Concept Development and Pre-Design for Engineered Logjam and Biorevetment Structures

King County Department of Natural Resources and Parks

Prepared by Herrera

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CONCEPT DEVELOPMENT AND PRE-DESIGN FOR ENGINEERED LOGJAM AND BIOREVETMENT STRUCTURES

White River at Countyline Levee Setback Project

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June 14, 2011

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INTRODUCTION

The King County River and Floodplain Management Section (County) is developing preliminary design plans for a levee setback project on the White River at the boundary between King and Pierce counties, Washington (Figure 1, Appendix A). The Countyline levee setback project (Countyline project) is both a flood hazard reduction project and a salmon recovery project located along the left (east) bank of the White River between river mile (RM) 4.9 and RM 6.1, which is upstream of the 8th Street Bridge located in the City of Sumner and downstream of the Burlington Northern & Santa Fe (BNSF) Railroad Bridge located in the City of Pacific. The project site comprises roughly 115 acres and includes a large forested wetland east of the left bank levee. The project site straddles the jurisdictional boundary of Pierce and King Counties, with the northern portion in King County and the southern portion in Pierce County. The boundary between the counties is located at approximately RM 5.56. The project area lies within the incorporated limits of the cities of Pacific and Sumner and in a portion of unincorporated Pierce County.

This memorandum presents the conceptual structure layout and designs for the restored floodplain area using engineered log structures (ELSs), which include engineered logjams (ELJs), a "biorevetment" structure, and a bank roughening structure. This memorandum summarizes the work completed in support of the concept design development.

Scope of Work

Herrera Environmental Consultants (Herrera) was retained under contract work order E00146T by the County to develop conceptual ELJ and biorevetment designs for the Countyline project. Herrera's scope of work for this phase of the project includes the following tasks and deliverables:

- Conduct a one-day site investigation with County staff to evaluate existing conditions and identify potential ELJ structure locations and a preferred alignment for the biorevetment.
- Identify design, permitting, construction, hydraulic, geomorphic, and habitat opportunities and constraints.
- Qualitatively assess existing flood hazards (including geomorphic and hydraulic) and the potential response in terms of these flood hazards to the project.
- Recommend design criteria and geotechnical analyses for the ELJs and the biorevetment.
- Develop preliminary construction costs and schedules for the ELJs and the biorevetment.
- Develop conceptual plans and details for up to four types of proposed structures including large mid-channel and bank deflector ELJ structures, a robust biorevetment, and bank roughening ELJ structures.
- Prepare a memorandum summarizing the conceptual design and basis for design.

Two-dimensional hydraulic and sediment transport modeling has been conducted by Herrera Environmental Consultants (Herrera) and Northwest Hydraulic Consultants (NHC), as a subconsultant, under a separate work order (Contract E00146E08, Work Order E00146P) to support the development of the conceptual engineering design. The models simulate existing conditions and the proposed conditions with the left bank levee removal only (i.e., ELJ structures were not included in the proposed condition model). Calibration of the hydraulic model is described in a report entitled Lower White River Levee Setback Hydraulic and Sediment Transport Modeling, RiverFlo2D Calibration Report, prepared by Herrera and NHC (2011). The methods and results of the hydraulic and sediment transport modeling for existing and proposed project site conditions will be presented in a Basis of Design Report to be produced during final project design. Final design of the project will be led by the County with assistance from Herrera under a separate contract.

BACKGROUND

The White River originates at the termini of the Emmons and Winthrop glaciers on Mt. Rainier and transports a high sediment load relative to other rivers in the region that do not drain active volcanoes. The project site is located on an alluvial fan formed from the deposition of sediment where the river leaves the steeper post-glacial valley of the White River canyon and enters the glacial valley of the Puget lowland (Collins and Montgomery 2011). At the project site, the White River is confined by levees or revetments on both banks and is experiencing documented sediment deposition and cumulative reduction in flood conveyance. Shallow flooding in January 2009 occurred in low lying areas along the right bank and over the left bank terrace near 142nd Avenue East. Landowners in the vicinity of 142nd Avenue East took post-flood actions to construct a berm along the terrace edge. Sediment deposition has been documented both within the confined channel and on the adjacent left bank forested floodplain near the County boundary line. At the project site, the White River and adjacent floodplain are incised into alluvial fan deposits and form a 4- to 10-foot-high terrace on the eastern margin of the project site.

During the early- to mid-twentieth century, the White River was permanently altered by flood control projects including dam construction, channel excavation, gravel removal, and levee and revetment construction. Prior to channel modifications, the river historically occupied two separate channel alignments. The main branch of the White River flowed to the northeast and into the present-day Green River. A secondary branch split from the White River at approximately RM 8.0 to form the Stuck River, which flowed south to join the Puyallup River. After a large flood event in 1906, permanent measures were taken to re-align the Lower White River into the Stuck River channel, significantly increasing the long-term discharge in the Puyallup River at Sumner. Construction of the Auburn Wall in 1915 made diversion of all of the flow of the White River into the Puyallup River drainage basin permanent (Collins and Sheikh 2004).

Levees and revetments were constructed during the early decades of the 20th century. Although it is unclear from historical archives exactly when construction of levees and revetments in the project reach began, construction certainly began after the signing of the Intercounty River Improvement agreement in 1914, and initial channel realignment and construction was likely completed before the completion of the Auburn Wall in 1915. These flood control features confined the active channel and isolated the river from its predevelopment floodplain. Consequently, the White River no longer migrates across the historical alluvial fan, but instead deposits sediment and conveys almost all flood flows within the constructed channel. Between 1915 and 1988, large volumes of gravel were periodically removed from the lower White River (including within the project area) to maintain flood conveyance capacity (Herrera 2010). Sediment deposition within the active channel has continued since gravel removal activities ended in the 1980s, substantially reducing the flood conveyance capacity.

Mud Mountain Dam, located at RM 29.7, was completed in 1948 by the U.S. Army Corps of Engineers (USACE) as a single-purpose flood control project. The primary authorized purpose of the Mud Mountain Dam is to control flood levels along the Lower Puyallup River. Flood control in the lower White River below the dam is a secondary purpose.

Project Description

The conceptual design presented in this memorandum is based on a preliminary biorevetment and setback levee alignment plan prepared by the County and refinements to conceptual ELJ designs and layouts presented to County staff by Herrera at two concept design workshops. The project area and project elements are shown in Figures 1, 2, and 3 (Appendix A). The conceptual ELS design for the Countyline project developed from this process includes the following elements:

- Remove approximately 3,500 lineal feet of the existing levee prism from the left bank of the White River. The upstream extent of the proposed levee removal is located across the river from the City of Pacific Park (near RM 6.0).
- Remove approximately 3,500 lineal feet of bank armoring material from the left bank of the White River, most of which is placed along the waterward toe of the existing left bank levee that will be removed.
- Construct a setback levee along the eastern perimeter of the wetland buffer on the eastern terrace in the southern half of the project site.
- Construct approximately 3,750 lineal feet of biorevetment and 1,440 lineal feet of bank roughening structures into the existing bank along the edge of the wetland terrace.
- Install mid-channel (apex) ELJ structures within the restored floodplain area.

The County is also proposing a levee setback project along the opposite bank (right bank) of the White River in the City of Pacific. This project (called the Right Bank project in this memorandum) proposes to remove a section of an existing revetment and a temporary floodwall that was placed after the January 2009 flood event and to construct a permanent setback levee. The proposed setback levee will have an upstream terminus in the vicinity of the northern end of the City of Pacific Park and extend around the perimeter of the City of Pacific Park, with a downstream alignment adjacent to residential housing and to a point downstream near the County boundary line. The goals of the Right Bank project are to provide additional flood protection and sediment storage capacity and to improve habitat conditions along the project reach. Design elements of the Countyline project will not preclude development of the Right Bank project.

Project Goals and Objectives

King County established specific goals and objectives for the Countyline project that form a basis for the development of the concept plans described in this memorandum. The goals and objectives for the Countyline project are as follows:

Goal 1: Restore riverine processes and functions to the lower White River and its floodplain within the project area (inside the proposed levees) in order to enhance salmonid rearing habitat, in particular for spring and fall Chinook, coho, and steelhead.

Objective 1.1: Allow natural channel movement within the project area by removing and setting back the existing levee along the left bank.

Objective 1.2: Encourage the formation of off-channel rearing habitat (pool complexes and side-channels), such as through installation and future natural recruitment of large wood, that will promote the return of the complexity, diversity, and morphology found in an unconstrained floodplain.

Objective 1.3: Provide off-channel flood refuge for salmonids by allowing a more natural frequency of inundation of the floodplain complex during flood events within the project boundaries.

Objective 1.4: Protect existing mature riparian buffer areas and restore a corridor of mature riparian vegetation within the project boundaries to provide shoreline and stream channel shading, invertebrate prey supply, and large wood recruitment.

Goal 2: Prevent an increase in flood and geomorphic hazards outside of the project area due to this restoration project and, if possible, reduce existing hazards.

Objective 2.1: Design the project to ensure flood and geomorphic hazards (on private property and associated with public infrastructure) outside of the project area do not increase due to the project.

Objective 2.2: Increase flood storage along the length of the project, which will also have a net benefit on flood elevations in the immediate vicinity of the project, particularly the right bank.

Objective 2.3: Avoid or minimize the need for sediment management actions.

Goal 3: Design and construct a project that best meets the goals and objectives of the project using the most cost-effective means.

Objective 3.1: Evaluate individual and collective project components based on cost-effectiveness and ability to achieve the goals and objectives for salmonid habitat (primarily) and flood hazards.

Objective 3.2: Avoid or minimize the need for remedial actions (habitat restoration or construction to avoid or repair damage to public facilities) by incorporating self-sustaining habitat restoration and flood hazard reduction components in the design.

Objective 3.3: Work with adjacent landowners to negotiate acquisitions or conservation easements.

Objective 3.4: Work with all stakeholders, including the City of Pacific, City of Sumner, Pierce County, Washington Department of Fish and Wildlife, the Puyallup Tribe of Indians, and the Muckleshoot Indian Tribe throughout the project development to foster project support and a clear understanding of any needs or issues.

GEOMORPHIC AND HYDRAULIC RESPONSE

Reconnecting the White River channel to the floodplain wetland is expected to reduce the existing flood hazard within most of the project reach. Additionally, flow divergence in the unconfined floodplain and the hydraulic roughness provided by woody debris and the proposed ELJs are expected to promote sediment deposition in the floodplain wetland. A recent study completed by the U.S. Geological Survey (Czuba et al. 2010) comparing river management options at the Countyline project site estimated that the levee setback option would result in an initial reduction in flood elevations of 3 to 6 feet along the project reach. The study also found that a gravel bar scalping option would initially reduce flood elevations by considerably less, or up to 1.3 feet, assuming a one-time removal of approximately 50,200 cubic yards of sediment. The results presented by Czuba et al. (2010), which are based on a simple one-dimensional steady state (HEC-RAS) hydraulic model, also found that sediment deposition would eventually reduce the amount of flood hazard relief provided by both river management options. Czuba et al. (2010) also found that the levee setback option would provide a longer duration of flood benefit relative to the gravel bar scalping option due to the larger increase in flood conveyance.

A qualitative assessment of the geomorphic and hydraulic response of the proposed project was performed using observation from the field investigation conducted by Herrera and County staff on May 20, 2010 and the preliminary results of the two-dimensional hydraulic and sediment transport modeling performed under a separate work order. The hydraulic and sediment transport modeling included 1) a no-action scenario to simulate the future channel and floodplain response over a six-year period (real-time hydrograph for the period 1989 to 1995) based on existing conditions and 2) a proposed conditions scenario simulating levee removal only over the same six-year period, without the proposed ELSs. Additional modeling of the proposed conditions will be performed as the design elements of the levee setback project are refined.

Based on the previous work described above, the potential geomorphic response to levee removal is expected to include sediment deposition and scour, channel migration, avulsion, and woody debris accumulation, recruitment, and export from the project site. Feedbacks between these geomorphic adjustments and hydraulics will further influence the extent and frequency of flooding within and surrounding the project site. Details of these anticipated geomorphic and hydraulic responses and potential hazards associated with them that must be addressed in the concept design are described below.

Sediment Aggradation and Flooding

Preliminary results of the existing conditions model (no-action scenario) indicate that both bed degradation and sediment aggradation on the order of several feet would occur in the White River channel throughout project reach. Bed changes will be dominated by aggradation and a corresponding reduction in the channel cross-sectional area and flood carrying capacity, as has been documented in the recent past. Based on preliminary results of the proposed conditions model (removal of the levee but without the ELJs and with most of the flow remaining in the White River channel), sediment aggradation in the White River is predicted to continue to a lesser degree relative to existing conditions. Most of the deposition would occur upstream of the 8th Street Bridge to approximately RM 6.0. Local erosion would occur at the downstream end of the gravel bar on the left bank near RM 6.05 (gravel bar 6, Figure 2) and the upstream portion of the gravel bar on the right bank near RM 5.95 (gravel bar 5, Figure 2). Erosion of this right bank gravel bar would be caused by the increase in hydraulic gradient to the east induced by the proposed levee removal.

Aggradation of up to 1 to 3 feet is predicted to occur locally within the floodplain wetland under proposed conditions. Aggradation in the wetland area is predicted to be limited to this amount because only a small fraction of the total discharge would flow into this area, and sediment deposition would be dispersed over a relatively large area. Furthermore, the sediment transport modeling conducted to date calculates bedload transport and deposition only and does not include the suspended sediment load, which may also deposit in the wetland area and result in greater aggradation depths than predicted by the current model. For example, overbank flows at RM 5.5 have deposited suspended sand within the wetland area to a depth sufficient to bury and kill numerous trees; therefore, sediment deposition in the setback area is likely to exhibit spatial variability and could be greater than the estimates from the proposed conditions model.

Based on a comparison of the water surface elevations for the existing conditions and proposed conditions hydraulic models, flood elevations during the peak flow of the six-year simulation (a discharge of approximately 15,253 cfs) are expected to decrease by several feet between RM 5.5 and RM 6.0. Although the proposed setback levee would reduce flooding on the left bank through the industrial and agricultural properties south of the floodplain wetland (across from RM 5.1), where river flow overtops the southeast end of the wetland terrace and crosses Stewart Road to the south during significant flood events, the concept design would increase flood elevations upstream of the 8th Street Bridge near RM 5.0 as a result of flow being routed back toward the main channel by the setback levee. As currently proposed, the levee removal would cause no substantial change in the water surface elevation on the right bank upstream of approximately RM 6.1; however, the model results indicate a potential increase in the water surface elevation at the upstream end of the floodplain wetland adjacent to approximate RM 6.0 (point A, Figure 2). The preliminary modeling was under review and yet to be validated at the time this report was prepared. However, refinements of the project conceptual design will be made under a separate contract to address areas of any increased flood hazard indicated by hydraulic modeling and thereby meet project Goal 2.

Additional modeling conducted for the project as design refinements proceed will consider partial and full avulsion scenarios of the White River into the restored left bank floodplain to better characterize the range of geomorphic and hydraulic conditions for the final design. Conceptual level model results available to date do not provide the detailed level of hydraulic information necessary for final design and the evaluation of the proposed ELJs, biorevetment, and bank roughening structures for the peak design flows they could be subjected to. Although sediment deposition in the floodplain will reduce flood storage over time, shifting deposition to the floodplain area is expected to reduce sediment delivery to the White River channel and downstream reaches, where aggradation has increased the flood hazard.

