

**LEVEE SETBACK FEASIBILITY ANALYSIS
PUYALLUP RIVER WATERSHED
PIERCE COUNTY, WASHINGTON
JUNE 19, 2008**

**FOR
PIERCE COUNTY PUBLIC WORKS & UTILITIES**

**Levee Setback Feasibility Analysis
Puyallup River Watershed
Pierce County, Washington
File No. 2998-012-00**

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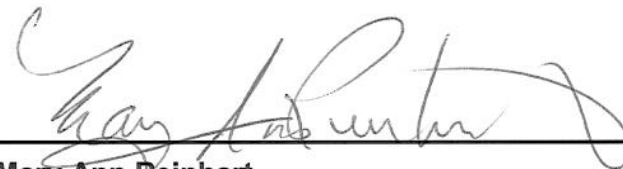
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TABLE OF CONTENTS

	<u>Page No.</u>
ACKNOWLEDGEMENTS	ACK-1
EXECUTIVE SUMMARY	ES-1
INTRODUCTION.....	1
REPORT ORGANIZATION.....	1
PROJECT BACKGROUND.....	1
PROJECT PURPOSE.....	2
PROJECT APPROACH	3
INITIAL APPROACH	3
FINAL PROJECT APPROACH.....	4
PRODUCTS AND MAJOR DELIVERABLES.....	4
SITE SELECTION.....	5
FEASIBILITY CRITERIA.....	6
PROJECT COSTS AND LAND AVAILABILITY FACTORS.....	6
PHYSICAL SITE ATTRIBUTES.....	6
GOAL 1 – INCREASE FLOODPLAIN CONNECTIVITY AND FLOOD STORAGE	7
GOAL 2 – REESTABLISH SHORT AND LONG-TERM GEOMORPHIC PROCESSES AND FUNCTION.....	8
GOAL 3 – MAXIMIZE AQUATIC HABITAT DIVERSITY AND USE	9
SITE PRIORITIZATION	9
PRIORITIZATION WORKBOOK.....	9
Assessment, Weighting and Ranking.....	10
NORMALIZATION.....	11
FEASIBILITY STUDY RESULTS.....	11
ESTIMATED PROJECT COSTS	11
LAND AVAILABILITY	12
Objective 1.1 – Maximum Area of Floodplain Inundation.....	12
Objective 1.2 – Maximum Storage Volume	12
Objective 1.3 – Minimize Remedial Actions	12
Objective 1.4 – Improve Flood Protection	12
Objective 2.1 – Promote Channel Migration within the Mapped Severe and/or Moderate Migration Potential Areas	12
Objective 2.2 - Promote Increased Channel Complexity and Multi-Channel (Braided) Reaches.....	13
Objective 2.3 - Promote More Natural Sediment Conveyance and Storage Processes	13
Objective 2.4 - Promote Natural Large Woody Debris (LWD) Recruitment and Pool Formation.....	13
Objective 2.5 - Minimize Downstream Impacts	13
Objective 2.6 - Improve Connectivity to Tributaries, Potential Wetlands or Springs, and Existing Secondary and Abandoned (Historic Meander) Channels	14
GOAL 3 - MAXIMIZE AQUATIC HABITAT DIVERSITY AND USE	14
FINAL PROJECT RESULTS.....	14
REFERENCES.....	15

TABLE OF CONTENTS (CONTINUED)

List of Tables

Table 1. Site List

List of Figures

Figure 1. Vicinity Map

Figure 2. Site Plan

APPENDICES

Appendix A – SRFB Grant, TAG and TIM Memorandums

Appendix B – Methods

Appendix C – Geomorphic Processes, Hydraulics and Hydrology

Appendix D – Site Catalogue

Appendix E – Prioritization Workbook

Appendix F – Limitations

Plate 1

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- Pierce County (PC)
 - Randy Brake – PC Water Programs Division
 - Hans Hunger - PC Water Programs Capital Improvement Program Manager
 - Dan Wrye - PC Water Programs Program Services Manager
 - Harold Smelt – PC Water Programs Manager
- TAG Members
 - David Renstrom - PC Water Programs Division
 - Tom Kantz - PC Special Projects
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EXECUTIVE SUMMARY

The Puyallup River is the primary drainage channel for the Puyallup Watershed, which drains the west and northwest sides of Mount Rainier and surrounding foothills. The Carbon and White Rivers are the major tributaries of the Puyallup River. The Puyallup Rivers has been confined by revetments and levees to reduce flooding and to open the floodplain to rural, industrial and residential development since about 1906. Most sections of the Lower Carbon and White Rivers have been similarly confined since the mid-1960's.

Pierce County Public Works and Utilities, Water Programs Division (Pierce County) contracted GeoEngineers, Inc. (GeoEngineers) to conduct a Levee Setback Feasibility Study for portions of the Puyallup, Carbon and White Rivers in Pierce County, Washington. The study was made possible by a grant from the Salmon Recovery Board (SRF Board) in 2005. Pierce County intends to use this study as a tool to evaluate the feasibility of 32 setback projects that would best reestablish dynamic channel forming process and recapture lost flood storage. The study also assesses which levee setback projects are best suited to restoring salmon habitat and salmon recovery. The 32 projects include 20 sites along the Puyallup River, 6 sites on the Carbon River and 6 sites on the White River. The study area is shown on Figures 1 and 2.

Pierce County created a project team to assist in the selection of proposed project sites and to determine criteria for the levee setback feasibility study. The project team consisted of members of Pierce County Water Programs staff, a Technical Advisory Group (TAG) convened by Pierce County Water Programs staff, and GeoEngineers. The TAG provided project sites for consideration and recommendations regarding the project approach, evaluation criteria, analytical methods, and a site prioritization strategy. The final approach and levee setback feasibility study criteria adopted by the project team, Pierce County and the TAG was developed in response to recommendations provided by the TAG.

A Prioritization Workbook and Site Catalogue were developed to assist Pierce County in assessing the feasibility of levee setback at the 32 sites using the adopted criteria. The Prioritization Workbook also included a function that allowed Pierce County to assign a weight to the criteria based on the considered importance of the criteria at the time of application. The Site Catalogue summarized site characteristics and some of the criteria used in the Workbook. The main criteria included:

- Project Costs,
- Land Availability,
- Goal 1 – Increase floodplain connectivity and flood storage,
- Goal 2 – Reestablish short and long-term geomorphic processes and function, and
- Goal 3 – Maximize aquatic habitat diversity and use.

Based on the current criteria and assigned weighting the top site for each water shed included South Fork (Site 14) on the Puyallup River, Alward Road (Site 26) on the Carbon River, and Countyline (Site 32) on the White River. Thirty percent design plans were completed for the South Fork Setback and Alward Road Setback Sites. A 3-D animation depicting the 32 sites at the 100-year flood state, both before and after levee setback as a public information/education and funding opportunity tool.

**LEEVE SETBACK FEASIBILITY ANALYSIS
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INTRODUCTION

This report presents the results of a Levee Setback Feasibility Analysis for the Puyallup, Carbon and White Rivers in Pierce County, Washington. The study area is shown on Figures 1 and 2. The project was originally visualized by staff from the Pierce County Department of Public Works and Utilities; Water Programs Division, and made possible in 2005 by a grant from the Salmon Recovery Funding Board (SRF Board). The grants are provided in Appendix A.

