MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

Hydraulic Analysis Report

St. Regis River
Mineral County, MT
October 8, 2018

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1.0 INTRODUCTION

As part of the Mapping Activity Statement (MAS) contract for Phase II of the Mineral County Modernization Project, DOWL completed a floodplain study of a 37.1-mile reach of the mainstem of the St. Regis River within Mineral County, MT. As described in the MAS contract, the new hydraulic study was to include Enhanced study levels with varying levels of detail. The study levels were related to the previous FEMA nomenclature that were described as 'Detailed – AE with BFE' and 'Limited Detail – AE with BFE'.

During the development of the hydraulic model, the channel bathymetry was used for the entire reach of the St. Regis River, including those previously described as 'Limited Detail'. The entire hydraulic model was developed using the same methods with the exception of the floodway analysis. Thus, the enhanced analysis used LiDAR topographic data, channel bathymetry, and field survey of all hydraulic structures. The study was developed using a single hydraulic model with six segments. Three of the segments included an enhanced level study with a floodway analysis (14.9-miles) and three of the segments included an enhanced level study without a floodway analysis (22.2-miles).

The St. Regis River Study begins at the confluence with the Clark Fork River (downstream limit) in the city of St. Regis and extends approximately 37.1 miles upstream. The new study for the St. Regis River implements updates that include higher resolution topographic information, discharge-frequency relations from a new hydrologic study, and advances in hydraulic modeling software. Included in this report are the details and information used to develop the 1-percent-annual-chance (100-year) and the 0.2-percent-annual-chance (500-year) floodplains as well as the floodway. The hydraulic analysis for the St. Regis River includes the evaluation of the 10%, 4%, 2%, 1%, 1% plus, and 0.2% annual chance (10-yr, 25-yr, 50-yr, 100-yr, 100-yr plus, and 500-yr, respectively) flood events. The 1% plus discharge is the total discharge that includes the average predictive error for the regression equation added to the discharge of the 1% flood event. DOWL completed the hydraulic analysis and floodplain mapping tasks using Light Detection and Ranging (LiDAR) mapping developed by Quantum Spatial in 2017, structural and bathymetric surveys completed by Pioneer Technical Services in 2017, and the hydrology report completed by Pioneer Technical Services in July 2017. All surveys, topographic and hydrologic data were previously submitted to (and approved by) FEMA in 2017. Figure 1 shows an overview of the study area for the St. Regis River floodplain delineation project.

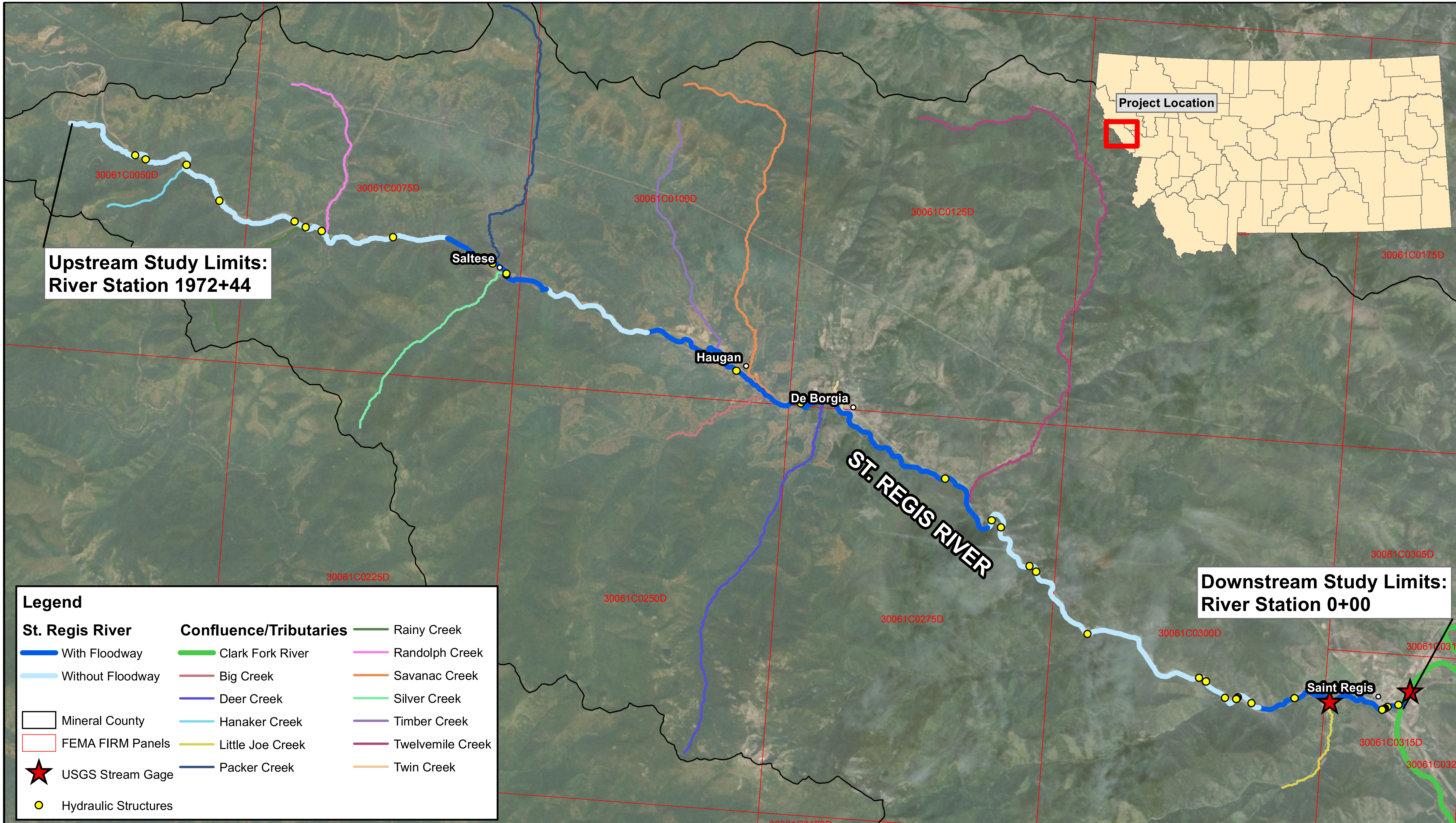

FIGURE 1: Project Overview

St. Regis River
Mineral County Detailed Floodplain Study

N W E S

0 1.25 2.5 5 7.5 10 Miles

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1.1 Previous Studies

The existing floodplain mapping for Mineral County has not been modernized to Digital Flood Insurance Rate Map (DFIRM) format. The effective mapping in Mineral County consists of 1982 Flood Hazard Boundary Maps that were converted to Flood Insurance Rate Maps (FIRM) in 1996. All effective mapping within Mineral County is dated and an approximate study level, with the exception of an 800-foot reach on Flat Creek in Superior, Montana.

2.0 WATERSHED DESCRIPTION

St. Regis River is a tributary to the Clark Fork River and is approximately 37 miles in length. The river originates in the Lolo National Forest near the Montana-Idaho border and flows southeasterly before joining the Clark Fork River at St. Regis, MT. The river flows through a steep valley, which is bounded by the Bitterroot Mountains to the south and the Coeur D'Alene Mountains to the north. The study area has terrain that varies from a high alpine environment at the headwaters and transitions to narrow inter-mountain valleys. The contributing drainage area of the St. Regis watershed is approximately 363 square miles.

The natural river flows through a steep valley with a narrow valley bottom. The channel is straight throughout most of the study reach with increased meanders and bends where the valley bottom widens near the towns of Saltese, Haugan, De Borgia, and St Regis. Vegetation throughout the study reach consists primarily of trees and grass with areas of brush in the valley bottom.

The river follows the alignment of Interstate 90 for most of the study reach. Many of the structures along the St. Regis River are interstate crossings and trail crossings that parallel the interstate. The density of structures increases as the river passes through the towns of Saltese, Haugan, De Borgia, and St. Regis. These towns have the greatest numbers of buildings and development within the study area. There is little to moderate development for the remainder of the study area. Spring snowmelt and ice jams have been primary causes of flooding on the St. Regis River.

