HIDDEN LAKE MANAGEMENT PLAN FEASIBILITY STUDY

SEPTEMBER 2014

AltaTerra

Executive Summary

Hidden Lake is a man-made lake located at the intersection of Innis Arden Way and 10th Avenue NW in the Boeing Creek Basin and Shoreview Park. The lake originated when Mr. William Boeing first dammed Boeing Creek to create a fishing pond and small hatchery near his estate; current ownership of Hidden Lake is shared between the City of Shoreline (Shoreview Park) and 5 private property owners. The City of Shoreline Surface Water Utility (City) spends a significant portion of its annual operation and maintenance budget to maintain Hidden Lake as an open water feature. Since 2002, the City has invested nearly $600,000 to remove deposited material (Figure ES-1). The purpose of this study was to identify alternative management options that would reduce costs associated with the City's management of Hidden Lake.

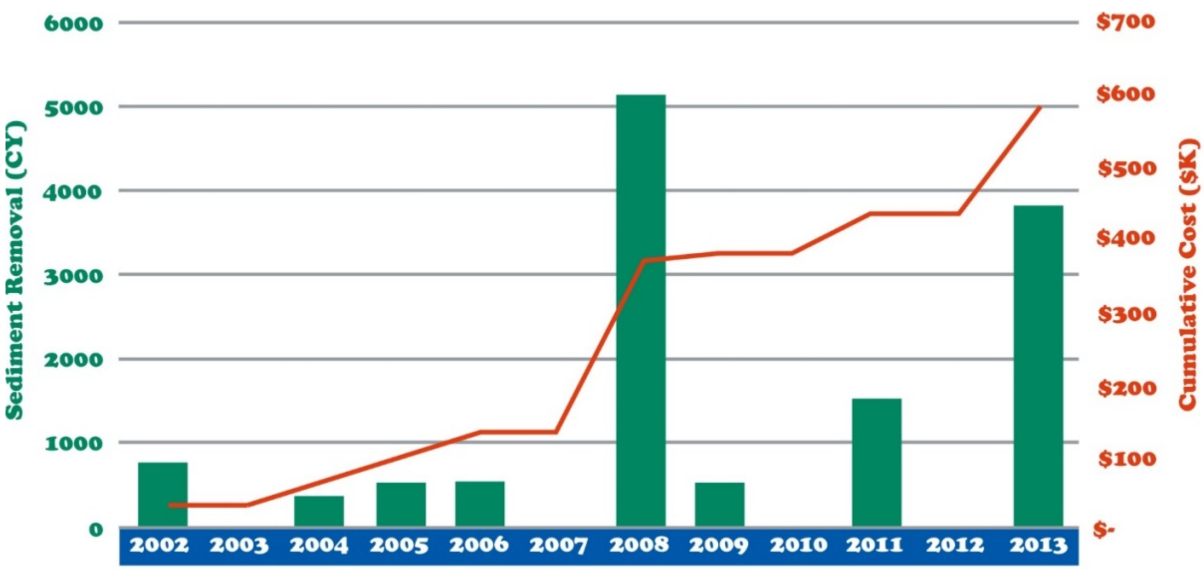

Figure ES-1. Record of Material Removal at Hidden Lake and Cumulative Cost between 2002 and 2013

The primary sources of material deposited in Hidden Lake are from landslides and hillslope failures in the Boeing Creek ravine upstream of Hidden Lake. Channel bank and bed erosion is another source of material, although this source is a much smaller contributor to overall material load (up to 10%). High stream flows from intense urban development and erosive geologic conditions have contributed to instability in Boeing Creek and high rates of material deposition in Hidden Lake. Material eroded from adjacent hillslopes and the channel itself is readily mobilized and transported to Hidden Lake during larger storm events.

Alternative evaluation focused on solutions that target the causes of erosion (flow), sources of material (channel and hillslopes), and mobilization and deposition of material. Eleven alternatives were initially considered and were narrowed down to five (including the no-action alternative) that would meet the City's goals (Table ES-1).

Table ES.1 List of Viable Alternatives

Alternative	Why?	Estimated Costs		
		One-time	Annual	Total (over 10-year timeframe)
Status Quo (keep dredging)	No-action alternative	$0	$54,000 (based on current annual average cost)	$540,000
Cease Dredging	No-cost alternative	$0	$2,500 (outlet maintenance)	$25,000
Remove Dam	Closest to "restoration"	$600,000	$8,000 (for 5 years of vegetation monitoring and maintenance)	$640,000
Lower Outlet with Cessation of Dredging	Intermediate solution though likely not that effective	$160,000	$2,500 (outlet maintenance)	$185,000
Upstream Flow Control*	Basin-wide benefits, possible very high cost	>$10,000,000	Varies	>$10,000,000

* As redevelopment occurs, upstream flow control should be pursued to begin reversing stream channel degradation, which is the result of decades of urban development without stormwater flow control. The cost estimate shown is based on implementation of flow control across the basin at the level needed to reduce degradation. Incremental steps to control flow are worthwhile.

The degradation of Boeing Creek has occurred over decades and will likely take decades more to stabilize, even with initiating adequate upstream flow control (which is currently lacking). As has been recommended in previous studies beginning in the 1980s, the City should continue to pursue implementation of flow control in the Boeing Creek basin, wherever possible. Reducing flows in Boeing Creek is the only sustainable approach to decreasing erosion processes that occur in the stream channel and adjacent hillslopes. Over time, the transport of material downstream to Hidden Lake would be reduced.

Outside of addressing one of the primary contributing factors (i.e., flow), the City will need to decide whether it continues to spend funds to remove material from Hidden Lake or on an alternative scenario, such as removing the Hidden Lake dam. There is public sentiment for keeping the lake, but the only feasible alternative over the near term is to continue material-removal activities. Allowing the lake to fill in with material or removing the Hidden Lake dam are alternatives that would result in ecological benefits and would reduce the City's long-term net maintenance costs.

1.0 Introduction

Hidden Lake is located at the intersection of Innis Arden Way and 10th Avenue NW in the Boeing Creek Basin (Figure 1). The lake originated when Mr. William Boeing first dammed Boeing Creek to create a fishing pond and small hatchery near his estate; current ownership of Hidden Lake is shared between the City of Shoreline (Shoreview Park) and 5 private property owners. Since its creation, the lake has undergone changes in condition from being an open water feature to a forested wetland. The City of Shoreline (City) spends a significant portion of its annual stormwater operation and maintenance budget to maintain Hidden Lake as an open water feature, having invested nearly $600,000 since 2002 to remove deposited sediment. The purpose of this study is to identify alternative management options that would reduce costs associated with the City's management of Hidden Lake.

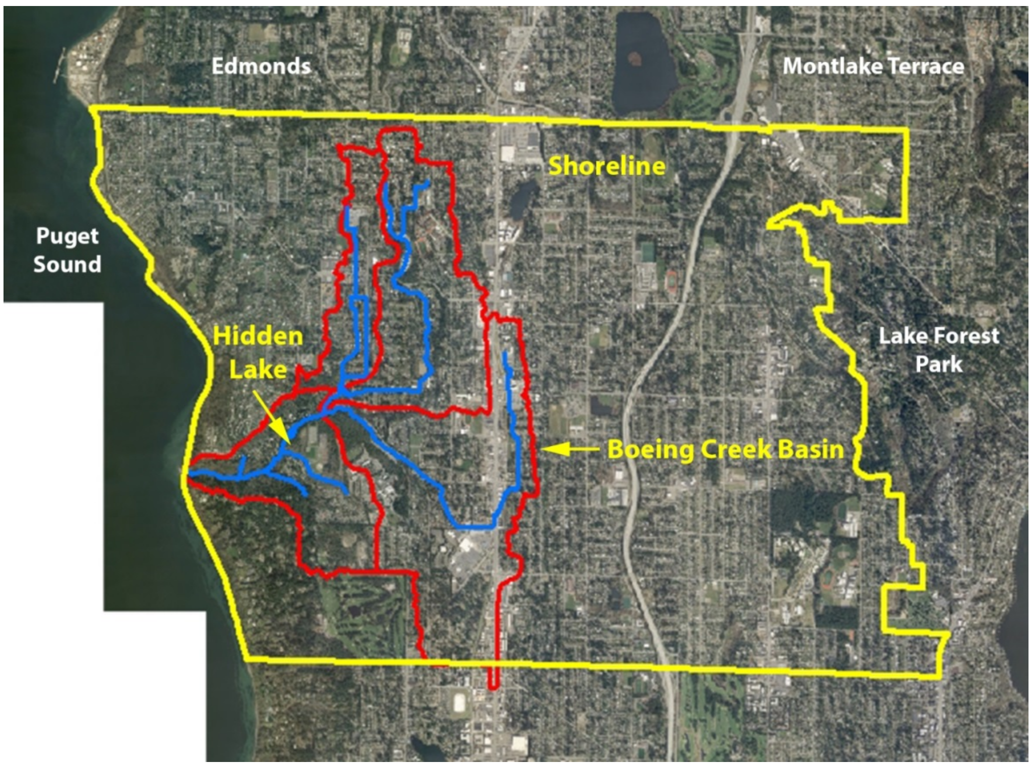

Figure 1. Hidden Lake Location and Vicinity Map

1.1 Goals and Objectives

The specific project objectives for the Hidden Lake Management Plan Feasibility Study are to:

- Identify alternatives that will reduce the net maintenance cost for managing Hidden Lake.
- Identify capital projects or strategies that could be incorporated in the City's next 6-year Capital Improvement Program (CIP) to achieve the above plan objectives.
- Maintain or improve water quality in Hidden Lake and Boeing Creek.

Additionally, goals in the development of alternative strategies include:

- Avoiding significant degradation of the area's aesthetics.
- Improving ecological conditions.
- Maintaining recreational benefits of Shoreview Park.

This study sought public input to gauge individual opinions about Hidden Lake, solicit ideas, and collect feedback on the alternatives considered.

2.0 Background and History

The history of Hidden Lake, the Boeing Creek Basin land use and development, and the geologic setting are all factors that influence Hidden Lake conditions and the City's current maintenance. A historical timeline of events is shown in Figure 2.

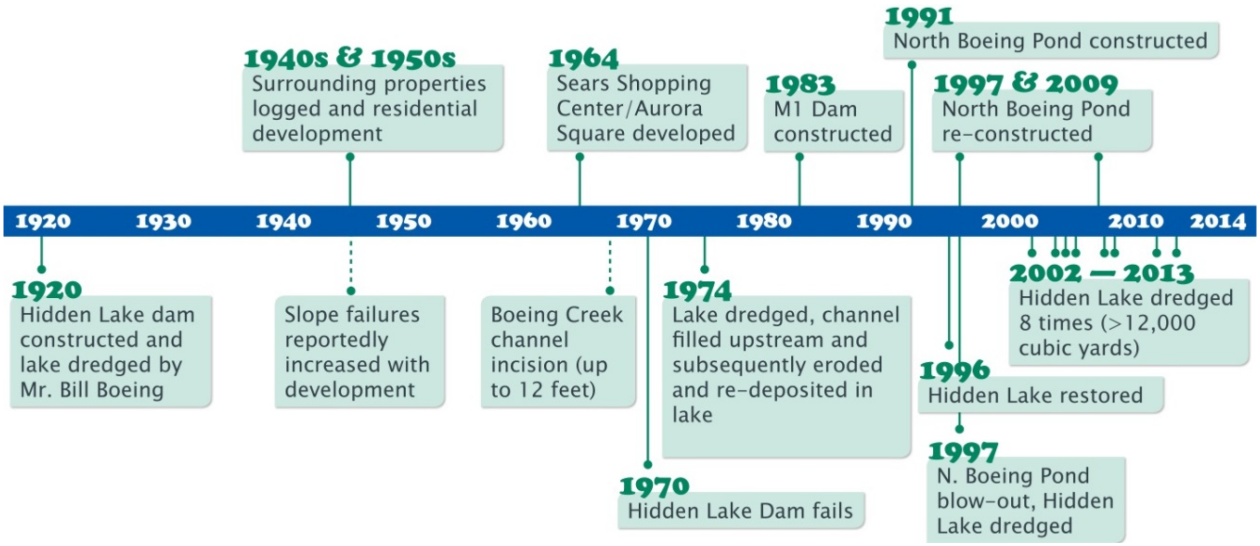

Figure 2. Timeline of Hidden Lake Events

2.1 Hidden Lake and Surrounding Vicinity

A review of aerial photographs from 1936 to recent times shows that the lake has not always been an open water feature (Figure 3). Aerial photographs from 1989 and 1995 do not show open water, indicating that sediment and material from upstream had likely filled in the lake and without active removal of that material, the lake reverted to a forested wetland surrounding Boeing Creek. In 1996, King County restored Hidden Lake to an open water body, and it has remained in this form since.

