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DESIGN ALTERNATIVES ANALYSIS

HIDDEN LAKE DAM REMOVAL PROJECT
SHORELINE, WASHINGTON

Prepared for
City of Shoreline

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

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HIDDEN LAKE DAM REMOVAL PROJECT
SHORELINE, WASHINGTON

Prepared for
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January 8, 2016 DRAFT

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EXECUTIVE SUMMARY

The City of Shoreline (City), via direction from its city council, has ceased dredging of sediments in Hidden Lake in response to a feasibility study of lake management alternatives (AltaTerra 2014), which illuminated the high cost of continuing to dredge the lake, as compared to other viable management options. With the decision to stop dredging the lake, the City needs to develop and implement a different approach to conveying Boeing Creek flows (including major flood flows) and sediments through the existing lake area and downstream of NW Innis Arden Way. Otherwise, Hidden Lake is expected to fill with sediment in the next 5 to 10 years, depending on the occurrence and magnitude of Boeing Creek flood events, and risks to NW Innis Arden Way and other utilities and infrastructure in the road right-of-way will arise if no action is taken to alter or remove the dam.

This report presents an analysis of three alternatives for alteration or removal of the dam and corresponding creek channel modifications in the existing lake area. The alternatives are intended to inform the City regarding a range of design strategies and to help the City select a preferred configuration for project design and implementation.

Description of the Alternatives

Alternative 1 is the simplest of the three alternatives. It would modify the existing dam and the lake outflow structures associated with it to preserve the long-term structural integrity of the dam. A concrete spillway would be constructed on the dam face, from the dam crest to an existing concrete pad near the entrance to the culverts at the NW Innis Arden Way crossing of Boeing Creek. The spillway crest elevation would be lower than the existing dam crest, thereby lowering the lake surface elevation by 3 to 4 feet, resulting in a smaller lake. No stream channel would be constructed through the lake bed. As the lake bed fills with sediment behind the dam, Boeing Creek would naturally create a channel(s), gradually sluicing out some of that sediment. Thereafter, the creek would reach equilibrium within the current lake footprint area, transporting inflowing sediment through the dam spillway and into the reach of Boeing Creek downstream of NW Innis Arden Way. Floodplain areas on both sides of the creek would most likely form in what is currently the lake footprint. Over time, vegetated wetland habitat is anticipated to colonize those floodplain areas. Because nonnative and invasive species (i.e., weeds) would likely grow in the new floodplain areas and invade wetlands, post-construction vegetation monitoring and management, including weed control measures and supplemental planting of native species, would be necessary.

Alternative 2 would remove the Hidden Lake dam and includes excavating new creek channels in the existing lake footprint. Two channels would split around higher ground near the middle of the existing lake, combining into a single channel excavated down to the entrance to the existing NW Innis Arden Way culverts. The new channel construction work would occur on City-owned park land (on the eastern side of the existing lake footprint) and on four privately owned parcels (on the western side). Secured large woody debris would be placed in the creek channels, where feasible, to enhance aquatic habitat. Areas adjacent to the new channels within the existing lake footprint would be planted with native vegetation. As with Alternative 1, post-construction vegetation monitoring and management would be necessary. Alternative 2 would construct floodplain areas with wetland characteristics that emulate pre-lake conditions and that would be similar to the naturally formed floodplain areas that would develop eventually under Alternative 1. The existing NW Innis Arden Way culverts and downstream channel conditions are barriers to fish passage. While Alternative 2 would not remove those barriers, the design (unlike that for Alternative 1) would enable potential future excavation through the roadway crossing to create a fish-passable stream section comparable to that described for Alternative 3. Following construction, aside from vegetation management, minimal maintenance activity would be needed for the creek to function as intended over the long term.

Alternative 3 is the largest of the three alternatives analyzed in this report, but a major component of it—improving fish passage by replacing the existing culverts beneath NW Innis Arden Way and modifying the creek channel downstream of the roadway—could also be a component of Alternative 2, in which case, Alternative 2 would become the largest of the three alternatives.

Alternative 3 would involve removing the dam and excavating a single new creek channel through the existing lake bed. Unlike Alternative 2, the channel excavation would be exclusively on City-owned land. Alternative 3 would also replace the NW Innis Arden Way culverts with a large box culvert or small bridge, and would modify the creek channel for a distance of about 150 feet downstream of the road to promote fish passage and improve habitat. In total, Alternative 3 would create and improve approximately 1,000 feet of creek channel from upstream of the lake to downstream of the road. Work would also include planting areas surrounding the new channel in the existing lake area and along the modified channel extents downstream of the road, which would mostly be forested vegetation. Because the channel bed and banks would be relatively steep and at a deeper elevation throughout the length of the creek modified by Alternative 3, it would be more difficult to re-establish floodplain areas and associated wetlands along the creek than under Alternative 2. As with Alternatives 1 and 2, post-construction vegetation monitoring and management would be necessary in much of the existing lake footprint.

Summary of Alternatives Analysis

The alternatives analysis considered hydrology and hydraulics, geotechnical conditions, geomorphology (including sediment transport and large woody debris), existing habitat and species, and cultural resources, as well as other factors. Those other factors include private-property ownership and related concerns, effects on Shoreview Park, effects on creek habitat and private property downstream of the lake, implementation costs (and how to cover them), long-term maintenance requirements and associated costs, potential to restore salmonid fish passage through the lake area, and the anticipated complexity in obtaining required permits and regulatory approvals (including potential mitigation requirements) to implement a project that alters the dam and the lake.

Results of the alternatives comparison are summarized below and in Table ES-1. In addition to helping the City select an alternative, the results can inform development of a preferred alternative that combines features of the alternatives considered in this alternatives analysis.

Table ES-1. Comparison of Alternatives.

Criteria	Alternative 1	Alternative 2	Alternative 3
Cost	$680,000	$2,350,000[a]	$5,200,000[b]
Required Participation of Several Adjacent Private Property Owners	No	Yes	No
Park Uses and Values	Low	High	High
Wetland Mitigation Likely Required	No	No	Yes
Fish Passage Benefits	No	No[c]	Yes
Other Habitat Benefits (e.g., waterfowl, forest, wetlands, amphibians, beaver)	Low	High	Medium
Downstream Suspended Sediment Loading	Low	Medium	High
Downstream Gravel Supply	Low (eventual)	High (immediate)	High (immediate)
Short-term Maintenance Needs	Low to Medium	Medium	Medium
Grant Funding Attractiveness	Low	Medium[d]	High
Permitting Complexity	Medium	Medium	High

[a] If the culverts beneath NW Innis Arden Way were replaced as part of this alternative to allow fish passage, the total cost would increase to approximately $5,550,000.

[b] The new box culvert or bridge beneath NW Innis Arden Way would require temporary closure of roadway traffic to excavate into the deep earth fill prism underlying the existing roadway. The deep excavation and associated traffic control requirements are significant cost components of Alternative 3.

[c] Fish passage could be achieved with Alternative 2 if the culverts beneath NW Innis Arden Way were replaced as under Alternative 3.

[d] Grant funding attractiveness would be rated high for Alternative 2 if fish passage improvements were included in it.

Findings of Hydrologic and Hydraulic Analyses

The hydrology of Boeing Creek in the project vicinity and downstream will not change significantly as result of implementing any of the three alternatives. Hydraulic modeling of existing conditions and the three alternatives revealed three key findings:

1. The lake has limited capacity to store floodwaters in the 100-year flood event, which is not an issue under existing conditions because the outlet manhole structure and associated piping that conveys creek flows through the dam to the culverts beneath NW Innis Arden Way are able to pass significant amounts of flow. The limited flood attenuation in the lake during higher flood flows means that the magnitude and timing of flood flows downstream of the dam site would not change with any of the alternatives (Herrera 2016). In fact, a slight decrease in the downstream peak flow is predicted for Alternative 3 and a greater decrease is predicted for Alternative 2 due to the difference between “dead” storage (lake volume occupied by water before a flood wave comes through) in the lake under existing conditions compared to the “live” flood storage created in the excavated channels and floodplain areas for Alternatives 2 and 3.

2. The lake outlet manhole structure and associated piping has sufficient capacity to convey moderate flood flows such that the model predicts minor lake elevation changes at increasing flow rates, and no overtopping of the dam in the 2-year flood. Thus, removing the existing lake outflow structures under any alternative would not cause a notable change in peak flow rates or flood duration during moderate flood events downstream of NW Innis Arden Way.

3. Model results for all three alternatives demonstrated a significant decrease in water surface elevations in the project area and extending upstream of the lake. This is because water surface elevations under existing conditions are governed by the geometry and elevation of the dam crest at the existing lake outlet, and lowering or removing the dam would result in a creek water surface elevation profile through the existing lake bed that is lower than the existing lake water surface, even during floods. Therefore, none of the alternatives would have adverse flooding effects on park land or private property upstream of the dam.

The creek hydrographs used as input to the hydraulic model are approximate and were derived based upon several sources of information. If a streamflow gage were installed at a location approximately 400 to 600 feet upstream of the existing lake, the flow data collected at that gage could be used to refine the model findings for design of a preferred alternative. Gage data would be particularly useful if it captured some large flow events before detailed project design is completed.

Findings of Geomorphic Analyses

Currently, there are unstable slopes in many locations along Boeing Creek, both upstream and downstream of the lake. Because the hydrology of the Boeing Creek basin as a whole will not change significantly as result of any of the three alternatives, such geomorphic patterns are expected to continue into the future.

The City’s lake dredging records indicate an average of 1,100 cubic yards of sediment deposition, predominantly sand, deposited in Hidden Lake per year between 2002 and 2013 (AltaTerra 2014). Total sediment load in the Boeing Creek basin is estimated to be approximately 2,500 cubic yards per year (Herrera 2016), indicating that roughly half of the sediment entering Boeing Creek flow each year has been retained in Hidden Lake. The material that passes through the lake is called wash load, the finest portion of suspended load. Finer-grained material, including some sand, likely remains suspended during turbulent and higher-velocity flood flows, and passes though the lake. Bedload (coarser material) transport volumes are much smaller—estimated to be approximately 300 cubic yards per year in Boeing Creek. No bedload currently reaches the Hidden Lake outlet. The only bedload (primarily gravel) downstream of the dam has been scavenged by the creek as it has incised into older historical creek deposits in the middle of the ravine downstream of NW Innis Arden Way.

All three alternatives would increase sediment delivery, over time, to the Boeing Creek channel downstream of Hidden Lake. The character and volume of that sediment will vary depending on the alternative.

The lake is expected to be filled with sediment in 5 to 10 years, unless an extremely rare flood event occurs sooner. It would take longer than that for a well-developed, stable channel to re-establish in the lake bed under Alternative 1. Until equilibrium channel conditions occur naturally, the landscape in the existing lake footprint would exhibit many isolated, ephemeral pools and, possibly, many braided channels. Following lowering of the dam spillway elevation under Alternative 1, there also would be a risk of a headcut (channel bed erosion and deepening propagating in the upstream direction, leading to some potentially undesirable effects upstream of the lake) developing until the creek profile stabilizes through the existing lake area. Some suspended sediment load would likely be stored for a longer period (for at least 20 years) in the lake reach as the floodplain aggrades. However, immediately following construction, much of the suspended sediment would be remobilized until a stable channel can form through the existing lake bed.

Of the three alternatives, Alternative 2 most closely mimics known predevelopment geomorphic conditions in the lake reach above NW Innis Arden Way. Bedload transport through the existing lake area would be enabled immediately after construction. Alternative 2 would also result in storage of some suspended sediment load in floodplain areas, particularly in the upstream portion of the existing lake. Therefore, channel degradation downstream of the lake likely would be reduced, while sand supply to the nearshore areas of Puget Sound at the creek mouth would increase. Because the constructed channel gradient would be relatively steep (4 percent or greater in parts of the site), significant engineering controls such as constructed boulder riffles and bank revetments would be required to prevent unwanted channel deformation under Alternative 2.

Like Alternative 2, Alternative 3 would immediately convey all bedload and suspended sediment load through the existing lake area to downstream reaches of Boeing Creek. Unlike Alternative 2, there would be essentially no capacity for storage of sediment in floodplain areas within the existing lake footprint. Most or all of the estimated 2,500 cubic yards of sediment supplied to the lake per year would be transported downstream of NW Innis Arden Way under Alternative 3, which would likely trigger channel migration and minor bank erosion accordingly, particularly downstream of the Seattle Golf Club diversion dam. Alternative 3 would result in the greatest sediment benefits in nearshore areas of Puget Sound within a few years of project construction, which is a goal of recovery planning for endangered Puget Sound Chinook salmon. Like Alternative 2, the constructed channel gradient would be relatively steep in parts of the site under Alternative 3, requiring significant but very feasible engineering controls.

Findings of Ecological Analyses

Hidden Lake provides open water habitat for fish, such as cutthroat trout, and waterfowl species. Under Alternative 1, the amount of open water habitat would decrease immediately as the lake level is lowered upon constructing the new dam spillway, and would decrease further over time as sediment fills the lake bed. However, as Boeing Creek re-establishes a channel and vegetated wetlands in the floodplain, a higher functioning wetland and stream area would develop. It is very likely that nonnative and invasive species (weeds), such as reed canarygrass and Himalayan blackberry, would occupy the new floodplain areas and invade wetlands under Alternative 1, decreasing their habitat value. Therefore, post-construction vegetation monitoring and management, including weed control measures and supplemental planting of native species, should be included if this alternative is implemented. Overall, the habitat created under Alternative 1 would function higher than existing conditions.

Alternative 2 is a controlled version of Alternative 1 in which the open water habitat in Hidden Lake would be manually converted to a complex wetland and stream area. Groundwater discharge into the new channel would occur a few feet above the constructed channel bed through much of the site, which would provide a downstream habitat benefit of increased base flow in Boeing Creek. Wetlands created in the existing lake area would be planted with native vegetation throughout the floodplain on both private and City-owned park property, and would be maintained to control the presence of invasive species. The combined wetland and stream habitat provided in Alternative 2 would be expected to function higher than that provided under Alternative 1 or 3.

Alternative 3 would provide a high functioning stream habitat through the reach on City park property, but, because of the steep and deeper nature of the constructed channel, little to no wetland habitat could be re-established adjacent to the channel. The floodplain west of the constructed channel could be allowed to establish vegetation naturally, as in Alternative 1. With the potential for nonnative, invasive species establishing in that area, post-construction vegetation monitoring and management is recommended if Alternative 3 is implemented. Similar to Alternative 2, groundwater discharge into the new channel would occur a few feet above the constructed channel bed through much of the site, which would provide a downstream habitat benefit, although less benefit than that under Alternative 2.

A compelling reason for the City to consider Alternative 3 is that improving fish passage conditions in creeks throughout the Puget Sound basin is a focus of local, state, and federal agencies and others engaged in salmon recovery. Therefore, it may be possible to obtain grant funding to cover some of the project cost, and it would also result in a greater ecological lift for Boeing Creek than Alternative 2 (and far greater than Alternative 1).

Input Received from Lakeside Residents and the General Public

Input received from lakeside residents and the general public to date was used to shape the distinct features of the three alternatives. Lakeside residents voiced several concerns and opinions, including:

- Concern about privacy and potential for trespassing, with elimination of the lake allowing park users or others to walk across the restored creek onto their land
- Concern for the loss of the lake and the unique habitats and aesthetic value it provides
- Concern about potentially reduced property values
- Potential for inadvertent impacts on mature trees west of the lake shoreline
- Potentially high cost of the project to the City and its taxpayers

- Potential for marshy conditions to develop in the existing lake bed that would attract mosquitoes and make it difficult to walk on the eastern edge of their property, which indicates less support for Alternative 2 as described herein
- Desire for ecological benefits to be achieved if the lake is converted to a different landform, which indicates less desire for Alternative 1 as described herein

Input received from the general public focused on the following topics.

- Effects of the project on the character of Boeing Creek downstream of Hidden Lake, and whether implementing the project means the City would pursue removing the Seattle Golf Club diversion dam
- A desire for improved trail(s) along the southeast side of the restored Boeing Creek channel in the existing lake bed
- Concern for the loss of a place that is popular for taking dogs to swim
- The unique ecological value that is contained within Shoreview/Boeing Creek Park and how the project could enhance that value; in relation to this, interest in placing informational signage about the ecological effects of the project

Permitting Expectations

Project activities undertaken for any of the three alternatives include clearing and grading and working within environmentally critical areas or critical area buffers, requiring permits from federal and state regulatory agencies and the City of Shoreline. Each alternative would require, at a minimum, a Clean Water Act Section 404 permit (for wetland impacts) from the US Army Corps of Engineers (USACE), a Hydraulic Project Approval from the Washington Department of Fish and Wildlife, a State Environmental Policy Act (SEPA) threshold determination from the City of Shoreline, a critical areas special use permit from the City of Shoreline, and onsite mitigation of temporary construction impacts. Project permitting is simplified because no species listed under the federal Endangered Species Act are present in the project area, and the project is expected to receive a determination of non-significance (DNS) or mitigated DNS on environmental elements analyzed under SEPA.

The complexity of permitting for each alternative differs in the way each alternative project configuration would comply with Clean Water Act Section 404, City of Shoreline code, and the mitigation that may be required for impacts on wetlands and buffers. Alternatives 1 and 2 would likely be covered under streamlined federal permitting requirements because compensation for wetland impacts would not likely be required. Alternative 3 may require more complex federal agency permitting because it would likely result in an overall decrease in wetland area and functions compared to existing conditions. In addition, offsite mitigation may be required for project impacts on wetlands and their buffers under Alternative 3.

Maintenance Implications

Alternative 1 would require a minor amount of maintenance attention from the City and would be similar to current maintenance (with no dredging). Maintenance activities would be focused on keeping the Hidden Lake dam spillway clear of debris, plus occasional inspections of the culverts beneath NW Innis Arden Way. To support permitting of Alternative 1, a commitment by the City for vegetation monitoring and management to prevent the spread of weeds would likely be needed.

Alternatives 2 and 3 would require greater maintenance attention than Alternative 1. Additional maintenance associated with these two alternatives would be related to expected permit requirements to assure planted vegetation survival, to control invasive weed growth in the existing lake footprint, and to assure that the constructed stream channel is functioning as intended. The inspection and maintenance needs for these three purposes would generally be focused within the first 5 to 10 years following construction. Thereafter, maintenance needs would likely be minimal.

INTRODUCTION

The City of Shoreline (City), via direction from its city council, has ceased dredging of sediments in Hidden Lake in response to a feasibility study of lake management alternatives (AltaTerra 2014). The study illuminated the high cost of continuing a dredging program, as compared to other viable management options. With the decision to stop dredging the lake, the City needs to develop and implement a different approach to conveying Boeing Creek flows (including major flood flows) and sediments through the existing lake area and downstream of NW Innis Arden Way. Otherwise, Hidden Lake is expected to fill with sediment in the next 5 to 10 years, depending on the occurrence and magnitude of Boeing Creek flood events, and risks to NW Innis Arden Way and other utilities and infrastructure in the road right-of-way will arise if no action is taken to alter or remove the dam.

