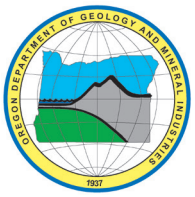
State of Oregon
Oregon Department of Geology and Mineral Industries
Brad Avy, State Geologist
www.OregonGeology.org

BASE FLOOD ELEVATION DETERMINATION BF-15-01

BASE FLOOD ELEVATION DETERMINATION FOR REACH OF NORTH SANTIAM RIVER, LINN AND MARION COUNTIES, OREGON

by Jed T. Roberts[1] and Matt C. Williams[1]



2015

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DISCLAIMER

The Oregon Department of Geology and Mineral Industries is not liable for any claimed damage from the use of this information. The Federal Emergency Management Agency may, at any time in the future, revise the Base Flood Elevations for this study area. This study and Base Flood Elevation determination does not supersede any existing or future detailed analyses or determination performed by a licensed professional engineer. This analysis and mapping does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size.

Oregon Department of Geology and Mineral Industries Base Flood Elevation Determination BF-15-01
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STUDY BACKGROUND

This study was conducted under a Base Flood Elevation Determination Service agreement dated January 20, 2015, between the Oregon Department of Geology and Mineral Industries (DOGAMI) and Boatwright Engineering. The purpose of this study was to develop 1% annual chance (100-year) water surface elevations, also known as Base Flood Elevations (BFEs), for a reach of North Santiam River in Linn and Marion counties, Oregon, between the cities of Jefferson and Stayton.

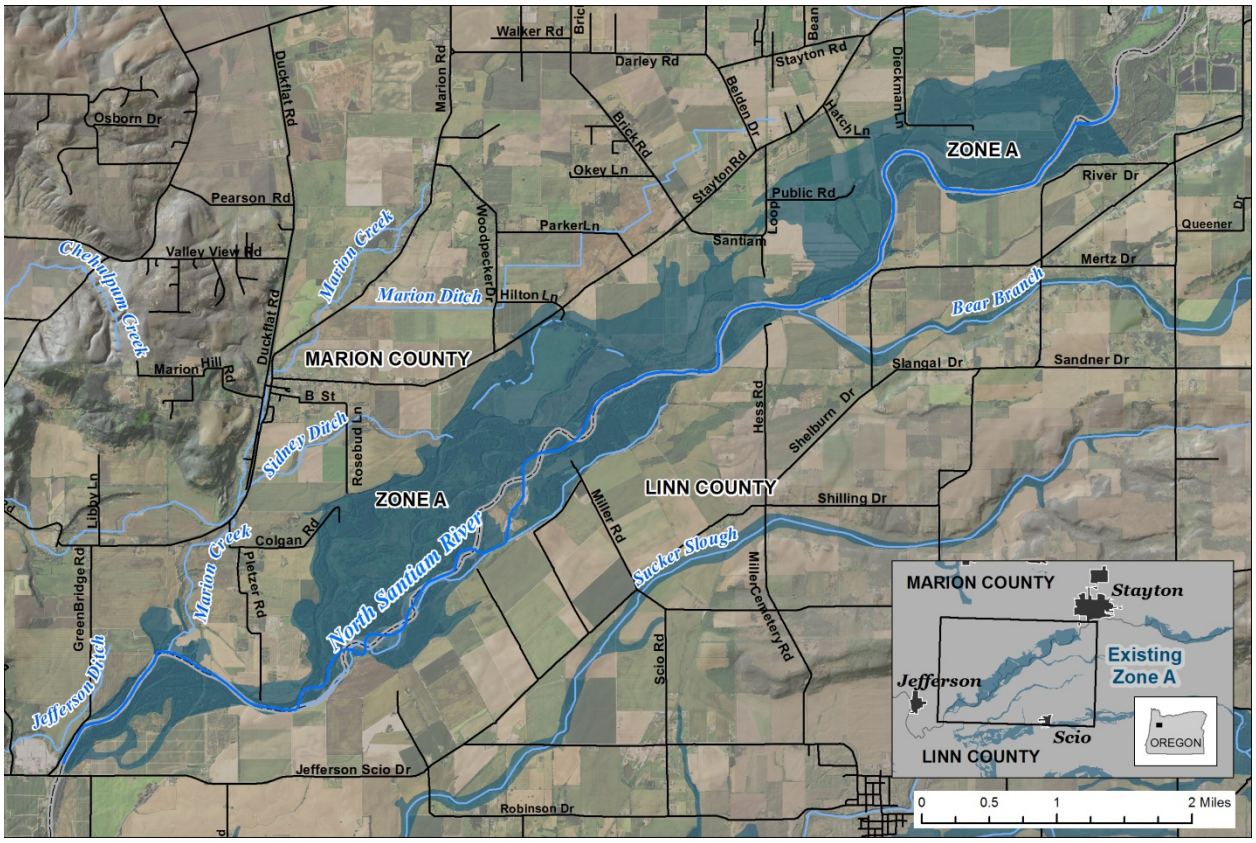
BFEs are determined primarily for administration of the National Flood Insurance Program (NFIP). The Federal Emergency Management Agency (FEMA) oversees the NFIP and issues Flood Insurance Rate Maps (FIRMs) that depict Special Flood Hazard Areas (SFHAs) within which flood insurance for structures is typically required. SFHAs are mapped by *detailed* or *approximate* methods:

- *Detailed analyses* are performed for streams in urban or suburban settings, and SFHAs mapped with this approach are designated as Zone AE, Zone AO, or Zone AH. The analyses incorporate field survey and flood frequency data into a hydraulic model. The resulting BFEs are mapped onto best available topographic data.
- *Approximate analyses* are performed for streams in rural areas, and SFHAs mapped with this approach are designated as Zone A. Unlike detailed analyses, the approximate analysis does not produce BFEs. Instead, this latter method has historically involved engineering judgment of hydraulics and hydrology to map SFHAs onto U.S. Geological Survey (USGS) topographic sheets.

The approximate analysis approach was used to map SFHAs that are shown on the currently effective FIRM for North Santiam River (Figure 1).

DOGAMI has partnered with FEMA through its Cooperating Technical Partner program to improve FIRMs by introducing high-resolution lidar (light detection and ranging) topographic data. As part of this effort DOGAMI has developed a FEMA-approved computer model-based approach to produce BFEs using lidar in areas designated approximate, enabling the Zone A SFHAs to be revised and updated. This same approach was applied for the current study to produce BFEs in an area where FEMA has not yet funded a lidar-based FIRM revision.

Figure 1. Zone A Special Flood Hazard Area mapped by FEMA in 2003 (Marion County) and 2010 (Linn County).



