MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

Hydrology Design Report

Junction Creek Detailed Floodplain Study
Beaverhead County, MT

By the Montana Department of Natural Resources and Conservation

March 2017

[Hydrologic Submittal per FEMA/MT DNRC MAS. No. 2016-01 Beaverhead County Modernization Project, Phase II]

HYDROLOGY DESIGN REPORT

Junction Creek

Beaverhead County, MT

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1.0 INTRODUCTION

As part of the Mapping Activity Statement (MAS) 2016-01 Beaverhead County Modernization Project, Phase II (Reference 1), DNRC is completing a new detailed riverine floodplain study, with floodway, for a section of Junction Creek in the town of Lima, MT. The new study begins approximately 1 mile upstream of the mouth of Junction Creek and extends approximately 1.5 miles southeast from the limits of the town of Lima (see **Figure 1**). DNRC has completed a hydrologic analysis to be utilized for the new study in Beaverhead County.

The study reach is currently mapped by FEMA using approximate and detailed methods. The study reach is located within the limits of the Town of Lima as well as a portion in Beaverhead County. A Flood Insurance Study (FIS) has been completed for the Town of Lima, MT dated March 4, 1986 (Reference 6); an update to the FIS will be completed as part of the MAS 2016-01. A FIS has been completed for Beaverhead County dated September 30, 1982 (Reference 5), and will be updated as part of the MAS 2016-01as well. Beaverhead County is a non-modernized county and as such still utilizes paper maps. A summary of the Flood Insurance Rate Map (FIRM) and Flood Boundary and Floodway Map (FBFM) panels covering this study reach is presented below (Reference 4):

Community	Community No.	Panels	Effective Date
Beaverhead County, MT	300001	3000012814A 3000013152A	09/30/1982
Town of Lima, MT	300177	3001770001B 3001770001	03/04/1986

This report summarizes the hydrologic analysis and results for the new detailed study stream reach described. The new study includes hydrologic analysis to estimate the 10-, 4-, 2-, 1-, 1+- and 0.2 percent-annual-chance flood discharges for Junction Creek.

1.1 LiDAR Collection

Qauntum Spacial, Inc. (QSI) is currently under contract with the DNRC to perform Light Detection and Ranging (LiDAR) acquisition of Lima, MT as part of the MAS 2016-01 for the purpose of supporting floodplain mapping projects. The LiDAR data will encompass the project reach for this study. Data collection is slated to be acquired this spring. Accuracy of the topographic data will meet FEMA standards for detailed level floodplain mapping.

1.2 Watershed Description

Junction creek originates in the mountains south of Lima and flows north through the corporate limits of Lima until is confluence with the Red Rock River. At its mouth the drainage area of Junction Creek is approximately 139 square miles. Junction Creek lies in one of the intermontane valleys in the Beaverhead River Basin within the Red Rock HUC-8 Watershed (10020001). The soils in these valleys consist of deep tertiary sediments in the upland terraces and benches, and river terrace soils (alluvial sand, gravel, silt, and clay) in the inner valley

(Reference 5). Peak precipitation generally occurs in the early summer months of May and June.

1.3 Effective FIS (Flood Insurance Study) Hydrology

As previously stated, the floodplain for this study reach of Junction Creek is currently mapped by FEMA. Of the mapped floodplain, the entire 2.3 miles of Junction Creek are detailed level mapping, as well as 1.2 miles of the Junction Creek Overflow; 0.3 miles of Alder Creek are approximate level mapping. Morrison-Maierle, Inc. performed the hydrologic and hydraulic analyses in 1979.

According to the FIS, a flooding problem occurs at the Union Pacific Railroad bridge approximately 1.2 miles upstream from Lima (Reference 6). Due to the restricted capacity of the railroad bridge (a small arched bridge) a significant amount of water is forced over the left bank and flows along a path to the west of the railroad, named Junction Creek Overflow. Three culverts, located where Alder Creek passes under the railroad, allow water to pass back to the main channel approximately 0.3 miles upstream from Lima. However, shallow flooding is caused by the remaining water between the railroad and Harrison Street. Another overflow occurs at Peat Street routing water back to the main channel of Junction Creek.

The hydrologic analysis for the effective study comprised of developing a regional relationship relating drainage area to discharge from nearby gaging stations to determine the flood frequency discharges since Junction Creek is an ungaged stream (Reference 6).

A summary of the current effective peak discharge values found in the FIS are provided in **Table 1**.

Table 1. Currently Effective Peak Flows

Site	Basin Area (mi^2)	Annual Chance Peak Discharges (cfs)			
		10%	2%	1%	0.2%
Junction Creek (above Union Pacific Railroad)	138	420	620	700	910
Junction Creek Overflow (Below Union Pacific Railroad)	138[1]	53	193	245	410

[1]Part of Junction Creek Drainage Area

1.4 Historic Data

Junction Creek is an ungaged stream, so nearby gages were analyzed to collect information. The Missouri River basin experienced extensive flooding in 1984, however it is unknown what the impact of flooding on Lima was at that time. Multiple nearby stream gages show 1984 as the historic peak of record including USGS gages 06013200, 06013400, 06013500, 06019500 (shown in **Figure 2**). The flooding was a result of prolonged heavy spring rains and intermittent heavy rainstorms through May causing considerable flooding in June.

Per discussion with a local citizen, in 1987 the town of Lima experienced severe flooding as a result of an ice dam break upstream of town. Similar to the flooding issues described in the effective FIS, the culverts under the railroad crossing were not able to convey the discharge and the town was flooded from the overflow as well as Junction Creek.

2.0 HYDROLOGIC ANALYSIS

The new detailed study project covers approximately 2.8 miles of Junction Creek, 1.1 miles of the Junction Creek Overflow and 0.3 miles of Alder Creek as seen in **Figure 1**. The study begins approximately one mile upstream from the mouth and extends approximately 1.5 miles southeast from the southern limits of the town of Lima.

Junction Creek is an ungaged stream. Regression equations are recommended when no stream gage is present. Typically the most recent published USGS Regression Equations are recommended (Reference 2), however, multiple methods were analyzed in order to determine discharges that are the most representative of the Junction Creek basin. The following methods were analyzed to estimate flood frequency discharge values for Junction Creek:

- USGS Montana Regression Equations,
- USGS Idaho Regression Equations,
- Weighted USGS MT-ID Regression Equations, and
- Regional Regression Analysis.

The following sections provide a description of each estimation method.