This report presents an analysis of alternatives for removing the dam or otherwise making the dam compatible with an expected condition of the lake filling with sediments in the coming years. The alternatives are intended to inform the City regarding a range of design strategies and to help the City select a preferred configuration for project design and implementation. Three distinct alternatives were developed and analyzed. Each alternative would modify the existing lake and its associated outflow structures to safely convey flood flows and manage sediments that will continue to be transported into the existing lake area in Boeing Creek during storm events in the basin. Two of the alternatives involve removal of the dam that impounds Hidden Lake, and the other alternative would lower the lake outlet elevation at the dam.

Numerous factors affect the City's decision regarding the future of Hidden Lake and the dam that impounds it, all of which are discussed in this report. The factors include private property ownership and related concerns, effects on Shoreview Park, effects on creek habitat and private property downstream of the lake, implementation costs (and how to cover them), long-term maintenance requirements and associated costs, potential to restore salmonid fish passage through the lake area, and the anticipated complexity in obtaining required permits and regulatory approvals (including potential mitigation requirements) to implement a project that alters the dam and the lake. Herrera Environmental Consultants, Inc. (Herrera) uses these factors to compare the alternatives in this report.

Background: Existing Flow Conveyance Conditions Relevant to Alternatives

Hidden Lake outflows are conveyed in a pair of 30-inch-diameter pipes that extend from the outlet control manhole (see Figure 1) to a concrete apron that routes the flow into a pair of 48-inch-diameter culverts beneath NW Innis Arden Way. The outlet control manhole and the 30-inch pipes have had the capacity to convey the highest flood flows observed by City staff, such that flow does not spill over the top of the dam except in the most extreme of flood events. The culverts beneath NW Innis Arden Way are large enough to pass all flood flows, sediment, and most waterborne debris to the Boeing Creek channel downstream of the road without inducing formation of a deep pool at their upstream entrance. The age of the culverts is uncertain, but it can be inferred that they were built (along with the road above them) at the same time as the homes in the area, which was in 1954 to 1955 (Eric Gilmore, personal communication November 24, 2015).

The City has inspected the culverts under NW Innis Arden Way and found that they are in good condition and do not need to be replaced in the near future due to assessed risk of failure. Although the culverts are apparently structurally sound, at roughly 60 years old, they are approaching the typical functional lifespan for comparable infrastructure. If one or both of the culverts were to fail during a flood event, complete loss of the roadway embankment and all associated infrastructure (utilities, guardrail, signage, etc.) could occur and the resultant cost of repairing the roadway and the associated infrastructure would be significant.

Figure 1. Existing Lake Outlet Structure as Viewed from the Dam.

With cessation of sediment removal by dredging in the lake, the lake is expected to fill with sediment in the coming years. The time period for that to occur depends on the occurrence and magnitude of Boeing Creek flood events. It is conceivable that the existing outlet control manhole could eventually become plugged with sediment and debris during a flood event, triggering flow over the top of the dam at all times. If that occurs, there is a risk of the earthen dam partially breaching because its spillway is not sufficiently armored to resist erosion. If the dam breaches, there is risk that soil and debris could clog the twin creek culverts beneath NW Innis Arden Way, potentially causing a catastrophic road washout, as noted above.

As described in the Hidden Lake Management Plan Feasibility Study (AltaTerra 2014), controlling sediment production and delivery in Boeing Creek is a long-term challenge for the City, which has no ability to stop sediment from entering the Hidden Lake area in the foreseeable future. Therefore, given that sediment will no longer be dredged from the lake and the resultant risks of dam failure and/or roadway culvert failure, a “no action” alternative is not viable for the City.

DESCRIPTION OF ALTERNATIVES

Three alternatives, representing a range of construction complexity and cost, are considered in this report. Each would modify the existing lake and its associated outflow configuration, as described in this section.

Alternative 1

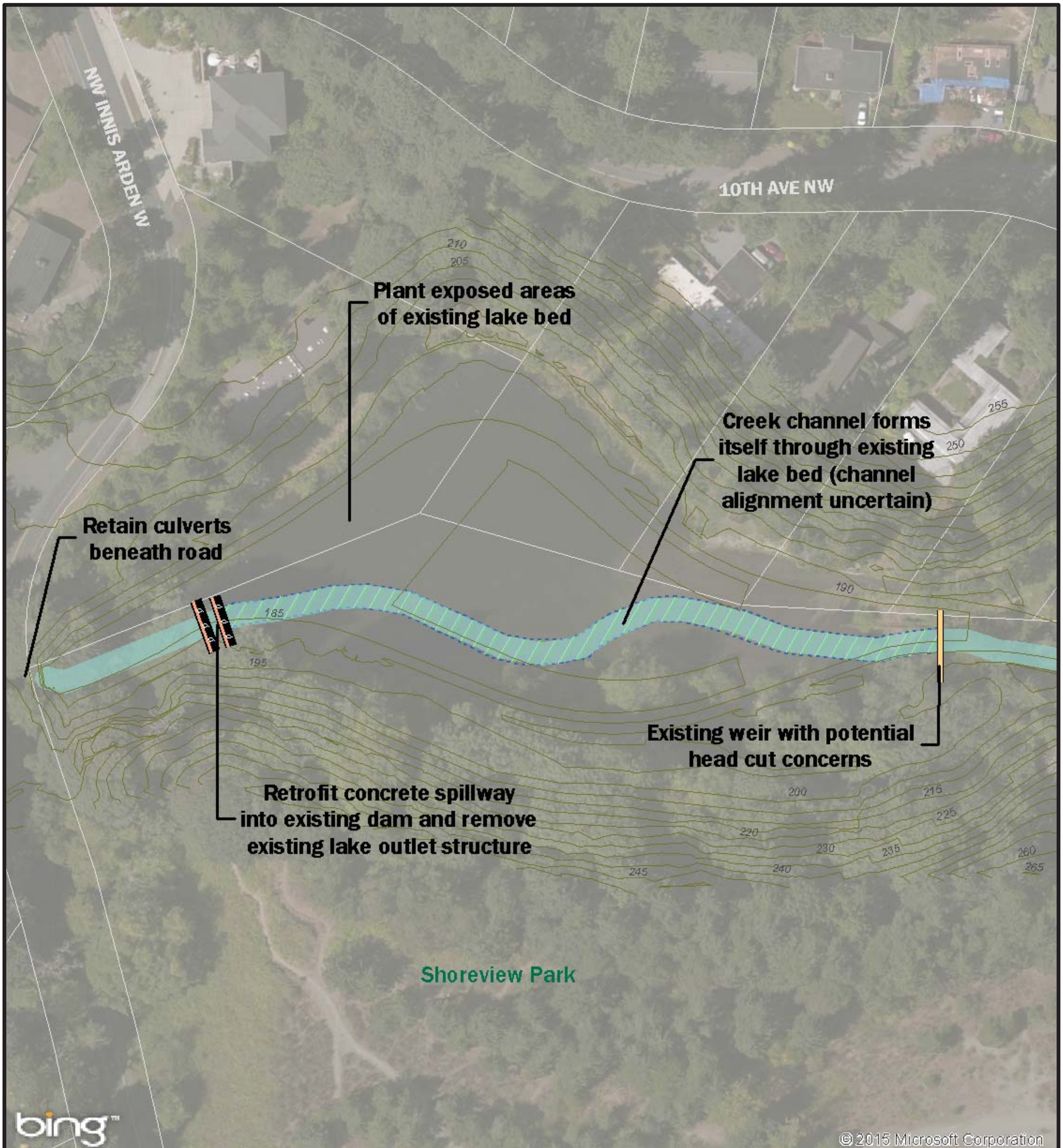
Alternative 1 is the simplest of the three alternatives. It would modify the existing dam and the lake outlet structures to preserve the long-term structural integrity of the dam. Figure 2 shows a basic layout of this alternative.

The dam is composed mainly of compacted soil but also contains rock gabion mattresses built into the downstream slope to resist erosion in major flood events. Without the rock gabion mattresses, flood flows spilling over the dam crest and down the southern embankment face could significantly erode the dam embankment soil.

Under Alternative 1, a concrete spillway approximately 90 feet long and 20 feet wide would be constructed from the dam crest to the existing concrete pad at the roadway culvert entrance area. A defined spillway channel would replace the gabion mattresses either partially or completely. The extents of the gabion mattresses were not certain as of the time this report was written, and additional analysis that is beyond the scope of this alternatives analysis would need to be conducted to determine if some of the gabions could be retained while making the remaining extents of the gabion mattresses structurally sound. The outlet control manhole and pipes extending from it through the dam would be decommissioned in place, thus minimizing disturbance to the lower part of the dam that is in solid condition.

No stream channel would be constructed through the lake bed. Boeing Creek would naturally create a channel(s), gradually sluicing out some of the sediment in the lake bed. Thereafter, the creek would reach an equilibrium configuration in the lake footprint that would enable transporting inflowing sediment through the dam spillway and into the reach of Boeing Creek downstream of NW Innis Arden Way. Floodplain areas on both sides of the creek would most likely form in what is currently the lake footprint. Over time, vegetated wetland habitat is anticipated to colonize those floodplain areas. Due to the urban nature of the Boeing Creek basin upstream of the lake and the seed bank within the sediment settling in the lake bed, there is a high likelihood that nonnative and invasive species (i.e., weeds) would occupy the new floodplain areas and invade wetlands. Post-construction vegetation monitoring and management, including weed control measures and supplemental planting of native species would be necessary.

So that all lake outflows pass over the existing dam, the new spillway crest elevation would be lower than the existing dam crest. Accordingly, the new lake would be smaller in area and the lake surface elevation would be 3 to 4 feet lower than at present. The timeframe for sediment to fill in the smaller lake would be dependent on the frequency and magnitude of Boeing Creek flows. Based upon the City’s dredging records since 2002, a reasonable expectation is that the remaining lake volume would fill with sediment within 5 to 10 years after constructing the new spillway in the dam.



Legend

- Approximate channel alignment
- Alignment uncertain
- Existing dam
- Existing weir
- Contour
- Parcel

Figure 2.
Alternative 1 Layout.

N

0 50 100 200 Feet

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Alternative 2

Alternative 2 would involve excavating new creek channels in the lake bed. The channels would be split around higher ground near the middle of the existing lake, combining into a single channel excavated down to the concrete pad at the entrance to the existing roadway culverts. This alternative would remove the earthen dam and the gabion mattresses in the downstream face of it, the lake outlet structures, and a creek flow bypass system previously used in conjunction with dredging operations near the upstream end of the lake. Areas adjacent to the new channels within the existing lake footprint would be planted with native vegetation. Alternative 2 would construct floodplain areas with wetland characteristics that emulate pre-lake conditions and that would be similar to the naturally formed floodplain areas that would develop eventually under Alternative 1. Figure 3 shows a basic layout of Alternative 2.

The existing culverts under NW Innis Arden Way would be retained as is. In the area of the existing dam, the side slopes of the excavated creek channel would be relatively steep to avoid disturbing a near-vertical slope on the east side of the dam and to minimize excavation on private property on the west side of the dam.

To reduce construction costs and provide floodplain area that is beneficial for aquatic habitat and for retaining some of the sediment volume delivered in Boeing Creek, the channel slope entering the upstream end of the existing lake would be steepened at approximately 4 to 6 percent to maximize floodplain area through the remainder of the existing lake footprint. The higher flow velocities and associated shear stress on the bed and banks induced in the steepened upstream channel section would require some erosion-resistant features.

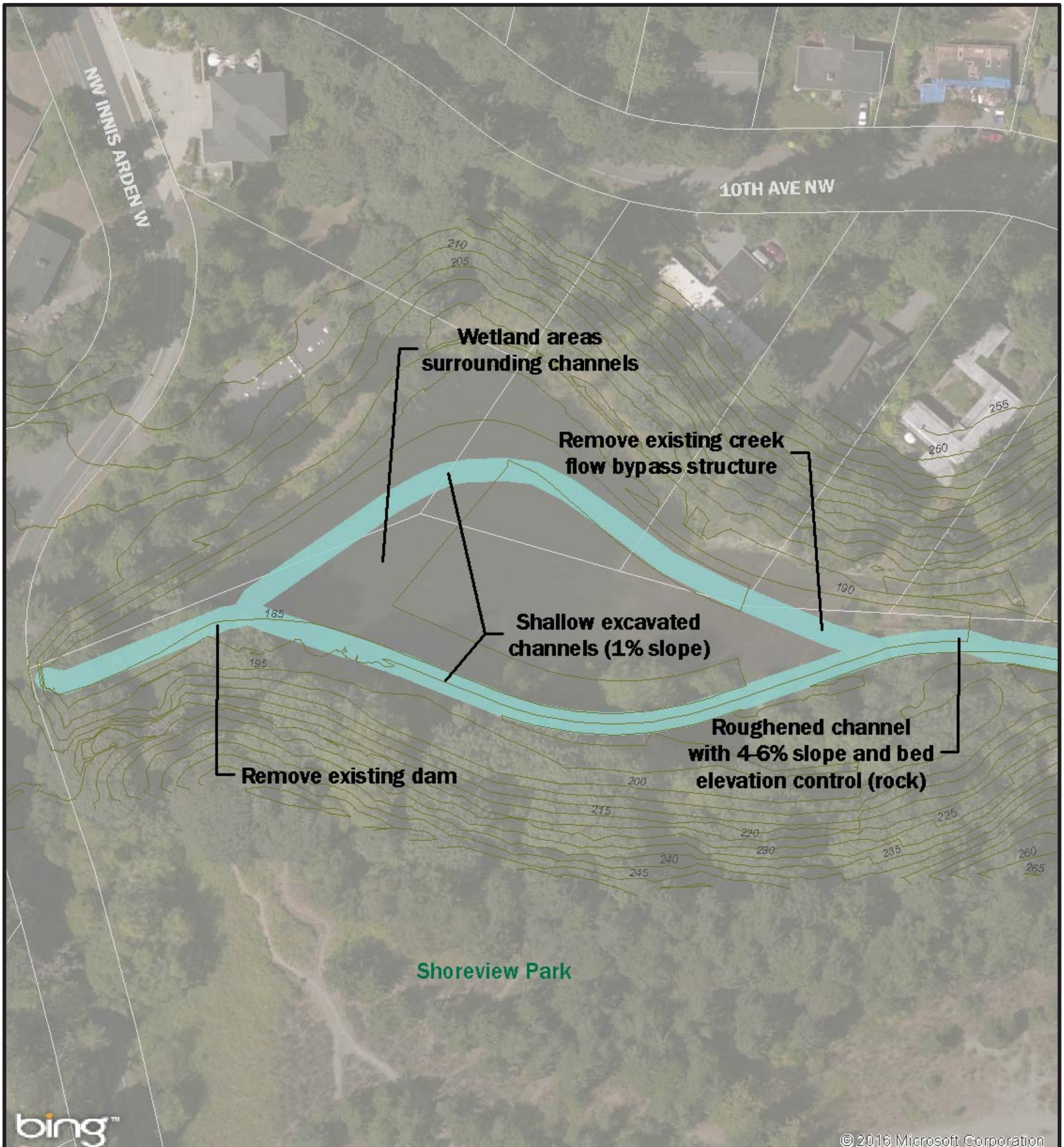
Through most of the existing lake footprint, the new channels would be relatively flat at approximately 1 percent slope. The flatter, more frequently inundated middle portion of the former lake footprint would lend itself to establishment of a vegetated wetland area. In addition to planting native vegetation, post-construction vegetation monitoring and management, including weed control measures and supplemental planting of native species, would be necessary.

Replacing the Culverts Beneath NW Innis Arden Way

The existing culverts beneath the road are a complete barrier to upstream fish passage. Creating conditions that promote fish passage through the project area is of interest to the City over the long term.

To allow fish passage in Boeing Creek from its mouth at Puget Sound to a point upstream of the existing lake, fish passage barriers farther downstream in the creek, primarily the Seattle Golf Club diversion dam, would also need to be removed via other projects. Removal of the Hidden Lake dam and restoring fish passage through the NW Innis Arden Way crossing could be a first major step in that larger fish passage restoration effort.

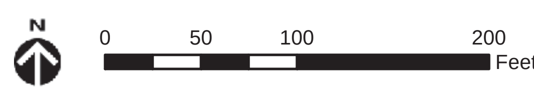
For purposes of this report, Alternative 3 includes fish passage components, but that is somewhat arbitrary. Replacing the culverts with a wider opening that simulates natural streamflow and improving channel conditions downstream of the road could also be included in Alternative 2. Alternative 1, which would retain part of the existing dam and install a steep spillway on the face of it, is not conducive to including fish passage components.



Legend

- Approximate channel alignment
- Contour
- Parcel

Figure 3.
Alternative 2 Layout.



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USDA, Aerial (2013)

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At the downstream end of the site, the single-thread channel approaching the NW Innis Arden Way culverts would be flat, with effectively no slope, to enable potential future excavation through the roadway crossing to create a fish-passable stream section comparable to that described for Alternative 3. The existing roadway culverts and downstream channel conditions are barriers to upstream fish passage. While it would not remove those barriers, the Alternative 2 design (unlike Alternative 1) would accommodate potential future fish passage improvements in this immediately downstream area. If the new channel approaching the culverts from the existing dam vicinity were set at a higher elevation profile than described above (which, in turn, would mean setting the channels through the existing lake bed at higher elevation), fish passage would be difficult to accomplish in the future without significant excavation and associated costs to re-plant vegetation and re-establish a stable channel further north of NW Innis Arden Way.

The Washington Department of Fish and Wildlife (WDFW) has design guidelines for "roughened channels" that are well-suited for the new, steeper channel section at the upstream end of the project site. A roughened channel is composed of large boulders, with smaller cobbles and sediment amid the boulders, that are sized to resist erosion in flood events while allowing fish passage at a wide range of flow levels, as occurs naturally in mountainous streams in the region (Barnard et al. 2013).

Secured large woody debris would be placed in the creek channels that are created within the existing lake footprint, where feasible, for enhanced aquatic habitat. A mix of native shrubs and trees would be planted in areas disturbed during construction on both sides of the new channels.

The new channel construction work would occur on City-owned park land (on the eastern side of the existing lake footprint) and on four privately owned parcels (on the western side). Following construction, aside from maintenance of vegetation plantings for several years to ensure that desired native vegetation survives and thrives, minimal maintenance activity would be needed for the creek to function as intended over the long term.

Alternative 3

Alternative 3 is the largest of the three alternatives analyzed for purposes of this report, but a major component of it—improving fish passage by replacing the existing culverts beneath NW Innis Arden Way and modifying the creek channel downstream of the roadway—could also be a component of Alternative 2, in which case, Alternative 2 would become the largest of the three alternatives.

