Figgins Creek Hydrologic Analysis - Bozeman Creek and Tributaries Digital Flood Insurance Rate Map Restudy Project

prepared for

Montana Department of Natural Resources and Conservation

1424 9th Avenue

Helena, Montana 59620-1601

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RESPEC CONSULTING & SERVICES

3810 Valley Commons Drive, Suite 4

Bozeman, Montana 59718

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1.0 INTRODUCTION

1.1 BACKGROUND

As part of the Mapping Activity Statement (MAS) contract for Bozeman Creek and Tributaries, Gallatin County, Montana (**Reference 5**), RESPEC is completing a detailed floodplain study for approximately 1.7 miles of Figgins Creek within Gallatin County, Montana. The Figgins Creek study limits extend from the confluence with Mathew-Bird Creek just south of Kagy Blvd at the downstream limit to the upstream limit of approximately 1,700 feet upstream of Alder Creek Drive. The project area is displayed in **Figure 1-1**.

A Flood Insurance Study (FIS) has been completed for Gallatin County, the most recent version in 2011 (**Reference 6**). Flood hazards are currently mapped as detailed Zone AE for the entire study area of Figgins Creek. The effective flooding for Figgins Creek is shown in **Figure 1-2**.

The hydrologic analysis for Figgins Creek is summarized in this report. The flood study will include the 10-, 4-, 2-, 1- and 0.2-percent-annual-chance (%AC) flood events.

1.2 Basin Description

The Figgins Creek watershed is located within the Bozeman Creek watershed (HUC 12 100200080905) with Figgins Creek being a left bank tributary to Mathew-Bird Creek. Figgins Creek flows in a northern direction from the agricultural lands north of Goldenstein Lane towards the City of Bozeman. Figgins Creek watershed encompasses an area of 1.01 mi^2 with the upper extents located along Goldenstein Lane. The topography of the watershed is classified as a low sloping valley. The watershed is largely comprised of agricultural and developing residential areas with soils classified in hydrologic soil group C.

1.3 Effective Hydrologic Analysis

As previously mentioned, flood hazards are currently mapped as detailed Zone AE for the entire study area of Figgins Creek. As detailed in the Gallatin County FIS which went effective in 2011, an original hydrologic analysis of Figgins Creek was completed in June 1979 by the U.S. Department of Agriculture, Natural Resources Conservation Service. A revised hydrologic analysis of Figgins Creek was completed by Morrison Maierle, Inc. in January 1985. The

effective FIS states that peak discharges for Figgins Creek were computed using regression equations developed from 10 gages near the study area.

1.4 Flooding History

Notable flooding within the watershed has been recorded along Bozeman Creek in April 1893, April 1948, April 1977, and most recently in May of 2011. All of these events were produced from either high rate snowmelt or rain on snow events. The FIS states that the 1948 event was the largest event with flood waters entering Bozeman (the City) causing considerable damage. There is no reference as to the history of flooding along Figgins Creek within the FIS and limited information available as to flooding along the spring creeks. Local administrators and citizens state that the higher discharges associated with the spring creeks south of Bozeman are largely attributed to receiving overflowing flood discharges diverted from Bozeman Creek.

1.5 Other Studies

The City of Bozeman (the City) was consulted for previous study information for Figgins Creek. Unfortunately, the City didn't have any hydrologic data concerning the 100-yr event for the watershed outside of the effective analysis. For development purposes the City requires that storm sewer facilities be sized for the 25-yr event and retention facilities be sized for the 10-yr 2-hr event. Since the focus of the present project is the 100-yr 24-hr event, these studies were considered negligible. However, the City referred to the Montana Department of Transportation (MDT) for as-built plans of Kagy Boulevard which was constructed in the 1980s. The as-built plans of Kagy Boulevard, included as Supplemental Data, were obtained and show four stream crossings through Kagy Boulevard: Middle Creek Ditch, Spring Creek, Weed Creek, and Sourdough Creek. From those plans, it is perceived that the four streams correspond to the present study streams of Figgins Creek, Mathew-Bird Creek, Flat Creek, and Bozeman Creek, respectively. The as-built plans contain a Hydraulic Data Summary for the four streams showing their station along the alignment, the type of encroachment, frequency and discharge information, and flood of record information. Both the design flood and the basic flood information correspond to the 100-yr recurrence interval flood. According to the plans, the flood of record for all streams except Figgins Creek occurred in 1973. No flood of record was identified for Figgins Creek. For Figgins Creek (referred to as Middle Creek Ditch), the 100-yr discharge is reported as 37 cubic feet per second (cfs). No other hydrologic information was provided so their hydrologic methods and parameters utilized are unknown, complicating direct comparisons to the present study.

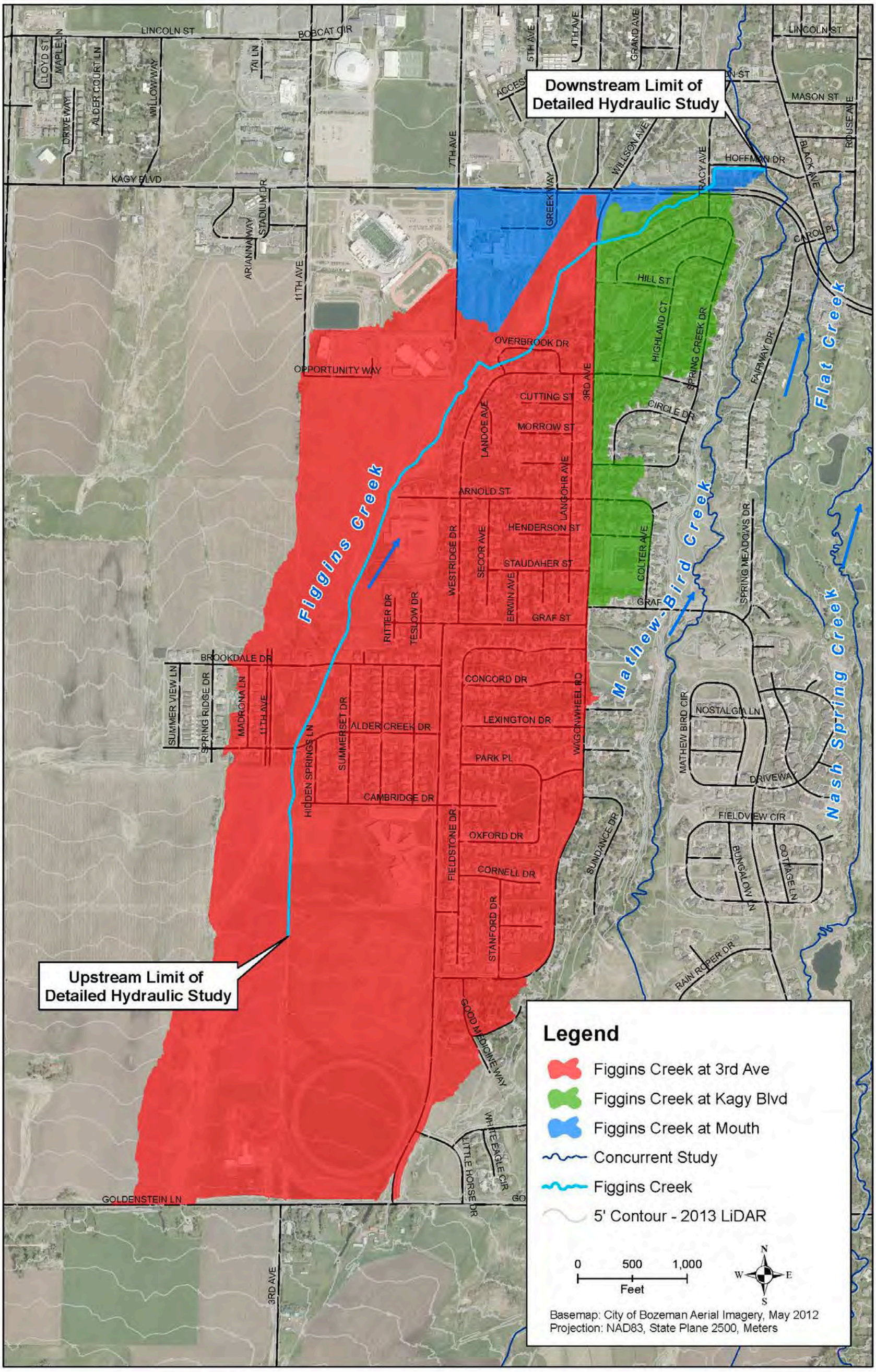


Figure 1-1. Figgins Creek watershed

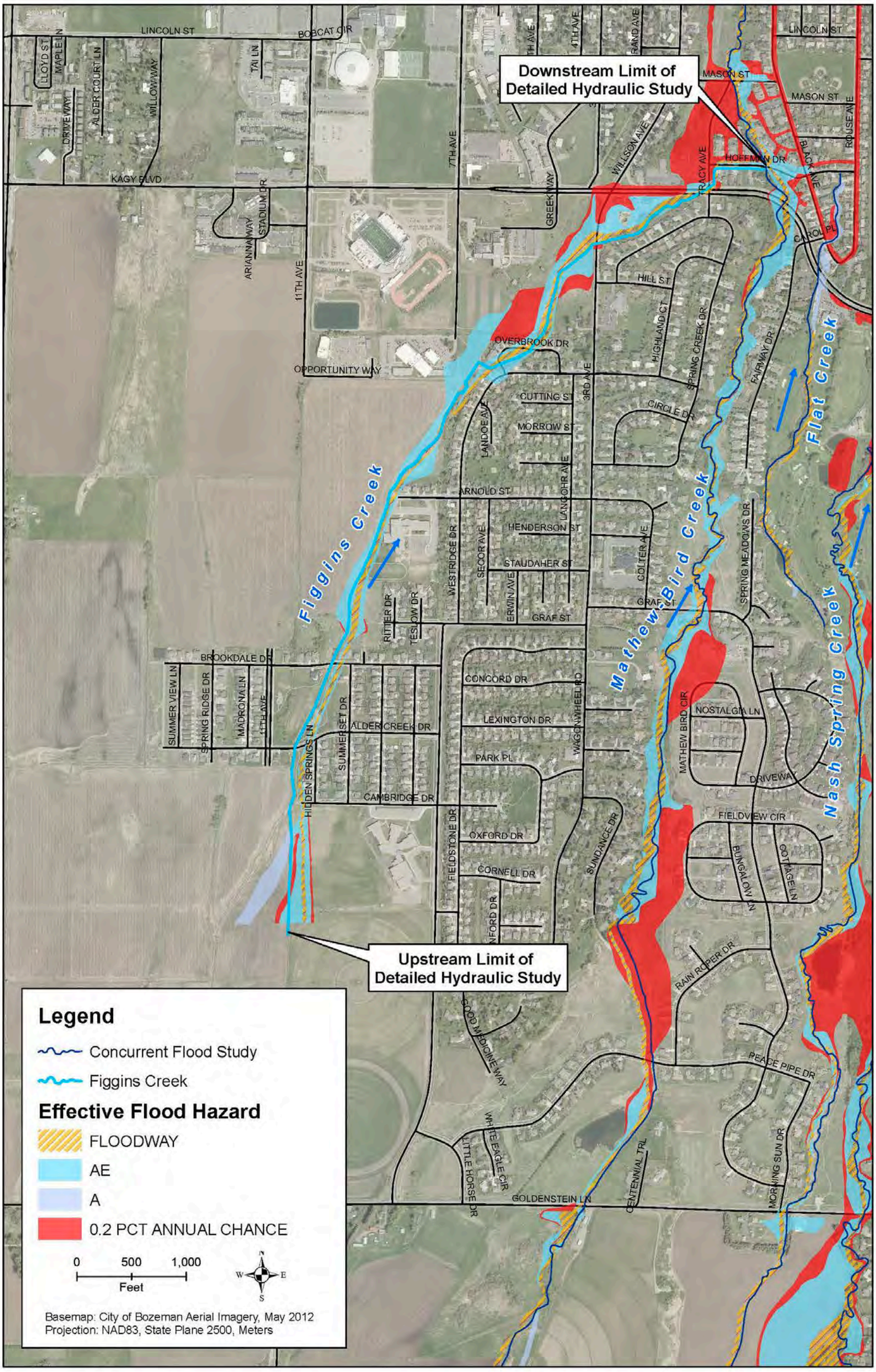


Figure 1-2. Effective flood hazard areas for Figgins Creek

2.0 HYDROLOGIC ANALYSES

Because no gage data is available for Figgins Creek, regional regression equations along with an HEC-HMS model were used to calculate the peak discharges. Discharges were calculated at major road crossings and locations of significant drainage area increases. By dividing the basin at structures and locations of significant inflows, the discharges applied to upstream reaches during the hydraulic analysis are not overly conservative. For the present study, flow change locations are located at: the mouth, Kagy Boulevard, at 3rd Avenue, upstream of 3rd Avenue, the former CMSP&P Railroad, Brookdale Drive, Alder Creek Drive, and upstream of Cambridge Drive. Coincidentally, the effective FIS states that the effective discharges were also calculated at Kagy Boulevard and the former CMSP&P Railroad.

It should be noted that there is an irrigation ditch present within the upper reach of the watershed that has the potential to distribute water to a neighboring watershed to the west of the Figgins Creek watershed. The amount of discharge split between Figgins Creek and the split channel appears to be controlled by a mechanical diversion. Hence, the split was assumed to be closed for the present study and it was assumed that the discharge lost through this ditch was negligible.

2.1 Regression Analysis

Regression analysis was performed to compute the annual peak discharges values for specific locations along Figgins Creek. Due to Figgins Creek being comprised of both rural and urban developing environments, the regional regression analysis for Montana was utilized as well as a weighted urban regression. These analyses are further detailed in the following sections.

2.1.1 Regional Regression Equation Analysis

Regional regression equations were used to compute the annual peak discharge values for the Figgins Creek drainage area. These equations are presented in *Methods for Estimating Flood Frequency in Montana Based on Data through Water Year 1998: U.S. Geological Survey (USGS) Water-Resources Investigations Report (WRIR) 03-4308* (**Reference 11**). USGS WRIR 03-4308 separates Montana into eight different regions based on topography and climatic conditions. The entire drainage area for Figgins Creek is located in the Upper Yellowstone-Central Mountain Region

USGS WRIR 03-4308 provides regression equations based on basin characteristics, active-channel width, bankfull width, and various weighted combinations of the methods. It also provides the Standard Error of Prediction (SEP) for all the methods. Smaller SEP percentages point to greater reliability of the regression equations used.

Prior to using the equations, values for the regression variables were estimated. All estimated variable values for the downstream reaches of Figgins Creek were within the acceptable range of values used to generate the regression equations. Locations of the Figgins Creek watershed upstream of 3rd Avenue do not meet the regression requirements as their contributing drainage areas are too small. It should be noted that the applicability of the regression estimates to Figgins Creek is considered to be less reliable than other methods. The locations of the stream gages referenced within USGS WRIR 03-4308 are comprised of streams whose defining discharges are largely determined from runoff whether it be from snowmelt, rainfall, or rain on snow events. The typical flood discharge found within Figgins Creek is a result of rainfall runoff. Also, the active-channel and bankfull widths measured for Figgins Creek during field reconnaissance are largely unsuitable for the regression methods due to man-made alterations of the natural channel in the form of road crossings, development, bank protection and grade control structures. The upper extents of the stream have been straightened through agricultural lands, a historic railroad, and developing residential areas. Because of this, the discharges for Figgins Creek derived from the regional regression equations should be used with caution. The range of values applied for the regression analyses are presented in **Table 2-1**.

ArcGIS 10.1 was used to estimate all variables for the basin characteristics equations in a manner consistent with the methods used by the USGS to formulate the regression equations. The drainage areas (A) were delineated using digital elevation models (DEM) developed from LiDAR developed by Photo Science, Inc. (**Reference 12**) and USGS Topographic Quadrangle Maps. Drainage area delineations utilized for the regression analysis are shown in **Figure 1-1** and the values are shown in **Table 2-1**.

The percentage of drainage area above elevation of 6000' (E_{6000}) was estimated by delineating the 6000' contour from the USGS Topographic Quadrangle maps. The delineated area above 6000' totals zero (0) mi^2.

The active-channel width and bankfull width for all basins were measured during field reconnaissance based on guidelines presented in USGS WRIR 03-4308. These values were taken along the stretch between 3rd Avenue and Kagy Blvd and are presented in **Table 2-1**. As can be seen from the values, the dimensions reflect those of a consistent urbanized channel.

