

Pierce County
Lower Puyallup River Flood Protection Investigation
Without-Project Analysis

APPENDIX G.
ECONOMIC ANALYSIS RISK INPUTS AND SUMMARY RESULTS

June 2009

APPENDIX G. ECONOMIC ANALYSIS RISK INPUTS AND SUMMARY RESULTS

The following sections have the HEC-FDA model inputs used for the modeling of economic damage under without-project conditions on the Puyallup River. These relationships include uncertainties in each of the following study areas: hydrology, hydraulics, geo-technical and economics.

HYDROLOGY

The same relationship was used for existing and future conditions. The input is in the form of a graphical exceedance probability-discharge function. Uncertainty is determined based on both the shape of the curve and the equivalent record length of 66 years. The table shows the most likely discharge for different events and the confidence limits based on plus or minus one and two standard deviations.

The screenshot displays the HEC-FDA software interface for configuring hydrology inputs. The main window is titled "Puyallup River - Exceedance Probability Functions with Uncertainty". It includes a menu bar (File, Edit, View, Help) and several input fields: Plan (Without), Stream (Puyallup River), Analysis Year (2007), Function (Puyallup River), and Description. There are radio buttons for "Analytical..." and "Graphical..." (selected), and buttons for "Function Statistics..." and "Plot...".

An overlaid dialog box, "Puyallup River - Probability Function St...", is open, showing "Input Graphical Probability Function" and "Uncertainty Computed from Ordered Events". It has an input field for "Equivalent Record Length (N)" set to 66, and "OK" and "Cancel" buttons.

Below the dialog boxes is a table titled "Confidence Limit Curves" with the following data:

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves			
		Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.9990	8,918.43	7,738.59	8,307.59	9,574.18	10,278.14
0.9900	9,000.00	7,816.41	8,387.35	9,657.39	10,362.81
0.9500	10,258.61	9,291.99	9,763.35	10,778.99	11,325.77
0.9000	11,000.00	9,391.04	10,163.74	11,905.08	12,884.64
0.8000	14,000.00	11,595.74	12,741.28	15,383.08	16,902.76
0.7000	16,600.25	13,973.68	15,230.44	18,093.26	19,720.53
0.5000	21,999.99	18,945.82	20,415.88	23,707.02	25,546.50
0.3000	27,807.68	24,095.51	25,885.15	29,873.00	32,091.75
0.2000	32,041.33	27,430.42	29,646.37	34,629.78	37,427.32
0.1000	38,999.98	33,756.29	36,283.53	41,919.82	45,058.24
0.0400	44,000.00	39,446.74	41,661.21	46,470.08	49,078.82
0.0200	46,000.00	41,291.93	43,582.46	48,551.64	51,244.88
0.0100	47,999.98	42,942.36	45,400.80	50,747.96	53,653.26
0.0040	52,572.42	46,687.79	49,542.81	55,787.29	59,198.77
0.0020	56,000.00	49,469.43	52,633.52	59,581.80	63,392.68
0.0010	59,417.89	52,223.21	55,704.48	63,378.84	67,603.76

HYDRAULICS

In-Channel Stage

The in-channel relationship is defined by the stage-discharge function with uncertainty. In this case, it is a triangular distribution with a most likely, minimum and maximum stage for each given discharge. On the Puyallup River, the stage would increase in the future for a given discharge due to sedimentation.

Existing Condition

Puyallup River - Stage-Discharge Function with Uncertainty

File Edit View Help

Plan: Without Stream: Puyallup River

Analysis Year: 2007 Damage Reach: Puyallup North

Function: Existing 2007 Use An Existing Function Plot...

Description: Tabulate...

Distribution Type
 None Normal Triangular Log Normal

Define Uncertainty
 Enter by Ordinate Calculate Set Stage Error...