Like Alternative 2, Alternative 3 would involve excavating a new creek channel through the lake bed after removing the dam structure and lake outlet structures. Alternative 3 would also replace the NW Innis Arden Way culverts with a large box culvert or small bridge, would remove the concrete pad near the upstream entrance to the culverts, and would modify the creek channel downstream of the road to smoothly transition the new channel profile through the road crossing and improve fish passage in a section of the downstream channel that currently hinders fish passage because it is steep and partly filled with riprap (large quarry rock). In total, Alternative 3 would involve creating and improving approximately 1,000 feet of creek channel from upstream of the lake to downstream of the road. Work would also include planting areas surrounding the new channel and extending across the entire existing lake area, which would mostly be forested vegetation, and planting disturbed areas adjacent to the creek downstream of the NW Innis Arden Way crossing. Figure 4 shows a basic layout of Alternative 3.

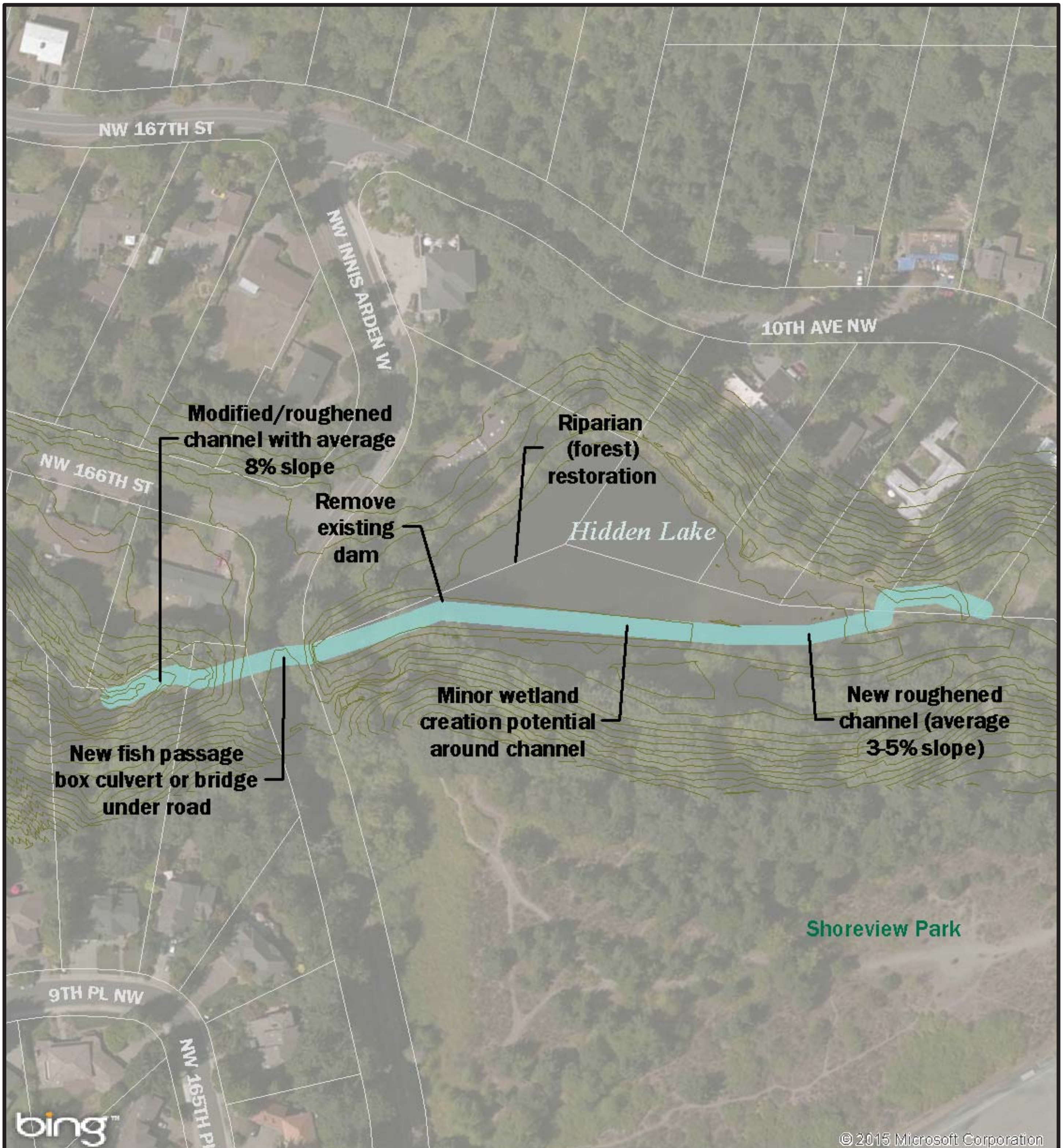
By replacing the roadway culverts with a structure that allows for natural stream channel conditions within it, creating better conditions for fish habitat and passage downstream of the road, and creating a gradual creek channel slope through the existing lake area, continuous fish passability would be restored from several hundred feet downstream of NW Innis Arden Way to the upstream end of the lake area.

A compelling reason for the City to consider this large-scale alternative is that improving fish passage conditions in creeks throughout the Puget Sound basin is a focus of local, state, and federal agencies and others engaged in salmon recovery. Therefore, it may be possible to obtain grant funding to cover some of the project cost, and it would also result in a greater ecological lift for Boeing Creek than Alternative 2 (and far greater than Alternative 1).

The new creek channel through the existing lake bed could be constructed exclusively on City-owned land within the eastern half of the lake. The channel slope would be relatively steep (4 percent on average) for the upstream half of the project area and also in the modified channel section downstream of NW Innis Arden Way (approximately 8 percent). Therefore, a roughened channel design approach (Barnard et al. 2013) would be used for those sections of the creek.

The new box culvert or bridge beneath NW Innis Arden Way would require temporary closure of roadway traffic to excavate into the deep earth fill prism underlying the existing roadway. The deep excavation and associated traffic control requirements are significant cost components of this alternative. The new culvert or bridge structure would be wider than the stream channel, per WDFW fish passage design requirements (Barnard et al. 2013).

A mix of native shrubs and trees would be planted in areas disturbed during construction on both sides of the new creek channel. Because the channel bed and banks would be relatively steep and at a deeper elevation throughout the length of the creek modified by Alternative 3, it would be more difficult to re-establish floodplain areas and associated wetlands along the creek than under Alternative 2. This is a consideration in comparing Alternatives 2 and 3, as discussed later in this report. As with Alternative 1, there is a high likelihood that the seed bank from the sediment delivered into the project area in Boeing Creek flow would enable weedy vegetation to occupy the new floodplain areas and invade wetlands. Portions of the lake bed that are not excavated for the new creek channel (on the west side) but that are no longer inundated by lake water would be vulnerable to invasive and weedy vegetation growth. Therefore, post-construction vegetation monitoring and management, including weed control measures and supplemental planting of native species, would be necessary in much of the existing lake footprint.



Legend

- Approximate channel alignment
- Contour
- Parcel

Figure 4.
Alternative 3 Layout.

N

0 75 150 300 Feet

HERRERA

USDA, Aerial (2013)

K:\Projects\Y2015\15-05984-000\Project\20160105_Deliverable\alt3.mxd (12/30/2015)

METHODS OF ANALYSIS

Hydrology and Hydraulics

Hydrologic analysis included consolidating data from previous studies for the Boeing Creek basin to develop inflow hydrographs at the upstream end of the Hidden Lake project area. Three flow scenarios were chosen, representing an extreme high flow scenario (100-year flood); a moderate, geomorphically significant flood (2-year flood); and an average base flow (mean annual flow). The hydrograph for the mean annual flow was assumed to be a constant flow of 2.7 cubic feet per second (cfs), based on data from the King County gage 4j (King County 2015a). The 100-year and 2-year flood hydrographs were developed using hydrograph shapes based upon available King County data for gages 4a and 4e (King County 2015b, 2015c) and scaling the hydrographs to the peak flow estimates from the Hidden Lake Management Plan Feasibility Study (AltaTerra 2014); those estimates are 227 cfs for the 100-year flood and 72 cfs for the 2-year flood. Development of the hydrographs is described in detail in the Hidden Lake Dam Removal Project Hydrologic, Hydraulic, and Sediment Transport Analysis memorandum (Herrera 2016).

Herrera performed hydraulic analysis of streamflow characteristics within the project area using the two-dimensional finite volume RiverFlow2D Plus hydrodynamic model. The analysis was done for existing conditions and the three alternatives. A two-dimensional model was chosen to best capture lateral distribution of flows and velocities that would not be captured in a one-dimensional model. The required model inputs included a topographic surface, hydraulic boundary conditions at the upstream and downstream limits of the model, and hydraulic roughness (Manning's "n") values for channel and floodplain areas. Details of the model development, input data, assumptions, and results are provided in Herrera (2016). Key existing hydraulic features, including the NW Innis Arden Way culverts and Hidden Lake outlet structure, were included in the model. The hydraulic characteristics predicted by the existing conditions model for those features were back-checked outside of the model to ensure they were being accurately represented.

Unsteady boundary conditions (i.e., a continuous hydrograph as opposed to a single flow value) were used for the 2-year and 100-year hydrologic events to better understand the existing flood flow attenuation effects of the lake and changes in that flow attenuation that could be expected for each alternative. Boeing Creek in the Hidden Lake area is delineated as a Zone A floodplain in the published Flood Insurance Rate Map for the project area. Zone A means that no Base Flood Elevations (for the 100-year flood event) have been established. Flood and erosion risks, and sediment transport characteristics were assessed by comparing the model results for existing conditions to the model results for each of the three alternatives.

Geotechnical Conditions

It is important to understand the subsurface soil conditions in the dam area and in the project area in general to be sure that the conceptual design and cost estimate for each alternative is accurate with respect to proposed earthwork. Documentation from previous geotechnical investigations at Hidden Lake (Shannon & Wilson 1995) were reviewed. Then, in September 2015, two new geotechnical borings were drilled in the dam to confirm soil characteristics within and beneath the dam. Appendix A contains a plan showing the locations of the new borings, as well as a geologic cross-section interpreted from the borings and the corresponding boring logs.

Geomorphology

Herrera conducted a geomorphic assessment of existing conditions, as well as potential changes in sediment transport and deposition under each alternative. The assessment was based upon existing information that was summarized primarily by AltaTerra (2014) and reconnaissance of Boeing Creek from upstream of Hidden Lake to the creek mouth at Puget Sound in June 2015. Herrera also used early maps of the area (GLO 1859) to understand predevelopment conditions. The reason for investigating predevelopment geomorphic conditions is that professional experience has shown that a suite of physical processes that have been occurring for centuries will likely continue to play a role in the formation of the landscape, given enough time, even in systems that have been altered by upstream development, which is the case for Boeing Creek.

Sediment Transport

Calculations were performed to estimate the sediment volume delivered to the lake and areas downstream using a recently developed sediment production model (Syvitski et al. 2003; Syvitski et al. 2005). Previous Hidden Lake sediment loading estimates, such as those provided by King County (1995), have been shown to be significantly underestimated (AltaTerra 2014). Sediment production rates in the Boeing Creek basin upstream of the lake are useful for determining the extent to which suspended sediment currently passes through the lake and for determining the geomorphic ramifications of the alternatives within the existing lake area and downstream. The sediment volume calculations are described further in Herrera (2016).

Large Woody Debris

Herrera prepared qualitative estimates of the large woody debris loading to Boeing Creek within the lake area and in downstream reaches of the creek under existing conditions and for each of the alternatives. Large woody debris enables habitat-forming processes, but it can also present risks to existing conveyance structures and increase future maintenance. The estimates were based upon past conditions observed and documented and upon anticipated future vegetation changes associated with each alternative.

Existing Habitat and Species

To determine the historical and current presence of wetlands and streams in and near the project area, Herrera reviewed available documentation and databases and conducted a site visit. Information gathered was used to classify and preliminarily rate existing wetlands and streams.

Wetlands identified within the project area were classified according to the US Fish and Wildlife Service classification system (Cowardin et al. 1979). That system is based on an evaluation of attributes such as vegetation class, hydrologic regime, salinity, and substrate. The wetlands were also classified according to the hydrogeomorphic system, which is based on an evaluation of attributes such as the position of the wetland within the surrounding landscape, the source and location of water just before it enters the wetland, and the pattern of water movement in the wetland (Brinson 1993).

Potential wetlands identified within the project area were preliminarily rated using *Washington State Wetland Rating System for Western Washington: 2014 Update* (Hruby 2014), hereafter referred to as the Ecology rating system. The Ecology rating system categorizes wetlands according to specific attributes such as rarity; sensitivity to disturbance; hydrologic, water quality, and habitat functions; and special characteristics (e.g., mature forested wetland, bog). The total score for all functions determines the wetland rating. The rating system consists of four categories, with Category I wetlands exhibiting outstanding functions and/or special characteristics, and Category IV wetlands exhibiting minimal attributes and functions. The rating categories are used to identify permitted uses in the wetland and its buffer, to determine the width of buffers needed to protect the wetland from adjacent development, and to determine mitigation requirements.

Streams are considered to be a type of fish and wildlife habitat conservation area, according to the City of Shoreline Code 20.80.260-300. A fish and wildlife conservation area is an area that supports regulated fish or wildlife species or habitats, typically identified by known point locations of specific species, habitat areas, or both.

Streams within the project area were classified in accordance with City of Shoreline Code 20.80.270 which specifies use of the Washington State Department of Natural Resources water typing system based on WAC 222-16-030. That system is based primarily on fish, wildlife, and human use, and consists of four stream types: Type S, F, Np, or Ns. Type S streams are those surface waters which are inventoried as “Shorelines of the State” under the Shoreline Management Master Program for the City of Shoreline, pursuant to RCW Chapter 90.58.030. Type F streams and waterbodies are those known to be used by fish, or that meet the physical criteria to be potentially used by fish. Fish streams may or may not have flowing water all year; they may be perennial or seasonal. Type Np streams have flow year round and may have spatially intermittent dry reaches downstream of perennial flow. Type Np streams do not meet the physical criteria of a Type F stream and have been proven not to contain fish. Type Ns streams do not have surface flow during at least some portion of the year, and do not meet the physical criteria of a Type F stream.

Cultural Resources

A cultural resources assessment was prepared for this project to determine if there are historical or archaeological resources within the project area that could be affected by any of the alternatives (CRC 2015). The assessment was based on published information sources, records on file with the Washington State Department of Archaeological and Historic Preservation (DAHP), field reconnaissance, and contacts with several Native American tribes in the area.

Public Input

The City has sought public input on this project dating back to the feasibility study of lake management alternatives (AltaTerra 2014). During the course of the alternatives analysis described in this report, five property owners along the west side of the lake were interviewed individually to gain their views on specific aspects of a potential dam and lake removal/modification project, and two additional meetings were subsequently held. The interviews were conducted in August and September 2015. A meeting was convened on October 20, 2015, with the owners of four of the properties along the west side of the lake to further discuss the project and obtain their input on the alternatives under consideration. On October 24, 2015, a meeting was convened in Shoreview Park to obtain input on the alternatives from the general public.

Permitting Considerations

Wetlands and streams in the project area are subject to a variety of federal and state regulations. Federal laws regulating wetlands include Sections 404 and 401 of the Clean Water Act (United States Code, Title 33, Chapter 1344 [33 USC 1344]). Washington State laws and programs designed to control the loss of wetland acreage include the State Environmental Policy Act (SEPA) and Section 401 of the Clean Water Act (a federal law that is implemented in Washington by the Department of Ecology (Ecology), as mandated by the Washington State Water Pollution Control Act). City of Shoreline Code section 20.80 specifies wetland and stream categories, required buffer widths, development standards, and mitigation requirements for critical areas in its jurisdiction.

A review of existing project site documentation was performed to assess permitting considerations likely to be associated with each of the alternatives under consideration. The City's knowledge of historical permitting procedures for dredging and maintenance in the Hidden Lake project area was also elicited via personal communications.

Cost

The construction cost of each alternative was developed to a sufficient level of detail to understand cost differences between the alternatives and range of magnitude of the project cost. The cost estimates were based on earthwork volumes derived in Civil3D (computer-aided design software), cost data from past projects constructed in the region, and professional judgment based upon Herrera's experience in design and construction of over 50 creek and river projects.

Maintenance Implications

The maintenance requirements that the City could expect for each alternative were assessed qualitatively based on experience with creek projects throughout the region and with input from City staff who know the project site well.

ANALYSIS RESULTS

Hydrology and Hydraulics

A summary of the hydrologic and hydraulic analyses is provided in this section. More detailed information can be found in Herrera (2016). Hydraulic model results for existing conditions and the three alternatives are shown in Figures 5 through 7. The hydraulic modeling revealed three key findings:

1. The lake has limited flood storage during the 100-year flood event, which is not an issue because the outlet structure and associated piping is low enough and large enough to convey a significant amount of flow. The limited flood attenuation in the lake during higher flood flows under existing conditions means that the downstream flood hydrograph peak would not change (in terms of flow magnitude and timing) for any of the alternatives (Herrera 2016). In fact, a slight decrease in the downstream peak flow is predicted for Alternative 3 and a significant decrease is predicted for Alternative 2 due to the difference between "dead" storage (lake volume occupied by water before a flood wave comes through) in the lake under existing conditions compared to the live flood storage in the excavated channel and floodplain for Alternatives 2 and 3.

2. The lake outlet manhole structure and associated piping has sufficient capacity during moderate floods such that the model predicts minor lake elevation changes at increasing flow rates, and no change in the hydrograph downstream of NW Innis Arden Way with respect to peak flow or flood duration.

3. Model results for all three alternatives demonstrated a significant decrease in water surface elevations in the project area and extending upstream of the lake. This is because water surface elevations under existing conditions are governed by the geometry and elevation of the dam crest at the existing outlet of the lake, and lowering or removing the dam would result in a creek water surface elevation profile through the existing lake bed that is lower than the existing lake water surface, even during floods. Therefore, the model results indicate that none of the alternatives would have adverse flooding effects on park land or private property upstream of the dam.

While the project team has confidence in these findings based on the modeling done to date, as discussed in Herrera (2016), the creek hydrographs used as input to the hydraulic model are approximate, derived based upon several sources of information. If a streamflow gage were installed at a location approximately 400 to 600 feet upstream of the existing lake, the flow data collected at that gage could be used to refine the model findings discussed herein. That would be particularly useful if some large flow events were captured in the gage data before detailed project design is completed.

Findings of the hydraulic modeling for existing conditions and each alternative are summarized below.

