APPENDIX A
HYDROLOGIC ANALYSIS METHODS AND RESULTS

A.1 HYDROLOGIC INFORMATION

Information on hydrology in the Tucannon River basin was available from multiple stream gages (both on the Tucannon River and its tributaries) and spatially distributed rainfall data. Subbasin delineations were also available for use in estimating discharge contributions from tributaries that are not gaged.

A.1.1 Stream Discharge Data

Stream discharge data were available from three gages on the Tucannon River and its major tributaries. See Figure 3 of the main report for a basin map including stream gage locations. The following sections provide a brief description of the gages used to help evaluate basin hydrology.

A.1.1.1 U.S. Geological Survey Gage near Starbuck, Washington

Discharge data in the Tucannon River near Starbuck were available from the U.S. Geological Survey (USGS) gage #13344500. The gage is located at approximately river mile (RM) 8.2, just downstream of the Smith Hollow road crossing and the confluence of the Smith Hollow tributary. The drainage basin upstream of the gage is approximately 431 square miles. The available period of record for the gage is from October 1, 1914, through September 30, 2010. Three significant data gaps exist in the period of record: one from water years 1918 to 1928, a second from water years 1932 to 1958, and a third from water years 1991 to 1994. A total of 54 water years are available in the gage data. Approved peak steamflow data were available for 53 of the water years (water year 2010 peak streamflow was not approved for publication at the time of this analysis).

A.1.1.2 Department of Ecology Gage near Marengo, Washington

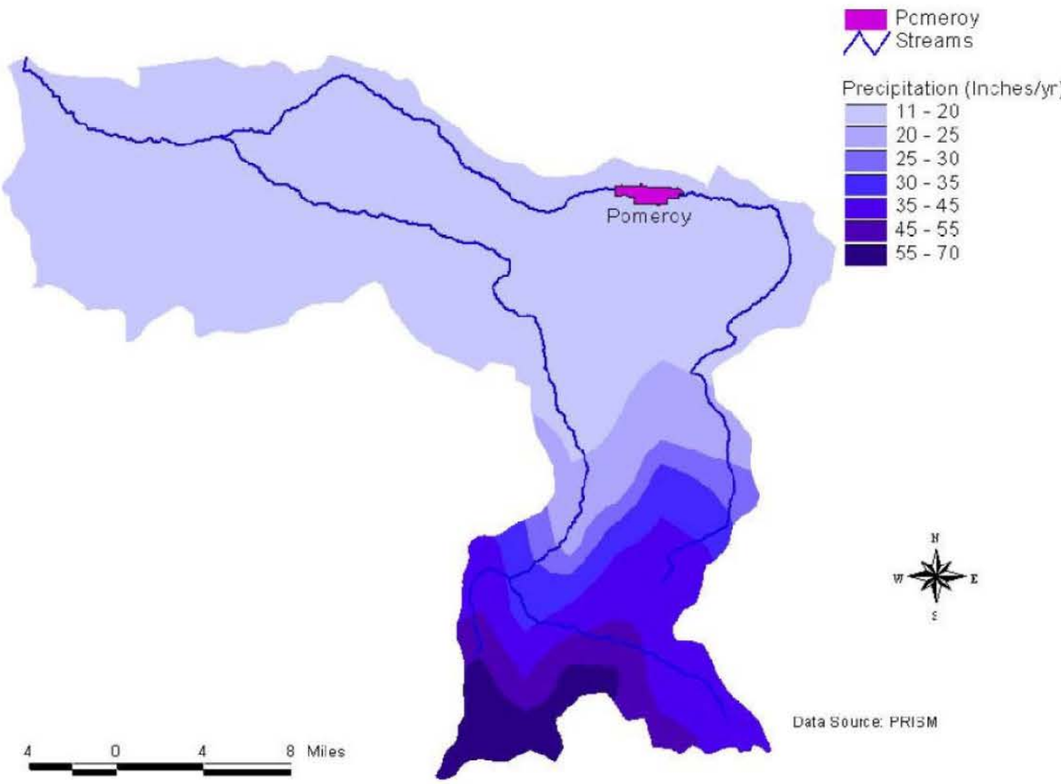
Discharge data in the Tucannon River near Marengo were available from the Washington State Department of Ecology (Ecology) gage 35B150. The gage is located at approximately RM 26.9, just downstream of Marengo and the Turner Road crossing. The drainage basin upstream of the gage is approximately 160 square miles. The available period of record for the gage is from June 2003 to the present. This location was also the site of a former USGS gage (#13344000). The available period of record for the former USGS gage is from water years 1913 to 1930. The data from the former USGS gage were not used in the analysis.

A.1.1.3 Department of Ecology Gage on Pataha Creek near the Mouth

Discharge data in Pataha Creek near the confluence with the Tucannon River were available from Ecology gage 35F050. The gage is located on Pataha Creek at approximately RM 1.2, just downstream of the State Route 261 crossing. Pataha Creek enters the Tucannon River at approximately RM 12.5. The drainage basin upstream of the gage is approximately 184 square miles.

A.1.2 Precipitation Data

Precipitation data for the basin were summarized in the Tucannon Subbasin Plan and were available as geospatial data from PRISM through MGS Engineering Consultants and the Oregon Climate Service (2006). The distribution of precipitation in the basin is highly dependent on elevation. Mean annual precipitation ranges from 10 inches at lower elevations to more than 40 inches at higher elevations. Figure A-1 shows the distribution of mean annual precipitation over the Tucannon River basin (CCD 2004).



Map by Ecopacific as shown in NPPC 2001, Figure 4.

Figure A-1
Mean Annual Precipitation Distribution – Tucannon River Basin

A.1.3 Basin Delineations

Basin and subbasin delineations are available as geospatial data (BLM 2009) for the Tucannon River. These delineations provided information on contributing area, basin shape, slope, and elevation. The major subbasins and gage locations in the Tucannon River basin are listed in Table A-1.

