Hydraulic Summary Report

West Gallatin River

Gallatin County, MT

Montana DNRC Cooperating Technical Partners Mapping Activity Statement (MAS): No. 2014-02

Prepared for
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SUBMITTED TO:

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Montana Department of Natural Resources and Conservation

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1.0 Introduction

As part of the Mapping Activity Statement (MAS) contract for the West Gallatin River in Gallatin County, Montana (FEMA 2014**)**, Morrison-Maierle, Inc. is completing an updated floodplain study for the West Gallatin River within Gallatin County, Montana. The West Gallatin River study limits extend from the confluence with the East Gallatin River at the downstream limit to approximately 30 miles upstream to just above the community of Gallatin Gateway, Montana, at the upstream study limit. The project area is shown on Figures 1A and 1B.

A Flood Insurance Study (FIS) has been completed for Gallatin County with an effective date of September 2, 2011 (FEMA 2011). The flood hazards currently mapped for the West Gallatin River are Zone A from the confluence with the East Gallatin River to the Interstate 90 (I-90) bridge and Zone AE from upstream of the I-90 Bridge to approximately ½ mile downstream of the upstream study limits. The uppermost ½ mile of the effective mapped area is Zone A.

This Summary Report details the information and methods used to develop the 1-percent-annual-chance (100-year) and 0.2-percent-annual-chance (500-year) floodplain. This study is based on the best available information including LIDAR, bathometric, structure survey and a new hydrologic analysis developed specifically for this mapping update. The LIDAR and bathymetric surveys were obtained by Photo Science, Inc. in conjunction with Gaston Engineering & Surveying, PC, in 2013 (Photo Science 2013 and Gaston 2013). The new hydrologic analysis and structural survey were completed by Morrison-Maierle, Inc. in the fall of 2014 (MMI 2015). The aforementioned surveys, topographic and hydrologic data were previously submitted to and approved by FEMA in 2013.

The hydraulic analysis for West Gallatin River is summarized in this report. The flood study includes the 10%, 4%, 1%, 1% plus, and 0.2% annual-chance flood events. The effective mapping shows the numerous split flows and overflow channels that exist along the lower half of the 30 stream mile study limits. The overflows and splits add an additional 26 stream miles, for a total of 56 stream miles of channel, and require an enhanced level of modeling to describe the complexities of the study reach; along with potential worse-case scenario analyses where non-levee embankments and other structures induce splits and overflows.

The Montana Department of Natural Resources (DNRC) and the study professional service contractor Morrison-Maierle, Inc. (MMI) have completed this study to meet the guidance and standards published in the FEMA Resource and Document Library to ensure the study complies with the National Flood Insurance Program.

A review of the effective Gallatin County, Montana FIS (FEMA 2011) retrieved the following pertinent data for the Baker Creek, Baker Creek Overflow, and the West Gallatin River:

A. Flow change locations:
   1. At Interstate Highway 90.
   2. State Highway 289 (Sheds Bridge).
   3. Upstream limit of study, approximately one river mile south of Gallatin Gateway.

B. The Manning's "n" value ranges:
   1. Channel from 0.038 to 0.050
   2. Overbanks from 0.060 to 0.150

C. Length of study reaches:
   1. Baker Creek – 58,034 feet above confluence with West Gallatin River.
   2. Baker Creek Overflow – 43,216 feet above confluence with Camp Creek.
   3. West Gallatin River – 150,775 feet above confluence with Gallatin River.

D. Structure Crossings:
   1. Baker Creek – 6
   2. Baker Creek Overflow – 8
   3. West Gallatin River – 9

The following sections of the report describes the technical data and hydraulic analysis used to determine the floodplain of Baker Creek, Baker Creek Overflow and the West Gallatin River located in Gallatin County, Montana and as shown below on Figures 1A and 1B.

Figure 1A. West Gallatin River Flooding Source Locations

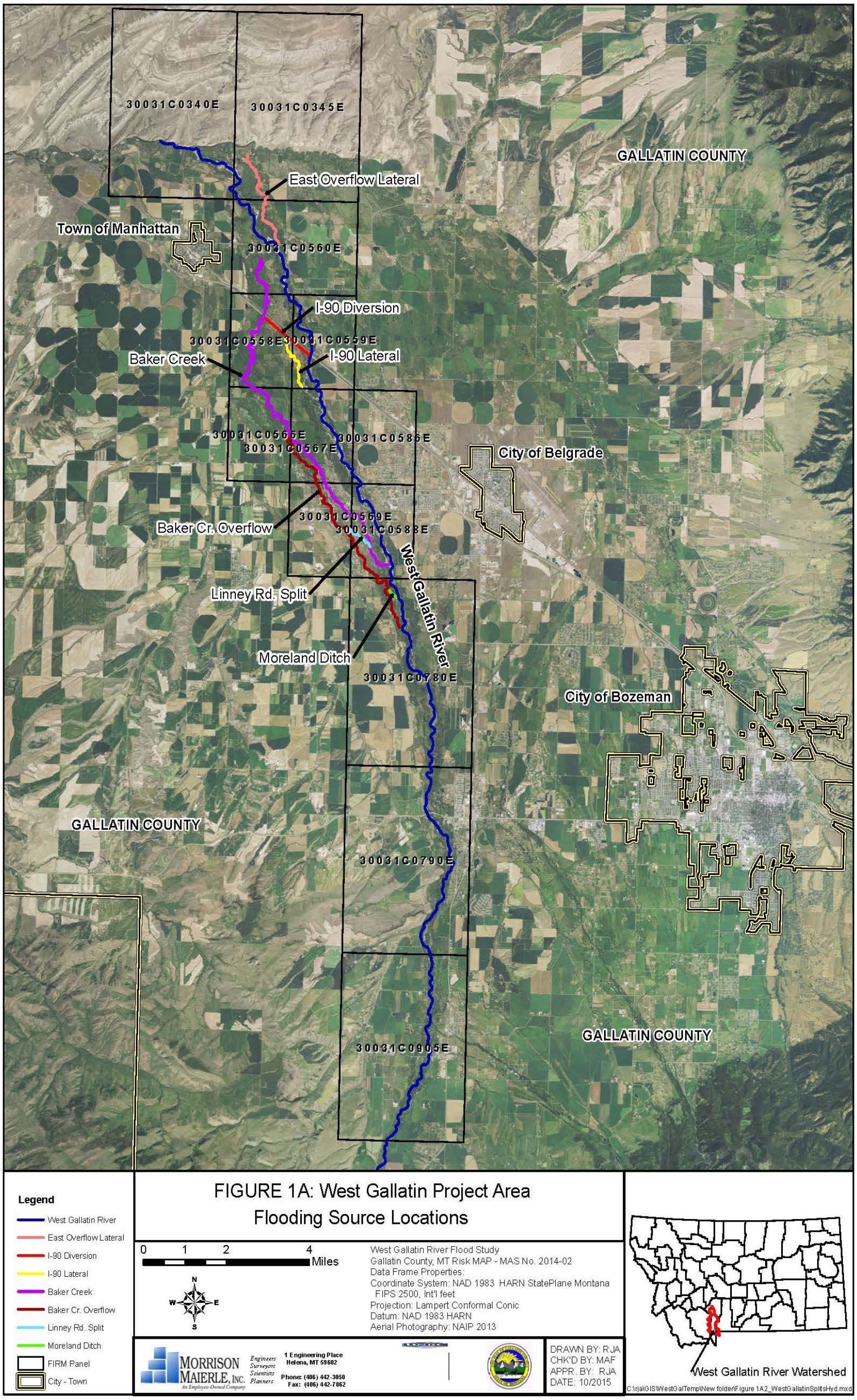
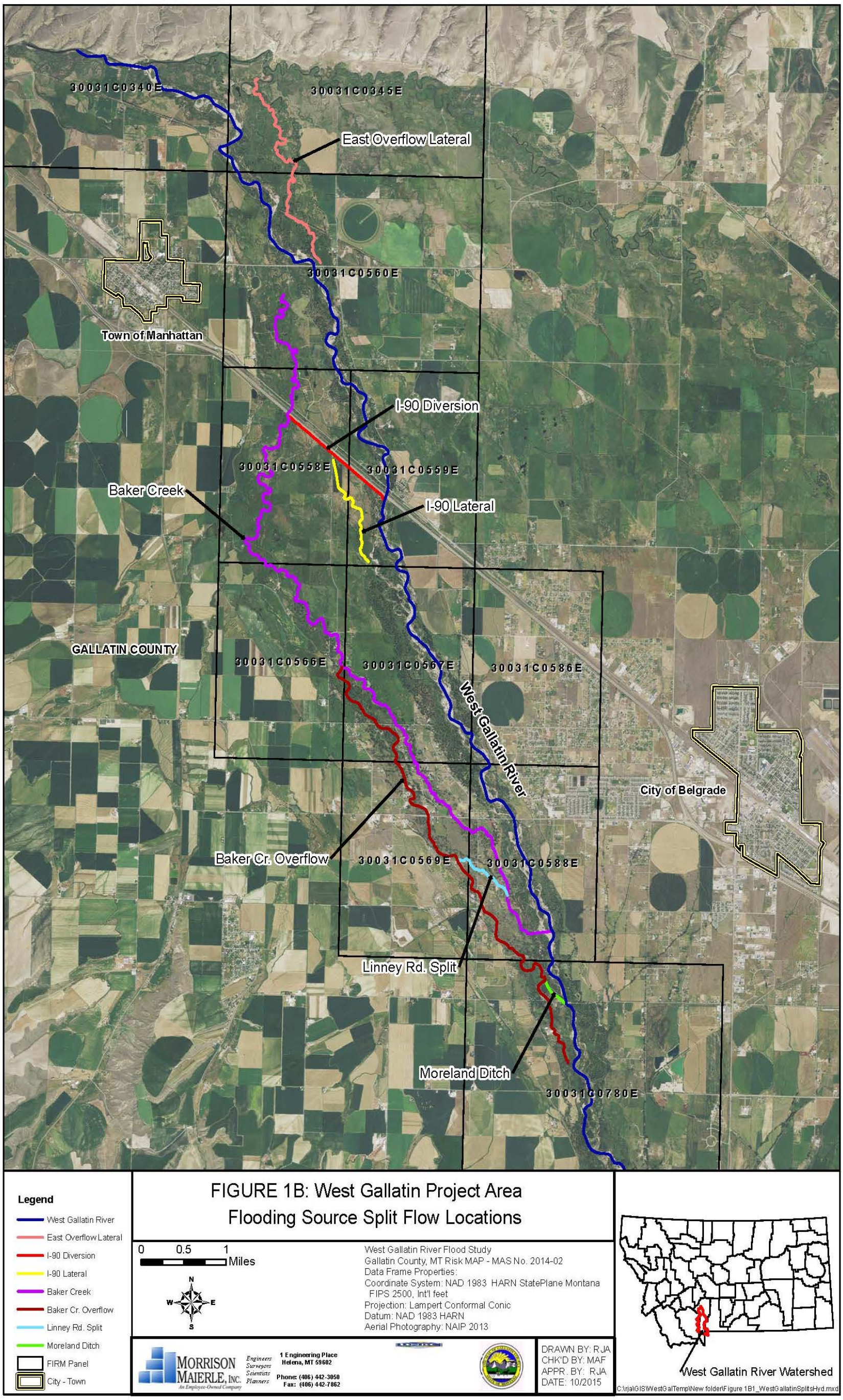


Figure 2B. West Gallatin River Flooding Source Split Flow Locations



1.1 Watershed Description

The West Gallatin River originates inside Yellowstone National Park, Wyoming. The West Gallatin River flows north from its headwaters in and adjacent to Yellowstone National Park. The West Gallatin River and its tributaries drain the Gallatin and Madison Ranges, eventually flowing near the towns of Belgrade and Manhattan, Montana where it joins the Missouri River near Three Forks, Montana. The river drains approximately 1,100 square miles at the confluence with the East Gallatin River.

Located in the Gallatin River watershed (HUC 8 10020008), the topography of the West Gallatin River varies from steep rugged mountains with peaks extending above 10,000 ft in the upper reaches to a broad valley floodplain with multi-thread active and relic channel features. Over geologic time scales, the West Gallatin River migrated over its current floodplain which was formed on glacial and alluvial deposits. The watershed above the upper study limit is mostly forested with narrow riparian corridors along the channel margins at the bottom of the steep valley slopes. The valley opens up to a broader floodplain once the West Gallatin River exits the Gallatin Canyon, just upstream of the community of Gallatin Gateway, Montana and the beginning of the study area. Through the study area, the West Gallatin River flows north through a broader valley characterized by a mature cottonwood forest and brush understory.

Land use along the West Gallatin River corridor and floodplain is primarily agriculture of hay and pasture with pockets of residential areas. Development along the lower West Gallatin River corridor is generally characterized more as medium-sized lots on the order of several to tens of acres with very little high density sub-divisions. These larger lot sizes retain the rural character of the valley, with pastures, hay fields, and cottonwood forests still the general land-use in the floodplain.

While there are numerous small irrigation features (diversions, headgates, and turnouts) along the West Gallatin River corridor, there are no major impoundments or diversion features that would have large-scale or broader influences on watershed hydrology for purposes of a flood insurance study. Other major infrastructure within the watershed include roads, highways, and railroads, with associated bridges and culverts. While these features are somewhat prevalent within and upstream of the study area, they do not significantly alter the watershed hydrology.

2.0 Hydrologic Analysis

This update to the flood study covers approximately 30 miles of the West Gallatin River, beginning at the confluence with the East Gallatin River and extending upstream approximately four river miles above of the community of Gallatin Gateway, Montana (Figure 1). Two active United States Geological Survey (USGS) gaging stations are located in the vicinity of the study area. The USGS gage 06043500 Gallatin River near Gallatin Gateway is on the West Gallatin River approximately six miles above the study area and has been in operation since 1890. USGS gage 06052500 Gallatin River at Logan, MT is approximately 5.6 miles below the confluence of the West and East Gallatin Rivers (downstream limit of study area) and has been in operation since 1895. A third USGS gaging station (USGS gage 06044000 Gallatin River near Salesville, MT) is no longer in service, but was operational from 1895 to 1923. This gage was located approximately 3.7 miles downstream of the Gallatin Gateway gage. Figure 1 identifies the gage locations. The summary data for the gages are listed in Table 1.

Table 1. Active and Historic USGS Gaging Stations near Project Area

Gaging Station Number	Gaging Station Name	Period of Record	Number Of Peaks in Record	Drainage Areas (mi^2)	Maximum Peak Discharge (cfs) / Year	Minimum Peak Discharge (cfs) / Year
06043500	Gallatin River near Gallatin Gateway	1890 – 2013 (123 years)	85	825(1)	9,160 / 1997	1,740 / 1934
06052500	Gallatin River at Logan, MT	1895 – 2013 (118 years)	94	1,795	9,840 / 1899	1,990 / 1941
06044000	Gallatin River near Salesville MT	1895 – 1923 (28 years)	15	833	10,000 / 1896	2,700 / 1905

(1) As currently published by USGS.

2.1 Hydrologic Analysis Procedure

The hydrologic analyses included flood frequency analysis following Bulletin 17B Guidelines at two stream gages (USGS 1982), along with drainage-area ratio adjustments for estimating peaks at ungagged sites per USGS WRIR 03-4308 (Parrett & Johnson 2004).The USGS PeakFQ software program (Flynn, Kirby and Hummel 2006) was used to perform the log-Pearson III flood frequency analysis. The analysis was summarized in the hydrologic report title 'Hydrology Design Report, West Gallatin River, Gallatin County, MT (MMI 2015) which was reviewed and approved by FEMA's National Service Provider (NSP) and the MT DNRC as documented in their letters dated April 6, 2015 and April 7, 2015, respectively. The summary of discharges for the West Gallatin River are presented in Table 2.

Table 2. Summary of Discharges for West Gallatin River

Location	Drainage Area (Square Miles)	USGS Analysis					
		Percent Annual Chance Peak Discharge (cfs)					
		10%	4%	2%	1%	1% plus	0.2%
Confluence with East Gallatin River	1099.8	7,664	8,766	9,535	10,269	10,937	11,859

The final model flows incorporated in the main stem West Gallatin River and the split flow reaches of Baker Creek, Baker Creek Overflow, East Overflow, I-90 Diversion, I-90 Lateral, Linney Road Split, and Moreland Ditch are discussed in Sections 3.10 and 3.11 of the report. Section 3.10 discusses the concepts of the West Gallatin River split flow reaches. Section 3.11 outlines the worst case scenario analysis to establish the final model flow rates of each reach. Table 32 provides a listing of the final model flow rates that were used for main stem West Gallatin River and the split flow reaches.

3.0 Hydraulics

The methods and techniques used to complete the hydraulic analysis of the West Gallatin River are presented below.

3.1 Hydraulic Analysis Overview and Procedures

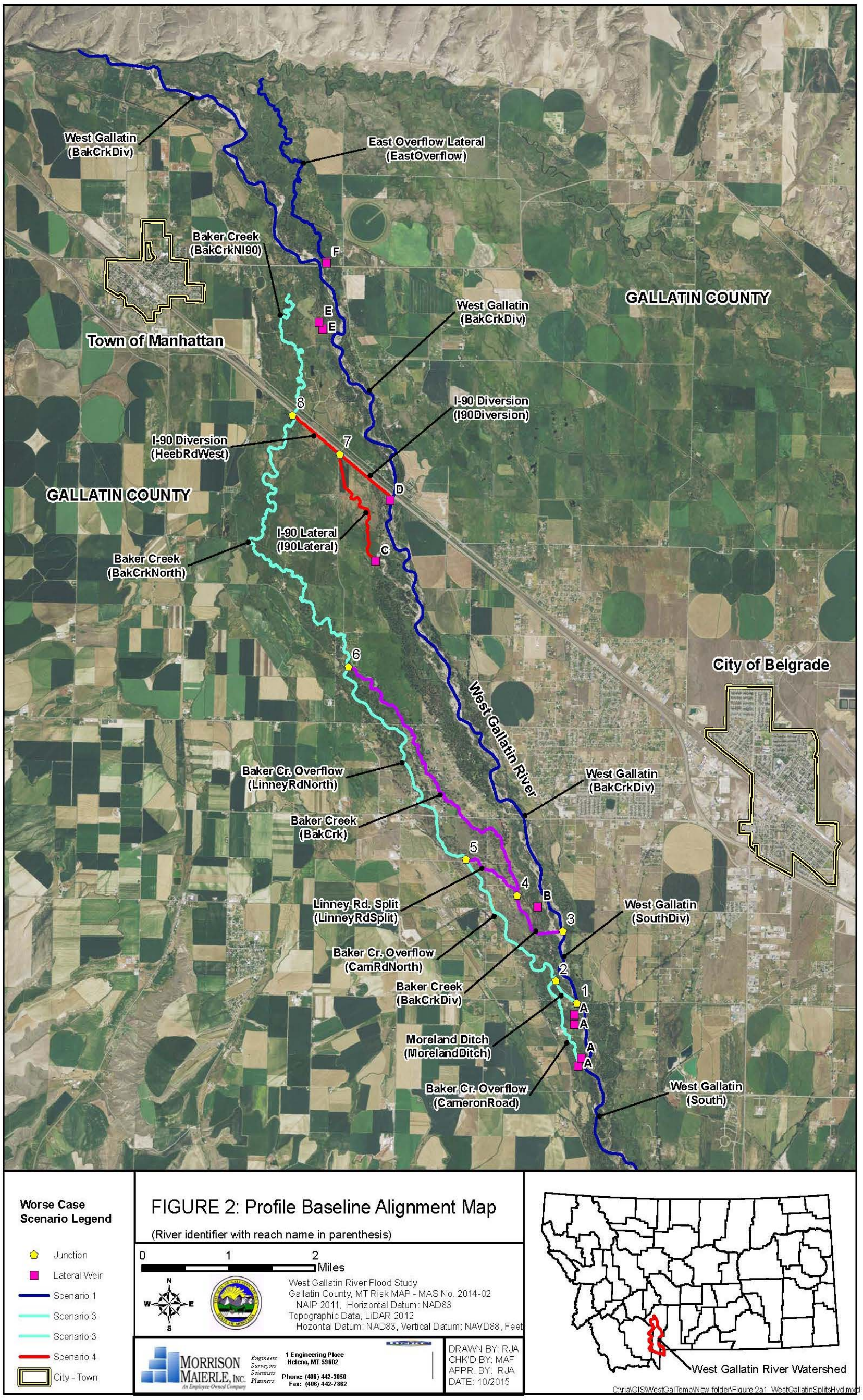
This update to the flood study covers approximately 30 miles of the West Gallatin River, beginning at the confluence with the East Gallatin River and extending approximately four river miles above the community of Gallatin Gateway, Montana. Appendix C of FEMA Guidelines and Specifications (FEMA 2009) was used as a guide for the West Gallatin hydraulic model development. The water surface elevations (WSEL's) were calculated with HEC-RAS, Version 4.1.0 hydraulic modeling software (USACE 2010). Cross sections were placed with ArcMap 10.1 (ESRI 2012) at locations where bathymetric surveys were completed and at structure locations along the floodplain. HEC-RAS for steady flow analysis, performs the standard step energy balance calculation between cross sections, starting at the most downstream cross section and moving upstream for a fully subcritical analysis.

Through the development of the hydraulic model, it was confirmed that floodwaters are directed throughout the floodplain through irrigation ditches and secondary channels away from the parent channel. In the event that the separated flow would not reconnect to the original stream channel within a distance of one mile, a new profile baseline was established. Junctions and lateral weirs were defined to model the flow split and a secondary flow path that would be created. Utilizing the flow optimization routine within HEC-RAS, the discharge split across the junction and lateral weirs was calculated ensuring that conservation of mass was balanced across the system while also balancing the energy equation. Lateral weirs were specified as a broad crested weir and utilize a weir coefficient of 0.5**.** In general, lateral weir coefficients should be lower than typical values used for inline weirs. The lower weir coefficients value is due to the energy/momentum loss associated with the turning flow lines from their downstream orientation to a lateral direction out of the river/reach (RAS Solution 2013). The discharge determined over each weir was calculated using the flow optimization routine within HEC-RAS.

During the analysis of many of the flow separations, it was determined that the amount of discharge separated from the parent channel is or would be directed by noncertified levee-like structures in the form of a roadway or elevated berm. In order to fully understand the risk associated with these structures, scenarios were analyzed in which the controlling structures were assumed to fail, resulting in a different proportioning of discharges for the respective reaches. To simulate the various scenarios, additional model plans and geometries were created to reflect the assumed failures of the respective manmade structure. A total of four (4) scenarios was developed in order to properly calculate the split flow analysis of the West Gallatin River. These scenarios are discussed in Section 3.11 of this report.

The profile baseline alignments, extents of split flows, locations of junctions, and lateral weirs are displayed on Figure 2.

Figure 2. West Gallatin River Profile Baseline Alignment Map



3.2 Topographic Data Acquisition

3.2.1 LiDAR Survey

Topographic survey data was completed in 2013 under Phase I of the project by Photo Science, Inc. in conjunction with Gaston Engineering & Surveying, PC. Phase I included discovery, along with acquisition and processing for 50.7 square miles of LiDAR data along with project corridor as well as bathymetric survey of the stream channel (Photo Science 2013 and Gaston 2013).

3.2.2 Field Survey

The field survey completed by MMI in the fall of 2014 (MMI 2015) included structure surveys for approximately 172 hydraulic structures (bridges, culverts, diversions, etc.) and site visit assessments of 50 additional structures. Table 3 provides a summary of the number of hydraulic structures and the relative ranking in priority with respect to the likely importance of the structure on the hydraulic modeling of the West Gallatin River and floodplain.

Table 3. Hydraulic Structure Survey Priority Summary

Structure Type	Priority		
	High	Medium	Low
Bridge	33	2	2
Culvert	22	4	25
Diversion	2	8	3
Headgate	4	2	3
Pedestrian Bridge	7	6	5
Private Bridge	19	8	12
Railroad Bridge	3	0	0
Turnout	0	0	2
Total	90	30	52

State plane coordinates used for this survey are referenced to the Montana Coordinate System, North American Datum of 1983 (NAD83-2011). Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88). Units are reported in International 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 in the Phase 1 portion of this project.

3.3 Profile Baseline

The stream channel centerlines of the West Gallatin River and the various split flow reaches were utilized to define the Profile Baselines of river stationing as stream distance in feet above the confluence with the respective receiving streams. The stream centerline of the West Gallatin River was utilized to define the Profile Baseline and river stationing as stream distance in feet above the confluence with the East Gallatin River. The stream stationing for all modeled split flow reaches references the stream distance in feet above its respective receiving stream. A list of all modeled reaches and their respective stationing reference is

presented in Table 4. The profile baseline is shown on the Work Maps included in Appendix A. The stream centerlines (Profile Baselines) were created using the LiDAR and 2011 & 2013 National Agricultural Imagery Program (NAIP) aerial imagery (USDA 2011, 2013). The summary of key features along each of the studied reaches is presented in Tables 5 through 12.

Table 4. Summary of River Station References

Reach	River Station Reference
West Gallatin River	Feet above confluence with East Gallatin River
Baker Creek	Feet above confluence with West Gallatin River
Baker Creek Overflow	Feet above confluence with Baker Creek
East Overflow Lateral	Feet above confluence with East Gallatin River
I-90 Lateral	Feet above confluence with I-90 Diversion
I-90 Diversion	Feet above confluence with Baker Creek
Linney Road Split	Feet above confluence with Baker Creek Overflow
Moreland Ditch	Feet above confluence with Baker Creek Overflow

Table 5. Key Features along West Gallatin River Profile Baseline

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
-2832	Cross Section	Normal depth downstream boundary condition – Gallatin River.	10,450	1
-516	Nixon Gulch Rd.	Structure ID-1 – clear span truss bridge with a total span of approximately 150' Gallatin River.	10,450	1
-121	Flow change location	Headwaters of Gallatin River.	10,450	1
0	Confluence with East Gallatin River	Downstream study limits – West Gallatin River.	10,205	1
20324	Flow change location	Flow splits from West Gallatin River to East Overflow via right bank lateral weir.	10,205	1
20764	Dry Creek Rd.	Structures ID4 – 8' diameter CSP culvert crossing at the west side channel of the multi-opening crossing.	10,269	1
20764	Dry Creek Rd.	Structures ID8 – 7'x10.8' CSPA culvert crossing at the middle west side channel of the multi-opening crossing.	10,269	1
20764	Dry Creek Rd.	Structures ID10 – 5'x6.9' CSPA culvert crossing at the middle east side channel of the multi-opening crossing.	10,269	1
20764	Dry Creek Rd.	Structures ID11 – two span bridge with a total span of approximately 195' at east side of multi-opening crossing.	10,269	1
20800	Pedestrian Path	Structure ID10 – clear span bridge with a total span of approximately 93' at the west side channel of the multi-opening crossing.	10,269	1
20800	Pedestrian Path	Structure ID11 – clear span bridge with a total span of approximately 170 at east side of multi-opening crossing'.	10,269	1
21688	Flow change location	Baker Creek confluence with West Gallatin River upstream of Dry Creek Road.	10,269	1
24752	Flow change location	Flow splits from the West Gallatin River to Baker Creek via left bank lateral weir.	9,037	1
26546	Flow change location	Flow splits from the West Gallatin River to Baker Creek via left bank lateral weir.	9,293	1
38076	Hwy 10	Structure ID36 – three span bridge with a total span of approximately 245'.	9,548	1
38331	MRL Railroad	Structure ID37 – four span bridge with a total span of approximately 295'.	9,548	1

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
38604	I-90 Eastbound Ln.	Structure ID38 – four span bridge with a total span of approximately 205'.	9,548	1
38860	Flow change location	Flow splits from the West Gallatin River to Baker Creek via left bank lateral weir.	9,548	1
42105	Flow change location	Flow splits from the West Gallatin River to Baker Creek via left bank lateral weir.	9,760	1
63279	Amsterdam Rd.	Structure ID75 – clear span bridge with a total span of approximately 20' at the west side channel of the multi-opening crossing.	9,760	1
63279	Amsterdam Rd.	Structure ID77 – clear span bridge with a total span of approximately 15' at the middle side channel of the multi-opening crossing.	9,760	1
63279	Amsterdam Rd.	Structure ID78 – three span bridge with a total span of approximately 180' at the primary channel of the multi-opening crossing.	9,760	1
68398	Flow change location	Flow splits from the West Gallatin River to Baker Creek via left bank lateral weir.	9,783	1
70410	Flow change location	Flow splits from the West Gallatin River to Baker Creek via left bank diversion structure ID96 at Junction 3.	9,824	1
75399	Cameron Bridge Rd.	Structure ID104 – clear span bridge with a total span of approximately 150' at the primary channel of multi-opening crossing.	9,824	1
75399	Cameron Bridge Rd.	Structure ID106 – 48" diameter CSP culvert crossing at the east side channel of the multi-opening crossing.	9,824	1
75431	Flow change location	Flow splits from the West Gallatin River to Moreland Ditch via left bank diversion structure ID103 at Junction 5.	9,824	1
75810	Flow change location	Flow splits from the West Gallatin River to Baker Creek Overflow via left bank lateral weir.	9,824	1
78758	Flow change location	Flow splits from the West Gallatin River to Baker Creek Overflow via left bank lateral weir.	9,953	1
79310	Flow change location	Flow splits from the West Gallatin River to Baker Creek Overflow via left bank lateral weir.	10,177	1
106835	Hwy 84 Sheds Bridge	Structure ID128 – two span bridge with a total span of approximately 150' at the primary channel of multi-opening crossing.	10,269	1
106835	Hwy 84 Sheds Bridge	Structure ID129 – 7' rise x 12' span twin RCB culvert crossing at the east side channel of the multi-opening crossing.	10,269	1
128558	Axtell Anceney Rd.	Structure ID151 – clear span bridge with a total span of approximately 21' at the west side channel of multi-opening crossing.	10,269	1

River Station (feet)	Feature	Description	1% AC Discharge (cfs) [1]	Model Plan Number[1]
128558	Axtell Anceney Rd.	Structure ID152 – clear span bridge with a total span of approximately 142' at the primary channel of multi-opening crossing.	10,269	1
141776	Mill Street	Structure ID157 – 4' rise x 5' span twin RCB culvert crossing at the west side channel of the multi-opening crossing..	10,269	1
141776	Mill Street	Structure ID158 – two span bridge with a total span of approximately 144' at the west channel of multi-opening crossing.	10,269	1
141776	Mill Street	Structure ID159 – 48' diameter CSP culvert crossing at the middle channel of the multi-opening crossing.	10,269	1
141776	Mill Street	Structure ID160 – two span bridge with a total span of approximately 160' at the west channel of multi-opening crossing.	10,269	1
163181	Upstream limit of study	Furthest upstream cross section – Upstream limit of reach	10,269	1

[1] Controlling scenario flow rates shown on Figure 2.

Table 6. Summary of Key Features along the Profile Baseline of Baker Creek

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
4584	Confluence with West Gallatin River	Downstream reach limits – confluence with West Gallatin River upstream of the Dry Creek Road.	1,717	3
4991	Flow change location	Discharge received from left bank lateral weir (RS 24751) along the West Gallatin River.	1,717	3
8777	Flow change location	Discharge received from left bank lateral weir (RS 26545) along the West Gallatin River.	1,505	3
15017	Highway 10	Structure ID15 – 4' rise x 6' span RCB culvert crossing at the west side channel of the multi-opening crossing.	1,287	3
15017	Highway 10	Structure ID16 – clear span bridge with a total span of approximately 43' at the middle channel of multi-opening crossing.	1,287	3
15017	Highway 10	Structure ID18 – two span bridge with a total span of approximately 52' at the east channel of multi-opening crossing.	1,287	3
15252	MRL Railroad	Structure ID22 – three span bridge with a total span of approximately 80' at the west channel of multi-opening crossing.	1,287	3
15252	MRL Railroad	Structure ID28 – two span bridge with a total span of approximately 48'' at the east channel of multi-opening crossing.	1,287	3
15441	I-90 Westbound	Structure ID17 – two span bridge with a total span of approximately 82' at the west channel of multi-opening crossing.	1,287	3
15441	I-90 Westbound	Structure ID25 – two span bridge with a total span of approximately 99' at the east channel of multi-opening crossing.	1,287	3
15508	I-90 Eastbound	Structure ID19 – two span bridge with a total span of approximately 80' at the west channel of multi-opening crossing.	1,287	3
15508	I-90 Eastbound	Structure ID24 – two span bridge with a total span of approximately 91' at the east channel of multi-opening crossing.	1,287	3
15615	Flow change location	Discharge received from I-90 Diversion along the West Gallatin River.	1,287	3
42252	Flow confluence	Baker Creek Overflow confluence with Baker Creek at Junction 6.	1,096	3
42651	Private Rd.	Structure ID52 – two span bridge with a total span of approximately 50'.	229	3
47932	Stage Coach Trail Rd.	Structure ID57 – two span bridge with a total span of approximately 35'.	229	3
52373	Private Rd.	Structure ID61 – clear span bridge with a total span of approximately 39'.	229	3
55758	Amsterdam Rd.	Structure ID73 – two span bridge with a total span of approximately 95'.	229	3

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
57766	Linney Rd.	Structure ID74 – 8.1' rise x12.7' span twin CSPA culvert crossing.	229	3
60727	Private Rd.	Structure ID87 – clear span bridge with a total span of approximately 25'.	229	3
61053	Private Rd.	Structure ID88 – clear span bridge with a total span of approximately 20'.	229	3
62594	Flow change location.	Linney Road Split divergence with Baker Creek at Junction 4.	229	3
63500	Flow change location.	Discharge received from left bank lateral weir (RS 68639) along the West Gallatin River.	458	3
66545	Inline Structure	Structure ID96 – Concrete structure with two 4' high x 5.5' wide slide gates	339	3
66547	Upstream limit of reach	Discharge received form diversion along the West Gallatin River at Junction 3.	339	3

[1] Controlling scenario flow rates shown on Figure 3.

Table 7. Summary of Key Features along the Profile Baseline of Baker Creek Overflow

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
0	Confluence with Baker Creek	Downstream reach limits – confluence with Baker Creek at Junction 5.	1,076	4
4904	Stage Coach Trail Rd	Structure ID58 – two span bridge with a total span of approximately 30'.	1,076	4
12627	Amsterdam Rd.	Structure ID66 – clear span bridge with a total span of approximately 10'.	1,076	4
16295	Flow change location	Discharge received from Linney Rd. Spit at Junction 5.	1,076	4
16480	Veltkamp Rd.	Structure ID80 – clear span bridge with a total span of approximately 14'.	1,056	4
18863	Linney Rd.	Structure ID92 – 5.4' rise x 7' span twin CSPA culvert crossing.	1,056	4
27543	Flow change location	Discharge received from Moreland Ditch at Junction 2.	1,056	4
29269	Cameron Bridge Rd.	Structure ID101 – 6.7' rise x 9.6' span CSPA culvert crossing.	444	4
30562	Flow change location	Discharge received from left bank lateral weir (RS 76300) along the West Gallatin River.	444	4
31012	Flow change location	Discharge received from left bank lateral weir (RS 76760) along the West Gallatin River.	319	4
32965	Flow change location	Discharge received from left bank lateral weir (RS 78957) along the West Gallatin River.	317	4
33456	Upstream limit of reach	Discharge received from left bank lateral weir (RS 79491) along the West Gallatin River.	92	4

[1] Controlling scenario flow rates shown on Figure 4.

Table 8. Summary of Key Features along the Profile Baseline of East Overflow Lateral

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
0	Confluence with East Gallatin River	Downstream reach limits – confluence with East Gallatin River.	64	1
16524	Upstream limit of reach	Discharge received from right bank lateral weir (RS 20706) along the West Gallatin River.	64	1
[1] Controlling scenario flow rates shown on Figure 2.				

Table 9. Summary of Key Features along the Profile Baseline of I-90 Diversion

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
0	Confluence with Baker Creek	Downstream reach limits – confluence with Baker Creek at Junction 8.	341	5
3617	Heeb Rd	Structure ID35 – 5' twin RCP culvert crossing.	341	5
3667	Flow change location	I-90 Lateral confluence with I-90 Diversion channel at Junction 7.	341	5
7829	Upstream limit of reach	Discharge received from left bank lateral weir (RS 39077) along the West Gallatin River.	319	5
[1] Controlling scenario flow rates shown on Figure 5.				

Table 10. Summary of Key Features along the Profile Baseline of I-90 Lateral

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
0	Confluence with I-90 Diversion	Downstream reach limits – confluence with I-90 Diversion at Junction 7.	23	5
7615	Upstream limit of reach	Discharge received from left bank lateral weir (RS 42754) along the West Gallatin River.	23	5
[1] Controlling scenario flow rates shown on Figure 5.				

Table 11. Summary of Key Features along the Profile Baseline of Linney Road Split

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
0	Confluence with Baker Creek Overflow	Downstream reach limits – confluence with Baker Creek Overflow channel at Junction 3.	229	3
926	Veltkamp Rd.	Structure ID83 – 3.5' rise x 5.7' span CSPA culvert crossing.	229	3
1640	Linney Rd.	Structure ID82 – clear span bridge with a total span of approximately 16'.	229	3
3455	Private Rd.	Structure ID89 – two span bridge with a total span of approximately 16'.	229	3
4181	Upstream limit of reach	Discharge received from Baker Creek at Junction 4.	229	3

[1] Controlling scenario flow rates shown on Figure 3.

Table 12. Summary of Key Features along the Profile Baseline of Moreland Ditch

River Station (feet)	Feature	Description	1% AC Discharge (cfs)	Model Plan Number[1]
0	Confluence with Baker Creek Overflow	Downstream reach limits – confluence with Baker Creek Overflow channel at Junction 20	612	4
1723	Cameron Bridge Rd.	Structure ID102 – 8.9' rise x 14.2' span CSPA culvert crossing.	612	4
1860	Inline Structure	Structure ID103 – Concrete structure with three 3' high x 5' wide slide gates	612	4
1870	Upstream limit of reach	Discharge received from the West Gallatin River at Junction 1.	612	4

[1] Controlling scenario flow rates shown on Figure 4.

3.4 Boundary Conditions

To establish a subcritical hydraulic analysis, HEC-RAS requires boundary condition input data at the first downstream cross section of the model reach. According to FEMA Guidelines and Specifications, Appendix C (FEMA 2009), absent established downstream elevation or control cross section, the starting water-surface elevations using normal depth boundary condition should be used at a cross section sufficiently downstream of the study limits. An energy slope of 0.0033 ft/ft (0.33%) is representative of the flood profile slope on the Gallatin River and was employed as the boundary condition for the river approximately 2,800 feet downstream of the study limits.

For the various split reaches, the downstream boundary condition was tied to its receiving water body utilizing the energy loss method. Therefore, the discharge realized for each reach was optimized so the energy loss through the split reach would equal the energy loss realized through the parent stream.

3.5 Development of Cross Section Geometries

The terrain data in the HEC-RAS models was predominately based on the aforementioned LiDAR data. Utilizing the GIS computer program ArcMap 10.1 (ESRI 2012), cross sections were placed perpendicular to flow and along estimated equipotential lines. Cross sections were extended in order to capture the boundaries of the 0.2-percent annual chance floodplain. Cross sections were placed at key locations along the reach, including: channel bathymetric survey locations, breaks in channel slope, abrupt changes in floodplain width, and structure locations.

LiDAR generated cross sectional geometries were combined with field surveyed bathymetry near structures for the West Gallatin River and split flow reaches. LiDAR and channel bathymetry were combined using the HEC-GeoRAS ‘Update Elevations’ tool to replace the LiDAR data with the stream channel bathymetry survey. This process was completed for both the West Gallatin River bathymetry data set and the bathymetry data collected adjacent to structures. These data, along with the LiDAR cross section data were exported to HEC-RAS as separate geometry files. The three land surface data sets were then merged using the HEC-RAS ‘Graphical Cross Section Editor’ tool to create composite cross sections to represent the best available data at each cross section location. Cross sections were filtered to less than 500 points per cross section as required by HEC-RAS.