	Discharge (cfs)	Stage (ft.)	Minimum Stage (ft.)	Maximum Stage (ft.)
1	1000.00	8.97	8.930	9.010
2	5000.00	9.79	9.650	9.870
3	9000.00	10.81	10.520	10.970
4	11000.00	11.38	11.020	11.590
5	14000.00	12.30	11.840	12.580
6	18000.00	13.62	13.050	13.980
7	22000.00	15.01	14.330	15.440
8	25000.00	16.06	15.330	16.540
9	28000.00	17.11	16.320	17.620
10	29000.00	17.45	16.650	17.970
11	31000.00	18.12	17.310	18.660
12	33000.00	18.78	17.950	19.320
13	35000.00	19.40	18.570	19.950
14	37000.00	20.00	19.170	20.540
15	39000.00	20.56	19.740	21.090
16	41000.00	21.08	20.280	21.580
17	43000.00	21.55	20.780	22.020
18	45000.00	21.97	21.230	22.390
19	47000.00	22.32	21.630	22.690
20	49000.00	22.62	21.980	23.000
21	51000.00	22.84	22.260	23.200
22	52000.00	22.93	22.380	23.250
23	56000.00	23.06	22.680	23.300

2017 Condition

(Note the slightly higher stages.)

Puyallup River - Stage-Discharge Function with Uncertainty

File Edit View Help

Plan: Without Stream: Puyallup River

Analysis Year: 2017 Damage Reach: Puyallup North

Function: Puyallup 10yr Use An Existing Function Plot...

Description: 2017 Future Sediment Condition Tabulate...

Distribution Type
 None Normal Triangular Log Normal

Define Uncertainty
 Enter by Ordinate Calculate Set Stage Error...

	Discharge (cfs)	Stage (ft.)	Minimum Stage (ft.)	Maximum Stage (ft.)
1	1000.00	8.96	8.910	8.960
2	3000.00	9.53	9.410	9.630
3	5000.00	10.14	9.950	10.340
4	7000.00	10.78	10.530	11.070
5	9000.00	11.45	11.130	11.820
6	11000.00	12.15	11.760	12.580
7	14000.00	13.23	12.740	13.740
8	17000.00	14.33	13.750	14.910
9	20000.00	15.43	14.780	16.070
10	22000.00	16.17	15.470	16.830
11	25000.00	17.25	16.500	17.940
12	28000.00	18.30	17.500	19.000
13	29000.00	18.63	17.830	19.900
14	31000.00	19.29	18.480	19.990
15	33000.00	19.91	19.100	20.610
16	35000.00	20.50	19.700	21.180
17	37000.00	21.04	20.260	21.700
18	39000.00	21.54	20.790	22.180
19	41000.00	21.99	21.290	22.600
20	43000.00	22.38	21.740	22.950
21	45000.00	22.71	22.140	23.240
22	47000.00	22.97	22.490	23.460
23	49000.00	23.25	22.780	23.700
24	51000.00	23.45	23.100	23.950
25	52000.00	23.50	23.110	23.970
26	56000.00	23.60	23.310	24.100