GeoEngineers, Inc. (GeoEngineers) was contracted by Water Programs Division to execute the project which included evaluating and developing a prioritization strategy for a total of 32 sites in the project area, including 20 sites on the Puyallup River, 6 sites on the Carbon River and 6 sites on the White River. The project was conducted under Pierce County Master Agreement No. 06-53106 (Work Order #1386-124-2).

REPORT ORGANIZATION

The following report presents the results of a multidisciplinary feasibility study involving the compilation of a large volume of information. Principle project components discussed in the report include the project background, the feasibility approach, prioritization strategy and general results.

Detailed discussions regarding the approach, methods, analyses and site characteristics are provided in the following appendices:

- Appendix A –Meeting Notes and Technical Memorandums
- Appendix B – Methods
- Appendix C – Geomorphic Processes, Hydrology and Hydraulics
- Appendix D – Prioritization Workbook
- Appendix E – Site Catalogue
- Appendix F – 30 Percent Design
- Appendix G – 3-D Flyover

PROJECT BACKGROUND

The Puyallup River Watershed drains the west and northwest sides of Mount Rainier and adjacent foothills. The Puyallup River is the primary drainage channel for the watershed; the Carbon and White Rivers are major tributaries of the Puyallup River. Combined, the three sub-basins drain approximately 900 square miles.

Historically, the Puyallup River Watershed consisted of two major sub-basins, the Puyallup and Carbon. However, a flood in November 1906 diverted the White River from its historic channel to a new channel alignment through the Stuck Valley and into the Puyallup River. The diversion added a large portion of the White River sub-basin to the Puyallup watershed. The new White River channel is likely still

adjusting to changes in the natural and developed environments, which include the influence of the Mud Mountain Dam and confinement by levees and revetments.

Beginning in 1906, levees and bank revetments were constructed along the lower Puyallup River downstream of Sumner. The levees reduced flooding and opened the floodplain to rural, industrial and residential development. Remaining sections of the Puyallup River and most sections of the Lower Carbon and White Rivers have been similarly confined since the mid-1960's.

Historic aerial photographs taken prior to levee construction show that many sections of the three rivers were up to three times wider than the currently confined river channels. The air photos also indicate that the main channels migrated laterally across the valley floor. In many places, levee placement not only straightened the channels, but also substantially altered the form and function of the main stem channels. The levees also disconnected the rivers from their respective floodplains. Over the past several decades the floodplains have been utilized for agriculture and, more recently, for urban development.

Detachment of the floodplains from their channel systems has resulted in the loss of channel complexity (multiple channels, meander bends, gravel bars) and floodplain process and function (flood water and sediment storage, riparian and wetland development). These changed conditions greatly reduced off-channel aquatic and riparian habitat for both fish and wildlife by reducing available food sources, cover, and water resources.

PROJECT PURPOSE

The principle purpose of this project is to evaluate and prioritize sites within the project best suited for setting back existing levees. This project is based on the premise that setting back levees will reconnect the main stem channel with its floodplain, which will in turn recover lost flood storage and aquatic habitat. This premise is consistent with established ecosystem restoration guidelines, which have shown that floodplain connectivity fosters dynamic channel forming processes, and that self-sustaining aquatic habitat follows healthy in-channel processes (Ehrenfeld 2000, Bates 2003). Recovery of aquatic habitat in this manner achieves the additional benefit of eliminating the exorbitant costs associated with multiple aquatic habitat restoration and flood storage projects.

The levee setback feasibility analysis project identified and ranked sites based on two factors:

1. The estimated property acquisition and project construction costs.
2. Physical site attributes and the ability of a site to recapture
 - Flood storage capacity
 - Dynamic channel forming, geomorphic processes, and
 - In-and off-channel aquatic habitat.

Additional components of the Levee Setback Feasibility study included the completion of 30 percent design plans for the South Fork Setback Levee and the Alward Road Setback Levee along the Puyallup and Carbon Rivers, respectively. A 3-D animation depicting the project area in flood state, both before and after the setback was also developed.

PROJECT APPROACH

INITIAL APPROACH

Initial evaluation of primary project goals and the variety of physical environments represented within the project area identified the need for a comprehensive approach of considerable breadth. The complexities of addressing and analyzing physical site attributes and cost factors required not only a multidisciplinary approach, but also consultation with stakeholders and other knowledgeable parties. At a minimum, the disciplines interacting over the course of the project included hydrology, riverine hydraulics, floodplain modeling, fluvial geomorphology, GIS/LiDAR modeling and analyses, fisheries biology, river engineering, and geotechnical engineering.

Consultation was provided by a Technical Advisory Group (TAG) convened by Pierce County Water Programs staff. The TAG consisted of representatives from Pierce County, King County, Puyallup Tribe, Muckleshoot Tribe, U.S. Army Corps of Engineers, Bureau of Reclamation, Washington State Department of Ecology, Washington State Department of Fish and Wildlife. The list of TAG members is provided in Appendix A. The TAG provided project sites for consideration, and recommendations regarding the project approach, suitability of prescribed evaluation criteria, analytic methods, and sites prioritization strategy. The comprehensive project approach adopted by the project team, Pierce County and the TAG, was developed in response to recommendations and dialog provided by the TAG.

The original project approach presented to the TAG is described in our Pierce County Scope of Services dated July 25, 2005 and summarized in Technical Information Memo #1 (TIM) dated January 27, 2006 (provided in Appendix A). This approach was based on a “process of site elimination” executed through several tiers of analyses. In this approach, all sites, regardless of the river system and/or river mile location, were to have been submitted to the analyses comprising a tier, and the poorest performing sites eliminated from further consideration. The elimination process was intended to admit to the final, most rigorous tier of analyses, only those sites most likely to achieve positive results following the setting back of levees.

Upon review of the original approach, the TAG expressed concerns regarding 1) the site elimination approach, and 2) the evaluation and comparison of individual sites relative to all sites in the study. The TAG recommended that early elimination of less favorable sites be abandoned in favor of subjecting all sites to all analysis, and prioritizing the entire suite of sites from most to least favorable with respecting to achieving primary project goals.

Several members of the TAG also recommended that the site prioritization process be conducted for each river system; in other words, three separate sets of prioritized sites would be produced, one each for the Puyallup, Carbon and White River systems. This recommendation stems from concerns that the significant physical age-related differences between the lower White River and the other two river systems represented a potential disadvantage to the White River sites.

Based on these and other comments and recommendations, the original project approach was revised and adopted by the TAG and Pierce County Water Programs. Information regarding the evolution of the project approach is summarized in our TIM #1 dated January 27, 2006 and TIM #2 dated March 3, 2006 in Appendix A. Meeting notes from the project review meetings are also presented in Appendix A. The final approach is presented below.