Channel Avulsion, Bank Erosion, and Natural Wood Debris Accumulation

Gravel bar development at the upstream inlet to the restored floodplain and the subsequent reduction in flow velocities in the White River near the inlet, as flows enter the floodplain wetland, could promote the formation of one or several natural logjams in the White River. If this occurs, the mainstem channel could be partially or fully blocked, thereby forcing a partial or full avulsion of the White River into the wetland. The avulsion could occur at the wetland inlet (at approximate RM 5.95) (Figures 2 and 3) and/or possibly downstream of the mature deciduous forest at approximate RM 5.5 (Figure 2) and result in the abandonment of all or part of the mainstem channel along the project reach. A channel avulsion into the wetland could potentially focus flows along the left bank terrace of the wetland. Natural logjam formation in the mainstem channel could also deflect flow towards the right bank and increase flood and erosion-related hazards along private property and existing infrastructure.

Woody debris recruited from upstream and within the floodplain wetland could accumulate on the proposed ELJ structures. Wood accumulations that become unstable (i.e. are mobilized during higher flows) would be released from the structures and delivered downstream during flood events. Wood transported out of the restored floodplain and back into the White River channel could accumulate on the center piers or abutments of the 8th Street Bridge and potentially increase the flood and scour-related hazards at the bridge. A wood study conducted by King County is assessing wood delivery to the project reach from upstream and wood accumulation, recruitment, and export from the project site (King County 2011). The scenario modeled in the wood study assumes a full avulsion of the White River into the setback area. Preliminary results of the wood study indicate an increase in wood flux downstream of the project site for the first year following an avulsion and a net reduction in wood flux downstream of the project site thereafter due to a net accumulation and storage of woody debris in the levee setback area.

PROJECT CONSTRAINTS AND OPPORTUNITIES

A list of potential project constraints and opportunities associated with levee removal and ELJ construction was developed during a workshop attended by staff from Herrera and the County. Project constraints can include various physical, economic, regulatory, and cultural issues that present a barrier to the achievement of the project goals and objectives. Opportunities represent ideas that provide additional project benefits, eliminate a project constraint, or allow the project goals to be met within these identified constraints. The various constraints and opportunities identified for this project are described in the following sections.

Constraints

Project constraints will limit the development, extent, and efficacy of the flood hazard reduction improvements and salmon recovery that can be accomplished with the Countyline project. The effectiveness of the project in achieving its goals and objectives will be limited by the constraints identified below.

Physical (habitat, geomorphic, and geologic)

- The project area encompasses a large forested wetland in the area of a former channel that would likely be re-activated under proposed conditions. Construction of ELJs in the wetland would disturb portions of the wetland during construction and require filling of smaller areas of the wetland within the footprint of the structures. These impacts would be self-mitigated by the off-channel habitat created by the project.

- The wetland encompasses several areas that are perennially inundated, while other areas have groundwater within 1 to 2 feet of the ground surface based on groundwater data collected by the County. Access into the wetland to complete geotechnical investigations, other site assessments, and to construct ELJs will be constrained by water levels and the extent of vegetation. Anchoring of ELJs will be constrained by the characteristics of the alluvial soils underlying the wetland soils, with gravely soils allowing pile driving and coarser substrate possibly requiring pre-drilling to allow pile installation.

- The project will substantially reduce existing standing water habitat and convert these areas to flowing water habitat, which is likely to have negative effects on amphibian breeding and some wildlife use.

- The risks associated with the flooding and geomorphic hazards previously summarized may constrain some of the project elements, including the extent of levee and bank armoring removal, levee setback design, and the location and number of ELJ structures.

Infrastructure, Property, and Public Safety

- Hydraulic and sediment transport modeling will be completed to evaluate potential flood levels and bed erosion or deposition that can be expected upstream of the inlet to the restored floodplain along the remaining levee and upstream to the BNSF Bridge. The extent of levee removal and placement of engineered structures may need to be modified if modeling results indicate an increase in flood and/or scour-related hazards to the BNSF Bridge, other infrastructure, or private property.

- Proximal and upstream wood recruitment, onsite wood accumulation, wood export from the project site, and associated hazards at the 8th Street Bridge will be evaluated during the project design phase using results of the wood study (King County 2011). The outcome of that evaluation may constrain the location, size, architecture, and number of ELJs constructed near the river channel, within the wetland, and along the left bank terrace. The project will need to be designed such that wood export from the project site does not increase hazards to public infrastructure such as the 8th Street Bridge. The project will include appropriate monitoring to evaluate future maintenance measures that may be needed to address adverse flow conditions caused by natural wood accumulations and affecting the project structures or adjacent public infrastructure (i.e. 8th Street Bridge)

- Private property on the terrace bordering the floodplain wetland must be protected from bank erosion and channel migration with the construction of the proposed biorevetment and bank roughening structures. In order to minimize wetland impacts and construction costs, the proposed structures must be constructed along the terrace edge bordering the east side of the floodplain wetland.

- The floodplain wetland is currently bordered by public and private property. As of this writing, the County has not yet acquired all properties needed to construct the project as illustrated by the current conceptual plan. Land rights are needed including property acquisition in fee or permanent easements for project construction and site management over time, as well as temporary rights of entry for more immediate access to the site for data collection.

- The Right Bank project is being planned primarily for flood hazard reduction in an area heavily used by the public and adjacent to a developed residential community. The Right Bank project design process is in its initial stages at this time. The design of both projects should remain coordinated as much as possible so that both projects are compatible with the other with respect to flood-related hazards to the surrounding public property, private property, and infrastructure.

- Coordination with numerous project stakeholders will be necessary for project success. Stakeholders include landowners, Pierce County, City of Pacific, City of Sumner, Muckleshoot Indian Tribe, Puyallup Tribe of Indians, Salmon Recovery Funding Board, and Natural Resource Damage Assessment Project Potentially Responsible Parties (PRPs) and its Trustees, in addition to local, state, and federal permitting agencies.

- Project planning will need to consider river recreational use and follow established County procedures for considering public safety when placing large wood in King County rivers.

Project Funding, Schedule, Permitting, and Regulatory Issues

- Preliminary construction costs for the Countyline project are estimated by King County to range from approximately $6,000,000 to $7,000,000, with approximately $3,211,000 of this total allocated for the ELSs. Preliminary construction costs for the ELS structures (as shown on Figures 2 and 3, Appendix A) estimated by Herrera are approximately $4,480,000. This cost, which includes a 30% contingency and 9.5% tax, is conservatively high to account for unknowns (i.e. subsurface conditions, flow characteristics and assumed construction methodologies) that will be determined during the final design phase. If the expected construction cost of the ELSs cannot be reduced as design proceeds, alternative design elements will need to be considered to utilize available funding.

- The setback levee must be in place, and the left bank of the wetland terrace must be protected prior to levee removal. Construction of the setback levee and revetment is estimated to require approximately 3 to 6 months depending on work production rates and the allowable construction timing for in-water work dictated by project permits. As a result, two separate construction phases (carried out over two summer construction seasons) will be necessary: one to construct the setback levee and revetment along the wetland terrace on the left bank, and one to remove the existing levee. Construction of ELJs in the floodplain wetland can be completed during either construction period, but will be constrained by the permitted work windows.

- Several local, state, and federal permit approvals will be required for the Countyline project. Depending on the extent and type of the construction actions, the type and number of permits required may vary. Review times for permit applications will affect the project schedule. The following permits and approvals may be necessary based on the current conceptual plan.

- At the local level, State Environmental Policy Act (SEPA) compliance will be necessary. Other permits and approvals at the local level from the cities of Sumner and Pacific and Pierce County could include a Floodplain Development Permit, Shoreline Permit, Clearing and Grading permit, Critical Areas review, and compliance with compensatory storage requirements for fill placed in the floodplain in relation to the setback levee.

- At the state level, a Hydraulic Project Approval (HPA) will be necessary from the Washington Department of Fish and Wildlife (WDFW) for work waterward of the ordinary high water mark (OHWM) of the river and floodplain wetland. The Washington State Department of Ecology (Ecology) may require a Clean Water Act Section 401 Water Quality Certification for work occurring in wetlands. In addition, a National Pollutant Discharge Elimination System (NPDES) permit will be required by Ecology if there is more than one acre of earth disturbance associated with construction activity. An Aquatic Use Authorization from the Washington Department of Natural Resources

(WDNR) will not be necessary for work along the shores of the White River because the river is not within WDNR jurisdiction.

- At the federal level, a Clean Water Act Section 404 Permit from the U.S. Army Corps of Engineers (Corps) is anticipated for work waterward of the OHWM and within regulated wetlands. Necessary approvals associated with the Corps permit include compliance with the Endangered Species Act (ESA) and Section 106 of the National Historic Preservation Act (NHPA).

- Several potential studies and environmental documentation will be necessary to support permits such as critical areas reports, a SEPA Environmental Checklist, a Conditional Letter of Map Revision (CLOMR) from the Federal Emergency Management Agency (FEMA), King and Pierce counties, cities of Sumner and Pacific floodplain/floodway review, geological assessments, geotechnical investigations, cultural resources assessments, and recreational use assessments. A Biological Assessment (BA) for ESA compliance will not be necessary because it is anticipated the project will use the U.S. Army Corps of Engineer's Programmatic BA for Restoration Actions in Washington State (2008).

Opportunities

Multiple opportunities were identified as integral to achieving the project goals and objectives within the constraints summarized above.

- Large, mid-channel ELJs can be positioned within the floodplain wetland in locations where a channel is anticipated to form, thereby providing opportunities for long-term wood accumulation and storage. Following levee removal, a channel avulsion into the wetland may occur at several locations; therefore, these ELJ types can be designed and positioned to allow flow to hit the structure from a large range of angles and to encourage formation of side channels. These ELJ types can also be placed to deflect flow away from the left bank and to split flows near the downstream end of the project. These hydraulic effects will dissipate energy as the flow re-enters the existing White River channel.

- Levee removal alone (without the construction of numerous ELJs) will provide salmonids access to the off-channel habitat within the large floodplain wetland and accomplish several of the County's habitat objectives. Disturbances and costs associated with ELJ construction in the wetland can be reduced by installing only the ELJs necessary to maintain or reduce geomorphic hazards due to the project. These ELJs will also provide additional fish habitat and meet the County's habitat objectives for the project.

- The boundary formed by the left bank of the wetland is highly irregular in plain view, with certain areas more or less prone to bank erosion because of their orientation with the direction of anticipated high flow velocities or shear stresses. Other areas located in the lee of terrace promontories may experience relatively lower (and less-erosive) flow velocities and shear stresses. The more-robust biorevetment can be placed along more erosion-prone areas, and less robust (and much less expensive) roughening structures can be placed along areas less prone to bank erosion.

- The constructability of ELJs within the wetland can be improved if water levels can be lowered to within a foot or two above the ground surface prior to construction. The water surface elevations of the river and wetland during the proposed construction period need to be compared to assess the influence of groundwater seepage and to determine the feasibility of this proposal. If feasible, water levels may be lowered by removing the existing culvert and grading an outlet channel near the downstream extent of the project (at approximate RM 5.1) and possibly by notching the remnant berms. This work could occur during removal of the downstream portion of the left bank levee and by installing temporary flow diversion measures (if necessary) around the outlet channel opening near the adjacent river bank to ensure river flow does not enter the wetland prior to completing construction of the structures and levee removal. Regardless of when the structures are built, removal of the downstream portion of the levee will naturally allow water to flow from the wetland back into the White River when water levels in the river are lower than in the wetland, thereby lowering water levels in the wetland during construction. Therefore, sequencing of structure construction, levee removal, and some lowering of surface water levels in the wetland can be developed to improve structure constructability and to minimize structure costs and habitat impacts. Structure constructability can also be evaluated by assessing seasonal surface and groundwater depths using the County's piezometric data.

- Removing a large portion of the existing left bank levee and establishing access to ELJ construction sites in the floodplain wetland will require removing a large quantity of trees and shrubs. This woody material can be incorporated into the ELJ structures, biorevetment, and bank roughening structures to reduce the need for imported woody material, which in turn reduces construction costs.

- Additional reductions in construction costs can be realized by using levee removal spoils as backfill material in the ELJs. This material is likely ideal for this function because of the anticipated course gradation, which improves structure longevity and factors of safety against structural deformation. Test pits and evaluation of materials in the existing levee will need to be conducted to confirm that levee removal spoils can be reused.

Structure Design Assumptions and Descriptions

Herrera completed conceptual designs for four ELS types: an apex (mid-channel) ELJ, a bank deflector ELJ, a biorevetment structure, and a bank roughening structure (Figures 2, 3, 4, and 5, Appendix A). Each structure type was developed to perform specific functions at the location where it may be located.

The conceptual designs for the structures discussed herein were developed based on the following factors:

- The project habitat and flood hazard reduction goals and objectives discussed previously,
- Approximate project construction budget provided by the County,
- Preliminary geotechnical and groundwater data provided by the County,
- Conceptual plans for the Right Bank project, and
- Preliminary hydraulic and sediment transport model results.

Although detailed structural stability and scour calculations were not completed for the various structure types, flow velocities and depths anticipated to occur within the project site were used to provide a general understanding of scour depths that may occur at the different ELJ types based on scour analyses performed for previous projects in similar riverine environments. As previously discussed, the structure concepts were developed assuming a full mainstem avulsion into the left bank floodplain. Flow velocities in the restored floodplain are expected to be less than velocities simulated within the confined reach of the White River in the hydraulic model due to roughness created by existing vegetation and the proposed ELJs, and due to the larger and unconfined flow conveyance area within the wetland.

The design objectives for the structures include minimizing the concentration of flow and reducing the angle of flow into the biorevetment and setback levee, encouraging channel complexity and side channel formation, minimizing construction disturbance within the wetland, and increasing floodplain roughness to achieve these other objectives.

Design Assumptions

The following general design assumptions were used to develop the concepts of the four proposed structure types:

- Full avulsion of the White River into the left bank floodplain wetland, subjecting structures to mainstem flow conditions. As discussed in previous sections, a full avulsion into the wetland could occur; therefore, the structures will need to be designed to withstand mainstem flow conditions.

- Maximum scour depths ranging from 20 to 25 feet. This range is based on results of multiple scour analyses completed by Herrera for previous ELS design projects, where structures were subjected to flow depths and velocities similar to those anticipated to occur within the wetland if a full or partial avulsion were to occur.

- Peak flow velocity of approximately 10 feet per second (ft/s). This value is based on the results of the proposed conditions hydraulic modeling completed by Herrera and NHC (2011), which indicated flow velocities of approximately 10 to 15 ft/s occurring in the existing White River for a maximum flow rate of 15,253 cubic feet per second (cfs) that was included in the simulation. Following a full avulsion of the White River into the wetland, flow velocities through the wetland are expected to be less than velocities simulated within the confined reach of the White River in the hydraulic model due to roughness created by existing vegetation and the proposed ELJs, and due to the larger and unconfined flow conveyance area within the wetland compared to the existing White River. The flow rate of 15,253 cfs is slightly less than the 50-year (15,400) and 100-year (15,600 cfs) return interval floods for the White River at the project site. The 100-year flow was not simulated by Herrera and NHC; however, because there is only 200 cfs difference between the 50-year and 100-year flows, the velocities associated with the maximum flow simulated (15,253 cfs) are within the anticipated range of velocities that could occur during the 100-year flow, which is the typical design flow rate referenced when designing engineered structures that are to be placed in or near rivers.

- Maximum flow depth in the wetland of approximately 10 feet. This value is based on the results of the proposed conditions (levee removal only) hydraulic modeling completed by Herrera and NHC (2011) for a flow of approximately 15,000 cfs, which indicated flow depths in the wetland of approximately 10 feet.

- Possible localized aggradation of up to 4 feet (to be determined during final design) at the location of the proposed ELJs, based on preliminary results of sediment transport modeling.