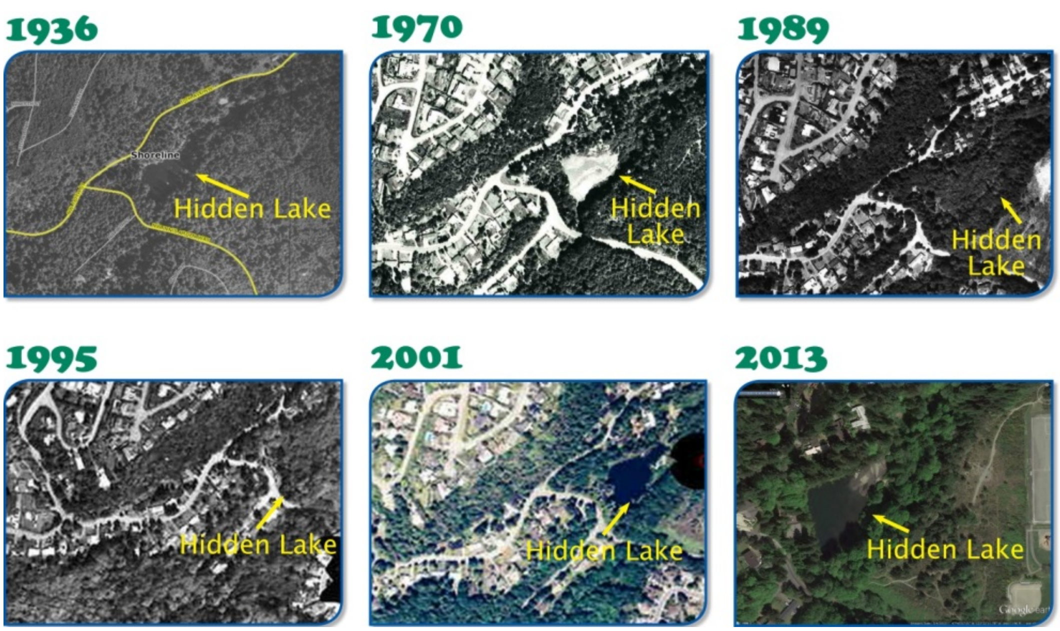

Figure 3. Hidden Lake Aerial Photographs

At the time Hidden Lake was constructed in the 1920s by William Boeing, the land surrounding Boeing Creek was primarily forested. As Mr. Boeing sold off pieces of his property in the 1950s and 1960s, the area developed into residential communities (e.g., Innis Arden). In the 1960s and 1970s, commercial development occurred along the Aurora Avenue Corridor, including the construction of Aurora Square (currently home to Sears and Central Market). Development in the Boeing Creek Basin over the years has resulted in changes to the hydrology of Boeing Creek and subsequent impacts to stream channel.

2.2 Geologic Conditions

The geology and topographic setting of Boeing Creek make it particularly susceptible to erosion and landslides. From its headwaters to Hidden Lake, the upper part of the Boeing Creek watershed drains about 1.8 square miles above the eastern edge of Puget Sound. Based on prior geologic mapping (Figure 4), the upper areas of the watershed are underlain primarily by glacial till, a surface layer typically just a few feet or tens of feet thick, which overlays sandy “advance outwash” deposited by glacial streams fed by the ice sheet that moved south into the central Puget Sound region about 17,000 years ago. This outwash is exposed almost continuously along both branches of Boeing Creek down almost to the elevation of Hidden Lake, with an overall thickness of up to 200+ feet.

This deposit is, by far, the most voluminous source of sediment being transported down the creek and into Hidden Lake. Thus, its physical properties are of particular significance to this study.

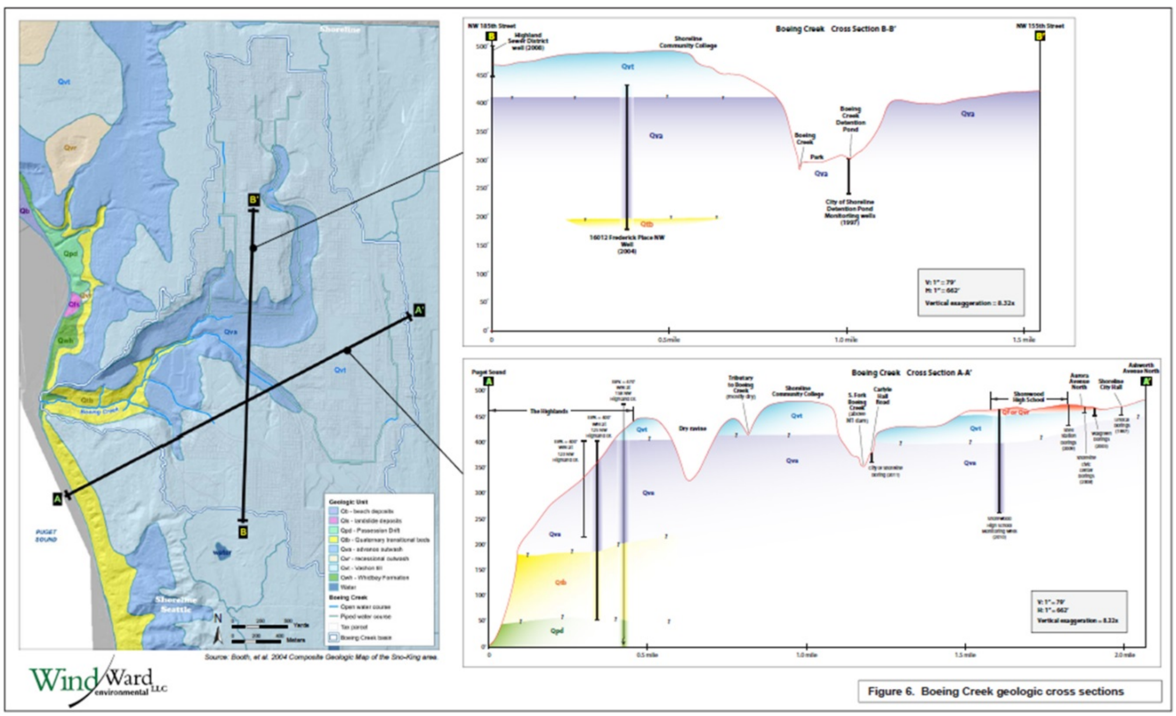

Figure 4. Geology and Topography

Advance outwash is predominantly a well-sorted, sand-sized deposit. Because it was laid down in front of the advancing ice sheet, it was subsequently overridden and thus compacted by the weight of up to several thousand feet of ice. As a result, it can stand in near-vertical slopes for many years. However, it is poorly cemented and therefore easily eroded by running water, and it can move downslope on hillsides as a result of soil creep, treethrow, or mass failure simply under its own weight. Once this material has entered the stream channel, the sand-sized material is rapidly transported by even relatively modest flows down the channel until reaching quiet water, which in this part of the channel network is Hidden Lake.

Local, discontinuous lenses of very fine sand and silt are also present in the advance outwash, particularly near the base of the unit (between about 180 and 200 feet in elevation, close to that of Hidden Lake) which tend to perch local groundwater above these layers wherever they occur. In these locations, hillside seeps and springs are found (and are commonly the only way to identify where such layers occur); the perched groundwater also raises the likelihood of hillslope landslides, which is one of the reasons why these failures do not occur uniformly throughout the canyon of Boeing Creek.

2.3 Significant Events and Stream Channel Impacts

There have been many documented impacts to Boeing Creek, particularly after the construction of Aurora Square. Prior to the City of Shoreline's incorporation in 1995, King County made many attempts to reduce these impacts. Events and impacts are described below.

2.3.1 Hidden Lake Dam Failure (1970)

Following construction of Aurora Square in 1964, Boeing Creek began incising, resulting in destabilization of adjacent hillslopes. The material that was eroded from the channel and hillslopes was transported downstream and Hidden Lake started to fill (King County 1995). After a major storm event in 1970, the Hidden Lake dam failed. King County attempted to re-establish the lake in 1974 by dredging deposited material from the lake and filling the incised channel upstream. This effort was not successful, and the placed material was again eroded and deposited back into Hidden Lake.

2.3.2 Stream Channel Erosion (documented since early 1980s)

Stream channel erosion of Boeing Creek has been recognized for many decades. In the early 1980s, over a decade after the initial development of the Aurora Boulevard/NE 160th Street commercial center, the channel became a classic field-trip site for University of Washington geology courses to observe the consequences of urban development on an intrinsically erosive, "sensitive" stream. Subsequent efforts in the 1980s along the mainstem channel below NE 160th Street (notably, construction of the M1 detention pond in 1983 and armoring of the channel immediately downstream) provided some relief but could not alter the fundamental trajectory of channel downcutting, which has resulted in oversteepening of the adjacent hillslopes and subsequent landsliding of new sediment into the channel. This sediment delivered to the channel from the adjacent hillslopes is then readily transported downstream.

2.3.3 Construction of M1 Dam (1983)

In another attempt to stabilize Boeing Creek, King County constructed the M1 dam in 1983. The M1 dam was just one of many dams proposed along Boeing Creek. In a 1980 report by Brown and Caldwell (Brown and Caldwell 1980), it was estimated that 48 acre-feet of detention could be provided in Boeing Creek itself utilizing 7 detention facilities and Hidden Lake itself. M1 was the only detention facility that was constructed with a storage capacity of around 9 acre-feet. Approximately 1, 700 linear feet of channel armoring at selected sites was also recommended.

2.3.4 Construction of North Boeing Pond (1991)

Similar to the M1 dam, the North Boeing Pond was constructed by King County in 1991 to detain up to 6.4 acre-feet of water in line with the North Fork of Boeing Creek.

2.3.5 North Boeing Pond Washout (1996)

The washout of the detention pond berm on the North Fork on New Year's Eve 1996 provided an unusual opportunity to explore short- and long-term rates of channel change. Students from the University of Washington's Center for Urban Water Resources Management measured cross sections on a roughly monthly basis for 21 months following the event (discussed below in Section 3). Their results indicated a massive wave of sediment filling the channel of Boeing Creek from the stepping stone confluence of the mainstem and North Fork down to Hidden Lake, followed by rapid erosion of that material.

2.3.6 Recent Large Rain Events

Large storm events in the past decade have resulted in further channel erosion, destabilization of hillslopes, and transport of eroded material downstream to Hidden Lake. In December 2007, a very large rain event resulted in Hidden Lake filling with over 5,000 cubic yards of material that was subsequently removed in 2008. A November 2012 rain event resulted in deposition of nearly 3,800 cubic yards of material that was removed in 2013.

2.4 Previous Management Actions

Attempts have been made to control flows to Boeing Creek, stabilize the Boeing Creek channel, and maintain Hidden Lake as an open water feature.

2.4.1 Flow Control

Three flow control facilities were constructed within the Boeing Creek Basin following construction of the Aurora Square shopping center: M1 dam detention facility, North Boeing Creek Pond, and Pan Terra Pond. The facilities provide a fraction of the flow control (estimated to be 10% or less) that is needed to alleviate channel degradation in Boeing Creek. Flow control facilities to protect stream channels have only been required by regulatory agencies in the last 20 years, whereas much of the Boeing Creek Basin was developed prior to 1990 and, thus, has few such facilities.

2.4.2 Channel Stabilization

Previous channel stabilization efforts are still present in Boeing Creek, including large rip-rap rock (up to 2 feet in diameter in some locations), concrete, and asphalt. Log grade-control structures are also present in the North Fork of Boeing Creek and the mainstem of Boeing Creek downstream of the stepping stone confluence of the North and South Forks. These structures were placed sometime after 1980, as they are not described in Brown and Caldwell's 1980 report.

2.4.3 Hidden Lake Management

There are a few reports of Hidden Lake filling with sediment and subsequently being dredged and restored as an open water feature. The first such attempt to restore Hidden Lake was in 1974, followed by a large-scale restoration in 1995. The most recent restoration occurred in 1997, following the deposition of large quantities of sediment that were transported downstream from the North Boeing Pond washout in 1996. The 1997 restoration effort included establishment of a sediment forebay and a bypass pipe designed to facilitate sediment removal by shunting water around the lake during maintenance activities. An easement through private parcels was also obtained by King County to provide access for maintenance. The City, through its incorporation in 1995, assumed maintenance of Hidden Lake from King County.

3.0 Current Conditions

Following incorporation the City accepted Hidden Lake and all public stormwater infrastructure and other facilities that were previously owned and/or maintained by the county. The City has been conducting maintenance according to the Boeing Creek Hidden Lake Restoration Operations and Maintenance Manual (King County, no date) ever since. Recommended maintenance includes inspection of the embankment and spillway for seepage, removal of debris and sediment accumulation around and in the control structure, and annual removal of sediment. The sediment forebay was designed to hold 300 cubic yards of material, and approximately 175 cubic yards of sediment was estimated by King County (1995) to be deposited annually.

The amount of material deposited in Hidden Lake has far surpassed what was anticipated by the King County engineers that designed the 1995 restoration. City records indicate over 13,000 cubic yards of material has been removed since 2002 (almost 6 times more than the original estimate) at a cost of nearly $600,000 (Figure 5).

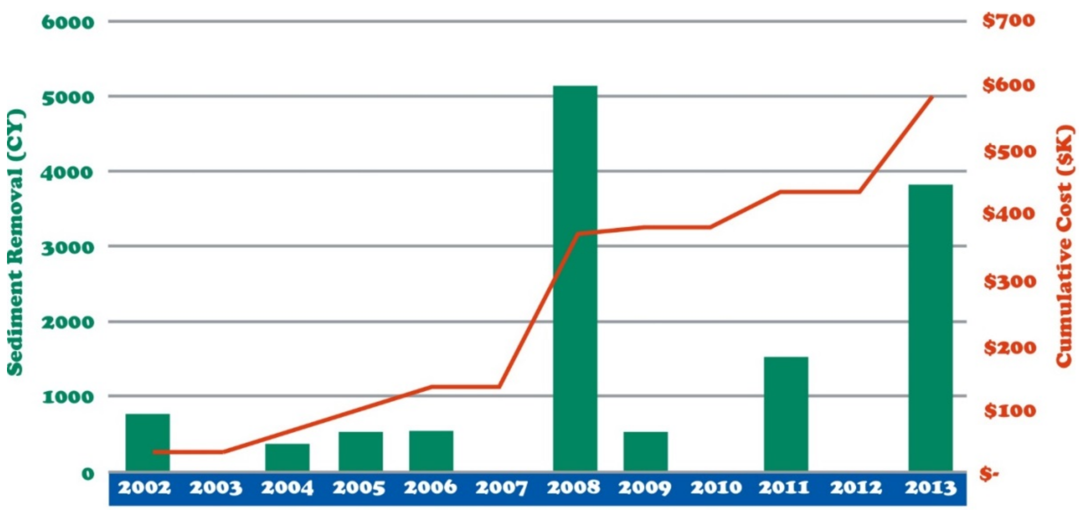

Figure 5. Record of Sediment Removal at Hidden Lake and Cumulative Cost between 2002 and 2013.

