YAKIMA RIVER BASIN
ECOSYSTEM RESTORATION
YAKIMA COUNTY, WASHINGTON

APPENDIX A

ENGINEERING APPENDIX

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Integrated Feasibility Report and Environmental Assessment

US Army Corps of Engineers®
Seattle District

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1 Introduction

The integrated Feasibility Report and Environmental Impact Statement presents the results of a U.S. Army Corps of Engineers (Corps) Ecosystem Restoration feasibility study undertaken to identify and evaluate alternatives for restoring degraded structures, functions, and processes in the Yakima River Basin, Washington. The Corps is undertaking this action in partnership with Yakima County.

Engineering calculations and studies were undertaken in order to support the development and evaluation of alternatives, to inform cost estimates including schedules and evaluation of risk, to provide preliminary designs for HTRW, cultural resources, and real-estate work, and to document the intended project performance. This appendix documents the results of the engineering work in accordance with ER 1110-2-1150.

1.1 General Project Background

The Yakima River Basin is a tributary to the Columbia River located just east of the central-cascade Mountain crest in Washington State. The Yakima River is a vital resource for Tribes, irrigators, recreationalists, local communities and endemic fish, wildlife and flora. Environmental degradation can be seen throughout the Yakima River Basin including a loss of natural ecosystem structures, functions, and processes necessary to support critical fish and wildlife habitat. The primary factors degrading habitat are river confinement and floodplain disconnection (roads, levees), hydrologic alterations (dams, irrigation withdrawals, flow regime changes, temperature changes), river and floodplain gravel mining (direct habitat loss, channel instability) (YRFMIST, 2004). The Corps, County and others have completed several flood damage reduction projects in the 1135 project vicinity that have significantly contributed to the historical degradation (see 1949 Levee and Channel Improvement Project). Two anadromous fish species (Columbia River bull trout and Middle Columbia River Steelhead) that use the river as their primary habitat are listed under the Endangered Species Act (ESA) and have experienced population declines. The impaired ecosystem has adversely affected riverine and wetland habitats that are critical to these and other listed species. Yakima County and its basin-wide partners, in an effort to address issues associated with flooding and habitat loss, developed the Gap to Gap Floodplain Restoration and Enhancement Plan which encompasses restoration efforts in reach that has been determined to have some of the best prospects for restoration within the basin (Stanford et al, 2002). The 1135 Project is a significant and critical piece of basin-wide restoration efforts.

1.2 Site Selection and Project Development

The four mile 1135 project reach is located between river mile (RM) 111 and RM 115 (approximate) within what is locally referred to as the Gap to Gap reach, a 10 mile stretch of the Yakima River between the bedrock constrictions at Selah Gap (RM 119) and Union Gap (RM 109).

As part of the planning process for the study, the Project Delivery Team (PDT), in coordination with interested stakeholders and the public, developed a series of measures to be considered as potential elements of the project solution. The primary goal of the project is, within the Gap top Gap reach, to restore the hydraulic connection between the floodplain and the river and associated ecosystem processes, to address habitat degradation for ESA-listed and other fish and wildlife species. To guide alternatives formulation, the study team identified the planning objectives of the study. Based on the problems identified in the study area, planning objectives include the following:

- Restore connectivity between the Yakima River and its historic floodplain; this allows ecosystem processes that form and sustain fish habitat to operate normally, including overbank flooding, sediment exchange, channel meander and formation, organic matter exchange, and large wood recruitment, for the 50-year period of analysis.
- Improve riparian habitat within the Gap to Gap Reach for mammals and birds through increased access to water sources in the floodplain, and a restored hydraulic regime that in turn supports native vegetation, for the 50-year period of analysis.
- Reconnect historic channels to restore lost fish habitat, for the 50-year period of analysis.

A recommended restoration plan was selected that includes levee realignment, spur dike removal, floodplain topographic restoration, side channel restoration, hydrologic enhancement of a disconnected floodplain channel, replacement of barrier culverts, and wetland reconnection. This Engineering Appendix outlines key design elements for the features included in the tentatively selected plan.

The tentatively selected plan includes the bolded items in the list below. Tentatively selected plan features are illustrated in Figure 1-1 and Figure 1-2 and Annex A; Sheets C-003 and C-004.

Measures Used for Final Step in Formulating Tentatively Selected Plan

The following measures remained after initial screening by the PDT and were used for plan formulation. All will be analyzed for NEPA purposes, and all will be presented in summary (10%) fashion in the DPR/EA. Only the measures in the Tentatively Selected Plan (in bold in the list below) will be developed to a feasibility level design and included in the Civil Design appendix.

Measure 1.0 **DID#1 Floodplain Process Restoration** (Remove DID#1 Levee, rebuild landward of historic floodplain area.)

Measure 1.1 **Floodplain Topographic Restoration** (Excavate material to encourage establishment of historic side channels; place material in old gravel pits. Ameliorates risk associated with potential capture of pits by main channel and associated headcutting; therefore, for plan formulation purposes, included with Measure 1.)

Measure 1.2 **KOA Floodplain Restoration** (Remove old levee and cross dike material no longer needed once DID#1 levee is realigned landward. Restores floodplain processes; provides material for new levee.)

Measure 2.0 **Sportsman Island Channel Restoration** (Reestablishes lost side channel habitat; ameliorates risk associated with potential capture of pits by main channel and associated headcutting.)

Measure 2.1 **Sportsman Upstream Groin Removal** (Restores natural flow pattern towards head of newly reestablished Sportsman channels.)

Measure 2.2 **Lake Buchanan Spurs** (Directs flow away from Buchanan Lake, old gravel pits just landward of right bank levee, and towards head of newly reestablished Sportsman channels.)

Measure 3.0 Nob Hill Floodplain Restoration (Realign levee and excavate pilot channels to restore floodplain processes.)

Measure 4.0 **Blue Slough Automated Headgate** (Allows reintroduction of normative flows to Blue Slough to support listed fish species.)

Measure 4.1 Blue Slough Culverts (Only needed if Headgate is installed; removes barrier culverts, allows for fish passage at higher flows, increases operating flow range for headgate)

Measure 4.2 Lower Blue Slough Connection (Improves flows in lower Blue Slough by reestablishing historic connections between main channel and lower slough.)

Measure 5.0 WSDOT Pilot Channels (Excavate material to encourage establishment of historic side channels; place material in old gravel pits. Creates conditions for side channels to naturally reestablish, increasing habitat for listed fish species.)

Measure 6.0 Greenway Trail Armor Removal (Creates conditions for side channels to naturally reestablish, increasing habitat for listed fish species.)

Measure 7.0 **Spring Creek Reconnection** (Removes fill form mouth of Spring Creek, a groundwater fed stream, allowing access to the stream from the river by listed fish species; creek would provide cold water, off-channel refuge.)

Notes: *1. Bolded items are in the current version of Tentatively Selected Plan.*
2. Measures 1.1 and 1.2 are needed in order to implement Measure 1, and so are treated as part of measure 1.0 when estimating costs and benefits for plan formulation purposes. Likewise 2.1 & 2.1 are treated as port of Measure 2.0.

These features included in the Tentatively Selected Plan are described in more detail in the following sections.

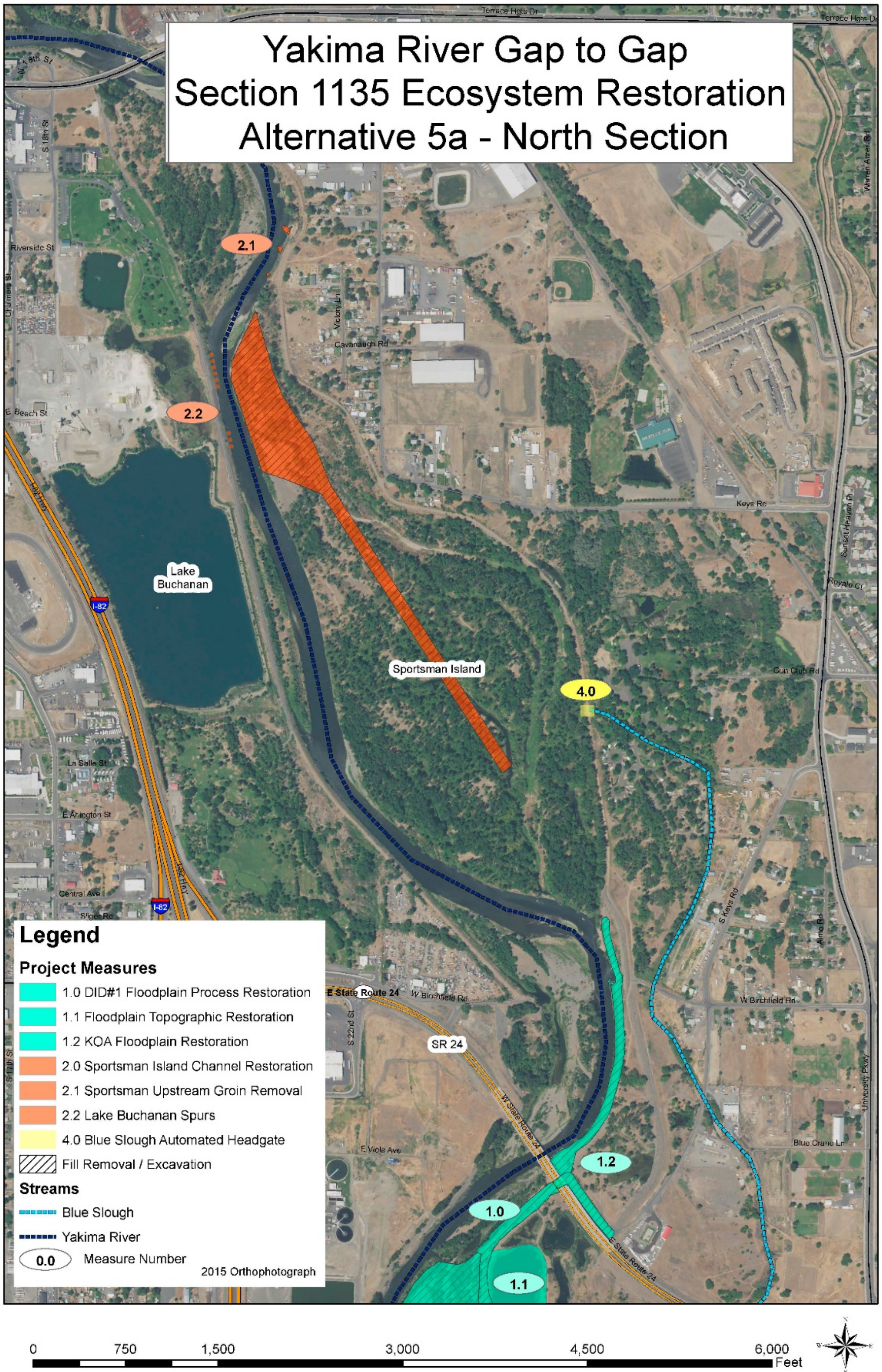

Figure 1-1. Tentatively Selected Plan– North Section

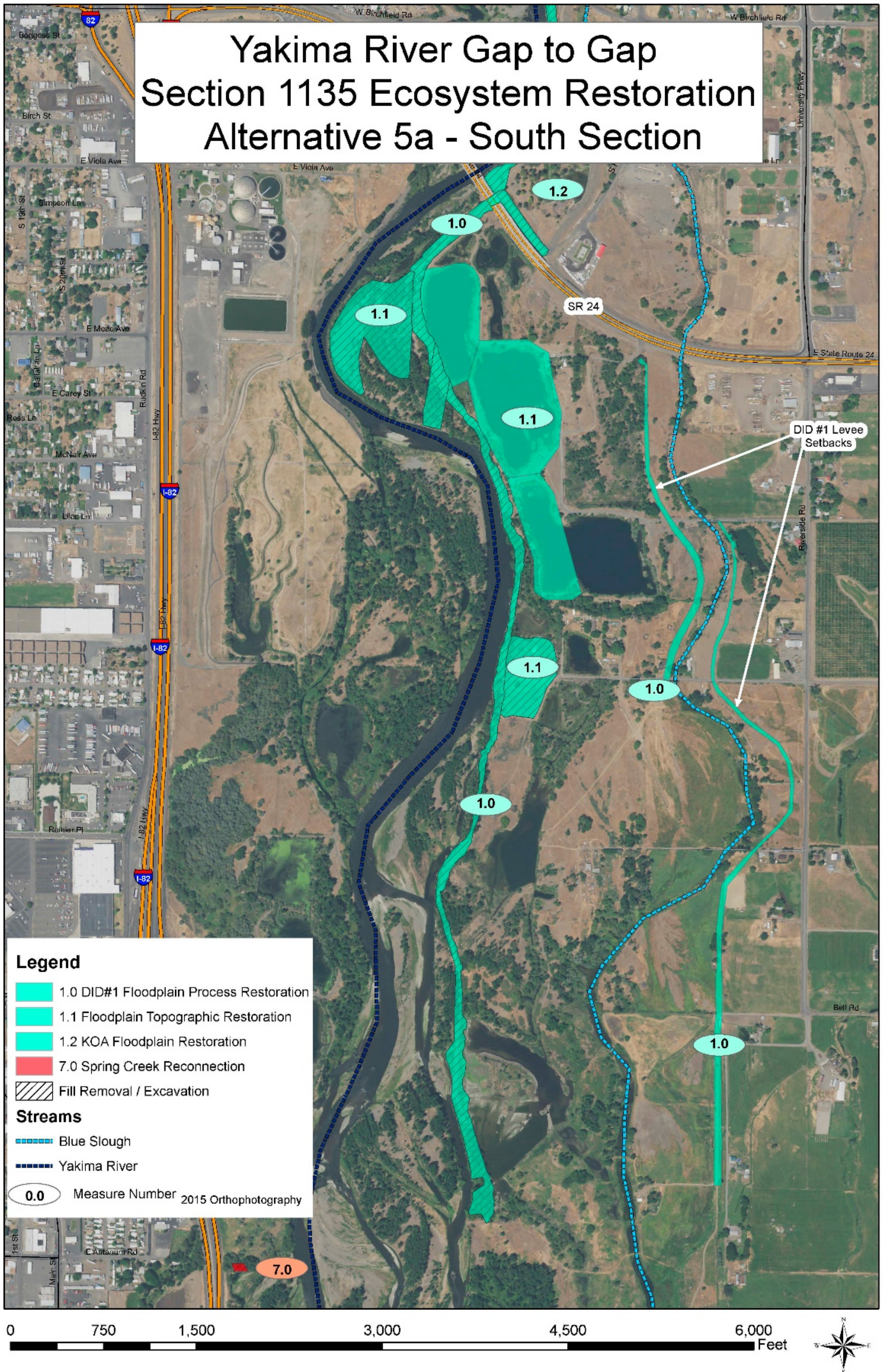

Figure 1-2. Tentatively Selected Plan– South Section

1.2.1 MEASURE 1.0 - DID#1 FLOODPLAIN PROCESS RESTORATION

(Remove existing DID#1 Levee, rebuild landward of historic floodplain area.)

The Measure 1.0 project features consist of removing the DID #1 levee (8,500 feet) and reconstructing the DID #1 levee (8,700 feet) eastward to restore hydrology and natural processes in the historic left bank floodplain from SR-24 approximately one mile to the south, while maintaining an equivalent level of protection to the area landward of the new levee alignment. This measure along with Measures 1.1 and 1.2 begins at the downstream end of Yakima Sportsman State Park, with a potential benefit area extending about 2 miles along the river. Approximately 1,900 acres of riparian and floodplain habitat are located within this reach and will benefit from restoration actions. 275 acres of floodplain will be reconnected to the river from this measure alone, which represents the single most beneficial action proposed under the TSP.

This feature primarily addresses the study objective to restore connectivity between the Yakima River and its historic floodplain and to a lesser extent the objectives to improve riparian habitat and reconnect historic channels. Mainstem flows would be diverted into the restored area as the river degraded the remnant (lowered) portion of the DID#1 levee, modifying existing swales and forming new channels behind the old levee. The dynamics of the river will be partly controlled by floodplain topographic restoration efforts (Measure 1.1) described below.

This measure includes replacement of existing 36-inch culverts under the new setback levee where it crosses over Blue Slough at un-named road and Lester Lane since they are at the end of their service life and would not last the duration of the project planning horizon.

1.2.2 MEASURE 1.1 - FLOODPLAIN TOPOGRAPHIC RESTORATION

(Excavate material to encourage establishment of historic side channels; place material in old gravel pits. Ameliorates risk associated with potential capture of pits by main channel and associated headcutting; therefore, for plan formulation purposes, included with Measure 1.)

