MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

Hydraulic Analysis and Floodplain Mapping Report

Blacktail Deer Creek
Beaverhead County, MT
November 6, 2018

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1.0 INTRODUCTION

As part of the Mapping Activity Statement (MAS) contract for Phase II of the Beaverhead County Modernization Project, DOWL completed a new enhanced level floodplain study of an 11-mile reach of Blacktail Deer Creek within Beaverhead County, MT. The Blacktail Deer Creek Study reach begins at the confluence with the Beaverhead River (downstream limit) and extends approximately 11 miles upstream. The downstream end of the study reach ties into the new enhanced level floodplain study for the Beaverhead River, which was completed in Phase II of the Beaverhead County Modernization Project. The new enhanced level study for Blacktail Deer Creek 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 Blacktail Deer Creek 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. DOWL completed the hydraulic analysis and floodplain mapping tasks using Light Detection and Ranging (LiDAR) mapping developed by Quantum Spatial in 2016, structural and bathymetric surveys completed by Morrison-Maierle in 2016, and the hydrology report completed by Pioneer Technical Services in April 2017. All surveys, topographic and hydrologic data were previously submitted to (and approved by) FEMA in 2016 and 2017.

Figures 1 through 3 show an overview of the study area for the Blacktail Deer Creek floodplain delineation project. Figure 1 shows an overview of the entire mapping reach. Figures 2 and 3 are zoomed exhibits along the upper and lower reaches that show key features and locations identified in the model.

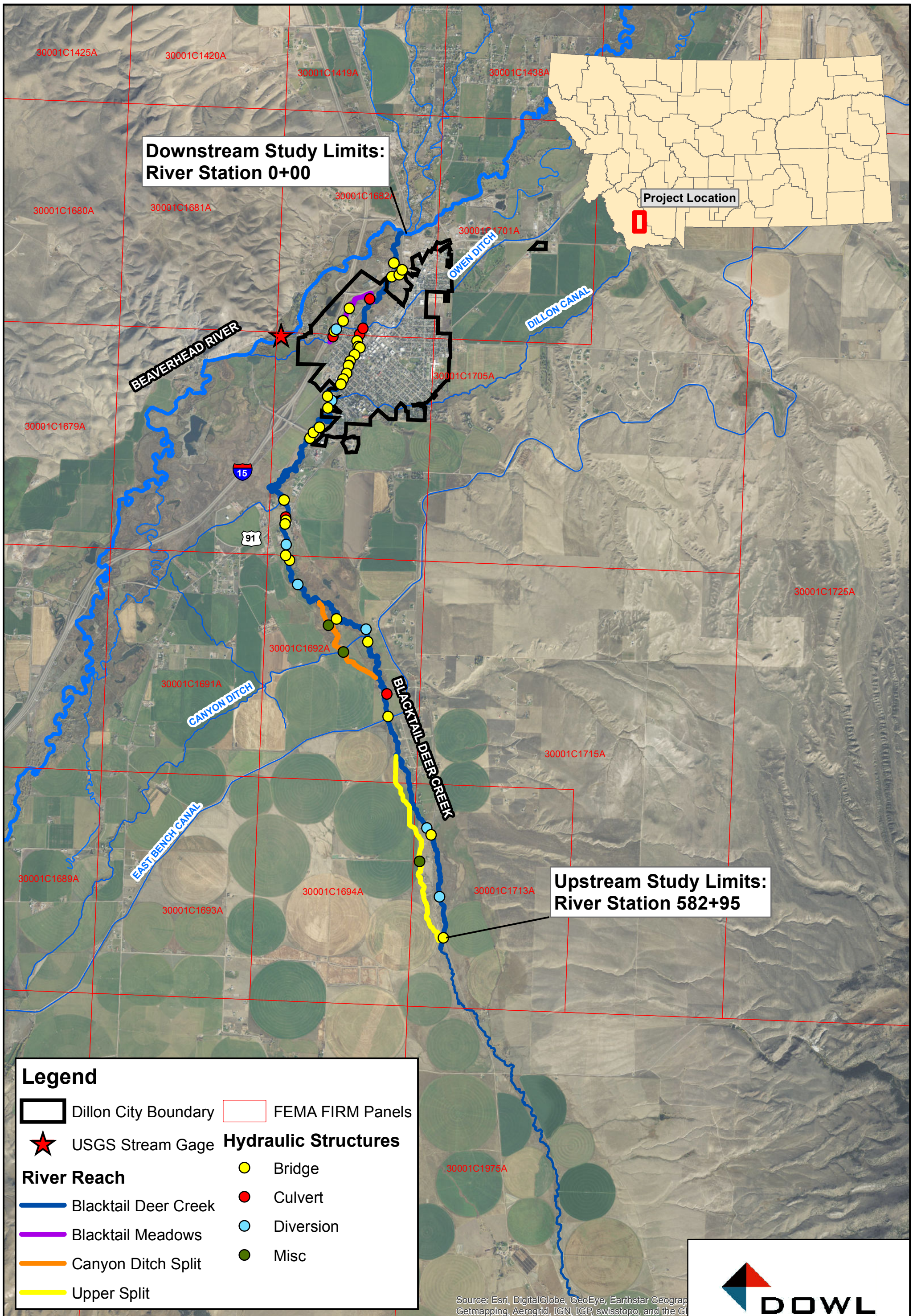

FIGURE 1: Project Overview

Blacktail Deer Creek
Detailed Floodplain Study

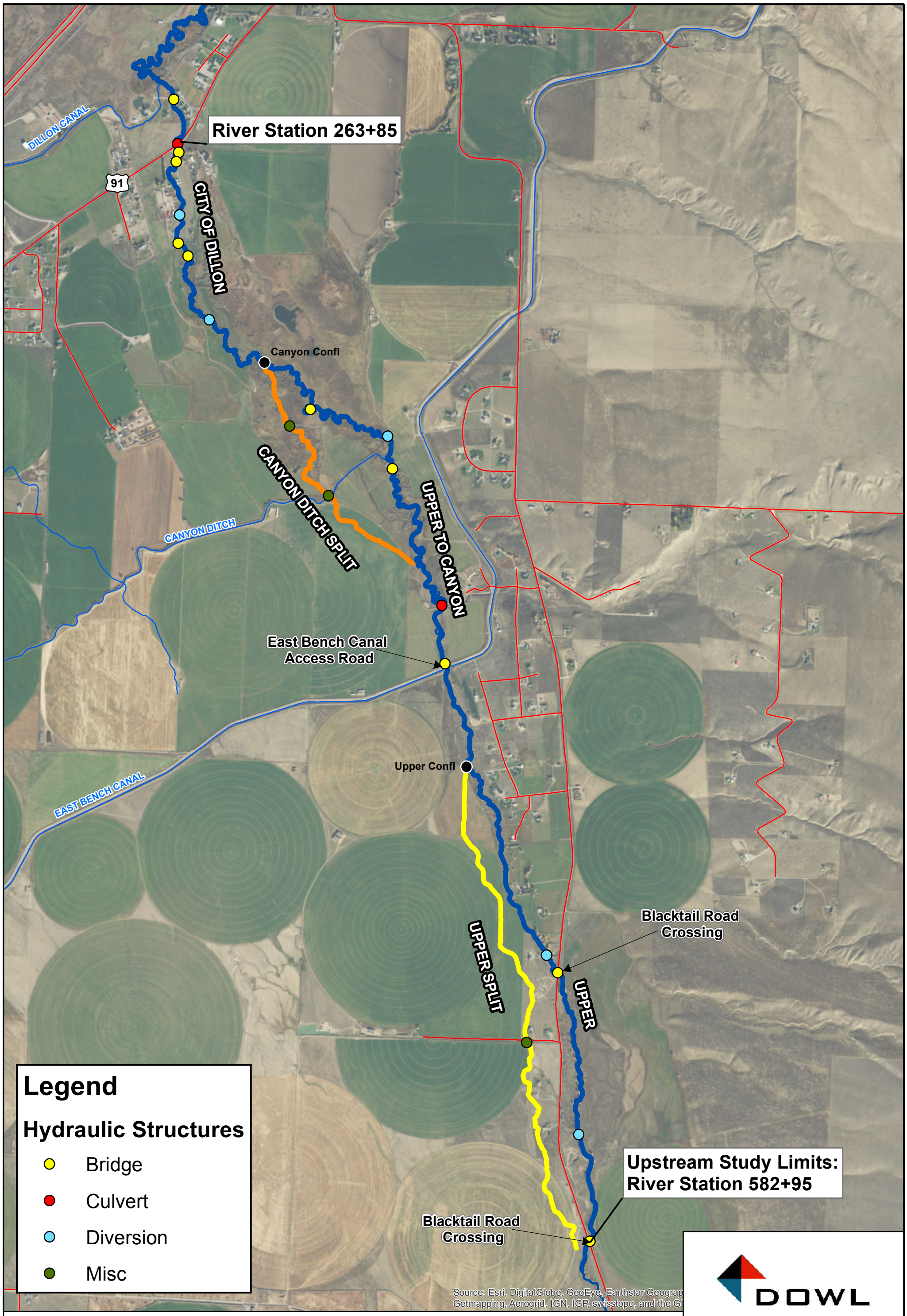

FIGURE 2: Project Overview Upper Reach

Blacktail Deer Creek
Detailed Floodplain Study

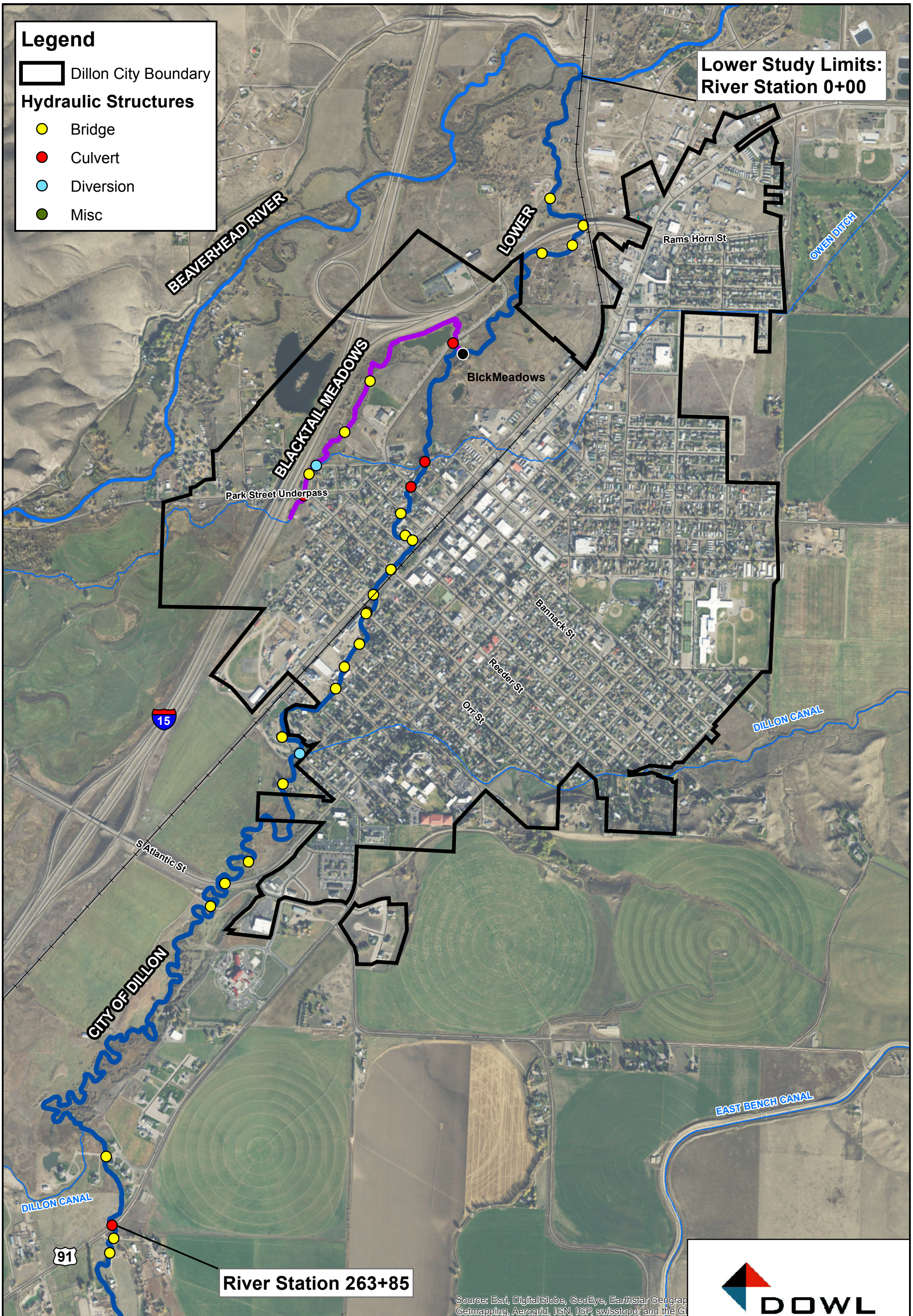

FIGURE 3: Project Overview Lower Reach

Blacktail Deer Creek
Detailed Floodplain Study

N W E S

0 0.1 0.2 0.4 0.6 0.8 Miles

DOWL

MONTANA DNRC

BEAVERHEAD COUNTY MT BEAVERHEAD wide·open·adventure

1.1 Previous Studies

Approximately 7 miles of the study reach for Blacktail Deer Creek is currently mapped. The current mapping includes approximately 5.5 miles of Zone A approximate level mapping and 1.5 miles of detailed level mapping within the corporate limits of the City of Dillon. The FIS states that Morrison-Maierle, Inc. completed all of the hydrologic and hydraulic analyses in December of 1979. The effective flood boundaries were published in the Flood Insurance Study (FIS) for Beaverhead County in 1982.

For the detailed level mapping, the effective hydraulic analysis was completed using the U.S. Army Corps of Engineers HEC-2 hydraulic software. The topographic information was obtained from field survey at each cross section. The starting water surface elevations were determined using the slope-area method. Manning's "n" values were established using the U.S. Geological Survey Water-Supply Paper 1849, engineering judgment based on aerial imagery, field inspection, and 'various texts' that were not specified in the FIS Report. The Manning's "n" values for the effective studies ranged from 0.035-0.070 for the channel and 0.038-0.080 for the overbanks.

For the approximate level mapping, the FIS report does not specifically state which method was used to establish the 100-year flood boundary. The general statement from the FIS expresses that one or more of the following methods was used: review of topographic maps with a scale of 1:24,000 and a contour interval of 20 feet, use of aerial photographs to distinguish changes in topography and vegetation cover, depths of flow from adjoining detailed study areas, field investigations, and engineering judgment.

2.0 WATERSHED DESCRIPTION

Blacktail Deer Creek is a tributary to the Beaverhead River and is approximately 38 miles in length. The creek originates in the Snowcrest Mountain Range in the Southern portion of Beaverhead County and flows northwesterly before joining the Beaverhead River near Dillon, MT. The creek meanders along the valley bottom, which is bounded by the Blacktail Mountain

Range to the south and the Ruby Mountain Range to the north. The study area is located in the lower portion of the valley where slopes are mild. The contributing drainage area at the upstream study limit is 354 square miles. The total contributing basin area at the downstream study limit is 377 square miles.

The valley bottom is predominantly agricultural rangeland that transitions to cultivated farmland as the valley widens near Timber Creek. The natural creek is sinuous and historic meander loops indicate the stream often experiences channel migration. Vegetation throughout the study reach is primarily cultivated farmland and open rangeland, with areas of brush and trees adjacent to the stream. A considerable length of Blacktail Deer Creek is channelized as it passes through the City of Dillon. There are many crossing structures through town and significant development in the overbanks. There is little to moderate development adjacent to the creek for the remainder of the study area.

In addition to the crossing structures, there are several irrigation diversion structures within the study area. The irrigation channels range in size from un-named, local channels to large irrigation canals that include the East Bench Canal and the Dillon Canal. The irrigation canals were not evaluated for the capacity to convey flow away from Blacktail Deer Creek. For this study, it is assumed that there are no inflows or outflows at any of the irrigation ditches. The flood flows from the hydrology report are retained in the model.

3.0 CHANNEL TOPOGRAPHY

The Blacktail Deer Creek channel along the upper reach is shallow compared to the lower reach, and has low channel banks that allow significant flood flow to be conveyed in the overbanks. In some areas of the upper reach, the topography results in a perched channel where the majority of the flow is conveyed in the overbanks. Flow splits are modeled for flow paths that have significantly different water surface elevations than the main channel.

As Blacktail Deer Creek transitions to the lower reach, the channel becomes wider and deeper than the channel in the upper reach. Within the City of Dillon, development around Blacktail Deer Creek has modified the channel section. Vertical retaining walls and other man-made improvements have been constructed to increase capacity and to stabilize the banks. Segments of the channel through the City of Dillon are also perched compared to the left and right overbanks. As flood flows increase within the City, water will overtop the left overbank first and only under extremely large events will the right overbank overtop. Floodwater in the left overbank is conveyed through the City's street grid and continues in a northwesterly direction until it reaches Owen Ditch near the Park Avenue Underpass. Floodwater in the right overbank will also flow through the city streets and travel in a northeasterly direction away from the Blacktail Deer Creek channel. During the 500-yr and 1% plus flood events, the hydraulic model shows that an insignificant amount of flow will leave Blacktail Deer Creek in the right overbank. For the hydraulic modeling, the overtopping flow remains in the main channel and the right overbank was not modeled or mapped.

To represent water flowing through the streets of Dillon, DOWL developed a one-dimensional model for the main channel of Blacktail Deer Creek and a two-dimensional model for modeling the flow through the City's streets. Lateral weirs in the one-dimensional model were used to calculate the flow leaving the main channel of Blacktail Deer Creek. Further details of the modeling approach are discussed in the Hydraulics Section of this report.

4.0 HYDROLOGY

Pioneer Technical Services completed the Beaverhead River Hydrologic Analysis for the enhanced studies of the Beaverhead River and Blacktail Deer Creek. 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 three different locations along Blacktail Deer Creek. A flow node was located at the stream gage on the stream and the other two flow nodes were at ungaged locations.

As part of the hydrologic study, the DNRC and USGS had an informal partnership to complete an updated flood frequency analysis of all the stream gages along the main stem of the Beaverhead River and the single gage on Blacktail Deer Creek (USGS Stream Gage 06017500). The updated analysis included data through Water Year 2016. The gage on Blacktail Deer Creek had 21 years of record with most of the data from the 1940s and 1950s. Considering the short and dated period of record, the results of the flood frequency analysis were also weighted with regional regression equations based on data through 2011. The results of the weighted analysis were selected to represent the flood flow frequency estimates for the flow node at the stream gage on Blacktail Deer Creek.

For the flow nodes at ungaged sites on Blacktail Deer Creek, the drainage area gage transfer method and regional regression equations were evaluated. The results of the regional regression equations were significantly higher than the results of the gage transfer and were similar in magnitude to the Beaverhead River flows. The drainage areas for the ungaged sites also meet the criteria in SIR 2015-5019-F, which recommends that the drainage areas of ungaged sites should be within 0.5 to 1.5 times the drainage area of the gaged site. From these conclusions, the drainage area gage transfer method was selected as the method to calculate the flow frequency estimates at the ungaged sites on Blacktail Deer Creek. Table 1 shows the USGS gage flows and the gage transfer flood flows used to model the Blacktail Deer Creek floodplain for the extents of this study.

Table 1: Blacktail Deer Creek Flood Flows

Flow Node Location	Approx. River Sta. (mi)	Drainage Area (mi^2)	Peak Discharge Estimates –Annual Chance Exceedance (cfs)					
			10%	4%	2%	1%	0.2%	1% +
Confluence with Beaverhead River	0.	377	516	680	824	984	1,417	1,503
USGS Stream Gage	24.	316	447	602	735	884	1,290	1,350

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 Blacktail Deer Creek flood study are presented below.

5.1 Hydraulic Analysis Overview

The new detailed study begins at the confluence with the Beaverhead River (Cross Section AA) and extends 19.1 miles upstream to roughly 5 miles south of the City of Dillon (Cross Section BN). Detailed work maps of the study reach are provided in Appendix B. The hydraulic models for Blacktail Deer Creek were developed following FEMA's publications Hydraulics: One Dimensional Analysis (Nov 2016) and Hydraulics: Two-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, inline 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.

Throughout development of the model, separate profile baselines were established to model side channels. At each of these locations, the side channel conveys a significant portion of the flow and water surface elevations in these side channels are disconnected from the water surface of the main channel. Junctions and lateral weirs were defined to model these flow split locations. Further details of each flow split location are discussed in later sections of this report.

The Blacktail Deer Creek channel is mostly perched throughout the City of Dillon. Water that overtops the left channel bank flows into the adjacent streets and then flows northwesterly toward Owen Ditch (Blacktail Meadows reach). Most of this flow is shallow, and typically flows through the streets and does not affect residences. The Blacktail Deer Creek main channel was modeled using a one-dimensional model with lateral weirs to determine the amount of flow spilling into the City streets. A separate two-dimensional model was developed to model the shallow flow through the City streets to Owen Ditch. The one-dimensional model assumes the overtopping flows from the laterals weirs are directly tied to cross sections in the Owen Ditch. Further details of the 1D and 2D modeling are discussed below.

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 Beaverhead County Modernization Project. The Beaverhead County Project included two sites: the Harlowton, Montana area of interest (AOI) and the Dillon, Montana AOI. Acquisition of the LiDAR for the Dillon AOI was completed on 04/04/2016 and 04/07/2016. 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 of the structures along the modeled reaches. Bathymetric cross sections were collected along the entire reach of the main channel of Blacktail Deer Creek. Morrison-Maierle performed the survey in November and December of 2016. During the hydraulic modeling task, DOWL identified a need for additional survey along Owen Ditch. Morrison-Maierle completed the additional survey in July of 2017. From thorough review of the structures and survey data, 47 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 stream channel centerlines of Blacktail Deer Creek and the three split flow reaches were used to define the profile baselines of each reach in the model. The river stationing of Blacktail Deer Creek is stream distance in feet above the confluence with the Beaverhead River. The stream station for all modeled split flow reaches reference the stream distance in feet above its respective receiving stream. Each split flow reach is displayed in Figures 1-3. A list of all the

modeled reaches and their respective stationing reference is presented in Table 2. The entire profile baseline is shown on the Work Maps included in Appendix B. The stream centerlines were 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 2: River Stationing

River Name	Reach Name	Starting River Station (ft)	Ending River Station (ft)	Junction Sta. (ft)
Blacktail Deer Creek	Upper	474+54	582+95	469+86
Upper Split	Split Left	3+45	105+14	0+00
Blacktail Deer Creek	Upper to Canyon	334+72	466+87	331+11
Canyon Ditch	Split Left	3+42	58+01	0+00
Blacktail Deer Creek	City of Dillon	59+00	330+67	56+87
Blacktail Meadows	Blacktail Meadows	1+52	43+41	0+00
Blacktail Deer Creek	Lower	1+81	56+35	-

5.3.1 Split Flow Analyses

During the initial development of the hydraulic model, three locations were identified that required split flow reaches. These locations are shown in Table 2 and the river names include Upper Split, Canyon Ditch Split, and Blacktail Meadows. By observing topography in these areas, it was apparent that the channels diverge from the main channel and will convey flow. Therefore, new profile baselines were established.

At each split flow location, the water surface must overtop the banks of the main channel before flow enters the split reach. Lateral weirs were used to compute the discharge from the main channel to the split flow reaches. Junctions were used where the split flow reaches converge with the main channel. To ensure flow continuity and select the appropriate energy equation to perform calculations across each junction, the split flow optimization routine in HEC-RAS was used. Lateral weirs were also placed along the divide between split flow paths to compute the

amount of flow passing between the split reach and the main channel. Again, the flow optimization routine within HEC-RAS was used to compute the flow across each lateral weir to ensure continuity.

5.3.1.1 Upper Split

The Upper Split channel was included to model the overtopping flows at Blacktail Road near Sta. 580+87. The left bank of Blacktail Deer Creek upstream from the Blacktail Road crossing is relatively low, and overtopping occurs during floods exceeding the 10 percent annual chance flood event. Flow is conveyed to the north in a natural drainage swale along the west side of Blacktail Road for roughly 1.2 miles before re-entering the main channel of Blacktail Deer Creek. The flow split allows different water surface elevations to be computed to map the flood hazards on both sides of Blacktail Road. A lateral weir was used to calculate the overtopping flows discharging into the side channel. Flows from this lateral weir are directed into cross section 105+14 and then continue downstream to junction “Upper Confl”.

5.3.1.2 Canyon Ditch

The Canyon Ditch channel was included to model flows leaving the left bank of Blacktail Deer Creek near River Sta. 420+61. The split flow was modeled from XS 58+01 at the lateral weir to the junction “Canyon Conflu”. Several lateral weirs and inline weirs are used in this reach to model private road crossings and areas of connectivity to the main channel.

5.3.1.3 Blacktail Meadows

The Blacktail Meadows channel was included to model the flow leaving the main channel that flows through the left overbank in the City of Dillon and eventually spills into Owen Ditch (Blacktail Meadows Reach). Overtopping flows in the main Blacktail Deer Creek reach are modeled using a series of lateral weirs. The flow spilling over these weirs is connected directly to the Blacktail Meadows reach. A two-dimensional flow area is used to map flood boundaries between the lateral weirs and the side channel. Further details of the two-dimensional model are discussed later. The Blacktail Meadows reach also has inflows from the Beaverhead River, where flood flows are being conveyed through the Park Avenue underpass. This reach extends roughly one mile downstream and rejoins the main Blacktail Deer Creek channel at Junction “BlckMeadows”.

5.4 Boundary Conditions

The HEC-RAS model was evaluated under the assumptions of subcritical flow and no backwater influence from the Beaverhead River. The normal depth option was selected as the downstream boundary condition of 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 0.0020 ft/ft was selected for the Blacktail Deer Creek reach.

The Beaverhead River contributes flows to Blacktail Deer Creek at two locations. The two locations are the Dillon Canal, upstream from the City of Dillon, and the W. Park Street underpass located on the west edge of town. To assess the potential for the Beaverhead River to affect the flood hazards along Blacktail Deer Creek, DOWL reviewed the potential for concurrent peaks flows. The basin characteristics of these streams have significant differences, especially in regards to the basin area and length. Thus, the flood response for each basin is also different and the time at which the peak flow occurs will be different. Furthermore, the Beaverhead River is attenuated by the Clark Canyon Dam, which also delays the time of the peak flow for the Beaverhead River near Dillon. Based upon these considerations and following FEMA guidance, a coincident peak analysis is not appropriate for the hydraulic analysis of Blacktail Deer Creek.

5.5 Cross Section Development

The terrain data in the HEC-RAS model was based on the LiDAR data and field survey data. GeoHECRAS Version 1.4.0 was used to place cross sections perpendicular to flow. A rough two-dimensional model was developed for the entire study reach to assist in the development of the one-dimensional model. Cross section extents were placed to bound the water surface of the 0.2-percent annual chance flood. Cross sections were placed at key locations along the reach, including bathymetric survey locations, breaks in channel slope, abrupt changes in the floodplain width, and at structure locations. 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.

5.5.1 Incorporation of Bathymetric Survey Data

Surveyed bathymetric cross sections were incorporated into the LiDAR based terrain model using the "interpolate river geometry" feature in GeoHECRAS (version 1.4.0). Cross sections were cut at each surveyed bathymetric cross section, and channel bank points were set at elevations close to the LiDAR water surface elevation to define the upper extent of the bathymetric data. The "interpolate river geometry" command was used to interpolate bathymetry between each surveyed bathymetric cross section within the defined bank points (LiDAR WSEL). The resulting bathymetry surface was merged with the LiDAR surface to generate the final terrain model surface. In areas were the interpolated bathymetric data was used, DOWL cut several cross sections to verify the interpolation matched closely with the LiDAR surveyed channel. In general, the interpolated bathymetric channel matches reasonable well with the LiDAR data.

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 from hydraulic calculations based on low-flow field measurements. A horizontal variation of Manning's n values was used in the model to simulate the changes in the channel and overbank roughness. The roughness of the channel bottom for the main channel ranges between 0.030 and 0.040, based on the composition of gravel and the slope of the channel. The roughness of the overbank areas range between 0.016 and 0.08, representing a range of land cover that includes paved streets, residential development, short grass, and highly vegetated areas of trees/brush. Table 3 shows the range of Manning's n values for each study reach.

Table 3: Roughness Coefficients

Flooding Source	Channel "n"	Overbanks "n"
Blacktail Deer Creek	0.030-0.040	0.016-0.080
Upper Split	0.05	0.050
Canyon Ditch	0.045-0.05	0.035-0.080
Blacktail Meadows	0.035-0.040	0.016-0.080

5.7 Non-Conveyance Areas

Ineffective flow limits near the bridge, culvert, irrigation diversion, 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 shows 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 available conveyance.

5.8 Blocked Obstructions

There are many structures in both the upper and lower limits of the model 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.

5.9 Hydraulic Structures

There are 47 crossings modeled over the length of the Blacktail Deer Creek study reach. Each structure was defined in the hydraulic model using the field survey data in addition to the LiDAR. A summary of the modeled structures in each reach are presented below in Table 4. The 'Structure ID' information corresponds to the structure identification numbers from the survey data. Throughout the study area, there are approximately 31 bridge structures, 7 culvert

crossings, and 9 miscellaneous and irrigation structures. The bridge structures range in size from pedestrian walkway bridges to an interchange overpass. The culverts range from double corrugated metal culverts to concrete box culverts. The irrigation structures range from concrete diversion structures with canal gates to irrigation flumes that constrict flow. The following photos illustrate the variety of crossing structures within the study reach.

Bridge crossings within the study area operate under both pressure and non-pressure conditions. Due to the perched nature of the channel and the low-lying overbanks, there are many locations where the majority of the flow is conveyed in the overbank and not across the structure. At several of these crossings, the structure in the main channel is overtopped. However, the significant flow in the overbank is controlling the water surface elevation. The bridge modeling approach was generally selected as pressure/weir for structures with overtopping. At many locations with the condition above, HEC-RAS defaults back to the energy equation for the highest flood flows. The bridge at River Station 34+16 is an example of this. For a few locations that were more sensitive, the bridge modeling approach was manually defined to use the energy equation.

Figure 4: Reeder's Street Bridge Crossing (43-ft Span Bridge)

Figure 5: Interchange Overpass Bridge (320-ft 4- Span Bridge)

Figure 6: Blacktail Road Concrete Box Culvert (6' x 4' RCB)

Figure 7: Double CMP at Private Road (6.2' x 3.8' CMPA)

Figure 8: Dillon Canal Diversion Structure (Two 6' x 5' Openings)

Table 4: 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 (ft)	Bridge Width (ft)	Number of Spans	Pier Shape	Pier Coefficients (Cd, K)	Bridge Modeling Approach	Length (ft)	Shape	Type	Dimensions
BDC_490	577+97	Blacktail Deer Creek	Upper	Blacktail Road	Bridge	15	24	1	--	--	Pressure/Weir	--	--	--	--
BDC_480	***Did Not Model***														
BDC_470	554+77	Blacktail Deer Creek	Upper	Diversion Structure	Inline Weir	15	10	1	--	--	--	--	--	--	--
BDC_460	519+41	Blacktail Deer Creek	Upper	Blacktail Road	Bridge	14	23.8	1	--	--	Pressure/Weir	--	--	--	--
BDC_450	514+59	Blacktail Deer Creek	Upper	Diversion Structure	Inline Weir	26	9.9	1	--	--	--	--	--	--	--
BDC_440	***Did Not Model***														
BDC_430	***Did Not Model***														
BDC_420	***Did Not Model***														
BDC_410	446+66	Blacktail Deer Creek	Upper to Canyon	East Bench Canal Access Road	Bridge	12	16.25	1	--	--	Pressure/Weir	--	--	--	--
BDC_400	433+27	Blacktail Deer Creek	Upper to Canyon	Private Road	Culvert	--	--	--	--	--	--	31	Box	RCB	3’ x 7’
BDC_380	386+39	Blacktail Deer Creek	Upper to Canyon	Private Road	Bridge	50	8.5	1	--	--	Pressure/Weir	--	--	--	--
BDC_370	378+95	Blacktail Deer Creek	Upper to Canyon	Diversion Structure	Culvert	--	--	--	--	--	--	11	Box	RCB	4.1 x 5.1
BDC_360	352+31	Blacktail Deer Creek	Upper to Canyon	Private Road	Bridge	26	6	1	--	--	Energy	--	--	--	--
BDC_350	***Did Not Model***														
BDC_340	308+66	Blacktail Deer Creek	City of Dillon	Diversion Structure	Inline Weir	19	10.3	1	--	--	--	--	--	--	--
BDC_330	290+80	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	35	9.8	1	--	--	Pressure/Weir	--	--	--	--
BDC_320	287+45	Blacktail Deer Creek	City of Dillon	Fence Over Blacktail Deer Creek	Bridge	36	1.4	1	--	--	Pressure/Weir	--	--	--	--
BDC_310	***Did Not Model***														
BDC_300	268+15	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	14	15.3	1	--	--	Pressure/Weir	--	--	--	--
BDC_290	265+76	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	12	18.2	1	--	--	Pressure/Weir	--	--	--	--
BDC_280	263+85	Blacktail Deer Creek	City of Dillon	State Hwy 91S	Culvert	--	--	--	--	--	--	30	Twin Box	RCB	4’ x 6’
BDC_270	253+28	Blacktail Deer Creek	City of Dillon	Lincoln Drive	Bridge	30	15.6	1	--	--	Energy	--	--	--	--
BDC_260	***Did Not Model***														
BDC_250	***Did Not Model***														
BDC_248	***Did Not Model***														
BDC_245	***Did Not Model***														
BDC_242	***Did Not Model***														
BDC_240	175+02	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	42	18.9	1	--	--	Energy	--	--	--	--
BDC_237	***Did Not Model***														

Table 4 cont.: 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 (ft)	Bridge Width (ft)	# of Spans	Pier Shape	Pier Coefficients (Cd, K)	Bridge Modeling Approach	Length (ft)	Shape	Type	Dimensions
BDC_232	***Did Not Model***														
BDC_230	166+18	Blacktail Deer Creek	City of Dillon	S. Atlantic Street / I-15 Overpass	Bridge	90	49.6	1	--	--	Energy	--	--	--	--
BDC_220	156+74	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	19	6.5	1	--	--	Pressure/Weir	--	--	--	--
BDC_215	***Did Not Model***														
BDC_210	133+75	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	15	13.9	1	--	--	Pressure/Weir	--	--	--	--
BDC_200	127+65	Blacktail Deer Creek	City of Dillon	Diversion Structure	Inline Weir	--	--	--	--	--	--	8	Twin Arch	CMPA	2.8’ x 4’
BDC_190	123+94	Blacktail Deer Creek	City of Dillon	Private Road	Bridge	18	20.5	1	--	--	Pressure/Weir	--	--	--	--
BDC_180	112+61	Blacktail Deer Creek	City of Dillon	Clark Street	Culvert	--	--	--	--	--	--	21	Twin Arch	CMPA	3.8’ x 6.2’
BDC_170	109+58	Blacktail Deer Creek	City of Dillon	E. Cornell Street	Bridge	19	18.9	1	--	--	Pressure/Weir	--	--	--	--
BDC_160	106+07	Blacktail Deer Creek	City of Dillon	E. Dillon Street	Bridge	18	19.5	1	--	--	Pressure/Weir	--	--	--	--
BDC_150	101+30	Blacktail Deer Creek	City of Dillon	E. Orr Street	Bridge	18	18.5	1	--	--	Pressure/Weir	--	--	--	--
BDC_140	100+99	Blacktail Deer Creek	City of Dillon	Pedestrian Crossing	Bridge	22	5.0	1	--	--	Pressure/Weir	--	--	--	--
BDC_130	98+18	Blacktail Deer Creek	City of Dillon	Railroad Crossing	Bridge	45	35	3	Three Cylinder, No Diaphragm	1.20, 1.05	Pressure/Weir	--	--	--	--
BDC_120	93+93	Blacktail Deer Creek	City of Dillon	W. Reeder Street	Bridge	43	38.9	1	--	--	Pressure/Weir	--	--	--	--
BDC_110	89+00	Blacktail Deer Creek	City of Dillon	S. Railroad Avenue	Bridge	43	35.75	1	--	--	Pressure/Weir	--	--	--	--
BDC_100	87+74	Blacktail Deer Creek	City of Dillon	Pedestrian Crossing	Bridge	48	6.6	1	--	--	Pressure/Weir	--	--	--	--
BDC_090	83+25	Blacktail Deer Creek	City of Dillon	Pedestrian Crossing	Bridge	47	6.6	1	--	--	Pressure/Weir	--	--	--	--
BDC_080	78+69	Blacktail Deer Creek	City of Dillon	W. Bannack Street	Culvert	--	--	--	--	--	--	49	Twin Box	RCB	4.5’ x 8’
BDC_070	74+88	Blacktail Deer Creek	City of Dillon	Owen Ditch Flume	Bridge	56	25	1	--	--	Energy	--	--	--	--
BDC_060	***Did Not Model***														
BDC_055	34+16	Blacktail Deer Creek	Lower	Private Road	Bridge	47	9.3	1	--	--	Pressure/Weir	--	--	--	--
BDC_050	29+57	Blacktail Deer Creek	Lower	Private Road	Bridge	33	9.4	2	Twin Cylinder, No Diaphragm	1.20, 1.05	Pressure/Weir	--	--	--	--
BDC_040	26+45	Blacktail Deer Creek	Lower	I-15 Overpass	Bridge	212	46	5	Four Cylinder, No Diaphragm	1.20, 1.05	Energy	--	--	--	--
BDC_030	19+69	Blacktail Deer Creek	Lower	Private Road	Bridge	41	9.55	1	--	--	Pressure/Weir	--	--	--	--
BDC_020	***Did Not Model***														
BDC_010	***Did Not Model***														

Table 4 cont.: 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 (ft)	Bridge Width (ft)	# of Spans	Pier Shape	Pier Coefficients (Cd, K)	Bridge Modeling Approach	Length (ft)	Type	Shape	Dimensions
-	60+27	Upper Split	Split Left	Minor Irrigation Ditch	Inline Weir	--	--	--	--	--	--	--	--	--	--
-	35+64	Canyon Ditch	Split Left	Canyon Ditch Embankment	Inline Weir	--	--	--	--	--	--	--	--	--	--
-	13+36	Canyon Ditch	Split Left	Farm Access	Inline Weir	--	--	--	--	--	--	--	--	--	--
OWD_080	39+88	Blacktail Meadows	Blacktail Meadows	W. Park Street	Culvert	--	--	--	--	--	--	54	Arch	CMPA	3.3’ x 5.4’
OWD_070	36+72	Blacktail Meadows	Blacktail Meadows	Pedestrian Crossing	Bridge	38	7.2	1	--	--	Energy	--	--	--	--
OWD_060	35+86	Blacktail Meadows	Blacktail Meadows	Diversion Structure	Inline Weir	--	--	--	--	--	--	--	--	--	--
OWD_045	29+17	Blacktail Meadows	Blacktail Meadows	Pedestrian Crossing	Bridge	42	4.7	1	--	--	Energy	--	--	--	--
OWD_015	21+58	Blacktail Meadows	Blacktail Meadows	Pedestrian Crossing	Bridge	43	4.7	1	--	--	Energy	--	--	--	--
OWD_010	2+54	Blacktail Meadows	Blacktail Meadows	Swenson Way	Culvert	--	--	--	--	--	--	106	Arch	CMPA	3’ x 4.8’
--	56+87	Blacktail Deer Creek	Lower City of Dillon	Junction: BlckMeadows	--	--	--	--	--	--	--	--	--	--	--
--	331+11	Blacktail Deer Creek	City of Dillon Upper to Canyon	Junction: Canyon Confl	--	--	--	--	--	--	--	--	--	--	--
--	469+86	Blacktail Deer Creek	Upper to Canyon Upper	Junction: Upper Confl	--	--	--	--	--	--	--	--	--	--	--

5.9.1 Lateral Weirs

Lateral weirs were used throughout the study reach to model flows leaving the main channel of Blacktail Deer Creek and flow exchanges along the divide of split flow reaches. Most of the lateral weirs in the Blacktail Deer Creek model use the flow optimization routines in HEC-RAS. Lateral weir coefficients are based on guidance from the Hydrologic Engineering Center (HEC) 2D Modeling User's Manual. Table 5 summarizes key details for all of the lateral weirs in the model.

Table 5: Lateral Weir Coefficients

River Name	Reach Name	Weir Starting River Station (ft)	Scenario Modeled	Weir Coefficient Selected	Optimization (Y/N)
Blacktail Deer Creek	Upper	581+91	Natural Ground, Overtopping Divde, Elevated < 1 foot	0.4 [1]	Y
Blacktail Deer Creek	Upper	510+06	Natural Ground, Overtopping Divde, Elevated < 1 foot	0.5	Y
Blacktail Deer Creek	Upper to Canyon	422+52	Natural Ground, Overtopping Divde, Elevated < 1 foot	0.5	Y
Blacktail Deer Creek	Upper to Canyon	351+84	Natural Ground, Non-elevated Overbank	0.2	Y
Blacktail Deer Creek	Upper to Canyon	341+14	Natural Ground, Non-elevated Overbank	0.2	N
Blacktail Deer Creek	City of Dillon	109+11	Railroad, not easily submerged, Elevated 1-3 feet [2]	0.5	Y
Blacktail Deer Creek	City of Dillon	105+81	Railroad, not easily submerged, Elevated 1-3 feet [2]	0.5	Y
Blacktail Deer Creek	City of Dillon	100+49	Railroad, Elevated < 1 foot	0.5	N
Blacktail Deer Creek	City of Dillon	99+55	Developed, Non-elevated Overbank	0.2	N
Blacktail Deer Creek	City of Dillon	97+89	Road, Elevated < 1 foot	0.5	Y
Blacktail Deer Creek	City of Dillon	79+39	Road / Developed Area, Non-elevated Overbank	0.2	Y
Upper Split	Split Left	37+70	Natural Ground, Non-elevated Overbank	0.2	N

[1] The weir coefficient was adjusted for model stability. It differs from the other weirs of the same scenario.
[2] Grain bins and closely spaced structures are blocking flow immediately upstream of weir. A lower weir coefficient was selected due to the flow restriction upstream and reduced approach velocities at the weir.

Four lateral weirs do not use the flow optimization routine. These include Sta. 99+55, 100+49, and 341+14 on Blacktail Deer Creek and Sta. 37+70 on the Upper split.

The lateral weir located between XS 100+13 and XS 98+53 in the City of Dillon Reach simulates water overtopping the right bank of the Blacktail Deer Creek channel. This weir shows overtopping flows for the 1% plus annual flood of approximately 35 cfs. The optimization feature was not selected for this lateral weir, and all flow was retained in the main channel. The flow over this weir is insignificant and would be limited to the city streets requiring no flood hazard mapping for the area East of Blacktail Deer Creek. This also corresponds with flood observations during the 1984 flood event.

The weir at Sta. 100+49 is located along the left overbank upstream of the railroad bridge at Sta. 98+18. Flow overtopping the weir at this location is not significant, and immediately re-enters Blacktail Deer Creek downstream of the bridge crossing. Therefore, the weir was not optimized and all flow was modeled through the bridge crossing.

The weir at Sta. 341+14 is located between XS 334+72 and XS 341+19 of the Upper to Canyon reach. The weir is placed near the location where the Canyon Ditch Split converges with Blacktail Deer Creek. This location is a low-lying area and there is not a divide between the reaches. The location of the weir is inundated for both streams and optimization will not impact flood boundaries. Based on these considerations, the optimization routine was not selected for this weir.

The lateral weir in the Upper Split reach is located between XS 37+71 and XS 3+45 and was placed due to limited terrain data. This weir effectively functions as the ineffective flow limit along this reach. Six cross sections don’t extend up to the 1% plus annual chance water surface elevation on the left side. However, the water surface is less that 0.2-ft above the terrain elevation. DOWL reviewed other topographic maps of this area and determined that this area is an ineffective flow zone. The optimization feature was not selected for this lateral weir to maintain all of the flood flow within the model.

5.10 Two Dimensional Model

A two-dimensional (2D) model was developed to evaluate the shallow flooding that occurs along the left overbank through the City of Dillon. A complex one-dimensional model would have been required to model the flow through the network of streets. Therefore, a 2D model was used in this location to better define the flood boundaries. The 2D model was developed using HEC-RAS version 5.0.3 and uses the same terrain developed for the 1D modeling.

In general, there are two common practices of modeling areas of non-conveyance using a two dimensional HEC-RAS model. The two methods include increasing the roughness values for the extents of the areas that are blocked or manually increasing the terrain elevations to incorporate the blocked area directly in the terrain file. DOWL reviewed the example problems included with the HEC-RAS software and found that the developers used a Manning's n value of 10 to represent buildings. DOWL also verified this value with a published conference paper titled, "Flooding in Urban Areas – 2D Modeling Approaches for Buildings and Fences." The findings from this paper indicated that assigning a Manning's n value between 5 and 20 will effectively block flow for the footprint of a building. DOWL has therefore selected a roughness value of 10 to model non-conveyance areas associated with buildings. The boundaries of Manning's roughness coefficients were established based on aerial imagery and are listed below.

- 10.00 - Houses
- 0.016 – Paved City Streets
- 0.030 – Blacktail Deer Creek Channel
- 0.035 – Large Grass Areas
- 0.080 – Area Within the City Blocks Between Houses

The extents of the 2D model are shown in Figure 9. The 2D modeling extents overlap the extents of the one-dimensional model along the adjacent portions of the Blacktail Meadows reach and the main channel of Blacktail Deer Creek. A 15-ft grid cell was used for the base mesh and breaklines were input as needed to further define topography and refine the cell spacing. In many areas, a grid spacing of 5-ft was used to effectively model the top of curb elevations and other high points in the terrain that control flow. Flow is input into the 2D model at four separate locations representing the four lateral weirs from the one-dimensional model. Flood flows do not leave the main channel during the 10% annual chance flood event. Simulations for all other flood events are included with the 2D model. The flow inputs for the 2D model are shown in Table 6.

In areas where the one-dimensional and two-dimensional models overlap, engineering judgement will be used to determine the appropriate mapping boundary.

Table 6: Flow Inputs for 2D Regulatory Model

Recurrence Interval	2D Regulatory Model Flow Inputs			
	Weir Sta. 10911	Weir Sta. 10581	Weir Sta. 10049	Weir Sta. 9789
10% AC	0	0	0	0
4% AC	0	5.76	0	0
2% AC	0	21.78	0	0
1% AC	0	45.97	1.07	24.27
0.2% AC	2.49	113.87	19.8	129.15
1%+ AC	4.3	128	25.28	153.77

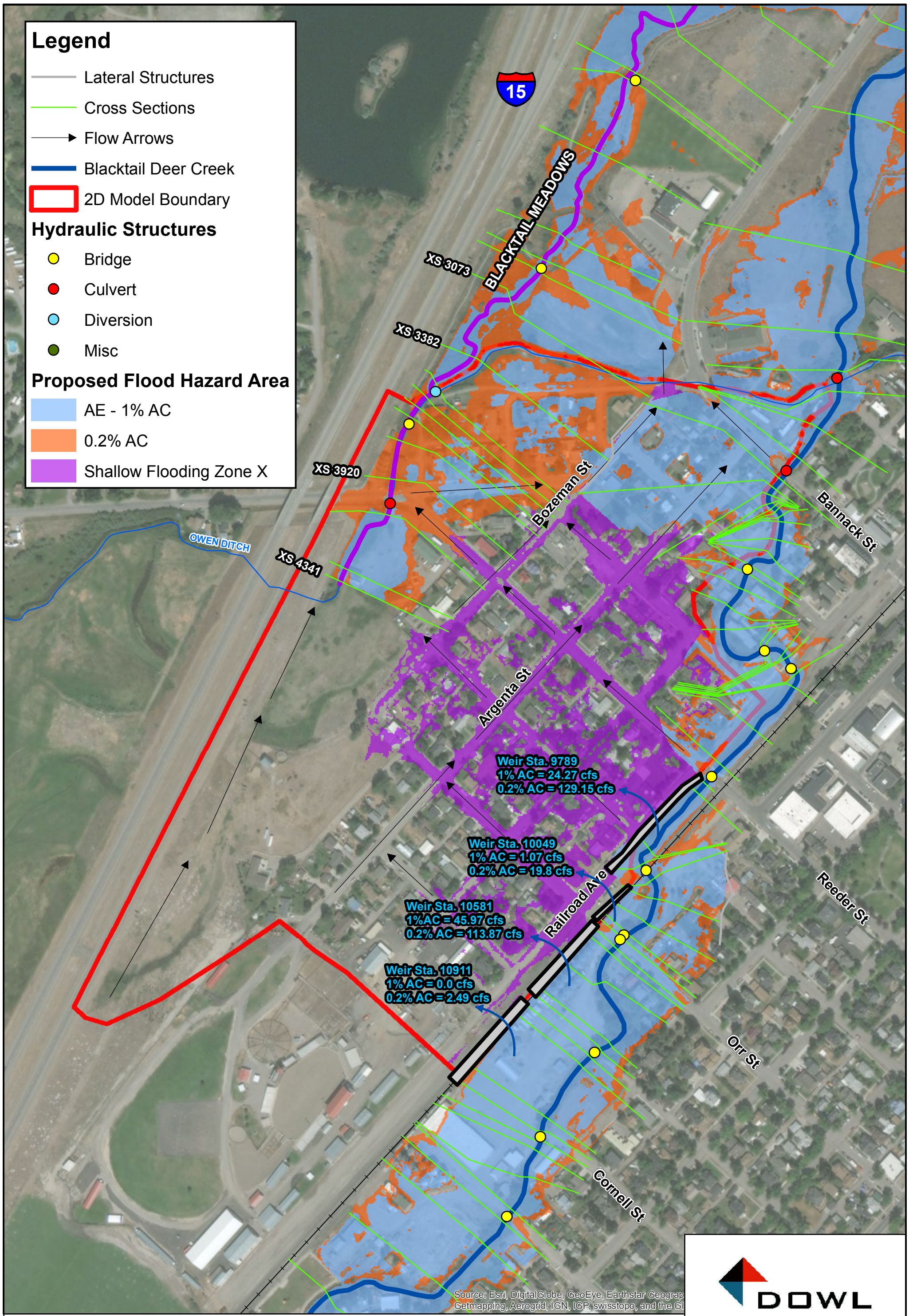

FIGURE 9: 2D Modeling Boundary

Blacktail Deer Creek
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5.12 Model Calibration

Calibration of the Blacktail Deer Creek model is based on the May 1984 flooding event, which was approximately the 1% annual chance flood. The peak flow for this event was 910 cfs and resulted in flooding throughout the Blacktail Deer Creek drainage. Flooding pictures in Appendix G show flooding extents along Blacktail Deer Creek as well as the flood response measures that were used during the flood event to prevent further flooding in the City of Dillon. It is important to note that the Reeder Street crossing was a 36-inch CMP culvert during the 1984 flood. Today, the crossing is a 43-ft clear span bridge. This culvert restricted the flood flows and resulted in a significant amount of flow being conveyed down Reeder Street. During the 1984 flood, sandbagging was used along both sides of Reeder Street. Flood flows appeared to be confined by the sandbagging efforts until the water reached Owen Ditch.

DOWL developed a 2D model to replicate the conditions during the May 1984 flood. The 2D Model was developed between the north and south interchange roadways that connect to Dillon (XS 25+62 – XS 166+71). This model was developed to calibrate model input parameters for the flood that occurred in May 1984. The estimated flowrate was 910 cfs. A 15-ft grid cell baseline was used and breaklines were incorporated to better define the topography. All structures through town are modeled using culverts with an opening area similar to the corresponding bridge. The Reeder Street crossing was adjusted to a 36-inch CMP culvert. Two weirs were incorporated into the 2D model along Reeder Street to simulate the sandbagging that took place. These weirs were set at 2-ft above the top of curb elevations. The model results are shown in Figure 10 and estimate flow depths ranging from 1-ft to 2-ft throughout the entire length of Reeder Street. This closely matches the height of the sandbags shown in Figure 11, which shows two to three sandbags placed on the top of the curb.

Specific locations of other photos taken during the 1984 flood event could not be determined. The extents of the flood mitigation implemented during the 1984 flood, and whether the flood protection measures remained after the flood is not known. Overall, the two-dimensional model used to assist in developing the one-dimensional model is a reasonable representation of the flood conditions observed during the 1984 flood event. Therefore, the results were used as a validation of the modeling approaches for the one-dimensional model developed for the Blacktail Deer Creek Study.

Figure 10: May 1984 2D Modeling Results

Figure 11: May 1984 Reeder Street Flooding

5.13 Supplemental 2D Models

DOWL developed two other supplemental 2D models to assist in the development of the one-dimensional model. One of these models was developed for the entire study reach and used a 20-ft grid cell spacing with only a few breaklines to define high points in the topography. This model was used to provide a better understanding of flow patterns, flow splits and effective flow limits along the upper reach for the 1% annual chance flood event. Information from the 2D model was used to develop the 1D floodplain model. Ineffective flow limits and flow split locations defined in the 1D model are representative of the results from this 2D model.

A more refined 2D model was developed for the area through the City of Dillon. This is the same model used for the May 1984 flood, however, the Reeder Street crossing was updated to the 43-ft bridge opening. This model was used to provide a better understanding of flow patterns, flow splits, crossing capacities, overtopping locations, and effective flow limits for the 1 percent annual chance flood event. Information from the 2D model was used to develop the 1D regulatory model.

5.14 Scenario Modeling

As described earlier, the Beaverhead River contributes flow to Blacktail Deer Creek at the Dillon Canal and the W. Park Street underpass. Coincidental peaks are not reasonable for Blacktail Deer Creek and the Beaverhead River, therefore a ‘worst case’ scenario was completed to compare the flood hazards of the Blacktail Deer Creek flood flows and the Beaverhead River flood flows. To complete the worst-case scenario, the flows contributing from the Beaverhead River are compared to the flows from Blacktail Deer Creek and the greater flow is used to map the flood hazards along Blacktail Deer Creek.

DOWL was provided discharges from the Beaverhead River that contribute to Blacktail Deer Creek at the Dillon Canal and the W. Park Street underpass. Near the Dillon Canal, the Beaverhead River contributes flow from two sources: the Dillon Canal and a split reach from Poindexter Slough. The discharges from these sources are shown in Table 7. As shown, the flood flows from Blacktail Deer Creek are greater than the discharges from the Beaverhead River. The flows from Blacktail Deer Creek are the ‘worst case’ at this location.

Table 7: Beaverhead River Inflows Near the Dillon Canal

Recurrence Interval	Discharges from Beaverhead River (cfs)			Blacktail Deer Creek Discharges (cfs)	Worst Case Discharges (cfs)
	Dillon Canal	Poindexter Overflow	Combined Flows		
10% AC	183.4	1.2	184.6	516	516
4% AC	224.4	10.7	235.1	680	680
2% AC	256.4	42.3	298.7	824	824
1% AC	310.0	101.2	411.2	984	984
0.2% AC	457.2	282.6	739.8	1417	1417
1%+ AC	457.2	282.6	739.8	1503	1503

The W. Park Street underpass contributes flow directly to XS 3920 of the Blacktail Meadows split flow reach. Therefore, the scenario at this location evaluates the flood flows in the Blacktail Meadows reach to compare the flows that result from the Blacktail Deer Creek hydrology to the flood flows that contribute from the Beaverhead River. As shown in Table 8, the flood flows from the Beaverhead River are greater than the discharges from Blacktail Deer Creek.

Table 8: Beaverhead River Inflows at W. Park Street

Recurrence Interval	Discharges from Beaverhead River (cfs)	Blacktaillacktail Meadows (cfs)	Worst Case Discharges (cfs)
10% AC	25	1	25
4% AC	33	7	33
2% AC	48	23	48 [1]
1% AC	104	71	104
0.2% AC	534	247	534
1%+ AC	656	288	656

[1] At XS 3073 the flow from Blacktail Deer Creek increases to 48.05 cfs. A flow change was modeled at this location to model the 'worst case' of 48.05.

The worst-case scenario for each flood profile was modeled. Figure 12 shows the inflows from the Blacktail Deer Creek model and the flows from the Beaverhead River at the W. Park Street

underpass. The final flows that were used to model the Blacktail Meadows reach are presented in Figure 12.

For the 0.2% AC and 1% 'plus' flood events, the flows contributing from the Beaverhead River were significantly greater than the flows from Blacktail Deer Creek. The increased flows also increased the water surface elevations, requiring modifications to the ineffective flow limits. A separate HEC-RAS geometry file was required to modify the elevations of the ineffective flow limits for the scenario analysis. The geometry file is named 'Worst Case Scenario'. Table 9 shows the HEC-RAS plans and the associated files used to complete the hydraulic analysis. A description of each HEC-RAS file is included in Table 10.

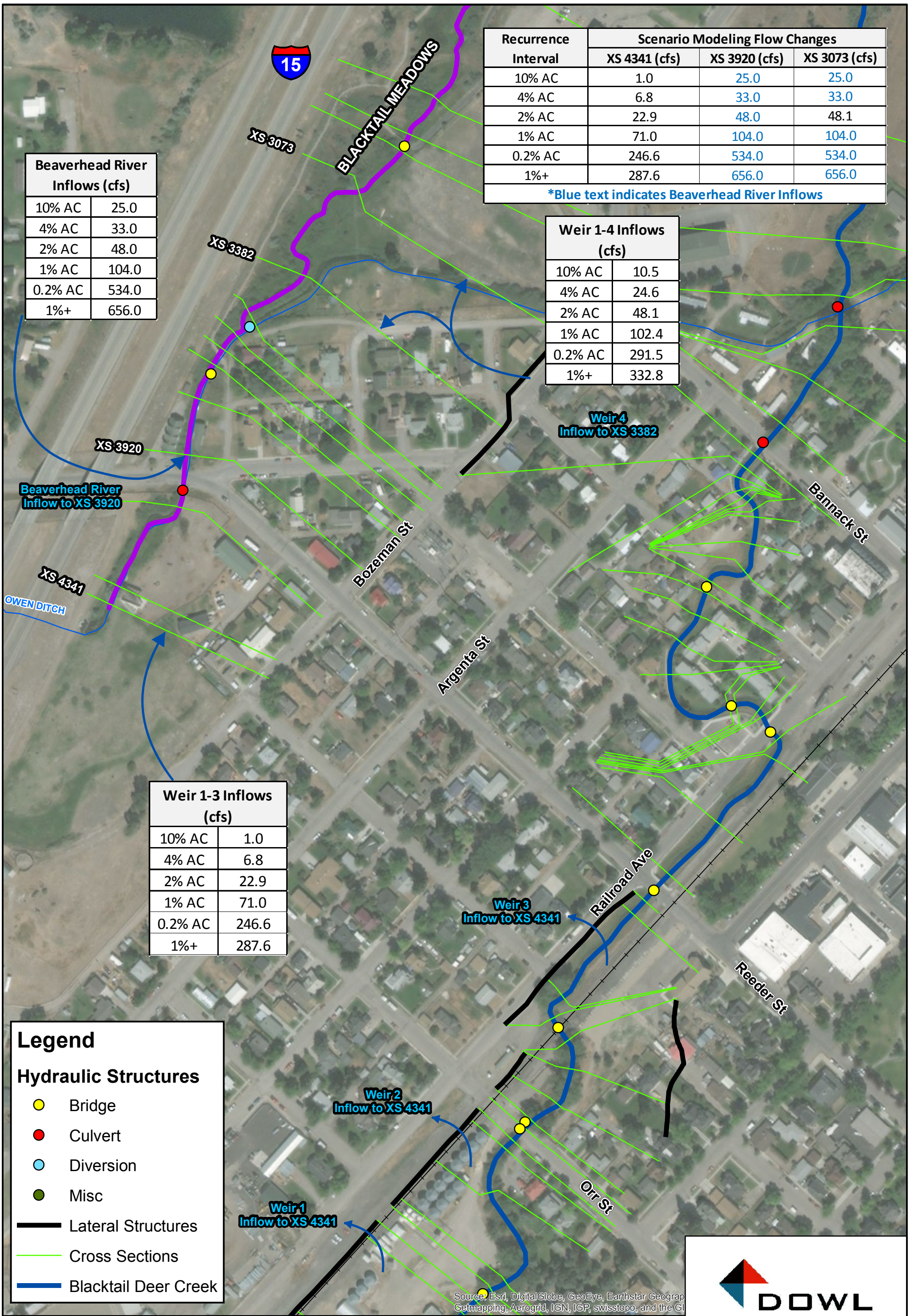
The HEC-RAS plan 'Worst Case Scenario' is the regulatory model used to complete the mapping and product deliverables. This model is also used to complete the floodway analysis.

Table 9: HEC-RAS File Management

Plan	Geometry File	Flow File
Multiple_Profiles_Optimized	BlacktailDeerCr_Study	BlacktailDeerCr_Study_Optimized
Multiple_Profiles_Hard_Entered	BlacktailDeerCr_Study	BlacktailDeerCr_Study_Hard_Entered
Worst Case Scenario	Worst Case Scenario	Worst Case Flows
BlacktailDeerCr_Regulatory_Floodway	Worst Case Scenario	Floodway

Table 10: HEC-RAS File Descriptions

File Name	File Type	Description
BlacktailDeerCr_Study	Geometry Data	Geometry used to complete the analysis with Blacktail Deer Creek as the only source of flow.
Multiple_Profiles_Optimized	Plan	Analysis performed for Blacktail Deer Creek using the flow optimization routine.
BlacktailDeerCr_Study_Optimized	Flow Data	Flow discharges with Blacktail Deer Creek as the only source. Flow optimization routine used.
Multiple_Profiles_Hard_Entered	Plan	Analysis performed for Blacktail Deer Creek. Flow optimization is not used – flow data entered manually.
BlacktailDeerCr_Study_Hard_Entered	Flow Data	Flow discharges are entered manually. Input values are the results of the flow optimizations in the Multiple_Profiles_Optimized plan.
Worst Case Scenario	Geometry Data	Separate geometry required to complete the scenario analysis.
Worst Case Scenario	Plan	Analysis performed for the worst-case scenario with consideration of the Beaverhead River flows contributing to the Blacktail Meadows Reach.
Worst Case Flows	Flow Data	Multiple_Profiles_Hard_Entered file is modified to include the 'Worst Case' discharges on the Blacktail Meadows Reach.
BlacktailDeerCr_Regulatory_Floodway	Plan	Floodway analysis using the 'Worst Case Scenario' geometry.
Floodway	Flow Data	1% AC flow data from the 'Worst Case Flows' used to complete the floodway analysis.



Beaverhead River Inflows (cfs)	
10% AC	25.0
4% AC	33.0
2% AC	48.0
1% AC	104.0
0.2% AC	534.0
1%+	656.0

Recurrence Interval	Scenario Modeling Flow Changes		
	XS 4341 (cfs)	XS 3920 (cfs)	XS 3073 (cfs)
10% AC	1.0	25.0	25.0
4% AC	6.8	33.0	33.0
2% AC	22.9	48.0	48.1
1% AC	71.0	104.0	104.0
0.2% AC	246.6	534.0	534.0
1%+	287.6	656.0	656.0

*Blue text indicates Beaverhead River Inflows

Weir 1-4 Inflows (cfs)	
10% AC	10.5
4% AC	24.6
2% AC	48.1
1% AC	102.4
0.2% AC	291.5
1%+	332.8

Weir 1-3 Inflows (cfs)	
10% AC	1.0
4% AC	6.8
2% AC	22.9
1% AC	71.0
0.2% AC	246.6
1%+	287.6

FIGURE 12: Scenario Modeling Flows

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5.15 Floodways

As discussed in the Introduction, the effective mapping for the study area includes Zone A approximate level mapping, with Zone AE level mapping throughout the City of Dillon. The hydraulic analysis for this study was performed using a steady state analysis. The enhanced study includes delineating the regulatory floodway by computing encroachments at each cross section.

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.

The floodway was computed starting at the most downstream cross section and calculations proceeded upstream, ensuring practical transitions between cross sections. As described previously, the study begins at the confluence with the Beaverhead River. The normal water surface elevations for the new model were used to determine the encroachments at the most downstream cross section. A few cross sections had negative surcharge values very close to 0.0-foot rise. These exceptions to the standard are documented in Appendix E.

Following FEMA guidance, the split flow reaches did not require a floodway analyses. The results of the floodway analysis for the main stem of Blacktail Deer Creek are summarized in the Floodway Data Tables presented in Appendix D.

5.16 CHECK-RAS

Version 2.0.1 of the cHECk-RAS software developed by FEMA was utilized to complete a thorough review of the hydraulic analyses performed in HEC-RAS. During the review process, a cHECk-RAS error occurred, and cHECk-RAS would not read the HEC-RAS geometry. For this reason, cHECk-RAS results are unavailable for the model submitted with this study. The results of a preliminary cHECk-RAS review are presented in Appendix E. The messages were reviewed and addressed as appropriate. In general, the unresolved messages were considered routine and customary. Explanations are documented to describe the reasonableness of unresolved messages.

In addition to the cHECk-RAS review, a thorough internal QA/QC review of the model was performed, which is 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 were included in the Hydraulic Data submittal, which included flood boundaries and depth grids. These boundaries were manually modified and smoothed to meet FEMA standards and best practices for floodplain mapping. These edits were required to address areas of backwater and small islands.

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, floodway boundary, profile baselines of each reach, cross section locations of the hydraulic model, and structure locations. Because the manual edits and automated smoothing processes can create discrepancies between the floodway widths in the hydraulic model and the mapped floodway widths, a review was performed so that all mapped floodway widths are within 5% of the widths in the hydraulic model. The details of this review are included in Appendix E. 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 Blacktail Deer Creek 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. Due to an error during the extraction process, the HEC-RAS results were manually copied into the RASPLOT databases. Once the HEC-RAS data is in the databases, RASPLOT exports the floodway data tables. No further editing was required for the floodway data tables.

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. For the split reaches, the water surface elevation profiles

and stream beds were extended to the confluence with Blacktail Deer Creek. The water surface elevation profiles and stream bed of Blacktail Deer Creek were extended to the confluence with the Beaverhead River. Backwater effects from the Beaverhead River were incorporated in the profile plots.

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APPENDIX A – TECHNICAL REPORTS

PIONEER TECHNICAL SERVICES, INC.

RESTORING OUR ENVIRONMENT ▸ DESIGNING OUR FUTURE

Beaverhead River Floodplain Study – Phase II

Beaverhead River Hydrologic Analysis

Montana DNRC

June 19, 2017

Pioneer Technical Services, Inc. 106 Pronghorn Trail, Bozeman Montana 59718

www.pioneer-technical.com

Beaverhead River Floodplain Study – Phase II

Beaverhead River Hydrologic Analysis

Prepared for:

State of Montana, Department of Natural Resources and Conservation
1424 9th Avenue
Helena, Montana 59620

Prepared by:

Pioneer Technical Services, Inc.
106 Pronghorn Trail
Bozeman, Montana 59718

Beaverhead River Floodplain Study – Phase II

Beaverhead River Hydrologic Analysis

June 19, 2017

I hereby certify that all work products (maps, reports, etc.) prepared for this project were done so under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.

George Austiguy P.E.

MONTANA
GEORGE E. AUSTIGUY
9528PE
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PROFESSIONAL ENGINEER
06-19-17

Date: 6/19/2017 Montana Registration No. 9528

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EXECUTIVE SUMMARY

Flood flow frequency calculations were conducted for a 41.4-mile reach of the mainstem Beaverhead River. The study reach extends from the Beaverhead\Madison County border, 1.0-miles upstream of USGS Gage Beaverhead River at Barretts (06016000). Information gathered from this analysis will be used for future floodplain studies and mapping projects.

The hydrology of the basin is primarily snowmelt driven, although significant flows can result from summer precipitation events. Land use in the Beaverhead River basin is primarily agricultural with irrigated farming and ranching operations.

The Beaverhead River is a major tributary to the Jefferson River and uppermost headwaters of the Missouri River located east of the continental divide in southwestern Montana. Originally the river was formed by the confluence of the Red Rock River and Horse Prairie Creek, which is now inundated by the Clark Canyon Reservoir (completed in 1964) approximately 23 miles southwest of Dillon (Uthman and Beck, 1998). The mainstem Beaverhead River now begins at the Clark Canyon Reservoir and flows northeast for approximately 64-miles where it joins the Big Hole River and Ruby River to form the Jefferson River. The entire Beaverhead watershed area encompasses approximately 4,778 square miles. The study watershed basin area from the Clark Canyon Reservoir to the Madison County border is approximately 3,619 square miles.

Beaverhead River basin elevations within the study area range from approximately 5,100 feet in Dillon to approximately 4,800 feet at Beaverhead Rock (Butler and Abdo, 2013). The watershed terrain varies from a high alpine environment in its headwaters to a heavily cultivated landscape in the northern reaches with expansive irrigated pasture lands, bracketed by rolling foothills, and low gradient slough networks. The hydrology of the basin is primarily snowmelt driven that is heavily regulated by the Clark Canyon Reservoir. During the summer and fall, flow in the Beaverhead is heavily reduced due to irrigation operations.

Rattlesnake Creek and Blacktail Deer Creek join the Beaverhead River near Dillon.

The primary cause of flooding on the Beaverhead River is spring snowmelt and historical records of ice jams. There are historical records from several U.S. Geological Survey (USGS) stream gages on the river that date back to 1908, documenting basin flood history.

Past flood studies for the mainstem of the Beaverhead River are limited. Within the mainstem Beaverhead River basin, a 1982 FEMA FIS exists for a portion of Beaverhead County. The USGS Report *Methods for Estimating Flood Frequency at Ungaged Sites in Montana Based on Data through Water Year 2011*, (Sando et al, 2015) was also an important study, which included flood frequency analyses for the Beaverhead River.

Flood flow frequency analysis was conducted to develop peak flow discharge estimates for the 50-, 10-, 4-, 2-, 1-, and 0.2-percent annual chance events. The 1%+ (plus) annual chance event

was also calculated. Peak flow estimates were calculated at 10 locations (flow nodes) within the watershed (6 gaged sites and 4 ungaged sites). Estimates at the gaged sites were conducted using Bulletin #17C methodologies. At the ungaged sites, peak flow estimates were calculated using the Two Station Logarithmic Interpolation method and the Drainage Area Gage Transfer method. These methods conform to standard engineering practice.

In the Beaverhead River watershed, the flood flow frequency estimates from this study produced significantly lower peak discharge estimates at the 1% and 0.2% annual chance flood potential than the 1982 FIS. In the middle and lower watershed reaches, the significant differences in peak flow estimates between this study and previous studies can be attributed to the longer gage record and periods of lower flows.

The hydrologic analysis documented in this report conforms to FEMA standards for detailed/enhanced level studies, and the recommended flows of this analysis are deemed reliable and suitable for future floodplain studies and hydraulic analyses.

1 INTRODUCTION

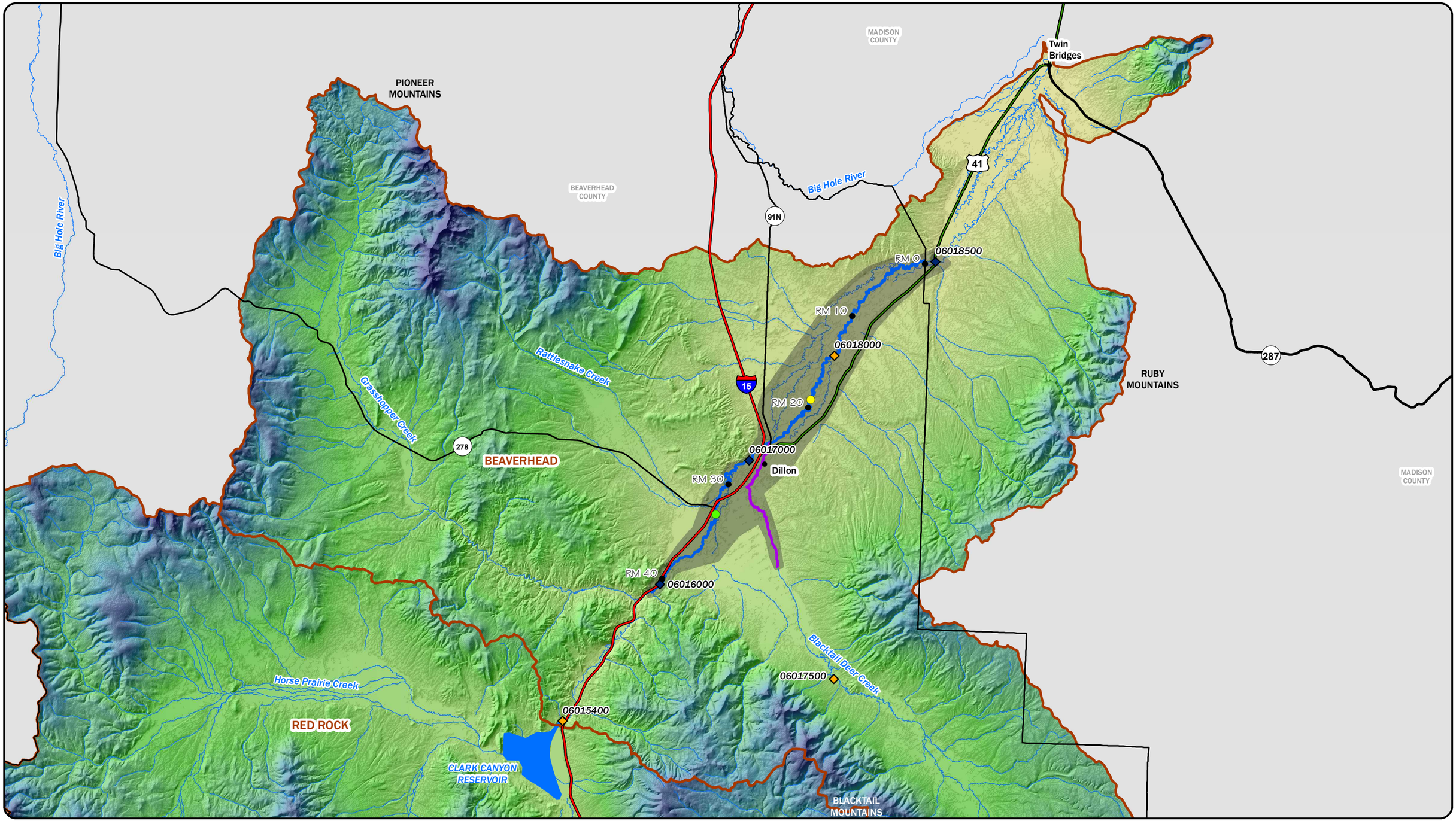
As part of the Beaverhead River Floodplain Study activities, the Montana Department of Natural Resources and Conservation (DNRC) contracted Pioneer Technical Services, Inc. (Pioneer) to complete a comprehensive peak flow hydrologic analysis for the mainstem Beaverhead River and Blacktail Deer Creek study reaches. Flood flow frequency calculations were conducted for a 41.4-mile reach of the mainstem Beaverhead River and 11-miles of Blacktail Deer Creek, a tributary to the Beaverhead River. The study does not include other tributaries. The Beaverhead River study reach extends from the river intersection with Madison County line north of Dillon upstream to a point 1-mile upstream from the USGS "Beaverhead River at Barretts" gage. This study area watershed encompasses approximately 3,618 square miles. The Blacktail Deer Creek study area watershed encompasses, approximately 377 square miles. Information gathered from this analysis will be used for both detailed/enhanced level and limited detail level hydraulic analyses and floodplain mapping. Figure 1 shows the project study reach.

1.1 Background Information

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP). As part of this program, FEMA supports flood hazard studies and prepares flood hazard maps and related documents. Most of the mainstem Beaverhead River in Beaverhead County is sparsely populated outside of Dillon with a predominantly rural environment. The existing floodplain mapping for the mainstem Beaverhead River includes either Approximate Zone A, Zone A0, or Zone A1-A30. These existing floodplain mapping studies terminate downstream of Dillon near Riverside Drive, typically date back to the early 1980s.

Approximate Zone A flood maps are developed using approximate methodologies and are not based on detailed hydraulic analysis. This level of flood mapping is often used in rural areas with low populations. Base Flood Elevations (BFEs) or flood depths are not identified in Approximate Zone A mapping (a BFE is the computed elevation to which floodwater is estimated to rise during the base flood). As a result, areas designated with Zone A flood mapping are difficult for local communities to manage and administer.

Detailed and Limited Detail mapping are similar in that both use standard hydrologic and hydraulic modeling methods to estimate BFEs and flood inundation areas. Both require the same topographic accuracy. However, Limited Detail mapping does not include floodway delineation, may not include 500-year floodplain delineation, and may allow some flexibility in the acquisition and modeling of bathymetric and structure survey data.



LEGEND

- RIVER MILES
- 1982 FIS STUDY DOWNSTREAM EXTENT
- 1982 FIS STUDY UPSTREAM EXTENT
- TOWNS
- MONTANA COUNTY BOUNDARIES
- ACTIVE USGS GAGE
- INACTIVE USGS GAGE
- NHS INTERSTATE
- NHS NON-INTERSTATE
- PRIMARY
- SECONDARY
- HUC 8 BOUNDARIES
- BLACKTAIL DEEK CREEK STUDY REACH
- BEAVERHEAD RIVER STUDY REACH
- STUDY AREA

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATE PLANE
DATUM: NAD 1983
UNITS: INT'L FEET
SOURCE: PIONEER, MSL, USGS

0 2.5 5 10
Miles

FIGURE 1

BEAVERHEAD RIVER STUDY AREA

PIONEER TECHNICAL SERVICES, INC.

DATE: 4/17/2017

Path: G:\DNRC\Mineral -Beaverhead County\Beaverhead County\CAD-GIS\GIS\BVRHD-GI-HYD-001-17.mxd

The DNRC, in partnership with FEMA, Beaverhead County, and other stakeholders, initiated work to produce new floodplain studies along a reach of the Beaverhead River below Clark Canyon Reservoir in Beaverhead County. This Beaverhead River Floodplain Study will provide the groundwork for completing floodplain mapping projects along the mainstem Beaverhead River and Blacktail Deer Creek.

This report documents the hydrologic analysis methodology and results completed along the mainstem Beaverhead River and Blacktail Deer Creek. This hydrologic analysis includes calculation of peak discharge estimates for the 50-, 10-, 4-, 2-, 1-, and 0.2-percent annual chance events at key flow change locations (such as significant tributary confluences, stream gages, and population centers) along the study reach. This hydrologic analysis also includes calculation of the 1% + (plus) annual chance discharge estimates. This hydrologic analysis conforms to FEMA standards for detailed/enhanced level studies (FEMA, 2016).

As part of this hydrologic analysis, the DNRC partnered with the USGS, under a non-formal agreement, to perform updated flood frequency analysis of all the stream gages along the mainstem Beaverhead River and single Blacktail Deer Creek gage through Water Year 2016. The USGS flood frequency analysis for the gaged locations was used to develop peak discharge estimates at the selected ungaged flow change locations.

1.2 Basin Description

The Beaverhead River is a major tributary to the Jefferson River and uppermost headwaters of the Missouri River located east of the continental divide in southwestern Montana. Originally the river was formed by the confluence of the Red Rock River and Horse Prairie Creek, which is now inundated by the Clark Canyon Reservoir approximately 23 miles southwest of Dillon (Uthman and Beck, 1998). The construction of Clark Canyon Dam began in 1961 with a date of closure on August 28, 1964. The river tributaries originate in the Beaverhead National Forest near the continental divide and Montana-Idaho border. The watershed is formed by the Pioneer Mountains to the west, Ruby Mountains to the east, and Tendoy, Snowcrest and Blacktail Ranges to the south (Butler and Abdo, 2013). The mainstem Beaverhead River begins at the Clark Canyon Reservoir and flows northeast for approximately 15 miles through the narrow Beaverhead Canyon before entering the upper Beaverhead basin at Barretts (Uthman and Beck, 1998). Rattlesnake Creek and Blacktail Deer Creek join the Beaverhead River near Dillon. Approximately 35 miles downstream of Dillon, the Beaverhead River joins the Big Hole River and Ruby River to form the Jefferson River (Figure 1). The entire Beaverhead watershed area encompasses approximately 4,778 square miles. The study watershed basin area from the Clark Canyon Reservoir to the Madison County border is approximately 3,619 square miles.

The Beaverhead River basin elevations within the study area range from approximately 5,100 feet in Dillon to approximately 4,800 feet at Beaverhead Rock (Butler and Abdo, 2013). The overall basin elevations range from 11,000 feet at the continental divide to 4,600 feet near the confluence with the Big Hole River (USACE, 1975). The terrain varies from a high alpine environment in its headwaters to a heavily cultivated landscape in the northern reaches with

expansive irrigated pasture lands, bracketed by rolling foothills, and low gradient slough networks. The hydrology of the basin is primarily snowmelt driven that is heavily regulated by the Clark Canyon Reservoir.

Land use in the Beaverhead River basin is primarily agricultural with irrigated farming and ranching operations. Most of the intensely farmed land is located within the Beaverhead River floodplain. Two major irrigation diversions exist on the Beaverhead: the Barretts diversion for the Canyon Ditch and East Bench Canal and West Side Canal near 10 mile Road. The Barretts Diversion does not provide any flood storage. During the summer and fall, flow in the Beaverhead is heavily reduced due to irrigation operations.

1.3 Flood History

The primary cause of flooding on the Beaverhead River is spring snowmelt and historical records of ice jams. There are historical records from several USGS stream gages on the river that document flooding history. The USGS stream gages at Barretts, at Dillon, and near Twin Bridges are representative of the mainstem Beaverhead flood history upstream of Dillon, at Dillon, and downstream of Dillon, respectively. The Barretts USGS Gage (06016000) has the longest, continuous flow record (1908-2016). The annual peak flow record for the Barretts gage is shown in Figure 2. Peak flow recurrence intervals shown in Figure 2 are based on previously published flood frequency analysis through Water Year 2011 (Scientific Investigations Report [SIR] 2015-5019-C) (Sando et al, 2015).

Figure 2 shows that the peak flood of record at Barretts post regulation (August 1964) occurred in 1984 with a flow of 3,000 cubic feet per second (cfs), exceeding the 1% chance annual flow of 2,480 cfs. The second highest flood on record occurred in 1971 with a flow of 2,190 cfs. In the 52-year period of record at the Barretts gage since construction of the Clark Canyon Dam, the 10-year flow has been exceeded twice.

Figure 2 Beaverhead River at Barretts (06016000)

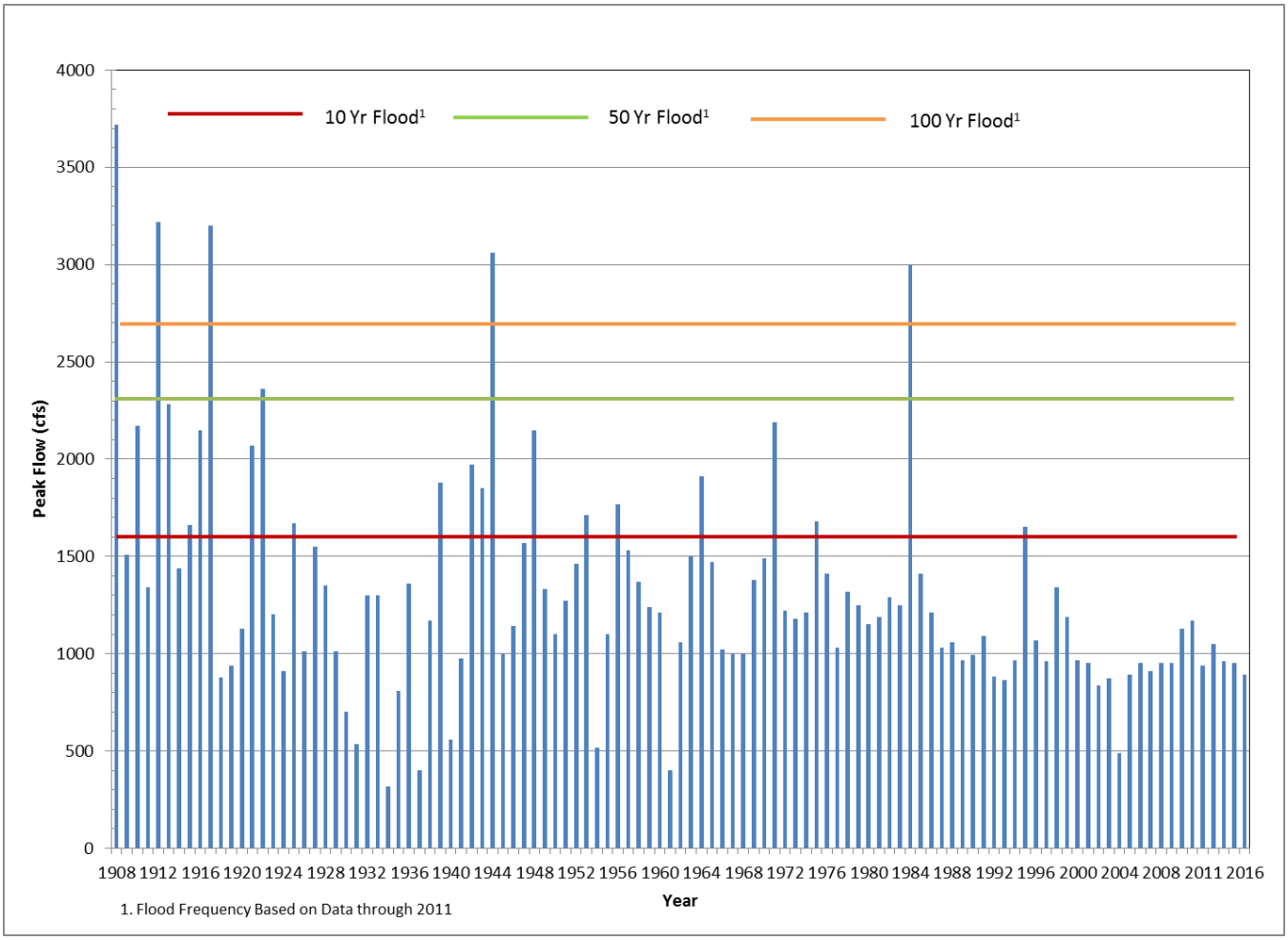


Figure 3 shows the non-continuous peak flow record from 1951 to 2016 (1951-1952, 1964-1971, 2002-2016) for the Beaverhead River gage at Dillon (USGS 06017000). Peak flow recurrence intervals shown in Figure 3 are based on previously published flood frequency analysis from SIR 2015-5019-C.

The flood of record at Dillon after 1964 regulation occurred in 1969 with a flow of 1,390 cfs, which is the only measured peak flow event greater than the 10-year flood. No recorded event since the construction of Clark Canyon Dam has exceeded the 50- or 100-year flows.

Figure 3 Beaverhead River at Dillon (06017000)

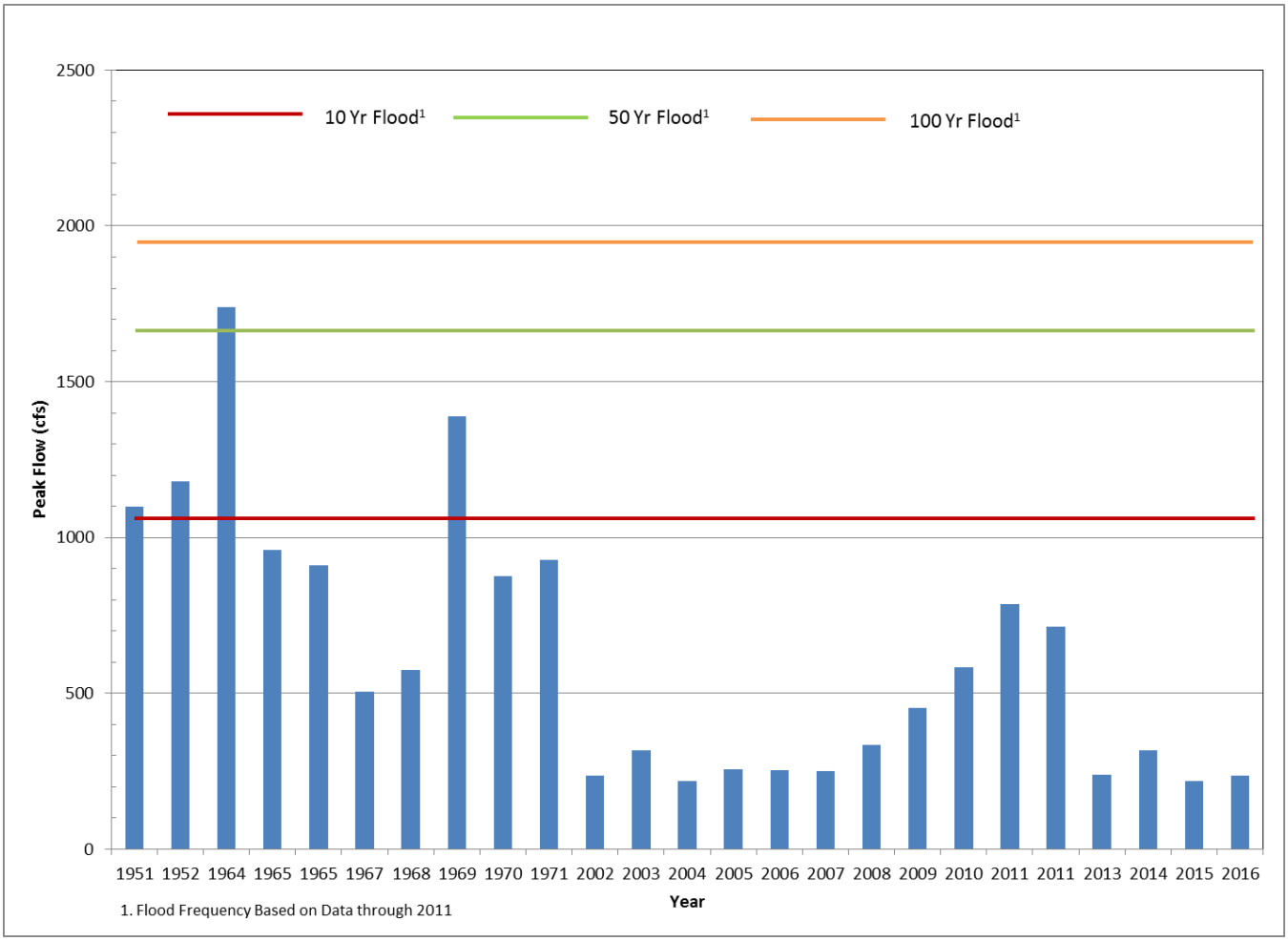
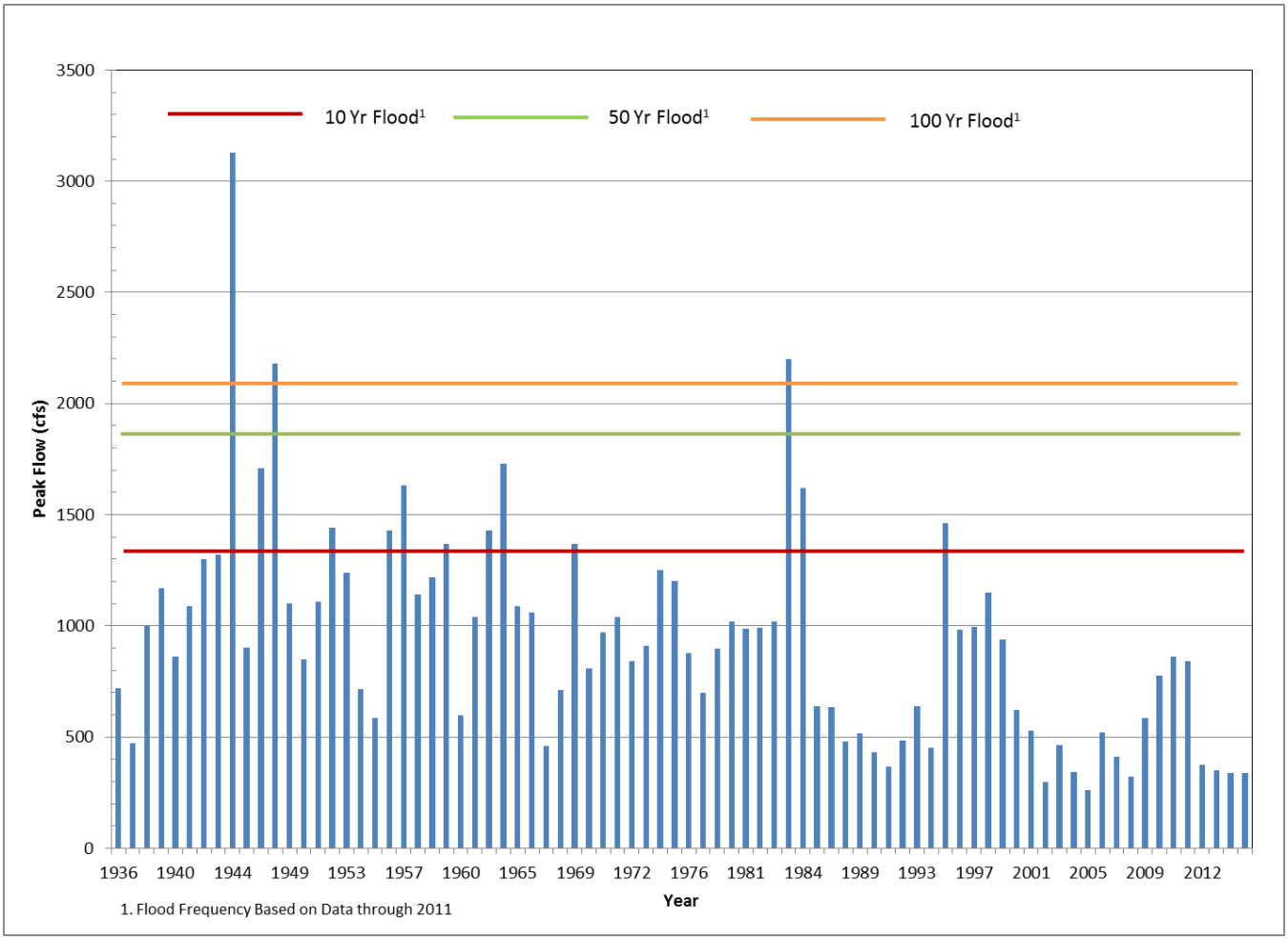


Figure 4 shows the annual peak flow record for the Beaverhead River gage near Twin Bridges (USGS 06018500) immediately downstream from Beaverhead Rock. Peak flow recurrence intervals shown in Figure 4 are based on previously published flood frequency analysis from SIR 2015-5019-C.

The Beaverhead River gage near Twin Bridges has 80 years of flow record (1936-2016). Since 1964, the gage has 52 years of record. During the post regulation period, the 10-year flow has been exceeded 4 times. The Beaverhead River post regulation flood of record near Twin Bridges occurred in 1984 with a flow of 2,200 cfs. Prior to regulation, the flood of record occurred in 1944 with a flow of 3,130 cfs.

Figure 4 Beaverhead River near Twin Bridges (06018500)



2 PAST STUDIES AND EXISTING FLOOD DATA

Past flood studies for the mainstem of the Beaverhead River are limited. Studies relevant to this hydrologic study are those that include peak flow frequency analyses. Within the mainstem Beaverhead River basin, a FEMA FIS exists for a portion of Beaverhead County. Table 1 shows a summary of the mainstem Beaverhead River and Blacktail Deer Creek Floodplain Mapping.

Table 1 Mainstem Beaverhead River and Blacktail Deer Creek Floodplain Mapping Summary

County	Map Panel Summary					Study Details			
	Community	# of FIRM Panels	# of FBFM Panels	FIRM Panel Effective Date	FIS Date	Stream	Approx (mi)	Detailed (mi)	Total (mi)
Beaverhead	Beaverhead Co.	14	0	9/30/1982	1/5/1982	Beaverhead	4	13	17
	Dillon, City of	1	0	7/5/1982		Blacktail Deer	5.5	1.5	7

Source: FEMA Map Service Center and 1982 FIS

FIRM: Flood Insurance Rate Map

FIS: Flood Insurance Study

mi: Miles measured along channel alignment

In addition to the FEMA FIS, USGS WRIR 03-4308 and SIR 2015-5019-C document the flood frequency analysis on several gages along the mainstem Beaverhead River. The gage on Blacktail Deer Creek has been inactive for several decades.

Prior to the FIS, the US Army Corp of Engineers (USACE) prepared a 1975 floodplain study (USACE Study) for Beaverhead County and DNRC. Some of the information in the USACE Study was used for the basis of the hydrology in the FIS study. These studies and investigations are discussed in more detail in the following sections.

2.1 City of Dillon and Beaverhead County Flood Insurance Study

The City of Dillon and Beaverhead County FIS (Beaverhead FIS) was issued on January 5, 1982 (FEMA, 1982). As part of the FIS, the mainstem Beaverhead River was studied using detailed and approximate methods. The hydrologic and hydraulic analyses were completed by Morrison-Maierle, Inc. in December 1979. The study area included the incorporated areas of the City of Dillon, Town of Lima, and the unincorporated areas of Beaverhead County. The FIS identified a major flood on the Beaverhead River post construction of the Clark Canyon Dam. Beaverhead at Barretts peaked on June 19, 1964 at 1910 cfs; downstream near Dillon peaked on June 21 at 1740 cfs; and north of Dillon on June 22 at only 1570 cfs. The reduction in peak flow with increase drainage area indicated that the major source of the runoff event was the upper drainage basin and also attributed to the numerous canals, abandoned channels, and sloughs that tend to allow floodwater to spread out. The 1964 flood was stated as being post

construction; however the date of closure for Clark Canyon is August 28, 1964. The June 1964 peak occurred before the closure date so it is not included in the post regulation period.

Hydrologic analysis results from the 1975 USACE Study were used in the FIS. The 1975 USACE study assumes the drainage above the Clark Canyon Dam does not contribute to flooding and assumes a constant discharge of 500 cfs from the reservoir. The Beaverhead River was reevaluated during the 1982 FIS to define flows in the slough area (Selway slough, Murray, Gilbert slough, and the Guidici ditch). These evaluations were performed using independent backwater computations of the slough and river with matching water surfaces upstream of the Old State Highway 91 Bridge. The study did not evaluate the potential for flooding from ice jams. Table 2 summarizes the estimated peak discharges from the 1982 Beaverhead FIS.

Table 2 Beaverhead FIS Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs)			
		10-Year	50-Year	100-Year	500-Year
Beaverhead River above Rattlesnake Creek	432	1,450	1,950	2,400	4,100
Beaverhead River below Rattlesnake Creek	563	1,500	2,250	2,900	5,200
Beaverhead River above Blacktail Deer Creek	574	1,400	2,300	2,800	5,000
Beaverhead River below Blacktail Deer Creek	1,016	1,850	2,900	3,500	6,200
Beaverhead River between Sections J and H	1,016	1,850	2,425	2,630	3,550
Beaverhead River at and below Section H	1,016	1,777	2,119	2,324	2,780
Beaverhead River Overbank	1,016	73	306	306	770
Blacktail Deer Creek at Dillon	442	352	550	740	940

2.2 US Army Corps of Engineers Floodplain Study

The USACE Floodplain Information for the town of Dillon (USACE Study) was issued on June 1975 (USACE, 1975). The study area included the mainstem Beaverhead River from approximately 4 miles upstream to 4 miles downstream from Dillon. The report defined the Intermediate Regional Flood (IRF) and Standard Project Flood (SPF). The IRF is defined as a flood having one percent probability of occurrence in any year, or base flood. The SPF is defined as a major flood that can be expected to occur from a severe combination of meteorological and hydrological conditions, excluding extremely rare combinations. The analysis used the operational USGS gages at the time for the Beaverhead River, Blacktail Deer Creek, and Grasshopper Creek.

At the time of the study, Dillon had experienced several floods. The study reports the following known historical floods:

- January 1937 – ice jam created flooding in Dillon;
- June 1944 – rain on snow event over several days flooded portions of Dillon with considerable damage to the Union Pacific Railroad and US Highway 91 between Lima and Dillon;
- Late May 1948 – flooding damaged road and bridges in Beaverhead County;
- January & February 1949 – ice jams at constricted channel locations resulting in overland flow that froze up to six feet in thickness;
- February 1951 – ice jam near Beaverhead Rock causing backwater flooding upstream causing evacuation of several farms and ranches; and
- January 1974 – similar event to 1951 resulting in personnel removing the ice obstructions with dynamite to relieve flood waters.

Hydrologic analyses were conducted on the gage records to estimate the peak discharge for the IRF and SRF at several locations along the Beaverhead River.

The peak discharges were based on the gaging records for Grasshopper Creek and Blacktail Deer Creek and comparison with Barretts gage. The gage analysis was used as a guide to develop similar data for the ungaged drainage areas between Clark Canyon Dam and the downstream limit of the study. Finally, the estimated floods were routed along the Beaverhead River at the selected locations. Table 3 summarizes the peak discharges from the USACE Study.

Table 3 USACE Study Peak Flow Summary

Flooding Source and Location	Drainage Area (Square Miles)	Effective Drainage Area (Square Miles)	Peak Discharges (cfs)	
			IRF	SPF
Upstream Limit	2,752	431	2,400	4,100
Beaverhead River above Rattlesnake Creek	2,753	432	2,400	4,100
Beaverhead River below Rattlesnake Creek	2,884	563	2,900	5,200
Beaverhead River above Blacktail Deer Creek	2,895	574	2,800	5,000
Beaverhead River below Blacktail Deer Creek	3,337	1,016	3,500	6,200
Downstream Limit	3,390	1,069	3,400	5,900

Source: USACE Study 1975

Effective drainage area – amount of flood-production drainage area downstream of Clark Canyon Dam

Comparison of the USACE Study to the Beaverhead FIS data shows the same peak flow values to the location downstream of Blacktail Deer Creek. After this point on the river, the Beaverhead FIS evaluated the flow reduction from overbank flows. Similar to the FIS, the USACE Study reports the peak flow attenuation downstream of Barretts. The study states that the attenuation is mainly due to the East Bench Canal and the physical characteristics of the Beaverhead River natural flood plain storage downstream from Barretts and the Beaverhead Canyon Gateway.

2.3 Water Resources Investigations Report 03-4308

The USGS WRIR 03-4308 developed annual peak discharges with recurrence intervals of 2, 5, 10, 25, 50, 100, 200, and 500 years (*T*-year floods) for 660 gaged sites in Montana and in adjacent areas of Idaho, Wyoming, and Canada, based on data through Water Year 1998 (Parret and Johnson, 2004). The flood-frequency information was used in regression analyses to develop equations relating *T*-year floods to various basin and climatic characteristics, active-channel width, and bankfull width. The equations can be used to estimate flood frequency at ungaged sites. Flood-frequency data typically were determined by fitting a log-Pearson Type III probability distribution using methods described by the Interagency Advisory Committee on Water Data (IACWD), Bulletin #17B (IACWD, 1982).

Table 4 provides the WRIR 03-4308 peak discharge summary for the USGS gages on the Beaverhead River. Table 4 shows that 100-year peak flows attenuate from Barretts to below Dillon and then begin to increase near Beaverhead Rock towards Twin Bridges. The attenuation between Barretts and below Dillon can be partly attributed to large irrigation diversions and floodplain storage and may also be influenced by non-congruent periods of records. The peak flow increase between downstream of Dillon and Beaverhead Rock is due to the inflow of major sloughs such as shown on Figure 1.

Table 4 WRIR 03-4308 Beaverhead River and Blacktail Deer Creek Peak Discharge Summary

USGS Station Number	USGS Station Name	Drainage Area (sq mi)	Years of Record	Peak Discharge (cfs) , indicated return interval (years) (cfs)						
				5	10	25	50	100	200	500
06018500	Beaverhead River near Twin Bridges, MT	3,619	34	1,210	1,430	1,710	1,920	2,120	2,320	2,590
06018000	Beaverhead River near Dillon, MT	3,484	19	1,010	1,100	1,210	1,280	1,350	1,410	1,490
06017000	Beaverhead River at Dillon, MT	2,895	10	1,310	1,520	1,770	1,940	2,100	2,260	2,460
06016000	Beaverhead River at Barretts, MT	2,737	34	1,500	1,720	2,010	2,240	2,480	2,730	3,090
06015400	Beaverhead River near Grant, MT	2,322	19	1,080	1,130	1,170	1,190	1,210	1,220	1,240
06017500	Blacktail Deer Creek near Dillon, MT	312	21	302	386	507	608	719	842	1,030

Based on systematic data through 1998

2.4 Scientific Investigations Report 2015-5019

The USGS SIR 2015-5019-C updated annual peak discharges with annual exceedance probabilities of 66.7, 50, 42.9, 20, 10, 4, 2, 1, 0.5, and 0.2 percent (return intervals of 1.5, 2, 2.33, 5, 10, 25, 50, 100, 200, and 500 years, respectively) for 725 gaged sites in or near Montana, based on data through Water Year 2011. Flood-frequency data typically were determined by fitting a log-Pearson Type III probability distribution using methods described by the Interagency Advisory Committee on Water Data (IACWD), Bulletin #17B (IACWD, 1982). The study was part of a larger study to develop an online StreamStats application for Montana, in conjunction with computing streamflow characteristics at gage stations, and estimate peak flow flood frequency at ungaged sites. Table 5 provides the SIR 2015-5019-C discharge summary for Beaverhead River gages for post Clark Canyon Dam construction and Blacktail Deer Creek.

The USGS SIR 2015-5019-F (Sando et al, 2015) selected 537 gaging stations from the gage study. The 537 gaging stations were segregated based on the following criteria: contributing drainage area less than about 2,750 square miles, peak-flow records unaffected by major regulation, small redundancy with nearby stations, and representation of peak-flow frequencies at sites within Montana. The gaging stations on the Beaverhead River were excluded from the dataset because the peak flow records are affected by major regulation due to the Clark Canyon Dam regulating more than 20 percent of the cumulative basin drainage area. The study used regression analyses to develop equations relating annual exceedance probability (AEP) flows to various basin and

climatic characteristics. The relationships developed for this study resulted in lower mean standard errors of prediction than previous regression analyses (Sand et al, 2015).

Table 5 SIR-2015-5019-C Beaverhead River and Blacktail Deer Creek Peak Discharge Summary

USGS Station Number	USGS Station Name	Drainage Area (sq mi)	Years of Record	Peak Discharge (cfs) , indicated return interval (years) (cfs)						
				5	10	25	50	100	200	500
06018500	Beaverhead River near Twin Bridges, MT	3,618	47	1,090	1,330	1,630	1,860	2,080	2,310	2,610
06018000	Beaverhead River near Dillon, MT	3,419	19	991	1,090	1,200	1,280	1,350	1,420	1,500
06017000	Beaverhead River at Dillon, MT	2,892	17	812	1,060	1,390	1,660	1,950	2,260	2,690
06016000	Beaverhead River at Barretts, MT	2,730	47	1,360	1,600	1,970	2,300	2,690	3,130	3,830
06015400	Beaverhead River near Grant, MT	2,316	19	1,120	1,170	1,230	1,270	1,300	1,330	1,360
06017500	Blacktail Deer Creek near Dillon, MT	316	21	301	384	503	603	713	834	1,010

Based on systematic data through 2011

2.5 Additional Previous Studies

Additional related previous studies conducted along the Beaverhead River involve water management, fisheries management or sediment management:

- *Hydrogeologic Investigation of the Lower Beaverhead Study Area, Beaverhead County, Montana, Groundwater Modeling Report*, *Open File Report 638*, Montana Bureau of Mines and Geology (Butler and Abdo, 2013).
- *Hydrogeology of the Upper Beaverhead Basin near Dillon, Montana, Open File Report 384*, Montana Department of Natural Resources and Conservation and Montana Bureau of Mines and Geology (Uthman and Beck, 1998).
- *Beaverhead River and Clark Canyon Reservoir Fishery Study,* US Department of the Interior, Bureau of Reclamation (Nelson, 1977).
- *Beaverhead River Flushing Flow Study, Technical Report SRH-2013-10*, Bureau of Reclamation (Klumpp and Randle, 2013).
- *Beaverhead Watershed Restoration Plan*, Beaverhead Watershed Committee (BWC), (BWC, 2013).

3 HYDROLOGIC ANALYSES AND RESULTS

The purpose of the hydrologic analyses conducted as part of this project is to develop peak flow discharge estimates for the 50-, 10-, 4-, 2-, 1-, and 0.2-percent annual exceedance probability events at key flow change locations (such as at significant tributary confluences, stream gages, and population centers) along the study reach. The analysis is organized into two sections:

1. USGS Stream Gage Analysis.
2. Ungaged Flow Node Analysis.

Throughout the study area, 7 locations (flow nodes) on the Beaverhead River and 3 locations on Blacktail Deer Creek were identified as having significant changes in streamflow or being at a critical location. Out of the 7 flow nodes on the Beaverhead, 2 are located at active USGS stream gage sites, 3 are located at discontinued USGS stream gage sites, and 2 are located between or downstream of stream gages (ungaged sites). Out of the 3 flow nodes on Blacktail Deer Creek, 1 is located at a discontinued USGS stream gage site, and 2 are located at ungaged sites. The river stationing used in this report is based on the Beaverhead River study alignment provided by the DNRC. The Blacktail Creek alignment is based on an alignment originally provided by the DNRC that was revised subsequently by DOWL. The Beaverhead River study alignment begins at the border of Madison and Beaverhead counties. The upstream end of this study reach ends at River Mile 41.4. The most upstream flow node is located at the Grant gaging station (USGS Station 06015400) approximately 12.8 river miles upstream from the study reach extent.

The Blacktail Deer Creek study alignment begins at the confluence with the Beaverhead River. The upstream end of the Blacktail Deer Creek study reach ends at River Mile 11.0. The most upstream flow node is located at the gaging station (USGS Station 06017500) approximately 13.0 river miles upstream from the study reach extent.

3.1 USGS Stream Gage Analysis

The USGS has historically maintained 5 stream gages along the Beaverhead River study reach, along with a single gage on Blacktail Deer Creek. USGS gaging station 06018500 Beaverhead River near Twin Bridges is downstream of the study reach but will be used in the analysis. The oldest records date back to 1908 at USGS gaging station 06016000 on the Beaverhead River at Barretts, with the period of record continuing until present. Currently, there are 3 (of the 5) USGS gaging stations being maintained on the mainstem Beaverhead River. The gage on Blacktail Deer Creek is not currently being maintained. Figure 1 shows the study reach and the locations of the USGS gaging stations used in the hydrologic analysis. The Barretts gage has the longest congruent period of record extending from 1908 to 2016 (109 years). Table 6 lists a summary of all the USGS stream gages (active and inactive) along the mainstem Beaverhead River and Blacktail Deer Creek.

In 2014 the USGS updated the regional regression equations used to estimate flood frequency at ungaged sites in Montana using stream gage data through 2011. As part of this effort, the USGS

conducted flood frequency analysis on the Beaverhead River. In conjunction with the hydrologic analysis and the regression equation update, the USGS collaborated with DNRC to conduct a flood frequency analysis for the mainstem Beaverhead River and Blacktail Deer Creek using gage data through 2016. This longer period of record should produce more accurate peak discharge estimates than those based on a shorter period of record. Results of the USGS flood frequency analysis based on data through 2016 have been employed in this hydrologic analysis.

This section summarizes the Beaverhead River flood frequency work conducted by the USGS. A detailed description and supporting information for the USGS flood frequency analysis is provided in Appendix A. The flood frequency analyses were performed following Bulletin #17C methods (USGS, 2016). Post-regulation systematic flood frequency calculations were completed for all 6 gages (Appendix A, Table B.2) shown in Table 6, using data through 2016. Figure 5 plots the systematic flood frequency results as a function of drainage area and Table 7 tabulates the results.

Table 6 Beaverhead River USGS Gage Summary

Station number	Station name	Drainage[1] Area (square miles)	Period of Systematic Record[2]	Number of Annual Peaks[2]	River Station (miles)
06018500	Beaverhead River near Twin Bridges, MT	3618	1936-1944, 1946-2016	80	N/A
06018000*	Beaverhead River near Dillon, MT	3419	1951-1952, 1964-1983	22	14.0
06017000	Beaverhead River at Dillon, MT	2892	1951-1952, 1964-1971, 2002-2016	25	26.7
06016000	Beaverhead River at Barretts, MT	2730	1908-2016	109	40.4
06015400*	Beaverhead River near Grant, MT	2316	1963-83	21	N/A
06017500*	Blacktail Deer Creek near Dillon, MT	316	1946-1953, 1955-1966, 1984	21	N/A

1. Source: National Watershed Information System (NWIS)
2. Data from USGS flood frequency analysis (Appendix A, Table B.1)

* Denotes inactive gage location

Figure 5 USGS Flood Frequency Estimates Systematic Record 1965 through 2016

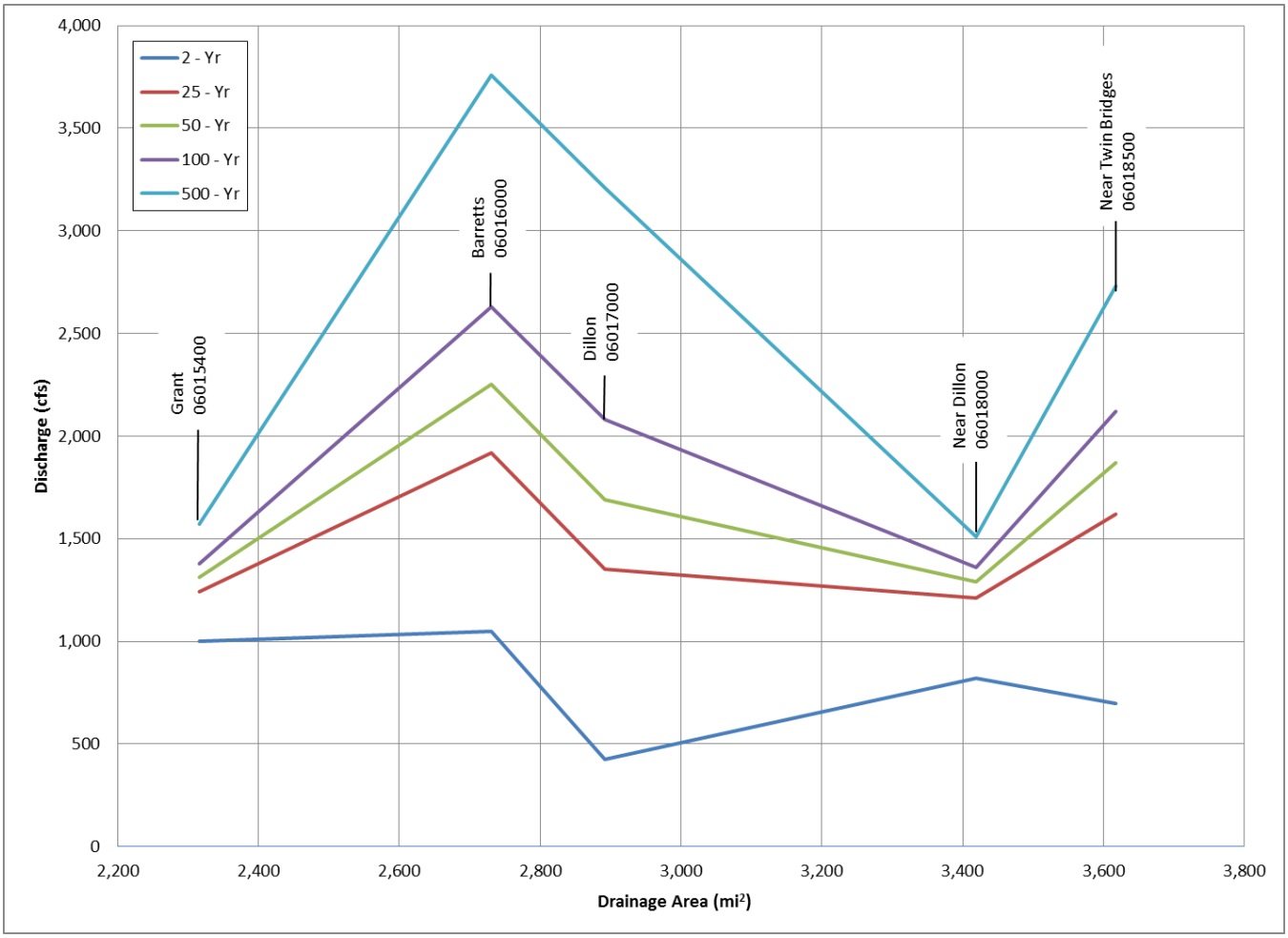


Table 7 Gage Flood Frequency Estimates Using Systematic Record

Station Number	Station name	Analysis Period of Record	Peak discharge, (cfs), for indicated exceedance probability (%)								
			66.67	50	20	10	4	2	1	0.5	0.2
			Peak discharge (cfs), for indicated return interval (years)								
			1.5	2	5	10	25	50	100	200	500
06018500	Beaverhead River near Twin Bridges, MT	1965–2016	562	696	1050	1300	1620	1870	2120	2380	2730
06018000	Beaverhead River near Dillon, MT	1965–83	738	820	996	1100	1210	1290	1360	1430	1510
06017000	Beaverhead River at Dillon, MT	1965–71; 2002–16	331	425	721	970	1350	1690	2080	2520	3210
06016000	Beaverhead River at Barretts, MT	1965–2016	976	1050	1320	1560	1920	2250	2630	3070	3760
06015400	Beaverhead River near Grant, MT	1965–83	974	1000	1090	1150	1240	1310	1380	1460	1570

Figure 5 indicates peak discharges do not consistently increase with increasing drainage area, as typically expected. These inconsistences can be related to non-congruent periods of record, large flow diversions, or variability in flood storage. To address the non-congruent periods of record, the MOVE.3 (Maintenance of Variance Extension, Type 3) was used to extend the historical gage records. The MOVE.3 method correlates streamflow at a short-term gaging station with a longer term index gaging station using a base 10 logarithmic transformation. The Move.3 method can be used for record extension when a linear relationship exists between the logarithms of the same-year peak discharges at the target station and a nearby index station. A post-regulation base period of 1965-2016 was selected for the record extension. Regulation occurs in a basin when flood flows are altered by reservoir operations or other water resource control structures (such as diversion dams). In this flood frequency analysis, gages were defined as regulated when greater than 20% of the basin lies upstream from reservoirs. The Clark Canyon Reservoir at the headwaters of the Beaverhead River is formed by the Clark Canyon Dam. The earthfill dam was constructed between 1961 and 1964. The dam regulates the peak flows on the Beaverhead River for all the mainstem USGS gage stations starting in 1965. The USGS in consultation with DNRC determined that the regulation on the Beaverhead River was significant enough to affect peak flows.

Annual peak estimates from the MOVE.3 analysis were determined to be generally reasonable and consistent with recorded upstream and downstream peaks.

Table 8 summarizes the Beaverhead River gage analysis flood frequency estimates using the extended record. Figure 6 plots the extended record analysis results.

The peak flow flood frequency results shown in Figure 6 still exhibit significant attenuation indicating much of the attenuation observed in the systematic flood frequency estimates (Figure 5) was not associated with non-congruent periods of records. In some cases, the flood frequency estimates did not increase with increasing drainage areas. Systematic peak flow data from corresponding periods were inspected and it was determined that in many cases the peaks tended to attenuate in the downstream direction, thereby validating that the peak flow flood frequency estimates may not increase with increasing drainage areas. Between the gage at Barretts (06016000) and gage at Dillon (06017000) there are several major diversions from the Beaverhead River. The Barretts diversion downstream of the gage at Barretts includes the East Bench Canal and Canyon Ditch. Just upstream of the Dillon gage is the West Side Canal. In addition to the major diversions, several other small diversions exist and along with inflow from Rattlesnake Creek can affect the flow in this reach. The discharge capacities for the East Bench Canal and West Side Canal are 440 cfs and 160 cfs, respectively (Butler and Abdo, 2013). The combined potential discharge for these two canals (600 cfs) is approximately 23% of the base flood flow (2,630 cfs) at Barretts. The base flood flow decreases 300 cfs between Barretts and Dillon. In combination with the inflow from Rattlesnake Creek, the combined irrigation diversion flow magnitudes are large enough to account for magnitude of flow attenuation exhibited in the peak flow flood frequency estimates.

The extended gage record shows additional base flood attenuation of 370 cfs between the gage at Dillon and gage near Dillon (06018000). Blacktail Deer Creek flows into the Beaverhead River between these two gages. Six or more small diversion ditches remove flow from the mainstem within this reach as well. The Beaverhead River floodplain to the north includes several major sloughs, including Albers Slough that may provide significant floodplain storage. Albers Slough meets the Beaverhead River at Beaverhead Rock, immediately upstream from Beaverhead River near Twin Bridges (06018500). The multiple flow diversions, ponds and significant floodplain storage potentially accounts for the continued attenuation of mainstem peak flows. Once the Albers Slough reports to the Beaverhead River, peak flows once again increase at the Twin Bridges gage.

Flood frequency peak flow estimates using the extended record data set establishes a congruent period of record for the mainstem Beaverhead River stream gages. Using the extended record data set reduces the downstream attenuation magnitude observed in the systematic record flood frequency analysis and will minimize the potential error associated with non-congruent periods of record.

For these reasons, flood flow frequency estimates using the post-regulation 2016 extended record data set, were selected to represent the annual chance flood potential at the Beaverhead River gaged locations.

Blacktail Deer Creek includes a single gage located upstream from the study reach and city of Dillon. The gage includes 21 years of record, mostly in the 1940s and 1950s. USGS performed an analysis of the systematic record and also weighted the results using regional regression equations. The annual precipitation record in Dillon shows several years with above average precipitation in the mid-1990s and a few recent years (Butler and Abdo, 2013). Potential streamflow responses to these wet years would not be included in the systematic record. Weighting the peak-flow frequency estimates can reduce the uncertainty from the short and dated gage record for Blacktail Deer Creek (USGS in draft, 2016). Table 9 compares the results for the analysis. The weighted values are greater than the short systematic record. The weighted results potentially reduce the uncertainty and use regional regression equations that were updated based on data through 2011 (Sando et al, 2015). For these reasons, flood flow frequency estimates using the weighted data set, were selected to represent the annual chance flood potential at the Blacktail Deer Creek gage location.

Table 10 compares flood frequency estimates between the 2011 SIR 2015-5019-C analysis and this study's 2016 extended record analysis. The SIR 2015-5019-C flood frequency estimates are a systematic analysis based on the entire period of record. The 2016 flood frequency analysis is based on the congruent period of record 1965 to 2016; therefore, some differences between the 2011 and 2016 peak flow estimates can be attributed to the different period of records used in the analysis.

Figure 7 compares selected recurrence intervals from Table 10 for the five Beaverhead River gages. In general, differences between the 2011\2016 flood frequencies are most prevalent at

the discontinued gages at Grant (0601540) and near Dillon (06018000). These two gages were discontinued in 1983 so the record extension has the largest impact on the systematic data. The gage at Barretts (06016000) and gage near Twin Bridges (06018500) show the closest agreement for the two datasets. These two gages have the longest systematic dataset. The gage at Dillon (06017000) shows higher flow values for the 2016 analysis compared to the dataset through 2011. The 2011 systematic dataset for this gage is only 17 years of record. Other than the two discontinued gages, the other gages show increases or very similar values for the events compared to the 2011 values.