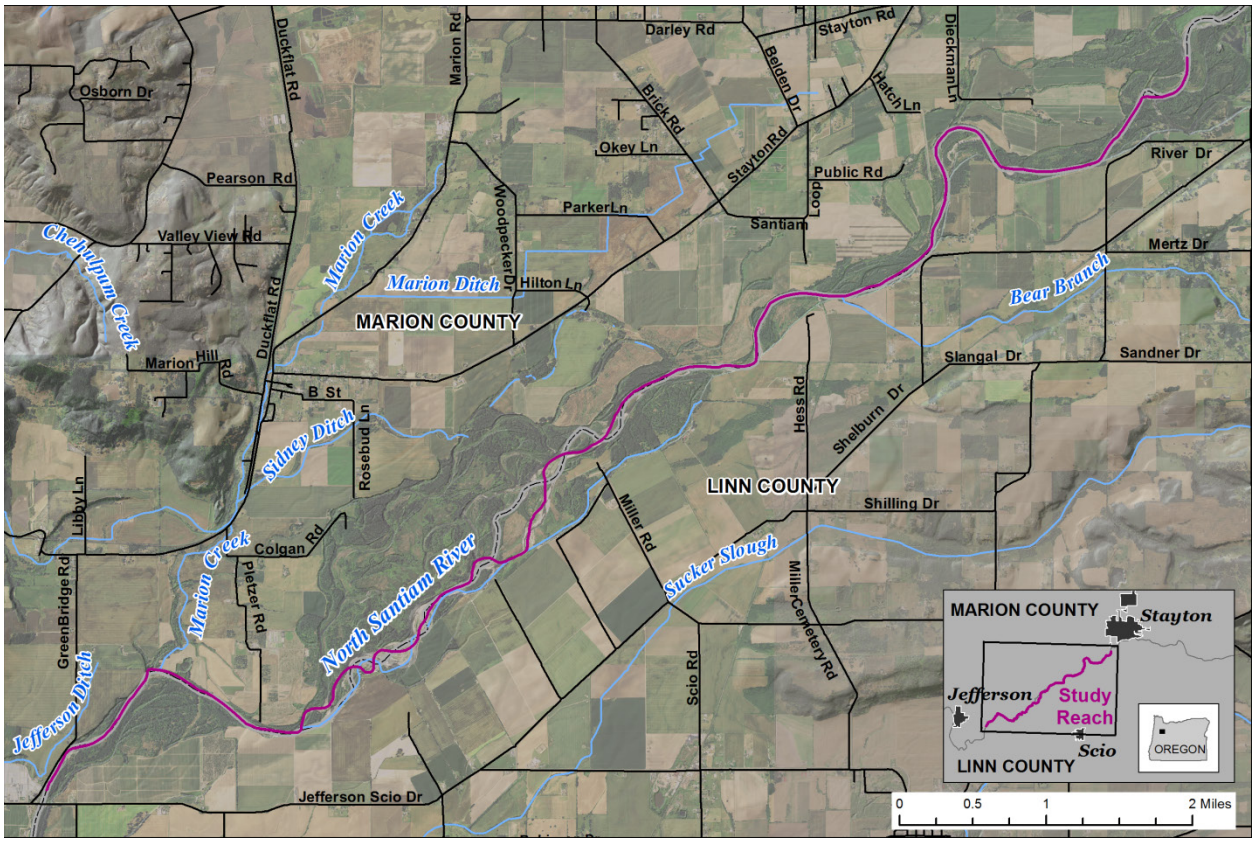
PHYSICAL SETTING

The North Santiam River watershed is a 766 square-mile subbasin (8-digit hydrologic unit code) within the Willamette River Basin. The watershed is characterized by steep forested uplands in the east and flat alluvial lowlands in the west. The lower North Santiam River, where the study reach is located, drains primarily agricultural areas (Figure 2). Mean annual precipitation in the subbasin is approximately 45 inches per year in lower elevations and 70 inches per year in higher elevations. The North Santiam River drains into the Santiam River, which is a tributary of the Willamette River. Flows on the North Santiam River are regulated at Detroit Dam, built in 1953 and operated by the U.S. Army Corps of Engineers.

The study reach is located along a highly active section of North Santiam River characterized by anastomosing[1] channels. The river has recently occupied a historic floodplain more than a mile wide along the study reach, clearly visible in bare earth lidar. Significant channel re-configuration was observed between acquisition of lidar and orthoimagery in 2008 and 2014, respectively.

[1] A multi-threaded channel pattern with stable, vegetated bars.

Figure 2. Location of study reach.



HYDROLOGIC ANALYSIS METHODS

Nine discharge locations were identified for this study. Locations were selected at the downstream terminus of the study reach and upstream based on a minimum drainage area reduction of 1 square mile (Figure 3).

The 100-year peak discharge was calculated by performing a log-Pearson Type III flood frequency analysis, as described in USGS Bulletin 17B, Guidelines for Determining Flood Flow Frequency (USGS, 1982). Peak discharges from the USGS stream gage on North Santiam River at Mehama (no. 14183000) were used. Peak discharges at this gage were available back to 1905. However, beginning in 1953, gage measurements reflect the effects of upstream flow regulation at Detroit Dam. Therefore, the flood frequency analysis performed here only took into account peak discharges between 1953 and 2013. Statistical skew of peak discharges recorded at a single gage must be accounted for in a flood frequency analysis. In many cases a generalized skew adjustment is applied using peak discharges from nearby gages. However, in this case a station skew adjustment was used because flow is regulated.

The analysis was performed using the USGS PeakFQ program (Veilleux and others, 2014). See Appendix C for the complete results of the analysis.

The 100-year peak discharge at the gage location was transformed to the nine ungaged discharge locations along the study reach. For the ungaged locations the 100-year peak discharge is given by the equation

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^a$$

where

Q_u = the 100-year peak discharge at the ungaged location, in cubic feet per second,
Q_g = the 100-year peak discharge at the gage location, in cubic feet per second,
A_u = the drainage area at the ungaged location, in square miles,
A_g = the drainage area at the gage location, in square miles, and,
a = the exponent of area from prediction equations in Table 10 of Cooper (2005).

The drainage area at the gaged location (A_g) is 654.4 square miles. The flood frequency analysis at the gage location yields a 100-year peak discharge (Q_g) of 53,370 cubic feet per second (cfs). The exponent of area for the 100-year discharge (a) is 0.9176. Drainage areas were determined using the USGS StreamStats for Oregon web tool (http://water.usgs.gov/osw/streamstats/oregon.html, USGS, 2015). The calculated 100-year peak discharges are listed in Table 1.

Figure 3. Modeled discharge locations.

