FINAL

Lower Taylor Creek
Preliminary Concept Designs

Prepared for:

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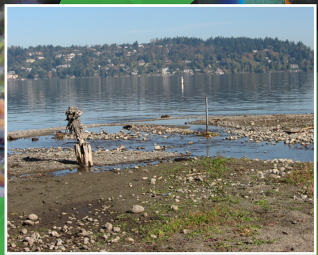
Seattle Public Utilities

21 February 2011

Prepared by:

OSBORN CONSULTING INCORPORATED

THE WATERSHED COMPANY



Seattle Public Utilities

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PURPOSE

Lower Taylor Creek, below Lakeridge Park, has a number of needs and opportunities for improving stream capacity, ensuring infrastructure integrity, and enhancing habitat. The condition of the culvert under Rainier Avenue S, a major transportation arterial, needs to be addressed in the near future. Settlement of a lawsuit at the mouth of Taylor Creek has introduced an opportunity to improve habitat and stream capacity downstream of Rainier Ave S, improve juvenile Chinook shoreline rearing habitat, and perhaps address some issues with flooding and culvert failure on private property. Upstream of Rainier Avenue S, there are additional opportunities for stream enhancement and fish passage barrier removal on SPU and Parks properties. While SPU's main interest is the Rainier Avenue S culvert replacement, it is efficient to consider the possible project elements collectively. The project area is lower Taylor Creek, from the shoreline of Lake Washington upstream to the culvert crossing under 68th Avenue S.

This Preliminary Concept Design Report was developed to identify possible stream and culvert alternatives and assess alternative advantages, disadvantages, issues, and conceptual level costs. The report is intended to provide ideas for discussion with residents, property owners, and interested stakeholders, as well as support SPU business case development.

PROJECT OBJECTIVES

Following is a list of project objectives identified by SPU:

- Replace the Taylor Creek culvert under Rainier Avenue S.
- Provide full fish passage between Lake Washington and the Lakeridge Park Ravine for all life stages and species of native salmonids.
- Pass Flows beyond the 25 year event to meet drainage service levels.
- Minimize any flow constrictions that effect flooding conditions.
- Improve stream, floodplain, riparian, and shoreline habitat.
- Ensure stream flows, stream channel configurations, gradient, and woody debris allows for proper sediment transport and minimizes stream and culvert maintenance needs.
- Increase floodplain and stream capacity and natural floodplain and stream functions.
- Improve spawning and rearing conditions for native salmonids, with an emphasis on juvenile Chinook rearing habitat along the lake shoreline and in the creek.
- Create passive recreation opportunities and connect to other recreational amenities.
- Provide public access to the lake shoreline.
- Provide and enhance pedestrian connections from the lake to Lakeridge Playground and Lakeridge Park
- Minimize detrimental impacts to surrounding property owners from the change in land use at the project site.
- If possible, provide full fish passage for native salmonids from Lake Washington into Lakeridge Park.

This conceptual design work was performed by Osborn Consulting Inc. (OCI) and The Watershed Company (TWC), from here on referred to as the OCI design team. The contents of this report include:

1. Documentation of the development and selection of project menu components on a reach by reach basis
2. Evaluation of selected project menu components for alternative stream and culvert alignments

Additional background and analysis information is provided in the appendices of this report. Project background and description of existing site conditions are provided in the *Conceptual Design for Lower Taylor Creek - Design Constraints and Considerations Memorandum* (**Appendix A**). Hydrologic and hydraulic analysis, including design flow, culvert size, and stream and floodplain recommendations, can be found in the *Conceptual Design for Lower Taylor Creek - Hydrologic and Hydraulic Analysis Memorandum* (**Appendix B**).

TAYLOR CREEK BACKGROUND

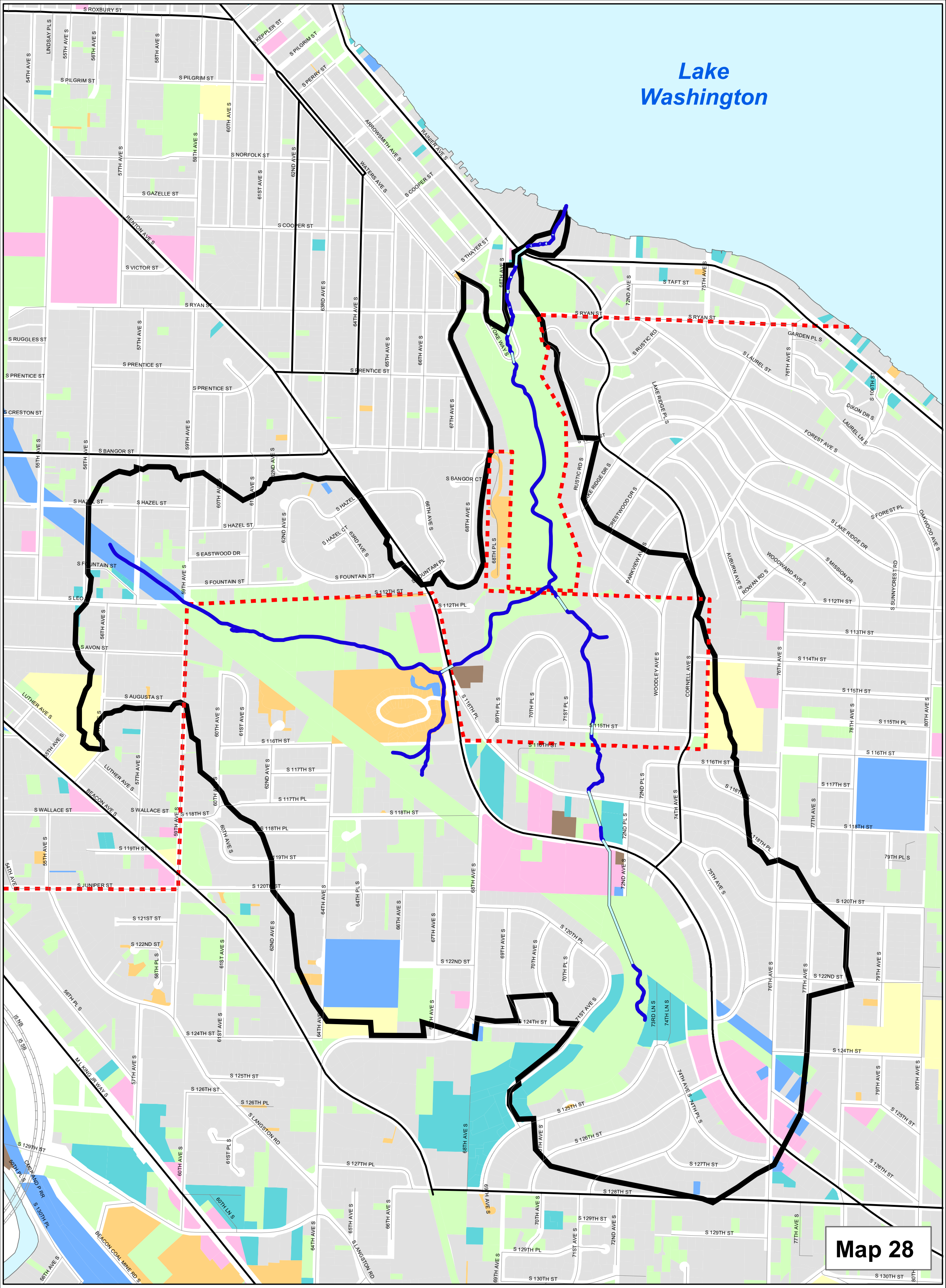
The bulk of this background was taken from the City of Seattle State of the Waters Report Volume 1. This report can be found online at:
seattle.gov/util/EnvironmentConservation/OurWatersheds/RestoreOurWaters/ProgramDocuments/index.htm

Taylor Creek is located in southeastern Seattle, (see SPU's State of the Water Report Map Folio - Map 28 on following page). The two forks of the stream originate in the Skyway area of unincorporated King County, and then join in the steep ravine of Lakeridge Park and run down to southern Lake Washington. In total, Taylor Creek and its tributaries are approximately 2.7 miles in length.

The Taylor Creek watershed covers an area of one square mile (640 acres). The upland plateau and headwaters area is underlain by silt, clay, sand, and gravel mixtures with low permeability and infiltration capacity, which can cause rapid surface water runoff and erosion where surface soils have been removed. The sediments and deposits in the stream ravine, however, tend to be dense and hard and are fairly resistant to erosive forces. The ravine walls are subject to landslides which provide gravel and sand to the stream channel.

The Taylor Creek watershed has been largely developed, although the stream ravine remains in a mostly forested condition due to Lakeridge Park. The watershed land uses include residential (50%), open space (21%), transportation (18%), and commercial and industrial (8%) areas.

The hydrology of the watershed has been altered by development and impervious surfaces. Modeling results indicate that the magnitude of the 2-year storm event has increased five-fold compared to pre-developed conditions. The flow frequency analysis conducted for this project estimate a 2-year storm event flow of 58 cubic feet per second (cfs), a 25-year event of 95 cfs and a 100-year event of 112 cfs. **Appendix B** documents the hydrology and hydraulic analysis completed for the preliminary concept designs.



Taylor Creek

Land Use

The City of Seattle

Produced by the City of Seattle

June 2007

0 250 500 1,000
Feet

N E S W

Legend

- Single Family
- Mutli-Family
- Industrial
- Parks/Vacant
- Schools
- Commercial
- Govt./Public Facility
- Other

Watercourse Segments

- Open Channel (Stream)
- Culvert
- City Boundary
- Arterials
- Watershed Boundary

PROCESS

Staff from SPU and the Parks departments visited the project site with members of the OCI design team. After the site visit and reviewing the *Hydrologic and Hydraulic Analysis Memorandum*, the OCI design team facilitated a brainstorming workshop session with the SPU project team (SPU and Parks) on November 16, 2010. Together, the SPU project team and the OCI design team developed and qualitatively analyzed a variety of conceptual alternatives to address the project objectives on a reach by reach basis (see page 1 for objectives).

Photo 1: Taylor Creek Delta at Lake Washington (photo by OCI)

The SPU project team's experience and history with the project were instrumental in identifying and/or eliminating alternatives and assessing their feasibility quickly. Over twenty alternatives were identified throughout the project area, as identified in **Appendix D**, Project Menu Components and Brainstorming Meeting Minutes. Nine preferred alternatives were selected as project menu components. These menu components included alternative creek and culvert alignments throughout the project area. The evaluation and conceptual design of the nine menu components developed by the OCI team is presented below.

PROJECT COMPONENTS MENU

The Lower Taylor Creek project area is broken into four reaches (See **Figure 1: Existing Conditions**) as described below:

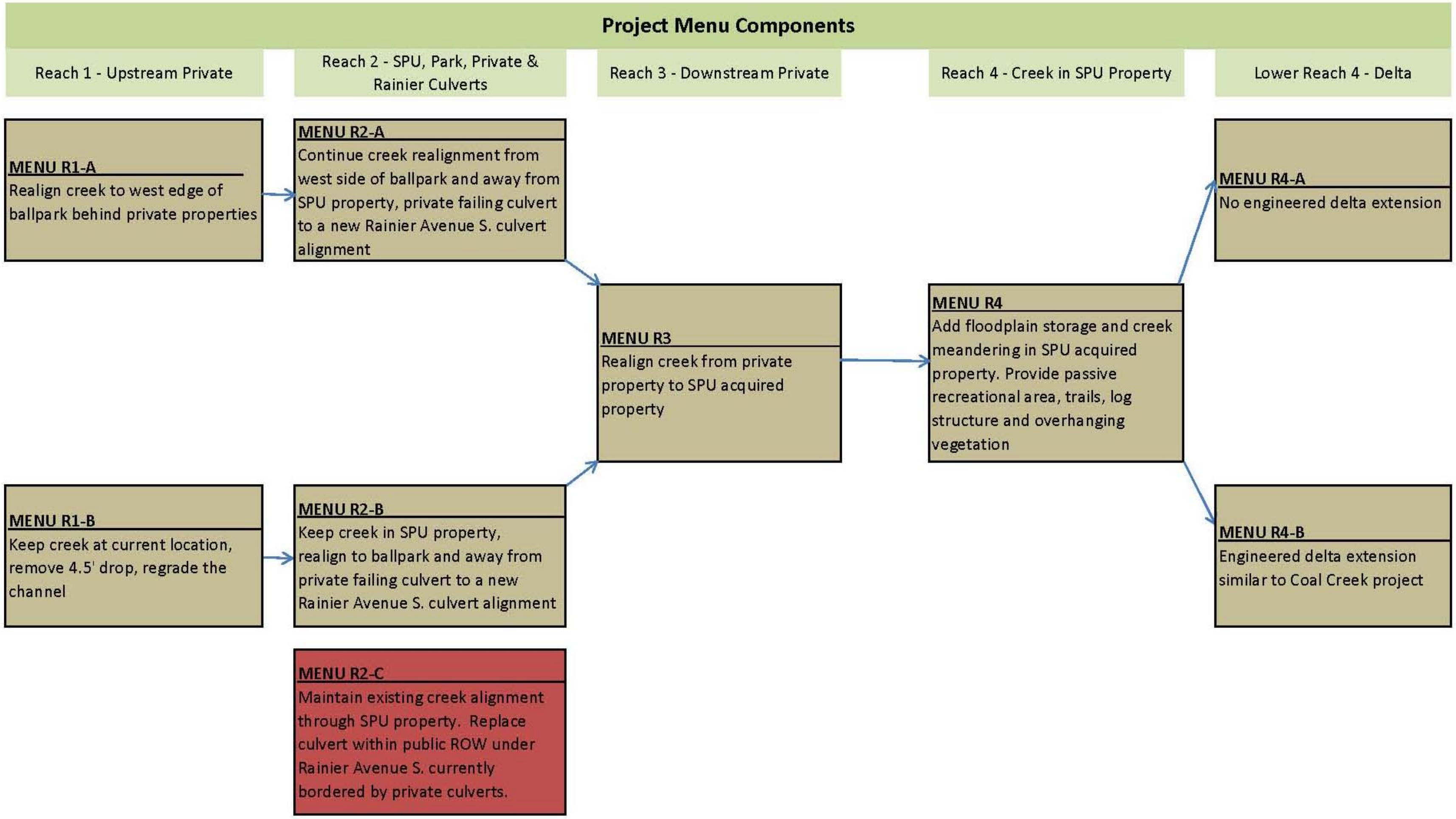
- Reach 1: This reach includes the most upstream portion of the project area. Located on the east side of 68th Avenue S, Reach 1 flows primarily through private property. This reach includes four existing driveway culverts and a 4.5-foot tall water feature.
- Reach 2: This reach begins on SPU property at the downstream side of the 4.5-foot high water feature and includes a series of piped culvert crossings of both public (Rainier Avenue S culvert) and private land. Private culvert crossings include a culvert under an apartment building on the upstream side of Rainier Avenue S and a culvert under a private access road on the downstream of Rainier Avenue S.
- Reach 3: This reach begins at the private culvert outfall and includes open channel and culvert sections of Lower Taylor Creek flowing through private property. Reach 3 terminates just upstream from SPU's shoreline parcels.
- Reach 4: This reach includes open channel and culvert sections, the mouth, and delta of Taylor Creek located on SPU's shoreline parcels.

Each reach was analyzed for existing site constraints and opportunities for reducing flooding, as well as improving stream capacity, floodplain storage, and habitat function. Alternatives explored include creek relocation, re-grading, better use of SPU and Park property, engineered delta extension, and recreational/pedestrian access. Issues and concerns were identified for each alternative and some alternatives were eliminated from detailed evaluation (see **Appendix D**). Nine alternatives were identified for further evaluation as menu components as shown in **Table 1: Project Menu Components**.

Photo 2: Taylor Creek near the mouth (photo by OCI)

As noted in the table, the existing alignment alternative (R2-C) was initially included but was quickly identified as problematic and was not included as one of the preferred alternatives. An explanation for excluding R2-C from the preferred alternatives is provided under the Reach 2 discussion.

A two part naming convention was used for the alternatives, where the first part of the title indicates what reach the menu component is located in and the second part indicates an option letter (A or B).


Project Menu Components
Reach 1 - Upstream Private
Reach 2 - SPU, Park, Private & Rainier Culverts
Reach 3 - Downstream Private
Reach 4 - Creek in SPU Property
Lower Reach 4 - Delta
MENU R1-A
Realign creek to west edge of ballpark behind private properties
MENU R2-A
Continue creek realignment from west side of ballpark and away from SPU property, private failing culvert to a new Rainier Avenue S. culvert alignment
MENU R3
Realign creek from private property to SPU acquired property
MENU R4
Add floodplain storage and creek meandering in SPU acquired property. Provide passive recreational area, trails, log structure and overhanging vegetation
MENU R4-A
No engineered delta extension
MENU R1-B
Keep creek at current location, remove 4.5' drop, regrade the channel
MENU R2-B
Keep creek in SPU property, realign to ballpark and away from private failing culvert to a new Rainier Avenue S. culvert alignment
MENU R4-B
Engineered delta extension similar to Coal Creek project
MENU R2-C
Maintain existing creek alignment through SPU property. Replace culvert within public ROW under Rainier Avenue S. currently bordered by private culverts.

CONCEPTUAL DESIGN ANALYSIS

Each menu component was evaluated for existing site conditions, constraints, opportunity for improvement, advantages and disadvantages, design and construction limitations and a ballpark cost estimate. Each menu component is presented under its specific reach.

REACH 1

Taylor Creek flows through Lakeridge Park, crosses 68th Avenue S. and flows through the front yards of private properties along 68th Avenue S. A fish passable culvert across 68th Avenue S. was installed in 1999, however, actual and potential barriers to upstream fish migration are currently located both upstream and downstream. Actual and potential barriers to upstream fish migration along this reach include:

- the weir immediately upstream of the 68th Avenue S. culvert with a vertical drop that limits fish passage during certain conditions,
- four driveway crossings, and
- a 4.5-foot drop-water feature at the driveway accessing the most downstream property of Reach 1 (10028 68th Avenue S).

Photo 3: Private driveway crossing with 4.5 ft drop - water feature (photo by OCI)

Downstream of the 68th Avenue S culvert, private property owners along 68th Avenue S. have reported flooding in the past. This reach has a relatively flat channel slope of 1.5% (excluding the 4.5-foot drop) that facilitates sediment deposition. The channel width and culvert dimensions vary in this reach with average dimensions stated below.

Reach 1 Average Channel Dimensions

- Average Bottom Width: 4.7 ft
- Average Top Width: 10.1 ft
- Average Depth: 1.5 ft
- Average Cross Sectional Area: 11.3 sf
- Average Driveway Culvert Length and Diameter: 20 ft and 1 ft

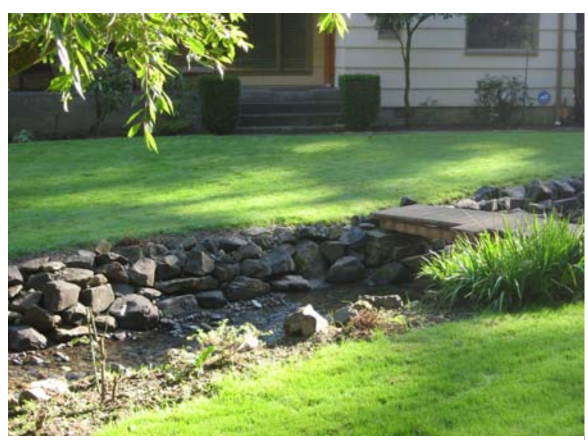


Photo 4: Taylor Creek Reach 1, adjacent to 68th Avenue S (photo by OCI)

Two creek alignments were evaluated for this reach, one alignment maintains the current channel alignment and the other relocates the stream channel to park property located behind the private properties along 68th Avenue S. These alignment options through Reach 1 make up menu components **R1-A** and **R1-B** as described below.

Menu Component R1-A

Description:

Menu Component R1-A realigns Taylor Creek to Park property (Lakeridge Playground). See **Figure 2 and 3**. This component also includes fish passage improvements to an existing weir upstream of the 68th Avenue S. culvert.

Conceptual Design:

The proposed trapezoidal channel will be sized to convey a 25 year design flow and contain a 100 year design flow (Refer to *Hydrologic and Hydraulic Analysis Memorandum*, November 2010, OCI). The proposed trapezoidal channel will include a floodplain bench and vegetated bench and buffer area as shown in **Figure 5 (Cross Section A).**

A consistent stream gradient along a meandering channel with stable banks will promote natural sediment transport and deposition patterns and flood control (see **Figure 7** for a profile view of the stream). A floodplain bench of four to eight feet will provide annual flood storage and estimates show that this can occur without impeding the ball field use and safety at Lakeridge Playground. Large woody debris and in-stream rock structures will provide bank stabilization and improved habitat.

Considerations:

While estimates show that there is sufficient space to realign Taylor Creek onto the western edge of Lakeridge Playground and to the east of properties along 68th Avenue S, the uses, safety, and maintenance of the park need to be examined in more detail to better determine the feasibility of this option.

The ultimate fate of the existing channel and culverts through private property will need to be assessed with property owners and regulatory agencies. The channel could remain to collect and convey local surface water runoff along 68th Avenue S; however; the channel may not need to remain at its current dimensions or alignment. For example, the channel may be partially filled in and converted to a vegetated swale, or filled in with underdrain pipe and gravel. Given the uncertainty, improvements or modifications to the abandoned channel have not been included in the cost estimate for this Menu Component.

Advantages:

- Provides fish passage.
- Moves the channel from private property into public right of way.
- Increased channel length and cross sectional area provides for better in-stream condition and habitat improvement.
- Avoids driveways and eliminates need for fish passage culverts.
- Reduced potential for flooding of private properties.
- Provides for a nice water feature through the ballpark.

- Stream meandering increases the stream's open channel length compared to the current alignment and improves habitat function and aesthetic appeal.
- Reduces SPU liability for flooding on private properties.

Disadvantages/Risks:

- Buffer impacts of relocating the stream have to be considered, though Parks and property owners can each provide part of the required buffer for the creek. Buffer requirements for enhancement projects would be subject to negotiation.
- Based on the proposed conceptual design the most upstream private property (#10050) would need to be purchased or an easement through the property would need to be negotiated along with removal of a shed on the property in the path of the channel. Property purchase was included in the construction cost estimate.
- Any change in realignment will need to assess changes in potential flooding risk compared to current conditions along 68th Avenue S.
- Due to existing topography near the backyard of the first upstream private property (steep hillside), construction site grading may be constricted.
- Construction of the new channel adjacent to the steep hillside could increase the risk of slope failure or landslides.
- No geological data is available in the area of the proposed creek realignment.
- Without purchase of the upstream property, this alternative could be a major earth moving project with high design and construction costs.

Cost Estimate

The construction cost for menu component R1-A is $817,500. An engineer's construction cost estimate is included in **Appendix E**.

Menu Component R1-B

Description:

Conceptual design of component R1-B maintains the current Taylor Creek alignment through the front yards of private properties along 68th Avenue S, replaces driveway culverts with fish passable culverts, and removes the 4.5 foot fish barrier downstream of the 10026 68th Avenue S driveway culvert by re-grading the stream channel (**Figure 3** and **Figure 7**). This component also includes fish passage improvements to an existing weir upstream of the 68th Avenue S culvert.

Conceptual Design:

The stream channel will be re-graded from the downstream side of the 68th Avenue S culvert through the 4.5 foot fish barrier. The existing channel through the four private properties on 68th Avenue S will be maintained. The channel cross section will be increased to convey the 25 year design flow and contain the 100 year design flow (Refer to *Hydrologic and Hydraulic Analysis Memorandum*, November 2010, OCI). The resulting trapezoidal channel with typical dimensions is shown in **Figure 5 (Cross Section B)**. A profile drawing showing a typical driveway culvert replacement at the location of the 4.5-ft drop is shown on **Figure 6** and **Figure 7**. The proposed channel side slopes are steeper than component R1-A to minimize the impact to private property.

The increased stream gradient achieved by eliminating the 4.5-foot drop will improve sediment transport, reduce deposition, and alleviate flooding through this reach. Banks will be stabilized with vegetation to support natural sediment transport and deposition patterns. No large woody debris is proposed with this component to minimize the project footprint through private property.

Considerations:

A narrower than standard buffer is present and would likely remain for the current alignment with minimal effective buffer widths and multiple driveway crossings.

Property owners along 68th Avenue S need to be consulted regarding their thoughts on stream improvements. There is also a possibility to remove one stream crossing if two homes would share a stream crossing instead of having individual ones.

Driveway culverts are typically private improvements and not covered by public utility funds. Grant or private funds may need to be obtained to cover driveway culvert expenses.

Advantages:

- Removes 4.5-foot fish barrier and replaces four driveway culverts to provide upstream fish passage.
- Increases channel conveyance capacity.
- Streambank vegetation provides some improvement in habitat function and stable channel banks.
- Using the current channel alignment will reduce the amount of excavation required for the project.

Disadvantages:

- The proposed channel improvements will result in increased channel width resulting in a loss of useable front yard area on private properties along 68th Avenue S.
- Utilities such as sewer and water line may have to be relocated if it falls within the proposed channel footprint.
- Expensive fish passable driveway culverts are needed.
- Limited opportunities for meandering due to presence of private property yards, buildings, and driveways.

Cost Estimate

The construction cost for menu component R1-B is $421,000. An engineer's construction cost estimate is included in **Appendix E**.

Additional Alternatives in Reach 1

During the workshop several other Reach 1 alternatives were identified and are summarized in greater detail as part of the meeting minutes included in **Appendix D.** Two of these additional alternatives are worth mentioning, as they may become more viable if funding, coordination with property owners or other factors prohibit the other preferred alternatives summarized above.

Reach 1 Status Quo

This option would maintain the existing stream alignment, driveway culverts and 4.5 foot drop. Advantages of this option are simply that there is no public work required on private property and there would be no cost incurred. The disadvantages are that the fish barrier would remain, along with the existing poor habitat and sediment deposition upstream of the 4.5-foot drop.

Re-Grade Stream through SPU Property

This option would eliminate the fish barrier on private property by backwatering or raising the elevation of the stream on the SPU property immediately downstream of the 4.5 foot drop – water feature. With this option there would be no work upstream of the SPU property. The advantages are cost savings relative to other options and elimination of the fish barrier without requiring work on private property. However, this would likely increase the flooding and sedimentation problems upstream of the drop and would not provide any habitat improvement.

REACH 2

Through this reach, Taylor Creek daylights for a short distance in the SPU property (10020 68th Avenue S.) and flows into a 36-inch diameter, 100-feet long concrete culvert. This culvert is under a private apartment complex (10005 Rainier Avenue S) next to Rainier Avenue S. This private apartment complex is showing signs of settling around the culvert. The downstream end of the 36-inch private culvert connects to the publically-owned culvert across Rainier Avenue S. Results of a video inspection provided by SPU indicate that this transition includes a drop and is failing. The Rainier Avenue S culvert is a 90-foot long box culvert which is 3-feet tall and 6-feet wide.

Photo 5: Taylor Creek on SPU owned property 10020 68th Avenue S (photo by OCI)

Immediately downstream of the box culvert, the creek flows through a 16-foot long, 42-inch round concrete culvert which passes under a shared private roadway/driveway that parallels Rainier Avenue S approximately ten feet lower below the Rainier Avenue S roadway elevation. The three part culvert system passing below Rainier Avenue S is a barrier to upstream fish migration.

This reach has an average slope of 3.0%. The average existing open channel width through this reach on SPU property is stated below.

Reach 2 Average Channel Dimensions

- Average Bottom Width: 5.78 ft
- Average Top Width: 16.29 ft
- Average Depth: 2.91 ft
- Average cross sectional area: 32.11 sf
- Total Culvert Length: 206 LF

Photo 6: Lakeridge Playfield and maintenance entrance (photo by OCI)

Two creek alignments and a new location for the Rainier Avenue S culvert crossing are evaluated in this reach. One alignment is an extension of Menu Component R1-A through Lakeridge Playfield. The other creek alignment, an extension of Menu Component R1-B, keeps the creek in the current location through the SPU property before also crossing Lakeridge Playfield. Both alignments connect to the new Rainier Avenue S Culvert alignment proposed to the east of the current Rainier Avenue S culvert crossing (**Figure 2 and 3)**. The alignment options through Reach 2 make up menu components **R2-A** and **R2-B** as described below.

Menu Component R2-A

Description:

Conceptual design of menu component R2-A continues the creek realignment from Reach 1 (either alternative) on Park property ballpark and away from the SPU property along 68th Avenue S. and the private failing culvert to a new Rainier Avenue S. culvert alignment (**Figure 2 and 3**).

Conceptual Design:

The proposed channel sizing and in-stream components provided for Reach 1 (Menu R1-A) will be continued through this reach. Adjacent to the 68th Avenue S SPU property, the proposed creek alignment will continue west towards the new Rainier Avenue S culvert. A typical channel cross section and a profile view are shown in **Figure 5 (Cross Section A)** and **Figure 7**. The profile view shows that the bottom of the proposed stream channel would be approximately 12-feet below the existing park ground elevation.

Large woody debris and in-stream rock structure will be added to enable habitat improvement, including pool formation with protective cover. This structure will also provide bank stabilization and direct sediment deposition patterns. The maintenance access to the ballpark will need to be moved to the east side of the ballpark and a slight rotation to the ball field could be required.

Based on the WDFW culvert design manual stream-simulation design method, a 14-foot span by 7'3" rise fish passable culvert with a slope of 2.5 percent is proposed. The stream simulation design method was selected over the zero slope method because it results in a lower rise and less expensive culvert. The selected rise is larger than necessary to convey design flows; the larger rise was selected for improved maintenance access.

The proposed Rainier Avenue S culvert alignment is east of the existing culvert. The new Rainier Avenue S culvert will discharge onto SPU property extending northward to Lake Washington (Reach 4). There is an existing driveway to a private access road, supported by a retaining wall, at the proposed culvert location. The new culvert is 126-feet long so it can cross both Rainier Avenue S and the private access road (at a slight skew). Headwalls are necessary at the culvert inlet and the outlet to accommodate the elevation change from the road/driveway to Taylor Creek. The bottom of the proposed culvert would be approximately 12-15 feet below the roadway surface. The Rainier Avenue S culvert profile drawing is shown on **Figure 6** and **Figure 7**. Design calculations and culvert details are included in **Appendix F**.