Table 2-1. Regression parameters

Description	Drainage Area, A (mi^2)	Percentage of basin above 6,000 feet in elevation, E_{6000} (%)	Active Channel Width W_{ac} (ft)	Bankfull Channel Width W_{bf} (ft)
Upper Yellowstone-Central Mountain Region Range of Values Used to Develop Regression Equations	0.47 - 2,032	0 - 100	1.0 - 150	2.5 - 170
Confluence with Mathew-Bird Creek	1.01	0.00	4.5	7.0
Kagy Blvd	0.96	0.00	4.5	7.0
3rd Ave	0.86	0.00	4.5	7.0

Regression equations for basin characteristics, active-channel width, and bankfull width were calculated for Figgins Creek at 3rd Avenue, Kagy Boulevard, and at the confluence with Mathew-Bird Creek independently. A weighted combination of the three methods was also computed for the three locations. All calculations were performed using the web-based USGS Flood Discharge at Ungaged Sites in Montana program. The program utilizes the equations presented in WRIR 03-4308. Results of the regression analyses are included below in **Section 3** of this report and the output data from the USGS web-based program is included in **Appendix A**.

2.1.2 Urban Weighted Regression

As previously mentioned, the Figgins Creek watershed is comprised of rural and urban environments. Since the regression analysis detailed in USGS WRIR 03-4308 is predominately based off of rural datasets, the regression methods detailed in *Flood Characteristics of Urban Watersheds in the United States USGS Water-Supply Paper 2207* (USGS WSP 2207) (**Reference 13**) were also used. The three parameter equations presented in USGS WSP 2207 provide methods for applying a basin development factor (BDF) to the rural regression estimates in order to account for the urbanization present within the watershed. For the three locations listed above in **Table 2-1**, the BDF was estimated to be seven (7) due to the Figgins Creek channel being constructed throughout the reach, storm drains present in more than 50% of the bottom 2/3 of the watershed as well as the presence of curb and gutter present in more than 50% of the bottom 2/3 of the watershed. Results of the regression analyses are included below in **Section 3** of this report.

As detailed within **Section 2.1.1**, the regression estimates based on the channel dimensions are likely less reliable as they have been manipulated and don't reflect the natural channel forming discharges. Hence, the urban weighted regression method was only applied to the regression results calculated using the basin and climatic characteristics.

2.2 Rainfall-Runoff Analysis

The Figgins Creek watershed was also analyzed using the rainfall-runoff method. This was done utilizing the U.S. Army Corps of Engineers' (USACE) HEC-HMS modeling program Version 3.5. The HEC-HMS modeling program is a graphical user interface designed to simulate a precipitation-runoff response in urban or natural watersheds. The model takes into account a user specified meteorological model, loss and transform method, and reach routing method for each individual subbasin entered into the program.

The meteorological model for Figgins Creek utilized a 24-hour design storm to simulate the rainfall over the watershed. The SCS Runoff Curve Number Method was used to model potential losses. The transform method used is the Curve Number Method described in National Engineering Handbook (**Reference 9**). The Muskingum-Cunge routing method was used to route the hydrograph through the watershed. Results of the HEC-HMS model are provided in **Section 3** with input parameters discussed in the following paragraphs.

2.2.1 Precipitation

Design storms used in the hydrologic analysis of Figgins Creek consisted of a 24-hour design storm distribution. Point precipitation depths for the 10-, 4-, 2-, and 1-percent-annual-chance storm events were taken from the isohyetal maps found in *NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume I – Montana* (**Reference 7)** for durations of 6 and 24 hours. All precipitation durations less than six hours were obtained using equations, figures and tables presented in *NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume I – Montana* and *Short Duration Rainfall Relations for the Western United States* (**Reference 1**). The 0.2-percent-annual-chance storm event precipitation values were extrapolated from a log-probability curve of the 10-, 4-, 2-, and 1-percent annual chance storm events. All point precipitation depths are displayed in **Table 2-2**. All pertinent data used to determine the depths are included in **Appendix B**.

Table 2-2. Design storm rainfall depths

Duration	50-Percent-Annual-Chance Depth (in)	20-Percent-Annual-Chance Depth (in)	10-Percent-Annual-Chance Depth (in)	4-Percent-Annual-Chance Depth (in)	2-Percent-Annual-Chance Depth (in)	1-Percent-Annual-Chance Depth (in)	0.2-Percent-Annual-Chance Depth (in)*
5 min	0.17	0.26	0.33	0.42	0.49	0.57	0.72
15 min	0.31	0.49	0.61	0.77	0.92	1.06	1.35
1 hr	0.45	0.72	0.91	1.13	1.34	1.54	1.94
2 hr	0.52	0.79	0.98	1.22	1.42	1.60	2.04
3 hr	0.59	0.85	1.05	1.30	1.48	1.66	2.08
6 hr	0.75	1.00	1.20	1.50	1.65	1.80	2.25
12 hr	0.94	1.26	1.53	1.88	2.09	2.25	2.81
24 hr	1.20	1.60	1.90	2.30	2.60	2.80	3.37

**0.2-percent-annual-chance precipitation depths were extrapolated from 50- to 1-percent-annual-chance depths.*

It should be noted that the utilized rainfall values were compared with the values referenced in the City of Bozeman's (the City) *Design Standards and Specifications Policy* (**Reference 3).** Comparison of the City's rainfall depths shows close correlation with the isohyetal maps found in *NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume I – Montana*. However, the short duration values taken from *NOAA Atlas 2, Precipitation-Frequency Atlas of the Western United States, Volume I – Montana* and *Short Duration Rainfall Relations for the Western United States* were more conservative (larger) than those estimated utilizing the City's values.

2.2.2 Loss Rate

The SCS Curve Number Method was chosen to model potential runoff loss with respect to soil type and land use conditions. The Figgins Creek watershed was divided into 24 subbasins. The subbasins utilized in the hydrologic modeling of Figgins Creek are shown in **Figure 2-1**. Drainage areas for the various subbasins are presented in **Table 2-3**. Soils coverage for the Figgins Creek watershed was obtained in Soil Survey Geographic (SSURGO) format from the Natural Resources Conservation Service (NRCS) Geospatial Data Gateway (**Reference 8**). The hydrologic soil groups present within the Figgins Creek watershed are displayed in **Figure 2-2**. Land use data was also obtained from the NRCS Geospatial Data Gateway as well as the City (**Reference 4**). The land use classifications present within the Figgins Creek watershed are displayed in **Figure 2-3**. Shapefiles containing the soils and land use data were intersected and clipped to the watershed boundary. This process resulted in a shapefile containing the land use associated to each soil type, along with the total area of each soil and land use combination within the watershed. The NRCS *Urban Hydrology for Small Watersheds Technical Release 55 (TR-55)* (**Reference 10**) was used to assign a set of curve numbers to each of the subbasins. When assigning curve numbers all areas were considered to be in good hydrologic condition

with an antecedent moisture condition of two (AMCII). An on-site evaluation of the watershed was conducted in addition to the examination of aerial imagery and land use coverage. This evaluation aided in assigning the most representative set of curve numbers to the different land use and vegetative cover types present in the watershed. The adopted land use curve numbers utilized for this study are shown in **Appendix C**.

Each subbasin's cumulative loss rate was determined by calculating an areal weighted-average curve number value. This final weighted-average curve numbers for the subbasins of Figgins Creek are shown in **Table 2-3**. Calculations for the curve number method are included in **Appendix D**.

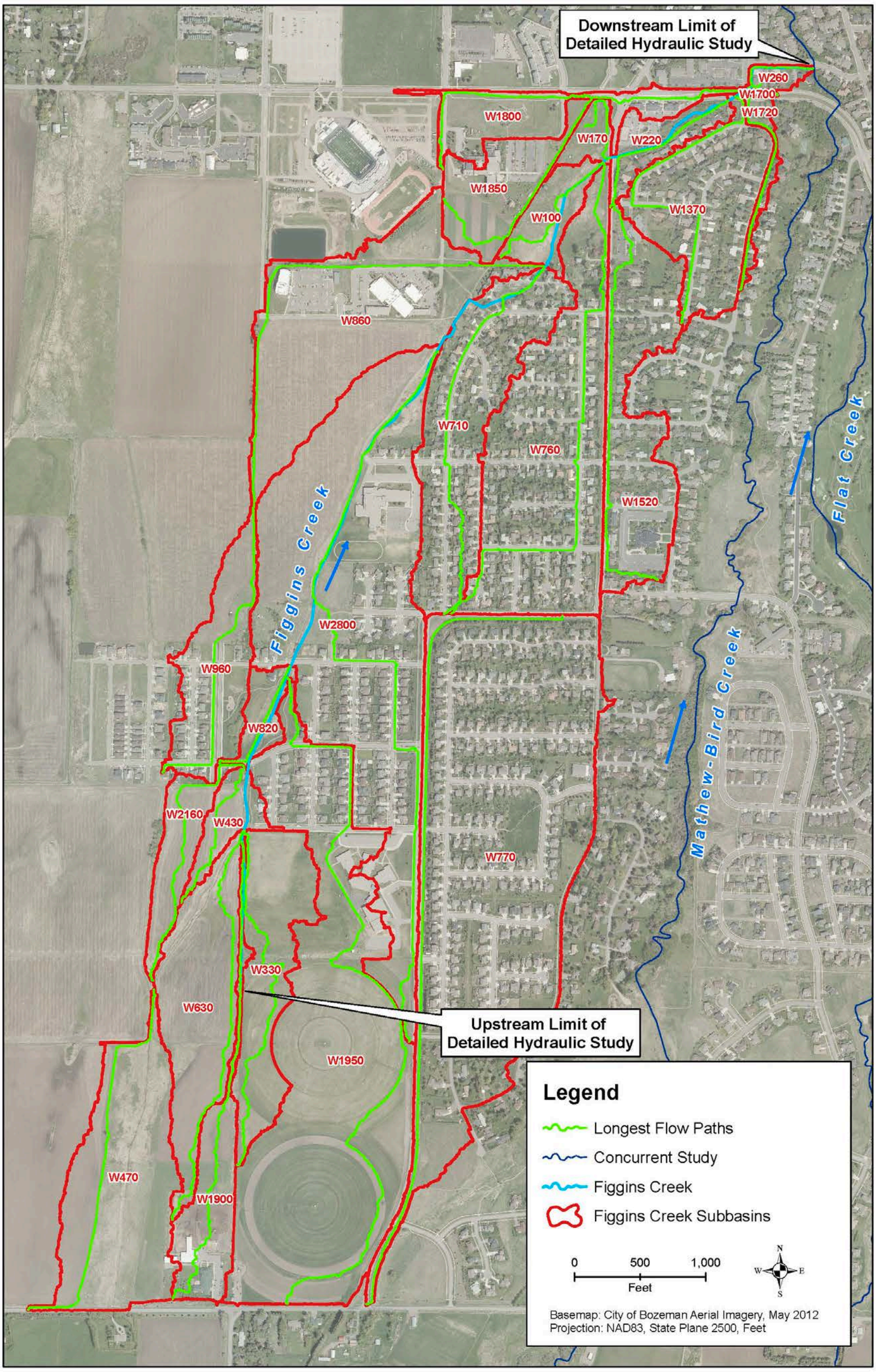


Figure 2-1. Subbasins and longest flow paths utilized for the hydrologic model

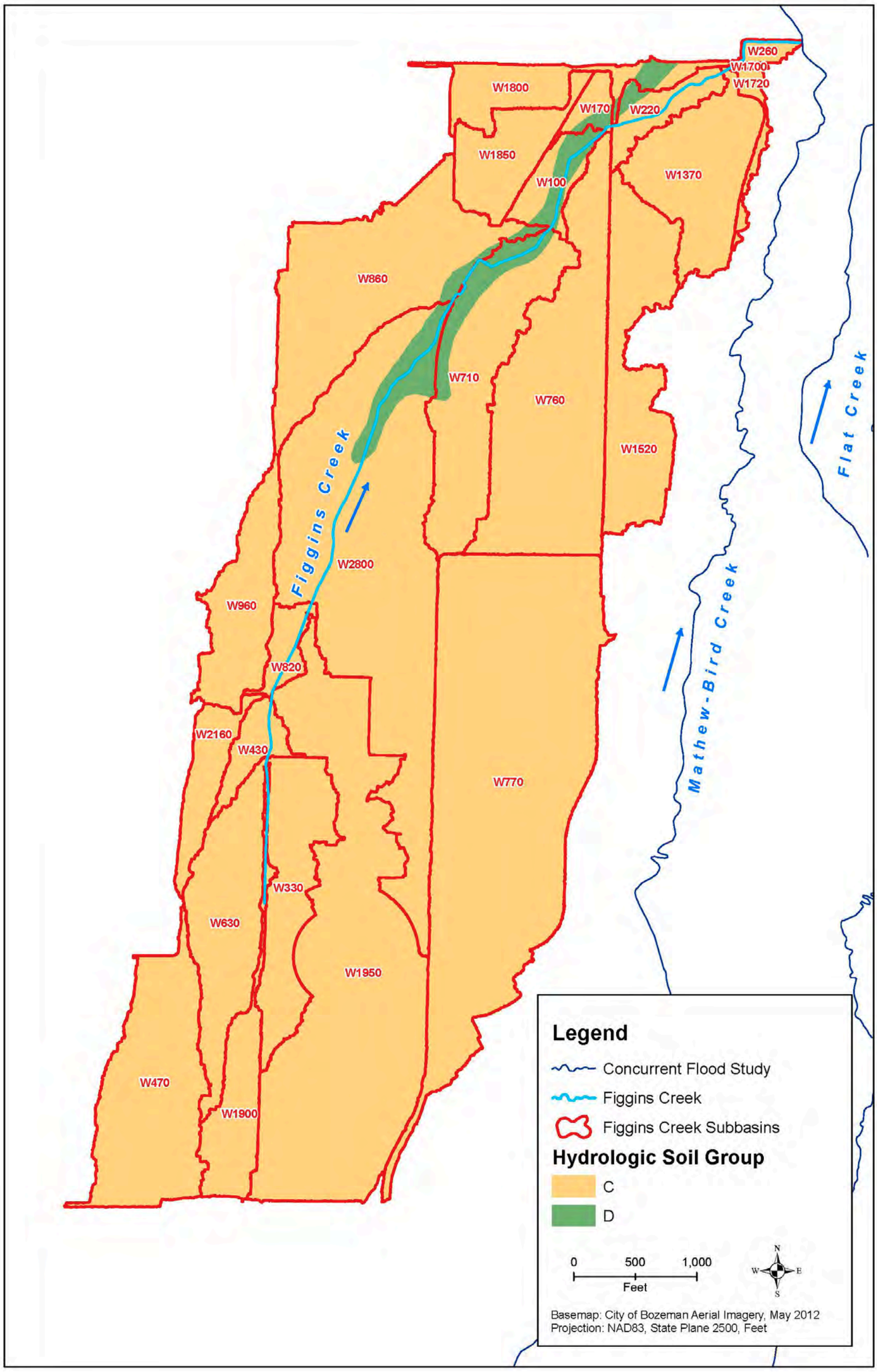


Figure 2-2. Hydrologic soil groups present within the Figgins Creek watershed

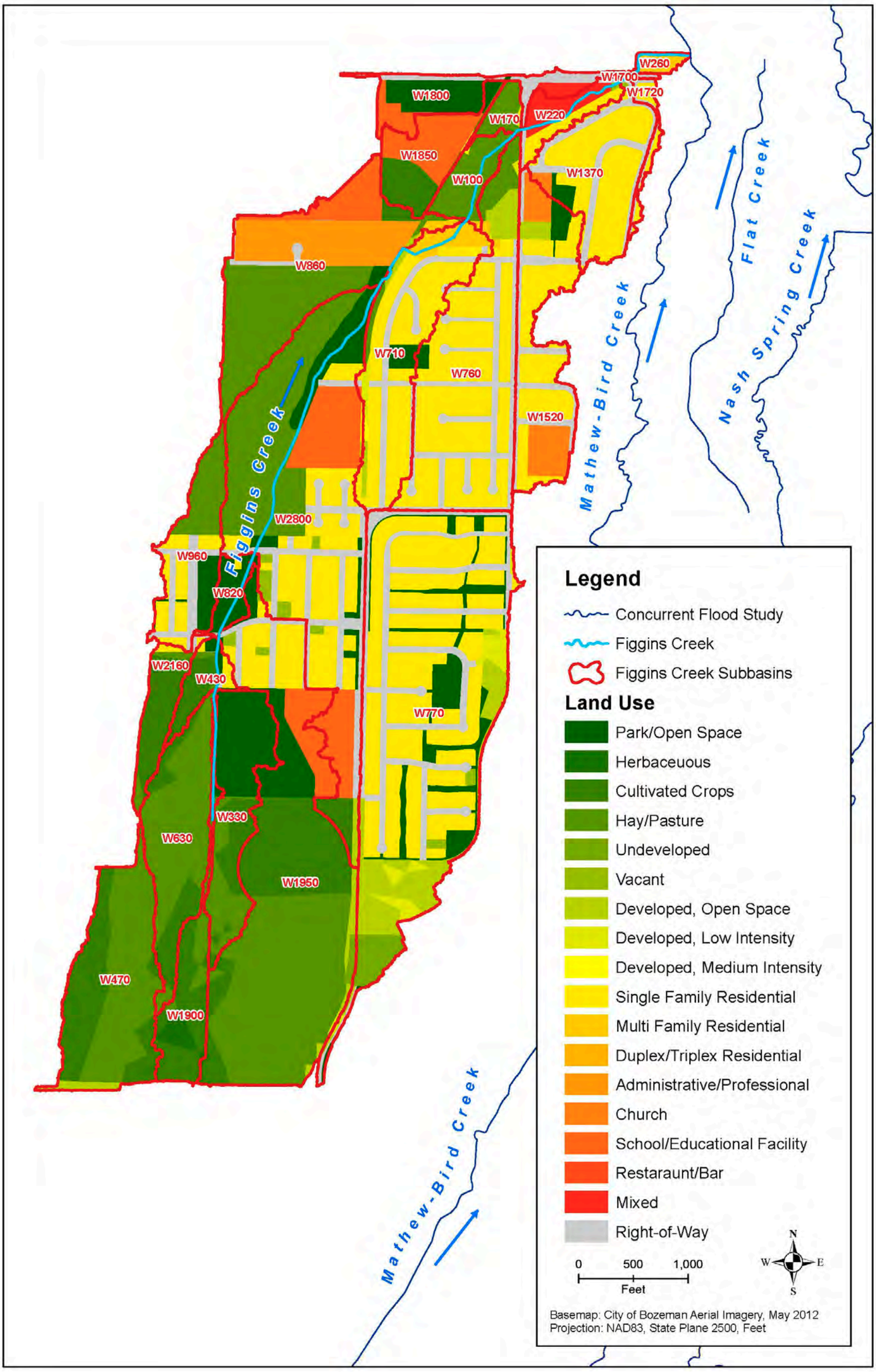


Figure 2-3. Descriptions of land uses present within the Figgins Creek watershed

2.2.3 Transform

In order to employ the SCS Dimensionless Unit Hydrograph method to distribute the runoff volume for the basin, the SCS lag time was required. The lag time for the basin was calculated using the Curve Number Lag Method described in the *National Engineering Handbook* (**Reference 9**). The lag time is calculated using the following equation:

$$L = (l^{0.8}(S+1)^{0.7}) / 1900Y^{0.5}$$

where L equals the lag time in hours; l is defined as the hydraulic length of the catchment in feet; Y represents the average watershed land slope in percent. Average watershed land slope is calculated with the equation:

$$Y = 100(CI)/A$$

where C is the summation of the length of the contour lines that pass through the watershed drainage area on the USGS quadrangle sheet in feet; I is the contour interval used on the quadrangle sheet in feet; and A is the drainage area of the basin, in square feet.