Table 8 Gage Flood Frequency Estimates Using Extended Record

Station Number	Station name	Analysis Period of Record	Peak discharge, (cfs), for indicated exceedance probability (%)								
			66.67	50	20	10	4	2	1	0.5	0.2
			Peak discharge (cfs), for indicated return interval (years)								
			1.5	2	5	10	25	50	100	200	500
06018500	Beaverhead River near Twin Bridges, MT	1965-2016	562	696	1,050	1,300	1,620	1,870	2,120	2,380	2,730
06018000	Beaverhead River near Dillon, MT	1965-2016	465	585	914	1,150	1,460	1,710	1,960	2,230	2,590
06017000	Beaverhead River at Dillon, MT	1965-2016	444	575	952	1,240	1,650	1,980	2,330	2,710	3,260
06016000	Beaverhead River at Barretts, MT	1965-2016	976	1,050	1,320	1,560	1,920	2,250	2,630	3,070	3,760
06015400	Beaverhead River near Grant, MT	1965-2016	828	889	1,100	1,280	1,570	1,820	2,120	2,460	2,990

Table 9 Blacktail Deer Creek Gage Flood Frequency Estimates

Station Number	Station name	Type of Peak Flow Estimate	Peak discharge, (cfs), for indicated exceedance probability (%)								
			66.67	50	20	10	4	2	1	0.5	0.2
			Peak discharge (cfs), for indicated return interval (years)								
			1.5	2	5	10	25	50	100	200	500
06017500	Blacktail Deer Creek near Dillon, MT	At-site	161	203	324	417	548	655	771	897	1,080
06017500	Blacktail Deer Creek near Dillon, MT	RRE wtd	165	210	341	447	602	735	884	1,050	1,290

Figure 6 USGS Flood Frequency Estimates Extended Record (1965-2016)

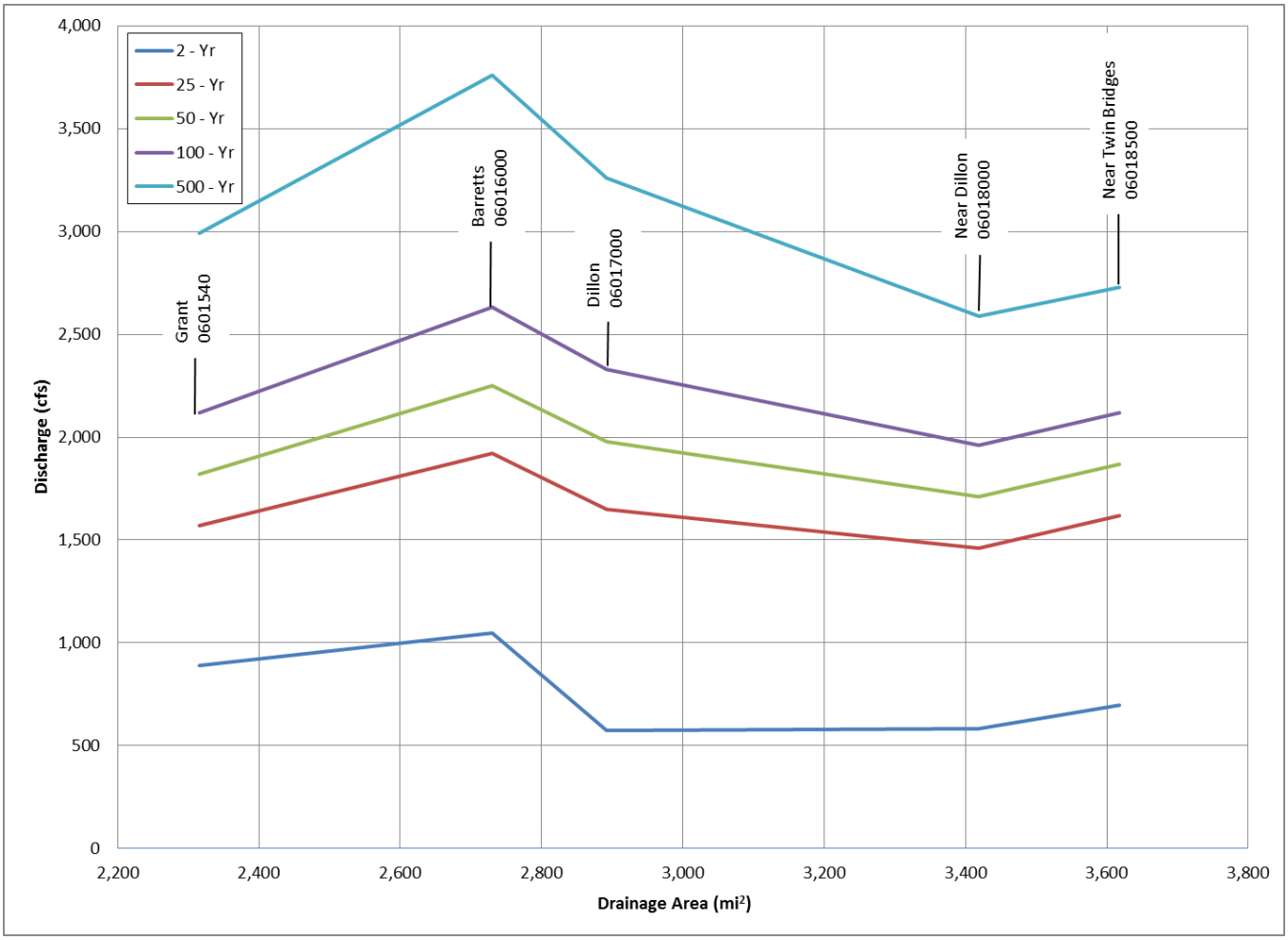


Figure 7 USGS Flood Frequency Estimates Comparison 2011 and 2016

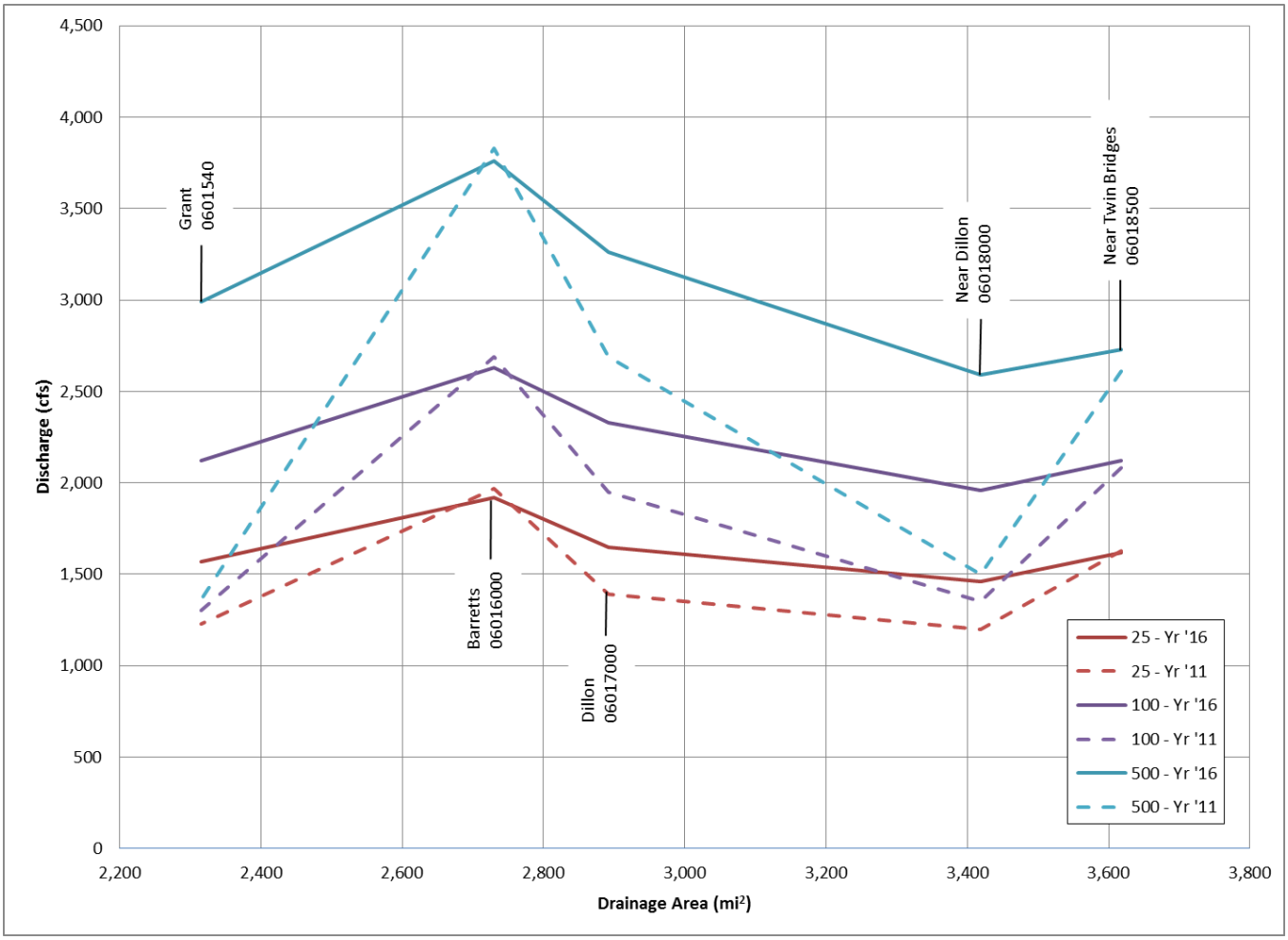


Table 10 USGS Flood Frequency Estimate Comparison 2011 and 2016

Station Number	Station Name	Peak Discharge, for Return Interval (years) (cfs)													
		5		10		25		50		100		200		500	
		2011	2016	2011	2016	2011	2016	2011	2016	2011	2016	2011	2016	2011	2016
06018500	Beaverhead River near Twin Bridges, MT	1,090	1,050	1,330	1,300	1,630	1,620	1,860	1,870	2,080	2,120	2,310	2,380	2,610	2,730
06018000	Beaverhead River near Dillon, MT	991	914	1,090	1,150	1,200	1,460	1,280	1,710	1,350	1,960	1,420	2,230	1,500	2,590
06017000	Beaverhead River at Dillon, MT	812	952	1,060	1,240	1,390	1,650	1,660	1,980	1,950	2,330	2,260	2,710	2,690	3,260
06016000	Beaverhead River at Barretts, MT	1,360	1,320	1,600	1,560	1,970	1,920	2,300	2,250	2,690	2,630	3,130	3,070	3,830	3,760
06015400	Beaverhead River near Grant, MT	1,120	1,100	1,170	1,280	1,230	1,570	1,270	1,820	1,300	2,120	1,330	2,460	1,360	2,990
06017500	Blacktail Deer Creek near Dillon, MT	301	324	384	417	503	548	603	655	713	771	834	897	1,010	1,080

Table 11 compares the results of the 1982 Beaverhead FIS study peak flow estimates with the peak estimates from the USGS flood frequency estimates using the extended gage records through 2016. Review of Table 11 indicates the FIS and USGS 2016 peak flow estimates are similar at the Barretts gage above Rattlesnake Creek (less than 10% difference) for all the recurrence intervals. The differences increase above and below the Beaverhead River confluence with Blacktail Deer Creek. In general the flows are lower using the USGS extended gage analysis through 2016 compared to the values published in the Beaverhead FIS (FEMA, 1982). These observed differences are likely related to the greater period of record data set used in the USGS 2016 analysis compared with the 1982 FIS data set.

Table 11 Beaverhead FIS Flood Frequency Estimate Comparison

Flooding Source and Location	Drainage Area[1] Square Miles	USGS Gage Drainage Area Square Miles	Peak Discharges (cfs)							
			10-Year		50-Year		100-Year		500-Year	
			FIS	2016	FIS	2016	FIS	2016	FIS	2016
Above Rattlesnake Creek / Beaverhead River at Barretts (06016000)	2,753	2,730	1,450	1,560	1,950	2,250	2,400	2,630	4,100	3,760
Below Rattlesnake Creek	2,884	NA	1,500	NA	2,250	NA	2,900	NA	5,200	NA
Above Blacktail Deer Creek / Beaverhead River at Dillon (06017000)	2,895	2,892	1,400	1,240	2,300	1,980	2,800	2,330	5,000	3,260
Below Blacktail Deer Creek / Beaverhead River near Dillon (06018000)	3,337	3,419	1,850	1,150	2,900	1,710	3,500	1,960	6,200	2,590

1. Source: Flood Plain Information – Beaverhead River (USACE, 1975)

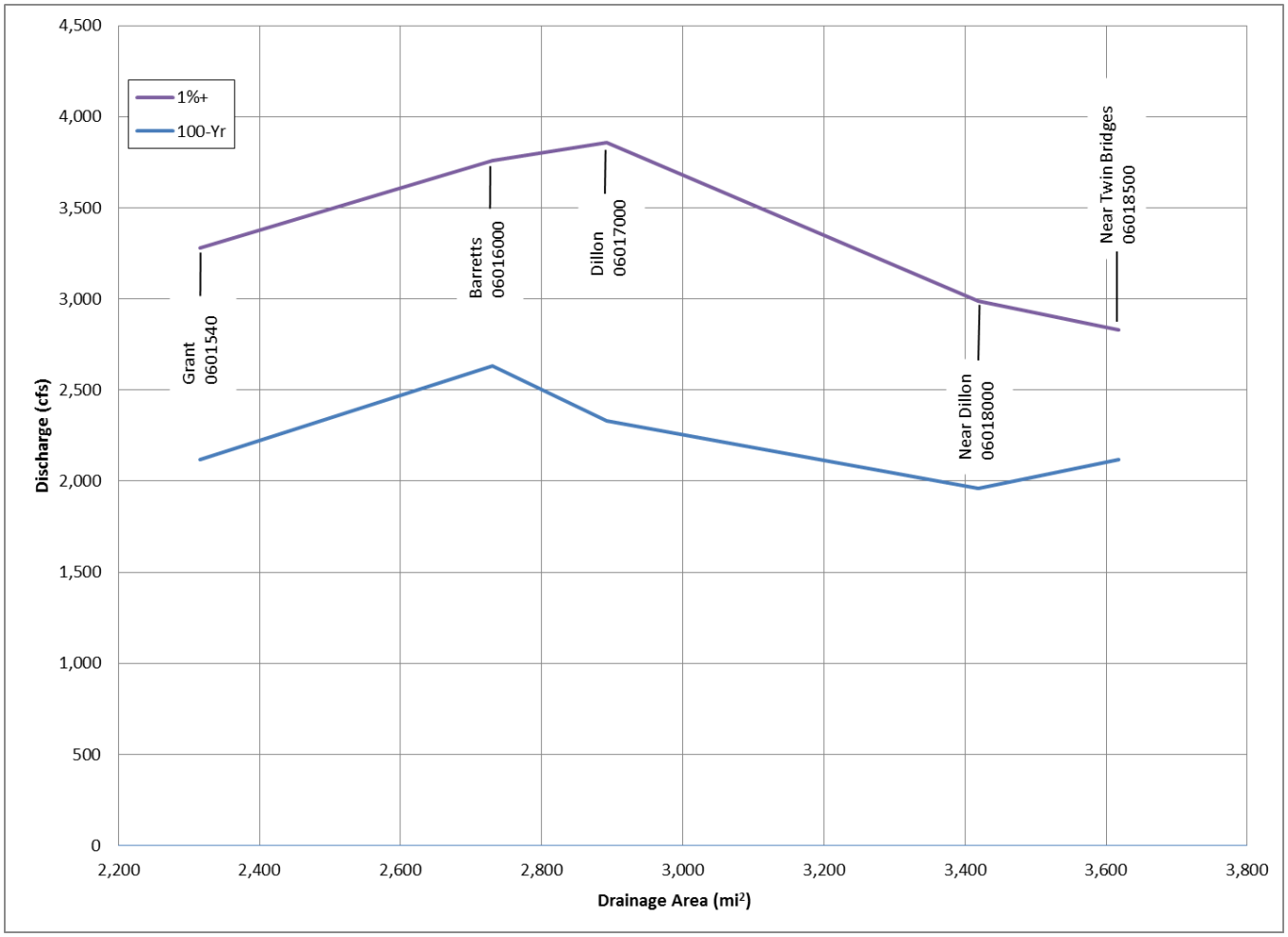
3.1.1 1% + Peak Flow Estimates

The 1%+ percent annual exceedance probability event was calculated to provide a confidence range that the 1% flood frequency peak flow estimates are likely to fall within. The flood-frequency estimates equations include an “average standard error of prediction” or “average standard error of estimate” percentage that was used to define its statistical 68% confidence interval (+/- one standard deviation). The resulting upper 84% confidence limit (+ one standard deviation) was used to determine the 1% + flood frequency peak flow estimates. The Beaverhead River 1%+ flood frequency peak flow estimates are based on the extended record 1% estimates presented in Table 8. For Blacktail Deer Creek, the 1%+ flood frequency peak flow estimate is based on the weighted “RRE wtd” 1% estimate presented in Table 9.

Table 12 USGS 1%+ Flood Frequency Estimates 2016

Station Number	Station Name	1% + Annual Exceedance Probably Peak discharge, (cfs)
06018500	Beaverhead River near Twin Bridges, MT	2,830
06018000	Beaverhead River near Dillon, MT	2,990
06017000	Beaverhead River at Dillon, MT	3,860
06016000	Beaverhead River at Barretts, MT	3,760
06015400	Beaverhead River near Grant, MT	3,280
06017500	Blacktail Deer Creek near Dillon, MT	1,350

Figure 8 USGS 1%+ Flood Frequency Estimates 2016



3.2 Flow Change Node Locations

Future flood studies will use hydraulic models that are composed of geometric data and streamflow data. To accurately model the Beaverhead River and Blacktail Deer Creek, the locations of major tributary confluences and other flow change locations must be identified. The results of this hydrologic analysis will be used as the streamflow data input at the tributary confluences within the hydraulic model. A detailed review of the study area was performed to identify all potential flow change locations (flow nodes) within the mainstem Beaverhead River and Blacktail Deer Creek. At each flow node, a drainage basin area was delineated and streamflow values were calculated for the various recurrence interval floods. Generally, the hydraulic models simulate flood events using steady-state conditions, and, therefore, the peak flow rate calculated at a flow node is projected to the next upstream flow node. This method was followed for the hydrologic analysis calculations. Flow nodes were assigned immediately upstream of major tributaries; this method of locating the flow nodes was employed so that the additional flow resulting from the tributary confluence is accurately reflected to the reach downstream of the confluence.

To identify significant flow change locations (flow nodes), hydrologic Unit Code (HUC) 12-digit watershed boundaries were used to initially locate the flow nodes. The HUC 12-digit watershed boundaries represent the smallest USGS-delineated watershed areas available in geographic information system (GIS) format. Using ArcGIS (Esri's GIS mapping software), flow nodes were located just upstream of the HUC 12 boundary intersection with the Beaverhead River mainstem.

This study uses the nearest Geographic Naming Information System (GNIS) hydrographic feature name for the ungaged flow node names. In some cases these features (typically tributary streams) flow into the mainstem Beaverhead River just downstream of the flow node. For hydrographic features that do not have a GNIS name, the river mile where the node is located is used as the node name.

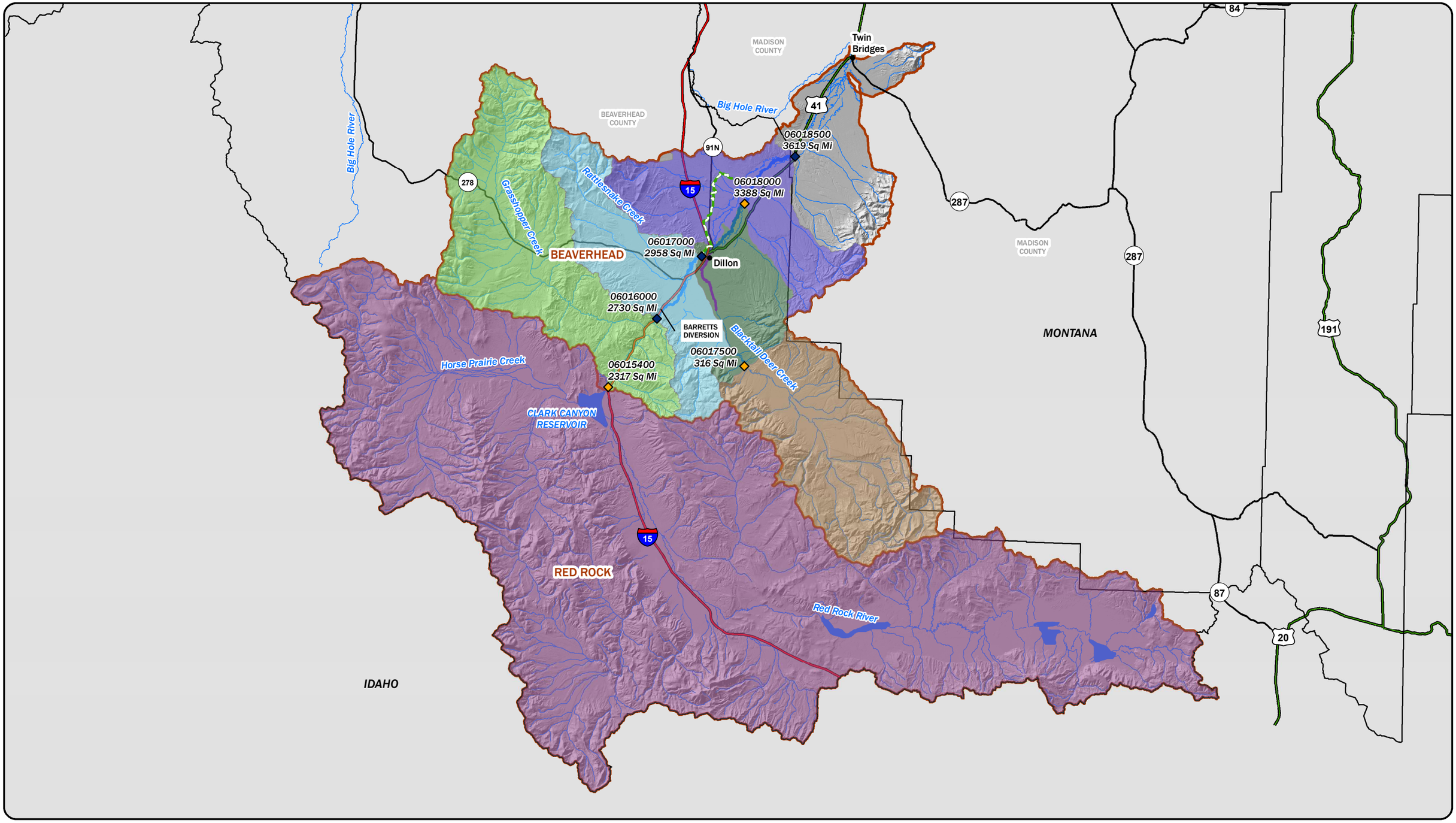
To avoid excessive flow changes between HUC 12 boundary nodes, additional flow nodes were located immediately downstream of towns, at the end of study reaches, at county borders, or where intermediate tributaries within the HUC 12 boundaries intersected the mainstem. One flow node was added downstream of Dillon. A total of 3 flow nodes were added as intermediate nodes between the HUC 12 boundaries. These town nodes and intermediate nodes are identified in Table 14.

The USGS NWIS watershed area data are GIS-calculated watershed areas using the National Hydrography Dataset Plus Version2 (NHDPlusV2) that integrates the National Elevation Dataset (NED) and the Watershed Boundary Dataset. The NHDPlusV2 NED uses 30-meter resolution DEMs. ESRI processed NHDPlus V2.1 and NED 30-meter DEMs to support the ESRI Watershed tool. The ESRI hydroconditioning process differs from the NHDPlus V2.1 process so the resulting watershed delineations do not always match the USGS delineations. In some cases, low gradient topography along with irrigation channels produced erroneous watershed boundaries that were

developed using GIS raster models. Where GIS raster models produced erroneous watershed boundaries, the HUC-12 polygons were used to calculate watershed areas.

As an accuracy check, the USGS gaging station watershed areas calculated using the Watershed tool or HUC-12 polygons, were compared to the USGS National Watershed Information System (NWIS) (http://waterdata.usgs.gov/nwis) published gaging station areas. Figure 9 shows the USGS gaging stations analyzed and the correlating GIS model-generated watershed areas within the study area. Table 13 shows the results of this comparison. Based on the 6 gaging stations analyzed, the ESRI GIS model calculates watershed areas that are within 1% of the USGS NWIS published areas except for the Beaverhead River at Dillon (06017000) gage (Appendix A). The GIS generated USGS watershed area boundary for this gage is aligned along a diversion ditch that intercepts flow and does not report to the Beaverhead River. LiDAR contours and elevations were reviewed along with the irrigation channel geometry and it was determined the USGS NWIS area was in error. Therefore the gage watershed area used for this analysis increases the drainage area upgradient from the diversion ditch by using the HUC-12 polygon, resulting in an area increase of 2.3%.

A total of 10 flow nodes were identified throughout the study reach, including 6 gaged locations and 4 ungaged locations. Table 14 is a summary of all flow nodes and the associated watershed areas. Figure 10 maps the flow node locations and corresponding watershed areas from Table 14.



LEGEND

- TOWNS
- MONTANA COUNTY BOUNDARIES
- ACTIVE USGS GAGE
- INACTIVE USGS GAGE
- WEST SIDE CANAL (APPROX.)
- HUC 8 BOUNDARIES
- BLACKTAIL DEEK CREEK STUDY REACH
- BEAVERHEAD RIVER STUDY REACH

USGS STATION
06017000
06017500
06018000
06015400
06018500
06016000

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATE PLANE
DATUM: NAD 1983
UNITS: INT'L FEET
SOURCE: PIONEER, MSL, USGS

0 4.5 9 18
Miles

FIGURE 9

PIONEER TECHNICAL SERVICES, INC.

BEAVERHEAD RIVER & BLACKTAIL DEER CREEK USGS WATERSHEDS

DATE: 3/27/2017

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Table 13 USGS and GIS Model Watershed Comparison

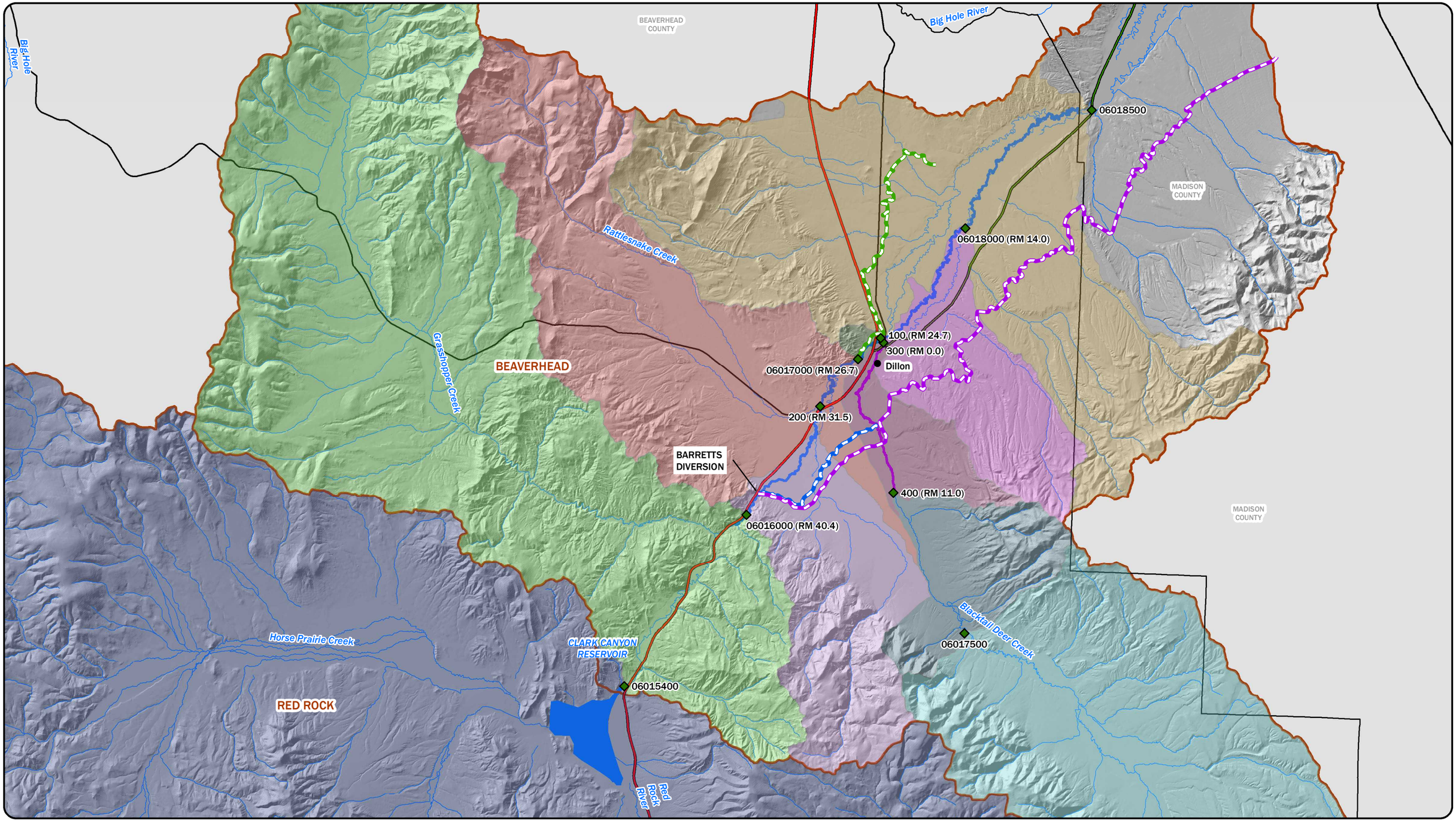
USGS Gage Station	Station Name	USGS Published Basin Area[1] (mi2)	Proposed Basin Area[2] (mi2)	Percent Change	Relative Accuracy of Areas
06018500	Beaverhead River near Twin Bridges, MT	3,618	3,619	-0.02%	100.0%
06018000	Beaverhead River near Dillon, MT	3,419	3,388	0.91%	99.1%
06017000	Beaverhead River at Dillon, MT	2,892	2,958	-2.29%	97.7%
06016000	Beaverhead River at Barretts, MT	2,730	2,730	0.00%	100.0%
06015400	Beaverhead River near Grant, MT	2,316	2,317	-0.02%	100.0%
06017500	Blacktail Deer Creek near Dillon, MT	316	316	-0.06%	99.9%

1. Source: National Watershed Information System (NWIS)
2. Cumulative basin areas (watershed areas) used for hydrological analysis.

Table 14 Flow Node and USGS Gage Station Information Used in Hydrologic Analyses

Node/USGS Station ID	Location Description	County	River Station[2] (mi)	GIS Incremental Basin Area (mi^2)	GIS Cumulative Basin Area (mi^2)
06015400	**Beaverhead River near Grant, MT**	**Beaverhead**		**2317**	**2317**
06016000	**Beaverhead River at Barretts, MT**	**Beaverhead**	40.4	**413**	**2730**
200[1]	Above Rattlesnake Creek	Beaverhead	31.5	71	2801
06017000	**Beaverhead River at Dillon, MT**	**Beaverhead**	**26.7**	**157**	**2958**
100[1]	Above Blacktail Deer Creek	Beaverhead	24.7	2	2960
06018000	**Beaverhead River near Dillon, MT**	**Beaverhead**	**14**	**428**	**3388**
06018500	**Beaverhead River near Twin Bridges, MT**	**Madison**		**231**	**3619**
06017500	**Blacktail Deer Creek near Dillon, Montana**	**Beaverhead**		**316**	**316**
400	Upstream extent of study area	Beaverhead	11.0	38	354
300	Confluence with Beaverhead River	Beaverhead	0	23	377

1. Denotes an additional flow node change downstream of a town reach or intermediate tributary not associated with HUC-12 boundary
2. River miles start at the downstream extent of each study reach (mi: miles)



LEGEND

- FLOW NODE (RIVER MILE)
- TOWNS
- MONTANA COUNTY BOUNDARIES
- CANYON DITCH (APPROX.)
- EAST BENCH CANAL (APPROX.)
- WEST SIDE CANAL (APPROX.)
- HUC 8 BOUNDARIES
- BLACKTAIL DEEK CREEK STUDY REACH
- BEAVERHEAD RIVER STUDY REACH

FLOW CHANGE BASIN/ USGS BASIN

- 06017500
- 400
- 300
- 06015400
- 06016000
- 200
- 06017000
- 100
- 06018000
- 06018500

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATE PLANE
DATUM: NAD 1983
UNITS: INT'L FEET
SOURCE: PIONEER, MSL, USGS

0 2 4 8
Miles

FIGURE 10

PIONEER TECHNICAL SERVICES, INC.

DELINEATED SUB BASIN AREAS AND FLOW NODE NOCATIONS

DATE: 3/27/2017

Path: G:\DNRC\Mineral -Beaverhead County\Beaverhead County\CAD-GIS\GIS\BVRHD-GI-HYD-003-17.mxd

3.3 Gage Transfer to Ungaged Sites

To calculate peak flood discharge estimates at the ungaged flow nodes, methods described in USGS SIR 2015-5109-F (Sando R, et al, 2015) were considered. These methods included estimating flood frequency using regional flood-frequency relations (regression analysis) and estimating flood frequency on gaged streams by translating gaged data to ungaged locations (drainage area gage transfer and logarithmic interpolation between two gaged sites).

The hydrologic regions defined in SIR 2015-5019-F indicate the Beaverhead River flows through the Southwest Region. Most of the mainstem Beaverhead River flow nodes are classified as affected by major regulation due to the Clark Canyon Dam. The SIR 2015-5019-F report indicates that using the regional regression equations on regulated streams might not be reliable and is not recommended. Additionally, the SIR 2015-5019-F report states that regression equations are possibly not reliable for an ungaged site that is outside the range of values used to develop the equations. The ungaged Beaverhead River flow node drainage areas are outside the range of values used to develop the Southwest Region regressions equations. Therefore, the regional regression equations were determined to be not applicable to the ungaged sites on the mainstem Beaverhead River.

Numerous USGS gaging stations are located on the mainstem Beaverhead River and all the ungaged Beaverhead River flow nodes are located between two gaging stations. Therefore the two site logarithmic interpolation method will be used to estimate peak flows at ungaged flow nodes on the Beaverhead River.

The ungaged flow nodes on Blacktail Deer Creek are located downstream of a single gage site. Therefore the two site logarithmic interpolation method is not applicable to the Blacktail Deer Creek Study reach. The ungaged flow node drainage areas meet the SIR 2015-5019-F guidance criteria for the drainage area gage transfer method (i.e. are within the ratio of 1.5 to 0.5 of the gage drainage area). Therefore the drainage area gage transfer method peak can be used to calculate peak flow frequency estimates at ungaged flow nodes on the Blacktail Deer Creek Study reach.

In addition to the drainage area gage transfer method, the regional regression method is also applicable to the Blacktail Deer Creek Study reach. The Blacktail Deer Creek drainage is not considered regulated and flow nodes within the Southwest Region have watershed areas that are within the watershed area limits as defined by SIR 2015-5019-F. Therefore it was determined that regional regression equations are applicable to the Blacktail Deer Creek study reach and will be used in addition to the drainage area transfer method to develop peak flow estimates for ungaged flow nodes.

3.3.1 Two Site Logarithmic Interpolation Method

The log interpolation method presented in SIR 2015-5019-F was used for analysis on ungaged sites between two gaged sites. In this method, the logarithm of the flood-frequency discharge estimates at the ungaged site is linearly interpolated based on discharge estimates and drainage basin areas of the upstream and downstream gaged sites. This method is presented in the equation below from SIR 2015-5019-F:

$$\log Q_{AEP,U} = \log \mathrm{Q}_{AEP,G1} + \frac{\log \mathrm{Q}_{AEP,G2} - \log \mathrm{Q}_{AEP,G1}}{\log \mathrm{DA}_{G2} - \log \mathrm{DA}_{G1}} (\log \mathrm{DA}_U - \log \mathrm{DA}_{G1})$$

where

log	is the base 10 logarithm
$Q_{AEP,U}$	is the AEP-percent peak flow at the ungaged site, in cfs
$Q_{AEP,G1}$	is the AEP-percent peak flow at the upstream gaged site, in cfs
$Q_{AEP,G2}$	is the AEP-percent peak flow at the downstream gaged site, in cfs
DA_{G2}	is the drainage area at the downstream gaged site, in square miles
DA_{G1}	is the drainage area at the upstream gaged site, in square miles
DA_U	is the drainage area at the ungaged site, in square miles

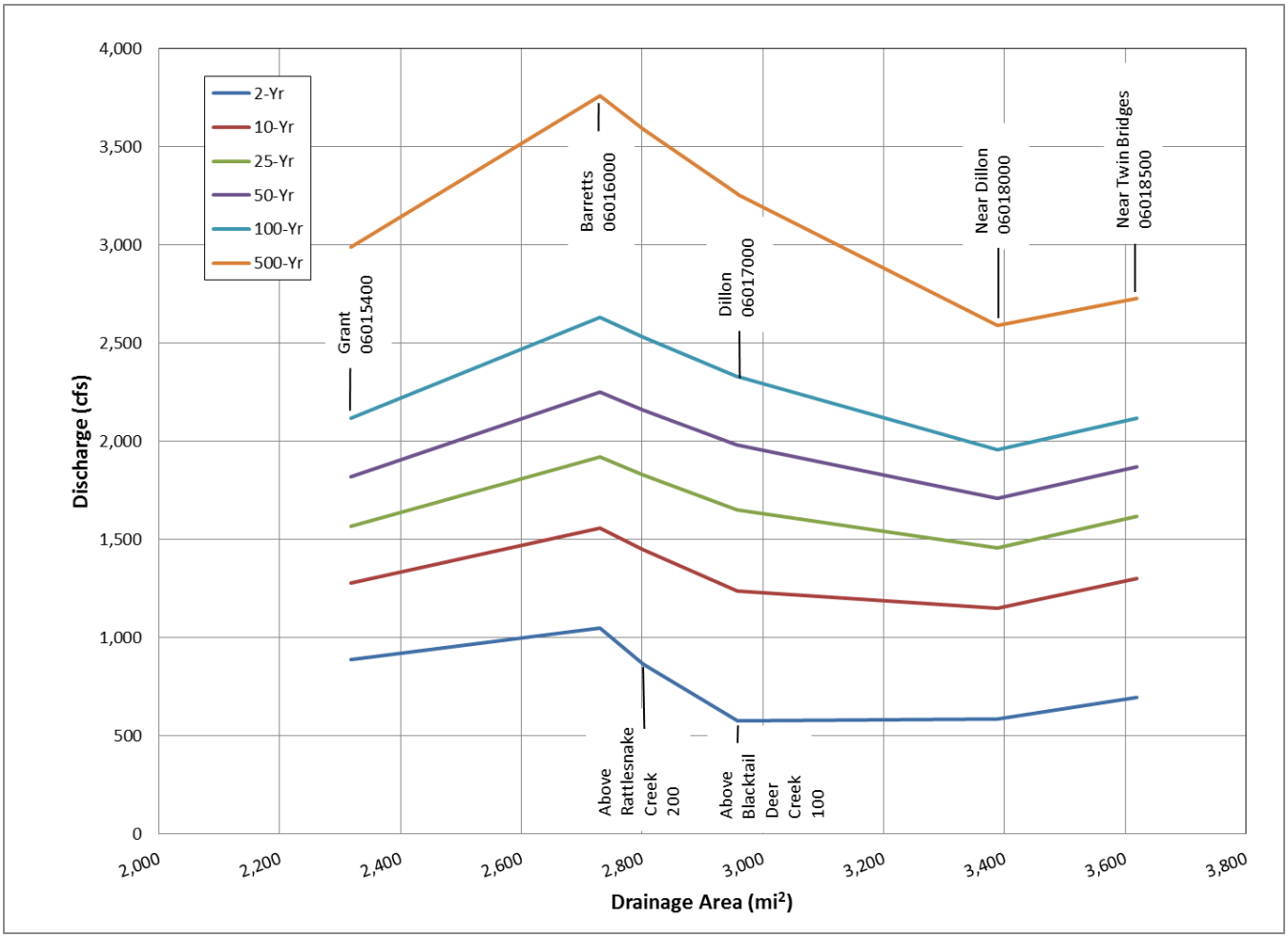
Table 15 shows the Beaverhead River calculation results. Figure 11 plots the relationship between the calculated discharge estimates and correlating drainage area. Results indicate estimated flows at the ungaged flow nodes are consistent with the gage site estimates and reach attenuation trends observed in the gaged sites data.

Table 15 Log Interpolation of 2016 Extended Period of Record Gage Results to Ungaged Flow Nodes

Node/USGS Station ID	Location Description	Log Interpolation of Gaged Analysis						
		Discharge (cfs)						
		50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% +
		2-year	10-year	25-year	50-year	100-year	500-year	
06015400	**Beaverhead River near Grant, MT**	**889**	**1,280**	**1,570**	**1,820**	**2,120**	**2,990**	**3,280**
06016000	**Beaverhead River at Barretts, MT**	**1,050**	**1,560**	**1,920**	**2,250**	**2,630**	**3,760**	**3,760**
200	Above Rattlesnake Creek	866	1,449	1,829	2,160	2,530	3,592	3,792
06017000	**Beaverhead River at Dillon, MT**	**575**	**1,240**	**1,650**	**1,980**	**2,330**	**3,260**	**3,860**
100	Above Blacktail Deer Creek	575	1,240	1,649	1,979	2,328	3,256	3,855
06018000	**Beaverhead River near Dillon, MT**	**585**	**1,150**	**1,460**	**1,710**	**1,960**	**2,590**	**2,990**
06018500	**Beaverhead River near Twin Bridges, MT**	**696**	**1,300**	**1,620**	**1,870**	**2,120**	**2,730**	**2,830**

* Sites on Blacktail Deer Creek were not included in the log linear interpolation method calculations.

Figure 11 Beaverhead River Log Interpolation Gage Analysis Results



3.3.2 Drainage Area Gage Transfer Method

Ungaged flow nodes located downstream of the Blacktail Deer Creek Gaging Station 06017500 near Dillon do not lie between two gaged stations on the same stream, therefore, the two site interpolation method cannot be employed. Estimating flood-frequency discharges for the ungaged flow nodes downstream of USGS Gaging Station 06017500 requires using the drainage area gage transfer method. This method, presented in SIR 2015-5019-F, uses a drainage area ratio of the ungaged flow node to the gaged station to transfer flow estimates from the gaged site to the ungaged site as shown below in the following equation (Sando R. et al, 2015):

$$Q_{AEP,U} = Q_{AEP,G}\left(\frac{\mathrm{DA}_U}{\mathrm{DA}_G}\right)^{\exp_T}$$

where

$Q_{T,U}$ is the AEP-percent peak flow at the ungaged site, in cfs

$Q_{T,G}$ is the AEP-percent peak flow at the gaged site, in cfs

DA_G is the drainage area at the gaged site, in square miles

DA_U is the drainage area at the ungaged site, in square miles

$\exp_T$ is the regression coefficient for a simple OLS regression relating to the log of the AEP-percent peak flow to log of drainage area within each region

Limitations for this method include a recommended drainage area ratio between 0.5 and 1.5. All flow node drainage area ratios were verified to be within the recommended range.

Regression coefficients shown in the equation above vary based on the hydrologic region and the AEP. The applicable regression coefficients provided in Table 16 were used in these calculations. The drainage area transfer method results are shown in Table 17, and Figure 12.

Results indicate Blacktail Deer Creek estimated peak flow magnitudes are reasonable in comparison with the mainstem Beaverhead River estimated peak flow magnitudes and increase with increasing drainage area.

Table 16 Drainage Area Gage Transfer Regression Coefficients

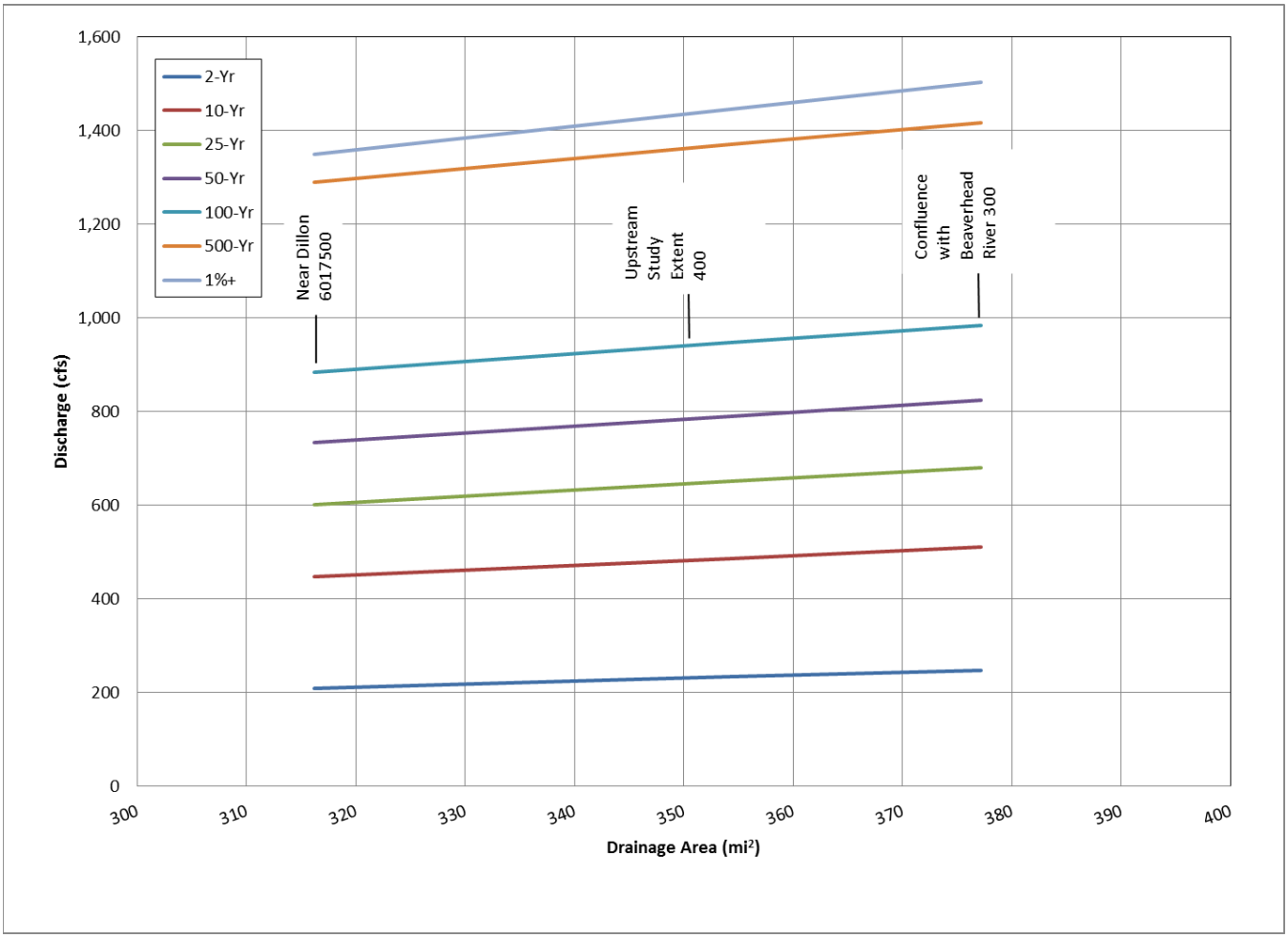
AE-percent Peak Flow	Regression Coefficient Relating AEP Flows to Drainage Area for Southwest Region
Q_{50}	0.939
Q_{10}	0.755
Q_4	0.690
Q_2	0.647
Q_1	0.609
$Q_{0.2}$	0.533

Source: SIR 2015-5019-F

Table 17 Drainage Area Gage Transfer Method Results for Blacktail Deer Creek Flow Node Locations Downstream of USGS Gage 06017500

Node/USGS Station ID	Location Description	Drainage Area Gage Transfer						
		Discharge (cfs)						
		50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% +
		2-year	10-year	25-year	50-year	100-year	500-year	
06017500	**Blacktail Deer Creek near Dillon, Montana**	**210**	**447**	**602**	**735**	**884**	**1,290**	**1,350**
400	Upstream extent of study area	234	487	651	791	947	1,370	1,447
300	Confluence with Beaverhead River	248	511	680	824	984	1,417	1,503

Figure 12 Blacktail Deer Creek Drainage Area Gage Transfer Results



3.3.3 Regional Regression Equations Method

Ungaged flow nodes located downstream of the Blacktail Deer Creek Gaging Station 06017500 near Dillon are not regulated and are within the drainage areas supported by the Southwest Region regression equations. The regression equations, presented in SIR 2015-5019-F, uses a drainage area (A) and percent of basin area above 6,000 feet (E_{6000}) as shown below in the following set of equations (Sando R. et al, 2015):

$$Q_{50} = 2.49A^{0.930}(E_{6000}+1)^{0.095}$$
$$Q_{10} = 31.9A^{0.796}(E_{6000}+1)^{-0.177}$$
$$Q_{4} = 79.8A^{0.750}(E_{6000}+1)^{-0.274}$$
$$Q_{2} = 142A^{0.721}(E_{6000}+1)^{-0.336}$$
$$Q_{1} = 238A^{0.696}(E_{6000}+1)^{-0.391}$$
$$Q_{0.2} = 655A^{0.649}(E_{6000}+1)^{-0.501}$$

where

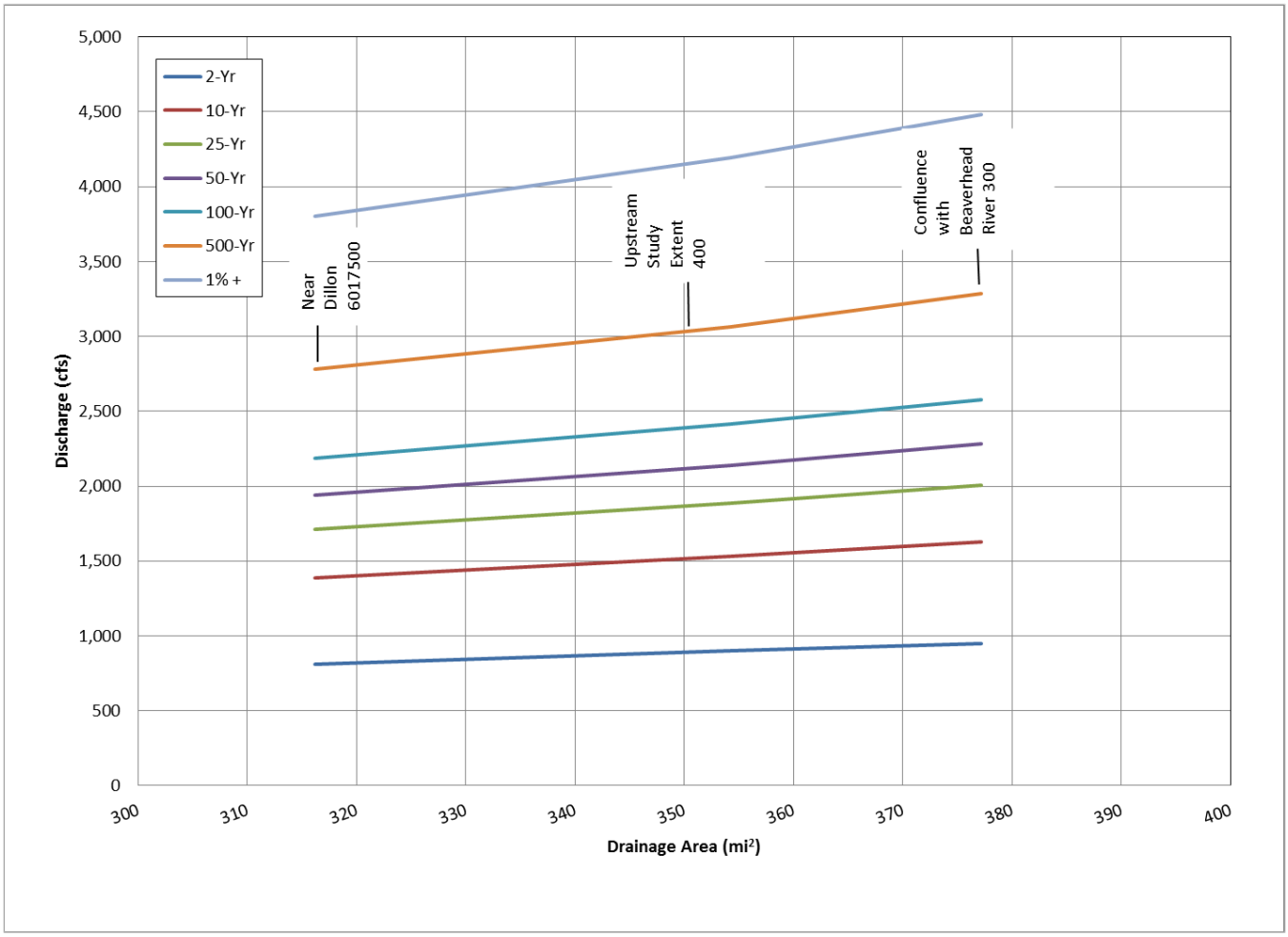
Q_x is the X annual exceedance probability peak flow magnitude, in cfs

A is the contributing drainage area, in square miles

E_{6000} is the percent of basin area above 6000 feet

The Southwest Region regression equation results are shown in Table 18, and Figure 13 shows the plot for the calculated peak discharges and correlating drainage areas. Appendix B provides the flood frequency calculations at the ungaged flow nodes.

Figure 13 Blacktail Deer Creek Regional Regression Equation Results



Regional regression calculation results indicate peak flow estimates are significantly greater than the drainage area gage transfer results and are similar in magnitude to the Beaverhead River peak flow estimates. The Beaverhead River peak flows that are similar in magnitude to the Blacktail Deer Creek regional regression peak flow estimates, are associated with much larger watershed areas than the Blacktail Deer Creek flow estimates. Due to the multiple gages on the

Beaverhead River mainstem, the Beaverhead River peak flow estimates are considered more accurate than the regression-based Blacktail Deer Creek peak flow estimates. The Blacktail Deer Creek regional regression peak flow estimates are not consistent with the mainstem Beaverhead River peak flow hydrology (i.e. the smaller Blacktail Deer Creek watershed should be producing significantly smaller peak flows than the mainstem Beaverhead River) or the Blacktail Deer Creek drainage area gage transfer results. Therefore Blacktail Deer Creek regional regression peak flow estimate were eliminated from further consideration.

Table 18 Blacktail Deer Creek Regression Results for Ungaged Flow Node Locations

Node/USGS Station ID	Location Description	Regional Regression Equations						
		Discharge (cfs)						
		50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% +
		2-year	10-year	25-year	50-year	100-year	500-year	
06017500	**Blacktail Deer Creek near Dillon, Montana**	**210**	**447**	**602**	**735**	**884**	**1,290**	**1,350**
400	Upstream extent of study area	899	1,532	1,886	2,138	2,413	3,064	4194
300	Confluence with Beaverhead River	948	1,627	2,008	2,281	2,578	3,283	4480

Appendix B provides the all flood frequency calculations at the ungaged flow nodes for both the Beaverhead River Study reach and the Blacktail Deer Creek Study reach. Appendix C provides the digital calculation files.

4 SUMMARY/DISCUSSION

A peak discharge frequency analysis was conducted for the mainstem Beaverhead River study reach and the Blacktail Deer Creek Study reach. The Beaverhead River Study reach extends 41.4-miles upstream from the Beaverhead/Madison County Boundary. The Blacktail Deer Creek Study area extends 11-miles upstream from the confluence with the Beaverhead River. Information gathered from this analysis will be used to support the Beaverhead County hydraulic analyses and floodplain mapping studies.

Previous flood studies on the Beaverhead River are limited. The most relevant earlier flood study was the City of Dillon and Beaverhead County FIS (Beaverhead FIS) (FEMA, 1982). The USGS WRIR 03-4308, published in 2004 was also an important study which included flood frequency analysis for multiple Beaverhead River gaging stations. The results of these previous studies were compared with the results of this study.

Flood frequency estimates for both gaged and ungaged sites were conducted. Peak flow estimates were calculated at 10 mainstem locations (flow nodes) within the watershed (6 gaged sites and 4 ungaged sites).

At the gaged sites, flood frequency estimates were conducted using two different gage record data sets; a systematic data set through 2016 and an extended record data set, 1965-2016. The flood flow frequency estimates were calculated using Bulletin #17C methodologies.

The Beaverhead River systematic record data set had variable and discontinuous periods of record between the stream gages and produced results where flood discharge did not always increase with increasing drainage area. To address these non-congruent periods of record, data extension methods were used to extend the historical gage records and create an extended record data set.

Flood flow frequency results from this study were compared with flood flow frequency estimates from the previous studies. In the Beaverhead River watershed, the flood flow frequency estimates from this study produced significantly lower peak discharge estimates at the 1% and 0.2% annual chance flood potential than the 1982 FIS. In the middle and lower watershed reaches, the significant differences in peak flow estimates between this study and previous studies can be attributed to the longer gage record and periods of lower flows.

The flood flow frequency estimates based on the gage extended record data set were determined to provide the most accurate peak flow estimates for the Beaverhead River basin, due to the long congruent period of record, which minimized errors associated with non-congruent periods of gage records. The flood flow frequency estimates based on the weighted gage record were determined to provide the most appropriate peak flow estimates for the

Blacktail Deer Creek basin, due to the recorded flows and larger regression dataset, which minimized errors associated with a short, discontinued and older gage record.

Flood flow frequency estimates were also developed at 4 ungaged locations. The ungaged sites (flow nodes) were located at major tributaries, population centers, and at the end of study reaches.

Peak flow 1%+ (plus) estimates were developed for all gaged locations using standard FEMA methodologies.

Three methods were considered for estimating peak flood discharges at ungaged flow nodes: 1) Regional Regression; 2) Two Station Logarithmic Interpolation method; and 3) the Drainage Area gage transfer method.

The regional regression method for ungaged flow nodes was not selected for the Beaverhead River Study reach due to the regulated classification for most of the Beaverhead River mainstem gages. In the Blacktail Deer Creek Study reach, both the regional regression method and the drainage area gage transfer analysis were used to calculate flood frequency peak flow estimates. It was determined that the Blacktail Deer Creek regional regression peak flow estimates produced results that were significantly greater than peak flow estimates using gage data. Due to the higher confidence associated with flood frequency estimates that are based on measured stream flows, the regional regression method for peak flow estimates was eliminated from further consideration.

The Two Station Logarithmic Interpolation method was used on 2 ungaged flow nodes on the Beaverhead River.

As stated previously, the drainage area gage transfer method was used on the 2 flow nodes located downstream of USGS Gaging Station 06017500 Blacktail Deer Creek near Dillon. This method was required for the downstream flow nodes because only a single gage record is available for Blacktail Deer Creek.

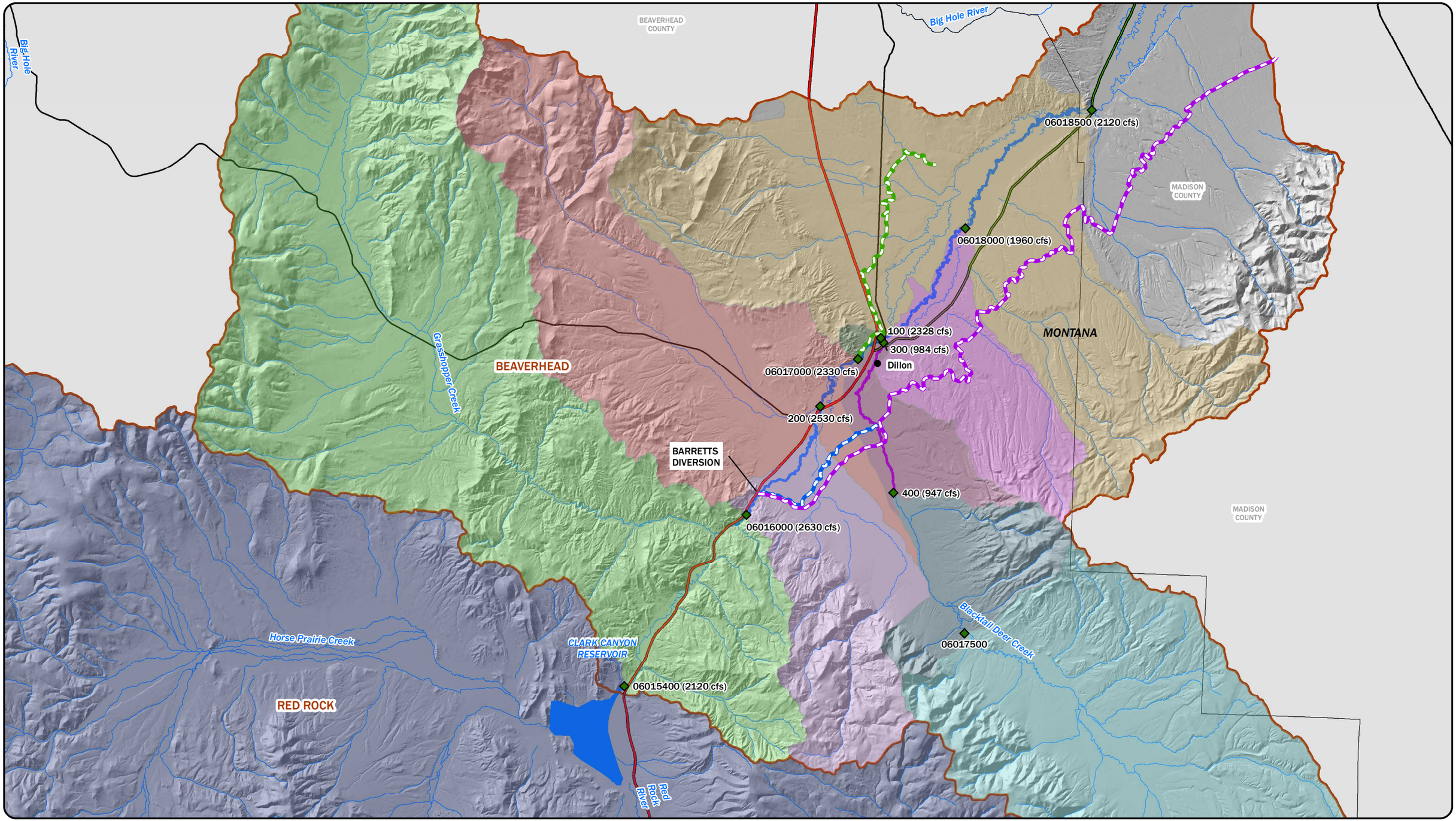
Table 19 summarizes the recommended flood frequency discharge rates for the Beaverhead River and the Blacktail Deer Creek Study reaches. Figure 14 shows the recommended 1% annual discharge for each flow node location.

The hydrologic analysis results provided in Table 19 represent the recommended discharges at each flow node location throughout the study reach. The methods used for hydrological analysis are industry accepted methods (Bulletin #17C and SIR 2015-5019-F) based on the Beaverhead River and Blacktail Deer Creek basin characteristics. This hydrologic analysis conforms to FEMA standards for detailed/enhanced level studies, and the recommended flows of this analysis are deemed reliable and suitable for future floodplain studies and hydraulic analyses.

Table 19 Flood Discharge Estimates from the Log Interpolation Method and Drainage Area Transfer Method

Node/USGS Station ID	Location Description	Peak Discharge (cfs)						
		50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% +
		2-year	10-year	25-year	50-year	100-year	500-year	
06015400	**Beaverhead River near Grant, MT**	**889**	**1,280**	**1,570**	**1,820**	**2,120**	**2,990**	**3,280**
06016000	**Beaverhead River at Barretts, MT**	**1,050**	**1,560**	**1,920**	**2,250**	**2,630**	**3,760**	**3,760**
200	Above Rattlesnake Creek	866	1,449	1,829	2,160	2,530	3,592	3,792
06017000	**Beaverhead River at Dillon, MT**	**575**	**1,240**	**1,650**	**1,980**	**2,330**	**3,260**	**3,860**
100	Above Blacktail Deer Creek	575	1,240	1,649	1,979	2,328	3,256	3,855
06018000	**Beaverhead River near Dillon, MT**	**585**	**1,150**	**1,460**	**1,710**	**1,960**	**2,590**	**2,990**
06018500	**Beaverhead River near Twin Bridges, MT**	**696**	**1,300**	**1,620**	**1,870**	**2,120**	**2,730**	**2,830**
06017500	**Blacktail Deer Creek near Dillon, Montana**	**210**	**447**	**602**	**735**	**884**	**1,290**	**1,350**
400	Upstream extent of study area	234	490	651	791	947	1,370	1,447
300	Confluence with Beaverhead River	248	516	680	824	984	1,417	1,503

1. **Denotes an additional flow node change downstream of a town or intermediate tributary not associated with HUC-12 boundary**



LEGEND

- FLOW NODE (PEAK FLOW)
- TOWNS
- MONTANA COUNTY BOUNDARIES
- CANYON DITCH (APPROX.)
- EAST BENCH CANAL (APPROX.)
- WEST SIDE CANAL (APPROX.)
- HUC 8 BOUNDARIES
- BLACKTAIL DEEK CREEK STUDY REACH
- BEAVERHEAD RIVER STUDY REACH

FLOW CHANGE BASIN/ USGS BASIN

- 06017500
- 400
- 300
- 06015400
- 06016000
- 200
- 06017000
- 100
- 06018000
- 06018500

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATE PLANE
DATUM: NAD 1983
UNITS: INT'L FEET
SOURCE: PIONEER, MSL, USGS

0 2 4 8
Miles

FIGURE 14

PIONEER TECHNICAL SERVICES, INC.

RECOMMENDED 1-PERCENT ANNUAL DISCHARGE FOR EACH LOCATION

DATE: 4/17/2017

Path: G:\DNRC\Mineral -Beaverhead County\Beaverhead County\CAD-GIS\GIS\BVRHD-GI-HYD-004-17.mxd

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Appendix A: USGS Flood Frequency Analysis

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Wyoming-Montana Water Science Center

Helena Office
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Helena, Montana 59601

Cheyenne Office
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February 16, 2017

Mr. Steve Story
Montana Department of Natural Resources
And Conservation
P.O. Box 201601
Helena, Montana 59620-1601

Dear Mr. Story:

The U. S. Geological Survey (USGS) recently prepared a draft Scientific Investigations Report ([1]Sando and others, 2017) documenting USGS' current (February 2017) peak-flow frequency analysis methods that are used in frequency analyses for a large Montana-wide streamgage network (of 725 streamgages). Reporting frequency analyses for a large statewide streamgage network poses several challenges. The frequency analyses reported by the USGS are used for many different applications, including bridge and culvert design, flood-plain mapping, dam and spillway design, analysis, and assessment, and instream-flow water rights requests. Design criteria and risk tolerance can substantially differ among these various frequency applications. Further, uncertainties related to effects of regulation and frequency-adjustment methods are important to consider when using frequency analyses for various purposes. Within this context, in many cases the USGS impartially reports multiple frequency analyses for a given streamgage to allow frequency-analysis users to make informed decisions relevant to their needs.

In cooperation with Montana Department of Natural Resources and Conservation (MT DNRC), the USGS recently computed frequency analyses for 14 streamgages in the Beaverhead River and Clark Fork Basins for publication in a data release; which currently is in draft form ([2]McCarthy and others, 2017). The frequency analyses were based on the methods described by [1]Sando and others (2017). For most of the 14 streamgages, there are multiple frequency analyses reported in the data release.

USGS and MT DNRC have had extensive discussions concerning the intended application of the frequency analyses in flood-plain mapping projects in relation to the selection of the most appropriate reported frequency analyses for the application. Based on the stated purpose of using the flood frequency analyses for flood plain mapping and the period of record and basin characteristics for each station, the type of flood frequency estimate listed for each station in Table 1 will yield the most appropriate peak-flow frequency estimate of the types of peak-flow estimates described in [1]Sando and others (2017). The following discussion explains briefly why each type of peak-flow estimate is most appropriate for each station.

[1]Sando, S.K., McCarthy, P.M., Chase, K.J., and Dutton, D.M., 2017, Methods for Peak-Flow Frequency Analysis and Reporting by the U.S. Geological Survey Wyoming-Montana Water Science Center Based on Data through Water Year 2015: U.S. Geological Survey Scientific Investigations Report 2017–XXXX, xx p.

[2]McCarthy, P.M., Sando, S.K., and Chase, K.J., 2017, Results of peak-flow frequency analysis for streamgages in the Beaverhead River and Clark Fork Basins, based on data through water year 2016: U.S. Geological Survey Data Release, XXXXXXXXXXXXXX.

Table 1. Most appropriate frequency analyses selected by MT DNRC based on discussions with USGS.

[Water year is the 12-month period from October 1 through September 30 and is designated by the year in which it ends. PILF, potentially influential low flow; U, unregulated; --, not applicable; R, regulated; BP, base period used in the Maintenance of Variance Type III record extension]

Streamgage identification number and analysis designation[1]	Streamgage name	Contributing drainage area, in square miles	Regulation status for analysis period[2]	Type of peak-flow frequency estimate[3]	Number of years of peak-flow records in analysis period	Analysis period of record, in water years
Most appropriate frequency analyses for Beaverhead River streamgages						
06015400.11	Beaverhead River near Grant, Montana	2,316	R (MAJ–dam)	MOVE.3	52	BP 1965–2016
06016000.10	Beaverhead River at Barretts, Montana	2,730	R (MAJ–dam)	At-site	52	1965–2016
06017000.11	Beaverhead River at Dillon, Montana	2,892	R (MAJ–dam)	MOVE.3	52	BP 1965–2016
06017500.03	Blacktail Deer Creek near Dillon, Montana	316	U	RRE wtd	--	--
06018000.11	Beaverhead River near Dillon, Montana	3,419	R (MAJ–dam)	MOVE.3	52	BP 1965–2016
06018500.10	Beaverhead River near Twin Bridges, Montana	3,618	R (MAJ–dam)	At-site	52	1965–2016
Most appropriate frequency analyses for Clark Fork streamgages						
12331800.01	Clark Fork near Drummond, Montana	2,516	U	MOVE.3	111	BP 1899–1908; 1911–23; 1929–2016
12334550.01	Clark Fork at Turah Bridge, near Bonner, Montana	3,657	U	MOVE.3	111	BP 1899–1908; 1911–23; 1929–2016
12340500.01	Clark Fork above Missoula, Montana	6,021	U	MOVE.3	111	BP 1899–1908; 1911–23; 1929–2016
12353000.01	Clark Fork below Missoula, Montana	9,017	U	MOVE.3	111	BP 1899–1908; 1911–23; 1929–2016
12354000.00	St. Regis River near St. Regis, Montana	304	U	At-site	42	1911–17; 1934; 1948; 1954; 1959–75; 2002–16
12354500.01	Clark Fork at St. Regis, Montana	10,728	U	MOVE.3	111	BP 1899–1908; 1911–23; 1929–2016
12389000.10	Clark Fork near Plains, Montana	19,964	R (MAJ–dam)	At-site	79	1938–2016
12391400.11	Clark Fork below Noxon Rapids Dam, near Noxon, Montana	21,709	R (MAJ–dam)	MOVE.3	79	BP 1938–2016

[1]The streamgage identification number and analysis designation is defined by XXXXXXXX.AB,
where,
XXXXXXXX is the streamgage identification number; A is the regulation status for the analysis period; and B is the type of peak-flow frequency analysis.
Values of A (regulation status) are defined as: A = 0, unregulated; and A = 1, regulated by major regulation.
Values of B (type of peak-flow frequency analysis) are defined as:
B = 0, at-site peak-flow frequency analysis conducted on recorded data;
B = 1, peak-flow frequency analysis conducted on combined recorded and synthesized data; synthesized data from maintenance of variance type III (MOVE.3) record extension procedure;
B = 3, at-site peak-flow frequency analysis weighted with results from RREs.

[2]Abbreviations for regulation status are defined as follows:
U, unregulated, where the cumulative drainage area upstream from all dams is less than 20 percent of the drainage area of the streamgage.
R (MAJ–dam): major dam regulation, where a single upstream dam has a drainage area that exceeds 20 percent of the drainage area of the streamgage.

[3]Abbreviations for type of frequency analysis are defined as follows:
At-site: peak-flow frequency analysis on recorded data.
RRE wtd: the at-site peak-flow frequency analysis was weighted with results from regional regression equations (RREs).
MOVE.3: peak-flow frequency analysis on combined recorded and synthesized data; synthesized data from maintenance of variance type III (MOVE.3) record extension procedure.

Discussion of Beaverhead River Basin streamgages

For the five main-stem Beaverhead River streamgages, the most appropriate frequency analyses are based on the regulated period of 1965–2016, which primarily is defined by the closure of Clark Canyon Dam in August 1964. Clark Canyon Reservoir has more than 300,000 acre-feet of storage capacity including dedicated flood-control storage; the location of Clark Canyon Dam accounts for between 65 to 100 percent of the drainage areas of the six Beaverhead River streamgages, substantially affecting the peak-flow records of these streamgages.

During the 1965–2016 regulated period, the five main-stem Beaverhead River streamgages have variable periods of record, ranging from 19 to 52 years of data collection. Differences in the timing of the periods of record can result in substantial inconsistencies in frequency estimates for hydrologically similar streamgages. The USGS uses Maintenance of Variance Type III (MOVE.3) record extension in cases of multiple streamgages on the same large river with variable periods of record but high cross correlation. For each streamgage, the MOVE.3 record extension procedure synthesizes estimated peak flows for years of missing record; this allows synchronization of the variable periods of record to a common long-term base period. Frequency analysis of the combined recorded and synthesized datasets provides synchronized frequency estimates that might be useful for several frequency applications, including floodplain mapping. The USGS considers MOVE.3 record extension as the preferred alternative for adjusting at-site frequency estimates for streamgages that qualify for application of the MOVE.3 procedure. Two of the main-stem Beaverhead River streamgages (06016000 and 06018500; table 1) have complete periods of record within the 1965-2016 regulated period; for these streamgages, the at-site frequency analyses are most appropriate. Three of the main-stem Beaverhead River

streamgages (06015400, 06017000, and 06018000; table 1) have years of missing record within the 1965–2016 regulated period; for these streamgages, the frequency analyses on the combined recorded and MOVE.3 synthesized datasets are most appropriate.

Blacktail Deer Creek near Dillon, Montana (streamgage 06017500; table 1) is on a tributary to the Beaverhead River and has a somewhat short period of record (21 years). The peak-flow dataset for streamgage 06017500 does not qualify for application of the MOVE.3 procedure. Uncertainties in the frequency analysis for streamgage 06017500 can be reduced by weighting the at-site frequency analysis with frequency results obtained from regional regression equations (RREs). For streamgage 06017500, the RRE-weighted frequency analysis is most appropriate.

Discussion of Clark Fork Basin streamgages

The seven streamgages on the main-stem Clark Fork are variable with respect to regulation effects. The five upstream streamgages (12331800, 12334550, 12340500, 12353000, and 12354500; table 1) are considered unregulated, with less than 20 percent of their basins affected by major dam regulation. The two downstream streamgages (12389000 and 12391400; table 1) are affected by major dam regulation.

The five unregulated main-stem Clark Fork streamgages (12331800, 12334550, 12340500, 12353000, and 12354500; table 1) have variable periods of record, ranging from 31 to 101 years of data collection. For each streamgage, MOVE.3 record extension was used to synthesize estimated peak flows for years of missing record to provide synchronization of the variable periods of record to a common 111-year base period. For the five unregulated main-stem Clark Fork streamgages (12331800, 12334550, 12340500, 12353000, and 12354500; table 1), frequency analyses on the combined recorded and MOVE.3 synthesized datasets are most appropriate.

Clark Fork near Plains, Montana (streamgage 12389000; table 1) and Clark Fork below Noxon Rapids Dam, near Noxon, Montana (streamgage 12391400; table 1) are downstream from the confluence of the Clark Fork and the Flathead River. Hungry Horse and Salish-Kootenai Dams in the upper Flathead River Basin are major regulation structures with more than 3 million acre-feet of storage capacity including dedicated flood-control storage. Locations of major dams account for between 40 to 43 percent of the drainage areas of streamgages 12389000 and 12391400, substantially affecting the peak-flow records of the two downstream Clark Fork streamgages (12389000 and 12391400). The regulated period for the two downstream streamgages is 1938–2016, which primarily is defined by the completion of Salish-Kootenai Dam in 1938.

During the 1938–2016 regulated period, the two downstream Clark Fork streamgages have variable periods of record, ranging from 54 to 79 years of data collection. Streamgage 12389000 has a complete period of record within the 1938–2016 regulated period; for this streamgage, the at-site frequency analysis is most appropriate. For streamgage 12391400 MOVE.3 record extension was used to synthesize estimated peak flows for years of missing record to provide synchronization with the 1938–2016 regulated period; for this streamgage, the frequency analysis on the combined recorded and MOVE.3 synthesized datasets is most appropriate.

St. Regis River near St. Regis, Montana (streamgage 12354000; table 1) is on a tributary to the Clark Fork and has 42 peak flow records between 1922 and 2016. The peak-flow dataset for streamgage 12354000 does not qualify for the application of the MOVE.3 procedure. The peak-flow dataset for streamgage 12354000 is a mixed population dataset and therefore a station skew was used in the analysis. Streamgage 12354000 is in the West hydrologic region of Montana, which has limited representation of mixed-population streamgages, and the independent estimates from the regional regression equations do not well represent sites with mixed-populations of peak-flows. Therefore, the most appropriate peak-flow frequency analysis for streamgage 12354000 is the at-site analysis.

Summary

Based on the information/data and statistical approaches described in [1]Sando and others (2017), the USGS considers the peak-flow analyses listed in Table 1 to be most appropriate for flood-plain mapping for these 14 streamgages. Other types of analyses might be more appropriate for other applications and methods developed in the future might be more appropriate for flood-plain mapping.

We hope you find this discussion of our study results useful and appreciate you choosing USGS as a provider of unbiased scientific information to use in your floodplain management activities.

Sincerely,

John M. Kilpatrick
Center Director

1

Table. Selected frequency analyses and estimated upper 84-percent confidence levels for the 1-percent annual exceedance probability peak flows.

[Water year is the 12-month period from October 1 through September 30 and is designated by the year in which it ends. U, unregulated; R, regulated; <, less than; NR, not reported; --, not applicable; BP, base period used in the Maintenance of Variance Type III record extension]

Map number (fig. 1)	Streamgage identification number and analysis designation[1]	Streamgage name	Contributing drainage area, in square miles	Regulation status for analysis period[2]	Type of peak-flow frequency estimate[3]	Number of years of peak-flow records in analysis period	Analysis period of record, in water years	Annual peak flow, in cubic feet per second, for indicated annual exceedance probability (AEP), in percent										Upper 84-percent confidence level for the 1-percent AEP peak-flow	Method for determining the upper 84-percent confidence level
								66.7	50	42.9	20	10	4	2	1	0.5	0.2		
23	06015400.11	Beaverhead River near Grant, Montana	2,316	R (MAJ–dam)	MOVE.3	52	BP 1965–2016	828	889	922	1,100	1,280	1,570	1,820	2,120	2,460	2,990	3,280	PeakFQv7.1 value adjusted for MOVE.3 analysis as described by Sando and others (2017; draft)[1]
26	06016000.10	Beaverhead River at Barretts, Montana	2,730	R (MAJ–dam)	At-site	52	1965–2016	976	1,050	1,100	1,320	1,560	1,920	2,250	2,630	3,070	3,760	3,760	PeakFQv7.1 value
28	06017000.11	Beaverhead River at Dillon, Montana	2,892	R (MAJ–dam)	MOVE.3	52	BP 1965–2016	444	575	639	952	1,240	1,650	1,980	2,330	2,710	3,260	3,860	PeakFQv7.1 value adjusted for MOVE.3 analysis as described by Sando and others (2017; draft)[1]
29	06017500.03	Blacktail Deer Creek near Dillon, Montana	316	U	RRE wtd	--	--	165	210	233	341	447	602	735	884	1,050	1,290	1,350	Confidence interval method for weighted frequency analysis (Sando and others, 2017; draft)[1] for 84-percent confidence level
30	06018000.11	Beaverhead River near Dillon, Montana	3,419	R (MAJ–dam)	MOVE.3	52	BP 1965–2016	465	585	644	914	1,150	1,460	1,710	1,960	2,230	2,590	2,990	PeakFQv7.1 value adjusted for MOVE.3 analysis as described by Sando and others (2017; draft)[1]
31	06018500.10	Beaverhead River near Twin Bridges, Montana	3,618	R (MAJ–dam)	At-site	52	1965–2016	562	696	760	1,050	1,300	1,620	1,870	2,120	2,380	2,730	2,830	PeakFQv7.1 value

[1]Sando, S.K., McCarthy, P.M., Chase, K.J., and Dutton, D.M., 2017, Methods for Peak-Flow Frequency Analysis and Reporting by the U.S. Geological Survey Wyoming-Montana Water Science Center Based on Data through Water Year 2015: U.S. Geological Survey Scientific Investigations Report 2017–XXXX, xx p.

Appendix B: Logarithmic Interpolation, Drainage Area Transfer and Regional Regression Calculations

Node/USGS Station ID	Location Description	County	Study Reach River Station (miles)	Incremental Basin Area (mi^2)	Cumulative Basin Area (mi^2)	Log Interpolation of Gaged Analysis						
						Estimated Discharge (cfs)						
						50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% + Annual Chance
						2-year	10-year	25-year	50-year	100-year	500-year	100-year +
06015400	**Beaverhead River near Grant, MT**	**Beaverhead**		**2317**	**2317**	**889**	**1,280**	**1,570**	**1,820**	**2,120**	**2,990**	**3,280**
06016000	**Beaverhead River at Barretts, MT**	**Beaverhead**	40.4	**413**	**2730**	**1,050**	**1,560**	**1,920**	**2,250**	**2,630**	**3,760**	**3,760**
200	Above Rattlesnake Creek	Beaverhead	31.5	71	2801	866	1,449	1,829	2,160	2,530	3,592	3,792
06017000	**Beaverhead River at Dillon, MT**	**Beaverhead**	**26.7**	**157**	**2958**	**575**	**1,240**	**1,650**	**1,980**	**2,330**	**3,260**	**3,860**
100	Above Blacktail Deer Creek	Beaverhead	24.7	2	2960	575	1,240	1,649	1,979	2,328	3,256	3,855
06018000	**Beaverhead River near Dillon, MT**	**Beaverhead**	**14**	**428**	**3388**	**585**	**1,150**	**1,460**	**1,710**	**1,960**	**2,590**	**2,990**
06018500	**Beaverhead River near Twin Bridges, MT**	**Madison**		**231**	**3619**	**696**	**1,300**	**1,620**	**1,870**	**2,120**	**2,730**	**2,830**

For locations that are ungaged and located between two gaged locations with reliable period of record (10 yrs)
Equation utilizes drainage areas and flows.

$$\log Q_{AEP,U} = \log Q_{AEP,G1} + [(\log Q_{AEP,G2} - \log Q_{AEP,G1}) / (\log DA_{G2} - \log DA_{G1})](\log DA_U - \log DA_{G1})$$

where

$Q_{AEP,U}$ is the AEP-percent peak flow at ungaged site U, in cubic feet per second; (7)

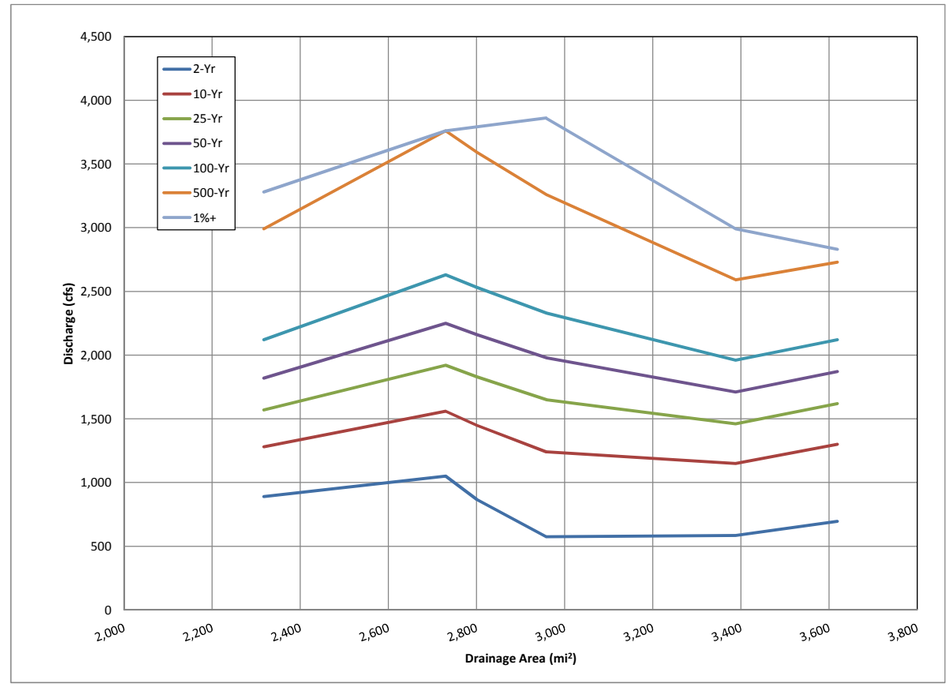
$Q_{AEP,G1}$ is the AEP-percent peak flow for the upstream gaging station $G1$, in cubic feet per second;

$Q_{AEP,G2}$ is the AEP-percent peak flow at the downstream gaging station $G2$, in cubic feet per second;

DA_{G2} is the drainage area at the downstream gaging station $G2$, in square miles;

DA_{G1} is the drainage area at the upstream gaging station $G1$, in square miles; and

DA_U is the drainage area at ungaged site U, in square miles.



Node/USGS Station ID	Location Description	County	Study Reach River Station (miles)	Individual Basin Area (mi^2)	Cumulative Basin Area (mi^2)	DA_U/DA_G	Drainage Area Gage Transfer Estimated Discharge (cfs) 50% Annual Chance 2-year	10% Annual Chance 10-year	4% Annual Chance 25-year	2% Annual Chance 50-year	1% Annual Chance 100-year	0.2% Annual Chance 500-year	1% + Annual Chance 100-year +
06017500	**Blacktail Deer Creek near Dillon, Montana**	**Beaverhead**		**316**	**316**	**-**	**210**	**447**	**602**	**735**	**884**	**1,290**	**1,350**
400	Upstream extent of study area	Beaverhead	11.0	38	354	1.12	234	487	651	791	947	1,370	1,447
300	Confluence with Beaverhead River	Beaverhead	0	23	377	1.19	248	511	680	824	984	1,417	1,503

For an ungaged site that is not located between two gaged locations
Recommended that the drainage ratio be within 0.5 to 1.5

*** Recommended ratio be within 0.5 to 1.5
*Southwest Region for regression coefficient

Equation recommended by SIR 2015-5019-F

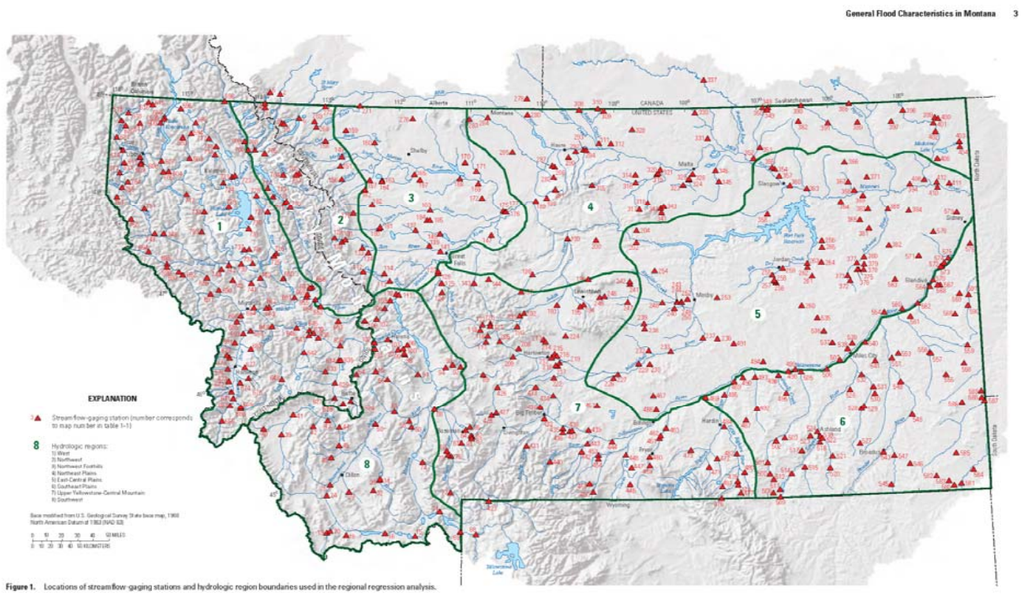
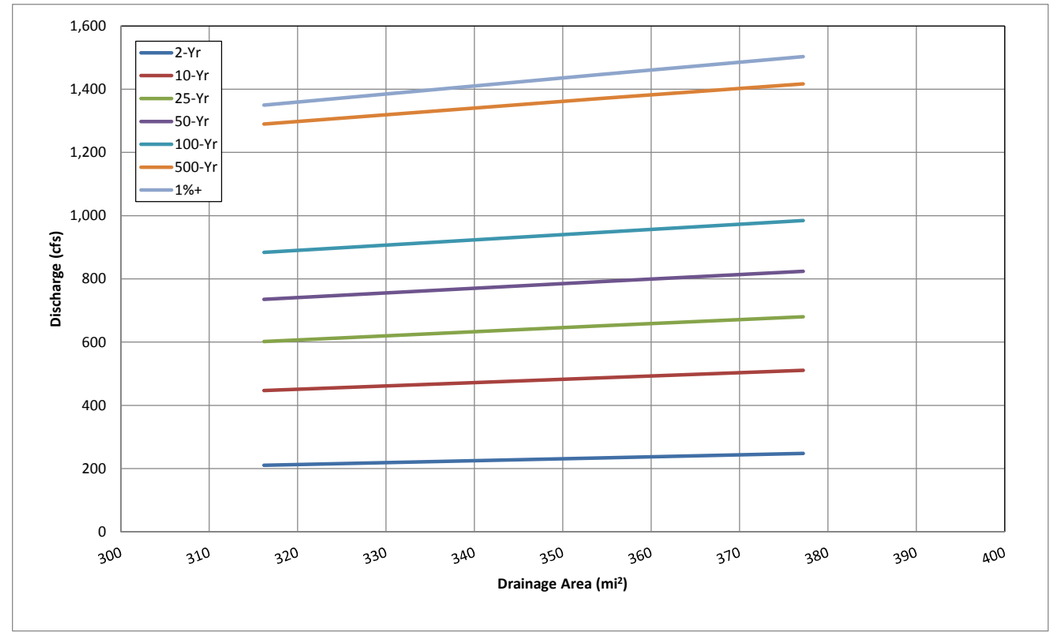


Figure 1. Locations of streamflow-gaging stations and hydrologic region boundaries used in the regional regression analysis.



$$Q_{AEP,U} = Q_{AEP,G}\left(\frac{DA_U}{DA_G}\right)^{exp_{AEP}} \quad (6)$$

where

$Q_{AEP,G}$ is the AEP-percent peak flow for gaging station G, in cubic feet per second;

DA_U is the drainage area at ungaged site U, in square miles;

DA_G is the drainage area at gaging station G, in square miles; and

exp_{AEP} is the regression coefficient for an OLS regression relating the log of the AEP-percent peak flow to the log of the drainage area within each region (table 5).

Table 5. Regression coefficients for ordinary least squares regressions relating annual exceedance probability percent peak flow to contributing drainage area for use with ungaged sites on gaged streams.

AEP-percent peak flow (Q_{AEP})	Regression coefficient relating Q_{AEP} to drainage area for indicated region: West Region	Northwest Region	Northwest Foothills Region	Northeast Plains Region	East-Central Plains Region	Southeast Plains Region	Upper Yellowstone-Central Mountain Region	Southwest Region
$Q_{66.7}$	0.858	0.922	0.606	0.684	0.500	0.541	0.942	0.999
Q_{50}	0.843	0.904	0.575	0.690	0.488	0.527	0.896	0.939
$Q_{42.9}$	0.836	0.890	0.564	0.681	0.483	0.523	0.866	0.911
Q_{20}	0.813	0.832	0.534	0.639	0.463	0.502	0.761	0.818
Q_{10}	0.794	0.790	0.522	0.611	0.449	0.487	0.697	0.755
Q_4	0.777	0.741	0.516	0.579	0.434	0.471	0.634	0.690
Q_2	0.766	0.707	0.517	0.557	0.423	0.460	0.595	0.647
Q_1	0.755	0.675	0.521	0.537	0.414	0.450	0.561	0.609
$Q_{0.5}$	0.746	0.644	0.526	0.519	0.404	0.441	0.532	0.576
$Q_{0.2}$	0.735	0.605	0.536	0.496	0.393	0.430	0.498	0.533

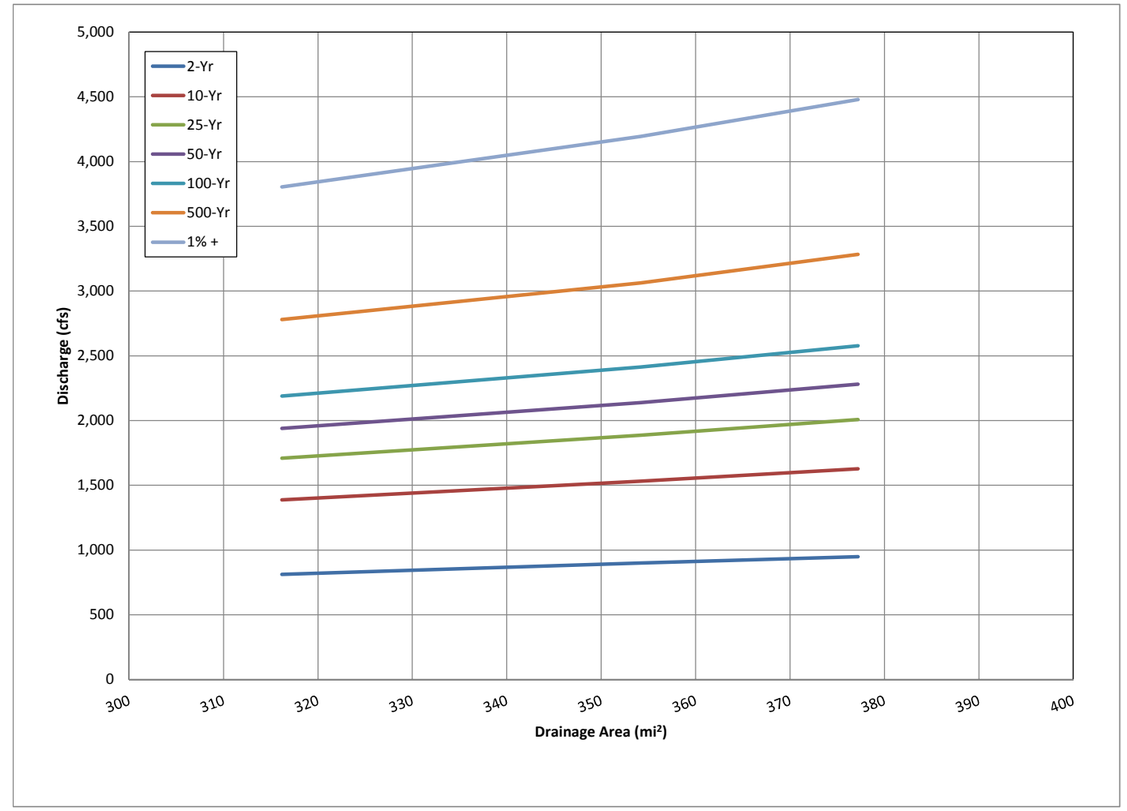
Node/USGS Station ID	Location Description	County	Study Reach River Station (miles)	Individual Basin Area (mi^2)	Cumulative Basin Area (mi^2)	E6000 (%)	Regional Regression Analysis Estimated Discharge (cfs) 50% Annual Chance 2-year	10% Annual Chance 10-year	4% Annual Chance 25-year	2% Annual Chance 50-year	1% Annual Chance 100-year	0.2% Annual Chance 500-year	1% + 100-year
06017500	**Blacktail Deer Creek near Dillon, Montana**	**Beaverhead**		**316**	**316**	96	812	1,388	1,710	1,939	2,189	2,780	3804
400	Upstream extent of study area	Beaverhead	11.0	38	354	91	899	1,532	1,886	2,138	2,413	3,064	4194
300	Confluence with Beaverhead River	Beaverhead	0	23	377	86	948	1,627	2,008	2,281	2,578	3,283	4480

Equation recommended by SIR 2015-5019-F

Southwest hydrologic region

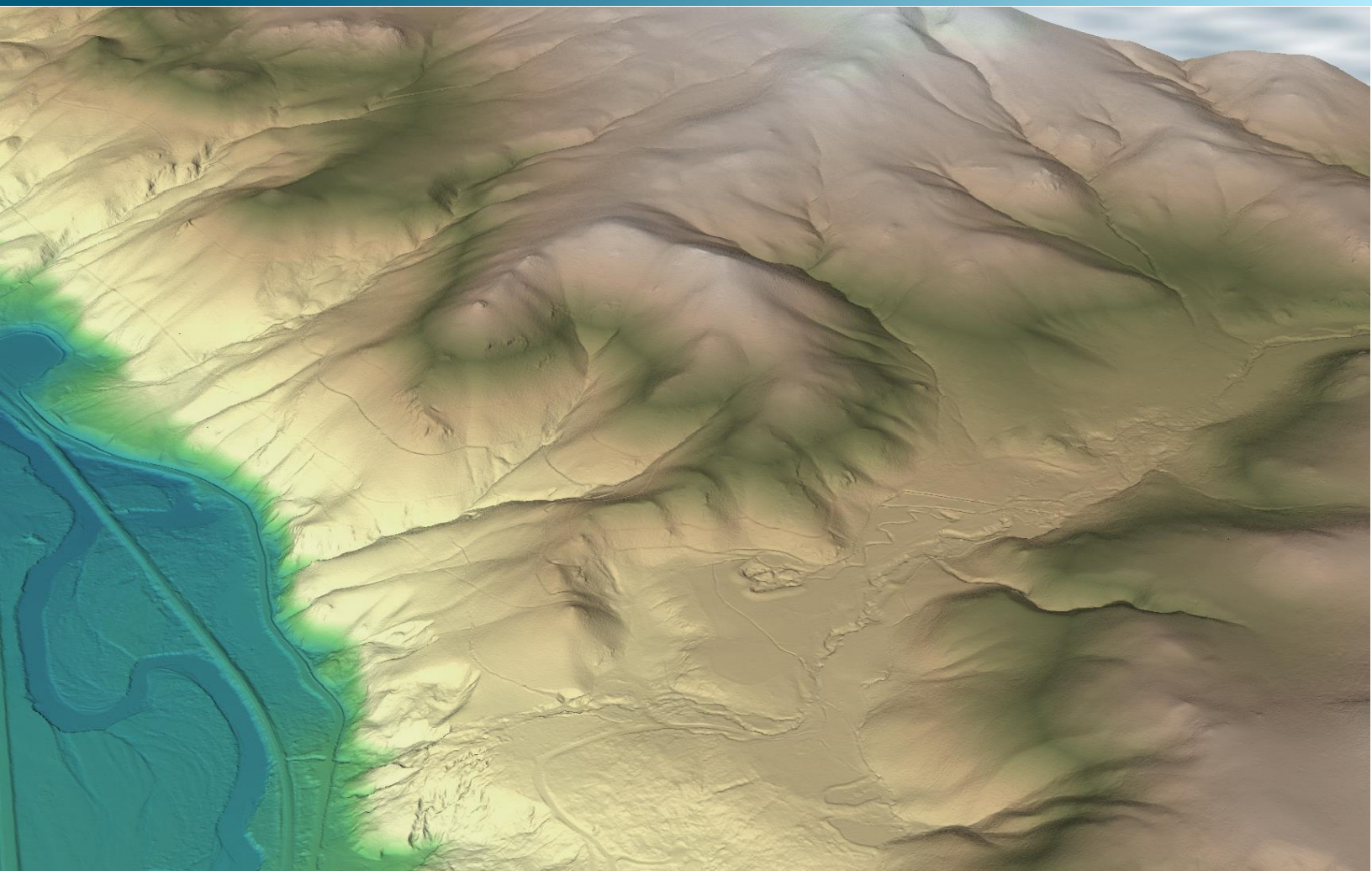
$$Q_{66.7} = 1.04\ A^{0.971}\ (E_{6000} + 1)^{0.195}$$
$$Q_{50} = 2.49\ A^{0.930}\ (E_{6000} + 1)^{0.095}$$
$$Q_{42.9} = 3.61\ A^{0.910}\ (E_{6000} + 1)^{0.053}$$
$$Q_{20} = 13.4\ A^{0.842}\ (E_{6000} + 1)^{0.088}$$
$$Q_{10} = 31.9\ A^{0.796}\ (E_{6000} + 1)^{-0.177}$$
$$Q_{4} = 79.8\ A^{0.750}\ (E_{6000} + 1)^{-0.274}$$
$$Q_{2} = 142\ A^{0.721}\ (E_{6000} + 1)^{-0.336}$$
$$Q_{1} = 238\ A^{0.696}\ (E_{6000} + 1)^{-0.391}$$
$$Q_{0.5} = 377\ A^{0.675}\ (E_{6000} + 1)^{-0.442}$$
$$Q_{0.2} = 655\ A^{0.649}\ (E_{6000} + 1)^{-0.501}$$

[Q_{AEP}, peak-flow magnitude, in cubic feet per second, for annual exceedance probability (AEP) in percent; n, number of streamflow-gaging stations used in developing regression equations for indicated hydrologic region; σ_δ^2, model error variance; MVP, mean variance of prediction; SEP, mean standard error of prediction; SEM, mean standard error of model; Pseudo R^2, pseudo coefficient of determination; A, contributing drainage area, in square miles; P, mean annual precipitation, in inches; F, percentage of basin that is forest; E_{5000}, percentage of basin above 5,000 feet elevation; SLP_{30}, percentage of basin with slope greater than 30 percent; ET_{SPR}, Mean spring (March–June) evapotranspiration, in inches per month; E_{6000}, percent of basin above 6,000 feet elevation]



Appendix C: Digital Data and Calculation Files

May 27, 2016



Dillon AOI, Beaverhead County LiDAR Technical Data Report

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Cover Photo: A view looking east from the southern end of the Dillon AOI. The image was created from the LiDAR bare earth model colored by elevation.

INTRODUCTION

This photo taken by QSI acquisition staff shows a view of the location of QSI's BEAV_01 monument, established within the Dillon AOI.

In late 2015, Quantum Spatial (QSI) was contracted by the Montana Department of Natural Resources & Conservation (MDNRC) to collect Light Detection and Ranging (LiDAR) data in the spring of 2016 for the Beaverhead County LiDAR project in Montana. The Beaverhead County project encompasses two sites: the Harlowton, Montana area of interest (AOI) and the Dillon, Montana AOI. QSI provided the Harlowton, Montana LiDAR delivery to MDNRC on January 27, 2016. This subsequent delivery provides LiDAR data acquired for the Dillon AOI only, and thereby concludes the contracted project agreement. Data were collected to aid MDNRC in assessing the topographic and geophysical properties of the area in order to facilitate floodplain mapping and hazard assessment.

This report accompanies the delivered LiDAR data for the Dillon, Montana AOI in Beaverhead County and documents contract specifications, data acquisition procedures, processing methods, and analysis of the final dataset including LiDAR accuracy and density. Acquisition dates and acreage are shown in Table 1, a complete list of contracted deliverables provided to MDNRC is shown in Table 2, and the project extent is shown in Figure 1.

Table 1: Acquisition dates, acreage, and data types collected on the Dillon AOI site

Project Site	Contracted Acres	Buffered Acres	Acquisition Dates	Data Type
Dillon AOI	37,620	39,962	04/04/2016, 04/07/2016	High resolution LiDAR

Deliverable Products

Table 2: Products delivered to the MDNRC for the Dillon AOI

Dillon, Montana Products Projection: UTM Zone 12 North Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID 12A) Units: Meters	
Points	LAS v 1.4 • All Returns • Raw Calibrated Flightline Swaths
Rasters	1.0 Meter Bare Earth Model • Hydro-flattened Bare Earth Model (ESRI Grid) • Hydro-flattened Bare Earth Model (ESRI Geodatabase) • Hydro-flattened Bare Earth Model (ASCII format)
Vectors	Shapefiles (*.shp) • Site Boundary • LiDAR Tile Index • Flightline Index • DEM Tile Index • Contours (0.5 m) • Ground Control and Check Points • Water Mask (3D Polygon Z) CAD Format • Water Mask (*.dxf) ESRI Geodatabase (*.gdb) • Contours (0.5 m)

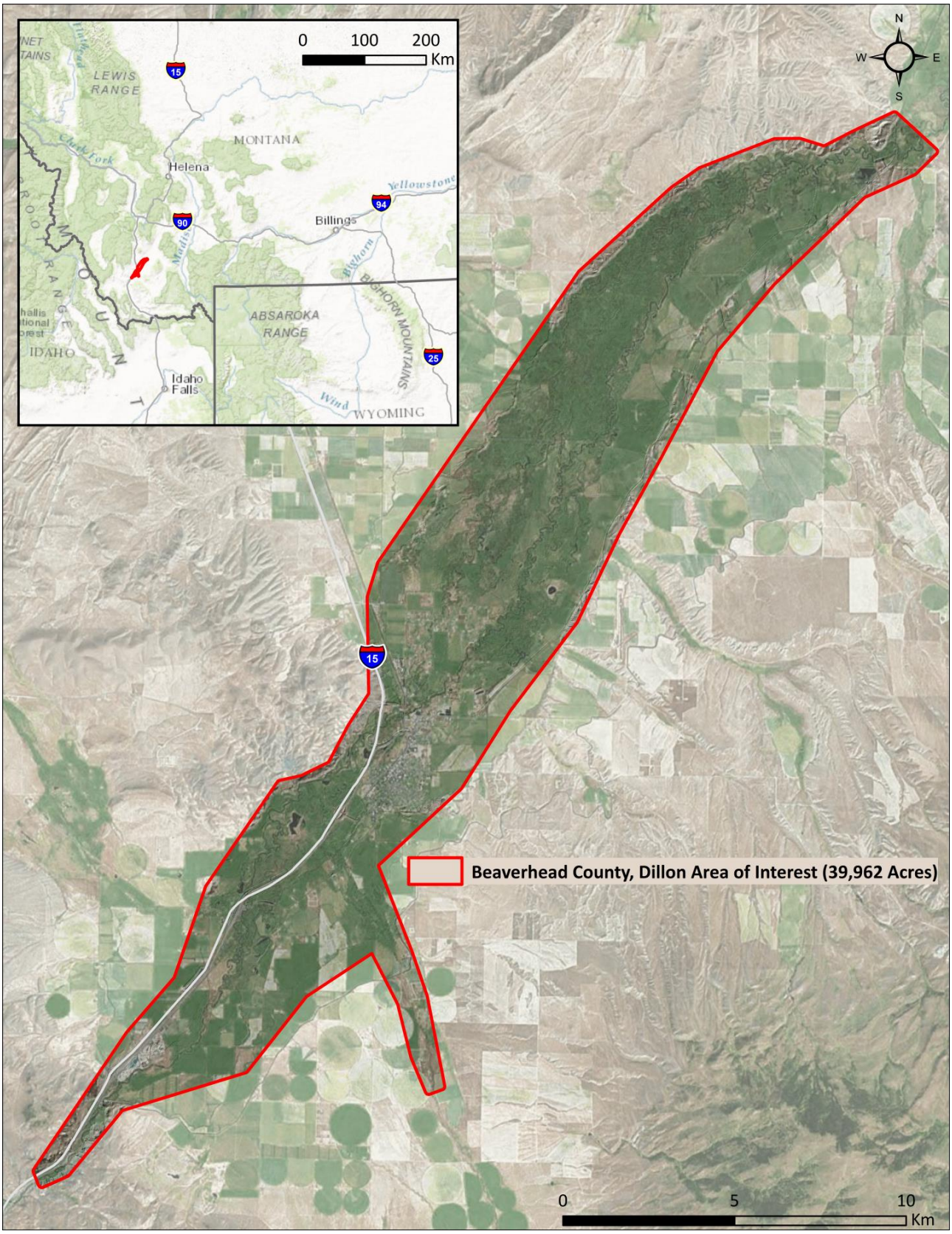

Figure 1: Location map of the Dillon AOI site in Montana

ACQUISITION

QSI's Cessna Caravan

Planning

In preparation for data collection, QSI reviewed the project area and developed a specialized flight plan to ensure complete coverage of the Dillon AOI LiDAR study area at the target point density of ≥8.0 points/m^2. Acquisition parameters including orientation relative to terrain, flight altitude, pulse rate, scan angle, and ground speed were adapted to optimize flight paths and flight times while meeting all contract specifications.

Factors such as satellite constellation availability and weather windows must be considered during the planning stage. Any weather hazards or conditions affecting the flights were continuously monitored due to their potential impact on the daily success of airborne and ground operations. In addition, logistical considerations including private property access and potential air space restrictions were reviewed.

Airborne LiDAR Survey

The LiDAR survey was accomplished using a Leica ALS80 system mounted in a Cessna Caravan 208. Table 3 summarizes the settings used to yield an average pulse density of ≥8 pulses/m^2 over the Dillon AOI. The Leica ALS80 laser system can record unlimited range measurements (returns) per pulse; however, it is not uncommon for some types of surfaces (e.g., dense vegetation or water) to return fewer pulses to the LiDAR sensor than the laser originally emitted. The discrepancy between first return and overall delivered density will vary depending on terrain, land cover, and the prevalence of water bodies. All discernible laser returns were processed for the output dataset.

Table 3: LiDAR specifications and survey settings

LiDAR Survey Settings & Specifications	
Acquisition Dates	04/04/2016, 04/07/2016
Aircraft Used	Cessna Caravan 208
Sensor	Leica ALS80
Survey Altitude (AGL)	1,800 m
Swath Width	965 m
Target Pulse Rate	310.8 kHz
Pulse Mode	Multiple Pulse in Air (2PiA)
Laser Pulse Diameter	39.6 cm
Mirror Scan Rate	58.4 Hz
Field of View	30°
GPS Baselines	≤13 nm
GPS PDOP	≤3.0
GPS Satellite Constellation	≥6
Maximum Returns	Unlimited
Intensity	8-bit, scaled to 16-bit
Resolution/Density	Average 8 pulses/m^2
Accuracy	$RMSE_Z$ ≤ 15 cm

Leica ALS80 LiDAR sensor

All areas were surveyed with an opposing flight line side-lap of ≥50% (≥100% overlap) in order to reduce laser shadowing and increase surface laser painting. To accurately solve for laser point position (geographic coordinates x, y and z), the positional coordinates of the airborne sensor and the attitude of the aircraft were recorded continuously throughout the LiDAR data collection mission. Position of the aircraft was measured twice per second (2 Hz) by an onboard differential GPS unit, and aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll and yaw (heading) from an onboard inertial measurement unit (IMU). To allow for post-processing correction and calibration, aircraft and sensor position and attitude data are indexed by GPS time.

Ground Control

Ground control surveys, including monumentation and ground survey points (GSPs), were conducted to support the airborne acquisition. Ground control data were used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data.

QSI-Established Monument BEAV_01

Monumentation

The spatial configuration of ground survey monuments provided redundant control within 13 nautical miles of the mission areas for LiDAR flights. Monuments were also used for collection of ground survey points using real time kinematic (RTK) survey techniques.

Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. QSI established two new monuments for the Dillon AOI LiDAR project (Table 4, Figure 2). New monumentation was set using 5/8” x 30” rebar topped with stamped 2 ½ " aluminum caps. QSI’s professional land surveying staff oversaw the establishment of all monuments.

Table 4: Monuments established for the Dillon AOI acquisition. Coordinates are on the NAD83 (2011) datum, epoch 2010.00.

Monument ID	Latitude	Longitude	Ellipsoid (meters)
BEAV_01	45° 16’ 04.22336”	-112° 38’ 30.17063”	1524.916
BEAV_02	45° 14’ 39.38963”	-112° 35’ 23.87876”	1526.372

To correct the continuously recorded onboard measurements of the aircraft position, QSI concurrently conducted multiple static Global Navigation Satellite System (GNSS) ground surveys (1 Hz recording frequency) over each monument. During post-processing, the static GPS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS[1]) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy.

Monuments were established according to the national standard for geodetic control networks, as specified in the Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards for geodetic networks.[2] This standard provides guidelines for classification of monument quality at the 95% confidence interval as a basis for comparing the quality of one control network to another. The monument rating for this project is shown in Table 5.

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[1] OPUS is a free service provided by the National Geodetic Survey to process corrected monument positions. http://www.ngs.noaa.gov/OPUS.

[2] Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards (FGDC-STD-007.2-1998). Part 2: Standards for Geodetic Networks, Table 2.1, page 2-3. http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part2/chapter2

Table 5: Federal Geographic Data Committee monument rating for network accuracy

Direction	Rating
1.96 * St Dev $_{NE}$:	0.010 m
1.96 * St Dev $_{z}$:	0.010 m

For the Dillon AOI LiDAR project, the monument coordinates contributed no more than 1.4 cm of positional error to the geolocation of the final ground survey points and LiDAR, with 95% confidence.

Ground Survey Points (GSPs)

Ground survey points were collected using real time kinematic survey techniques. A Trimble R7 base unit was positioned at a nearby monument to broadcast a kinematic correction to a roving Trimble R10 GNSS receiver. All GSP measurements were made during periods with a Position Dilution of Precision (PDOP) of ≤ 3.0 with at least six satellites in view of the stationary and roving receivers. When collecting RTK data, the rover records data while stationary for five seconds, then calculates the pseudorange position using at least three one-second epochs. Relative errors for any GSP position must be less than 1.5 cm horizontal and 2.0 cm vertical in order to be accepted. See Table 6 for Trimble unit specifications.

GSPs were collected in areas where good satellite visibility was achieved on paved roads and other hard surfaces such as gravel or packed dirt roads. GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads due to the increased noise seen in the laser returns over these surfaces. GSPs were collected within as many flightlines as possible; however the distribution of GSPs depended on ground access constraints and monument locations and may not be equitably distributed throughout the study area (Figure 2).

Table 6: Trimble equipment identification

Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R10	Integrated Antenna R10	TRMR10	Rover

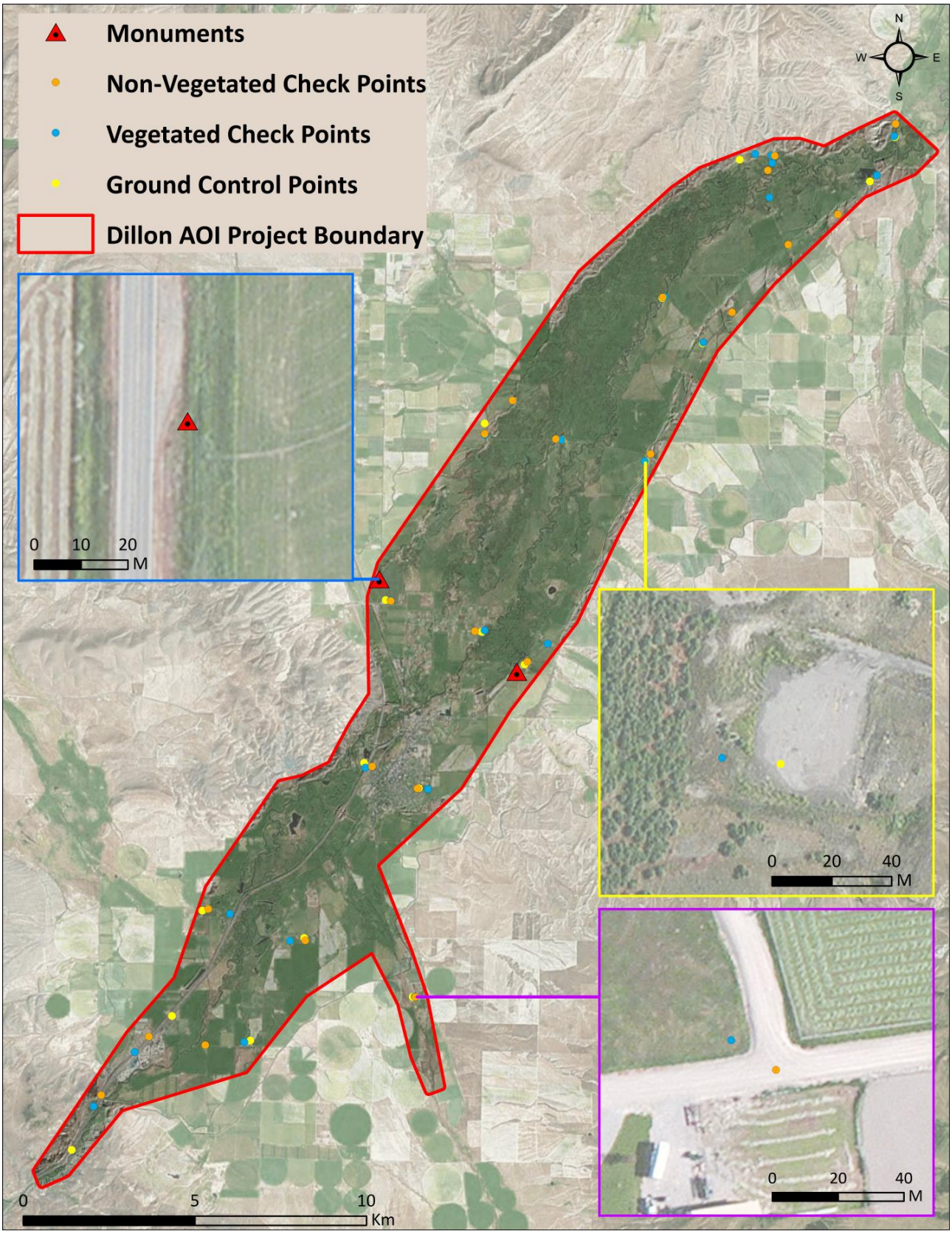
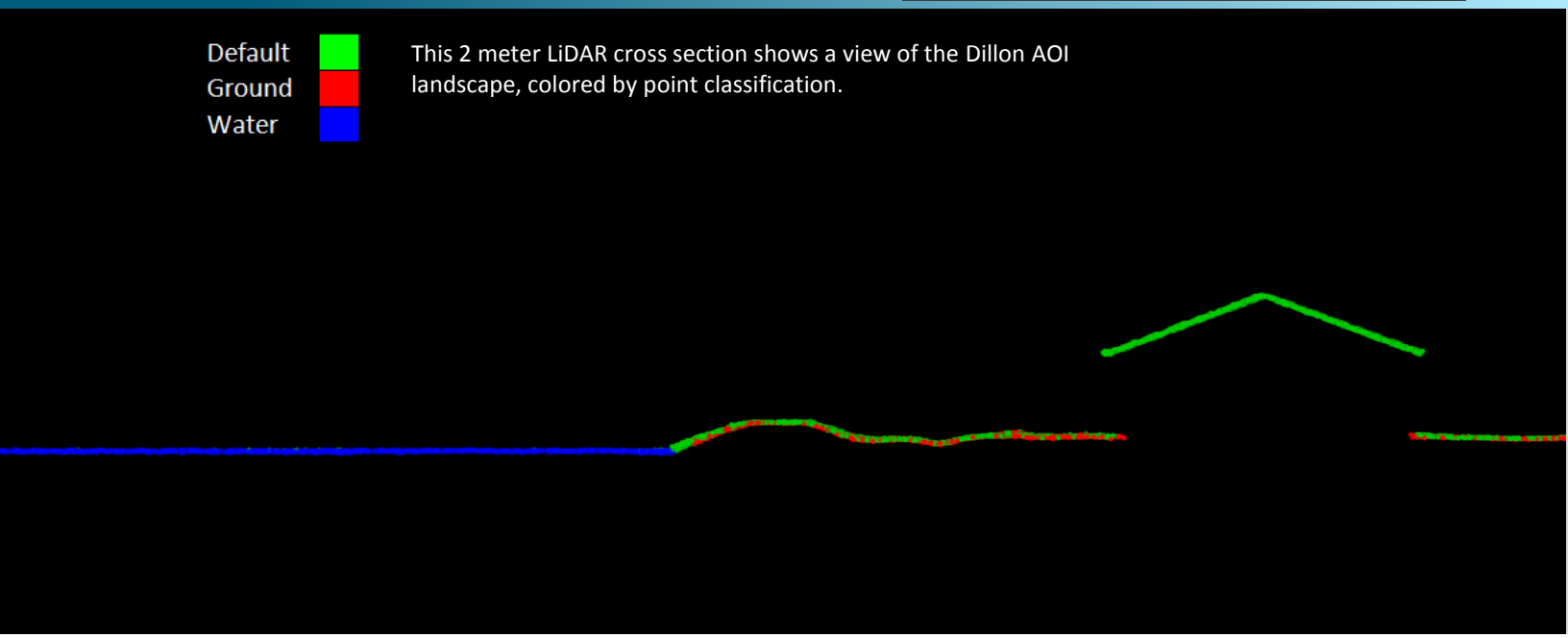


Figure 2: Ground survey location map



This 2 meter LiDAR cross section shows a view of the Dillon AOI landscape, colored by point classification.

LiDAR Data

Upon completion of data acquisition, QSI processing staff initiated a suite of automated and manual techniques to process the data into the requested deliverables. Processing tasks included GPS control computations, smoothed best estimate trajectory (SBET) calculations, kinematic corrections, calculation of laser point position, sensor and data calibration for optimal relative and absolute accuracy, and LiDAR point classification (Table 7). Processing methodologies were tailored for the landscape. Brief descriptions of these tasks are shown in Table 8.

Table 7: ASPRS LAS classification standards applied to the Dillon AOI dataset

Classification Number	Classification Name	Classification Description
1	Default/Unclassified	Laser returns that are not included in the ground class, composed of vegetation and man-made structures
2	Ground	Laser returns that are determined to be ground using automated and manual cleaning algorithms
7	Noise	Laser returns that are often associated with birds, scattering from reflective surfaces, or artificial points below the ground surface
9	Water	Laser returns that are determined to be water using automated and manual cleaning algorithms
10	Ignored Ground	Ground points proximate to water's edge breaklines; ignored for correct model creation
11	Withheld	Laser returns that have intensity values of 0 or 255

Table 8: LiDAR processing workflow

LiDAR Processing Step	Software Used
Resolve kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data. Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with sensor head position and attitude recorded throughout the survey.	Waypoint Inertial Explorer v.8.6
Calculate laser point position by associating SBET position to each laser point return time, scan angle, intensity, etc. Create raw laser point cloud data for the entire survey in *.las (ASPRS v. 1.2) format. Convert data to orthometric elevations by applying a geoid12a correction.	Waypoint Inertial Explorer v.8.6 Leica Cloudpro v. 1.2.2
Import raw laser points into manageable blocks (less than 500 MB) to perform manual relative accuracy calibration and filter erroneous points. Classify ground points for individual flight lines.	TerraScan v.16
Using ground classified points per each flight line, test the relative accuracy. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Calculate calibrations on ground classified points from paired flight lines and apply results to all points in a flight line. Use every flight line for relative accuracy calibration.	TerraMatch v.16
Classify resulting data to ground and other client designated ASPRS classifications (Table 7). Assess statistical absolute accuracy via direct comparisons of ground classified points to ground control survey data.	TerraScan v.16 TerraModeler v.16
Generate bare earth models as triangulated surfaces. Export all surface models as ESRI GRIDs, ESRI Geodatabase, and ASCII format at a 1 meter pixel resolution.	TerraScan v.16 TerraModeler v.156 ArcMap v. 10.2.2

Feature Extraction

Hydro-flattening and Water's edge breaklines

Water bodies within the Dillon AOI were flattened to a consistent water level. These include lakes and other closed water bodies with a surface area greater than 2 acres. The hydro-flattening process eliminates artifacts in the digital terrain model caused by both increased variability in ranges or dropouts in laser returns due to the low reflectivity of water.

Hydro-flattening of closed water bodies was performed through a combination of automated and manual detection and adjustment techniques designed to identify water boundaries and water levels. Boundary polygons were developed using an algorithm which weights LiDAR-derived slopes, intensities, and return densities to detect the water's edge. The water edges were then manually reviewed and edited as necessary.