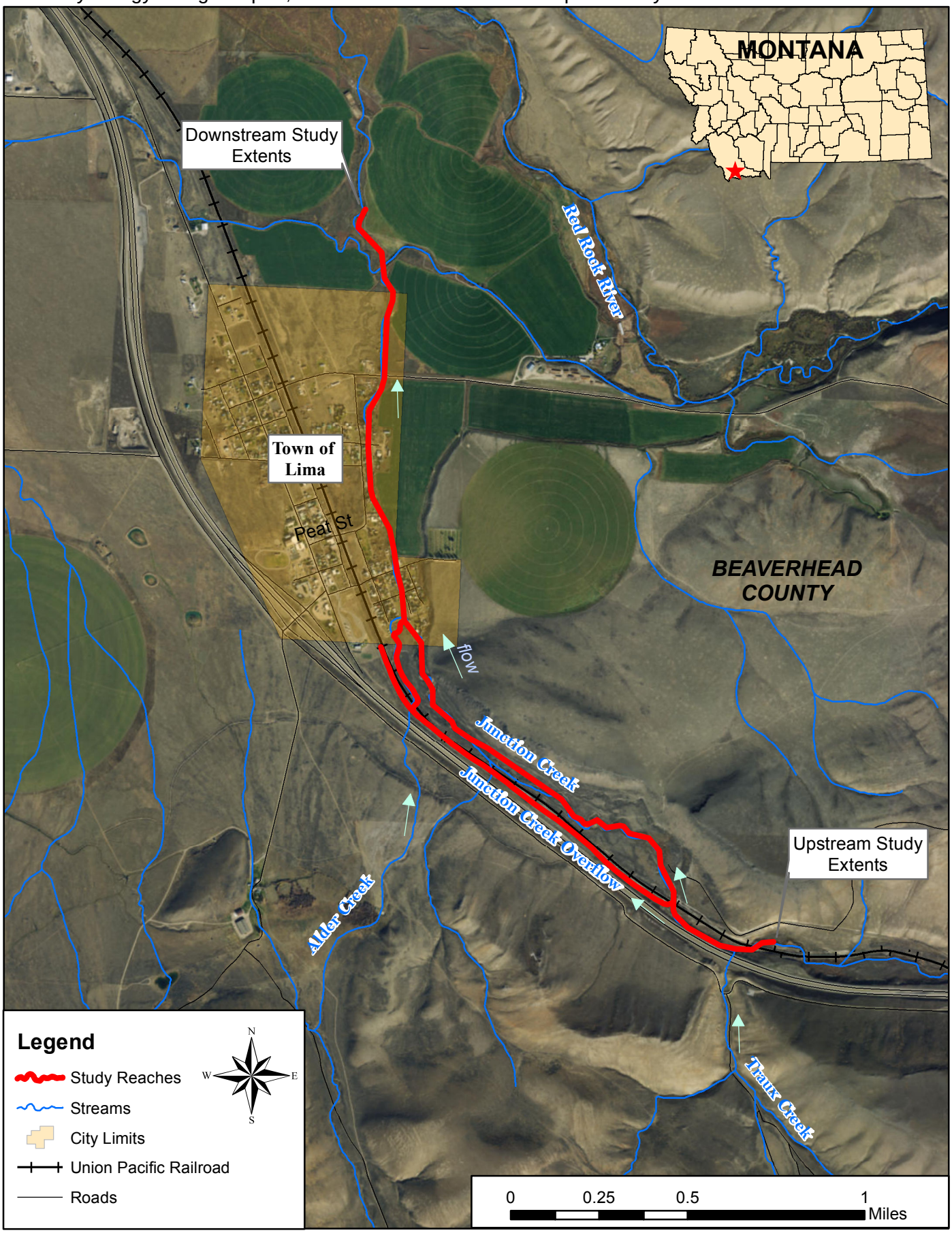


Figure 1: Study Reach Site Map

2.1 USGS Montana Regional Regression Equations

The first method of estimating flood frequency discharges on Junction Creek is through the use of U.S. Geological Survey (USGS) published regression equations for Montana (Reference 11). In 2016 the USGS published the Scientific Investigations Report (SIR) 2015-5019 titled *Montana StreamStats* which was an update to the USGS Water Resources Investigations Report (WRIR) 03-4308 titled *Methods for estimating flood frequency in Montana based on data through water year 1998* published in 2004. The SIR 2015-5019 publication documents standard practices throughout its chapters for estimating peak flow discharges at gaged and ungaged stream locations throughout Montana. Chapter F, titled *Methods for Estimating Peak-Flow Frequencies at Ungaged Sites in Montana Based on Data through Water Year 2011,* focuses on regional regression equations.

Regional regression equations were developed by the USGS by analyzing the relationship between basin characteristics and peak flow frequencies at select gages and splitting the state into 8 hydrologically similar regions. The study reach for this project is located in the "Southwest" region of Montana, and the regression equations for the region are based on drainage basin characteristics variables of:

1) drainage area, and
2) percent of the basin above 6000 feet.

The Southwest regression equations are applicable to basins with a drainage area between 0.42 and 2,472.17 square miles and an elevation above 6000 feet between 0 and 100 percent. The Junction Creek drainage basin falls within these ranges. The USGS regional regression equations and all pertinent information are published in SIR 2015-5019F (Reference 11).

The USGS online StreamStats v4.0 application was used to collect the basin characteristics for Junction Creek (Reference 12). StreamStats allows the user to select a location on a stream and delineate the watershed boundary in order to determine the basin characteristics at any location along a stream. The downstream extent of the study reach for Junction Creek was selected using StreamStats and the basin delineation was checked as recommended. The resulting drainage area for Junction Creek at the downstream study extent is approximately 132 square miles with 100 percent of the basin above 6000 feet (Appendix A). Results of the USGS Regional Regression analysis using these basin characteristics are provided in **Table 2**.

Table 2: USGS Montana Regional Regression Estimates for Junction Creek

Recurrence Interval (Annual Chance)	Discharge Estimates (cfs)	SEP (%)
10%	690	69.7
4%	880	68.6
2%	1,020	68.7
1%	1,170	70.5
0.2%	1,540	76.4

Smaller Standard Error of Prediction (SEP) percentages generally point to greater reliability of the regression equations used. USGS WRIR 03-4308 also provides regression equations for Montana, but as the SEP is higher and SIR 2015-5019 provides additional years of data in its analysis, the results were not evaluated for estimating flows on Junction Creek. FEMA's guidance (Reference 3) is to use the most recent published data.

There is a considerable amount of hydrologic variability in Montana's southwest region, particularly between the northern and southern extents. The northern extent of the Southwest region is where five of the eight hydrologic regions converge, exposing the high variability of gage data in that area of Montana. The Junction Creek drainage basin lies in the southwest corner of the southwest region in Montana, as seen in Appendix A. The percent of the basin elevation above 6000 feet generally decreases toward the northern portion of the southwest region in Montana, which has a significant effect on the outcome of the regression analysis as generally lower elevations correlate to higher discharges in this region.

2.2 USGS Idaho Regional Regression Equations

The second method of estimating flood frequency discharges on Junction Creek is through the use of USGS published regression equations for Idaho (Reference 13). This method was analyzed due to the proximity of Lima to the Montana-Idaho border. USGS published the Scientific Investigations Report (SIR) 2016-5083 titled *Estimating Peak-Flow Frequency Statistics for Selected Gaged and Ungaged Sites in Naturally Flowing Streams and Rivers in Idaho*. The SIR 2016-5083 publication documents standard practices for estimating peak flow discharges at ungaged stream locations throughout Idaho. The methods of developing regional regression equations in Idaho are extremely similar to those used in Montana.

Regional regression equations were developed by the USGS by analyzing the relationship between basin characteristics and peak flow frequencies at select gages across Idaho. The state was divided into 7 hydrologically similar regions. The study reach for this project is located in Region 6_8 of Idaho. This region boundary includes a portion of Montana and encompasses the Junction Creek basin area as can be seen in Figure 3 in SIR 2016-5083 (Reference 13),

also attached in Appendix A. The regression equations for the region are based on drainage basin characteristics variables of:

3) drainage area, and
4) mean annual precipitation.

The Region 6_8 regression equations are applicable to basins with a drainage area between 2.77 and 3,740 square miles and mean annual precipitation between 18.9 and 54.6. The Junction Creek drainage basin area falls within this range, however the annual precipitation is just under the minimum range. This does not mean the equations are not applicable, only that the associated error in **Table 3** may be higher than what is reported and outside of the range for which the equations were developed. Since the annual precipitation is less than 1 inch below the minimum of this range, it is well within the margin of error of the mean annual precipitation estimate. The USGS regional regression equations and all pertinent information are published in SIR 2016-5083 (Reference 13).

