Appendix C

Economics

Puyallup River Basin
Flood Risk Management Feasibility Study

Department of the Army
Seattle District, US Army Corps of Engineers

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Economics Appendix

Contents

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Appendix C-1

Economics

Economic Appendix

Puyallup River Basin

Flood Risk Management Feasibility Study

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Table of Contents

Tables

Figures

1. Overview

The study area is comprised of the floodplains of the major populated tributaries within the Puyallup River Basin (basin) (Figure 1-1). The basin is diverse and is comprised of three glacially-fed rivers, the Puyallup River and its tributaries, the White River and the Carbon River. Each of these major river systems originates on the northern slopes of Mount Rainier and join together upstream of the city of Tacoma (the third largest city in the state of Washington) before draining into Puget Sound. The study area is located in Pierce County, Washington with the exception of a portion of the study area north of the main stem of the White River located in King County.

- The Puyallup River drains the northwest slope of Mount Rainier and flows northwest for approximately 50 miles before discharging into Commencement Bay in the city of Tacoma, Washington. Clear Creek (RM 2.7) and Clarks Creek (RM 5.8) are tributaries to the Lower Puyallup River (Figure 4).

- The White River drains the northeastern slope of Mount Rainier and flows in a general northwest direction for about 50 miles before turning southward and entering the Puyallup River from the north at RM 10.3. The White River is the largest tributary to the Puyallup River. Mud Mountain Dam (MMD), a federally authorized flood control project, is located at RM 29.6 on the White River.

- The Carbon River originates on the north face of Mount Rainier at the Carbon Glacier and enters the Puyallup River at RM 17.3. South Prairie Creek at RM 5.8 is a major tributary to the Carbon River.

The upper watershed is primarily rural and is composed largely of public and private forest lands. The lower reaches are densely populated and include major residential areas and industrial hubs including the Port of Tacoma. Two Federally recognized tribes are located in study area: the Puyallup Tribe of Indians and the Muckleshoot Indian Tribe.

The Puyallup River Basin includes the cities of Tacoma, Fife, Puyallup, Sumner, Auburn, and Orting, and large areas of unincorporated Pierce County which all drains a watershed of approximately 1,040 square miles. More than 12,000 structures are located within the 0.2% (1/500) annual chance exceedance (ACE) floodplain in the study area (Pierce County Tax Parcels, Pierce County, 2010). Existing development in the floodplain within the Puyallup River study area includes residential development, industrial and commercial development, critical infrastructure such as schools and water treatment plants, and major transportation infrastructure, including Interstate 5, railroad lines and the Port of Tacoma.

The study area includes 29 levee segments currently in the USACE National Levee Database (NLD). This includes twenty-seven non-federal levees and two federally owned and operated levees. The river hydrology is also modified by Mud Mountain Dam, a Corps authorized and constructed project. MMD is a federal flood control project located on the White River at RM 29.6. MMD was authorized as Mud Mountain Reservoir by the Flood Control Act of 22 June 1936, 74th Congress, 2nd Session. The Flood Control Act of 1938 provided for operation and maintenance (O&M) of the project by the Corps and the

Flood Control Act of 1944 authorized construction and O&M of recreational facilities. In addition, the Flood Control Act of June 28, 1938 provided for the construction and maintenance of a channel conveyance project on the Lower Puyallup River. Completed in 1950, the federally constructed and maintained levees were built from RM 0.7 to RM 2.8 on the Lower Puyallup River and were authorized as a companion project to MMD. The levees are 2.2 miles in length on the left and right banks and allow for an in-channel conveyance capacity of 50,000 cfs.

The Puyallup Basin currently contains lands from two Federally-recognized tribes: The Puyallup Tribe of Indians and the Muckleshoot Indian Tribe (see Figure 1-1). Muckleshoot Tribal land is primarily located around the City of Auburn on parcels that span both sides of the White River. Puyallup Tribal lands are located on the Lower Puyallup River, downstream of the confluence with the White River. Puyallup Tribal lands are unusual in that per an 1857 Executive Order, the Tribe has ownership rights over the bed of the river in this area.

Due to the configuration of the Puyallup River, the river is described for planning and modeling purposes as the Lower Puyallup River (RM 0.0 – RM 10.3), Middle Puyallup River (RM 10.3 – RM 17.4) and Upper Puyallup River RM (17.4 – RM 29.6). A map of the five study reaches that make up the Puyallup Basin study area is shown in Figure 1-2. Figure 1-3 through Figure 1-7 show the cities and major infrastructure in the study area, by study reach.

In this report, as in all new Corps reports that discuss flood risk management, the risk of an individual storm or flood event occurring is expressed as the *annual chance of exceedance* (ACE), which is the probability that the specified discharge, or flood event, could be equaled or exceeded during any given year. Uncertainty exists in a number of variables which are the results of knowledge uncertainty or natural variability. Therefore, the flood risk is communicated in terms of annual exceedance probability (AEP), or the probability that flooding will occur in any given year considering the full range of possible annual floods, along with uncertainty surrounding that mean estimate. Annual chance of exceedance (ACE) and annual exceedance probability (AEP) may be used interchangeably in this report.

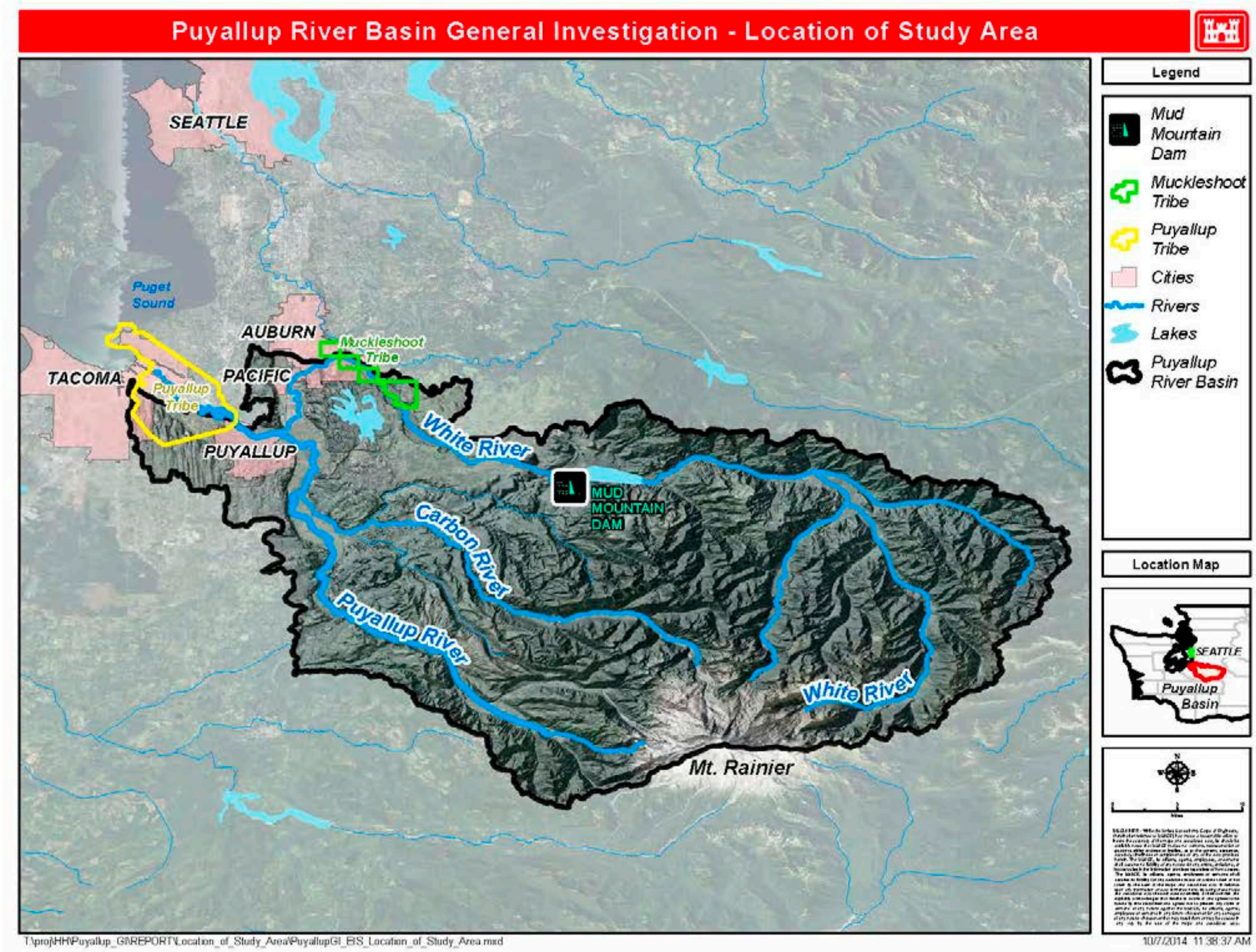

Figure 1-1. Puyallup River Basin

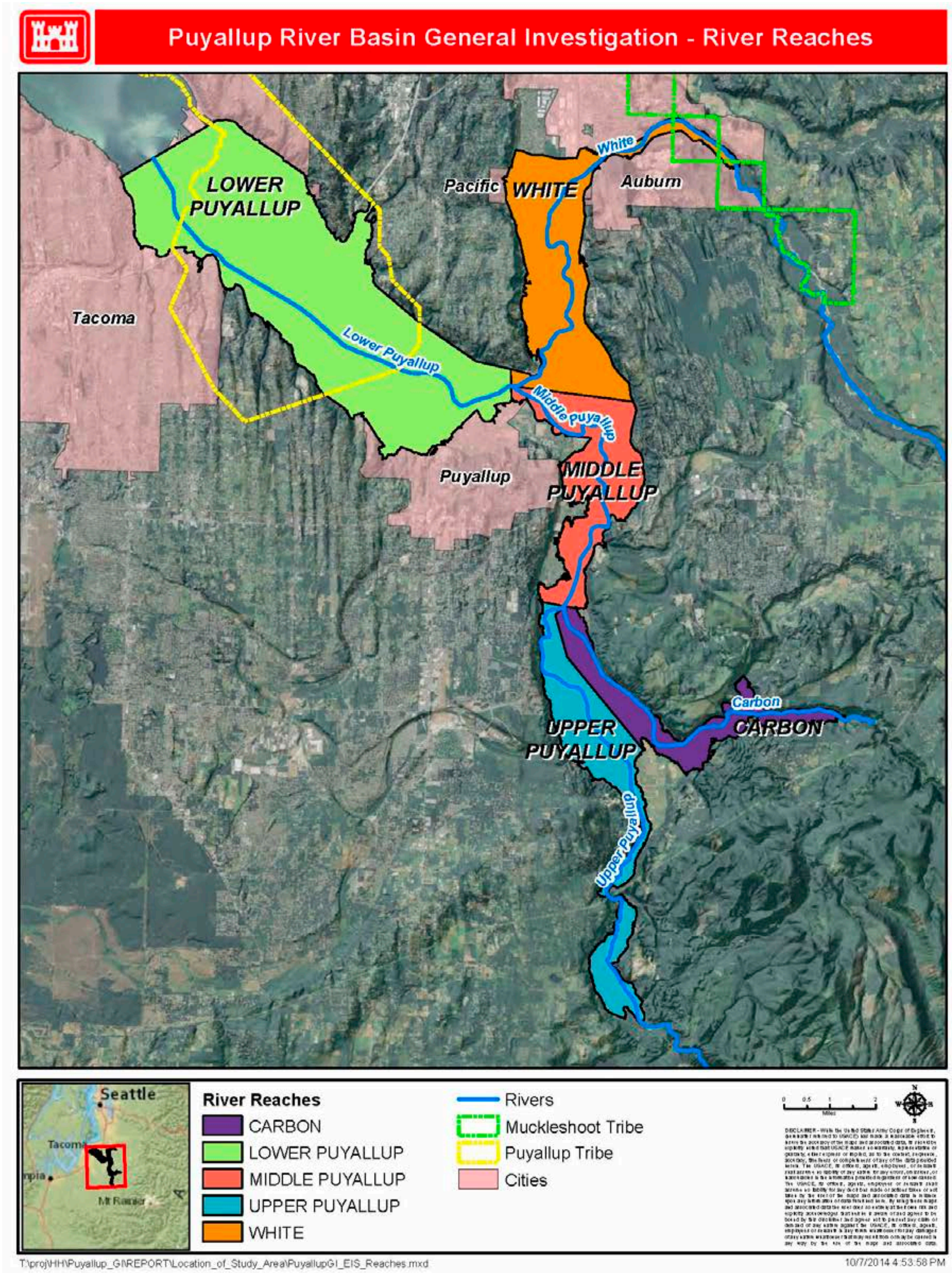

Figure 1-2. Puyallup River GI Study Reaches[1]

[1] [1] The boundaries for each reach reflect the 0.2% Annual Chance Exceedance (ACE) event, plus a given buffer initially used to assure that the structure inventory in the analyses would cover a sufficient area for all future modeling events

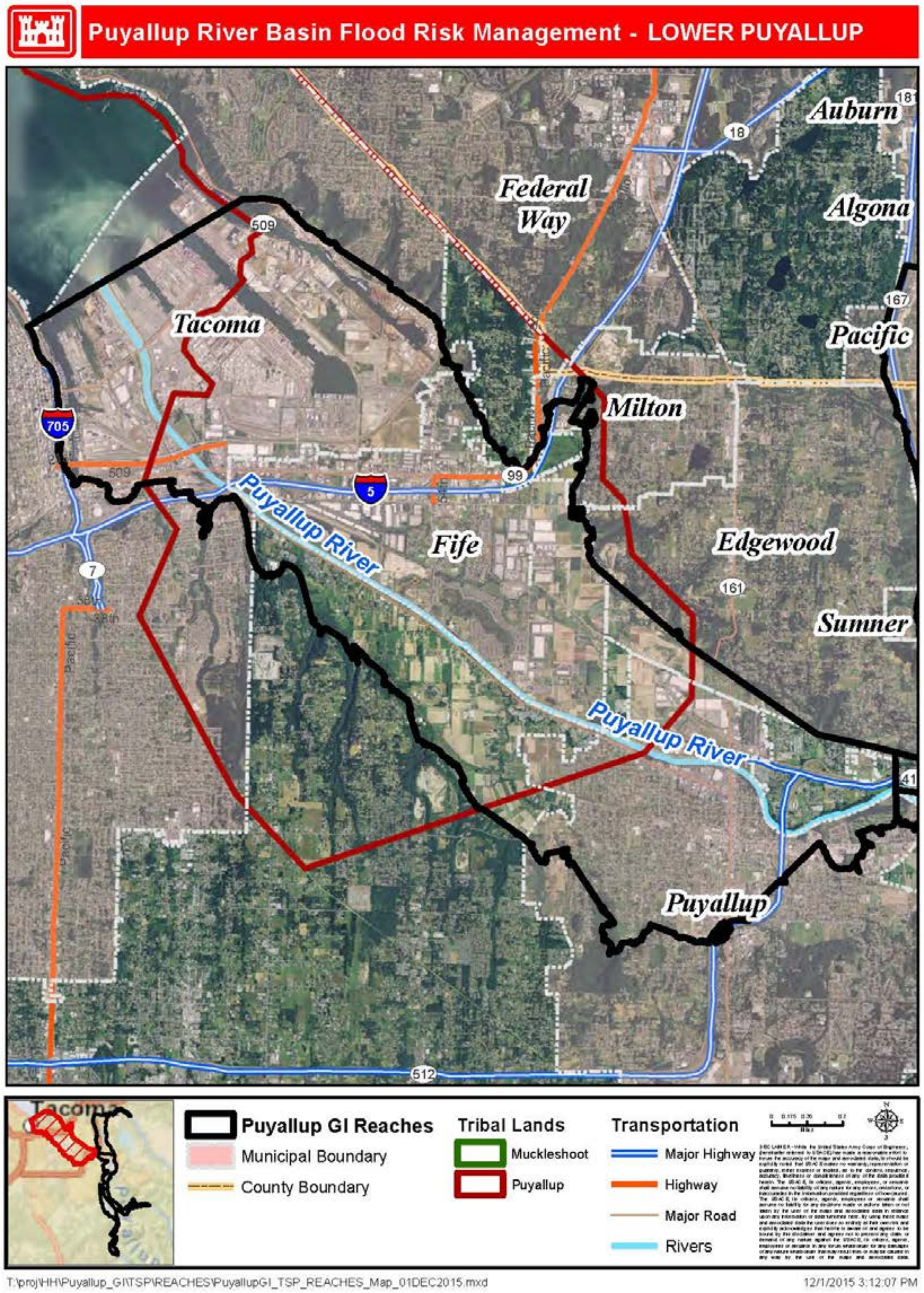

Figure 1-3. Lower Puyallup Reach

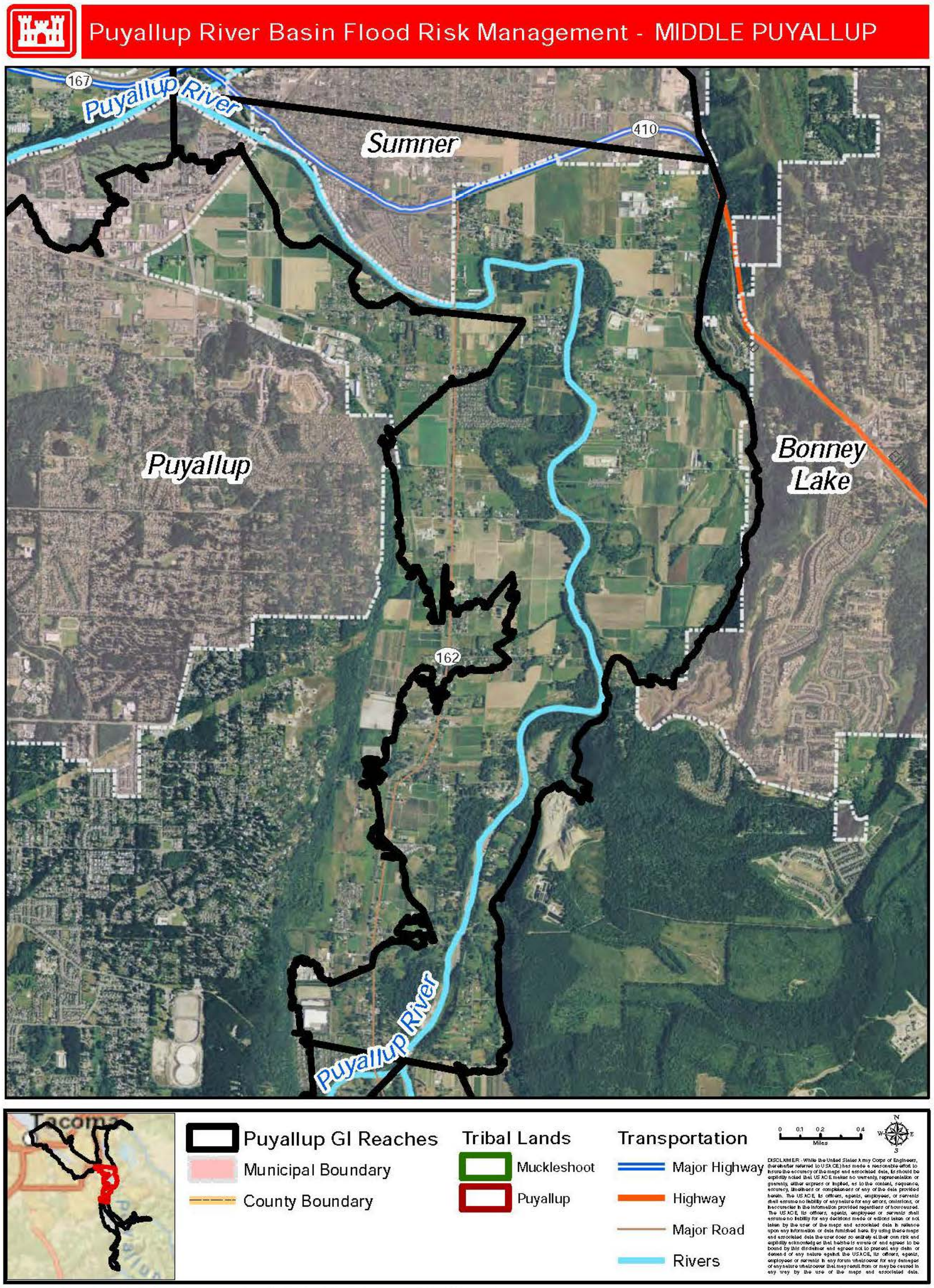

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Figure 1-4. Middle Puyallup Reach

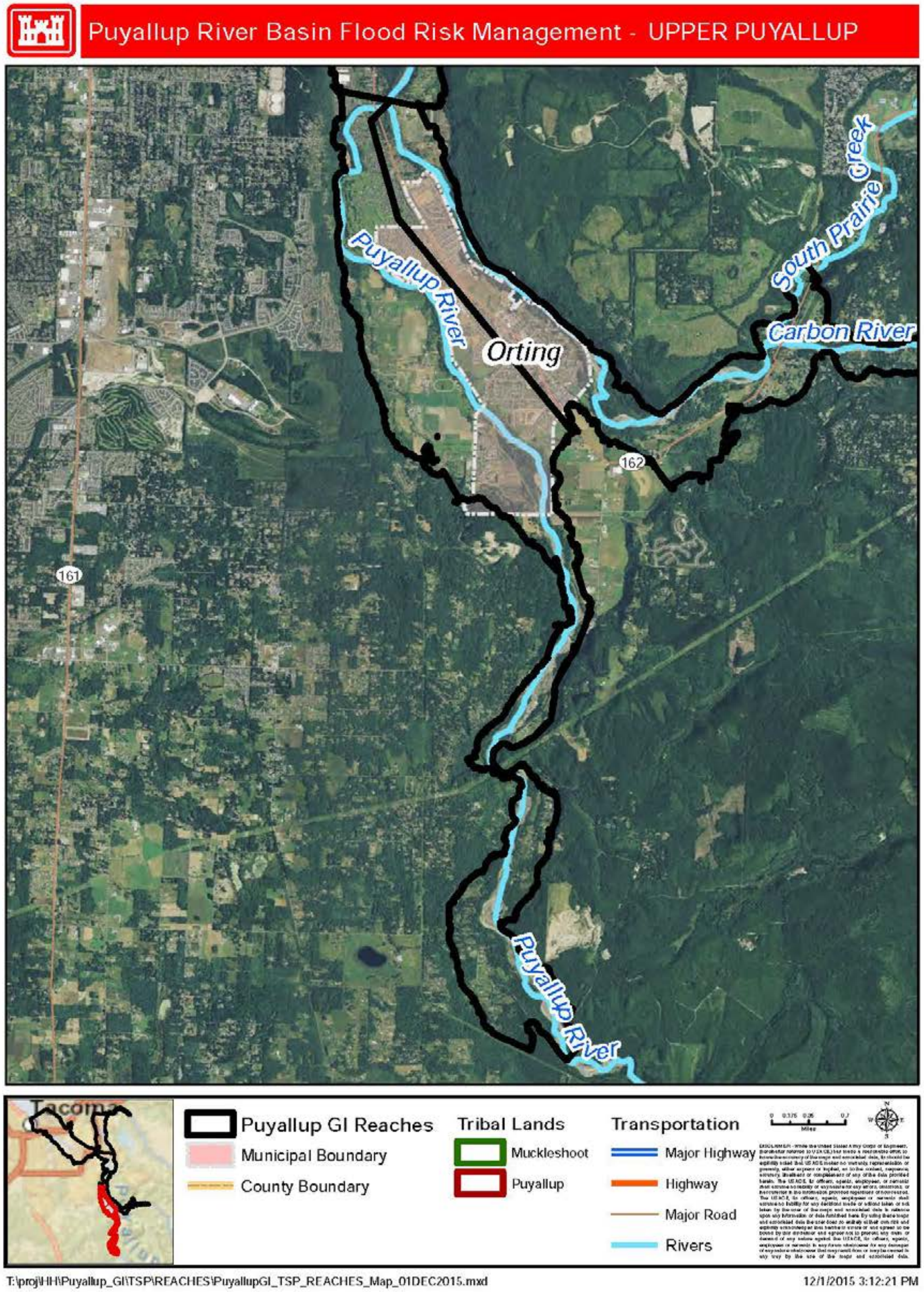


Figure 1-5. Upper Puyallup Reach

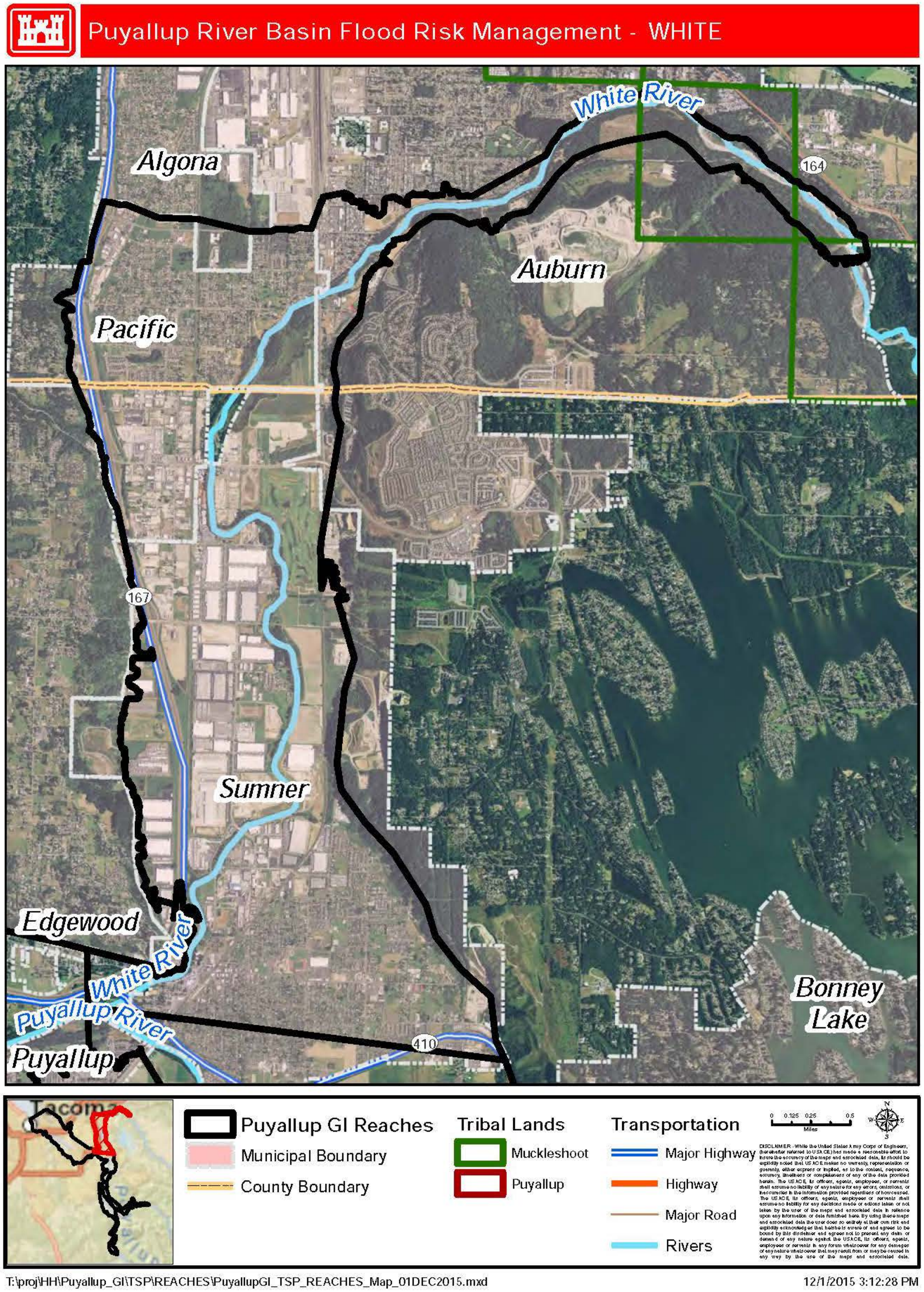


Figure 1-6. White River Reach

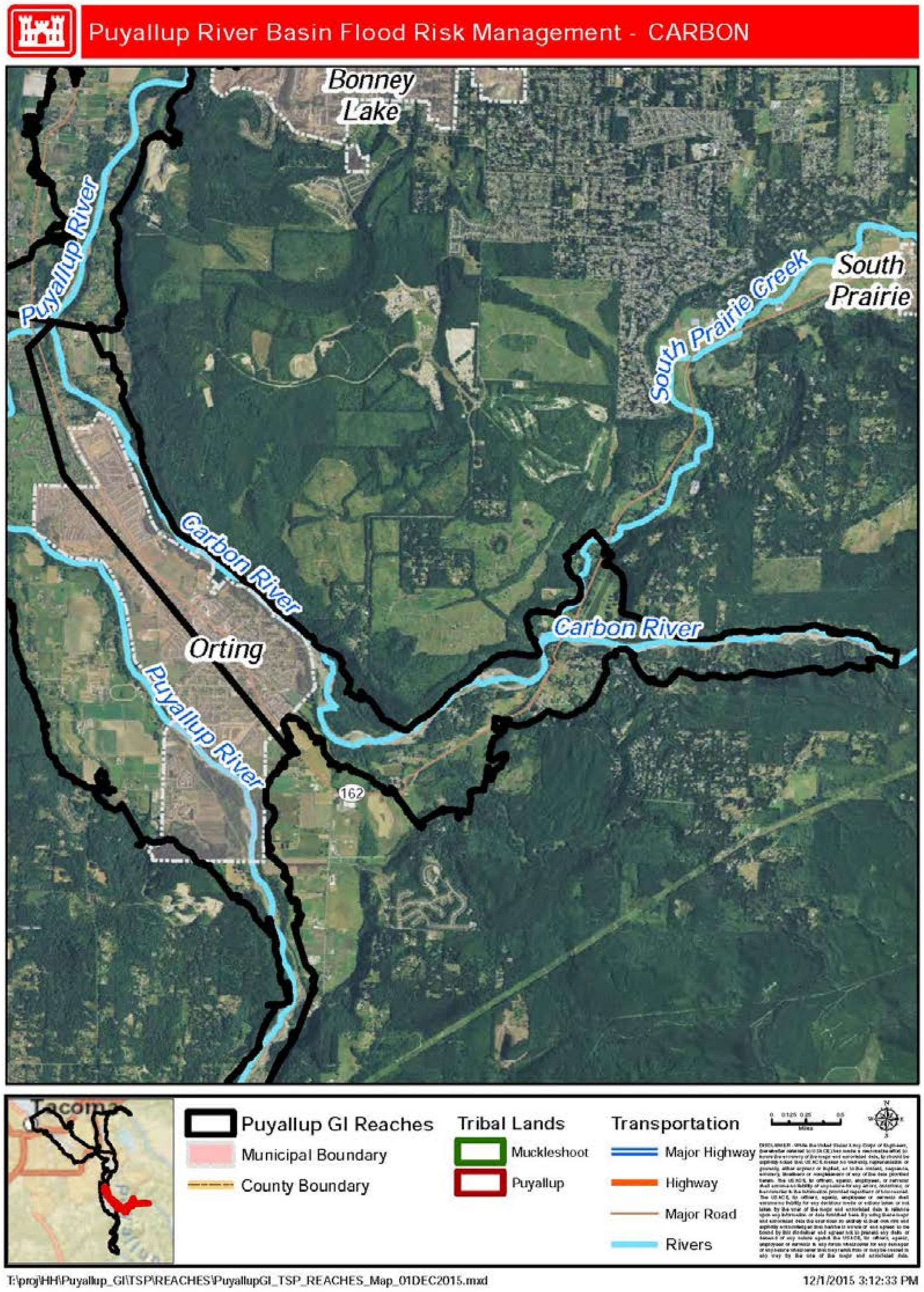


Figure 1-7. Carbon River Reach

2. Purpose and Scope of Economic Analyses

The purpose of this report is to present the results of the economic analysis performed for the Puyallup River Basin Flood Risk Management Feasibility Study in support of Tentatively Selected Plan (TSP) recommendation. The report documents the existing conditions within the study area and proposed alternative plans to improve flood risk management, and designate the tentative National Economic Development (NED) Plan for purposes of estimated Federal interest for the Puyallup River Basin. The report presents findings related to flood risk, potential flood damages and potential flood risks management benefits.

2.1. Methodology

The economic analysis is conducted in accordance with standards, procedures, and guidance of the U.S. Army Corps of Engineers. They include the following:

- Engineering Regulation (ER) 1105-2-100, "Planning Guidance Notebook", dated 22 April 2000, as amended;
- Economic and Environmental Principles and Guidelines for Water Resources Implementation Studies (P&G), dated March 1983;
- Engineering Manual (EM) 1110-2-1619, "Risk-Based Analysis for Flood Damage Reduction Studies", dated 1 August 1996*;*
- ER 1105-2-101, "Risk-Based Analysis of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies", dated 3 January 2006;
- Economic Guidance Memorandum (EGM) 04-01, "Generic Depth-Damage Relationships for Residential Structures with Basements", dated 10 October 2003;
- EGM 09-04, "Generic Depth-Damage Relationships for Vehicles", dated 22 June 2009;
- HEC-FDA Flood Damage Reduction Analysis User's Manual (version 1.4), dated October 2014; and
- EGM 16-01, "Federal Interest Rates for Corps of Engineers Project for Fiscal Year 2016", dated 14 Oct 2015.

The economic evaluation was performed over a 50-year period of analysis. All values are presented in October 2015 price levels, and amortization calculations are based on the Fiscal Year 2016 Federal discount rate of 3.125 percent as published in Corps of Engineers Economic Guidance Memoranda (EGM) unless stated otherwise due to incremental evaluations that have occurred since the feasibility study was initiated.

3. Floodplain Area and Inventory

3.1. Structural Inventory

A structural inventory was completed based on data gathered from assessor's parcel data from both Pierce and King Counties, and field survey of structures within the floodplain. Structures were determined to be within the economic study area by using Geographical Information Systems (GIS) to compare the 0.2% (1/500) Annual Chance Exceedance (ACE) floodplain boundary (plus a buffer) with the spatially referenced assessor parcel numbers (APN). Information from the assessor's parcel database (such as land use, building square footage, address) was supplemented during field visitation by adding fields for foundation height, specific business activity for non-residential structures, building condition, type of construction, and number of units, for example. Where square footage was not available, the Google Earth measuring tool was used to estimate square footage. Parcels with structures were categorized by land use and grouped into the following structural damage categories:

1) Residential (RES) –

    a. Single family residential (SFR) – includes all parcels represented by a single unit such as detached single family homes, individually owned condominiums and townhomes

    b. Multifamily residential (MFR) – includes residential parcels with more than one unit such as apartment complexes, duplexes and quadplex units. Each parcel may have multiple structures.

2) Commercial (COM) – includes retail, office buildings, restaurants, etc.

3) Industrial (IND) – includes warehouses, light and heavy manufacturing facilities.

4) Public (PUB) – includes both public and semi-public uses such as post offices, fire departments, government buildings, schools and churches.

5) Farm building (FARM) – includes farm buildings on agricultural parcels.

All parcels with structures were assigned to one of the listed categories.

The without-project damages and with-project benefits are based on potential damages to residential structures and contents, non-residential (commercial, industrial, public, and farm), and vehicles. The study area was divided into five study reaches, or economic impact areas, for purposes of this economic analysis: Lower Puyallup River, Middle Puyallup River, Upper Puyallup River, Carbon River, and Lower White River. These reaches were also divided further by left and right bank, or where specific measures were identified during measures and alternatives development and screening. The delineation of these five reaches can be found in Figure 1-2.

Further, the HEC-RAS unsteady flow hydraulic model using cross sections to model the riverine portions of the study and a network of storage areas to model the floodplain areas. The model contains approximately 185 storage areas. The riverine and floodplain regions are connected by lateral structures representing levees, roads, railroads, etc. adjacent to the rivers. The storage areas are connected to each other where appropriate using storage area connections. Storage areas function as 'bathtubs' which pool water in the floodplain. Water can flow from storage area to storage area via the storage area connections as appropriate. The main purpose of this approach is to allow for the computation of floodplain water surface elevations which can be different from that of the river since volume of water is insufficient to fill up storage areas to the same elevation as the river in most areas. The approach also allows for the flow of water in directions perpendicular to the main channel. The storage areas were grouped in to economic study reaches as shown in Figure 3-1 and defined in Table 3-1 to allow for a more manageable number of damage reaches. The storage areas are grouped in to 31 of the 40 economic reaches to allow for analysis of floodplain flooding in without and with-project conditions. Each of these economic reaches comprised of storage areas is assigned to a riverine cross-section known as an index location. Further, riverine reaches are represented by an upstream and downstream river cross section, as well as an index location which falls within these cross-sections. It should be noted that each of the economic study reaches which contains storage areas has a downstream station which ends in 880168. This is because structures contained in storage areas are assigned to pseudo cross sections with water surface elevation data. For cross sections 600001-880168, the first 2-3 digits represent the economic study reach (e.g. 60x is used for all structures located in DR_60), and the last 2-3 digits represent the unique storage area ID numbers numbered 1 through 185 (e.g. DR_60 contains three storage areas with cross sections 600001, 600002, and 600003). This approach is further documented in Appendix A-4, Hydrology and Hydraulics, Support of FDA Analysis.

To better communicate flood risk, economic reaches were grouped into the five study reaches. The assignment of economic reaches to study reach is also shown in Table 3-1.

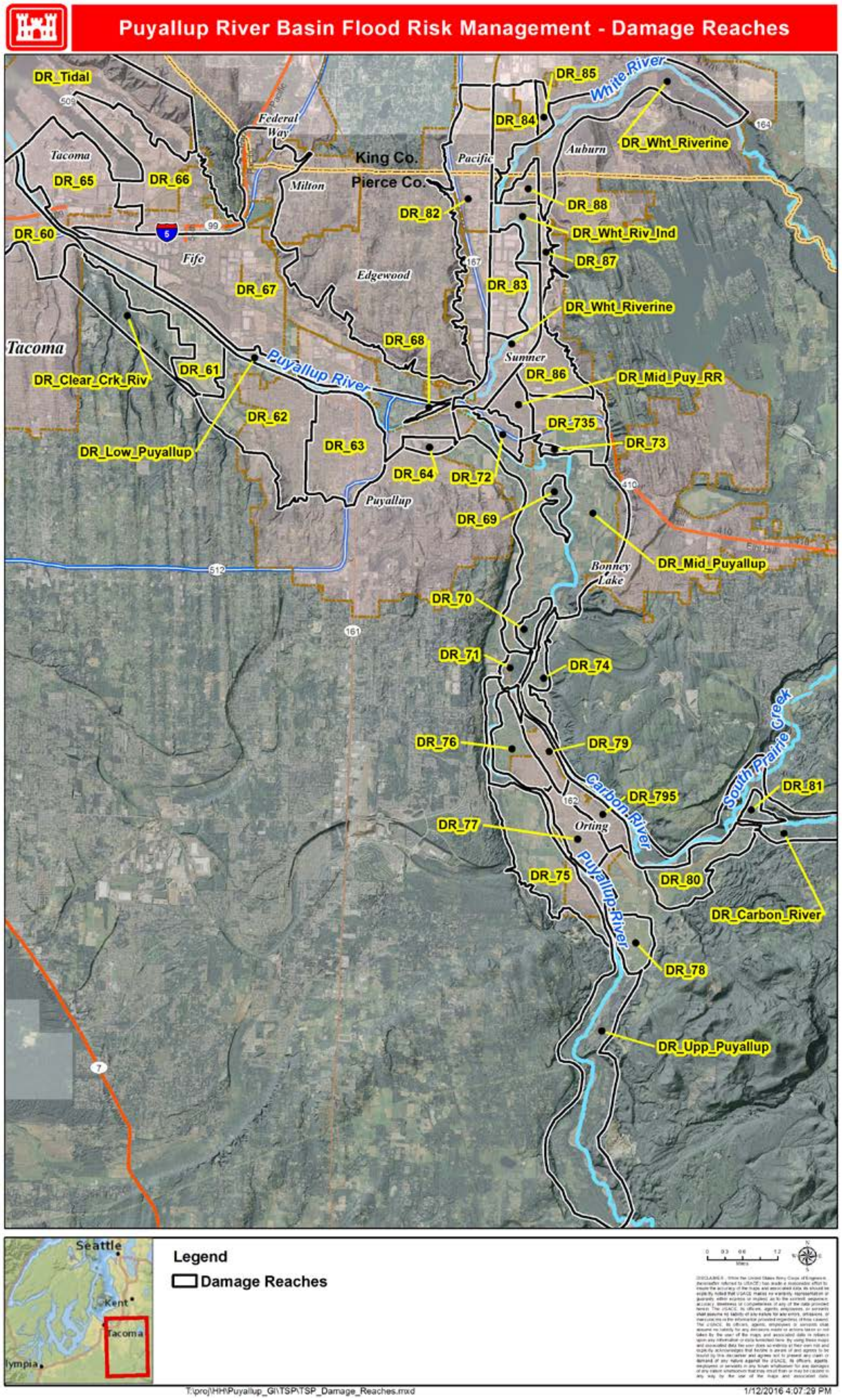


Figure 3-1. Puyallup Economic Damage Reaches

Table 3-1. Economic Damage Reaches and Study Reach Assignments

Economic Damage Reach	Reach Description	Study Reach	Beginning Station	Ending Station	Bank	Index Station
DR_79	Carbon Left Orting	Carbon River	3530.09	880168	Left	3530.09
DR_795	carbon left orting	Carbon River	15144.39	880168	Left	15144.39
DR_80	Carbon Left Voight Creek	Carbon River	31242.38	880168	Left	31242.38
DR_81	Carbon Right	Carbon River	34095.42	880168	Right	34095.42
DR_Carbon_River	Carbon River riverine	Carbon River	631.79	44337.57	Both	17602.05
DR_60	Lower Puyallup Left below I-5	Lower Puyallup	9944.71	880168	Left	9944.71
DR_61	Clear Creek	Lower Puyallup	23804.34	880168	Left	23804.34
DR_62	Puyallup River LB@ Clarks Creek	Lower Puyallup	36382.51	880168	Left	36382.51
DR_63	Puyallup River lower LB above Clarks Creek	Lower Puyallup	44521.29	880168	Left	44521.29
DR_64	Puyallup River lower LB @ confluence	Lower Puyallup	51940.04	880168	Left	51940.04
DR_65	LPuyallup RB below I-5	Lower Puyallup	10752.54	880168	Right	10752.54
DR_66	Hylebos Creek	Lower Puyallup	27506.92	880168	Right	42525.43
DR_67	L Puyallup RB	Lower Puyallup	42525.43	880168	Right	42525.43
DR_68	L Puyallup RB at Confluence	Lower Puyallup	51940.04	880168	Right	51940.04
DR_Clear_Crk_Riv	Clear Creek riverine	Lower Puyallup	16169.93	18198.66	Left	16169.93
DR_Low_Puyallup	Below White River riverine	Lower Puyallup	457.06	54231.88	Both	29296.27
DR_Tidal	Tidal	Lower Puyallup	0	16000	Both	1112.04
DR_69	Middle Puyallup LB1	Middle Puyallup	73625.21	880168	Left	73625.21
DR_70	Middle Puyallup LB2	Middle Puyallup	85543.26	880168	Left	85543.26
DR_71	Middle Puyallup LB3	Middle Puyallup	91508.88	880168	Left	91508.88
DR_72	SR 410	Middle Puyallup	59586.72	880168	Right	59586.72
DR_73	Middle Puyallup Right Sumner	Middle Puyallup	66487.63	880168	Right	66487.63
DR_735	Middle Puyallup Right Sumner	Middle Puyallup	68762.66	880168	Right	68762.66
DR_74	Puyallup Carbon Junction RB	Middle Puyallup	90534.35	880168	Right	90534.35
DR_Mid_Puyallup	Between Carbon and White Rivers riverine	Middle Puyallup	54599.21	92603.25	Both	78846.67
DR_Mid_Puy_RR	Middle Puyallup RR	Middle Puyallup	63841.51	65007.8	Right	63841.51
DR_75	U Puyallup Ortling Left	Upper Puyallup	117207.2	880168	Left	117207.2
DR_76	Upper Puyallup RB High Cedars	Upper Puyallup	96489.84	880168	Right	96489.84
DR_77	Upper Puyallup RB Ford	Upper Puyallup	119316	880168	Right	119316
DR_78	Upper Puyallup RB Orting	Upper Puyallup	122018.7	880168	Right	122018.7
DR_Upp_Puyallup	Upper Puyallup riverine	Upper Puyallup	93034.85	152710.7	Both	126980.7
DR_82	Lower White RB Valley Wall	White River	7504.48	880168	Right	7504.48
DR_83	Lower White RB	White River	15930.34	880168	Right	15930.34
DR_84	Pacific RB	White River	29676.23	880168	Right	29676.23
DR_85	Lower White RB above Pacific	White River	34653.57	880168	Right	34653.57
DR_86	Lower White LB Sumner	White River	1298.362	880168	Left	1298.362
DR_87	Lower White LB	White River	19506.57	880168	Left	19506.57
DR_88	White River County Line LB	White River	29130.41	880168	Left	29130.41
DR_Wht_Riverine	White Riverine	White River	433.43	55590.45	Both	30164.5
DR_Wht_Riv_Ind	White River industrial park	White River	22032.25	26259.54	Both	22032.25

Structure counts (assuming levee breaches on the Lower Puyallup) for a 0.2% (1/500) annual chance of exceedance (ACE) event are presented by study reach in Table 3-2.

Table 3-2. Structural Inventory – Base Condition

River Reach	Number of Structures within 0.2% (1/500) ACE Floodplain					
	Commercial	Farm Building	Industrial	Public	Residential	TOTAL
Carbon River	13	8	3	14	276	314
Lower Puyallup	474	25	391	66	5,566	6,522
Middle Puyallup	99	22	27	27	2,209	2,384
Upper Puyallup	24	14	4	13	1,476	1,531
White River	86	4	115	13	1,347	1,565
TOTAL	**696**	**73**	**540**	**133**	**10,874**	**12,316**

3.2. Value of Damageable Property – Structures and Contents

Marshall & Swift (M&S) was used to determine depreciated replacement values (DRV) for structures located within the study area. Depreciated replacement values were based on information contained in the Pierce and King County assessor databases, as well as field survey. Specific data used to develop DRV's included construction class, construction quality, structure occupancy type, structure square footage, and structure condition. This valuation was originally estimated at the October 2014 price level and was updated to the October 2015 price level (update factor = 1.002). Depreciation was based on age and structure condition to determine depreciation factors. For structures with incomplete information (i.e. structure square footage), mean depreciated replacement values were assigned based on structure occupancy type. Field survey was conducted to verify assessor data including structure occupancy type, as well as collect data on foundation height. The survey was conducted on 100 percent of non-residential occupancy types and 20 percent of residential occupancy types using a stratified random sample for single-story with basement, single-story no basement, two-story with basement, two-story no basement, multi-family residential structures, and mobile homes.

Content values for non-residential structures were based on content values developed by expert elicitation for the *American River Watershed Project, California, Folsom Modification and Folsom Dam Raise Projects Economic Reevaluation Report*, dated February 2008. The expert elicitation panel provided their best estimates for a series of 'prototypical' activity types based on the non-residential structure occupancy types. Content value estimates were estimated as a function of structure occupancy type, structure square footage, and content value per square footage. Depreciated content values were fit to either a normal (mean, standard deviation) or triangular distribution (minimum, mean, maximum). The depreciated content values (and their uncertainty) were updated to October 2015 prices. Structure types included in the American River ERR include prototypical grocery stores, warehouses, churches, offices, restaurants, retail stores, schools, etc., which are not unique to that area and are similar to those in the Puyallup study area.

The total value of damageable property (structures, contents, and vehicles) within the Puyallup River Basin 0.2% (1/500) ACE event is estimated at $5.4 billion. Table 3-3 displays the total value of damageable property. Table 3-4 displays the structure, content, and vehicle value as a percentage of value for each occupancy class, whereas the total percentage for each occupancy class is presented as a percentage of total value (e.g. commercial occupancy is 17%, industrial occupancy is 31%, and residential occupancy is 47% of overall value). The total structure value as a percentage of total value by reach is also presented. For example, the Lower Puyallup makes up 63% and the White River makes up of 16% of total value in the 0.2% ACE floodplain, or $3.4 billion and $873 million, respectively.

Table 3-3. Value of Damageable Property, Base Condition (Value in $1,000s)

Occupancy Class	Commercial				Farm Building			
Reach	**Structure**	**Content**		**Total**	**Structure**	**Content**		**Total**
Carbon River	$4,028	$3,300		$7,328	$771	$1,146		$1,917
Lower Puyallup	398,036	293,181		691,216	3,089	3,870		6,959
Middle Puyallup	53,858	40,788		94,646	1,804	2,489		4,293
Upper Puyallup	8,385	5,950		14,335	1,192	1,721		2,913
White River	75,628	54,744		130,372	252	339		591
Total	***$539,934***	***$397,963***		***$937,897***	***$7,108***	***$9,566***		***$16,674***
Occupancy Class	**Industrial**				**Public**			
Reach	**Structure**	**Content**		**Total**	**Structure**	**Content**		**Total**
Carbon River	$157	$167		$325	$9,601	$3,962		$13,563
Lower Puyallup	592,980	662,926		1,255,905	123,207	46,526		169,733
Middle Puyallup	15,253	22,245		37,498	28,359	9,780		38,139
Upper Puyallup	347	349		696	12,504	4,624		17,127
White River	199,098	184,465		383,562	16,632	4,804		21,437
Total	***$807,835***	***$870,152***		***$1,677,987***	***$190,304***	***$69,696***		***$260,000***
Occupancy Class	**Residential**				**Total - All Structures**			
Reach	**Structure**	**Content**	**Vehicle**	**Total**	**Structure**	**Content**	**Vehicle**	**Total**
Carbon River	$30,255	$15,128	$2,141	$47,523	$44,813	$23,703	$2,141	$70,656
Lower Puyallup	845,620	422,813	43,167	1,311,600	1,962,932	1,429,316	43,167	3,435,414
Middle Puyallup	329,290	164,646	17,512	511,448	428,565	239,947	17,512	686,024
Upper Puyallup	216,797	108,399	11,447	336,643	239,224	121,044	11,447	371,715
White River	217,637	108,819	10,447	336,902	509,247	353,172	10,447	872,865
Total	***$1,639,600***	***$819,804***	***$84,713***	***$2,544,117***	***$3,184,780***	***$2,167,181***	***$84,713***	***$5,436,675***

Table 3-4. Value of Damageable Property as a Percentage of Total Value by Occupancy Class and Overall, Base Condition

Occupancy Class	Commercial				Farm Building			
Reach	**Structure**	**Content**		**Total**	**Structure**	**Content**		**Total**
Carbon River	1%	1%		1%	11%	12%		11%
Lower Puyallup	74%	74%		74%	43%	40%		42%
Middle Puyallup	10%	10%		10%	25%	26%		26%
Upper Puyallup	2%	1%		2%	17%	18%		17%
White River	14%	14%		14%	4%	4%		4%
Total	***58%***	***42%***		***17%***	***43%***	***57%***		***0%***
Occupancy Class	**Industrial**				**Public**			
Reach	**Structure**	**Content**		**Total**	**Structure**	**Content**		**Total**
Carbon River	0%	0%		0%	5%	6%		5%
Lower Puyallup	73%	76%		75%	65%	67%		65%
Middle Puyallup	2%	3%		2%	15%	14%		15%
Upper Puyallup	0%	0%		0%	7%	7%		7%
White River	25%	21%		23%	9%	7%		8%
Total	***48%***	***52%***		***31%***	***73%***	***27%***		***5%***
Occupancy Class	**Residential**				**Total - All Structures**			
Reach	**Structure**	**Content**	**Vehicle**	**Total**	**Structure**	**Content**	**Vehicle**	**Total**
Carbon River	2%	2%	3%	2%	1%	1%	3%	1%
Lower Puyallup	52%	51%	51%	52%	62%	66%	51%	63%
Middle Puyallup	20%	20%	21%	20%	13%	11%	21%	13%
Upper Puyallup	13%	13%	14%	13%	8%	6%	14%	7%
White River	13%	13%	12%	13%	16%	16%	12%	16%
Total	***64%***	***32%***	***3%***	***47%***	***59%***	***40%***	***2%***	***100%***

4. Depth-Damage Relationships

Damages to structures and contents were determined based on depth of flooding relative to the structures first floor elevation. First floor elevations were determined based upon visual estimates during windshield surveys in the study area. To compute these damages, depth-damage curves (DDC) were used. These curves assign loss as a percentage of value for each structure. The deeper the relative depth, the greater the percentage of value damaged. The sources of the relationships were different depending on land use. For residential structures, Institute for Water Resources DDC's were used in accordance with Economic Guidance Memorandum (EGM) 04-01. The non-residential structure DDC's used were originally developed for the May 1997 "Morganza to the Gulf, Louisiana Feasibility Study". For Puyallup, the long-duration versions of the DDC's were used based on inland, freshwater, long duration flooding with similar business types to those structures in the Puyallup study area. Floods are inland, freshwater, and long duration with flood ranges of two days to just over a week. Water drains slowly from the floodplain using an interior drainage network consisting of culverts, gates, and pumps. Depth-damage curves for non-residential contents were taken from the February 2008 "American River Watershed Project, California, Economic Re-evaluation Report (ERR)" expert elicitation for long-duration flooding. Structures contained within the Puyallup Basin are of similar use and construction as structures evaluated for the American River ERR in California, as well as similar flooding characteristics (inland, freshwater, long-duration). Structure types included in the American River ERR include protypical grocery stores (Safeway), churches (7th Day Aventist), offices (Bank of America), restaurants—fast food (McDonalds), schools (Tahoe Elementary School), retail stores (Ethan Allen), etc., with different curves developed for single-story and two-story structures where appropriate. Depth-damage relationships are shown in Table 4-1 through Table 4-4.