Once polygons were developed the initial ground classified points falling within water polygons were reclassified as water points to omit them from the final ground model. Elevations were then obtained from the filtered LiDAR returns to create the final breaklines and lakes were assigned a consistent elevation for an entire polygon within these breaklines.

Water boundary breaklines were then incorporated into the hydro-flattened DEM by enforcing triangle edges (adjacent to the breakline) to the elevation values of the breakline. This implementation corrected interpolation along the hard edge. Water surfaces were obtained from a TIN of the 3-D water edge breaklines resulting in the final hydro-flattened model (Figure 3).

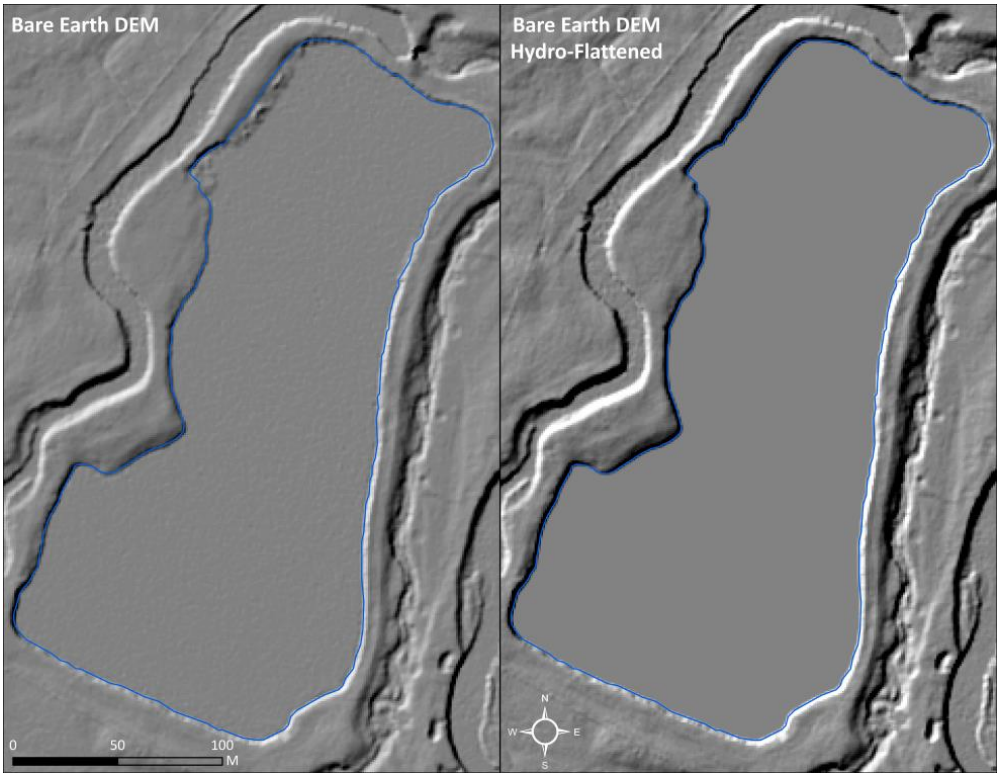


Figure 3: Example of hydro-flattening in the Dillon AOI LiDAR dataset

Contours

Contour generation from LiDAR point data required a thinning operation in order to reduce contour sinuosity. The thinning operation reduced point density where topographic change is minimal (i.e., flat surfaces) while preserving resolution where topographic change was present. Model key points were selected from the ground model every 20 feet with the spacing decreased in regions with high surface curvature. Generation of model key points eliminated redundant detail in terrain representation, particularly in areas of low relief, and provided for a more manageable dataset. Contours were produced through TerraModeler by interpolating between the model key points at even elevation increments.

Elevation contour lines were then intersected with ground point density rasters and a confidence field was added to each contour line. Contours which crossed areas of high point density have high confidence levels, while contours which crossed areas of low point density have low confidence levels. Areas with low ground point density are commonly beneath buildings and bridges, in locations with dense vegetation, over water, and in other areas where laser penetration to the ground surface was impeded (Figure 4).

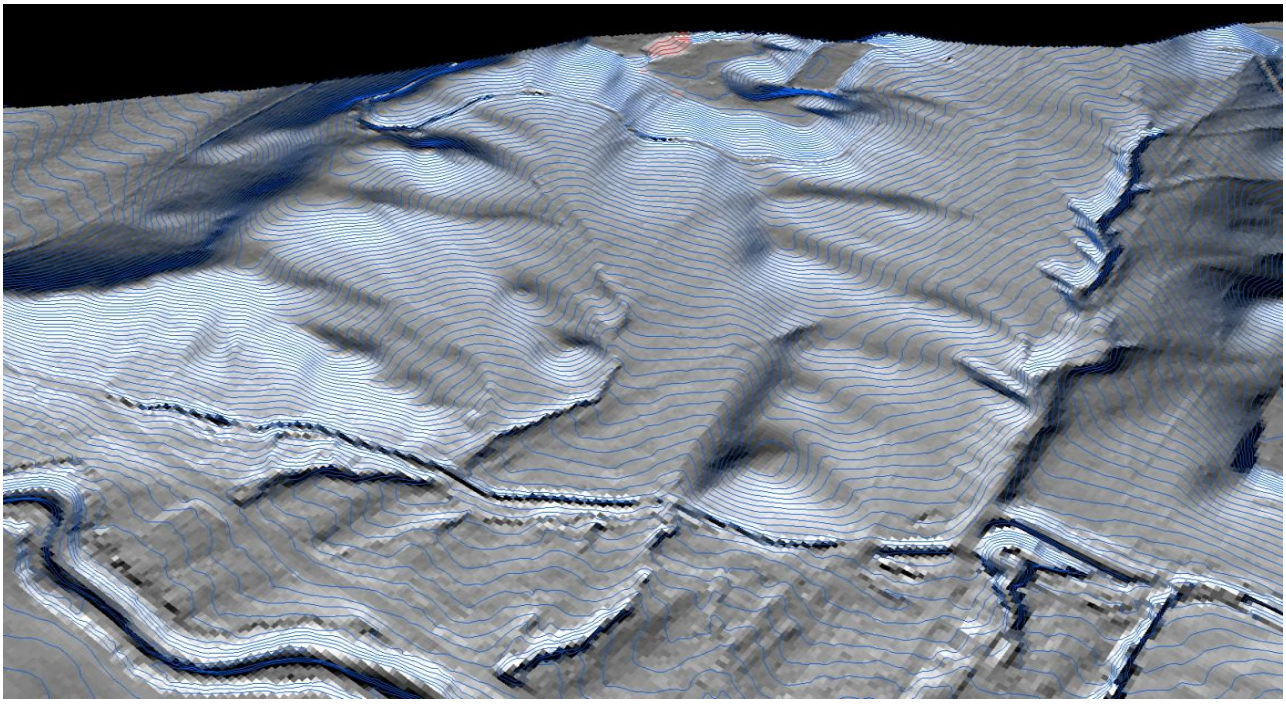
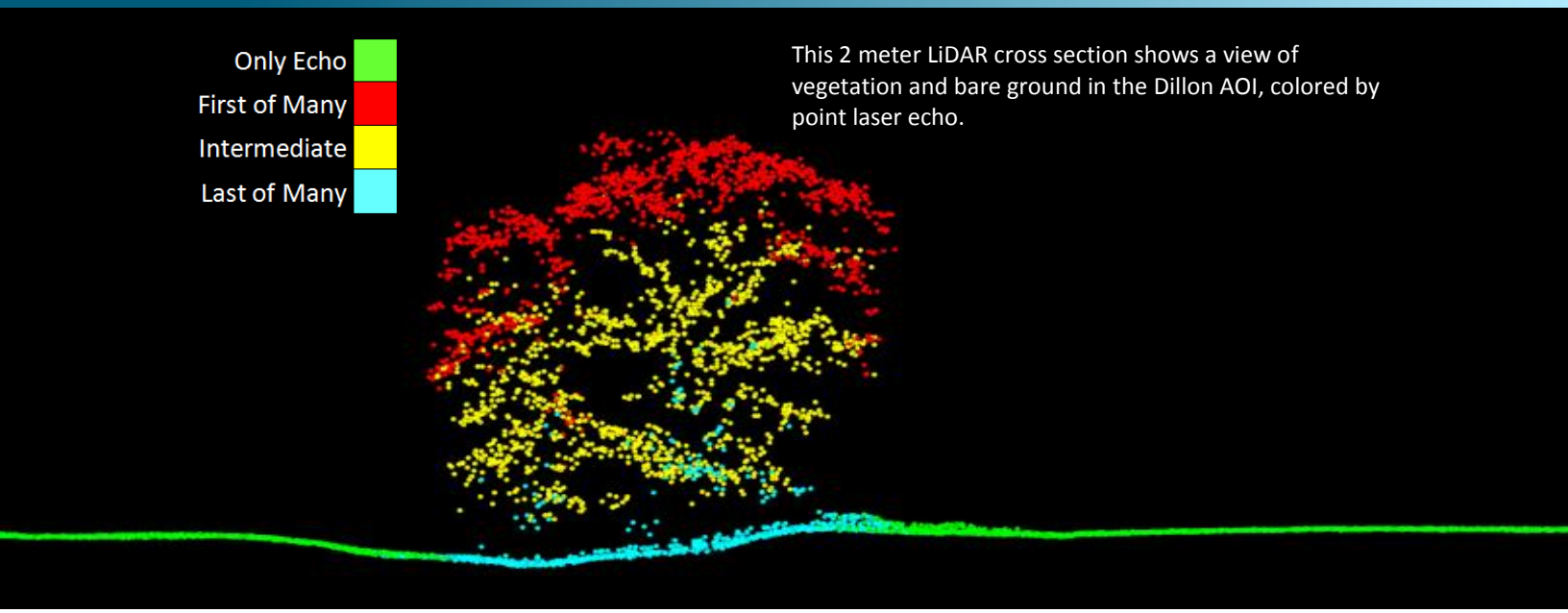


Figure 4: Contours draped over the Dillon AOI bare earth elevation model. Blue contours represent high confidence while the red contours represent low confidence.



This 2 meter LiDAR cross section shows a view of vegetation and bare ground in the Dillon AOI, colored by point laser echo.

LiDAR Density

The acquisition parameters were designed to acquire an average first-return density of 8 points/m^2. First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns from a single pulse were not considered in first return density analysis. Some types of surfaces (e.g., breaks in terrain, water and steep slopes) may have returned fewer pulses than originally emitted by the laser. First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas the highest feature could be a tree, building or power line, while in areas of unobstructed ground, the first return will be the only echo and represents the bare earth surface.

The density of ground-classified LiDAR returns was also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may penetrate the canopy, resulting in lower ground density.

The average first-return density of LiDAR data for the Dillon AOI was 11.09 points/m^2 while the average ground classified density was 6.95 points/m^2 (Table 9). The statistical and spatial distributions of first return densities and classified ground return densities per 100 m x 100 m cell are portrayed in Figure 5 through Figure 7.

Table 9: Average LiDAR point densities

Classification	Point Density
First-Return	11.09 points/m^2
Ground Classified	6.95 points/m^2

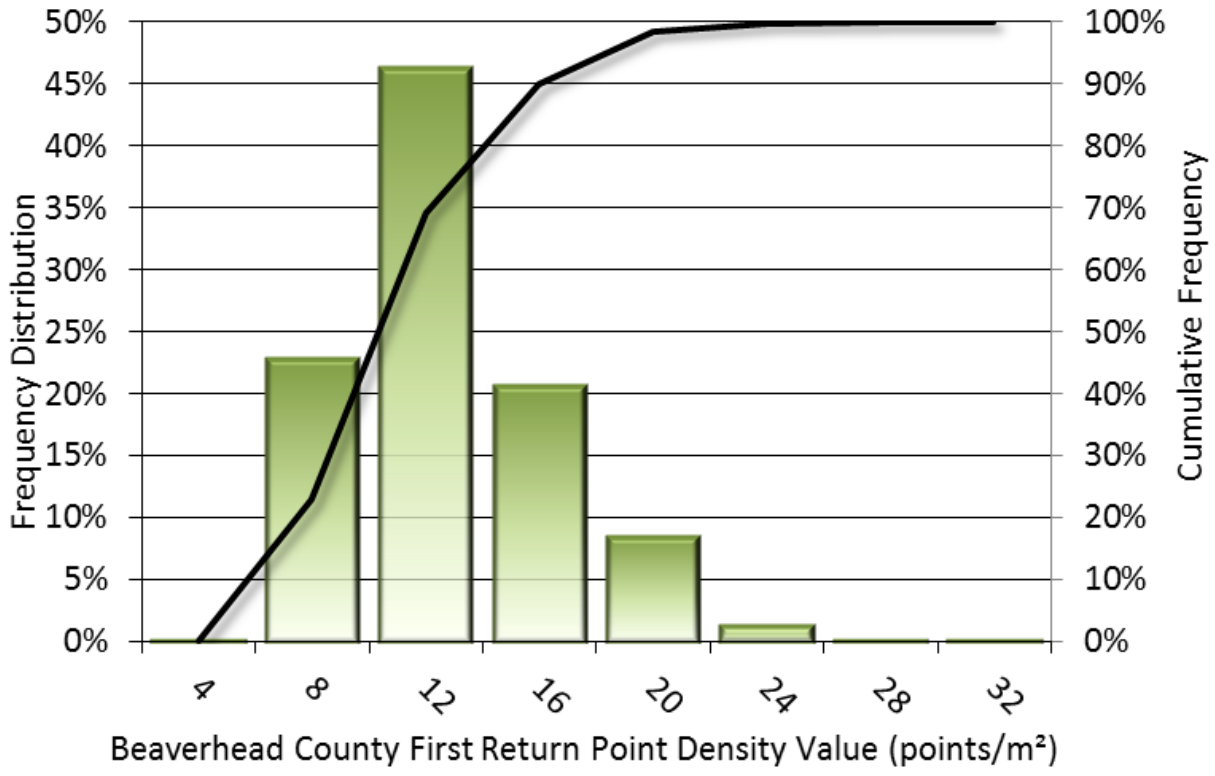


Figure 5: Frequency distribution of first return point density values per 100 x 100 m cell

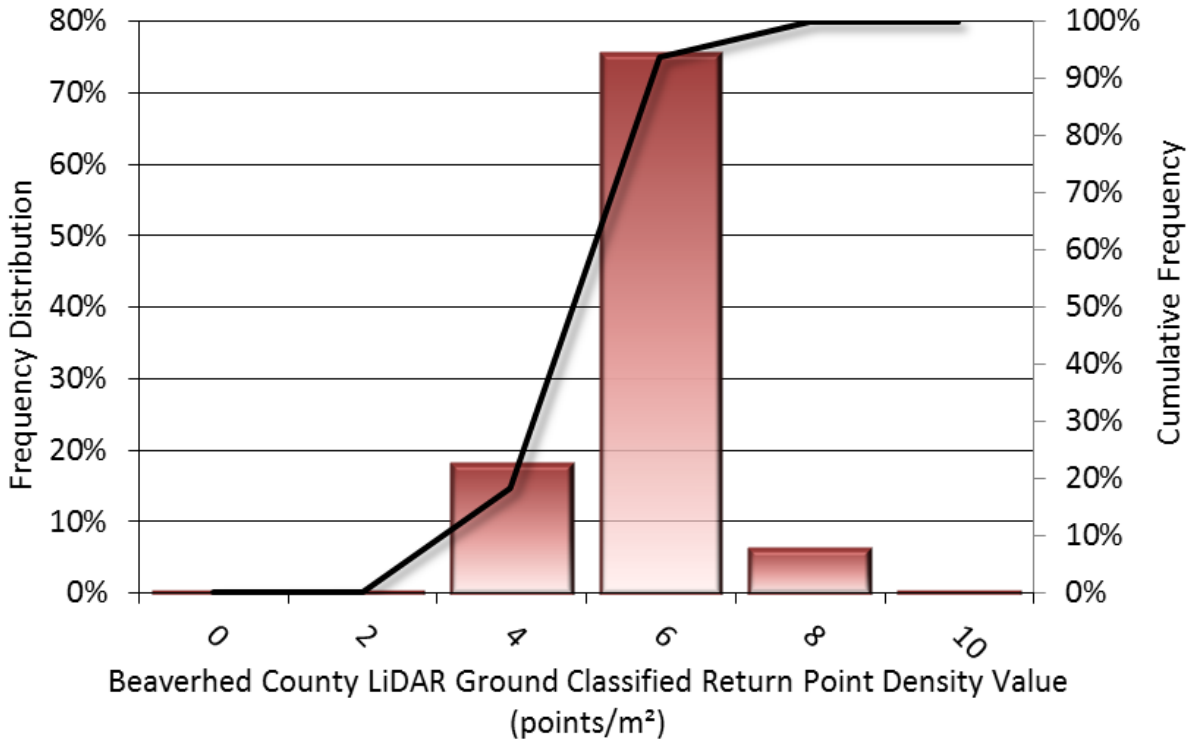


Figure 6: Frequency distribution of ground-classified return point density values per 100 x 100 m cell

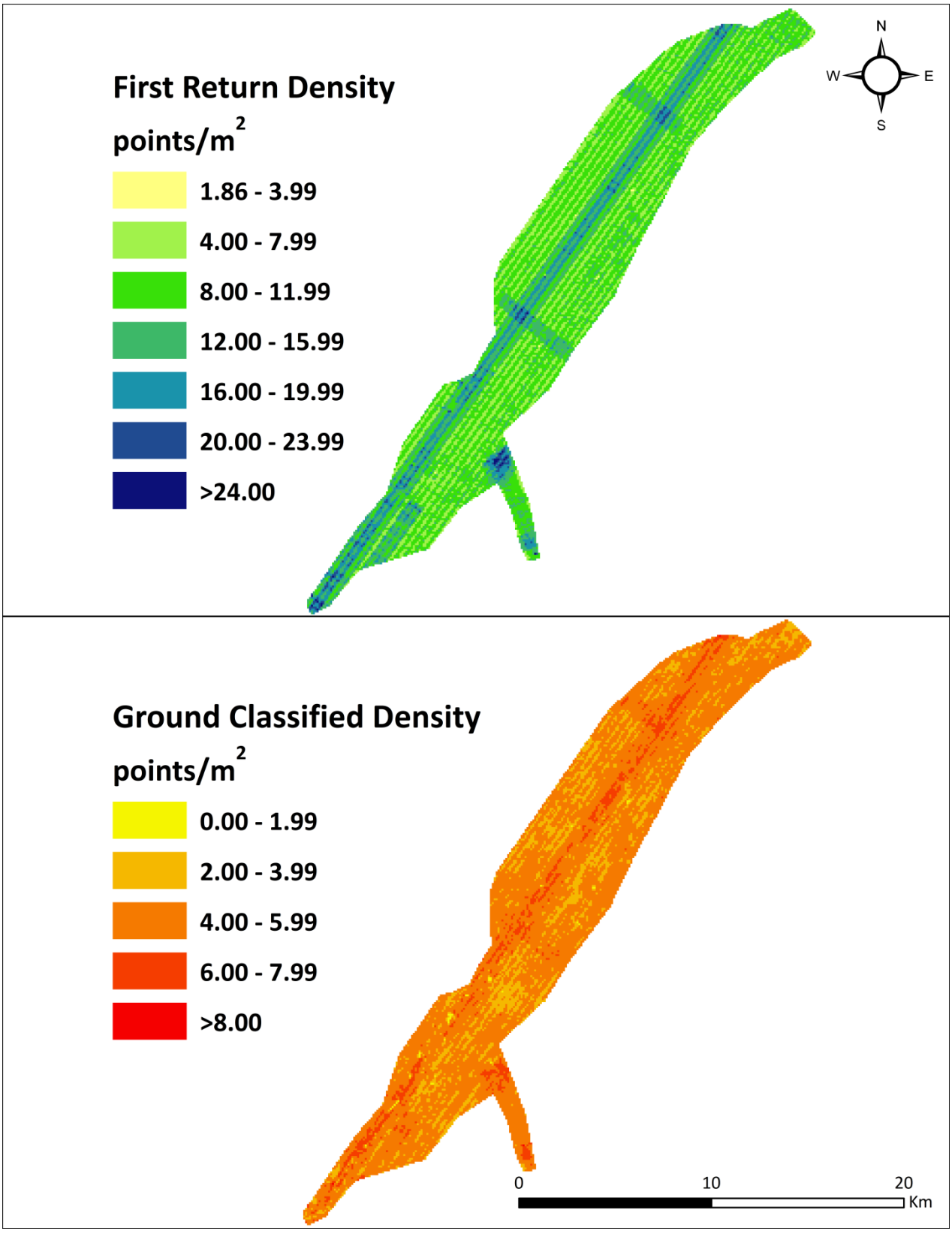


Figure 7: First return and ground-classified point density map for the Dillon AOI (100 m x 100 m cells)

LiDAR Accuracy Assessments

The accuracy of the LiDAR data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). See Appendix A for further information on sources of error and operational measures used to improve relative accuracy.

LiDAR Non-Vegetated Vertical Accuracy

Non-Vegetated Vertical Accuracy (NVA) was assessed according to guidelines presented in the FGDC National Standard for Spatial Data Accuracy[3]. NVA compares known ground quality assurance point data collected on open, bare earth surfaces with level slope (<20°) to the triangulated surface generated by the LiDAR points. NVA is a measure of the accuracy of LiDAR point data in open areas where the LiDAR system has a high probability of measuring the ground surface and is evaluated at the 95% confidence interval (1.96 * RMSE), as shown in Table 10.

The mean and standard deviation (sigma σ) of divergence of the ground surface model from ground check point coordinates are also considered during accuracy assessment. These statistics assume the error for x, y, and z is normally distributed, and therefore the skew and kurtosis of distributions are also considered when evaluating error statistics. For the Dillon AOI survey, 22 ground check points were withheld in total resulting in a non-vegetated vertical accuracy of 0.029 meters (Figure 8).

Table 10: NVA results

Absolute Accuracy	
Sample	22 points
NVA (1.96*RMSE)	0.029 m
Average	-0.003 m
Median	-0.010 m
RMSE	0.015 m
Standard Deviation (1σ)	0.015 m

[3] Federal Geographic Data Committee, ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA EDITION 1, Version 1.0, NOVEMBER 2014. http://www.asprs.org/PAD-Division/ASPRS-POSITIONAL-ACCURACY-STANDARDS-FOR-DIGITAL-GEOSPATIAL-DATA.html.

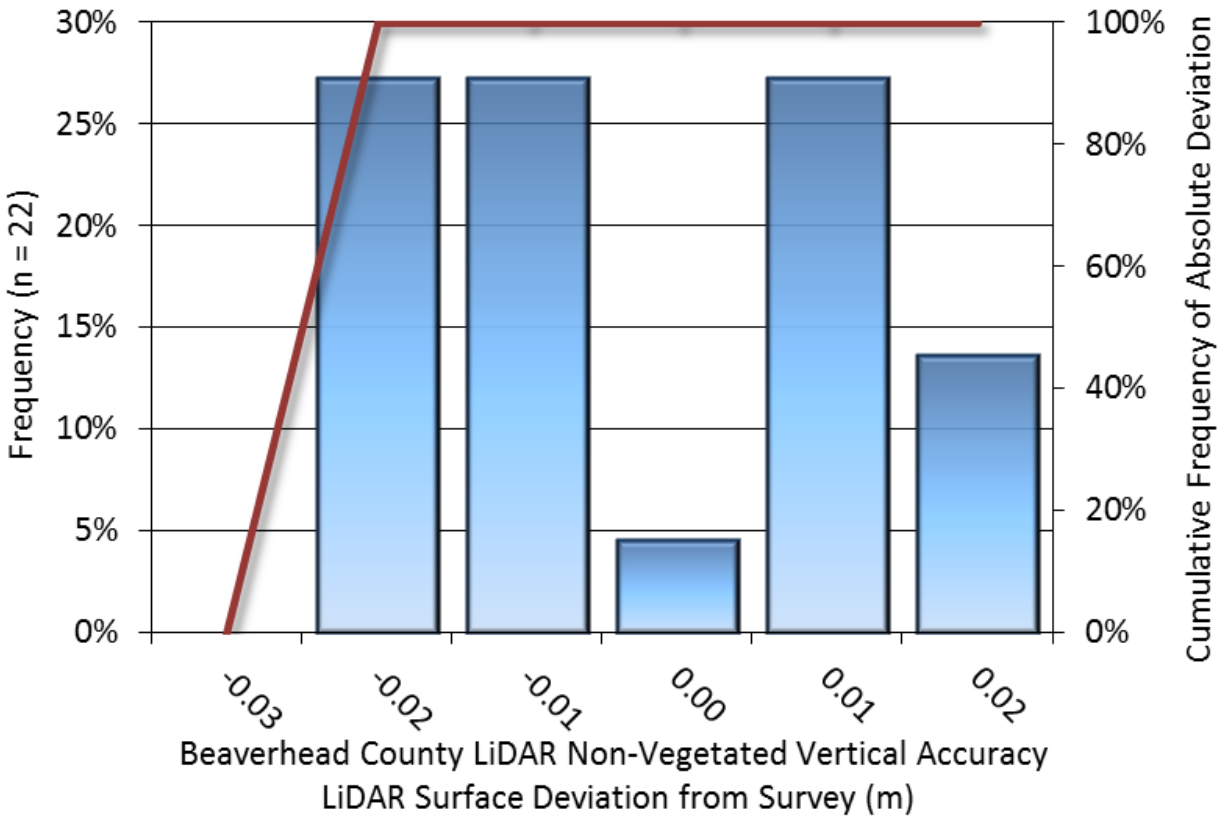


Figure 8: Frequency histogram for LiDAR surface deviation from ground check point values

LiDAR Vegetated Vertical Accuracy

QSI also assessed vertical accuracy using Vegetated Vertical Accuracy (VVA) reporting. VVA compares known ground quality assurance point data collected over vegetated surfaces using land class descriptions to the triangulated ground surface generated by the ground classified LiDAR points. VVA is evaluated at the 95th percentile (Table 11, Figure 9).

Table 11: Vegetated Vertical Accuracy for the Dillon AOI Project

Vegetated Vertical Accuracy (VVA)	
Sample	22 points
Average Dz	0.031 m
Median	0.025 m
RMSE	0.047 m
Standard Deviation (1σ)	0.035 m
95th Percentile	0.080 m

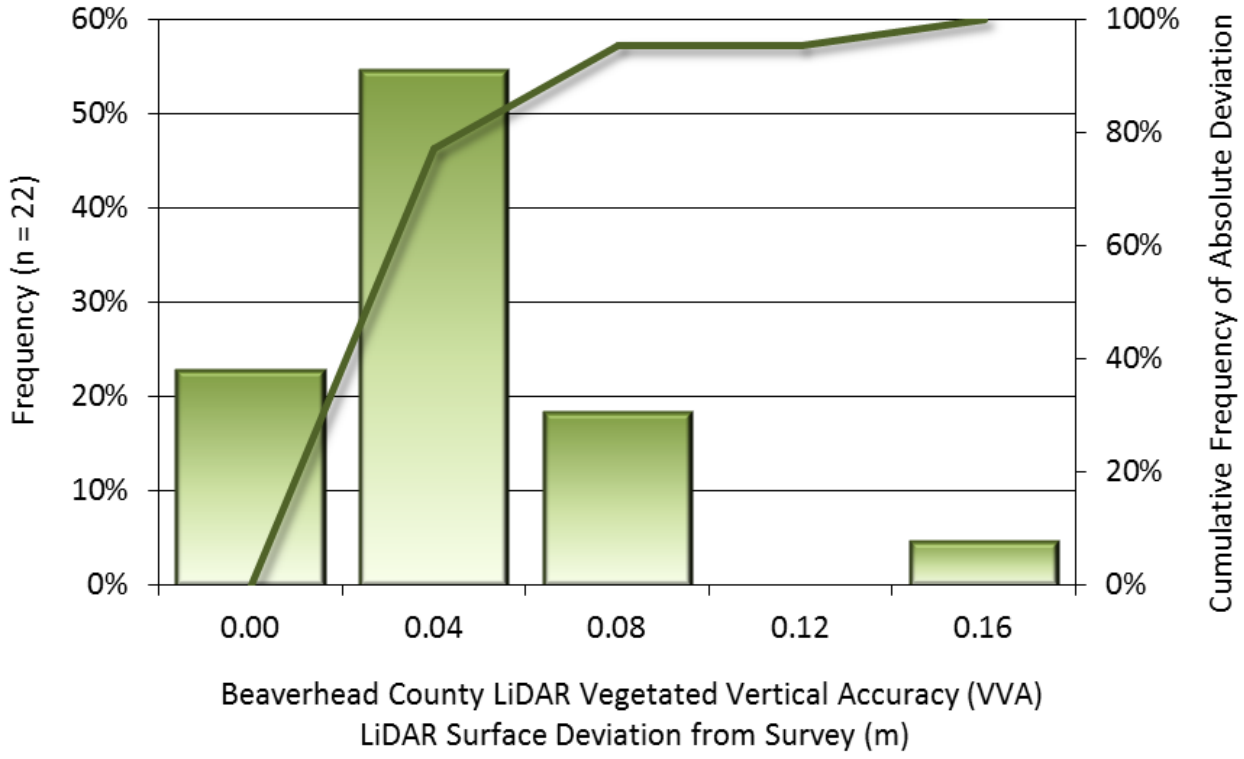


Figure 9: Frequency histogram for LiDAR surface deviation from all land cover class point values (VVA)

LiDAR Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the LiDAR system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the Dillon AOI LiDAR project was 0.017 meters (Table 12, Figure 10).

Table 12: Relative accuracy results

Relative Accuracy	
Sample	31 surfaces
Average	0.017 m
Median	0.017 m
RMSE	0.017 m
Standard Deviation (1σ)	0.001 m
1.96σ	0.002 m

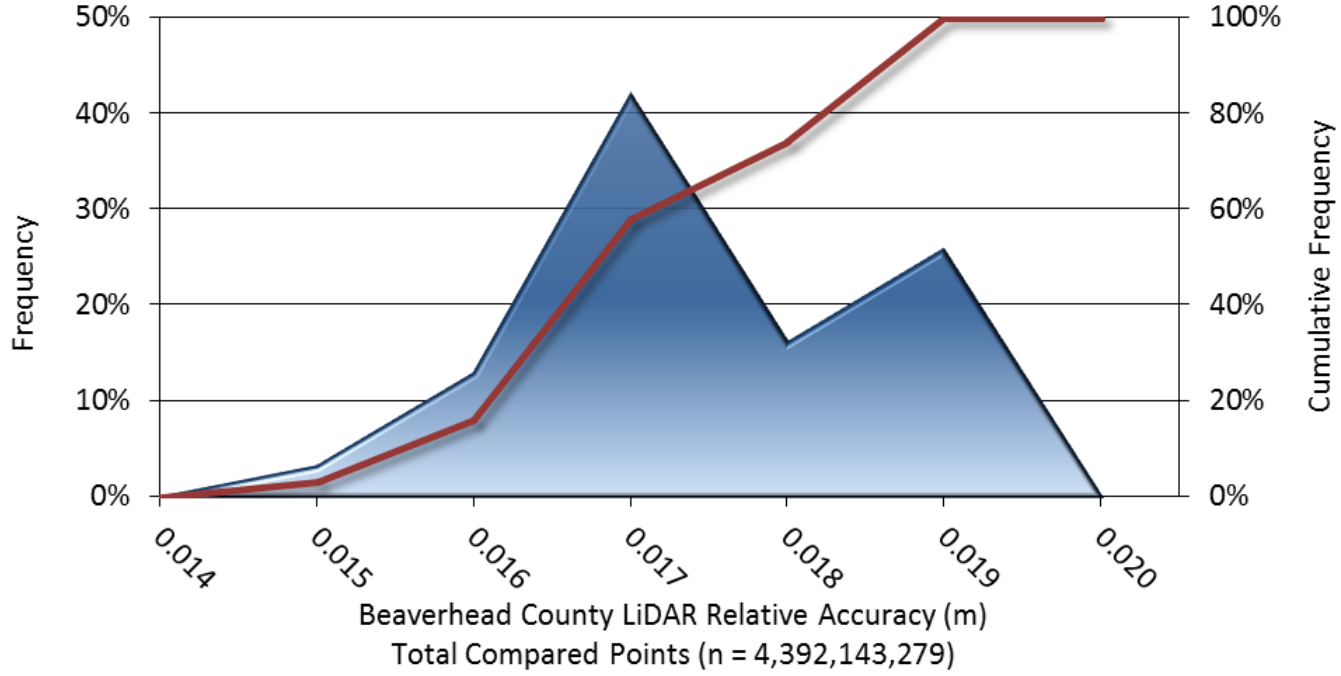


Figure 10: Frequency plot for relative vertical accuracy between flight lines

Figure 11: View looking northeast across a meandering river in the central part of the Dillon AOI. The image was created from the LiDAR bare earth model overlaid with the above-ground point cloud and USDA NAIP imagery.

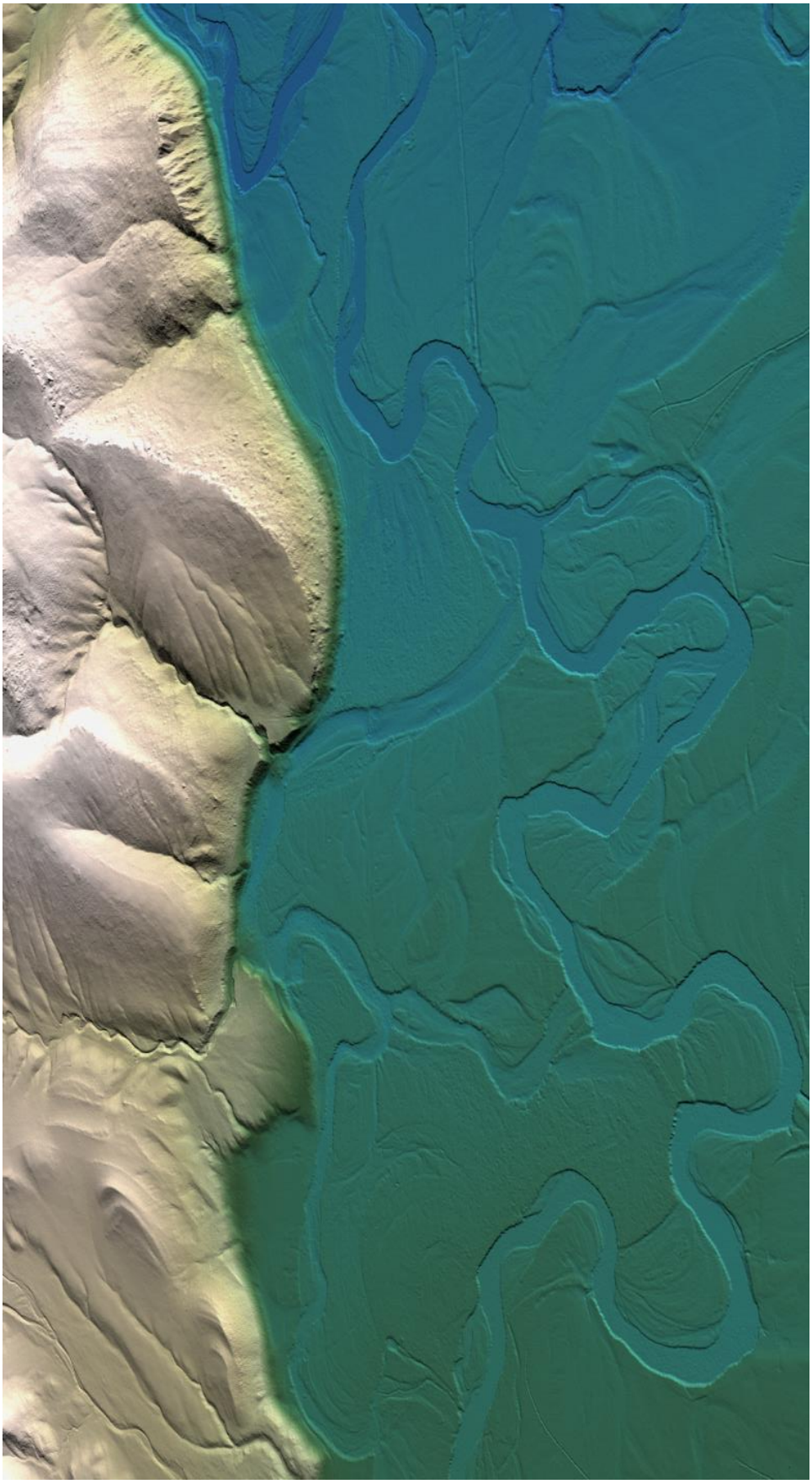


Figure 12: The top image is a bare earth model, colored by elevation. It is view looking down and slightly north in the northern part of the Dillon AOI.

GLOSSARY

1-sigma (σ) Absolute Deviation: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed data set.

1.96 * RMSE Absolute Deviation: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed data set, based on the FGDC standards for Non-Vegetated Vertical Accuracy (NVA) reporting.

Accuracy: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma σ) and root mean square error (RMSE).

> **Absolute Accuracy:** The vertical accuracy of LiDAR data is described as the mean and standard deviation (sigma σ) of divergence of LiDAR point coordinates from ground survey point coordinates. To provide a sense of the model predictive power of the dataset, the root mean square error (RMSE) for vertical accuracy is also provided. These statistics assume the error distributions for x, y and z are normally distributed, and thus we also consider the skew and kurtosis of distributions when evaluating error statistics.
>
> **Relative Accuracy:** Relative accuracy refers to the internal consistency of the data set; i.e., the ability to place a laser point in the same location over multiple flight lines, GPS conditions and aircraft attitudes. Affected by system attitude offsets, scale and GPS/IMU drift, internal consistency is measured as the divergence between points from different flight lines within an overlapping area. Divergence is most apparent when flight lines are opposing. When the LiDAR system is well calibrated, the line-to-line divergence is low (<10 cm).
>
> **Root Mean Square Error (RMSE):** A statistic used to approximate the difference between real-world points and the LiDAR points. It is calculated by squaring all the values, then taking the average of the squares and taking the square root of the average.

Data Density: A common measure of LiDAR resolution, measured as points per square meter.

Digital Elevation Model (DEM): File or database made from surveyed points, containing elevation points over a contiguous area. Digital terrain models (DTM) and digital surface models (DSM) are types of DEMs. DTMs consist solely of the bare earth surface (ground points), while DSMs include information about all surfaces, including vegetation and man-made structures.

Intensity Values: The peak power ratio of the laser return to the emitted laser, calculated as a function of surface reflectivity.

Nadir: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flight line.

Overlap: The area shared between flight lines, typically measured in percent. 100% overlap is essential to ensure complete coverage and reduce laser shadows.

Pulse Rate (PR): The rate at which laser pulses are emitted from the sensor; typically measured in thousands of pulses per second (kHz).

Pulse Returns: For every laser pulse emitted, the number of wave forms (i.e., echos) reflected back to the sensor. Portions of the wave form that return first are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

Real-Time Kinematic (RTK) Survey: A type of surveying conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

Post-Processed Kinematic (PPK) Survey: GPS surveying is conducted with a GPS rover collecting concurrently with a GPS base station set up over a known monument. Differential corrections and precisions for the GNSS baselines are computed and applied after the fact during processing. This type of ground survey is accurate to 1.5 cm or less.

Scan Angle: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

Native LiDAR Density: The number of pulses emitted by the LiDAR system, commonly expressed as pulses per square meter.

Relative Accuracy Calibration Methodology:

Manual System Calibration: Calibration procedures for each mission require solving geometric relationships that relate measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration was completed and reported for each survey area.

Automated Attitude Calibration: All data were tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flight line and used for line-to-line testing. System misalignment offsets (pitch, roll and heading) and scale were solved for each individual mission and applied to respective mission datasets. The data from each mission were then blended when imported together to form the entire area of interest.

Automated Z Calibration: Ground points per line were used to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

LiDAR accuracy error sources and solutions:

Type of Error	Source	Post Processing Solution
GPS (Static/Kinematic)	Long Base Lines	None
	Poor Satellite Constellation	None
	Poor Antenna Visibility	Reduce Visibility Mask
Relative Accuracy	Poor System Calibration	Recalibrate IMU and sensor offsets/settings
	Inaccurate System	None
Laser Noise	Poor Laser Timing	None
	Poor Laser Reception	None
	Poor Laser Power	None
	Irregular Laser Shape	None

Operational measures taken to improve relative accuracy:

Low Flight Altitude: Terrain following was employed to maintain a constant above ground level (AGL). Laser horizontal errors are a function of flight altitude above ground (about 1/3000th AGL flight altitude).

Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return (i.e., intensity) is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes can be maintained.

Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of ±15° from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.

Quality GPS: Flights took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). Before each flight, the PDOP was determined for the survey day. During all flight times, a dual frequency DGPS base station recording at 1 second epochs was utilized and a maximum baseline length between the aircraft and the control points was less than 13 nm at all times.

Ground Survey: Ground survey point accuracy (<1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. Ground survey points are distributed to the extent possible throughout multiple flight lines and across the survey area.

50% Side-Lap (100% Overlap): Overlapping areas are optimized for relative accuracy testing. Laser shadowing is minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the nadir portion of one flight line coincides with the swath edge portion of overlapping flight lines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.

Opposing Flight Lines: All overlapping flight lines have opposing directions. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flight line(s), making misalignments easier to detect and resolve.

SURVEY REPORT
Blacktail Deer Creek Flood Study,
Beaverhead Countywide Project
Mapping Activity Statement No. 2016-01

Prepared for:
Montana Department of Natural Resources and Conservation
1424 9th Avenue
Helena, MT 59620
Contract: WO-MM-143

Prepared by:
Morrison-Maierle
1 Engineering Place
PO Box 6147
Helena, MT 59604

MMI PN: 1447.046

March 3, 2017

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Figure 2. BEAVERHEAD RIVER AREA SITE MAP 5

1.0 PROJECT OVERVIEW

1.1 PROJECT DESCRIPTION

The Blacktail Deer Creek flood study, part of the Beaverhead Countywide Project, consists of hydraulic analysis and floodplain mapping for approximately 11 miles of Blacktail Deer Creek. This survey report summarizes the activities associated with the structure and bathymetric surveys.

1.2 PROJECT LOCATION

The Blacktail Deer Creek flood study extends approximately 11 miles upstream from the confluence with the Beaverhead River in the City of Dillon, Montana. Refer to Figure 2, Beaverhead River Area Site Map.

1.3 GUIDELINES AND STANDARDS

Guidelines and Standards relative to the survey activities were downloaded from the FEMA website at http://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping and included:

- *Data Capture Guidance – General (Nov 2016)*
- *Data Capture Guidance – Workflow Details (May 2016)*
- *Data Capture Technical Reference (Nov 2016)*
- *FIRM Database Guidance (Nov 2016)*
- *FIRM Database Technical Reference (Nov 2016)*

Mapping Activity Statement No. 2016-01 dated *June 30, 2016,* provides survey standards and deliverables for this project.

1.4 DATUM

State plane coordinates generated this survey are referenced to the Montana Coordinate System, North American Datum of 1983 (NAD83-2011). Units are reported in International feet. Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88). Units are reported in U.S. Feet. GNSS-derived orthometric heights (elevations) were computed using Geoid 12A. These datum and units are identical to those used for the LiDAR calibration control points previously established by other firms.

2.0 PROJECT PLANNING

2.1 STRUCTURE IDENTIFICATION

The study area included 52 hydraulic structures (bridges, culverts, diversions, etc.) identified during a desktop review and provided by the MT DNRC which might potentially influence the water surface elevations on the Blacktail Deer Creek and adjacent floodplain. An additional desktop review prior to the field work in combination with the field investigation yielded a total of 56 hydraulics structure sites where field survey was necessary to capture the potential impact of hydraulic structures on water surface elevations due to the hydraulic structures.

2.2 LANDOWNER CONTACTS

Prior to performing survey field work, notification letters were sent to all land owners of parcels within the anticipated survey extents. Land ownership for these parcels was determined using the Montana Cadastral data provided thorough the Montana Cadastral Mapping Project. These data were used in ESRI Shapefile format to delineate property boundaries and their corresponding parcel owner names and addresses. Survey extents were first determined by automatically selecting in ArcMap all parcels within 500-feet of any survey feature such as a hydraulic structure, bathymetric cross section, or control point. This parcel selection was then refined by manually de-selecting any parcels that appeared outside of the anticipated survey extents. This analysis resulted in 79 individual notification letters to landowners. A tracking spreadsheet was created to track landowner correspondence and concerns, and was updated by both the DNRC and Morrison-Maierle.

2.3 SURVEY WORK MAPS

Survey work maps were prepared for use in the field by survey crews. The maps included the preliminary locations of cross sections to be surveyed in the detailed reaches, along with structure locations and control. Digital data was uploaded to field computers to provide real-time navigation along the cross sections.

2.4 POINT LABELING CONVENTION

Blocks of points to be used for the survey data collection were reserved for each reach as follows:

- Crew 1 40,000-59,999
- Crew 2 60,600-69,9999

3.0 FIELD WORK

3.1 CONTROL VERIFICATION AND DENSIFICATION

A control survey was performed in 2016 by Gaston Engineering to support the LiDAR and imagery acquisition. Control data was provided to Morrison-Maierle by Gaston Engineering. This control was the basis for the structure and bathymetric surveys conducted by Morrison-Maierle.

Prior to data collection the control points utilized by Morrison-Maierle were occupied with survey-grade GNSS receivers and tested for accuracy. All points utilized by the field survey crew were within acceptable limits. Two U.S. Coast and Geodetic monuments within proximity to the project area were also surveyed. An additional control point was established from the existing control and served as the RTK base station setup point for the entire Blacktail Deer Creek survey.

3.2 SURVEY METHODOLOGY

Structure and bathymetric surveys were completed using Global Navigation Satellite System (GNSS) real-time kinematic (RTK) methods of survey. Trimble R8 Model-3 GNSS receivers were used, with Trimble TSC3 survey controllers and Trimble Access software. Prior to data collection, a “checkpoint” observation was done on a known control point to verify the base and rover setup. Cross section and structure data was then collected using the feature codes and guidelines outlined in FEMA Data Capture Technical Reference, November 2016.

Survey data was downloaded, backed up on a thumb drive, and uploaded to the Morrison-Maierle. network server on a daily basis. The Survey Manager reviewed progress daily and coordinated the field effort as needed to meet the fast track schedule.

The structure survey data was uploaded for spatial analysis in AutoDesk Civil3D 2017. The survey point review was completed weekly during the survey effort. All survey points feature codes were reviewed for duplication, feature location, and compliance with stream direction conventions. The structure survey data were spot check for potential elevation errors by comparing the point elevation along the channel banks to the LDAR based terrain model. Spatial accuracy was assessed by verifying the survey points nearly matched aerial photography using ESRI ArcMap 10.4.

After the review of the survey point data was completed, the tables for the weekly structure survey shapefiles were exported and combined. The total number of points was checked against the raw survey data to verify the dataset was complete. The final survey point table was finalized from the complete survey point record of reviewed data. The final survey point table was then re-imported to a spatial format using Esri ArcMap version 10.4.

4.0 PERSONNEL AND DUTIES

Ken Salo, PE:	Project Management
Luke Carlson, PE:	Field work, data analysis and feature code QA/QC
Gunnar Getchell, PLS:	Survey crew supervision; survey data QA/QC
Jeff Roe, PLS:	Field work and survey data processing

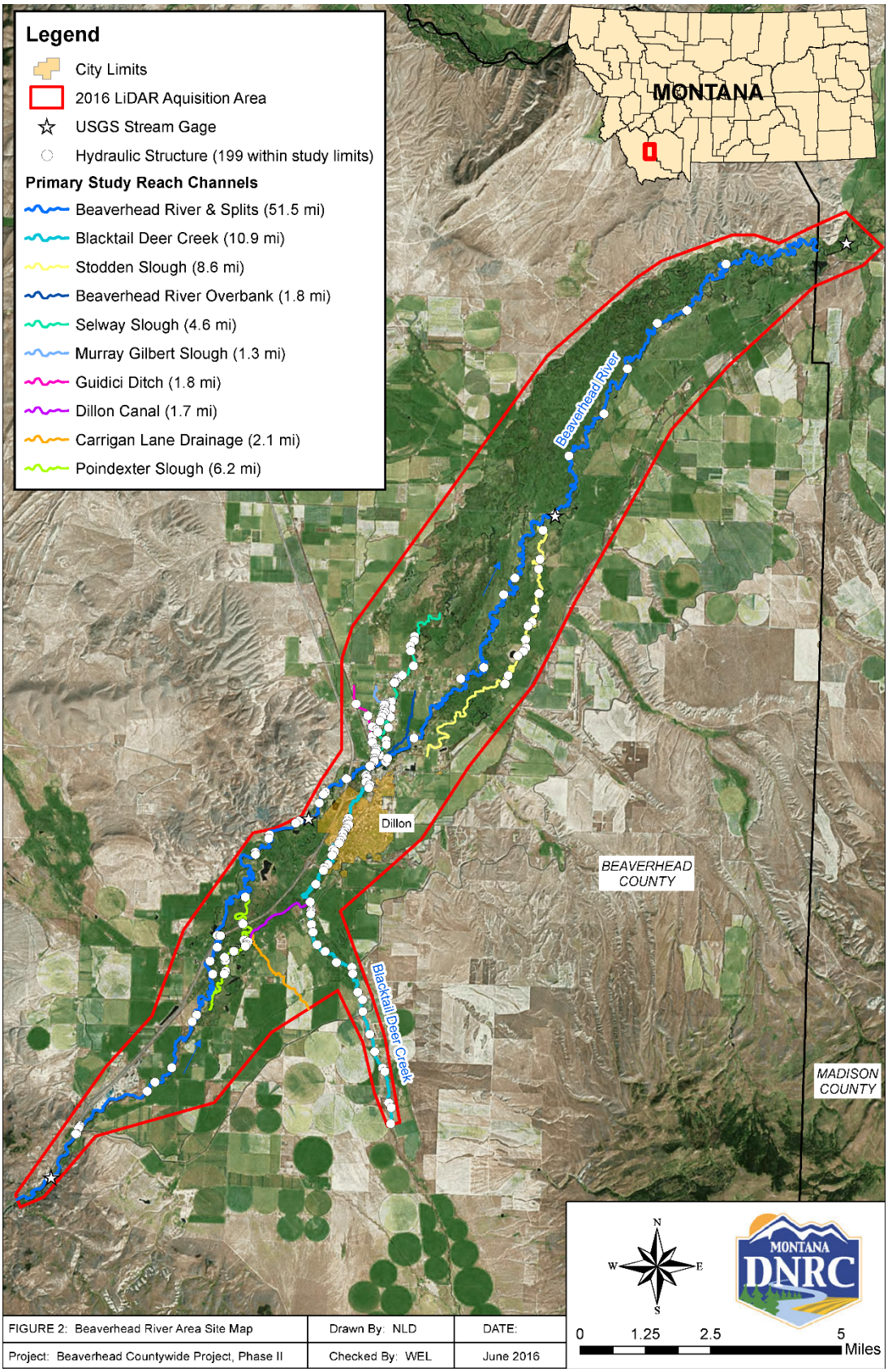
5.0 DATES OF FIELD SURVEYS

Blacktail Deer Creek	November 29 – December 20, 2016

6.0 QA/QC

QA/QC	Comments	Date; By
Guidelines and Specifications	Verify we are using the latest: http://www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping	20Nov16; 28Feb17; Gunnar Getchell
Control Checks	Review field survey checkpoints for accuracy prior to data collection each day; review additional OPUS solutions	Daily through field work; Jeff Roe
Feature Codes	Review feature codes for deviation from standard FEMA codes. Revise with additional features codes.	3Mar17 Jeff Roe
Review Structure List	Verify structure list reflects field investigation and updates.	24Feb17; Luke Carlson
Review Structure ID/Naming Convention	Ensure that the structure ID shown on the sketch and field notes is identical to its filename, the photo filename, photo folder, and the revised Structure Data Table spreadsheet. 5 places to compare	3Mar17;Jeff Roe and Luke Carlson
Review General Folder	Project Narrative; Survey Report; Certificate of Compliance; Metadata	01Mar17; Gunnar Getchell, 03Mar17Luke Carlson
Review Correspondence Folder	Landowner template; Landowner conversations	3Mar17; Jeff Roe
Review Survey/Photos Folder	Structure Photos	1Mar17; Marco Franchi
Review Survey/Sketches Folder	Structure Sketches	3Mar17; Luke Carlson
Review Survey/Supplemental Folder	Digital Survey data folder with point listing and feature code readme; Spatial folder with shapefiles; and additional folder for all other survey data	3Mar17; Jeff Roe
Review As-Built Folder	N/A	N/A

Figure 2. Blacktail River Area Site Map



Project Narrative

Beaverhead County, Montana

Morrison Maierle

engineers ▪ surveyors ▪ planners ▪ scientists

1. INTRODUCTION 3
2. SCOPE OF WORK 3
3. TECHNICAL AND NON-TECHNICAL ISSUES 4
4. INFORMATION FOR NEXT MAPPING PARTNER 4

1. Introduction

On November 8, 2016, FEMA and the Montana Department of Natural Resources and Conservation (DNRC) entered into an agreement to provide flood hazard structure and bathymetric survey for the Beaverhead River, Blacktail Deer Creek and Junction Creek within Beaverhead County, Montana. The FEMA Case ID for the aforementioned project is 17-08-0252s. The Beaverhead River Study includes:

- The Beaverhead River from the Beaverhead County eastern county line upstream approximately 52 stream-miles to approximately three stream-miles south of Barretts, Montana.
- Approximately 28 stream-miles of side channels and split flow paths from the Beaverhead River in the vicinity of Dillon, Montana including portions of the Carrigan Lane Drainage, the Dillon Canal, the Guidici Ditch, the Murray Gilbert Slough, the Poindexter Slough, the Selway Slough, and the Stodden Slough.
- Blacktail Deer Creek from the confluence with the Beaverhead River in Dillon, MT upstream approximately 11 stream-miles to a west-to-east crossing under Blacktail Road south of Dillon, Montana.
- Junction Creek from approximately ½ stream-mile downstream of the Lima Dam Road to approximately 1.75 stream-miles upstream of the Slader Street bridge in Lima, MT.

The purpose of this study is to investigate the existence and severity of flood hazards and to revise the Flood Insurance Study (FIS) for Beaverhead County. This study is comprised of both detailed and limited detailed analyses. Previous studies of these water courses in Beaverhead County utilized both approximate and detailed methods.

According to the Untied State Census Bureau, the population of Beaverhead County was 9,291 people, and the total land area was 5,572 square miles. Populations were based on 2015 estimates; land areas were based on 2010 estimates.

There are county-wide effective Flood Insurance Rate Maps (FIRM) for Beaverhead County.

The Beaverhead River and Blacktail Deer Creek portions of the project are within the Beaverhead eight order Hydrologic Unit Code (HUC8) watershed (10020002). The Junction Creek portion of the project is within the Red Rock HUC8 watershed (10020001).

2. Scope of Work

The scope of work as stated in the contract between the MT DNRC and Morrison-Maierle includes field survey of the Beaverhead River and associated splits, Blacktail Deer Creek, and Junction Creek including structure and survey and bathymetric survey in detailed study areas. The field survey must be completed and submitted in accordance with FEMA Guidelines and Standards in effect at the November 2016 updates and revisions cycle.

The structure survey includes approximately 191 structures identified by the DNRC utilizing a desk-level review of the project areas. The bathymetric survey includes approximately 59 stream-miles of the Beaverhead River and associated splits, approximately 11 stream-miles of Blacktail Deer Creek, and approximately 2.8 miles of Junction Creek (exclusive of potential splits).

3. Technical and Non-Technical Issues

Survey control for the project was provided by Gaston Engineering and Surveying P.C. The control used for the detailed survey and control points checked by the survey field crew were correct at the time of the field work.

The survey for the Beaverhead River and associated splits, Blacktail Deer Creek, and Junction Creek in Beaverhead County involved landowner notification and coordination, site visits to 191 hydraulic structures and approximately 73 miles of bathymetric mapping, all in accordance with the FEMA Guidance including:

- *Guidance for Flood Risk Analysis and Mapping Data Capture - Workflow Details* (May 2016)
- *Guidance for Flood Risk Analysis and Mapping Data Capture - General* (Nov 2016)
- *Data Capture Technical Reference (Nov 2016)*

Landowner coordination was generally very well received with occasional questions about the need to access property and the purpose/impact of the floodplain survey. However, no landowner resistance was encountered during the field survey work.

Portions of the survey were completed in snow and ice conditions. These conditions made accessing structures and stream cross-section locations more challenging that typically encountered in the fall and spring. However, all survey data represents bare ground or below water channel bottom information. Some areas include structure and cross-section photos where the land surface is covered in snow and the channel is partially frozen making assessment of roughness values more challenging based on the photos. Generally, the cross section notes and structure sketches included in this submission include field notes that may assist the hydraulic engineering in determining the appropriate roughness parameters for that feature.

4. Information for Next Mapping Partner

For the Musselshell River Study, structural and bathymetric surveys were performed on an approximate 52 mile reach of the Beaverhead River both upstream and downstream of Dillon, MT, on an approximate 11 mile reach of Blacktail Deer Creek near Dillon, MT, and on an approximate 4.7 mile reach of Junction Creek in Lima, MT in Beaverhead County. Survey data was collected and reported in the NAD83 horizontal datum and in the NAVD88 vertical datum in units of feet.

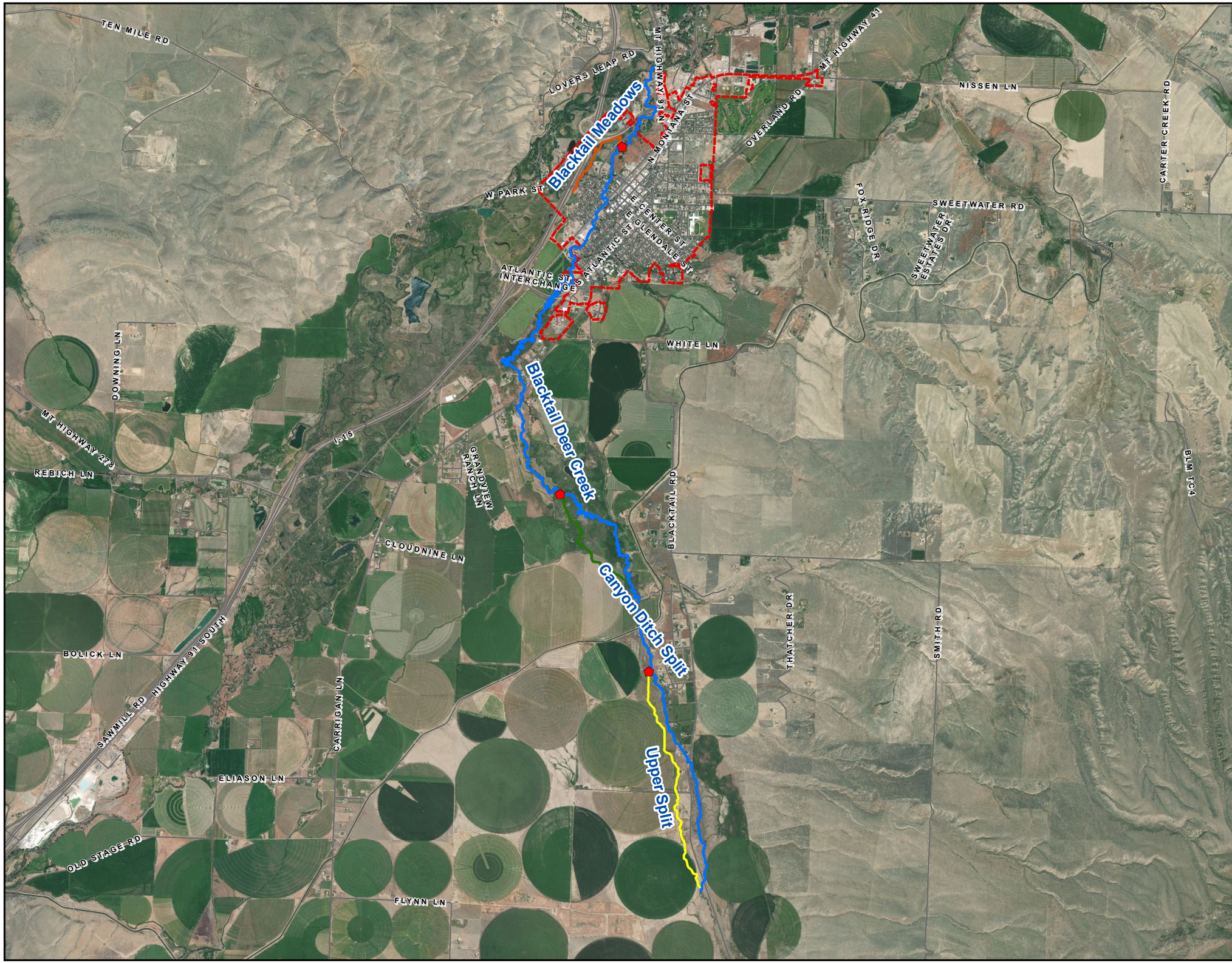
Supplemental information including all potential structures field investigated, whether or not they were surveyed and short comments for each structure, field notebooks, raw survey point files, survey point correction cross-reference spreadsheets, survey point spatial files, the stream

centerlines that formed the basis for the field investigation, and a survey report detailing survey approach and methodology.

APPENDIX B – WORKING MAPS

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Profile Baseline (Varies by Color)
- City Of Dillion
- Roads

Labels

- A Cross Section Letter
- 1234 Stream Station 1234.56 Water Surface Elevation

0 1,875 3,750 7,500 Feet

DATA FRAME PROPERTIES
Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Intl
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot
1" = 250'

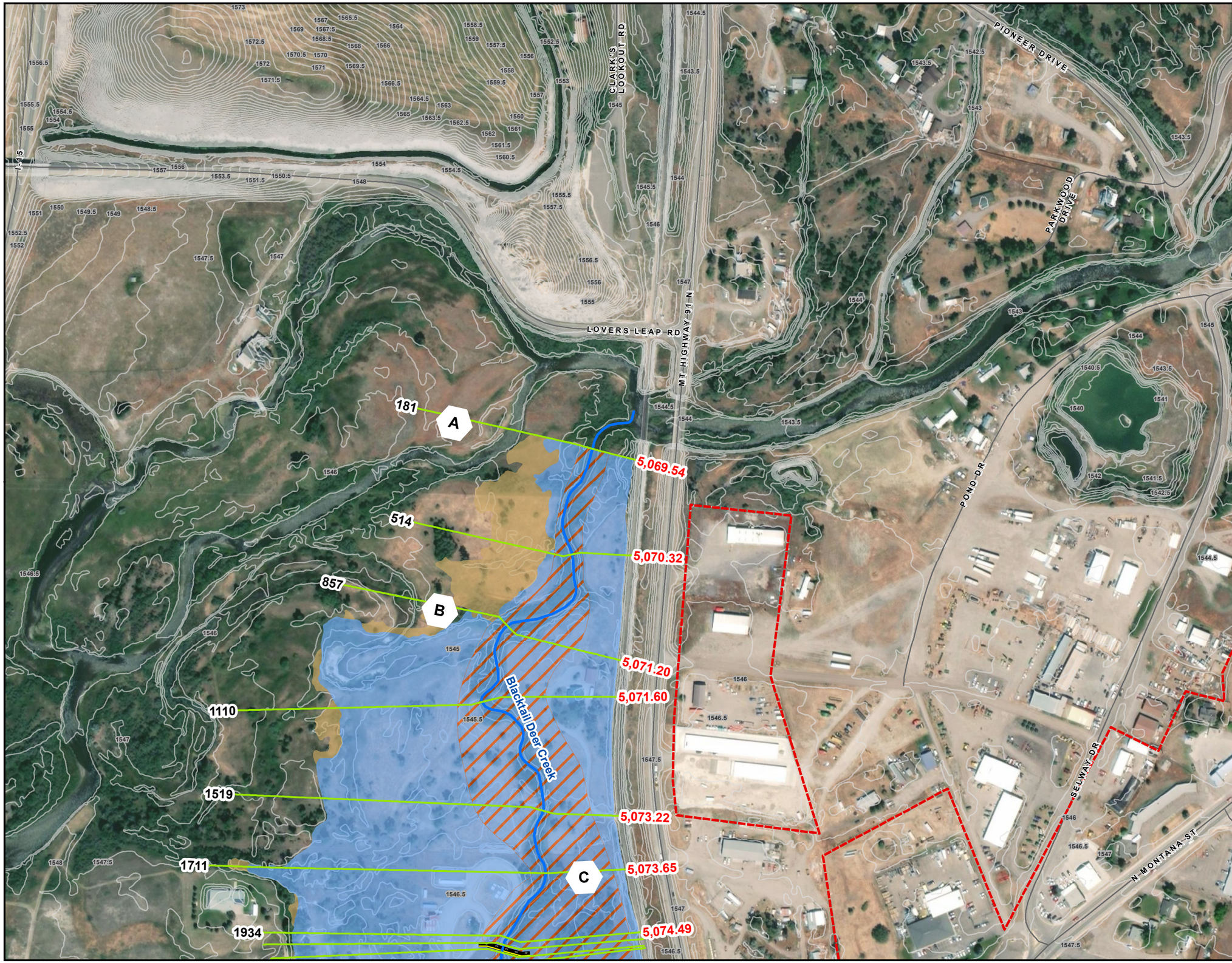
Note; This map shows the regulatory water surface elevations as well as the stream stationing. The proposed floodplain boundary is also mapped.

DOWL

Blacktail Deer Creek Index Map

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
- FLOODWAY
- 1% AC (100 yr)
- 0.2% AC (500 yr)
- 1% AC Depth Less Than 0.5 Feet
- Contours
- Roads

Labels

A Cross Section Letter

1234 Stream Station 1234.56 Water Surface Elevation

0 125 250 500 Feet

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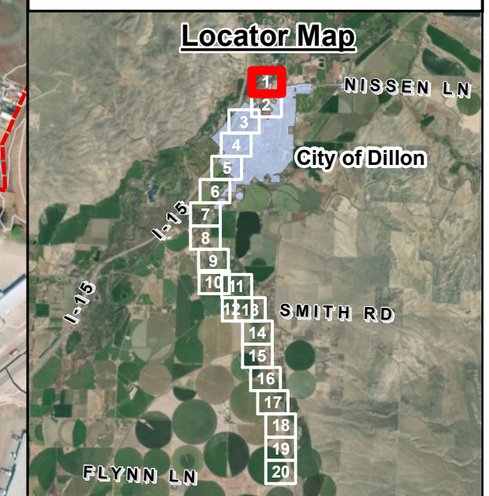
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

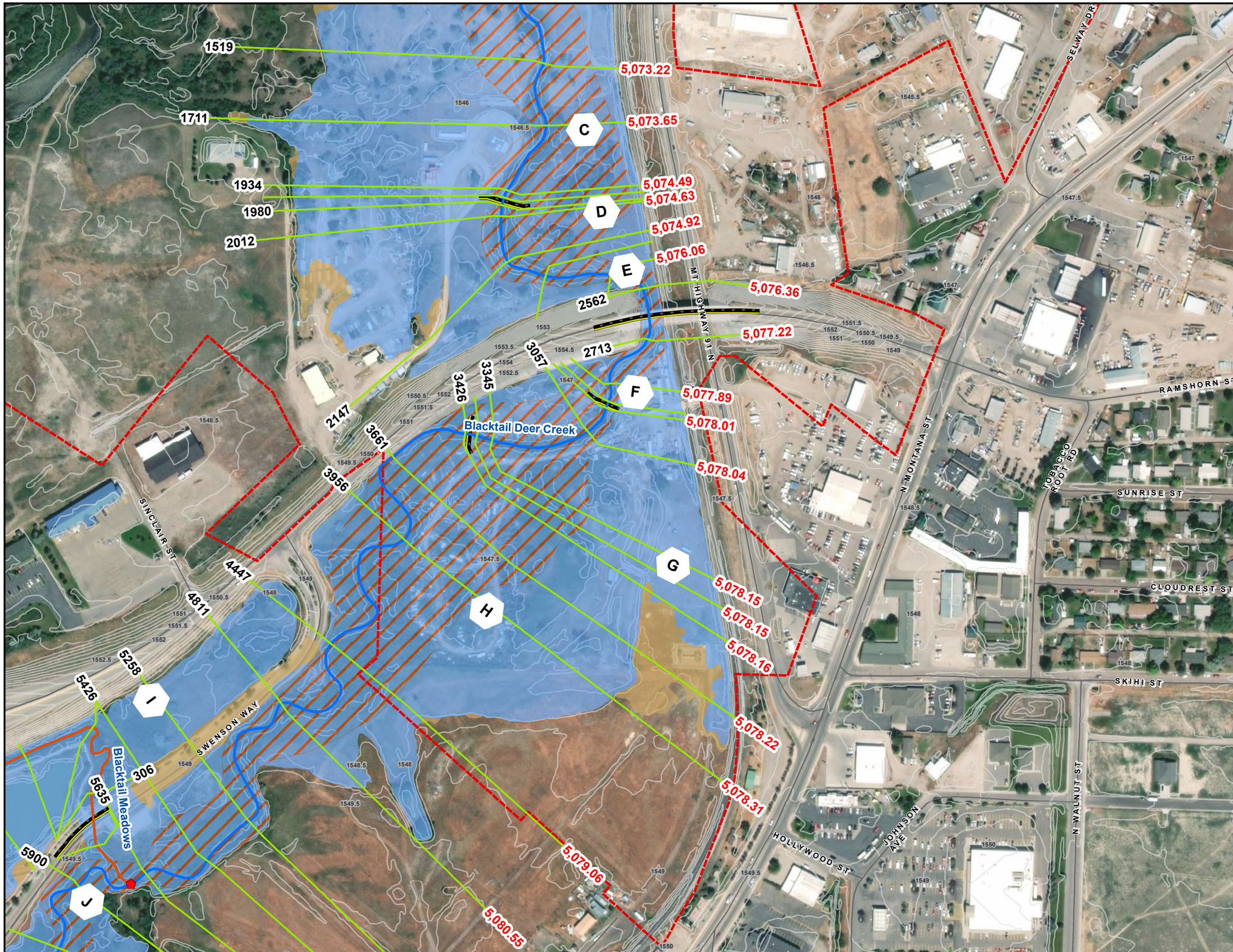
Locator Map



Blacktail Deer Creek
Map 1 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



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BEAVERHEAD COUNTY

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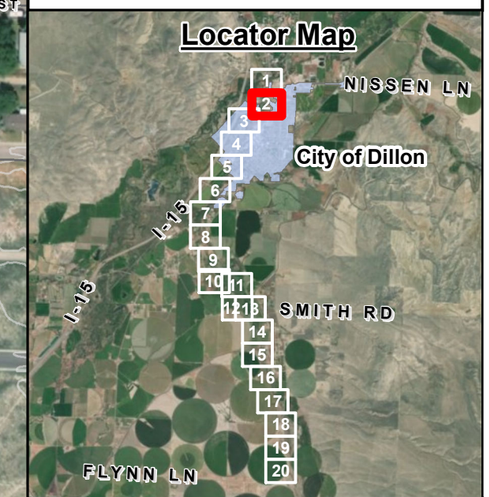

Blacktail Deer Creek
Map 2 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019

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MONTANA DNRC

BEAVERHEAD COUNTY

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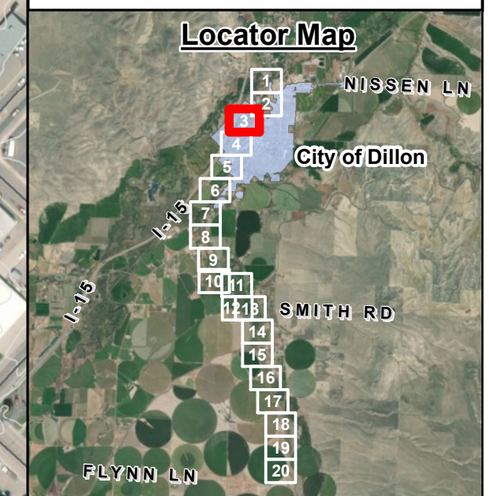
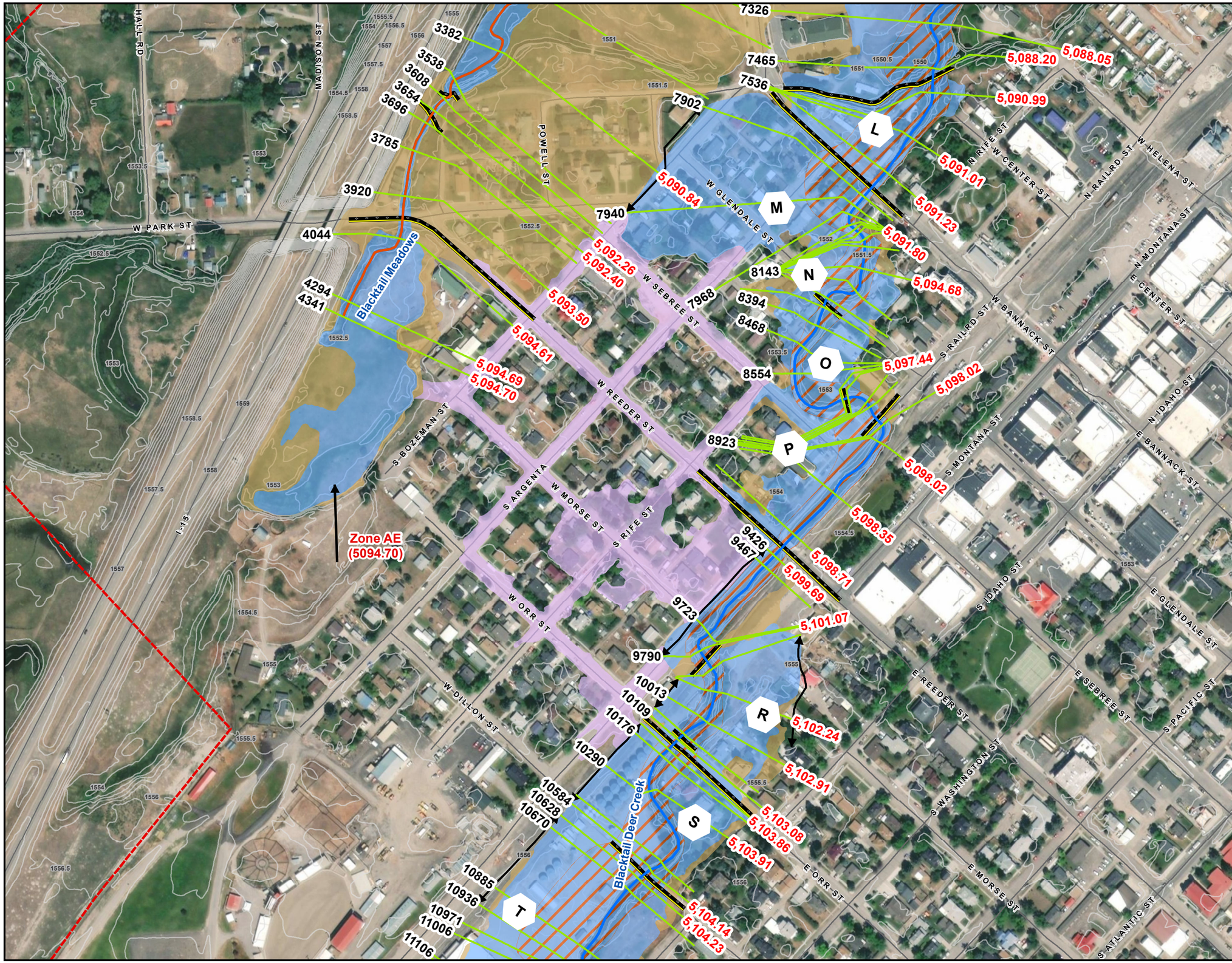


Blacktail Deer Creek
Map 3 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



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DOWL

MONTANA DNRC

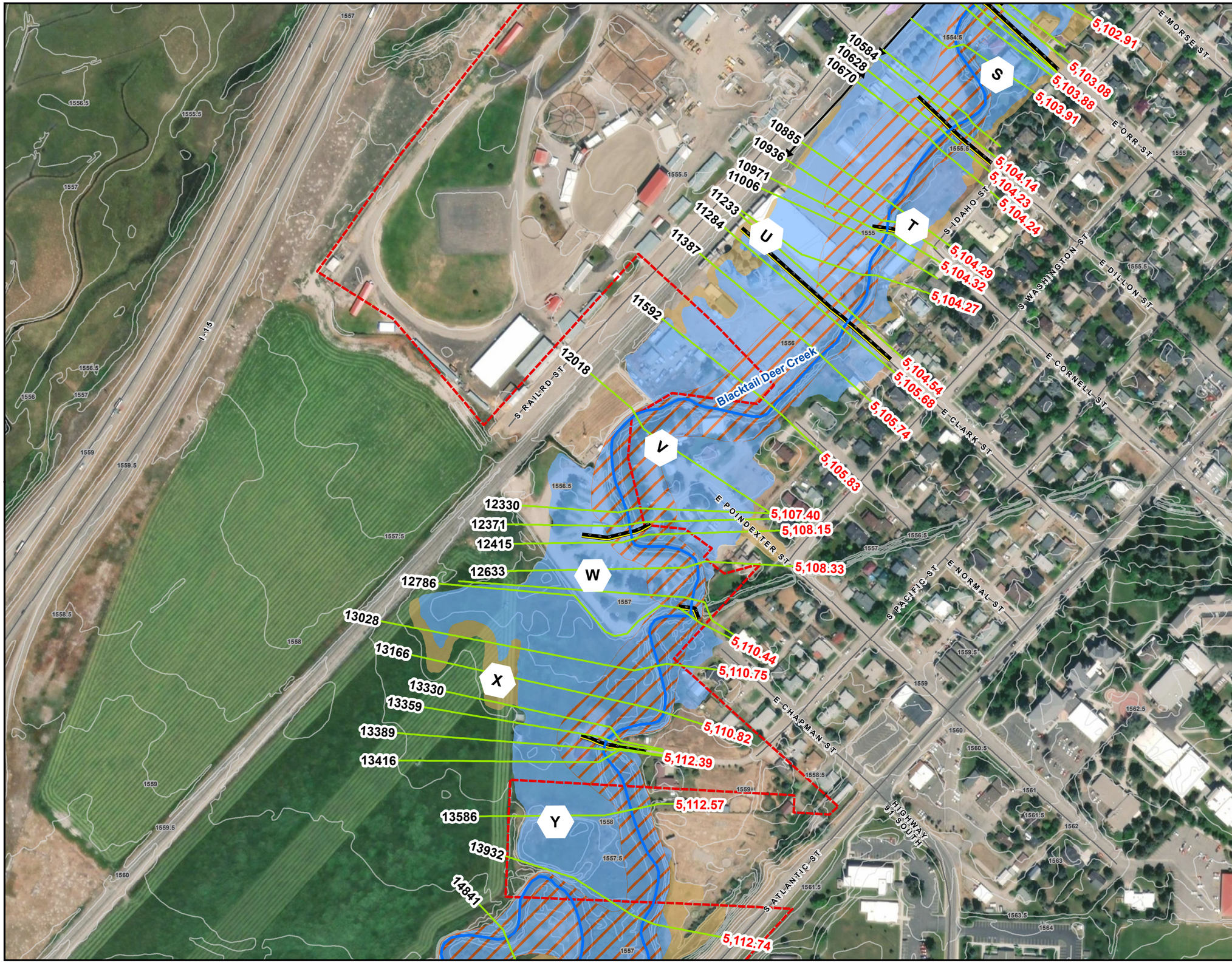
BEAVERHEAD COUNTY

Locator Map

Blacktail Deer Creek
Map 4 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



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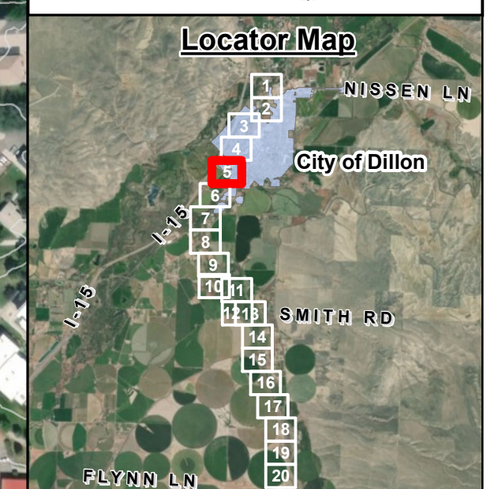

Blacktail Deer Creek
Map 5 of 20

Blacktail Deer Creek Hydraulic Workmaps

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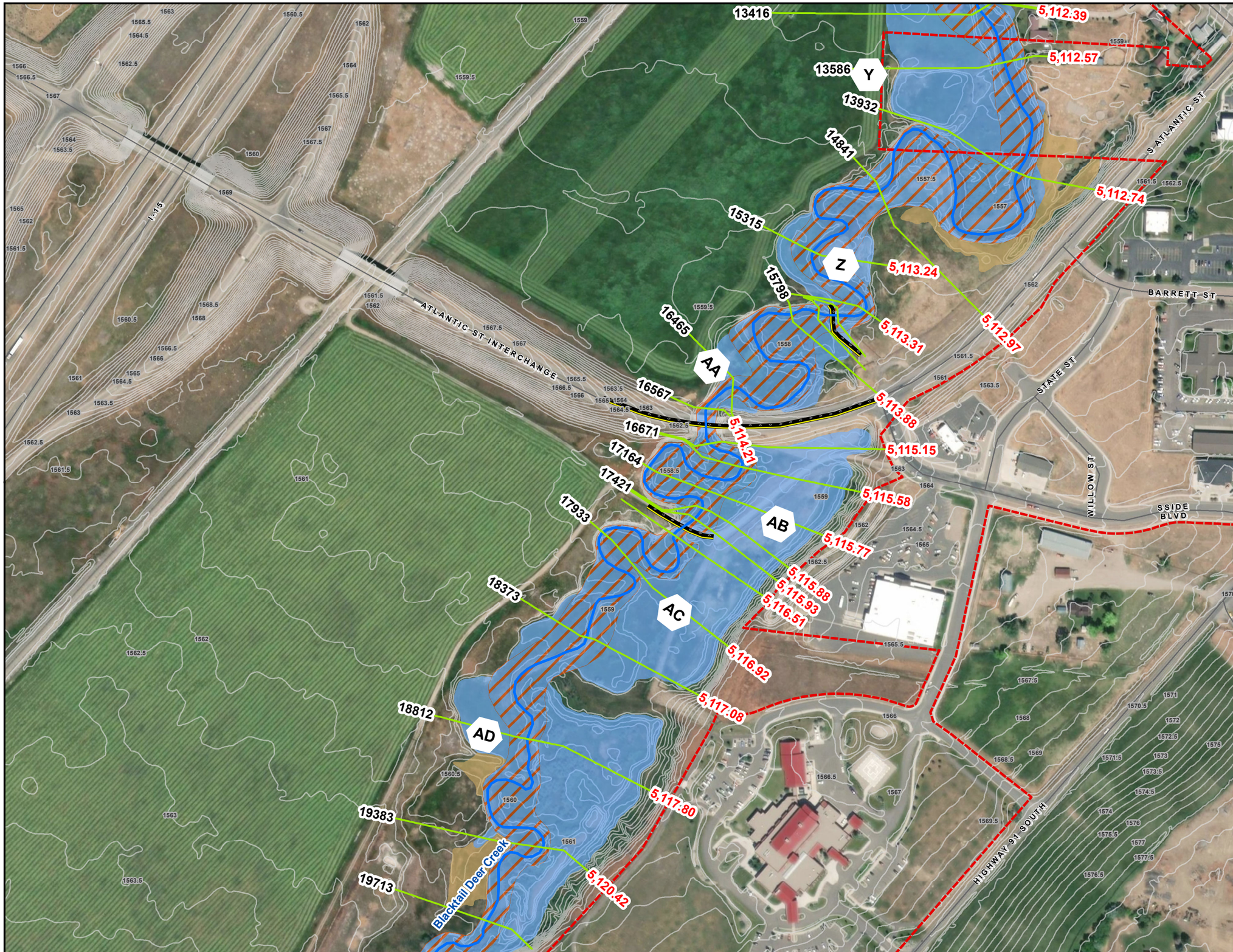

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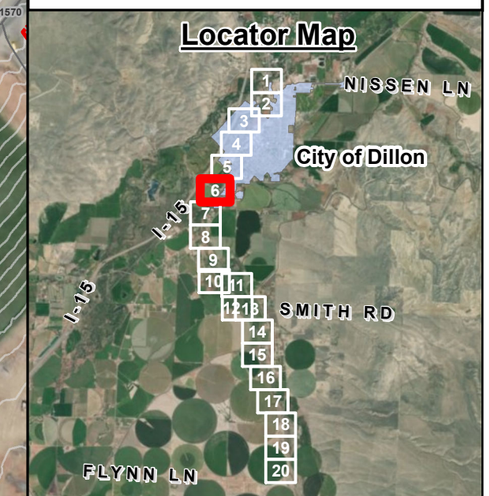
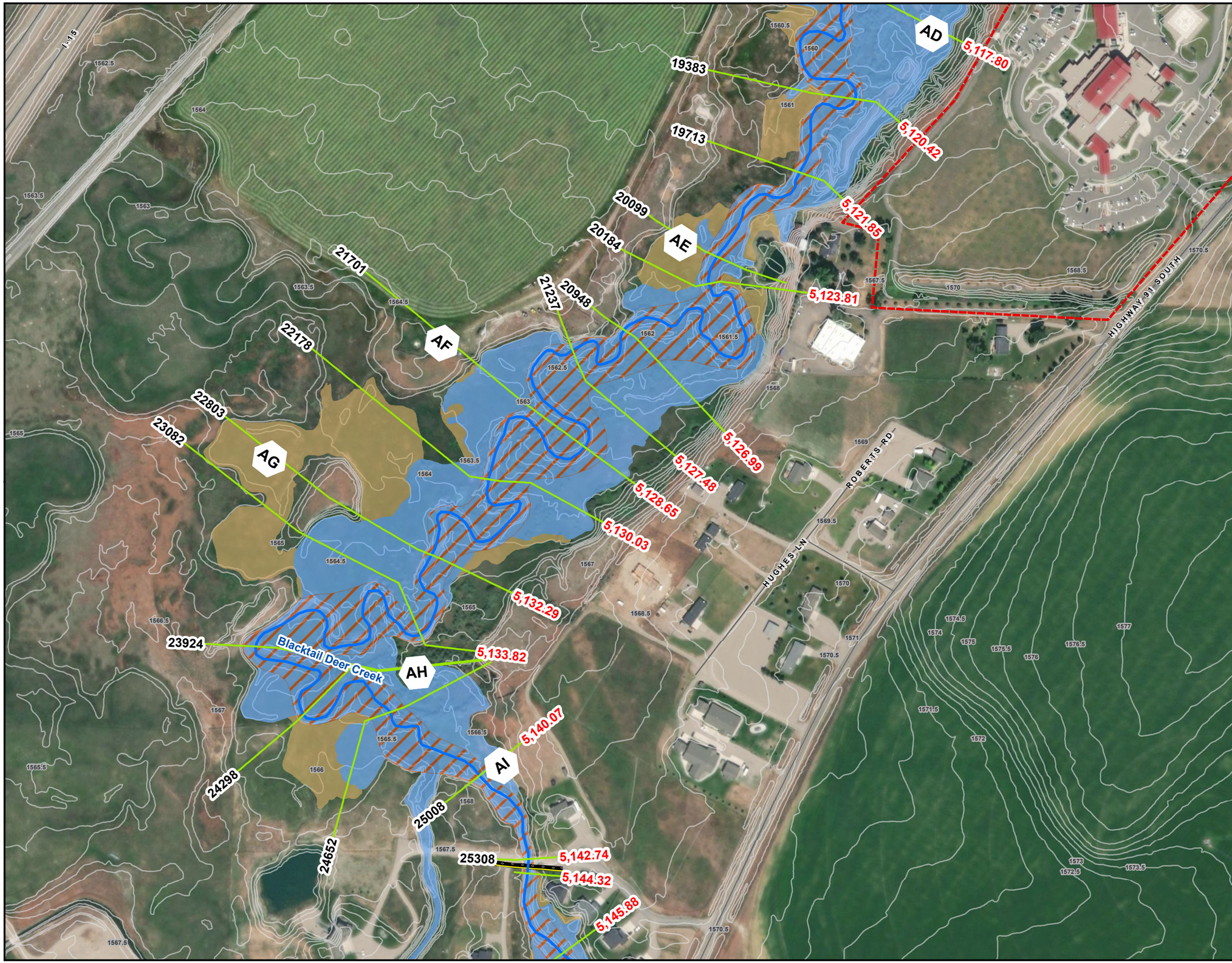


Blacktail Deer Creek
Map 6 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
- FLOODWAY
- 1% AC (100 yr)
- 0.2% AC (500 yr)
- 1% AC Depth Less Than 0.5 Feet
- Contours
- Roads

Labels

A Cross Section Letter

1234 Stream Station 1234.56 Water Surface Elevation

0 125 250 500 Feet

DATA FRAME PROPERTIES
Coordinate System: NAD 1983 StatePlane Montana FIPS 2500 Feet Intl
Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot
1" = 250'

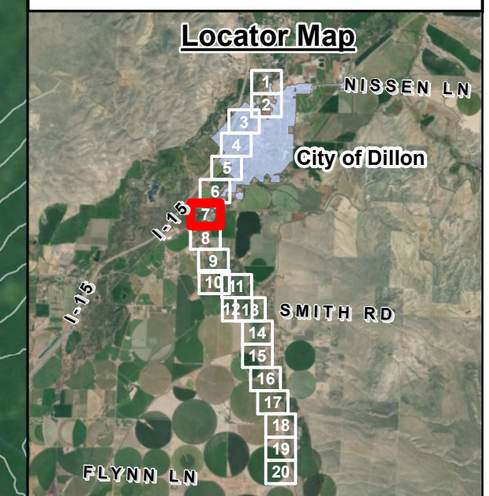
Note; This map shows the regulatory water surface elevations as well as the stream stationing. The proposed floodplain boundary is also mapped.

DOWL

MONTANA DNRC

BEAVERHEAD

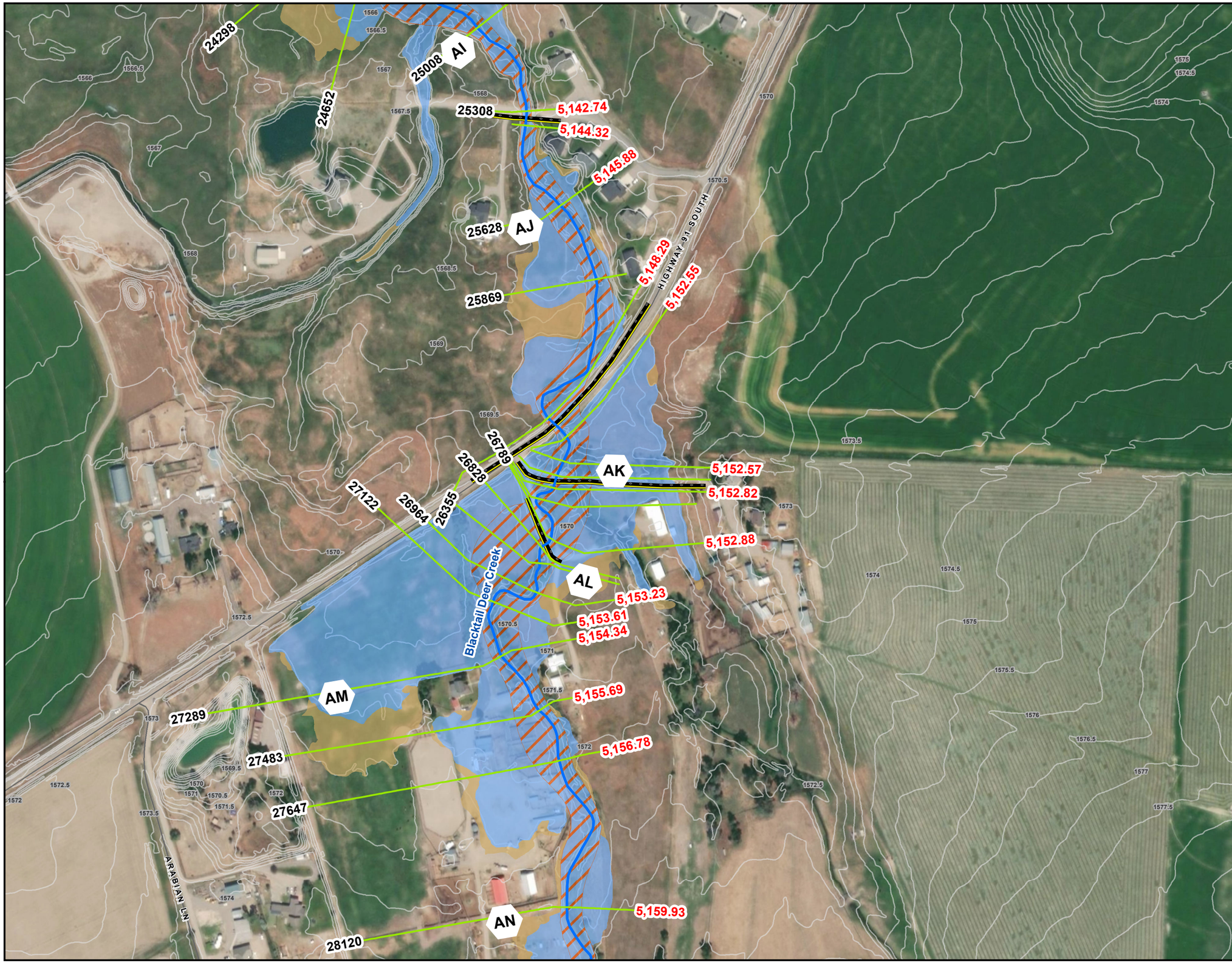
Locator Map



Blacktail Deer Creek
Map 7 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
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- Profile Baseline (Varies by Color)
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- FLOODWAY
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- Roads

Labels

A Cross Section Letter

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Projection: Lambert Conformal Conic
Datum: North American 1983
Units: Foot
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DOWL

MONTANA DNRC

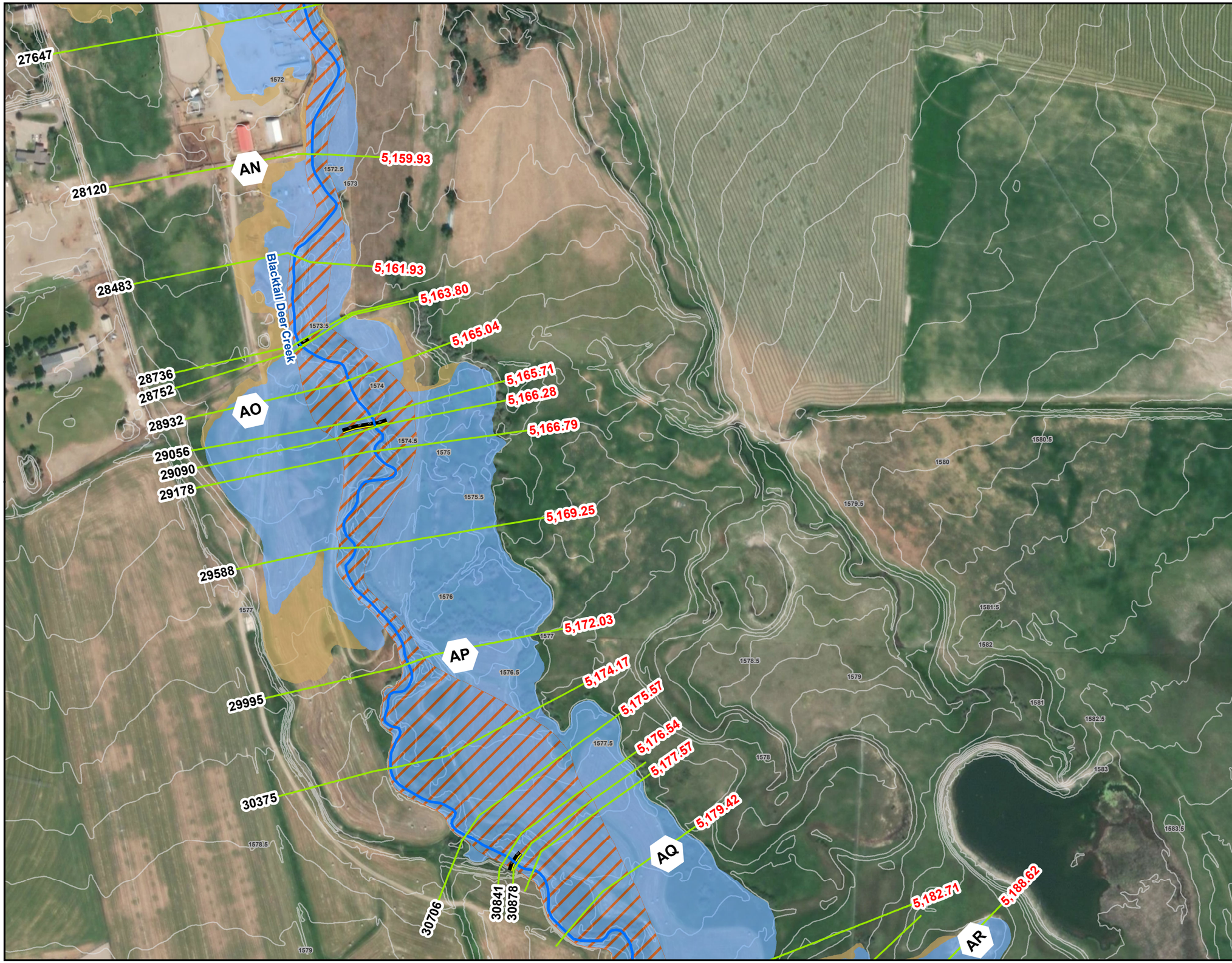
BEAVERHEAD COUNTY

Locator Map

Blacktail Deer Creek
Map 8 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
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- Roadway Crossings
- Profile Baseline (Varies by Color)
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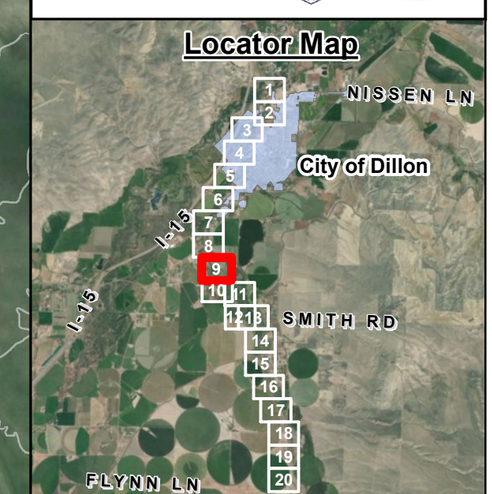
Note; This map shows the regulatory water surface elevations as well as the stream stationing. The proposed floodplain boundary is also mapped.

DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

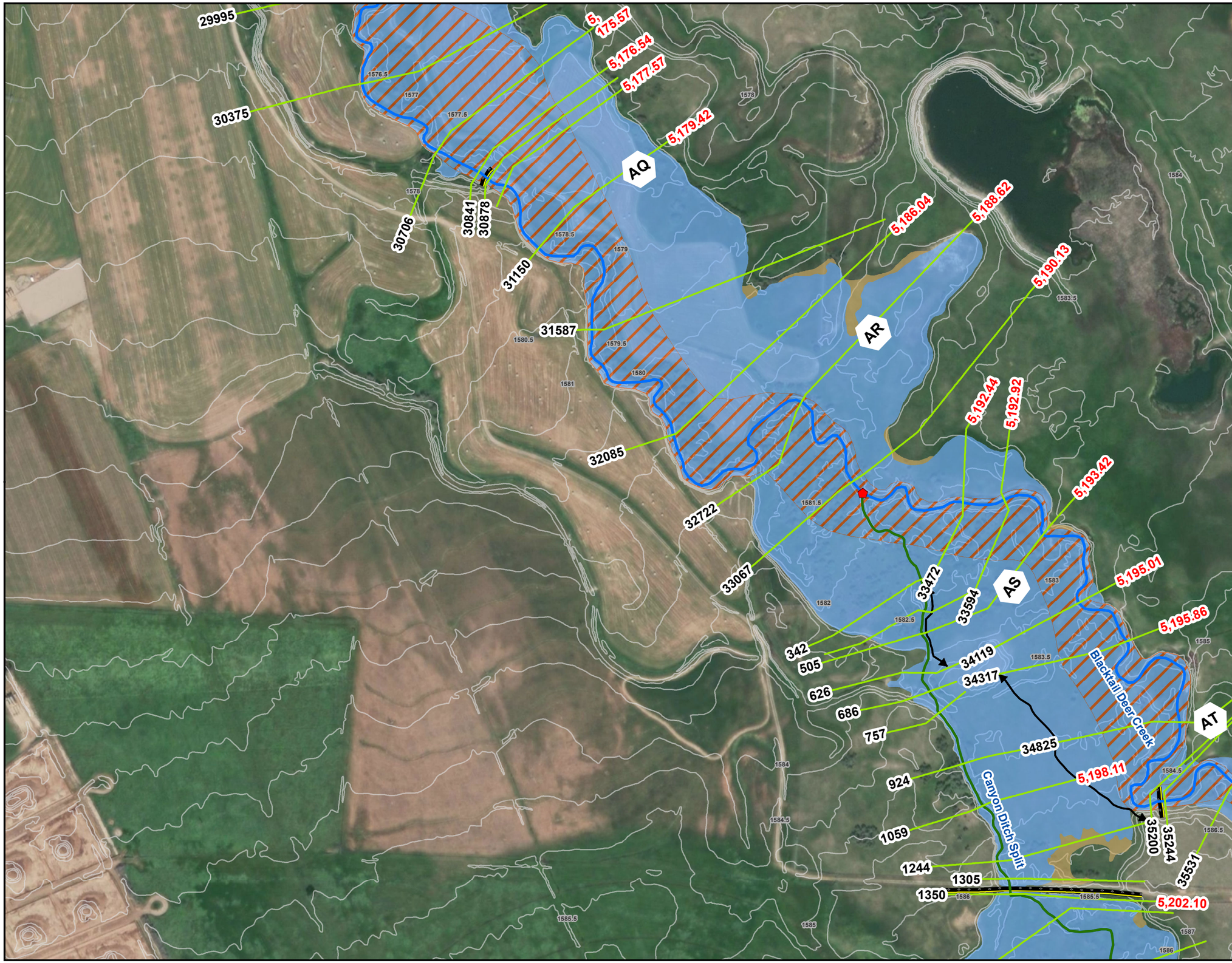
Locator Map



Blacktail Deer Creek
Map 9 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
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- 1% AC (100 yr)
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Units: Foot
1" = 250'

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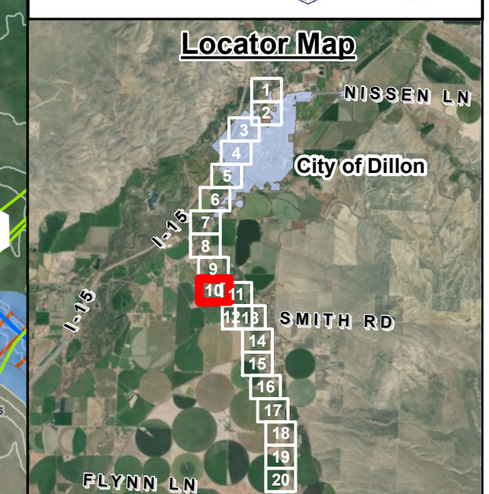
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

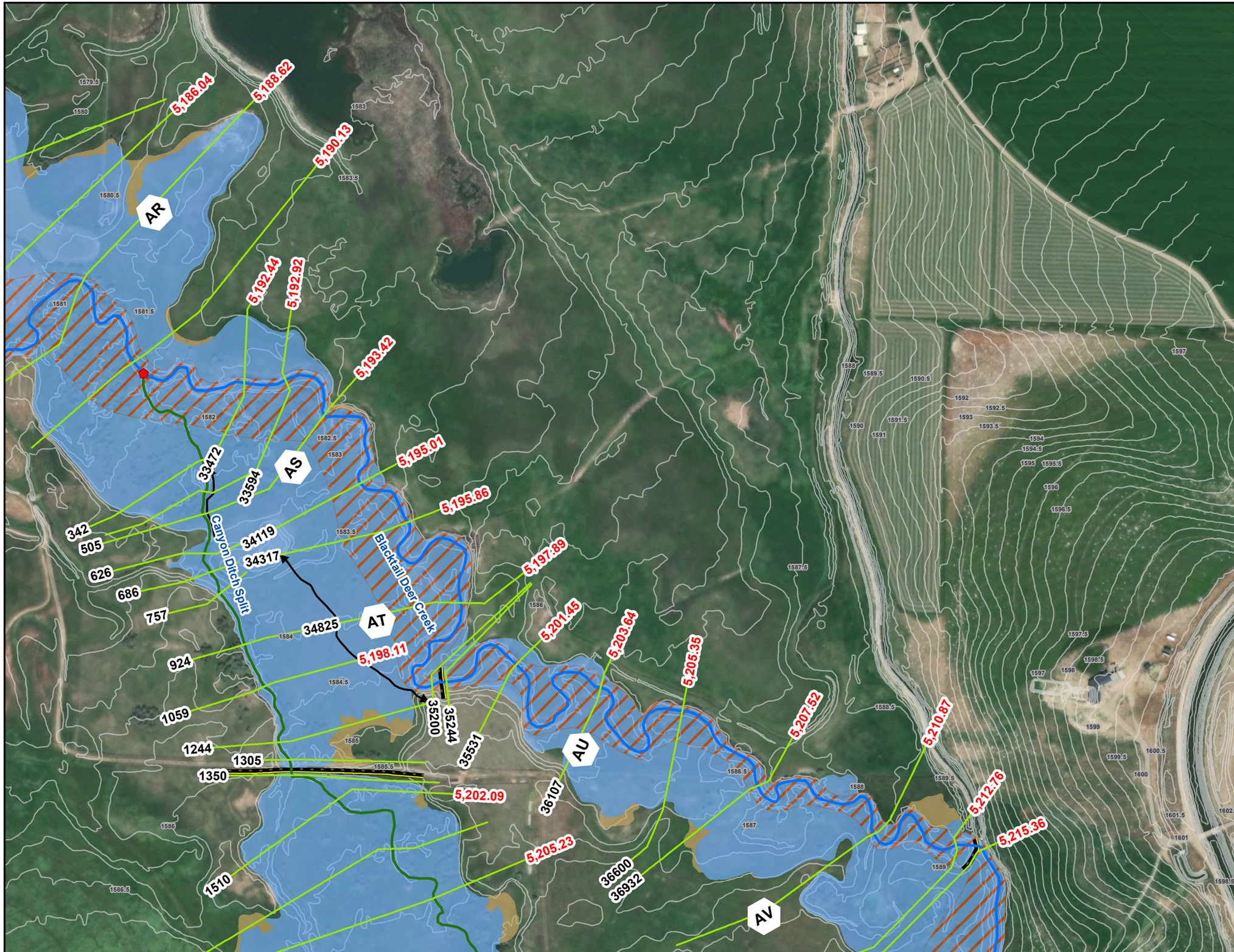
Locator Map



Blacktail Deer Creek
Map 10 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
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1" = 250'

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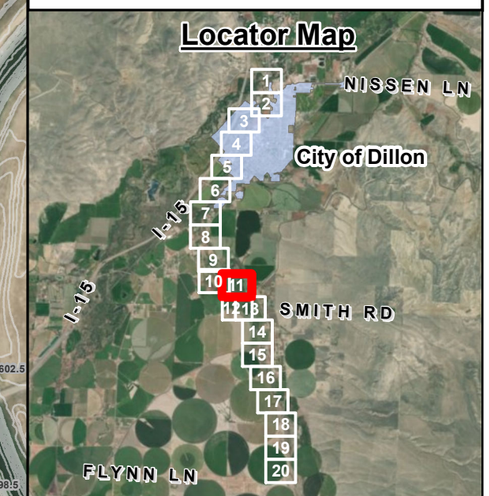
DOWL

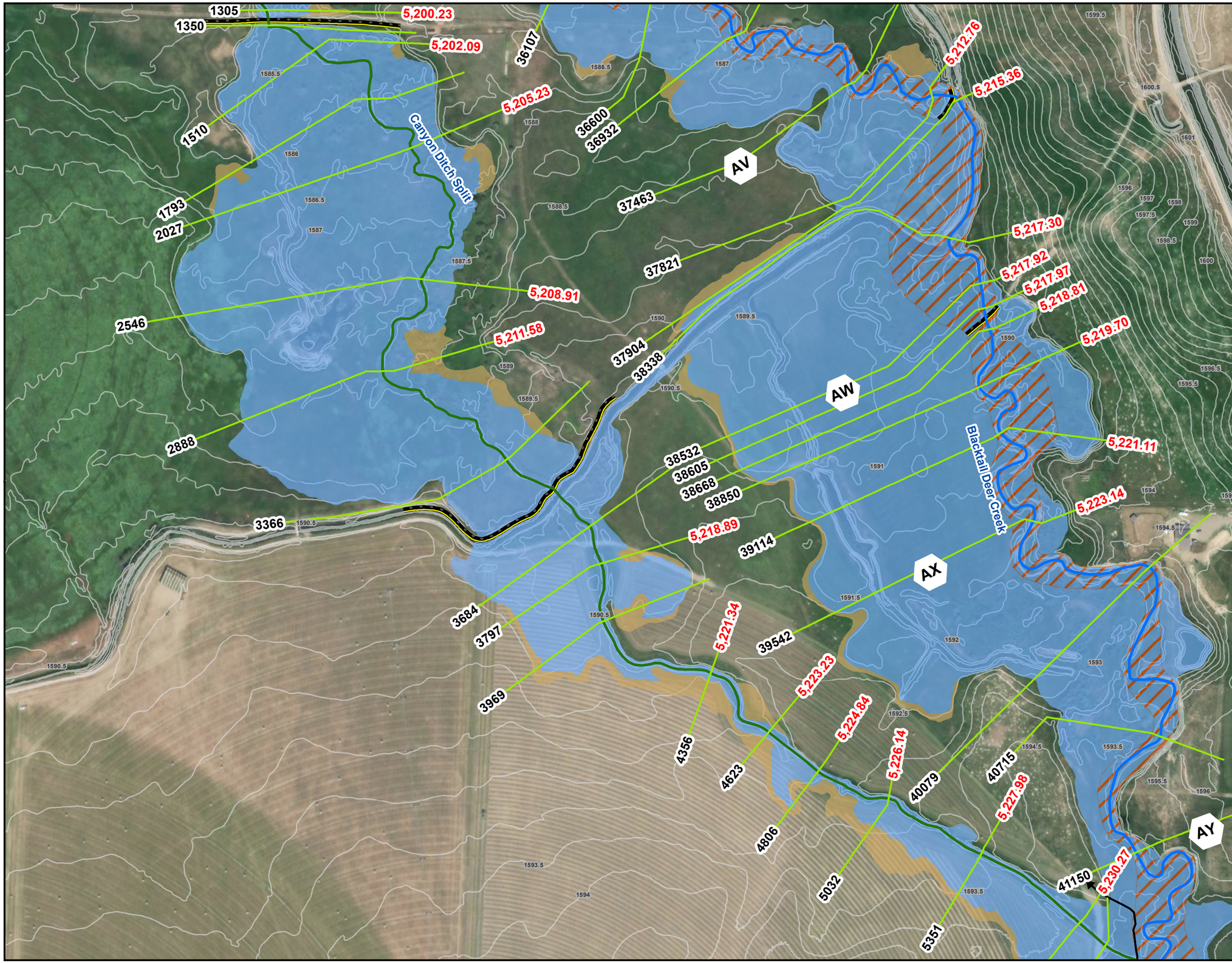
Locator Map



Blacktail Deer Creek
Map 11 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
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- 1% AC (100 yr)
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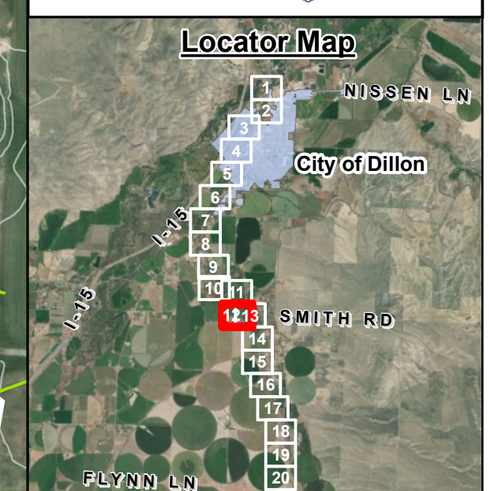
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

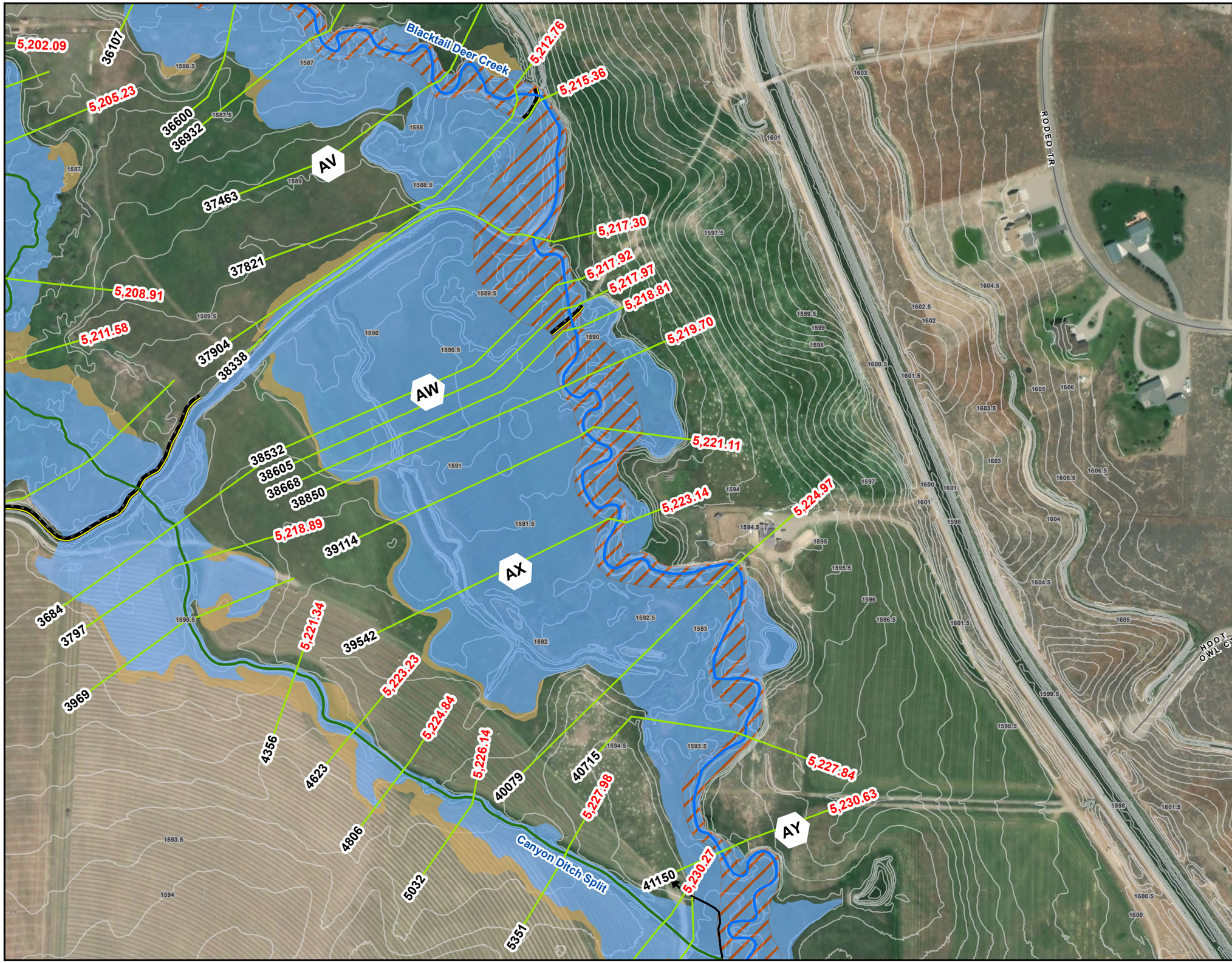
Locator Map



Blacktail Deer Creek
Map 12 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
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- 1% AC (100 yr)
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A Cross Section Letter

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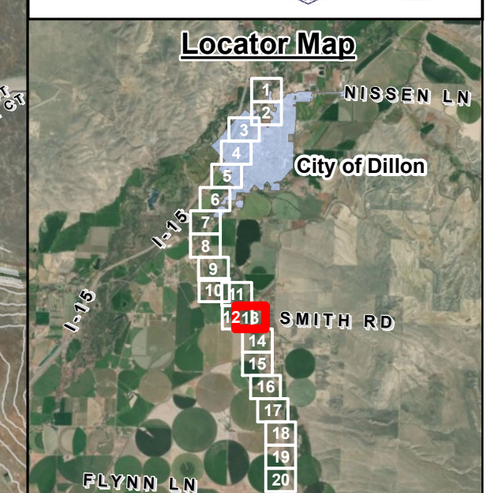
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

Locator Map



Blacktail Deer Creek
Map 13 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019

Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
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DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

Locator Map

Blacktail Deer Creek
Map 14 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019

Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
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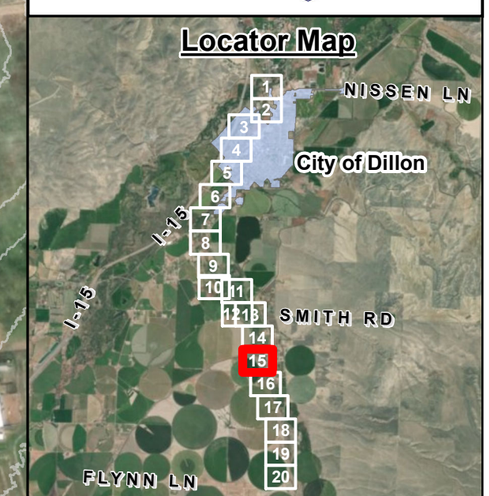
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

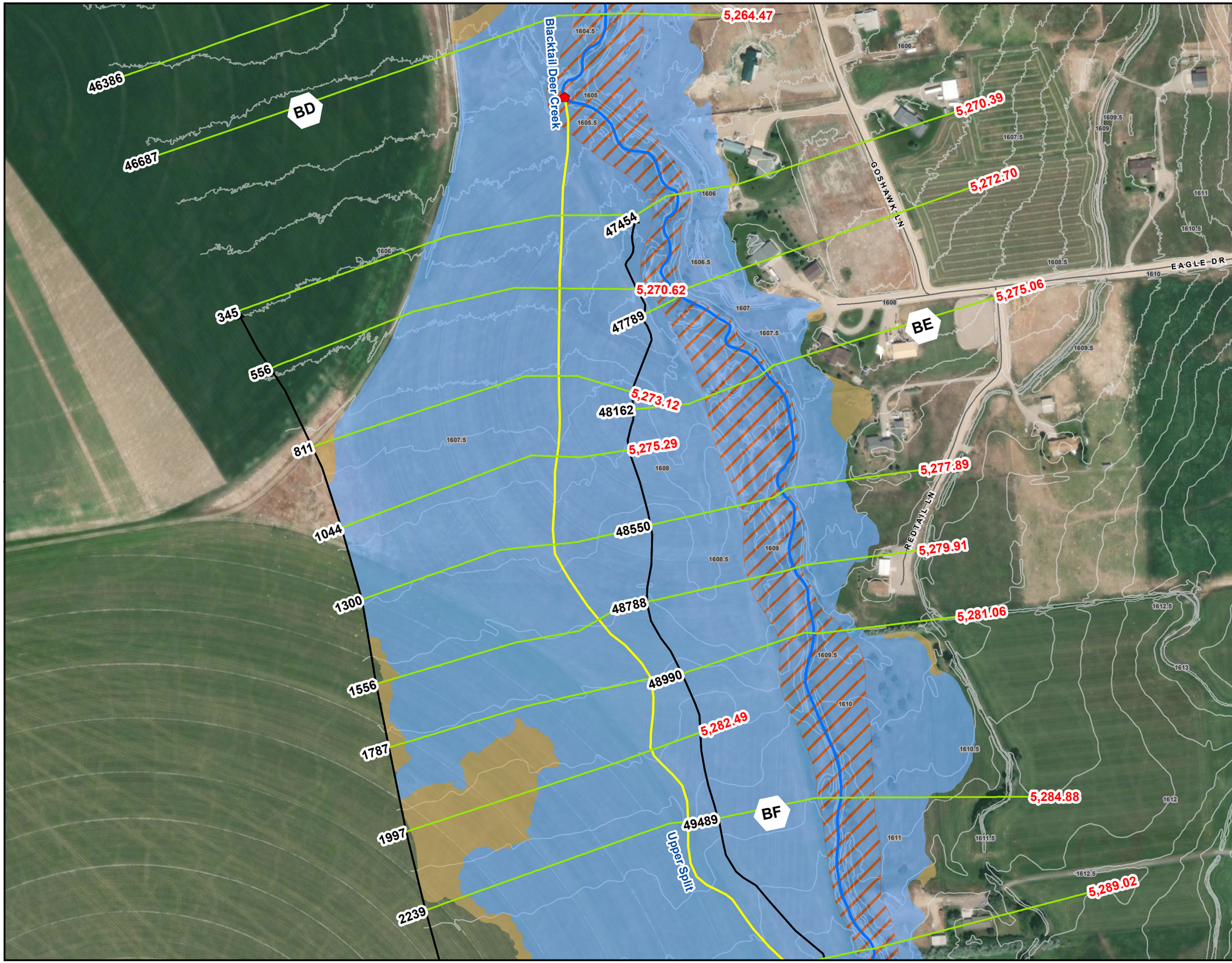
Locator Map



Blacktail Deer Creek
Map 15 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
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- 1% AC (100 yr)
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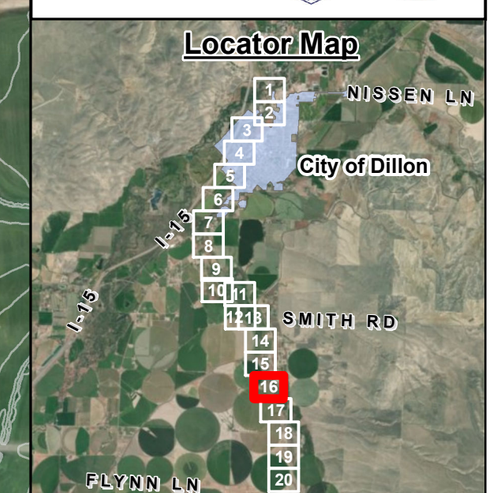
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