FINAL PROJECT APPROACH

The final approach adopted by Pierce County Water Programs Division and the TAG includes the following elements:

- Select a list of levee setback sites based on an agreed upon set of guidelines and parameters.
- Rank 32 selected sites based on the feasibility of setting back the levee at each site using three goals, each with multiple objectives developed by the Project Team, Pierce County and the TAG. The objectives for each goal include rigorous analysis involving qualitative and quantitative analysis to determine the following:
 - Floodplain elevations favorable for achieving main channel connectivity with the floodplain following the setback
 - Presence of abandoned channels and/or topographic low points on the floodplain surface
 - Flood storage capacity
 - Character of existing in-channel geomorphic processes
 - Sufficient sediment transport capacity to accommodate site needs
 - High potential for channel forming processes to improve aquatic habitat without intervention
- Evaluate each site using a property acquisition cost/benefit analysis and the potential for property acquisition.
- Evaluate each site using estimated levee setback project costs.
- Develop a strategy and methodology to prioritize and weight sites.
- Design a prioritization workbook spreadsheet to compile selected site attributes, results of quantitative and qualitative analysis, acquisition costs, project costs, and weighted values for the 32 sites.
- Apply the prioritization strategy to the workbook and rank the sites

PRODUCTS AND MAJOR DELIVERABLES

Intermediate deliverables for this project included:

- Meeting notes with action items to be carried out by TAG, GeoEngineers and County
- Compilation of relevant existing GIS coverages
- TIM 1 describing criteria, methods, prioritization strategy, and draft scoping document for phases I and II
- Final draft scoping document for phases I and II
- Draft Prioritization Workbook dated August, 2006
- Draft report, 30 percent design drawings and documentation and 3-D fly over for County review

Deliverables for the project include:

- This final report
- A Site Catalogue containing detailed descriptions for the 32 selected sites
- HEC RAS models calibrated to the 2-year recurrence interval storm

- Relative Surface Elevation Model showing depth of flooding for the 2 year storm
- The Site Prioritization Workbook
- 30 percent Design plans for two sites
- A GIS generated 3-D fly-over showing the 100-year flood water surface with existing levees and proposed levee setbacks throughout the project area. The County intends to use the 3-D visualization as a public information/education and funding opportunity tool.

SITE SELECTION

A list of preliminary sites was compiled for the Feasibility Study from several sources:

- Thirteen potential habitat restoration sites identified in the “Restoration Opportunities on the Puyallup River: Restoration Site Catalogue” by Pacific International Engineering (January 1999). Most of these sites were selected for potential habitat expansion in the form of abandoned channels, oxbow lakes, and wetlands to benefit specific life stages of Chinook salmon.
- Eleven potential sites were identified in the Pierce County Comprehensive Flood Control Management Plan (CFCMP) (Pierce County 1991). The CFCMP site selections are based primarily on potential improvements in flood storage.
- Seven potential sites were identified by the TAG.
- Ten of the potential sites were identified by the project team and County Staff based on a preliminary evaluation.

These source lists comprised a total of 41 potential setback sites distributed throughout the project area, although many other sites likely existed on the Puyallup, and the Carbon and White Rivers that represent opportunities for channel/floodplain reconnection.

In general, the final site selection was based on the following criteria:

1. Site must be at least partly in Pierce County,
2. Site must be located within the Puyallup River Basin Valley (i.e. not a site in the foothills),
3. Site must be located on the Puyallup, White or Carbon River (i.e. not on a tributary),
4. Levees must exist on the site,
5. Site has not been restored or in the process being restored,
6. Sufficient data must be available from which to conduct specified analyses.
7. The site must be capable of meeting the proposed goals.

In March of 2007, GeoEngineers and Pierce County reviewed the 41 sites initially identified and, using the above criteria, selected 32 sites for the levee set back feasibility study.

The final sites selected included 20 sites on the Puyallup River, 6 sites on the Carbon River and 6 sites on the White River. The final site list and a list of sites that were not selected are presented in Table 1. The general locations of the 32 sites are shown on the Site Map, Figure 2. A detailed description of each site is presented in the Site Catalogue in Appendix E.

FEASIBILITY CRITERIA

The Project team developed the preliminary feasibility criteria for the levee setback study. The criteria included three goals, estimated project costs and land availability. The criteria were provided to the TAG and Pierce County for review and changes were made based on the review comments. Some of the information derived from these review meetings is summarized in our TIM #1 and TIM #2 and meeting notes prepared by Pierce County (Appendix A).

A brief summary of the goals, objectives, project costs, land availability and methods used to approximate the criteria is provided below. A more detailed presentation of the goals, objectives, and methods is provided in the Methods Section in Appendix B, Hydrology and Hydraulics Section in Appendix C, and in the Prioritization Workbook in Appendix D.

PROJECT COSTS AND LAND AVAILABILITY FACTORS

Projects costs and land availability are important measures of project feasibility, in terms overall project costs. Even though some of the sites look favorable for levee setback based on Goals 1, 2 and 3, the land may not be readily available to the County for purchase, or the cost of constructing a new levee may overshadow the benefit of the project..

The estimated project cost for each site includes rough estimates associated with 1) the purchase of the portion of the parcels that make up the site, 2) design and permitting, and 3) levee removal and construction costs of the project. Estimated construction costs were provided by Pierce County based on similar projects already completed by the County. Parcel prices are based on 2006-2007 market values. The estimate also includes maintenance and monitoring costs of \$10,000 for each project. Site land value and construction costs are normalized to eliminate biases based on site size and levee length Pierce County and private parcels are shown on Plate 1. Criteria associated with determining project costs are summarized in Appendix D, Figure D-2.

Land availability was evaluated using August 2007 county assessor data for the number of parcels contained within each site, as well as the number of parcels currently owned by Pierce or King Counties or that contain a County right-of-way. Availability also was assessed via a series of questions posed to Pierce County staff regarding their knowledge of land owner willingness to sell out, and local support for the project. Criteria associated with land availability are summarized in Figure D-3.

PHYSICAL SITE ATTRIBUTES

Physical attributes of sites were evaluated based on their ability to recover floodplain and channel processes, and potential habitat function as defined in the Project Purpose section of this report. Subsequently, feasibility criteria were developed to address the goals outline below:

Goal 1 – Increase floodplain connectivity and flood storage

Goal 2 – Reestablish short and long-term geomorphic processes and function

Goal 3 – Maximize aquatic habitat diversity and use

The ability of a site to meet these goals was addressed by one or more objectives, each of which consists of analyses designed to measure specific attributes. It should be noted that the three goals are interrelated and that some objectives may apply to more than one goal. (i.e. a levee removal that improved floodplain connectivity would likely also help reestablish geomorphic function that would likely create better fish habitat).

Following is a discussion of Goals and related objectives.

GOAL 1 – INCREASE FLOODPLAIN CONNECTIVITY AND FLOOD STORAGE

This goal is a major focus of the Levee Setback Feasibility Study. Four objectives were established to assess the potential for floodplain connectivity and flood storage following a levee setback. The methods used to evaluate Goal 1 Objective are summarized below.

Objective 1.1 - Maximize Area of Floodplain Inundation at High Frequency Storm Events

This objective uses water surface elevations predicted for the 2- and 5-year recurrence interval floods to evaluate the extent to which post-set back channel/floodplain connectivity is achieved. GeoEngineers modified and updated flood studies developed by Northwest Hydraulic Consultants for the Puyallup, Carbon, and White Rivers. The flood studies were developed from the US Army Corps of Engineers' Hydraulic Engineering Center River Analysis System (HEC-RAS) software. The updated models were used to calculate the extent and area of floodplain inundation expected from the 2- and 5-year recurrence discharges at each site (Figure D-4). HEC-RAS is the industry standard for one dimensional analysis to estimate water surface analysis and floodplain inundation.

Objective 1.2 - Maximize Storage Volume at Low Frequency Events

This objective uses calculated flood water volume on the floodplain as a measure of a site's flood storage capacity. Flood water storage was estimated based on HEC-RAS model results for a range of flows similar to the 25-, 50-, and 100-year recurrence interval storms over a range of storm durations. Large flood events in the Puyallup River watershed typically have a duration of greater than 96 hours. Events in the Carbon River typically experience a flood duration that lasts near 72 hours. Under regulation, the White River has a flood duration of about 30 hours.

