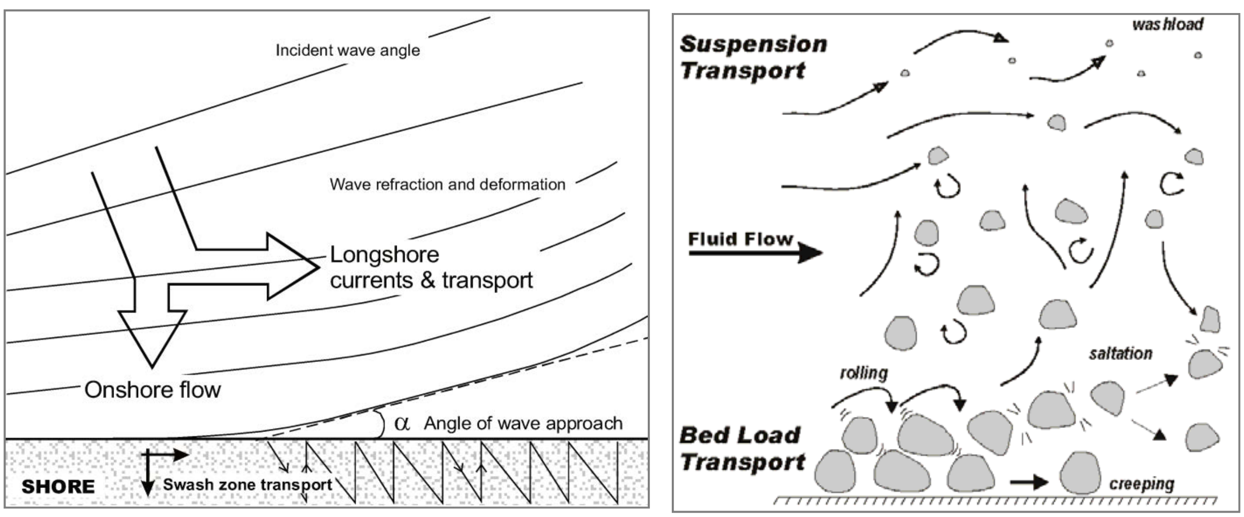

Diagram 5. Littoral Currents and Sediment Transport Mechanics. (Adapted from Dawe 2006)

Whether a particle is transported in suspension or by bedload is typically a function of the fluid velocity and the size, shape, and density of the grain. Fine particles have low critical threshold velocities and are more readily set into motion. Coarser particles are more resistant to moving and may require higher velocities to set in motion. It is generally accepted that gravel is transported as bedload, and that sands and finer material are transported through a combination of both bedload and suspension depending on the wave conditions (Dawe 2006). In most nearshore systems, including the Lake Line study area, both of these mechanisms play a role.

3.3 SEDIMENTATION ANALYSES

The findings from the field investigation and sedimentation processes evaluation suggest that the study area is in a net depositional area, regardless of whether the Lake Line is in place. The following primary conclusions were made based on our analyses:

- Submerged aquatic vegetation appears to play a role in limiting both the initiation of sediment movement and deposition patterns within the Lake Line study area. The aquatic vegetation is of significant density and height that it likely impacts vessel navigation and can create a perceived shoaling condition.
- The sediment depositional patterns on both sides of the Lake Line are essentially the same and appear to have reached a state of dynamic equilibrium with respect to uniform deposition across the Lake Line.
- Lyons and McAleer creeks and erosion of shoreline areas within and outside the study area appear to be the primary sources of sediment. The in-place decomposition of aquatic vegetation may also be a source of shoaling material.
- The north end of Lake Washington is in a "downdrift" littoral cell with respect to lacustrine sediment transport processes, which results from the predominant wind, wave, and current directions in the lake.
- The dominant southerly wind-wave direction produces a net longshore current from southwest to northeast. This is supported by analysis of aerial photography and observations in the field.
- Once set in motion, sediments migrate in the nearshore zone through a combination of bedload and suspension transport.

4.0 CONCLUSIONS AND RECOMMENDATIONS

It is our opinion that the study area is in a net depositional littoral cell of Lake Washington and will continue to experience accretion of sediments. It is also our opinion that the Lake Line sewer pipeline, where originally emergent, likely had some localized effect on the sedimentation immediately within the vicinity of its alignment. However, the sedimentation volumes are overwhelmingly more attributable to the location of the study area being at the north end of the lake and to natural sedimentation processes in the study area.

5.0 REFERENCES

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FIGURES

DATE:	07/07/11
DRAWN BY:	NAC
CHECKED BY:	RKB
GIS FILE:	0773_2011_VM

PROJECT NAME:	KENMORE LAKEBED
PROJECT NUMBER:	0773-001
STREET ADDRESS:	NA
CITY, STATE:	KENMORE,WASHINGTON

0 0.25 0.5 0.75 1 Miles

APPROXIMATE SCALE IN MILES

SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

FIGURE 1
STUDY AREA VICINITY MAP

11/16/2010

SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

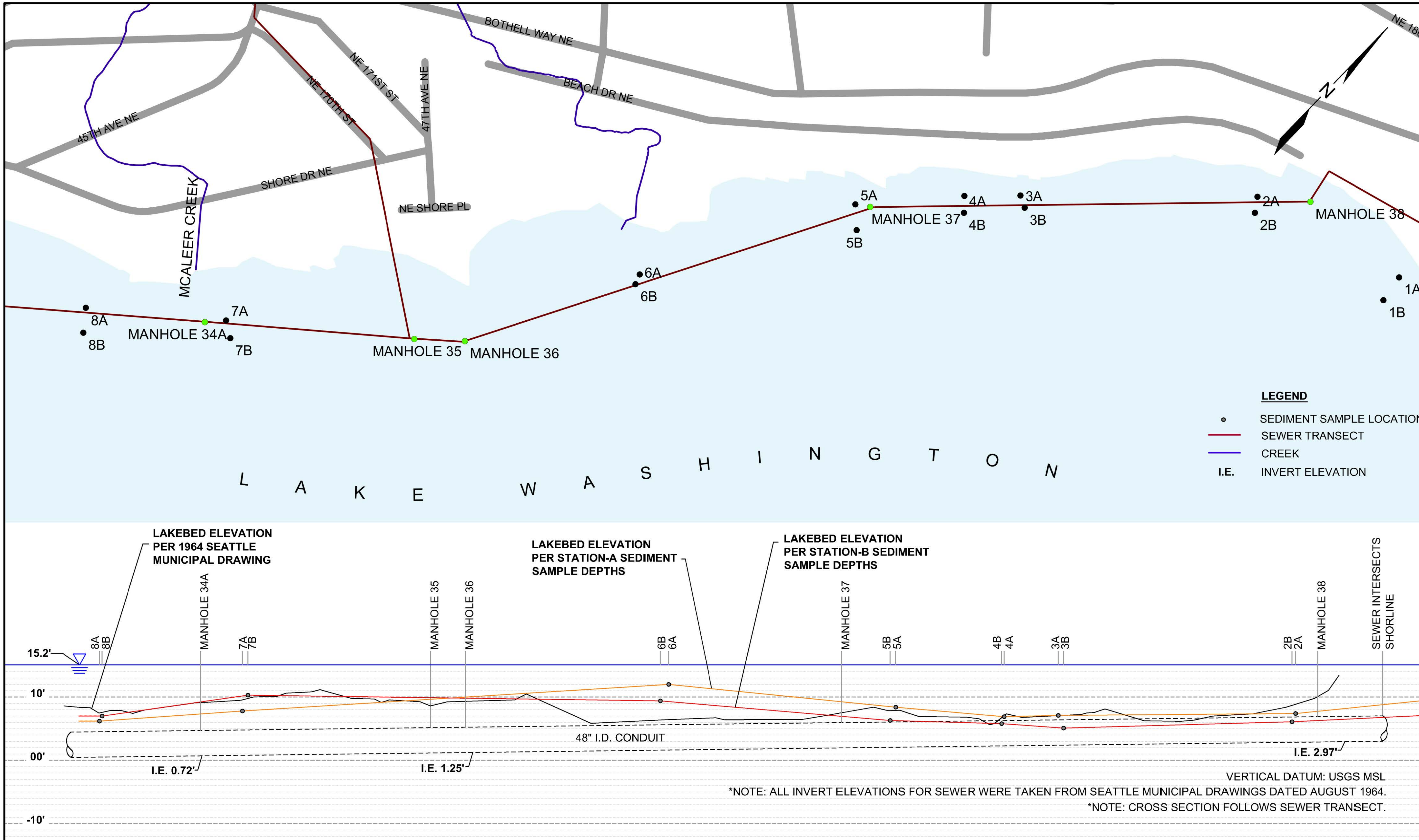
DATE: 07/07/11
DRAWN BY: .... NAC
CHECKED BY: .... RKB
GIS FILE: .... 0773_2011_EL

PROJECT NAME: .... KENMORE LAKEBED
PROJECT NUMBER: 0773-001
STREET ADDRESS: .... NA
CITY, STATE: .... KENMORE,WASHINGTON

0 200 400 600 800 Feet
APPROXIMATE SCALE IN FEET

FIGURE 2
EXPLORATION LOCATION PLAN

File: P:\0773 Kenmore Lakebed\Technical\GIS\MXDs\basemap.mxd



SoundEarth Strategies
WWW.SOUNDEARTHINC.COM

DATE: 7/12/2011
DRAWN BY: VPB
CHECKED BY: RKB
CAD FILE: 0773_2011_XS

PROJECT NAME: KENMORE LAKEBED
PROJECT NUMBER: 0773-001
STREET ADDRESS: NA
CITY, STATE: KENMORE, WASHINGTON

REGION:

0 150 300 600
APPROXIMATE SCALE IN FEET (HORIZONTAL)
20X VERTICAL EXAGGERATION

FIGURE 3
PROFILE SECTION ALONG SEWER TRANSECT

P:\0773 KENMORE LAKEBED\TECHNICAL\CAD\BASEMAP\0773-001-01_XS.DWG
7/15/2011

TABLE

SoundEarth Strategies

Table 1
Summary of Sediment Sampling and Analytical Results
Kenmore Lakebed
Kenmore, Washington

Sample ID	Sample Location		Sample Depth (feet)[1]	Corrected Lakebed Surface Elevation (feet)[1]			Sample Interval (Lakebed surface to bottom of boring in feet)	Sample Date	USCS Classification	Median Grain-Size Diameter D_{50} (mm)[2]	Moisture Content (% Dry Mass)[2]	Particle Distribution (%)[3]			
	Latitude	Longitude		Corps of Engineers Datum	MSL Datum	Metro Datum						Gravel	Sand	Silt	Clay
1-A	N 47° 45.425'	W 122° 16.028'	4.5	17.8	10.8	110.8	0.0	06/16/11	poorly graded SAND	0.19	27	0.0	97.0	3.0	
1-B	N 47° 45.411'	W 122° 16.024'	7.4	14.8	7.8	107.8	0.0	06/16/11	sandy SILT	0.07	57	0.0	48.4	51.6	0.0
2-A	N 47° 45.403'	W 122° 16.149'	7.7	14.5	7.5	107.5	0.0	06/16/11	silty SAND with organics	0.18	81	0.0	75.5	23.6	0.9
2-B	N 47° 45.396'	W 122° 16.142'	9.0	13.2	6.2	106.2	0.0 - 0.8	06/16/11	SILT with sand	0.04	103	0.0	23.4	74.2	2.4
3-A	N 47° 45.316'	W 122° 16.279'	8.0	14.2	7.2	107.2	0.0	06/16/11	silty SAND with organics	0.08	88	0.0	55.5	43.7	0.8
3-B	N 47° 45.313'	W 122° 16.270'	10.0	12.2	5.2	105.2	0.0	06/16/11	SILT with organics	0.03	157	0.0	8.6	88.9	2.5
4-A	N 47° 45.295'	W 122° 16.309'	8.2	14.0	7.0	107.0	0.0 - 0.3	06/16/11	silty SAND with organics	0.09	92	1.7	60.3	38.1	
							0.3-1.4	06/16/11	SILT	0.02	176	0.0	8.9	87.4	3.7
4-B	N 47° 45.289'	W 122° 16.300'	9.3	12.9	5.9	105.9	0.0 - 0.3	06/16/11	silty SAND with organics	0.11	84	0.0	63.2	36.8	
							0.3-1.19	06/16/11	SILT with organics	0.02	212	0.0	10.8	86.0	3.2
5-A	N 47° 45.252'	W 122° 16.364'	6.7	15.5	8.5	108.5	0.0	06/16/11	poorly graded SAND with silt	0.20	32	0.1	92.5	7.4	
5-B	N 47° 45.243'	W 122° 16.349'	8.8	13.4	6.4	106.4	0.0-0.8	06/16/11	silty SAND with organics	0.09	86	0.0	59.3	39.8	0.9
							0.8-2.3	06/16/11	SILT with organics	0.03	202	0.0	13.0	83.1	3.9
6-A	N 47° 45.147'	W 122° 16.443'	3.1	19.1	12.1	112.1	0.0	06/16/11	poorly graded SAND	0.39	22	12.8	86.4	0.8	
6-B	N 47° 45.142'	W 122° 16.440'	5.7	16.5	9.5	109.5	0.0	06/16/11	poorly graded SAND	0.34	30	3.8	94.4	1.8	
7-A	N 47° 44.978'	W 122° 16.643'	7.3	14.9	7.9	107.9	0.0	06/16/11	poorly graded SAND	0.31	28	10.9	88.0	1.1	
7-B	N 47° 44.973'	W 122° 16.631'	4.8	17.4	10.4	110.4	0.0	06/16/11	NO SAMPLE RECOVERY						
8-A	N 47° 44.931'	W 122° 16.726'	8.9	13.3	6.3	106.3	0.0	06/16/11	poorly graded SAND	0.33	27	7.6	89.1	3.3	
8-B	N 47° 44.921'	W 122° 16.714'	8.1	14.1	7.1	107.1	0.0-0.6	06/16/11	poorly graded SAND with silt	0.28	37	6.0	86.7	7.2	
							0.6-1.0	06/16/11	silty SAND	0.08	61	0.0	55.3	44.7	

NOTES:

Matrix for all samples was sediment.

Analyses conducted by HWA GeoSciences Inc., of Bothell, Washington.

[1]Lake Level on sample date, June 16, 2011, was 22.15 feet. (USACE datum), as recorded at Kenmore gage.

[2]Determined in general accordance with ASTM D2216.