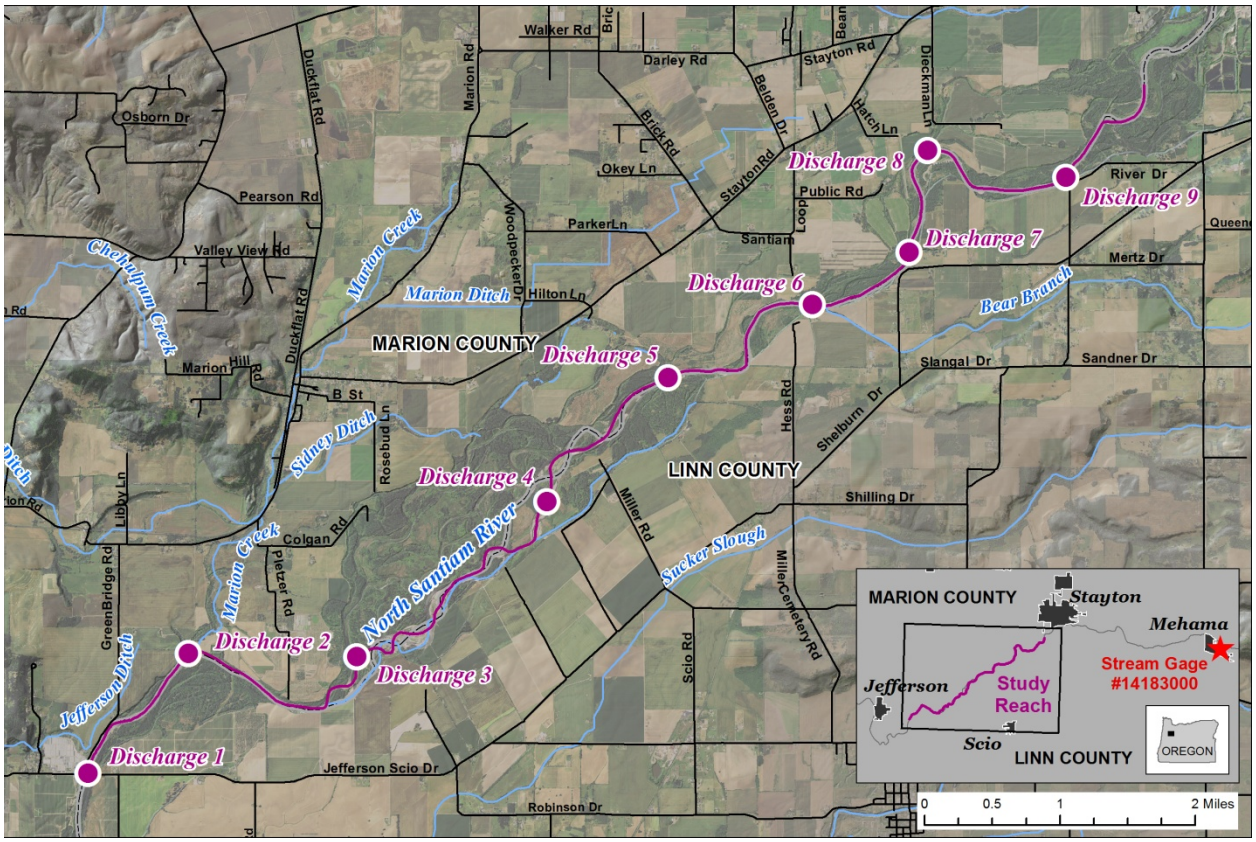


Table 1. Summary of 100-year flood discharges.

Discharge Location	Drainage Area (sq. mi.)	100-Year Peak Discharge (cfs)
1	732	59,155
2	731	59,081
3	713	57,746
4	711	57,596
5	710	57,522
6	707	57,298
7	693	56,257
8	692	56,183
9	690	56,033

cfs is cubic feet per second.