Table 4-1. Depth-Damage Curves for Residential Structures and Contents

Category		Depth of Flooding Above the First Floor in Feet							
		-4	-1	0	1	3	5	10	15
1-Story	Structure	0%	2%	13%	23%	40%	53%	73%	80%
	Content	0%	2%	8%	13%	22%	29%	38%	40%
2-Story	Structure	0%	3%	9%	15%	26%	36%	56%	68%
	Content	0%	1%	5%	9%	16%	21%	32%	37%
Split	Structure	0%	6%	7%	9%	17%	29%	63%	84%
	Content	0%	2%	3%	5%	11%	20%	46%	61%
1-Story w/basement	Structure	5%	19%	26%	32%	46%	59%	80%	81%
	Content	6%	13%	16%	19%	25%	30%	39%	39%
2-Story w/Basement	Structure	5%	14%	18%	22%	32%	42%	65%	76%
	Content	5%	10%	12%	14%	18%	22%	34%	49%
Split w/Basement	Structure	5%	14%	19%	23%	33%	44%	65%	69%
	Content	4%	9%	12%	14%	18%	22%	26%	26%
Mobile Home - Short Duration	Structure	0%	6%	10%	45%	46%	66%	66%	66%
	Content	0%	0%	0%	38%	69%	90%	90%	90%
Mobile Home - Long Duration	Structure	0%	6%	10%	45%	96%	96%	96%	96%
	Content	0%	0%	0%	85%	99%	99%	99%	99%

Table 4-2. Depth-Damage Curves for Non-Residential Structures, Long Duration

Category	Depth of Flooding Above the First Floor in Feet						
	-1	0	1	3	5	10	15
1-Story Long Duration	0%	7%	22%	31%	32%	54%	86%
2-Story Long Duration	0%	5%	15%	22%	23%	46%	80%

Table 4-3. Depth-Damage Curves for Non Residential Contents, 1-Story

Category	Depth of Flooding Above the First Floor in Feet						
	-1	0	1	3	5	10	15
Food Stores	0%	0%	78%	100%	100%	100%	100%
Furniture - Retail	0%	0%	98%	100%	100%	100%	100%
Grocery Store	0%	0%	87%	100%	100%	100%	100%
Hotel - Full Service	0%	0%	88%	100%	100%	100%	100%
Medical	0%	0%	75%	100%	100%	100%	100%
Office	0%	0%	97%	100%	100%	100%	100%
Restaurant	0%	0%	91%	100%	100%	100%	100%
Fast Food Restaurant	0%	0%	88%	100%	100%	100%	100%
Retail	0%	0%	80%	100%	100%	100%	100%
Service - Auto	10%	10%	74%	100%	100%	100%	100%
Shopping Centers	0%	0%	96%	100%	100%	100%	100%
Heavy Industrial	0%	0%	33%	77%	100%	100%	100%
Light Industrial	0%	0%	88%	99%	100%	100%	100%
Warehouse	0%	0%	84%	100%	100%	100%	100%
Churches	0%	0%	73%	99%	99%	99%	100%
Government	0%	0%	97%	100%	100%	100%	100%
Recreation	0%	0%	98%	100%	100%	100%	100%
Schools	0%	0%	88%	100%	100%	100%	100%
Farms	0%	0%	56%	100%	100%	100%	100%

Table 4-4. Depth-Damage Curves for Non Residential Contents, 2-Story

Category	Depth of Flooding Above the First Floor in Feet						
	-1	0	1	3	5	10	15
Food Stores	0%	0%	38%	56%	56%	67%	100%
Furniture - Retail	0%	0%	47%	56%	56%	67%	100%
Grocery Store	0%	0%	42%	56%	56%	67%	100%
Hotel - Full Service	0%	0%	44%	56%	56%	67%	100%
Medical	0%	0%	36%	56%	56%	67%	100%
Office	0%	0%	46%	56%	56%	67%	100%
Restaurant	0%	0%	44%	56%	56%	67%	100%
Fast Food Restaurant	0%	0%	42%	56%	56%	67%	100%
Retail	0%	0%	38%	56%	56%	67%	100%
Service - Auto	3%	3%	39%	56%	56%	67%	100%
Shopping Centers	0%	0%	46%	56%	56%	67%	100%
Heavy Industrial	0%	0%	7%	31%	50%	50%	100%
Light Industrial	0%	0%	88%	99%	100%	100%	100%
Warehouse	0%	0%	40%	56%	56%	67%	100%

Category	Depth of Flooding Above the First Floor in Feet						
	-1	0	1	3	5	10	15
Churches	0%	0%	35%	55%	55%	66%	100%
Government	0%	0%	45%	56%	56%	68%	100%
Recreation	0%	0%	47%	56%	56%	67%	100%
Schools	0%	0%	42%	56%	56%	67%	100%

5. Uncertainty and Other Damage Categories

5.1. Storage Areas and Structure Assignments using GIS

GIS was used to assign centroids to each parcel within the study area. These points were moved to correspond with structures located within those parcels. Hydraulic modeling in HEC-RAS produced inundation outputs for rivers and storage areas within the basin which were overlaid on terrain in GIS to determine flood elevations and the depths for each river cross section and storage area. Structure points were assigned to the nearest riverine cross-section or storage area depending on their spatial location, and the same terrain data was used to derive structure elevation. Structure elevation, along with foundation height, is one of the key inputs for the economic structure inventory in computing damages at each individual structure with the application of the depth-damage curves presented in Section 4. The process of grouping storage areas into economic damage reaches, assigning structure centroids to storage areas or riverine cross sections, and development of hydrologic and hydraulic inputs to the economic modeling is described further in Section 6.2 and in Appendix A-4, Hydrology and Hydraulics, Support of FDA Analysis.

5.2. Economic Uncertainty Parameters

There are many factors considers in the analysis of flood damages which contain many sources of uncertainty, both within and outside of hydrologic, hydraulic, and economic modeling. Because of these uncertainties, flood damages are represented by a range of values instead of a single number to acknowledge that there are parameters for which we do not have perfect knowledge. Uncertainty in computing flood damage modeling can be described as knowledge uncertainty (e.g. stochastic measurement error) or natural variability. Natural variability is generally larger and includes factors that vary naturally within the boundaries of the model and usually has a greater impact on the economic analysis. For example, peak flows are influenced by factors that are difficult or impossible to model (or are not included in the model for other reasons) such as antecedent basin wetness, the temperature during storm events, the moment-to-moment intensity and geographic distribution of rainfall. Knowledge uncertainty includes factors that we cannot model with precision or measure properly such as stage uncertainty as a function of variation or measurement error in Manning n-values. Knowledge uncertainty is included in the economic parameters described below included structure and content values, depth-damage curves, and first floor elevations. It is important to note that knowledge uncertainty and its risk associated risk can be reduced or “bought down”. Natural variability, on the other hand, is large unavoidable and thus this risk cannot be bought down. It is important to consider the types of uncertainties, how to account them, and what risks (probability x consequence) they have to decision making or undesirable outcomes. Errors in measurement, variation in classification and judgment can lead to differences in values. For this study, in accordance with EM 1110-2-1619, uncertainties in the following parameters were considered in the damage estimation:

- Structure Values
- Content Ratio or Values

- Depth-Damage Percentage Curves
- First Floor Elevations (Ground Elevation and Foundation Height)

Structure values were determined as a function of Marshall & Swift values per square foot, square footage and estimated depreciation based on assessor data obtained from Pierce and King Counties. Detailed structure information was available for approximately 95% of structures located in the study area which included square footage, structure occupancy type, construction type, year built and year improved, as well as construction quality and structure condition. To estimate the value of structures, a normal distribution was applied which consists of a mean and standard deviation as shown in Table 5-2. Risk and uncertainty was also included in the depth-damage curves for residential structures and contents that were imported into HEC-FDA and applied during the Monte Carlo simulations. Depth-damage functions were a mix of normal and triangular distributions, where triangular distributions consist of a lower limit (minimum value), an upper limit (maximum value), and a mode (most likely value) as shown in Table 5-1.

The error type of first-floor elevation is estimated to be 0.9 feet based on Corps guidance in EM 1110-2-1619 (see Table 5-3) where ground elevation error is 0.4 feet based on 3-foot aerial contours and foundation height uncertainty error is 0.5 feet based on windshield survey method of foundation heights (plus or minus one vertical step).

In addition, standard deviations for all four variables were used for all structure occupancy types within the HEC-FDA model and applied during HEC-FDA's Monte Carlo simulation of the Expected Annual Damages. These coefficients of variation were based upon standard deviations for representative structures for each structure occupancy type.

The following tables summarize the uncertainty distribution applied to the various economic inventory inputs by structure occupancy type. Distributions are either represented by a normal (mean and standard deviation) or triangular distribution (minimum, mean, and maximum value).

Table 5-1. Economic Uncertainties of Depth-Damage Curves by Structure Occupancy Type

Structure Occupancy Type	Description	Damage Category Name	Structure	Content	Other
SFR1	Single-family residential, 1-story	RES	Normal%	Normal%	Normal%
SFR2	Single-family residential, 2-story	RES	Normal%	Normal%	Normal%
SFRB1	Single-family residential, 1-story with basement	RES	Normal%	Normal%	Normal%
SFRB2	Single-family residential, 2-story with basement	RES	Normal%	Normal%	Normal%
SFRS	Single-family residential, split-level	RES	Normal%	Normal%	Normal%
SFRBS	Single-family residential, split-level with basement	RES	Normal%	Normal%	Normal%
SFRMH	Mobile home	RES	Triangular%	Triangular%	Normal%
MFR1	Multi-family residential, 1-story	RES	Normal%	Normal%	Normal%
MFR2	Multi-family residential, 2-story	RES	Normal%	Normal%	Normal%
FARM	Farm buildings	FB	Normal%	Triangular%	NE*
C-AUTO1	Commercial auto sales, 1-story	COM	Normal%	Triangular%	NE
C-AUTO2	Commercial auto sales, 2-story	COM	Normal%	Triangular%	NE
C-DEAL1	Full service auto dealership, 1-story	COM	Normal%	Triangular%	NE
C-DEAL2	Full service auto dealership, 2-story	COM	Normal%	Triangular%	NE
C-FOOD1	Commercial food retail, 1-story	COM	Normal%	Triangular%	NE
C-FOOD2	Commercial food retail, 2-story	COM	Normal%	Triangular%	NE
C-FURN1	Furniture store, 1-story	COM	Normal%	Triangular%	NE
C-FURN2	Furniture store, 2-story	COM	Normal%	Triangular%	NE
C-GROC1	Commercial grocery store, 1-story	COM	Normal%	Triangular%	NE
C-GROC2	Commercial grocery store, 2-story	COM	Normal%	Triangular%	NE
C-HOS1	Hospital, 1-story	COM	Normal%	Triangular%	NE
C-HOS2	Hospital, 2-story	COM	Normal%	Triangular%	NE
C-HOTEL1	Hotel, 1-story	COM	Normal%	Triangular%	NE
C-HOTEL2	Hotel, 2-story	COM	Normal%	Triangular%	NE
C-MED1	Commercial medical, 1-story	COM	Normal%	Triangular%	NE
C-MED2	Commercial medical, 2-story	COM	Normal%	Triangular%	NE
C-OFF1	Commercial office, 1-story	COM	Normal%	Triangular%	NE
C-OFF2	Commercial office, 2-story	COM	Normal%	Triangular%	NE
C-REST1	Commercial restaurant, 1-story	COM	Normal%	Triangular%	NE
C-REST2	Commercial restaurant, 2-story	COM	Normal%	Triangular%	NE
C-RESTFF1	Commercial fast food restaurant, 1-story	COM	Normal%	Triangular%	NE
C-RESTFF2	Commercial fast food restaurant, 2-story	COM	Normal%	Triangular%	NE
C-RET1	Commercial retail, 1-story	COM	Normal%	Triangular%	NE
C-RET2	Commercial retail, 2-story	COM	Normal%	Triangular%	NE
C-SERV1	Commercial service-auto, 1-story	COM	Normal%	Triangular%	NE
C-SERV2	Commercial service-auto, 2-story	COM	Normal%	Triangular%	NE
C-SHOP1	Commercial shopping center, 1-story	COM	Normal%	Triangular%	NE
C-SHOP2	Commercial shopping center, 2-story	COM	Normal%	Triangular%	NE
I-HV1	Industrial heavy manufacturing, 1-story	IND	Normal%	Triangular%	NE
I-HV2	Industrial heavy manufacturing, 2-story	IND	Normal%	Triangular%	NE
I-LT1	Industrial light, 1-story	IND	Normal%	Triangular%	NE
I-LT2	Industrial light, 2-story	IND	Normal%	Triangular%	NE
I-WH1	Industrial warehouse, 1-story	IND	Normal%	Triangular%	NE

Structure Occupancy Type	Description	Damage Category Name	Structure	Content	Other
I-WH2	Industrial warehouse, 2-story	IND	Normal%	Triangular%	NE
P-CH1	Public church, 1-story	PUB	Normal%	Triangular%	NE
P-CH2	Public church, 2-story	PUB	Normal%	Triangular%	NE
P-GOV1	Public government building, 1-story	PUB	Normal%	Triangular%	NE
P-GOV2	Public government building, 2-story	PUB	Normal%	Triangular%	NE
P-REC1	Public recreation/assembly, 1-story	PUB	Normal%	Triangular%	NE
P-REC2	Public recreation/assembly, 2-story	PUB	Normal%	Triangular%	NE
P-SCH1	Public and private schools, 1-story	PUB	Normal%	Triangular%	NE
P-SCH2	Public and private schools, 2-story	PUB	Normal%	Triangular%	NE
*NE – Not evaluated					

Table 5-2. Economic Uncertainties by Structure Occupancy Type, continued

Structure Occupancy Type	Content to Structure Value Ratio (%)	First Floor Stage Error		Structure Value Error		Content / Structure Value Ratio Error		Other / Structure Value Ratio Error	
		Error Type	Std Dev (ft.)	Error Type	Std Dev (%)	Error Type	Std Dev (% increment)	Error Type	Std Dev (% increment)
SFR1	100	Normal	0.9	Normal	12	Normal	12	Normal	15
SFR2	100	Normal	0.9	Normal	12	Normal	12	Normal	15
SFRB1	100	Normal	0.9	Normal	12	Normal	12	Normal	15
SFRB2	100	Normal	0.9	Normal	12	Normal	12	Normal	15
SFRS	100	Normal	0.9	Normal	12	Normal	12	Normal	15
SFRBS	100	Normal	0.9	Normal	12	Normal	12	Normal	15
SFRMH	50	Normal	0.9	Normal	14	Normal	12	Normal	15
MFR1	100	Normal	0.9	Normal	12	Normal	12	Normal	15
MFR2	100	Normal	0.9	Normal	12	Normal	12	Normal	15
FARM		Normal	0.9	Normal	20	Normal	8	None	
C-AUTO1		Normal	0.9	Normal	12	Normal	16	None	
C-AUTO2		Normal	0.9	Normal	12	Normal	16	None	
C-DEAL1		Normal	0.9	Normal	12	Normal	12	None	
C-DEAL2		Normal	0.9	Normal	12	Normal	12	None	
C-FOOD1		Normal	0.9	Normal	11	Normal	27	None	
C-FOOD2		Normal	0.9	Normal	11	Normal	27	None	
C-FURN1		Normal	0.9	Normal	12	Normal	20	None	
C-FURN2		Normal	0.9	Normal	12	Normal	20	None	
C-GROC1		Normal	0.9	Normal	12	Normal	4	None	
C-GROC2		Normal	0.9	Normal	12	Normal	4	None	
C-HOS1		Normal	0.9	Normal	12	Normal	46	None	
C-HOS2		Normal	0.9	Normal	12	Normal	46	None	
C-HOTEL1		Normal	0.9	Normal	12	Normal	3	None	
C-HOTEL2		Normal	0.9	Normal	12	Normal	3	None	
C-MED1		Normal	0.9	Normal	11	Normal	46	None	
C-MED2		Normal	0.9	Normal	11	Normal	46	None	
C-OFF1		Normal	0.9	Normal	13	Normal	16	None	
C-OFF2		Normal	0.9	Normal	13	Normal	14	None	
C-REST1		Normal	0.9	Normal	12	Normal	3	None	

Structure Occupancy Type	Content to Structure Value Ratio (%)	First Floor Stage Error		Structure Value Error		Content / Structure Value Ratio Error		Other / Structure Value Ratio Error	
		Error Type	Std Dev (ft.)	Error Type	Std Dev (%)	Error Type	Std Dev (% increment)	Error Type	Std Dev (% increment)
C-REST2		Normal	0.9	Normal	12	Normal	3	None	
C-RESTFF1		Normal	0.9	Normal	12	Normal	13	None	
C-RESTFF2		Normal	0.9	Normal	12	Normal	13	None	
C-RET1		Normal	0.9	Normal	12	Normal	18	None	
C-RET2		Normal	0.9	Normal	12	Normal	18	None	
C-SERV1		Normal	0.9	Normal	12	Normal	4	None	
C-SERV2		Normal	0.9	Normal	12	Normal	4	None	
C-SHOP1		Normal	0.9	Normal	11	Normal	23	None	
C-SHOP2		Normal	0.9	Normal	11	Normal	23	None	
I-HV1		Normal	0.9	Normal	12	Normal	31	None	
I-HV2		Normal	0.9	Normal	12	Normal	31	None	
I-LT1		Normal	0.9	Normal	12	Normal	19	None	
I-LT2		Normal	0.9	Normal	12	Normal	19	None	
I-WH1		Normal	0.9	Normal	14	Normal	31	None	
I-WH2		Normal	0.9	Normal	14	Normal	31	None	
P-CH1		Normal	0.9	Normal	13	Normal	40	None	
P-CH2		Normal	0.9	Normal	13	Normal	40	None	
P-GOV1		Normal	0.9	Normal	12	Normal	16	None	
P-GOV2		Normal	0.9	Normal	12	Normal	8	None	
P-REC1		Normal	0.9	Normal	12	Normal	13	None	
P-REC2		Normal	0.9	Normal	12	Normal	13	None	
P-SCH1		Normal	0.9	Normal	14	Normal	33	None	
P-SCH2		Normal	0.9	Normal	14	Normal	33	None	

Table 5-3. First-Floor Elevation Error[2]

Table 6-5
First-Floor Elevation Error and Standard Deviation Calculated from Results in *Accuracy of Computed Water Surface Profiles* (USACE 1986)

Method of Elevation Estimation	Error,[1] in ft	Standard Deviation,[2] in ft
Field survey, hand level	± 0.2 @ 50’	0.10
Field survey, stadia	± 0.4 @ 500’	0.20
Field survey, conventional level	± 0.05 @ 800’	0.03
Field survey, automatic level	± 0.03 @ 800’	0.02
Aerial survey, 2-ft contour interval	± 0.59	0.30
Aerial survey, 5-ft contour interval	± 1.18	0.60
Aerial survey, 10-ft contour interval	± 2.94	1.50
Topographic map, 2-ft contour interval	± 1.18	0.60
Topographic map, 5-ft contour interval	± 2.94	1.50
Topographic map, 10-ft contour interval	± 5.88	3.00

[1] Errors for aerial survey and topographic maps are calculated at the 99-percent confidence level, assuming the deviations from the true elevation are normally distributed with zero mean and indicated standard deviations.
[2] Standard deviation for field survey assumes that error represents a 99-percent confidence interval and assuming normal distribution.

[2] Table taken from EM 1110-2-1619, Risk Based Analysis for Flood Damage Reduction Studies, dated 1 Aug 1996

5.3. Other Damage Categories

5.3.1. Vehicles

Losses to automobiles were determined as a function of the number of vehicles per residence, average value per automobile, estimated percentage of autos removed from area prior to inundation, and depth of flooding above the ground elevation. Depth-damage relationships for autos were taken from EGM 09-04 and modified based on weighted average of distributions of car types (SUV, truck, sedan, sports car, etc) in Pierce County, Washington.

Average vehicle values for new and used vehicles were obtained from Kelley Blue Book based on two classes and five types of vehicles: domestic, import; and motor home, motorcycle, pickup truck, sedan, and sport utility vehicle (SUV). The representative sample of vehicles was sough with a median age according to the R.L. Polk Company's Annual Vehicle Population Report for 2008. Vehicles listed for sale within 200 miles of the study area and with similar mileage were also sought for greater consistency.

Information for determining the approximate distribution by type of vehicle and value was obtained from the Washington State Department of Licensing, where the class distribution of all vehicles registered in Pierce County was applied to the approximated vehicles per household based on U.S. Census data. Once data was obtained, all Pierce County information was applied to the vehicle category breakdown as proposed in the EGM, and as shown in Table 5-4.

Table 5-4. Distribution of Vehicles in Pierce County, Washington (2013)[3]

Vehicle Category	Frequency	% of Total
Motor Home	7,201	1%
Motorcycle	27,381	5%
Truck	131,421	23%
Sedan	262,841	47%
Sport Utility Vehicle	131,421	23%
Total	560,264	100%

The length of potential warning time and the access to a safe evacuation route to a flood-free location was considered in estimating the number of vehicles that would likely remain in the floodplain. The percentage of vehicles that are likely to be at the residence at the time the flood waters reach the property and the availability of safe evacuation routes are a function of the amount of warning residents have. The EGM suggests that with 6-12 hours of warning, 80% of residents move a vehicle. And with greater than 12 hours of warning, 88% of residents move a vehicle. It is assumed residents would receive 12 hours of warning for inundation regardless of whether or not a levee breaches, given that most levee failures are likely to occur at or near the top of levee elevation.

[3] Washington State Department of Licensing, (13) Motor Vehicle Registration by Class and County, Calendar 2013, accessed online: https://fortress.wa.gov/dol/vsd/vsdFeeDistribution/DisplayReport.aspx?rpt=2013C00-6301.csv&countBit=1

Damages for vehicles begin once flood depth has reaches 0.5 feet, and this damage curve can be seen in Table 5-5. Vehicle counts were estimated using an assumption of 1.9 vehicles per residential structure based on U.S. Census data. Depreciated replacement value for vehicles was based on the weighted value of vehicles in Pierce County, or $7,739 at the October 2015 price level. Uncertainty in vehicle value was incorporated using a normal distribution and a standard deviation of 15 percent. Vehicles were added to residential structure imports in the "Other" valuation category and damages to residential structures, contents and vehicles is presented in the expected annual damage estimates.

Table 5-5. Depth-Damage Curve for Average Vehicle in Pierce County

Depth (ft)	0.5	1	2	3	4	5	6	7	8	9	10
% Damage	5.1%	22.5%	39.4%	54.4%	67.8%	79.3%	89.2%	95.1%	99%	100%	100%
Std Dev	4.5%	3.7%	3.0%	2.6%	2.6%	2.9%	3.4%	3.8%	4.3%	4.8%	4.8%

5.3.2. Emergency Costs, Cleanup Costs, Road Damages, and Transportation Delays

Economic costs associated with various emergency related damage categories (evacuation, debris activities, public services, utilities, etc) has not been conducted for this study, except for traffic-related costs associated with detours and extra time traveling due to the potential of major roads being threating by flooding in the Puyallup Basin. For the other emergency related damage categories, initial model calculations for other Corps studies have shown estimates ranging from 1-3% as a proportion of structure and content damages. These emergency related costs are relatively minimal when compared to structural damages. Nevertheless, it is recognized that in order to detail the magnitude of flooding problems in the Puyallup Basin, the economic analyses can be conducted. However, because these damage categories are not expected to drive plan selection, they were omitted from the analysis. If deemed necessary, emergency costs, road damages and traffic disruption analyses can be conducted during refinement of the TSP.

5.3.3. Agricultural Losses

ER 1105-2-100, Appendix E, beginning on page E-113 includes specific guidance for studies where the primary damages occur to agricultural crops. Primary damages in this evaluation focus on the crop damage, loss of stored crops, and loss of farm equipment. These damages are directly related, and evaluated with special consideration for the expected time of seasonal flooding as well as the variability associated with crop prices and yields. The identified hydrologic/hydraulic variables, discharge associated with exceedence frequency and conveyance roughness and cross-section geometry, also apply to agricultural studies.

Based on empirical analyses conducted for past Corps projects and professional judgment, the project delivery team expects agricultural damages to total less than 5% of total project damages; amounts which are not expected to drive plan selection or affect overall Federal interest. Many crops in the Puyallup Basin are grown outside of the flood season, so crop losses are expected to be minimal.

However, clean-up costs and land restoration costs would be a cost related to flooding of agricultural cropland.

Flood damages associated with farm buildings was included in this analysis to address agricultural damages. These damages are considered in the overall alternatives evaluation and will be further evaluated as the tentatively selected plan is refined.

5.3.4. Transportation Delays

A simplified transportation delay analysis was conducted to capture increased vehicle operating costs and time value of money associated with detours in response to flooding of Interstate-5 (I-5), a major north-south corridor in the Seattle-Tacoma-Bellevue metro area. Several roads in the Puyallup floodplain are subject to floods. However, the greatest impacts to transportation detours and delays are assumed to be associated with I-5 flooding with an average daily traffic count of 187,000 in 2014 (WSDOT, 2014, based on milepost 136.75 before SR 99 ramp/S837 permanent recorder number). The availability of detour routes for I-5 flooding depends on availability of other roads which intersect the floodplain.

Based on hydraulic and hydrologic (H&H) analysis, locations, depths, and frequencies of flooding of major roads were identified as shown in Figure 5-1. I-5 flooding at location 1 is in the vicinity of the Port of Tacoma and lies between Olympia and Seattle along this route.

Given the H&H analysis, two detour scenarios were analyzed for this simplified transportation analysis. Detour routes are based on a north-south commute from approximately Olympia south of the project area to Seattle north of the study area capture impacts of transportation reroutes.

The first detour is for flooding of I-5 only, with other major state routes available for detours around the I-5 overtopping location, would add approximately 7.6 trips miles one-way and an additional 0.4 hours of commute time. This is estimated to occur with approximately a 5% ACE event assuming levee failure.

The second detour is for a major, infrequent flood event which could inundate not only I-5, but other major state routes which intersect the study area. Historically, flooding of I-5 in Centralia and Chehalis approximately 60 miles south of the study area have led to long detours which require trucks and other vehicles to travel down to Interstate-84 near Portland, over to the Tri-Cities in Washington State (Richland, Kennewick, Pasco) and over to Seattle via Snoqualmie Pass along Interstate-90 (see map of major detour route below, taken from WSDOT Research Report WA-RD 832.1, Travel Costs Associated with Flood Closures of State Highways Near Centralia/Chehalis, Washington). Because flooding in the project area has not occurred, this reroute is thought to be conservative and a best estimate at this time for what transportation reroutes may look like for trucks and cars which choose to take a detour as opposed to cancelling or postponing their trip(s). This major reroute would add approximately 485.1 additional trip miles one-way and an additional 7 hours of commute time. Flooding is estimated to last approximately 4 days for this major reroute scenario. This is estimated to occur with approximately a 0.5% ACE event assuming levee failure and levee overtopping. Table 5-6 summarizes the incremental miles and time compared to a no flood scenario in the table below, and Figure 5-2 and Figure 5-3 display the minor and major detours, respectively.

Table 5-6. Incremental Miles and Time Associated with Detour Routes

Route	Approx % ACE event	Miles	Hours	Delay Miles per Trip	Delay Hours per Trip	Average Days of Reroute	Average Daily Traffic Counts (WSDOT 2014)	% of Trucks
Normal I-5 Route (Olympia<-->Seattle), No Detour	N/A	60.9	1.1	0	0	--	187,000	7%
Minor I-5 Reroute	5% ACE	68.5	1.4	7.6	0.4	2	187,000	7%
Major I-5 Reroute	0.5% ACE	546	8.5	485.1	7.0	4	187,000	7%

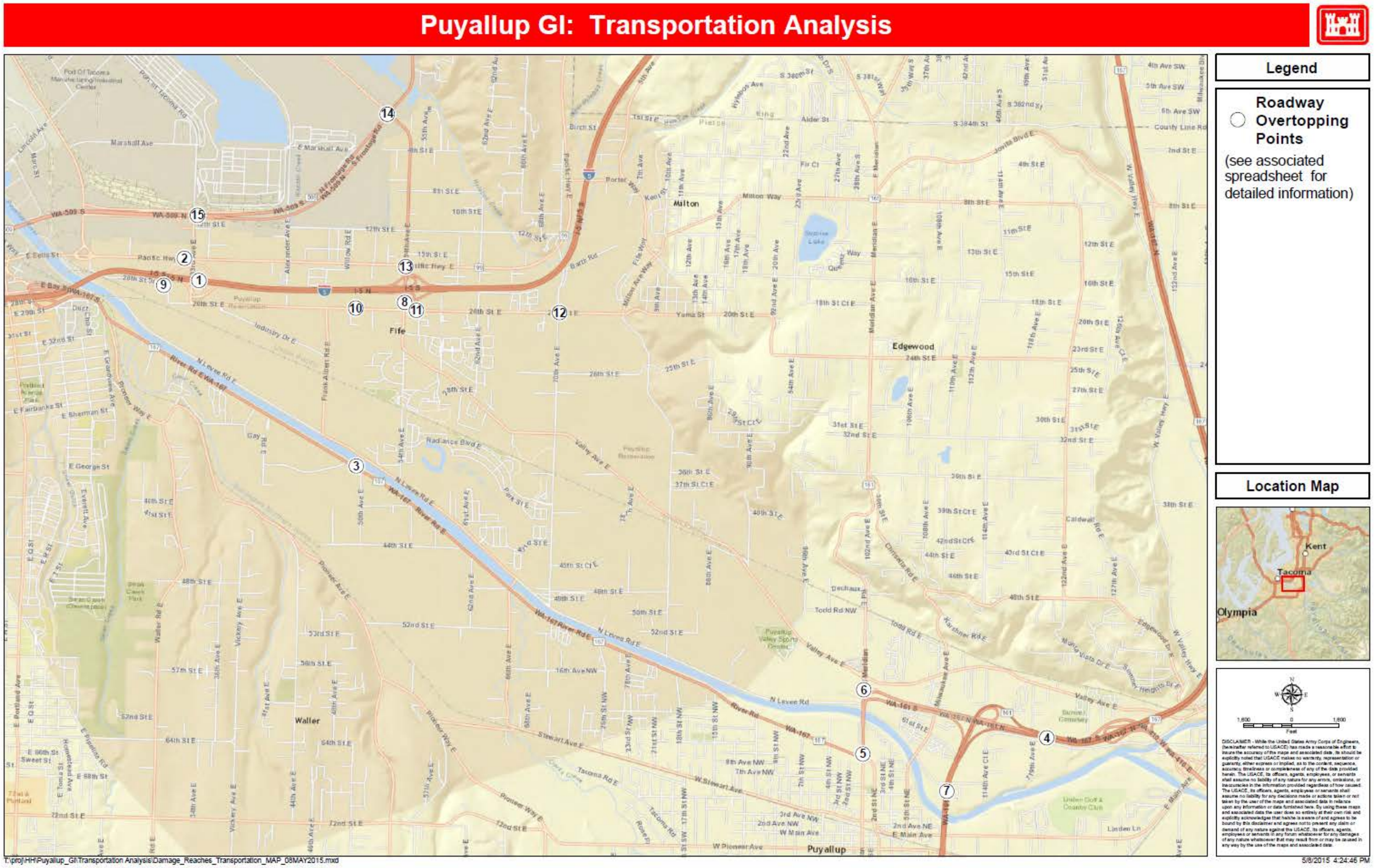


Figure 5-1. Transportation Analysis

Location 1 near the Port of Tacoma/Fife was identified as a potential overtopping location for Interstate-5.

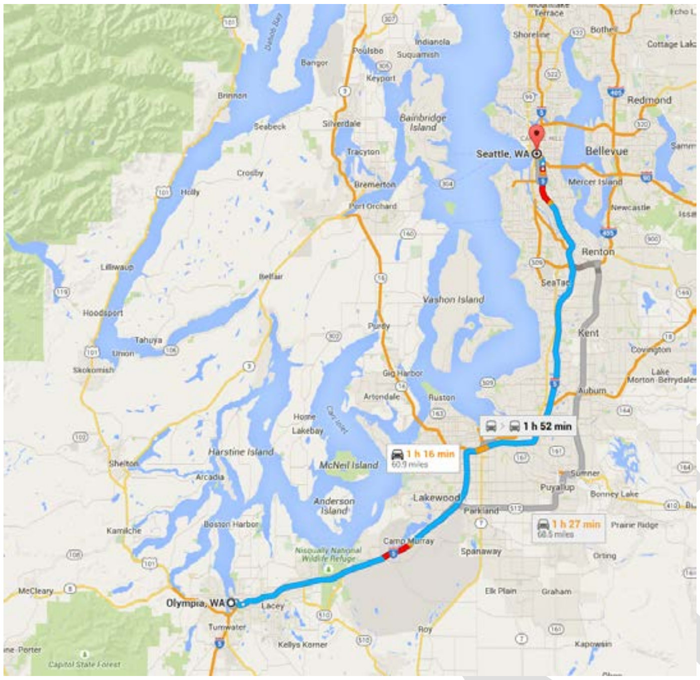


Figure 5-2. Minor I-5 Reroute Map[4]

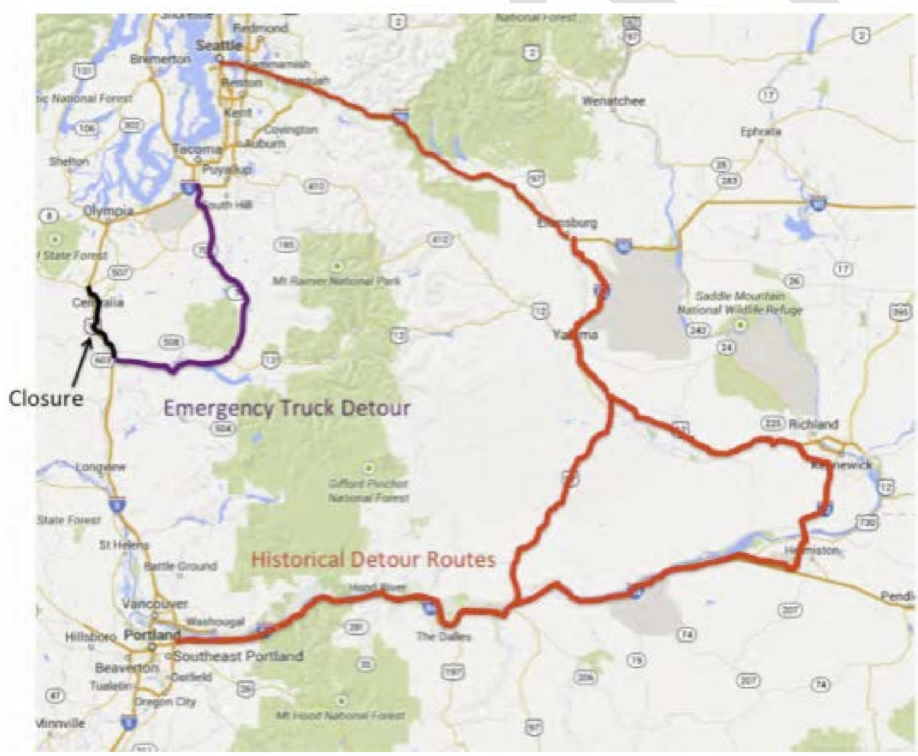


Figure 5-3. Major I-5 Reroute Map based on historical flooding of I-5 in Chehalis/Centralia[5]

[4] Source: Google Maps
[5] Source: http://www.wsdot.wa.gov/research/reports/fullreports/832.1.pdf

Costs were estimated for the incremental operating costs and the value of time associated with the additional travel time for the detour routes. These damages are estimated based on Corps guidance, ER 1105-2-100, Planning Guidance Notebook.

Incremental vehicle operating costs were estimated for each of the two detour routes based on average daily traffic counts, additional mileage for the reroute, and variable operating cost per mile as shown in Table 5-7. The variable operating cost per mile of $0.19 was obtained from AAA 2014 driving cost estimates for an average vehicle. Incremental vehicle operating costs per day was estimated to be the product of the trips, additional mileage, and operating cost per mile. Based on a recent Washington State Department of Transportation Research Report on travel costs associated with I-5 and other state route closures, approximately 42 percent of people would chose to take a detour route as opposed to other options such as cancelling, postponing, or utilizing another transportation mode to reach their intended destinations. This percentage was applied to estimate vehicle operating costs for the two detours given the estimated closures of two days for the minor detour and four days for the major detour. This resulted in a mean vehicle operating cost of $227,000 for the minor detour and $28,956,000 for the major detour. A standard deviation was applied to assume plus or minus a day to these detour estimates, or $113,000 for the minor detour and $7,239 for the major detour.

Opportunity costs, or the value of time costs, were estimated for the increased travel time that would be required to take the two detour routes as shown in Table 5-8. These are based on the same assumption that 42 percent of people would not take a detour route given the estimate closure durations. The value of time is based, in part, on the trip purpose. Work trips, for instance, have a higher opportunity of cost time if there are multiple employees carpooling and incurring the opportunity cost associated with the detour. Trip purposes were broken out by work, social and recreational, and other and proportions are based on the latest National Household Transportation Survey (NHTS 2009). Vehicle occupancy for work trips is estimated to be 1.25 per vehicle based on previous Seattle District studies. The value of time is not estimated for additional occupants in vehicles with other trip purposes. Rather, they assume the opportunity costs is for one occupant in one vehicle. Median household income per hour for Pierce County is used to estimate the value of time. For Pierce County, the latest U.S. Census American Community Survey indicated the median household income was $59,204, which is approximately $28 per hour assuming 2,080 working hours per year (U.S. Census 2013). A percentage was applied to this hourly estimate based on trip purpose obtained from the Planning Guidance Notebook. The estimated opportunity cost is $1,113,000 for the minor detour and $40,111,000 for the major detour. A standard deviation was applied to assume plus or minus a day to these detour estimates, or $557,000 for the minor detour and $10,000 for the major detour.

Table 5-7. Incremental Vehicle Operating Costs

Route	Average Daily Traffic Counts*	Incremental Distance (Miles)	Vehicle Operating Cost (VOC) - $/Mile **	Total VOC/Day ($'000s)	# Days	Total VOC ($'000s)	Std Dev ($'000s)
Minor I-5 Reroute	187,000	7.6	$0.19	$270	2	$227	$113
Major I-5 Reroute	187,000	485.1	$0.19	$17,236	4	$28,956	$7,239

*Location S837, All Vehicles - Passenger
**Operating cost per mile (Source: Average operating costs per mile, AAA 2014 Edition, Your Drive Costs, http://publicaffairsresources.aaa.biz/wp-content/uploads/2014/05/Your-Driving-Costs-2014.pdf)

Table 5-8. Incremental Opportunity of Time Costs

Route	AADTC (All Vehicles - Assumed Passenger)	Incremental Time 1-Way (Hours)	Percentages by Trip Purpose*	Assumed Occupants / Vehicle	VOT**** % Median Household Income (Including Driver)	Days of Detour	Median Household Income per Hour (Pierce County)**	Trip Purpose	Total VOT by Trip Purpose ($'000s)***	Std Dev (1-day value, $'000s)
Minor I-5 Reroute	187000	0.4	25.0%	1.25	53.8%	2.0	$28	Work	$293	$147
	187000	0.4	30.0%	1	60.0%	2.0	$28	Soc/Rec	$314	$157
	187000	0.4	45.0%	1	64.5%	2.0	$28	Other	$506	$253
Total, I-5 minor reroute									***$1,113***	***$557***
Major I-5 Reroute	187000	7.0	25.0%	1.25	53.8%	4.0	$28	Work	$10,564	$2,641
	187000	7.0	30.0%	1	60.0%	4.0	$28	Soc/Rec	$11,310	$2,827
	187000	7.0	45.0%	1	64.5%	4.0	$28	Other	$18,237	$4,559
Total, I-5 major reroute									***$40,111***	***$10,028***

*Percentages by Trip Purpose Source: National Household Transportation Survey, 2009, http://nhts.ornl.gov/2009/pub/stt.pdf
**Based on Pierce County median household income, 2013, U.S. Census Bureau 2013 American Community Survey ($59,204 / 2080 hours)
***On average only 42 percent of trips normally occurring on I-5 in the Centralia/Chehalis area are estimated to occur. (Source: http://www.wsdot.wa.gov/research/reports/fullreports/832.1.pdf)
****VOT = vehicle occupancy type

The operating costs and opportunity costs were combined to estimate total damage associated with transportation delays. These are summarized in the Table 5-9 with the stages (elevation) that are estimated to trigger these closures based on the information obtained by hydrology and hydraulics.

Table 5-9. Point Estimates for Detour Route Scenarios

Stage	Damage ($'000s)	Std Dev (+/- 1-day delay, $'000s)	Scenario
12.49	$0	$0	Zero-damage, no flooding of major roadways
12.5	$1,340	$670	I-5 Minor Reroute: Minor delay associated with I-5 closure (2 days, with +/- 1 day for std dev) Approx associated with a 5% ACE or greater flood.
18.4	$69,067	$17,267	I-5 Major reroute: Major delay associated with I-5 closure (4 days, with +/- 1 day for std dev) Approx associated with a 0.5% ACE or greater flood.

Interpolating between the point estimates for the minor and major delays above, a stage-damage function with a normal distribution assumed to be plus or minus a day of detours was developed and input into the economic analysis as shown in Table 5-10. It is assumed that other major roads would continue to be available in the event that I-5 floods for events prior to an 18.4 foot stage, but detour durations may increase up to five days for an 18 foot stage. It is assumed for larger and infrequent events that detour durations and reroutes would be similar to the major reroute, thus damages are assumed to remain constant after a 19 foot stage at the I-5 overtopping location.

Table 5-10. Stage-Damage Function with Uncertainty (Normal Distribution) for Transportation Delays

Stage	Damage ($'000s)	Std Dev ($'000s)
12	$0	$0
13	$1,340	$670
14	$1,742	$670
15	$2,144	$670
16	$2,546	$670
17	$2,948	$670
18	$3,350	$670
19	$69,067	$17,267
24	$69,067	$17,267

This stage-damage curve was translated to the DR_65 index location using the approximate ACE information and stage information at river cross section 10752.54. The resulting stage-damage function with uncertainty was input into HEC-FDA to compute expected annual damages for transportation delays.

Table 5-11. Stage-Damage Function with Uncertainty (Normal Distribution) for Transportation Delays translated to DR_65 Index Location

	Without Project		With Project	
Stage	Damage ($'000s)	Std Dev ($'000s)	Damage ($'000s)	Std Dev ($'000s)
12	$0	$0	$0	$0
17.5	$1,340	$670	$0	$0
18	$1,742	$670	$0	$0
18.5	$2,144	$670	$0	$0
19	$2,546	$670	$0	$0
19.5	$69,067	$17,267	$69,067	$17,267
22.5	$69,067	$17,267	$69,067	$17,267

6. Without-Project Damages

6.1. HEC-FDA Model

For the Puyallup River GI Feasibility Study, expected annual damages were estimated using the US Army Corps of Engineers, FRM-PCX certified risk-based Monte Carlo simulation program HEC-FDA v. 1.2.5a and v. 1.4 depending on timing of the iteration of analysis. This project formally transitioned to v. 1.4 in September 2015 per Corps guidance on transition of studies to this latest version of the model.

Risk is a function of both probability and consequence, and the fact that risk inherently involves chance leads directly to a need to describe and plan for uncertainty. Corps policy has long been to acknowledge risk and uncertainty in anticipating floods and their impacts and to plan accordingly. In a flood risk management study, risk is defined as the probability of failure during a flood event and the resulting consequence. Uncertainty is a measure of the imprecision of knowledge of variables in a project plan. Historically, that planning relied on analysis of the expected long-term performance of flood-damage reduction measures, application of safety factors and freeboard, designing for worse case scenarios, and other indirect solutions (such as engineering judgment) to compensate for uncertainty. These indirect approaches were necessary because of the lack of technical knowledge of the complex interaction of uncertainties in estimating hydrologic, hydraulic, geotechnical, and economic factors due to the complexities of the mathematics required for doing otherwise. However, with advances in statistical hydrology and the availability of computerized analysis tools (such as HEC-FDA described below), it is now possible to improve the evaluation of uncertainties in the hydrologic, hydraulic, geotechnical, and economic functions. Through this risk analysis, and with careful communication of the results, the public can be better informed about what to expect from flood-damage reduction projects and thus can make more informed decisions. The determination of expected annual damages (EAD) for a flood reduction study must take into account complex and uncertain hydrologic, hydraulic, geotechnical, and economic information:

- Hydrologic - The discharge-frequency function describes the probability of floods equal to or greater than some discharge Q,
- Hydraulics - The stage-discharge function describes how high (stage) the flow of water in a river channel might be for a given volume of flow discharge,
- Geotechnical - The geotechnical levee failure function describes the levee failure probabilities vs. stages in channel with resultant stages in the floodplain, and
- Economics - The stage-damage function describes the amount of damage that might occur given certain floodplain stages.

6.2. Estimation of Expected Annual Damages (EAD)

To find the damage for any given flood frequency, the discharge for that frequency is first located in the peak discharge (discharge-frequency) graph (graph #1), then the river channel stage associated with that discharge value is determined in the peak stage (stage-discharge) graph (graph #2). Once the levees fail according to a levee fragility curve (graph #3) and water enters the floodplain, the stages (water depths) in the floodplain inundate structures and cause damage (graph #4, left side). HEC-FDA uses a sampling of the curves within the uncertainty bounds of these relationships to generate the probability damage curves used in EAD calculations. By plotting this damage and repeating for process many times, the damage-frequency curve is determined (graph #4, right side). EAD is then computed by finding the area under the flood damage-frequency curve by integration for the without, interim, and with project conditions. Reductions in EAD attributable to projects are flood reduction benefits. Uncertainties are present for each of the functions discussed above and these are carried forth from one graph to the next, ultimately accumulating in the EAD. These uncertainties are shown in Figure 6-1 as "error bands" located above and below the hydrologic, hydraulic and economics curves.

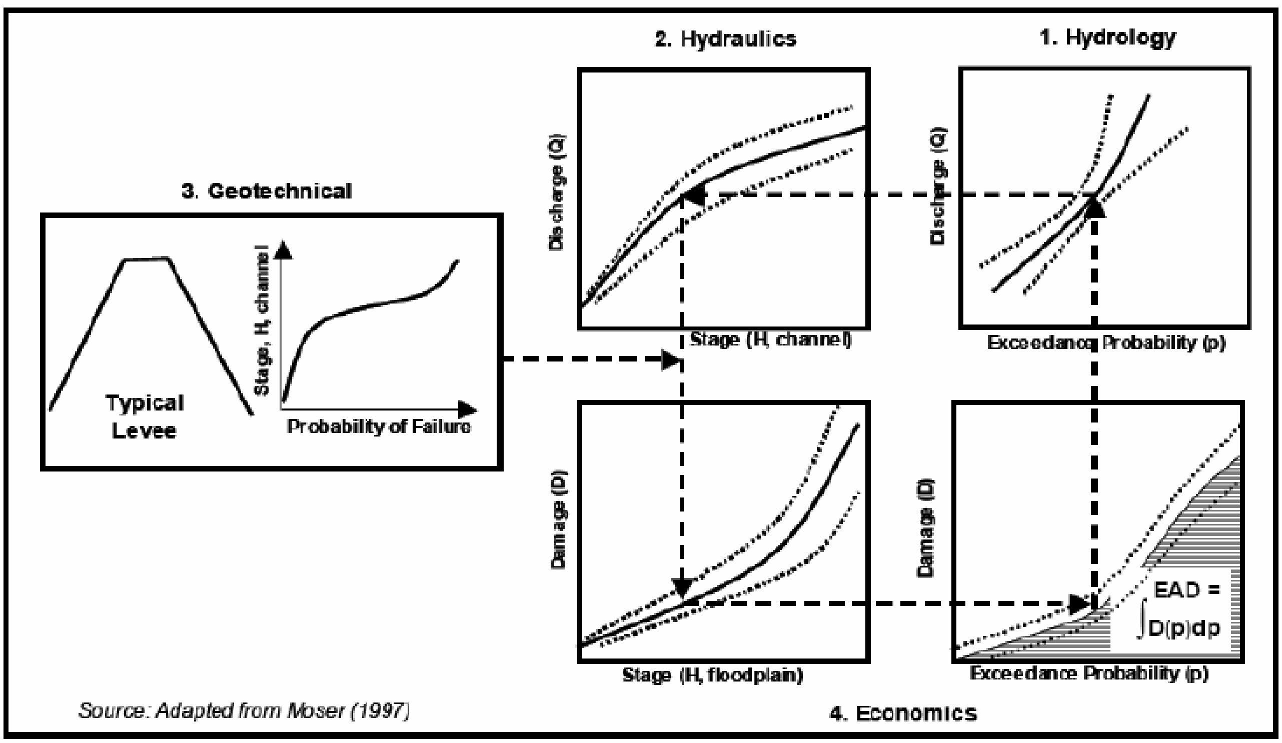


Figure 6-1. Uncertainty in Discharge, Stage, and Damage in Determination of Expected Annual Damages

Some of the important uncertainties specific to the Puyallup River Basin Feasibility Study are summarized below. Key hydrologic and hydraulic uncertainties, as well as the hydraulic modeling conducted in support of the HEC-FDA modelling of flood damages is documented in Appendix A-4, Hydrology and Hydraulics, Support of FDA Analysis.

Hydrologic - Uncertainty factors include hydrologic data record lengths that are often short or do not exist, precipitation-runoff computational methods that are not precisely known, and imprecise knowledge of the effectiveness of flow regulation. A detailed description of hydrologic modeling and uncertainties is contained in Appendix A-4.

Hydraulics - Uncertainty arising from the use of simplified models to describe complex hydraulic phenomena, including the lack of detailed sediment modeling, geometric data, misalignments of hydraulic structures, debris load, infiltration rates, embankment failures, material variability, and from errors in estimating slope and roughness factors. For all reaches, a standard deviation in stage of 1.3 feet and 1.6 feet was used for stages tied to a 1% ACE event or less frequent in the base and future conditions, respectively. Larger uncertainty in the future condition is associated with uncertainty in sedimentation. See Appendix A-4 for additional information related to hydraulic modeling and key uncertainties.

Geotechnical – Under without project conditions, levee fragility curves were developed and input into HEC-FDA for three damage reaches identified in Section 6.3.

Economics - Uncertainty concerning land uses, depth/damage relationships, structure/content values, structure locations, first floor elevations, the amount of debris and mud, flood duration, and warning time and response of floodplain inhabitants (flood fighting).

The following conditions were forecasted for the most likely scenario if no Federal (Corps) flood risk management project were implemented in the study area. This establishment of the future without-project condition is required in the second step of the Corps planning process. The future without-project condition is used as the baseline against which the results and impacts of proposed study alternatives are compared for the same period of analysis. The future without-project condition is synonymous with the No Action Alternative under NEPA. These forecasts of future conditions are from the base year (year when a project is expected to be operational) to the end of the period of analysis (50 years). A 50-year period of analysis is assumed based on the period of time over which any alternative plan would have significant benefits effects with minimal to no changes in reservoir operations proposed (see Section 7.1). Future without-project conditions for this study are projected assuming base year 2026 and a 50-year period of analysis out to 2076.

The 1% and 0.2% ACE floodplains are forecasted to experience greater impacts from flooding under future conditions, increasing the risk to life safety, existing structures and critical infrastructure, as well as additional development that is expected to occupy the floodplain in the future. Traffic delays, school closures, railroad losses, decreased public service, and commercial and industrial business closures are also forecasted to occur for events more frequent than the 1% ACE flood event. Many of the existing levees do not provide adequate protection to a greater number of structures in the floodplain and poses a life safety risk to a greater population which inhabits that floodplain. It is forecasted that as channel capacity decreases from sedimentation the ability of the levees to provide the necessary protection will be further compromised.

Hydrologic trends with climate change show a likely increase in river flows and transported sediment during the 50-year planning period of analysis. Sediment material conveyance and consequential deposition in the Puyallup River, White River and Carbon River creates an impediment to flood flow conveyance, raises water surface elevations during flood flows and sometimes redirects flows in a way that increases channel migration risks. Channel capacity in the Puyallup riverine system will continue to decrease and flood risks will continue to occur at lower discharges in the future than it does today. Sediment loading will continue to affect rivers downstream of Mount Rainier as long as this stratovolcano is actively producing sediment at the headwaters and large flood events transport the sediment into the fluvial system.

With the current system of levees, risk of flooding from unexpected problems, larger floods or uncertainty associated with the reliability of the existing levees will remain. However, no quantifiable changes to the levee reliability can be inferred. Barring unforeseen events, Pierce County is expected to continue its maintenance and any minor damages done to the levees throughout this time period are expected to be repaired. Therefore, the levee structures are expected to perform similarly in the future without-project condition as they do currently. Under the authority of P.L. 84-99, the Corps' Seattle District can provide temporary flood assistance to meet the immediate threat, and will be undertaken only to supplement state and local efforts. Corps emergency efforts are not intended to provide permanent solutions to flood problems. The County is expected to continue other flood risk management efforts and seek to implement other recommendations in the County's 2013 Flood Hazard management Plan.

To adequately capture flood damages that would be imposed within Basin, the future without-project conditions assess flood conditions under MMD releases at 12,000 cfs as authorized in the approved MMD Water Control Manual, despite the temporary, approved operational deviation from the Water Control Manual under which MMD currently operates.