- Subsurface conditions consisting predominately of mixtures of sand, silt, and some gravel extending to the anticipated pile embedment depth of 35 to 50 feet below existing grade. This assumption is based on the logs for borings completed on the top of the terrace along the edge of the wetland by King County (2010), the locations of which are illustrated in Figure 2.

- Water conditions during construction of the ELSs that include the following: Surface water at or above the ground surface, or groundwater within 1 to 2 feet of the ground surface, within the setback area to the toe of wetland terrace bank, but not including the surface of the wetland terrace. This is based on Herrera's observations of the site during the May 2010 site investigation with County staff and groundwater elevation data for the months of June through September 2009 provided by the County for four piezometers installed within the wetland.

Structure Descriptions

Four ELS types are proposed for this project: apex (mid-channel), bank deflector, biorevetment, and bank roughening structures (Figures 4 and 5, Appendix A). An apex ELJ is a large robust engineered structure that resembles a natural stable accumulation of large logs in the middle of a channel with a large gravel bar that has developed immediately behind the logs on the downstream side. A bank deflector ELJ is similar to the apex ELJ except the structure is embedded into a channel bank similar to a natural stable accumulation of large logs along a channel bank. The biorevetment structure is a series of individual engineered structures, each consisting of several logs arranged in a manner to create a very roughened and robust wall that armors the bank. A bank roughening structure is a series of individual engineered structures, each consisting of a few logs that protrude from the bank into the channel to provide a roughened surface, but does not provide the level of protection against the high flow velocities and shear stresses that would be resisted by the biorevetment structure.

All four structure types are engineered to resist hydraulic loads from impending flow and the buoyant forces on the wood material when the structure is submerged. All four structure types vary in size and complexity, but all consist of a matrix of multiple layers of horizontally oriented large "key" logs (with and without attached rootwads) that are secured in place by vertical timber piles embedded well below the anticipated scour depth, and by ballast material (i.e. native bank material, river alluvium, or imported rock) placed over and around the key logs within the interior core of the structure. The key logs protrude from the waterward face of the structure and function to secure racking and slash material (described below), to accumulate wood debris, and to deflect flow around the waterward sides of structure.

The structural stability and resistance of the four proposed structure types to hydraulic loads would be achieved with the use of vertically placed timber piles. The piles would serve as the foundation for placing interlocking key logs, racking logs, slash, and ballast material. For each proposed structure, it is assumed that timber piles will be embedded vertically below the channel bed and extend above the top of the structure. The piles would be designed to resist lateral and uplift forces, provide an anchored network for securing the key structural wood members, and provide a stable framework around which the structure may settle. The piles would also maintain the general architecture of the as-built structure. Horizontal key logs extending waterward from the structure interior core would be placed or secured (by virtue of position, fasteners, or ballast) against the piles to transfer hydraulic loads to the piles, resist lateral and uplift forces, provide large-scale hydraulic roughness, catch floating woody debris, secure woody slash and racking material that prevents straining of flow through the structure core, and serve as a platform matrix for the log ballast and structure backfill material. The use of fasteners (e.g., chain, cable, or steel pins) will be determined during the final design phase and should be based on the type of ballast material used for backfilling over the logs after consideration of any hazards to the 8th Street Bridge.

The boring logs completed by the County (King County 2010) indicate subsurface conditions along the east perimeter of the wetland terrace consist predominantly of sand and silt, with minor amounts of? Gravel, to depths of up to 50 feet below the terrace surface, which will likely allow the timber piles to be installed using traditional pile driving techniques. Soil borings proposed within the wetland were not completed by the time of this report; however, general subsurface conditions are likely to be similar to those along the terrace perimeter, but may be slightly coarser within the upper zone because of the coarser alluvium deposited along the historical Stuck and White River channel alignments within the wetland. Driving timber piles into thick beds of cobbles and large compacted gravels is often difficult without damaging the piles; therefore, if subsurface conditions in the wetland indicate that driving of timber piles in not feasible, then pre-drilling through the alluvium may be necessary to install the piles to the required embedment depth. Alternatively, steel H-piles or pipe piles may be considered if pile driving or pre-drilling for placement of timber piles is not feasible from a constructability standpoint or is cost prohibitive. Steel piles are typically easier to drive because of their smaller cross sectional area compared to a timber pile, but material costs for steel piles are typically more than timber piles, resulting in a greater overall cost for steel pile installation. Steel piles were not considered at this time for the structure concepts presented in this report based on the County's request to maximize the use of natural materials (i.e. wood and native alluvium from ELJ excavations and levee and revetment removal spoils).

For the apex, bank deflector, and biorevetment structures, racked wood material would comprise the upstream and waterward external faces of the structures, giving them the appearance of a large tangle of densely packed logs. The racking material is important for minimizing flow piping and straining through the structure and absorbing the erosive forces of the impinging water before contact with the internal backfilled alluvium ballast is made. The racking material would thereby prevent the interior of the structure from destabilizing. For the apex ELJs, prevention of flow straining is also important for the safety of recreational users of the river. For the apex, bank deflector, and biorevetment structures, layers of wood slash would be placed around the outside periphery of the structure at the interface of the interior ballast material and the exterior piles, key logs, and racking material. Slash would be placed with every layer of key logs and racking to fill voids between the racking, key logs, and piles. This slash material would act as a curtain between the interior ballast and the key logs, helping to keep the interior alluvium intact by significantly limiting water piping into and through the structures until the vegetation cover and root cohesion is established along the outer surfaces of the structure. Racking and slash material is not proposed for the bank roughening structures because these structures are meant only to provide additional bank roughness and flow deflection in relatively low flow velocities areas; however, it could be added during the design phase of this project if the need is substantiated.

Apex (Mid-channel) and Bank Deflector ELJs

Apex ELJs are large, robust engineered structures that would be located landward of the existing left bank levee and within the wetland (Figures 2, 3, and 4, Appendix A). Their primary functions are to provide natural, erosion-resistant hard points within the wetland to diffuse flow energy, prohibit flows from becoming fixed along the left bank, split flows to create multi-channel complexes that enhance habitat, provide large scale roughness within the wetland, engage existing side channels and encourage side channel formation, provide pool habitat and substrate for benthic communities, and provide opportunities for wood debris accumulation. Flow may hit these structures from several directions upstream;

therefore, the wood face of the apex ELJs affords approximately 180 degrees of possible angle of attack to maximize effectiveness in influencing flow and protecting the ELJ itself from erosion.

At the north end of the wetland near the upstream terminus of the levee removal extents, the concept design includes three apex ELJs (ELJs 1, 2, and 3) positioned along the left bank side of the relic channel within the wetland. These ELJs would engage flows entering the wetland from the northwest and are oriented to deflect flows away from the left bank and private property to the east until flows establish a general southwestern direction through the wetland. At the south end of the wetland and upstream of the future confluence with the existing White River channel, three apex ELJs (ELJs 4, 5, and 6) are positioned within the wetland to deflect flows approaching from either directly upstream within the wetland, or from the left bank of the existing White River channel, away from the left bank of the wetland terrace. These ELJs are also positioned to split and diffuse flow re-entering the existing White River channel. These ELJs would reduce the potential for concentrated flows being directed towards the right bank of the river. Final placement and orientation of the six apex ELJs shown in Figures 2 and 3 (Appendix A) is preliminary and will be refined during the final design phase pending results of hydraulic and sediment transport modeling.

If project construction funds can accommodate additional structures, two apex ELJs could also be located within the central portion of the wetland (shown as optional apex ELJs in Figures 2 and 3, Appendix A) to provide additional flow deflection. These additional apex ELJs are not critical to protecting the left bank or the right bank and would primarily provide additional habitat benefits, hydraulic complexity, and opportunities for woody debris accumulation. Alternatively, strategically placed rows of piles could be installed near the County boundary line within the wetland to collect debris in lieu of the optional apex ELJs to encourage natural log jam formation, floodplain roughening, and habitat creation and to reduce the potential for significant impingement of flow against the biorevetment. Upon accumulating woody debris, scour associated with the increased drag could destabilize the row of piles and release woody debris into the White River. This option is not shown on the concept figures, but was discussed with the County, as this technique has been applied successfully in other river projects and may warrant further consideration during the final design phase.

Preliminary drafts of the proposed structure layout provided to the County showed several bank deflector ELJs along the eastern perimeter of the wetland terrace. The bank deflector ELJs were removed from the final conceptual design due to preliminary construction budget limitations and because adequate bank protection can be accomplished using the engineered biorevetment and bank roughening structures described below. Details of the bank deflector ELJs are provided in Figure 4 (Appendix A).

Engineered Biorevetment and Bank Roughening Structures

These structures are placed along the entire left (east) bank of the wetland terrace in the concept design (Figures 2, 3 and 5, Appendix A). Because the alignment of the entire left bank is highly irregular, the possibility of flow becoming fixed along the entire left bank is considered low, and thus bank protection can be accomplished using a combination of biorevetment and bank roughening structures instead of the larger bank deflector ELJs. Their primary functions are to provide continuous bank protection and flow deflection along the left bank of the wetland terrace. The biorevetment structures are designed to be much more robust than the bank roughening structures and thus would be placed where high velocity flows may become fixed along the more exposed and protruding segments of the left bank and adjacent to private property and infrastructure. These locations, which are where the biorevetment structures are to be located, occur between control points A and B, C and D, E and F, and F and G on Figures 2 and 3 (Appendix A). The bank roughening structures are less robust and thus would be placed where flow velocities are anticipated to be lower, such as in the hydraulically protected areas in the lee of a protruding “arm” of the left bank. These locations, which are where the bank roughening structures are to be located, occur between control points B and C, and points D and E on Figures 2 and 3 (Appendix A).

Both structure types would provide continuous bank protection by adding roughness to reduce flow velocities and channel shear stresses along the bank. Key logs for each structure are oriented to provide an irregular face that would deflect flows away from the bank along any one segment to minimize the potential of flow becoming fixed along the bank. These structures would provide opportunities to accumulate wood debris during floods, which would further deflect flows away from the bank. Additional wood accumulations in proximity to these structures enhance their function to buffer erosive flows and would provide pool habitat and substrate for benthic communities. The tops of the structures would be planted with native vegetation to restore riparian functions along the top of bank and to provide root cohesion for additional stability and strength along the terrace edge.

Recommendations for Final Design Development

The proposed ELJs should be designed to achieve a minimum factor of safety (FS) against vertical buoyancy and lateral forces for a specified hydraulic flood event. Buoyant forces are directed upward on submerged wood and are equivalent to the weight of the water displaced by the volume of submerged wood. Lateral forces on the piles include earth surcharge loads due to backfilling the structure and hydraulic drag loads applied to the key logs projecting waterward of the structure that are transferred to the piles.

Recommended Design Criteria and Analyses

Based on discussions with County staff while developing the structure concepts and based on experience with comparable projects that are performing well, the following summarizes the recommended design criteria for finalizing the design of the four proposed structure types:

- 100-year flow design event as basis for estimating scour depths and calculating hydraulic loads on structures
- Maximum anticipated aggradation depth for the design life of the structure
- Structure buoyancy: FS of 2.0 to account for uncertainty in retention of ballast material over the service life of the structure.
- Pile overturning (pullout): FS of 1.3 to 1.5 for the 100-year flow event based on previous, similar projects that met performance standards after enduring large flood events.
- Pile failure due to bending and shear: FS of 1.3 to 1.5 for the 100-year flow event based on previous, similar projects that met performance standards after enduring large flood events.

As previously described, a full avulsion of the White River into the left bank floodplain wetland could allow the full force of the 100-year flow design event to interact with all of the proposed ELSs in the floodplain. Flow depths and velocities resulting from this scenario should be developed during the project design phase and should assume a full avulsion of the entire White River into the wetland to provide conservative estimates of peak hydraulic conditions.

To evaluate pile overturning and bending, scour calculations should be completed to provide an estimate of the probable vertical exposure of the embedded piles during the design flow event. Apex ELJs should be evaluated for pier scour and abutment scour using appropriate scour equations in published guidance documents. The results of the scour calculations should be evaluated and used to complete a subsequent pile analysis. Abutment scour calculations should be focused on assessing scour over approximately the outer 1/4 to 1/3 of the apex ELJ structure since this part of the structure mimics bridge abutments. Pier scour calculations should be focused on assessing scour along the entire face of the ELJ. The biorevetment and bank roughening structures should be evaluated for abutment scour assuming flow is fixed along the face of the structures, and for bend scour for flow that has a measurable radius of curvature but does not necessarily encounter an abutment-type blockage.

To assess the feasibility of driving timber piles into the wetland soils and the underlying alluvium, the County should complete a wave equation analysis program (WEAP) analysis. Input parameters should be developed based on results from the County's geotechnical investigation for borings located within the wetland and along the left bank where the biorevetment and bank roughening structures are proposed.

A pile analysis should be completed to evaluate shear and bending stresses and pile overturning. This could be accomplished using the software program LPile. The County should develop the geotechnical parameters from the subsurface investigations performed for the project. Standard input parameters needed for evaluation in alluvial (non-bedrock) environments that should be obtained and used in the LPile analysis include, but are not limited to, the following:

- Recommended load vs. displacement (p-y) curve type soil model (e.g. Reese Sand) for the applicable subsurface conditions.
- Soil unit weight and average effective unit weight
- Soil internal friction angle
- Soil modulus parameter (i.e., the initial tangent modulus of the p-y curve or k value in pounds per cubic inch)
- The soil strain parameter (E50).

Preliminary Construction Costs and Assumptions

Herrera developed preliminary construction costs for the proposed ELSs (Table 1). Detailed construction cost estimates for the individual structure types are included in Appendix B. The preliminary construction costs, which include a 30% contingency and 9.5% sales tax, are conservative to account for assumed construction methods and unknowns, including subsurface conditions and flow characteristics at the structures, which will be much better understood during the final design phase. Unit prices incorporated in the cost estimates may decrease as additional information becomes available during development of the final design. In addition, as project costs are refined, the structure design (number of structures and structure architecture) can be modified as needed to accommodate the available construction budget, while meeting the other project goals. The following discussion focuses on the major factors that will influence the costs of the various structure types.

Several design and construction assumptions were made while developing the preliminary construction costs to provide the County with conservative planning-level estimates for project budgeting purposes. Apex ELJs constructed within wet environments (i.e., within the middle of the wetland) will require more labor, material, and equipment use than those constructed on higher and dryer ground due to the need for more intensive water management, potentially greater difficulty in setting logs in the base of the structure, and need for more water quality protection measures. Thus, the "wet" apex ELJs will likely have a higher unit cost than "dry" apex ELJs. Apex ELJs 2, 3, 4, 6 and the two optional apex ELJs are considered "wet" structures because they are within the wetland; apex ELJs 1 and 5 are considered "dry" structures because of their close proximity to the left bank levee along the White River, and because the existing grade at their location is 2- to 4-feet higher than that of their adjacent "wet" structures. The biorevetment and bank roughening structures are considered "dry" structures because they will likely be constructed from the bank, the base of the structure does not need to be keyed in well below the toe of bank, and the work area isolation and water management needed per structure is anticipated to be less intensive than that needed for the "wet" apex ELJs. Unit costs developed for "wet" apex ELJs assumed that the additional water management measures would add approximately 15 percent of total structure construction cost to the unit cost of each structure. Water management costs for "dry" apex ELJs, as well as the biorevetment and bank roughening structures were assumed to account for only 5 percent of the total structure construction cost.

Table 1.
Summary of preliminary construction costs for the engineered log structures.