3.0 CHANNEL TOPOGRAPHY

The channel along the lower section of the St. Regis River has a slope ranging from 0.5 to 1 percent. The channel is significantly steeper along the upper section of the river with slopes ranging from 1 to 8 percent. Much of the channel reach is bound by steep, mountainous slopes. Significant flood flows are conveyed within the channel and there is minimal flow area in the overbanks. The valley bottom widens in several areas and the channel becomes wide and shallow. These locations have larger flood benches within the valley bottom that allow flood flows to access the overbanks. The valley of the St. Regis River is impacted by the construction of roads throughout the study reach. Interstate 90 has had the greatest impact on the natural floodplain and encroaches into the floodplain in many locations. The 4-lane interstate was constructed in the late 1970s and early 1980s.

4.0 HYDROLOGY

Pioneer Technical Services, Inc. completed the St. Regis River Hydrologic Analysis for the study area. The analysis estimated peak flows at key locations for the 50, 10, 4, 2, 1, and 0.2-percent annual chance flood events. The '1-percent plus' peak flow was also developed. Flows were calculated for flow nodes at ten different locations along the St. Regis River. One flow node was located at the active USGS stream gage site and one was located downstream of the stream gage. The eight remaining flow nodes are located upstream of the stream gage (ungaged sites).

During the initial review of the Hydraulic Data Task submittal, there was a concern that the peak discharges and peak stages in the upper reach of the St. Regis River were significantly over estimated. Using these discharges, many of the structure crossings in this reach developed significant backwater and supported that the discharges in the upper reach were overestimated. In response to this comment, Pioneer Technical Services, Inc. calculated peak flows for an additional flow node on the St. Regis River. The additional flow node (Node 50) is located approximately midway between flow node 100 and the upper limit of the study. More details of the hydrologic analysis are included in Appendix A.

As part of the hydrologic study, the DNRC and USGS worked together to complete an updated flood frequency analysis of the single gage on the St. Regis River (USGS Stream Gage 12354000).

The updated analysis included data through Water Year 2016. The gage on the St. Regis River has non-congruous flow data from 1911 to 2016.

Flood frequency analyses were performed following the Bulletin #17C methods (USGS, 2016). The USGS stream gage (12354000) is a mixed population dataset and a station skew was used in the analysis. The St. Regis River USGS gage is within the West hydrologic region of Montana, which has a limited representation of mixed-population stream gages. These independent estimates from the regional regression equations do not accurately represent sites with mixed-populations of peak flows.

Considering the data gaps during the periods of record, flood flow frequency estimates using the systematic data set (at-site analysis), were selected to represent annual chance flood potential at the gage location on the St. Regis River. The 2016 flood frequency analysis was compared to the 2011 SIR 2015-5019 analysis, and the results of both USGS analyses compared well. Table 1 shows the USGS peak discharge estimates used at the streamflow gage.

Table 1: St. Regis River Flood Flows

USGS Stream Gage	Station Name	Drainage Area (mi^2)	Peak Discharge Estimates –Annual Chance Exceedance (cfs)					
			10%	4%	2%	1%	0.2%	1% +
12354000	St. Regis River near St. Regis, MT	316	6,410	9,150	12,000	15,900	30,600	22,300

The drainage area gage transfer method was used to estimate flood-frequency discharges at the ungaged flow nodes on the St. Regis River. The drainage area gage transfer calculation methods produced larger peak flow estimates than the regional regression methods. Because these estimates were developed from measured flows, they were determined to be the most reasonable peak flow estimates for the ungaged locations. Results of the drainage area gage transfer method are provided in Table 2 and river station flow change locations are provided in Figure 2.

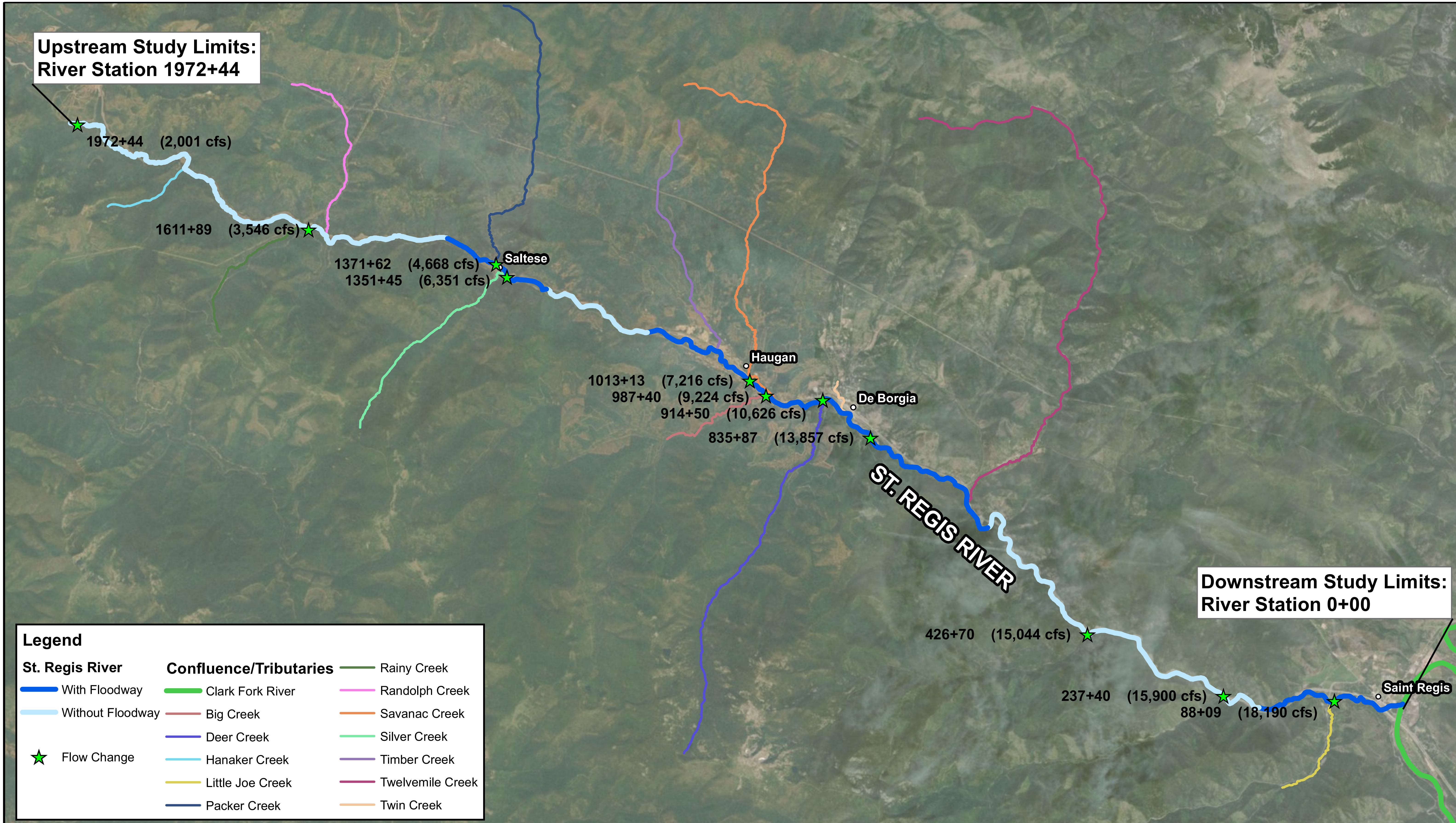

FIGURE 2: Flow Change Locations

St. Regis River
Mineral County Detailed Floodplain Study

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W E
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0 1.25 2.5 5 7.5 10 Miles

Table 2: St. Regis River Drainage Area Gage Transfer Discharges

Node Number	HEC-RAS River Station	Location Description	Drainage Area Gage Transfer Discharge (cfs)					
			10%	4%	2%	1%	0.2%	1% +
900	88+09	Lower St. Regis River	7,394	10,509	13,755	18,190	34,882	25,511
12354000	237+40	St. Regis River near St. Regis, MT	6,410	9,150	12,000	15,900	30,600	22,300
800	426+70	River Mile 4.3	6,047	8,643	11,345	15,044	28,994	21,099
700	835+87	River Mile 7.9	5,547	7,943	10,437	13,857	26,766	19,435
600	914+50	Downstream of De Borgia	4,196	6,044	7,973	10,626	20,670	14,903
500	987+40	Deer Creek	3,616	5,225	6,907	9,224	18,010	12,937
400	1013+13	Savenac Creek	2,793	4,058	5,384	7,216	14,181	10,120
300	1351+45	Big Creek	2,442	3,558	4,730	6,351	12,524	8,908
200	1371+62	Downstream of Saltese	1,766	2,592	3,460	4,668	9,279	6,546
100	1611+89	St. Regis River Headwaters	1,323	1,953	2,618	3,546	7,101	4,974
50	1972+44	Midway between Node 100 and US end of Study	725	1,084	1,465	2,001	4,068	2,806

For more details on the hydrologic analysis, the hydrologic report for the study area is included in Appendix A.