6.3. Levee Breach and Floodplain Assignments by Economic Reach and Event

Three without-project levee breach scenarios were developed and evaluated to determine the inundation area for flood events of different magnitude within the study area. The modeled levee breaches impact the adjacent floodplain areas, so the associated economic damage reach for with the levee fragility curve is assigned. The Enclosure includes the levee fragility curves modeled as part of the existing and future-without project conditions. The fragility curve assigned to the three reaches (DR_67 on the Lower Puyallup right bank above I-5 along North Levee Road, DR_65 on the Lower Puyallup below I-5 in the vicinity of the Port of Tacoma, and DR_60 on the Lower Puyallup left bank) are primarily associated with their assigned reaches for flooding prior to overtopping. For all other areas in the basin, which includes several leveed areas, flooding in the floodplain is associated with levee overtopping. Figure 6-3 is a summary, or composite, of the 1% (1/100) ACE inundation areas for the entire study area from all evaluated breaches that have less than a 90% reliability for a given mean annual exceedance event (in this case 1%) and levee overtopping locations. While this floodplain is larger than would likely be seen in a single flood/breach event, it is meant to represent the relative residual risk for the area from all remaining breach locations (i.e. failure of a levee in one location may reduce water surfaces and reduce failure potential of other levees in the basin). The inundation figure shows that several communities along the Puyallup and White Rivers would be flooded, including portions of the Port of Tacoma near the mouth of the Puyallup River. Additionally, several evacuation routes and major transportation corridors are at risk in the Lower Puyallup reach. The other inundation maps presented in Chapter 3 and for the future-without project condition were also developed as a composite floodplain that considered levee failure or overtopping.

Geotechnical issues, such as under-seepage breach failures, result in large volume flood floods at high velocities that are sudden and unpredictable. These failures allow for minimal warning time and minimal time for effective implementation of evacuation and emergency plans. Study area flood events generally occur during the winter months when cold air and water temperatures significantly increase the risk of death by exposure. Flooding is generally 1 to 3 feet in densely populated areas which pose life safety risks with consideration of evacuations, with deeper flooding in floodplain areas. Environmental justice communities, or those populations who are minority and low-income and may have disproportionately high and adverse health and environmental effects associated with flooding, may have difficulty evacuating in the event of a flood. Figures 6 and 7 in Attachment 1 to this report show population below the poverty level and percent of population in a minority group, respectively. Notable areas are on the Lower Puyallup right bank near Fife and White River right bank near Auburn and Pacific. The probability of unexpected levee failure, sediment aggradation impacting channel capacity, and the consequence of basin-wide flooding presents a continued threat to public safety, property, and critical infrastructure in the Puyallup Basin in the future.

Additionally, severity of flooding on life safety risk is also affected by the effectiveness of evacuation plans and warning systems. Pierce County has a Comprehensive Emergency Management Plan which is assessed for each of the river reaches based on flood severity. Flood severity is based on a four phase flood warning system this is determined by discharge volumes. For example, the Lower Puyallup warning is based on discharge volumes on the Puyallup River gage at Puyallup as shown in the following table.

Table 6-1. Flood Warning System for Lower Puyallup River SPA[6]

Flood Severity	Discharge (cfs)	Description
Phase 1	Less than 25,000	No flooding is occurring; however, river flows may be at elevated flow stages.
Phase 2	25,000 – 30,000	Minor flooding is likely to occur. Low lying areas may flood due to overtopping.
Phase 3	30,000 – 45,000	Moderate flooding is likely to occur. Adjacent property may be flooding and have more dangerous high-velocity flow and debris.
Phase 4	Greater than 45,000	Severe flooding is likely to occur. Adjacent and nearby property may be flooding with a very dangerous high-velocity flow, debris and deep water.

6.4. Event Damages

Single-event damages for the 50%, 10%, 5%, 2%, 1%, 0.5% and 0.2% ACE flood events were computed in the HEC-FDA model. Floodplains were based upon existing levees being breached (the levee was modeled with a hole in it at the breach location), which means that the event damage curve (prior to levee insertion in FDA) may appear relatively flat with high damages beginning at frequent events. This issue it mitigated by the insertion of a levee height and fragility curve into HEC-FDA. The application of the levee fragility curve in FDA truncates the stage damage curve during EAD calculations for those

[6] Pierce County Rivers Flood Hazard Management Plan, Risk Assessment, dated Feb 2012. Prepared with the assistance of URS.

events where a levee failure or overtopping does not occur. The 5% (1/20), 1% (1/100), and 0.2% (1/500) ACE damages are presented in Table 6-2 and represent the damages if a levee breach to the Lower Puyallup from the dominating breach location were to occur in the existing condition. Damages associated with levee failure on the Lower Puyallup is estimated to occur between a 10% and 5% ACE flood event, whereas damages associated with overtopping is estimated to occur after a 2% ACE flood event. These damages can be cross-referenced with levee information included as an attachment to this report. The damages represent single-event damages which were generated based on stage-damage estimates which include economic uncertainty parameters described in Section 5.2.

The 5% (1/20), 1% (1/100), and 0.2% (1/500) ACE damages for the without-project condition future year 2064 condition are presented below in Table 6-4 and represent the damages if a levee breach to the Lower Puyallup from the dominating breach location were to occur. The future without-project conditions reflects the damage value associated with the assumed future sedimentation that was incorporated in to the hydraulic (H&H) analysis to allow for bed aggradation and reduced channel capacity in the future. The most recent 25-year historic bed aggradation data was applied to river bed profiles for a 50-years in to the future by doubling the historic sedimentation. Based on this assumption which increases river bed elevations one to five feet depending on location in the system, overbank flooding increases in a future condition as shown in Figure 6-5. A more detailed sediment model is in development to better understand the risk associated with sedimentation in the Puyallup Basin, and specifically to future flood conditions in the basin. This sediment model will replace the analytical approach taken for the draft report and will likely result in different river bed elevation predictions which may change the optimization of features during the evaluation of National Economic Development (NED) as described in Section 8. This analysis will inform feasibility-level design and will be documented in the final feasibility report.

Table 6-2. Without-Project Base Condition Probability-Damage Functions (Structures, Contents, and Vehicles), by Study Reach (Oct 2015 Prices, 3.125% Discount Rate, $1,000s)

	Commercial			Farm Buildings			Industrial			Public			Residential			TOTAL		
Reach/% ACE	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**
Carbon River	$0	$0	$0	$449	$511	$525	$113	$175	$220	$0	$0	$0	$1,092	$1,762	$3,015	$1,654	$2,449	$3,760
Lower Puyallup	5,809	27,387	108,853	526	1,064	1,702	2,117	28,695	178,268	2,478	9,635	18,097	8,553	29,853	109,269	19,482	96,634	416,188
Middle Puyallup	3,369	3,419	9,482	163	167	195	251	437	18,110	0	8	2,225	4,080	10,446	47,468	7,863	14,476	77,481
Upper Puyallup	0	0	220	162	191	197	0	0	0	0	0	54	767	927	4,050	929	1,119	4,521
White River	2,303	2,584	12,831	1	1	55	24,728	25,923	109,639	0	0	0	21,391	21,529	25,475	48,423	50,037	148,001
TOTAL	**11,482**	**33,389**	**131,385**	**1,300**	**1,935**	**2,675**	**27,208**	**55,230**	**306,237**	**2,478**	**9,643**	**20,376**	**35,883**	**64,517**	**189,277**	**78,351**	**164,714**	**649,950**

Table 6-3. Without-Project Base Condition Value as Percentage of Total Damage by % ACE and Study Reach

	Commercial			Farm Buildings			Industrial			Public			Residential			TOTAL		
Reach/% ACE	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**
Carbon River	0%	0%	0%	35%	26%	20%	0%	0%	0%	0%	0%	0%	3%	3%	2%	2%	1%	1%
Lower Puyallup	51%	82%	83%	40%	55%	64%	8%	52%	58%	100%	100%	89%	24%	46%	58%	25%	59%	64%
Middle Puyallup	29%	10%	7%	13%	9%	7%	1%	1%	6%	0%	0%	11%	11%	16%	25%	10%	9%	12%
Upper Puyallup	0%	0%	0%	12%	10%	7%	0%	0%	0%	0%	0%	0%	2%	1%	2%	1%	1%	1%
White River	20%	8%	10%	0%	0%	2%	91%	47%	36%	0%	0%	0%	60%	33%	13%	62%	30%	23%
TOTAL	**15%**	**20%**	**20%**	**2%**	**1%**	**0%**	**35%**	**34%**	**47%**	**3%**	**6%**	**3%**	**46%**	**39%**	**29%**	**100%**	**100%**	**100%**

Table 6-4. Without-Project Future Condition Probability-Damage Functions (Structures, Contents, and Vehicles), by Study Reach (Oct 2015 Prices, 3.125% Discount Rate, $1,000s)

	Commercial			Farm Buildings			Industrial			Public			Residential			TOTAL		
Reach/% ACE	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**
Carbon River	$0	$0	$0	$449	$511	$525	$113	$175	$220	$0	$0	$0	$1,092	$1,762	$2,506	$1,654	$2,449	$3,251
Lower Puyallup	25,936	61,744	128,459	735	1,300	1,739	13,720	76,620	200,326	4,920	11,788	18,469	13,433	49,788	120,854	58,745	201,240	469,846
Middle Puyallup	0	47	1,296	164	166	237	126	3,318	20,364	0	246	4,676	4,979	16,114	41,770	5,268	19,892	68,343
Upper Puyallup	1,045	1,292	1,506	165	211	312	0	0	0	1,275	1,794	2,346	7,260	8,774	11,292	9,744	12,071	15,456
White River	12,361	12,486	16,942	24	25	55	64,956	66,444	136,162	0	0	8	29,665	30,108	39,056	107,006	109,064	192,223
TOTAL	**39,342**	**75,570**	**148,203**	**1,537**	**2,214**	**2,869**	**78,915**	**146,558**	**357,071**	**6,195**	**13,828**	**25,499**	**56,428**	**106,545**	**215,478**	**182,418**	**344,716**	**749,120**

Table 6-5. Without-Project Future Condition Value as Percentage of Total Damage by % ACE and Study Reach

	Commercial			Farm Buildings			Industrial			Public			Residential			TOTAL		
Reach/% ACE	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**	**5%**	**1%**	**0.2%**
Carbon River	0%	0%	0%	29%	23%	18%	0%	0%	0%	0%	0%	0%	2%	2%	1%	1%	1%	0%
Lower Puyallup	66%	82%	87%	48%	59%	61%	17%	52%	56%	79%	85%	72%	24%	47%	56%	32%	58%	63%
Middle Puyallup	0%	0%	1%	11%	8%	8%	0%	2%	6%	0%	2%	18%	9%	15%	19%	3%	6%	9%
Upper Puyallup	3%	2%	1%	11%	10%	11%	0%	0%	0%	21%	13%	9%	13%	8%	5%	5%	4%	2%
White River	31%	17%	11%	2%	1%	2%	82%	45%	38%	0%	0%	0%	53%	28%	18%	59%	32%	26%
TOTAL	**22%**	**22%**	**20%**	**1%**	**1%**	**0%**	**43%**	**43%**	**48%**	**3%**	**4%**	**3%**	**31%**	**31%**	**29%**	**100%**	**100%**	**100%**

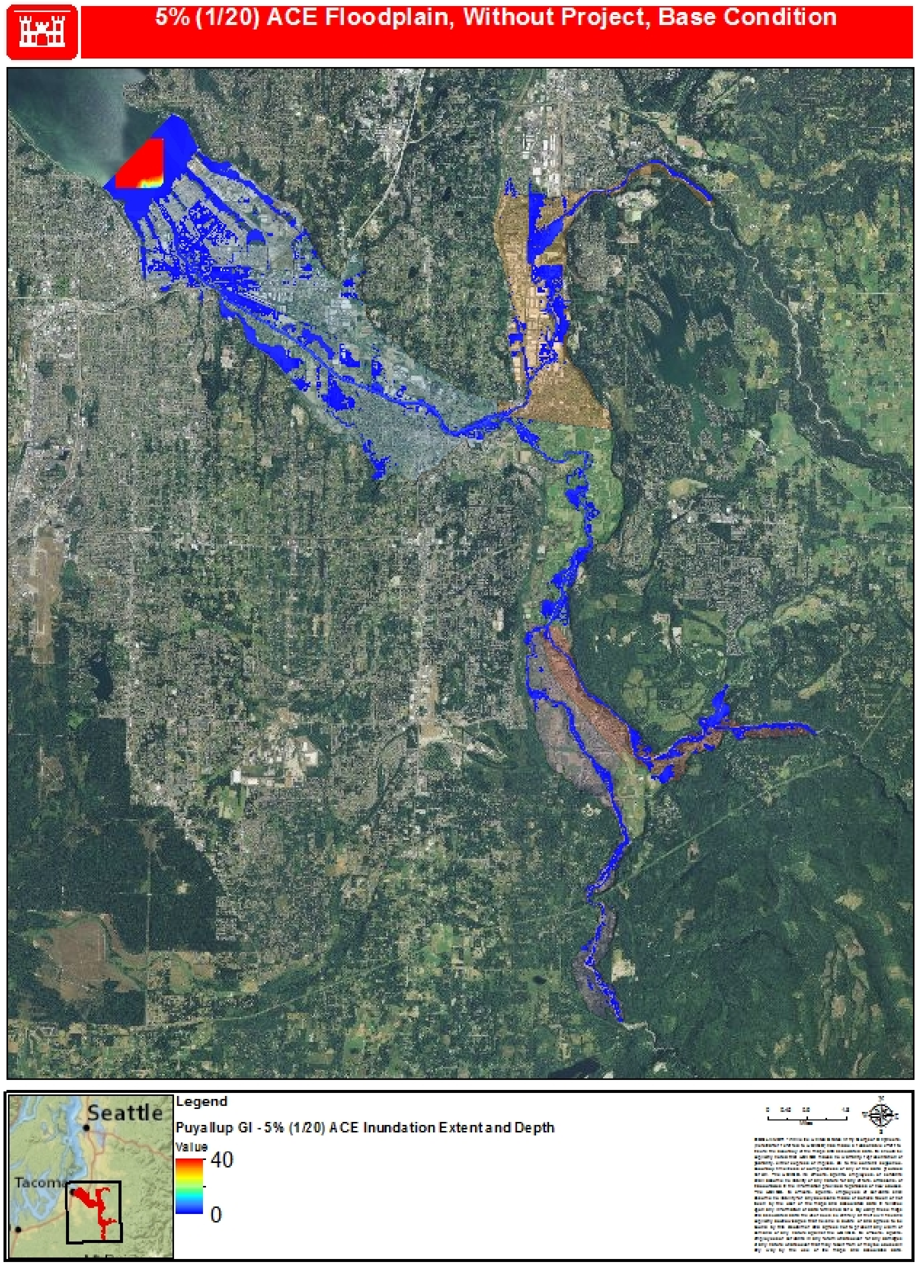


Figure 6-2. 5% (1/20) ACE Composite Without-Project Base Condition Floodplain

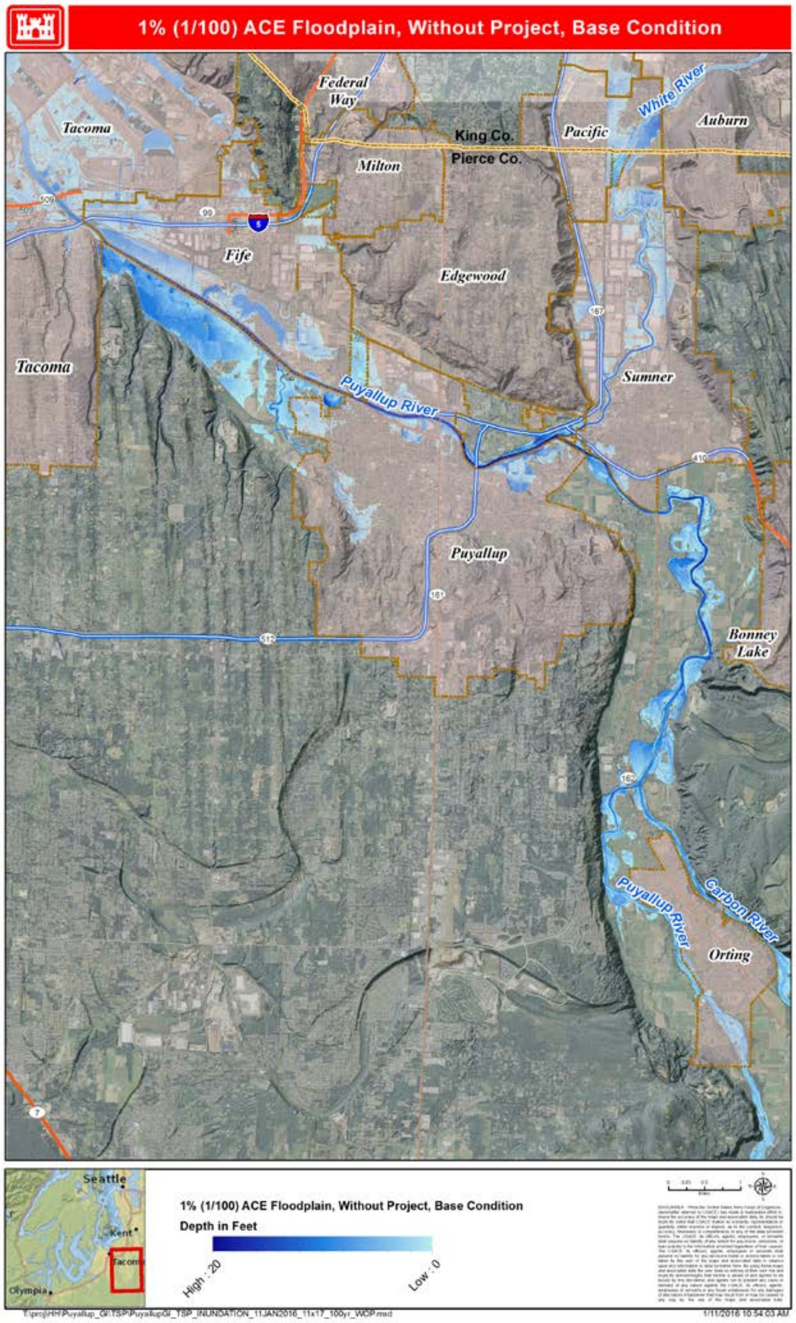


Figure 6-3. 1% (1/100) ACE Composite Without-Project Base Condition Floodplain

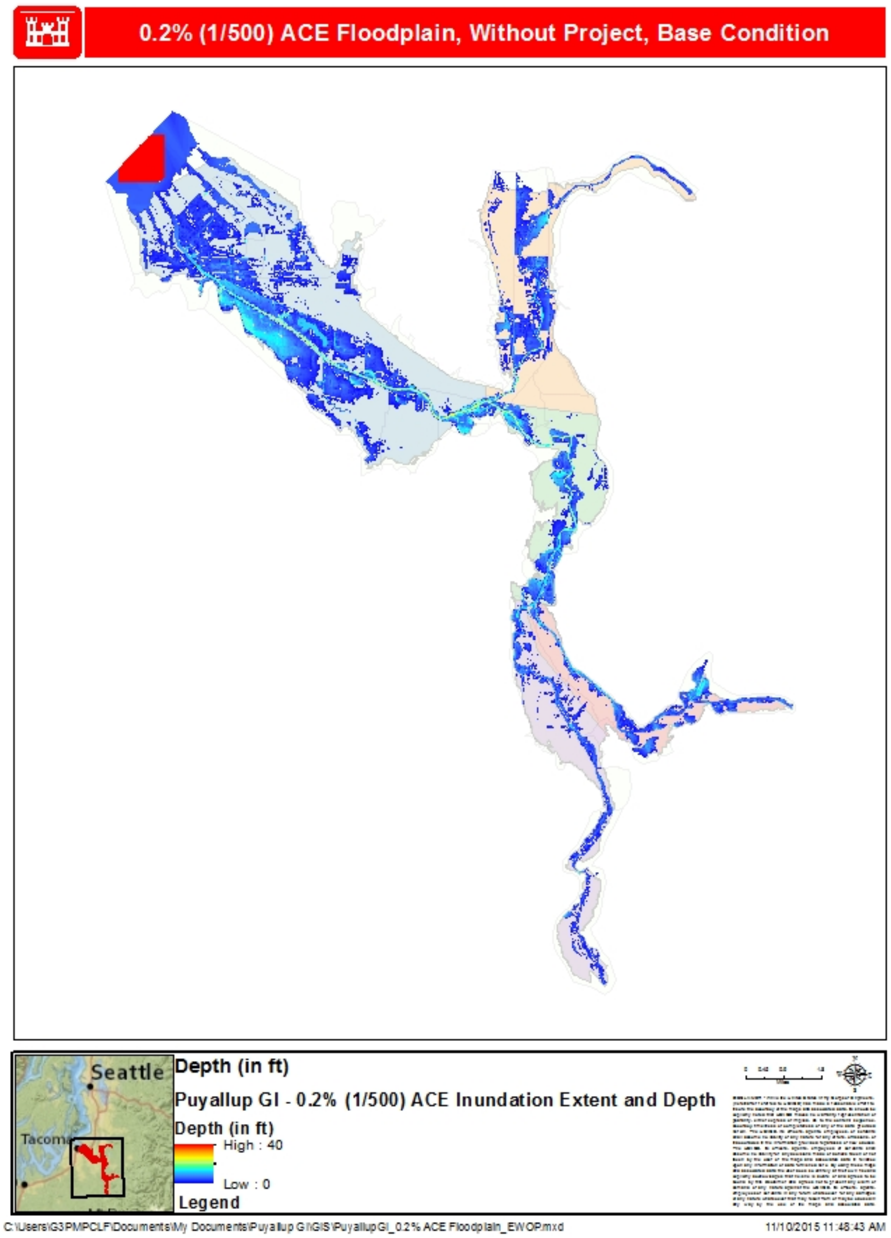


Figure 6-4. 0.2% (1/500) ACE Composite Without-Project Base Condition Floodplain

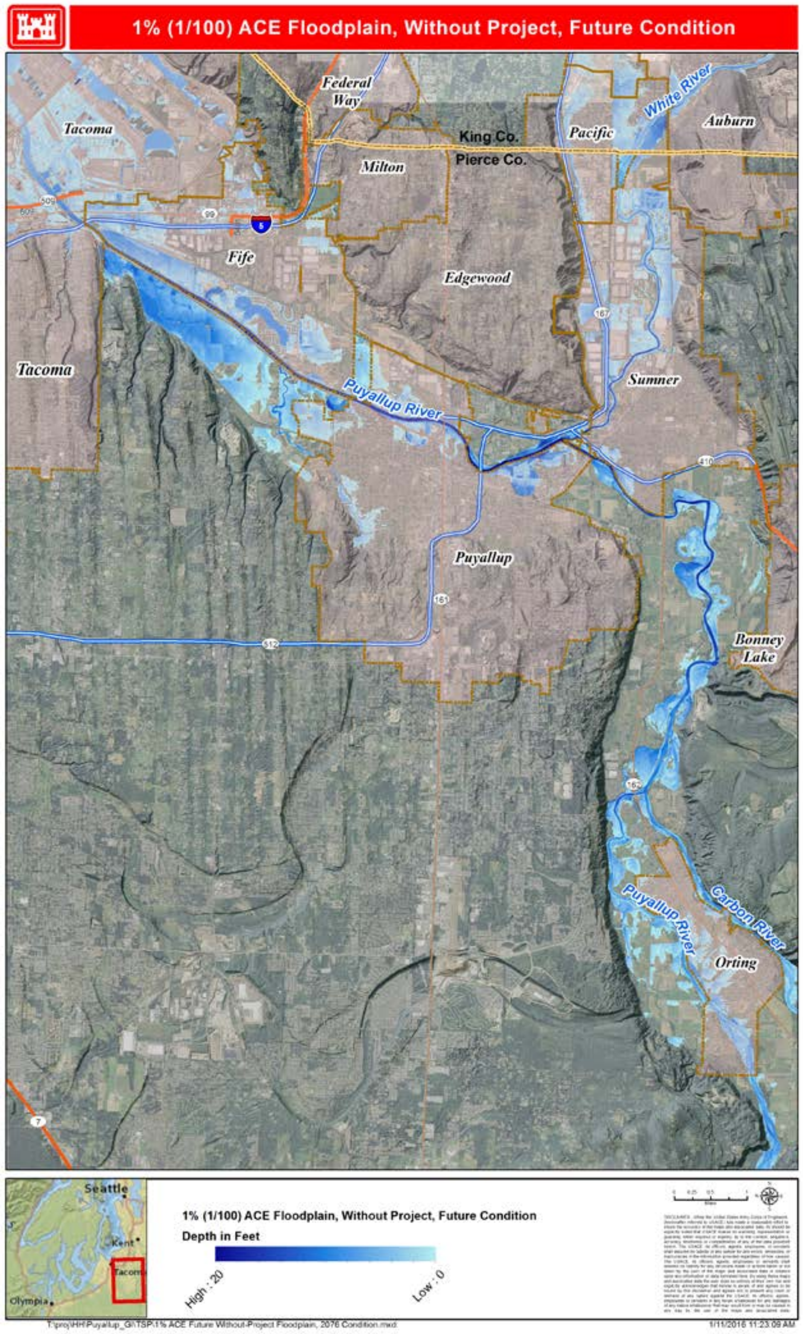


Figure 6-5. 1% ACE Composite Without-Project Future Condition Floodplain

6.5. Expected Annual Damages – Existing and Future Without-Project Conditions

Expected annual damages presented in this section utilize the current Federal discount rate of 3.125 percent (fiscal year 2016) and costs are reported at the October 2015 price level. Discounting is used to convert future monetary values to present values and the Federal discount rate is established annually for the formulation and economic evaluation of plans for water and related land resources. The interest rate for discounting converts benefits and costs to a common time basis, in this case October 2015.

The HEC-FDA without-project conditions model expected annual damage (EAD) results for structures, contents, and automobiles for the existing without-project condition are shown, by reach, in Table 6-6. Total study area without-project EAD is estimated at $41.5 million. Table 6-6 displays EAD as a percentage by occupancy class for each reach. For example, the EAD for Lower Puyallup is 31% commercial, 1% farm building, 37% industrial, 6% public, 19% residential, and 6% transit delays. Further, the Lower Puyallup and White River reaches contribute 23% and 69% of total EAD, respectively; and industrial and residential occupancies contribute 23% and 63% of EAD in the without-project base condition, respectively. While there is greater value in the Lower Puyallup reach with high concentrations of residential and industrial structures, the White River is subject to more frequent flooding under future without-project assumptions related to Mud Mountain Dam releases of 12,000 cfs and channel capacity on the White River estimated to be around 7,500 cfs today.

Table 6-6. Without-Project Base Condition Expected Annual Damages (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Building	Industrial	Public	Residenti al	Transit Delays	Total EAD
Carbon River	$0	$57	$5	$1	$84	0	$147
Lower Puyallup	2,920	85	3,585	562	1,804	617	$9,572
Middle Puyallup	85	20	312	53	1,705	0	$2,182
Upper Puyallup	23	119	0	19	751	0	$892
White River	1,031	1	5,796	0	21,918	0	$28,747
Total EAD	**$4,059**	**$281**	**$9,706**	**$635**	**$26,242**	**$617**	**$41,540**

Table 6-7. Without-Project Base Condition EAD by Occupancy Class and Reach, as a Percentage of Reach EAD (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Building	Industrial	Public	Residential	Transit Delays	EAD as a % of Total EAD
Carbon River	0%	39%	3%	1%	57%	0%	0%
Lower Puyallup	31%	1%	37%	6%	19%	6%	23%
Middle Puyallup	4%	1%	14%	2%	78%	0%	5%
Upper Puyallup	3%	13%	0%	2%	84%	0%	2%
White River	4%	0%	20%	0%	76%	0%	69%
Total EAD	**10%**	**1%**	**23%**	**2%**	**63%**	**1%**	**100%**

Table 6-8 displays EAD estimates for the future condition. Similarly, Table 6-9 displays EAD as a percentage by occupancy class for each reach. The without-project future condition is the most likely condition expected to exist in the future in the absence of a proposed water resources project and constitutes the benchmark against which alternatives are evaluated. The economic analysis assumes development will continue in urban growth areas as defined by city land use plans by either developing vacant lands or replacing existing development with more dense development and multifamily residences, as well as growth in Port-related business and infrastructure as the economy grows locally in Puget Sound and nationally. Currently there is not consistency between city land use and development codes, but a recommendation of the Pierce County Flood Hazard Management Plan is to adopt best practices for floodplain development which includes no development in floodways and at a minimum elevating structures above the FEMA 1% ACE floodplain. For the purposes of the economic analysis, the base structure inventory as of 2014 was used to project flood damages but it should be acknowledged that future development would pose additional risks to property damage and life safety in the Study area. New development is assumed to be elevated above the 1% ACE flood elevation and therefore will not be subject to restrictions under Section 308 of WRDA 1990. The future condition EAD estimates include sediment analysis and NOAA intermediate sea-level rise projections of less than 1 foot near Commencement Bay on the Lower Puyallup reach.

Table 6-9. Without-Project Future Condition EAD by Occupancy Class and Reach, as a Percentage of Reach EAD (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	EAD as a % of Total EAD
Carbon River	0%	42%	4%	0%	54%	0%	0%
Lower Puyallup	27%	1%	42%	5%	19%	6%	23%
Middle Puyallup	1%	1%	26%	3%	69%	0%	5%
Upper Puyallup	9%	2%	0%	13%	76%	0%	11%
White River	12%	0%	26%	0%	62%	0%	61%
Total EAD	**15%**	**0%**	**27%**	**3%**	**54%**	**1%**	**100%**

Table 6-10 summarizes equivalent annual damages in the Study area, or damages over the 50-year period of analysis which includes the results of the without-project base condition. Equivalent annual damages have been computed and are the expected annual damages that have been converted to a single present worth value and then amortized over the analysis period using the federally mandated discount rate of 3.125% (FY16 discount rate). Table 6-11 displays equivalent EAD as a percentage by occupancy class for each reach, where the Lower Puyallup and White River reaches account for 23% and 64% of equivalent EAD for this study area, respectively.

Table 6-8. Without-Project Future Condition Expected Annual Damages (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total EAD
Carbon River	$0	$56	$5	$0	$71	$0	$132
Lower Puyallup	4,755	119	7,305	931	3,208	985	$17,303
Middle Puyallup	51	38	894	96	2,376	0	$3,455
Upper Puyallup	797	147	2	1,129	6,418	0	$8,494
White River	5,483	3	11,598	38	28,154	0	$45,276
Total EAD	**$11,086**	**$363**	**$19,804**	**$2,194**	**$40,227**	**$985**	**$74,660**

Table 6-9. Without-Project Future Condition EAD by Occupancy Class and Reach, as a Percentage of Reach EAD (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	EAD as a % of Total EAD
Carbon River	0%	42%	4%	0%	54%	0%	0%
Lower Puyallup	27%	1%	42%	5%	19%	6%	23%
Middle Puyallup	1%	1%	26%	3%	69%	0%	5%
Upper Puyallup	9%	2%	0%	13%	76%	0%	11%
White River	12%	0%	26%	0%	62%	0%	61%
Total EAD	**15%**	**0%**	**27%**	**3%**	**54%**	**1%**	**100%**

Table 6-10. Without-Project Condition, Equivalent Annual Damages (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total Equivalent EAD
Carbon River	$0	$57	$5	$0	$79	$0	$141
Lower Puyallup	3,606	98	4,977	700	2,329	755	$12,465
Middle Puyallup	73	27	534	69	1,956	0	$2,659
Upper Puyallup	313	129	1	434	2,859	0	$3,736
White River	2,697	2	7,267	14	24,251	0	$34,231
Total	**$6,689**	**$313**	**$12,784**	**$1,217**	**$31,474**	**$755**	**$53,232**

Table 6-11. Without-Project Condition, Equivalent Annual Damages by Occupancy Class and Reach, as a Percentage of Reach Equivalent Annual Damages (Oct 2015 price level, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Equivalent EAD as a % of Total Equivalent EAD
Carbon River	0%	40%	4%	0%	56%	0%	0%
Lower Puyallup	29%	1%	40%	6%	19%	6%	23%
Middle Puyallup	3%	1%	20%	3%	74%	0%	5%
Upper Puyallup	8%	3%	0%	12%	77%	0%	7%
White River	8%	0%	21%	0%	71%	0%	64%
Total	13%	1%	24%	2%	59%	1%	100%

6.6. Project Performance – Without-Project Conditions

In addition to damages estimates, HEC-FDA reports flood risk in terms of project performance. Three statistical measures are provided, in accordance with ER 1105-2-101, to describe performance risk in probabilistic terms. These include annual exceedance probability, long-term risk, and assurance by event.

- Annual exceedance probability measures the chance of having a damaging flood in any given year.
- Long-term risk provides the probability of having one or more damaging floods over a period of time.
- Assurance is the probability that a target stage will not be exceeded during the occurrence of a specified flood.

The worst project performance statistics may not necessarily be associated with the breach location producing the most economic damages. For example, multiple locations along a levee system or multiple levees can cause flooding in the Lower Puyallup right bank area which includes the Port of Tacoma. One location on a system can cause more significant annual damages in the area, when the project performance for another location which floods the same area can be worse than the more damaging location. The performance estimates represent the highest annual exceedance probability (AEP) and associated EAD damage estimate for each modeled levee breach. Additionally, multi-source flooding was considered in this evaluation. There are three creeks which may increase interior flooding as a result of existing and proposed flood risk management measures on the system: Clear Creek and Clarks Creek on the Lower Puyallup left bank, and Government canal on the White River right bank, water cannot drain if river stages are too high in the Puyallup and White Rivers until flood stages have dropped, allowing gates on those creeks to operate and outlet to the mainstem channels.

Several levees within the study area do not meet current USACE levee maintenance criteria and have performance vulnerabilities prior to overtopping.

Table 6-12 summarizes the estimated performance of levees with and without geotechnical fragility (the risk of poor geotechnical performance of the levee at a given water surface elevation or flood frequency) along the Lower Puyallup reach left and right banks to show the significance of the geotechnical condition of the levees in overall levee performance. Although failure is most likely to occur near the top of levee, the likelihood that the levee on the Lower Puyallup right bank (DR_67) would contain the 1% ACE peak flow is nearly twice as great at 13% if there were levee integrity concerns. With levee fragility, that assurance for the same peak flow condition is 6%.

Table 6-12. Performance of Existing Levees

Median Flood Frequency	Assurance with Fragility	Assurance without Fragility
Lower Puyallup Right Bank (DR_67)		
10% (1/10)	57%	93%
1% (1/100)	6%	13%
0.5% (1/200)	0.2%	3%
Lower Puyallup Left Bank (DR_60)		
10% (1/10)	88%	99%
1% (1/100)	49%	65%
0.5% (1/200)	26%	46%

Project performance for select locations in each of the five study reaches under existing and future without-project conditions is displayed in Table 6-13 and Table 6-14, respectively. Several of these reaches have a high likelihood of exceeding channel capacity, especially on the White River (see DR_84) with nearly an annual chance of being exceeded. This is due to changed conditions on the White River with increased sedimentation which has significantly reduced channel capacity to nearly 7,500 cfs, which is less than the annual peak flow. In recent years, Mud Mountain Dam has operated under a deviated flow to minimize flooding on the White River. This deviated operation is not a long-term solution to the problems on the White River and reduced outflows may actually allow for long-term sedimentation. An assumption of the future without- and with-project conditions is that the dam would operate per its Water Control Plan. See Section 7.1 for more information on why modified dam operations were not carried forward as a measure. This is also discuss in the main report. Additionally, high annual exceedance probabilities at certain locations on the Lower and Middle Puyallup (DR_67 and DR_77) have been computed. For the Upper Puyallup, this segment of levee is lower than adjacent levees and is would overtop first in the event of an 8% (~1/12) ACE or greater flow in the base condition. For the Lower Puyallup at DR_67, the annual exceedance probability is driven by the levee fragility curve which has a breach initiating at approximately a 20% (1/5) ACE or greater peak flow in the base condition. Of course, there is uncertainty associated with the fragility curve and it should be noted that the likelihood of failure for the 20% ACE peak flow is very low and may not be observed for many flood seasons. Performance for both of these locations have been confirmed with hydraulic modeling in HEC-RAS. The increase in annual exceedance probabilities in the future condition is tied to decreased channel capacity associated with sedimentation and sea-level rise of approximately one foot on the Lower Puyallup near Commencement Bay based on NOAA intermediate sea-level change projections.

Table 6-13. Project Performance – Without-Project Base Condition for Select Economic Damage Reaches

Economic Damage Reach	Study Reach	Target Stage	Annual Exceedance Probability		Long-Term Risk			Assurance by Event				
			Median	Expected	10-year	30-year	50-year	10%	5%	2%	1%	0.20%
DR_60	Lower Puyallup	17.75	6.91%	7.33%	53%	90%	98%	88%	75%	84%	49%	26%
DR_65	Lower Puyallup	18.5	6.87%	7.36%	53%	90%	98%	87%	71%	55%	40%	16%
DR_67	Lower Puyallup	39.59	21.47%	20.20%	90%	100%	100%	57%	30%	14%	6%	0%
DR_735	Middle Puyallup	76.59	0.22%	0.39%	4%	11%	18%	100%	100%	98%	89%	40%
DR_77	Upper Puyallup	233.94	5.33%	8.44%	59%	93%	99%	63%	43%	34%	28%	14%
DR_795	Carbon River	192.11	1.31%	1.96%	18%	45%	63%	100%	87%	63%	40%	7%
DR_84	White River	74.76	99.90%	99.80%	100%	100%	100%	0%	0%	0%	0%	0%

Table 6-14. Project Performance – Without-Project Future Condition for Select Economic Damage Reaches

Economic Damage Reach	Study Reach	Target Stage	Annual Exceedance Probability		Long-Term Risk			Assurance by Event				
			Median	Expected	10-year	30-year	50-year	10%	5%	2%	1%	0.20%
DR_60	Lower Puyallup	17.75	8.80%	10.22%	66%	96%	100%	78%	60%	48%	37%	21%
DR_65	Lower Puyallup	18.5	9.00%	9.82%	64%	96%	99%	78%	62%	50%	36%	16%
DR_67	Lower Puyallup	39.59	32.55%	31.51%	98%	100%	100%	40%	16%	7%	3%	1%
DR_735	Middle Puyallup	76.59	0.42%	0.89%	9%	24%	36%	100%	97%	87%	71%	24%
DR_77	Upper Puyallup	233.94	99.90%	99.85%	100%	100%	100%	0%	0%	0%	0%	0%
DR_795	Carbon River	192.11	1.33%	2.00%	18%	45%	64%	100%	87%	62%	38%	6%
DR_84	White River	74.76	99.90%	99.80%	100%	100%	100%	0%	0%	0%	0%	0%

7. With-Project Damages and Benefits

This section will describe how benefits of flood risk management of the final array of alternatives were estimated. Benefits were determined by incorporating increments of levee fixes into the HEC-FDA model that represent various with-project improvements. Flood risk management benefits equal the difference between the without project damages and the with-project residual damages.

7.1. Initial and Final Array of Alternatives

Many conceptual alternatives were considered during the plan formulation process. See the main report for a detailed description of all conceptual alternatives.

The final array of alternatives includes two action alternatives in addition to the No Action as described below. The screening and evaluation of these alternatives is described in Chapter 3 of the main report. During design and analysis of the alternatives, some additional measures were screened out due to inability to reduce flood risks and life safety risks as described in Section 3.2.4 of the main report. Measures in Alternative 2 and Alternative 3 were sited in approximate locations of the study area. The reformulated Final Array of Alternative Plans is described in detail below.

The Corps used a 1% ACE probability as a starting point for the concept-level design used in evaluation and comparison of the Final Array of Alternatives, This was for all reaches in the Study area except the lower Puyallup River reach, where a conceptual 0.5% ACE was assumed in the base condition and 0.1% ACE at the end of the planning period of analysis. This is based on Pierce County service objectives outlined in the County's Rivers Flood Hazard Management Plan and Comprehensive Plan goals. Much of the basin has existing flood risk management features that provide critical protection; however, recent experiences with flooding and sediment aggradation makes their service and performance unacceptable the sponsor. The Lower Puyallup reach Federal levees in combination with the Mud Mountain Dam flood operations were designed to regulate to a 50,000 cfs flow in that reach, which at the time was roughly equated to a 1 percent AEP. On the White River, conditions continue to change from year to year with sediment aggradation and modified dam operations. The right bank has been densely developed since construction of the dam with residential and some commercial, transitioning to an industrial park which includes a number of manufacturing distribution centers with close proximity to the ports of Tacoma and Seattle. The Port of Tacoma is located in the Lower Puyallup reach and residual flooding, though infrequent when considering all possible flood events, would result in high consequences that are not adequately captured by the damages to port-related structures and contents alone. Note that the percent ACE probability used for evaluation and comparison of alternatives may not be the same as a final design performance with assurance, which will be defined during the feasibility-level design NED analysis of the TSP, as additional design information is available and the TSP is optimized by conducted an incremental evaluation on levee and floodwall heights to identify the scale which reasonably maximized net benefits for NED and reduces residual risk to life safety. This information will be documented in the final FR/EIS.

As noted earlier, all river mile locations, and levee or floodwall lengths and heights for measures during the plan formulation process are approximate and based on professional judgment and/or concept-level design. River miles, heights and other characteristics of measures included in the TSP will be refined for the recommended plan during feasibility-level design analysis, based on additional information from sedimentation modeling, geotechnical and utility survey data, economic analysis/optimization, comments received on the DFR/EIS during public, technical, legal, and policy reviews, and will be documented in the final FR/EIS.

Alternative 1: No Action Alternative

The No Action Alternative assumes the future without-project conditions in the absence of any additional Federal action beyond O&M of existing authorized projects to estimate whether planning objectives would be achieved without a Federal project. Any reasonable activities to be pursued by state and local interests in the absence of a Federal project are assumed to be undertaken. The No Action Alternative forms the basis against which all other alternatives plans are measured.

Pierce County and King County would continue to acquire repetitively damaged properties within the floodplain as funding becomes available from FEMA and/or other sources, construct small scale levee modification projects such as the Calistoga Levee Setback and the Countyline Setback Levee. Those levee structures eligible for P.L. 84-99 rehabilitation assistance under P.L. 84-99 would continue to be repaired as they are damaged by flood events. In addition, the Corps would continue to maintain the Federal Authorized Levees to contain flows of 50,000 cfs. Levee reliability of those Pierce County projects that are not a part of the P.L. 84-99 program would continue to be an increasing concern due to challenging local budget and schedule limitations.

Sediment deposition would continue to occur within the system, decreasing channel conveyance and increasing flood risks. MMD would operate per its authorized Water Control Plan and could increase flood risks downstream as channel conveyance further decreases due to aggradation. Further, significant environmental resources are anticipated to continue to experience levels of degradations throughout the planning horizon.

Significant long-term risk of flooding would remain over the period of analysis under the No Action Alternative.

Alternative 2: Levee Modification Alternative

This alternative (Figure 7-1) would modify the existing levee system to manage flood risk by setting back an existing levee, increasing existing levee heights, improving existing levee reliability, or constructing new levees or floodwalls. The proposed levee modifications would be the primary flood risk management measure within this alternative and would work with other flood risk management measures in the alternative, including flow control structures and property acquisition, to reduce flood risk in the Basin. This is a passive approach to managing sediment, where levees are modified in order to accommodate the sediment deposition expected over the planning period of analysis.

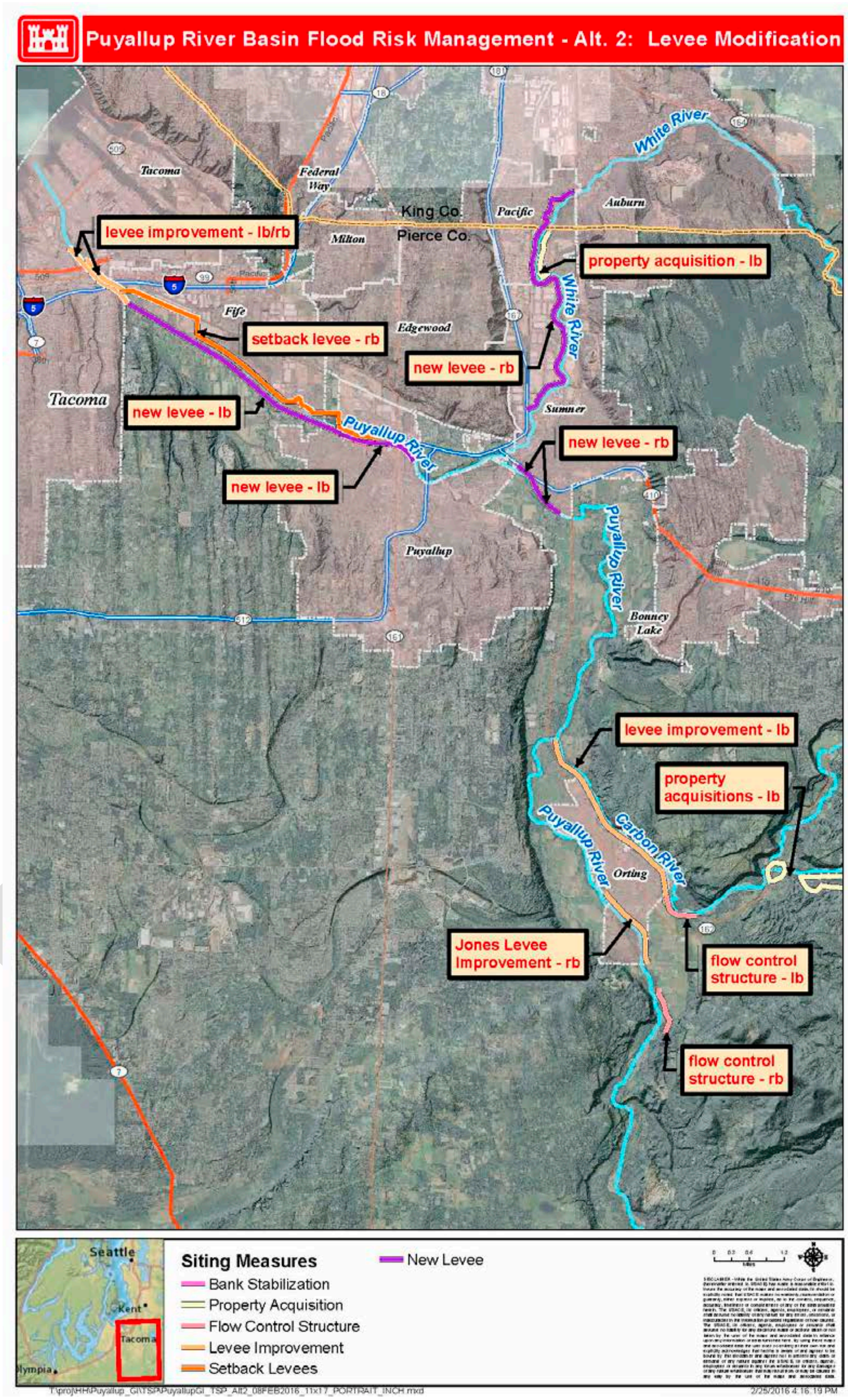


Figure 7-1. Alternative 2 - Levee Modification Alternative

Alternative 3: Sediment Management with Levee Modification Alternative

Alternative 3 (Figure 7-2) would manage sediment and its effects by including mainstem dredging as the primary measure to manage flood risks in the Basin. This alternative would include some new levees and levee improvements to manage flood risks that the dredging measure could not provide alone. The dredging and levee modification measures would work with other measures in the alternative, such as flow control structures and property acquisition, to increase channel capacity and reduce flood risks in the Basin.

Table 7-1 further describes of Alternatives 2 and 3.

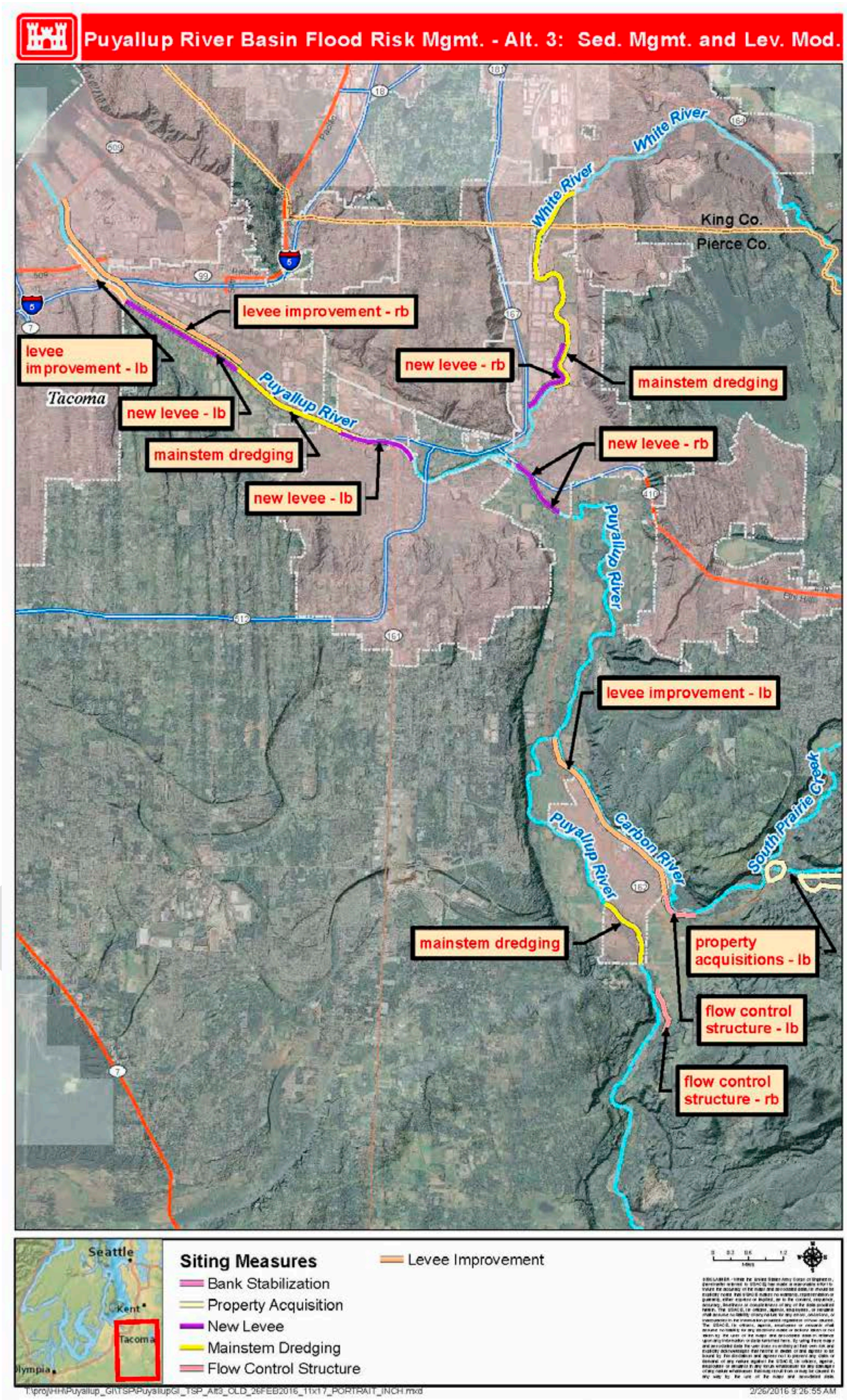


Figure 7-2. Alternative 3 – Sediment Management with Levee Modification Alternative

Table 7-1. Alternative 2 and Alternative 3 Descriptions

Measure	Alternative 2 – Levee Modification Alternative	Alternative 3 – Sediment Management with Levee Modification Alternative
General Description	Alternative 2 would modify the existing levee system to manage flood risk by setting back an existing levee, increasing existing levee heights, improving existing levee reliability, or constructing new levees or floodwalls. The proposed levee modifications would be the primary flood risk management measure within this alternative and would work with other flood risk management measures in the alternative such as flow control structures and property acquisition to reduce flood risk in the Basin. This is a passive approach to managing sediment, where levees are modified in order to accommodate the sediment deposition expected over the planning period of analysis. O&M activities would focus on semi-annual inspections and reports, proper operation and maintenance of culverts and floodwall closures, and periodic levee maintenance activities to include repair and replacement of damaged or deficient components.	Alternative 3 would manage sediment and its effects by including mainstem dredging as the primary measure to manage flood risks in the Basin. This alternative would include some new levees and levee improvements to manage flood risks that the dredging measure could not provide alone. The dredging and levee modifications measures would work with other measures in the alternative, such as flow control structures and property acquisition, to increase channel capacity and reduce flood risks in the Basin. This alternative would require initial construction dredging and subsequent maintenance dredging. ZOver the planning period of analysis, maintenance dredging is anticipated to occur one time within the lower Puyallup River, one time in the lower White reach, three times in the White River at City of Pacific, and two times in the upper Puyallup reach. The frequency of the maintenance dredging could be a challenging responsibility for the sponsor. O&M activities for the levee modifications would focus on semi-annual inspections and reports, proper operation and maintenance of culverts and floodwall closures, and periodic levee maintenance activities to include repair and replacement of damaged or deficient components.
	Lower Puyallup River	
Federal Authorized Levees	The existing Federal Authorized Levees (FAL) extend from RM 0.7 to RM 2.7 on the right bank and RM 0.7 to RM 2.9 on the left bank. This measure would raise a section of the existing left and right banks of the FAL along the lower Puyallup River. The authorized capacity of the Federal Levees is 50,000 cfs, which was intended to provide protection from floods up to 1% ACE magnitude. This measure was evaluated and compared at a 0.5% ACE probability. The FAL right bank levee would be raised from RM 2.0 to 2.7, and the FAL left bank levee would be raised from RM 1.5 to 2.9.	The existing Federal Authorized Levees (FAL) extend from RM 0.7 to RM 2.7 on the right bank and from RM 0.7 to RM 2.9 on the left bank of the lower Puyallup River. This measure would raise a section of the existing left and right bank levees over an area where it is less effective to dredge due to tidal influences. The authorized capacity of the Federal Levees is 50,000 cfs, which was intended to provide protection from floods with magnitude up to the 1% ACE flood event. This measure was evaluated and compared at a 0.5% ACE probability. The FAL right bank levee would be raised from RM 2.0-2.7, and the FAL left bank levee would be raised from RM 1.5 to RM 2.9.
Mainstem Dredging	Dredging is not included in Alternative 2 because the levee setback measure in Alternative 2 is intended to reduce flood risk by increasing conveyance capacity.	Mainstem dredging would occur once during construction and would include dredging between RM 3.1 and RM 7.4 (a total of 98 acres of riverbed and approximately one million cy) to increase channel conveyance capacity. The dredging is intended to deepen the lower Puyallup River by approximately 3 feet for 5.5 miles. Material removed during dredging would be characterized for physical characteristics and contaminants. If material is suitable it would either be used for construction activities or placed in a permitted placement site. Contaminated material would be placed in a site designated for placed of contaminated material. Maintenance dredging would be necessary. The lower Puyallup River and lower White River would be dredged once during the period of analysis while the White River near Pacific would be dredged three times and the upper Puyallup River would be dredged twice. Maintenance dredging is further detailed in Appendix A (Hydraulics and Hydrology). Alternative 3 would require initial construction dredging and subsequent maintenance dredging. Maintenance dredging is anticipated to occur within the lower Puyallup River one time over the planning timeframe.
North Levee Road Levee Raise	This levee raise measure is not included in Alternative 2 because the levee setback measure in Alternative 2 is intended to reduce flood risk in this area.	This measure would raise the existing North Levee Road levee from RM 2.7 to RM 4.9. The levee modification would manage flood risks to residential, commercial, and industrial properties.
North Levee Road A Setback	This measure would setback the existing North Levee Road levee on the right bank of the lower Puyallup River extending from RM 2.7 to the end of the North Levee Road at RM 8.1. The levee would be setback from RM 2.7 to RM 4.2 (Frank Albert Road) approximately 1,000 ft, from RM 4.2 to RM 6.0 approximately 80-100 ft, from RM 6.0 to RM 7.1 approximately 600 ft, and from RM 7.1 to RM 8.1 approximately 80-100 ft. The setback levee alignment would be approximately 32,000 linear feet with approximate levee heights ranging from 6 to15 feet. The proposed levee	This levee setback measure is not included in Alternative 3 because the mainstem dredging measure that is part of Alternative 3 is intended to increase channel capacity.

