US Army Corps
of Engineers®
Seattle District

CENTRALIA FLOOD RISK MANAGEMENT PROJECT

CHEHALIS RIVER, WASHINGTON

DRAFT Close-Out Report
January 2012

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1 INTRODUCTION

1.1 Project Authority

The Centralia Flood Risk Management Project was authorized in Section 1001(46) of the Water Resources Development Act of 2007 (Public Law 110-114). The authorization reads as follows:

> "The project for flood damage reduction, Centralia, Chehalis River, Lewis County, Washington: Report of the Chief of Engineers dated September 27, 2004, at a total cost of $123,770,000, with an estimated Federal cost of $74,740,000 and an estimated non-Federal cost of $49,030,000."

1.2 Project Sponsorship

The State of Washington Office of Financial Management is the non-Federal sponsor for the Centralia Flood Risk Management Project. The State of Washington signed a Design Agreement with the Army Corps of Engineers (Corps) to enter into the Pre-Construction, Engineering and Design (PED) phase in June 2008. The Washington State Department of Transportation (WSDOT) serves as the liaison and provides project management for the Office of Financial Management.

1.3 Project Area

The project area includes the mainstem Chehalis River, its floodplain and tributaries from the South Fork Chehalis River confluence to Grand Mound, and includes the cities of Centralia and Chehalis, in Lewis County, Washington. Tributaries entering the study area include the Skookumchuck and Newaukum rivers, Salzer, China, Coal, Bunker, and Lincoln creeks, among others. Studies along the Skookumchuck River extend upriver to Skookumchuck Dam and include the town of Bucoda in Thurston County.

1.4 2007 Authorized Project

The 2007 WRDA authorized the Corps in cooperation with the non-federal sponsor to pursue the following plan described below:

Construction of a levee system designed to provide 100-year level of protection along the Chehalis River from approximately river mile (RM) 75 to RM 64 and along most of the lower 2 miles of both Dillenbaugh Creek and Salzer Creek; Construction of a levee along the lower approximately 2 miles of Skookumchuck River to the confluence with Coffee Creek that would provide 100-year level of protection; Raising in elevation approximately eight structures that would incur induced damages from increased inundation as a result of the project; Modification of Skookumchuck Dam to allow 11,000 acre-fee of flood storage.

1.5 Project History

The Chehalis River and Tributaries General Investigation study was originally authorized in 1946. Active through FY 1988, the study produced three Interim Feasibility Reports. In June 1984 the Corps completed an Interim Feasibility Report that recommended Congress authorize the modification of the private dam on the Skookumchuck River to provide flood storage. This would reduce flood damages in the Skookumchuck valley, the town of Bucoda and the city of Centralia. Subsequently, in Section 402(a) of the 1986 Water Resources Development Act

(Public Law 99-662) Congress authorized the Corps to construct the "works of improvement" that were recommended in the 1984 report. The City of Centralia assumed non-Federal sponsorship for design studies in February of 1988. Work continued through 1990 when further project design work was stopped because the Corps found that the project was not economically justified. The useful information developed during the design process was provided to the local governments in a Wrap-up Report in May 1992.

The cities of Centralia and Chehalis have been subject to repeated flooding for many years. This flooding has caused extensive damage to private and public property and periodic closure of critical transportation routes resulting in significant economic losses. Following the severe 1996 floods, public interest in flood damage reduction significantly increased. In 1997, the Chehalis Basin Partnership ("Partnership") was established through an interlocal agreement. The Partnership serves as a planning unit under the Watershed Planning Act, and as a citizen's advisory council under the Salmon Recovery Act.

Also in 1997, Lewis County contracted with a consultant for studies to identify possible changes to the Corps' 1984 proposal that could result in a potential economically justified project. The County wanted a community-based alternative to the WSDOT proposal for improvements to Interstate Highway 5 (I-5) that might include raising the I-5 grade near Centralia and Chehalis by up to 12 feet. The Seattle District and Lewis County collaborated to re-evaluate the flood damage reduction project in the Chehalis River Basin. The general reevaluation study was conducted in response to Resolution 2581 of the U.S. House of Representatives Committee on Transportation and Infrastructure, which directed a review of the previous Corps report recommendations in the study area and reevaluation of flooding and environmental problems and solutions. The General Reevaluation Report (GRR) recommended setback levees on the Chehalis River and the Skookumchuck River, modifications to the Skookumchuck Dam to provide flood storage, and mitigation for environmental impacts. The recommendations in the GRR were constrained to those with no unmitigated upstream and downstream negative effects.

The Centralia Flood Damage Reduction General Reevaluation Report (GRR) and Environmental Impact Statement were finalized in April 2004. They were followed by a Chief's Report in September 2004, Record of Decision in January 2006 and project authorization in Section 1001(46) of the Water Resource Development Act (WRDA) of 2007.

In December 2007 and 2009, a series of storms caused significant flood damage to communities in the Chehalis River Basin. In some areas of the upper basin, the intensity of rainfall was significantly greater and more sustained than in anyone's recollection. The December 2007 and 2009 flooding renewed local and state interest in pursuing a variety of flood damage reduction efforts for the basin.

The 2008 Washington State Legislature, through House Bills 3374 and 3375, appropriated $50 million in state general obligation bonds to the Office of Financial Management (OFM), working with and through other state agencies, the Chehalis Basin Flood Control Authority ("Flood Authority"), and other local governments, to participate in flood hazard mitigation projects for the Chehalis River Basin. Of the authorized funding, $2.5 million is intended for basin-wide study and projects to be identified by the Flood Authority. Of the remaining funds, as much as needed is intended to be used for the non-federal sponsor share of the 2007 WRDA authorized project. The Chehalis Basin Flood Control Authority was established in April 2008, with Lewis County acting as lead agency, and membership including Grays Harbor and Thurston Counties, the cities of Chehalis, Centralia, Montesano, and Aberdeen, the towns of Pe Ell and Bucoda, and the Confederated Tribes of the Chehalis Reservation.

1.6 Prior Reports

A series of Corps of Engineers reports related to flood control in the Chehalis River basin have been produced dating back to 1931. Corps of Engineers reports on the Chehalis Basin completed in 1931, 1935, and 1944 all concluded that flood control improvements were not economically justified. However in 1944 Congress authorized a levee system to protect Aberdeen, Hoquiam, and Cosmopolis. The authorization expired in 1952. An interim report was transmitted to Congress in November 1978, recommending construction of a levee system to protect the south side of the Chehalis River at its mouth in the City of Aberdeen and town of Cosmopolis.

In the Chehalis-Centralia area, the lower 1,700 feet of Coffee Creek was modified in 1966 under the authority of Section 208 of the 1954 Flood Control Act. A floodplain information report was completed in June 1968 for the Chehalis River and Skookumchuck River in the Chehalis-Centralia area. A hydraulic floodway study for the same area was completed in August 1974. A second hydraulic floodway study was completed in March 1976 covering the Chehalis and Newaukum rivers in the vicinity of Chehalis. A comprehensive framework study of the water and related land needs of the Columbia River-North Pacific region was completed in 1972 under the direction of the Pacific Northwest Rivers Basin Commission, identifying the Chehalis-Centralia area as an area where levees should be constructed for urban flood damage reduction.

In 1982 the Corps released the Feasibility Report and Environmental Impact Statement for Centralia, Washington Flood Damage Reduction. The report recommended modifications to Skookumchuck Dam (provision of a low-level flood control outlet, and raising the reservoir elevation to provide flood control storage). This project was later found to be economically unjustified based upon updated economic studies during the PED phase. In February 1992 the Corps prepared the Skookumchuck Dam Modification Project, Centralia, Washington Wrap-Up Report, summarizing PED studies and data.

1.7 Purpose of the 2011 Closeout Report

The purpose of this closeout report is to document and summarize the work completed during the Preconstruction, Engineering and Design phase of the project between execution of the Design Agreement in 2008 and now. This report presents the work leading up to the determination that the authorized project is no longer economically justified and therefore no longer in the federal interest. Additionally, due to the current funding climate throughout the Corps of Engineers, it is pertinent for the team to document work completed to date in the event that the project is put on hold due to lack of federal funding availability. This report is not intended to serve as an approving document for and anticipated changes or reformulation that may be required, This document is only meant to serve as a informational report to document work completed to date as well as potential paths forward should funding become available in future fiscal years.

2 SCOPE OF POST-2007 AUTHORIZATION WORK

2.1 Background

In June 2008 the Pre-Construction, Engineering, and Design (PED) phase was initiated following the signing of the Design Agreement. The PED phase was initiated at a total estimated cost of $15 million. The PED phase was divided into 2 parts. The first part of the PED phase was to reevaluate the effects of the December 2007 and 2009 flood events that caused significant damage to the project area including residential, commercial, and transportation damages. The second phase of PED was to continue design of the authorized project to a 100% level of design suitable to go to construction.

2.2 Plan Formulation

The Chief's report authorized the Centralia Flood Damage Reduction Project contingent upon a reformulation of the environmental mitigation. After execution of the design agreement in 2008 the team focused on updating project changes since the GRR. The changes included reevaluation of the levee heights and fragility curves for the authorized designs, reevaluation the Skookumchuck Dam modifications, and reevaluation the environmental mitigation. Due to significant flooding in 2007 and 2009 the District was prompted to include economic and hydraulic updates to verify if the project still offered 100 year protection. As a result of these economic and hydraulic updates the District determined that the previous 100 year flood used to determine the level of protection provided by the project was no longer valid. The authorizing language in the Water Resources Development Act of 2007 authorized the project to construct the levee system to a specific height, but not a level of protection. This authorizing language was analyzed and confirmed by Mona Thomason, Chief, Planning Branch, and Sue Leong, Office of Counsel. Along with this update to the hydrologic and hydraulics, the economic benefits were also recalculated. Because the project no longer provided a 100 year level of protection, the recalculated benefits do not include the avoided cost of raising interstate 5. Because of the constraints of Executive Order 11988, the WSDOT construction must be above the 100 year flood elevation. Mitigation is required to offset loss of wetlands and flooding impacts of new construction. This loss of benefits, along with other updates, resulted in a B/C of 0.65.

2.3 Updated Hydrology and Hydraulics

2.3.1 <u>General</u>

The hydrology and hydraulics related to the project were updated to incorporate an additional ten years of observed hydrologic data since the last analysis was performed. The general approach of the 2003 analysis was followed. Updated Hydrology and Hydraulics (H&H) is required for the subsequent risk and uncertainty analysis that is used to quantify the project's level of performance (what return interval flood does the project protect against) and determine the benefit-cost ratio of the project.

Most significant to the hydrological update is that the additional ten years of record includes two significant flood events-December 2007 and January 2009. The incorporation of this data served to increase flow values of given probability flood events-i.e. 0.01 annual chance exceedance or 100-year flood.

The difficulty with quantifying the hydrology and hydraulics of the Twin Cities Project is the lack of known streamflows in the project area. Stream gages exist upstream and downstream of the project area but the area consists of many physical features (floodplain, levees, railroad and highway embankments, etc.) that have a significant impact on how water moves through the area that it is difficult to extrapolate the statistics from a single stream gage to the project area. Adding to this challenge is the large spatial variability of contributing sub-basins from flood to flood.