HEC-GeoRAS was used to develop the stage-volume data required for each site. HEC-RAS was used to create models for each site showing the existing condition, the site with all the proposed left-bank levee setbacks in place and the site with all of the right bank setbacks in place (Figure D-5, Appendix D).

Objective 1.3 - Minimize Remedial Actions Necessary to Accomplish the Goal

This objective focuses on the potential for the main stem channel to reconnect with abandoned historic geomorphic or habitat-related features. This objective uses estimated volumes of excavated soil as a measure of the effort and cost required to achieve hydraulic reconnection with existing site features such as abandoned side channels. Estimated soil volumes were calculated using a standardized 100-foot-wide channel. The depth of the constructed channel was determined by estimating the difference between the elevation of floodplain feature and the elevation of surface water in the existing water course. The length of the excavated channel was measured from the feature to the main stem channel (Figure D-6, Appendix D)

Objective 1.4 - Improve and Maintain Flood Protection

This objective addresses the potential for a site to improve local flood protection. Several methods were used to determine if the set back project would improve flood protection, including replacing existing levees that are frequently overtopped or damaged, improving existing levees upstream, downstream and/or across stream, buying-out frequently flooded properties, and addressing levee conditions favoring the trapping of flood water on landward sides of levees (Figure D-7, Appendix D).

GOAL 2 – REESTABLISH SHORT AND LONG-TERM GEOMORPHIC PROCESSES AND FUNCTION

Goal 2 addresses the expected response of the river channel at each site to a levee setback. Preferable channel responses include the reestablishment of more dynamic flow patterns, channel alignments, channel forming processes, and channel complexity over time. Six separate objectives were established to evaluate channel response. The methods used to evaluate Goal 2 Objective are summarized below. A more detailed description and methodologies are included in Appendices B and C.

Objective 2.1 - Promote Channel Migration Within the Mapped Severe and/or Moderate Migration Potential Areas

This objective uses the presence of previously mapped Severe and Moderate Channel Migration Potential Areas (MPA) to measure the likelihood of reestablishing channel migration processes on a site following a levee setback. GIS methods were used to map and measure the MPA on a site. The MPA was compared to the total area of the site (Figure D-8, Appendix D).

Objective 2.2 - Promote Increased Channel Complexity and Multi-Channel (Braided) Reaches

This objective evaluated the site's ability to increase channel complexity by looking at the pre-levee channel patterns and conditions. The assessment method involved comparing the existing (2005) width of the high flow channel to the historic, pre-levee (1931) channel complexity. The existing width of the high flow channel is treated as a measure of the channels potential to move and respond favorably to the levee setback. The historic, pre-levee channel complexity is used as a measure of the potential post setback channel (Figure D-9, Appendix D).

Objective 2.3 - Promote More Natural Sediment Conveyance and Storage Processes

This objective evaluated the channels ability to transport and/or deposit sediment at the site before and after setting the levee back during the 5- and 25-year recurrence interval storm events. HEC-RAS was used to create three steady state models for the 5- and 25-year recurrence intervals. HEC-RAS was also used to calculate the critical shear stress values at several locations on the site. The critical shear stress values indicate the amount of force required to maintain transport or movement of particular grain sizes. These values were used to evaluate the sites ability to move or deposit sediment (Figure D-10, Appendix D).

Objective 2.4 - Promote Natural Large Woody Debris (LWD) Recruitment and Pool Formation

LWD within the channel and riparian vegetation in the adjacent floodplain contributes to channel forming processes and floodplain development. Riparian forests of any species and size are important in side channel development, pool and riffle formation, and aquatic habitat. Currently, very little in-channel LWD is present within the project area. This objective evaluated whether a site has the long-term potential to provide LWD to both main channel and off-channel areas and whether it has the short-term potential to provide LWD for habitat or pool formation within existing off-channel features following the setback. The relative quantity and density of riparian stands adjacent to floodplain features were determined from recent aerial photos and LiDAR. The presence of large conifers was estimated from aerial photographs and field observations (Figure D-11, Appendix D).

Objective 2.5 - Minimize Downstream Impacts

This objective assesses the potential for a levee setback to cause adverse impacts (flooding, erosion) on local or downstream infrastructure or channel conditions. Infrastructure considerations include existing levees, roads, bridge supports and abutments. Current sediment transport conditions were used to evaluate downstream impacts by estimating changes in erosion or deposition under the 5- and 25-year recurrence interval storm events. Critical sheer stress values estimated in Objective 2.3 were used to

determine the sediment transport capacity at a site and as an indicator of downstream impacts (Figure D-12, Appendix D).

Objective 2.6 - Improve Connectivity to Tributaries, Potential Wetlands or Springs, and Existing Secondary and Abandoned (Historic Meander) Channels

This objective uses the existence of existing tributaries, wetland, springs and abandoned channels as a measure of potential hydrologic connectivity between the floodplain features and main stem channel environments. Wetland and existing water feature locations were obtained from the Pierce County GIS hydrology and wetland databases. Side channels and springs were identified from the CMZ Analyses, infrared aerial photographs and topographic maps (Figure D-13, Appendix D).

GOAL 3 – MAXIMIZE AQUATIC HABITAT DIVERSITY AND USE

The objective of Goal 3 is to improve the existing salmonid habitat, including spawning, rearing and maturation habitats in existing high use areas. The Goal 3 objective incorporates habitat parameters from Pierce County's Ecosystem Diagnosis and Treatment (EDT's) model and the length of the EDT's Geographic Area (EGA) to apply a potential restoration benefit to each site. A weighting function is included to give a relative importance of Coho salmon (*Oncorhynchus tshawytscha*) to Chinook salmon (*Oncorhynchus kisutch*), if desired. Both Coho salmon and Chinook were weighted equally with a "1" for this project. GIS was used to determine the location of the EDT's geographic area and the EGA's restoration benefit length at each site, as well as the portion of the restoration benefit length occupied by the site (Figure D-14, Appendix D).

SITE PRIORITIZATION

Potential setback sites were evaluated and assessed based on the results of the individual analyses described above. The results of analyses reflect the strengths and weaknesses of each site as measured by the Objectives, and forms the baseline character is each site. Sites were then prioritized with respect to their specific drainages (Puyallup, Carbon, White River), the, and the level of importance (weighted value) assigned to specific Goals, Objectives, Project Costs and Land Availability, which were used as prioritization criteria. Given the number and variety of analyses, the project team developed a prioritization tool (an Excel Workbook) to aid in the identification of sites offering the greatest flood storage and ecologic benefit to a given drainage.

PRIORITIZATION WORKBOOK

The Prioritization Workbook was designed to provide an unbiased assessment of site benefits and setback feasibility from the cumulative results of analyses described above. The workbook performs the following functions:

1. Provides detailed information regarding the methods and variables used to evaluate the Objectives of Goals 1, 2, and 3, Project Costs and Land Availability
2. Calculates and correlates the results for each analysis and evaluation.
3. Tallies the resulting score of each criteria.
4. Prioritizes and ranks the sites from each river system based on weighted values assigned to Goals, Objectives, Project Costs and Land Availability.