[3]Determined in general accordance with ASTM D422.

% = percent

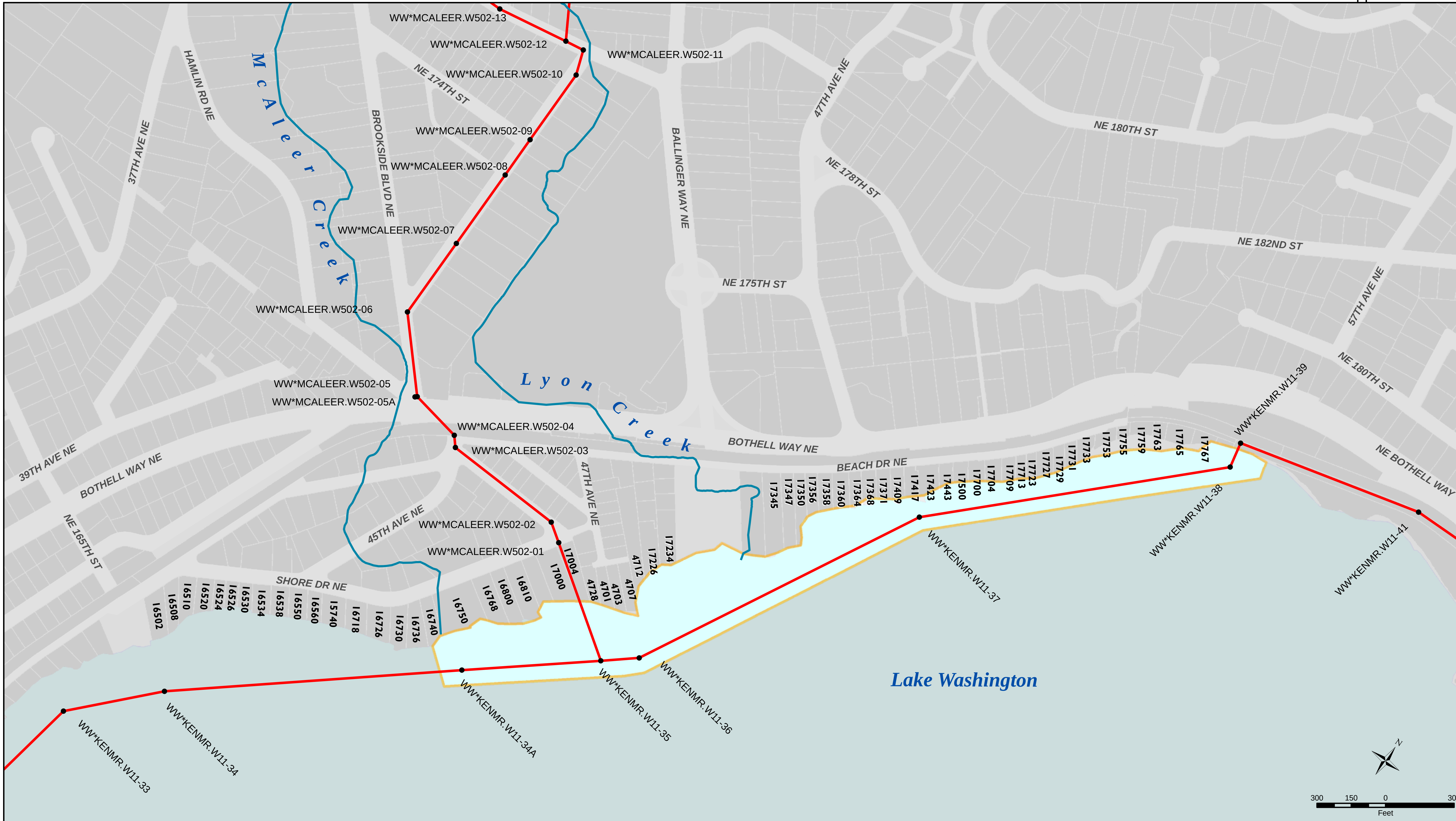
ASTM = American Society for Testing and Materials

mm = millimeters

USACE = U.S. Army Corps of Engineers

USCS = Unified Soil Classification System

APPENDIX A
KING COUNTY MAPS/DRAWINGS

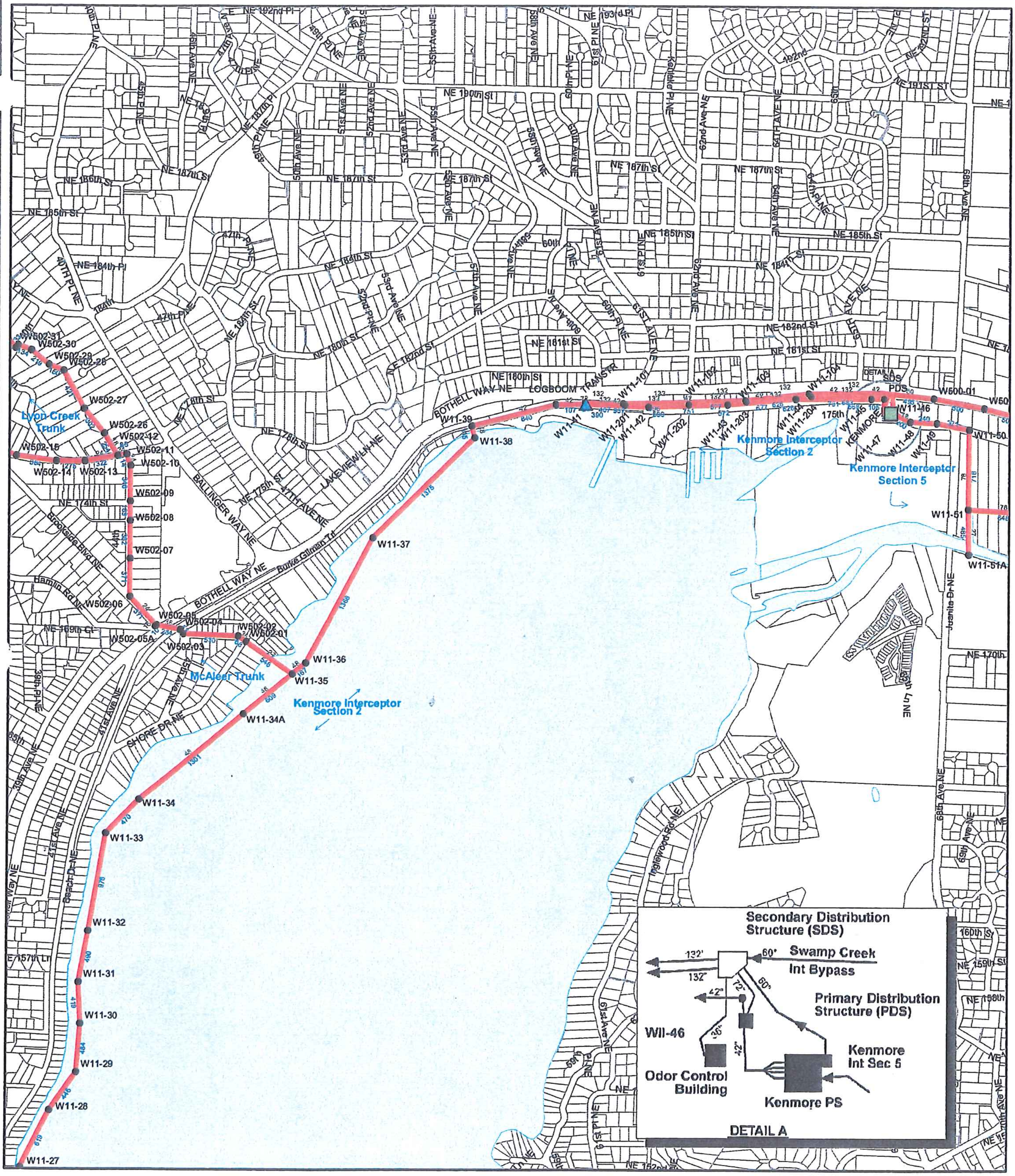


King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: \\dnrp1\projects\wtd\projects\legal\projects\Lakeline_33to41_mailing.mxd
Shaun O'Neil 20100716

Creeks
KC_WTD Manholes
KC-WTD Conveyance
Project Area

Kenmore Lakeline
Lakebed Analysis
August 2010



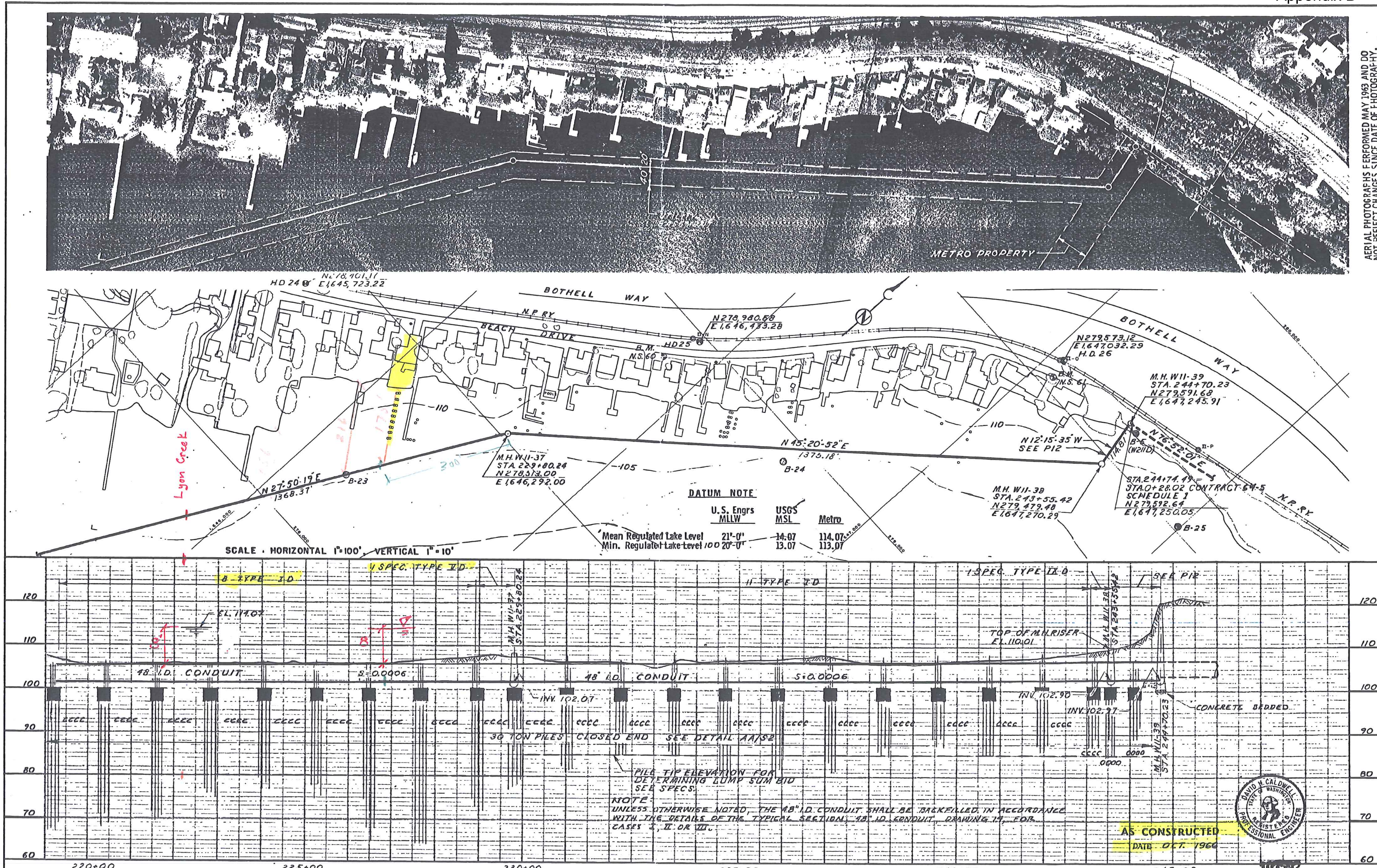
Kenmore Interceptor Section 2 B

WW*KENMR

500 0 500 1000 Feet

Map produced by GIS staff, Wastewater Treatment Division (WTD), King County Department of Natural Resources. WTD disclaims any warranty for use of this digital product beyond that for which it was designed. Neither this digital product, nor any portion thereof may be reproduced in any form or by any means without the expressed written authorization of WTD. This document includes data copyrighted by the Kroll Map Company and is being used with their permission. Use is restricted.