Photo 7: Existing private driveway/access road off of Rainier Avenue S. (photo by OCI)

Advantages:

- Provides upstream fish passage across Rainier Avenue S.
- Increases channel length and cross sectional area to provide for better in-stream habitat conditions.
- New Rainier Avenue S. culvert length is shorter than the current culvert, allowing a higher proportion of open channel. This is preferred by WDFW.
- Stream meandering also increases the stream's open channel length compared to the current alignment.
- Removes stream from the private culvert under the apartment building.
- Utilizes the park property ballpark and provides for a nice water feature through the ballpark.
- Ballpark use is maintained as the dimensions of the ballpark are not affected.
- Removes creek away from SPU property and opens up the possibility of other uses for that piece of land.

Disadvantages:

- Existing Rainier Avenue S culvert might still have several years of service left.
- Traffic on the major arterial, Rainier Avenue S will be impacted during installation of new culvert.
- Utilities might have to be relocated along the new culvert and creek alignment from ballpark.
- Maintenance access to ballpark needs to be moved.
- No geological data is available in the area of the proposed realignment of creek.
- This will be a major earth moving project which might translate to high design and construction cost.

- Culvert relocation requires coordination with property owners regarding construction disturbances to the joint use driveway that provides access to residences west and east of the project.

Cost Estimate

The construction cost for menu component R2-A is $486,800. An engineer's construction cost estimate is included in **Appendix E**.

Menu Component R2-B

Description:

Conceptual design of component R2-B modifies the current creek alignment through SPU property on 68th Avenue S. to allow creek realignment through Lakeridge Playfield to the new Rainier Avenue S. culvert alignment (**Figure 2 and 3**).

Conceptual Design:

The stream channel gradient from the removed 4.5-foot fish barrier downstream of 10026 68th Avenue S driveway will be continued through the adjoining SPU property and to the ballpark. Within the SPU property, the proposed creek alignment will move east toward the ballpark. The creek will continue through the ballpark to the new Rainier Avenue S culvert. A typical channel cross section and a profile view are shown in **Figure 5 (Cross Section A)** and **Figure 7**. The profile view shows that the bottom of the proposed stream channel would be approximately 12-feet below the existing park ground elevation.

Large woody debris and in-stream rock structure will be added to enable habitat improvement, including pool formation with protective cover. This structure will also provide bank stabilization and direct sediment deposition patterns. The maintenance access to the ballpark will need to be moved to the east side of the ballpark.

The proposed Rainier Avenue S culvert location and dimensions are the same as in Menu R2-A. Based on the WDFW culvert design manual stream-simulation design method, a 14-foot span by 7'3" rise fish passable culvert is proposed (2.5 percent slope). The stream simulation design method was selected over the zero slope method because it results in a lower rise and less expensive culvert. The selected rise is larger than necessary to convey design flows; the larger rise was selected for improved maintenance access.

The proposed Rainier Avenue S culvert alignment is east of the existing culvert. The new Rainier Avenue S culvert will discharge onto SPU property extending northward to Lake Washington (Reach 4). There is an existing driveway to a private access road, supported by a retaining wall, at the proposed culvert location. The new culvert is 126-feet long so it can cross both Rainier Avenue S. and the private access road (at a slight skew). Headwalls are necessary at the culvert inlet and the outlet to accommodate the elevation change from the road/driveway to Taylor Creek. The bottom of the proposed culvert would be approximately 12-15 feet below the roadway surface. The Rainier

Avenue S culvert profile drawing is shown on **Figure 6** and **Figure 7**. Design calculations and culvert details are included in **Appendix F**.

Advantages:

- Provides upstream fish passage across Rainier Avenue S.
- Increased channel length and cross sectional area to provide for better in-stream habitat conditions.
- New Rainier Avenue S culvert length is shorter than the current culvert, allowing a higher proportion of open channel. This is preferred by WDFW.
- Stream meandering also increases the stream's open channel length compared to the current alignment.
- Removes stream from the private culvert under the apartment building.
- Utilizes a corner of the park property ballpark and provides for a nice water feature, though less than component R2-A
- Ballpark use is maintained as the dimensions of the ballpark are not affected.
- Keeps more of the creek alignment on the 68th Avenue S. SPU property, maintaining and improving its use as fish and wildlife habitat.

Disadvantages:

- Existing Rainier Avenue S culvert might still have several years of service left.
- Traffic on the major arterial, Rainier Avenue S will be impacted during installation of new culvert.
- Utilities might have to be relocated along the new culvert and creek alignment from ballpark.
- Maintenance access to ballpark needs to be moved.
- No geological data is available in the area of the proposed realignment of creek.
- This will be a major earth moving project which might translate to high design and construction cost.
- Culvert relocation requires coordination with property owners regarding construction disturbances to the joint use driveway that provides access to residences west and east of the project.

Cost Estimate

The construction cost for menu component R2-B is $486,800. An engineer's construction cost estimate is included in **Appendix E**.

Menu Component R2-C

Menu Component R2-C includes maintaining the existing stream alignment alternative all the way through Reach 2. This was identified as an alternative early on in this process and documented as an option at the SPU workshop. This includes maintaining the open channel on SPU property and replacing the 3-part culvert system under the apartment complex, Rainier Avenue S and the private access road.

This option was identified early on as problematic. The public culvert under Rainier Avenue S is bordered by two private culverts. Replacing the public portion of the culvert only would not be feasible. Replacing the private culverts on either side of the Rainier

Avenues S culvert would require extensive private property coordination or acquisition and be cost prohibitive. In addition, public funds are typically limited to use on private property. Therefore this option was not included as a preferred alternative and did not undergo a detailed review or cost assessment.

Cost Estimate

Although a detailed cost assessment was not completed. It is assumed that the cost for menu component R2-C would exceed $1,200,000. This is based on the culvert cost estimates for R2-A and R2-B and the additional acquisition cost of the apartment complex and required improvements to the acquired property.

REACH 3

This reach includes a small section of the creek downstream of existing Rainier Avenue S culvert and the SPU acquired property to the east. The creek flows through two private properties 10020 Rainier Avenue S and 10018 Rainier Avenue S. On 10020 Rainier Avenue S, the creek flows through a 20 foot long 48-inch round concrete culvert. On 10018 Rainier Avenue S, the creek continues downstream and flows into a 15 foot long half pipe.

Flooding of property has been reported by both property owners in this reach. No easements exist in this reach for channel improvement. This reach has an average slope of 3.2%. The average channel dimensions in this reach are stated below.

Reach 3 Average Channel Dimensions

- Average Bottom Width: 6.02 ft
- Average Top Width: 8.25 ft
- Average Depth: 2.13 ft
- Average cross sectional area: 15.20 sf

One menu component was explored in this reach after eliminating several potential alternatives for channel improvement. This menu component moves the existing creek away from the private properties and to the SPU acquired property. The new creek alignment through the SPU property is discussed in Reach 4.

Photo 8: Culvert at private access road, start of Reach 3 (photo by OCI)

Menu Component R3

Description:

Conceptual design of menu component R3 realigns the creek from private properties downstream of Rainier Avenue S culvert towards the SPU acquired property (**Figure 2 and 4**).

Conceptual Design:

The existing stream channel through the two private properties (10020 Rainier Avenue S and 10018 Rainier Avenue S) will be abandoned. With the new alignment of Rainier Avenue S culvert, the creek will be relocated downstream of the Rainier Avenue S culvert and the creek follows through SPU's shoreline property.

Considerations:

The ultimate fate of the existing channel and culverts through private property will need to be assessed with property owners and regulatory agencies. The channel could remain to collect and convey local surface water runoff, however, the channel may not need to remain at its current dimensions or alignment. For example, the channel may be partially filled in and converted to a vegetated swale, or filled in with underdrain pipe and gravel. Given the uncertainty, improvements or modifications to the abandoned channel have not been included in the cost estimate for this Menu Component.

There will be a loss of stream habitat through this reach. It is anticipated that stream improvements in Reaches 2 and 4 will offset this habitat loss. The habitat loss versus that improved will be evaluated further in environmental permits required for this project.

Advantages:

- Reduced potential for flooding of private properties.
- Moves the channel from private property into public right of way.
- Eliminates need for fish passage culverts on private property.
- Reduces liability of SPU.
- Potential for using the abandoned channel for stormwater conveyance and/or treatment such as a biofiltration swale, infiltration trench, wet pond etc.

Disadvantages/Risks:

- Risk of unsatisfied property owners over the loss of the stream through their property.

Cost Estimate

The cost of physically abandoning the stream channel in Reach 3 is negligible and hence, no costs were calculated for this reach. Any improvements or modifications in the reach will need to be determined with affected property owners and possibly regulatory agencies. There are also limitations to the use of public utility funds on private property. Costs associated with modifications in Reach 3 will need to be evaluated at a later time if and when such improvements are identified.

REACH 4

Reach 4 extends from the outlet of the proposed new culvert crossing of Rainier Avenue S onto SPU's shoreline properties and extends downstream across those properties to the Taylor Creek delta in Lake Washington.

Photo 9: Start of Taylor Creek delta, looking upstream (photo by OCI)

The existing stream channel through the upper part of this reach is deep, narrow, and heavily armored in tight quarters amongst houses and driveways, providing generally poor habitat conditions and limited opportunities for improvement without adjoining land use changes. SPU's acquisition of these properties has provided opportunities for increased sediment storage, habitat enhancement, and public access for passive recreation.

The lower section of Reach 4 is characterized by a channel that becomes shallower with a decreasing gradient and increasing deposition as it approaches the lake. The accumulated deposition forms a fairly distinct delta area at the shore that extends outward into the lake. This is an expected result of ongoing natural processes, though it has been accelerated and complicated by the lowering of Lake Washington by about 9 feet in 1916 (Chrzastowski, 1983) and the urbanization of the Taylor Creek basin which has increased stream flows and sediment supply (Perkins Geosciences, 2007). Taylor Creek delta formation and growth have been problematic to property owners in the past, primarily because the delta has encroached on piers, making the water depth alongside them too shallow to moor boats. Fish habitat improvements envisioned for lower Reach 4 include:

- Adult salmonid fish passage upstream, across the delta and into the creek at all lake levels (primarily by coho, sockeye, and cutthroat) and;
- Use of the lower stream and shallow delta areas for rearing by juvenile salmonid fish, including juvenile threatened Chinook salmon originating from natural streams other than Taylor Creek, such as the Cedar River.

The average slope across Reach 4 is relatively flat at approximately 1.8%, contributing to deposition as expected. Average channel dimensions are stated below.

Reach 4 Average Channel Dimensions

- Average Bottom Width: 6.2 ft
- Average Top Width: 9.4 ft
- Average Depth: 2.1 ft
- Average Cross Sectional Area: 16.4 sf
- Total Length of Existing Culverts: estimated 30 ft

Two menu components are evaluated in this reach, and are described below. Proposed enhancements for upper Reach 4 (proposed with both R4-A and R4-B) provide a wider floodplain with sediment storage, native revegetation, placement of in-stream and streambank large woody debris habitat features, and passive recreational facilities.

Potential enhancements described for lower Reach 4 (Menu R4-B) primarily involve the placement of large woody debris in quantities and of a configuration to provide a more or less defined channel across the delta area for adult fish passage. This approach is not entirely natural, but has been used with success at the mouth of Coal Creek. Passive recreational facilities also continue into lower Reach 4 as a pathway and picnic area.

The two options through Reach 4 make up menu components **R4-A** and **R4-B** as described below.

Menu Component R4-A

Description:

Conceptual design of component R4 realigns Taylor Creek through the upstream, non-delta portions of SPU's property which extend from Rainier Avenue S to Lake Washington (**Figure 4** - Cross Section C and above/upstream).

Conceptual Design:

The proposed channel through upper Reach 4 as depicted on **Figure 5 (Cross Section C)** provides a wide floodplain bench as habitat, providing favorable soil moisture conditions for the growth of emergent vegetation and space for log structure placement. Large woody debris will be placed generously along the channel to provide various habitat functions including the formation of pool depressions with attendant cover along the thalweg of the channel (lowest point along a cross section). The excavated bench will also accommodate sediment storage. Stream banks and other open space areas not needed for the placement of passive recreational facilities will be planted with a diverse assortment of native plant species ranging in size from ground cover such as ferns and Oregon grape to shrubs such as salmonberry and red osier dogwood to trees such as cedar and big leaf maple.

Photo 10: Taylor Creek Reach 4 (photo by OCI)

Passive recreational facilities would include an access trail from Rainier Avenue S crossing a footbridge over the creek and leading to a picnic area at the lake. Space has also been reserved (see **Item #2 on Figure 4**) for additional park amenities to include possible limited playground equipment and/or an additional picnic area. An existing crosswalk across Rainier Avenue S connecting to Lakeridge Park will be signalized to improve access and enhance safety. Lakeridge Park includes restrooms, ball fields, a playground, tennis courts, trails, and other facilities.

Considerations:

Though stream flow has been diverted away from Reach 3, the relic channel from that reach may still remain in some form and provide inflow to upper Reach 4 as a stormwater and biofiltration swale. Possible improvements have not been included in the cost estimate for this menu component.

By providing extensive floodplain bench areas, the overall channel will be somewhat oversized with respect to flow conveyance capacity. As a result, wood placement is not expected to be problematic in that regard. Furthermore, residential structures and pavement on the property will be removed, eliminating flooding concerns.

The specifics of this design component will be heavily dependent on the results of additional sediment transport modeling and analysis that will provide an understanding of expected deposition patterns and quantities. Sediment load calculations will help determine the rate at which available sediment storage capacity will be filled, the shape, the size and location of the channel, placed log structures and floodplain benches and/or determine that additional storage and sediment management is needed.

Advantages:

- Eliminates driveway and access road crossings, thereby improving fish passage and increasing the amount of open channel (estimated 30 linear feet of culvert removed).
- Reduced potential for flooding on private properties.
- Stream meandering increases the stream's open channel length compared to the current alignment and improves habitat and aesthetic appeal.
- Increased channel cross sectional area generally provides for better in-stream conditions and habitat improvement, and specifically provides space for the placement of generous quantities of large woody debris.
- Provides public access to the lake along a pathway adjoining a natural stream feature with opportunities for passive recreational activities including landscape viewpoints and fish and wildlife watching.

Disadvantages:

- Public access to the lake may be over-used, becoming a popular beach or swimming area to the detriment of habitat and an annoyance to adjoining property owners.
- Creation of a wide cross section with an extensive floodplain would involve significant earth moving with associated design, permitting, and construction costs.

Cost Estimate

The construction cost for menu component R4-A is $902,400. An engineer's construction cost estimate is included in **Appendix E**.

Menu Component R4-B

Description:

Conceptual design of component R4-B includes the R4-A improvements described above and realigns Taylor Creek through the downstream, delta portions of the SPU acquired properties on and near the shore of Lake Washington (**Figure 2 and 4**).

Conceptual Design:

The proposed enhancement actions in the delta areas of lower Reach 4, as depicted on **Figure 5 (Cross Section D)**, are to provide and maintain some channel definition across the delta, primarily through the placement of large woody debris. This placed wood will function like channel banks to confine and maintain stream flow definition such that upstream passage across the delta by adult salmonid fish (coho, cutthroat, and sockeye) will be possible at all or most lake levels. Entry by such fish into small tributaries of Lake Washington is problematic and the circumstances are somewhat unusual because the lake has a “reverse hydroperiod” whereby it is maintained at a high level in summer and a low level in winter, contrary to the normal and natural regime. Adult fish returning in the late fall and winter when the lake level is low, but would naturally be higher, find water depths across the deltas is too shallow to provide ease of passage. This anomaly is a result of lake level management activities undertaken by the Corps of Engineers at the Hiram M. Chittenden locks in Ballard. Large woody debris placement in the shallow delta areas of the lake and lowermost channel section is also expected to benefit juvenile Chinook salmon originating from primarily the Cedar River as they rear in the lake each spring in preparation for their seaward migration (Tabor et. al. 2002). Delta and lakeshore areas will also be planted with overhanging vegetation to the benefit of juvenile Chinook salmon and other juvenile salmonids.

Considerations:

Though creation of somewhat defined channels across delta areas is not an entirely natural process, it is proposed in response to the unnatural conditions of:

- the “reverse” Lake Washington hydroperiod,
- the lowering of Lake Washington in 1916, and
- the increased sediment supply in Taylor Creek due to urbanization, all as described above.

The proposed treatment is an intermediate-term solution, which may function for decades, but eventually the delta will lengthen into the lake. As it lengthens, the gradient will eventually be reduced to the extent that the channel will fill in and avulse (change course) to reach the lake along a shorter and steeper pathway. Source control of sediments in the upper watershed (not part of this project) will help to extend the life of these proposed improvements.

As with R4-A, the specifics of this design component will be heavily dependent on the results of additional sediment transport modeling and analysis that will provide an understanding of expected deposition patterns and quantities. Sediment load calculations will help determine the rate at which available sediment storage capacity will be filled, the shape, the size and location of the channel, placed log structures and floodplain benches and/or determine that additional storage and sediment management is needed.

Advantages:

- Provides adult salmonid fish passage into Taylor Creek in spite of delta growth and artificial management of the lake level resulting in a “reverse hydroperiod.”
- Places large woody debris in shallow delta areas of the lake and lower, placid stream section for volitional use as rearing habitat by juvenile Chinook salmon and other juvenile salmonids.
- Directs sediment deposition further off-shore.
- See also the Advantages for R4-A provided above.

Disadvantages:

- This is an intermediate-term and not necessarily a permanent solution.
- This design has only been used in one location in Lake Washington and is experimental. The benefits are not yet well proven.
- Safety could be a concern for boaters in the lake.
- See also the Disadvantages for R4-A provided above.

Cost Estimate

The construction cost for menu component R4-B is $1,027,400. An engineer's construction cost estimate is included in **Appendix E**.

PERMITTING REQUIREMENTS OVERVIEW (REACHES 1- 4)

Based on conceptual design considerations and other available information, the following permits may be required (**Table 2: Anticipated Permits)**. These requirements are expected to be the same or similar for each of the reaches or alternatives considered, though more scrutiny may be given to Reach 4 with respect to ESA review due to the possible presence of and/or closer proximity to threatened Chinook salmon.

<table>
<tr><th colspan="3">Table 2: Anticipated Permits</th></tr>
<tr><th>Anticipated Permits</th><th>Agency</th><th>Permitting Level of Effort</th></tr>
<tr><td>SEPA</td><td rowspan="4">City of Seattle</td><td rowspan="7">High</td></tr>
<tr><td>Shoreline Permit</td></tr>
<tr><td>Critical Areas Permit</td></tr>
<tr><td>Land Disturbance Permit</td></tr>
<tr><td>404 Nationwide Permit (NWP)</td><td>U.S. Army Corps of Engineers</td></tr>
<tr><td>Hydraulic Project Approval (HPA)</td><td>Washington Department of Fish and Wildlife</td></tr>
<tr><td>401 Water Quality Certificate</td><td>Washington Department of Ecology</td></tr>
</table>

A high level of permitting effort is anticipated for this project, which involves work within "waters of the state" and therefore within Shoreline jurisdiction. The permitting process will be lengthy, involving a need to mitigate for any impacts to wetlands and/or fish production. Each of the proposed project components and alternatives is expected to provide net, intermediate and long term benefits to fish and wildlife habitat. However, shorter-term, during-construction impacts would need to be minimized and justified. This would affect the efforts and costs of final design, construction, and permitting, including ESA consultation and the preparation of a Biological Evaluation report associated with the 404 Nationwide Permit (NWP) application to the U.S. Army Corps of Engineers.

OPTION COMPARISON

Three options were developed, composed of the various project component alternatives. These options include:

- Option A: comprised of R1-A, R2-A, and R4-B.
- Option B: comprised of R1-B, R2-B, and R4-A.
- Option C: existing alignment and R4-A.

Option A

If having the creek on public property is a priority, the recommended plan is Option A. Option A is the only menu component combination that completely relocates Taylor Creek into Public right of way (SPU and Parks property). Additional benefits include:

- Restores fish access through the entire project area.
- Allows for the largest channel cross sectional area, widest floodplain bench, and the most habitat improvement with addition of large woody debris and other habitat features.
- Fewest possible culvert crossings (under Rainier Avenue S only).

However, the Option A is also the most costly ($2,332,000), could have the largest effect on private property (10050 68th Avenue S and potentially others along 68th Avenue S), and substantially affect uses of the Lakeridge Playground.

Option B

If relocation onto public right of way is not a high priority, then Option B comprised of R1-B, R2-B, and R4-A is a less expensive option with many of the same benefits as Option A. Option B is less expensive because it:

- does not include experimental delta improvements at the mouth,
- does not require purchase of additional property, and
- restores fish access through the entire project area, most of the time. Without improvements at the mouth, fish access may be restricted when lake levels are low. The estimated Option B construction cost is $1,820,000 (which includes $421,000 worth of improvements on private property).

Option C

While our preliminary analysis indicates that realignment of Taylor Creek under Rainier Avenue S provides options that are more cost and habitat effective, discussions with the affected property owners will be important for determining whether the existing alignment can be abandoned. Therefore, we have maintained Option C in the assessment of alternatives. See **Table 3** for a summary of each of the alignment options and estimated costs.

NEXT STEPS

This report is intended to be a starting point for project development. Assuming funding and city priorities do not change, SPU anticipates the following timeline for this project.

- 2011: Discuss project options and components with adjacent property owners and start public outreach.
- 2012-2013: Develop project designs, conduct public review, and complete permitting. Check in with property owners and interested community members and stakeholders at significant design milestones.
- 2013-2015: Tentative construction window.

Table 3: Options Comparison						
		Reach 1	**Reach 2**	**Reach 3**	**Reach 4**	**Overall**
Option A	***Description***	Realign to east side of homes	Connect eastern channel alignment with new culvert crossing under Rainier to the east of the existing culvert	Abandon	Stream meanders and floodplain, delta extension	• Relocates creek entirely onto public property. • Restores fish access through entire project area. • Provides the greatest reduction in private property flooding. • Provides the greatest habitat improvement. • Eliminates all of the private culverts. • Requires private property acquisition. • Requires extensive coordination with property owners and the parks department. • Includes experimental delta extension work
	Costs	$817,500	$486,800	$0	$1,027,400	$2,332,000
Option B	***Description***	Keep existing alignment, replace culverts, remove barrier	Connect existing channel alignment with new culvert crossing under Rainier to the east of the existing culvert	Abandon	Stream meanders and floodplain	• Does not require purchase of additional property. • Requires improvements on private property. • Restores fish passage through creek, but does not provide fish access year round since delta extension work is not included. • High level of habitat improvement.
	Costs	$421,000	$486,800	$0	$902,400	$1,820,000
Option C	***Description***	No change	Replace Rainier Ave S culvert in current alignment	No change	Stream meanders and floodplain	• Replacing culvert only under Rainier Ave S is not possible and would require replacement of adjacent private property culverts. • Requires extensive private property work and acquisition. • Requires improvements on private property. • Does not address fish blockage on private property (4.5 foot water feature).
	Costs	$0	$1,200,000[1]	$0	$902,400	$2,103,000

[1] Assumes $400,000 for public portion of culvert, $700,000 for private property acquisition and improvements to the acquired property, and $100,000 for extending the culvert under private access road.

REFERENCES

The following design manuals, technical memorandums and reports were reviewed to develop this report:

Memoranda prepared as part of this project

Conceptual Design for Lower Taylor Creek - Data Gaps Memorandum, 2010, Osborn Consulting Inc. (Appendix C)

Conceptual Design for Lower Taylor Creek - Design Constraints and Considerations Memorandum, 2010, Osborn Consulting Inc. (Appendix A)

Conceptual Design for Lower Taylor Creek - Hydrologic and Hydraulic Analysis Memorandum, 2010, Osborn Consulting Inc. (Appendix B)

Documents prepared by others

Design of Road Crossings for Fish Passage, 2003, Washington State Department of Fish and Wildlife (WDFW)

PERC Map and CAD files provided by SPU

The Taylor Creek, Phase 2 Predesign Report on Creek Improvement Alternatives near Rainier Avenue, 2000, Thomas/Wright, Inc.

Taylor Creek Sediment Study, July 2007, Perkins Geosciences

Chrzastowski, M. 1983. Historical changes to Lake Washington and route of the Lake Washington Ship Canal, King County, Washington. Department of the Interior, U.S. Geological Survey, WRI 81-1182

Tabor et al. 2002. Nearshore Habitat use by Juvenile Chinook in Lentic Systems of Lake Washington Basin, Annual Report 2002. U.S. Fish and Wildlife Service