The cross sections are shown in the Hydraulic Work Maps attached in Appendix A.

3.6 Hydraulic Structures

The geometries of hydraulic structures along the West Gallatin River and the split flow reaches were developed with the structures survey discussed in Section 3.2.2. A summary of the modeled structures along each reach is presented below in Tables 13 through 18. Approximately 97 bridge and 51 culvert crossing structures, as shown in Table 3, exist within the study limits. The bridge structures range from Interstate and state highway crossings to county and private roadway and pedestrian crossings. The Montana Rail Link (MRL) railroad crosses the West Gallatin River north of the I-90 crossings and proceeds north to Helena, Montana.

For all the modeled structures, the expansion and contraction coefficients of the two upstream cross sections along with the one downstream cross sections were increased from the minimum of 0.1 and 0.3, to 0.3 and 0.5, respectively. This hydraulic modeling practice was made to account for the increased head loss associated with the relatively abrupt transitions and varying velocities that accompany the expansion and contraction of flows.

The bridge modeling approach is set for both high and low flow methods based on the types of bridge construction. The high flow methods consist of the either the Energy (Standard Step) or Pressure/Weir flow. The Energy method is the standard step calculation method if the bridge low chord has freeboard and/or if the road approaching the bridge is lower and the bridge is perched above the approach road. The Pressure/Weir flow method is the high flow method for when flood waters impact and/or overtop the bridge structure.

The low flow methods include the Energy, Momentum or Yarnell. The energy method is set if the bridge is a clear span structure with no piers. The Momentum Balance and Yarnell equation methods are used if the structure is constructed with mid-span piers. The Momentum and Yarnell methods are low flow methods to account for the hydraulic forces due water moving around the piers. The momentum method requires setting the Drag Coefficient (C_D) and the Yarnell equation requires setting the K Coefficient based on the pier shape. Most of the pier shapes for the bridge structures consist of circular piers, twin-cylinder piers with connecting diaphragms or elongated piers with semi-circular ends. The C_D and K coefficients used for the structures are summarized in below:

Pier Shape	C_D	K
Circular	1.20	1.05
Twin-cylinder with connecting diaphragms	1.60	0.95
Elongated piers with semi-circular ends	1.33	0.90
Square nose	2.00	1.25
Ten pile trestle bent	1.20	2.50

A summary of the hydraulic model settings for each structure along each reach is presented below in Tables 19 through 24. Photographs 1 and 2 are examples of the I-90 highway structures with twin-cylinder piers with connecting diaphragms. Photograph 3 is of the MRL structure crossings with elongated piers with semi-circular ends. Photograph 4 shows the clear span pedestrian structure upstream of Dry Creek Road Bridge crossing. Photographs of all the structures are provided in Appendix C.

Photograph 1: Upstream face of Westbound Lane I-90 Bridge ID-38 Crossing.

Photograph 2: Upstream Face of West Dry Creek Road Bridge ID-11 Crossing.

Photograph 3: Upstream face of MRL Railroad Bridge ID-37 Crossing.

Photograph 4: Pedestrian Structure Upstream of Dry Creek Road Bridge ID-11 Crossing.

Table 13. Summary of Modeled Hydraulic Structures along West Gallatin River

Structure ID Roadway	River Station	Type	Approx. Total Bridge Span (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Photo Page Appendix C
1 – Nixon Gulch Rd.	-516	Bridge	150	–	–	–	–	1
4 – Dry Creek Rd.	20764	Culvert	–	74	CSP	Round	8	2
8 – Dry Creek Rd.	20764	Bridge	100	–	–	–	–	3
8 – Pedestrian Path	20800	Bridge	93	–	–	–	–	3
10 – Dry Creek Rd.	20764	Culvert	–	62	CSPA	Arch	7.4x11.5	4
11 – Dry Creek Rd.	20764	Bridge	195	–	–	–	–	5
11 – Pedestrian Path	20800	Bridge	170	–	–	–	–	5
36 – Hwy 10	38076	Bridge	245	–	–	–	–	16
37 – MRL Railroad	38331	Bridge	295	–	–	–	–	17
38 – I-90 Westbound Ln.	38529	Bridge	205	–	–	–	–	18
39 – I-90 Eastbound Ln.	38604	Bridge	205	–	–	–	–	19
75 – Amsterdam Rd.	63279	Bridge	20	–	–	–	–	27
77 – Amsterdam Rd.	63279	Bridge	15	–	–	–	–	28
78 – Amsterdam Rd.	63279	Bridge	180	–	–	–	–	29
104 – Cameron Bridge Rd.	75399	Bridge	150	–	–	–	–	42
106 – Cameron Bridge Rd.	75399	Culvert	–	30	CSP	Round	48	43
128 – Hwy 84 Sheds Bridge	106835	Bridge	150	–	–	–	–	44
129 – Hwy 84 Sheds Bridge	106835	Culvert	–	95	RCB	Twin Box	7x12	45
151 – Axtell Anceney Rd.	128558	Bridge	21	–	–	–	–	46
152 – Axtell Anceney Rd.	128558	Bridge	142	–	–	–	–	47
157 – Mill Street	141776	Culvert	–	37	CSP	Round	48	48
158 – Mill Street	141776	Bridge	144	–	–	–	–	49
159 – Mill Street	141776	Culvert	–	30	RCB	Twin Box	4x5	50
160 – Mill Street	141776	Bridge	160	–	–	–	–	51
163 – Dry Creek Rd.	20764	Culvert	–	64	CSPA	Twin Arch	5x6.9	52
165 – Dry Creek Rd.	20764	Culvert	–	60	CSPA	Arch	7x10.8	53

Table 14. Summary of Modeled Hydraulic Structures along Baker Creek

Structure ID Roadway	River Station	Type	Approx. Total Bridge Span (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Photo Page Appendix C
15 – Highway 10	15017	Culvert	–	56	RCB	Box	4x6	6
16 – Highway 10	15017	Bridge	43	–	–	–	–	7
18 – Highway 10	15017	Bridge	52	–	–	–	–	9
22 – MRL Railroad	15252	Bridge	80	–	–	–	–	11
28 – MRL Railroad	15252	Bridge	48	–	–	–	–	14
17 – I-90 Westbound	15441	Bridge	82	–	–	–	–	8
25 – I-90 Westbound	15441	Bridge	99	–	–	–	–	13
19 – I-90 Eastbound	15508	Bridge	80	–	–	–	–	10
24 – I-90 Eastbound	15508	Bridge	91	–	–	–	–	12
52 – Private Rd.	42651	Bridge	58	–	–	–	–	20
57 – Stage Coach Trail Rd.	47932	Bridge	35	–	–	–	–	21
61 – Private Rd	52373	Bridge	39	–	–	–	–	23
73 – Amsterdam Rd.	55758	Bridge	95	–	–	–	–	25
74 – Linney Rd.	57766	Culverts	–	40	CSPA	Twin Arch	8.1x11.1	26
84 – Heidner Lane	60727	Bridge	6	–	–	–	–	33
87 – Heidner Lane	60727	Bridge	25	–	–	–	–	34
88 – Private Rd.	61053	Bridge	20	–	–	–	–	35
96 – Diversion Structure	65545	Gated	–	–	–	–	–	38

Table 15. Summary of Modeled Hydraulic Structures along Baker Creek Overflow

Structure ID Roadway	River Station	Type	Approx. Total Bridge Span (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Photo Page Appendix C
58 – Stage Coach Trail Rd.	4904	Bridge	30	–	–	–	–	22
66 – Amsterdam Rd.	12627	Bridge	10	–	–	–	–	24
80 – Veltkamp Rd.	16480	Bridge	14	–	–	–	–	30
92 – Linney Rd.	18863	Culverts	–	60	CSPA	Twin Arch	5.4x7	37
101 – Cameron Bridge Rd.	29269	Culvert	–	41	CSPA	Arch	6.7x9.6	39

Table 16. Summary of Modeled Hydraulic Structures along I-90 Diversion

Structure ID Roadway	River Station	Type	Approx. Total Bridge Span (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Photo Page Appendix C
35 – Heeb Road	3617	Culverts	–	77	CSP	Round	5	15

Table 17. Summary of Modeled Hydraulic Structures along Linney Road Split

Structure ID Roadway	River Station	Type	Approx. Total Bridge Span (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Photo Page Appendix C
83 – Veltkamp Rd.	926	Culvert	–	35	CSPA	Arch	3.5x5.7	32
82 – Linney Rd.	1640	Bridge	16	–	–	–	–	31
89 – Private Rd.	3455	Bridge	16	–	–	–	–	36

Table 18. Summary of Modeled Hydraulic Structures along Moreland Ditch

Structure ID Roadway	River Station	Type	Approx. Total Bridge Span (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size	Photo Page Appendix C
102 – Cameron Bridge Rd.	1723	Culvert	–	165	CSPA	Arch	8.9’x14.3’	40
103 – Diversion Structure	1860	Gated	–	–	–	–	–	41

Table 19. Summary of Model Settings for Structures along West Gallatin River

Structure ID Roadway	River Station	Type	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
1 – Nixon Gulch Rd.	-516	Bridge	0.3	0.5	Energy	Pressure/Weir
4 – Dry Creek Rd.	20764	Culvert	0.3	0.5	Energy	Pressure/Weir
8 – Dry Creek Rd.	20764	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
8 – Pedestrian Path	20800	Bridge	0.3	0.5	Energy	Energy
10 – Dry Creek Rd.	20764	Culvert	0.3	0.5	Energy	Pressure/Weir
11 – Dry Creek Rd.	20764	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
11 – Pedestrian Path	20800	Bridge	0.3	0.5	Energy	Energy
36 – Hwy 10	38076	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
37 – MRL Railroad	38331	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
38 – I-90 Westbound Ln.	38529	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
39 – I-90 Eastbound Ln.	38604	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
75 – Amsterdam Rd.	63279	Bridge	0.3	0.5	Energy	Pressure/Weir
77 – Amsterdam Rd.	63279	Bridge	0.3	0.5	Energy	Pressure/Weir
78 – Amsterdam Rd.	63279	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
104 – Cameron Bridge Rd.	75399	Bridge	0.3	0.5	Energy	Pressure/Weir
106 – Cameron Bridge Rd.	75399	Culvert	0.3	0.5	Energy	Pressure/Weir
128 – Hwy 84 Sheds Bridge	106835	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
129 – Hwy 84 Sheds Bridge	106835	Culvert	0.3	0.5	Energy	Pressure/Weir
151 – Axtell Anceney Rd.	128558	Bridge	0.3	0.5	Energy	Pressure/Weir
152 – Axtell Anceney Rd.	128558	Bridge	0.3	0.5	Energy	Pressure/Weir
157 – Mill Street	141776	Culvert	0.3	0.5	Energy	Pressure/Weir
158 – Mill Street	141776	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
159 – Mill Street	141776	Culvert	0.3	0.5	Energy	Pressure/Weir
160 – Mill Street	141776	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
163 – Dry Creek Rd.	20764	Culvert	0.3	0.5	Energy	Pressure/Weir
165 – Dry Creek Rd.	20764	Culvert	0.3	0.5	Energy	Pressure/Weir

Table 20. Summary of Model Settings for Structures along Baker Creek

Structure ID Roadway	River Station	Type	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
15 – Highway 10	15017	Culvert	0.3	0.5	Energy	Pressure/Weir
16 – Highway 10	15017	Bridge	0.3	0.5	Energy	Pressure/Weir
18 – Highway 10	15017	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
22 – MRL Railroad	15252	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
28 – MRL Railroad	15252	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
17 – I-90 Westbound	15441	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
25 – I-90 Westbound	15441	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
19 – I-90 Eastbound	15508	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
24 – I-90 Eastbound	15508	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
52 – Private Rd.	42651	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Energy
57 – Stage Coach Trail Rd.	47932	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
61 – Private Rd	52373	Bridge	0.3	0.5	Energy	Energy
73 – Amsterdam Rd.	55758	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
74 – Linney Rd.	57766	Culverts	0.3	0.5	Energy	Pressure/Weir
84 – Heidner Lane	60727	Bridge	0.3	0.5	Energy	Pressure/Weir
87 – Heidner Lane	60727	Bridge	0.3	0.5	Energy	Energy
88 – Private Rd.	61053	Bridge	0.3	0.5	Energy	Pressure/Weir
96 – Diversion Structure	65545	Gated	–	–	–	–

Table 21. Summary of Model Settings for Structures along Baker Creek Overflow

Structure ID Roadway	River Station	Type	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
58 – Stage Coach Trail Rd.	4904	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
66 – Amsterdam Rd.	12627	Bridge	0.3	0.5	Energy	Pressure/Weir
80 – Veltkamp Rd.	16480	Bridge	0.3	0.5	Energy	Pressure/Weir
92 – Linney Rd.	18863	Culverts	0.3	0.5	Energy	Pressure/Weir
101 – Cameron Bridge Rd.	29269	Culvert	0.3	0.5	Energy	Pressure/Weir

Table 22. Summary of Model Settings for Structures along I-90 Diversion

Structure ID Roadway	River Station	Type	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
35 – Heeb Road	3617	Culverts	0.3	0.5	Energy	Pressure/Weir

Table 23. Summary of Model Settings for Structures along Linney Road Split

Structure ID Roadway	River Station	Type	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
83 – Veltkamp Rd.	926	Culvert	0.3	0.5	Energy	Pressure/Weir
82 – Linney Rd.	1640	Bridge	0.3	0.5	Energy	Pressure/Weir
89 – Private Rd.	3455	Bridge	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir

Table 24. Summary of Model Settings for Structures along Moreland Ditch

Structure ID Roadway	River Station	Type	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
102 – Cameron Bridge Rd.	1723	Culvert	0.3	0.5	Energy	Pressure/Weir
103 – Diversion Structure	1860	Gated	–	–	–	–

3.7 Roughness Coefficients

Roughness coefficients are values representing the frictional resistance water experiences when passing overland or through a channel. They are used in the calculations to determine water surface elevations. Eight land classes were developed for the study area. The land classes were developed based on aerial interpretation and Montana Department of Revenue Land Classification Units. The classification work resulted in a spatial layer covering the study area. The Manning's roughness values assigned within the hydraulic model were determined based on field observation, aerial photography, land-use mapping and the USGS publication, 'Guide to Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains' (USGS 1982). The USGS guide was used to develop minimum, maximum, and initial Manning's values for each land class. The initial land class Manning's values were assigned to the spatial land classification data set and the HEC-GeoRAS application was used to assign the spatial based roughness data to the model cross-sections.

The roughness data were evaluated at each cross-section in HEC-RAS and adjustments to the horizontal limits were made to fit with the terrain data represented by the cross section. Adjustments to the roughness values were also made as needed during hydraulic model development. The adjustments to the HEC-RAS roughness values remained within the range of acceptable values determined for each land class. Roughness coefficients are provided in Table .

Table 25: Roughness Coefficients

Flooding Source	Channel "n"	Overbank "n"
West Gallatin River	0.038-0.040	0.055-0.10
Baker Creek Split Flow	0.040	0.055-0.080
Baker Creek Overflow Split Flow	0.040	0.055-0.080
East Overflow Split Flow	0.040	0.055-0.080
I-90 Diversion Split Flow	0.055-0.080	0.055-0.080
I-90 Lateral Split Flow	0.053-0.055	0.055-0.080
Linney Road Split Flow	0.040	0.055-0.080
Moreland Ditch Split Flow	0.040	0.055-0.080

3.8 Areas of Non-Conveyance

As shown on the Hydraulic Work Maps attached in Appendix A, there are areas within split flow reaches where backwater conditions exist or provide limited or no conveyance in the stream wise direction. For these areas, the ineffective Flow Area Method was implemented to model and calculate the total effective conveyance for each cross section. Review of the modeled cross sections in HEC-RAS will also display numerous depression areas that are not hydraulically connected to the stream body. These areas were also classified as ineffective in order for the model to correctly calculate the available conveyance and the HEC-RAS flow optimization process.

Areas of flow expansion and contraction at the cross sections bounding structures were also assigned areas of non-conveyance in order to force the one-dimensional steady state model to calculate the head loss due to two-dimensional flow contraction and expansion. The flow contraction and expansion areas were calculated using a 1:1 stream wise to lateral direction and a 4:1 ratio, respectively. The ratios of expansion and contraction were developed using the cross sectional velocities as recommended in the *HEC-RAS Reference Manual* (USCOE 2010).

3.9 Model Calibration

The model calibration was completed with the aerial photography taken by the Montana Department of Transportation (MDT) during the most recent high water event occurring in June 1997. MDT obtained the photography on June 6, 1997 after the peak of the event. The peak flow rate of 9,160 cfs was recorded at USGS gage 06043500 West Gallatin River near Gallatin Gateway, Montana on June 2, 1997. A comparison of the 10% annual-chance water surface elevations (WSE's) was calibrated, since the photographs were taken four days after the peak of the event and the flow rate when the flow rate was representative of a 10% annual-chance event.

The comparison of WSE's at river stations near the Gallatin Gateway were calibrated, since they are close to the gage and are not affected by the split flow divergences of the West Gallatin River. The differences in water surface elevations (WSE) was estimated by observing the extents of the high water on the aerials and comparing to the contour information from the LiDAR mapping. The differences, as shown on Table 26, ranged from 0.1 to 0.9 feet. Based on these difference, Morrison-Maierle, Inc. recommends that the HEC-RAS model is reasonably calibrated.

Table 26. Summary of Model Calibration

River Station Location	WSE 6/6/1997 Aerial Photo (feet)	WSE HEC-RAS Model (feet)	Difference (feet)
141398	4910	4910.1	0.1
140884	4905	4904.7	0.3
141948	4915	4915.8	0.8
143943	4925	4925.6	0.6
190959	5035.5	5036.4	0.9

3.10 Split Flow Analysis

As discussed in Section 3.1 of the report, there are four flow scenarios occurring throughout the West Gallatin River floodplain. With the development of the hydraulic model and review of the initial results, locations were identified in which discharge overflowed the one or both banks of the channel or via a diversion structure so the resultant overflow would be directed away from the parent West Gallatin River channel. In the event that the separated flow would not reconnect to the original stream channel within a distance of one mile, a new profile baseline for the overflow channel was established. Junctions and lateral weirs were defined to model the flow split and the secondary flow path that would be created. Utilizing the flow optimization option within HEC-RAS, the discharge split across the junction and lateral weirs was calculated ensuring that conservation of mass was balanced across the system while also balancing the energy equation. Lateral weirs were also specified as a broad crested weir and utilized a weir coefficient of 0.5**.** In general, lateral weir coefficients should be lower than typical values used for inline weirs. The lower weir coefficients value is due to the energy/momentum loss associated with the turning flow lines from their downstream orientation to a lateral direction out of the river/reach (RAS Solution 2013). The discharge determined over each weir was calculated using the flow optimization option within HEC-RAS.

Given the complex nature of the West Gallatin River watercourse, a systematic approach was developed to the optimization process in order to properly calculate the split discharges across the lateral weirs and junctions. There are points of divergence within split flow system which are dependent upon the separation of discharges located further upstream. This flow divergence from the West Gallatin River commences approximately one-half river mile upstream of the Cameron Bridge Road crossing and was modeled with lateral weirs conveying flow from the west bank to the Baker Creek Overflow Channel. The next downstream divergence is located at the Moreland Ditch diversion structure upstream and adjacent to the Cameron Bridge Road. This flow diversion was modeled with the inline structure feature to calculate the hydraulics of the vertical lift slide gates associated with this structure. The following sections describes the four flow scenarios that were developed to the optimization process in order to properly calculate the split flow discharges.

3.11 Split Flow Scenario Analysis

Throughout the modeled reaches of the West Gallatin River floodplain, many manmade structures exist. Many of the structures along the West Gallatin River floodplain not only control the flood elevations, they also control the amount of discharge received by many of the split flow channels. In these cases, a separate scenario was analyzed in which it was assumed that the controlling structure failed or was not operated during a flood event. The following sections of the report summarize the controlling flow scenarios representing the basis of floodplain mapping for the modeled reaches of the West Gallatin River floodplain.

3.11.1 West Gallatin River, Flow Scenario #1

The West Gallatin River worst case scenario flow scenario would occur when the slide gates located at the Moreland Ditch and Baker Creek South diversion structures (Photographs 5 and 6) are fully closed during a flood event. By modeling the gates fully closed, more discharge would be routed to the West Gallatin River while minimizing the flows diverted to Baker Creek and the Baker Creek Overflow channels. These structures are operated by the Moreland Canal Company and the worst case scenario represents a flood event occurring before the diversion structure gates are opened for the irrigation season or closed for operational purposes such as to avoid damage to the irrigation infrastructure. The resultant peak annual chance discharges for the West Gallatin, Flow Scenario #1, are listed in Table 27 and shown on Figure 3**.** The applicable HEC-RAS plan analyzed for this flow scenario is plan number one as shown in Table 31.

Photograph 5: Moreland Diversion Structure Upstream of Cameron Bridge Road crossing.

Photograph 6: Upstream Face of Baker Creek South Diversion Structure.

Table 27. Peak Discharges West Gallatin, Flow Scenario #1

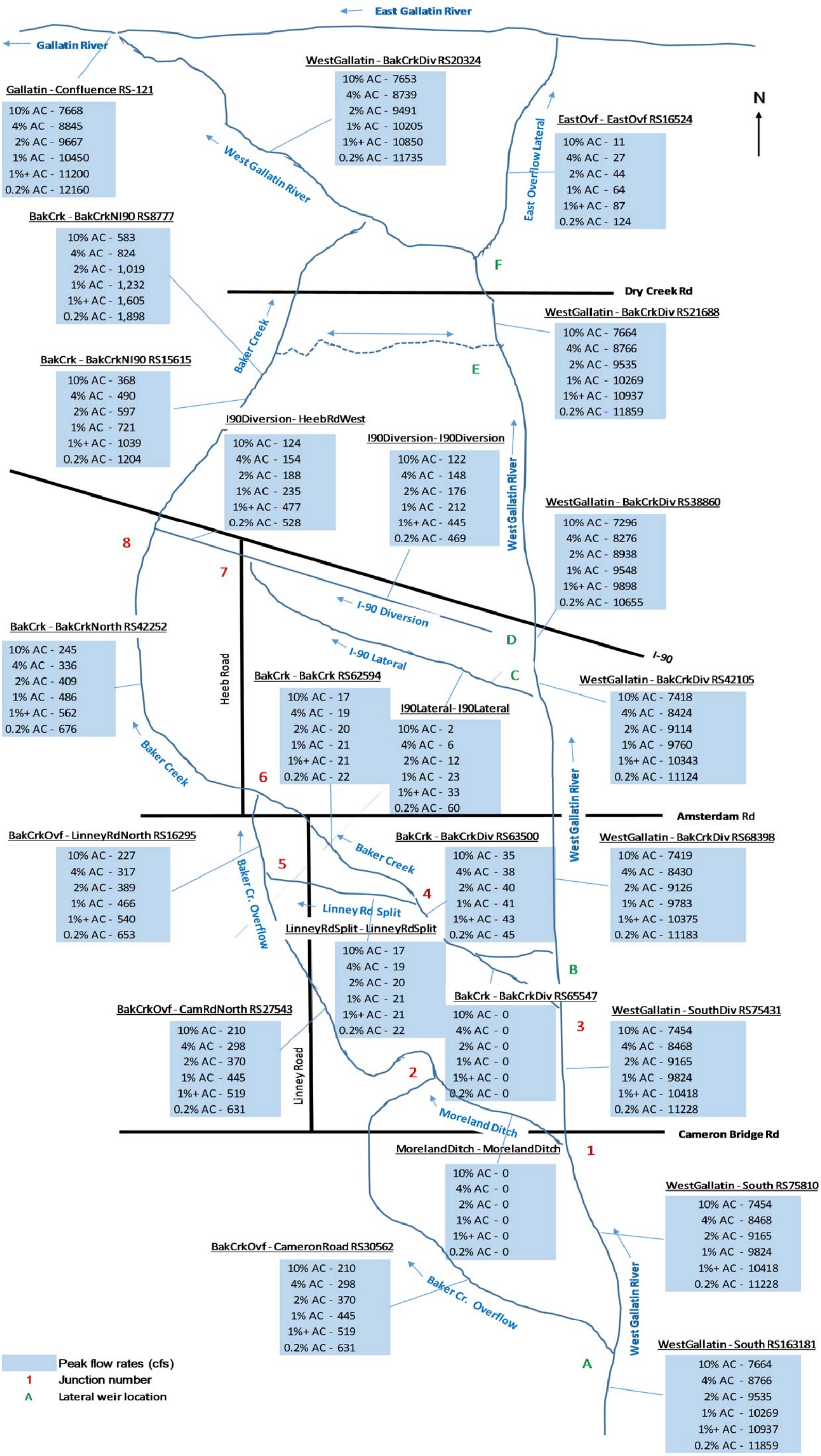
River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
BakCrk	BakCrkDiv	65547	0.01	0.01	0.01	0.01	0.01	0
	BakCrkDiv	63500	35	38	40	41	43	45
	BakCrk	62594	17	19	20	21	21	22
	BakCrkNorth	42252	245	336	409	486	562	676
	BakCrkNI90	15615	368	490	597	721	1039	1204
	BakCrkNI90	8777	484	661	811	976	1318	1538
	BakCrkNI90	4991	583	824	1019	1232	1605	1898
BakCrkOvf	CameronRoad	33456	24	49	70	92	112	142
	CameronRoad	32965	158	221	269	316	359	421
	CameronRoad	31012	158	221	270	318	364	428
	CameronRoad	30562	210	298	370	445	519	631
	CamRdNorth	27543	210	298	370	445	519	631
	LinneyRdNorth	16295	227	317	389	466	540	653
EastOvf	EastOvf	16524	11	27	44	64	87	124
I90Diversion	I90Diversion	7829	122	148	176	212	445	469
	HeebRdWest	3667	124	154	188	235	477	528
I90Lateral	I90Lateral	7615	2	6	12	23	33	60
LinneyRdSplit	LinneyRdSplit	4181	17	19	20	21	21	22
MorelandDitch	MorelandDitch	1870	0.01	0.01	0.01	0.01	0.01	0.01
WestGallatin	South	163181	7664	8766	9535	10269	10937	11859
	South	79310	7640	8717	9465	10177	10825	11717
	South	78758	7506	8545	9266	9953	10578	11438
	South	76476	7506	8545	9265	9951	10573	11431
	South	75810	7454	8468	9165	9824	10418	11228
	SouthDiv	75431	7454	8468	9165	9824	10418	11228
	BakCrkDiv	70410	7454	8468	9165	9824	10418	11228
	BakCrkDiv	68398	7419	8430	9126	9783	10375	11183
	BakCrkDiv	42105	7418	8424	9114	9760	10343	11124
	BakCrkDiv	38860	7296	8276	8938	9548	9898	10655
	BakCrkDiv	26546	7181	8105	8724	9293	9619	10321
	BakCrkDiv	24752	7081	7942	8516	9037	9332	9961
	BakCrkDiv	21688	7664	8766	9535	10269	10937	11859
	BakCrkDiv	20324	7653	8739	9491	10205	10850	11735
Gallatin	BakCrkDiv	-121	7668	8845	9667	10450	11200	12160

Lateral Weir Flow Data Summary Table

River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
WestGallatin	South A	79491	24	49	70	92	112	142
	South A	78957	134	172	199	225	248	279
	South A	76760	0	0	1	2	4	8
	South A	76300	51	77	100	127	155	202
	BakCrkDiv B	68639	35	38	40	41	43	45
	I90Lat C	42754	2	6	12	23	33	60
	I90Div D	39077	122	148	176	212	445	469
	BakCrkConflu E	26545	115	172	214	255	279	334
	BakCrkConflu E	24751	99	162	208	257	287	360
	EastOvf F	20706	11	27	44	64	87	124

Flow rates optimized with HEC-RAS model

Figure 3. West Gallatin River, Flow Scenario #1 Map



3.11.2 Baker Creek, Flow Scenario #2:

The Baker Creek worst case flow scenario would occur when the Baker Creek South diversion structure (Photograph 6) and the Baker Creek North diversion structure (Photograph 7) fail during a flood event. Both structures, as shown in the photographs below, are likely to fail due to the lack of substantive concrete abutment walls and/or flood resistant structural elements. By modeling the failure of both structures during a flood event, more discharge would be routed to the Baker Creek channel. The resultant peak annual chance discharges for the Baker Creek, Flow Scenario #2, are listed in Table 28 and shown on Figure 4**.** The applicable HEC-RAS plan analyzed for this flow scenario is plan number three as shown in Table 31.

Photograph 7: Upstream Face of Baker Creek North Diversion Structure.

Table 28. Peak Discharges Baker Creek, Flow Scenario #2

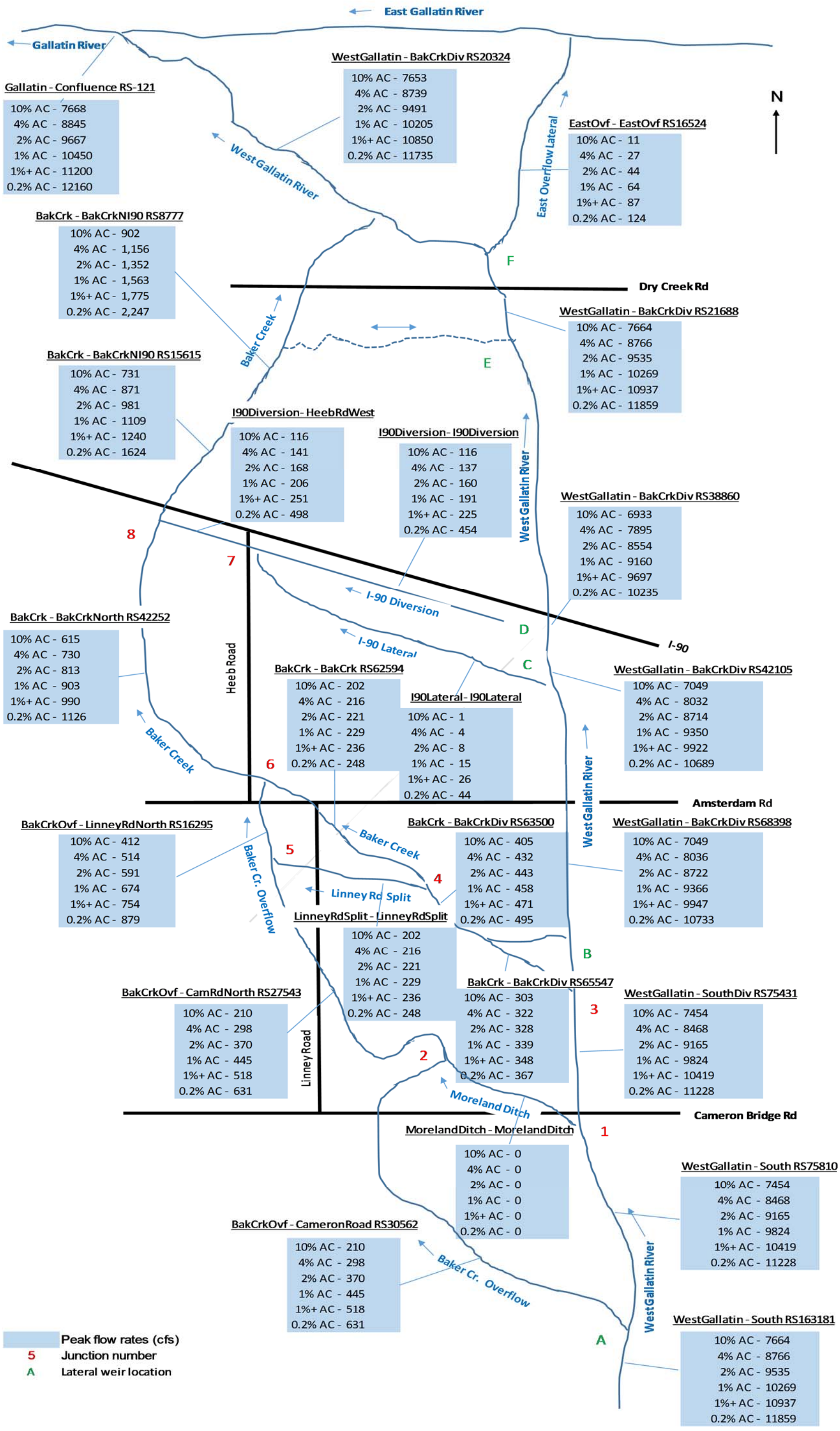
River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
BakCrk	BakCrkDiv	65547	303	322	328	339	348	367
	BakCrkDiv	63500	405	432	443	458	471	495
	BakCrk	62594	202	216	221	229	236	248
	BakCrkNorth	42252	615	730	813	903	990	1126
	BakCrkNI90	15615	731	871	981	1109	1240	1624
	BakCrkNI90	8777	827	1018	1170	1338	1505	1927
	BakCrkNI90	4991	902	1156	1352	1563	1775	2247
BakCrkOvf	CameronRoad	33456	24	49	70	92	112	142
	CameronRoad	32965	159	221	269	316	359	421
	CameronRoad	31012	159	221	270	319	364	429
	CameronRoad	30562	210	298	370	445	518	631
	CamRdNorth	27543	210	298	370	445	518	631
	LinneyRdNorth	16295	412	514	591	674	754	879
EastOvf	EastOvf	16524	11	27	44	64	87	124
I90Diversion	I90Diversion	7829	116	137	160	191	225	454
	HeebRdWest	3667	116	141	168	206	251	498
I90Lateral	I90Lateral	7615	1	4	8	15	26	44
LinneyRdSplit	LinneyRdSplit	4181	202	216	221	229	236	248
MorelandDitch	MorelandDitch	1870	0.01	0.01	0.01	0.01	0.01	0.01
WestGallatin	South	163181	7664	8766	9535	10269	10937	11859
	South	79310	7640	8717	9465	10177	10825	11717
	South	78758	7505	8545	9266	9953	10578	11438
	South	76476	7505	8545	9265	9950	10573	11430
	South	75810	7454	8468	9165	9824	10419	11228
	SouthDiv	75431	7454	8468	9165	9824	10419	11228
	BakCrkDiv	70410	7151	8146	8837	9485	10071	10861
	BakCrkDiv	68398	7049	8036	8722	9366	9947	10733
	BakCrkDiv	42105	7049	8032	8714	9350	9922	10689
	BakCrkDiv	38860	6933	7895	8554	9160	9697	10235
	BakCrkDiv	26546	6837	7748	8365	8931	9432	9932
	BakCrkDiv	24752	6762	7610	8183	8706	9162	9612
	BakCrkDiv	21688	7664	8766	9535	10269	10937	11859
	BakCrkDiv	20324	7653	8739	9491	10205	10850	11735
Gallatin	BakCrkDiv	-121	7668	8845	9667	10450	11200	12160

Lateral Weir Flow Data Summary Table

River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
WestGallatin	South A	79491	24	49	70	92	112	142
	South A	78957	134	172	199	225	248	279
	South A	76760	0	0	1	2	4	8
	South A	76300	51	77	100	127	155	202
	BakCrkDiv B	68639	102	110	115	119	123	128
	I90Lat C	42754	1	4	8	15	26	44
	I90Div D	39077	116	137	160	191	225	454
	BakCrkConflu E	26545	96	148	189	229	265	303
	BakCrkConflu E	24751	76	138	182	225	270	320
	EastOvf F	20706	11	27	44	64	87	124

Flow rates optimized with HEC-RAS model

Figure 4. Baker Creek, Flow Scenario #2 Map



3.11.3 Baker Creek Overflow Channel, Flow Scenario #3:

The Baker Creek Overflow Channel worst case flow scenario would occur when the slide gates located at the Moreland Ditch diversion structure (Photographs 5) are fully opened during a flood event. This structure is constructed with a concrete abutment wall that is keyed into the river bank and it is more probable that the gates would be fully opened during a flood event versus the abutment wall failing during a flood event. By modeling the gates fully open, more discharge would be routed to the Baker Creek Overflow Channel. The resultant peak annual chance discharges for the Baker Creek Overflow Channel, Flow Scenario #3, are listed in Table 29 and shown on Figure 5**.** The applicable HEC-RAS plan analyzed for this flow scenario is plan number four as shown in Table 31.