3.1 Geomorphology

Previous data collected on Boeing Creek from 1997 to 2001 (after the North Boeing Pond washout) and again in 2011 as part of the Boeing Creek Basin Plan (Windward 2013) were used to compare current geomorphic conditions in Boeing Creek.

The washout of the detention pond berm on the North Fork on New Year's Eve 1996 provided an unusual opportunity to explore short- and long-term rates of channel change. Following this event, students from the University of Washington's Center for Urban Water Resources Management measured cross sections on an approximately monthly basis for 21 months. They found that a massive wave of sediment filling the channel of Boeing Creek from the stepping stone confluence of the mainstem and North Fork down to Hidden Lake, followed by rapid erosion of that material and the eventual reestablishment of a channel that largely resembled the size and morphology of its pre-washout counterpart (Figure 6). The initial recovery of a defined channel form occurred within a few weeks of the initial failure; by April 1997 (less than 4 months after the washout), the channel had recovered a form that remained largely stable through the end of the monitoring period (September 1998, nearly 2 years after the initial washout). The project concluded with the surveying of a downstream longitudinal profile of the thalweg – the deepest point of the channel – from the stepping stone confluence to Hidden Lake in the summer of 2001.

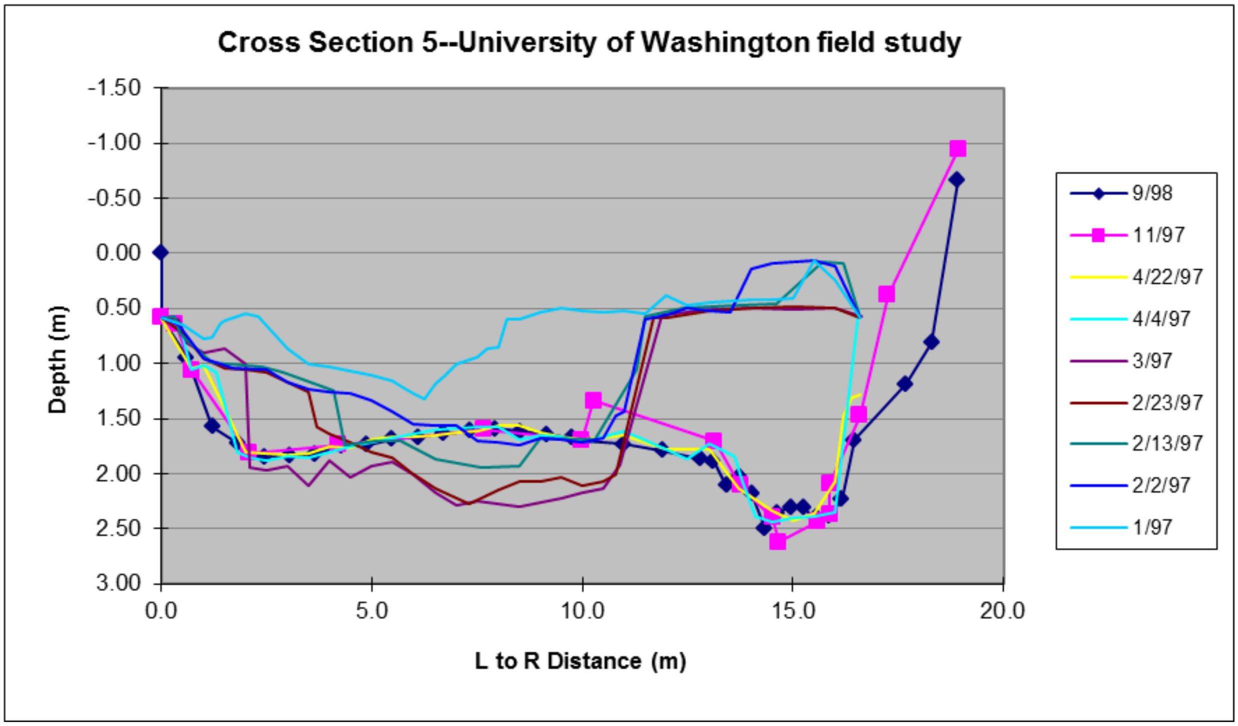

Figure 6. University of Washington Field Study. Example of cross-section data collected over the 21 months following washout of the North Fork detention pond (1997-1998). This cross section is about 300 feet upstream of Hidden Lake. This figure illustrates the sediment transport capability of Boeing Creek. Several feet of sediment was deposited in the channel following the 1997 washout (light blue line at top). In less than a year, the sediment had moved through the system (pink line with points).

Geomorphological cross sections were measured during an investigation completed in 2011, with most of the cross sections located on the mainstem between the M1 dam and the stepping stone confluence. These were done as part of the Boeing Creek Basin Plan, a project that characterized basin-wide surface water and stormwater management issues and developed solutions. As a one-time set of measurements, data did not provide information about the evolution of the channel, but they can now be used to provide another baseline measurement from which to evaluate subsequent change.

For the present investigation, a new longitudinal profile was surveyed from the M1 dam downstream to Hidden Lake (about 3000 feet) (Figure 7) and several cross sections at the approximate (or exact) location of prior cross sections were also measured (Figure 8).

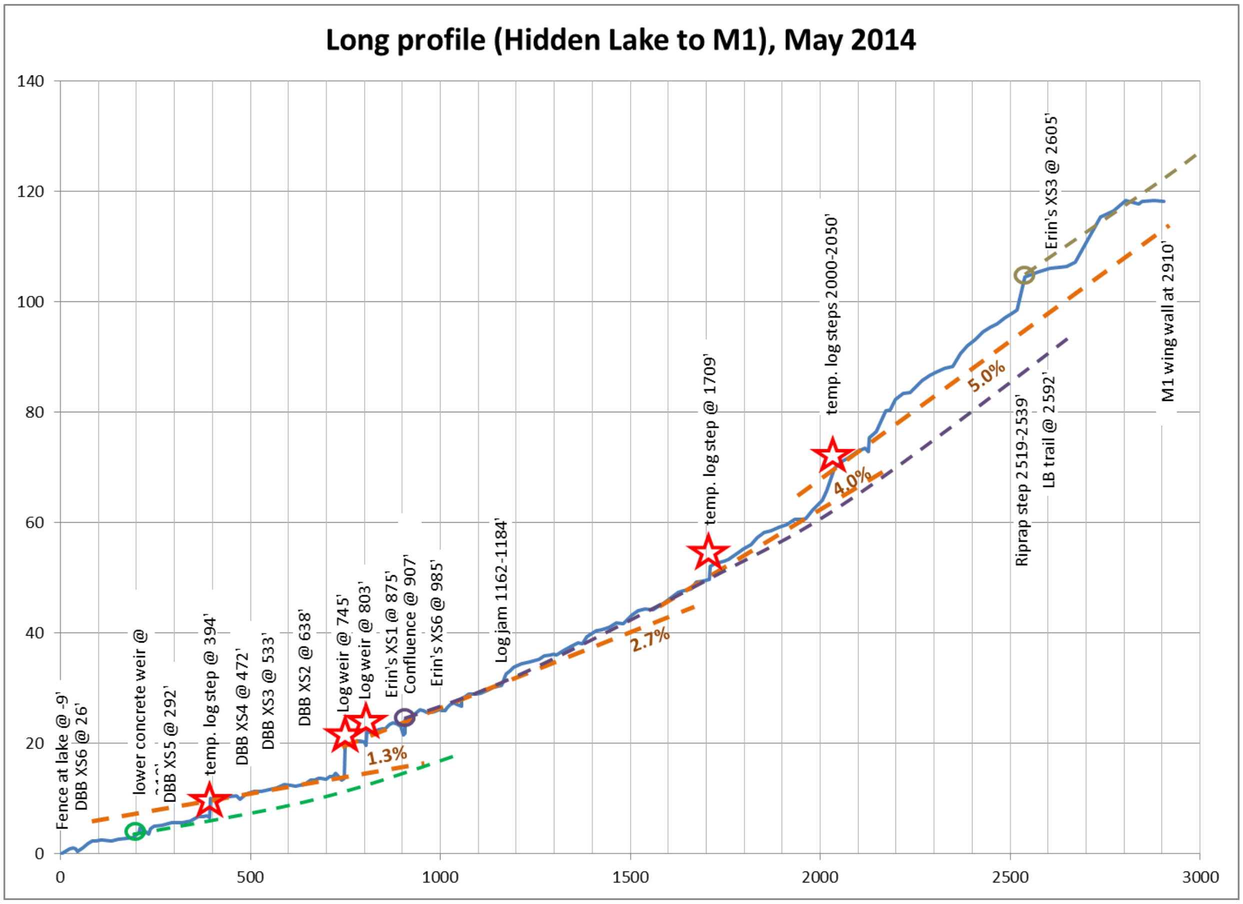

Figure 7. Surveyed Longitudinal Profile (May 2014). The blue line is the stream-bottom profile at the deepest point of the flow (the "thalweg"); the smooth dashed brown lines with associated percentages approximate the average local bed slope. Currently stable bed locations that may be prone to future erosion or washout are marked with red stars; stable bed locations that are judged unlikely to fail are denoted with circles. The vertical distance between the brown lines (local bed profile) and the colored dashed line immediately below it, typically a few feet up to as much as 10 feet, represents our judgment of the potential magnitude of future vertical incision should the ephemeral grade controls at the red stars ever fail.

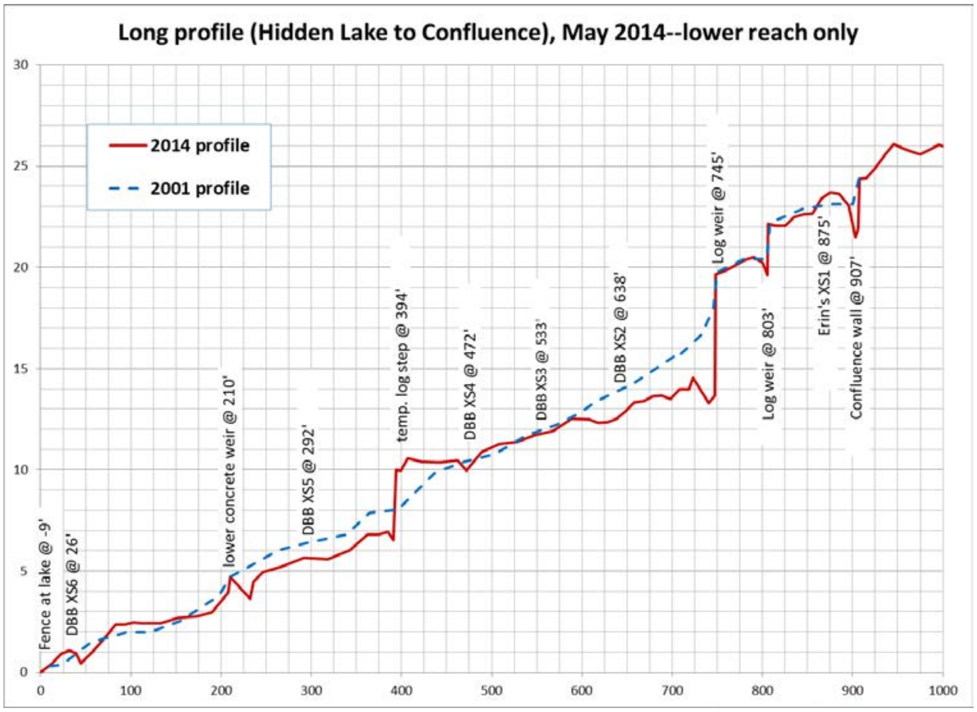

Figure 8. Comparison of 2001 and 2014 Longitudinal Profiles in the 900 feet of Boeing Creek between the stepping stone confluence and Hidden Lake. Good alignment of profiles in both the vertical and horizontal dimensions was possible because of the concrete structures at 210 feet and 907 feet and a long-lived log weir at 745 feet. The difference between the 2001 and 2014 profiles show downcutting that has occurred in the intervening 13 years between measurements. Downcutting is estimated to be an average of 1 foot over the entire reach.

Whether comparing the 1997-1998 cross sections, the 2001 longitudinal profile, or the 2011 cross sections, multi-year data indicate continuous channel erosion at almost every location as follows:

- Downstream of the stepping stone confluence, cross sections from the 1997-1998 University of Washington study were difficult to locate precisely, but could generally be identified within about 10 feet from field descriptions and photographs. Findings suggest deepening of the channel by about 1 foot or less, consistent with the changes indicated at respective locations in the 2001 longitudinal profile. Channel widening of 5-15 feet in the intervening 17 years is also indicated (a phenomenon that is well-recognized by users of the streamside trail within Boeing Creek Park), although with greater uncertainty due to the imprecise relocation of prior cross section locations (as an example, see Figure 9).