Measure	Alternative 2 – Levee Modification Alternative	Alternative 3 – Sediment Management with Levee Modification Alternative
	modification would manage flood risks to residential, commercial and industrial properties by increasing conveyance capacity in the river.	
River Road Levee Floodwall	A new floodwall would be added along the River Road Levee on the left bank of the lower Puyallup River extending from RM 2.9 to RM 7.2. This floodwall would reduce risks to the transportation corridor and residential, commercial and industrial structures. The floodwall height would range from 3-6 feet, with the average of approximately 5 feet.	A new floodwall would be added along the River Road Levee on the left bank of the lower Puyallup River extending from RM 2.9 to RM 4.9. This floodwall would reduce risks to the transportation corridor and residential, commercial, and industrial structures. The floodwall height would range from 3-4 feet with the average closer to 3 feet.
Lower Puyallup River Extension Levee	This new extension levee on the left bank of the lower Puyallup River would be from RM 7.2 to RM 8.6. The new extension levee would be 7,200 feet and would incorporate about 1,100 feet of the existing River Road Levee. The levee height would vary between 8-13 feet. In areas where the levee is 8 feet tall, there would be about 3.5 of additional fill placed on the existing berm.	This new extension levee on the left bank of the lower Puyallup River would be from RM 7.2 – RM 8.6. The new extension levee would be 7,200 feet and incorporates about 1,100 feet of the existing River Road Levee. The levee height would vary between 8-13 feet. In areas where the levee is 8 feet tall, there will be about 3.5 of additional fill placed on the existing berm.
	White River	
Mainstem Dredging	Dredging is not part of Alternative 2.	Dredging in this location would remove accumulated sediment near Stewart Street Bridge and RM 6 (near East Valley Highway), A Street to R Street, and other locations as determined. Mainstem dredging would occur once during construction and is proposed to increase conveyance capacity from RM 2.1 to RM 4.5 and RM 4.9 to RM 6.2 along the White River (a total of 59 acres of river bed and approximately one million cy). The dredging is intended to deepen the lower White River by approximately 7.5 feet for 3 miles and the White near the town of Pacific by approximately 3.2 feet for 1.1 miles. Material removed during dredging would be characterized for physical characteristics and contaminants. If material is suitable it would either be used for construction activities or placed in a permitted placement site. Contaminated material would be placed in a site designated for placed of contaminated material. Maintenance dredging would be necessary and is further detailed in Appendix A (Hydraulics and Hydrology). Alternative 3 would require initial construction dredging and subsequent maintenance dredging. Maintenance dredging is anticipated to occur within the lower White reach one time and White River at City of Pacific three times over the planning timeframe.
White River New Levees	This measure proposes new levees along the right bank of the White River to manage flood risks to residential, commercial, and industrial properties. The new levees would extend from RM 1.7 to RM 4.5 and RM 4.9 to 6.2 at Pacific Park.	This measure proposes new levees along the right bank of the White River to manage flood risks to residential, commercial, and industrial properties. The new levees would extend from RM 1.7 to RM 2.8. These levees are considered in areas where dredging alone would not provide sufficient flood risk reduction due to backwater from the Lower Puyallup River.
Property Acquisition	With this non-structural measure, 35 acres of property would be acquired, consisting of 14 parcels that would be impacted between RM 4.6 to RM 5.0 along the left bank of the White River. These properties have experienced repetitive flood impacts and are at risk of additional adverse flood impacts.	Not included in Alternative 3.
	Middle Puyallup River	
Highway 410 Floodwall and Levee	This measure would add a combination of a new levee and new floodwall that would provide protection to the adjacent SR 410 and residential properties. Floodwalls are generally used where there are space limitations. The levee section is proposed between RM 10.7 – 11.0 and the floodwall would be located between RM 11.0 to 11.8. The height of the levee and floodwall would vary between 6-12 feet.	This measure would add a combination of a new levee and new floodwall that would provide protection to the adjacent to SR 410 and residential properties. Floodwalls are generally used where there are space limitations. The levee section is proposed between RM 10.7 to 11.0 and the floodwall will be located between RM 11.00 to 11.8. The height of the levee and floodwall would vary between 6-12 feet.
	Upper Puyallup River	

Measure	Alternative 2 – Levee Modification Alternative	Alternative 3 – Sediment Management with Levee Modification Alternative
Mainstem Dredging	Dredging is not part of Alternative 2.	Mainstem dredging would occur once during construction from RM 21.3 to RM 22.7 along the upper Puyallup River Jones levee (a total of 36 acres of river bed and approximately a half-million cy). The dredging is intended to deepen the upper Puyallup River by a depth of approximately 2.5 feet for 1.4 miles. Material removed during dredging would be characterized for physical characteristics and contaminants. If material is suitable it would either be used for construction activities or placed in a permitted placement site. Contaminated material would be placed in a site designated for placed of contaminated material. Maintenance dredging would be necessary and is further detailed in Appendix A (Hydraulics and Hydrology). Alternative 3 would require initial construction dredging and subsequent maintenance dredging. Maintenance dredging is anticipated to occur within the upper Puyallup reach two times over the planning timeframe.
Jones Levee Improvement	An existing segment of the Jones Levee from RM 21.3 to RM 22.5 along the right bank of the upper Puyallup River would be modified. This measure would modify the levee in place by increasing the levee heights by approximately 1.5 feet to 6.5 feet as well as improving the river-side erosion protection. This levee modification would also include a control structure on the riverward side of the Ford Levee.	Levee improvements would include improvements to sustain the reliability of the levee system after dredging. In addition, a control structure would be constructed on the riverward side of the Ford Levee from RM 23.4 to RM 23.6 to deflect flows from the levee and stop repetitive damages.
	Carbon River	
Lower Carbon River Levee Improvement	This levee improvement would consist of raising from the Riddell Levee (RM 0.0 to 1.7) Orting Treatment Plant Levee (RM 1.7 to 3.1), and the Bridge Street Levee (RM 3.1 to 3.7). This measure would improve the reliability of the existing levee structures and raise the height of the levee to contain flood flows while reducing flood risks to the City of Orting, SR 162, and the Orting Treatment Plant. The levee height would be raised from 0-4 feet. A more efficient downstream tie-in section up to 7 feet in height would be constructed for the Riddell Levee section. This measure would also include a flow control structure design at the upstream end of the Bridge Street Levee between RM 3.2 and RM 4.0 to train flows away from the toe of the Bridge Street Levee and stop repetitive damages.	This levee improvement would consist of raising from the Riddell Levee (RM 0.0 to 1.7) Orting Treatment Plant Levee (RM 1.7 to 3.1), and the Bridge Street Levee (RM 3.1 to 3.7). This measure would improve the reliability of the existing levee structures and raise the height of the levee to contain flood flows while reducing flood risks to the City of Orting, SR 162, and the Orting Treatment Plant. The levee height would be raised from 0-4 feet. A more efficient downstream tie-in section up to 7 feet in height would be constructed for the Riddell Levee section. This measure would also include a flow control structure design at the upstream end of the Bridge Street Levee between RM 3.2 and RM 4.0 to train flows away from the toe of the Bridge Street Levee and stop repetitive damages.
Property Acquisition	This non-structural measure would include acquiring approximately 140 acres of property along the Carbon River that has experienced repetitive flood impacts and continues to be at risk to adverse flood impacts. Structures within the acquisition area would be demolished or relocated. Property acquisitions are considered along the Carbon River near SR 162 Bridge which is a known constriction point and behind Alward Road Segment 1 Levee.	This non-structural measure would include acquiring approximately 140 acres of property along the Carbon River that have experienced repetitive flood impacts and those structures that are at risk to adverse flood impacts. Structures within the acquisition area would be demolished or relocated. Property acquisitions are considered along the Carbon River near SR 162 Bridge which is a known constriction point and behind Alward Road Segment 1 Levee.
	Additional Measures	
Dredge materials placement sites	Dredging is not part of Alternative 2, so this measure is not included.	For the three mainstem dredging measures in Alternative 3, a suitable placement site would be needed to accommodate the estimated dredge volumes: 98 acres of riverbed and approximately one million cy from the lower Puyallup, 36 acres of river bed and approximately a half-million cy from the upper Puyallup reach, and a total of 59 acres of river bed and approximately one million cy from the White River reach.

Removal of MMD Operations Measure from Final Array of Alternative Plans

The measure to optimize MMD operations was removed from subsequent alternative iterations. The idea behind this measure was to potentially specify some lower MMD outflow, which might have allowed for scaled back alternative features along the White River. Currently, MMD limits releases to no more than 12,000 cfs, if possible, per the current Water Control Manual.

There were two main reasons for deleting this measure. One has to do with MMD's Discharge Regulation Schedule (DRS) which specifies minimum releases at high inflow-pool conditions. Subsequent investigation indicates that at 1% ACE and larger events, the DRS would likely be triggered, thus overriding any new lower target outflow replacing the current 12,000 cfs value. For large floods of the magnitude the GI project would most likely be designed for on the White River, it appears the MMD DRS would negate a new lower target flow value.

The second reason for deleting this measure has to do with sediment transport. Lower outflows would decrease the sediment transport capacity through the White River below MMD. This is a concern as it could lead to increased deposition rates in the vicinity of the city of Pacific and/or elsewhere in the White River over those which have historically occurred. This would require higher levees/floodwalls to contain the increased sediment deposition and/or the inclusion of maintenance dredging. This concern regarding altered sediment transport capacity was voiced by the USACE Committee on Channel Stabilization in the committee's report on the Puyallup system.

7.2. TSP Identification and Separable Elements Analysis

The evaluation of the final array of alternatives is described in Section 3.3 in the main report. Based on the qualitative evaluation and comparison analysis, Alternative 2: Levee Modification Alternative is presented as the recommended tentatively selected plan (TSP) because it is more cost-effectively meets the flood risk management objectives, has the least adverse impacts to environmental resources and is most likely to be supported by the sponsor and the public. Criteria other than economic efficiency was considered in the screening of Alternative 3, as is documented in detail in the main report. They include the ability to implement sediment management alternatives, land ownership, and environmental impacts. As part of the final report, there will be additional documentation on outstanding risks and uncertainties associated with sedimentation and its impact on project performance.

The TSP was further evaluated to determine if all of the components within the plan would meet economic justification with a benefit-cost ratio greater than 1.0. Separable areas or elements are defined for the Study as the subdivision of the Study area's flood risk based on hydrologic and hydraulic characteristics and functions with identifiable and distinct economic benefits. In general, components were combined within study reaches, yielding separable elements for the lower Puyallup River, the middle Puyallup River, the upper Puyallup River, the White River, and the Carbon River. As previously discussed, the Corps used a 1% ACE probability as a starting point for the concept-level design used in evaluation and comparison of the Final Array of Alternatives, This was for all reaches in the Study area except the lower Puyallup River reach, where a conceptual 0.5% ACE was assumed in the base condition and 0.1% ACE at the end of the planning period of analysis. This is based on Pierce County service objectives outlined in the County's Rivers Flood Hazard Management Plan and Comprehensive Plan goals. Note that the percent ACE probability used for evaluation and comparison of alternatives may not be the same as a design performance with assurance, which will be defined during the feasibility-level design analysis of the TSP, as additional design information is available and the TSP is optimized to identify the NED plan which reasonably maximized net benefits for NED and reduces residual risk to life safety. This information will be documented in the final FR/EIS. Cost engineering was completed for conceptual designs for features within each reach and economic analysis was completed to determine the economic benefits of each separable element. HEC-FDA was used to evaluate residual and reduced flood damages for these separable elements, and the plan as a whole.

Preliminary economic analysis based on levee overtopping provided economic justification improvements to the Upper Puyallup, Middle Puyallup and the White River. Economic justification was not found for improvements to the Carbon River, and the Lower Puyallup River reach improvements had shown marginal justification. The overall benefit-cost ratio was estimated to be approximately 2.4 with all of the TSP features included. The results of the first iteration of separable elements analysis is presented in Table 7-2. Note that this analysis was conducted in Fiscal Year 2015 (FY15) using October 2014 prices and the FY15 discount rate of 3.375 percent and was not revised to current price levels and discount rate.

Table 7-2. Economic Analysis of Separable Elements, 1st Iteration (Oct 2014 prices, 3.375% discount rate, $1,000s)

Reach	Total Cost (w/ contingency)	Annualized Cost	Annual Benefit (Equiv. Annual Damages Reduced)	Net Benefits	BCR
Lower Puyallup	$252,279	$10,948	$12,159	$1,211	1.1
Middle Puyallup	$3,873	161	2,872	2,710	17.8
Upper Puyallup	$21,358	890	1,879	989	2.1
White River	$48,196	2,009	18,923	16,915	9.4
Carbon River	$24,803	1,034	82	(952)	0.1
Totals	$350,510	$15,042	$35,915	$20,873	2.4

The sponsor noted that the Clear Creek features previously included in the lower Puyallup River reach were being implemented unilaterally on a local level and requested that the Clear Creek features be considered in the future without-project condition rather than as part of the TSP. As a result, the costs of the improvements to Lower Puyallup reach were consequently reduced. The hydraulic analysis and costs were updated, along with economics.

7.2.1. Annual Benefits and Residual Damages

The TSP addressed levee fragility concerns on both the right and left banks of the Lower Puyallup with measures carried forward for this plan, therefore no levee fragility and resulting floodplain assignments were applied to the with-project condition. The with-project hydraulic modeling included overbank and levee overtopping for floods which exceed levee heights. These were input into HEC-FDA to determine residual damages and annual benefits. Residual damages can be found in Table 7-3 and Table 7-5, and annual benefits can be found in Table 7-4 and

Table 7-6, respectively. Residual equivalent annual damages and damages reduced for the with-project condition are presented in Table 7-7 and Table 7-8, respectively. It should be noted that residual damages increase nearly five times from the base to future year. This is based on sedimentation and associated river bed elevation changes which affect channel capacity in multiple locations but especially the White River, as well as intermediate sea-level rise projects which affect primarily the Lower Puyallup reach near commencement.

Table 7-3. Residual Annual Damages by Reach, With-Project Base Condition (Oct 2015 prices, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total EAD	% of Total
Carbon River	$0	$50	$8	$0	$66	$0	$124	2.1%
Lower Puyallup	1,219	24	1,050	95	308	0	2,696	45.4%
Middle Puyallup	24	18	50	41	394	0	528	8.9%
Upper Puyallup	0	117	0	5	591	0	713	12.0%
White River	687	0	1,019	0	172	0	1,879	31.6%
Total EAD	**$1,931**	**$210**	**$2,128**	**$140**	**$1,532**	**$0**	**$5,941**	100%
% of Total	32.5%	3.5%	35.8%	2.4%	25.8%	0.0%	100%	

Table 7-4. Annual Benefits by Reach, With-Project Base Condition (Oct 2015 prices, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total EAD Reduced	% of Total
Carbon River	$0	$7	-$3	$1	$18	$0	**$23**	0.1%
Lower Puyallup	1,701	61	2,535	467	1,496	617	**6,877**	19.3%
Middle Puyallup	61	2	262	12	1,311	0	**1,647**	4.6%
Upper Puyallup	23	2	0	14	160	0	**199**	0.6%
White River	344	1	4,777	0	21,746	0	**26,867**	75.4%
Total EAD Reduced	**$2,128**	**$72**	**$7,570**	**$495**	**$24,730**	**$617**	**$35,612**	100%
% of Total	6.0%	0.2%	21.3%	1.4%	69.4%	1.7%	100%	

Table 7-5. Residual Annual Damages by Reach, With-Project Future Condition (Oct 2015 prices, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total EAD	% of Total
Carbon River	$0	$52	$4	$0	$55	$0	**$111**	0.4%
Lower Puyallup	3,170	65	4,333	258	486	150	**8,463**	30.4%
Middle Puyallup	40	36	220	79	708	0	**1,084**	3.9%
Upper Puyallup	20	158	3	130	1,154	0	**1,464**	5.3%
White River	4,838	0	9,161	336	2,341	0	**16,676**	60.0%
Total EAD	**$8,068**	**$312**	**$13,720**	**$804**	**$4,743**	**$150**	**$27,797**	100%
% of Total	29.0%	1.1%	49.4%	2.9%	17.1%	0.5%	100%	

Table 7-6. Annual Benefits by Reach, With-Project Future Condition (Oct 2015 prices, 3.125% discount rate, $1,000s)

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total EAD Reduced	% of Total
Carbon River	$0	$4	$1	$0	$16	$0	**$21**	0.20%
Lower Puyallup	1,585	54	2,972	673	2,722	835	**8,840**	23.20%
Middle Puyallup	11	2	674	17	1,668	0	**2,371**	4.60%
Upper Puyallup	777	-$11	-1	999	5,264	0	**7,029**	11.40%
White River	645	3	2,437	-298	25,813	0	**28,601**	60.60%
Total EAD Reduced	**$3,018**	**$51**	**$6,084**	**$1,390**	**$35,484**	**$835**	**$46,862**	100%
% of Total	14.90%	0.50%	26.50%	2.90%	53.90%	1.30%	100%	

Table 7-7. Residual Equivalent Annual Damages, With Project Conditions, Oct 2015 prices ($1,000s), 3.125% discount rate

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total Equivalent Annual Damages	% of Total
Carbon River	$0	$51	$6	$0	$62	$0	$119	0.8%
Lower Puyallup	1,949	39	2,278	156	375	56	4,854	34.4%
Middle Puyallup	30	25	114	55	512	0	736	5.2%
Upper Puyallup	7	132	1	52	801	0	994	7.0%
White River	2,240	0	4,065	126	984	0	7,415	52.5%
Total Equivalent Annual Damages	**$4,227**	**$248**	**$6,465**	**$388**	**$2,733**	**$56**	**$14,117**	100%
% of Total	29.9%	1.8%	45.8%	2.8%	19.4%	0.4%	100%	

Table 7-8. Equivalent Annual Damages Reduced Benefit, With Project Conditions, Oct 2015 prices ($1,000s), 3.125% discount rate

River Reach	Commercial	Farm Buildings	Industrial	Public	Residential	Transit Delays	Total Equivalent Annual Damages Reduced	% of Total
Carbon River	$0	$6	-$1	$0	$17	$0	$22	0.1%
Lower Puyallup	1,657	59	2,699	544	1,954	699	7,611	19.5%
Middle Puyallup	43	2	420	14	1,444	0	1,923	4.9%
Upper Puyallup	306	-3	0	382	2,058	0	2,742	7.0%
White River	457	2	3,202	-112	23,267	0	26,816	68.6%
Total Equivalent Annual Damages Reduced	**$2,462**	**$65**	**$6,319**	**$829**	**$28,741**	**$699**	**$39,115**	100%
% of Total	6.3%	0.2%	16.2%	2.1%	73.5%	1.8%	100%	

In accordance with ER 1105-2-101, flood damages reduced were determined as mean values and by probability exceeded. Table 7-9 shows the benefits for each study reach for the 75%, 50%, and 25% probability that benefit exceeds indicated value. The damage reduced column represents the mean benefit for each increment and the 75%, 50%, and 25% represent the probability that the flood damage reduction benefits exceed the number in that column for that reach. For example, study reach White River has an average (mean) benefit of $27.5 million, but a 50% confidence that benefits could be greater than $27.9 million, 75% confidence that benefits could exceed $22.1 million, and 25% confidence that benefits could exceed $32.2 million. This range is the probability distribution of damages reduced and represents the uncertainty in the benefit estimates and incorporates all the uncertainties in hydrology, hydraulics, geotechnical and economic inputs to the HEC-FDA modelling. The uncertainty in damages reduced should be considered when selecting an optimal plan during the plan formulation process. Judgment should be used to determine if an alternative meets a reasonable level of confidence regarding positive net benefits and identifying if changes in net benefits from alternative to alternative are significant.

Table 7-9. Probability Distribution of Equivalent Annual Damages Reduced by Study Reach (Oct 2015 prices 3.125% discount rate, $1,000s)

	Equivalent Annual Damages ($1,000s)			Probability Damage Reduced		
River Reach	**Without Project**	**With Project**	**Damage Reduced**	**75%**	**50%**	**25%**
Carbon River	$141	$119	$22	$12	$27	$34
Lower Puyallup	11,729	4,854	6,876	1,797	3,550	10,689
Middle Puyallup	2,658	736	1,923	999	1,446	2,428
Upper Puyallup	3,736	994	2,742	1450	2,365	3,706
White River	34,930	7,415	27,516	22,126	27,881	32,183
Total Equivalent Annual Damages Reduced	**$53,195**	**$14,117**	**$39,078**	**$26,384**	**$35,269**	**$49,040**

7.2.2. Project Performance – With-Project

Project performance for each reach or alternative is identified by the residual index location that has the highest AEP which causes flooding within the economic damage reach. For some of the economic damages reaches, the with-project AEP may be the same as the without-project AEP, even though the annual damages may change because areas may flood from multiple locations and an alternative may address one source of flooding while not addressing another source of flooding to the same reach. Alternatively, fixing the most likely or significant source of flooding may reduce overall flood damage even if the AEP remains unchanged with a given measure. The overall/combined likelihood that the area will get flooded is reduced as levee reaches are fixed or additional flood risk measures are implemented. This combined chance of flooding is difficult to quantify, so the representative index point for the economic damage reach is used.

Project performance for select locations in each of the five study reaches under existing and future without-project conditions is displayed in Table 7-10 and Table 7-11, respectively.

Table 7-10. Project Performance - With Project Base Condition for Select Economic Damage Reaches

Economic Damage Reach	Study Reach	Target Stage	Annual Exceedance Probability		Long-Term Risk			Assurance by Event				
			Median	Expected	10-year	30-year	50-year	10%	5%	2%	1%	0.20%
DR_60	Lower Puyallup	21.12	0.01%	0.02%	0%	0%	1%	100%	100%	100%	100%	96%
DR_65	Lower Puyallup	21.81	0.01%	0.06%	1%	2%	3%	100%	100%	100%	97%	82%
DR_67	Lower Puyallup	47.04	0.14%	0.12%	1%	4%	6%	100%	100%	99%	95%	65%
DR_735	Middle Puyallup	76.59	0.22%	0.40%	4%	11%	18%	100%	100%	97%	86%	36%
DR_77	Upper Puyallup	240.76	0.01%	0.01%	0%	0%	0%	100%	100%	100%	100%	100%
DR_795	Carbon River	195.36	0.20%	0.31%	3%	9%	15%	100%	100%	99%	94%	47%
DR_84	White River	83.05	0.01%	0.02%	0%	1%	1%	100%	100%	100%	100%	100%

Table 7-11. Project Performance - With Project Base Conditions for Select Economic Damage Reaches

Economic Damage Reach	Study Reach	Target Stage	Annual Exceedance Probability		Long-Term Risk			Assurance by Event				
			Median	Expected	10-year	30-year	50-year	10%	5%	2%	1%	0.20%
DR_60	Lower Puyallup	21.12	0.01%	0.05%	1%	2%	3%	100%	100%	99%	98%	89%
DR_65	Lower Puyallup	21.81	0.01%	0.18%	2%	5%	9%	100%	100%	98%	94%	73%
DR_67	Lower Puyallup	47.04	0.21%	0.25%	2%	7%	12%	100%	100%	97%	89%	55%
DR_735	Middle Puyallup	76.59	0.46%	0.86%	8%	23%	35%	100%	97%	88%	71%	26%
DR_77	Upper Puyallup	240.76	0.01%	9.00%	1%	3%	4%	100%	99%	98%	98%	95%
DR_795	Carbon River	195.36	0.17%	0.33%	3%	9%	15%	100%	100%	99%	92%	49%
DR_84	White River	83.05	0.01%	0.63%	6%	17%	27%	98%	98%	97%	97%	95%

7.2.3. Net Benefit Analysis and BCR Uncertainty

With benefits calculations complete, annual costs need to be derived to complete the benefit cost analysis. Economic feasibility and project efficiency are determined through benefit cost analysis. For a project or increment to be feasible, benefits must exceed costs and the most efficient alternative is the one that maximizes net benefits (annual benefits minus annual costs).

Table 7-12 summarizes the Net Benefits and Benefit-to-Cost ratio ranges for each of the draft array of alternatives. The low annual benefit represents the 75% confidence (that benefits will exceed the indicated value), the mid represents the 50% and the high annual benefit represents the 25% confidence level. Net benefit and benefit-to-cost ratio (BCR) mean values and ranges were calculated in a Monte-Carlo simulation using the confidence outputs on the benefits from HEC-FDA. The mean net benefit and BCR represent the mean results from this Monte-Carlo simulation. The low, mid, and high range represent the 50% confidence range (25, 50, and 75%), given the inputs the analysis. In other words, there is greater confidence that net benefits and BCR will exceed the low values and less confident as you move toward the high values, with the best estimate being the mean values. This analysis did not consider uncertainty in the costs, therefore no distribution for costs was developed. Rather, the costs presented include contingency with 80% confidence. More detailed costs estimates will be developed for additional analyses of the tentatively selected plan for optimization of National Economic Development (NED) benefits.

Table 7-12. Net Benefits/Benefit-to-Cost Ratio Ranges for the Refined TSP Plan (October 2015 prices, 3.125% discount rate, in $1,000s)

					Annual Net Benefits Confidence			Benefit-Cost Ratio Confidence		
Separable Reach	**Equivalent Annual Benefits (Mean)**	**Annual Costs (w/ OMRR&R)**	**Annual Net Benefits**	**Benefit-Cost Ratio**	**75% (High)**	**50% (Mid)**	**25% (Low)**	**75% (High)**	**50% (Mid)**	**25% (Low)**
Lower Puyallup	$6,876	$11,203	-$4,327	0.6	-$9,406	-$7,653	-$514	0.2	0.3	1.0
Middle Puyallup	1,923	890	$1,033	2.2	109	556	1,538	1.1	1.6	2.7
Upper Puyallup	2,742	400	$2,342	6.9	1,050	1,965	3,306	3.6	5.9	9.3
White River	27,516	2,927	$24,589	9.4	19,199	24,954	29,256	7.6	9.5	11.0
Total	***$39,078***	***$15,430***	***$23,648***	***2.5***	***$10,954***	***$19,839***	***$33,610***	***1.7***	***2.3***	***3.2***

The refined TSP results in approximately $24 million in net benefits and a 2.5 benefit-cost ratio based on mean benefit (or EAD reduced) estimates (October 2015 prices, 3.125 percent discount rate). Figure 7-3 displays the residual 1% (1/100) ACE floodplain base condition for the refined TSP Plan. The population at risk from flooding with project in the residual 1% (1/100) ACE floodplain is estimated to be 2,100 a reduction of at least 33,800 from 34,900 people from the 1% ACE floodplain without a project based on residential structures subject to flooding and a 2.59 per household population estimate for Pierce County (Census 2010) and direct jobs of approximately 4,400 from industrial lease tenants at the Port of Tacoma[7]. Further, Figure 7-4 displays the residual 1% ACE floodplain for the future condition.

It is worth pointing out that although the Lower Puyallup is not economically justified on its own, it is directly tied to the regulation of Mud Mountain Dam which affects the White and Lower Puyallup reaches. It is also protecting the largest proportion of population and investment in the basin. Without addressing these residual risks on this reach to some extent, any recommended plan would be incomplete. This is one reach in particular that will need to be refined for National Economic Development (NED) as described in Section 8.

[7] Port of Tacoma Economic Impact. 2014. http://portoftacoma.com/sites/default/files/POT_EconomicImpactsOnePager2014.pdf. Accessed online 25 Jan 2016.

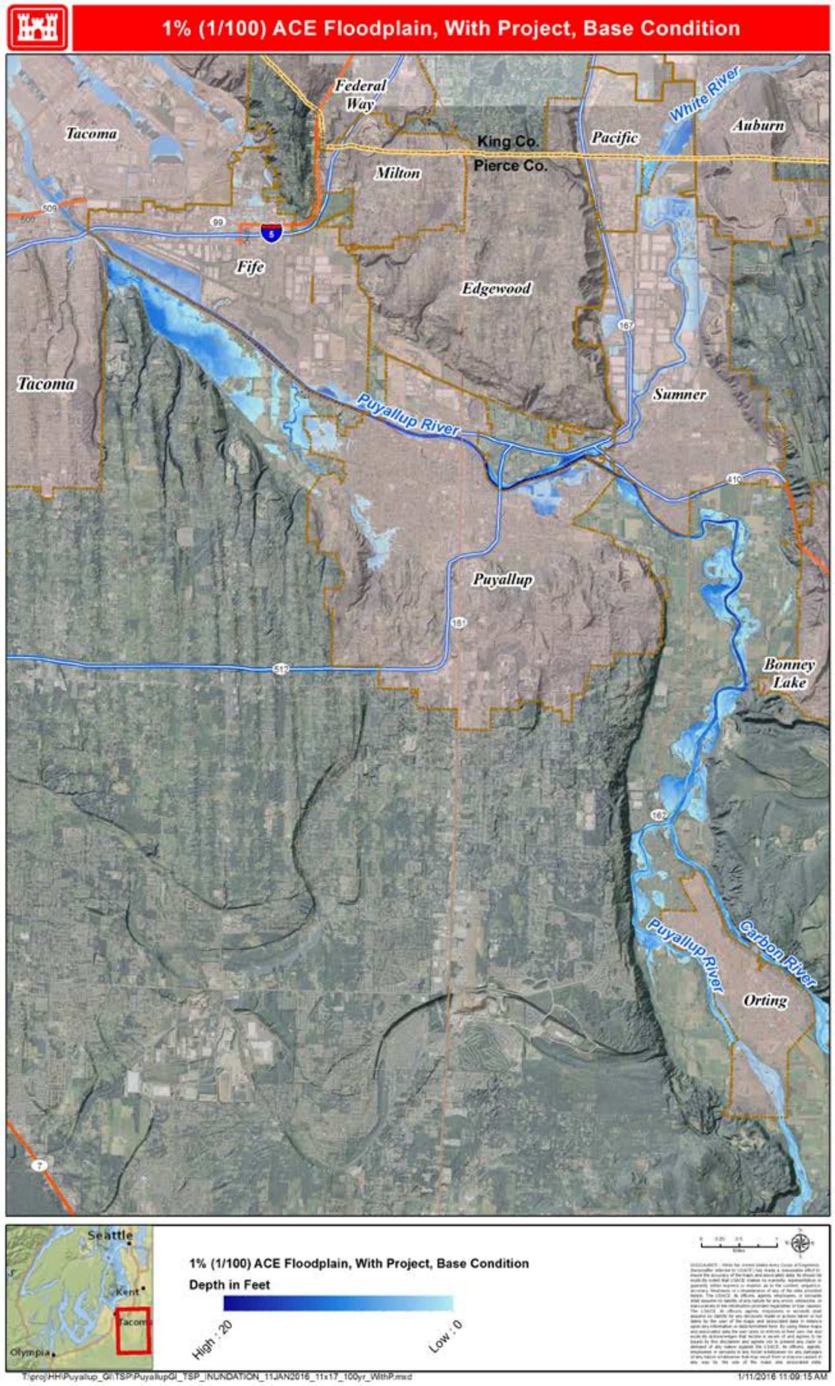


Figure 7-3. Residual 1% ACE Floodplain of the Refined TSP Plan, Base Condition

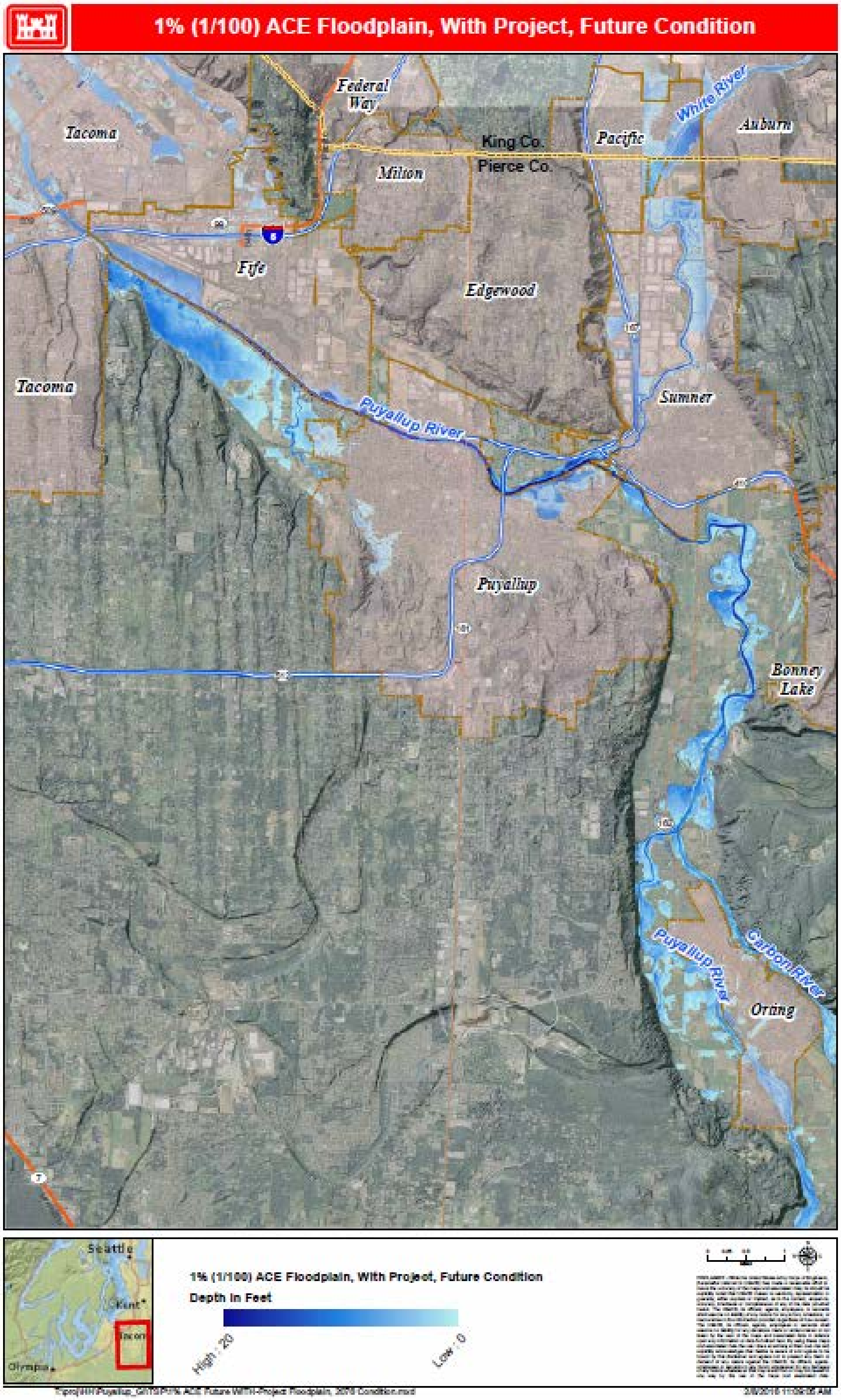


Figure 7-4. Residual 1% ACE Floodplain of Refined TSP, Future Condition

7.2.4. Summary of TSP Measures, by Planning Iteration

A comparison of the TSP (Alternative 2) features associated with each iteration of plan formulation from initial array of alternatives to TSP selection is included in Table 7-13 below. Figure 7-5 displays those features being carried forward in the recommended TSP for this draft report.

Table 7-14 summarizes the investment costs and benefits of the refined TSP compared to the No Action alternative. Based on October 2015 price levels, the estimated project first cost is $341,144,000. Project first cost refers to the cost estimate that includes, among other things, preconstruction engineering and design costs, construction costs, lands, easements, right-of-way, relocation, and disposal (LERRD) values, and contingencies. Estimated average annual costs are $15.4 million including interest during construction based on a 3.125% interest rate, a period of analysis of 50 years, construction ending in 2025 (estimated 66 month construction duration), and $600,000 or less annual operations and maintenance expenses throughout the Study area. The total average annual flood damage reduction benefits would be $39.1 million with net benefits of $23.7 million a benefit-cost ratio of 2.5 to 1. Additional information related to the plan formulation process is in Chapter 3 of the main report.

Table 7-13. Comparison of Features in Alternative 2 by Plan Formulation Iteration

Reach	Feature	Initial Array of Alternatives	Final Array of Alternatives	TSP	Notes
Lower Puyallup	Federal Authorized Levee	X	X	X	
	North Levee Road A-Setback	X	X	X	
	River Road Levee Floodwall	X	X	X	
	Lower Puyallup Extension Levee	X	X	X	
	Clear Creek Levee	X	X		Local implementation
Middle Puyallup	Highway 410 Levee/Floodwall	X	X	X	
Upper Puyallup	Jones Levee Improvement	X	X	X	
White River	White River New Levee	X	X	X	
	Property Acquisition	X	X	X	
	MMD Operational Changes	X			Technically infeasible
Carbon River	Lower Carbon River Levee Improvement	X	X		Not economically justified
	Property Acquisition	X	X		Not economically justified

Table 7-14. Summary of Costs and Benefits for Refined TSP (Oct 2015 prices, 3.125% discount rate)

	No Action	Alternative 2 (Refined TSP)
Investment Cost		
First Cost	-	$341,144,000
Interest During Construction	-	$30,092,000
Subtotal	-	$371,236,000
Annual Cost		
Interest and Amortization	-	$14,773,000
OMRR&R	-	$600,000
Subtotal	-	$15,373,000
Annual Flood Risk Management Benefits	-	**$39,078,000**
Annual Net Benefits	-	**$23,705,000**
Benefit-to-Cost Ratio (3.125%)	-	**2.5:1**

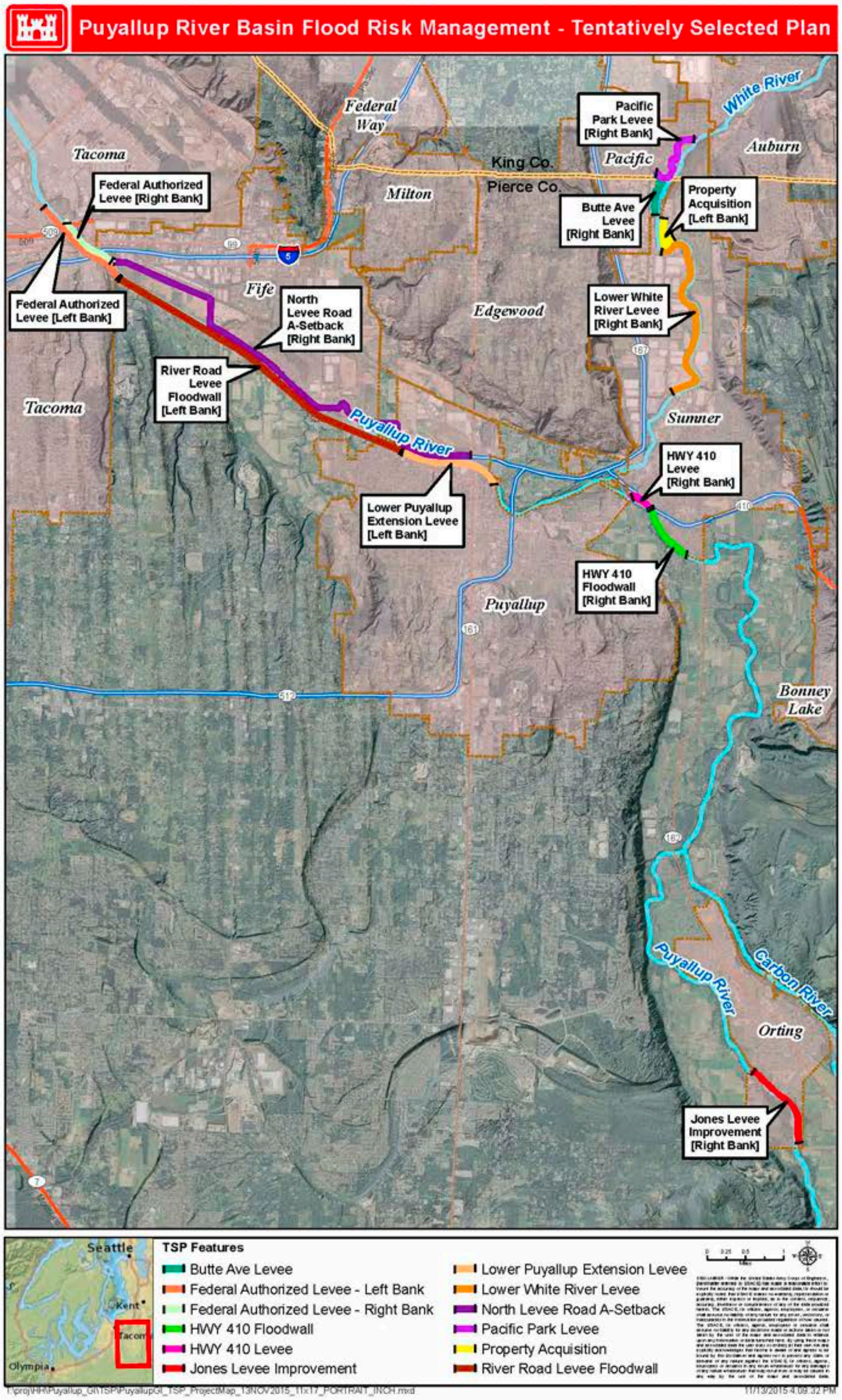


Figure 7-5. TSP Features

8. Conclusions

Optimization of the TSP to identify the recommended NED plan, to include the rationale for selection and a discussion of the optimization analysis and risks and uncertainties, will be completed during the feasibility-level design analysis as additional detailed information is available, following public, technical, legal, and policy reviews of the draft FR/EIS. The outcome of this iteration will be documented in the final FR/EIS. Optimization of TSP will include an evaluation of a range of levee and/or floodwall heights for each of the TSP features to identify the scale which reasonably maximizes net benefits (the difference between annualized benefits and annualized costs over the period of analysis) where benefits are greater than costs, while providing reduced residual risk to life safety and property. It is anticipated that the scale of features, particularly on the lower Puyallup reach, may be reduced based on performance estimates of the current design and the marginal benefit-cost ratio. The optimization will also incorporate sediment transport modelling information which will replace the assumed sediment aggradation that was included in the economic analysis to date and analysis of life safety, including critical infrastructure and evacuation routes, and lands subject to development for Executive Order 11988 as described further in Chapter 5 of the main report.

Corps policy establishes four accounts to facilitate the evaluation and display of the effects of the recommended plan. These accounts are National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED), and Other Social Effects (OSE). These four accounts encompass all significant effects of plan implementation, including economic, socioeconomic, and environmental effects that must be considered in water resources planning. Effects of the recommended plan in the four evaluation accounts are displayed in Table 8-1, and will be updated for the final report.

Table 8-1. Summary of Accounts for Economic, Environmental and Other Social Effects of TSP

Evaluation Account	TSP: Levee Modification Alternative
NED Account	The national economic development (NED) account displays changes in the economic value of the national output of goods and services. The current design of the TSP provides an estimated $39.1 million in equivalent average annual benefits, with mean net benefits of $23.7 million and a mean benefit-cost ratio of 2.5 (ranging from 1.7 to 3.2 with a 75%-25% confidence bound) at the October 2015 price level and 3.125 percent discount rate. The feasibility-level analysis will consider various scales of TSP features to determine scales which reasonably maximize net benefits. The results of this analysis, including project performance estimates, will be presented in the final report.
RED Account	The regional economic development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output and population. This will be analyzed as part of feasibility-level design using RECONS and presented in the final report.
EQ Account	The environmental quality (EQ) account displays non-monetary effects on significant natural and cultural resources. This analysis is documented in the main report.

Evaluation Account	TSP: Levee Modification Alternative
OSE Account	The other social effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts. The population at risk from flooding with project in the residual 1% (1/100) ACE floodplain is estimated to be 2,100, a reduction of at least 33,800 from 34,900 people from the 1% ACE floodplain without a project based on residential structures subject to flooding and a 2.59 per household population estimate for Pierce County (Census 2010) and direct jobs of approximately 4,400 from industrial lease tenants at the Port of Tacoma[8]. Life safety, floodplain population including employment, environmental justice communities, critical infrastructure, and potentially developable acreage will be analyzed as part of feasibility-level design and presented in the final report.

Finally, the key outstanding risk and uncertainties are summarized below, as well as a description of future analysis to include Executive Order 11988 compliance and residual risk. Additional information related to the RED and OSE accounts, as well as Executive Order 11988 compliance is included as an attachment to this appendix.

Risk and Uncertainty

Risk and uncertainty is fundamental to all water resource planning and communication. This study incorporated risk management framework principles and risk-informed planning into its plan formulation process.

- Risk analysis and communication was used following ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, and Engineering Manual (EM) 1110-2-1619, *Risk-Based Analysis for Flood Risk Management*.
- Uncertainty was captured through cost engineering's mandatory center of expertise (MCX) cost and schedule risk analysis to establish cost contingencies. Risks to project cost and schedule were documented in a risk register found in Appendix D (Cost Estimate).
- Risks were assessed and managed throughout the study process, in coordination with the Corps' Vertical Team.
- Specific risk and uncertainty remaining includes the extent of potential induced and transferred flood risk resulting from confined flood flows associated with new or modified levees to areas in the floodplain. To minimize and mitigate these uncertainties, more detailed hydraulic modeling of the TSP will be conducted during the feasibility-level design analysis to better understand the flood risks associated with the specific features of the TSP to other areas in the floodplain. Nonstructural measures such as elevating homes, relocations, developing evacuation routes and plans, as well as structural measures can be evaluated on an incremental basis during the feasibility-level design analysis to reduce induced and/or residual flood risks once the risk is better understood. This

[8] Port of Tacoma Economic Impact. 2014. http://portoftacoma.com/sites/default/files/POT_EconomicImpactsOnePager2014.pdf. Accessed online 25 Jan 2016.

additional evaluation will be conducted as part of optimization of TSP features for NED to reasonably maximize benefits relative to cost and will be documented in the final FR/EIS.

- Future Without-Project Construction: Pierce County and King County have identified projects that may be constructed before the Study will be completed and construction is initiated. A potential funding source has been identified for some of these projects, but these projects are not fully funded for construction at this time. If funding falls through on these projects, there is a risk to having to modify the TSP. Other County projects where funding was certain have been identified and included in the future without-project analysis of the Study. The Corps will continue to work closely with the County as the TSP is refined and detailed design analysis is conducted after the Agency Decision Milestone (ADM) to ensure assumptions on projects to be constructed by the County are still accurate.

Executive Order 11988

Executive Order (EO) 11988 (May 24, 1977) requires a Federal agency, when taking an action, to avoid short and long term adverse effects associated with the occupancy and the modification of a floodplain. The agency must avoid direct and indirect support of floodplain development whenever floodplain siting is involved. In addition, the agency must minimize potential harm to or in the floodplain and explain why the action is proposed. Additional floodplain management guidelines for EO 11988 were also provided in 1978 by the Water Resources Council.

Corps implementation guidance in Engineering Regulation (ER) 1165-2-26 (March 30, 1984), states the following in Paragraph 6:

EO 11988 has as an objective the avoidance, to the extent possible, of long-and short-term adverse impacts associated with the occupancy and modification of the base floodplain and the avoidance of direct and indirect support of development in the base flood plain wherever there is a practicable alternative. Under the Order, the Corps is required to provide leadership and take action to:

- Avoid development in the base flood plain unless it is the only practicable alternative;
- Reduce the hazard and risk associated with floods;
- Minimize the impact of floods on human safety, health and welfare; and
- Restore and preserve the natural and beneficial values of the base floodplain.

General procedures to implement Executive Order include eight steps as outlined and evaluated for the Puyallup River Basin Flood Risk Management Feasibility Study.

1. Determine if the proposed action is in the base floodplain (1/100 year floodplain or 1% ACE).
2. If the action is in the floodplain, identify and evaluate practicable alternatives to locating in the base floodplain.
3. Provide public review.
4. Identify the impacts of the proposed action and any expected losses of natural and beneficial floodplain values.

5. Minimize threats to life and property and to natural and beneficial floodplain values. Restore and preserve natural and beneficial floodplain values.
6. Reevaluate alternatives.
7. Issue findings and a public explanation.
8. Implement the action.

Screening of measures and alternatives for this Study considered impacts to the floodplain and minimizing induced development. The feasibility-level design analysis and optimization of TSP features for National Economic Development (NED) will include evaluation and documentation of the eight-step process to comply with the EO. The approach will include an evaluation of potentially developable land in the floodplain for the No Action Alternative and refined NED Plan. Economic drivers such as population projections and development demand will also be considered as part of this analysis. Impacts to life safety, evacuation routes, environmental justice communities, and critical infrastructure will also be documented in support of this analysis in the final FR/EIS.

Residual and Transferred Risks

As the TSP is refined during feasibility-level design analysis and NED optimization, more information will be communicated with regard to residual risk (i.e. the risk that remains with implementation of the recommended plan) and transferred (i.e. induced) risk. This communication will include a discussion of levee performance, remaining or residual flood damage potential, and change in flood inundation estimates. The residual risk analysis will include an evaluation of population at risk, life safety, evacuation routes, environmental justice communities, critical infrastructure, and economic damages of the No Action and refined plan recommendation. This will be documented in the final FR/EIS.

9. References

AAA. 2014. AA 2014 Edition, Your Drive Costs. Accessed online 20 May 2015. Available online: http://publicaffairsresources.aaa.biz/wp-content/uploads/2014/05/Your-Driving-Costs-2014.pdf.

Economic and Environmental Principles and Guidelines for Water Resources Implementation Studies (P&G). Dated March 1983.

Economic Guidance Memorandum (EGM) 04-01. Generic Depth-Damage Relationships for Residential Structures with Basements. 10 October 2003

EGM 09-04. Generic Depth-Damage Relationships for Vehicles. 22 June 2009

EGM 16-01. Federal Interest Rates for Corps of Engineers Project for Fiscal Year 2016. 14 Oct 2015.

Engineering Manual (EM) 1110-2-1619. Risk-Based Analysis for Flood Damage Reduction Studies. 1 August 1996.

Engineering Regulation (ER) 1105-2-100. Planning Guidance Notebook. 22 April 2000, as amended.

ER 1105-2-101. Risk-Based Analysis of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies. 3 January 2006.

ER 1165-2-26. Implementation of Executive Order 11988 on Flood Plain Management. 30 March 1984.

Kelly Blue Book. 2015. Accessed online 20 May 2015.

NHTS (National Household Transportation Survey). National Household Transportation Survey. 2009. Accessed online 20 May 2015. Available at: http://nhts.ornl.gov/2009/pub/stt.pdf

Pierce County. 2012b. Pierce County Flood Risk Assessment, Pierce County Public Works & Utilities Water Programs Division. Prepared with the assistance of URS. Tacoma, Washington. February 2012.