The Prioritization Workbook was also designed as a flexible, interactive tool that can be modified to meet future Pierce County needs. A detailed explanation of the Prioritization Workbook is provided in Appendix D.

Assessment, Weighting and Ranking

The results of quantitative analyses and qualitative evaluations for each site were compiled on designated workbook spreadsheets; one spreadsheet per Objective. A summary of all input data and analytic results for each Objective are provided in Appendix D.

In preparation for prioritization, the results of each analyses were assigned an assessed value, based on the range of results produced from all sites. Typically, the assessed values were assigned on a relative basis as follows:

- NA = site could not be evaluated for this objective
- 0 = site did not meet the objective
- 1 - 4 = Based on a standard percentile method, which partitions the range of results from all sites in a particular river system. The results of specific analyses were partitioned into five percentiles: lowest, 25th, 50th, 75th, and 100th. A value of 4 was assigned to the lowest or highest percentile, depending on which value represented the most beneficial criteria for the site. A value of 1 was assigned to the least beneficial percentile.

The prioritization strategy was carried out in two stages: assignment of a weighted value of importance (Weighting Function) to individual Objectives, and then again to Goals 1, 2, 3, Project Costs and Land Availability. This strategy allowed Pierce County to plug in different Weighting Functions to help determine the sensitivity of some sites to changes in weighted value and overall perspective (i.e. determining what objectives are more or less important). Once established, the areas of greatest importance to the study were appropriately weighted.

Guidelines for assigning Weighting Functions to Objectives and Goals include the following;

- Assign Weighted Function values for Goals from 0 to 4
- Assign a Weighting Function of 0 to any Objective that has no importance to the prioritization.
- Apply a calibration factor to account for differences in the number of Objectives comprising each Goal. (See Appendix D)

The workbook was provided to Pierce County staff to develop Weighting Function values for Goal, Objectives, Project Costs and Land Availability. For the purposes of this project, Pierce County Staff assigned the following values to Weighting Functions:

- Project costs = 1
- Land Availability = 2
- Goal 1 = 2
- Goal 2 = 2
- Goal 3 = 4
- Individual Objective 1.1: Weighting of 3
- Individual Objective 1.2: Weighting of 3
- Individual Objective 1.3: Weighting of 3
- Individual Objective 1.4: Weighting of 3
- Individual Objective 2.1: Weighting of 4
- Individual Objective 2.2: Weighting of 4
- Individual Objective 2.3: Weighting of 4

- Individual Objective 2.4: Weighting of 4
- Individual Objective 2.5: Weighting of 2
- Individual Objective 2.6: Weighting of 4
- Individual Objective 3.0: Weighting of 24

The Weighting Function values assigned by Pierce County staff place the greatest importance on environmental measures more beneficial to aquatic species and their habitat and to maintain consistency with the primary focus of the granting agency, the Washington State Salmon Recovery Funding Board (SRFB). Objectives 3.0, 2.1 through 2.4 and 2.6 were weighted heavily because of the direct relationships known to exist between healthy, dynamic channel forming processes, the development of diverse and sustainable aquatic habitat, and salmon recovery. While Objectives 1.1 through 1.4 are important factors in this project, the more immediate benefits are slanted more towards flood storage and protection. Therefore, the individual objectives under this goal received lower weighting values.

The final site prioritization for each of the Puyallup, Carbon and White River systems is provided on the Workbook Summary sheet, Figure D-1. The site with the highest Weighted Priority Value is given a System Rank of 1. Proposed sites with a rank of 1 represent the most favorable set-back sites, given the assigned weighting values for each Goal, Objective and Factor. Sites in the Puyallup River System are ranked values 1 through 20, sites in the Carbon River System are ranked values 1 through 6, and sites in the White River System are ranked values 1 through 6.

NORMALIZATION

In order to compensate for the variability in the site characteristics, Project Costs, Goal 1 and Goal 2 were normalized to remove the site bias that would be a factor when comparing the sites. Some site characteristics, like site area, land value, levee length, project costs, and flood inundation area, used in the matrix would give some sites an intrinsic advantage or disadvantage over other sites. For example: area and project cost are included as site characteristics; as a result, larger area sites might rank higher than smaller sites, but the cost of those larger sites might give the an intrinsically lower rank because cost is so much higher than for the smaller sites. To help minimize the affects of these characteristics, some of the values assessed to the site characteristics factors are normalized. This normalization allows the characteristics for each site to be evaluated as if each site is relatively the same size, construction costs at each site are about the same, etc.

FEASIBILITY STUDY RESULTS

A brief summary of the results of the feasibility study is provided below. Please refer to the Prioritization Workbook in Appendix D and the Site Catalogue in Appendix E for a complete summary of site characteristics and discussion.

ESTIMATED PROJECT COSTS

Generally, total project costs corresponded directly with the number of privately owned parcels contained within each site. Among the 32 sites, total project costs varied from \$17,891,867 for the Alward Road site (Site 26) (67 privately owned parcels) to \$2,223,543 for the Pacific Park site (Site 31) (0 privately owned parcels).

The length of levees to be removed at the sites ranged between 8,923 feet at the Alward Road site and 141 feet at the Interurban-White site. The length of levee setback ranged from 9,853 feet at the Alward Road site and 1,491 feet at the 24th Street East Setback (B) (Site 29) (Plate 1, Figure D-2).

LAND AVAILABILITY

Most of the proposed levee setback sites contain either private or County owned properties. Pierce County owns 100 percent of the Pacific Park site (Site 31) on the Carbon River. Pierce County owns from 0.5 to 80 percent of 15 sites; the remaining sites are privately owned.

The willingness of private property owners to sell out was provided by Pierce County staff. The assessment was based on the county's knowledge of owner interest in a potential buy-out. Property owners of 14 of the 32 sites were previously contacted; of these, 8 of the 32 sites responded with at least some interest in a property acquisition plan. At the time of the County evaluation, there was local support for 10 of the sites, and no support for 2 of the sites, the Carbon Confluence (Site 21) and the Right Bank Carbon (Site 22) (Figure D-3). Support for the remaining sites is unknown at this time.

Objective 1.1 – Maximum Area of Floodplain Inundation

The maximum annual area of floodplain inundation volumes over a five year period for the post setback sites ranged between 26,988 acre-feet of inundation at the Interurban-White Site (Site 27) and 2,111,168 acre-feet at the 116th Reconnection site (Site 10) (Figure D-4).

Objective 1.2 – Maximum Storage Volume

The Alward Road site (Site 26) showed the greatest ability to store water for the 25- 50- and 100-year flow events, while the 8th Street East Setback (B) site (Site 29) showed the least ability to store water for those same events (Figure D-5).

Objective 1.3 – Minimize Remedial Actions

Many of the sites contained desirable flood plain features, such as abandoned channels and wetlands, that are currently isolated from the main river channel. Nineteen of the 32 sites contain flood plain features that require no excavation to achieve reconnection following levee removal. Eight of the sites will require excavation, the amount of excavated soil required ranged between 17,642 cubic feet at the Calistoga, (Site 18) and 957,596 cubic feet Sumner Setback site (Site 15) at the site. Two of the 32 sites contain no flood plain features at all or they contain flood plain features that will not be inundated (Figure D-6).

Objective 1.4 – Improve Flood Protection

The Alward site (Site 26) was the most likely to improve flood protection. Construction of a new setback levee, designed to provide 100-year protection will reduce the extent of downstream flooding; it will also reduce repair costs that typically result from significant flooding events. The Countyline (Site 32) and the South Fork (Site 14) sites are the next highest ranking sites (Figure D-7).