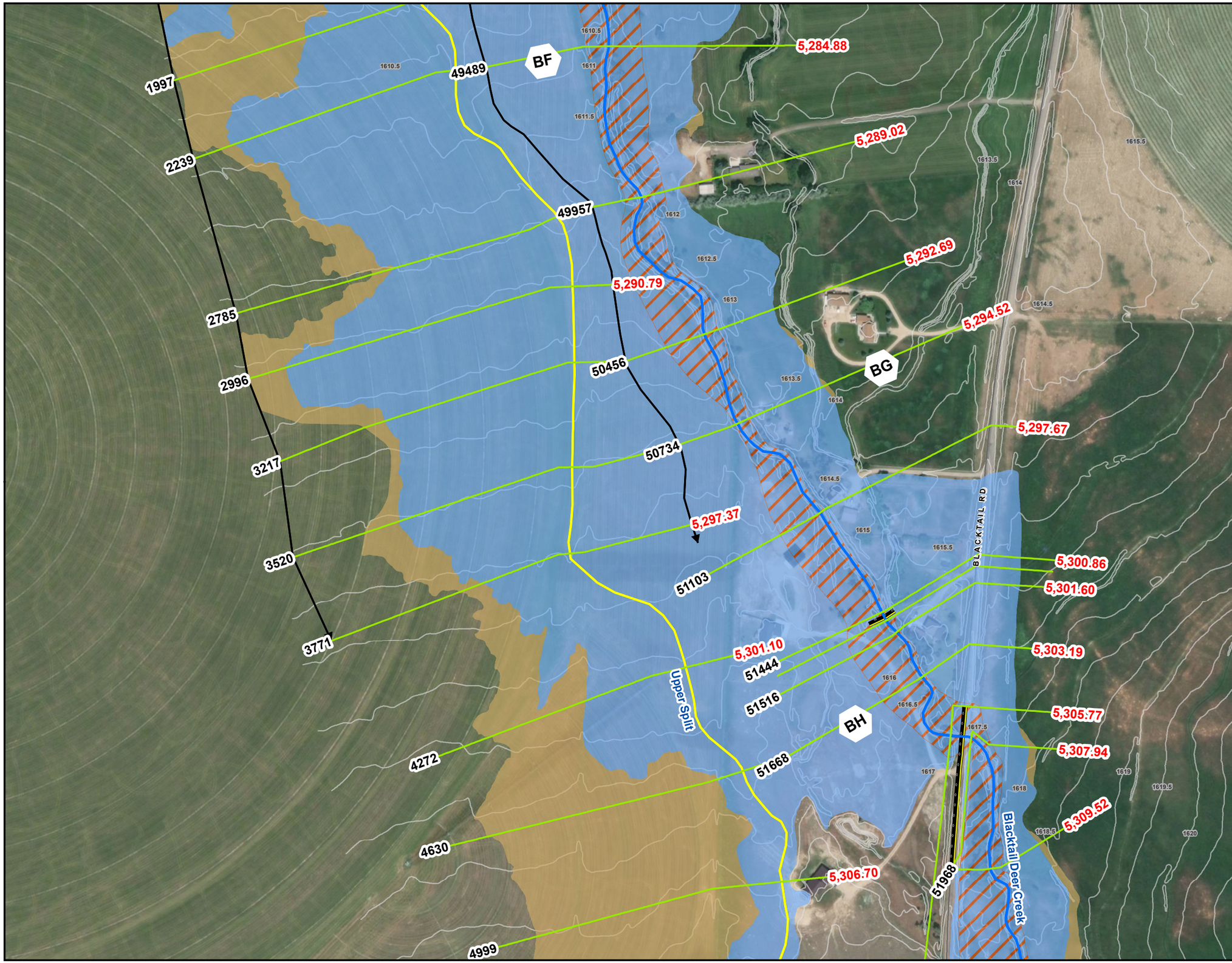
Locator Map



Blacktail Deer Creek
Map 16 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
- City Of Dillion
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- 1% AC (100 yr)
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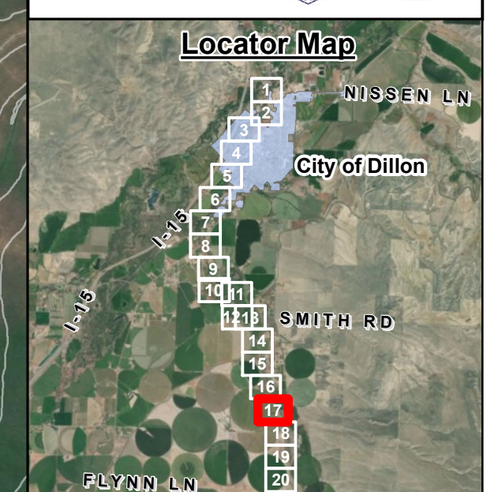
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

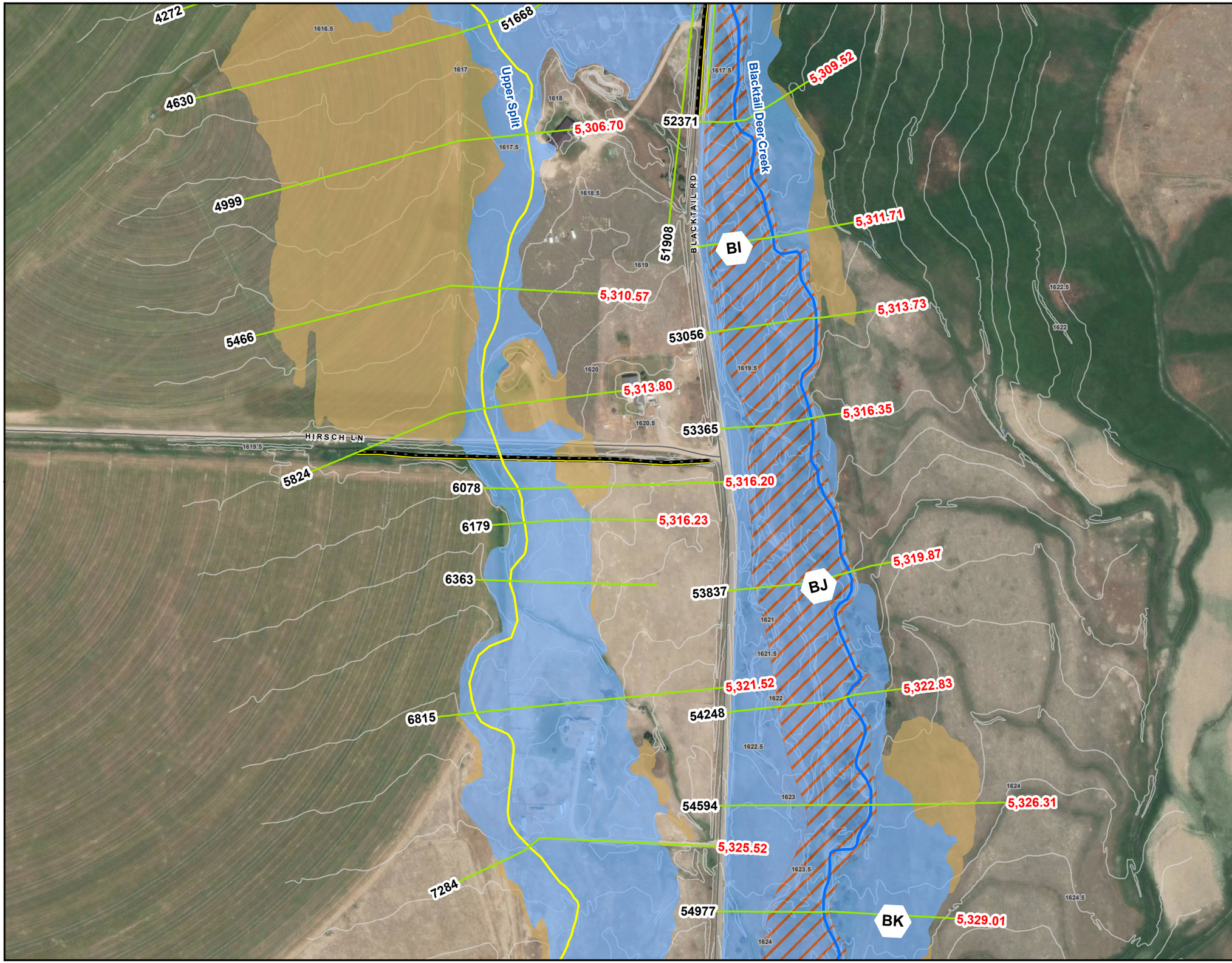
Locator Map



Blacktail Deer Creek
Map 17 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
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DOWL

MONTANA DNRC

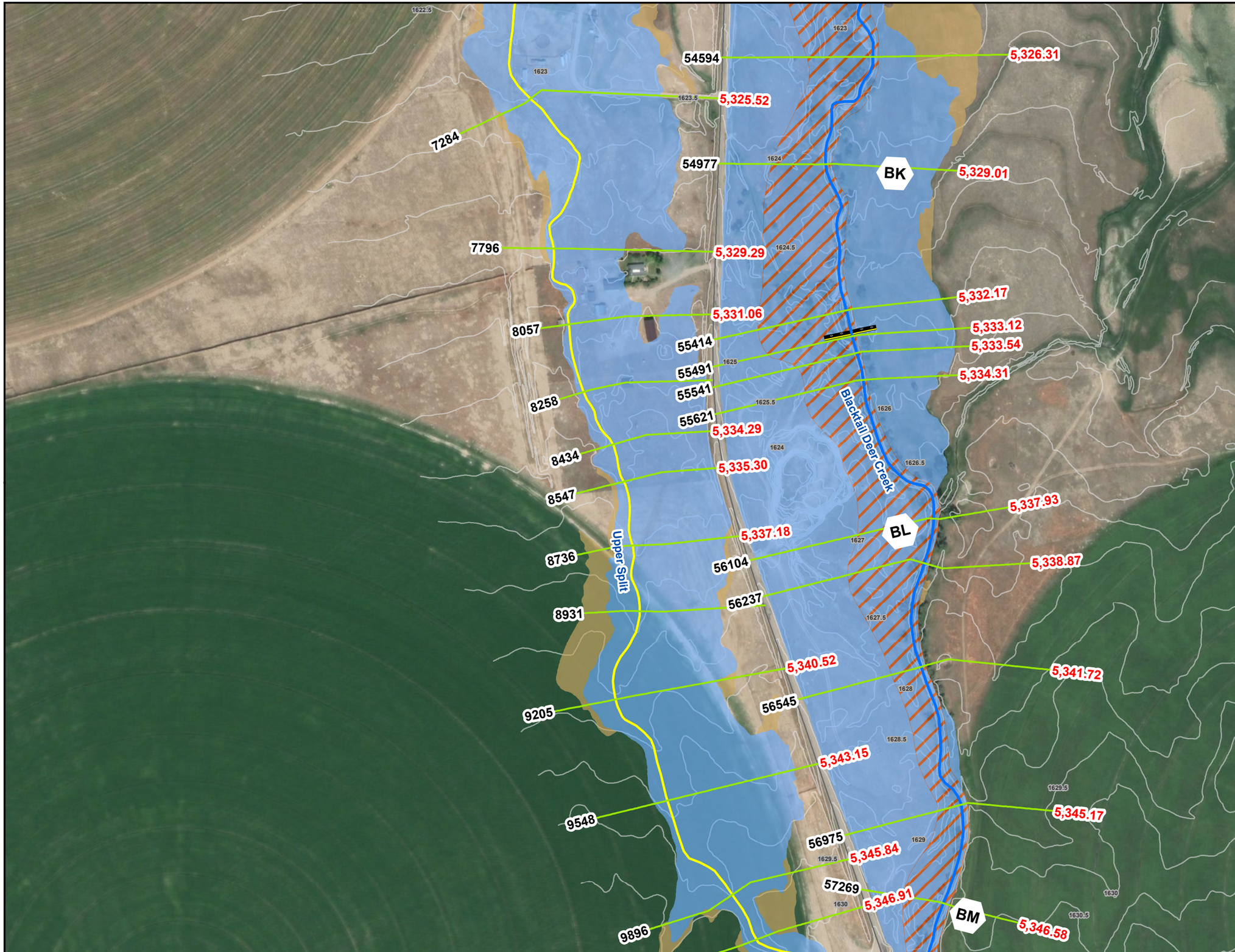
BEAVERHEAD COUNTY

Locator Map

Blacktail Deer Creek
Map 18 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
- LateralStructures
- Roadway Crossings
- Profile Baseline (Varies by Color)
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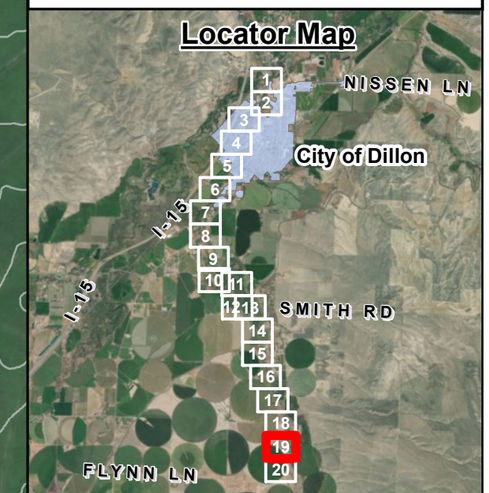
DOWL

MONTANA DNRC

BEAVERHEAD COUNTY

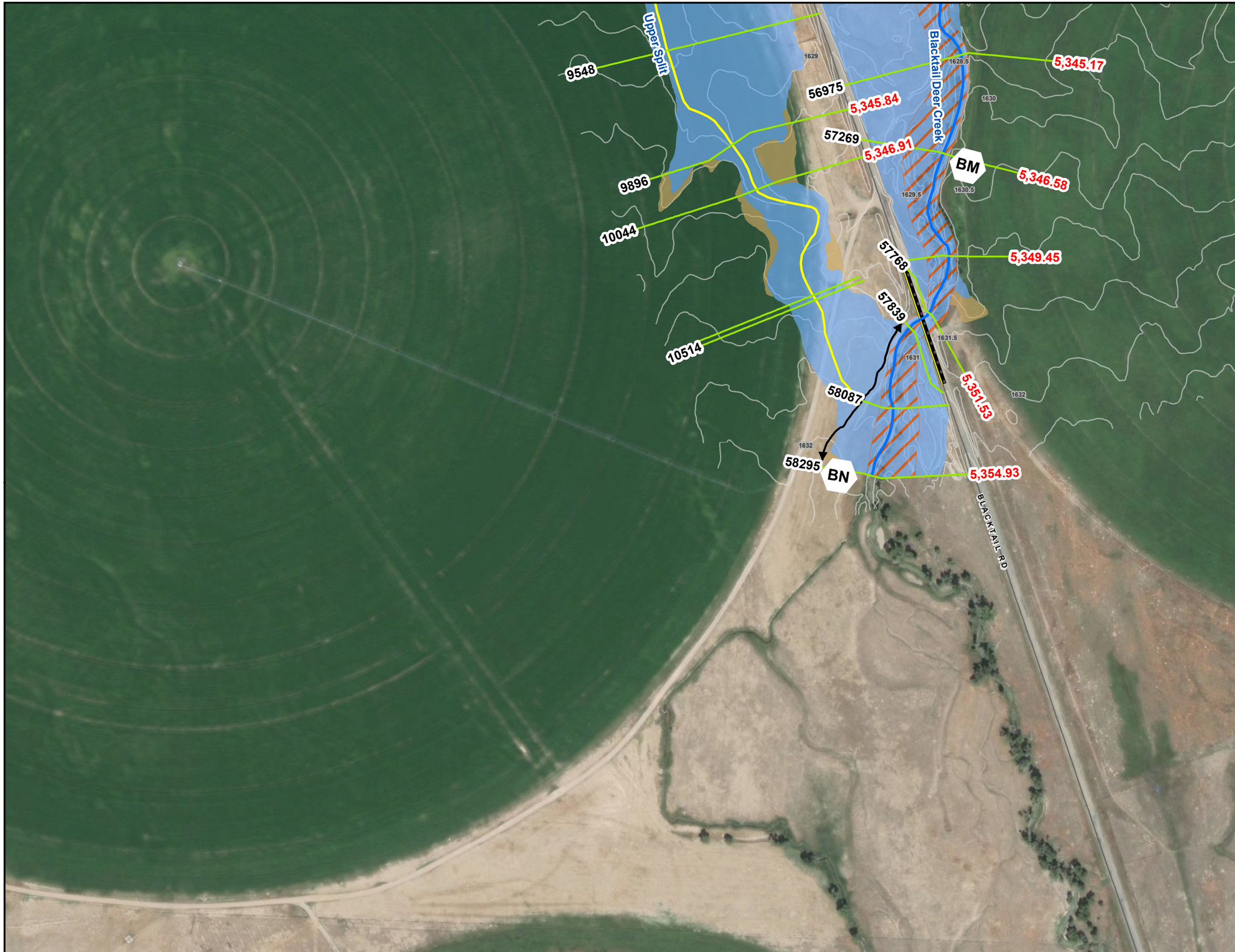
Locator Map



Blacktail Deer Creek
Map 19 of 20

Blacktail Deer Creek Hydraulic Workmaps

DATE: JANUARY 3, 2019



Legend

- River Junctions
- Cross Sections
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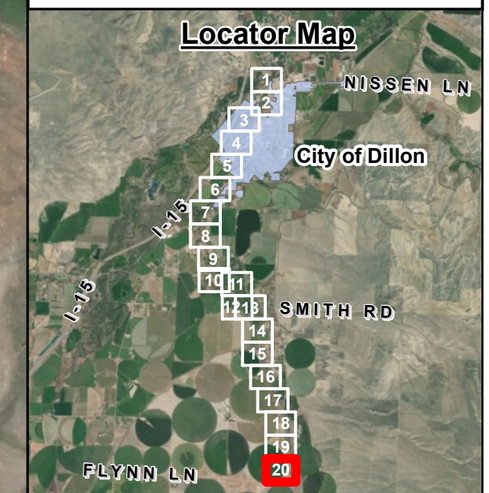
DOWL

MONTANA DNRC

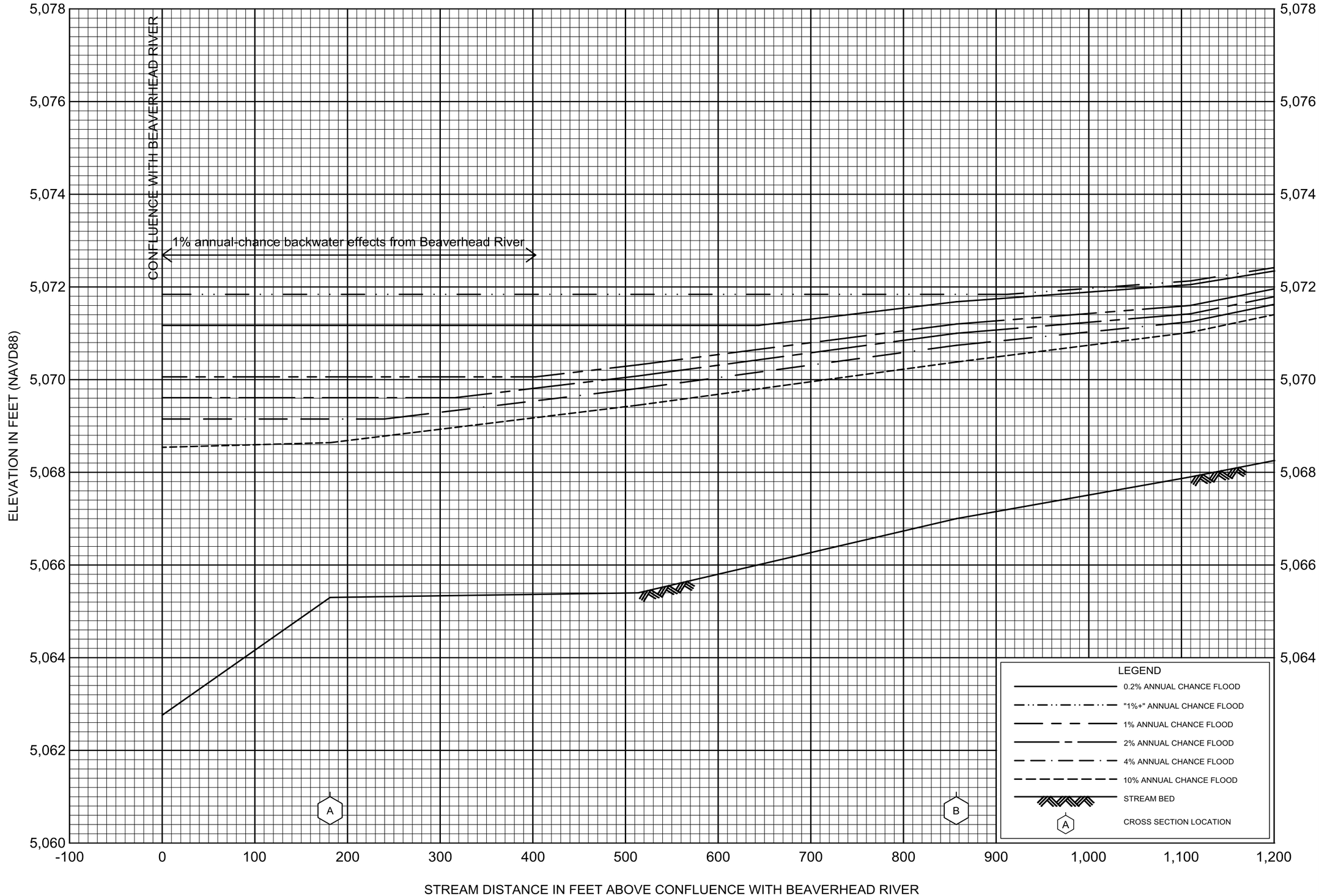
BEAVERHEAD COUNTY

Locator Map



Blacktail Deer Creek
Map 20 of 20

APPENDIX C – FLOOD PROFILES



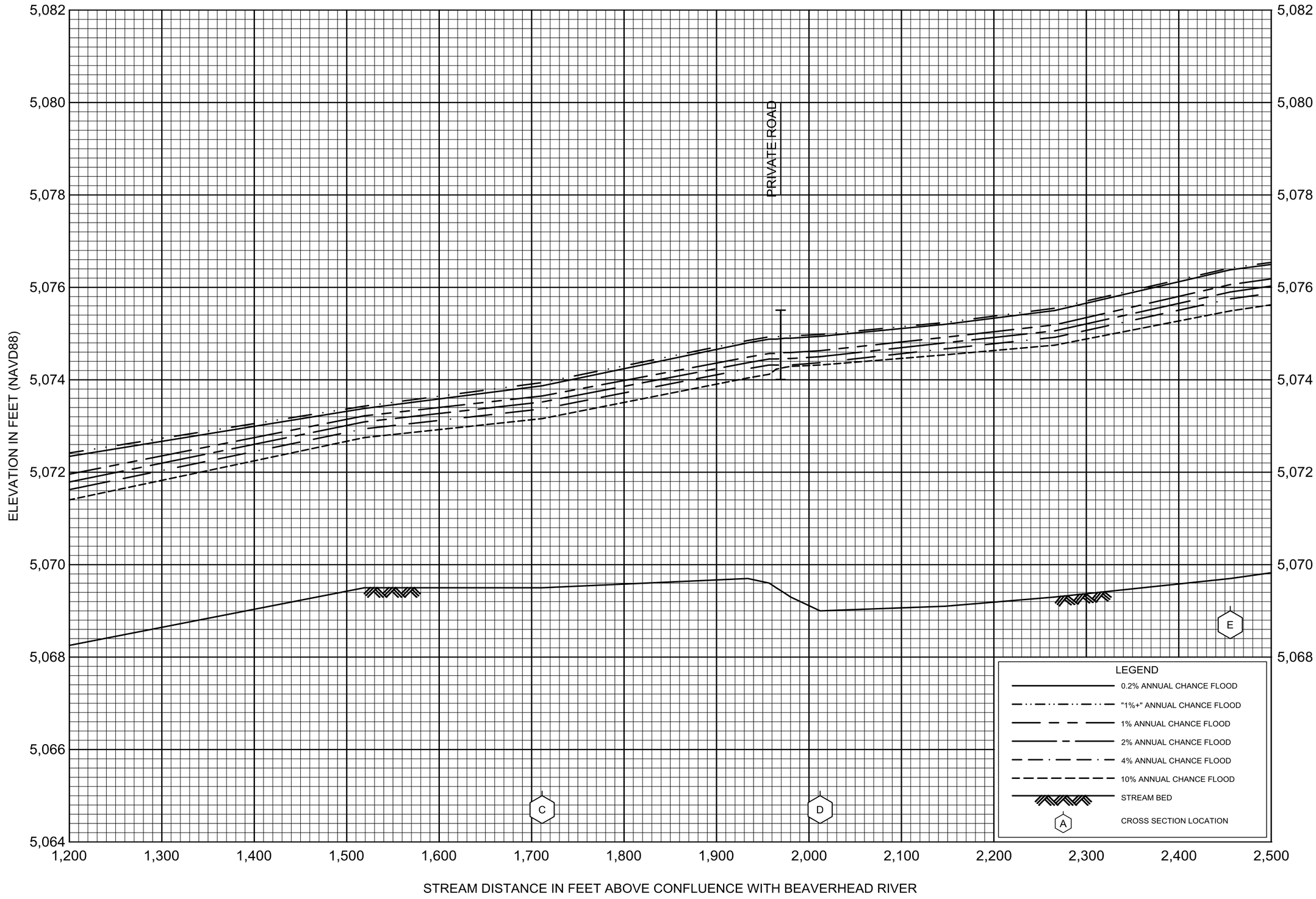
FLOOD PROFILES

BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



FLOOD PROFILES

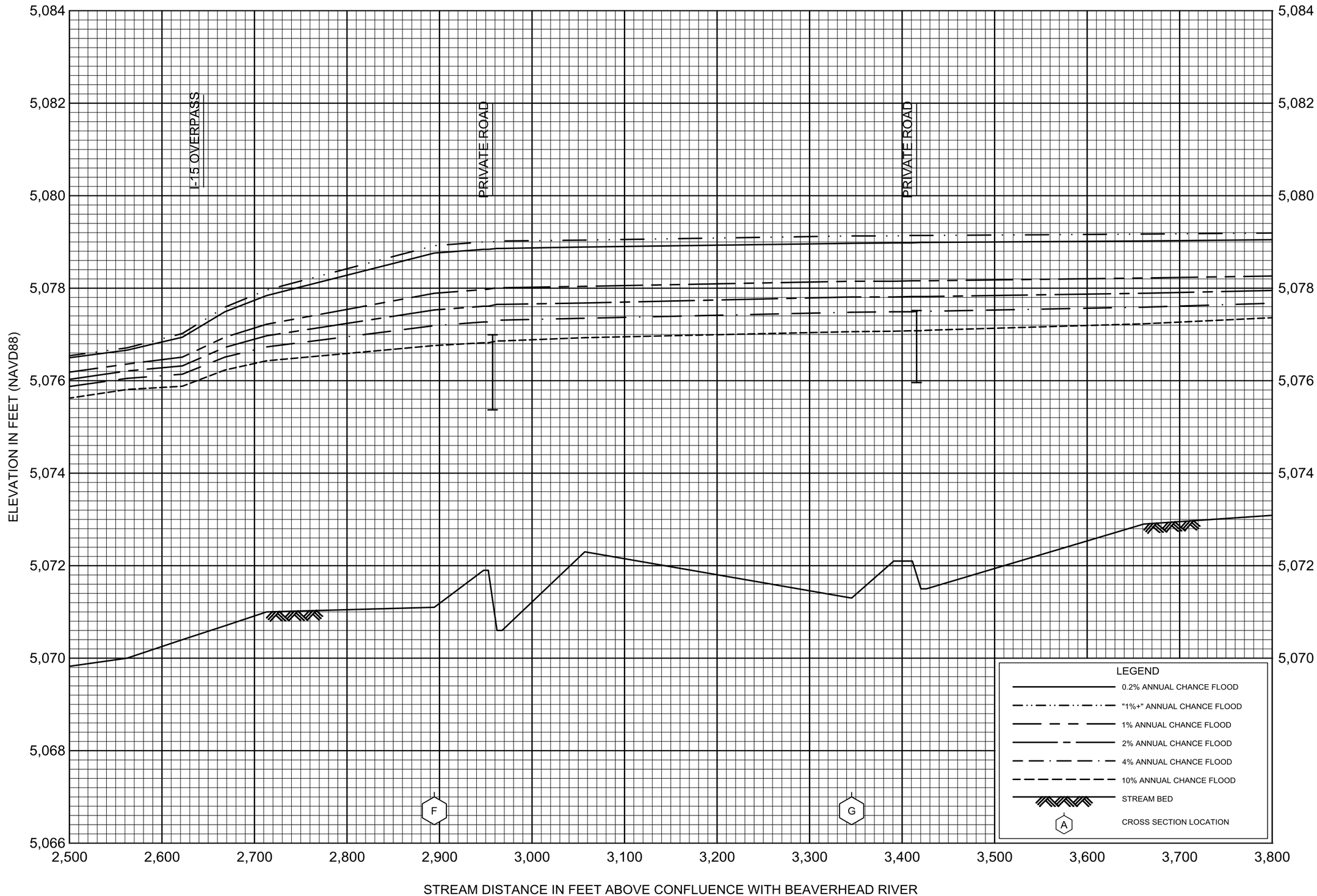
BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

02P



FLOOD PROFILES

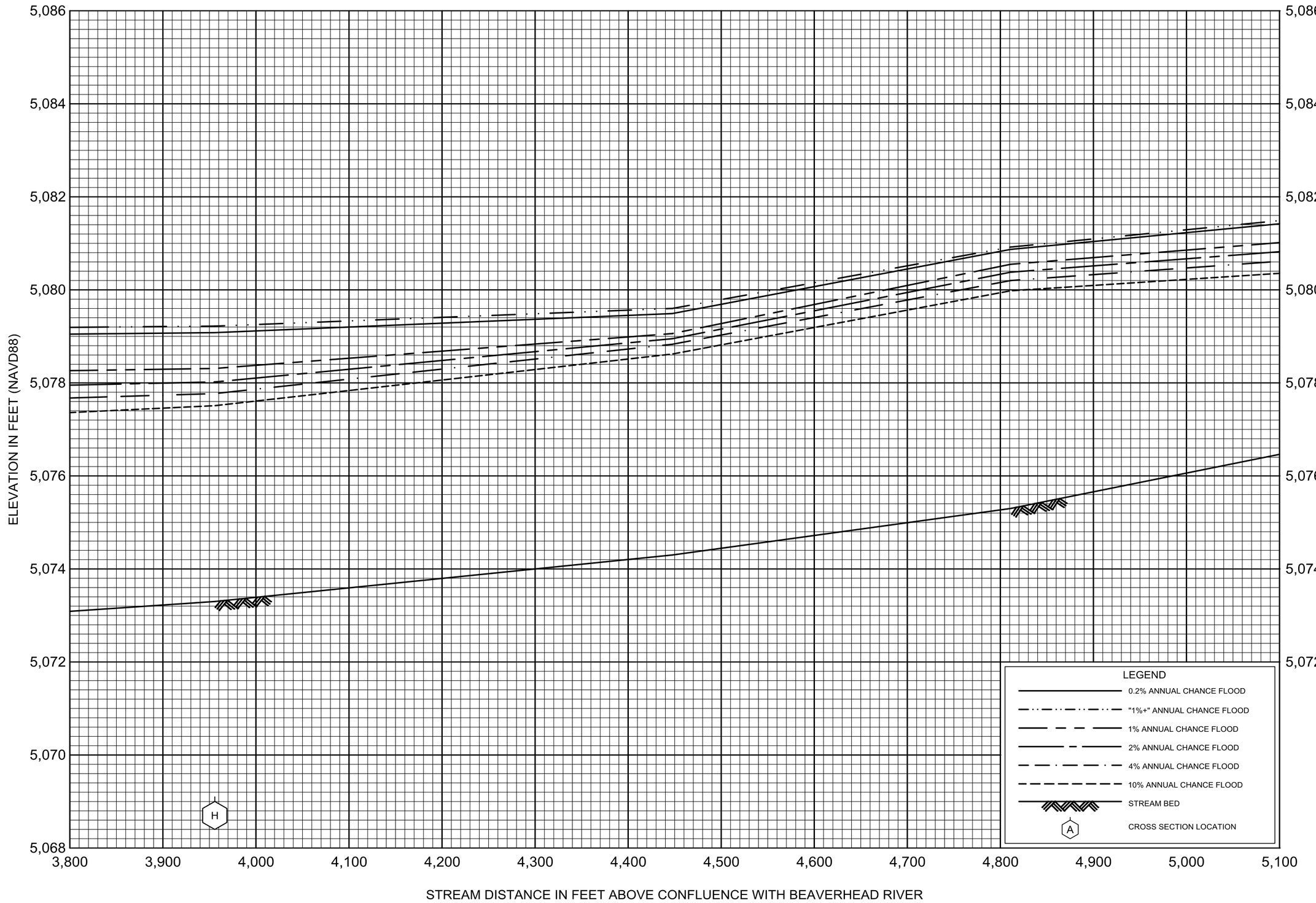
BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

03P



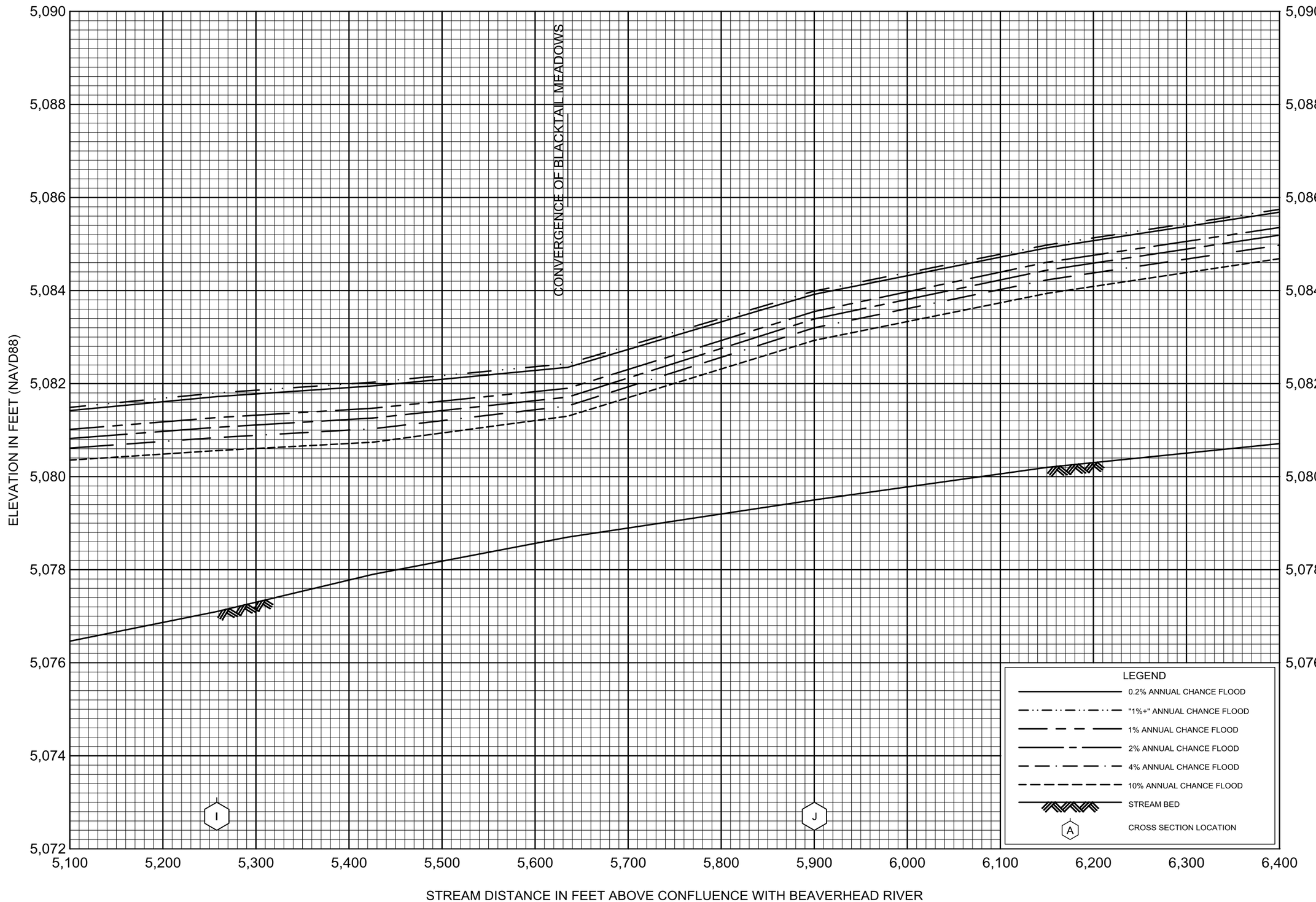
FLOOD PROFILES

BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



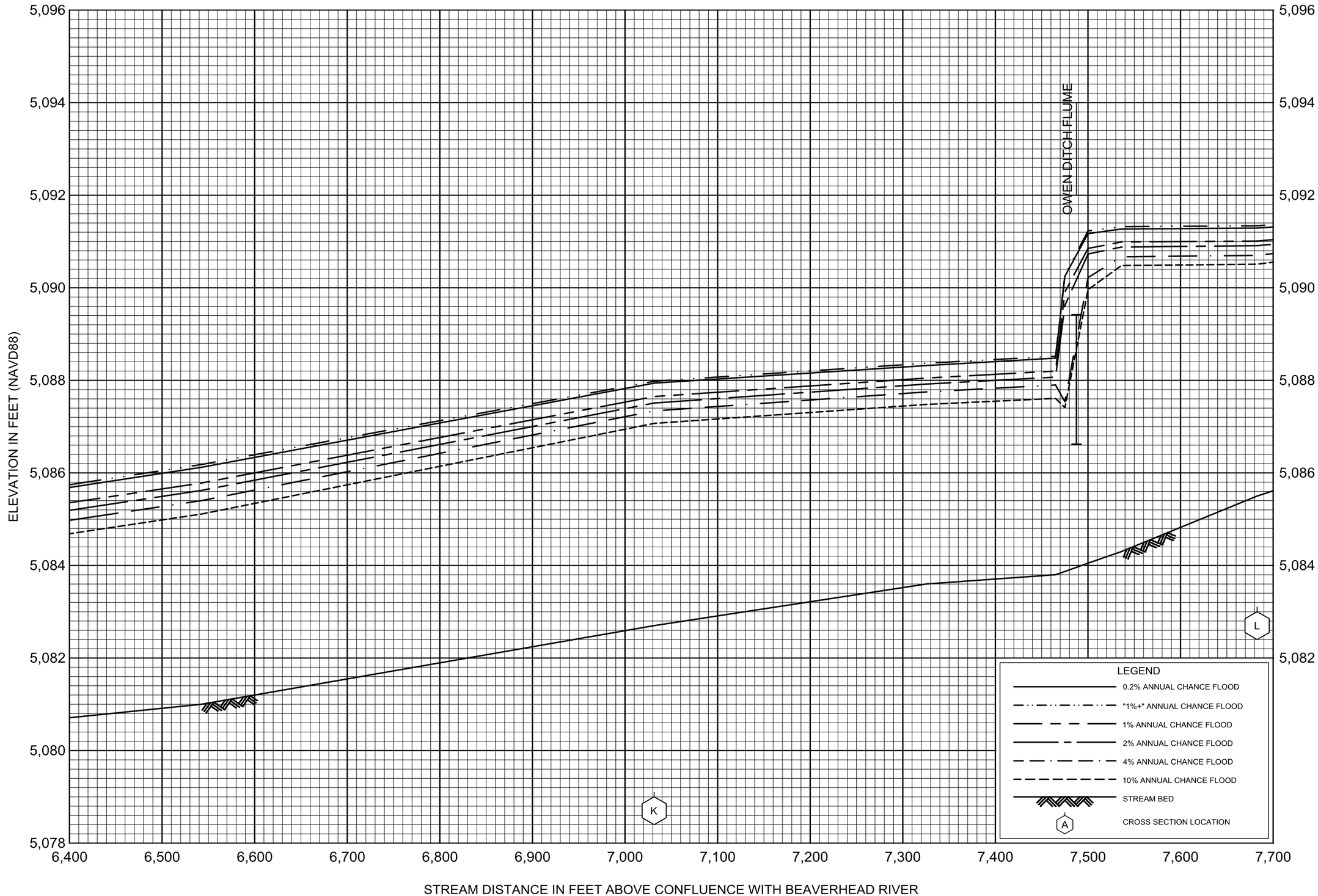
FLOOD PROFILES

BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



FLOOD PROFILES

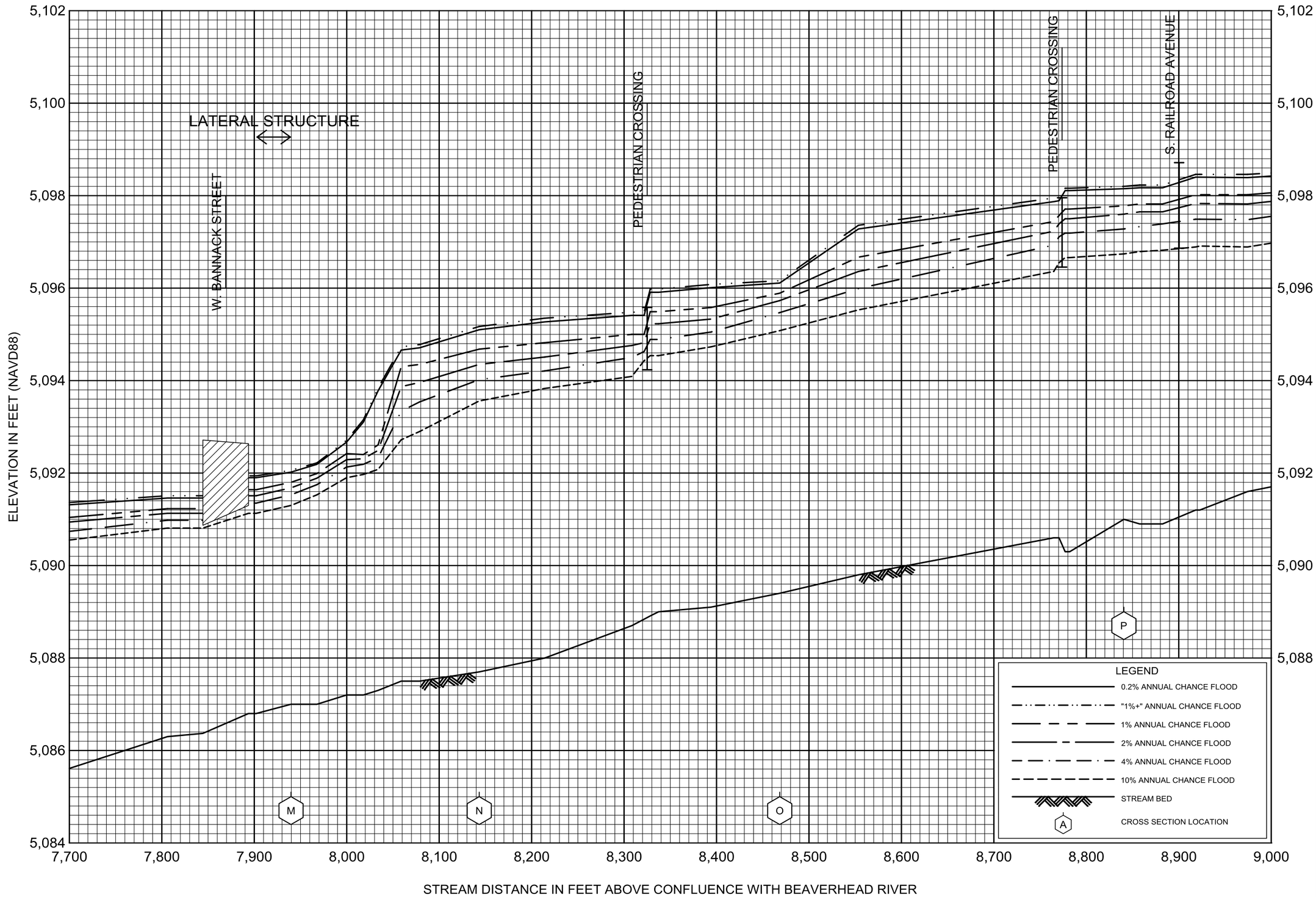
BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

06P



FLOOD PROFILES

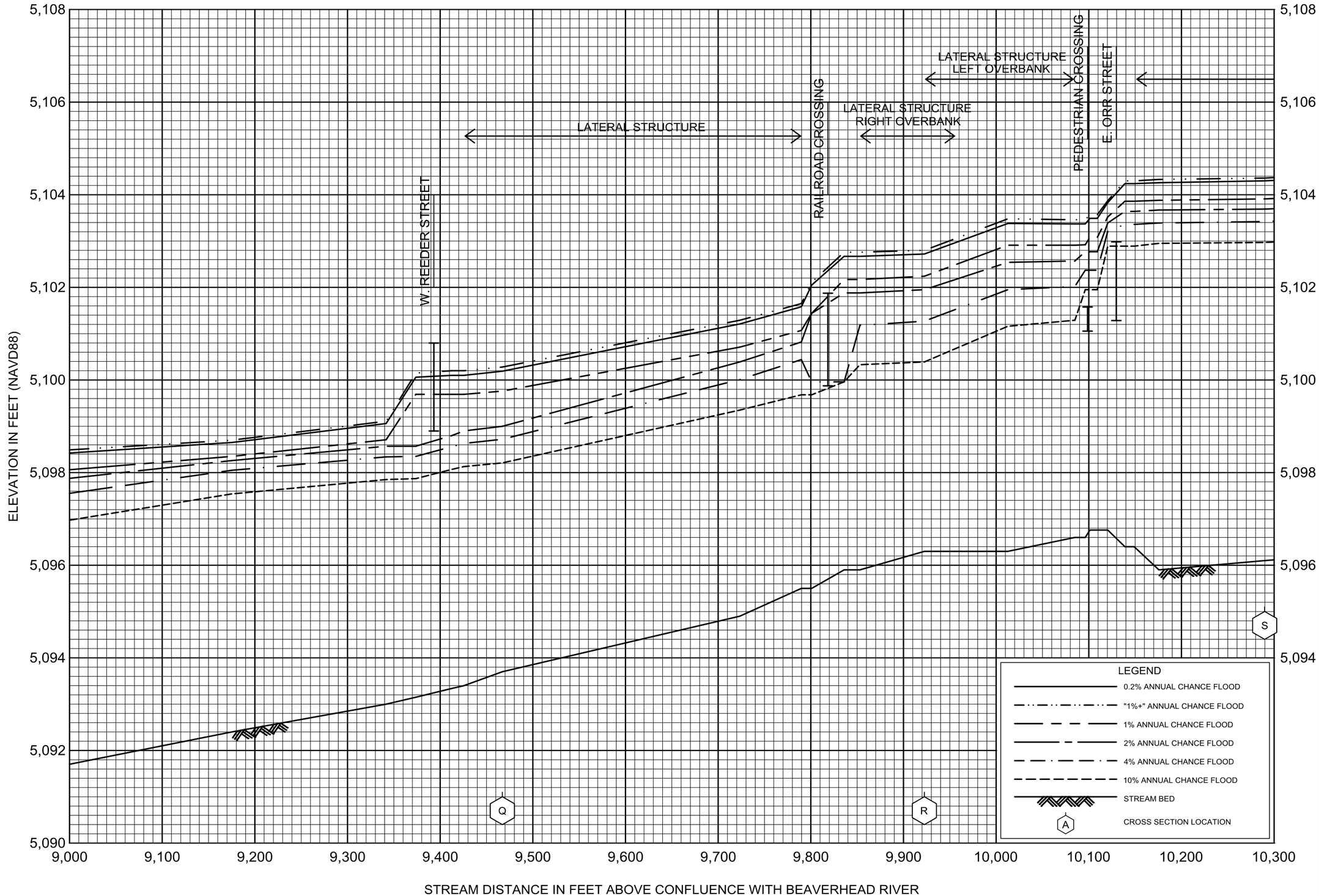
BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

07P



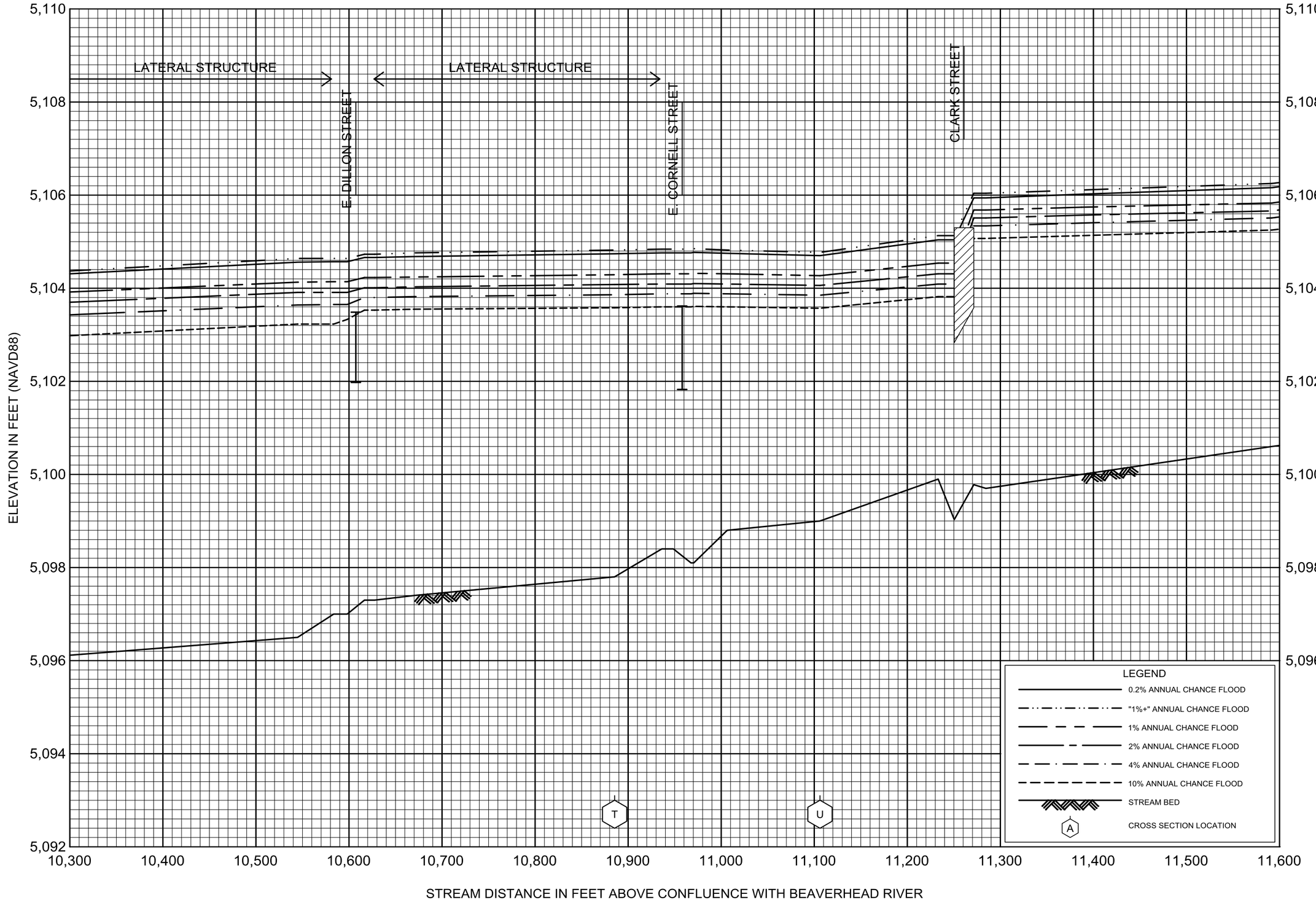
FLOOD PROFILES

BLACKTAIL DEER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



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BEAVERHEAD COUNTY, MT

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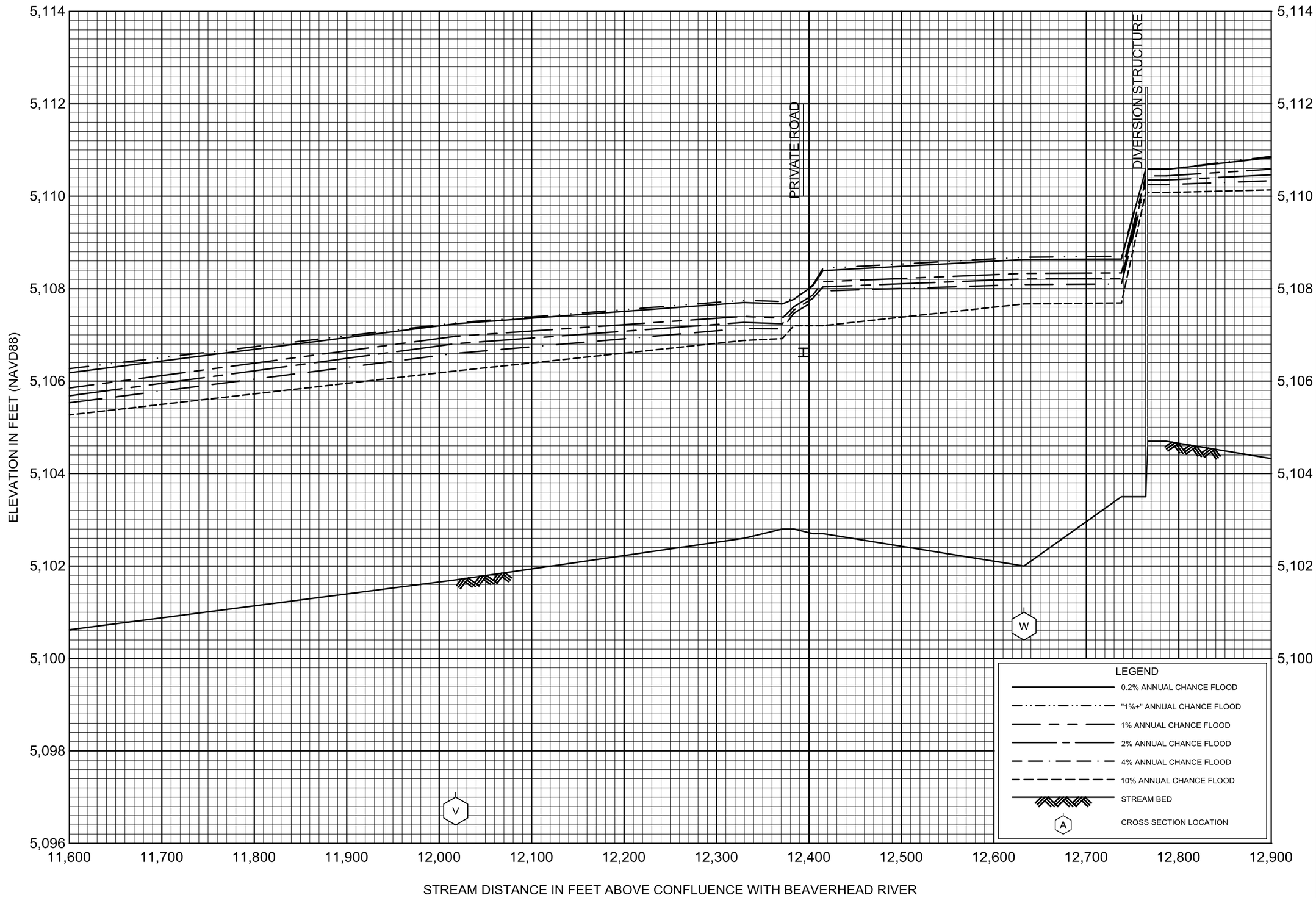

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BEAVERHEAD COUNTY, MT

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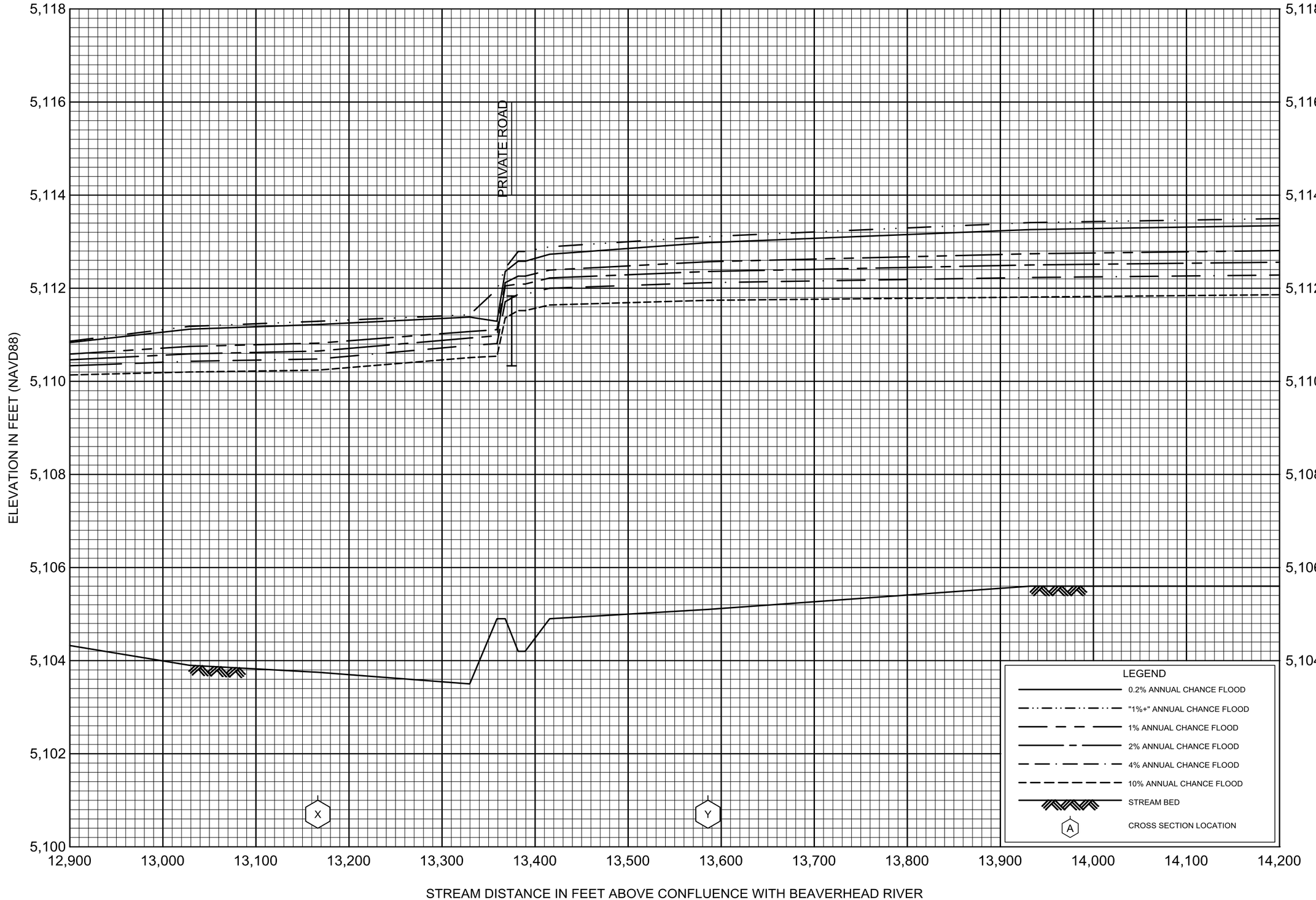

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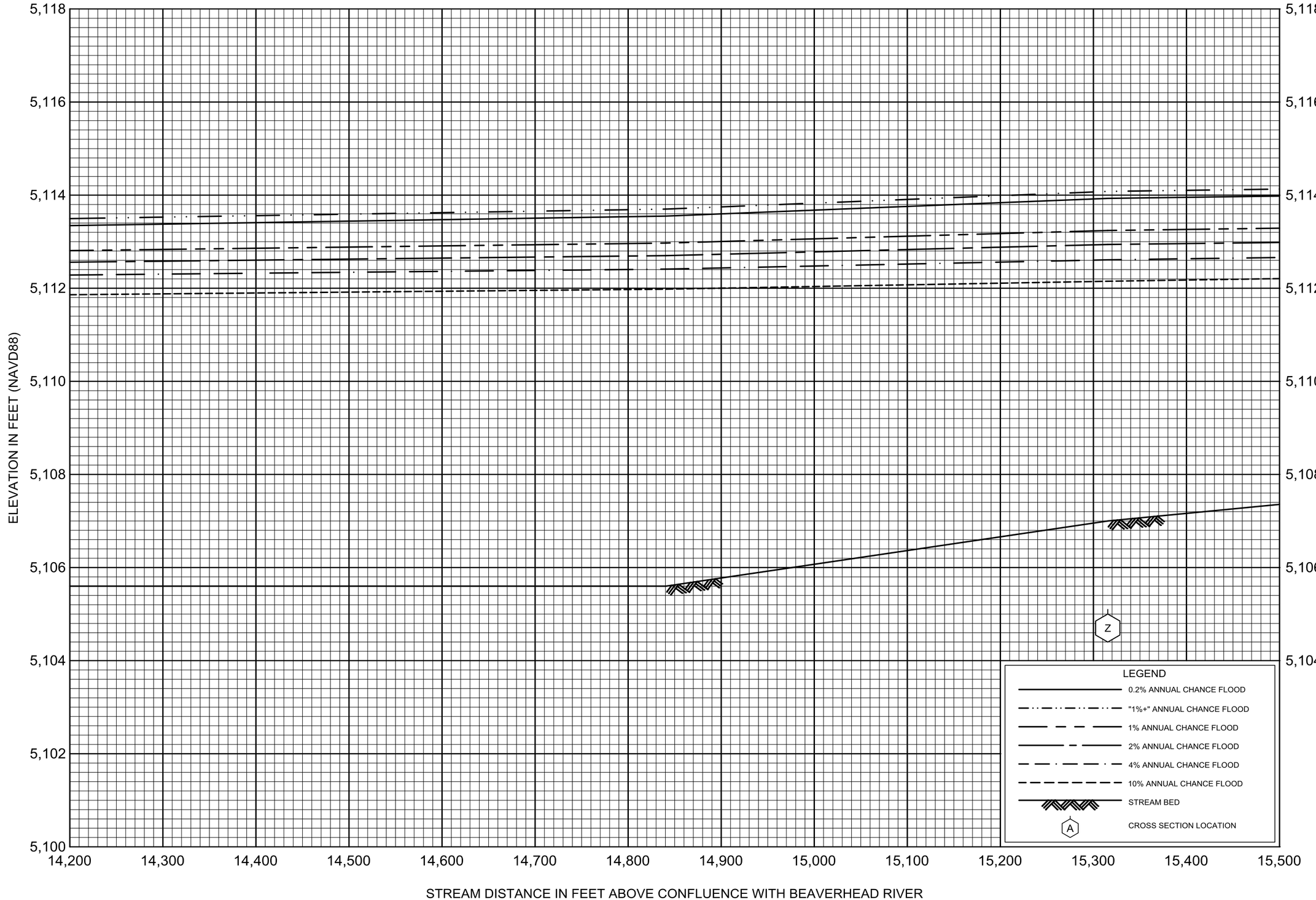

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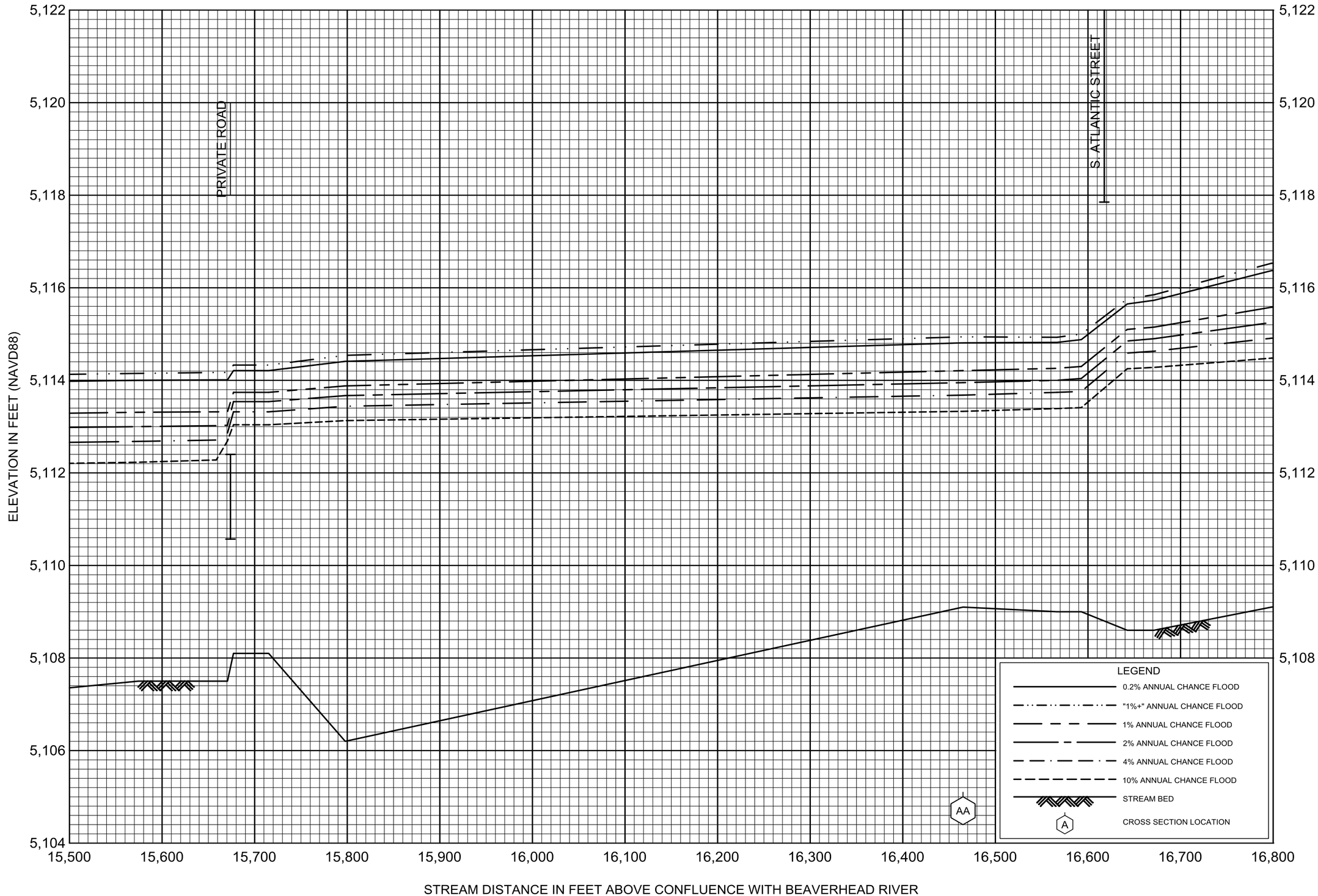

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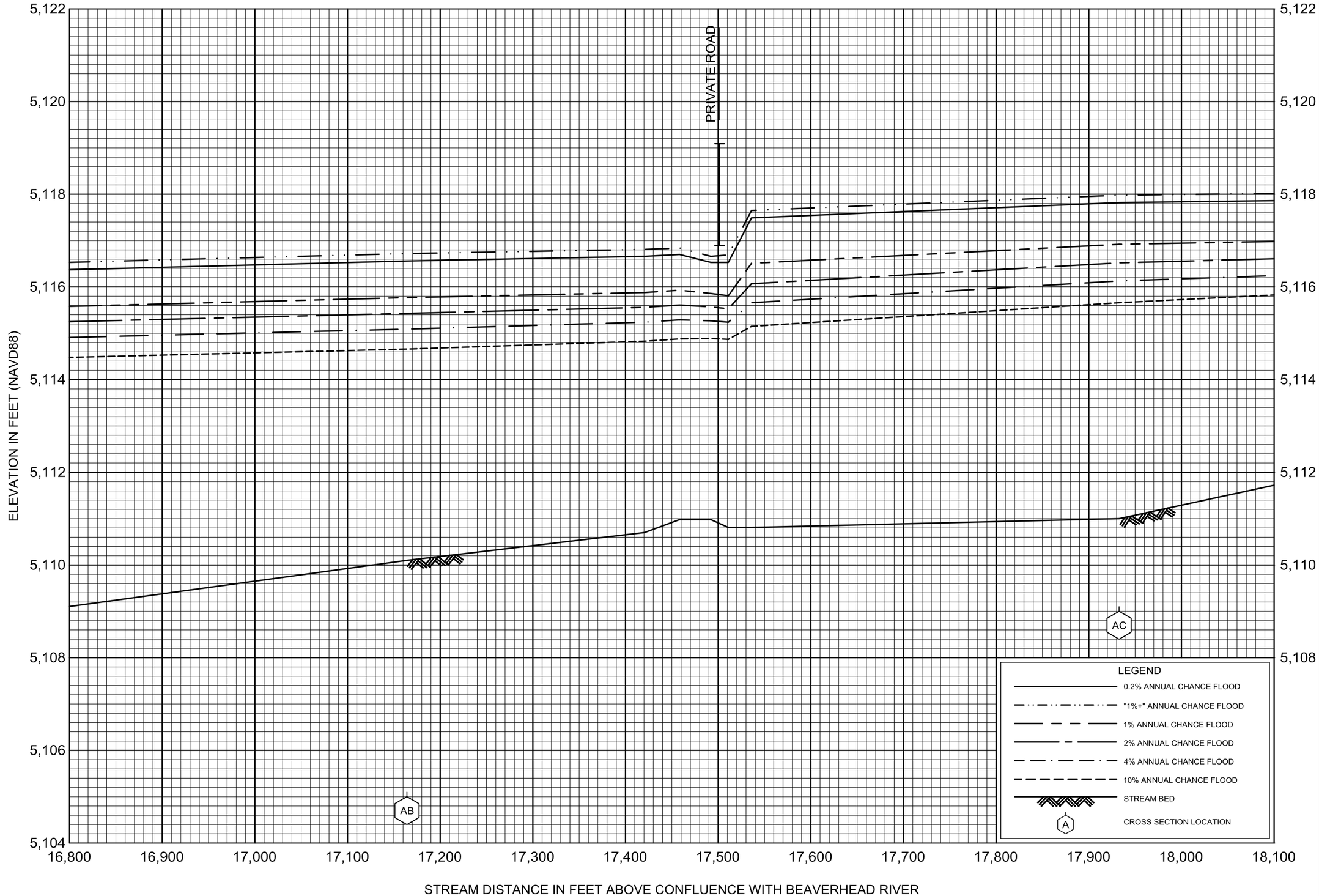

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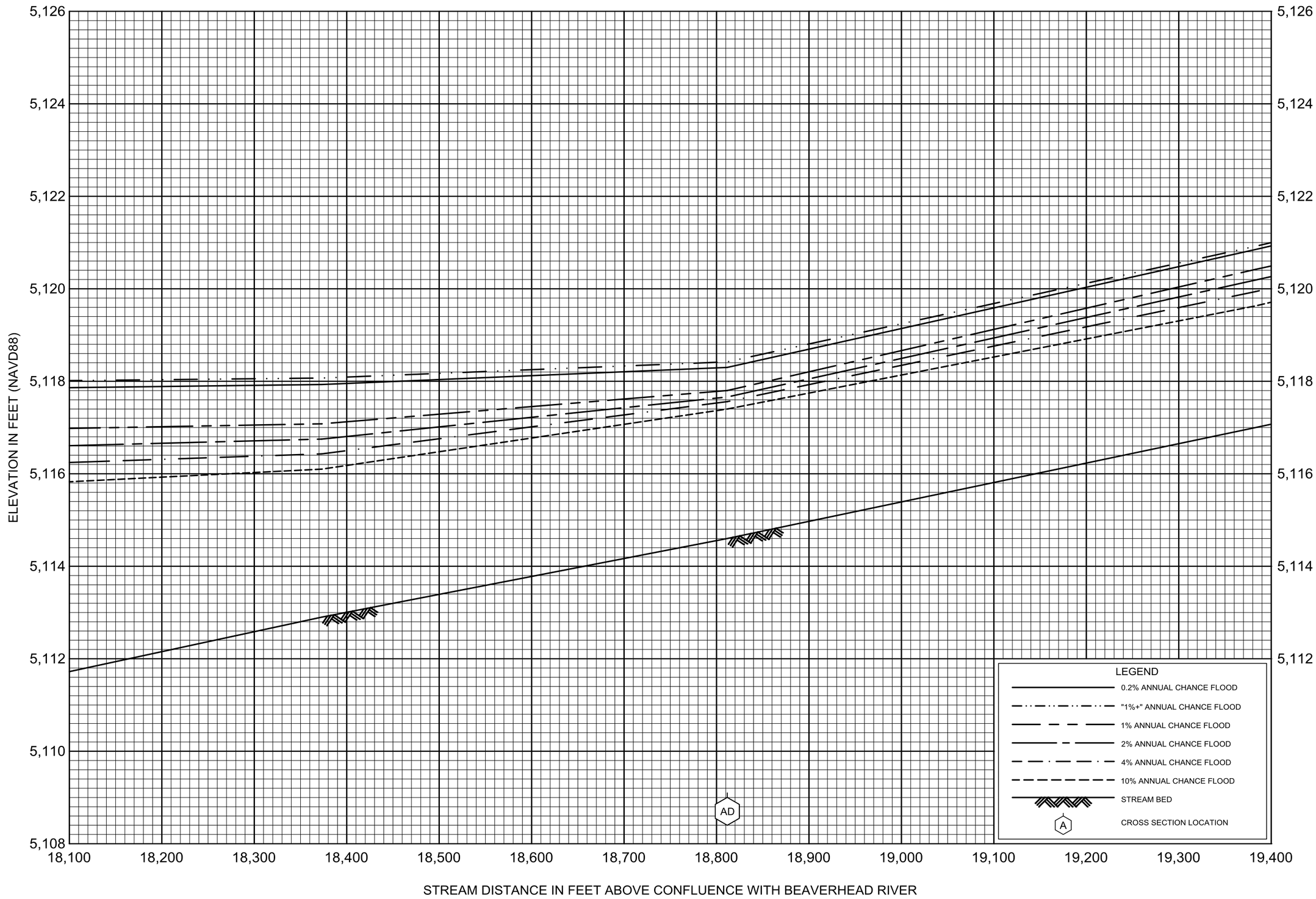

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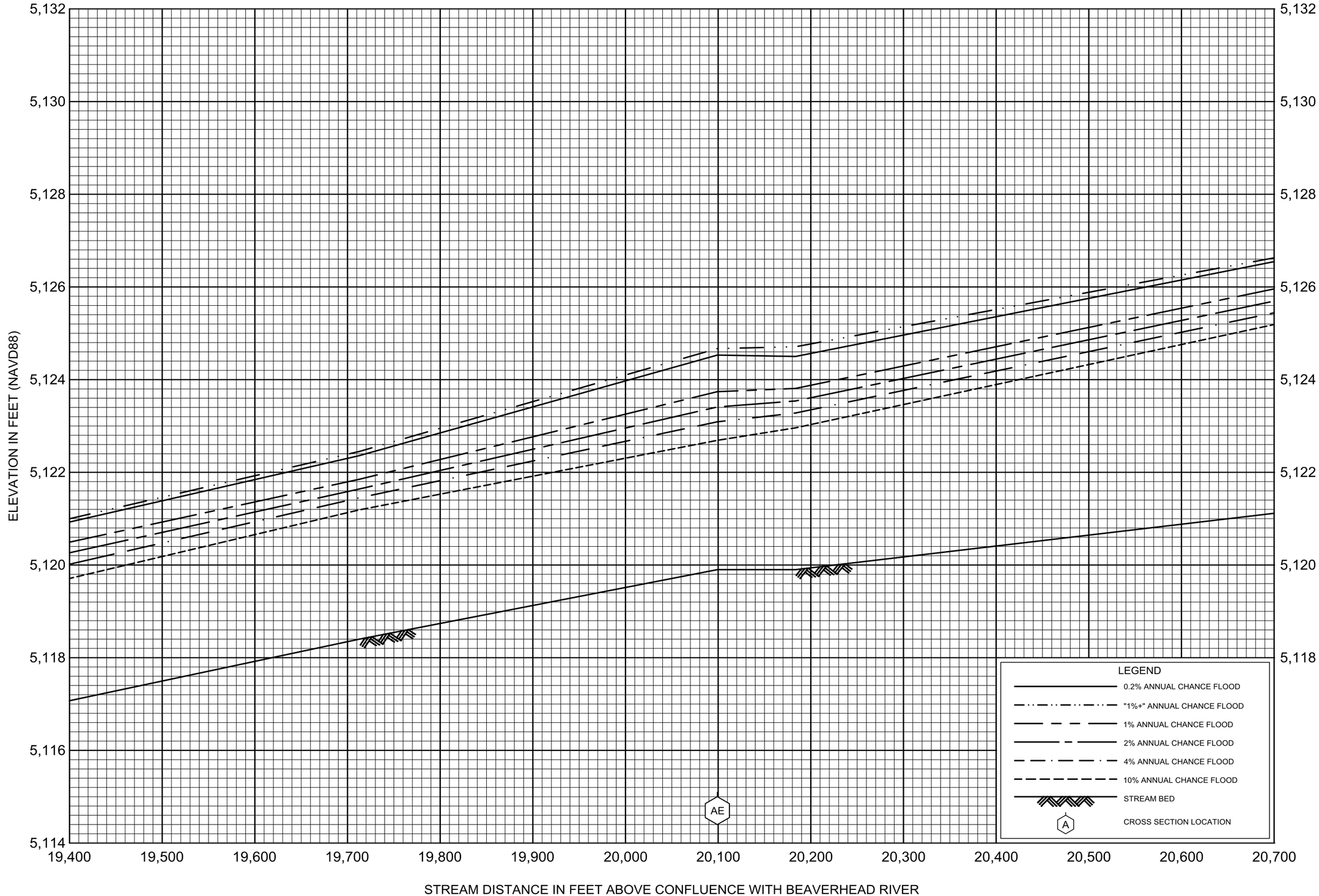

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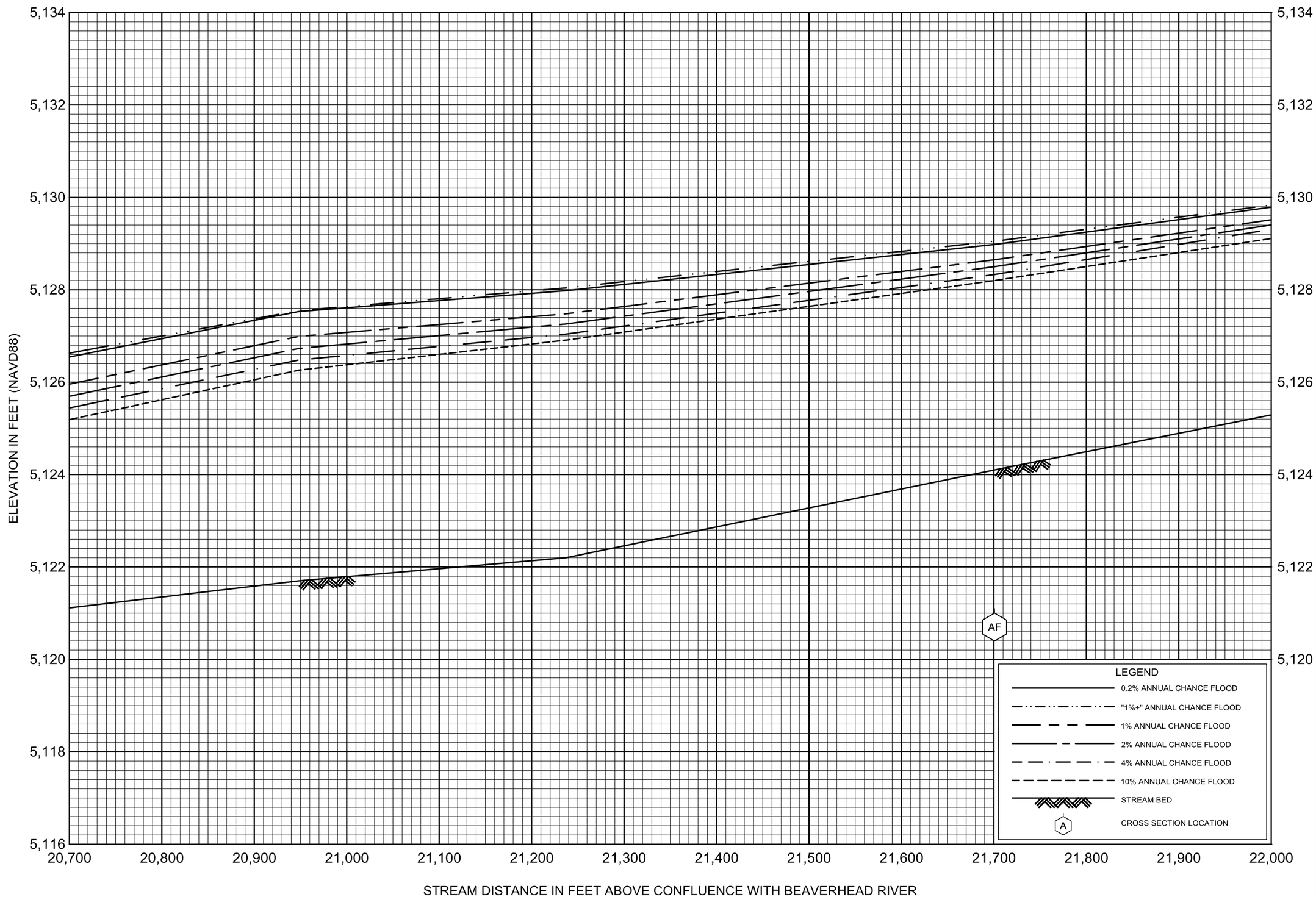

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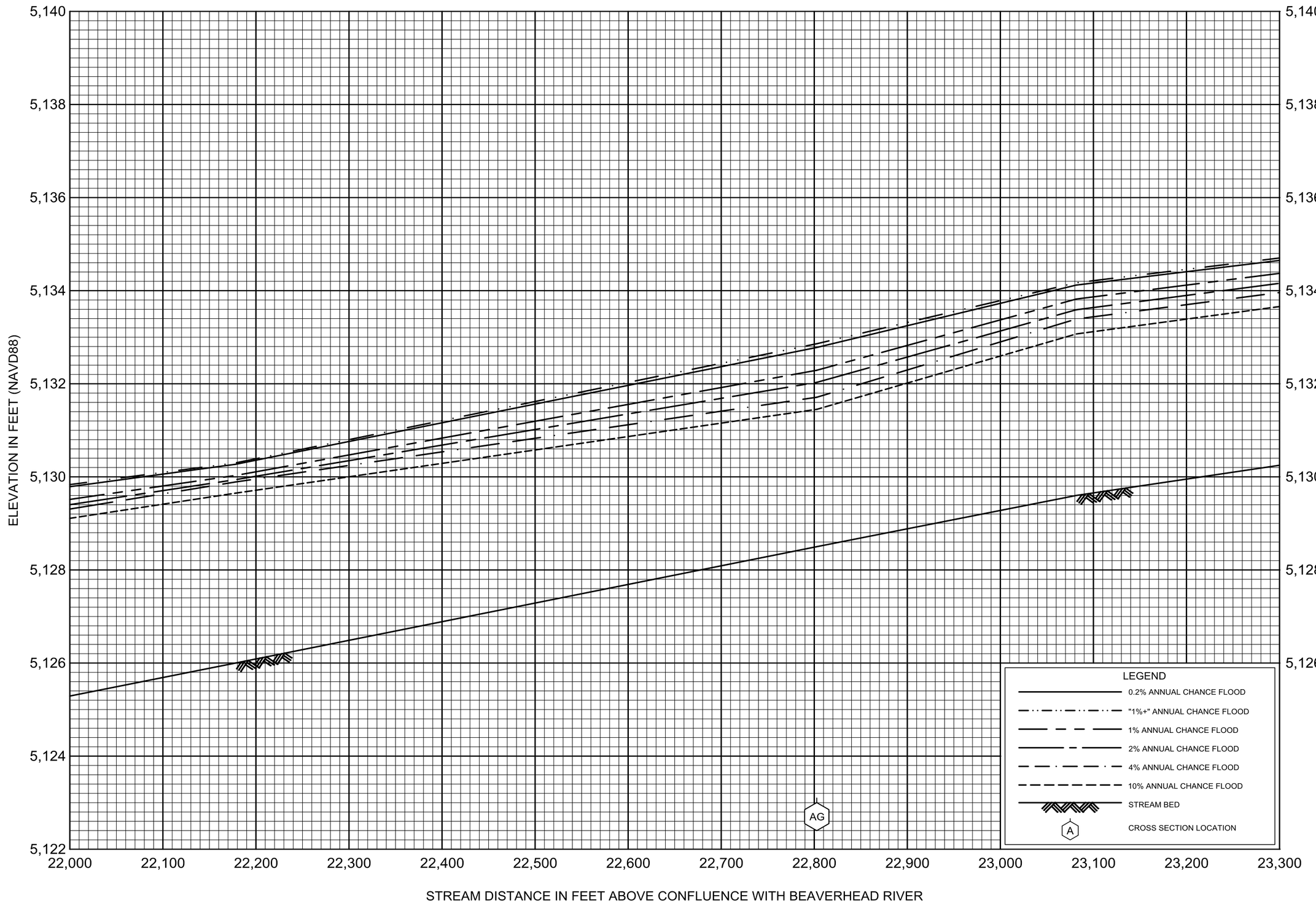

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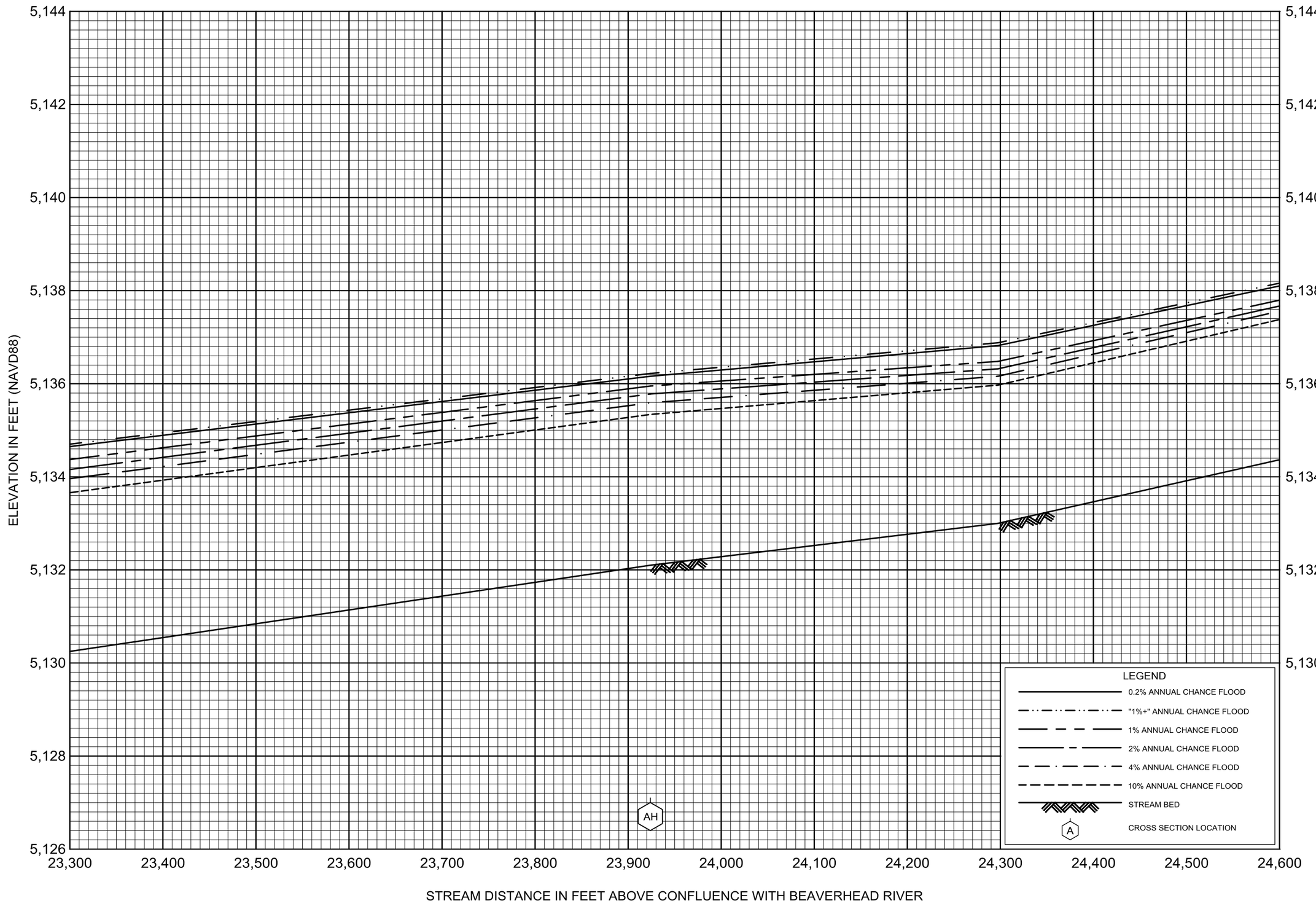

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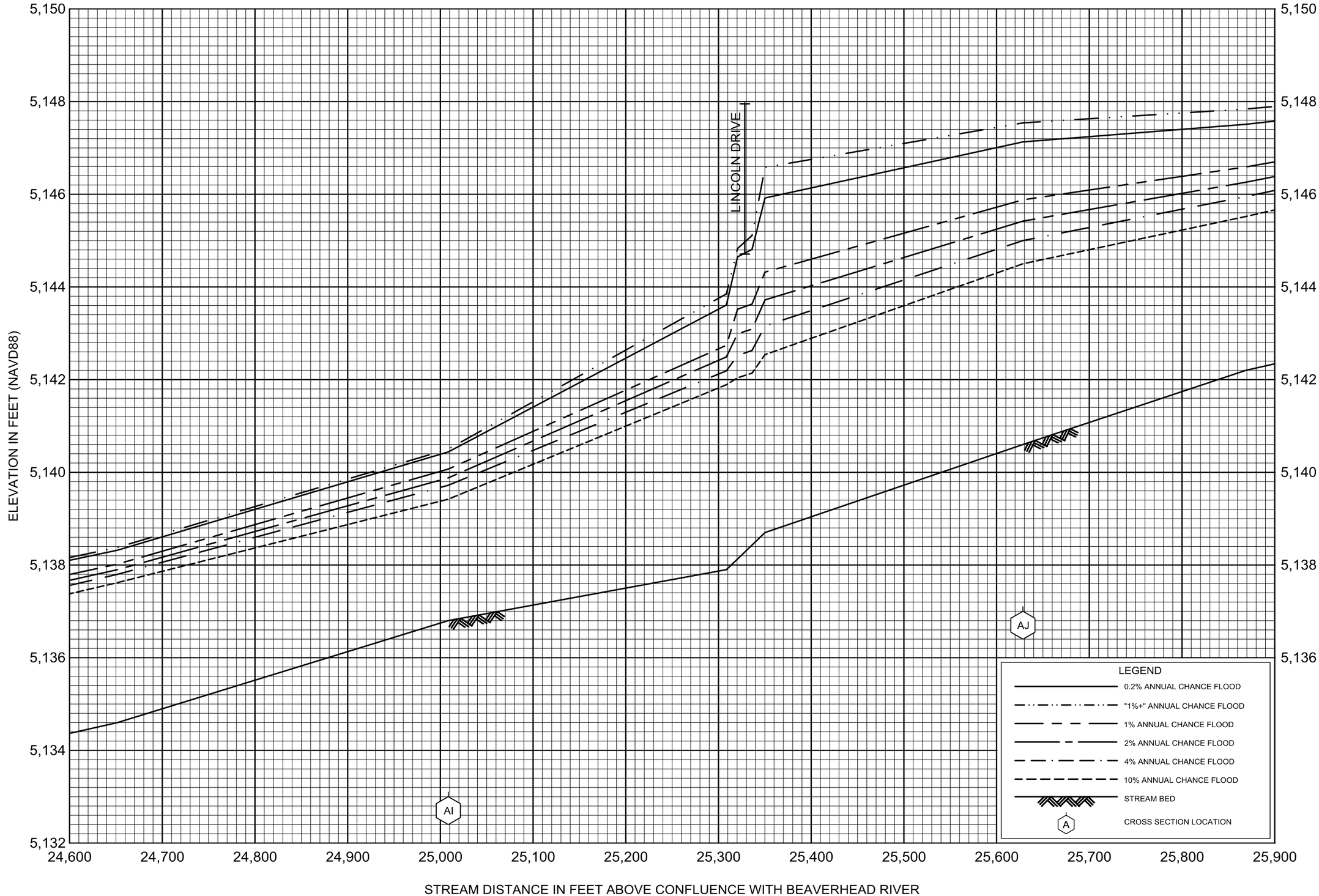

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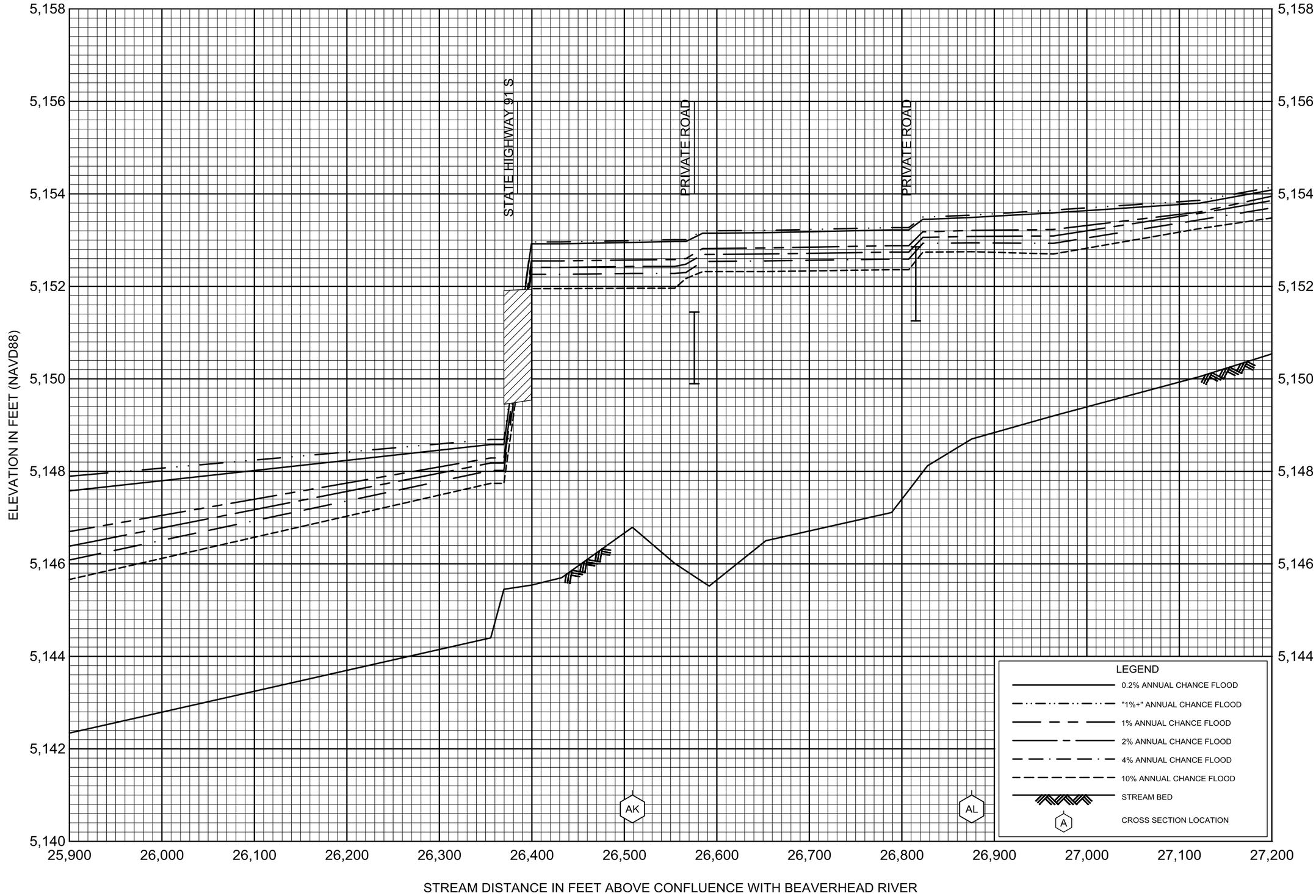

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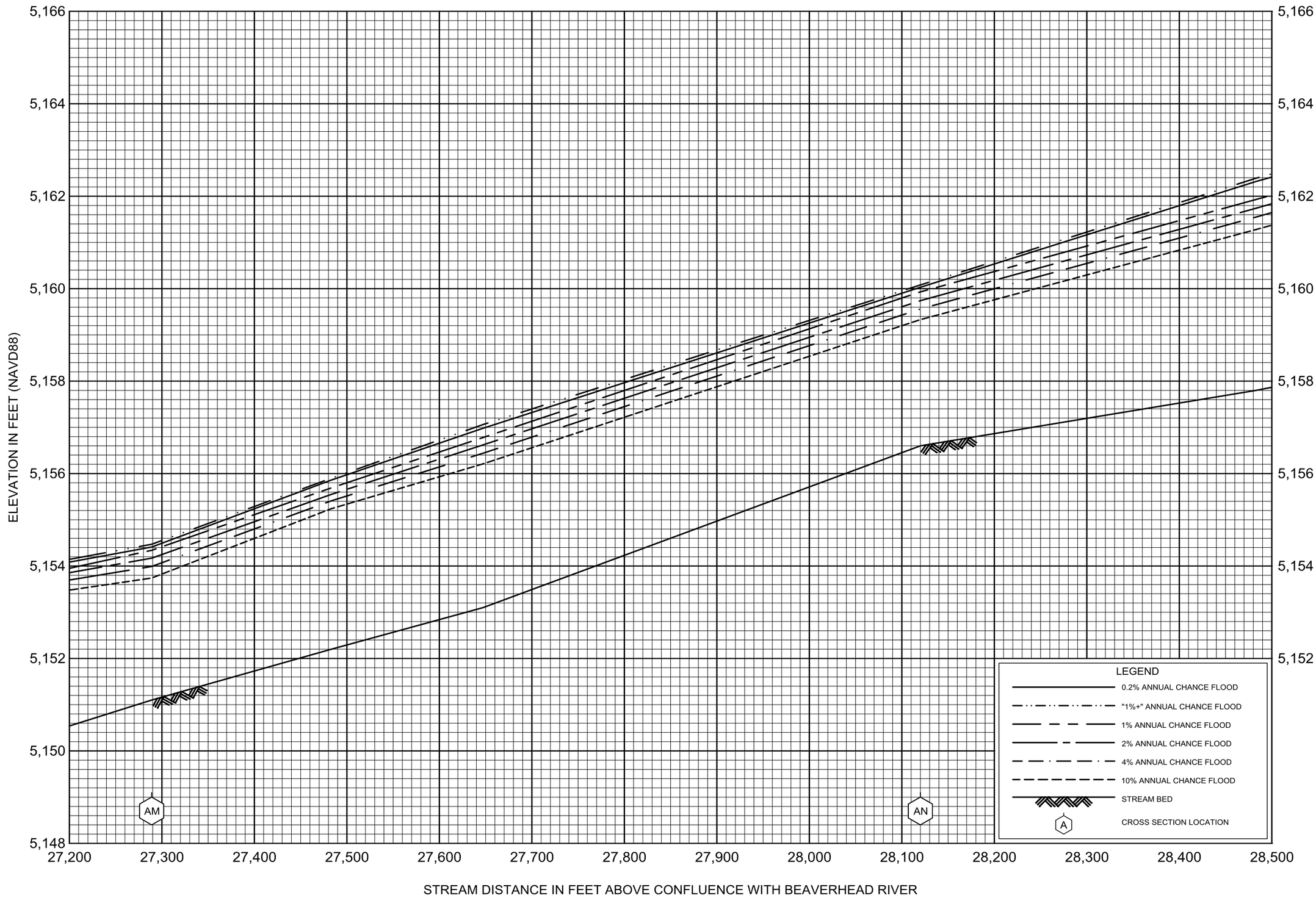

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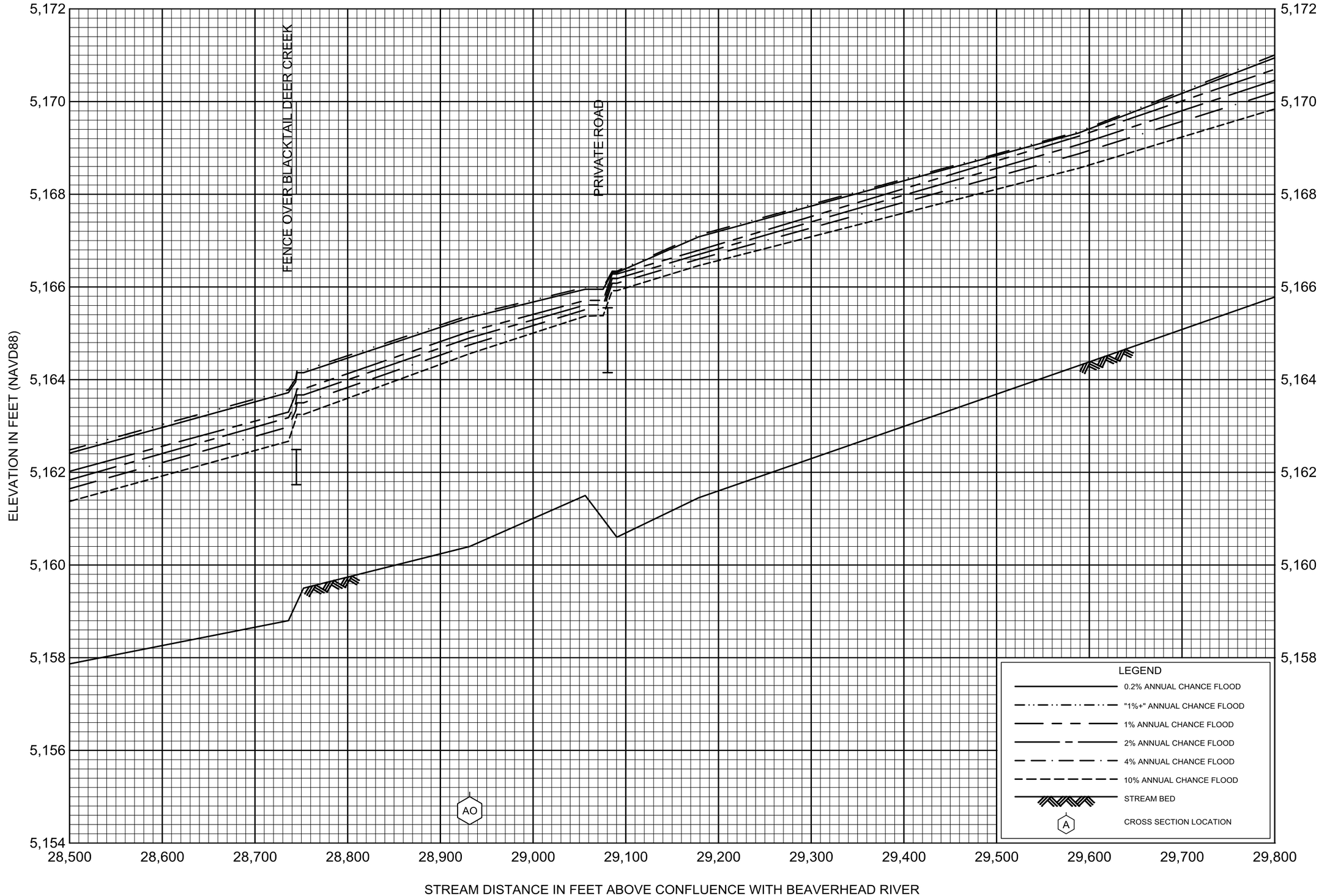

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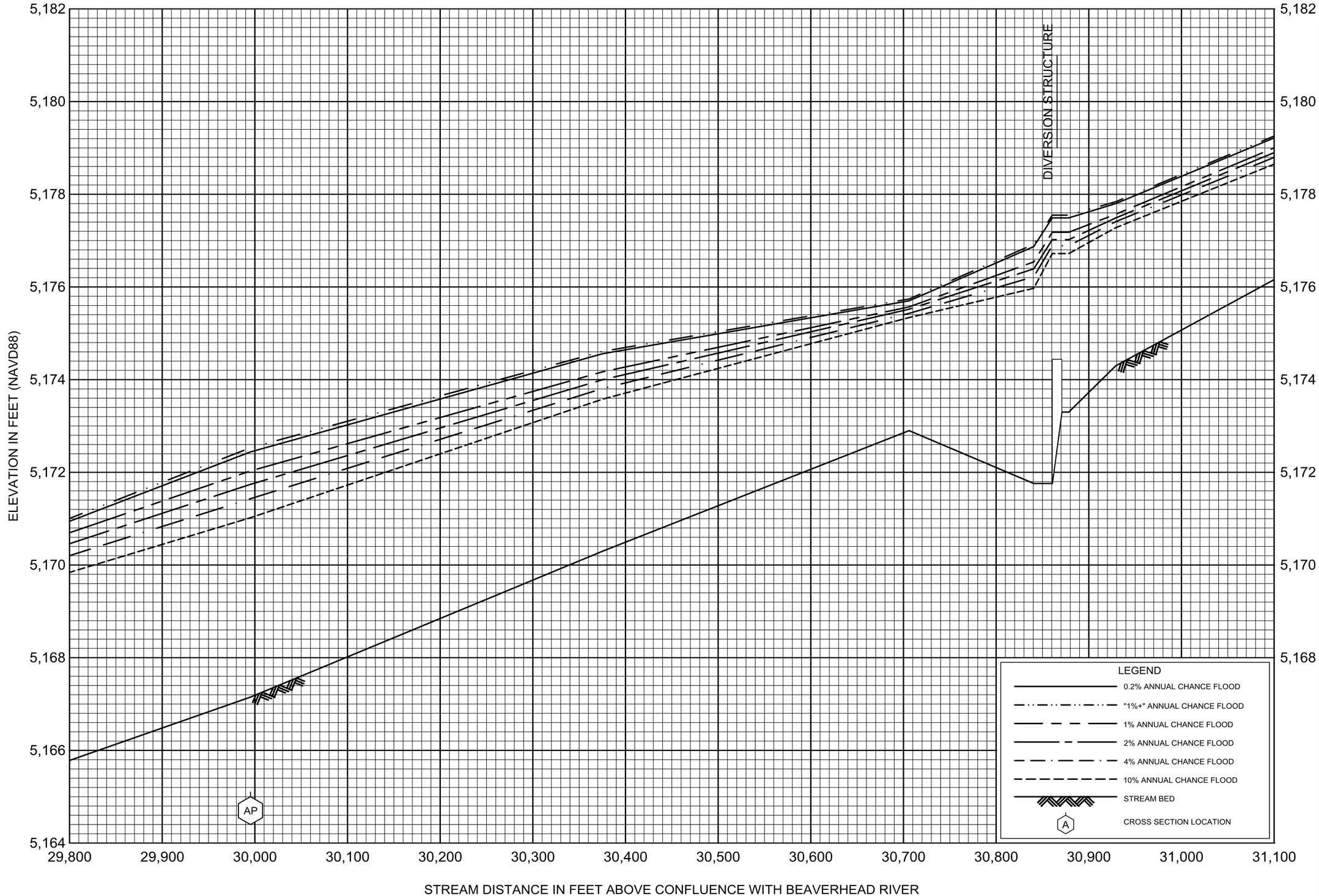

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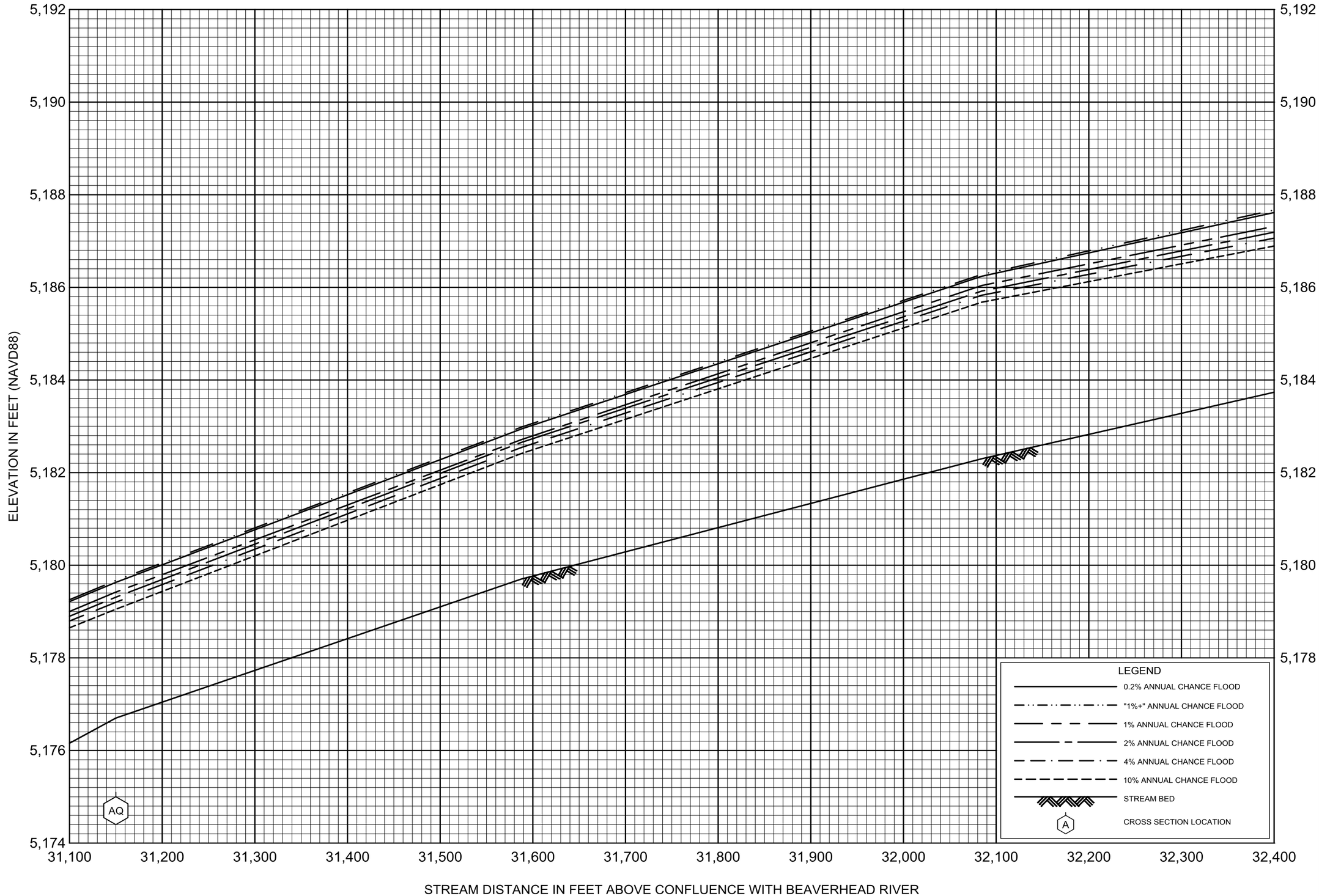

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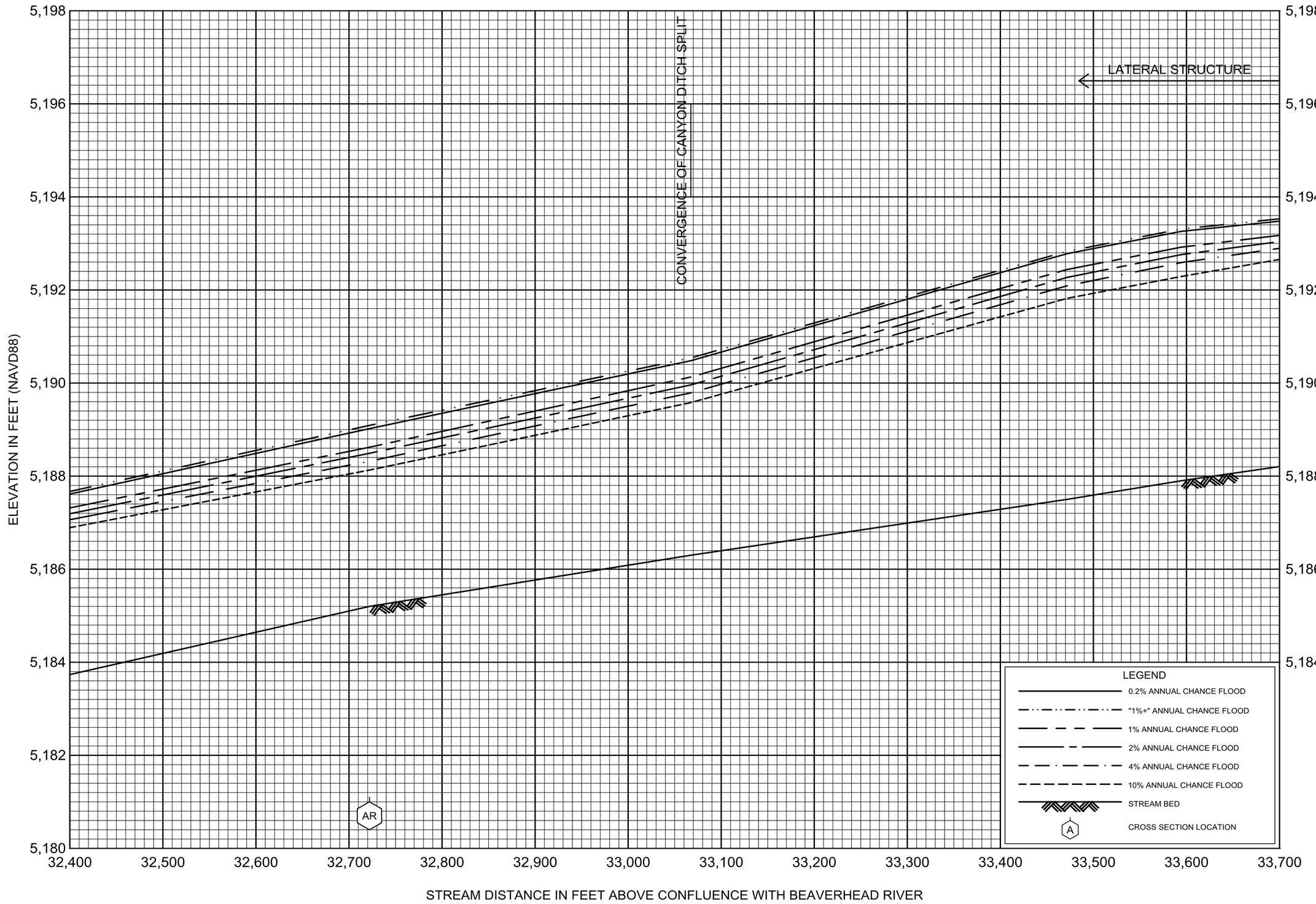

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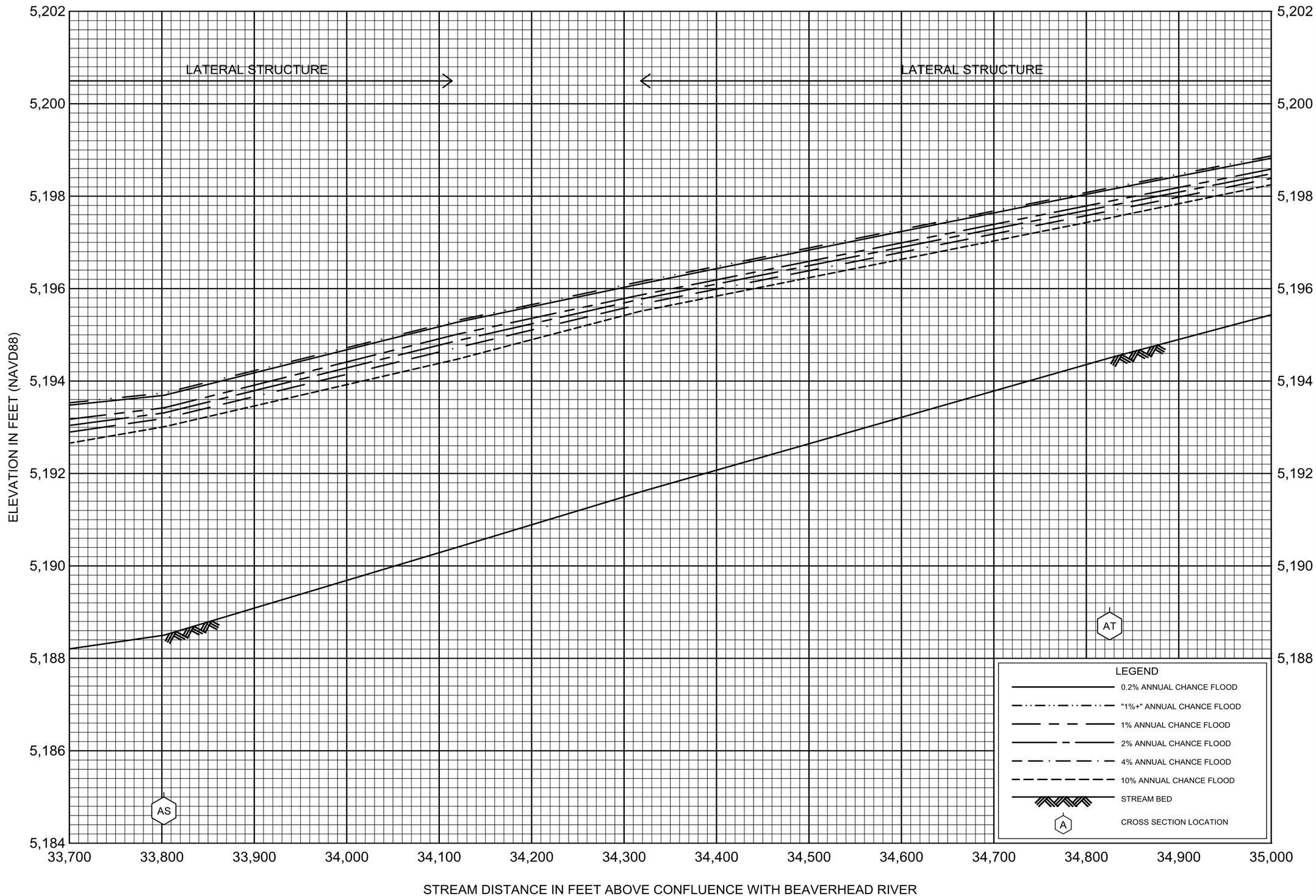

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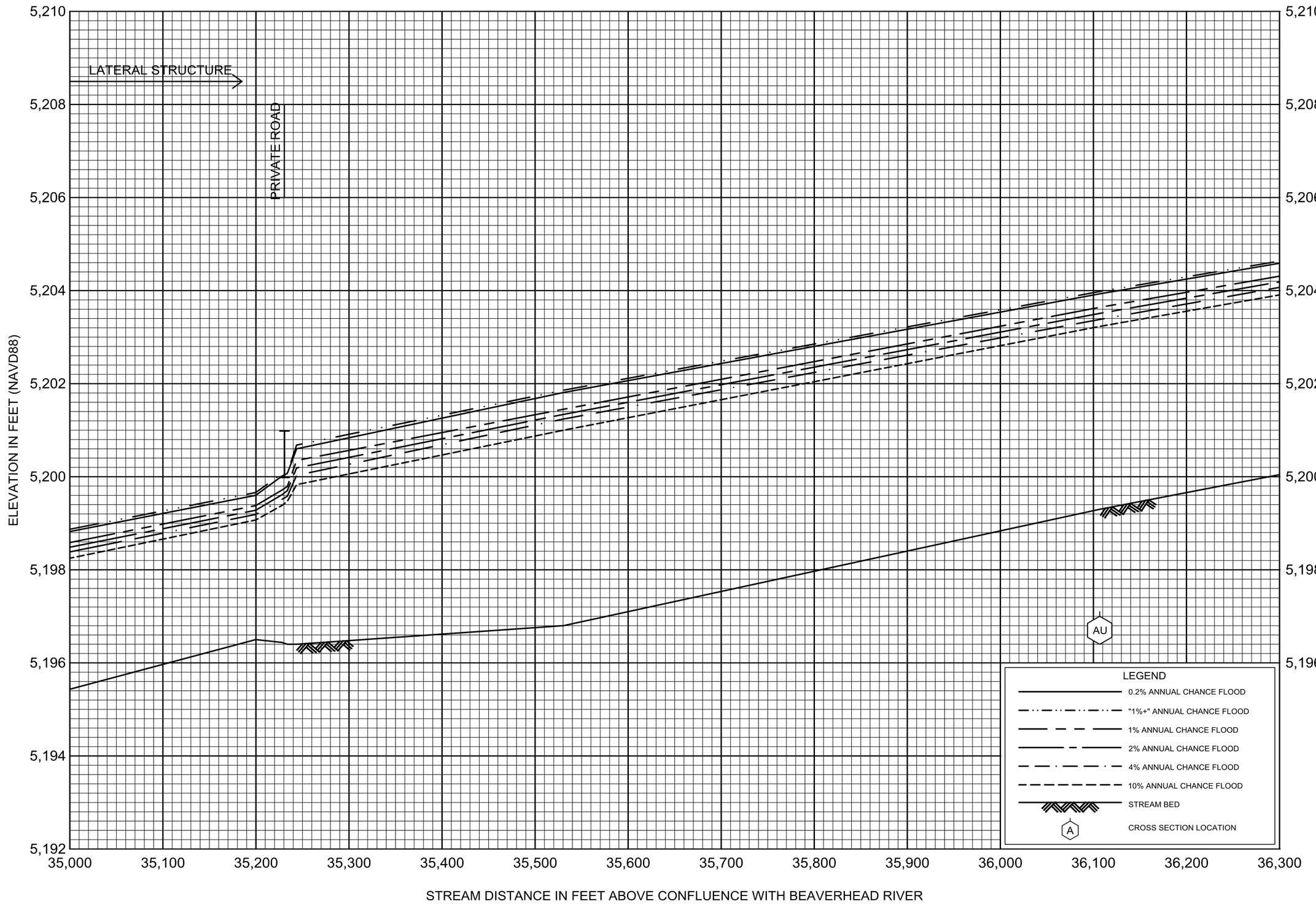

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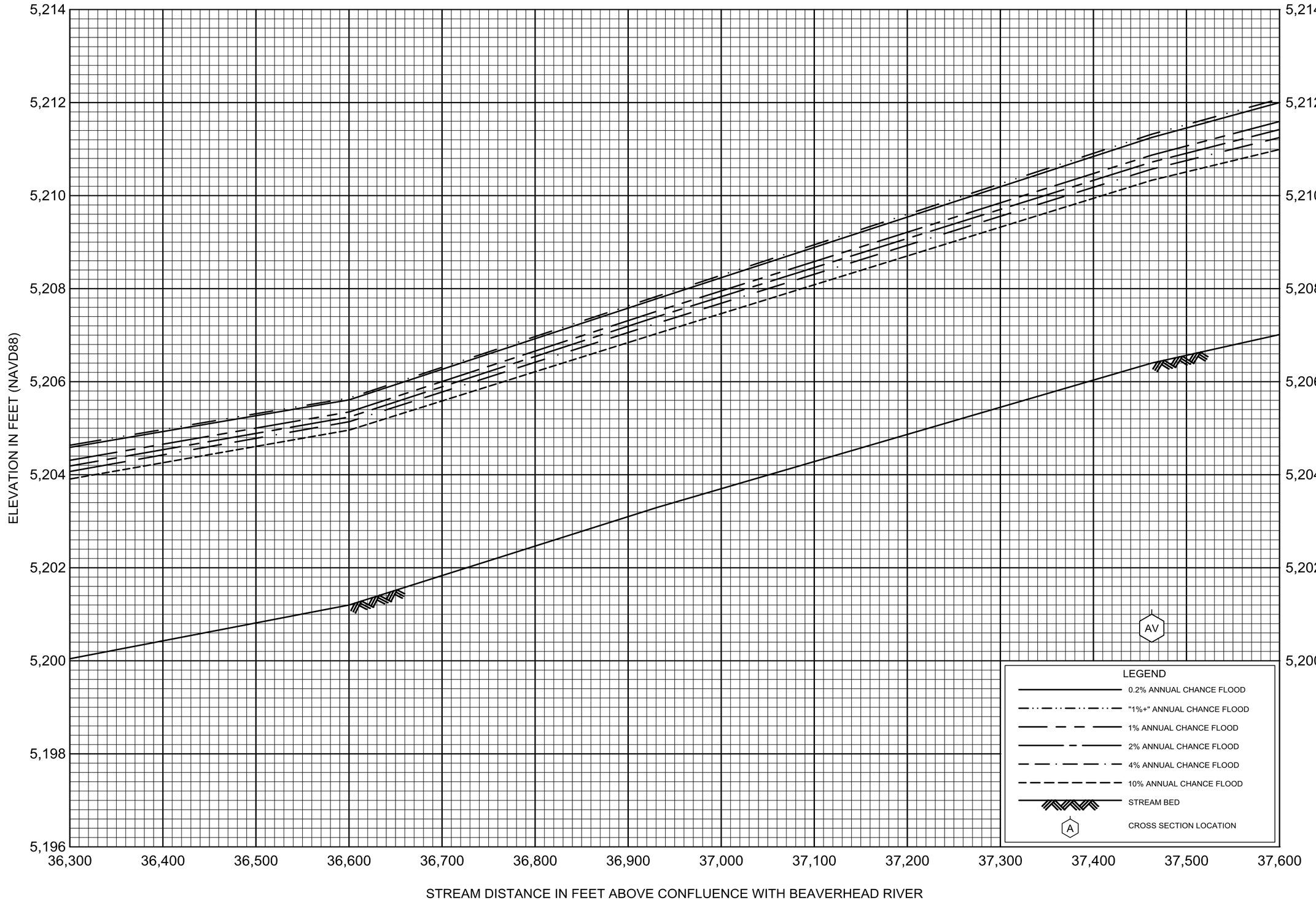