Table A-1

Major Subbasins and Flow Change Locations

Major Tributary/ Location on River	Location (RM)	Tributary Area (sq mi)	Basin Area Above Confluence (sq mi)	Basin Area Below Confluence (sq mi)	Basin Area Increase (sq mi)
Mouth	0	-	504	504.0	14.0
Kellogg Creek	4.8	34.5	455.5	490.0	58.5
Starbuck Gage	8.2	-	431.5	431.5	0.77
Smith Hollow	8.6	20.6	410.1	430.7	25.8
Pataha Creek *(Gaged)*	12.3	184.8	220.1	404.9	189
Willow Creek	14.8	29.9	186.4	216.3	56.3
Marengo Gage	26.9	-	160	160.0	22.2
Tumalum Creek	35.6	16.0	121.8	137.8	19.7
Cummings Creek	37.9	19.9	98.3	118.2	42.1
Little Tucannon R.	48.2	8.4	67.7	76.1	12.4
Panjab Creek	50.2	25.4	38.3	63.7	25.4
Above Panjab Creek	55.2	-	38.3	-	-

Notes:

1. Entries that are not tributaries do not have a tributary area associated with them.
2. Total increase in drainage area includes Tucannon River Valley hill slope area and tributary area.
3. RM = river mile
4. sq mi = square miles

A.2 HYDROLOGIC ANALYSIS

An hydrologic analysis was conducted for the Tucannon River and its major tributaries to develop peak flow hydrology. The goal of the analysis was to provide reasonable estimates of discharge in the river through the study area ranging from the 1- to 100-year return period. The results were then used as flow input to the hydraulic model and also to aid with the processes of reach delineation and characterization.

A.2.1 Flood Magnitude and Frequency Analysis

A flood magnitude and frequency analysis for the Tucannon River was conducted using peak discharge data from the gage at Starbuck. Two methods were used in the selection of the peak discharge event series for the flood magnitude and frequency analysis:

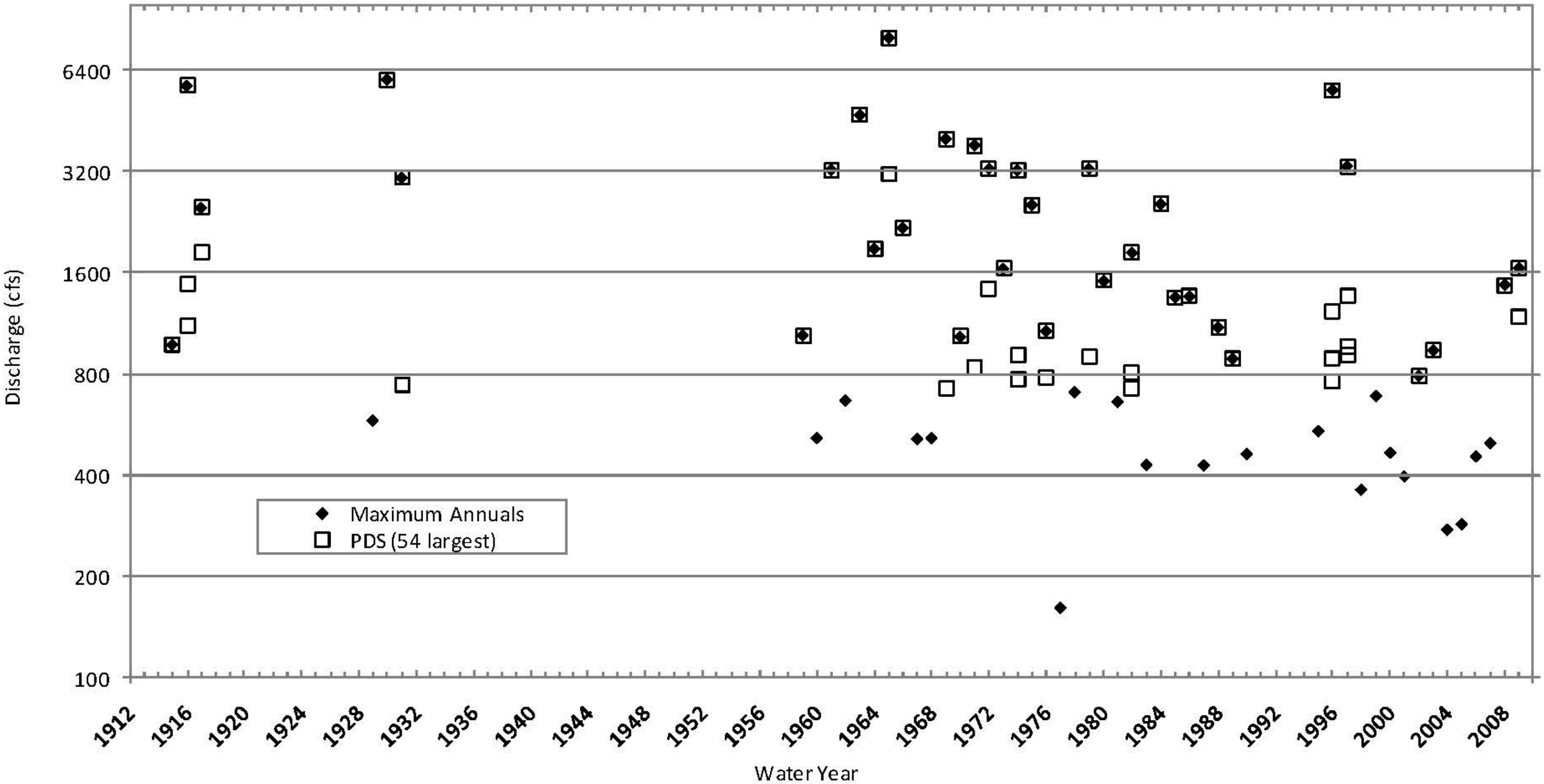
1. The series of annual peak discharges for the period of record.
2. All independent discharge peaks above a threshold of 720 cubic feet per second (cfs). This threshold provided a series of 54 independent flood events (equivalent to the number of years of record). This selection method is also known as a partial duration series (PDS) analysis (Madsen et al. 1997).

The two peak discharge series selection methods were justified given the nature of the basin hydrology (i.e., the occurrence of drought years with no appreciable flood event) and the goals of the analysis. The peak discharges series are shown with respect to water year in Figure A-2. The drought year peak discharges can be seen below the PDS threshold of 720 cfs. Each peak discharge series was used to develop a Log-Pearson Type III (LP3) exceedance probability curve. Overall, the PDS method typically provides larger peak discharges for the more frequent events (i.e., 1- and 2-year return periods) while only providing slightly smaller peak discharges for the less frequent flood events when compared to using the annual peak discharge series method. The results of the LP3 analysis using both data sets are shown in Table A-2 and in Figure A-3.

Table A-2

Flood Magnitude and Frequency at the Starbuck Gage

Return Period (yr)	Annual Exceedance Probability	LP3, Annual Peaks Peak Discharge (cfs)	LP3, Peaks Over Threshold Peak Discharge (cfs)	Percent Difference
1	100%	147	484	230%
2	50%	1,183	1,517	28%
5	20%	2,640	2,743	4%
10	10%	4,057	3,898	-4%
25	4%	6,465	5,861	-9%
50	2%	8,775	7,770	-11%
100	1%	11,583	10,140	-12%



B:\Projects\0687_ColumbiaConservationDistrict\100687-01.01_TucannonRiver\Eval_and_Calcs\Hydrology\Peak_Flow_Hydrology_2.xlsx

Notes:

1) Annual peak discharges from USGS gage 13344500 for the approved period of record (1915-2009).
2) Partial Duration Series (PDS) is the 54 largest events in the period of record. The PDS method is also known as the Peaks Over Threshold method. A partial-duration flood series is a list of all flood peaks that exceed a chosen base stage or discharge, regardless of the number of peaks occurring in a year (also called basic-stage flood series, or floods above a base).