Table 29. Peak Discharges Baker Creek Overflow Channel, Flow Scenario #3

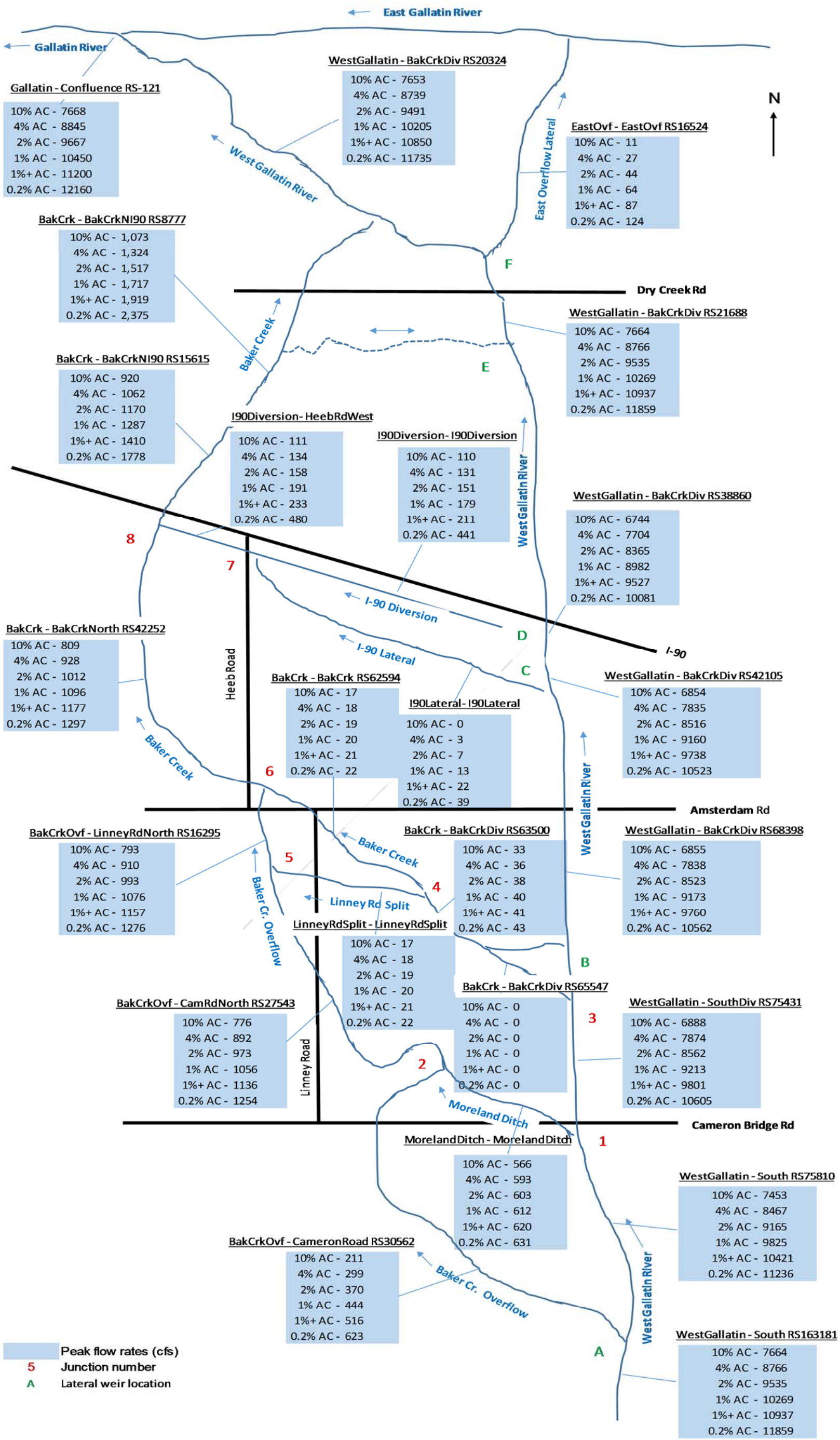
River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
BakCrk	BakCrkDiv	65547	0.01	0.01	0.01	0.01	0.01	0
	BakCrkDiv	63500	33	36	38	40	41	43
	BakCrk	62594	17	18	19	20	21	22
	BakCrkNorth	42252	809	928	1012	1096	1177	1297
	BakCrkNI90	15615	920	1062	1170	1287	1410	1778
	BakCrkNI90	8777	1007	1199	1347	1505	1664	2070
	BakCrkNI90	4991	1073	1324	1517	1717	1919	2375
BakCrkOvf	CameronRoad	33456	24	49	70	92	112	142
	CameronRoad	32965	159	221	269	317	360	421
	CameronRoad	31012	158	221	270	319	364	428
	CameronRoad	30562	211	299	370	444	516	623
	CamRdNorth	27543	776	892	973	1056	1136	1254
	LinneyRdNorth	16295	793	910	993	1076	1157	1276
EastOvf	EastOvf	16524	11	27	44	64	87	124
I90Diversion	I90Diversion	7829	110	131	151	179	211	441
	HeebRdWest	3667	111	134	158	191	233	480
I90Lateral	I90Lateral	7615	0	3	7	13	22	39
LinneyRdSplit	LinneyRdSplit	4181	17	18	19	20	21	22
MorelandDitch	MorelandDitch	1870	566	593	603	612	620	630.84
WestGallatin	South	163181	7664	8766	9535	10269	10937	11859
	South	79310	7640	8717	9465	10177	10825	11717
	South	78758	7505	8545	9266	9952	10577	11438
	South	76476	7506	8545	9265	9950	10573	11431
	South	75810	7453	8467	9165	9825	10421	11236
	SouthDiv	75431	6888	7874	8562	9213	9801	10605
	BakCrkDiv	70410	6888	7874	8562	9213	9801	10605
	BakCrkDiv	68398	6855	7838	8523	9173	9760	10562
	BakCrkDiv	42105	6854	7835	8516	9160	9738	10523
	BakCrkDiv	38860	6744	7704	8365	8982	9527	10081
	BakCrkDiv	26546	6657	7567	8188	8764	9273	9789
	BakCrkDiv	24752	6591	7442	8018	8552	9018	9484
	BakCrkDiv	21688	7664	8766	9535	10269	10937	11859
	BakCrkDiv	20324	7653	8739	9491	10205	10850	11735
Gallatin	BakCrkDiv	-121	7668	8845	9667	10450	11200	12160

Lateral Weir Flow Data Summary Table

River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
WestGallatin	South A	79491	24	49	70	92	112	142
	South A	78957	134	172	199	225	247	279
	South A	76760	0	0	1	2	4	8
	South A	76300	52	78	100	125	152	195
	BakCrkDiv B	68639	33	36	38	40	41	43
	I90Lat C	42754	0	3	7	13	22	39
	I90Div D	39077	110	131	151	179	211	441
	BakCrkConflu E	26545	86	137	177	217	253	292
	BakCrkConflu E	24751	67	125	170	212	255	305
	EastOvf F	20706	11	27	44	64	87	124

Flow rates optimized with HEC-RAS model

Figure 5. Baker Creek Overflow Channel, Flow Scenario #3 Map



3.11.4 I-90 Diversion, Flow Scenario #4:

The I-90 Diversion worst case flow scenario would occur when the I-90 diversion structure located on the left bank of the West Gallatin River upstream of the I-90 crossing fails during a flood event. By modeling the failure of the structure, more of the West Gallatin River flows would discharge into the I-90 Diversion channel and be routed to the Baker Creek channel. The resultant peak annual chance discharges for the I-90 Diversion, Flow Scenario #4, are listed in Table 30 and shown on Figure 6**.** The applicable HEC-RAS plan analyzed for this flow scenario is plan number five as shown in Table 31.

Table 30. Peak Discharges I-90 Diversion, Flow Scenario #4

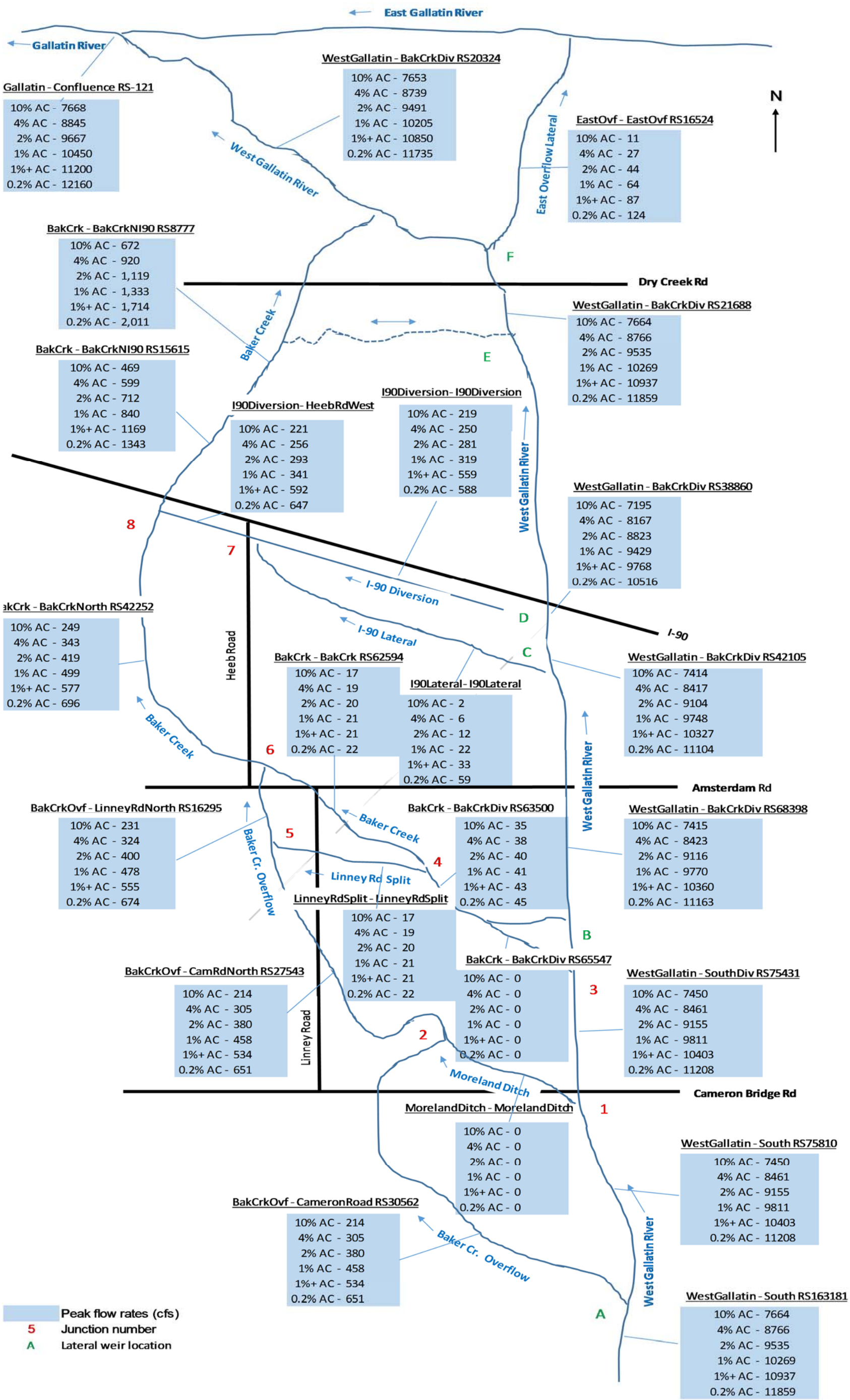
River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
BakCrk	BakCrkDiv	65547	0.01	0.01	0.01	0.01	0.01	0
	BakCrkDiv	63500	35	38	40	41	43	45
	BakCrk	62594	17	19	20	21	21	22
	BakCrkNorth	42252	249	343	419	499	577	696
	BakCrkNI90	15615	469	599	712	840	1169	1343
	BakCrkNI90	8777	579	764	919	1087	1439	1666
	BakCrkNI90	4991	672	920	1119	1333	1714	2011
BakCrkOvf	CameronRoad	33456	25	49	70	92	113	144
	CameronRoad	32965	159	222	272	320	364	427
	CameronRoad	31012	159	222	273	323	370	438
	CameronRoad	30562	214	305	380	458	534	651
	CamRdNorth	27543	214	305	380	458	534	651
	LinneyRdNorth	16295	231	324	400	478	555	674
EastOvf	EastOvf	16524	11	27	44	64	87	124
I90Diversion	I90Diversion	7829	219	250	281	319	559	588
	HeebRdWest	3667	221	256	293	341	592	647
I90Lateral	I90Lateral	7615	2	6	12	22	33	59
LinneyRdSplit	LinneyRdSplit	4181	17	19	20	21	21	22
MorelandDitch	MorelandDitch	1870	0.01	0.01	0.01	0.01	0.01	0.01
WestGallatin	South	163181	7664	8766	9535	10269	10937	11859
	South	79310	7639	8717	9465	10177	10824	11715
	South	78758	7505	8544	9263	9949	10573	11432
	South	76476	7505	8544	9262	9946	10567	11421
	South	75810	7450	8461	9155	9811	10403	11208
	SouthDiv	75431	7450	8461	9155	9811	10403	11208
	BakCrkDiv	70410	7450	8461	9155	9811	10403	11208
	BakCrkDiv	68398	7415	8423	9116	9770	10360	11163
	BakCrkDiv	42105	7414	8417	9104	9748	10327	11104
	BakCrkDiv	38860	7195	8167	8823	9429	9768	10516
	BakCrkDiv	26546	7085	8002	8616	9182	9498	10193
	BakCrkDiv	24752	6992	7846	8416	8936	9223	9848
	BakCrkDiv	21688	7664	8766	9535	10269	10937	11859
	BakCrkDiv	20324	7653	8739	9491	10205	10850	11735
Gallatin	BakCrkDiv	-121	7668	8845	9667	10450	11200	12160

Lateral Weir Flow Data Summary Table

River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% AC+	0.2% AC
WestGallatin	South A	79491	25	49	70	92	113	144
	South A	78957	135	173	201	227	250	283
	South A	76760	0	0	2	3	6	11
	South A	76300	54	82	106	135	164	214
	BakCrkDiv B	68639	35	38	40	41	43	45
	I90Lat C	42754	2	6	12	22	33	59
	I90Div D	39077	219	250	281	319	559	588
	BakCrkConflu E	26545	109	165	206	247	270	323
	BakCrkConflu E	24751	93	155	200	246	275	345
	EastOvf F	20706	11	27	44	64	87	124

Flow rates optimized with HEC-RAS model

Figure 6. I-90 Diversion, Flow Scenario #4 Map



3.11.5 Split Flow Analysis Results

The results of the split flow analysis determined the peak flow rates that would be diverted from the West Gallatin River and conveyed to the split flow reaches of Baker Creek, Baker Creek Overflow, East Overflow, I-90 Diversion, I-90 Lateral, Linney Road Split, and Moreland Ditch. These flow rates, as listed in Table 32 and shown on Figure 7, display the flow scenarios that the hydraulic modeling, regulatory mapping, water surface profiles and Base Flood Elevations (BFE) have been determined for the regulatory purposes of the West Gallatin River floodplain.

Table 31 summarizes the HEC-RAS plans for each scenario analyzed. The regulatory scenario multiple profile and floodway plans are plan numbers six and seven, respectively.

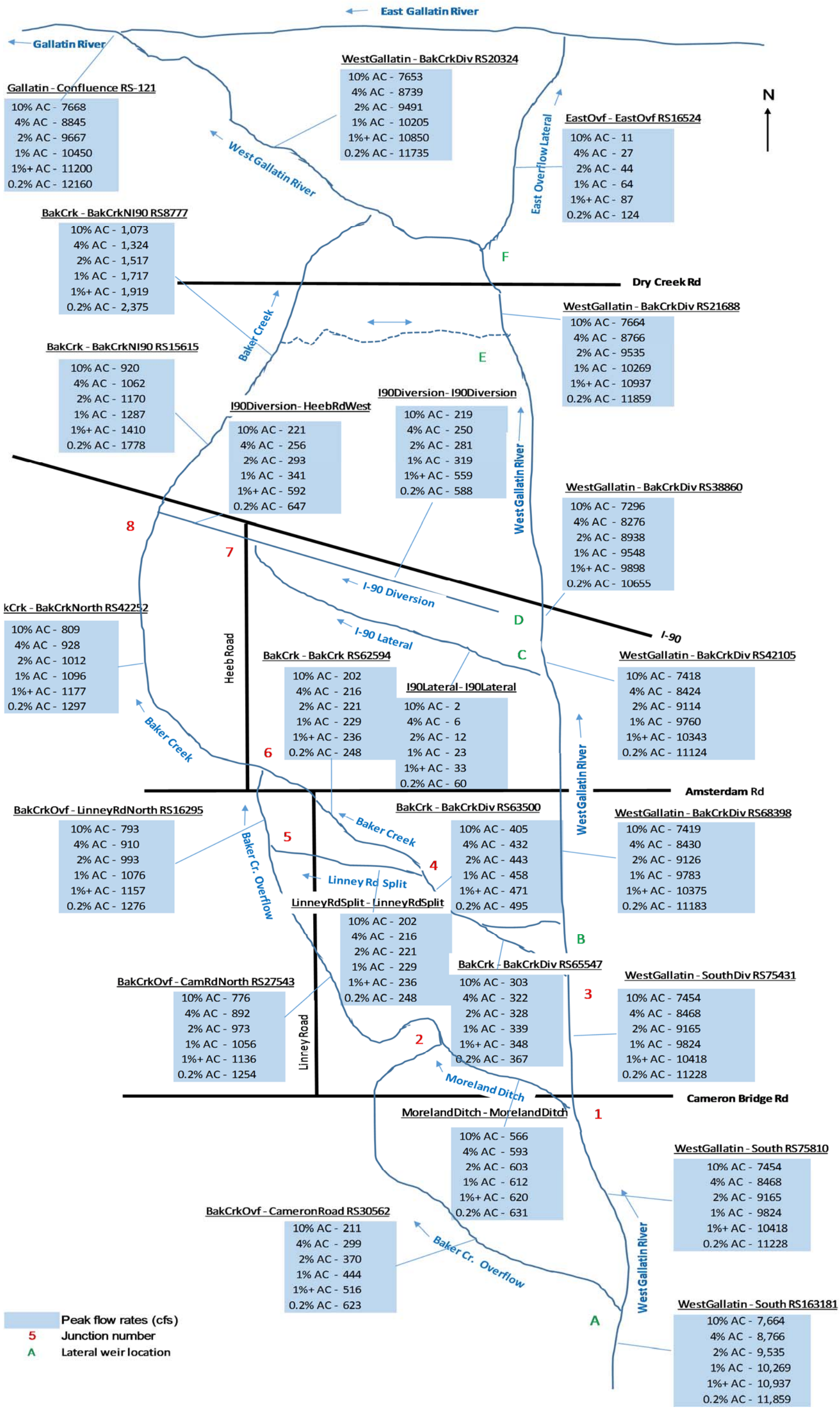
Table 31. HEC-RAS Model Scenario Plans

Reach	Model Scenario Plan	HEC-RAS Plan Number
West Gallatin River Multiple Profile	*Existing_Conditions_Gates_Closed*	1
West Gallatin River Floodway	*Existing_Conditoins_Gates_Closed_Floodway*	2
Baker Creek	*Baker_Creek_Worst_Case_Scenario*	3
Baker Creek Overflow	*Baker_Creek_Overflow_Worst_Case_Scenario*	4
East Overflow Lateral	*Existing_Conditions_Gates_Closed*	1
I-90 Lateral	*I90_Diversion_Worst_Case_Scenario*	5
I-90 Diversion	*I90_Diversion_Worst_Case_Scenario*	5
Linney Road Split	*Baker_Creek_Worst_Case_Scenario*	3
Moreland Ditch	*Baker_Creek_Overflow_Worst_Case_Scenario*	4
West Gallatin River Regulatory Multiple Profile	*WestGallatin_Regulatory*	6
West Gallatin River Regulatory Floodway	*WestGallatin_Regulatory_Floodway*	7

Table 32. Final Model Split Flow Rates

River	Reach	River Sta	Recurrence Interval Flow (cfs)					
			10% AC	4% AC	2% AC	1% AC	1% Plus	0.2% AC
BakCrk	BakCrkDiv	65547	303	322	328	339	348	367
	BakCrkDiv	63500	405	432	443	458	471	495
	BakCrk	62594	202	216	221	229	236	248
	BakCrkNorth	42252	809	928	1,012	1,096	1,177	1,297
	BakCrkNI90	15615	920	1,062	1,170	1,287	1,410	1,778
	BakCrkNI90	8777	1,007	1,199	1,347	1,505	1,664	2,070
	BakCrkNI90	4991	1,073	1,324	1,517	1,717	1,919	2,375
BakCrkOvf	CameronRoad	33456	24	49	70	92	112	142
	CameronRoad	32965	159	221	269	317	360	421
	CameronRoad	31012	158	221	270	319	364	428
	CameronRoad	30562	211	299	370	444	516	623
	CamRdNorth	27543	776	892	973	1,056	1,136	1,254
	LinneyRdNorth	16295	793	910	993	1,076	1,157	1,276
EastOvf	EastOvf	16524	11	27	44	64	87	124
I90Diversion	I90Diversion	7829	219	250	281	319	559	588
	HeebRdWest	3667	221	256	293	341	592	647
I90Lateral	I90Lateral	7615	2	6	12	23	33	60
LinneyRdSplit	LinneyRdSplit	4181	202	216	221	229	236	248
MorelandDitch	MorelandDitch	1870	566	593	603	612	620	631
WestGallatin	South	163181	7,664	8,766	9,535	10,269	10,937	11,859
	South	79310	7,640	8,717	9,465	10,177	10,825	11,717
	South	78758	7,506	8,545	9,266	9,953	10,578	11,438
	South	76476	7,506	8,545	9,265	9,951	10,573	11,431
	South	75810	7,454	8,468	9,165	9,824	10,418	11,228
	SouthDiv	75431	7,454	8,468	9,165	9,824	10,418	11,228
	BakCrkDiv	70410	7,454	8,468	9,165	9,824	10,418	11,228
	BakCrkDiv	68398	7,419	8,430	9,126	9,783	10,375	11,183
	BakCrkDiv	42105	7,418	8,424	9,114	9,760	10,343	11,124
	BakCrkDiv	38860	7,296	8,276	8,938	9,548	9,898	10,655
	BakCrkDiv	26546	7,181	8,105	8,724	9,293	9,619	10,321
	BakCrkDiv	24752	7,081	7,942	8,516	9,037	9,332	9,961
	BakCrkDiv	21688	7,664	8,766	9,535	10,269	10,937	11,859
	BakCrkDiv	20324	7,653	8,739	9,491	10,205	10,850	11,735
Gallatin	BakCrkDiv	-121	7,668	8,845	9,667	10,450	11,200	12,160

Figure 7. Final Flow Scenario Map



3.12 Floodways

The floodways were computed for the West Gallatin River at each cross section. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections and are presented in the Floodway Data Tables in Appendix D. In cases where the floodway and 1% annual-chance floodplain are either close together or collinear, the work maps show only the floodway boundary.

In Montana, the designated floodway is developed using a 0.5-foot surcharge instead of the Federal maximum of 1.0 foot (MDNRC, 2014). These criteria take precedence over the minimum Federal criteria for purposes of regulating development in the floodplain, as set forth in the Code of Federal Regulations, 24 CFR, 1910 (d). The floodways computed for this study are based on a maximum increase of 0.5 foot with a respective encroachment limits and surcharge allowance due the history of dynamic lateral migration on the West Gallatin River.

For a variety of hydraulic modeling reasons, it is not technically possible to have 0.5 feet of surcharge allowance at all cross sections. The 0.5 foot allowance is a maximum limit that cannot be exceeded at any cross section throughout the study reach. Due to the equal conveyance reduction method of floodway modeling, the encroachment at cross sections both up and down gradient may produce a surcharge at the intermediate cross section that exceeds the 0.5 foot maximum limit. Therefore, some cross sections as shown in the Floodway Data Table have surcharges of less than the 0.5 foot limit.

Determination of whether separate regulatory floodways were to be completed for the split flow reaches was verified in accordance with Appendix C (FEMA 2009). This protocol includes calculating the water-surface elevations for the total flow in the main channel and comparing the water-surface elevations with the reduced flow rate due to divergence to the split flow reaches. If the difference in water-surface elevations is greater than the 0.5 foot maximum regulatory surcharge, than a separate regulatory floodway is to be delineated for the split flow channels of the mainstream. This was completed on the West Gallatin River and the differences in WSE's was on the order of 0.1 to 0.2 feet. Therefore, the floodways for the split flow reaches of Baker Creek, Baker Creek Overflow, East Overflow, I-90 Diversion, I-90 Lateral, Linney Road Split, and Moreland Ditch were not determined and only the identified 1% and 0.2% annual chance floodplain delineations are included on the floodplain work maps.

The applicable HEC-RAS plan analyzed for the West Gallatin floodway analysis is plan number 2.

3.13 CHECK-RAS

FEMA's automated review software CHECK-RAS, Version 2.0.1 (FEMA 2011) was utilized to verify the acceptability of the hydraulic analyses described above. Due to the size and complexity of the West Gallatin River and Splits HEC-RAS model, CHECK-RAS was not able to load the data file, execute and complete the review. Therefore no CHECK-RAS review messages were obtained and documented for this floodplain study update.

To complete the Quality Assurance and Quality Control of the hydraulic modeling, Morrison-Maierle, Inc. completed an internal HEC-RAS model review and QA-QC checklist of the hydraulic modeling. These completed internal checklists are included in Appendix E of the report.

4.0 Floodplain Mapping

Floodplain mapping was prepared using ESRI ArcMap 10. 1 and HEC-GeoRAS 10.1 toolbar. HEC-GeoRAS determines the floodplain area by intersecting the LiDAR DEM with a separate DEM representing the profile of the 1% (or 0.5%) annual-chance event. The resulting floodplains for the 1% and 0.5% annual-chance flood events are displayed within the hydraulic work maps provided in Appendix A. Along with the flooding extents, the work map also displays the stream profile baseline of each respective reach along with the cross sections utilized during the hydraulic analysis. The layout of the cross sections and structures under existing conditions is presented on the work maps. The WSEL attributed to each cross section is from the controlling worst case scenario for each respective cross section. The base map of the hydraulic work map is the 2013 NAIP aerial photograph.

Typically, islands that were determined to be higher than the adjacent 1% annual-chance water surface profile and less than one acre in size were not delineated. Large backwater areas that extended through multiple cross sections were also modified to represent the elevation associated with the location where the backwater initiates from the man channel. These two adjustments provide a slight variance in the mapped widths versus the top widths described by the HEC-RAS mode at selected locations.

5.0 Flood Insurance Study Products

Digital profiles of the 10%, 4%, 2%, 1%, 1%+, and 0.2% annual-chance water surface elevations for the study were created using FEMA's RASPLOT software (FEMA 2013). Additional information, edits and formatting were made using AutoCAD. Profiles were developed following Appendix J, Section J.2.2 of FEMA Guidelines and Specifications. The profiles illustrating the results of the study are included in Appendix B.

6.0 References

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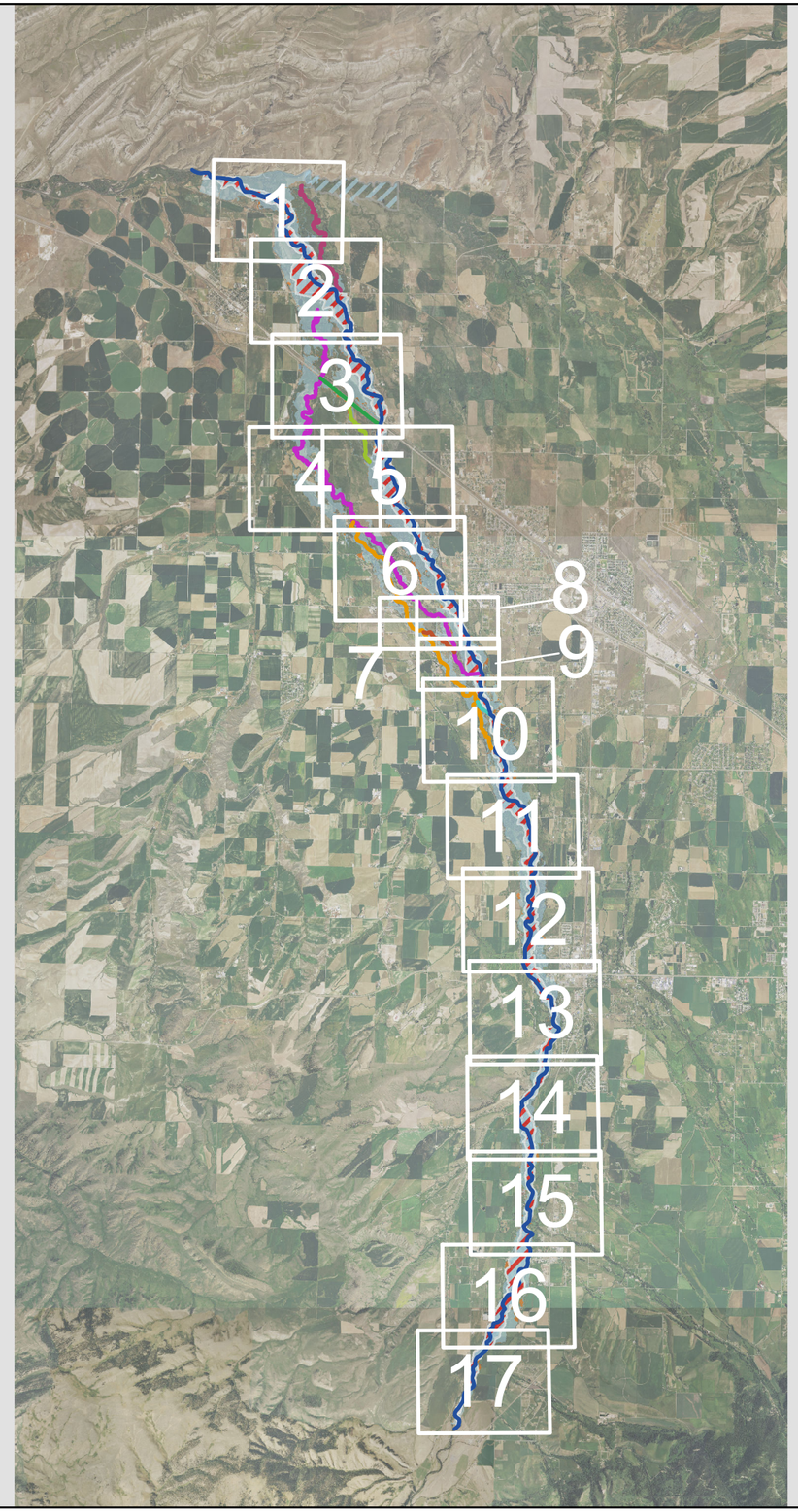
APPENDIX

Appendix A – Hydraulic Work Maps



GALLATIN COUNTY TOPOGRAPHIC WORKMAPS

LEGEND

Profile Baseline
- Baker Creek
- Baker Creek Overflow
- East Overflow
- I-90 Diversion
- I-90 Lateral
- Linney Rd
- Moreland Ditch
- West Gallatin

Proposed Flood Hazard Area
- 0.2% AC
- AE - 1% AC
- FLOODWAY
- Hydraulic Crossings
- Modeled Junction
- Lateral Weir
- 10' Contour
- 5' Contour

Labels
- (A) Cross Section Letter
- 79,726 River Station
- 4,700.0 Water Surface Elevation

0 7,500 15,000 22,500 Feet

Hydraulic Work Map - West Gallatin River Flood Study
Gallatin County, MT Risk MAP - MAS No. 2014-02
NAIP 2011, Horizontal Datum: NAD83
Topographic Data, LiDAR 2012
Hozontal Datum: NAD83, Vertical Datum: NAVD88, Feet

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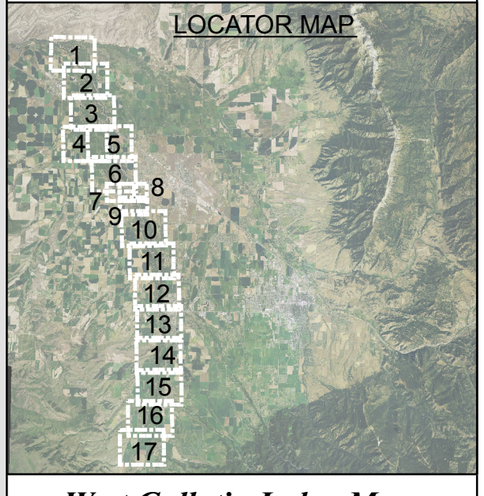
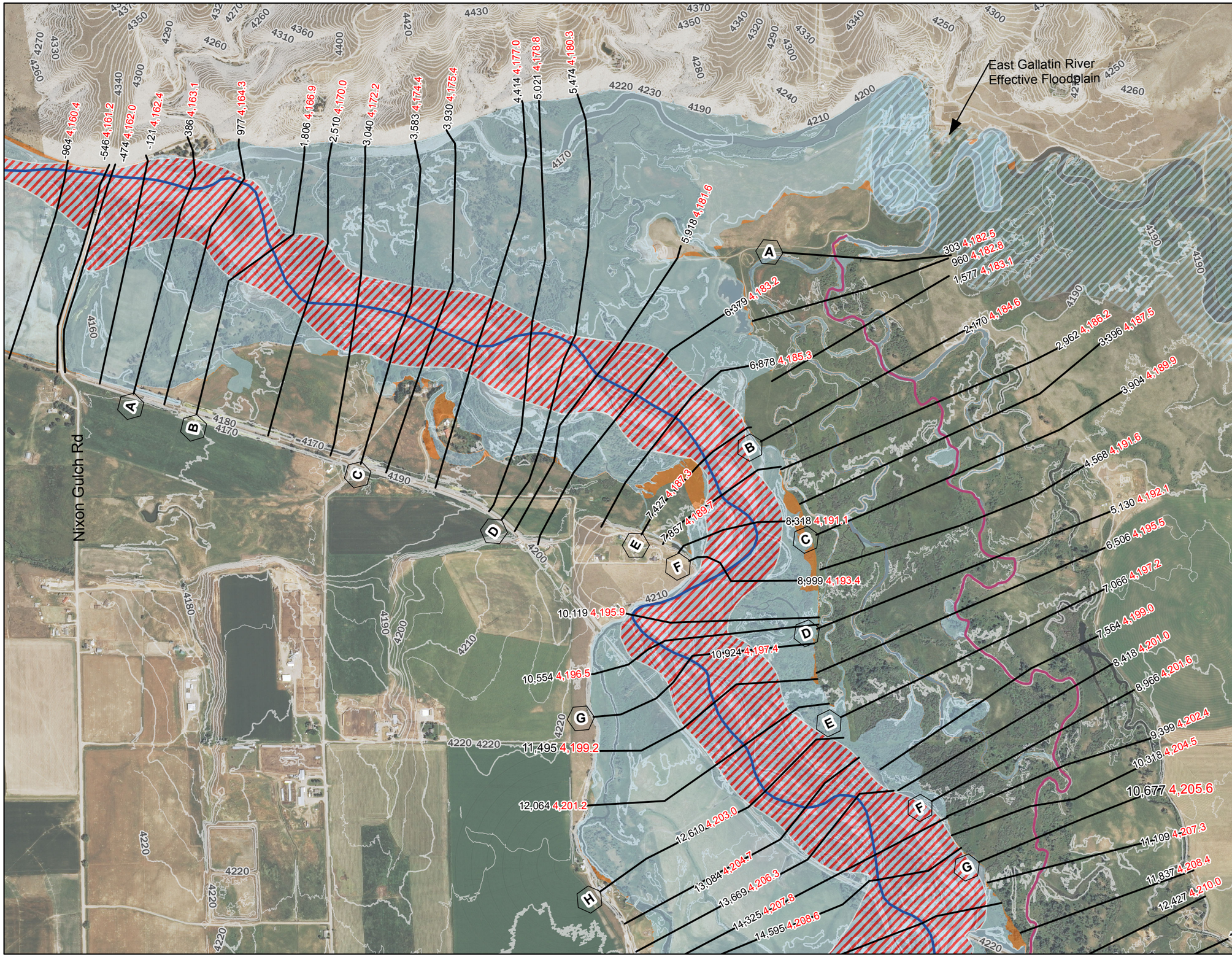
LOCATOR MAP



West Gallatin Index Map

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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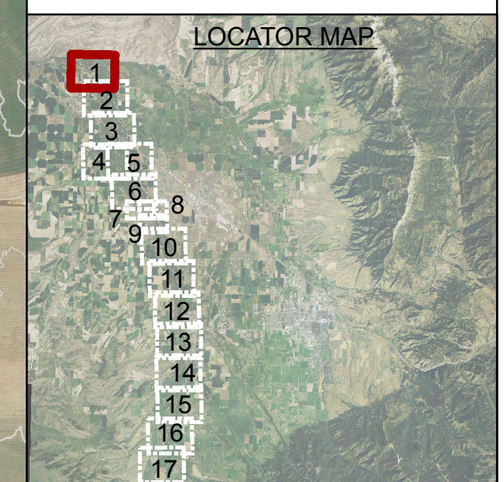
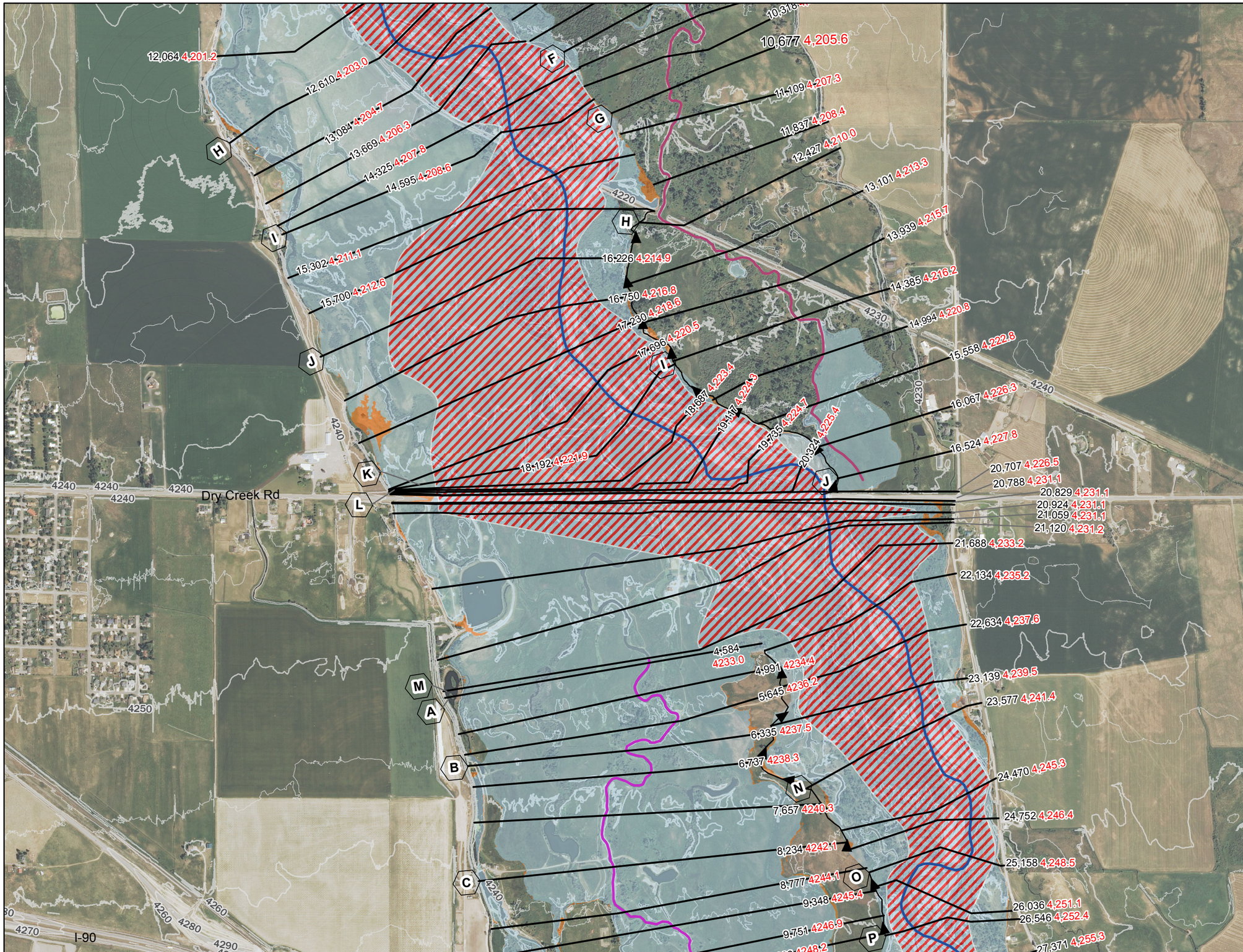
LOCATOR MAP



