SEDIMENT MONITORING PLAN

HIDDEN LAKE

Prepared for
City of Shoreline

Prepared by
Herrera Environmental Consultants, Inc.

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HIDDEN LAKE

Prepared for
City of Shoreline
17500 Midvale Avenue North
Shoreline, Washington 98133-4905

Prepared by
Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206-441-9080

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Cover photo taken December 3, 2007, looking south from the inlet of the lake immediately after a large sedimentation event.

INTRODUCTION

The City of Shoreline (the City) seeks to monitor sediment accumulation in Hidden Lake as it plans to remove or otherwise modify the dam impounding the lake, because the rate at which sediment accumulates in the existing lake is a factor affecting the timing of the City's actions. Boeing Creek flows through Hidden Lake at the western edge of Shoreview Park (Figure 1). The City is the steward of the lake and owns the eastern half of it, as part of Shoreview Park. The western half of the lake is in private ownership.

Hidden Lake is a constructed feature, originally built by William Boeing in the early twentieth century (Herrera 2016). After more than 20 years of being filled in with sediment, King County restored the lake to its present-day configuration in 1996. The City has found that significant sediment excavation would be required to maintain the current configuration of the lake. Without excavation, the lake will eventually fill in with sediment derived primarily from landsliding along the Boeing Creek banks during high flow events upstream of the lake, as it has done in the past.

Monitoring of sediment accumulation levels in the lake will include survey of three staked locations within the lake, all within City property. It is intended that once the stakes are initially placed, the monitoring plan may be implemented by personnel without specialized training, including City parks maintenance or public works staff. However, monitoring will require a boat or raft to access the monitoring locations.

Existing Site Conditions Summary

Herrera (2016) performed an alternatives analysis of the project site that documented existing conditions in the lake. The document included an analysis of hydraulics and geomorphology, a topographic survey, and an assessment of ecological functions. This alternatives analysis built on earlier work that assessed the feasibility of dam removal (AltaTerra 2014) and characterized the Boeing Creek basin (TetraTech 2004; Windward Environmental et al. 2013).

From these analyses it was determined that Hidden Lake will have sedimentation issues indefinitely, primarily due to sediment transported in Boeing Creek from upstream of the lake. Sediment inputs were estimated to be 2,500 cubic yards per year on average, with about half of that amount being deposited in the lake under typical conditions (Herrera 2016). This quantity is an average annual estimate, with potential for much greater sediment deposition in extreme high flow events that can occur at any time.

The lake can be divided broadly into three areas: a creek delta at the upstream (north) end, the main body of the lake, and the outlet area at the downstream (south) end (Figure 2). Each of these parts of the lake should be monitored as the physical conditions within each are distinct.

Legend

- Project area
- Stream
- Parcel

Figure 1.
Vicinity and Site Map for Hidden Lake in Shoreline, Washington.

N

0 150 300 600 Feet

HERRERA

USDA, Aerial (2013)

K:\Projects\Y2015\15-05984-000\Project\Sediment_Monitoring_Plan\vicinity_map.mxd (8/8/2016)

Legend

- Sediment Monitoring Points
- Bathymetric Survey Contours
- Sediment Monitoring Profile
- Lake Area
- Non-CityOwned Parcel

Figure 2.
Sediment Monitoring Points and Profile, Hidden Lake, Shoreline, Washington..

N

0 40 80 160 Feet

HERRERA

USDA, Aerial (2013)

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As of October 2015, the delta area had a water (and sediment) storage capacity of approximately 1,500 cubic yards below the lake outlet structure elevation with an average depth of 6 feet at the center and about 3 feet on the edges (based upon bathymetric survey data collected for project analysis and preliminary design purposes). The main part of the lake had a total water storage capacity of approximately 7,000 cubic yards in October 2015 with an average depth of 6 feet in the center of the lake and 3 feet on the edges. The lake outlet area is quite small at fewer than 200 cubic yards of water storage capacity, but the bathymetry here is more complicated due to the presence of the outlet structure.

Prior to re-establishing the lake in the mid-1990s, AltaTerra (2014) estimated that the total volume of the lake would be 7,000 cubic yards, which is considerably less volume than the October 2015 survey indicates. It is likely that successive dredging between 1997 and 2013, when 13,000 cubic yards was removed from the lake, expanded the lake capacity. The recent lake bed survey data is considered to be reasonably accurate, better than previous estimates, for the City’s planning purposes. However, during monitoring stake installation on October 21, 2016, it was discovered that several inches to several feet of deposition had occurred in the delta area since the 2015 survey. Thus, the storage volumes estimated from the October 2015 survey are greater than existed as of early November 2016, when this plan was prepared and finalized.