LOWER TAYLOR CREEK CONCEPTUAL DESIGN
EXISTING CONDITIONS

Seattle Public Utilities

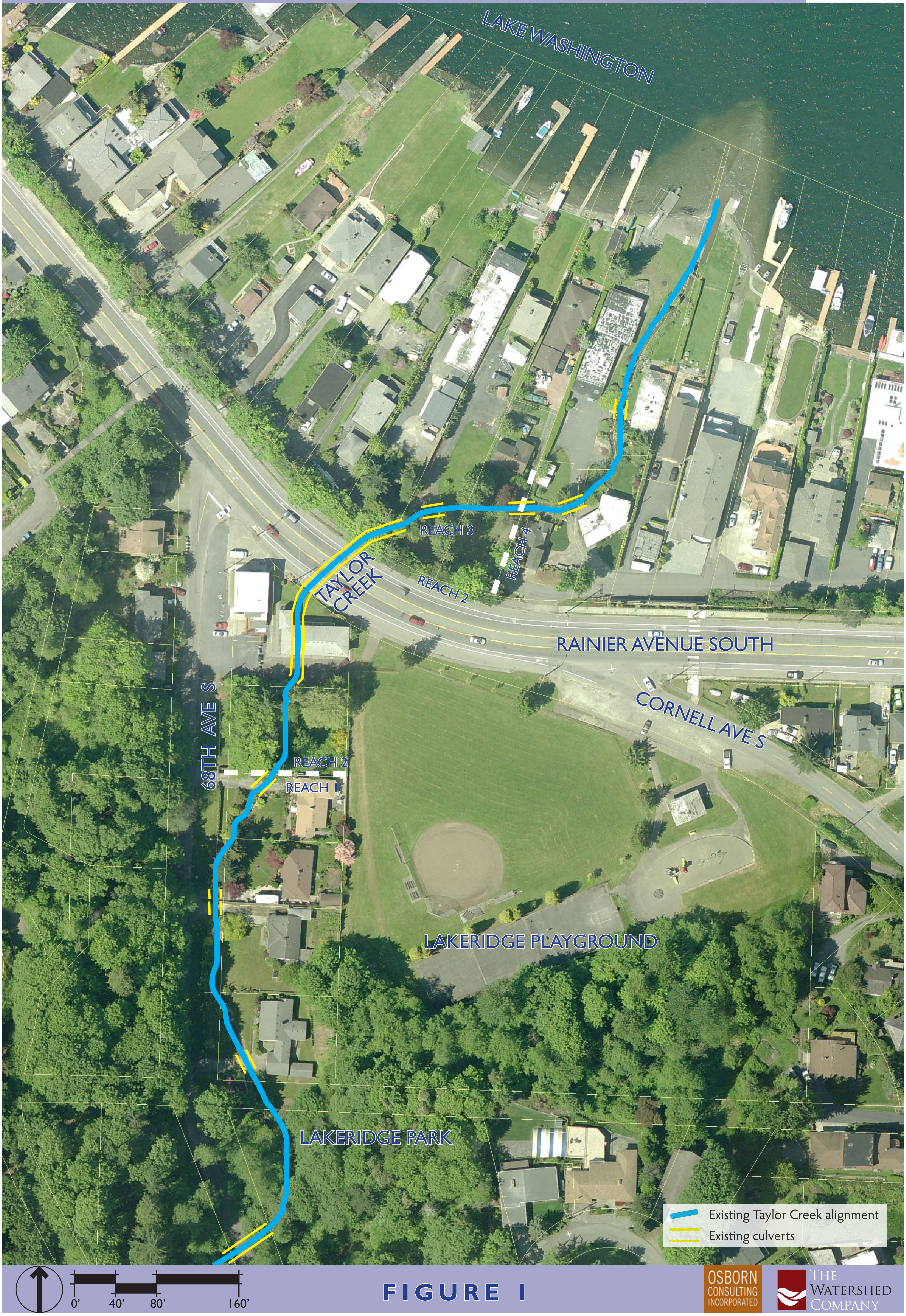


FIGURE 1

OSBORN CONSULTING INCORPORATED
THE WATERSHED COMPANY

LOWER TAYLOR CREEK CONCEPTUAL DESIGN
ALIGNMENT OVERVIEW

Seattle Public Utilities

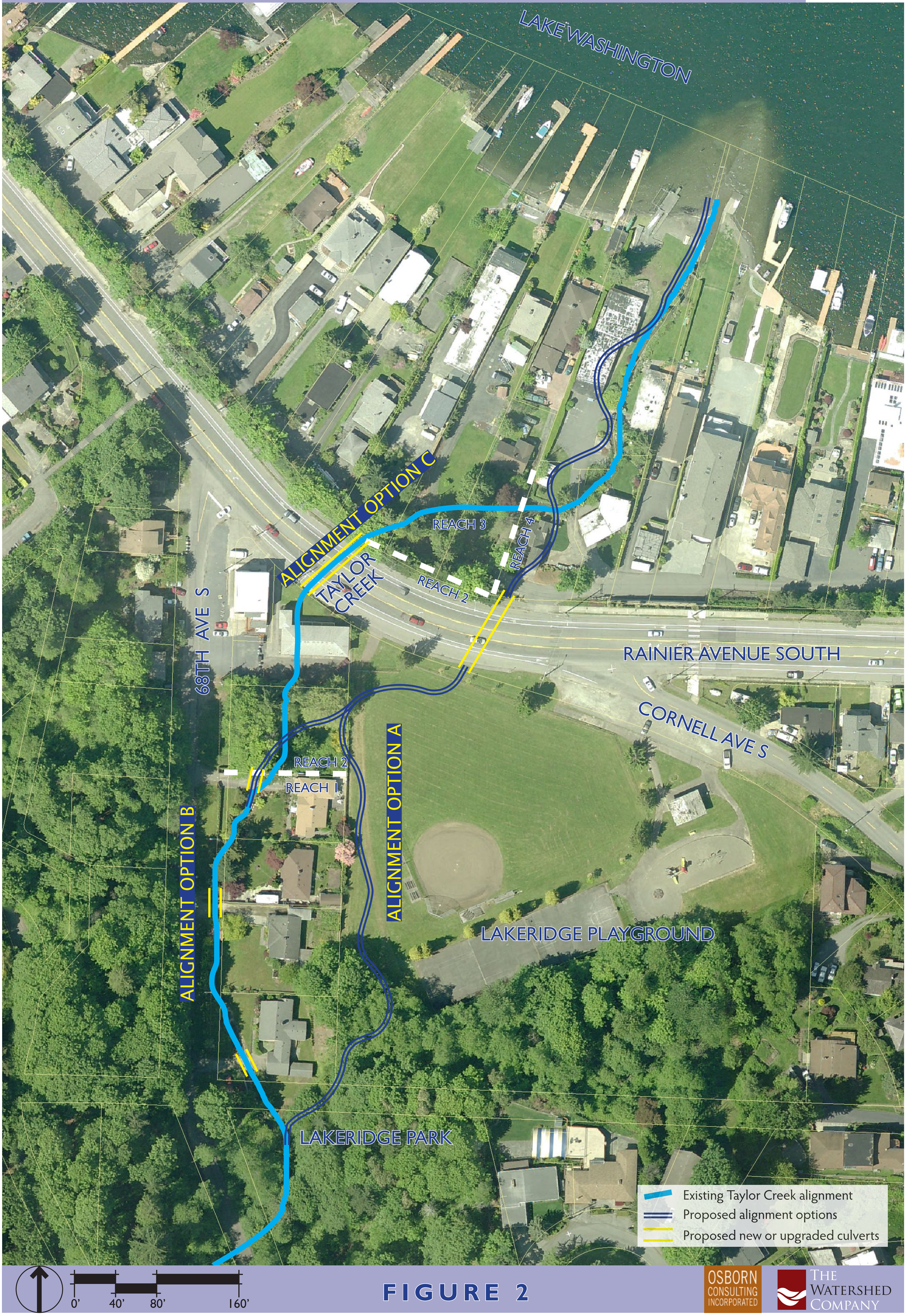


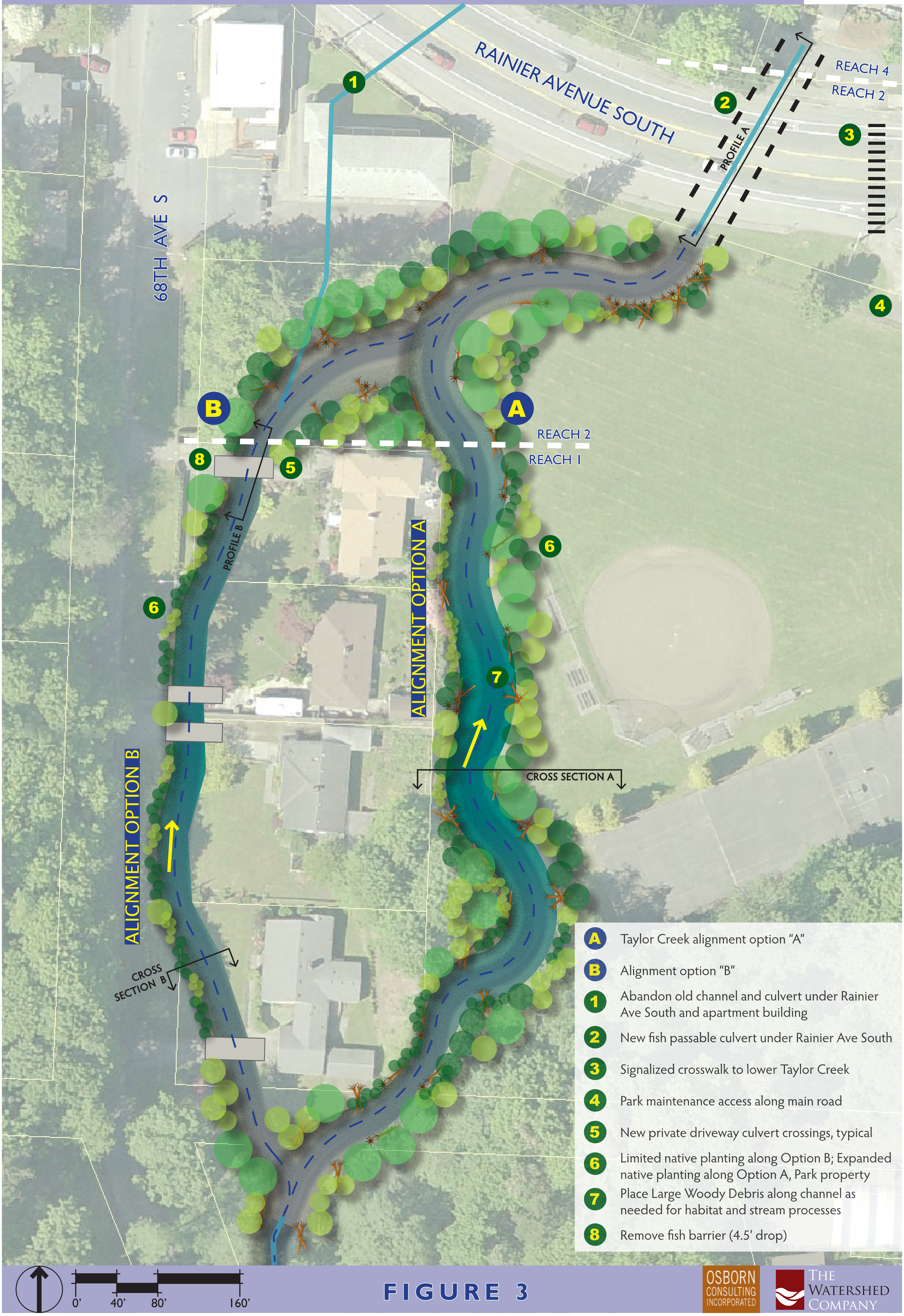
FIGURE 2

OSBORN CONSULTING INCORPORATED

THE WATERSHED COMPANY

TAYLOR CREEK CONCEPTUAL DESIGN
UPPER REACH ALIGNMENT ALTERNATIVES

Seattle Public Utilities



- **A** Taylor Creek alignment option "A"
- **B** Alignment option "B"
- **1** Abandon old channel and culvert under Rainier Ave South and apartment building
- **2** New fish passable culvert under Rainier Ave South
- **3** Signalized crosswalk to lower Taylor Creek
- **4** Park maintenance access along main road
- **5** New private driveway culvert crossings, typical
- **6** Limited native planting along Option B; Expanded native planting along Option A, Park property
- **7** Place Large Woody Debris along channel as needed for habitat and stream processes
- **8** Remove fish barrier (4.5' drop)

FIGURE 3

OSBORN CONSULTING INCORPORATED

THE WATERSHED COMPANY

TAYLOR CREEK CONCEPTUAL DESIGN
LOWER REACH LAYOUT

Seattle Public Utilities

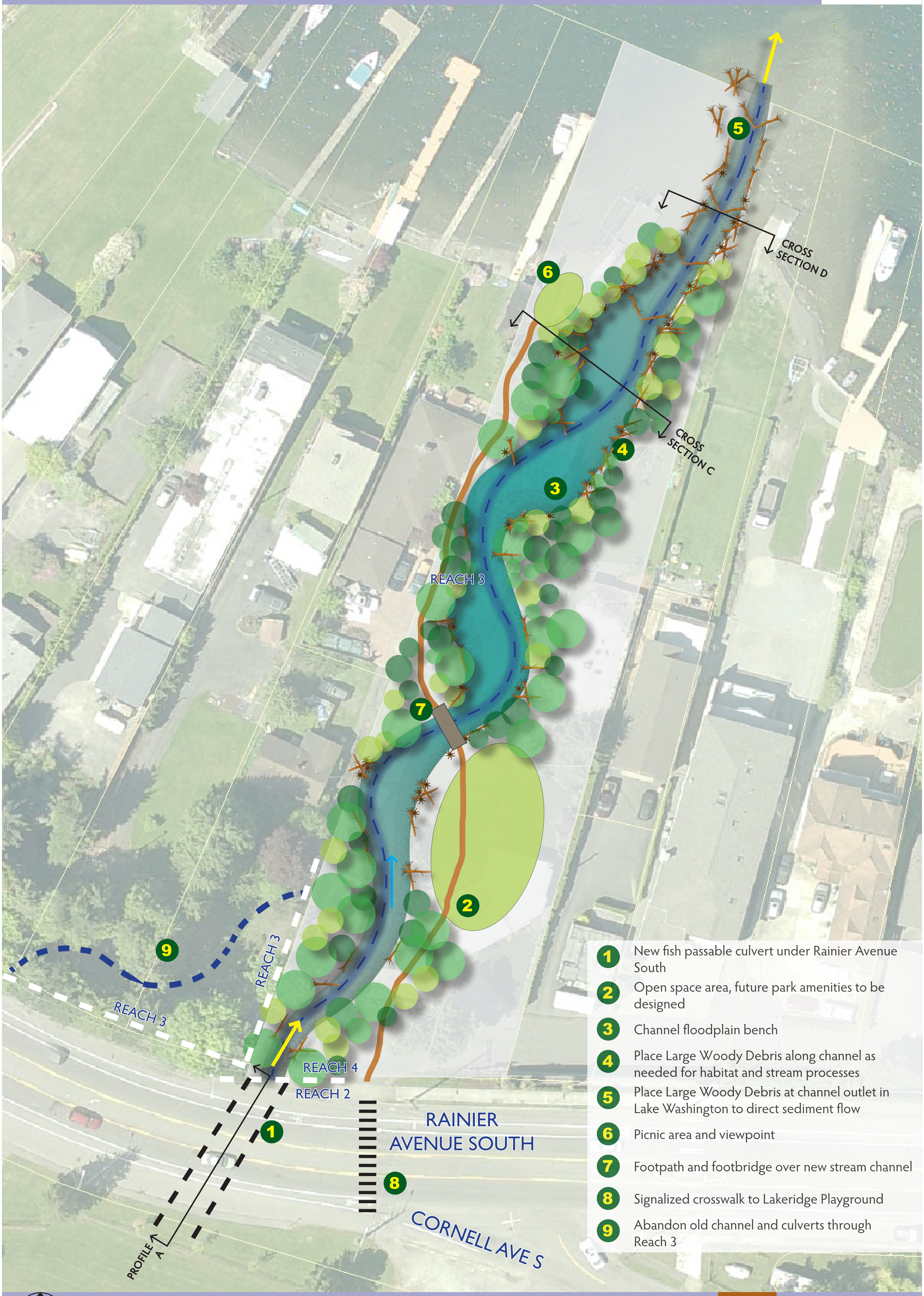


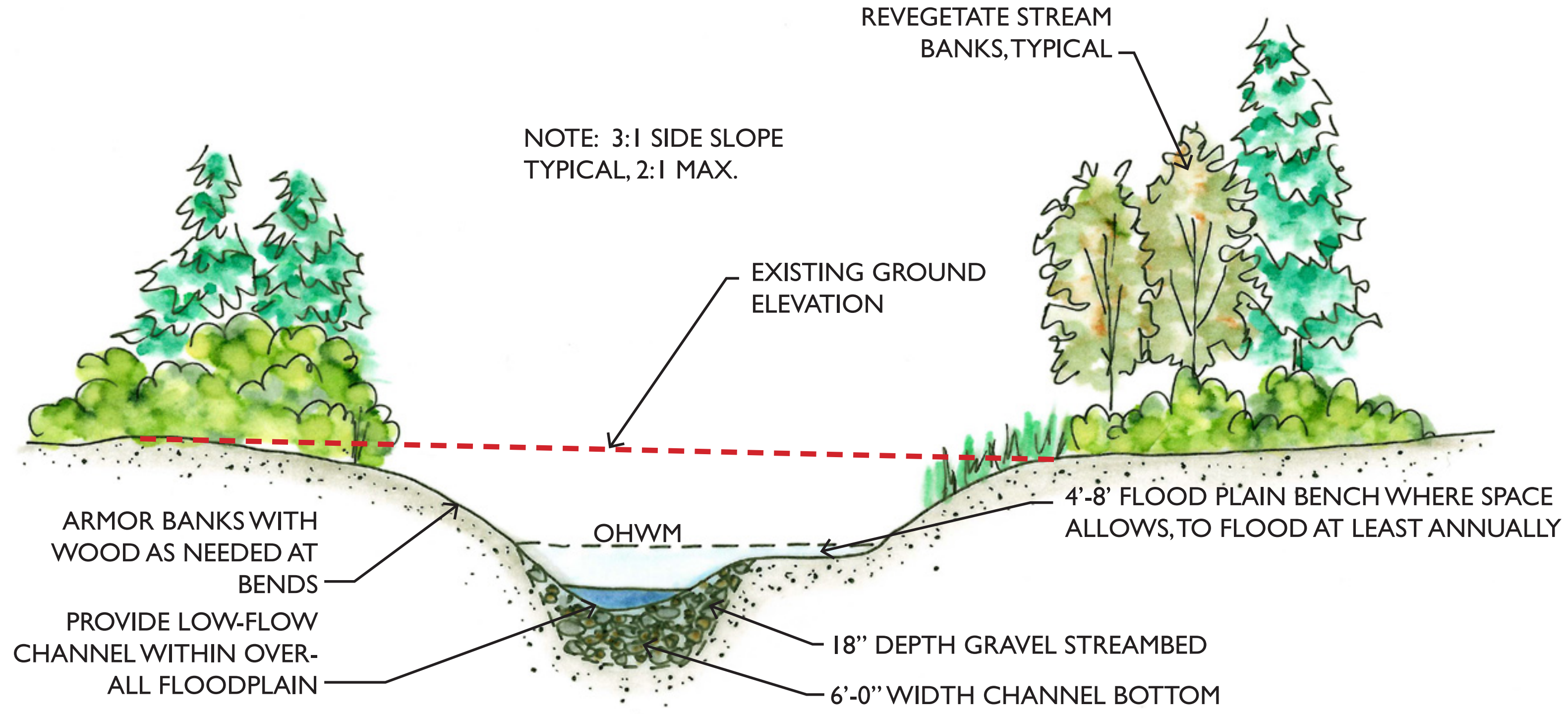
FIGURE 4

OSBORN CONSULTING INCORPORATED

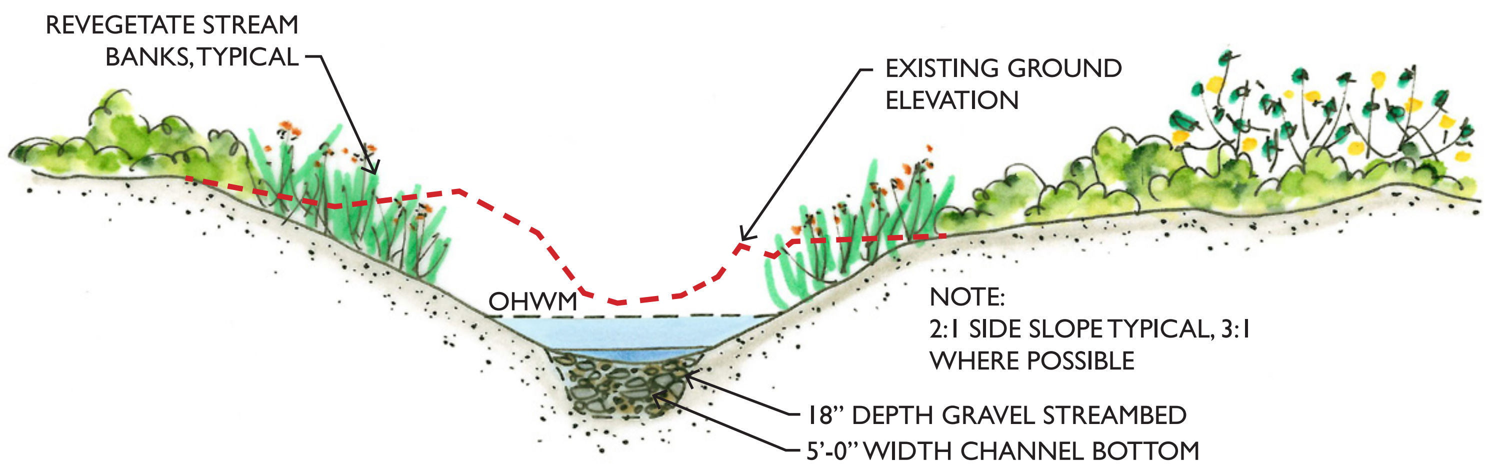
THE WATERSHED COMPANY

TAYLOR CREEK CONCEPTUAL DESIGN
CROSS SECTIONS

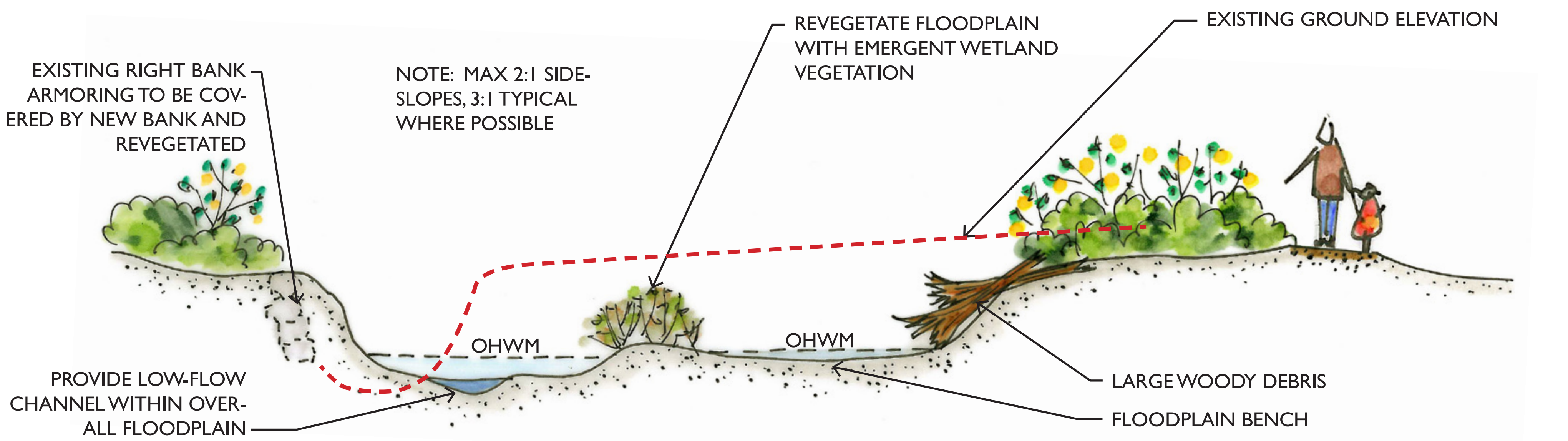
Seattle Public Utilities



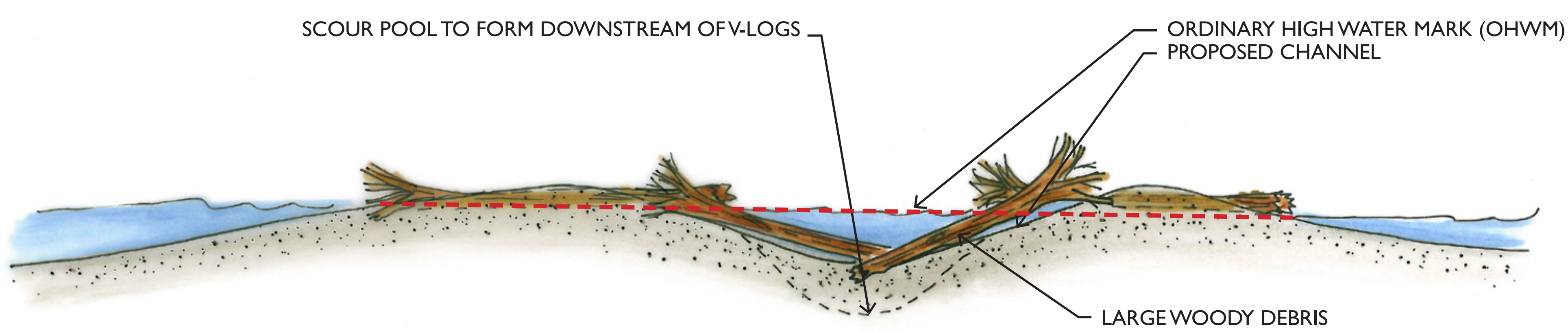
A CROSS SECTION A - Reach 1 through Lakeridge Playground



B CROSS SECTION B - Reach 1 section through residences, typ.



C CROSS SECTION C - Reach 4 section through channel and floodplain bench



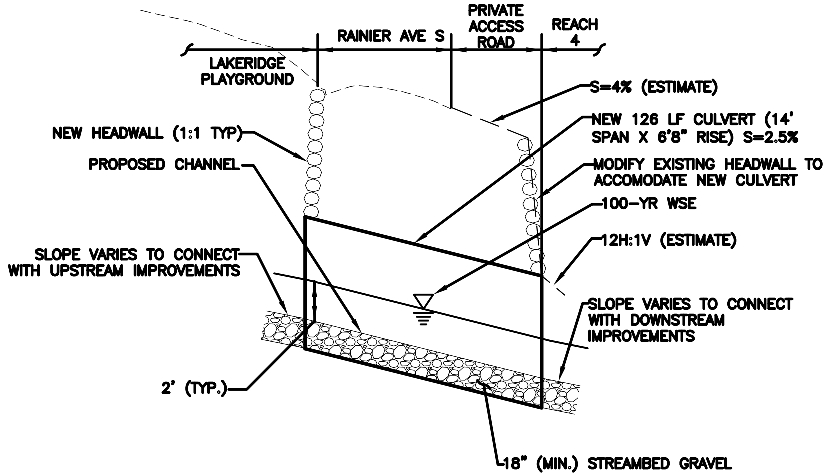
D CROSS SECTION D - Reach 4 outlet to Lake Washington

0' 5' 10' 20'

FIGURE 5

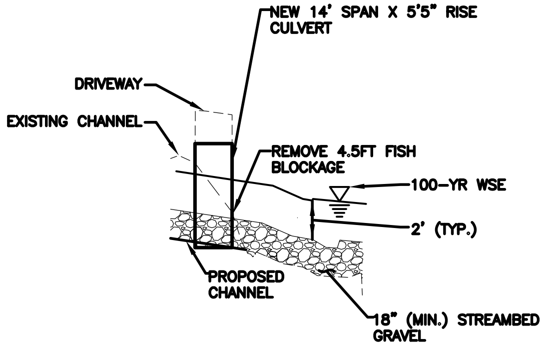
OSBORN CONSULTING INCORPORATED

THE WATERSHED COMPANY



A RAINIER AVENUE SOUTH CULVERT PROFILE VIEW

VERTICAL SCALE: 1"=100'
HORIZONTAL SCALE: 1"=10'



B DRIVEWAY CULVERT PROFILE VIEW

VERTICAL SCALE: 1"=100'
HORIZONTAL SCALE: 1"=10'

FIGURE 6: LOWER TAYLOR CREEK CONCEPTUAL DESIGN
CULVERT PROFILE DRAWINGS

Seattle Public Utilities

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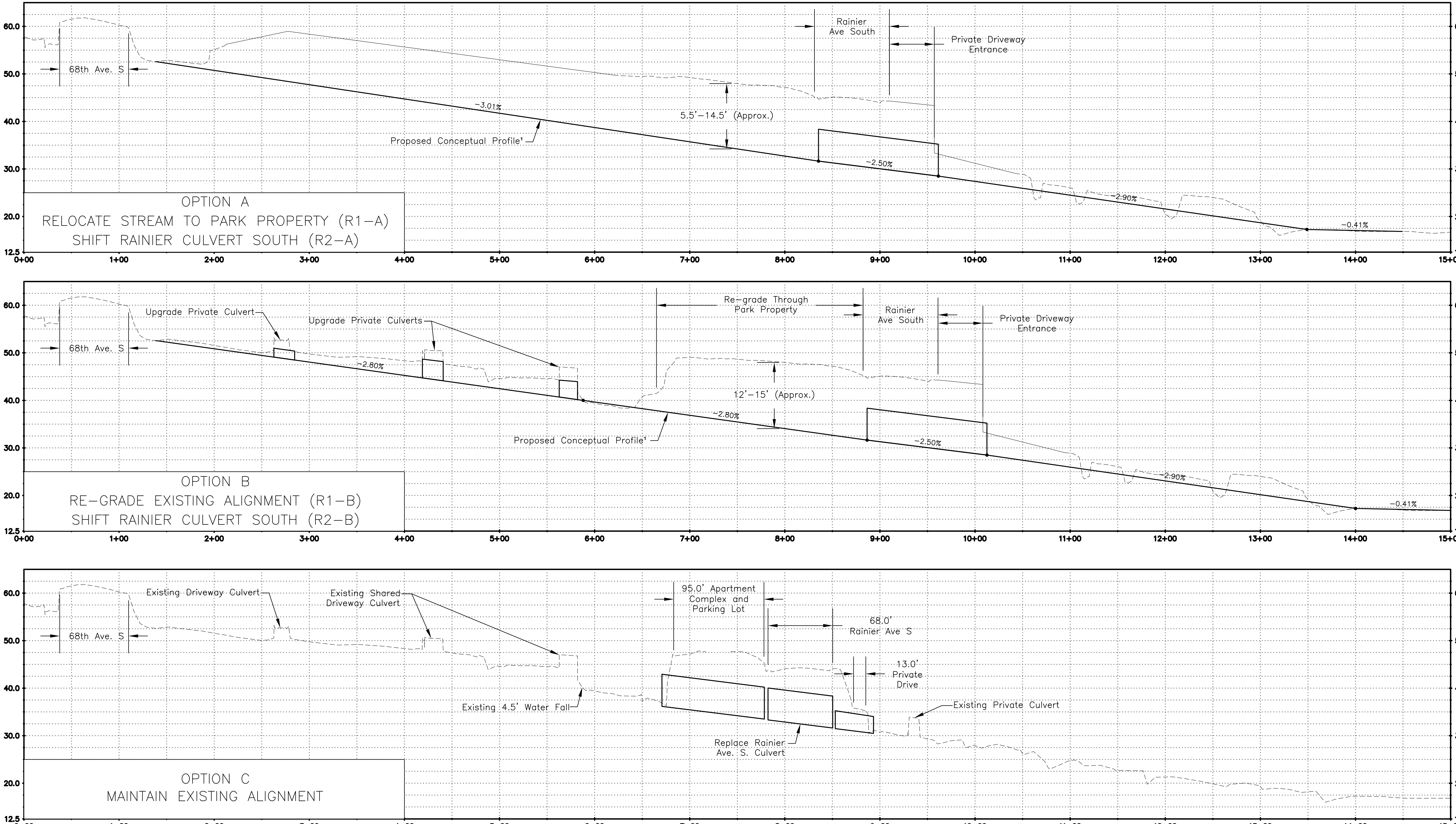
THE WATERSHED COMPANY



Legend

Existing Ground Profile — Estimated Surface Data — Proposed Conceptual Profile¹ — Proposed Culvert

FIGURE 7 – PROFILE VIEWS

1. Sediment Transport Analysis and Additional Design Needed to Determine Actual Average Slope and Slope Variation.

DESIGNED BY	TJO
DRAWN BY	BAY
CHECKED BY	LCR

OSBORN CONSULTING INCORPORATED
OSBORN CONSULTING, INC.
10800 NE 8th Street, Suite 150 Ph (425) 451–4009
Bellevue, WA. 98004 Fax (425) 451–4901

NO.	DATE	REVISION	BY

Seattle Public Utilities
Drainage and Wastewater Quality Division
Seattle, WA 98124

Lower Taylor Creek
Preliminary Concept Designs
FIGURE 7 – PROFILE VIEWS

JOB# / DWG	DATE
10-100045	02/21/11
SCALE	SHEET
H: 1"=100 V: 1"=20	1 of 1

Appendix A: Conceptual Design for Lower Taylor Creek – Design Constraints and Considerations Memorandum, 2010, Osborn Consulting, Inc.

10800 NE 8TH STREET
SUITE 150
BELLEVUE, WA 98004
(425) 451-4009

Date:	November 08, 2010
To:	Julie Crittenden, Project Manager, Seattle Public Utilities
CC:	Greg Johnston, The Watershed Company
From:	Laura Ruppert, P.E., and Tarelle Osborn, P.E. Osborn Consulting, Inc.
Subject:	Conceptual Design for Lower Taylor Creek – Design Constraints and Considerations Memorandum

Table of Contents

REFERENCES

The following design manuals, technical memorandums and reports were reviewed in the development of this memorandum:

- *Design of Road Crossings for Fish Passage*, 2003, Washington State Department of Fish and Wildlife (WDFW)
- *Anadromous Salmonid Passage Facility Design*, National Marine Fisheries Service Northwest Region, February 2008, (NOAA Fisheries)
- *Taylor Creek Culverts Phase 2 – 90% Plans*, August 2005, Seattle Public Utilities.

INTRODUCTION

This memorandum presents the design constraints and considerations that will affect the design and implementation of the Lower Taylor Creek Improvements project. The project includes replacement of the culvert under Rainier Avenue South and adjacent private property, lower Taylor Creek stream enhancement, and flood reduction and habitat improvement along the entire reach as well as the shoreline. This work is being conducted by Osborn Consulting, Inc. (OCI) under contract with Seattle Public Utilities (SPU).

BACKGROUND AND PURPOSE

SPU has been studying the lower reach of Taylor Creek for several years with the goal of removing its fish passage barriers, alleviating flooding and excessive sediment loading, and restoring stream habitat for anadromous salmonid fish and other aquatic and terrestrial wildlife. Taylor Creek runs from the Skyway area of unincorporated King County into Lakeridge Park/Deadhorse Canyon in the City of Seattle and ultimately discharges to southern Lake Washington (see **Figure 1**). The culvert under Rainier Avenue South is the #1 SPU fish passage barrier on the city-wide prioritized list of projects. With the recent acquisition of properties near the Lake Washington shoreline downstream of the Rainier Avenue South culvert; the goals of the project now include improving lake shore habitat and creating a passive recreational site near the lake front. The purpose of this conceptual design work is to take a comprehensive look at all of the goals and develop possible stream alignments and culvert configurations.

