# Appendix C
# Hydrologic Analysis Methods and Results

This appendix describes the methods used to develop the hydrology for the Touchet River HEC-RAS model. Flood recurrence intervals for the 2-, 5-, 10-, 25-, 50-, and 100-year events were estimated using data from the U.S. Geological Survey (USGS) StreamStats database (USGS 2019a). The gage data for this basin were limited and incomplete, with some gages only having records in the mid-1900s and some with data dating back only 10 to 15 years. Due to the lack of a complete hydrology data set, the entire model hydrology was developed using the regressions in the USGS StreamStats database (USGS 2019a).

## 1.1 Hydrologic Data

### *1.1.1 Stream Gage Data*

The streamflow gages on the Touchet River provided an incomplete set of flow data with data from the mid-1900s and the past 15 years. The potential sources of discharge data are shown in Table C-1. In addition to discontinuity, the more recent data provided by the Washington State Department of Ecology (Ecology) gages were inaccurate for the highest flows, which are needed to statistically determine flood recurrence intervals. Inaccuracy in peak flow measurements was related to high water levels. Ecology reports that nearly all the yearly and monthly peak data points at these gages were above the rating and were either extrapolated or estimated (Ecology 2019). The available hydrologic data, therefore, did not provide a sufficiently continuous or accurate data set to develop flood recurrence intervals.

**Table C-1**
**Touchet River Hydrologic Data Sources**

| Data Source | | Data Type | Data Timeframe |
|---|---|---|---|
| USGS Gages (USGS 2019b) | 14017000 Touchet River @Bolles | Daily Data | 2/01/1924 to 10/10/1989 |
| | 14016500 North Fork Touchet Near Dayton | Daily Data | 4/01/1941 to 9/29/1968 |
| Ecology Gages (Ecology 2019) | 32B100 Touchet River @ Bolles[1] | 15-Minute Data | 6/2002 to 11/2002 and 1/2007 to Present |
| | 32E050 NF Touchet above Dayton | 15-Minute Data | 12/2002 to Present |

Note:

1. This gage is in the same location as the old USGS gage at Bolles, but the two North Fork Touchet gages from USGS and Ecology are in different locations.

### 1.1.2 USGS StreamStats Database

Because the gage data were inaccurate and incomplete, regressions from the USGS StreamStats database were used to determine peak flow profiles for all the subbasins (USGS 2019a). The peak flow discharges were determined directly from the database using a regression equation that accounts for basin area, mean annual precipitation, and basin percent forest cover (Mastin et al. 2016). The constants from Region 1 encompassing southeast Washington and Northeast Oregon were used, and the basin area, annual precipitation, and percent forest cover were obtained directly from the data in the StreamStats database (USGS 2019a). The regression to determine basin peak discharges is shown in Equation C-1.

**Equation C-1 (Mastin et al. 2016)**

$$Q = \frac{aA^b 10^{cP}}{10^{dCAN}}$$

where:

a,b,c,d = given constants for the particular regression region and recurrence interval
A = basin area (mi^2)
P = mean basin annual precipitation (in)
CAN = basin % forested