Floodplain topographic modification downstream of the SR-24 Bridge on left bank of the Yakima River is intended to ameliorate risk associated with potential capture of the Newland gravel pits/ponds by the main channel and consists of three project actions:

1) Remove aggraded point bar material that has resulted from the fixed meander (formerly the location of the WWTP outfall) downstream of the SR 24 bridge. This action will allow re-initiation of normal channel migration processes, also distribute energy more evenly across the channel, and reduce the potential for immediate avulsion into the pits due to the large material contained in the bar (just downstream of the narrow SR24 bridge opening.

2) Place all excavated and unsuitable material into the three pits strategically to reduce the risk and effect of floodplain pit capture that could –result in as much as 5.5 of degradation under a worst-case avulsion scenario. The effects of the down-cutting could extend upstream as far as 14,000 feet over 25 years based on morphodynamic modeling(Annex D-2); and 3) remove mining tailings from the floodplain that are artifacts of floodplain mining operations to allow the river more conveyance and wetted area within the new setback limits

and deposit that material in the former pits. These actions increase active floodplain area, lower flood elevations, and increase habitat within the reach, while ameliorating risk associated with potential pit capture by the main channel.

The area that will be restored/enhanced consists of a large (20 acre) vegetated point bar riverward of the DID 1 levee, and the extensive (now abandoned) 86 acre gravel mining complex known as the Newland Pits, which consist of 3 large ponds that range from 10-60 feet in depth, and 14 acres of upland disposal piles will be removed from the floodplain and placed in the pits.

Once the floodplain is regraded it is expected that the river would go out of bank at less than a 1-year frequency and spread out across the active limits and begin sculpting side channels along the left margin of the DID#1 levee. Pilot channels would also be excavated to focus the flow energy into areas most likely to remain stable while the floodplain adjusts to levee removal.

Since the pits/ponds cannot be completely filled to their original grade given the limited scope and budget of the 1135 project, strategically placed causeways will be built across the ponds up to the elevation of the undisturbed floodplain to dissipate and redirect flow energy. In addition, all large trees and woody vegetation cleared as part of the project will be used as backfill within the ponds. The woody material will increase roughness and channel stability within the partially filled pits and enhance habitat. Disturbed areas will be hydro-seeded. Riparian revegetation will consist of natural recruitment from adjacent stands and seed sources.

1.2.3 Measure 1.2 - KOA Floodplain Restoration

(Remove old levee and cross dike material no longer needed once DID#1 levee is realigned landward. Restores floodplain processes; provides embankment material for new levee.)

The PDT proposes to remove all 2,000 feet of a remnant portion of levee isolating the river from a viable 16 acre off channel area upstream of SR 24 between the highway and Sportsman Island on the left bank and removal of 750 lineal feet spur dike isolating this area from the DID #1 setback area downstream. At this location, 3,000 feet of the Federal levee was set back in 2012; however, 2,000 feet of the old levee remains, degrading riparian process for 16 acres. Removal of the remnant levee is required for full restoration. Similarly the spur dike at SR 24 (underneath the highway) needs to be removed to allow water to flow freely from the KOA site into the DID #1 restored area. The spur dike fill and KOA levee fill will be reincorporated into the new DID #1 setback levee (or placed in the Newland Pits if unsuitable to restore floodplain topography). This measure directly restores riparian process and function to 16 acres and is required to achieve the full benefits of Measures 1.0 and 1.1. Note that the federal levee and highway have been designed to accommodate the increased erosion and scour risk associated with this restoration effort, however once the spur dike is removed, an 1060 feet long, 80 feet wide, 5-foot thick buried grade control sill will be installed to help mitigate the risks of floodplain overflows avulsing into the Newland Pits, since this could lead to widespread channel instability and habitat degradation. Disturbed areas will be hydro-seeded. Riparian revegetation will consist of natural recruitment from adjacent stands and seed sources.

1.2.4 Measure 2.0 - Sportsman Island Channel Restoration

(Reestablishes lost side channel habitat; ameliorates risk associated with potential capture of pits by main channel and associated headcutting.)

In the 1940s the Corps and Yakima County dredged a new low flow river channel, built new levees and cleared the active channel of woody material between the Terrace Heights Bridge and the SR 24 Bridge. This action caused the channel to shift away from its old location (where the side channel is proposed) to the new channel and become entrained upon the right bank Federal levee. Recent flood repairs upstream have reinforced this flow pattern. Previous to the channel improvement projects the river was anabranched into 2 or more large threads in this reach at low flow. In the last several decades the river has occupied a single deep narrow channel at low flow, the side channel size has reduced, and the river has developed 3 “fixed” meanders. The “fixed meanders” have caused the associated point bars to aggrade with generally finer sands and gravels, which has buried most of the former side channel habitat on Sportsman Island. The main river channel has narrowed and incised, greatly simplifying available habitat and limiting spawning opportunities. These altered riverine processes are expected to continue into the future without this project measure.

Construction of this side channel directly restores 19 acres of side channel habitat, reconnects the upstream and downstream ends of the island allowing for additional conveyance to mitigate risk associated with potential downstream pit capture and headcutting, creates a more even distribution of stream power across this leveed reach (improving spawning conditions) , and reconnects various side channels along the alignment. The as-built channel will be inundated at less than the annual flow which will relieve pressure on the adjacent right bank levee by redistributing flow away from the levee and reducing flood stages.

This measure, located at the upper end of the project footprint, would include excavation of two relatively straight side channels requiring removal of approximately 81,000 cubic yards of deposited material and woody debris. The primary channel is 3884 LF long, the secondary channel is 1382 LF long. Excavated material from this channel would be contributed towards Measure 1.2. A large channel mouth would be constructed at the head of the island that would then funnel into a 100-foot wide channel that would tie in to an existing channel towards the downstream end of the island. A 3-foot deep 30-foot wide low flow (pilot) channel would be constructed along the bottom of both side channels. These channels are expected to enlarge and widen rapidly due to the erodibility of the bed materials and channel alignment.

No LWD structures, pool riffle sequences, or bioengineering of streambanks will be included as high flows and natural processes are expected to rapidly sculpt the banks and bed of the side channel, adding complexity (sinuosity, large wood, pool-riffle sequences, bars, side channels) that will be initially absent from the as-built channel. Erosion of the banks and bed of the side channel provide a valuable source of gravel to the river in the short run. Full capture of the side channels by the river would not be viewed as a negative since the river would still have access to existing main channel at high flows and if downstream headcutting was initiated, this would reduce pressure on the right bank levee near Buchanan lake. The constructed side channels would convey surface water to a smaller natural side channel that runs along the toe of the left bank federal levee that feeds water into Blue Slough via an irrigation diversion culvert. Occasional removal of blockages or strategic placement of large wood to ensure adequate water flow to the Blue Slough water supply side channel may be required on occasion.

1.2.5 MEASURE 2.1 - SPORTSMAN UPSTREAM GROIN REMOVAL

(Restores natural flow pattern towards head of newly reestablished Sportsman channels.)

A series of groins or bendway weirs were placed by the COE following the 1996 flood to prevent erosion along the federal project left bank levee. These groins have been effective at preventing erosion along the levee, but have been equally effective at shifting main flows towards the downstream right bank levee near Buchanan lake, depositing material at the top end of the Sportsman Island, and preventing flow in side channels throughout the island. This measure would remove the three most downstream groins to restore the natural flow pattern of the river and encourage access to the island and its side channel habitat. Groin removal will also allow more water to be funneled into the Sportsman Island channel – measure 2.1. A total of 375 cubic yards or riprap will be removed. This material will either be reincorporated into Measure 2.2 or Measure 1.1 depending on the size and condition of the rock. Design phase investigations will determine if additional slope work will be needed to ensure that the left bank integrity is not significantly altered.

1.2.6 MEASURE 2.2 - LAKE BUCHANAN SPURS

(Directs flow away from Buchanan Lake, old gravel pits just landward of right bank levee, and towards head of newly reestablished Sportsman channels.)

A series of low spurs along the existing right bank federal levee adjacent to Buchanan Lake are proposed to increase local water surface elevations directing flow into the new channel excavated through the island (measure 2.0) and reduce velocities and stream power in the main channel at the base of the right bank federal project levee which separates the main stem from Buchanan Lake. The spurs will be located at two sites along the levee, spaced 120 feet apart, and would be constructed of large riprap. A total of 900 cubic yards of riprap will be installed.

1.2.7 MEASURE 4.0 - Blue Slough AUTOMATED HEADGATE

(Allows reintroduction of normative flows to Blue Slough to support listed fish species.)

An irrigation culvert diverts water to Blue Slough (relic channel) from the Yakima River though the left bank Federal levee within Sportsman Island halfway at the apex of the old meander that has been filled in by sediment and vegetation growth. The irrigation culvert is controlled by a manually operated slide gate accessed by a wooden plank way from the levee crest. The slide gate controls are elevated to allow operation during high flows. A concrete headwall is located at the entrance and a riprap energy dissipater is located at the outlet. The condition of the culvert is unknown, however the slide gate has been locked shut for several years. It is presumed that the culvert is at the end of its useful life and will need replacement. Restoration of flow to Blue Slough would restore surface water hydrology to 9,200 lineal feet (approximately 10 acres) of relic channel that is only wet seasonally when ground water elevations are high.

This project proposes to replace the existing culvert in-kind and upgrade the slide gate to an automatic flow controlled gate (Rubicon Slip-Meter or equivalent) to ensure the flows do no exceed thresholds that would result in downstream flooding. Upgrades to the culvert entrance include removal of accumulated sediment and debris, installation of a trash rack, and installation of flow control weirs to ensure adequate head at low flows is available. At the outlet the existing energy dissipater would be replaced with a large pre-formed scour pool lined with riprap or large river cobbles to dissipate energy at the culvert outlet, and provide resting areas to allow adult salmonids access to the culvert. A flow control weir would be added at the outlet of the scour pool to partially backwater the culvert outlet to facilitate upstream passage at low flows by juveniles.

The automated headgate can be programmed to supply a specific flow or a range of flows depending on the upstream stage. The gate measures flow ultrasonically and adjusts accordingly. The preferred gate is solar powered and can be operated manually if needed.

Under current conditions the gate can supply up to 120 cfs when the river rises to the top of the levee. This discharge is expected to cause downstream flooding due to several undersized culverts that cross Blue Slough.

1.2.8 Measure 7.0 - Spring Creek Reconnection

(Removes fill form mouth of Spring Creek, a groundwater fed stream, allowing access to the stream from the river by listed fish species; creek would provide cold water, off-channel refuge.)

Spring Creek is a natural side channel of the Yakima River. During construction of Interstate 82 in the 1970's, a gravel pit was constructed in the floodplain, Spring Creek now flows across the compacted former haul road to this pit, creating an approximate 3 foot waterfall into the former pit. This has is disconnected this valuable spawning and rearing habitat from the Yakima River, preventing fish access to the fresh, cold water of spring creek. Spring Creek reconnection involves the removal of this compacted road bed from the mouth of Spring Creek, a groundwater fed stream, providing access to rare cold water off-channel habitat for listed species.

1.3 Design Features

Table 1-1 summarizes the project features developed in the conceptual design of the Tentatively Selected Plan.

Table 1-1. Design Features

Project Feature	Description of Project Feature	Approx. Quantity
DID#1 levee removal	Remove DID#1 Levee, rebuild landward of historic floodplain area. Replace existing culverts where levees cross Blue Slough. Add closure gate to culvert at Lester Lane crossing.	94,064 cubic yards (CY) levee removal; 12,750 CY fill new west levee segment, 18,080 CY fill new east levee segment

Floodplain topographic restoration	Excavate material to encourage establishment of historic side channels; place material in old gravel pits. Ameliorates risk associated with potential capture of pits by main channel and associated headcutting; therefore, for plan formulation purposes, included with Measure 1.	54,305 CY floodplain excavation (cut) 242,434 CY causeways (fill)
KOA Floodplain restoration	Remove old levee and cross dike material no longer needed once DID#1 levee is realigned landward. Restores floodplain processes; provides material for new levee.	31,000 CY KOA levee removal (cut) 12,300 CY SR 24 cross dike removal (cut)
Sportsman Island Channel Restoration	Reestablishes lost side channel habitat; ameliorates risk associated with potential capture of pits by main channel and associated headcutting.	81,000 (cut)
Sportsman Upstream Groin Removal	Restores natural flow pattern towards head of newly reestablished Sportsman channels.	3,374 CY (cut)
Lake Buchanan Spurs	Directs flow away from Buchanan Lake, old gravel pits just landward of right bank levee, and towards head of newly reestablished Sportsman channels.	900 CY (fill)
Blue Slough Automated Headgate	Allows reintroduction of normative flows to Blue Slough to support listed fish species.	1 automated headgate, trash rack, 36-in. replacement culvert
Spring Creek Reconnection	Removes fill from mouth of Spring Creek, a groundwater fed stream, allowing access to the stream from the river by listed fish species; creek would provide cold water, off-channel refuge.	590 CY floodplain grading (cut)

1.4 HYDROLOGY

Flows through the project area tend to be on the order of 1,500 cfs during the lowest summer to fall periods (October) and roughly 15,000 cfs during a “bankfull” (2-year) recurrence event. Average annual flows are roughly 3,500 cfs at Union Gap, which is less than the combined average annual flow at the upstream gages due to agricultural diversions (Roza canal, etc). Yakima River flows primarily originate from snowmelt and rainfall on the eastern slope of the Cascade Mountains in the fall and winter, and are augmented by reservoir releases in dry months. Average flows are highest during the months of April, May, and June as a result of spring snowmelt runoff (Figure 1-3), however, peak flood flows typically occur during the winter. Winter flood flows are associated with warm temperatures and rainfall on melting snow pack, and typically follow precipitation periods that have saturated soils, producing greater rates of runoff (Yakima County, 2007).

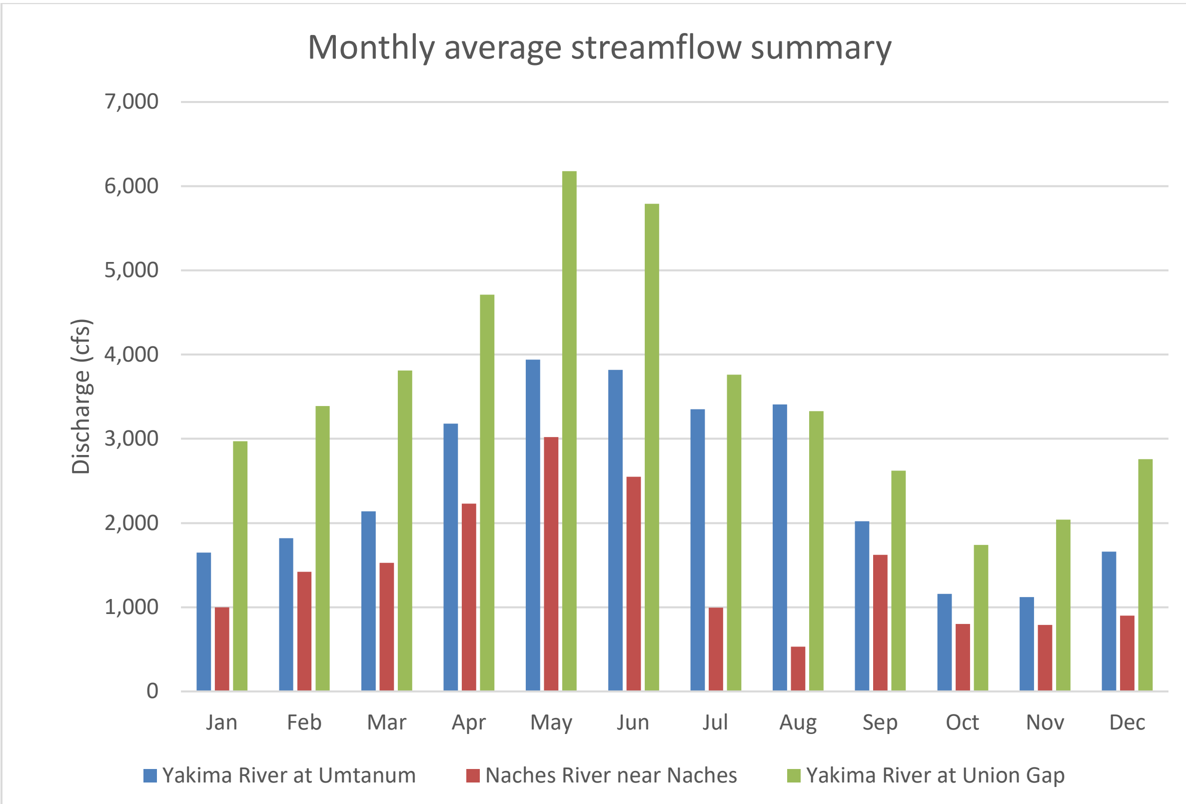

Figure 1-3. Monthly average streamflow summary, Gap to Gap reach

1.5 HYDRAULIC DESIGN

The principle restoration strategy (levee removal and setback) is informed by several previous studies of Yakima Basin limiting factors (Eitemiller et al, 2002; BPA 2001; Clark 2003; Stanford et al, 2002; Freudenthal et al 2005) and has a sound scientific basis (Ward and Stanford, 1995; Ward et al, 1999; National research Council, 2002, Beechie et al, 2010). The restoration strategy removes engineered hard points and obstructions to flow and allows the river to access previous floodplain channels and riparian areas. The river is then allowed to perform geomorphic work to modify the floodplain topography through erosion, deposition, large wood recruitment, etc. Due to the topographic gradient between the river and restored area, the river is expected to quickly reoccupy disconnected channels and swales within the restored area, creating a large increase in connected aquatic habitat in a short time period. This strategy is called process-based restoration and is a becoming a preferred approach in the restoration community of practice due to its direct linkage with root causes of ecosystem impairment, and greater sustainability and cost effectiveness (Beechie et al, 2010). Restoration success for this project is dependent on the rivers ability to access and modify the floodplain, not on the frequency or size of specific channel forms. Given current channel conditions the chances for success appear high.