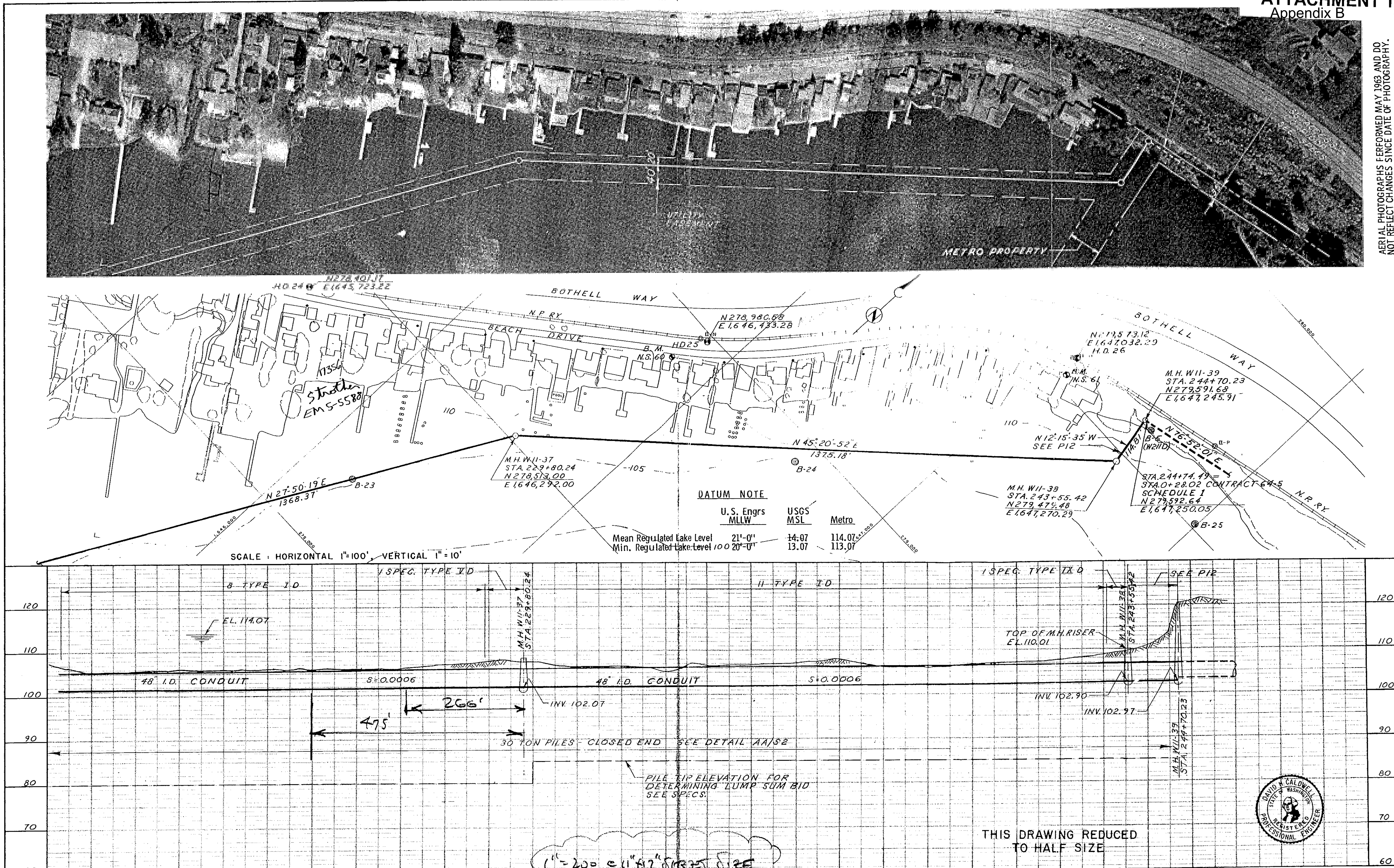
King County
Department of Natural Resources and Parks
Wastewater Treatment Division



DESIGNED JFL DRAWN DLO CHECKED JFL	METROPOLITAN ENGINEERS BROWN AND CALDWELL — CAREY AND KRAMER HILL AND INGMAN — R.W. BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE SUBMITTED: Design Engineer - Metropolitan Engineers; RECOMMENDED: Project Engineer - Metropolitan Engineers; APPROVED: Chief Engineer - Metropolitan Engineers; APPROVED: D.N. Caldwell, For Metropolitan Engineers; APPROVED: For Municipality of Metropolitan Seattle SCALE AS NOTED	FILE W211C DATE AUG. 1964	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 STA. 219+50 TO STA. 244+70.23 (END)	DRAWING NUMBER P9 SHEET NUMBER 22 OF 27

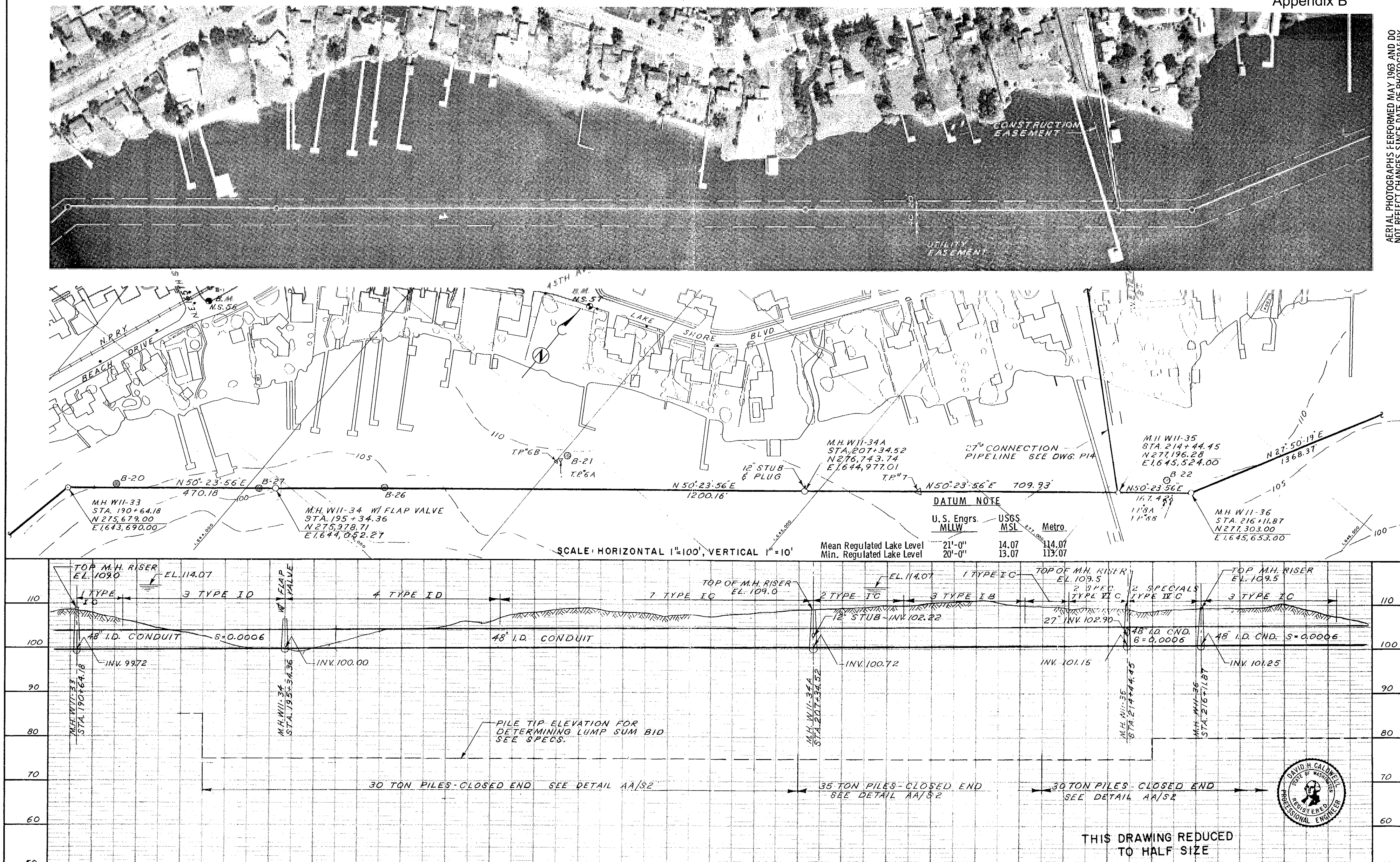
ATTACHMENT 1B
Appendix B

2/2



DESIGNED JFL / DRAWN DLO / CHECKED JFL	METROPOLITAN ENGINEERS: BROWN AND CALDWELL; CAREY AND KRAMER; HILL AND INGMAN; R. W. BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE. Submitted: Design Engineer – Metropolitan Engineers; Recommended: Project Engineer – Metropolitan Engineers; Approved: Chief Engineer – Metropolitan Engineers; Approved: For Metropolitan Engineers; Approved: For Municipality of Metropolitan Seattle	SCALE AS NOTED
FILE W211C / DATE AUG. 1964	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 STA. 219+50 TO STA. 244+70.23 (END)	DRAWING NUMBER P9 / SHEET NUMBER 22 OF 27

ATTACHMENT 1B
Appendix B
1/2



	U. S. Engrs. MLLW	USGS MSL	Metro
Mean Regulated Lake Level	21'-0"	14.07	114.07
Min. Regulated Lake Level	20'-0"	13.07	113.07

DESIGNED J.F.L. · DRAWN D.L.O. · CHECKED J.F.L.

METROPOLITAN ENGINEERS
BROWN AND CALDWELL · CAREY AND KRAMER
HILL AND INGMAN · R.W. BECK AND ASSOCIATES

MUNICIPALITY OF METROPOLITAN SEATTLE

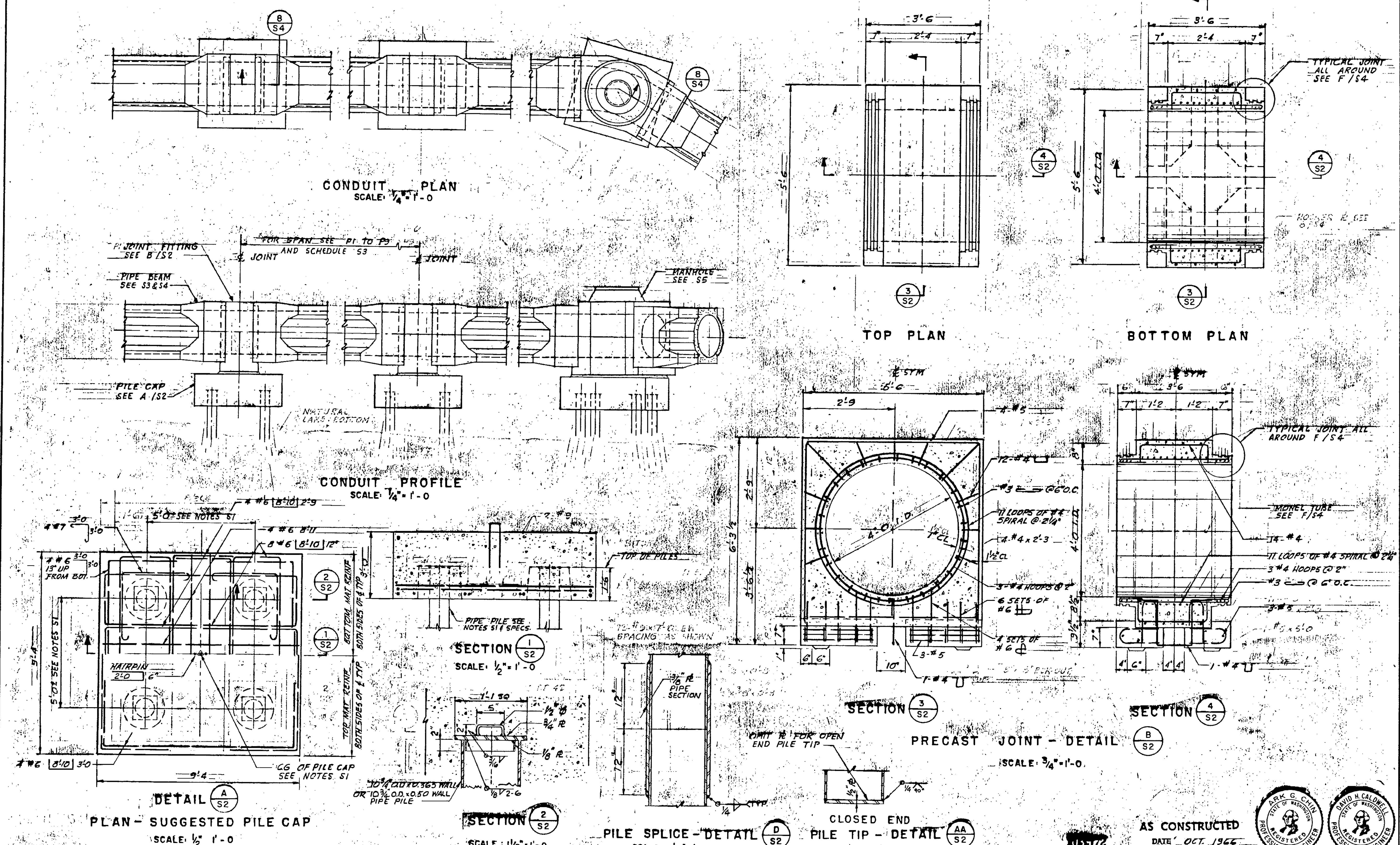
SUBMITTED: Design Engineer - Metropolitan Engineers · RECOMMENDED: Project Engineer - Metropolitan Engineers · APPROVED: Chief Engineer - Metropolitan Engineers · APPROVED: For Metropolitan Engineers · APPROVED: For Municipality of Metropolitan Seattle