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost
1	Apex ELJ (dry location) with driven piles	2	EA	$150,000	$300,000
2	Apex ELJ (wet location) with driven piles	4	EA	$164,000	$656,000
3	Bank deflector ELJ with driven piles	0	EA	$136,000	–
4	Robust biorevetment with driven piles	3,750	LF	$470	$1,762,500
5	Bank roughening with driven piles	1,440	LF	$190	$ 273,600
6	Mobilization and additional TESC/water management (assumed 5% of construction)	1	LS	$144,000	$150,000
Construction Subtotal					$3,142,100
Contingency (30%)					$ 942,630
Subtotal					$4,084,730
Sales Tax (9.5%)					$388,049
Total with Contingency and Tax (rounded to nearest $10,000)					$4,480,000

Notes:

1. Costs for optional apex structures, as shown on Figures 2 and 3 in Appendix A, are not included in the above summary.
2. Bank deflector ELJs are not proposed in the final conceptual design due to overall cost effectiveness of having one continuous biorevetment without bank deflector ELJs, as the biorevetment is considered adequately robust unto itself. Unit costs for bank deflector ELJs are included in the above summary for reference only in the event these structures are deemed appropriate during the final design phase.
3. EA – each (i.e. number of structures)
4. LF – lineal feet (i.e. length of bank protected by structure)
5. LS – lump sum for work item(s)

Coarse alluvium is necessary to complete backfilling of all apex ELJs. For these structures, the fine-grained material excavated at each structure location is assumed to be insufficient for backfilling because it would be highly susceptible to erosion by overtopping flood flows. Therefore, the unit cost for each apex ELJ included in Table 1 assumes 50% of the backfill material would consist of an imported mixture of sand, gravel, and cobble, and the remaining 50% of the backfill material would be obtained from the existing levee removal spoils (which are assumed to consist of a mixture of sand, gravel, cobble, and boulders). The County indicated levee removal spoils will be available for constructing the apex ELJs if the structures are built during either the first or second year of construction. All levee spoils used in the apex ELJs will likely need to be temporarily stockpiled onsite prior to placement in the structure, which adds additional material handling costs for each structure. Native spoils produced while constructing the biorevetment and bank roughening structures should satisfy backfilling requirements for those structures; thus, no additional imported material was assumed to be required since these structures will be built into the existing bank.

As described previously, all of the conceptual structure designs include timber piles embedded in alluvium below the existing wetland ground surface. The unit costs for all structures types included in Table 1 assume that piles will be driven using industry standard pile driving means and methods. This assumption is based on ELJ construction projects designed by Herrera and constructed by King County and Seattle Public Utilities in 2008 and 2009 on the Tolt River, where timber piles were driven into substrate containing sand, gravels, silt, and some cobbles, which is the general subsurface condition anticipated to be encountered in the Countyline project area based on geotechnical data for the project site (Shannon & Wilson 2009, King County 2010). Following completion of all site geotechnical investigations and the County's completion of the WEAP analysis, the feasibility of driving piles should be determined. If pile driving is not feasible for some or all the structures, then the alternative means and methods of installing the timber piles should consider casing and drilling pilot holes (shafts) into the alluvium to allow pile placement. If casing and drilling is required for the apex ELJs, then structure unit costs can increase from $15,000 to $50,000 (or 1.5 to 3.0 times the cost of pile driving) depending on subsurface conditions. The unit cost can be expected to rise with coarser substrate. If casing and drilling is required for the biorevetment structures, then unit costs can increase from $7,000 to $18,000 (or 4 to 6 times the cost of pile driving) depending on subsurface conditions. Unit costs for constructing apex ELJs and the biorevetment structure with casing and drilling are also included in Appendix B. If more expensive pile installation is necessary, either the structure architecture should be revised or the number of structures reduced to remain within the County's construction budget. Alternatively, the feasibility of installing steel H-piles or steel pipe piles could also be investigated during the final design phase. Structure concepts and costs presented in this report did not consider using steel piles.

The unit costs for all structures types included in Table 1 do not include costs for optional log ballast such as riprap, because design assumptions were based on assuming imported gravel and cobble mixtures and levee removal spoils would provide adequate ballast and resistance to erosion. Based on the final architectural configuration and location of the structures, the pile and buoyancy analyses, hydraulic modeling results, the acceptable factor of safety for structure failure, and the type and gradation of proposed backfill material, these structures may include the placement of riprap to provide additional ballast over the logs. The placement of riprap, either loosely placed or in the form of strategically placed tethered rock anchors to increase the factor of safety against log and ballast mobilization, can increase the unit cost from $1,500 to $5,000 for the biorevetment and up to $22,000 for each apex ELJ. Although the unit cost for placement of tethered rock anchors is significantly higher than that of loosely placed material ($70 to $90 per ton versus $20 to $40 per ton), typically the volume (or tonnage) of material needed for anchor placement is much less than that of loosely placed material and thus results in overall reduced cost for imported material.

ELJ Construction Recommendations and Timelines

The County intends to construct the project over the span of two construction seasons (two years). Prior to levee removal, the left bank of the floodplain wetland should be protected and the setback levee in place to minimize erosion and flood hazards along adjacent private properties that could occur following levee removal. The major construction elements during Year 1 should include the setback levee, vegetated buffers, and the biorevetment and bank roughening structures. The major construction elements during Year 2 should include removal of the existing levee prism and bank armoring, removal of the existing culvert, and outlet channel modifications.

Construction of the apex ELJs can occur during either Year 1 or Year 2. If they are constructed during Year 1, levee and bank armoring material may be available for backfilling the structures. If not, additional material may need to be imported to supplement the assumed quantity of imported material for that purpose. During Year 1, it is possible that sufficient flood protection will remain until project completion if the landward half of some sections of the levee is excavated to provide the backfill material required for the apex ELJs. Some of the relatively wider sections of the levee may contain historical dredge materials (alluvium) from the river channel, which are ideal for backfilling the structures. If the apex ELJs are constructed during Year 2, levee and bank armoring removal spoils including gravel, cobbles, and riprap could be used to satisfy structure backfilling requirements; however, sequencing of the structure construction and removal of the levee prism and bank armoring should be developed to verify material quantities available for the structures and avoid construction delays.

For Year 1 construction, assuming the apex ELJs are constructed during Year 2, the time required to construct the biorevetment and bank roughening structures will be based primarily on the rate of pile installation; only after the piles are installed can the structures be completed. On the Tolt River restoration project constructed in 2008 and 2009, an average of approximately seven timber piles were installed each day during construction using one piece of equipment and associated crew; simultaneous installations did not occur. There are approximately 434 piles associated with the biorevetment and bank roughening structures in the conceptual design plan for the Countyline project, so approximately 62 working days may be needed to complete pile installation assuming an equivalent production rate with one piece of equipment. Approximately 31 working days would be required with two simultaneous pile driving installations at the same rate. The in-water work window on the White River per the Washington Department of Fish and Wildlife (WDFW) guidance is from July 16th through August 15th, which is 23 days (not working weekends) or 30 days (including working on weekends) if the in-water work window applies to work within the wetland. In this case, three simultaneous pile driving installations may be needed to complete the work by August

15th. If the allowable work window for Year 1 is extended, then the number of pile installation crews can be adjusted accordingly to complete work on time.

For Year 2 construction, the time required to construct the apex ELJs will also be based on pile installation rates and the number of days required to assemble the structures and complete backfilling, provide access to the structure locations, and manage water. Removal of the levee and bank armoring will likely be restricted to occur within the allowable work window from July 16th to August 15th; therefore, construction of the apex ELJs will likely occur during this time. Construction of one apex ELJ is estimated to require approximately 10 to 15 working days per structure, or 60 to 90 days total for all six apex ELJs included in the concept design if none of them are constructed simultaneously. At this rate, three simultaneous installations will be required to install all six apex ELJs within the in-water work window.

Herrera developed preliminary construction schedules for Year 1 and Year 2 construction seasons, which are included in Appendix C. The schedules include timeline estimates for constructing the ELSs. The schedules also include preliminary timeline estimates provided by the County for completion of all associated earthwork designed by the County. Only the major work elements associated with each construction year are included; details of constructing those elements are not provided in the preliminary schedules.

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APPENDIX A

Project Figures

Figure 1.
Vicinity map of the Countyline project site and project area.

GENERAL NOTES:

1. LEVEE REMOVAL ZONE SHOWN IS APPROXIMATE AND IS BASED ON PREVIOUS PROJECT CONCEPTUAL DESIGN PLANS DEVELOPED BY KING COUNTY. ACTUAL EXTENTS OF REMOVAL TO BE DETERMINED BY KING COUNTY DURING PROJECT DESIGN PHASE.
2. WETLAND BUFFERS, SETBACK LEVEES, REVEGETATION, ACCESS ROADS AND OTHER WORK TO OCCUR ALONG THE LEFT BANK TERRACE TO BE DESIGNED BY KING COUNTY AND IS NOT SHOWN. BUFFER WIDTH WILL VARY BASED ON LOCAL JURISDICTIONAL REQUIREMENTS.
3. LOCATION AND ORIENTATION OF PROPOSED ENGINEERED STRUCTURES SHOWN IS APPROXIMATE AND WILL BE FINALIZED DURING PROJECT DESIGN PHASE.
4. CONSTRUCTION BUFFERS, TESC MEASURES, ACCESS ROADS, STAGING AND STOCKPILE AREAS NOT SHOWN.
5. LEVEE REMOVAL AND CONSTRUCTION OF ENGINEERED STRUCTURES LANDWARD OF EXISTING LEVEE TO BE PHASED OVER TWO CONSTRUCTION PERIODS. YEAR 1 WORK WILL INCLUDE CONSTRUCTION OF FEATURES LANDWARD OF THE EXISTING LEVEE. YEAR 2 WORK WILL INCLUDE LEVEE REMOVAL AND CONSTRUCTION OF ANY OTHER ENGINEERED STRUCTURES AND INFRASTRUCTURE NEEDED TO COMPLETE PROJECT.

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NUM.	REVISION	BY	DATE

APPROVED:	XX	XX
PROJECT MANAGER:	DEB SCHRIEBNER	01/11
DESIGNED:	B. SCOTT	01/11
REVIEWED:	C. BRUMMER	01/11
DESIGN ENTERED:	L. TURNIDGE	01/11

FED. AID No. XX
PROJECT No. XX
SURVEY No. XX
MAINTENANCE DIVISION No. XX

HERRERA ENVIRONMENTAL CONSULTANTS
2200 Sixth Avenue
Suite 1100
Seattle, Washington
98121-1820
206-441-9080
206-441-9108 FAX
http://www.herrerainc.com

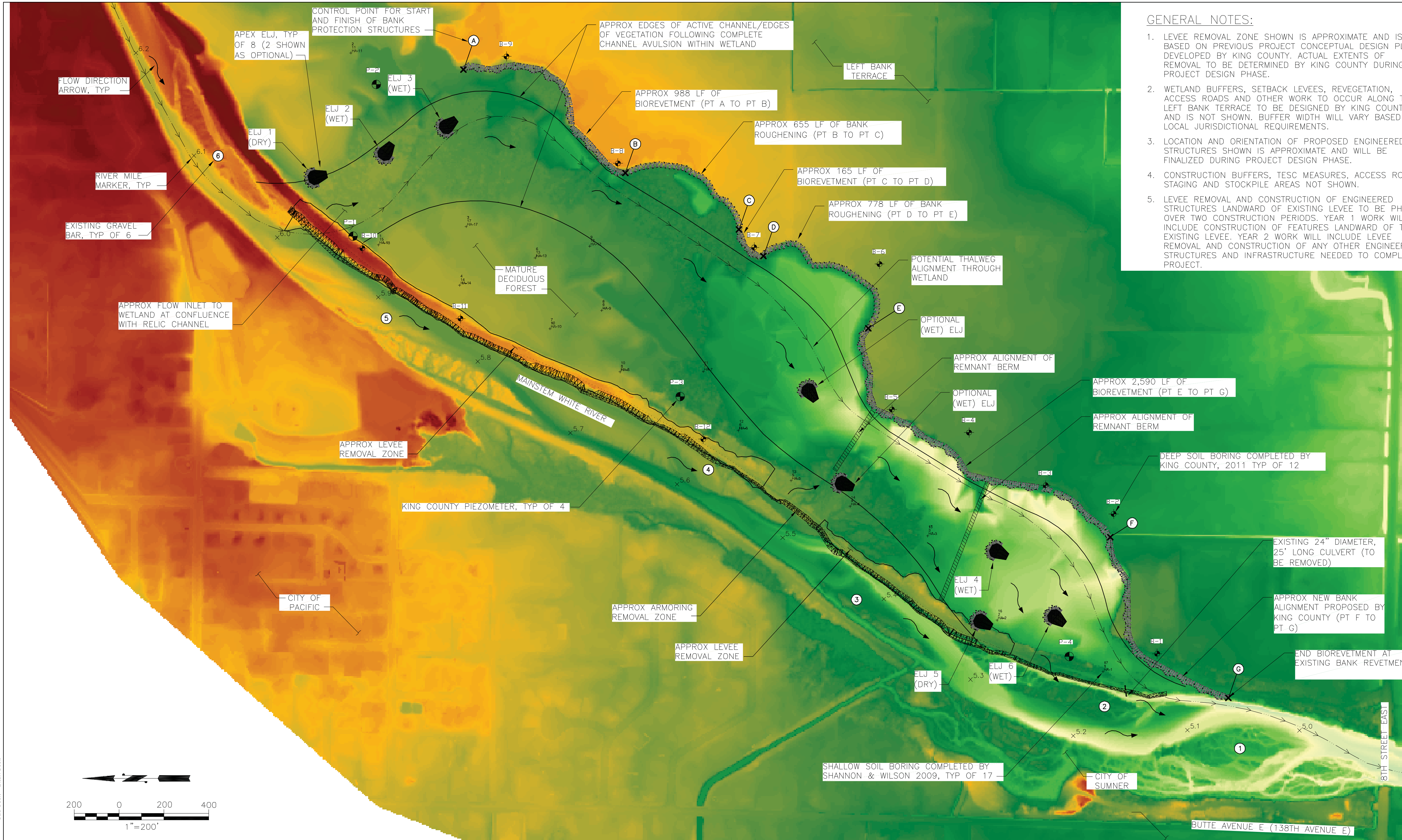
King County
Department of Natural Resources and Parks
Water and Land Resources Division
River and Floodplain Management Section
Bob Burns, Interim Director

WHITE RIVER AT COUNTYLINE
CONCEPT DEVELOPMENT AND PREDESIGN FOR ENGINEERED LOG STRUCTURES

PROPOSED ENGINEERED LOG STRUCTURE SITE PLAN WITH 2009 AERIAL PHOTO

SHEET 1 OF 4 SHEETS

FIGURE 2



GENERAL NOTES:

1. LEVEE REMOVAL ZONE SHOWN IS APPROXIMATE AND IS BASED ON PREVIOUS PROJECT CONCEPTUAL DESIGN PLANS DEVELOPED BY KING COUNTY. ACTUAL EXTENTS OF REMOVAL TO BE DETERMINED BY KING COUNTY DURING PROJECT DESIGN PHASE.
2. WETLAND BUFFERS, SETBACK LEVEES, REVEGETATION, ACCESS ROADS AND OTHER WORK TO OCCUR ALONG THE LEFT BANK TERRACE TO BE DESIGNED BY KING COUNTY AND IS NOT SHOWN. BUFFER WIDTH WILL VARY BASED ON LOCAL JURISDICTIONAL REQUIREMENTS.
3. LOCATION AND ORIENTATION OF PROPOSED ENGINEERED STRUCTURES SHOWN IS APPROXIMATE AND WILL BE FINALIZED DURING PROJECT DESIGN PHASE.
4. CONSTRUCTION BUFFERS, TESC MEASURES, ACCESS ROADS, STAGING AND STOCKPILE AREAS NOT SHOWN.
5. LEVEE REMOVAL AND CONSTRUCTION OF ENGINEERED STRUCTURES LANDWARD OF EXISTING LEVEE TO BE PHASED OVER TWO CONSTRUCTION PERIODS. YEAR 1 WORK WILL INCLUDE CONSTRUCTION OF FEATURES LANDWARD OF THE EXISTING LEVEE. YEAR 2 WORK WILL INCLUDE LEVEE REMOVAL AND CONSTRUCTION OF ANY OTHER ENGINEERED STRUCTURES AND INFRASTRUCTURE NEEDED TO COMPLETE PROJECT.