The Idaho Regression Equations were applied to the Junction Creek basin using the same variables collected from StreamStats v4.0 described above in Section 2.1. The resulting drainage area for Junction Creek at the downstream study extent is approximately 132 square miles with 18 inches of rainfall annually (Appendix A). Results of the USGS Idaho Regional Regression analysis using these basin characteristics along with the SEP calculated for the Junction Creek basin are provided in **Table 3**.

Table 3: USGS ID Regional Regression Estimates for Junction Creek

Recurrence Interval (Annual Chance)	Discharge Estimates (cfs)	SEP (%)
10%	430	65.9
4%	580	70.5
2%	690	73.8
1%	830	77.7
0.2%	1160	87.1

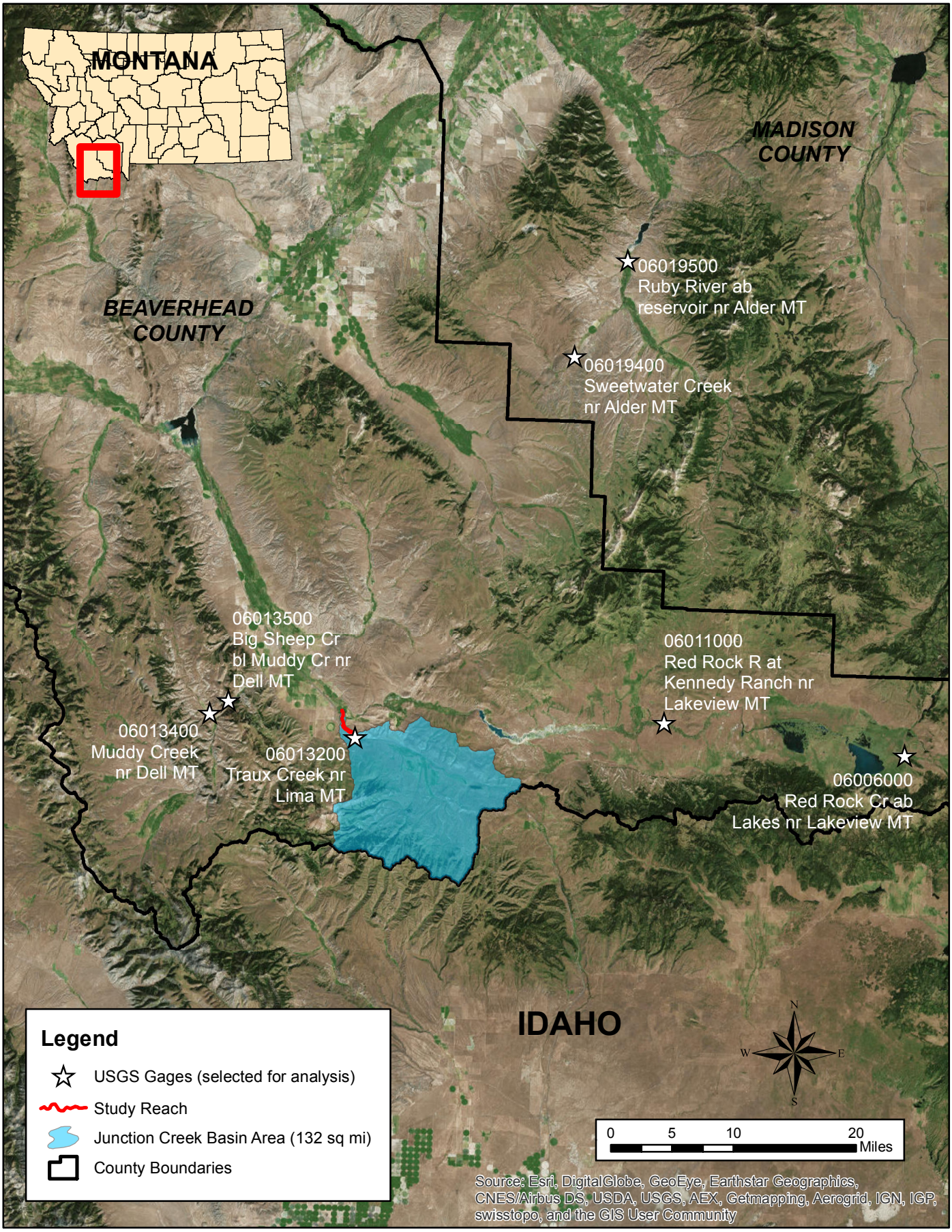


Figure 2. Junction Creek Basin Area and Stream Gage Locations

2.3 Weighted MT-ID Regression Equations

The third method employed to determine flood frequency discharge estimates for Junction Creek is to weight the USGS Montana and Idaho regression equations. The drainage area for Junction Creek lies right on the border of Montana and Idaho as seen in **Figure 2**. As discussed in section 2.2 there is overlap between Montana's Southwest Region and Idaho's Region 6_8 which indicates hydrologically similar properties. Two streamgages from Montana were also included in developing Idaho's Regression Equations for Region 6_8.

The method for weighting the regression equations was discussed with Montana USGS staff to ensure appropriate methodology was used. The analysis included weighting the regression equation discharge results by using the associated variances for each recurrence interval in the following equation:

$$Q_{wtd} = \frac{Q_a * V_b + Q_b * V_a}{V_b + V_a}$$

where *Q* is the discharge, and *V* is the variance. Results of weighting the Montana and Idaho Regression Equations are below in **Table 4**.

Table 4: Weighted USGS MT-ID Regional Regression Estimates for Junction Creek

Recurrence Interval (Annual Chance)	Discharge Estimates (cfs)	SEP (%)
10%	540	45.6
4%	720	46.7
2%	850	47.7
1%	1000	49.3
0.2%	1360	53.7

The standard error of prediction (SEP) is significantly decreased by weighting the equations. This method is more representative of the Junction Creek basin due to its location and the similar hydrologic properties between the southwest region in Montana and Region 6_8 in Idaho.

2.4 Site Specific Regional Regression Analysis

As previously mentioned, there is no stream gage located on Junction Creek. However, there are a number of gages nearby. For comparison purposes, a site specific regional regression analysis was done using nearby gages. The gages selected for this analysis are summarized in **Table 5** and can be seen in **Figure 2**.

Table 5: Stream Gage Summary Table

Gage Name	Site Number	Basin Area (mi^2)	Period of Record	Number of Annual Peaks	Highest Peak of Record (cfs) / Year Recorded
Traux Creek near Lima MT	06013200	4	1960-74, 1984	16	40 / 1984
Red Rock Creek above Lakes near Lakeview MT	06006000	37	1997–2017	20	293 / 1997
Muddy Creek nr Dell MT	06013400	63	1960–74, 1984	16	197 / 1962
Sweetwater Creek near Alder MT	06019400	82	1974–91	18	344 / 1991
Big Sheep Cr bl Muddy Cr nr Dell MT	06013500	279	1946–53, 1960–91	40	1,400 / 1984
Red Rock R at Kennedy Ranch nr Lakeview	06011000	321	1937–42, 1945–54, 1956–67, 1984	29	1,360 / 1952
Ruby River above reservoir, nr Alder	06019500	534	1939–2017	78	3,810 / 1984

The selected gages have similar basin characteristics to Junction Creek with an emphasis on 100 percent of the basin above elevation 6000, with the exception of gage 06019500 which has 91 percent basin elevation above 6000 feet. The selected gages also represent a distribution of drainage areas both smaller and larger than the Junction Creek basin area of 132 square miles. Period of record, years the gage was active, when peak flows occurred, and regulation status were analyzed for each gage as well as the basin characteristics.