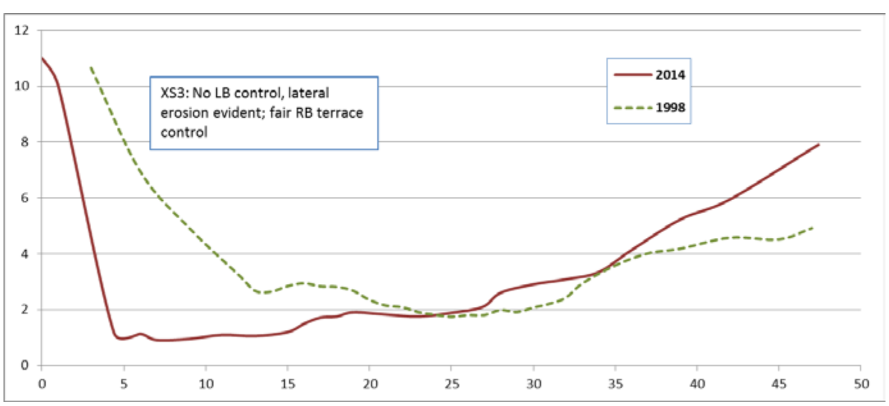

Figure 9. 1997-1998 Survey – Cross Section 5. Data shows a common pattern of relatively modest incision but significant widening. Vertical exaggeration 2:1.

- The 2001 longitudinal profile, although of limited extent (about 900 feet from the stepping stone confluence to Hidden Lake), provides the best opportunity to make a precise comparison to conditions in 2014 because permanent structures in the stream have permitted a near-perfect alignment of these two surveys. Their comparison (Figure 8) shows pervasive, though not ubiquitous, channel erosion of about 1 foot throughout much of the reach. Local deposition has occurred behind a new (but temporary) natural log step at 394 feet; and a constructed log weir at 745 feet has induced some additional erosion immediately downstream, recognizable in the cross section comparison and also in the field. A plunge pool has also developed just downstream of the concrete wall located at 907 feet that marks the stepping stone confluence of the North Fork and mainstem.
- Upstream of the stepping stone confluence, 3 cross sections from 2011 suggest relative stability of the channel form over the last 3 years, although one (XS6) displays about 1 foot of additional channel incision (Figure 10). However, recent landslides and other hillslope failures indicate that the mainstem is not quiescent; rather, sediment is continuing to be generated from the hillslopes abutting Boeing Creek, but the channel is transporting that sediment without significant alteration in its overall form or size.

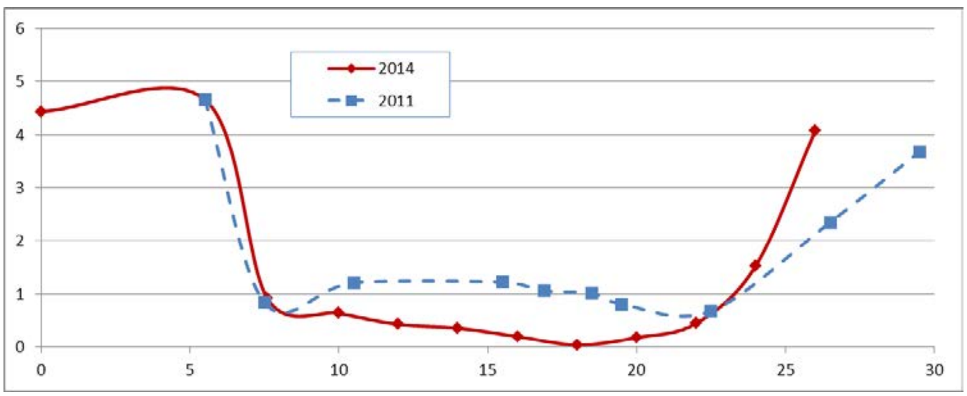

Figure 10. Cross Section E6. Taken 87 feet upstream of the stepping stone confluence on the South Fork of Boeing Creek, with up to about 1 foot of incision over the past 3 years. Vertical exaggeration 2:1.

A simple mass balance can be calculated to compare the volume of sediment generated by channel expansion (since a larger channel must result in additional sediment being released downstream) to the dredged volumes from Hidden Lake. This can allow for determination of whether the bulk of material arriving at the lake is originating from erosion of the channel itself or from other sources, of which the adjacent hillslopes are the primary source. Two pieces of data are available: 1) the volume of sediment that has been released by the observed expansion of the channel, and 2) the volume of sediment dredged from the lake.

- Channel expansion can be approximated by the magnitude of observed channel changes from repeat surveys. Below the stepping stone confluence, the 2001 and 2014 longitudinal profiles comparison (Figure 8) is the best data source. An average of about a 1-foot incision over about half of the profile length can be seen, with an average channel width (from the cross sections) of about 20 feet. Thus, 1 x (907/2) x 20 ≈ 9,000 cubic feet over this 13-year interval, or about 26 cubic yards per year. An equivalent calculation is not possible for the (longer) channel reach upstream of the stepping stone confluence because the 2001 profile did not extend that far, but we estimate that no more than one-third of that channel reach (2000 feet in total) expresses a similar magnitude of change, based on the extent of raw, vertical streambanks and the limited magnitude of cross-sectional change from 2011 to 2014. It is therefore judged that even a generous estimate of sediment delivery from channel expansion will be no more than 100 cubic yards per year, and likely somewhat less than this amount.

- The City of Shoreline keeps accurate dredging records for the maintenance of Hidden Lake, which report that 12,976 cubic yards have been dredged from 2002 through 2013 (Figure 5), for an average removal of about 1,000 cubic yards per year – ten times (or more) the likely rate of sediment production from channel expansion alone.

Based on observations of landslide and hillslope failures in the Boeing Creek ravine coupled with channel measurements and records of sediment removal in Hidden Lake, it appears that hillslope-derived sources of sediment account for up to 90% of the material deposited in Hidden Lake.

3.2 Biological Conditions

Biological conditions in Boeing Creek were evaluated in 2012 as part of the Boeing Creek Basin Plan (Windward 2013) and again for this study. Additionally, a functional assessment of ecological conditions in Hidden Lake was conducted to compare existing functions to potential changes resulting from different alternative management scenarios.

3.2.1 Fisheries

As part of the Boeing Creek Basin Plan, fish passage barriers on Boeing Creek were cataloged, a review of historical fish usage was performed, and an electrofishing survey was conducted to update past findings.

3.2.1.1 Fish Passage Barriers

There are at least 4 complete fish barriers downstream of Hidden Lake, including the following:

- A steel-pile dam at the Seattle Golf and Country Club,
- Riprap cascades below Innis Arden Way,
- Innis Arden Way culverts, and
- Hidden Lake dam.

Additionally, the box culvert under the Burlington Northern Santa Fe (BNSF) Railway railroad at the mouth of Boeing Creek may hinder upstream fish passage during certain tidal and/or flow conditions. The culvert was installed in 1995 in part to improve fish passage conditions.

Upstream of Hidden Lake, there are fish passage barriers for resident cutthroat trout and planted juvenile coho salmon at log weirs in the mainstem of Boeing Creek and at the M1 dam and North Boeing Detention Pond.

3.2.1.2 Historical and Current (2012) Fish Usage

Anadromous salmonids, including coho and chum salmon and sea-run cutthroat trout and occasional Chinook salmon have been observed (Design 2004) in the downstream reach of Boeing Creek from the mouth at Puget Sound to approximately 2,300 feet upstream at the steel pile dam.

Upstream of Hidden Lake, cutthroat trout and juvenile coho salmon have been previously documented and were confirmed during electrofishing in 2012. The cutthroat trout upstream of Hidden Lake are believed to be an isolated, self-sustaining, non-migratory population. The juvenile coho are believed to be present because of outplanting activities associated with "Salmon in the Classroom," or similar programs carried out by a number of local educators and their students in cooperation with the Washington Department of Fish and Wildlife (WDFW) (Design 2004; Barnes 2012). Typically, juveniles are able to reside in these upper reaches for a year before migrating downstream to Puget Sound and the Pacific Ocean to mature. However, those coho that survive to return to Boeing Creek as adults are not able to access the upper stream reaches where they lived as juveniles because of impassable barriers; rather, they are confined to the lower stream reaches downstream of the sheet pile dam for spawning.

3.2.2 Wetlands

Wetlands were documented during 2012 as part of the Boeing Creek Basin Plan (Windward 2013). The only two wetlands present in the reach of Boeing Creek upstream (including Hidden Lake) are Hidden Lake itself and a small seep wetland near the stepping stone confluence of the North and South Forks of Boeing Creek.

3.2.2.1 Hidden Lake

Hidden Lake is a Category III depressional wetland according to the Washington State Department of Ecology's (Ecology's) wetland rating system for Western Washington (Hruby 2004). It is less than 2 acres in size and provides a moderate level of wetland functions, including water quality, hydrology, and habitat. In order to compare existing wetland functions to potential future wetland functions under different sediment management scenarios, the Credit-Debit Method (Ecology 2012) for calculating compensatory mitigation in wetlands in Western Washington was used. The results of the Credit-Debit method are described in Attachment A and in Section 5.0 Alternatives Evaluation.

3.2.3 Riparian Conditions

Riparian conditions along the main stem of Boeing Creek and its north and south tributaries within Shoreview and Boeing Creek Park are generally forested along both banks and the stream banks. Approximately 6 acres of riparian forest is adjacent to Boeing Creek (ranging from 100 to 250 feet wide) and more than 30 acres of coniferous and coniferous/deciduous forest is present in Boeing Creek and Shoreview Parks (Seattle Urban Nature 2008).

4.0 Public Outreach and Stakeholder Input

Two public meetings were held to gather input and concerns from the public. The 2 public meetings were held at Shoreview Park on May 6 and July 1, 2014. The meetings were well attended by residents from around Hidden Lake and neighboring areas as well as park users. In addition, the City and project team also presented to the City of Shoreline Parks Board on three separate occasions.

4.1 May 6th Meeting

The purpose of the first public meeting on May 6, 2014, was to provide an opportunity for the City and project team to present why the Feasibility Study was being conducted and gather initial questions and concerns regarding management of Hidden Lake. The following are general concerns captured at the first meeting:

- The cost of dredging Hidden Lake and if it is the City's responsibility to continue to absorb the cost.
- Environmental impacts to both habitat and downstream if dredging was stopped and Hidden Lake is left to return to more natural settings.
- Upstream development and growth and how it contributes to the sediment issues in Hidden Lake.

4.2 July 1st Meeting

The second public meeting on July 1, 2014, was an opportunity to present the proposed alternatives from the Study and gather input from the public. Questions and concerns on the following issues were captured at the second meeting:

- Slope failure and where it occurs and how it contributes to the sediment.
- Stabilizing the channels and whether analysis has been conducted to find solutions for channel stabilization.
- Whether erosion is occurring naturally as part of the wilderness setting.

- If Hidden Lake is left to fill in naturally what impacts it will have downstream.
- Upstream commercial development needs to do more to address stormwater retention.

In addition to the 2 public meetings, the City also conducted a short written survey to gather input from the public regarding their priority goals for Hidden Lake as well as their preferred alternative. The survey was made available online, at the public meeting, and as a mail-in option. A total of eight survey responses were received with half being from Parks users and half from lakeside residents. Most of the respondents were aware that Hidden Lake is not a natural feature, and half of the respondents would be willing to pay higher taxes or form a local improvement district to continue maintenance dredging.

Survey participants were asked to rank four alternatives according to priority. The highest ranked alternative was Alternative 3: Remove Dam or Lower Outlet, followed by Alternative 2: Cease Dredging, Alternative 3: Upstream Flow Control, and Alternative 1: Status Quo.

4.3 Parks Board Meetings

The project team and Surface Water Utility staff met with the Parks Board three times to (1) provide an overview of the project, (2) present alternatives, and (3) visit Hidden Lake and discuss alternatives in more detail. After the third meeting, the Parks Board made a unanimous recommendation to pursue removing the dam.

5.0 Alternatives Evaluation

A brainstorming meeting was held with the project team at the beginning of this project to develop a list of alternatives to reduce the City's maintenance costs for Hidden Lake. Nine technical alternatives (presented in Table 1) were initially considered. Two additional alternatives were brought forth from the public at the July public meeting (Alternatives 10 and 11 in Table 1). Additionally, several financial alternatives were not evaluated. The City may want to consider other options for transferring or sharing the cost of on-going sediment removal. If that is the case, an evaluation of different financial alternatives should occur at that time.

Table 1. Alternatives Evaluated

Alternative	Brief Description
1	Status quo (keep dredging)
2	Cease dredging
3	Remove dam
4	Lower outlet
5	Upstream flow control
6	Convert lake to stormwater facility similar to M1 or Boeing Creek Park
7	Install grade control
8	Stabilize channel and adjacent hillslopes
9	Bypass high flows around Boeing Creek and discharge at Hidden Lake
10	Pipe Boeing Creek between M1 dam and the stepping stone confluence
11	Bypass high flows and sediment from just upstream of Hidden Lake to a point below Innis Arden Way

5.1 Considerations and Evaluation Criteria

Alternatives were screened against the following considerations: 1) ability to meet the project objectives, 2) technical feasibility, and 3) ecological benefit.

Additionally, other factors such as environmental permitting and public support were assessed. Table 2 summarizes the initial project screening. Attachment B includes more detailed project descriptions, considerations, assumptions, and estimated costs.