The approach taken was to use the Chehalis River near Grand Mound streamgage (U.S.G.S. No. 12027500) as a starting point for the hydrology. This gage is located about 15 river miles downstream of the project footprint and has a record length of 80 years. Relationships between flow values at the Grand Mound gage and stream gages upstream of the project (Chehalis River near Doty, Newaukum River near Chehalis and Skookumchuck River below Bloody Run Creek), as well as the intervening ungaged sub-basins were then estimated. Based on these relationships, flow values at the above upstream locations were computed for nine return intervals at the Grand Mound gage. These flows were then routed through an unsteady flow hydraulic model. Flows and water surface elevations from the hydraulic model were then used for the risk and uncertainty analysis portion of the study. Use of the hydraulic model allowed for the impacts of physical features in the basin on the movement of water to be factored into the analysis. In general, water surfaces for a given annual exceedance probability flood event are higher in this analysis compared to the 2003 analysis.

The last part of the H&H effort was working with Economics PDT members (Don Bisbee, Charyl Barrow, Scott Long) to set up the FDA model for the risk-based analysis. The results of the hydraulic model effort were used as inputs to the FDA model.

2.3.2 Hydraulic Model

The hydraulic model used is based on the HEC-RAS platform run in unsteady flow mode. This model allows for the impacts of floodplain storage, channel storage, sub-basin timing, and lateral flow over physical features such as levees, railroad alignments and road alignments on hydrology to be considered. The model extends from the USGS gage at Doty (12020000 RM 101) to Porter (12031000, RM 33) on the Chehalis River. In addition, downstream portions of the South Fork Chehalis River, Stearns Creek, Newaukum River, Dillenbaugh Creek, Salzer Creek, Skookumchuck River, Lincoln Creek, and Black River are included. Figure 1 below is a schematic of the hydraulic model. The schematic shows upstream boundary locations and location of stream gages. The three gages on the mainstem Chehalis River, @ Centralia, @Waste Water Treatment Plant (WWTP) and near Adna are all stage-only gages.

The model is based on the geometry used in the UNET hydraulic model from the previous work on this project. Prior to this current analysis, the UNET model geometry was converted to the HEC-RAS format as part of a FEMA NFIP re-mapping effort. This is the version of the model Seattle District picked up for use in the current project update. Cross section data remains late 1990’s vintage as used in the UNET model. Some of the topographic features included in the model have been updated based on newer LIDAR data in the area. Additionally, the HEC-RAS platform offers some features that the UNET platform does not such as better elevation definition for lateral weirs and storage area connections as well as the ability to geo-reference cross sections and storage area delineations for mapping of model results.

Hydrologic inputs are based on point inflows at upstream boundary locations and locations where a stream of significance enters-typically a sub-basin with a drainage area of greater than 10 square miles. Smaller sub-basins are represented by using a uniformly distributed hydrograph along the particular watercourse. The downstream boundary condition of the model is simply the latest stage-discharge rating curve for the USGS gage on the Chehalis River at Porter.

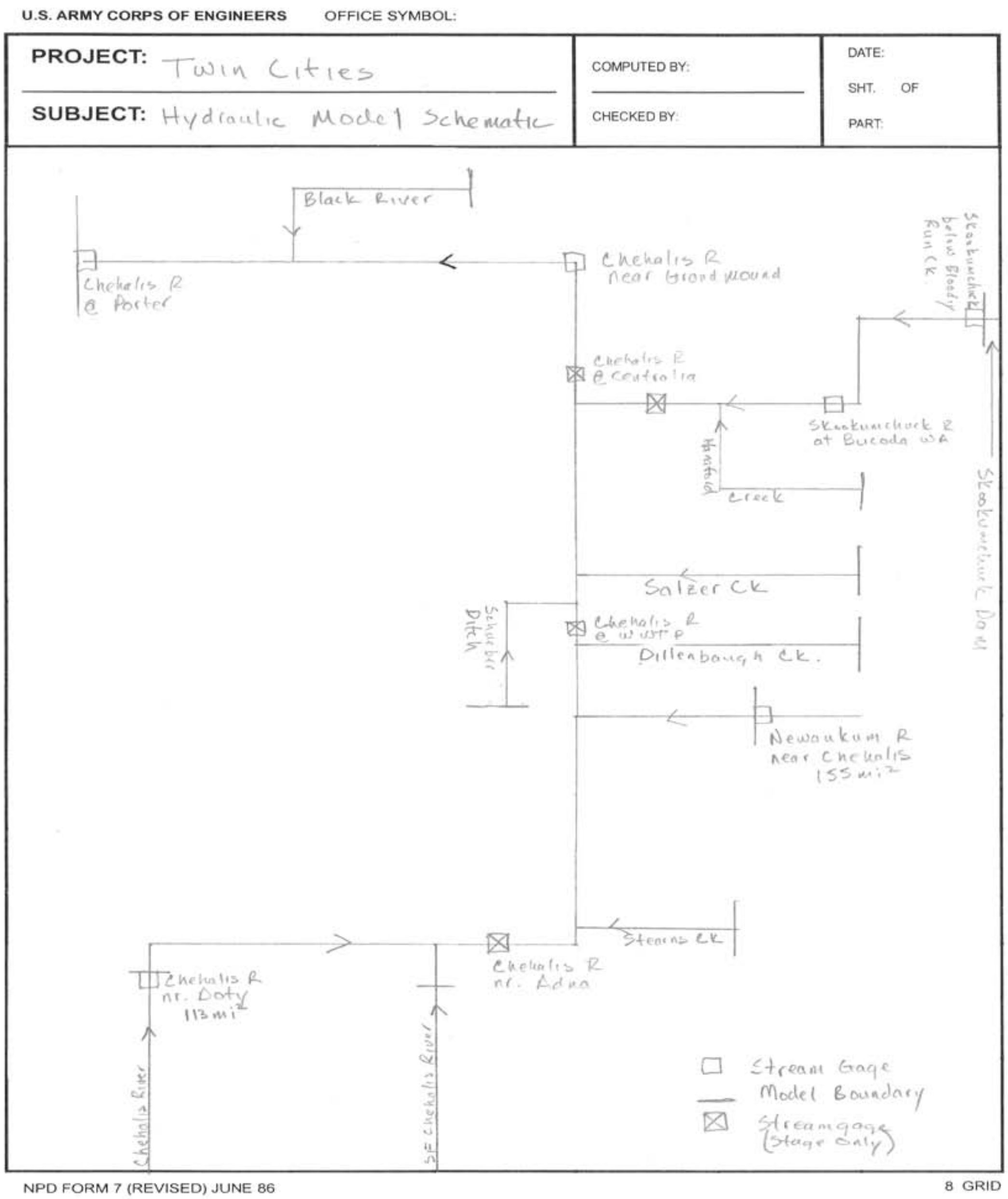

Figure 1 Hydraulic Modeling Schematic

The hydraulic model was calibrated to the extent possible using the January 2009 flood event and verified using the December 2007 and February 1996 floods. The purpose of the calibration/verification process is to adjust model parameters (typically Manning's n) such that observed water surface elevations from observed events can be reliably simulated. The more accurate the observed event hydrology the more accurate the calibration of hydraulic model parameters is. Uncertainty of observed event flow values has a bearing on the confidence that can be placed on hydraulic model coefficients and thus the computed water surface elevations. One of the challenges in the calibration/verification process for this particular situation is estimating the ungaged sub-basin contribution for specific events. Unfortunately, many of the stream gages that are representative of the ungaged sub-basins are no longer operating and were not operating during the recent large flood events. Some of these gages include Elk Creek, S.F. Chehalis River near Boistfort, Lincoln Creek, Black River and Rock Creek.

In terms of hydrologic data for model calibration, there are a number of stream gages in the basin but most are well removed from the project footprint. At the upstream extent of the project, the total drainage area is about 600 square miles, of which only 268 square miles are represented as gaged upstream boundary conditions (observed flow hydrographs) in the model. The locations are the Chehalis River at Doty (113 square miles) and the Newaukum River near Chehalis (155 square miles) USGS streamflow gages. On the Skookumchuck River observed flow data is available from the Skookumchuck River below Bloody Run Creek (66 square miles) and downstream at the Skookumchuck River near Bucoda gages (112 square miles). At the mouth of the Skookumchuck River, the drainage area for this sub-basin is 190 square miles. Downstream of the project, there is the Chehalis River near Grand Mound gage. At this location, the drainage area of the basin is 895 square miles.

The approach taken to estimate the specific event ungaged hydrographs needed at hydraulic model boundaries is to plot observe hydrographs at gage locations where available based on flow per square mile and apply these as pattern hydrographs at sub-basins that have similar characteristics., These ungaged estimates were reviewed for reasonableness, were adjusted based on precipitation data and relationships between discontinued and existing stream gages from past flood events.

Another modified version of the hydraulic model geometry was created to reflect the presence of the project's proposed levees. This version, along with the project discharge hydrographs from Skookumchuck Dam comprises the with-project version of the hydraulic model.

2.3.3 Statistical Hydrology

The statistical hydrology is based on the frequency curve generated for the Chehalis River near Grand Mound. See Figure 2 for the curve. Since the data will be used in a risk and uncertainty analysis, as per ER 1110-2-1450 (USACE, 1994) values from the 'computed' probability curve are used. Except when used in a risk and uncertainty analysis, Corps practice is the use the curve which includes the expected probability adjustment. The 0.01 annual chance probability flood event peak flow rate is about 77,000 cfs. This is an increase of roughly 5,000 cfs from that used in the 2003 GRR.