The hydrology, hydraulics and geomorphology of the Gap to Gap of the Yakima River have been extensively studied by the Corps and others (NHC 2015, USBR 2010, Yakima County 2007). Numerical modeling includes 1-dimensional steady, unsteady and morphodynamic analysis with SRH-1D (USBR, 2010, NHC 2015) and with HEC-RAS (USBR 2010, USACE, this study). 2-dimensional numerical modeling has been conducted with SRH-2D by NHC (2015) and with HEC-RAS 5.0 as part of this study. Studies have focused on identifying problems and understanding the implications of restoration on channel forming processes, habitat and flooding.

For the 1135 study the Corps updated an existing 1-dimensional HEC-RAS model used previously to assist with PL-84 99 levee repairs in the vicinity of the project was updated to RAS 5.0. All cross sections in the project vicinity were recut from the most recent LiDAR. Channel n values were adjusted based on current land cover, and overbank portions of the model were converted to 2-dimensional storage areas.

The updated model was then run with a range of steady discharges to understand with and without project hydraulic conditions. The model results indicate that the existing DID #1 levee crest is an average of 2 feet of above the 100-year flood (1% Annual exceedance probability) water surface elevation but due to a low spot is vulnerable to overtopping near SR 24. Constructing the 1135 project will significantly reduce flood elevations by allowing the river to access large areas of the floodplain over the entire flow regime. Flood elevation reductions extend upstream as far as the Terrace Heights Bridge. The model was also used to estimate floodplain elevations and set the levee crest elevations. The models are not rigorously calibrated and rely upon channel survey data collected in 2005. Given the dynamics of the river it is recommended that updated channel bathymetry and LiDAR be collected in the Gap to Gap reach to support the design effort.

The Sportsman's Channel area has two purposes – to help spread out the expected down cutting caused by lowering flood water surface elevations near SR 24 (caused by DID 1 levee removal and setback), and to restore side channel habitat degraded by historical channel improvement and levee works. The constructed side channel will divert up to half the river flow after the river begins to erode the channel banks and bed. Due to the large amount of trees along the banks and straight channel alignment, bank erosion is expected to occur which will recruit large wood to the channel, initiating erosion, deposition and formation of meanders, logjams, and pool-riffle sequences.

The Blue Slough automated headgate is intended to provide a near-permanent surface water supply (and thus aquatic habitat) to a large, isolated relic channel that currently flows ephemerally when groundwater elevations are above the bottom of the channel. The existing diversion culvert will be replaced in kind, and the inlet and outlet works upgraded to provide reliable performance and flow control. The flow rate in the channel will be higher than at present but much lower than the flows that formed the channel prior to being disconnected from the river by levee construction, which indicates that the Slough will not be dynamic once surface water hydrology is restored. Due to the presence of adjacent development (residential, commercial, industrial, agricultural) and infrastructure flows will need to be carefully managed to prevent nuisance flooding.

Minimal channel work is planned, as the channel has not been highly modified. Riparian vegetation will recruit and establish once hydrology is restored. Replacement of undersized driveway culverts downstream of the diversion structure (not part of this project) would allow for more than doubling of the discharge that can be diverted without causing nuisance flooding and will improve fish passage. Once the project is complete, it sets the stage for future enhancement efforts along the Slough (revegetation, addition of complexity, culvert upgrades) by others.

Generally channels constructed as part of the 1135 project are intended to set the stage for restoration but be allowed to deform over time unless otherwise shown as armored (alluvial channel design method, see WDFW SHRG Chapter 5, NRCS NEH 654 Chapter 9). Armoring is used in isolated areas as a risk mitigation measure to maintain water surface elevations where down-cutting or erosion could threaten adjacent infrastructure (SR 24 Bridge, Federal Levee next to Buchanan Lake). Please see the next sections for hydraulic design summaries by measure. See the H&H annex for detailed discussion of previous studies, hydraulic analysis methodology and results, and additional justification of the hydraulic designs.

1.6 Civil Design

This section discusses the key elements of the civil design and determines the gross volumes associated with each feature included in the Feasibility report. The discussion includes the major components, construction, access and staging considerations.

1.6.1 Staging and Access

Based on evaluation of the site topography and predominant land use, approximately 3.7 acres of staging areas would be utilized. Staging would be anywhere within the project construction limits and the staging areas shown on the plans. Access will be at the locations shown on the plans.

1.6.2 General Construction Methodology

Specific timing restrictions will be required for in-water work to protect fish and wildlife however these are unlikely to be a significant factor due to the fact that much of the site work is out of the water. Work restrictions may be required under site-specific permit requirements. Because of the very dry conditions in the Yakima valley, construction may be performed year round, however the time of year work is performed has a strong influence on surface and groundwater levels. Summer and fall irrigation releases result in elevated water levels, as do fall and winter floods however base flow elevations in the winter are significantly lower than they are in the summer. Measures that may include in-water work include the Sportsman Island side channel and spur dike replacements and Newland Pond causeway construction. It is likely that the Blue Slough headgate replacement will need to be constructed in late fall just prior to the start of flood season when water levels are typically low. Setback levee construction can occur at any time during the year provided the DID#1 levee and SR 24 spur dike remains in place until the levee work is complete. Levee removal should only occur during non-flood periods. Careful planning will be necessary to ensure work can be completed when river conditions are favorable since the lowest flows are typically experienced in October and November when flooding from the west side of the Cascades can spill over into the Yakima Basin. Pilot channel construction can occur at any time provided other requisite measures are complete. Any excavated materials not re-used in levee construction will be taken to the Newland Ponds for disposal. The stormwater pollution prevention plan and stormwater best management practices will be determined during Pre-construction Engineering and Design (PED). Generally the following are included:

- Existing roadways or travel paths will be used whenever possible and stream crossings minimized.
- The number of temporary access roads will be minimized and roads will be designed to avoid adverse effects like creating excessive erosion and avoiding crossing slopes greater than 30%.
- All temporary access-ways not needed for future access will be removed (including gravel surfaces) and re-planted by the end of the in-water work period and before project completion.
- As much as practicable, any large wood, native vegetation, weed-free topsoil, and native channel material displaced by construction will be stockpiled for use during site restoration.
- When construction is finished, the construction area will be cleaned up and rehabilitated (replanted and reseeded) as necessary.
- Prepare a Work Area Isolation Plan for all water crossing requiring flow diversion or isolation.
- Within seven calendar days of completion of site improvements, any disturbed bank and riparian areas shall be protected using native vegetation or other erosion control measures as appropriate.

1.6.3 Survey & Topography

Multiple survey data sources were used to develop a topographic surface for hydraulic model and a basemap and contours for civil engineering component. Site conditions exterior of the main river channel have not changed significantly since time of survey. The data sources are as follows:

- LiDAR data acquisition performed by Quantum Spatial, 4020 Technology Parkway, Sheboygan, WI 53083
    - Geodetic ground control data acquisition performed by Rogers Surveying, Inc., 1455 Columbia Park Trail, Suite 201, Richland, WA 99352
    - Horizontal mapping datum: WGS 1984 (NAD83/91), vertical datum: NAVD '88.
    - LiDAR data acquisition on November 14-15 and 19-20, 2013, as well as on January 31, 2014.
    - Delivery consisted of Bare Earth ASCII files, Bare Earth Digital Elevation Models (DEM), hydro-flattened, as ESRI grid, and one- and two-foot contours.
- Ortho-photo of Yakima River and vicinity, 2013. Yakima County GIS
- Parcel lines, Yakima County GIS

1.6.4 Utilities

A cursory review of the County GIS database revealed two 12" forced sewer mains within the project area. The County contacted the owner and found that the location of these mains is along the toe of the south side of SR24. In this location, the setback levee is proposed to be constructed here, and does not include any excavation beyond the 1' grubbing. There are already access roads constructed over the sewer main. The owner indicated that the project may have little impact to the sewer lines, and that design and construction (2006) of these mains may have taken into account the planned future levee setback in this area. Further coordination with the owner is recommended.

1.7 Geotechnical Design

This section presents background information for the geotechnical design and construction of the proposed environmental restoration features for the Yakima Section 1135 Study.

Proposed features of design include DID#1 Levee demolition, cross dike demolition, KOA levee demolition, levee embankment material and riprap salvage from demolition activities, and setback levee construction downstream of State Route 24 (SR 24). The setback would replace the existing DID#1 levee, also known as Moxee Bridge or Yakima Segment 7 in the National Levee Database. Although the setback levee features are ecosystem restoration features, they were designed according to USACE levee design standards, and text throughout this section references general design standards for levees. The setback levee elements will replace several structures proposed for removal while maintaining flood protection for residential and agricultural lands. The features are designed to be resilient for the 50-year study period assuming normal operations and maintenance. This standard protects the initial investment of the ecosystem restoration project.

1.7.1 Geologic Setting

The Yakima River Valley is located in Central Washington, flowing through Ellensburg, Yakima, and Tri-Cities until it reaches the Columbia River. The Yakima River flows southeast from its headwaters in the Cascade Mountains at Keechelus Lake and descends through the foothills and plains along Interstate 90. The river has cut its way through the Umtanum Range and Selah Gap.

1.7.2 Local Geology

The project site is located adjacent to the Yakima River in a broad (approximately 15-mile wide), flat river valley in the City of Yakima, Yakima County. Geologic mapping for the site was obtained from the *Geologic Map of the Yakima Valley and Union 7.5-minute Quadrangles, Yakima County, Washington* (Polenz et al. 2010). Near-surface geology at the site is mapped as Quaternary age alluvium (Qa). Alluvium at the site typically consists of loose to medium dense, silty sand with gravel (Yakima County 2014). Hills above the river valley (to the north and south) are generally mapped as glacial till (Qgt) with various ice contact deposits mapped between the upland glacial till and lowland alluvium. Occasional peat (Qp) zones are mapped in the valley, although not in the vicinity of the explorations for this study.

1.7.3 Subsurface Explorations

A subsurface exploration program for the project has not yet occurred. This should be completed at the start of the Engineering and Design phase and should consist of borings, test pits, sample recovery, laboratory testing, and other techniques along and near the proposed setback levee alignment and in the vicinity of other major features, such as the Blue Slough Headgate. Explorations were performed in the area to inform a hazardous, toxic, and radioactive waste (HTRW) investigation. In the absence of site-specific subsurface data, drilling logs from the nearby Yakima Authorized Left and Right Bank levees (Appendix B-1) were reviewed, in addition to local well logs from the Department of Ecology. Shannon &

Wilson, under contract with Yakima County, has performed recent borings along the existing Yakima Authorized Levees. Although these are not in the immediate vicinity of the proposed project features, soil conditions are expected to be similar.

1.7.4 Laboratory Testing

Geotechnical analytical laboratory testing will be performed on soil samples during the future subsurface exploration program to include, but not limited to, visual classification, moisture content determinations, grain size analyses, hydrometer analyses, fines content determinations, Atterberg limits, and organic content. These laboratory tests are needed to evaluate index and engineering properties of the soils in order to inform levee design.

1.7.5 Soil Conditions

In general, subsurface conditions within the project area are consistent with the geologic history of the area. Based on site reconnaissance and review of information from previous geotechnical studies, we conclude that to the depth of interest for the proposed work, the project sites are underlain varying layers of Alluvium (Qa) (Holocene) and alluvial terrace deposits (Qt) (Pleistocene). Typically, these deposits consist of silt, sand, and gravel of diverse composition. Cobbles are typical throughout the soil column.

The soil parameters (not site-specific, though located nearby and considered to be similar) were determined from previous existing exploration data, existing laboratory data, empirical relationships, and experience with similar soil types of the region. Soil design parameters listed in Table 1-2 may be used for the setback levee design. Pending site-specific exploration, this table should be reviewed, revised, and updated to reflect local soil conditions. Site-specific explorations should be conducted during the next design phase to confirm conditions beneath proposed features.

Table 1-2. Soil Parameters

Soil Type	Soil Type (USCS)	Saturated Unit Weight (γ, pcf)	Friction Angle (Effective Stress, drained) (ϕ, degrees)	Cohesion (Effective Stress, drained) (c, psf)	Horizontal Hydraulic Conductivity (K_H, ft/day)	Ratio of Vertical to Horizontal Hydraulic Conductivity (K_V/K_H)
Sandy GRAVEL	GP, GW	130 (120-140)	38 (35-46)	0 (n/a)	400 (100-1000)	0.35 (0.25-0.5)
Slightly Silty, Sandy GRAVEL	GP-GM; GW-GM	130 (120-140)	38 (35-46)	0 (0-100)	100 (10-600)	0.35 (0.25-0.5)
Silty SAND	SM	120 (115-125)	32 (30-38)	0 (n/a)	0.06 (0.03-0.4)	0.2 (0.1-0.3)
Sandy SILT	ML	110 (100-125)	28 (24-36)	0 (0-100)	0.006 (0.002-0.01)	0.2 (0.1-0.3)

Cobbles and Riprap	n/a	115 (110-120)	45 (40-50)	0 (0)	1000	1

Note that the single value shown represents a preliminary design value, while the ranges shown in parentheses represent potential variability of the property. Under Total Stress, undrained conditions, shear strength values may vary slightly for the silty materials (SM and ML). The friction angle can decrease by 1-2 degrees, while the cohesion can increase to 100 psf (0-400 range typical).

1.7.6 PROPOSED SETBACK LEVEE FILL

For setback levee fill, the following soil specifications are recommended as a typical levee gradation used for Northwest levee construction: USCS soil classification of SP-SM or SM, free of organics and debris, with LL<50, and a gradation meeting the following specifications in Table 1-3. However, based on locally available materials, materials are most likely to be gravels, such as GP, GW, or GP-GM. The gradation is likely to vary, especially by exceeding the 3-inch size due to the presence of cobbles. Efforts should be made to remove excessive cobbles and boulders prior to placing embankment material. Construction monitoring plan must include means and method of screening cobbles and boulders that are larger than one-half the lift thickness at the intended location.

Table 1-3. Typical Levee Embankment Fill Gradation

Sieve Designation	Percent Passing
3 inch	90-100
1 inch	70-95
½ inch	60-90
No. 4	50-85
No. 40	20-55
No. 200	10-20

Based on initial quantity calculations, the required fill for the setback levees will total approximately 26,617 CY of fill, 2400 CY of gravel surfacing, and 435 CY of riprap. These quantities include an a 15% allowance above neat line quantities for loose to compact soil state,

At this time, no fill is anticipated to be imported from external sources. All of the borrow material required for new setback levee construction will be obtained from demolition activities associated with this ecosystem restoration project. There are three main features that will be demolished: 1. Existing DID#1 Levee, also known as Moxee Bridge in the National Levee Database (NLD) or Yakima Segment 7; 2. Cross Dike. This is currently at the downstream end of the Yakima Authorized Project, Left Bank Levee and was recently reworked during a levee setback project constructed in 2012. This feature was constructed by WSDOT as a bridge approach for a past configuration of SR 24 over the Yakima River; 3. KOA Levee. This is a section of levee that was replaced by the 2012 setback project mentioned in number 2 above. It was previously part of the line of protection and downstream tie-in for the Yakima Authorized Project, Left Bank Levee.