Table 2. Alternatives Considered, Predicted Outcomes, Estimated Costs, and Pros and Cons

Alternative	Brief Description	Predicted Outcome	Estimated Cost			Pros	Cons
			One-time	Annual	Over 10 years		
1	Status Quo (keep dredging)	No change	$0	$54,000 annually (based on average current costs) with likely high year-to-year variability	$540,000	• Remains a lake • Provides open water habitat for larger cutthroat trout • Waterfowl habitat	• Surface Water Utility continues to incur cost of sediment removal • Corps permit likely needed for continued dredging. Such federal permitting would be expensive and may ultimately be denied.
2	Cease Dredging	Lake converts to a forested wetland over time	$0	$2,500 annually for outlet and dam inspection and maintenance	$25,000	• Surface Water Utility reduces long-term maintenance costs • Maximizes wetland and riparian areas (ecological lift compared to lake) • Higher functioning wetland area would form	• Loss of aesthetic associated with open water • Outlet still requires some periodic maintenance

Alternative	Brief Description	Predicted Outcome	Estimated Cost			Pros	Cons
			One-time	Annual	Over 10 years		
3	Remove Dam with Cessation of Dredging	Sediment transported through reach to downstream locations	$600,000	$8,000 (assumed for 5 years of vegetation monitoring and maintenance)	$640,000	• Closest to restoration, since lake is man-made • Sediment removal needs would be reduced or eliminated • Higher functioning wetland and stream area would be created • Potential grant funding available for dam removal	• Eliminates possibility of returning to a lake in the future • Culverts under Innis Arden Way would need to be monitored for blockage by debris during extreme events
4	Lower Outlet with Cessation of Dredging	Provides some gradient for which to move sediment across lake	$160,000	$2,500 (outlet maintenance)	$185,000	• Increase in wetland area • Extension of stream channel would likely form over time	• All drawbacks of Alternative 2 (cease dredging), through with a smaller footprint • Marginal benefits for substantial cost
5	Upstream Flow Control	Slowly reverse effects of past high flows; with enough flow control, channel and adjacent hillslopes would begin to stabilize	Varies – likely >$10,000,000	Varies	>$10,000,000	• Addresses the ultimate cause of on-going problems • Can be done independent of Boeing Creek and Hidden Lake • Will begin to occur without additional public cost via redevelopment (flow control is required by the City for all new projects) • Can be dispersed throughout the City • Improved water quality in Boeing Creek	• Benefits may not be realized for decades (or longer) • Sediment removal would still be needed in the medium term, but may be reduced over time • Many large facilities or hundreds of small facilities would be necessary to control flow adequately • Facility costs can be high, especially when land is needed

Alternative	Brief Description	Predicted Outcome	Estimated Cost			Pros	Cons
			One-time	Annual	Over 10 years		
6	Convert Lake to Stormwater Facility similar to M1 or Boeing Creek Park	Marginal flow control benefits to reach downstream of Hidden Lake	As for Alternative 1, with one-time capital cost <$10,000	$54,000 (dredging will still be needed)	$550,000	• Modestly increased cost (dredging to continue, dam modification to be made)	• No benefit for on-going sediment removal • Negligible flow control benefits • Fluctuating water levels could impact plant communities and ecological conditions • Aesthetics would be reduced through smaller open water area
7	Install grade control	Reduced channel down-cutting upstream of stepping stone confluence	$520,000	$20,000 - $54,000 (dredging still needed, but may be reduced)	$720,000 - $1,060,000	• Reduced in-channel contribution to sediment load (similar to grade control in mainstem)	• Low benefit, since most of the sediment appears to be coming from hillslope sources • Access for construction would be challenging in order to avoid riparian impacts
8	Stabilize Channel and adjacent hillslopes	Reduced channel down-cutting, bank stabilization, and sediment transport reduction upstream of stepping stone confluence	$2,400,000	$0 - $20,000 (need for dredging would likely be reduced, but not eliminated)	$2,400,000 - $2,600,000	• Reduce in-channel and hillslope contribution to sediment load • Reduction in dredging frequency	• High-cost alternative, would take years of sediment removal at current cost to pay for project • May be difficult to permit • Access for construction would be challenging

Alternative	Brief Description	Predicted Outcome	Estimated Cost			Pros	Cons
			One-time	Annual	Over 10 years		
9	Bypass high flows around Boeing Creek and discharge at Hidden Lake	Reduced sediment mobilization in the area where sediment sources are most problematic (between M1 dam and stepping stone confluence)	>$3,000,000	$0	>$3,000,000	• Decreased frequency of sediment removal at Hidden Lake • Could be very effective	• Very high cost alternative (>36-inch diameter pipe size would be needed), would take years of sediment removal at current cost to pay for project • Likely not permittable
10	Pipe Boeing Creek between M1 dam and the stepping stone confluence	Reduced sediment mobilization in the area where sediment sources are most problematic (between M1 dam and stepping stone confluence)	Very high – not estimated (infeasible)	$0	Not estimated (infeasible)	• Decreased frequency of sediment removal in Hidden Lake	• Very high cost • Not permittable; would require an Environmental Impact Statement (EIS) - level project that would face severe opposition and likely would not be approved. • Degradation of existing stream habitat • Degradation of park aesthetics in vicinity of trail
11	Pipe high flows and sediment from just upstream of Hidden Lake to a point downstream of Innis Arden Way	Bypass sediment and flow around Hidden Lake	Very high – not estimated (infeasible)	$0	Not estimated (infeasible)	• Eliminates need for dredging while preserving Hidden Lake as an open-water feature	• Physically infeasible: sediment load is delivered via a 1.3% channel; cannot be transported 800 feet around the lake without an additional ~10+ feet of relatively uniform vertical drop • Very high cost • Likely not permittable

Several of the alternatives have significant shortcomings in one or more of the following categories:

- The cost of the alternative would exceed the cost of continued maintenance and, therefore, not meet the City's primary objective of reducing long-term net maintenance costs. The following alternatives were of such high cost that the net cost of continued maintenance would not be reduced.
    - Alternative 5 (if at public expense) – Upstream flow control
    - Alternative 7 –Stabilize channel
    - Alternative 9 – High flow bypass
    - Alternative 10 – Pipe Boeing Creek
    - Alternative 11 – Short sediment and flow bypass
- The project has low or marginal benefits for reducing rates of sediment inflow to Hidden Lake over the near term, or relative to ecological or aesthetic considerations. These included:
    - Alternative 5 – Upstream flow control
    - Alternative 6 – Convert lake to stormwater facility
    - Alternative 8 – Install grade control
- The project is not feasible for technical or environmental permitting reasons. The following alternatives fit this category:
    - Alternative 9 – High flow bypass
    - Alternative 10 – Pipe Boeing Creek (infeasible because of permitting)
    - Alternative 11 – Short sediment and flow bypass (technically not feasible)

6.0 Summary

Hidden Lake and Boeing Creek have a long and varied history. Erosion in Boeing Creek and subsequent sedimentation in Hidden Lake has been occurring for decades and appears to have accelerated in the 1970s following more intense upstream development and direct routing of stormwater to Boeing Creek. The degradation of Boeing Creek has occurred over decades and would likely take decades more to stabilize, even with initiating adequate upstream flow control (which is currently lacking). As has been recommended in previous studies beginning in the 1980s, the City should continue to pursue implementation of flow control in the Boeing Creek basin, wherever possible. Over the long term, reducing flows in Boeing Creek is the only sustainable approach to reduce erosion processes occurring in the stream channel and adjacent hillslopes and over time would help reduce the transport of that sediment downstream to Hidden Lake.

Outside of addressing one of the primary contributing factors (i.e., flow), the City will need to decide whether it continues to spend Surface Water Utility funds to remove sediment from Hidden Lake or spend money on an alternative scenario, such as removing the Hidden Lake dam. There is public sentiment for keeping the lake, but the only feasible alternative for achieving this outcome over the near term is to continue sediment-removal activities. Allowing the lake to fill in with sediment or removing the Hidden Lake dam, however, are alternatives that would result in ecological benefits and would reduce the City's long-term net maintenance costs; however, these management options may reduce the aesthetic appeal offered by an open water lake. At this point in time, there are several barriers to anadromous fish migration to the upstream reaches of Boeing Creek. None of the alternatives evaluated will likely have any significant affect, positive or negative, for anadromous salmon populations, however, dam removal could be considered a first step in restoring access to anadromous fish, but would require the removal or modification of many other downstream barriers.

7.0 References

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Attachment A

TECHNICAL MEMORANDUM

Date: June 12, 2014
To: Erin Nelson, AltaTerra Consulting
From: Hugh Mortensen, Katy Crandall, Greg Johnston
Project Number: 140119
Project Name: Shoreline Hidden Lake Management Plan

Subject: Alternatives Analysis – Wetland and Stream Habitat

The overriding assumption for this habitat analysis was to evaluate the predicted condition of the Hidden Lake area after the site has reached a state of equilibrium with respect to sediment for each of the following alternatives.

1) Continue dredging to keep current conditions
2) Stop dredging Hidden Lake (no modification to outlet)
3) Stop dredging and remove the dam at the downstream end of Hidden Lake
4) Stop dredging and modify the outlet structure of the lake, but leave the dam
5) Create a stormwater facility (continue dredging, lower the base lake level, and restrict the outlet)

Wetland Function

The City of Shoreline is interested in researching alternative management options for Hidden Lake located along Boeing Creek. To aid in this investigation, the Credit-Debit Method (*Department of Ecology's Calculating Credits and Debits for Compensatory Mitigation in Wetlands of Western Washington, March 2012, Publication #10-06-011*) was used to determine possible changes to wetland function at Hidden Lake. The wetland "score", functional "lift" and "mitigation credits" were calculated for future wetland conditions under each of the five alternatives.

Potential future wetland conditions were estimated based on a review of previously documented site conditions and current, on-site observations.

1) Keep Dredging/Existing Conditions/Status Quo (HGM – Depressional)
Estimated Size: 1.7 acres

FUNCTION	Improving Water Quality	Hydrologic	Habitat
Rating of Site Potential	L	L	L
Rating of Landscape Potential	H	H	M
Rating of Value	L	L	H
Score Based on Ratings	**5**	**5**	**6**

2) Stop Dredging Only (HGM – Riverine)
Estimated Size: 1.7 acres

FUNCTION	Improving Water Quality	Hydrologic	Habitat
Rating of Site Potential	H	H	M
Rating of Landscape Potential	H	M	M
Rating of Value	M	H	H
Score Based on Ratings	**8**	**8**	**7**

3) Remove Dam (HGM – Riverine)
Estimated Size: 1.5 acres

FUNCTION	Improving Water Quality	Hydrologic	Habitat
Rating of Site Potential	M	M	M
Rating of Landscape Potential	H	M	M
Rating of Value	M	H	H
Score Based on Ratings	**7**	**7**	**7**

4) Modify Outlet (HGM – Riverine) Estimated Size: 1.6 acres			
FUNCTION	**Improving Water Quality**	**Hydrologic**	**Habitat**
Rating of Site Potential	M	M	M
Rating of Landscape Potential	H	M	M
Rating of Value	M	H	H
Score Based on Ratings	**7**	**7**	**7**

5) Stormwater Facility (HGM – Depressional) Estimated Size: 1.7 acres			
FUNCTION	**Improving Water Quality**	**Hydrologic**	**Habitat**
Rating of Site Potential	M	M	M
Rating of Landscape Potential	H	H	M
Rating of Value	L	H	H
Score Based on Ratings	**6**	**8**	**7***

*This step in the rating method does not incorporate the negative habitat effects fluctuating water levels have on vegetation (encourages invasive weeds) or amphibians (disrupt egg survival). Therefore, this score is artificially high, but gets adjusted in the mitigation values below.

Functional "Lift" *(score with proposed option – score for existing conditions)*

FUNCTION	Improving Water Quality	Hydrologic	Habitat	Total
Option 1 (status quo)	0	0	0	0
Option 2 (stop dredging)	+3	+3	+1	+7
Option 3 (dam removal)	+2	+2	+1	+5
Option 4 (modify outlet)	+2	+2	+1	+5
Option 5 (stormwater facility)	+1	+3	+1	+5

*Option one is considered the baseline; the zero scores represent the current functional state compared to the other options, which in the case all happen to be positive numbers (represents improvement over Option 1). It should not be interpreted that Option 1 is devoid of these functions.

The alternative management scenarios (Options 2 – 5) all show a functional lift with respect to water quality, hydrologic, and habitat function. The lift in functions for Options 3 and 4 are the same.

"Mitigation Credits" *(functional lift X estimated wetland area X assumed risk factor [same for all])*

FUNCTION	Improving Water Quality	Hydrologic	Habitat	Total
Option 1 (status quo)	NA	NA	NA	NA
Option 2 (stop dredging)	3.417	3.417	1.139	7.973
Option 3 (dam removal)	2.01	2.01	1.005	5.025
Option 4 (modify outlet)	2.144	2.144	1.172	5.36
Option 5 (stormwater facility)	0.68	2.04	0.68	3.4

This "mitigation credit" calculation shows how Ecology would value the changes proposed under the different scenarios. It takes into account the size of the wetland and a "risk factor" which varies under different types of mitigation. A risk factor of 0.67 (re-establishment of aquatic bed, shrub, or forest community) was used in Options 1 through 4. Under Option 5, we anticipate that an emergent vegetation community would become established where water levels fluctuate significantly. Establishing a wetland dominated by native herbaceous plants, especially in fluctuating water levels, is usually more difficult than one dominated shrubs and forest. Therefore, a risk factor of 0.5 was used which results in fewer of mitigation credits available.