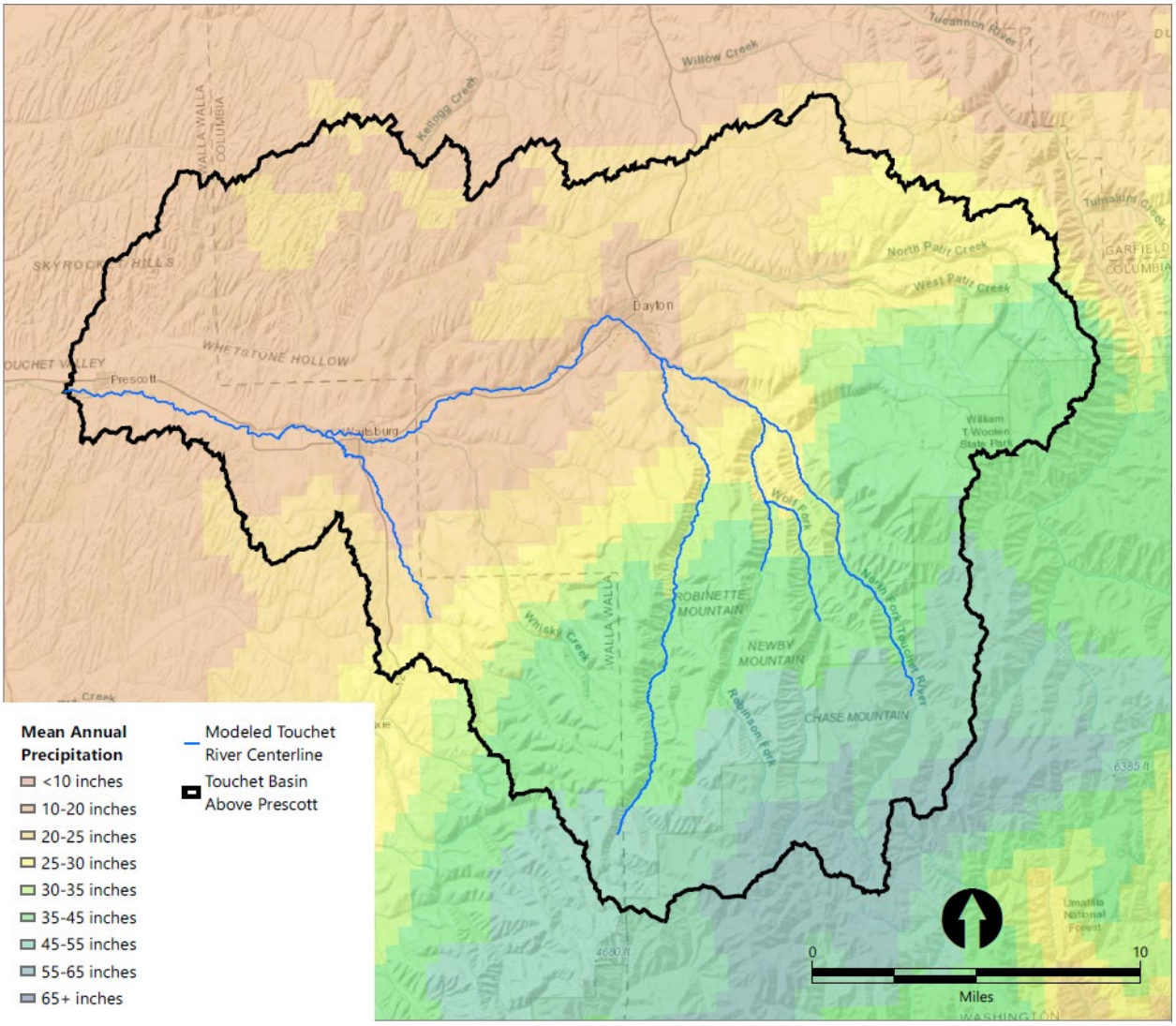
| Regression region | Number of stations used in analysis | Form of the regression equation | Annual exceedance probability | Constant | Coefficents | | | $S_p$ (percent) | $R^2_{pseudo}$ | SEM (percent) | Range of values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *a* | *b* | *c* | *d* | | | | *A* | *P* | CAN |
| 1 | 93 | $Q = aA^b 10^{cP}/10^{dCAN}$ | 0.5 | 3.846 | 0.745 | 0.032 | 0.0078 | 95.04 | 85.1 | 90.72 | 0.25–3,304 | 9.82–52.45 | 0.0–77.4 |
| | | | 0.2 | 12.106 | 0.713 | 0.028 | 0.0098 | 71.93 | 87.66 | 68.33 | | | |
| | | | 0.1 | 22.080 | 0.695 | 0.026 | 0.0107 | 70.67 | 86.72 | 66.91 | | | |
| | | | 0.04 | 42.170 | 0.674 | 0.024 | 0.0117 | 77.42 | 83.38 | 73.12 | | | |
| | | | 0.02 | 63.826 | 0.661 | 0.023 | 0.0124 | 84.76 | 80.32 | 79.92 | | | |
| | | | 0.01 | 92.470 | 0.649 | 0.022 | 0.0130 | 93.55 | 77.01 | 88.08 | | | |
| | | | 0.005 | 129.42 | 0.637 | 0.021 | 0.0136 | 103.98 | 73.32 | 97.75 | | | |
| | | | 0.002 | 193.20 | 0.624 | 0.020 | 0.0143 | 118.69 | 68.66 | 111.33 | | | |

Note:
1. Annual exceedance probabilities of 0.5, 0.2, and 0.1 correspond to 2-, 5-, and 10-year events.