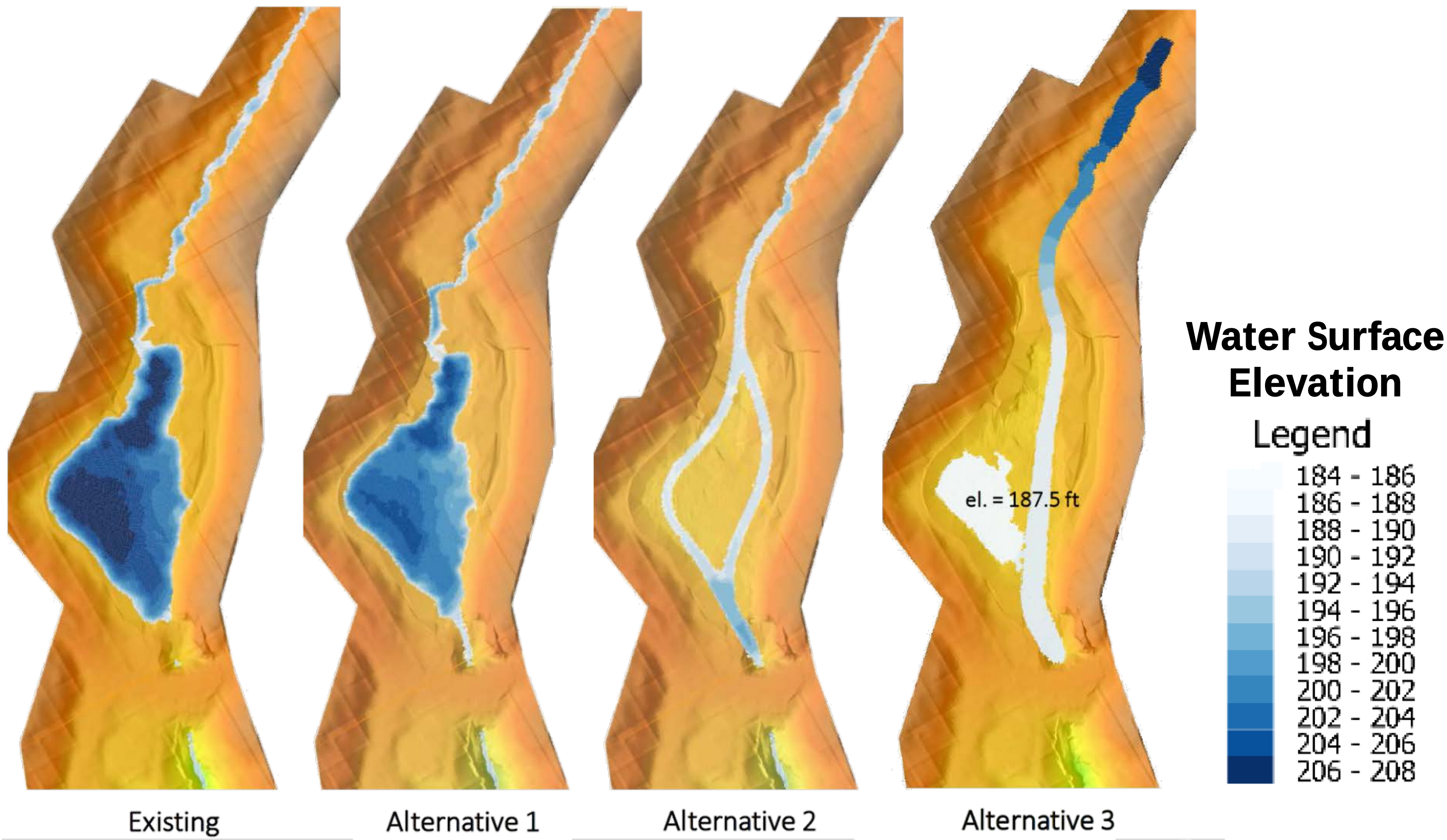


Figure 5. Modeled Boeing Creek Water Surface Elevations in the Project Area under Mean Annual Flow Conditions.

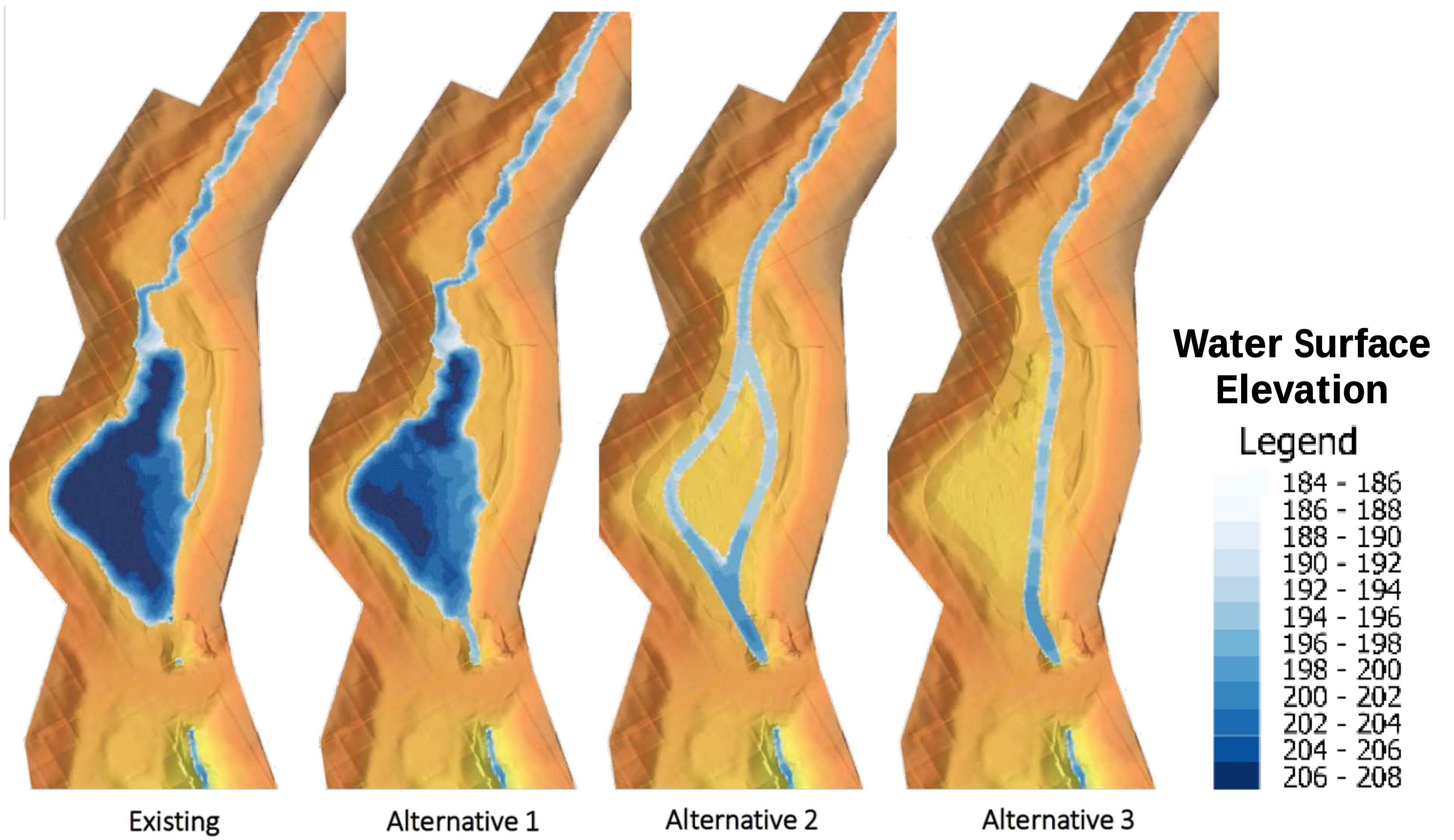


Figure 6. Modeled Boeing Creek Water Surface Elevations in the Project Area at the Peak of the 2-Year Recurrence Flood Flow.

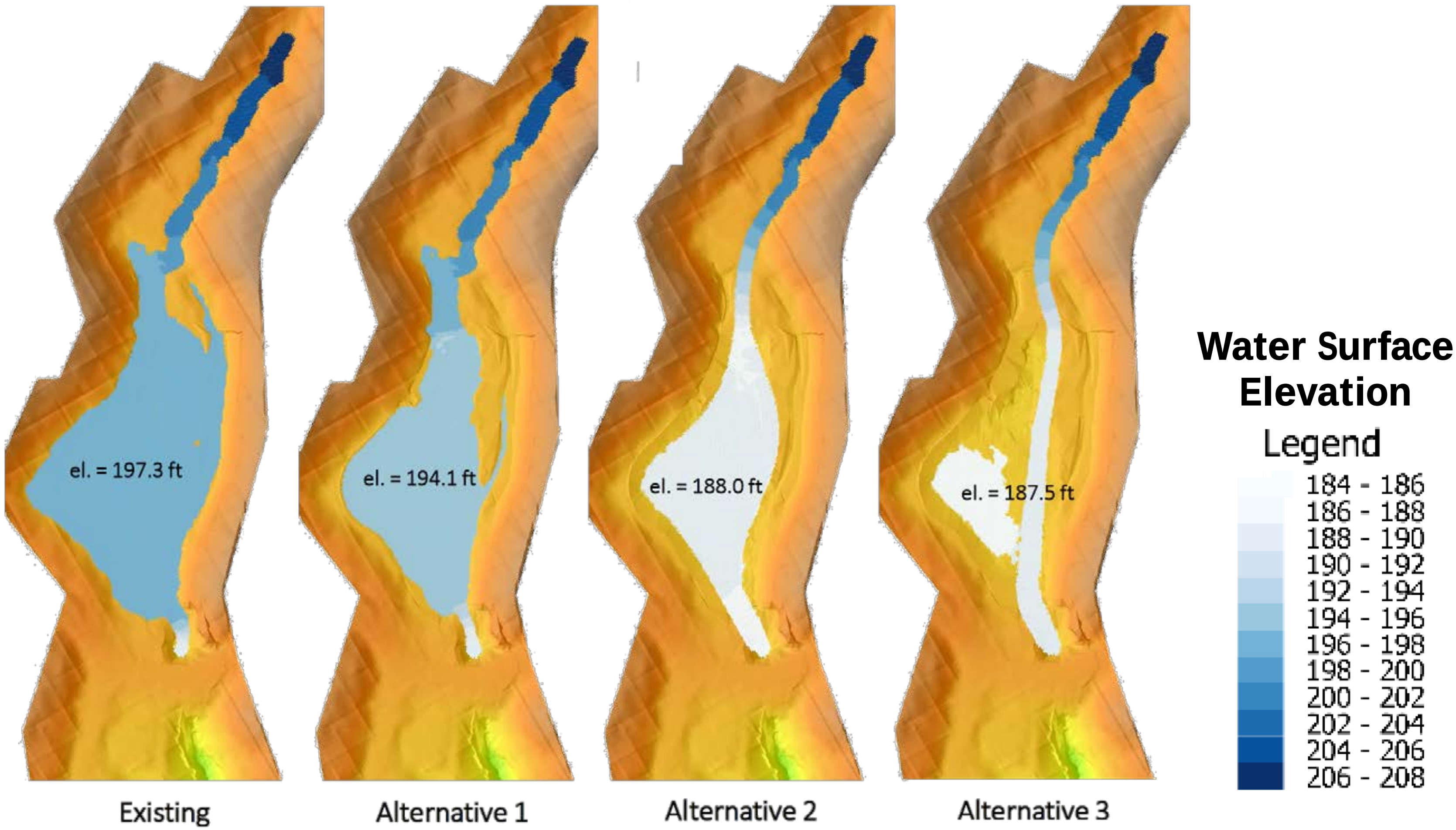


Figure 7. Modeled Boeing Creek Water Surface Elevations in the Project Area at the Peak of the 100-Year Recurrence Flood Flow.

Existing Conditions

The model results indicate that the lake outflow system is capable of conveying the entire 2-year flood event (with minor attenuation of the peak flow rate occurring in the lake), but the lake outflow system is overwhelmed in the 100-year flood event. Significant overtopping of the dam is simulated for the 100-year flood event. The lake may provide some flood flow storage and peak flow attenuation for flows greater than the 2-year flood.

Alternative 1

The Alternative 1 model results show that lowering the lake outlet elevation by 3 to 4 feet would lower the water surface elevation profile upstream of the dam by the equivalent amount. Widespread inundation would still occur similar to the existing lake, analogous to simply lowering the lake water surface elevation by 3 to 4 feet. However, that depth of inundation would lessen over time as the lake fills with sediment.

Lowering the lake outlet would result in increased flow velocities in the creek at the upstream entrance to the lake and at the dam spillway. In the 100-year flood event, the velocity in these areas was simulated to be in the range of 5 to 9 feet per second (fps). The high velocity flow over the dam during floods dictates that the spillway be designed to resist erosion, which is why Alternative 1 assumes a reinforced concrete spillway. The increased flow velocities in the creek near the entrance to the lake would be similar to existing flow velocities upstream and downstream of the project area. Thus, the new creek channel that would form in the existing lake bed under Alternative 1 would be able to function similar to the existing upstream and downstream channel sections.

At the entrance to the culverts under NW Innis Arden Way, the model results suggest flow velocities would increase and the direction of concentrated velocity would change. If Alternative 1 is selected for implementation, this issue should be evaluated further to assess scour and other erosion risks at the culverts, and corresponding mitigation measures to prevent culvert damage.

Alternative 1 would trigger slower flow velocities through the existing lake area compared to Alternatives 2 and 3. Therefore, sediment deposition would be expected in the remaining lake area until an equilibrium is reached and a channel is naturally cut through the existing lake bed.

A slight increase in the peak flow rate downstream of the dam was simulated for Alternative 1 for the 100-year flood, but this change is likely within the limitations and expected variability (“noise”) of the model. Minimal peak flow attenuation occurs in the lake during higher flood flows in the existing condition, as evidenced in the 100-year flood model results. This means that reduction or elimination of the lake storage volume will not notably affect peak flows downstream of NW Innis Arden Way.

Increased flow velocities at the upstream end of the lake were noted in the model results for Alternative 1. Higher velocities could induce channel bed erosion. Headcutting (lowering of the channel bed propagating in the upstream direction) could be an issue in that area until the appropriate coarse sediment that is resistant to erosion can be delivered as described in the *Geomorphology* section below. Alternatively, bed grade control measures could be constructed in the vulnerable, upstream section of the channel to prevent headcutting.

Alternative 2

The Alternative 2 model results show inundation on the newly created floodplain roughly 2 feet deep with in-channel flow depths up to 6 feet in the 100-year flood event. The 2-year model results suggest that floodwaters would generally be contained in the new creek channel(s), whereas part of the intent of this alternative is to create frequently activated floodplain areas. Therefore, if Alternative 2 is selected for implementation, the floodplain elevation should be lowered more in design compared to what was modeled. The “dead” water storage in the lake area (water storage volume that is occupied before flood flow passes through the lake) would be eliminated and replaced with “live” storage in the active floodplain areas during moderate to extreme flood events. This effect would be greatest under Alternative 2, compared to the other alternatives, because it would create the largest amount of floodplain. The live storage would attenuate peak flow rates to some extent downstream of NW Innis Arden Way.

The model simulates maximum flow velocities on the order of 8 to 9 fps in the roughened channel area entering the existing lake footprint, and 1 to 6 fps in the channels through the existing lake area during the 100-year flood event. The variable velocity gradients in the floodplain area predicted for Alternative 2 also suggest an increase in hydraulic complexity that could increase sediment transport and overbank sediment deposition, and also diversify aquatic habitat. Given the lack of coarse sediment in the lake bed to resist erosion, coarse streambed gravels and cobble material would need to be imported to build a stable channel bed that would withstand high shear stresses when flood flows generate high velocities.

As with Alternative 1, the model results for Alternative 2 suggest flow velocities would increase and the direction of concentrated velocity would change approaching the upstream entrance to the culverts beneath NW Innis Arden Way. If Alternative 2 is selected for implementation, this issue should be evaluated further to assess scour and other erosion risks at the culverts, and corresponding mitigation measures to prevent culvert damage.

A slight decrease in the peak flow rate is predicted downstream of NW Innis Arden Way in the 100-year flood event, but not to an extent that would notably affect flooding of land along the creek banks or erosion of the banks by turbulent water.

Alternative 3

The Alternative 3 model results show limited floodplain activation on the left (south) bank with in-channel flow depths of about 6 feet for the 100-year flood, suggesting limited floodplain inundation and less potential off-channel habitat gain compared to Alternative 2. Similar but slightly lesser peak flow velocities were simulated for Alternative 3 in the 100-year flood event, compared to Alternative 2, in the steeper channel sections. Regardless, the design of the new and modified channel bed and banks would need to include durable elements that resist erosion during flood flows. Alternative 3 would result in slightly reduced peak flow downstream of NW Innis Arden Way in the 100-year flood event, but less of a reduction than Alternative 2 because Alternative 3 would create less floodplain area to temporarily store floodwater upstream of the road.

Alternative 3 requires special consideration for channel bank design to maintain a predictable channel alignment because the current lake bed near the upstream end of the site is low enough that the new channel could shift location without durable confinement. The simulated flow depths and velocities in the creek channel where it enters the existing lake indicate that the right (west) bank of the modified channel could be vulnerable to erosion and flow overtopping it. This concern could be offset by inclusion of stout bank protection measures in that area, such as a wood crib structure or large rock to armor the bank and resist erosion.

Geotechnical Information

The two new borings advanced through the dam in September 2015 encountered fill overlying native glacial deposits or recent alluvium.

- In boring B-1, located due south of the lake outlet structure on the downstream side of the dam crest, encountered fill to a depth of about 10 feet, which consisted of variable soils including medium dense sand, silty sand with gravel, and medium stiff lean clay and sandy clay. The fill appears to be the material placed for construction of the dam. Below a depth of 10 feet, the boring encountered glacial deposits consisting of hard lean clay and very stiff to hard silt. Groundwater was encountered at a depth of approximately 9 feet.
- In boring B-2, on the west side of the dam, fill was encountered to a depth of about 10 feet and consisted of medium stiff to stiff sandy clay. The fill overlies recent alluvium, which was likely deposited in the historical drainage channel of Boeing Creek. The recent alluvium consisted of very loose silty sand to a depth of 17 feet over medium stiff fat clay to the bottom of the boring at 31.5 feet below ground surface. Groundwater was encountered at a depth of about 9 feet.

The soils encountered in the new borings are similar to those found in geotechnical borings reported in Shannon & Wilson (1995). Implications of the geotechnical findings for the alternatives are summarized below.

Alternative 1

Under Alternative 1, any soil removed from the dam would be hauled off site. The hauled soil would be suitable for backfill at another site. However, the soils are very moisture-sensitive due to the large amount of silt and clay content, so they will be difficult to place and properly compact if they become wet. Therefore, excavation, placement, and compaction of the excavated soil should be done during drier weather.

Alternative 1 would entail excavating an estimated 440 cubic yards of dam fill, and placement of less than 20 cubic yards of earth fill on the periphery of the new spillway.