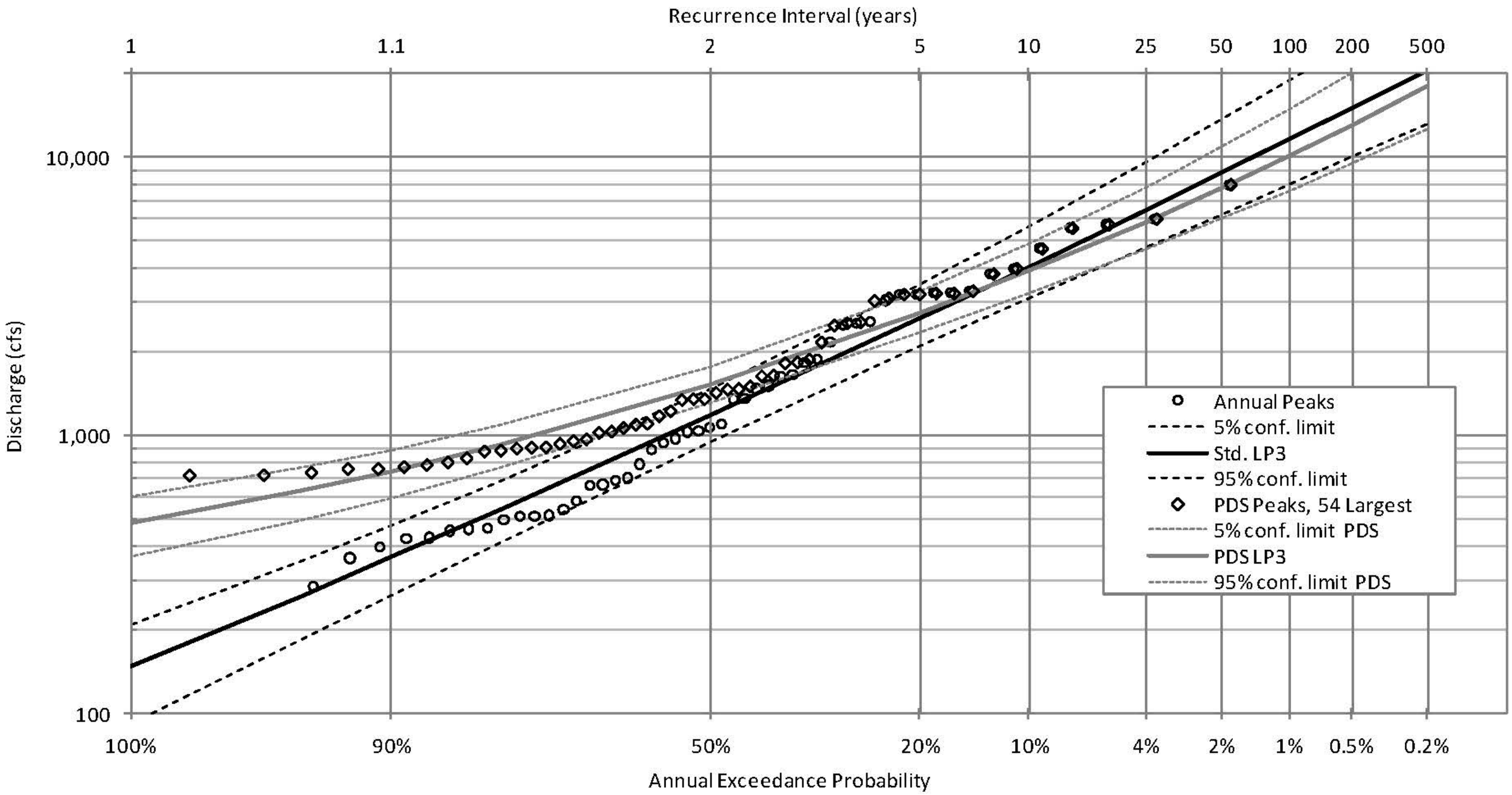
ANCHOR QEA

Figure A-2

Historical Peak Discharges – Tucannon River at Starbuck

Tucannon River Geomorphic Assessment and Habitat Restoration Study

Columbia Conservation District



Notes:

1) Annual peak discharges from USGS gage 13344500 for the approved period of record (1915-2009).
2) The Log Pearson Type 3 (LP3) analysis is for all annual peaks using HEC-SSP software.
3) Washington State Stream Stats regressions for the drainage area.
4) Partial Duration Series (PDS) is the 54 largest events in the period of record.
5) The LP3 analysis is for the PDS using HEC-SSP software.
6) Also shown for each analysis are the 5% and 95% confidence limits.

B:\Projects\0687_ColumbiaConservationDistrict\100687-01.01_TucannonRiver\Eval_and_Calcs\Hydrology\Peak_Flow_Hydrology_2.xlsx

Figure A-3

Flood Frequency Analysis – Tucannon River at Starbuck

Tucannon River Geomorphic Assessment and Habitat Restoration Study

Columbia Conservation District

ANCHOR QEA

It is important to note the large difference in the peak discharge between the LP3 analysis using the annual peaks series and the PDS for the 1-year return period. Using the annual peak discharges series for the LP3 analysis yields a 1-year return period discharge less than the mean annual discharge. However, using the PDS method for the LP3 analysis yields a 1-year return period discharge roughly 3 times the magnitude of the mean annual discharge. This difference is the result of drought years in the annual peak discharge series and the absence of small peak discharges from drought years in the PDS method. As the exceedance probability decreases, the results of the two methods become more similar, with the PDS method providing a slightly smaller discharge for return periods longer than 5 years.

For the 1-year return period, the peak discharge from the LP3 analysis using the PDS was used for subsequent analysis. For the 2-, 5-, 10-, 25-, and 100-year return period, the peak discharges from the LP3 analysis using the annual peak discharge series were used for subsequent analysis.