HYDRAULIC ANALYSIS METHODS

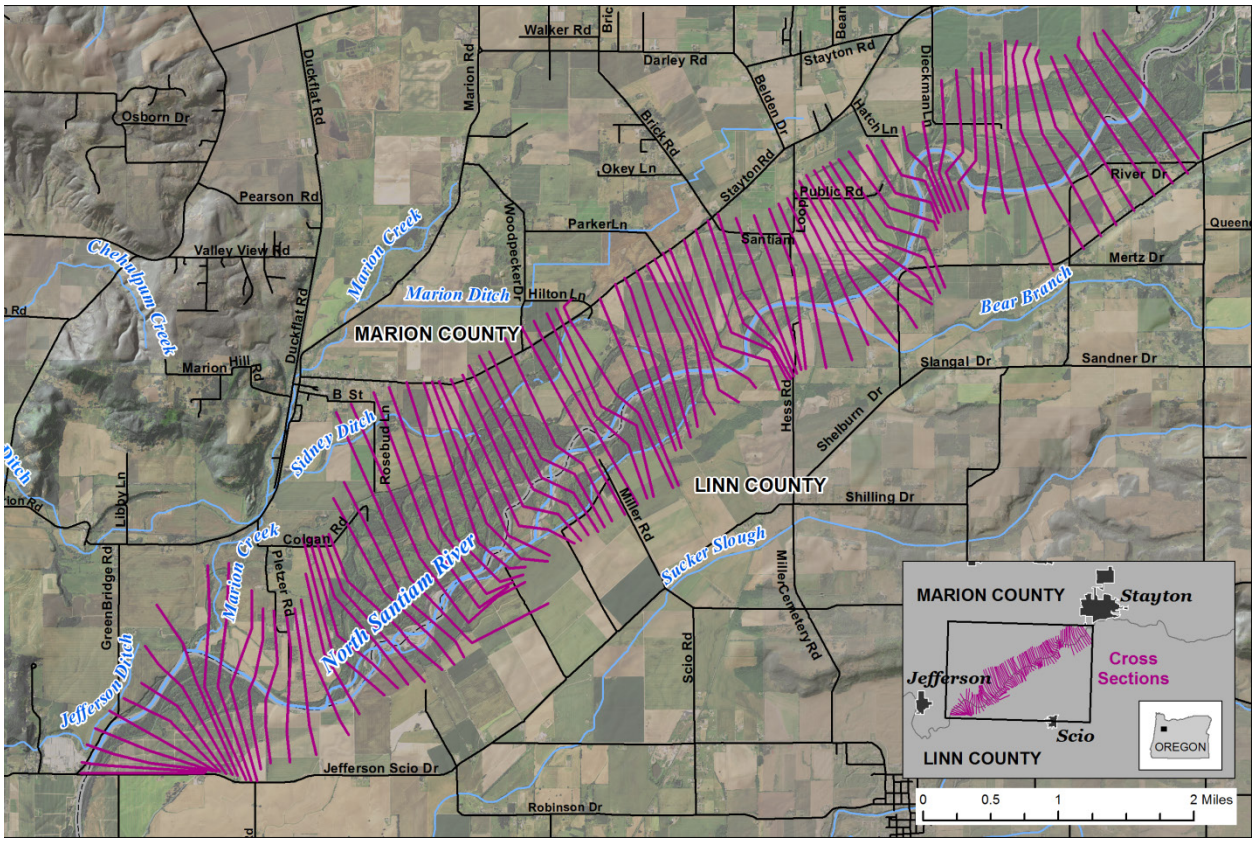
To produce simulated water surface elevations of the 100-year peak discharge, a steady flow hydraulic model was developed using the Hydrologic Engineering Center River Analysis System (HEC-RAS 4.1) produced by the U.S. Army Corps of Engineers (Brunner, 2010). Geometric input data were developed using the Esri ArcGIS® for Desktop Advanced 10.2 software package, the Esri ArcGIS 3D Analyst™ and Spatial Analyst™ extensions, and the HEC-GeoRAS 10.1 add-on produced by USACE (Ackerman, 2011).

Geometric data layers, including stream centerline, flowpaths, bank stations, and cross-sections, were digitized from a hillshade raster derived from a 3-foot resolution lidar digital elevation model (DEM). The lidar DEM was derived from ground classified points with an average density of 0.15 per square foot. The vertical accuracy for the lidar acquisition area is ± 0.13 feet on flat surfaces. Lidar acquisition for the study area took place in October 2008 (DOGAMI, 2010).

Eighty-seven (87) cross-sections were spaced approximately 500 feet apart and perpendicular to the stream centerline (Figure 4). Both upstream and downstream reach boundary conditions were defined as known water surface elevations from BFEs published by FEMA (2003). It was necessary to perform a vertical datum conversion of the published BFEs from the National Geodetic Vertical Datum of 1929 (NGVD29) to the North American Vertical Datum of 1988 (NAVD88). The vertical datum conversion was achieved using the National Geodetic Survey VERTCON web tool (Mulcare, 2004). The vertical datum conversion is +3.4 feet at both the upstream and downstream locations.

Manning's roughness coefficients were determined for the study area overbank areas using the 2011 National Land Cover Dataset (Jin and others, 2013). Land cover types were assigned a coefficient from land descriptions provided by Chow (1959). Overbank coefficients were found to range from 0.02 to 0.1 throughout the study area. A single in-channel coefficient of 0.04 was assigned on the basis of the regular presence of pools and shoals and overall lack of vegetation in the gravel-dominated channels, as seen in the 2014 orthoimagery.

Figure 4. Location of cross-sections used for hydraulic analysis.



SUMMARY OF RESULTS

The results of hydraulic modeling show that BFEs range from 258.9 feet (NAVD88) at the downstream terminus of the study reach to 416.8 feet (NAVD88) at the upstream terminus. Table 2 shows BFEs at cross-sections selected approximately every river mile (Appendix A) throughout the study reach.