Pierce County. 2010b. Rivers Flood Hazard Management Plan Economic Analysis. Final Report. Prepared by Entrix, Inc., for Pierce County Public Works and Utilities, Surface Water Division, Tacoma, Washington. October 2010.

Pierce County. 2012a. Pierce County Flood Hazard Management Plan, Pierce County Public Works & Utilities Water Programs Division. Tacoma, Washington. February 2012.

Pierce County. 2013a. Comprehensive Plan of Development, Pierce County Flood Control Zone District. September 2013.

Port of Tacoma. 2014. Economic Impact. Accessed 25 January 2016. Online at: http://portoftacoma.com/sites/default/files/POT_EconomicImpactsOnePager2014.pdf.

R.L. Polk & Company. 2008. Annual Vehicle Population Report for 2008.

Section 308 of WRDA 1990

USACE (U.S. Army Corps of Engineers). 1997. Morganza to the Gulf, Louisiana Feasibility Study. May 1997.

USACE. 2008. American River Watershed Project, California, Folsom Modification and Folsom Dam Raise Projects Economic Reevaluation Report. February 2008.

USACE. 2014. HEC-FDA Flood Damage Reduction Analysis User's Manual (version 1.4). October 2014.

U.S. Census. 2010. 2010 Census.

U.S. Census. 2013. American Community Survey.

WSDOL (Washington State Department of Licensing). Motor Vehicle Registration by Class and County, Calendar 2013. Accessed online 20 May 2015. Available at: https://fortress.wa.gov/dol/vsd/vsdFeeDistribution/DisplayReport.aspx?rpt=2013C00-6301.csv&countBit=1

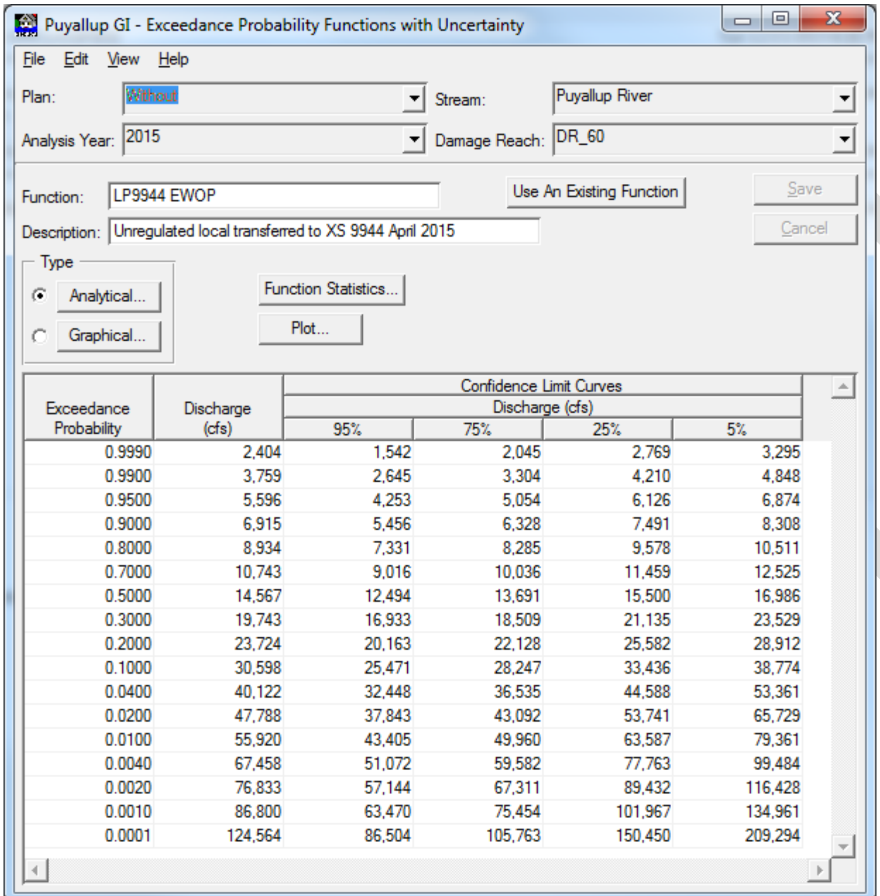
WSDOT (Washington State Department of Transportation). 2014a. Annual Traffic Report, 2014.

WSDOT. 2014b. WSDOT Research Report WA-RD 832.1, Travel Costs Associated with Flood Closures of State Highways Near Centralia/Chehalis, Washington. September 2014. Accessed online 20 May 2015. Available at: http://www.wsdot.wa.gov/research/reports/fullreports/832.1.pdf.

Enclosure – HEC-FDA Model Inputs

Hydrology Inputs

Lower Puyallup, DR_60, Left Bank (shown below); Lower Puyallup, DR_65, Right Bank; Lower Puyallup, DR_67, Right Bank; Middle Puyallup, DR_735, Right Bank; White, DR_85, Right Bank -- Without Project Base Condition, Unregulated Exceedance Probability Function with Flow Transform



Puyallup GI - Exceedance Probability Functions with Uncertainty

File Edit View Help

Plan: Without

Stream: Puyallup River

Analysis Year: 2015

Damage Reach: DR_60

Function: LP9944 EWOP

Use An Existing Function

Save

Cancel

Description: Unregulated local transferred to XS 9944 April 2015

Type

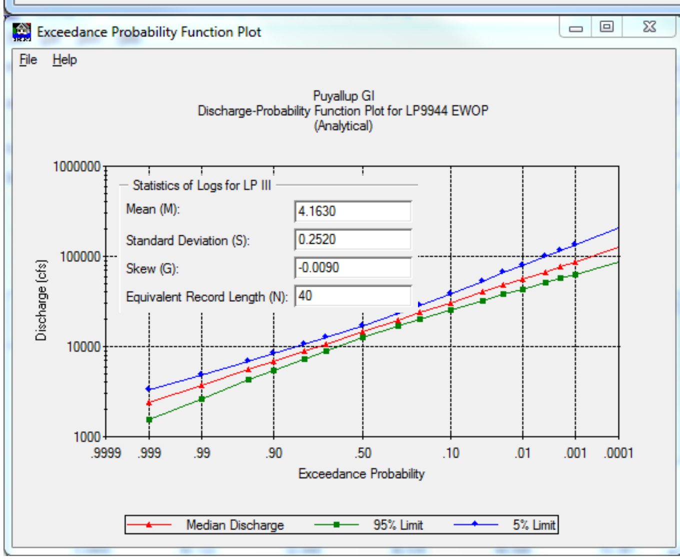
Analytical...

Graphical...

Function Statistics...

Plot...

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		95%	75%	25%	5%
0.9990	2,404	1,542	2,045	2,769	3,295
0.9900	3,759	2,645	3,304	4,210	4,848
0.9500	5,596	4,253	5,054	6,126	6,874
0.9000	6,915	5,456	6,328	7,491	8,308
0.8000	8,934	7,331	8,285	9,578	10,511
0.7000	10,743	9,016	10,036	11,459	12,525
0.5000	14,567	12,494	13,691	15,500	16,986
0.3000	19,743	16,933	18,509	21,135	23,529
0.2000	23,724	20,163	22,128	25,582	28,912
0.1000	30,598	25,471	28,247	33,436	38,774
0.0400	40,122	32,448	36,535	44,588	53,361
0.0200	47,788	37,843	43,092	53,741	65,729
0.0100	55,920	43,405	49,960	63,587	79,361
0.0040	67,458	51,072	59,582	77,763	99,484
0.0020	76,833	57,144	67,311	89,432	116,428
0.0010	86,800	63,470	75,454	101,967	134,961
0.0001	124,564	86,504	105,763	150,450	209,294



Upper Puyallup, DR_77, Right Bank, Without Project Base Condition – Unregulated Exceedance Probability Function with Flow Transform

Puyallup GI - Exceedance Probability Functions with Uncertainty

File Edit View Help

Plan: Without   Stream: Puyallup River

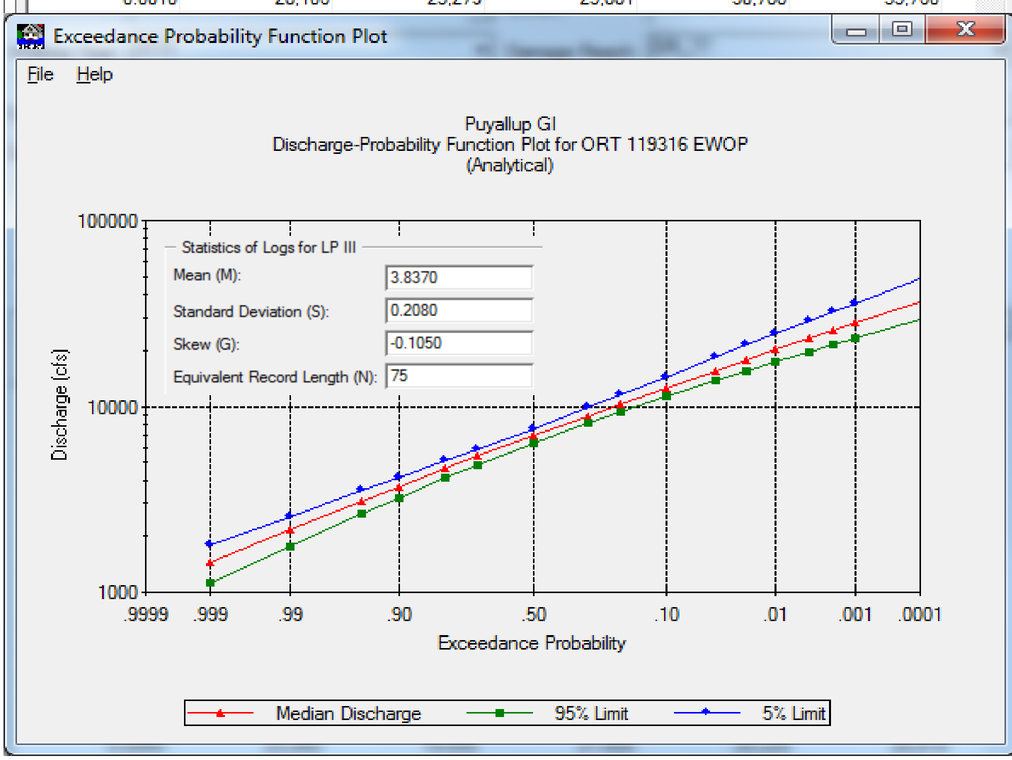
Analysis Year: 2015   Damage Reach: DR_77

Function: ORT 119316 EWOP   Use An Existing Function   Save

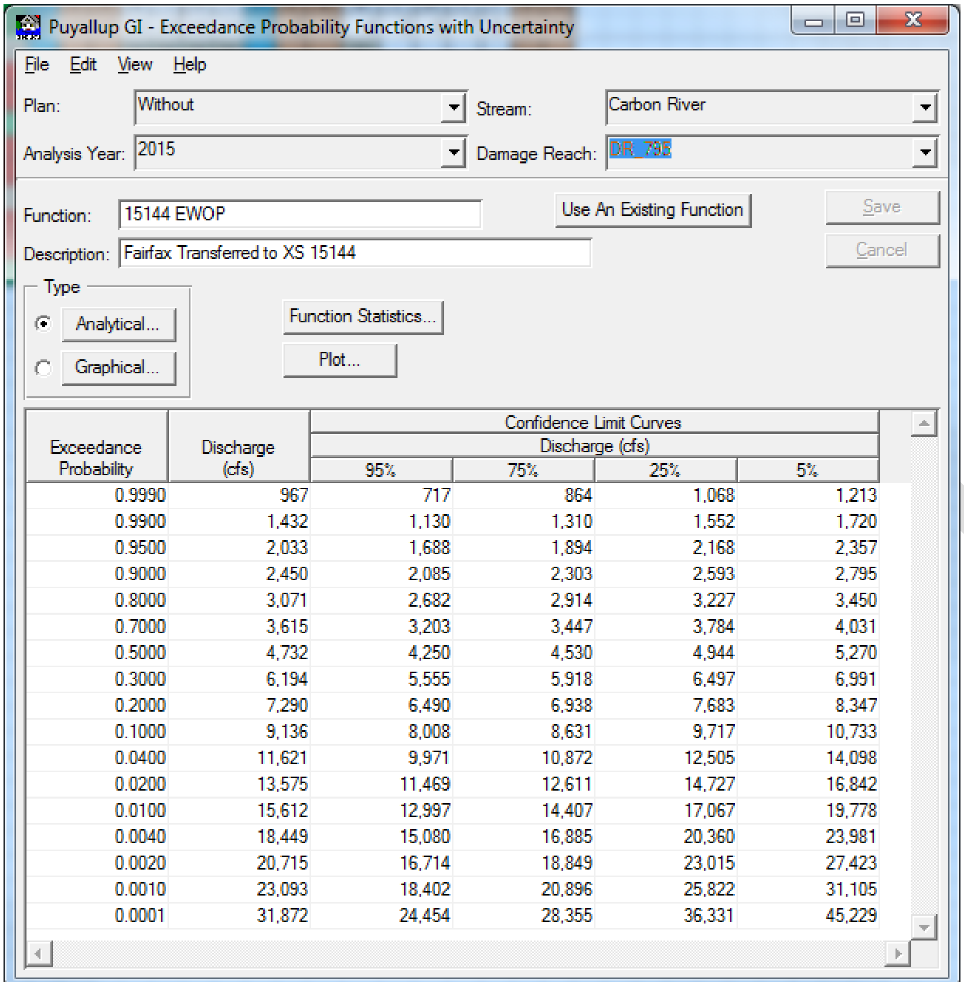
Description: Orting transferred to XS 119316   Cancel

Type: (•) Analytical... ( ) Graphical...   Function Statistics...   Plot...

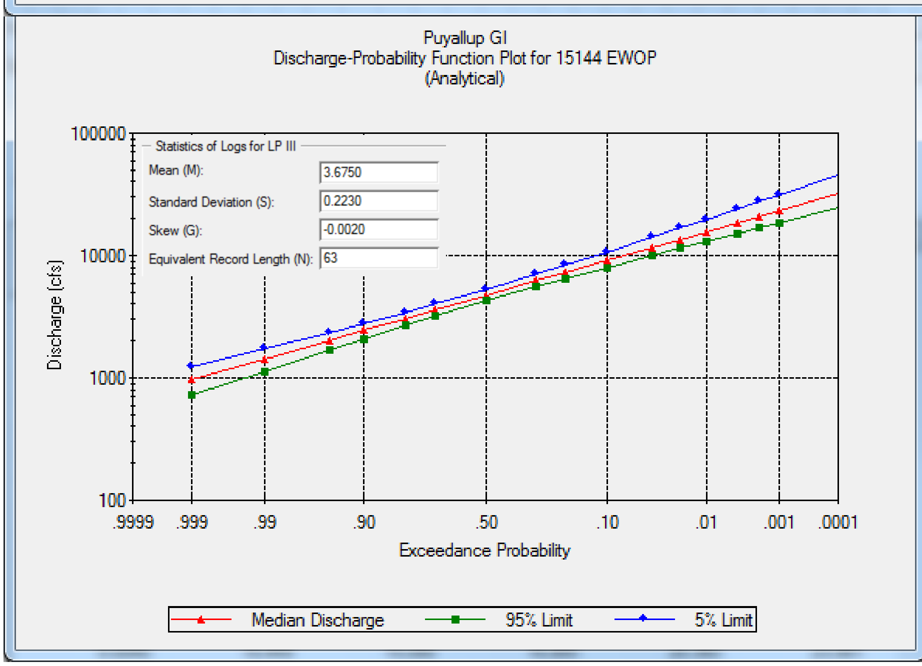
Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		95%	75%	25%	5%
0.9990	1,455	1,121	1,318	1,591	1,784
0.9900	2,173	1,771	2,011	2,332	2,555
0.9500	3,082	2,630	2,900	3,258	3,505
0.9000	3,700	3,227	3,510	3,885	4,146
0.8000	4,604	4,105	4,402	4,802	5,086
0.7000	5,378	4,855	5,164	5,592	5,904
0.5000	6,928	6,322	6,674	7,192	7,596
0.3000	8,885	8,091	8,543	9,255	9,851
0.2000	10,305	9,325	9,877	10,778	11,560
0.1000	12,621	11,273	12,024	13,299	14,454
0.0400	15,614	13,706	14,757	16,605	18,340
0.0200	17,880	15,502	16,805	19,137	21,372
0.0100	20,173	17,287	18,860	21,720	24,504
0.0040	23,260	19,650	21,608	25,228	28,814
0.0020	25,658	21,456	23,728	27,971	32,225
0.0010	28,106	23,279	25,881	30,788	35,760



Carbon, DR_795, Left Bank, Without Project Base Condition – Unregulated Exceedance Probability Function with Flow Transform



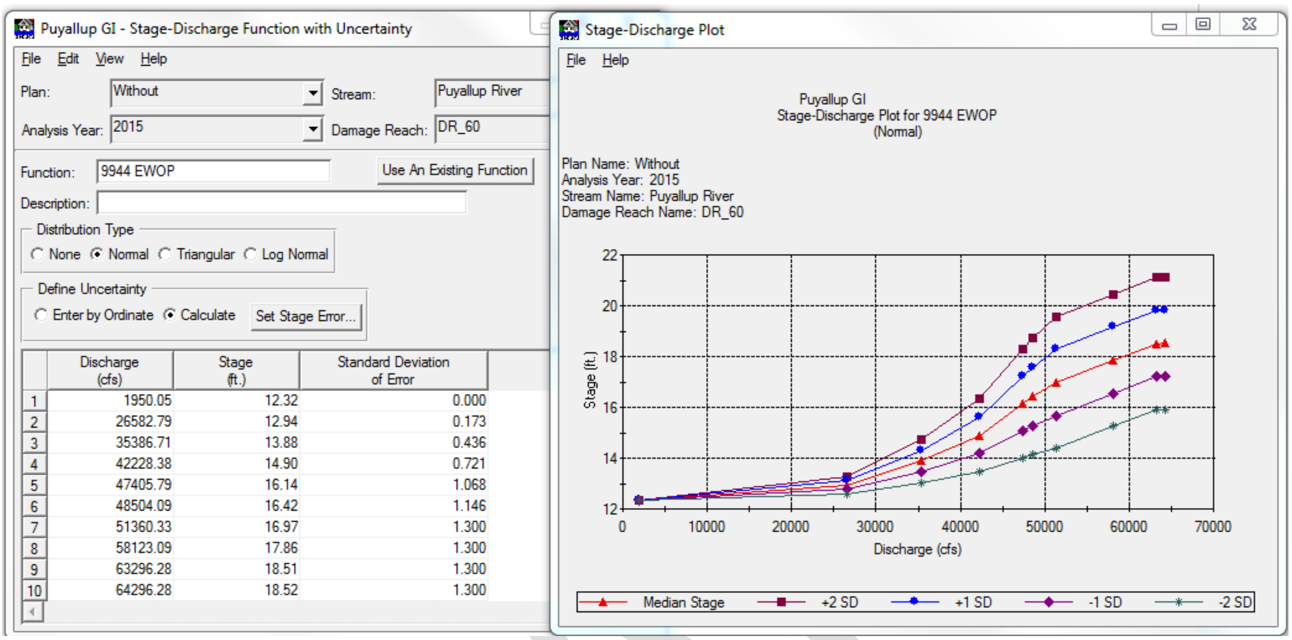
Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		95%	75%	25%	5%
0.9990	967	717	864	1,068	1,213
0.9900	1,432	1,130	1,310	1,552	1,720
0.9500	2,033	1,688	1,894	2,168	2,357
0.9000	2,450	2,085	2,303	2,593	2,795
0.8000	3,071	2,682	2,914	3,227	3,450
0.7000	3,615	3,203	3,447	3,784	4,031
0.5000	4,732	4,250	4,530	4,944	5,270
0.3000	6,194	5,555	5,918	6,497	6,991
0.2000	7,290	6,490	6,938	7,683	8,347
0.1000	9,136	8,008	8,631	9,717	10,733
0.0400	11,621	9,971	10,872	12,505	14,098
0.0200	13,575	11,469	12,611	14,727	16,842
0.0100	15,612	12,997	14,407	17,067	19,778
0.0040	18,449	15,080	16,885	20,360	23,981
0.0020	20,715	16,714	18,849	23,015	27,423
0.0010	23,093	18,402	20,896	25,822	31,105
0.0001	31,872	24,454	28,355	36,331	45,229



Hydraulic Inputs

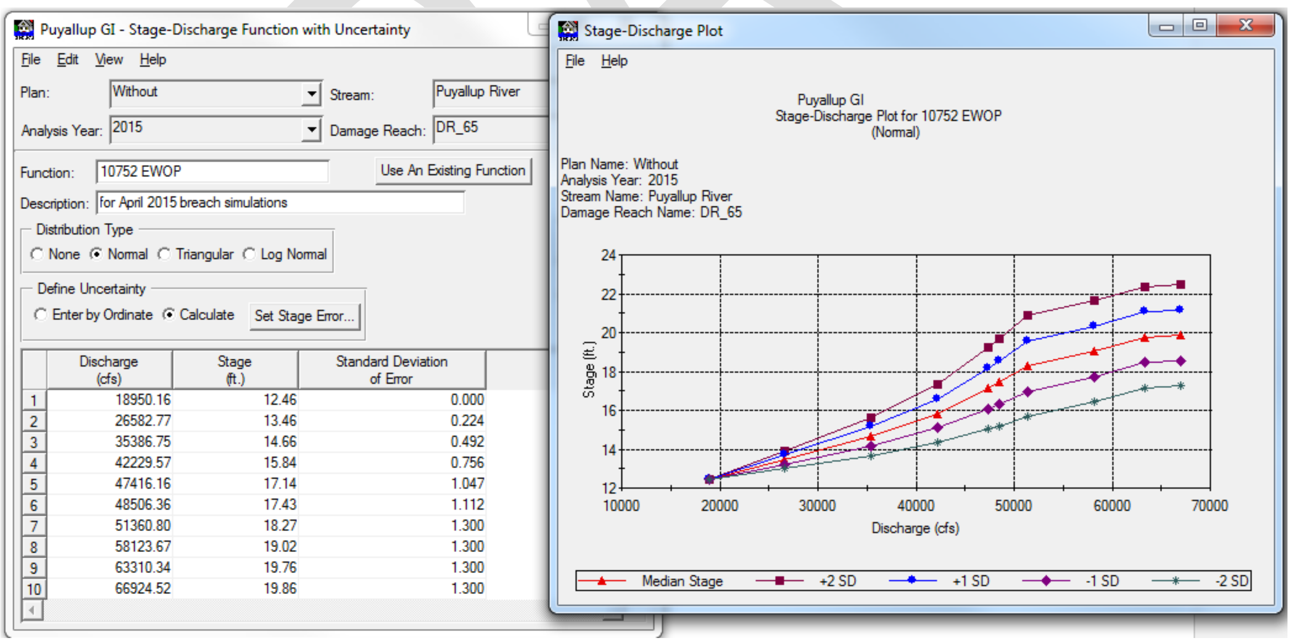
Stage-discharge functions with normal uncertainty for the following reaches:

Lower Puyallup, DR_60, Left Bank, Without Project Base Condition



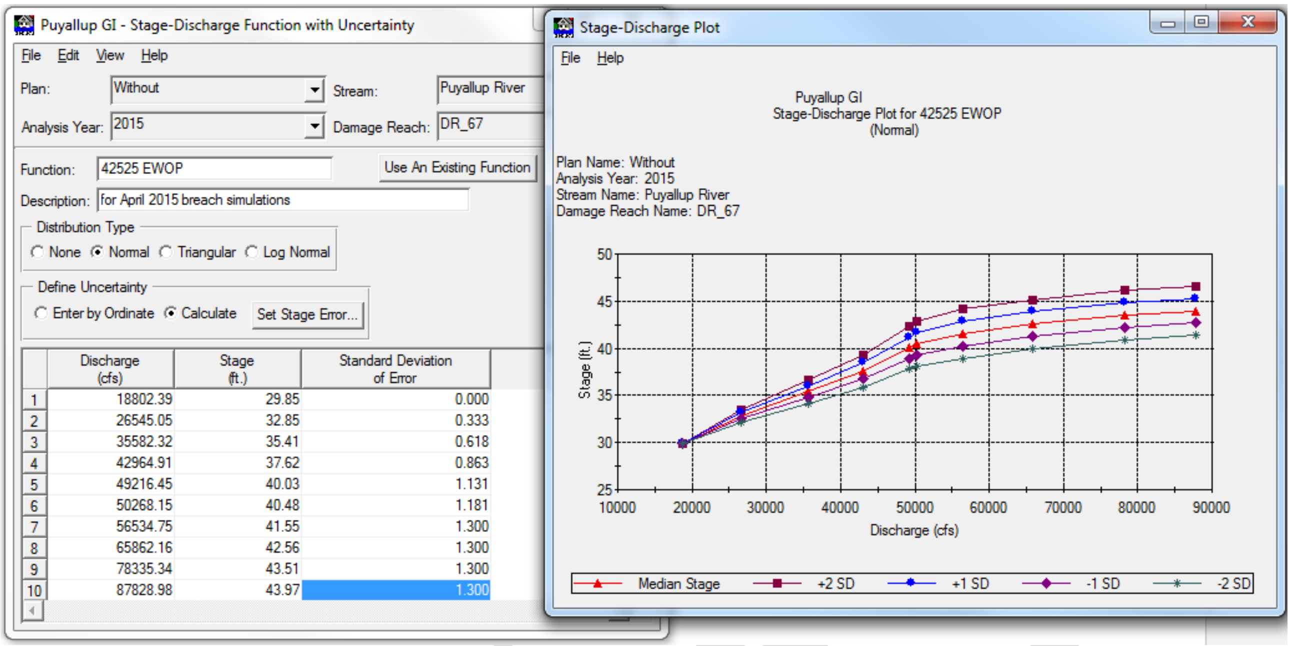
	Discharge (cfs)	Stage (ft.)	Standard Deviation of Error
1	1950.05	12.32	0.000
2	26582.79	12.94	0.173
3	35386.71	13.88	0.436
4	42228.38	14.90	0.721
5	47405.79	16.14	1.068
6	48504.09	16.42	1.146
7	51360.33	16.97	1.300
8	58123.09	17.86	1.300
9	63296.28	18.51	1.300
10	64296.28	18.52	1.300

Lower Puyallup, DR_65, Right Bank, Without Project Base Condition

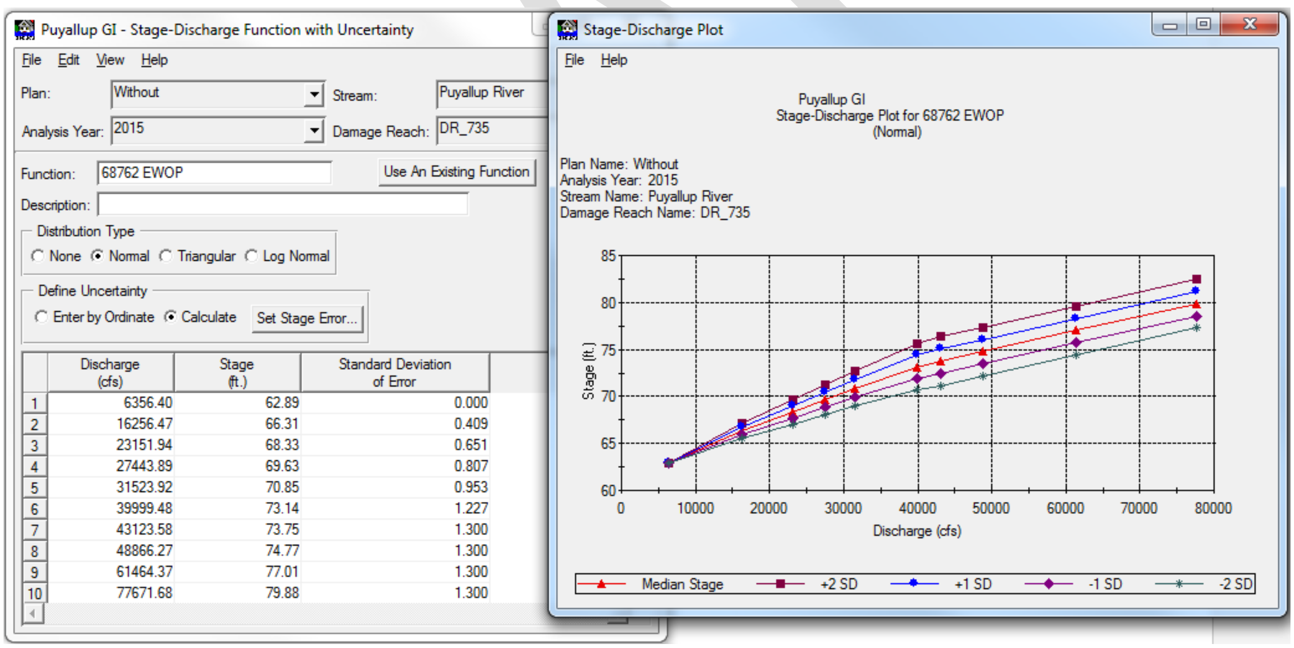


	Discharge (cfs)	Stage (ft.)	Standard Deviation of Error
1	18950.16	12.46	0.000
2	26582.77	13.46	0.224
3	35386.75	14.66	0.492
4	42229.57	15.84	0.756
5	47416.16	17.14	1.047
6	48506.36	17.43	1.112
7	51360.80	18.27	1.300
8	58123.67	19.02	1.300
9	63310.34	19.76	1.300
10	66924.52	19.86	1.300

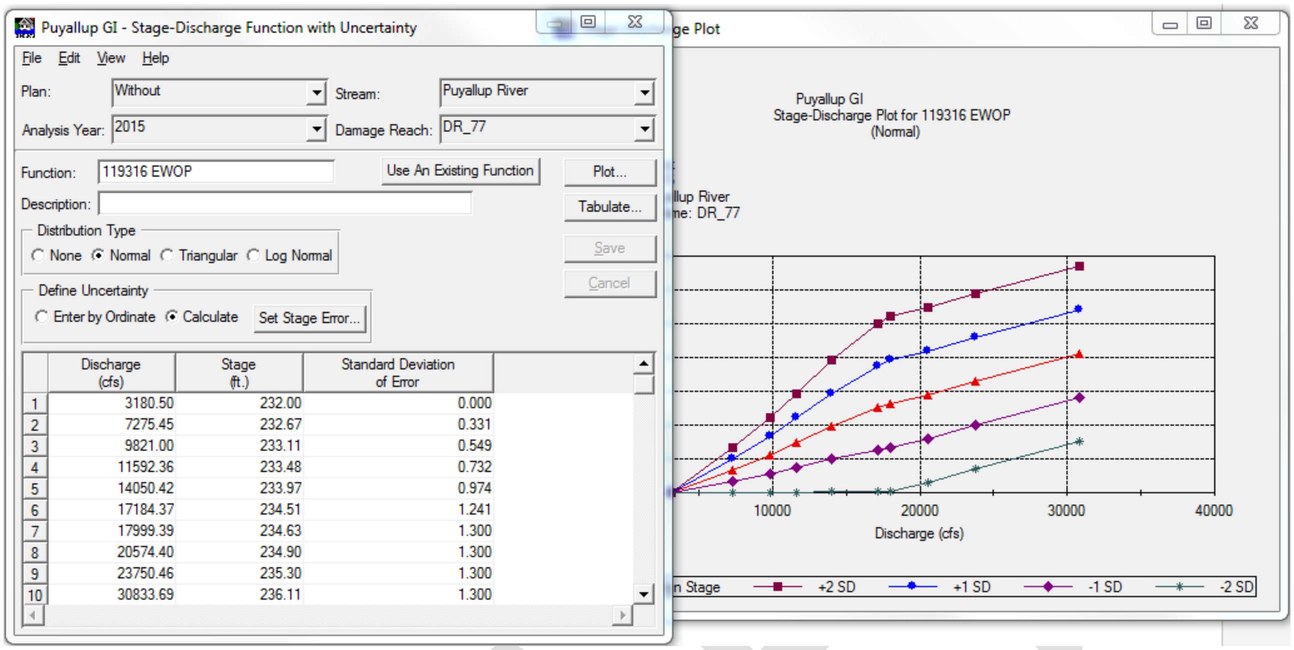
Lower Puyallup, DR_67, Right Bank, Without Project Base Condition



Middle Puyallup, DR_735, Right Bank, Without Project Base Condition

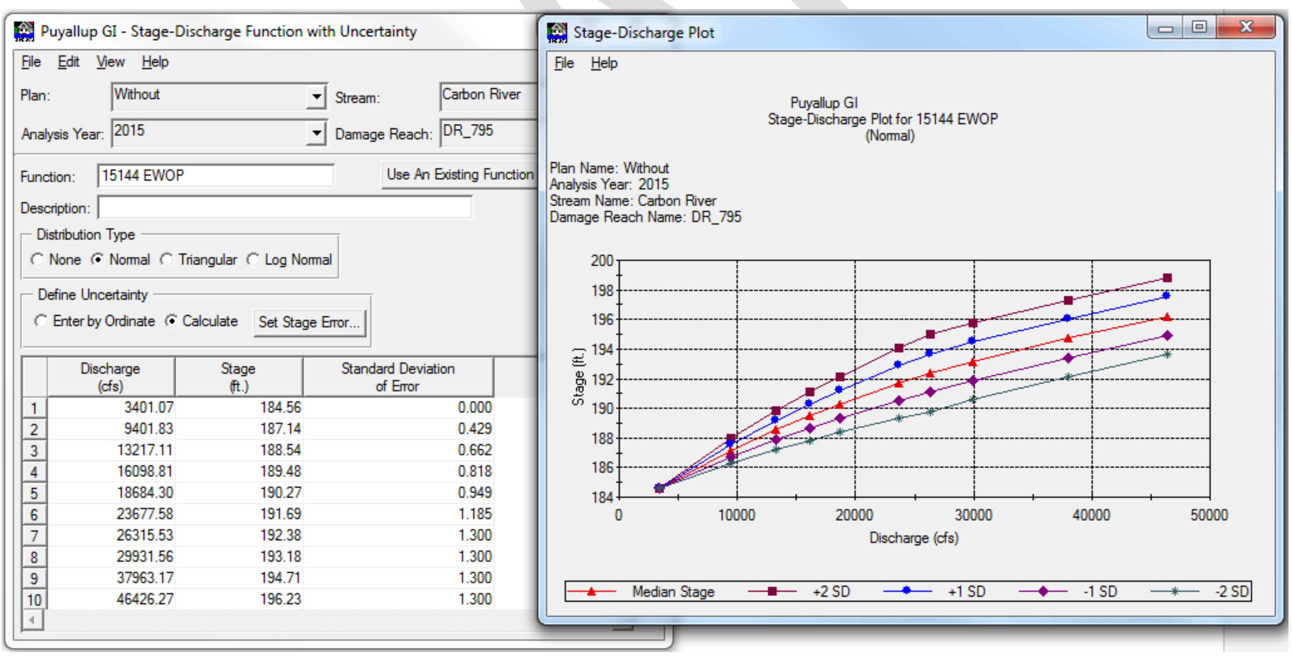


Upper Puyallup, DR_77, Right Bank, Without Project Base Condition



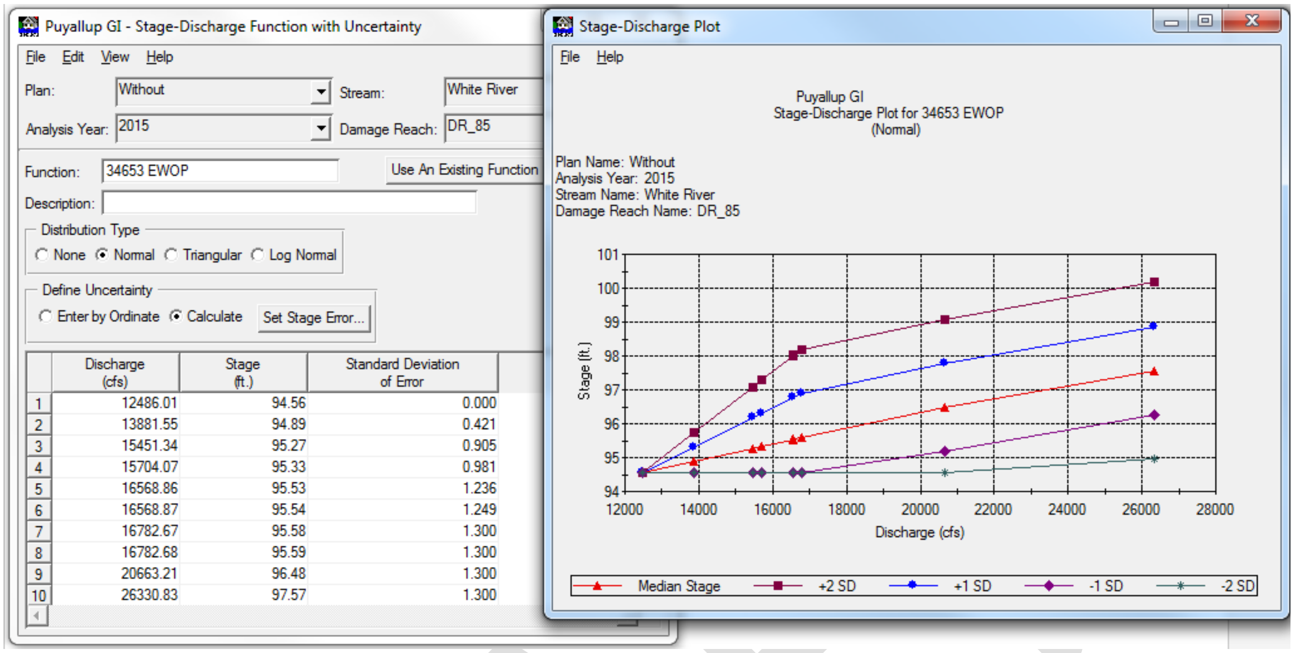
	Discharge (cfs)	Stage (ft.)	Standard Deviation of Error
1	3180.50	232.00	0.000
2	7275.45	232.67	0.331
3	9821.00	233.11	0.549
4	11592.36	233.48	0.732
5	14050.42	233.97	0.974
6	17184.37	234.51	1.241
7	17999.39	234.63	1.300
8	20574.40	234.90	1.300
9	23750.46	235.30	1.300
10	30833.69	236.11	1.300

Carbon, DR_795, Left Bank, Without Project Condition, 2015



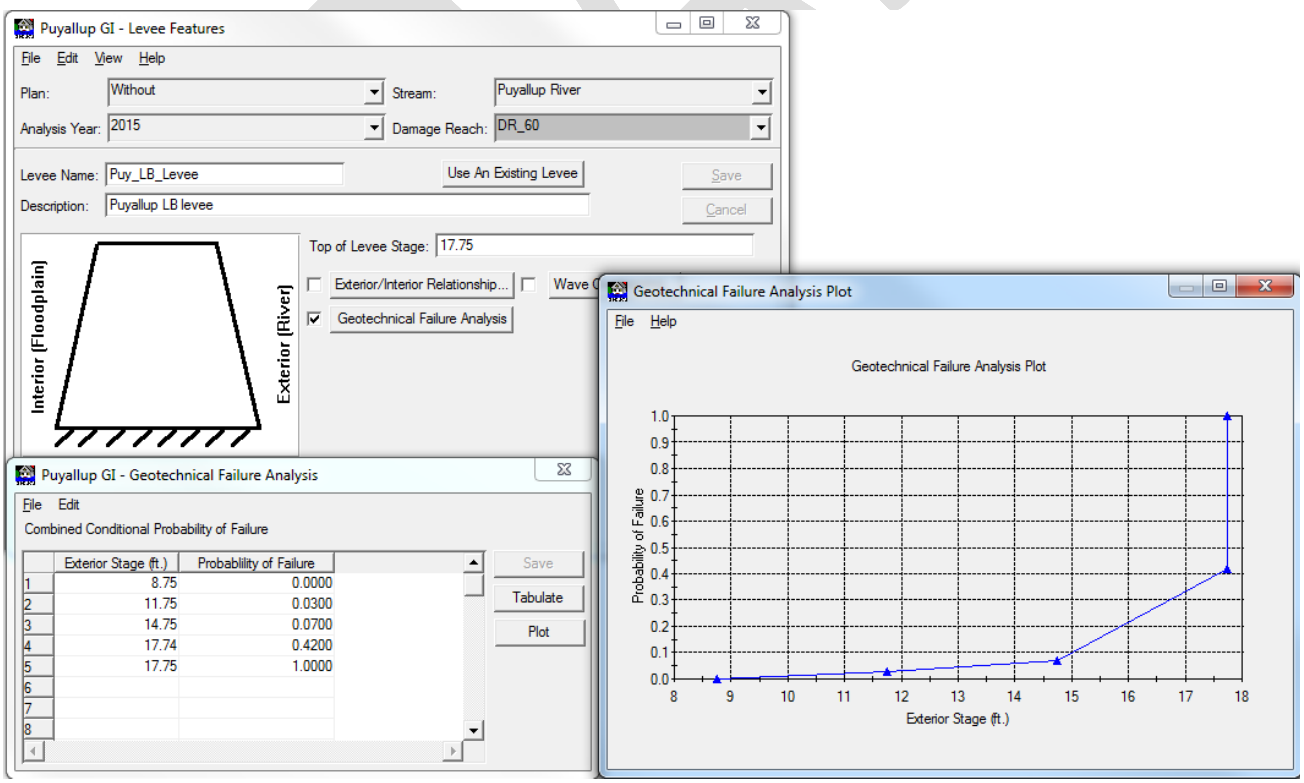
	Discharge (cfs)	Stage (ft.)	Standard Deviation of Error
1	3401.07	184.56	0.000
2	9401.83	187.14	0.429
3	13217.11	188.54	0.662
4	16098.81	189.48	0.818
5	18684.30	190.27	0.949
6	23677.58	191.69	1.185
7	26315.53	192.38	1.300
8	29931.56	193.18	1.300
9	37963.17	194.71	1.300
10	46426.27	196.23	1.300

White, DR_85, Right Bank, Without Project Base Condition

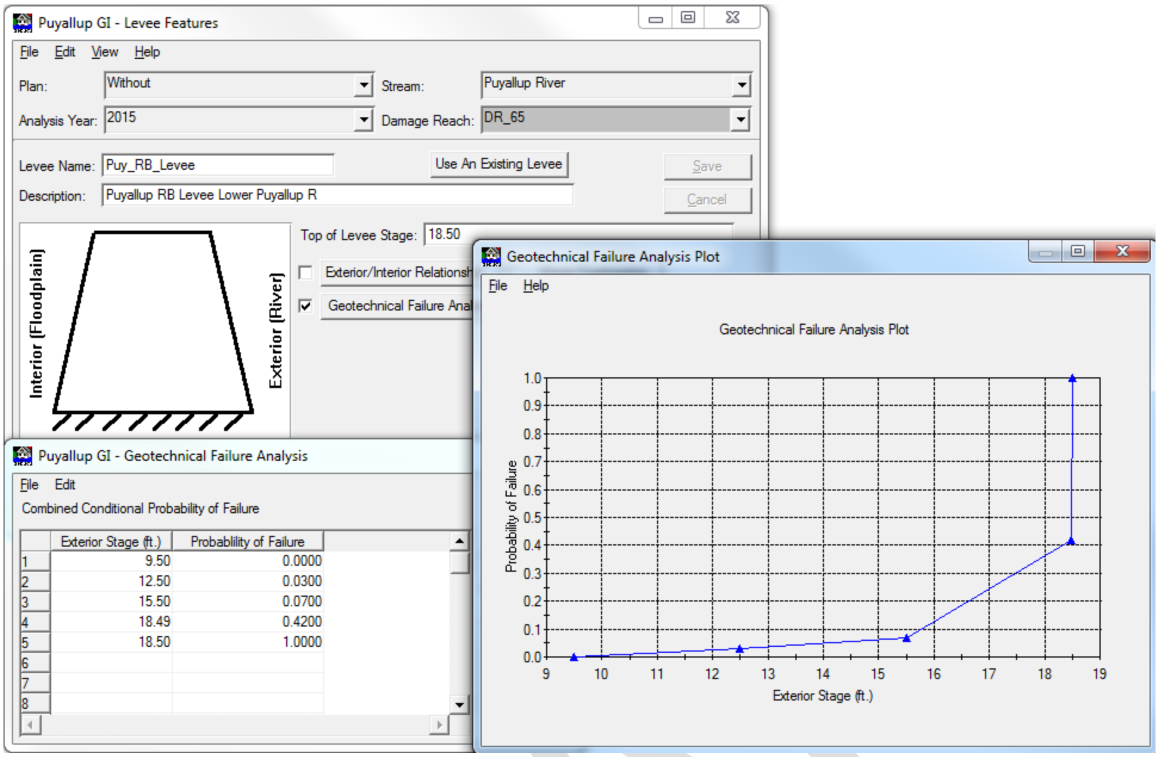


Levee Inputs

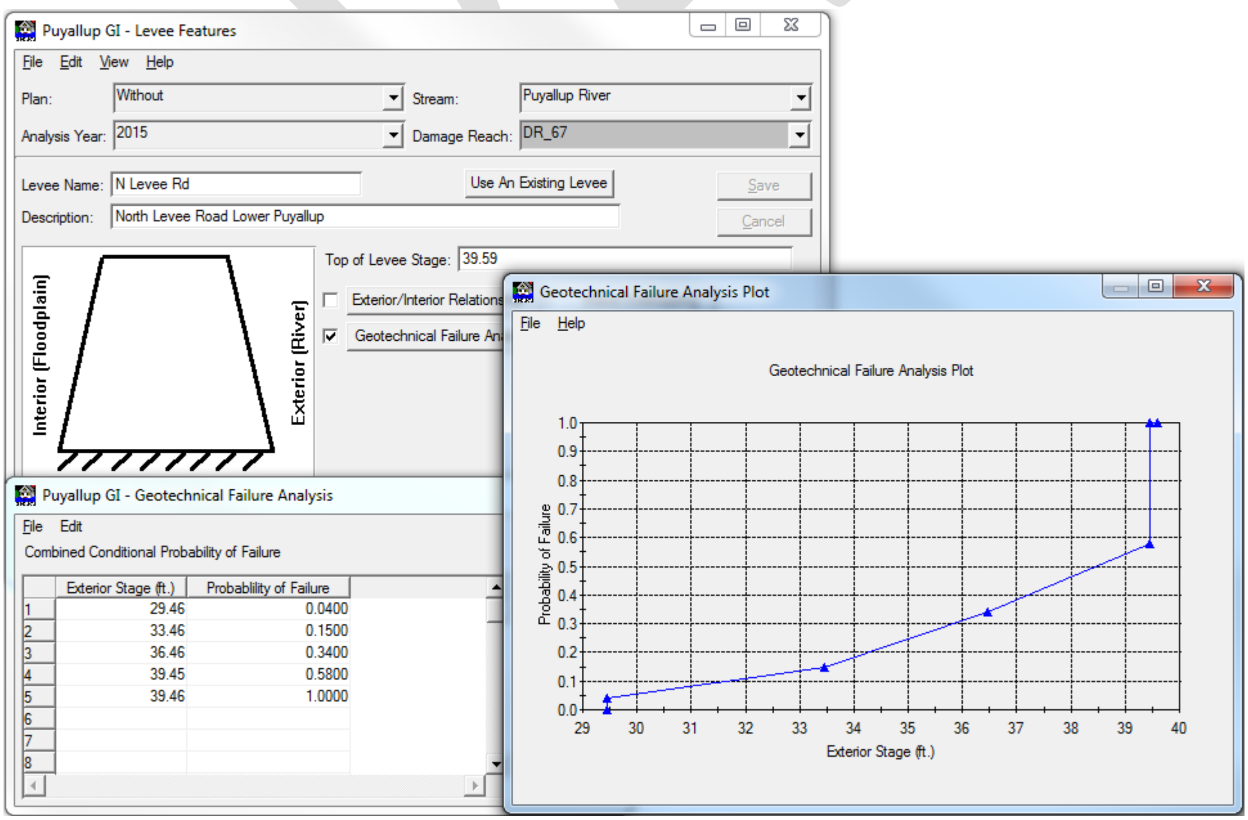
Lower Puyallup, DR_60, Left Bank, Without Project Base/Future Condition levee fragility curve



DR_65, Lower Puyallup, Right Bank, Without Project Base/Future Condition levee fragility curve



DR_67, Lower Puyallup, Right Bank, North Levee Road, Without Project Base/Future Condition levee fragility curve



Levee Assignments, Without Project Condition

Levee Assignments

File View Help

Puyallup GI
Levee Assignments

Plan Name	Year	Stream Name	Damage Reach Name	Levee Name	Levee Description
Without	2015	Puyallup River	DR_60	Puy_LB_Levee	Puyallup LB levee
		Puyallup River	DR_61	DR 61 WOP levee	DR 61 without project
		Puyallup River	DR_62	DR62 WOP TOL	DR 62 without top of levee
		Puyallup River	DR_63	River Rd	River Rd Puyallup River
		Puyallup River	DR_64	DR_64	
		Puyallup River	DR_65	Puy_RB_Levee	Puyallup RB Levee Lower Puyallup R
		Puyallup River	DR_66	DR66 WOP levee	DR 66 without project
		Puyallup River	DR_67	N Levee Rd	North Levee Road Lower Puyallup
		Puyallup River	DR_68	DR_68WOP	
		Puyallup River	DR_69	DR69 WOP levee	DR 69 without project
		Puyallup River	DR_70	DR70 WOP levee	DR 70 without project
		Puyallup River	DR_71	DR71 WOP levee	DR 71 without project
		Puyallup River	DR_72	DR 72 WOP levee	DR 72 without project
		Puyallup River	DR_73	DR73 WOP levee	DR 73 without project
		Puyallup River	DR_735	DR735 WOP levee	DR 735 without project
		Puyallup River	DR_74	DR74 WOP levee	DR 74 without project
		Puyallup River	DR_75	DR75 WOP levee	DR 75 without project
		Puyallup River	DR_76	DR76 WOP levee	DR 76 without project
		Puyallup River	DR_77	DR77 WOP levee	DR 77 without project
		Puyallup River	DR_78	DR78 WOP levee	DR 78 without project
		Puyallup River	DR_Clear_Crk_Riv	ClearCr TOL	Clear Creek elevation
		Puyallup River	DR_Low_Puyallup	DR LP without	DR Lower Puyallup top of levee WOP ave
		Puyallup River	DR_Mid_Puyallup	******	******
		Puyallup River	DR_Mid_Puy_RR	******	******
		Puyallup River	DR_Upp_Puyallup	DR UP WOP levee	DR Upp Puy ave without project
		Carbon River	DR_79	DR79 WOP levee	DR79 without project
		Carbon River	DR_795	DR795 WOP levee	DR 795 without project
		Carbon River	DR_80	DR80 WOP levee	DR 80 without project
		Carbon River	DR_81	DR81 WOP levee	DR 81 without project
		Carbon River	DR_Carbon_River	DR_Carbon	Carbon River bank left bank
		White River	DR_82	DR82 WOP levee	DR 82 without project
		White River	DR_83	DR83 WOP levee	DR 83 without project
		White River	DR_84	DR84 WOP levee	DR 84 without project
		White River	DR_85	DR85 WOP levee	DR 85 without project
		White River	DR_86	******	******
		White River	DR_87	DR87 WOP levee	DR 87 without project
		White River	DR_88	DR88 WOP levee	DR 88 without project
		White River	DR_Wht_Riverine	DR_Wht_Riverine	Right bank bank elevation
		White River	DR_Wht_Riv_Ind	DR_Wht_Riv_Ind	White industrial left bank elevation
		Tidal	DR_Tidal	******	******

****** - A levee has not been assigned for this plan/year/stream/damage reach combination.
* - The levee is not correct. See Help for more information on what could be wrong.

Levee Assignments, With Project Condition

Levee Assignments

File View Help

Puyallup GI
Levee Assignments

Plan Name	Year	Stream Name	Damage Reach Name	Levee Name	Levee Description
With Project	2015	Puyallup River	DR_60	DR_60 WP	DR_60 levee raise
		Puyallup River	DR_61	DR 61 WP levee	DR 61 without project
		Puyallup River	DR_62	DR62 WP TOL	DR 62 With Project top of levee
		Puyallup River	DR_63	DR_63 WP	DR_63 levee raise
		Puyallup River	DR_64	DR_64	
		Puyallup River	DR_65	DR_65 WP	DR_65 levee raise
		Puyallup River	DR_66	DR66 WP levee	DR 66 With Project project
		Puyallup River	DR_67	River_Rd_WP	River Road Levee Lower Puyallup
		Puyallup River	DR_68	DR_68WOP	
		Puyallup River	DR_69	DR69 WOP levee	DR 69 without project
		Puyallup River	DR_70	DR70 WOP levee	DR 70 without project
		Puyallup River	DR_71	DR71 WOP levee	DR 71 without project
		Puyallup River	DR_72	DR 72 WP levee	DR 72 With Project project
		Puyallup River	DR_73	DR73 WOP levee	DR 73 without project
		Puyallup River	DR_735	DR735 WOP levee	DR 735 without project
		Puyallup River	DR_74	DR74 WOP levee	DR 74 without project
		Puyallup River	DR_75	DR75 WOP levee	DR 75 without project
		Puyallup River	DR_76	DR76 WOP levee	DR 76 without project
		Puyallup River	DR_77	DR77 WP levee	DR 77 With Project project
		Puyallup River	DR_78	DR78 WOP levee	DR 78 without project
		Puyallup River	DR_Clear_Crk_Riv	DR_Clear_Crk	Clear Creek with project
		Puyallup River	DR_Low_Puyallup	DR LP WP	DR Lower Puyallup top of levee WP avera
		Puyallup River	DR_Mid_Puyallup	******	******
		Puyallup River	DR_Mid_Puy_RR	******	******
		Puyallup River	DR_Upp_Puyallup	DR UP WP levee	DR Upp Puy ave With Project project
		Carbon River	DR_79	DR79 WP levee	DR79 With Project project
		Carbon River	DR_795	DR795 WP levee	DR 795 With Project project
		Carbon River	DR_80	DR80 WOP levee	DR 80 without project
		Carbon River	DR_81	DR81 WOP levee	DR 81 without project
		Carbon River	DR_Carbon_River	DR_Carbon	Carbon River bank left bank
		White River	DR_82	DR82 WP levee	DR 82 With Project project
		White River	DR_83	DR83 WP levee	DR 83 With Project project
		White River	DR_84	DR84 WP levee	DR 84 With Project project
		White River	DR_85	DR85 WOP levee	DR 85 without project
		White River	DR_86	******	******
		White River	DR_87	DR87 WOP levee	DR 87 without project
		White River	DR_88	DR88 WOP levee	DR 88 without project
		White River	DR_Wht_Riverine	DR_Wht_Riverine	Right bank bank elevation
		White River	DR_Wht_Riv_Ind	DR_Wht_Riv_Ind	White industrial left bank elevation
		Tidal	DR_Tidal	******	******

****** - A levee has not been assigned for this plan/year/stream/damage reach combination.
* - The levee is not correct. See Help for more information on what could be wrong.