Alternative 2

If desired, the materials comprising the dam fill could be reused on site for other purposes as part of constructing Alternative 2, such as creating mounds in the floodplain for diversifying growth conditions for vegetation plantings. For any dam fill that is hauled off site, considerations for that material are the same as described for Alternative 1.

As configured for purposes of this analysis, Alternative 2 would entail excavating an estimated 12,850 cubic yards of dam fill and (mostly) lake bed sediments, and placement of approximately 170 cubic yards of fill for the banks in some locations along the new stream channel.

Alternative 3

Alternative 3 has less potential for reuse of dam fill material on site compared to Alternative 2. For any dam fill that is hauled off site, considerations for that material are the same as described for Alternative 1.

As configured for purposes of this analysis, Alternative 3 would entail excavating an estimated 6,800 cubic yards of dam fill and (mostly) lake bed sediments, and placement of approximately 30 cubic yards of fill for the banks in some locations along the new stream channel. These volumes do not include excavation of the embankment beneath NW Innis Arden Way to remove and replace the culverts (which would result in net excess of soil to haul off site or reuse on site). They also do not include excavation or fill related to work in the channel downstream of NW Innis Arden Way that was not evaluated in detail.

Geomorphology

Current geologic and geomorphic conditions are well described in the feasibility study (AltaTerra 2014) and earlier planning documents (King County 1995). As described in those works, the surficial geology of the area is typical of the Puget Lowland, being composed of a thick (200 feet) deposit of outwash sand, overlying a relatively thin unit of lacustrine silt and clay, on top of glacially overrun pre-Fraser glacial sediments. The outwash sand deposit generates relatively large landslides in the creek corridor immediately upstream of the lake and smaller slope sloughing downstream of NW Innis Arden Way. It contributes large volumes of sediment to the creek, albeit somewhat fine grained (i.e., sand). The instability of the outwash sand upstream of the lake has been exacerbated by human disturbance and hydrologic changes due to development, as documented in AltaTerra (2014).

The geomorphology of Boeing Creek is reflective of this geologic pattern, with a relative decrease in channel slope through the easily erodible outwash sediments at the lake's current location. However, contrary to King County (1995), research performed for this analysis suggests that, if there had been a natural lake prior to the construction of the original Hidden Lake dam in the 1920s, it was quite small, because no lake is shown on the earliest maps of the area (GLO 1859). Approximately 800 feet downstream of NW Innis Arden Way is a 9-foot-tall dam made of sheet-pile, which was formerly used by the Seattle Golf Club for irrigation water supply. The creek channel is completely full of sediment just upstream of that dam, so the dam no longer actively impounds sediment throughput, although it likely protects against erosion of private property along the right bank.

Downstream of Hidden Lake, the creek is deeply incised into the more competent and less erodible pre-Fraser sediments. In several locations in that reach, erosion has occurred down to well consolidated, pre-Fraser sediments (Figure 8). The channel slope is moderate through this reach down to the creek mouth at the Puget Sound shoreline.

Figure 8. Exposed Pre-Fraser Sediments in the Bed of Boeing Creek Downstream of the Seattle Golf Club Diversion Dam.

All three alternatives under consideration would increase sediment delivery, over time, to the Boeing Creek channel downstream of Hidden Lake. The character and volume of that sediment will vary depending on the alternative, as described in the *Sediment Transport* section below.

Currently, there are unstable slopes in many locations along Boeing Creek, both upstream and downstream of the lake. Examples include an area upstream of the lake in Boeing Creek Park caused by erosion from high storm flows, and an area downstream of the Seattle Golf Club diversion dam caused by channel incision that is a direct effect of sediment starvation due to sediment impoundment within Hidden Lake. Because the hydrology of the Boeing Creek basin as a whole will not change significantly as result of any of the three alternatives, such geomorphic patterns are expected to continue into the future.

The mode of ravine slope failure downstream of the Seattle Golf Club diversion dam may be changed by increased sediment delivery downstream of Hidden Lake, which would occur under any of the three alternatives. These downstream areas are currently at risk to slope failure because the creek channel continues to incise, heightening already tall, near vertical banks. The most affected areas have incised several feet within the last few decades. With increased sediment supply, the channel incision will slow and may even stop. However, the delivery of additional sediment, particularly bedload (consisting of gravel with minor amounts of coarse sand), will initiate deposition and ultimately lead to lateral channel migration in areas where the local slope is relatively low (less than a few percent). Channel migration could trigger bank instability and may initiate landslides. Most changes would likely occur downstream of the Seattle Golf Club diversion dam, particularly immediately downstream of the dam, because the channel profile in the reach between NW Innis Arden Way and the diversion dam is too steep to initiate sediment deposition and, thereafter, channel migration. Because the Boeing Creek channel is far from residences and other development downstream of the golf club diversion dam, such anticipated changes induced by any of the Hidden Lake alternatives are not expected to pose significant risk of slope failure affecting adjacent private development.

Sediment Transport

Basin Sediment Delivery Estimates

Sediment transport estimates developed over 20 years ago during design of King County's Hidden Lake Restoration Project (King County 1995) were significantly lower than the actual amount of sediment that was supplied to the lake after that project was completed. The City's lake dredging records indicate an average of 1,100 cubic yards of sediment deposition in Hidden Lake per year between 2002 and 2013 (AltaTerra 2014). The grain size character of the dredged sediment has been predominantly sand.

Using a modern sediment production model (Syvitski et al. 2003, Syvitski et al. 2005), total sediment load in the Boeing Creek basin is estimated to be approximately 2,500 cubic yards per year (Herrera 2016). This means that roughly half of the sediment entering Boeing Creek flow each year has been retained in Hidden Lake. The material that passes through the lake is wash load, the finest portion of suspended load. It is expected that finer-grained material, including some sand, remains in suspension during turbulent and higher-velocity flood flows, and passes though the lake in the existing condition.

Bedload transport volumes are much smaller. Based upon the relationship of bedload with suspended load, the Syvitski model yields a calculation of approximately 300 cubic yards per year of bedload in Boeing Creek. This volume is corroborated by AltaTerra (2014), which found creek channel widening (due to erosion from storm events after a former dam failed in one of the two primary tributaries upstream of the lake) equating to approximately 100 cubic yards of eroded creek bank soil per year. Currently, no bedload reaches the Hidden Lake outlet. The only bedload (primarily gravel) downstream of the dam has been scavenged by the creek as it has incised into older historical creek deposits in the middle of the ravine downstream of NW Innis Arden Way.

King County's documentation supporting the Hidden Lake Restoration Project (King County 1995) reveals that a justification for the environmental benefits of the project was reducing fine sediment deposition that hindered coho salmon spawning productivity in lower reaches of Boeing Creek. The fine sediment of most concern to coho salmon spawning gravels (i.e., fine sand, silt and clay) may pass through Hidden Lake in the current condition, and material of that size is increasingly being removed upstream of Hidden Lake via stormwater management practices that were not in place in the early 1990s. Although basin sediment supply and hydrologic extremes are still pronounced compared to predevelopment conditions in the basin, the effects of Hidden Lake on coho spawning habitat in lower Boeing Creek are less now than were stated more than 20 years ago (King County 1995).

Each of the three alternatives would deliver additional sediment to lower Boeing Creek downstream of NW Innis Arden Way, but in different ways. The following subsections describe the anticipated differences among the alternatives.

Alternative 1

Based upon the sediment volumes excavated in the lake reconstruction effort in the 1990s, it is expected that it will take between 5 and 10 years for the lake to be filled with sediment unless an extremely rare flood event occurs sooner. It would take longer than that for a well-developed, stable channel to re-establish in the lake bed under Alternative 1. Once a channel is re-established under Alternative 1, the former lake reach of the creek would continue to store significant quantities of sediment. The creek would mostly pass only suspended load until an equilibrium is reached wherein the creek's floodplain in the lake reach no longer has capacity to store sediment and bedload also passes farther downstream. In the interim until equilibrium channel conditions occur naturally, the landscape of the existing lake would exhibit many isolated, ephemeral pools and, possibly, many braided channels.

With Alternative 1, there is also a risk of a headcut developing and propagating upstream of the lake, as noted previously. The headcut risk would persist until a well-defined channel reforms and the creek profile stabilizes through the lake area. Some suspended sediment load would likely be stored for a longer period (for at least 20 years) in the lake reach as the floodplain aggrades. However, immediately following construction, much of the suspended sediment would be remobilized until a stable channel can form through the existing lake footprint.

Alternative 2

Of the three alternatives, Alternative 2 most closely mimics known predevelopment geomorphic conditions in the lake reach above NW Innis Arden Way. Because a channel would be constructed that connects the existing lake inlet to the culverts at NW Innis Arden Way, bedload transport through the lake reach would be enabled immediately after construction. Alternative 2 would also result in storage of some suspended sediment load in floodplain areas, particularly in the upstream portion of the existing lake where the channel slope would be flatter than in the downstream portion of the lake and dam area, when flows greater than a 2-year recurrence flood event activate floodplain areas. Therefore, channel degradation downstream of the lake likely would be reduced, while sand supply to the nearshore areas of Puget Sound at the creek mouth would increase.

Because the constructed channel gradient would be relatively steep at 4 percent or greater in parts of the site, significant engineering controls such as constructed boulder riffles and bank revetments would be required to prevent unwanted channel deformation. Such features are assumed in the conceptual design of this alternative.

Alternative 3

Like Alternative 2, Alternative 3 would immediately convey all bedload and suspended sediment load through the existing lake area to downstream reaches of Boeing Creek. Unlike Alternative 2, there would be essentially no capacity for storage of sediment in floodplain areas within the existing lake footprint. Most or all of the estimated 2,500 cubic yards of sediment supplied to the lake per year would be transported downstream of NW Innis Arden Way. This additional sediment volume would likely trigger channel migration, particularly downstream of the Seattle Golf Club diversion dam, as described previously. Alternative 3 would result in the greatest sediment benefits in nearshore areas of Puget Sound within a few years of project construction, which would likely increase its salmon recovery grant funding potential because increased sediment supply to nearshore areas of Puget Sound is a goal of recovery planning for endangered Puget Sound Chinook salmon.

As with Alternative 2, the constructed channel gradient would be relatively steep in parts of the site, requiring significant engineering controls such as constructed boulder riffles and bank revetments to prevent unwanted channel deformation. Such features are assumed in the conceptual design of this alternative.

Large Woody Debris

Large woody debris is important in a healthy riverine and estuarine ecosystem. However, the production of large woody debris upstream of Hidden Lake in the Boeing Creek basin is extremely limited due to land development and stormwater control facilities. Within the Boeing Creek Park and Hidden Lake reaches of the creek, the supply of large woody debris is also limited, though less so, because of past disturbance and relative immaturity of the woody vegetation. Therefore, the supply of large woody debris is such that, even prior to the lake being re-established in the 1990s, the culverts under NW Innis Arden Way rarely clogged with large woody debris (King County 1995). More recent woody debris accumulation at the lake outlet manhole structure appears to be the result of beaver activity, as described in the following section.

Downstream of the Seattle Golf Club diversion dam, a significant amount of large woody debris is supplied to the creek (Figure 9). Most of the debris has been delivered in conjunction with past landslides, but ongoing landsliding indicates that the supply will be sufficient in the future for producing high quality instream habitat conditions in the downstream reach, despite the wood supply limitations from upstream.

Figure 9. Photograph of Large Woody Debris in Boeing Creek Downstream of the Seattle Golf Club Diversion Dam.

Beaver Activity

Beaver are present in the Hidden Lake area (Eric Gilmore, personal communication, November 29, 2015). Each of the three alternatives under consideration could result in modified beaver activity and associated effects on the geomorphic character of Boeing Creek within and downstream of the current Hidden Lake wetted area. Alternatives 1 and 2 could invite greater beaver activity in the current footprint of Hidden Lake because they would allow for ponding of water in floodplain areas and slower flow velocities. Alternative 3 would discourage beaver from using the current lake area because the steeper channel gradient would not be conducive to dam and lodge building by beaver. In general, where beaver dams persist, the increased woody debris in the stream provides beneficial habitat for fish and other aquatic species by diversifying the habitat types and hydraulic conditions (Malison et al. 2015).

Habitat Characteristics

Historical and Existing Wetlands

The earliest documentation of wetland conditions in the project area was obtained from the Hidden Lake Restoration Project report (King County 1995), which characterizes and classifies the wetlands as they existed at Hidden Lake in 1995, prior to the lake being completely dredged in 1997. Wetland classification was based on King County Code criteria from 1995. Three wetlands, called Wetlands A, B, and C, were identified along the edges of Boeing Creek within the present-day lake footprint (see figure in Appendix B). Wetland A was a Class III, riverine, palustrine, scrub-shrub wetland along the southwestern edge of Boeing Creek. Wetland B was a Class III, slope, palustrine, emergent and scrub-shrub wetland located along a steep bank on the southeast side of Boeing Creek. Wetland C was a Class II, riverine, palustrine, forested wetland located on both sides of Boeing Creek and throughout most of the floodplain.

To characterize present day conditions, Herrera consulted existing documentation and conducted a site reconnaissance. The National Wetlands Inventory (USFWS 2015), City of Shoreline wetland inventory (Shoreline 2015), and WDFW Priority Species and Habitat database (WDFW 2015b) indicate one wetland within the project area, which includes Hidden Lake and the vegetated areas around the open water. That wetland is classified as a depressional, palustrine, scrub-shrub, and seasonally flooded, diked/impounded wetland. The wetland is fed by water entering the depression from Boeing creek and controlled by both the dam and an outfall structure that controls the water storage within the lake. Herrera's site reconnaissance confirmed the mapped conditions, identified additional forested and emergent wetland communities surrounding the lake, and identified a potential riverine, palustrine, scrub-shrub wetland at the north end of Hidden Lake along Boeing Creek. Additionally, Herrera noted potential slope wetlands along the southeastern portion of the lake, likely created by groundwater expressing from the steep slopes along City-owned park property.

The Watershed Company rated Hidden Lake as a Category III wetland (Hruby 2004; AltaTerra 2014). It is expected to remain a Category III wetland under the revised Ecology rating system (Hruby 2014) and will be confirmed during the critical areas analysis. Hidden Lake and the adjacent palustrine forested, scrub-shrub, and emergent wetlands are estimated to cover approximately 2 acres (Tetra Tech 2004; AltaTerra 2014). In its current condition, Hidden Lake provides water quality functions as the dam is a constricted outlet and the lake receives stormwater runoff from the contributing basin. It provides hydrologic functions as it stores water during storm events; and it provides habitat functions with an interspersion of habitats for fish and wildlife.

Boeing Creek

The Boeing Creek Basin Plan (Windward 2013) documents historical fish presence in Boeing Creek, fish species observed recently upstream and downstream of Hidden Lake, and fish passage barriers from Hidden Lake to the creek mouth at Puget Sound. Among the species that historically used and currently use the creek, coho salmon and cutthroat trout are considered to be target species of interest in the context of enhancing or restoring habitat favorable to them in the alternatives discussed in this report. Chinook and chum salmon have also been found in the lower reach of the creek close to the mouth. Potential effects of the alternatives on those salmon species are important to consider. As discussed previously, the King County project that restored Hidden Lake to its current form in the mid-1990s used removal of fine sediments (trapped by the lake) and resultant benefits to salmon spawning in lower reaches of the creek as justification for the environmental benefits of the project.

Forage fish habitat has been lost extensively throughout Puget Sound because of shoreline armoring (Penttila 2007). Nearshore sediment starvation associated with shoreline armoring is particularly pronounced near the Boeing Creek mouth due to the near continuous riprap revetment associated with the BNSF rail line between Seattle and Everett. Forage fish are crucial to the food web that supports many marine species in Puget Sound (Penttila 2007). Herrera (2013) documented that potential intertidal forage fish (i.e., surf smelt and sand lance) spawning habitat is much greater than documented spawning in the nearshore reach that would be affected under any of the alternatives. Because documented forage fish spawning habitat is primarily near stream outlets, as they are the only areas that have the necessary sediment (WDFW 2015a), forage fish spawning habitat would likely be greatly expanded near the creek mouth if more sediment is allowed to move through the lake reach of Boeing Creek. The habitat expansion would be proportional to the amount of sediment passed through the lake reach, which varies amongst the alternatives, as described previously.

Effects of Alternatives on Habitats

Alternative 1

Hidden Lake provides open water habitat for fish, such as cutthroat trout, and waterfowl species. Under Alternative 1, the amount of open water habitat would decrease immediately as the lake level is lowered upon constructing the new dam spillway, and would decrease further over time as sediment fills the lake bed and Boeing Creek re-establishes a channel and vegetated wetlands in the floodplain, leading to formation of a higher functioning wetland and stream area. However, due to the urban nature of the Boeing Creek basin and the seed bank within the sediment settling in the lake bed, there is a high likelihood that nonnative and invasive species (i.e., weeds), such as reed canarygrass (*Phalaris arundinacea*) and Himalayan blackberry (*Rubus armeniacus*), would occupy the new floodplain areas and invade wetlands. While wetlands dominated by reed canarygrass perform water quality and hydrologic functions, the habitat value provided is low compared to an interspersion of native vegetation communities. Therefore, post-construction vegetation monitoring and management would yield a better ecological outcome under Alternative 1, including weed control measures and supplemental planting of native species. (Note that the cost estimate for this alternative (see Appendix C) does not account for these measures.) Overall, the habitat created under Alternative 1 would function higher than existing conditions.

Alternative 2

Alternative 2 is a controlled version of Alternative 1 in which the open water habitat in Hidden Lake would be manually converted to a complex wetland and stream area. Groundwater discharge into the new channel would occur a few feet above the constructed channel bed in much of the site, which would provide a downstream habitat benefit of increased base flow due to shallow groundwater and surface water mixing, or hyporheic exchange, in the project area. Wetlands would be planted with native vegetation throughout the floodplain on both private and City-owned park property, and would be maintained to control the presence of invasive species. The combined wetland and stream habitat provided in Alternative 2 would be expected to function higher than that provided under Alternative 1 or 3.

Alternative 3

Alternative 3 would provide a high functioning stream habitat through the reach on City park property, but, because of the steep and deeper nature of the constructed channel, little to no wetland habitat could be re-established adjacent to the channel. The floodplain west of the constructed channel could be allowed to establish vegetation naturally, as in Alternative 1, with potential for nonnative, invasive species establishing throughout that area. Also as in Alternative 1, post-construction vegetation monitoring and management would yield a better ecological outcome, including weed control measures and supplemental planting of native species. (Note that the cost estimate for Alternative 3 [see Appendix C] does not account for these measures.) Similar to Alternative 2, groundwater discharge into the new channel would occur a few feet above the constructed channel bed through much of the site, which would provide a downstream habitat benefit of increased base flow due to groundwater and hyporheic exchange in the project area. The hyporheic exchange under Alternative 3 would provide less benefit than that under Alternative 2 because there would be an overall lesser area of stream channel in which that process occurs.