West Gallatin Map 1 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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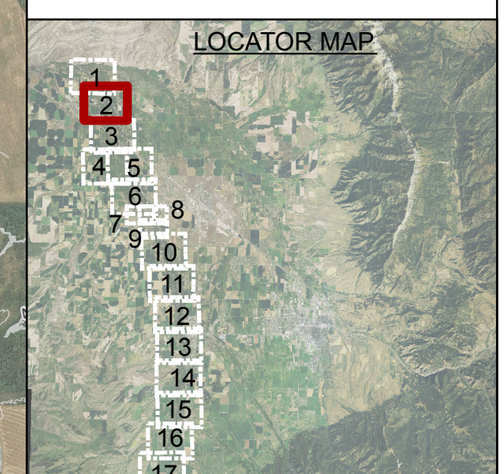
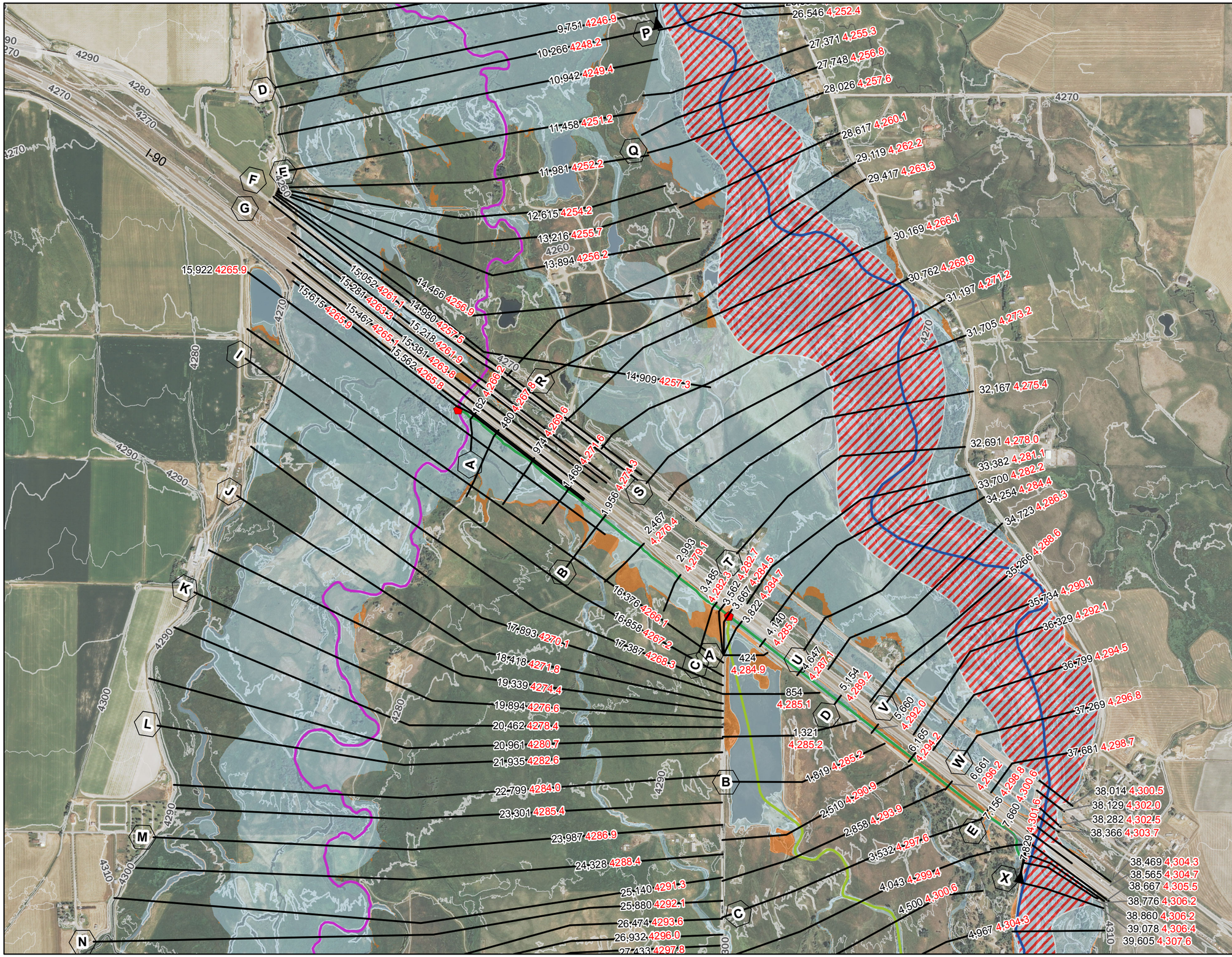


West Gallatin Map 2 of 17



GALLATIN COUNTY TOPOGRAPHIC WORKMAP

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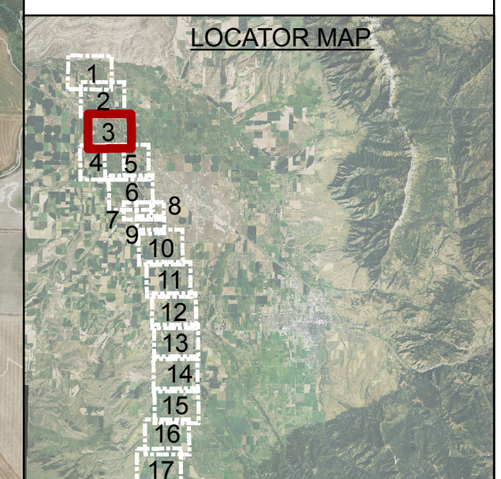
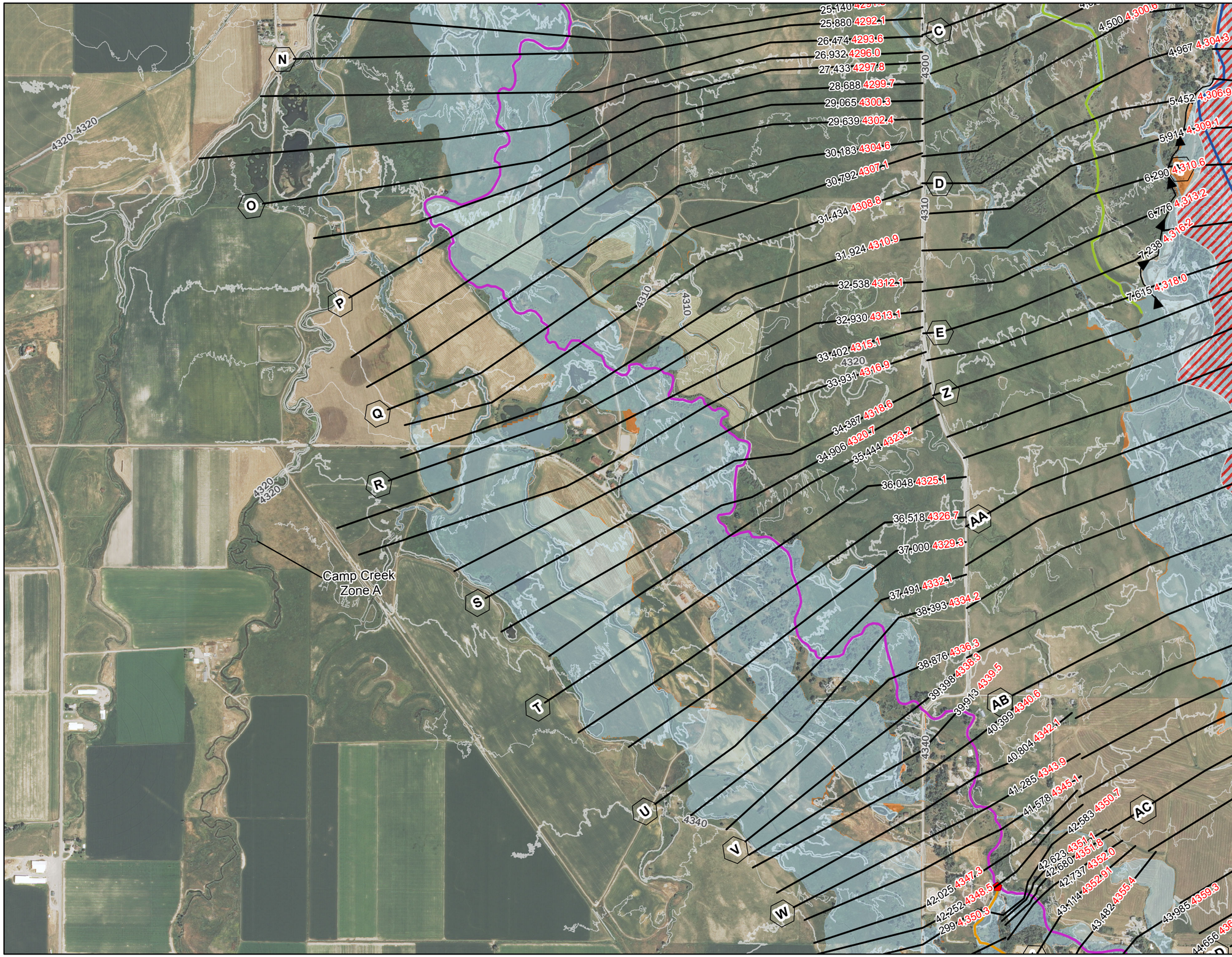


West Gallatin Map 3 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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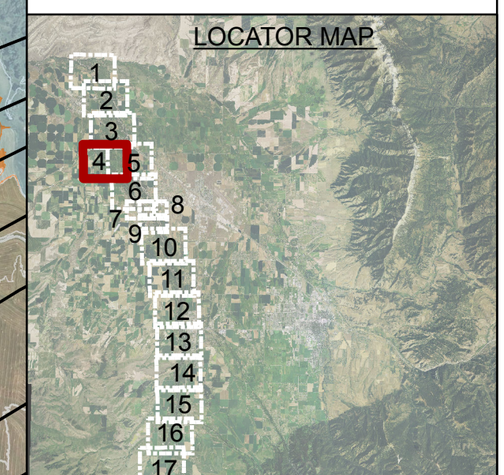
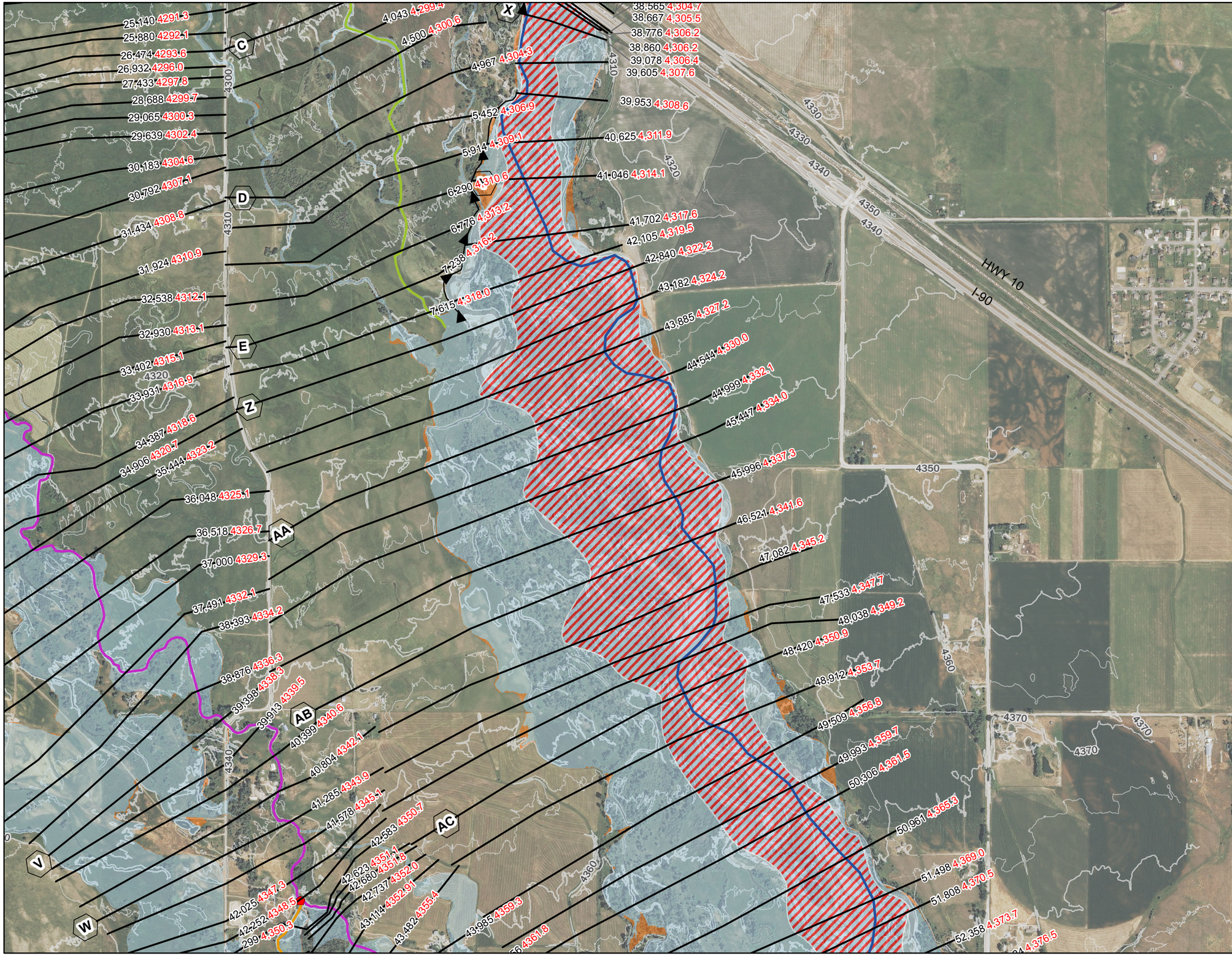


West Gallatin Map 4 of 17



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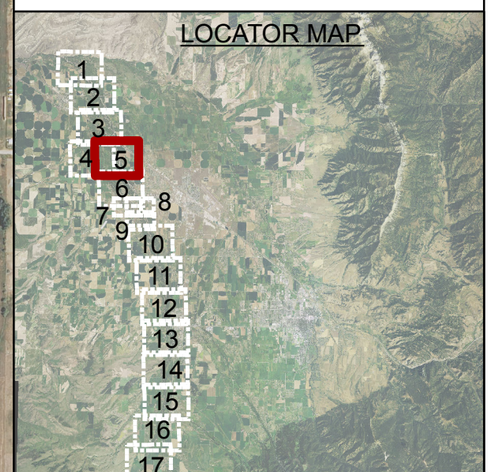
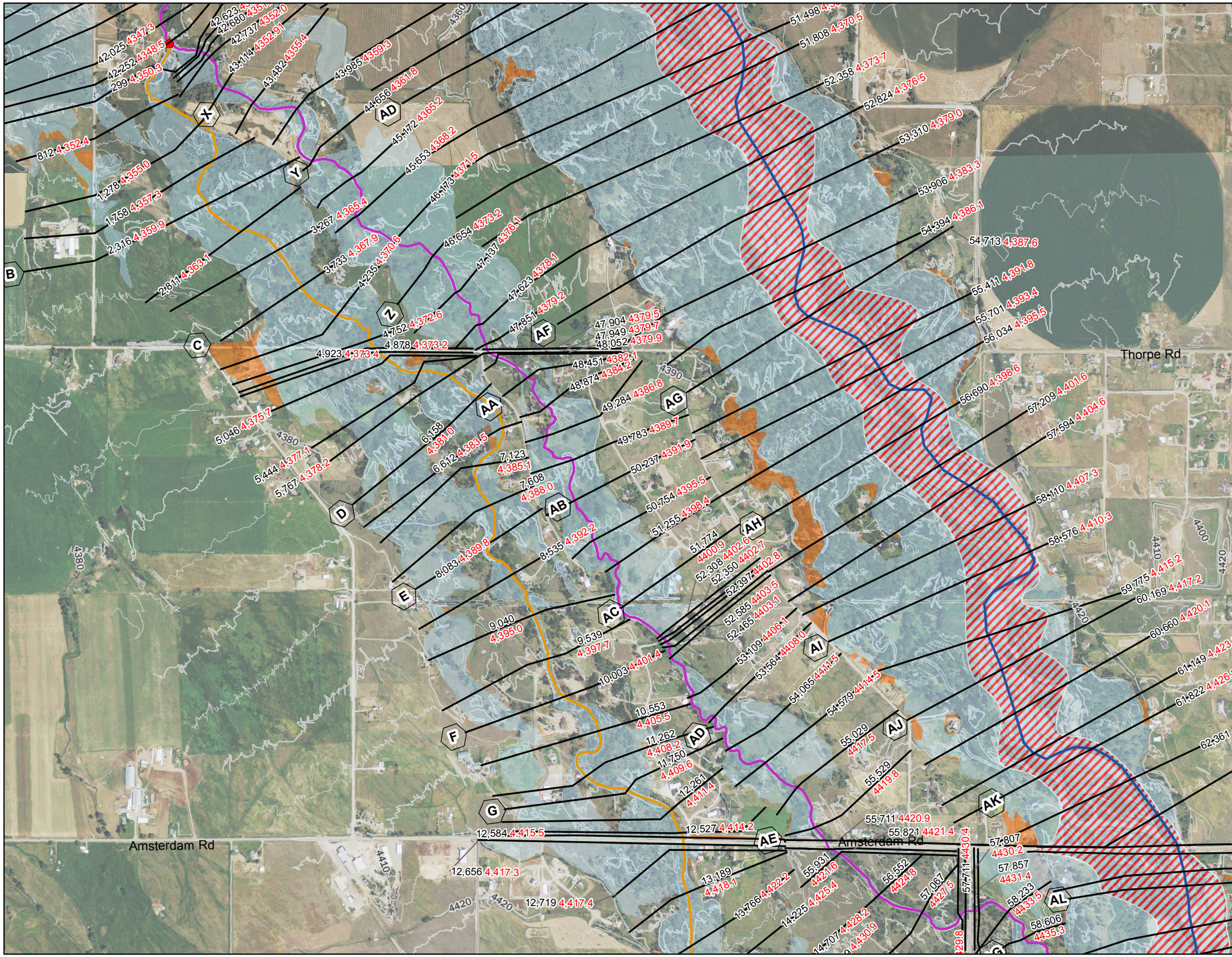


West Gallatin Map 5 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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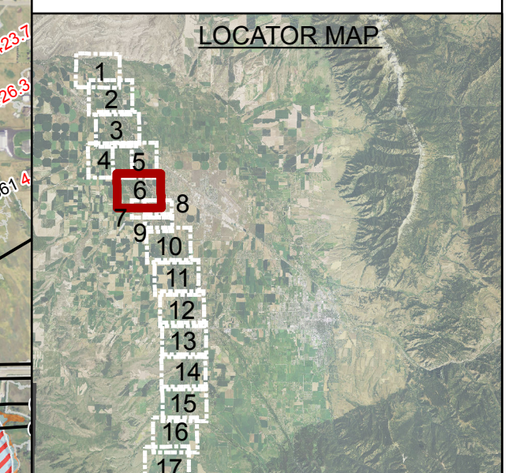
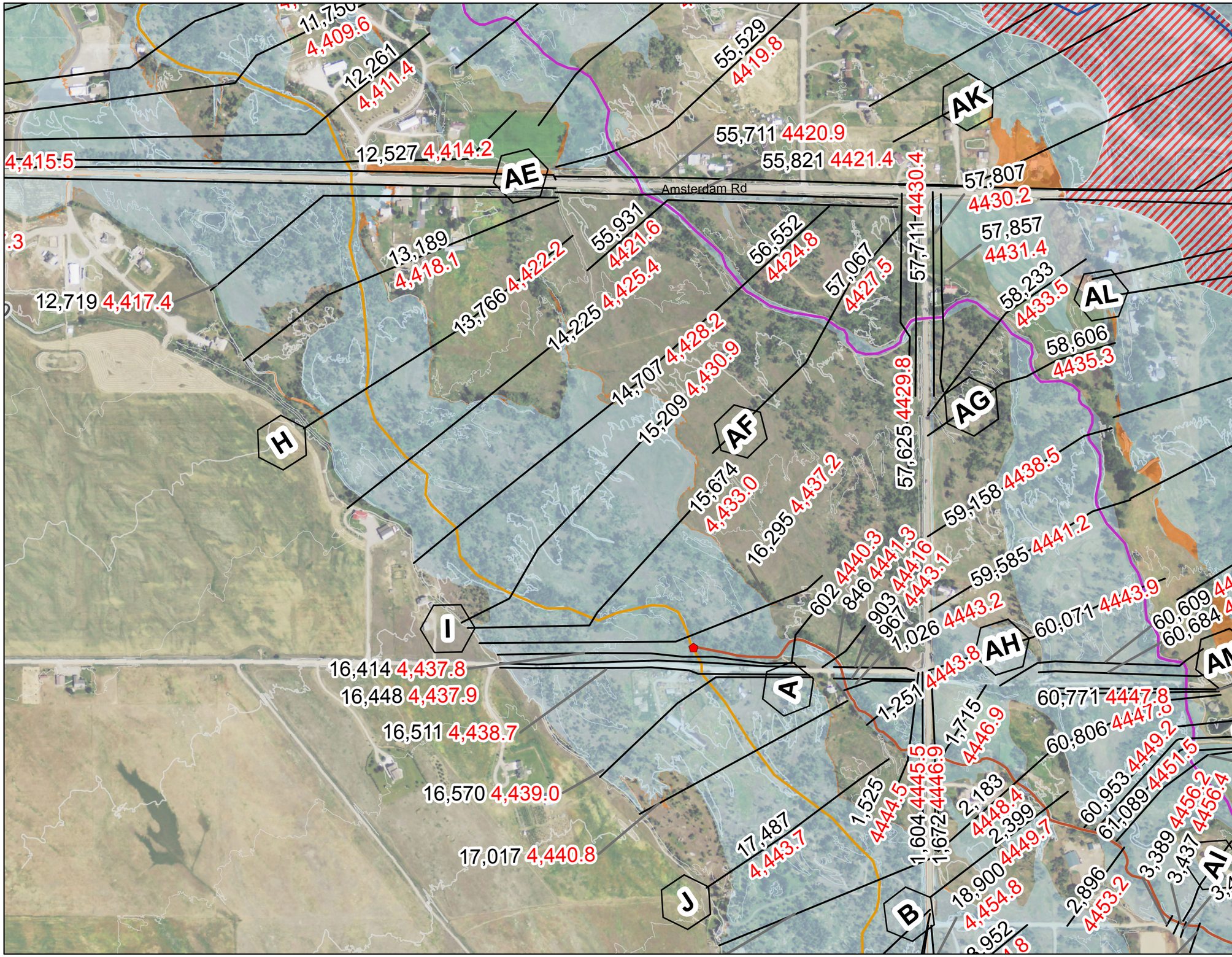


West Gallatin Map 6 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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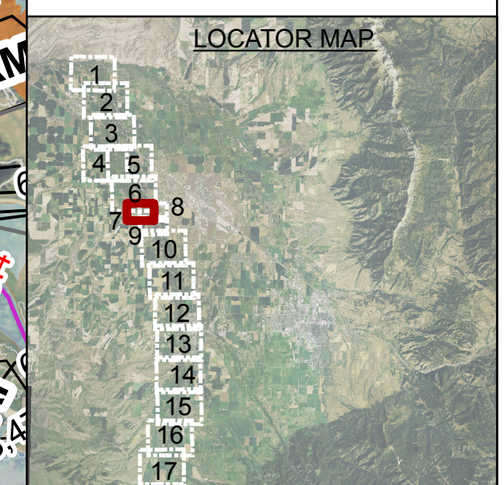
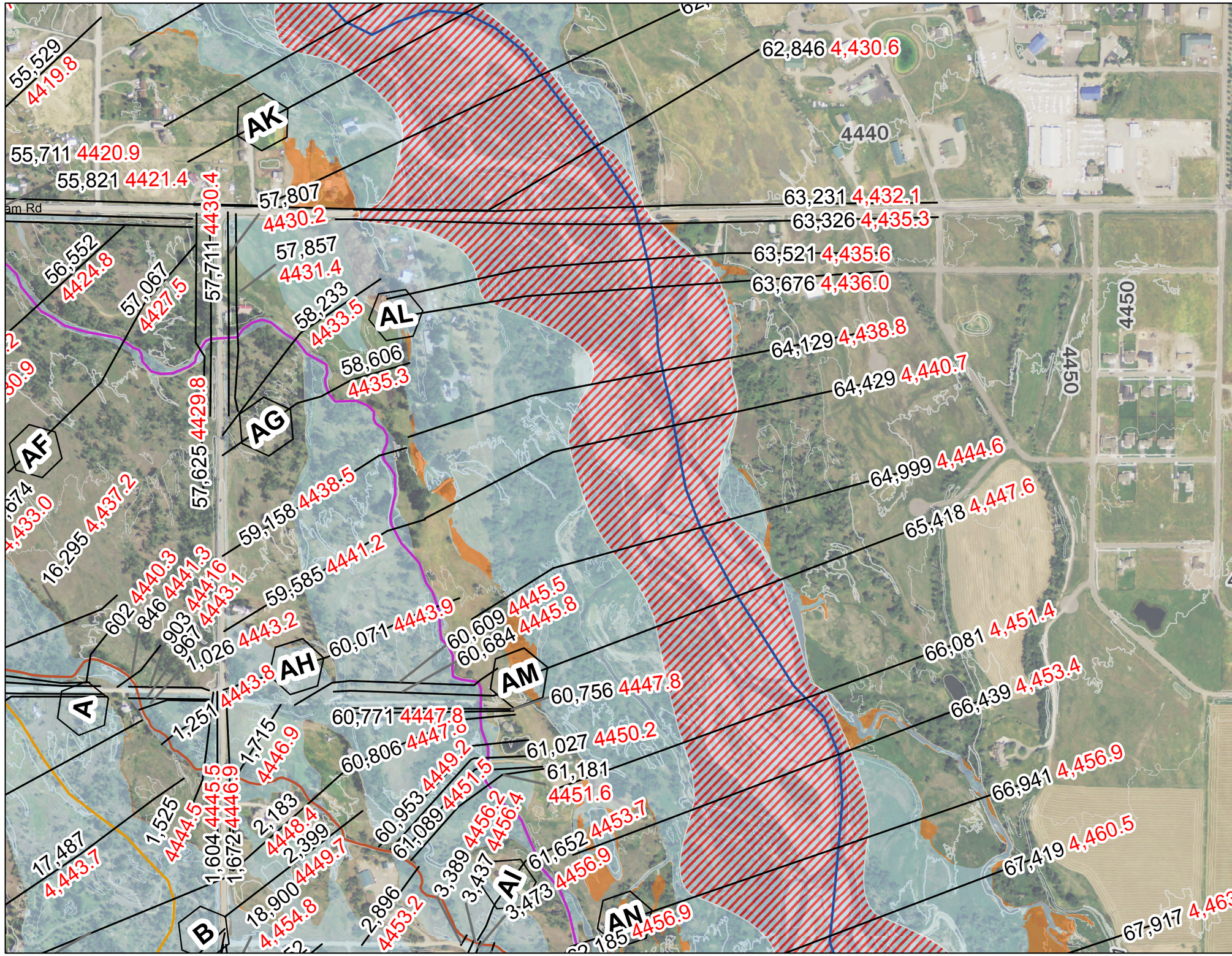
LOCATOR MAP



West Gallatin Map 7 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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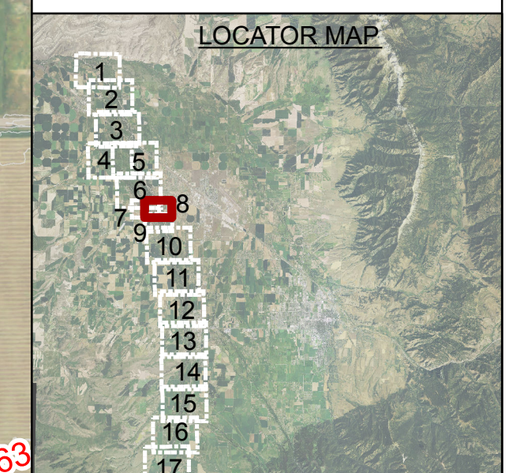
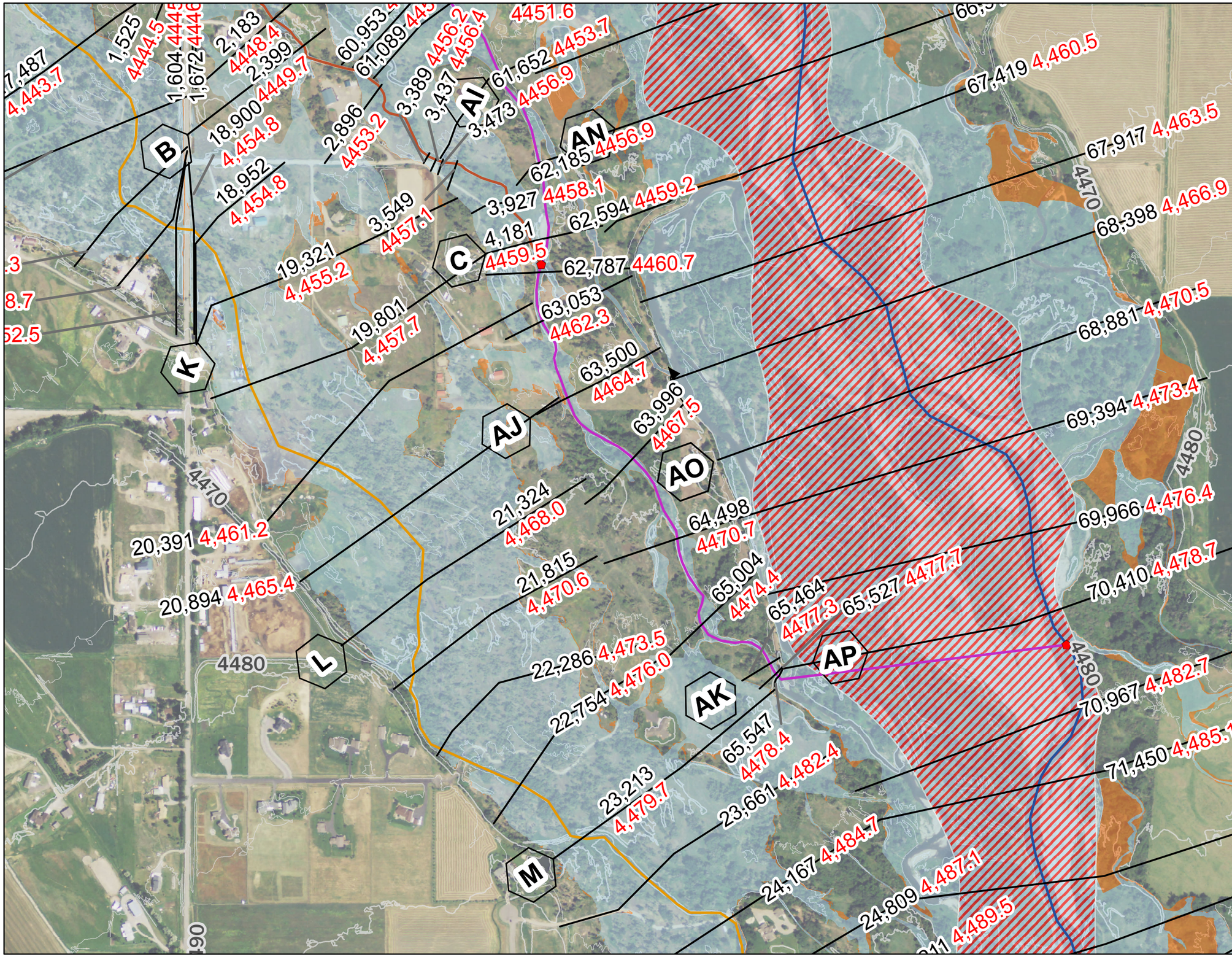
LOCATOR MAP



West Gallatin Map 8 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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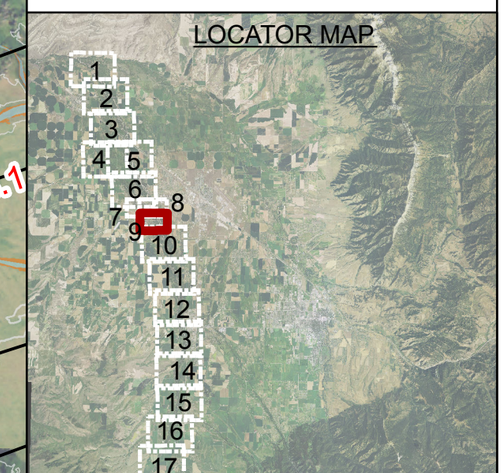
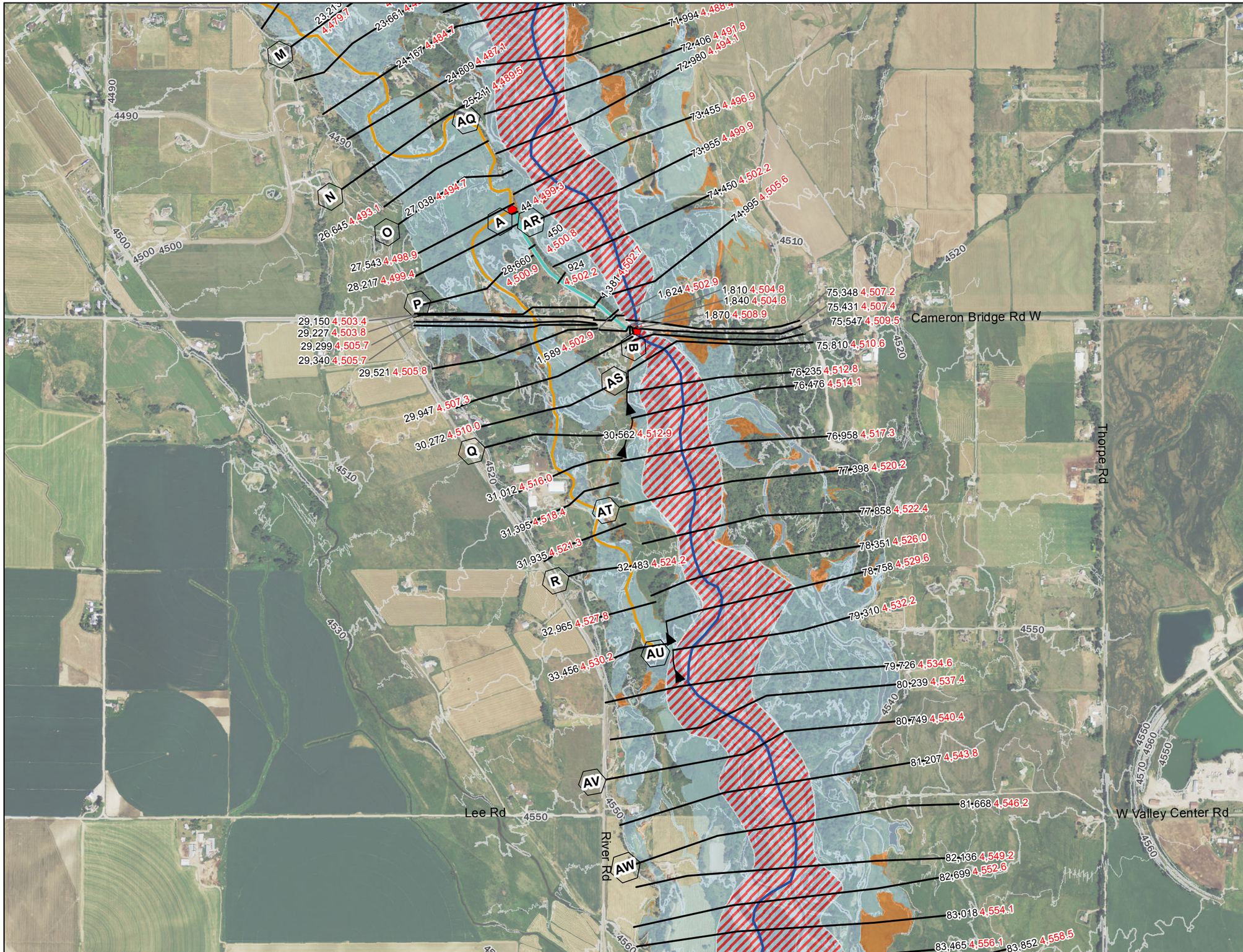


West Gallatin Map 9 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



LEGEND

Profile Baseline
- Baker Creek
- Baker Creek Overflow
- East Overflow
- I-90 Diversion
- I-90 Lateral
- Linney Rd
- Moreland Ditch
- West Gallatin

Proposed Flood Hazard Area
- 0.2 % AC
- AE - 1% AC
- FLOODWAY
- Hydraulic Crossings
- Modeled Junction
- Lateral Weir
- 10' Contour
- 5' Contour

Labels
- A Cross Section Letter — 79,726 River Station
- 4,700.0 Water Surface Elevation

0 500 1,000 1,500 Feet

Hydraulic Work Map - West Gallatin River Flood Study
Gallatin County, MT Risk MAP - MAS No. 2014-02
NAIP 2011, Horizontal Datum: NAD83
Topographic Data, LiDAR 2012
Hozontal Datum: NAD83, Vertical Datum: NAVD88, Feet

MONTANA DNRC

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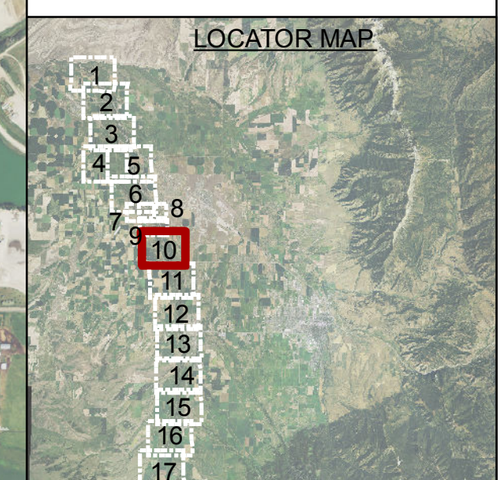
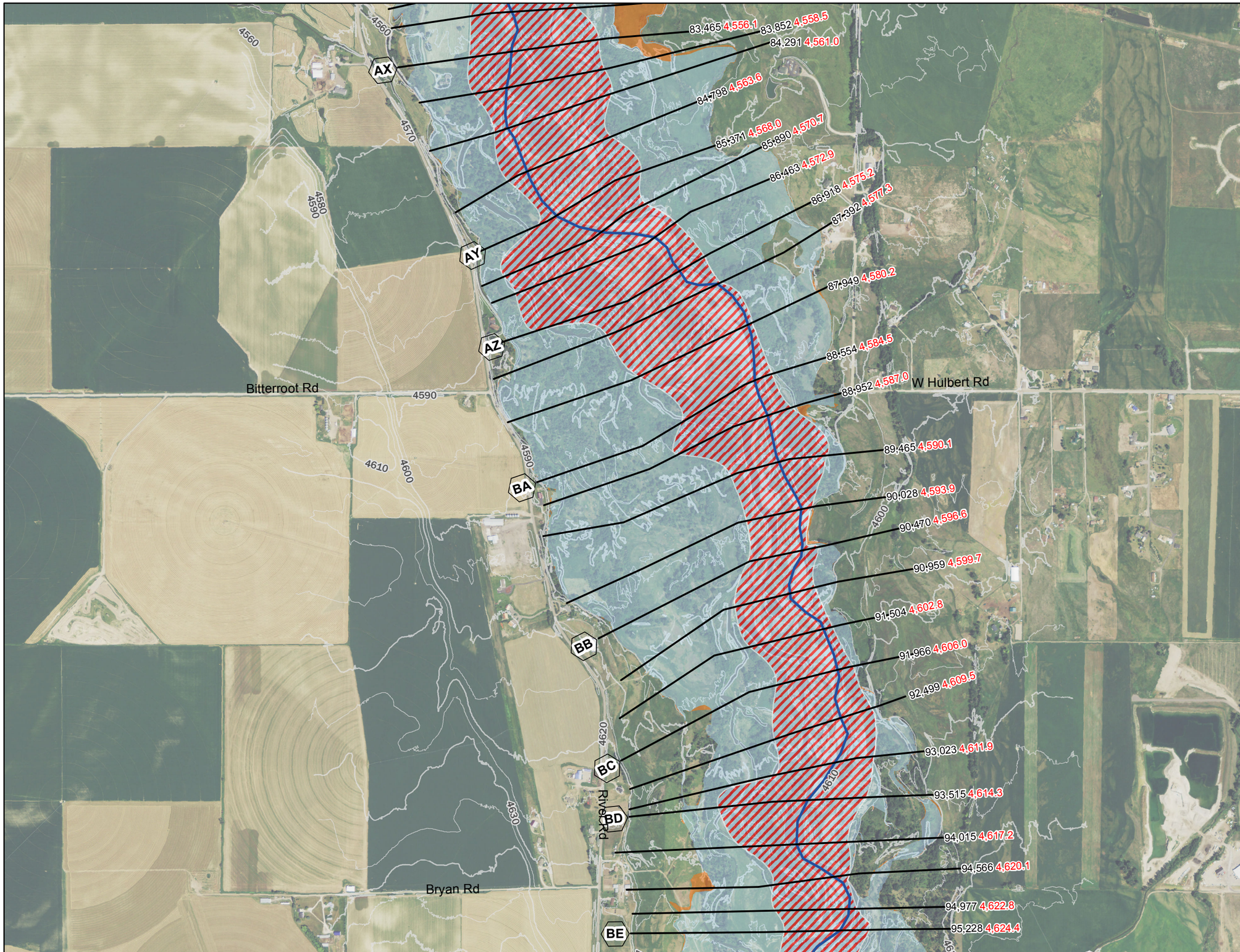
LOCATOR MAP