Path: O:\proj\Y2009\09-04375-240\Draft Cadfiles\Figures\For Final Memo (June 2011)\Proposed Site Plan_060611.dwg
Plot Date: 6/6/2011 4:33 PM Cad User: Brian Scott

FIELD BOOK:	XX	XX–XXXX
SURVEYED:	XX	XX–XXXX
SURVEY BASE MAP:	XX	XX–XXXX
CHECKED:	XX	XX–XXXX

NUM.	REVISION	BY	DATE

APPROVED:	XX	XX
PROJECT MANAGER:	DEB SCHRIEBNER	01/11
DESIGNED:	B. SCOTT	01/11
REVIEWED:	C. BRUMMER	01/11
DESIGN ENTERED:	L. TURNIDGE	01/11

FED. AID No. XX
PROJECT No. XX
SURVEY No. XX
MAINTENANCE DIVISION No. XX

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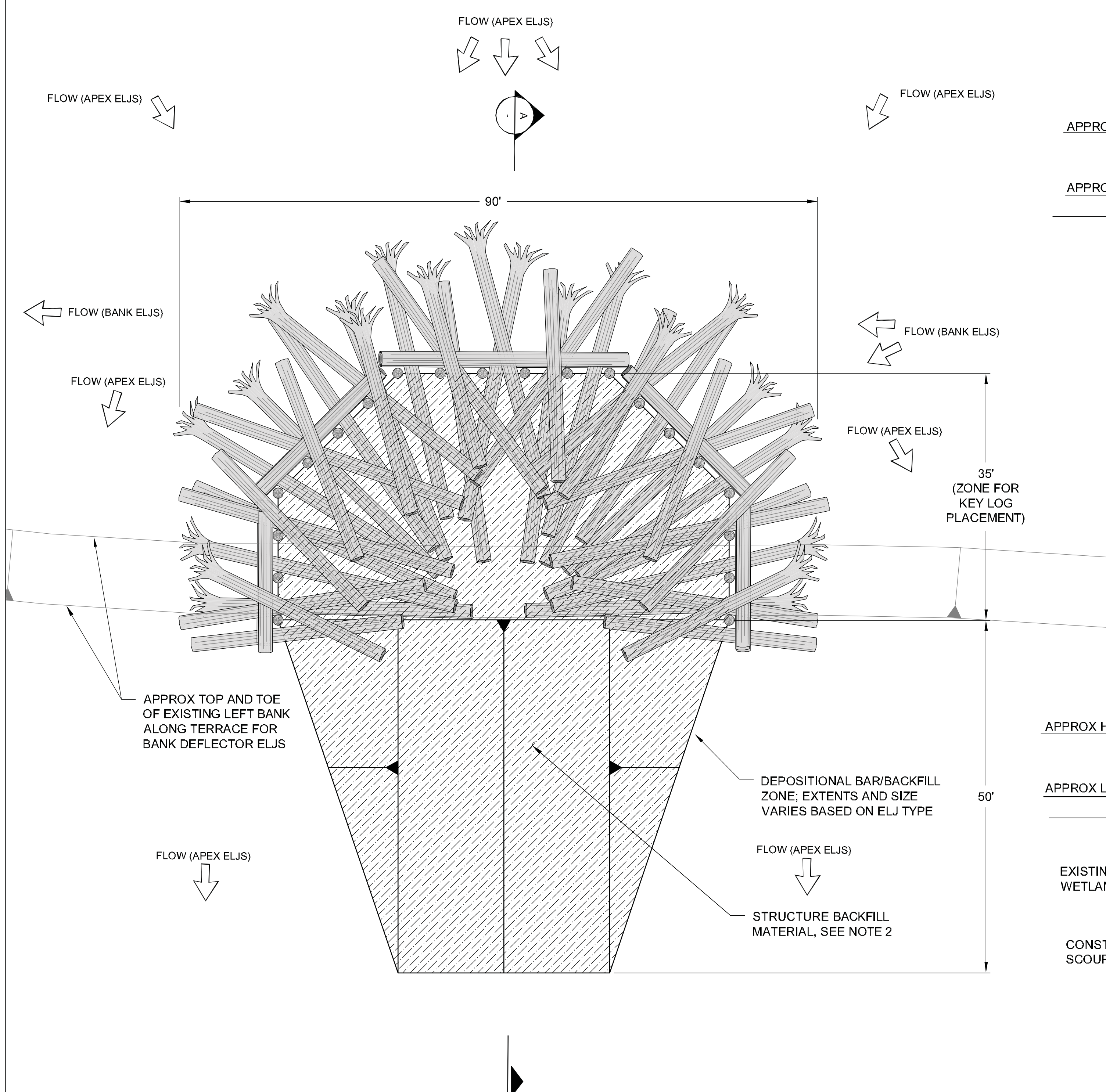
WHITE RIVER AT COUNTYLINE CONCEPT DEVELOPMENT AND PREDESIGN FOR ENGINEERED LOG STRUCTURES

PROPOSED ENGINEERED LOG STRUCTURE SITE PLAN WITH 2009 LIDAR

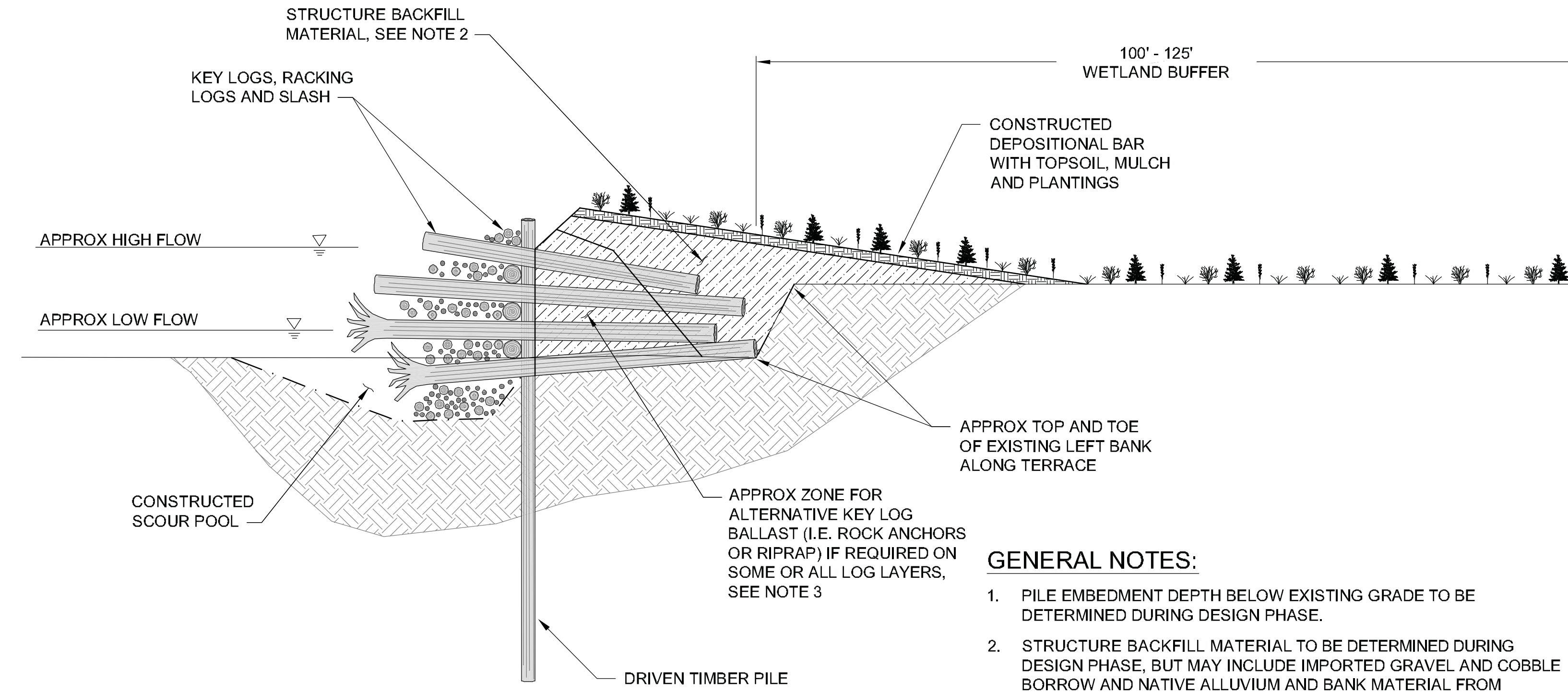
SHEET 2 OF 4 SHEETS

FIGURE 3



APEX AND BANK DEFLECTOR ELJ - PLAN VIEW (1 / -)

SCALE: 1" = 10'

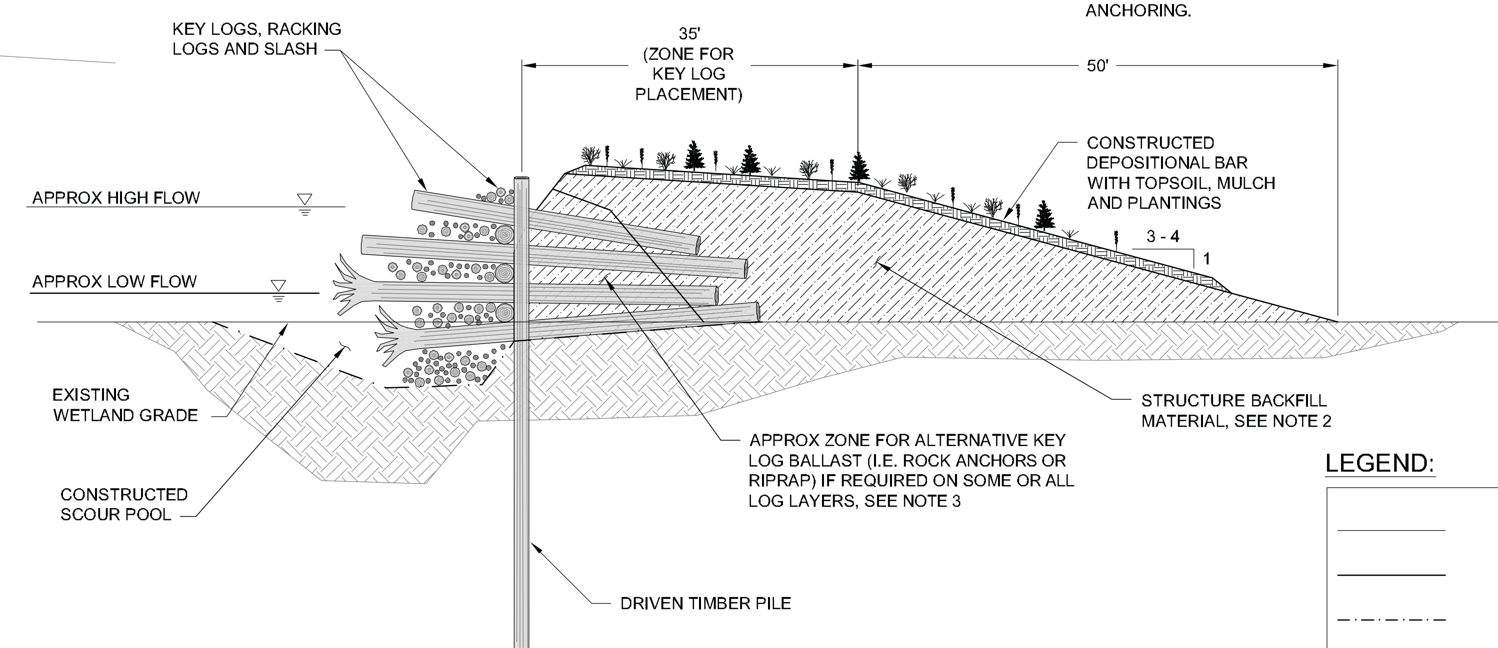


BANK DEFLECTOR ELJ - SECTION (A / -)

SCALE: 1" = 10'

GENERAL NOTES:

1. PILE EMBEDMENT DEPTH BELOW EXISTING GRADE TO BE DETERMINED DURING DESIGN PHASE.
2. STRUCTURE BACKFILL MATERIAL TO BE DETERMINED DURING DESIGN PHASE, BUT MAY INCLUDE IMPORTED GRAVEL AND COBBLE BORROW AND NATIVE ALLUVIUM AND BANK MATERIAL FROM STRUCTURE EXCAVATION AND LEVEE REMOVAL ACTIVITIES.
3. KEY LOG BALLAST TO BE DETERMINED DURING DESIGN PHASE, BUT MAY INCLUDE TETHERED ROCK ANCHORS, IMPORTED RIPRAP, AND NATIVE COBBLES AND BOULDERS PRODUCDED DURING STRUCTURE EXCAVATION AND LEVEE REMOVAL ACTIVITIES.
4. KEY LOGS MAY BE CHAINED TO PILES TO PROVIDE ADDITIONAL ANCHORING.