Objective 2.1 – Promote Channel Migration within the Mapped Severe and/or Moderate Migration Potential Areas

Site areas for the 32 sites range between 150,649 square feet at the Interurban White site (Site 27) to 6,190,596 square feet at the Alward site (Site 26). The percent of the site area that is within the severe migration potential area ranged between 1 percent at the Interurban White site (Site 27) to 100 percent at the Sportsman Reconnection (Site 8), 190th Avenue Upstream (Site 20), Carbon Confluence (Site 21), Right Bank Carbon (Site 22) and Bridge Street (Site 24) sites (Figure D-8).

Objective 2.2 - Promote Increased Channel Complexity and Multi-Channel (Braided) Reaches

The average width of the historic (1931) active channel measured at all 32 sites varied from 100 to 160 feet. The average width of the historic (1931) high flow corridor measured at each site varied from 150 and 700 feet. Four sites were not covered in the 1931 photographs and, therefore, are not included in the calculations.

The average width of the existing active channel (2005) varied from between 64 and 230 feet, although the majority of the channel widths measured less than 100 feet. The average high flow corridor width in 2005 ranged between 106 feet and 400 feet.

Based on the review of the 1931 photographs, 17 of the 32 sites had complex channels. However, low channel complexity was observed in 2005, with only 1 to 2 channel threads observable at most of the sites. Three sites, 190th Avenue upstream (Site 20), High School (Site 23) and Bridge Street (Site 24), had 2 or more channel threads. All but four sites contained in-channel bars in the 2005 aerial photographs. The average 1931 and 2005 channel widths are presented in Appendix D, Figure D-9.

Objective 2.3 - Promote More Natural Sediment Conveyance and Storage Processes

Sediment conveyance and storage processes at the site were based on the estimated diameter of sediment grains and the force, or excess shear stress, required to transport the sediment at the 5- and 25-year recurrence intervals under both existing and future levee setback conditions. Sites were evaluated for sediment conveyance based on the relative differences between the upstream, middle and downstream shear stresses at a site. The results indicated that sediment conveyance and storage processes would benefit from levee setback at 18 of the 32 sites for the 5-year recurrence interval and 24 of the 32 sites would benefit for the 25-year recurrence interval (Figure D-10).

Objective 2.4 - Promote Natural Large Woody Debris (LWD) Recruitment and Pool Formation

In general, there is a lack of LWD and mature riparian cover along the entire length of the study. Riparian woodlands are present in low lying areas in 29 of the 32 sites, however only 4 of those sites have wooded areas that are most likely to contribute LWD to off-channel habitat function. Fourteen of the 32 sites have recruitable large diameter conifers. It should be noted that recruitment of LWD from upstream does occur, as observed during the November 2006 flood event (Figure D-11).

Objective 2.5 - Minimize Downstream Impacts

Downstream impacts were determined by comparing the transport capacity of the river using pre- and post levee setback conditions for the 5- and 25-year recurrence interval storm events. The transport capacity was evaluated using excess transport and excess shear stress values from the HEC-RAS model output. If the potential for deposition and/or erosion expected downstream of a site did not increase for given conditions, only minor downstream impacts would be expected following the setting back of the levee at a site. A more detailed explanation of how the sites were evaluated is provided in Appendix D, Figure D-12.

Results for the Puyallup River sites indicate that only minor downstream impacts would be expected at 15 sites for the 5-year event, and at 17 sites for the 25-year event. Results also indicated that only the Union Pacific site (Site 1), would cause appreciable downstream impacts following the levee setback.

Results for the Carbon River sites indicate no appreciable downstream impacts at any of the six proposed setback sites for both the 5- and 25-year events.

White River results indicate that no downstream impacts would be expected at 4 of the 6 White River sites. The remaining 2 White River sites, 8th Street (Site 29) and Pacific Pointbar (Site 30) would likely cause moderate downstream impacts in the form of sediment deposition.

Objective 2.6 - Improve Connectivity to Tributaries, Potential Wetlands or Springs, and Existing Secondary and Abandoned (Historic Meander) Channels

Ten of the 32 sites contain tributaries that could be reconnected; 11 contain wetlands; 18 contain side channels and 8 contain springs or ponds that could be reconnected (Figure D-13).

GOAL 3 - MAXIMIZE AQUATIC HABITAT DIVERSITY AND USE

Review of the GIS data and information provided in the Pierce County EDT model indicates that all sites contain at least a small portion of an EGA. The percentage contained ranges from 3.8 percent EGA at the Carbon Confluence (Site 22) to 44.9 percent at the 8th Street East Setback (B) site (Site 29). The Union Pacific Setback site (Site 1) showed the greatest benefit to coho Restoration and the 8th Street East Setback (B) (Site 29) site showed the greatest benefit to Chinook Restoration. A more detailed explanation of how the sites were evaluated is provided in Appendix D, Figure D-14. A summary of the top five sites for Goal 3 included:

- 190th Avenue downstream (Site 19)
- Union Pacific Setback (Site 1)
- Alward Road (Site 26)
- 8th Street E Setback (B) (Site 29)
- Countyline Site (Site 32)

FINAL PROJECT RESULTS

The feasibility analyses was based on the premise that reconnection of the river and its floodplain is crucial to developing dynamic channel forming processes, and that healthy in-channel processes is a key element of self-sustaining aquatic habitat. In order to address the breadth and complexity of this project, all sites were subjected to three distinct sets of evaluation criteria; 1) floodplain reconnection potential (which included future flood storage), 2) recovery of dynamic in-channel/flood plain processes, and 3) Salmon habitat Recovery potential.

The analyses and evaluations summarized in this report were used to characterize each site with respect to the project premise, and more specifically the evaluation criteria set forth above. These characterizations, presented in the Site Catalogue (Appendix E), describe unique physical attributes and restoration/flood storage benefits associated with each specific site. Upon review of the Catalogue it is clear that each and every site has great potential for providing benefit to habitat recovery and/or flood storage.

A principle outcome of the project, however, was the selection just a few sites for production of 30 percent design drawings. Site selection was accomplished through the Prioritization Workbook, developed for this project. As described above, the top ranked site from each River System was identified on the basis of 1) the results of all evaluation criteria analyses, and 2) the assignment of Weighting Function values (provided by Pierce County Staff). Based on the physical merits of each site, and the assigned weighting function values, the top ranked sites for each river system are:

- Puyallup River Watershed: South Fork (Site 14)
- Carbon River Watershed: Alward Road (Site 26)
- White River Watershed: Countyline Site (Site 32).

It is important to note that the information comprising the Prioritization Workbook were derived from available data and conditions observed from historic and current (2005-2007) documentation. Because the Prioritization Workbook was intentionally designed to be a flexible tool, it can be modified to include new data and more detail analyses to reflect the ever-changing conditions within the watersheds. Weighting Functions Values may also be modified to accommodate relative changes in the importance of Goals and Objectives as the future needs of the County change, or as a means of searching for potential projects to meet specific criteria for Granting and Funding opportunities.

Thirty percent design drawings were prepared for the South Fork and Alward Road sites; Auto-Cad files for these drawings are provided on a CD under separate cover. Thirty 30 percent design drawings have not been prepared for the Countyline Site at this time due to limitations posed by the Feasibility Analysis Scope and Budget and because stream restoration planning and design for this site had been started by King County.