Little information about the DID#1 levee is known, although it is assumed to be constructed of silty sandy GRAVEL with cobbles, similar to other levees in the area. The Cross Dike was partially excavated and reconfigured in 2012, exposing its embankment soils for inspection. Because its original purpose was as a highway bridge approach, it is constructed of very compact, granular fill meeting WSDOT and AASHTO standards. The KOA Levee was the previous Federal levee, so it is assumed to be constructed of silty sandy GRAVEL with cobbles. It is currently assumed that all three structures to be demolished will provide adequate levee embankment material to construct new levees. However, prior to reusing of any of the existing levee embankment material, the structural fill should be free of debris, roots, wood, scrap material, vegetation, refuse, soft unsound particles, and deleterious materials. Soil samples should be obtained from each of these features for laboratory testing and characterization, to include at least grain size distribution, proctor density, and compaction.

There are numerous quarries within hauling distance of the City of Yakima in the unexpected event that additional fill import might be required.

Setback levee construction will consist of a maximum 8-inch loose lifts of soil compacted to 95% of ASTM 1557 maximum density. Compaction equipment shall be a combination of static or dynamic pressure, kneading, and vibration actions to compact/densify the structural fill. Pre-approved rollers shall be used for fill compaction. With the aforementioned soil type, gradation, and compaction assumptions, the constructed soil properties used for design analysis can be found in Table 1-4.

Table 1-4. Soil Parameters for Typical Levee Fill

Soil Type (USCS)	Unit Weight (γ, pcf)	Friction Angle (φ, degrees)	Cohesion (c, psf)	Hydraulic Conductivity (K, ft/day)
Embankment Fill (GP-GM; GW-GM)	130	38	0	100

1.7.7 Disposal Sites

The Newland Pits will be used for disposal of all surplus inorganic and organic material generated in construction and demolition. However, materials such as asphalt, concrete, or other waste may not be disposed in the pits and will require proper handling. For cost estimating purposes, all spoil is assumed to be disposed of in the old gravel pits. Majority of soil is anticipated to be free draining sand, gravel, and cobbles. Trees and other plants are also expected. During disposal, some soils will be placed in a trapezoidal berm configuration across the ponds in order to subdivide them into smaller units. Final configuration of these berms is not critical; however, future design phases should analyze a stable and safe configuration for placing this fill in an underwater configuration. It is understood that as fill placement proceeds across a given pond, dump trucks would be driving upon previously placed material. It must be stable enough to carry this equipment load.

Spoil from the removal of the existing DID#1 Levee, Cross Dike, and KOA Levee will be used for levee embankment fill. Stripping and over excavation for foundation preparation of the setback levee may provide suitable material for top soil to cover levee embankment slopes. Import material may need to be blended to provide suitable top soil mix.

1.7.8 Rock Sources for Erosion Protection

For levee embankment locations requiring riprap armor, it is assumed that demolition of several existing features will provide more than the necessary material needed. Sources of riprap may include Sportsman Groin Removal, KOA Levee Removal, Cross Dike Removal, and DID#1 Levee Removal.

Rock quality assessments have not been made on these potential sources. This is recommended during a later design phase. Riprap present on the cross dike was recently installed in 2012 and has never been loaded by the Yakima River, so it should be an excellent source. Riprap present on the KOA Levee is located against the riverbank but is still assumed to be in good condition. Little information is known about the DID#1 levee or its riprap condition.

1.7.9 Filter Blanket for Riprap Blankets

All instances of riprap protection for overtopping or riverward erosion protection will have a minimum 1-foot filter blanket beneath the riprap armor. This filter blanket will be designed in accordance with EM 1110-2-1901: Seepage Analysis And Control For Dams, Change 1 (USACE,1993) based on the future selection of a levee fill material. Typical practice in Seattle District is to utilize a 1-foot blanket of 2 inch to 4 inch spall rock.

1.7.10 Groundwater Studies

No specific groundwater studies have been conducted in the project area. However, based on granular and highly permeable soil conditions, the groundwater table is expected to follow the river level.

1.7.11 Levee Underseepage Analysis

Underseepage and seepage through the typical setback levee cross sections should be estimated using methods presented in USACE manuals (EM 1110-2-1913, April 30, 2000; EM 1110-2-1901, February, 2005) during the Engineering and Design phase. This analysis may be accomplished using the finite element modeling program, SEEP/W by GEO-SLOPE International.

Hydraulic conductivity estimates were attained through grain-size analyses using correlations and empirical equations, such as Hazen equation, as well as typical values based on soil classification. In-situ permeability testing has not been completed during any past geotechnical explorations. Prolonged seepage conditions could cause piping of the silty sand setback levee material, though past performance indicates a low likelihood of this happening. Seepage analysis should be conducted to illustrate whether the exit gradients experienced at the landward toe of the setback levee under design flood steady state seepage conditions are conducive to seepage or piping. At this time, no seepage mitigation is recommended for the levee design. Foundation soils of minimal fines content are anticipated to experience high underseepage quantities resulting in ponding landward of the setback levee structure similar to conditions that presently exist.

1.7.12 Setback levee Slope Stability Analysis

Global stability analyses should be performed for static and steady state seepage loading conditions during design phase. Slope stability of the proposed setback levee should be evaluated at representative sections along the setback levee alignments in accordance with EM 1110-2-1913: Design and Construction of Levees, Section 6-5 (USACE, 2000) and EM 1110-2-1902: Slope Stability (USACE, 2003). This analysis may be accomplished using the limit equilibrium modeling program, SLOPE/W by GEO-SLOPE International. The Factors of Safety (FS) should be calculated using the Spencer method which satisfies both moment and force equilibrium, and considers both shear and normal interslice forces. The following loading conditions were analyzed:

1) **End of construction (Static).** This case represents undrained conditions for impervious embankment and foundation soils; i.e., excess pore water pressure is present because the soil has not had time to drain since being loaded. Results from laboratory Q (unconsolidated-undrained) tests are applicable to fine-grained soils loaded under this condition while results of S (consolidated-drained) tests can be used for pervious soils that drain fast enough during loading so that no excess pore water pressure is present at the end of construction. The end of construction condition is applicable to both the riverside and landside slopes.

   End of construction analysis did not account for significant development of pore pressures in the shallow embankment soils. Foundation soils are relatively permeable and deposited in relatively thin strata. A static slope stability utilizing piezometric surface equivalent to the assumed groundwater table and effective strengths of soils may be used. This assumption can be confirmed in later design phases when time rate of consolidation is explored and construction phases are determined. The minimum required FS is 1.3 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).

2) **Sudden drawdown.** This case represents the condition whereby a prolonged flood stage saturates at least the major part of the upstream embankment portion and then falls faster than the soil can drain. This causes the development of excess pore water pressure which may result in the upstream slope becoming unstable. For the selection of the shear strengths see Table 6-1a of EM 1110-2-1913.

   The rapid drawdown loading condition was not analyzed. Based on indications of available setback levee fill sources and design permeability, the setback levee soils will be relatively permeable and not develop significant excess pore water pressures along the riverward slope. This assumption can be confirmed at a later design phase.

3) **Steady seepage from full flood stage (fully developed phreatic surface)**. This condition occurs when the water remains at or near full flood stage long enough so that the embankment becomes fully saturated and a condition of steady seepage occurs. This condition may be critical for landside slope stability. Design shear strengths should be based on Table 6-1a of EM 1110-2-1913.

This condition represents the long-term stability where the water level on the setback levee is at the design high water level. Effective soil strength parameters were used for the foundation soils. Pore pressures were imported from the steady state seepage model for use in this stability model. This condition is applicable to the landside slope, the minimum required FS is 1.4 according to EM 1110-2-1913: USACE Design and Construction of Levees, Table 6-1b (USACE, 2000).

4) **Earthquake.** Earthquake loadings are not normally considered in analyzing the stability of levees because of the low probability of earthquake coinciding with periods of high water. Levees constructed of loose cohesionless materials or founded on loose cohesionless materials are particularly susceptible to failure due to liquefaction during earthquakes. Depending on the severity of the expected earthquake and the importance of the levee, seismic analyses to determine liquefaction susceptibility may be required. Review Engineering Regulation ER 1110-2-1806 Earthquake Design and Evaluation for Civil Works Projects during the next design phase.

1.7.13 Setback levee Settlement Analysis

For this level of design, without having one-dimensional consolidation laboratory test data, settlement values were estimated. Since the foundation soils are typically gravels (poorly to well graded) and permeability is high, it is anticipated that the majority of the primary settlement will occur during construction. Significant secondary compression is not anticipated due to the absence of highly organic or plastic soils, based on nearby borings and typical foundation conditions around the Yakima River. For feasibility design, a maximum expected value of 6 inches of settlement could be accounted for in the uncertainty in material quantities in the cost estimate. Future design phases should more accurately estimate the anticipated settlement along the proposed project alignments and add this to the top of levee design profile. Furthermore, it should be clear that settlement analysis be conducted on the levee embankment portion of the section, with the gravel driving course existing above that. The post-settlement final grade for design should be at the top of the embankment material.

Following site-specific exploration, laboratory testing should be performed to determine appropriate consolidation parameters to refine the settlement estimate. One-dimensional consolidation theory should be applied for the calculation of settlement, if applicable. Additional time-rate of construction estimates may also be completed during subsequent design phases where deemed necessary. Atterberg limit testing of should also be conducted to determine whether the fines exhibit plastic or non-plastic characteristics. Coefficients of consolidation and of recompression can be calculated based on the one-dimensional consolidation laboratory testing implementing typical Casagrande construction methods to determine the pre-consolidation stress. Since the foundation soils are predominantly alluvial, they are anticipated to be normally-consolidated.

2 Measure 1.0 Part 1 of 2 - DID#1 Levee Removal

(Annex A, Sheet CD-101)

2.1 Site Description

The Diking and Improvement District #1 (DID#1) Levee spans 8900 lineal feet of the Yakima River between SR 24 and the south project boundary. The privately owned and maintained levee contained the flood of record (1996) with active flood fighting but is vulnerable in several places to overtopping. The existing levee crest elevation is about 2-feet above the 1% AEP (100-year) water surface elevation, on average along this segment. This measure would remove approximately 8,900 lineal feet (all) of the levee. This work requires approximately 94,000 CY of material excavation (levee fill, riprap, vegetation). This measure also entails removal of four structures, as marked on the plans in Annex A of this report. This work is adjacent to and integral with the removal of all of remaining portions of the KOA levee (2,000 lineal feet, 31,000 CY) and removal of all of an existing training levee located underneath the SR24 highway bridge (740 feet, 12,000 CY). Removal of these upstream segments connects a restored area upstream of SR 24 to the Newland pits area and allows for full hydraulic reconnection of the site.

2.2 Hydraulic Design

Yakima County has obtained or is working to obtain necessary real estate between and inclusive of the existing DID#1 levee and the proposed setback alignment. To achieve maximum restoration benefit, all of the levee will be removed down to the original floodplain elevation, with the exception of a portion that is adjacent to the Newland Ponds, which will vary in elevation. The expected overtopping frequency of the as-built former levee footprint will be about the 5-year recurrence interval.

2.2.1 Design Considerations

To allow the river to rework the floodplain following restoration riprap will be removed from the river for the entire length of levee except for the 1,600 foot portion (station 52+00 to 68+00) that is at the outside of a large meander to keep the river from avulsing into the Newland pits. Note that the floodplain topographic restoration (Measure 1.2) includes swales cut below the original floodplain elevation to convey water into the ponds at less than the 5-year recurrence interval flow. It is expected that the river will begin to erode channels into the pond area across the lowered levee surface and establish permanently wetted low flow channels within 5 years' time.

2.2.2 Risk, Next Steps, and Future Work

River migration, erosion, and avulsion are the major geomorphic risks for Measure 1.0 and 1.2. It is expected that hydraulic modeling of the Newland pit regrading (measure 1.2) will help refine the design of Measure 1.0 and 1.2 to manage these risks successfully when coupled with monitoring and adaptive management.

Note that the model used in this study has not been calibrated to ensure that the overtopping frequency will be as desired. Once updated channel data are obtained, the model should be carefully calibrated. All identified plan elements should then be added to the model terrain to assess the hydrologic response and gravel pit avulsion potential and of the current design concept. It is recommended that a fully-2D verification model be developed once the 1-D/2D model has been calibrated and refined to assess if flow patterns, elevations, velocities, etc. are sensitive to the model setup (i.e. does the avulsion potential look significantly different in the fully 2D model). If the full 2D model is significantly different all future design iterations should be assessed with the full 2D model rather than the 1D/2D model. In addition, existing morpho-dynamic (sediment transport) models should be refined in concert with the design revisions to assess the effects of sedimentation on channel conditions and flood elevations.

2.3 Civil Design

2.3.1 Levee lowering

The work includes 94,064 cubic yards (CY) levee removal encompassing 8,900 LF (all) of the existing levee to the elevation shown on the plans (typically adjacent grade of floodplain).

2.3.2 Staging and Access

Based on evaluation of the site topography and predominant land use, approximately 4.8 acres of staging areas would be utilized. Staging would be anywhere within the project construction limits and the staging areas shown on the plans. Access will be at the locations shown on the plans.

2.3.3 Construction Methodology

Construction would be after peak snow melt and irrigation season when the Yakima River is low to avoid risk of flooding unless the setback levees are in place. If the setback levees are in place, the construction can proceed provided river levels are low enough to access the material to be removed. The construction methodology is to field stake the excavation limits and to clear and grub all large trees and vegetation, then remove riprap, and grade the levee down to the design elevation (adjacent grade). The excavated materials will be placed in the Newland Ponds/pits as part of the floodplain topographic restoration measure. No specialized equipment is anticipated to be needed for this work. Fish exclusion work should not be necessary. Large volume dump trucks and excavators may be used to increase production.

2.3.4 Survey/GIS/Topography

2013 LiDAR flown by the USACE was used for this design and quantity estimation. Yakima County GIS layers (ortho photo, parcels) were also used.

2.3.5 Risk, Next Steps, and Future Work

During PED, the design catch point will be field staked and the project walked to determine any modifications needed for final plans and specifications. Modifications may be a change in levee removal elevation, omitting areas where the removal of trees and habitat will be more disruptive than removing the levee.

2.4 Geotechnical Design

The DID#1 Levee removal involves removal of approximately 94,000 CY of levee embankment, riprap and woody material. Based on the Initial Eligibility Inspection Report (on file at NWS Soils Section), the levee embankment material is silty sandy gravel. It is assumed that all existing levee embankment materials will be suitable for reuse in the DID#1 Setback Levee. During the next design phase, samples should be taken of this material to determine its engineering properties and adequacy for design. Any excess material may be placed in the Newland Pits. Excavation of slopes for the removal of the DID#1 will not exceed a 1.5H:1V slope to ensure stability of the slopes during levee removal, according to EM 385-1-1: Safety and Health Requirements Manual, Sloping and Benching, 25.C.01.a., Table 25-1, Figure 25-1, Type C soil (USACE, 2014).

2.5 PLANTING PLAN

For levee removal (existing DID#1 levee, KOA levee, and cross dike), revegetation of the excavated area should consist of hydroseed with native grass mix for erosion-control, with the intent to minimize invasive species. Some damage to existing trees during levee removal is expected, but most of the roots will remain. Damage to the trees may actually increase the likelihood of re-sprouting from the roots for cottonwood, coyote willow, and other species. The large area (approx. 14 acres) shown below in Figure 2-1 consists primarily of invasive weeds and will be further disturbed by levee removal. This area should be hydroseeded and, if the project is done over the winter or late spring, live parts of trees salvaged from other actions could be "planted" here. If work is not done during winter when plants are dormant, salvaged parts of trees could be buried here, with the remaining area replanted with cottonwood. Some areas may require localized application of spray for at least a year after project completion to regulate invasive species.