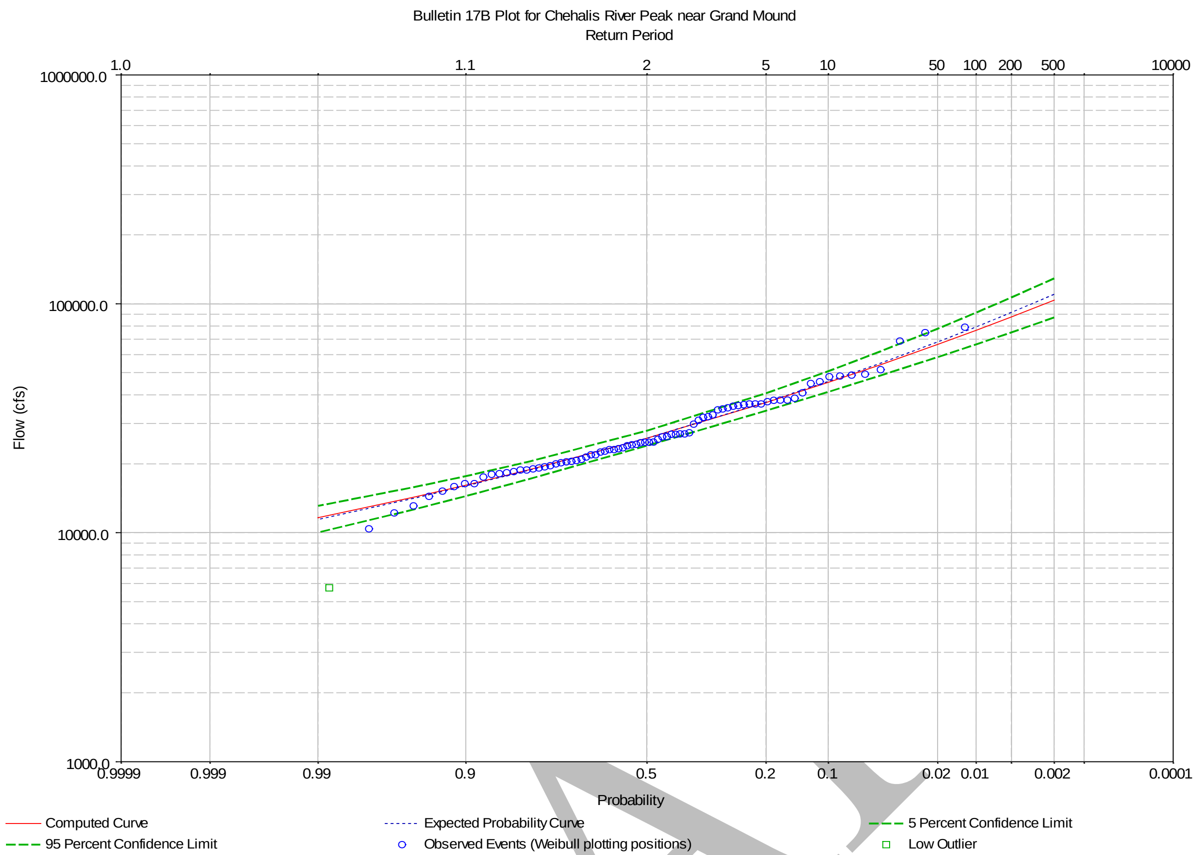

Figure 2 Updated Peak Flow Frequency Curve Chehalis River near Grand Mound

Relationships of peak flow at Grand Mound to that of locations corresponding to the upstream boundaries of the hydraulic model (see Figure 1) were estimated. The Grand Mound frequency curve and these estimated relationships were the starting point for the construction of inflow hydrographs for the hydraulic model. As much of the basin upstream of the project footprint is ungaged (about 332 square miles on the upstream Chehalis), this was estimated using the Grand Mound-specific stream gage relationship that most closely matched the sub-basin of interest's physical characteristics (slope, elevation, area, etc.). This is similar to how the ungaged hydrology was estimated for the hydraulic model calibration/verification process. As most of the sub-basins in the model domain are at lower elevations than those where we have streamgage data, most often the Newaukum River near Chehalis gage was used. Based on analysis of discontinued streamgages representative of low elevation sub-basins, the Newaukum gage seems to match up the best to the lower elevation, mid basin drainages. The process was repeated for 1-day, 3-day, 7-day, etc. flow values (and the various return intervals) until complete hydrographs could be shaped.

Of notable challenge was how to handle the contribution of Skookumchuck reservoir. Given that part of the authorized project is flood control at Skookumchuck dam, there would need to be with and without project discharge data sets. As was done with the 2003 work, given that there is no formal flood control operation at Skookumchuck Dam, for the without project case it was assumed that at the start of each statistical flood event Skookumchuck reservoir would be at the spillway crest elevation, 477-feet. In the past there has been some incidental benefits realized due to the presence of the dam. An example of this is the December 2007 flood event. At the onset of this flood, the reservoir was unusually low. As a result, it did not reach an elevation where involuntary spill occurred until after the local flow on the Skookumchuck River below the dam peaked. It should be kept in mind that the period of record data at the Grand Mound stream gage (which our flood statistics are based on) does reflect this incidental ‘flood control’ from the dam. It is likely not a significant value at Grand Mound, but theoretically the Grand Mound frequency curve would be slightly higher if for every flood the reservoir had been at the spillway crest at the start of each flood.

The authorized project calls for modification of Skookumchuck Dam by constructing a new lower level outlet works. This modification, which would increase the hydraulic capacity of the dam at pool elevations below the spillway crest, would allow for better management of flood control space. The proposed with-project operation calls for managing 11,000 acre-feet of flood storage (requiring the reservoir be kept at elevation 455-feet during flood season) at the reservoir to reduce peak flows on the Skookumchuck River. Based on the 2003 GRR, the operation calls for limiting outflows from the dam to keep the flow in the Skookumchuck River at the Pearl street bridge at or below 5,000 cfs if possible.

To estimate the discharge from the dam for both the with and without project cases, the current effort utilized an HEC-5 reservoir model. For the without project case a range of inflow hydrographs, based on the estimate relationship between Grand Mound flow and flow at the Skookumchuck River at Vail streamgage (upstream of the dam-flow values scaled to the dam site), were computed and routed through the HEC-5 model. For the without project case the discharge was simply based on a discharge rating curve for the spillway, inflow throughout time and the volume-elevation relationship for the reservoir. For the with-project case the procedure was more iterative. An estimate of the coincident local inflow below the dam was included. Discharges were computed to either keep the discharge at Pearl Street to 5000 cfs or if this was not possible to keep flows as low as possible. The result was a family of discharge hydrographs for the 0.99 through the 0.002 annual probability flood events for use in the hydraulic model. This analysis assumed that the full 11,000 acre-feet of flood storage was available for all calculations.

2.3.4 Production Hydraulic Model Runs

Once the hydraulic model was calibrated and the statistical hydrology compiled the next step was to run the model for the 0.99 through 0.002 annual probability flood events for the without project cases. After each run the results were checked and the flow values computed at the Grand Mound gage location were compared with the corresponding return interval from the frequency curve-Figure 2.

The goal is to have the flow values computed by the model come out close to the statistical values computed earlier. Keep in mind the values representing upstream hydrological contributions are based on relationships with observed flow values at Grand Mound. These relationships are not perfect. The goal was to have the computed peak flow values at Grand Mound match up within about 5 percent of those from the frequency curve. In order to reflect the assumption that Skookumchuck Dam was always full at the start of each flood but the Grand Mound record actually reflects data where this was not always the case (see earlier discussion), we tried to ensure the computed flow values were slightly higher than the values from the frequency curve. In the event that adjustment was needed, the model inputs that were adjusted were the hydrographs representing the uniform ungaged local inflow. It was felt that among all the hydrologic inputs to the model, this component was the one with the most uncertainty. In just about every case were an adjustment was needed, the uniform local inflow had to be reduced as the flow values computed at Grand Mound were higher than those from the frequency curve.

The adjusted hydrology from the without project model runs were then plugged into the with-project version of the hydraulic model. The only difference between the with- and without-project hydrology used in the model was the contribution representing outflow from Skookumchuck Dam. The with-project version incorporates the hydrograph from the flood regulation.

The results of the hydraulic modeling indicate that the project levees serve to keep more flow in the river and as a result many locations on the riverward side of the levees see higher water surface elevations with the project for a given set of hydrological conditions. These increases on the Chehalis River range from about one-foot in the vicinity of Mellon Street to a few tenths of a foot just upstream of the project, based on an estimate of the 0.01 annual chance flood. On the Skookumchuck River with project water surfaces are generally lower due lower flows from flood regulation at Skookumchuck Dam. However, there are some locations on the Skookumchuck where the proposed levees constrict river flow enough, that despite the reduced flows from regulation, the resulting water surfaces are higher with the project in place. An example of this is immediately upstream of Harrison Street in Centralia. On the Chehalis River, downstream of the propose levee project, water surface elevations are more or less the same with and without project. The reduction if flow from Skookumchuck flood regulation offsets the additional flow confined to the river due to the presence of the proposed levees.

2.4 Risk and Uncertainty Analysis

2.4.1 General

The risk and uncertainty analysis was accomplished using the computer model HEC-FDA. The results of the H&H analyses, structure inventory and Economic parameters (see Economics section) are the main inputs to the FDA model. The main outputs are project performance in terms of conditional non-exceedance probability and expected annual damage. The latter is used in the benefit-cost ratio computation.

2.4.2 Structure Inventory

For this part of the analysis a structure inventory was provided by the economics team. Each structure contains geospatial data so the structure could be located within the project area. For the spatial domain of the structure inventory appropriate damage reaches were defined. These areas were based on the hydraulic model setup. As discussed elsewhere, the hydraulic model is comprised of riverine areas along study area streams (modeled with cross sections) and storage areas (‘bath tub’ areas behind levees, railroad alignments, or road grades) or riverine areas. HEC-FDA requires that the study area is broken up into a system of damage reaches. For this study, damage reaches were defined based on areas that had common statistical flow values, rating curves, and water surface profiles. For areas modeled as storage areas, each storage area was defined as its own damage reach. Damage reaches were delineated in GIS and each structure in the inventory was assigned to a damage reach relative to where it fell with respect to the damage reaches. For this update, not all the damage reaches exactly corresponded to those from the 2003 analysis. Also within GIS, ground elevations were assigned to each structure from a terrain model. First floor elevations were then computed by adding the ground elevation at each structure to the height above ground values provide by Economics. The structure inventory was then imported into the FDA program, where depth-damage curves for each damage reach were computed for use in the risk and uncertainty computations.

The representation of individual structures and the internal computation of the damage reach depth-damage curves is a key difference between this update study and the approach used in the 2003 GRR (USACE, 2003). The 2003 study computed these curves outside of HEC-FDA and entered them directly into the program. The inclusion of the individual structures in FDA, and the subsequent internal computation of the depth-damage curves, resulted in a much more complex FDA model for this analysis as compared to the 2003 analysis. The different approach to the handling of the structures necessitating incorporating more damage reaches than was used in 2003. Unfortunately this makes it difficult to compare the results for individual damages reaches with those from the earlier study. See the Economics Section of this document for more discussion about this.

2.4.3 H&H Inputs

In general, each damage reach needs water surface profiles, a discharge-frequency relationship (with uncertainty), and a discharge-stage relationship for the 0.99 through 0.002 annual probability flood events. In addition, river elevation-storage area elevation (aka exterior interior) relationships can be specified for damage reaches behind levees or other structures behind physical features such as levees or railroad alignments where the water surface differs from that of the river. All of this information was extracted from the results of the hydraulic modeling.

2.4.4 Levee Data

Information pertaining to levees can also be represented in FDA. FDA uses top of levee elevations and fragility curve data in the risk-based calculations. Inclusion of fragility curves, if deemed appropriate, recognizes that levees or other features functioning like levees, can fail and flood off-channel areas at river stages below the top of the structure. Probabilities of this occurring can be assigned and will be factored into the risk-based computation. Given the ‘perched’ nature of the river/floodplain, levees were sometimes coded into the FDA program for this study even though no formal levee existed. This was to recognize that sometimes flow can be contained within the river channel at an elevation higher than some locations elsewhere in the floodplain.