Table 2. Summary of 100-year flood elevations.

Reference Cross-Section[1]	Location Description	BFE (ft. NAVD88[2])
NSR-1	Just upstream of Jefferson Scio Drive	258.9
NSR-2	1.2 miles upstream of Jefferson Scio Drive	271.3
NSR-3	2.9 miles upstream of Jefferson Scio Drive	288.9
NRS-4	4.9 miles upstream of Jefferson Scio Drive	316.9
NSR-5	6.4 miles upstream of Jefferson Scio Drive	340.7
NSR-6	7.9 miles upstream of Jefferson Scio Drive	361.9
NSR-7	8.7 miles upstream of Jefferson Scio Drive	371.7
NSR-8	9.6 miles upstream of Jefferson Scio Drive	383.4
NSR-9	10.7 miles upstream of Jefferson Scio Drive	400.9
NSR-10	11.7 miles upstream of Jefferson Scio Drive	416.8

[1]See Appendix A for map of reference cross-sections.

[2]North American Vertical Datum of 1988.

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APPENDIX A: MAP OF HYDRAULIC ANALYSIS RESULTS

Attached to this report is a map depicting the hydraulic analysis results of the 100-year peak discharge for the study reach of the North Santiam River.

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BASE FLOOD ELEVATION DETERMINATION REPORT BF-15-01

Portion of North Santiam River, Marion and Linn Counties, Oregon

By Jed T. Roberts and Matt C. Williams

(See accompanying report.)

N

Modeled 1% Chance Flood Depths

- 0-2 feet
- 2-4 feet
- 4-6 feet
- 6-8 feet
- 8 feet and above

134.7 NSR1 — Reference Cross-Section with Water Surface Elevation in Feet (NAVD88)

- Study Reach
- Stream
- County Boundary
- Road
- Township and Range Boundary
- Taxlot Boundary

Upstream Limit of Study

Downstream Limit of Study

MARION COUNTY

LINN COUNTY

City of Stayton

City of Jefferson

City of Scio

North Santiam River

Pleasant Grove Rd

Darley Rd

Stayton Rd

Osborn Dr

Pearson Rd

Valley View Rd

Marion Hill Rd

Duckflat Rd

Marion R

Brick Rd

Belden Dr

Hatch Ln

Dieckman Ln

Okey Ln

Stayton Rd

Public Rd

Loop

River Dr

Mertz Dr

Parker Ln

Woodpecker Dr

Hilton Ln

Santiam

B St

Rosebud Ln

Hess Rd

Slangal Dr

Sandner Dr

Shelburn Dr

Shilling Dr

Township 9 South

Township 10 South

Miller Rd

Colgan Rd

Pletzer Rd

Libby Ln

GreenBridge Rd

Wiley Rd

Cemetery Hill Rd

Miller Cemetery Rd

Scio Rd

Jefferson Scio Dr

Range 3 West

Range 2 West

Range 2 West

Range 1 West

Main St

3rd St

5th St

6th St

7th St

High St

Salamander St

NSR1 258.9

NSR2 271.3

NSR3 288.9

NSR4 316.9

NSR5 340.7

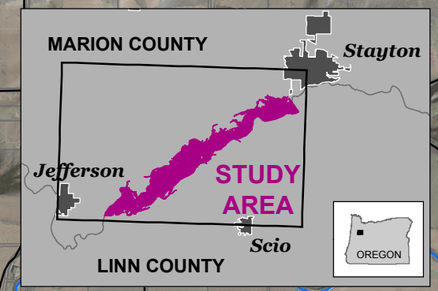
NSR6 361.9

NSR7 314.7

NSR8 383.4

NSR9 400.9

NSR10 416.8



0 0.5 1 2 Miles

APPENDIX B: HYDRAULIC ANALYSIS DATA PACKAGE

Attached to this report is a data package containing the input and output datasets used to perform this study. It includes:

- HEC-RAS 4.1 model
- HEC-GeoRAS 10.1 input geometry data in GIS format
    - Cross-sections
    - Stream centerlines
    - Flowpaths
    - Bridges
- HEC-GeoRAS 10.1 output data in GIS format
    - 100-year flood zone
    - 100-year water surface elevation grid
    - 100-year depth grid
    - Cross-sections with computed 100-year water surface elevations
- 3-foot resolution lidar DEM in GIS format
- North Santiam River study reach output data in GIS format
    - 100-year flood zone
    - 100-year water surface elevation grid
    - 100-year depth grid
- PeakFQ hydrology input and output files