Figure 2-1. Area to be Re-vegetated as Part of DID#1 Levee Removal

3 MEASURE 1.0 PART 2 OF 2 - DID#1 SETBACK LEVEE

(Annex A, Sheets CS-101 through CS-119)

3.1 Site Description

The existing Diking and Improvement District #1 (DID#1) Levee spans 8900 lineal feet of the Yakima River between SR 24 and the south project boundary. It is on the left bank of the Yakima River, downstream of the Yakima Authorized Project, Left Bank Levee. The area is mainly open land with some sparsely located private properties and residences. Inspection of aerial imagery suggests many historic channels across the area. Blue Slough flows through this project area; the levee design will need to accommodate this slough. The privately owned and maintained levee contained the flood of record (1996) with active flood fighting but is vulnerable in several places to overtopping. This measure would replace the levee with a new levee constructed to modern standards, including USACE risk based analysis procedures. The existing levee reduces flood risks for 540 acres. The new levee would maintain existing levels of flood risk for 265 acres of residential, commercial, and agricultural property. The remaining 275 acres of floodplain will be restored.

3.2 Hydraulic Design

Yakima County provided shape files that show the preferred setback alignment following Blue Slough, a relict river channel and formerly active side channel. Note that the existing levee confines the river to 20% to 50% of its historical active width (roughly from the treatment plant to Blue Slough) between SR 24 and the downstream end of the DID 1 levee. The proposed levee alignment would follow the eastern extent of the historical active limit (as defined by the age of floodplain alluvium) but would still protect flood-prone properties east of Blue Slough. This would restore floodplain processes to most of the historic active channel area between SR 24 and the downstream end of the DID 1 levee. Elevated levee access roads will cross Blue Slough at Unnamed Road and Lester Lane which will necessitate replacement of existing culverts.

3.2.1 Design Considerations

The proposed 10% design setback levee crest profiles are shown in Figure 40 and Figure 41 of the H&H Annex.

The existing DID#1 levee contains the 1% AEP (100-year) flood with varying levels of assurance (i.e. probability of containment). For purposes of preliminary design, the average distance from the computed flood elevation to top of levee was used to estimate the preliminary crest elevations that would maintain existing levels of flood risk. A formal probabilistic evaluation of levee performance has not been conducted but will be conducted per the requirements of ER 1105-2-101 to demonstrate that the setback facility mitigates for the increase in flood risk that will occur if the setback levee is not constructed. This will be conducted in PED by updating the H&H data with most current data, and formally assessing the uncertainty in hydrology, hydraulics and sedimentation under existing conditions and with project conditions. The average probability of containment under existing conditions along the existing levee will then be used to back out the design crest elevation for the setback levee segments that maintains the same level of flood risk.

The lower 400 feet of each setback levee segment will require protection from erosion with a blanket of riprap. Assume a 3-foot thick blanket of class III (assumed size of material to be harvested from existing DID#1 levee) riprap will be keyed into the ground extend to the top of the 100-year flood profile, for an average height of 5 feet. See Figure 41 of H&H Annex.

In areas outside of those requiring riprap, a native revegetation erosion protection design provided by Yakima County will be utilized. The design includes native seed mix on the landward (lee) side of the levee, and riverward side where riprap is not used. A 15 foot wide swath along the toe will be interplanted with native shrubby species (15 foot stem density assumed). 15 feet from the toe a line of cottonwood saplings will be planted. These plantings will create hydraulic roughness along the toe and slope of the levee to help keep velocities from becoming erosive. See Figure 41 of the H&H Annex.

3.2.2 Risk, Next Steps, and Future Work

Note that the model used in this study has not been calibrated to ensure that the overtopping frequency will be as desired. Once updated channel data are obtained, the model should be carefully calibrated. All identified plan elements should then be added to the model terrain to assess the hydrologic response and gravel pit avulsion potential and of the current design concept. It is recommended that a fully-2D verification model be developed once the 1-D/2D model has been calibrated and refined to assess if flow patterns, elevations, velocities, etc. are sensitive to the model setup (i.e. does the avulsion potential look significantly different in the fully 2D model). If the full 2D model is significantly different all future design iterations should be assessed with the full 2D model rather than the 1D/2D model. In addition, existing morpho-dynamic (sediment transport) models should be refined in concert with the design revisions to assess the effects of sedimentation on channel conditions and flood elevations. Hydrologic uncertainty will be evaluated, as well as effects of setback levee on residual risks (i.e. transferred risk due to raising levee in addition to setting back) before the final levee crest elevation is determined.

3.3 Civil Design

The new levee would consist of two segments. The west segment, 2,790 feet long, ranges in height from 0 to 6 feet (average of 4.3 feet). The east segment, 5900 feet long, also ranges in height from 0 to 6 feet (average of 3.3 feet).

The setback levee crest width is 14 feet wide with a 6-inch-thick gravel driving surface and with 3H:1V riverward slopes and 3H:1V landward slopes. A planting berm will be placed at the riverward toe of the setback levee to allow for planting of native vegetation.

The area on the left bank of the river where the two setback levees will be constructed includes approximately 8,690 lineal feet of new setback levee construction with a planting strip at the riverward toe. This work requires 6,255 CY of setback levee material, 2,050 CY of planting berm material, 705 CY of topsoil, 2,125 CY of stripping, 662 CY of wearing course, 115 CY of riprap and 85 CY of filter material.

3.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be in the locations shown on the plans. Numerous roads, ramps, channel crossings, driveways, and access points exist throughout the project area, although additional access points may need to be created to support construction of this new setback levee feature. To the maximum extent possible, existing roads will be utilized to access the project extents.

3.3.2 Construction Methodology

Construction would likely be in the drier summer months to facilitate access and construction. The dry construction season is of higher importance when placing earth embankment fill due to moisture control and compaction requirements. However, other activities related to setback construction preparation, such as clearing, grubbing, stripping, and exploration trenching could proceed during wet winter months without negative impact. These activities must occur prior to placing levee embankment fill. The DID#1 Setback Levee will be constructed in lifts, reaching specified levels of compaction, up to the design grade profile.

3.3.3 Survey/GIS/Topography

See section 1.6.3 for a full description of information used throughout the design.

3.3.4 Levee Access During High Water Events for PL84-99 Eligibility

It is assumed that Yakima County will request that the new DID #1 setback levee be included in the PL84-99 levee rehabilitation assistance program. The PL 84-99 program eligibility criteria require that the levee be accessible by truck during floods to allow for monitoring and any emergency repairs that need to occur before floodwaters recede. As plans develop during the design phase, County and Corps designers will ensure that trucks can drive onto the levee at the upstream end of the west segment (at SR 24) and drive continuously to the south end of the east segment, where there will be a turnaround. Secondary access ramps and routes will be refined as needed during the design phase to meet local access needs. Risk, Next Steps, and Future Work

3.3.5 Risks, Next Steps and Future Work

A detailed site survey should be conducted during the design phase to improve knowledge of existing site conditions. Other design details that will require further attention during the next phase will be: turnarounds at the start/end of the alignment; access ramps and gates; access roads; tie-in details to other features, such as to SR 24 at the upstream end, and interior drainage (stormwater conveyance) design.

3.4 Geotechnical Design

The DID#1 Setback Levee is approximately 8,690 linear feet in length and varies in height along its alignment from 0-6 feet (5 feet typical). The setback levee was designed for standard river loadings without overtopping. Riprap is generally not required, except in one location, so erosion protection will be provided by grass cover to the maximum extent possible. However, due to Yakima's desert climate, few grasses survive, and a hybrid system of shrubs located near the riverward toe will help to provide local velocity reductions and ground cover.

3.4.1 Subsurface Explorations and Soil Classification

See Section 1.7.3 above. Subsurface explorations have not yet been performed, so design was based on existing borings in the area upstream, mainly from the Yakima Authorized Project levees (As-Builts, USACE 1954; Geotechnical Engineering Report, Shannon & Wilson, 2013). Native foundation soils are typically consistent with predominantly dense to very dense sandy gravel with cobbles and boulders. The surface layer may be loose, medium to fine sand, up to 4 feet thick. There can be occasional layers of loose to medium dense silty, sandy gravel.

Subsequent design phases should include further site-specific subsurface explorations to better classify the anticipated soils beneath the proposed setback levee alignment. These explorations could include boring, SPT, and laboratory testing.

3.4.2 Design Considerations

Using the existing federal levee projects as a starting point in conjunction with the EM 1110-2-1913 Design and Construction of Levees (USACE, 2000), the typical section with side slopes of 3H:1V for both riverward and landward slopes and a crown width of 14 feet should be sufficient to meet seepage and stability design criteria. A 6-inch thick gravel driving surface will be placed on the crown. Additional design criteria details are listed in the following sections. Future design phases should include detailed analysis on the crown width and side slopes; it may be possible to reduce these parameters and save project costs.

Standard practice in Seattle District includes at least a gravel driving surface on the levee crown. This provides erosion resistance, rutting/pothole resistance, and strength to drive vehicles and equipment (inspection, construction, floodfight, etc.). The top width of 14 feet was selected as an average width of the existing structure (varies 8-20 feet). Standard practice in NWS is to utilize a minimum 12-foot-wide crown (10 feet per EM 1110-2-1913).

3.4.3 Seepage

Seepage results for the typical 3H:1V riverside and 3H:1V landside slopes for the DID#1 Setback Levee were estimated based on the same typical section of the Yakima Authorized Project Federal Levees upstream. Subsequent design phases should compute seepage estimates based on site-specific foundation soil data. Foundation soils are expected to be coarse grained gravels and sandy gravels with cobbles, which have high permeability. Based on historic performance of the Federal project upstream, no seepage mitigation measures are anticipated to be required to meet the required factor of safety against seepage. No additional seepage mitigation measures are recommended at this design phase. However, gravelly soils with limited fines content could be expected to experience some underseepage quantities resulting in localized ponding landward of the setback levee structure.

Note that there are several small ponds near the landward toe of the proposed setback alignment. These ponds, similar to excavations near the toe, can increase seepage erosion concerns. Subsequent design phases should evaluate the influence of these ponds near the toe and realign the levee if necessary.

3.4.4 Slope Stability

Slope stability for the typical 3H:1V riverside and 3H:1V landside design slopes is expected to meet required factors of safety for loading conditions. Subsequent design phases should specifically analyze the stability based on site-specific foundation data. Levee embankment material will be provided from existing levee embankments to-be-demolished by this project. These existing structures have slopes as steep as 2H:1V and are loaded by the river during floods; therefore, these same embankment materials are reasonably expected to perform better in a flatter 3H:1V design condition. Subsequent design phases should confirm that the stability analysis of the landward slope meets a 1.4 factor of safety for long term steady state seepage and 1.3 for static loading.

3.4.5 Settlement

For this level of design, without having one-dimensional consolidation laboratory test data, settlement values were estimated. Since the foundation soils are typically gravels (poorly to well graded) and permeability is high, it is anticipated that the majority of the primary settlement will occur during construction. Significant secondary compression is not anticipated due to the absence of highly organic or plastic soils, based on nearby borings and typical foundation conditions around the Yakima River. For feasibility design, a maximum expected value of 6 inches of settlement could be accounted for in the uncertainty in material quantities in the cost estimate. Future design phases should more accurately estimate the anticipated settlement along the proposed project alignments and add this to the top of levee design profile.

Based on available soil information, settlement for the DID#1 Setback Levee is estimated to be less than 6 inches. Predominantly only coarse grained soils exist that would experience negligible settlement during construction.

3.4.6 Wet Weather Considerations

In the Yakima Valley, wet weather generally begins about mid-October and continues through about May, although rainy periods could occur at any time of the year. Thus, it would be advisable to schedule earthwork during the drier weather months of June through September. However, it is also worth noting that summer months may be extremely hot and arid, complicating moisture-sensitive operations with excessive drying or desiccation. Soil with fines contents higher than 5 to 8 percent is highly susceptible to changes in water content and tends to become unstable and difficult or impossible to compact if the moisture content significantly exceeds the optimum. During wet weather months, the groundwater levels could increase (following the stage in the Yakima River), resulting in seepage into site excavations. Performing earthwork during dry weather would reduce these problems and costs associated with rainwater, trafficability, and handling of wet soil. Placing and compacting fill for the new setback levee may not be practicable during wet weather.

3.4.7 Setback Levee Planting Plan

The setback levee is designed with a vegetation planting plan. The typical setback levee prism as described above will be planted with only sod cover. However, due to Yakima County’s desert climate, grass is not expected to thrive; therefore, another means of ground cover is desired. For additional ecological benefits, the area riverward of the toe of the setback levee will be planted with a 15-foot-wide swatch of small shrubs. At a minimum distance of 15 feet from the riverward levee toe, a row of cottonwood trees will be planted. Additional area riverward of the levee may be planted with various schemes.

3.4.8 Non-Project Features

The proposed setback alignment ties into State Route 24 (SR24), approximately 1,000 feet east of the bridge abutment that spans the Yakima River. The next upstream levee segment, Yakima Authorized Project Left Bank, ties into SR24 at this bridge abutment. Therefore, this 1,000 foot stretch of SR24 would be included in the levee system. At this time, it is anticipated to be suitable to function as a levee. The crest width of the highway embankment is approximately 75 feet (2 lanes each direction, shoulders, barricades, sidewalks), and embankment material has been sufficiently compacted to meet state highway standards. Embankment materials are anticipated to be locally sourced.

Washington State Department of Transportation (WSDOT) is the owner/operator of this highway and has not yet been approached regarding this topic of the highway becoming part of the levee system. It is recommended that this coordination begin as soon as possible since it will be mostly independent from design of this feasibility project.

Subsequent design will need to obtain designs or as-builts of the highway section to assess suitability and functionality as a levee. Engineering analysis include seepage, stability, and settlement of the highway, as well as elevation adequacy to meet desired level of protection. Near the location of the setback levee tie-in to the highway, the highway embankment is approximately 10 feet tall, which is several feet taller than the proposed setback. Therefore, level of protection is anticipated to be appropriate.

3.4.9 Risk, Next Steps, and Future Work

The DID#1 Setback Levee requires several stages of future work. Having not completed a subsurface exploration, there is some risk regarding foundation conditions assumed thus far. This risk is relatively low, based on nearby borings and soil information as well as engineering knowledge of the local area. Soil conditions are fairly typical and composed of similar materials.

The presence of several ponds near the landward toe also increases likelihood of seepage erosion issues. If the alignment is re-evaluated, as proposed in the paragraph above, the ponds should be avoided to the maximum extent practicable. No matter where the alignment ends up, the influence of these ponds on levee performance should be characterized in subsequent design phases.

Tie-in details at the upstream end should be reviewed for maximum efficiency and providing required access to the levee structure. Endpoint termination details should also be reviewed; either turnarounds for dump trucks or ramps to natural ground should be provided. The entire access scheme must be considered, especially if the design continues to utilize a discontinuous levee alignment. This type of configuration makes it more difficult to travel from the endpoint of one levee segment to the initial point of the next downstream segment, rather than driving along one continuous top of levee access road.

Transition details should also be reviewed as the levee goes from sections not requiring riprap to sections that do require riprap.

Related to the tie-in location, WSDOT will need to be consulted regarding inclusion of SR24 into the levee system. Because both the upstream levee segment, Yakima Authorized Left Bank, and the proposed setback levee tie into SR24, this highway may need to be included as a levee segment in the system for approximately 1,000 feet. Appropriate coordination will need to take place prior to design to ensure WSDOT is agreeable to this condition. Designs or as-builts for the highway embankment will need to be reviewed and analyzed for suitability of this embankment as a levee.

The vegetation and planting plan should be further revised in accordance with ETL 1110-2-583: Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures (USACE, 2014). The current planting plan does not allow any trees within 15 feet of the riverward toe, in accordance with the requirements of the ETL. However, small shrubs with shallow root systems are proposed in the feasibility design, existing within that 15-foot zone from the riverward toe. This vegetation is permitted to provide ground cover and localized erosion protection in the absence of grass, since this is a desert climate. Subsequent design phases could consider additional options to configure vegetation into the levee design, such as adding planting berms.

Site-specific subsurface exploration should be completed. This could include drilling borings, performing SPT, and possibly pushing a CPT or performing GPR. The use of CPT may be difficult due to the large grain size of the foundation soils (gravels, cobbles, and boulders). Because the DID#1 Setback Levee may reconfigure its alignment slightly with a different Blue Slough crossing, it may be best to figure out that item before exploration to ensure borings are located beneath the proposed alignment.

A laboratory testing program should be completed in support of the subsurface exploration in order to determine site-specific soil characteristics and properties to be used to refine and improve the design. Testing should include at least the following tests: grain size, Atterberg limits, one-dimensional consolidation, permeability.

Further design refinements required include: slope stability; seepage; and settlement. Time rate of consolidation analysis is planned for the next engineering design phase to better plan for settlement along the alignment. Slope stability characteristics should be further explored to confirm slope stability loading conditions are appropriate.