West Gallatin Map 10 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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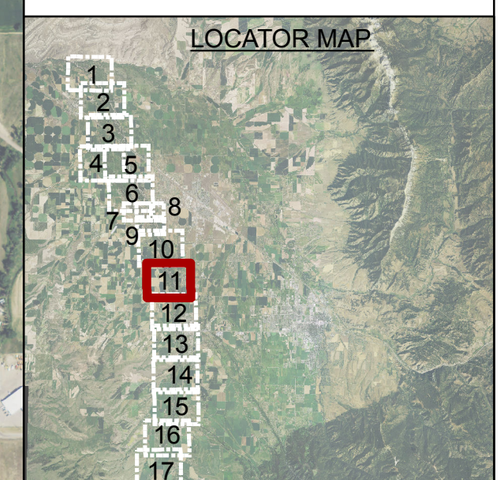
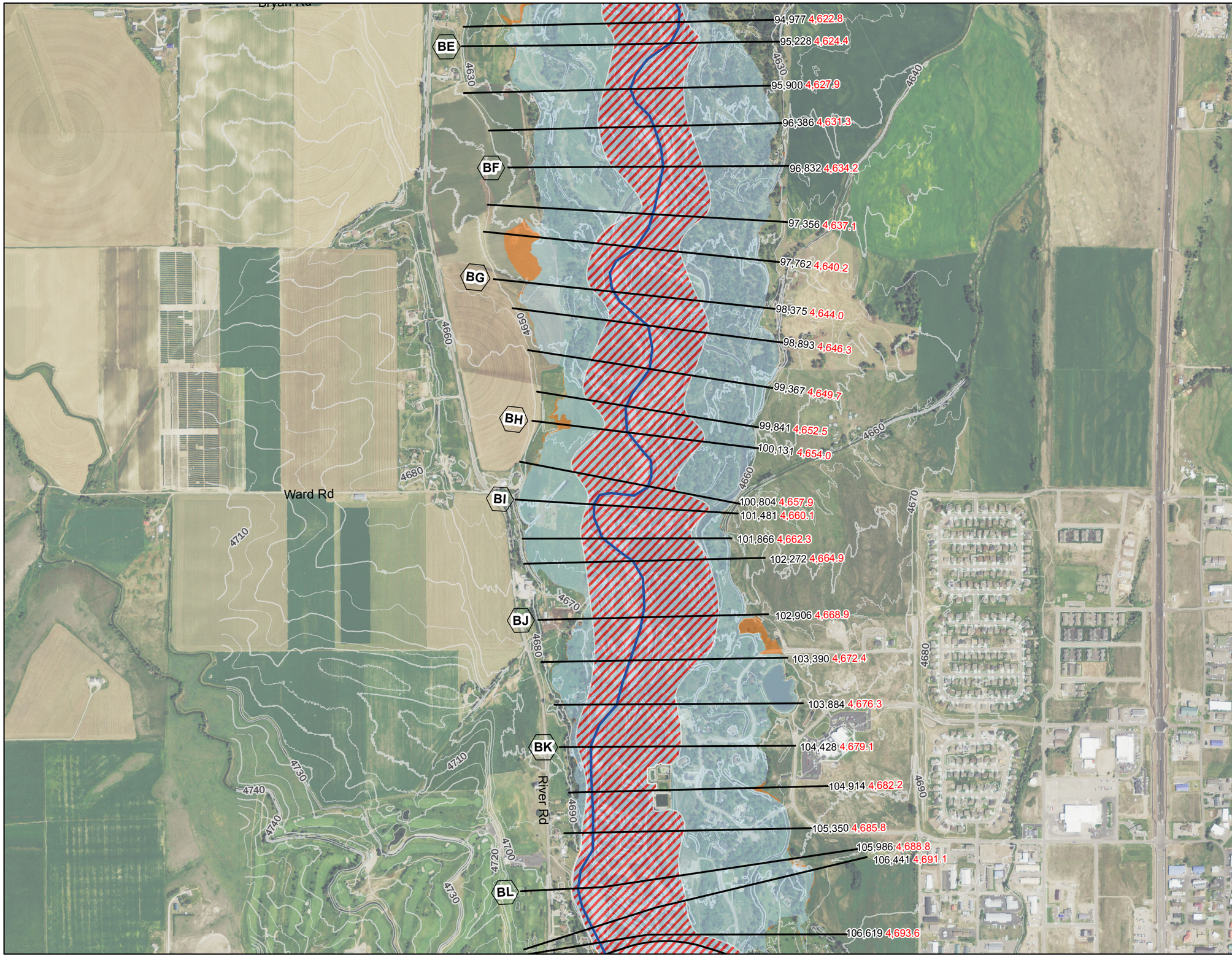


West Gallatin Map 11 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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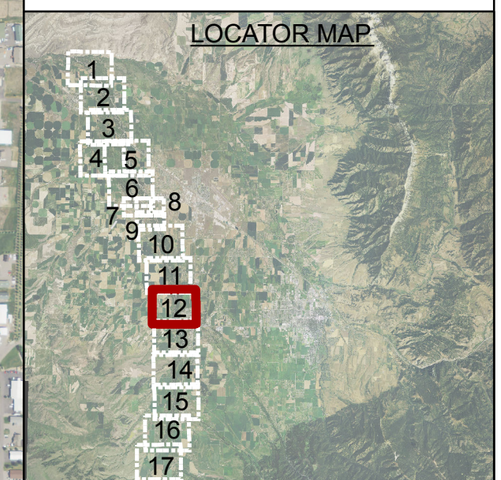
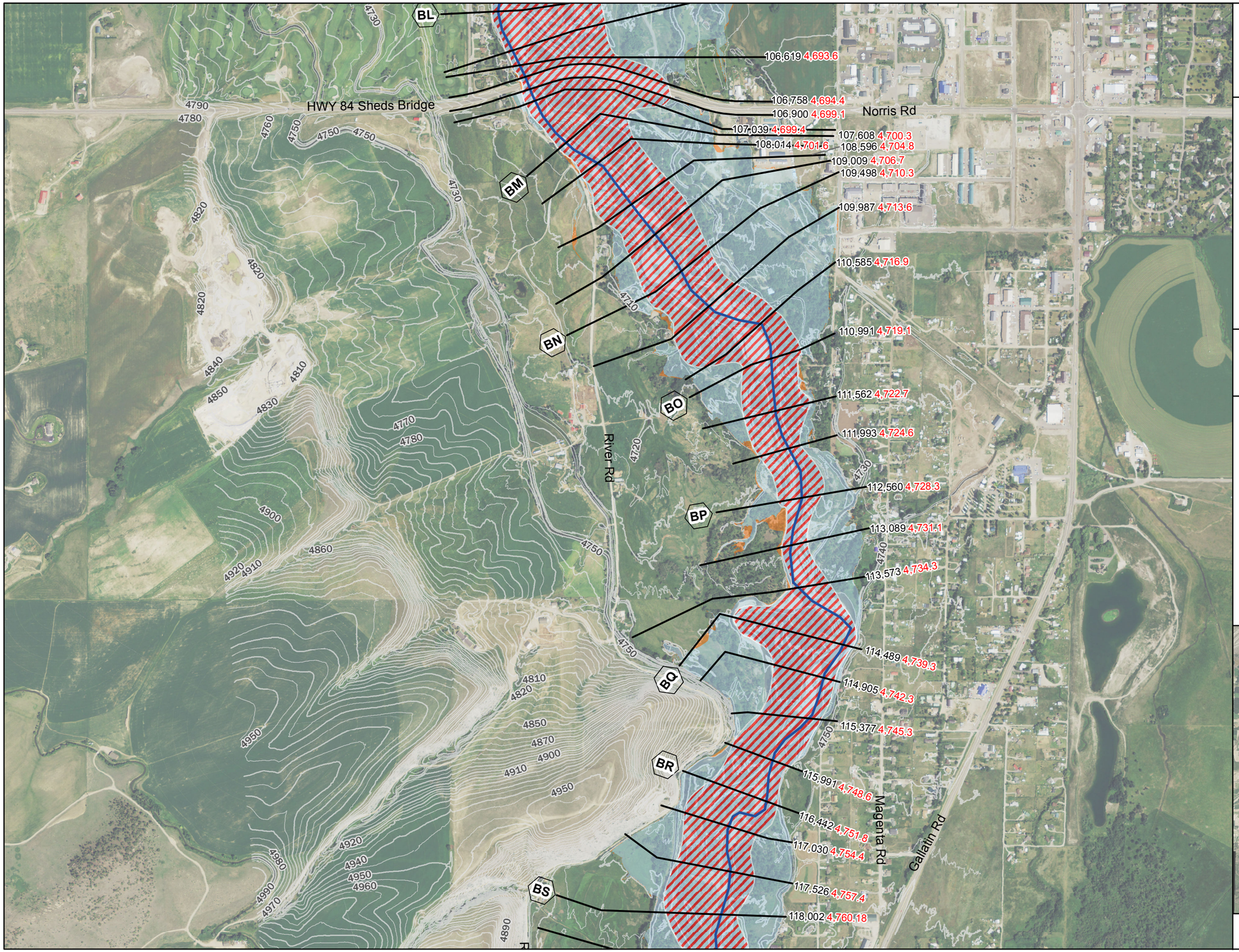


West Gallatin Map 12 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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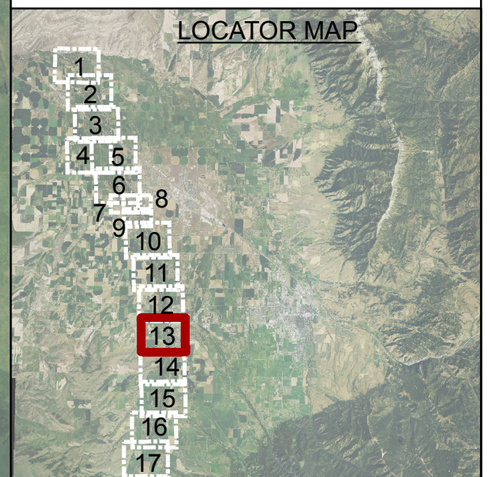
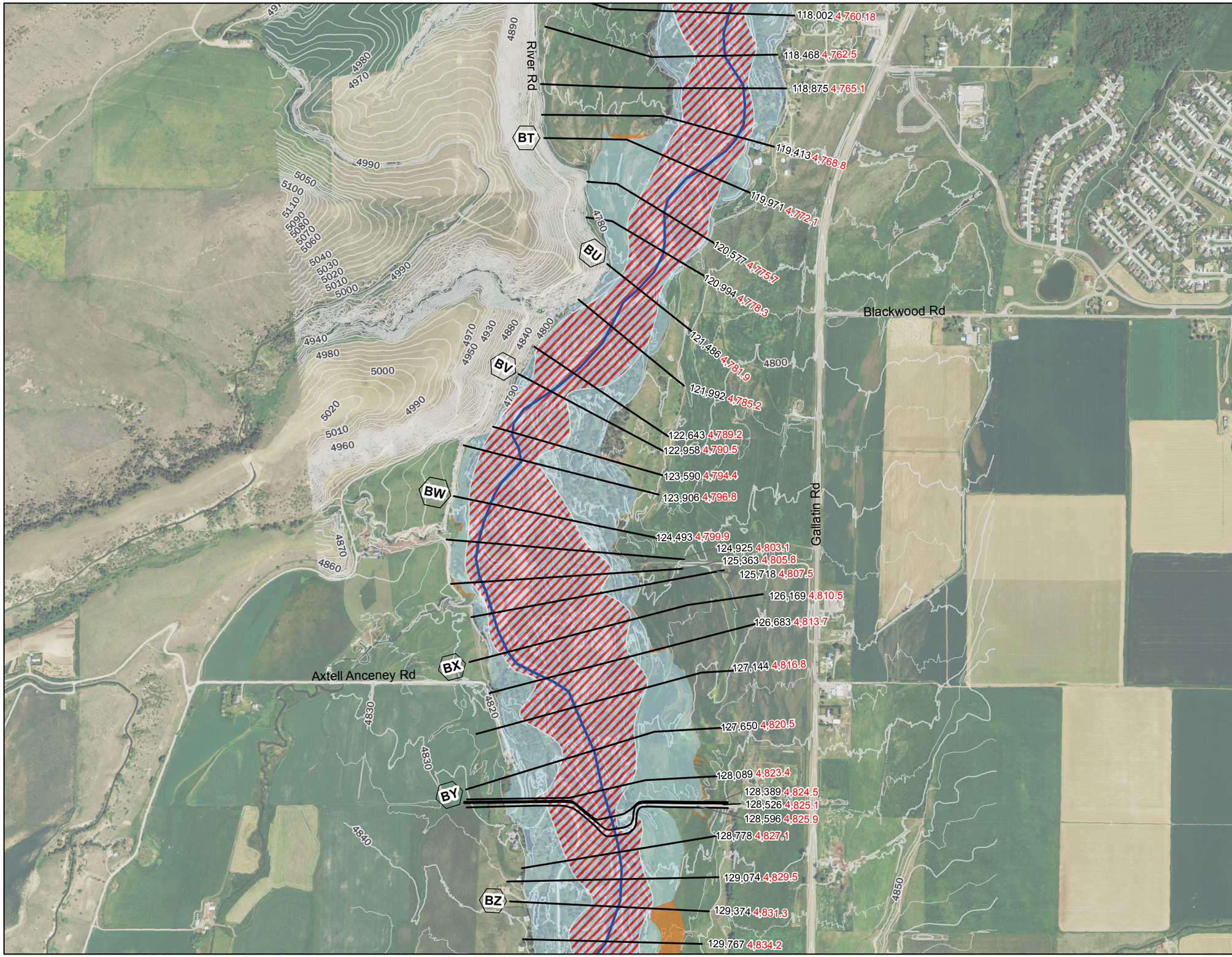


West Gallatin Map 13 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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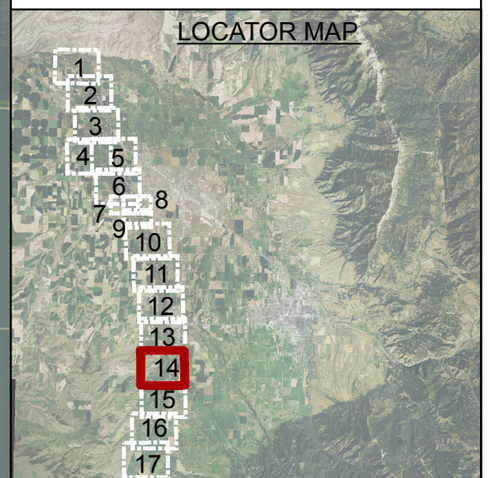
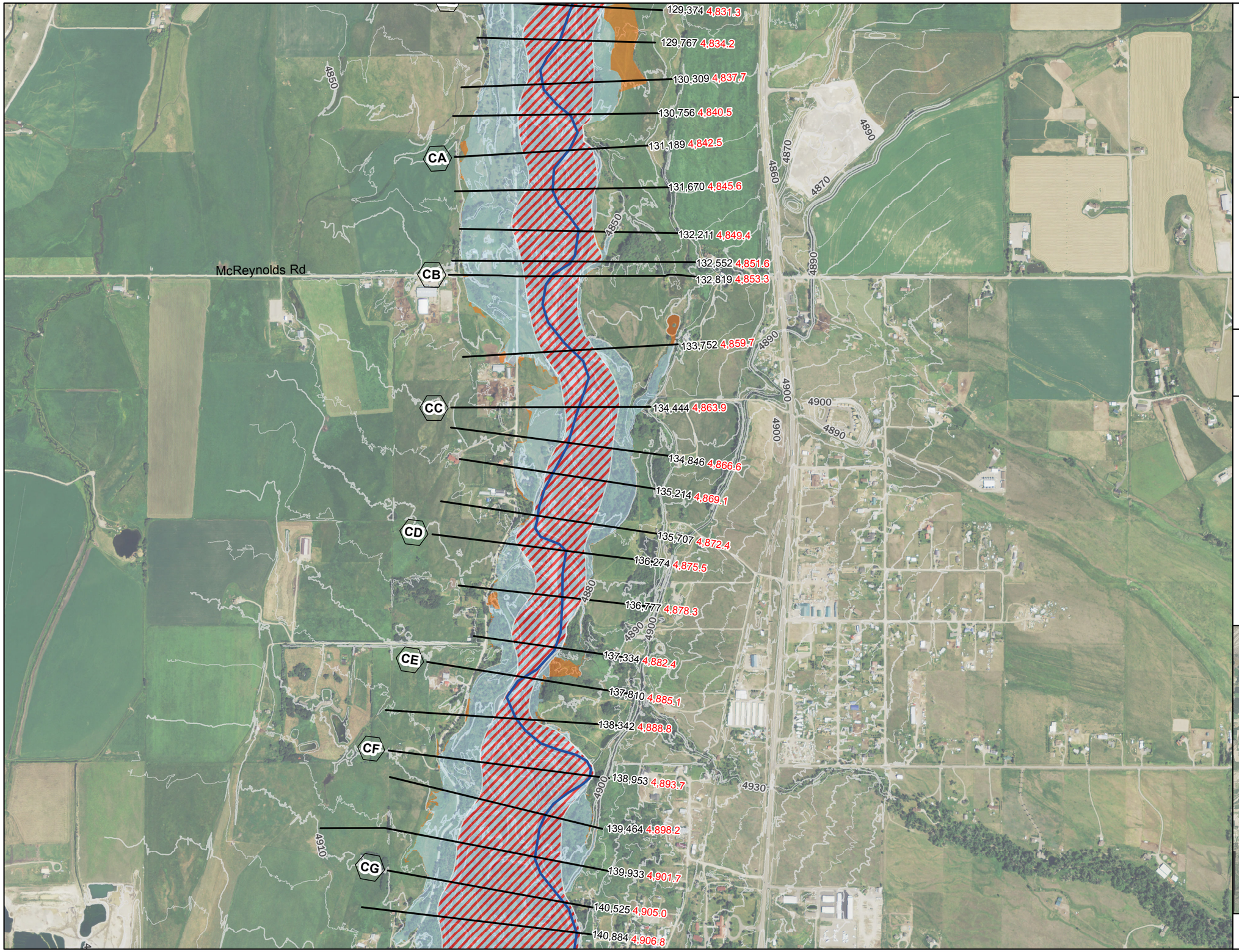


West Gallatin Map 14 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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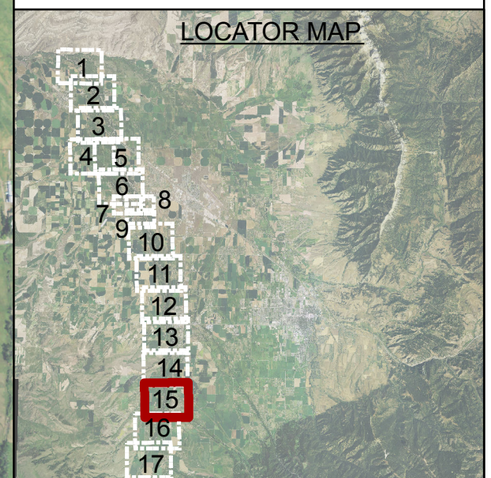
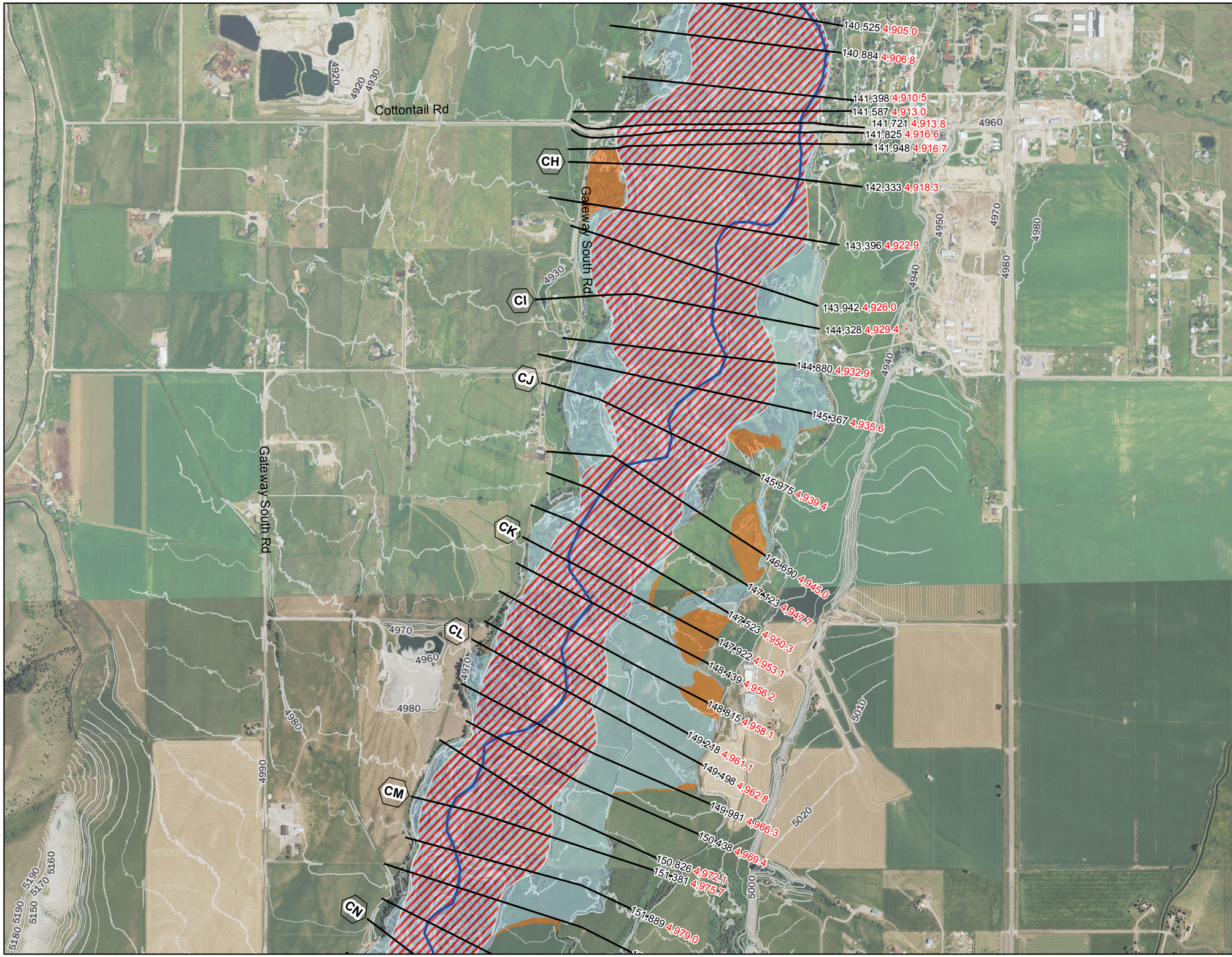


West Gallatin Map 15 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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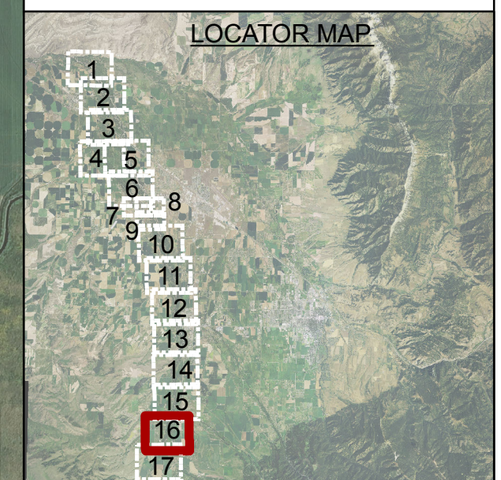
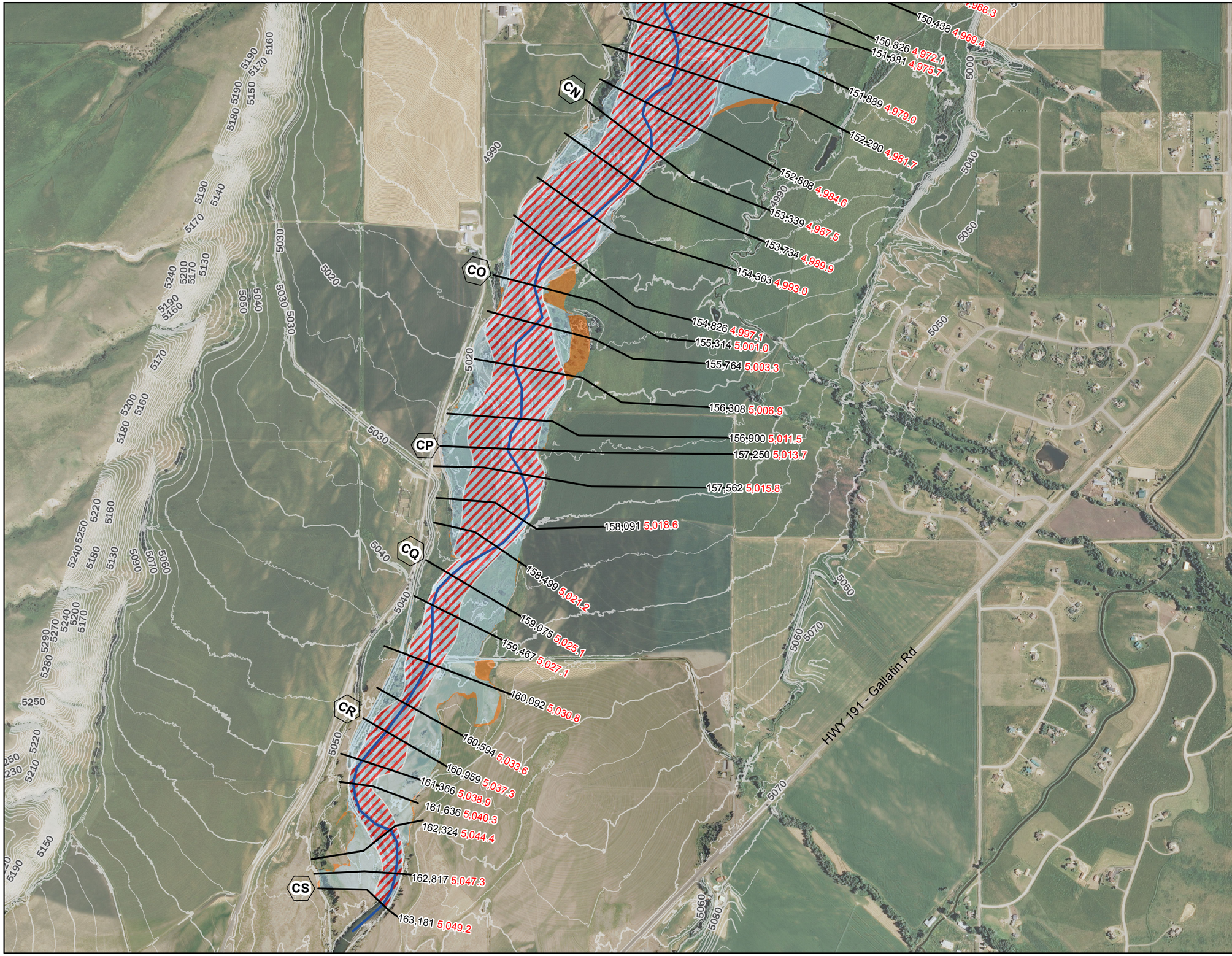


West Gallatin Map 16 of 17

GALLATIN COUNTY TOPOGRAPHIC WORKMAP



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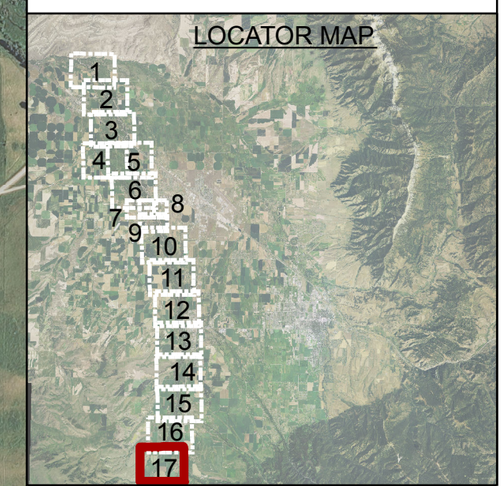
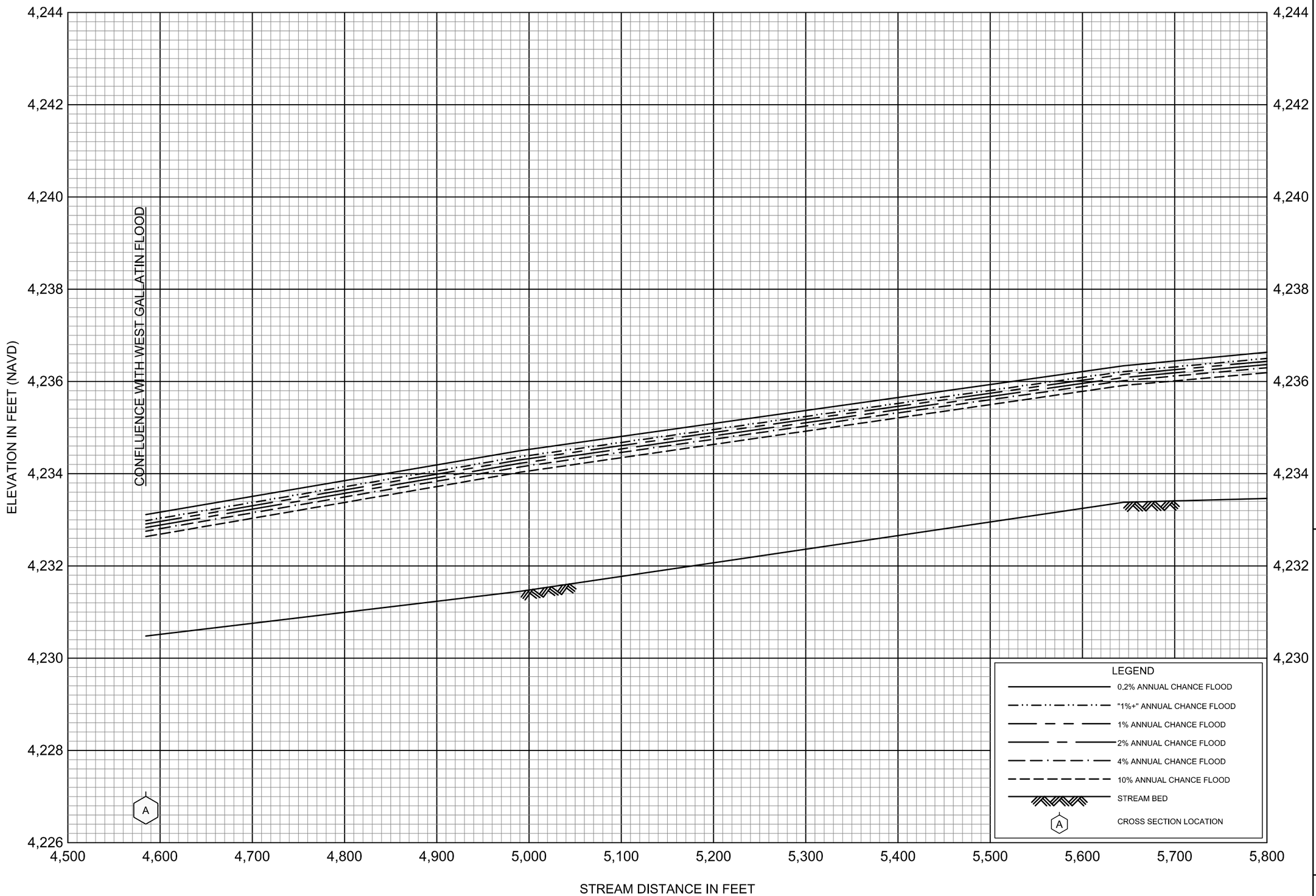


West Gallatin Map 17 of 17

Appendix B – Profiles



FLOOD PROFILES

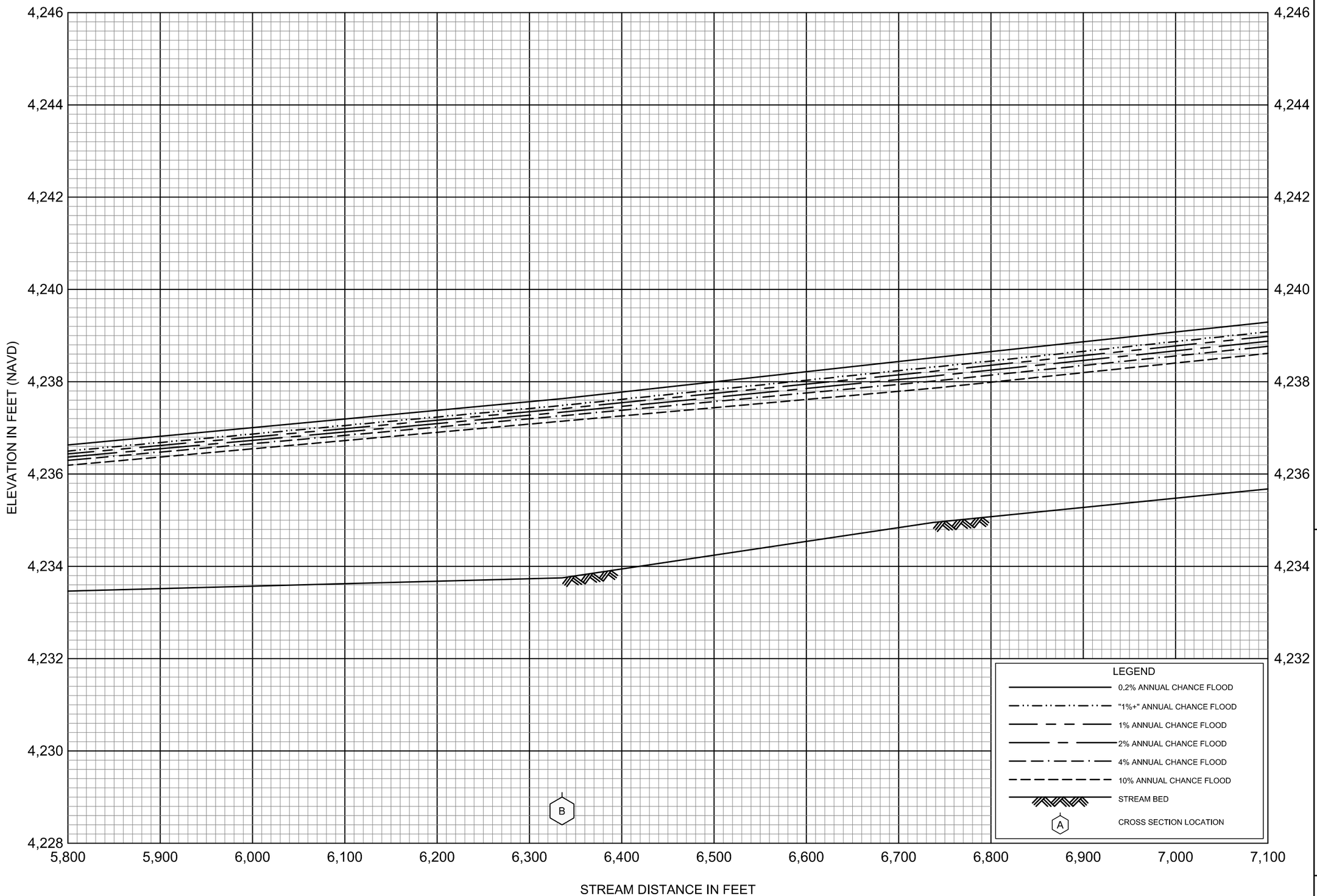
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

001P



FLOOD PROFILES

BAKER CREEK

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GALLATIN COUNTY, MT

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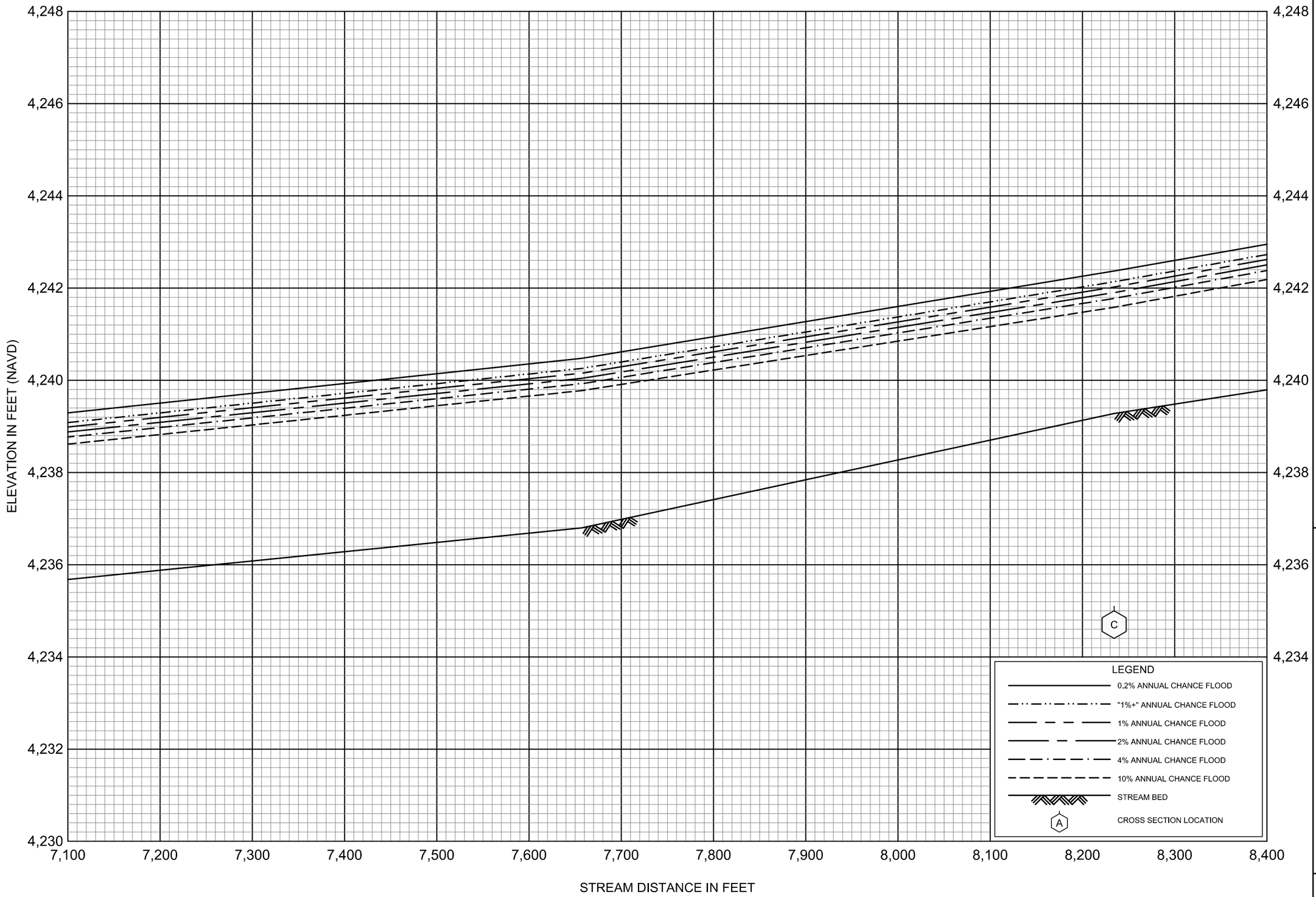
002P



FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

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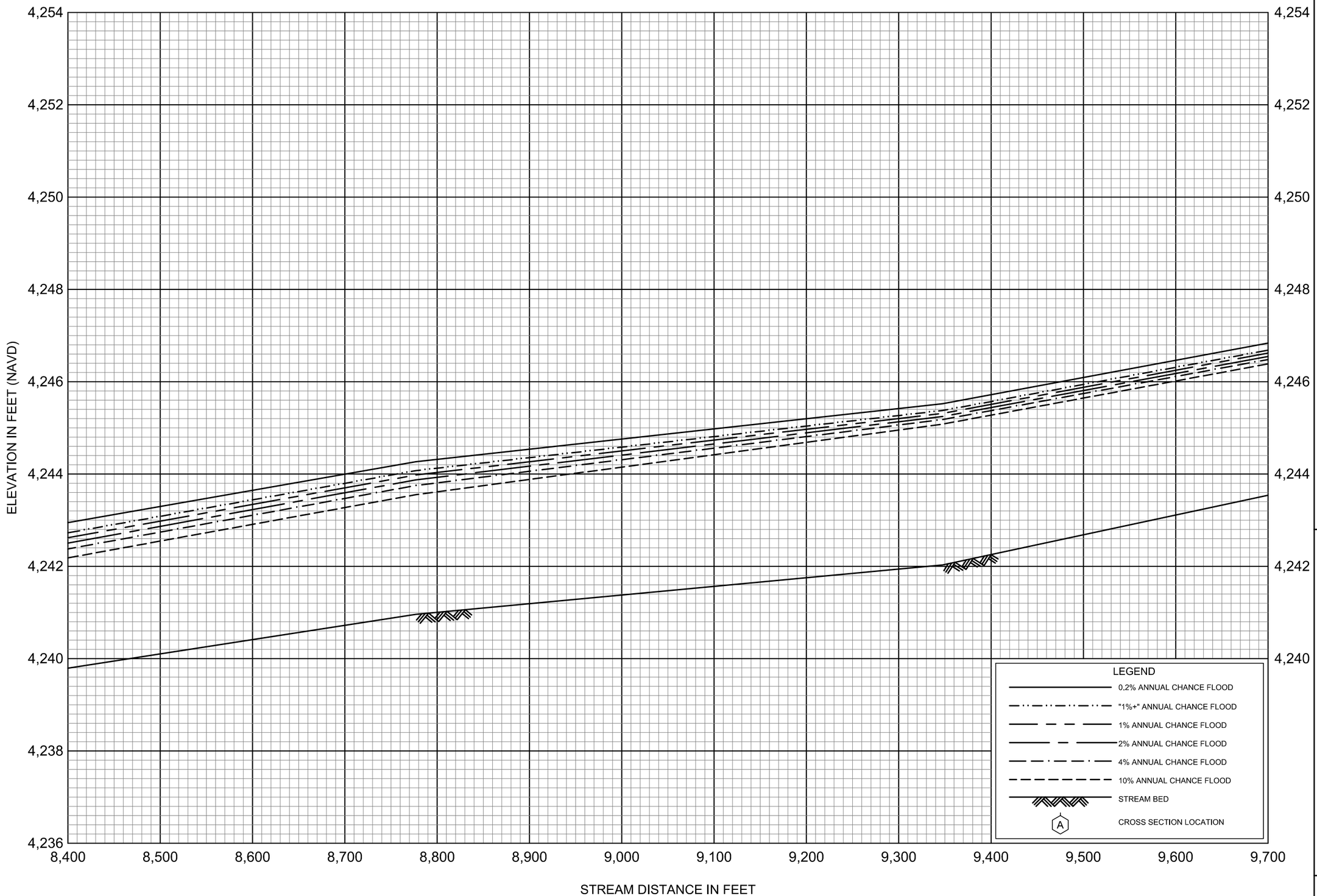
003P



FLOOD PROFILES

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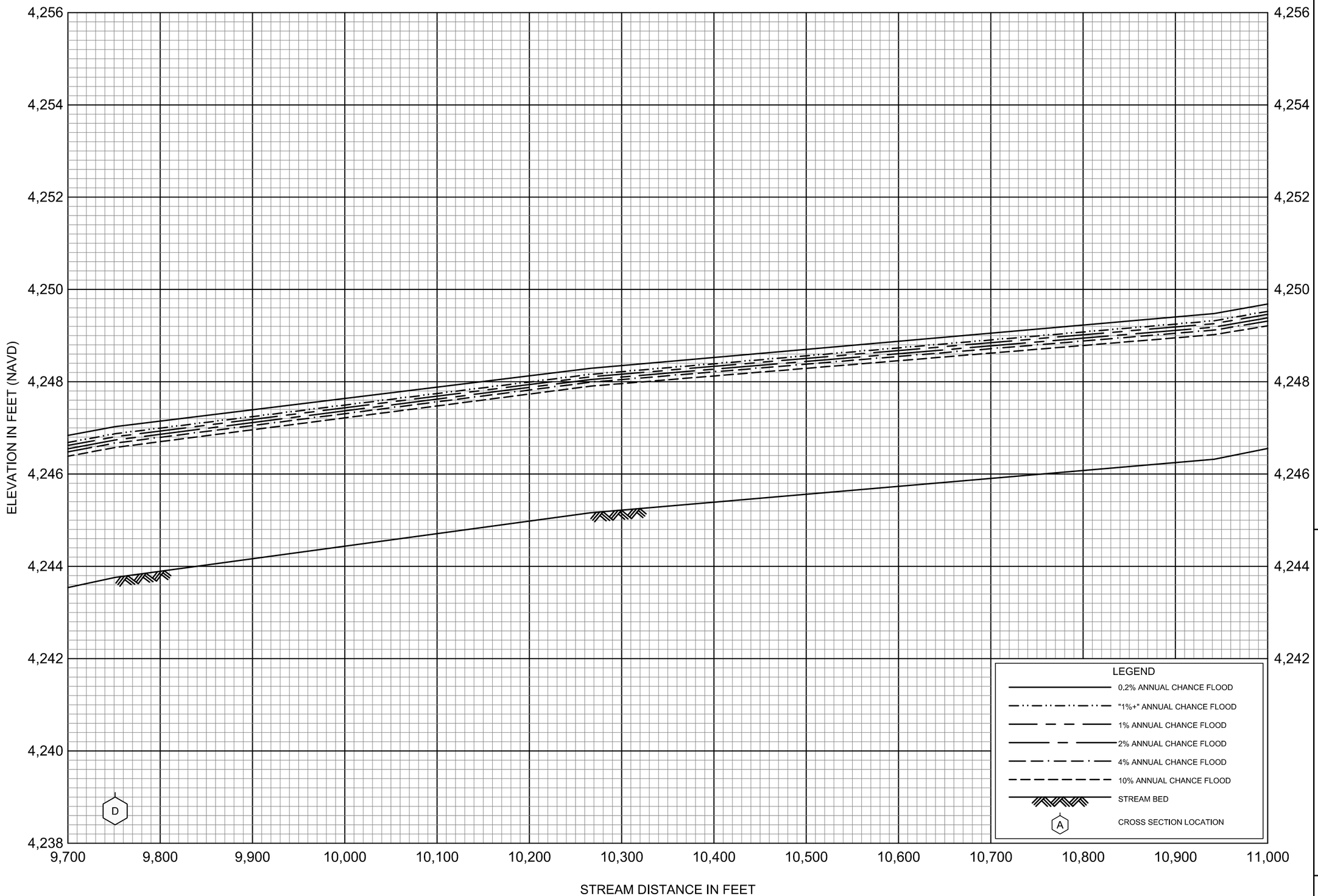

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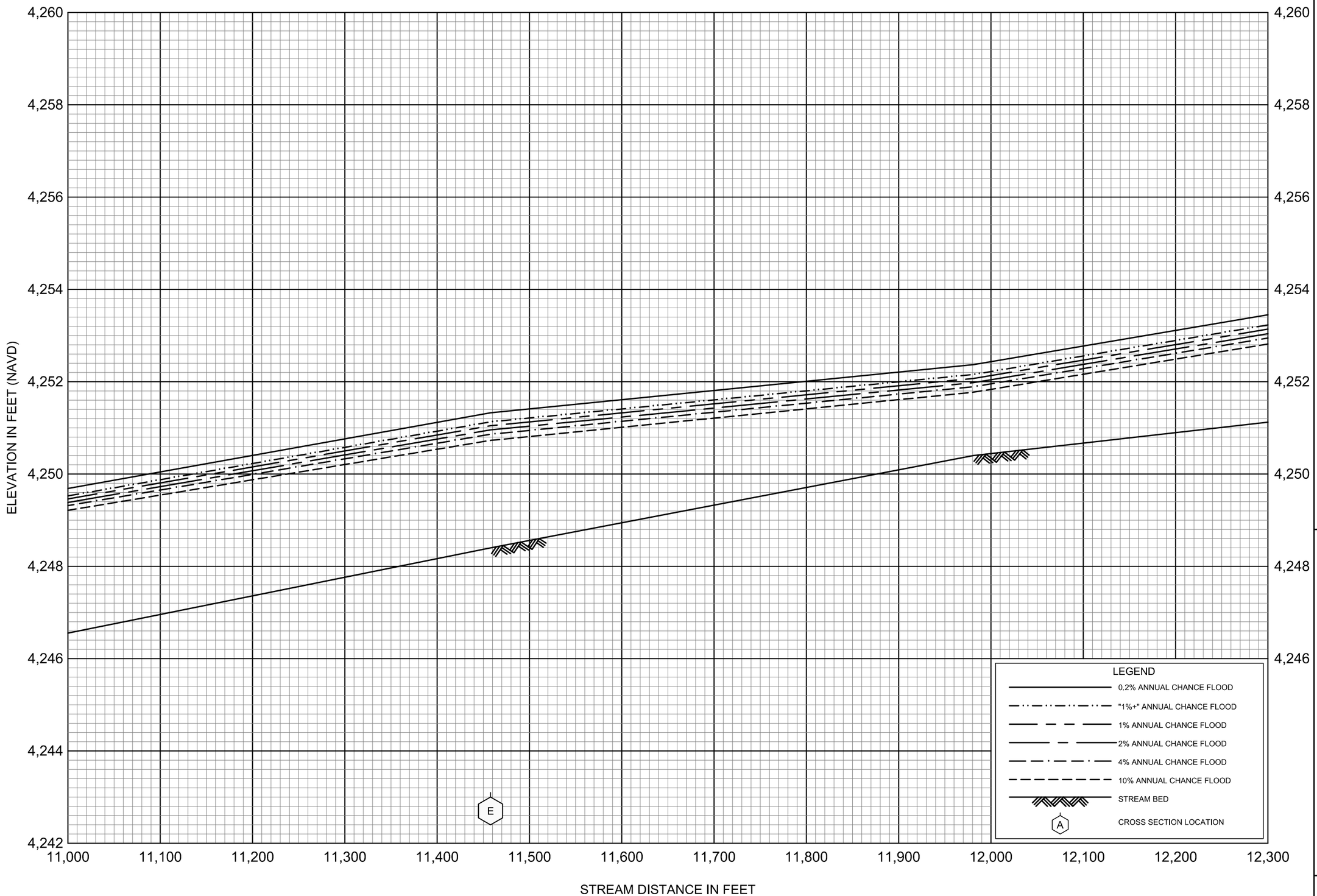

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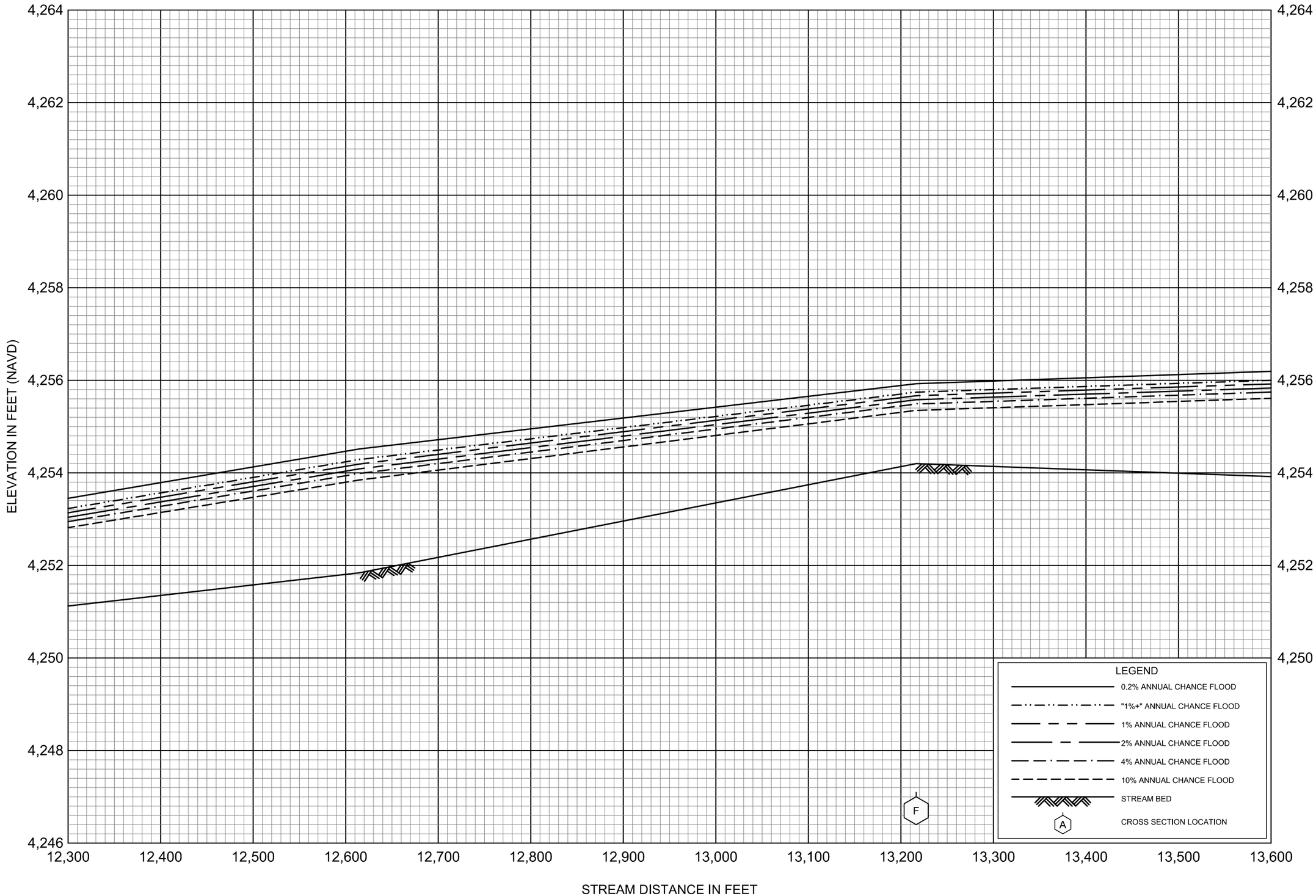

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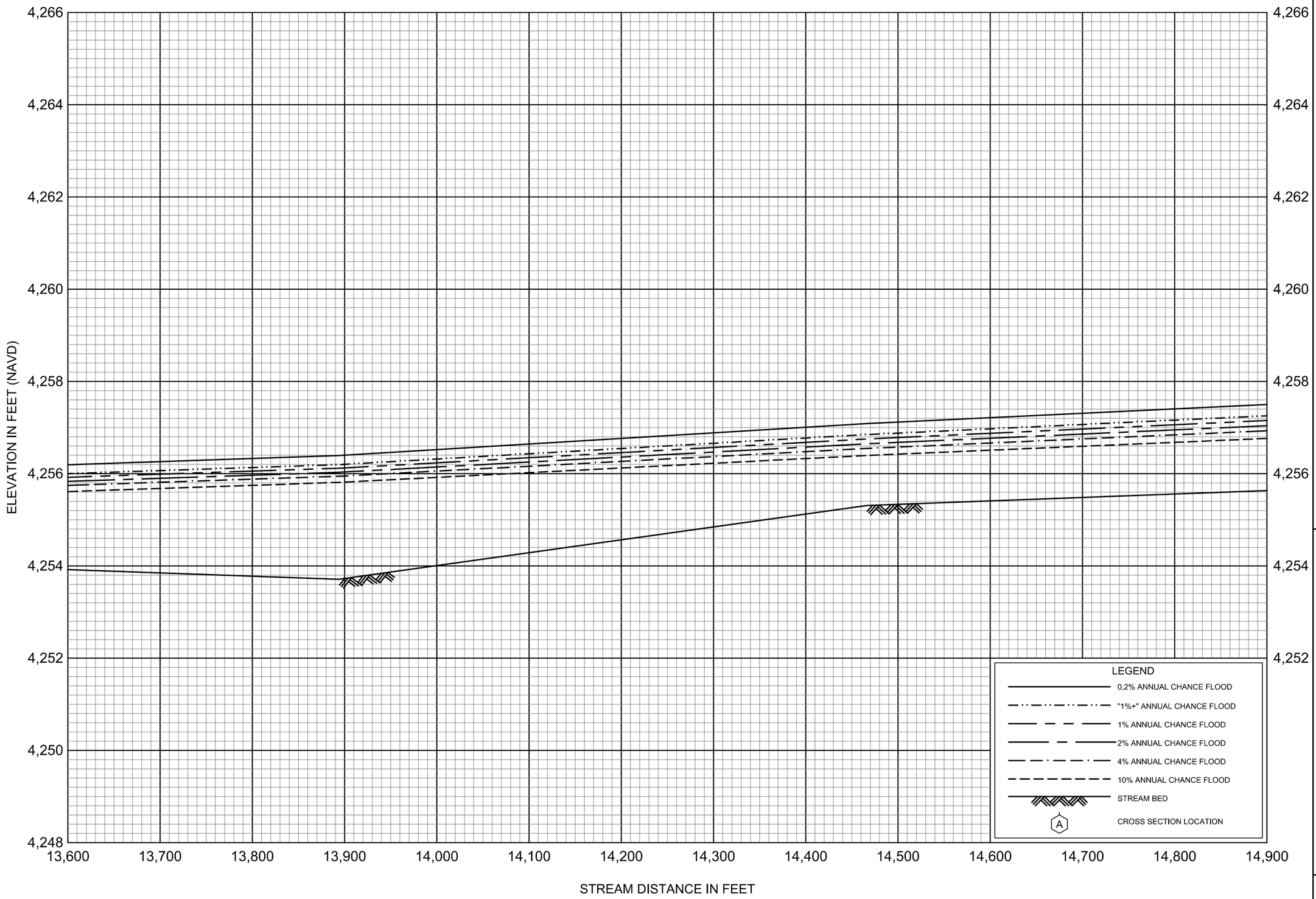

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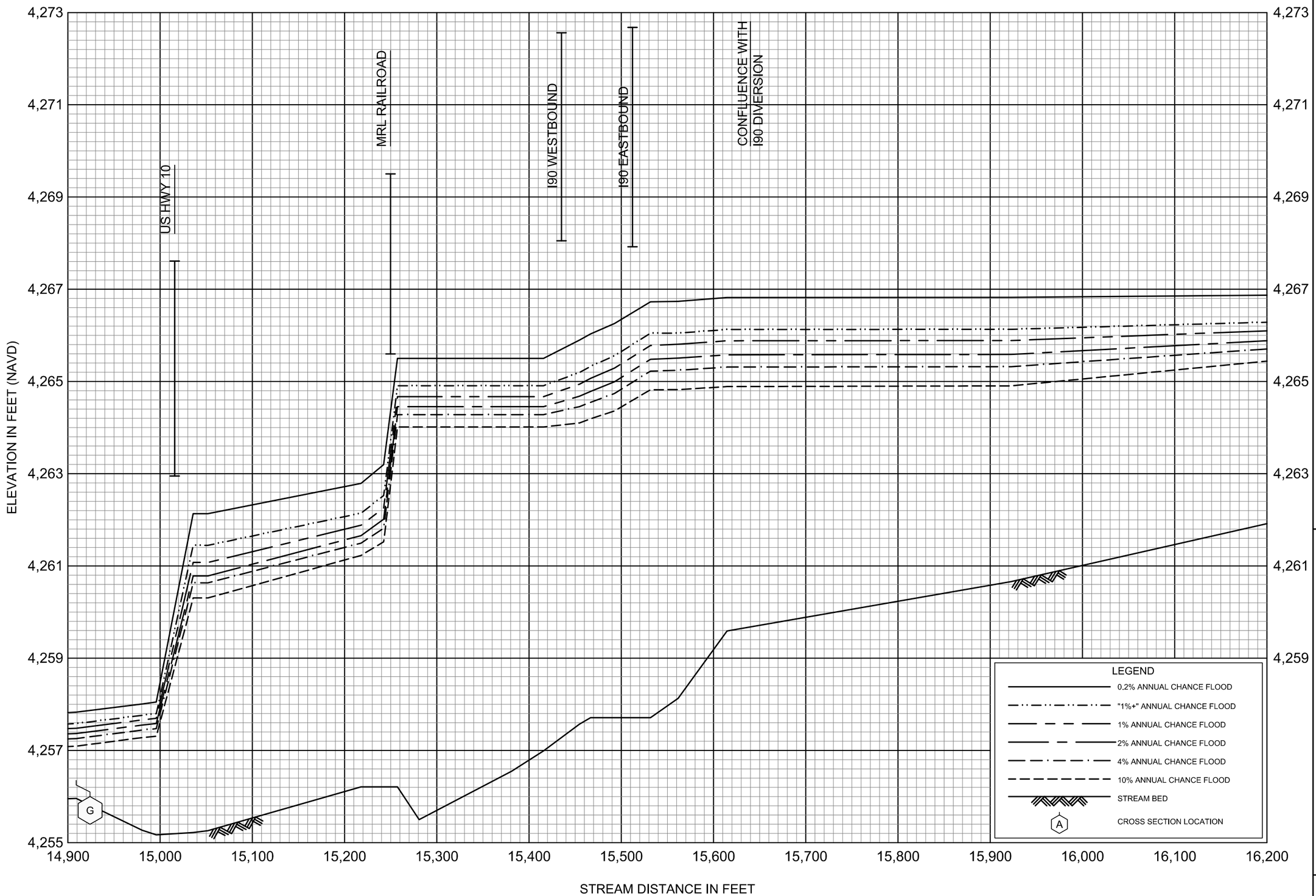

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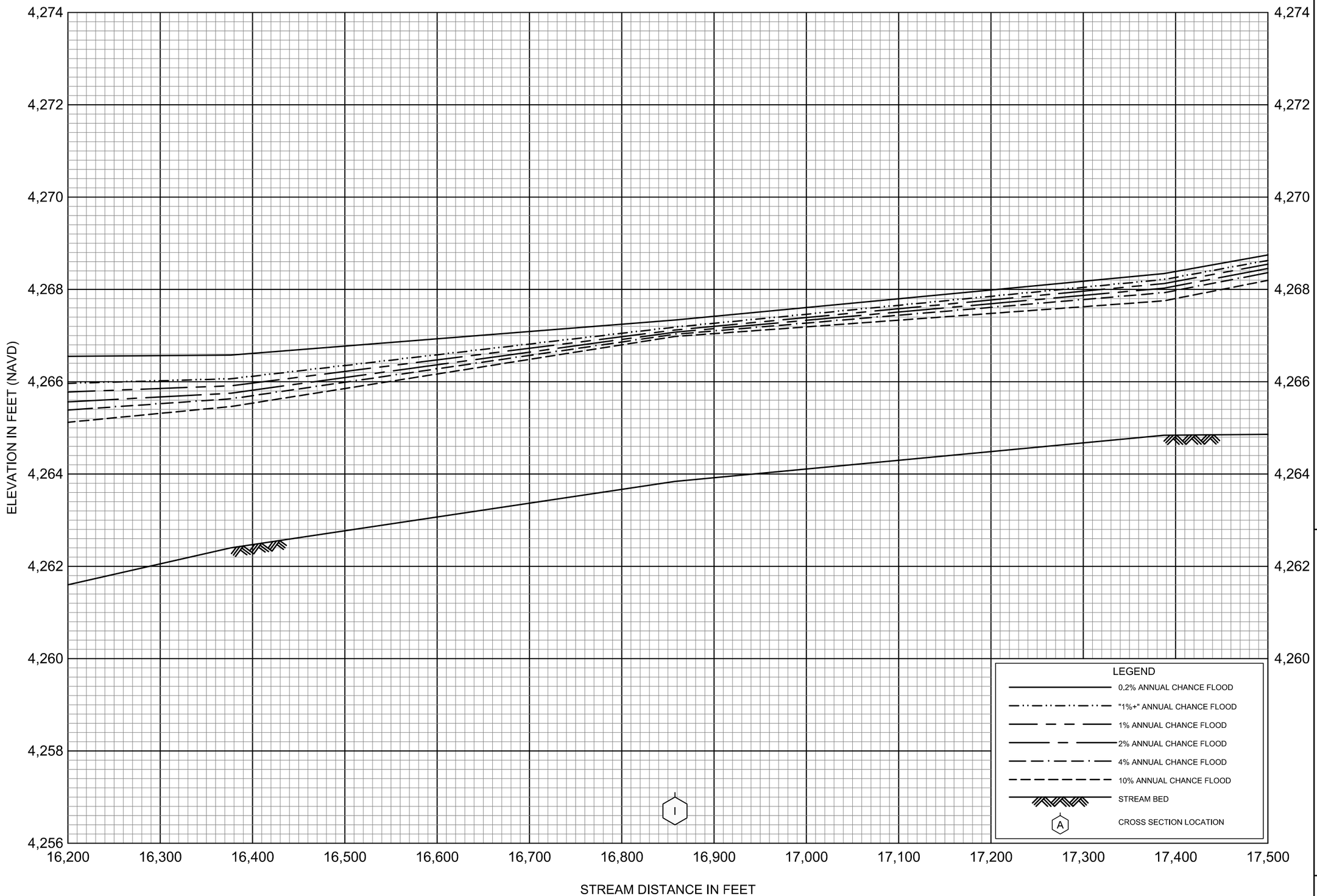

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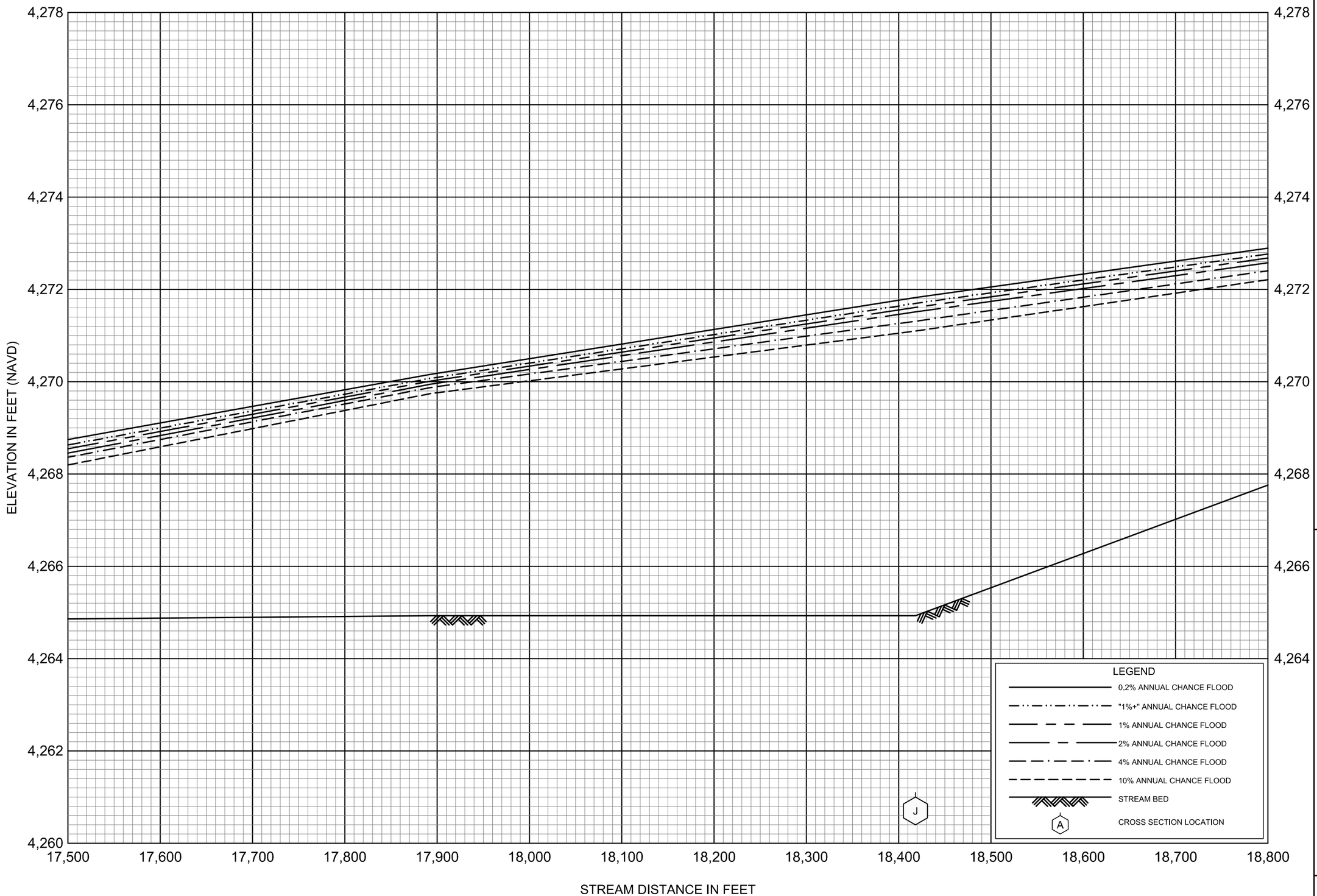

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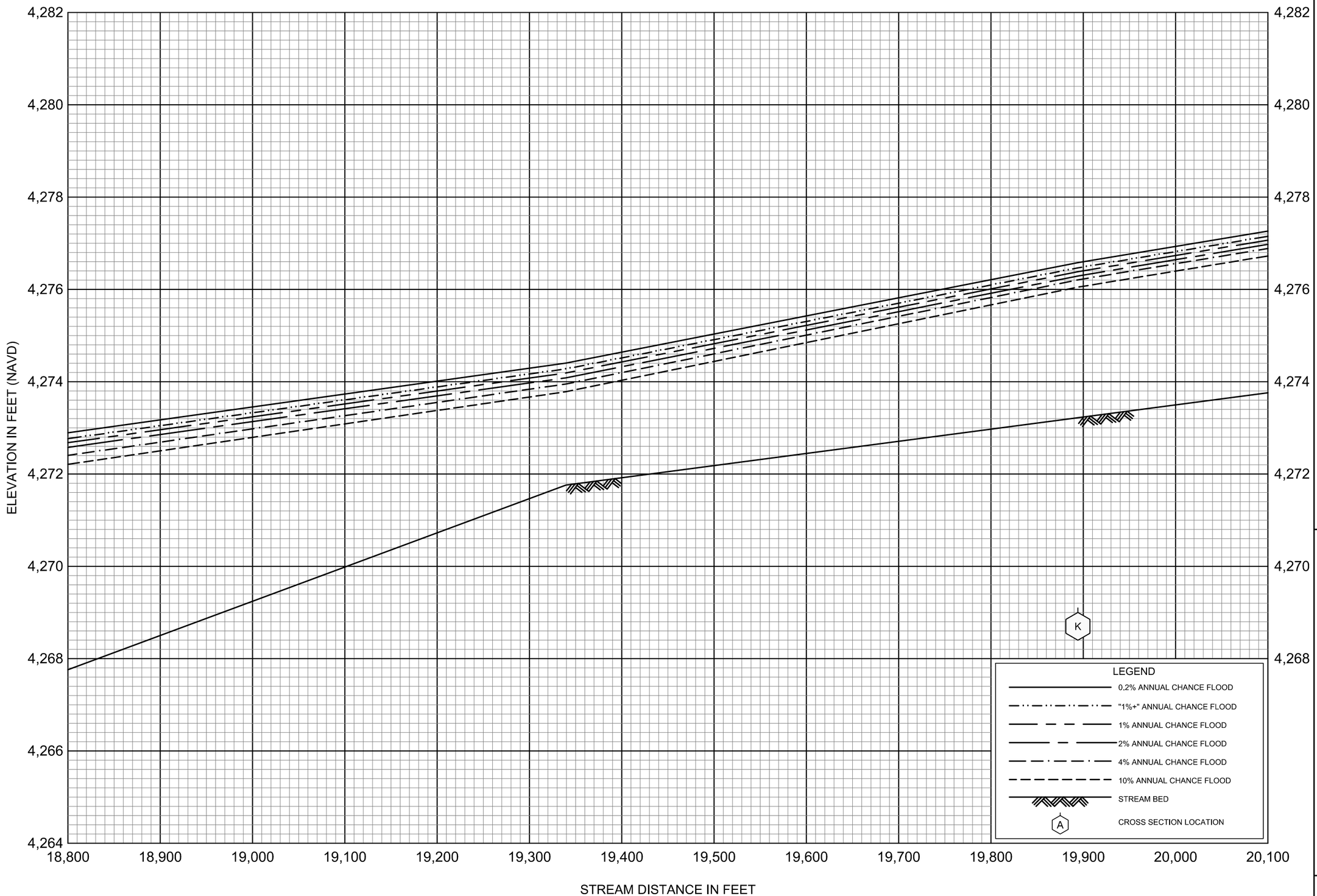

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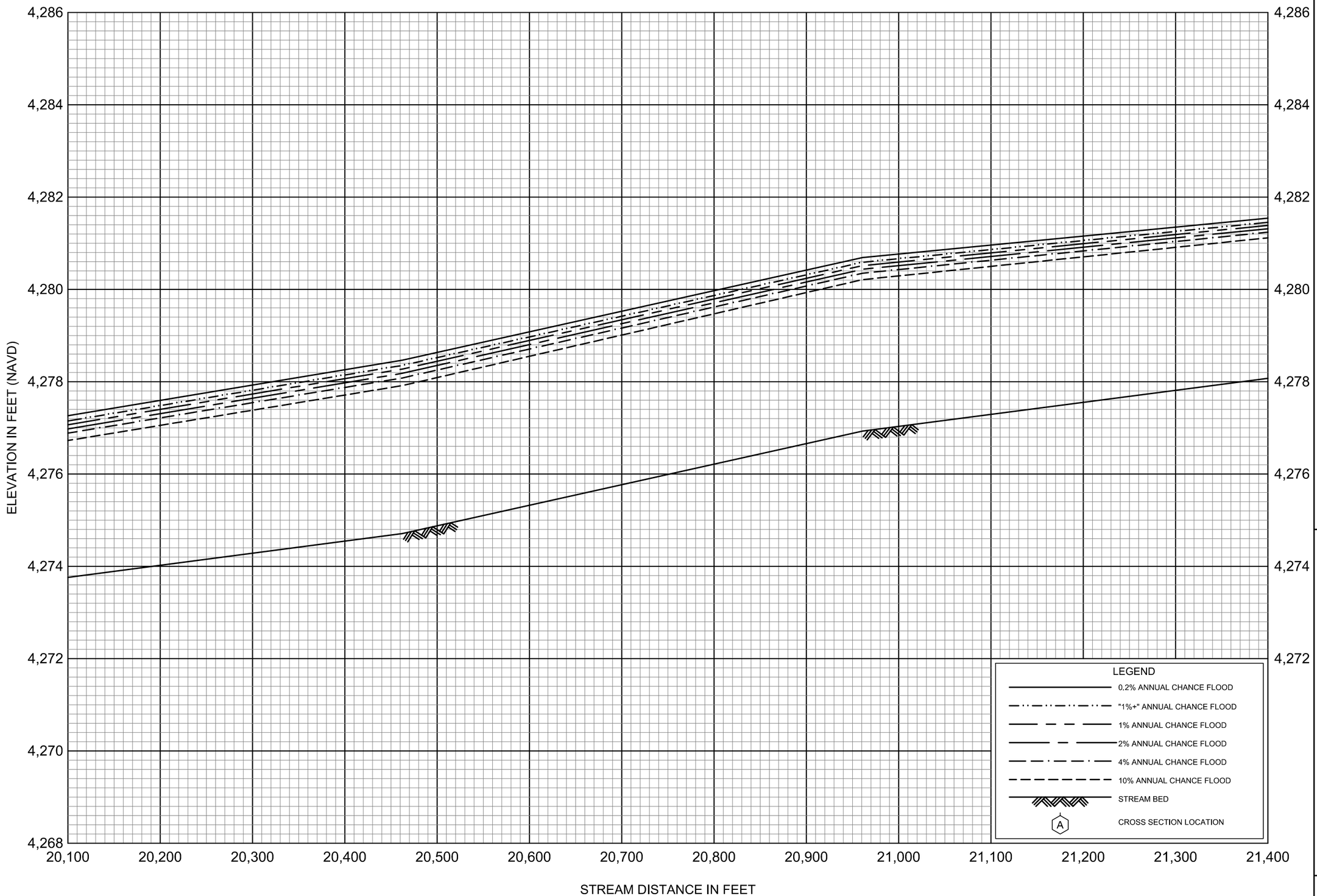

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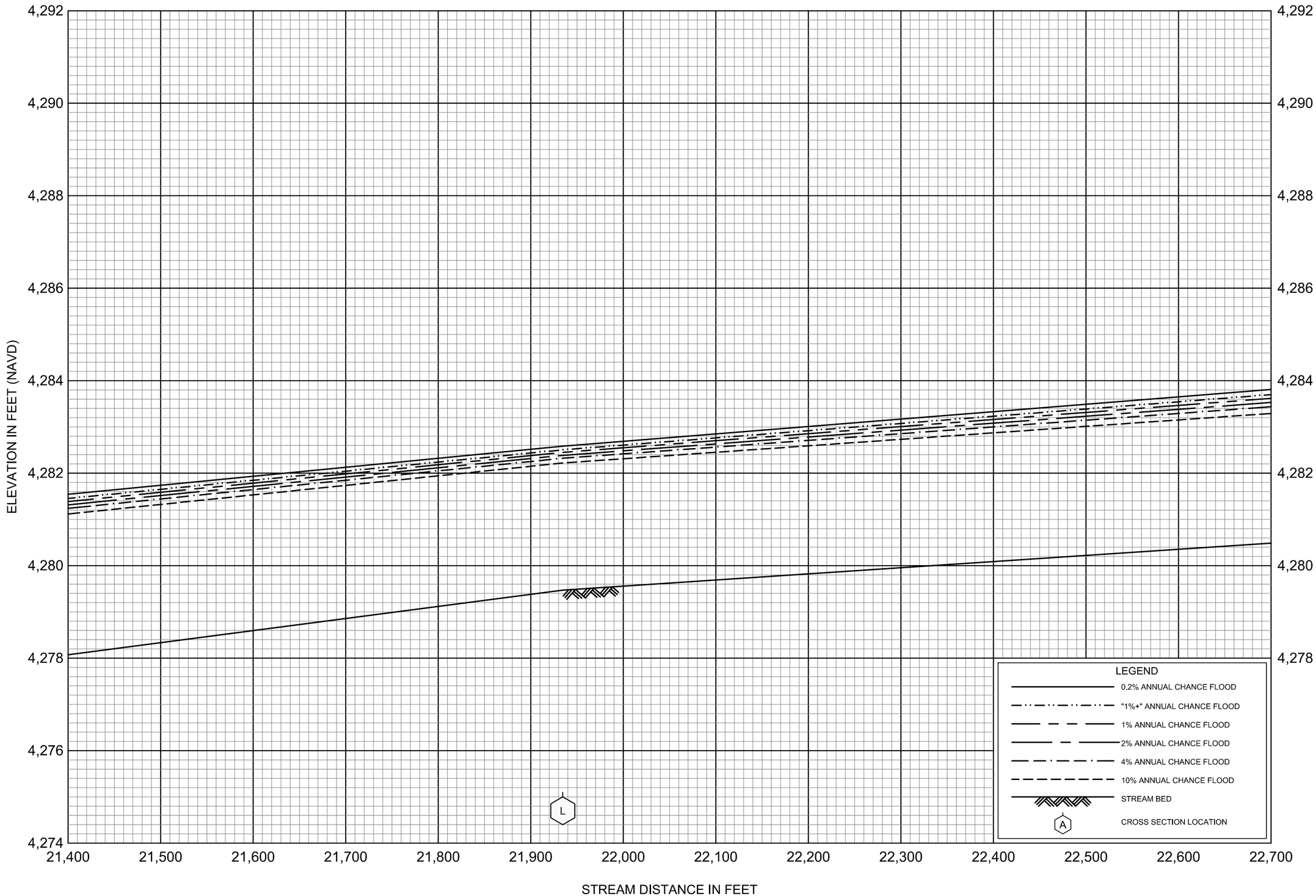