SCALE AS NOTED · FILE W211C · DATE AUG. 1964

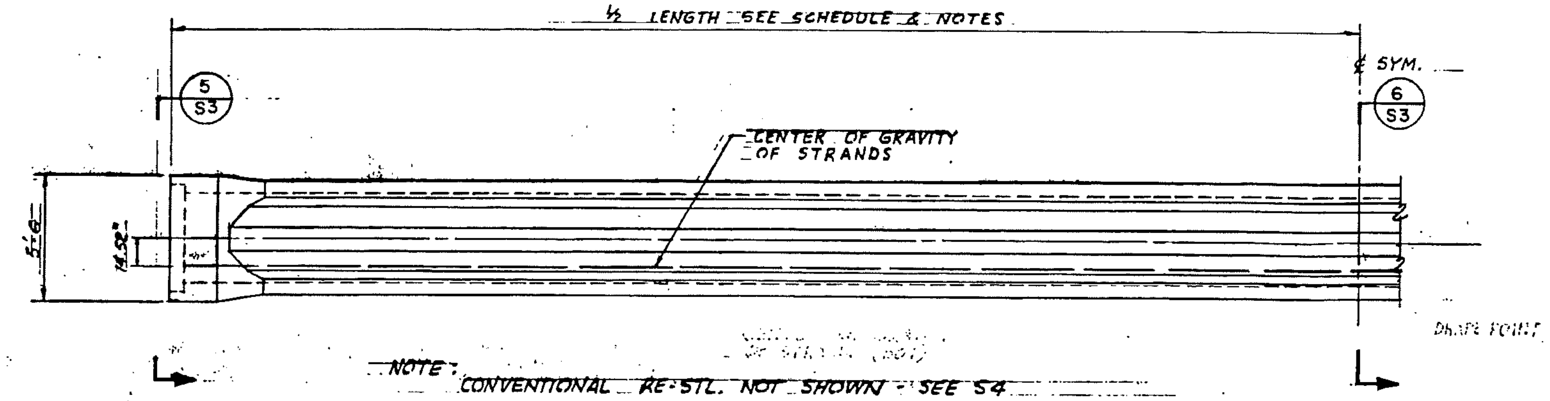
WEST POINT SYSTEM

KENMORE INTERCEPTOR SECTION 2
STA. 191+00 TO STA. 219+50

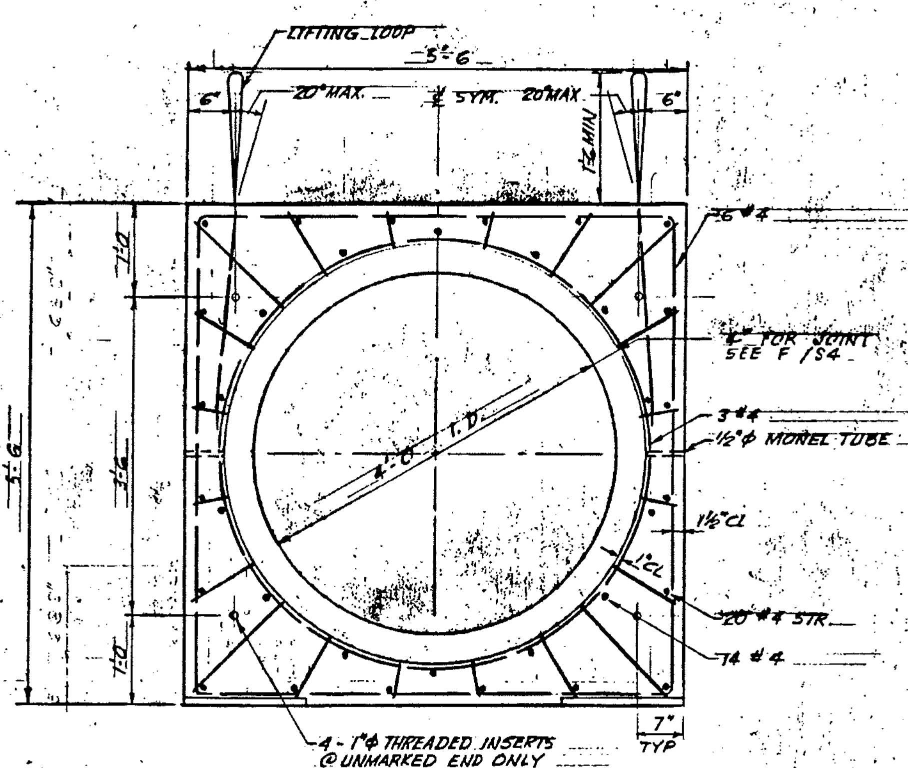
DRAWING NUMBER P8
SHEET NUMBER 21 OF 27



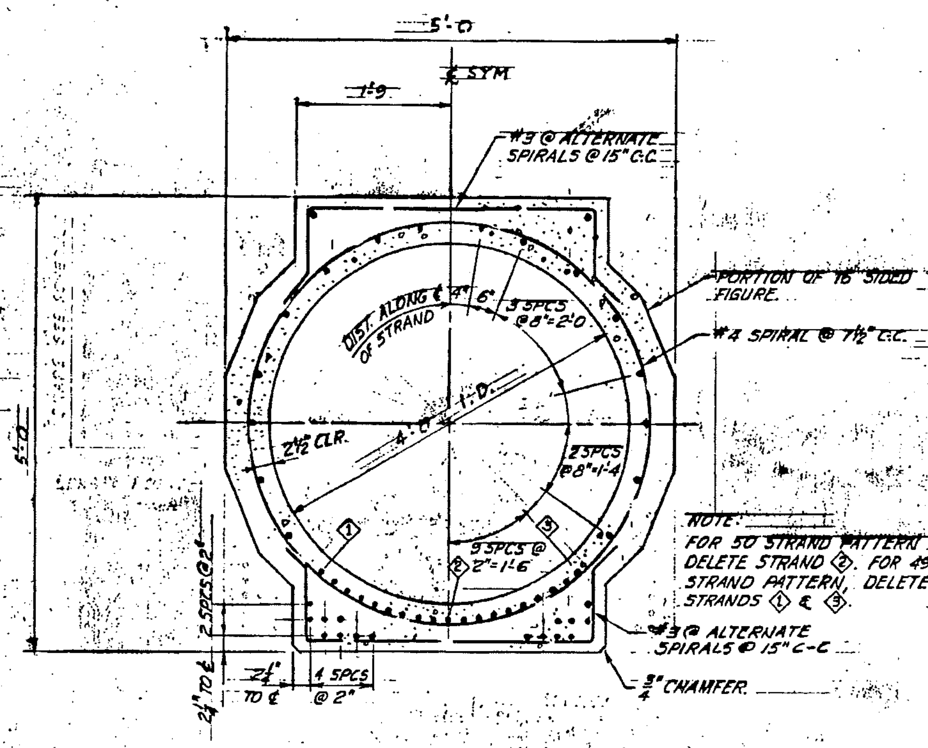
DESIGNED MGD DRAWN WG CHECKED AGC	METROPOLITAN ENGINEERS BROWN AND CALDWELL — CAREY AND KRAMER HILL AND INGMAN — R.W. BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE SUBMITTED (Design Engineer - Metropolitan Engineers) · RECOMMENDED (Project Engineer - Metropolitan Engineers) · APPROVED (Chief Engineer - Metropolitan Engineers) · APPROVED (For Metropolitan Engineers) · APPROVED (For Municipality of Metropolitan Seattle) SCALE AS NOTED · FILE W 211C · DATE AUG 1964	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 PRECAST JOINT AND SUGGESTED PILE CAP PLANS, SECTIONS AND DETAILS
				DRAWING NUMBER S2 SHEET NUMBER 5 of 27



ELEVATION PRESTRESSED PIPE BEAM - DETAIL C/S3
NO SCALE



END SECTION 5/S3
SCALE: 1" = 1'-0



CENTER SECTION 6/S3
SCALE: 1" = 1'-0

PRESTRESSED PIPE BEAM SCHEDULE

BEAM DATA			½ ϕ STRAND DATA															
TYPE	CLASS	LENGTH	TOTAL REQ'D	A	B	C	D	E	F	G	H	J	K	L	M	N	P	DRAPE AT ℄
I	A B C D	80.0' 90.0' 100.0' 120.0'	60		4	4	2			2			4	6	10	12	16	33"
II	A B C D	74.0' - 80.0' 82.0' - 90.0' 93.0 - 100.0' 110.0' - 120.0'	60		4	4	2			2			4	6	10	12	16	33"
III	A B C D	67.0' - 74.0' 75.0' - 82.0' 85.0' - 93.0' 100.0 - 110.0'	48			4		4	2				6		10	6	16	33"
IV	A B C D	61.0' - 67.0' 68.0' - 75.0' 77.0' - 85.0' 90.0' - 100.0'	40			4	4						4	4	8		16	33"
V	A B C D	54.0' - 61.0' 60.0' - 68.0' 68.0' - 77.0' 80.0' - 90.0'	32	2	4						2		4		4		16	32"
VI	A B C D	47.0' - 54.0' 52.0' - 60.0' 59.0' - 68.0' 70.0' - 80.0'	26			4	2								4		16	29"
VII	A B C D	41.0' - 47.0' 45.0' - 52.0' 51.0' - 59.0' 60.0' - 70.0'	20	4										2		6	8	28"
VIII	A B C D	33.0' - 41.0' 37.0' - 45.0' 42.0' - 51.0' 50.0' - 60.0'	14	2							2	2	2				6	38"
IX	A B C D	30.0' - 33.0' 30.0' - 37.0' 30.0' - 42.0' 30.0' - 50.0'	10	2										2			6	28"

NOTE:
STRAND DATA VOID

PRESTRESSED CONCRETE NOTES

CONCRETE DESIGN STRESSES:
f'c = 6000 PSI, ULTIMATE STRENGTH @ 28 DAYS
f'ci = 5000 PSI (AT TRANSFER)

PRESTRESSING STRANDS:
f's = 250,000 PSI, ULTIMATE
f'si = 180,000 PSI, INITIAL TENSION
fs = 150,000 PSI, AFTER LOSSES

GENERAL NOTES:

1. PLACE STRANDS SYMMETRICALLY ABOUT THE CENTER LINE BEGINNING AT THE EXTERIOR ROW.
2. TYPE I PIPE BEAM LENGTH SHALL BE AS SHOWN IN SCHEDULE.
3. TYPE II THROUGH TYPE IX PIPE BEAM LENGTHS SHALL BE DETERMINED BY THE CONTRACTOR.
4. LENGTHS AND DETAILS OF PIPE BEAMS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO FABRICATION.
5. IN PLACE JOINT TOLERANCE SHALL BE AS INDICATED ON F/S4. DETAILS, INCLUDING TOLERANCES, OF JOINT SHALL BE SUBMITTED TO THE ENGINEER FOR ACCEPTANCE.
6. ALL EXPOSED STRAND ENDS SHALL BE CUT FLUSH WITH THE CONCRETE SURFACE AND COATED WITH COAL TAR EPOXY. MINIMUM THICKNESS 25 MILS.

ARK G. CHIN — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER
DAVID H. CALDWELL — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER

5373
AS CONSTRUCTED
DATE OCT. 1966

DESIGNED MCD DRAWN WG CHECKED KLW	METROPOLITAN ENGINEERS BROWN AND CALDWELL — CAREY AND KRAMER HILL AND INGMAN — R W BECK AND ASSOCIATES	MUNICIPALITY OF METROPOLITAN SEATTLE SUBMITTED Ark G. Chin, Design Engineer - Metropolitan Engineers RECOMMENDED John L. Arnett, Project Engineer - Metropolitan Engineers APPROVED Fraser J. Norman, Chief Engineer - Metropolitan Engineers APPROVED D. H. Caldwell, For Metropolitan Engineers APPROVED Fred E. Lange, For Municipality of Metropolitan Seattle SCALE AS NOTED	FILE W 211 C DATE AUG 1964	WEST POINT SYSTEM	KENMORE INTERCEPTOR SECTION 2 PRESTRESSED PIPE BEAM SECTIONS, DETAIL AND SCHEDULE	DRAWING NUMBER S3 SHEET NUMBER 6 OF 27

5712668

Entered in System

UTILITY EASEMENT

THE UNDERSIGNED, hereinafter called Grantors, for themselves, their heirs, successors and assigns, and in consideration of Ninety and no/100 - - - - Dollars ($90.00) the receipt and sufficiency of which is hereby acknowledged, do by these presents convey and warrant unto the Municipality of Metropolitan Seattle, hereinafter called Municipality, its successors and assigns, a perpetual easement for the purpose of installing, constructing, operating, maintaining, repairing and replacing sewer trunk lines at a depth of more than *10* feet below the controlled low water elevation as established by the U. S. Corps of Engineers at the date of this grant over, above, across, in, along and under the following described tract of land situate in King County, State of Washington:

That portion of Lot 20 and 21, Block 5, Cedar Park Addition, Division No. 4, according to plat thereof recorded in Volume 33 of Plats, page 14, records of King County, included within a strip of land 60 feet in width lying 20 feet westerly (shoreward) and 40 feet easterly (lakeward) of the following described line:

Beginning at a point on the easterly extension of the northerly line of Section 27, Township 26 North, Range 4 East, W.M., distant South 88°11'43" East 357.19 feet along said northerly line and easterly extension thereof from the north quarter corner of said Section 27; thence North 15°16'14" West 26.97 feet; thence North 36°55'42" West 196.40 feet; thence North 58°25'07" West 286.42 feet; thence North 20°00'38" West 356.52 feet; thence North 01°18'25" West 263.07 feet; thence North 07°38'14" East 624.54 feet; thence North 17°15'00"East 657.58 feet; thence North 13°11'11" West 425.21 feet; thence North 17°24'03" West 1271.65 feet; thence North 16°27'59" East 589.16 feet; thence North 30°03'26" West 227.61 feet; thence North 42°06'59" West 857.39 feet; thence North 04°49'15" West 103.37 feet to point of terminus on the easterly extension of the northerly line of Section 22, Township 26 North, Range 4 East, W.M., said point being distant South 88°54'44" East 428.88 feet along said northerly line and easterly extension thereof from the northeast corner of the NW quarter of the NW quarter of said Section 22.

This easement is granted subject to the following terms and conditions:

1. All right, title and interest which may be used and enjoyed without interfering with the easement rights herein conveyed are reserved to the Grantors.

2. Municipality shall protect and save harmless Grantors from and against any and all claims, demands, loss, damage, expense and liability of every kind and description and for any damage to or loss or destruction of property whatsoever suffered by Grantors, their heirs, successors and assigns, or by any persons, firms or corporations, because of the installation, construction, operation, maintenance, repair and/or replacement of said sewer trunk lines.

DATED this 4th day of March, 1964.

[signature]

STATE OF WASHINGTON)
) ss.
COUNTY OF KING)

On this 14th day of March, 1964 before me the undersigned, a Notary Public in and for the State of Washington, duly commissioned and sworn, personally appeared

GLADYS PAINE ALLIN, a widow

to me known to be the individual__ described in and who executed the foregoing instrument, and acknowledged to me that she signed and sealed the said instrument as her free and voluntary act and deed for the uses and purposes therein mentioned.

WITNESS my hand and official seal hereto affixed the day and year in this certificate above written.