3.5 Operations and Maintenance

Operation and maintenance of this levee structure will be necessary to ensure proper functioning of the levee in order to maintain flood protection and ecological benefits at the site. Maintenance zones should extend 15 feet from both the riverward and landward levee toes. This maintenance zone is not visible on the feasibility-level design plan set but may be added during subsequent design phases and should remain free of unwanted vegetation and unauthorized encroachments. Sod cover, shrubs, and riprap maintenance will be necessary to ensure proper functioning of erosion protection.

At the completion of the Ecosystem Restoration projects, an operation manual detailing proper maintenance practices will be provided to the local sponsor. It is expected that the setback levee will be eligible for rehabilitation assistance under the PL 84-99 program (Public Law 84-99 Flood Control and

Coastal Emergency Act) and will be inspected routinely to ensure proper operations and maintenance of the structure are ongoing.

3.6 Planting Plan

The setback levee is designed with a vegetation planting plan. The setback levee prism as described above will be hydroseeded on the landward side with native grasses. On the riverward side, native grass seed mix will be used to hydroseed where riprap for erosion control is not necessary. For ecological and erosion benefits, the 15 feet riverward of the toe of the setback levee will be planted with small native shrub species. Cottonwood saplings will be planted at the riverward extent of the shrub plantings (minimum of 15 feet from the levee embankment).

Along part of the overlapping setback levee area, in the vicinity of Blue Slough, additional shrubs may be planted to enhance the slough. These shrubs may exist within 15 feet of either levee embankment. Subsequent design phases will need to examine distances, vegetation free zones, and buffers, while weighing ecological benefits and levee safety. A vegetation variance may be required for this project to allow woody vegetation within the vegetation-free zones, as identified in ETL 1110-2-583. Most of the setback levee is on easements on private property, which may limit the total available area for planting in this vicinity. The current easement is 100 feet wide.

4 Measure 1.1 - Floodplain Topographic Restoration

(Annex A, Sheets CS-401-403)

4.1 Site Description

The site slated for topographic restoration of the left bank floodplain south of SR24 can be divided into two locations 1) a point bar riverward of the existing DID#1 levee and 2) gravel pits and tailings landward of the existing DID#1 levee.

Riverward of the levee, large flood deposits have been continually accumulating since the construction of the federal project levees, DID#1, and the WWTP levee located on right bank. In particular, a large slug of coarse sediment located halfway through the bar has blocked off flow through existing channels. This sediment slug is the focus of this measure. Prior to the construction of the levees, the main channel width was in excess of 500 feet. Following levee construction, the main channel has gradually shifted to the right bank and is now locked in place against the WWTP levee, while large flood deposits continue to be deposited on the left bank point bar. Currently, the main channel is approximately 120 feet wide consisting of coarse material that provides little habitat. Measure 1.1 will include excavation of approximately 100,000 cubic yards of this course bar material and haul to fill adjacent gravel pits.

Landward of the levee, a suite of gravel mining ponds exist ranging in depth from 10 to 60 (average 38) feet deep, and cover over 22 acres of free water surface within the measure 1.1 footprint. Gravel mining in this floodplain area began prior to 1971, and generally ended 2005, although a portion of one gravel pit is still in operation for discharge of process water. Just south of the 3 larger ponds lies a 14 acre area where rejected material has been placed. Measure 1.1 will partially fill the gravel pits with surplus material from the project via constructing causeways that will reduce pit capture risk. The rejected material found in a portion of the 14 acre will be removed and placed in the pits via causeways

4.2 HYDRAULIC DESIGN

4.2.1 DESIGN CONSIDERATIONS

On the point bar riverward of the levee, removal of the accumulated course sediment that is highest in elevation will be removed (ranging from 1 to 8 feet deep), allowing for conveyance through the point bar at flows ranging from 3,400 cfs at Cut Site 7, 4800 cfs at Cut Site 8 and 5,200 cfs at Cut Site 2.

Pond fill – the rationale behind the pond fill design using causeways is an attempt to limit or minimize water surface elevation drop, and resultant upstream headcuts, as the pits get captured by the river over time. By breaking the existing pits into a network of smaller pits the impact of pit capture on local water surface elevation and development of locally steep water surface slopes will be reduced as due to the reduce widening of the water surface.

To increase the resiliency of the Yakima County pit fill concept, any trees and woody vegetation cleared from channel or floodplain grading will be placed in the ponds with root wads and attached limbs and partially ballasted with excavated floodplain sediment to create large scale hydraulic roughness, dissipate energy, increase channel stability and improve habitat in the ponds. Some of the wood will float freely and be held in place by partially or fully buried trees and logs. Enough material would be used that it would be redundant even if portions were lost to floods. Buried engineered posts or piles could be considered for inclusion in the design phase if a higher assurance of retention and stability is required. Incorporation of LW into the pit capture mitigation design will constitute a beneficial reuse of the clearing debris because it improves the habitat value of the ponds by increasing shading (temperature control), cover (juvenile rearing) and substrate and hydraulic diversity (complexity, primary productivity) and reduces reliance upon river bedload to fill the ponds.

4.2.2 RISK, NEXT STEPS, AND FUTURE WORK

Note that the model used in this study has not been calibrated to ensure that the overtopping frequency will be as desired. Once updated channel data are obtained, the model should be carefully calibrated. All identified plan elements should then be added to the model terrain to assess the hydrologic response and gravel pit avulsion potential and of the current design concept. It is recommended that a fully-2D verification model be developed once the 1-D/2D model has been calibrated and refined to assess if flow patterns, elevations, velocities, etc. are sensitive to the model setup (i.e. does the avulsion potential look significantly different in the fully 2D model). If the full 2D model is significantly different all future design iterations should be assessed with the full 2D model rather than the 1D/2D model. In addition, existing morpho-dynamic (sediment transport) models should be refined in concert with the design revisions to assess the effects of sedimentation on channel conditions and flood elevations. This will be desirable to set the final floodplain grading elevations.

4.3 Civil Design

Excavation of point bar material riverward of the existing DID#1 levee consists of 54,300 cubic yards over 10.7 acres that will be hauled to adjacent gravel pits landward of the existing levee. This cleared vegetative material will be used in the remnant ponds and causeways as feasible, or stockpiled in the floodplain landward of the existing levee for roughness and habitat features. Where possible clumps of live vegetation will be salvaged and placed along the perimeter of ponds to help revegetate the site.

Material removed from the gravel mine tailings area south of the ponds will be used to create causeways as part of the gravel pit filling in measure 1.1.

Gravel pit filling in this measure includes the use of all excavated material within the project footprint not suitable for constructing the setback levee. This includes concrete, earthen, and organic materials. Approximately 242,000 cubic yards of excavated material will be available for filling the gravel pits via causeway construction.

4.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans.

4.3.2 Construction Methodology

Excavation of point bar material will be conducted using heavy excavation equipment as well as off road trucks. Excavation will ideally occur during low flows and in the dry. Mine tailings will be removed and hauled to the gravel pits with heavy excavation equipment and off-road trucks during the drier summer months. Gravel pit infill will be conducted by end dumping material, and using a tracked dozer to push the material into the pit thereby constructing the causeways. This activity can occur at any time of year, however extremely cold weather may slow the process if gravel pit freezing becomes a problem. (Groundwater fed, they very rarely freeze)

4.3.3 Survey/GIS/Topography

2013 LiDAR flown by the USACE was used for this design and quantity estimation. Yakima County GIS layers (ortho photo, parcels) were also used. Pit bathymetry was collected in 2014 by private consultants for the County.

4.3.4 Risk, Next Steps, and Future Work

A revegetation plan will likely be developed as part of the PED phase to accelerate restoration of this site. Preferred planting locations, elevations and communities need to be identified. Hydraulic modeling will guide the final grading plan for this site. Design changes will result from the modeling to maximize use of fill and to minimize pit capture risk. The County may also elect to increase the amount of fill being placed within the pits to further buy down risks using separate funding which could impact the design.

4.4 Geotechnical Design

This design feature is mainly a disposal area for excess material generated from excavations and existing levee removal. Several embankments and berms will be constructed across and through the ponds in an effort to dissect them into smaller units or chunks.

4.4.1 Subsurface Explorations and Soil Classification

No subsurface exploration was conducted in this area, however it is assumed to have similar foundation conditions to the Yakima Authorized Levee that is directly upstream.

4.4.2 Design Considerations

Several embankments and berms will be constructed across and through the ponds to dissect them. These embankments will be constructed of excess excavated materials from existing levee removal. Soils are expected to be silty sandy gravel to sandy gravel. These embankments will have a 15-foot-wide crown and 1.5H:1V side slopes. They will be constructed by end-dumping material into the pond to build up the top surface above the water level by 6 to 8 feet, making progress across the pond.

4.4.3 Risk, Next Steps, and Future Work

At this time, no further work is required to assess the feasibility of this design feature. Based on utilization of granular and free-draining materials to construct the embankments, there should be no problems constructing underwater. Furthermore, recent construction of the Sportsman setback in 2012 on the Yakima Authorized Left Bank Levee, this same technique was utilized with similar material without incident. Another large pond is located just north of SR 24, near the downstream terminus of the Federal levee. Setback construction went through this pond and required that embankment fill material be placed underwater. This structure is currently performing well, as noted on recent levee inspections.

4.5 Operations and Maintenance

Little operations or maintenance are foreseen for this project feature. There is presently no plan to maintain the embankments into the future following construction. They are sacrificial structures to segment and divide the ponds.

4.6 Planting

No planting is planned for this feature at this time. However, bare soils should be hydroseeded to prevent localized erosion from runoff. Shrubs and trees may also be planted on the embankments or around the shoreline of the ponds to provide shade and cooler water.

5 Measure 1.2 - KOA Floodplain Restoration

(Annex A, Sheets CD-102, CS-601)

5.1 Site Description

The PDT proposes to remove all 2,100 feet of a remnant portion of levee (KOA levee) isolating the river from a viable 16 acre off channel area upstream of SR 24 between the highway and Sportsman Island on the left bank and removal of 750 lineal feet spur dike (Cross Dike) isolating this area from the DID#1 setback area downstream. At this location a large portion of the Federal levee was set back in 2012; however approximately 2,100 feet of the old levee remains, degrading riparian process for 16 acres. This remnant, existing levee continues to erode around an abandoned remnant bridge abutment near its upstream end at West Birchfield Road. Removal of the remnant levee is required for full restoration. Since there is an open space between the 2012 setback levee and the abandoned section of levee, flowing water can enter the KOA area during high flows (less than 1-year recurrence) and has been observed during the December 2015 flood and other events. As the remnant levee erodes, the frequency of inundation will increase with time. Similarly, the cross dike along SR 24 needs to be removed to allow water to flow freely from the KOA site into the DID#1 restored area.

5.2 Hydraulic Design

Removal of both the SR 24 cross dike and the abandoned portion of the Yakima Authorized Project, Left Bank Levee is necessary to open up the floodplain at this location, utilize the full span of the newly constructed SR 24 bridge, and provide acceptable levee embankment fill material for the DID#1 Setback Levee. This abandoned portion of levee is unnecessary following the construction of an emergency setback levee in 2012.

5.2.1 Design Considerations

A total of 31,000 cubic yards from the abandoned federal project left bank levee and 12,900 cubic yards of the cross dike along will be excavated, loaded, hauled, and placed at the new setback alignment (as part of Measure 1.0). Excavation elevations will tie into existing floodplain grade to match natural conditions. A buried riprap grade control sill will be constructed at the SR 24 Bridge and shaped along the existing cross dike alignment using material in this location to allow flood flows to overtop and enter the downstream floodplain. The riprap sill will be 1,060 feet long, spanning 600 feet of the former cross dike length, and 400 feet of the northernmost portion of the existing DID #1 levee (after it is removed).

5.2.2 Risk, Next Steps, and Future Work

The existing federal levee upstream of SR 24 next to the restoration project has been armored and designed to withstand channel migration and contact with the levee. Scour and erosion risks are not expected to change significantly provided that the riprap sill performs as intended. The current configuration has been evaluated with 1D and 2D modeling, however this work needs to be updated as the design is refined to ensure erosion risks (associated with the river flowing through the Newland Ponds area) are kept at manageable levels.

5.3 Civil Design

The Cross Dike fill and KOA levee fill will be reincorporated into the new DID#1 Setback Levee (or placed in the Newland Pits if unsuitable to restore floodplain topography). This measure directly restores riparian process and function to 16 acres and is required to achieve the full benefits of Measures 1.0 and 1.1. Note that the Federal levee and highway have been designed to accommodate the increased erosion and scour risk associated with this restoration effort, however once the spur dike is removed, an 1,060 feet long, 78 feet wide, 5 feet thick buried grade control sill will be installed to help mitigate the risks of floodplain overflows avulsing into the Newland Pits, since this could lead to widespread channel instability and habitat degradation.

5.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access and haul routes would be constructed that would cross under the SR24 bridge connecting this site to the proposed setback levee site where the excavated material will be used for embankment construction.

5.3.2 Construction Methodology

Construction would occur in the drier summer months when the flows are low and flooding around the work area is minimal. Large excavation equipment and off road trucks would be necessary to quickly remove the material and transport it to the setback levee site.

5.3.3 Survey/GIS/Topography

2013 LiDAR flown by the USACE was used for this design and quantity estimation. Yakima County GIS layers (ortho photo, parcels) were also used.

5.3.4 Risk, Next Steps, and Future Work

5.4 Geotechnical Design

This project will be removing several existing levee embankments; one that is abandoned and another that will become obsolete upon completion of the DID#1 Setback Levee. Excavation will proceed to natural ground elevation, removing all existing levee embankment fill material. Riprap will also be removed from the riverward slope of both embankments (KOA remnant levee and cross dike). This riprap may be stockpiled for use on the DID#1 Setback Levee.

5.4.1 Subsurface Explorations and Soil Classification

No subsurface exploration is required for this action. All excavation will proceed above ground and terminate at adjacent natural ground elevations.

It is expected that all existing levee embankment soils to-be-removed will consist of silty sandy gravel and well graded gravels. These materials have served as existing levee embankment for many decades and are considered suitable for reuse as levee embankment material.

5.4.2 Design Considerations

Excavation slopes should not exceed 1.5H:1V, according to EM 385-1-1: Safety and Health Requirements Manual, Sloping and Benching, 25.C.01.a., Table 25-1, Figure 25-1, Type C soil (USACE, 2014). Existing levee slopes vary from 2-3H:1V.

5.4.3 Risk, Next Steps, and Future Work

During subsequent design phases, soil samples should be retrieved from the KOA remnant levee and the cross dike in order to perform laboratory testing for characterization. At a minimum, grain size should be determined and standard Proctor compaction tests performed to determine the compaction curves and optimum moisture contents of the proposed borrow materials.

Rock quality determination may also be performed to better characterize the existing riprap that is proposed for reuse in the setback levee. Stone for reuse should be competent and solid, not heavily weathered, fractured, or otherwise deteriorated.

5.5 Operations and Maintenance

No operation or maintenance will be required for this design feature; it is only a removal and demolition of existing structures.

5.6 Planting Plan

Disturbed areas will be hydro-seeded. Riparian revegetation will consist of natural recruitment from adjacent stands and seed sources.

6 Measure 2.0 - Sportsman Island Channel Restoration

(Annex A, Sheets CS-201 and C-202)

6.1 Site Description

In the 1940s the Corps and Yakima County dredged a new low flow river channel, built new levees and cleared the active channel of woody material between the Terrace Heights Bridge and the SR 24 Bridge. This action caused the channel to shift away from its old location (where the side channel is proposed) to the new channel and become entrained upon the right bank Federal levee. Recent flood repairs upstream have reinforced this flow pattern. Previous to the channel improvement projects the river was anabranched into 2 or more large threads in this reach at low flow. In the last several decades the river has occupied a single deep narrow channel at low flow, the side channel size has reduced, and the river has developed 3 “fixed” meanders. The “fixed meanders” have caused the associated point bars to aggrade with generally finer sands and gravels, which has buried most of the former side channel habitat on Sportsman Island. The main river channel has narrowed and incised, greatly simplifying available habitat and limiting spawning opportunities. These altered riverine processes are expected to continue into the future without this project measure.