List of Levees

File View Help

Puyallup GI
List of Levees

Name	Top of Levee Stage	Damage Reach Name	Stream Name	Description
Puy_LB_Levee	17.75	DR_60	Puyallup River	Puyallup LB levee
River Rd	37.13	DR_63	Puyallup River	River Rd Puyallup River
Puy_RB_Levee	18.50	DR_65	Puyallup River	Puyallup RB Levee Lower Puyallup R
N Levee Rd	39.59	DR_67	Puyallup River	North Levee Road Lower Puyallup
ClearCr TOL	26.73	DR_Clear_Crk_Riv	Puyallup River	Clear Creek elevation
DR 61 WOP levee	27.75	DR_61	Puyallup River	DR 61 without project
DR66 WOP levee	39.59	DR_66	Puyallup River	DR 66 without project
DR LP without	31.99	DR_Low_Puyallup	Puyallup River	DR Lower Puyallup top of levee WOP average
DR62 WOP TOL	35.75	DR_62	Puyallup River	DR 62 without top of levee
DR 72 WOP levee	51.18	DR_72	Puyallup River	DR 72 without project
DR73 WOP levee	67.01	DR_73	Puyallup River	DR 73 without project
DR735 WOP levee	76.59	DR_735	Puyallup River	DR 735 without project
DR69 WOP levee	78.84	DR_69	Puyallup River	DR 69 without project
DR70 WOP levee	101.65	DR_70	Puyallup River	DR 70 without project
DR74 WOP levee	114.90	DR_74	Puyallup River	DR 74 without project
DR71 WOP levee	119.22	DR_71	Puyallup River	DR 71 without project
DR76 WOP levee	130.10	DR_76	Puyallup River	DR 76 without project
DR75 WOP levee	217.11	DR_75	Puyallup River	DR 75 without project
DR77 WOP levee	233.94	DR_77	Puyallup River	DR 77 without project
DR78 WOP levee	249.58	DR_78	Puyallup River	DR 78 without project
DR UP WOP levee	237.24	DR_Upp_Puyallup	Puyallup River	DR Upp Puy ave without project
DR79 WOP levee	135.87	DR_79	Carbon River	DR79 without project
DR795 WOP levee	192.11	DR_795	Carbon River	DR 795 without project
DR80 WOP levee	305.00	DR_80	Carbon River	DR 80 without project
DR81 WOP levee	332.63	DR_81	Carbon River	DR 81 without project
DR82 WOP levee	52.45	DR_82	White River	DR 82 without project
DR83 WOP levee	58.73	DR_83	White River	DR 83 without project
DR87 WOP levee	47.95	DR_87	White River	DR 87 without project
DR88 WOP levee	83.80	DR_88	White River	DR 88 without project
DR84 WOP levee	74.76	DR_84	White River	DR 84 without project
DR85 WOP levee	94.85	DR_85	White River	DR 85 without project
River_Rd_WP	47.04	DR_67	Puyallup River	River Road Levee Lower Puyallup
DR 61 WP levee	31.21	DR_61	Puyallup River	DR 61 without project
DR66 WP levee	35.78	DR_66	Puyallup River	DR 66 With Project project
DR LP WP	37.05	DR_Low_Puyallup	Puyallup River	DR Lower Puyallup top of levee WP average
DR62 WP TOL	42.52	DR_62	Puyallup River	DR 62 With Project top of levee
DR 72 WP levee	61.28	DR_72	Puyallup River	DR 72 With Project project
DR77 WP levee	240.76	DR_77	Puyallup River	DR 77 With Project project
DR UP WP levee	239.07	DR_Upp_Puyallup	Puyallup River	DR Upp Puy ave With Project project
DR79 WP levee	140.24	DR_79	Carbon River	DR79 With Project project
DR795 WP levee	195.36	DR_795	Carbon River	DR 795 With Project project
DR82 WP levee	68.94	DR_82	White River	DR 82 With Project project
DR83 WP levee	60.23	DR_83	White River	DR 83 With Project project
DR84 WP levee	83.05	DR_84	White River	DR 84 With Project project
DR_64	48.79	DR_64	Puyallup River	
DR_68WOP	39.13	DR_68	Puyallup River	
DR_60 WP	21.12	DR_60	Puyallup River	DR_60 levee raise
DR_63 WP	48.88	DR_63	Puyallup River	DR_63 levee raise
DR_65 WP	21.81	DR_65	Puyallup River	DR_65 levee raise
DR_Clear_Crk	26.73	DR_Clear_Crk_Riv	Puyallup River	Clear Creek with project
DR_Carbon	202.01	DR_Carbon_River	Carbon River	Carbon River bank left bank
DR_Wht_Riverine	82.03	DR_Wht_Riverine	White River	Right bank bank elevation
DR_Wht_Riv_Ind	80.50	DR_Wht_Riv_Ind	White River	White industrial left bank elevation
Puy_LB_NoFrag	17.75	DR_60	Puyallup River	Puyallup LB levee without fragility
Puy_RB_NoFragility	18.50	DR_65	Puyallup River	Puyallup RB Levee Lower Puyallup R without fra
N Levee Rd_NoFragility	39.59	DR_67	Puyallup River	North Levee Road Lower Puyallup without fragilit

Attachment 1 – Socioeconomics Report

Attachment 2 – RED and OSE Accounts, and EO 11988 Compliance Documentation

Appendix C-2

Economics

Socioeconomics Report

Puyallup River Basin

Flood Risk Management Feasibility Study

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Socioeconomics of the Puyallup River Basin General Investigation Study Area

Prepared for

U.S. Army Corps of Engineers – Seattle District

November 2011

Prepared by

Northern Economics

880 H Street, Suite 210
Anchorage, Alaska 99501
Phone: (907) 274-5600
Fax: (907) 274-5601
Email: mail@norecon.com

119 N Commercial Street, Suite 190
Bellingham, WA 98225
Phone: (360) 715-1808
Fax: (360) 715-3588

PROFESSIONAL CONSULTING SERVICES IN APPLIED ECONOMIC ANALYSIS

Principals:
Patrick Burden, M.S. – President
Marcus L. Hartley, M.S. – Vice President
Jonathan King, M.S.

Consultants:
Joel Ainsworth, B.A.
Alexus Bond, M.A.
Leah Cuyno, Ph.D.
Michael Fisher, MBA
Cal Kerr, MBA
Alejandra Palma, M.A.
Bill Schenken, MBA
Don Schug, Ph.D.
Katharine Wellman, Ph.D.

Administrative Staff:
Diane Steele – Office Manager
Terri McCoy, B.A.
Michelle Humphrey, B.S.

Northern Economics

880 H Street, Suite 210
Anchorage, Alaska 99501
Phone: (907) 274-5600
Fax: (907) 274-5601
Email: mail@norecon.com

119 N Commercial Street, Suite 190
Bellingham, WA 98225
Phone: (360) 715-1808
Fax: (360) 715-3588

Preparers

Team Member	Project Role	Firm
Bill Schenken, MBA	Project Manager	Northern Economics, Inc.
Marcus Hartley, MS	Principal in Charge	Northern Economics, Inc.
Don Schug, PhD	Socioeconomic Analyst	Northern Economics, Inc.
Cal Kerr, MBA	Analyst	Northern Economics, Inc.
Erik Pipkin	GIS Analyst	Anchor QEA
Terri McCoy	Editor	Northern Economics, Inc.

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Contents

Table **Page**

Figure	Page

Abbreviations

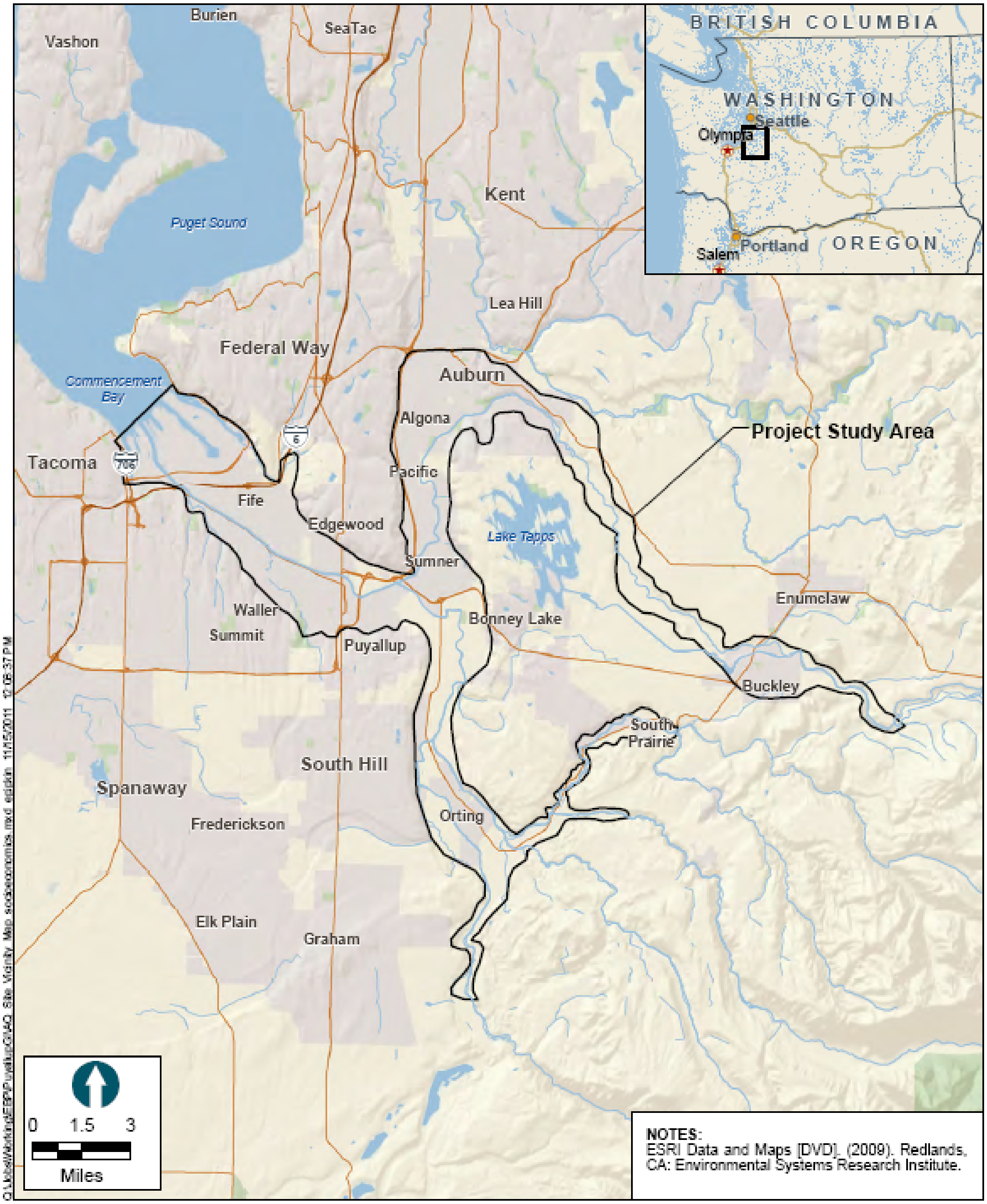
ADTC	Average Daily Traffic Count
BNSF	Burlington Northern Santa Fe
CBD	Central Business District
FAZ	Forecast Analysis Zone
FIRES	Financial, Insurance, Real Estate and Services
GovEd	Government and Education
I-	Interstate
PSRC	Puget Sound Regional Council
SR	State Road
WTCU	Wholesale Trade, Transportation, Communication, and Utilities
WWTP	Wastewater Treatment Plant

1 Introduction

The U.S. Army Corps of Engineers–Seattle District contracted with Anchor QEA and its sub-contractor, Northern Economics, Inc., to prepare a socioeconomic profile in response to Task 4 of the Puyallup River Basin General Investigation Flood Damage Reduction Feasibility Study, Contract No. W912W-08-D-1006 Task Order No.17. The purpose of the socioeconomic profile is to describe the current social and economic characteristics of the General Investigation Study Area (hereafter, Study Area) and surrounding communities, and to forecast future socioeconomic conditions within and around the Study Area under the Future Without Project condition.

The heavy black line in Figure 1 outlines the boundaries of the Study Area. The socioeconomic profile encompasses this area and the surrounding communities, including the urban and industrial areas of Tacoma, the Port of Tacoma, and Fife; the residential areas of Puyallup, Bonney Lake, Sumner, Auburn, Edgewood, Algona, Pacific, and Enumclaw; and the rural places of Buckley, Orting and South Prairie.

Figure 1. General Investigation Study Area and Surrounding Region



ANCHOR QEA
720 OLIVE WAY, SUITE 1900 | SEATTLE, WA 98101 | (206) 287-9130

Figure 1
General Investigation Study Area and Surrounding Region
Socioeconomics of the Puyallup River Basin
General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

Source: Anchor QEA

2 Existing Socioeconomic Conditions

This section examines existing socioeconomic conditions within and around the Study Area, including demographic, economic, environmental justice populations, public infrastructure, land use, and transportation characteristics. Socioeconomic data are presented for King and Pierce Counties and the communities that are located completely or partially within the boundaries of the Study Area.

Socioeconomic data are also presented for the four River Sections of the Study Area: Lower Puyallup, Upper Puyallup, White River, and Carbon River. Data were compiled using census block group boundaries, which do not conform exactly to River Section boundaries. Therefore, the populations presented are the best estimate of the River Section populations. Figure 2 shows the block groups used for each River Section.

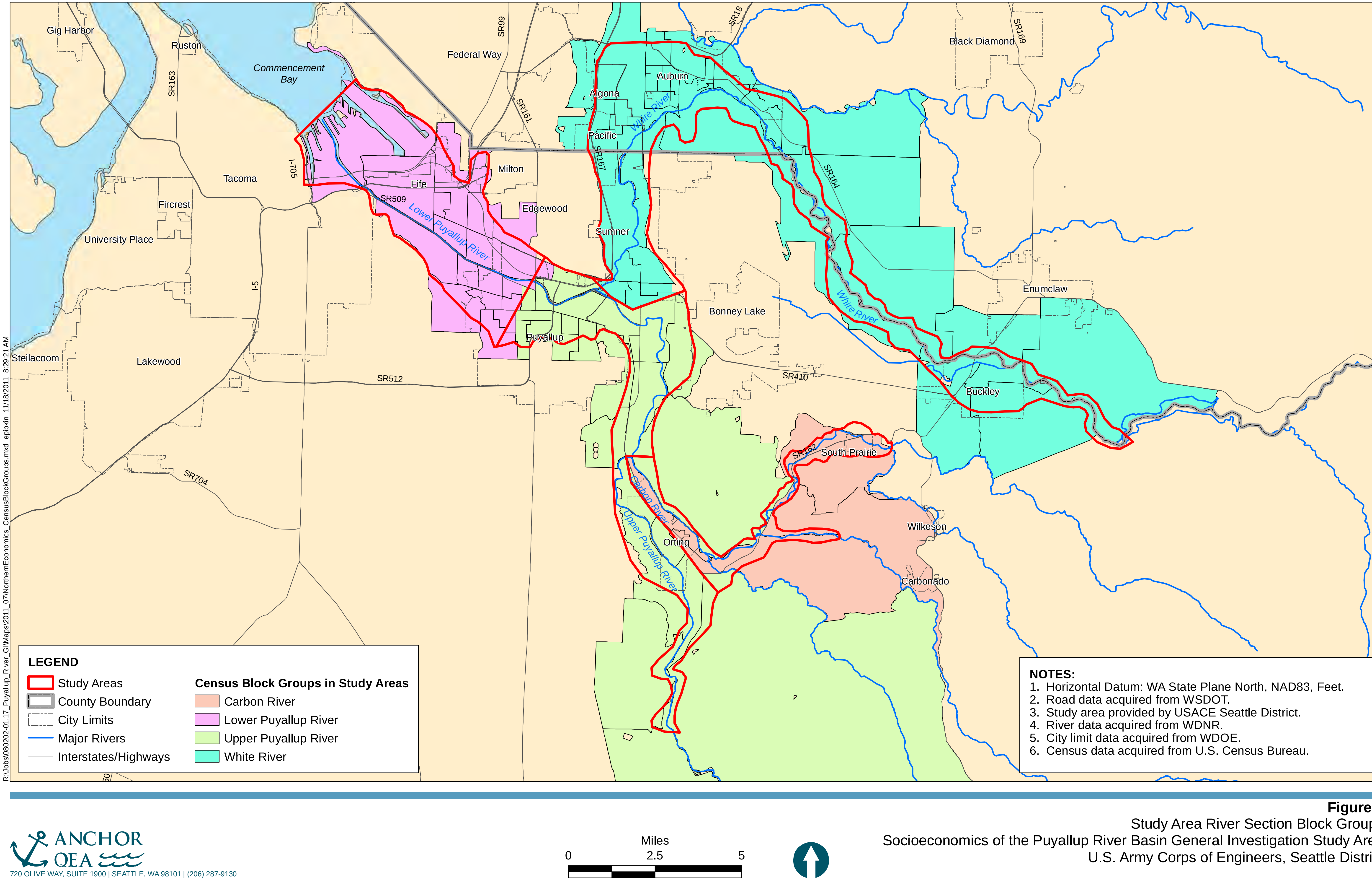


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Figure 2
Study Area River Section Block Groups
Socioeconomics of the Puyallup River Basin General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

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2.1 Demographics

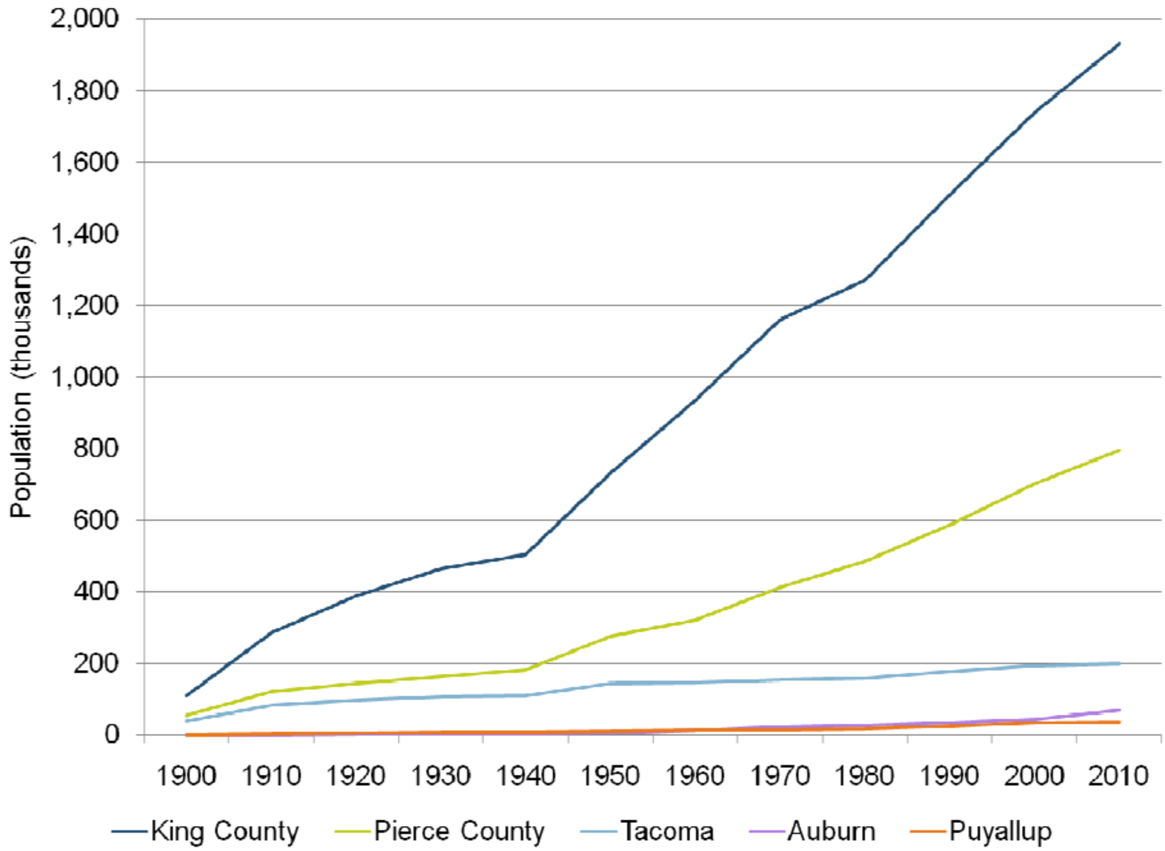
2.1.1 Population

The Study Area lies within both King and Pierce Counties. King County has the largest population of any county in Washington State because it includes the large cities of Seattle and Bellevue, both of which are located outside of the Study Area. The portion of the Study Area within King County is in south King County, which has a population density far lower than the two main metro centers. Pierce County is the second most populous county in the State because it includes the large urban area of Tacoma. Part of Tacoma lies within the Study Area.

Figure 3 shows the population trends in Pierce and King Counties from 1900 to 2010. Both counties have shown consistent population growth since 1940. The period during and after World War II was characterized by increased economic activity mainly due to expansion of The Boeing Company, which had its corporate headquarters in Seattle until 2001.

Figure 3 also shows the populations of the three major cities that lie partially within the Study Area: Tacoma, Auburn and Puyallup. Tacoma, with a population of nearly 200,000 in 2010, is the third largest city in Washington. The city grew rapidly during and immediately after World War II, but then population growth slowed until the 1990s, when efforts were made to revitalize the city center. The next largest city located partially within the Study Area is Auburn, which has experienced rapid growth in the past ten years due to annexations that added over 16,000 people. Puyallup experienced steady population growth through the 20th century and also added just over 2,000 residents through annexations in the 2000s.

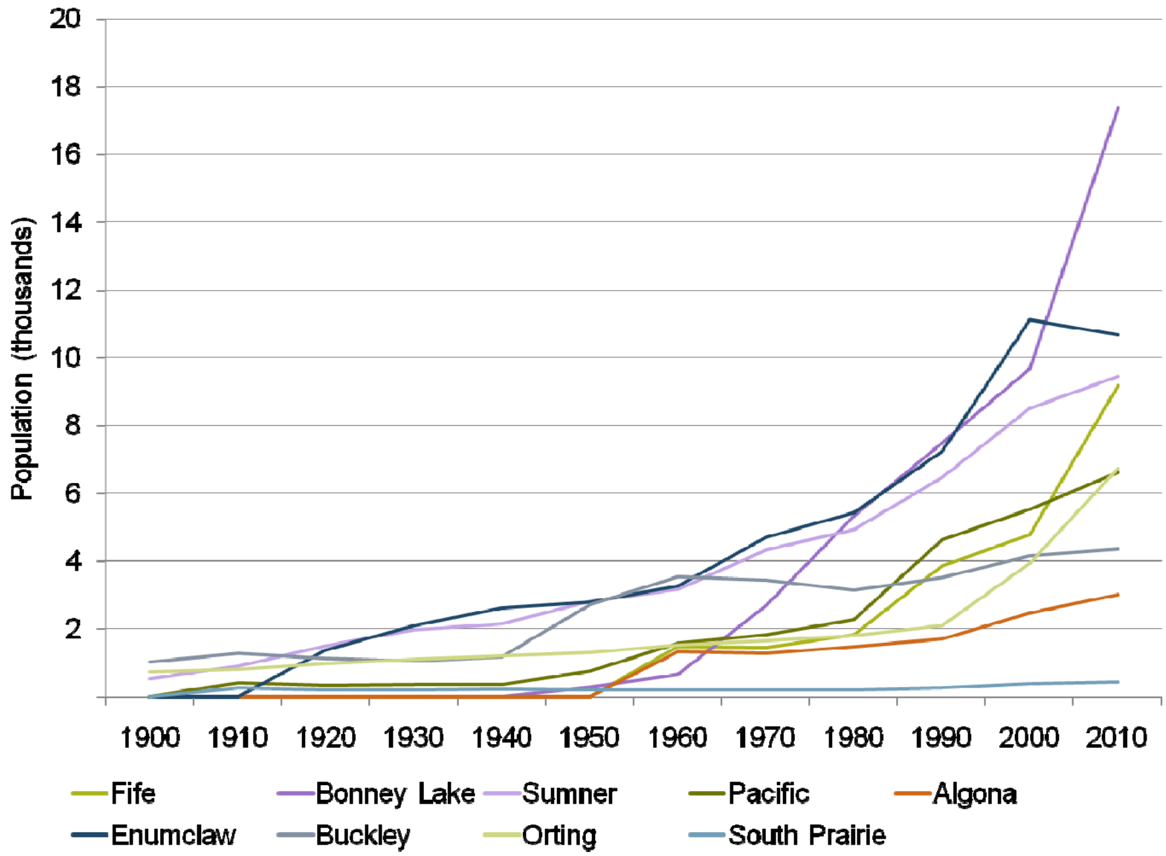
Figure 3. Population of Counties and Major Cities in the Study Area, 1900-2010



Source: Washington State OFM, 2002; U.S. Census Bureau, 2010.

Figure 4 shows the population trends in the smaller communities in the Study Area from 1900 to 2010. Bonney Lake experienced rapid growth in the 2000s due to annexations, and had 17,374 residents by 2010. The population of Enumclaw grew rapidly during the 1980s and 1990s and then decreased in the 2000s due to a building moratorium caused by sewage treatment capacity constraints. The remaining communities in the Study Area had populations of less than 10,000 in 2010. All of these communities have seen population increases during the past several years. Edgewood, which had a population of 9,387 in 2010, has only one year of population data due to its recent incorporation. Table 1 shows the 2010 populations for of all of the smaller Study Area communities.

Figure 4. Population of Smaller Communities in the Study Area, 1900-2010



Source: Washington State OFM, 2002; U.S. Census Bureau, 2010.

Table 1. Population of City, County and Study Area Communities, 2010

Place	Population
Washington	6,724,540
King County	1,931,249
Pierce County	795,225
Lower Puyallup	
Tacoma	198,397
Fife	9,173
Edgewood	9,387
Upper Puyallup	
Puyallup	37,022
Bonney Lake	17,374
White River	
Sumner	9,451
Pacific	6,606
Algona	3,014
Auburn	70,180
Enumclaw	10,669
Buckley	4,354
Carbon River	
Orting	6,746
South Prairie	434

Source: U.S. Census Bureau, 2010.

Table 2 shows the approximate populations of the Study Area River Sections in 2010. The White River area had the largest population since it includes large portions of Auburn, Sumner, Algona and Pacific. The Upper Puyallup contains a large portion of Puyallup and all of Orting. The Lower Puyallup includes Fife and a portion of Tacoma. Most of the Lower Puyallup is an industrial and commercial area with relatively little residential development. The Carbon River is a rural area with most of its population concentrated in and around South Prairie.

Table 2. Population of Study Area River Sections, 2010

Study Area Section	Population
Lower Puyallup River	27,874
Upper Puyallup River	36,456
White River	62,649
Carbon River	9,276

Source: U.S. Census Bureau, 2010.

Figure 5 shows the population density of the Study Area and surrounding region. The number of persons per square mile is highly variable across the region, with the highest population density occurring in the Tacoma area. However, the Port of Tacoma, which is the only portion of Tacoma located in the Study Area, has a low population density due to its industrial nature. The population density increases to the east due to the presence of Puyallup and Sumner. Moving north from

Sumner, industrial land uses dominate and consequently population density is again low. The most densely populated portion of the Study Area is the area around downtown Auburn. Continuing east on the White River, the population density is low until the community of Buckley is reached. South of Puyallup the population density is low until reaching Orting. The far reaches of the Upper Puyallup and Carbon River areas are sparsely populated except for South Prairie.

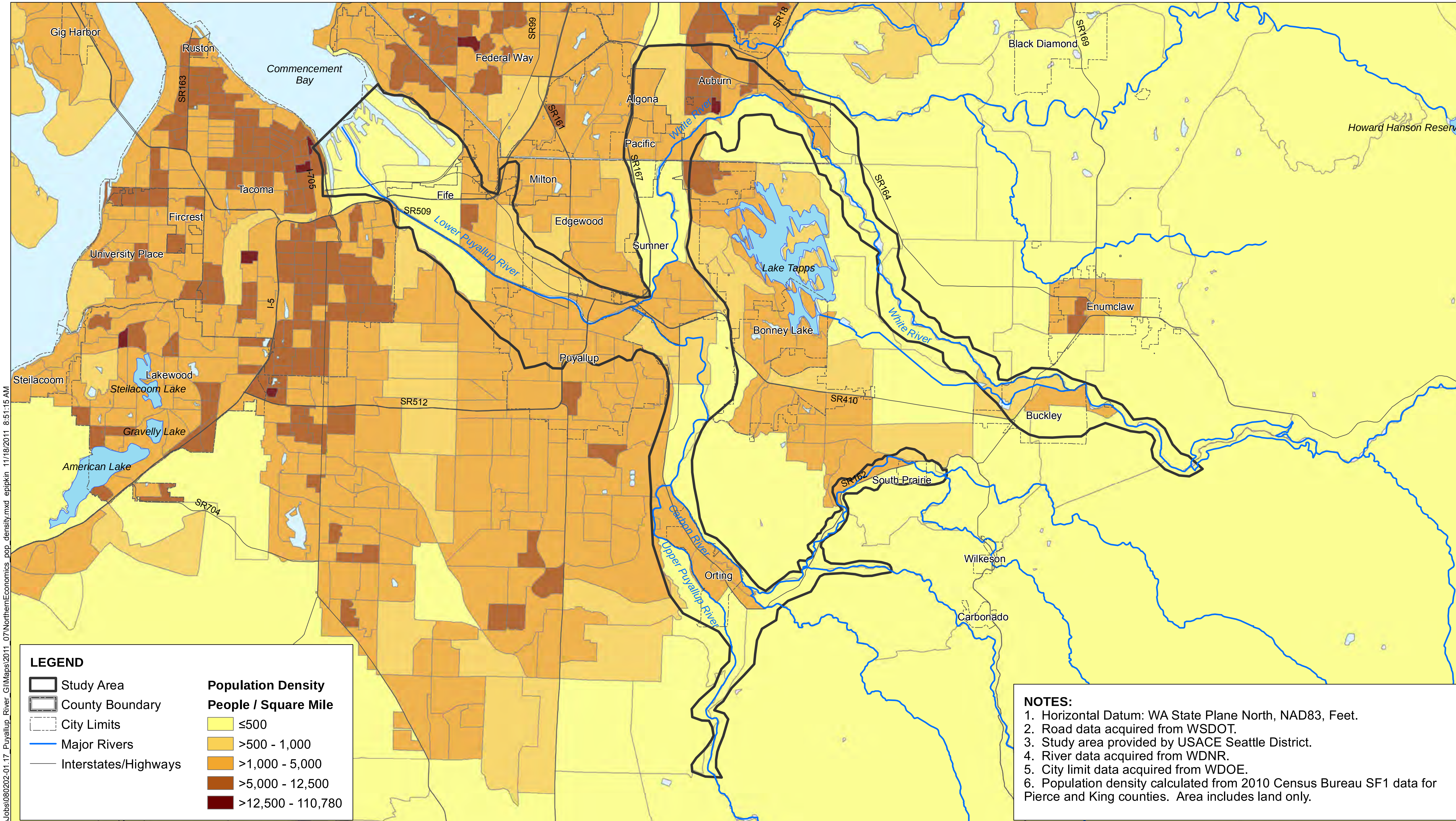


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Figure 5
Population Density of the Study Area and Surrounding Region, 2010
Socioeconomics of the Puyallup River Basin General Investigation Study Area
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2.1.2 Age and Gender

Table 3 shows the gender and age characteristics of the state, counties, and Study Area communities in 2010. The characteristics of King and Pierce Counties are similar to those of the state as a whole. The highest median age occurs in Edgewood, while the lowest is in Fife. The communities of Fife, Orting, Bonney Lake and Algona have the greatest population percentages under five years old, while the communities of Sumner, Enumclaw, Edgewood and Buckley have the greatest population percentages sixty-five or older.

Table 3. Gender and Age Characteristics in the State, King and Pierce Counties, and Study Area Communities, 2010

	Percent by Gender		Percent by Age			
Place	**Male**	**Female**	**Under 5 Years**	**18 Years and Over**	**65 Years and Over**	**Median Age**
State of Washington	49.8	50.2	6.5	76.5	12.3	37.3
King County	49.8	50.2	6.2	78.6	10.9	37.1
Pierce County	49.4	50.6	7.0	75.1	11.0	35.9
Lower Puyallup						
Tacoma	49.4	50.6	7.0	77.0	11.3	35.1
Fife	50.4	49.6	9.3	74.3	6.5	30.9
Edgewood	49.9	50.1	4.5	78.4	14.0	44.3
Upper Puyallup						
Puyallup	48.0	52.0	6.5	76.4	12.4	36.8
Bonney Lake	50.3	49.7	8.0	71.5	6.4	34.5
White River						
Sumner	48.2	51.8	6.7	75.6	14.9	38.2
Pacific	50.0	50.0	7.7	71.9	7.2	32.8
Algona	50.8	49.2	8.2	71.6	6.6	33.1
Auburn	49.4	50.6	7.4	74.1	10.2	34.4
Enumclaw	47.8	52.2	6.1	75.5	14.9	38.9
Buckley	50.3	49.7	5.9	77.5	13.0	39.9
Carbon River						
Orting	50.7	49.3	8.8	69.3	10.2	32.7
South Prairie	51.8	48.2	5.5	74.2	11.1	40.6

Source: U. S. Census Bureau, 2010 Census.

Table 4 shows that the age composition of the River Section populations is fairly close to the state average. The population of the Carbon and White River Sections are slightly younger than the state as a whole, with relatively large populations under five years old and small sixty-five or older populations. The comparatively large sixty-five or older population of Upper Puyallup results in a high median age.

Table 4. Gender and Age Characteristics in the Study Area River Sections

Place	Percent by Gender		Percent by Age			Median Age
	Male	Female	Under 5 Years	18 Years and Over	65 Years and Over	
Lower Puyallup River	51.9	48.1	6.5	78.1	10.4	36.6
Upper Puyallup River	49.4	50.6	6.4	75.8	12.4	39.3
White River	49.8	50.2	7.1	74.2	10.6	36.5
Carbon River	51.4	48.6	6.9	72.6	9.7	37.3

Source: U. S. Census Bureau, 2010 Census.
Note: The median age is the weighted average for block group populations.

2.2 Housing

Table 5 shows the housing characteristics of the state, King and Pierce Counties, and Study Area communities. Densely populated Tacoma accounted for about half of the total housing units of the Study Area communities in 2010. The percentage of housing units in the Study Area communities that were occupied in 2010 was slightly higher than in the state as a whole. The median value of an owner-occupied unit was highest in Edgewood ($344,100) and lowest in South Prairie ($191,400) in the 2005 – 2009 period.

Table 5. Housing Characteristics in the State, King and Pierce Counties, and Study Area Communities

Place	Number of Housing Units (2010)	Occupied Units (%) (2010)	Median Value of Owner-Occupied Units ($) (2005-2009)
State of Washington	2,885,677	90.8	277,600
King County	851,261	92.7	398,600
Pierce County	325,375	92.2	262,400
Lower Puyallup			
Tacoma	85,786	91.6	235,200
Fife	3,895	93.5	295,500
Edgewood	3,801	94.9	344,100
Upper Puyallup			
Puyallup	16,171	92.4	282,600
Bonney Lake	6,394	93.7	290,300
White River			
Sumner	4,279	93.0	273,600
Pacific	2,422	93.7	262,300
Algona	1,018	93.6	221,300
Auburn	27,834	93.6	275,000
Enumclaw	4,420	94.4	268,100
Buckley	1,669	95.3	254,100
Carbon River			
Orting	2,361	92.5	241,400
South Prairie	174	95.4	191,400

Source: U. S. Census Bureau, 2010 Census; American Community Survey, 2010.

Table 6 shows housing characteristics in the River Sections in 2010. The area along the White River had the greatest number of housing units, which reflects its relatively large population.

Table 6. Housing Characteristics in the Study Area River Sections

Place	Number of Housing Units (2010)	Occupied Units (%) (2010)
Lower Puyallup River	11,799	92.4
Upper Puyallup River	15,094	91.6
White River	24,627	93.6
Carbon River	3,437	93.9

Source: U. S. Census Bureau, 2010 Census.

2.3 Economy

2.3.1 Lower Puyallup

Economic activity and employment in the Study Area communities is concentrated in the Tacoma area. The city's location halfway between Olympia and Seattle provides it access to many modes of transportation, natural resources, economical power sources, and a deep, sheltered harbor, all of which have contributed to Tacoma's development as a successful industrial center. Regional shopping centers have emerged in Tacoma to provide goods and services for the city and the region, while the emphasis in downtown has changed to professional offices, international finance, government, education, and cultural facilities (Puget Sound Regional Council, 2002).

The Port of Tacoma, which is located at the western end of the Study Area, is a public municipal corporation established in 1918 by the citizens of Pierce County. The port is one of the busiest container ports in North America, handling nearly $28 billion in trade in 2010 (Port of Tacoma, 2011). In addition to containers, the port handles bulk, breakbulk, project, heavy-lift cargoes, and automobiles. The port includes a 2,500-acre industrial area consisting primarily of shipping terminals, but a mix of heavy and light industrial and water-related commercial uses are also located in the area. U.S. Oil and Refining operates a refinery in the industrial area, with a capacity of 39,000 barrels of oil per day.

The Port of Tacoma is an "economic engine" for the region, with terminal services and property rentals generating $103.3 million dollars of revenue in 2010 (Port of Tacoma, 2011). According to a Port of Tacoma study released in 2005, the port's economic impact on Pierce County includes approximately 43,000 total jobs (including those directly or indirectly related to port activities) with $637 million in annual wages (Martin Associates, 2005).

The City of Fife has established itself as a thriving warehouse, distribution, and transportation district due to easy access to the Port of Tacoma and Interstate 5 (I-5). The Emerald Queen Casino and Hotel, which is owned and operated by the Puyallup Tribe, Gruma Mission Foods, Milgard Windows, Comcast, Gensco and Federal Express are the largest employers in Fife.

There are commercial areas on the east side of Edgewood along West Valley Road and on the west side along the Meridian corridor. There are limited industrial areas in the south that border the Study Area.

2.3.2 Upper Puyallup

Puyallup is home to the Puyallup Fair, the largest annual privately run fair in Washington. The fair, which traditionally runs for two weeks in September and one weekend in April, annually records well over one million visitors and serves as an anchor for unique local businesses and restaurants. On the other side of Highway 512 is a growing medical park, anchored by the $450 million renovation and expansion of the Good Samaritan Hospital. Significant industrial development has also occurred in the South Hill Business and Technology Center, the Park in Puyallup Industrial Park and the Valley Avenue corridor immediately west of the Park in Puyallup. South of Puyallup is the South Hill Mall, which is the fifth largest mall in the region. Agriculture has been a historic economic mainstay of the Puyallup Valley for more than 100 years, and it is still a major economic activity for the area north of the Puyallup River and south of Highway 167. An important agricultural-related employer is the Western Washington Research and Extension Center, which is the largest branch agricultural station of Washington State University.

Most of the economic activity in Bonney Lake is located along the SR 410 corridor, with large retail businesses being the major employers. There is little industry in Bonney Lake, but there is some agriculture in the Fennel Creek Corridor.

2.3.3 White River

There is a heavy industrial area along the White River, just north of downtown Sumner. Extended beyond that is large area zoned for light industrial that is part of the Sumner-Pacific industrial area, which covers about 2,100 acres. The area includes warehousing activities, with companies such as Costco, Solo Cup Company and NYK Logistics represented, as well as large construction companies such as Manke Lumber and Peterson Brothers. Agriculture also remains an important economic activity for Sumner, but the future of agriculture in the area is a matter of debate. Recently, for example, the City of Puyallup requested an expansion of its urban growth area to the south to include 182 acres that are zoned for rural and agriculture uses. However, the Pierce County Planning Commission denied the proposal, citing concerns about loss of agricultural land.

There are several facilities of economic importance in Auburn. The Boeing Company plant in southeast Auburn is the largest airplane parts plant in the world. The plant has 2.1 million square feet of production space. In 2008, construction began on a new parking garage and medical building for the Auburn Regional Medical Center, located directly north of city hall. The SuperMall of the Great Northwest is located in Auburn near the Boeing plant with nearly one million square feet of retail space. Other facilities include the Muckleshoot Casino, which is owned and operated by the Muckleshoot Tribe, Green River Community College and the Emerald Downs Racetrack.

Enumclaw is a rural agricultural town with some industrial areas. The area around Enumclaw is especially known for its dairy and equestrian industry. The Enumclaw Expo Center annually hosts the King County Fair, which is the oldest agricultural fair west of the Mississippi River, the Pacific Northwest Scottish Highland Games, and other exhibitions and festivals.

The Alderton-McMillin[1] planning area remains a predominately agricultural community, with hundreds of acres of area lands still devoted to agriculture and agriculture-related businesses continuing to be an important economic base of the area. Many farmers in the area have resisted the subdivision of their lands as has occurred in other areas of Pierce County such as the Lower Puyallup valley.

[1] Alderton and McMillin are unincorporated communities between Sumner and Orting along the Upper Puyallup River. Census data for these communities are reported in the Upper Puyallup River Section.

2.3.4 Carbon River

Orting also continues to have active agricultural lands within and around the city, but there has been substantial residential growth in recent years. South Prairie has limited commercial activities, and its economy is partly sustained by tourists bound for Mount Rainier National Park.

2.3.5 Employment by Industry

Table 7 shows employment in King and Pierce Counties and Study Area communities by major industrial sector in 2011. The employment data provided by the Puget Sound Regional Council (PSRC) only include “covered employment”, that is, full- and part-time jobs in the labor force that are “covered” under state and federal unemployment insurance laws and programs. Certain categories of employment are excluded, such as self-employed individuals, active military, proprietors, railroad workers, unpaid family workers, and all other workers not covered by unemployment insurance laws.

As shown in Table 7, both King and Pierce Counties have fairly diverse economies. In both counties, retail and services are among the leading sectors. In the Lower Puyallup, Fife has strong manufacturing and wholesale trade and utilities sectors due to its proximity to the Port of Tacoma. Puyallup has a particularly large services sector compared to surrounding communities.

In the White River area, Auburn has a strong manufacturing sector because of the presence of the Auburn Boeing Plant. Sumner and Algona share parts of this same industrial area, and consequently also have relatively large manufacturing sectors. Employment in Enumclaw appears to be dominated by the finance, insurance and real estate, retail, and service sectors; however, it is important to note that agricultural employment, which is an important economic activity in Enumclaw, is not represented in the PSRC data. Sector-specific data for the Carbon River communities is limited due to the small number of jobs in those communities.

Table 7. Percent Employment by Sector in King and Pierce Counties and Study Area Communities, 2011

Place	Construction and Resources	Finance, Insurance and Real Estate	Manufacturing	Retail	Services	Wholesale, Trade and Utilities	Government	Education	Total Employment
King County	4.4	5.9	8.8	9.3	48.5	8.9	7.9	6.4	**1,099,639**
Pierce County	6.5	4.5	6.1	11.6	40.7	8.0	13.8	8.7	**258,277**
Lower Puyallup									
Tacoma	2.8	5.5	6.6	10.4	48.7	6.4	13.3	6.2	**97,223**
Fife	10.6	2.7	10.2	12.3	23.6	32.2	6.5	1.8	**11,462**
Edgewood	27.5	2.0	2.5	8.6	26.3	9.1	2.4	21.6	**1,191**
Upper Puyallup									
Puyallup	4.3	3.4	2.3	22.1	50.3	5.7	3.5	8.3	**20,582**
Bonney Lake	3.6	3.6	0.4	32.3	44.8	0.6	5.2	9.5	**4,161**
White River									
Sumner	24.8	3.2	16.6	8.4	15.6	23.7	2.1	5.6	**8,789**
Pacific	30.3	0.0	3.8	0.9	6.4	58.5	0.0	0.0	**1,819**
Algona	5.3	n/a	68.6	n/a	5.4	18.8	1.2	0.0	**1,843**
Auburn	5.7	2.0	20.1	12.6	28.2	14.7	9.3	7.5	**37,371**
Enumclaw	4.6	13.9	5.9	15.7	38.8	3.1	7.0	11.0	**4,240**
Buckley	12.9	1.0	2.3	3.8	14.4	1.8	50.9	13.0	**1,958**
Carbon River									
Orting	n/a	2.2	n/a	4.8	35.0	0.3	23.3	29.8	**1,066**
South Prairie	30.5	0.0	0.0	n/a	42.4	n/a	11.9	0.0	**59**

Source: Puget Sound Regional Council, 2011.

Income and unemployment data for the Study Area communities are presented in Table 8. The residents of King County enjoy the highest per capita personal incomes in the state, which reflects the more robust urban/industrial conditions generated by the Seattle metropolitan and other urbanized areas of the county. Pierce County is slightly below the state average for per capita personal income. Edgewood had the highest per capita income ($37,927) of all of the Study Area communities during the 2005 – 2009 period, while Pacific City had the lowest ($20,226). Pacific City also had an especially high unemployment rate (6.7 percent) during this period.

Table 8. Average Per Capita Income and Unemployment in the State, King and Pierce Counties, and Study Area Communities, 2005-2009

Place	Per Capita Income	Percent Unemployed
State of Washington	29,320	4.6
King County	37,797	4.0
Pierce County	27,265	4.8
Lower Puyallup		
Tacoma	25,215	5.4
Fife	24,935	6.4
Edgewood	37,927	4.0
Upper Puyallup		
Puyallup	28,540	4.1
Bonney Lake	29,212	4.3
White River		
Sumner	25,556	6.0
Pacific	20,226	6.7
Algona	22,902	5.6
Auburn	26,291	5.3
Enumclaw	29,132	4.9
Buckley	21,627	5.0
Carbon River		
Orting	22,820	2.4
South Prairie	33,479	1.9

Source: U. S. Census Bureau, American Community Survey 2009.

2.4 Environmental Justice Populations

Executive Order 12898 on Environmental Justice requires that each federal agency address disproportionately high and adverse health or environmental effects of its programs, policies, and activities on minority and low-income populations. The population groups to be considered in an analysis of environmental justice were defined by the Interagency Working Group on Environmental Justice, which was established by Executive Order 12898 to implement the order's requirements. Low-income populations are defined as those living below the established poverty level. A minority is any individual classified as American Indian, Alaska Native, Asian, Pacific Islander, African American, or Hispanic.

Figure 6 shows the distribution of low-income populations in the Study Area and surrounding region, while Figure 7 shows the distribution of minority populations. There are high concentration "pockets" of low-income and minority populations throughout the Study Area and surrounding region, but most of these pockets are in the Tacoma area. The large minority area between the White and Green Rivers southeast of the city of Auburn is the reservation of the Muckleshoot Tribe, one of the largest Native American groups in Washington.

The poverty data in Figure 6 are from the 2000 census since 2010 data were not available for this report. The figure shows that the area around the Port of Tacoma and into Fife and north Puyallup has a relatively high concentration of poverty compared to other parts of the study. Another area of relatively high low-income populations is the western side of Auburn. The Muckleshoot Tribe shows moderate concentrations of low-income populations similar to areas outside of Orting and Buckley.

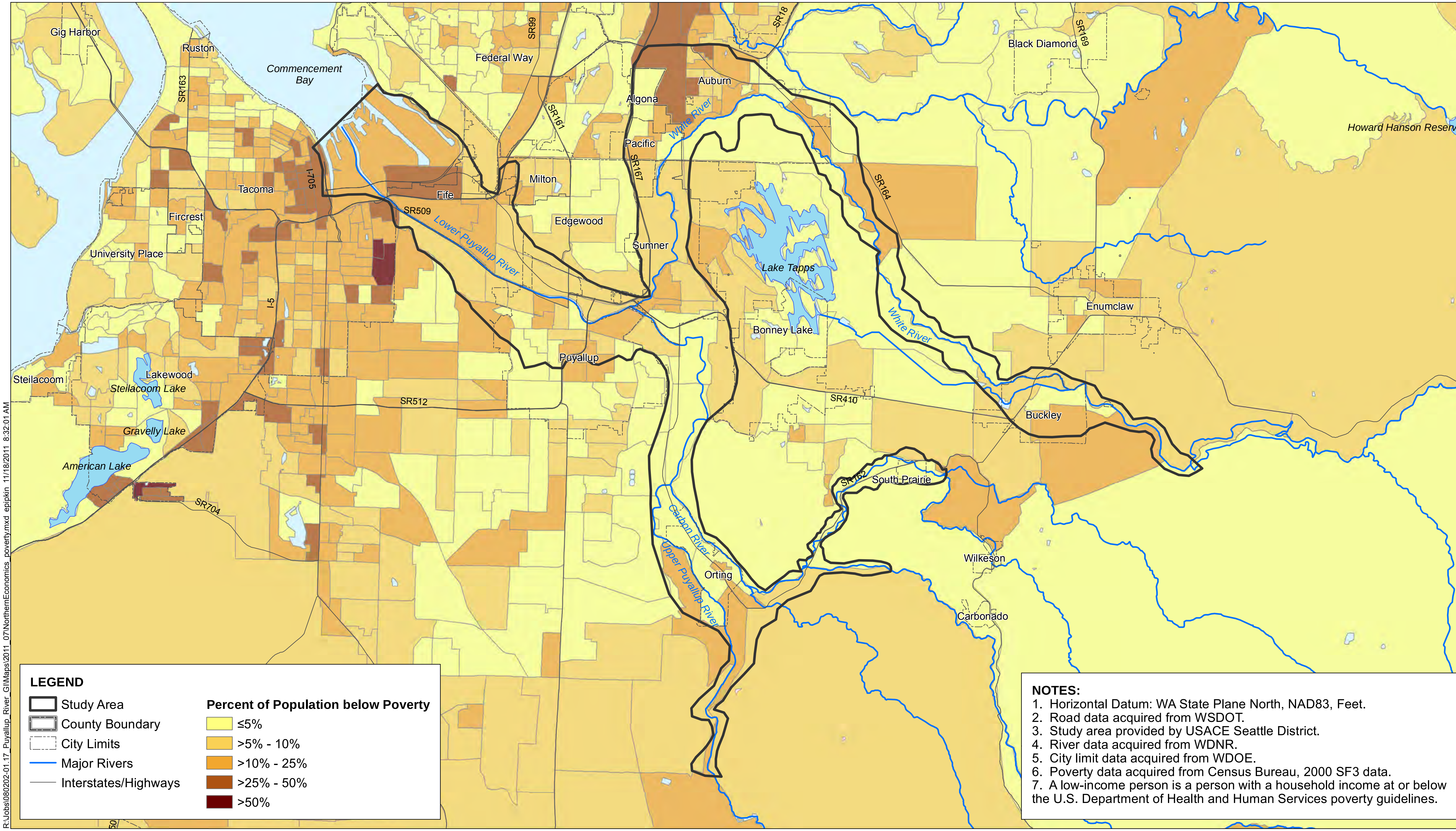

Figure 6

Percent of Population Below the Poverty Level in the Study Area and Surrounding Region, 2000

Socioeconomics of the Puyallup River Basin General Investigation Study Area

U.S. Army Corps of Engineers, Seattle District

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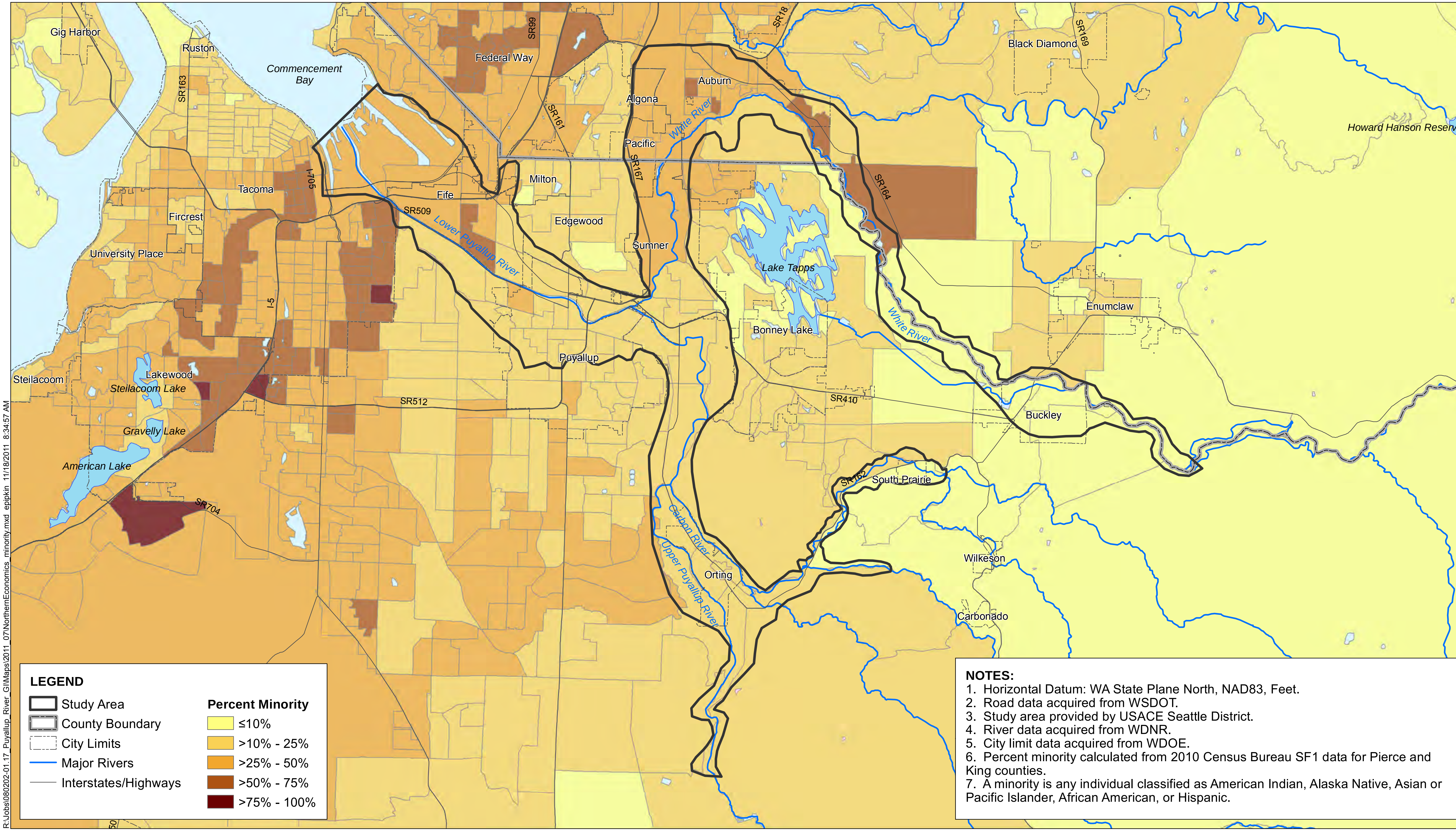

Figure 7
Percent of Population in a Minority Group in the Study Area and Surrounding Region, 2000
Socioeconomics of the Puyallup River Basin General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

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Table 9 shows the percentage of each minority group in the State of Washington, King and Pierce Counties, and Study Area communities in 2010. Asians and Hispanics are the largest minority groups in a number of cities and towns. The Fife Valley has traditionally been a farming area, with many Japanese-Americans owning (and farming) land within the area (Federal Highway Administration and Washington State Department of Transportation, 2006). However, with the urbanization (zoning and land use changes) of the area, particularly within the city limits of Fife, it has become more difficult economically for the farmers to continue operations in this area. Consequently, many Japanese-American farmers have recently been retiring from farming and leasing or selling their property. Much of the farmland in the area today is leased by farmers who employ anywhere from two to ten farmhands who work on a temporary/seasonal basis. While these temporary farmhands are primarily Hispanic, the Hispanics residing in and around the Study Area are not necessarily associated with farming operations (Federal Highway Administration and Washington State Department of Transportation, 2006). The communities of Enumclaw, Buckley, Orting, and South Prairie have relatively small minority populations.