APEX ELJ - SECTION (A / -)

SCALE: 1" = 10'

LEGEND:

(thin line)	EXISTING GRADE
(heavy line)	PROPOSED GRADE
(dash-dot line)	EXCAVATION LIMITS
(hatch)	TOP SOIL TYPE B AND MULCH
(hatch)	STRUCTURE BACKFILL MATERIAL
(hatch)	EXISTING SUBSTRATE

Path: O:\proj\Y2009\09-04375-240\Draft Cadfiles\Figures\For Final Memo\Proposed Concept ELJs_032911.dwg
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Cad User: Brian Scott

FIELD BOOK:	XX	XX-XXXX
SURVEYED:	XX	XX-XXXX
SURVEY BASE MAP:	XX	XX-XXXX
CHECKED:	XX	XX-XXXX

NUM.	REVISION	BY	DATE

APPROVED:	XX	XX
PROJECT MANAGER:	DEB SCHRIEBNER	01/11
DESIGNED:	B. SCOTT	01/11
REVIEWED:	C. BRUMMER	01/11
DESIGN ENTERED:	L. TURNIDGE	01/11

FED. AID No. XX
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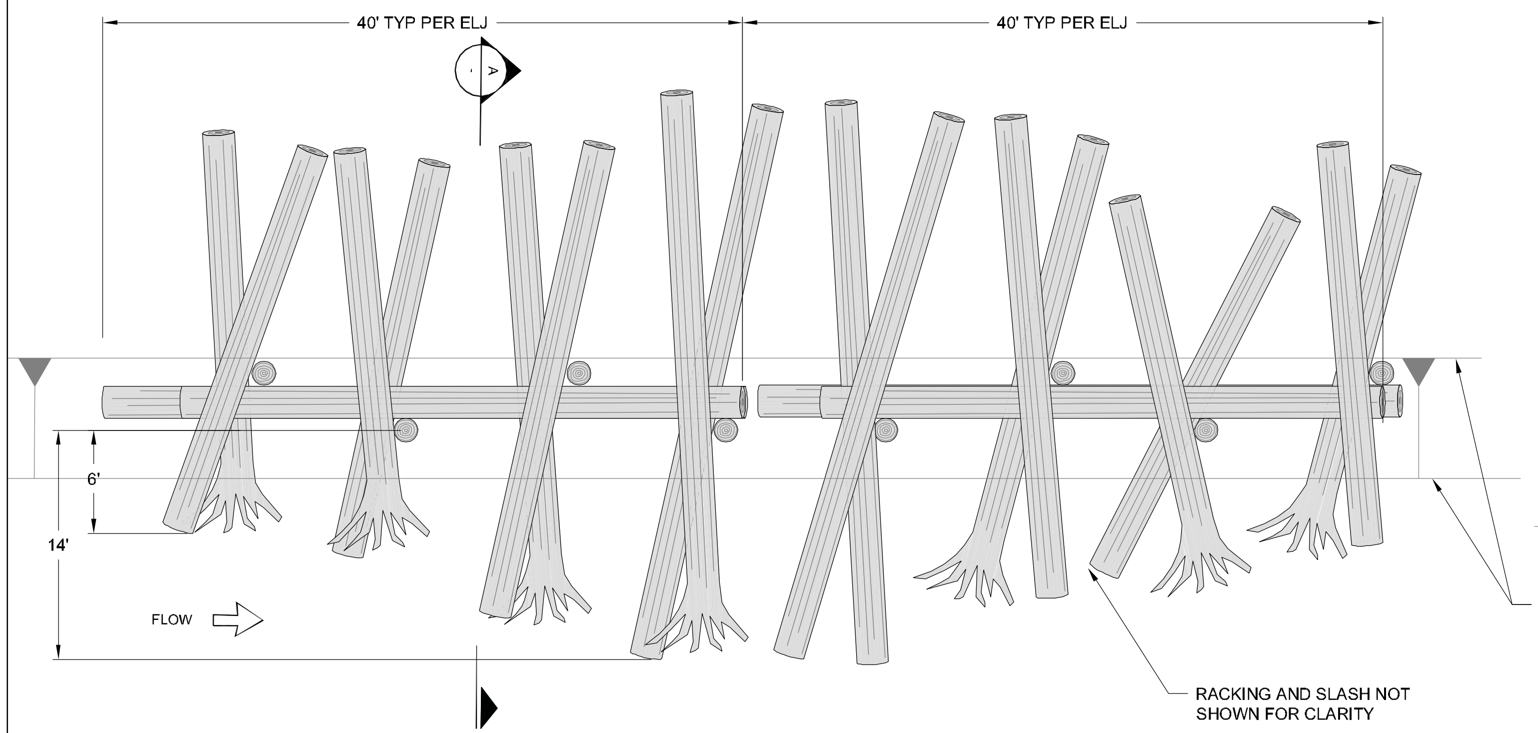
WHITE RIVER AT COUNTYLINE
CONCEPT DEVELOPMENT AND PREDESIGN
FOR ENGINEERED LOG STRUCTURES

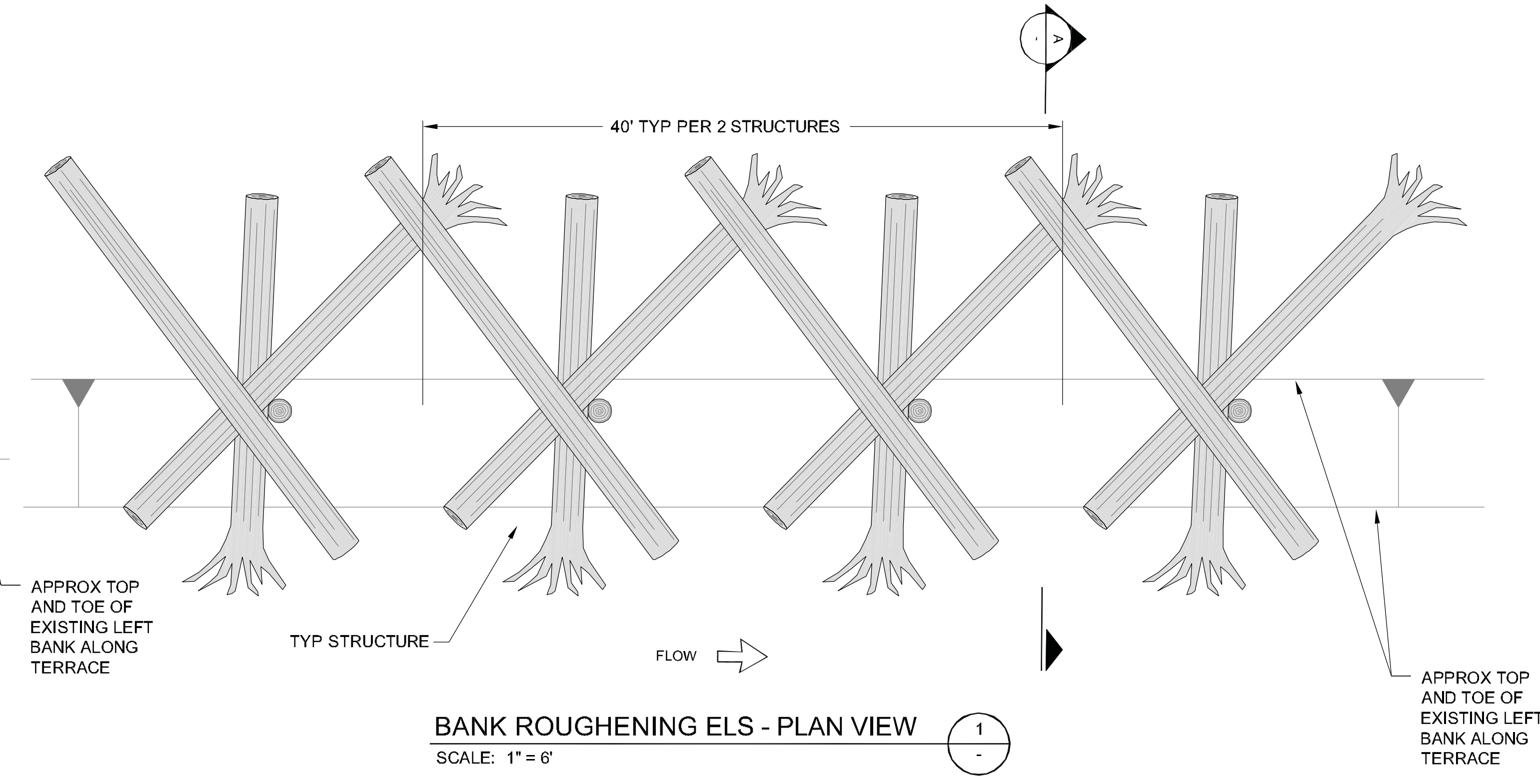
PROPOSED APEX (MID-CHANNEL) AND BANK DEFLECTOR STRUCTURES

SHEET 3 OF 4 SHEETS

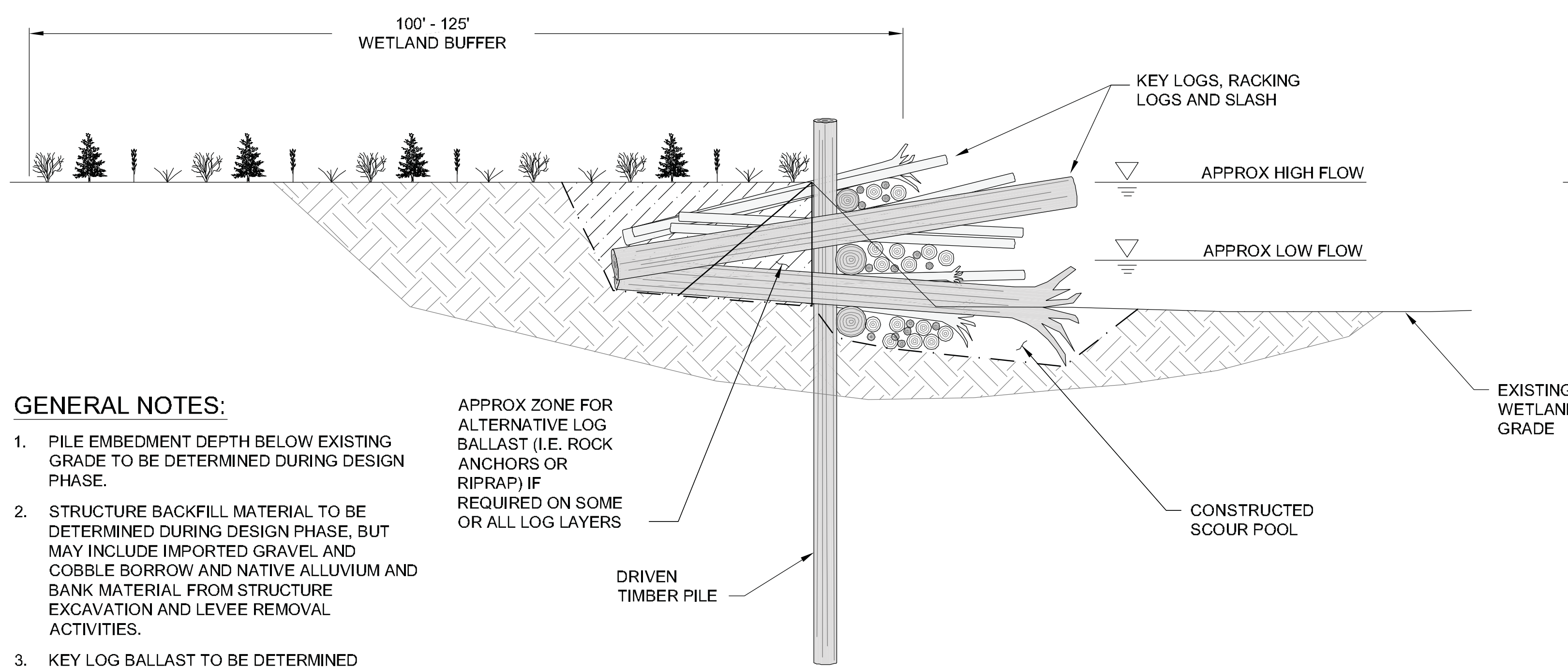
FIGURE 4



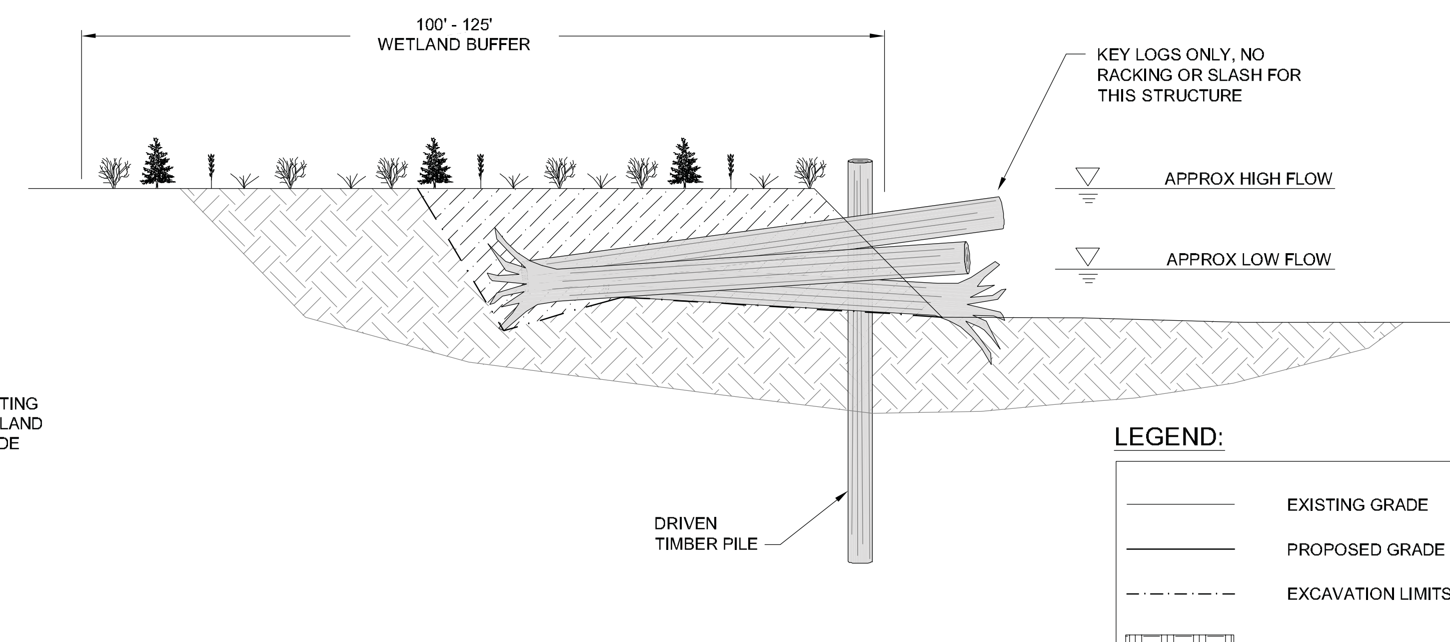
BIOREVETMENT ELS - PLAN VIEW (1/-)
SCALE: 1" = 6'



BANK ROUGHENING ELS - PLAN VIEW (1/-)
SCALE: 1" = 6'



BIOREVETMENT ELS - SECTION (A/-)
SCALE: 1" = 6'

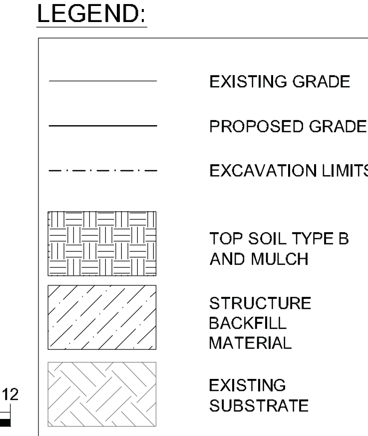


BANK ROUGHENING ELS - SECTION (A/-)
SCALE: 1" = 6'

GENERAL NOTES:

1. PILE EMBEDMENT DEPTH BELOW EXISTING GRADE TO BE DETERMINED DURING DESIGN PHASE.
2. STRUCTURE BACKFILL MATERIAL TO BE DETERMINED DURING DESIGN PHASE, BUT MAY INCLUDE IMPORTED GRAVEL AND COBBLE BORROW AND NATIVE ALLUVIUM AND BANK MATERIAL FROM STRUCTURE EXCAVATION AND LEVEE REMOVAL ACTIVITIES.
3. KEY LOG BALLAST TO BE DETERMINED DURING DESIGN PHASE, BUT MAY INCLUDE TETHERED ROCK ANCHORS, IMPORTED RIPRAP, AND NATIVE COBBLES AND BOULDERS PRODUCDED DURING STRUCTURE EXCAVATION AND LEVEE REMOVAL ACTIVITIES.
4. KEY LOGS MAY BE CHAINED TO PILES TO PROVIDE ADDITIONAL ANCHORING.