5.0 HYDRAULIC MODELING

Details of the methods used to complete the hydraulic analysis for the St. Regis River flood study are presented below.

5.1 Hydraulic Analysis Overview

The new enhanced study begins at the confluence with the Clark Fork River (Cross Section A) and extends 37.1 miles upstream to Lookout Pass at the Montana-Idaho border (Cross Section EZ). Detailed work maps of the study reach are provided in Appendix B. The hydraulic models for the St. Regis River were developed following the FEMA publication Hydraulics: One-Dimensional Analysis (Nov 2016). The hydraulic modeling was performed using the United States Army Corp of Engineers (USACE) HEC-RAS, Version 5.0.3 hydraulic modeling software (Sept 2016). DOWL used GeoHEC-RAS to develop the preliminary model, including cross section locations, bank stations, Manning's n values, channel and overbank flow lengths, lateral structures, road profiles, and ineffective flow limits. Minor modifications to these original inputs were necessary to calibrate the model to the observed flooding events and improve model stability.

A large portion of the St. Regis River flows through a narrow valley with a well-defined channel. Common modeling approaches were employed for these reaches and did not require special features such as lateral weirs. There are several locations along the study reach that required more complex model features to effectively represent the impacts of infrastructure and changes in topography. The St. Regis River main channel was modeled using a one-dimensional model with lateral weirs to compute overtopping flows in key locations. The modeling approach for each of these lateral weirs is discussed in greater detail in the Lateral Weirs section of this report.

A complex reach of the model extends from the mouth of the canyon upstream of the town of St. Regis to the confluence with the Clark Fork River at the BNSF railroad crossing. Significant flooding occurs in the town of St. Regis, which is caused from the backwater effects of the BNSF railroad. The interstate impacts flow patterns throughout this reach as well. A supplemental two-dimensional model was developed for this reach to better understand flow patterns and assist with the development of the one-dimensional model. This information was helpful in determining overtopping conditions and ineffective flow limits. Further details of the modeling near the town of St. Regis are discussed in section 5.10 Modeling Methods: Town of St. Regis.

5.2 Topographic Mapping Acquisition

The LiDAR and field survey were provided in the Universal Transverse Mercator Zone 12 projection and the Montana Coordinate System, respectively. Both data sets are referenced to the North American Datum of 1983 (NAD83-2011), with elevations referenced to the North American Vertical Datum of 1988 (NAVD88). LiDAR units are reported in meters. The field survey is reported with horizontal units of international feet and vertical units of U.S. feet. LiDAR units were converted to feet for incorporation into the hydraulic model.

5.2.1 LiDAR Survey

Topographic survey data was completed in 2016 by Quantum Spatial for the Mineral County Modernization Project. The Mineral County project included two sites: the Clark Fork area of interest (AOI) and the St. Regis AOI. Acquisition of the LiDAR for the St. Regis AOI was completed from 7/31/2017 to 8/22/2017. More information on the LiDAR acquisition and post-processing is included in Appendix A.

5.2.2 Field Survey

Field survey was collected for all structures along the modeled reach of the mainstem of the St. Regis River. Bathymetric cross sections were collected along the entire reach of the main channel of the St. Regis River. Pioneer Technical Services, Inc. performed the survey between November of 2016 and July of 2017. During the hydraulic modeling task, DOWL identified a need for additional survey of a culvert crossing under the BNSF railroad east of the town of St. Regis. Pioneer completed the additional survey in April of 2018. The 36” steel culvert has a capacity of approximately 140 cfs. The capacity of this culvert is less than 0.5% of the 0.2-percent-annual-chance flood (34,882 cfs) and less than 1% of the 1-percent-annual-chance flood (18,190 cfs). Considering the capacity of the culvert relative to the flood flows, the culvert was excluded from the HEC-RAS model. Based on review of the structures and survey data, 38 structures were determined to be hydraulically significant and were included in the hydraulic analysis. More information on the field survey is included in Appendix A.

5.3 Profile Baseline

The centerline of the channel for the St. Regis River was used to define the profile baseline for the hydraulic model. The river stationing of the St. Regis River is stream distance in feet above the confluence with the Clark Fork River. The starting and ending sections of the modeled river reach are presented in Table 3. The entire profile baseline is shown on the Work Maps included in Appendix B. The river centerline was established using the LiDAR and 2015 National Agricultural Imagery Program (NAIP) aerial imagery (USDA 2015). Due to the course resolution of the NAIP Imagery, greater resolution ESRI aerial imagery was also referenced.

Table 3: River Stationing

River Name	Starting River Station (ft)	Ending River Station (ft)
St. Regis River	4+40	1972+44

5.4 Boundary Conditions

The HEC-RAS model was evaluated under the assumptions of subcritical flow and no backwater influence from the Clark Fork River. The normal depth option was selected as the downstream boundary condition for the starting water surface elevations. The channel and water surface slope near the downstream study limits were evaluated using the LiDAR and field survey. A representative slope of 0.005 ft/ft was selected for the St. Regis River reach.

5.5 Cross Section Development

The terrain data in the HEC-RAS model was based on the LiDAR data coupled with field survey data. GeoHECRAS Version 2.1.0 was used to place cross sections perpendicular to flow direction. Cross section extents were placed to encompass the water surface of the 0.2-percent-annual-chance flood. Cross sections were placed with a target spacing of 300 to 500 feet and additional cross sections were added at key locations along the reach. These locations include structure crossings, bathymetric survey locations, breaks in channel slope, and abrupt changes in the floodplain width. Additional cross sections were added in areas with model instabilities. In general, contraction and expansion coefficients were set at 0.1 and 0.3, respectively. For cross sections near structures, the contraction and expansion coefficients were set to 0.3 and 0.5. The values of the coefficients were increased to 0.6 and 0.8 for several crossings with significant expansion and contraction. All cross sections with expansion and contraction coefficients outside the standard values are documented in Appendix F.

5.5.1 Processing of Bathymetric Survey Data

Pioneer Technical Services, Inc. developed a terrain surface from the surveyed bathymetric cross sections and merged the new surface with the LiDAR data. Upon review of the bathymetric surface, it was determined that modeled terrain surface was higher than the LiDAR data at the interface of the two terrain models in many areas. These areas were located between the surveyed cross sections where the bathymetric terrain surface was extrapolated from the survey data and may not represent the actual terrain.

These surfaces required further processing to arrive at a final terrain surface to use for the hydraulic model. DOWL developed the final surface using the LiDAR data and incorporated the bathymetric data where the bathymetric surface was lower in elevation than the LiDAR. The resulting terrain surface was used to develop the hydraulic model.

5.6 Manning's Roughness Coefficients

The Manning's roughness values assigned within the hydraulic model were determined based on field observations, aerial photography, recommendations in Chow's *Open-Channel Hydraulics* and the USDA's *Photographic Guidance for Selecting Flow Resistance Coefficients in High-Gradient Channels*. Sections of the upper reach of the St. Regis River have slopes ranging from 0.5 to 8 percent. The *USDA's High Gradient Channels* publication indicates that mountainous streams with high gradients tend to flow in subcritical conditions due to internal energy loss of the flow, and that Manning's roughness values correspondingly increase in these locations. Manning's roughness values in steep sections of the river reach were evaluated in comparison to streams represented in USDA's *High-Gradient Channels*. The most representative stream was found to be in the Eastern Italian Alps near Rio Cordon, Italy. The stream has a slope of 7.9% with a Manning's roughness value of 0.13 for high flow and 0.18 for low and mid flow. A horizontal variation of Manning's n values was used in the model to simulate the changes in the roughness for the channel and overbanks. The roughness of the channel bottom for the main channel ranges between 0.045 and 0.15, dependent on the composition of cobbles and the slope of the channel. The roughness of the overbank areas range between 0.016 and 0.15, representing a range of land cover that includes paved streets, residential development, short grass, and highly vegetated areas of trees/brush. Table 4 shows the range of Manning's n values for the St. Regis River relative to the slope of the channel.