A.2.2 Basin Area Discharge Scaling

To calculate the discharge contributions for ungaged flow change locations on the Tucannon River, the basin area scaling method developed by Thomas et al. (1994) and referenced in the USGS Fact Sheet *Methods for Estimating Flood Magnitude and Frequency in Washington* (2001) was used. Thomas' basin area scaling method (Equation A-1) uses the basin area proportions and a regional exponent to scale discharges from a gaged location to an ungaged location. The method is suitable for ungaged basins with a basin area between 50 and 150% of the gaged location basin area.

$$Q_u = Q_g \left(\frac{A_u}{A_g}\right)^x \qquad \text{(A-1)}$$

where:

Q_u	=	is the peak discharge, in cfs, at the ungaged site for a specific recurrence interval
Q_g	=	is the peak discharge, in cfs, at the gaged site for a specific recurrence interval
A_u	=	is the contributing drainage area, in square miles, at the ungaged site
A_g	=	is the contributing drainage area, in square miles, at the gaged site

x = is the exponent for the region in which both sites are located

The regional exponent (x) for the Tucannon River basin is 0.59 (Table 3, USGS 2001). The results of this method applied to the major tributary basin areas are shown in Table A-3 as flow proportion percentages.

It should be noted that several ungaged flow change locations in the upper basin are less than 50% of the gage location's basin area. These estimates are beyond the recommended limitations of the method and should therefore be compared with other methods for determining basin contributions including stream gage data correlations.

A.2.3 Stream Gage Correlations

To improve the flow estimates provided by the basin area scaling method, correlations between discharge at the Starbuck gage and two other gages (Marengo and Pataha) were made. Although the period of record at these gages is not sufficiently long to conduct a flood frequency analysis using the LP3 method, the gage data were sufficient to develop reasonable discharge correlations to the gage at Starbuck. To develop the correlation, mean daily discharges at the Marengo and Pataha Creek gages were plotted against mean daily discharges greater than or equal to 400 cfs at the Starbuck gage and a linear trend line with an origin of (0,0) was fit to the data. These correlations showed that:

- Discharge at the Marengo gage was typically 87% of the discharge at the Starbuck gage (Figure A-4)
- Discharge at the Pataha Creek gage was typically 11% of the discharge at the Starbuck gage (Figure A-5)

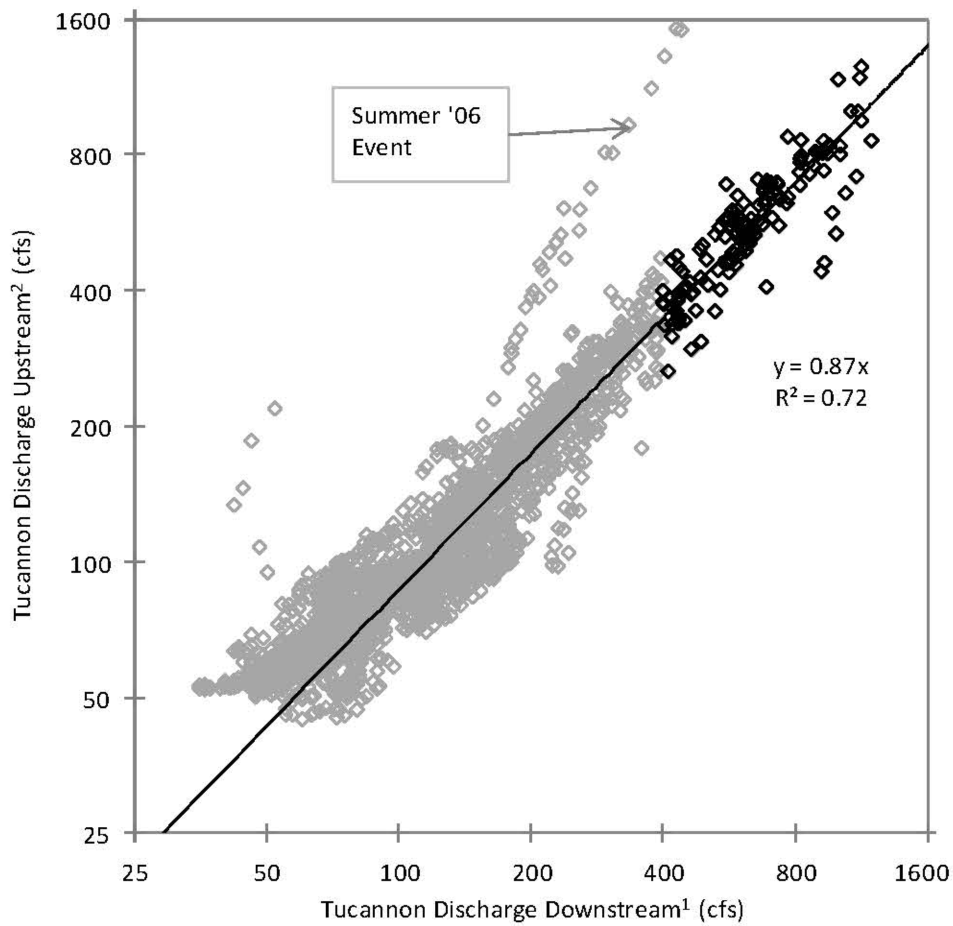
The results of applying these gage correlation corrections to the basin area scaling method are shown in the column titled "Flow as % of Starbuck, w/ gage corrections" in Table A-3 as flow proportion percentages. The table also shows the difference in flow proportions between the basin area scaling method and the gage correlation corrections to the basin area scaling method. The flow change locations and discharge contributions are also shown in Figures A-6 and A-7 with respect to RM.

Table A-3

Flow Change Locations Discharge Proportions

Major Tributary/ Location on River	Thomas (1994) flow proportion as % of Starbuck	Flow as % of Marengo[5]	Flow as % of Starbuck, w/ gage corrections	Difference in Proportion
Kellogg Creek	108%	-	108%	0%
Starbuck Gage	100%	-	100%	0%
Smith Hollow[1,3]	100%	-	100%	0%
Pataha Creek[2]	96%	-	99%	3%
Willow Creek[3]	67%	-	88%	21%
Marengo Gage[4,5]	56%	100%	87%	31%
Tumalum Creek	51%	92%	80%	29%
Cummings Creek	47%	84%	73%	26%
Little Tucannon R.	36%	64%	56%	20%
Panjab Creek	32%	58%	51%	18%
Above Panjab Creek	24%	43%	37%	13%

Notes:
1. For the purposes of modeling, the discharge downstream of Smith Hollow was assumed to be equivalent to the discharge at the Starbuck gage.
2. The gage correlation correction for Pataha Creek is 11% of the discharge at Starbuck.
3. The remainder of the discharge proportion for the gage correction method was split evenly between Smith Hollow and Willow Creek, with both tributaries accounting for 1% of the discharge at the Starbuck gage.
4. The gage correlation correction for the Marengo gage is 87% of the discharge at Starbuck.
5. Proportioning of the discharge at Marengo to tributaries used Thomas' basin area scaling method with Marengo as the gaged location.