Figure 1: Vicinity Map

OCI, under contract with SPU, will develop stream/culvert conceptual alternatives that consider project objectives and assess alternative advantages, disadvantages, and cost. This work assignment will support discussions with the Taylor Creek community and stakeholders and development of an implementation business case for SPU. The main project objectives will include:

- Replace the Taylor Creek culvert under Rainier Avenue South to provide full fish passage.
- Improve stream, floodplain, riparian and shoreline habitat with the goals of improving fish passage throughout the project area, spawning and rearing conditions for native salmonids, and restoring more natural sediment transport.
- Create passive recreational opportunities and enhanced pedestrian connection to the lake shoreline.
- Minimize detrimental impacts to surrounding properties owners from the change in land use at the project site.
- Address flooding issues on properties adjacent to the creek.

The Consultant Team, including OCI and The Watershed Company (TWC), along with SPU and Parks staff visited the project site on October 19, 2010. The Consultant Team reviewed the existing documents and stream conditions. Following the visit and review of existing documentation, the following design constraints and considerations memorandum was prepared.

EXISTING SITE CHARACTERISTICS

The project area under consideration in this contract is lower Taylor Creek from just upstream of the lower 68th Avenue S. culvert to the shoreline of Lake Washington (see **Figure 2: Project Evaluation Area**). Following is a summary of the existing site characteristics starting at the upstream end of the project limits.

The fish passable culvert under 68th Avenue S. was installed in 1999, however, the weir immediately upstream of the culvert has a vertical drop that limits fish passage during certain conditions. Taylor creek flows downstream through the front yards of four private properties and corresponding driveway culverts along 68th Avenue S. Owners of these private properties have reported that the creek overtops its banks and floods their properties. The creek flows over a 4.5 foot vertical drop downstream of the 10020 68th Avenue S. property driveway (upstream of SPU property). This drop is a major fish passage barrier in the project evaluation area. The creek daylights for a short distance in the SPU property and flows into a 36-inch diameter, 100 foot long concrete culvert. This private culvert is under an apartment complex next to Rainier Avenue S. This private apartment complex is showing signs of settling around the culvert. The downstream end of the 36-inch private culvert connects to the publically-owned culvert across Rainier Avenue S. The video inspection indicates that this transition includes a drop and is failing. The Rainier Avenue S. culvert is a 90 foot long box culvert which is 3-feet tall and 6-feet wide.

Immediately downstream of the box culvert, the creek flows through a 16-foot long, 42-inch round concrete culvert which passes under a shared private roadway/driveway that parallels Rainier Avenue S approximately ten feet lower below the Rainier Avenue S roadway elevation. The three part culvert system passing below Rainier Avenue S is a fish barrier.

Continuing downstream, the creek daylights and flows into a 15 foot long half pipe on private property. Taylor Creek meanders through several culverts and open channel sections on the private property that SPU is planning to acquire before reaching Lake Washington.

There is a delta where the mouth of Taylor Creek meets Lake Washington. The delta limits the use of docks by adjacent property owners. Fish passage by adult returning salmonids across the delta is limited because there is not a clearly defined channel and at times flow is too shallow for fish to swim upstream into Taylor Creek. Recent sediment studies by others indicate the primary sources of sediment loading are mass wasting and channel erosion in Deadhorse Canyon (upper section of Lakeridge Park) exacerbated by the high and flashy flows of an urbanized basin and an incised creek channel.

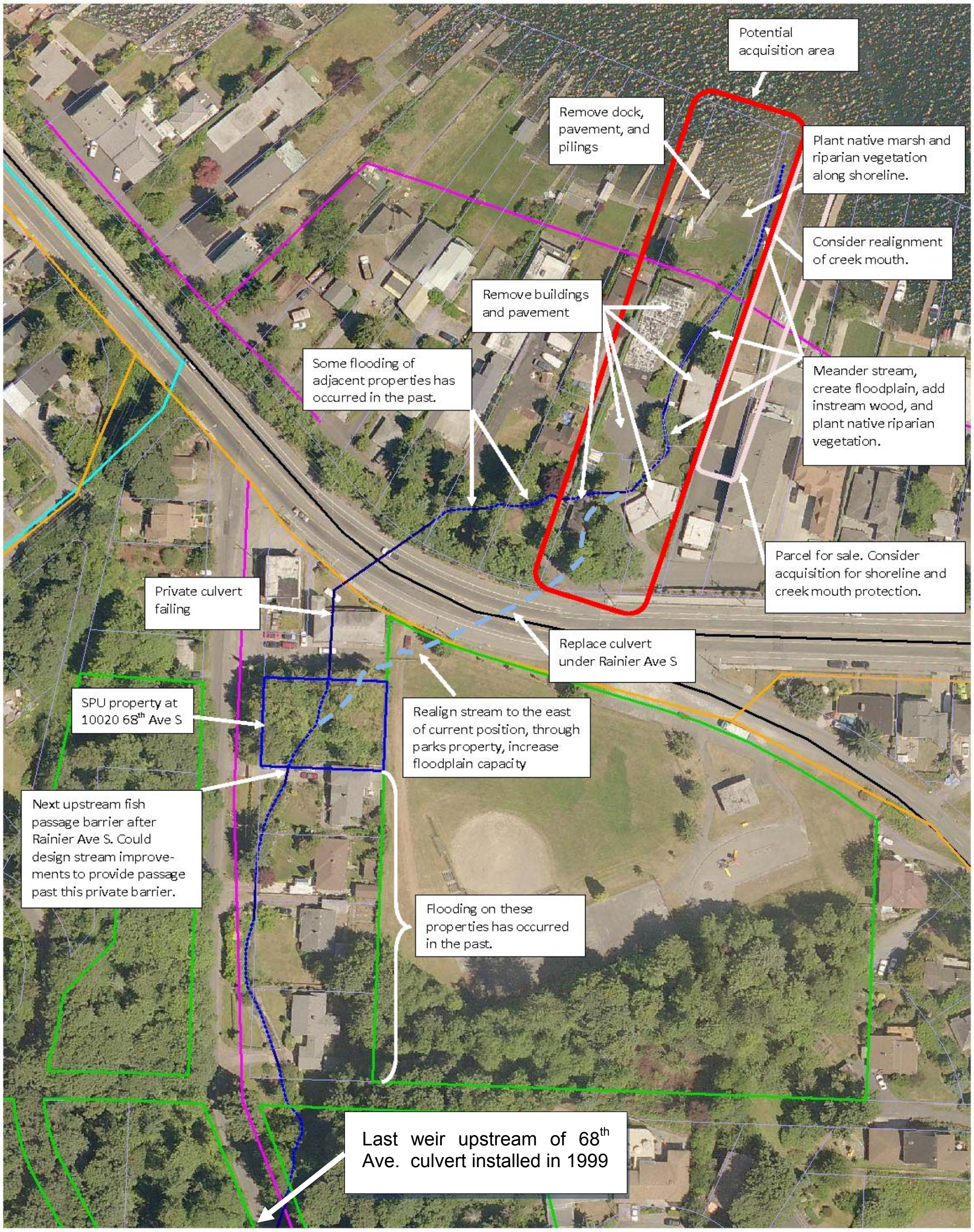


Figure 2: Project Evaluation Area

PROJECT SITE LIMITING FACTORS/CONSTRAINTS

Based on site reconnaissance and review of the base map and technical documents furnished by SPU, the following project site limiting factors or constraints have been identified to fulfill the project goals and objectives.

- Limited Right-of-Way along 68th Avenue S. may limit the design options available on channel improvements and fish blockage removal at private driveways
- Reducing the jump height at the 4.5-foot water fall (downstream of 10028 68th Avenue S.) may require channel modifications across the four upstream private properties on 68th Avenue S. in order to make up the grade. Some of this channel regrading could occur passively if the weir were removed or lowered and the channel were allowed to regrade itself upstream. Ideally, large woody debris and channel complexity added to the downstream reach would help to trap the sediment from the natural regrading process and allow for a more natural transport to the mouth. This would need to be analyzed and carefully considered during design.
- New alignments of Rainier Avenue S. culvert will be on Parks property. The constraints associated with this will be coordination with Parks Department to:
    - Maintain the purpose of the field and the ball field dimensions
    - Provide maintenance access
- There are some constraints associated with crossing Rainier Avenue S. as stated below,
    - Rainier Avenue S. is a busy arterial road which will limit construction method and schedule
    - Conflict with utilities along Rainier Avenue S. has to be considered
    - Permitting Limitations: Previous preferred alternative of baffles through one existing culvert was not accepted by WDFW
- Constraints associated with private properties downstream of Rainier Avenue S. include
    - Narrow Channel
    - Public opinion on location of creek is unknown
- Inverts of existing culvert/structures on private property that will remain will be a design constraint. These fixed points along the stream gradient will determine the extent that the profile can be modified and still provide fish, sediment and water passage.
- In the SPU property acquisition area downstream of Rainier Avenue S. culvert,
    - Location of existing sewer has to be evaluated
    - Public opinion on public recreational facility is unknown
    - Narrow property limits options for delta restoration
    - Permitting might limit improvements to existing delta (i.e. extending the channel into the lake, above- and below-surface grading to provide optimum depths for juvenile Chinook, etc.)
- Sediment transport in Taylor Creek and the delta in Lake Washington may constrain options for improvements at the mouth.

- Lake Washington has a “reverse hydroperiod” imposed by the Hiram Chittenden Locks at Ballard whereby the lake level is managed to be higher in summer and lower in winter, which is the opposite of what would tend to occur in a more natural lake system. The reverse hydroperiod creates design constraints because it results in shallower water at the mouth of the creek in the fall when adult salmonids migrate upstream to spawn. The reverse hydroperiod also limits planting emergent vegetation along the shoreline which might benefit juvenile Chinook salmon.

PROJECT DESIGN CRITERIA AND CONSIDERATIONS

The design criteria that will govern the project are briefly discussed below.

FISH PASSAGE DESIGN CRITERIA

The *Design of Road Crossings for Fish Passage* (Washington State Department of Fish and Wildlife (WDFW), 2003) manual will be used as a guideline for fish passage improvements. We anticipate using the no-slope or stream simulation design option because they are the least design intensive and are WDFW’s preferred design options. The hydraulic design option would only be used if the no-slope or stream simulation options result in a culvert that is too large to fit within the constraints (geometry and/or utility) of Rainier Avenue S.

The ***no-slope design option*** is a simplified fish passage design which requires few technical calculations or additional survey. According to this design option, the width the culvert must be at least as wide if not wider than the channel bankfull width. The culvert is installed with no-slope and is countersunk a minimum of 20-percent at the downstream end and maximum 40-percents at the upstream end. This design option results in culverts suitable for passage by adults and juveniles of all species.

The ***stream simulation design option*** is similar to the no-slope deign option in that very few technical calculations are necessary and it results in culverts wider than the channel bankfull width. The difference with the stream simulation design option is that the culvert can be installed at a slope of up to 125-percent of the upstream channel slope. Stream simulation culverts are usually the preferred alternative for steep channels and longer crossings. This design option results in culverts suitable for passage by adults and juveniles of all species.

The ***hydraulic design option*** is the least preferred design option by WDFW. This design option should only be considered if the no-slope and stream simulation design options result in culverts that are larger than what will work within the existing site constraints. Of the three options, the hydraulic design option is the most design intensive and typically results in smallest culverts.

Under the hydraulic design option, the culvert is sized to meet velocities and flow depth criteria for the target fish species for passage within the migration season. The velocity and depth criteria are intended to provide passage conditions for the weakest and smallest individuals of each species. WDFW does not define fish passage criteria for juvenile salmonids. Instead, WDFW assumes passable conditions for juveniles if the design meets the need of adult trout. To establish more conservative design standards for juvenile passage, the Anadromous Salmonid Passage Facility Design, (NOAA Fisheries, 2008) will be used as a guideline for juvenile fish passage design criteria. **Table 1** provides the design criteria for culvert installation under the Hydraulic design option.

Table 1: Fish Passage Design Criteria for Culvert Installation

Design Criteria (for culverts 60 to 100 LF)	Adult Trout	Adult Pink or Chum Salmon	Adult Chinook, Coho, Sockeye, or Steelhead	Juvenile Salmonids*
Maximum Velocity (feet per second)	4.0	4.0	5.0	1.0
Minimum Water Depth (feet)	0.8	0.8	1.0	0.5
Maximum Hydraulic Drop in culvert (feet)	0.8	0.8	1.0	0.13-0.33
Maximum Hydraulic Drop at a weir (feet)				0.7-1.0

* Juvenile Design Criteria from *Anadromous Salmonid Passage Facility Design,* (NOAA, 2008)

Therefore, the criteria in **Table 1** should be the goal for improvement but not necessarily the required design threshold.

CONVEYANCE DESIGN CRITERIA

The channel and culvert will be designed in accordance with the following recommended guidelines:

- One foot minimum freeboard will be provided between the 25-year water surface elevation and the top of the banks.
- Safe conveyance of the 100-year storm.
- Design flows will be derived from gage data provided by SPU.

Where the guidelines above do not fit within site constraints, then the following deviations may be acceptable:

- Infrequent flooding of Lakeridge Playground (based on discussions during 10/19/10 site visit suggest).
- Proposed water surface elevations shall not exceed existing water surface elevations.

STABLE CHANNEL DESIGN

Streambed gravel design will be designed in accordance with recommendations provided in the WDFW *Design of Road Culverts for Fish Passage* 2003 resulting in a streambed gravel gradation that represents a natural sediment distribution. A quick sheer stress analysis for the bed and bends will be conducted for straight reaches and bends in the channel. The recommended stable channel design will include cross section that vary in bank treatments or stream features as necessary at various cross sections to withstand the calculated shear stress. The bank treatments can vary from rock armored or series of Large Woody debris (LWD) along with straw, coir mats, vegetation etc.

LAKE WATER LEVEL FLUTUATION

Conceptual restoration designs will account for the reverse hydroperiod of Lake Washington in improving creek access for adult salmonids in the fall and maintaining shallow rearing habitat for juvenile Chinook salmon in the spring.

PUBLIC INVOLVEMENT

Discussions during the 10/19/10 site visit suggested there may be some flexibility in channel alignment/dimension with regard to private property. For example:

- Are home owners who currently flood open to channel improvements on their private property that may provide them with a flood improvement in addition to the design goals stated above?
- Do property owners see the creek as an asset? Would they be upset to see it relocated?

Public Involvement is not included in OCI's scope of work for this project. Public opinions, if provided, will be taken into consideration during the alternatives analysis.

CONSTRUCTION STANDARDS

The following documents and guidelines will be used in developing conceptual plans and cost estimates for the project.

- American Public Works Association (APWA), Standard Specification.
- Washington State Department of Transportation (WSDOT) Standard Specifications for Road, Bridge, and Municipal Construction, 2010.
- Department of Ecology (DOE), Stormwater Management Manual for Western Washington, 2005.
- City of Seattle's Standard Specifications and Standard Plans for Road, Bridge and Municipal Construction, 2011 (to be published at the beginning of the year)
- Seattle Department of Transportation (SDOT), Seattle Right-of-Way Improvements Manual.
- Seattle Department of Transportation (SDOT), City of Seattle Traffic Control Manual for In-Street Work, 2005.

- Seattle Department of Transportation (SDOT), Street and Sidewalk Pavement Opening and Restoration, Director's Rule 5-2009

More specific guidelines will developed later as this project moves into final design.

NEXT STEPS:

Data Gap Memorandum

A data gap memorandum accompanying this technical memorandum has been prepared to identify the data gaps and provide recommendations to address high priority gaps. Follow up with SPU is needed to obtain missing data identified in this memorandum that is critical to move forward with the next task identified in the project contract.

Hydraulic Analysis

A technical memorandum documenting culvert and stream design flow conditions, culvert sizing recommendations, and stream/floodplain sizing recommendations will be submitted on or before November 12, 2010.

Brainstorming Session

A brainstorming session is scheduled for November 16, 2010 with the SPU project team. The session will involve developing and analyzing different alternatives or solutions to address the project objectives. This session will be extremely valuable and cost effective, as the SPU project team's experience and familiarity with the project will help identify and/or eliminate alternatives and assess its feasibility quickly. OCI will then develop, in detail, each alternative and evaluate its advantages and disadvantages along with rough project cost for each alternative. Results of this study will be presented to SPU in December 2010.

Appendix B: Conceptual Design for Lower Taylor Creek – Hydrologic and Hydraulic Analysis Memorandum, 2010, Osborn Consulting, Inc.

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BELLEVUE, WA 98004
(425) 451-4009

Date:	November 22, 2010
To:	Julie Crittenden, Project Manager, Seattle Public Utilities
CC:	Greg Johnston, The Watershed Company
From:	Laura Ruppert, P.E., and Tarelle Osborn, P.E. Osborn Consulting, Inc.
Subject:	Conceptual Design for Lower Taylor Creek – Hydrologic and Hydraulic Analysis Memorandum

Table of Contents

PURPOSE

This memorandum documents hydrologic and hydraulic analysis performed by Osborn Consulting Inc. (OCI) including: design flow, culvert size, and stream and floodplain recommendations. This memorandum is a Task 2 Deliverable. For project background and description of existing site conditions please reference *Conceptual Design for Lower Taylor Creek - Design Constraints and Considerations Memorandum.* The recommendations provided in this memorandum will aid in the qualitative analysis of design alternatives. However; recommendations should be revisited when the preferred alternative progresses to a design phase.

REFERENCES

The following design manuals, technical memorandums and reports were reviewed in the development of this memorandum:

- *Design of Road Crossings for Fish Passage*, 2003, Washington State Department of Fish and Wildlife (WDFW)
- SPU flow gage data (STA 401) February 2004 - September 2010.
- PERC Map and CAD files provided by SPU
- Conceptual Design for Lower Taylor Creek - Design Constraints and Considerations Memorandum, 2010, Osborn Consulting Inc.
- Conceptual Design for Lower Taylor Creek - Data Gaps Memorandum, 2010, Osborn Consulting Inc.
- Guidelines for Determining Flood Flow Frequency - Bulletin 17B of the Hydrologic Subcommittee; 1981; U.S. Department of the Interior Geological Survey
- The Taylor Creek, Phase 2 Predesign Report on Creek Improvement Alternatives near Rainier Avenue, 2000, Thomas/Wright, Inc.
- Taylor Creek Sediment Study, July 2007, Perkins Geosciences

HYDROLOGIC ANALYSIS

As explained in OCI's 2010 *Conceptual Design for Lower Taylor Creek - Data Gaps Memorandum*, previous hydrologic analysis performed by others predicted design flows that greatly exceeded recorded gage flows automatically collected from 2004 to 2010. For example, the 2-yr peak flow predicted by SBUH and SWMM analyses were over 30-percent greater than the maximum peak flow recorded on the gage. Since the gage period of data includes some record precipitation events for the region, we know the flow analyses performed by others are too high.

In view of this discrepancy, it was decided (by SPU and OCI) that the six years of stream flow data from gage STA401 (2/4/2004 through 9/15/2010) was the best available information and a flow frequency analysis was performed to generate peak design flows. Typically flow frequency analyses are performed using a longer period of record; however; this remains the preferred method for this project since the predicted flows from the 1999 report are so far off from gage data. Gage STA401 is located on the mainstem of Lower Taylor Creek within the project area.

FLOW FREQUENCY ANALYSIS

Flow Frequency Analysis (FFA) is performed using the annual peak flow for each year in the period of record. The STA401 gage data did not have complete years for 2004 (missing January) or 2010 (missing October-December). Since the missing months are typically high flow months in Seattle, the accuracy of the annual peak estimate is affected. To mitigate this, peak flows were estimated by averaging the peak flows of the missing month in the other years provided. For example, the peak monthly flow used for January 2004 is the average of the peak monthly January flow for years: 2005 through 2010. The monthly peaks and annual peak flows are summarized in **Table 1**.

Table 1: Gage STA401 Monthly and Annual Peak Flows

Year	2004	2005	2006	2007	2008	2009	2010
January	47.69	55.83	66.21	52.59	12.36	64.41	34.72
February	9.48	22.57	26.51	24.16	6.59	10.64	9.79
March	8.36	2.33	12.95	15.37	13.25	10.77	31.50
April	1.09	30.03	8.54	4.46	5.88	29.83	20.24
May	12.03	14.65	5.65	7.12	10.15	17.99	13.22
June	2.81	69.59	16.64	26.13	13.96	2.73	8.00
July	1.62	10.30	1.11	0.67	7.64	0.47	2.62
August	51.67	4.41	0.27	12.99	36.06	4.60	2.88
September	27.50	7.25	6.30	18.73	2.29	28.81	14.23
October	24.16	9.63	4.01	10.11	4.79	46.38	16.51
November	22.40	16.59	68.29	21.60	33.82	40.63	33.89
December	37.76	41.62	75.18	75.87	13.63	42.37	47.74
Annual	51.67	69.59	75.18	75.87	36.06	64.41	47.74

Gage data not available; value is average of available monthly peaks

The gage data also has some periods (gaps) where no flow rate is provided. Documentation provided with the gage data indicates gaps represent either missing, bad/not useable, equipment failure, or no data available. The data gaps tend to occur at period of very low flow; therefore; the risk that these gaps may contain a peak monthly flow is also very low.

The flow frequency analysis is performed using the Pearson Type III distribution with log transformation of the data (aka log-Pearson Type III distribution) which uses a skew coefficient to calculate statistical peak flows. The skew coefficient is sensitive to extreme events; thus it is difficult to obtain accurate skew estimates from small samples (i.e. samples fewer than 25-years). The accuracy of the estimated skew coefficient can be improved by using a generalized skew, or regional skew, based on data from several nearby sites. Flow frequency calculations were performed using each of the skew coefficients listed below:

- Puget Sound Generalized/Regional Skew = 0.02
- Actual Skew (6-yrs gage data) = (0.86)
- Average of Regional and Actual = (0.42)

The regional skew resulted in the highest and most conservative design flows; therefore those flows were selected for use as design flows. Results of the flow frequency analysis are provided in **Appendix A**. Recommended Lower Taylor Creek Design Flows for conceptual design are provided in **Table 2**.

Table 2 : Lower Taylor Creek Design Flows					
Flow Frequency (years)	1.25	2	10	25	100
Peak Flow (CFS)	46.2	58.2	83.1	95.0	111.8

Further hydrologic analysis should be performed as project moves into the design phase to assure that the peak flows are not sensitive to the assumptions made with the limited gage data.

HYDRAULIC ANALYSIS

Design flows reported above were used for conceptual design of hydraulic components for proposed Lower Taylor Creek cross sections, culverts, and stable channel design.

The project area is broken into four reaches (See **Appendix B** for plan and profile figures). The existing characteristics of open channel sections for each reach are provided in **Table 3**.

- Upper: Aside from the culvert crossing at 68th, this most upstream reach flows primarily through private property. Fish blockages along this reach include driveway culverts and a 4.5-foot drop/water feature.
- Middle - Rainier Avenue S: This reach includes culvert or piped crossings of both public and private (Rainier Ave. S) land.
- Lower Middle - Private: This reach includes open channel and culvert sections of Taylor Creek flowing through private property.
- Lower - Public: This reach includes open channel and culvert sections, the mouth, and delta of Taylor Creek located on property that is currently being acquired by SPU.

Table 3: Existing Channel Characteristics				
	1. Upper	2. Middle-Rainier	3. Lower-Mid	4. Lower
Stations	0+00 to 4+68	4+68 to 7+67	7+67 to 9+50	9+50 to 13+90
Reach Length	468 LF	299 LF	183 LF	440 LF
Average Slope*	2.8% / 1.5%**	3.0%	3.2%	1.8%
Average Bottom Width	4.69 FT	5.78 FT	6.02 FT	6.16 FT
Average Top Width	10.14 FT	16.29 FT	8.25 FT	9.43 FT
Average Depth	1.53 FT	2.91 FT	2.13 FT	2.10 FT
Average Cross Sectional Area	11.34 SF	32.11 SF	15.20 SF	16.37 SF

*Average slope for the entire project reach is 2.6%.

**This average slope of 2.8% is over the entire length of the reach including a 4.5-foot drop (water feature) in the channel. The typical slope through this reach, excluding the 4.5-foot drop is 1.5%.

CHANNEL SLOPE

The average existing channel slope through the project area is 2.6%; comprised primarily of slopes in the 2.0% to 3.0% range as shown in **Table 3** above. At this time it is unknown if the design will maintain the existing average bed slope for each reach, regrade so that the stream throughout the project area has an average slope of 2.6%, or a combination of these options. Because of this uncertainty, this memorandum provides some typical sizing guidelines that can be applied at the conceptual alternative analysis level for a quantitative analysis and alternative screening. The channel width and culvert dimensions vary depending on the channel slope, therefore the recommendations below provide a range of design dimensions indicating the channel width if the slope and/or channel side slopes are modified.

CHANNEL SIZING

Proposed typical channels are sized to convey the design flows provided above using Manning's Equation. Since the proposed alignment and extent of regrading have not been determined, we have sized four typical channel sections to be used as a design guide for establishing the proposed alignment and profile. The proposed trapezoidal channel dimensions provided in **Table 4** are sized to provide 1-ft of freeboard at the 25-year flow and contain the 100-year flow. See **Appendix C** for Manning's Equation Calculations.

Table 4: Proposed Trapezoidal Channel Dimensions				
	A	B	C	D
Profile Slope	2.0 %	2.0 %	3.0 %	3.0%
Side Slope	2H:1V	3H:1V	2H:1V	3H:1V
Bottom Width	6.0 FT	6.0 FT	6.0 FT	6.0 FT
1.25-yr	1.2'd, 10.6'w	1.1'd, 12.6'w	1.1'd, 10.2'w	1.0'd, 12.0'w
25-yr	1.7'd, 12.8'w	1.6'd, 15.6'w	1.55'd, 12.2'w	1.45'd, 14.7'w
100-yr	1.9'd, 13.6'w	1.75'd, 16.5'w	1.7'd, 12.8'w	1.6'd, 15.6'w
Top width = 25-yr WSEL + 1 VFt*	2.7'd, 16.8'w	2.6'd, 21.6'w	2.55'd, 16.2'w	2.45'd, 20.7'w

*One vertical foot freeboard at the 25-yr design storm was identified as a design guideline.

One vertical foot of freeboard at the 25-year design storm also provides nearly a foot of freeboard at the 100-yr storm. If a less conservative design is acceptable to SPU, we might want to consider modifying the design constraint. One option is to provide one foot of freeboard at the 1.25-year water surface elevation and lay back the side slopes to a shallower slope. This option still provides capacity for the 100-yr storm plus potentially more habitat and restores a more natural transport of sediment through the system.

CULVERT SIZING

The culvert sizing recommendations in this section apply to road and driveway crossings throughout the project area. Culvert sizing for this project will need to consider the following:

- WDFW fish passage requirements,
- adequate conveyance capacity,
- freeboard for improved maintenance access and reduced risk of debris clogs.

The OCI design team analyzed sizing for the two preferred WDFW design options: no-slope, and stream simulation. Both design options are based on channel width, as opposed to hydraulic capacity. To establish an existing, bankfull channel width representative cross sections both upstream and downstream of Rainier Avenue South were identified. Stations 3+00 and 8+00 were selected as representative cross sections; both have a bankfull width of 9-feet. The proposed channel widths were also considered. The proposed wetted width at the 1.25-year design flow (a typical channel forming flow) ranges from 10-feet wide to 12.6-feet wide; thus larger culverts are necessary if the bankfull channel is widened.

With the proposed culvert alignment undecided at this time, these culvert dimensions are for conceptual purposes only and will require modifications as the design moves forward. Conceptual level culvert width sizing is provided in **Table 5**.

Table 5: Preliminary Culvert Sizing					
Channel Bankfull Width (dimensions in feet)		No Slope		Stream Simulation	
		Box	Round*	Box**	Round***
Existing	9.0	9.0	11.3	12.8	14.1
Proposed	12.6	12.6	15.8	17.1	18.8

*Diameter = 1.25*width; accounts for reduced width when culvert is countersunk

**Width = 1.2*(bankfull)+2

***Diameter = 1.1*box width

The allowable culvert length varies depending on the design option, culvert rise, and bed slope both through the culvert and the adjacent channel. Since the culvert must be countersunk at either end, a larger rise (or diameter) for the no-slope option allows for a longer culvert. While long culverts are associated with higher cost and fewer habitat benefits, length may be necessary for crossing major arterials such as Rainier Avenue South. As a point of reference, the existing Rainier Avenue South box culvert is 90-feet long and the average length for driveway culverts is approximately 12-feet long. Example allowable culvert lengths for various slopes and diameters are provided in **Table 6**.

Table 6: Estimated Allowable Culvert Lengths

Design Option	Diameter or Rise (ft)	Max Length (ft)	Channel Slope
No slope	5	50	2%
No slope	6	60	2%
No slope	10	100	2%
No slope	5	33	3%
No slope	6	40	3%
No slope	10	67	3%

The benefit of the Stream Simulation option is that it allows for culverts to be sloped so it can accommodate steeper and longer crossings than the No Slope option. This translates into a cost savings associated with shorter and/or lower rise culverts. For example, the stream simulation option will allow for a lower rise culvert to make the Rainier Avenue South crossing and may require shorter culvert lengths at driveway crossings. The actual lengths for Stream Simulation culvert crossings will need to be assessed with site specific information.

Previous study: the *Taylor Creek, Phase 2 Predesign Report on Creek Improvement Alternatives near Rainier Avenue* (Predesign Report) reports that WDFW requested 14-feet wide by 6-feet high box culverts for the Holyoke culverts upstream of our project area. Further, the Predesign Report documents that due to unspecified "space limitations" the optimum width for the culvert crossing the apartment property is 6-feet wide. Based on the channel sizing performed above, a 6-feet wide culvert has hydraulic capacity. However, significant additional analysis would be necessary to show the proposed culvert would meet the requirements of the Hydraulic Design Option (WDFW's least preferred design option). Utility or other conflicts that may limit the allowable culvert width will need to be addressed when the preferred culvert alignment is selected.