SEDIMENT MONITORING PLAN

The sediment monitoring plan is designed to ensure that the City has an accurate, ongoing assessment of the rate of water storage loss in Hidden Lake so that future management of the lake and Boeing Creek can occur in a proactive and well-planned manner. Adaptive management actions based upon the results of the monitoring are discussed in a separate section below.

Anticipated Changes

Sedimentation is not expected to be uniform throughout the lake. The delta area at the north end will almost certainly fill first as it has in the past, as the creek delta progrades (advances) into the main body of the lake. The material deposited in the delta will likely be coarser and composed primarily of bedload (coarse sand and gravel). The progradation rate through the delta area will be relatively fast because the delta is laterally confined by surrounding topography, and the only way it can grow is by prograding.

Beyond the delta, sediment deposition in the main body of the lake will consist of mostly suspended load, which is typically fine sand, silt, and clay. This is the dominant form of deposition in the main and outlet areas of the lake at this time. If the delta progrades into the main body of the lake before it fills with suspended load, the delta progradation rate will slow considerably because of the relatively large width of the lake compared to the creek channel width upstream of it. Since most of the storage capacity of the lake is in the main area, complete filling of the delta area with deltaic bedload does not necessarily pose a risk for clogging of the lake outlet. However, if the delta area is completely filled with sediment, that will be a warning sign that filling of the main body of the lake may occur more rapidly in the near future because the trapping efficiency (and sedimentation rate) of the main part of the lake may increase with closer proximity to the delta front.

It is difficult to forecast whether the relative rates of delta progradation and whole-lake filling will be the dominant factor in threatening the integrity of the lake outlet infrastructure. An indication of the looming threat of the outlet structure being overwhelmed and initiating persistent flow over the dam spillway will be if and when the outlet area begins to vegetate. Vegetation will likely begin to grow in that area when water depths of less 1 foot persist throughout the growing season. Depths of less than 1 foot will probably be colonized by reed canary grass (*Phalaris arundinacea*), the existing dominant pioneering vegetation at the edges of the lake. Vegetation colonization near the outlet will likely set in motion significant changes there, compromising the outlet structure and likely dramatically increasing the amount of flow passing over the dam spillway.

Monitoring Protocol

Monitoring stakes were placed in the lake on October 21, 2016. The water surface elevation on that date was at 193.0 feet (NAVD88). Three stakes were placed: one each in the delta, main, and outlet areas of the lake, all of which are on City–owned property in the lake bed. Water depth measurements should be taken at least once per year at each stake, after the wet season is over, and more frequently if the City wants more data points to track the pace of sediment accumulation. The stakes are necessary for consistency in the monitoring locations and for accuracy of depth measurements.

Each stake is made of 10-foot-long, half-inch-diameter rebar, typically with 4 feet of embedment and with approximately 6 inches of stake length protruding above the lake water surface. The rebar is capped to aid in recovery and prevent accidental injury. The caps are painted dark green to make them less obvious to lake users and residents.

The stake locations were mapped using a handheld GPS unit. For each monitoring visit, the information to be collected is simply a measurement of the water depth using a stadia rod. The lake bed is soft, particularly near the outlet; therefore, the stadia rod should be pushed downward until refusal. A secondary measurement of the distance between the current water surface and the outlet invert elevation should also be obtained prior to proceeding with the monitoring. If the initial depth measurement at the outlet structure is greater than 6 inches, the caps on the monitoring stakes may be nearly submerged and difficult to locate. Therefore, in this case the outlet structure rim should be cleaned of debris to allow the lake level to drop before depth measurements are obtained at the stakes. If a stake is clearly altered in its vertical embedment (i.e., it is protruding more than 1 foot above the water surface) or appears to have been removed entirely without the City's consent, a stake could readily be placed again using the mapped location of the original and a handheld GPS unit to navigate to that location, and ensuing water/sediment depth measurements would once again accurately track sediment accumulation at that location.

All of the monitoring access is assumed to be accomplished via a boat or raft, although over time the delta stake may eventually become exposed and accessible via land. Given enough time, it may become completely buried. Placement of the stakes in (initially) open water will minimize the risk of disturbance of the monitoring stakes and provide a conservative estimate of the lake storage capacity.

To complement the numerical data obtained via water depth measurements at the monitoring stakes, photographs should be obtained at key locations to monitor overall changes in the lake. "Photo points" with the same direction of view in each photograph, taken over time, should be established. One key photo point location is on the dam at the lake outlet structure. Another is at a distinct promontory looking at the fence near the boundary between the delta and main areas of the lake along the Hidden Lake Loop Trail in Shoreview Park. A time series has already begun to be collected by Herrera at the loop trail promontory and is shown in Figure 3. As can be seen in these photos, the shoreline advanced several feet between June 2015 and October 2016. Herrera has photographs of other locations, including the City maintenance access point near the outlet structure, and those photographs are available upon request.