Stream and Riparian Habitat

	Alternative #	Description	Habitat Pros	Habitat Cons
Lake Options	1	Status Quo	1. Maintains open water as fish habitat for larger cutthroat and any planted rainbow, supports a small sports fishery. 2. Provides refuge habitat for fish during times of low flow, flood flows, high temperatures, etc., whenever stream conditions may be poor. 3. Retains high volume of water as fish habitat which would likely contribute to being able to support a larger fish population and/or biomass than a single thread stream or even shallower water/wetlands over the same area. 4. More waterfowl habitat.	1. Possibly less non-waterfowl bird habitat. 2. Possibly less primary productivity due to lower macrophyte density. 3. Continues impacts associated with dredging – turbidity, possible fish and aquatic insect mortality, disturbance along lakeshore, bed, and access route, impacts at disposal sites, etc. 4. Continues impacts to fish and other aquatic biota due to bypassing flows, fish capture and removal, etc.
	2	Stop Dredging	1. Possibly more non-waterfowl bird habitat. 2. Possibly more primary productivity 3. Eliminates impacts associated with dredging – turbidity, possible fish and aquatic insect mortality, disturbance along lakeshore, bed, and access route, impacts at disposal sites, etc. 4. Eliminates impacts to fish and other aquatic biota due to bypassing flows, fish capture and removal, etc. 5. Leaves option open to resume dredging without re-building outlet structure. 6. Maximizes wetland and riparian area.	1. Reduces or eliminates open water as fish habitat for larger cutthroat and any planted rainbow, reduces or eliminates options for sports fishery. 2. Reduces possible refuge habitat for fish during times of low flow, flood flows, high temperatures, etc., whenever stream conditions may be poor. 3. Reduces volume of water as fish habitat. Higher water volume may contribute to being able to support a larger fish population and/or biomass than a single thread stream or even shallower water/wetlands over the same area. 4. Less waterfowl habitat. 5. Aggradation and deposition at the inlet and eventually filling the lake; delta and braided channel formation. 6. Outlet still requires maintenance
	3	Remove Dam	Includes "stop dredging Pros. Comes closest to "restoration" in that a stream channel through the present Hidden Lake could eventually form or be formed with a steeper gradient that could transport sediment. Less deposition or channel aggradation near the inlet.	Includes "stop dredging Cons. Also, eliminates the option of returning to the status quo. Unless a significant amount of sediment is allowed to deposit prior to dam removal, sudden lowering of the lake elevation might and probably would cause habitat losses extending for some distance upstream from the lake due to the potential for headcutting and downcutting.
	4	Lower Lake Outlet	Includes "stop dredging Pros. 1. Provides some channel gradient across the former lake area to transport sediment. 2. Increases Stream channel, wetland, and riparian areas. 3. Less cost than removing dam.	Includes "stop dredging Cons. 1. Reduces open-water, lake habitat similar to the stop dredging option. Less waterfowl and no lake refuge for larger fish or during low flows. Must restore outlet to return to the status quo.

Lake Options	5	Stormwater Facility	Includes habitat pros of "status quo", continue dredging, but to a lesser degree. The lake will just be smaller because much of its present "dead" storage will be replaced with "live" storage. The lake will only be full for brief periods during storm events and will otherwise be only partially full depending on how much dead storage is retained. Channel sections downstream of the lake will benefit somewhat from lower peaks and less variable flows resulting in reduced erosion.	Includes habitat cons of "status quo", continue dredging. However, direct impacts associated with dredging may be somewhat less because more of the sediments to be removed will be above the water line at the time of dredging when stream flows and lake levels are low. An additional impact to habitat will result from the highly fluctuating lake level which will reduce the robustness and functioning of shore-line plant communities. Emergent vegetation will suffer, and plant species may be limited to those able to tolerate highly variable water levels such as perhaps willow but also invasive weeds such as reed canarygrass. When the lake is low in summer, vegetation along the shore will be much sparser, shading the lake less and providing less input of organic plant materials and insects, to the detriment of fish habitat. Lower lake levels needed to generate live storage will result in a smaller lake by area and volume, resulting in a lesser amount of habitat available for aquatic and water-dependent species such as fish and waterfowl. Habitat quality will also likely be reduced as described.

Attachment B

Alternative:	Continue Dredging (Status Quo)	
Estimated cost (2014)	One-time: $0	
	Annual: $54,000	

Project Location:

Description

This is the status-quo alternative. Continued dredging would result in no changes.

Assumptions and Considerations

- Review the need for an Army Corps permit to continue dredging.
- No changes to existing ecology.

Planning Level Cost Estimate

Based on current average annual dredging costs, it is estimated that maintenance will continue to cost approximately $54,000 per year.

Alternative:	Cease Dredging (No Action)
Estimated cost (2014)	One-time: $0 Annual: $2,500

Project Location:

Description

This is a no-action alternative. Discontinuing dredging would result in Hidden Lake filling up with sediment over time. The lake would likely shift to a forested wetland with little to no open water habitat. The lake has a volume of approximately 7,000 cubic yards. At the current rate of deposition, it would fill within a decade.

Assumptions and Considerations

- Hidden Lake would take on a much different aesthetic.
- Recreational lake opportunities would be diminished over time.
- No permitting required (assumes no outlet changes or maintenance needed).
- Easement still required to maintain the outlet.

Planning Level Cost Estimate

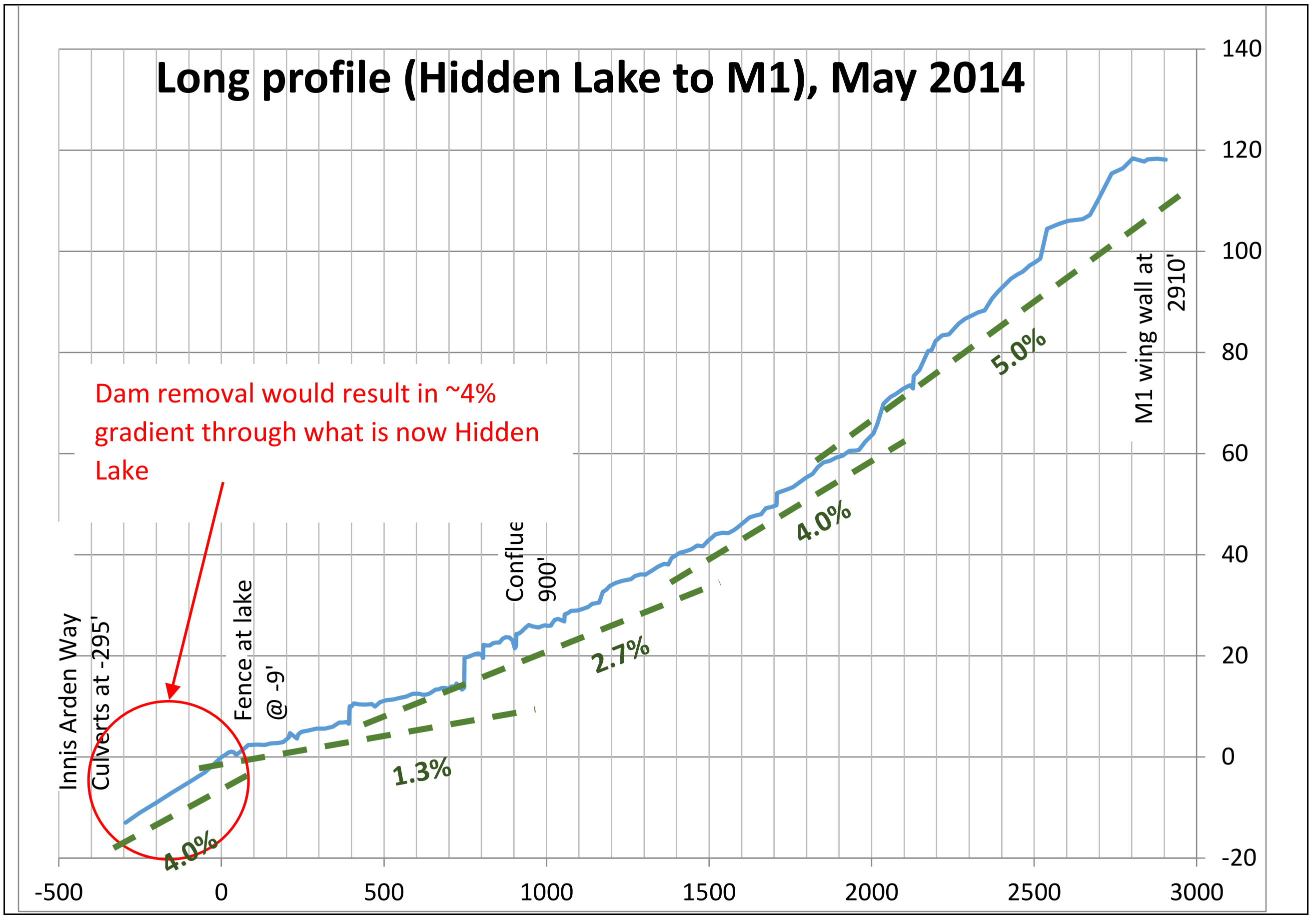
The outlet and dam embankment would still require inspection and maintenance. The City currently spends an estimated $2,500 year for this component of Hidden Lake maintenance.

Alternative:	Remove Dam
Estimated cost (2014)	One-time:~$607,000
	Annual: $8,000 (for five years)

Project Location:

Description

Hidden Lake dam would be removed, essentially eliminating the lake, and allowing the stream channel to flow unabated through this reach. The existing culverts through Innis Arden Way would remain. Elimination of the lake would allow sediment to pass through to the downstream reach of Boeing Creek, re-establishing an average gradient of approximately 4% through what is now Hidden Lake. The current channel gradient upstream of the lake ranges from 1.3% to 5%, and observations indicate this grade is sufficient to transport the sand-sized material presently deposited in Hidden Lake.


Long profile (Hidden Lake to M1), May 2014
Dam removal would result in ~4% gradient through what is now Hidden Lake
Innis Arden Way Culverts at -295'
Fence at lake @ -9'
Conflue 900'
M1 wing wall at 2910'
4.0%
1.3%
2.7%
4.0%
5.0%
140
120
100
80
60
40
20
0
-20
-500
0
500
1000
1500
2000
2500
3000

Assumptions and Considerations

- Sediment accumulated in Hidden Lake behind the dam would be removed.
- The Hidden Lake embankment, control structure, bypass pipe, and sediment forebay submerged berm would be removed; a grade control structure where the channel currently meets the lake would be installed to avoid propogating upstream incision (and further sediment delivery).
- A new trash rack or structure to catch debris would be installed upstream of the Innis Arden Way culverts.
- Existing easements would be used to access site for construction and follow-on vegetation monitoring and maintenance.
- A new channel would be allowed to form naturally during the first year; follow-on restoration and riparian plantings would occur, with installation of streambed gravel, larger rocks, and large wood to support a stable step-pool morphology through the area previously occupied by the lake.
- Environmental permitting would be extensive, but likely viewed positively by regulatory agencies since significant habitat benefits could be shown and the project would qualify as restoration. Permits anticipated include:
    - **Local:** Critical Areas Special Use Permit. This exception "allows development by a public agency or utility when the strict application of the critical areas standards would otherwise unreasonably prohibit the provision of public services." Environmental review, pursuant to the SEPA, would also be required as part of the local permitting process.
    - **State**: WDFW: Hydraulic Project Approval (HPA), Ecology: Section 401 Permit and individual Water Quality Certification and Coastal Zone Management Consistency determination.
    - **Federal**: Corps Section 404 Permit. Excavation or filling within Hidden Lake would fall under the jurisdiction of the Corps under Section 404 of the Clean Water Act. Due to the fact that dam removal would restore the historic stream channel and re-establish riparian wetlands, the project is likely to qualify for a Nationwide Permit (NWP) 27 – Aquatic Habitat Restoration, Establishment, and Enhancement Activities. As part of the Corps permit process, a showing of compliance with the Endangered Species Act (ESA) (Biological Evaluation or equivalent) and Section 106 of the National Historic Preservation Act (Cultural Resource Assessment or equivalent) would be required.

Planning Level Cost Estimate

DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL COST
Mobilization	1	LS	8%	$9,600.00
Site Survey	2	acre	$6,000	$12,000.00
Temporary Erosion and Sediment Control, stream bypass, fish removal	1	LS	$30,000.00	$30,000.00
Excavation, including haul	2,000	CY	$25.00	$50,000.00
Removal of structures or obstructions	1	LS	$5,000.00	$5,000.00
Trash rack(s)	1	LS	$5,000.00	$5,000.00
Streambed sediment (cobbles, gravel, boulders)	300	CY	$100.00	$30,000.00
Log w ith root w ad	40	Each	$1,500.00	$60,000.00
Vegetation monitoring and maintenance	5	LS per year	$8,000.00	$40,000.00
Riparian restoration	1	acre	$65,000.00	$65,000.00
	Subtotal Project Cost			**$306,600.00**
	Design Allowance		**15%**	**$45,990.00**
	Tax		**10%**	**$33,496**
	Easement Acquisition			
	Engineering Design		**40%**	**$122,640**
	Permitting		**25%**	**$76,650**
	Construction Management		**20%**	**$61,320.00**
	TOTAL PROJECT COST			**$646,696.05**

Alternative:	Lower Lake Outlet
Estimated cost (2014)	One-time: $160,000
	Annual: $2,500

Project Location:

Description

The outlet at the downstream end of Hidden Lake would be lowered, reducing the water level elevation and decreasing the size of the lake. Adjusting the outlet would increase the gradient through this reach and potentially facilitate sediment transport through the reach to downstream.