2057 Condition

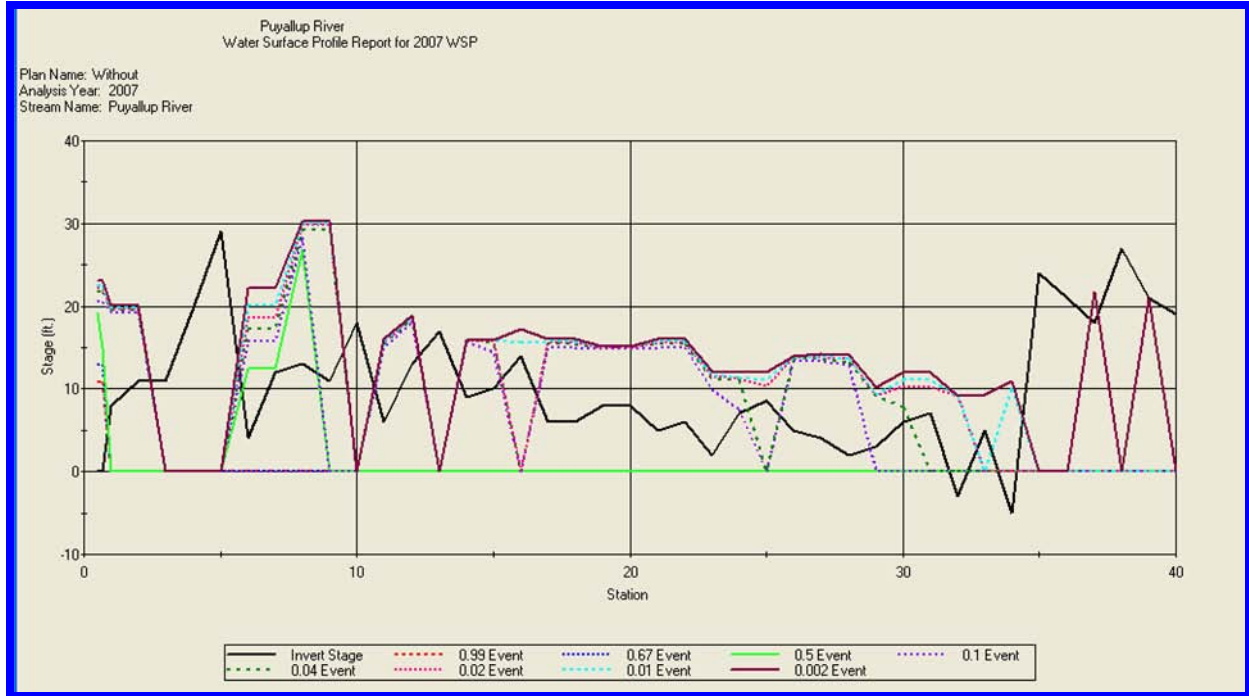
(Note the slightly higher stages.)

Puyallup River - Stage-Discharge Function with Uncertainty					
File Edit View Help					
Plan: Without					
Analysis Year: 2007					
Function: Puyallup 50yr					
Description:					
Distribution Type					
<input type="radio"/> None <input type="radio"/> Normal <input checked="" type="radio"/> Triangular <input type="radio"/> Log Normal					
Define Uncertainty					
<input checked="" type="radio"/> Enter by Ordinate <input type="radio"/> Calculate <input type="button" value="Set Stage Error..."/>					
	Discharge (cfs)	Stage (ft.)	Minimum Stage (ft.)	Maximum Stage (ft.)	
1	1000.00	9.01	8.970	9.070	
2	3000.00	9.61	9.490	9.730	
3	5000.00	10.25	10.040	10.480	
4	7000.00	10.92	10.630	11.240	
5	9000.00	11.62	11.240	12.010	
6	11000.00	12.33	11.880	12.790	
7	14000.00	13.43	12.880	13.980	
8	17000.00	14.54	13.920	15.160	
9	20000.00	15.66	14.960	16.320	
10	22000.00	16.39	15.660	17.070	
11	25000.00	17.47	16.700	18.170	
12	28000.00	18.51	17.720	19.210	
13	29000.00	18.84	18.050	19.540	
14	31000.00	19.49	18.690	20.180	
15	33000.00	20.10	19.310	20.780	
16	35000.00	20.68	19.900	21.330	
17	37000.00	21.21	20.450	21.840	
18	39000.00	21.69	20.970	22.290	
19	41000.00	22.12	21.440	22.690	
20	43000.00	22.50	21.860	23.030	
21	45000.00	22.81	22.230	23.300	
22	47000.00	23.06	22.550	23.510	
23	49000.00	23.30	22.800	23.750	
24	51000.00	23.45	22.990	23.950	
25	52000.00	23.50	23.050	23.970	
26	56000.00	23.60	23.130	24.100	