RICHARD F. MURRAY NOTARY PUBLIC COMMISSION EXPIRES JAN. 17, 1968 STATE OF WASHINGTON

Richard F. Murray
Notary Public in and for the State of Washington, residing at Seattle

STATE OF WASHINGTON)
) ss.
COUNTY OF KING)

On this ____ day of ____________________, 1964 before me the undersigned, a Notary Public in and for the State of Washington, duly commissioned and sworn, personally appeared

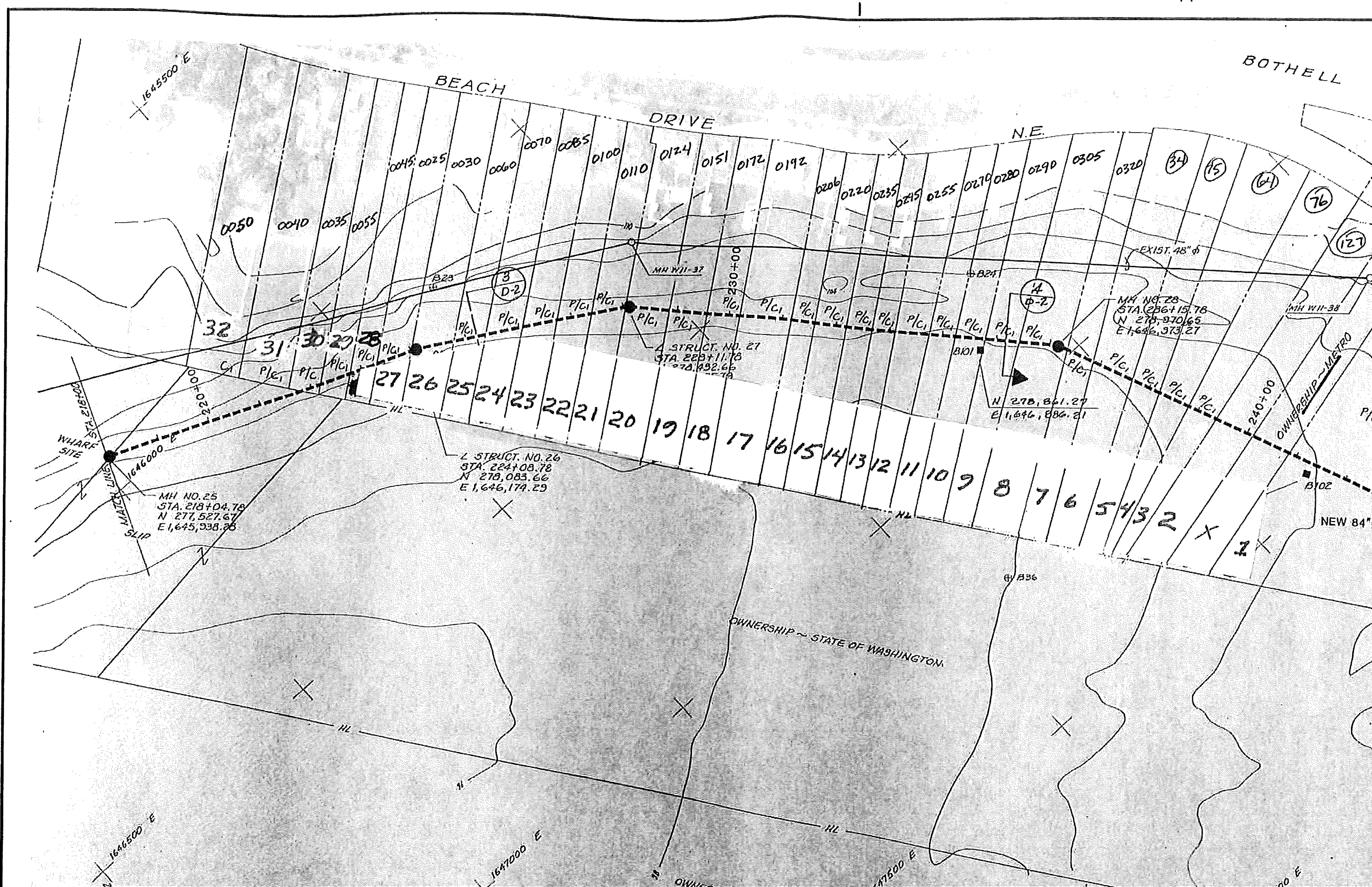
____

to me known to be the individual__ described in and who executed the foregoing instrument, and acknowledged to me that ______ signed and sealed the said instrument as __________ free and voluntary act and deed for the uses and purposes therein mentioned.

WITNESS my hand and official seal hereto affixed the day and year in this certificate above written.

____
Notary Public in and for the State of Washington, residing at ________

Filed for Record Mar. 19 1964 3:01 P.M.
Request of Metro



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STA. 218+00
MATCH LINE
SLIP
1646000 E
MH NO. 25
STA. 218+04.78
N 277,527.67
E 1,645,938.28
℄ STRUCT. NO. 26
STA. 224+08.78
N 278,083.66
E 1,646,174.29
℄ STRUCT. NO. 27
STA. 228+11.78
MH NO. 28
STA. 236+15.78
N 278,970.65
E 1,646,973.27
N 278,861.27
E 1,646,886.21
OWNERSHIP ~ METRO
OWNERSHIP ~ STATE OF WASHINGTON
NEW 84"
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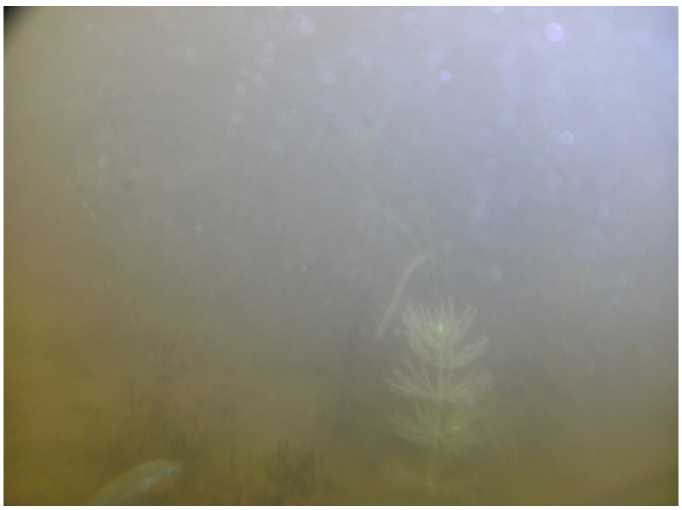
1646500 E
1647000 E

APPENDIX B
FIELD INVESTIGATION PHOTOGRAPHS

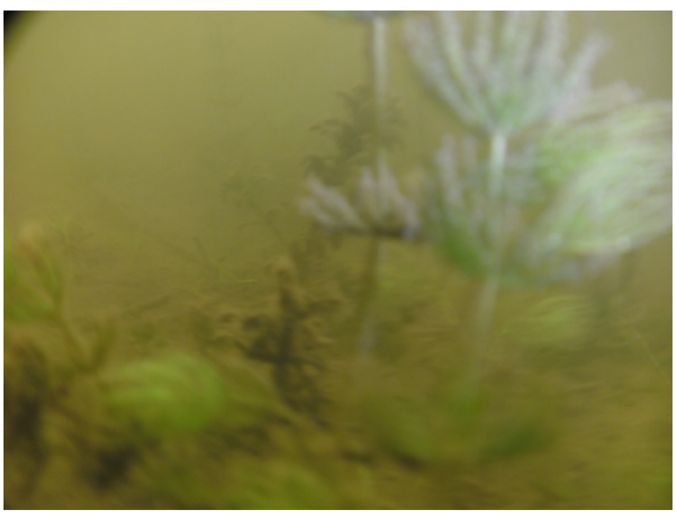
Photograph 1. Lake Line alignment, looking southwest.

Photograph 2. Survey vessel.

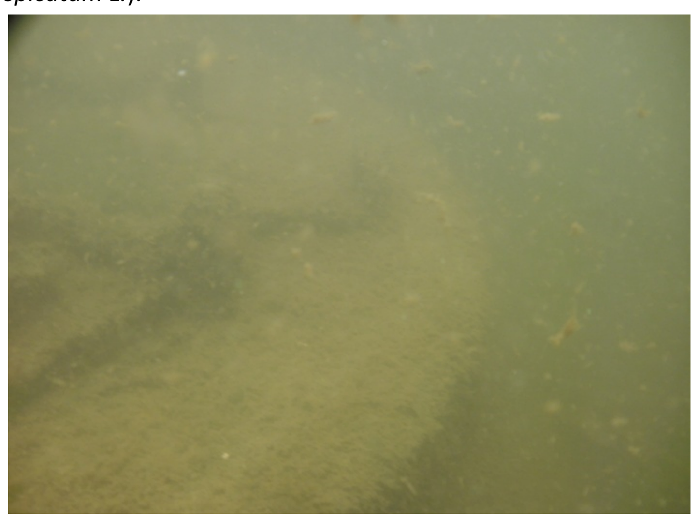


Photograph 3. Typical visibility while diving.

Photograph 4. Eurasian watermilfoil (*Myriophyllum spicatum L.*).



Photograph 5. Eurasian watermilfoil (*Myriophyllum spicatum L.*).



Photograph 6. Manhole 35.

SoundEarth Strategies			FIELD INVESTIGATION PHOTOGRAPHS
	Project No.:	0773-001	Kenmore Lake Line Lakebed
	Date:	July 15, 2011	Sedimentation Analysis
	Drawn By:	J. Lally	Lake Washington
	Chk By:	R. Bixby	King County, Washington
	File ID:	Site Photographs_.docx	

Photograph 7. Manhole 35 lifting eye.

Photograph 8. Facing northwest at 17364 Beach Drive Northeast residence.

Photograph 9. Facing south at Manhole 35.

Photograph 10. Representative core sample (Sample 2B). Top of core is at right.

Photograph 10. Representative core sample (Sample 4A, shoreward of Lake Line). Top of core is at right.

Photograph 11. Representative core sample (Sample 4B, lakeward of Lake Line). Top of core is at right.

SoundEarth Strategies

Project No.:	0773-001
Date:	July 15, 2011
Drawn By:	J. Lally
Chk By:	R. Bixby
File ID:	Site Photographs_.docx

FIELD INVESTIGATION PHOTOGRAPHS

Kenmore Lake Line Lakebed
Sedimentation Analysis
Lake Washington
King County, Washington

APPENDIX C

HWA GEOSCIENCES, INC. MATERIAL LABORATORY REPORT

HWA GEOSCIENCES INC.
Geotechnical & Pavement Engineering • Hydrogeology • Geoenvironmental • Planning & Permitting • Inspection & Testing

September 15, 2011
HWA Project No. 2011-068-T100

Lally Consulting, Inc.
2811 Fairview Avenue East, Suite 1004
Seattle, Washington 98102

Attention: Mr. John Lally, P.E.

Subject: **Materials Laboratory Report**
Grain Size Testing
Lakeline Lakebed Analyses
Kenmore, Washington

Dear Mr. Lally;

As requested, HWA GeoSciences Inc. (HWA) performed laboratory testing for the subject project. Herein we present the results of our laboratory analyses, which are summarized on the attached reports. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE INFORMATION: The subject samples were delivered to our laboratory on June 17, 2011 by Lally Consulting personnel. The samples were delivered in small sealable plastic bags. Each bag was designated with a number and a letter depicting the sample location and few samples were also labeled with the depth of sampling.

MOISTURE CONTENT OF SOIL: The moisture content of the soil samples (percent by dry mass) were determined in general accordance with ASTM D 2216. Sample "*2-B 9-13in*" was composed of woody organics and did not contain enough material to conduct a grain size analysis. The moisture content of this sample was determined as **732.8%.** The results of the remaining samples are shown on the attached Figures.

PARTICLE SIZE ANALYSIS OF SOILS: Selected samples were tested to determine the particle distribution of material in general accordance with ASTM D422. The results are summarized on the attached Grain Size Distribution reports, which also provide information regarding the classification of the sample and the moisture content at the time of testing.

21312 30th Drive SE
Suite 110
Bothell, WA 98021.7010

Tel: 425.774.0106
Fax: 425.774.2714
www.hwageo.com

CLOSURE: Experience has shown that test values on soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested samples may represent. HWA also makes no warranty as to how representative either the samples tested or the test results obtained are to actual field conditions. It is a well established fact that sampling methods present varying degrees of disturbance that affect sample representativeness.

No copy should be made of this report except in its entirety.

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

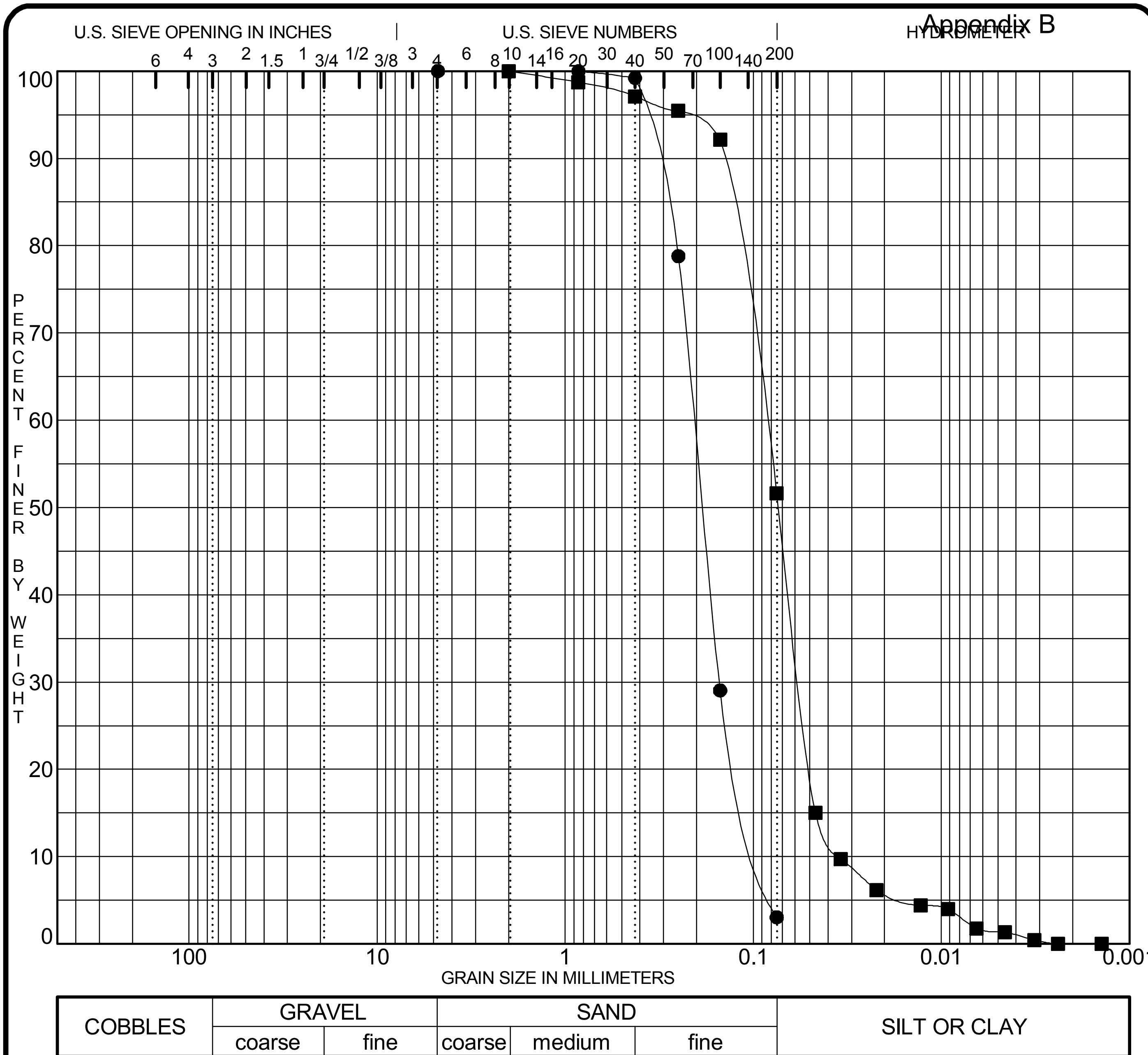
HWA GEOSCIENCES INC.