Table 4: Roughness Coefficients

Flooding Source	Channel Slope (%)	Channel "n"	Overbanks "n"
St. Regis River	< 1	0.045-0.050	0.016-0.09
	1-2	0.075	0.016-0.09
	2-4	0.10	0.016-0.15
	> 4	0.15	0.016-0.15

5.7 Non-Conveyance Areas

Ineffective flow limits near the bridges, culverts, and natural constrictions are set to approximate a 1:1 contraction upstream and a 2:1 expansion downstream. A review of the modeled cross sections in HEC-RAS also reveals numerous depression areas and small side channels that are not hydraulically connected to the main channel. These areas were also classified as ineffective to represent the active areas of conveyance. Cross sections with ineffective flow limits have been documented and are included in Appendix F.

5.8 Blocked Obstructions

There are many structures throughout the study reach that block the flow within the defined cross sections. Buildings are modeled using the blocked obstructions feature in HEC-RAS to prevent conveyance at these locations. Only buildings that block effective flow are incorporated into the model; buildings located within non-conveyance areas (ineffective) are not incorporated. Cross sections with blocked obstructions have been documented and are included in Appendix F.

5.9 Hydraulic Structures

There are 36 crossings modeled throughout the study reach of the St. Regis River including 32 bridge crossings and 4 culvert crossings. Each structure was defined in the hydraulic model using the field survey data in combination with the LiDAR. A summary of the modeled structures in each reach are presented in Table 5. The 'Structure ID' information corresponds to the structure identification numbers from the survey data. The crossings at 1732+33 and 1798+18 in the hydraulic model include more than one structure identified from the survey. Therefore, the hydraulic model uses 36 crossings to model all 38 structures identified in Table 5. The bridge structures range in size from small private road bridges to interchange overpasses. The culverts range from double corrugated metal culverts to concrete arch culverts. The following photos illustrate the variety of crossing structures within the study reach.

Bridge crossings within the study area operate under both pressurized and non-pressurized conditions. Due to the steep topography of the St. Regis River and the limited capacity for flood flows to be conveyed in the overbanks, many of the structures develop significant backwater during large flood events. At many of these crossings, the main channel structure is overtopped. The pressure/weir bridge modeling approach has been selected for structures that experience overtopping or significant backwater, and a trigger elevation has been set following best practices for modeling structures.

Several bridges along the St. Regis River are highly skewed to the direction of flow, with skew angles exceeding 45 degrees. The HEC-RAS manual and other sources address flow patterns through highly skewed bridges. When approaching the bridge opening, flow will turn somewhat before it passes through these bridge openings. With this consideration, the effective area of these severely skewed bridge openings is larger than the area that would be estimated by applying the measured skew angle at the upstream approach section. Structures on the St. Regis River with skew angles greater than 45 degrees have been modeled using the maximum 45 degree skew angle allowed by HEC-RAS.

Figure 3: Old US 10 (187-ft, 3-Span Bridge)

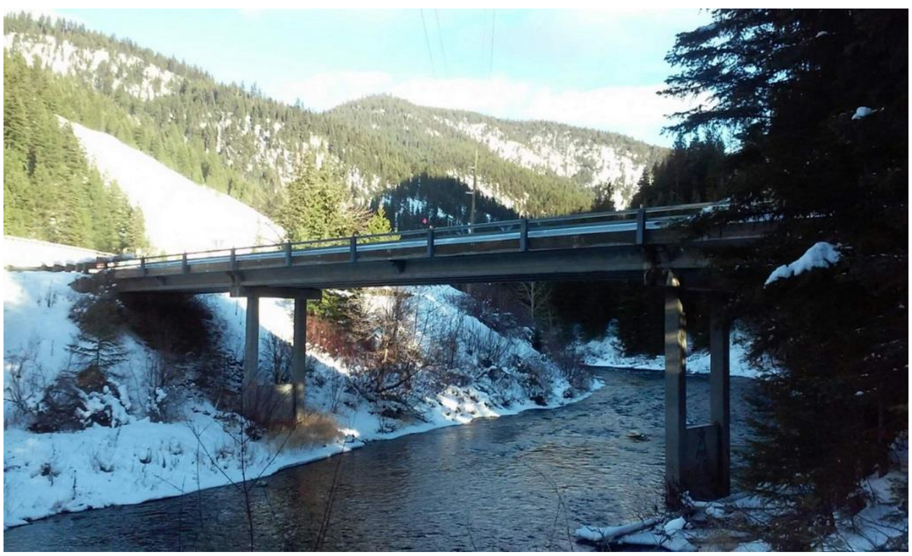

Figure 4: MT Highway 889 (146-ft, 3-Span Bridge)

Figure 5: Milwaukee Trail Road (120-ft, 2-Span Bridge)

Figure 6: National Forest 810D (35-ft Span Bridge)

Figure 7: Northern Pacific Trail (14’ x 14.4’ Concrete Arch)

Table 5: Summary of Hydraulic Structures and Key Features

Structure ID (if available)	River Station	River Name	Reach Name	Feature Description	Feature Type	Bridge Data						Culvert Data			
						Approx. Total Span Length[1] (ft)	Bridge Width (ft)	Number of Spans	Pier Type	Pier Coefficients (Cd, K)	Bridge Modeling Approach	Length (ft)	Shape	Type	Dimensions
B49	5+03	St. Regis River	St. Regis River	Railroad Crossing	Bridge	99.7	20.4	1	--	--	Pressure Weir	--	--	--	--
B50	17+56	St. Regis River	St. Regis River	Old US 10	Bridge	187.0	31.5	3	Bull Nosed Wall Pier	1.33, 0.95	Pressure Weir	--	--	--	--
B51	20+98	St. Regis River	St. Regis River	I-90 West Off-Ramp	Bridge	207.1	29.2	3	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir	--	--	--	--
B52	22+22	St. Regis River	St. Regis River	I-90 West Bound	Bridge	241.3	43.4	3	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir[2]	--	--	--	--
B53	23+10	St. Regis River	St. Regis River	I-90 East Bound	Bridge	241.1	43.2	3	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir[2]	--	--	--	--
B54	24+36	St. Regis River	St. Regis River	I-90 East On-Ramp	Bridge	258.6	39.1	3	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir	--	--	--	--
B56	95+76	St. Regis River	St. Regis River	Little Joe Road	Bridge	139.1	32.3	2	Square Nosed Wall Pier	2.0, 1.25	Pressure Weir[2]	--	--	--	--
B57	139+74	St. Regis River	St. Regis River	I-90 East Bound	Bridge	193.4	43.4	2	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir	--	--	--	--
B58	194+42	St. Regis River	St. Regis River	I-90 West Bound	Bridge	303.0	43.1	4	Circular Pier	1.20, 0.90	Energy Only	--	--	--	--
B59	214+32	St. Regis River	St. Regis River	I-90 West On-Ramp	Bridge	121.9	28.6	2	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir	--	--	--	--
B60	216+31	St. Regis River	St. Regis River	I-90 West Bound	Bridge	277.9	43.4	3	Sharp Nosed Wall Pier	1.39, 1.05	Energy Only	--	--	--	--
B61	217+26	St. Regis River	St. Regis River	I-90 East Bound	Bridge	274.3	43.3	3	Sharp Nosed Wall Pier	1.39, 1.05	Energy Only	--	--	--	--
B62	234+22	St. Regis River	St. Regis River	2 Mile Road	Bridge	137.5	15.2	3	Bull Nosed Wall Pier	1.33, 0.95	Pressure Weir	--	--	--	--
B63	263+14	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Bridge	386.9	88.2	4	Circular Pier	1.20, 0.90	Pressure Weir	--	--	--	--
B64	272+80	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Bridge	394.4	88.9	4	Circular Pier	1.20, 0.90	Pressure Weir	--	--	--	--
B65	426+25	St. Regis River	St. Regis River	MT HWY 889	Bridge	145.5	16.1	3	Square Nosed Wall Pier	2.0, 1.25	Energy Only	--	--	--	--
B66	526+90	St. Regis River	St. Regis River	I-90 East Bound	Bridge	291.1	47.3	4	Circular Pier	1.20, 0.90	Pressure Weir	--	--	--	--
B67	538+59	St. Regis River	St. Regis River	I-90 East Bound	Bridge	379.6	42.1	4	Circular Pier	1.20, 0.90	Pressure Weir	--	--	--	--
B68	605+09	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Bridge	632.5	88.1	4	Circular Pier with Cross Brace	1.33, 1.05	Energy Only	--	--	--	--
B69	634+79	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Bridge	444.7	86	3	Circular Pier with Cross Brace	1.33, 1.05	Energy Only	--	--	--	--