A spreadsheet developed by the Montana Department of Transportation (MDT) called the MDT Regression Program was used to determine the flood frequency discharges for Junction Creek. The MDT Regression Program utilizes gage data which was obtained from the USGS publication SIR 2015-5019C titled *Peak-Flow Frequency Analyses and Results Based on Data through Water Year 2011 for Selected Streamflow-Gaging Stations in or near Montana* (Reference 10). The basin characteristics used for each gaging station were drainage area and percent basin elevation above 6000 feet, consistent with the variables used in SIR 2015-5019C for this region due to their high correlation. The MDT Regression Program then generates an equation in the form of

$$Q = X^a Y^b C$$

where Q is the peak flow for a specific recurrence interval, X and Y are the appropriate basin characteristics, C is a constant, and a and b are exponents calculated by the program. Correlation coefficients and standard error are calculated as well (Reference 8). Results from the Regional Regression Analysis for Junction Creek as well as the SEP calculated by the MDT Regression Program are below in **Table 6.** The calculation spreadsheet is included in Appendix B.

Table 6. Regional Regression Estimates for Junction Creek

Recurrence Interval (Annual Chance)	Discharge Estimates (cfs)	SEP (%)
10%	410	40.1
4%	530	37.7
2%	630	40.4
1%	720	45.4
0.2%	950	60.9

Due to the ambiguity in the available gage data and the subsequent discussion, it was determined this method is not appropriate for estimating peak flood frequency discharges on Junction Creek. Several of the gages indicate mixed population data; this area is susceptible to rain on snow events as well as ice related flooding. When analyzing the time of year peak flows occur at the gages, it varies considerably from as early as April to as late as July which is also a good indicator of mixed population data. As it is extremely difficult to distinguish the populations of data, these gages were not analyzed as mix population sites by USGS. Although the period of record for each selected gage is long enough to perform a flood frequency analysis, several of the gages have fairly short periods of record with only 20 years or less of data. Therefore, this method is not a very conservative approach and may not accurately portray the flooding risk on Junction Creek.

2.5 Ungaged Site Selection

Due to the short reach length and lack of tributaries in the study reach, the same discharge will be applied to the entire study reach. One main tributary, Traux Creek, exists near the upstream end of the study extent of Junction Creek. However, due to the proximity to the upstream study extent and relatively low flow no flow change is required at this location. The split flow that occurs on Junction Creek Overflow due to the limited capacity of the bridge at the railroad crossing will be evaluated in the hydraulic model.

3.0 RESULTS COMPARISON & SELECTED DISCHARGES

Four methods of estimating flood frequency discharges on Junction Creek were analyzed including USGS Regression Equations for Montana and Idaho, weighting Montana and Idaho Regression Equations, and a site specific regional regression analysis. A comparison of the results is in **Table 7**.

Table 7. Summary of Discharge Estimates for Junction Creek

Recurrence Interval (% Annual Chance)	Discharge Estimates (cfs)			
	MT Regression Equations	ID Regression Equations	Weighted MT-ID Regression Equations	Regional Regression Analysis
10%	690	430	540	410
4%	880	580	720	530
2%	1,020	690	850	630
1%	1,170	830	1000	720
0.2%	1,540	1160	1360	950

Selected discharges are shown in RED.

The recommended method is to weight the USGS Montanan and Idaho Regression Equations. The USGS Montana Regression Equations alone are not representative of the Junction Creek basin due to the variability in gages used between the southern and northern portion of the Southwest Region. The Junction Creek drainage basin lies along the southern border of the Southwest Region, which is also the state border of Montana and Idaho. Idaho's Region 6_8 encompasses this boundary and overlaps into Montana. Montana's Southwest region and Idaho's Region 6_8 have extremely similar hydrologic characteristics, and a weighted estimate is the most representative of the Junction Creek basin.

The 1-percent plus calculation was determined by calculating the 84% confidence interval and adding the error to the 1% annual chance discharge. A comparison of the recommended flood frequency discharge estimates and the currently effective discharges for Junction Creek are below in **Table 8**.

Table 8: Selected Discharges

Location	Drainage Area (mi²)	Selected vs. Currently Effective	Peak Discharge Estimates (cfs)					
			10%	4%	2%	1%	1%+	0.2%
Junction Creek at downstream study extents	132	Selected	540	715	850	1000	1930	1360
		Currently Effective	420	-	620	700	-	910

4.0 REFERENCES

1. Federal Emergency Management Agency (FEMA), 2016, *Montana DNRC Cooperating Technical Partners Flood Risk Project Mapping Activity Statement (MAS):* No. 2016-01, Beaverhead County Modernization Project, Phase II.

2. Federal Emergency Management Agency (FEMA), May 2016, Guidance for Flood Risk Analysis and Mapping, General Hydrologic Considerations.

3. Federal Emergency Management Agency (FEMA), 2009, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix C: Guidance for Riverine Flooding Analyses and Mapping.

4. Federal Emergency Management Agency (FEMA), Flood Insurance Rate Map (FIRM) and Flood Boundary and Floodway Map (FBFM):

Community	Community No.	Panels	Effective Date
Beaverhead County, MT	300001	3000012814A 3000013152A	09/30/1982
Town of Lima, MT	300177	3001770001B 3001770001	03/04/1986

5. *Flood Insurance Study City of Dillon, Town of Lima, and Unincorporated Areas of Beaverhead County, Montana,* (1982). Federal Emergency Management Agency.

6. *Flood Insurance Study Town of Lima, MT Beaverhead County,* (1986). Federal Emergency Management Agency.

7. Interagency Advisory Committee on Water Data. (1982). *Guidelines for Determining Flood Flow Frequency: Bulletin #17B of the Hydrology Committee* (Rev. Sept. 1981 ; ed.). Reston, Va.: U.S. Dept. of the Interior, Geological Survey, Office of Water Data Coordination.

8. Montana Department of Transportation (MDT), October 2, 1995, *AASHTO Drainage Manual, Chapter 7 Hydrology*.

9. McCarthy, Peter, Dutton, DeAnn M., Sando, Steven K., and Sando, Roy, 2015, *Montana StreamStats- A Method for Retrieving Basin and Streamflow Characteristics in Montana.* U.S. Dept. of the Interior, U.S. Geological Survey, Scientific Investigations Report (SIR) 2015-5019-A.

10. Sando, Steve, McCarthy, Peter M., and Dutton, D.M., 2015, *Peak-Flow Frequency Analyses and Results Based on Data through Water Year 2011 for Selected Streamflow-Gaging Stations in or near Montana*. U.S. Dept. of the Interior, U.S. Geological Survey, SIR 2015-5019-C.

11. Sando, Roy, Sando, S.K., McCarthy, P.M., and Dutton, D.M., 2015, *Methods for Estimating Peak-Flow Frequency at Ungaged Sites in Montana Based on Data through Water Year 2011*. U.S. Dept. of the Interior, U.S. Geological Survey SIR 2015-5019-F.

12. USGS StreamStats. Basin Characteristics and Regression Equation Output Report, Retrieved March 16, 2017 from https://streamstatsags.cr.usgs.gov/streamstats/

13. Wood, Molly S., Fosness, Ryan L., Skinner, Kenneth D., and Veilleux, Andrea G., 2016, *Estimating Peak-Flow Frequency Statistics for Selected Gaged and Ungaged Sites in Naturally Flowing Streams and Rivers in Idaho.* U.S. Dept. of the Interior, U.S. Geological Survey SIR 2016-5083.