The parameter S in the Lag equation is a storage term and is defined as:

$$S = (1000 / CN) – 10$$

in which CN represents the dimensionless curve number described in **Section 2.2.2**.

Both the hydraulic length of the catchment and the average watershed land slope were calculated using ArcGIS 10.1 with the LiDAR and 10-m DEM datasets, respectively. The path of the hydraulic length for each subbasin is shown in **Figure 2-1**. The slope tool within ArcGIS calculates slope for each cell of the DEM, from which an average is then obtained. In comparisons performed in previous studies, it was discovered that the average basin slope obtained through the ArcGIS slope tool compared well to the same parameter obtained by measuring contour lines. Initial calculations of the watershed slope were performed with the LiDAR dataset, which includes many steep slopes along the channel and other small scale artificial topographic features such as building footprints. The method for calculating lag time and time of concentration was developed with topography from USGS quadrangle maps utilizing the length of contour lines and contour interval within the basin. The topography shown on those maps is the same dataset as the USGS 10-m DEM. Therefore, the USGS 10-m DEM dataset was used for the average basin slope calculation to better align with how the method was developed.

HEC-HMS then uses the lag time parameter to internally calculate the time of concentration (t_c) for the watershed using the following equation:

$$t_c = L / 0.6$$

The results of the described calculations are provided in **Table 2-3**. Supplemental information and calculations are provided in **Appendix F**.

Table 2-3. Summary of hydrologic parameters for each basin

HMS Basin	Area (mi^2)	Composite CN	Hydraulic Length (ft)	Average Watershed Land Slope (%)	Lag (min)	Tc (hr)
W100	0.0113	77.5	1605.0	1.5	24.7	0.7
W170	0.0051	76.4	917.2	1.6	15.5	0.4
W220	0.0111	85.5	1702.8	2.3	16.0	0.4
W260	0.0028	90.5	726.0	1.7	7.8	0.2
W330	0.0335	75.5	3757.7	1.5	50.8	1.4
W430	0.0089	79.9	1548.2	1.4	22.9	0.6
W470	0.0546	76.9	3271.9	1.4	45.5	1.3
W630	0.0396	75.7	3932.1	1.5	52.4	1.5
W710	0.0507	86.2	3612.5	2.2	29.2	0.8
W760	0.0802	85.9	4966.6	2.0	40.0	1.1
W770	0.1655	83.6	6415.8	1.5	60.9	1.7
W820	0.0072	75.4	1293.7	2.0	18.8	0.5
W860	0.0698	81.8	4199.0	1.8	42.3	1.2
W961	0.0282	82.0	2784.1	1.4	34.6	1.0
W1370	0.0378	86.9	3008.0	2.9	21.4	0.6
W1520	0.0448	87.7	3796.9	2.9	25.1	0.7
W1700	0.0005	97.7	298.1	1.8	3.6	0.1
W1720	0.0043	90.0	1919.3	3.0	13.0	0.4
W1800	0.0213	84.4	3417.4	1.9	31.6	0.9
W1850	0.0208	83.3	2185.9	3.2	17.9	0.5
W1900	0.0218	78.3	4319.4	1.4	54.9	1.5
W1950	0.1364	78.2	7515.8	1.5	83.7	2.3
W2160	0.0139	80.8	2587.0	1.4	33.7	0.9
W2800	0.1379	82.4	7304.5	1.7	65.9	1.8

**According to the SCS Handbook, the engineer should use a Tc equal to 0.1 hr (6 min) if the computed Tc is less than 0.1 hr.*

2.2.4 Routing

To computationally route the runoff hydrograph through the watershed, the Muskingum-Cunge routing method was chosen. This routing routine approximates the diffusion method, allowing the model to describe the physical nature of the basin and thus the attenuation potential. Within the HEC-HMS model the Muskingum-Cunge method allows the user to define an eight-point cross section to describe the channel and overbank geometries, roughness values, lengths and slopes for each reach. Routing reaches were delineated using ArcGIS 10.1. The eight-point channel cross sections, lengths and slopes were created for each reach of Figgins Creek using the LiDAR topographic dataset. The Manning's *n* roughness values assigned within the HEC-HMS model were determined based on site visits, aerial photography, and engineering judgment. *Open Channel Hydraulics* by Ven Te Chow (**Reference 2**) provided tables of roughness coefficients for different surfaces. Assigned Manning's values throughout the simulated reaches varied from 0.040 – 0.050 for the channels to represent a meandering channel with stones and objects of variable form roughness. Manning's values of 0.040 – 0.12 were utilized in the overbanks to describe floodplains representing grasses to dense vegetation.

Review of the existing hydraulic profile and physical characteristics of the watershed shows that there is the potential for storage upstream of the Kagy Boulevard and 3rd Avenue stream crossings. The potential attenuation of discharges related to the available storage was inspected utilizing the Modified-Puls routing method. Upon review of the results calculated using the Modified-Puls routing routine, it was shown that the runoff volume produced by the simulated events exceeded the available storage upstream of the Kagy Boulevard and 3rd Avenue with insignificant differences of the results produced utilizing the Muskingum-Cunge method. Hence, utilization of the Modified-Puls method was disregarded.

3.HYDROLOGIC ANALYSES RESULTS

3.1 Summary of Discharges

The effective discharges used for Figgins Creek are shown in **Table 3-1**. Results of the various methods described in **Section 2** are summarized in **Table 3-2** through **Table 3-9**. A comparison of the flow change locations for the effective data with those of the present study are displayed in **Figure 3-1**.

Table 3-1. Effective discharges for Figgins Creek

Location	Drainage Area (mi^2)	10-Percent-Annual-Chance Discharge (cfs)	4-Percent-Annual-Chance Discharge (cfs)	2-Percent-Annual-Chance Discharge (cfs)	1-Percent-Annual-Chance Discharge (cfs)	0.2-Percent-Annual-Chance Discharge (cfs)
Above Kagy Boulevard	1.3	119	*N/A*	188	207	266
Above CMSP&P Railroad	0.8	110	*N/A*	171	186	233
Approximately 0.4 miles upstream from CMSP&P Railroad	0.6	103	*N/A*	159	171	209
Approximately 1.0 miles upstream from CMSP&P Railroad	0.4	99	*N/A*	150	159	190

Table 3-2. Resultant discharges for Figgins Creek at mouth

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
2004 USGS Regional Regression Equations - Basin Characteristics	Discharge (cfs)	43	83	126	182	377
	SEP	66.0%	60.0%	59.1%	60.3%	69.3%
2004 USGS Regional Regression Equations - Active Channel Width	Discharge (cfs)	125	225	327	456	884
	SEP	70.6%	76.4%	82.8%	90.1%	111.3%
2004 USGS Regional Regression Equations - Bankfull Width	Discharge (cfs)	101	182	266	372	731
	SEP	74.4%	79.9%	86.4%	93.9%	116.1%
2004 USGS Regional Regression Equations - Weighted Basin, Active Channel & Bankfull Widths	Discharge (cfs)	67	110	152	203	377
	SEP	52.8%	54.2%	56.7%	59.7%	69.3%
1983 Urban Regression - Basin Characteristics	Discharge (cfs)	98	162	228	310	566
HEC-HMS (HEC-HMS Element Mouth)	Discharge (cfs)	93	153	203	246	367

Table 3-3. Resultant discharges for Figgins Creek through Kagy Boulevard

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
2004 USGS Regional Regression Equations - Basin Characteristics	Discharge (cfs)	41	80	122	176	365
	SEP	66.0%	60.1%	59.1%	60.3%	69.4%
2004 USGS Regional Regression Equations - Active Channel Width	Discharge (cfs)	125	225	327	456	884
	SEP	70.6%	76.4%	82.8%	90.1%	111.3%
2004 USGS Regional Regression Equations - Bankfull Width	Discharge (cfs)	101	182	266	372	731
	SEP	74.4%	79.9%	86.4%	93.9%	116.1%
2004 USGS Regional Regression Equations - Weighted Basin, Active Channel & Bankfull Widths	Discharge (cfs)	66	108	148	197	365
	SEP	52.8%	54.2%	56.8%	59.7%	69.4%
1983 Urban Regression - Basin Characteristics	Discharge (cfs)	93	156	221	299	547
HEC-HMS (HEC-HMS Element Kagy Culvert)	Discharge (cfs)	91	149	198	240	360

Table 3-4. Resultant discharges for Figgins Creek through 3rd Avenue

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
2004 USGS Regional Regression Equations - Basin Characteristics	Discharge (cfs)	38	74	113	164	340
	SEP	66.1%	60.2%	59.2%	60.4%	69.5%
2004 USGS Regional Regression Equations - Active Channel Width	Discharge (cfs)	125	225	327	456	884
	SEP	70.6%	76.4%	82.8%	90.1%	111.3%
2004 USGS Regional Regression Equations - Bankfull Width	Discharge (cfs)	101	182	266	372	731
	SEP	74.4%	79.9%	86.4%	93.9%	116.1%
2004 USGS Regional Regression Equations - Weighted Basin, Active Channel & Bankfull Widths	Discharge (cfs)	63	102	139	185	340
	SEP	52.8%	54.3%	56.9%	59.8%	69.5%
1983 Urban Regression - Basin Characteristics	Discharge (cfs)	86	144	204	278	507
HEC-HMS (HEC-HMS Element US 3rd Ave)	Discharge (cfs)	86	142	189	229	346

Table 3-5. Resultant discharges for Figgins Creek upstream of 3rd Avenue

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
HEC-HMS (HEC-HMS Element J508)	Discharge (cfs)	53	89	120	148	226

Table 3-6. Resultant discharges for Figgins Creek at former CMSP&P Railroad

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
HEC-HMS (HEC-HMS Element Old RR)	Discharge (cfs)	40	68	94	115	174

Table 3-7. Resultant discharges for Figgins Creek through Brookdale Drive

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
HEC-HMS (HEC-HMS Element BrookdaleDrive)	Discharge (cfs)	23	42	58	72	110

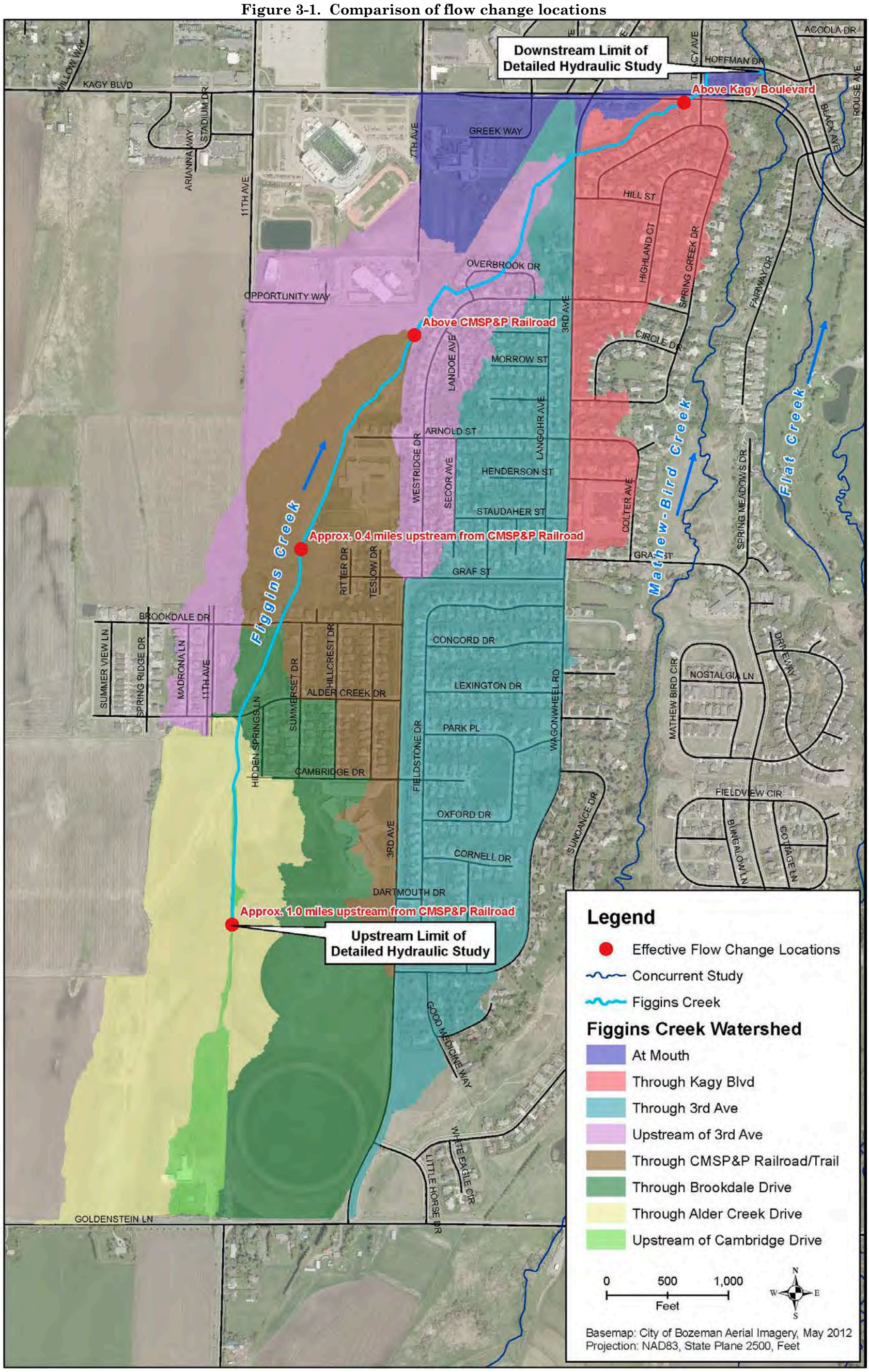
Table 3-8. Resultant discharges for Figgins Creek at Alder Creek Drive

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
HEC-HMS (HEC-HMS Element AlderCreekDr)	Discharge (cfs)	15	27	38	48	75

Table 3-9. Resultant discharges for Figgins Creek upstream of Cambridge Drive

Method	Description	10%-Annual-Chance	4%-Annual-Chance	2%-Annual-Chance	1%-Annual-Chance	0.2%-Annual-Chance
HEC-HMS (HEC-HMS Element US Cambridge)	Discharge (cfs)	10	19	27	34	52

Figure 3-1. Comparison of flow change locations



3.2 Recommended Discharges

In review of the discharges listed in **Table 3-2** through **Table 3-9**, one can see that there is a vast difference in calculated discharges of those methods dependent upon basin characteristics (basin characteristic regression and HEC-HMS) versus those produced from channel characteristics (active-channel and bankfull widths). As previously discussed the active-channel width and bankfull width regression equations were determined to be inappropriate due to the aforementioned man-made alterations to the natural channel. Due to this, the regression estimates utilizing the channel characteristics should be utilized for comparison purposes only. Although the weighted regression estimates provide a slightly lower SEP, it too is reliant on the channel characteristics and is therefore considered inapplicable. It should be noted that other weighted regression estimates based on channel characteristics were performed. However, due to the aforementioned lack of confidence in the channel variables, the results were not displayed in the above tables. The results of all performed regression analyses can be found in **Appendix B**.