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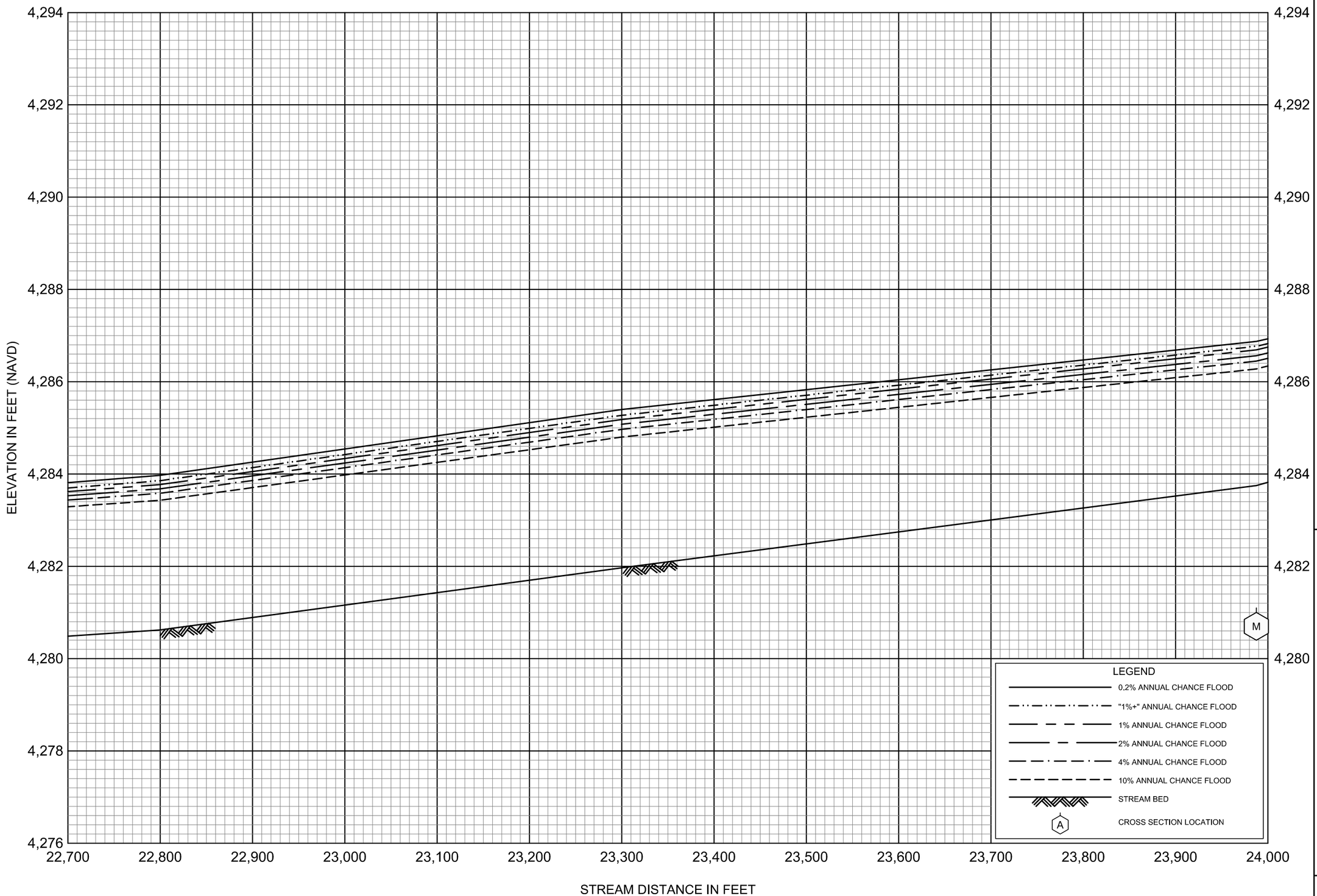

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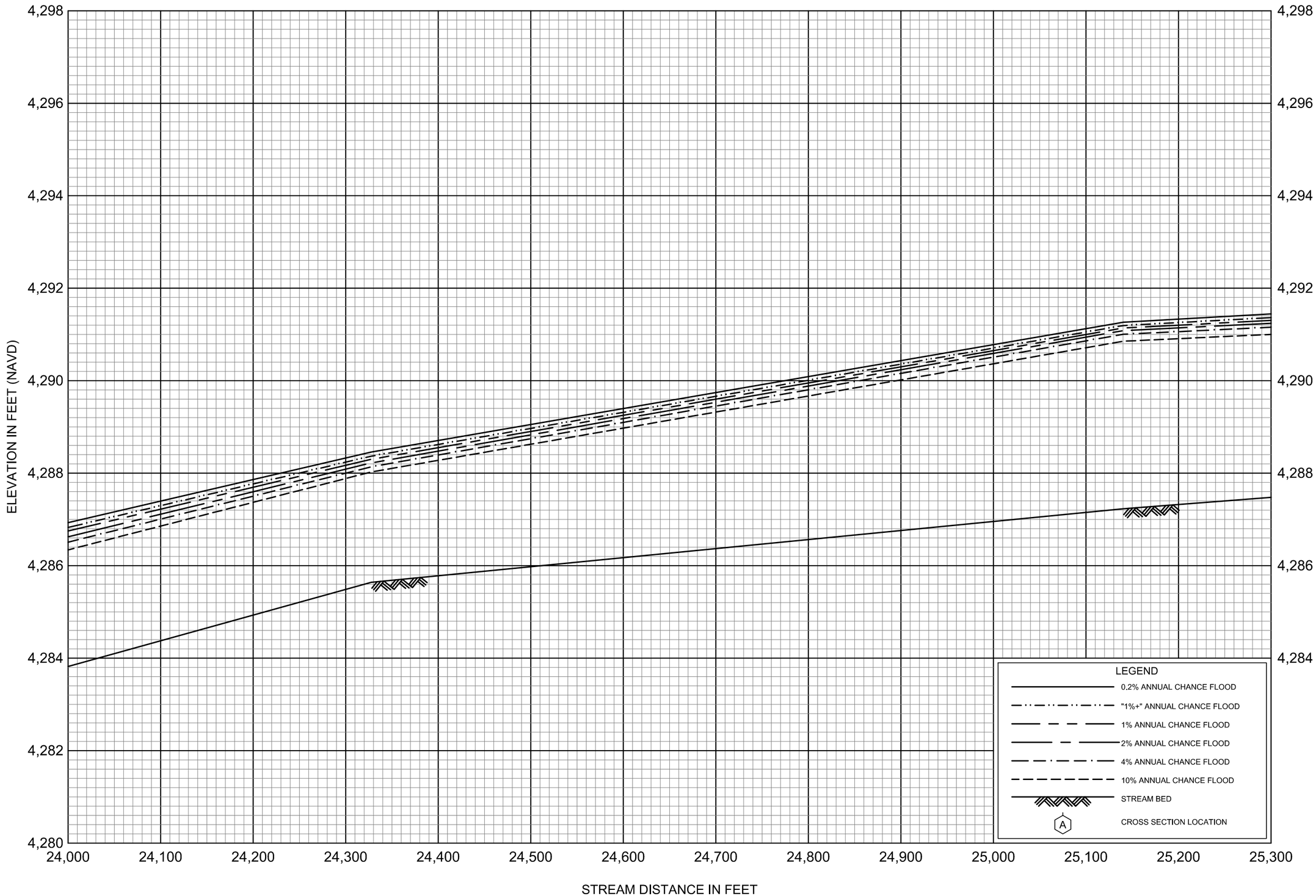

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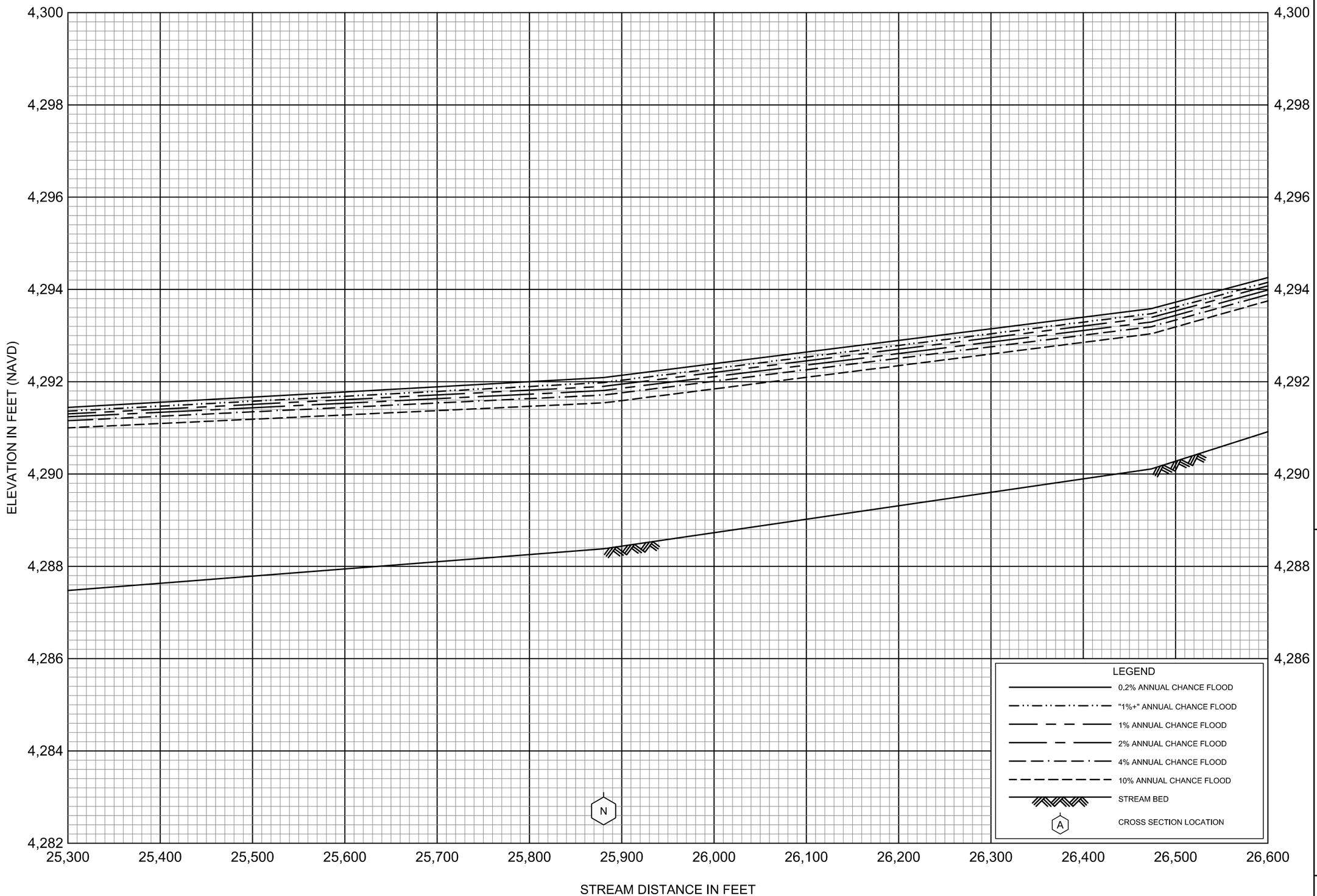

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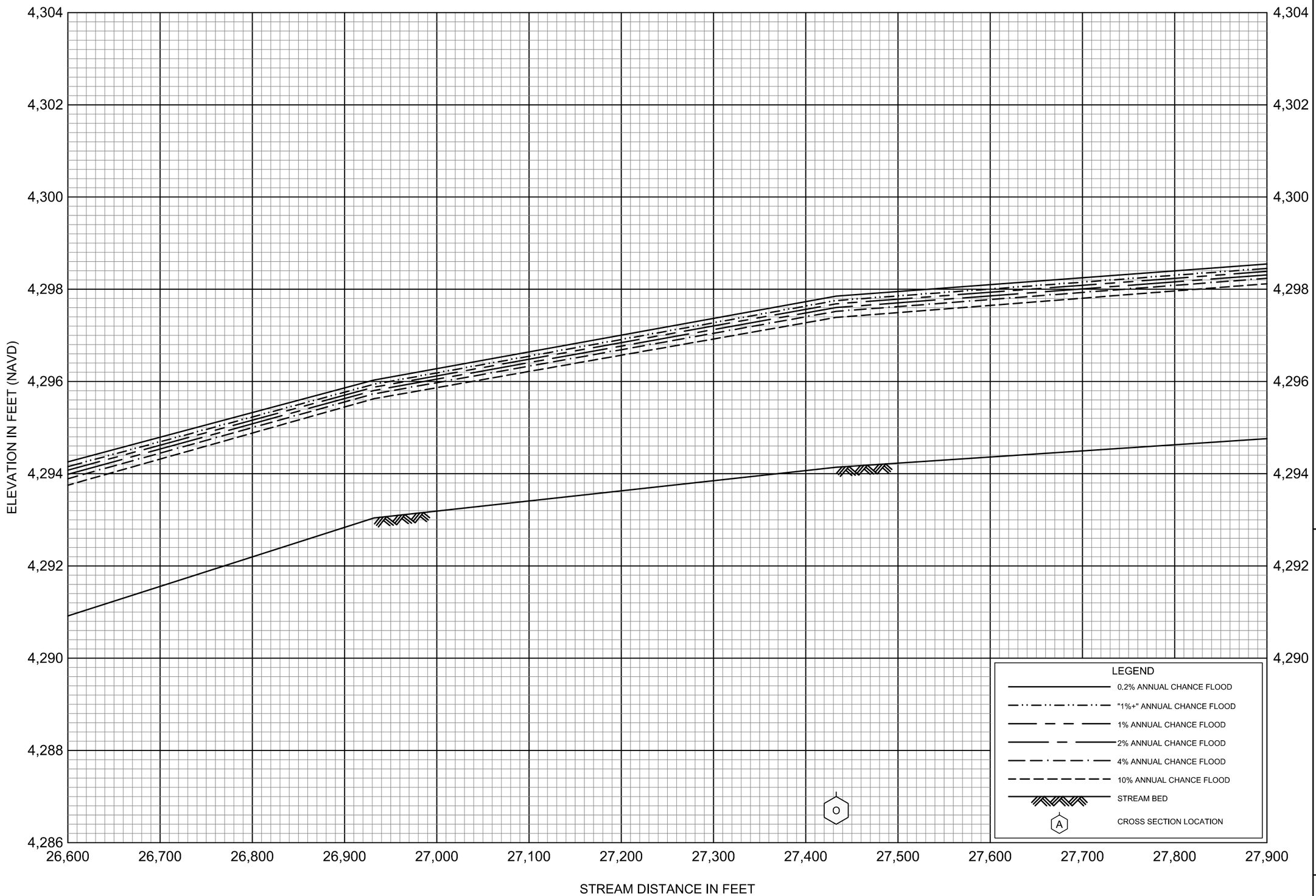

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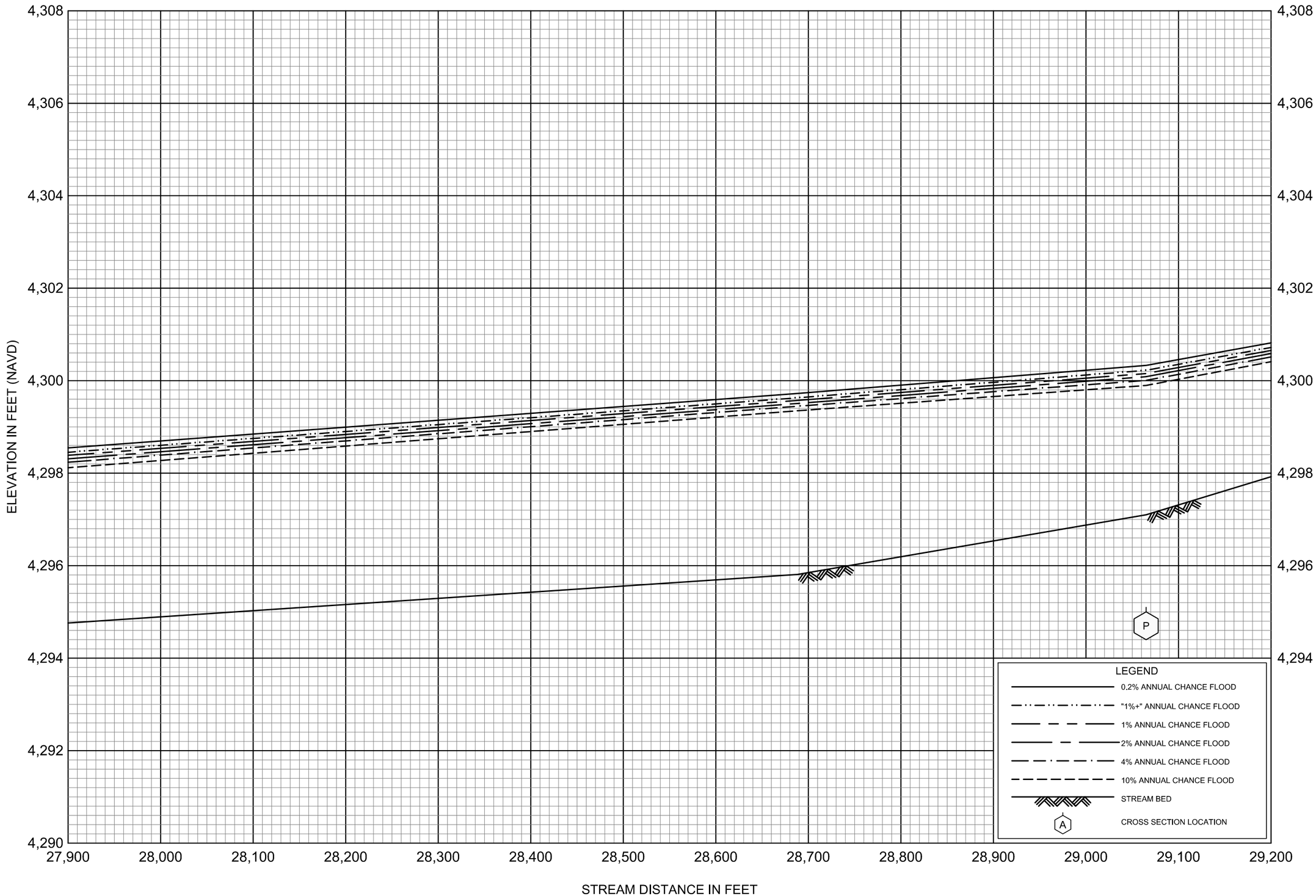

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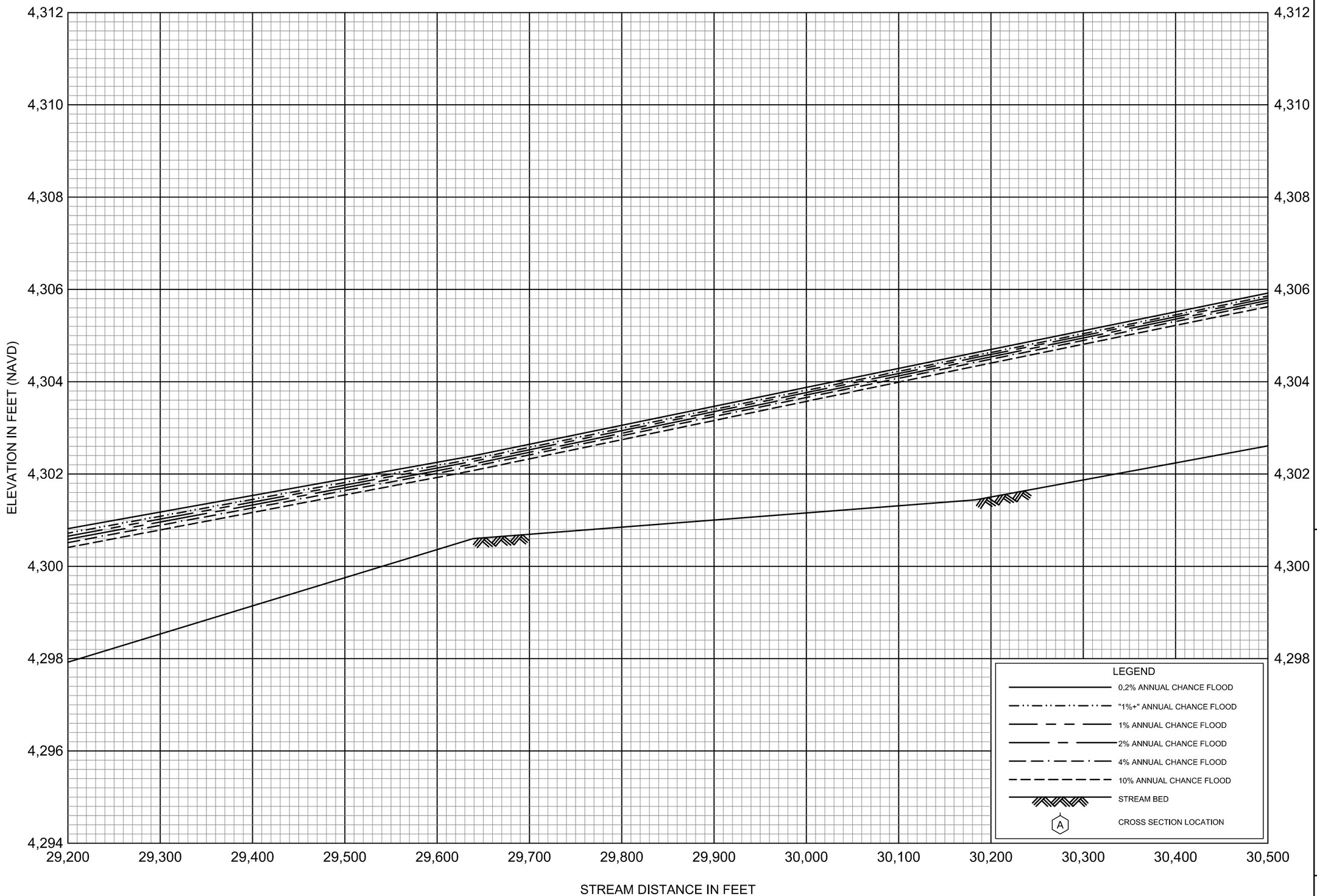


FLOOD PROFILES

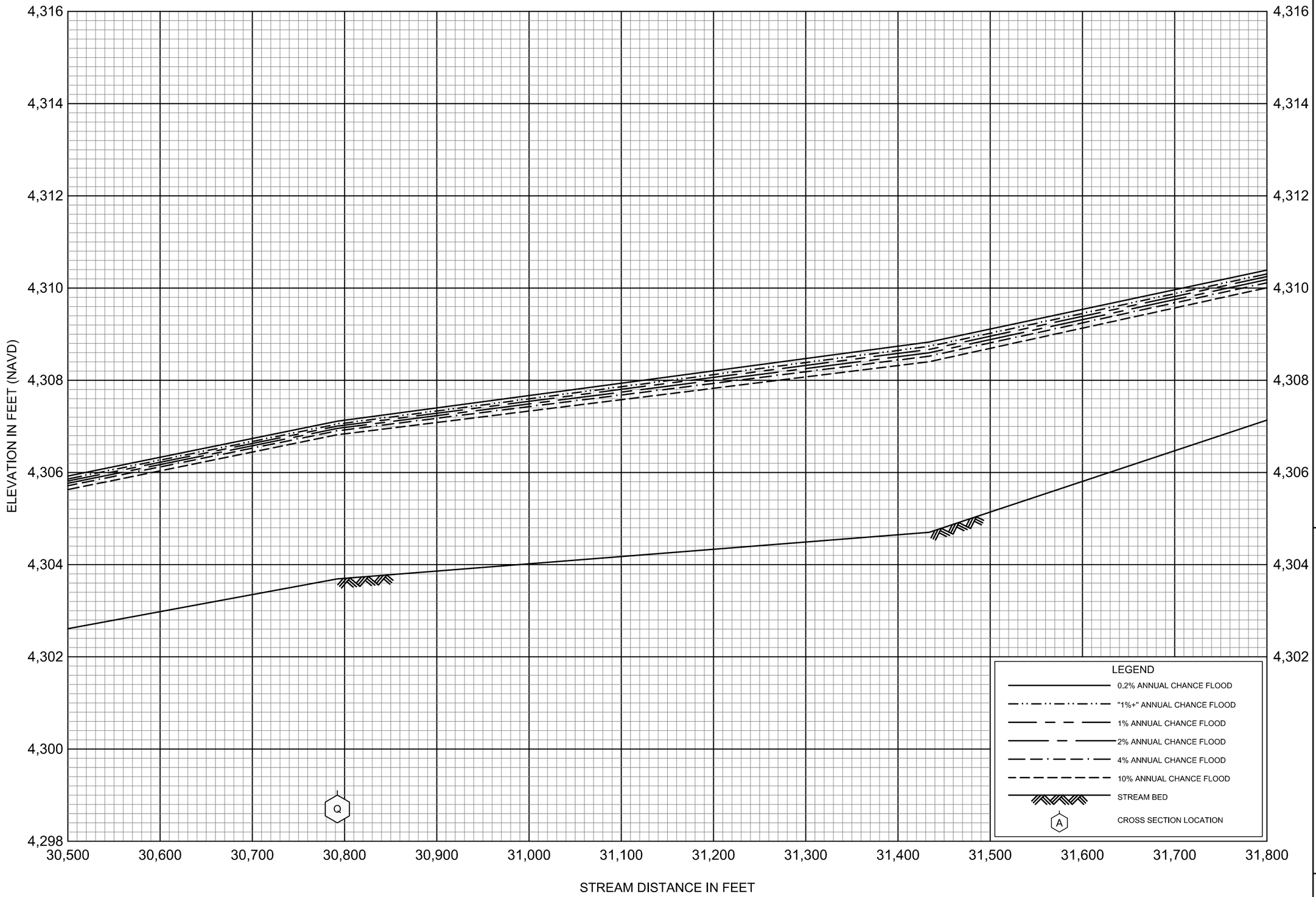
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

020P



FLOOD PROFILES

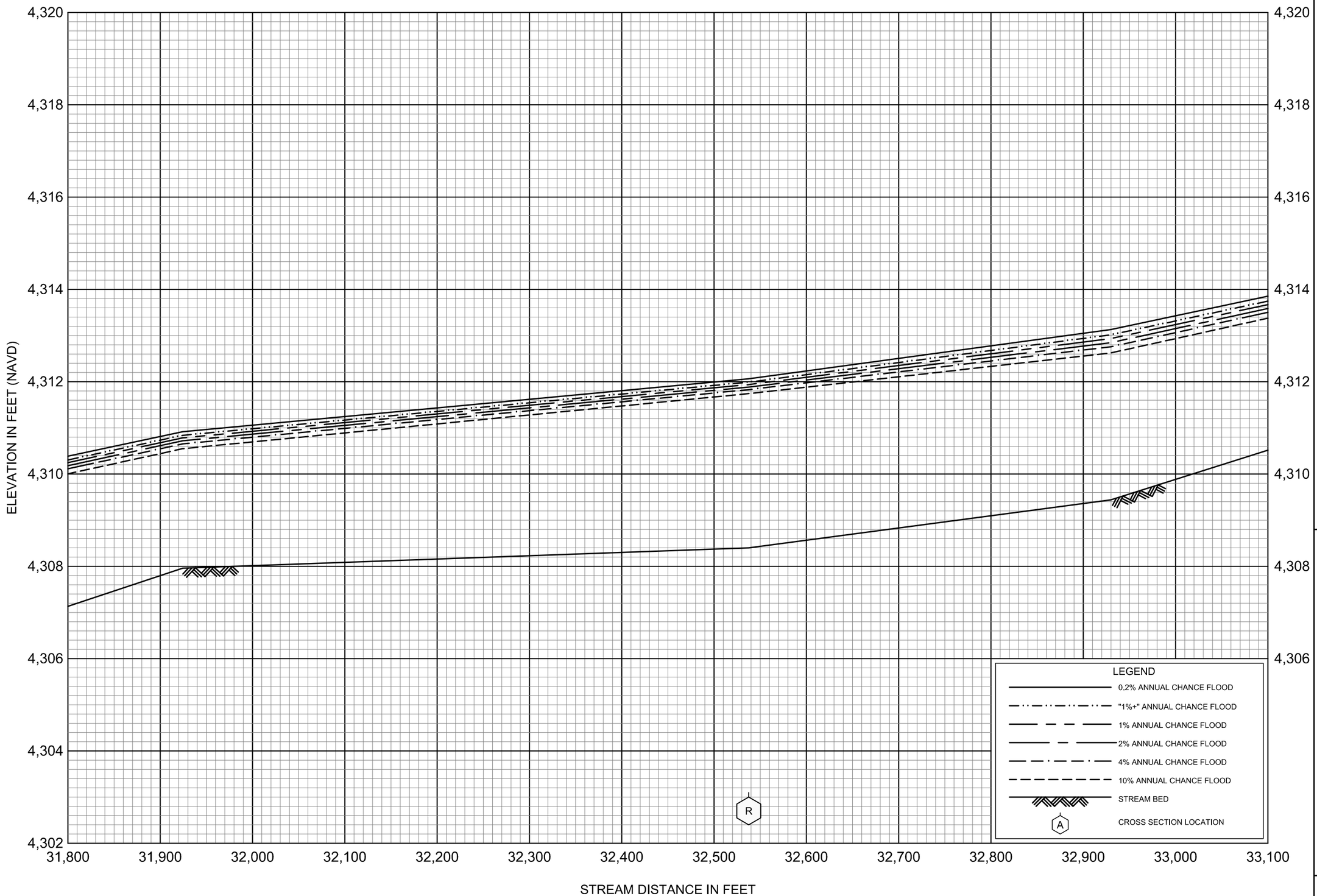
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

021P



FLOOD PROFILES

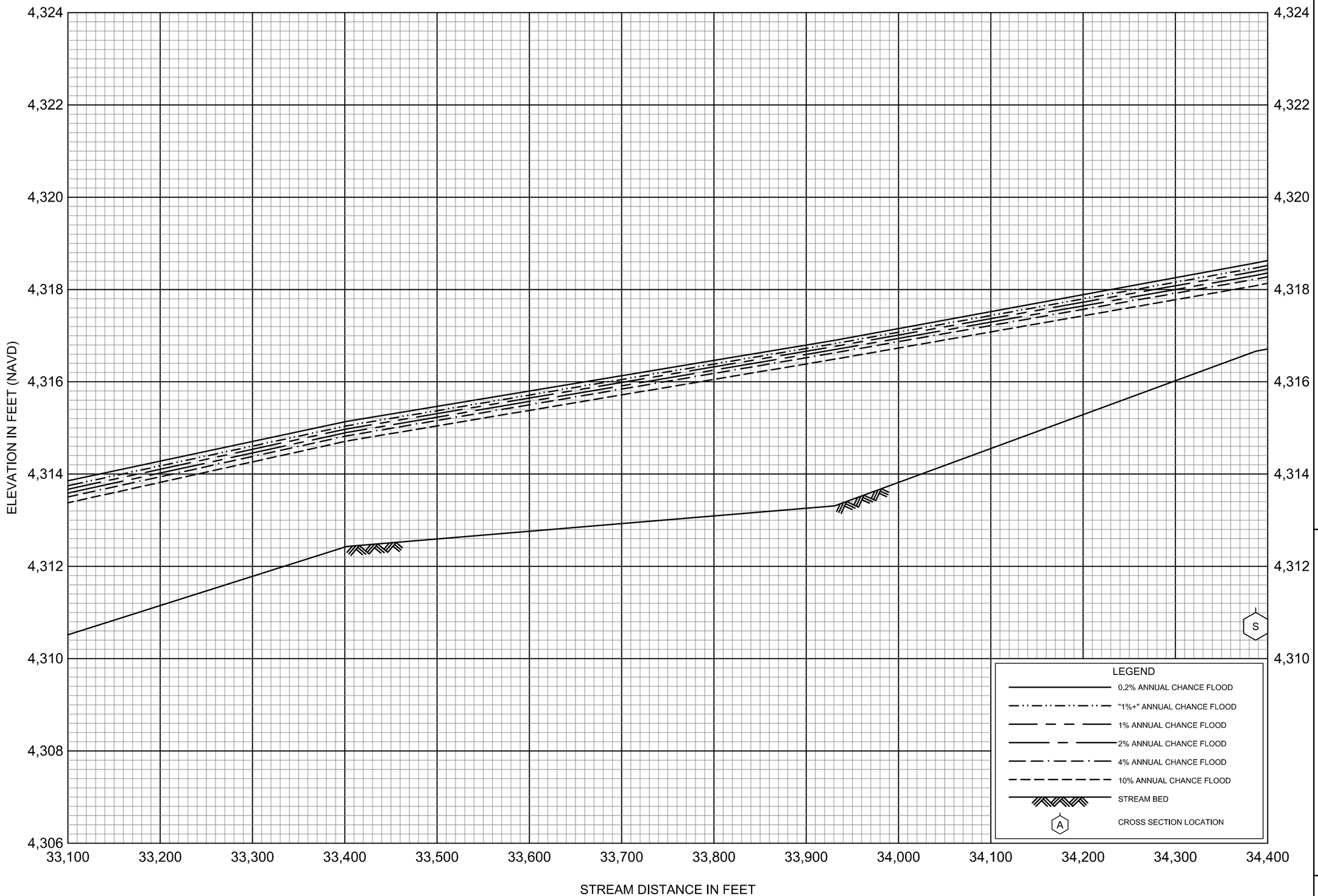
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

022P



FLOOD PROFILES

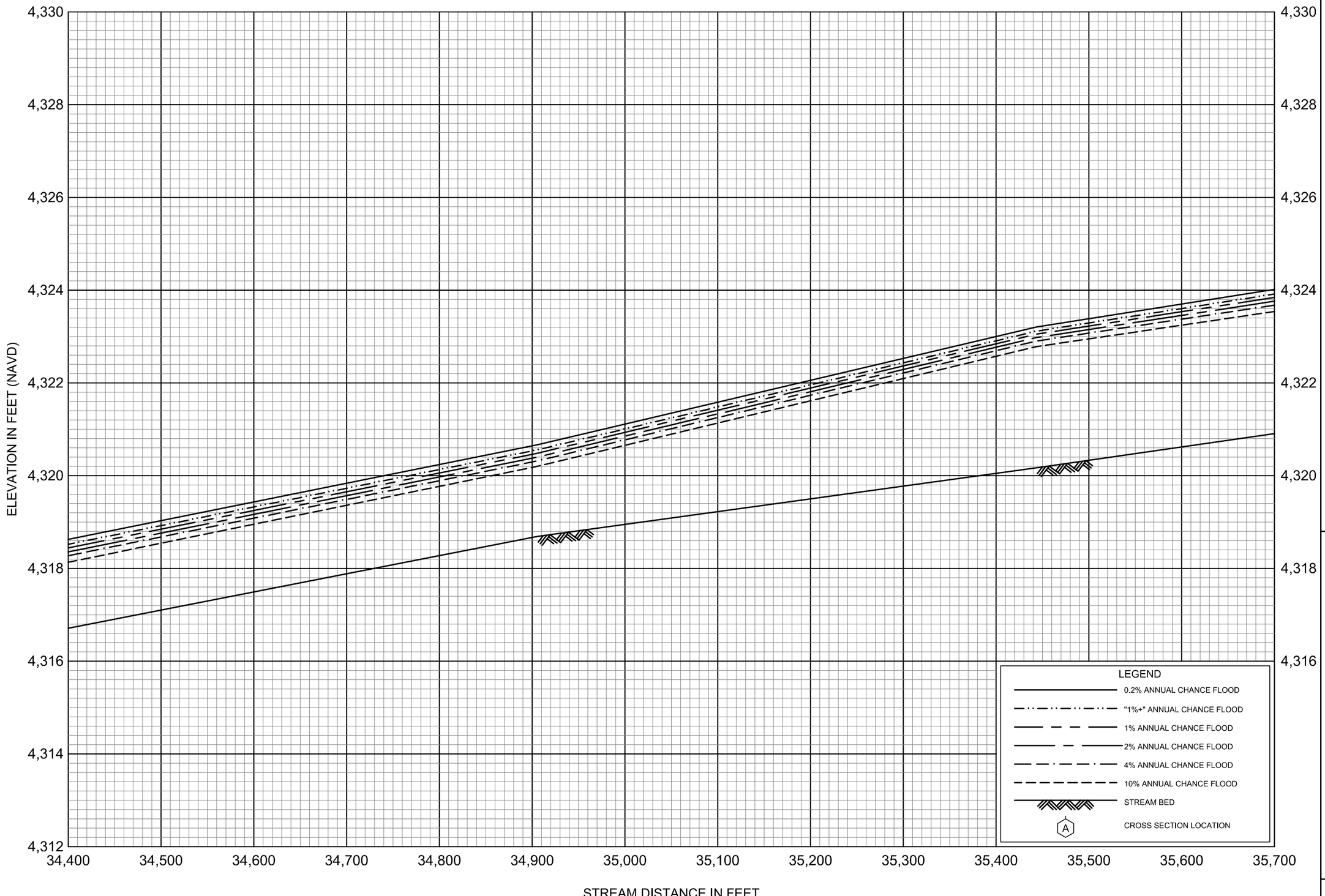
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