Table 9. Percent of Population in the State, King and Pierce Counties, and Study Area Communities in a Minority Group, 2010

Place	White	Black or African American	Alaska Native and American Indian	Asian	Native Hawaiian and Other Pacific Islander	Hispanic	Total Minority
State of Washington	77.3	3.6	1.5	7.2	0.6	11.2	27.3
King County	68.7	6.2	0.8	14.6	0.8	8.9	35.0
Pierce County	74.2	6.8	1.4	6.0	1.3	9.2	29.5
Lower Puyallup							
Tacoma	64.9	11.2	1.8	8.2	1.2	11.3	39.3
Fife	55.2	8.2	3.0	15.5	2.7	17.4	51.8
Edgewood	90.4	1.0	0.9	2.5	0.3	4.4	11.8
Upper Puyallup							
Puyallup	84.4	2.1	1.4	3.8	0.7	6.9	18.9
Bonney Lake	88.8	1.3	1.0	2.4	0.2	6.1	14.4
White River							
Sumner	87.3	1.2	1.0	2.4	0.4	10.1	18.2
Pacific	69.2	3.1	1.9	9.0	1.8	15.1	35.2
Algona	67.1	3.3	1.7	11.7	2.0	15.9	38.8
Auburn	70.5	4.9	2.3	8.9	2.3	12.9	34.4
Enumclaw	91.8	0.5	1.0	0.9	0.1	6.6	11.2
Buckley	93.0	0.6	0.8	0.8	0.1	3.1	8.1
Carbon River							
Orting	87.9	1.5	1.4	1.3	0.5	7.2	15.4
South Prairie	92.4	0.5	2.5	0.7	0	1.2	7.8

Source: U. S. Census Bureau, 2010 Census.

Note: Total minority population was calculated by taking the Total population and subtracting the 'White Alone' and 'Some Other Race Alone' fields and adding back in the 'Hispanic, White Alone' and 'Some Other Race Alone, Hispanic' fields.

Table 10 shows the minority populations in the Study Area River Sections in 2010. The Lower Puyallup has the highest percentage of minorities due to its relatively large Asian and Hispanic populations. The White River has a large Hispanic population and a comparatively large American Indian population. As noted above, part of the Muckleshoot Indian Reservation is in White River. Both the Upper Puyallup and Carbon River have minority populations that are approximately half of that of the state as a whole.

Table 10. Percent of Population in the Study Area River Sections in a Minority Group, 2010

Place	White	Black or African American	Alaska Native and American Indian	Asian	Native Hawaiian and Other Pacific Islander	Hispanic	Total Minority
Lower Puyallup River	74.7	4.2	2.3	7.2	1.2	12.2	30.9
Upper Puyallup River	87.4	1.2	1.3	2.7	0.4	6.2	15.5
White River	76.1	3.1	4.0	4.3	1.2	12.9	28.6
Carbon River	90.1	1.1	1.2	1.3	0.3	5.4	12.3

Source: U. S. Census Bureau, 2010 Census.

Note: Total minority population was calculated by taking the Total population and subtracting the 'White Alone' and 'Some Other Race Alone' fields and adding back in the 'Hispanic, White Alone' and 'Some Other Race Alone, Hispanic' fields.

2.5 Utilities

Major utility service is prevalent throughout the Study Area including electrical, water and wastewater utility services. Tacoma Power provides electrical service to the Tacoma portion of the Study Area and the Town of Fife. Tacoma Power generates electricity from several dams, none of which are in the Study Area. Puget Sound Energy provides electrical service to the areas east of Tacoma from Puyallup to Enumclaw. Puget Sound Energy operates a power generation system in the Lower Puyallup Watershed, which includes a diversion of the White River at Buckley and power generation facility at the outfall in Dieringer. Puget Sound Energy also operates a relatively small power plant on the Puyallup River at Electron.

Tacoma Water provides water service to most of the Study Area and surrounding region including Tacoma, Fife, Puyallup, and Bonney Lake, either directly or through reselling to local utilities. The Green River Watershed is the primary water supply. Tacoma Water also draws on 24 wells. The main well field is located southwest of the Study Area in south Tacoma. Figure 8 shows the areas in and around the study area that have water service. The spatial data for King County water purveyors were not available and are not shown.

There are eight wastewater treatment plants (WWTP) in the Study Area as shown in Figure 8. Pierce County's Chambers Creek Regional Wastewater Treatment Plant serves portions of the Study Area and is located east of Tacoma in University place, outside of the Study Area. The following sections describe the locations of the WWTPs within the Study Area and other utility services for cities where they differ from the above utility services.

2.5.1 Lower Puyallup

Fife

The Fife water system draws from ground water resources through a system of city-owned wells. Currently, two wells are in operation. However, city wells do not provide all the necessary water. The city buys additional water from the City of Tacoma to meet the water demand. In the summer months, up to 50 percent of the city's water is supplied through connections to the Tacoma water system.

The Fife sanitary sewer system was installed in 1968 and consists of trunk sewer mains, lift stations, and collection mains. The relatively level topography of Fife requires lift stations at periodic points to allow the sewage to flow. Treatment is provided by the City of Tacoma, which operates the Tacoma Central Wastewater Treatment Plant located within the Study Area on the south bank of the Puyallup River near the Port of Tacoma.

Edgewood

The Mt. View-Edgewood Water Company provides water to the City of Edgewood. The company draws on a spring and 11 wells. As of 2007, the majority of Edgewood residences and businesses treated sanitary sewage with septic tanks and drain fields. The city's sewer plan calls for a phased approach to constructing a sewer system starting with a line along Meridian Avenue. The city began construction on the first phase in January of 2010.

The Cherrywood Mobile Home Manor has an onsite WWTP that treats water from the mobile home park.

2.5.2 Upper Puyallup

Puyallup

The City of Puyallup's water system serves the majority of the city's Urban Growth Area (UGA), excluding the southwestern corner and the eastern portions of the UGA. The southwestern corner of the UGA receives water service from Fruitland Mutual Water Company and Tacoma Public Utilities. The eastern portion of the UGA receives water service from the Valley Water District. The city draws on Salmon Springs and six wells and the system has one treatment plant for Well #17. In addition, some areas are served by an intertie with Tacoma Water. The City of Puyallup maintains a sewer system and a WWTP located within the Study Area on the south bank of the Puyallup River.

Bonney Lake

The City of Bonney Lake maintains a water system that is supplied by Grainger Springs, Victor Falls Springs, Tacoma Point Well Field, and Ball Park Well. The City of Bonney Lake also maintains a sewer system and partners with the City of Sumner for the treatment of the sewage at the Sumner WWTP.

2.5.3 White River

Sumner

The City of Sumner maintains a water system, sewer system, and a wastewater treatment plant, which is located within the Study Area at the confluence of the White and Puyallup Rivers. In 2005, Sumner upgraded the treatment plant.

Pacific

The City of Pacific has a water system supplied by a well in Algona. Pacific also has a wastewater system that sends its wastewater into King County's regional sewage system and ultimately the South Treatment Plant. The South Treatment Plant, which serves south King County, is located outside of the Study Area in Renton, Washington.

Algona

The City of Algona maintains a water system and purchases water from the City of Auburn. The city also maintains a wastewater system that feeds wastewater into King County's South Treatment Plant.

Auburn

The City of Auburn uses a combination of ten wells and two springs to provide water in and around the city. The city maintains emergency interties with the Cities of Bonney Lake, Kent, and Pacific. The city also maintains a wastewater system that feeds into King County's South Treatment Plant.

Enumclaw

The City of Enumclaw has three water sources to the east of the city: Boise Springs, Watercress Spring and Well, and PC Johnson Wellfield. The city also has an emergency intertie connected to the Tacoma Water pipeline, which passes through the city; however, the intertie has not been used since 2003. In 2009, Enumclaw completed the expansion of their WWTP located outside of the Study Area in the south part of the town.

Buckley

The City of Buckley has a water system and a wastewater system. Buckley currently has an agreement to use the Rainier School WWTP located within the Study Area northeast of the Town Center on the south bank of the White River. The Buckley WWTP, shown in Figure 8, is currently not in operation.

2.5.4 Carbon River

Orting

The City of Orting draws on three wells and four springs. A fourth well is under construction. The city has a wastewater collection system and a WWTP located within the Study Area just north of the Orting City Center on the south bank of the Carbon River. The city is systematically replacing parts of the system to meet Washington Department of Ecology standards.

South Prairie

South Prairie's water system is fed primarily by the Tubbs Road Well and includes iron and manganese treatment facilities. South Prairie also has a wastewater system and treatment plant located within the Study Area in the town center near the post office.

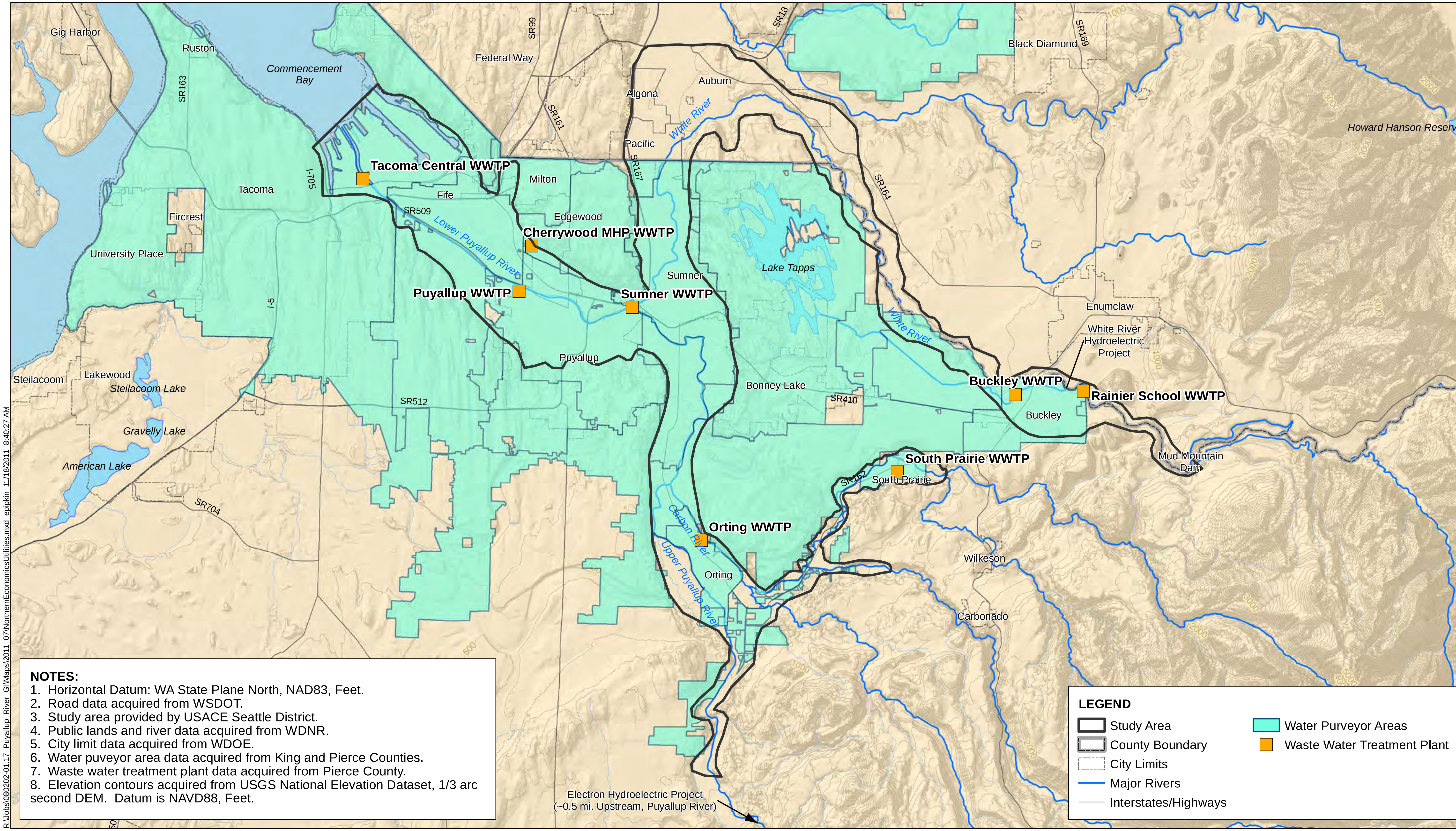

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Figure 8
Wastewater Treatment Plants and Water Purveyors in the Study Area
Socioeconomics of the Puyallup River Basin General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

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2.6 Land Use

This section characterizes land use in the Study Area and surrounding communities. The discussion includes information on the residential, commercial, and industrial zoning in the area. In general, land use changes from high density industrial and commercial activity near the Port of Tacoma, to predominantly single-family home areas mixed with commercial and light industrial areas around Puyallup, to rural agricultural areas with residential developments near Enumclaw.

Figure 9 shows zoning for the Study Area at the county level. Only county-designated zoning information is displayed. The Lower Puyallup is mostly within the city boundaries of Tacoma, Fife, and Puyallup. There is an area south of the Puyallup River that Pierce County designated as Agricultural Resources Lands.[2] Immediately northeast of the residential area around Puyallup is a small section of commercially zoned land that the county designated as an Employment Center.[3] There is a pocket of residential land north of Puyallup that includes a small area zoned for mixed use. Immediately southeast is another commercially zoned area that the county designated as an Employment Center.

North along the White River are the cities of Sumner, Pacific, Algona, and Auburn. Southeast of Auburn the land is zoned for agriculture with one dwelling unit per thirty-five acres.

South along the Puyallup River is the Alderton-McMillin[4] planning area, which is mostly designated by the county as Agricultural Resource Lands. There is a Rural Industrial Center just north of Orting.[5] Outside of the cities in the Upper Puyallup and Carbon River, the area is mostly designated as Agricultural Resource Lands.

The following subsections describe land uses within the Study Area communities.

2.6.1 Lower Puyallup

Tacoma

The portion of Tacoma in the Study Area can be split into two areas: a sliver of downtown and the port area. The downtown portion is mostly commercial areas with residential and government areas as well. The health services and government sectors are the largest employers in downtown Tacoma. The Governance and Justice Center for Pierce County is located on the far western edge of the Study Area along I-705 in downtown Tacoma. This center includes the Pierce County Executive Office, County Council, Sheriff, and various county services. South of there, on the south side of I-5, is the county's Medical Center, which consists of Community Services, Medical Examiner, and Human Services.

About one-half of the six-square-mile Port of Tacoma is developed with manufacturing, light industrial, and distribution/wholesale uses; about one-quarter is in public rights-of-way and

[2] Agriculture Resource Lands is a Pierce County zoning designation that allows one dwelling unit per ten acres and agriculture.

[3] Employment Center is a Pierce County zoning designation that allows a wide variety of industrial uses and limited commercial uses.

[4] Alderton and McMillin are unincorporated communities between Sumner and Orting along the Upper Puyallup River. Census data for these communities are reported in the Upper Puyallup River Section.

[5] Rural Industrial Center is a Pierce County zoning designation that allows light industrial uses that are related to food or agriculture or intermediate manufacturing and final assembly. It does not allow heavier industrial uses that produce substantial waste byproducts or wastewater discharge or noise impacts incompatible with a rural area.

waterways; and about one-tenth is presently vacant. Major manufacturing and industrial uses include paper manufacturing, container and bulk (shipping) terminals, boat building, chemical processing, oil refining, lumberyards, and wood-product mills.

Fife

Fife is almost entirely within the Study Area. Only 10 percent of Fife's land is single-family homes, which are mostly in the south portion of the city. Two percent of Fife's land is multi-family residential, which consists of apartments in the center of the city. Fife's primary business district runs along Pacific Highway East and I-5, where there are substantial amounts of commercial land uses and small residences. There are also a number of commercial uses including car dealerships and manufactured housing outlets along 20th Street East. Industrial areas are located between I-5 and the river as well as further to the southeast. About 15 percent of Fife is industrial area and nearly 9 percent is commercial area.

Fife is completely within the Puyallup Tribe's reservation lands. The reservation is one of the most urban Indian reservations in the United States and extends into parts of Tacoma, Puyallup, and Edgewood.

Edgewood

The City of Edgewood is predominantly single-family residential areas, with some limited areas of mixed single and multi-family housing. There are commercial areas on the east side along West Valley Road and on the west side along Meridian. There are limited industrial areas in the south that are in the Study Area.

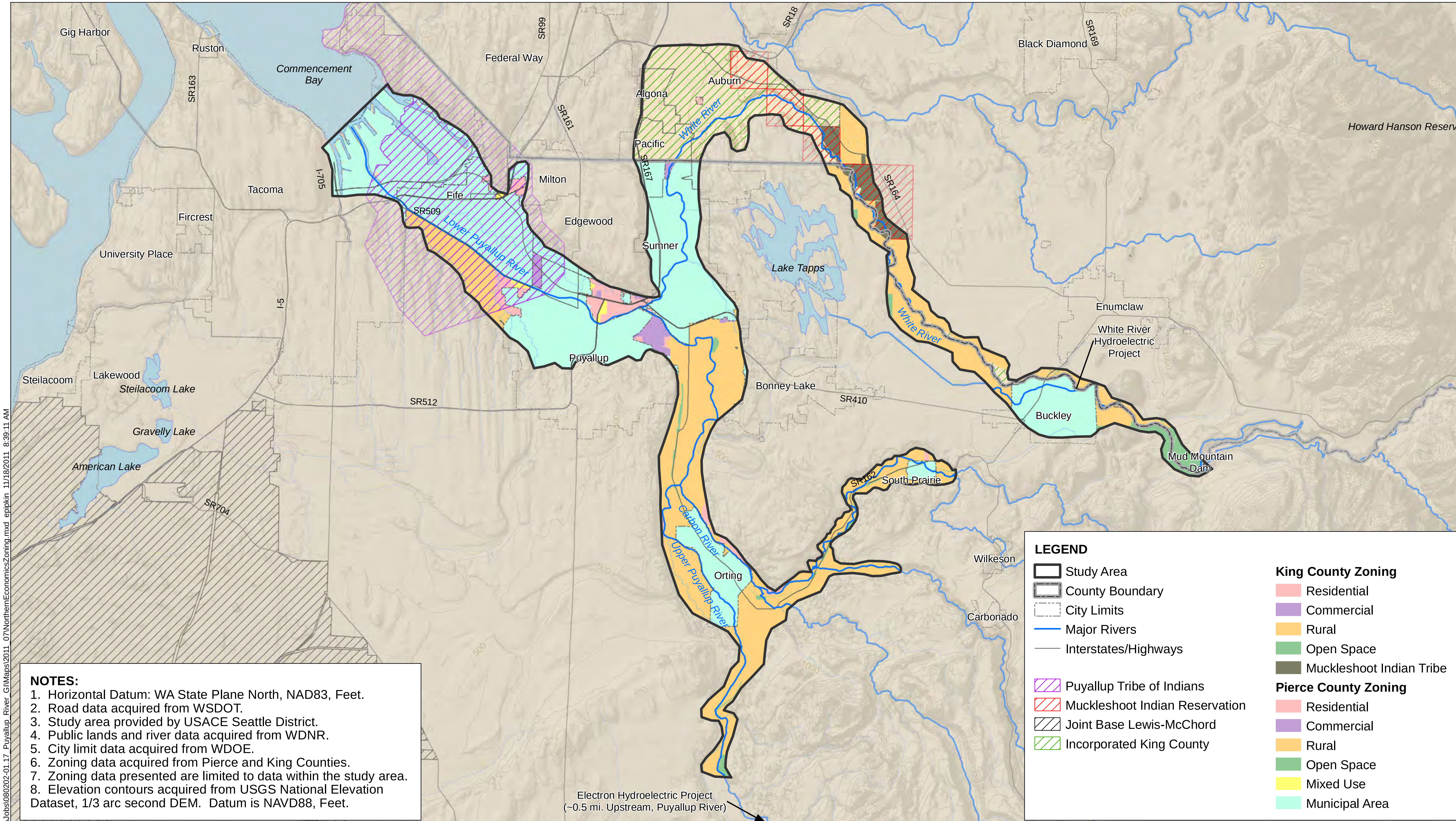

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Figure 9
County Level Zoning in the Study Area
Socioeconomics of the Puyallup River Basin General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

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2.6.2 Upper Puyallup

Puyallup

Puyallup and the surrounding areas are predominantly residential, with most of the residential areas consisting of single-family homes. Less than 1 percent of the land area is designated industrial and only 1.5 percent designated commercial. Most of the northern portion of Puyallup, which is in the Study Area, was in agricultural production until recently, and agriculture is still the major land use for the area north of the Puyallup River and south of Highway 167. Most of the converted land area is currently in large-lot residential use or mobile home parks. There are also several commercial and warehouse developments in the area.

Bonney Lake

Bonney Lake is predominantly a single-family home residential community, with 51 percent of the land area used this way. Commercial uses are primarily along State Route 410. There is little industry in Bonney Lake, but there is some agriculture in the Fennel Creek Corridor. Very little of Bonney Lake is in the Study Area.

Alderton-McMillin

Alderton and McMillin are unincorporated communities treated as one planning area in the Pierce County Comprehensive Plan. The communities are located just north of Orting, near where the Puyallup River and the Carbon River meet. Generally, the community has not experienced as much of the development and growth as seen elsewhere due to the nature of the land (flooding, high water tables and volcanic hazards) and many farmers continue to farm as opposed to selling their land to developers. Currently, the primary land use in the community is for agriculture, forestry, fishing and mining (37 percent). The second predominant land use is residential (29 percent). Commercial and industrial lands occupy less than two percent of the community. Most of the Alderton-McMillin planning area is within the Study Area.

2.6.3 White River

Sumner

Sumner is centered on a concentrated downtown area with small-lot residential development with some higher densities along the Puyallup River in the south part of town. There is a heavy industrial area along the White River, just north of downtown. Extended beyond that is a large area zoned for light industrial that is part of the Sumner-Pacific industrial area. All most all of Sumner is in the Study Area.

Pacific

Approximately 40 percent of Pacific's land area is located in Pierce County, and 60 percent is in King County. The residential portion of Pacific, located within King County, consists mostly of single-family residential. The bulk of the commercial and industrial lands are located in Pierce County. Almost all of Pacific is in the Study Area.

Algona

Algona is predominately single-family homes and contains a mix of light and medium residential, commercial, and light industrial land. There are also some open spaces. Algona is almost entirely within the study area.

Auburn

The City of Auburn comprehensive plan characterizes the city in three parts. East Auburn, partially in the Study Area, contains the majority of the residential area. West Auburn, half in the Study Area, contains the heavy industrial and commercial areas. The downtown area, partially in the Study Area, is in the middle with mixed commercial, residential, and civic uses. Over half of Auburn is residential area and 22 percent is heavy commercial and industrial. The southern city limits of Auburn include Muckleshoot Tribe reservation lands.

Enumclaw

Enumclaw is a rural agricultural town with mostly single-family residential areas and a commercial center. There are some industrial areas in the town. The land surrounding Enumclaw on the north and west is agricultural land. To the east is forest land. Enumclaw took ownership of the former King County Fairgrounds in 2007 and renamed it the Enumclaw Expo Center. The city is currently in the process of developing a master plan for the site, which will not significantly alter typical uses of the space. Enumclaw borders but is not in the Study Area.

Buckley

Buckley is predominately single-family residential with a concentrated commercial core that runs along SR 410. There are limited industrial areas. Most of Buckley is in the Study Area.

2.6.4 Carbon River

Orting

Orting is a rural town with small-lot residential development. There is a commercial center and limited zoning for light manufacturing within the city. Agricultural lands are active within and around the city. There are two major developments planned and/or underway in the vicinity of Orting. Cascadia is a planned community encompassing 4,720 acres of land northeast of Orting. It is planned to include 6,000 new homes, an employment center, and a variety of commercial and civic uses. It represents one of the largest remaining entitled master-planned community developments in the Seattle metro area and is a key component of Pierce County's urban growth plans. The Buttes is a 90-acre development southeast of Orting, between Poplar Creek and the Puyallup River that will ultimately consist of approximately 90 homes. Most of Orting is in the Study Area.

South Prairie

The Town of South Prairie is predominantly single-family residential with limited commercial activities. Most of South Prairie is in the Study Area.

2.7 Transportation

As discussed in the following sections, the Study Area contains an extensive transportation network that connects both regional centers and international markets.

Roads

Figure 10 shows the traffic volumes for I-5 and other highways in and around the Study Area. I-5, the Pacific Northwest's primary north-south corridor, runs north to the middle of Tacoma, then turns east through Fife before proceeding north to Federal Way and onwards to Canada. I-5 has the highest traffic volumes in the study area with an Average Daily Traffic Count (ADTC) ranging from 154,000 to 179,000. There are several state routes that are important to the Study Area. State Route (SR) 167, commonly referred to as the "Valley Freeway," is a four-lane separated freeway from Sumner, through Pacific to Auburn that continues north through Kent to Renton. The ADTC ranges from 75,000 to 91,000 on this section. The portion of SR 167 that connects Sumner to Tacoma is a four-lane highway on the banks of the lower Puyallup known as "River Road" and its ADTC ranges from 25,000 to 99,000. SR 410 connects Yakima to the Puget Sound. Near the Study Area, it connects Enumclaw, Buckley, Bonney Lake, and Sumner. Many of these towns have prominent commercial areas along SR 410. Within the Study Area near Sumner, the ADTC ranges from 19,000 to 50,000.

Further out of the urban areas, SR 162 connects Sumner to Orting with an ADTC ranging from 17,000 to 20,000 within the Study Area. SR 164 connects Auburn to Enumclaw while passing through the Muckleshoot Reservation with an ADTC ranging from 9,400 to 17,000. Also, SR 18 passes through Auburn and connects Federal Way to I-90 just west of North Bend.

Air

The Seattle-Tacoma International Airport (SeaTac) is the main airport for the region and is located about 15 miles north of the Study Area. Over 31 million passengers used the airport in 2010, making it the 22nd busiest airport in the U.S. It was the 20th busiest air cargo airport in the U.S. in 2008.

Adjacent to the Study Area, just east of Orting and south of Puyallup, is Thun Field, a small aircraft airport with approximately 90,000 take-offs and landings per year. Auburn Municipal Airport is just north of downtown Auburn, with approximately 165,000 take-offs and landings per year.

Rail

The Union Pacific Railroad heads south from Kent goes through Pacific then turns west near Sumner on the north side of the Puyallup River and crosses through the north part of Puyallup along the river as it approaches the Port of Tacoma. From the port it continues east into to Tacoma before heading south. The line is used exclusively for freight.

Burlington Northern Santa Fe Railway (BNSF) operates a railway that parallels the Union Pacific line to the east. As is comes south through Auburn it crosses the White River and goes through Sumner, crossing the Puyallup River, before turning east into Puyallup. It stays on the south side of the Lower Puyallup River before entering the Port of Tacoma. From there the line heads south towards Vancouver, Washington.

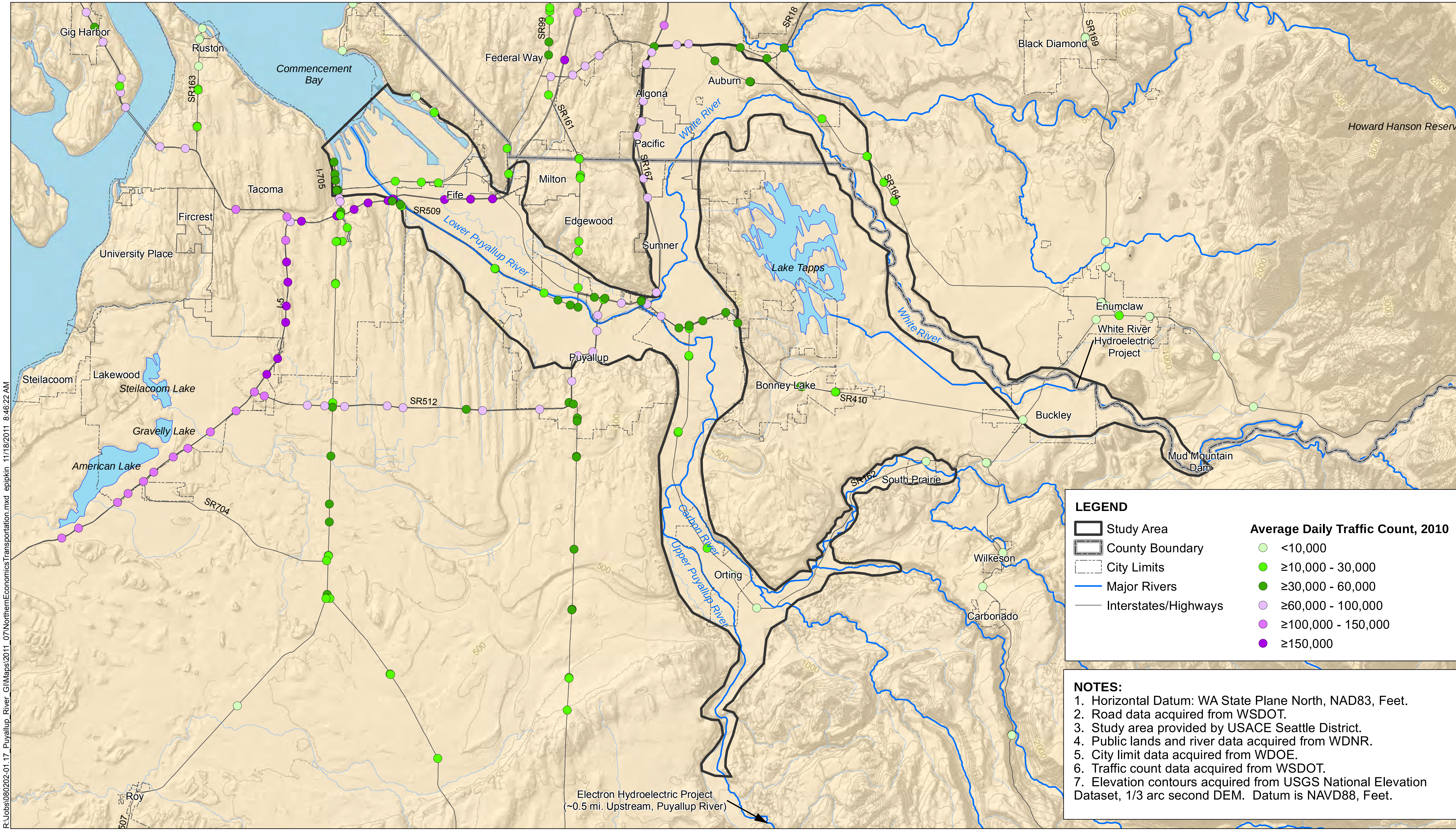
Amtrak Cascades provides regional passenger rail service that connects Portland, Oregon to Vancouver, British Columbia using the BNSF rail lines. The only stop in the Study Area is the Tacoma Station, which is near the Port of Tacoma and downtown Tacoma border (Amtrak Cascades, 2011). There are as many as four trains a day in each direction.

Regional commuter rail service operated by BNSF on behalf of Sound Transit, known as Sounder Commuter Rail, connects much the Study Area to Tacoma and Seattle. The portion of the Sounder line in the Study Area starts in Tacoma and has stations in Puyallup, Sumner and Auburn, and then continues north to Seattle.

Tacoma Public Utilities operates Tacoma Rail, which operates lines that run into Chehalis and three that serve South Tacoma, Quadlock, and Olympia. The main operation of the Tacoma Rail is moving traffic into and out of the Port of Tacoma (Tacoma Public Utilities, 2011).

Water

The Port of Tacoma, described in section 2.6.1, is the only seaport in the Study Area. The Puyallup River is navigable and some industries use the river to transport goods.



LEGEND

- Study Area
- County Boundary
- City Limits
- Major Rivers
- Interstates/Highways

Average Daily Traffic Count, 2010

- <10,000
- ≥10,000 - 30,000
- ≥30,000 - 60,000
- ≥60,000 - 100,000
- ≥100,000 - 150,000
- ≥150,000

NOTES:

1. Horizontal Datum: WA State Plane North, NAD83, Feet.
2. Road data acquired from WSDOT.
3. Study area provided by USACE Seattle District.
4. Public lands and river data acquired from WDNR.
5. City limit data acquired from WDOE.
6. Traffic count data acquired from WSDOT.
7. Elevation contours acquired from USGS National Elevation Dataset, 1/3 arc second DEM. Datum is NAVD88, Feet.

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Figure 10
Traffic Volumes in the Study Area and Surrounding Region
Socioeconomics of the Puyallup River Basin General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

3 Future Without Project

The Future Without Project condition draws on information presented in the PSRC's *2006 Population, Households and Employment Forecast* to estimate the future socioeconomic characteristics of the Study Area and surrounding region. Since the release of the PSRC forecast, the nation has entered a recession that was not accounted for in the forecast, and some jurisdictions have changed local zoning ordinances. Nevertheless, the forecast represents the best available data on future socioeconomic conditions within the Study Area and surrounding region.

The figures and tables provided below include 2000 data as well as projections for 2010 through 2040 since the geographic units used by PSRC to model and report its small-area forecasts differ from those in the Existing Socioeconomic Conditions section. The units used by PSRC are forecast analysis zones (FAZs), which are built up from traffic analysis zones. FAZ boundaries follow census tract boundaries and thereby facilitate the use of census data to build projections. For the purposes of this study, the FAZs of interest are those in the vicinity of the Study Area (Figure 11). Table 11 shows the census places or portions of census places included in each of the FAZs of interest.

Table 11. PSRC Forecast Analysis Zones (FAZs) and Census Places

Forecast Analysis Zone	Census Places
All of Tacoma	Tacoma minus the Port of Tacoma
Tacoma Central Business District (CBD)	A subarea of Tacoma
Fife Area	Fife plus the Port of Tacoma
Puyallup/Frederickson	Puyallup
Sumner/Bonney Lake	Bonney Lake Sumner Edgewood Orting South Prairie Buckley
Auburn Area	Pacific Algona Auburn
Enumclaw Area	Enumclaw

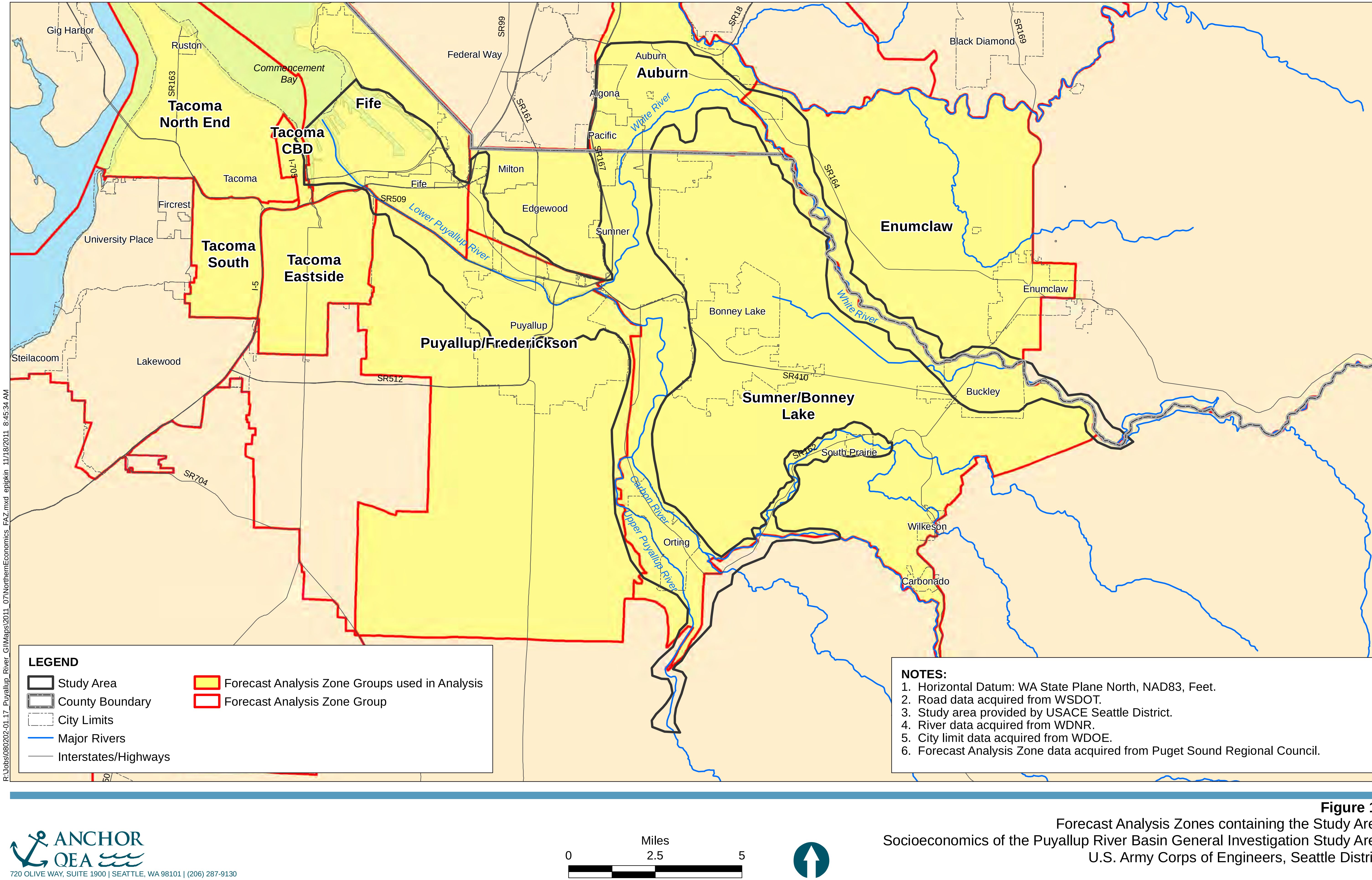

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Figure 11
Forecast Analysis Zones containing the Study Area
Socioeconomics of the Puyallup River Basin General Investigation Study Area
U.S. Army Corps of Engineers, Seattle District

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3.1 Demographics

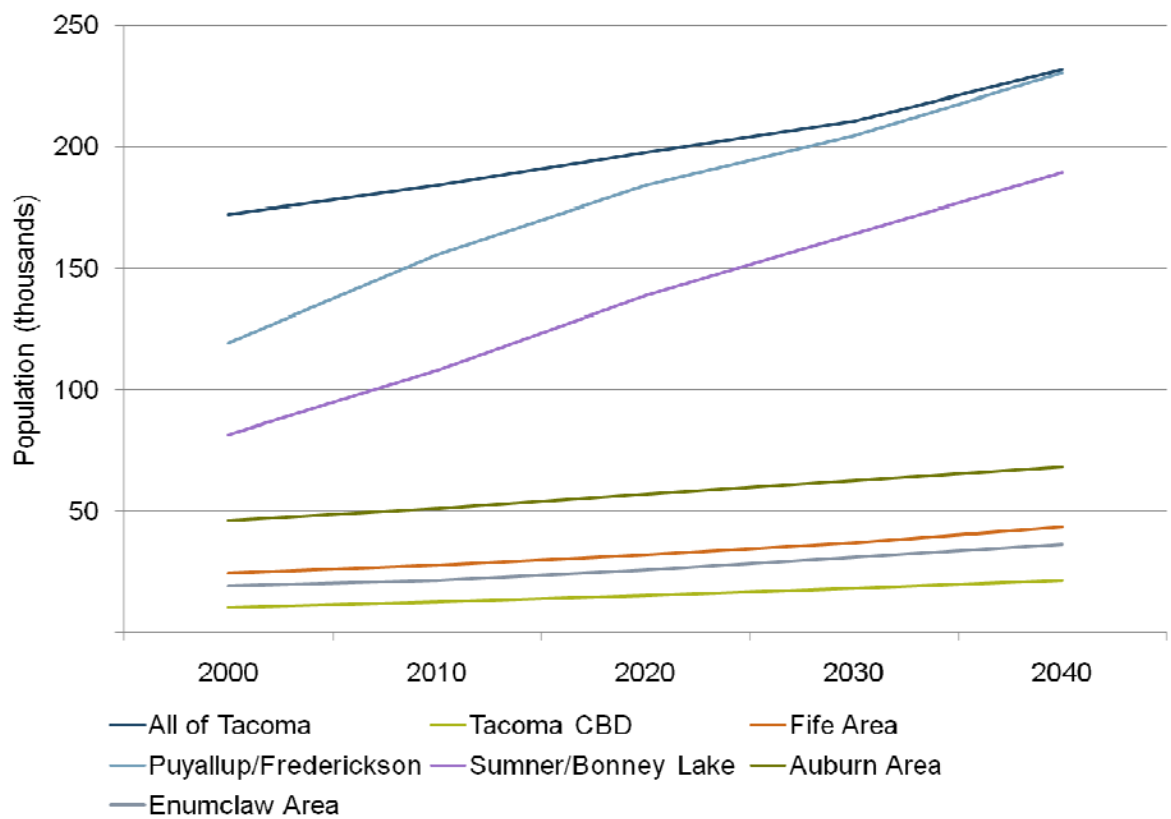
The demographics section presents the PSRC population and household forecasts for the FAZs in the vicinity of the Study Area.

3.1.1 Population Projection

According to the PSRC forecasts, the population will increase within all of the FAZs of interest. Population growth for the All of Tacoma zone appears modest relative to its size, but is considerable considering that most of the land area is developed and population increases will occur through increased density. The growth in the Tacoma CBD, nearly doubling over the next 30 years, reflects the increased density forecasted. The Fife Area's population is expected to continue to grow slowly, as it is expected to remain predominately industrial and commercial. Puyallup/Fredrickson and Sumner/Bonney Lake are projected to experience substantial population growth, with Sumner/Bonney Lake nearly doubling due to plans to accommodate new single-family residential and increased densities near urban centers. The Enumclaw Area is also poised for substantial growth due to planned single-family development and infill. The forecast for the Auburn Area shows moderate growth as most of the added housing will be infill.

The PSRC 2000 population estimate and the 2010 to 2040 forecast for the FAZs of interest are graphed in Figure 12 and shown in detail in Table 12. Table 12 also includes calculations of the absolute population change from 2010-2040 and the absolute change as a percent of the 2010 population.

Figure 12. Past and Projected Population in the FAZs of Interest, 2000-2040



Source: Puget Sound Regional Council, 2006.

Table 12. Past and Projected Population in the FAZs of Interest, 2000-2040

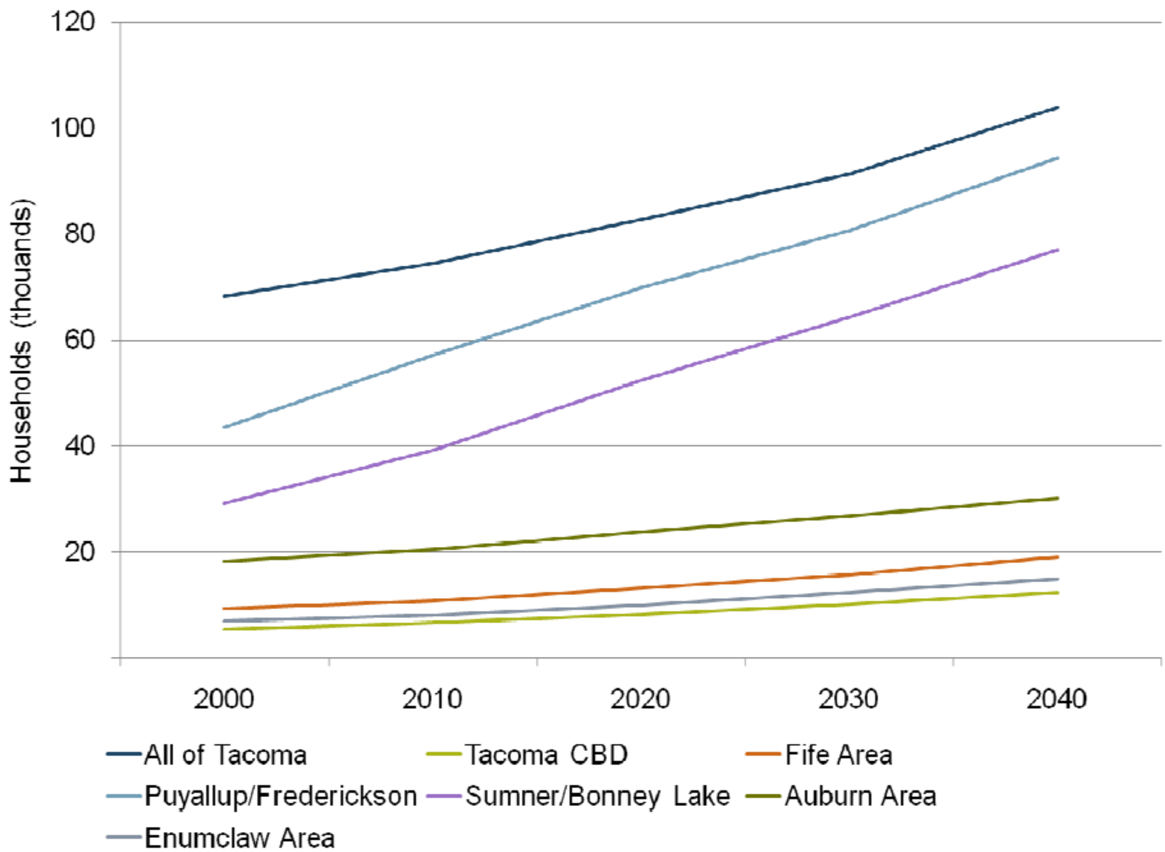
Zone	Year					Change from 2010 – 2040	
	2000	2010	2020	2030	2040	Absolute	Percent
All of Tacoma	172,467	184,207	197,786	210,642	231,844	47,637	26
Tacoma CBD	10,499	12,713	15,454	18,471	21,958	9,245	73
Puyallup/Frederickson	119,322	155,845	184,393	204,966	230,764	74,919	48
Sumner/Bonney Lake	81,773	108,169	139,113	164,465	189,513	81,344	75
Fife Area	24,889	28,032	32,425	37,231	43,699	15,667	56
Auburn Area	46,298	51,130	57,362	62,863	68,481	17,351	34
Enumclaw Area	19,437	21,966	26,204	31,299	36,555	14,589	66

Source: Puget Sound Regional Council, 2006.

3.1.2 Number of Households Projection

The PSRC forecast of the number of households shows the number of households in the FAZs of interest growing faster than the population. This suggests that household sizes will decrease and that there will be a greater need for housing units relative to the population.

Figure 13. Past and Projected Number of Households in Zones, 2000-2040



Source: Puget Sound Regional Council, 2006.

Table 13. Past and Projected Number of Households in the FAZs of Interest, 2000-2040

	Year					Change from 2010 – 2040	
Zone	2000	2010	2020	2030	2040	Absolute	Percent
All of Tacoma	68,318	74,424	82,758	91,285	103,895	29,471	40
Tacoma CBD	5,436	6,590	8,195	10,112	12,329	5,739	87
Puyallup/Frederickson	43,449	57,124	69,918	80,669	94,315	37,191	65
Sumner/Bonney Lake	29,177	39,270	52,434	64,404	77,041	37,771	96
Fife Area	9,431	10,861	13,087	15,651	19,115	8,254	76
Auburn Area	18,267	20,506	23,735	26,850	30,171	9,665	47
Enumclaw Area	6,978	8,048	9,963	12,352	14,956	6,908	86

Source: Puget Sound Regional Council, 2006.

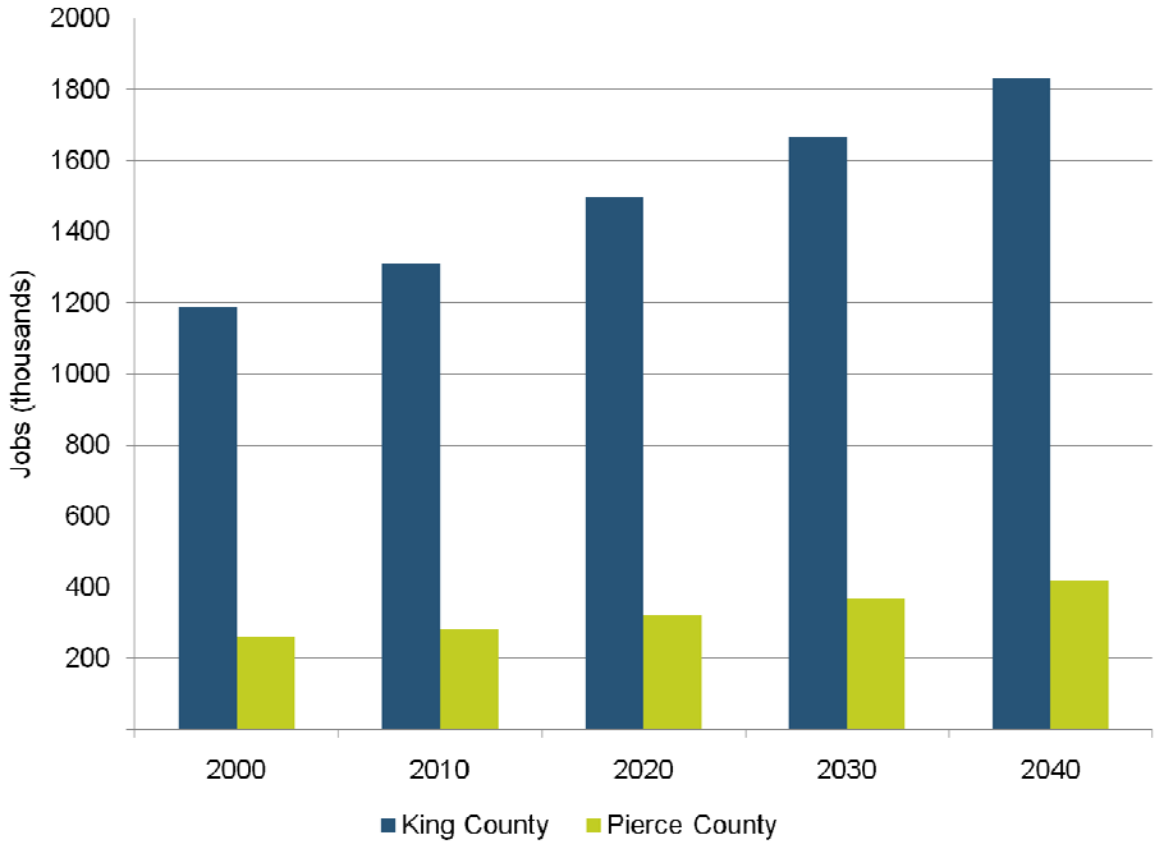
3.2 Economy

This section examines PSRC's employment forecast for the FAZs in the vicinity of the Study Area. Much of the employment data presented is organized according to PSRC's five major industry sectors: retail; manufacturing; wholesale trade, transportation, communication, and utilities (WTCU); financial, insurance, real estate, and services (FIRES); and government and education (GovEd).