STABLE CHANNEL DESIGN

Sediment is a known concern in the Lower Taylor Creek system; numerous studies have been performed analyzing erosion in the upper watershed and the growing delta at the mouth. The specific elements of stable channel design are difficult to determine at this preliminary/conceptual point in the project; therefore; this section recommends two general guidelines to keep in mind as this project progresses through the conceptual design phase.

Sediment transport and shear stress are highly interrelated. The goal is to design a channel that will pass sediment through the system or deposit sediment in desired locations, yet the newly constructed banks and channel need to be robust enough to withstand the shear stress caused by the high velocity runoff during peak events. A stable channel designed to withstand the estimated shear stresses is needed to avoid erosion and failure of the newly designed stream channel and banks. These guidelines will aid in the qualitative analysis of design alternatives but will need to be revisited when the preferred alternative progresses to a design phase.

Sediment Transport

The upper project reach (Reach 1) is currently depositional. This is a result of the channel profile transitioning from a steep slope through the ravine farther upstream to a relatively flat channel. Deposition occurs because the flatter channel has lower velocities and consequently lower sediment transport capacity. Deposition in this reach has resulted in a smaller cross sectional flow area than the other reaches and flooding during storm events. One opportunity to improve sediment transport through this reach is to increase the channel slope from 1.5% to as much as 2.8% by removing the 4.5-foot drop and either regrading the reach at a constant slope or allowing it to regrade itself passively. This results in channel grading across four private properties along 68th Avenue South. The sediment transport capacity of the downstream reaches will have to be assessed to ensure the deposition problem is not translated to a downstream reach. For example, if sediment transport through Reach 1 is improved then sediment transport improvements at the channel mouth are also necessary to avoid increased private impacts associated with delta growth. Ideally, large woody debris and channel complexity, including some areas of widened flood plain, will be added throughout the project area to help trap sediment at desired locations and support a more natural transport to the mouth. This would need to be analyzed and carefully considered during design.

As mentioned above, the mouth of Taylor Creek (Reach 4) is also depositional as evident by the large delta. It may be difficult to increase the channel slope through this reach without also modifying the channel slope of the upstream Reach 3.

In summary, sediment transport is directly tied to channel slope and velocity and should be considered when developing alternatives. Until preferred alternatives are selected, detailed sediment transport analysis cannot be performed.

Shear Stress

Shear stress for the bed, bank, and bends was calculated for each of the proposed channel sections A through D and are summarized in **Table 7** (see **Appendix D** for calculations). **Table 8** summarizes the various material options to be used for the channel and channel banks and their permissible shear stress. Proposed channel sections shall be designed to tolerate the predicted maximum shear stress. Utilizing these tables, the typical channel cross-section would require streambed gravel for the streambed, vegetated coir wraps along the banks of straight reaches and rockery for reinforcement at bends. Additional lining material options, including soil bioengineering techniques, are provided in **Appendix D**.

Table 7: Shear Stress Calculation Summary

Channel	t_{bed}	t_{bank}	t_{bend}
A	2.13	1.66	3.10
B	2.00	1.56	2.91
C	3.04	2.37	4.45
D	2.85	2.22	4.16
Average	2.50	1.95	3.66

Table 8: Permissible Shear Stress of Various Materials	
Material	Permissible Shear Stress (psf)
Straw with net	1.4
Coir mats and fabrics	Approx. 1-3 (varies by product)
Synthetic mats	Approx. 2-8 (varies by product)
Class A vegetation Weeping lovegrass: excellent stand, average height 30” Yellow Bluestem Ischaemum: excellent stand, average height 36"	3.7
Class B vegetation Kudzu: dense or very dense growth, uncut Bermuda grass: good stand, average height 12” Native grass mix (long and short Midwest grasses): good stand, unmowed Weeping lovegrass: good stand, average height 13” Lespedeza sericea: good stand, not woody, average height 19” Alfalfa: good stand, uncut, average height 11” Blue gamma: good stand, uncut average height 13”	2.1
Class C vegetation Crabgrass: fair stand, uncut (10”-48”) Bermuda grass: good stand, mowed, average height 6” Common lespedeza: good stand, uncut, average height 11” Grass-legume mix: good stand, uncut (6”-8”) Centipedegrass: very dense cover, average height 6” Kentucky bluegrass: good stand (6”-12”)	1.0
Class D vegetation Bermuda grass: good stand, cut to 2.5-inch height Common lespedeza: excellent stand, uncut (average height 4.5”) Buffalo grass: good stand, uncut (3”-6”) Grass-legume mix: good stand, uncut (4”-5”) Lespedeza sericea: very good stand cut to 2-inch height	0.6
Class E vegetation Bermuda grass: good stand, cut to 1.5-inch height Bermuda grass: burned stubble	0.4
1-inch gravel	0.3
2-inch gravel	0.7
6-inch rock riprap	2.0
12-inch rock riprap	4.0

NEXT STEPS:

The analysis and sizing summarized in this memorandum are to be used as tools/guidelines as the conceptual design progresses and alternatives are identified. The hydrology and hydraulics will need to be revisited as the alternatives are more specifically identified and the design progresses.

WORKSHOP WITH SPU STAFF AND OCI DESIGN TEAM

A brainstorming workshop session is scheduled for November 16, 2010 with the SPU project team and OCI design team. The session will involve developing and analyzing different alternatives or solutions to address the project objectives. This session will be extremely valuable and cost effective, as the SPU project team's experience and familiarity with the project will help identify and/or eliminate alternatives and assess its feasibility quickly. OCI will then develop, in detail, each alternative and evaluate its advantages and disadvantages along with rough project cost for each alternative. Results of this study will be presented to SPU in December 2010.

Appendix A: Flow Frequency Analysis

FLOW FREQUENCY ANALYSIS: Lower Taylor Creek

Annual peak flows based on SPU provided gage data (5 min. time steps)

						EV I	
return(yr)	*p*	*zp*	*K*	*log(Q)*	***Q***	*K*	*Q*
1.25	0.200	-0.839	-0.840	1.66	**46.16**	-0.82	48
1.58	0.367	-0.337	-0.340	1.72	**53.00**	-0.45	53
2	0.500	0.000	-0.003	1.76	**58.19**	-0.16	58
2.33	0.571	0.177	0.174	1.79	**61.12**	0.00	60
5	0.800	0.839	0.838	1.87	**73.46**	0.72	71
10	0.900	1.281	1.283	1.92	**83.12**	1.30	80
25	0.960	1.757	1.764	1.98	**94.95**	2.04	91
50	0.980	2.064	2.074	2.01	**103.49**	2.59	99
100	0.990	2.337	2.352	2.05	**111.77**	3.14	108

average	60.1	1.77
std.dev.	15.2	0.12
skew	-0.53	-0.86 (skew of actual data)
		0.02 Use Regional Skew

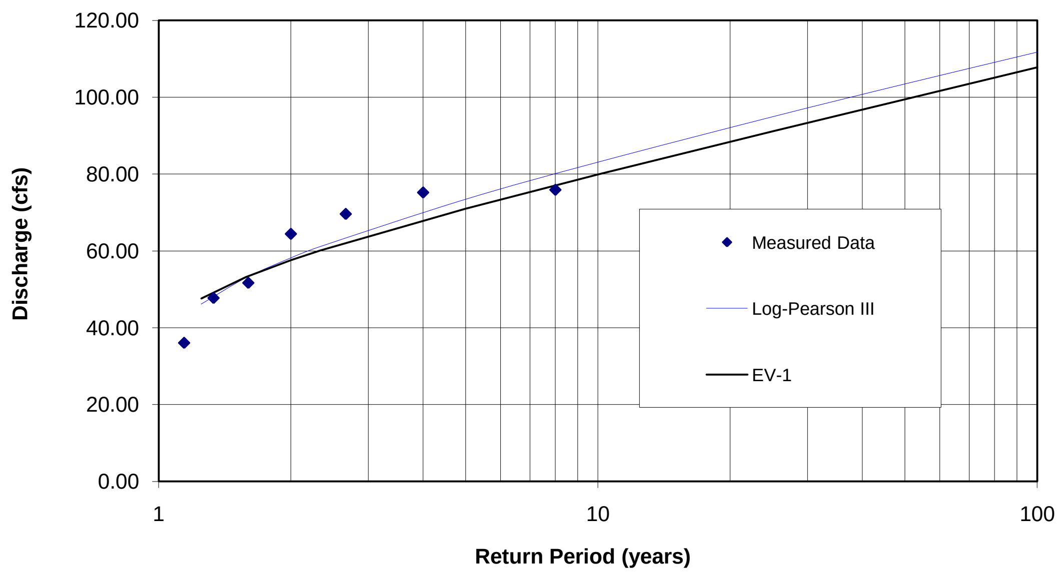
Design Flows			
skew:	Regional	Average	Actual
return(yr)	0.02	-0.42	-0.86
1.25	46.16	46.52	47.09
1.58	53.00	54.00	55.10
2	58.19	59.37	60.54
2.33	61.12	62.30	63.39
5	73.46	73.75	73.72
10	83.12	81.85	80.20
25	94.95	90.84	86.59
50	103.49	96.76	90.35
100	111.77	102.10	93.44

Ues of Regional Skew results in most conservative design flows.

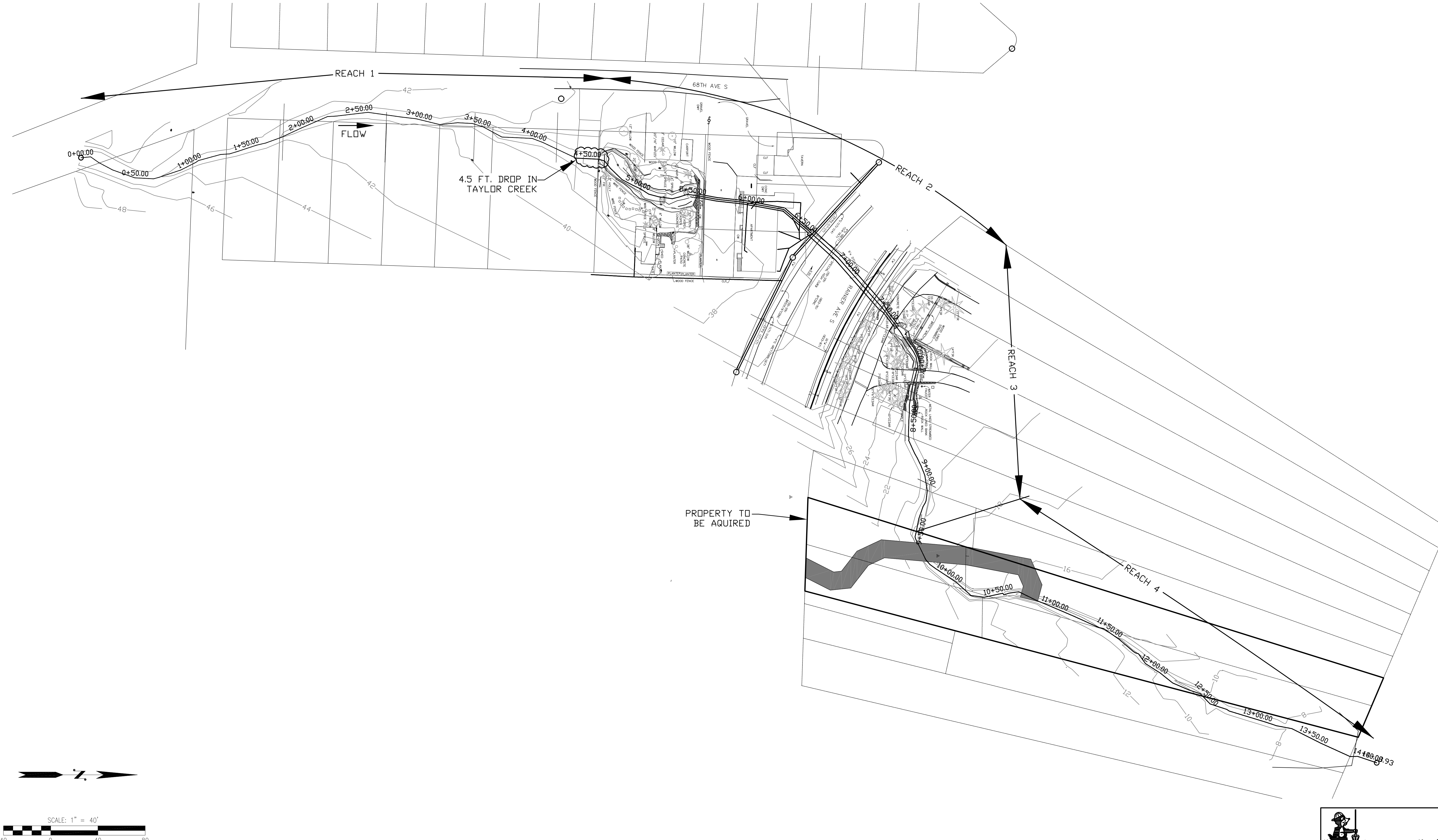
*Bulletin 17B recommends averaging calculated skew with regional skew estimate

Regional skew coefficient (of logarithms) = 0.02 from Bulletin 17B Map

year	*flow, cfs*	*log(flow)*	*rank*	*P=m/(N+1)*	*T=1/P*
2004	51.67	1.71	5	0.625	1.60
2005	69.59	1.84	3	0.375	2.67
2006	75.18	1.88	2	0.250	4.00
2007	75.87	1.88	1	0.125	8.00
2008	36.06	1.56	7	0.875	1.14
2009	64.41	1.81	4	0.500	2.00
2010	47.74	1.68	6	0.750	1.33

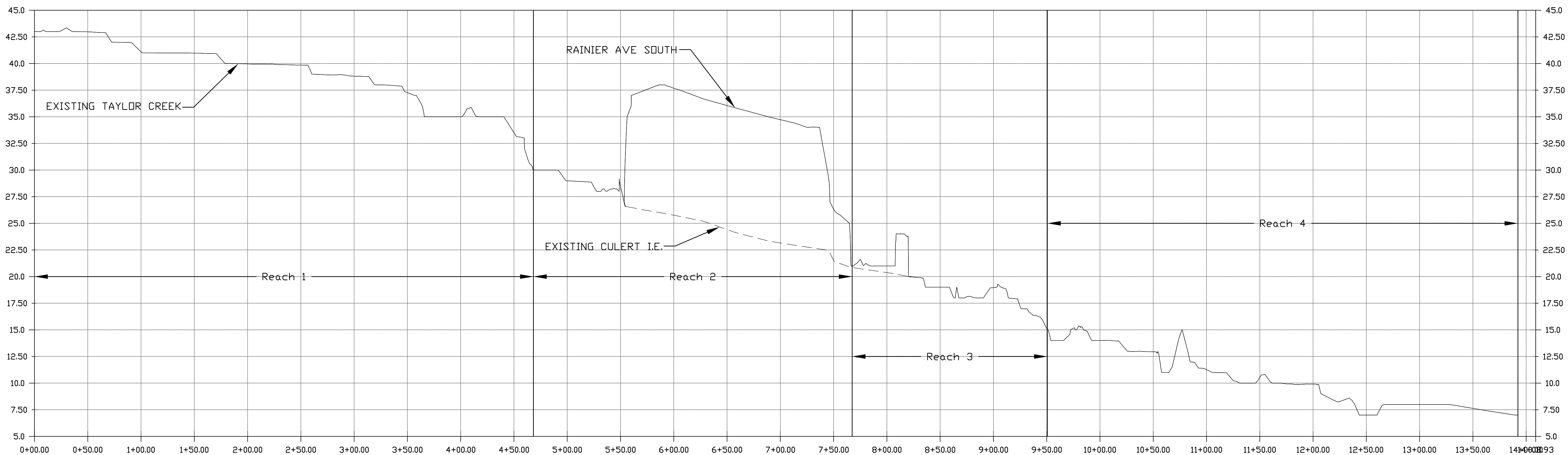


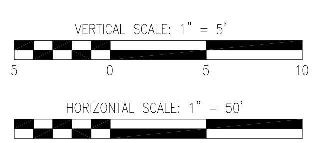
Appendix B: Plan and Profile



Call 2 Working Days Before You Dig
1-800-424-5555
Utilities Underground Location Center (ID,MT,ND,OR,WA)

DESIGNED BY LR	OSBORN CONSULTING INCORPORATED	OSBORN CONSULTING, INC. 10800 NE 8th Street, Suite 150 Bellevue, WA. 98004 Ph (425) 451-4009 Fax (425) 451-4901	NO.	DATE	REVISION	BY	Seattle Public Utilities PO Box 34018 Seattle, WA 98124-4018	Seattle Public Utilities Conceptual Design for Taylor Creek Plan	JOB# / DWG R00-24-10-01	DATE 11/10/10
DRAWN BY BAY									SCALE H: 1"=40' V: n/a	SHEET 1 of 2
CHECKED BY LR										





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(ID,MT,ND,OR,WA)

DESIGNED BY LR	OSBORN CONSULTING INCORPORATED	OSBORN CONSULTING, INC.	NO.	DATE	REVISION	BY	Seattle Public Utilities	Seattle Public Utilities	JOB# / DWG R00-24-10-01	DATE 11/10/10
DRAWN BY BAY		10800 NE 8th Street, Suite 150 Ph (425) 451-4009					PO Box 34018	Conceptual Design for Taylor Creek	SCALE H: 1"=50' V: 1"=5'	SHEET 2 of 2
CHECKED BY LR		Bellevue, WA. 98004 Fax (425) 451-4901					Seattle, WA 98124-4018	Profile		

Appendix C: Channel Sizing

(A)

TRAPEZOIDAL CHANNEL ANALYSIS
RATING CURVE COMPUTATION

November 8, 2010

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Channel Bottom Slope (ft/ft)................................	0.02
Manning's Roughness Coefficient (n-value)..................	0.04
Channel Left Side Slope (horizontal/vertical)..............	2.0
Channel Right Side Slope (horizontal/vertical).............	2.0
Channel Bottom Width (ft)...................................	6.0
Minimum Flow Depth (ft).....................................	0.1
Maximum Flow Depth (ft).....................................	2.4
Incremental Head (ft).......................................	0.1

COMPUTATION RESULTS

Flow Depth (ft)	Flow Rate (cfs)	Flow Velocity (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq ft)	Top Width (ft)	
0.1	0.68	1.1	0.625	0.019	0.119	0.62	6.4	
0.2	2.19	1.71	0.695	0.045	0.245	1.28	6.8	
0.3	4.34	2.19	0.737	0.075	0.375	1.98	7.2	
0.4	7.09	2.61	0.768	0.105	0.505	2.72	7.6	
0.5	10.39	2.97	0.791	0.137	0.637	3.5	8.0	
0.6	14.25	3.3	0.811	0.169	0.769	4.32	8.4	
0.7	18.65	3.6	0.827	0.201	0.901	5.18	8.8	
0.8	23.59	3.88	0.842	0.234	1.034	6.08	9.2	
0.9	29.08	4.14	0.854	0.267	1.167	7.02	9.6	
1.0	35.12	4.39	0.865	0.3	1.3	8.0	10.0	
1.1	41.72	4.63	0.876	0.332	1.432	9.02	10.4	← 1.25 YR
1.2	48.88	4.85	0.885	0.365	1.565	10.08	10.8	
1.3	56.61	5.06	0.894	0.398	1.698	11.18	11.2	← 2 YR
1.4	64.93	5.27	0.902	0.432	1.832	12.32	11.6	
1.5	73.84	5.47	0.909	0.465	1.965	13.5	12.0	
1.6	83.35	5.66	0.916	0.498	2.098	14.72	12.4	
1.7	93.47	5.85	0.923	0.532	2.232	15.98	12.8	← 25 YR
1.8	104.21	6.03	0.929	0.565	2.365	17.28	13.2	
1.9	115.58	6.21	0.935	0.599	2.499	18.62	13.6	← 100 YR
2.0	127.6	6.38	0.941	0.633	2.633	20.0	14.0	
2.1	140.27	6.55	0.947	0.666	2.766	21.42	14.4	
2.2	153.6	6.71	0.952	0.7	2.9	22.88	14.8	
2.3	167.61	6.87	0.957	0.734	3.034	24.38	15.2	
2.4	182.3	7.03	0.962	0.769	3.169	25.92	15.6	
→ 2.7 (1 Ft Freeboard @ 25 YR)							16.8	

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Dodson & Associates, Inc., 5629 FM 1960 West, Suite 314, Houston, TX 77069
Phone:(281)440-3787, Fax:(281)440-4742, Email:software@dodson-hydro.com

(B)

TRAPEZOIDAL CHANNEL ANALYSIS
RATING CURVE COMPUTATION

November 8, 2010

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Channel Bottom Slope (ft/ft)...............................	0.02
Manning's Roughness Coefficient (n-value)..................	0.04
Channel Left Side Slope (horizontal/vertical)...............	3.0
Channel Right Side Slope (horizontal/vertical)..............	3.0
Channel Bottom Width (ft)..................................	6.0
Minimum Flow Depth (ft)....................................	0.1
Maximum Flow Depth (ft)....................................	2.3
Incremental Head (ft)......................................	0.1

COMPUTATION RESULTS

Flow Depth (ft)	Flow Rate (cfs)	Flow Velocity (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq ft)	Top Width (ft)	
0.1	0.69	1.09	0.624	0.019	0.119	0.63	6.6	
0.2	2.22	1.69	0.694	0.044	0.244	1.32	7.2	
0.3	4.45	2.15	0.736	0.072	0.372	2.07	7.8	
0.4	7.34	2.55	0.767	0.101	0.501	2.88	8.4	
0.5	10.86	2.9	0.791	0.13	0.63	3.75	9.0	
0.6	15.03	3.21	0.811	0.16	0.76	4.68	9.6	
0.7	19.84	3.5	0.828	0.19	0.89	5.67	10.2	
0.8	25.33	3.77	0.842	0.221	1.021	6.72	10.8	
0.9	31.49	4.02	0.855	0.251	1.151	7.83	11.4	
1.0	38.34	4.26	0.867	0.282	1.282	9.0	12.0	
1.1	45.91	4.49	0.878	0.313	1.413	10.23	12.6	← 1.25 YR
1.2	54.21	4.71	0.888	0.344	1.544	11.52	13.2	
1.3	63.26	4.92	0.897	0.375	1.675	12.87	13.8	← 2 YR
1.4	73.07	5.12	0.906	0.407	1.807	14.28	14.4	
1.5	83.68	5.31	0.914	0.439	1.939	15.75	15.0	
1.6	95.09	5.5	0.922	0.471	2.071	17.28	15.6	← 25 YR
1.7	107.32	5.69	0.929	0.503	2.203	18.87	16.2	
1.8	120.4	5.87	0.936	0.535	2.335	20.52	16.8	← 100 YR
1.9	134.35	6.04	0.943	0.568	2.468	22.23	17.4	
2.0	149.18	6.22	0.949	0.6	2.6	24.0	18.0	
2.1	164.9	6.38	0.955	0.633	2.733	25.83	18.6	
2.2	181.55	6.55	0.961	0.667	2.867	27.72	19.2	
2.3	199.14	6.71	0.967	0.7	3.0	29.67	19.8	
2.6 (1 FT Freeboard at 25-YR)							21.6	

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TRAPEZOIDAL CHANNEL ANALYSIS
RATING CURVE COMPUTATION

November 8, 2010

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Channel Bottom Slope (ft/ft)	0.03
Manning's Roughness Coefficient (n-value)	0.04
Channel Left Side Slope (horizontal/vertical)	2.0
Channel Right Side Slope (horizontal/vertical)	2.0
Channel Bottom Width (ft)	6.0
Minimum Flow Depth (ft)	0.1
Maximum Flow Depth (ft)	2.3
Incremental Head (ft)	0.1

COMPUTATION RESULTS

Flow Depth (ft)	Flow Rate (cfs)	Flow Velocity (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq ft)	Top Width (ft)	
0.1	0.84	1.35	0.765	0.028	0.128	0.62	6.4	
0.2	2.68	2.09	0.851	0.068	0.268	1.28	6.8	
0.3	5.32	2.69	0.903	0.112	0.412	1.98	7.2	
0.4	8.68	3.19	0.94	0.158	0.558	2.72	7.6	
0.5	12.73	3.64	0.969	0.206	0.706	3.5	8.0	
0.6	17.45	4.04	0.993	0.254	0.854	4.32	8.4	
0.7	22.84	4.41	1.013	0.302	1.002	5.18	8.8	
0.8	28.9	4.75	1.031	0.351	1.151	6.08	9.2	
0.9	35.62	5.07	1.046	0.4	1.3	7.02	9.6	
1.0	43.02	5.38	1.06	0.449	1.449	8.0	10.0	← 1.25 YR
1.1	51.09	5.66	1.072	0.499	1.599	9.02	10.4	
1.2	59.87	5.94	1.084	0.548	1.748	10.08	10.8	← 2 YR
1.3	69.34	6.2	1.094	0.598	1.898	11.18	11.2	
1.4	79.52	6.45	1.104	0.647	2.047	12.32	11.6	
1.5	90.43	6.7	1.113	0.697	2.197	13.5	12.0	
1.6	102.08	6.93	1.122	0.747	2.347	14.72	12.4	← 25 YR
1.7	114.47	7.16	1.13	0.797	2.497	15.98	12.8	← 100 YR
1.8	127.63	7.39	1.138	0.848	2.648	17.28	13.2	
1.9	141.56	7.6	1.145	0.898	2.798	18.62	13.6	
2.0	156.28	7.81	1.153	0.949	2.949	20.0	14.0	
2.1	171.79	8.02	1.159	1.0	3.1	21.42	14.4	
2.2	188.12	8.22	1.166	1.051	3.251	22.88	14.8	
2.3	205.28	8.42	1.172	1.102	3.402	24.38	15.2	
→ 2.55	(1 Ft Freeboard @ 25 YR)						16.2	

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(D)

TRAPEZOIDAL CHANNEL ANALYSIS
RATING CURVE COMPUTATION

November 8, 2010

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Channel Bottom Slope (ft/ft)	0.03
Manning's Roughness Coefficient (n-value)	0.04
Channel Left Side Slope (horizontal/vertical)	3.0
Channel Right Side Slope (horizontal/vertical)	3.0
Channel Bottom Width (ft)	6.0
Minimum Flow Depth (ft)	0.1
Maximum Flow Depth (ft)	2.3
Incremental Head (ft)	0.1

COMPUTATION RESULTS

Flow Depth (ft)	Flow Rate (cfs)	Flow Velocity (fps)	Froude Number	Velocity Head (ft)	Energy Head (ft)	Flow Area (sq ft)	Top Width (ft)	
0.1	0.84	1.34	0.764	0.028	0.128	0.63	6.6	
0.2	2.72	2.06	0.85	0.066	0.266	1.32	7.2	
0.3	5.45	2.64	0.902	0.108	0.408	2.07	7.8	
0.4	8.99	3.12	0.939	0.151	0.551	2.88	8.4	
0.5	13.3	3.55	0.969	0.195	0.695	3.75	9.0	
0.6	18.4	3.93	0.993	0.24	0.84	4.68	9.6	
0.7	24.3	4.29	1.014	0.286	0.986	5.67	10.2	
0.8	31.02	4.62	1.032	0.331	1.131	6.72	10.8	
0.9	38.56	4.93	1.048	0.377	1.277	7.83	11.4	
1.0	46.96	5.22	1.062	0.423	1.423	9.0	12.0	← 1.25 YR
1.1	56.23	5.5	1.075	0.469	1.569	10.23	12.6	
1.2	66.39	5.76	1.088	0.516	1.716	11.52	13.2	← 2 YR
1.3	77.47	6.02	1.099	0.563	1.863	12.87	13.8	
1.4	89.5	6.27	1.11	0.61	2.01	14.28	14.4	
1.5	102.48	6.51	1.119	0.658	2.158	15.75	15.0	← 25 YR
1.6	116.46	6.74	1.129	0.706	2.306	17.28	15.6	← 100 YR
1.7	131.44	6.97	1.138	0.754	2.454	18.87	16.2	
1.8	147.46	7.19	1.146	0.803	2.603	20.52	16.8	
1.9	164.54	7.4	1.154	0.851	2.751	22.23	17.4	
2.0	182.7	7.61	1.162	0.901	2.901	24.0	18.0	
2.1	201.96	7.82	1.17	0.95	3.05	25.83	18.6	
2.2	222.35	8.02	1.177	1.0	3.2	27.72	19.2	
2.3	243.89	8.22	1.184	1.05	3.35	29.67	19.8	
2.45 (1 Ft Freeboard at 25YR)							20.7	

Appendix D: Shear Stress Calculations

Shear Stress Calculations

Project: Lower Taylor Creek

Date: November 10, 2010

Table #: Shear Stress Calculation Summary			
Channel	t_{bed}	t_{bank}	t_{bend}
A	2.13	1.66	3.10
B	2.00	1.56	2.91
C	3.04	2.37	4.45
D	2.85	2.22	4.16
Min	2.00	1.56	2.91
Average	2.50	1.95	3.66
Max	3.04	2.37	4.45

Shear Stress Calculations

Project: Lower Taylor Creek
Date: November 10, 2010
Channel: A

Bed Shear Stress in a Straight Reach

$t_{bed}=US_eR_h$

t_{bed} = maximum bed shear stress in psf
U = 62.4 lbs/ft^3
S_e= energy slope (assumed worst case bed slope, since no hydraulic model available)
R_h= hydraulic radius in ft (Area/Wetted Perimeter)

		channel bottom and side slope:	6	2	
		channel depth:	2.7		
U =	62.4	Crosssectional Area* =	30.8		Crosssectional Area inc
S_e=	2.00%	Wetted Perimeter* =	18.1		Bankfull width assume
R_h=	1.70				

*Assumes worst case scenerio of area and perimeter combination

t_{bed} = 2.13
t_{bank} = 1.66

Shear Stress in Bends

$t_{bend}=t_{bed}K_b$

t_{bend} = maximum shear stress on bank and bed in a bend (psf)
t_{bed} = maximum shear stress in adjacent straight reach (psf)
K_b= bend coefficeint (dimensionless) $2.4e^{-0.0852(Rc/b)}$