Table 5: Summary of Hydraulic Structures and Key Features

Structure ID (if available)	River Station	River Name	Reach Name	Feature Description	Feature Type	Bridge Data						Culvert Data			
						Approx. Total Span Length[1] (ft)	Bridge Width (ft)	Number of Spans	Pier Type	Pier Coefficients (Cd, K)	Bridge Modeling Approach	Length (ft)	Shape	Type	Dimensions
B79	728+28	St. Regis River	St. Regis River	Milwaukee Trail Road	Bridge	119.6	15.1	2	Sharp Nosed Wall Pier	1.39, 1.05	Pressure Weir	--	--	--	--
B84	914+16	St. Regis River	St. Regis River	Deep Creek Road	Bridge	110.9	14.1	2	Square Nosed Wall Pier	2.0, 1.25	Pressure Weir	--	--	--	--
B85	943+11	St. Regis River	St. Regis River	Olympian Trail	Bridge	78.1	18.9	1	--	--	Pressure Weir	--	--	--	--
B94	1031+42	St. Regis River	St. Regis River	Big Creek Road	Bridge	116.3	18.3	2	Bull Nosed Wall Pier	1.33, 0.95	Energy Only	--	--	--	--
B100	1353+42	St. Regis River	St. Regis River	Private Road	Bridge	125.6	11.4	6	Elongated Wooden Piles	1.33, 0.95	Pressure Weir	--	--	--	--
B101	1354+74	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Bridge	194.2	93.9	3	Circular Pier	1.20, 0.90	Energy Only	--	--	--	--
B104	1375+38	St. Regis River	St. Regis River	Packer Creek Road	Bridge	57.2	14.2	1	--	--	Pressure Weir	--	--	--	--
B107	1390+34	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Bridge	139.4	84.3	3	Circular Pier	1.20, 0.90	Pressure Weir	--	--	--	--
B108	1497+69	St. Regis River	St. Regis River	Northern Pacific Railway	Bridge	99.5	10.5	6	Elongated Wooden Piles	1.33, 0.95	Pressure Weir	--	--	--	--
B111	1594+04	St. Regis River	St. Regis River	National Forest 810D	Bridge	35.3	14.9	1	--	--	Pressure Weir	--	--	--	--
B112	1616+55	St. Regis River	St. Regis River	Taft Bypass Forest Service Road	Culvert	--	--	--	--	--	--	55.6	Pipe Arch	CMP	9.5’ x 13.5’
B113	1630+62	St. Regis River	St. Regis River	Rainy Creek Road	Bridge	27.7	14.9	1	--	--	Pressure Weir	--	--	--	--
B114	1732+33	St. Regis River	St. Regis River	Private Road	Bridge	35.0	14.2	1	--	--	Pressure Weir[2]	--	--	--	--
B115	1730+74	St. Regis River	St. Regis River	Private Road	Bridge	15.6	14.7	1	--	--	Pressure Weir	--	--	--	--
B116/B117	1798+18	St. Regis River	St. Regis River	I-90 E.B. / W.B. & Hanker Creek Road	Culvert	--	--	--	--	--	--	255.7	Circular	Double CMP	9.5’
B118	1860+88	St. Regis River	St. Regis River	Northern Pacific Trail	Culvert	--	--	--	--	--	--	67.3	Arch	Concrete	14’ x 14.4’
B119	1879+94	St. Regis River	St. Regis River	I-90 East Bound & West Bound	Culvert	--	--	--	--	--	--	349.3	Circular	CMP	15’

[1]Approximate Total Span Length is the bridge span length provided from hydraulic structure assessment
[2]Multiple Opening Analysis used to evaluate bridge

5.9.1 Lateral Weirs

Lateral weirs were used throughout the study reach to model flows leaving the main channel of the St. Regis River. Table 6 summarizes key details for the lateral weirs in the model.

Table 6: Lateral Weir Coefficients

River Name	Reach Name	Weir Starting River Station (ft)	Scenario Modeled	Weir Coefficient Selected	Optimization (Y/N)
St. Regis River	St. Regis River	1623+60	Roadway, 3 ft. or higher above natural ground	2.0	Y
St. Regis River	St. Regis River	1498+39	Natural Ground, Overtopping Divide, Elevated < 1 foot	0.5	N
St. Regis River	St. Regis River	1393+42	Natural Ground, Overtopping Divide, Elevated < 1 foot	0.5	N
St. Regis River	St. Regis River	955+38	Roadway, 3 ft. or higher above natural ground	2.0	Y
St. Regis River	St. Regis River	86+21	Roadway, 3 ft. or higher above natural ground	1.5	N

As indicated in Table 6, two of these lateral weirs use the flow optimization routine in HEC-RAS. Lateral weir coefficients are based on guidance from the Hydrologic Engineering Center (HEC) 2D Modeling User's Manual.

The lateral weir at Sta. 955+38 is used to model the culvert crossing at Sta. 943+11. At this location, water is flowing parallel to the road alignment and begins to spill the roadway laterally before reaching the culvert crossing. The lateral weir is connected to a cross section downstream of the culvert crossing where all the flow that spills over the lateral structure re-enters the hydraulic model.

The lateral weir at Sta. 1623+60 is located along the right overbank upstream of the Taft Bypass Forest Service Road culvert at Sta. 1616+55. At this location, water is flowing parallel to the road alignment and begins to spill the roadway laterally before reaching the culvert crossing. Overtopping flows re-enter the St. Regis River immediately downstream of the culvert crossing.

The remaining three lateral weirs do not use the flow optimization routine. These include Sta. 1498+39, 1393+42, and 86+21.

The lateral weir at Sta. 1498+39 is located along the right overbank upstream of the bridge at Sta. 1497+69. Flow overtopping the weir at this location is minor. When optimized, less than 20 cfs overtops during the 1-percent-annual-chance flood event. During the 0.2-percent-annual-chance flood event, approximately 220 cfs overtops the lateral weir (3% of the total flow). Overtopping flows re-enter the St. Regis River a short distance downstream. Considering the minor flows leaving the main channel and the short distance before re-entering the main channel, a flow split with a separate river reach was not included in the hydraulic model. Therefore, the weir was not optimized and all flow was modeled through the culvert crossing.

The lateral weir at Sta. 1393+42 is located along the right overbank upstream of the interstate bridge crossing at Sta. 1390+34. Flow overtopping the weir at this location is minor. When optimized, approximately 20 cfs overtops during the 1-percent-annual-chance flood event. For this reason an additional river reach was not included in the hydraulic model. During the 0.2 percent-annual-chance flood event, the overtopping flow continues to a culvert that crosses the interstate a short distance downstream.

The lateral weir at Sta. 86+21 is located along the westbound lane of Interstate 90 and is bounded between the upstream cross-section at Sta. 88+09 and the downstream cross-section at Sta. 32+52. This location is described in more detail in the following section.

5.9.1.1 Supplemental Analysis and Mapping near Culvert at Sta. 1616+55

There are complicated hydraulics near the culvert crossing at Sta. 1616+55 and the lateral weir at Sta. 1623+60. As a result, two areas in this reach are not mapped by the automated processes of the hydraulic model. Therefore, a supplemental analysis was completed to establish water surface elevations and flood boundaries for the locations shown in Figure 8 below.