Harold Benny
Materials Laboratory Manager

Steven E. Greene, L.G., L.E.G.
Vice President

Attachments:

Figures 1-11 Gradation Curves



	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**1-A**	**0.0 -**	**poorly graded SAND**	**27**				**1.23**	**2.3**
■	**1-B**	**0.0 -**	**sandy SILT**	**57**				**1.06**	**2.5**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**1-A**	**0.0**	**0.21**	**0.19**	**0.151**	**0.0903**	**0.0**	**97.0**	**3.0**	
■	**1-B**	**0.0**	**0.09**	**0.07**	**0.057**	**0.0348**	**0.0**	**48.4**	**51.6**	**0.0**

PROJECT **Lakeline Lakebed Analyses -**

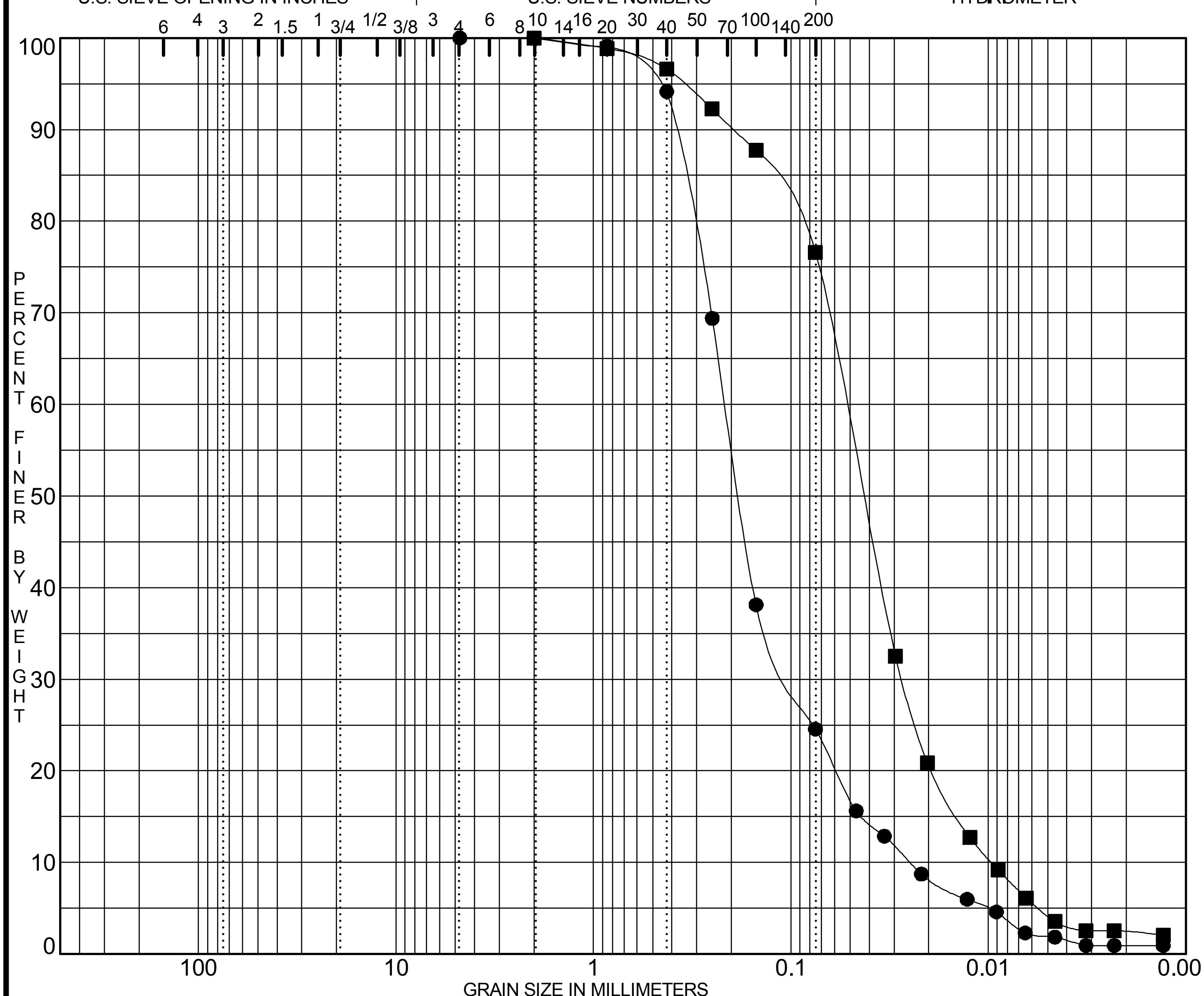
JOB NO. **2011-068 T100**

DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.

Appendix B



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**2-A**	**0.0 -**	**silty SAND with organics**	**81**				**1.84**	**8.6**
■	**2-B**	**0.0 - 0.8**	**SILT with sand**	**103**				**1.46**	**5.5**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**2-A**	**0.0**	**0.21**	**0.18**	**0.099**	**0.0249**	**0.0**	**75.5**	**23.6**	**0.9**
■	**2-B**	**0.0**	**0.05**	**0.04**	**0.027**	**0.0096**	**0.0**	**23.4**	**74.2**	**2.4**

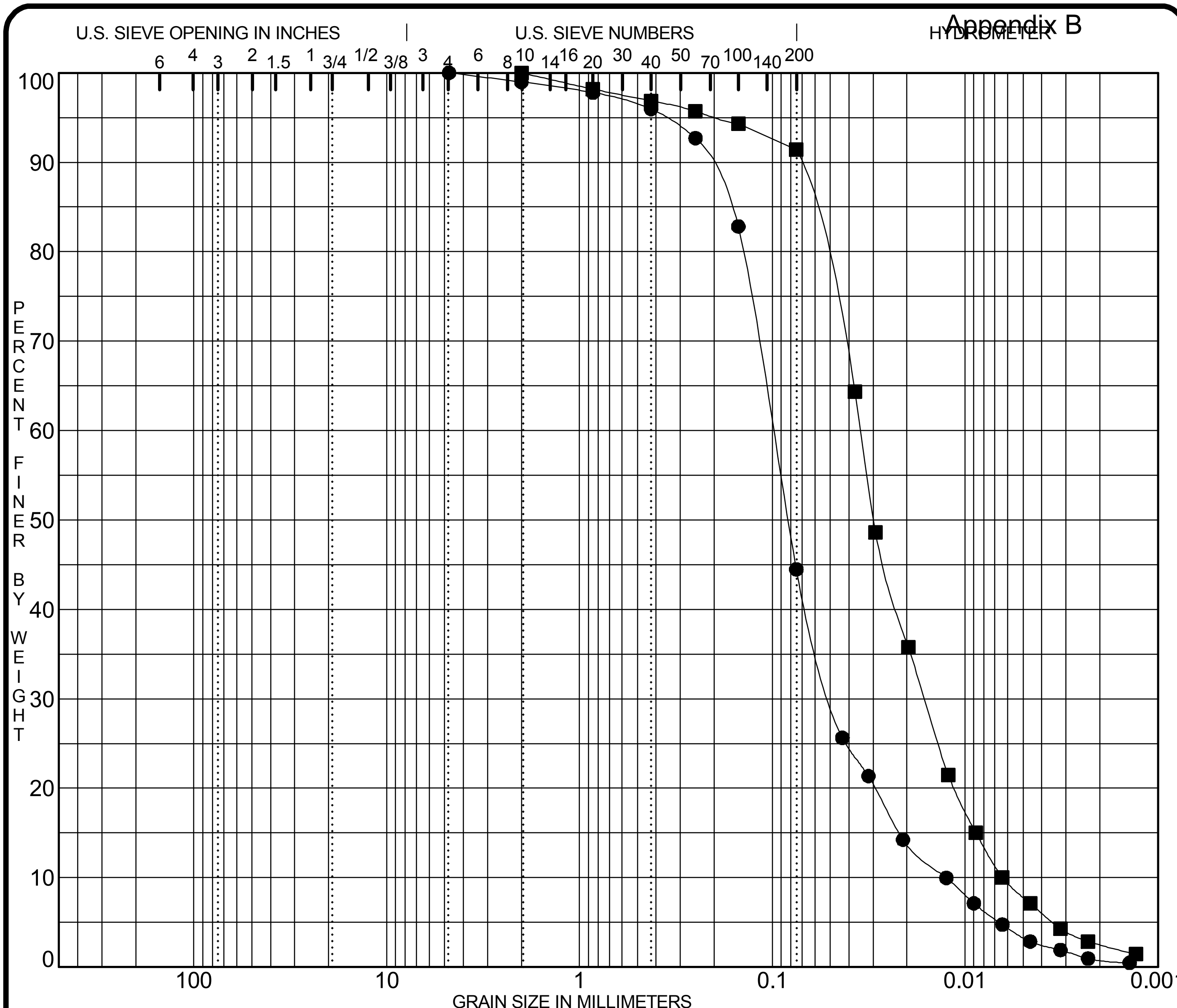
PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**

DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**3-A**	**0.0 -**	**silty SAND with organics**	**88**				**1.94**	**7.9**
■	**3-B**	**0.0 -**	**SILT with organics**	**157**				**1.19**	**5.4**

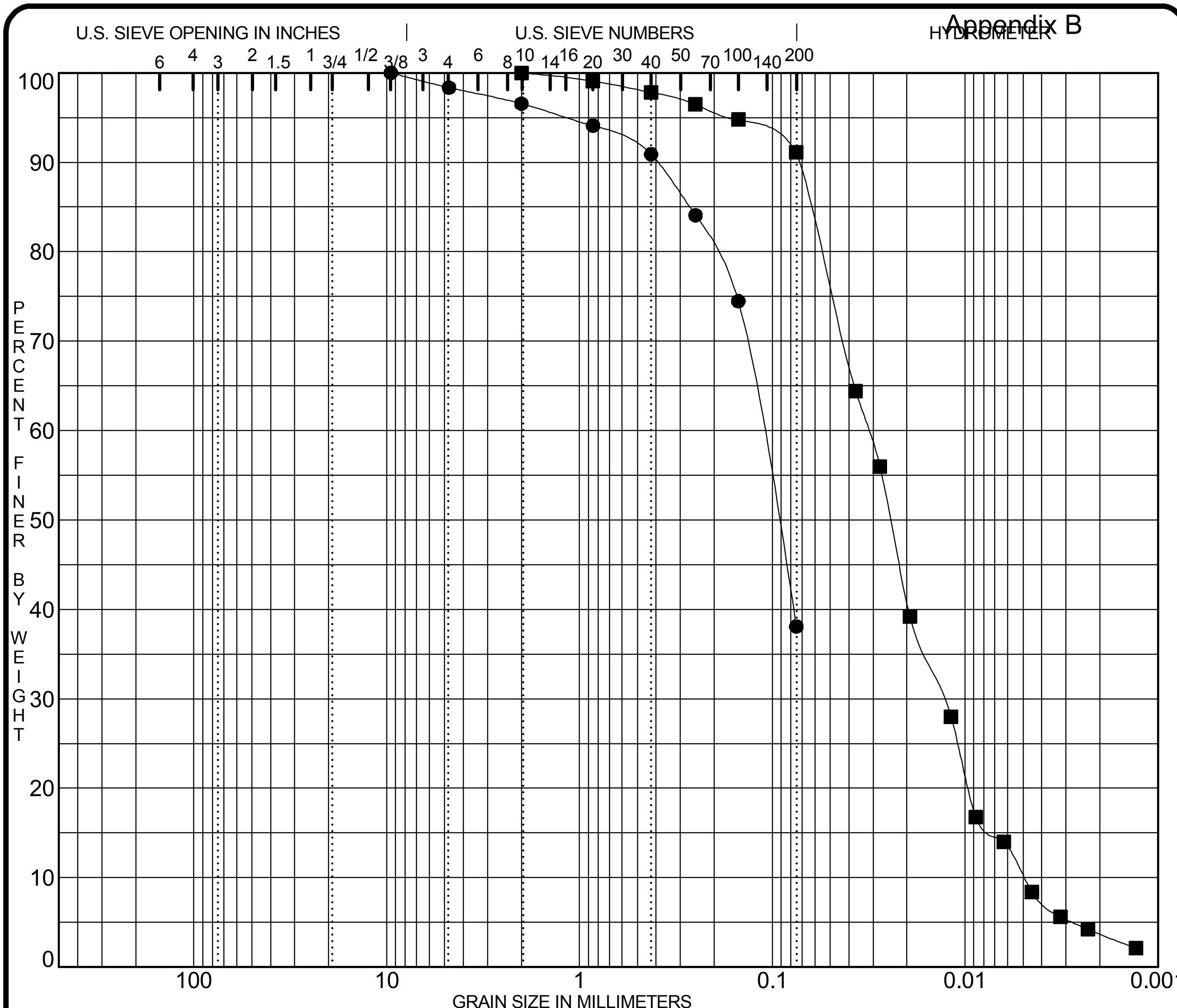
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**3-A**	**0.0**	**0.10**	**0.08**	**0.049**	**0.0126**	**0.0**	**55.5**	**43.7**	**0.8**
■	**3-B**	**0.0**	**0.03**	**0.03**	**0.016**	**0.0064**	**0.0**	**8.6**	**88.9**	**2.5**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**4-A**	**0.0 - 0.3**	**silty SAND with organics**	**92**					
■	**4-A**	**0.3 - 1.4**	**SILT**	**176**				**1.06**	**6.4**