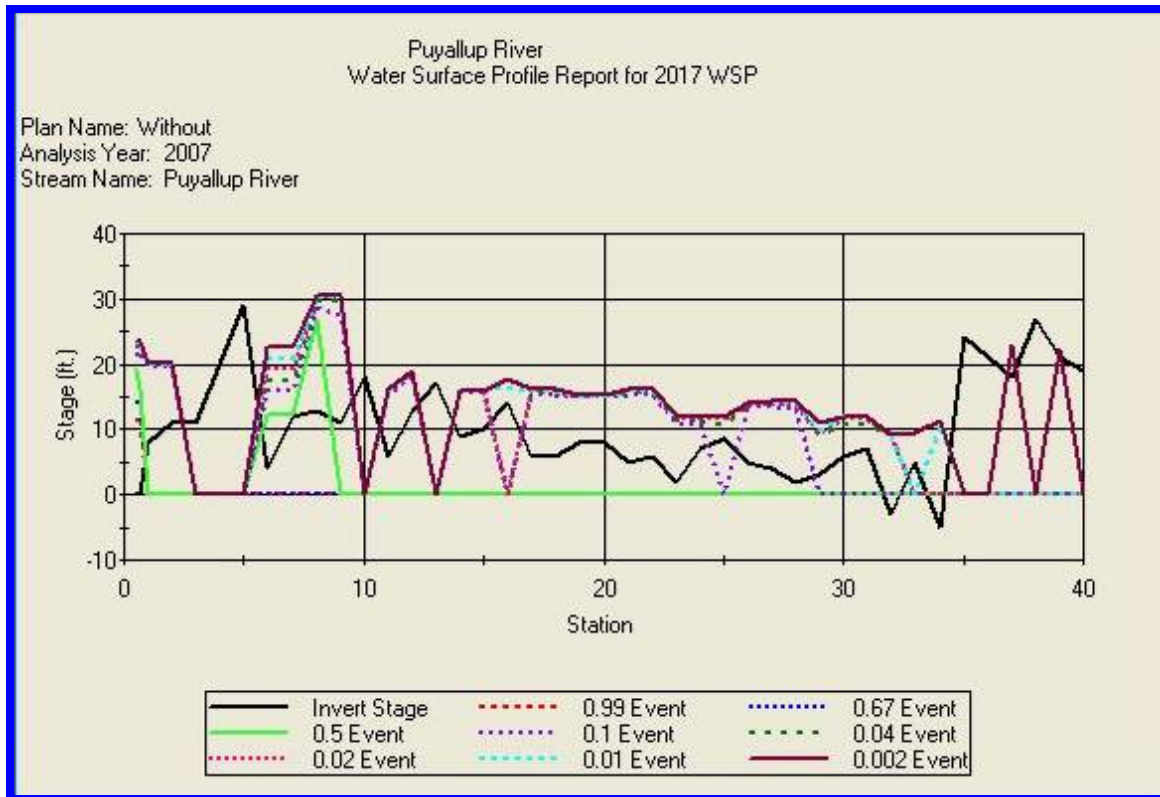
Floodplain Water Surface Elevations

Depths in the floodplain were determined based on water surface elevations for various events for different stations or storage areas. These water surface elevations would vary between existing and future conditions and levee failure assumptions. Below is the existing condition with levee failures up to 3 feet below the top of levee.