Construction of this side channel directly restores 20 acres of side channel habitat, reconnects the upstream and downstream ends of the island allowing for additional conveyance to mitigate risk associated with potential downstream pit capture and headcutting, creates a more even distribution of stream power across this leveed reach (improving spawning conditions) , and reconnects various side channels along the alignment. The as-built channel will be inundated at the moderate winter flow (4000 cfs) which will relieve pressure on the adjacent right bank levee by redistributing flow away from the levee and reducing flood stages.

6.2 Hydraulic Design

6.2.1 Design Considerations

This measure, located at the upper end of the project footprint, would include excavation of two relatively straight side channels (Channel A and Channel B) requiring removal of approximately 81,000 cubic yards of alluvium and woody debris. Excavated material from these channels would be contributed towards Measure 1.1. The design consists of two smaller anabranch channels at the head of the island (Channel A; 1384 LF long, Channel B; 820 LF long) with varying top width, but similar low flow channel dimensions. These channel sections combine to form the remainder of the Channel A alignment, a 70-foot wide 2,550 LF long primary side channel/anabranch that would tie in to an existing natural side channel towards the downstream end of the island. Note that the combined section of Channel A is 70 feet wide (at top) with a 35 feet wide (at top) pilot/low flow channel. These channels are expected to enlarge and widen rapidly due to the erodibility of the bed materials and channel alignment.

No LWD structures, pool riffle sequences, or bioengineering of streambanks will be included as high flows and natural processes are expected to rapidly sculpt the banks and bed of the side channel, adding complexity (sinuosity, large wood, pool-riffle sequences, bars, side channels) that will be initially absent from the as-built channel. Erosion of the banks and bed of the side channel provide a valuable source of gravel to the river in the short run. Full capture of the side channel by the river would not be viewed as a negative since the river would still have access to existing main channel at high flows and if downstream headcutting was initiated, this would reduce pressure on the right bank levee near Buchanan lake.

6.2.2 Risk, Next Steps, and Future Work

Note that the model used in this study has not been calibrated to ensure that the overtopping frequency into the constructed channel will be as desired. Once updated channel data are obtained, the model should be carefully calibrated. All identified plan elements should then be added to the model terrain to assess the hydrologic response and gravel pit avulsion potential and of the current design concept. It is recommended that a fully-2D verification model be developed once the 1-D/2D model has been calibrated and refined to assess if flow patterns, elevations, velocities, etc. are sensitive to the model setup (i.e. does the avulsion potential look significantly different in the fully 2D model). If the full 2D model is significantly different all future design iterations should be assessed with the full 2D model rather than the 1D/2D model. In addition, existing morpho-dynamic (sediment transport) models should be refined in concert with the design revisions to assess the effects of sedimentation on channel conditions and flood elevations. This will be desirable to set the final channel grading elevations.

6.3 Civil Design

The excavated channel sections have a 30-ft low flow bottom width; with 1H:1V or steeper side slopes, and a high flow bottom width ranging from 70 to 1,000 feet . The depth of cut would vary from 0 to 9-ft and be 5,200 feet in total combined length. The existing outlet bottom elevation is estimated to be about 1004.6-ft NAVD88. The constructed channel slope is -0.26% for Channel A, and 0.31% for the Channel B.

6.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans.

The proposed excavation channel area will require a temporary road through a treed area, and crosses a small side channel.

Access will be in the locations shown on the plans and will not require crossing the mainstem Yakima River. One water crossing is anticipated the size and location is dependent on the river flows and location. Temporary culverts are likely necessary.

6.3.2 Construction Methodology

Construction would be in the drier summer and fall months when the Yakima River is low to facilitate access. The construction methodology is to provide a temporary crossing across the existing channel. Working from the island, excavate the new channel. The final connection would be at the existing channel. The excavated materials would be hauled to the gravel pits for infill as part of measure 1.1.

6.3.3 Survey/GIS/Topography

2013 LiDAR flown by the USACE was used for this design and quantity estimation. Yakima County GIS layers (ortho photo, parcels) were also used.

6.3.4 Risk, Next Steps, and Future Work

Construction would need to occur outside of the flood window, which is generally November – May to avoid stranding equipment. Estimation on tree quantity would provide insight on how much additional fill will be available for measure 1.1. Updated survey or LiDAR information would be useful in material estimation as recent similar excavation activities have occurred at the project site which may affect quantities of this measure. The impact of the recent small scale excavation activity is low compared to the large scale of this design.

6.4 Geotechnical Design

No subsurface explorations were performed in the vicinity of the side channel reconnection. All channel slopes were designed to mimic naturally occurring slopes of the existing channels. Because materials excavated from this feature will not be used in support of any levee construction, it is unnecessary to perform subsurface explorations or soil characterizations of the proposed channel excavations. All excavated materials from this activity will be disposed of in the Newland Ponds. However, confirmation of channel design slopes shall occur during a subsequent design phase.

6.5 Operations and Maintenance

The inlet and outlet should both be monitored for wood accumulation, and removal of trapped wood may be necessary to sustain desired connectivity to the main river. It is not possible to predict the occurrence of this, and judgment will be required to evaluate how much wood accumulation is tolerable. This constructed side channel would convey surface water to a smaller side channel that runs along the toe of the Yakima Authorized Left Bank Levee that feeds water into Blue Slough via an irrigation diversion culvert.

Occasional removal of blockages, or strategic placement of large wood to ensure adequate water flow to the Blue Slough water supply side channel, may be required on occasion.

6.6 Planting Plan

An objective of this channel is to provide off channel habitat as well as flood conveyance. The proposed channel is surrounded by riparian vegetation including cottonwood and shrub species. It is likely that following construction of the channel, regrade and natural processes will engage the channel, and native cottonwood and other shrub species will begin to populate the area naturally. Therefore, no planting plan will be necessary.

7 Measures 2.1 and 2.2 - Sportsman Upstream Groin Removal & Lake Buchanan Spurs

(Annex A, Sheet CS-202)

7.1 Site Description

Following the 1996 flood, the USACE placed a series of bendway weirs or groins along the left bank of the Yakima River along the riverward slope of the Federal Project levee to reduce levee erosion. The groins have been very effective in slowing velocities along the left bank levee, and steering the river through the turn. The installation of these groins has caused river flows to be directed straight towards the right bank of the Federal Project levee immediately downstream, reducing the velocities of currents that would engage the head of the Sportsman Island below the groins on the left bank. This situation has caused aggradation at the island head, further simplifying the channel in this reach. By removing the existing spurs (Measure 2.1) the flow of the river is expected to reengage with the head of Sportsman Island. By constructing a series of spurs along the right bank federal levee near Buchanan Lake (just downstream), Measure 2.2 would both increase water surface elevations to steer flow into the reconstructed side channel (Measure 2.0) and push flow off of the toe of the Federal levee.

7.2 Hydraulic Design

7.2.1 Design Considerations

Measure 2.1 would remove the riprap comprising the three most downstream groins to allow flows to engage the Sportsman Island channel inlet being constructed as measure 2.0. The groins can be accessed off of the top of the federal left bank levee with a tracked excavator, which will key the proposed groins into the existing embankment per the plans.

Measure 2.2 would construct a series of spurs along the right bank levee towards the head of the Sportsman Island, and just upstream of Lake Buchanan will be placed within the ordinary high water mark of the main stem of the Yakima River. These spurs will be placed on top of existing levee armor and will extend beyond the toe of the levee a short distance onto inundated river bed material. A scour analysis has not been completed – the design is based on similar applications elsewhere. It is expected that the tips of the spurs will scour and launch into the bed, forcing the thalweg to the left off of the levee toe and increasing head loss at high flows. Because the stone proposed consists of large angular boulders the spurs are likely to withstand scouring.

7.2.2 Risk, Next Steps, and Future Work

Note that the model used in this study has not been calibrated to ensure that the overtopping frequency into the constructed channel will be as desired. Once updated bathymetric data are obtained, the model should be carefully calibrated. All identified plan elements should then be added to the model terrain to assess the hydrologic response and gravel pit avulsion potential and of the current design concept. It is recommended that a fully-2D verification model be developed once the 1-D/2D model has been calibrated and refined to assess if flow patterns, elevations, velocities, etc. are sensitive to the model setup (i.e. does the avulsion potential look significantly different in the fully 2D model). If the full 2D model is significantly different all future design iterations should be assessed with the full 2D model rather than the 1D/2D model. In addition, existing morpho-dynamic (sediment transport) models should be refined in concert with the design revisions to assess the effects of sedimentation on channel conditions and flood elevations. This will be desirable to estimate scour near the spur dikes, left bank revetment, and to determine the appropriate spur dike size, location, and spacing.

7.3 Civil Design

Removal of the three groins on left bank is estimated to involve the excavation of 374 cubic yards. Excavation will remove all large riprap reasonably accessible by machinery from the bank. Material larger than 1-foot in diameter will be removed. Material will be stockpiled along the left bank levee.

The spurs are tentatively located at two sites (six at the upstream site and three at the downstream site). The spacing between the spurs is 120 feet. Each structure is approximately 40 feet long, with the top of the spur set near the 2-year flood stage. The design velocity along the toe of the levee was estimated from HEC-RAS modeling to be approximately 15.5 feet/second. The spurs be constructed of very large riprap, a tentative D_{50} size of 3.3 feet (1.4 ton).

7.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access would be provided along the federal project right bank prism, and the machinery would work directly from the levee prism.

7.3.2 Construction Methodology

Construction would be during low flow and low velocity months during fall and winter so that the equipment operators and supervisors can visually observe structure limits and stability.

7.3.3 Survey/GIS/Topography

2013 Orthophotos, as well as terrain composed of 2013 LiDAR and 2014 Bathymetry were used to design the removal of groins and installation of spurs. Hydraulic model cross-sections were used to estimate the extent of the groins to be removed as well as the depth at which the spurs need to be installed.

7.3.4 Risk, Next Steps, and Future Work

Despite much effort by the County and the USACE, the original design sheets or as-builts have not been located for the 3 groins to be removed. Material removal quantities were estimated using 2013 aerial photography and hydraulic model cross-sections near the groins. Model cross-sections were not located on any one groin, so estimations were made on the depth, extent, and total volumes based on adjacent cross-sections. A field survey of the volumes of these groins would increase the accuracy of the material estimate and cost for these features.

7.4 Geotechnical Design

7.4.1 Risk, Next Steps, and Future Work

At this time, there are no anticipated risks with the removal of the groins. Future work could include exploration and characterization of the foundation soils where new groins are to be placed.

7.5 Operations and Maintenance

Maintenance of the groin removal sites would be consistent with the current 1955 operations and maintenance manual for the federal project levee system, and the local/federal partnership.

Maintenance requirements of the newly installed spurs will be determined in the PED phase.

7.6 Planting Plan

No planting is expected at the either of the groin removal or spur construction sites, as the area impacted is limited to existing armor faces along a federal levee prism. This is consistent with USACE levee operation and maintenance guidelines.

8 Measure 4.0 - Blue Slough Automated Headgate (Annex A, Sheets CS-301, C-501)

8.1 Site Description

An irrigation culvert diverts water to Blue Slough (relic channel) from the Yakima River though the left bank Federal levee within Sportsman Island halfway at the apex of the old meander that has been filled in by sediment and vegetation growth. The irrigation culvert is controlled by a manually operated slide gate accessed by a wooden plank way from the levee crest. The slide gate controls are elevated to allow operation during high flows. A concrete headwall is located at the entrance and a riprap energy dissipater is located at the outlet. The condition of the culvert is unknown, however the slide gate has been locked shut for several years. It is presumed that the culvert is at the end of its useful life and will need replacement. Restoration of flow to Blue Slough would restore surface water hydrology to 9,200 lineal feet of relic channel that is only wet seasonally when ground water elevations are high.

8.2 Hydraulic Design

This project proposes to replace the existing culvert in-kind and upgrade the slide gate to an automatic flow controlled gate to ensure the flows do no exceed thresholds that would result in downstream flooding. Upgrades to the culvert entrance include removal of accumulated sediment and debris, installation of a trash rack, and installation of flow control weirs to ensure adequate head at low flows is available. At the outlet the existing energy dissipater would be replaced with a large pre-formed scour pool lined with riprap or large river cobbles to dissipate energy at the culvert outlet, and provide resting areas to allow adult salmonids access to the culvert. A flow control weir would be added at the outlet of the scour pool to partially backwater the culvert outlet to facilitate upstream passage at low flows by juveniles.

Under current conditions the gate can supply up to 120 cfs when the river rises to the top of the levee. This discharge is expected to cause downstream flooding due to several undersized culverts that cross Blue Slough at Sportsman Island, Blue Crane Lane, and Lester Lane.

8.2.1 Design Considerations

The automated headgate (Rubicon Slip-Meter type 3-3-12 or equivalent) can be programmed to supply a specific flow or a range of flows depending on the upstream stage. The gate measures flow ultrasonically and adjusts accordingly. The preferred gate is solar powered and can be operated manually if needed.

If the existing in-situ soils consist of 12-inch minus coarse granular material then no imported lining will be necessary for the pre-formed scour pool energy dissipater.

8.2.2 Risk, Next Steps, and Future Work

Survey data is very limited. Lidar has been used for hydraulic modeling. At small discharges the errors in the underlying cross section data are non-trivial. Full topographic survey of the slough and all culverts from side channel to the connection with the DID 1 restored area is necessary to complete design.

Resource agencies have not been consulted on the design of this facility. It is possible that large scope and cost increases could occur once stakeholder feedback is provided.

In addition, the following actions are recommended in the design phase:

- The headgate should be designed collaboratively with project stakeholders to ensure that a cost effective project can be realized within the constraints of the ERP.
- Once detailed design criteria are determined evaluate seasonal hydrology and determine ideal flow shaping to maximize habitat productivity.
- Get detailed surveys of all culverts and the Blue Slough channel and refine the backwater hydraulic model.
- Install stage recorders and piezometers to assess seasonal variations in river and side channel surface/groundwater elevations to determine if channel is likely to go dry and if so at what flows.
- Consider replacement of downstream culverts and/or enlargement or deepening of the existing ephemeral channel prior to diversion could significantly reduce flood risk and

should be investigated in the design phase. This will allay local stakeholder and County concerns regarding flooding and allow for more normative hydrology.

- In the design phase, evaluate feasibility of surface or groundwater fed channel connection to headgate. A groundwater fed channel has the advantages of steadier hydraulic conditions and reduced O&M if sufficient flows can be assured.
- Consider reconnecting Blue Slough to the Yakima with a new diversion structure located 1,200 feet upstream that would connect to the large ponds in Sportsman Island. This would significantly increase the habitat value of the project and may reduce O&M at the culvert entrance.
- Refine the conceptual design into two or more cost effective alternatives to evaluate in more detail. Optimize design for fish passage, cost effectiveness, reliability (O&M)
- Complete hydraulic design of alternatives to optimize flow conditions for fish passage

8.3 Civil Design

The existing 36-inch diameter, 72-foot-long CMP will be replaced in kind. The existing concrete headwall will be retained. A new trash rack will be mounted in front of the new gate. The trash rack bars will consist of ½-inch round stock spaced 0.5 foot on center. The solar panel and control module pedestal needs to be mounted to a 3-foot dimeter, 4 foot deep concrete tube embedded into the levee to resist overturning wind loads. The power supply cable will extend from the pedestal below the plywood plank-way to the new headgate lift motor assembly. A 180 cubic yard pre-formed scour pool lined with 12-inch minus river rock or riprap will be constructed at the outlet. A boulder weir will be placed at the outlet of the pool across the width of the existing channel to serve as stage control at the culvert outlet.

Yakima County plans to replace existing culvert crossings at Sportsman Island, Blue Crane Lane, and Lester Lane with precast 6-ft by 6-ft box culverts embedded and backfilled 2 feet with streambed gravel. All culverts will have 45 degree precast wing walls. Roads will be resurfaced to match existing conditions. Streambed gravel will match WSDOT specifications.

8.3.1 Staging and Access

Staging would be anywhere within the project construction limits and staging areas shown on the plans. Access will be primarily from the top of the left bank levee, down the levee slopes to both sides of the culvert. Staging will be in the main project staging area.

Assume work will occur within a 30 foot buffer of all other culverts to be replaced. Access will be on local roads to the crossing.