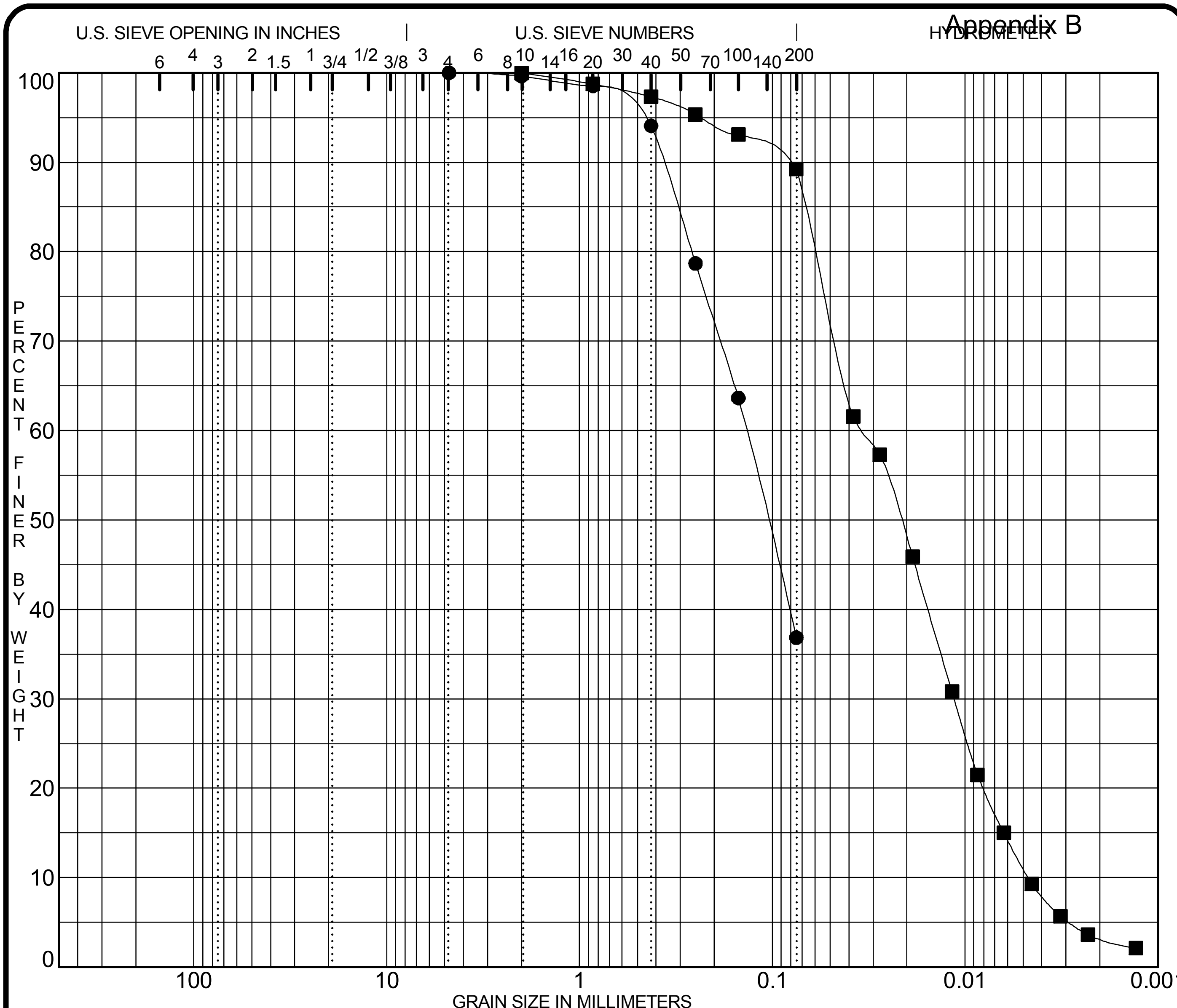
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**4-A**	**0.0**	**0.11**	**0.09**			**1.7**	**60.3**	**38.1**	
■	**4-A**	**0.3**	**0.03**	**0.02**	**0.013**	**0.0050**	**0.0**	**8.9**	**87.4**	**3.7**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**4-B**	**0.0 - 0.3**	**silty SAND with organics**	**84**					
■	**4-B**	**0.3 - 1.9**	**SILT with organics**	**212**				**0.82**	**7.2**

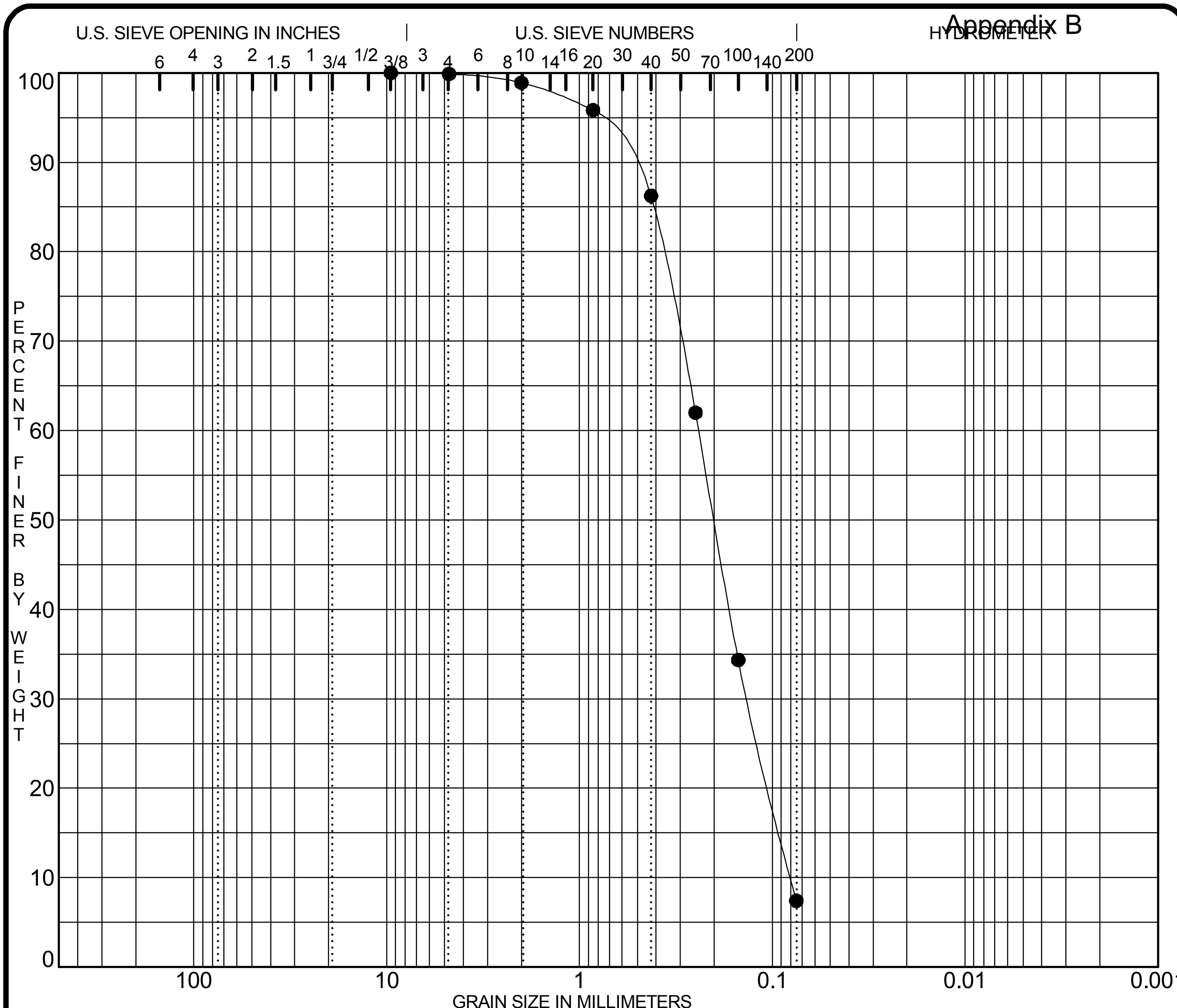
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**4-B**	**0.0**	**0.14**	**0.11**			**0.0**	**63.2**	**36.8**	
■	**4-B**	**0.3**	**0.03**	**0.02**	**0.011**	**0.0047**	**0.0**	**10.8**	**86.0**	**3.2**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**5-A**	**0.0 -**	**poorly graded SAND with silt**	**32**				**0.93**	**3.0**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**5-A**	**0.0**	**0.24**	**0.20**	**0.134**	**0.0802**	**0.1**	**92.5**	**7.4**	

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**

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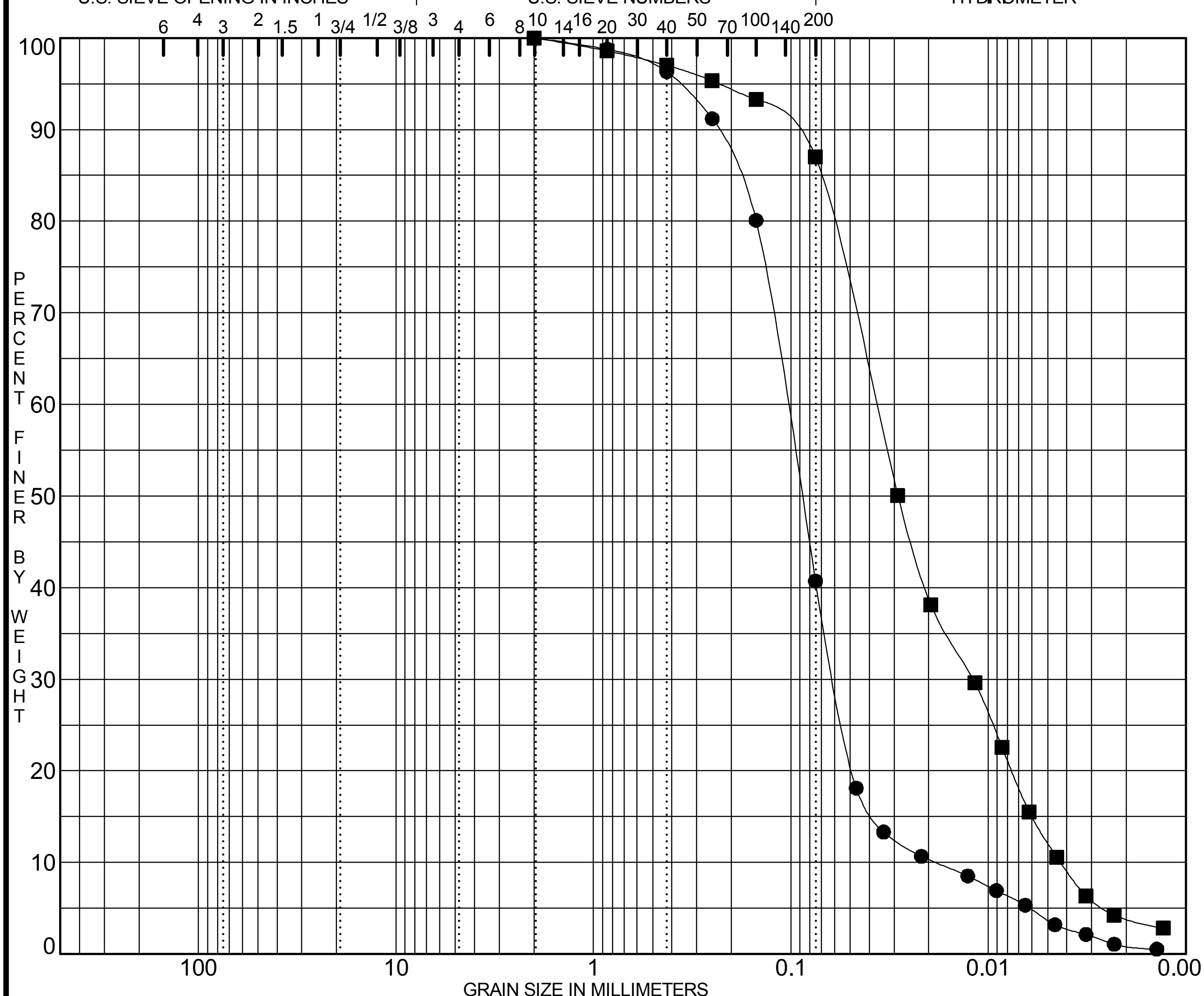
HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**5-B**	**0.0 - 0.8**	**silty SAND with organics**	**86**				**1.84**	**5.7**
■	**5-B**	**0.8 - 2.3**	**SILT with organics**	**202**				**0.90**	**8.6**

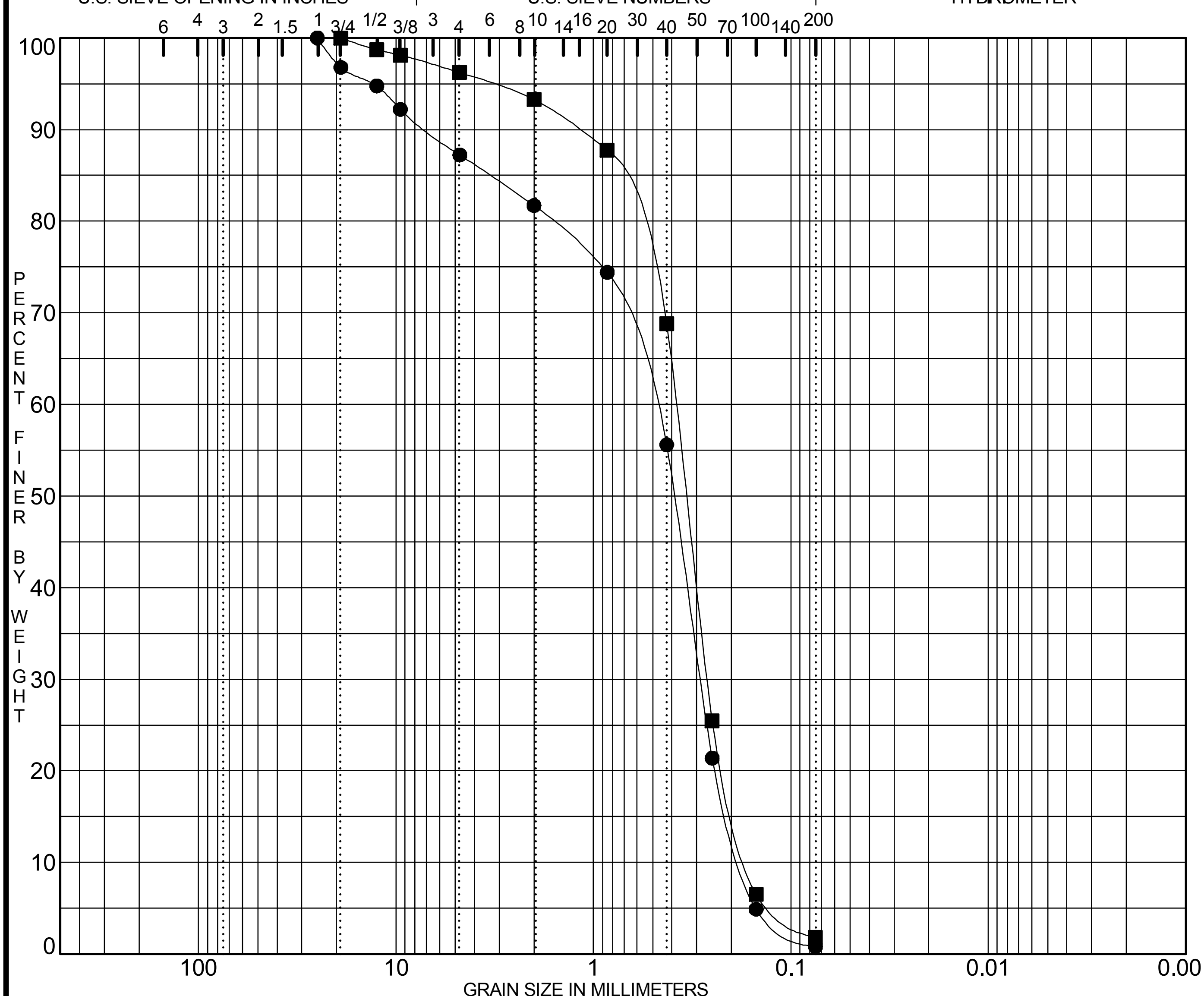
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**5-B**	**0.0**	**0.11**	**0.09**	**0.060**	**0.0185**	**0.0**	**59.3**	**39.8**	**0.9**
■	**5-B**	**0.8**	**0.04**	**0.03**	**0.012**	**0.0043**	**0.0**	**13.0**	**83.1**	**3.9**