Comparisons of the basin characteristics regression estimates with the results of the hydrologic model do not show a close approximation. A possible reason for the difference is that the basin characteristics regression is based off a regional data source while the hydrologic model describes the immediate conditions of the Figgins Creek watershed. The regression estimates are comprised of largely mountainous areas whose flood events are predominately comprised of snowmelt and rain on snow. While these are typically the types of events associated with high runoff for mountain streams, Figgins Creek is considered a valley stream with a spring source. Therefore, its flood events are likely produced from runoff resultant of large rainfall events. Another explanation for the difference in regression and HEC-HMS results is that the datasets utilized to create the regression estimates are largely rural areas while the HEC-HMS model accounts for the development and urban environment of the present watershed.

Comparison of the urban weighted regression results with those of the HEC-HMS model show a reasonable approximation. However the limits of the regression parameters still apply to the urban weighted regression. Therefore, the regression methods do not apply to locations upstream of 3rd Avenue. Applying the calculated discharges of the urban weighted regression at 3rd Avenue to the upstream extents would be overly conservative and a poor representation of the hydraulic characteristics present within the watershed. Hence, the HEC-HMS model is considered the most appropriate method for determining peak flow estimates for the Figgins Creek as not only does it account for the development within the watershed but also allows for a more accurate calculation of discharge in the upstream reaches.

It should be noted that the recommended discharges for the downstream portions of the watershed are considerably higher than the effective discharges for Figgins Creek. Similar to

the comparisons mentioned above, the differences are likely due to gages utilized for the regression estimates of the effective study being comprised of streams whose flood events are largely dependent upon snowmelt and whose environments are predominately forested and rural. Another reason for the increase in discharges from the effective studies is that when the effective study was performed (1985), the Figgins Creek watershed was largely rural. However, in the 28 years since the study was completed, the downstream portions of the watershed have been steadily developing with residential and commercial uses replacing the open fields once predominant. Comparisons of the effective discharges for locations upstream of 3rd Avenue actually show a resemblance to the recommended discharges. The contributing area from the former CMSP&P Railroad crossing and upstream is still largely agricultural. The effective FIS also references a higher drainage area than that measured for the present study. This can be attributed to two differences; difference in topographic datasets utilized to delineate the watersheds and the effective study neglecting to account for Goldenstein Lane. The present study utilized a topographic dataset created from Light Detection and Ranging (LiDAR) which is likely more accurate than the dataset utilized in 1986 which was likely the USGS Topographic Quadrangle maps. The other reason for the discrepancy in drainage areas is the difference in how the present and effective studies account for Goldenstein Lane. The present study recognizes the elevated profile of the roadway with the inherent roadside drainage directing runoff east towards Mathew-Bird Creek. The area contributing to the runoff diverted to Mathew-Bird Creek is approximately the difference in area of the effective and present studies (approximately 0.28 mi^2).

Recommended 10-, 4-, 2-, 1- and 0.2-percent annual chance discharges for all locations of Figgins Creek are presented below in **Table 3-10**. These discharges are proposed for use in the hydraulic analysis of Figgins Creek.

Table 3-10. Recommended discharges for Figgins Creek

Location	Drainage Area (mi2)	10%-Annual-Chance Discharge (cfs)	4%-Annual-Chance Discharge (cfs)	2%-Annual-Chance Discharge (cfs)	1%-Annual-Chance Discharge (cfs)	0.2%-Annual-Chance Discharge (cfs)
At Mouth	**1.01**	93	153	203	246	367
Through Kagy Boulevard	**0.96**	91	149	198	240	360
Through 3rd Ave	**0.86**	86	142	189	229	346
Reach upstream of 3rd Ave	**0.61**	53	89	120	148	226
Formerly CMSP&P Railroad	**0.45**	40	68	94	115	174
Through Brookdale Drive	**0.32**	23	42	58	72	110
Through Alder Creek Drive	**0.16**	15	27	38	48	75
Upstream of Cambridge Drive	**0.12**	10	19	27	34	52

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APPENDIX A

REGRESSION ANALYSES

Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana -- (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	Figgins - Through 3rd Ave HMS Element: US 3rd Ave
Region:	Upper Yellowstone
Estimation method:	Weighted estimate based on Basin and Climatic Characteristics, Active-channel width, and Bankfull width
Drainage area in square miles:	0.8646
Percent basin above 6,000 feet:	0
Width of active channel in feet:	4.5
Width of bank full channel in feet:	7

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: A =      0.86 E6 =     0.
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	5.	97.6	1.3	20.
5	19.	75.3	6.4	59.
10	38.	66.1	13.9	103.
25	74.	60.2	29.5	187.
50	113.	59.2	45.6	282.
100	164.	60.4	64.7	413.
200	228.	63.4	86.9	599.
500	340.	69.5	119.8	963.

METHOD: Regression on active channel width
Flood frequency estimates for
Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: WAC = 4.50

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	71.	68.6	25.2	200.
10	125.	70.6	43.2	361.
25	225.	76.4	72.4	697.
50	327.	82.8	98.0	1090.
100	456.	90.1	125.8	1650.
200	616.	98.6	155.6	2440.
500	884.	111.3	197.5	3960.

METHOD: Regression on bank full channel width
Flood frequency estimates for
Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: WBF = 7.00

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 1, 2 and 3
Flood frequency estimates for
Figgins - Through 3rd Ave
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	16.	67.9	5.7	44.
5	39.	53.7	16.9	90.
10	63.	52.8	27.5	143.
25	102.	54.3	43.9	237.
50	139.	56.9	57.9	336.
100	185.	59.8	73.7	463.
200	240.	63.3	91.4	629.
500	340.	69.5	119.8	963.

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Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - Through 3rd Ave** HMS Element: US 3rd Ave
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Active-channel width and Bankfull width**
Width of active channel in feet:	**4.5**
Width of bank full channel in feet:	**7**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on active channel width
 Flood frequency estimates for
 Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: WAC =      4.50
 RI        DISCHARGE  STD ERR OF              90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2         24.        72.3              8.2                71.
     5         71.        68.6             25.2               200.
    10        125.        70.6             43.2               361.
    25        225.        76.4             72.4               697.
    50        327.        82.8             98.0              1090.
   100        456.        90.1            125.8              1650.
   200        616.        98.6            155.6              2440.
   500        884.       111.3            197.5              3960.


 METHOD: Regression on bank full channel width
 Flood frequency estimates for
           Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: WBF =      7.00
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 2 and 3
Flood frequency estimates for
Figgins - Through 3rd Ave
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	68.	68.1	24.2	188.
10	120.	70.4	41.8	344.
25	220.	76.4	71.5	678.
50	327.	82.8	98.7	1090.
100	456.	90.1	126.8	1640.
200	616.	98.6	156.9	2420.
500	884.	111.3	199.2	3920.

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - Through 3rd Ave** HMS Element: US 3rd Ave
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Basin and Climatic Characteristics and Active-channel width**
Drainage area in square miles:	**.8646**
Percent basin above 6,000 feet:	**0**
Width of active channel in feet:	**4.5**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: A =      0.86 E6 =     0.
 RI        DISCHARGE  STD ERR OF                90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2          5.        97.6                1.3                20.
     5         19.        75.3                6.4                59.
    10         38.        66.1               13.9               103.
    25         74.        60.2               29.5               187.
    50        113.        59.2               45.6               282.
   100        164.        60.4               64.7               413.
   200        228.        63.4               86.9               599.
   500        340.        69.5              119.8               963.
```

```
 METHOD: Regression on active channel width
 Flood frequency estimates for
```

Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: WAC = 4.50

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	71.	68.6	25.2	200.
10	125.	70.6	43.2	361.
25	225.	76.4	72.4	697.
50	327.	82.8	98.0	1090.
100	456.	90.1	125.8	1650.
200	616.	98.6	155.6	2440.
500	884.	111.3	197.5	3960.

METHOD: Combined methods 1 and 2
Flood frequency estimates for
Figgins - Through 3rd Ave
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	16.	67.9	5.7	44.
5	40.	58.8	16.4	100.
10	65.	56.4	27.1	155.
25	104.	56.1	43.7	248.
50	140.	57.5	57.8	341.
100	185.	59.8	73.7	463.
200	240.	63.3	91.4	629.
500	340.	69.5	119.8	963.

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Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - Through 3rd Ave** HMS Element: US 3rd Ave
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Basin and Climatic Characteristics and Bankfull width**
Drainage area in square miles:	**.8646**
Percent basin above 6,000 feet:	**0**
Width of bank full channel in feet:	**7**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: A =      0.86 E6 =     0.
 RI        DISCHARGE  STD ERR OF                90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2          5.        97.6                1.3                20.
     5         19.        75.3                6.4                59.
    10         38.        66.1               13.9               103.
    25         74.        60.2               29.5               187.
    50        113.        59.2               45.6               282.
   100        164.        60.4               64.7               413.
   200        228.        63.4               86.9               599.
   500        340.        69.5              119.8               963.
```

```
 METHOD: Regression on bank full channel width
 Flood frequency estimates for
```

Figgins - Through 3rd Ave
Upper Yellowstone-Central Mountain Region: WBF = 7.00

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 1 and 3
Flood frequency estimates for
Figgins - Through 3rd Ave
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	7.	91.1	2.0	27.
5	34.	59.6	13.5	85.
10	57.	56.7	23.8	137.
25	96.	56.2	40.1	229.
50	133.	57.6	54.7	323.
100	178.	59.9	71.0	447.
200	235.	63.4	89.4	615.
500	340.	69.5	119.8	963.

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana -- (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	Figgins - Through Kagy Culvert HMS Element: US Kagy Culvert
Region:	Upper Yellowstone
Estimation method:	Weighted estimate based on Basin and Climatic Characteristics, Active-channel width, and Bankfull width
Drainage area in square miles:	0.9626
Percent basin above 6,000 feet:	0
Width of active channel in feet:	4.5
Width of bank full channel in feet:	7

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: A =      0.96 E6 =     0.
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	6.	97.4	1.5	22.
5	21.	75.2	6.9	64.
10	41.	66.0	15.1	112.
25	80.	60.1	32.0	202.
50	122.	59.1	49.3	304.
100	176.	60.3	69.9	444.
200	246.	63.3	93.7	644.
500	365.	69.4	129.0	1030.

METHOD: Regression on active channel width
Flood frequency estimates for
Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: WAC = 4.50

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	71.	68.6	25.2	200.
10	125.	70.6	43.2	361.
25	225.	76.4	72.4	697.
50	327.	82.8	98.0	1090.
100	456.	90.1	125.8	1650.
200	616.	98.6	155.6	2440.
500	884.	111.3	197.5	3960.

METHOD: Regression on bank full channel width
Flood frequency estimates for
Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: WBF = 7.00

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 1, 2 and 3
Flood frequency estimates for
Figgins - Through Kagy Culvert
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	16.	67.9	5.8	45.
5	40.	53.7	17.5	93.
10	66.	52.8	28.8	149.
25	108.	54.2	46.3	250.
50	148.	56.8	61.6	356.
100	197.	59.7	78.8	493.
200	257.	63.2	98.1	672.
500	365.	69.4	129.0	1030.

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - Through Kagy Culvert** HMS Element: US Kagy Culvert
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Active-channel width and Bankfull width**
Width of active channel in feet:	**4.5**
Width of bank full channel in feet:	**7**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on active channel width
 Flood frequency estimates for
 Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: WAC =      4.50
 RI        DISCHARGE  STD ERR OF              90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2         24.        72.3              8.2                71.
     5         71.        68.6             25.2               200.
    10        125.        70.6             43.2               361.
    25        225.        76.4             72.4               697.
    50        327.        82.8             98.0              1090.
   100        456.        90.1            125.8              1650.
   200        616.        98.6            155.6              2440.
   500        884.       111.3            197.5              3960.


 METHOD: Regression on bank full channel width
 Flood frequency estimates for
           Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: WBF =      7.00
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 2 and 3
Flood frequency estimates for
Figgins - Through Kagy Culvert
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	68.	68.1	24.2	188.
10	120.	70.4	41.8	344.
25	220.	76.4	71.5	678.
50	327.	82.8	98.7	1090.
100	456.	90.1	126.8	1640.
200	616.	98.6	156.9	2420.
500	884.	111.3	199.2	3920.

Montana Flood-Frequency and Basin-Characteristic Data

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - Through Kagy Culvert** HMS Element: US Kagy Culvert
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Basin and Climatic Characteristics and Active-channel width**
Drainage area in square miles:	**.9626**
Percent basin above 6,000 feet:	**0**
Width of active channel in feet:	**4.5**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: A =      0.96 E6 =     0.
 RI        DISCHARGE  STD ERR OF                90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2          6.        97.4                1.5                22.
     5         21.        75.2                6.9                64.
    10         41.        66.0               15.1               112.
    25         80.        60.1               32.0               202.
    50        122.        59.1               49.3               304.
   100        176.        60.3               69.9               444.
   200        246.        63.3               93.7               644.
   500        365.        69.4              129.0              1030.
```

```
 METHOD: Regression on active channel width
 Flood frequency estimates for
```

Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: WAC = 4.50

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	71.	68.6	25.2	200.
10	125.	70.6	43.2	361.
25	225.	76.4	72.4	697.
50	327.	82.8	98.0	1090.
100	456.	90.1	125.8	1650.
200	616.	98.6	155.6	2440.
500	884.	111.3	197.5	3960.

METHOD: Combined methods 1 and 2
Flood frequency estimates for
Figgins - Through Kagy Culvert
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	16.	67.9	5.8	45.
5	42.	58.8	16.9	103.
10	68.	56.3	28.4	162.
25	110.	56.0	46.1	261.
50	149.	57.4	61.5	362.
100	197.	59.7	78.8	493.
200	257.	63.2	98.1	672.
500	365.	69.4	129.0	1030.

Montana Flood-Frequency and Basin-Characteristic Data

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - Through Kagy Culvert** HMS Element: US Kagy Culvert
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Basin and Climatic Characteristics and Bankfull width**
Drainage area in square miles:	**.9626**
Percent basin above 6,000 feet:	**0**
Width of bank full channel in feet:	**7**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: A =      0.96 E6 =     0.
 RI        DISCHARGE  STD ERR OF                90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2          6.        97.4                1.5                22.
     5         21.        75.2                6.9                64.
    10         41.        66.0               15.1               112.
    25         80.        60.1               32.0               202.
    50        122.        59.1               49.3               304.
   100        176.        60.3               69.9               444.
   200        246.        63.3               93.7               644.
   500        365.        69.4              129.0              1030.
```

```
 METHOD: Regression on bank full channel width
 Flood frequency estimates for
```

Figgins - Through Kagy Culvert
Upper Yellowstone-Central Mountain Region: WBF = 7.00

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 1 and 3
Flood frequency estimates for
Figgins - Through Kagy Culvert
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	8.	91.0	2.2	28.
5	35.	59.6	14.1	88.
10	60.	56.6	24.9	143.
25	101.	56.2	42.4	241.
50	141.	57.5	58.2	343.
100	190.	59.8	76.0	477.
200	252.	63.2	96.1	659.
500	365.	69.4	129.0	1030.

Montana Flood-Frequency and Basin-Characteristic Data

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana -- (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	Figgins - At Mouth HMS Element: Mouth
Region:	Upper Yellowstone
Estimation method:	Weighted estimate based on Basin and Climatic Characteristics, Active-channel width, and Bankfull width
Drainage area in square miles:	1.008
Percent basin above 6,000 feet:	0
Width of active channel in feet:	4.5
Width of bank full channel in feet:	7

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: A =      1.01 E6 =     0.
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	6.	97.4	1.5	23.
5	22.	75.1	7.2	66.
10	43.	66.0	15.7	115.
25	83.	60.0	33.1	209.
50	126.	59.1	51.0	314.
100	182.	60.3	72.3	459.
200	254.	63.2	96.8	664.
500	377.	69.3	133.2	1070.

METHOD: Regression on active channel width
Flood frequency estimates for
Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: WAC = 4.50

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	71.	68.6	25.2	200.
10	125.	70.6	43.2	361.
25	225.	76.4	72.4	697.
50	327.	82.8	98.0	1090.
100	456.	90.1	125.8	1650.
200	616.	98.6	155.6	2440.
500	884.	111.3	197.5	3960.