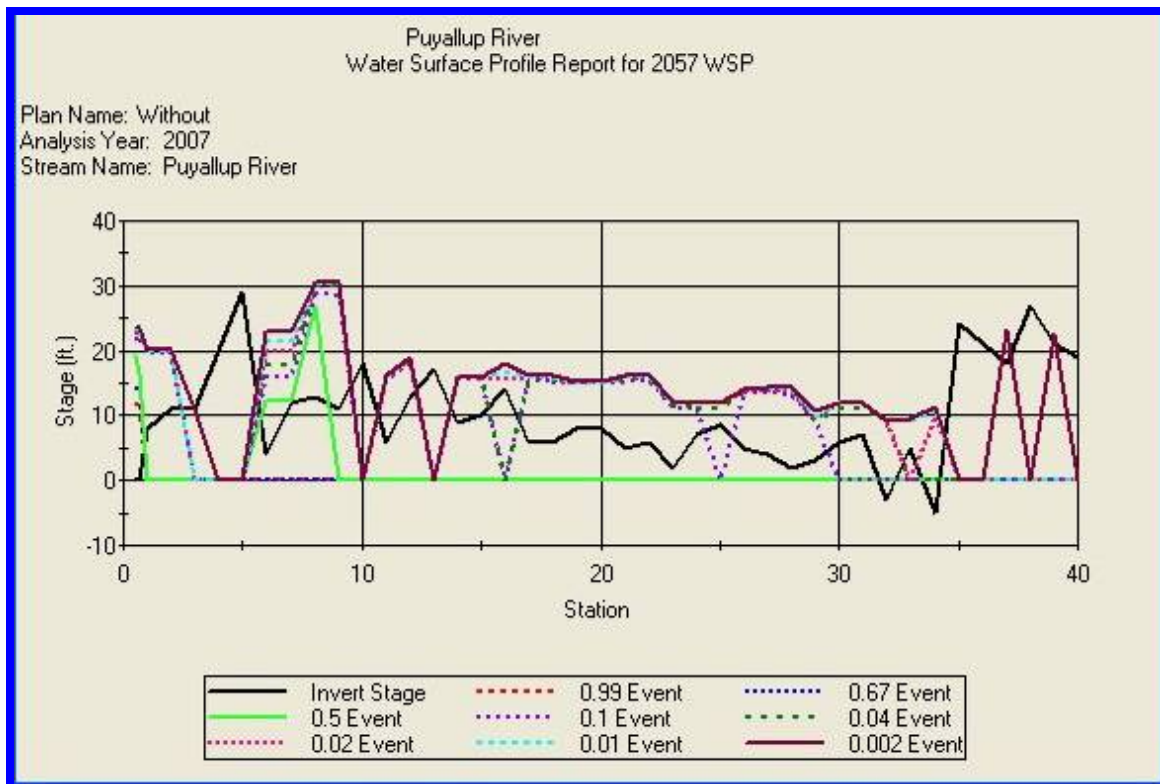
Existing Condition



2017 Condition

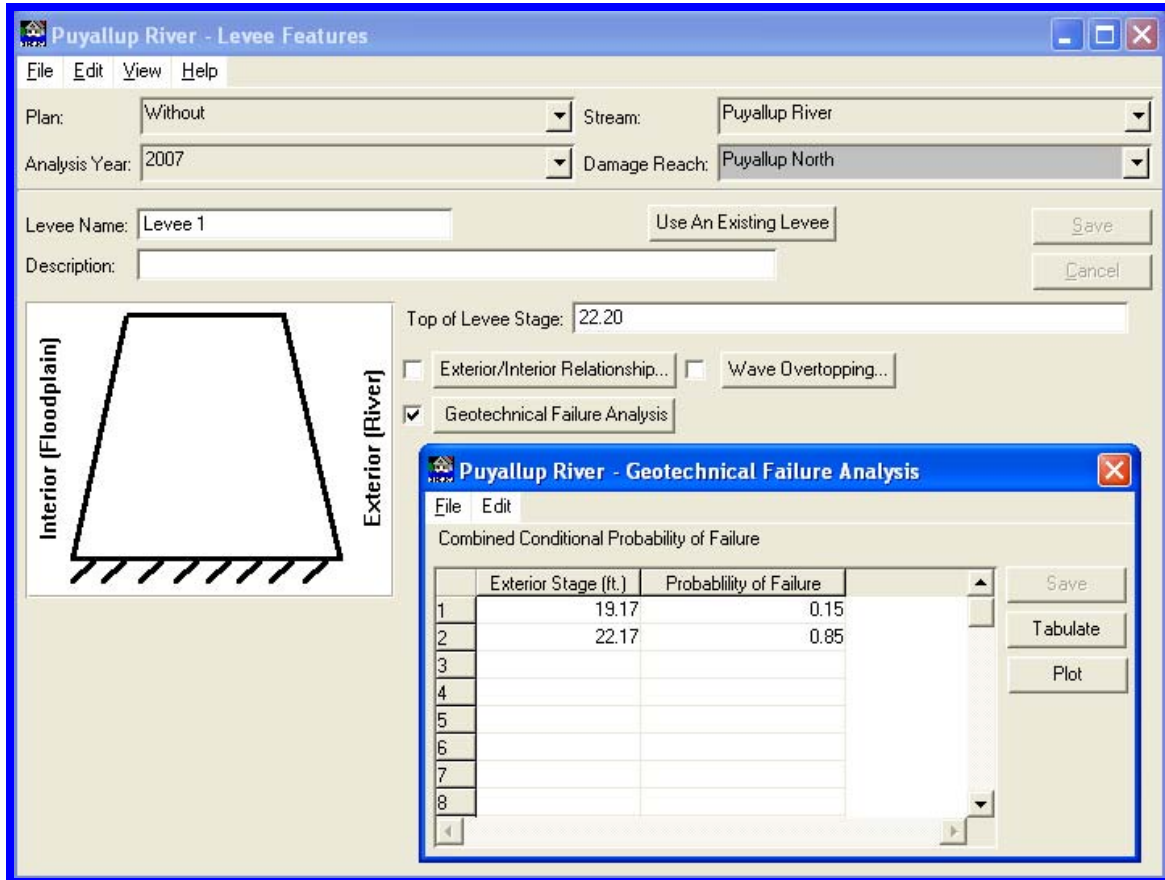


2057 Condition



GEOTECHNICAL

Levee uncertainty was modeled using levee failure probability points (PNP/PFP). The PNP, or probable non-failure point corresponds to the stage where the probability of levee failure is estimated to be 15%. The PFP, or probable failure point corresponds to the stage where the probability of failure is estimated to be 85%. For this study, the levee failure probability points were identified for the right bank (north side of river). Geotechnical analysis indicated that the levees on the left bank (south side of river) were not expected to fail under modeled hydraulic scenarios. These identified right bank levee failure points were assumed to be the same under both existing and future without project conditions.



ECONOMICS

Economic uncertainty in the HEC-FDA model is represented in the stage-damage functions. The model performs a Monte Carlo simulation, integrating the water surface elevation and structural inventory with uncertainties in value, first floor elevation, and percent damage. It calculates an aggregated stage damage function for each category and reach, which has a normal distribution with mean and standard deviation.