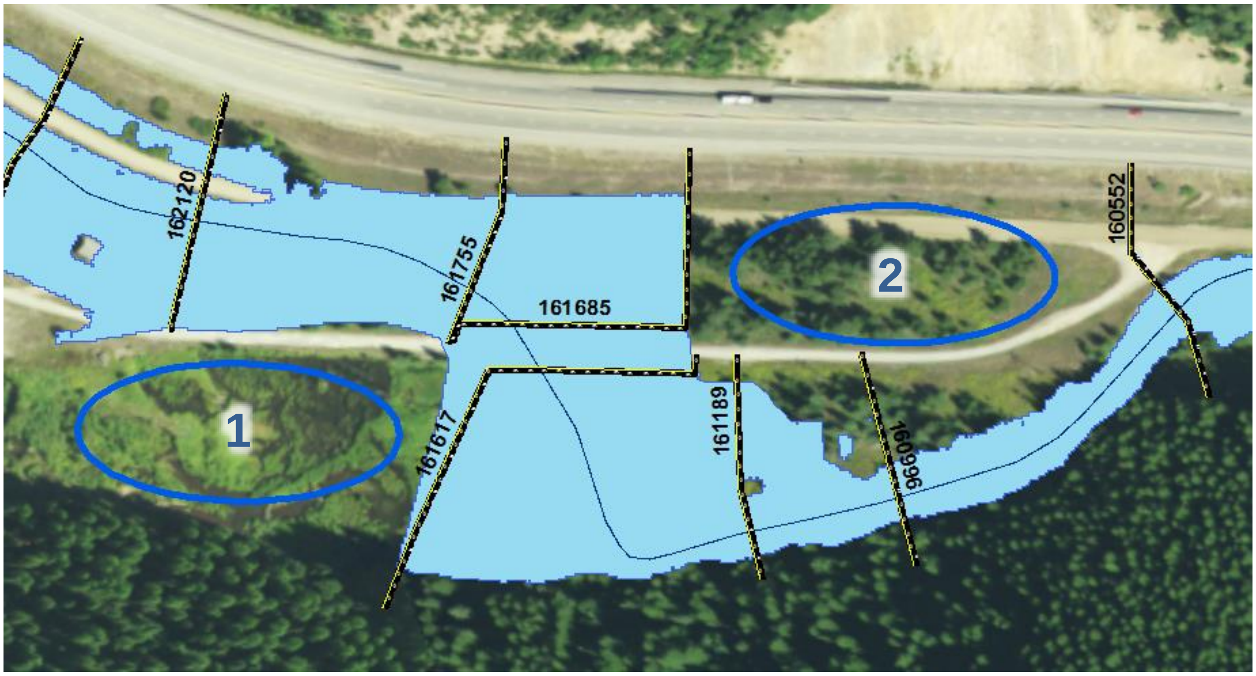

Figure 8: Locations with Supplemental Analysis

The water surface elevation at Area 1 will be determined using a backwater analysis with the water surface elevation from the cross section at Sta. 1616+17. The flood boundary that results from this water surface elevation will be mapped. The lateral weir at Sta. 1623+60 is located along the road north of Area 1 and computes the flow overtopping the road at this location. The flood extents of the flow overtopping the road will be mapped along the top of the road. The flood boundary from the top of the road down to the backwater boundary will be defined manually using engineering judgment. The conceptual flood boundaries at this location are shown in Figure 9.

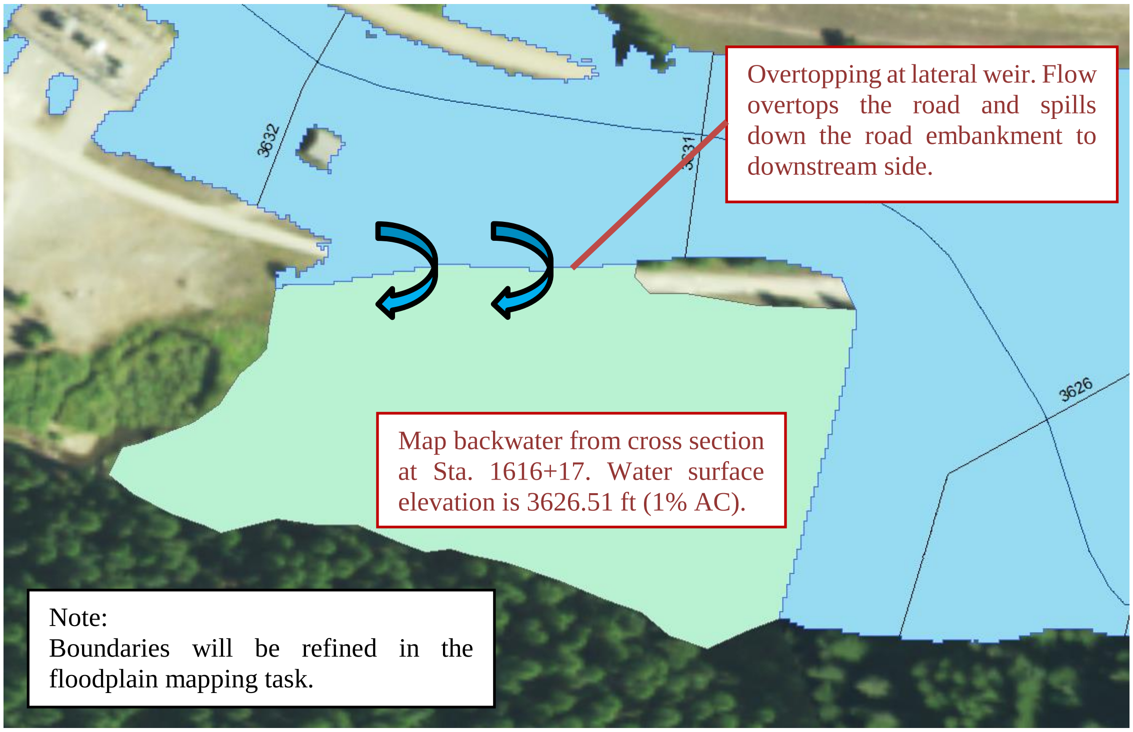

Figure 9: Conceptual Mapping of Area 1

For Area 2, a more detailed analysis was completed. An independent model was completed using a lateral weir to compute the amount of flow that continues east on the north side of the road before joining the main channel. The analysis was a duplicate of the regulatory model except for the addition of the lateral weir. The results of the model showed that 195 cfs and 312 cfs would flow on the north side of the road during the 1% and 0.2% annual chance events, respectively. A profile was cut along the roadway at the location of overtopping (See Figure 10) and a rating curve was developed for this section. The water surface elevation at the point of overtopping is 3620.10 ft and 3620.40 ft for the 1% and 0.2% annual chance events, respectively. The water surface elevation at the upstream extent of Area 2 was established from XS 1616+85 in the regulatory model. The water surface elevation at XS 1616+85 is 3630.64 ft and 3631.40 ft for the 1% annual chance and 0.2% annual chance events, respectively. With a known water surface at the upstream extent of Area 2 (Point A) and the location of overtopping (Point B), the water surface in this reach was established using a constant slope between the known water surface elevations. Base flood elevations (BFEs) were also determined. Automated GIS processes were used to map the water surface against the terrain. The results of the analysis are shown in Figure 10.