Assumptions and Considerations

- Hidden Lake would have a much different aesthetic than is there now.
- Recreational lake opportunities would be diminished.
- Existing easements would be used for maintenance of lake outlet.
- Environmental permitting would include:

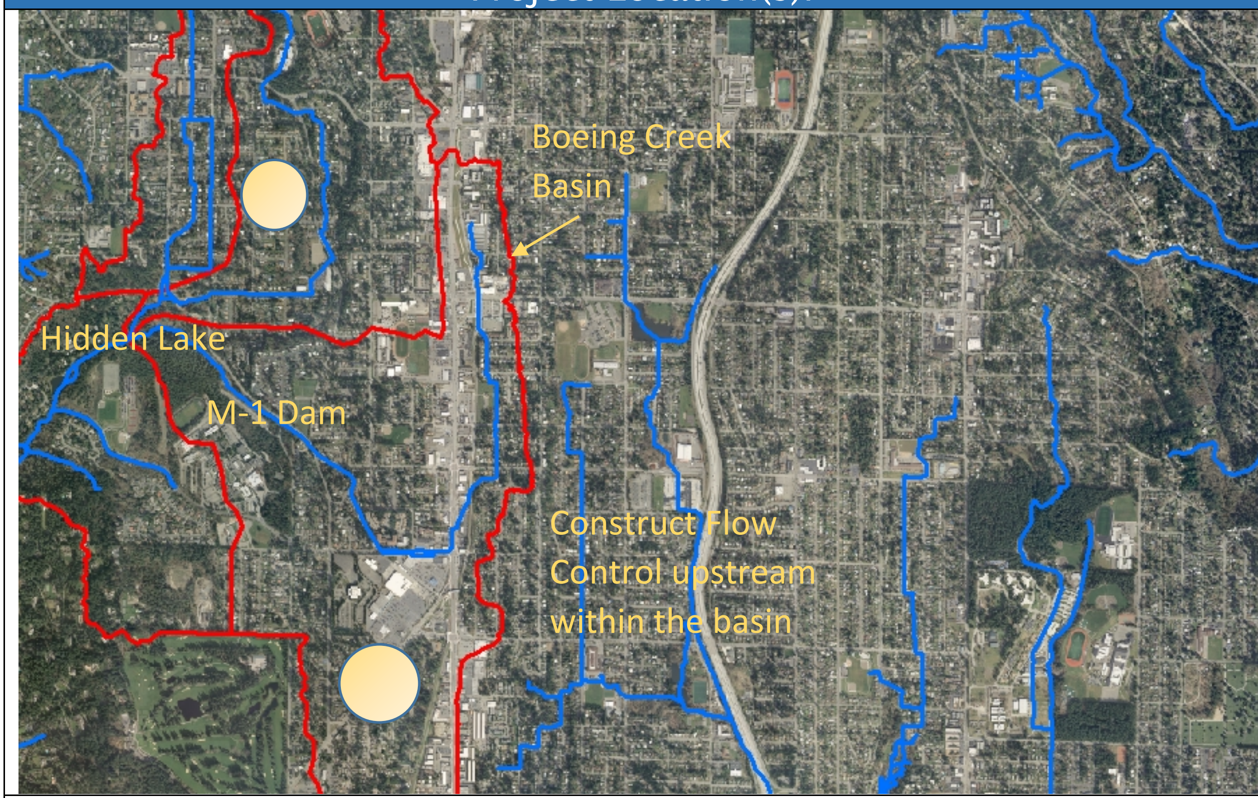
  Assuming that lowering of the outlet structure could be accomplished without disturbing lakebed sediments (no fill or excavation), this project could proceed without the need for permits from the Corps or Ecology. Lowering of the structure could be viewed as an exempt activity by the City and a SEPA exemption may also be warranted. WDFW would require issuance of a HPA; however, the project would likely not face significant permitting hurdles from WDFW.

Planning Level Cost Estimate

DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL COST
Mobilization	1	LS	8%	$4,800.00
Site Survey	2	acre	$6,000	$12,000.00
Temporary Erosion and Sediment Control, stream bypass, fish removal	1	LS	$30,000.00	$30,000.00
Excavation, including haul	1,000	CY	$25.00	$25,000.00
Modification of structure	1	LS	$5,000.00	$5,000.00
		Subtotal Project Cost		**$76,800.00**
		Design Allowance	**30%**	**$23,040.00**
		Tax	**10%**	**$9,485**
		Easement Acquisition		
		Engineering Design	**20%**	**$15,360**
		Permitting	**25%**	**$19,200**
		Construction Management	**20%**	**$15,360.00**
		TOTAL PROJECT COST		**$159,244.80**

Alternative:	Upstream Flow Control
Estimated cost (2014)	One-time: Varies (up to $10 million)
	Annual: Varies

Project Location(s):



Description

Flow control in the Boeing Creek Basin is not adequate to reduce channel degradation in Boeing Creek and subsequent mobilization and transport of sediment downstream to Hidden Lake. With an estimated 1,200 acres upstream, and assuming enough storage is necessary to store 1 inch of water over the land area that drains to Hidden Lake (likely a minimum amount for significant benefits), an estimated 100 acre-feet of live storage would be needed. Currently, approximately 14 acre-feet of detention is provided, with an estimated deficit of 86 acre-feet. The M1 dam is sized for approximately 9 acre-feet for reference (i.e., an additional 9 M1 dams would be needed). As redevelopment occurs, flow control will be built into new projects, such as the deep stormwater infiltration facilities that were recently constructed as part of the Shorewood High School renovation and construction. The City may also wish to accelerate installation of flow control facilities in parts of the City that will not redevelop soon in order to begin the process of improving conditions in Boeing Creek and alleviating sedimentation at Hidden Lake. Specific locations for flow control projects are not recommended, but the City should look for opportunities wherever possible.

Modifying existing in-stream detention facilities, such as M1 or the North Boeing Pond, would provide marginal incremental flow benefits.

Assumptions and Considerations

The most comprehensive assessment of the value of widespread flow control has been provided by King County's 2012 "Stormwater Retrofit Analysis and Recommendations for Juanita Creek Basin." A modeling study applied to a small suburban watershed on the northeast shores of Lake Washington, it concluded that flow control using LID techniques could be quite effective in stabilizing stream channels and improving in-stream ecology, but the retrofit costs would exceed several hundred million dollars for a watershed the size of Boeing Creek. Partial implementation should result in proportionate benefits; this alternative could therefore be implemented in combination with others to set a (very) long-term trajectory of systemic improvements for the basin while addressing the acute issues with less effective, but also less expensive, short-term measures.

Planning Level Cost Estimate

Flow control stormwater retofit to current standards would cost in excess of $10,000,000, based on estimates from the Juanita Creek Retrofit Analysis that estimated it would cost $200,000,000 to retrofit 1 square mile of basin area.

Flow / Source/ Mobilization / Sediment Deposition	Alternative:	Convert to Stormwater Facility
	Estimated cost (2014)	One-time: <$10,000
		Annual: $54,000

Project Location:

Description

Hidden Lake would be modified functionally to serve as a stormwater detention facility. Currently, it provides no "live" storage — the lake is kept at a constant elevation. If the outlet structure was adjusted to lower the lake level or even drain it during non-storm periods, additional storage and flow control could be provided during large rain events.

Assumptions and Considerations

- No excavation or lake modification would be necessary. Only the outlet structure would be modified.
- Sediment removal would still be required. This alternative provides no benefit to reducing sediment removal.
- Flow control benefits would be negligible, given the limited volume of the lake relative to the upstream watershed.
- Environmental permits would be needed, including:
    - **Local:** SEPA, Critical Areas Code
    - **State:** HPA from WDFW, potential consultation with Ecology (401)
    - **Federal:** Corps – none needed. This assumes this can be done by only modifying the outlet with no grading in stream, lake or wetlands.

Planning Cost Estimate

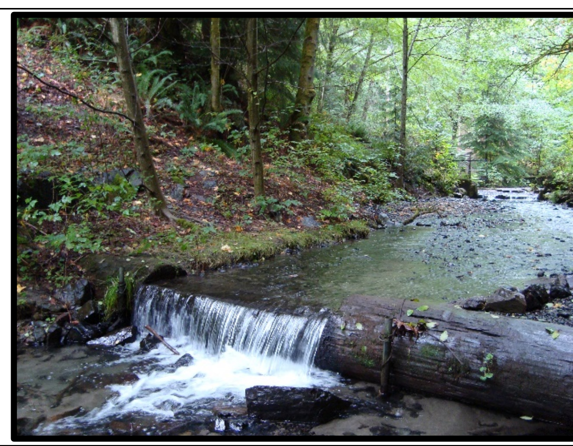
A detailed cost estimate was not prepared. It is assumed that outlet modification would cost less than $10,000. Sediment removal would still be needed, as this alternative doesn't provide any benefit for sediment source reduction or sediment transport through Hidden Lake. Sediment would continue to deposit in Hidden Lake and require removal.

Alternative:	Grade Control
Estimated cost (2014)	One-time: $520,000 Annual: $20,000 to $54,000

Project Location:

Description

Log weirs, similar to what is in place in the North Fork of Boeing Creek and the mainstream (photo at right is an example) downstream of the stepping stone confluence would be placed in the reach between the M1 dam and the confluence to provide channel grade control and help prevent additional future downcutting.



Assumptions and Considerations

- Grade control logs would be spaced approximately 150 feet apart in the South Fork of Boeing Creek between the M1 dam and the confluence (similar spacing to what is presently along the North Fork and mainstem).
- To minimize impacts to riparian corridor, work would be conducted by hand (material dropped from a helicopter).
- Environmental permits would include:
  - **Local**: SEPA, Critical Areas Code
  - **State:** HPA from WDFW, potential consultation with Ecology (401)
  - **Federal:** Corps 404 permitting, including localized stream & wetland delineation, Endangered Species Act consultation (if needed), and cultural resources study

Planning Level Cost Estimate

DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL COST
Mobilization	1	LS	8%	$7,032.00
Temporary Erosion and Sediment Control, stream bypass, fish removal	1	LS	$30,000.00	$30,000.00
Boulders, large rocks, anchors for log structures	195	CY	$100.00	$19,500.00
Construction geotextile	3,900	SF	$3.00	$11,700.00
Removal of structures or obstructions	1	LS	$2,000.00	$2,000.00
Grade control logs	13	Each	$1,900.00	$24,700.00
Riparian restoration	1,040	LF	$100.00	$104,000.00
Equipment rental and operation OR hand-work (labor)	1	LS	$50,000.00	$50,000.00
	Subtotal Project Cost			**$248,932.00**
	Design Allowance		**30%**	**$74,679.60**
	Tax		**10%**	**$30,743**
	Easement Acquisition			**$25,000**
	Engineering Design		**20%**	**$49,786**
	Permitting		**15%**	**$37,340**
	Construction Management		**20%**	**$49,786.40**
	TOTAL PROJECT COST			**$516,267.30**

Alternative:	Channel Stabilization
Estimated cost (2014)	One-time: $2,400,000
	Annual: $0 – $20,000

Project Location:

Description

The incised channel of the South Fork of Boeing Creek would be filled with large rocks and large wood between the M1 Dam and the stepping stone confluence. The photo at right is an example from Madsen Creek (King County project), near Renton, Washington. The large material would halt further degradation of the channel bed and help to stabilize adjacent slopes, which in turn would reduce the primary sources of downstream-transported sediment.

Assumptions and Considerations

- To minimize impacts, a helicopter or large mobile crane may be needed to place material.
- Trail adjacent to Boeing Creek may be impacted in some locations.
- Environmental permitting would include:
  - **Local**: SEPA, Critical Areas Code
  - **State**: HPA from WDFW, potential consultation with Ecology (401)
  - **Federal:** Corps 404 permitting, including stream & wetland delineation, Endangered Species Act consultation (if needed), and cultural resources study

Permits would not likely be granted by local, state, or federal agencies since the ecological improvements would not be justified by the damage caused by equipment access to the channel through steep, forested, high-quality buffers.

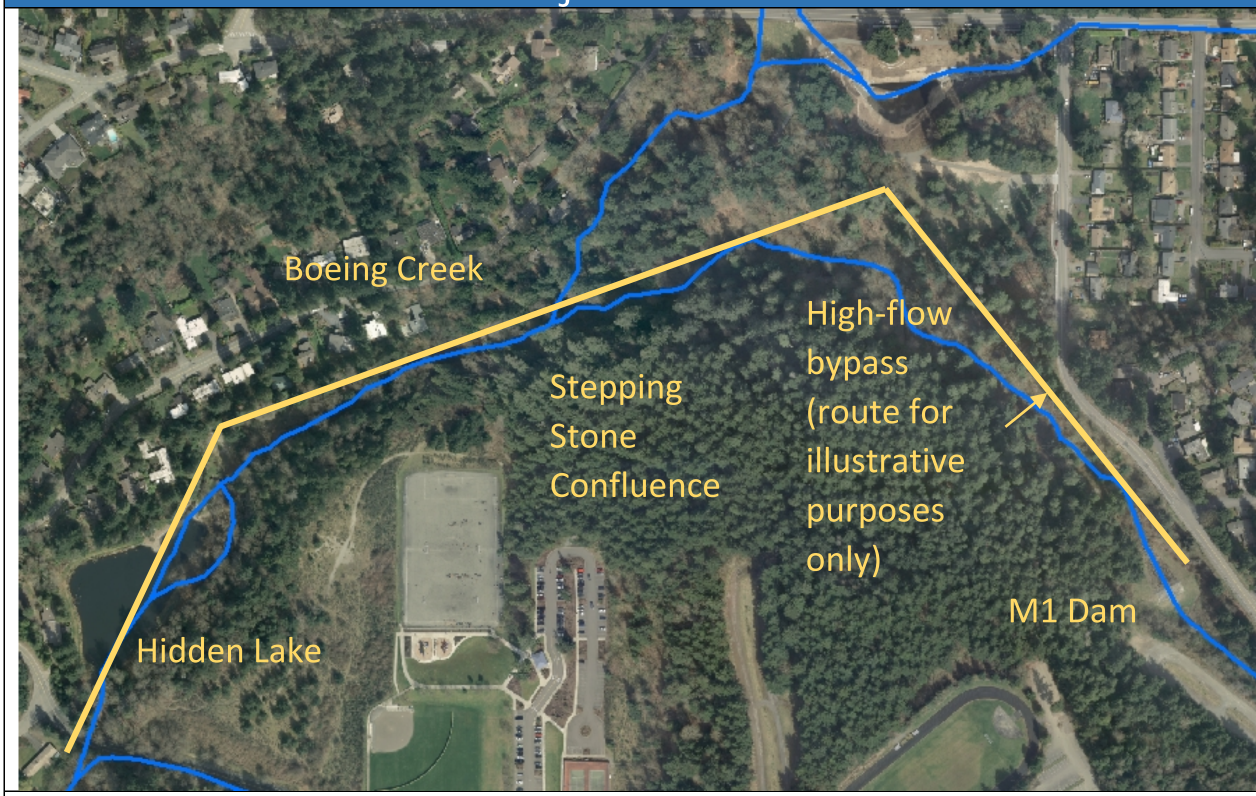
- Sediment sources and transport would be reduced eventually, but dredging may still be needed to keep an open water environment, although to a lesser extent.