2.4.5 Uncertainty

The last H&H related component included in the FDA model is the uncertainty of the flow-frequency curve and the discharge-stage rating curve. The uncertainty about the flow-frequency curve is computed within FDA by specifying an ‘equivalent record length’. FDA computes the uncertainty based on a procedure called order statistics. Since we are in effect transferring the statistics of the Grand Mound gage to other ungaged locations via the hydraulic model, the equivalent record length value is based on the actual record length at Grand Mound and adjusted (lower) based on the transfer method used. Guidance on the adjustment is provided in EM 1110-2-1619. Everything else being equal, the adjustment generally is greater the farther removed from the gage location the transfer point is. The Grand Mound gage has a record length of 80 years. For this analysis, based on guidance in EM 1110-2-1619, locations along the Chehalis River below the Skookumchuck confluence used a equivalent record length of 60 years. Locations on the Chehalis upstream of the Skookumchuck confluence used an equivalent record length of 40 years because these areas are yet farther removed from Grand Mound. Locations along the Skookumchuck used an equivalent record length of 30-years to reflect the shorter record length and the fact that much of the flow is a computation of outflow from Skookumchuck Dam.

The uncertainty of the discharge-stage rating curve is based on the assumption that uncertainties are distributed normally about the specified curve. As such, the parameter entered in a standard deviation. This value is based both on a sensitivity analysis using the hydraulic model and guidance found in EM 1110-2-1619. Based on guidance and the sensitivity analysis, a maximum standard deviation of one-foot is used at all locations. The one foot standard deviation value is specified for the discharge-stage level corresponding to the 0.01 annual probability flood event and larger floods. Below the 0.01 event, FDA lowers the standard deviation based on the rating curve.

2.4.6 Risk Based Project Performance

The risk-based analysis shows that in most locations the proposed levees for the with project conditions (and Skookumchuck Dam flood regulation) do not provide a conditional non-exceedance probability (the probability of an area behind a levee not getting wet) with respect to the 0.01 annual chance (100-year) flood event of 95% or greater. In terms floodplain mapping, this is the level of assurance required by the Corps of Engineers to ‘map an area behind a levee as dry’. The statistical events that have been modeled for this analysis represent the best estimate of the ‘most likely’ 0.99 through 0.02 annual chance flood events. At most locations, particularly along the Chehalis River and along Salzer Creek, the hydraulic modeling shows that the ‘most likely’ 0.01 annual chance flood would not overtop the proposed levees. However, when the uncertainty piece is factored in, the risk-based analysis indicates that were the 0.01 flood to occur (recognizing that due to uncertainty it may not look like the ‘most likely’ 0.01 flood we have modeled) we cannot say that the project would keep areas behind the levees dry with a 95-percent level of assurance. The component of the risk-based analysis, the expected annual damages results, is discussed in the Economics section of this document.

2.4.7 References (applies to both Section 2.2 and 2.3)

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2.5 Updated Economics

2.5.1 Purpose and Scope

The economic scope of the Centralia GRR is to provide updated inundation damages based on current conditions and price levels. The main purpose of an "economic update" is to ensure that the project is still economically justified, meaning that the benefits of the project are greater than the costs to construct it. The Centralia economic update indicates there is a high probability that the project is no longer economically justified.

The certified version 1.2.4 of the Hydraulic Engineering Center Flood Damage Analysis (HEC-FDA) model was populated with Hydraulic and Hydrologic (H&H) and economic data and run with risk and uncertainty. The model shows the "Without-Project" Expected Annual Damages[1] (EAD) as $17,028,450 and the "With-Project" EAD as $9,975,500 and the resulting EAD reduced or annual benefits attributable to the project as $7,052,950.

The current estimate of Total Project Annual Costs at the current federal interest rate of 4 1/8% over the project lifetime of 50 years is $10,439,000.

Annual Benefits of $7,052,950 compared to annual costs of $10,439,000 results in a Benefit to Cost Ratio (BCR) of 0.68.

Based on economic update methodology guidance in Engineering Circular 11-2-100 the scope of the economic update was determined to require a Level 3 Economic Reevaluation, which means that the conditions, economics, and engineering have changed so significantly that full reanalysis is warranted. The scope for a Level 3 Economic Reevaluation is as follows:

- Collect all new Economic and Engineering Data
- Fully Update Benefits
- Obtain Current Cost Estimates
- Show BCR and RBRCR (Remaining Benefits Remaining Costs Ratio) at current price levels

[1] Using the term "Expected" implies that the damages have been probability weighted. The estimated damages are multiplied by the estimated annual probability of incurring them. For example a 100- year flood has an "annual exceedence probability" of .01. If this event causes $10 million in damages the Expected Annual Damage (EAD) is $100,000

- No new Plan Formulation
- No new NEPA

The Chiefs Report, the basis for the authorized project, was based on the 2003 GRR, revised and price updated to 2004 prices. The 2003 GRR is based on 2002 price levels and the physical and hydrologic conditions that existed between 1998 and 2001. The damage assessment from the 2003 effort was conducted by employing HEC-FDA and HEC-EAD models. Structure and content data were first evaluated using @RISK add-on for Excel externally to the HEC-FDA model. The @RISK spreadsheet was used to generate the appropriate stage/damage references with uncertainty for entry into the HEC-FDA model. The HEC-FDA models including the externally generated stage-damage curves are available, but the original spreadsheets used to generate the stage/damage curves are not.

2.5.2 Model Certification & HEC-FDA Models

The HEC-FDA model and the @RISK stage/damage curves used in the 2003 GRR were created prior to the 2009 adoption of model certification requirements in Engineering Circular EC 1105-2-412 Assuring the Quality of Planning Models. The newly adopted certification requirements precluded using the externally generated functions and required the use of the certified version of HEC-FDA for the update. These new requirements led to significantly different functions in the updated model compared to the 2003 model.

The latest certified version of HEC-FDA (1.2.4) was used to estimate Without and With-Project Annual damages with Risk and Uncertainty. Version 1.2.5 was released subsequently. HEC determined that the changes were not significant enough to require moving the data to version 1.2.5.

2.5.3 Damage Categories

The 2003 GRR used the following major damage categories:

- Residential Structures and Contents
- Public Structures and Contents
- Commercial Structures and Contents
- Industrial Structures and Contents
- Clean-up
- Emergency
- Agriculture
- Public Assistance (PA)
- Temporary Rental Assistance (TRA)
- Transportation
- Avoided Costs of Raising I-5

The update used similar damage categories, but some of the data used for the TRA, PA, Cleanup, and Emergency categories was not available in the 2003 report and therefore not supportable. These categories were accounted for in other categories for the update.

The update planned the following damage categories:

- Residential Structures and Contents
- Public Structures and Contents
- Commercial Structures and Contents
- Industrial Structures and Contents
- Agriculture
- Public Infrastructure
- Multi Family Residential
- Transportation Infrastructure
- Avoided Costs of Raising I-5

Some of the damage categories do not have damage estimates prepared and so have not been incorporated into the HEC-FDA model for the update. The categories are Agriculture, Public Infrastructure, Transportation Infrastructure, and avoided costs of raising I-5. There will be no benefits accruing to agriculture therefore Agriculture is a residual damage. Public Infrastructure (Roads, Streets, Utilities, etc.) have partial estimates, however reasonable estimates show that this category would not likely add more than a few hundred thousand dollars to the expected annual damages. Transportation Infrastructure captures the economic damages due to delays and detours of I-5 and railroad traffic. I-5 and railroad economic costs due to detours and delays are estimated to be approximately $10 million per day each or $20 million per day total. However, the project will not prevent railroad closures and thus cannot claim avoided costs of railroad impacts as benefits. These impacts would be considered residual damages. I-5 damages (estimated to be less than $100,000 in EAD) have not been included in the update because the study was paused prior to completing the necessary calculations. Avoided Costs of Raising I-5 cannot be included in benefits because the project performance does not provide a 90% probability of containing the .01% annual event.

The avoided costs of raising I-5 were included in the 2003 GRR because it was expected that a 20-mile stretch of I-5 would have to be raised in the without-project conditions. The 2003 project was estimated to have provided project performance of a 90% probability of containing the 0.01% annual event, so the avoided costs were counted as a benefit.

2.5.4 Structure Occupancy Types

Structure Occupancy Types (SOTs) are the internal functions used by the certified version of HEC-FDA to relate inundation depths with estimated damages for the various types of structures. The 2003 model used stage/damage curves for that purpose, a practice considered standard at the time. The models used to derive the damage functions employed in the 2003 GRR are no longer available. The update used the SOT functions based on the best available information.

2.5.5 Structure Modules

Economic information in the model is described in terms of structures. Structure damages are estimated using the SOT functions. Structure inundation depths are related to the H&H information at stream stations. Each structure must have a stream station and SOT assigned to it.

One of the issues that arose due to internalizing the structure data was that in the With-Project condition, some structures would be at risk of inundation from different stream stations or streams. HEC-FDA does not have a function that allows the station or stream to change as a result of With-Project conditions. One way to compensate for this limitation is to use two structure modules; one for the Existing Conditions (EC) or Without-Project Conditions where each structure is assigned to the EC stream and stream station and another module with the same structures but With-Project stream and stream stations assigned.

There are two structure modules in the HEC-FDA model: “Base” for the Without Project or Existing Conditions and “WP” for the With-Project conditions.

2.5.6 Structure Data

According to the Economics Appendix D of the 2003 GRR (Dated June of 2003) a total of 4358 structures in the flood plain were inventoried, including 294 Commercial & Industrial structures, 3926 residential structures and 138 Public structures.

For the update, in July of 2009 13,922 structures were inventoried in the project area of Lewis County of which 7503 were determined to be in the 500-year flood plain. Included in the 7503 structure were 1510 Commercial/Industrial, 5603 Residential, 109 Multi-Family Residential, 169 Public, and 112 Farm Buildings. It is estimated that there are less than 1500 mostly residential and farm structures in Thurston County that should be inventoried and added to the structure database. Reasonable scenarios and estimates do not indicate that there is a likely probability that these additional structures would generate enough additional project benefits to result in a BCR of greater than 1.

2.5.7 Review and Comments

Two reviews were conducted on the economic update. The first was a District Quality Control (DQC) and the second was conducted by the Hydraulic Engineering Center (HEC);these comments are included in the attached appendix. Both reviews raise a number of issues, but none of the issues were communicated as being significant enough to impact the results. The model was revised addressing some of the major issues raised in the reviews, and some sensitivity runs on the beginning damage depths for the homes with basements and split levels were conducted that showed a low sensitivity to this issue.

2.6 Environmental Analysis and Mitigation

2.6.1 Significant Environmental Impacts and Mitigation

The Interagency Committee for assessing project impacts and mitigation was restarted in 2010. Scoping for the project identified potential project impacts to 1) wetlands, 2) Riparian forests, 3) Fisheries, 4) Water Quality (could be captured in 1, 2 &3), and 5) Floodplain loss (Could be captured by real estate actions. ESA listed species are not in the project area. Wildlife impacts were assumed to be captured through analysis of riparian and wetland impacts.

The group worked with Tetra Tech to modify and use the existing impact and mitigation model to assess project impacts and develop initial costs and locations for project mitigation. Based on the 2003 report and new input from the group and the public at large, Tetra Tech evaluated 25 possible mitigation sites. The results of this initial review resulted in the draft *Twin Cities Flood Damage Reduction Project Mitigation Site Evaluations Report* (Tetra Tech, 2010) included as an appendix to this report. The mitigation report estimated direct impacts to approximately 35 acres of wetlands and indirect effects to approximately 235 acres of wetland floodplain and 244 acres of undeveloped non-wetland floodplain. Based on these impact estimates it was calculated that mitigation costs would be approximately $20 million. This impact assessment did not cover mitigation costs for modifications to Skookumchuck Dam. The Tetra Tech report only represents an estimate of the potential project impacts and mitigation. As described in the wetlands section, further work will be needed to refine the impacts and mitigation estimates.