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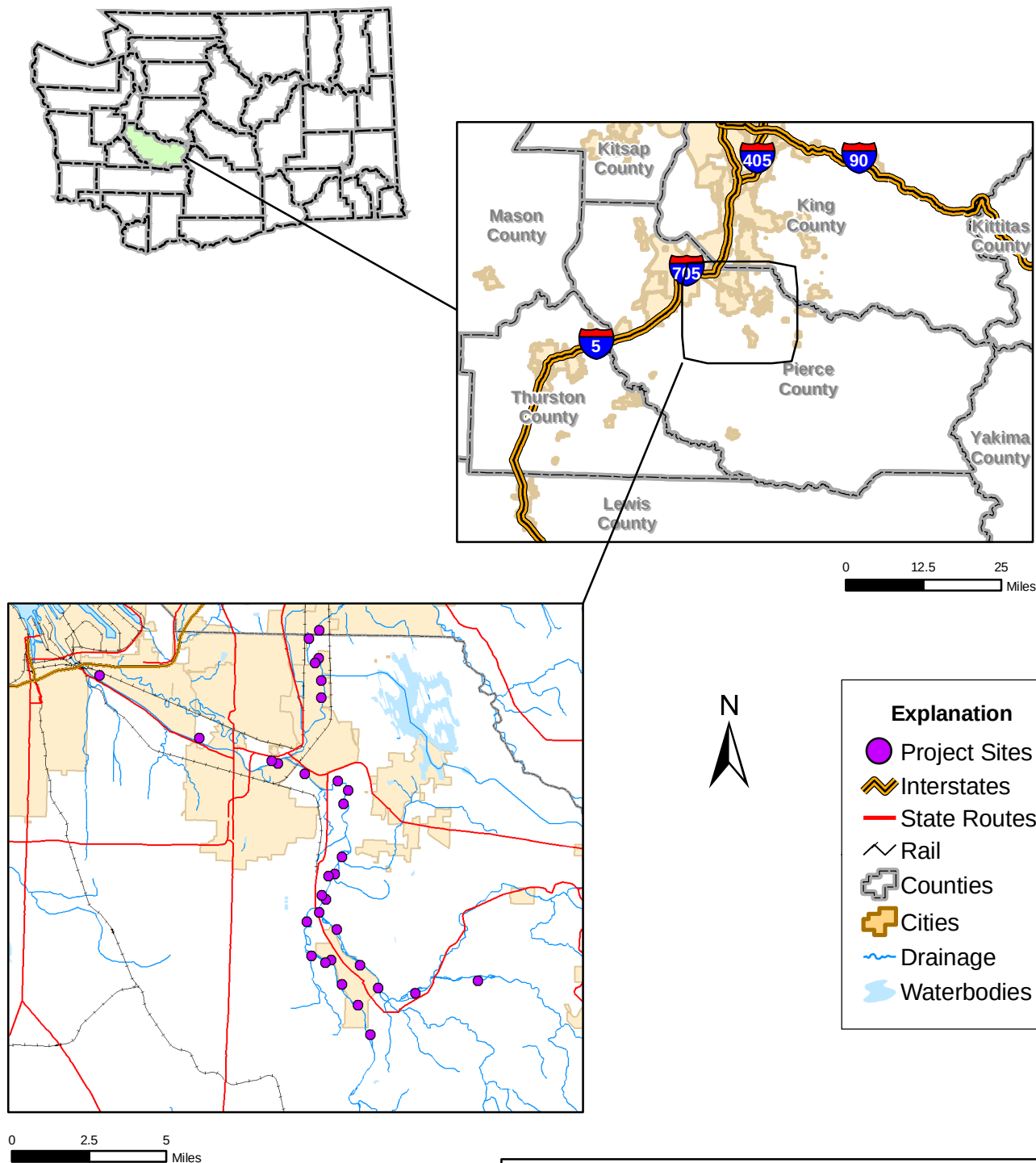
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TABLE 1 - SITE LIST

Sites And Source Of Consideration For Levee Set-Back Evaluation								
Final Sites for Evaluation		Site Location				Source Information		
Proposed Site Name	Site Num	System	Bank	Begin (Rivermile)	End (Rivermile)	Source of Site Recommendation	Source ID	Common Name
Union Pacific Setback	1	Puyallup	right	2.6	3.7	Restoration Site Catalog	Site 1	Union Pacific Setback
Wetland Oxbow Reconnection	2	Puyallup	right	4.6	5.7	Restoration Site Catalog	Site 2	Wetland Oxbow Reconnection
Freeman Oxbow Wetland Setback	3	Puyallup	right	6.7	7.3	Restoration Site Catalog	Site 3	Freeman Oxbow Wetland Setback
White/Puyallup Confluence Reconnection	4	Puyallup	right	9.4	10.2	Restoration Site Catalog	Site 4	White/Puyallup Confluence Reconnection
Golf Course Oxbow Setback	5	Puyallup	left	9.6	10.5	Restoration Site Catalog	Site 5	Golf Course Oxbow Setback
Sumner Setback	6	Puyallup	left	10.7	11.6	Restoration Site Catalog	Site 6	Sumner Setback
Riverside DR (Mobile Home)	7	Puyallup	right	12.2	12.7	GEI & Pierce County	NA	
Riverside Park	8	Puyallup	right	12.8	13.5	GEI & Pierce County	NA	
Sportsman Reconnection	9	Puyallup	left	13.2	14	Restoration Site Catalog	7	Sportsman Reconnection
116th ST Reconnection/Setback	10	Puyallup	left	15.7	16.7	Restoration Site Catalog	9	116th ST Reconnection/Setback
Canyon Falls Creek	11	Puyallup	right	15.9	16.7	GEI & Pierce County	NA	
McCutcheon Rd / 128th St (10)	12	Puyallup	right	16.7	17.5	Restoration Site Catalog	10	128th ST Setback
Upper Puyallup Confluence	13	Puyallup	left	16.8	17.5	GEI & Pierce County	NA	
South Fork Setback	14	Puyallup	left	17.7	18.4	Restoration Site Catalog	12	South Fork Setback
Horse Haven	15	Puyallup	left	19.2	19.6	GEI & Pierce County	NA	
150th street	16	Puyallup	left	19.6	23	GEI & Pierce County	NA	
Gratzer Ave NE HCOT	17	Puyallup	right	19.8	20.5	Comprehensive Plan	A R122-127	Gratzer Ave NE HCOT
Calistoga	18	Puyallup	right	20.6	21.2	GEI & Pierce County	NA	
190th Ave downstream	19	Puyallup	right	21.3	22.5	Comprehensive Plan	A R128-135	190th Ave E HCOT (downstream)
190th Ave upstream	20	Puyallup	right	22.6	23.3	Comprehensive Plan	A R135-139	190th Ave E HCOT (upstream)
Carbon Confluence	21	Carbon	left	0	0.4	Comprehensive Plan	E R101-105	
Right Bank Carbon	22	Carbon	right	0.8	1.2	Restoration Site Catalog	11	Lower Carbon Setback (right)
High School	23	Carbon	left	2	2.7	Comprehensive Plan	A L10-20 (JM)	Orting-Carbon HCOT
Bridge Street	24	Carbon	left	3.1	3.7	Comprehensive Plan	A L10-20 (JM)	Orting-Carbon HCOT
West (Guy) Setback	25	Carbon	left	4.3	5.4	GEI & Pierce County	NA	
Carbon Valley	26	Carbon	left	6.4	8.7	GEI & Pierce County	NA	
Interurban-White	27	White	right	2.6	2.8	Tag input	NA	Interurban-White Site
24th St E Point bar	28	White	left	3.2	3.5	Tag input	NA	24th St E Point bar
8th St E Setback (B)	29	White	left	3.9	4.4	GEI & Pierce County	NA	
Pacific Point bar	30	White	right	4	4.5	Tag input	NA	Pacific Point bar
Pacific Park	31	White	left	5.1	7.3	Comprehensive Plan	B L60-66 (JM)	8th St E Setback
County line	32	White	right	5.1	5.5	Tag input	NA	County line site
Proposed Sites Removed from the Evaluation List								
Pacific Ave Setback	White	right	0.8	1.6	C	Comprehensive Plan	B R46-51 (JM)	No lowland/Developed
Golf Course Oxbow Setback	Puyallup	left	9.3	9.5	C	Restoration Site Catalog	Site 5	Restoration Project Completed
72nd St E	Puyallup	right	11.1	11.8	C	Comprehensive Plan	D R68-74 (JM)	Developed
96th ST Oxbow Reconnection	Puyallup	right	14	14.5	C	Restoration Site Catalog	Site 8	Restoration Project Completed
128th St E	Puyallup	left	15.9	16.4	C	Comprehensive Plan	E L97-101	Combined With 116th
Colburn McCutcheon	Puyallup	right	16.7	17.5	A	Comprehensive Plan	E R101-105	Combined With 128th (13)
Lower Carbon Setback (Puyallup)	Puyallup	right	19.85	20.15	C	Restoration Site Catalog	Site 11	Developed
Soldiers Home Setback	Puyallup	left	21.2	22.6	C	Restoration Site Catalog	Site 13	Restoration Project Completed
Calistoga St HCOT	Puyallup	left	21.3	21.6	C	Comprehensive Plan	A L128-135	Too Close to Solders home
Lower Carbon Setback (right)	Carbon	right	1.65	2	C	Restoration Site Catalog	Site 11	No lowland