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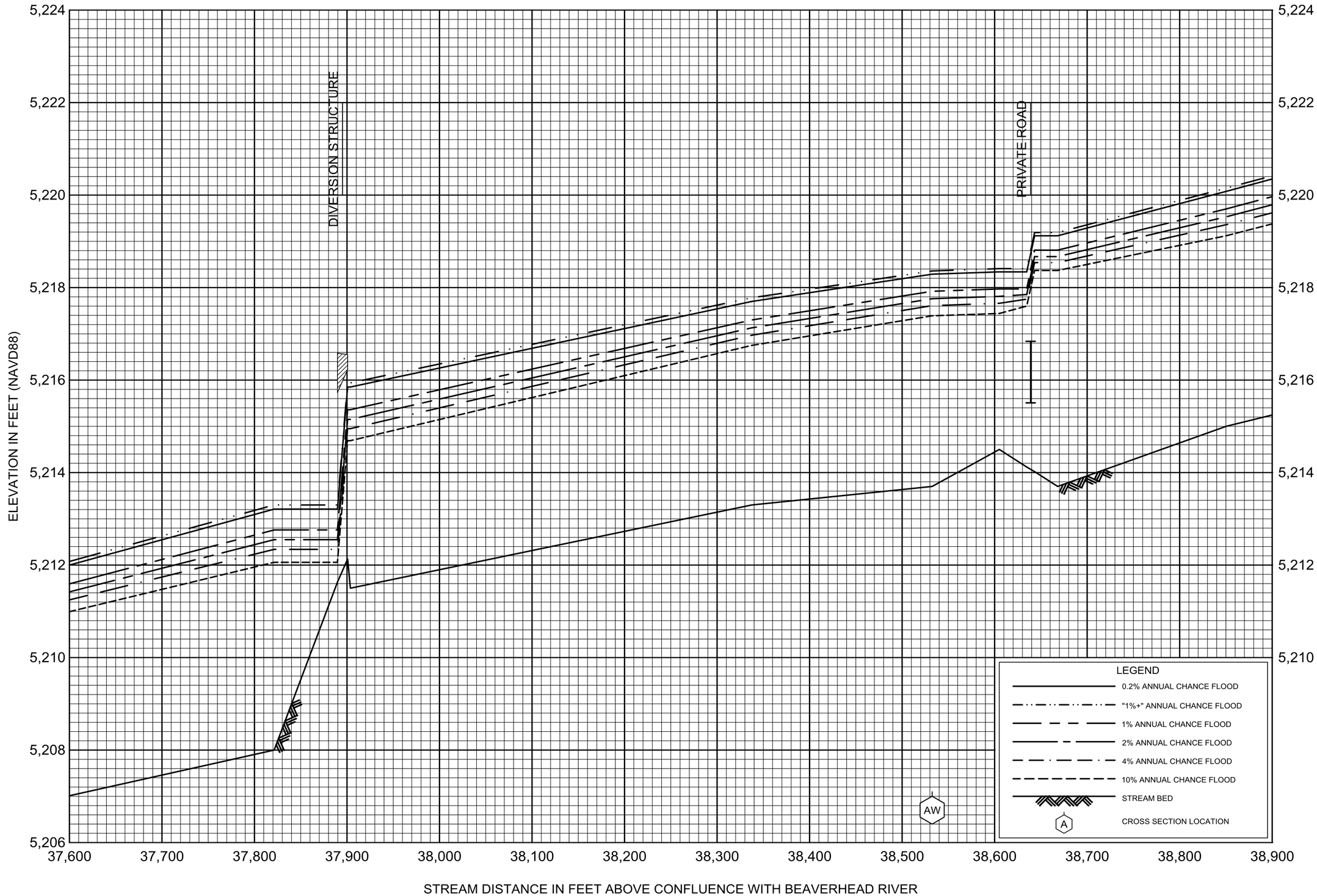

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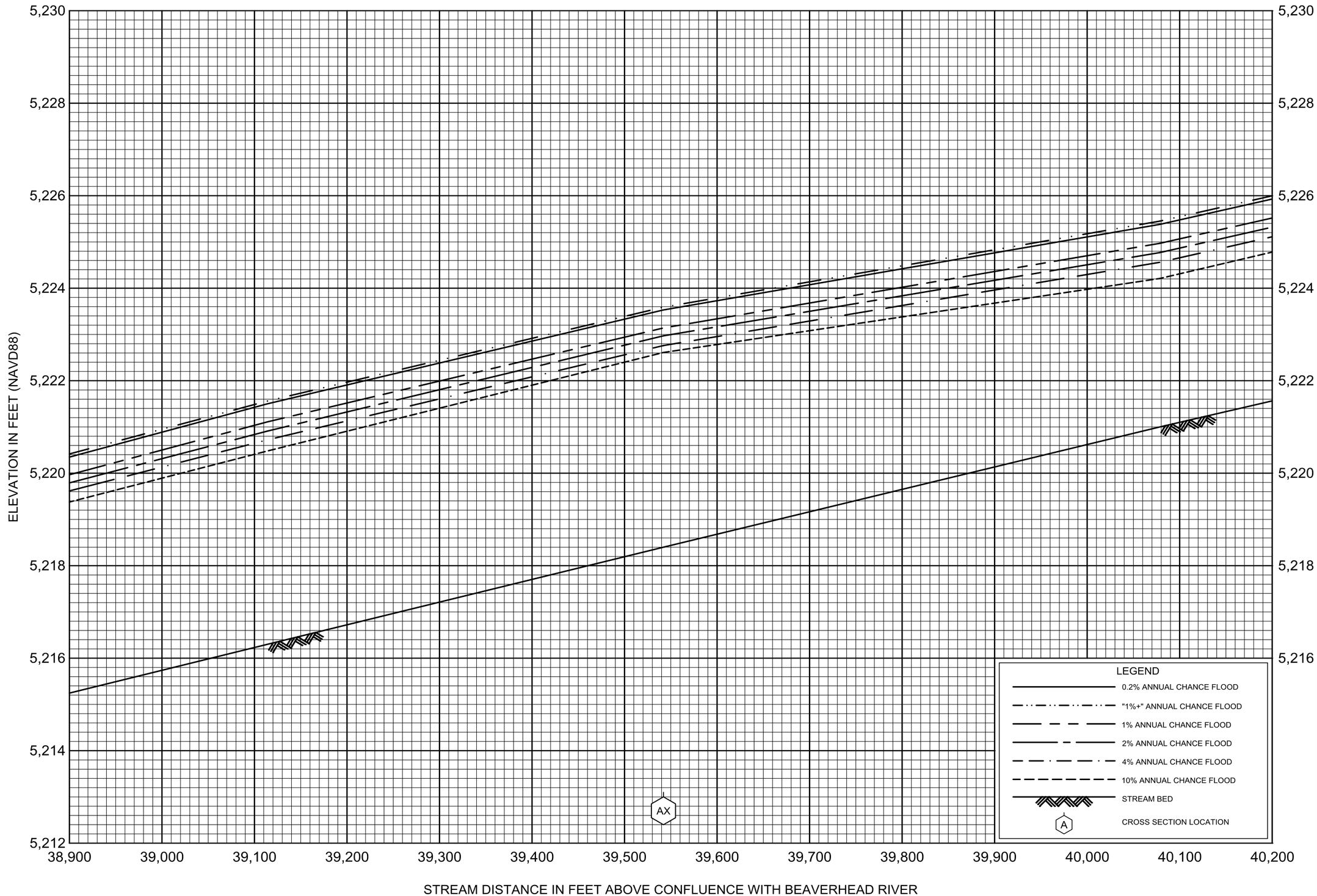

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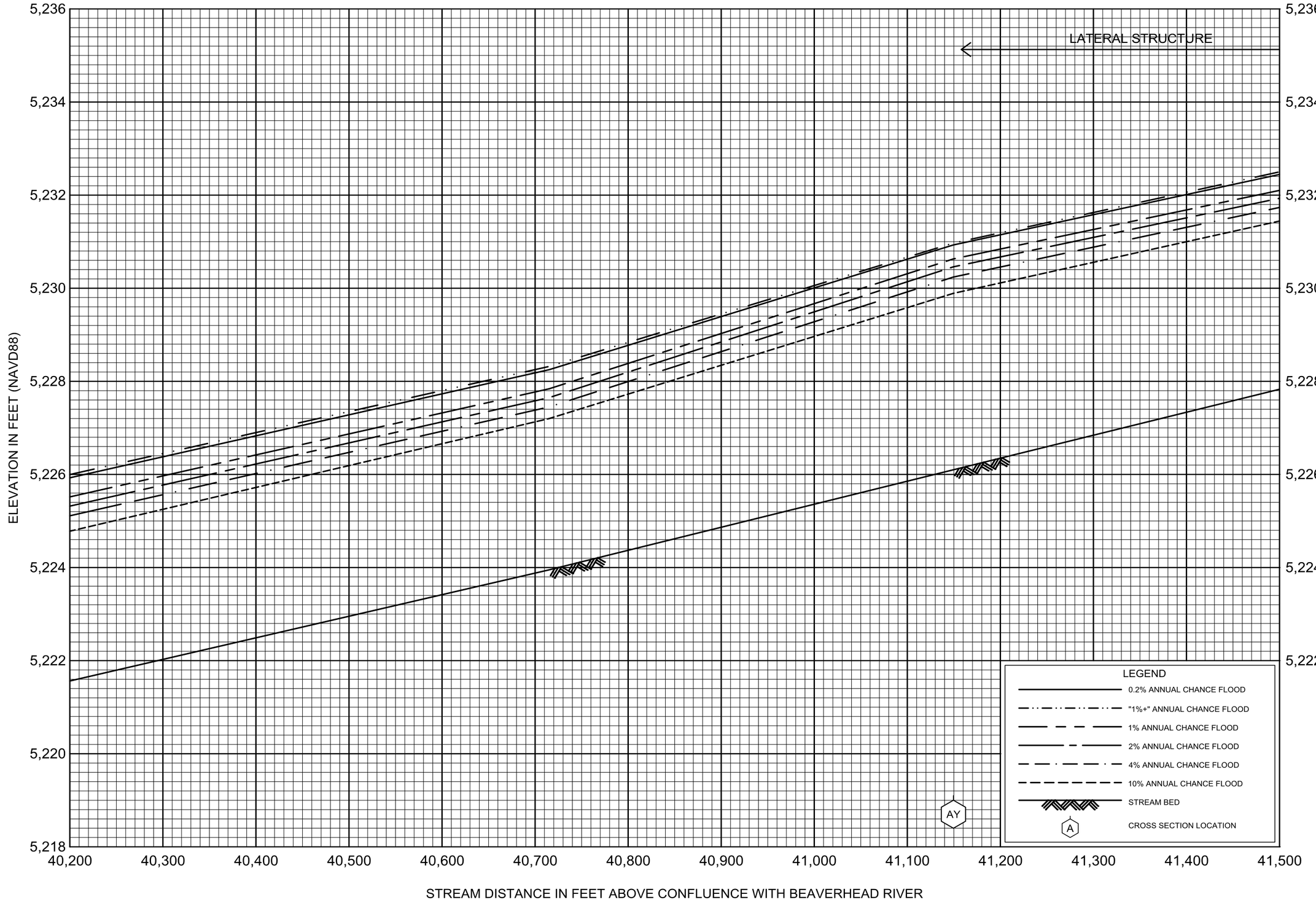

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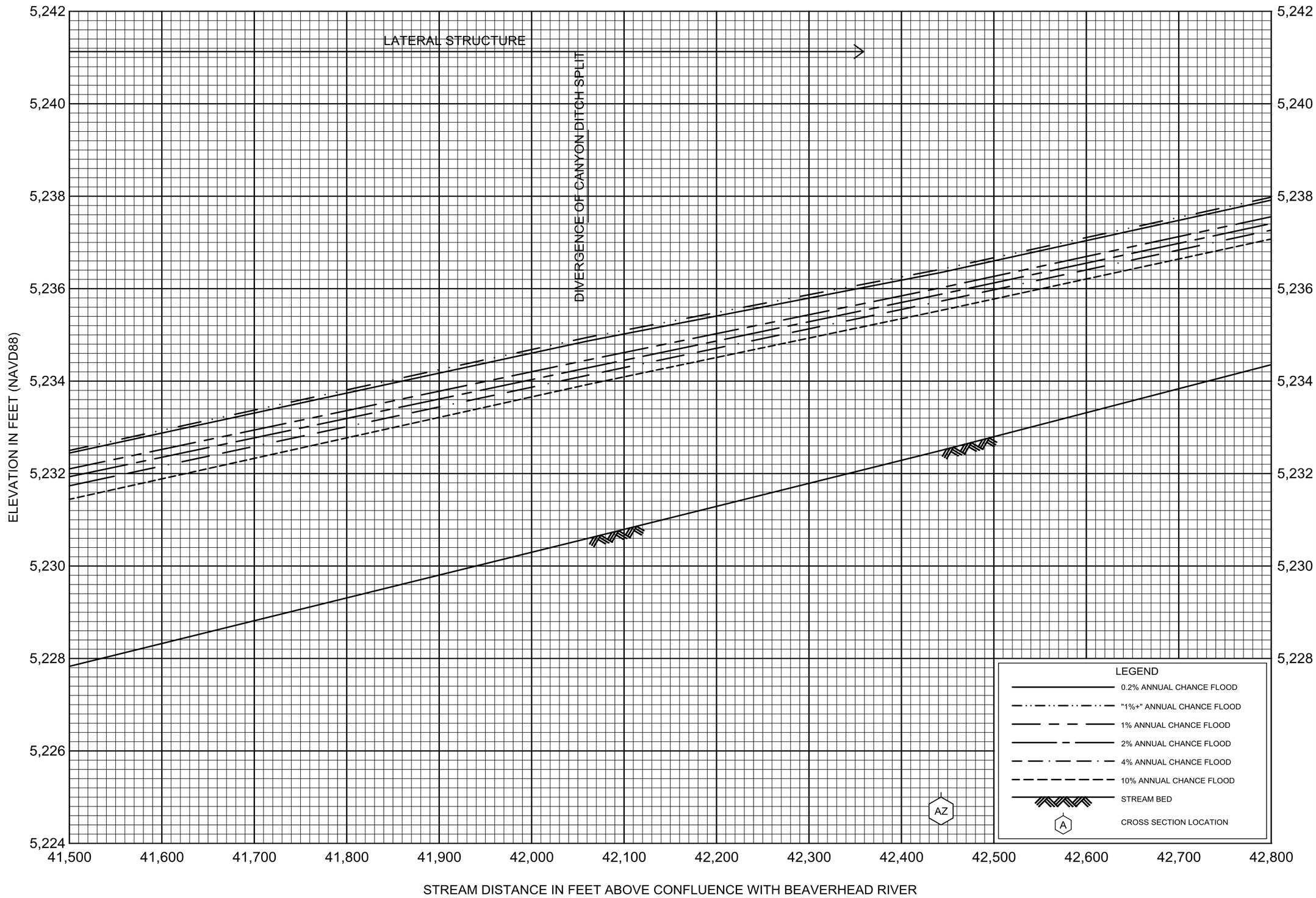

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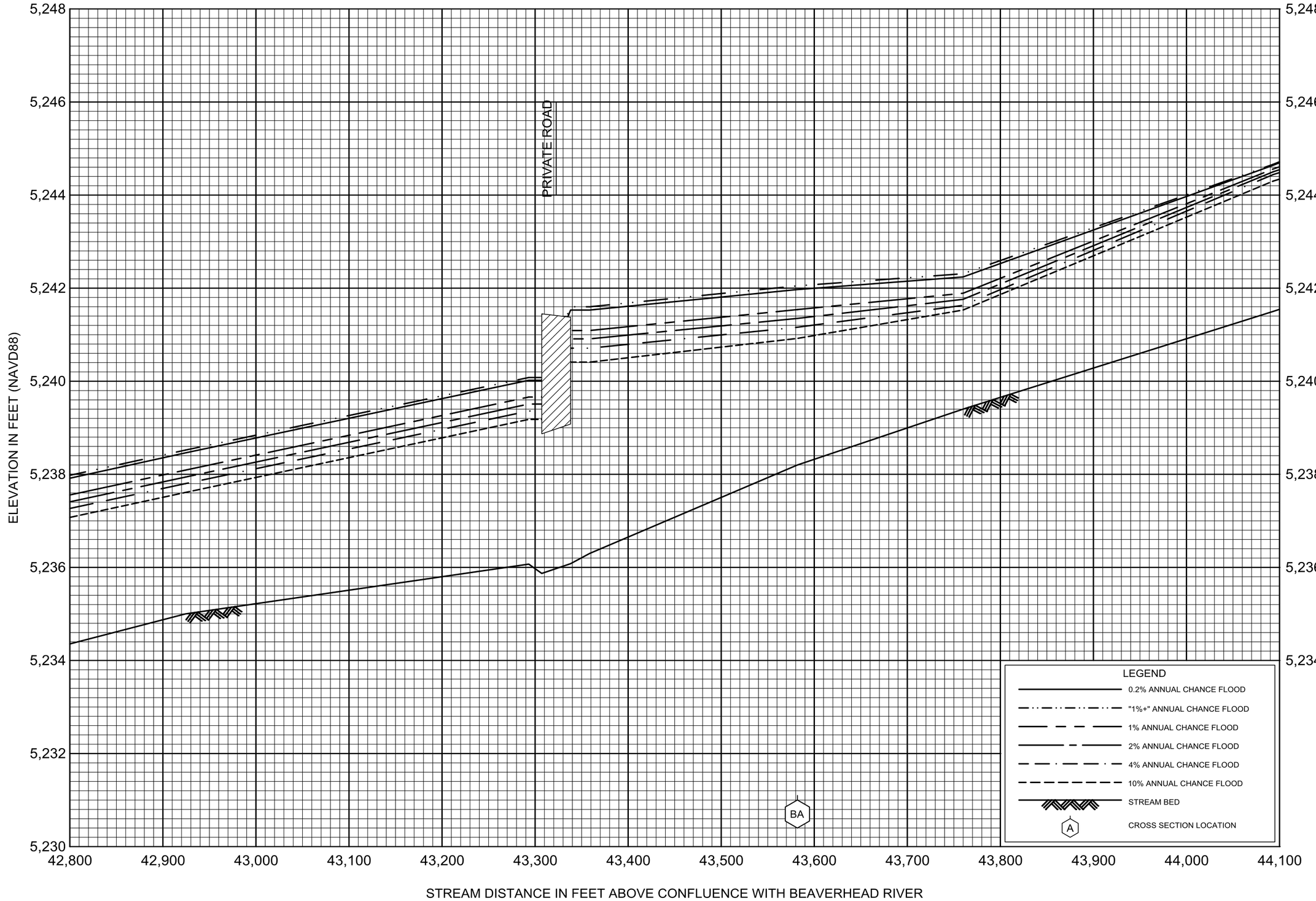

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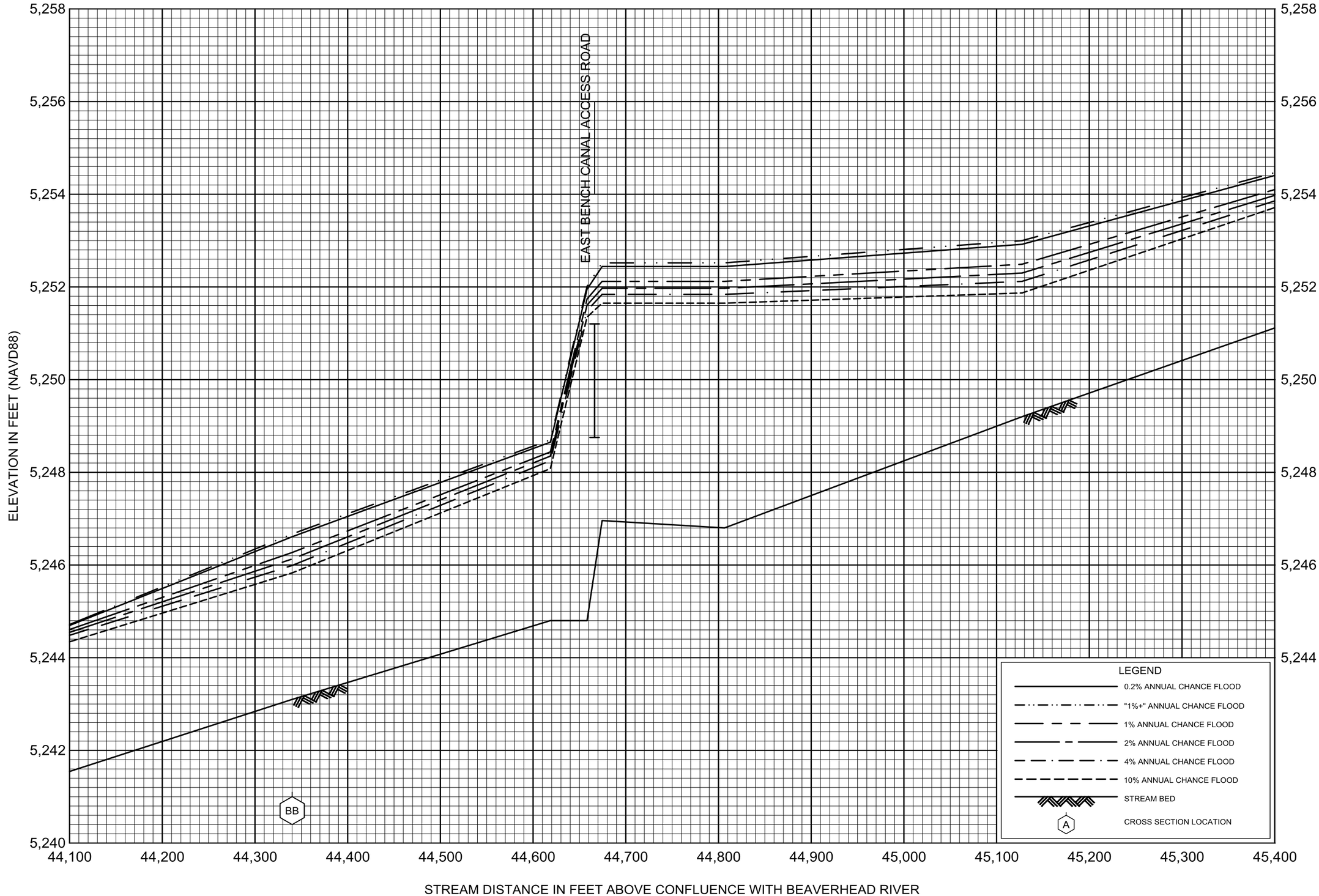

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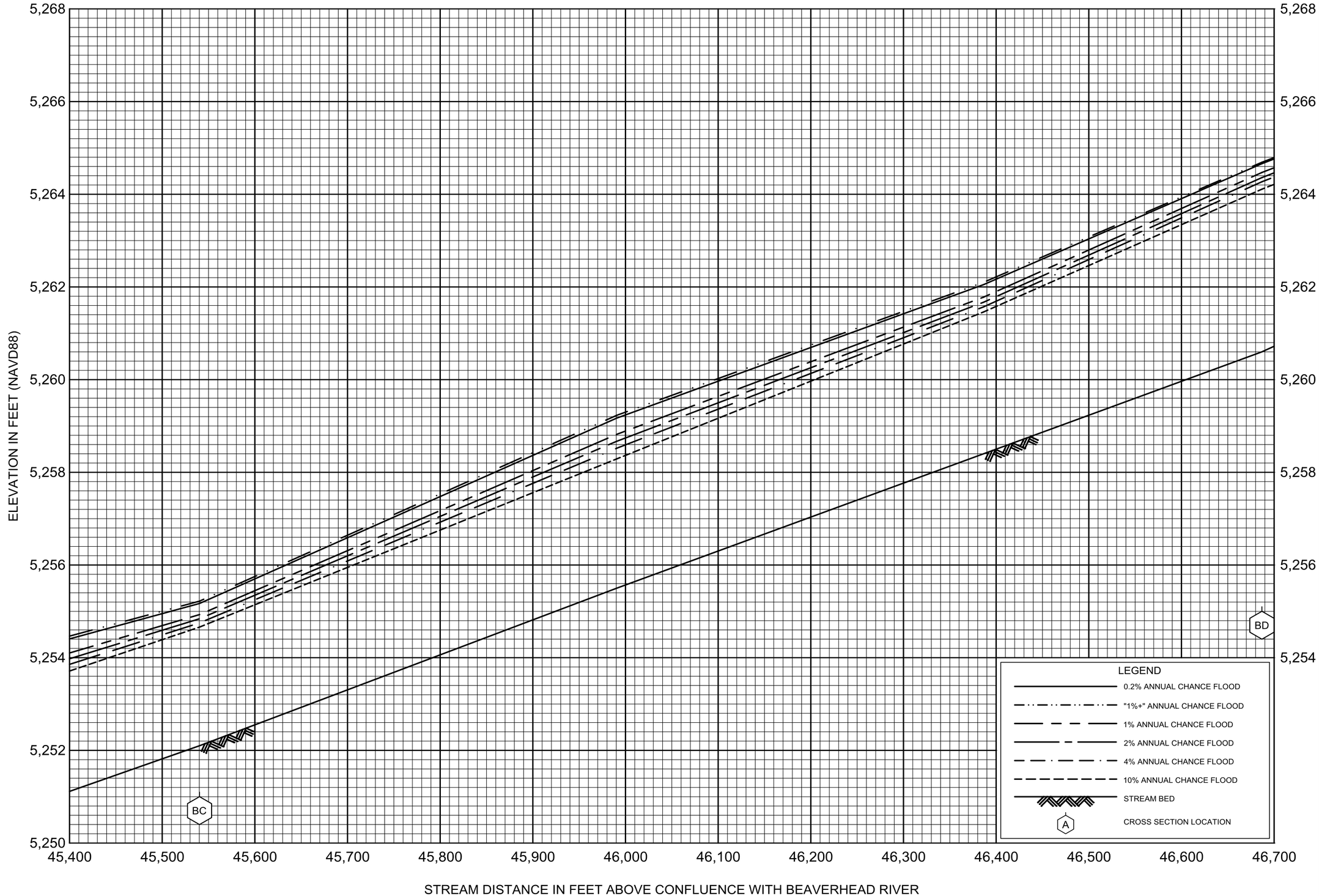

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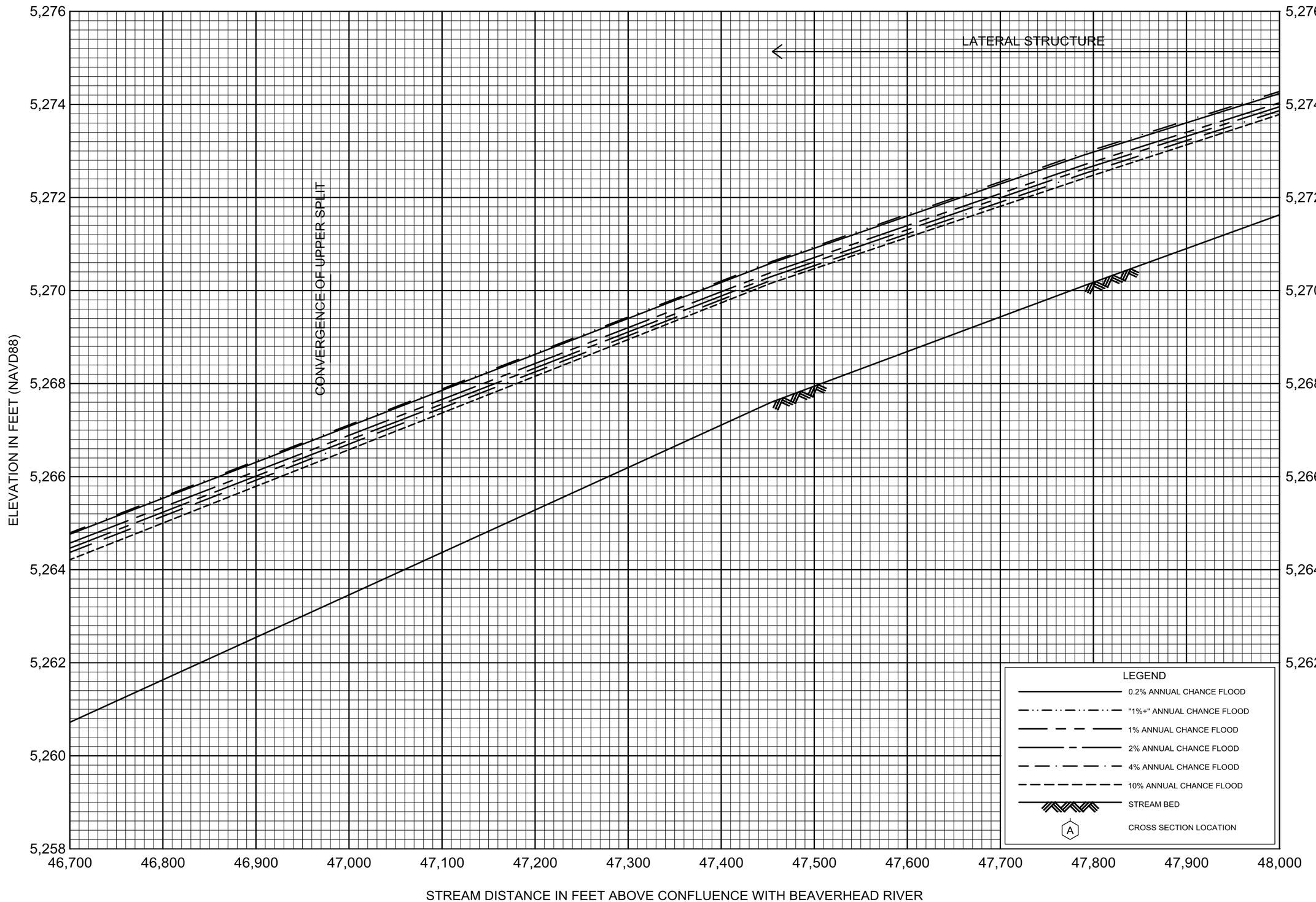

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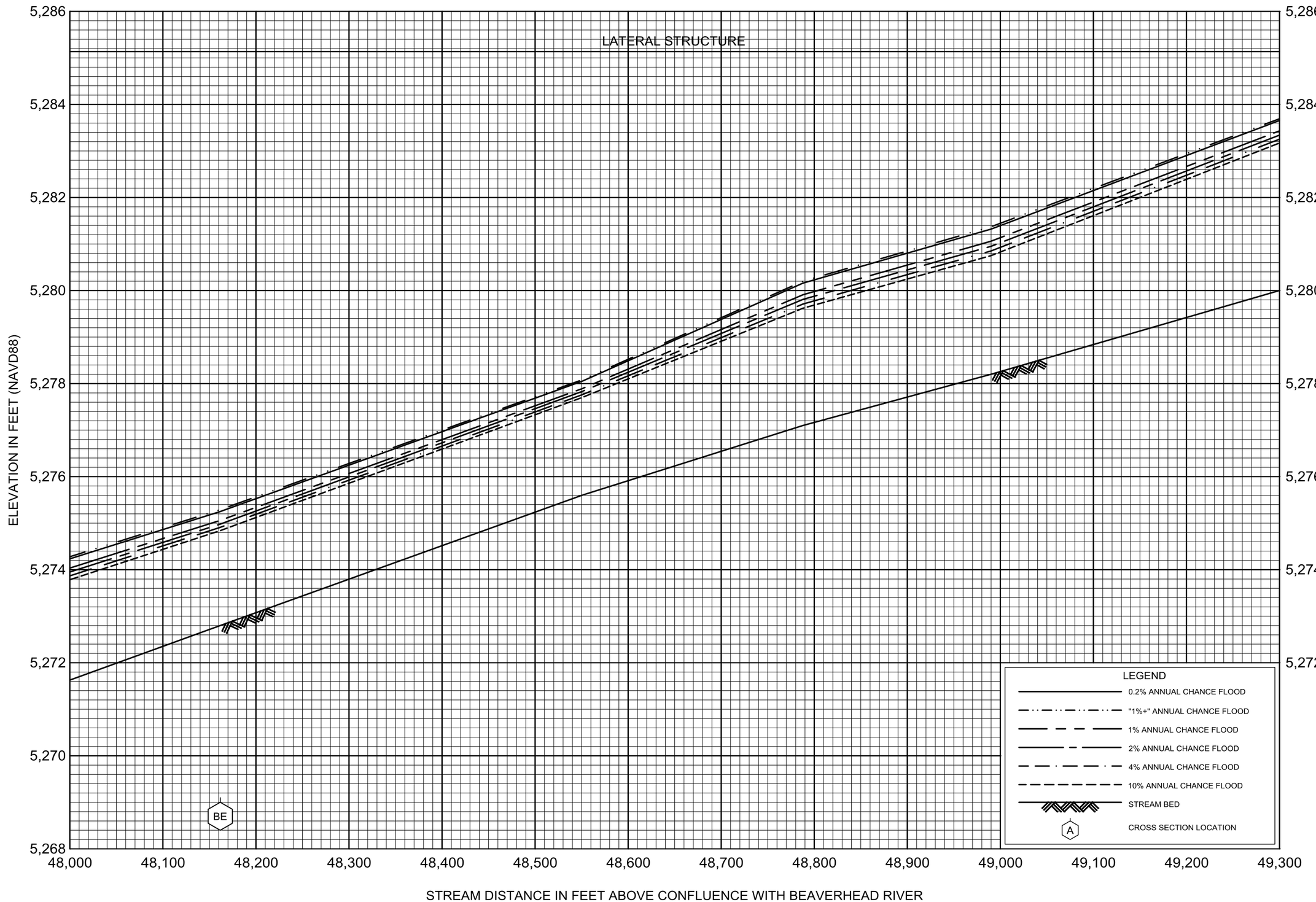

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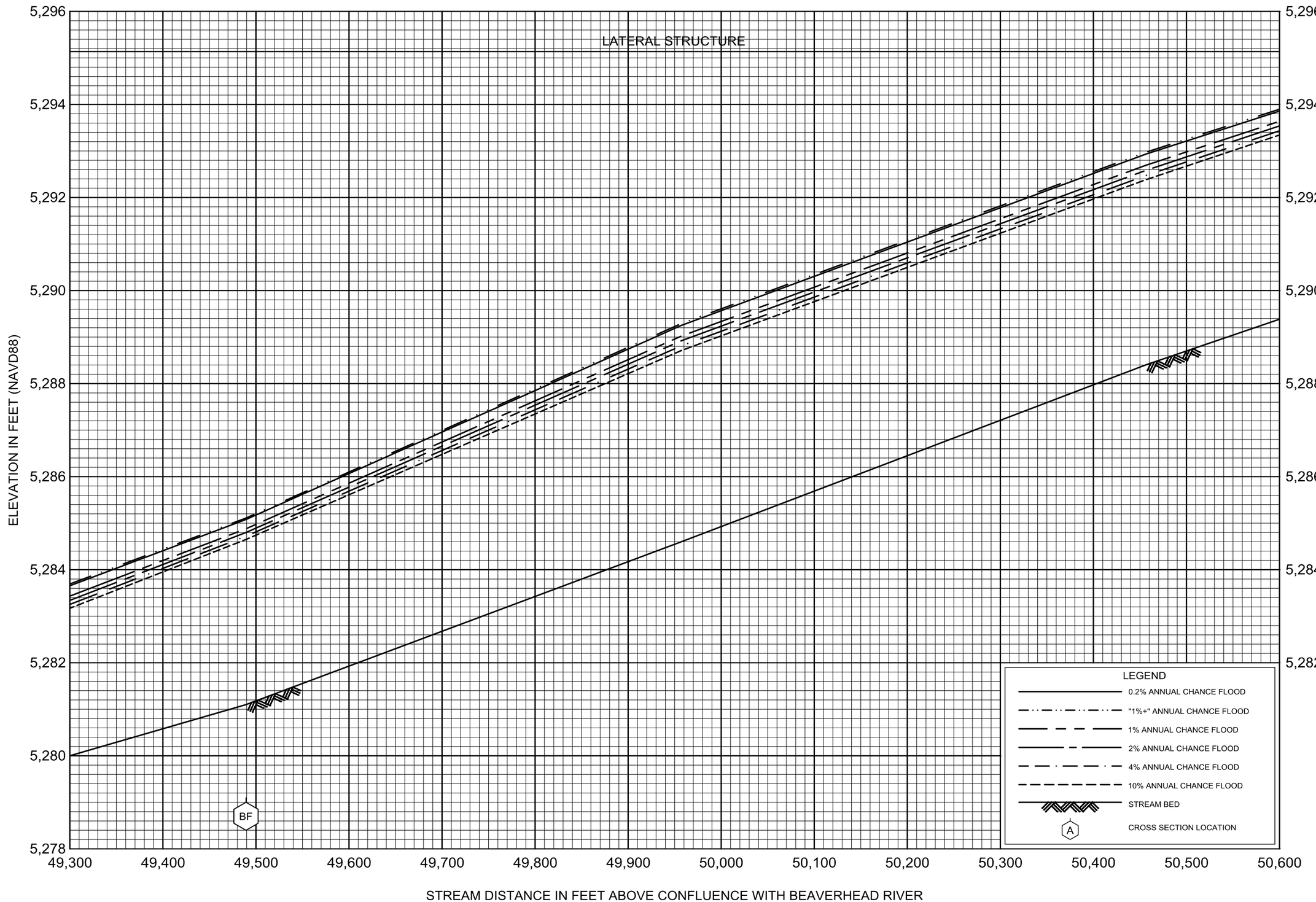

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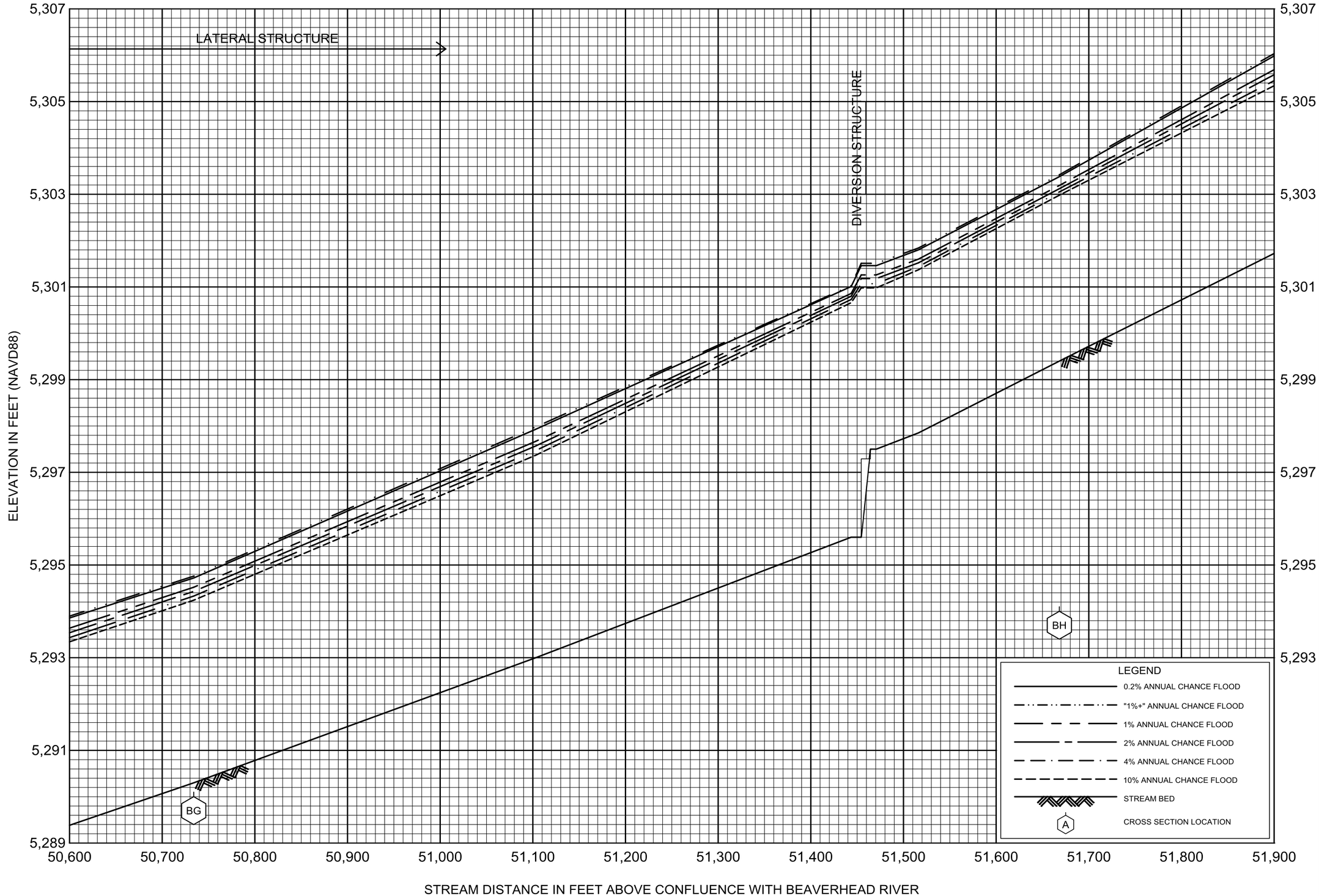

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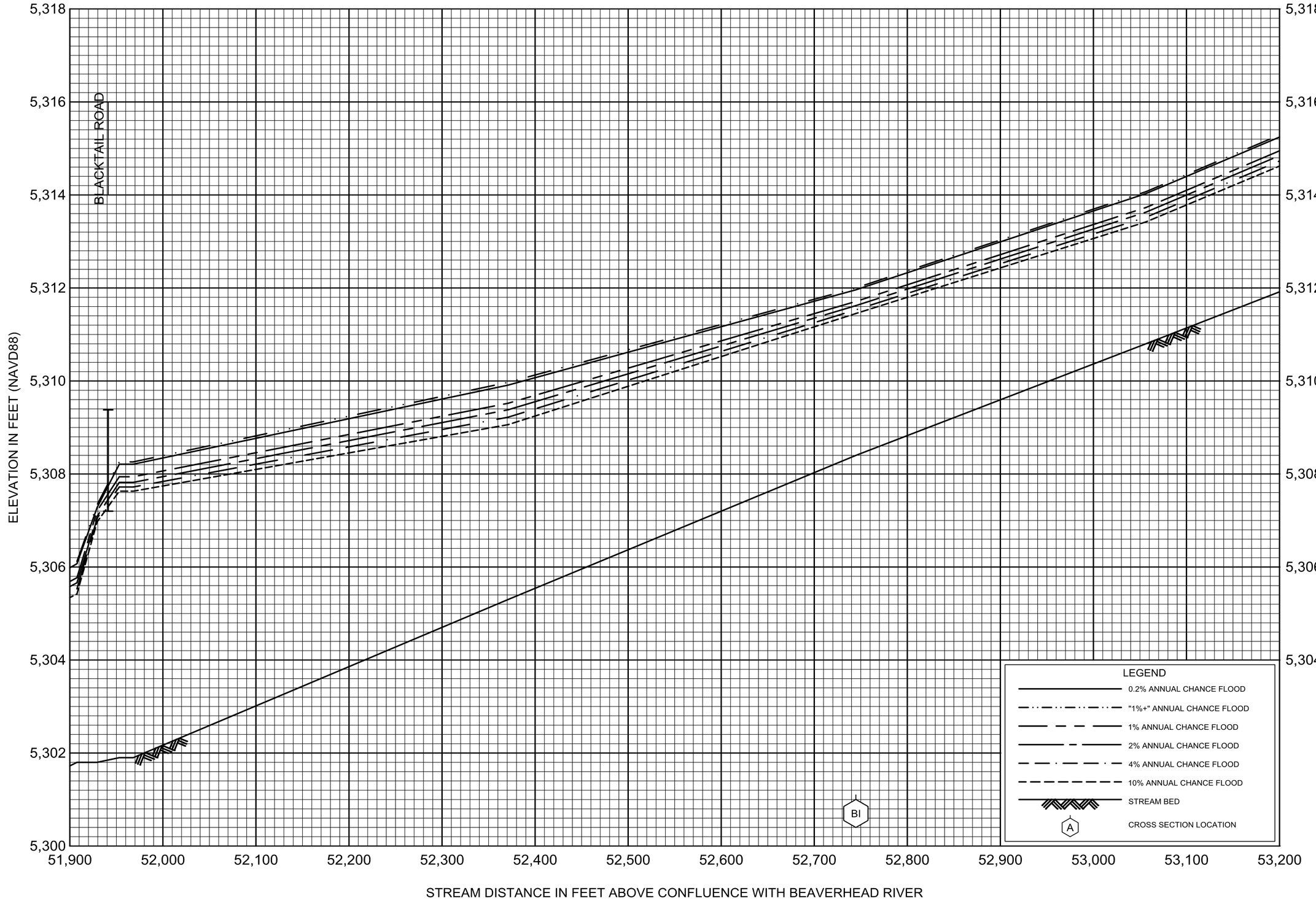

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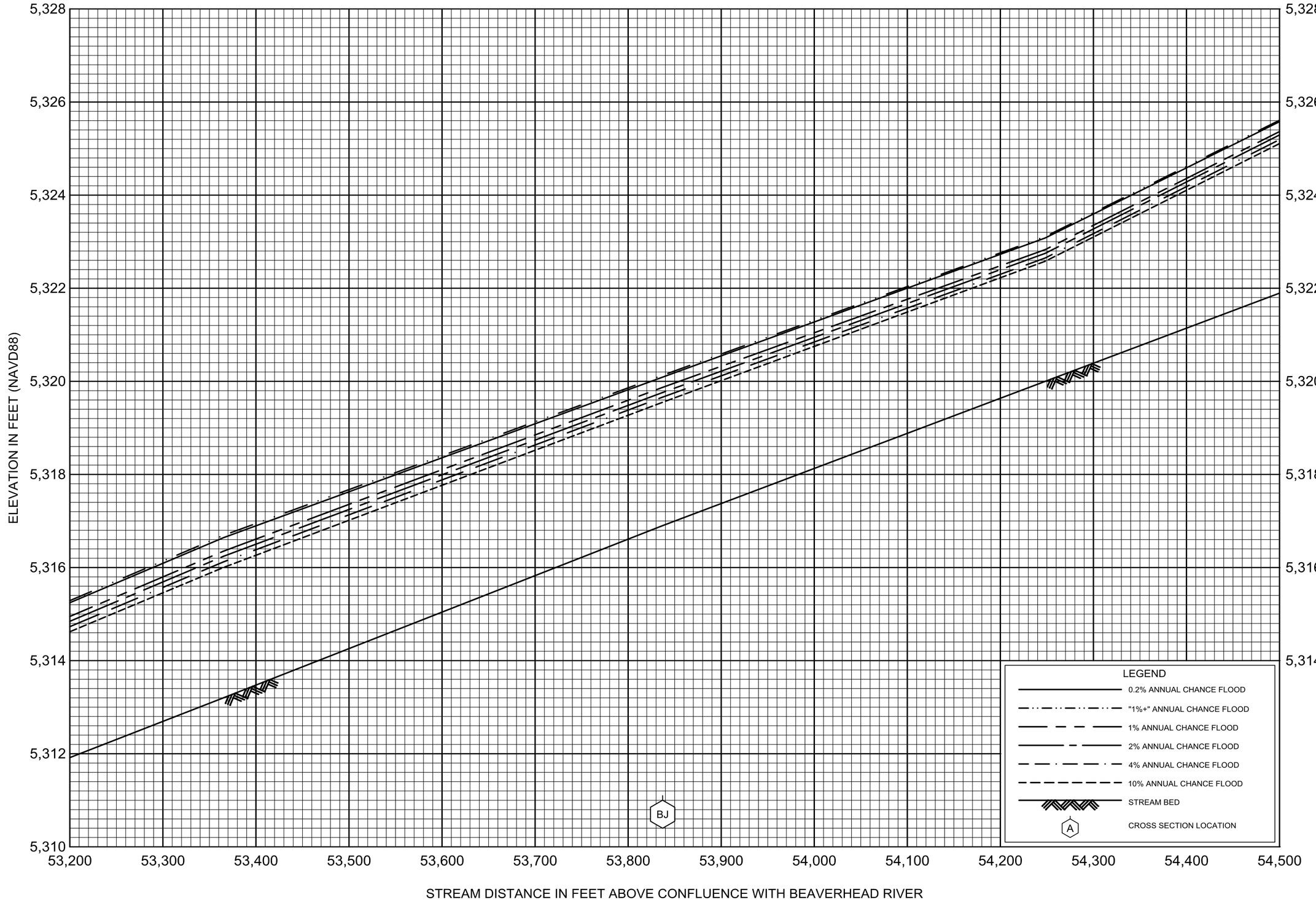

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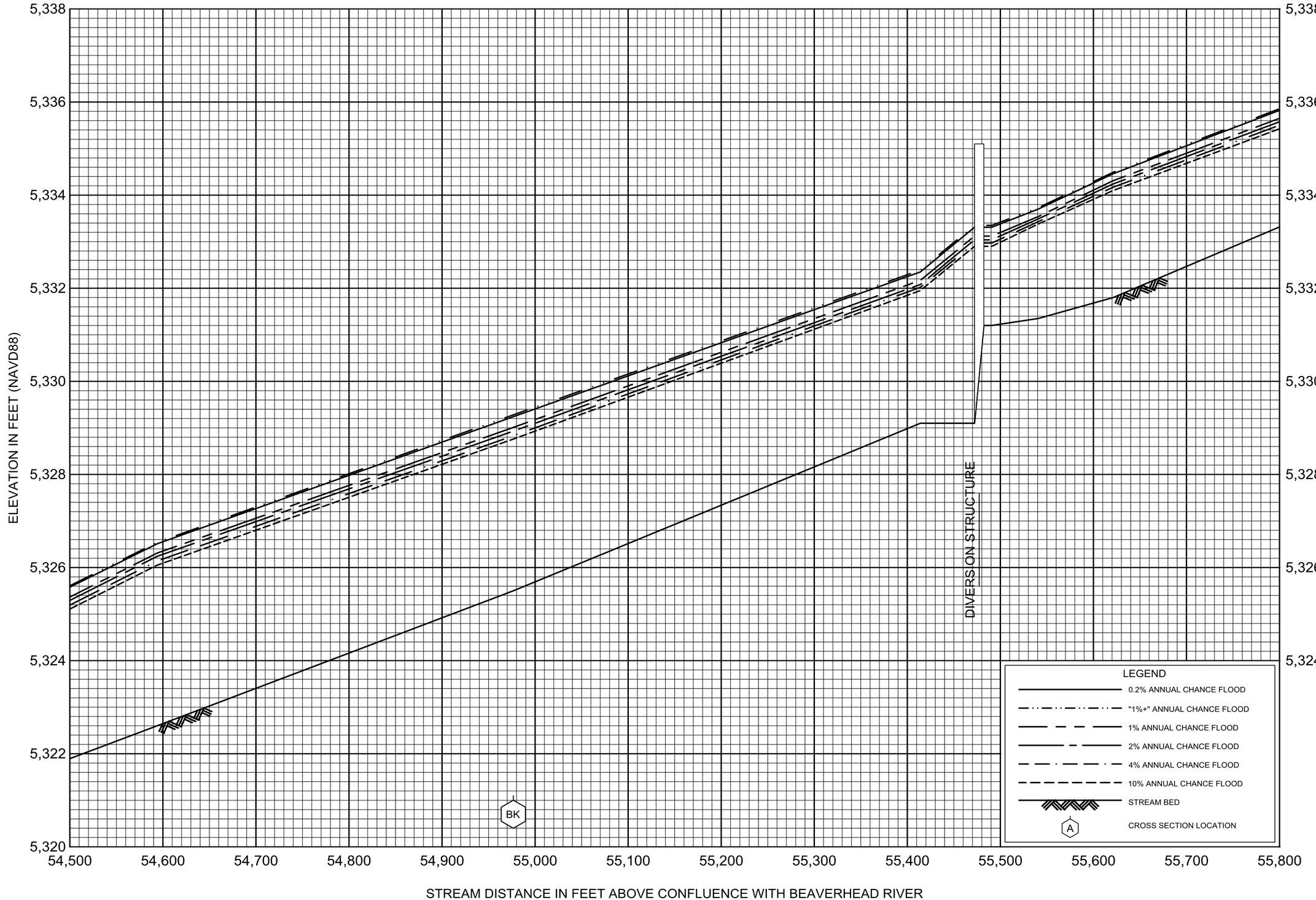

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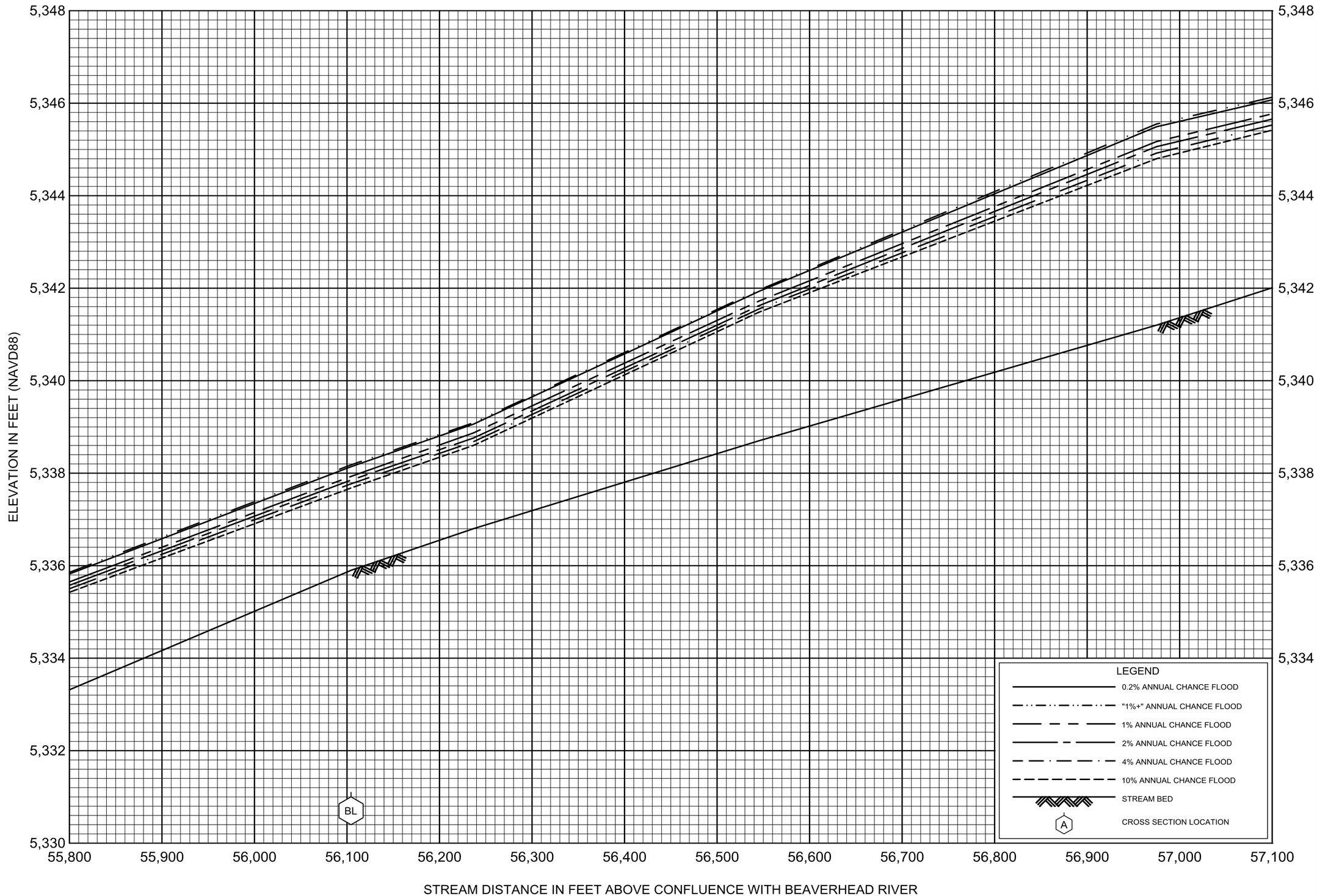

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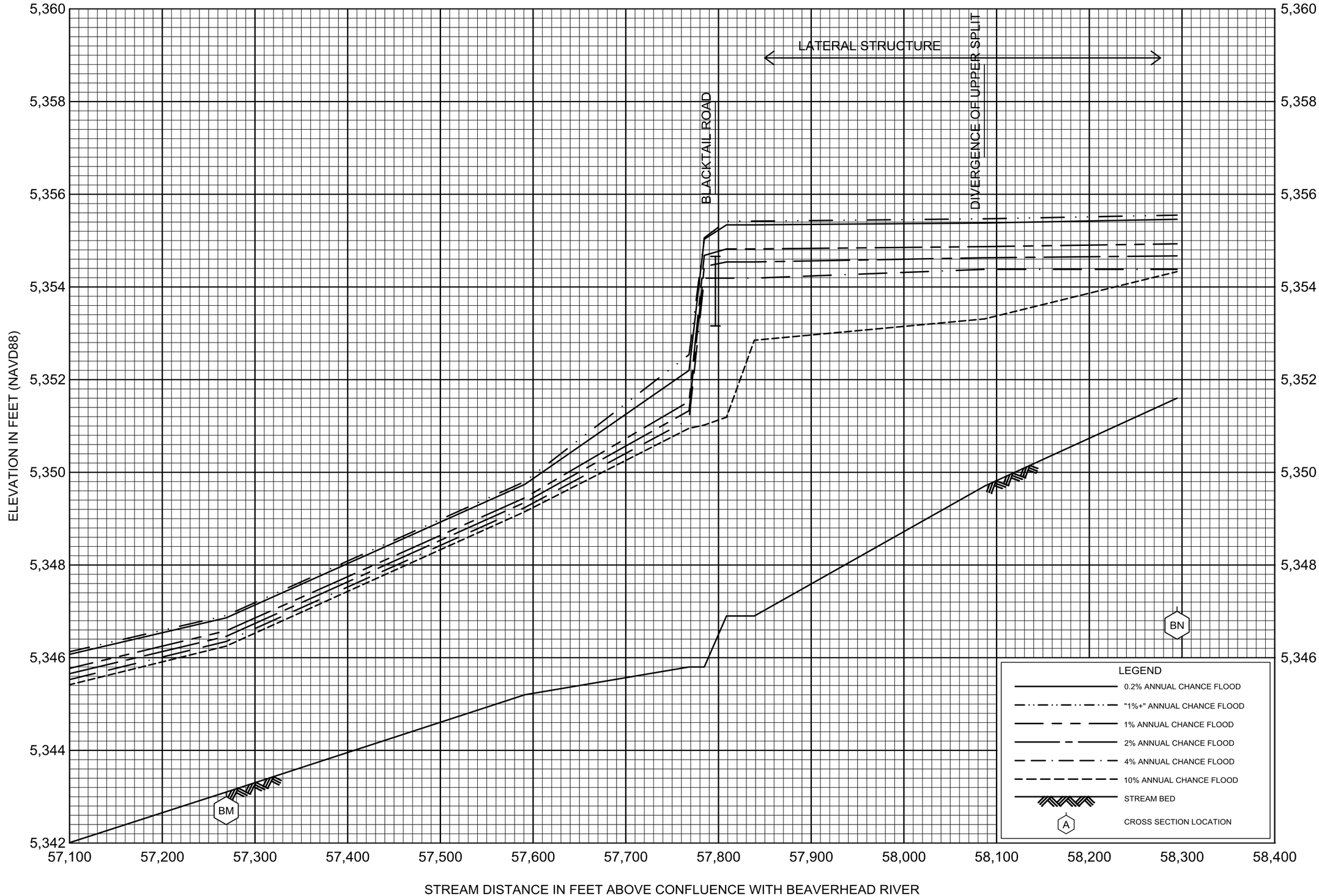

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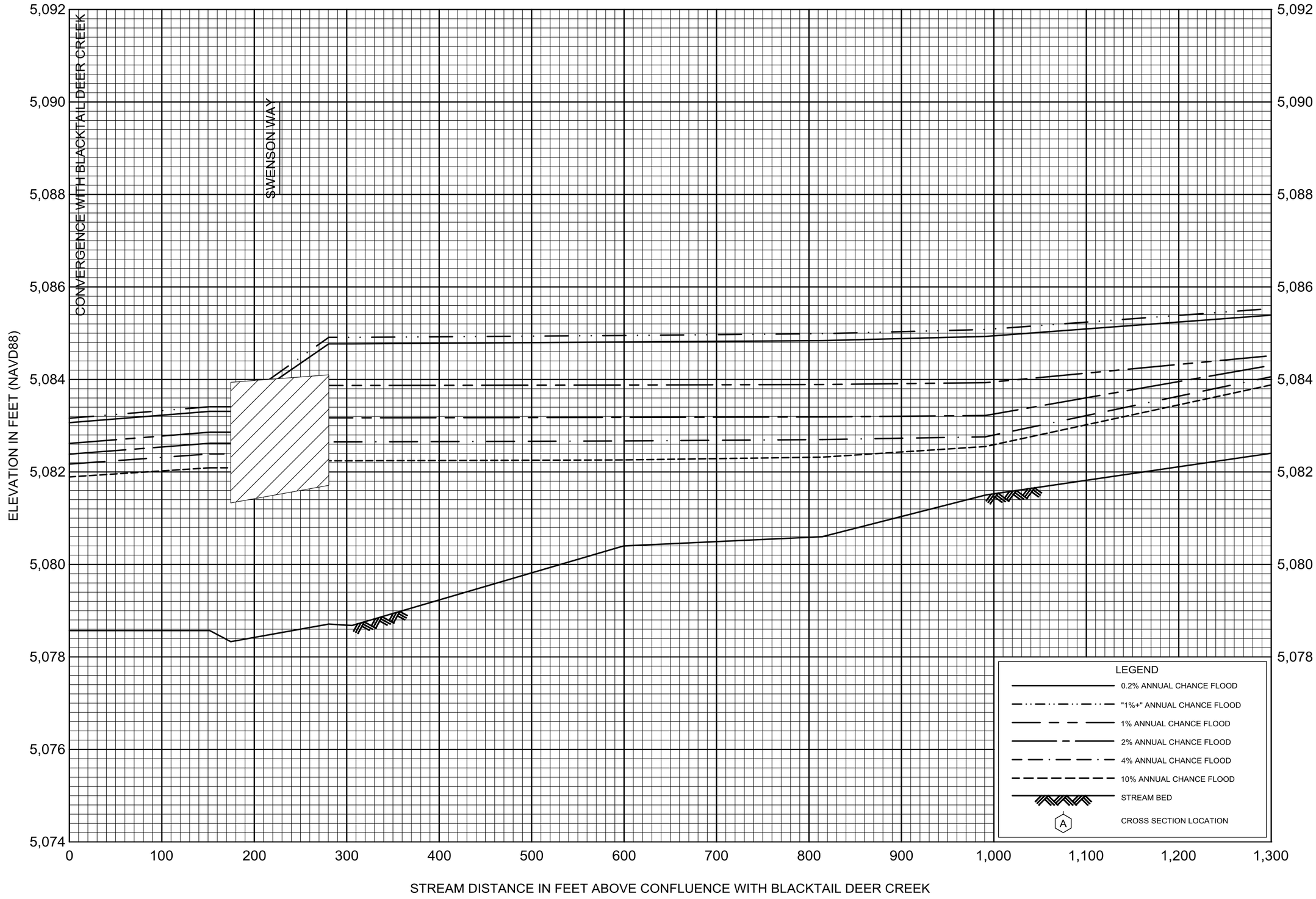

FLOOD PROFILES

BLACKTAIL MEADOWS

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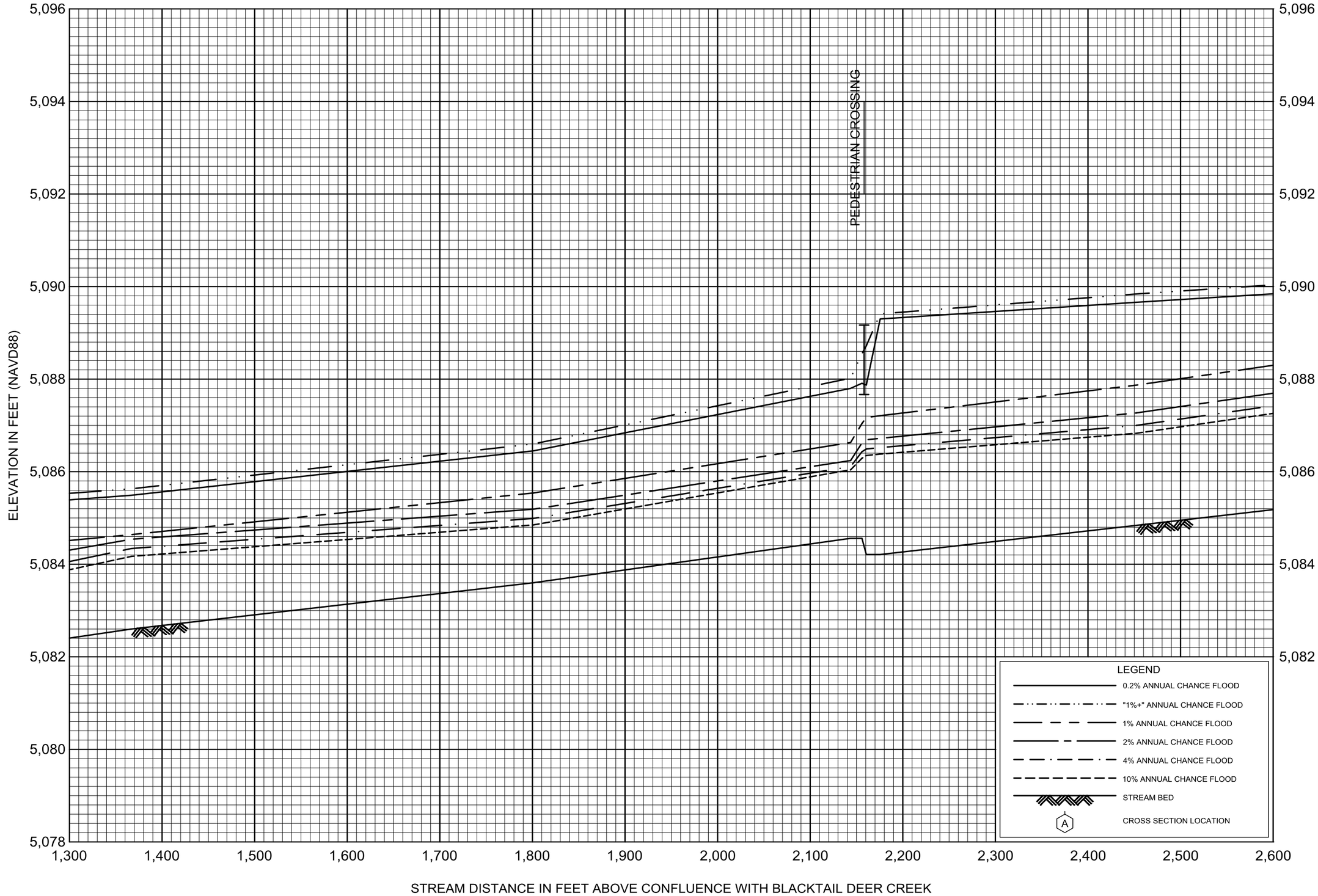
BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



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BLACKTAIL MEADOWS

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BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

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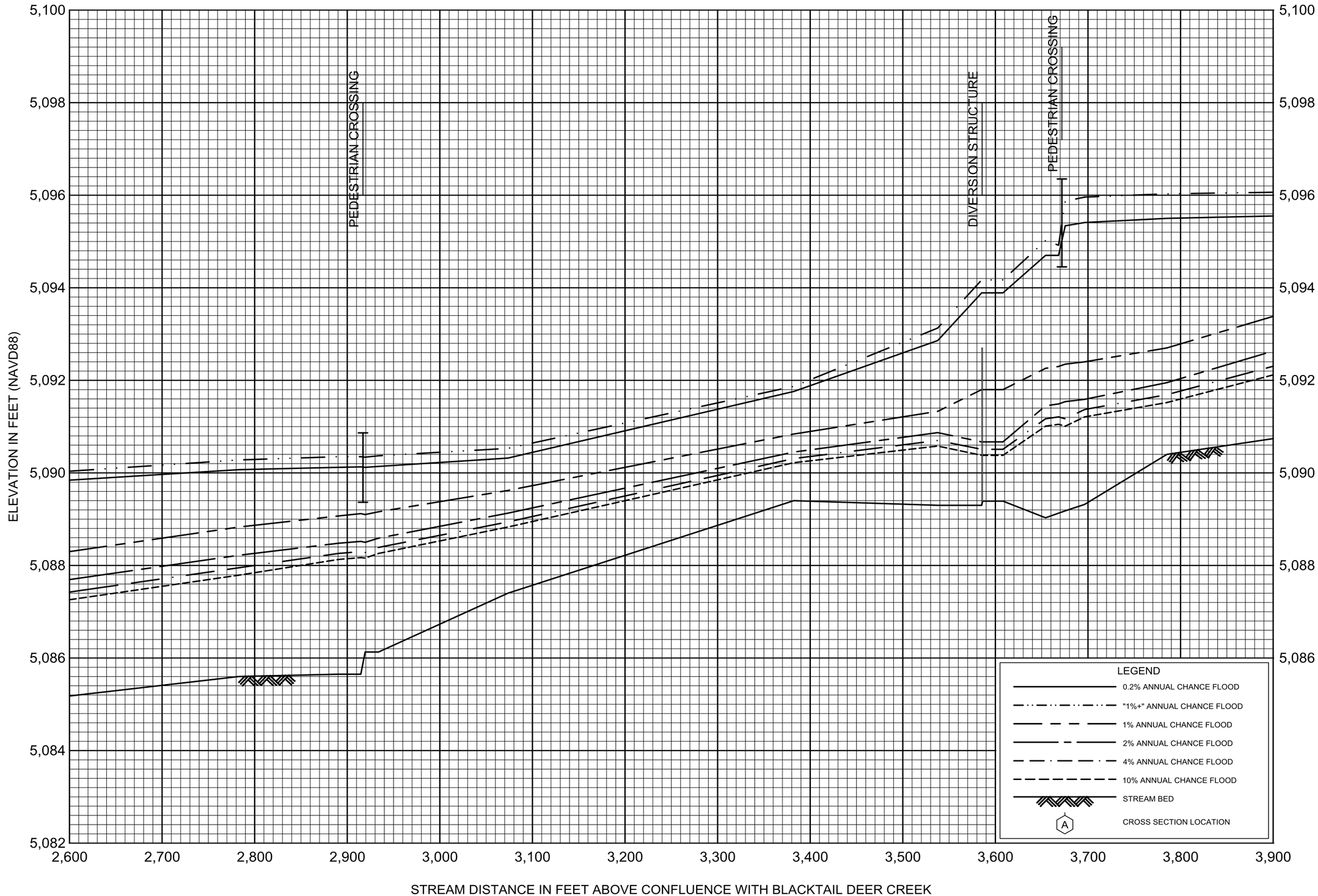

FLOOD PROFILES

BLACKTAIL MEADOWS

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BEAVERHEAD COUNTY, MT

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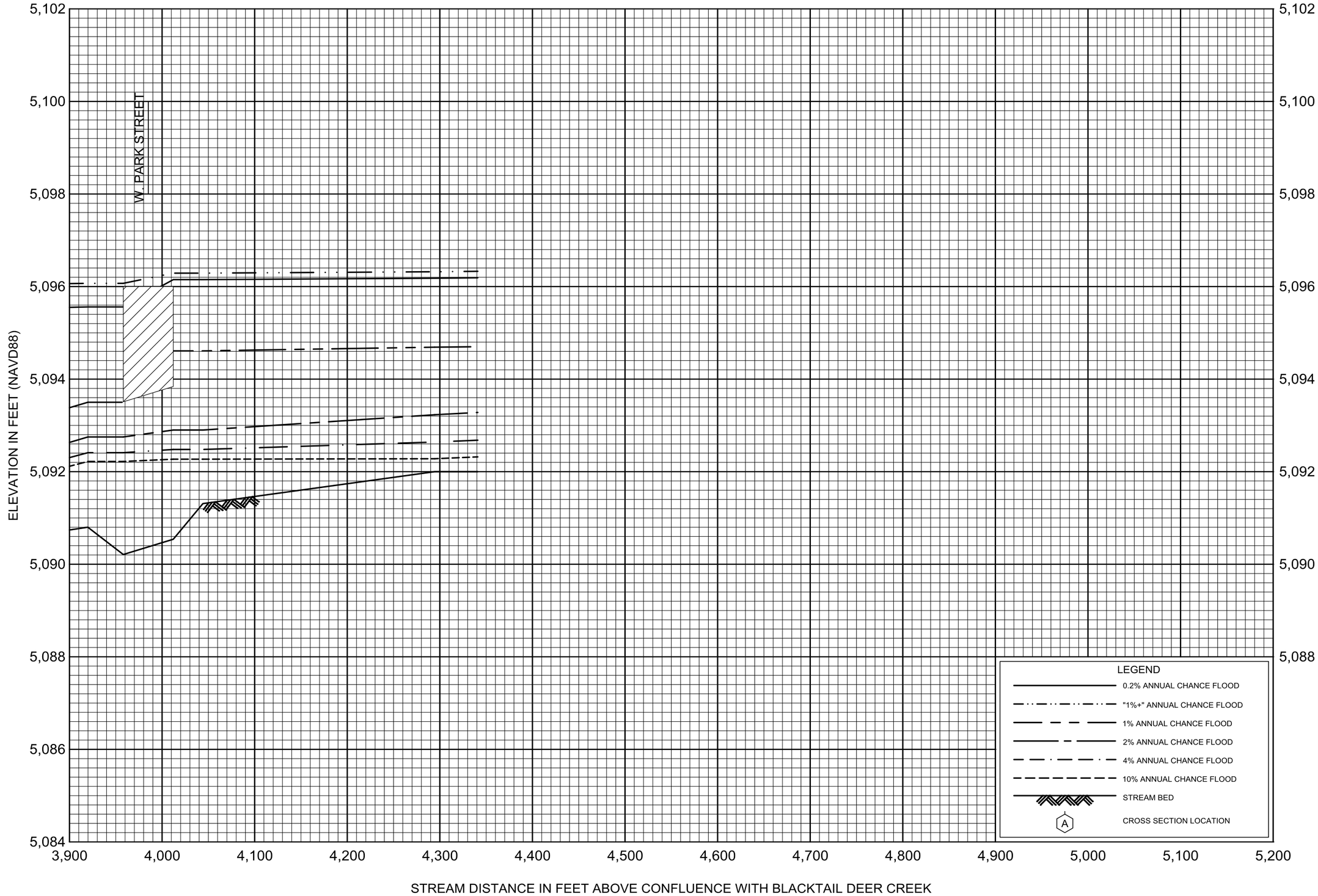

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BEAVERHEAD COUNTY, MT

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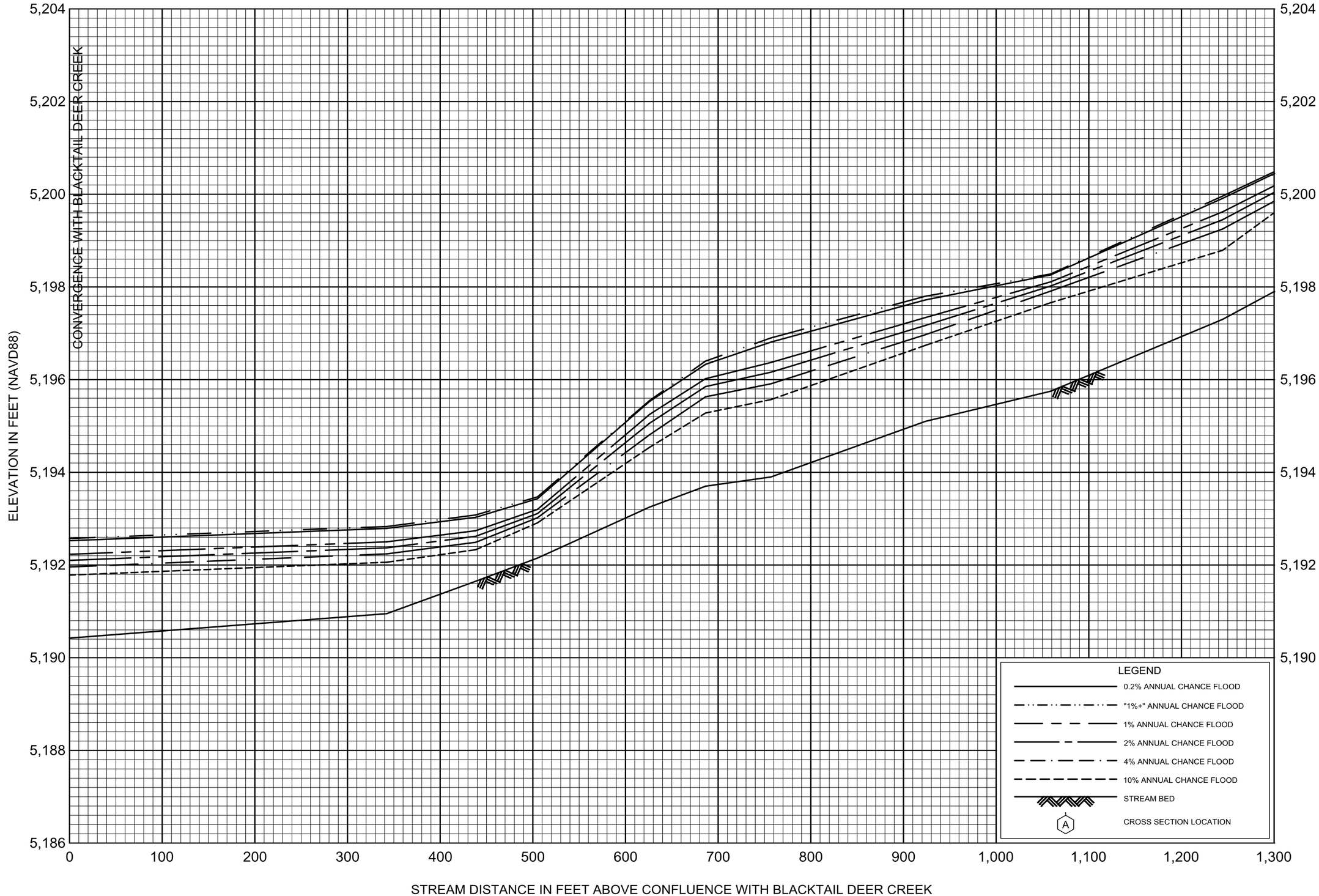

FLOOD PROFILES

CANYON DITCH SPLIT

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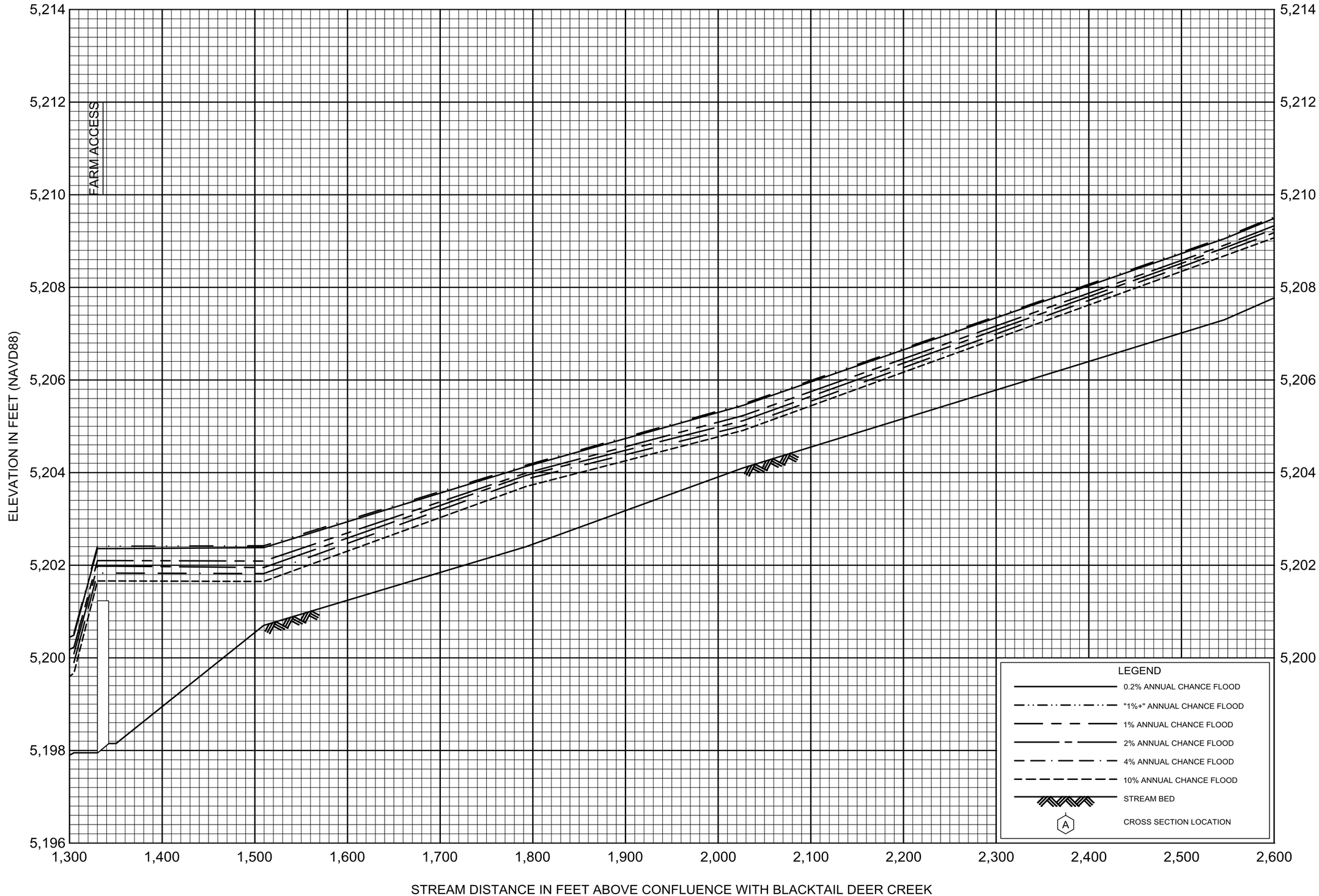
BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



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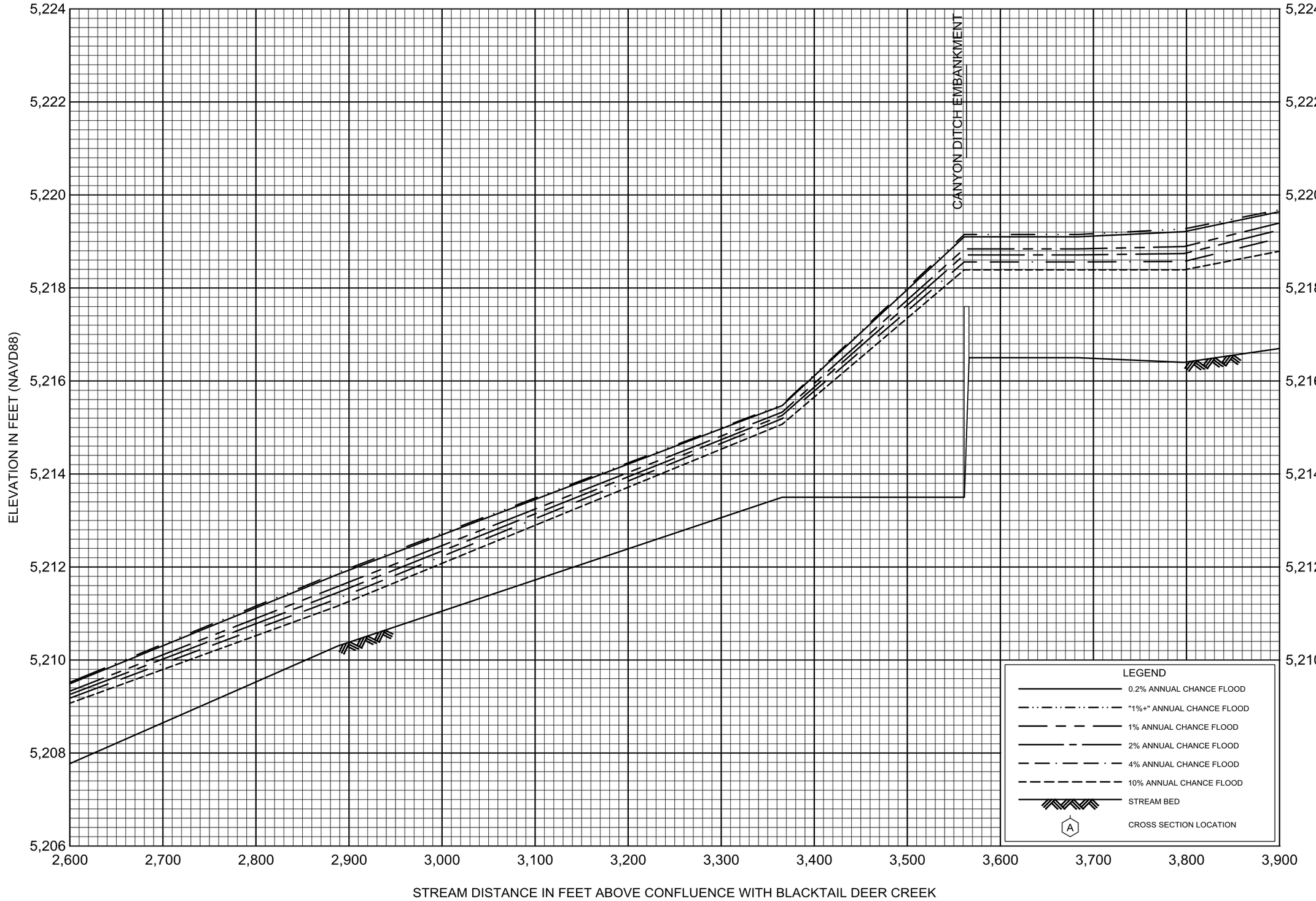
BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



FLOOD PROFILES

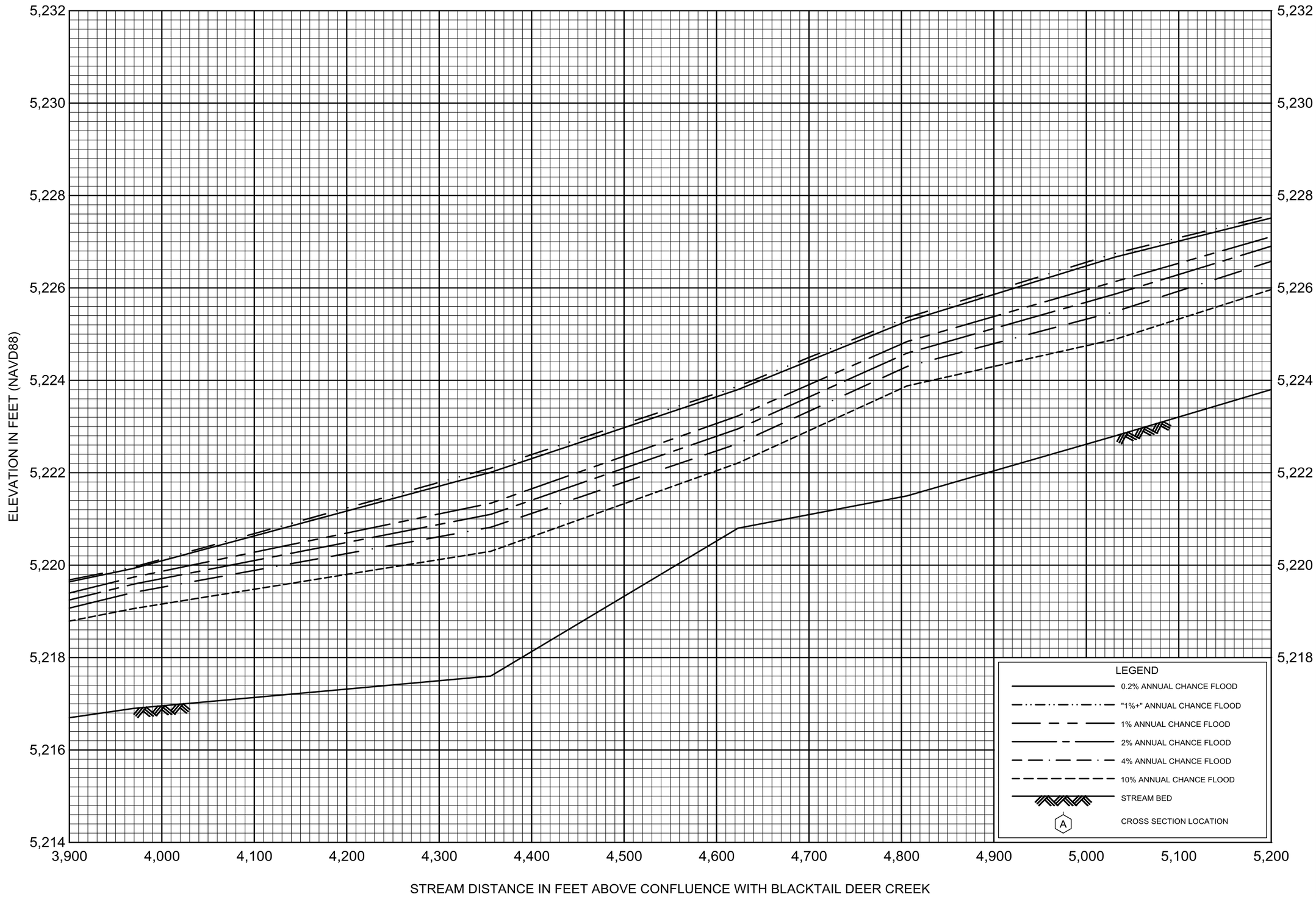
CANYON DITCH SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

03P



FLOOD PROFILES

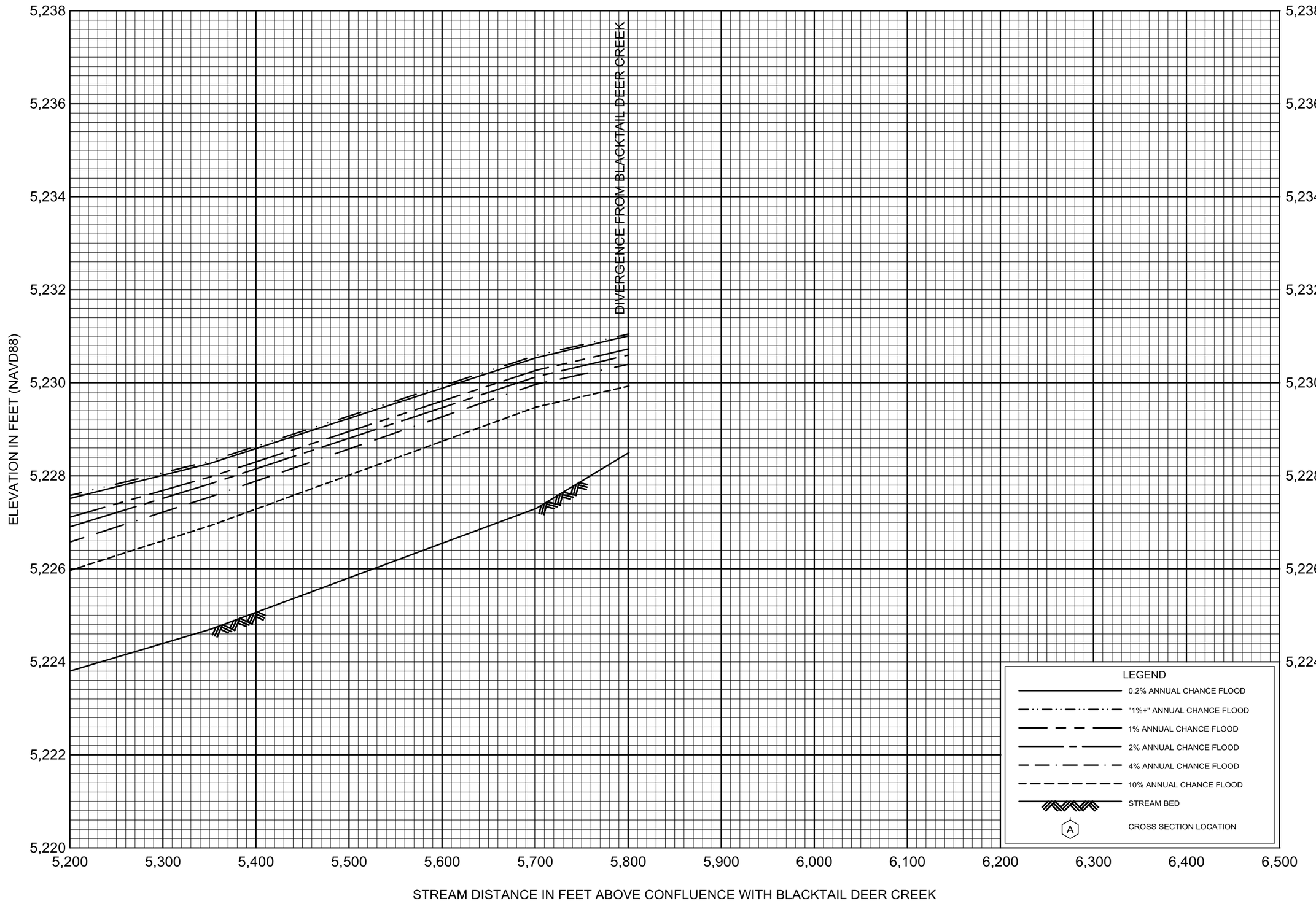
CANYON DITCH SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

04P



FLOOD PROFILES

CANYON DITCH SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

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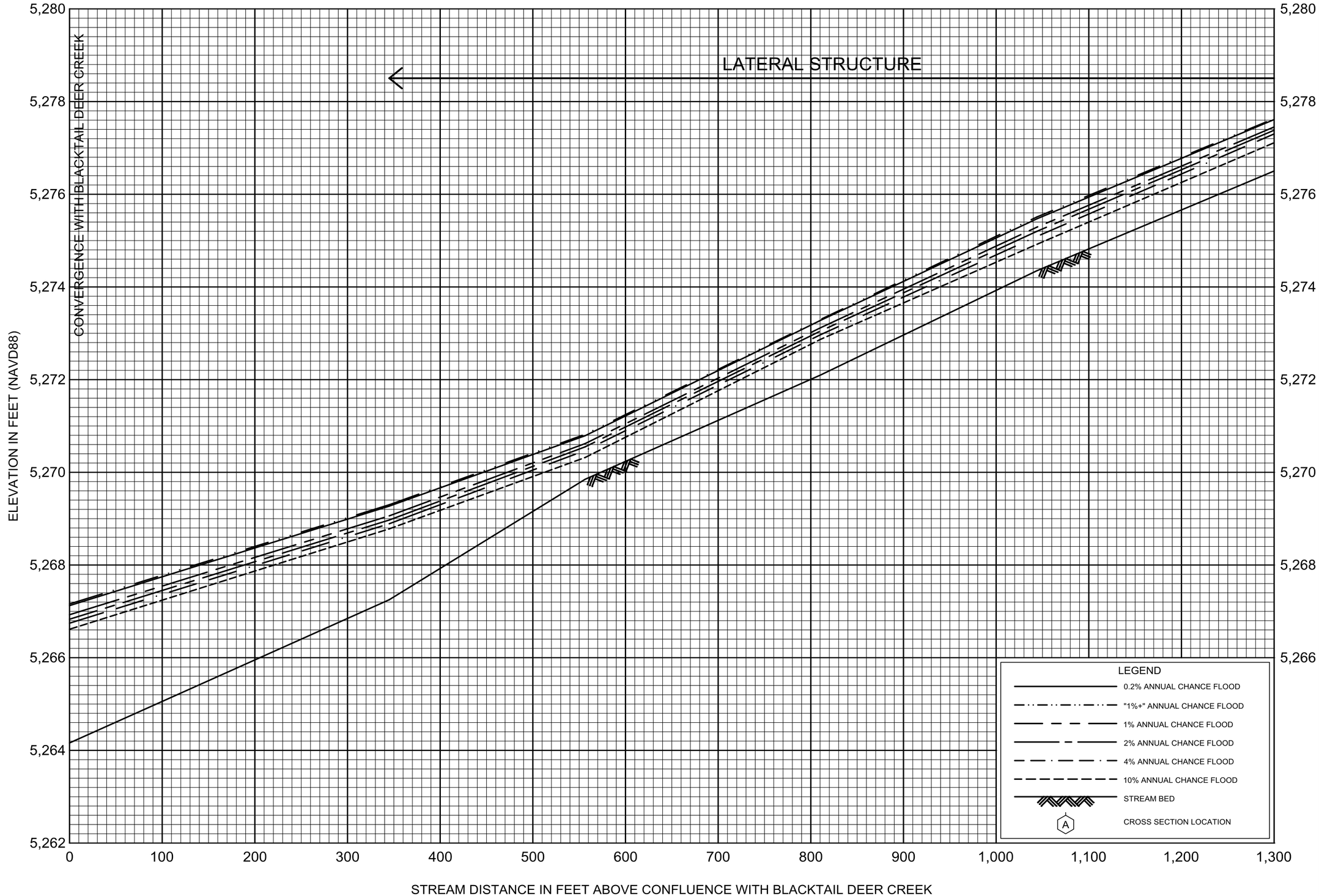


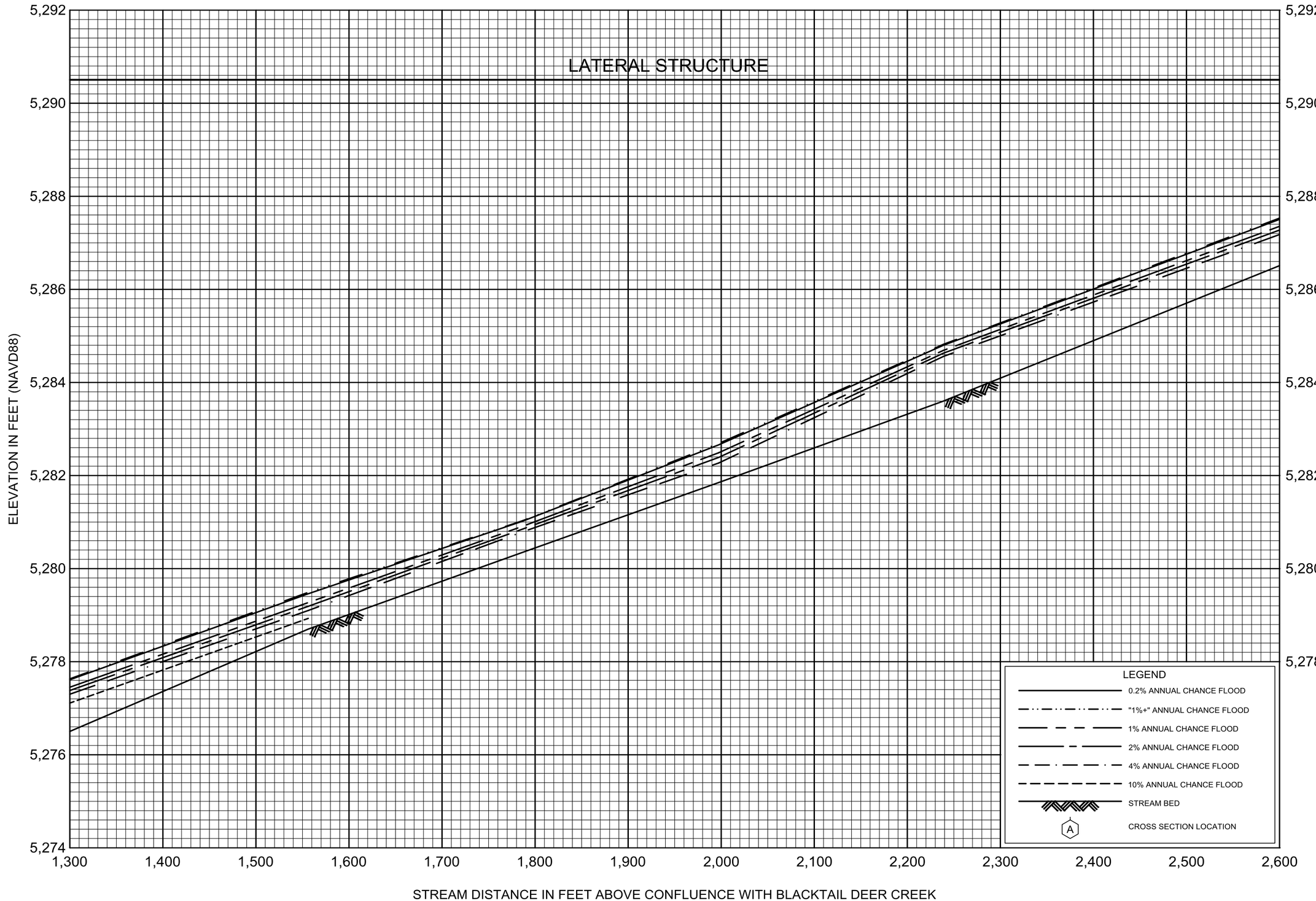
FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



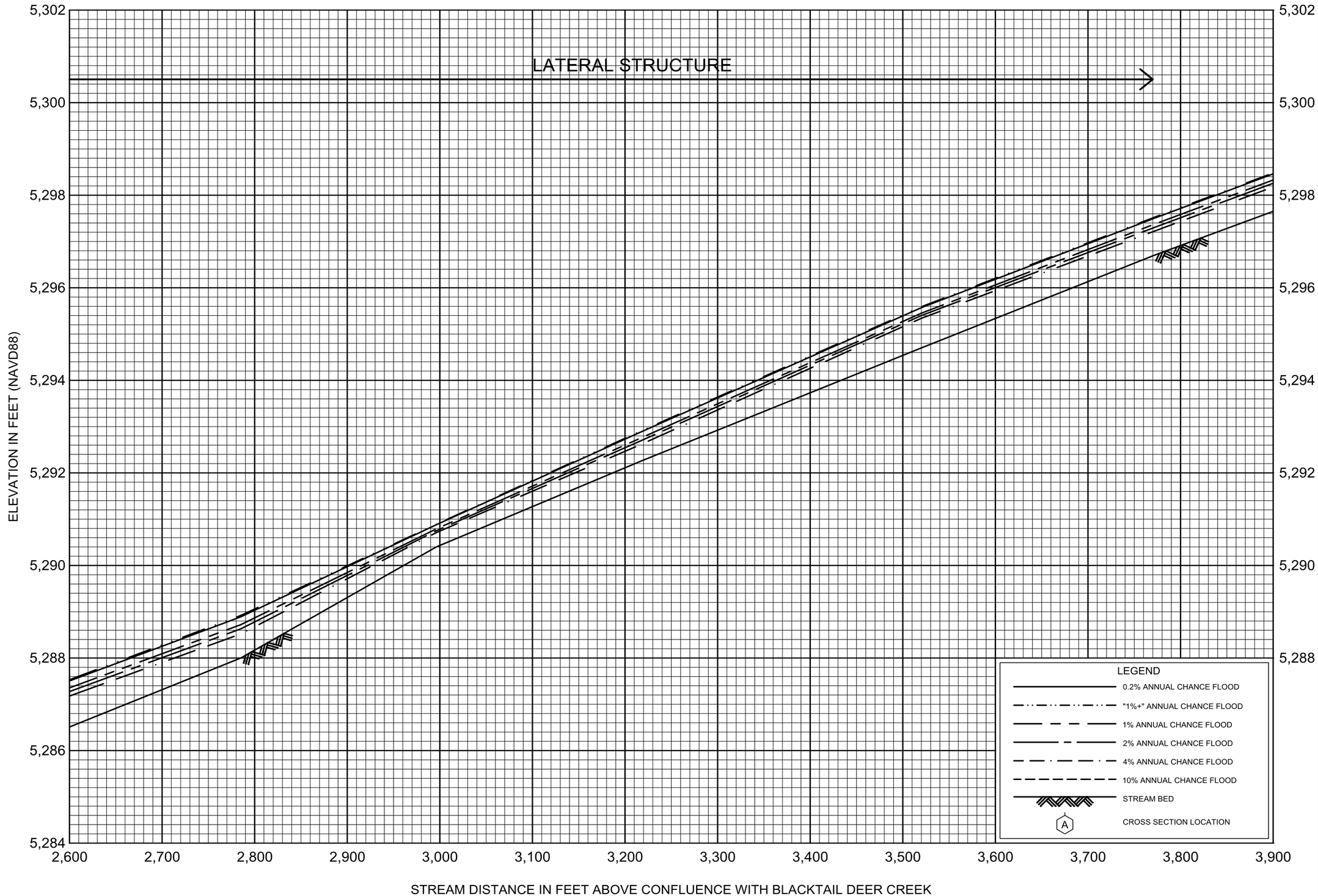
FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

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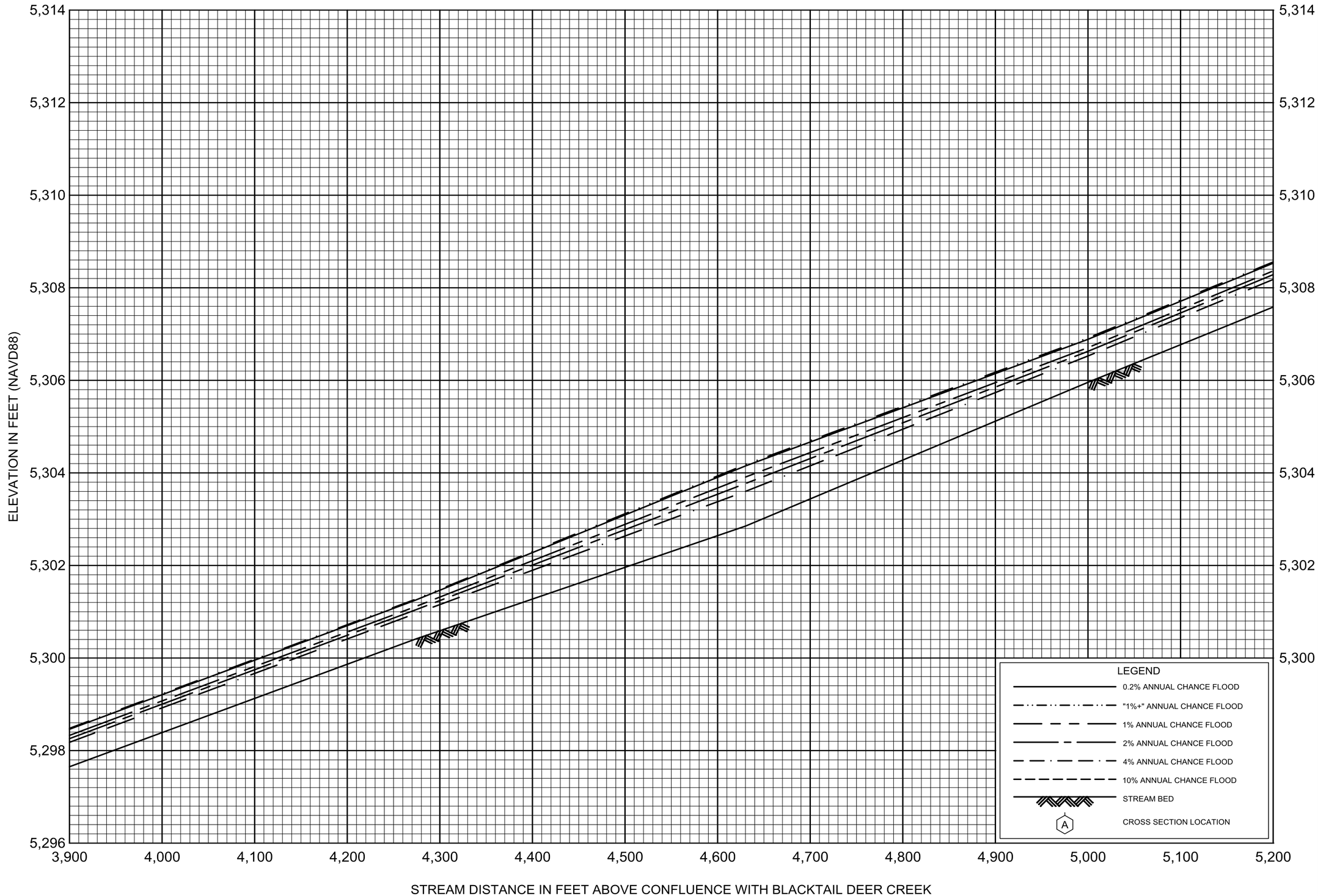

FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

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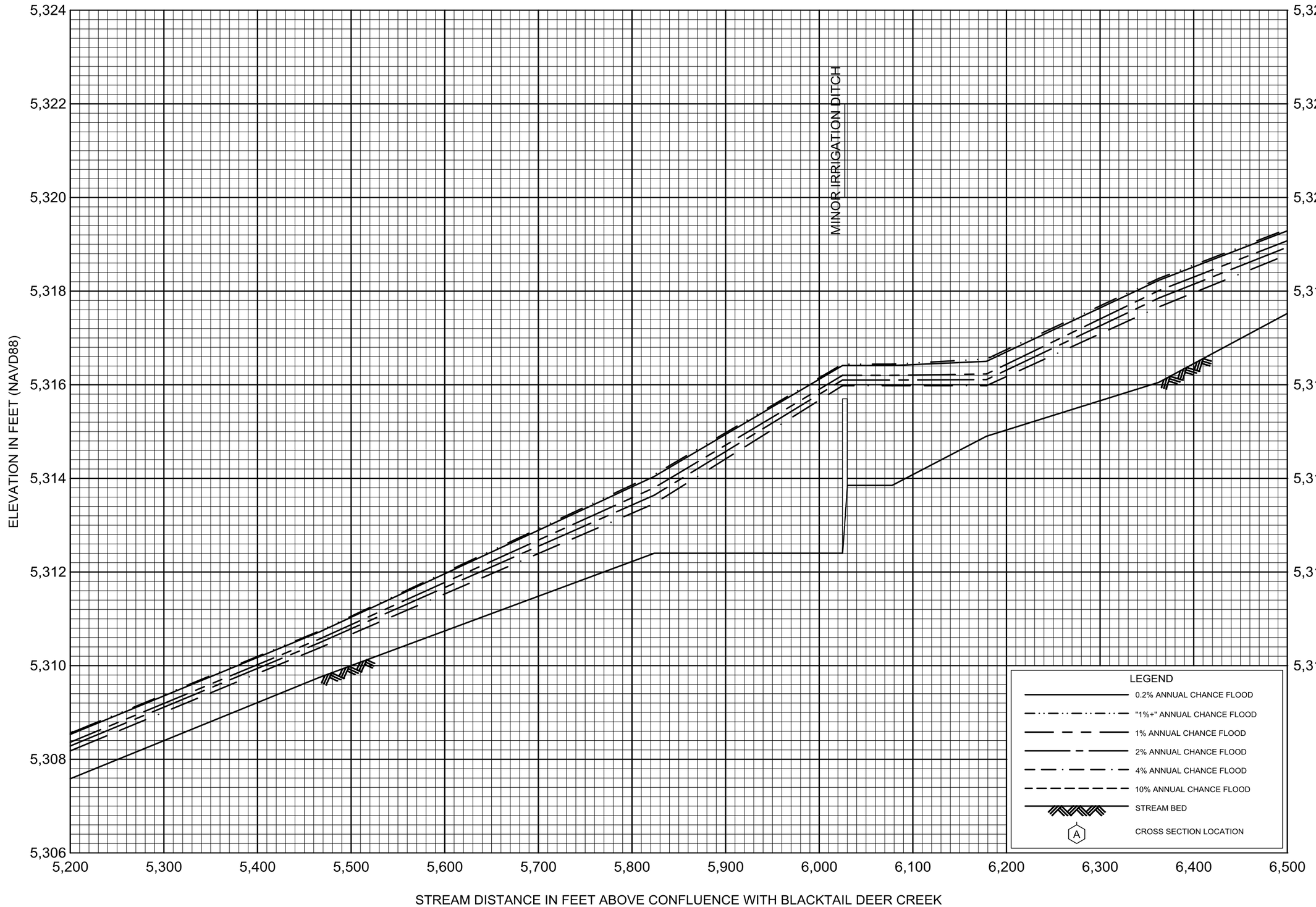

FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

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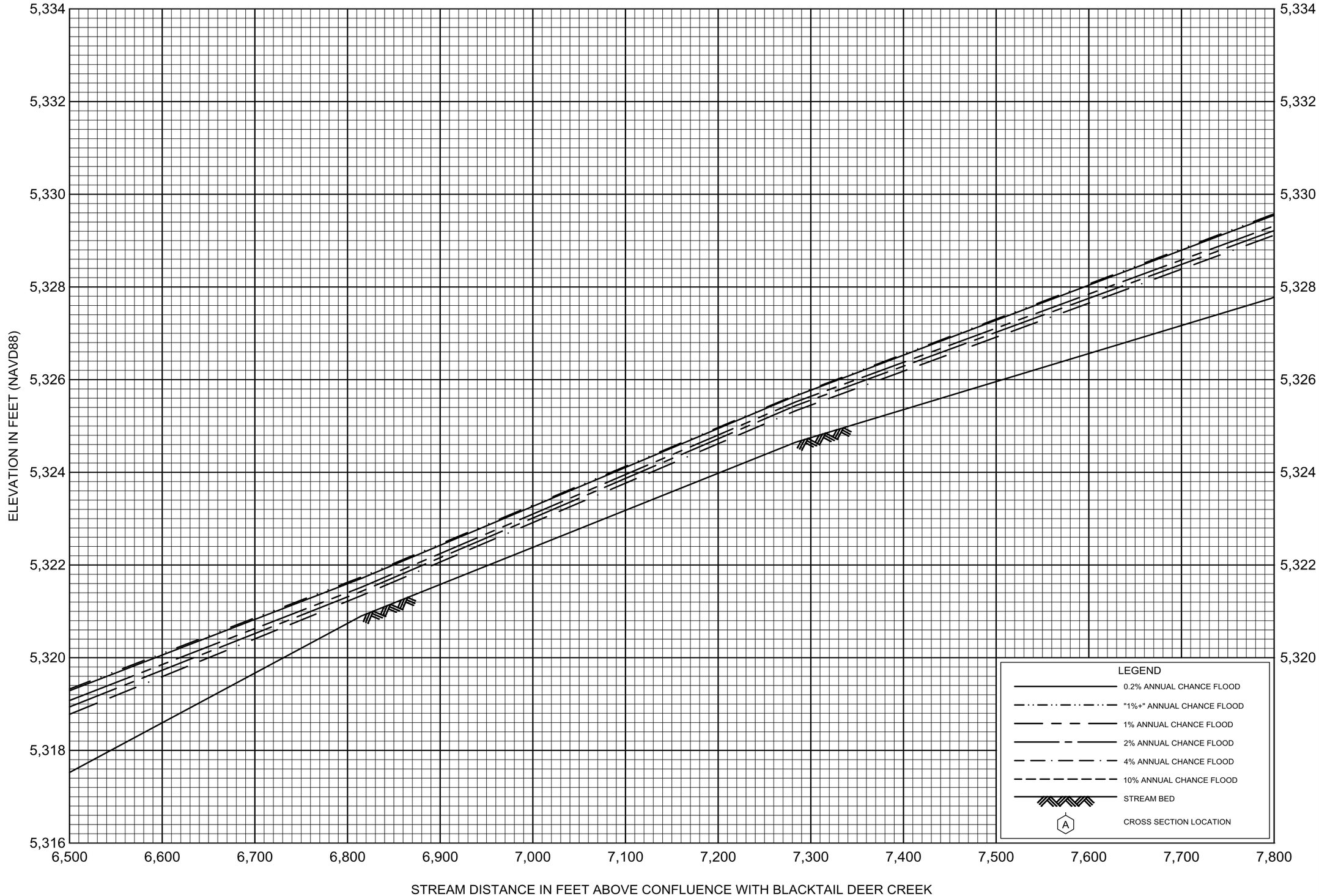

FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

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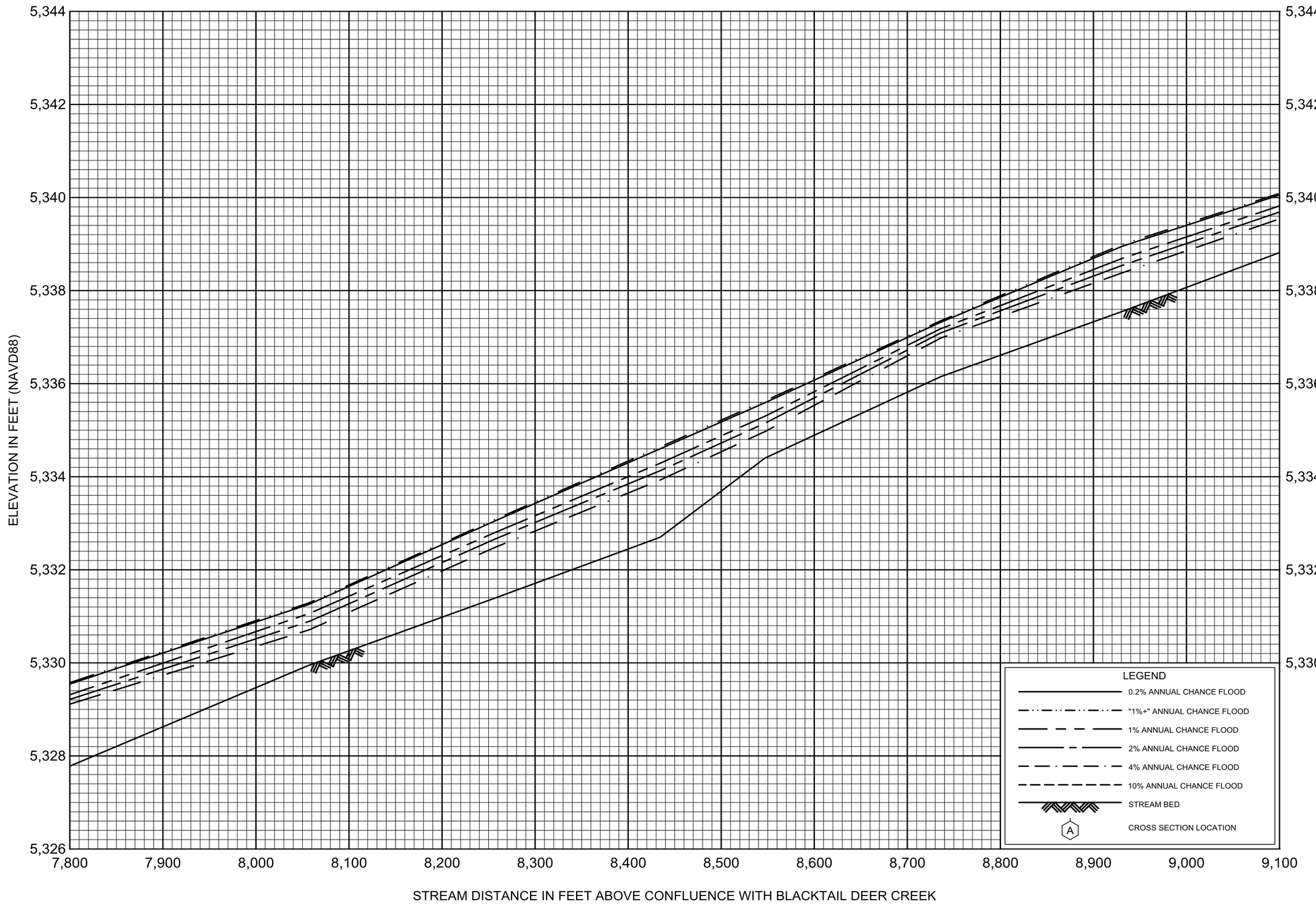


FLOOD PROFILES

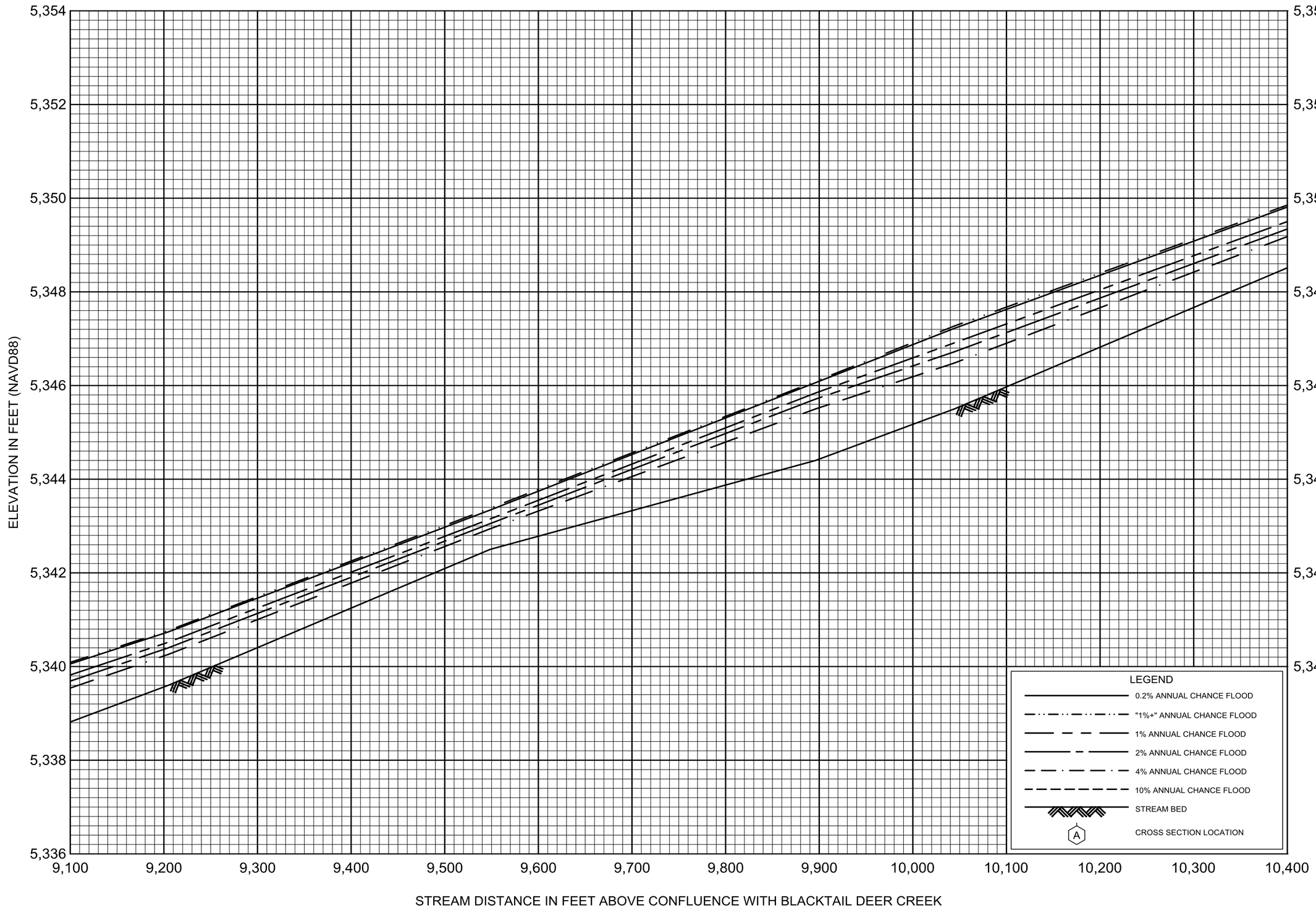
UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

07P



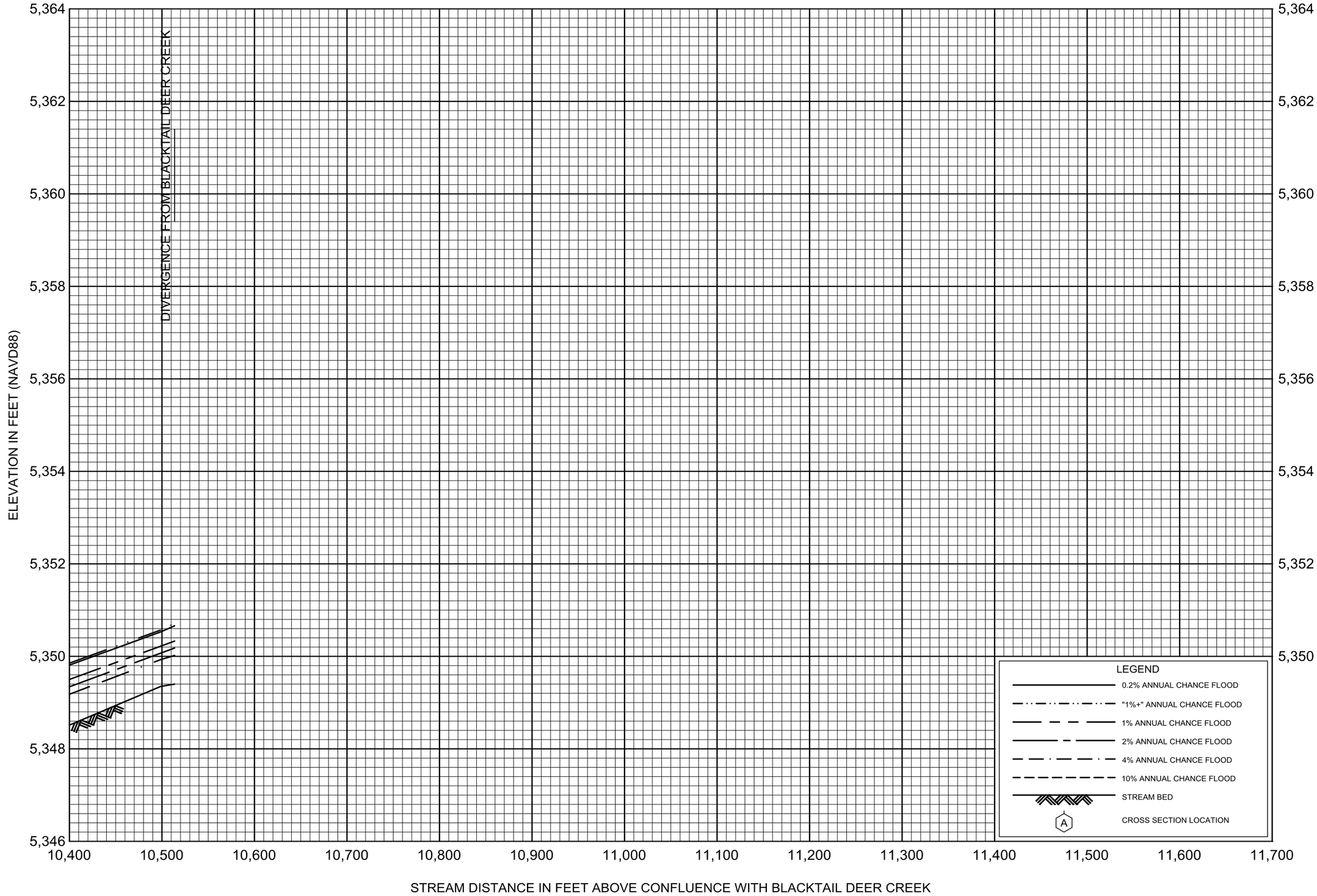
FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES



FLOOD PROFILES

UPPER SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

09P

APPENDIX D – FLOODWAY DATA TABLES

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE [1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	181	86	264	3.7	5,069.5	5,069.5	5,070.0	0.5
B	857	241	501	2.0	5,071.2	5,071.2	5,071.6	0.4
C	1,711	236[2]	265	3.7	5,073.7	5,073.7	5,073.9	0.2
D	2,012	437	619	1.6	5,074.6	5,074.6	5,075.1	0.5
E	2,456	78	175	5.6	5,076.1	5,076.1	5,076.4	0.3
F	2,894	179	518	1.9	5,077.9	5,077.9	5,078.2	0.3
G	3,345	492	1,437	0.7	5,078.1	5,078.1	5,078.6	0.5
H	3,956	417	710	1.4	5,078.3	5,078.3	5,078.8	0.5
I	5,258	177	455	2.2	5,081.3	5,081.3	5,081.6	0.3
J	5,900	99	217	4.1	5,083.6	5,083.6	5,084.0	0.4
K	7,031	93	276	3.2	5,087.6	5,087.6	5,088.0	0.4
L	7,683	167[2]	252	3.5	5,091.0	5,091.0	5,091.1	0.1
M	7,940	172[2]	192	4.8	5,091.8	5,091.8	5,092.1	0.3
N	8,143	124	283	3.2	5,094.7	5,094.7	5,094.7	0.0
O	8,468	43	162	5.6	5,095.9	5,095.9	5,096.2	0.3
P	8,841	138	291	3.1	5,097.8	5,097.8	5,098.2	0.4
Q	9,467	72	224	4.1	5,099.8	5,099.8	5,099.8	0.0
R	9,923	53	184	5.1	5,102.2	5,102.2	5,102.4	0.2
S	10,290	109	375	2.6	5,103.9	5,103.9	5,104.4	0.5
T	10,885	215	634	1.6	5,104.3	5,104.3	5,104.7	0.4
U	11,106	178[2]	317	3.1	5,104.3	5,104.3	5,104.8	0.5

[1] Feet above confluence with Beaverhead River

[2] Floodway top width includes width of high ground area

TABLE 24

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

FLOODWAY DATA

FLOODING SOURCE: BLACKTAIL DEER CREEK

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE [1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
V	12,018	122	250	3.9	5,107.0	5,107.0	5,107.1	0.1
W	12,633	163	396	2.5	5,108.3	5,108.3	5,108.5	0.2
X	13,166	246	430	2.3	5,110.8	5,110.8	5,111.0	0.2
Y	13,586	98	428	2.3	5,112.6	5,112.6	5,113.0	0.4
Z	15,315	183	673	1.5	5,113.2	5,113.2	5,113.7	0.5
AA	16,465	61	258	3.8	5,114.2	5,114.2	5,114.6	0.4
AB	17,164	250	742	1.3	5,115.8	5,115.8	5,116.0	0.2
AC	17,933	132	395	2.5	5,116.9	5,116.9	5,117.1	0.2
AD	18,812	87	173	5.7	5,117.8	5,117.8	5,118.3	0.5
AE	20,099	79	235	4.2	5,123.7	5,123.7	5,124.0	0.3
AF	21,701	269	436	2.3	5,128.6	5,128.6	5,129.1	0.5
AG	22,803	94	243	4.0	5,132.3	5,132.3	5,132.6	0.3
AH	23,924	130	337	2.9	5,136.0	5,136.0	5,136.4	0.4
AI	25,008	60	156	6.3	5,140.1	5,140.1	5,140.5	0.4
AJ	25,628	77	252	3.9	5,145.9	5,145.9	5,145.9	0.0
AK	26,509	109	490	2.0	5,152.6	5,152.6	5,153.1	0.5
AL	26,876	238	593	1.7	5,153.2	5,153.2	5,153.7	0.5
AM	27,289	92	179	5.5	5,154.3	5,154.3	5,154.6	0.3
AN	28,120	62	159	6.2	5,159.9	5,159.9	5,160.4	0.5
AO	28,932	243	344	2.9	5,165.0	5,165.0	5,165.3	0.3
AP	29,995	69	200	4.9	5,172.0	5,172.0	5,172.2	0.2

[1] Feet above confluence with Beaverhead River

[2] Floodway top width includes width of high ground area

TABLE 24

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

FLOODWAY DATA

FLOODING SOURCE: BLACKTAIL DEER CREEK

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE [1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
AQ	31,150	260	293	3.4	5,179.4	5,179.4	5,179.8	0.4
AR	32,722	253	469	2.1	5,188.6	5,188.6	5,189.0	0.4
AS	33,802	122	224	3.5	5,193.4	5,193.4	5,193.8	0.4
AT	34,825	247[2]	244	3.2	5,197.9	5,197.9	5,198.2	0.3
AU	36,107	161	296	2.7	5,203.6	5,203.6	5,204.1	0.5
AV	37,463	70	153	5.2	5,210.9	5,210.9	5,211.2	0.3
AW	38,532	203	423	1.9	5,217.9	5,217.9	5,218.3	0.4
AX	39,542	90	209	3.8	5,223.1	5,223.1	5,223.3	0.2
AY	41,150	41	124	6.4	5,230.6	5,230.6	5,230.9	0.3
AZ	42,443	95	206	4.8	5,236.0	5,236.0	5,236.4	0.4
BA	43,582	216	358	2.7	5,241.5	5,241.5	5,241.9	0.4
BB	44,340	252	301	3.3	5,246.3	5,246.3	5,246.7	0.4
BC	45,540	179	218	4.5	5,254.9	5,254.9	5,255.1	0.2
BD	46,687	201[2]	258	3.8	5,264.5	5,264.5	5,264.9	0.4
BE	48,162	206[2]	261	2.4	5,275.1	5,275.1	5,275.5	0.4
BF	49,489	162[2]	204	3.8	5,284.9	5,284.9	5,285.1	0.2
BG	50,734	45	110	7.1	5,294.5	5,294.5	5,294.7	0.2
BH	51,668	145	152	5.1	5,303.2	5,303.2	5,303.2	0.0
BI	52,745	204[2]	219	3.6	5,311.7	5,311.7	5,311.8	0.1
BJ	53,837	291[2]	296	2.6	5,319.9	5,319.9	5,320.1	0.2
BK	54,977	176[2]	208	3.7	5,329.0	5,329.0	5,329.4	0.4

[1] Feet above confluence with Beaverhead River

[2] Floodway top width includes width of high ground area

TABLE 24

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

FLOODWAY DATA

FLOODING SOURCE: BLACKTAIL DEER CREEK

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE [1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
BL	56,104	240[2]	251	3.1	5,337.9	5,337.9	5,338.3	0.4
BM	57,269	135	194	4.0	5,346.6	5,346.6	5,346.8	0.2
BN	58,295	143	224	4.4	5,354.9	5,354.9	5,355.2	0.3

[1] Feet above confluence with Beaverhead River

[2] Floodway top width includes width of high ground area

TABLE 24

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED COMMUNITIES

FLOODWAY DATA

FLOODING SOURCE: BLACKTAIL DEER CREEK

APPENDIX E – MODEL REVIEW

Exceptions to the standard model inputs.