The following curves represent existing stage-damage functions for right bank (north) and left bank (south) reaches for: residential, commercial, and industrial as examples. In total, the model was constructed of 144 stage damage functions for the 12 damage categories for each of the six flooding conditions (existing, 2017, 2057 for both levee failure and overtopping) and both reaches.

Puyallup River - Stage-Damage Function at Index Location with Uncertainty

File Edit View Help

Plan: Without Stream: Puyallup River

Analysis Year: 2007 Damage Reach: Puyallup North

Damage Category: Residential

Function: Use An Existing Function

Description:

Define Uncertainty
 None Normal Triangular Log Normal

	Stage (ft.)	Damage (\$1,000's)	Standard Deviation of Error
8	17.00	0.00	0.00
9	18.00	0.00	0.00
10	19.00	0.00	0.00
11	20.00	0.00	0.00
12	21.00	7280.63	1765.71
13	22.00	7730.77	1773.87
14	23.00	8177.46	1776.00
15	24.00	11589.78	1741.83

Plot...
 Tabulate...
 Save
 Cancel

Analysis Year: 2007 Damage Reach: Puyallup South

Damage Category: Residential

Function: Use An Existing Function

Description:

Define Uncertainty
 None Normal Triangular Log Normal

	Stage (ft.)	Damage (\$1,000's)	Standard Deviation of Error
4	13.00	0.00	0.00
5	14.00	0.00	0.00
6	15.00	33.26	15.59
7	16.00	84.10	23.91
8	17.00	173.98	31.36
9	18.00	296.92	34.07
10	19.00	453.28	48.00
11	20.00	690.63	74.60
12	21.00	1169.15	69.70
13	22.00	3248.94	427.18
14	23.00	8648.80	404.90
15	24.00	10856.96	278.79