Figure 3. Photographs Taken in 2015 and 2016 from Photo Point at Hidden Lake Loop Trail Promontory.

In addition to monitoring lake sedimentation, the City should routinely examine the creek valley upstream of the lake within Shoreview Park and Boeing Creek Park as part of its regular park maintenance activities. Small (on the order of 1,000 cubic yards and smaller) landslides are expected to continue as they have throughout the history of the parks. However, if a larger large landslide is noticed, adaptive management actions as described below should be taken.

INITIAL SEDIMENT MONITORING RESULTS

Following installation of monitoring stakes in the lake on October 21, 2016, it was possible to compare the lake bed elevation at each of the stake locations with lake bed bathymetric survey collected in June 2015. To complement the measurements at the stakes, depth measurements were taken approximately 50 feet apart between the stakes and at the outlet structure. The resultant comparison of lake bed elevation changes between summer 2015 and fall 2016 is shown in Figure 4. Care should be taken in direct comparisons of the data because the topographic survey measurements taken in 2015 were made with sonar (acoustic) equipment, while the sediment monitoring protocol involves penetration of a stadia rod to refusal in the lake bed. Near the lake outlet, where considerable silt and clay is deposited, the soft bed likely triggered higher bed elevation readings in the sonic measurements than those defined by pushing a stadia rod gently to refusal. However, as can be seen in the data plotted in Figure 4, up to several feet of sediment deposited near the delta front at the upstream end of the lake in the 16 months from June 2015 to October 2016. Given the remaining storage volume in the lake, and evidence of sediment accumulation since summer 2015, it appears that forecasting complete filling of the lake with sediment in the time frame of 2020 to 2025 remains accurate.

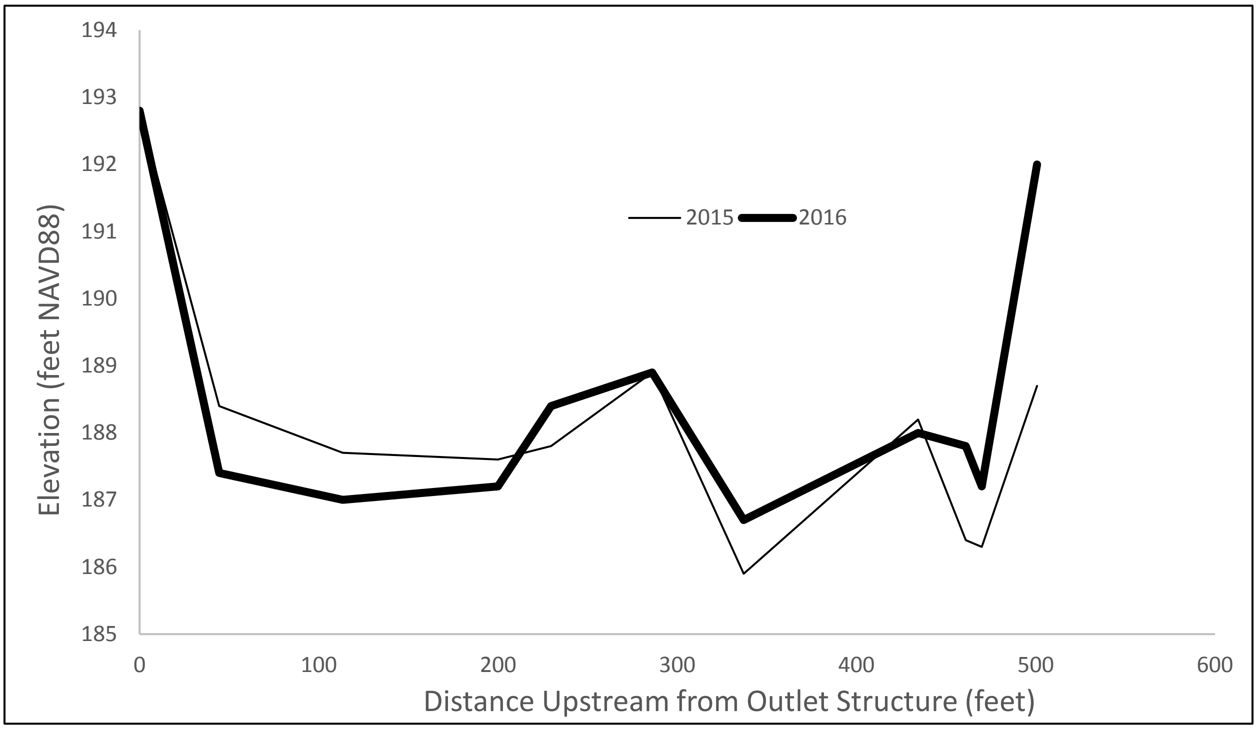

Figure 4. Lake Bed Elevation Profile Comparison between 2015 and 2016.
Note: The outlet elevation is 192.6, with a water surface elevation on of 193.0 on the stake installation and initial monitoring visit.