Cultural Resources

The cultural resources assessment (CRC 2015) found that "… given the steep topography of the area, dynamic erosional and depositional environment, historical logging, modern land development, and Hidden Lake and Boeing Creek environmental restoration activities the potential for encountering significant, intact archaeology is extremely low." Therefore, for the current phase of project planning, cultural resources do not have any bearing on the alternatives analysis.

Public Input

Input received from lakeside residents and the general public to date was used to shape the distinct features of the three alternatives presented in this report. Specific feedback obtained from the public is summarized below.

Private Property Owners

Lakeside residents voiced several concerns and opinions about the project and on the three alternatives, including:

- Concern about privacy and potential for trespassing, with elimination of the lake allowing park users or others to walk across the restored creek onto their land
- Concern for the loss of the lake and the unique habitats and aesthetic value it provides

- Concern about potentially reduced property values
- Potential for inadvertent impacts on mature trees west of the lake shoreline
- Potentially high cost of the project to the City and its taxpayers
- Potential for marshy conditions to develop in the existing lake bed that would attract mosquitoes and make it difficult to walk on the eastern edge of their property, which indicates less support for Alternative 2 as described herein
- Desire for ecological benefits to be achieved if the lake is converted to a different landform, which indicates less desire for Alternative 1 as described herein

General Public

Input received during the course of this alternatives analysis from the general public focused on the following topics:

- Effects of the project on the character of Boeing Creek downstream of Hidden Lake, and whether implementing the project means the City would pursue removing the Seattle Golf Club diversion dam
- A desire for improved trail(s) along the southeast side of the restored Boeing Creek channel in the existing lake bed
- Concern for the loss of a place that is popular for taking dogs to swim
- The unique ecological value that is contained within Shoreview/Boeing Creek Park and how the project could enhance that value; in relation to this, interest in placing informational signage about the ecological effects of the project

Permitting Considerations

Wetland and stream regulations imposed by state and federal agencies and the City of Shoreline will apply to any future activities planned for the project. Filling and other alteration of wetlands and streams is regulated under the federal Clean Water Act, the state Hydraulic Code, the State Environmental Policy Act (SEPA), and the City of Shoreline Critical Areas Code. The City of Shoreline Code also establishes required buffer widths for wetlands and streams. Federal, state, and City regulations require mitigation for impacts on wetlands and streams, and the City also regulates impacts on the buffers of wetlands and streams.

Clean Water Act Sections 404 and 401

Section 404 of the federal Clean Water Act regulates the placement or removal of soil or other fill, grading, or alteration (hydrologic or vegetative) in waters of the United States, including wetlands (33 USC 1344). The US Army Corps of Engineers (USACE) administers the permitting program under the act. The permits include nationwide (general) permits for specific types of projects (e.g., maintenance) involving small areas of fill, grading, or alteration. Individual permits are required for projects not covered under nationwide permits, including those with large areas of disturbance and/or quantity of fill. The USACE does not regulate wetland buffers.

Section 401 of the Clean Water Act requires that proposed dredge (removal) and fill activities permitted under Section 404 be reviewed and certified to ensure that such activities meet state water quality standards (i.e., Section 401 Water Quality Certification). In Washington State, this certification is administered by Ecology and applies to all Section 404 permits. The Section 401 Water Quality Certification is achieved for projects through the Section 404 nationwide permitting process subject to conditions of the nationwide permit. An Individual Section 401 Water Quality Certification and associated review is required if nationwide permit conditions are not met (e.g., greater than a half-acre of wetland disturbance) and typically in instances where an Individual Section 404 permit is required.

State Hydraulic Code

The Washington Department of Fish and Wildlife (WDFW) administers the Hydraulic Project Approval (HPA) program under the state Hydraulic Code, which was specifically designed to protect fish life. An HPA permit is required for projects that will use, divert, obstruct, or change the natural flow or bed of any of the salt or fresh waters of the state.

State Environmental Policy Act

The SEPA review process provides a way to identify possible environmental impacts that may result from government decisions. Information provided during the process helps agency decision makers, applicants, and the public understand how a proposal will affect the environment including, but not limited to, aquatic resources (e.g., lakes, wetlands), shorelines, earth, plants, and animals. Under SEPA, the City of Shoreline is the lead agency for the proposed project and is responsible for identifying and evaluating potential adverse environmental impacts.

City of Shoreline Critical Areas Code

The City of Shoreline passed a new Critical Areas Ordinance on December 7, 2015, which includes revisions to critical areas regulations contained in the City's Development Code (Chapter 20.80). Information pertaining to critical areas that is presented in this report is based on the revised code, which will become effective on February 1, 2016.

Wetlands

The City of Shoreline Code (20.80.320) requires that wetlands be classified according to the Ecology rating system (Hruby 2014). Buffers are required around each wetland in order to protect the wetland's functions and values. For each classification of wetland (Categories I through IV), the code specifies a base buffer width. This width is then adjusted according to habitat function level.

Hidden Lake is estimated to be a Category III wetland with a habitat score of 6 to 7 points, thus, the buffer would be 165 feet (City of Shoreline Code Table 20.80.330(A)(1)). The buffer width will be confirmed after the wetland is delineated and rated. In addition, a 15-foot building or impervious surface setback line is required from the edge of the wetland buffers.

Streams

Streams are classified under the Fish and Wildlife Habitat Conservation Area section of the City of Shoreline Code (20.80.270(E)). Boeing Creek within the project area is likely to be classified as a Type F stream because it provides accessible fish habitat and/or because the project would allow fish access. Streams of this rating are required to have a 75-foot-wide buffer if only non-anadromous fish are present and a 115-foot-wide buffer if anadromous fish are present. The buffer is measured from the ordinary high water mark on each side of the stream (City of Shoreline Code Table 20.80.280(1)). In addition, a 15-foot building or impervious surface setback line is required from the edge of the stream buffers.

Permitting Complexity of Alternatives

Project activities undertaken for any of the three alternatives include clearing and grading and working within critical areas or critical area buffers, which will require several potential permits from federal and state regulatory agencies and the City of Shoreline. Each alternative would require, at a minimum, a Clean Water Act Section 404 permit from USACE, an HPA from WDFW, a SEPA threshold determination from the City of Shoreline, a critical areas special use permit from the City of Shoreline, and onsite restoration of temporary impacts.

Several factors make permitting less complex for all three alternatives, including the lack of presence of species listed under the federal Endangered Species Act and an anticipated determination of non-significance (DNS) or mitigated DNS on environmental elements analyzed under SEPA. The complexity of permitting for each alternative differs in the way each project would comply with Clean Water Act Section 404, City of Shoreline code, and the mitigation that may be required for impacts on wetlands and buffers.

Alternative 1

Alternative 1 would likely be covered under USACE Nationwide Permit 27 for aquatic habitat restoration, establishment, and enhancement activities. Removal or abandonment of the outlet structure combined with cessation of lake dredging would promote re-establishment of stream and wetland habitat and naturally occurring riverine wetland processes that result in a net increase in aquatic resource functions and services.

The invert elevation of the artificial outlet located at the downstream end of Hidden Lake currently regulates the hydrologic connectivity of the vegetated wetlands along the perimeter of the lake. The concrete spillway that would be constructed as part of Alternative 1 would replace the function of the outlet structure, which would be abandoned in place. A lower invert elevation associated with the concrete spillway would lower the water table of the lake, which could drain portions of existing wetlands at the perimeter of the lake, thereby converting them to uplands. However, according to longstanding practice and the currently proposed rule defining Waters of the US under the Clean Water Act, those wetlands may not be regulated (i.e., jurisdictional) because they are supported by water that is impounded by artificial means (Federal Register 2014-07142). Furthermore, according to City of Shoreline Code 20.80.310, wetlands do not include those artificial wetlands intentionally created from non-wetland sites. Existing wetlands along the southeast edge of the lake with hydrology supported by seeps are not expected to be affected by Alternative 1.

However, regardless of wetland jurisdiction, as sediment fills in the lake and vegetation colonizes, Alternative 1 is anticipated to result in re-establishment of wetlands, contributing to an overall increase in wetland area that is equivalent to or greater than the area of wetlands delineated prior to restoration of the lake in the mid-1990s. As a result, in accordance with federal and state regulations, and City of Shoreline code, Alternative 1 would result in no net loss of wetland functions and area; therefore, additional compensatory mitigation would not likely be required.

Alternative 2

Similar to Alternative 1, Alternative 2 would also likely be covered under USACE Nationwide Permit 27 for aquatic habitat restoration, establishment, and enhancement activities. In addition to removal or abandonment of the lake outlet structure, project activities include re-establishment of stream and wetland conditions that would result in net increases in aquatic resource functions and services.

Alternative 2 would involve creating low gradient channels with low-lying banks through the existing lake footprint with a high groundwater table that supports re-establishment of saturated wetland conditions during low flows and occasional overbank flooding of wetlands during high flows. Similar to Alternative 1, Alternative 2 is anticipated to result in re-establishment of wetlands that contributes to an overall increase in wetland area that is equivalent to or greater than the area of wetlands delineated prior to restoration of the lake in the mid-1990s. As a result, in accordance with federal and state regulations, and City of Shoreline code, Alternative 2 would result in no net loss of wetland functions and area; therefore, additional compensatory mitigation would not likely be required.

Alternative 3

Compared to Alternatives 1 and 2, Alternative 3 could be more difficult to obtain coverage under USACE Nationwide Permit 27, in which case an Individual 404 Permit may be necessary. USACE Nationwide Permit 27 requires projects to provide an overall lift in wetland and stream functions. Alternative 3 would likely result in an overall decrease in wetland area and functions, while Alternatives 1 and 2 would provide the same or more ecological functions than under existing conditions.

Alternative 3 would increase aquatic resource functions associated with restoring fish passage upstream of NW Innis Arden Way and restoring Boeing Creek throughout the footprint of the existing lake. However, due to the depth of the re-established channel, a lower groundwater table is less likely to support re-establishment of adjacent wetlands, which require saturated soil conditions. In addition, removing or abandoning the existing lake outlet structures and deepening the channel profile beneath NW Innis Arden Way could have a larger effect of draining existing wetlands than Alternatives 1 and 2. (Existing wetlands along the southeast edge of the lake with hydrology supported by seeps would not likely be affected.) Therefore, Alternative 3 would likely result in an overall decrease in wetland area and functions when compared to existing conditions and conditions prior to restoration of the lake in the mid-1990s. As a result, in accordance with federal and state regulations, and City of Shoreline code, Alternative 3 could require compensatory mitigation for wetland impacts. The design of

Alternative 3 does not include constructing wetlands on site; therefore, offsite mitigation may be required for project impacts on wetlands and buffers.

To support coverage under USACE Nationwide Permit 27 and eliminate the need to provide compensatory mitigation, the grading plan for Alternative 3 could be revised to include additional excavation of low-lying bench habitat along the west side of the channel that supports wetland re-establishment and, therefore, result in no net loss of wetland area and functions when compared to existing conditions. Doing so would extend the construction area into private properties on the west side of the site.

Cost

Estimated costs for each alternative are tabulated in Appendix C. The estimates are planning-level estimates suitable for comparing the alternatives to each other and for planning approximate project design, permitting, and construction costs. Regardless of the alternative selected by the City, cost estimates would be refined as more is learned about the specific configuration of the proposed project and regulatory agencies provide input on wetland mitigation requirements.

Maintenance Implications

Alternative 1

Alternative 1 would require a minor amount of maintenance attention from the City. Maintenance activities would be focused on keeping the Hidden Lake dam spillway clear of debris, plus occasional inspections of the culverts beneath NW Innis Arden Way. The level of maintenance activity under Alternative 1 would be comparable to current maintenance at the site, excluding sediment dredging. To support permitting of this alternative, it may also be necessary to monitor and maintain areas where vegetation re-establishes within the prior lake footprint to prevent the spread of weeds.

Alternatives 2 and 3

Alternatives 2 and 3 would require greater maintenance attention from the City than Alternative 1. Additional maintenance associated with these two alternatives would be related to expected permit requirements to ensure planted vegetation survival, to control invasive weed growth in the existing lake footprint, and to ensure that the constructed stream channel is functioning as intended. The inspection and maintenance needs for these three purposes would generally be focused within the first 5 to 10 years following construction. Thereafter, maintenance needs would likely be minimal.

COMPARISON OF ALTERNATIVES

Several evaluation criteria were used to compare the alternatives. They are listed in Table 1. The results of this comparison are informative for considering how a preferred alternative could involve a combination of features and be a hybrid of the distinct alternatives presented in this report.

Table 1. Comparison of Alternatives.

Criteria	Alternative 1	Alternative 2	Alternative 3
Cost	$680,000	$2,350,000[a]	$5,200,000[b]
Required Participation of Several Adjacent Private Property Owners	No	Yes	No
Park Uses and Values	Low	High	High
Wetland Mitigation Likely Required	No	No	Yes
Fish Passage Benefits	No	No[c]	Yes
Other Habitat Benefits (e.g., waterfowl, forest, wetlands, amphibians, beaver)	Low	High	Medium
Downstream Suspended Sediment Loading	Low	Medium	High
Downstream Gravel Supply	Low (eventual)	High (immediate)	High (immediate)
Short-term Maintenance Needs	Low to Medium	Medium	Medium
Grant Funding Attractiveness	Low	Medium[d]	High
Permitting Complexity	Medium	Medium	High

[a] If the culverts beneath NW Innis Arden Way were replaced as part of this alternative to allow fish passage, the total cost would increase to approximately $5,550,000.

[b] The new box culvert or bridge beneath NW Innis Arden Way would require temporary closure of roadway traffic to excavate into the deep earth fill prism underlying the existing roadway. The deep excavation and associated traffic control requirements are significant cost components of Alternative 3.

[c] Fish passage could be achieved with Alternative 2 if the culverts beneath NW Innis Arden Way were replaced as under Alternative 3.

[d] Grant funding attractiveness would be rated high for Alternative 2 if fish passage improvements were included in it.

REFERENCES

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

Barnard, R.J., J. Johnson, P. Brooks, K.M. Bates, B. Heiner, J.P. Klavas, D.C. Ponder, P.D. Smith, and P.D. Powers. 2013. Water Crossings Design Guidelines, Washington Department of Fish and Wildlife, Olympia, Washington. <http://wdfw.wa.gov/hab/ahg/culverts.htm>.

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. Technical Report WRP-DE-4. US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. August 1993.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. Publication FWS/OBS-79/31. US Department of the Interior, Fish and Wildlife Service, Office of Biological Services.

CRC. 2015. Cultural Resources Assessment for the Hidden Lake Dam Removal Project. Prepared for Herrera Environmental Consultants, Inc. by Cultural Resource Consultants, Inc., Bainbridge Island, Washington.

Environmental Laboratory. 1987. Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi. January 1987.

Environmental Laboratory. 2010. Regional Supplement to the Corps of Engineers Wetlands Delineation Manual: Western Mountains, Valleys, and Coast Region. Technical Report TR-08-13. US Army Corps of Engineers, Engineer Research and Development Center, Wetlands Regulatory Assistance Program, Vicksburg, Mississippi.

GLO. 1859. Township No. 26 North, Range No. 3 East Willamette Meridian. General Land Office.

Herrera. 2013. Data Compilation Report for the WRIA 8 Beach Nourishment Project: Task 1 Memorandum. Prepared for King County Water and Land Resources Division and Snohomish County Surface Water Management Division by Herrera Environmental Consultants, Inc., Seattle Washington. March 5, 2013.

Herrera. 2016. Hidden Lake Dam Removal Project Hydrologic, Hydraulic, and Sediment Transport Analyses. Prepared for City of Shoreline by Herrera Environmental Consultants, Inc., Seattle, Washington.

Hruby, T. 2004. Washington State Wetland Rating System for Western Washington—Revised. Washington State Department of Ecology Publication 04-06-025. August 2004.

Hruby, T. 2014. Washington State Wetland Rating System for Western Washington: 2014 Update. Washington State Department of Ecology, Olympia, Washington. Publication #14-06-029. October 2014.

King County. 1995. Hidden Lake Restoration Project. King County Surface Water Management Division. July 11, 1995.

King County, 2015a. King County Hydrologic Information Center Gage Metadata 04j – Boeing Creek off Beach DR Stream Gauge. <http://green2.kingcounty.gov/hydrology/GaugeMetaData.aspx?G_ID=3>.

King County, 2015b. King County Hydrologic Information Center Gage Metadata 04a – Boeing Creek below NW 175th St. Stream Gauge. <http://green2.kingcounty.gov/hydrology/GaugeMetaData.aspx?G_ID=73>.

King County, 2015c. King County Hydrologic Information Center Gage Metadata 04e – Boeing Creek below Boeing Dam Stream Gauge. <http://green2.kingcounty.gov/hydrology/GaugeMetaData.aspx?G_ID=77>.

Malison, R.L., L.A. Eby, and J.A. Stanford. 2015. Juvenile salmonid growth, survival, and production in a large river floodplain modified by beavers (*Castor canadensis*). Canadian Journal of Fisheries and Aquatic Sciences 72(11):1639–1651.

Penttila, D. 2007. Marine Forage Fishes in Puget Sound. Puget Sound Nearshore Partnership Report No. 2007-03. Published by Seattle District, US Army Corps of Engineers, Seattle, Washington.

Shannon & Wilson. 1995. Geotechnical Engineering Report: Hidden Lake Restoration Project, King County, Washington. Prepared for R.W. Beck by Shannon & Wilson, Inc., Seattle, Washington.

Shoreline, City of. 2015. Wetland Inventory Map. City of Shoreline Online GIS. Accessed August 12, 2015. <http://www.cityofshoreline.com/government/departments/public-works/gis>.

Syvitski, J.P.M., A.J. Kettner, S.D. Peckham, and S.J. Kao. 2005. Predicting the Flux of Sediment to the Coastal Zone: Application to the Lanyang Watershed, Northern Taiwan. Journal of Coastal Research 21(3):580–587.

Syvitski, J.P.M., S.D. Peckham, R. Hilberman, and T. Mulder. 2003. Predicting the Terrestrial Flux of Sediment to the Global Ocean: A Planetary Perspective. Sedimentary Geology 162(1-2):5–24.

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

USFWS. 2015. National Wetlands Inventory wetlands maps. Accessed December 1, 2015. <http://www.fws.gov/wetlands/index.html>.

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

WDFW. 2015a. SalmonScape mapping system. Washington Department of Fish and Wildlife. Accessed December 2, 2015. <http://wdfw.wa.gov/mapping/salmonscape/index.html>.

WDFW. 2015b. Priority Species and Habitat Database. Provided by Washington Department of Fish and Wildlife. November 30, 2015.