Appendix A

Basin Characteristics

- USGS StreamStats Report for Junction Creek
- Montana Hydrologic Regions for Regression Equations Figure (SIR 2015-5019)
- Idaho Hydrologic Regions for Regression Equations Figure (SIR 2016-5083)

StreamStats Report_Junction Creek in Lima, MT

Region ID:

MT

Workspace ID:

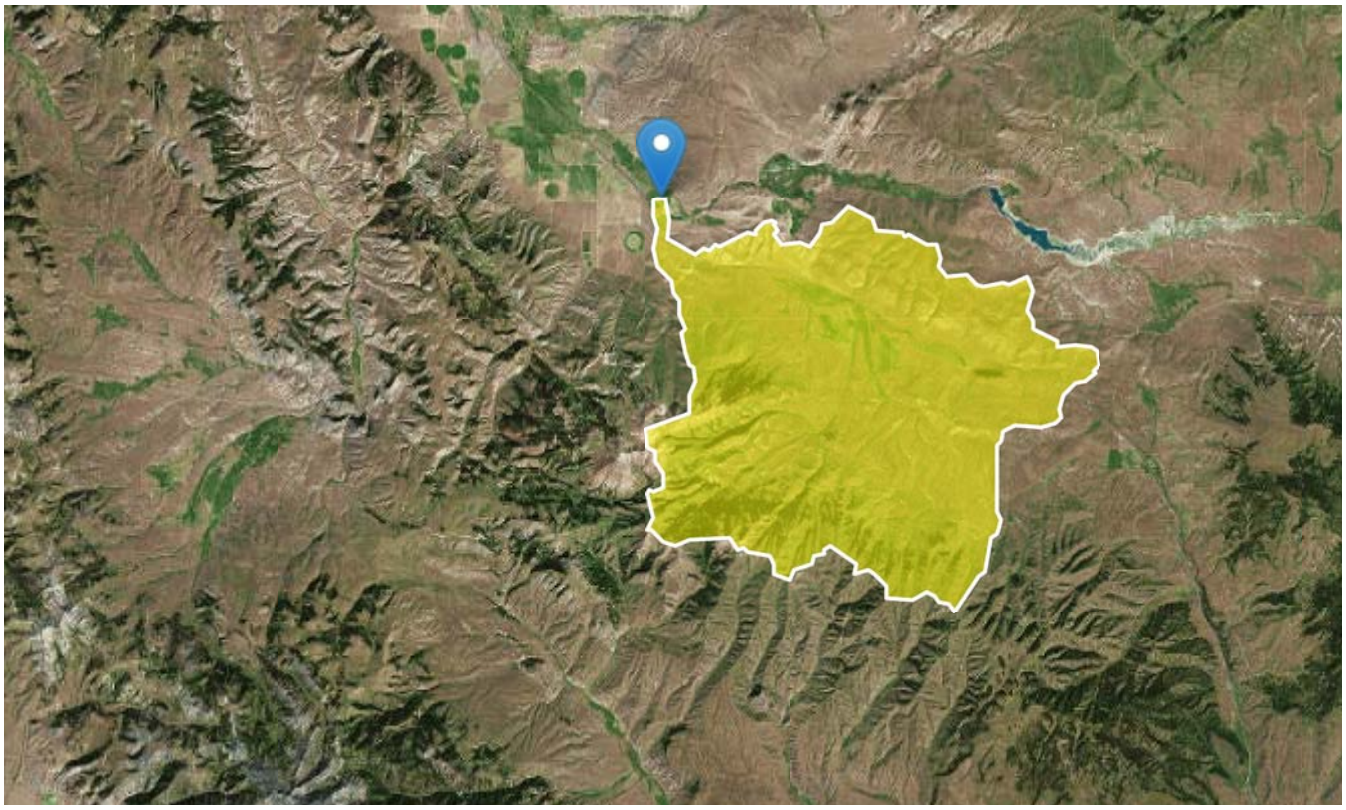
MT20170316132011649000

Clicked Point (Latitude, Longitude):

44.64910, -112.58989

Time:

2017-03-16 13:20:43 -0600



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream (total drainage area minus non-contributing areas within basin)	132.1	square miles
EL6000	Percent of area above 6000 ft	100	percent
ELEV	Mean Basin Elevation	7330.2	feet
PRECIP	Mean Annual Precipitation	17.96	inches
FOREST	Percentage of area covered by forest	11.3	percent

Peak-Flow Statistics Parameters [100 Percent (132 square miles) SW Region BasinC 2015 5019F]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	132.1	square miles	0.42	2480
EL6000	Percent above 6000 ft	100	percent	0	100

Peak-Flow Statistics Flow Report [100 Percent (132 square miles) SW Region BasinC 2015 5019F]

Statistic	Value	Unit	Average standard error of prediction	Lower Prediction Interval	Upper Prediction Interval
1.5 Year Peak Flood	293	ft^3/s	117.8	62.9	1370
2 Year Peak Flood	362	ft^3/s	96	96	1370
2 33 Year Peak Flood	392	ft^3/s	90.1	110	1400
5 Year Peak Flood	545	ft^3/s	76.9	179	1660
10 Year Peak Flood	687	ft^3/s	72.1	239	1980
25 Year Peak Flood	878	ft^3/s	71.3	309	2490
50 Year Peak Flood	1020	ft^3/s	72	358	2900
100 Year Peak Flood	1170	ft^3/s	73.8	403	3410

Statistic	Value	Unit	Average standard error of prediction	Lower Prediction Interval	Upper Prediction Interval
200 Year Peak Flood	1320	ft^3/s	76.5	442	3970
500 Year Peak Flood	1540	ft^3/s	80.3	494	4830

Peak-Flow Statistics Citations

Sando, Roy, Sando, S.K., McCarthy, P.M., and Dutton, D.M.,2016, Methods for estimating peak-flow frequencies at ungaged sites in Montana based on data through water year 2011: U.S. Geological Survey Scientific Investigations Report 2015–5019–F, 30 p. (http://dx.doi.org/10.3133/sir20155019F)