METHOD: Regression on bank full channel width
Flood frequency estimates for
Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: WBF = 7.00

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 1, 2 and 3
Flood frequency estimates for
Figgins - At Mouth
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	16.	67.9	5.9	46.
5	41.	53.7	17.7	94.
10	67.	52.8	29.3	152.
25	110.	54.2	47.4	256.
50	152.	56.7	63.2	365.
100	203.	59.7	81.1	507.
200	264.	63.1	101.1	692.
500	377.	69.3	133.2	1070.

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - At Mouth** HMS Element: Mouth
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Active-channel width and Bankfull width**
Width of active channel in feet:	**4.5**
Width of bank full channel in feet:	**7**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on active channel width
 Flood frequency estimates for
 Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: WAC =      4.50
 RI        DISCHARGE  STD ERR OF              90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2         24.        72.3              8.2                71.
     5         71.        68.6             25.2               200.
    10        125.        70.6             43.2               361.
    25        225.        76.4             72.4               697.
    50        327.        82.8             98.0              1090.
   100        456.        90.1            125.8              1650.
   200        616.        98.6            155.6              2440.
   500        884.       111.3            197.5              3960.


 METHOD: Regression on bank full channel width
 Flood frequency estimates for
           Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: WBF =      7.00
```

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 2 and 3
Flood frequency estimates for
Figgins - At Mouth
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	68.	68.1	24.2	188.
10	120.	70.4	41.8	344.
25	220.	76.4	71.5	678.
50	327.	82.8	98.7	1090.
100	456.	90.1	126.8	1640.
200	616.	98.6	156.9	2420.
500	884.	111.3	199.2	3920.

Montana Flood-Frequency and Basin-Characteristic Data

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - At Mouth** HMS Element: Mouth
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Basin and Climatic Characteristics and Active-channel width**
Drainage area in square miles:	**1.008**
Percent basin above 6,000 feet:	**0**
Width of active channel in feet:	**4.5**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: A =      1.01 E6 =     0.
 RI        DISCHARGE  STD ERR OF                90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2          6.        97.4                1.5                23.
     5         22.        75.1                7.2                66.
    10         43.        66.0               15.7               115.
    25         83.        60.0               33.1               209.
    50        126.        59.1               51.0               314.
   100        182.        60.3               72.3               459.
   200        254.        63.2               96.8               664.
   500        377.        69.3              133.2              1070.
```

```
 METHOD: Regression on active channel width
 Flood frequency estimates for
```

Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: WAC = 4.50

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	24.	72.3	8.2	71.
5	71.	68.6	25.2	200.
10	125.	70.6	43.2	361.
25	225.	76.4	72.4	697.
50	327.	82.8	98.0	1090.
100	456.	90.1	125.8	1650.
200	616.	98.6	155.6	2440.
500	884.	111.3	197.5	3960.

METHOD: Combined methods 1 and 2
Flood frequency estimates for
Figgins - At Mouth
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	16.	67.9	5.9	46.
5	42.	58.8	17.2	105.
10	69.	56.3	28.9	165.
25	112.	56.0	47.2	267.
50	153.	57.4	63.1	371.
100	203.	59.7	81.1	507.
200	264.	63.1	101.1	692.
500	377.	69.3	133.2	1070.

Montana Flood-Frequency and Basin-Characteristic Data

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Montana Flood-Frequency and Basin-Characteristic Data

Estimate Flood Discharges at Ungaged Sites in Montana – (continued)

Summary of Estimation Parameters Selected:

Name for this estimation:	**Figgins - At Mouth** HMS Element: Mouth
Region:	**Upper Yellowstone**
Estimation method:	**Weighted estimate based on Basin and Climatic Characteristics and Bankfull width**
Drainage area in square miles:	**1.008**
Percent basin above 6,000 feet:	**0**
Width of bank full channel in feet:	**7**

Flood Discharge Estimation:

(In the Flood Discharge table, RI is the Recurrence Interval, in years; STD ERR is the Standard Error; and 90% PRED. INTERVAL is the 90% Prediction Interval, in cubic feet per second)

```
 METHOD: Regression on basin characteristics
 Flood frequency estimates for
 Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: A =      1.01 E6 =     0.
 RI        DISCHARGE  STD ERR OF                90% PRED. INTERVAL
             (cfs)      PREDICTION(%)
     2          6.        97.4                1.5                23.
     5         22.        75.1                7.2                66.
    10         43.        66.0               15.7               115.
    25         83.        60.0               33.1               209.
    50        126.        59.1               51.0               314.
   100        182.        60.3               72.3               459.
   200        254.        63.2               96.8               664.
   500        377.        69.3              133.2              1070.
```

```
 METHOD: Regression on bank full channel width
 Flood frequency estimates for
```

Figgins - At Mouth
Upper Yellowstone-Central Mountain Region: WBF = 7.00

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	22.	160.6	3.4	148.
5	57.	73.3	19.1	171.
10	101.	74.4	33.3	305.
25	182.	79.9	56.2	588.
50	266.	86.4	76.5	926.
100	372.	93.9	98.7	1410.
200	506.	102.8	122.6	2090.
500	731.	116.1	156.3	3420.

METHOD: Combined methods 1 and 3
Flood frequency estimates for
Figgins - At Mouth
Region 7

RI	DISCHARGE (cfs)	STD ERR OF PREDICTION(%)	90% PRED. INTERVAL	
2	8.	91.0	2.2	29.
5	36.	59.6	14.3	89.
10	61.	56.6	25.4	146.
25	104.	56.1	43.5	247.
50	145.	57.5	59.8	352.
100	196.	59.8	78.3	490.
200	259.	63.2	99.1	679.
500	377.	69.3	133.2	1070.

Montana Flood-Frequency and Basin-Characteristic Data

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Figgins Creek
Conversion of Rural Regression to Urban
Following procedures referenced in USGS WSP 2207 (Sauer et al)

At Mouth

	Regression	
	Rural	Urban
2		N/A
5		N/A
10	43	98
25	83	162
50	126	228
100	182	310
500	377	566

A = **1.01**
BDF = **7**

Kagy Blvd

	Regression	
	Rural	Urban
2		N/A
5		N/A
10	41	93
25	80	156
50	122	221
100	176	299
500	365	547

A = **0.96**
BDF = **7**

3rd Ave

	Regression	
	Rural	Urban
2		N/A
5		N/A
10	38	86
25	74	144
50	113	204
100	164	278
500	340	507

A = **0.86**
BDF = **7**

APPENDIX B

RAINFALL DEPTH CALCULATIONS AND REFERENCES

	2YR	5YR	10YR	25YR	50YR	100YR	500YR
5 min	0.17	0.26	0.33	0.42	0.49	0.57	0.72
15 min	0.31	0.49	0.61	0.77	0.92	1.06	1.35
1 hr	0.45	0.72	0.91	1.13	1.34	1.54	1.94
2 hr	0.52	0.79	0.98	1.22	1.42	1.60	2.04
3 hr	0.59	0.85	1.05	1.30	1.48	1.66	2.08
6 hr	0.75	1.00	1.20	1.50	1.65	1.80	2.25
12 hr	0.94	1.26	1.53	1.88	2.09	2.25	2.81
24 hr	1.20	1.60	1.90	2.30	2.60	2.80	3.37

Values taken from Figures 19-30 of *Precipitation-Frequency Atlas of the Western United States, Volume I - Montana*

Values calculated using Equations 3 & 5 of *Precipitation-Frequency Atlas of the Western United States, Volume I - Montana - East of the divide calcs*

Values interpolated between 2YR and 100YR using Figure 6 of *Precipitation-Frequency Atlas of the Western United States, Volume I - Montana*

Values calculated using Equations 7 & 8 of *Precipitation-Frequency Atlas of the Western United States, Volume I*

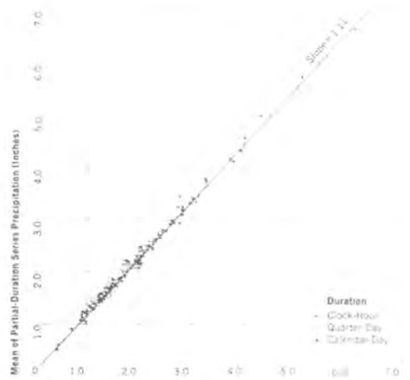
Values interpolated using Figure 17 of *Precipitation-Frequency Atlas of the Western United States, Volume I - Montana*

Values calculated using Table 11 of *Precipitation-Frequency Atlas of the Western United States, Volume I - Montana*

Values determined using ratios provided in *Short Duration Rainfall for the Western United States* (Arkell & Richards) - Front Face and High Plains North Region

Extrapolated using normal-probability relationship

Figure 5. *Relation between annual and partial-duration series.*



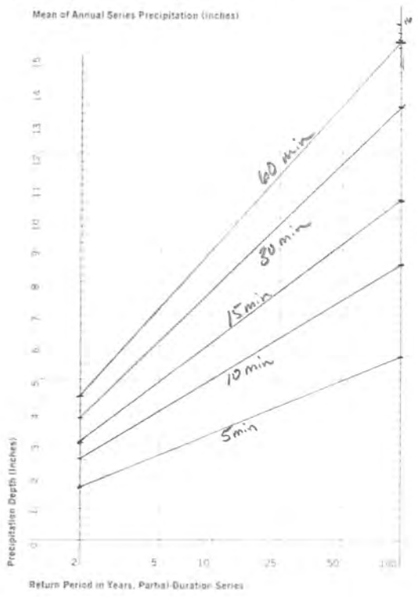


Figure 6. *Precipitation depth versus return period for partial-duration series.*

Figure 7. *Principal paths of moisture inflow in the western United States for storms producing large precipitation amounts. Tinted areas are major orographic barriers.*

portant. Next, an examination was made of factors that combined topographic and meteorologic considerations, such as distance and direction to moisture sources. Each factor considered was a measure of some physical reality, and each was understandably related to variation in the precipitation-frequency regime.

Finally, various climatological and meteorological factors that could be indexes of variation of the precipitation-frequency values were considered. The procedure used for developing interpolating equations was a multiple-regression screening technique. This process was done by computer using a least-squares technique. The computer program was capable of accepting a total of 174 independent variables for as many locations as data were available. The number of variables screened for the various relations ranged between 60 and 100. This does not mean that 60 or more completely different factors could be identified. For example, several factors might involve different measures of slope. Moreover, these measures of slope might be over different distances or have different orientations. In each instance, the practice was to permit the computer to select the most critical of the various measures of each factor.

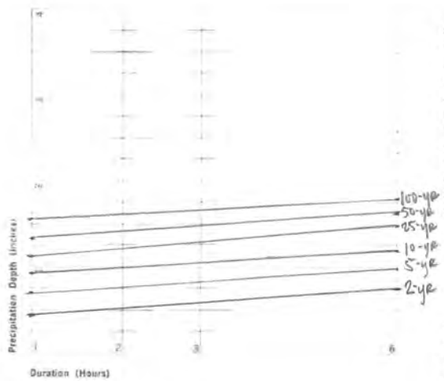
Although the computer program treated each variable as linear during the regression analysis, it was possible through internal computations to use logarithms, powers, roots, reciprocals, or combinations of any or all of the factors. The computer program selected the single variable most highly correlated with the precipitation-frequency value under investigation. The next step was to select the variable that, combined with the variable already selected, would explain the greatest variation in the precipitation-frequency values. The third, fourth, fifth, and further variables were selected in a similar manner. The program continued to select

Region of applicability	Corr. coeff.	No. of stations	Mean of computed stn. values (inches)	Standard error of estimate (inches)
Gila, Williams, and lower Colorado River Basins (1)	0.84	86	1.66	0.21
Little Colorado, San Juan, and Virgin River Basins, except higher elevations of south-facing slopes (2)[1]	0.81	105	1.36	0.20
Higher elevations of south-facing slopes of Little Colorado, San Juan, and Virgin River Basins (2)[1]	0.93	41	1.31	0.13
Rio Grande Basin north of El Paso, Tex. (3)	0.77	110	1.35	0.18
East of Continental Divide and Sangre de Cristo Mountains to generalized 7,000-ft contour from southern Wyoming to southern tip of Sangre de Cristo Mountains (4)	0.83	122	1.43	0.22
Upper Colorado and Gunnison River Basins and Green River Basin below confluence of Green and Yampa Rivers (5)	0.79	69	1.12	0.13
Yampa River Basin, Green River Basin above confluence of Green and Yampa Rivers, and Bear River Basin east of Wasatch Mountains (6)	0.83	29	1.03	0.08
Mountains of central Utah (7)	0.85	89	1.35	0.18
Western Utah and Nevada, except Snake and Virgin River Basins and spillover zone east of Sierra Nevada crest (8)	0.71	79	1.03	0.15
Western Utah and Nevada, except Snake and Virgin River Basins and spillover zone east of Sierra Nevada crest (8)	0.71	55	1.04	0.15
Big Horn River Basin above Saint Xavier and major portions of North Platte, Powder, Tongue, and Yellowstone River Basins (9)	0.78	55	1.25	0.21
Upper Missouri River Basin above Holter Dam, Mont., Snake River Basin above Alpine, Wyo., and upper Yellowstone River Basin above Springdale, Mont. (10)	0.76	57	1.19	0.16
From generalized 4,000-ft contour on east to crests of Crazy and Little Belt Mountains and Lewis Range on west (11)	0.80	52	1.67	0.26
West of Continental Divide, but east of Bitterroot Range and Cabinet and Selkirk Mountains (12)	0.85	44	1.36	0.17
Mountainous region of eastern Washington and Oregon and of Idaho west of Bitterroot Range crest and Continental Divide, and north of southern boundary of Snake River Basin—excluding Snake River Valley below a generalized 5,000-ft contour (13)	0.78	147	1.44	0.24
Orographic region east of crest of Cascade Range and west of Snake River Basin (14)	0.50	115	1.75	0.35
Western slopes of Coast Ranges, Olympic Mountains, and Cascade Range (15)	0.87	125	3.69	0.48
Eel River Basin, southern portion of Klamath River Basin, and Cottonwood, Elder, Thomas, and Glasgow Creeks (16)	0.91	39	4.19	0.50
Russian River, Cache and Putah Creeks, and coastal drainages west of Russian River (17)	0.84	63	5.31	0.78
Santa Cruz Mountains and La Panza, Santa Lucia, and Coast Ranges (18)	0.95	55	4.32	0.45
Diablo, Gabilan, and Temblor Ranges (19)	0.82	58	2.21	0.35
San Rafael, San Bernardino, Santa Monica, and San Gabriel Mountains (20)	0.88	149	3.98	0.59
Santa Ana, Santa Rosa, Cuyote, and other extreme southern coastal mountains (21)	0.88	34	2.44	0.33
Northern Sierra Nevada north of Mokelumne River Basin (22)	0.92	84	4.56	0.53
Southern Sierra Nevada south of Consumnes River Basin (23)	0.88	61	3.43	0.53
Southeastern desert region of California (24)	0.89	41	1.07	0.16
Spillover zone east of Sierra Nevada crest (25)	0.94	41	2.05	0.27
Spillover zone east of crest of coastal mountains of southern California (26)	0.97	10	2.08	0.15

[1] Numbers in parentheses refer to geographic regions shown in figure 8.
[2] Two different equations were used in region 2. See text for explanation.
[3] Two different equations were used in region 8. See text for explanation.

Table 3. *Statistical parameters for relations used for interstation interpolation of 2- or 24-hr precipitation values*

Figure 16. *Precipitation depth-duration diagram (1 to 6 hrs).*



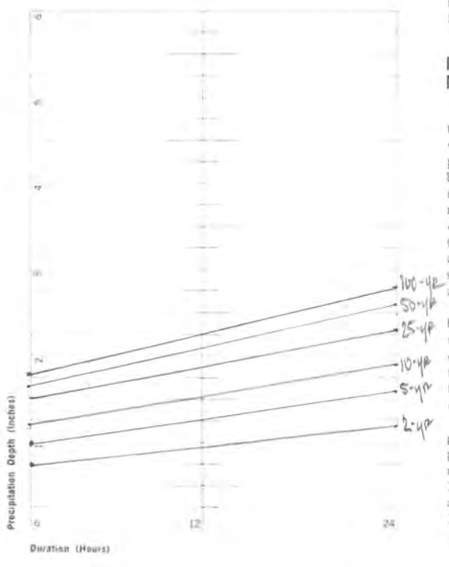


Figure 17. *Precipitation depth-duration diagram (6 to 24 hrs).*

Estimates for 2- and 3-hr (120- and 180-min) precipitation-frequency values. To obtain estimates of precipitation-frequency values for 2 or 3 hrs, plot the 6-hr value from the Atlas maps and the 1-hr value on the nomogram of figure 16. Then draw a straight line connecting the 1- and 6-hr values, and read the 2- and 3-hr values from the nomogram. This nomogram is independent of return period. It was developed using data from the same regions used to develop the 1-hr equations. The slight differences found in data from east and west of the Continental Divide were smaller than the sampling error inherent in the data, so one nomogram will serve for all sections of Montana. The mathematical solution from the data used to develop figure 16 gives the following equations for estimating the 2- and 3-hr values:

$$2\text{ hr} = 0.250\ (6\text{ hr}) + 0.750\ (1\text{ hr}), \qquad (7)$$

$$3\text{ hr} = 0.467\ (6\text{ hr}) + 0.533\ (1\text{ hr}) \qquad (8)$$

Estimates for 12-hr (720-min) precipitation. To obtain estimates for the 12-hr duration, plot values from the 6- and 24-hr maps on the nomogram of figure 17. The 12-hr estimates can then be read at the intersection of the line connecting these points with the 12-hr duration line of the nomogram.