U =	62.4	Crosssectional Area* =	30.8
S_e=	2.00%	Wetted Perimeter* =	18.1
R_h=	1.70		

t_{bed} =	2.13	b = bottom width of channel at bend (ft)	6
K_b=	1.46	Rc = radius of curvature of bend	35

t_{bend} = 3.10

Shear Stress Calculations

Project: Lower Taylor Creek
Date: November 10, 2010
Channel: B

Bed Shear Stress in a Straight Reach

$t_{bed}=US_eR_h$

t_{bed} = maximum bed shear stress in psf
U = 62.4 lbs/ft^3
S_e= energy slope (assumed worst case bed slope, since no hydraulic model available)
R_h= hydraulic radius in ft (Area/Wetted Perimeter)

		channel bottom and side slope:	6	3	
		channel depth:	2.6		
U =	62.4	Crosssectional Area* =	35.9		Crosssectional Area inc
S_e=	2.00%	Wetted Perimeter* =	22.4		Bankfull width assume
R_h=	1.60				

*Assumes worst case scenerio of area and perimeter combination

t_{bed} = 2.00
t_{bank} = 1.56

Shear Stress in Bends

$t_{bend}=t_{bed}K_b$

t_{bend} = maximum shear stress on bank and bed in a bend (psf)
t_{bed} = maximum shear stress in adjacent straight reach (psf)
K_b= bend coefficeint (dimensionless) $2.4e^{-0.0852(Rc/b)}$

U =	62.4	Crosssectional Area* =	35.9
S_e=	2.00%	Wetted Perimeter* =	22.4
R_h=	1.60		

t_{bed} =	2.00	b = bottom width of channel at bend (ft)	6
K_b=	1.46	Rc = radius of curvature of bend	35

t_{bend} = 2.91

Shear Stress Calculations

Project: Lower Taylor Creek
Date: November 10, 2010
Channel: C

Bed Shear Stress in a Straight Reach

$t_{bed}=US_eR_h$

t_{bed} = maximum bed shear stress in psf
U = 62.4 lbs/ft^3
S_e= energy slope (assumed worst case bed slope, since no hydraulic model available)
R_h= hydraulic radius in ft (Area/Wetted Perimeter)

		channel bottom and side slope:	6	2	
		channel depth:	2.55		
U =	62.4	Crosssectional Area* =	28.3		Crosssectional Area inc
S_e=	3.00%	Wetted Perimeter* =	17.4		Bankfull width assume
R_h=	1.63				

*Assumes worst case scenerio of area and perimeter combination

t_{bed} = 3.04
t_{bank} = 2.37

Shear Stress in Bends

$t_{bend}=t_{bed}K_b$

t_{bend} = maximum shear stress on bank and bed in a bend (psf)
t_{bed} = maximum shear stress in adjacent straight reach (psf)
K_b= bend coefficeint (dimensionless) $2.4e^{-0.0852(Rc/b)}$

U =	62.4	Crosssectional Area* =	28.3
S_e=	3.00%	Wetted Perimeter* =	17.4
R_h=	1.63		

t_{bed} =	3.04	b = bottom width of channel at bend (ft)	6
K_b=	1.46	Rc = radius of curvature of bend	35

t_{bend} = 4.45

Shear Stress Calculations

Project: Lower Taylor Creek
Date: November 10, 2010
Channel: D

Bed Shear Stress in a Straight Reach

$t_{bed}=US_eR_h$

t_{bed} = maximum bed shear stress in psf
U = 62.4 lbs/ft^3
S_e= energy slope (assumed worst case bed slope, since no hydraulic model available)
R_h= hydraulic radius in ft (Area/Wetted Perimeter)

		channel bottom and side slope:	6	3	
		channel depth:	2.45		
U =	62.4	Crosssectional Area* =	32.7		Crosssectional Area inc
S_e=	3.00%	Wetted Perimeter* =	21.5		Bankfull width assume
R_h=	1.52				

*Assumes worst case scenerio of area and perimeter combination

t_{bed} = 2.85
t_{bank} = 2.22

Shear Stress in Bends

$t_{bend}=t_{bed}K_b$

t_{bend} = maximum shear stress on bank and bed in a bend (psf)
t_{bed} = maximum shear stress in adjacent straight reach (psf)
K_b= bend coefficeint (dimensionless) $2.4e^{-0.0852(Rc/b)}$

U =	62.4	Crosssectional Area* =	32.7
S_e=	3.00%	Wetted Perimeter* =	21.5
R_h=	1.52		

t_{bed} =	2.85	b = bottom width of channel at bend (ft)	6
K_b=	1.46	Rc = radius of curvature of bend	35

t_{bend} = 4.16

Table 2. Permissible Shear and Velocity for Selected Lining Materials[1]

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
D. Goff, K. (1999).
E. Gray, D.H., and Sotir, R.B. (1996).
F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
H. Norman, J. N. (1975).
I. Schiechtl, H. M. and R. Stern. (1996).
J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

Appendix C: Conceptual Design for Lower Taylor Creek – Data Gaps Memorandum, 2010, Osborn Consulting, Inc.

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SUITE 150
BELLEVUE, WA 98004
(425) 451-4009

Date:	October 29, 2010
To:	Julie Crittenden, Project Manager, Seattle Public Utilities
CC:	Greg Johnston, The Watershed Company
From:	Laura Ruppert, P.E., and Tarelle Osborn, P.E. Osborn Consulting, Inc.
Subject:	Conceptual Design for Lower Taylor Creek – Data Gaps Memorandum

Table of Contents

PURPOSE

This memorandum identifies existing data gaps in SPU provided data, documents how critical it is to fill the gaps in order to provide the deliverables identified in this work assignment, and requests additional data if necessary.

BACKGROUND

OCI, under contract with SPU, will develop stream/culvert conceptual alternatives that consider project objectives and assess alternative advantages, disadvantages, and cost. This work assignment will support development of an implementation business case for SPU.

SPU has been studying the lower reach of Taylor Creek for several years. SPU provided OCI with a base map and existing reports/documents about the site and stream conditions; a list of documents provided by SPU is provided in **Appendix A**. Following OCI's review of the information provided and site visit with SPU staff, data gaps were identified.

DATA GAPS

This section documents existing data gaps and how critical it is to fill the gaps to provide the deliverables identified in this work assignment. Recommendations for additional data are made as needed.

Project Mapping

SPU provided a partial base map in AutoCAD format that includes: 2-ft contours, sanitary sewer, overhead power and water, property lines, and building footprints.

Data Gaps

1. The base map does not cover the entire project area.
    - Base map does not include 10044 and 10042 Rainier Ave. South or the shoreline of Lake Washington.
    - Base map does not include Lakeridge Playground property.
2. The existing barriers to upstream fish migration are not included in the base map.
    - Location of last weir upstream of 68th Ave culvert
    - Existing culverts
        - Driveway culverts along 68th Ave. S.
        - Culvert under the apartment building (10005)
        - Culvert crossing Rainier Ave. S.
        - Multiple private culverts downstream of Rainier Ave.
    - The 4.5-ft driveway waterfall on private property.
3. Stream alignment is not well defined along private property on 68th Ave and downstream of Rainier Ave.
    - Point data may improve channel definition. The CAD file includes a layer identified as Points however, the layer appears empty.
4. Missing edge of pavement (or other impervious surface) along Rainier Ave. S. and 68th Ave. S. (including private property driveways)
5. Missing stormdrain lines and CBs
6. Utilities such as fire hydrant, water meters, manholes
7. 68th Ave. S and Holyoke culverts do not appear to be shown correctly. Culverts are shown as 72-inch diameter; however, the *Taylor Creek Sediment Study* says 14-ft wide culverts were installed in 1999.

Is it Critical?

Yes, an updated base map is critical to development of conceptual designs and preparation of conceptual alternative graphics.

Additional data needs.

At a minimum, the limits of the base map should be extended to include the entire project area and the locations of existing fish barriers should be added. The base map (in PDF format) for the *Taylor Creek Culverts – Phase 2* (90% submittal in August, 2005) includes the fish barriers (and many of the other data gaps listed above) from the 4.5-ft driveway waterfall through the outfall of the Rainier Ave. S culvert on private property. OCI requests SPU provide the CAD files for the *Taylor Creek Culverts – Phase 2.*

- OCI notified SPU about the data gaps in the base map prior to submittal of this memorandum. OCI and SPU are currently working together to resolve the situation.

Taylor Creek Design Flows

OCI's review of SPU provided documents found conflicting information for design flows. Flow data was found in three sources:

- *Taylor Creek Culverts Modification Predesign Report*; June 1999; Thomas/Wright, Inc. This report documents hydrologic analyses using both SBUH and SWMM. A table of SWMM runoff results is provided below (only SWMM results are provided as it is the more accurate model of the two).

Table 3.2.2 SWMM Runoff Results

Return Frequency (years)	2	10	25	100
Storm Duration (hour)	24	24	24	24
Precipitation (inches)	2	2.9	3.4	3.9
Basin 100 Peak Discharge (cfs)	11	16	18	22
Basin 200 Peak Discharge (cfs)	13	19	22	26
Basin 300 Peak Discharge (cfs)	44	66	76	92
Basin 400 Peak Discharge (cfs)	33	50	57	68
Combined Peak Discharge (cfs) (mouth of Taylor Creek)	100	151	174	208

- *Taylor Creek Sediment Study Report*; July 2007; Perkins GeoSciences
  Table 1: Significant precipitation or stream discharge events for Taylor Creek during period of gage record of this includes Taylor Creek gage data and identifies 51 CFS (the maximum flow in the 3-yr gage period) as a 15-yr, 24-hr storm.

- Six years of stream flow data from gage STA401 (2/4/2004 through 9/15/2010)
  In the 6-years of gage data, 75.87 CFS is the maximum peak flow (12/3/2007). During the 10/19/2010 site visit, SPU staff indicated gage data prior to 2004 was not accurate.

Data Gap

The Gage data (STA401) and hydrologic analysis performed in 1999 indicate very different design storms. The gage data provided has some periods (gaps) where no flow rate is provided.

Is it Critical?

If culverts are sized using the No-Slope or Stream-Simulation Design Options, then flow data is not critical. Flow data becomes critical if the culverts are sized using the Hydraulic Design Option (less favorable to WDFW; results in smaller culverts). Flow data is critical for channel design (for capacity and for stable channel design); especially since private properties flood under existing conditions.

We recommend performing a flow frequency analysis using the six years of gage data provided by SPU. Typically flow frequency analyses are performed using a longer period of record; however; we still see this as the preferred method since the flows from the 1999 report are so far off from gage data.

Since the flow frequency analysis looks at the maximum peak flow for each year, the gaps in flow data are not critical (assuming gaps are occurring at low or normal flow opposed to during the peak in a given year). OCI will assume that the provided flow data is the best available information

Additional data needs.

No, there are no additional data needs at this time. At a site visit on October 19, 2010, SPU directed OCI to use the gage data and confirmed that flow gage STA401 is recording properly and is located in Lower Taylor Creek (as opposed to up in the headwaters or on a tributary).

Public Involvement

Data Gap

Discussions during the 10/19/10 site visit suggested there may be some flexibility in channel alignment/dimension with regard to private property. However, the desires of private property owners remain unknown, for example:

- Are home owners who currently flood open to channel improvements on their private property that may provide them with a flood improvement in addition to the design goals stated above?
- Do property owners see the creek as an asset? Would they be upset to see it relocated onto public property?

Public Involvement is not included in OCI's scope of work for this project.

Is it Critical?

This is not critical for conceptual alternatives analysis; however, an understanding of property owners' opinions may allow for some alternatives to be quickly ruled out. It is understood that conceptual design alternatives may be necessary to communicate with property owners and determine if they see the creek as an asset or nuisance on their property.

Additional data needs.

There are no additional data needs at this time. If SPU has already been in contact with property owners and knows their stance on channel improvements on their property, then that would be good to know. However; if such conversations have not already occurred then it might be worth waiting until conceptual designs are complete.

Soils and Geotechnical Information for the Project Area

Data Gap

Design of channel realignment, culvert replacement, and any work providing fish passage and other habitat types across the delta would all benefit from some level of soils and geotechnical information throughout the project area. For example knowledge of sediment types and densities on the delta would help with anchor design for log structures.

Is it Critical?

Perhaps not for conceptual design, but this area of information should be kept in mind to address during final design.

Additional data needs.

There are no additional data needs at this time, in order to proceed with conceptual design.

NEXT STEPS

OCI requests that SPU communicate (email or telephone is fine) if additional data requests will be provided (and by when), or if OCI should proceed with the data as-is.

Appendix A: List of Available Materials

Lower Taylor Creek Conceptual Design: List of Available Materials

9/30/2010

Relevant Electronic Files (on FTP site, internally at J/USM/WS736/Public/Taylor lower designs)

- Inspection of Taylor Creek culvert Rainier Ave: From June 2008. Information includes video of inspection of both the public and upstream private culverts, photos of the culvert vicinity, side sewer card, and aerial map. Electronic files in "Inspection" folder.
- Sediment Study: Sue Perkins, Perkins Geosciences conducted a sediment study of the Taylor Creek watershed, with a focus on the influence of sediment on the stream delta. The study was conducted in 2007. There is the report, an addendum, and 3 appendices. Electronic files in the "Taylor Creek Sediment Study" folder.
- Photographs: There are a number of photographs of the creek and delta. There is a woody debris survey that goes along with a number of the photos. These are included electronically in the "Taylor Creek Pictures" file.
- Culvert Replacement Project: SPU got to 90% design on improvements to the Rainier Ave S culvert before the project was put on hold. The files include the 90% designs for the 2005 project, pictures of the area on top of the culvert, the Project Development Plan, and supporting power point presentations that have useful pictures and information, including a record of the fish barriers throughout the project area. Electronic files are in the folder "Taylor Creek Rainier Avenue Culvert Project"
- Stream flow and level data: Available from March 2004 to present. Data request submitted to Ali Tabaei on September 27. Ali will work with Laura Ruppert to get her the data.
- Physical Channel Conditions report, includes Taylor Creek – Stoker and Perkins. Draft from 2008. Katherine – is there a final? I also found an erosion report in the Watershed Assessment files – channel conditions folder- is this different information or the same as in the Stoker report?
- Watershed Assessment maps.
- State of the Waters Report. 2007. Includes summary of Taylor Conditions and maps include erosion stage, fish use, forest and instream habitats, etc. A CD can be provided or online at: http://www.cityofseattle.net/util/Services/Drainage_&_Sewer/Keep_Water_Safe_&_Clean/RestoreOurWaters/ProgramDocuments/index.htm
- Fish Distribution in Seattle Streams, including Taylor Creek. USFWS report. Online at http://www.fws.gov/wafwo/fisheries/wwfish_pub4.html. See second report from top.
- Subsurface geology information?
- Base map and survey of the area. I would imagine we have this because of the earlier Taylor Creek projects. Kathy Laughlin is contact for earlier culvert work. Karen York to investigate.

Hard Copy Materials

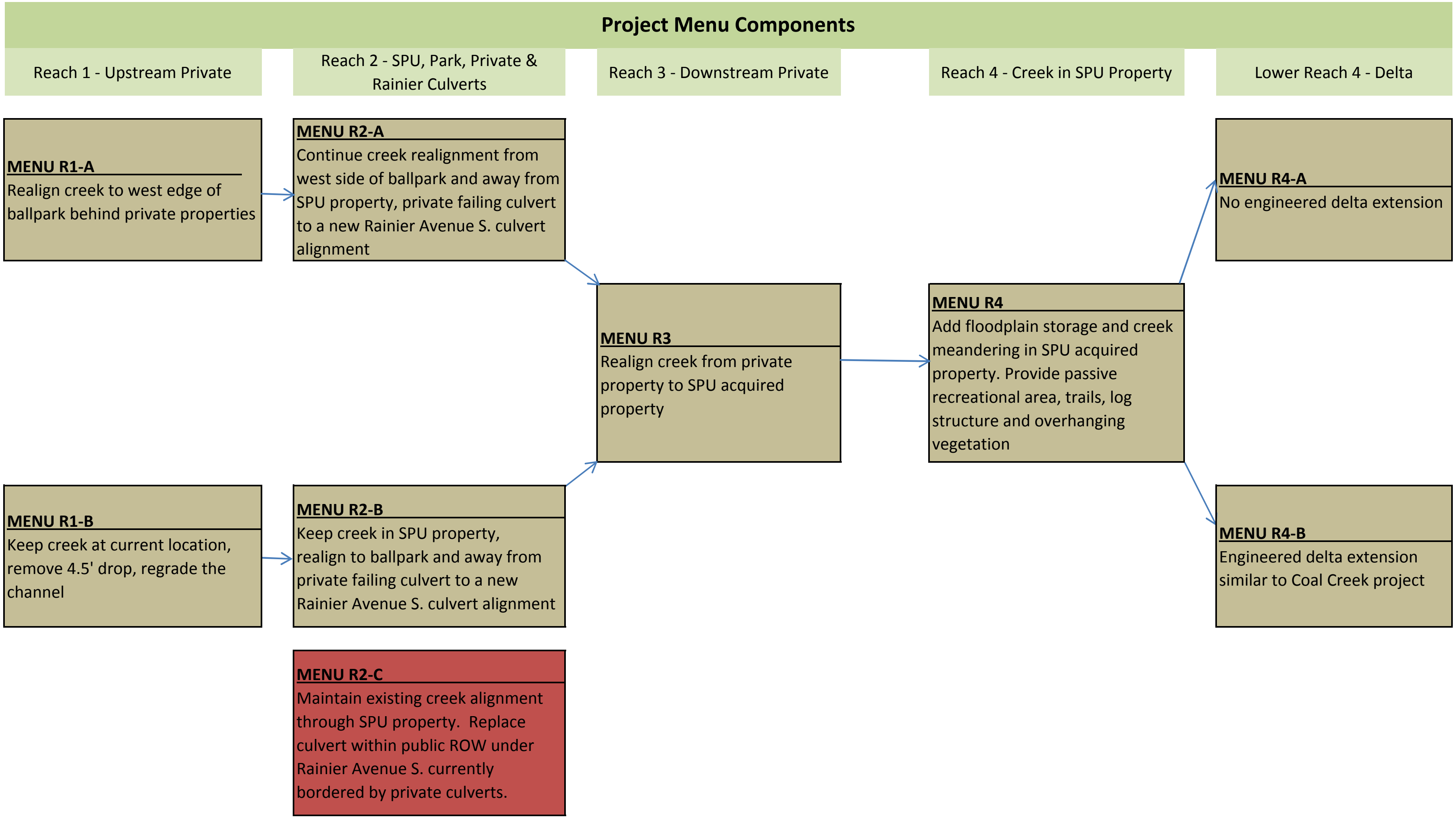
- Taylor Creek Culverts Modification Predesign Report. June 1999. Prepared by Thomas/Wright. The study assessed stream habitat and fish passage blockages from 400 feet upstream of the Holyoke culvert to the stream mouth. The report includes fisheries evaluation, hydrologic/hydraulic analysis, and some design concepts and recommendations for reducing peak discharges.
- Taylor Creek Phase 2 Predesign report on creek improvement alternatives near Rainier Avenue. May 2000. Prepared by Thomas/Wright. Report evaluated alternatives to convey Taylor Creek under Rainier Ave and eliminate the vertical drop at the Guth Residence (just upstream of SPU's property at 10020 68th Ave S).
- Memo from Sue Perkins to Bill Taylor regarding Taylor Creek sediment transport issues. Memo summaries sedimentation observations and provides recommendations for fixes and further study.
- Email from Bob Bernard with WDFW regarding sediment gradation for Taylor Creek.
- Skyway Park Hydraulic Study. August 2001. King County report. Evaluated the stormwater flow to Skyway Park and calculated the flooding and stormwater discharge from the park. I am not sure if wetland detention proposed was constructed. May be of limited use.
- Taylor Creek in Deadhorse Canyon. 1970 University of Washington report. Includes information about physical and biological conditions and history.
- Taylor Creek Restoration Phase 3 Concept Design report. March 2002. Prepared by Otak. Addresses nick point upstream of Holyoke Way. Was this work actually completed?
- Email chain between 3/22/2005 and 4/18/2005 between the SPU PM and the regulatory agencies on the proposed Rainier Ave culvert fish passage work.
- Fish passage designs from Thomas/Wright. No data. Assume prior to SPU's 90% design work on the 2005 project.
- Taylor Creek Regional Pond Hydrologic and Hydraulic Analysis, 1/12/99. Contains calculations and summary of the Taylor Creek Detention Pond and effect on Taylor watershed hydrology. This appears to be the west fork wetland.
- JARPA application for the 2005 canceled project.
- Summary of Taylor Creek fish data collected by Washington Trout. Draft dated 4/21/2006
- Survey of creek from lake through the properties SPU is acquiring. Dated 3/2/2005.
- Welcome to Deadhorse Canyon- Taylor Creek. A report put together by the stewards of the creek. Has some good history of the area.
- Lakeridge park (Deadhorse Canyon) Forest Restoration plan. Parks Department 1995.
- 3-year monitoring results for projects constructed in 1999. Documents results of the 68th and Holyoke culvert replacements. Can we find electronically?

- Miscellaneous sheets: Taylor creek profile, morphology by reach, basin map with topo (repeat with watershed assessment reports and maps?)
- Taylor Creek morphology, erosion and sediment transport summary, 2001.

<u>Materials Found but Deemed Not Useful</u>

- Engineered Log Jam project: A scope of work was developed to conduct an assessment of sediment storage potential in the creek ravine upstream of Holyoke. No work was conducted. Files did not appear to be helpful for this project. Scopes of work and some field notes on a woody debris survey available. Files not included.
- Headwater wetlands: There are a number of files about development proposals and other wetland related work in the headwater areas (West Hill Drainage Study, Brooks Village wetland delineation and off-site drainage, maybe others).Files do not appear to provide helpful information about hydrology of the stream or sediment issues. Files not included.
- Hydrology data prior to 2004: Appears to be data from 2000-2004. Collected by Geotivity and of questionable accuracy/quality. Kathy Laughlin has files, I think electronically.
- Runoff Production Potential – analysis of stormwater runoff production based on land characteristics like slope, sub-basin area, geology.
- Video of culvert conditions form pre-2004. Is on VHS. May not be useful given more recent survey in 2008.

Appendix D: Project Menu Components and Brainstorming Meeting Minutes



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Reach 1 - Upstream Private Properties on 68th Ave. S.				
No.	**Menu Component Description**	**Elements and Issues**	**Further Analysis**	**Reason**
1	Realign creek to the back of private properties on 68th Ave. S. adjacent to park property ball field	Regrade the channel Consider sediment transport and deposition Maintain park use Need to buy at least one private property on the upstream section to aid smooth realignment of creek or investigate the feasibility of earthwork and grading required to go around the existing house. Consider buffer impacts: 1) Parks and property owners can each provide part of the buffer, 2) a narrower than standard buffer may still be preferable to leaving the creek in front yards with minimal effective buffer widths and multiple driveway crossings Property owners' opinion is unknown. SPU is responsible for negotiations and coordination with property owners Site grading might be a constraint Soil condition unknown Major earth moving project	Yes Option A	
2	Realign creek to the back of the first two private properties on the upstream end of the creek on 68th Ave. S. and loop around the ballpark on the east side	Regrade the channel Consider sediment transport and deposition Need to buy at least one private property on the upstream section to aid smooth realignment of creek or investigate the feasibility of earthwork and grading required to go around the existing house. Consider buffer impacts, application of standard buffer widths could encumber a significant area in the Park Property owners' opinion is unknown. SPU is responsible for negotiations and coordination with property owners Site grading might be a constraint Major earth moving project	No	This major loop around the ballpark impacts existing park use and may be high cost.
3	Keep the creek at the current location and regrade of channel from 68th Ave. S. culvert to the SPU property including the 4.5' drop fish passage barrier under private driveway	Remove 4.5' fish passage barrier Regrade the channel Consider sediment transport and deposition Check for sewer and service line conflicts Channel improvement may involve increasing the channel width Replace driveway culverts with fish passage culverts	Yes Option B	
4	Shared access road for all private properties on 68th Ave. S. with a single driveway culvert (or at least combining some)	Is ROW available for access road? Habitat improvement is not achieved Property owners' opinion is unknown	No	SPU will investigate.
5	Purchasing all private property on 68th Ave. S.	Property owners' opinion is unknown Larger area for channel improvement and alluvial fan Project cost might be significantly high	No	Purchasing of properties is not an option for now
6	Realign creek to the west side of 68th Ave. S. and install a fish passable culvert across 68th Ave. S. to SPU property	Minimal habitat improvement; Narrow channel alignment with no buffer(road on one side hill slope on the other). Property owners' opinion is unknown. SPU is responsible for negotiations and coordination with property owners Project cost might be significantly high Soil condition unknown Major earth moving project	No	It will be major earth moving project and will not be considered for now.

Reach 2 - SPU & Park Property, Private and Rainier Ave. S. Culverts				
No.	**Menu Component Description**	**Elements and Issues**	**Further Analysis**	**Reason**
1	Continue creek realignment from Reach 1 No. 1 on Park property (behind private property on 68th Ave. S.) along the west side of the ballpark and cross Rainier Ave. S. at new alignment	Consider meander and backwater channel on SPU property Consider sediment transport and deposition Need to move ballpark maintenance access road Property owners' opinion is unknown. SPU is responsible for negotiations and coordination with property owners Maintain park use Shorter and perpendicular culvert length to the east of current culvert alignment Check if private properties downstream of Rainier Ave. S. culvert can access their property from the west side of the access road.	Yes Option A	
2	Continue creek realignment from Reach 1 No. 2 (loop the creek around the ballpark) then flow west on the ballpark perimeter and cross Rainier Ave. S. at new alignment	Major loop around Can daylight stream in the loop around section Creek will move away from SPU property on 68th Ave. S. Property owners; opinion is unknown. SPU is responsible for negotiations and coordination with property owners Major earth moving project Maintain park use Check if private properties downstream of Rainier Ave. S. culvert can access their property from the west side of the access road. Consider sediment transport and deposition	No	This major loop around the ballpark impacts existing park use and may be high cost.
3	Continue creek alignment from Reach 1 No. 2 (loop the creek around the ballpark) then flow west on the ballpark perimeter and cross Rainier Ave. S. at new alignment with a bigger box culvert with pedestrian trial that runs all the way to the lake	Major loop around Can daylight stream in the loop around section Creek will move away from park property on 68th Ave. S. Property owners' opinion is unknown. SPU is responsible for negotiations and coordination with property owners Major earth moving project Maintain park use Check if private properties downstream of Rainier Ave. S culvert can access their property from the west side of the access road. Consider sediment transport and deposition	No	The box culvert with pedestrian trail is not going to be explored further as it is not desirable or may not be feasible financially due to the very wide culvert, or actually bridge, that would be required. This major loop around the ballpark impacts existing park use and may be high cost.
4	Keep creek in SPU property on 68th Ave. S. and realign to ballpark toward the new alignment of Rainier Ave. S culvert (downstream of Reach 1 No. 3)	Keep existing channel alignment along 68th Ave. S. Shorter and perpendicular culvert length to the east of current culvert alignment Realign creek on park property on 68th Ave. S. to aid new culvert alignment Use SPU property as sediment depositional or alluvial fan area Move creek on ballpark property and away from the failing apartment complex private culvert Check if private properties downstream of Rainier Ave. S. culvert can access their property from the west side of the access road. Consider sediment transport and deposition	Yes Option B	
5	Provide high flow bypass for the creek	Keep existing channel location Minimal habitat improvement Flooding of private properties on 68th Ave. S. and downstream of Rainier Avenue S. reduced Maintenance intensive, expensive Can look at keeping current alignment of Rainier Ave. S. culvert Consider sediment transport and deposition	No	Maintenance intensive, expensive, keeping current alignment of Rainier culvert is not feasible, sediment will tend to drop out and accumulate at diversion point.
6	Swap land between apartment complex and park property on 68th Ave. S.	Can look at keeping current alignment of Rainier Ave. S. culvert Property negotiations have to be undertaken	No	keeping current alignment of Rainier Ave. S. culvert is not feasible

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Reach 3 - Private Properties Downstream of Rainier Ave. S. Culvert				
No.	**Menu Component Description**	**Elements and Issues**	**Further Analysis**	**Reason**
1	Realign creek from private property to SPU acquired property with the new alignment of Rainier Ave. S. culvert, abandon existing creek alignment through private property (Reach 2 No. 1 -4)	Property owners' opinion unknown. SPU is responsible for negotiations and coordination with property owners	Yes	
		Move creek onto SPU acquired property with new alignment of Rainier Ave. S. culvert		
		Improve abandoned channel for stormwater conveyance and/or treatment		
		Check access road gradient		
		Check if private properties downstream of Rainier Av e. S. culvert can access their property from the west side of the access road.		
		Consider sediment transport and deposition		
2	Keep current location of creek through private property (Reach 2 No. 5 & 6)	May have to keep current Rainier Ave. S. culvert alignment (not desirable)	No	Current alignment of Rainier Ave. S. culvert is not desirable; however, if property owners do not agree to relocate the creek we need to explore this option
		Consider sediment transport and deposition		
3	Split the stream downstream of access road culvert. One branch remains in current alignment and the other branch will be directed towards the SPU acquired property	Need to check access road gradient	No	Current alignment of Rainier Ave. S. culvert is not desirable
		Need to verify if they will be sufficient flow for fish migration and egg incubation between the two alignments		
		Diversion structure needed to split flows and associated maintenance cost		
		Consider sediment transport and deposition		

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Reach 4 - Creek in SPU Acquired Property

No.	Menu Component Description	Elements and Issues	Further Analysis	Reason
1	Realign the creek at current location, armor one side and extend the other side for additional floodplain storage	Flooding of and migration of channel onto neighboring properties may be an issue Beneficial to fish Consider sediment transport and deposition	Yes*	
2	Keep the creek at current location provide meandering and added floodplain storage	Consider sediment transport and deposition	Yes*	
3	Move the creek to the middle of property, with more meandering and added floodplain storage	Consider sediment transport and deposition	Yes*	
4	Move the creek outlet upstream of its current discharge location on the SPU acquired property	Consider sediment transport and deposition	Yes*	
5	Provide passive recreational area, trails, log structure and overhanging vegetation etc.	Consider sediment transport and deposition	Yes*	
6	Connection to hyporheic zone (reference: confluence project in Thornton Creek)		No	Testing is underway and hence results are not available to check feasibility

**** Combined into a single menu component***
Add floodplain storage and creek meandering in SPU acquired property. Provide passive recreational area, trails, log structures and overhanging vegetation. (Applies to Options A & B)

Lower Reach 4 - Delta

No.	Menu Option Description	Elements and Issues	Further Analysis	Reason
1	No engineered delta extension	let the delta grow Need to evaluate impact on neighboring docks Consider sediment transport and deposition Benefits depend on what is engineered upstream of the delta.	Yes Option A	
2	Engineered delta extension similar to Coal Creek project	Beneficial to fish Need to evaluate impact on neighboring docks Consider sediment transport and deposition Intermediate solution that will last for couple of decades	Yes Option B	

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Appendix E: Construction Cost Estimates

SEATTLE PUBLIC UTILITIES

LOWER TAYLOR CREEK CONCEPTUAL DESIGN

OCI PROJECT No. 10-100043

February 7, 2011

ENGINEER'S CONSTRUCTION COST ESTIMATE

R1-A, New Channel on Park Property	$	818,000
R1-B, Fish Passage Improvements on Private Property	$	421,000
R2-A, New Rainier Ave Culvert (connects with R1-A)	$	487,000
R2-B, New Rainier Ave Culvert (connects with R1-B)	$	487,000
R4-A, Full channel restoration without engineered outfall	$	903,000
R4-B, Full channel restoration with engineered outfall	$	1,028,000
Construction Cost - Option A (R1-A, R2-A, R4-B)	$	2,333,000
(rounded)	**$**	**2,340,000**
Construction Cost - Alternative B (R1-B, R2-B, R4-A)	$	1,811,000
(rounded)	**$**	**1,820,000**

OSBORN CONSULTING INC.
1800 112th Avenue NE
Suite 220-E
Bellevue, WA 98004
(425) 451-4009

MENU R1-A					
DESCRIPTION: Realign creek to the Park property ball park behind the private properties on 68th Avenue S.					
PLANNING LEVEL COST OPINION					
Item No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Amount**
Construction Elements					
1	Clearing and Grubbing	1.6	AC	$ 6,300.00	$ 10,080.00
2	Excavation Incl. Haul	1,700	CY	$ 45.00	$ 76,500.00
3	Large Woody Debris	1	LS	$ 55,000.00	$ 55,000.00
4	Utility Relocate	-	LS	$ -	$ -
5	Restoration/Planting	57,000	SF	$ 1.50	$ 85,500.00
6	Streambed Gravel	280	CY	$ 60.00	$ 16,800.00
7	Weir Modification	1	EA	$ 500.00	$ 500.00
8	Purchase 10050 68th Ave S	1	LS	$ 286,500.00	$ 286,500.00
				Subtotal Construction Elements	$ 530,880.00
Required Ancillary Items					
9	Dewatering and Stream Bypass		5%		$ 26,544.00
10	Erosion and Sedimentation Control		3%		$ 13,272.00
11	Traffic Control		0%		$ -
12	Contingency		20%		$ 106,176.00
				Subtotal Ancillary	$ 145,992.00
				Subtotal Construction + Ancillary	$ 676,872.00
Mobilization and Sales Tax					
13	Mobilization		10%		$ 67,687.20
14	State Sales Tax		9.8%		$ 72,966.80
				Subtotal Tax/Mobilization	$ 140,654.00
				Subtotal Construction + Ancillary + Mobilization	$ 817,526.00
2011 Dollars				**Total Estimated Cost (rounded)**	$ 817,500.00

Notes:
1. The above cost opinion is in 2011 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of construction will depend on actual labor and materials including final design elements.
3. Engineering, Permitting and Construction Management costs are not included.