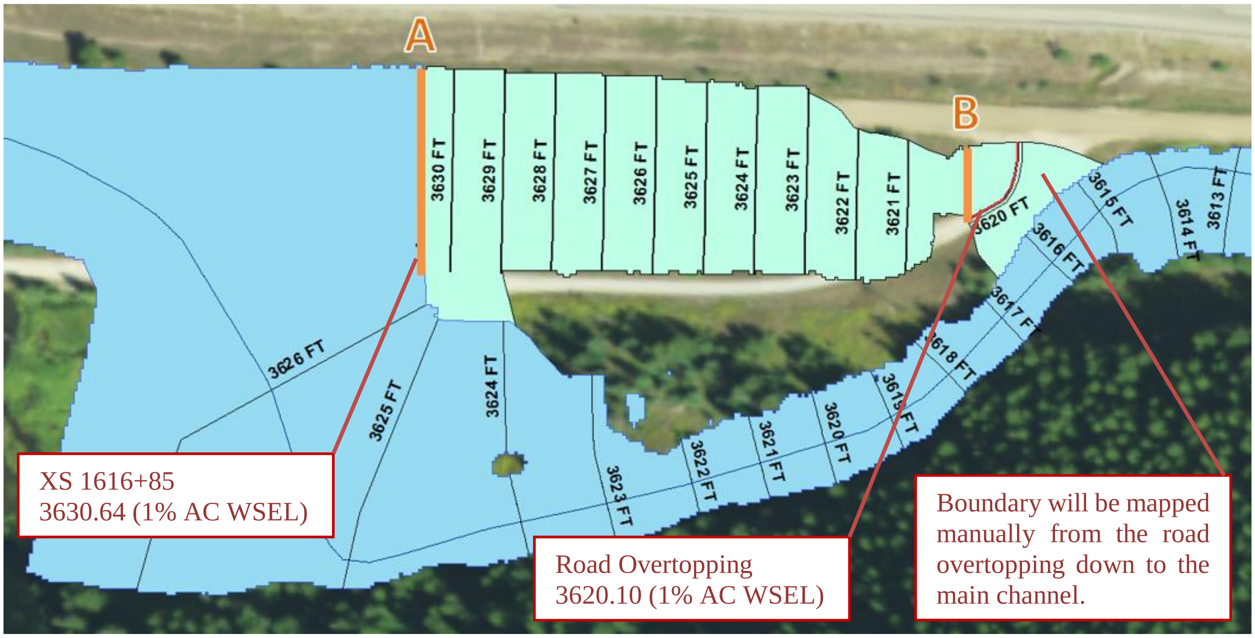

Figure 10: Analysis and Mapping for Area 2

5.9.2 St. Regis Levee System

A levee system was constructed to protect the town of St. Regis in January of 1930. Table 7 below summarizes the information published by the National Levee Database. As shown, the levee was originally designed to protect against a 0.014-percent-annual-chance (75-Year) flood event. The levee is not accredited by FEMA and does not provide protection for Flood Insurance Rate Maps (FIRM). Based on the model results of this study, the levee is overtopped between the 0.4 and 0.2-percent-annual-chance flood event. Because the levee is not accredited by FEMA, the levee has been modeled to follow the natural valley method and will not impact the flood mapping.

Table 7: St. Regis Levee System

System Name	Fc System ID	Segment Name	Design Frequency	FIRM Protection Provided	Construction Completion Date
St. Regis	5505000271	St. Regis	0.014	No	01-Jan-30

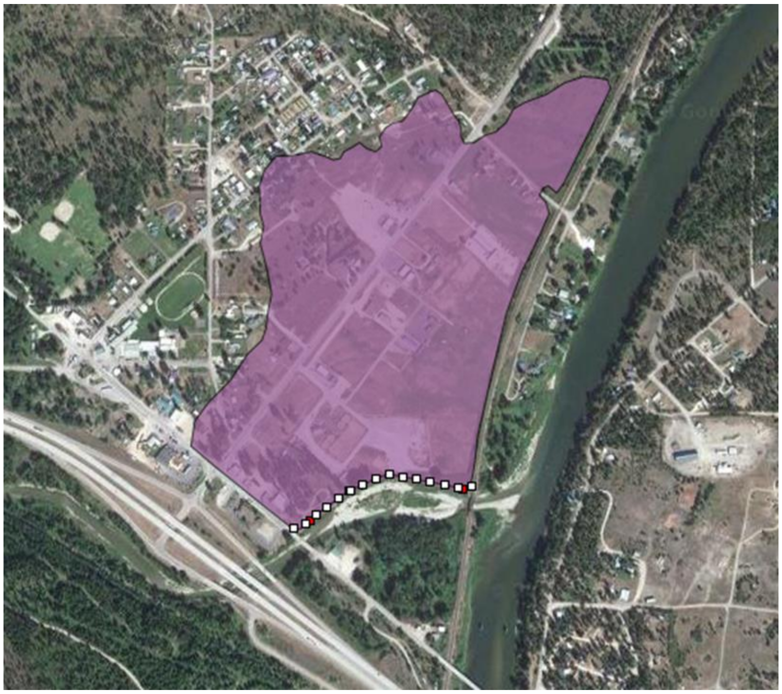

Figure 11: St. Regis Levee Alignment

5.10 Modeling Methods: Town of St. Regis

As the St. Regis River emerges from the canyon upstream of the City of St. Regis, flood flows overtop the interstate upstream of the bridge at Sta. 139+74. Flood flows will overtop the road during the ‘1 percent plus’ and 0.2-percent-annual-chance (500-year) flood events and continue down the opposite side of the interstate for a short distance before joining the backwater developed from the bridge at Sta. 95+76. This structure has a multiple opening with an underpass that will convey flow during larger events and a bridge crossing in the main channel that conveys flow for all flood events.

Review of the flow patterns in the two-dimensional model shows a small fraction of the flow that passes through the underpass will leave the main channel. This flow is difficult to quantify in a one-dimensional model and was not calculated. Most of the flow passing through the underpass re-enters the main channel. Flow may also leave the main channel at locations where overtopping occurs between XS 88+09 and XS 32+52. This overtopping flow is quantified by the lateral weir at Sta. 86+21, which captures the highest elevation of the interstate. When the weir is optimized, approximately 3,500 cfs will leave the main channel during the 0.2-percent-annual-chance event. This is a relatively minor flow compared to the total flow of 34,882 cfs. Therefore, the weir was not optimized and all flow is considered to remain in the main channel. The interstate is not a certified levee and the floodplain boundary located on the east side of the interstate will be mapped using the water surface elevation in the main channel for the 0.2-percent-annual-chance and '1-percent plus' flood events. During the 1-percent-annual-chance flood event, flow does not overtop the interstate and is confined to the main channel throughout this reach.

The St. Regis River passes through a series of five bridges before reaching the town of St. Regis. The significant backwater developed from the BNSF railroad reaches to the downstream end of these structures. Thus, the backwater from the BNSF railroad is the primary cause of flooding for structures near the town of St. Regis. The flow patterns described above are shown in Figure 12.