8.3.2 Construction Methodology

Construction would be in late summer to avoid risk of high flows occurring during when the culvert is being replaced. Before the culvert is replaced site work will occur. This includes installing BMPs around areas to be disturbed, and diverting any flowing water away from work areas. Accumulated sediment near the existing culvert entrance will removed and disposed. Boulder level control weirs will be installed and construction of the scour pool energy dissipater will occur. Next, the old slide gate will be removed and the existing culvert will be excavated out of the levee. The subgrade for new culvert will be prepared by excavating to depth and width to install pipe. Pumping of groundwater will be necessary at the outlet scour pool energy dissipater and along the culvert subgrade if the culvert foundation is saturated. Well points may need to be installed at the entrance and exit to draw the water table down sufficiently. Gravel bedding will be placed and compacted. The CMP will be placed in a continuous length and attached to the headwall with a watertight flange or grouted to the headwall. The culvert will be carefully backfilled with drainage material for downstream 1/3 of pipe length, and backfilled with excavated levee prism material for remainder after verifying water-tightness. Any disturbed riprap will be carefully replaced to original lines and grades. The head-gate will be installed, as will the control pedestal, and tested to verify operability. The trash rack will be installed. The levee slopes and disturbed areas will then be hydroseeded. The levee roadway will be restored to its original condition.

The same approach will be used to replace culverts at locations downstream of the primary diversion structure. The primary difference is that the replacement culverts will be pre-cast concrete boxes. These will be delivered in sections and placed with a truck mounted crane or excavator. To facilitate streambed placement in the culverts, the culverts will be 3-sided (bottom, walls) and a lid placed on top after the streambed material is placed and compacted. The lid will and precast sections be connected per manufacturer specifications. Pre-cast headwalls and wing walls will placed in a similar manner.

8.3.3 Survey/GIS/Topography

2013 LiDAR provided by the USACE was used to obtain the excavation quantities for the proposed channel.

8.3.4 Risk, Next Steps, and Future Work

- Survey all existing culverts and investigate utilities along Blue Slough.
- Refine O&M and adaptive management plan to address channel blockages, fish passage and riparian corridor issues that affect project performance.

8.4 Geotechnical Design

Replacement of the Blue Slough inlet works and culvert will require excavation into the existing Yakima Authorized Project, Left Bank Levee. It is recommended that the existing pipe be completely removed and replaced. This will require excavation and reconstruction of the existing levee embankment in the vicinity of the culvert. Figure 8-1 and Figure 8-2illustrate the as-built conditions of the headgate as it pertains to the levee.

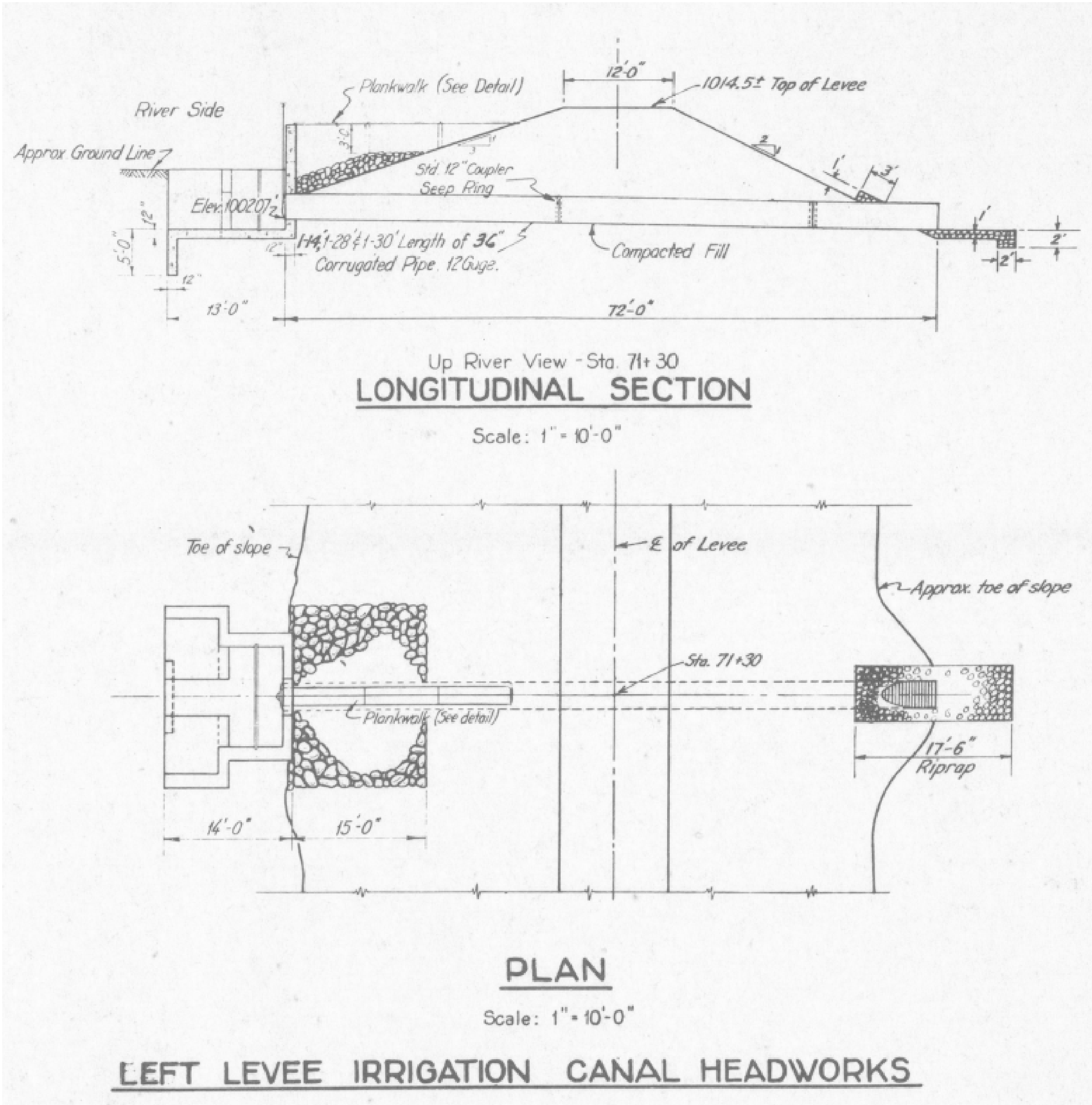

Figure 8-1. Existing Blue Slough Headworks and Culvert – Plan and Longitudinal Section

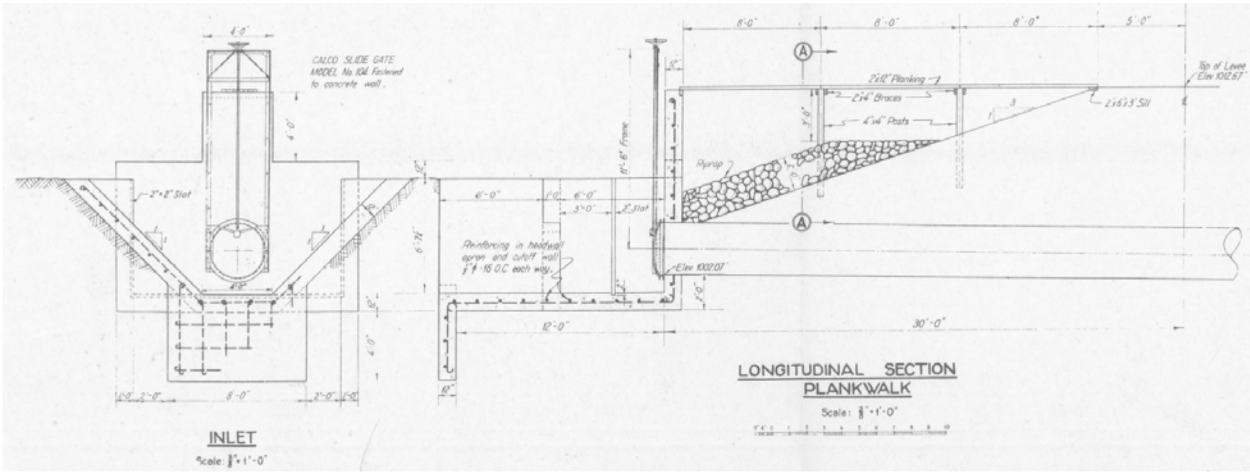

Figure 8-2. Existing Blue Slough Headworks Inlet – Longitudinal Section

8.4.1 Subsurface Explorations and Soil Classification

No subsurface exploration is planned for this design feature. However, if the concrete headworks is to be replaced, then an exploration should be conducted into the foundation conditions.

8.4.2 Design Considerations

Slope excavation limits are typically based on EM 385-1-1: Safety and Health Requirements Manual, which designates the steepest slope of 1.5H:1V (Sloping and Benching, 25.C.01.a., Table 25-1, Figure 25-1, Type C soil. USACE, 2014). However, since this excavation is to install a new pipe through the levee embankment, the governing regulation is EM 1110-2-2300: General Design and Construction Considerations for Earth and Rock-Fill Dams. An excavation slope of 2H:1V shall be the steepest allowable in order to facilitate adequate compaction and bonding of backfill with the sides of the excavation (6-6. Adjacent to Outlet Conduits. USACE, 2004). Excavations will occur in both the upstream and downstream directions along the levee alignment, down to a depth of at least the bottom of the existing pipe. Other Engineering Manuals that also describe culvert designs are: EM 1110-2-1913: Design and Construction of Levees, Chapter 8; and EM 1110-2-2902: Conduits, Culverts, and Pipes.

8.4.3 Risk, Next Steps, and Future Work

Risks include potential flooding while the levee is excavated; however, this can be avoided by performing this construction during known low-flow conditions.

Installing the new culvert will require special emphasis in the compaction program on the need to obtain sufficient densities in each lift on either side of the conduit along the backfill-conduit contact to verify adequate compaction in these and other critical zones (EM 1110-2-2300, 9-8. Compaction Control, b. Field compaction. USACE, 2004). If proper backfill compaction is not achieved, pipe deflection, joint separation, settlement, or seepage may occur, potentially leading to levee failure. Other pertinent design guides should also be used, such as EM 1110-2-1913 and EM 1110-2-2902.

Next steps will include detailing all requirements from Engineering Manuals and Regulations pertaining to pipes through levee embankments. Additional engineering references exist to describe pipes or conduits through embankments (FEMA, NRCS, USBR). During the design phase, specifications should be written to ensure proper construction techniques are utilized and proper pipe design is followed. Construction monitoring plan must address this topic. Construction QC will be paramount to ensure proper techniques are utilized.

8.5 Operations and Maintenance

As part of the levee inspection rating guidelines, visual or video inspection of the interior of culverts is required to be completed every 5 years in order to verify the interior condition of the pipe. To maintain eligibility of the levee in the PL84-99 inspection and rehabilitation program, video inspections will be required on this timeline. Periodic maintenance may be required for closure gates and other mechanical elements of this structure. Riprap required in the stilling basin area will need to be maintained clear of vegetation. Any displaced rock should be replaced.

9 Measure 7.0 - Spring Creek Reconnection

(Annex A, Sheets CS-501 and 502)

9.1 Site Description

Spring Creek reconnection occurs at the very southern end of the project footprint between the right bank of the mainstem of the Yakima River, and Interstate 82 at river mile 109. The last mile of Spring Creek flows through a mixed urban and agricultural setting, flows beneath Interstate 82, and terminates at the confluence with the Yakima River at river mile 109. The mouth of the creek is surrounded by active floodplain, but bound by the Interstate 82 road prism on the west end. An earthen berm exists at the mouth of Spring Creek that prevents fish from entering its cold fresh water habitat. This measure will remove the berm that prevents fish from entering spring creek. The site is located near WSDOT and Yakama Fisheries land.

9.2 Hydraulic Design

This project is low scope and has not undergone hydraulic analysis. It is presumed that the existing and with project hydraulic conditions during major floods are identical and that the only hydraulic changes are during low flow periods.

9.2.1 Design Considerations

Existing fill will be removed such that the depths and velocities along Spring Creek return to normative conditions.

9.2.2 Risk, Next Steps, and Future Work

A hydraulic model will be constructed during the design phase to verify that there are no unanticipated hydraulic changes resulting from this measure and that all grading areas are identified.

9.3 Civil Design

Reconnecting Spring Creek for fish access would require the excavation of 590 cubic yards, which would be side cast and graded in adjacent floodplain. Excavation extent is expected to be confined to an approximate 100’ by 100’ area.

9.3.1 Staging and Access

Staging would be limited to the amount of land required to unload an excavator or backhoe along the Interstate 82 shoulder and right-of-way. Distance for machinery travel would be less than 500 feet from the staging area. Smaller machinery may be desired in order to gain access to the site while minimizing disturbance to existing vegetation such as trees and shrubs. This work would likely be completed in a day or two, and construction of a formal staging area would be necessary.

9.3.2 Construction Methodology

Construction would be in the fall and winter months when the groundwater table is low and vegetation begins to become dormant. One piece of excavation equipment would be necessary.

9.3.3 Survey/GIS/Topography

Excavation extents and quantities were developed using 2013 LiDAR provided by the USACE.

9.3.4 Risk, Next Steps, and Future Work

A detailed on-site assessment of how to minimize impact to vegetation (clearing) and equipment access logistics would better inform the cost to do the work. Ground survey will

9.4 Geotechnical Design

This design feature includes excavation and removal of an existing berm. Excavated materials would not be used for setback levee construction but would instead be disposed of in the Newland Ponds.

9.4.1 Subsurface Explorations and Soil Classification

No subsurface exploration is planned or required to support this design feature.

9.4.2 Design Considerations

There are no additional design considerations.

9.4.3 Risk, Next Steps, and Future Work

At this time, there are no next steps or future work planned for this design feature.

9.5 Operations and Maintenance

10 Hazardous, Toxic and Radioactive Waste (HTRW)

A Phase II HTRW investigation was complete in July 2014. There were no sampling results that warranted further evaluation or investigation within the footprint of the tentatively selected plan, including the DID#1 levee site. Please refer to Appendix I – HTRW, for additional information.

11 Cost Considerations

Cost estimates have been developed for the tentatively selected plan. Please refer to Detailed Project Report/Environmental Assessment Appendix E – Cost Engineering, for additional information.

12 Schedule for Design and Construction

The pre-construction, engineering and design (PED) phase will include additional refinements of design (65%, 95%, 100%) and associated analysis (e.g., additional survey data, LiDAR, etc.) for features included in the tentatively selected plan. It is anticipated that this phase will last approximately 2 years.

Construction will likely be completed in two phases over two to three years:

- Phase I: Setback levee construction, KOA levee removal, Sportsman's channels, sportsman's spur dikes
- Phase II: DID 1 levee removal, Blue Slough headgate replacement

13 Outline Of Specifications

The following information outlines the specifications that will be included in the contract documents during PED:

DIVISION 0 PROCUREMENT AND CONTRACTING

00 01 15 List of Drawings
00 41 00 Bid Schedules

DIVISION 1 GENERAL REQUIREMENTS

01 11 00 Summary of Work
01 14 00 Work Restrictions
01 00 10 Supplementary Requirements
01 00 50 Site Specific Supplementary Requirements
01 02 50 Measurement and Payment
01 03 50 Modification Procedures
01 06 00 Water Quality Standards
01 06 10 Environmental Protection
01 35 26 Government Safety Requirements
01 35 40 Environmental Management
01 45 00 Quality Control Systems (QCS)
01 32 00 Project Schedule
01 33 00 Submittal Procedures
01 57 20 Environmental Protection
013 56A Storm Water Pollution Prevention Measures
01 45 10 Contractor Quality Control

01 50 00 Construction Facilities and Temporary Controls
01 56 00 Diversion and Care of Water
01 57 23 Temporary Storm Water Pollution Control
01 56 10 Dust Control
01 56 50 Construction Spoils Handling
01 74 19 Construction and Demolition Waste Management
01 62 35 Recycled/Recovered Materials
01 7 0 20 As-Built Records and Drawings
01 70 30 Warranty of Construction
01 78 00 Closeout Submittals

DIVISION 31 EARTHWORK

31 00 00 Earthwork
31 05 19 Geotextile
31 11 00 Clearing and Grubbing
31 32 11 Soil Surface Erosion Control
31 32 39 Bioengineering Practices for Stream Bank Stabilization

DIVISION 32 EXTERIOR IMPROVEMENTS

32 92 19 Seeding
32 92 23 Sodding
32 92 26 Sprigging
32 93 00 Exterior Plants
32 96 00 Transplanting Exterior Plants

DIVISION 35 WATERWAYS AND MARINE CONSTRUCTION

35 41 19 Stone, Channel Protection for Structures
35 41 00 Levee Construction
35 44 00 In-stream and Floodplain Habitat Construction

14 ANNEXES

Note: Annexes are available electronically and are not included in printed versions of Appendix H.

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