APPENDIX C: PEAKFQ FLOOD FREQUENCY ANALYSIS RESULTS

```
 Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
 Version 7.1         Annual peak flow frequency analysis      Run Date / Time
 3/14/2014                                                    02/17/2015 16:05

            Station - 14183000  NORTH SANTIAM RIVER AT MEHAMA, OR

                    I N P U T   D A T A   S U M M A R Y

               Number of peaks in record            =       61
               Peaks not used in analysis           =        0
               Systematic peaks in analysis         =       61
               Historic peaks in analysis           =        0
               Beginning Year                       =     1953
               Ending Year                          =     2013
               Historical Period Length             =        0
               Generalized skew                     =    0.135
                    Standard error                  =    0.550
                    Mean Square error               =    0.303
               Skew option                          = STATION SKEW
               Gage base discharge                  =      0.0
               User supplied high outlier threshold =   --
               User supplied PILF (LO) criterion    =   --
               Plotting position parameter          =     0.00
               Type of analysis                       BULL.17B
               PILF (LO) Test Method                     GBT
               Perception Thresholds            =   Not Applicable
               Interval Data                    =   Not Applicable

 *********  NOTICE  --  Preliminary machine computations.        *********
 *********  User responsible for assessment and interpretation.  *********

   WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                   0.0
   WCF198I-LOW OUTLIERS BELOW FLOOD BASE WERE DROPPED.       1      7006.8
   WCF162I-SYSTEMATIC PEAKS EXCEEDED HIGH-OUTLIER CRITERION.   1   55261.9
  *WCF151I-17B WEIGHTED SKEW REPLACED BY USER OPTION.     0.439     0.563  -1


                                  Kendall's Tau Parameters

                                                    MEDIAN   No. of
                                       TAU    P-VALUE    SLOPE   PEAKS
                                  ----------------------------------------
            SYSTEMATIC RECORD     -0.009      0.926     -5.903    61

1

 Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.002
 Version 7.1         Annual peak flow frequency analysis      Run Date / Time
 3/14/2014                                                    02/17/2015 16:05

            Station - 14183000  NORTH SANTIAM RIVER AT MEHAMA, OR


          ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

                     FLOOD BASE                   LOGARITHMIC
                ----------------------  --------------------------------
                           EXCEEDANCE                STANDARD
                 DISCHARGE PROBABILITY     MEAN     DEVIATION     SKEW
```

SYSTEMATIC RECORD	0.0	1.0000	4.3194	0.1667	-0.469
BULL.17B ESTIMATE	7006.8	0.9836	4.3269	0.1467	0.563

BULL.17B ESTIMATE OF MSE OF AT-SITE SKEW 0.1236

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	<-- FOR BULLETIN 17B ESTIMATES --> VARIANCE OF EST.	95% CONFIDENCE INTERVALS LOWER	UPPER
0.9950		6563.	--	--	--
0.9900		7503.	--	--	--
0.9500	12920.	10590.	----	11500.0	14190.0
0.9000	14130.	12560.	----	12720.0	15390.0
0.8000	15890.	15280.	----	14510.0	17180.0
0.6667	17930.	18150.	----	16540.0	19280.0
0.5000	20570.	21500.	----	19120.0	22090.0
0.4292	21850.	22980.	----	20340.0	23500.0
0.2000	27840.	28990.	----	25780.0	30440.0
0.1000	33230.	33340.	----	30390.0	37090.0
0.0400	40720.	38260.	----	36540.0	46750.0
0.0200	46810.	41560.	----	41400.0	54900.0
0.0100	53370.	44590.	----	46510.0	63900.0
0.0050	60450.	47400.	----	51930.0	73860.0
0.0020	70740.	50830.	----	59640.0	88700.0

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.003
Version 7.1 Annual peak flow frequency analysis Run Date / Time
3/14/2014 02/17/2015 16:05

Station - 14183000 NORTH SANTIAM RIVER AT MEHAMA, OR

I N P U T D A T A L I S T I N G

WATER YEAR	PEAK VALUE	PEAKFQ CODES	REMARKS
1953	23800.0	K	
1954	26500.0	K	
1955	17600.0	K	
1956	25300.0	K	
1957	21500.0	K	
1958	17700.0	K	
1959	18600.0	K	
1960	15000.0	K	
1961	35800.0	K	
1962	17200.0	K	
1963	26200.0	K	
1964	20600.0	K	
1965	58400.0	K	
1966	16000.0	K	
1967	13800.0	K	
1968	17400.0	K	
1969	20900.0	K	
1970	21100.0	K	
1971	21100.0	K	
1972	43300.0	K	