Prepared by: OCI
Date: 1/7/11

MENU R1-A

DESCRIPTION: Realign creek to the Park property ball park behind the private properties on 68th Avenue S.

Item No.	Comments			
1	850	LF x	80	ft wide
2	4	ft depth	13	ft ave. width
6	6	ft bottom		
8	www.zillow.com			
9	assumes existing channel used for bypass			
11	No road crossings			

Prepared by: OCI
Date: 1/7/11

MENU R1-B					
DESCRIPTION: Keep creek at the current location, regrade and remove 4.5 foot fish barrier					
PLANNING LEVEL COST OPINION					
Item No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Amount**
Construction Elements					
1	Clearing and Grubbing	0.7	AC	$ 6,300.00	$ 4,410.00
2	Excavation Incl. Haul	700	CY	$ 45.00	$ 31,500.00
3	Large Woody Debris	1	LS	$ -	$ -
4	Driveway Culvert (5'5"rise x 14'span x 22.5'long)	4	EA	$ 41,700.00	$ 166,800.00
5	Utility Relocate	1	LS	$ 4,000.00	$ 4,000.00
6	Restoration/Planting	23,200	SF	$ 1.50	$ 34,800.00
7	Streambed Gravel	270	CY	$ 60.00	$ 16,200.00
8	Weir Modification	1	EA	$ 500.00	$ 500.00
				Subtotal Construction Elements	$ 258,210.00
Required Ancillary Items					
9	Dewatering and Stream Bypass		10%		$ 25,821.00
10	Erosion and Sedimentation Control		3%		$ 7,746.30
11	Traffic Control		2%		$ 5,164.20
12	Contingency		20%		$ 51,642.00
				Subtotal Ancillary	$ 90,373.50
				Subtotal Construction + Ancillary	$ 348,583.50
Mobilization and Sales Tax					
13	Mobilization		10%		$ 34,858.35
14	State Sales Tax		9.8%		$ 37,577.30
				Subtotal Tax/Mobilization	$ 72,435.65
				Subtotal Construction + Ancillary + Mobilization	$ 421,019.15
2011 Dollars				**Total Estimated Cost (rounded)**	$ 421,000.00

Notes:
1. The above cost opinion is in 2011 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at
3. Engineering, Permitting and Construction Management costs are not included.

Prepared by: OCI
Date: 1/7/11

MENU R1-B

DESCRIPTION: Keep creek at the current location, regrade and remove 4.5 foot fish barrier

Item No.	Comments			
1	800	LF x	40	ft wide
2	2	ft depth	11	ft ave. width
5	Assume service line relocations at each house			
7	6	ft bottom		
9	Stream bypass needed			
11	Driveway crossings			

Prepared by: OCI
Date: 1/7/11

MENU R2-A

DESCRIPTION: Continue creek alignment from Menu R1-A on ball park, away from SPU property and private failing culvert to a new culvert alignment of Rainier Avenue S.

PLANNING LEVEL COST OPINION

Item No.	Item	Quantity	Unit	Unit Price	Amount
Construction Elements					
1	Clearing and Grubbing	0.7	AC	$ 6,300.00	$ 4,410.00
2	Excavation Incl. Haul	800	CY	$ 45.00	$ 36,000.00
3	Large Woody Debris	1	LS	$ 30,000.00	$ 30,000.00
4	Rainier Ave. S Culvert (6'8"r x 14'span x 126LF)	1	EA	$ 161,200.00	$ 161,200.00
5	Utility Relocate	1	LS	$ 12,000.00	$ 12,000.00
6	Relocate Park Maintenance Access	1	LS	$ 1,500.00	$ 1,500.00
7	Restoration/Planting	26,800	SF	$ 1.50	$ 40,200.00
8	Streambed Gravel	130	CY	$ 60.00	$ 7,800.00
				Subtotal Construction Elements	$ 293,110.00
Required Ancillary Items					
9	Dewatering and Stream Bypass		5%		$ 14,655.50
10	Erosion and Sedimentation Control		3%		$ 7,327.75
11	Traffic Control		10%		$ 29,311.00
12	Contingency		20%		$ 58,622.00
				Subtotal Ancillary	$ 109,916.25
				Subtotal Construction + Ancillary	$ 403,026.25
Mobilization and Sales Tax					
13	Mobilization		10%		$ 40,302.63
14	State Sales Tax		9.8%		$ 43,446.23
				Subtotal Tax/Mobilization	$ 83,748.85
				Subtotal Construction + Ancillary + Mobilization	$ 486,775.10
2011 Dollars				**Total Estimated Cost (rounded)**	$ 486,800.00

Notes:
1. The above cost opinion is in 2011 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at
3. Engineering, Permitting and Construction Management costs are not included.

Prepared by: OCI
Date: 1/7/11

MENU R2-A

DESCRIPTION: Continue creek alignment from Menu R1-A on ball park, away from SPU property and private failing culvert to a new culvert alignment of Rainier Avenue S.

Item No.	Comments			
1	400	LF x	80	ft wide
2	4	ft depth	13	ft ave. width
5	Utilities in Rainier Ave. South			
8	6	ft bottom		
9	assumes existing channel used for bypass			
11	Culvert crosses major arterial			

MENU R2-B					
DESCRIPTION: Continue to keep current creek alignment from Menu R1-B in SPU property, realign to ball park and away from private failing culvert to a new culvert alignment across Rainier Avenue S.					
PLANNING LEVEL COST OPINION					
Item No.	**Item**	**Quantity**	**Unit**	**Unit Price**	**Amount**
Construction Elements					
1	Clearing and Grubbing	0.7	AC	$ 6,300.00	$ 4,410.00
2	Excavation Incl. Haul	800	CY	$ 45.00	$ 36,000.00
3	Large Woody Debris	1	LS	$ 30,000.00	$ 30,000.00
4	Rainier Ave. S Culvert (6'8"r x 14'span x 126LF)	1	EA	$ 161,200.00	$ 161,200.00
5	Utility Relocate	1	LS	$ 12,000.00	$ 12,000.00
6	Relocate Park Maintenance Access	1	LS	$ 1,500.00	$ 1,500.00
7	Restoration/Planting	26,800	SF	$ 1.50	$ 40,200.00
8	Streambed Gravel	130	CY	$ 60.00	$ 7,800.00
				Subtotal Construction Elements	$ 293,110.00
Required Ancillary Items					
9	Dewatering and Stream Bypass		5%		$ 14,655.50
10	Erosion and Sedimentation Control		3%		$ 7,327.75
11	Traffic Control		10%		$ 29,311.00
12	Contingency		20%		$ 58,622.00
				Subtotal Ancillary	$ 109,916.25
				Subtotal Construction + Ancillary	$ 403,026.25
Mobilization and Sales Tax					
13	Mobilization		10%		$ 40,302.63
14	State Sales Tax		9.8%		$ 43,446.23
				Subtotal Tax/Mobilization	$ 83,748.85
				Subtotal Construction + Ancillary + Mobilization	$ 486,775.10
2011 Dollars				**Total Estimated Cost (rounded)**	$ 486,800.00

Notes:
1. The above cost opinion is in 2011 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available
3. Engineering, Permitting and Construction Management costs are not included.

Prepared by: OCI
Date: 1/7/11

MENU R2-B

DESCRIPTION: Continue to keep current creek alignment from Menu R1-B in SPU property, realign to ball park and away from private failing culvert to a new culvert alignment across Rainier Avenue S.

Item No.	Comments			
	*longer than opt. A, but includes some ex. Channel			
1	400	LF* x	80	ft wide
2	4	ft depth	13	Engineer's Cost Estimate
5	Utilities in Rainier Ave. South			
8	6	ft bottom		
9	assumes existing channel used for bypass			
11	Culvert crosses major arterial			

MENU R4-A

DESCRIPTION: Realign creek through acquired property to include natural meander pattern and flood plain benches. No engineered delta extension at the mouth.

PLANNING LEVEL COST OPINION

Item No.	Item	Quantity	Unit	Unit Price	Amount
Construction Elements					
1	Clearing and Grubbing	5.3	AC	$ 6,300.00	$ 33,390.00
2	House Demolition	4	EA	$ 20,000.00	$ 80,000.00
3	Channel Excavation Incl. Haul	2,100	CY	$ 45.00	$ 94,500.00
4	Large Woody Debris	1	LS	$ 90,000.00	$ 90,000.00
5	Utility Relocate	1	LS	$ 10,000.00	$ 10,000.00
6	Restoration/Planting	143,900	SF	$ 1.50	$ 215,850.00
7	Streambed Gravel	350	CY	$ 60.00	$ 21,000.00
8	Footpath (gravel or hog fuel)	800	LF	$ 16.00	$ 12,800.00
				Subtotal Construction Elements	$ 557,540.00
Required Ancillary Items					
9	Dewatering and Stream Bypass		10%		$ 55,754.00
10	Erosion and Sedimentation Control		3%		$ 16,726.20
11	Traffic Control		1%		$ 5,575.40
12	Contingency		20%		$ 111,508.00
				Subtotal Ancillary	$ 189,563.60
				Subtotal Construction + Ancillary	$ 747,103.60
Mobilization and Sales Tax					
13	Mobilization		10%		$ 74,710.36
14	State Sales Tax		9.8%		$ 80,537.77
				Subtotal Tax/Mobilization	$ 155,248.13
				Subtotal Construction + Ancillary + Mobilization	$ 902,351.73
2011 Dollars				**Total Estimated Cost (rounded)**	$ 902,400.00

Notes:
1. The above cost opinion is in 2011 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available
3. Engineering, Permitting and Construction Management costs are not included.

MENU R4-A

DESCRIPTION: Realign creek through acquired property to include natural meander pattern and flood plain benches. No engineered delta extension at the mouth.

Item No.	Comments			
1	1050	LF x	220	ft wide lot
2	Estimated Price			
3	4	ft depth	13	ft ave. width
5	Remove utilities to demo'd housese			
6	150	ft w.		
7	6	ft bottom		
9	Stream bypass needed			
11	crosses local access road			

Prepared by: OCI
Date: 1/7/11

MENU R4-B							
DESCRIPTION: Realign creek through acquired property to include natural meander pattern and flood plain benches. Restore the creek mouth with an engineered delta extension.							
PLANNING LEVEL COST OPINION							
Item No.	**Item**	**Quantity**	**Unit**		**Unit Price**		**Amount**
Construction Elements							
1	Clearing and Grubbing	6.1	AC	$	6,300.00	$	38,430.00
2	House Demolition	4	EA	$	20,000.00	$	80,000.00
3	Channel Excavation Incl. Haul	2,400	CY	$	45.00	$	108,000.00
4	Large Woody Debris	1	LS	$	115,000.00	$	115,000.00
5	Utility Removal	1	LS	$	10,000.00	$	10,000.00
6	Restoration/Planting	164,400	SF	$	1.50	$	246,600.00
7	Streambed Gravel	400	CY	$	60.00	$	24,000.00
8	Footpath (gravel or hog fuel)	800	LF	$	16.00	$	12,800.00
					Subtotal Construction Elements	$	634,830.00
Required Ancillary Items							
9	Dewatering and Stream Bypass		10%			$	63,483.00
10	Erosion and Sedimentation Control		3%			$	19,044.90
11	Traffic Control		1%			$	6,348.30
12	Contingency		20%			$	126,966.00
					Subtotal Ancillary	$	215,842.20
					Subtotal Construction + Ancillary	$	850,672.20
Mobilization and Sales Tax							
13	Mobilization		10%			$	85,067.22
14	State Sales Tax		9.8%			$	91,702.46
					Subtotal Tax/Mobilization	$	176,769.68
					Subtotal Construction + Ancillary + Mobilization	$	1,027,441.88
2011 Dollars					**Total Estimated Cost (rounded)**	$	1,027,400.00

Notes:
1. The above cost opinion is in 2011 dollars and does not include future escalation, financing, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at
3. Engineering, Permitting and Construction Management costs are not included.

MENU R4-B

DESCRIPTION: Realign creek through acquired property to include natural meander pattern and flood plain benches. Restore the creek mouth with an engineered delta extension.

Item No.	Comments
1	1200 LF x 220 ft wide lot
2	Estimated Price
3	4 ft dep 13 ft ave. width
5	Remove utilities to demo'd houses
6	150 ft w.
7	6 ft bottom
9	Stream bypass needed
11	crosses local access road

This sheet documents sources of unit price information and the development of lump sum prices.

WSDOT Standard Bid Item; Average low bids for 2010-2011			**Comment**	**Use**
Clearing and Grubbing	AC	$ 6,266.00	Ave bid; 1.18ac march 2010	$ 6,300.00
Ditch Excavation Incl. Haul (QTY>500)	CY	$ 45.00		$ 45.00
Ditch Excavation Incl. Haul (QTY<500)	CY	$ 45.00		$ 45.00
Streambed Gravel (Sediment/Cobbles)	CY	$ 60.00		$ 60.00
Unit Price based on recent project experience				
Site Restoration	SF	$ 1.50	Planting for bank & buffer enhancement	$ 1.50

Culvert Cost:	Driveway	Rainier	
Material incl. culvert + headwall ($/LF)	$ 600	$ 290	Based on data from Contech
Culvert Footings ($/LF)	$ 300	$ 300	Based on data from Contech
Culvert length	22.5	126.0	
Material Subtotal	$ 20,250	$ 74,340	Incl. culvert, headwall and footings
Asphalt driveway/road Restoration	$ 1,111	$ 12,444	4"for driveway; 8" rainier; 2ton/CY; $100/ton
Labor/Installation	$ 20,250	$ 74,340	Estimated 100% of material cost
Subtotal	*$ 41,611*	*$ 161,124*	
Unit Price (rounded)	**$ 41,700**	**$ 161,200**	

Large Woody Debris (assumes # logs shown on Figures)

$/log: $ 1,000.00

Menu Component	# logs	LS Price
R1-A	55	$ 55,000
R1-B	0	$ -
R2 (A or B)	30	$ 30,000
R4-A	115	$ 115,000
R4-B	90	$ 90,000

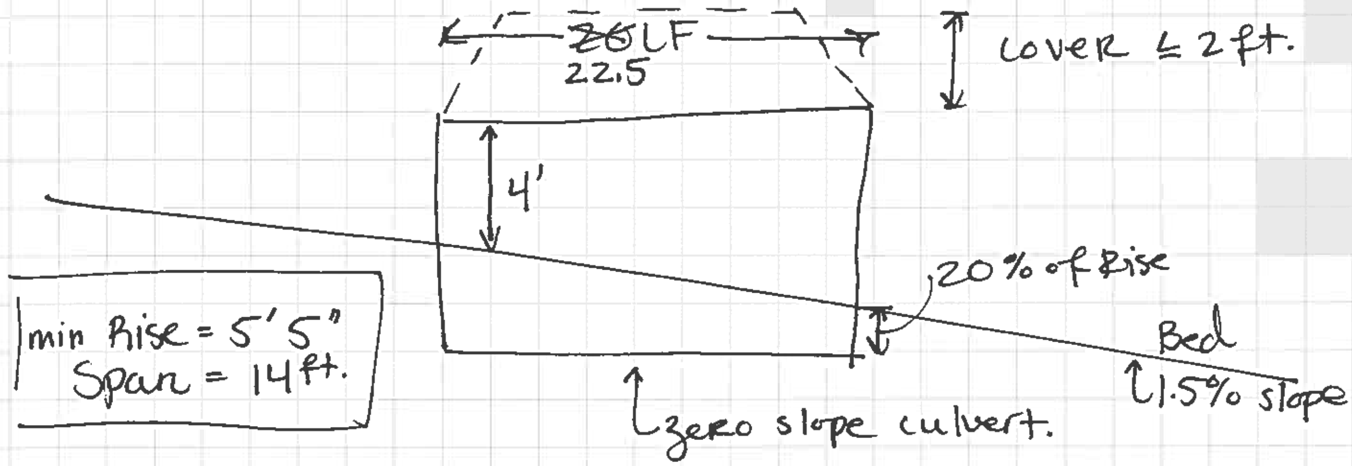
Prepared by: OCI
Date: 1/7/11

Appendix F: Culvert Details

- Conceptual Design Sketch
- Email Correspondence with manufacturer
- Manufacturer provided product information

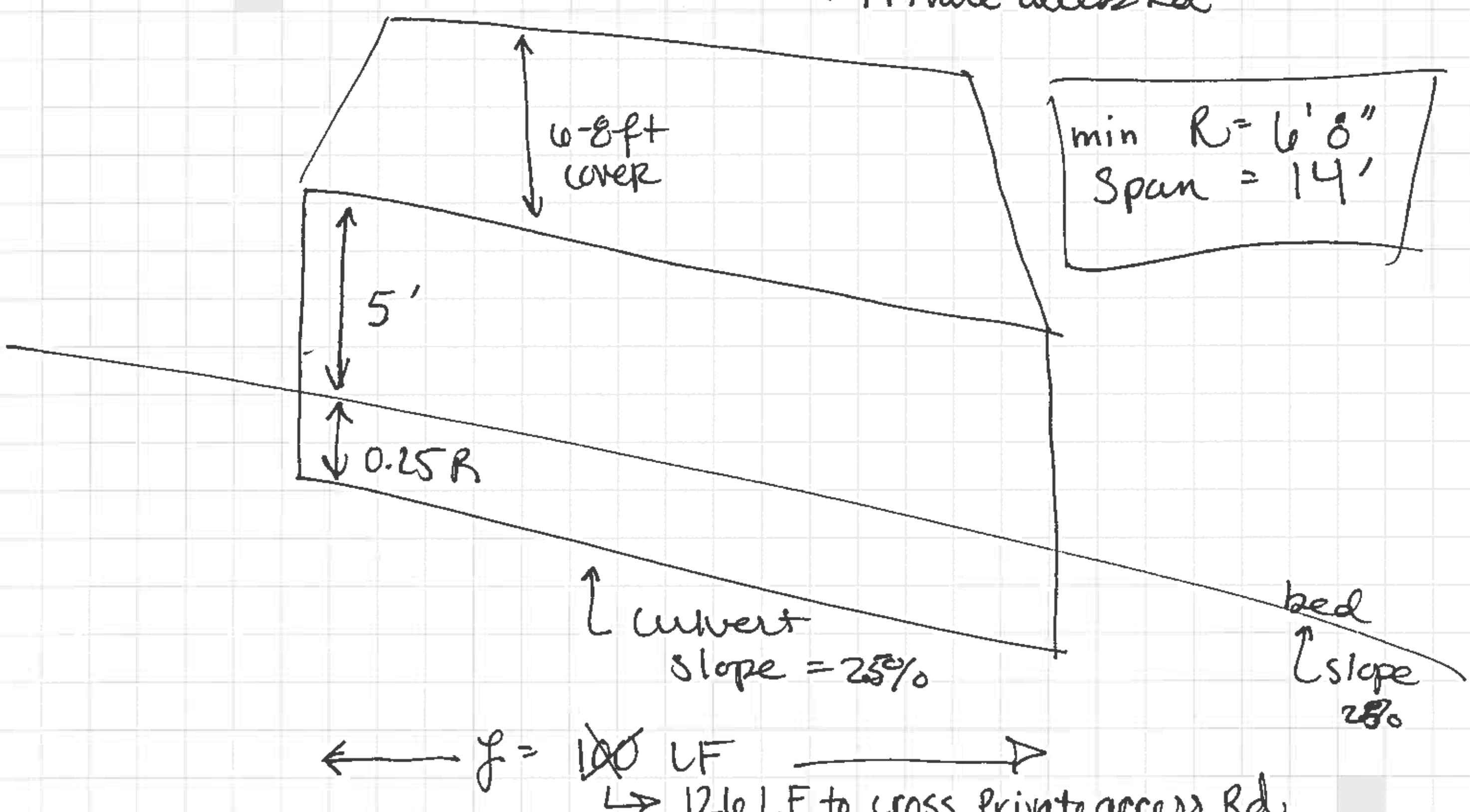
Lower Taylor Creek
conceptual design
(LR, 1/5/11)

Driveway culverts:
(four total)



Profile View

Rainier Ave. South Culvert.
Major arterial (5-Lane Rd.)
+ Private access Rd



Profile View

Laura Ruppert

From: Scott, Mike [scottm@contech-cpi.com]
Sent: Monday, January 10, 2011 7:31 PM
To: Laura Ruppert
Subject: FW: Culvert Quote Needed - More Information - Seattle Public Utilities - Lower Taylor Creek - Conceptual Design

Laura:

We've summarized the answers up here, but also included individual responses in red below.

For ALBC's the culvert itself generally makes up about half the overall cost (assuming standard headwalls and wingwalls). Obviously, longer wingwalls and/or taller headwalls will skew that percentage down.

Foundations can be assumed to cost approximately $200 to $400 per linear foot of footing, each side; if foundation soils have a good bearing capacity, about 4000 psf or more, then the cost will be on the low end. Weaker soils translate into larger footings and higher cost. Remediation of the soils or overexcavation/replacement with rock is always an alternative.

→ $600/LF

The driveway culverts, each with length 22.5', and with headwalls but no wingwalls, cost about $13,500 (the material is light enough that we could get an LTL Freight rate). The Rainier Ave. South culvert, at 103.5', and assuming an Aluminum Structural Plate (ALSP) Single Radius Arch (SRA) with standard aluminum headwalls but no wingwalls, would cost about $30,000 (maybe a little less, depending on the freight rate we can use).

→ $290/LF

We can also generate more formal estimates in the near future.

Mike Scott
Project Consultant, Field Marketing
CONTECH Construction Products Inc.
19706 9th Place West | Lynnwood, WA 98036
Off: 425-835-0440 | Mob: 206-979-8732 | Fax: 425-835-0480
scottml@contech-cpi.com
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From: Laura Ruppert [mailto:Laura@osbornconsulting.com]
Sent: Wednesday, January 05, 2011 1:46 PM
To: Scott, Mike
Cc: 'Deepa Mungasavalli'
Subject: RE: Culvert Quote Needed - More Information

Hi Mike,
Happy New Year. I hope you had an enjoyable holiday season.
Our conceptual design deliverable is approaching so I'm looking at culvert costs again.
I have answers to a couple of your questions:

1. These are fish passable culverts.
2. Assume headwalls are needed.
3. No wingwalls
4. Refined culvert dimensions are attached

I also have a couple of follow up questions for you.

1. I noticed ALBC 18 and ALBC 25 have very different costs per LF; why is that? See above
2. The ALBC costs include headers and wing walls; approximately what percent of the cost is just the culvert? About 50% in this case
3. We have not designed footings yet but know they will be needed if we go with a bottomless culvert. Do you know a ball park cost that we should include in our estimate? Assume $200 to $400 per linear foot of footing, each side – on the low end for soils with good bearing capacity, on the high end for weaker soils
4. I like your suggestion of using a bottomless arch culvert. Fish and Wildlife seems to prefer bottomless and then we won't need to place as much fill as with the round culverts. Can you please provide updated, preliminary costs for the two culverts shown on the attached sketch? Updated estimates, assuming lengths divisible by 4.5', standard headwalls and no wingwalls, above.

Thanks,

Laura Ruppert, P.E.

425.451.4009 office
206.240.5480 mobile
<snip!>

From: Scott, Mike [mailto:scottm@contech-cpi.com]
Sent: Thursday, December 02, 2010 8:53 AM
To: deepa
Subject: RE: Culvert Quote Needed - More Information
Importance: High

Deepa:

If the message that I sent to you yesterday and attachments (see below) will require you to go into more detail than you are prepared to at this time (due to conceptual stage of project), we can offer the following to get you started.

We have provided some information below in green on products that most closely approximate the rise and span indicated, but in the case of the box culverts, the available aluminum box culverts (ALBC) shapes are way, way different than the dimensions that you requested. If you prefer concrete (i.e., Con/Span), then you need to know that the standard spans are 12', 14', 16', and then 20', and we also would like to define the headwalls and wingwalls to some extent. We have included the budgetary cost estimates without headwalls or wingwalls to illustrate that if they were included, then the system would be much more expensive than even the price shown.

For the round shapes, we are assuming that you mean a simple round culvert that would be filled in at the bottom to achieve the desired rise – but that needs to be clarified. For example, it may be preferable to use a bottomless arch shape if you want an open-bottom arch. We have not considered footing options either, so that needs to be kept in mind.

All of that being said, here are some initial numbers for your consideration:

Box Culvert

1. Rise : 5.7 ft, Length: 20 ft, Span: 12.6', slope: 0%
   ALBC 18, 12'-7" span x 5'-2" rise, 22.5 LF, and including standard Headwalls and wingwalls, about $19,800
   Con/Span 12' span, 6' rise, 20LF, no HW's or WW's, about $19,600
2. Rise: 10 ft, Length: 100 ft, Span: 14', slope: 2%
   ALBC 25, 14'-1" span x 6'-2" rise, 103.5 LF, and including standard HW's and WW's, about $59,800
   Con/Span 14' Span x 10' rise, 100LF, no HW's or WW's, about $115,800
3. Rise: 10 ft, length: 100 ft, span: 17', slope: 2%
   ALBC 40, 17'-9" span x 3'-10" rise, 103.5 LF, and including standard HW's and WW's, about $69,900
   Con/Span 20' Span x 10' rise, 100LF, no HW's or WW's, about $153,000

Round Culvert

1. Rise: 5.7 ft, length: 20 ft, dia.: 15.8', slope: 0%
   Multiplate 16' diameter Round, 10ga, 20LF, no HW's or WW's, about $17,200
2. Rise: 10 ft, length: 100 ft, dia: 15.8', slope: 2%
   Multiplate 16' diameter Round, 10ga, 100LF, no HW's or WW's, about $65,200

3. Rise: 10 ft, length: 100 ft, dia: 18', slope: 2%
   Multiplate 18' diameter Round, 8ga, 100LF, no HW's or WW's, about $77,900

CONTECH can offer several different options for these, including our plate structures (MULTI-PLATE and ALUMINUM STRUCTURAL PLATE as well as ALUMINUM BOX CULVERTS), and Precast Concrete options with CON/SPAN three sided arch structures. We can provide both open bottom and closed structures in multiple shapes.

To better understand the requirements here, please let us know what kind of loading could be expected (such as traffic loading overhead or a deep fill to be designed as dead load and for allowable depth of cover considerations). Also it is important to understand if wing walls and head walls will be required. A site plan or some cross section drawings would be very helpful if they are available. Also, if these are fish passable culverts, please let us know (especially important when considering metal plate structures and whether or not aluminum structural plate is a better choice for fish habitat). See attached Bridge Info Sheet (if you can supply more details using this it would be helpful).