Notes:

1. All locations and features shown are approximate.
2. This drawing is for informational purposes. It is intended to assist in showing features discussed in an attached document. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
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Data Sources: Topographic hillshape from USGS10-m DEMs.
County boundaries, cities, and waterbodies from Department of Ecology.
Lambert Conformal Conic, Washington State Plane South
North American Datum 1983

Vicinity Map

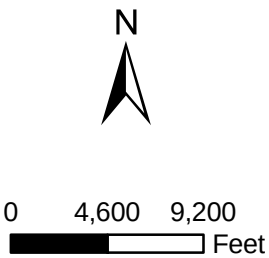
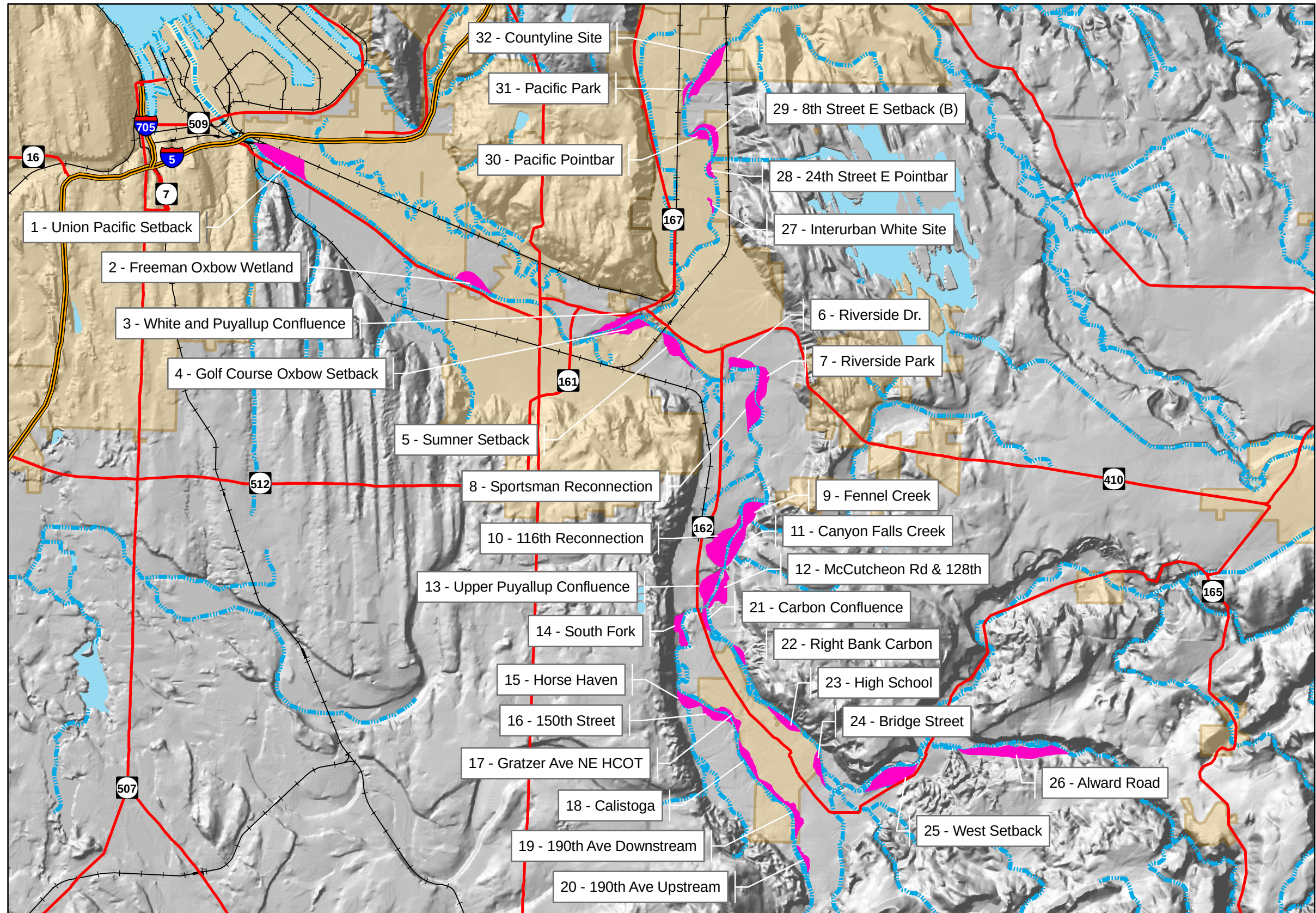
**Levee Set-Back Evaluation:
Puyallup / White / Carbon River Systems
Pierce County, Washington**

GEOENGINEERS

Figure 1

Pierce County
Public Works and Utilities
Water Programs Division

Office: BAM Path: P:\212998012\001\GIS\MapX\Deliverables\Site Map.mxd Last Modified May 12, 2008 MLT



Explanation

- Site Locations
- State Routes
- Interstates
- Rail
- Waterbodies
- Drainage
- Cities



Notes:
1. The locations of all features shown are approximate.
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Data Sources: Topographic Hillshade from USGS10m-DEMs, County Boundaries, cities, and waterbodies from Department of Ecology.

Site Map

Figure 2

Levee Setback Evaluation
Puyallup / White / Carbon Rivers Systems
Pierce County, Washington