Estimates for less than 1 hr. To obtain estimates for durations of less than 1 hr, the values in table 11 are applied to the 1-hr value for the return period of interest.

Illustration of Use of Precipitation-Frequency Maps, Diagrams, and Equations.

To illustrate the use of these maps, values were read from figures 19 to 30 for the point at 47°00′ N. and 110°00′ W. These values are shown in boldface type in table 12. Because not all points are as easy to locate as latitude-longitude intersections, and because there may be some slight registration differences in printing, precise interpolation between isolines is difficult; the values read from the maps should be plotted on the return-period diagram of figure 6. This has been done for the 24-hr values in table 12 (fig. 18a). On this nomogram the 25-yr value appears somewhat above the line, so the value read from the maps is corrected (as shown by the strikeout in table 12); such corrected values are adopted in preference to the original readings.

The 2- and 100-yr 1-hr values for the point were computed from equations (3) and (5), since the point is east of the Continental Divide. The 2-yr 1-hr value is estimated at 0.50 in. from equation (3); using equation (5) (and an elevation of 4,400 ft), the 100-yr 1-hr value is 1.53 in. By plotting these 1-hr values on figure 6 and connecting them with a straight line, one can obtain estimates for return periods of 5, 10, 25, and 50 yrs.

The 2- and 3-hr values can be estimated by using the nomogram of figure 16. The 1- and 6-hr values for the desired return period are obtained as above. Plot these points on the figure 16 nomogram and connect them with a straight line; the estimates for 2 or 3 hrs can be read at the intersections of the connecting line and the 2- and 3-hr vertical lines. An example is shown in figure 18b for the 100-yr return period. The values of the 100-yr 2-hr (1.70 in.) and 100-yr 3-hr (1.85 in.) are in italics on table 12.

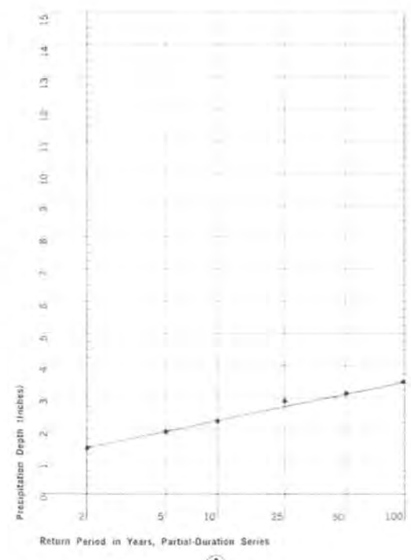
Table 11. *Adjustment factors to obtain n-minute estimates from 1-hr values.*

Duration (min)	5	10	15	30
Ratio to 1-hr	0.29	0.45	0.57	0.79

(Adapted from U.S. Weather Bureau Technical Paper No. 40, 1961.)

Table 12. *Precipitation data for depth-frequency atlas computation point 47°00′ N., 110°00′ W.*

	1-hr	2-hr	3-hr	6-hr	24-hr
2-yr	0.50			**0.88**	**1.47**
5-yr				**1.19**	**1.96**
10-yr				**1.42**	**2.30**
25-yr				**1.78**	**2.77** ~~2.84~~
50-yr				**1.98**	**3.18**
100-yr	*1.53*	*1.70*	*1.85*	**2.18**	**3.50**



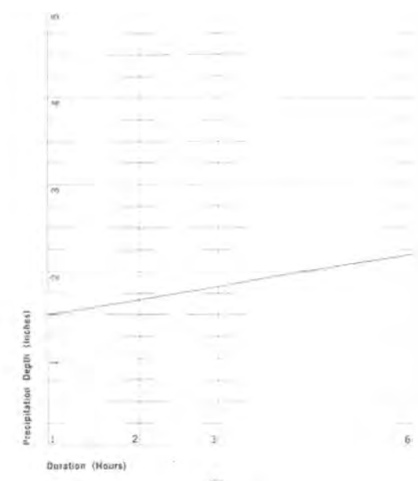


Figure 18. *Illustration of use of precipitation-frequency diagrams using values from precipitation-frequency maps and relations at 47°00′ N., 110°00′ W.*

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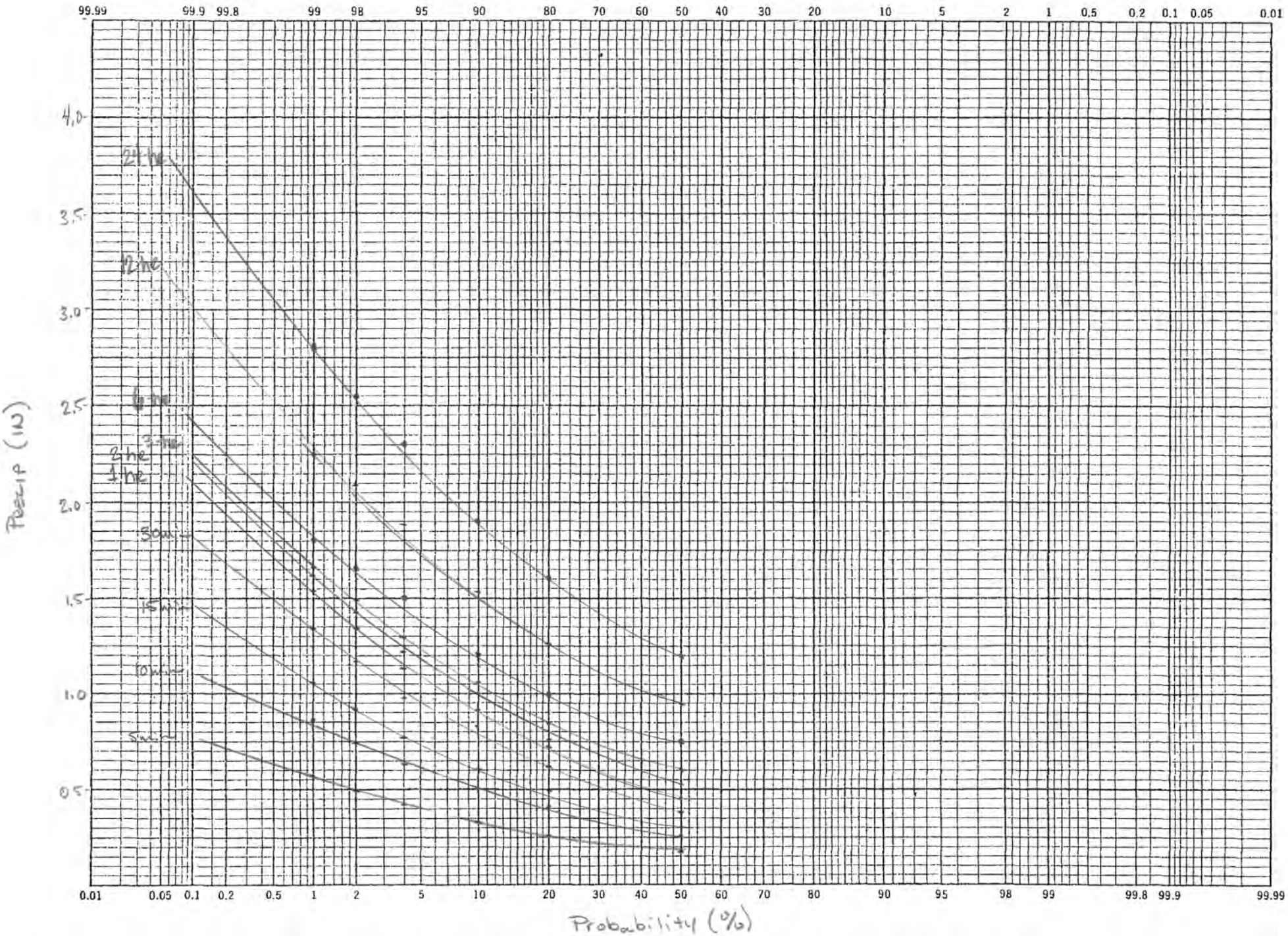

APPENDIX C

CURVE NUMBER LOOK-UP TABLE

Land Use Category	Hydrologic Soil Group				Description	Assumption	Reference	Source
	A	B	C	D				
Cultivated Crops	58	72	81	85	Cultivated Crops	Close-seeded or broadcast legumes or rotation meadow straight row	Engineering Hydrology - Principles and Practices (Ponce)	NLCD
Developed, Low Intensity	60	70	80	85	Developed, Low Intensity	1/2 acre lots - vegetation established	Engineering Hydrology - Principles and Practices (Ponce)	
Developed, Medium Intensity	61	75	83	87	Developed, Medium Intensity	1/4 acre lots - vegetation established	Engineering Hydrology - Principles and Practices (Ponce)	
Developed, Open Space	39	61	74	80	Developed, Open Space	Lawns, parks, cemeteries with vegetation established	Engineering Hydrology - Principles and Practices (Ponce)	
Hay/Pasture	39	61	74	80	Hay/Pasture	Pasture, grassland or range for grazing - Good hydrologic conditions	Engineering Hydrology - Principles and Practices (Ponce)	
Herbaceous		62	74	85	Herbaceous	Good hydrologic conditions	Engineering Hydrology - Principles and Practices (Ponce)	
AP	77	85	90	92	Administrative Professional - An establishment in which overall management functions occur and/or in which a recognized profession is maintained for the conduct of that profession.	Apartments - multi-family residential and town houses	Engineering Hydrology - Principles and Practices (Ponce)	City of Bozeman
CHURCH	89	92	94	95	A building where persons regularly assemble for religious worship and which, together with its accessory buildings and uses, is maintained and controlled by a religious body organized to sustain public worship.	Resemble commercial	Engineering Hydrology - Principles and Practices (Ponce)	
DTR	77	85	90	92	Duplex/Triplex Residential - A building, or a portion thereof, used for occupancy by two or three households living independently of each other, with the units completely separated by a common wall, floor and/or ceiling and reside on one lot; including apartments and condos.	Dual residential - multi-family residential and town houses	Engineering Hydrology - Principles and Practices (Ponce)	
MFR	77	85	90	92	Multi-Household Residential - A building, or portion thereof, used for occupancy by four or more households living independently of each other, with the units completely separated by a common wall, floor and/or ceiling; apartments, condos.	Multi-family residential - Town houses	Engineering Hydrology - Principles and Practices (Ponce)	
MIXED	65	77	84	88	More than one principal use occurring on one lot.	For Figgins Creek - Largely commercial with approx. 40% deciduous forest		
POS	39	61	74	80	Park or Open Space - Parks, trails, recreational areas and other places that are capable of being used by the public for recreation, relaxation and social purposes. May include private land serving a property owners association for similar purposes	Park/Open Space	Engineering Hydrology - Principles and Practices (Ponce)	
RB	89	92	94	95	Restaurant/Bar - A restaurant, coffee shop, cafeteria, grill, short order café, luncheonette, sandwich stand, drugstore, soda fountain, serving food; or an establishment where alcoholic beverages are served on premises.	Commercial		
ROW	98	98	98	98	Rights-of-Way - A public way established or dedicated for public purposes by duly recorded plat, deed, grant, easement, governmental authority or by operation of law; roads; railroads.	Right-of-way/Paved roads: curbs and storm sewers	Engineering Hydrology - Principles and Practices (Ponce)	
SEF	68	79	86	89	School/Educational Facility - Any building or part thereof which is constructed or used for public or private education or instruction; when not conducted as a commercial enterprise for the profit of individual owners or stockholders.	School and education facilities (?) - open space poor condition (grass covers less than 50%)	Engineering Hydrology - Principles and Practices (Ponce)	
SFR	61	75	83	87	Single-Household Residential - A building used for residential occupancy by one household, including multiple residences that share a common wall, as long as only one dwelling unit lies upon a single lot; townhomes. Also may include an accessory dwelling unit.	Single family residential - 1/4 acre lots - vegetation established	Engineering Hydrology - Principles and Practices (Ponce)	
UDV	63	75	83	87	Undeveloped - Land that is no longer, or has never been, in agricultural use and is not ready to be occupied by buildings (needs to be subdivided; needs infrastructure)	Figgins Creek - Based upon Bozeman City aerial, UDV areas of Figgins Creek watershed appear to be used for agricultural purposes - small grain, straight row		
VACANT	77	86	91	94	Vacant - Land that is currently developed and ready to be occupied by buildings but is unoccupied; no buildings or buildings requiring significant improvement in order to be used.	Graded areas - pervious areas only with no vegetation	Engineering Hydrology - Principles and Practices (Ponce)	