ADAPTIVE MANAGEMENT ACTIVITIES

Table 1 summarizes the measurements to be taken and the criteria for recommended action to modify the existing dam and lake outlet configuration. It is recommended that action be taken under three different possible situations that reflect the relative influence of bedload versus suspended load deposition described above. They are:

1. The main body of the lake is full of sediment and the outlet area approaches water depths of less than 3 feet.

2. The main body of the lake has a water depth of less than 1 foot at the monitoring stake location and the outlet area has a water depth of less than 2 feet.

3. The outlet area has a water depth of less than 1 foot.

Table 1. Summary of Elevations and Depths at Monitoring Sites, Along with Triggers for Actions.

Monitoring Site	GPS Coordinates (Northing / Easting)[a]	Water Depth at Time of Installation (feet)	Elevation of Lake Bed at Time of Installation (feet, NAVD88)	Elevation of Trigger for Action (feet, NAVD88)
Delta	278,189 / 1,262,457	5.2	187.8	N/A
Main	278,026 / 1,262,299	4.6	188.4	193(1), 192(2)
Outlet	277,857 / 1,262,229	5.6	187.4	190(1), 191(2), 192(3)

[a] Coordinate system: NAD 1983 HARN State Plane, Washington North, FIPS 4601 (feet)

If these elevation triggers are met at the end of the wet season, preparations should be made immediately to modify the dam and/or lake outlet to prevent flow from persistently overtopping the dam in its current (2016) spillway configuration. It is likely that when these triggers are met, only 1 or 2 years remain before the lake is completely full of sediment and the risk of clogging of the existing outlet structure and damage to NW Innis Arden Way increases dramatically.

Although there is no trigger specifically for adaptive management related to sediment depth measurements in the delta area, that data will be valuable in determining the trend in bedload deposition and the location of the delta front. If the delta monitoring stake site becomes dry, recent aerial photographs via Google Earth should be consulted regularly (annually) to track the location of the delta front and to make sure that the monitoring location in the body of the lake is not anomalous in terms of spatial sediment deposition patterns. If there is any indication that the main lake monitoring stake location is not accurately characterizing sediment deposition, a geomorphologist should be contacted to assess whether deltaic evolution has abnormally influenced the main lake monitoring location and this plan should be updated accordingly.

If a large landslide (in excess of 2,000 cubic yards) occurs in the reach of Boeing Creek within Shoreview Park and Boeing Creek Park, additional monitoring should be performed immediately, even if it is outside of the annual monitoring mentioned above. A landslide of this size has the capability of quickly filling the lake in a single sediment transport event, or in a subsequent event(s) that continues to erode the unstable slope, even if the lake had substantial storage capacity remaining before the landslide occurred. However, an event of this magnitude, which is not entirely unexpected, would reset the profile of Boeing Creek and may increase or decrease the sediment supplied to the lake over time. Determination of the likely effects of landsliding on the creek profile and sedimentation in the lake could only be made by a qualified geomorphologist. Therefore, after assessing the cause and size of any large landslide upstream of the lake, a geomorphologist should be contacted to assess the likely change in sediment supply to the lake and the consequences that would have on the City's management of the lake.

REFERENCES

AltaTerra. 2014. Hidden Lake Management Plan Feasibility Study. Prepared for City of Shoreline by AltaTerra Consulting LLC, Seattle, Washington.

Herrera. 2016. Alternatives Analysis: Hidden Lake Dam Removal Project. Prepared for the City of Shoreline by Herrera Environmental Consultants, Inc., Seattle, Washington.

Tetra Tech. 2004. Boeing Creek Basin Characterization Report. Prepared for City of Shoreline by Tetra Tech/KCM, Inc., Seattle, Washington.

Windward Environmental et al. 2013. Boeing Creek Basin Plan. Prepared for the City of Shoreline by Windward Environmental LLC, Osborn Consulting Inc., and The Watershed Company. March 2013.

ADDITIONAL PHOTO POINT REFERENCE PHOTOS

Outlet photo point, taken February 21, 2015 (IMG_0299.JPG)

Middle lake shore photo point, taken February 21, 2015 (IMG_0338.JPG)

Delta photo point, taken June 6, 2016 (IMG_6401.JPG)