In addition, a watershed characterization was completed by Washington State Department of Ecology for the project area. The watershed characterization was used to assess if the mitigation sites being considered were appropriate on a watershed scale.

As part of the mitigation analysis effort, potential levee realignments were explored. There are three major alignment changes conceptually evaluated: Reach 1 Game Farm, Reach 4 Fair Grounds, and Reach 4 Landfill. Refer to the Civil Section for more information. The implementation of these design changes would significantly reduce the mitigation requirements for the project.

Work was started with Department of Ecology to develop necessary information for processing a Section 401 Water Quality Certification. Early in the process, Ecology noted that the Corps would have to utilize the current Wetland Rating Methodology to assess debits and credits for development of mitigation. Progress was made in relating the Ecology methodology with the mitigation methodology developed by Tetra Tech. A constraint developed on the issue of out-of-kind mitigation. While Ecology does not necessarily disagree with mitigating for wetland impacts with out-of-kind mitigation, further documentation of these actions were needed. Coordination with FAA regarding potential mitigation sites resulted in a verbal determination that a large portion of the potential wetland mitigation sites would not impact the Centralia Airport. However, no formal coordination was accomplished.

2.6.2 Wetlands

Potential impacts to wetland resources were determined to be a major component of project impacts. Potential wetlands in the project area were originally identified in 2003. Wetland resources were fully delineated or assessed by means other than field verification depending on where right-of-entry to property was secured by Tetra Tech, on behalf of the Corps. Wetlands were assessed primarily through aerial photography, National Wetlands Inventory maps, and drive by. In 2009 additional potential wetlands were identified that could be impacted by the proposed project. At that time, all known potential wetland resources were documented, or existing documentation was updated. As in 2003, the level of documentation was dictated by our ability to access property with proper right-of-entry. The impact of this is the level of documentation could lead to improper classification of wetlands.

In the Wetland and Waters of the U.S. Delineation, Rating, and Impact Assessment Final Report (January 2010) provided to the Corps by Tetra Tech, 45 wetlands are identified. The wetlands can be grouped into three categories: (1) those fully delineated and documented on-site, (2) assessed from adjacent property but not fully documented and (3) wetlands that were identified by aerial photos or other remote means. Corps biologist performed field verifications on some of the wetlands, again based on access from right-to-entry documents. This information is summarized in Table 1. Note that two areas previously identified as potential wetland areas where determined to be non-wetlands, and seven wetlands were verified. There are an additional 36 potential wetland areas that will require field delineations project area.

While the Final Report is well written, the supporting documentation has many errors. The individual Wetland Determination Data Forms, or data sheets, (Final Report, Appendix E) are not identified in a way where they can be readily associated with a wetland. The 65 data sheets have some 85 errors, many of which make them unusable as defensible delineation documents. All 45 wetlands identified in the Final Report have been assigned categories from the *Washington State Rating System – Western Washington (Second Edition)*. Only 17 rating forms were provided in the Final Report. Some of the rating forms were prepared without a site visit. Others were prepared based on information taken from old rating forms from an earlier version of the rating system, resulting in inaccurate scores and categories. For future work in this project area, none of the data sheets or rating forms provided in the Final Report should be considered viable for use. New Rating forms were completed on wetlands where Corps biologist had right-of-entry to the property of interest.

Table 1 summarized the current status of documentation for wetlands identified in the Appendix G of the 2003 GRR. “Wetland presence verified by Corps Biologist” indicates that a qualified Crops staff did an on-site verification of the wetland. “Delineation Required” is noted when the final report had insufficient information to document the presence of a wetland, and further field work is required to complete the assessment or delineation. “Determined non-wetland by COE” indicates the location identified as a potential wetland by Tetra Tech was determined to be a non-wetland by qualified Corps staff.

Table 1. Summary of Wetland Resources and Documentation.

Wetland	Documentation Status		
	Wetland presence verified by Corps Biologist*	Delineation Required	Determined non-wetland by COE
A1		X	
A2	X		
A3	X		
C1		X	
C2		X	
C3		X	
C4		X	
C5			X
D1		X	
D2		X	
D3		X	
D4		X	
D5		X	
D6		X	
E1		X	
E2		X	
E3		X	
E4		X	
E5		X	
E6		X	
F1		X	
F2		X	
F3		X	
F4		X	
F5		X	
F6		X	
F7		X	
G1		X	
G2		X	
G3		X	
G4		X	
G5		X	
G6	X		
G7	X		
G8	X		
G9		X	
G10	X		
H1		X	
H2		X	
H3		X	
H4		X	
H5		X	
H6		X	
I1	X		
I2			X

Any future wetland resource documentation in this project area should be completed using the most current versions of the *Regional Supplement of the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region,* and the *Washington State Rating System – Western Washington.* Use of the Regional Supplement is required, and use of the Rating System is recommended so that restoration/mitigation efforts will be compatible with other state documents and permitting processes.

Tetra Tech also provided the Corps with GIS shape files that were used to prepare various Figures in the Final Report. In general, the shape files are a reasonable representation of the wetland resources, but tend to over-state the actual wetland boundaries. Field verification frequently showed the actual wetland boundary was 10 to 20 feet from the GIS/GPS shape file boundary. This is likely due to the accuracy of the GPS equipment used in the field. It is recommended that any delineated wetland boundaries be recorded with GPS equipment with sub-meter accuracy.

2.7 Cultural Resources

2.7.1 Archaeology

Section 106 of the National Historic Preservation Act of 1966, as amended (NHPA; 16 USC 470), requires that Federal agencies identify, evaluate and assess the effects of undertakings on sites, buildings, structures, or objects listed in or eligible for listing in the National Register of Historic Places (NRHP). The Corps' Planning Guidance Notebook (Engineering Regulation 1105-1-100, Appendix C) provides direction in formulating Section 106 compliance procedures for Civil Works projects, including flood damage reduction. Recently-amended Washington State laws also apply on non-Federal lands such as the project area. These laws include the Archaeological Sites and Resources Act (RCW 27.53), Indian Graves and Records Act (27.44 RCW) and the Abandoned and Historic Cemeteries and Historic Graves Act (68.60 RCW). The affected tribes are the federally recognized Confederated Tribes of the Chehalis Reservation and the Cowlitz Tribe. The two Tribes had equal standing on this project and worked closely together in their roles as Section 106 Tribal consulting parties. The Corps conducted Section 106 consultation with Richard Bellon and Mark White of the Confederated Tribes of the Chehalis Reservation and Dave Burlingame and Ed Arthur of the Cowlitz Tribe, WSDOT Archaeologist Roger Kiers, and Department of Archaeology and Historic Preservation (DAHP) State Archaeologist Rob Whitlam.

Due to the critical importance of the project and the need to begin archaeological studies during FY09, on 9 July 2008, the Corps awarded Contract No. W912DW-06-D-1010, Task Order 0004, to the Cultural Resources Section's IDIQ contractor AMEC Earth & Environmental, Inc., to complete intensive archaeological surveys for the project. Deliverables included an intensive survey of three existing PL-84-99 levees: Airport, Salzer Creek, Skookumchuck Levees, and eight option parcels. The three existing PL-64-99 levees were selected for Section 106 archaeological compliance studies due to the fact that they would likely be included in new levee routes, and there were existing right-of-entries that allowed for archaeological studies to be conducted. Because they would likely be included in new levee routes the three levees were considered to be in a preliminary Section 106, direct Area of Potential Effects (APE). In addition to the three existing levees in the direct APE, the contract included archaeological studies at a total of eight relatively large additional Option parcels that are owned by the Cities of Centralia and Chehalis (PL 84-99 project sponsors). The Option 1 through 8 parcels were considered part of the working indirect APE, and the options were awarded as right-of-entries were obtained.

The field studies tasked in the contract's Statement of Work (SOW) employed a geoarchaeological approach and required an equal effort in identifying both prehistoric and historic-period archaeological sites that were potentially eligible for the NRHP.

The base contract's purpose was to conduct intensive archaeological surveys within the right-of-ways of three existing levees. The owners of these three non-Federal levees participate in the Corps' Public Law (PL) 84-99 (33 USCA 701n) program, which consists of flood fight and rehabilitation. As PL 84-99 levees the Corps has existing perpetual right-of-entries to each levee right-of-way that allowed for the base field studies tasked within the SOW. Within the levee right-of-ways individual land owners retained ownership of cultural material collected on their lands, but were encouraged to donate them to the Confederated Tribes of the Chehalis Reservation. Within the Option 1 through 8 parcels temporally diagnostic artifacts were retained for analysis. Other types of cultural materials was not collected; they were recorded in the field and returned to the surface or test hole in which they were found.

At the present time (1 August 2011) the archaeological contract will soon be closed out once final payment is made. The final report, and artifacts and records have been delivered to the Seattle District. The report provides information on the following:

1. Where work was completed
2. Where work was performed and where follow-on investigations are recommended
3. Areas that do not require additional analysis

2.7.2 Built Environment

No significant work on historical structures has been conducted on the Centralia Flood Damage Reduction project.

2.8 Engineering Design and Analysis

This period of work started with updating the 2002 35% plans to current CADD software at a 35% level, these became the 2010 plans. The 2010 plans were then in the process of being updated to incorporate the new 2011 100-year level of protection. The plans with the 2011 100-year level of protection are not complete but will be considered the 2011 plans.

2.8.1 Authorized Project:

a. Recreated and updated the 35% design drawings from 2002. The 2010 drawings were left at 35% design and a new set of those files was modified for the 2011 100 year level of protection update. The 2011 work was left in the middle of the first iteration of finding the new levee elevations when work on the authorized project was halted. The 2011 drawing files are updated with the preliminary levee elevations. The plans and profiles were updated to show the preliminary elevations as well. Estimates regarding locations were made at where alignment shifts would be needed and where the alignment requires extension to high ground.

b. Minor Alignment changes were made from a constructability stand point. This predominately included removing sharp bends from Levee sections.

c. The type of flood protection (Levee or Flood Wall) in most reaches was modified. There were some discrepancies between 2002 sources so the 2010 plans are not consistent with the 2002 plans. Since the Cost/Benefit Ratio was not positive, the discrepancies were identified but not pursued.

d. Research was done into Railroad Closures and Road Closures. Places where the closure structures would be needed were also identified.

e. New and Existing Culverts were identified and located on the drawings

f. New quantities were calculated from the 2010 plans. These quantities included 1 foot for settlement. However they were not used for the cost estimate. Overall quantities increased and would have a negative impact on the BCR.

g. The 2002 neatline quantities were compared with the 2010 neatline quantities. They were found to be significantly different. The difference in fill quantity varied by reach, however for the entire project the 2010 fill quantity is approximately 20% more than the 2002 fill quantity. The 2010 cut quantity is 20 times more than the 2002 cut quantity because the flood wall excavation was not included in 2002. These quantities do not include the removal of any existing levees. It is also unclear what 2002 quantities Cost Engineering Used. There were many sources with different quantities. It was also unclear how the 2002 quantities were calculated. It appears that they used the 100-yr level of protection plus 3 feet for the levee elevations then added 1 foot to the levee elevations for settlement. The quantities also added 10% for compaction, 10% for settlement, and 20% for overall contingency.

h. The supporting documentation was organized into a 2 project binders.

i. The Design Documentation Report (DDR) was converted to a word document and the tables were updated.