1973	23100.0	K
1974	22500.0	K
1975	26900.0	K
1976	22100.0	K
1977	4730.0	K
1978	26600.0	K
1979	21500.0	K
1980	18100.0	K
1981	27800.0	K
1982	19400.0	K
1983	19900.0	K
1984	17000.0	K
1985	15700.0	K
1986	29500.0	K
1987	15300.0	K
1988	17600.0	K
1989	21600.0	K
1990	24900.0	K
1991	18400.0	K
1992	16200.0	K
1993	18900.0	K
1994	12400.0	K
1995	20700.0	K
1996	53800.0	K
1997	21100.0	K
1998	18000.0	K
1999	25300.0	K
2000	35500.0	K
2001	8600.0	K
2002	22800.0	K
2003	16400.0	K
2004	17800.0	K
2005	12100.0	K
2006	19400.0	K
2007	28500.0	K
2008	15000.0	K
2009	25700.0	K
2010	23500.0	K
2011	36400.0	K
2012	28300.0	K
2013	19400.0	K

Explanation of peak discharge qualification codes

PeakFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.004
Version 7.1 Annual peak flow frequency analysis Run Date / Time

3/14/2014 02/17/2015 16:05

Station - 14183000 NORTH SANTIAM RIVER AT MEHAMA, OR

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	B17B ESTIMATE
1965	58400.0	0.0161	0.0161
1996	53800.0	0.0323	0.0323
1972	43300.0	0.0484	0.0484
2011	36400.0	0.0645	0.0645
1961	35800.0	0.0806	0.0806
2000	35500.0	0.0968	0.0968
1986	29500.0	0.1129	0.1129
2007	28500.0	0.1290	0.1290
2012	28300.0	0.1452	0.1452
1981	27800.0	0.1613	0.1613
1975	26900.0	0.1774	0.1774
1978	26600.0	0.1935	0.1935
1954	26500.0	0.2097	0.2097
1963	26200.0	0.2258	0.2258
2009	25700.0	0.2419	0.2419
1956	25300.0	0.2581	0.2581
1999	25300.0	0.2742	0.2742
1990	24900.0	0.2903	0.2903
1953	23800.0	0.3065	0.3065
2010	23500.0	0.3226	0.3226
1973	23100.0	0.3387	0.3387
2002	22800.0	0.3548	0.3548
1974	22500.0	0.3710	0.3710
1976	22100.0	0.3871	0.3871
1989	21600.0	0.4032	0.4032
1957	21500.0	0.4194	0.4194
1979	21500.0	0.4355	0.4355
1970	21100.0	0.4516	0.4516
1971	21100.0	0.4677	0.4677
1997	21100.0	0.4839	0.4839
1969	20900.0	0.5000	0.5000
1995	20700.0	0.5161	0.5161
1964	20600.0	0.5323	0.5323
1983	19900.0	0.5484	0.5484
1982	19400.0	0.5645	0.5645
2006	19400.0	0.5806	0.5806
2013	19400.0	0.5968	0.5968
1993	18900.0	0.6129	0.6129
1959	18600.0	0.6290	0.6290
1991	18400.0	0.6452	0.6452
1980	18100.0	0.6613	0.6613
1998	18000.0	0.6774	0.6774
2004	17800.0	0.6935	0.6935
1958	17700.0	0.7097	0.7097
1955	17600.0	0.7258	0.7258
1988	17600.0	0.7419	0.7419
1968	17400.0	0.7581	0.7581
1962	17200.0	0.7742	0.7742
1984	17000.0	0.7903	0.7903
2003	16400.0	0.8065	0.8065
1992	16200.0	0.8226	0.8226
1966	16000.0	0.8387	0.8387
1985	15700.0	0.8548	0.8548

```
      1987    15300.0     0.8710      0.8710
      1960    15000.0     0.8871      0.8871
      2008    15000.0     0.9032      0.9032
      1967    13800.0     0.9194      0.9194
      1994    12400.0     0.9355      0.9355
      2005    12100.0     0.9516      0.9516
      2001     8600.0     0.9677      0.9677
      1977     4730.0     0.9839      0.9839
  1

   End PeakFQ analysis.
     Stations processed :       1
     Number of errors   :       0
     Stations skipped   :       0
     Station years      :      61


  Data records may have been ignored for the stations listed below.
  (Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
  (2, 4, and * records are ignored.)

   For the station below, the following records were ignored:

   FINISHED PROCESSING STATION:  14183000       USGS NORTH SANTIAM RIVER AT MEHAMA


   For the station below, the following records were ignored:

FINISHED PROCESSING STATION:
```