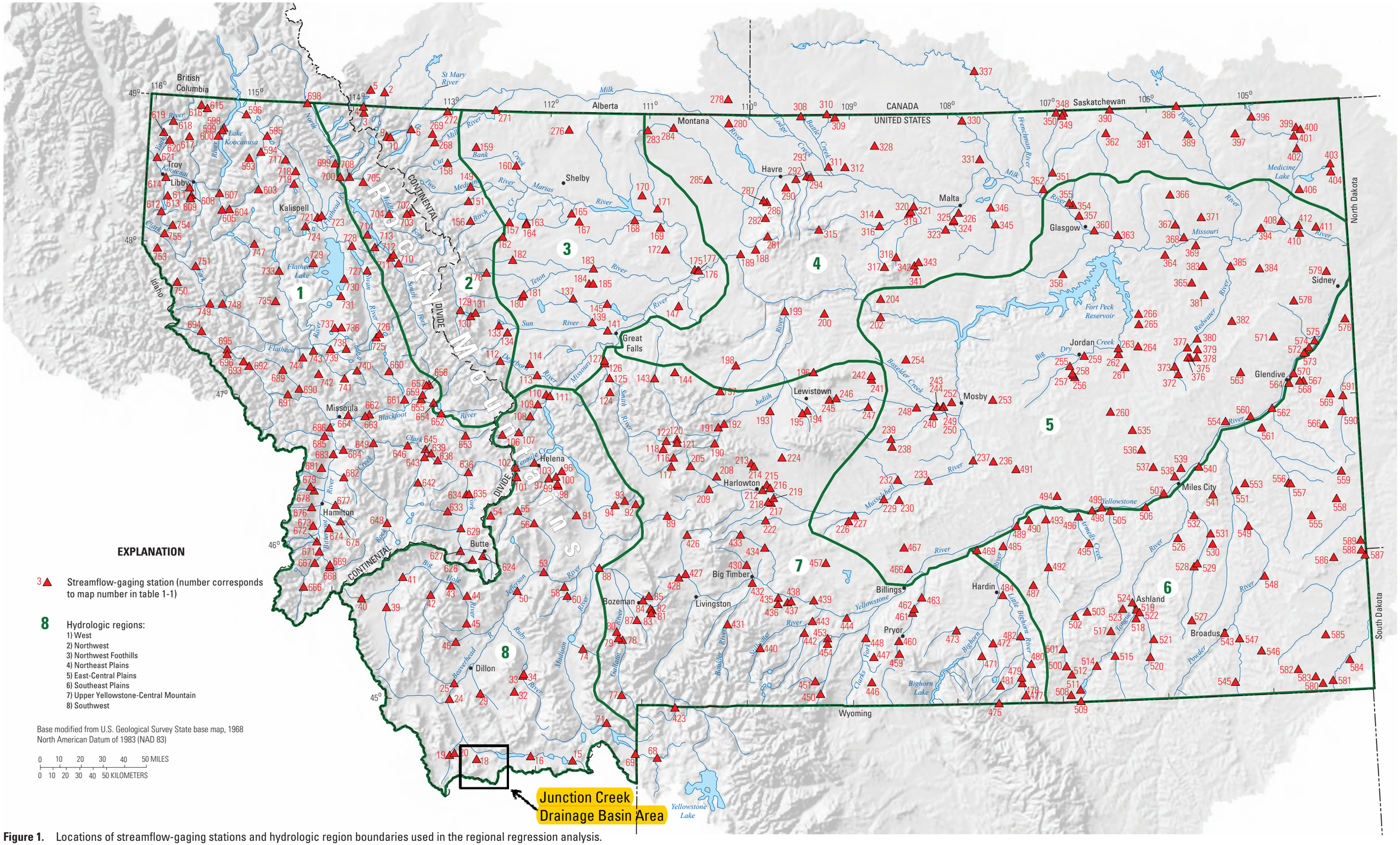


Figure 1. Locations of streamflow-gaging stations and hydrologic region boundaries used in the regional regression analysis.

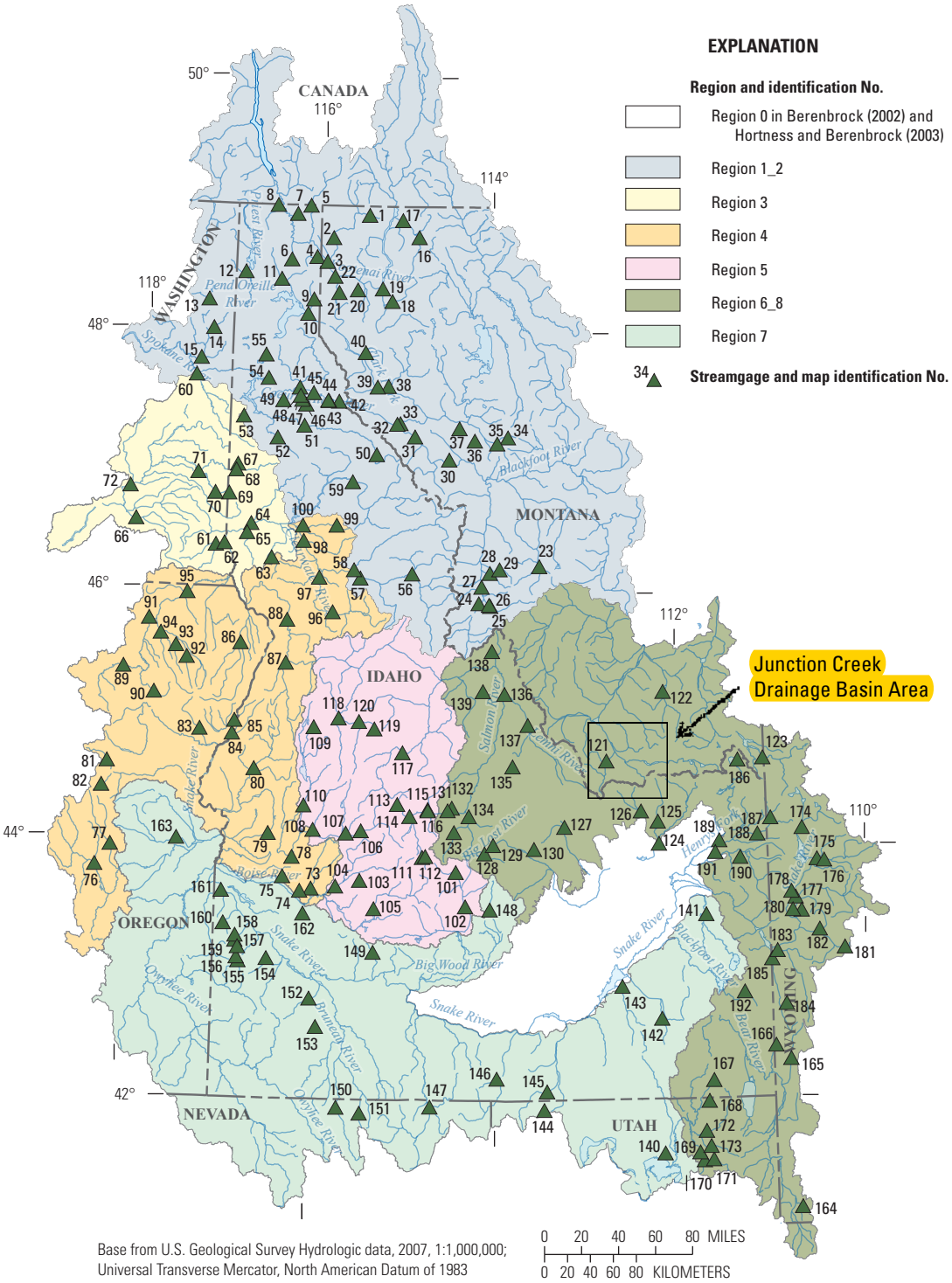


Figure 3. Locations of streamgages in Idaho and bordering States selected for the regional peak-flow regression analysis (area in southeastern Idaho shown in white was excluded because of extent of regulation, groundwater-surface water interactions, and infiltration).