LEGEND:



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FIELD BOOK: XX XX-XXXX
SURVEYED: XX XX-XXXX
SURVEY BASE MAP: XX XX-XXXX
CHECKED: XX XX-XXXX

NUM. | REVISION | BY | DATE

APPROVED: XX XX
PROJECT MANAGER: DEB SCHRIEBNER 01/11
DESIGNED: B. SCOTT 01/11
REVIEWED: C. BRUMMER 01/11
DESIGN ENTERED: L. TURNIDGE 01/11

FED. AID No. XX
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WHITE RIVER AT COUNTYLINE
CONCEPT DEVELOPMENT AND PREDESIGN
FOR ENGINEERED LOG STRUCTURES

PROPOSED BIOREVETMENT AND BANK ROUGHENING STRUCTURES

SHEET 4 OF 4 SHEETS

FIGURE 5

APPENDIX B

Preliminary Construction Cost Estimates for Engineered Log Structures

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: **White River at Countyline Concept Development and Predesign for Engineered Log Structures**
Project #: **09-04375-250**
Client: **King County Department of Natural Resources and Parks, Water and Land and Resource Division**
Date Modified: 4/1/11
Spread sheet by: BS
Checked by: IBM
Checked Date: 4/9/11

Apex ELJ without Scour Apron and Driven Piles

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.40	AC	$ 10,000	$ 4,000	Assume an area of 120ft x 120 ft per structure
2	Structure Excavation Inc. Haul	1,300	CY	$ 10	$ 13,000	Assume all spoils not suitable for backfilling; excavation, loading, hauling and disposal of spoils; 1,300 cy total excavated & not used
3	Pile Driving	20	EA	$ 1,000	$ 20,000	20 total 50' long piles/ELJ @ 35' embedment ($20/LF (for total pile length) per Pile Inc. on 1/10/11)
4	ELJ Construction	1	EA	$ 9,360	$ 9,360	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 3 days for: 2 pieces of machinery, 1 laborer and 1 supervisor; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 50' long w/rootwad	0	EA	$ 1,200	$ -	Material cost only
6	Log: 24" dia, 45' long w/rootwad	0	EA	$ 1,100	$ -	Material cost only
7	Log: 24" dia, 40' long w/rootwad	16	EA	$ 1,000	$ 16,000	Material cost only
8	Log: 24" dia, 35' long w/rootwad	0	EA	$ 900	$ -	Material cost only
9	Log: 24" dia, 30' long w/rootwad	5	EA	$ 800	$ 4,000	Material cost only
10	Log: 24" dia, 25' long w/rootwad	0	EA	$ 750	$ -	Material cost only
11	Log: 18" dia, 30' long w/rootwad	0	EA	$ 500	$ -	Material cost only
12	Log: 24" dia, 50' long	0	EA	$ 900	$ -	Material cost only
13	Log: 24" dia, 45' long	0	EA	$ 800	$ -	Material cost only
14	Log: 24" dia, 40' long	12	EA	$ 700	$ 8,400	Material cost only
15	Log: 24" dia, 35' long	5	EA	$ 600	$ 3,000	Material cost only
16	Log: 24" dia, 30' long	7	EA	$ 500	$ 3,500	Material cost only
17	Log: 24" dia, 25' long	6	EA	$ 450	$ 2,700	Material cost only
18	Log: 24" dia, 20' long	6	EA	$ 400	$ 2,400	Material cost only
19	Log: 18" dia, 50' long	20	EA	$ 600	$ 12,000	Pile, material cost only
20	Log: 18" dia, 30' long	0	EA	$ 450	$ -	Pile, material cost only
21	Racking Logs: 4"-16" dia, 15' - 30' long	300	EA	$ 30	$ 9,000	Material cost only
22	Slash Material	300	CY	$ 30	$ 9,000	Material cost only
23	Top Soil Type B	130	CY	$ 30	$ 3,889	Material furnishing and placement; assume 3,500 sf @ 1' deep
24	Bark or Wood Chip Mulch	32	CY	$ 30	$ 972	Material furnishing and placement; assume 3,500 sf @ 0.25' deep
25	Select Borrow	700	CY	$ 25	$ 17,500	Imported backfill material for ballast; assume 50% of structure backfill material provided by levee spoils. Material placed in structure excavation areas and for depositional bar. 1,400 cy needed for backfilling; 700 cy of import material needed.
26	Haul and Place Levee Spoils	700	CY	$ 5	$ 3,500	Haul from temporary stockpile and place in structure.
27	TESC/Water Management (Dry ELJ)	1	EA	$ 7,111	$ 7,111	Assume 5% of ELJ construction cost for ELJs in the dry
28	TESC/Water Management (Wet ELJ)	1	EA	$ 21,333	$ 21,333	Assume 15% of ELJ construction cost for ELJs in the wet
	Construction Subtotal per dry Structure				$ 149,332	
	Construction Subtotal per wet Structure				$ 163,554	
	Optional Ballast					
	Drilled 3-4 Man Rock per ELJ	264	TON	$ 85	$ 22,440	Assume $25/ton based on previous ELJ construction projects. Weight based on structure buoyancy requirements. Includes hauling, dumping, etc. $90 per rock for drilling based on quote from local quarry; assume 88 anchors/176 1.5-ton rocks per ELJ.

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: **White River at Countyline Concept Development and Predesign for Engineered Log Structures**
Project #: **09-04375-250**
Client: **King County Department of Natural Resources and Parks, Water and Land and Resource Division**
Date Modified: 4/1/11
Spread sheet by: BS
Checked by: IBM
Checked Date: 4/9/11

Apex ELJ with Scour Apron and Driven Piles

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.40	AC	$ 10,000	$ 4,000	Assume an area of 120ft x 120 ft per structure
2	Structure Excavation Inc. Haul (Structure)	1,300	CY	$ 10	$ 13,000	Assume twice the excavation needed as without scour apron; Assume 1/2 of spoils not suitable for backfilling; excavation, loading, hauling and disposal of spoils; 2,600 cy total excavated & 1,300 cy not used
3	Structure Excavation (Scour Apron)	1,300	CY	$ 5	$ 6,500	Assume spoils for scour apron are suitable for backfilling over apron
3	Pile Driving	20	EA	$ 800	$ 16,000	20 total 40' long piles/ELJ @ 25' embedment; assume 10lf/pile less than without scour apron ($20/LF (for total pile length) per Pile Inc. on 1/10/11)
4	ELJ Construction	1	EA	$ 9,360	$ 9,360	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 3 days for: 2 pieces of machinery, 1 laborer and 1 supervisor; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 50' long w/rootwad	0	EA	$ 1,200	$ -	Material cost only
6	Log: 24" dia, 45' long w/rootwad	0	EA	$ 1,100	$ -	Material cost only
7	Log: 24" dia, 40' long w/rootwad	16	EA	$ 1,000	$ 16,000	Material cost only
8	Log: 24" dia, 35' long w/rootwad	0	EA	$ 900	$ -	Material cost only
9	Log: 24" dia, 30' long w/rootwad	5	EA	$ 800	$ 4,000	Material cost only
10	Log: 24" dia, 25' long w/rootwad	0	EA	$ 750	$ -	Material cost only
11	Log: 18" dia, 30' long w/rootwad	0	EA	$ 500	$ -	Material cost only
12	Log: 24" dia, 50' long	0	EA	$ 900	$ -	Material cost only
13	Log: 24" dia, 45' long	0	EA	$ 800	$ -	Material cost only
14	Log: 24" dia, 40' long	12	EA	$ 700	$ 8,400	Material cost only
15	Log: 24" dia, 35' long	5	EA	$ 600	$ 3,000	Material cost only
16	Log: 24" dia, 30' long	7	EA	$ 500	$ 3,500	Material cost only
17	Log: 24" dia, 25' long	6	EA	$ 450	$ 2,700	Material cost only
18	Log: 24" dia, 20' long	6	EA	$ 400	$ 2,400	Material cost only
19	Log: 18" dia, 40' long	20	EA	$ 500	$ 10,000	Pile, material cost only
20	Log: 18" dia, 30' long	0	EA	$ 450	$ -	Pile, material cost only
21	Racking Logs: 4"-16" dia, 15' - 30' long	300	EA	$ 30	$ 9,000	Material cost only
22	Slash Material	300	CY	$ 30	$ 9,000	Material cost only
23	Top Soil Type B	130	CY	$ 30	$ 3,889	Material furnishing and placement; assume 3,500 sf @ 1' deep
24	Bark or Wood Chip Mulch	32	CY	$ 30	$ 972	Material furnishing and placement; assume 3,500 sf @ 0.25' deep
25	Select Borrow	700	CY	$ 25	$ 17,500	Imported backfill material for ballast; assume 50% of structure backfill material provided by levee spoils. Material placed in structure excavation areas and for depositional bar. 1,400 cy needed for backfilling; 700 cy of import material needed.
26	Haul and Place Levee Spoils	700	CY	$ 5	$ 3,500	Haul from temporary stockpile and place in structure.
27	Heavy Loose Riprap	596	TN	$ 40	$ 23,822	Scour apron: 3350 sf x 3ft deep @ 1.6TN/CY
28	TESC/Water Management (Dry ELJ)	1	EA	$ 8,327	$ 8,327	Assume 5% of ELJ construction cost for ELJs in the dry
29	TESC/Water Management (Wet ELJ)	1	EA	$ 24,382	$ 24,382	Assume 15% of ELJ construction cost for ELJs in the wet

Construction Subtotal per dry Structure $ 174,871
Construction Subtotal per wet Structure $ 190,925

Optional Ballast

Drilled 3-4 Man Rock per ELJ	264	TON	$ 85	$ 22,440	Assume $25/ton based on previous ELJ construction projects. Weight based on structure buoyancy requirements. Includes hauling, dumping, etc. $90 per rock for drilling based on quote from local quarry; assume 88 anchors/176 1.5-ton rocks per ELJ.

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: White River at Countyline Concept Development and Predesign for Engineered Log Structures
Project #: 09-04375-250
Client: King County Department of Natural Resources and Parks, Water and Land and Resource Division
Date Modified: 4/1/11
Spread sheet by: BS
Checked by: IBM
Checked Date: 4/9/11

Apex ELJ (Case & Drill to Place Piles)

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.40	AC	$ 10,000	$ 4,000	Assume an area of 120ft x 120 ft per structure
2	Structure Excavation Inc. Haul	1,300	CY	$ 10	$ 13,000	Assume all spoils not suitable for backfilling; excavation, loading, hauling and disposal of spoils; 1,300 cy total excavated & not used
3	Pile Placement and Pre-Drilling	20	EA	$ 2,625	$ 52,500	20 total 50' long piles/ELJ @ 35' embedment ($75/LF engr estimate for drilling and placing pile)
4	ELJ Construction	1	EA	$ 3	$ 3	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 3 days for: 2 pieces of machinery, 1 laborer and 1 supervisor; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 50' long w/rootwad	0	EA	$ 1,200	$ -	Material cost only
6	Log: 24" dia, 45' long w/rootwad	0	EA	$ 1,100	$ -	Material cost only
7	Log: 24" dia, 40' long w/rootwad	16	EA	$ 1,000	$ 16,000	Material cost only
8	Log: 24" dia, 35' long w/rootwad	0	EA	$ 900	$ -	Material cost only
9	Log: 24" dia, 30' long w/rootwad	5	EA	$ 800	$ 4,000	Material cost only
10	Log: 24" dia, 25' long w/rootwad	0	EA	$ 750	$ -	Material cost only
11	Log: 18" dia, 30' long w/rootwad	0	EA	$ 500	$ -	Material cost only
12	Log: 24" dia, 50' long	0	EA	$ 900	$ -	Material cost only
13	Log: 24" dia, 45' long	0	EA	$ 800	$ -	Material cost only
14	Log: 24" dia, 40' long	12	EA	$ 700	$ 8,400	Material cost only
15	Log: 24" dia, 35' long	5	EA	$ 600	$ 3,000	Material cost only
16	Log: 24" dia, 30' long	7	EA	$ 500	$ 3,500	Material cost only
17	Log: 24" dia, 25' long	6	EA	$ 450	$ 2,700	Material cost only
18	Log: 24" dia, 20' long	6	EA	$ 400	$ 2,400	Material cost only
19	Log: 18" dia, 50' long	20	EA	$ 600	$ 12,000	Pile, material cost only
20	Log: 18" dia, 30' long	0	EA	$ 450	$ -	Pile, material cost only
21	Racking Logs: 4"-16" dia, 15' - 30' long	300	EA	$ 30	$ 9,000	Material cost only
22	Slash Material	300	CY	$ 30	$ 9,000	Material cost only
23	Top Soil Type B	130	CY	$ 30	$ 3,889	Material furnishing and placement; assume 3,500 sf @ 1' deep
24	Bark or Wood Chip Mulch	32	CY	$ 30	$ 972	Material furnishing and placement; assume 3,500 sf @ 0.25' deep
25	Select Borrow	700	CY	$ 25	$ 17,500	Imported backfill material for ballast; assume 50% of structure backfill material provided by levee spoils. Material placed in structure excavation areas and for depositional bar. 1,400 cy needed for backfilling; 700 cy of import material needed.
26	Haul and Place Levee Spoils	700	CY	$ 5	$ 3,500	Haul from temporary stockpile and place in structure.
27	TESC/Water Management (Dry ELJ)	1	EA	$ 8,268	$ 8,268	Assume 5% of ELJ construction cost for ELJs in the dry
28	TESC/Water Management (Wet ELJ)	1	EA	$ 24,805	$ 24,805	Assume 15% of ELJ construction cost for ELJs in the wet
				Construction Subtotal per dry Structure	$ 173,632	
				Construction Subtotal per wet Structure	$ 190,169	
	Optional Ballast					
	Drilled 3-4 Man Rock per ELJ	264	TON	$ 85	$ 22,440	Assume $25/ton based on previous ELJ construction projects. Weight based on structure buoyancy requirements. Includes hauling, dumping, etc. $90 per rock for drilling based on quote from local quarry; assume 88 anchors/176 1.5-ton rocks per ELJ.

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: **White River at Countyline Concept Development and Predesign for Engineered Log Structures**
Project #: **09-04375-250**
Client: **King County Department of Natural Resources and Parks, Water and Land and Resource Division**
Date Modified: 4/1/11
Spread sheet by: BS
Checked by: IBM
Checked Date: 4/9/11

Bank Deflector ELJ without Scour Apron and Driven Piles

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.40	AC	$ 5,000	$ 2,000	Assume an area of 120ft x 120 ft per structure
2	Structure Excavation Inc. Haul	1,300	CY	$ 10	$ 13,000	Assume all spoils not suitable for backfilling; excavation, loading, hauling and disposal of spoils; 1,300 cy total excavated & not used
3	Pile Driving	20	EA	$ 1,000	$ 20,000	20 total 50' long piles/ELJ @ 35' embedment ($20/LF (for total pile length) per Pile Inc. on 1/10/11)
4	ELJ Construction	1	EA	$ 9,360	$ 9,360	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 3 days for: 2 pieces of machinery, 1 laborer and 1 supervisor; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 50' long w/rootwad	0	EA	$ 1,200	$ -	Material cost only
6	Log: 24" dia, 45' long w/rootwad	0	EA	$ 1,100	$ -	Material cost only
7	Log: 24" dia, 40' long w/rootwad	16	EA	$ 1,000	$ 16,000	Material cost only
8	Log: 24" dia, 35' long w/rootwad	0	EA	$ 900	$ -	Material cost only
9	Log: 24" dia, 30' long w/rootwad	5	EA	$ 800	$ 4,000	Material cost only
10	Log: 24" dia, 25' long w/rootwad	0	EA	$ 750	$ -	Material cost only
11	Log: 18" dia, 30' long w/rootwad	0	EA	$ 500	$ -	Material cost only (vertical racking), 16 logs shown on concept
12	Log: 24" dia, 50' long	0	EA	$ 900	$ -	Material cost only
13	Log: 24" dia, 45' long	0	EA	$ 800	$ -	Material cost only
14	Log: 24" dia, 40' long	12	EA	$ 700	$ 8,400	Material cost only
15	Log: 24" dia, 35' long	5	EA	$ 600	$ 3,000	Material cost only
16	Log: 24" dia, 30' long	7	EA	$ 500	$ 3,500	Material cost only
17	Log: 24" dia, 25' long	6	EA	$ 450	$ 2,700	Material cost only
18	Log: 24" dia, 20' long	6	EA	$ 400	$ 2,400	Material cost only
19	Log: 18" dia, 50' long	20	EA	$ 600	$ 12,000	Pile, material cost only
20	Log: 18" dia, 30' long	0	EA	$ 450	$ -	Pile, material cost only
21	Racking Logs: 4"-16" dia, 15' - 30' long	300	EA	$ 30	$ 9,000	Material cost only
22	Slash Material	300	CY	$ 30	$ 9,000	Material cost only
23	Top Soil Type B	0	CY	$ 30	$ -	Material furnishing and placement
24	Bark or Wood Chip Mulch	0	CY	$ 30	$ -	Material furnishing and placement
25	Select Borrow	500	CY	$ 25	$ 12,500	Imported backfill material for ballast; assume 50% of structure backfill material provided by levee spoils. Material placed in structure excavation areas and for depositional bar. 1,000 cy needed for backfilling; 500 cy of import material needed.
26	Haul and Place Levee Spoils	500	CY	$ 5	$ 2,500	Haul from temporary stockpile and place in structure.
27	TESC/Water Management	1	EA	$ 6,343	$ 6,343	Assume 5% of ELJ construction cost

Construction Subtotal per Structure $ 135,703

Optional Ballast

	Drilled 3-4 Man Rock per ELJ	264	TON	$ 85	$ 22,440	Assume $25/ton based on previous ELJ construction projects. Weight based on structure buoyancy requirements. Includes hauling, dumping, etc. $90 per rock for drilling based on quote from local quarry; assume 88 anchors/176 1.5-ton rocks per ELJ.