2.8.2 <u>There are three major environmental mitigation alignment changes conceptually evaluated:</u>

a. Reach 1 Game Farm, Reach 4 Fair Grounds, and Reach 4 Landfill.
b. Reach 1 Game Farm: it was proposed to move the Levee closer to the Game Farm. This area is not currently used by the Game Farm and is on better foundation materials and minimizes impact on wetlands.
c. Reach 4 Fair Grounds: When work was stopped, the Project Development Team (PDT) has not agreed on the new alignment but would prefer to use a flood wall along the wetlands to minimize the foot print and provide camping area for the Fair Grounds. This alignment would also move the existing Salzer Creek levee. Additional information is needed from cost engineering and Real Estate to determine the most cost effective alternative if future work on the project is conducted.
d. Reach 4 Landfill: The 2002 alignment is in the mitigation wetland. Two alignments are considerd, north of the wetland and south of the wetland. When work was stopped, the PDT has proposed to use the south alignment along the southern most monitoring road of the landfill. Additional information from cost engineering is required to determine if a flood wall or levee is the most cost effective alternative. Impact on the wetlands to the east must also be minimized.

2.8.3 Geotechnical Engineering

The geotechnical work in 2011 focused on studying the fragility curves of the levee embankments along the new alignment which consists of 16 reaches as shown in plates C-003 and C-004. The cross sections were provided by Civil along the levee alignment every 50 feet of their length. The following section paragraphs discuss the methodology used in developing the fragility curves and the considered mechanism of failure.

Fragility Curves Approach

Fragility curves are functions that describe the probability of failure, conditioned on the load, over a selected range of loads to which a system might be exposed. The shape of a fragility curve describes uncertainty in the capacity of the system to withstand a load or, alternatively, uncertainty in what load will cause the system to fail. If there is little uncertainty in capacity or demand, the fragility curve will take the form of a step function, as shown in Figure 2.6.1 (a). A step function has a probability of failure (Pf) = 0 below the critical load and a Pf=1 above the critical load. The step function shows certainty that the system will fail at a critical load and is appropriate for brittle and well-understood systems. For elastic, less understood, or complex systems, there is uncertainty in the capacity of the system to withstand a load. In these cases, the fragility curve takes the form of an S-shaped function, as shown in Figure 2.6.1 (b). The S-shaped function implies that, over a certain range of demand, the state of the system can only be evaluated with some probability. The S-shaped fragility curve is appropriate when there is uncertainty in the capacity of the system to withstand a load.

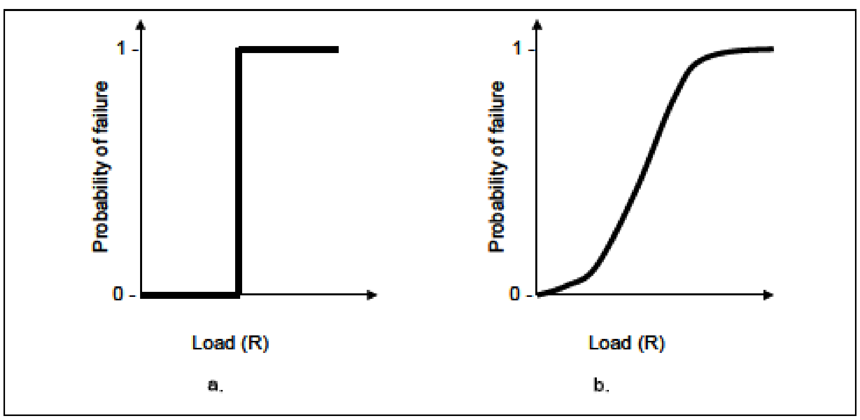

Figure 3 Conceptual Fragility Curves

The probability of failure depends upon the relationship between capacity and demand. As demand increases relative to capacity, the probability of failure approaches one.

The fragility curves analysis was performed using an in-house Excel Spreadsheet that uses Taylor's Series method to calculate the Reliability Index β. To obtain Pf from β, a probability distribution on the performance function must be assumed. A normal distribution is generally used for ease of calculation; however, the performance function is often taken as *ln* FOS, implying that the factor of safety (FOS) is lognormally distributed. Given this assumption and the value of β, the required probability values are easily calculated from the properties of the assumed distribution. To calculate β, the moments of the performance function must be calculated from the moments of the parameters, based on a Taylor's series expansion of the performance function about the expected values. The expected value of the performance function is obtained by evaluating the function using the expected values of the parameters. The variance is obtained by summing the products of the partial derivatives of the performance function (taken at the mean parameter values) and the variances of the corresponding parameters.

In addition to overtopping, two mechanisms of failure were considered in the fragility curves analysis; static slope instability and exit seepage gradient.

The levee sections evaluated for new construction. Per discussion with Mr. Dale Munger, a geotechnical subject matter expert, USACE HQ in May 2011, the following criteria should apply to new levee construction:
$Pf \leq 2\%$
Static FOS ≥ 1.4
Exit seepage gradient ≤ 0.5

Static Slope Stability
Slope stability analyses were performed using Slope/W (Geo-Slope International, Ltd., 2007). The FOS are calculated using the Spencer method, which satisfies both moment and force equilibrium, and considers both shear and normal interslice forces. The optimization option was selected in Slope/W, which optimizes the FOS after the initial failure plane or slip surface has been estimated. In the optimization, the slip surface is divided into a number of straight line segments. The end points of the line segments are then moved to probe the possibility of a lower safety factor.

Exit Seepage Gradient
Seepage analyses were performed using SEEP/W (Geo-Slope International, Ltd., 2007) which is a finite element numerical model that can mathematically simulate the real physical process of water flowing through a particulate medium.

The seepage force is the force that is exerted on the soil mass due to moving the water through the resisting soil. The hydraulic gradient in the soil is computed as the total head loss divided by distance of flow between the two measured head locations, or in a finite element formulation, the gradient matrix is computed for all points within a single element based on the coordinates of the element nodes and a shape function which determines how the total head is distributed within the element.

A quick condition exists when the upward force on a soil particle equals the total particle weight, or when the seepage force equals the submerged weight of the soil. If the pore-water pressure is high enough such that the effective stress is reduced to zero or less, then it is possible a quick condition exists.

Analyses and Results

Table 2.6.1 presents a summary of the 16 reaches considered in this project together with the recommended stations for analyses, the heights of the levees at the stations, and available representative borings for subsurface soil profiles. The recommended levee stations were selected as being the most critical from stability perspective. The levees proposed side slope is 1V:2H.

For the current scope of work, we performed fragility curves analyses on three (3) levee cross sections; Reaches 1, 4, and 7. Soil information was obtained from bore holes installed by the USACE for the Chehalis-Centralia Levee Study, 1978 to 1979. The levees have not experienced significant modification since this time and the bore hole information is assumed to be adequate for this analysis. The soil conditions at each levee station were considered based on the boring at or near that station. Boring logs may be found in the plans set for the project.

To develop fragility curves, both hydraulic and strength soil properties were varied within a range that is considered applicable to the soil type selected from the appropriate bore hole log. Soil types in the models were not varied, but assumed to be as selected from the bore hole logs. Strength properties were varied for the soil regions that are anticipated to affect the stability of the levee. The hydraulic properties were varied for the foundation soil layer that is directly below the levee section where water movement is anticipated to affect the exit gradient and the FOS against piping and seepage. Since the levees are proposed and yet to be constructed, it is assumed the hydraulic properties of the embankment material will not vary considerably. The above properties were varied at each run at a different water level behind the levee. The water level was varied from roughly 20% of levee height to one foot below the crest elevation.

Tables 3 and 4 show the values and ranges considered in the analyses for soil strength properties and hydraulic properties, respectively. It should be noted that the property values and ranges listed in the two tables are specific for the three analyzed levees based on the encountered soil conditions and limited information on the relative density or consistency of the soils.

Table 2 Centralia, WA Flood Damage Reduction Levee Stations for Geotechnical Analyses

Reach	Length (ft)	Station	H (ft)	Boring
1	14,361	39+50	10	79-PA-15
2	681	Flood Wall		
3	7,303	14+10	12	79-PA-18
4	12,814	113+50	20	79-PA-19
5	6,199	56+60	19	78-RD-2
6	985	Flood Wall		
7	13,849	9+40	16	15
8	2,045	18+90	16	30
9	2,946	15+50	15	37
10	1,742	Flood Wall		
11	2,317	11+30	10	79-PA-5
12	3,819	34+20	17	79-PA-6
13	3,056	Flood Wall		
14	2,086	1+70	14	79-PA-8
15	3,813	26+00	11.5	79-PA-9
16	3,379	19+00	9.5	79-PA-10

Table 3 Soil Strength Properties Used in Slope/W Analysis

Material	Unit Weight, γ (pcf)		Friction Angle, ϕ (degrees)		Undrained Shear Strength, Su (psf)	
	Default Value	Range	Default Value	Range	Default Value	Range
Embankment Fill	132	127-137	34	31-37		
Clay	115				1,000	750 – 1,250
Silt	115	110-120	28	24-31		
Sand	120		30			
Gravel	130		38			

Table 4 Soil Hydraulic Properties Used in Seep/W Analysis

Material	Buoyant Unit Weight, γ' (pcf)		Horizontal Hydraulic Conductivity, k_h (cm/sec)		Hydraulic Conductivity Ratio k_h/k_v	
	Default Value	Range	Default Value	Range	Default Value	Range
Embankment Fill	69.6		3.0E-04		1	
Clay	52.6	47.6 – 57.6	3.0E-05	1.5E-05 - 4.5E-05	1	1 -2
Silt	52.6	47.6 – 57.6	1.0E-04	3.0E-05 - 1.5E-04	1	1 -2
Sand	57.6		3.0E-04		1	
Gravel	67.6		3.0E-03		1	

General results and recommendations are discussed as follows:

- The fragility curves as a tool for Pf analysis is a good means to study the stability of the proposed levee design. However, the main input of such analyses is the soil profile, stratigraphy, and soil strength and hydraulic properties. For this project, the borings per each reach are spaced far from each other in a frequency much less than the common state of practice. As a general comment, the results presented below may vary significantly upon the availability of new subsurface information in the form of soil borings, samples, field test results, and lab test results.

- The results for Reaches 1 and 4 showed that where loose silt was encountered as a foundation soil directly under the levee embankment, the slope stability Pf was found to be high and not meeting the target maximum Pf of 2% even at shallow water levels.

- The FOS against instability at the two above levees ranged from less than 1 (PF=1) at higher water levels to about 1.3 at shallow water level, which is still lower than the target FOS of 1.4.

- The results of the Pf in seepage showed that at Reach 4 the Pf is lower than at Reach 1. This is due to the considerably longer distance of water movement under the levee section, and hence the head pressure loss and lower exit gradient.