### 1.1.3 Precipitation Data

The USGS StreamStats database uses geospatial precipitation data from the PRISM climate model developed at Oregon State University to estimate streamflow (OSU 2019). A map of the 30-year annual average (1981 to 2010) precipitation estimates for the Touchet basin is shown in Figure C-1.

**Figure C-1**
**Mean Annual Precipitation Distribution –Touchet River Basin**




Note: Precipitation data were drawn from the Oregon State University PRISM climate model (OSU 2019) and represent the 30-year (1981 to 2010) annual average.

## *1.1.4 Basin Delineations*

Basin and subbasin delineations are available as geospatial data through the USGS StreamStats database (USGS 2019a) for the Touchet River. These delineations provided information on contributing area, basin shape, slope, and elevation. Basin breaks were based on factors including incoming tributaries or landmarks like bridges. The selected subbasins and gage locations in the Touchet basin are listed in Table C-2. These locations are also shown on the map in Figure C-2.

**Table C-2**
**Touchet River Tributaries and Basin Areas**

| North Fork | | Wolf Fork | | Robinson Fork | |
|---|---|---|---|---|---|
| **Location** | **Basin Area ($mi^2$)** | **Location** | **Basin Area ($mi^2$)** | **Location** | **Basin Area ($mi^2$)** |
| Downstream of Wolf Fork | 101.94 | Upstream of North Fork | 41.86 | Upstream of Wolf Fork | 15.55 |
| Downstream of Jim Creek | 40.52 | Downstream of Robinson Fork | 37.38 | Upstream of Model | 13.36 |
| Downstream of Lewis Creek | 27.85 | Downstream of Coates Creek | 15.96 | | |
| Downstream of Spangler Creek | 16.85 | | | | |
| **South Fork** | | **Mainstem Touchet** | | **Coppei Creek** | |
| **Location** | **Basin Area ($mi^2$)** | **Location** | **Basin Area ($mi^2$)** | **Location** | **Basin Area ($mi^2$)** |
| Upstream of Mainstem | 43.64 | Downstream of Whetstone Creek | 478.07 | Upstream of Mainstem | 36.48 |
| at First Crossing | 38.45 | at Bolles USGS Gage | 357.42 | at Meinberg Road | 35.17 |
| Downstream of Unnamed Trib. | 35.56 | Downstream of Coppei Creek | 349.42 | at Mccowan Road | 25.67 |
| at Second Crossing | 29.91 | Downstream of Whiskey Creek | 299.42 | Below Forks | 23.15 |
| Downstream of Griffin Fork | 19.07 | Downstream of Patit Creek | 229.2 | | |
| Downstream of Burnt Fork | 12.28 | Downstream of Forks | 158.44 | | |
| Upstream of Model | 4.6 | | | | |