APPENDIX A

Geotechnical Exploration Information

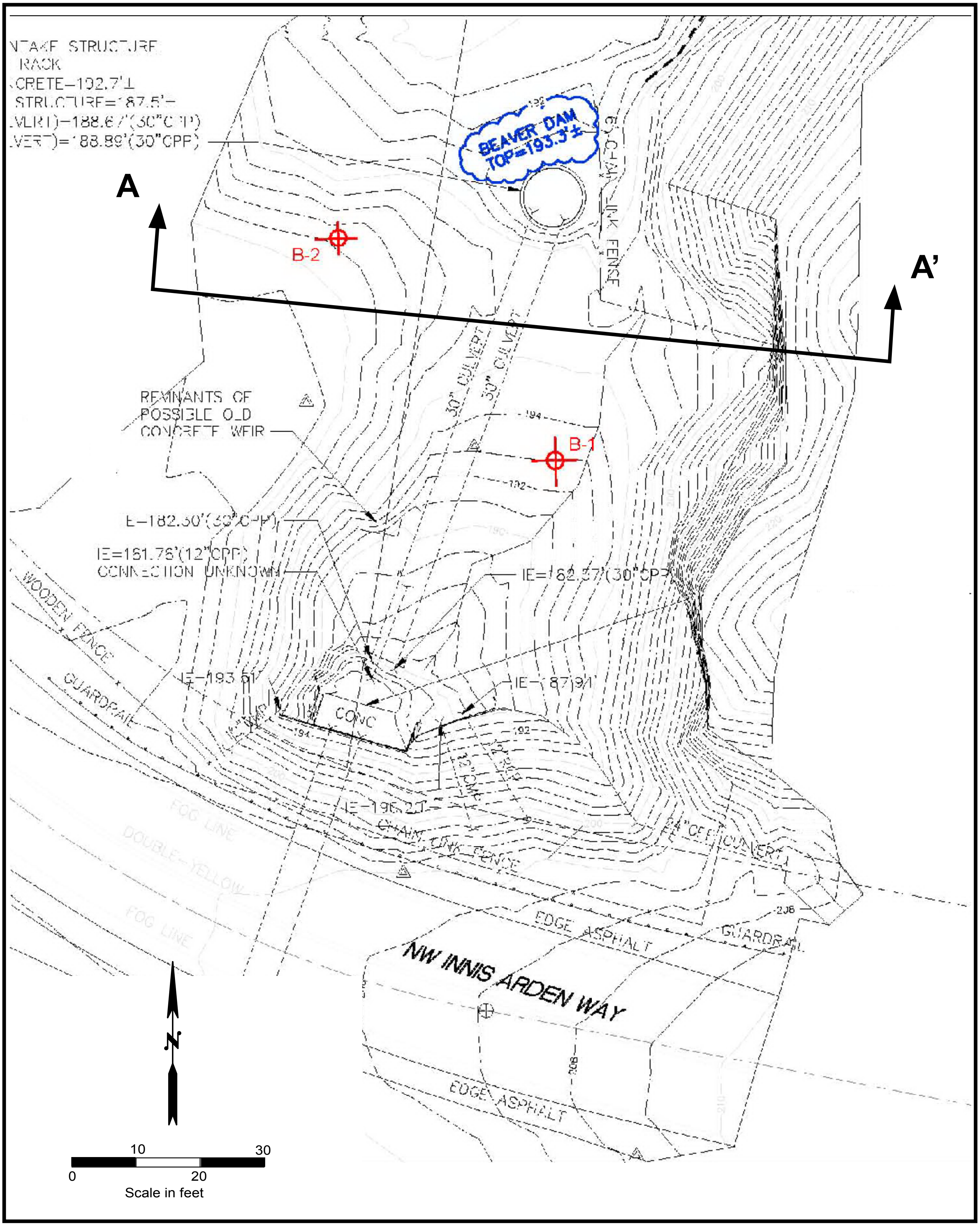


FIGURE 1
Site Plan

October 2015

PERRONE CONSULTING, INC., P.S.
Project No. 15126

Hidden Lake Dam Removal
for Herrera Environmental Consultants

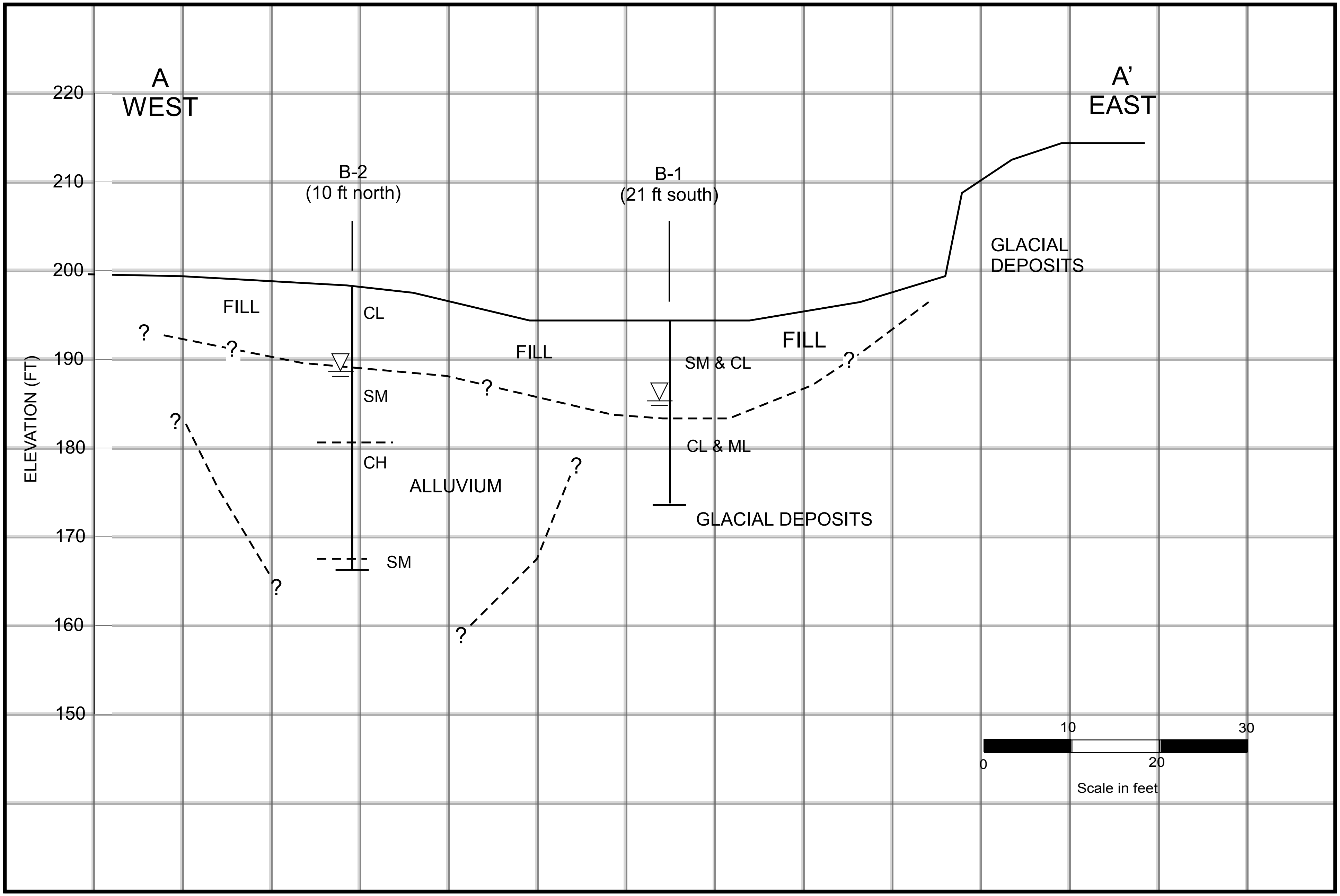


FIGURE 2
Subsurface Profile Section A-A'

October 2015

PERRONE CONSULTING, INC., P.S.
Project No. 15126

Hidden Lake Dam Removal
for Herrera Environmental Consultants

PERRONE CONSULTING, INC.
11220 Fieldstone Lane NE
Bainbridge Island, WA 98110
Telephone: (206) 778-8074

Key to Log of Boring

Project: Hidden Lake Dam Removal
Shoreline, Washington

UNIFIED SOIL CLASSIFICATION SYSTEM AND SYMBOL CHART

MAJOR DIVISIONS			SYMBOLS	DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS LITTLE OR NO FINES	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO.4 SIEVE		GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES APPRECIABLE AMOUNT OF FINES	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
MORE THAN 50% OF MATERIAL COARSER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SANDS LITTLE OR NO FINES	SW	Well-graded sands, gravelly sands, little or no fines
	MORE THAN 50% OF COARSE FRACTION PASSING NO.4 SIEVE		SP	Poorly graded sands, gravelly sands, little or no fines
		SANDS WITH FINES APPRECIABLE AMOUNT OF FINES	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50	ML	Inorganic silts, very fine sands, rock flour, silty/clayey fine sands or clayey silts of slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
MORE THAN 50% OF MATERIAL FINER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silt
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT	Peat, humus, swamp soils with high organic content

NOTE: DUAL SYMBOLS USED FOR BORDERLINE CLASSIFICATIONS

Blow Count / Density and Consistency Relationship

Coarse-Grained Soils		Fine-Grained Soils	
Relative Density	N, SPT Blows / Foot	Relative Consistency	N, SPT Blows / Foot
Very loose	0 - 4	Very soft	<2
Loose	5 - 10	Soft	2 - 4
Medium dense	11 - 30	Medium stiff	5 - 8
Dense	31 - 50	Stiff	9 - 15
Very dense	>50	Very Stiff	16 - 30
		Hard	>30

Minor Descriptors

Trace clay, silt, sand, gravel	<5%
Few clay, silt, sand, gravel	5 - 10%
Little clay, silt, sand, gravel	15 - 25%
Some clay, silt, sand, gravel	30 - 45%

Moisture Content

Dry	Absence of moisture, dusty
Moist	Damp but no visible water
Wet	Visible free water, from below the water table

Abbreviations

AL	Atterberg Limits
C	Consolidation
DS	Direct Shear
HA	Hydrometer Analysis
LL	Liquid Limit
LV	Laboratory Vane Shear
N	Number of hammer blows for last 12 inches driven
OVA	Organic Vapor Analyzer
Pc	Constant Head Permeability
Pf	Falling Head Permeability
PI	Plasticity Index
PP	Pocket Penetrometer
SA	Sieve Analysis
SG	Specific Gravity
TV	Torvane Shear
TX	Triaxial Shear

Sampler Symbols

- 2-inch-O.D. Split Spoon Sampler Driven with 140-lb Hammer and 30-inch Drop (SPT)
- 3-inch-O.D. Split Spoon Sampler with Brass Rings Driven with 140-lb Hammer and 30-inch Drop
- 2-inch-O.D. Split Spoon Sampler Driven with 140-lb Hammer and 18-inch Drop
- Grab Sample
- 3-inch-O.D. Shelby Tube Sampler

Piezometer Symbols

- Pipe in cement grout
- Pipe in filter pack
- Pipe in bentonite-cement
- Slotted pipe in filter pack
- Pipe in bentonite seal
- Vibrating wire piezometer

Groundwater Level Symbols

- Water level at time of drilling (ATD)
- Water level measured in piezometer

General Notes

1. Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.
2. Soil descriptions are recorded in the following order: SOIL CLASSIFICATION (USCS Symbol), relative density or consistency, color, moisture, plasticity or gradation, angularity, minor constituents, additional comments (organics, odor, etc.) [GEOLOGIC UNIT].

Figure A-1

PERRONE CONSULTING, INC.
11220 Fieldstone Lane NE
Bainbridge Island, WA 98110
Telephone: (206) 778-8074

Log of Boring B-1

Project: Hidden Lake Dam Removal Shoreline, Washington

Borehole Location: **41 feet due south of dam outlet structure**
Drilling Contractor: **Geologic Drill Exploration, Inc.**
Drilling Method: **Hollow-Stem Auger**
Drill Rig Type: **Diedrich D-50 with 7-inch-OD auger**

Date(s) Drilled: **September 1, 2015**
Logged By: **V. J. Perrone**
Total Depth of Borehole: **19.0 feet**
Surface Elevation / Datum: **193 ft / NAVD88**

Elevation, feet	Depth, feet	SAMPLES: Number	SAMPLES: Blows per 6 inches (N)	SAMPLES: Recovery, %	MATERIAL DESCRIPTION	Lab Tests	Moisture Content, %	Dry Unit Weight, pcf	REMARKS
193	0				Organic forest duff				
					COBBLES to 6 inches, angular [FILL]				
					POORLY GRADED SAND WITH SILT (SP-SM), brownish gray, moist, fine to medium sand, few fines [FILL]				
190					LEAN CLAY (CL), very stiff, gray, moist [FILL]				
		1	8-12-14 (26)	44	SILTY SAND WITH GRAVEL (SM), medium dense, gray, moist, fine to coarse sand, some angular gravel, little fines [FILL]				
	5	2	6-8-8 (16)	33					
					SANDY LEAN CLAY WITH GRAVEL (CL), very stiff, gray, moist, little fine to coarse sand, little angular gravel [FILL]				
185		3	9-8-10 (18)	17					Redrive 7.5-10 ft with D&M sampler; piece of wire in sample. Drive another D&M 10-11 ft for more sample; recover 12 inches of pea gravel (slough?).
		3A		33	Becomes brown, wet, increased gravel (groundwater ▼)				
	10	4	6-12-14 (26)	67	LEAN CLAY (CL), hard, gray, moist [GLACIAL DEPOSIT]				PP>4.5 tsf
180		5	10-13-17 (30)	67	SILT (ML), very stiff to hard, gray, moist, nonplastic, massive [GLACIAL DEPOSIT]				
	15								
175		6	10-14-18 (32)	100	LEAN CLAY (CL), hard, gray, moist [GLACIAL DEPOSIT]				PP>4.5 tsf
	20				**Bottom of boring at depth of 19.0 feet** **Groundwater level at 9.1 feet in open hole after drilling.** **Borehole backfilled with bentonite chips.**				
170									
	25								
165									
	30								

PERRONE CONSULTING, INC.
11220 Fieldstone Lane NE
Bainbridge Island, WA 98110
Telephone: (206) 778-8074

Log of Boring B-2

Project: Hidden Lake Dam Removal
Shoreline, Washington

Borehole Location: **7 feet south, 33 feet west of dam outlet structure**	Date(s) Drilled: **September 1, 2015**
Drilling Contractor: **Geologic Drill Exploration, Inc.**	Logged By: **V. J. Perrone**
Drilling Method: **Hollow-Stem Auger**	Total Depth of Borehole: **31.5 feet**
Drill Rig Type: **Diedrich D-50 with 7-inch-OD auger**	Surface Elevation / Datum: **198 ft / NAVD88**

Elevation, feet	Depth, feet	SAMPLES: Type Number	SAMPLES: Blows per 6 inches (N)	SAMPLES: Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Lab Tests	Moisture Content, %	Dry Unit Weight, pcf	REMARKS
	0					Organic forest duff				
						SILTY SAND WITH GRAVEL (SM) [FILL]				Near-surface soil logged from cuttings.
						SANDY LEAN CLAY (CL), medium stiff, brownish gray, moist, low to medium plasticity, little fine to coarse sand, few gravel [FILL]				
195		1	4-3-3 (6)	100						
	5	2	4-5-5 (10)	100		Becomes stiff, with trace organic pieces				
190		3	4-5-6 (11)	100						
	10					SILTY SAND (SM), very loose, gray, wet, fine sand, some fines [ALLUVIUM]				
		4	2-1-1 (2)	100						
185		5	3-2-3 (5)	56		Becomes loose, fine to medium sand, little fines				
	15	6	5-4-4 (8)	78		Tree root in tip of sampler				
						FAT CLAY WITH SAND (CH), very stiff, gray, moist, little sand and gravel [ALLUVIUM]				
180		7	1-2-4 (6)	67						PP=2.5 tsf
	20	8	1-2-2 (4)	100		Becomes medium stiff to stiff, no gravel				PP=0.75 tsf PP=1.5 tsf
175										
	25	9	2-4-1 (5)	89		Becomes soft				PP=0.25 tsf
						Wood in sampler shoe				
170										
	30					Becomes stiff				

Project: Hidden Lake Dam Removal
Shoreline, Washington

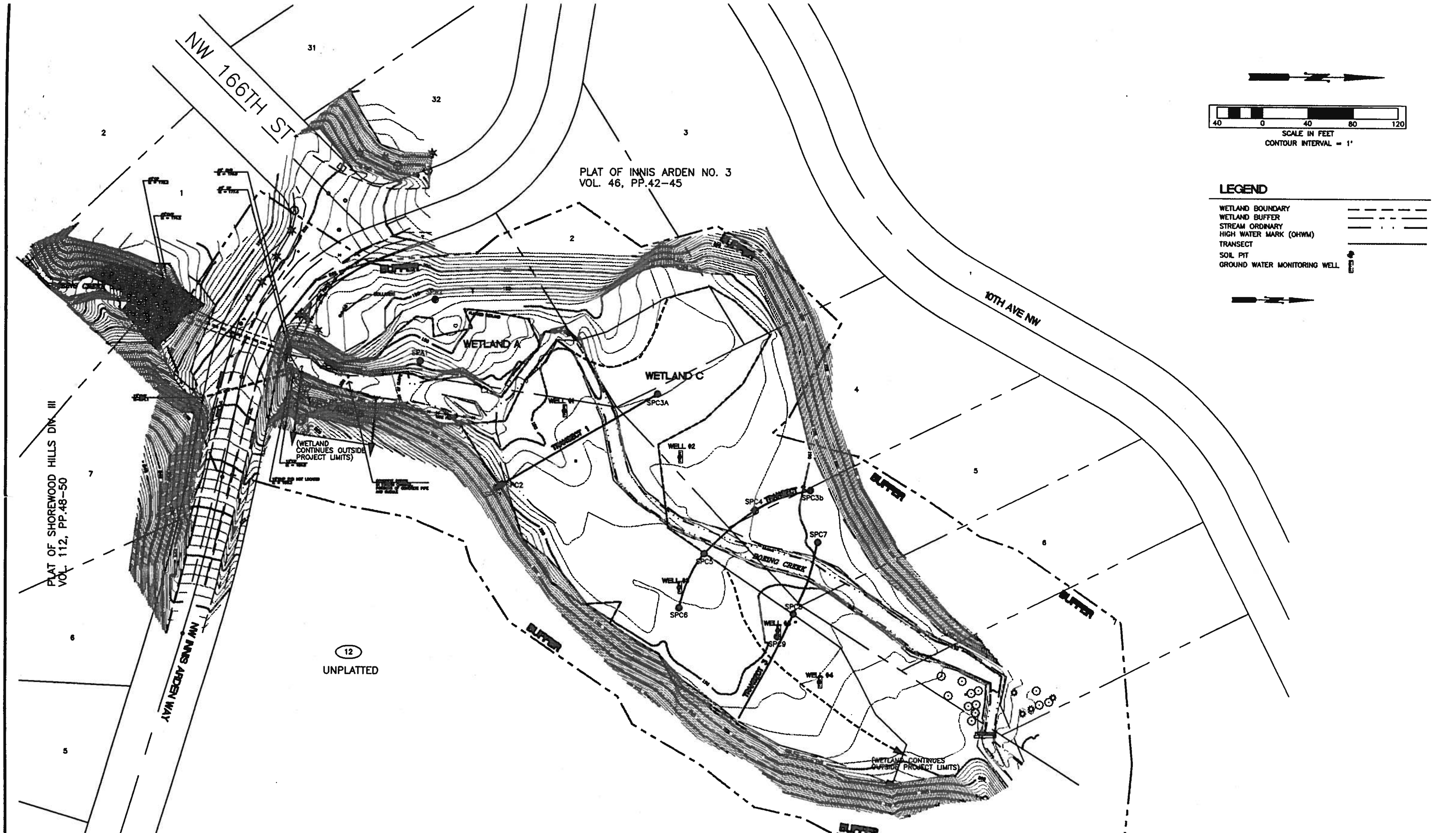
Log of Boring B-2

Elevation, feet	Depth, feet	Type	Number	Blows per 6 inches (N)	Recovery, %	Graphic Log	MATERIAL DESCRIPTION	Lab Tests	Moisture Content, %	Dry Unit Weight, pcf	REMARKS
	30		10	4-7-12 (19)	100		FAT CLAY WITH SAND (CH) [ALLUVIUM] (continued)				PP=1.5 tsf
							SILTY SAND (SM), medium dense, gray, moist, fine sand [ALLUVIUM]				
							Bottom of boring at depth of 31.5 feet				
							Groundwater not encountered at time of drilling.				
							Borehole backfilled with bentonite chips.				
165											
	35										
160											
	40										
155											
	45										
150											
	50										
145											
	55										
140											
	60										
135											
	65										

PERRONE CONSULTING, INC.