- At reach 7, medium stiff clay is modeled as the foundation soil directly under the levee embankment. The considered strength properties values resulted in satisfactory FOS against instability (FOS>1.4). The system showed to be insensitive to variation within the selected range of undrained shear strength of the foundation soil, and the Pf remained at zero.

- The considered hydraulic properties values for the medium stiff clay when analyzing Reach 7 levee embankment resulted in satisfactory FOS against seepage (exist gradient <0.5) in some cases where the water level is shallow. Exit gradient increases to about 0.7 when Kh was modeled as twice Kv at higher water levels, however, the system showed to be insensitive to such variation and the Pf remained at zero.

The fragility curve results indicate the proposed new levee section with 1 vertical to 2 horizontal side slopes will not be adequate for some reaches of the levee system. The side slopes will need to be reduced to meet the slope stability and seepage criteria. The decrease in slopes of the levee section will result in the need for additional fill and potentially more real estate adjacent to the levees to account for the increased footprint of the new levee.

Skookumchuck Dam

Modifications were proposed to the existing, private, water supply dam on the Skookumchuck River to provide a maximum of 11,000 acre-feet of flood control storage. The modification required an embankment stability evaluation to include developing earthquake ground motions and to perform liquefaction analyses. This work was conducted in 2001 and 2002 by Shannon & Wilson, Inc. under contract to COE. As part of the dam owner’s fulfillment of a periodic re-licensing requirement, they submitted their own stability analysis in 2004 to the Federal Energy Regulatory Commission (FERC) disputing the COE analysis as too conservative. FERC accepted the owner’s conclusions, based on their own follow-on field investigations and analyses of liquefaction and embankment stability.

In 2011, the COE contracted Shannon & Wilson, Inc. to evaluate the 2004 follow-on analyses. The evaluation concluded that the COE and the dam owners generally agree on the ground motion parameters for the site, and the soil characteristics along the downstream foundation. However, the owners chose to average the densities of the foundation soils to assess the liquefaction potential. This averaging of blow counts likely masks relatively thin layers of liquefiable soil that can result in slope instability. Shannon & Wilson performed a parametric study along a section of the dam to examine the effects of varying assumed location, extent, and strength of the liquefiable soils on the FOS and calculated post-seismic FOS to vary between about 0.8 and 2.3.

The owners performed simplified displacement analyses (Makdisi and Seed, 1978) reporting crest displacements that could range between 1 and 16 centimeters for a magnitude 7.5 and 8.25 earthquakes. However, the Makdisi and Seed (1978) deformation analysis is not intended to be used for estimation of dam displacements resulting from potentially liquefiable soil in post-seismic conditions. Shannon & Wilson did not perform deformation analyses as numerous assumed subsurface dam soil strength properties would be required. The potential variation of assumed subsurface dam properties would likely result in a wide range of displacements making any conclusions tenuous. Additional subsurface explorations are recommended to define the nature and extent of the materials in the embankment and abutments to improve the confidence of the liquefaction and stability study results.

2.8.4 Geology

No activity since 2007

2.9 Lands, Easements, Rights-of-Way, Relocations & Disposal Areas (LERRD)

Estimated LERRD costs for the authorized project total approximately $13,334,400, including a 20% contingency. The portion of non-Federal incidental costs associated with LERRD acquisition and certification activities total approximately $1,452,000. The estimated cost for project lands is estimated at $11,882,400, including a 20% contingency. Estimated Federal costs associated with the Certification of Lands and implementation of the proposed project total approximately $669,600, including a 20% contingency.

2.10 Cost Engineering

2.10.1 2003 Total Project Cost

The 2003 estimate was based on a 35% design. A contingency of 35% was used on costs associated with modifications to Schookumchuck Dam and contingency of 25% was used on costs associated with levees and floodwalls. The 2003 Government Cost Estimate was developed by Walla Walla Corps of Engineers, Cost Engineering Section from information and design provided by the Project Sponsors contractor and Corps Staff.

A preliminary review of the 2003 Cost Estimate conducted in 2011 by the Seattle District Cost Engineering section found that the 2003 current working estimate (CWE) did not include the following required markups; Job Office Over Head (JOOH), Home Office Overhead (HOOH), profit, bond, insurance, & excise tax. The review also found that the estimated haul distance for materials was low at 3 miles per round trip and no load, haul and disposal of excavated material on-site was included. In addition estimated fuel prices could not be verified in the 2003 estimate. The conclusion of this review was that it is likely that the 2003 estimate could be too low due to the missing markups, minimal haul distance, no disposal costs of excavated materials and fuel prices.

2.10.2 2011 Total Project Cost

The 2011 Total Project Cost (TPC) fully funded project estimate was found to be $205,423,000. This estimate was developed and reviewed by the Seattle Cost Engineering section and considered to be more conceptual (10%) in comparison to 35% engineering designs, with contingency developed through evaluation of project risks. The updated design and cost estimate were required by the 2004 Chief of Engineers Report. Per provisions provided in ER 1110-2-1302 (Civil Works Cost Engineering), EI 01D010 (Construction Cost Estimates, and ETL 1110-2-573 (Construction Cost Estimating for Civil Works) and using assumed risk, cost engineering set a contingency of 63% on costs associated with modifications to Skookumchuck Dam and a contingency of 45% on costs associated with levees and floodwalls. The contingency applied for the levees and floodwalls was based on uncertainties in the current level of design, including incomplete design, undefined mechanical systems, and uncertain environmental mitigation requirements. Reference the attached spreadsheet in the appendix for a break out of contingency calculation for Skookumchuck Dam. The escalation cost factors used for the 2011 estimate were determined from EM 1110-2-1304 Civil Works Construction Cost Index System.

Costs and contingencies associated with Lands, Easements, Rights of way, Relocations, and Disposal (LERRD) were provided by the USACE Seattle District Real Estate section (Section 2.9).

The 2011 TPC includes additional cost elements that were not included in the 2002 estimate. Additional cost elements that were added to the 2011 TPC include increased haul distances, load & haul costs for excavated material, a cofferdam, diversion of water, grouting and relief wells, intake tower, bridge, gates, stop logs and associated hydraulic systems.

2.10.3 Comparison of 2003 versus 2011 Total Project Cost

In comparing the 2003 versus the 2011 costs, the following information was determined:

- Due to the use of the assumed risk, contingencies of planning, engineering and design (PED) and construction management costs increased from 2003 to 2011.
- The PED cost for 2003 was $4.5 Million ($6.0 M 2010 dollars) whereas the PED cost in 2011 is $18.6 Million (in 2010 dollars).
- The construction management cost for 2003 was $4.5 Million ($6.0 M 2010 dollars) whereas the construction management cost in 2011 is $18.6 Million.
- Actual estimated PED and construction management costs were determined but were based on percentages of construction cost provided the PM.

In addition, the unburdened cost (capital cost excluding contingency, oversight and contractor profit) for Skookumchuck Dam modifications in 2003 estimate was reported to be $4.8 Million ($6.3 Million in 2010 dollars). The unburdened cost for Skookumchuck Dam modifications in 2011 is estimated to be $12.1 Million.

The estimated contract cost for levees and floodwalls in 2003 is $29.4 M ($38.7 M in 2010 dollars) versus estimated contract cost for levees and floodwalls in 2011 is $68.4M (in 2010 dollars).

3 MAJOR REMAINING TASKS

3.1 Hydrology and Hydraulics

The main outstanding H&H related task is to finish the technical documentation regarding the hydraulic modeling in preparation for a formal review. This effort is currently about 50-percent finished.

As the focus the last four or five months has been on the FDA analysis, the H&H documentation of this part is incomplete. In coordination with Economics, technical documentation for the risk-based analysis need to be prepared to a level required for a formal technical review.

Below is a list and brief explanation of some of the recommendations for future H&H related work on this project. These efforts would be necessary for any of the options recommended in

Section 4 but would be dependent upon what locations were focused on under any of the potential paths forward.

- Check and adjust the geo-referencing of the HEC-RAS model cross sections and storage areas. This does not impact the hydraulic computations but it would make generating inundation maps a lot easier. Currently the model has some gaps between storage areas and cross sections as well as between storage areas that are adjacent to each other.
- Reconfigure China Creek in the model to reflect actual physical conditions. Currently (as was done in 2003) China Creek is modeled simply as several storage areas connected by topographic features acting like weirs. It was done this way in 2003 as the real concern was how much, and how far up, the project increased water surface elevations on the lower portion of China Creek.
- Remodel the West Centralia (Outlet Store Area) location using either a 2D model or within the RAS model as a series of storage areas connected to each other based on appropriate features. Under the existing model this area is difficult to capture accurately. This area can be flooded from the Skookumchuck River flowing overland by way of Reynolds Avenue. The RAS model can handle the water getting to Reynolds Ave accurately. However, once the water starts to flow to the west side of I-5 modeling results become muddled. In order to mitigate for this the reach was modeled with a very high roughness value to try to capture the possible route of flowing water.
- A more detailed regulation plan for Skookumchuck Dam needs to be developed and an analysis performed that reflects the imperfect nature of the data used and the humans operating the project. Flood Regulation Details. The ‘regulation plan’ used to derive the with project discharges was simplistic and potentially overly optimistic as to how the 11,000 A-F of flood storage could be managed. The approach (as was the case with the 2003 work) was based on having perfect information and is not realistic. The rule curve for Skookumchuck Reservoir elevations shows the minimum flood season drawdown to be elevation 455 ft. If the project were to have a seasonal rule curve where summer or non flood season pool elevations would be higher, then these ‘shoulder’ periods should be looked at closely to ensure they occur during times when they do not increase flood risk.
- It is suggested that more effort be spent collecting observed water surface elevations for frequent events to verify the model better. Typically there is interest in getting the details of large floods correct in the hydraulic models. However, in this case the results of the FDA analysis appear to be very sensitive to the more frequent events- the 10, 20 year events. Given the nature of this system, it is believed the energy loss mechanisms are different and/or greater for large floods versus small ones. For example, there are locations where the floodplain is wide and the river very sinuous. Literature indicates that for these reaches, and for large floods with lots of water in the floodplain, the channel-floodplain interaction could very well be introducing another energy loss component that, within RAS would be reflected as a higher n value. These are the type of events that our models tend to be calibrated to. There have been attempts to reflect this to the limited degree data and literature allow. Collecting comprehensive water surface elevations for frequent events would improve the product for the type of economic analysis a flood risk reduction project requires.

- Addition of new stream gages. One of the biggest problems with this system is quantifying the hydrological contributions of the small, mid-basin tributaries. While there are a lot of gages in the Chehalis basin, there really are not any (the Newaukum come closest) that are representative of the physical characteristic found with sub-basins like Hanford Creek or Scatter Creek. Hopefully the two new streamgages (Elk and Salzer Creeks) funded by the Corps' basinwide G.I. will help fill some gaps.
- Additional analysis should be performed to see if the magnitude of the flow leaving the Newaukum River and going to Dillenbaugh Creek can be quantified. At very high flows, the Newaukum River, upstream of the streamgage, can overflow into Dillenbaugh Creek. This causes two problems. 1) The Newaukum record probably is resulting in lower flows on the upper portion of the frequency curve and 2) Dillenbaugh is seeing more flow than it can generate based merely on its basin area.