Appendix B

Hydrologic Calculations

- Weighted Montana and Idaho Regression Equation Calculations
- MDT Regression Program Calculations

Region 6_8 Idaho
Equation

Q10=0.0534 A^(0.713)*P^(1.91)

MEV	0.06			
Variable	Value	Units	Exponent	Var^(exp)
Constant	0.0534		1	0.0534
Area	132	sq. mi	0.713	32.50642528
Precip	18	inches	1.91	249.7873754
Computed Value				433.5916946
Log Computed Value				2.637080955

Covariance Matrix

0.31272	-0.01409	-0.18973
-0.01409	0.00317	0.00502
-0.18973	0.00502	0.12080

Vector x matrix

1.00000
2.12057
1.25527

$$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$$ = 0.007983

SEPi	0.260736	65.87654
Variance	0.067983	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.437888	
Log Q100	2.637081	
Upper prediction interval	1188.416	
lower prediction interval	158.1952	

Weighted log Q	2.732349	
Weighed Q	539.9445	
Averaged Q	560.3322	
Variance Weighted	0.035587	
SEPi weighted	0.188646	45.56974
student's t for 90%	1.644856	
CI (log units)	0.310296	
Upper prediction interval	1103.177	
Lower prediction interval	264.2731	

Southwest Region MT
Equation

Q10 = 31.9 A^(0.796) (E6000 + 1)^(-0.177)

MEV	0.072			
Variable	Value	Units	Exponent	Var^(exp)
Constant	31.9		1	31.9
Area	132	sq. mi	0.796	48.75025
Percent 6000	100	percent	-0.177	0.44181
Computed Value				687.0726
Log Computed Value				2.837003

Covariance Matrix

0.04707	-0.00489	-0.01935
-0.00489	0.00350	-0.00097
-0.01935	-0.00097	0.01156

Vector x matrix

1.00000
2.12057
2.00000

$$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$$ = 0.002681

SEPi	0.273278	69.69983
Variance	0.074681	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.45895	
Log Q100	2.837003	
Upper prediction interval	1976.756	
lower prediction interval	238.8098	

Region 6_8 Idaho
Equation

Q4=0.118*A^(0.698)*P^(1.76)

MEV	0.067			
Variable	Value	Units	Exponent	Var^(exp)
Constant	0.118		1	0.118
Area	132	sq. mi	0.698	30.21068718
Precip	18	inches	1.76	161.9122131
Computed Value				577.1945481
Log Computed Value				2.76132222

Covariance Matrix

0.35524	-0.01616	-0.21512
-0.01616	0.00360	0.00580
-0.21512	0.00580	0.13675

Vector x matrix

1.00000
2.12057
1.25527

$$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$$ = 0.009137

SEPi	0.275929	70.52105
Variance	0.076137	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.463403	
Log Q100	2.761322	
Upper prediction interval	1677.743	
lower prediction interval	198.5725	

Weighted log Q	2.854329	
Weighed Q	715.0383	
Averaged Q	727.3495	
Variance Weighted	0.037213	
SEPi weighted	0.192907	46.70278
student's t for 90%	1.644856	
CI (log units)	0.317305	
Upper prediction interval	1484.684	
Lower prediction interval	344.3694	

Southwest Region MT
Equation

Q4 = 79.8 A0.750 (E6000 + 1)-0.274

MEV	0.07			
Variable	Value	Units	Exponent	Var^(exp)
Constant	79.8		1	79.8
Area	132	sq. mi	0.75	38.94309
Percent 6000	100	percent	-0.274	0.282368
Computed Value				877.5044
Log Computed Value				2.943249

Covariance Matrix

0.05241	-0.00498	-0.02191
-0.00498	0.00361	-0.00109
-0.02191	-0.00109	0.01303

Vector x matrix

1.00000
2.12057
2.00000

$$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$$ = 0.002791

SEPi	0.269798	68.62903
Variance	0.072791	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.453107	
Log Q100	2.943249	
Upper prediction interval	2490.898	
lower prediction interval	309.131	

Region 6_8 Idaho
Equation

Q2=0.198*A^(0.688)*P^(1.66)

MEV	0.072			
Variable	Value	Units	Exponent	Var^(exp)
Constant	0.198		1	0.198
Area	132	sq. mi	0.688	28.77099388
Precip	18	inches	1.66	121.2697154
Computed Value				690.8319477
Log Computed Value				2.839372413

Covariance Matrix

0.38955	-0.01783	-0.23562
-0.01783	0.00394	0.00642
-0.23562	0.00642	0.14962

Vector x matrix

1.00000
2.12057
1.25527

$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$ = 0.010068

SEPi	0.286476	73.83479
Variance	0.082068	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.481115	
Log Q100	2.839372	
Upper prediction interval	2091.642	
lower prediction interval	228.1694	

Weighted log Q	2.928533	
Weighed Q	848.2687	
Averaged Q	854.4422	
Variance Weighted	0.038616	
SEPi weighted	0.196509	47.66627
student's t for 90%	1.644856	
CI (log units)	0.323229	
Upper prediction interval	1785.512	
Lower prediction interval	402.9992	

Southwest Region MT
Equation

Q2 = 142 A0.721 (E6000 + 1)-0.336

MEV	0.07			
Variable	Value	Units	Exponent	Var^(exp)
Constant	142		1	142
Area	132	sq. mi	0.721	33.80133
Percent 6000	100	percent	-0.336	0.212104
Computed Value				1018.052
Log Computed Value				3.00777

Covariance Matrix

0.05731	-0.00511	-0.02426
-0.00511	0.00378	-0.00122
-0.02426	-0.00122	0.01441

Vector x matrix

1.00000
2.12057
2.00000

$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$ = 0.002933

SEPi	0.270062	68.70985
Variance	0.072933	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.453549	
Log Q100	3.00777	
Upper prediction interval	2892.807	
lower prediction interval	358.2786	

Region 6_8 Idaho
Equation

Q1=0.314*A^(0.679)*P^(1.58)

MEV	0.078			
Variable	Value	Units	Exponent	Var^(exp)
Constant	0.314		1	0.314
Area	132	sq. mi	0.679	27.5340248
Precip	18	inches	1.58	96.23444767
Computed Value				832.0126041
Log Computed Value				2.920129905

Covariance Matrix

0.42558	-0.01957	-0.25716
-0.01957	0.00430	0.00707
-0.25716	0.00707	0.16316

Vector x matrix

1.00000
2.12057
1.25527

$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$ = 0.011043636

SEPi	0.298402	77.6770698
Variance	0.089044	
Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.501144	
Log Q100	2.92013	
Upper prediction interval	2637.996	
lower prediction interval	262.4132	

Weighted log Q	3.000275	
Weighed Q	1000.634	<-This is the 1-percent
Averaged Q	1001.843	
Variance Weighted	0.041044	
SEPi weighted	0.202593	49.3060383
student's t for 90%	1.644856	
CI (log units)	0.333237	
Upper prediction interval	2155.321	
Lower prediction interval	464.5567	
student's t for 84%	1.405073	
CI (log units)	0.284658	
Upper prediction interval	1927.23	<- This is the 1 percent plus
Lower prediction interval	519.5378	

Southwest Region MT
Equation

$$Q_1 = 238\ A^{0.696}\ (E_{6000} + 1)^{-0.391}$$

MEV	0.073			
Variable	Value	Units	Exponent	Var^(exp)
Constant	238		1	238
Area	132	sq. mi	0.696	29.9171
Percent 6000	100	percent	-0.391	0.164555
Computed Value				1171.674
Log Computed Value				3.068807

Covariance Matrix

0.06313	-0.00534	-0.02699
-0.00534	0.00403	-0.00138
-0.02699	-0.00138	0.01604

Vector x matrix

1.00000
2.12057
2.00000

$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$ = 0.00314

SEPi	0.275935	70.52288
Variance	0.07614	
Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.463413	
Log Q100	3.068807	
Upper prediction interval	3405.805	
lower prediction interval	403.0823	

Region 6_8 Idaho
Equation

Q0.2=0.789*A^(0.659)*P^(1.41)

MEV	0.093			
Variable	Value	Units	Exponent	Var^(exp)
Constant	0.789		1	0.789
Area	132	sq. mi	0.659	24.97228143
Precip	18	inches	1.41	58.875449
Computed Value				1160.030628
Log Computed Value				3.064469456