APPENDIX D

CURVE NUMBER CALCULATIONS

Figgins Creek Curve Number Calculations

BASIN	LAND USE CATEGORY	SOIL MAP UNIT #	SUBREGION CN	SUBREGION AREA (mi^2)	SUBBASIN AREA (mi^2)	PERCENT OF SUBBASIN	CUMULATIVE PERCENT	AREA-WEIGHTED CN	CUMULATIVE CN	COMPOSITE CN
W100	Hay/Pasture	D	80.0	0.01	0.01	51.05%	51.0%	40.8	40.8	
W100	MFR	D	92.0	0.00	0.01	0.15%	51.2%	0.1	41.0	
W100	Developed, Medium Intensity	C	83.0	0.00	0.01	0.95%	52.2%	0.8	41.8	
W100	Hay/Pasture	C	74.0	0.00	0.01	37.68%	89.8%	27.9	69.7	
W100	MFR	C	90.0	0.00	0.01	1.74%	91.6%	1.6	71.2	
W100	Hay/Pasture	C	74.0	0.00	0.01	8.42%	100.0%	6.2	77.5	**77.5**
W1370	CHURCH	C	94.0	0.00	0.04	2.58%	2.6%	2.4	2.4	
W1370	POS	C	74.0	0.00	0.04	4.09%	6.7%	3.0	5.4	
W1370	ROW	C	98.0	0.01	0.04	26.74%	33.4%	26.2	31.7	
W1370	SFR	C	83.0	0.00	0.04	2.26%	35.7%	1.9	33.5	
W1370	SFR	C	83.0	0.01	0.04	25.89%	61.6%	21.5	55.0	
W1370	SFR	C	83.0	0.01	0.04	30.59%	92.1%	25.4	80.4	
W1370	SFR	C	83.0	0.00	0.04	7.33%	99.5%	6.1	86.5	
W1370	SFR	C	83.0	0.00	0.04	0.27%	99.7%	0.2	86.7	
W1370	VACANT	C	91.0	0.00	0.04	0.26%	100.0%	0.2	86.9	**86.9**
W1520	CHURCH	C	94.0	0.00	0.04	7.00%	7.0%	6.6	6.6	
W1520	CHURCH	C	94.0	0.01	0.04	13.99%	21.0%	13.2	19.7	
W1520	Developed, Open Space	C	74.0	0.00	0.04	3.91%	24.9%	2.9	22.6	
W1520	POS	C	74.0	0.00	0.04	4.77%	29.7%	3.5	26.2	
W1520	ROW	C	98.0	0.01	0.04	20.90%	50.6%	20.5	46.6	
W1520	SFR	C	83.0	0.00	0.04	8.12%	58.7%	6.7	53.4	
W1520	SFR	C	83.0	0.00	0.04	5.08%	63.8%	4.2	57.6	
W1520	SFR	C	83.0	0.00	0.04	3.14%	66.9%	2.6	60.2	
W1520	SFR	C	83.0	0.01	0.04	15.69%	82.6%	13.0	73.2	
W1520	SFR	C	83.0	0.00	0.04	0.68%	83.3%	0.6	73.8	
W1520	SFR	C	83.0	0.00	0.04	10.32%	93.6%	8.6	82.3	
W1520	SFR	C	83.0	0.00	0.04	6.40%	100.0%	5.3	87.7	**87.7**
W170	Developed, Low Intensity	D	85.0	0.00	0.01	4.69%	4.7%	4.0	4.0	
W170	Hay/Pasture	D	80.0	0.00	0.01	21.90%	26.6%	17.5	21.5	
W170	ROW	D	98.0	0.00	0.01	0.79%	27.4%	0.8	22.3	
W170	Developed, Low Intensity	C	80.0	0.00	0.01	0.05%	27.4%	0.0	22.3	
W170	Developed, Low Intensity	C	80.0	0.00	0.01	0.61%	28.0%	0.5	22.8	
W170	Developed, Low Intensity	C	80.0	0.00	0.01	0.01%	28.1%	0.0	22.8	
W170	Developed, Medium Intensity	C	83.0	0.00	0.01	1.58%	29.6%	1.3	24.1	
W170	Hay/Pasture	C	74.0	0.00	0.01	68.14%	97.8%	50.4	74.6	
W170	POS	C	74.0	0.00	0.01	0.06%	97.8%	0.0	74.6	
W170	ROW	C	98.0	0.00	0.01	0.44%	98.3%	0.4	75.0	
W170	ROW	C	98.0	0.00	0.01	0.29%	98.6%	0.3	75.3	
W170	Hay/Pasture	C	74.0	0.00	0.01	1.44%	100.0%	1.1	76.4	**76.4**
W1700	MFR	C	90.0	0.00	0.00	2.49%	2.5%	2.2	2.2	
W1700	MIXED	C	84.0	0.00	0.00	0.39%	2.9%	0.3	2.6	
W1700	ROW	C	98.0	0.00	0.00	97.12%	100.0%	95.2	97.7	**97.7**
W1720	ROW	C	98.0	0.00	0.00	46.81%	46.8%	45.9	45.9	
W1720	SFR	C	83.0	0.00	0.00	24.52%	71.3%	20.4	66.2	
W1720	SFR	C	83.0	0.00	0.00	28.67%	100.0%	23.8	90.0	**90.0**
W1800	AP	D	92.0	0.00	0.02	0.13%	0.1%	0.1	0.1	
W1800	MIXED	D	88.0	0.00	0.02	4.67%	4.8%	4.1	4.2	
W1800	RB	D	95.0	0.00	0.02	0.04%	4.8%	0.0	4.3	
W1800	ROW	D	98.0	0.00	0.02	4.60%	9.4%	4.5	8.8	
W1800	ROW	D	98.0	0.00	0.02	1.44%	10.9%	1.4	10.2	
W1800	AP	C	90.0	0.00	0.02	0.00%	10.9%	0.0	10.2	
W1800	Developed, Low Intensity	C	80.0	0.00	0.02	0.12%	11.0%	0.1	10.3	
W1800	Developed, Low Intensity	C	80.0	0.00	0.02	0.00%	11.0%	0.0	10.3	
W1800	Hay/Pasture	C	74.0	0.00	0.02	0.29%	11.3%	0.2	10.5	
W1800	MIXED	C	84.0	0.00	0.02	0.66%	11.9%	0.6	11.1	
W1800	MIXED	C	84.0	0.00	0.02	0.46%	12.4%	0.4	11.4	
W1800	MIXED	C	84.0	0.00	0.02	3.67%	16.1%	3.1	14.5	
W1800	POS	C	74.0	0.00	0.02	0.51%	16.6%	0.4	14.9	
W1800	ROW	C	98.0	0.00	0.02	18.55%	35.1%	18.2	33.1	
W1800	ROW	C	98.0	0.00	0.02	4.61%	39.8%	4.5	37.6	
W1800	SEF	C	86.0	0.00	0.02	0.06%	39.8%	0.0	37.6	
W1800	SEF	C	86.0	0.00	0.02	18.51%	58.3%	15.9	53.6	
W1800	POS	C	74.0	0.01	0.02	41.69%	100.0%	30.8	84.4	**84.4**
W1850	Developed, Low Intensity	C	80.0	0.00	0.02	0.02%	0.0%	0.0	0.0	
W1850	Developed, Medium Intensity	C	83.0	0.00	0.02	0.85%	0.9%	0.7	0.7	
W1850	Hay/Pasture	C	74.0	0.00	0.02	4.39%	5.3%	3.2	4.0	
W1850	POS	C	74.0	0.00	0.02	0.01%	5.3%	0.0	4.0	
W1850	ROW	C	98.0	0.00	0.02	0.07%	5.3%	0.1	4.0	
W1850	SEF	C	86.0	0.01	0.02	57.89%	63.2%	49.8	53.8	
W1850	POS	C	74.0	0.00	0.02	4.42%	67.6%	3.3	57.1	
W1850	Cultivated Crops	C	81.0	0.01	0.02	32.36%	100.0%	26.2	83.3	**83.3**
W1900	Cultivated Crops	C	81.0	0.01	0.02	61.65%	61.6%	49.9	49.9	
W1900	Cultivated Crops	C	81.0	0.00	0.02	0.01%	61.7%	0.0	49.9	
W1900	Hay/Pasture	C	74.0	0.00	0.02	20.75%	82.4%	15.4	65.3	
W1900	Hay/Pasture	C	74.0	0.00	0.02	3.55%	86.0%	2.6	67.9	
W1900	Herbaceuous	C	74.0	0.00	0.02	12.13%	98.1%	9.0	76.9	
W1900	Herbaceuous	C	74.0	0.00	0.02	0.55%	98.6%	0.4	77.3	
W1900	POS	C	74.0	0.00	0.02	1.36%	100.0%	1.0	78.3	**78.3**
W1950	Cultivated Crops	C	81.0	0.03	0.14	20.03%	20.0%	16.2	16.2	
W1950	Cultivated Crops	C	81.0	0.01	0.14	4.09%	24.1%	3.3	19.5	
W1950	Developed, Low Intensity	C	80.0	0.00	0.14	0.18%	24.3%	0.1	19.7	
W1950	Developed, Open Space	C	74.0	0.00	0.14	1.36%	25.7%	1.0	20.7	
W1950	Developed, Open Space	C	74.0	0.00	0.14	0.30%	26.0%	0.2	20.9	
W1950	Developed, Open Space	C	74.0	0.00	0.14	0.02%	26.0%	0.0	20.9	
W1950	Developed, Open Space	C	74.0	0.00	0.14	0.20%	26.2%	0.2	21.1	
W1950	Developed, Open Space	C	74.0	0.00	0.14	0.18%	26.4%	0.1	21.2	
W1950	Developed, Open Space	C	74.0	0.00	0.14	0.03%	26.4%	0.0	21.2	
W1950	Developed, Open Space	C	74.0	0.00	0.14	0.00%	26.4%	0.0	21.2	
W1950	Hay/Pasture	C	74.0	0.06	0.14	44.89%	71.3%	33.2	54.5	
W1950	Hay/Pasture	C	74.0	0.00	0.14	0.24%	71.5%	0.2	54.6	
W1950	Herbaceuous	C	74.0	0.00	0.14	0.09%	71.6%	0.1	54.7	
W1950	POS	C	74.0	0.00	0.14	0.08%	71.7%	0.1	54.8	
W1950	ROW	C	98.0	0.00	0.14	3.39%	75.1%	3.3	58.1	
W1950	POS	C	74.0	0.01	0.14	7.12%	82.2%	5.3	63.4	
W1950	SFR	C	83.0	0.00	0.14	0.00%	82.2%	0.0	63.4	
W1950	SFR	C	83.0	0.00	0.14	0.34%	82.6%	0.3	63.6	
W1950	SFR	C	83.0	0.00	0.14	3.54%	86.1%	2.9	66.6	
W1950	SFR	C	83.0	0.01	0.14	3.78%	89.9%	3.1	69.7	
W1950	SFR	C	83.0	0.00	0.14	0.01%	89.9%	0.0	69.7	
W1950	SFR	C	83.0	0.00	0.14	0.44%	90.3%	0.4	70.1	
W1950	UDV	C	83.0	0.00	0.14	0.84%	91.2%	0.7	70.8	
W1950	POS	C	74.0	0.00	0.14	1.34%	92.5%	1.0	71.8	
W1950	VACANT	C	91.0	0.00	0.14	0.08%	92.6%	0.1	71.9	
W1950	VACANT	C	91.0	0.00	0.14	0.32%	92.9%	0.3	72.1	
W1950	VACANT	C	91.0	0.00	0.14	0.23%	93.1%	0.2	72.4	
W1950	SEF	C	86.0	0.01	0.14	6.85%	100.0%	5.9	78.2	**78.2**
W2160	Cultivated Crops	C	81.0	0.01	0.01	79.99%	80.0%	64.8	64.8	
W2160	Hay/Pasture	C	74.0	0.00	0.01	5.63%	85.6%	4.2	69.0	
W2160	Hay/Pasture	C	74.0	0.00	0.01	6.23%	91.8%	4.6	73.6	
W2160	POS	C	74.0	0.00	0.01	0.17%	92.0%	0.1	73.7	
W2160	ROW	C	98.0	0.00	0.01	3.00%	95.0%	2.9	76.6	
W2160	SFR	C	83.0	0.00	0.01	3.99%	99.0%	3.3	79.9	
W2160	SFR	C	83.0	0.00	0.01	1.00%	100.0%	0.8	80.8	**80.8**
W220	MIXED	D	88.0	0.00	0.01	11.27%	11.3%	9.9	9.9	
W220	ROW	D	98.0	0.00	0.01	0.12%	11.4%	0.1	10.0	
W220	Developed, Low Intensity	C	80.0	0.00	0.01	0.00%	11.4%	0.0	10.0	
W220	MIXED	C	84.0	0.00	0.01	0.65%	12.0%	0.5	10.6	
W220	MIXED	C	84.0	0.00	0.01	40.86%	52.9%	34.3	44.9	
W220	ROW	C	98.0	0.00	0.01	0.02%	52.9%	0.0	44.9	

Figgins Creek Curve Number Calculations

BASIN	LAND USE CATEGORY	SOIL MAP UNIT #	SUBREGION CN	SUBREGION AREA (mi^2)	SUBBASIN AREA (mi^2)	PERCENT OF SUBBASIN	CUMULATIVE PERCENT	AREA-WEIGHTED CN	CUMULATIVE CN	COMPOSITE CN
W220	ROW	C	98.0	0.00	0.01	9.27%	62.2%	9.1	54.0	
W220	SFR	C	83.0	0.00	0.01	36.37%	98.6%	30.2	84.2	
W220	VACANT	C	91.0	0.00	0.01	1.44%	100.0%	1.3	85.5	
W220	Hay/Pasture	C	74.0	0.00	0.01	0.00%	100.0%	0.0	85.5	**85.5**
W260	DTR	C	90.0	0.00	0.00	0.78%	0.8%	0.7	0.7	
W260	MFR	C	90.0	0.00	0.00	93.05%	93.8%	83.7	84.4	
W260	ROW	C	98.0	0.00	0.00	6.17%	100.0%	6.0	90.5	**90.5**
W2800	Developed, Low Intensity	D	85.0	0.00	0.14	0.03%	0.0%	0.0	0.0	
W2800	Hay/Pasture	D	80.0	0.00	0.14	0.01%	0.0%	0.0	0.0	
W2800	POS	D	80.0	0.00	0.14	3.33%	3.4%	2.7	2.7	
W2800	ROW	D	98.0	0.00	0.14	0.12%	3.5%	0.1	2.8	
W2800	SEF	D	89.0	0.00	0.14	0.46%	4.0%	0.4	3.2	
W2800	SFR	D	87.0	0.00	0.14	0.58%	4.5%	0.5	3.7	
W2800	POS	D	80.0	0.01	0.14	3.63%	8.2%	2.9	6.6	
W2800	Cultivated Crops	C	81.0	0.00	0.14	2.57%	10.7%	2.1	8.7	
W2800	Developed, Low Intensity	C	80.0	0.00	0.14	0.02%	10.8%	0.0	8.7	
W2800	Developed, Medium Intensity	C	83.0	0.00	0.14	0.21%	11.0%	0.2	8.9	
W2800	Developed, Open Space	C	74.0	0.00	0.14	0.15%	11.1%	0.1	9.0	
W2800	Developed, Open Space	C	74.0	0.00	0.14	0.94%	12.1%	0.7	9.7	
W2800	POS	C	74.0	0.00	0.14	0.73%	12.8%	0.5	10.3	
W2800	POS	C	74.0	0.00	0.14	0.14%	12.9%	0.1	10.4	
W2800	POS	C	74.0	0.00	0.14	0.67%	13.6%	0.5	10.9	
W2800	POS	C	74.0	0.00	0.14	0.81%	14.4%	0.6	11.5	
W2800	ROW	C	98.0	0.02	0.14	13.43%	27.8%	13.2	24.6	
W2800	ROW	C	98.0	0.00	0.14	0.42%	28.3%	0.4	25.0	
W2800	SEF	C	86.0	0.01	0.14	10.00%	38.3%	8.6	33.6	
W2800	POS	C	74.0	0.00	0.14	0.00%	38.3%	0.0	33.6	
W2800	SFR	C	83.0	0.00	0.14	0.59%	38.8%	0.5	34.1	
W2800	SFR	C	83.0	0.00	0.14	3.17%	42.0%	2.6	36.8	
W2800	SFR	C	83.0	0.01	0.14	3.72%	45.7%	3.1	39.8	
W2800	SFR	C	83.0	0.00	0.14	0.84%	46.6%	0.7	40.5	
W2800	SFR	C	83.0	0.00	0.14	0.23%	46.8%	0.2	40.7	
W2800	SFR	C	83.0	0.00	0.14	3.20%	50.0%	2.7	43.4	
W2800	SFR	C	83.0	0.00	0.14	0.02%	50.0%	0.0	43.4	
W2800	SFR	C	83.0	0.01	0.14	3.68%	53.7%	3.1	46.5	
W2800	SFR	C	83.0	0.00	0.14	1.46%	55.2%	1.2	47.7	
W2800	SFR	C	83.0	0.00	0.14	0.22%	55.4%	0.2	47.9	
W2800	SFR	C	83.0	0.00	0.14	0.14%	55.5%	0.1	48.0	
W2800	SFR	C	83.0	0.00	0.14	3.44%	59.0%	2.9	50.8	
W2800	SFR	C	83.0	0.00	0.14	0.40%	59.4%	0.3	51.2	
W2800	SFR	C	83.0	0.00	0.14	0.84%	60.2%	0.7	51.9	
W2800	Hay/Pasture	C	74.0	0.04	0.14	31.71%	91.9%	23.5	75.3	
W2800	VACANT	C	91.0	0.00	0.14	0.21%	92.1%	0.2	75.5	
W2800	VACANT	C	91.0	0.00	0.14	0.23%	92.4%	0.2	75.7	
W2800	POS	C	74.0	0.00	0.14	0.03%	92.4%	0.0	75.7	
W2800	VACANT	C	91.0	0.00	0.14	0.82%	93.2%	0.7	76.5	
W2800	VACANT	C	91.0	0.00	0.14	0.47%	93.7%	0.4	76.9	
W2800	VACANT	C	91.0	0.00	0.14	0.24%	93.9%	0.2	77.1	
W2800	SEF	C	86.0	0.01	0.14	6.07%	100.0%	5.2	82.4	**82.4**
W330	Cultivated Crops	C	81.0	0.01	0.03	19.44%	19.4%	15.7	15.7	
W330	Cultivated Crops	C	81.0	0.00	0.03	1.11%	20.5%	0.9	16.6	
W330	Cultivated Crops	C	81.0	0.00	0.03	0.71%	21.3%	0.6	17.2	
W330	Cultivated Crops	C	81.0	0.00	0.03	0.70%	22.0%	0.6	17.8	
W330	Hay/Pasture	C	74.0	0.01	0.03	27.61%	49.6%	20.4	38.2	
W330	Hay/Pasture	C	74.0	0.00	0.03	0.03%	49.6%	0.0	38.2	
W330	POS	C	74.0	0.02	0.03	50.39%	100.0%	37.3	75.5	**75.5**
W430	Cultivated Crops	C	81.0	0.01	0.01	63.55%	63.6%	51.5	51.5	
W430	Hay/Pasture	C	74.0	0.00	0.01	4.40%	68.0%	3.3	54.7	
W430	Hay/Pasture	C	74.0	0.00	0.01	2.30%	70.3%	1.7	56.4	
W430	POS	C	74.0	0.00	0.01	13.01%	83.3%	9.6	66.1	
W430	ROW	C	98.0	0.00	0.01	0.62%	83.9%	0.6	66.7	
W430	ROW	C	98.0	0.00	0.01	0.60%	84.5%	0.6	67.3	
W430	POS	C	74.0	0.00	0.01	2.56%	87.1%	1.9	69.2	
W430	SFR	C	83.0	0.00	0.01	0.06%	87.1%	0.1	69.2	
W430	SFR	C	83.0	0.00	0.01	2.15%	89.3%	1.8	71.0	
W430	SFR	C	83.0	0.00	0.01	10.74%	100.0%	8.9	79.9	**79.9**
W470	Cultivated Crops	C	81.0	0.02	0.05	32.24%	32.2%	26.1	26.1	
W470	Cultivated Crops	C	81.0	0.00	0.05	8.56%	40.8%	6.9	33.0	
W470	Developed, Open Space	C	74.0	0.00	0.05	3.47%	44.3%	2.6	35.6	
W470	Hay/Pasture	C	74.0	0.03	0.05	55.74%	100.0%	41.2	76.9	**76.9**
W630	Cultivated Crops	C	81.0	0.00	0.04	8.09%	8.1%	6.6	6.6	
W630	Cultivated Crops	C	81.0	0.01	0.04	16.13%	24.2%	13.1	19.6	
W630	Hay/Pasture	C	74.0	0.03	0.04	75.76%	100.0%	56.1	75.7	
W630	POS	C	74.0	0.00	0.04	0.01%	100.0%	0.0	75.7	**75.7**
W710	AP	D	92.0	0.00	0.05	0.19%	0.2%	0.2	0.2	
W710	Developed, Low Intensity	D	85.0	0.00	0.05	0.01%	0.2%	0.0	0.2	
W710	Developed, Low Intensity	D	85.0	0.00	0.05	0.46%	0.7%	0.4	0.6	
W710	Hay/Pasture	D	80.0	0.00	0.05	0.01%	0.7%	0.0	0.6	
W710	Developed, Open Space	D	80.0	0.00	0.05	1.40%	2.1%	1.1	1.7	
W710	Hay/Pasture	D	80.0	0.00	0.05	2.46%	4.5%	2.0	3.7	
W710	MFR	D	92.0	0.00	0.05	6.63%	11.2%	6.1	9.8	
W710	POS	D	80.0	0.00	0.05	0.18%	11.3%	0.1	9.9	
W710	ROW	D	98.0	0.00	0.05	0.46%	11.8%	0.5	10.4	
W710	ROW	D	98.0	0.00	0.05	0.00%	11.8%	0.0	10.4	
W710	SFR	D	87.0	0.00	0.05	0.44%	12.2%	0.4	10.7	
W710	SFR	D	87.0	0.00	0.05	6.60%	18.8%	5.7	16.5	
W710	SFR	D	87.0	0.00	0.05	0.00%	18.8%	0.0	16.5	
W710	POS	D	80.0	0.00	0.05	0.30%	19.1%	0.2	16.7	
W710	Developed, Low Intensity	C	80.0	0.00	0.05	1.90%	21.0%	1.5	18.2	
W710	Developed, Medium Intensity	C	83.0	0.00	0.05	0.66%	21.7%	0.5	18.8	
W710	Hay/Pasture	C	74.0	0.00	0.05	0.00%	21.7%	0.0	18.8	
W710	Developed, Open Space	C	74.0	0.00	0.05	1.82%	23.5%	1.3	20.1	
W710	MFR	C	90.0	0.00	0.05	0.04%	23.6%	0.0	20.2	
W710	MFR	C	90.0	0.00	0.05	2.90%	26.5%	2.6	22.8	
W710	MFR	C	90.0	0.00	0.05	0.01%	26.5%	0.0	22.8	
W710	POS	C	74.0	0.00	0.05	4.05%	30.5%	3.0	25.8	
W710	ROW	C	98.0	0.01	0.05	18.10%	48.6%	17.7	43.5	
W710	ROW	C	98.0	0.00	0.05	0.22%	48.8%	0.2	43.7	
W710	SEF	C	86.0	0.00	0.05	0.20%	49.0%	0.2	43.9	
W710	SFR	C	83.0	0.00	0.05	0.19%	49.2%	0.2	44.1	
W710	SFR	C	83.0	0.00	0.05	1.79%	51.0%	1.5	45.6	
W710	SFR	C	83.0	0.01	0.05	21.38%	72.4%	17.7	63.3	
W710	SFR	C	83.0	0.00	0.05	3.06%	75.4%	2.5	65.8	
W710	SFR	C	83.0	0.00	0.05	0.22%	75.7%	0.2	66.0	
W710	SFR	C	83.0	0.01	0.05	14.32%	90.0%	11.9	77.9	
W710	SFR	C	83.0	0.01	0.05	10.02%	100.0%	8.3	86.2	**86.2**
W760	Hay/Pasture	D	80.0	0.00	0.08	0.02%	0.0%	0.0	0.0	
W760	Developed, Low Intensity	C	80.0	0.00	0.08	0.32%	0.3%	0.3	0.3	
W760	Developed, Low Intensity	C	80.0	0.00	0.08	0.05%	0.4%	0.0	0.3	
W760	Developed, Low Intensity	C	80.0	0.00	0.08	0.00%	0.4%	0.0	0.3	
W760	Developed, Open Space	C	74.0	0.00	0.08	4.83%	5.2%	3.6	3.9	
W760	MFR	C	90.0	0.00	0.08	0.69%	5.9%	0.6	4.5	
W760	POS	C	74.0	0.00	0.08	1.12%	7.0%	0.8	5.3	
W760	ROW	C	98.0	0.02	0.08	26.39%	33.4%	25.9	31.2	
W760	SFR	C	83.0	0.00	0.08	1.08%	34.5%	0.9	32.1	
W760	SFR	C	83.0	0.00	0.08	0.01%	34.5%	0.0	32.1	
W760	SFR	C	83.0	0.02	0.08	20.48%	55.0%	17.0	49.1	
W760	SFR	C	83.0	0.00	0.08	5.06%	60.0%	4.2	53.3	
W760	SFR	C	83.0	0.00	0.08	5.36%	65.4%	4.5	57.7	