3.2.1 King and Pierce County Employment Projections

As shown in Figure 14, King County is expected to experience substantial employment growth over the coming decades. According to PSRC's projections, employment will grow by 600,000 in King County, and approximately 160,000 in Pierce County.

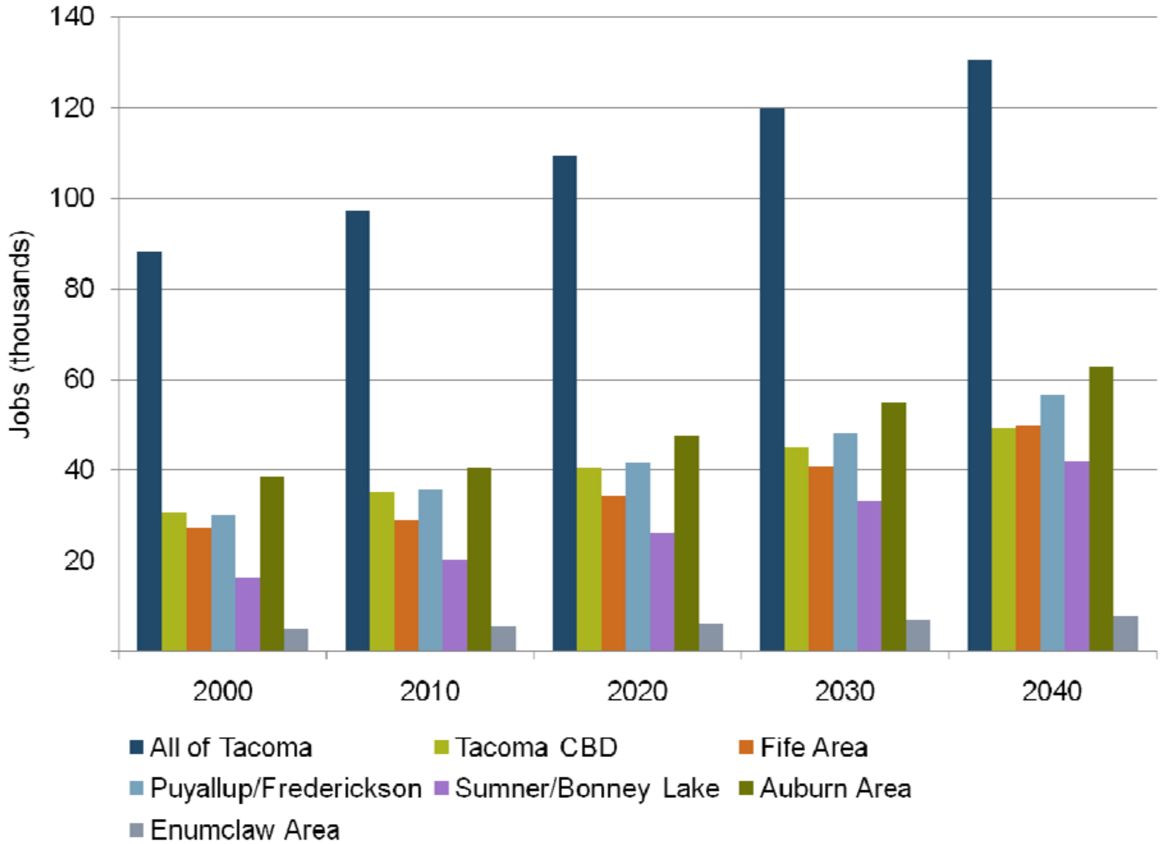
Figure 14. Past and Projected Employment in King and Pierce Counties, 2000-2040



Source: Puget Sound Regional Council, 2006.

All of the FAZs of interest are projected to see positive employment growth; however, Puyallup/Frederickson and the Auburn Area are expected to see the largest total growth in employment through 2040. The Fife Area is also expected to see job growth toward the end of the projection cycle, surpassing the employment forecast for the Tacoma CBD.

Figure 15. Past and Projected Employment in the FAZs of Interest, 2000-2040

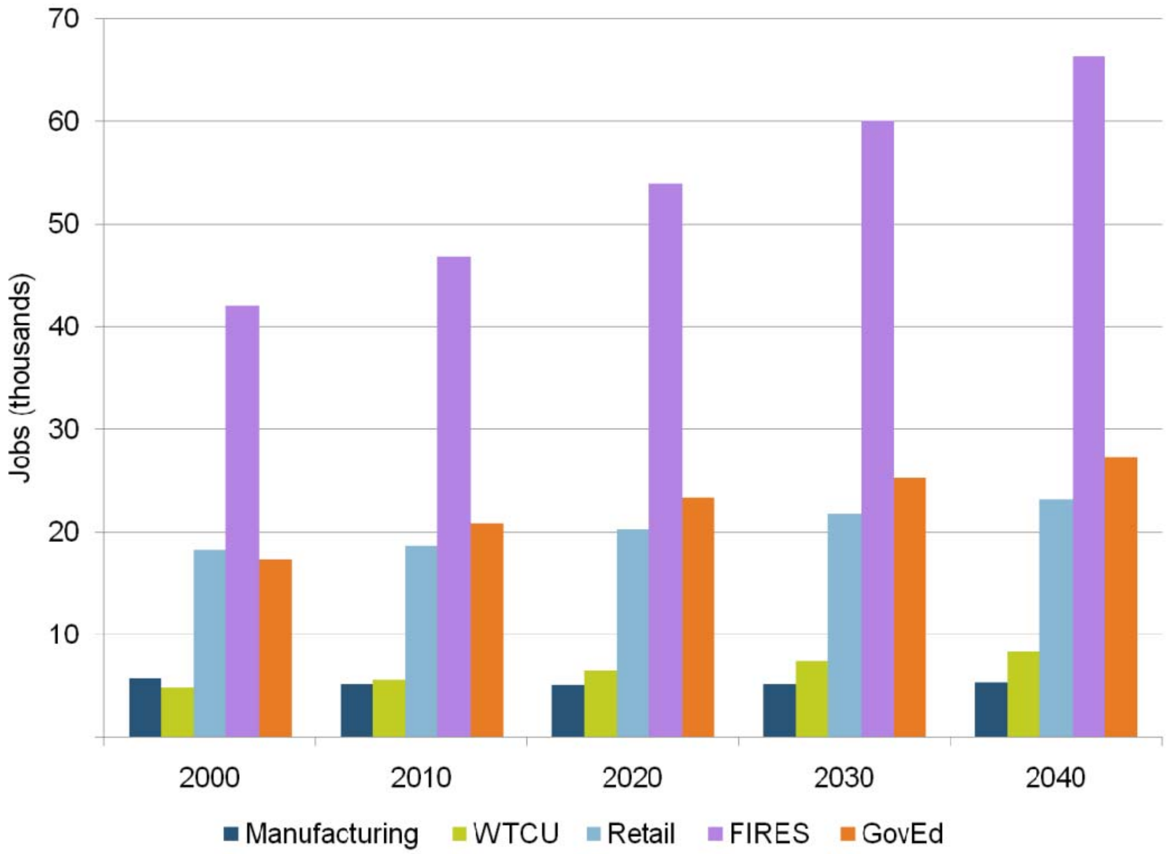


Source: Puget Sound Regional Council, 2006.

3.2.2 All of Tacoma Employment Forecast

Figure 16 illustrates the employment forecast for the All of Tacoma zone. Though only a subsection of Tacoma is included within the Study Area, the city is expected to have a substantial impact on the surrounding local economies. The FIRES sector is expected to become a larger economic sector relative to other sectors within the zone. Additionally, the All of Tacoma zone is projected to experience a decrease in manufacturing, while the WTCU sector is expected to grow in relative importance. The retail and GovEd sectors are both expected to see growth in employment through 2040, but will likely remain unchanged as a proportion of the zone's overall economic structure.

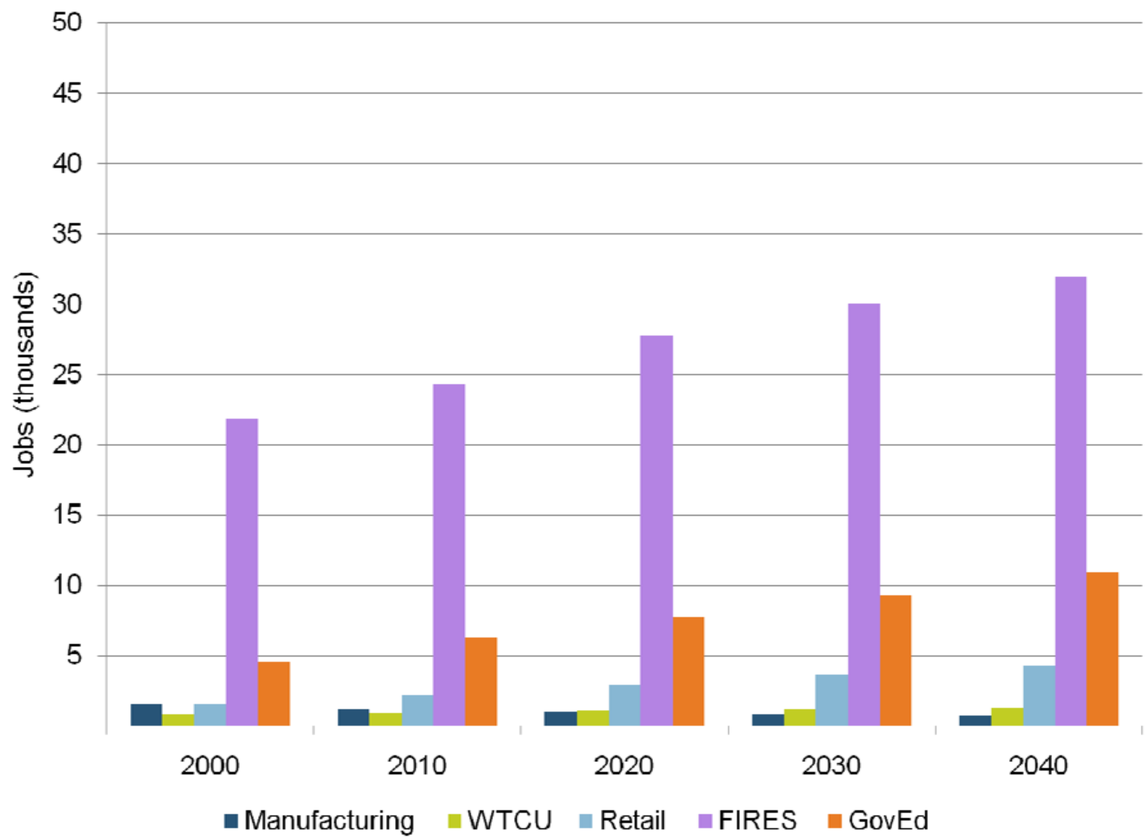
Figure 16. Past and Projected Employment by Industry in Tacoma, 2000-2040



Source: Puget Sound Regional Council, 2006.

As illustrated in Figure 17, a rapidly growing technology and professional services sector in the city, represented by the FIRES sector, is expected to boost employment in the Tacoma CBD by approximately 10,000 jobs through 2040. Additionally, the GovEd sector is expected to increase in response to a growing population, yielding increased demand for services. Although the retail sector is projected to grow slightly in relative importance to the area, the general structure of the economy will remain mostly unchanged through 2040.

Figure 17. Past and Projected Employment by Industry in Tacoma CBD, 2000-2040

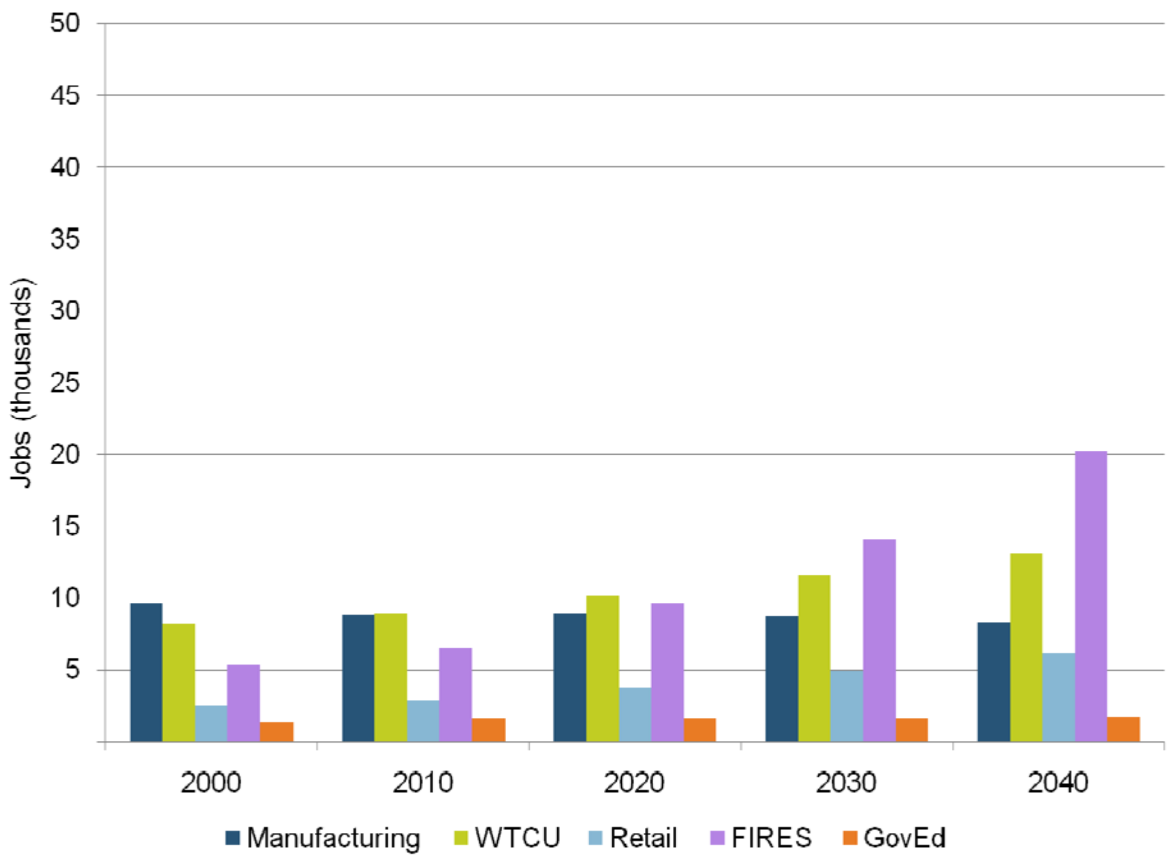


Source: Puget Sound Regional Council, 2006.

3.2.3 Fife Area Employment Forecast

Figure 18 shows that the Fife Area is expected to see substantial growth in the FIRES sector in the coming decades. Manufacturing, however, is expected to see a reduction in employment through 2040. As an access point to several important transportation routes, the WTCU sector will likely fill in some of the gaps left by the manufacturing sector, as the economic structure changes to take advantage of the area's proximity to the Port of Tacoma and other transportation connections. Government and retail will also see employment growth, but are not expected to see significant changes in size relative to other industries in the area.

Figure 18. Past and Projected Employment by Industry in Fife Area, 2000-2040

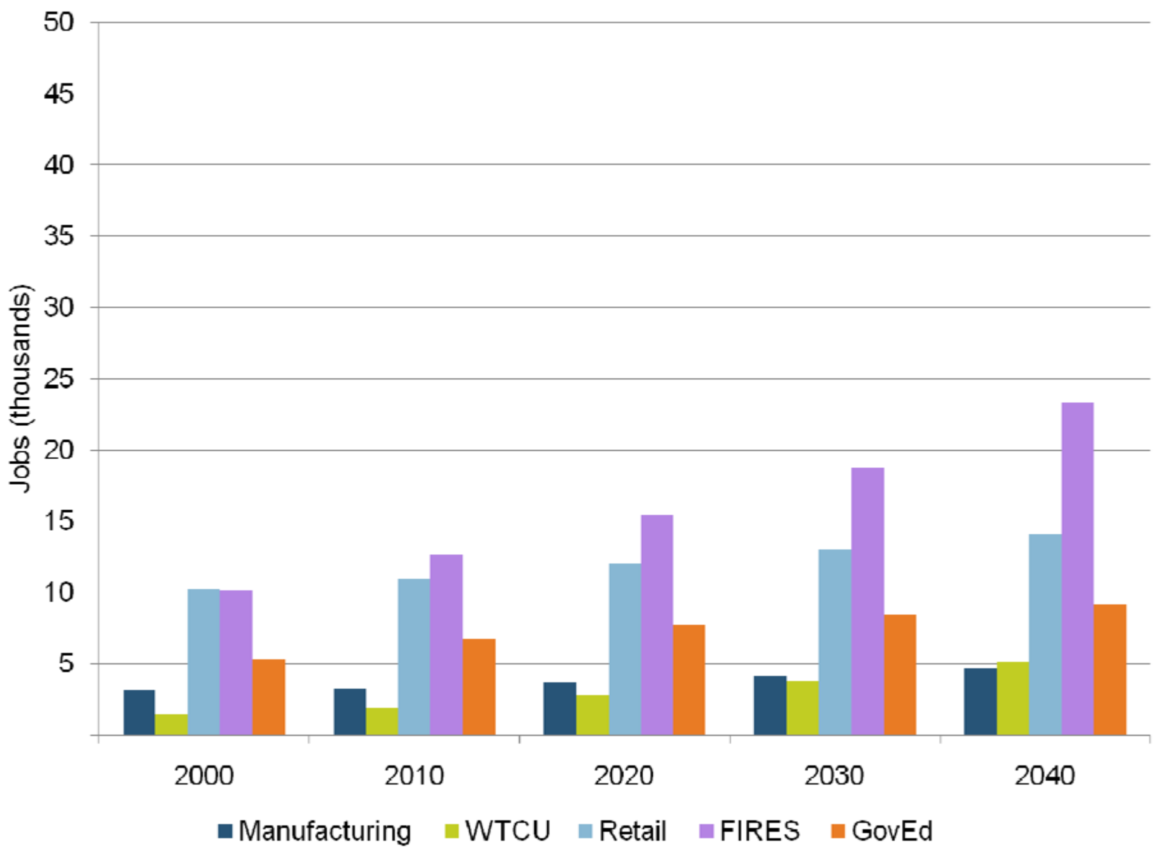


Source: Puget Sound Regional Council, 2006.

3.2.4 Puyallup/Frederickson Employment Forecast

Puyallup/Frederickson is expected to have robust economic growth across a variety of sectors through 2040. As Figure 19 illustrates, the FIRES sector will become the most significant industry in the zone, growing by well over 10,000 jobs. As a major shopping hub in the region, Puyallup/Frederickson is also projected to experience growth in its retail sector. Although all sectors are expected to see growth in the coming decades, the manufacturing sector will likely maintain a relative small share of employment.

Figure 19. Past and Projected Employment by Industry in Puyallup/Frederickson, 2000-2040

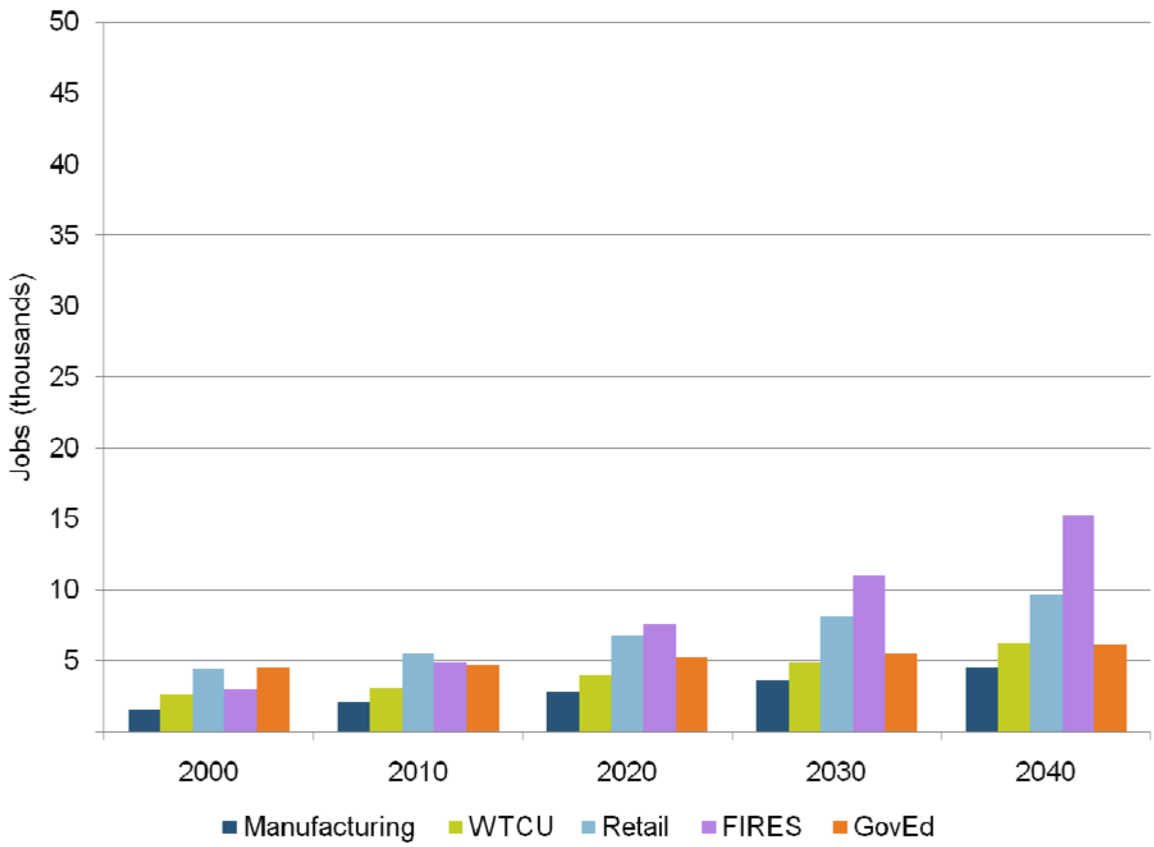


Source: Puget Sound Regional Council, 2006.

3.2.5 Sumner/Bonney Lake Employment Forecast

Sumner/Bonney Lake is projected to experience growth across a variety of sectors. Figure 20 illustrates that under the PSRC forecast, the FIRES sector is likely to become a more significant economic indicator in the area, growing by over 12,000 jobs through 2040. Although the FIRES sector is expected to increase in both real employment and relative importance, the economic structure of the other economic sectors in Sumner/Bonney Lake will remain largely unchanged in the coming decades.

Figure 20. Past and Projected Employment by Industry in Sumner/Bonney Lake, 2000-2040

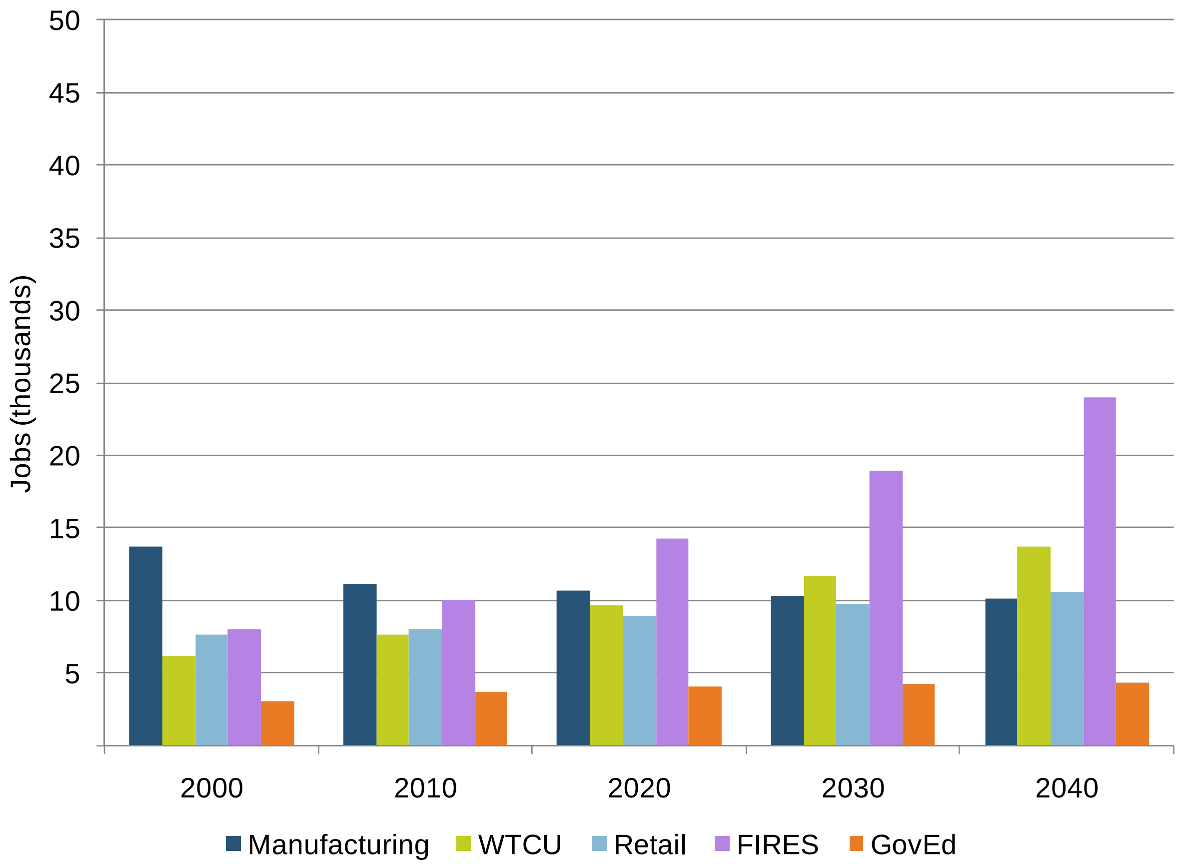


Source: Puget Sound Regional Council, 2006.

3.2.6 Auburn Area Employment Forecast

The Auburn Area is home to the Auburn Boeing Plant and Green River Valley Industrial Complex. However, despite the manufacturing presence, the Auburn Area is expected to experience structural changes to its local economy over the coming decades. As illustrated in Figure 21, the manufacturing sector is expected to shrink, while other economic indicators will experience positive growth. As in the other areas described in this profile, the FIRES sector in the Auburn Area is projected to grow substantially, in real employment and relative importance through 2040. Both the WTCU and retail sectors are also expected to become more prominent in the future. The GovEd sector is expected to grow but account for the smallest share of employment through 2040.

Figure 21. Past and Projected Employment by Industry in Auburn Area, 2000-2040

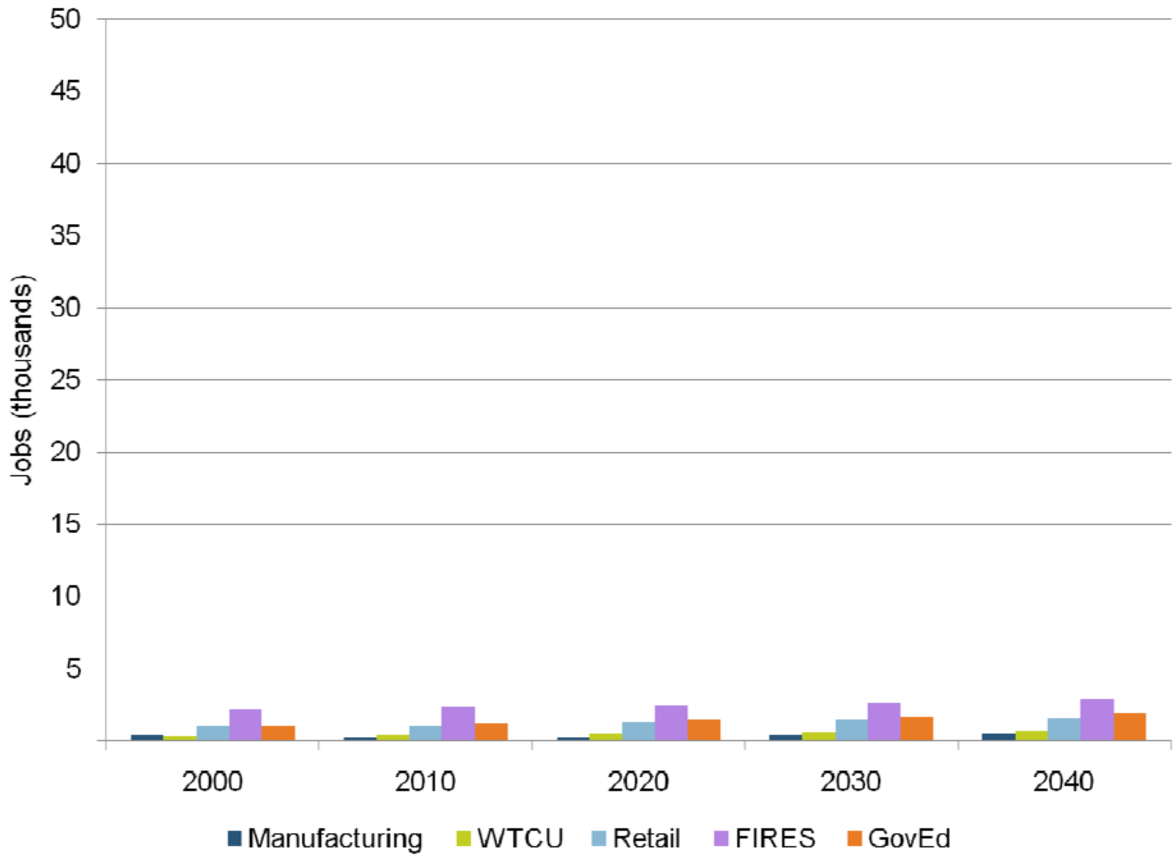


Source: Puget Sound Regional Council, 2006.

3.2.7 Enumclaw Area Employment Forecast

Figure 22 shows that the Enumclaw Area is expected to see relatively small changes to neither the structure of the area's economy, or total employment growth through 2040. The FIRES and GovEd sectors are projected to remain the two largest sectors in the zone.

Figure 22. Past and Projected Employment by Industry in Enumclaw Area, 2000-2040



Source: Puget Sound Regional Council, 2006.

3.3 Land Use

The future of land use in the Study Area and surrounding region is guided by policies resulting from Washington State's Growth Management Act of 1990. The Act requires cities and counties to develop policies to establish a framework to address planning issues across jurisdictional boundaries. The PSRC is responsible for coordinating the planning policies of King, Kitsap, Pierce, and Snohomish Counties. In 2009, the PSRC completed the latest long-range growth management, environmental, economic and transportation strategy, known as *Vision 2040,* to guide future employment and population growth for the central Puget Sound region.

A key concept of *Vision 2040* is directing future development into the urban growth area, while focusing new housing and jobs in cities and within a limited number of designated regional growth centers. Regional growth centers are compact urban centers that are intended to accommodate a significant proportion of future regional population and employment growth by concentrating housing, shopping, work, entertainment, civic uses, and other activities. The regional strategy of *Vision*

2040 also contains a number of manufacturing/industrial centers, which are existing employment areas with intensive, concentrated manufacturing and industrial land uses that cannot be easily mixed with other activities.

Figure 23 shows the urban growth area, designated regional growth centers, and manufacturing/industrial centers for the Study Area and surrounding region. The eastern portion of the Study Area is designated as an urban growth area, while the western portion is not except for the areas near Enumclaw and Buckley. There are currently five regional growth centers designated in Pierce County: Puyallup–Downtown (in the Study Area), Puyallup–South Hill, Lakewood, Tacoma–Downtown (partially in the Study Area), and Tacoma Mall. The currently designated manufacturing/industrial centers are the Port of Tacoma (in the Study Area) and Frederickson. Additional information on these regional growth centers and manufacturing/industrial centers are provided in the sections below.

Figure 23. PSRC Urban Growth Area, Regional Growth Centers and Manufacturing/Industrial Centers

Source: Adapted from Puget Sound Regional Council, 2009.

3.3.1 Lower Puyallup

Tacoma

Tacoma's downtown and the vicinity surrounding the Tacoma Mall are designated regional growth centers. The City of Tacoma has amended its comprehensive plan and development regulations to direct greater development and density into the downtown area and mixed-use centers. In addition, the city has developed various incentives and programs to attract new investment to these areas. The Port of Tacoma's industrial area is the only designated manufacturing/industrial center in the Study Area.

Tacoma's comprehensive plan also calls for the development of three mixed-use areas, including Lower Portland Avenue, McKinley and 34th & Pacific. All of these areas are south of I-5 near the downtown central business district and the Port of Tacoma.

Fife

The urban growth area for the City of Fife is in the north part of town, just north of I-5. The city's comprehensive plan calls for the addition of 112 acres of new residential development in the south and eastern portions of the city adjacent to existing development, for low to high densities. The plan also calls for the adding of residential uses within new and existing commercial areas through mixed use designations. Fife has not designated any lands within the urban growth area as agricultural, but it does have policies to encourage the conservation of agricultural land within the city limits.

Edgewood

The City of Edgewood plans to develop a town center along Meridian Avenue near the City Hall. The town center plans call for gathering places and public buildings and commercial development. The city also plans to support a range of housing densities including zero lot line and townhouse developments. Edgewood plans to continue to support agriculture within the city, as it has historically been a part of the area.

3.3.2 Upper Puyallup

Puyallup

Puyallup is surrounded by urban growth area. The city plans to maintain the single-family character of its neighborhoods while accommodating some increased density through the use of smaller lots, accessory dwelling units, and townhouse clusters. In addition, medium and high densities are planned for in the downtown and South Hill neighborhoods with street-level commercial activities.

Downtown Puyallup is a designated regional growth center, and the city intends to revitalize the downtown commercial center and is developing its Pioneer Park downtown "civic center." This effort includes a public library, senior activity center, and private residential and commercial projects. The city continues to develop a three-mile long riverfront recreation/commuter trail project known as Riverwalk Trail. Puyallup also plans to encourage the transformation of commercial sectors along arterial roads into transportation-oriented developments where possible.

Bonney Lake

Single-family homes will continue to be the main land use in Bonney Lake. The city plans to increase medium and high density residential development near the commercial development along SR 410. The SR 410 corridor will continue to be the commercial center with increases in "commercial light industry" areas in the eastern portion.

3.3.3 White River

Sumner

The City of Sumner is planning for infill in residential neighborhoods to accommodate future population, including allowing some high-density residential areas. The city plans to continue expanding the Sumner-Pacific industrial area, with a goal of 20,000 jobs by 2040. The Sumner-Pacific Manufacturing/Industrial Center is a "candidate" regional center, which means it is being considered for a regional-level designation but has not yet received approval by the PSRC. The city will continue to support agriculture through existing ordinances, although it believes that the prevalence of agriculture in the area will decline.

Pacific

According to the Pierce County Buildable Lands report, Pacific is in the process of transitioning the limited residential areas that are within Pierce County to commercial and industrial uses. The goal is to increase the employment by 200 percent and decrease the population by one-third in order to better balance the population with jobs, creating a more "economically stable community" (Pierce County Planning, 2002).

Algona

There appear to be few land use changes in the future for Algona, though it does have some vacant and redevelopable residential, commercial, and industrial land.

Auburn

The City of Auburn is planning to continue population growth. Downtown Auburn has been designated a regional growth center, and the city plans to continue to develop the downtown area into a commercial center that provides local goods and services to the surrounding neighborhoods. There will also be higher density residential development near the downtown zone. The city plans to protect the character of the existing single-family residential areas and encourage the development of more single-family residential areas, especially in currently undeveloped areas.

Enumclaw

The City of Enumclaw is planning for a substantial increase in commercial and residential development in the years ahead now that the over 10-year-old sanitary sewer connection and associated building moratorium has been lifted with the 2009 completion of the WWTP expansion. A significant amount of the city's growth is forecasted for the eastern end of the SR 410 corridor. Several developments are in the planning or development stages, while others await permits to be issued. Future development along the SR 410 corridor is expected to include agricultural, residential, and commercial development. Enumclaw plans to protect existing single-family residential development and continue it along the edges of the city with buffer zones for agricultural lands. There are also plans for higher density areas in the city center and commercial areas along SR 410 that will include mixed use areas. In addition, Enumclaw has made continued agricultural activity a priority by planning to reduce conflicts with residential areas through the use of buffer areas.

Buckley

Buckley plans to continue to develop predominantly single-family areas with some higher density areas near the commercial center. The city also plans a light-industrial and commercial area to the west of the commercial center.

3.3.4 Carbon River

Alderton-McMillin

The 2007 Alderton-McMillin Community Plan calls for the use of several strategies to preserve agricultural land in the area and maintain its rural character. Outside of some designations for rural neighborhood centers and rural industrial centers, the majority of the area is designated Rural 10, which allows one house per ten acres.

Orting

Growth is expected to occur on the northeast and south sides of Orting as agricultural tracts are converted to residential uses, schools, and other public facilities.

South Prairie

South Prairie expects more single-family residential with various lot sizes. The town also hopes to spur some light industrial development. The 2002 Pierce County Buildable Lands Report indicates that there is little development pressure in South Prairie due to its distance from employment centers.

3.4 Public Infrastructure

There are two significant public infrastructure projects that are not described elsewhere in the report. Recently, Pierce County began work on a $305 million project to improve and expand the Chamber Creek Regional Wastewater Treatment Plant. The project is expected to meet treatment capacity needs through 2040 (Ramsaur, 2011).

The Washington State Department of Transportation is contributing to an effort to build a high-speed passenger line from Eugene, Oregon to Vancouver, British Columbia. The plan calls for improving the existing BNSF passenger rail line to allow for faster train travel. The overall project is divided into small projects and several of them are underway, including improvements in rail transportation in Tacoma. This project has the potential to increase the importance of the rail line to the regional economy.

4 References

Amtrak Cascades. *Tacoma Station*. Available at http://www.amtrakcascades.com/Tacoma.htm. Accessed August 30th, 2011.

Bureau of Economic Analysis, U.S. Department of Commerce. Database of Local Area Personal Income accounts, "CA04". Available at http://www.bea.gov/regional/downloadzip.cfm. Accessed August 30th, 2011.

City of Auburn. *City of Auburn Comprehensive Plan*. Ordinance No. 6280. 2009.

City of Bonney Lake. *Bonney Lake Comprehensive Plan*. February 2007.

City of Edgewood. *City of Edgewood Comprehensive Plan*. 2009.

City of Enumclaw. *Winds of Tomorrow: Comprehensive Plan for the City of Enumclaw: 2005 to 2022*. June 2005.

City of Fife, Community Development Department. 2005 City of Fife Comprehensive Plan. 2005.

City of Orting. *Orting Comprehensive Plan 2008*. 2008.

City of Puyallup. *Comprehensive Plan: City of Puyallup 1994*. 2009.

City of Sumner Community Development Department. *Sumner Comprehensive Plan 2010*. December 2010.

City of Tacoma, Community and Economic Development Department. *City of Tacoma Comprehensive Plan as amended June 2011*. 2011.

Federal Highway Administration and Washington State Department of Transportation. *SR 167 Puyallup to SR 509 Tier I1 Final Environmental Impact Statement*. 2006.

Gray and Osborne, Inc. Engineering Consultants. *City of Puyallup Water System Plan*. Prepared for the City of Puyallup. April 2011.

Kask Consulting, Inc. Consultant. *Comprehensive Plan, 2002-2022: Town of South Prairie*. Prepared for the Town of South Prairie. 2007.

Martin Associates. *The Economic Impact of the Port of Tacoma*. May 2005.

Parametrix. Engineering Consultant. *Comprehensive Water System Plan: Town of South Prairie*. Prepared for the Town of South Prairie. April 2007.

Parametrix. Engineering Consultant. *Edgewood General Sewer Plan*. Prepared for the City of Edgewood. Revised June 2007.

Pierce County Planning and Land Services Department. *Alderton-McMillin Community Plan: A Component of the Pierce County Comprehensive Plan*. Ordinance No. 2007-41s2. 2007.

Pierce County Planning and Land Services Department. *Pierce County Buildable Lands Report*. 2002.

Pierce County Planning and Land Services. *Pierce County Comprehensive Plan*. Title 19a. 2010.

Port of Tacoma. *Annual Report 2010*. 2011.

Puget Sound Energy. *Puget Sound Energy Service Area Map*. March 2011.

Puget Sound Regional Council. *2010 Covered Employment Estimates by Tract*. 2011. Accessed October 6th, 2011. Available at http://psrc.org/data/employment/covered-emp.

Puget Sound Regional Council. *Important Update on PSRC Land Use Forecasts*. Available at http://psrc.org/data/forecasts/land-use-forecasts-update/ . Accessed August 30th, 2011.

Puget Sound Regional Council. *PSRC Population, Household and Employment Forecast*. 2006.

Puget Sound Regional Council. *Vision 2040: The Growth Management, Environmental, Economic and Transportation Strategy for the Central Puget Sound Region*. 2009.

RH2 Engineering. Engineering Consultant. *City of Bonney Lake Comprehensive Sewer System Plan*. Prepared for the City of Bonney Lake. February 2009.

Ramsaur, Tim. Wastewater Utility manager. Pierce County. Press release: "Treatment plant expansion serves growth, protects Sound." May 2011.

Tacoma Public Utilities. *Why Tacoma Public Utilities Owns a Railroad*. Available at http://www.mytpu.org/tacomarail/about/history.htm. Accessed August 30th, 2011.Mt. View-Edgewood Water Company. *About Us*. Available at http://www.mtvewater.com/about/about.htm. Accessed August 30th, 2011.

The Enumclaw Courier-Herald. "New era for city sewage begins." October 3, 2007. Accessed August 26, 2011.

Transpo Group. Transportation Consultants. *410 Corridor Study*. Prepared for the City of Enumclaw. June 2010.

U.S. Census Bureau, 2010 Census. American FactFinder. Available online at http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml. Accessed August 29, 2011.

U.S. Census Bureau, 2000 Census. American FactFinder. Available online at http://factfinder.census.gov/home/saff/main.html?_lang=en. Accessed August 29, 2011.

U.S. Census Bureau, 2005-2009 American Community Survey. American FactFinder. Available online at http://factfinder.census.gov/home/saff/main.html?_lang=en. Accessed August 29, 2011.

Washington State Department of Transportation. *High-Speed Passenger Rail*. Available at http://www.wsdot.wa.gov/Funding/stimulus/passengerrail.htm. Accessed August 30th, 2011.

Washington State Office of Financial Management. Database of Decennial Population counts for the state, counties and Cities: 1890 to 2000. September 2002. Available at http://www.ofm.wa.gov/pop/decseries/historicalpop.xls. Accessed August 2011.

Appendix C-3

Economics

RED and OSE Accounts, and EO 11988 Compliance Documentation

Puyallup River Basin

Flood Risk Management Feasibility Study

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RED and OSE Accounts, and EO 11988 Compliance Documentation

The following outlines the analysis that will be conducted during feasibility-level design to evaluate the Regional Economic Development (RED) and Other Social Effects (OSE) accounts, as well as document the 8-step process to comply with Executive Order (EO) 11988, Wise Use of Floodplains, and support compliance documentation with EO 12898, Environmental Justice. Please note that these analysis have not been completed for purposes of selecting a plan, but will be a consideration in the optimization of the National Economic Development (NED) plan as part of feasibility-level design.

1.0 REGIONAL ECONOMIC DEVELOPMENT ANALYSIS

Purpose and Methodology

The U.S. Army Corps of Engineers (USACE) *Planning Guidance Notebook* (ER 1105-2-100) states that while National Economic Development (NED) and Environmental Quality accounts are required, display of the Regional Economic Development (RED) effects are discretionary. The Corps' NED procedures manual affirms that RED benefits are real and legitimate; however, the concern (from a Federal perspective) is that they are often offset by RED costs in other regions. Nevertheless, for the local community these benefits are important and can help them in making their preferred planning decisions.

Although the RED account is often examined in less detail than the NED, it remains useful. For example, Hurricane Katrina caused a significant economic hardship to not just the immediate Gulf Coast but for entire counties, watersheds, and the State of Louisiana. Besides the devastating damage to homes (which are often captured by the NED account), hundreds of thousands lost their jobs, property values fell, and tourism and tax revenues declined significantly and moved to other parts of the U.S. In this example, the RED account can provide a better depiction of the overall impact to the region.

The distinction between NED and RED is a matter of perspective, not economics. A non-Federal partner may consider the impacts at the state, regional, and local levels to be a true measure of a project's impact or benefit, whereas from the Corps' perspective, this may not constitute a national benefit. Gains in RED to one region may be partially or wholly offset by losses elsewhere in the nation. For example, if a Federal project enables a firm to leave one state to locate in the newly-protected floodplain of another state, the increase in regional income for a project area may come at the expense of the former area's loss. As such, they may not influence the net value of the nation's output of goods and services and should be excluded from NED computations.

RED Concepts

The RED account has been given less emphasis in the Corps' past or current guidance. Perhaps the most extensive statement on RED appeared in the Principles and Standards:

> *"Through its effects—both beneficial and adverse—on a region's income, employment, population, economic base, environment, social development and other factors, a plan may exert a significant influence on the course and direction of regional development. The regional development account embraces several types of beneficial effects, such as (a) increased regional income, (b) increased regional employment, (c) population distribution, (d) diversification of regional economic base, and (e) enhancement of environmental conditions of special regional concern."*

Econometric analysis allows for the evaluation of the full range of economic impacts related to specific economic activities (construction and procurement) by calculating direct, indirect, and induced effects of the activities in the specific geographical designation.

- Direct effects: consist of economic activity contained exclusively within the designated sector. This includes all expenditure made by the companies or organizations in the industry and all employees who work directly for them.
- Indirect effects: define the creation of additional economic activity that results from linked business, suppliers of goods and services, and provisions of operating inputs.
- Induced effects: measure the consumption expenditures of direct and indirect sector employees.

Input-output (I/O) models are characterized by their ability to evaluate the effects of industries on each other. Unlike most typical measures of economic activity that examine only the total output of an industry or the final consumption demand provided by a given output, I/O models provide a much more comprehensive view of the interrelated economic impacts. I/O analysis is based on the notion that there is a fundamental relationship between the volume of output of an industry and the volume of the various inputs used to produce that output. Industries are often grouped into production, distribution, transportation, and consumption. Additionally, the I/O model can be used to quantify the multiplier effect. In economics, the multiplier effect refers to the idea that an increase in spending can lead to even greater increase in income and consumption, as monies circulate or multiply through the economy.

Flood Risk Management RED Considerations

There are particular effects for each type of project improvement as they relate to the RED account. The estimation of RED flood-related effects can be very complex. At a minimum, the RED analysis should include a qualitative description of the types of businesses at risk from flooding, particularly those that could have a significant adverse impact (output, employment, etc.) upon the community or regional economies if their operations should be disrupted by flooding and how this would be affected by the recommended project. The potential RED effects to flood risk management projects will be summarized based on the factors in the table below.

Table. Potential RED Effects to Flood Risk Management

RED Factor	Potential RED Effects
Construction	Additional construction related activity and resulting spillovers to suppliers.
Revenues	Increased local business revenues as a consequence of reduced flooding, particularly from catastrophic floods.
Tax Revenues	Increased income and sales taxes from the direct project and spillover industries.
Employment	Short-term increase in construction employment; with catastrophic floods, significant losses in local employment (apart from the debris and repair businesses, which may show temporary gains).
Population Distribution	Disadvantaged groups may benefit from the creation of a flood-free zone.
Increased Wealth	Potential increase in wealth for floodplain residents as less is spent on damaged property, repairs, etc. and potential increase in property values.

Regional Economic Development (RED) Results

A variety of software programs are available to determine the RED impacts for each project. Depending on the level of effort, project purpose, precision requirements and size of the study area, application will most likely vary. The Corps of Engineers' Institute for Water Resources (IWR) along with the Louis Berger Group has developed a regional economic impact modeling tool called Regional Economic System (RECONS) that provides estimates of regional and national job creation, retention and other economic measures. The expenditures made by the Corps for various services and products generate economic activity that can be measured in jobs, income, sales, and gross regional product (GRP). RECONS automates calculations and generates estimates of economic measures associated with the Corps' annual Civil Works program spending. RECONS was built by extracting multipliers and other economic measures from more than 1,500 regional economic models that were built specifically for the Corps' project locations by the Minnesota IMPLAN Group. These multipliers were then imported into a database and RECONS matches various spending profiles to the matching industry sectors by location to produce economic impact estimates. RECONS will be used as a mean to document the performance of direct investment spending of the Corps, as it allows users to evaluate project and program expenditures associated with the annual expenditure.

For this analysis, the Seattle metropolitan area (Seattle-Tacoma-Olympia Metropolitan Statistical Area), Pierce County, and the State of Washington will be used as the geographic designation to assess the overall economic impacts of the construction funds. This places a frame around the economic impacts where the activity is internalized. Leakages (payments made to imports or value added sectors, which do not in turn re-spend the dollars within the area) are not included in the total impacts.

2.0 OTHER SOCIAL EFFECTS ANALYSIS

The other social effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts (National Economic Development, Regional Economic Development or Environmental Quality).

This metric will evaluate components critical to life safety such as population at risk including environmental justice populations, loss of life potential, critical infrastructure and evacuation routes, and wise use of floodplains (lands that may be developed in the future with or without a proposed project). These effects will be summarized in the table that follows for the No Action Plan and the TSP which has been optimized for National Economic Development during feasibility-level design.

Table. Potential OSE Effects

Other Social Effects	No Action	NED Plan
Population at Risk		
Loss of Life		
Critical Infrastructure		
Evacuation Routes		
Wise Use of Floodplains		
Social Vulnerability		
Residual Risk and Consequences (other than NED damages)		

3.0 EXECUTIVE ORDER 11988 COMPLIANCE SUPPORTING DOCUMENTATION

Executive Order (EO) 11988 (May 24, 1977) requires a Federal agency, when taking an action, to avoid short and long term adverse effects associated with the occupancy and the modification of a floodplain. The agency must avoid direct and indirect support of floodplain development whenever floodplain siting is involved. In addition, the agency must minimize potential harm to or in the floodplain and explain why the action is proposed. Additional floodplain management guidelines for EO 11988 were also provided in 1978 by the Water Resources Council.

Corps implementation guidance in Engineering Regulation (ER) 1165-2-26 (March 30, 1984), states the following in Paragraph 6:

The Executive Order has as an objective the avoidance, to the extent possible, of long-and short-term adverse impacts associated with the occupancy and modification of the base floodplain and the avoidance of direct and indirect support of development in the base flood plain wherever there is a practicable alternative. Under the Order, the Corps is required to provide leadership and take action to:

a. Avoid development in the base flood plain unless it is the only practicable alternative;

b. Reduce the hazard and risk associated with floods;

c. Minimize the impact of floods on human safety, health and welfare; and

d. Restore and preserve the natural and beneficial values of the base floodplain.

General procedures to implement Executive Order include eight steps as outlined and evaluated for the Puyallup River Basin Flood Risk Management Feasibility Study.

1. Determine if the proposed action is in the base floodplain.
2. If the action is in the base floodplain, identify and evaluate practicable alternatives to the action or to location of the action in the base floodplain.

The decision on whether a practicable alternative exists will be based on weighing the advantages and disadvantages of flood plain sites and non-flood plain sites. Factors to be taken into consideration include, but are not limited to, conservation, economics, aesthetics, natural and beneficial values served by flood plains, impact of floods on human safety, locational advantage, the functional need for locating the development in the floodplain, historic values, fish and wildlife habitat values, endangered and threatened species, Federal and State designations of wild and scenic rivers, refuges, etc. and, in general, the needs and welfare of the people. The test of practicability will apply to both the proposed

Corps action and to any induced development likely to be caused by the action. Identification and evaluation of practicable alternatives shall include consideration of alternative sites (carrying out the proposed action outside the flood plain); alternative actions (other means which accomplish the same purpose as the proposed action); and no action. When a determination is made that no practicable alternative to undertaking an action in the flood plain exists, it will be appropriately documented and the features or qualities of the floodplain that make it advantageous over alternative non-floodplain sites shall be described and adequately supported.

3. If the action must be in the floodplain, advise the general public in the affected area and obtain their views and comments.
4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial floodplain values. Where actions proposed to be located outside the base floodplain will affect the base floodplain, impacts resulting from these actions should also be identified.
5. If the action is likely to induce development in the base floodplain, determine if a practicable non-floodplain alternative for the development exists.
6. As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial floodplain values. This should include reevaluation of the “no action” alternative.
7. If the final determination is made that no practicable alternative exists to locating the action in the floodplain, advise the general public in the affected area of the findings.
8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order as stated.

The wise use of floodplains concept, as described in EO 11988, will be incorporated as a life safety for this study under the Other Social Effects account.