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**6-A**	**0.0 -**	**poorly graded SAND**	**22**				**0.93**	**2.8**
■	**6-B**	**0.0 -**	**poorly graded SAND**	**30**				**1.11**	**2.3**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**6-A**	**0.0**	**0.50**	**0.39**	**0.286**	**0.1757**	**12.8**	**86.4**	**0.8**	
■	**6-B**	**0.0**	**0.38**	**0.34**	**0.264**	**0.1647**	**3.8**	**94.4**	**1.8**	

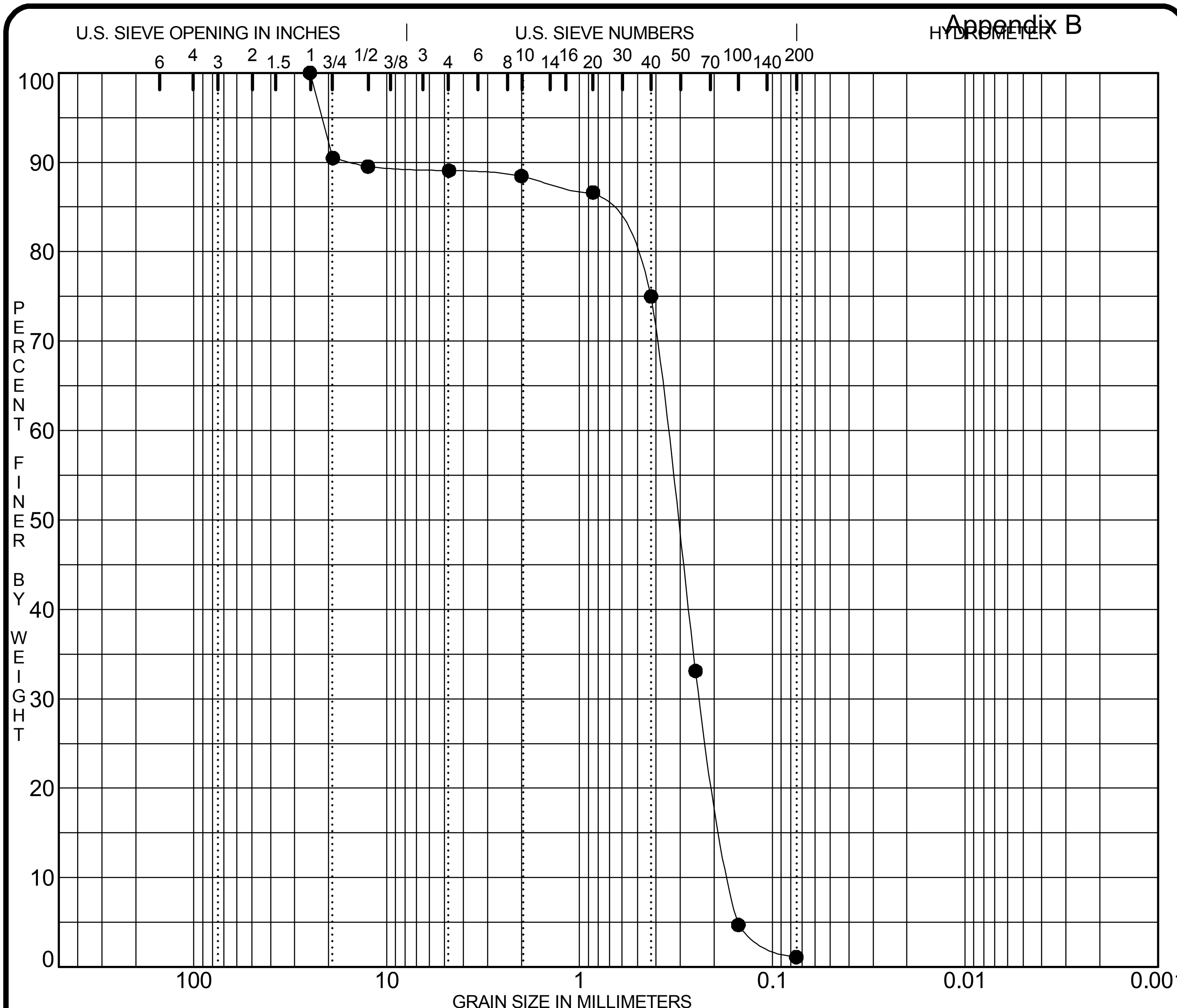
PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**

DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**7-A**	**0.0 -**	**poorly graded SAND**	**28**				**0.96**	**2.1**

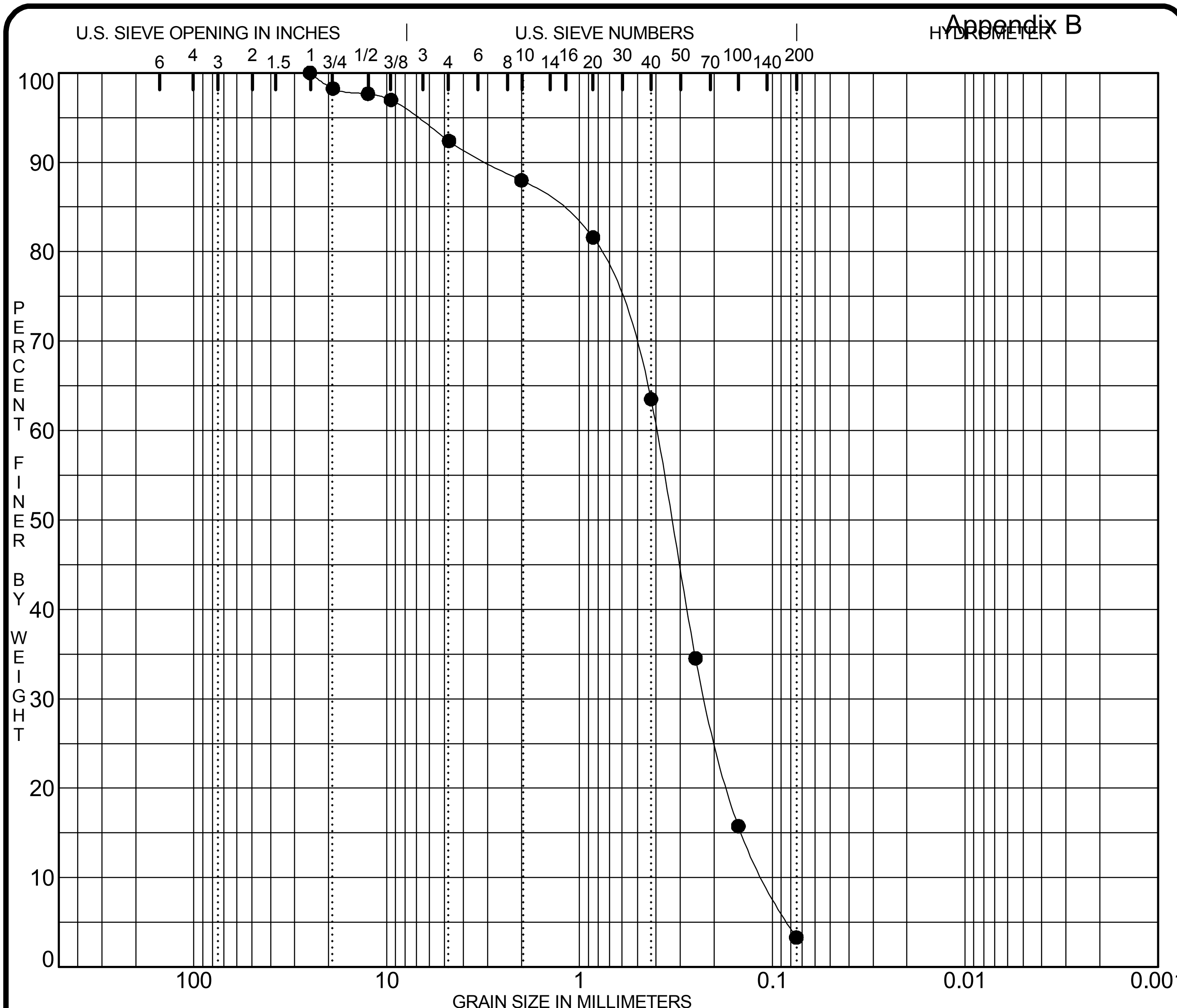
	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**7-A**	**0.0**	**0.35**	**0.31**	**0.236**	**0.1650**	**10.9**	**88.0**	**1.1**	

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**8-A**	**0.0 -**	**poorly graded SAND**	**27**				**1.13**	**3.7**

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**8-A**	**0.0**	**0.40**	**0.33**	**0.221**	**0.1089**	**7.6**	**89.1**	**3.3**	

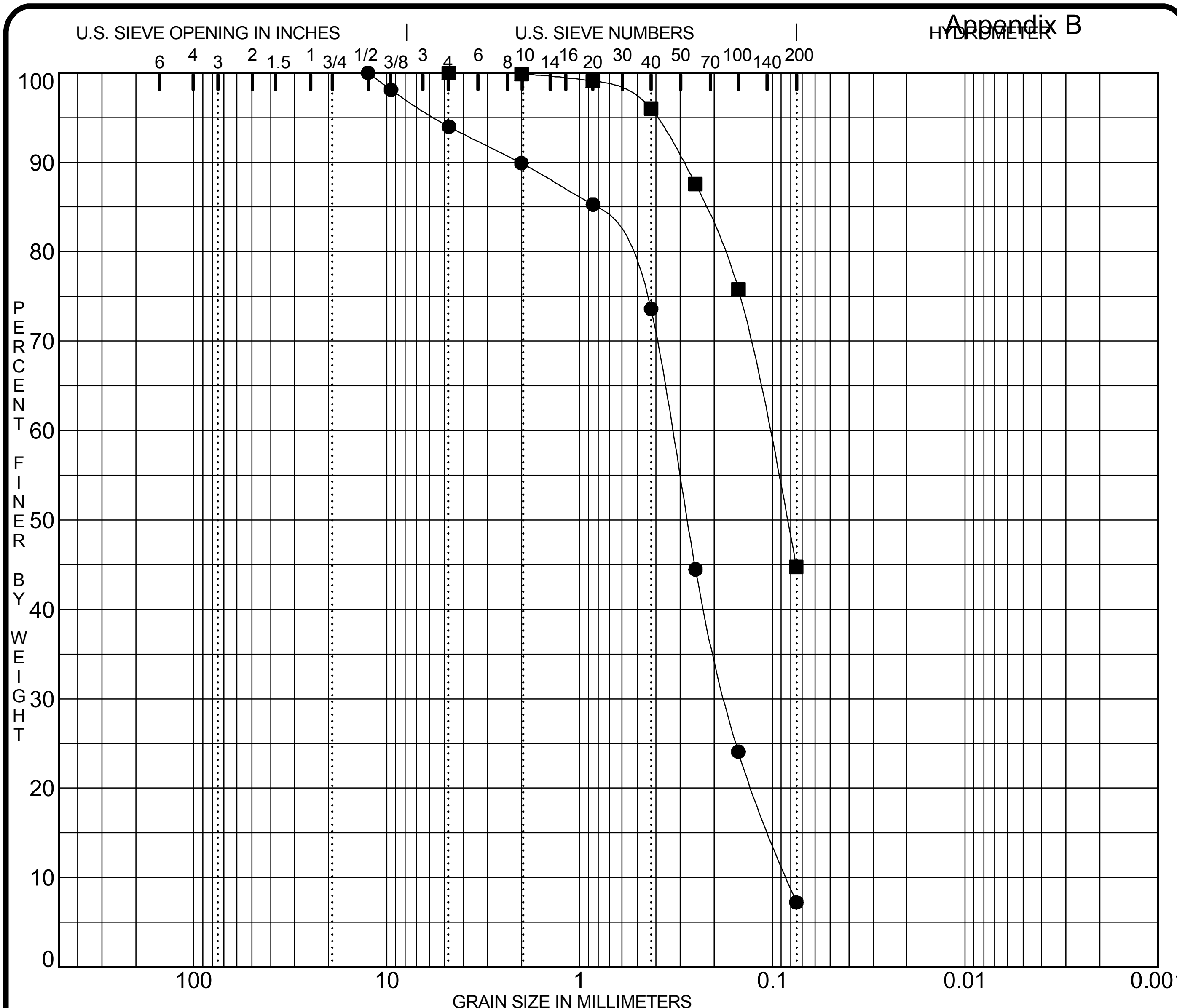
PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.

Appendix B



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	MC%	LL	PL	PI	Cc	Cu
●	**8-B**	**0.0 - 0.6**	**poorly graded SAND with silt**	**37**				**1.09**	**3.9**
■	**8-B**	**0.6 - 1.0**	**silty SAND**	**61**					

	Specimen Identification		D60	D50	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**8-B**	**0.0**	**0.33**	**0.28**	**0.174**	**0.0840**	**6.0**	**86.7**	**7.2**	
■	**8-B**	**0.6**	**0.11**	**0.08**			**0.0**	**55.3**	**44.7**	

PROJECT **Lakeline Lakebed Analyses -**

JOB NO. **2011-068 T100**
DATE **9/15/11**

GRADATION CURVES

HWA GeoSciences Inc.