3.2 Economics

As with H&H, the focus has been on FDA analysis and obtaining a reasonable estimate of the BCR. The main outstanding economic related tasks are:

- Incorporate the structures in the 500-year flood plain outside of Lewis County
- Complete the estimation of damages for Agriculture, Public Infrastructure, and Transportation Impacts
- Complete technical documentation.

3.3 Environmental Analysis and Mitigation

3.3.1 Mitigation Assessment

The mitigation assessment was not completed and the assessment needs to be reformulated using a new methodology which is better suited to assessing project impacts (see section 4). In addition, fisheries impacts from Skookumchuck Dam modification need to be assessed. Formal coordination with FAA is required to determine if potential mitigation sites are located at a sufficient distance from the Centralia Airport. NRCS needs to be contacted concerning impacts to prime and unique farmlands.
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3.3.2 Project Alignments

Following the mitigation sequencing guidance, alignment changes were assessed in three areas (Fairgrounds, Landfill and the WDFW Pheasant Farm). Designs for each of these alignment changes will be refined in the next study pahse.

There is one more mitigation change that was proposed along Dillenbaugh Creek. The proposal is to divert Dillenbaugh Creek into another old stream channel which would affect the proposed levee alignments in the area. This change has been proposed but has not made any forward progress and needs to be examined for potential mitigation of fish impacts. (also impacts to RE, Civil, Geotech, H&H, archaeology).

3.3.3 Recommendation for future work: Mitigation Model reformulation

The existing mitigation model is outdated and does not have the proper documentation to successfully go through Corps model review. Based on agency input and documented reluctance to move forward with out-of-kind mitigation without more documentation, it is recommended that future mitigation formulation focus on working with 3 to 5 separate environmental accounts based on the impact areas of concern scoped above. The accounts could be wetlands, fisheries, riparian, water quality, and floodplains. For wetland impacts, the Washington State Department of Ecology Wetlands rating system could be used. This will also meet Ecology's 401 certification requirements. Fisheries impacts could be evaluated using the EDT methodology which has been developed for the Chehalis system. Riparian forest impacts and mitigation could be evaluated using existing HEP models such as yellow warbler to assess riparian impacts. The use of separate accounts will make it simpler for agencies to buy off on mitigation formulation. If there is a need to combine the analyses to come up with one number and facilitate out-of-kind mitigation, then a Multi-Criteria Decision Making (MCDM) methodology should be applied to the analysis. There might be some problems with double counting of impacts but if we allow for the use of the same mitigation sites for mitigation of separate accounts that should cover this issue. Other items to consider are how preservation will be credited, and how time lag for mitigation will be handled. Successful implementation of WRDA 2007 Mitigation guidelines should help avoid this concern since mitigation would be accomplished either before or concurrent with the project construction. The use of mitigation banks should continue to be pursued.

Another issue to keep track of in the future is impacts to Heritage oaks and prairie areas. A separate methodology will need to be developed to assess.

3.3.4 Project Alignments and new alignments

All new and existing project alignments need to be reexamined to determine if there are other alignment shifts that could reduce direct project environmental impacts.

3.4 Cultural Resources

3.4.1 Archaeology

In addition to the AMEC task order, a sole source contract was awarded to the Chehalis Tribe to prepare and Ethnographic and Traditional Cultural Properties study in cooperation with the Cowlitz Tribe. At the present time an early draft of the report is being reviewed. This contract is scheduled to be totally completed and closed out by the end of FY11.

The project archaeologist is presently working with the Chehalis Tribe to develop artifact donation forms that will be sent to the respective land owners requesting that they donate all cultural material and records resulting from the studies carried out on their lands to the Tribe. The 2011 AMEC confidential report made recommendations for additional testing at all three levees during the final design stage of the project. Also, due to the high number of archaeological sites anticipated to be located along the new levee route, professional archaeological monitoring should be planned for during all ground disturbance activities related to project construction. Once right-of-entries are received for the proposed new levee route intensive archaeological surveys will be necessary in order to comply with the NHPA. In addition, if work is proposed at the Skookumchuck Dam that has the potential to affect historic properties, it may be necessary to conduct additional testing and data recovery at significant archaeological sites discovered during Corps initiated studies carried out in 2001.

3.5 Engineering Design and Analysis

3.5.1 Civil Engineering

1) There is one more mitigation change that was proposed along Dillenbaugh Creek. The proposal is to divert Dillenbaugh Creek into another old stream channel which would affect the proposed levee alignments in the area.

2) The Regional Waste Water Reclamation Plant on Louisiana in Chehalis was established to have been built using the NAVD 29 datum. The existing levee around the plant was built at elev. 180 ft but the 2002 and 2010 plans show the new levees to have an elevation of 182 ft. The preliminary 2011 project levee elevation in this location indicate approximate levee elevation of 184.5 feet. These levees should undergo redesign to accommodate the 100 year level of protection.

3) The elevation of I-5 was also compared with the 2010 and 2011 elevations elevations. There is a concern at the end of Reach 10 where the edge of I-5 is lower than the end of the flood wall. Also the Salzer Creek Bridge is lower than the surrounding levees.

4) For the 2011 plans, all of the alignments need to be extended to high ground. The alignments need to be shifted in order to keep from encroaching on the river, buildings, and roads.

3.5.2 Geotechnical Engineering

- As mentioned in Section 2.6.2, the current study was performed on three reaches. The results indicate that the Pf depends on levee height, geometry, water level, and significantly on selected ranges of strength and hydraulic soil properties. Therefore, the future geotechnical work should focus on finishing the Pf analyses on the remaining 13 reaches with refinement in the selection of representative cross sections and soil properties if more information is available.

- To enhance the accuracy of the obtained results, it is recommend to perform more subsurface explorations consisting of adequately spaced boreholes with adequate depth at all the 16 reaches. The boreholes could be supplemented with CPTs, which require relatively less time and cost, in order to capture the variation in the subsurface conditions between the boreholes.

- A comprehensive lab test program is recommended on selected soil samples to accurately model the soil properties and hence their practical ranges of variation. The soil tests may include, sieve analysis, moistures content, hydrometer, Atterberg limits, and consolidation.

3.5.3 Recommendation for future work

To reduce some of the more significant unknown factors, SPT borings should be conducted in the downstream slope of Skookumchuck dam. The results of these explorations would be used to evaluate the liquefaction potential and undrained residual shear strength of the foundation soils at these exploration locations. Two-dimensional site response modeling and Newmark (1965) slope displacement analyses could be performed to estimate dam crest displacements if the subsurface conditions beneath the dam shell and shear wave velocity of the dam foundation and shell were known. Two dimensional site response modeling could be used to perform post-seismic deformation analyses that could be used to evaluate the suitability of raising the operating pool to higher levels. In addition, it is recommended that explorations such as backhoe test pits be accomplished along the crest to evaluate the as-built top of the core of the dam.

Lands, Easements, Rights-of-Way, Relocations & Disposal Areas (LERRD)If the project is to continue under the existing authorization in some form or through any of the four recommendations provided in Section 4, Rights of Entry for additional environmental mitigation assessments, design and geotechnical analysis would need to be obtained. A takings analysis for the project would also need to be completed. An update to the estimated land costs would need to be accomplished as well as an update to the REP which was previously accomplished for the Chehalis GRR report in 2003. Lastly, any construction activity would require land acquisition by the non federal sponsor.

3.6 Cost Engineering

If the project is to continue under the existing authorization in some form, associated cost estimates for each level of design would need to be performed. For the final design, a government cost estimate and BCOE would also need to be completed.

4 RECOMMENDATIONS AND CONCLUSIONS FOR FUTURE WORK

The following options were identified in a conference call with Northwestern Division for proceeding forward on the Centralia Flood Damage Reduction Project:

1. Because the B/C is below 1, upon the sponsor’s request, terminate the project. Flood solutions may be pursued under the Chehalis Basin GI (need local sponsor) or as smaller components under a CAP authority.

This option would be able to utilize existing data developed under the Centralia Flood Damage Reduction project. While this data would not be counted for in-kind services towards the non-Federal cost share, it would lower the overall total project cost. One aspect of this option would be that there would be no competing projects vying for benefits. All benefits in the study area would be claimed by one project. Because a GI for the Chehalis Basin focusing on ecosystem restoration is currently active, work in kind is creditable at the present time. Crediting for in kind services associated with flood damage reduction is not creditable until a non federal sponsor commits to supporting the flood portion of the study. Accelerated or advanced funding from a non federal sponsor for the GI is not expected to be available in the near future. Executing a study under a CAP authority is also a future option, however, is not viable presently because

HQUSACE is not allowing initiation of new start CAP studies. Once new starts are allowed under the CAP authority, small scale flood or ecosystem restoration project would be a potential path forward in the Chehalis basin. These studies have a limit on federal funding but could include studies such as non-structural solutions, improved protection for small levee segments (e.g. the waste water treatment facility), or small ecosystem restoration studies that provide ancillary flood storage. The timeline for CAP studies from initiation to construction is more expedited relative to the GI process. The timeline for a dual purpose GI is on the magnitude of several years to study completion. Design and construction after Congressional authorization would also take multiple years to complete.

2. Because the B/C is below 1, upon the sponsor's request, fully reformulate the project under a General Reevaluation Report.

Under this option, a General Reevaluation Report would be developed. The study could utilize existing data from the previously authorized project but would be required to conduct a full scale feasibility study and meet all necessary HQUSACE milestones. Under this option, many of the remaining tasks under Section 3 of this report would be pursued to support reformulation. The scope of the study could be similar to the Centralia Flood Damage Reduction project or could be expanded to include a basin wide analysis. This option would require new congressional authorization for construction under a WRDA.

3. Conduct a limited Post Authorization Change Report and remove unjustified separable elements or modify separable elements to a level where they are justified.

This option would require an initial technical analysis of the existing authorized project to determine if any features within the project could be considered separable and stand alone. These features would have to provide protection without significant additional modifications that would go outside of the scope of the existing authorization. Minor design modifications to provide additional level of protection could be identified as a Locally Preferred Plan and would, at a minimum, require HQUSACE approval. Design of separable elements would be initiated at a 10% design level due to the existing progress of the Centralia Flood Damage Reduction project. There are uncertainties with moving forward with this option as it is not yet know if there are feasible separable elements that are both stand alone and economically justified. Under this option, many of the remaining tasks under Section 3 of this report would be pursued to support applicable separable elements. This option would allow for more timely construction of flood protection features without wholly relying on a new study. There are some remaining policy issues associated with this option that have not been fully analyzed. Additional coordination is needed with the District Chief of Planning and vertical coordination to determine if individual elements of an authorization can be executed while the project as a whole remains unjustified. Additional information will be added to this section once those policy issues are resolved. Additional examples of potentially viable separable elements will also be provided at a later date.

4. Execute option 3 above and concurrently proceed forward with a basin wide flood risk management study under the Chehalis Basin GI.

This option combines portions of option 1 and 3 mentioned above. This option would allow for some features to get constructed without requiring congressional authorization yet include a basin wide study approach and implementation of future flood risk management measures to address more widespread flooding. The same caveats as mentioned in options 1 and 3 above are also applicable under this option.