Floodway Surcharge Values		
Flooding Source	Cross Section	Explanation for exception to the standard values
BlacktailDeerCr	Structure at 7488	The floodway profile has a more significant drawdown through the structure crossing than the base profile. There is a negative surcharge in the internal bridge crossing. Surcharge values at the upstream and downstream cross sections are positive.
BlacktailDeerCr	8059	The upstream and downstream encroachment stations were set with minimal encroachment into the 100-yr floodplain. When the floodplain is encroached in this location, the flow velocities increase and the water surface elevations decrease. Unable to achieve a positive surcharge value.
BlacktailDeerCr	8079	The upstream and downstream encroachment stations were set with minimal encroachment into the 100-yr floodplain. When the floodplain is encroached in this location, the flow velocities increase and the water surface elevations decrease. Unable to achieve a positive surcharge value.
Expansion / Contraction Coefficients		
Flooding Source	Cross Section	Explanation for exception to the standard values
BlacktailDeerCr	7968	Contraction and expansion coefficients were increased from the standard 0.1 and 0.3 to 0.3 and 0.5, respectively. The stream experiences expansion and contraction as flow expands out of the main channel and accesses the overbanks. Increasing the coefficients provided a more stable hydraulic model.
BlacktailDeerCr	8000	Contraction and expansion coefficients were increased from the standard 0.1 and 0.3 to 0.3 and 0.5, respectively. The stream experiences expansion and contraction as flow expands out of the main channel and accesses the overbanks. Increasing the coefficients provided a more stable hydraulic model.
BlacktailDeerCr	8018	Contraction and expansion coefficients were increased from the standard 0.1 and 0.3 to 0.3 and 0.5, respectively. The stream experiences expansion and contraction as flow expands out of the main channel and accesses the overbanks. Increasing the coefficients provided a more stable hydraulic model.
BlacktailDeerCr	8034	Contraction and expansion coefficients were increased from the standard 0.1 and 0.3 to 0.3 and 0.5, respectively. The stream experiences expansion and contraction as flow expands out of the main channel and accesses the overbanks. Increasing the coefficients provided a more stable hydraulic model.

Quality Management: Floodplain Mapping Task

Project Name:	**Blacktail Deer Creek**	**Project Number:**	**4036.21432.01**
Modeler(s):	**Josh Robbins**	**Client:**	**MTDNRC**
Floodplain Mapping:	**Drew Vance**		
Review:	**Josh Robbins**	**Date:**	**11/02/2018**

All items listed below have been carefully reviewed and verified to be complete.

Reviewer Signature and Date*:

Joshua Robbins

	1. Floodplain Mapping:
Completed	**Checklist Element**
☒	1. Floodway is mapped over the profile baseline.
☒	2. Floodway widths in FWDTs are within the allowed tolerance of the actual width of GIS data. Document the comparison to include in the QAQC submittal.
☒	3. Large “arms” of ineffective flow area have been delineated using the BFE at point of intersection with the main flow area.
☒	4. Features have been “cleaned up” to minimum level of detail for the FIRM panels. (Very narrow backwater arms, narrow areas of flood fringe, etc.) Compass Guidance: Eliminate SFHA areas where the width is less than 1/32 graphic of an inch.
☒	5. Flood hazard boundary polygons do not overlap.
☒	6. Features are singlepart as described in the topology rules in the FIRM Database Technical Reference.
☒	7. VERSION_ID consistent across all FIRM Database Tables.
☒	8. All FIRM Database Tables are consistent with corresponding deliverables.
☒	9. Small islands have been address following FEMA guidance and applying engineering judgment.
☒	10. Identify structures added and removed from flood hazard area.

Floodway Quality Review

Cross Section	River	Reach	Station	Letter	Floodway Width	Mapped Floodway Width	Difference in Mapping and Model
181.17 A	Blacktail Deer Creek	Lower	181.17	A	85.8	85.8	0.1%
514	Blacktail Deer Creek	Lower	514		83.8	83.8	0.0%
857 B	Blacktail Deer Creek	Lower	857	B	241.1	241.1	0.0%
1110	Blacktail Deer Creek	Lower	1110		257.5	257.5	0.0%
1519	Blacktail Deer Creek	Lower	1519		347.1	347.2	0.0%
1711 C	Blacktail Deer Creek	Lower	1711	C	235.9	235.9	0.0%
1934	Blacktail Deer Creek	Lower	1934		430.0	430.0	0.0%
1957	Blacktail Deer Creek	Lower	1957		404.0	410.8	1.7%
1980	Blacktail Deer Creek	Lower	1980		400.8	400.8	0.0%
2012 D	Blacktail Deer Creek	Lower	2012	D	437.2	437.2	0.0%
2147	Blacktail Deer Creek	Lower	2147		328.6	328.6	0.0%
2266	Blacktail Deer Creek	Lower	2266		205.0	205.0	0.0%
2456 E	Blacktail Deer Creek	Lower	2456	E	77.9	77.9	0.0%
2562	Blacktail Deer Creek	Lower	2562		73.3	73.2	0.0%
2713	Blacktail Deer Creek	Lower	2713		70.4	70.4	0.0%
2894 F	Blacktail Deer Creek	Lower	2894	F	179.5	179.5	0.0%
2948	Blacktail Deer Creek	Lower	2948		162.0	162.0	0.0%
2968	Blacktail Deer Creek	Lower	2968		143.8	143.8	0.0%
3057	Blacktail Deer Creek	Lower	3057		170.8	170.8	0.0%
3345 G	Blacktail Deer Creek	Lower	3345	G	492.2	492.2	0.0%
3391	Blacktail Deer Creek	Lower	3391		521.6	521.5	0.0%
3426	Blacktail Deer Creek	Lower	3426		520.4	520.3	0.0%
3661	Blacktail Deer Creek	Lower	3661		545.9	545.9	0.0%
3956 H	Blacktail Deer Creek	Lower	3956	H	417.4	417.4	0.0%
4447	Blacktail Deer Creek	Lower	4447		255.0	255.0	0.0%
4811	Blacktail Deer Creek	Lower	4811		207.5	207.4	0.0%
5258 I	Blacktail Deer Creek	Lower	5258	I	176.9	176.9	0.0%

5426	Blacktail Deer Creek	Lower	5426		186.1	186.0	0.0%
5635	Blacktail Deer Creek	Lower	5635		83.2	83.2	0.0%
5900 J	Blacktail Deer Creek	City of Dillon	5900	J	99.5	99.5	0.0%
6150	Blacktail Deer Creek	City of Dillon	6150		135.4	135.4	0.0%
6542	Blacktail Deer Creek	City of Dillon	6542		118.1	118.1	0.0%
7031 K	Blacktail Deer Creek	City of Dillon	7031	K	93.4	93.4	0.0%
7326	Blacktail Deer Creek	City of Dillon	7326		127.2	127.2	0.0%
7465	Blacktail Deer Creek	City of Dillon	7465		178.1	176.4	1.0%
7536	Blacktail Deer Creek	City of Dillon	7536		244.4	244.4	0.0%
7683 L	Blacktail Deer Creek	City of Dillon	7683	L	167.1	167.1	0.0%
7806	Blacktail Deer Creek	City of Dillon	7806		163.7	163.7	0.0%
7902	Blacktail Deer Creek	City of Dillon	7902		206.6	206.6	0.0%
7940 M	Blacktail Deer Creek	City of Dillon	7940	M	171.8	171.8	0.0%
7968	Blacktail Deer Creek	City of Dillon	7968		100.9	100.9	0.0%
8000	Blacktail Deer Creek	City of Dillon	8000		53.8	53.8	0.0%
8018	Blacktail Deer Creek	City of Dillon	8018		31.5	31.4	0.1%
8034	Blacktail Deer Creek	City of Dillon	8034		28.1	28.1	0.0%
8059	Blacktail Deer Creek	City of Dillon	8059		74.8	74.8	0.0%
8079	Blacktail Deer Creek	City of Dillon	8079		96.1	96.1	0.0%
8143 N	Blacktail Deer Creek	City of Dillon	8143	N	123.8	123.8	0.0%
8214	Blacktail Deer Creek	City of Dillon	8214		160.1	160.1	0.0%
8308	Blacktail Deer Creek	City of Dillon	8308		98.0	98.0	0.0%
8337	Blacktail Deer Creek	City of Dillon	8337		72.4	72.4	0.0%
8394	Blacktail Deer Creek	City of Dillon	8394		65.8	65.8	0.0%
8468 O	Blacktail Deer Creek	City of Dillon	8468	O	42.9	42.9	0.0%
8554	Blacktail Deer Creek	City of Dillon	8554		38.2	38.2	0.0%
8765	Blacktail Deer Creek	City of Dillon	8765		140.9	140.8	0.0%
8782	Blacktail Deer Creek	City of Dillon	8782		138.5	138.5	0.0%
8841 P	Blacktail Deer Creek	City of Dillon	8841	P	138.1	138.0	0.0%
8858	Blacktail Deer Creek	City of Dillon	8858		143.3	143.3	0.0%
8923	Blacktail Deer Creek	City of Dillon	8923		170.2	170.2	0.0%
8974	Blacktail Deer Creek	City of Dillon	8974		140.9	140.9	0.0%
9175	Blacktail Deer Creek	City of Dillon	9175		67.5	67.5	0.0%

9342	Blacktail Deer Creek	City of Dillon	9342		66.4	66.3	0.0%
9426	Blacktail Deer Creek	City of Dillon	9426		60.7	60.7	0.0%
9467 Q	Blacktail Deer Creek	City of Dillon	9467	Q	71.5	71.5	0.0%
9723	Blacktail Deer Creek	City of Dillon	9723		69.0	72.3	4.5%
9790	Blacktail Deer Creek	City of Dillon	9790		106.6	103.3	3.2%
9853	Blacktail Deer Creek	City of Dillon	9853		70.0	70.0	0.0%
9923 R	Blacktail Deer Creek	City of Dillon	9923	R	53.1	53.1	0.0%
10013	Blacktail Deer Creek	City of Dillon	10013		88.9	88.9	0.0%
10085	Blacktail Deer Creek	City of Dillon	10085		68.2	68.2	0.0%
10109	Blacktail Deer Creek	City of Dillon	10109		93.4	93.4	0.0%
10149	Blacktail Deer Creek	City of Dillon	10149		123.8	123.9	0.0%
10176	Blacktail Deer Creek	City of Dillon	10176		125.8	125.8	0.0%
10290 S	Blacktail Deer Creek	City of Dillon	10290	S	108.9	108.9	0.0%
10545	Blacktail Deer Creek	City of Dillon	10545		201.1	201.1	0.0%
10584	Blacktail Deer Creek	City of Dillon	10584		208.0	208.0	0.0%
10628	Blacktail Deer Creek	City of Dillon	10628		219.9	219.9	0.0%
10670	Blacktail Deer Creek	City of Dillon	10670		222.0	222.0	0.0%
10885 T	Blacktail Deer Creek	City of Dillon	10885	T	214.9	214.9	0.0%
10936	Blacktail Deer Creek	City of Dillon	10936		229.3	229.3	0.0%
10971	Blacktail Deer Creek	City of Dillon	10971		226.5	226.5	0.0%
11006	Blacktail Deer Creek	City of Dillon	11006		192.4	192.4	0.0%
11106 U	Blacktail Deer Creek	City of Dillon	11106	U	178.1	178.1	0.0%
11233	Blacktail Deer Creek	City of Dillon	11233		172.3	172.3	0.0%
11284	Blacktail Deer Creek	City of Dillon	11284		169.7	169.7	0.0%
11387	Blacktail Deer Creek	City of Dillon	11387		189.2	189.2	0.0%
11592	Blacktail Deer Creek	City of Dillon	11592		201.5	201.5	0.0%
12018 V	Blacktail Deer Creek	City of Dillon	12018	V	122.2	122.1	0.0%
12330	Blacktail Deer Creek	City of Dillon	12330		247.3	247.3	0.0%
12371	Blacktail Deer Creek	City of Dillon	12371		210.3	210.2	0.0%
12415	Blacktail Deer Creek	City of Dillon	12415		180.6	180.6	0.0%
12633 W	Blacktail Deer Creek	City of Dillon	12633	W	163.0	163.0	0.0%
12738	Blacktail Deer Creek	City of Dillon	12738		158.9	158.9	0.0%
12786	Blacktail Deer Creek	City of Dillon	12786		130.1	130.1	0.0%

13028	Blacktail Deer Creek	City of Dillon	13028		215.8	215.8	0.0%
13166 X	Blacktail Deer Creek	City of Dillon	13166	X	246.2	246.2	0.0%
13330	Blacktail Deer Creek	City of Dillon	13330		180.0	180.0	0.0%
13359	Blacktail Deer Creek	City of Dillon	13359		166.0	166.0	0.0%
13389	Blacktail Deer Creek	City of Dillon	13389		165.5	165.5	0.0%
13416	Blacktail Deer Creek	City of Dillon	13416		167.4	167.4	0.0%
13586 Y	Blacktail Deer Creek	City of Dillon	13586	Y	97.6	97.6	0.0%
13932	Blacktail Deer Creek	City of Dillon	13932		114.3	114.3	0.0%
14841	Blacktail Deer Creek	City of Dillon	14841		118.9	118.9	0.0%
15315 Z	Blacktail Deer Creek	City of Dillon	15315	Z	183.2	183.2	0.0%
15574	Blacktail Deer Creek	City of Dillon	15574		96.3	96.3	0.0%
15659	Blacktail Deer Creek	City of Dillon	15659		86.4	86.4	0.0%
15715	Blacktail Deer Creek	City of Dillon	15715		97.5	97.4	0.0%
15798	Blacktail Deer Creek	City of Dillon	15798		126.3	126.3	0.0%
16465 AA	Blacktail Deer Creek	City of Dillon	16465	AA	60.6	60.6	0.0%
16567	Blacktail Deer Creek	City of Dillon	16567		57.1	57.0	0.0%
16671	Blacktail Deer Creek	City of Dillon	16671		91.4	92.9	1.7%
16798	Blacktail Deer Creek	City of Dillon	16798		115.4	115.4	0.0%
17164 AB	Blacktail Deer Creek	City of Dillon	17164	AB	249.9	249.9	0.0%
17421	Blacktail Deer Creek	City of Dillon	17421		102.6	102.6	0.0%
17458	Blacktail Deer Creek	City of Dillon	17458		103.6	103.6	0.0%
17536	Blacktail Deer Creek	City of Dillon	17536		106.7	106.7	0.0%
17933 AC	Blacktail Deer Creek	City of Dillon	17933	AC	131.7	131.7	0.0%
18373	Blacktail Deer Creek	City of Dillon	18373		164.4	164.3	0.0%
18812 AD	Blacktail Deer Creek	City of Dillon	18812	AD	86.5	86.5	0.0%
19383	Blacktail Deer Creek	City of Dillon	19383		111.8	111.8	0.0%
19713	Blacktail Deer Creek	City of Dillon	19713		66.4	66.4	0.0%
20099 AE	Blacktail Deer Creek	City of Dillon	20099	AE	78.8	78.8	0.0%
20184	Blacktail Deer Creek	City of Dillon	20184		58.0	58.0	0.0%
20948	Blacktail Deer Creek	City of Dillon	20948		147.8	147.8	0.0%
21237	Blacktail Deer Creek	City of Dillon	21237		146.8	146.8	0.0%
21701 AF	Blacktail Deer Creek	City of Dillon	21701	AF	268.7	268.7	0.0%
22178	Blacktail Deer Creek	City of Dillon	22178		142.2	142.2	0.0%

22803 AG	Blacktail Deer Creek	City of Dillon	22803	AG	94.3	94.3	0.0%
23082	Blacktail Deer Creek	City of Dillon	23082		88.3	88.3	0.0%
23924 AH	Blacktail Deer Creek	City of Dillon	23924	AH	129.9	129.9	0.0%
24298	Blacktail Deer Creek	City of Dillon	24298		218.0	218.0	0.0%
24652	Blacktail Deer Creek	City of Dillon	24652		105.0	105.0	0.0%
25008 AI	Blacktail Deer Creek	City of Dillon	25008	AI	60.0	60.0	0.0%
25308	Blacktail Deer Creek	City of Dillon	25308		27.8	27.8	0.1%
25350	Blacktail Deer Creek	City of Dillon	25350		46.0	45.9	0.0%
25628 AJ	Blacktail Deer Creek	City of Dillon	25628	AJ	77.0	77.0	0.0%
25869	Blacktail Deer Creek	City of Dillon	25869		66.9	66.9	0.0%
26355	Blacktail Deer Creek	City of Dillon	26355		199.2	199.2	0.0%
26432	Blacktail Deer Creek	City of Dillon	26432		102.8	102.8	0.0%
26509 AK	Blacktail Deer Creek	City of Dillon	26509	AK	108.9	108.8	0.0%
26554	Blacktail Deer Creek	City of Dillon	26554		144.9	144.9	0.0%
26592	Blacktail Deer Creek	City of Dillon	26592		162.8	162.8	0.0%
26653	Blacktail Deer Creek	City of Dillon	26653		185.7	185.7	0.0%
26789	Blacktail Deer Creek	City of Dillon	26789		217.2	207.4	4.7%
26828	Blacktail Deer Creek	City of Dillon	26828		221.6	222.4	0.4%
26876 AL	Blacktail Deer Creek	City of Dillon	26876	AL	237.8	237.8	0.0%
26964	Blacktail Deer Creek	City of Dillon	26964		227.9	227.9	0.0%
27122	Blacktail Deer Creek	City of Dillon	27122		124.0	124.0	0.0%
27289 AM	Blacktail Deer Creek	City of Dillon	27289	AM	92.3	92.3	0.0%
27483	Blacktail Deer Creek	City of Dillon	27483		107.0	107.0	0.0%
27647	Blacktail Deer Creek	City of Dillon	27647		111.1	111.1	0.0%
28120 AN	Blacktail Deer Creek	City of Dillon	28120	AN	61.8	61.8	0.0%
28483	Blacktail Deer Creek	City of Dillon	28483		122.5	122.5	0.0%
28736	Blacktail Deer Creek	City of Dillon	28736		109.3	109.3	0.0%
28752	Blacktail Deer Creek	City of Dillon	28752		125.3	125.3	0.0%
28932 AO	Blacktail Deer Creek	City of Dillon	28932	AO	243.0	243.0	0.0%
29056	Blacktail Deer Creek	City of Dillon	29056		284.0	284.0	0.0%
29090	Blacktail Deer Creek	City of Dillon	29090		239.2	239.2	0.0%
29178	Blacktail Deer Creek	City of Dillon	29178		218.0	218.0	0.0%
29588	Blacktail Deer Creek	City of Dillon	29588		93.6	93.6	0.0%

29995 AP	Blacktail Deer Creek	City of Dillon	29995	AP	68.9	68.9	0.0%
30375	Blacktail Deer Creek	City of Dillon	30375		431.1	431.1	0.0%
30706	Blacktail Deer Creek	City of Dillon	30706		399.0	399.0	0.0%
30841	Blacktail Deer Creek	City of Dillon	30841		324.9	324.9	0.0%
30878	Blacktail Deer Creek	City of Dillon	30878		307.0	307.0	0.0%
30929	Blacktail Deer Creek	City of Dillon	30929		286.6	286.6	0.0%
31150 AQ	Blacktail Deer Creek	City of Dillon	31150	AQ	259.8	259.8	0.0%
31587	Blacktail Deer Creek	City of Dillon	31587		194.5	194.5	0.0%
32085	Blacktail Deer Creek	City of Dillon	32085		181.1	181.1	0.0%
32722 AR	Blacktail Deer Creek	City of Dillon	32722	AR	252.7	252.7	0.0%
33067	Blacktail Deer Creek	City of Dillon	33067		205.1	205.1	0.0%
33472	Blacktail Deer Creek	pper to Canyo	33472		173.3	173.3	0.0%
33594	Blacktail Deer Creek	pper to Canyo	33594		208.0	208.0	0.0%
33802 AS	Blacktail Deer Creek	pper to Canyo	33802	AS	122.1	122.1	0.0%
34119	Blacktail Deer Creek	pper to Canyo	34119		126.0	126.0	0.0%
34317	Blacktail Deer Creek	pper to Canyo	34317		213.3	213.3	0.0%
34825 AT	Blacktail Deer Creek	pper to Canyo	34825	AT	247.4	247.4	0.0%
35200	Blacktail Deer Creek	pper to Canyo	35200		91.7	91.7	0.0%
35244	Blacktail Deer Creek	pper to Canyo	35244		83.2	83.2	0.1%
35531	Blacktail Deer Creek	pper to Canyo	35531		73.4	73.4	0.0%
36107 AU	Blacktail Deer Creek	pper to Canyo	36107	AU	160.8	160.8	0.0%
36600	Blacktail Deer Creek	pper to Canyo	36600		102.5	102.4	0.1%
36932	Blacktail Deer Creek	pper to Canyo	36932		60.7	60.7	0.0%
37463 AV	Blacktail Deer Creek	pper to Canyo	37463	AV	70.2	70.2	0.0%
37821	Blacktail Deer Creek	pper to Canyo	37821		114.9	114.9	0.0%
37904	Blacktail Deer Creek	pper to Canyo	37904		91.1	89.4	1.9%
38338	Blacktail Deer Creek	pper to Canyo	38338		223.2	223.2	0.0%
38532 AW	Blacktail Deer Creek	pper to Canyo	38532	AW	202.9	202.9	0.0%
38605	Blacktail Deer Creek	pper to Canyo	38605		139.6	139.6	0.0%
38668	Blacktail Deer Creek	pper to Canyo	38668		94.7	94.7	0.0%
38850	Blacktail Deer Creek	pper to Canyo	38850		198.7	198.7	0.0%
39114	Blacktail Deer Creek	pper to Canyo	39114		186.6	186.6	0.0%
39542 AX	Blacktail Deer Creek	pper to Canyo	39542	AX	90.4	90.4	0.0%

40079	Blacktail Deer Creek	pper to Canyo	40079		86.9	86.9	0.0%
40715	Blacktail Deer Creek	pper to Canyo	40715		50.6	50.6	0.0%
41150 AY	Blacktail Deer Creek	pper to Canyo	41150	AY	40.9	40.8	0.0%
42061	Blacktail Deer Creek	pper to Canyo	42061		120.4	120.4	0.0%
42443 AZ	Blacktail Deer Creek	pper to Canyo	42443	AZ	94.7	94.7	0.0%
42924	Blacktail Deer Creek	pper to Canyo	42924		170.0	170.0	0.0%
43293	Blacktail Deer Creek	pper to Canyo	43293		190.1	190.1	0.0%
43359	Blacktail Deer Creek	pper to Canyo	43359		156.7	156.7	0.0%
43582 BA	Blacktail Deer Creek	pper to Canyo	43582	BA	216.1	216.1	0.0%
43760	Blacktail Deer Creek	pper to Canyo	43760		263.1	263.1	0.0%
44093	Blacktail Deer Creek	pper to Canyo	44093		240.5	240.5	0.0%
44340 BB	Blacktail Deer Creek	pper to Canyo	44340	BB	252.5	252.4	0.0%
44619	Blacktail Deer Creek	pper to Canyo	44619		186.0	186.0	0.0%
44806	Blacktail Deer Creek	pper to Canyo	44806		193.5	193.5	0.0%
45127	Blacktail Deer Creek	pper to Canyo	45127		206.1	206.1	0.0%
45540 BC	Blacktail Deer Creek	pper to Canyo	45540	BC	178.9	178.9	0.0%
45991	Blacktail Deer Creek	pper to Canyo	45991		160.4	160.4	0.0%
46386	Blacktail Deer Creek	pper to Canyo	46386		228.7	228.7	0.0%
46687 BD	Blacktail Deer Creek	pper to Canyo	46687	BD	201.5	201.5	0.0%
47454	Blacktail Deer Creek	Upper	47454		118.1	118.1	0.0%
47789	Blacktail Deer Creek	Upper	47789		78.4	78.4	0.0%
48162 BE	Blacktail Deer Creek	Upper	48162	BE	206.2	206.2	0.0%
48550	Blacktail Deer Creek	Upper	48550		141.2	141.2	0.0%
48788	Blacktail Deer Creek	Upper	48788		164.1	164.0	0.0%
48990	Blacktail Deer Creek	Upper	48990		191.1	191.1	0.0%
49489 BF	Blacktail Deer Creek	Upper	49489	BF	162.2	162.1	0.0%
49957	Blacktail Deer Creek	Upper	49957		117.4	117.4	0.0%
50456	Blacktail Deer Creek	Upper	50456		159.4	159.4	0.0%
50734 BG	Blacktail Deer Creek	Upper	50734	BG	45.2	45.2	0.0%
51103	Blacktail Deer Creek	Upper	51103		146.9	146.9	0.0%
51444	Blacktail Deer Creek	Upper	51444		120.8	120.8	0.0%
51471	Blacktail Deer Creek	Upper	51471		158.3	158.3	0.0%
51516	Blacktail Deer Creek	Upper	51516		157.9	157.9	0.0%

51668 BH	Blacktail Deer Creek	Upper	51668	BH	144.9	144.8	0.0%
51908	Blacktail Deer Creek	Upper	51908		225.0	228.7	1.6%
51968	Blacktail Deer Creek	Upper	51968		119.3	119.3	0.0%
52371	Blacktail Deer Creek	Upper	52371		119.9	119.9	0.0%
52745 BI	Blacktail Deer Creek	Upper	52745	BI	204.1	204.1	0.0%
53056	Blacktail Deer Creek	Upper	53056		298.0	298.0	0.0%
53365	Blacktail Deer Creek	Upper	53365		200.8	200.8	0.0%
53837 BJ	Blacktail Deer Creek	Upper	53837	BJ	290.9	290.9	0.0%
54248	Blacktail Deer Creek	Upper	54248		230.2	230.2	0.0%
54594	Blacktail Deer Creek	Upper	54594		208.4	208.4	0.0%
54977 BK	Blacktail Deer Creek	Upper	54977	BK	175.7	175.7	0.0%
55414	Blacktail Deer Creek	Upper	55414		280.6	280.7	0.0%
55491	Blacktail Deer Creek	Upper	55491		263.3	263.3	0.0%
55541	Blacktail Deer Creek	Upper	55541		189.6	189.6	0.0%
55621	Blacktail Deer Creek	Upper	55621		183.1	183.1	0.0%
56104 BL	Blacktail Deer Creek	Upper	56104	BL	239.9	239.9	0.0%
56237	Blacktail Deer Creek	Upper	56237		244.1	244.1	0.0%
56545	Blacktail Deer Creek	Upper	56545		102.5	102.5	0.0%
56975	Blacktail Deer Creek	Upper	56975		86.7	86.7	0.0%
57269 BM	Blacktail Deer Creek	Upper	57269	BM	135.2	135.2	0.0%
57591	Blacktail Deer Creek	Upper	57591		88.5	88.5	0.0%
57768	Blacktail Deer Creek	Upper	57768		53.4	53.3	0.0%
57839	Blacktail Deer Creek	Upper	57839		67.7	67.7	0.0%
58087	Blacktail Deer Creek	Upper	58087		111.4	111.4	0.0%
58295 BN	Blacktail Deer Creek	Upper	58295	BN	143.3	143.3	0.0%

Quality Management: Hydraulic Data Task – 2nd Submittal

Project Name:	**St. Regis River – Mainstem**	**Project Number:**	**4036.21432.01**
Modelers:	**Josh Robbins, Adam Zwemke**	**Client:**	**MTDNRC**
Review:	**Josh Robbins**	**Date:**	**6/7/2018-6/8/2018**
Senior Review:	**Greg Gabel**	**Date:**	**6/8/2018**

All comments from the initial QA Review have been addressed and verified by a DOWL reviewer.

Reviewer Signature and Date*: Greg Gabel 6/8/2018

DOWL Modeler Signature and Date*: Joshua W Robbins 6/8/2018

	1. Hydraulic Modeling
Completed	**Checklist Element**
☒	1. All comments have been addressed.
☒	2. DFIRM Database tables are consistent with Hydraulic Model, FWDTs, and Profile Plots.
	Floodway Data Tables (FWDTs)
Completed	**Checklist Element**
☒	3. All comments have been addressed.
☒	4. Products are consistent with the results of the regulatory hydraulic model.
	Profile Plots
Completed	**Checklist Element**
☒	5. All comments have been addressed.
☒	6. Products are consistent with the results of the regulatory hydraulic model.
	DFIRM Database Products
Completed	**Checklist Element**
☒	7. All comments have been addressed.
☒	8. Products are consistent with the results of the regulatory hydraulic model.

Quality Management: Enhanced Floodplain Studies

Project Name:	Blacktail Deer Creek Floodplain Study	**Project Number:**	4036.21432.01
DOWL Modeler:	Josh Robbins	**Client:**	**Montana DNRC**
DOWL Reviewer:	**Greg Gabel**	**Date:**	**10-13-2017**

All items listed below have been carefully reviewed and verified to be complete.

Reviewer Signature and Date*: 10-13-2017

DOWL Modeler Signature and Date*: 10-13-2017

	1. Hydraulic Modeling
Completed	**Checklist Element**
☑	1. Cross sections are spaced between 300 – 500 feet.
☑	2. Cross sections extend beyond the flood boundary of the 0.2% annual chance event. Documented 6 XS that don't meet this criteria.
☑	3. Bathymetry incorporated into each cross section and process has been documented.
☑	4. Bank stations are appropriate for each cross section and there is continuity throughout the model. (Bank stations located below 100YR WSEL to allow for encroachment) Documented several XS that don't meet this criteria.
☑	5. Appropriate roughness values have been assigned for the extent of the model (Manning's "n").
☑	6. HEC-RAS set to search for "Multiple Critical Depths."
☑	7. Contraction and Expansion Coefficients have been selected for cross sections at each structure crossing.
☑	8. Entrance loss coefficients have been selected for each culvert crossing.
☑	9. The downstream boundary condition has been selected and is appropriate.
☑	10. The bridge modeling approach is assigned correctly for each crossing. Where the ratio of EGL to the (Existing Ground)/(Low Chord Elev.) is greater than 1.2, the Pressure/Weir method has been selected. Use Yarnell and momentum when there are piers impacting the flow.
☑	11. Ineffective flows near structures are approximately located at a 1:1 expansion upstream and 2:1 expansion downstream.
☑	12. Ineffective flows have been entered throughout the model and are located at the correct elevation. (There is continuity of flow between cross sections for each profile).
☑	13. Flow profiles do not default to critical depth or there is a reasonable explanation for the flow reaching critical depth.
☑	14. The model has been calibrated.
☑	15. All floodway surcharges are less than or equal to 0.5 feet.
☐	16. Blocked obstructions at each cross section have been documented (if used). Has not been documented because of the quantity of houses in the model.

☑	17. Stationing of the model matches the distance along the stream profile baseline.
☑	18. Split flow paths have been identified and a floodway has been developed for the split reach if necessary.
☑	19. cHECk-RAS errors have been resolved. cHECk-RAS software ran initially and these comments were addressed. Second run of cHECk-RAS wouldn't run.
☑	20. The model includes results for the 'Multiple Profiles' and 'Floodway' plans.
☑	21. If necessary, the model includes an 'Optimized' plan that uses the Flow Optimization Routine to calculate flow changes and a 'Hard Entered' plan where the resulting flow changes have been manually input.
☑	22. Metadata has been analyzed with Metaman.
☑	23. DFIRM Database tables are consistent with Hydraulic Model, FWDTs, and Profile Plots.
	2. Floodway Data Tables (FWDTs)
Completed	**Checklist Element**
☑	24. Footnote has been completed to document the stationing reference location. (E.G. Feet above the confluence with Beaverhead River)
☑	25. If necessary, include footnote "Floodway top width includes width of high ground area".
☑	26. Stationing and letter of each cross section match the hydraulic model and length along the profile baseline.
☐	27. Floodway widths in FWDTs are within the allowed tolerance of the actual width of GIS data. Document the comparison to include in the QAQC submittal. –Floodway GIS was not digitized for the Hydraulic Data Task.
☑	28. Floodway "Width", "Section Area", and "Mean Velocity" values are the same as the hydraulic model output.
☑	29. "Increase" column in FWDTs is equal to the difference between the "Without Floodway" and "With Floodway" columns in the FWDTs. There are no rounding errors.
	3. Profile Plots
Completed	**Checklist Element**
☑	30. Set the vertical and horizontal scales that will be used for each flooding source.
☑	31. Label the beginning and end of each profile (e.g. lower junction with main channel, 'split from main channel', 'lower junction with abc split', upper junction with abc split, etc.)
☑	32. Check the labels and symbols for bridges and culverts.
☑	33. Stationing of lettered cross sections and features (bridges, etc.) match the hydraulic model.
☑	34. Profiles show the backwater influence from other flooding sources.
	4. Floodplain Mapping
Completed	**Checklist Element**
☑	35. Floodway is mapped over the profile baseline.
☐	36. Large "arms" of ineffective flow area have been delineated using the BFE at point of intersection with the main flow area. Not Completed for this submittal.
☐	37. Features have been "cleaned up" to minimum level of detail for the FIRM panels. (Very narrow backwater arms, narrow areas of flood fringe, etc.) Not Completed for this submittal

	Compass Guidance: Eliminate SFHA areas where the width is less than 1/32 graphic of an inch.
☐	38. Flood hazard boundary polygons do not overlap. Not Completed for this submittal
☐	39. Features are singlepart as described in the topology rules in the FIRM Database Technical Reference. Not Completed for this submittal
☐	40. VERSION_ID consistent across all FIRM Database Tables. Not Completed for this submittal
☐	41. All FIRM Database Tables are consistent with corresponding deliverables. Not Completed for this submittal
☐	42. Islands that are less than 0.5 acre in size and less than two feet above base flood elevation are included in the SFHA. Not Completed for this submittal
☐	43. Identify structures added and removed from flood hazard area. Not Completed for this submittal

cHECk-RAS Report

HEC-RAS Project: *blacktaildeercreek.prj*
Plan File: *blacktaildeercreek.p02*
Geometry File: *blacktaildeercreek.g02*
Flow File: *blacktaildeercreek.f02*
Report Date: *9/27/2017*

Message ID	Message	Cross sections affected	
BR LF 01	This is ($strucname$). The selected profile is $profilename$. Type of flow is low flow because, 1. EGEL 3 of $egel3$ is less than or equal to MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is less than MxLoCdU of $mxlocdu$.	7488(Bridge-UP); 8325(Bridge-UP); 8774(Bridge-UP); 8900(Bridge-UP); 9393(Bridge-UP); 9818(Bridge-UP); 10099(Bridge-UP); 10130(Bridge-UP); 10607(Bridge-UP); 10958(Bridge-UP); 12394(Bridge-UP); 13375(Bridge-UP); 15674(Bridge-UP); 16618(Bridge-UP); 17502(Bridge-UP); ~~51941~~(Bridge-UP); ~~5779~~7(Bridge-UP); 35231(Bridge-UP); 38639(Bridge-UP); 44666(Bridge-UP); 2158(Bridge-UP); 2917(Bridge-UP); 3672(Bridge-UP)	
BR LF 03	This is the upstream internal Bridge Section ($secno3$). The selected profile is $profilename$. Type of flow is low flow. Critical depth occurs at the BRU section. However, input BrSelMthd is not Momentum. Select Momentum as the Low Flow Method and rerun the plan.	~~7488~~(Bridge-UP); ~~8325~~(Bridge-UP); ~~8774~~(Bridge-UP); ~~8900~~(Bridge-UP); ~~9393~~(Bridge-UP); ~~9818~~(Bridge-UP); ~~10099~~(Bridge-UP); ~~10130~~(Bridge-UP); ~~10607~~(Bridge-UP); ~~10958~~(Bridge-UP); ~~12394~~(Bridge-UP); ~~13375~~(Bridge-UP); ~~15674~~(Bridge-UP); ~~16618~~(Bridge-UP); ~~17502~~(Bridge-UP); ~~51941~~(Bridge-UP); ~~5779~~(Bridge-UP); ~~35231(Bridge-UP)~~; ~~38639~~(Bridge-UP); ~~44666(Bridge-UP)~~; ~~2158~~(Bridge-UP); ~~2917~~(Bridge-UP); ~~3672~~(Bridge-UP)	Comment addressed
BR PW 02	This is a Bridge Section. The selected profile is $profilename$. Type of flow is submerged pressure and weir flow because, 1. EGEL 3 of $egel3$ is greater than MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is equal to or greater than MxLoCdU of $mxlocdu$. 3. WSEL 2 of $wsel2$ is equal to or greater than MxLoCdD of $mxlocdd$.	25328(Bridge-UP); 26576(Bridge-UP); 26815(Bridge-UP); 28745(Bridge-UP); 29080(Bridge-UP); 1969(Bridge-UP); 2645(Bridge-UP); 2957(Bridge-UP); 3416(Bridge-UP)	
BR PW 04	This is a Bridge Section. High Flow Method is Energy Only. The selected profile is $profilename$. Type of flow is submerged pressure and weir flow. However, the EGEL difference between Sections 3 and 2 is more than 1.0 foot. Press/Weir should be selected as the High Flow Method.	25328(Bridge-UP); 2645(Bridge-UP)	Comment addressed
CV CF 01	This is ($strucname$). Culvert Chart # is $chart$ and Scale # is $scale$. Culvert entrance shape is $shape$. Culvert entrance loss coefficient is $inputentlosscoef$. It should be equal to $entlosscoef$. Please refer to Table 6-3 and Table 6-4 on Page 6-26 of HEC-RAS Hydraulic Reference Manual	43327; 254	Comment addressed
CV LF 01	This is ($strucname$). The selected profile is $profilename$. Type of flow is low flow because, 1. EGEL 3 of $egel3$ is less than or equal to MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is less than MxLoCdU of $mxlocdu$.	7869; 11261; 37895; 43327; 254; 3988	

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CV LW 03	This is ($strucname$). The tolerance ratio of {(QWeir + Qculv) - QTotal}/Qtotal is more than 0.01. Please investigate the problem.	7869; 11261; 37895; 43327; 254; 3988	Comment addressed
CV PW 01	This is ($strucname$). The selected profile is $profilename$. Type of flow is pressure and weir flow because, 1. EGEL 3 of $egel3$ is greater than MinTopRd of $Min_El_Weir_Flow$. 2. EGEL 3 of $egel3$ is greater than MxLoCdU of $MxLoCdU$.	26385	Comment addressed
CV PW 03	This is ($strucname$). The tolerance ratio of {(QWeir + Qculv) - QTotal}/Qtotal is more than 0.01. Please investigate the problem.	7869; 11261; 37895; 43327; 254; 3988	Comment addressed
IW TF 01e	This is an InlineWeir section. The selected profile is $profilename$. There is no flow at the structure.	30866(InlineWeir); 51459(InlineWeir); 55477(InlineWeir); 1336(InlineWeir); 3564(InlineWeir); 6027(InlineWeir)	Comment addressed
IW TF 04	This is an Inline Weir. The selected profile is $profilename$. Type of flow is UNKNOWN. cHECk-RAS cannot find MxLoCd or MnTpRd elevation or the given conditions do not satisfy the type of flow specified in the cHECk-RAS program. Please review the ground and road data and the encroachment stations, or please review the message IW TF 01 for inline weir to determine the type of flow.	12765(InlineWeir); 30866(InlineWeir); 51459(InlineWeir); 55477(InlineWeir); 3586(InlineWeir); 1336(InlineWeir); 3564(InlineWeir); 6027(InlineWeir)	Inline Weirs without culvert/structure below road profile. Reviewed and comment is okay.
NT RC 01L	All of the left overbank Manning's "n" values are less than 0.030. The "n" values for the overbank areas are usually larger than 0.030 (Chow, 1959, page 113). The "n" value(s) should be re-evaluated. Follow the procedure outlined to compute the overbank "n" value(s) for a natural floodplain (FHWA, 1984). Or follow the procedure outlined to compute the "n" values for urban development (USGS, 1977). Please submit supporting information on the evaluation of the "n" values.	6150; 7326; 7465; 7488(Bridge-DN); 7488(Bridge-UP); 7536; 7683; 7806; 7869(Culvert-DN); 7869(Culvert-UP); 7902; 7939(-DN); 7939(-UP); 7940; 7968; 8000; 8018; 8034; 8059; 8079; 8143; 8214; 8308; 8325(Bridge-DN); 8765; 8774(Bridge-DN); 8774(Bridge-UP); 8782; 8841; 8858; 8900(Bridge-DN); 8900(Bridge-UP); 8923; 8974; 9175; 9342; 9393(Bridge-DN); 9393(Bridge-UP); 9426; 9467; 9723; 9789(-DN); 9789(-UP); 9790; 9818(Bridge-DN); 9818(Bridge-UP); 9853; 9923; 9955(-DN); 9955(-UP); 10013; 10049(-DN); 10049(-UP); 10085; 10099(Bridge-DN); 10099(Bridge-UP); 10109; 10130(Bridge-DN); 10130(Bridge-UP); 10149; 10176; 10290; 10545; 10581(-DN); 10581(-UP); 10584; 10607(Bridge-DN); 10607(Bridge-UP); 10628; 10670; 10885; 10911(-DN); 10911(-UP); 10936; 10958(Bridge-DN); 10958(Bridge-UP); 10971; 11006; 11106; 11233; 11261(Culvert-DN); 11261(Culvert-UP); 11284; 11387; 11592; 12330; 12371; 12394(Bridge-DN); 12394(Bridge-UP); 12415; 12633; 12738; 26432; 26576(Bridge-UP); 26592; 26653; 26789; 26815(Bridge-DN); 27483; 3661; 4447; 4811; 5258; 5426; 5635; 5900.12; 3920; 3988(Culvert-DN)	Comment not valid. All of the overbank Manning's "n" values are not less than 0.03.

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NT RC 01R	All of the right overbank "n" values are less than 0.030. Manning's "n" values for the overbank areas are usually larger than 0.030 (Chow, 1959, page 113). The "n" value(s) should be re-evaluated. Follow the procedure on pages 17 and 54 of (FHWA, 1984) to compute the overbank "n" value for the natural floodplain. Or follow the procedure in (USGS, 1977) to compute the "n" value for urban development. Please submit supporting information on the evaluation of "n" value.	6542; 7326; 7488(Bridge-UP); 7536; 7683; 7806; 7869(Culvert-DN); 8214; 8308; 8325(Bridge-DN); 8325(Bridge-UP); 8337; 8394; 8900(Bridge-UP); 8923; 9175; 9342; 9393(Bridge-DN); 9393(Bridge-UP); 9426; 9467; 9723; 9789(-DN); 9789(-UP); 9790; 9818(Bridge-DN); 9818(Bridge-UP); 9853; 10130(Bridge-UP); 10149; 10176; 10670; 10885; 10911(-DN); 10911(-UP); 10936; 10958(Bridge-DN); 10958(Bridge-UP); 10971; 11006; 11261(Culvert-UP); 11284; 11592; 12018; 12330; 12371; 12394(Bridge-UP); 12415; 12633; 12765(InlineWeir-UP); 12786; 25628; 2948; 2957(Bridge-DN); 2957(Bridge-UP); 2968; 3345; 3391; 3416(Bridge-DN); 3416(Bridge-UP); 3426; 3661; 3956; 51444; 51459(InlineWeir-UP); 51471; 51668; 51908; 51941(Bridge-DN); 3073; 3382; 3538; 3586(InlineWeir-DN); 3586(InlineWeir-UP); 3608; 3654; 3672(Bridge-DN); 3672(Bridge-UP); 3696; 3785; 3920; 3988(Culvert-DN); 3988(Culvert-UP); 4044	Comment not valid. All of the overbank Manning's "n" values are not less than 0.03.
NT RC 03C	All of the channel "n" values are equal to or less than 0.025. The "n" value of the channel is usually greater than 0.025. The "n" values or the Channel Bank stations should be re-evaluated. Select the Channel Bank stations to include bank slopes and low flow channel to represent a confined cross section. Channel Bank stations must not be placed at the banks of the low flow channel, at the bottom of the channel, or above the 1%-annual-chance water-surface elevation. Let HEC-RAS compute the composite "n" values by using the Horizontal Variation in "n" Values option within the channel (HEC, 2010, HEC-RAS Reference Manual, page 2-6). Or follow the procedure on pages 9 and 52 of (FHWA, 1984) to compute the total channel "n" value. Please submit supporting information on the evaluation of "n" value.	8765; 8774(Bridge-DN); 8774(Bridge-UP); 8782; 8841; 8858; 8900(Bridge-DN); 8900(Bridge-UP); 8923; 8974; 9175; 9342; 9393(Bridge-DN); 9393(Bridge-UP); 9426; 9467; 10885; 10958(Bridge-UP); 10971; 11261(Culvert-UP); 11284; 12633; 3661	Comment not valid. All of the channel Manning's "n" values are not less than 0.025.
NT RC 05	The left overbank n-value of $nlob$ and the right overbank n-value of $nrob$ are less than or equal to the channel n-value of nch. Follow the procedure in (FHWA, 1984) to compute the n-value for the natural floodplain and the channel. Or follow the procedure in (USGS, 1977) to compute the n-value for urban development. Please submit supporting information on the evaluation of n-values.	10885; 10911(-DN); 10911(-UP); 10936; 10958(Bridge-DN); 10958(Bridge-UP); 10971; 11261(Culvert-UP); 11284; 12371; 12633; 13416; 23924; 25628; 26576(Bridge-UP); 26592; 26815(Bridge-UP); 27483; 27647; 28483; 28932; 29995; 30375; 30866(InlineWeir-DN); 32085; 50456; 50734; 54977; 58191(-DN); 58191(-UP); 58295; 38605; 38850; 44619; 44666(Bridge-DN); 254(Culvert-UP); 306; 2917(Bridge-DN); 505; 626; 757; 1510; 2546; 3797; 3969; 4356; 4623; 4806; 5032; 5351; 5701; 5801; 344.96; 556; 811; 1044; 1556; 1787; 1997; 2239; 2785; 2996; 3217; 3520; 3646(-DN); 3646(-UP); 3771; 4272; 4630; 4999; 5466; 5824; 6027(InlineWeir-UP); 6078; 6179; 7284; 7796; 8057; 8258; 8434; 8547; 8736; 8931; 9548; 9896; 10044; 10499; 10514	Comment not valid.

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NT RS 01S2C	This is Section 2 of a hydraulic structure. Channel n value of $chl2$ is less than the channel n value of $chl1$ at Section 1. Normally the channel "n" value at Section 2 represents the reach between Section 2 and Section 1, and is higher than the "n" value within the hydraulic structure. Please change the "n" value or provide supporting information for the use of the lower "n" value.	8765	
NT RS 01S3C	This is Section 3 of a hydraulic structure. Channel n value of $chl3$ is less than the channel n value of $chl4$ at Section 4. Normally the channel "n" value at Section 3 represents the reach between Section 3 and Section 4, and is higher than the "n" value within the hydraulic structure. Please change the "n" value or provide supporting information for the use of the lower "n" value.	10971; 11284; 13389	
NT RS 02BDC	This is the Downstream Bridge Section (BRD). The channel n value of $chldn$ for the downstream internal bridge opening section is equal to or larger than the channel n value of $chl2$ at Section 2. Usually, the channel "n" value of the bridge opening section represents the area below the bridge deck and is less than the channel "n" value of Section 2. The "n" value for Section 2 represents the natural valley channel section roughness for the reach between Section 3 and Section 4. Please change the "n" value of the internal bridge opening section or provide supporting information for the use of the higher "n" value.	7488(Bridge-DN); 8325(Bridge-DN); 8774(Bridge-DN); 8900(Bridge-DN); 9393(Bridge-DN); 9818(Bridge-DN); 10099(Bridge-DN); 10130(Bridge-DN); 10607(Bridge-DN); 10958(Bridge-DN); 13375(Bridge-DN); 16618(Bridge-DN); 17502(Bridge-DN); 25328(Bridge-DN); 26576(Bridge-DN); 26815(Bridge-DN); 28745(Bridge-DN); 29080(Bridge-DN); 1969(Bridge-DN); 2645(Bridge-DN); 2957(Bridge-DN); 3416(Bridge-DN); 51941(Bridge-DN); 57797(Bridge-DN); 35231(Bridge-DN); 38639(Bridge-DN); 44666(Bridge-DN); 2158(Bridge-DN); 3672(Bridge-DN)	Roughness of the channel bottom is consistent roughness values are equal.
NT RS 02BUC	This is the Upstream Bridge Section (BRU). The channel n value of $chlup$ for the upstream internal bridge opening section is equal to or larger than the channel n value of $chl3$ at Section 3. Usually, the channel "n" value of the bridge opening section represents the area below the bridge deck and is less than the channel "n" value of Section 3. The "n" value for Section 3 represents the natural valley channel section roughness for the reach between Section 3 and Section 4. Please change the "n" value of the internal bridge opening section or provide supporting information for the use of a higher "n" value.	7488(Bridge-UP); 8325(Bridge-UP); 8774(Bridge-UP); 8900(Bridge-UP); 9393(Bridge-UP); 9818(Bridge-UP); 10099(Bridge-UP); 10130(Bridge-UP); 10607(Bridge-UP); 10958(Bridge-UP); 12394(Bridge-UP); 13375(Bridge-UP); 15674(Bridge-UP); 16618(Bridge-UP); 17502(Bridge-UP); 25328(Bridge-UP); 26576(Bridge-UP); 28745(Bridge-UP); 29080(Bridge-UP); 1969(Bridge-UP); 2645(Bridge-UP); 2957(Bridge-UP); 3416(Bridge-UP); 51941(Bridge-UP); 57797(Bridge-UP); 35231(Bridge-UP); 38639(Bridge-UP); 44666(Bridge-UP); 2158(Bridge-UP); 2917(Bridge-UP); 3672(Bridge-UP)	Roughness of the channel bottom is consistent roughness values are equal.
NT TB 01S2	This is Section2 of a hydraulic structure. The contraction and expansion loss coefficients are cc and ce. They should be equal to 0.3 and 0.5, respectively, for typical structure sections according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010).	10109; 1957; 2948; 3391; 51444	Comment Addressed.

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NT TL 01S3	This is Section3 of a hydraulic structure. The contraction and expansion loss coefficients are cc and ce. They should be equal to 0.3 and 0.5, respectively, for typical structure sections according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010).	9853; 1980; 2968; 3426; 55491	Reviewed: expansion and contraction coefficients are appropriate.
NT TL 01S4	This is Section 4 of a hydraulic structure. The contraction and expansion loss coefficients are cc and ce. They should be equal to 0.3 and 0.5, respectively according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010)..	7683; 8394; 8841; 8974; 9467; 12633; 13028; 15798; 25628; 29178; 2012; 3057; 3661; 38338; 45127; 599; 2452; 3073; 4294; 3797; 6179	Reviewed: expansion and contraction coefficients are appropriate.
NT TL 02	Contraction and expansion loss coefficients are cc and ce, respectively. However, this cross section is not at a hydraulic structure. They should be equal to 0.1 and 0.3 according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010).	7940; 7968; 8000; 8018; 8034; 8079; 9723; 10290; 10545; 29588	Reviewed: expansion and contraction coefficients are appropriate.
ST DT 03	This is ($Structure$) section. The Contraction Length is longer than the Expansion Length. Section 4 channel distance of $Length_Chnl4$ is longer than Section 2 channel distance of $Length_Chnl2$. Section 4 and Section 1 should be relocated. The HEC-RAS geometry file may need to be recreated using a GIS program.	7488(Bridge-UP); 8900(Bridge-UP); 9818(Bridge-UP); 10130(Bridge-UP); 10607(Bridge-UP); 12394(Bridge-UP); 12765(InlineWeir-UP); 16618(Bridge-UP); 17502(Bridge-UP); 26576(Bridge-UP); 1969(Bridge-UP); 2645(Bridge-UP); 2957(Bridge-UP); 3416(Bridge-UP); 51941(Bridge-UP); 57797(Bridge-UP); 37895(Culvert-UP); 38639(Bridge-UP); 44666(Bridge-UP); 254(Culvert-UP); 2917(Bridge-UP); 3672(Bridge-UP); 3988(Culvert-UP); 1336(InlineWeir-UP)	Reviewed: XS placed near field survey and placed at best location upstream/downstream of meander bends.
ST GD 02BD	This is the Downstream Bridge Section. There is only one bridge. However, the low cord line crosses the ground line at more than two locations. The ground and deck/roadway data should be checked.	7488(Bridge); 8325(Bridge); 8774(Bridge); 8900(Bridge); 9818(Bridge); 10099(Bridge); 10958(Bridge); 16618(Bridge); 29080(Bridge); 1969(Bridge); 2957(Bridge); 3416(Bridge); 51941(Bridge); 38639(Bridge); 2158(Bridge); 2917(Bridge)	Reviewed: Road/Deck data is appropriate
ST GD 02BU	This is the Upstream Bridge Section. There is only one bridge. However, the low cord line crosses the ground line at more than two locations. The ground and deck/roadway data should be checked.	7488(Bridge); 8325(Bridge); 8774(Bridge); 8900(Bridge); 9818(Bridge); 12394(Bridge); 29080(Bridge); 1969(Bridge); 2957(Bridge); 3416(Bridge); 51941(Bridge); 38639(Bridge); 2158(Bridge); 2917(Bridge); 3672(Bridge)	Reviewed: Road/Deck data is appropriate
ST IF 01S2L	This is Section 2 of a hydraulic structure. The highest flood frequency that has low or pressure flow is $profilename$. However, the Left Ineffective Flow station was not considered at Section 2. The ineffective flow station and elevation should be inserted. The left ineffective flow elevation should be equal to wsel2 of $wsel$. The placement of the left ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	7869(Culvert); 10099(Bridge); 10130(Bridge); 10607(Bridge); 10958(Bridge); 11261(Culvert); 15674(Bridge); 16618(Bridge); 17502(Bridge); 55477(InlineWeir); 35231(Bridge); 43327(Culvert); 44666(Bridge); 3586(InlineWeir); 3672(Bridge); 3988(Culvert)	Ineffective flow station is not necessary.

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XS BO 01R	Block Obstruction. Flow Code will be "BR". The block obstruction elevation is higher than the right bank elevation. Lower the block obstruction elevation to the bank elevation or provide an explanation. This option is suitable to fill isolated depression areas.	1110	Blocked obstruction used to model individual building.
XS BO 02L	Multiple Block Obstruction. The Flow Code will be MBL. The block obstruction elevation is higher than the left bank elevation. The ground elevation within the block obstruction is lower than the highest discharge WSEL. The block obstruction is not within the block ineffective flow stations. If it is, the ineffective flow elevation is lower than the highest discharge WSEL. This option is suitable to represent individual buildings within the floodway. Compute appropriate "n" values to represent a group of buildings as outlined in (USGS, 1977) or use the Ineffective Flow option.	28120	Blocked obstruction used to model individual building.
XS CD 01	Critical Depth occurs at $assignedname$ flood. Flow Code will be "C". The Ineffective flow option is used. The Ineffective Flow elevation is equal to or higher than the Critical WSEL. Please investigate whether this selection is appropriate.	5900.12; 6150; 6542; 7031; 7326; 7465; 7536; 7902; 7940; 7968; 8000; 8018; 8034; 8059; 8079; 8143; 8214; 8308; 8337; 8394; 8468; 8554; 8765; 8782; 8841; 8858; 8923; 8974; 9175; 9342; 9467; 9723; 9790; 9853; 9923; 10013; 10085; 10109; 10149; 10176; 10290; 11592; 12018; 12330; 12371; 12415; 12633; 12738; 12786; 13028; 13166; 13330; 13359; 13389; 13416; 13586; 13932; 16671; 16798; 17164; 17421; 17458; 17536; 17933; 18373; 18812; 19383; 19713; 20099; 20184; 20948; 21237; 21701; 22178; 22803; 25628; 28932; 5426; 47453.84; 47789; 48162; 48550; 48788; 48990; 49489; 49957; 50456; 50734; 51103; 51444; 51471; 51516; 51668; 51908; 51968; 52371; 52745; 53056; 53365; 53837; 54248; 54594; 54977; 55414; 55491; 55541; 55621; 56104; 56237; 56545; 56975; 57269; 57768; 57839; 58087; 58295; 33471.67; 33594; 34119; 35200; 35244; 36107; 36600; 36932; 37463; 37821; 37904; 38338; 38532; 38605; 38668; 38850; 39114; 39542; 40079; 40715; 41150; 43359; 43582; 43760; 44619; 44806; 45127; 45540; 45991; 46386; 46687; 151.85; 306; 599; 815; 991; 1367; 2144; 2176; 2783; 2891; 2934; 3073; 3382; 3538; 3608; 3654; 3696; 3785; 3920; 4294; 34236; 438; 505; 626; 686; 757; 924; 1059; 1244; 1305; 1350; 1510; 1793; 2027; 2546; 2888; 3366; 3684; 3797; 3969; 4806; 34496; 556; 811; 1044; 1300; 1556; 1787; 1997; 2996; 3217; 3520; 3771; 4272; 4630; 4999; 5466; 5824; 6078; 6815; 7284; 7796; 8057; 8736; 8931; 9205; 9548; 9896; 10044; 10499; 10514	Critical Depths reviewed and addressed. Remaining critical depths are appropriate.

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XS CD 02	Critical Depth occurs at $assignedname$ flood. Flow Code will be "C". The smallest channel n-value is less than 0.025. Please investigate whether this selection is appropriate	3661	Comment Addressed.
~~XS CT 03~~	~~Maximum number of iterations is $maxnoiter$. It should be the default value of 20.~~		
XS DC 04L	There is no flow on the right overbank at the downstream cross section $presecno$ for the 1%-annual-chance flood. There is no flow on the left overbank at this Section $secno$. Consider placing a cross section in between these sections. The HEC-RAS geometry file may need to be recreated using a GIS program.	6150; 6542; 7031; 7968; 8000; 8018; 8034; 8059; 8079; 8143; 10545; 12018; 13932; 14841; 15315; 18812; 19383; 19713; 20099; 20184; 20948; 21237; 21701; 22178; 22803; 5900.12; 47789; 48162; 48550; 48788; 48990; 49489; 49957; 50456; 50734; 53056; 53365; 53837; 54248; 54594; 56104; 56237; 56545; 56975; 57269; 33594; 33802; 34317; 34825; 36600; 36932; 39542; 40079; 40715; 41150; 42061; 44093; 45991; 46386; 46687; 47453.84; 991; 1367; 33471.67; 438; 505; 626; 686; 757; 924; 1059; 2027; 2546; 4356; 4623; 4806; 5032; 5351; 5701; 5801; 342.36; 556; 811; 1044; 1300; 1556; 1787; 1997; 2239; 2785; 2996; 3217; 3520; 4272; 4630; 4999; 6815; 7284; 7796; 8057; 8258; 8434; 8547; 8736; 8931; 9205; 9548; 9896; 10044; 10499; 10514	Reviewed: Natural topography limits flow. Modeling approach is appropriate.
XS DC 04R	There is no flow on the left overbank at the downstream cross section $presecno$. There is no flow on the right overbank at this Section $secno$ for the 1%-annual-chance flood. Consider placing a cross section in between these sections. The HEC-RAS geometry file may need to be recreated using a GIS program.	6150; 6542; 7031; 7968; 8000; 8018; 8034; 8059; 8079; 8143; 10545; 12018; 13932; 14841; 15315; 18812; 19383; 19713; 20099; 20184; 20948; 21237; 21701; 22178; 22803; 5900.12; 47789; 48162; 48550; 48788; 48990; 49489; 49957; 50456; 50734; 53056; 53365; 53837; 54248; 54594; 56104; 56237; 56545; 56975; 57269; 33594; 33802; 34317; 34825; 36600; 36932; 39542; 40079; 40715; 41150; 42061; 44093; 45991; 46386; 46687; 47453.84; 991; 1367; 33471.67; 438; 505; 626; 686; 757; 924; 1059; 2027; 2546; 4356; 4623; 4806; 5032; 5351; 5701; 5801; 342.36; 556; 811; 1044; 1300; 1556; 1787; 1997; 2239; 2785; 2996; 3217; 3520; 4272; 4630; 4999; 6815; 7284; 7796; 8057; 8258; 8434; 8547; 8736; 8931; 9205; 9548; 9896; 10044; 10499; 10514	Reviewed: Natural topography limits flow. Modeling approach is appropriate.
XS DF 01L	Divided flow. Flow code will be DL. The $assignedname$ flood discharge has a divided flow. The starting and ending stations of the cross section should not extend beyond the watershed boundary of the studied stream. Please review the extent of the cross section. If the cross section extends beyond the watershed boundary then the cross sections need to be trimmed and the HEC-RAS geometry file may need to be recreated using a GIS program. Or use the ineffective flow option, if it has not been considered, to limit the extent of the cross section or to block the divided flow area if it is a local depression.	23082; 24652; 28752; 29056; 29995; 181.17; 857; 1110; 1934; 1957; 1980; 2012; 2147; 4447; 4811; 5258; 5635	Reviewed: Modeling approach is appropriate.

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XS DF 01R	Divided flow. Flow code will be DR. The $assignedname$ flood discharge has a divided flow. The starting and ending stations of the cross section should not extend beyond the watershed boundary of the studied stream. Please review the extent of the cross section. If the cross section extends beyond the watershed boundary then the cross section needs to be trimmed and the HEC-RAS geometry file may need to be recreated using a GIS program. Or use the ineffective flow option, if it has not been considered, to limit the extent of the cross section or to block the divided flow area if it is a local depression.	26432; 26592; 26653; 26828; 26876; 26964; 27289; 27483; 27647; 28120; 28736; 29090; 29588; 30706; 30841; 32085; 33067; 3426; 3661	Reviewed: Modeling approach is appropriate.
XS DT 02L	The Left overbank distance of lob is greater than the channel distance of chl by more than two times. The Left overbank distance may be in error. Please review the creation of left overbank, channel and right overbank distances. The HEC-RAS geometry file may need to be recreated using a GIS program. Please resolve the differences between the distances.	7940; 7968; 27289	Comment addressed.
XS EC 01BDL	Cross section extended vertically. Flow Code willbe ER. The $assignedname$ WSEL of $wsel$ is higher than the starting combined GR and Road station elevation of $grelv$. The Left_Sta_Eff is equal to the starting GR station. Section 2 and/or the Road section should be expanded to cover the $assignedname$ floodplain. The HEC-RAS geometry file may need to be recreated using a GIS program. Or use the lid option at the upstream and downstream internal sections and a lateral weir to determine the amount of overflow down the roadway. Or provide explanation why the cross section should not be expanded.	1969(Bridge-DN)	Flow extended vertically at the ineffective flow station. Water surface is bounded by the cross section topography.
XS EC 01BDR	Cross section extended vertically. Flow Code will be ER. The $assignedname$ WSEL of $wsel$ is higher than the ending combined GR and Road station elevation of $grelv$. The Rght_Sta_Eff is equal to the ending GR station. Section 2 and/or the Road section should be expanded to cover the $assignedname$ floodplain. The HEC-RAS geometry file may need to be recreated using a GIS program. Or use the lid option at the upstream and downstream internal sections and a lateral weir to determine the amount of overflow down the roadway. Or provide explanation why the cross section should not be expanded.	1969(Bridge-DN)	Flow extended vertically at the ineffective flow station. Water surface is bounded by the cross section topography.

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XS EC 01BUL	Cross section extended vertically. Flow Code will be EL. The $assignedname$ WSEL of $wsel$ is higher than the starting combined GR and Road station elevation of $grelv$. The Left_Sta_Eff is equal to the starting GR station. Section 3 and/or the Road section should be expanded to cover the $assignedname$ floodplain. The HEC-RAS geometry file may need to be recreated using a GIS program. Or use the lid option at the upstream and downstream internal sections and a lateral weir to determine the amount of overflow down the roadway. Or provide explanation why the cross section should not be expanded.	1969(Bridge-UP)	Flow extended vertically at the ineffective flow station. Water surface is bounded by the cross section topography.
XS EC 01L	Cross section extended vertically. Flow Code will be EL. The $assignedname$ WSEL of $wsel$ is higher than the starting GR station elevation of $grelv$. The Left_Sta_Eff is equal to the starting GR station. If there is divided flow then cross section should be trimmed or the ineffective flow station should be used to block the divided flow. If there is no divided flow then the cross section should be expanded to cover the $assignedname$ floodplain.The HEC-RAS geometry file may need to be recreated using a GIS program. Or provide explanation why the cross section should not be expanded.	23082; 23924; 24652; 25350; 28752; 4447; 4811; 5258	Flow extended vertically at the ineffective flow station. Water surface is bounded by the cross section topography.
XS FS 01	The name of the stream is $streamname$. $frictionslopename$ method was used. The Average Conveyance method should be selected.		
XS IF 02L	Flow code will be MIL. Multiple (block) Ineffective Stations are selected for the left overbank at this River Station. This is not Section 2 or Section 3 of Multiple Openings or Multiple Culverts. Please explain why the multiple blocks ineffective flow option was used. Consider using the normal ineffective flow option.	26876; 26964; 27122; 27289; 27483; 27647; 28120; 28483; 29995; 30841; 30878; 32085; 33067	Multiple ineffective flow stations used to model multiple profiles.
XS IF 02R	Flow code will be MIR. Multiple (block) Ineffective Stations are selected for the right overbank at this River Station. This is not Section 2 or Section 3 of Multiple Openings or Multiple Culverts. Please justify why the Multiple Blocks Ineffective Flow option was used. Consider using the normal Ineffective Flow option.	6150; 7031; 7326; 7465; 7940; 7968; 8000; 8018; 8034; 8059; 8143; 8214; 8308; 8337; 8394; 8468; 8554; 8765; 8782; 8841; 8858; 8923; 9342; 9790; 9853; 9923; 10013; 10085; 12330; 12371; 12415; 12738; 13932; 17536; 17933; 18812; 20099; 20184; 21237; 21701; 22803; 23924; 24652; 28932; 29178; 514; 5426; 47789; 48162; 48550; 48788; 48990; 49489; 51908; 51968; 55621; 56975; 57768; 57839; 58087; 35244; 36600; 38668; 38850; 39114; 44806; 45127; 45540; 46386; 151.85; 306; 599; 815; 991; 2783; 2891; 3073; 438; 505; 626; 924; 1059; 1244; 1305; 1350; 1510; 1793; 2027; 2546; 2888; 3684; 3969; 344.96; 1044; 1300; 2996; 3217; 3520; 4272; 5824; 6815; 7796; 8057; 8736; 9896; 10044	Multiple ineffective flow stations used to model multiple profiles.

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XS IF 03L	The Left Ineffective Flow Station is within the channel. The Left Ineffective Flow Station of $ineffstal$ is greater than the LeftBankSta of $bankstal$. The Left Ineffective Flow Station or the LeftBankSta should be adjusted.	32085; 32722; 33067.	Comment is invalid. Ineffective stations are outside channel.
XS IF 03R	The Right Ineffective Flow Station is within the channel. The Right Ineffective Flow Station of $ineffstar$ is less than the RightBankSta of $bankstar$. The Right Ineffective Flow Station or the RightBankSta should be adjusted.	6150; 7031; 7940; 7968; 8000; 8018; 8034; 8059; 8143; 8468; 13932; 18812; 20099; 20184; 21237; 21701; 22803; 23082; 24652; 514; 5426; 47789; 48162; 48550; 48788; 48990; 49489; 55621; 56975; 36600; 39114; 45540; 46386; 438; 505; 626; 924; 1059; 1793; 2027; 2546; 3969; 344.96; 1044; 1300; 2996; 3217; 3520; 4272; 7796; 8057; 8736; 9896; 10044	Comment is invalid. Ineffective stations are outside channel.
XS JT 01	The Junction option is used. For Flood Insurance Studies, this option should be used if the tributary and main stream can have coincident peaks. It is appropriate to use for approximate-studied streams; if the discharges at different time periods are known from the rainfall-runoff model; for loop analysis; and for unsteady flow analysis. The Junction should be removed if the above conditions are not satisfied. Refer to the Help section for information on how to remove a Junction. Sample XS JT 01 HEC-RAS files can be downloaded from http://www.fema.gov/library/viewRecord.do?id=2300 under the Cross Section Check Data Sets section.		
XS JT 02	The name of the junction is $junctionname$. The length from the $riverreach1$ to the $riverreach2$ is equal to zero. Please insert the length across the junction in the Junction Data window in HEC-RAS if the junction can be considered.		

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ST IF 01S2R	This is Section 2 of a hydraulic structure. The highest flood frequency that has low or pressure flow is $profilename$. However, the Right Ineffective Flow Station was not considered at Section 2. The ineffective flow station and elevation should be inserted. The right ineffective flow elevation should be equal to wsel2 of $wsel$. The placement of the right ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	7869(Culvert); 10607(Bridge); 10958(Bridge); 11261(Culvert); 13375(Bridge); 15674(Bridge); 16618(Bridge); 51459(InlineWeir); 37895(Culvert); 38639(Bridge); 43327(Culvert); 2158(Bridge); 3564(InlineWeir)	Modeling approach is appropriate. Ineffective not necessary.
ST IF 01S3L	This is Section 3. The highest flood frequency that has low or pressure flow is $profilename$. However, the Left Ineffective Flow station was not considered at Section 3. The ineffective flow station and elevation should be inserted. The left ineffective flow elevation should be equal to lmntprdu of $lmntprdu$. The placement of the left ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	7488(Bridge); 9393(Bridge); 10099(Bridge); 10130(Bridge); 10607(Bridge); 10958(Bridge); 11261(Culvert); 15674(Bridge); 16618(Bridge); 17502(Bridge); 55477(InlineWeir); 57797(Bridge); 35231(Bridge); 43327(Culvert); 2917(Bridge); 3586(InlineWeir); 3672(Bridge); 3988(Culvert); 6027(InlineWeir)	Modeling approach is appropriate. Ineffective not necessary.
ST IF 01S3R	This is Section 3 of a hydraulic structure. The highest flood frequency that has low or pressure flow is $profilename$. However, the Right Ineffective Flow station was not considered at Section 3. The ineffective flow station and elevation should be inserted. The right ineffective flow elevation should be equal to rmntprdu of $rmntprdu$. The placement of the right ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	7869(Culvert); 9393(Bridge); 10607(Bridge); 10958(Bridge); 11261(Culvert); 12765(InlineWeir); 13375(Bridge); 15674(Bridge); 51459(InlineWeir); 37895(Culvert); 2158(Bridge); 3988(Culvert); 3564(InlineWeir)	Modeling approach is appropriate. Ineffective not necessary.
ST IF 02S2L	This is Section 2. The selected profile is $profilename$. Weir flow occurs at ($strucname$). However, left ineffective flow station was not considered at Section 2. The ineffective flow station and elevation should be inserted. The left ineffective flow elevation should be less than the wsel2 of $wsel$ of the $profilename$ profile. The placement of the left ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	25328(Bridge); 26385(Culvert); 26576(Bridge); 26815(Bridge); 2645(Bridge); 2957(Bridge); 3416(Bridge)	Modeling approach is appropriate. Ineffective not necessary.

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ST IF 02S2R	This is Section 2. The selected profile is $profilename$. Weir flow occurs at ($strucname$). However, right ineffective flow station was not considered at Section 2. The ineffective flow station and elevation should be inserted. The right ineffective flow elevation should be less than the wsel2 of $wsel$ of the $profilename$ profile. The placement of the right ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	25328(Bridge); 1969(Bridge); 2957(Bridge)	Modeling approach is appropriate. Ineffective not necessary.
ST IF 02S3L	This is Section 3. The selected profile is $profilename$. Weir flow occurs at ($strucname$). However, left ineffective flow station was not considered at Section 3. The ineffective flow station and elevation should be inserted. The left ineffective flow elevation should be equal to lmntprdu of $lmntprdu$. The placement of the left ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	25328(Bridge); 26385(Culvert); 26576(Bridge); 26815(Bridge); 2645(Bridge); 2957(Bridge); 3416(Bridge)	Modeling approach is appropriate. Ineffective not necessary.
ST IF 02S3R	This is Section 3. The selected profile is $profilename$. Weir flow occurs at ($strucname$). However,right ineffective flow station was not considered at Section 3. The ineffective flow station and elevation should be inserted. The right ineffective flow elevation should be equal to rmntprdu of $rmntprdu$. The placement of the right ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	25328(Bridge); 1969(Bridge); 2957(Bridge)	Modeling approach is appropriate. Ineffective not necessary.
ST IF 05S2L	This is Section 2 of a hydraulic structure. The left ineffective flow station is within the opening area of the structure. The left ineffective flow station of $ineffstal$ is greater than the downstream left abutment station of $abutstal$ at ($strucname$). The Left ineffective flow station should be adjusted.	30841(InlineWeir)	Ineffective stations are located within the weir stationing and block areas of non-conveyance. Ineffective flow stations do not block bridge/culvert opening.
ST IF 05S2R	This is Section 2 of a hydraulic structure. The right ineffective flow station is within the opening area of the structure. The right ineffective flow station of $ineffstar$ is less than the upstream right abutment station of $abutstar$ at ($strucname$). The Right ineffective flow station should be adjusted.	7465(Bridge); 8308(Bridge); 8765(Bridge); 8858(Bridge); 9342(Bridge); 9790(Bridge); 12371(Bridge); 12738(InlineWeir); 51908(Bridge); 57768(Bridge); 151.85(Culvert); 2891(Bridge); 1305(InlineWeir); 5824(InlineWeir)	Ineffective stations are located within the weir stationing and block areas of non-conveyance. Ineffective flow stations do not block bridge/culvert opening.

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ST IF 05S3L	This is Section 3 of a hydraulic structure. The left ineffective flow station is within the opening area of the structure. The left ineffective flow station of $ineffstal$ is greater than the upstream left abutment station of $abutstal$ at ($strucname$). The Left ineffective flow station should be adjusted.	26592(Bridge); 26828(Bridge); 30878(InlineWeir)	Ineffective stations are located within the weir stationing and block areas of non-conveyance. Ineffective flow stations do not block bridge/culvert opening.
ST IF 05S3R	This is Section 3 of a hydraulic structure. The right ineffective flow station is within the opening area of the structure. The right ineffective flow station of $ineffstar$ is less than the upstream right abutment station of $abutstar$ at ($strucname$). The Right ineffective flow station should be adjusted.	8337(Bridge); 8782(Bridge); 8923(Bridge); 9853(Bridge); 12415(Bridge); 51968(Bridge); 38668(Bridge); 44806(Bridge); 306(Culvert); 1350(InlineWeir); 3684(InlineWeir)	Ineffective stations are located within the weir stationing and block areas of non-conveyance. Ineffective flow stations do not block bridge/culvert opening.
ST IF 07S1L	This is Section 1. Left Ineffective flow option was considered at this section. However, it should be a fully expanded cross section. Ineffective flow stations and elevations should be cleared from this section, unless the areas beyond the ineffective flow stations are not within the flow path of the stream. This message should be ignored if this section is Section 3 of the downstream structure.	26653(Bridge); 28483(Bridge); 30706(InlineWeir); 1934(Bridge)	Ineffective stations are used to block areas of non-conveyance.
ST IF 07S1R	This is Section 1. Right Ineffective flow option was considered at this section. However, it should be a fully expanded cross section. Ineffective flow stations and elevations should be cleared from this section, unless the areas beyond the ineffective flow stations are not within the flow path of the stream. This message should be ignored if this section is Section 3 of the downstream structure.	7326(Bridge); 8214(Bridge); 8554(Bridge); 8841(Bridge); 12330(Bridge); 26509(Bridge); 28932(Bridge); 30706(InlineWeir); 3345(Bridge); 2783(Bridge); 1244(InlineWeir); 2888(InlineWeir)	Ineffective stations are used to block areas of non-conveyance.
ST IF 07S4L	This is Section 4. Left Ineffective flow option was considered at this section. However, it should be a fully expanded cross section. Ineffective flow stations and elevations should be cleared from this section, unless the areas beyond the ineffective flow stations are not within the flow path of the stream. This message should be ignored if this section is Section 2 of the upstream structure.	26653(Bridge); 26876(Bridge); 2012(Bridge)	Ineffective stations are used to block areas of non-conveyance.

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ST IF 07S4R	This is Section 4. Right Ineffective flow option was considered at this section. However, it should be a fully expanded cross section. Ineffective flow stations and elevations should be cleared from this section, unless the areas beyond the ineffective flow stations are not within the flow path of the stream. This message should be ignored if this section is Section 2 of the upstream structure.	8394(Bridge); 8841(Bridge); 8974(Bridge); 12633(Bridge); 28932(Bridge); 29178(Bridge); 3661(Bridge)	Ineffective stations are used to block areas of non-conveyance.
ST IF 10S2L	This is Section 2 of a ($Structure$). More than one set of Left Ineffective Flow Stations were considered. There is only one structure at this location. Multiple Block Ineffective Flow option should not be used unless the area blocked by the ineffective flow stations can be considered non conveyance. cHECk-RAS will only check the ineffective flow elevations adjacent to the structure opening.	7465(Bridge); 8308(Bridge); 8765(Bridge); 8858(Bridge); 9342(Bridge); 9790(Bridge); 10085(Bridge); 10109(Bridge); 12371(Bridge); 13359(Bridge); 17458(Bridge); 26789(Bridge); 51908(Bridge); 57768(Bridge); 35200(Bridge); 38605(Bridge); 44619(Bridge); 151.85(Culvert); 2144(Bridge); 2891(Bridge); 3654(Bridge); 3920(Culvert)	Ineffective stations are used to block areas of non-conveyance. Many of these locations use normal ineffective flow stations.
ST IF 10S2R	This is Section 2 of a ($Structure$). More than one set of Right Ineffective Flow Stations were considered. There is only one structure at this location. Multiple Block Ineffective Flow option should not be used unless the area blocked by the ineffective flow stations can be considered non conveyance. cHECk-RAS will only check the ineffective flow elevations adjacent to the structure opening.	1957(Bridge)	Ineffective stations are used to block areas of non-conveyance.
ST IF 10S3L	This is Section 3 of a ($Structure$). More than one set of Left Ineffective Flow Stations were considered. There is only one structure at this location. Multiple Block Ineffective Flow option should not be used unless the area blocked by the ineffective flow stations can be considered non conveyance. The cHECk-RAS will only check the ineffective flow elevations adjacent to the structure opening.	7536(Bridge); 8337(Bridge); 8782(Bridge); 8923(Bridge); 9853(Bridge); 10109(Bridge); 10149(Bridge); 12415(Bridge); 13389(Bridge); 16671(Bridge); 17536(Bridge); 51968(Bridge); 57839(Bridge); 35244(Bridge); 38668(Bridge); 43359(Culvert); 44806(Bridge); 306(Culvert); 2176(Bridge); 2934(Bridge); 3696(Bridge)	Ineffective stations are used to block areas of non-conveyance. These locations use normal ineffective flow stations.
ST IF 10S3R	This is Section 3 of a ($Structure$). More than one set of Left Ineffective Flow Stations were considered. There is only one structure at this location. Multiple Block Ineffective Flow option should not be used unless the area blocked by the ineffective flow stations can be considered non conveyance. cHECk-RAS will only check the ineffective flow elevations adjacent to the structure opening.	26592(Bridge); 26828(Bridge); 1980(Bridge)	Ineffective stations are used to block areas of non-conveyance. These locations use normal ineffective flow stations.

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APPENDIX F – SUPPLEMENTAL STRUCTURE INFORMATION

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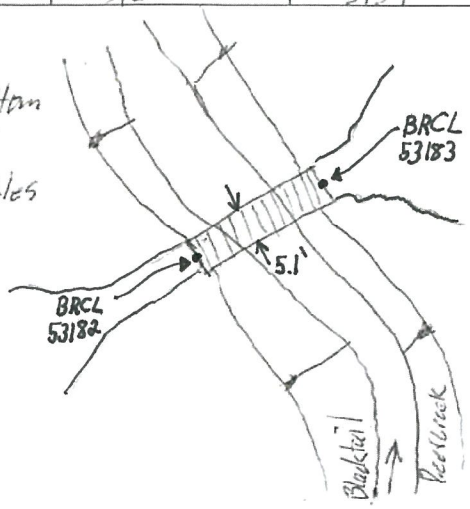
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDL-010				Crew: LDG/JRR	
Stream/Road Name: Blacktail Deer Creek / Private Bridge				Date: 12/15/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
53180 - 53193	NA	53194-53207	53180-53185	NA	NA
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3155	3156	3157	3158	3159	

Channel bottom composed of 6" minus cobbles + gravel

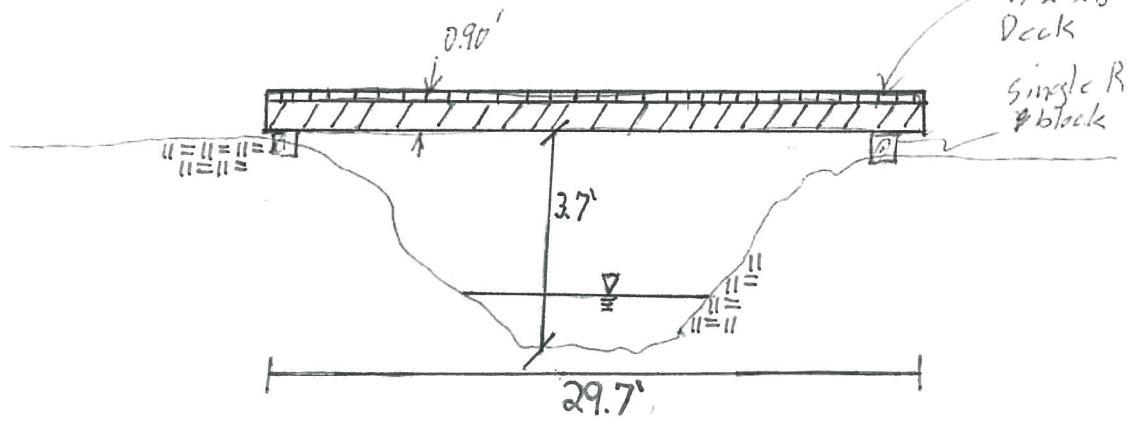


Log/Power pole pedestrian bridge is simply supported without abutments or tie downs + is not hydraulically significant as it would float in high water. Full structure survey not completed.

Plan View

Power pole bridge w/ 2"x8" plank Deck

Single RR tie bedding + block



US Profile View

BDC_010_01_DSCH

BDC_010_01_DSFACE

BDC_010_01_OTXS

BDC_010_01_USCH

BDC_010_01_USFACE

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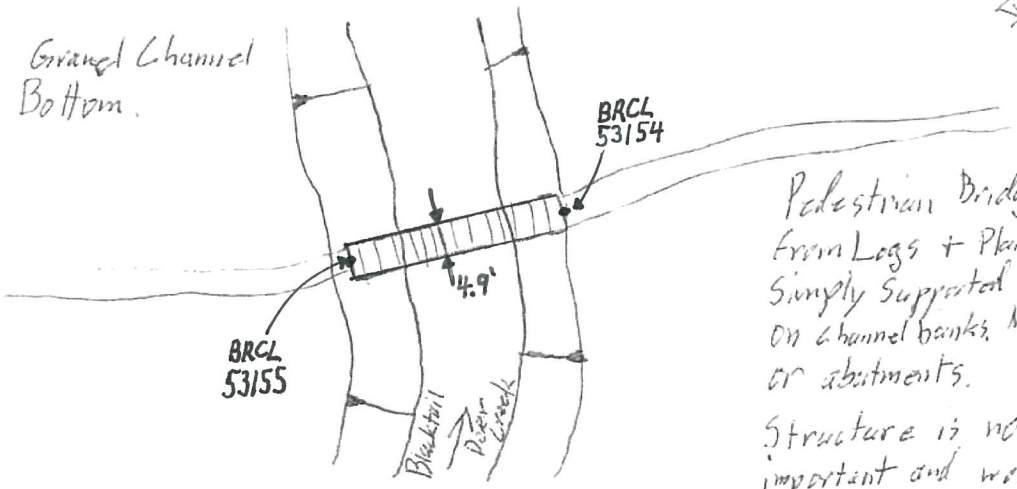
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-020				Crew: LDC / JRK	
Stream/Road Name: Blacktail Deer Creek / Private Bridge				Date: 12/14/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
53152-53165	NA	53166-53179	53152-53157	NA	NA
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3149	3150	3151	3152	3153, 3154	

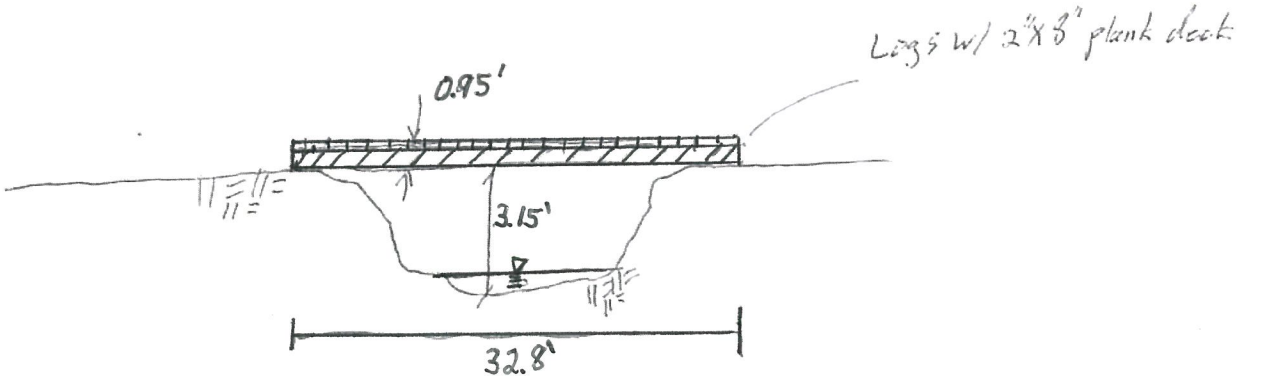
Delete



Plan View

Pedestrian Bridge constructed from Logs + Planking for deck. Simply Supported by resting on channel banks. No apparent tie down or abutments.

Structure is not hydraulically important and would float in a flood event. Full structure survey not completed



US Profile View

BDC_020_01_DSCH

BDC_020_01_DSFACE

BDC_020_01_OTXS

BDC_020_01_USCH

BDC_020_01_USFACE

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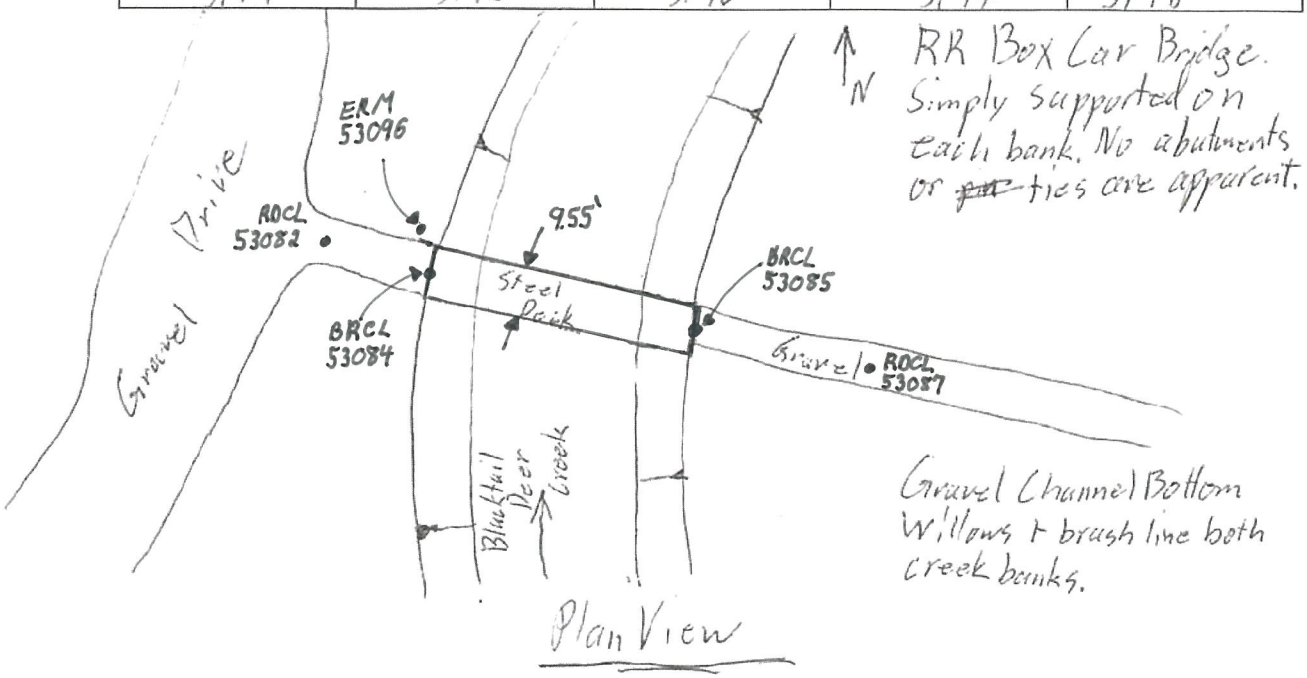
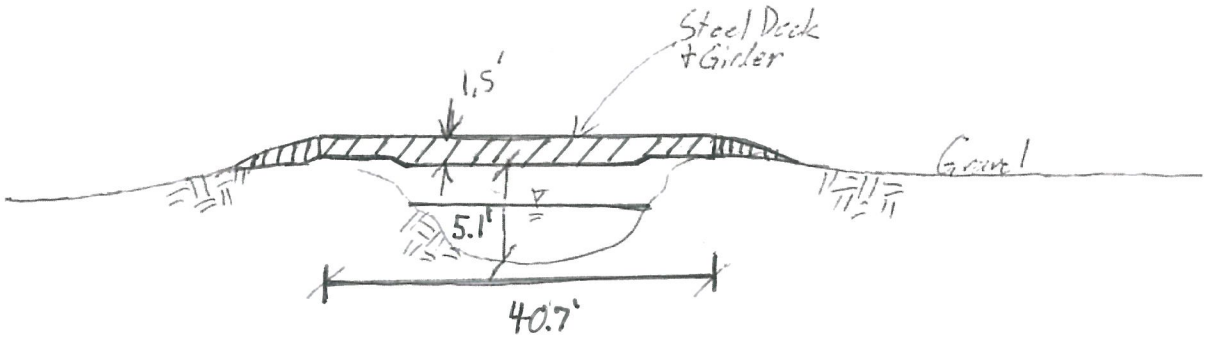
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_030				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek/ Private Bridge				Date: 12/14/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
53081-53096	53139-53151	53126-53138	53081-53087	53111-53125	53097-53110
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3144	3145	3146	3147	3148	



Plan View



US Profile View

BDC_030_01_DSCH

BDC_030_01_DSFACE

BDC_030_01_OTXS

BDC_030_01_USCH

BDC_030_01_USFACE

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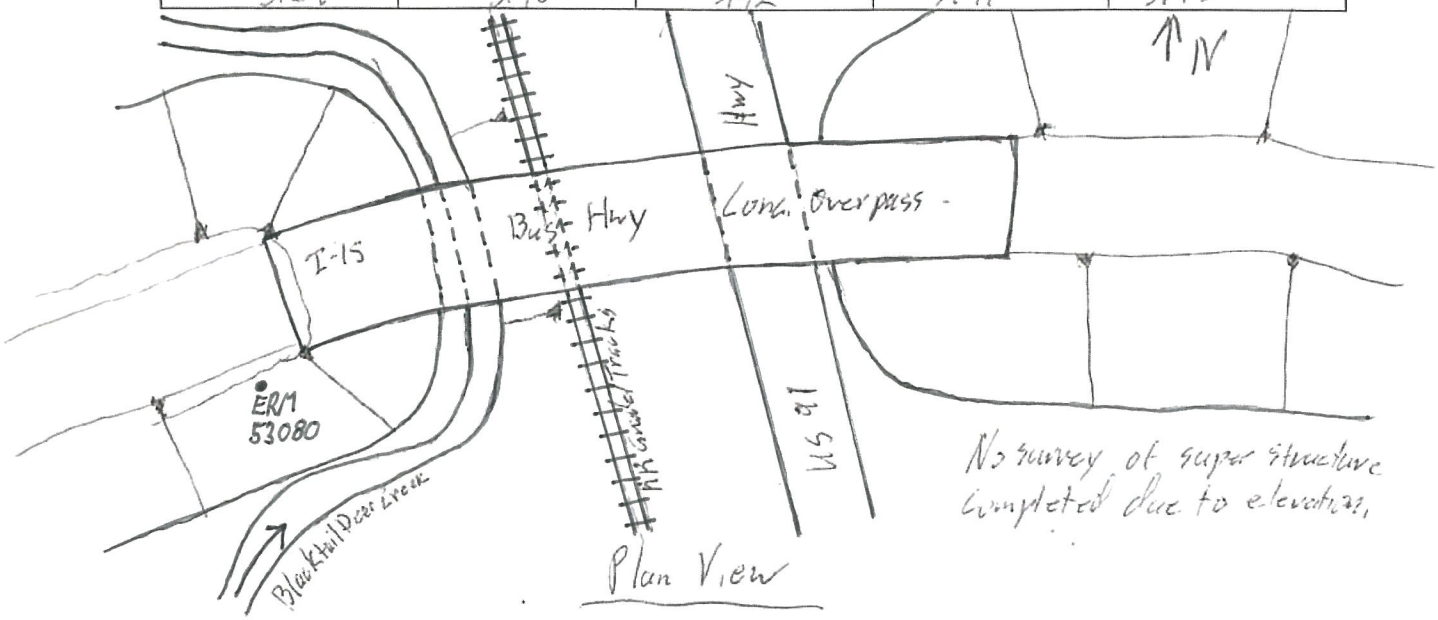
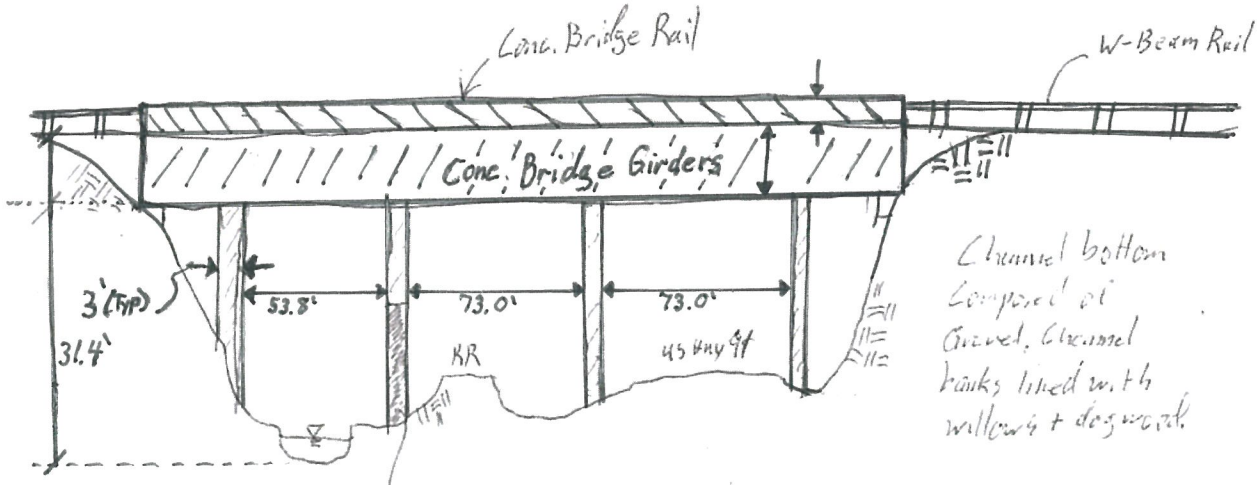
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BPL-040				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek/I-15 Bus.				Date: 12/14/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
53072-53079	53039-53051	53024-53038	53072-53075	53052-53061	53062-53071
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3139	3140	3142	3141	3143	



No survey of super structure completed due to elevation.



Channel bottom composed of Gravel. Channel banks lined with willows + dogwood.

Typical Pier is composed of 3 3' ϕ columns w/ pile cap @ low chord.

This pier only, ≈ 12' high diaphram poured between three ~~pier~~ columns bridge bent.