Notes:

1) Discharge at the USGS Starbuck Gage (13344500), RM 8.6, drainage area 431.5 sq mi
2) Discharge at the Ecology Marengo Gage (35B150), RM 26.9, drainage area 160 sq mi
3) Grey data points are not included in the regression; these are discharges less than 400 cfs at the Starbuck gage.

B:\Projects\0687_ColumbiaConservationDistrict\100687-01.01_TucannonRiver\Eval_and_Calcs\Hydrology\Annual_Flow_Analysis_Tucannon_R.xlsx

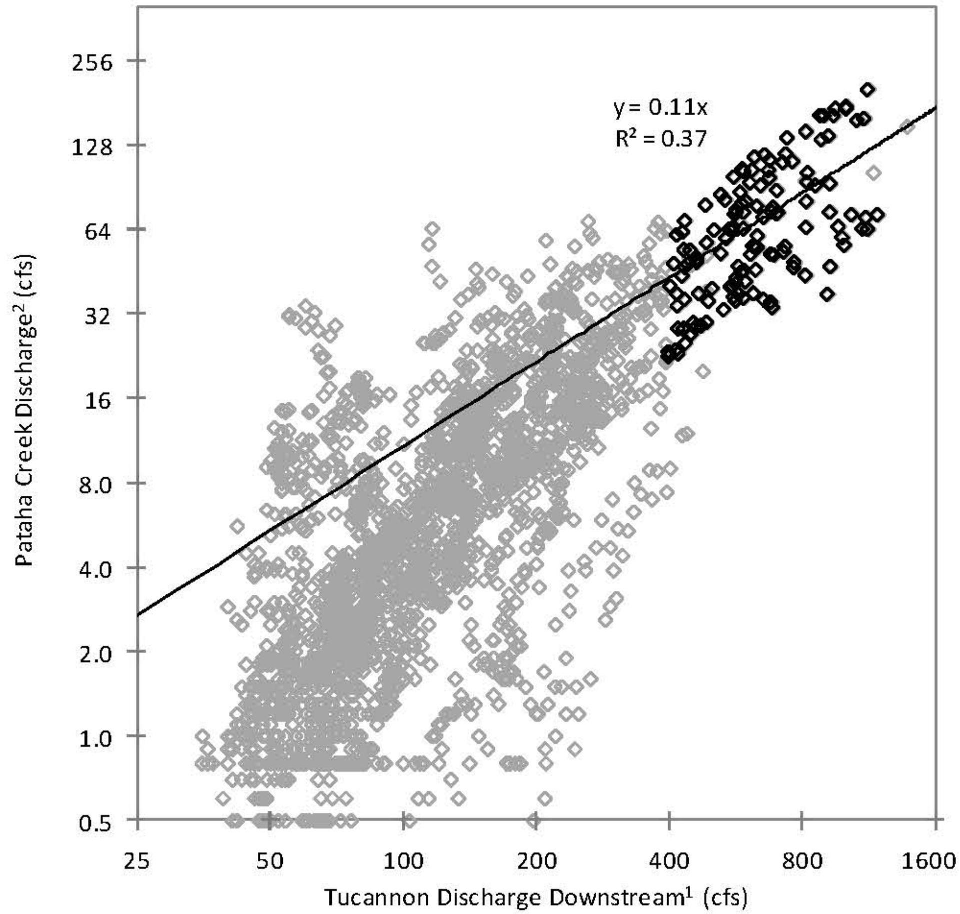
ANCHOR QEA

Figure A-4

Discharge Correlations – Starbuck and Marengo Gages

Tucannon River Geomorphic Assessment and Habitat Restoration Study

Columbia Conservation District



Notes:

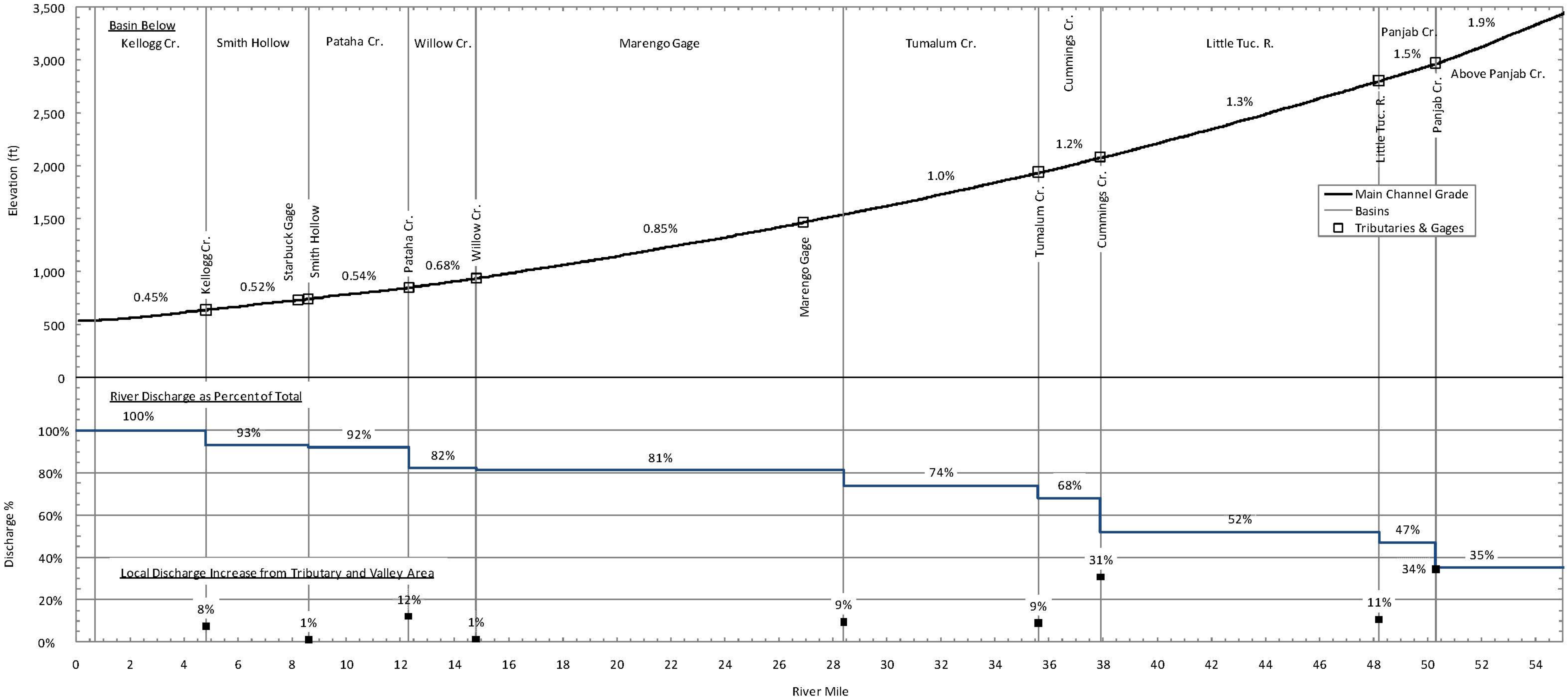
1) Discharge at the USGS Starbuck Gage (13344500), RM 8.6, drainage area 431.5 sq mi
2) Discharge in Pataha Creek at Ecology Gage (35F050), drainage area 184.8 sq mi
3) Grey data points are not included in the regression; these are discharges less than 400 cfs at the Starbuck gage.