Note:
$mi^2$: square mile

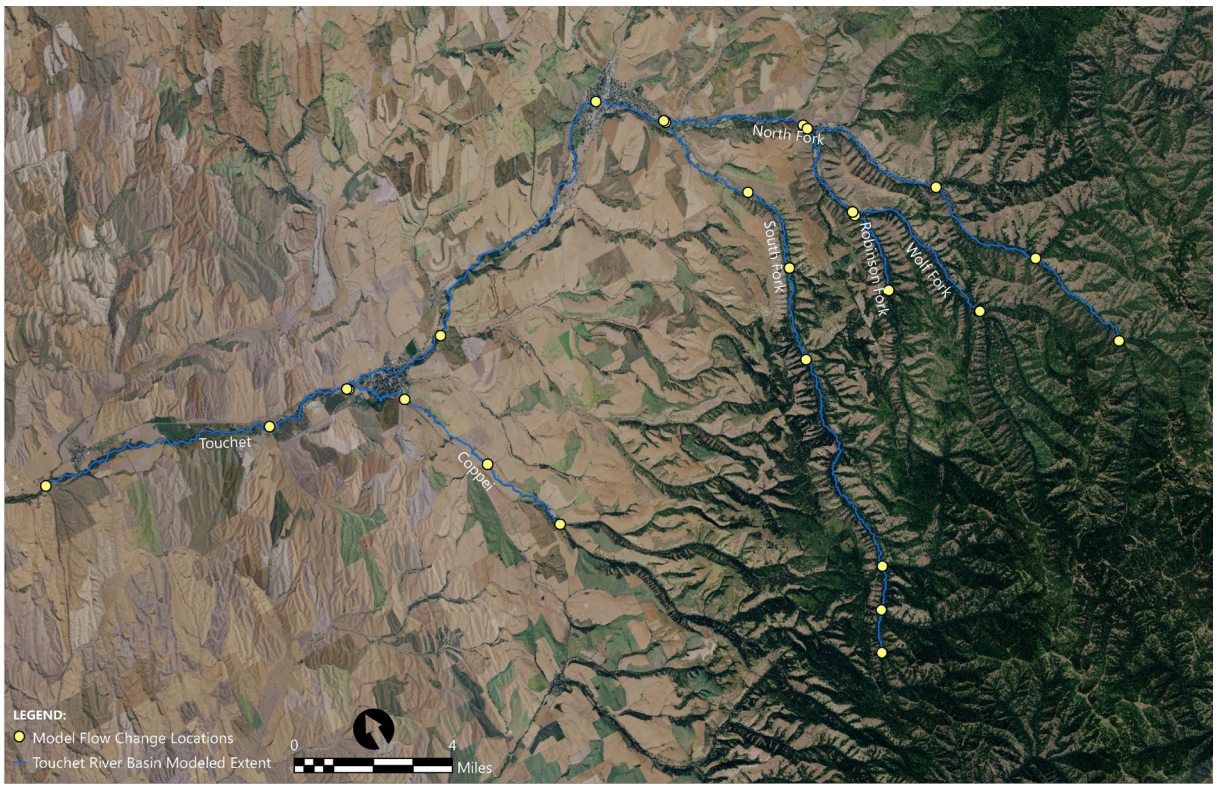
## 1.2 Hydrologic Analysis

### *1.2.1 Flood Recurrence Interval Analysis*

Recurrence intervals for the 2-, 5-, 10-, 25-, 50-, and 100-year events were calculated using the USGS StreamStats database (USGS 2019a) at each of the locations shown in Table C-2 and Figure C-2. These peak flow profiles were used as inputs to the 1D HEC-RAS model of the Touchet basin. The extent of the model is outlined in Figure C-2. Hydrologic calculation points were added at the upstream ends of each tributary. In addition, peak flow recurrence intervals were calculated below the mouth of each major tributary in addition to landmarks such as bridges and stream gages.

An error in the StreamStats database provided a challenge for computing the hydrology at junctions within the model. Running flood discharge computations in StreamStats immediately above the junctions and manually summing the values significantly overestimated running StreamStats immediately below the same confluence (USGS 2019a). To avoid having a large amount of flow erroneously created at each confluence, a StreamStats calculation was made downstream of each junction and upstream of the junction on the smaller of the two tributaries, but not upstream of the junction on the larger tributary. This method ensured flood discharges increased from upstream to downstream throughout the basin while obeying conservation of flow at the junctions.