Planning Cost Estimate

DESCRIPTION	QTY	UNIT	UNIT PRICE	TOTAL COST
Mobilization	1	LS	8%	$85,760.00
Temporary Erosion and Sediment Control, stream bypass, fish removal	1	LS	$30,000.00	$30,000.00
Streambed sediment (cobbles, gravel, boulders)	4,400	CY	$100.00	$440,000.00
Removal of structures or obstructions	1	LS	$2,000.00	$2,000.00
Log with root wad	400	Each	$1,500.00	$600,000.00
Equipment rental and operation	1	LS	$50,000.00	$50,000.00
		Subtotal Project Cost		**$1,207,760.00**
		Design Allowance	**30%**	**$362,328.00**
		Tax	**10%**	**$149,158**
		Easement Acquisition		**$25,000**
		Engineering Design	**20%**	**$241,552**
		Permitting	**15%**	**$181,164**
		Construction Management	**20%**	**$241,552.00**
		TOTAL PROJECT COST		**$2,408,514.36**

Flow · Source/ Mobilization · Sediment Deposition	Alternative:	Bypass High Flows
	Estimated cost (2014)	One-time: >$3,000,000
		Annual: $0

Project Location:



Description

A high-flow bypass would be installed at the M1 dam and route all discharges above a low-flow threshold around Boeing Creek (and thus the open channel that has experienced downcutting and slope instability) to a discharge point downstream of Hidden Lake. This alternative was previously suggested in 1980; at that time, the pipe size was estimated to be 4 to 5 feet in diameter to contain the full stream flow.

Assumptions and Considerations

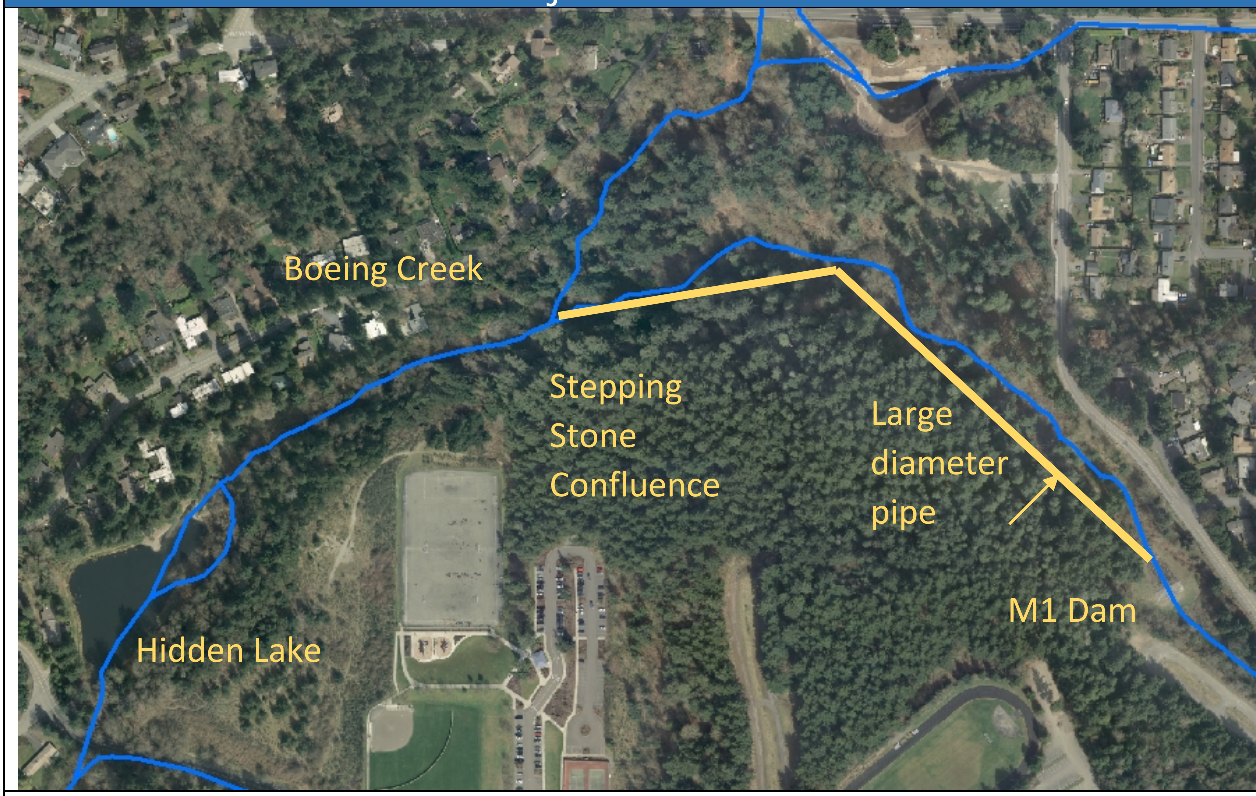
- The bypass pipe would extend from M1 dam to Hidden Lake, although it could be designed to discharge directly to Puget Sound (for considerably more cost).
- Routing flow away from the stream could have ecological impacts as well as impacts to in-stream water rights. Boeing Creek is closed to further surface water appropriation (WAC 173-508-040) because of potential damage to the fishery due to loss of base flows. Removal of any flow may not be allowed.
- Environmental permits needed include:
  - **Local:** SEPA, Critical Areas Code
  - **State:** HPA from WDFW, potential consultation with Ecology (401)
  - **Federal:** Corps 404 permitting, including localized stream and wetland delineation, Endangered Species Act consultation (if needed), and cultural resources study
- High-flow bypasses are generally not a preferred option by the regulatory agencies. WDFW in particular, who is charged with the protection of fish life, views bypasses as problematic for a variety of often valid reasons. These include sediment transport (either depletion or sedimentation), fish entrapment/passage, maintenance, long-term failures, and in-stream impacts on the bypassed reach. For these reasons, permitting a bypass with WDFW (as well as the other agencies) while other options exist would be difficult, expensive, time-consuming, and unlikely.

Planning Cost Estimate

The 1980 Brown and Caldwell report evaluated this alternative. The estimated cost in 1980 for installation of a bypass pipe (48 inches to 60 inches in diameter) from Greenwood Avenue North to Innis Arden Way was in the range of $3,000,000-$4,000,000. The 2014 cost for such a project would thus be well in excess of $3,000,000. An updated cost estimate was not developed because the assumed cost of this project is outside the range of what would be acceptable to reduce the City's net long-term maintenance costs, and is likely infeasible from a permitting perspective as well.

Alternative:	Bypass All Flows
Estimated cost (2014)	No cost estimated (infeasible)

Project Location:



Description

Boeing Creek would be placed in a pipe between the M1 dam and the confluence of the north and south tributaries. The pipe is assumed to be concrete and 5’ in diameter, based on the 1980 Brown and Caldwell report that included a similar stream bypass, although newer materials (e.g., high density polyethylene pipe) could be substituted.

Assumptions and Considerations

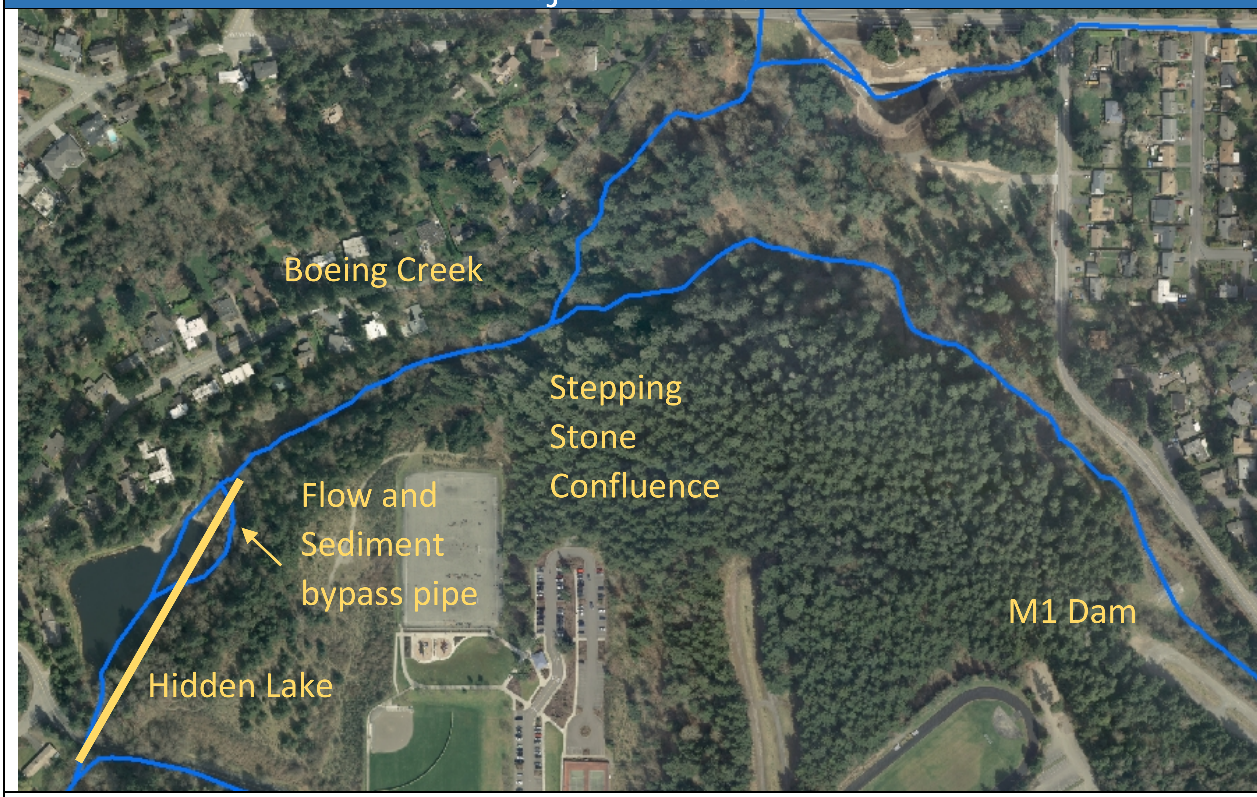
This project would likely not be approved due to significant political, public, and regulatory hurdles unless there was overwhelming significant public or environmental benefit, none of which has been identified.

Planning Cost Estimate

This alternative is estimated to cost well over $2,000,000, especially when considering that an EIS would be required to advance the project forward to environmental review.

Alternative:	Short Flow & Sediment Bypass
Estimated cost (2014)	No cost estimated (infeasible)

Project Location:



Description

A bypass pipe ~800 feet long would collect flow and sediment from Boeing Creek immediately above Hidden Lake, carrying the combined material to a discharge point immediately below Innis Arden Way. Although conceptually attractive as the least disruptive of the alternatives to keep sediment-laden flow out of Hidden Lake, the topography of the basin renders any passive (i.e., gravity-driven) system physically impossible unless trenching along the eastern edge of Hidden Lake and under Innis Arden Way, to depths of at least ten feet, accompanied pipe installation.

Assumptions and Considerations

- Given prior estimates of a 4 feet to 5 feet diameter pipe necessary to carry clear-water flows, a pipe with sufficient capacity to carry sediment as well would likely need to be 6 feet or more in diameter.
- If the flow is at full capacity with respect to sediment loads during high-flow events, then a pipe grade at least as steep as that of the channel itself (i.e., >1%) would likely be necessary to maintain transport.
- The hydraulics of moving sediment-laden flows from an open channel to a confined pipe are quite challenging; in a confined valley they might prove insurmountable. Head losses at the inlet would likely induce some build-up of sediment regardless of design, necessitating periodic maintenance.
- Environmental permits needed would include:
    - **Local:** SEPA, Critical Areas Code
    - **State:** HPA from WDFW, potential consultation with Ecology (401)
    - **Federal:** Corps 404 permitting, including localized stream and wetland delineation, Endangered Species Act consultation (if needed), and cultural resources study
- Bypasses are generally not a preferred option by the regulatory agencies, although the regulatory hurdles are the least of the challenges that would face implementation of this option.

Planning Cost Estimate

Given its infeasibility, no cost estimate was made for this alternative. It would likely prove to be the most expensive of all options considered.