Figure A-5

Discharge Correlations – Tucannon River at Starbuck and Pataha Creek Gages

Tucannon River Geomorphic Assessment and Habitat Restoration Study

Columbia Conservation District



Notes:

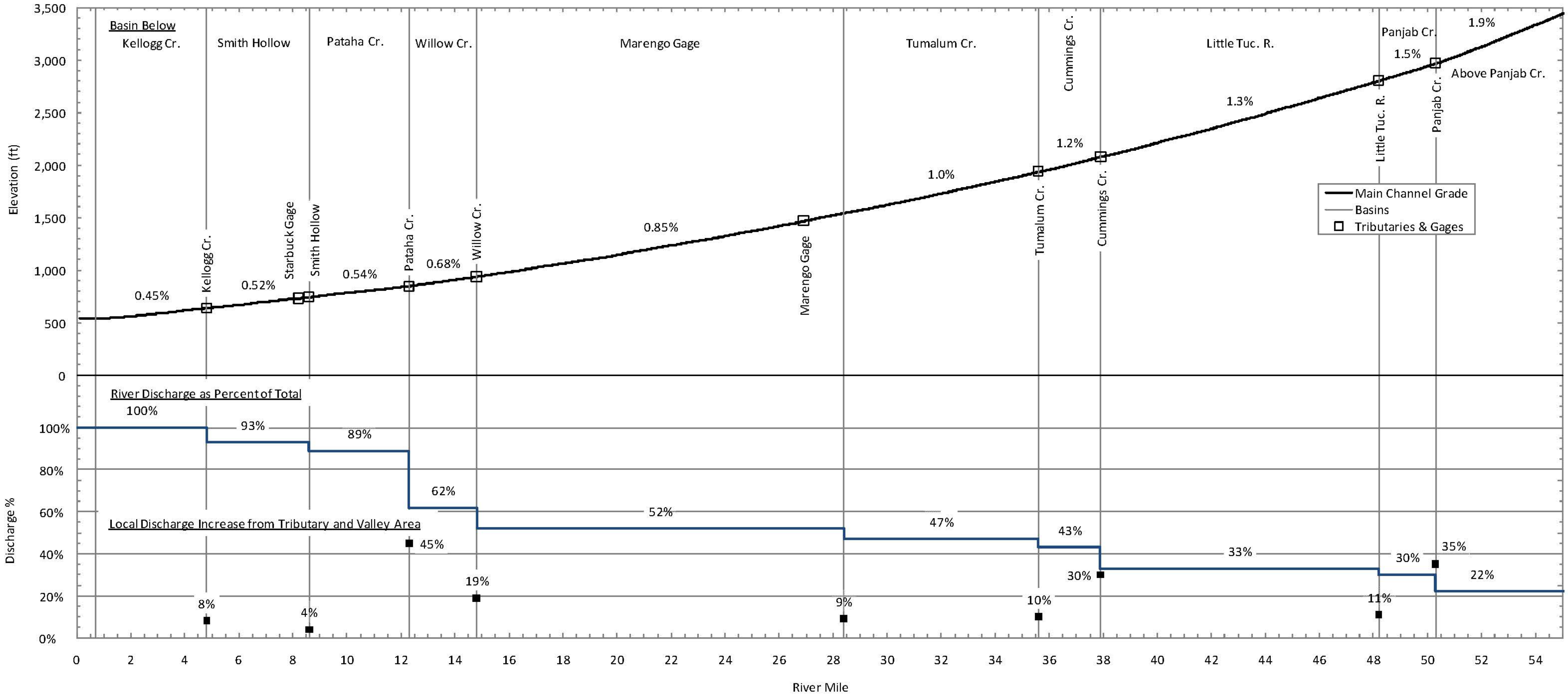
1) Notes Main channel grade elevation based on aerial LiDAR from 2010
2) River stationing developed by Anchor QEA (2010) using aerial photography for channel centerline delineation
3) Slope shown for each basin is the average channel slope calculated at 100 ft intervals
4) For additional information on discharge increase from tributaries and hills slopes see discussion in the text

B:\Projects\Columbia Conservation District\Tucannon River (100687-01.01)\Eval_and_Calcs\Reach Delineation\Reach-Basin_Slopes.xlsx

ANCHOR QEA

Figure A-6

Tucannon River Hydrology – Flow Change Locations and Discharge Contributions (Higher Flow Values)
Tucannon River Geomorphic Assessment and Habitat Restoration Study
Columbia Conservation District



Notes:

1) Notes Main channel grade elevation based on aerial LiDAR from 2010
2) River stationing developed by Anchor QEA (2010) using aerial photography for channel centerline delineation
3) Slope shown for each basin is the average channel slope calculated at 100 ft intervals
4) For additional information on discharge increase from tributaries and hills slopes see discussion in the text

B:\Projects\0687_ColumbiaConservationDistrict\100687-01.01_TucannonRiver\Eval_and_Calcs\Sed_Trans\Sed_Mob_Plots_all_w_Confine-Reaches.xlsx

ANCHOR QEA

Figure A-7
Tucannon River Hydrology – Flow Change Locations and Discharge Contributions (Lower Flow Values)
Tucannon River Geomorphic Assessment and Habitat Restoration Study
Columbia Conservation District

Table A-3 shows the basin area scaling method's underestimation of the discharge at Marengo and overestimation of discharge from Pataha Creek. The differences can be attributed to differences in the shape of the contributing areas and the distribution of mean annual precipitation in the basins. Although the Pataha Creek subbasin comprises approximately 43% of the contributing area to the Tucannon River at the Starbuck gage, it produces a significantly smaller percentage of the discharge as shown by the gage data correlation. Two primary factors reduce the relative discharge contribution of Pataha Creek:

- The long and narrow shape of the Pataha Creek basin is not conducive to producing large peak discharges.
- The Pataha Creek basin receives less precipitation per area compared to the upper portion of the Tucannon River. For example, only 8.8% of the Pataha Creek subbasin receives more than 30 inches of precipitation per year, compared to nearly 59% of the Tucannon River Basin above Pataha Creek.