US Profile View

BDC_040_01_DSCH

BDC_040_01_DSFACE

BDC_040_01_OTXS

BDC_040_01_USCH

BDC_040_01_USFACE

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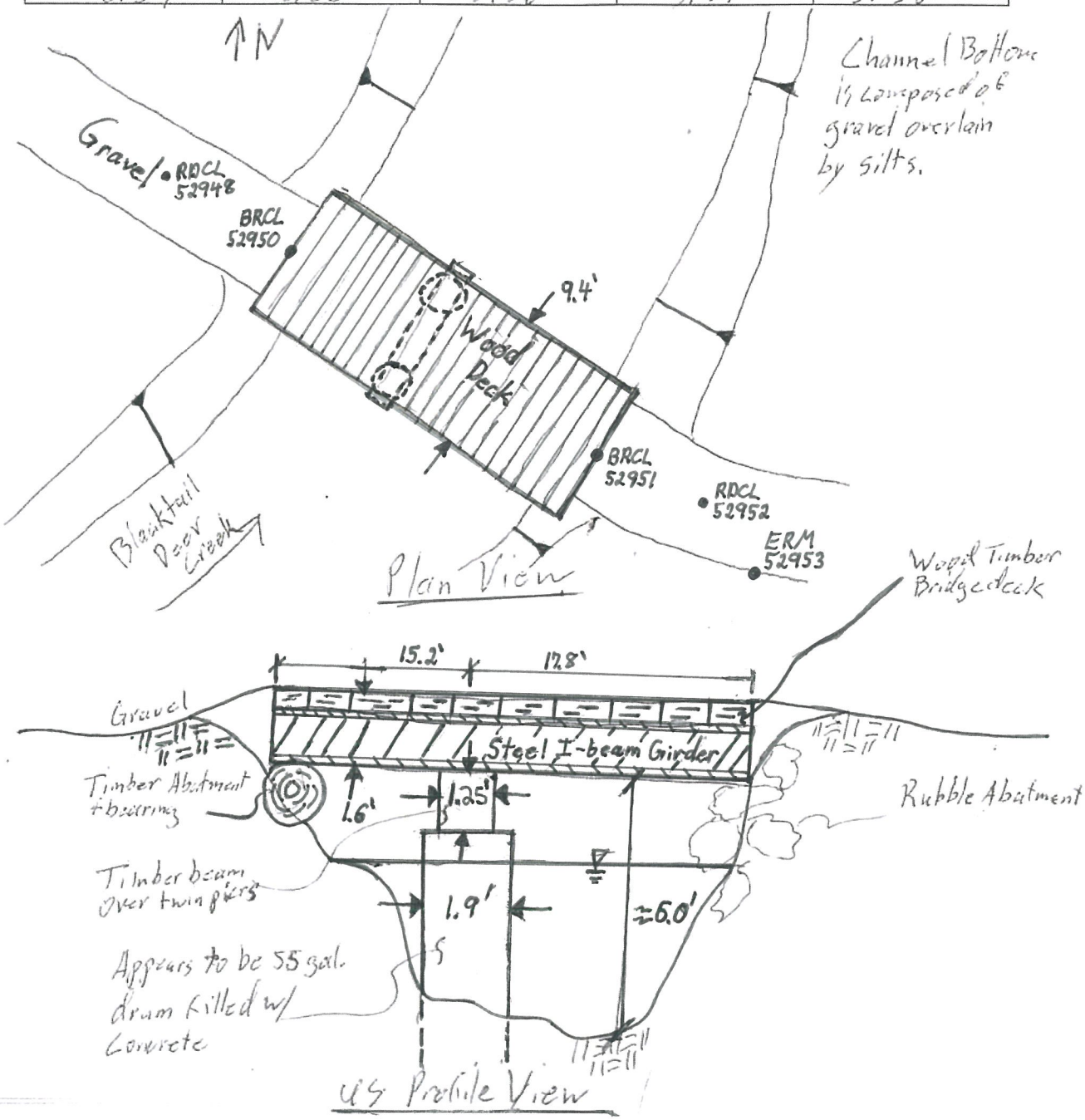
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_050				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / Private Bridge				Date: 12/14/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52948-52965	53008-53023	52995-53007	52948-52952	52982-52994	52966-52981
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3134	3135	3136	3137	3138	



BDC_050_01_DSCH

BDC_050_01_DSFACE

BDC_050_01_OTXS

BDC_050_01_USCH

BDC_050_01_USFACE

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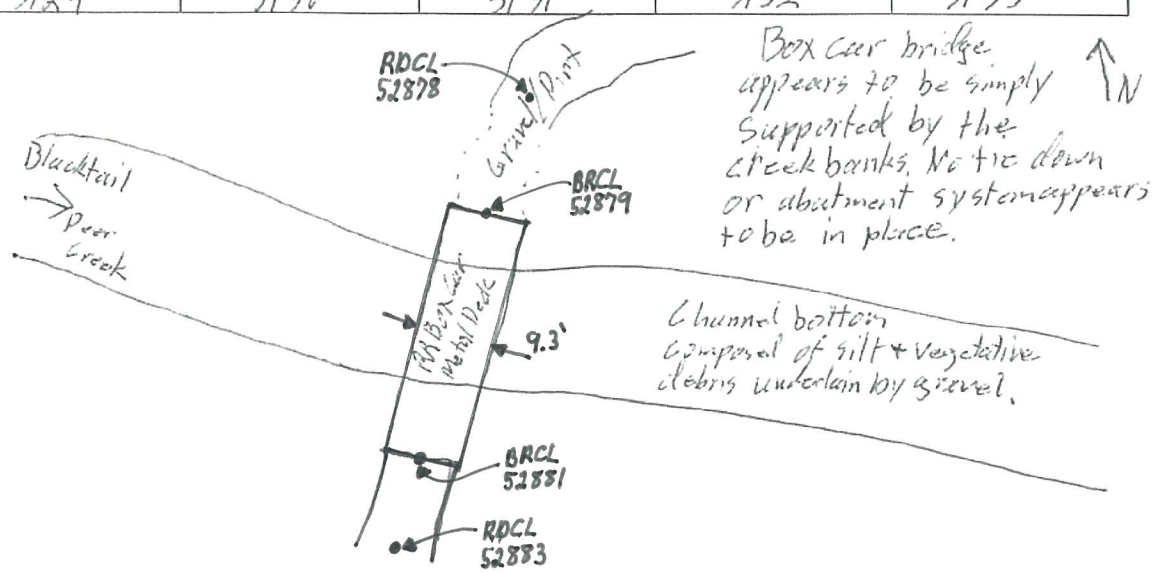
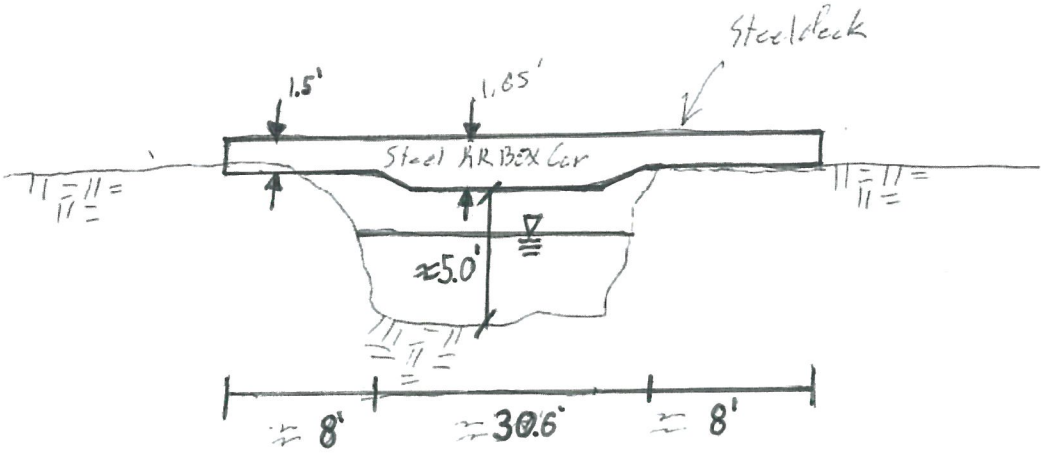
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-055				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / Private bridge				Date:	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52878-52891	52892-52905	52906-52919	52878-52883	52920-52935	52936-52947
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3129	3130	3131	3132	3133	



Plan View



US Profile View

BDC_055_01_DSCH

BDC_055_01_DSFACE

BDC_055_01_OTXS

BDC_055_01_USCH

BDC_055_01_USFACE

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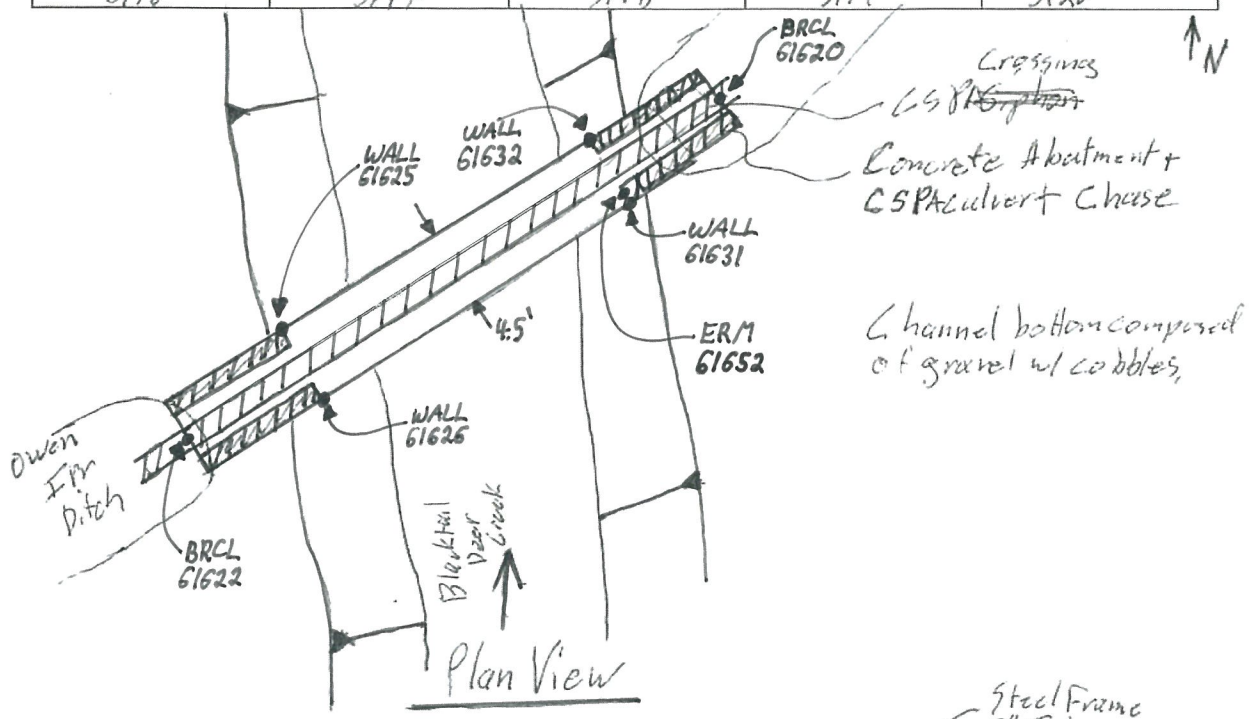
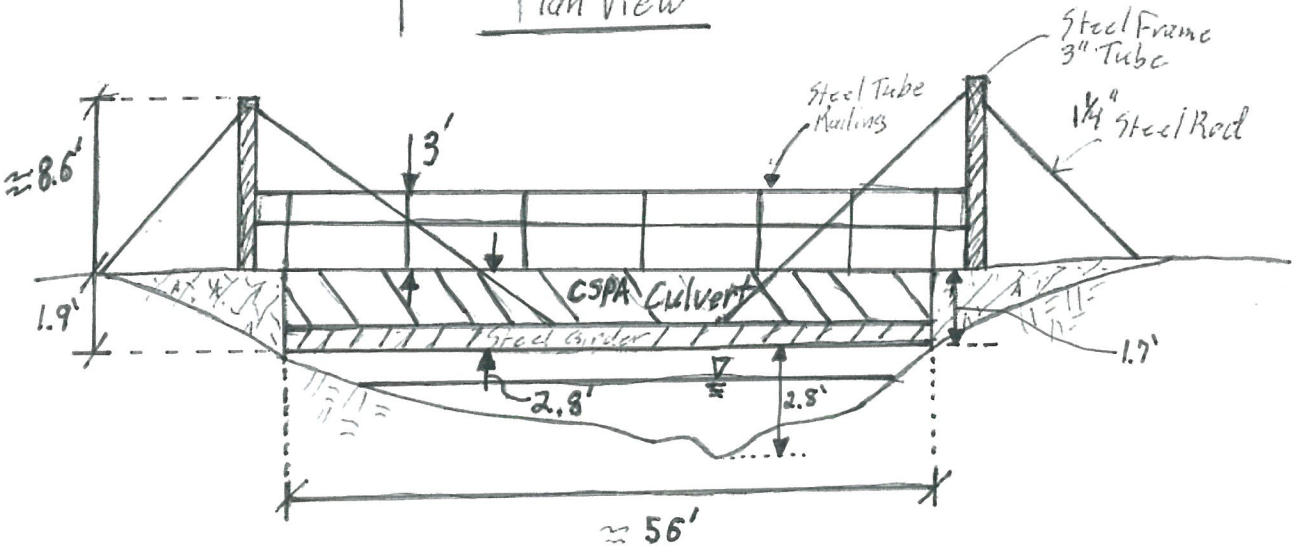
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDG-070				Crew: LDC / JRK	
Stream/Road Name: Blacktail Deer Creek / Irr ~~Siphon~~ crossing ↳ Owen Ditch				Date: 12/09/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61618-61652	52793-52807	52808-52824	61618-61624	61665-61679	61653-61664
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3116	3117	3118	3119	3120	



Plan View



US Profile View

BDC_070_01_DSCH

BDC_070_01_DSFACE

BDC_070_01_OTXS

BDC_070_01_USCH

BDC_070_01_USFACE

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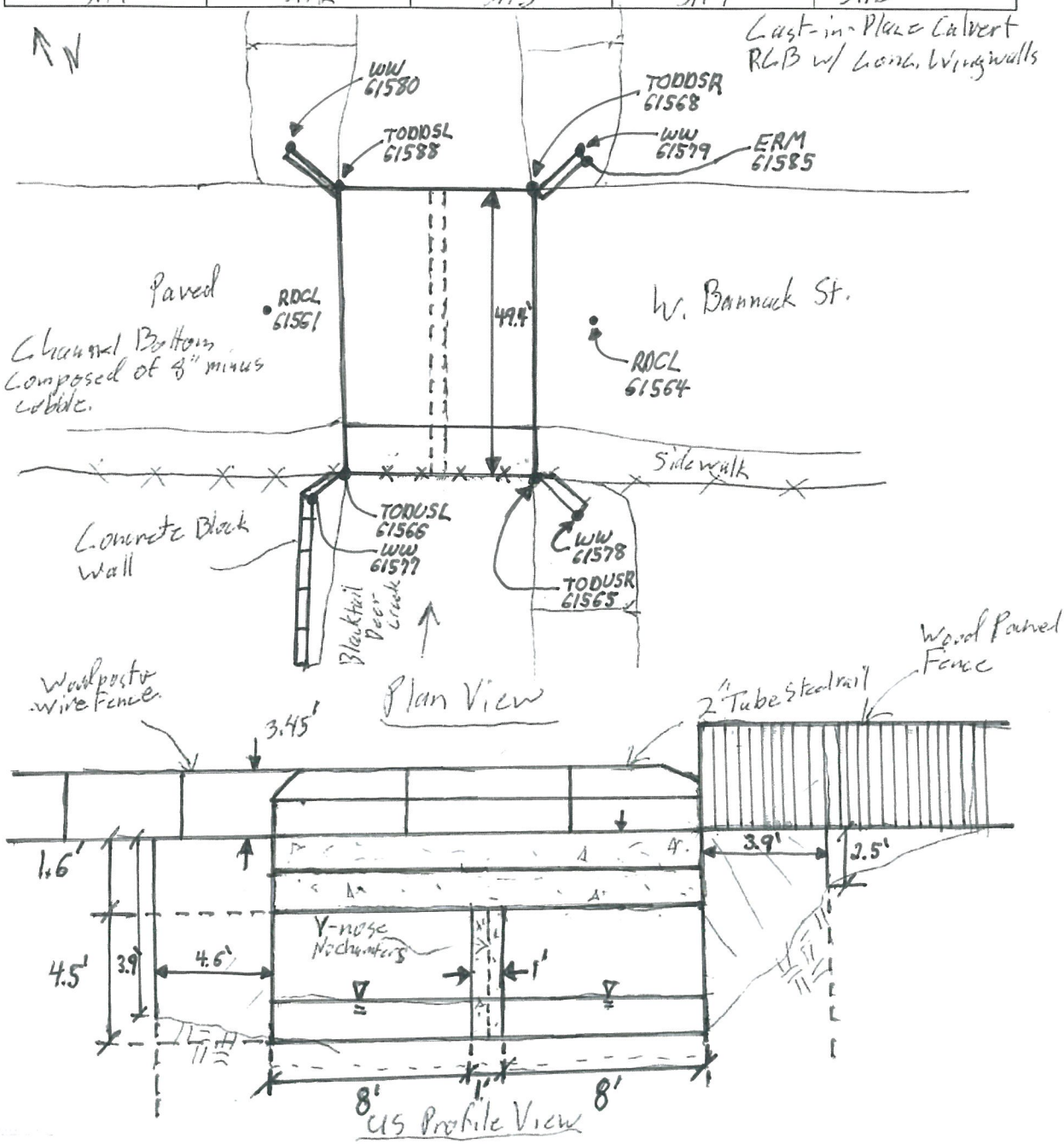
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDL-080				Crew: LDC / JKR	
Stream/Road Name: Blacktail Deer Creek / W. Bannack St.				Date: 12/09/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61561-61596	61606-61617	61594-61604	61561-61564	52764-52792	52757-52781
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3111	3112	3113	3114	3115	



BDC_080_01_DSCH

BDC_080_01_DSFACE

BDC_080_01_OTXS

BDC_080_01_USCH

BDC_080_01_USFACE

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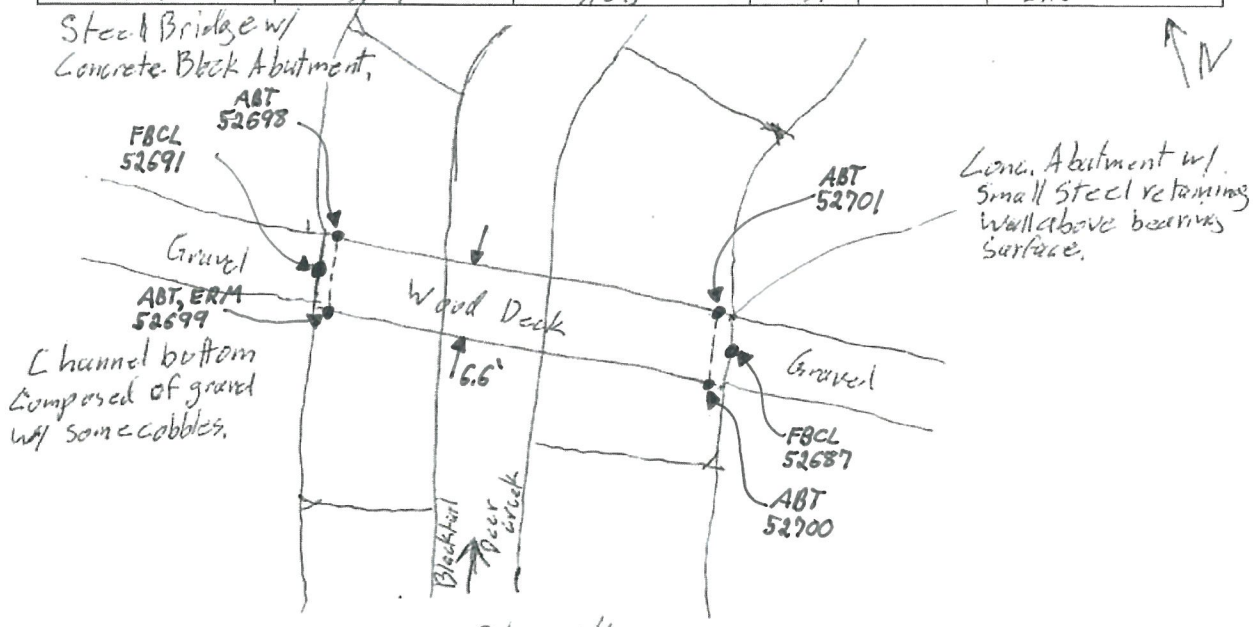
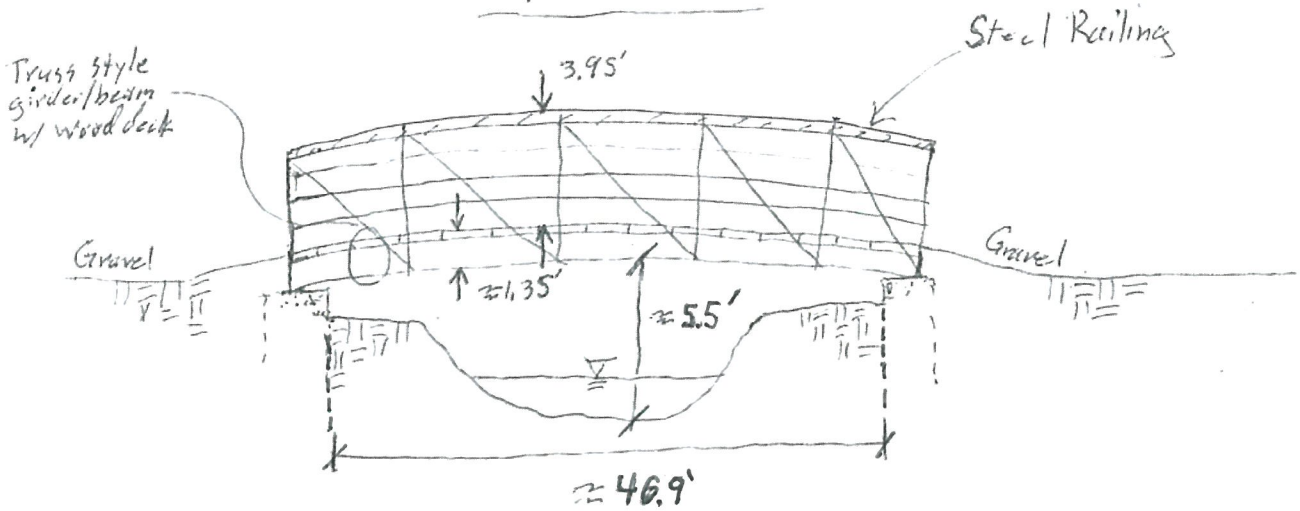
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: ~~BR~~ BDC-090				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / Pedestrian Bridge				Date: 12/09/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52685-52721	52738-52756	52722-52737	52685-52693	61548-61560	61535-61547
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3106	3107	3108	3109	3110	



Plan View



US Profile View

BDC_090_01_DSCH

BDC_090_01_DSFACE

BDC_090_01_OTXS

BDC_090_01_USCH

BDC_090_01_USFACE

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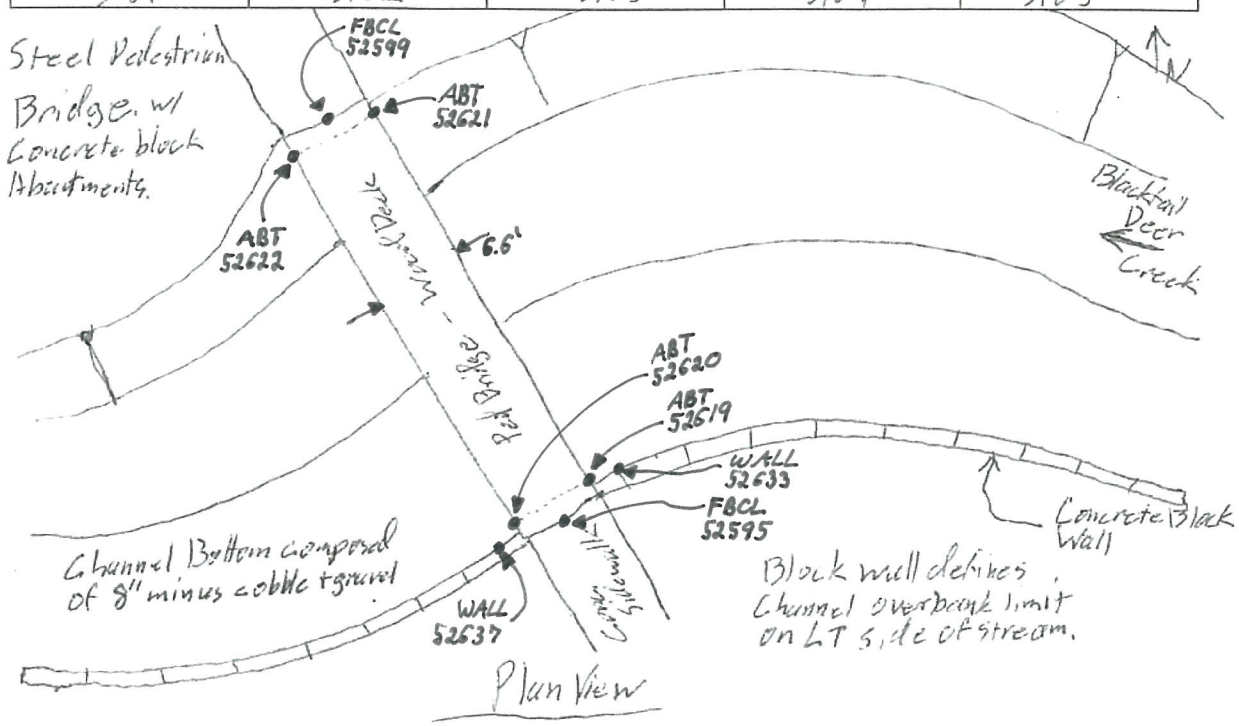
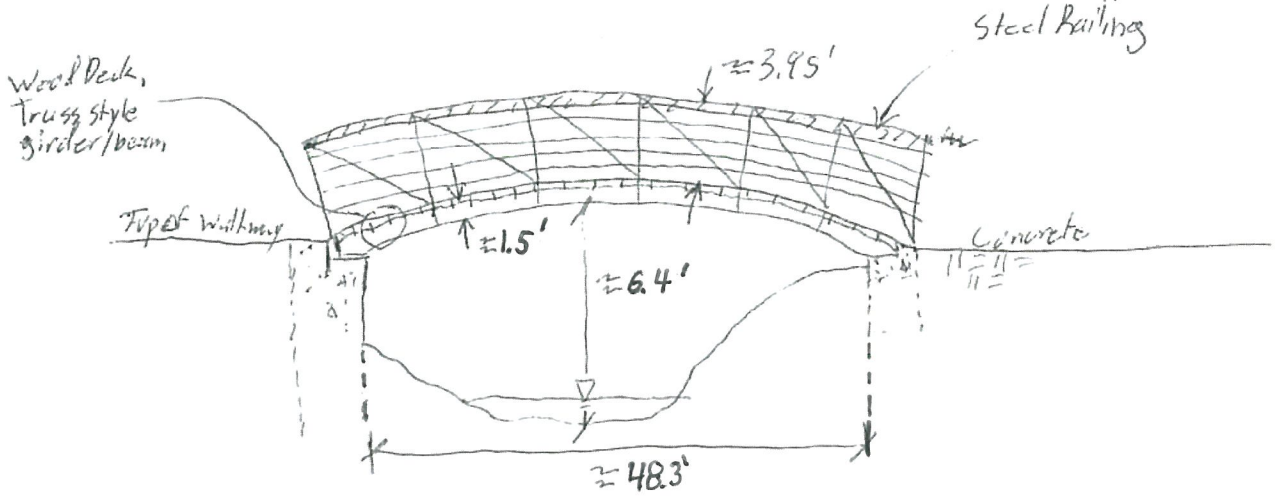
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-100				Crew: LDC-100	
Stream/Road Name: Blacktail Deer Creek / Ped Bridge				Date: 12/09/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52594-52640	52673-52684	52657-52672	52594-52600	52641-52656	52578-52593
↳ and 40001-40002					
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3101	3102	3103	3104	3105	





US Profile View

BDC_100_01_DSCH

BDC_100_01_DSFACE

BDC_100_01_OTXS

BDC_100_01_USCH

BDC_100_01_USFACE

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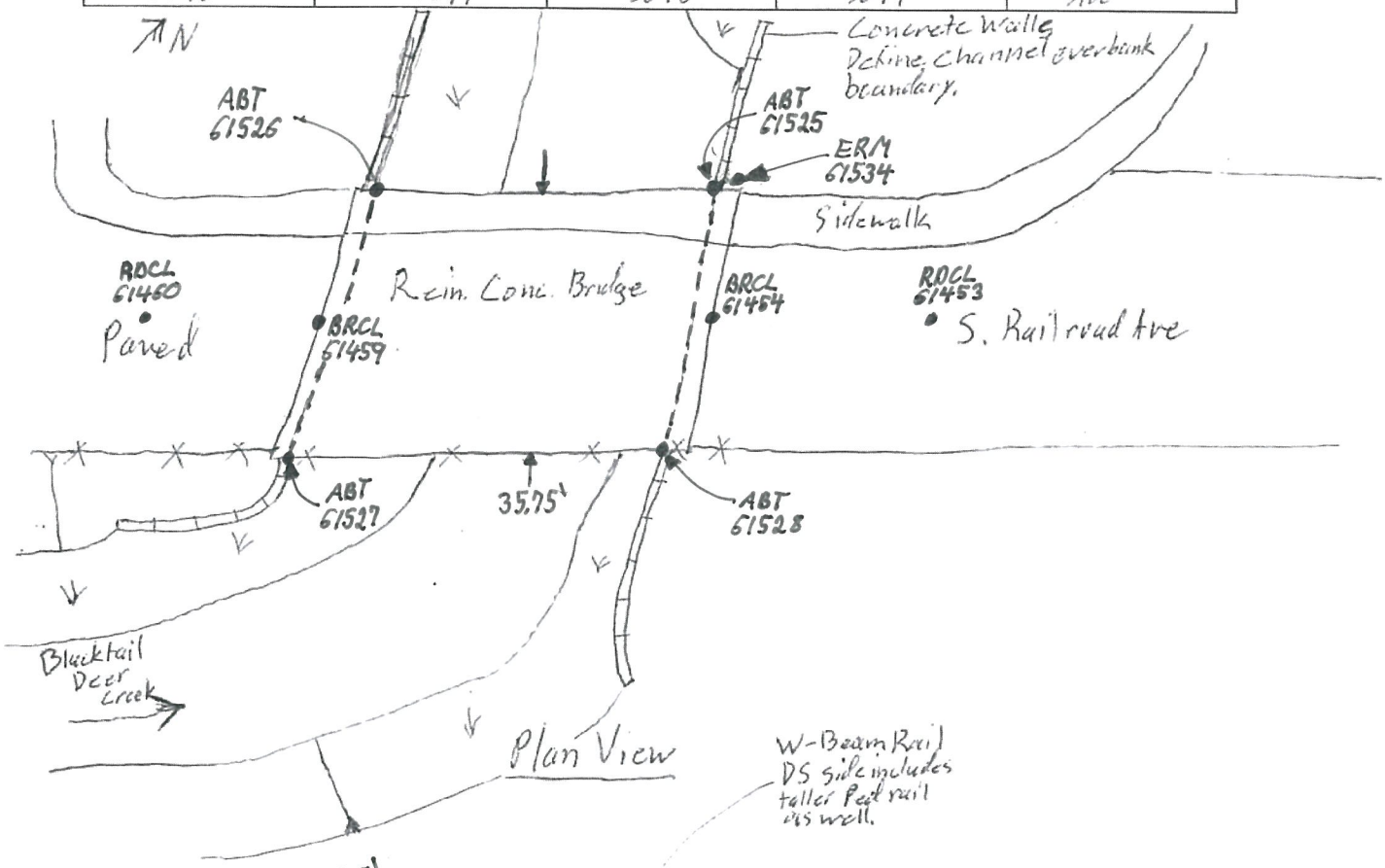
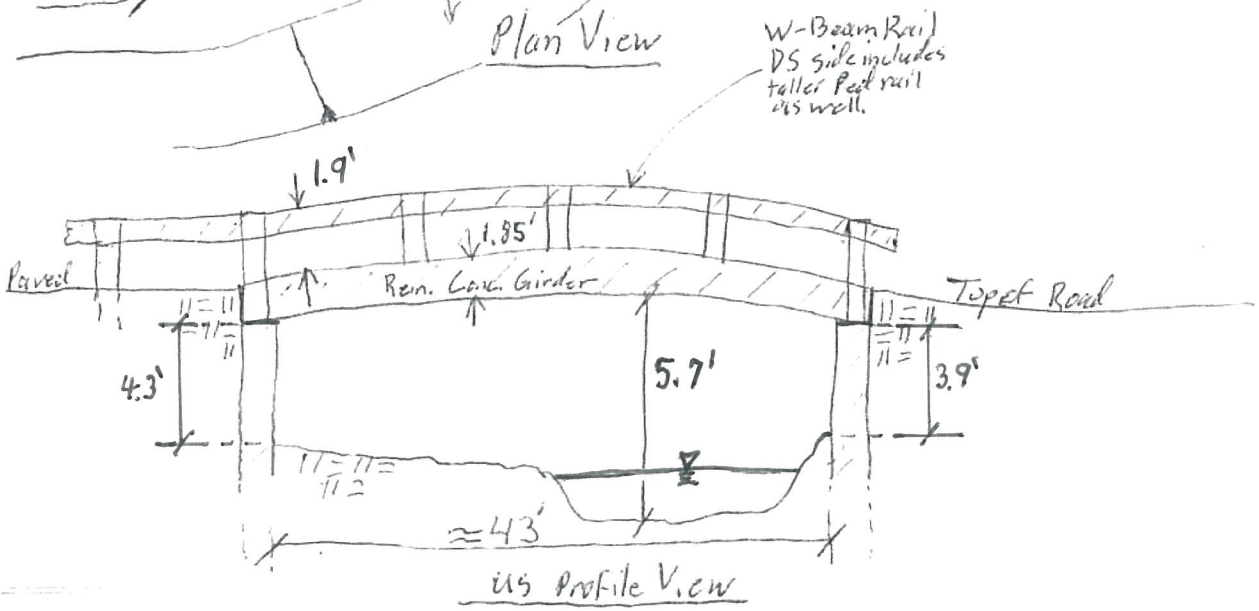
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_110				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / S. RailRoad Ave.				Date: 12/8/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61453-61534	52578-52593	52558-52577	61453-61460	52543-52557	52526-52542
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3096	3097	3098	3099	3100	





BDC_110_01_DSCH

BDC_110_01_DSFACE

BDC_110_01_OTXS

BDC_110_01_USCH

BDC_110_01_USFACE

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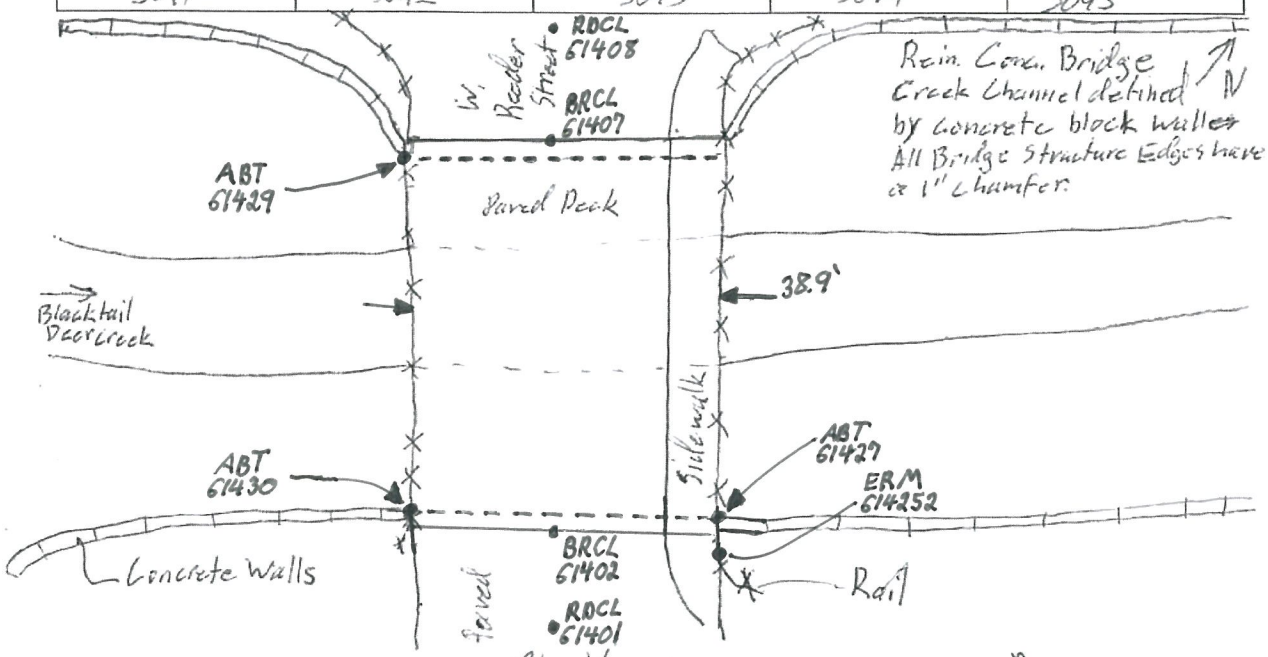
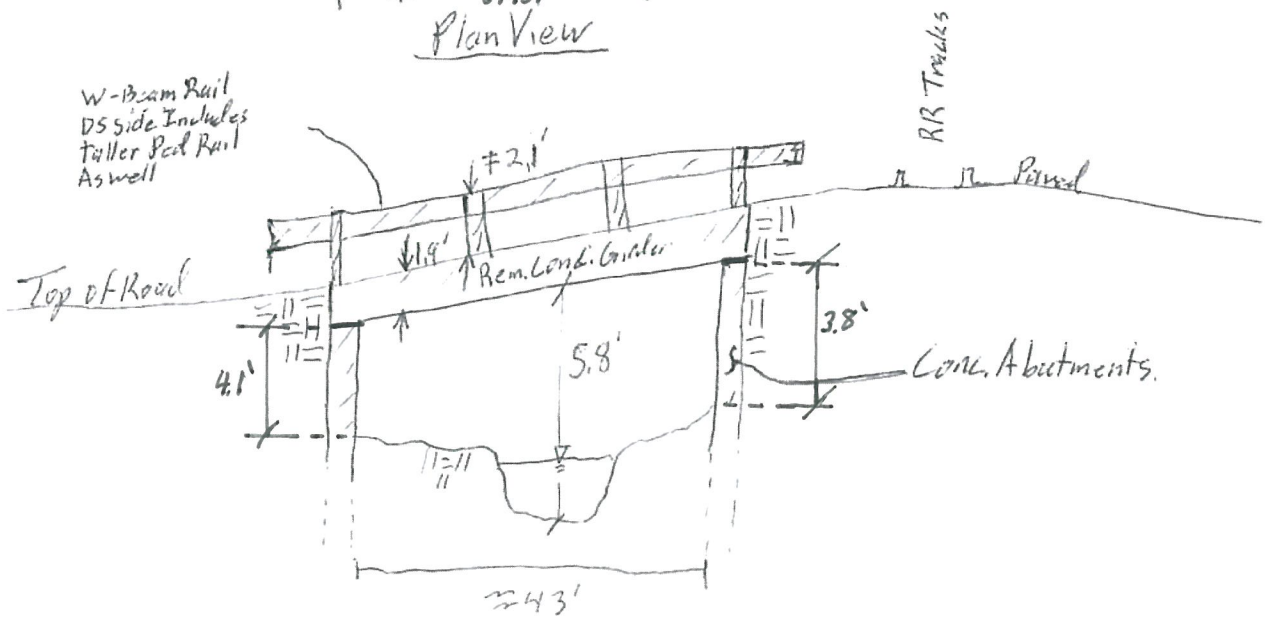
Hydraulic Structure Survey Form:

Structure ID: BDC_120				Crew: LDC / JRK	
Stream/Road Name: Blacktail Deer Creek / W. Reeder St.				Date: 12/8/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61372-61452	52507-52525	52489-52506	61400-61408	52473-52488	52462-52472
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3091	3092	3093	3094	3095	



Plan View



US Profile View

BDC_120_01_DSCH

BDC_120_01_DSFACE

BDC_120_01_OTXS

BDC_120_01_USCH

BDC_120_01_USFACE

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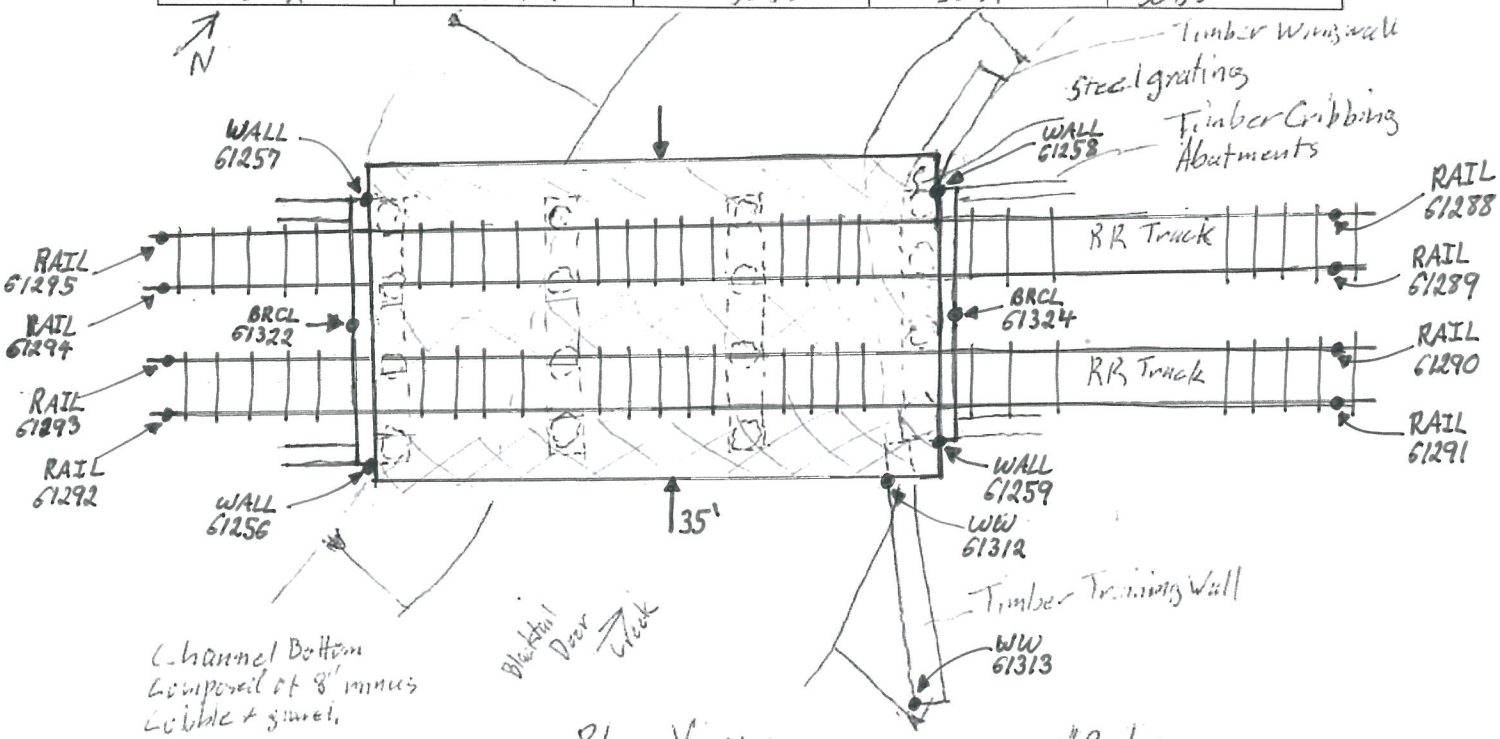
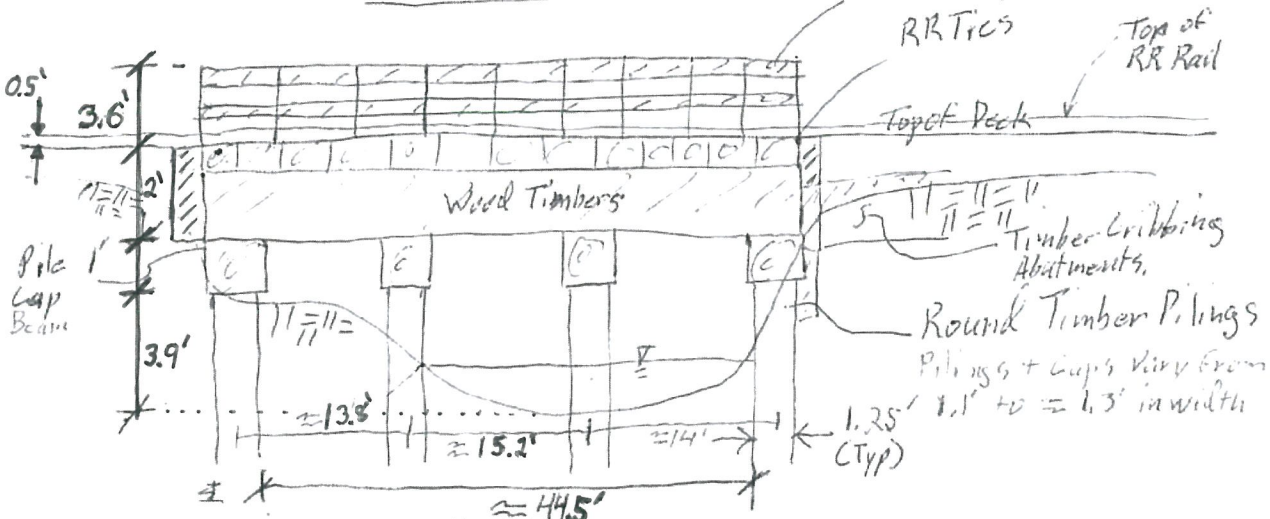
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDG-130				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / RR Bridge				Date: 12/8/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61248-61324	52406-52415	52396-52405	61283-61284	52384-52395	52370-52383
Photos: and 61291-61292					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3081	3082	3083	3084	3085	



Plan View



US Profile View

BDC_130_01_DSCH

BDC_130_01_DSFACE

BDC_130_01_OTXS

BDC_130_01_USCH

BDC_130_01_USFACE

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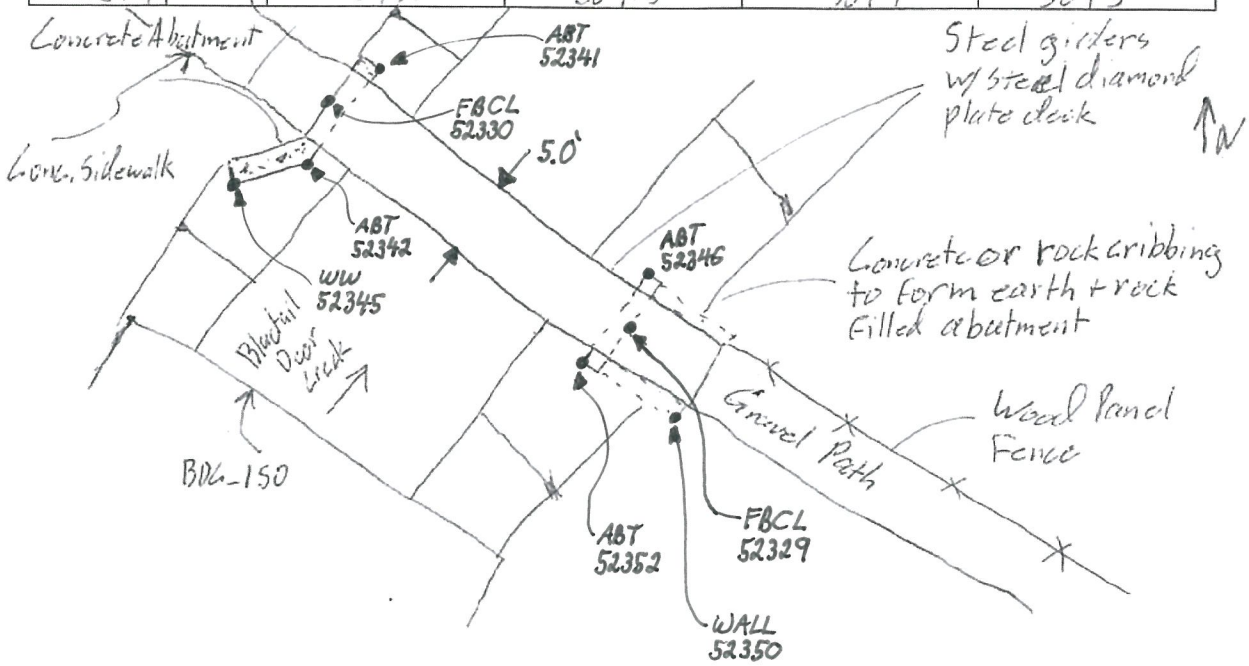
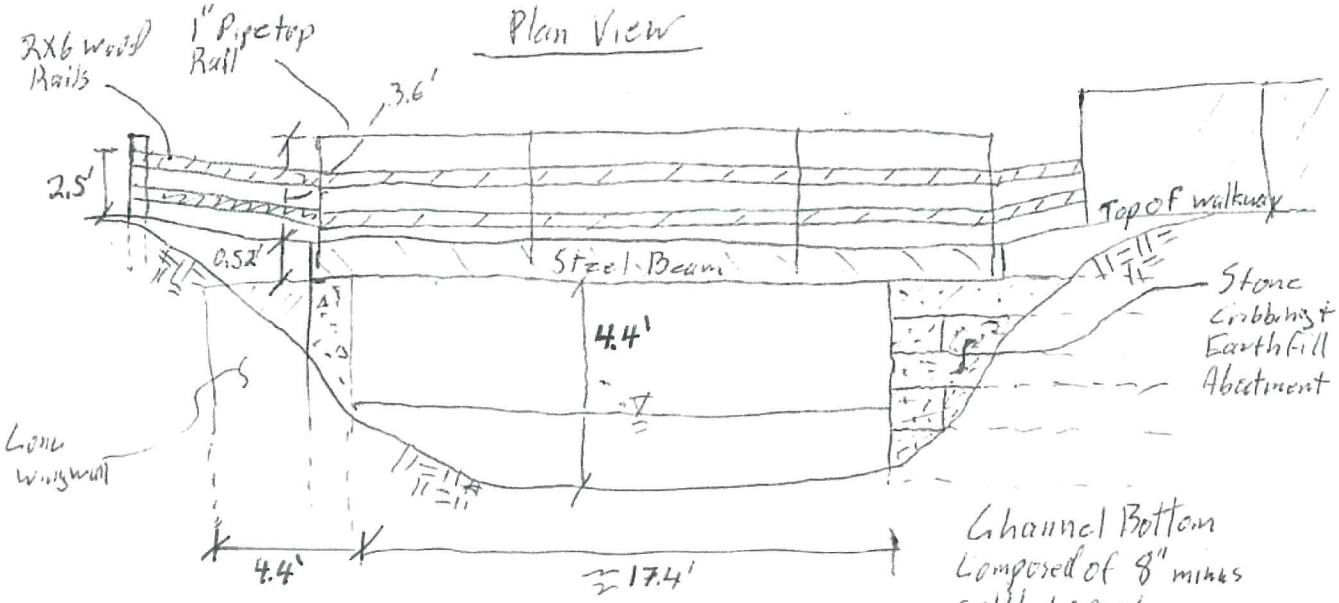
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: ~~Blank~~ BDC-140				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / Ped Bridge				Date: 12/8/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52327-52369	52267-52280	52254-52266	52327-52332	52240-52253	NA
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3071	3072	3073	3074	3075	



Plan View



US Profile View

BDC_140_01_DSCH

BDC_140_01_DSFACE

BDC_140_01_OTXS

BDC_140_01_USCH

BDC_140_01_USFACE

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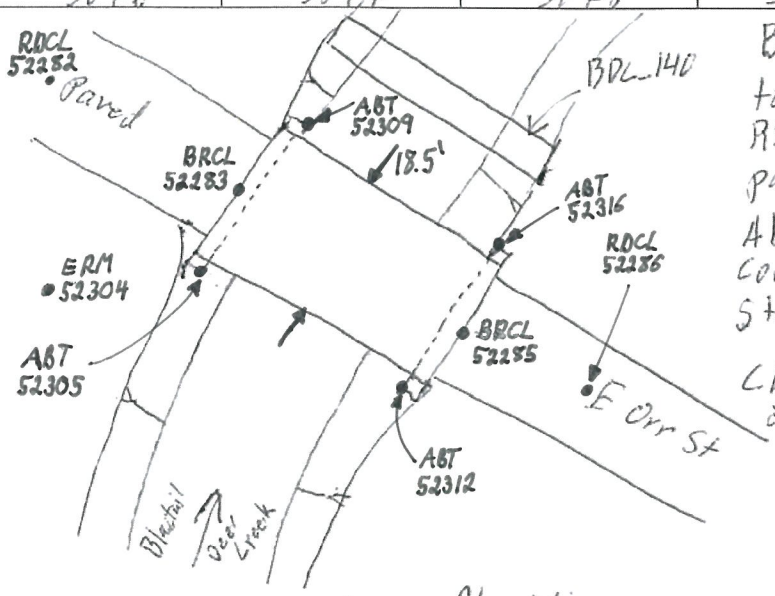
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDG-150				Crew: LDG/JRR	
Stream/Road Name: Blacktail Deer Creek / E Orr Street				Date: 12/4/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52281-52326	NA	52240-52253	52281-52287	52225-52239	52209-52224
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3076	3077	3075	3079	3080	

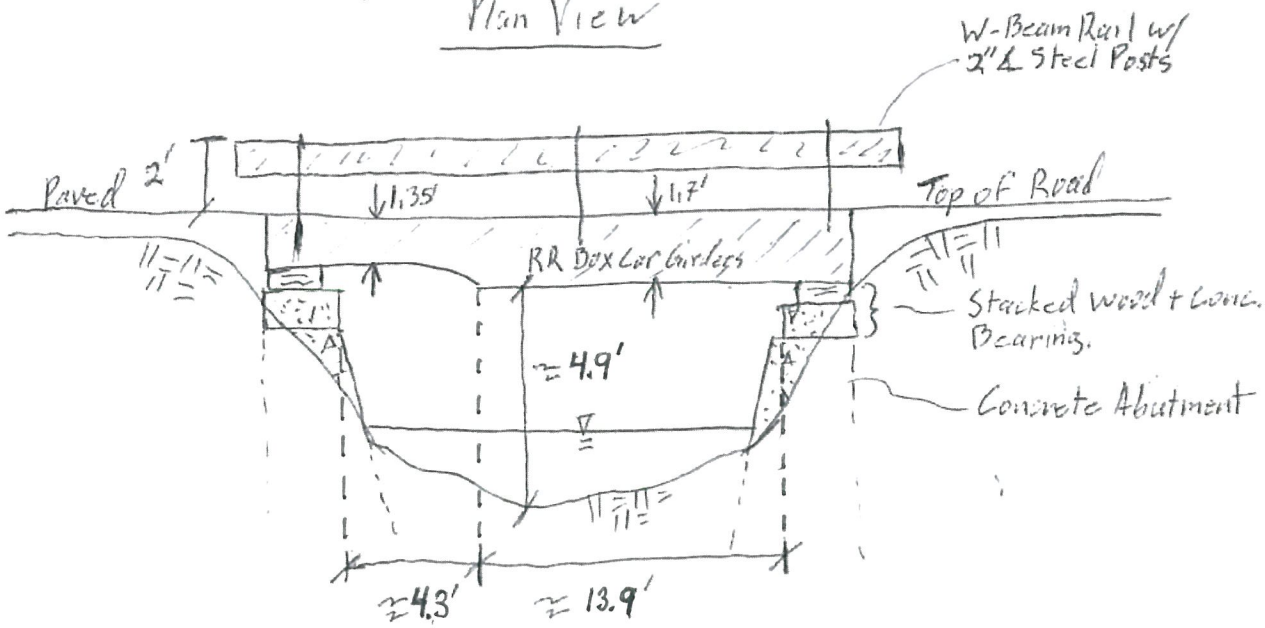


Bridge Girders appear to be manufactured from RR Box Cars. Deck is paved w/ Asphalt

Abutments appear to be a combination of poured and stacked concrete bearings.

Channel bottom is composed of 8' minus cobble + gravel.

Plan View



US Profile View

BDC_150_01_DSCH

BDC_150_01_DSFACE

BDC_150_01_OTXS

BDC_150_01_USCH

BDC_150_01_USFACE

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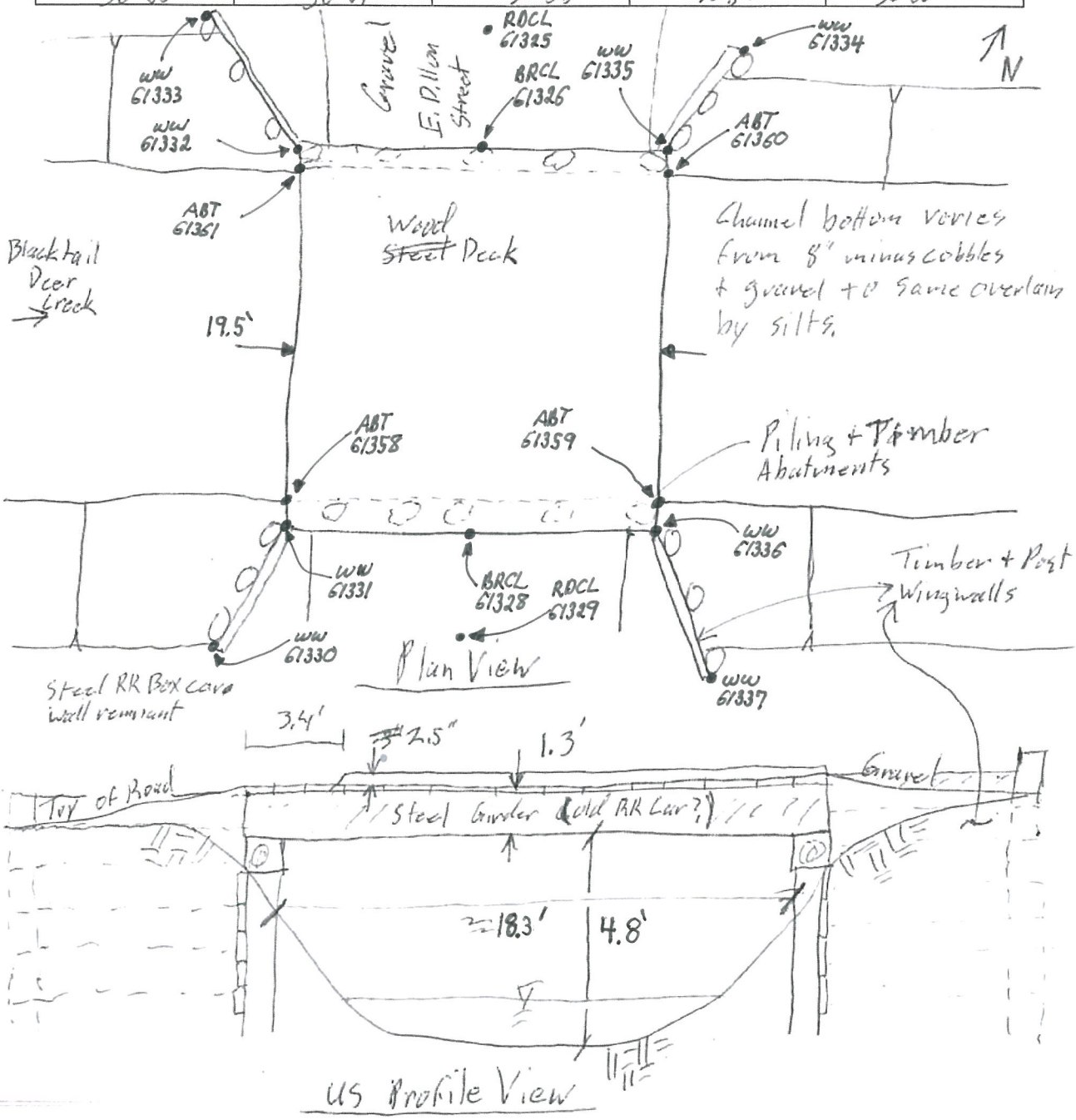
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-160				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / E. Dillon St.				Date: 12/8/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61325-61361	52446-52461	61362-61371	61325-61329	52431-52445	52416-52430
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3086	3087	3088	3089	3090	



BDC_160_01_DSCH

BDC_160_01_DSFACE

BDC_160_01_OTXS

BDC_160_01_USCH

BDC_160_01_USFACE

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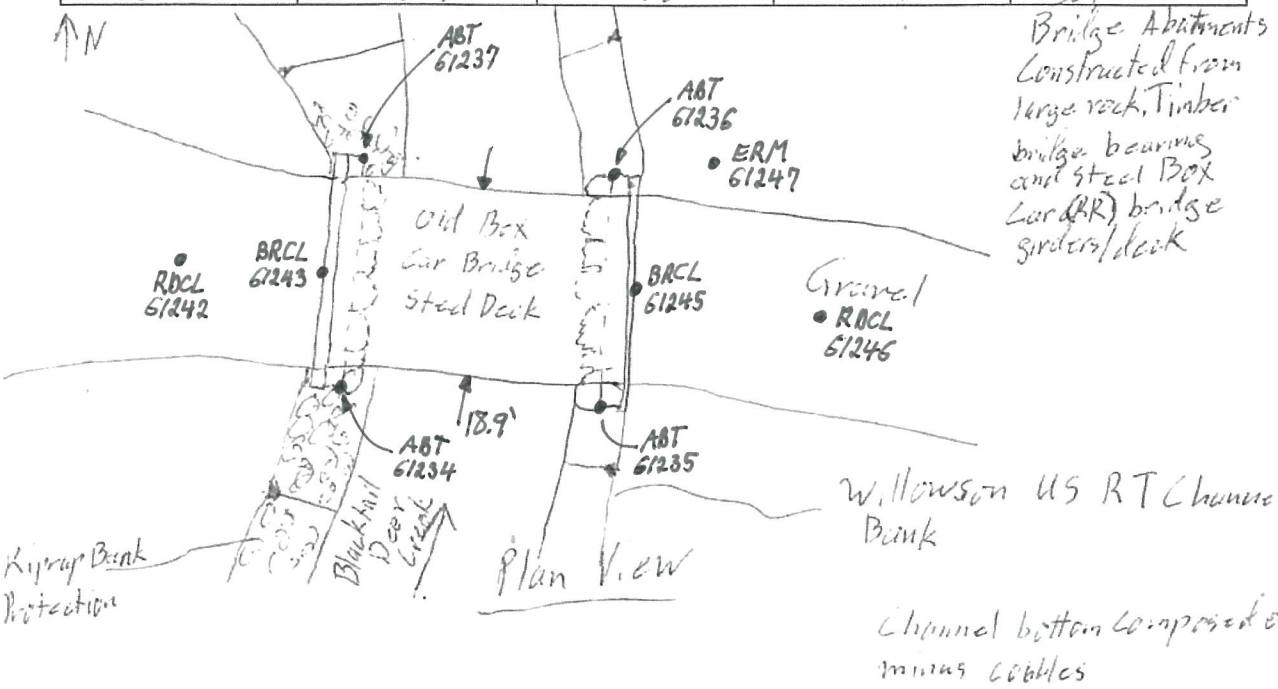
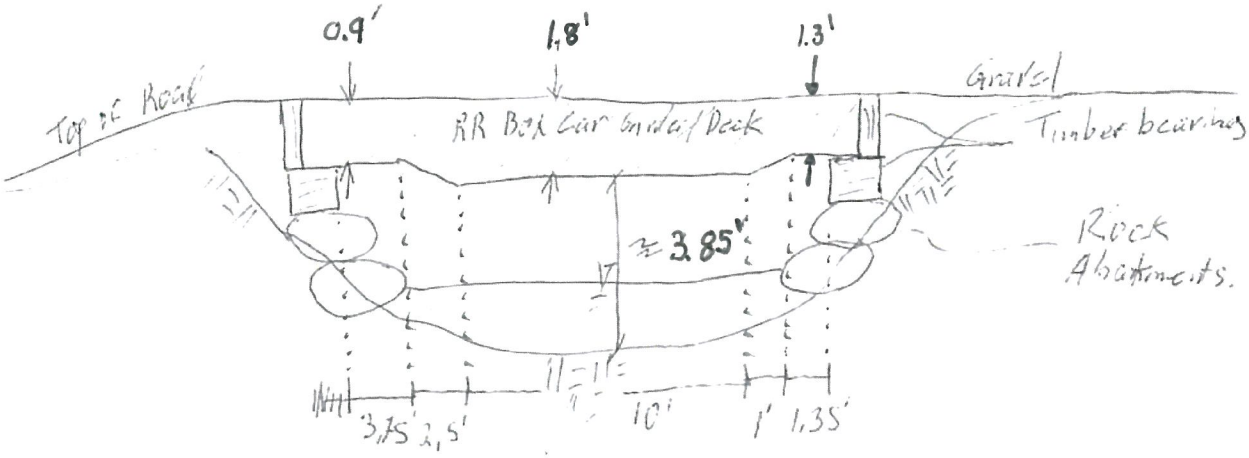
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_170				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / E Cornell St.				Date: 12/07/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
61218-61247	52196-52208	52184-52195	61242-61246	52173-52183	52163-52172
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3066	3067	3068	3069	3070	



Plan View



US Profile View

BDC_170_01_DSCH

BDC_170_01_DSFACE

BDC_170_01_OTXS

BDC_170_01_USCH

BDC_170_01_USFACE

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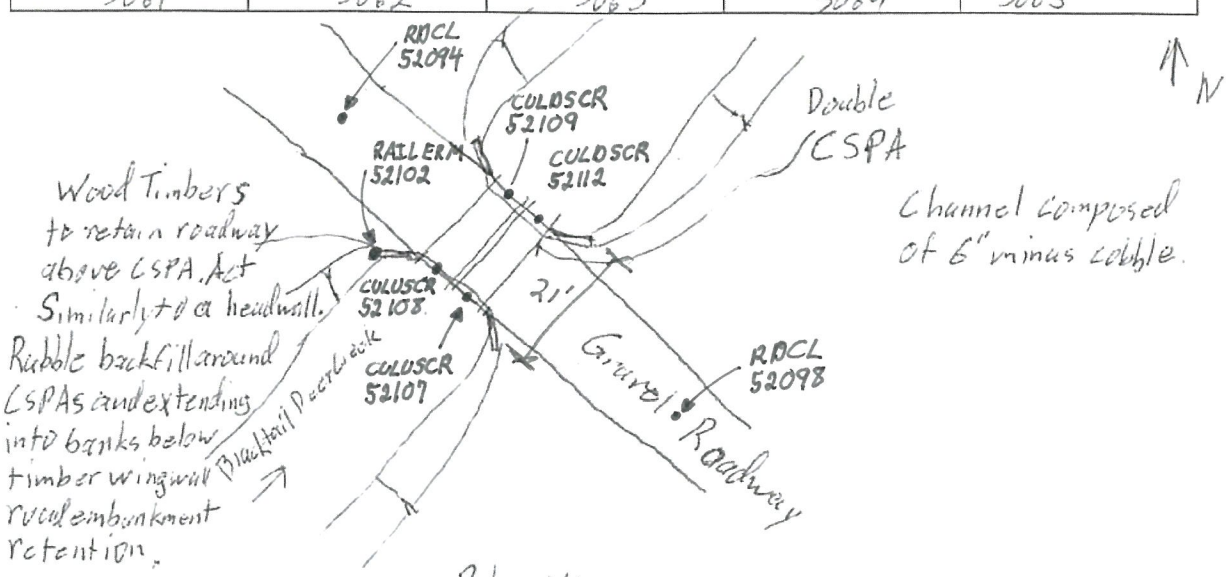
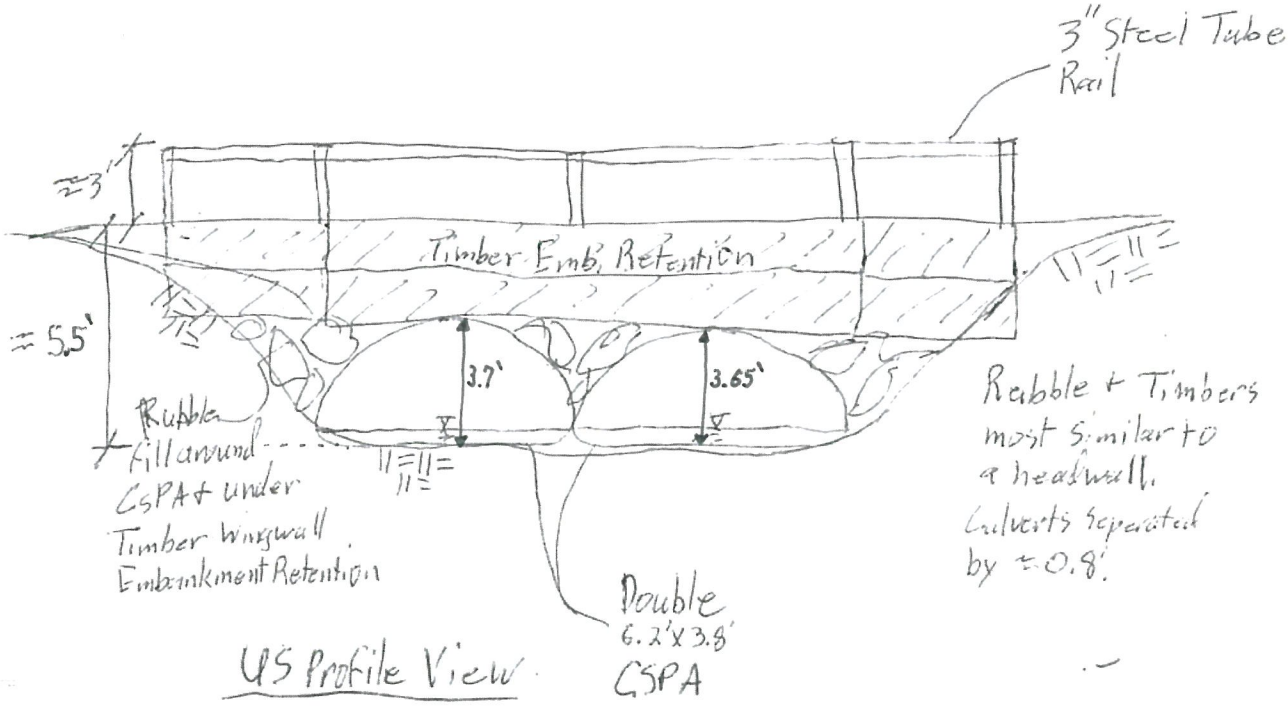
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-180				Crew: LDC/JBR	
Stream/Road Name: Blacktail Deer Creek / Clark St.				Date: 12/7/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52094-52114	52115-52124	52125-52135	52094-52098	52136-52148	52149-52162
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3061	3062	3063	3064	3065	



Plan View



US Profile View

BDC_180_01_DSCH

BDC_180_01_DSFACE

BDC_180_01_OTXS

BDC_180_01_USCH

BDC_180_01_USFACE

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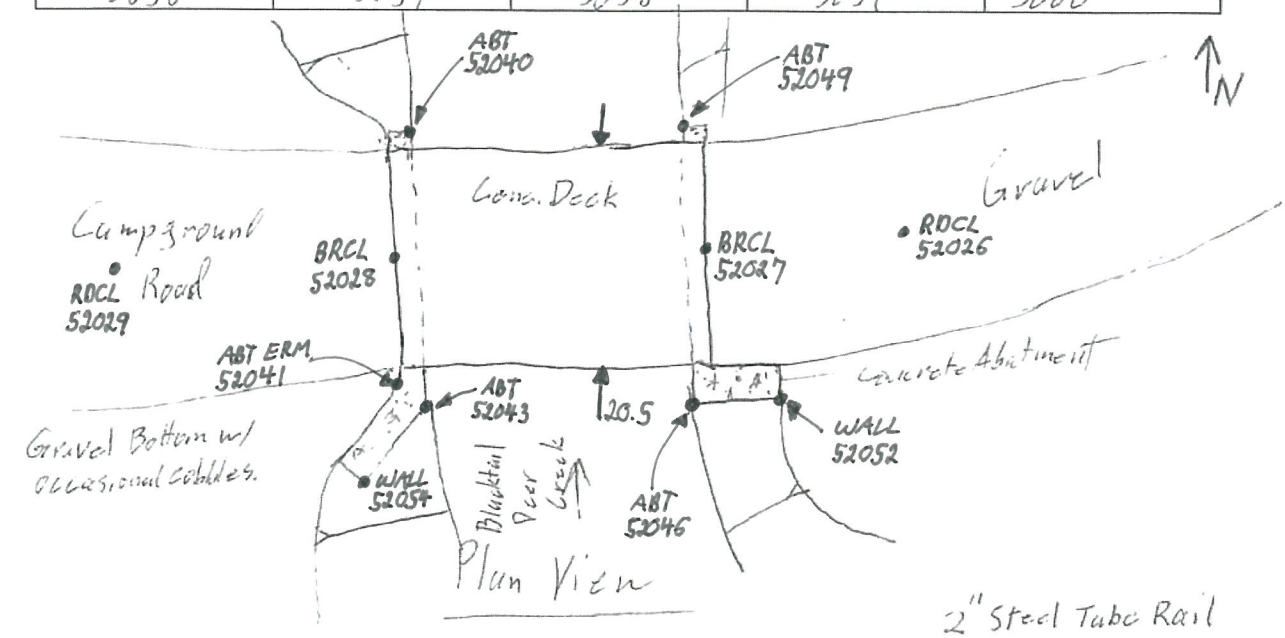
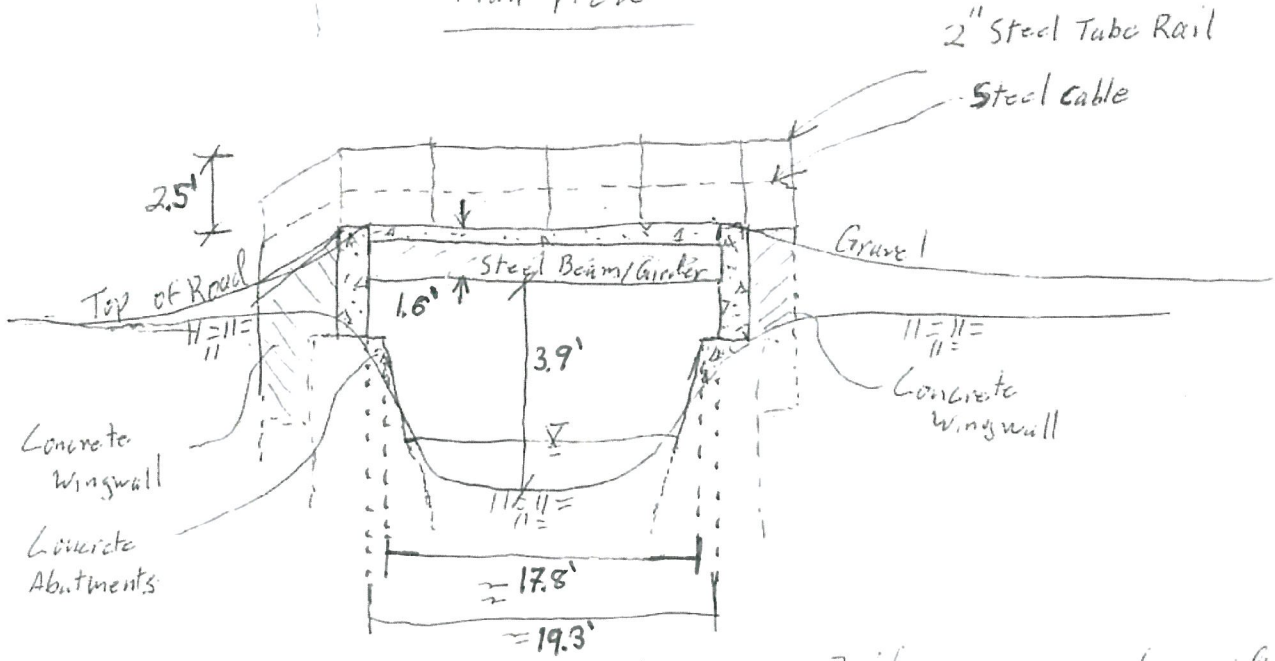
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC 190				Crew: LDC/JRR	
Stream/Road Name: Blacktail Dear Creek / Private Rd Campground				Date: 12/7/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
52025-52065	61205-61217	61194-61204	52025-52029	52081-52093	52066-52080
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3056	3057	3058	3059	3060	





Bridge was expanded in width to US side. DS. girder is not as tall as the US girder.

BDC_190_01_DSCH

BDC_190_01_DSFACE

BDC_190_01_OTXS

BDC_190_01_USCH

BDC_190_01_USFACE

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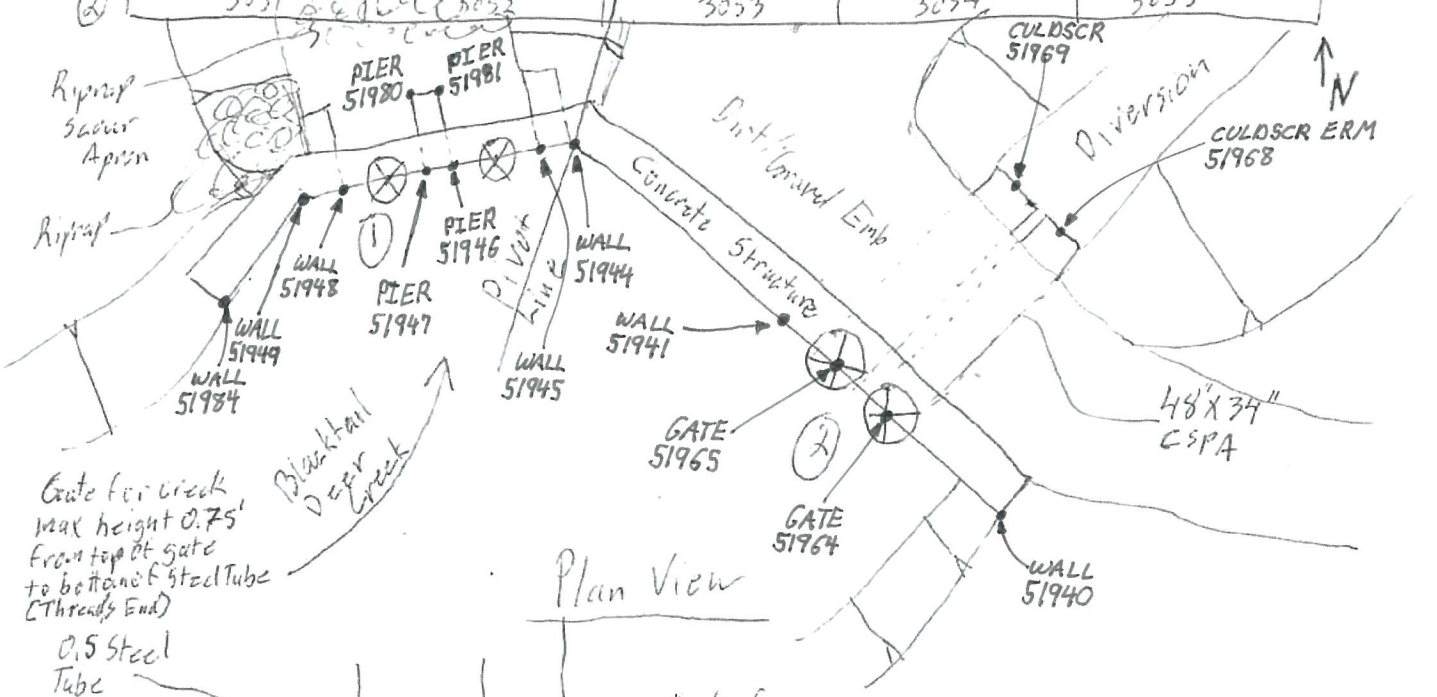
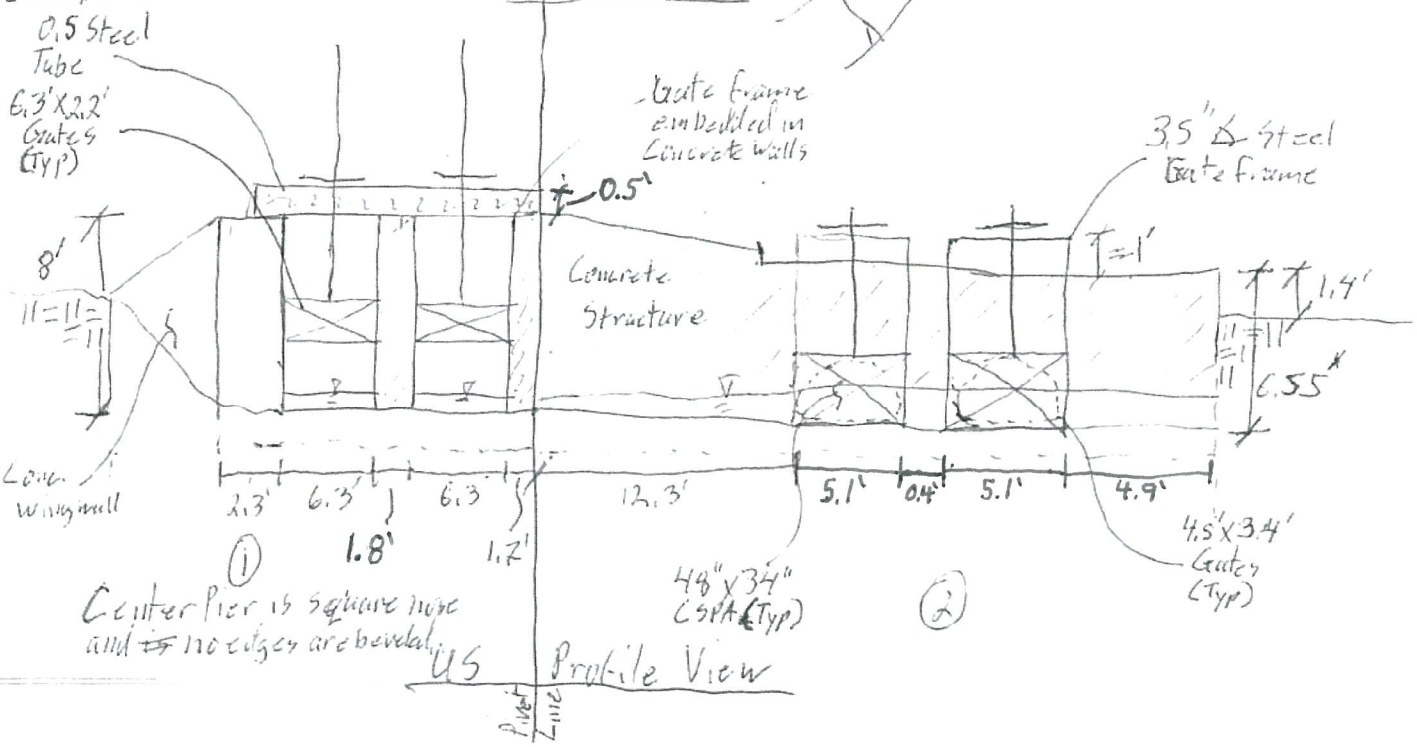
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BD6-200				Crew: LDL/JRR	
Stream/Road Name: Blacktail Deer Creek/Diversion				Date: 12/07/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51940-51984	52010-52024	51985-52009	51940-51949	61177-61193	61164-61176

Photos:

	DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
1	3046	3047	3048	3049	3050
2	3051	3052	3053	3054	3055





BDC_200_01_DSCH

BDC_200_01_DSFACE

BDC_200_01_OTXS

BDC_200_01_USCH

BDC_200_01_USFACE

BDC_200_02_DSCH

BDC_200_02_DSFACE

BDC_200_02_OTXS

BDC_200_02_USCH

BDC_200_02_USFACE

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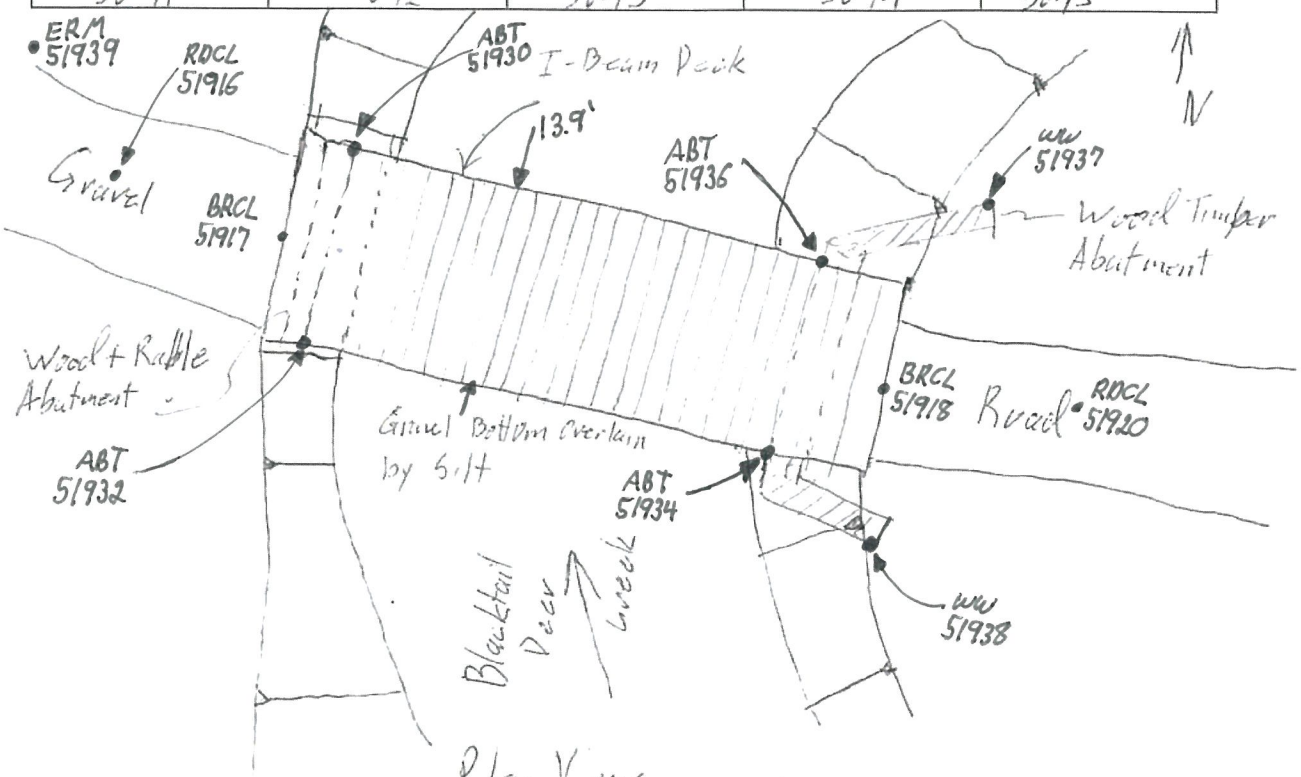
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

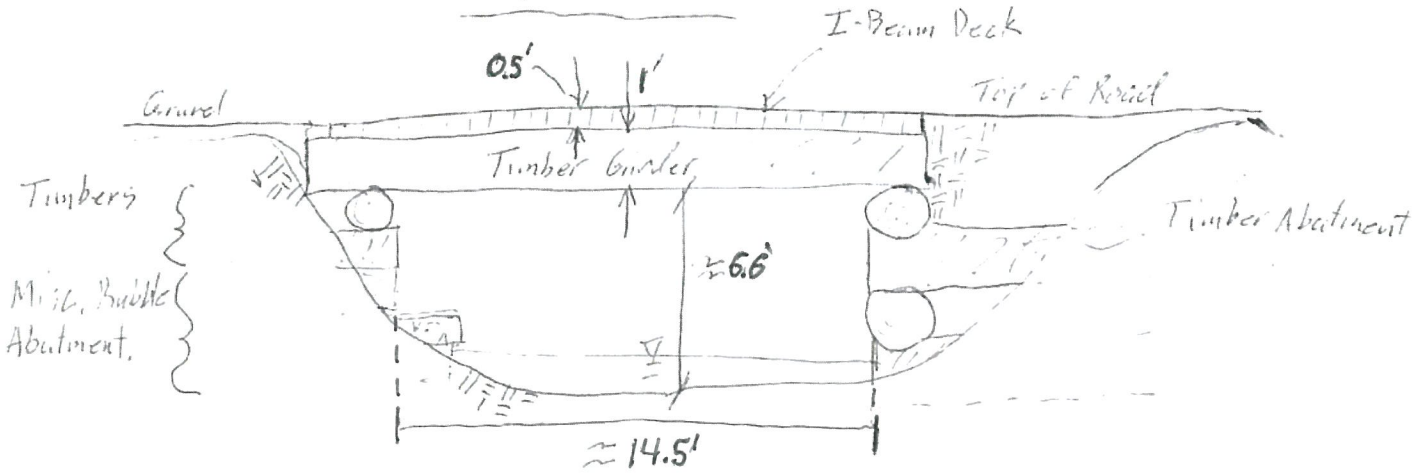
Structure ID: BDC-210				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / Private Rd				Date: 12/07/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51915-51938	61151-61163	61136-61150	51915-51920	61122-61135	61111-61121

Photos:

DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
3041	3042	3043	3044	3045



Plan View



US Profile View

BDC_210_01_DSCH

BDC_210_01_DSFACE

BDC_210_01_OTXS

BDC_210_01_USCH

BDC_210_01_USFACE

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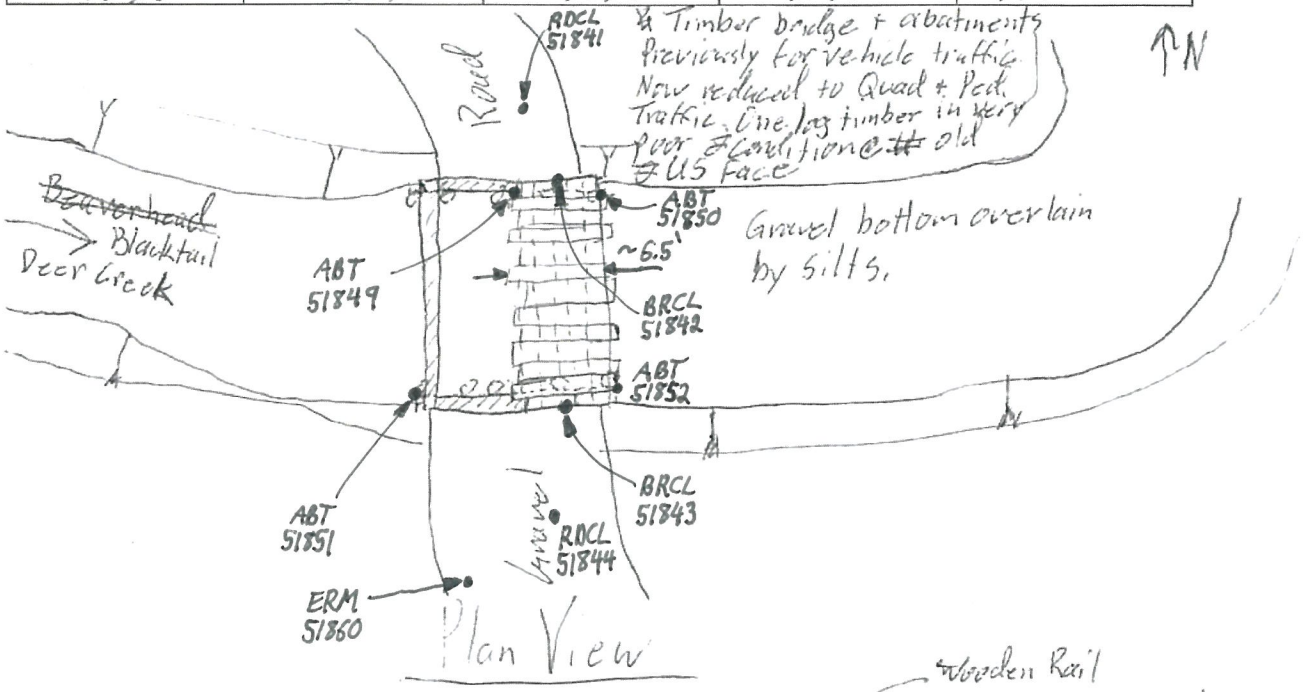
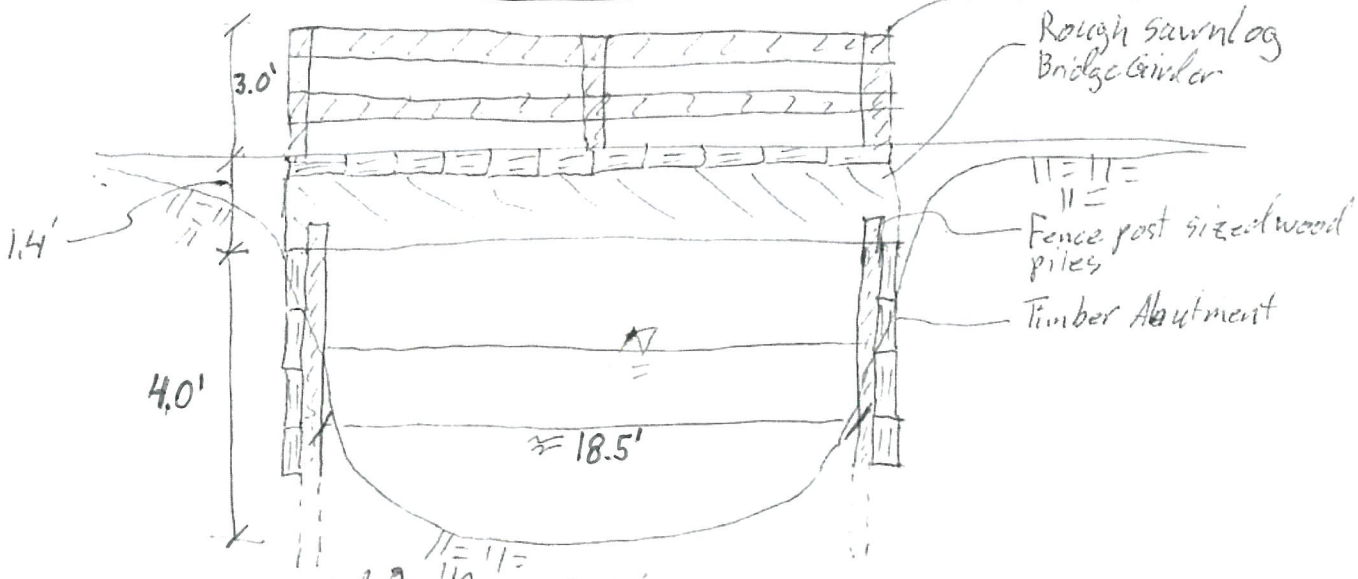
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-220				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / Private Rd				Date: 12/6/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51841-51859	61098-61110	61086-61097	51841-51844	51875-51888	51861-51874
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3036	3037	3038	3039	3040	



Plan View



US Profile View

BDC_220_01_DSCH

BDC_220_01_DSFACE

BDC_220_01_OTXS

BDC_220_01_USCH

BDC_220_01_USFACE

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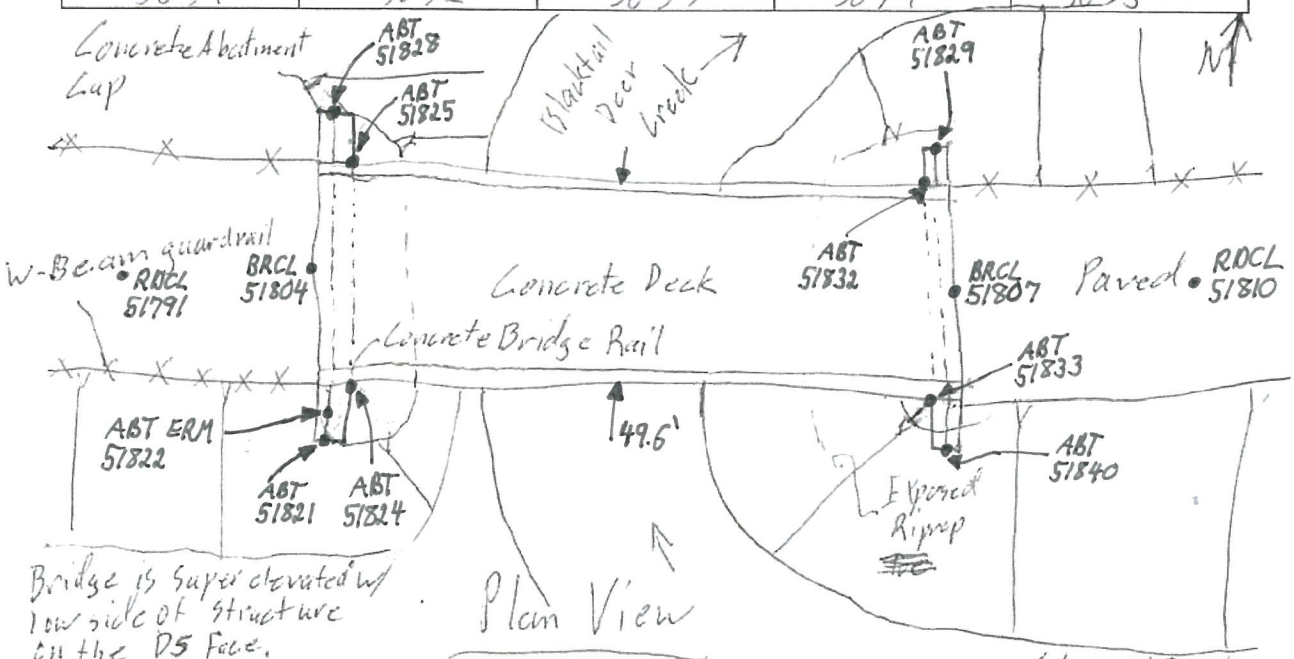
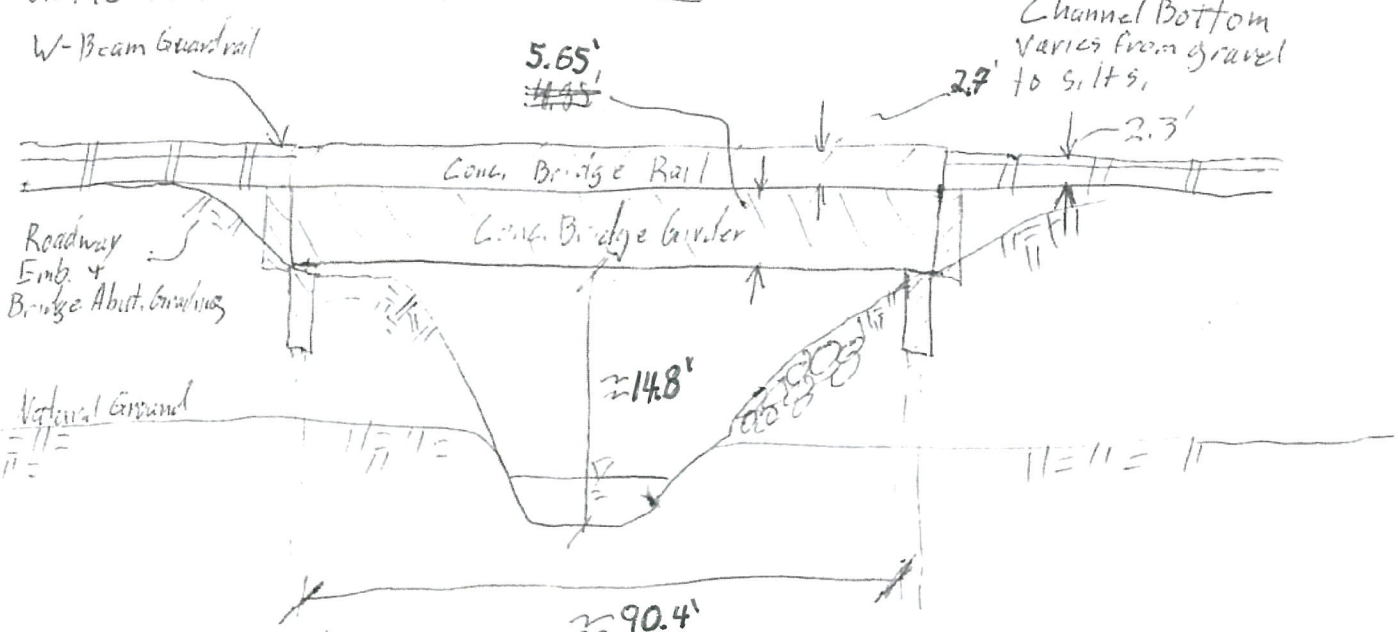
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDL_230				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / S. Atlantic St + I-15 Bus.				Date: ~~6/~~ 12/1/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51786-51840	61061-61071	61046-61060	51788-51816	61030-61045	61015-61029
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3031	3032	3033	3034	3035	





BDC_230_01_DSCH

BDC_230_01_DSFACE

BDC_230_01_OTXS

BDC_230_01_USCH

BDC_230_01_USFACE

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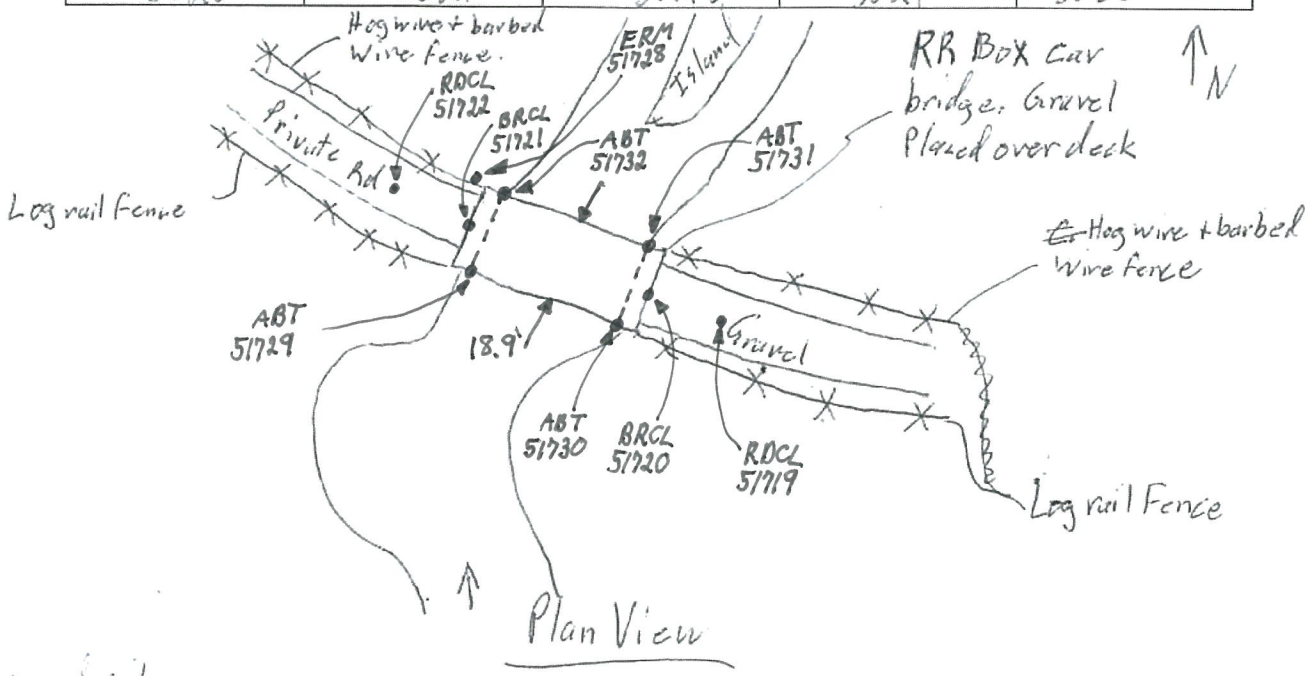
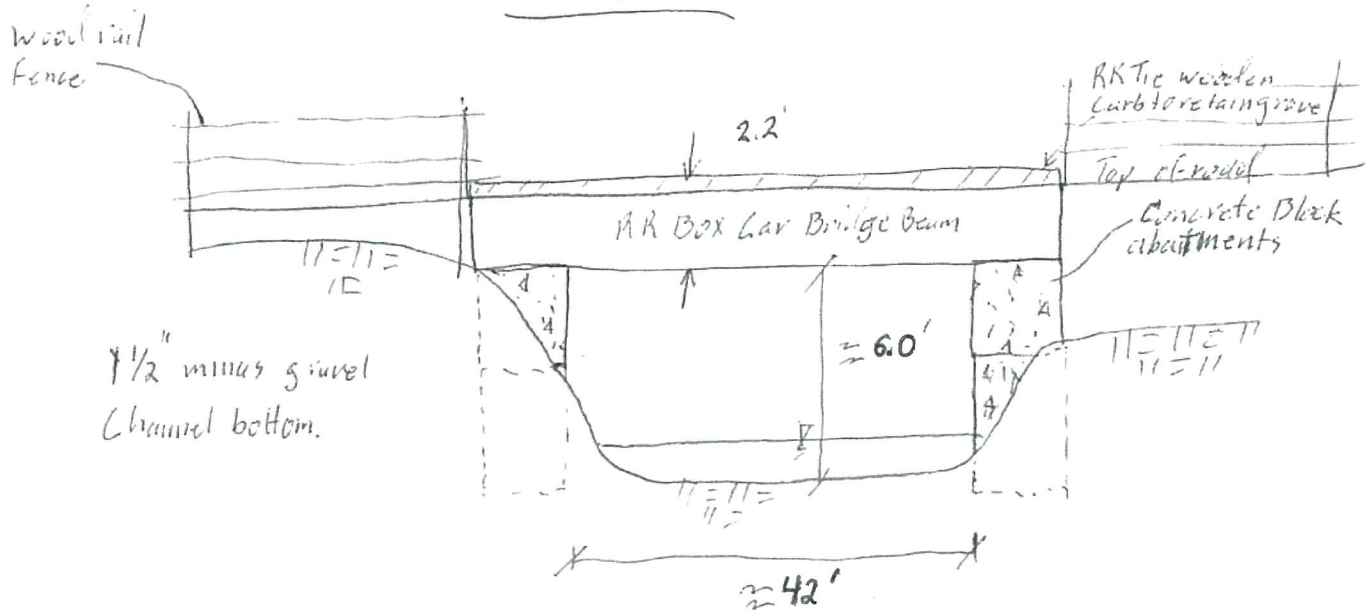
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDL-240				Crew: LDL/JRR	
Stream/Road Name: Blacktail Deer Creek/Private Rd				Date: 12/6/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51718-51736	51772-51785	51760-51771	51718-51723	51748-51759	51737-51747
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3026	3027	3028	3029	3030	



Plan View



US Profile View

BDC_240_01_DSCH

BDC_240_01_DSFACE

BDC_240_01_OTXS

BDC_240_01_USCH

BDC_240_01_USFACE

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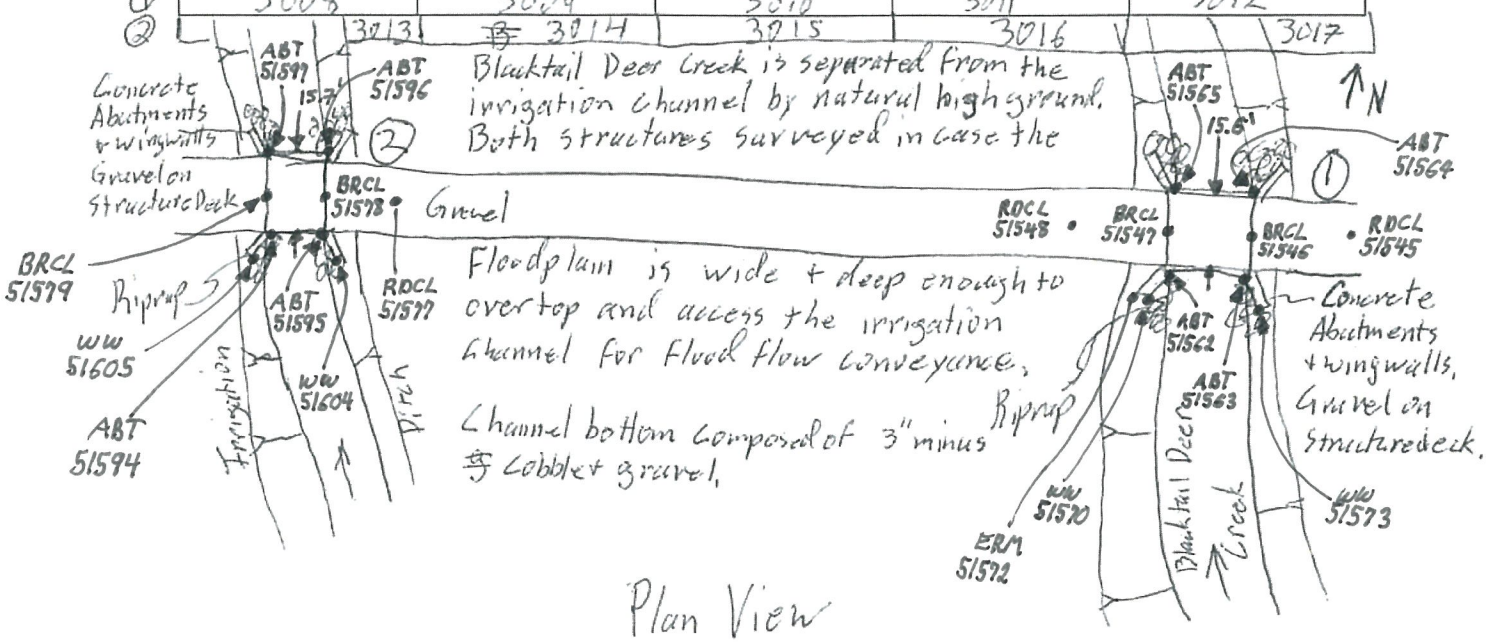
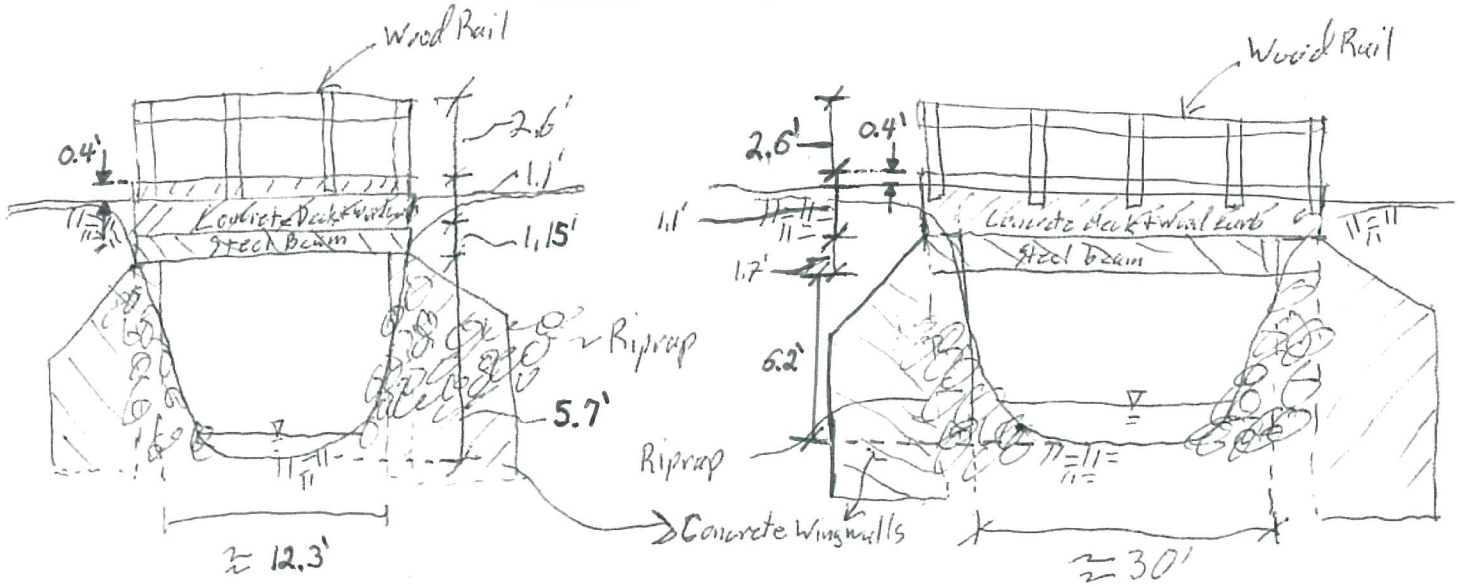
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-270				Crew: LDG/JRR	
Stream/Road Name: Blacktail Deer Creek/Lincoln Dr.				Date: 12/6/2016	
Point Numbers (.job file name):					
	Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
Blacktail Deer Cr.	51544-51575	60970-60981	60958-60969	51544-51549	60945-60957	60930-60944
Irrigation Ditch	51576-51605	51644-51656	51631-51643	Photos: 51576-51581	51617-51630	51606-51616

	DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
①	3008	3009	3010	3011	3012
②	3013	~~B~~ 3014	3015	3016	3017



Plan View



② US Profile View ①

BDC_270_01_DSCH

BDC_270_01_DSFACE

BDC_270_01_OTXS

BDC_270_01_USCH

BDC_270_01_USFACE

BDC_270_02_DSCH

BDC_270_02_DSFACE

BDC_270_02_OTXS

BDC_270_02_USCH

BDC_270_02_USFACE

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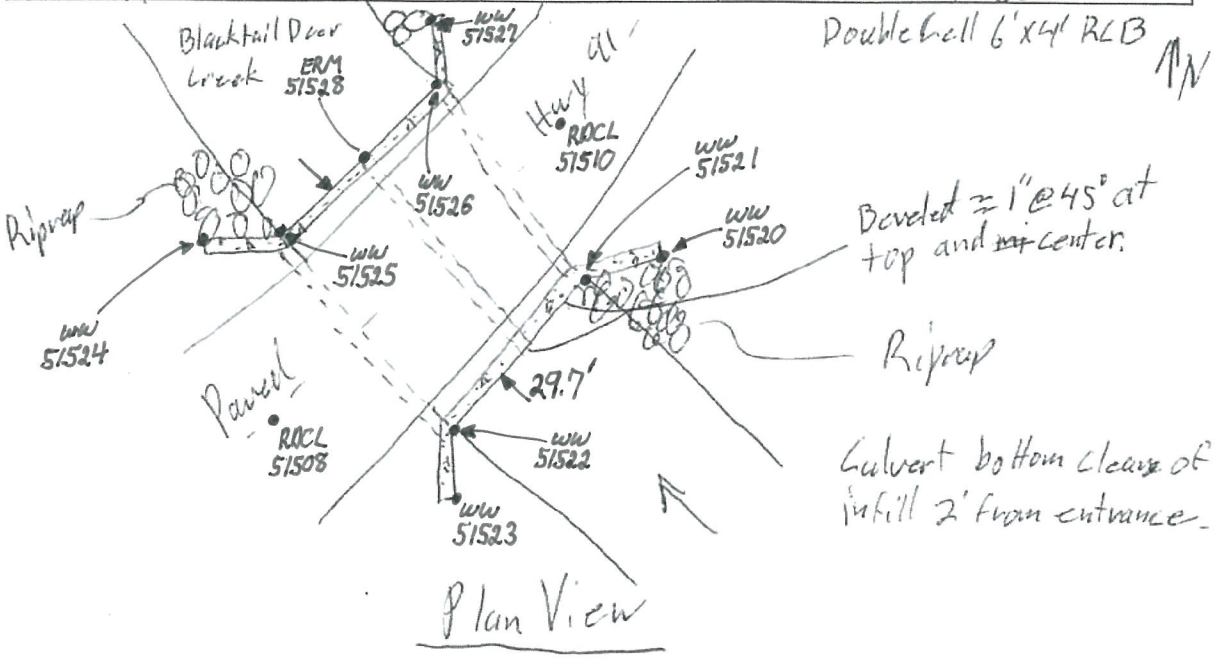
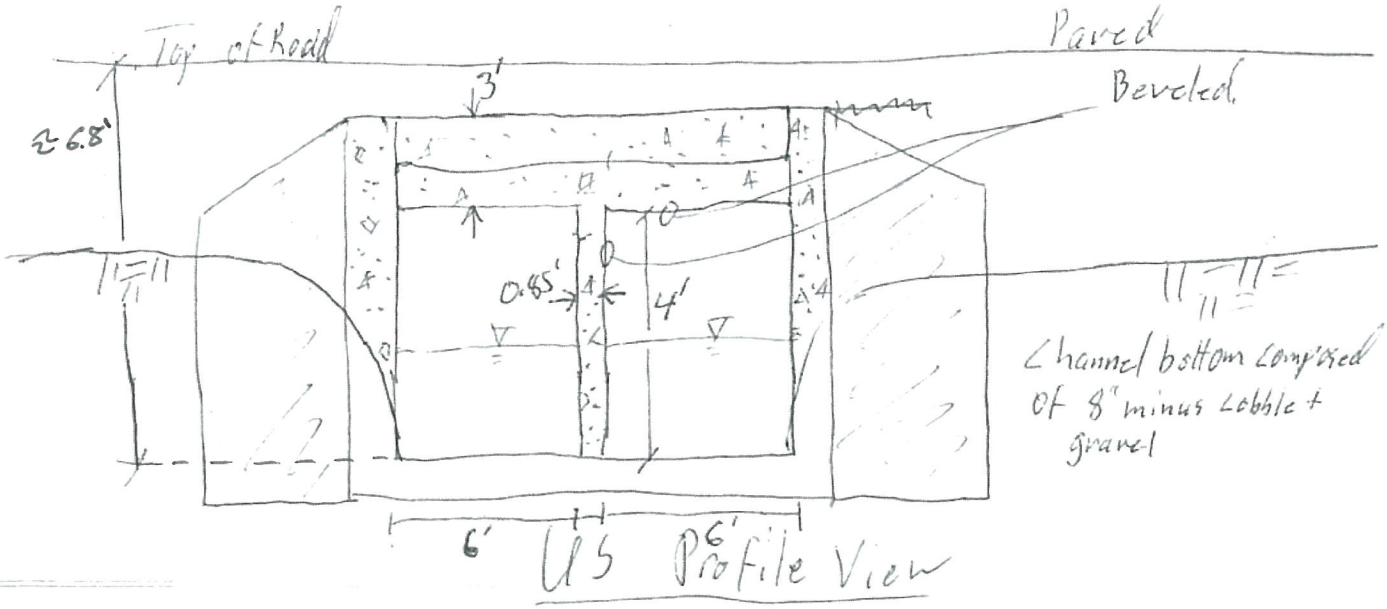
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDL-230				Crew: LDL/JRB	
Stream/Road Name: Blacktail Deer Creek				Date: 12/2/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51507-51532	51533-51543	60914-60929	51507-51511	60900-60913	60888-60899
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
3007	3006	3005	3004	3003	





BDC_280_01_DSCH

BDC_280_01_DSFACE

BDC_280_01_OTXS

BDC_280_01_USCH

BDC_280_01_USFACE

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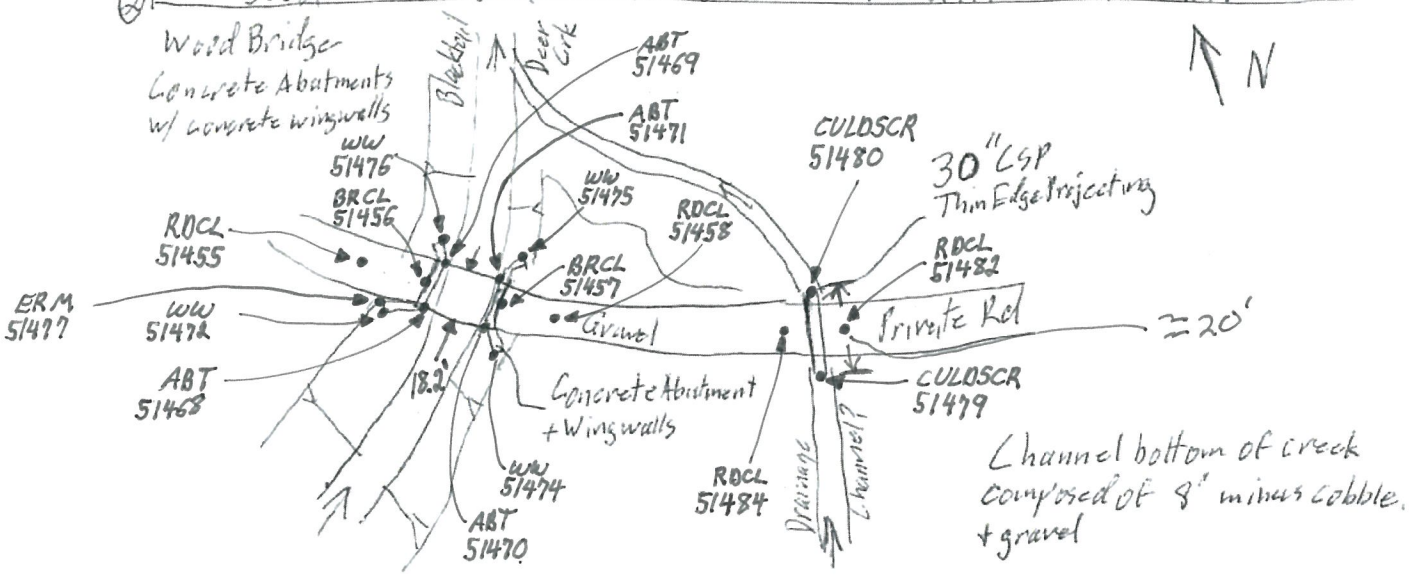
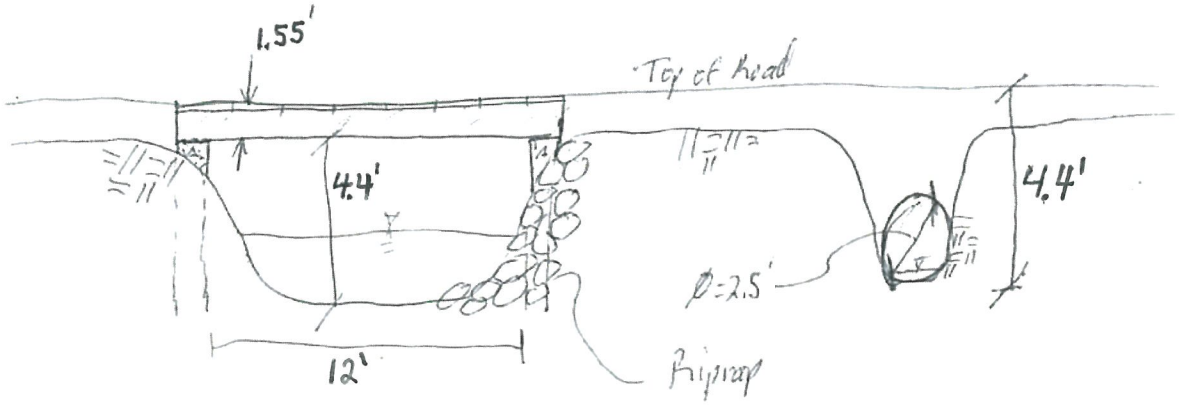
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: ~~Blackt~~ ~~BDC3~~ BDC-290					Crew: LDL/JRR	
Stream/Road Name: Blacktail Deer Creek / Private Rd.					Date: 12/2/16	
Point Numbers (.job file name):						
	Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
Blacktail Deer Cr.	51454-51477	60875-60887	60865-60874	51454-51459	60843-60853	60854-60864
Drainage Channel	51478-51483	60875-60887	51496-51506	Photos 51482-51484	51485-51495	NA

	DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
①	2997	2996	2995	2994	2993
②	3002	3001	3000	2999	2998



Plan View



US Profile View

BDC_290_01_DSCH

BDC_290_01_DSFACE

BDC_290_01_OTXS

BDC_290_01_USCH

BDC_290_01_USFACE

BDC_290_02_DSCH

BDC_290_02_DSFACE

BDC_290_02_OTXS

BDC_290_02_USCH

BDC_290_02_USFACE

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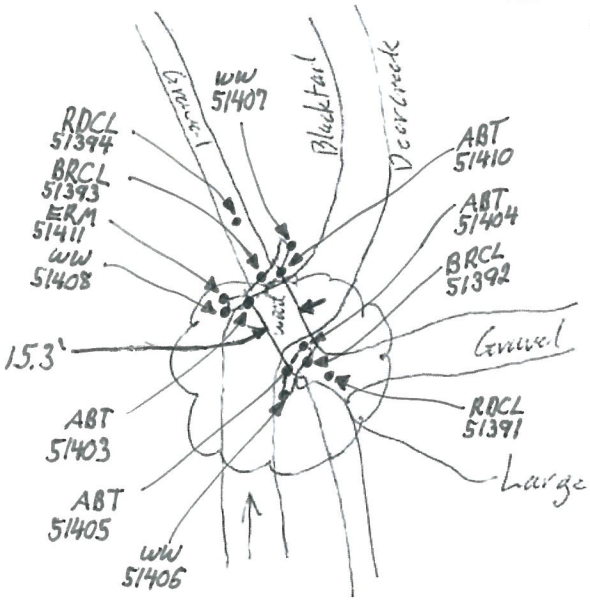
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_300				Crew: LDC/JRK	
Stream/Road Name: Blacktail Deer Creek/Private Rd				Date: 12/2/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51388-51411	51443-51453	51432-51442	51388-51394	51424-51431	51412-51423
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2992	2991	2990	2989	2988	

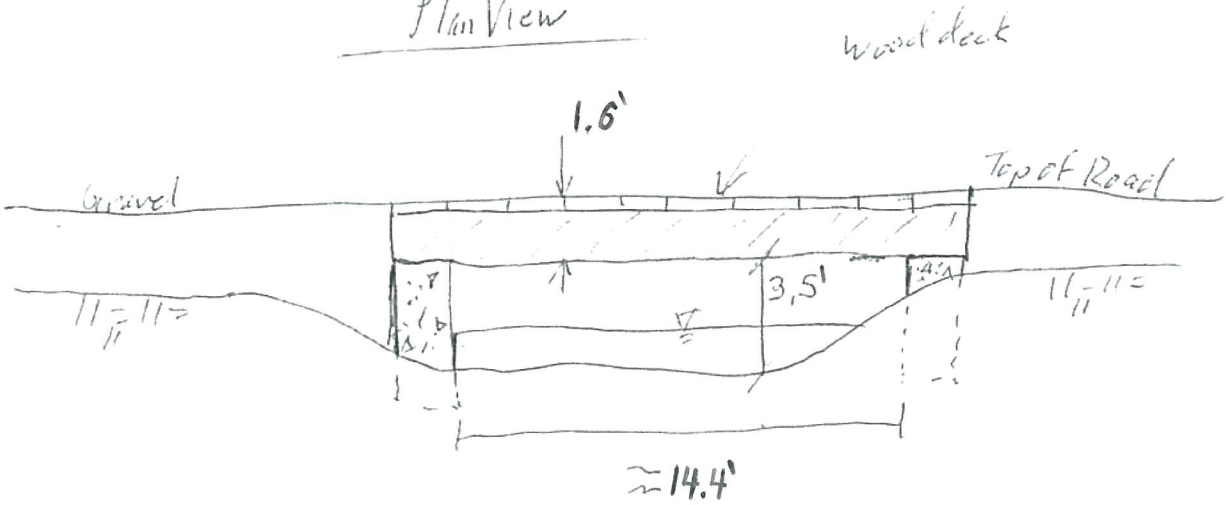


Timber bridge on concrete abutments.
Abutments ≈ 30° skew to Roadway

N

Channel bottom composed of 4" minus cobble + gravel

Plan View



US Profile View

BDC_300_01_DSCH

BDC_300_01_DSFACE

BDC_300_01_OTXS

BDC_300_01_USCH

BDC_300_01_USFACE

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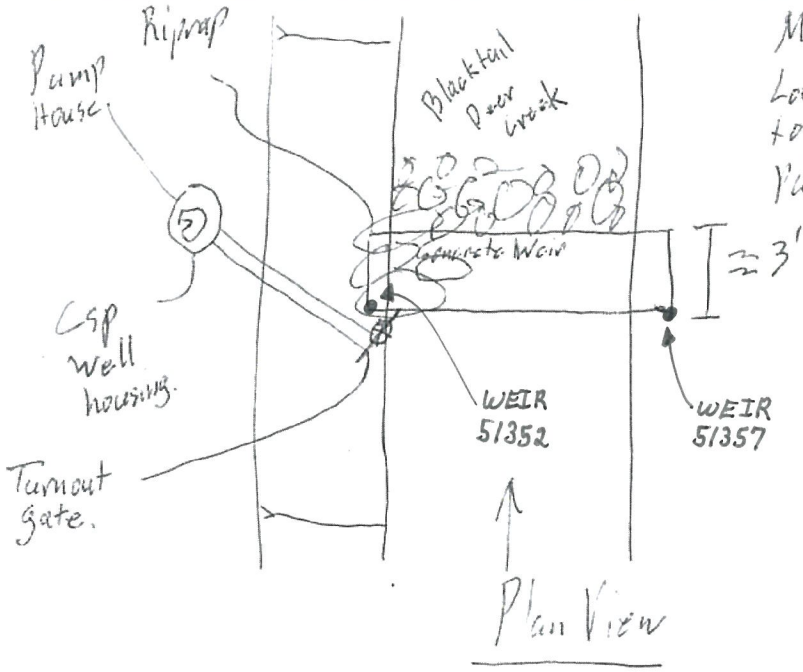
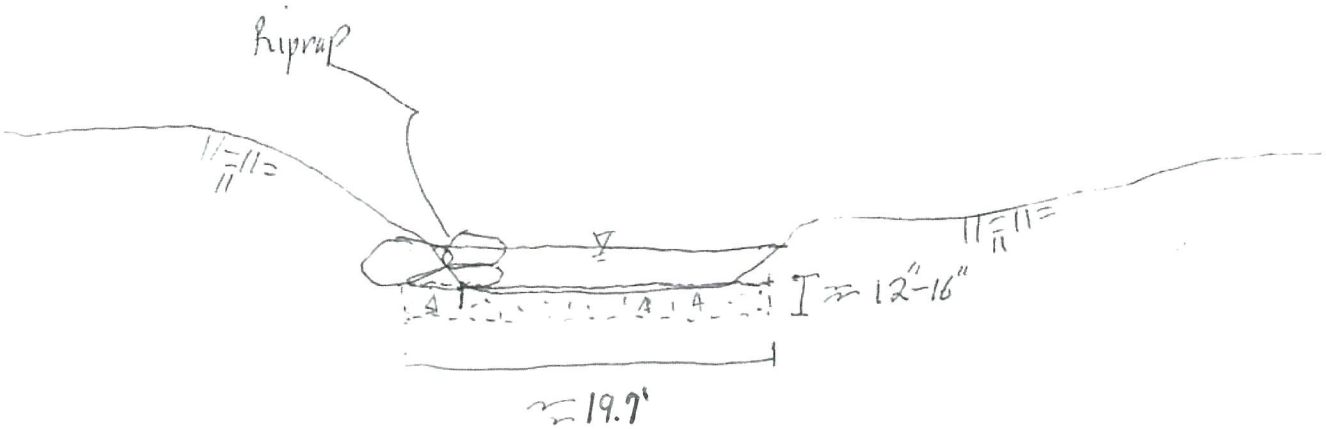
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_310				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / Private Long Diversion Weir				Date: 12/2/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51352-51357	NA	51374-51386	51349-51359	51360-51373	NA
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2983	2984	2985	2986	2987	



Minor run-of-the river/ Low head concrete weir to provide head for Water Pump.