**Figure C-2**
**Touchet Basin Hydrologic Calculation Points**

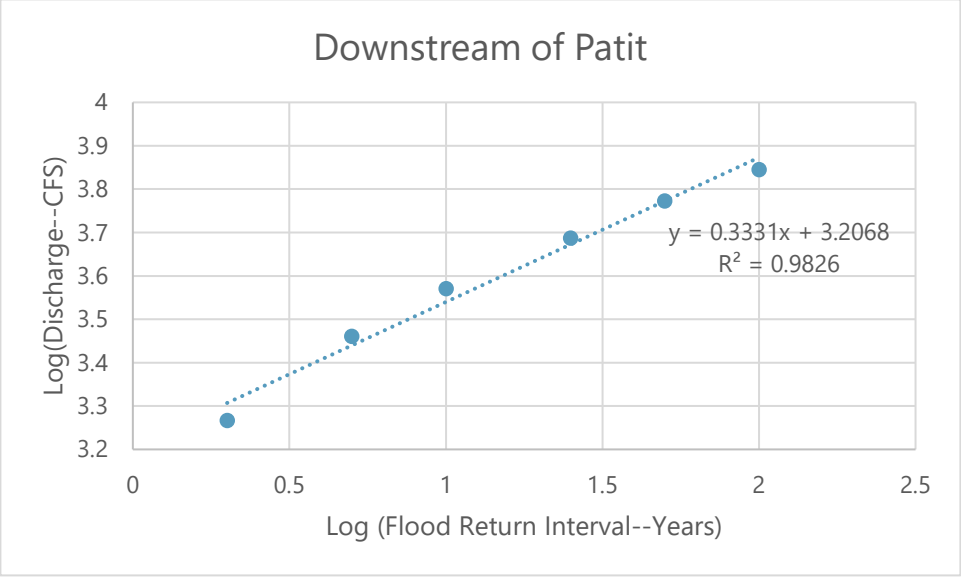



## *1.2.2 1-Year Flows*

The 1-year flows for all the tributaries were estimated by graphical interpolation using the discharges for the 2- to 100-year peak floods previously obtained from the StreamStats database. The 2- to 100-year floods for each model flow change location were plotted on a log-log plot, and the linear trendline was calculated and used to determine the 1-year flood. An example of the graphical interpolation process is shown in Figure C-3. The base ten exponential of the y-intercept on each graph was the calculated 1-year flood discharge. The values were then checked using a 1-year flood

generated using a Log-Pearson Type III approach on available gage data from the mainstem at Bolles and the North Fork.

**Figure C-3**
**Graphical Interpolation to Determine 1-Year Discharge for Tributaries**




## *1.2.3 Final Flows Used for Modeling*

Final reporting of the basin and tributary hydrology is provided in Table C-3. These flows, measured in cfs, were used in the final modeling effort, in addition to the standard return period statistics. The river mile within each fork or tributary is reported in addition to the flood recurrence intervals. The ultimate use of these data was to develop inundation extents for a floodplain connectivity analysis.

**Table C-3**
**Model Hydrology**

| River Mile of Flow Change | Tributary/ Location Name | Flow (cfs) per Return Period | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1-year | 2-year | 5-year | 10-year | 25-year | 50-year | 100-year |
| **North Fork Model Hydrology** | | | | | | | | |
| 3.95 | Downstream of Wolf Fork | 1,061 | 1,200 | 1,700 | 2,080 | 2,600 | 3,070 | 3,530 |
| 8.22 | Downstream of Jim Creek | 643 | 727 | 993 | 1,200 | 1,480 | 1,740 | 1,980 |
| 11.92 | Downstream of Lewis Creek | 542 | 607 | 777 | 912 | 1,090 | 1,260 | 1,410 |
| 15.36 | Downstream of Spangler Creek | 418 | 467 | 574 | 662 | 779 | 889 | 989 |
| **Wolf Fork Model Hydrology** | | | | | | | | |
| 0.07 | Upstream of North Fork | 506 | 578 | 842 | 1,050 | 1,340 | 1,600 | 1,860 |
| 3.04 | Downstream of Robinson Fork | 477 | 542 | 762 | 935 | 1,170 | 1,390 | 1,590 |
| 7.92 | Downstream of Coates Creek | 309 | 349 | 461 | 550 | 672 | 782 | 888 |
| **Robinson Fork Model Hydrology** | | | | | | | | |
| 0.04 | Upstream of Wolf Fork | 223 | 257 | 379 | 477 | 615 | 740 | 865 |
| 2.5 | Upstream of Model | 203 | 233 | 331 | 410 | 520 | 619 | 717 |