APPENDIX B

Wetlands Delineated by King County for Hidden Lake Restoration Project



KING COUNTY DEPARTMENT OF PUBLIC WORKS
Paul Tanaka, Director
SURFACE WATER MANAGEMENT DIVISION

FIGURE 5

PROJECT PLAN AND SENSITIVE AREAS

HIDDEN LAKE

KING COUNTY, WASHINGTON

APPENDIX C

Planning-Level Cost Estimates

Engineering Cost Estimate for Conceptual Design - Alternative 1

Project: Hidden Lake Dam Removal
Herrera Project #: 15-05984-000
Client: City of Shoreline

Date Modified: 12/9/2015
Spreadsheet by: M. Beggs
Checked by: I. Mostrenko, M. Ewbank
Latest Date Checked: 1/6/2016

Alternative 1

Bid Item #	Spec Section	Item Description	Quantity	Unit	Unit Cost	Price	Total Price	Comments
		Mobilization	**1**	**LS**	**$ 20,300.00**		**$ 20,300.00**	8% of construction subtotal (Div 2 - Div 8 work items)
		Temporary Erosion and Sediment Control	**1**	**LS**	**$ 21,700.00**		**$ 21,700.00**	Assumes 10% of all other items except water management
		Water Management	**1**	**LS**	**$ 14,600.00**		**$ 14,600.00**	Assumes only pumping prior to construction,$3000/month pump and hose rental, $10/hour operation (2.8 gals/hour), assumes 6-inch pump continuously operating for 15 days, +20% for logistics and maintenance (From Port Susan). Assuming creek at low flow (0.2 cfs)
		Traffic Control	**1**	**LS**	**$ 8,000.00**		**$ 8,000.00**	comparable to McAleer Creek/Goheen project bids
		Stabilized Construction Entrance	**1**	**EA**	**$ 2,500.00**		**$ 2,500.00**	
		Demolition of Current Spillway	**1**	**LS**	**$ 8,700.00**		**$ 8,700.00**	
		Excavation and Disposal of Material	150	CY	$ 50.00	$ 7,500.00		See Volumes Spreadsheet (rough est from KC 96 plans)
		Topsoil Removal and Stockpile	100	CY	$ 12.00	$ 1,200.00		
		Remove/Abandon Existing Lake Outlet	**1**	**LS**	**$ 3,500.00**		**$ 3,500.00**	Remov manhole ~$1.5k, fill pipes with CDF ~$2k
		Site Clearing - Clearing and Grubbing and Stripping and Stockpiling of Topsoil	**0.4**	**AC**	**$ 14,300.00**		**$ 5,800.00**	Price from UBA. Rough est from CAD
		Common Excavation Including Haul	**425**	**CY**	**$ 35.00**		**$ 14,900.00**	Quantity from CAD. Includes control of water, removal, loading, hauling, and disposal, Assumes $6 exc+$27 haul and disposal+$2 per cy for water management.
		New Spillway	**1**	**LS**	**$ 26,600.00**		**$ 26,600.00**	
		Concrete	74	CY	$ 125.00	$ 9,259.26		400 psi concrete with no add mixtures, slab is 1' thick on a slope that is 10:1 or less; Quote from Ron Anderson- Salmon Bay Sand and Gravel
		Rebar	2.7	TON	$ 1,040.00	$ 2,778.88		assume 2 mats of #4 rebar 12" on center, both directions; calculation as follows: (# of 20' rebar sticks for 2 mats)*(20ft/stick)*(0.668lb/ft #4 rebar)/(200lb/ton); cost from Far West steel
		Labor	4	DAY	$ 2,500.00	$ 10,000.00		Assumes a crew of 5 at $50/hr; 1 day to form, 1 day to place rebar, 2 days to pour
		Equipment	2	DAY	$ 2,250.00	$ 4,500.00		$255/ hour boom pump truck, 2 day pour @ 10 hour day; broom finish (no equipment needed); price estimated by Kyle
		Grade Control at Upstream End of Lake	**1**	**LS**	**$ 121,200.00**		**$ 121,200.00**	
		Excavation	1318	CY	$ 20.00	$ 26,351.11		
		Boulders	1044	TON	$ 80.00	$ 83,526.30		Assumes placement and stockpile included
		Cobbles	241	TON	$ 35.00	$ 8,432.94		Assumes placement and stockpile included
		Salvage Sediment	144	CY	$ 20.00	$ 2,884.44		Assumes placement and stockpile included
		Hydroseeding	**0.4**	**AC**	**$ 2,200.00**	**$ 880.00**	**$ 880.00**	Assumes the same area as the planting area
		Planting	**2.0**	**AC**	**$ 12,000.00**	**$ 24,000.00**	**$ 24,000.00**	Clearing area + lake area (outside 10' wide "channel" area) CAD 1.6 ac
		Bark, Hog Fuel or Wood Chip Mulch	**20**	**CY**	**$ 12.00**		**$ 300.00**	Includes temporary access routes (18ft x 100ft x 0.25ft) and incedental amount for staging area preparation as well as removal as needed

Construction Subtotal	$	273,000	
Tax (9.5%)	$	26,000	
Construction Total (roundup to 1000's)	$	299,000	
Contingency (50%)	$	150,000	
Construction Total with Contingency	$	449,000	
Permitting	$	35,000	
Design	$	50,000	
Construction Management & Administration (20% of Construction Cost)	$	89,800	
Post-construction Vegetation Monitoring and Supplemental Planting	$	50,000	start 5 years after construction complete, when lake bed likely getting full with sediment
GRAND TOTAL	$	680,000	

Engineering Cost Estimate for Conceptual Design - Alternative 2

Project: Hidden Lake Dam Removal
Herrera Project #: 15-05984-000
Client: City of Shoreline

Date Modified: 12/9/2015
Spreadsheet by: M. Beggs
Checked by: I. Mostrenko, M. Ewbank
Latest Date Checked: 1/6/2016

Alternative 2

Bid Item #	Spec Section	Item Description	Quantity	Unit	Unit Cost	Price	Total Price	Comments
		Mobilization	**1**	**LS**	**$ 80,900.00**		**$ 80,900.00**	8% of construction subtotal (Div 2 - Div 8 work items)
		Temporary Erosion and Sediment Control	**1**	**LS**	**$ 27,300.00**		**$ 27,300.00**	Assumes 3% of all other items except water management
		Water Management (Incl. Streamflow Bypass)	**1**	**LS**	**$ 75,000.00**		**$ 75,000.00**	based on bid cost for Coal Creek culvert replacement in Bellevue
		Traffic Control	**1**	**LS**	**$ 30,000.00**		**$ 30,000.00**	rough estimate, needs input from City
		Stabilized Construction Entrance	**1**	**EA**	**$ 2,500.00**		**$ 2,500.00**	
		Demolition of Current Spillway	**1**	**LS**	**$ 8,700.00**		**$ 8,700.00**	
		Disposal of Material	150	CY	$ 50.00	$ 7,500.00		See Volumes Spreadsheet (rough est from KC 96 plans)
		Topsoil Removal and Stockpile	100	CY	$ 12.00	$ 1,200.00		
		Demolition of Lake Outlet Conveyance	**1**	**LS**	**$ 3,500.00**		**$ 3,500.00**	Pull manhole ~$1.5K and remove pipes ~$2K
		Site Clearing - Clearing and Grubbing and Stripping and Stockpiling of Topsoil	**1**	**AC**	**$ 14,300.00**		**$ 14,300.00**	Price from UBA. 600 ft of RB road from dalys to top, 20 ft wide. ~0.4 ac near daly
		Common Excavation Including Haul	**12700**	**CY**	**$ 35.00**		**$ 444,500.00**	Quantity from CAD. Includes control of water, removal, loading, hauling, and disposal, Assumes $6 exc+$27 haul and disposal+$2 per cy for water management.
		Roughened Channel	**1**	**LS**	**$ 120,000.00**		**$ 120,000.00**	roughened channel length=330 FT; width= 25FT; area=8250
		Import Riprap	1222	CY	$ 77.00	$ 94,111.11		Assumed 4 FT deep; price from Manashtash
		Import Streambed Cobble	306	CY	$ 60.00	$ 18,333.33		Asumes 1' deep over the roughened channel area
		Placement of Riprap	1222	CY	$ 6.00	$ 7,333.33		Price from Manashtash, 1 exc. 15 minute delivery r/t, place w/ 2 exc.s needed, 0.2 hour to place (2 Exc+op, laborer 0.2hr @ $150/hr)
		Wood Revetment	**1**	**LS**	**$ 211,000.00**		**$ 211,000.00**	Length= 550 FT assumes same revetment as goheen scaled by 5, there are 2 channels so assume a length of 1100FT
		Type 1 log: 14-18" Dia. 10' with rootwad	44	EA	$ 750.00	$ 33,000.00		engineer's estimate (Ian)
		Type 2 log: 14-18" Dia. 8-10' without rootwad	61	EA	$ 300.00	$ 18,300.00		engineer's estimate (Ian)
		Type 3 log: 14-18" Dia. 15' without rootwad	50	EA	$ 500.00	$ 25,000.00		engineer's estimate (Ian)
		Slash/Racking - salvage, haul, and placement	6	LS	$ 300.00	$ 1,800.00		Price fom Goheen (material only); salvaged from site clearing operation
		Light loose riprap	578	TON	$ 60.00	$ 34,680.00		Price fom Goheen (material only)
		Rebar Nails	220	EA	$ 10.00	$ 2,200.00		Price fom Goheen (material only); for pinning log structure together
		Installation	17	DAY	$ 5,600.00	$ 95,200.00		RSMeans 2010 - crew daily rate assuming 8 hr day ($5600): foreman $432.80, 1 laborer $408.40, Operator $514.40 each, 1.5cy excavator $1118.70, 1cy excavator $881.76 chainsaw $36.75, crawler carrier with operator $1280. (Goheen)
		Floodplain and In-channel wood (Type 1 Logs)	**26**	**EA**	**$ 750.00**		**$ 19,500.00**	Assumes 1/6 of the amount of wood used in the revetment. Price is an engineer's estimate (Ian)
		Hydroseeding	**1**	**AC**	**$ 2,200.00**		**$ 2,200.00**	Assumes the same area as the planting area. Midchannel island ~0.7 ac + grubbing area
		Planting	**1**	**AC**	**$ 12,000.00**		**$ 12,000.00**	
		Bark, Hog Fuel or Wood Chip Mulch	**535**	**CY**	**$ 12.00**		**$ 6,500.00**	Includes temporary access routes (18ft x 3200ft x 0.25ft) and incedental amount for staging area preparation as well as removal as needed
		Streambed Gravel	**391**	**CY**	**$ 60.00**		**$ 23,500.00**	Assumes streambed cobble is 1' thick placed along the length of the rock revetment. Assumes the channel is 21 ft. wide (from CAD)
		Trail Modifications	**1**	**LS**	**$ 10,000.00**		**$ 10,000.00**	Assumes trail realignment needed on park side near roughened channel, and near current lake edge

Construction Subtotal	**$ 1,091,400**
Tax (9.5%)	**$ 103,700**
Construction Total (roundup to 1000's)	**$ 1,196,000**
Contingency (50%)	**$ 598,000**
Construction Total with Contingency	**$ 1,794,000**
Permitting	**$ 45,000**
Design	**$ 150,000**
Construction Management & Administration (20% of Construction Cost)	**$ 358,800**
GRAND TOTAL	**$ 2,350,000**
Optional Additive Cost : New Fish Passage Culvert/Bridge and Downstream Channel Improvements	**$ 3,200,000**

Engineering Cost Estimate for Conceptual Design - Alternative 3

Project: Hidden Lake Dam Removal
Herrera Project #: 15-05984-000
Client: City of Shoreline

Date Modified: 12/9/2015
Spreadsheet by: M. Beggs
Checked by: I. Mostrenko, M. Ewbank
Latest Date Checked: 1/6/2016

Alternative 3

Bid Item #	Spec Section	Item Description	Quantity	Unit	Unit Cost	Price	Total Price	Comments
		Mobilization	**1**	**LS**	**$ 170,100.00**		**$ 170,100.00**	8% of construction subtotal (Div 2 - Div 8 work items)
		Temporary Erosion and Sediment Control	**1**	**LS**	**$ 40,300.00**		**$ 40,300.00**	Assumes 2% of all other items except water management
		Water Management (Incl. Streamflow Bypass)	**1**	**LS**	**$ 75,000.00**		**$ 75,000.00**	based on bid cost for Coal Creek culvert replacement in Bellevue
		Traffic Control	**1**	**LS**	**$ 30,000.00**		**$ 30,000.00**	rough estimate, needs City input
		Stabilized Construction Entrance	**2**	**EA**	**$ 2,500.00**		**$ 5,000.00**	
		Demolition of Current Spillway	**1**	**LS**	**$ 8,700.00**		**$ 8,700.00**	
		Disposal of Material	150	CY	$ 50.00	$ 7,500.00		See Volumes Spreadsheet (rough est from KC 96 plans)
		Topsoil Removal and Stockpile	100	CY	$ 12.00	$ 1,200.00		
		Demolition of Lake Outlet Conveyance	**1**	**LS**	**$ 3,500.00**		**$ 3,500.00**	Manhole ~+1.5k, pull or pack pipe 2k
		Site Clearing - Clearing and Grubbing and Stripping and Stockpiling of Topsoil	**0.75**	**AC**	**$ 14,300.00**		**$ 10,725.00**	Price from UBA. 400 ft of RB road from dalys to top, 20 ft wide. ~0.4 ac near daly
		Common Excavation Including Haul	**6800**	**CY**	**$ 35.00**		**$ 238,000.00**	Quantity from CAD. Includes control of water, removal, loading, hauling, and disposal, Assumes $6 exc+$27 haul and disposal+$2 per cy for water management.
		Roughened Channel	**1**	**LS**	**$ 108,900.00**		**$ 108,900.00**	roughened channel length=300 FT; width= 25 FT; area=7500SF
		Import Riprap	1111	CY	$ 77.00	$ 85,555.56		Assumed 4 FT deep; price from Manashtash
		Import Streambed Cobble	278	CY	$ 60.00	$ 16,666.67		Asuumes 1' deep over the roughened channel area
		Placement of Riprap	1111	CY	$ 6.00	$ 6,666.67		Price from Manashtash, 1 exc. 15 minute delivery r/t, place w/ 2 exc.s needed, 0.2 hour to place (2 Exc+op, laborer 0.2hr @ $150/hr)
		Rock/wood Revetment	**1**	**LS**	**$ 57,000.00**		**$ 57,000.00**	
		Import Riprap	309	CY	$ 77.00	$ 23,818.67		Revetment length= 464 FT; depth= 3 FT; Height= 6 FT (SHOULD EVALUATE IN CAD); Price from Manastash
		Import Quarry Spalls	45	CY	$ 45.00	$ 2,025.00		Assumes 6 inches deep, cost is an engineer's estimate (Ian)
		Placement of Riprap	309	CY	$ 6.00	$ 1,856.00		Price from Manashtash, 1 exc. 15 minute delivery r/t, place w/ 2 exc.s needed, 0.2 hour to place (2 Exc+op, laborer 0.2hr @ $150/hr)
		Type 1 log: 14-18" Dia. 10' with rootwad	39	EA	$ 750.00	$ 29,250.00		Assumes 1/4 of the amount of wood used in the Alt. 2 wood revetment. Cost is an engineer's estimate (Ian)
		Hydroseeding	**0.75**	**AC**	**$ 2,200.00**		**$ 1,700.00**	Assumes the same area as the planting area. Daly's 0.4 ac + the remaining lake area outside props
		Planting	**0.75**	**AC**	**$ 12,000.00**		**$ 9,000.00**	
		Bark, Hog Fuel or Wood Chip Mulch	**535**	**CY**	**$ 12.00**		**$ 6,500.00**	Includes temporary access routes (18ft x 3200ft x 0.25ft) and incedental amount for staging area preparation as well as removal as needed
		Streambed Gravel	**361**	**CY**	**$ 60.00**		**$ 21,700.00**	Assumes streambed cobble is 1' thick placed along the length of the rock revetment. Assumes the channel is 21 ft. wide (from CAD)
		Trail Modifications	**1**	**LS**	**$ 10,000.00**		**$ 10,000.00**	Assumes trail realignment needed on park side near roughened channel, and near current lake edge
		New Fish Passage Culvert (NW Innis Arden Way) and Channel Improvements Downstream of Road	**1**	**LS**	**$ 1,500,000.00**		**$ 1,500,000.00**	proportioned from Red Creek bridge and Coal Creek culvert project low bids

Construction Subtotal	**$ 2,296,200**
Tax (9.5%)	**$ 218,200**
Construction Total (roundup to 1000's)	**$ 2,515,000**
Contingency (50%)	**$ 1,258,000**
Construction Total with Contingency	**$ 3,773,000**
Permitting	**$ 75,000**
Design	**$ 400,000**
Construction Management & Administration (20% of Construction Cost)	**$ 754,600**
Post-construction Vegetation Monitoring and Supplemental Planting	**$ 110,000**
GRAND TOTAL	**$ 5,200,000**