Covariance Matrix

0.51616	-0.02392	-0.31141
-0.02392	0.00521	0.00869
-0.31141	0.00869	0.19732

Vector x matrix

1.00000
2.12057
1.25527

$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$ = 0.01348

SEPi	0.326312	87.10132
Variance	0.10648	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.548017	
Log Q100	3.064469	
Upper prediction interval	4097.196	
lower prediction interval	328.4371	

Weighted log Q	3.132729	
Weighed Q	1357.465	
Averaged Q	1351.449	
Variance Weighted	0.047798	
SEPi weighted	0.218628	53.70593
student's t for 90%	1.644856	
CI (log units)	0.359612	
Upper prediction interval	3106.996	
Lower prediction interval	593.0848	

Southwest Region MT
Equation

Q0.2 = 655 A0.649 (E6000 + 1)-0.501

MEV	0.083			
Variable	Value	Units	Exponent	Var^(exp)
Constant	655		1	655
Area	132	sq. mi	0.649	23.78222
Percent 6000	100	percent	-0.501	0.099046
Computed Value				1542.868
Log Computed Value				3.188329

Covariance Matrix

0.07826	-0.00604	-0.03402
-0.00604	0.00477	-0.00181
-0.03402	-0.00181	0.02028

Vector x matrix

1.00000
2.12057
2.00000

$x_i^T \left(X^T \Lambda^{-1} X\right)^{-1} x_i$ = 0.003732

SEPi	0.294503	76.40948
Variance	0.086732	

Confidence Limit	90	percent
number of gages in regression	48	
number of variables in regression	2	
t	1.679427	
CI (log units)	0.494596	
Log Q100	3.188329	
Upper prediction interval	4818.646	
lower prediction interval	494.0064	

INPUT:

Name	Gage Number	Drainage Area mi^2	E6000		66.7	50.0	42.9	20.0	10.0	4.0	2.0	1.0	0.5	0.2
					1.5	2	2.33	5	10	25	50	100	200	500
Traux Cr nr Lima	6013200	4.02	100.0		2	5	7	22	45	87	128	176	230	309
Big Sheep bl Muddy Cr nr Dell	6013500	279	97.0		261	330	363	516	649	827	964	1110	1250	1460
Muddy Cr nr Dell	6013400	63.1	100.0		44	61	69	109	145	192	228	264	301	350
Red Rock R at Kennedy Ranch nr Lak	6011000	321	100.0		621	718	760	917	1020	1140	1210	1270	1330	1390
Sweetwater Creek near Alder, Montan	6019400	82	100.0		38	62	77	167	280	487	697	964	1300	1860
Red Rock Cr ab Lakes nr Lakeview	6006000	37	100.0		140	164	175	224	264	314	352	389	428	479

OUTPUT:

					Drainage Area mi^2										Drainage Area mi^2								
Station	Name	Drainage	E6000	0	Q	Q									Q	Q	Q	Q	Q				
		Area mi^2	0	0	1.5	2	5	10	25	50	100	200	500	1.5	2	5	10	25	50	100	200	500
	Junction Creek	132	100		151.3	202.4	347.6	456.4	604.1	720.6	841.7	969.0	1145.8	156.5	201.3	325.3	414.1	534.1	626.3	721.2	820.3	954.6

Area^	0.705272526	Area^	0.652836735
x	14.57869547	E6000^	-4.2153423
		x	4606725665

Correlation Coef.	0.960	0.965
Std. Error	38.30%	40.09%

						Area Calcualted		2 Variables	
Gage Number	**Drainage Area mi^2**	**E6000 0**	**0 0**		**Q10**	**Q10**	Gf	**Q10**	Gf
6013200	4.02	100			45	38.9	1.2	42.4	1.1
6013500	279	97			649	773.6	0.8	767.4	0.8
6013400	63.1	100			145	271.2	0.5	255.8	0.6
6011000	321	100			1020	854.1	1.2	739.7	1.4
6019400	82	100			280	326.2	0.9	303.5	0.9
6006000	37	100			264	186.1	1.4	180.5	1.5
6019500	534	91			1620	1222.9	1.3	1534.6	1.1

Area^	0.615794564	Area^	0.549417164
x	29.87073957	E6000^	-5.336115964
		x	1.71716E+12

Correlation Coef.	0.950	0.960
Std. Error	37.87%	37.66%

						Area Calcualted		2 Variables	
Gage Number	**Drainage Area mi^2**	**E6000 0**	**0 0**		**Q25**	**Q25**	Gf	**Q25**	Gf
6013200	4.02	100			87	70.4	1.2	78.4	1.1
6013500	279	97			827	957.7	0.9	948.0	0.9
6013400	63.1	100			192	383.4	0.5	356.1	0.5
6011000	321	100			1140	1044.1	1.1	870.4	1.3
6019400	82	100			487	450.6	1.1	411.2	1.2
6006000	37	100			314	276.0	1.1	265.6	1.2
6019500	534	91			1990	1428.4	1.4	1904.1	1.0

Area^	0.565019492	Area^	0.489339868
x	45.65784821	E6000^	-6.083926873
		x	8.45162E+13

Correlation Coef.	0.932	0.948
Std. Error	41.23%	40.39%

						Area Calcualted		2 Variables	
Gage Number	**Drainage Area mi^2**	**E6000 0**	**0 0**		**Q50**	**Q50**	Gf	**Q50**	Gf
6013200	4.02	100			128	100.2	1.3	113.4	1.1
6013500	279	97			964	1099.8	0.9	1087.2	0.9
6013400	63.1	100			228	474.9	0.5	436.4	0.5
6011000	321	100			1210	1190.5	1.0	967.4	1.3
6019400	82	100			697	550.6	1.3	496.1	1.4
6006000	37	100			352	351.2	1.0	336.1	1.0
6019500	534	91			2290	1587.2	1.4	2202.8	1.0

Area^	0.524845053	Area^	0.441495171
x	64.88983085	E6000^	-6.700543178
		x	2.10342E+15

Correlation Coef.	0.906	0.928
Std. Error	46.21%	45.41%

Gage Number	Drainage Area mi^2	E6000 0	0 0		Q100	Area Calcualted Q100	Gf	2 Variables Q100	Gf
6013200	4.02	100			176	134.7	1.3	154.4	1.1
6013500	279	97			1110	1246.6	0.9	1230.8	0.9
6013400	63.1	100			264	571.4	0.5	520.6	0.5
6011000	321	100			1270	1341.8	0.9	1067.7	1.2
6019400	82	100			964	655.6	1.5	584.5	1.6
6006000	37	100			389	431.8	0.9	411.3	0.9
6019500	534	91			2600	1752.7	1.5	2514.7	1.0

Area^	0.459377718	Area^	0.360879238
x	121.6047874	E6000^	-7.918347312
		x	1.12522E+18

Correlation Coef.	0.825	0.862
Std. Error	60.53%	60.88%

						Area Calcualted		2 Variables	
Gage Number	**Drainage Area mi^2**	**E6000 0**	**0 0**		**Q500**	**Q500**	Gf	**Q500**	Gf
6013200	4.02	100			309	230.4	1.3	270.8	1.1
6013500	279	97			1460	1615.9	0.9	1591.7	0.9
6013400	63.1	100			350	816.3	0.4	731.4	0.5
6011000	321	100			1390	1723.4	0.8	1315.5	1.1
6019400	82	100			1860	920.7	2.0	803.9	2.3
6006000	37	100			479	638.8	0.7	603.2	0.8
6019500	534	91			3430	2177.3	1.6	3335.7	1.0