| River Mile of Flow Change | Tributary/ Location Name | Flow (cfs) per Return Period | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1-year | 2-year | 5-year | 10-year | 25-year | 50-year | 100-year |
| **South Fork Model Hydrology** | | | | | | | | |
| 0.05 | Upstream of Mainstem | 539 | 624 | 978 | 1,260 | 1,670 | 2,040 | 2,420 |
| 3.32 | at First Crossing of South Fork Rd | 533 | 612 | 917 | 1,160 | 1,500 | 1,810 | 2,120 |
| 6.05 | Downstream of Unnamed Trib. | 519 | 594 | 870 | 1,090 | 1,390 | 1,670 | 1,940 |
| 8.91 | at Second Crossing of South Fork Rd | 466 | 530 | 746 | 916 | 1,150 | 1,360 | 1,570 |
| 15.61 | Downstream of Griffin Fork | 360 | 407 | 539 | 643 | 785 | 913 | 1,040 |
| 16.98 | Downstream of Burnt Fork | 273 | 309 | 408 | 487 | 595 | 694 | 788 |
| 18.22 | Upstream of Model | 125 | 143 | 196 | 238 | 297 | 351 | 403 |
| **Mainstem Touchet Model Hydrology** | | | | | | | | |
| 0.06 | Downstream of Whetstone Creek | 2080 | 2,430 | 4,340 | 5,910 | 8,240 | 10,400 | 12,700 |
| 7.15 | at Bolles USGS Gage | 1950 | 2,260 | 3,820 | 5,080 | 6,900 | 8,570 | 10,300 |
| 9.9 | Downstream of Coppei Creek | 1944 | 2,250 | 3,780 | 5,020 | 6,800 | 8,430 | 10,100 |
| 13.25 | Downstream of Whiskey Creek | 1771 | 2050 | 3,390 | 4,470 | 6,020 | 7,430 | 8,900 |
| 21.96 | Downstream of Patit Creek | 1610 | 1850 | 2,890 | 3,720 | 4,870 | 5,930 | 7,000 |
| 23.82 | Downstream of Forks | 1415 | 1610 | 2,360 | 2,940 | 3,740 | 4,460 | 5,180 |

| River Mile of Flow Change | Tributary/ Location Name | Flow (cfs) per Return Period | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1-year | 2-year | 5-year | 10-year | 25-year | 50-year | 100-year |
| **Coppei Creek Model Hydrology** | | | | | | | | |
| 0.06 | Upstream of Mainstem | 367 | 441 | 851 | 1,210 | 1,780 | 2,320 | 2,930 |
| 2.23 | at Meinberg Road | 367 | 441 | 847 | 1,200 | 1,760 | 2,300 | 2,890 |
| 5.21 | at Mccowan Road | 351 | 417 | 756 | 1,050 | 1,490 | 1,910 | 2,370 |
| 8.07 | Below Forks | 350 | 415 | 736 | 1,010 | 1,420 | 1,810 | 2,230 |

## 1.3 References

Ecology (Washington State Department of Ecology), 2019. Flow Monitoring Network. Available at: https://fortress.wa.gov/ecy/eap/flows/regions/state.

Mastin, M.C., C.P. Konrad, A.G. Veilleux, and A.E. Tecca, 2016. *Magnitude, frequency, and trends of floods at gaged and ungaged sites in Washington, based on data through water year 2014*. Version 1.1, October 2016. U.S. Geological Survey Scientific Investigations Report No. 2016–5118, 70 pp. Available at: https://pubs.er.usgs.gov/publication/sir20165118.

OSU (Oregon State University Climate Service), 2019. PRISM Climate Group. Available at: http://prism.oregonstate.edu. Map Created September 2019.

USGS (U.S. Geological Survey), 2019a. StreamStats in Washington. Available at: https://streamstats.usgs.gov/ss/.

USGS, 2019b. National Water Information System: Mapper. Available at: https://maps.waterdata.usgs.gov/mapper/index.html?state=wa.