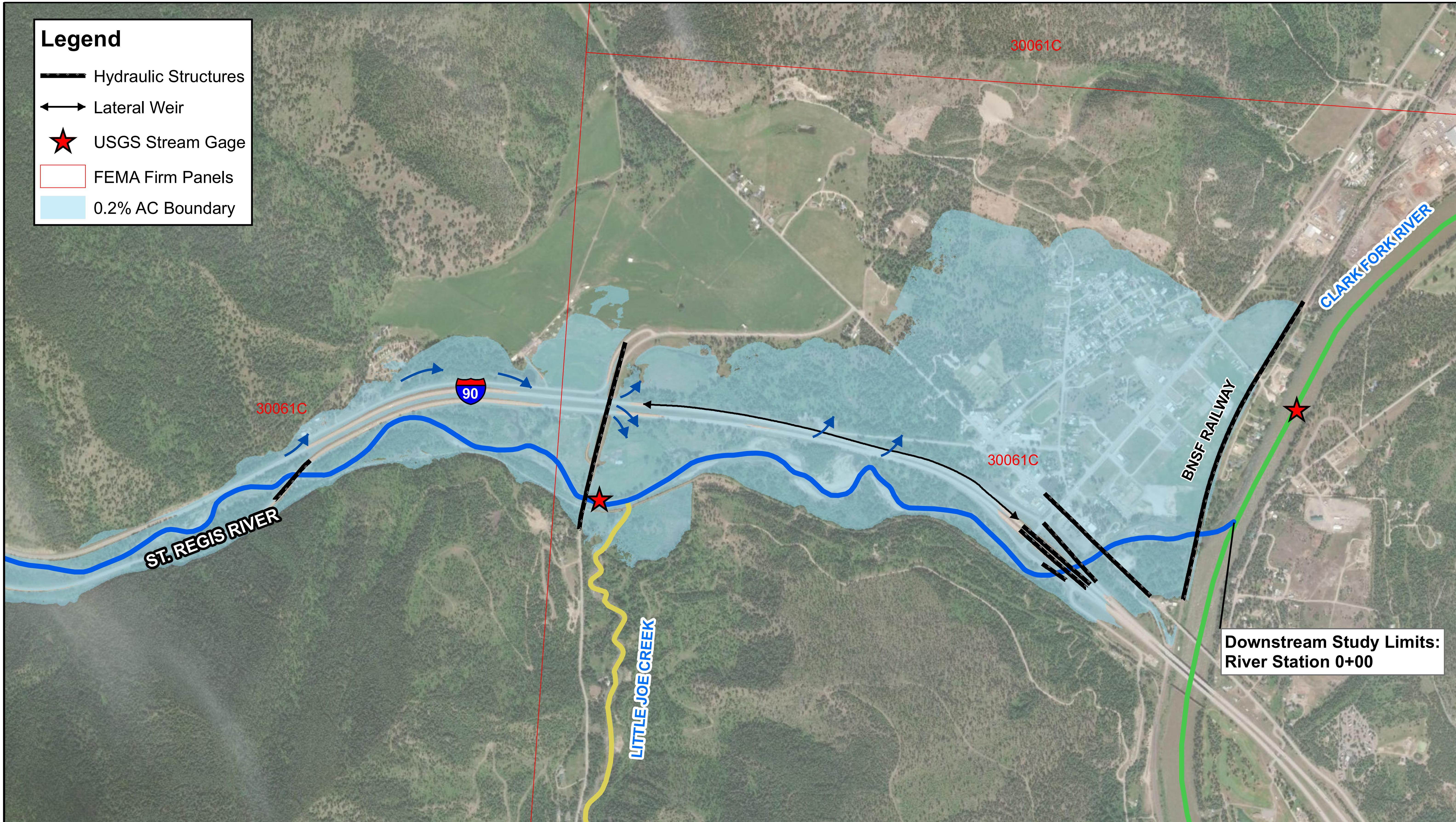

FIGURE 12: Flow Patterns near St. Regis

St. Regis River
Mineral County Detailed Floodplain Study

N W E S

0 0.125 0.25 0.5 0.75 1 Miles

5.11 Model Calibration

Calibration of the St. Regis River model is based on the January 1974 flooding event, which was approximately the 4% annual-chance-flood event (25-year). Further, the model results were compared to the water surface elevations recorded by the St. Regis River gage near St. Regis, Montana. The peak flow for the January 1974 event was 9,640 cfs and resulted in flooding throughout the St. Regis River drainage. Flooding pictures provided by the Montana Department of Natural Resources and Conservation show flooding extents along the St. Regis River near the town of Haugen, Montana. Due to the large size of the raster datasets, the photographs were not included with the submittal. In 1974, Interstate 90 had not been expanded to its present four-lanes. DOWL compared three areas along the river reach that were unaffected by the expansion of Interstate 90. Water surface elevations and top widths from the model were compared to the peak flow of the January 1974 storm (9,640 cfs) and the daily mean discharge (7,440 cfs) on the day the aerial photos were collected. Table 8 lists the water surface elevations and top widths from the 1974 flood.

Table 8: Historic Flood Events

River Station	Flow Comparison	WSEL (ft)	Top Width (ft)
106125	Peak Flow (1/16/74)	3139.22	545
	Flood Photos	3139	522
	Daily Mean Discharge (1/17/74)	3138.84	514
102528	Peak Flow (1/16/74)	3117.33	91
	Flood Photos	3117	89
	Daily Mean Discharge (1/17/74)	3116.45	87
92143	Peak Flow (1/16/74)	3057.45	301
	Flood Photos	3057	212
	Daily Mean Discharge (1/17/74)	3056.56	208

For calibration near the downstream reach of the St. Regis River, water surface elevations of several historical events at the USGS Gage Station near St. Regis, Montana (No. 12354000) were compared to water surface elevations in the model. The gage is immediately downstream of the bridge crossing at RS 95+76. Water surface elevations in the model are reasonable representations of the gaged water surface elevations that were observed during the historical events. Differences between measured and model simulated water surface elevations during the 1933 and 1974 storms are likely due to snow and ice jams during winter storms. The 1933 flood, which was approximately the 500-year event, is the largest flow on record. However, the bridge and road that existed at that time immediately upstream of the gage were likely considerably different than what exists today. The results of these various comparisons provided in Table 9 were used as validation of the modeling for the St. Regis River Study.

Table 9: Comparison of Model Results and Stream Gage Data

Date	Flow (cfs)	Gage WSEL (ft)	Model WSEL (ft)
1/16/1974[1]	9,640	2,656.13	2657.38
5/28/1913	6,220	2,656.45	2656.34
12/20/1933[1,2]	29,000	2,663.25	2660.71
5/19/1954	11,000	2,658.15	2657.73
3/19/2017	5,820	2,656.91	2656.19
5/13/1971	5,620	2,655.42	2656.11
5/7/1916	5,900	2,656.25	2656.22

[1]Differences at gage caused by winter effects (snow/ice jams)
[2]Constrictions due to bridge/road overtopping

Figure 13: January 1974 Flooding near Haugan, MT

5.12 Floodways

The effective mapping for the study area is Zone A approximate level mapping. The hydraulic analysis for this study will produce Zone AE level mapping for the entire study reach. Segments of the study include a floodway analysis that requires delineating the regulatory floodway by computing encroachments at each cross section. The segments of the study that include a floodway analysis are shown in Table 10.

Table 10: St. Regis River Floodway River Stationing

Floodway Analysis	River Station	
	Start	End
Completed	4+40	184+03
No Analysis	187+05	640+65
Completed	644+50	1163+54
No Analysis	1167+81	1295+52
Completed	1299+93	1434+86
No Analysis	1439+06	1972+44

The encroachments are calculated using a maximum allowable surcharge that is determined by the governing criteria of the specific study area. The Federal regulations specify a maximum allowable surcharge of 1.0 foot, however, the State of Montana requirements take precedence if they are more stringent than the Federal requirements. Therefore, the floodway analysis was performed using the maximum allowable surcharge of 0.5 feet as required in Montana. Two cross sections near structures had a negative surcharge value very close to a 0.0-foot rise. These exceptions to the standard are documented in Appendix F.

The floodway was computed starting at the most downstream cross section of each study reach that is an enhanced level analysis with floodway. The calculations proceeded upstream and the floodway limits were placed to ensure practical transitions between cross sections. As described previously, the study begins at the confluence with the Clark Fork River. The normal water surface elevations for the new model were used to determine the encroachments at the most downstream cross section. The work maps include encroachment stations with points at each cross section. The final floodway will be digitized for the next submittal and included in the flood hazard area for the FIRM products.

The results of the floodway analysis for the St. Regis River are summarized in the Floodway Data Tables presented in Appendix D.

5.13 Quality Review

DOWL has developed an internal QA/QC process to complete a detailed review of the Hydraulic Data and Floodplain Mapping tasks for floodplain studies. The review includes a detailed review performed by a water resources engineer as well as a senior level review. The details of this review are included in Appendix E.

6.0 FLOODPLAIN MAPPING

The RAS Mapper utility in HEC-RAS version 5.0.3 was used in conjunction with ESRI ArcMap 10.2 to perform the floodplain mapping. The raw model outputs are included with this Hydraulic Data submittal, which includes flood boundaries and depth grids. The flood hazard boundaries will be refined during the floodplain mapping task and the floodway will be digitized.

Hydraulic work maps were developed to display the results of the floodplain mapping and are included in Appendix B. The work maps include the raw floodplain boundaries of the 1 and 0.2-percent-annual-chance flood events, the profile baseline of the St. Regis River, cross section locations of the hydraulic model, and structure locations. The basemap for the work maps is the 2015 National Agriculture Imagery program (NAIP) aerial photograph.

7.0 FLOOD INSURANCE STUDY PRODUCTS

The Flood Insurance Study products required for the St. Regis River flood study include floodway data tables and flood profiles. These products were developed using RASPLOT Version 3.0. This software extracts the results from the HEC-RAS analysis and creates databases for each stream modeled. Once the HEC-RAS data is in the databases, RASPLOT exports the floodway data tables. Floodway data tables were developed for the segments of the study that included a floodway analysis.

For creating the profiles, RASPLOT requires the user to enter information for the plot extents and labels. Once these inputs are manually entered, the profile information is exported to DXF files. The DXF files were reviewed and the placement of several labels was adjusted using the DXF editor before exporting to PDFs. No edits were made to the water surface elevations from HEC-RAS.

8.0 REFERENCES

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APPENDIX A – TECHNICAL REPORTS

APPENDIX B – WORKING MAPS

APPENDIX C – FLOOD PROFILES

APPENDIX D – FLOODWAY DATA TABLES

APPENDIX E – MODEL REVIEW

APPENDIX F – HEC-RAS MODEL DOCUMENTATION

APPENDIX G – HEC-RAS MODEL OUTPUTS