Figgins Creek Curve Number Calculations

BASIN	LAND USE CATEGORY	SOIL MAP UNIT #	SUBREGION CN	SUBREGION AREA (mi^2)	SUBBASIN AREA (mi^2)	PERCENT OF SUBBASIN	CUMULATIVE PERCENT	AREA-WEIGHTED CN	CUMULATIVE CN	COMPOSITE CN
W760	SFR	C	83.0	0.01	0.08	16.82%	82.2%	14.0	71.7	
W760	SFR	C	83.0	0.00	0.08	2.78%	85.0%	2.3	74.0	
W760	SFR	C	83.0	0.01	0.08	9.31%	94.3%	7.7	81.7	
W760	Hay/Pasture	C	74.0	0.00	0.08	5.69%	100.0%	4.2	85.9	**85.9**
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.04%	0.0%	0.0	0.0	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.18%	0.2%	0.1	0.2	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	1.64%	1.9%	1.3	1.5	
W770	POS	C	74.0	0.00	0.17	0.26%	2.1%	0.2	1.7	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.28%	2.4%	0.2	1.9	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.46%	2.9%	0.4	2.3	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	1.02%	3.9%	0.8	3.1	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.01%	3.9%	0.0	3.1	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.16%	4.1%	0.1	3.2	
W770	Developed, Low Intensity	C	80.0	0.00	0.17	0.01%	4.1%	0.0	3.2	
W770	Developed, Open Space	C	74.0	0.00	0.17	0.01%	4.1%	0.0	3.2	
W770	Developed, Open Space	C	74.0	0.00	0.17	0.14%	4.2%	0.1	3.3	
W770	Developed, Open Space	C	74.0	0.02	0.17	11.51%	15.7%	8.5	11.9	
W770	Developed, Open Space	C	74.0	0.00	0.17	0.20%	15.9%	0.1	12.0	
W770	Developed, Open Space	C	74.0	0.00	0.17	0.06%	16.0%	0.0	12.1	
W770	Developed, Open Space	C	74.0	0.00	0.17	0.08%	16.1%	0.1	12.1	
W770	Hay/Pasture	C	74.0	0.00	0.17	0.01%	16.1%	0.0	12.1	
W770	POS	C	74.0	0.00	0.17	1.46%	17.5%	1.1	13.2	
W770	POS	C	74.0	0.00	0.17	0.15%	17.7%	0.1	13.3	
W770	POS	C	74.0	0.00	0.17	0.11%	17.8%	0.1	13.4	
W770	POS	C	74.0	0.00	0.17	1.62%	19.4%	1.2	14.6	
W770	POS	C	74.0	0.00	0.17	0.92%	20.3%	0.7	15.3	
W770	POS	C	74.0	0.00	0.17	0.06%	20.4%	0.0	15.3	
W770	POS	C	74.0	0.00	0.17	2.75%	23.1%	2.0	17.3	
W770	POS	C	74.0	0.01	0.17	3.47%	26.6%	2.6	19.9	
W770	POS	C	74.0	0.00	0.17	1.26%	27.9%	0.9	20.8	
W770	POS	C	74.0	0.00	0.17	0.10%	28.0%	0.1	20.9	
W770	POS	C	74.0	0.00	0.17	0.27%	28.2%	0.2	21.1	
W770	ROW	C	98.0	0.03	0.17	18.53%	46.8%	18.2	39.3	
W770	ROW	C	98.0	0.00	0.17	0.00%	46.8%	0.0	39.3	
W770	ROW	C	98.0	0.00	0.17	0.38%	47.1%	0.4	39.7	
W770	SFR	C	83.0	0.01	0.17	5.49%	52.6%	4.6	44.2	
W770	SFR	C	83.0	0.00	0.17	0.52%	53.2%	0.4	44.6	
W770	SFR	C	83.0	0.00	0.17	0.54%	53.7%	0.4	45.1	
W770	SFR	C	83.0	0.01	0.17	4.54%	58.2%	3.8	48.9	
W770	SFR	C	83.0	0.00	0.17	1.33%	59.6%	1.1	50.0	
W770	SFR	C	83.0	0.00	0.17	0.93%	60.5%	0.8	50.7	
W770	SFR	C	83.0	0.00	0.17	2.02%	62.5%	1.7	52.4	
W770	SFR	C	83.0	0.00	0.17	0.18%	62.7%	0.1	52.6	
W770	SFR	C	83.0	0.00	0.17	1.94%	64.7%	1.6	54.2	
W770	SFR	C	83.0	0.00	0.17	0.94%	65.6%	0.8	55.0	
W770	SFR	C	83.0	0.00	0.17	1.81%	67.4%	1.5	56.5	
W770	SFR	C	83.0	0.00	0.17	0.94%	68.3%	0.8	57.2	
W770	SFR	C	83.0	0.00	0.17	1.73%	70.1%	1.4	58.7	
W770	SFR	C	83.0	0.00	0.17	0.99%	71.1%	0.8	59.5	
W770	SFR	C	83.0	0.01	0.17	3.06%	74.1%	2.5	62.0	
W770	SFR	C	83.0	0.00	0.17	2.80%	76.9%	2.3	64.4	
W770	SFR	C	83.0	0.00	0.17	2.28%	79.2%	1.9	66.3	
W770	SFR	C	83.0	0.00	0.17	2.59%	81.8%	2.1	68.4	
W770	SFR	C	83.0	0.00	0.17	0.72%	82.5%	0.6	69.0	
W770	SFR	C	83.0	0.00	0.17	1.86%	84.4%	1.5	70.6	
W770	SFR	C	83.0	0.00	0.17	0.98%	85.4%	0.8	71.4	
W770	SFR	C	83.0	0.00	0.17	2.43%	87.8%	2.0	73.4	
W770	SFR	C	83.0	0.00	0.17	2.36%	90.1%	2.0	75.3	
W770	SFR	C	83.0	0.00	0.17	1.03%	91.2%	0.9	76.2	
W770	SFR	C	83.0	0.00	0.17	1.38%	92.6%	1.1	77.3	
W770	SFR	C	83.0	0.00	0.17	1.45%	94.0%	1.2	78.6	
W770	SFR	C	83.0	0.00	0.17	1.64%	95.7%	1.4	79.9	
W770	SFR	C	83.0	0.00	0.17	0.32%	96.0%	0.3	80.2	
W770	UDV	C	83.0	0.01	0.17	3.37%	99.3%	2.8	83.0	
W770	VACANT	C	91.0	0.00	0.17	0.26%	99.6%	0.2	83.2	
W770	VACANT	C	91.0	0.00	0.17	0.33%	99.9%	0.3	83.5	
W770	VACANT	C	91.0	0.00	0.17	0.02%	100.0%	0.0	83.5	
W770	VACANT	C	91.0	0.00	0.17	0.04%	100.0%	0.0	83.6	**83.6**
W820	POS	C	74.0	0.00	0.01	0.00%	0.0%	0.0	0.0	
W820	ROW	C	98.0	0.00	0.01	4.20%	4.2%	4.1	4.1	
W820	SFR	C	83.0	0.00	0.01	4.12%	8.3%	3.4	7.5	
W820	SFR	C	83.0	0.00	0.01	0.14%	8.5%	0.1	7.7	
W820	VACANT	C	91.0	0.00	0.01	0.18%	8.6%	0.2	7.8	
W820	POS	C	74.0	0.01	0.01	91.36%	100.0%	67.6	75.4	**75.4**
W860	AP	D	92.0	0.00	0.07	1.21%	1.2%	1.1	1.1	
W860	Developed, Low Intensity	D	85.0	0.00	0.07	0.08%	1.3%	0.1	1.2	
W860	Hay/Pasture	D	80.0	0.00	0.07	0.22%	1.5%	0.2	1.4	
W860	Developed, Open Space	D	80.0	0.00	0.07	0.32%	1.8%	0.3	1.6	
W860	MFR	D	92.0	0.00	0.07	0.94%	2.8%	0.9	2.5	
W860	POS	D	80.0	0.00	0.07	1.36%	4.1%	1.1	3.6	
W860	AP	C	90.0	0.02	0.07	30.60%	34.7%	27.5	31.1	
W860	Developed, Low Intensity	C	80.0	0.00	0.07	0.00%	34.7%	0.0	31.1	
W860	Hay/Pasture	C	74.0	0.00	0.07	1.05%	35.8%	0.8	31.9	
W860	MFR	C	90.0	0.00	0.07	0.36%	36.1%	0.3	32.2	
W860	ROW	C	98.0	0.00	0.07	2.26%	38.4%	2.2	34.4	
W860	SEF	C	86.0	0.01	0.07	13.63%	52.0%	11.7	46.2	
W860	Hay/Pasture	C	74.0	0.03	0.07	45.84%	97.9%	33.9	80.1	
W860	Cultivated Crops	C	81.0	0.00	0.07	2.12%	100.0%	1.7	81.8	**81.8**
W960	Hay/Pasture	C	74.0	0.00	0.03	0.01%	0.0%	0.0	0.0	
W960	POS	C	74.0	0.00	0.03	0.90%	0.9%	0.7	0.7	
W960	POS	C	74.0	0.00	0.03	0.34%	1.2%	0.3	0.9	
W960	ROW	C	98.0	0.01	0.03	23.70%	24.9%	23.2	24.2	
W960	SFR	C	83.0	0.00	0.03	3.72%	28.7%	3.1	27.2	
W960	SFR	C	83.0	0.00	0.03	3.67%	32.3%	3.0	30.3	
W960	SFR	C	83.0	0.00	0.03	2.74%	35.1%	2.3	32.6	
W960	SFR	C	83.0	0.00	0.03	5.45%	40.5%	4.5	37.1	
W960	SFR	C	83.0	0.00	0.03	3.95%	44.5%	3.3	40.4	
W960	SFR	C	83.0	0.00	0.03	3.77%	48.3%	3.1	43.5	
W960	SFR	C	83.0	0.00	0.03	2.50%	50.8%	2.1	45.6	
W960	Hay/Pasture	C	74.0	0.01	0.03	34.53%	85.3%	25.6	71.1	
W960	POS	C	74.0	0.00	0.03	14.70%	100.0%	10.9	82.0	**82.0**

APPENDIX E

LAG TIME CALCULATIONS

Calculation of Lag Time

Basin	CN	Avg Basin Slope (%)	Longest flow path (ft)	Tc (hr)	Tc (min)	Lag (min)
W100	77.5	1.48	1605.05	0.69	41.17	24.70
W1370	86.9	2.89	3007.98	0.59	35.63	21.38
W1520	87.7	2.89	3796.94	0.70	41.83	25.10
W170	76.4	1.64	917.21	0.43	25.81	15.48
W1700	97.7	1.79	298.13	0.07	6.00	3.60
W1720	90.0	3.02	1919.31	0.36	21.61	12.97
W1800	84.4	1.95	3417.37	0.88	52.65	31.59
W1850	83.3	3.18	2185.95	0.50	29.91	17.95
W1900	78.3	1.39	4319.41	1.53	91.52	54.91
W1950	78.2	1.46	7515.76	2.33	139.53	83.72
W2160	80.8	1.39	2587.03	0.94	56.19	33.71
W220	85.5	2.30	1702.78	0.44	26.69	16.01
W260	90.5	1.69	726.04	0.22	13.02	7.81
W2800	82.4	1.74	7304.54	1.83	109.75	65.85
W330	75.5	1.53	3757.65	1.41	84.60	50.76
W430	79.9	1.40	1548.21	0.64	38.22	22.93
W470	76.9	1.41	3271.86	1.27	75.92	45.55
W630	75.7	1.53	3932.13	1.46	87.38	52.43
W710	86.2	2.20	3612.48	0.81	48.60	29.16
W760	85.9	1.99	4966.58	1.11	66.62	39.97
W770	83.6	1.52	6415.76	1.69	101.49	60.89
W820	75.4	2.04	1293.72	0.52	31.36	18.82
W860	81.8	1.80	4198.99	1.17	70.50	42.30
W960	82.0	1.38	2784.14	0.96	57.62	34.57

**According to the SCS Handbook, the engineer should use a Tc equal to 0.1 hr (6 min) if the computed Tc is less than 0.1 hr.*