For initial consideration I have attached plate and precast concrete structure details sheets. Once we have a little more information we can narrow down appropriate shapes to select.

If it would be easier to meet with you personally and discuss your options, I would be happy to do that as well. Just let me know.

Thanks,

Mike Scott
Project Consultant, Field Marketing
CONTECH Construction Products Inc.
19706 9th Place West | Lynnwood, WA 98036
Off: 425-835-0440 | Mob: 206-979-8732 | Fax: 425-835-0480
scottml@contech-cpi.com
www.contech-cpi.com
From: deepa [mailto:deepa@osbornconsulting.com]
Sent: Wednesday, December 01, 2010 2:51 PM
To: Scott, Mike
Subject: RE: Culvert Quote Needed

The first options in both box culverts and round culverts are no slope options.

Thanks,

Deepa Mungasavalli, E.I.T.
Osborn Consulting Inc.,
www.osbornconsulting.com

Please Note New Address:
1800 112th Avenue NE, Suite 220-E
Bellevue, WA 98004

Office: 425.451.4009
Cell: 425.894.0171

From: deepa [mailto:deepa@osbornconsulting.com]
Sent: Wednesday, December 01, 2010 12:25 PM
To: 'scottml@contech-cpi.com'
Subject: Culvert Quote Needed

Mike,

We are looking at ball park prices for conceptual design phase and need some quotes on culvert sizes. Below are the details.

Box Culvert

~~4.~~ Rise : 5.7 ft, Length: 20 ft, Span: 12.6', ~~slope: 2.5%~~
5. Rise: 10 ft, Length: 100 ft, Span: 14', slope: 2%
6. Rise: 10 ft, length: 100 ft, span: 17', slope: 2%

Round Culvert

~~4.~~ Rise: 5.7 ft, length: 20 ft, dia.: 15.8'~~, slope: 2.5%~~
5. Rise: 10 ft, length: 100 ft, dia: 15.8', slope: 2%
6. Rise: 10 ft, length: 100 ft, dia: 18', slope: 2%

Please let me know if these details are sufficient for you or you need more information. We are looking at comparison prices for closed available culvert sizes for above mentioned requirement.

Thanks,

Deepa Mungasavalli, E.I.T.
Osborn Consulting Inc.,
www.osbornconsulting.com

Please Note New Address:
1800 112th Avenue NE, Suite 220-E
Bellevue, WA 98004

Office: 425.451.4009
Cell: 425.894.0171

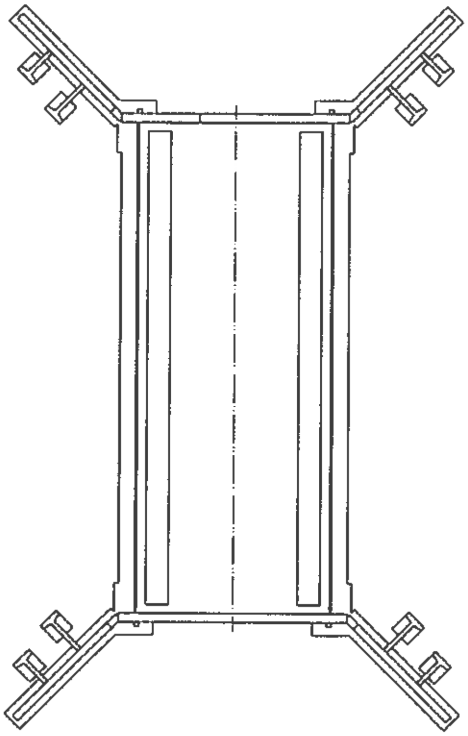
CONTECH®
CONSTRUCTION PRODUCTS INC.

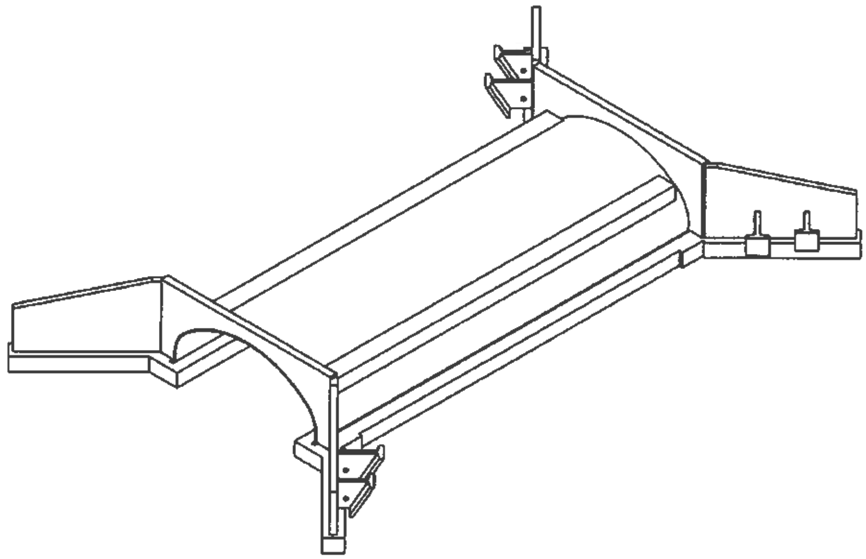
STRUCTURES PRODUCT GUIDE

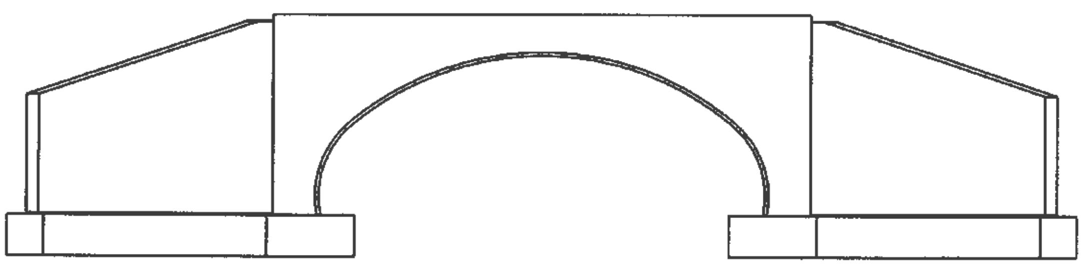
	PRODUCT	SPAN RANGE	FEATURES & BENEFITS
PLATE			
	MULTI-PLATE® & Aluminum Structural Plate (MP & ALSP) ← Recommended	5' to 26'	• Long history of strength, durability and economy • Variety of sizes and shapes available • Prefabrication of parts allows for fast and easy installation • Ideal structures for rehabilitation and relining
	Aluminum Box Culvert (ALBC)	8'-9" to 35'	
	SUPER-SPAN™ & SUPER-PLATE® (SS & SP)	19' to 52'	
	Bridge Plank	2' to 5'-10" (net span between bridge stringers)	• Economical solution for bridge deck rehabilitation and new construction
PRECAST			
	CON/SPAN® Bridge Systems	12' to 60'	• Fully engineered, modular systems • Precast arch units, headwalls and wingwalls mean fast installation • Clear span, three-sided structures provide natural bottom for environmental applications
	BEBO® Arch Systems	12' to 102'	
	CON/STORM® Concrete Culvert Systems	Up to 8'	• Lightweight arch units reduce freight and installation costs • Crane typically not required to install
TRUSS			
	U.S. Bridge®	Vehicular 10' to 300'	• Selection of standard truss styles available, in addition to limitless custom options • Prefabricated structure for ease of design and installation • AISC Major Bridge Certified • Variety of finish, decking and rail options for each project • 35-year warranty for galvanized vehicular bridges • Can be paired with precast abutments for complete bridge system
	Continental® Bridges	Pedestrian Up to 400'	

CONTECH®
CONSTRUCTION PRODUCTS INC.

Structural Plate Details







DESIGN SPECIFICATIONS

AASHTO:
Standard Specifications for Highway Bridges 17th Edition - Section 12
LRFD Bridge Design Specifications - Section 12

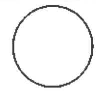
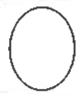
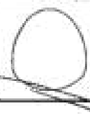
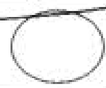
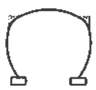
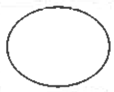
ASTM:
MULTI-PLATE® - A-796, 6″ x 2″ corrugation
Aluminum Structural Plate - B-790, 9″ x 2 1/2″ corrugation

AREMA Manual For Railway Engineering, 2006 - Section 4.9

AISI Handbook of Steel Drainage & Highway Construction Products - Chapter 4

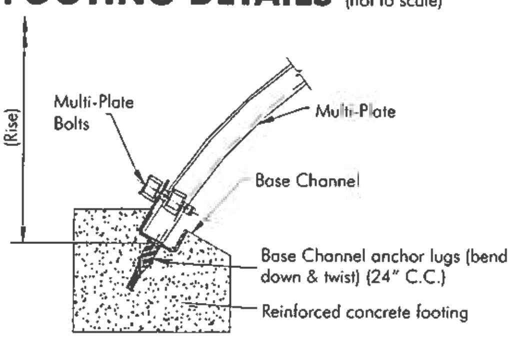
CONTECH®
STRUCTURAL PLATE

STRUCTURE SHAPE GEOMETRY

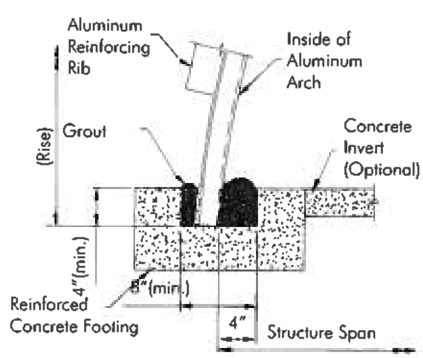
Shapes		Sizes — Span x Rise	Steel	Height of Cover* Steel (Ft.)	Aluminum	Height of Cover* Aluminum (Ft.)
Round		5'-0" to 26'-0"	Yes	1 - 308 3.5 - 56	Yes	1.25 - 45 1.5 - 20
Vertical Ellipse		4'-8" x 5'-2" to 25' x 27'-7"	Yes	1 - 308 3.5 - 56	Yes	1.25 - 45 1.5 - 20
Underpass*		12'-2" x 11'-0" to 20'-4" to 17'-9"	Yes	2 - 22 3 - 14	Yes	1.25 - 33 1.50 - 13
Single Radius Arch Recommended		6' x 1'-10" to 25' x 12'-6"	Yes	1 - 257 3.5 - 56	Yes	1.25 - 45 1.5 - 20
~~Horizontal Ellipse*~~		7'-4" x 5'-6" to 14'-11" x 11'-2"	Yes	1 - 16 2 - 16	Yes	1.25 - 14 1.25 - 9
Pipe Arch*		6'-1" x 4'-7" to 20'-7" x 13'-2"	Yes	1 - 16 3 - 8	Yes	1.25 - 24 2 - 7
Low-Profile Arch*		20'-1" x 7'-6" to 45'-0" x 18'-8"	Yes	2 - 20 4 - 18	Yes	2 - 20 4 - 18
High-Profile Arch*		20'-1" x 9'-1" to 35'-4" x 20'-0"	Yes	2 - 20 4 - 18	Yes	2 - 20 4 - 18
Pear-Arch*		23'-11" x 23'-4" to 30'-4" x 25'-10"	Yes	2 - 12 3 - 12	Not Available	N/A
Pear*		23'-8" x 25'-5" to 29'-11" x 31'-3"	Yes	2 - 12 3 - 12	Not Available	N/A
Horizontal Ellipse*		19'-4" x 12'-9" to 37'-2" x 22'-2"	Yes	2 - 20 4 - 18	Yes	2 - 20 4 - 18
Box Culvert*		8'-9" x 2'-6" to 35'-3" x 13'-7"	Not Available	Not Available	Yes	1.4 - 5

* Based on 4000 PSF allowable bearing for shapes with invert, ɣ = 120 PCF, H/HS 20 live load. AASHTO Section 12 Standard Specifications.

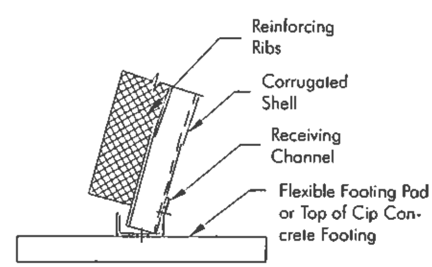
FOOTING DETAILS (not to scale)



Steel Base Channel Example

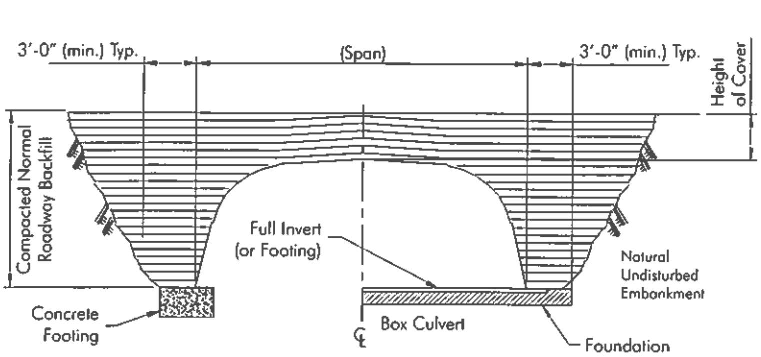


Slotted Concrete Footing Example

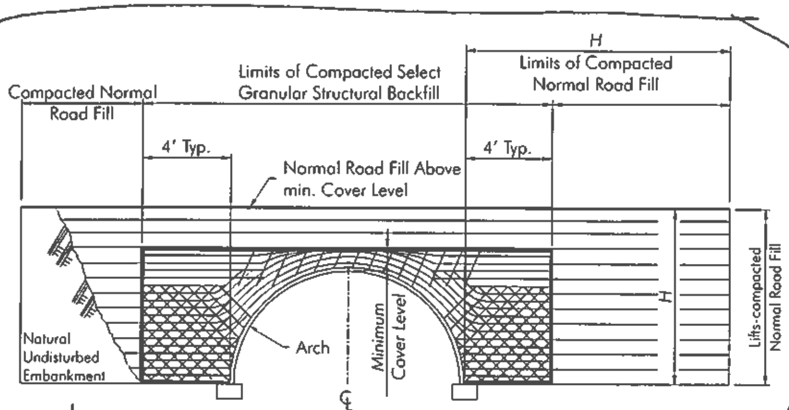


Aluminum Receiving Channel Example

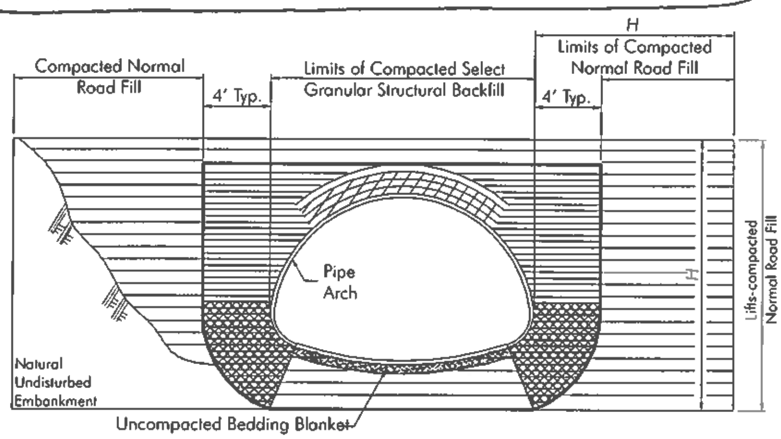
BACKFILL DETAILS (not to scale)



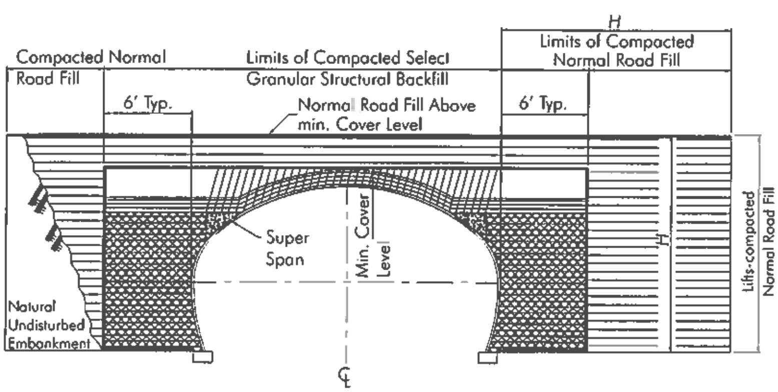
Typical Backfill Section - ALBC



Typical Backfill Section - Single Radius Arch

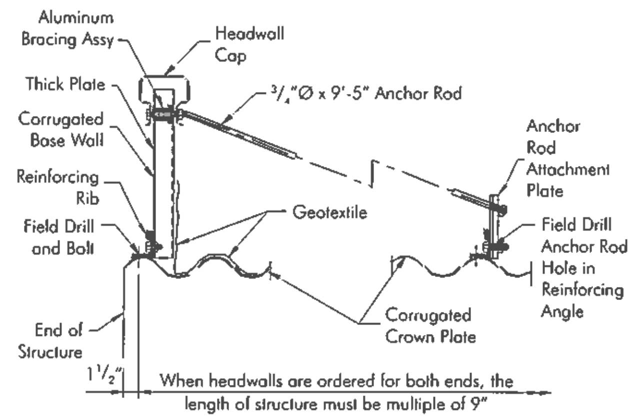


Typical Backfill Section - Pipe Arch

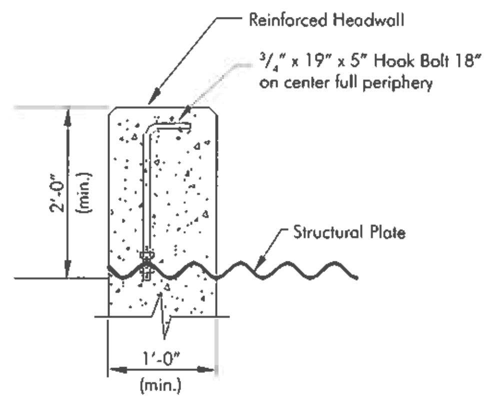


Typical Backfill Section - Super Span

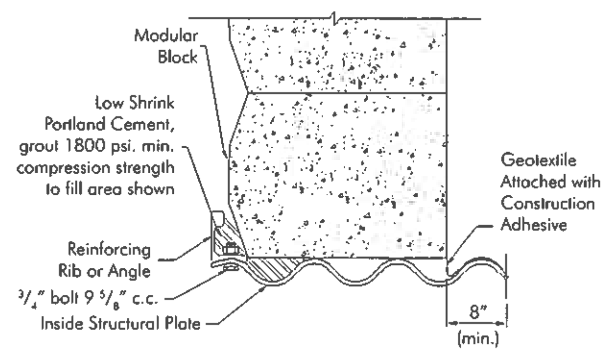
HEADWALL DETAILS (not to scale)



Aluminum Headwall Section Example

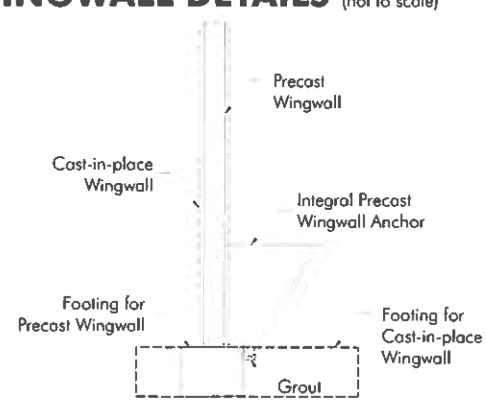


Concrete Headwall Section Example



Keystone Headwall Section Example

WINGWALL DETAILS (not to scale)



Precast Wingwall Section Example

SINGLE RADIUS ARCH

Span Feet	Rise Ft.-In.	Area Ft.²
6.0	1'-10"	7.9
	2'-4"	10.0
	3'-2"	15.0
7.0	2'-5"	12.0
	2'-10"	15.0
	3'-8"	20.0
8.0	2-11"	17.0
	3'-4"	20.0
	4'-2"	26.6
9.0	2'-11"	19.0
	3'-11"	26.5
	4'-8"	33.6
10.0	3'-6"	25.0
	4'-5"	34.0
	5'-3"	41.0
11.0	3'-6"	27.8
	4'-6"	37.0
	5'-9"	50.0
12.0	4'-1"	35.0
	5'-0"	45.0
	6'-3"	59.0
13.0	4'-1"	38.0
	5'-1"	49.0
	6'-9"	65.0
14.0	4'-8"	47.0
	5'-7"	58.5
	7'-3"	80.7
15.0	4'-8"	50.0
	5'-8"	63.0
	7'-9"	92.6
16.0	5'-3"	60.0
	7'-1"	86.0
	8'-4"	105.0
17.0	5'-3"	63.0
	7'-2"	92.0
	8'-10"	119.0
18.0	5'-9"	75.0
	7'-8"	104.6
	8'-11"	126.0
19.0	6'-4"	87.0
	8'-3"	118.0
	9'-5"	140.7
20.0	6'-4"	91.0
	8'-3"	124.0
	10'-0"	156.0
21.0	6'-11"	104.6
	8'-10"	139.0
	10'-6"	172.0
22.0	6'-11"	109.0
	8'-11"	146.0
	11'-0"	190.0
23.0	8'-0"	134.0
	9'-10"	171.0
	11'-6"	208.0
24.0	8'-6"	149.0
	10'-4"	188.0
	12'-0"	226.6
25.0	8'-7"	155.0
	10'-10"	206.0
	12'-6"	246.0
26.0	8'-7"	161.2
	11'-0"	214.9
	13'-1"	266.7

Driveway

Rainier Ave

PIPE ARCH

R_c Corner Radius = 18"

R_c Corner Radius = 31"

Span Ft.-In.	Rise Ft.-In.	Area Ft.²
6'-1"	4'-7"	22
6'-4"	4'-9"	24
6'-9"	4'-11"	26
7'-0"	5'-1"	29
7'-3"	5'-3"	31
7'-8"	5'-5"	33
7'-11"	5'-7"	36
8'-2"	5'-9"	38
8'-7"	5'-11"	41
8'-10"	6'-1"	43
9'-4"	6'-3"	46
9'-6"	6'-5"	49
9'-9"	6'-7"	52
10'-3"	6'-9"	55
10'-8"	6'-11"	58
10'-11"	7'-1"	61
11'-5"	7'-3"	64
11'-7"	7'-5"	68
11'-10"	7'-7"	71
12'-4"	7'-9"	74
12'-6"	7'-11"	78
12'-8"	8'-1"	82
12'-10"	8'-4"	85
13'-3"	9'-4"	98
13'-6"	9'-6"	102
14'-0"	9'-8"	106
14'-2"	9'-10"	111
14'-5"	10'-0"	115
14'-11"	10'-2"	120
15'-4"	10'-4"	124
15'-7"	10'-6"	129
15'-10"	10'-8"	134
16'-3"	10'-10"	138
16'-6"	11'-0"	143
17'-0"	11'-2"	148
17'-2"	11'-4"	153
17'-5"	11'-6"	158
17'-11"	11'-8"	163
18'-1"	11'-10"	168
18'-7"	12'-0"	174
18'-9"	12'-2"	179
19'-3"	12'-4"	185
19'-6"	12'-6"	191
19'-8"	12'-8"	196
19'-11"	12'-10"	202
20'-5"	13'-0"	208
20'-7"	13'-2"	214

ROUND

Span Ft.	Diameter PI	Area Ft.²
5	60	19.1
8	96	50.0
11	132	95.7
14	168	156.0
17	204	231.0
20	240	320.6
23	276	425.0
26	312	543.9

ALUMINUM BOX CULVERT

Structure Number	Span Ft.-In.	Rise Ft.-In.	Area Ft.²
1	8'-9"	2'-6"	18.4
3	9'-7"	4'-1"	32.6
5	10'-6"	5'-7"	48.1
7	11'-4"	7'-2"	65.0
8	10'-2"	2'-8"	23.0
10	10'-11"	4'-3"	39.5
12	11'-8"	5'-9"	57.2
14	12'-5"	7'-4"	76.0
15	11'-7"	2'-10"	28.1
17	12'-3"	4'-5"	46.9
20	13'-3"	6'-9"	76.9
21	13'-0"	3'-0"	33.8
23	13'-7"	4'-7"	64.8
25	14'-1"	6'-2"	76.6
26	14'-5"	3'-3"	40.0
28	14'-10"	4'-10"	63.2
30	15'-4"	6'-5"	87.2
33	15'-10"	3'-6"	46.8
34	16'-0"	4'-3"	59.5
36	16'-4"	5'-11"	85.2
38	16'-6"	6'-8"	98.3
39	16'-10"	8'-3"	124.8
40	17'-9"	3'-10"	54.4
42	18'-7"	5'-4"	82.5
44	19'-5"	6'-11"	111.9
46	20'-3"	8'-5"	142.6
47	19'-1"	4'-2"	63.3
49	19'-9"	5'-8"	93.6
51	20'-6"	7'-3"	125
53	21'-2"	8'-10"	157.6
54	20'-4"	4'-6"	73.1
56	20'-11"	6'-1"	105.5
58	21'-6"	7'-8"	139.0
60	22'-1"	9'-3"	173.3
61	21'-7"	4'-11"	83.8
63	22'-1"	6'-6"	118.4
65	22'-6"	8'-1"	153.7
67	23'-0"	9'-8"	189.8
68	22'-9"	5'-4"	95.5
70	23'-2"	6'-11"	132.1
72	23'-6"	8'-6"	169.3
74	23'-10"	10'-1"	207.0
75	24'-0"	5'-9"	108.2
77	24'-3"	7'-4"	146.8
79	24'-5"	8'-11"	185.7
81	24'-8"	10'-6"	225
82	25'-2"	6'-2"	122.0
84	25'-3"	7'-9"	162.4
86	25'-4"	9'-5"	202.9
87	25'-5"	10'-2"	223.3
88	26'-7"	5'-5"	111.6
90	27'-5"	7'-0"	153.4
92	28'-3"	8'-7"	196.5
94	29'-1"	10'-1"	241.0
95	27'-10"	5'-10"	125.4
97	28'-7"	7'-5"	169.4
99	29'-4"	9'-0"	214.6
101	30'-1"	10'-7"	260.9
102	29'-1"	6'-4"	140.2
104	29'-8"	7'-11"	186.4
106	30'-4"	9'-5"	233.6
108	31'-0"	11'-0"	281.8
109	30'-3"	6'-9"	156.1
111	30'-10"	8'-4"	204.4
113	31'-4"	9'-11"	253.5
115	31'-11"	11'-6"	303.5
116	31'-5"	7'-3"	173.1
118	31'-10"	8'-10"	223.4
120	32'-4"	10'-4"	274.4
122	32'-9"	12'-0"	326.1
123	32'-7"	7'-9"	191.3
125	32'-11"	9'-4"	243.4
127	33'-3"	10'-11"	296.4
129	33'-8"	12'-6"	349.5
130	33'-8"	8'-3"	210.5
132	33'-11"	9'-10"	264.5
134	34'-2"	11'-5"	319.0
136	34'-5"	13'-1"	373.8
137	34'-9"	8'-9"	230.9
139	34'-11"	10'-4"	286.7
141	35'-1"	12'-0"	342.7
143	35'-3"	13'-7"	399.0

MPSS - LOW PROFILE ARCH

Structure Number	Maximum Span	Rise Ft.-In.	Approx. Area Ft.²
69A15	19'-5"	6'-9"	105
75A18	21'-6"	7'-9"	133
81A18	23'-0"	8'-1"	147
87A18	24'-6"	8'-3"	161
93A18	25'-11"	8'-7"	176
99A21	28'-1"	9'-6"	212
102A21	28'-10"	9'-8"	220
108A24	30'-11"	9'-11"	237
111A30	32'-4"	12'-3"	319
117A24	33'-2"	11'-1"	289
123A24	34'-7"	11'-4"	308
126A24	35'-4"	11'-5"	318
129A30	37'-10"	12'-11"	383
129A36	39'-4"	14'-4"	441
*138A39	*42'-3"	15'-5"	510
*144A51	*45'-0"	18'-8"	675

* Structures require additional transverse stiffeners

MPSS - HIGH PROFILE ARCH

Structure Number	Maximum Span	Rise Ft.-In.	Approx. Area Ft.²
69A15-9	20'-1"	9'-1"	152
75A15-18	21'-6"	11'-8"	215
78A15-18	22'-3"	11'-10"	224
81A15-18	23'-0"	11'-11"	234
81A18-15	23'-8"	11'-10"	238
87A15-24	24'-6"	13'-9"	288
87A21-15	25'-9"	12'-10"	280
90A21-24	26'-6"	15'-3"	347
93A21-15	27'-3"	13'-2"	301
99A21-15	28'-9"	13'-5"	323
99A24-24	29'-5"	16'-5"	412
102A24-30	30'-1"	18'-0"	466
108A24-30	31'-7"	18'-4"	496
111A24-18	32'-4"	15'-5"	420
114A30-18	34'-4"	17'-0"	490
117A30-18	35'-1"	17'-1"	504
123A30-18	36'-7"	17'-4"	533
126A30-18	37'-4"	17'-6"	547

HORIZONTAL ELLIPSE

Structure Number	Span Ft.-In.	Rise Ft.-In.	Approx. Area Ft.²
24E15	7'-4"	5'-6"	31.6
30E18	9'-2"	6'-9"	48.2
33E15	9'-7"	6'-4"	46.7
36E18	10'-8"	7'-3"	60.1
36E21	11'-0"	8'-0"	68.2
39E21	11'-8"	8'-3"	75.1
39E24	12'-0"	8'-11"	84.1
42E21	12'-5"	8'-6"	82.2
42E24	12'-9"	9'-2"	91.7
45E21	13'-2"	8'-9"	89.6
45E24	13'-6"	9'-6"	99.6
48E24	14'-3"	9'-9"	107.8
48E27	14'-7"	10'-5"	118.7
48E30	14'-11"	11'-2"	129.9

MPSS = MULTI-PLATE SUPERSPAN

This is a partial list, please see CONTECH Construction Products Plate Design Guide for complete details.

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