Plot...
 Tabulate...
 Save
 Cancel

Puyallup River - Stage-Damage Function at Index Location with Uncertainty

File Edit View Help

Plan: Without Stream: Puyallup River

Analysis Year: 2007 Damage Reach: Puyallup North

Damage Category: Commercial

Function: AggDmg008679 Use An Existing Function

Description:

Define Uncertainty
 None Normal Triangular Log Normal

	Stage (ft.)	Damage (\$1,000's)	Standard Deviation of Error
7	16.00	0.00	0.00
8	17.00	0.00	0.00
9	18.00	0.00	0.00
10	19.00	0.00	0.00
11	20.00	4.06	26.75
12	21.00	18679.81	2486.38
13	22.00	25945.36	4559.21
14	23.00	37843.66	6313.89
15	24.00	60861.42	4958.43

Plot...
 Tabulate...
 Save
 Cancel

Analysis Year: 2007 Damage Reach: Puyallup South

Damage Category: Commercial

Function: Use An Existing Function

Description:

Define Uncertainty
 None Normal Triangular Log Normal

	Stage (ft.)	Damage (\$1,000's)	Standard Deviation of Error
4	13.00	0.00	0.00
5	14.00	0.00	0.00
6	15.00	0.06	0.41
7	16.00	0.45	2.25
8	17.00	0.97	3.64
9	18.00	2.80	7.13
10	19.00	6.82	12.46
11	20.00	13.45	16.59
12	21.00	38.17	22.97
13	22.00	134.30	31.15
14	23.00	465.70	72.80
15	24.00	745.89	80.43

Plot...
 Tabulate...
 Save
 Cancel

Puyallup River - Stage-Damage Function at Index Location with Uncertainty

File Edit View Help

Plan: Without Stream: Puyallup River

Analysis Year: 2007 Damage Reach: Puyallup North

Damage Category: Industrial

Function: AggDmg008682 Use An Existing Function

Description:

Define Uncertainty
 None Normal Triangular Log Normal

	Stage (ft.)	Damage (\$1,000's)	Standard Deviation of Error
10	19.00	0.00	0.00
11	20.00	0.00	0.00
12	21.00	34566.23	6343.18
13	22.00	36458.56	6209.26
14	23.00	37640.34	6208.29
15	24.00	41679.23	6451.48

Plot...
 Tabulate...
 Save
 Cancel

Analysis Year: 2007 Damage Reach: Puyallup South

Damage Category: Industrial

Function: Use An Existing Function

Description:

Define Uncertainty
 None Normal Triangular Log Normal

	Stage (ft.)	Damage (\$1,000's)	Standard Deviation of Error
4	13.00	0.00	0.00
5	14.00	0.00	0.00
6	15.00	12.24	16.24
7	16.00	36.61	23.90
8	17.00	59.30	21.57
9	18.00	70.86	18.81
10	19.00	75.11	18.42
11	20.00	76.59	18.53
12	21.00	77.45	18.60
13	22.00	97.15	23.48
14	23.00	137.83	22.14
15	24.00	144.11	22.82

Plot...
 Tabulate...
 Save
 Cancel

SUMMARY RESULTS

The HEC-FDA model provides economic output in the form of Expected Annual Damage (EAD). The model can compute EAD under with-project and without-project conditions and determine 75-percent, 50-percent and 25-percent probability that benefits will exceed the value. In the case of this study, we only have analyzed the without-project condition so the probabilistic benefits are all equal to zero. EAD was computed for both reaches and for the six flooding conditions.

The following are the total results for aggregated damage, including structure, content and auto damage under the existing without-project condition with levee failures.

- Right Bank—\$4,685,040
- Left Bank—\$686,520
- **Total—\$5,371,560**