The stream gage correlation results are consistent with previously published hydrologic analysis results (Hecht et al. 1982). Hecht et al. focused on a single water year (1980) and found that, relative to total average annual flow at the Starbuck gage, Pataha Creek contributed approximately 11% of the average annual flow while the Tucannon basin upstream of Pataha Creek contributed approximately 85% of the flow.

A.2.4 Model Discharges

Given the uncertainty in both the flood magnitude and frequency analysis and the proportioning of discharge to ungaged tributaries, the hydraulic model was run using a higher and lower discharge for the selected return periods.

The higher discharges values were calculated for the flow change locations using the basin area scaling method (Thomas et al. 1994) with corrections for flow contribution at known locations and allocation of remaining flows between flow correction locations. This process set the discharge in the Tucannon River at the Marengo gage to 87% of the discharge at the Starbuck gage. It also reduced to contribution of Pataha Creek to only 11% of the discharge at the Starbuck gage. These modifications to the basin area scaling method allocated a larger proportion of the discharge to the wetter upper portions of the basin.

The lower discharges values were calculated for the flow change location using only the basin area scaling method (Thomas et al. 1994) without corrections for flow contribution at known locations. This process estimated the discharge in the Tucannon River at the Marengo gage to be 56% of the discharge at the Starbuck gage. It also estimated the contribution of Pataha Creek to be 29% of the discharge at the Starbuck gage. The basin area scaling method distributed the discharge contributions evenly based exclusively on basin area without regard for variation in precipitation. Compared to the method used to develop the higher discharges, this method reduced the discharge in the upper portions of the river and increased the contribution of lower elevation tributaries.

The discharges used in the hydraulic model are shown in Tables A-4 and A-5. These discharges allow the examination of a wide range of hydraulic conditions along the length of the Tucannon River while representing uncertainties in basin hydrology.

Table A-4
Higher Flood Discharges Values (cfs)

Flow Change (RM)	Tributary/Location Name	Return Period (years)						
		1	2	5	10	25	50	100
4.8	Kellogg Creek	522	1,275	2,845	4,373	6,969	9,458	12,485
8.6	Smith Hollow[1]	484	1,183	2,640	4,057	6,465	8,775	11,583
12.3	Pataha Creek	479	1,171	2,613	4,016	6,401	8,687	11,467
14.8	Willow Creek	426	1,041	2,323	3,570	5,689	7,722	10,193
28.4	Marengo Gage[2]	421	1,029	2,296	3,529	5,625	7,634	10,077
35.6	Tumalum Creek	386	943	2,103	3,232	5,151	6,991	9,228
37.9	Cummings Creek	352	861	1,920	2,951	4,704	6,384	8,427
48.2	Little Tucannon R.	272	664	1,481	2,276	3,627	4,923	6,498
50.2	Panjab Creek	245	598	1,334	2,050	3,267	4,433	5,852
55.2	Above Panjab	181	443	988	1,518	2,420	3,284	4,335

Table A-5
Lower Flood Discharges Values (cfs)

Flow Change (RM)	Tributary/Location Name	Return Period (years)						
		1	2	5	10	25	50	100
4.8	Kellogg Creek	522	1,275	2,845	4,373	6,969	9,458	12,485
8.6	Smith Hollow[1]	484	1,183	2,640	4,057	6,465	8,775	11,583
12.3	Pataha Creek	466	1,140	2,542	3,907	6,227	8,451	11,156
14.8	Willow Creek	322	787	1,756	2,699	4,301	5,838	7,706
28.4	Marengo Gage[2]	270	659	1,470	2,259	3,601	4,887	6,451
35.6	Tumalum Creek	247	604	1,346	2,069	3,297	4,475	5,907
37.9	Cummings Creek	225	551	1,229	1,889	3,011	4,087	5,394
48.2	Little Tucannon R.	174	425	948	1,457	2,322	3,151	4,160
50.2	Panjab Creek	157	383	854	1,312	2,091	2,838	3,746
55.2	Above Panjab	116	283	632	972	1,549	2,102	2,775

Notes:
1. For the purposes of modeling, the discharge downstream of Smith Hollow was assumed to be equivalent to the discharge at the Starbuck gage.
2. The flow change location for the Marengo gage was moved up to RM 28.4 to better model the increase in discharge near the Marengo gage.

A.2.5 Basin Data Tables and Plots

Full reporting of the basin and tributary hydrology is provided in Tables A-6 and A-7. Table A-6 presents the basin data using the higher flood discharge values and Table A-7 presents the basin data using the lower flood discharge values. The tables provide additional information on flow change locations and conditions in the Tucannon River between flow change locations. Additional information includes:

- The reach where the flow change occurs
- The elevation of the flow change location
- The main channel gradient between flow change locations
- The change in river discharge as the proportion of the total, increase of total, and local increase
- The slope discharge product for the 2-, 10-, and 100-year return period discharge

The information presented in these tables was used in reach delineation and descriptions (see Appendix D). Information presented in these tables is also displayed in Figures A-6 and A-7 for the higher and lower discharges, respectively.

Table A-6
Basin Data Table – Higher Discharge Values

Reach	Flow Change Location (RM)[1,2]	Flow Change Name	Drainage Area (mi^2) Tributary Only	Drainage Area (mi^2) Tucannon Above Tributary	Drainage Area (mi^2) Tucannon Below Tributary	Drainage Area (mi^2) Total Increase[3]	Elevation[4] (ft)	Channel Gradient (ft/ft)[5]	Return Period Peak Discharge (cfs) 2-year	Return Period Peak Discharge (cfs) 10-year	Return Period Peak Discharge (cfs) 100-year	Change in Tucannon Discharge Proportion of Total	Change in Tucannon Discharge Increase of Total	Change in Tucannon Discharge Local Increase	Slope Discharge Product, 2-year (cfs)	Slope Discharge Product, 10-year (cfs)	Slope Discharge Product, 100-year (cfs)
1	0	*Mouth*[6]	-	504	504	14.0	540	0.00	1,275	4,373	12,485	100%	-	-	0.00	0.00	0.00
3	4.8	Kellogg Cr.	34.5	456	490	58.5	638	0.0045	1,275	4,373	12,485	100%	7%	8%	5.68	19.5	55.6
3	8.2	*Starbuck Gage*	-	432	432	0.77	731	0.0052	1,183	4,057	11,583	93%	0%	0%	6.15	21.1	60.2
3	8.6	Smith Hollow	20.6	410	431	25.8	744	0.0049	1,183	4,057	11,583	93%	1%	1%	5.79	19.9	56.7
4	12.3	Pataha Cr.	185	220	405	189	848	0.0054	1,171	4,016	11,467	92%	10%	12%	6.36	21.8	62.3
5	14.8	Willow Cr.	29.9	186	216	56.3	939	0.0068	1,041	3,570	10,193	82%	1%	1%	7.03	24.1	68.8
7	28.4	*Marengo Gage*	-	160	160	22.2	1,549	0.008	1,029	3,529	10,077	81%	7%	9%	8.70	29.8	85.2
8	35.6	Tumalum Cr.	16.0	122	138	19.7	1,942	0.010	943	3,232	9,228	74%	6%	10%	9.63	33.0	94.3
8	37.9	Cummings Cr.	19.9	98.3	118	42.1	2,083	0.012	861	2,951	8,427	68%	15%	30%	10.3	35.3	101
10	48.2	Little Tuc. R.	8.36	67.7	76.1	12.4	2,806	0.013	664	2,276	6,498	52%	5%	11%	8.80	30.2	86.1
10	50.2	Panjab Cr.	25.4	38.3	63.7	25.4	2,973	0.015	598	2,050	5,852	47%	12%	35%	8.95	30.7	87.6
10	55.2	*Above Panjab*	-	38.3	-	-	3,469	0.019	443	1,518	4,335	35%	-	-	8.50	29.1	83.2