US Profile View

BDC_310_01_DSCH

BDC_310_01_DSFACE

BDC_310_01_OTXS

BDC_310_01_USCH

BDC_310_01_USFACE

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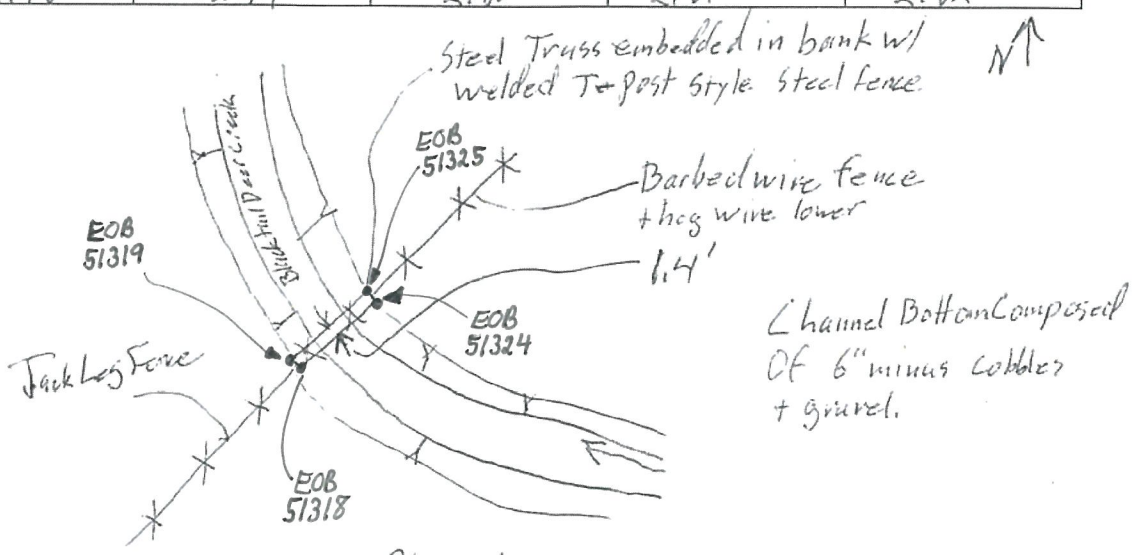
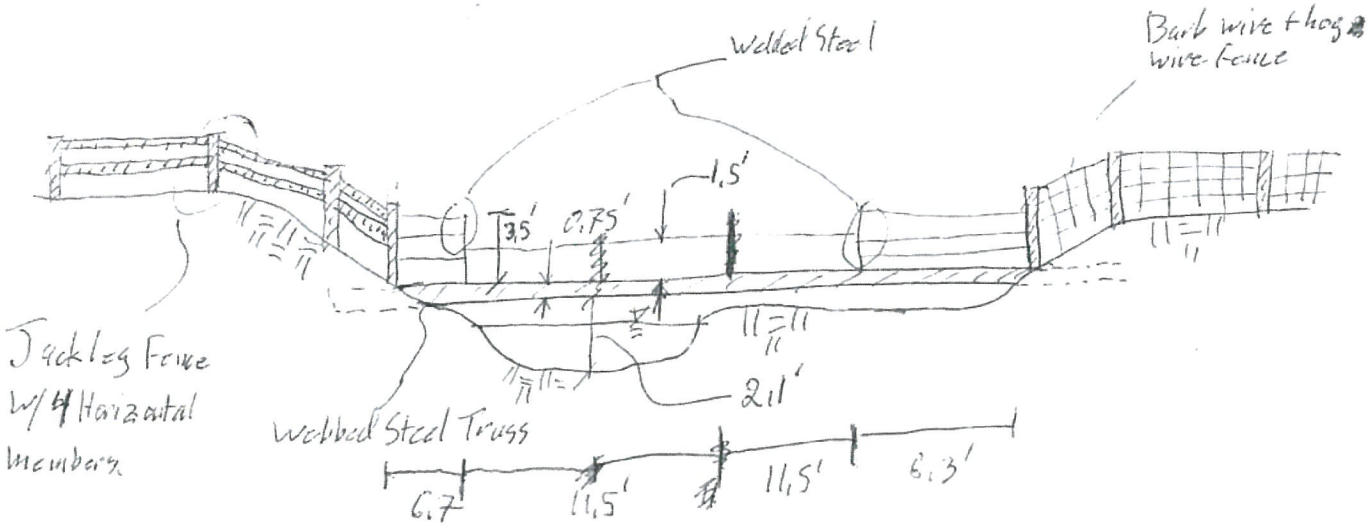
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BD6-320				Crew: LPC/TRR	
Stream/Road Name: Blacktail Deer Creek / Fence Over Creek				Date: 12/2/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51318-51325	NA	51326-51336	51318-51324	51337-51348	NA
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2978	2979	2980	2981	2982	



Plan View



US Profile View

BDC_320_01_DSCH

BDC_320_01_DSFACE

BDC_320_01_OTXS

BDC_320_01_USCH

BDC_320_01_USFACE

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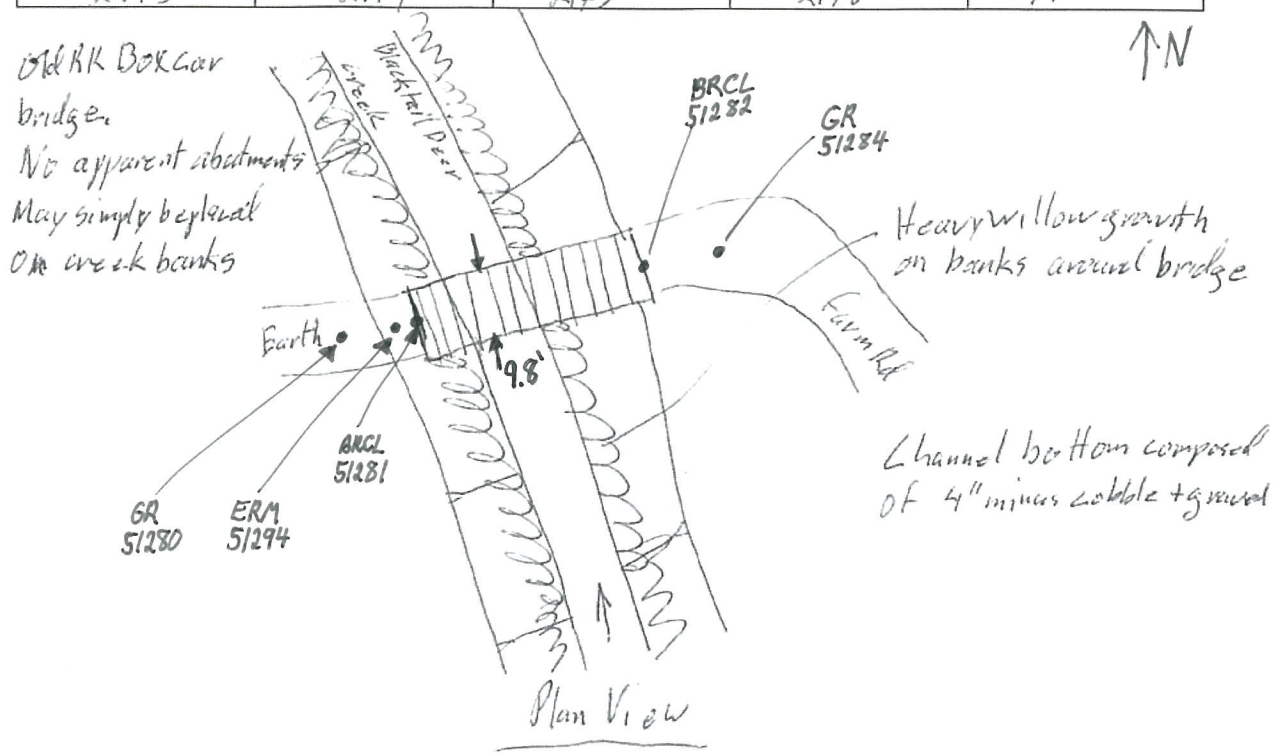
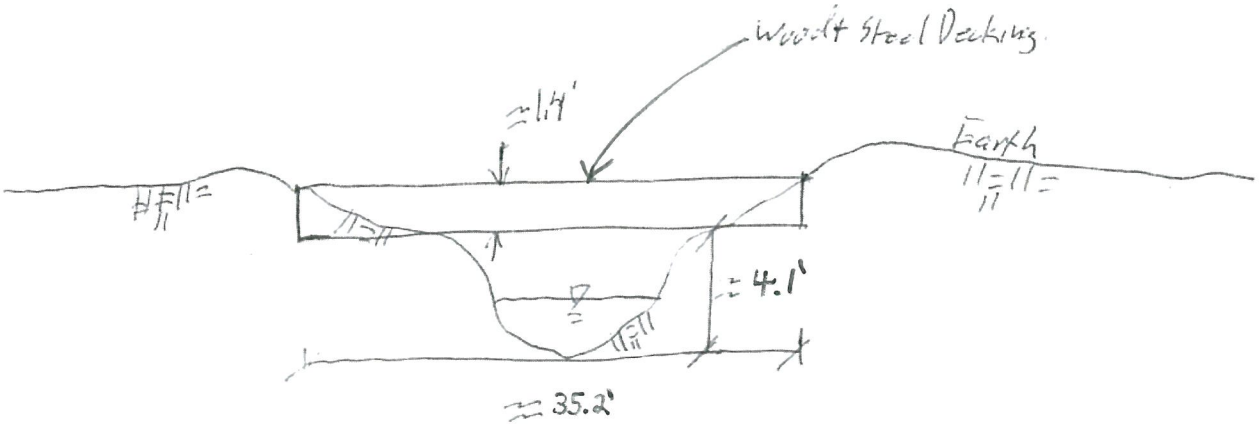
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-330				Crew: LDC / JRR	
Stream/Road Name: Blacktail Deer Creek / Private Rd				Date: 12/2/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51279-51294	60820-60831	60832-60842	51279-51285	51306-51317	51295-51305
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2973	2974	2975	2976	2977	



Plan View



US Profile View

BDC_330_01_DSCH

BDC_330_01_DSFACE

BDC_330_01_OTXS

BDC_330_01_USCH

BDC_330_01_USFACE

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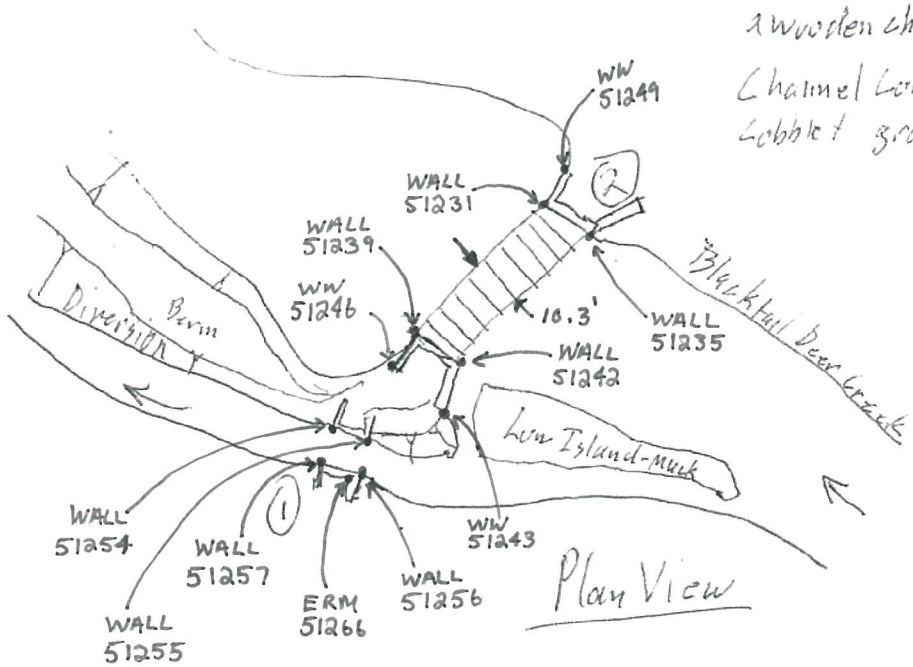
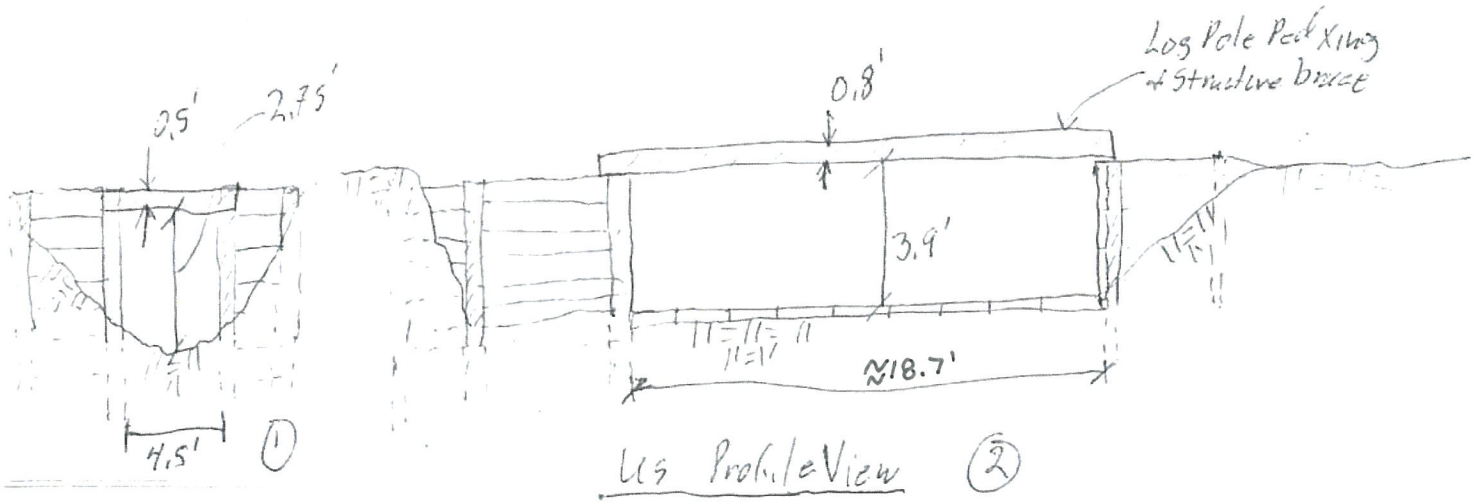
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_340				Crew: LDC/JRB	
Stream/Road Name: Blacktail Deer Creek / Diversion				Date: 12/2/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51217-51266	51267-51278	60784-60807	51217-51224 &	60771-60783	60759-60770
Photos: 51236-51237					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2966	2967	2968	2969	2970	

Timber Diversion structure w/ 2 wooden chutes + stop logs
Channel Composed of 6" minus cobble + gravel





BDC_340_01_DSCH

BDC_340_01_DSFACE

BDC_340_01_OTXS

BDC_340_01_USCH

BDC_340_01_USFACE

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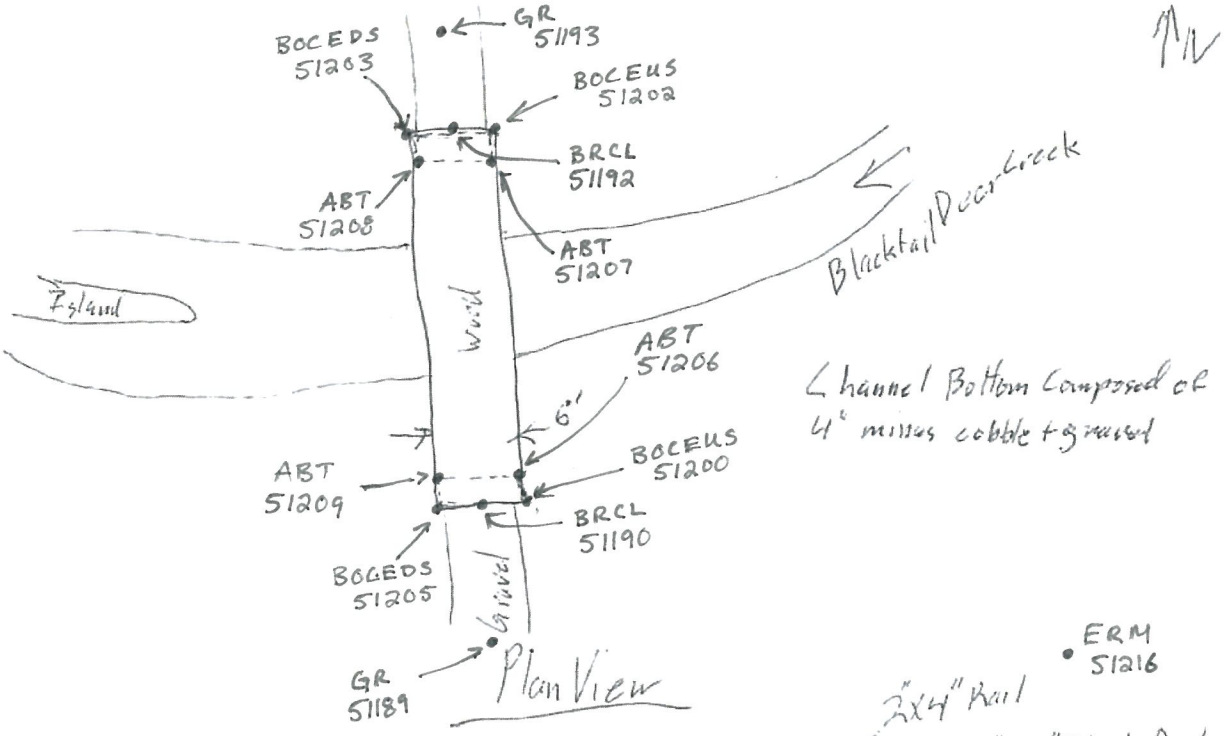
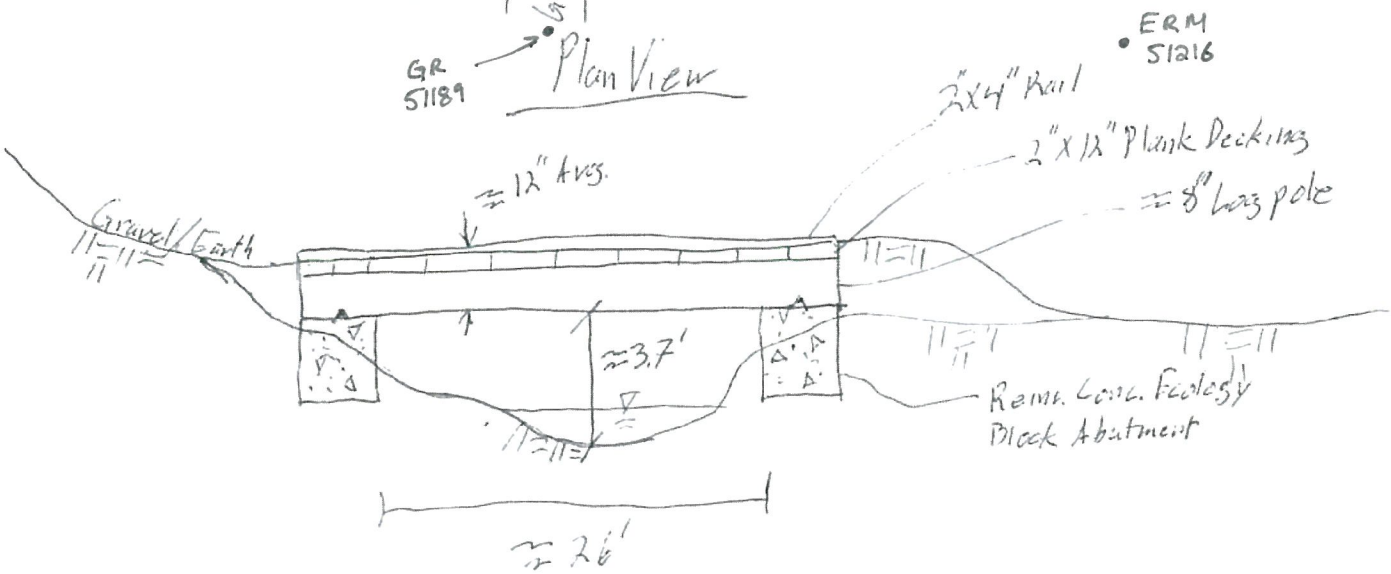
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-360				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / Private Road				Date: 12/2/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51188-51216	60707-60719	60694-60706	51188-51195	60683-60693	60672-60682
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2955	2956	2957	2958	2959	





US Profile View

BDC_360_01_DSCH

BDC_360_01_DSFACE

BDC_360_01_OTXS

BDC_360_01_USCH

BDC_360_01_USFACE

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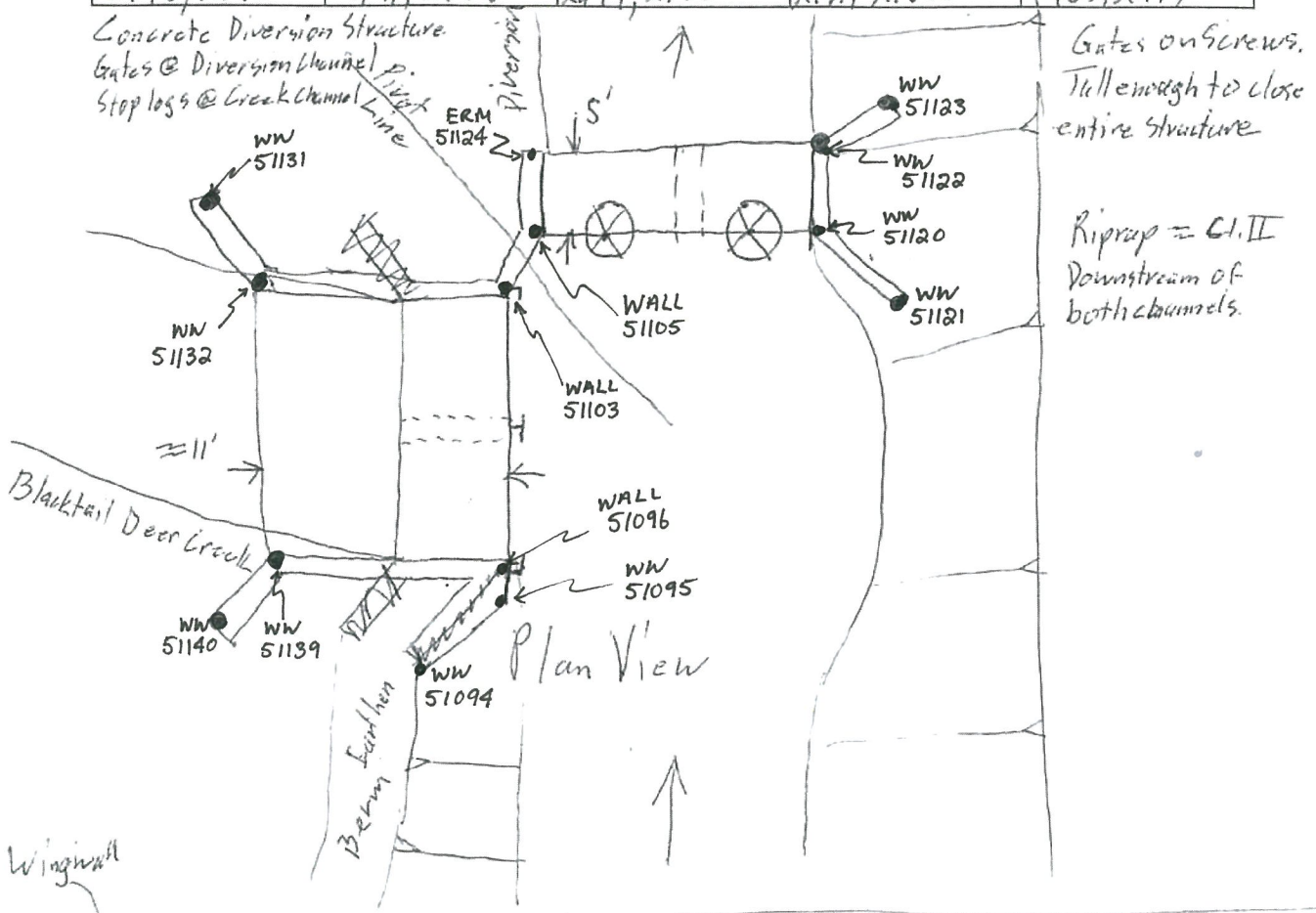
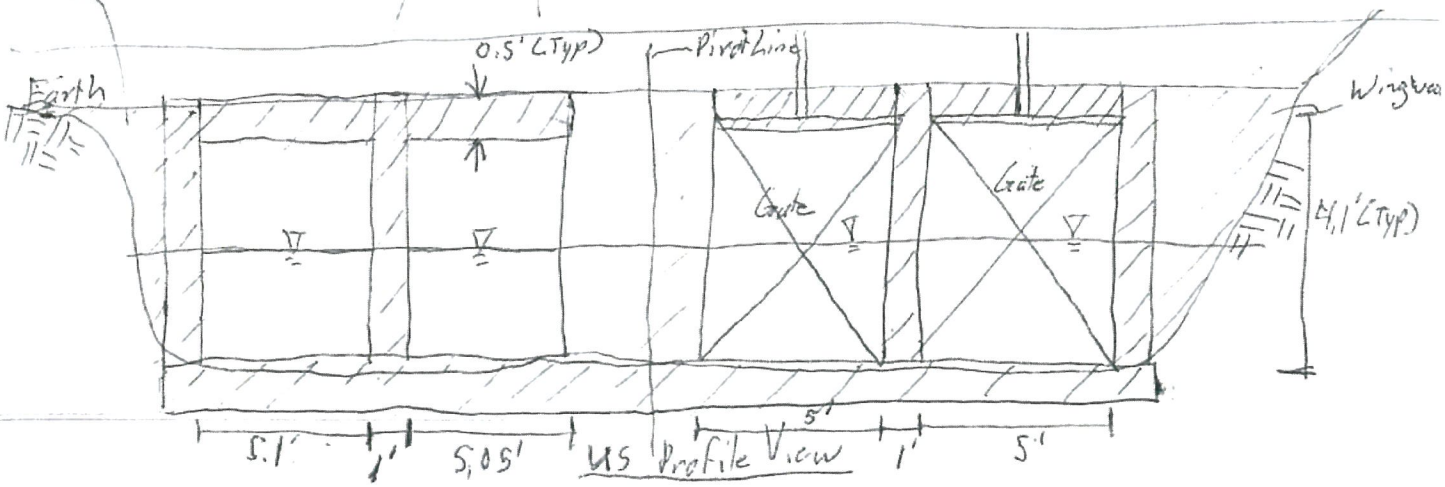
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_370				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / Diversion				Date: 12/1/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51094-51152	60660-60671	51153-51177	51095-51096, 51103	51092-51093	60640-60649
Photos: 51105, 51120 & 60650-60659					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2945, 2946	2947, 2948	2949, 2950	2951, 2952	2953, 2954	





BDC_370_01_DSCH

BDC_370_01_DSFACE

BDC_370_01_OTXS

BDC_370_01_USCH

BDC_370_01_USFACE

BDC_370_02_DSCH

BDC_370_02_DSFACE

BDC_370_02_OTXS

BDC_370_02_USCH

BDC_370_02_USFACE

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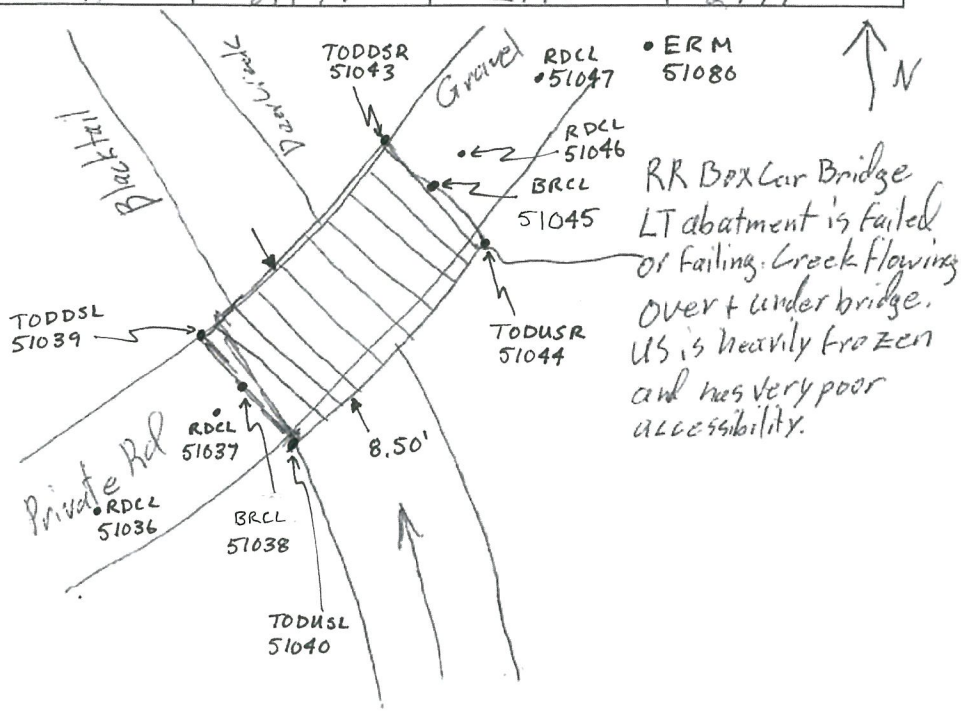
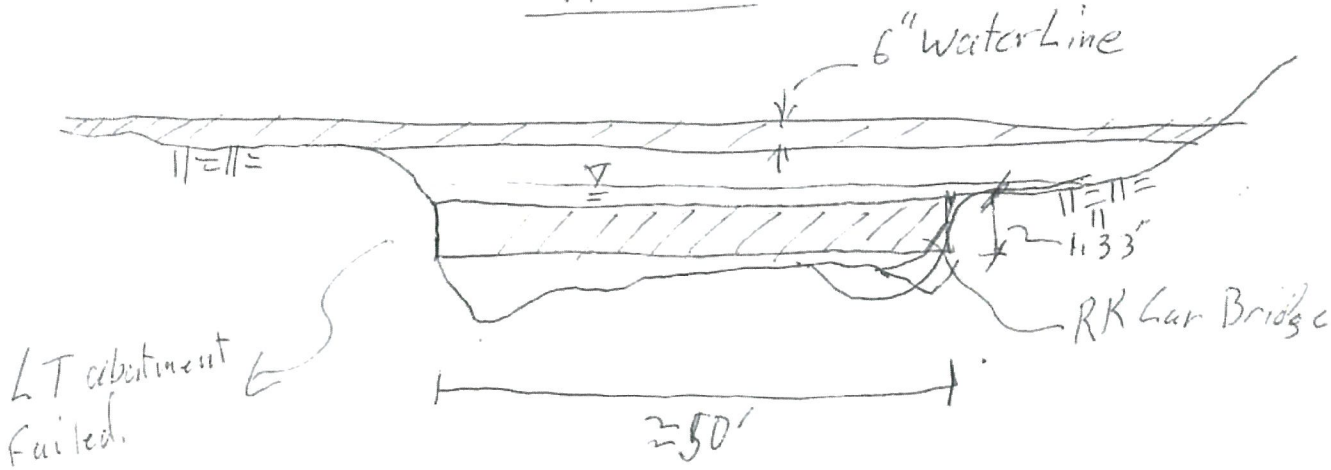
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_340				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek/Private Rd				Date: 12/1/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
51035-51049 & 51080	51081-51091	60625-60639	51035-51038 & 51045-51048	51050-51063	51064-51079
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2940	2941	2942	2943	2944	



Plan View



US Profile View

BDC_380_01_DSCH

BDC_380_01_DSFACE

BDC_380_01_OTXS

BDC_380_01_USCH

BDC_380_01_USFACE

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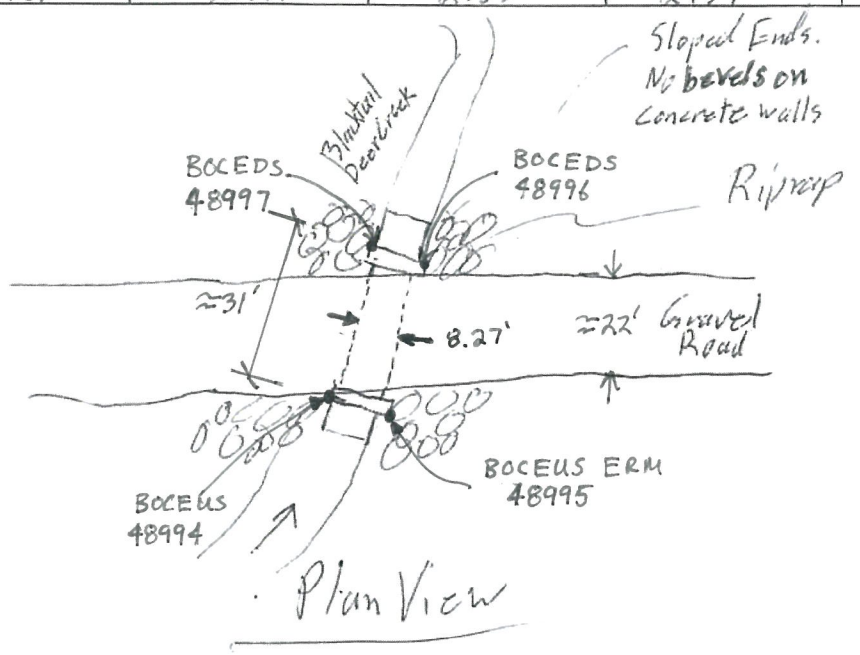
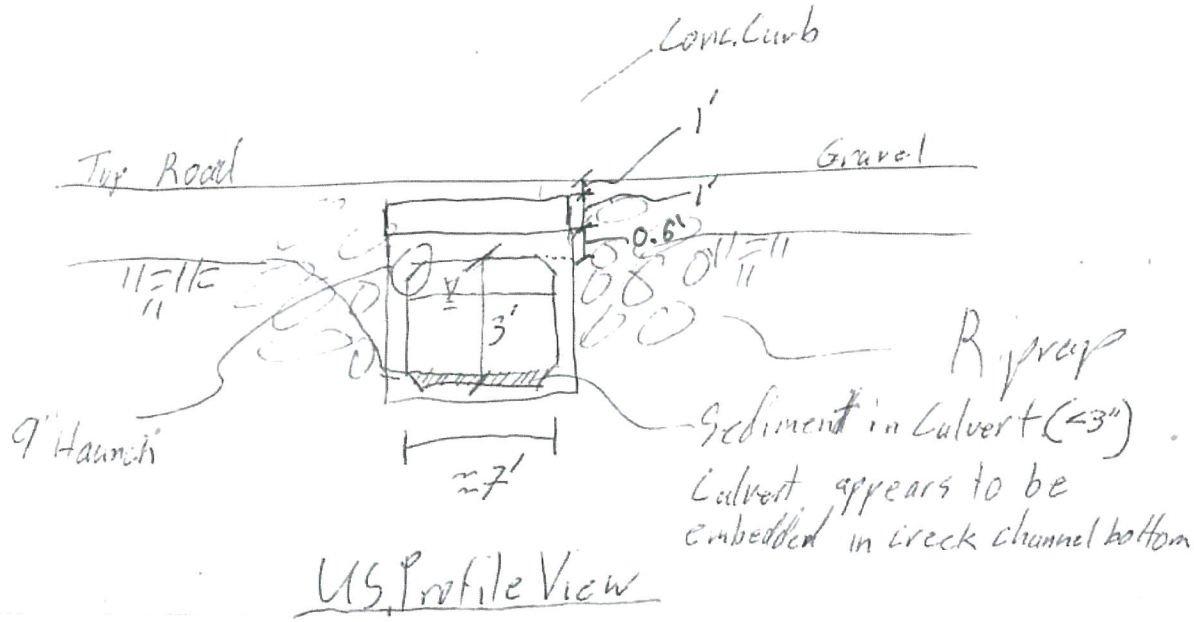
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_400				Crew: LDC/JRK	
Stream/Road Name: Blacktail Deer Creek/Private Rd				Date: 12/1/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48985-48999	62589-62599	62577-62588	48985-48991	51011-51022	51001-51010 & 49000
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2931	2932	2933	2934	2935	





BDC_400_01_DSCH

BDC_400_01_DSFACE

BDC_400_01_OTXS

BDC_400_01_USCH

BDC_400_01_USFACE

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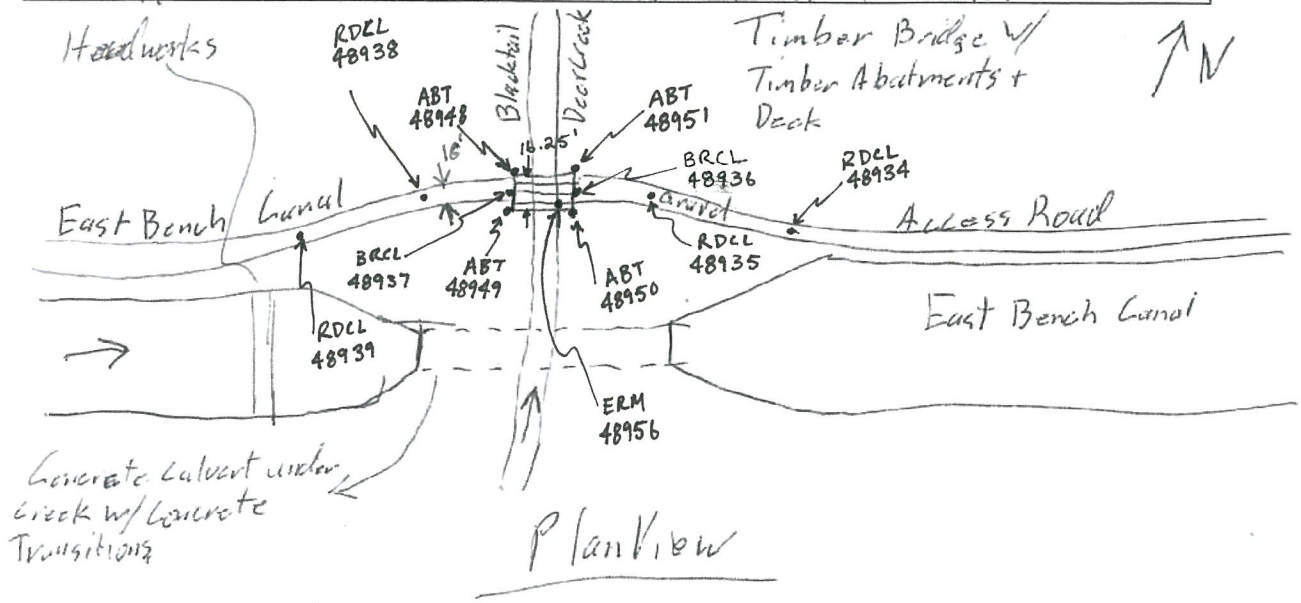
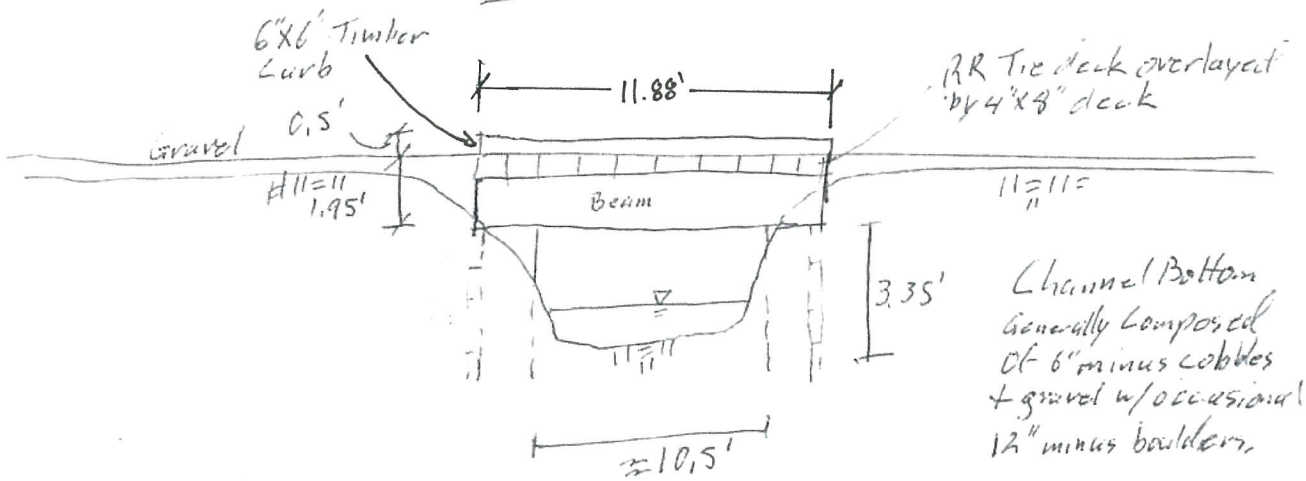
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC ~~30~~ 410				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek / East Bench Canal Access Rd				Date: 12/01/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48934 - 48956	62565 - 62576	62552 - 62564	48934 - 48939	48970 - 48984	48957 - 48969
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2926	2927	2928	2929	2930	



Plan View



US Profile View

BDC_410_01_DSCH

BDC_410_01_DSFACE

BDC_410_01_OTXS

BDC_410_01_USCH

BDC_410_01_USFACE

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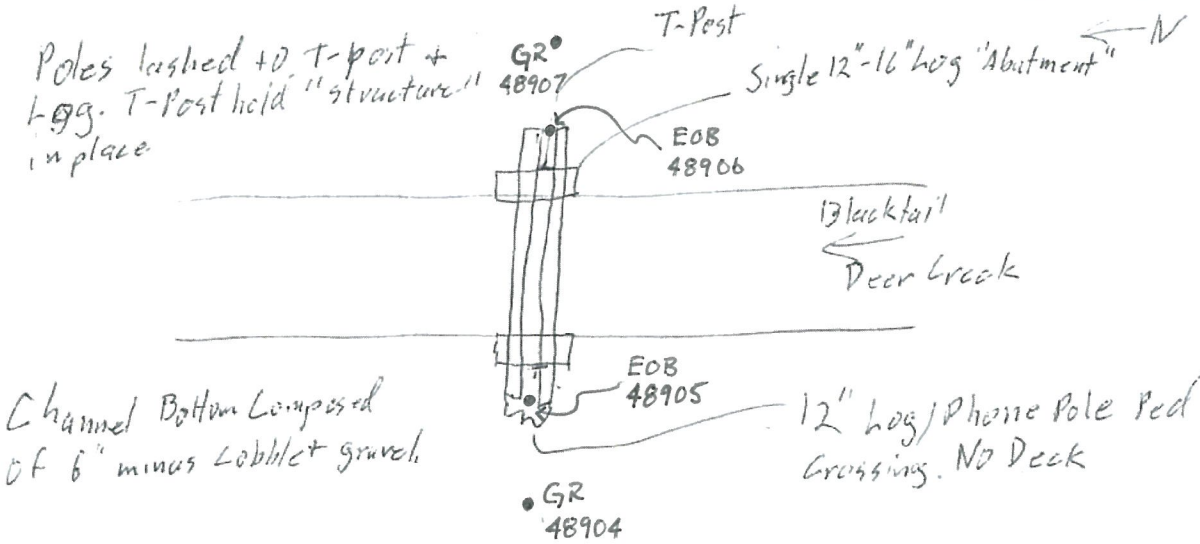
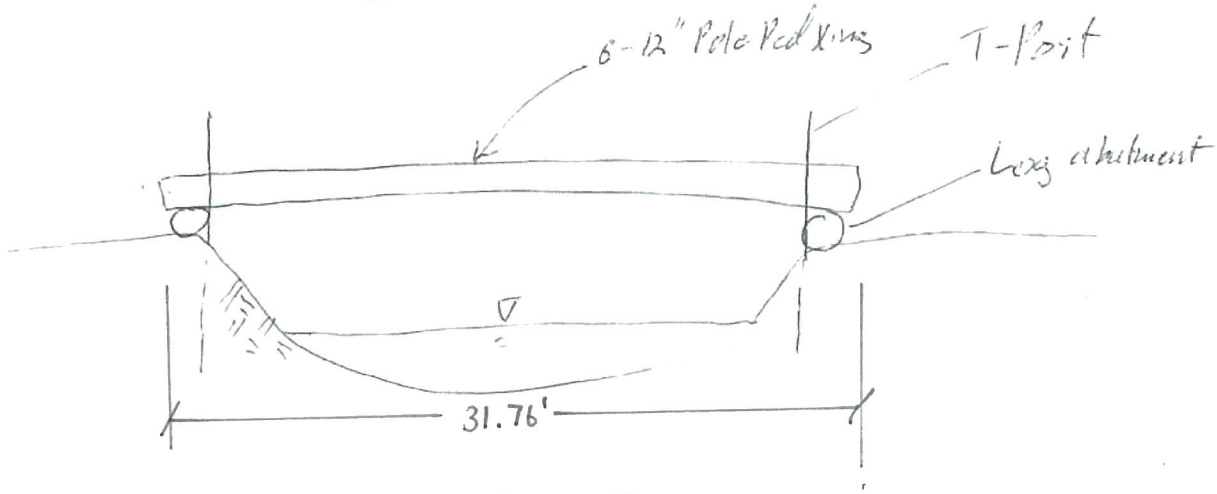
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID BDC-440				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek/Diversion				Date: 12/1/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48903-48908	N/A	N/A	48903-48908	48909-48922	N/A
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2913	2914	2915	2916	2917	



Plan View



US Profile View

BDC_440_01_DSCH

BDC_440_01_DSFACE

BDC_440_01_OTXS

BDC_440_01_USCH

BDC_440_01_USFACE

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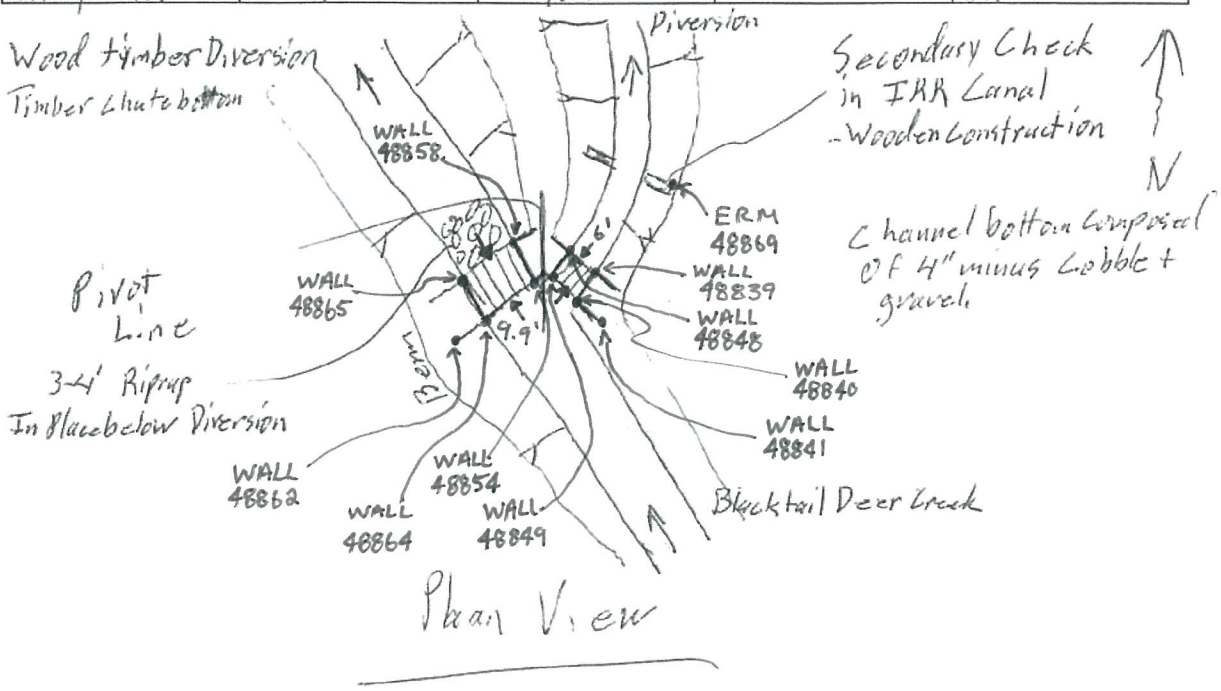
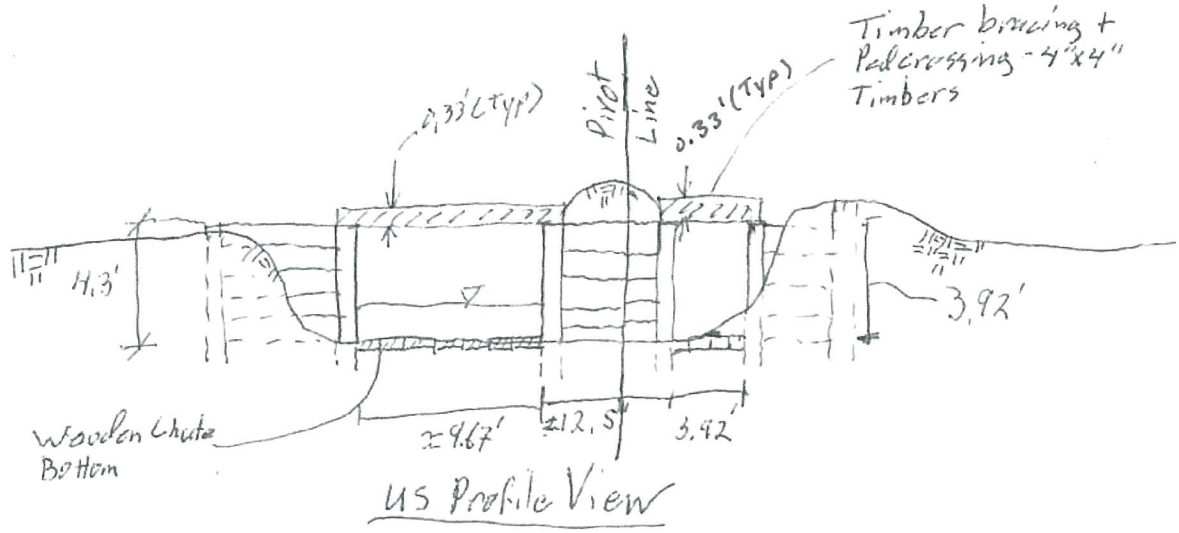
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_450				Crew: LDC/JRR	
Stream/Road Name: Blacktail Deer Creek/ Diversion				Date: ~~##~~ 12/1/2016	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48837-48869	62499-62516	62481-62498	48837-48838	48880-48892	48870-48879
Photos: 48866-48868					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2911, 2912	2909	2908	2910	2907	



Plan View



US Profile View

BDC_450_01_DSCH

BDC_450_01_DSFACE

BDC_450_01_OTXS

BDC_450_01_USCH

BDC_450_01_USFACE

BDC_450_02_DSFACE

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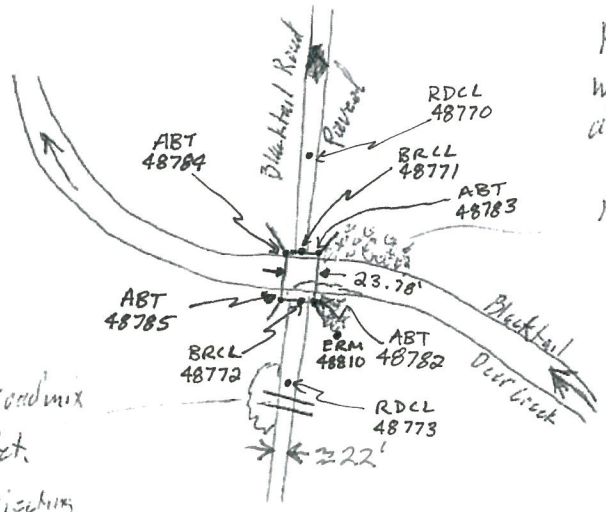
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-460				Crew: LDL/JRR	
Stream/Road Name: Blacktail Deer Creek/ Blacktail Rd				Date: 11/30/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48770 - 48824	48825 - 48836	62468-62486	48770-48773	62457-62467	62447-62456
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2904, 2906	2902	2901	2903	2900, 2905	



Rein. Conc. Bridge ↑ w/ Rein. Conc. Abutments and wing walls

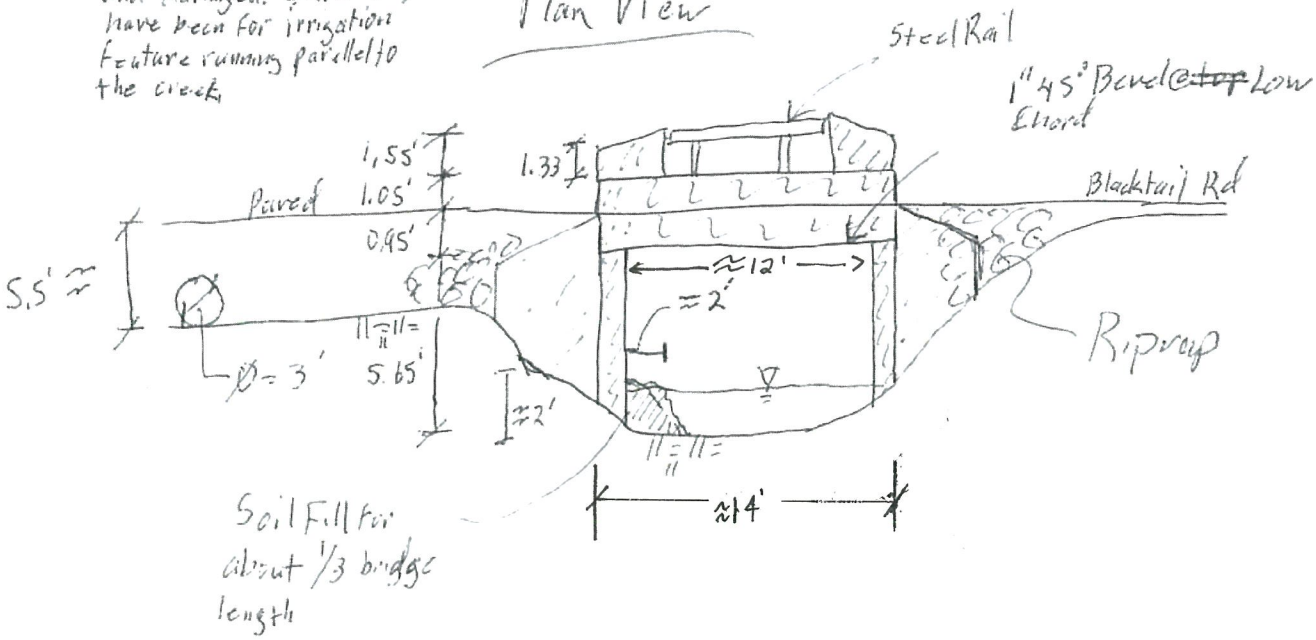
Riprap Bank protection

Channel Bottom Composed of 6" minus cobbles.

3' Csp Filled w/ roadmix berm @ outlet.

Culvert Inlet is projecting and damaged. Culvert may have been for irrigation feature running parallel to the creek.

Plan View



US Profile View

BDC_460_01_DSCH

BDC_460_01_DSFACE

BDC_460_01_OTXS

BDC_460_01_USCH

BDC_460_01_USFACE

BDC_460_02_DSFACE

BDC_460_02_USFACE

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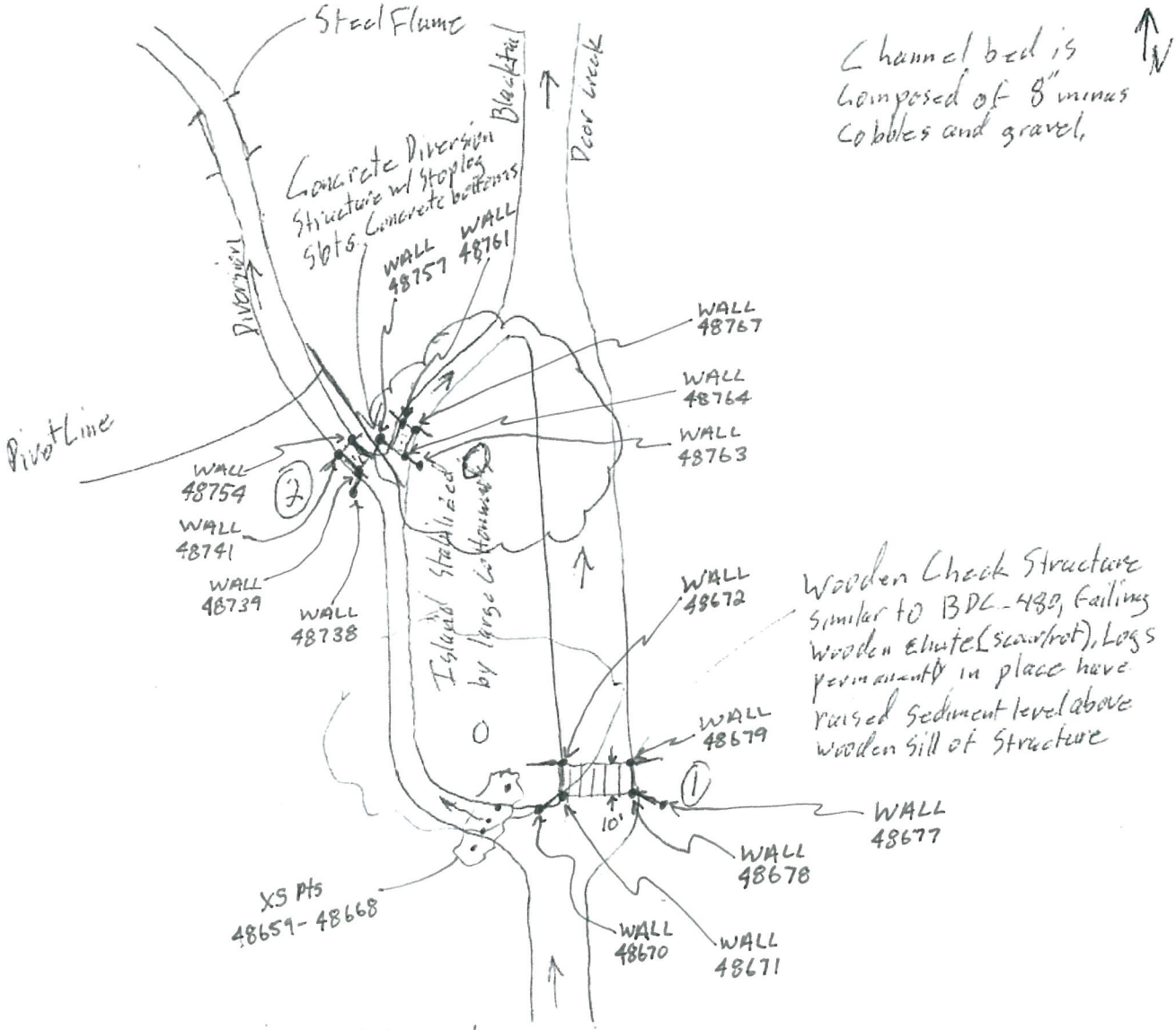
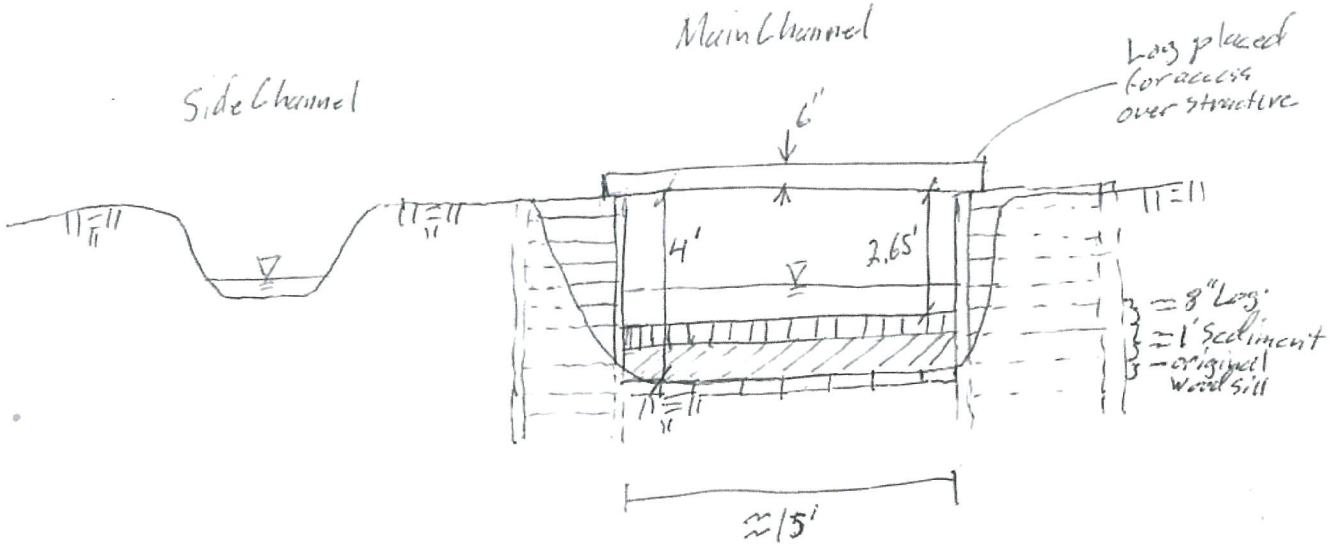
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC-470				Crew: LDC/JRB	
Stream/Road Name: Blacktail Deer Creek / Diversion				Date: 11/20/18	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
① 48669-48681	62401-62422 48736	48717-48735	48671 & 48678	48682-48703	48704-48716
② 48737-48769	62355-62371	62372-62400	Photos: 48739, 48764, 48754	62401-62422 & 48736	48717-48735

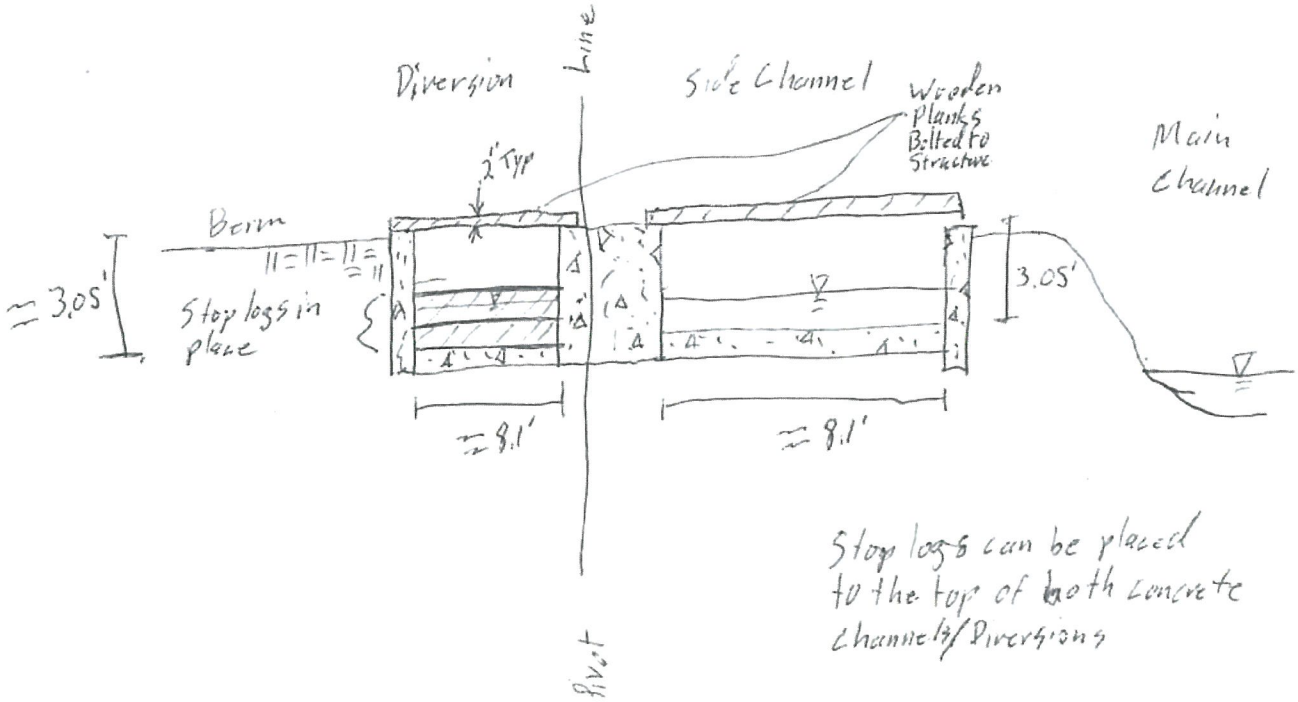
	DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
①	2887	2893	2894	2895	2892
②	2886	2889	2891	2890	2888



Plan View



① US Profile View



② US Profile View

BDC_470_01_DSCH

BDC_470_01_DSFACE

BDC_470_01_OTXS

BDC_470_01_USCH

BDC_470_01_USFACE

BDC_470_02_DSCH

BDC_470_02_DSFACE

BDC_470_02_OTXS

BDC_470_02_USCH

BDC_470_02_USFACE

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Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDL_480	Crew: LDC/JRR
Stream/Road Name: Blacktail Deer Creek / Diversion	Date: 11/30/16

Point Numbers (.job file name):

Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48591 - 48635	48636 - 48645	48646 - 48658	48628 & 48602	62342-62354 & 48590	62330-62341

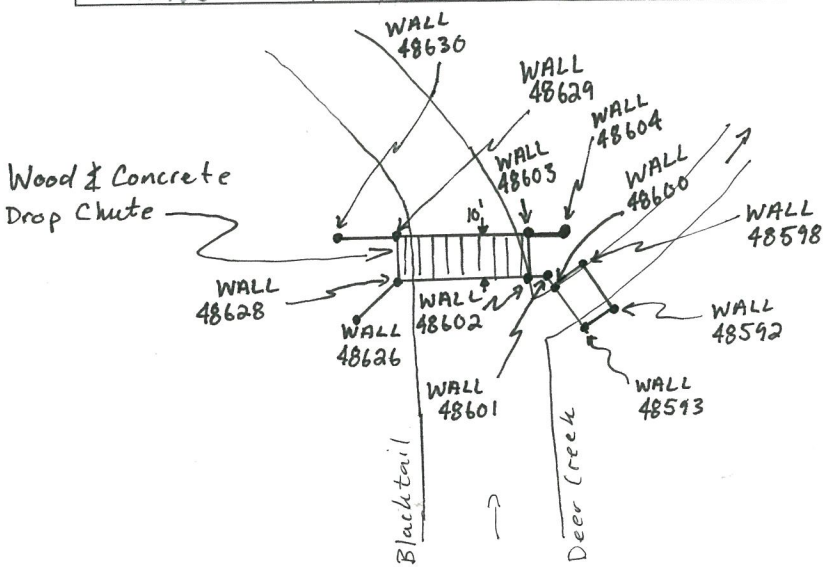
Photos:

DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
2885	2882	2881	2884	2883

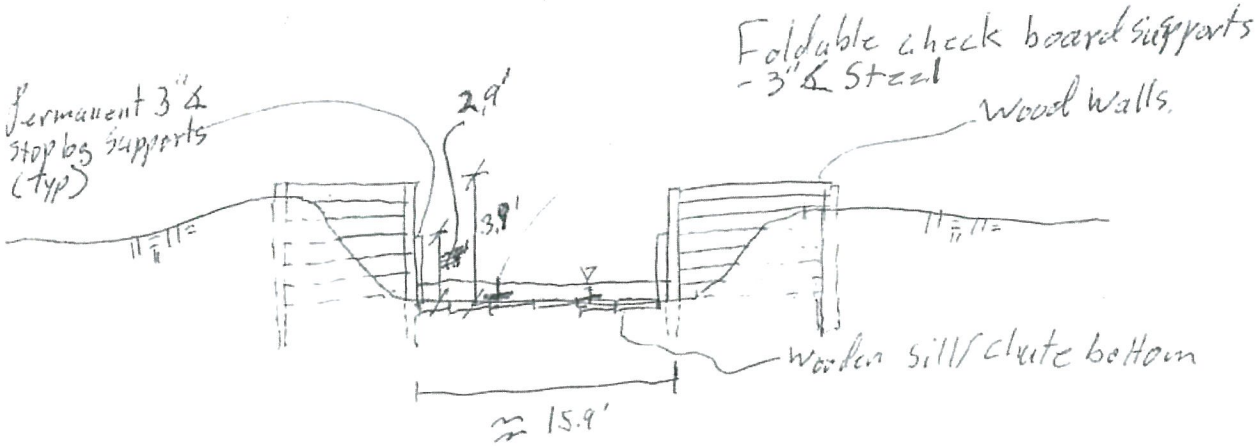
N ↑

Wooden Irrigation Diversion
2-3' drop down chute
from US to DS

Channel bottom is 3' minus cobble



PLAN VIEW



US Profile View

BDC_480_01_DSCH

BDC_480_01_DSFACE

BDC_480_01_OTXS

BDC_480_01_USCH

BDC_480_01_USFACE

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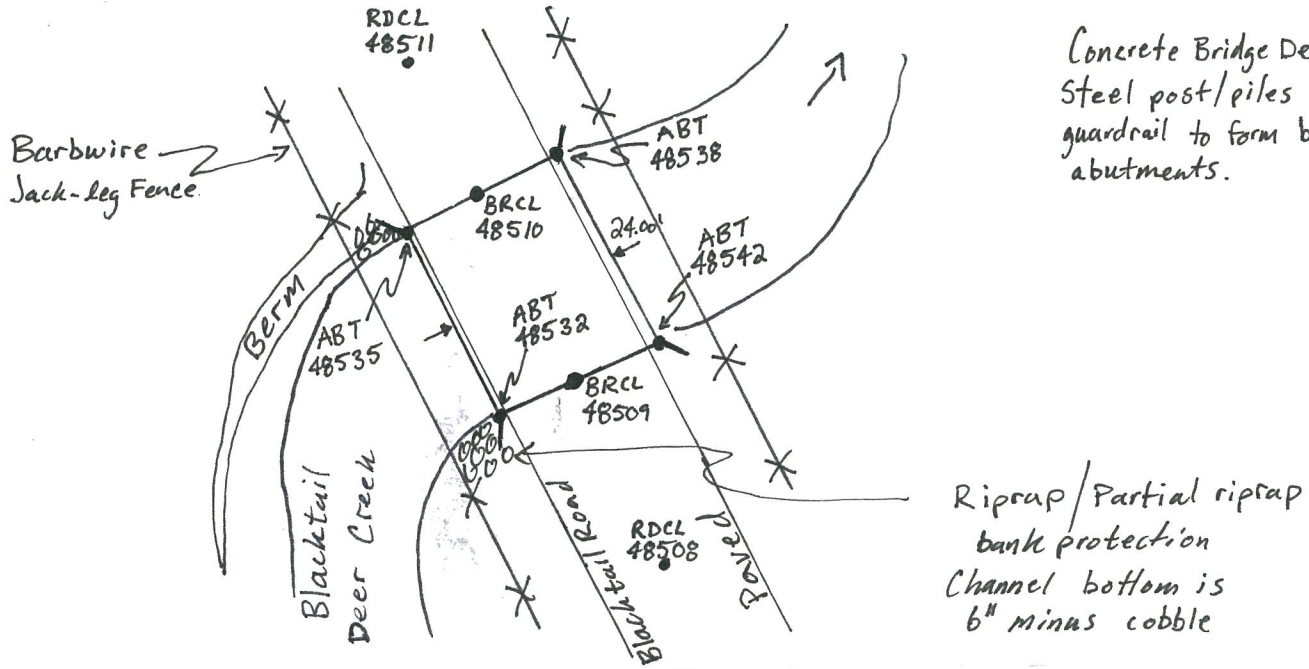
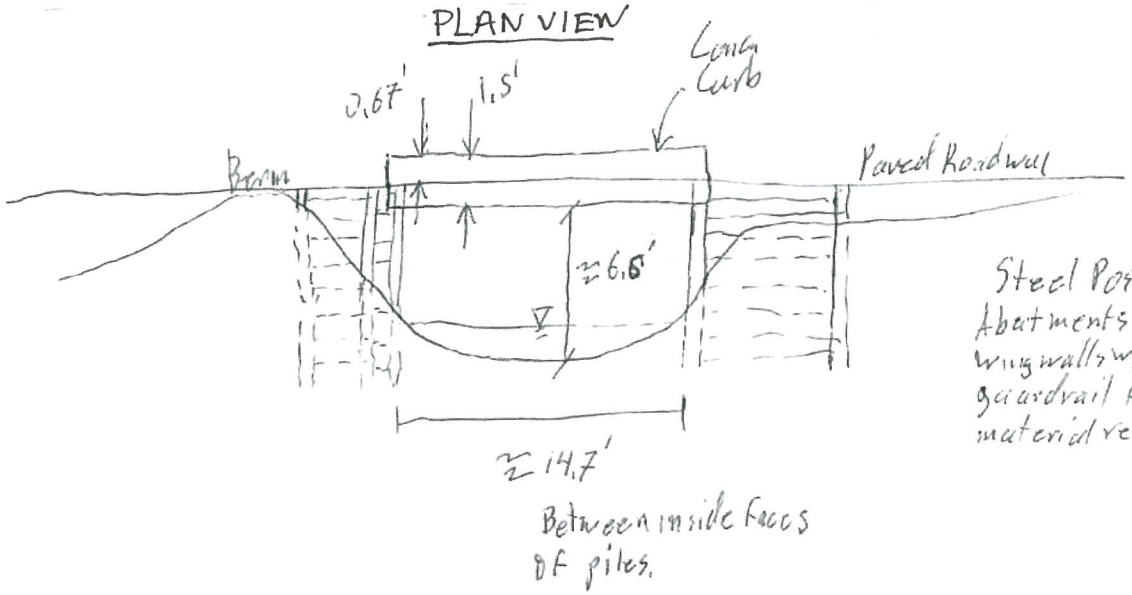
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: BDC_490				Crew: LDC / JKR	
Stream/Road Name: Blacktail Deer Creek / Blacktail Road				Date: 11/30/16	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
48504-48507 & 48512-48562	48575-48589	48563-48574	48508-48511	62307-62317	62295-62306
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
2874	2875	2876	2877	2878	



PLAN VIEW



CS Profile View

BDC_490_01_DSCH

BDC_490_01_DSFACE

BDC_490_01_OTXS

BDC_490_01_USCH

BDC_490_01_USFACE

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Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

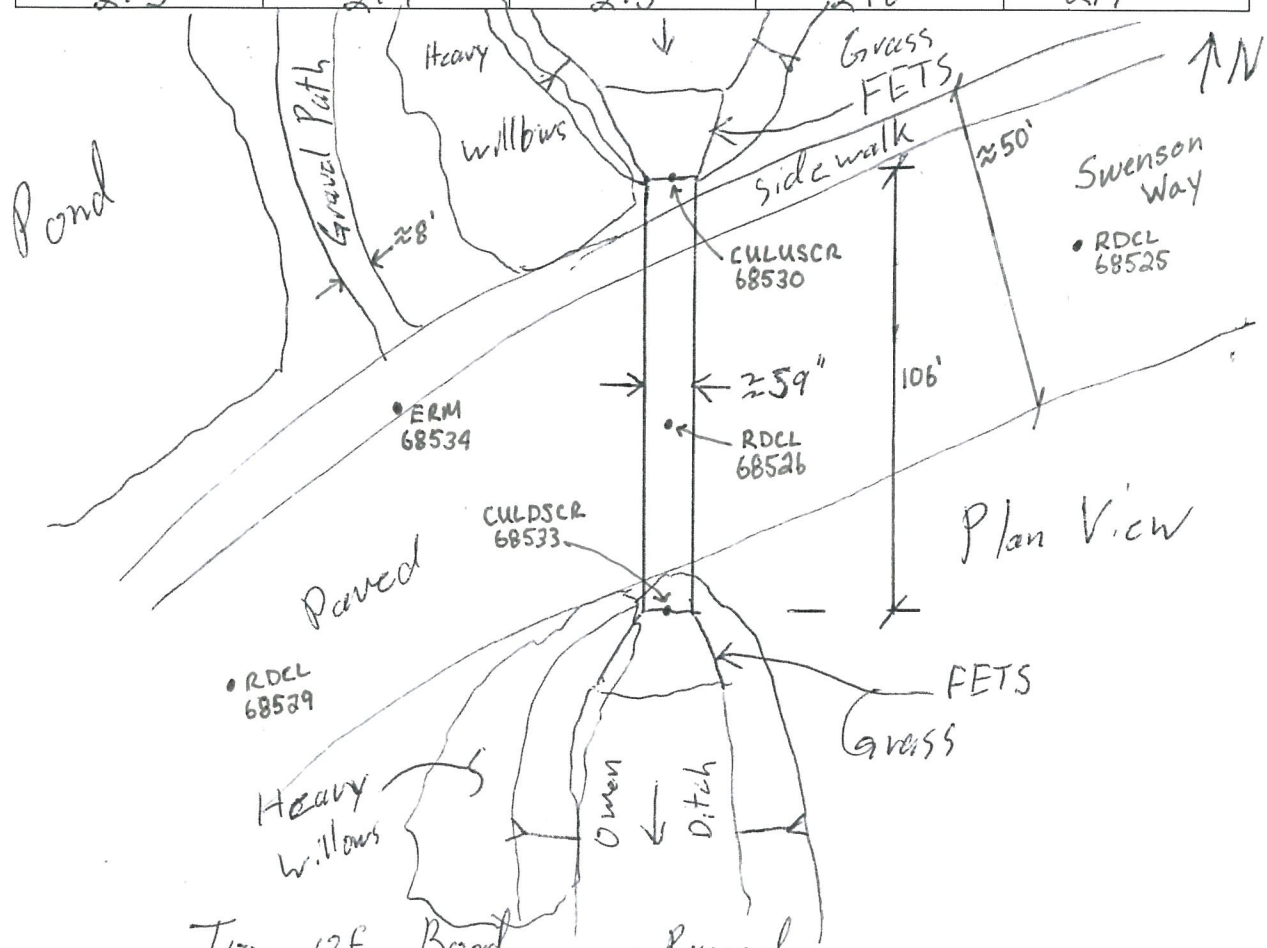
Structure ID: OWD-010	Crew: LDC/JJR
Stream/Road Name: Owen Ditch Split/ Swenson Way	Date: 7/27/17

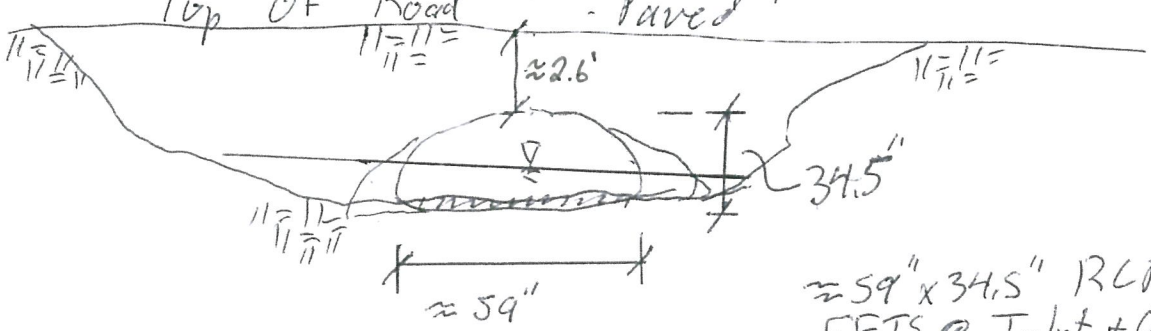
Point Numbers (.job file name):

Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68525 - 68534	68572 - 68581	68561 - 68571	68525 - 68529	68550 - 68560	68535 - 68549

Photos:

DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
213	214	215	216	217





≈59" x 34.5" RCPA
FETS @ Inlet + Outlet

US Profile View

OWD_010_01_DSCH

OWD_010_01_DSFACE

OWD_010_01_OTXS

OWD_010_01_USCH

OWD_010_01_USFACE

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Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

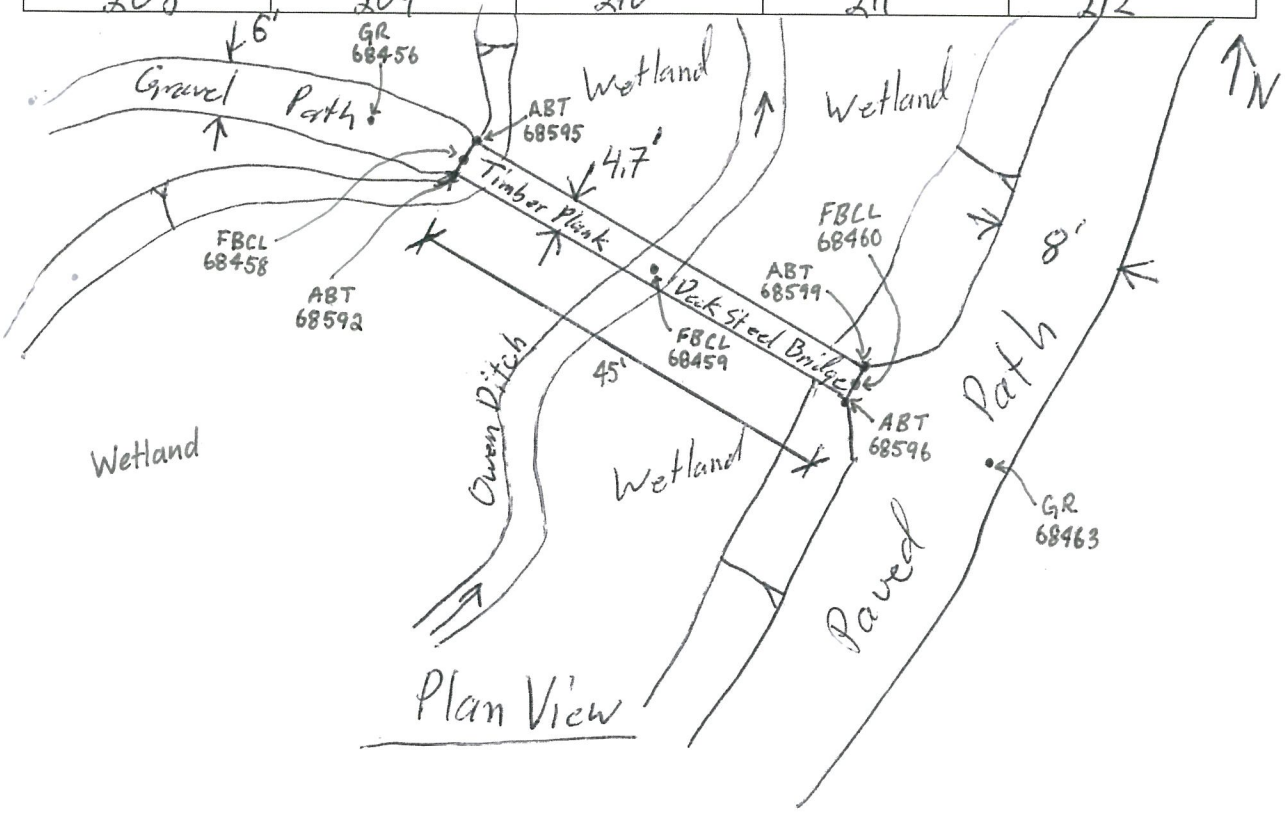
Structure ID: OWD-015 split	Crew: LDC/JJR
Stream/Road Name: Owen Ditch / Pedestrian Path Bridge	Date: 7/27/17

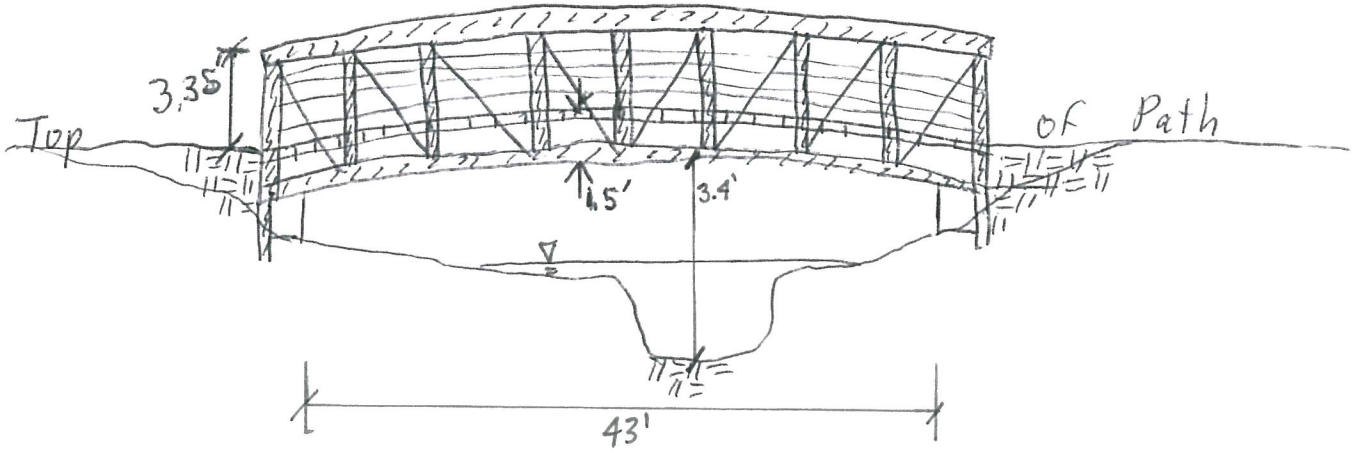
Point Numbers (.job file name):

Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68456-68481, 68592-68607	68514 - 68524	68503 - 68513	68456 - 68463	68491 - 68502	68482 - 68490

Photos:

DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
208	209	210	211	212





US Profile View

OWD_015_01_DSCH

OWD_015_01_DSFACE

OWD_015_01_OTXS

OWD_015_01_USCH

OWD_015_01_USFACE

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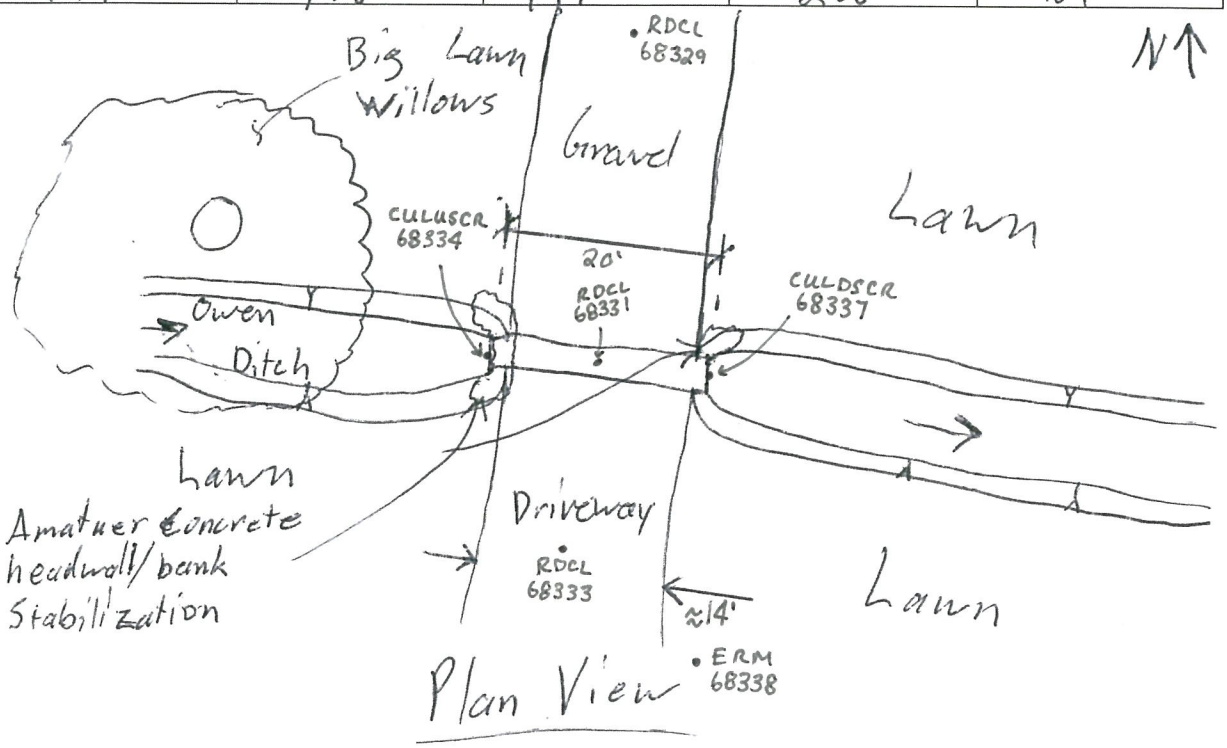
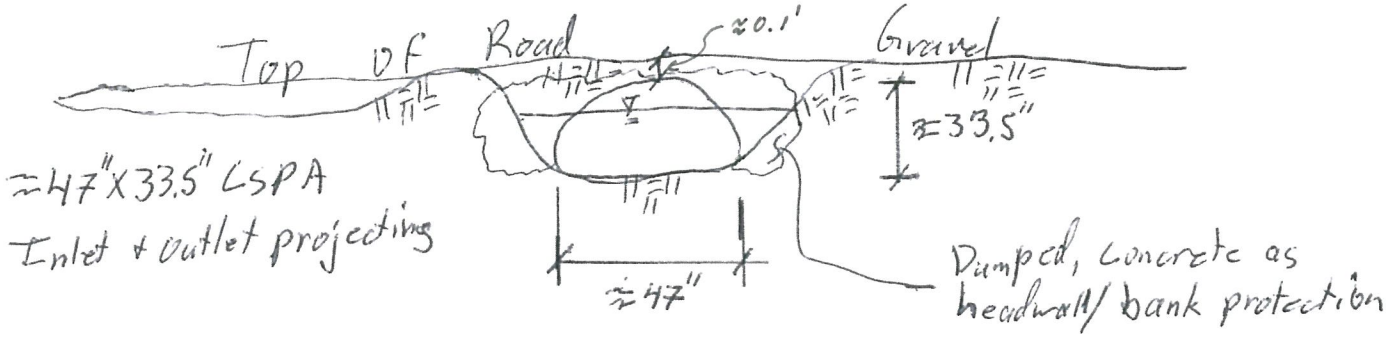
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: OWD_030				Crew: LDC/JJR	
Stream/Road Name: Owen Ditch / Private Drive				Date: 7/27/17	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68329-68338	68360-68370	68356-68359	68329-68333	68339-68349	68584-68589
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
197	198	199	200	201	



Plan View



US Profile View

OWD_030_01_DSCH

OWD_030_01_DSFACE

OWD_030_01_OTXS

OWD_030_01_USCH

OWD_030_01_USFACE

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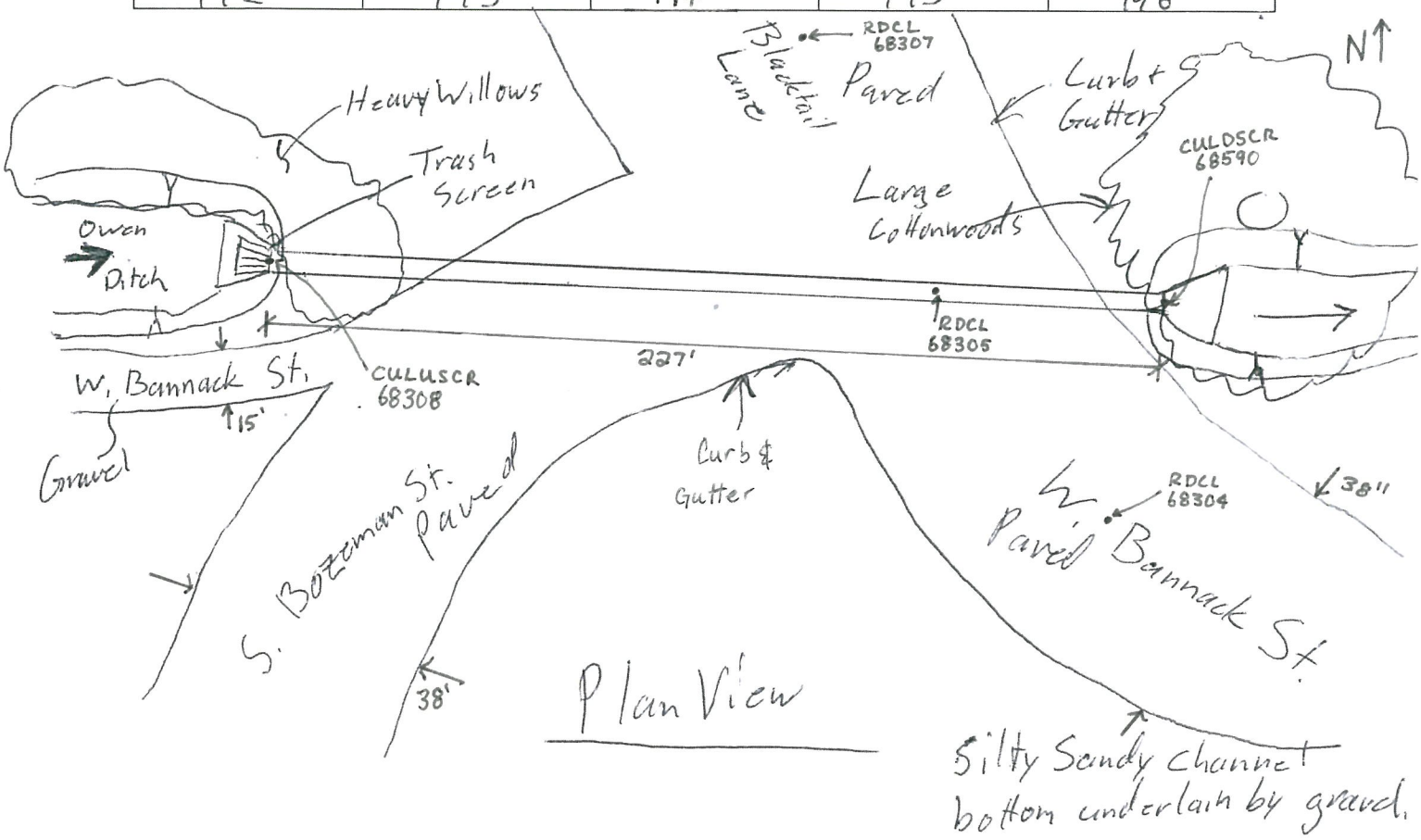
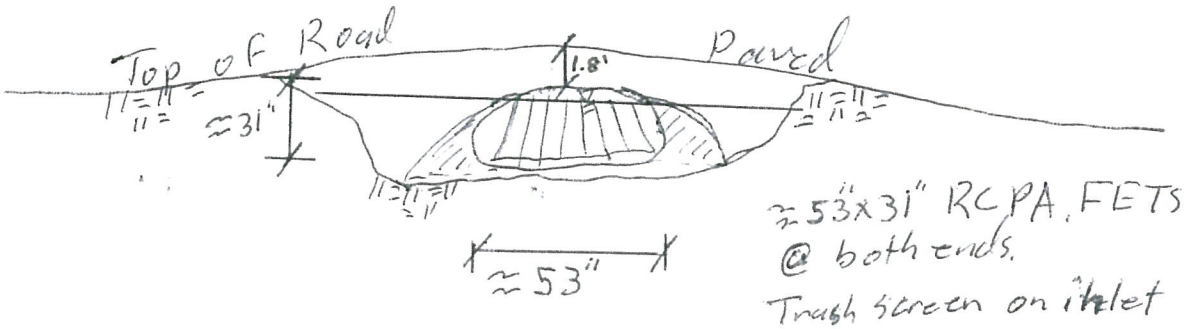
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: OWD-040				Crew: LDC/JJR	
Stream/Road Name: Owen Ditch / W. Bannack Street				Date: 7/27/17	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68304 - 68311 ← 68590-68591 ↲	68339 - 68349	68584 - 68589	68304 - 68307	68322 - 68328	68312 - 68321
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
192	193	194	195	196	





US Profile View

OWD_040_01_DSCH

OWD_040_01_DSFACE

OWD_040_01_OTXS

OWD_040_01_USCH

OWD_040_01_USFACE

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Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

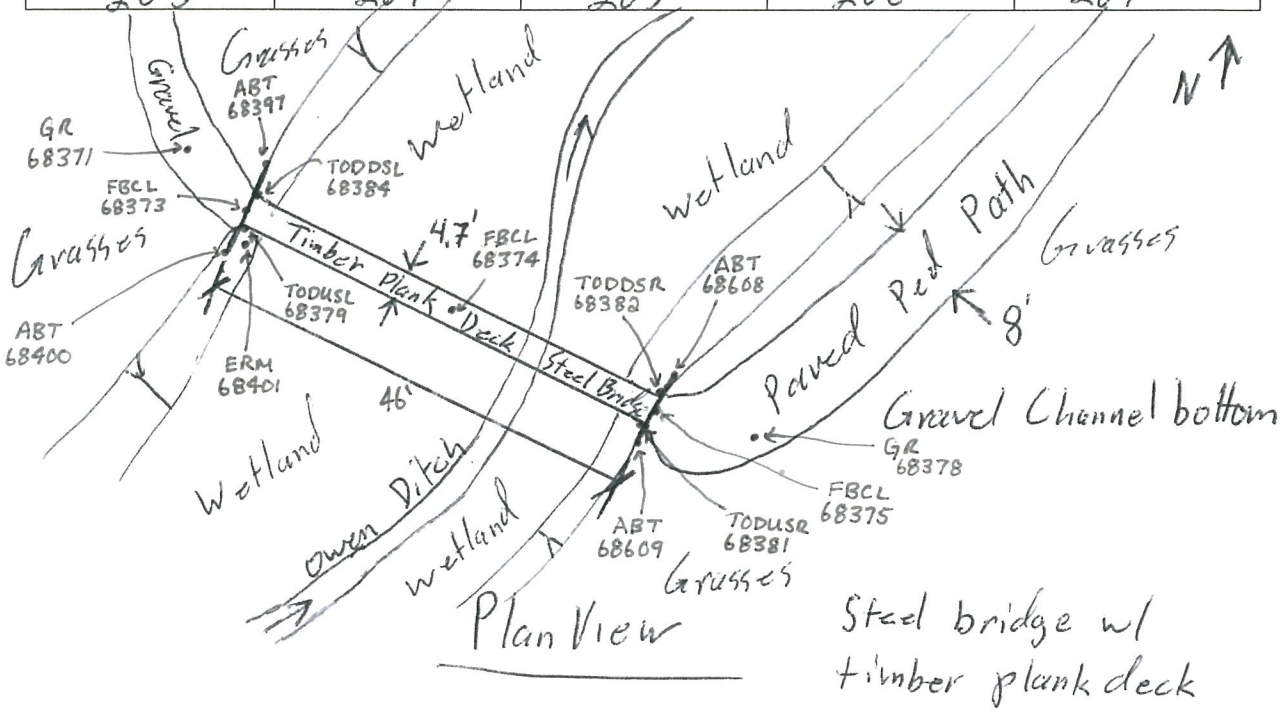
Structure ID: OWD_045	Crew: LDL/JJR
Stream/Road Name: Owen Ditch Split / Ped Bridge	Date: 7/27/17

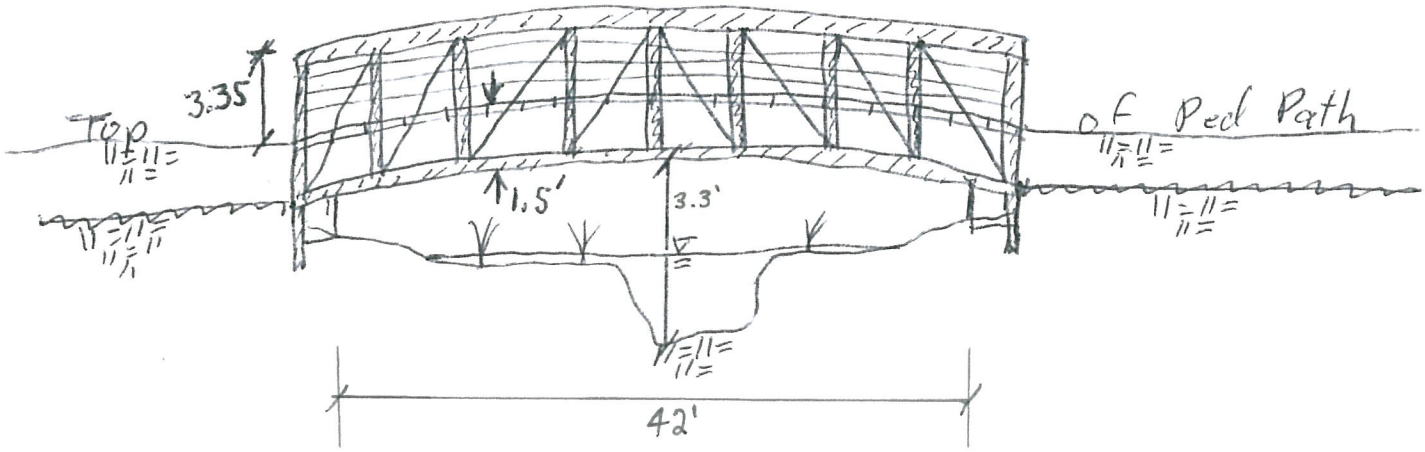
Point Numbers (.job file name):

Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68371-68403	68442-68455	68428-68441	68371-68378	68415-68427	68404-68414
68608-68609					

Photos:

DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
203	204	205	206	207





US Profile View

OWD_045_01_DSCH

OWD_045_01_DSFACE

OWD_045_01_OTXS

OWD_045_01_USCH

OWD_045_01_USFACE

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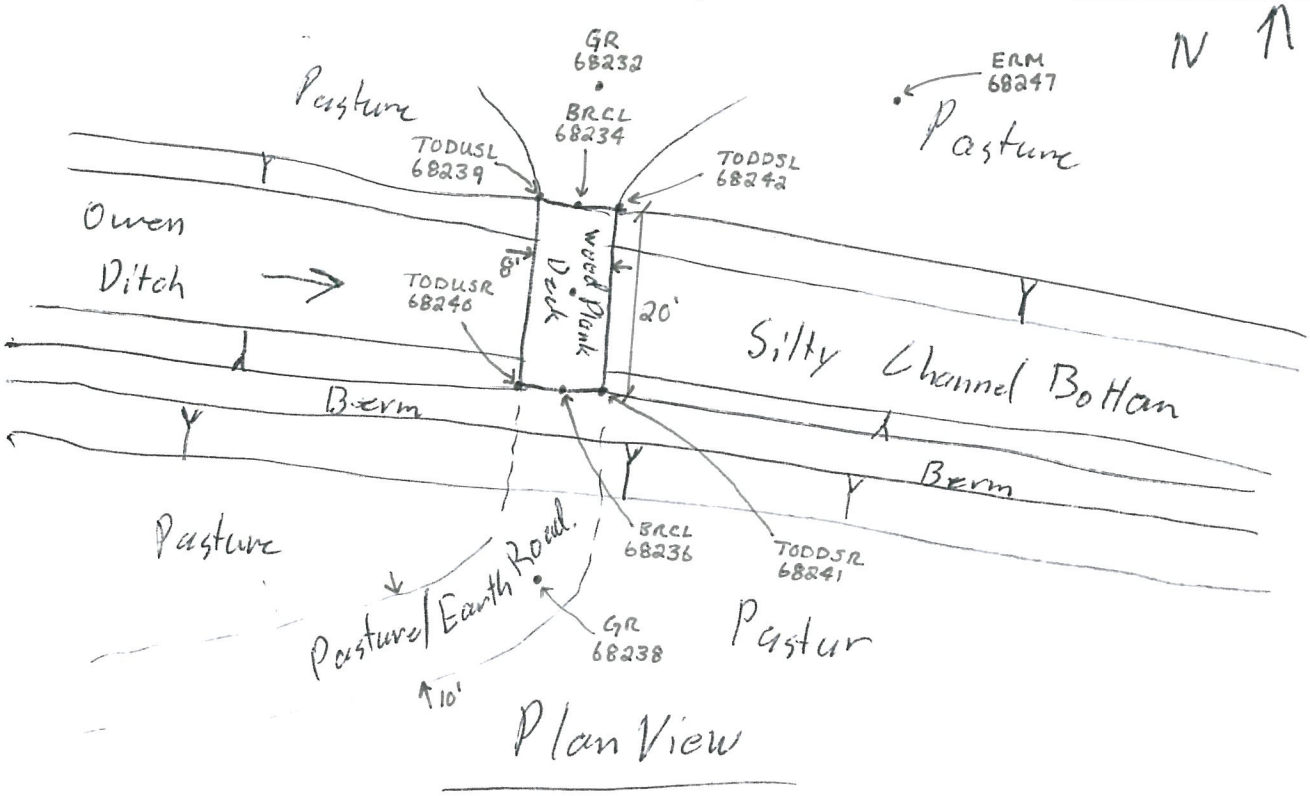
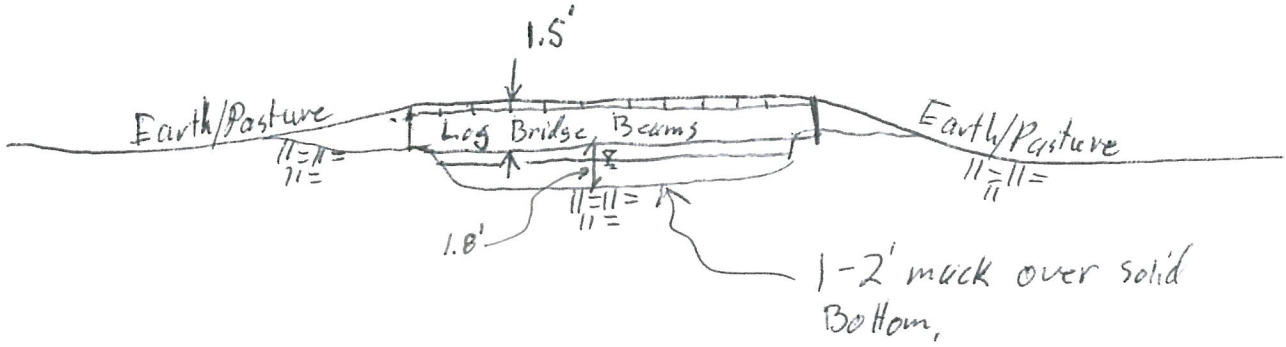
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: OWD-050				Crew: LDL/JJR	
Stream/Road Name: Owen Ditch/ Private Farm x'ing				Date: 7/27/17	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68232 - 68246	68290 - 68303	68277 - 68289	68232 - 68238	68262 - 68276	68248 - 68261
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
187	188	189	190	191	



Plan View



US Profile View

OWD_050_01_DSCH

OWD_050_01_DSFACE

OWD_050_01_OTXS

OWD_050_01_USCH

OWD_050_01_USFACE

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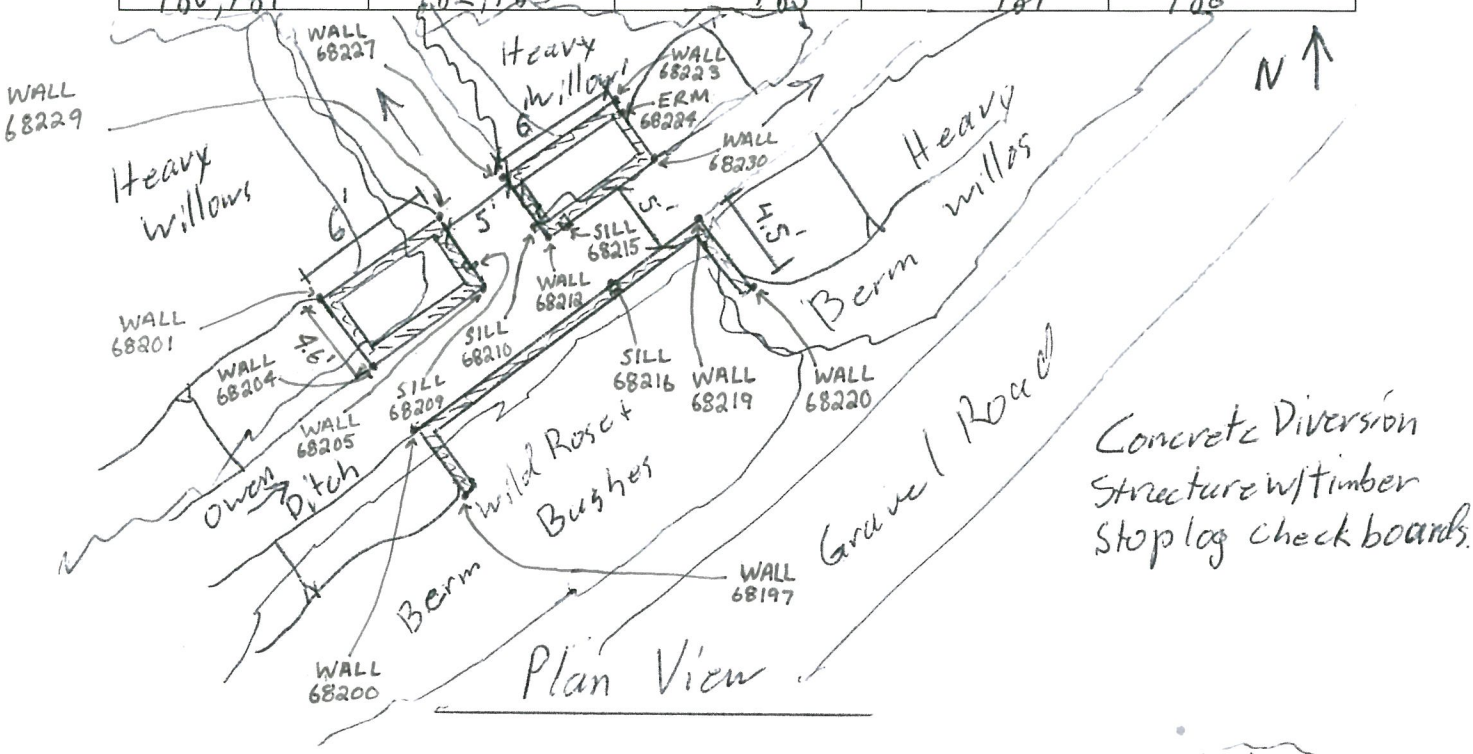
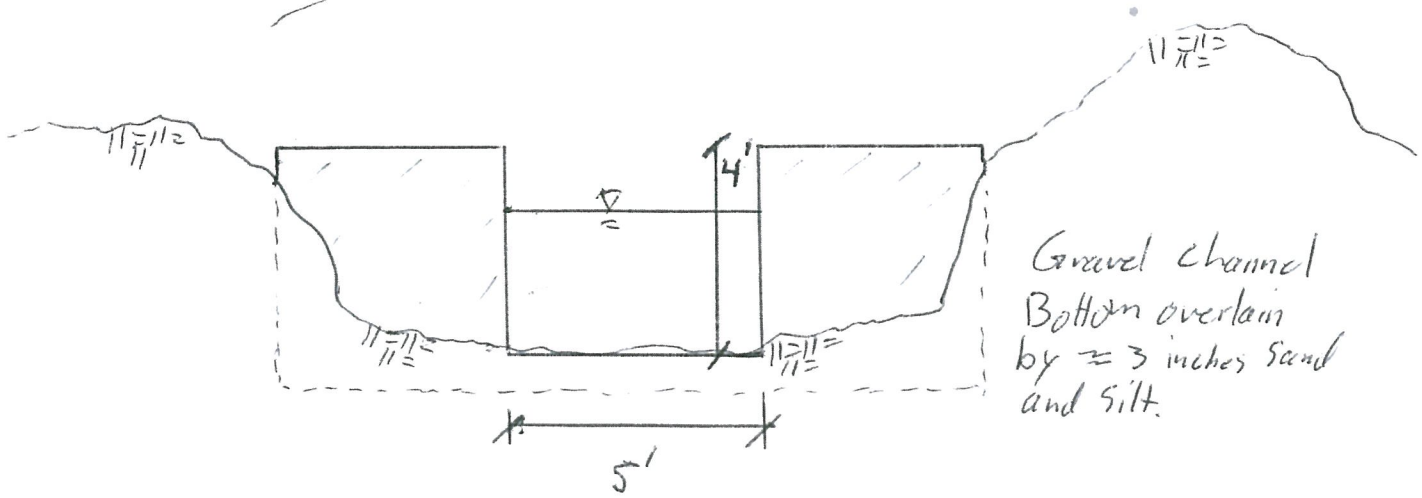
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: OWD-060				Crew: LDC/JJR	
Stream/Road Name: Owen Ditch/Canal Diversion				Date: 7/27/17	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68197 - 68231	68182 - 68196	68158 - 68181	68204 - 68205, 68212	68143 - 68157	68126 - 68142
Photos: 68230					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
180, 181	182, 183	185	184	186	



Concrete Diversion Structure w/timber Stoplog check boards.



Gravel channel Bottom overlain by ≈ 3 inches Sand and Silt.

US Profile View

OWD_060_01_DSCH

OWD_060_01_DSFACE

OWD_060_01_OTXS

OWD_060_01_USCH

OWD_060_01_USFACE

OWD_060_02_DSCH

OWD_060_02_DSFACE

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Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

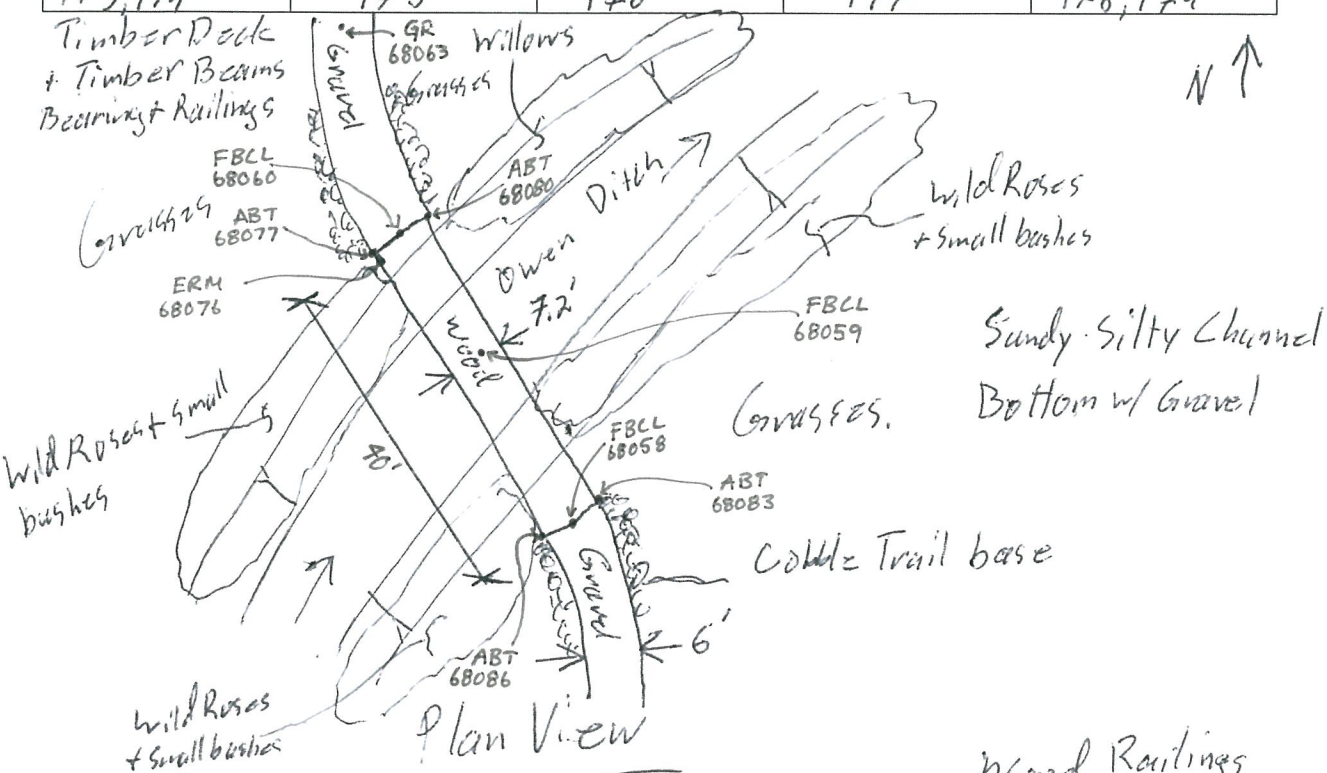
Structure ID: OWD-070	Crew: LDC/JJR
Stream/Road Name: Owen Ditch/Ped Path Bridge	Date: 7/27/17

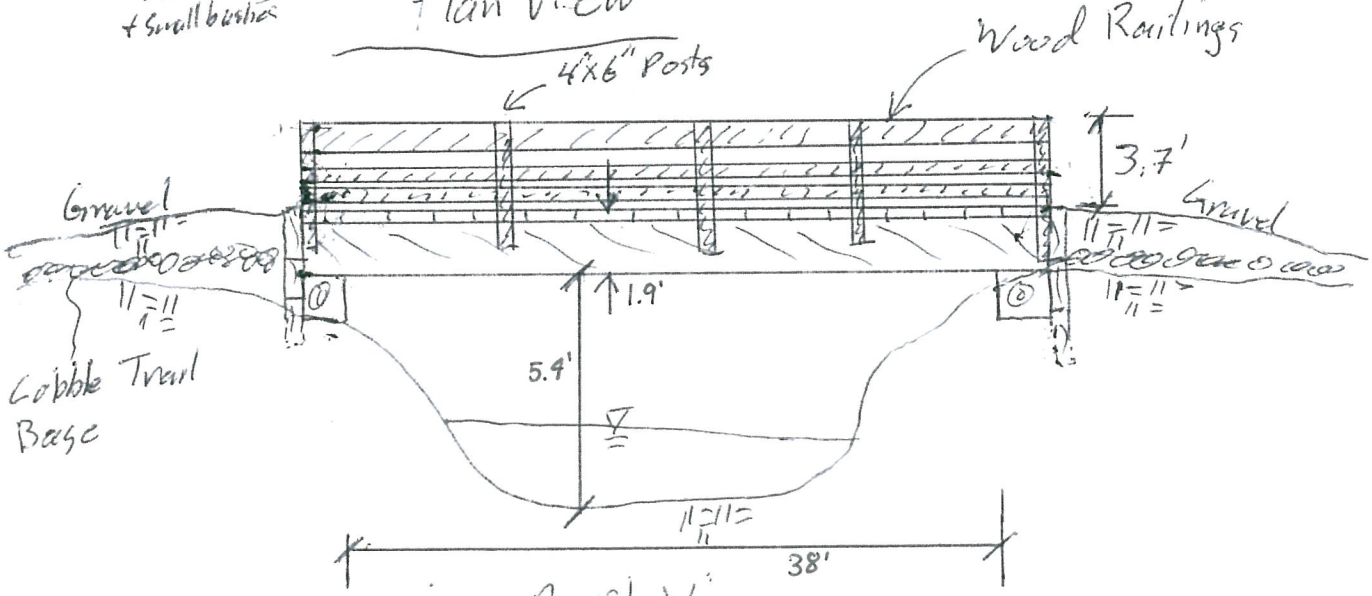
Point Numbers (.job file name):

Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68056-68093, 68582-68583	68143-68157	68126-68142	68056-68063	68109-68125	68094-68108

Photos:

DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:
173, 174	175	176	177	178, 179





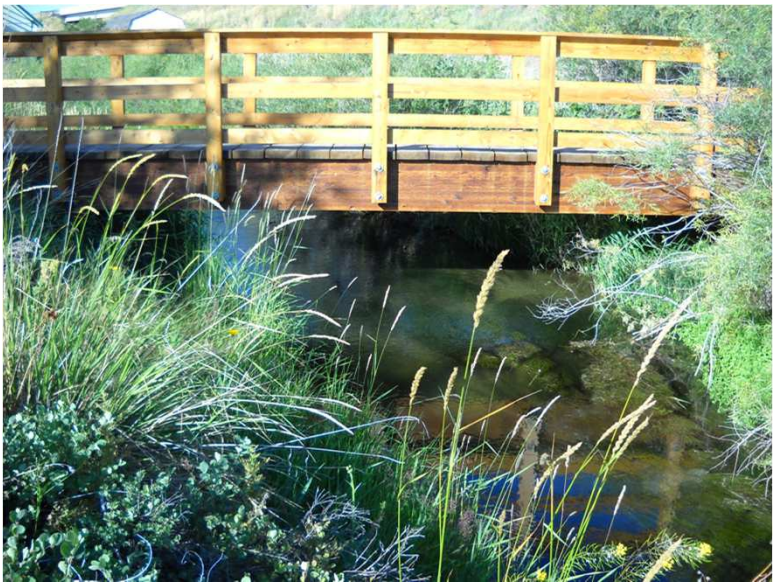
OWD_070_01_DSCH

OWD_070_01_DSFACE

OWD_070_01_OTXS

OWD_070_01_USCH

OWD_070_01_USFACE



OWD_070_02_DSFACE

OWD_070_02_USFACE

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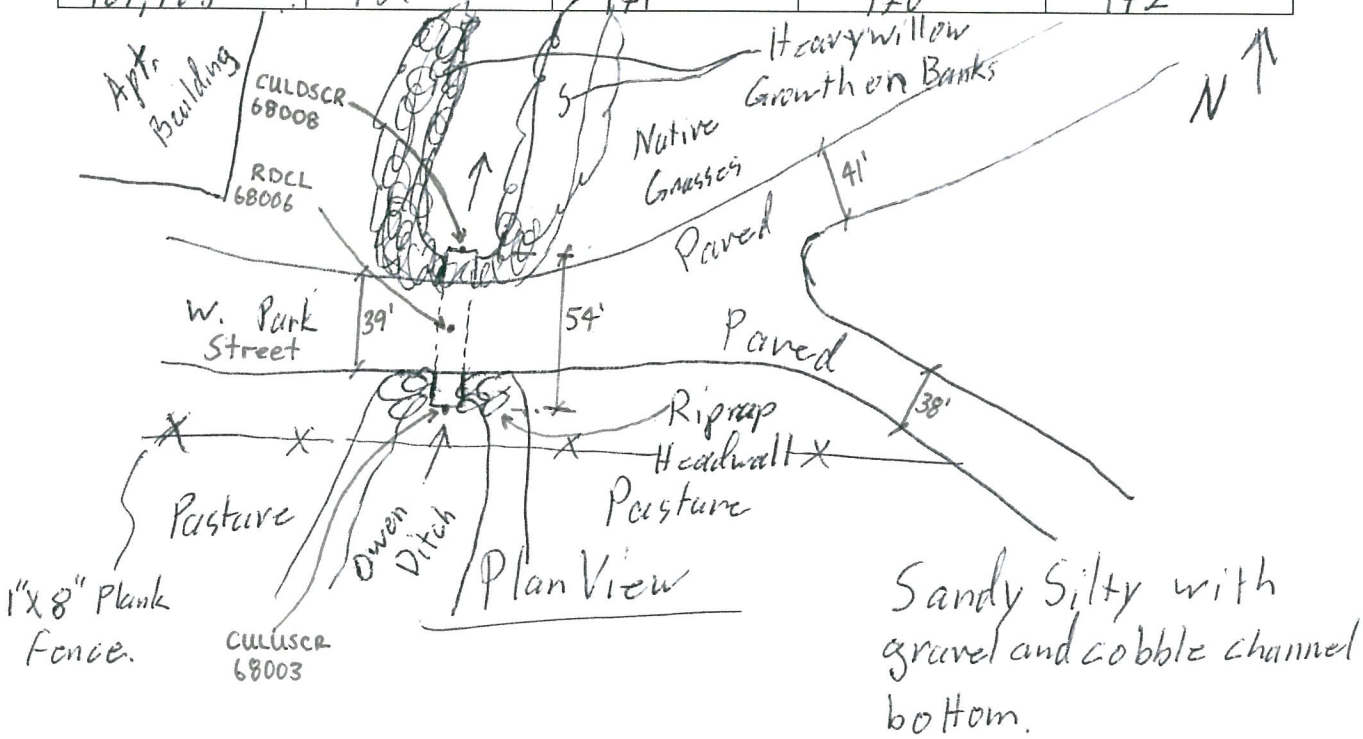
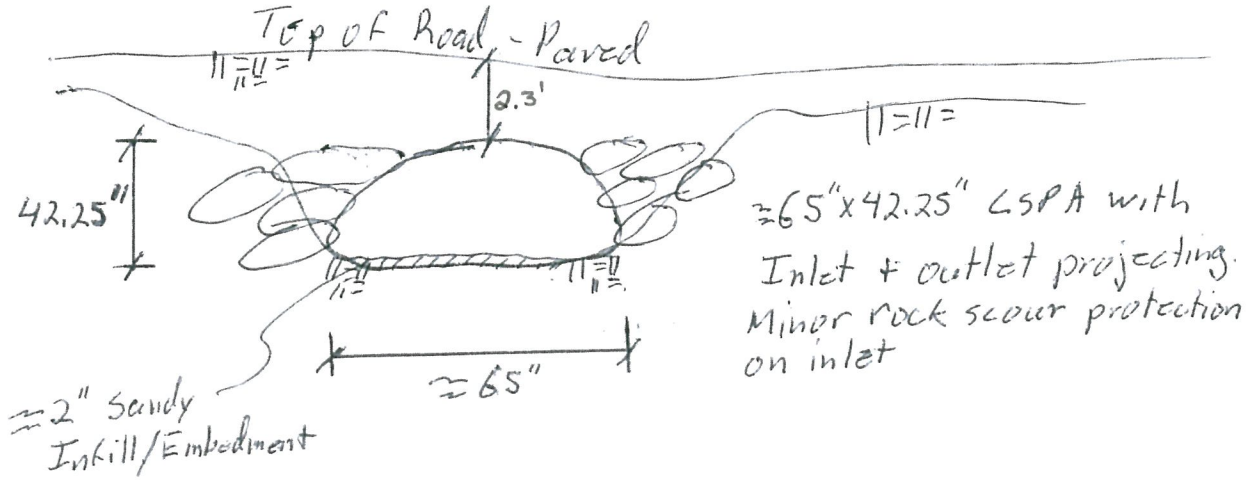
Beaverhead County Flood Studies, MT
Hydraulic Structure Survey Form:

Structure ID: OWD_080				Crew: LDC/JJR	
Stream/Road Name: Owen Ditch / W. Park Street				Date: 7/27/17	
Point Numbers (.job file name):					
Structure Pts:	XS 1 Pts:	XS 2 Pts:	Crest Profile Pts:	XS 3 Pts:	XS 4 Pts:
68003 - 68009	68044 - 68055	68033 - 68043	68005 - 68007	68022 - 68032	68010 - 68021
Photos:					
DS face of structure:	From structure looking DS:	From structure looking US:	Overtopping XS looking left to right:	US face of the structure:	
167, 168	169	171	170	172	





OWD_080_01_DSCH

OWD_080_01_DSFACE

OWD_080_01_OTXS

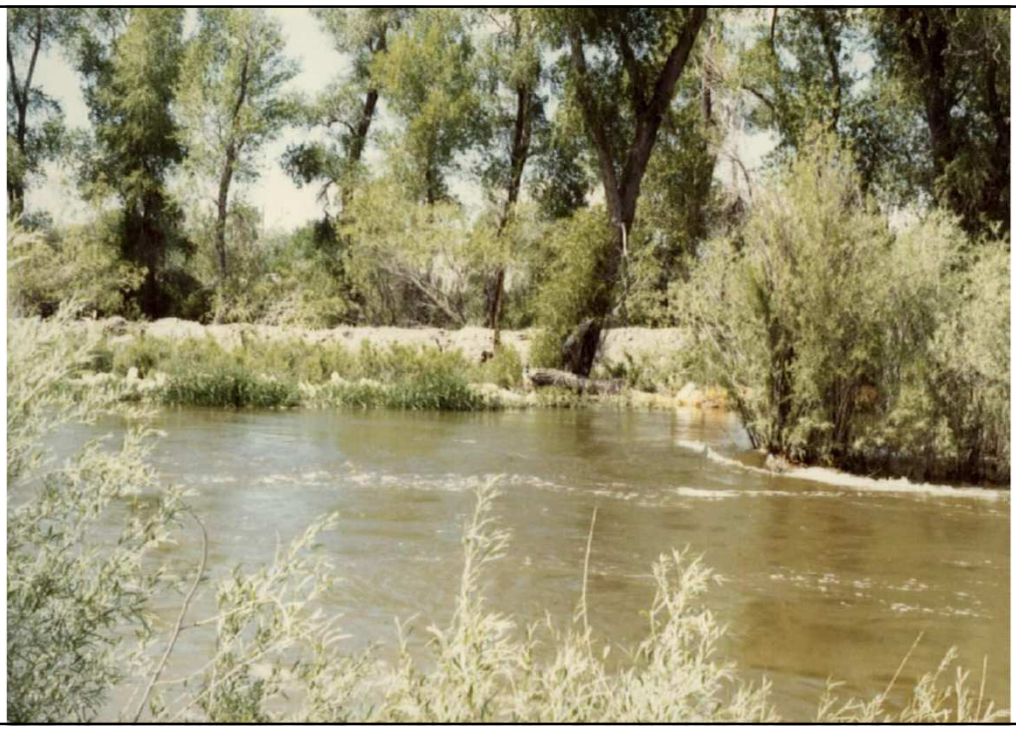
OWD_080_01_USCH

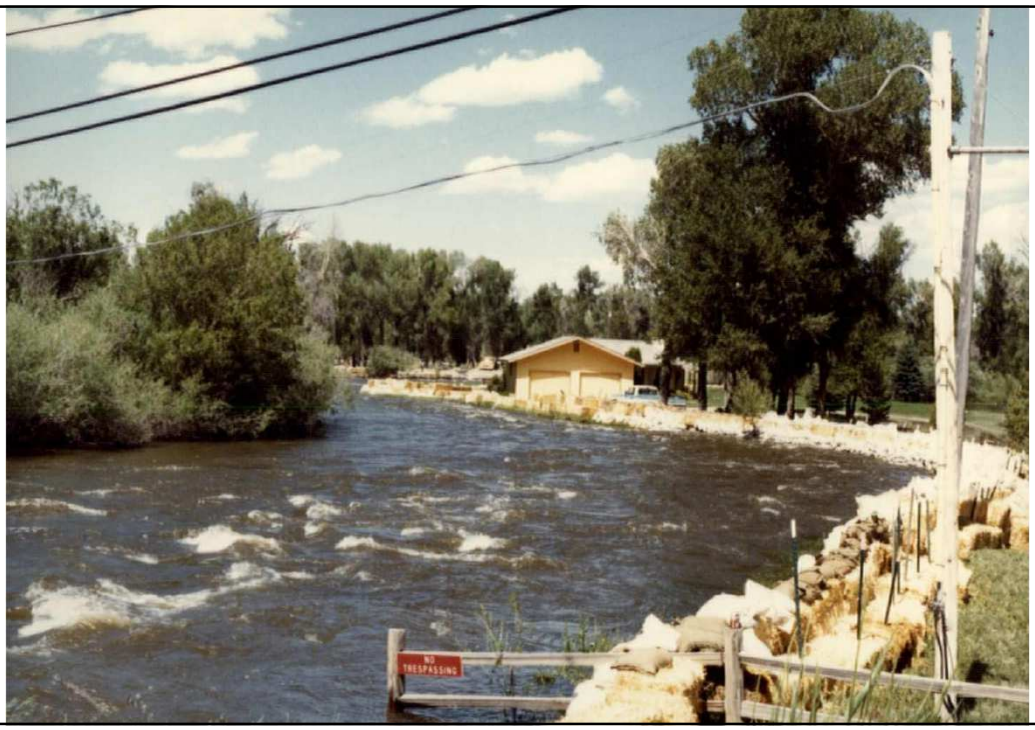
OWD_080_01_USFACE

OWD_080_02_DSFACE

APPENDIX G – HISTORIC FLOODING

Historic Flood Photographs

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Jefferson

Silver Star