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: **White River at Countyline Concept Development and Predesign for Engineered Log Structures**
Project #: **09-04375-250**
Client: **King County Department of Natural Resources and Parks, Water and Land and Resource Division**
Date Modified: 4/1/11
Spread sheet by: BS
Checked by: IBM
Checked Date: 4/9/11

Bank Deflector ELJ with Scour Apron and Driven Piles

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.40	AC	$ 5,000	$ 2,000	Assume an area of 120ft x 120 ft per structure
2	Structure Excavation Inc. Haul (Structure)	1,300	CY	$ 10	$ 13,000	Assume twice the excavation needed as without scour apron; Assume 1/2 of spoils not suitable for backfilling; excavation, loading, hauling and disposal of spoils; 2,600 cy total excavated & 1,300 cy not used
3	Structure Excavation (Scour Apron)	1,300	CY	$ 5	$ 6,500	Assume 1/2 spoils are suitable for backfilling
3	Pile Driving	20	EA	$ 800	$ 16,000	20 total 40' long piles/ELJ @ 25' embedment; assume 10lf/pile less than without scour apron ($20/LF (for total pile length) per Pile Inc. on 1/10/11)
4	ELJ Construction	1	EA	$ 9,360	$ 9,360	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 3 days for: 2 pieces of machinery, 1 laborer and 1 supervisor; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 50' long w/rootwad	0	EA	$ 1,200	$ -	Material cost only
6	Log: 24" dia, 45' long w/rootwad	0	EA	$ 1,100	$ -	Material cost only
7	Log: 24" dia, 40' long w/rootwad	16	EA	$ 1,000	$ 16,000	Material cost only
8	Log: 24" dia, 35' long w/rootwad	0	EA	$ 900	$ -	Material cost only
9	Log: 24" dia, 30' long w/rootwad	5	EA	$ 800	$ 4,000	Material cost only
10	Log: 24" dia, 25' long w/rootwad	0	EA	$ 750	$ -	Material cost only
11	Log: 18" dia, 30' long w/rootwad	0	EA	$ 500	$ -	Material cost only (vertical racking), 16 logs shown on concept
12	Log: 24" dia, 50' long	0	EA	$ 900	$ -	Material cost only
13	Log: 24" dia, 45' long	0	EA	$ 800	$ -	Material cost only
14	Log: 24" dia, 40' long	12	EA	$ 700	$ 8,400	Material cost only
15	Log: 24" dia, 35' long	5	EA	$ 600	$ 3,000	Material cost only
16	Log: 24" dia, 30' long	7	EA	$ 500	$ 3,500	Material cost only
17	Log: 24" dia, 25' long	6	EA	$ 450	$ 2,700	Material cost only
18	Log: 24" dia, 20' long	6	EA	$ 400	$ 2,400	Material cost only
19	Log: 18" dia, 40' long	20	EA	$ 500	$ 10,000	Pile, material cost only
20	Log: 18" dia, 30' long	0	EA	$ 450	$ -	Pile, material cost only
21	Racking Logs: 4"-16" dia, 15' - 30' long	300	EA	$ 30	$ 9,000	Material cost only
22	Slash Material	300	CY	$ 30	$ 9,000	Material cost only
23	Top Soil Type B	0	CY	$ 30	$ -	Material furnishing and placement
24	Bark or Wood Chip Mulch	0	CY	$ 30	$ -	Material furnishing and placement
25	Select Borrow	500	CY	$ 25	$ 12,500	Imported backfill material for ballast; assume 50% of structure backfill material provided by levee spoils. Material placed in structure excavation areas and for depositional bar. 1,000 cy needed for backfilling; 500 cy of import material needed.
26	Haul and Place Levee Spoils	500	CY	$ 5	$ 2,500	Haul from temporary stockpile and place in structure.
27	Heavy Loose Riprap	596	TN	$ 40	$ 23,822	Scour apron: 3350 sf x 3ft deep @ 1.6TN/CY
28	TESC/Water Management	1	EA	$ 7,684	$ 7,684	Assume 5% of ELJ construction cost
				Construction Subtotal per Structure	$ 161,366	
	Optional Ballast					
	Drilled 3-4 Man Rock per ELJ	264	TON	$ 85	$ 22,440	Assume $25/ton based on previous ELJ construction projects. Weight based on structure buoyancy requirements. Includes hauling, dumping, etc. $90 per rock for drilling based on quote from local quarry; assume 88 anchors/176 1.5-ton rocks per ELJ.

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: White River at Countyline Concept Development and Predesign for Engineered Log Structures
Project #: 09-04375-250
Client: King County Department of Natural Resources and Parks, Water and Land and Resource Division
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Biorevetment with Driven Piles

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.02	AC	$ 5,000	$ 92	Assume a 20'x40' area to clear along the bank
2	Structure Excavation	370	CY	$ 4	$ 1,481	Assume spoils are suitable for backfilling after log placement; 250sf x 40ft of excavation per 40ft structure
3	Pile Driving	4	EA	$ 525	$ 2,100	4 total 35' long piles/ELJ @ 25' embeddment ($15/LF (for total pile length) per Pile Inc. on 1/10/11)
4	ELJ Construction	1	EA	$ 1,840	$ 1,840	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 1 day for: 1 piece of machinery and 1 operator; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 35' long w/rootwad	1	EA	$ 900	$ 900	Material cost only
6	Log: 24" dia, 30' long w/rootwad	1	EA	$ 800	$ 800	Material cost only
7	Log: 24" dia, 25' long w/rootwad	2	EA	$ 750	$ 1,500	Material cost only
8	Log: 24" dia, 40' long	1	EA	$ 700	$ 700	Material cost only
8	Log: 24" dia, 35' long	2	EA	$ 600	$ 1,200	Material cost only
9	Log: 24" dia, 30' long	1	EA	$ 500	$ 500	Material cost only
10	Log: 24" dia, 25' long	2	EA	$ 450	$ 900	Material cost only
11	Log: 18" dia, 35' long	0	EA	$ 400	$ -	Material cost only
12	Log: 18" dia, 35' long	4	EA	$ 500	$ 2,000	Pile, material cost only
13	Racking Logs: 4"-16" dia, 15' - 30' long	80	EA	$ 30	$ 2,400	Material cost only
14	Slash Material	80	CY	$ 30	$ 2,400	Material cost only
15	Top Soil Type B	0	CY	$ 30	$ -	Material furnishing and placement
16	Bark or Wood Chip Mulch	0	CY	$ 30	$ -	Material furnishing and placement
17	TESC/Water Management	1	EA	$ 564	$ 564	Assume 3% of ELJ construction cost

Construction subtotal per structure	$	19,378
Total no. of structures (Option 1)		90
Construction subtotal based on total no. of structures	$	1,743,994
Total LF of bank to be protected		3,743
Construction subtotal per LF	$	466

Segment 1 Length	988
Segment 2 Length	165
Segment 3 Length	2,590
Total Segment Length	3,743

Preliminary Engineering Construction Cost Estimate for Concept Design

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Biorevetment (Case & Drill to Place Piles)

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.02	AC	$ 5,000	$ 92	Assume a 20'x40' area to clear along the bank
2	Structure Excavation	370	CY	$ 4	$ 1,481	Assume spoils are suitable for backfilling after log placement; 250sf x 40ft of excavation per 40ft structure
3	Pile Placement and Pre-Drilling	4	EA	$ 2,625	$ 10,500	20 total 50' long piles/ELJ @ 35' embedment ($75/LF engr estimate for drilling and placing pile)
4	ELJ Construction	1	EA	$ 1,840	$ 1,840	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 1 day for: 1 piece of machinery and 1 operator; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 35' long w/rootwad	1	EA	$ 900	$ 900	Material cost only
6	Log: 24" dia, 30' long w/rootwad	1	EA	$ 800	$ 800	Material cost only
7	Log: 24" dia, 25' long w/rootwad	2	EA	$ 750	$ 1,500	Material cost only
8	Log: 24" dia, 40' long	1	EA	$ 700	$ 700	Material cost only
8	Log: 24" dia, 35' long	2	EA	$ 600	$ 1,200	Material cost only
9	Log: 24" dia, 30' long	1	EA	$ 500	$ 500	Material cost only
10	Log: 24" dia, 25' long	2	EA	$ 450	$ 900	Material cost only
11	Log: 18" dia, 35' long	0	EA	$ 400	$ -	Material cost only
12	Log: 18" dia, 35' long	4	EA	$ 500	$ 2,000	Pile, material cost only
13	Racking Logs: 4"-16" dia, 15' - 30' long	80	EA	$ 30	$ 2,400	Material cost only
14	Slash Material	80	CY	$ 30	$ 2,400	Material cost only
15	Top Soil Type B	0	CY	$ 30	$ -	Material furnishing and placement
16	Bark or Wood Chip Mulch	0	CY	$ 30	$ -	Material furnishing and placement
17	TESC/Water Management	1	EA	$ 816	$ 816	Assume 3% of ELJ construction cost

Construction subtotal per structure	$ 28,030
Total no. of structures (Option 1)	90
Construction subtotal based on total no. of structures	$ 2,522,674
Total LF of bank to be protected	3,743
Construction subtotal per LF	$ 674

Segment 1 Length	988
Segment 2 Length	165
Segment 3 Length	2,590
Total Segment Length	3,743

Preliminary Engineering Construction Cost Estimate for Concept Design

Project: **White River at Countyline Concept Development and Predesign for Engineered Log Structures**
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Bank Roughening with Driven Piles

Item No.	Item Description	Qty	Unit	Unit Cost	Total Cost	Notes
1	Clearing	0.02	AC	$ 5,000	$ 92	Assume a 20'x40' area to clear along the bank
2	Structure Excavation	111	CY	$ 4	$ 444	Assume spoils are suitable for backfilling after log placement and logs are trenched in at 250sf x 4ft per log per 40ft structure
3	Pile Driving	2	EA	$ 375	$ 750	2 total 25' long piles/ELJ @ 15' embeddment each ($15/LF (for total pile length) per Pile Inc. on 1/10/11)
4	ELJ Construction	1	EA	$ 920	$ 920	Per ELJ, just wood assembly, not including excavation, backfilling or planting: assume 0.5 day for: 1 piece of machinery and 1 operator; assume machine cost of $120/hr ,and supervisor and laborer cost of $60/hr and $40/hr, $400/day fuel
5	Log: 24" dia, 30' long w/rootwad	2	EA	$ 800	$ 1,600	Material cost only
6	Log: 24" dia, 25' long w/rootwad	2	EA	$ 750	$ 1,500	Material cost only
7	Log: 24" dia, 30' long	2	EA	$ 500	$ 1,000	Material cost only
8	Log: 18" dia, 25' long	2	EA	$ 400	$ 800	Pile, material cost only
9	Racking Logs: 4"-16" dia, 15' - 30' long	0	EA	$ 30	$ -	Material cost only
10	Slash Material	0	CY	$ 30	$ -	Material cost only
11	Top Soil Type B	0	CY	$ 30	$ -	Material furnishing and placement
12	Bark or Wood Chip Mulch	0	CY	$ 30	$ -	Material furnishing and placement
13	TESC/Water Management	1	EA	$ 213	$ 213	Assume 3% of ELJ construction cost

Construction Subtotal per Structure	$ 7,319
Total no. of structures (Option 1)	37
Construction subtotal based on total no. of structures	$ 270,820
Total LF of bank to be protected	1,433
Construction subtotal per LF	$ 189

	Option 1
Segment 1 Length	655
Segment 2 Length	778
Total Segment Length	1,433

APPENDIX C

Preliminary Construction Schedules for Year 1 and Year 2

White River at Countyline Concept Development and Pre-Design for Engineered Log Structures

Year 1 Preliminary Construction Schedule

Major Work Items:

Engineered biorevetment and bank roughening structures

Setback levee

Buffer Plantings

Task No.	Task Name		Start	Finish
1	Contract Set Complete		2/1/12	2/1/12
	Contracting			
2		Advertise for Bid	3/1/12	3/22/12
3		Bids Due	3/22/12	3/22/12
4		Contractor Selection	3/22/12	4/12/12
5		Award Bid	4/12/12	4/12/12
6		Notice to Proceed	4/19/12	4/19/12
	Construction			
7		Mobilize	5/1/12	5/8/12
8		Erosion Control Work	5/8/12	10/1/12
9		Clearing	5/8/12	5/29/12
10		Pile and Structure Installation	6/1/12	10/1/12
11		Levee Construction	6/1/12	10/1/12
12		Plantings	10/1/12	11/1/12
	Demobilization			
13		Remove Erosion Control	10/1/12	10/8/12
14		Site Cleanup	10/1/12	10/8/12
15		Remove Equipment	10/8/12	10/15/12
16		Closeout	11/1/12	12/1/12

White River at Countyline Concept Development and Pre-Design for Engineered Log Structures

Year 2 Preliminary Construction Schedule

Major Work Items:
Removal of existing levee prism and bank armoring
Culvert removal and outlet channel modifications
Apex ELJ Construction

Task No.	Task Name		Start	Finish
1	Contract Set Complete		2/1/12	2/1/12
	Contracting			
2		Advertise for Bid	3/1/13	3/22/13
3		Bids Due	3/22/13	3/22/13
4		Contractor Selection	3/22/13	4/12/13
5		Award Bid	4/12/13	4/12/13
6		Notice to Proceed	4/19/13	4/19/13
	Construction			
7		Mobilize	7/1/13	7/8/13
8		Erosion Control Work	7/8/13	9/30/13
9		Clearing for ELJs and Earthwork	7/8/13	7/22/13
10		Pile and Structure Installation	7/22/13	9/30/13
11		Levee Removal	7/8/13	9/30/13
12		Culvert Removal	8/1/13	8/8/13
13		Outlet Channel Modifications	8/8/13	9/1/13
	Demobilization			
14		Remove Erosion Control	10/1/12	10/8/12
15		Site Cleanup	10/1/12	10/8/12
16		Remove Equipment	10/8/12	10/15/12
17		Closeout	11/1/12	12/1/12