Notes:
1. Flow change locations are reported to the nearest tenth of a mile.
2. River miles (RM) are based on 2010 main channel center line alignment as delineated by Anchor QEA using aerial photographs.
3. Total increase in drainage area includes Tucannon River Valley hill slope area and tributary area.
4. Elevations are from 2010 Aerial LiDAR bare earth returns.
5. Slope for basins is the averaged 100-foot channel segment gradient below the flow change location to the next flow change location.
6. Although total drainage area increases by 14 square miles between Kellogg Creek and the mouth of the river, no appreciable increase in peak discharge is expected from the valley wall slopes.

Table A-7

Basin Data Table - Lower Discharge Values

Reach	Flow Change Location (RM)[1,2]	Flow Change Name	Drainage Area (mi^2) Tributary Only	Tucannon Above Tributary	Tucannon Below Tributary	Total Increase[3]	Elevation[4] (ft)	Channel Gradient (ft/ft)[5]	Return Period Peak Discharge (cfs) 2-year	10-year	100-year	Change in Tucannon Discharge Proportion of Total	Increase of Total	Local Increase	Slope Discharge Product, 2-year (cfs)	Slope Discharge Product, 10-year (cfs)	Slope Discharge Product, 100-year (cfs)
1	0	*Mouth*[6]	-	504	504	14.0	540	0.00	1,275	4,373	12,485	100%	-	-	0.00	0.0	0.0
3	4.8	Kellogg Cr.	34.5	456	490	58.5	638	0.0045	1,275	4,373	12,485	100%	7%	8%	5.68	19.5	55.6
3	8.2	*Starbuck Gage*	-	432	432	0.77	731	0.0052	1,183	4,057	11,583	93%	0%	0%	6.15	21.1	60.2
3	8.6	Smith Hollow	20.6	410	431	25.8	744	0.0049	1,183	4,057	11,583	93%	3%	4%	5.79	19.9	56.7
4	12.3	Pataha Cr.	185	220	405	189	848	0.0054	1,140	3,907	11,156	89%	28%	45%	6.20	21.2	60.6
5	14.8	Willow Cr.	29.9	186	216	56.3	939	0.0068	787	2,699	7,706	62%	10%	19%	5.31	18.2	52.0
7	28.4	*Marengo Gage*	-	160	160	22.2	1,549	0.008	659	2,259	6,451	52%	4%	9%	5.57	19.1	54.5
8	35.6	Tumalum Cr.	16.0	122	138	19.7	1,942	0.010	604	2,069	5,907	47%	4%	10%	6.17	21.1	60.3
8	37.9	Cummings Cr.	19.9	98.3	118	42.1	2,083	0.012	551	1,889	5,394	43%	10%	30%	6.58	22.6	64.5
10	48.2	Little Tuc. R.	8.36	67.7	76.1	12.4	2,806	0.013	425	1,457	4,160	33%	3%	11%	5.63	19.3	55.1
10	50.2	Panjab Cr.	25.4	38.3	63.7	25.4	2,973	0.015	383	1,312	3,746	30%	8%	35%	5.73	19.6	56.1
10	55.2	*Above Panjab*	-	38.3	-	-	3,469	0.019	283	972	2,775	22%	-	-	5.43	18.7	53.2

Notes:
1. Flow change locations are reported to the nearest tenth of one mile.
2. River miles (RM) are based on 2010 main channel center line alignment as delineated by Anchor QEA using aerial photographs.
3. Total increase in drainage area includes Tucannon River Valley hill slope area and tributary area.
4. Elevations are from 2010 Aerial LiDAR bare earth returns.
5. Slope for basins is the averaged 100 feet channel segment gradient below the flow change location to the next flow change location.
6. Although total drainage area increases by 14 square miles between Kellogg Creek and the mouth of the river, no appreciable increase in peak discharge is expected from the valley wall slopes.

A.3 REFERENCES

BLM (Oregon Bureau of Land Management), 2009. Watershed Boundaries Oregon and Washington. GIS Shapefile.

CCD (Columbia Conservation District), 2004. *Tucannon Subbasin Plan.* Prepared for Northwest Power and Conservation Council. May 2004.

Hecht, B., R. Enkelboll, C. Ivor, P. Baldwin, 1982. Sediment transport, water quality, and changing bed conditions, Tucannon River, southeastern Washington. Report prepared for the USDA Soil Conservation Service, Spokane, WA, April 1982.

Madsen, H., P. F. Rasmussen, and D. Rosbjerg, 1997. *Comparison of annual maximum series and partial duration series methods for modeling extreme hydrologic events: 1. At-site modeling*, Water Resources Research, 33(4), 747–757.

MGS Engineering Consultants and Oregon Climate Service, 2006. *Precipitation Intensity Cells for Washington State*. Raster Digital Data, Mean Annual Precipitation. Available at: http://www.prism.oregonstate.edu/

NPPC (Northwest Power Planning Council), 2001. Map by Ecopacific, Figure 4. Portland, Oregon.

Thomas, B.E., Hjalmarson, H.W., and Waltemeyer, S.D., 1994. *Methods for estimating magnitude and frequency of floods in southwestern United States*. U.S. Geological Survey Open- File Report 93-419, 211 p.

USGS (U.S. Geological Survey), 2001. Fact Sheet on *Methods for Estimating Flood Magnitude and Frequency in Washington*.

APPENDIX B
SEDIMENT TRANSPORT AND MOBILITY ANALYSIS METHODS AND RESULTS