023P



FLOOD PROFILES

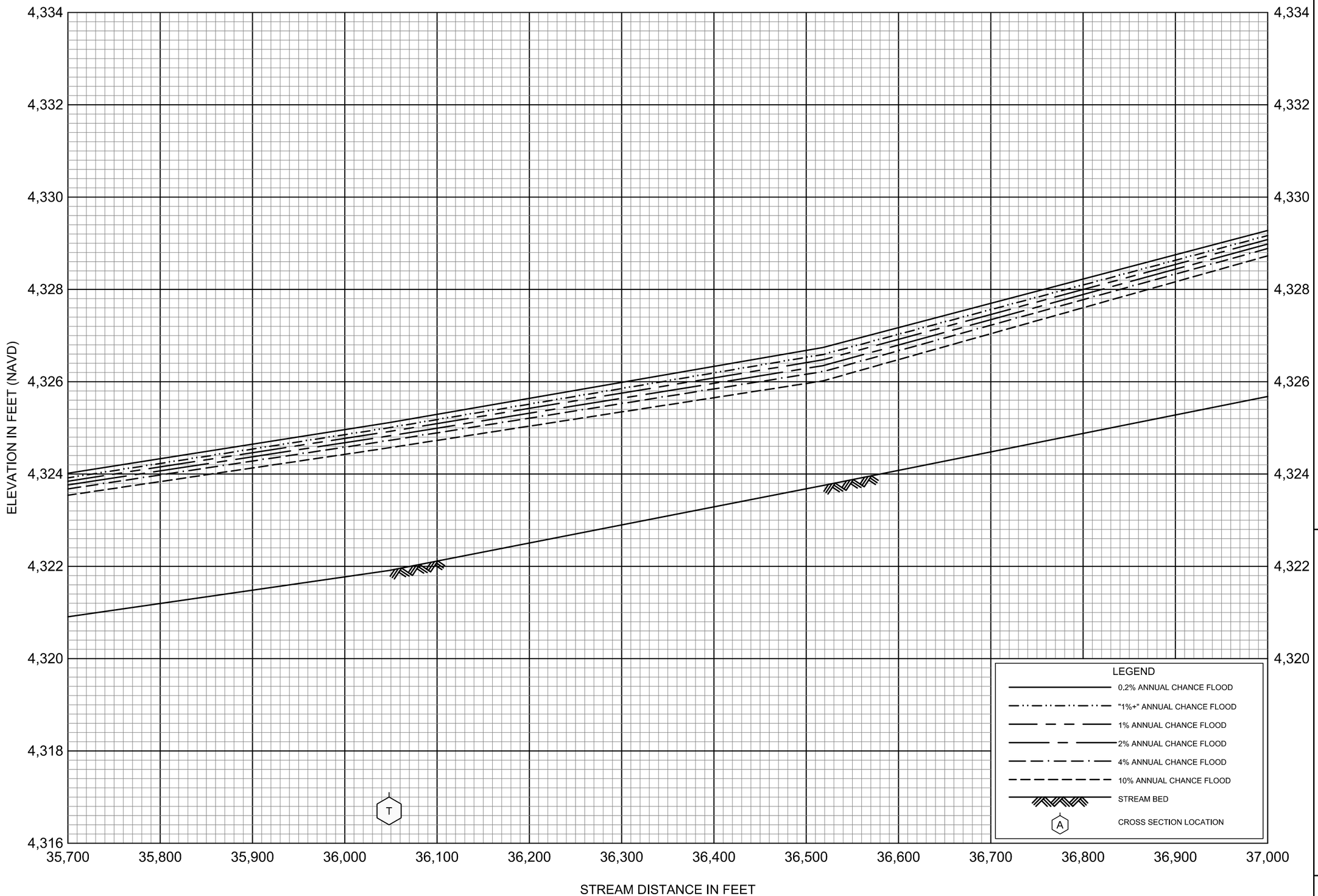
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

024P



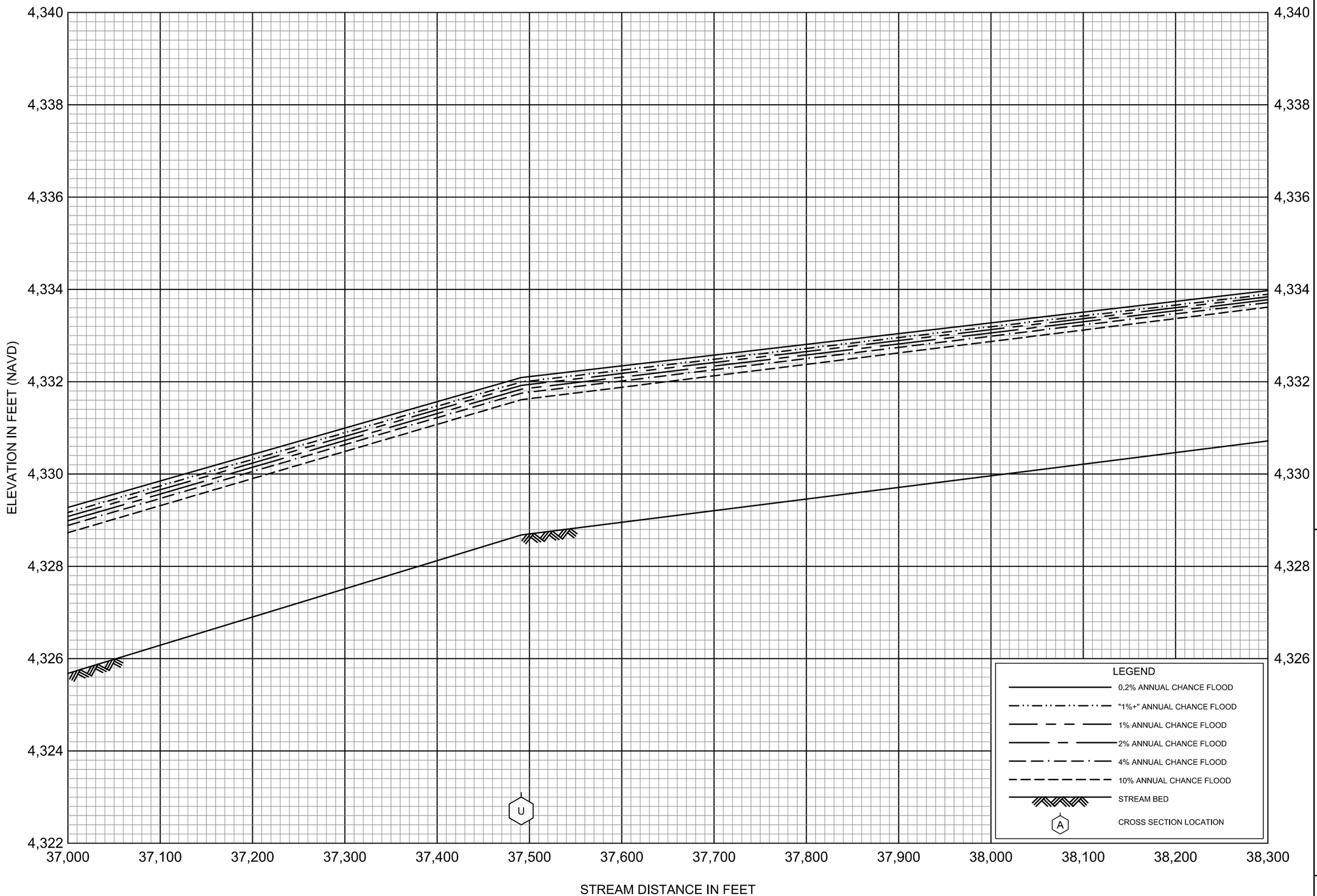
FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

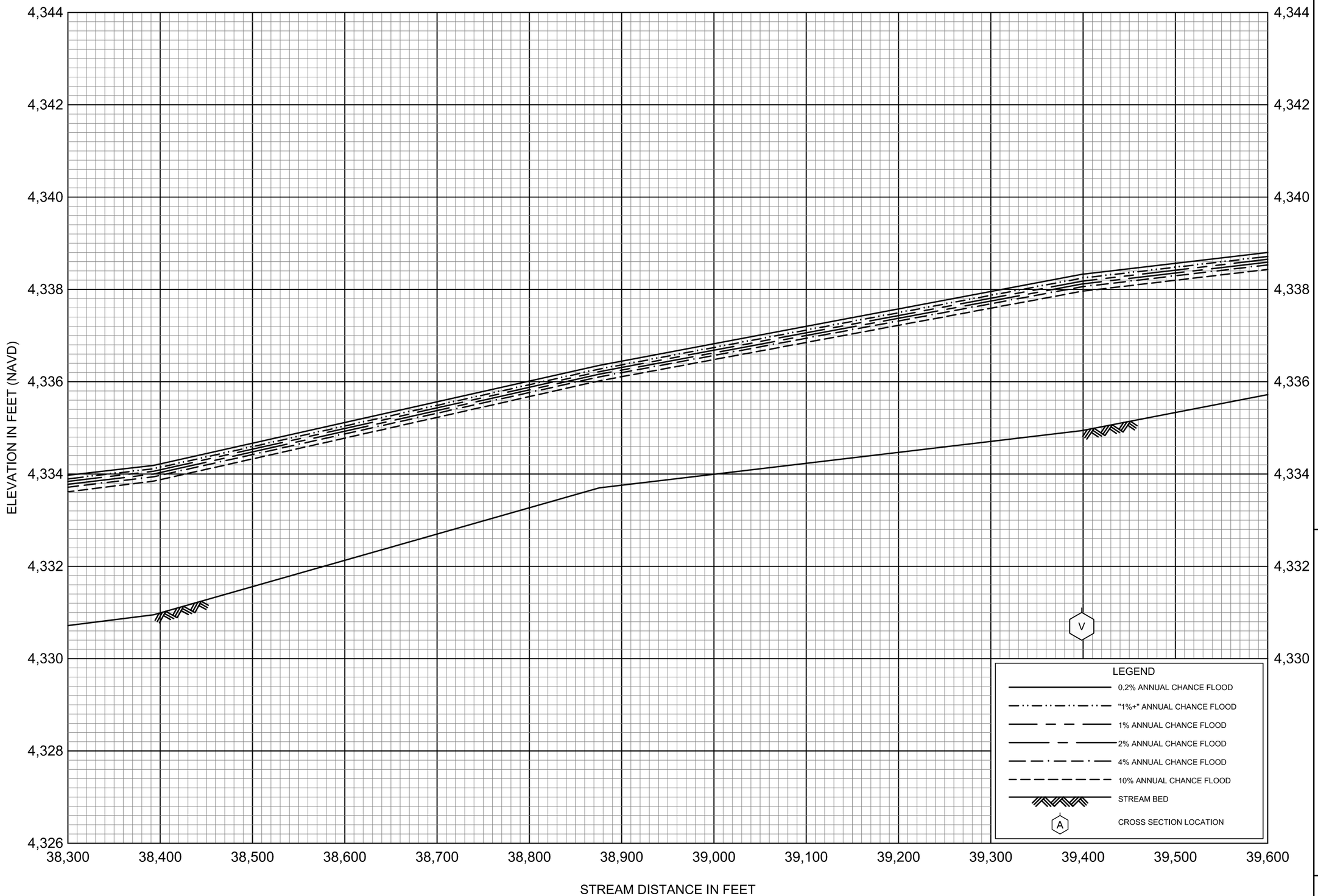
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

026P



FLOOD PROFILES

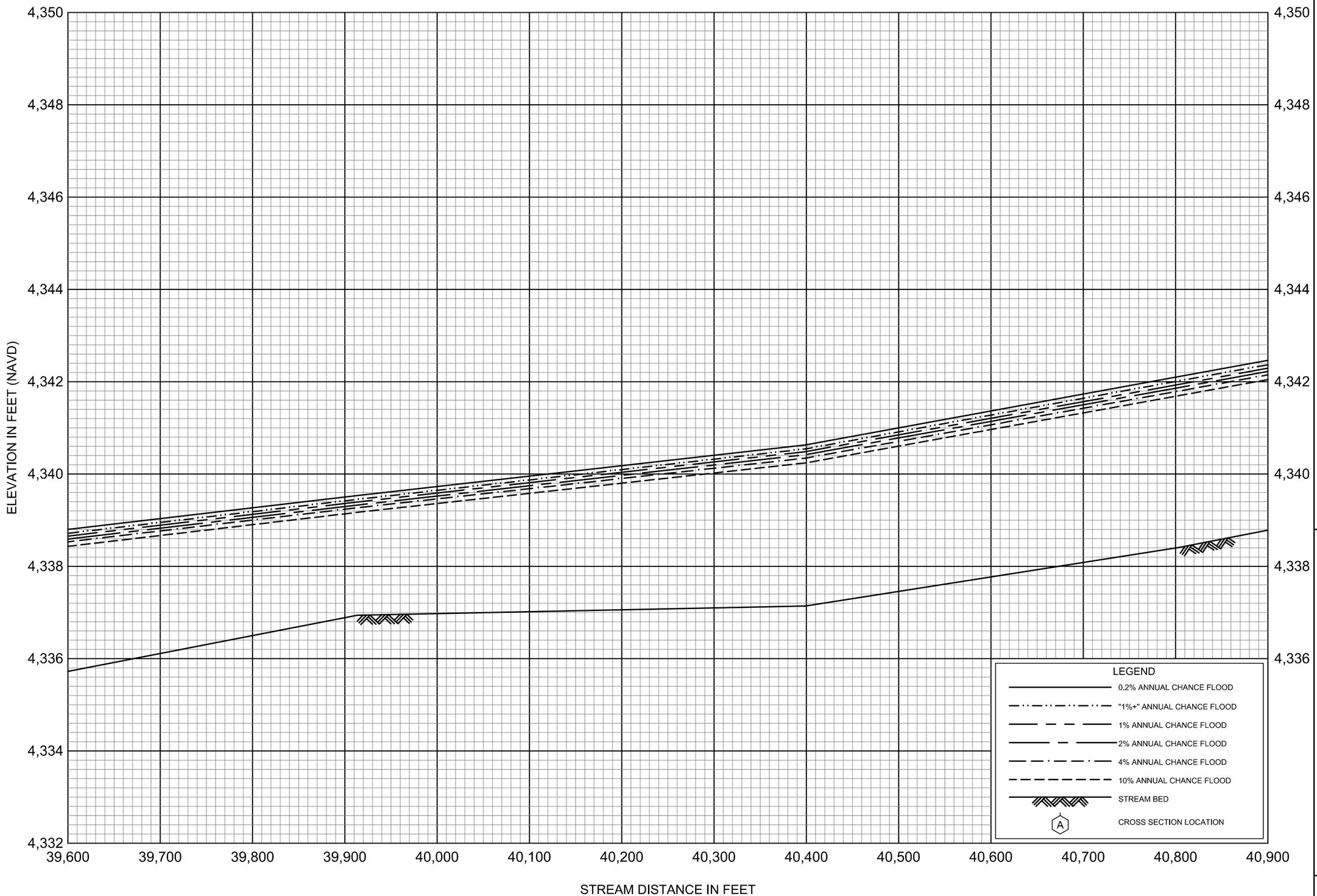
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

027P



FLOOD PROFILES

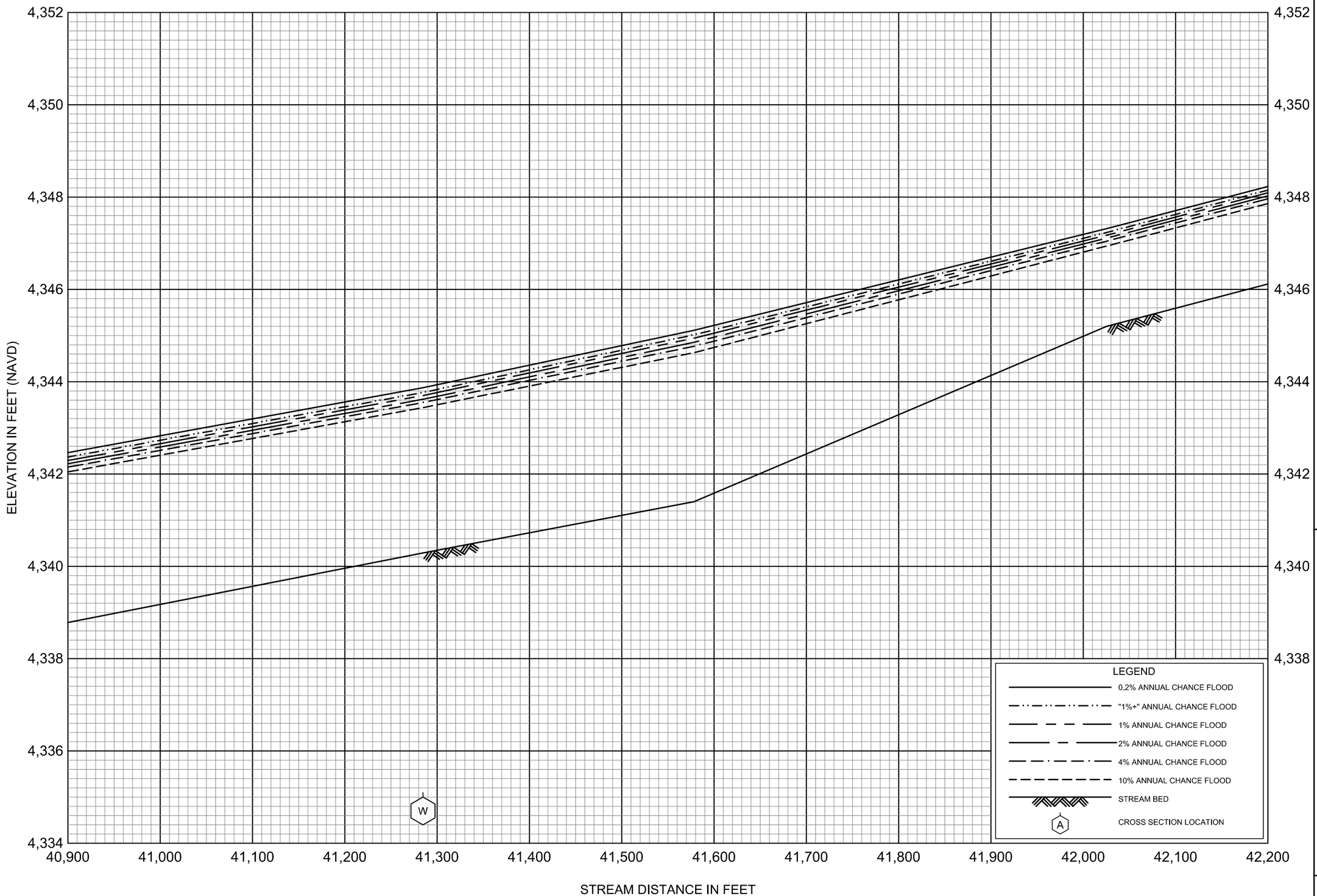
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

028P



FLOOD PROFILES

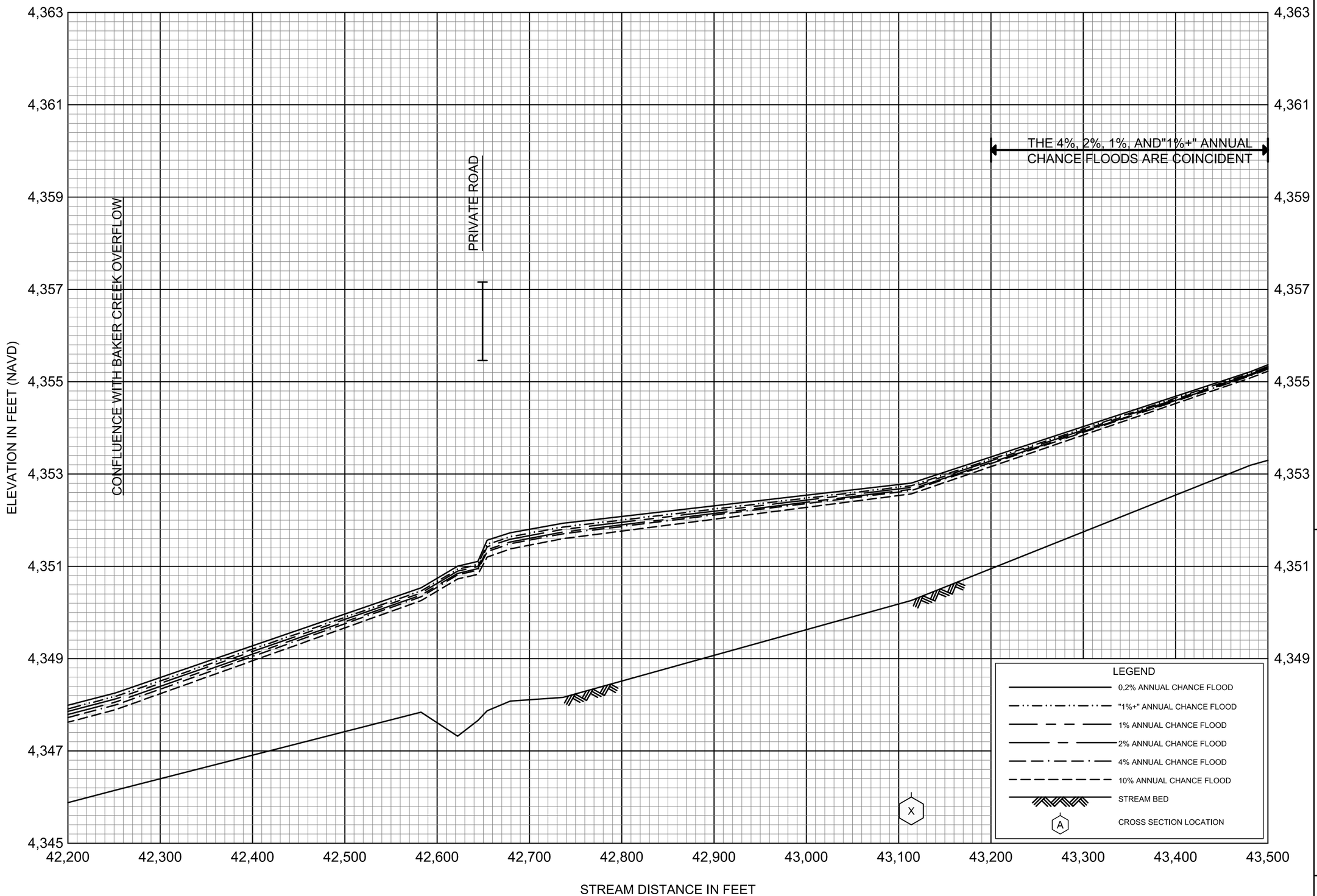
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

029P



FLOOD PROFILES

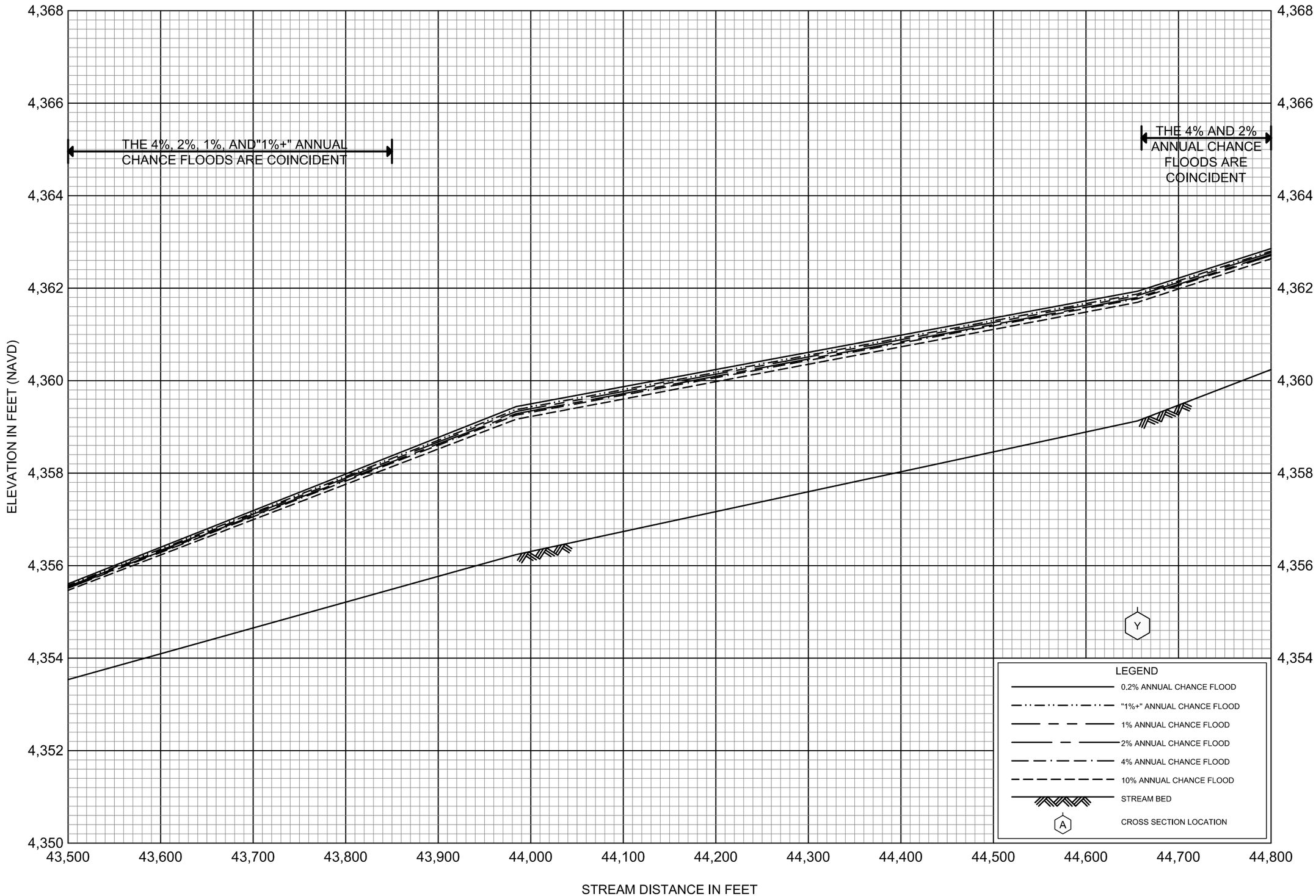
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

030P



FLOOD PROFILES

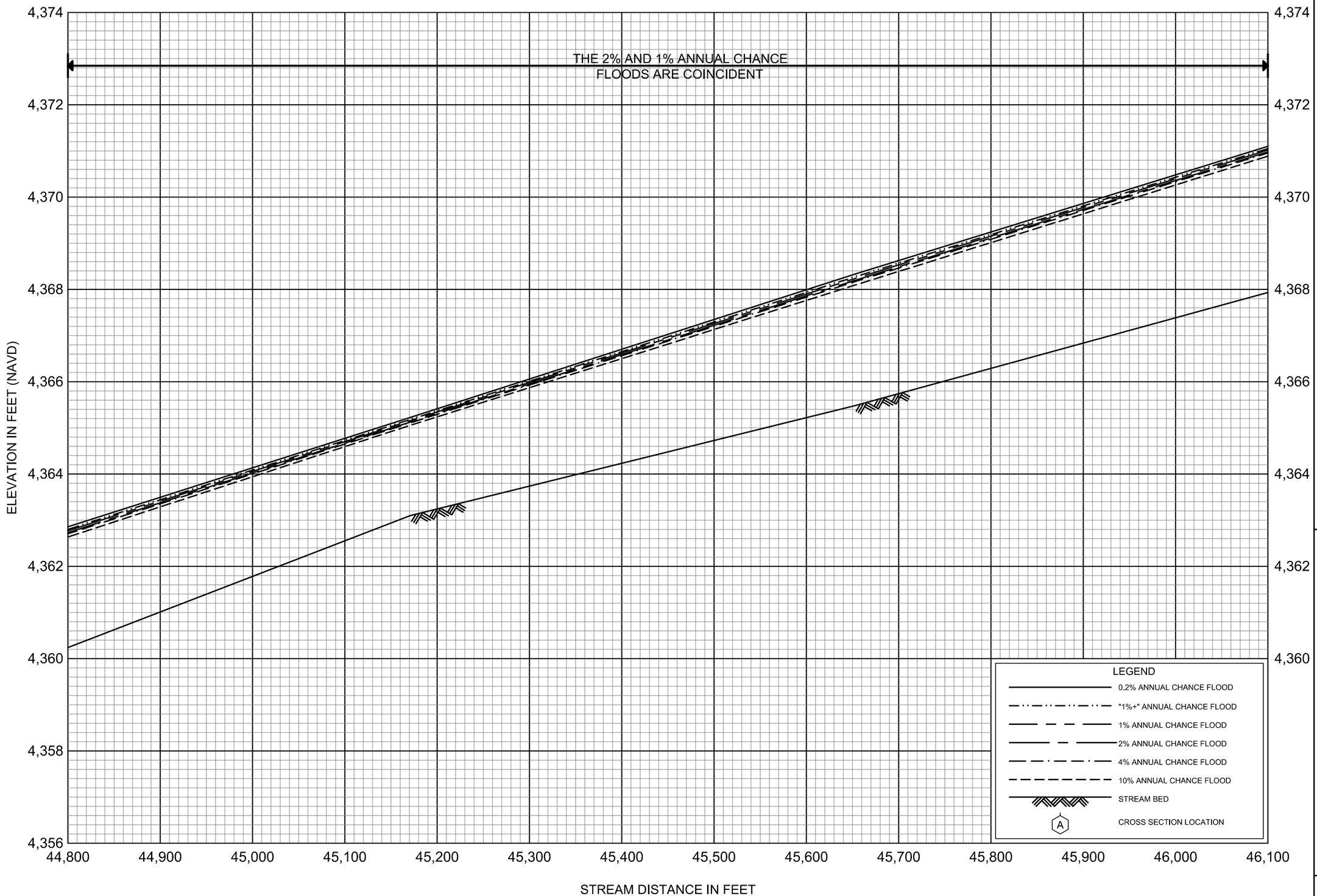
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

031P



FLOOD PROFILES

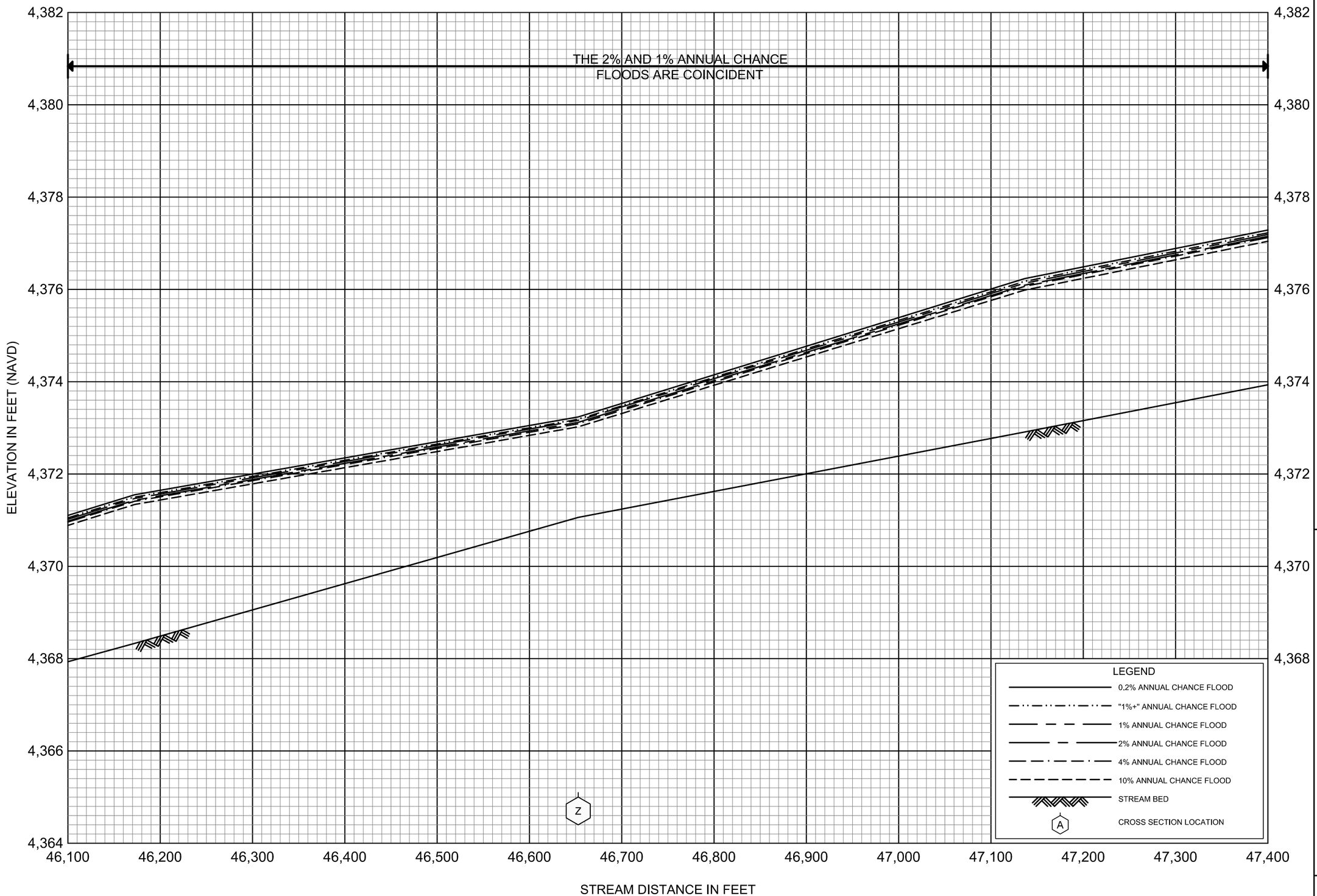
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

032P



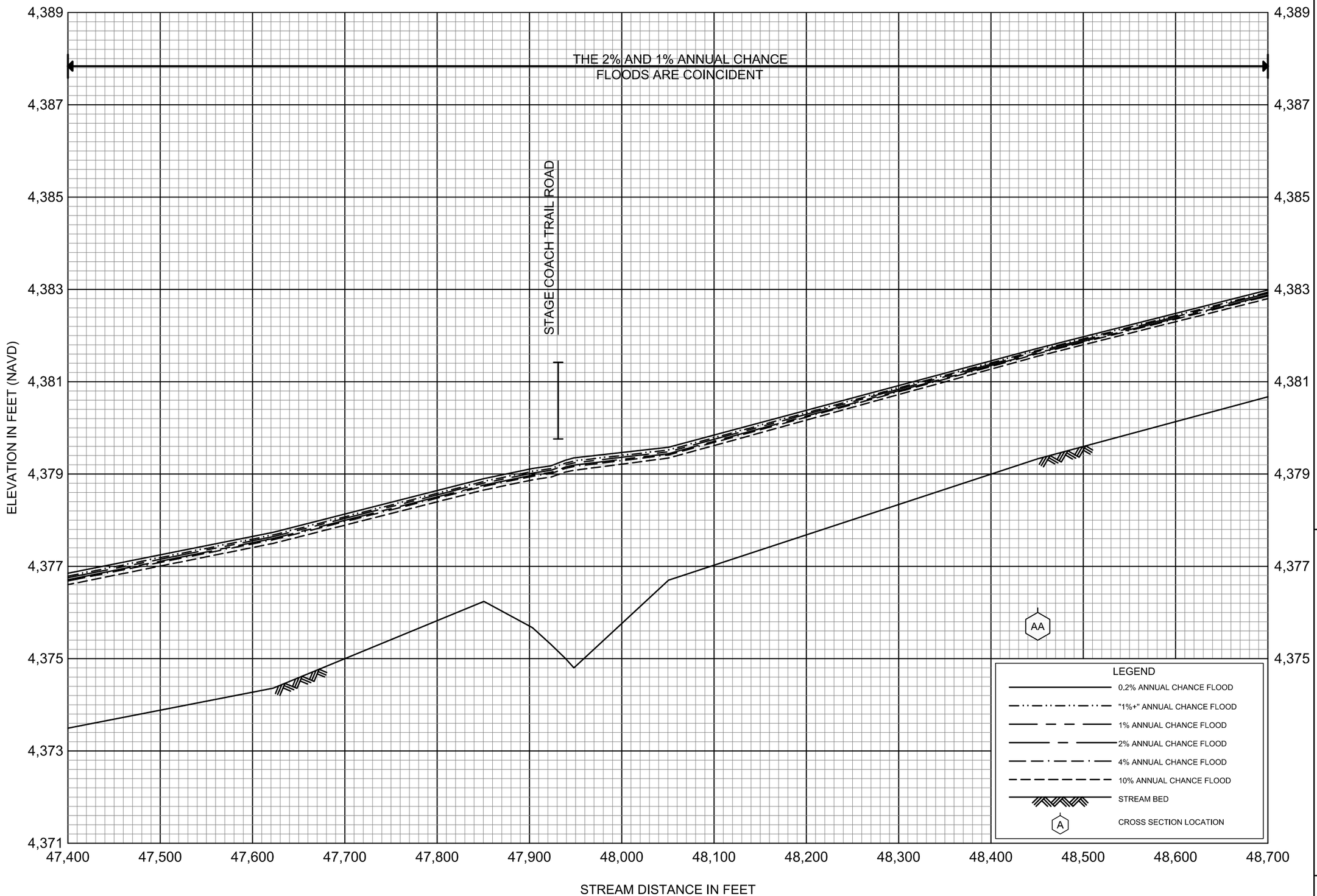
FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

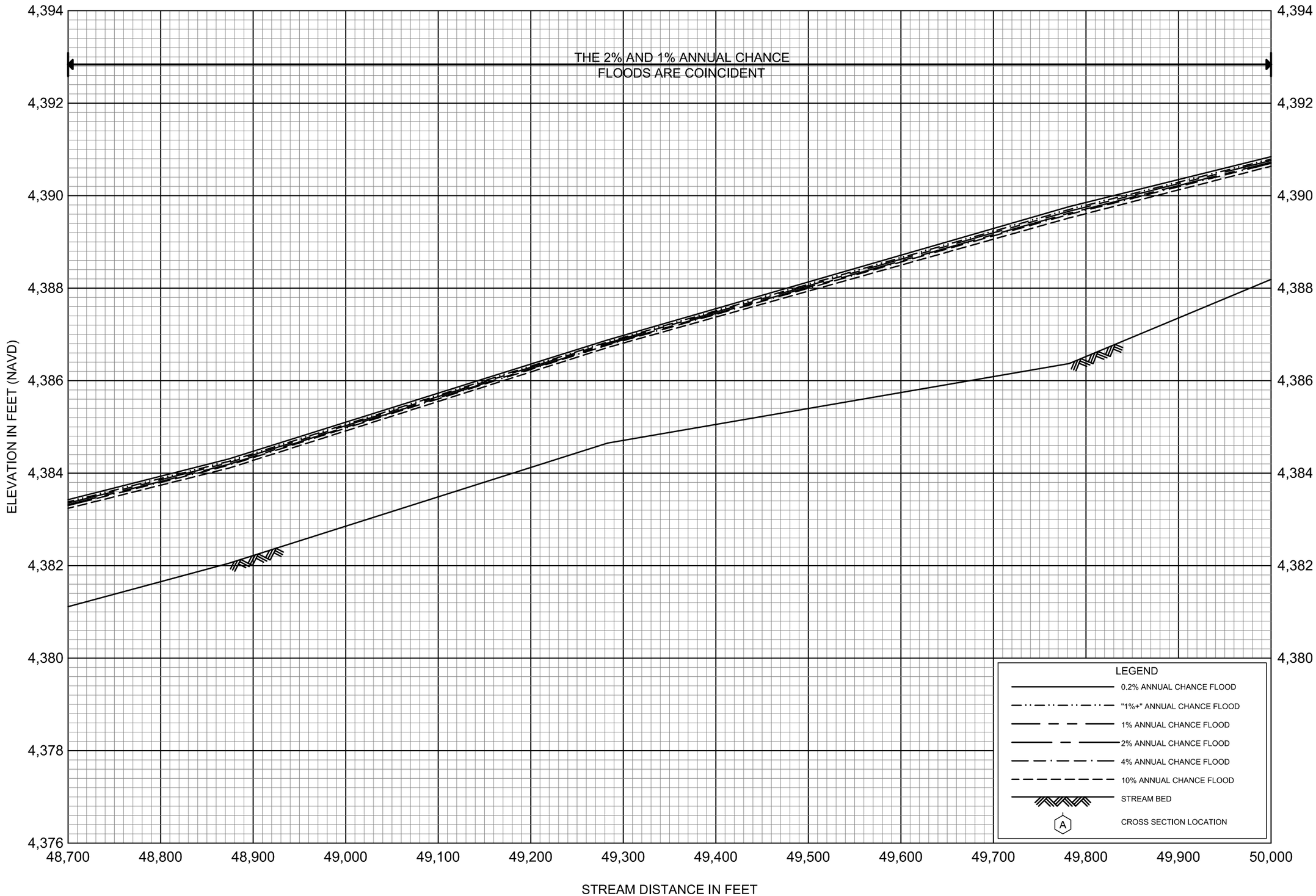
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

034P



FLOOD PROFILES

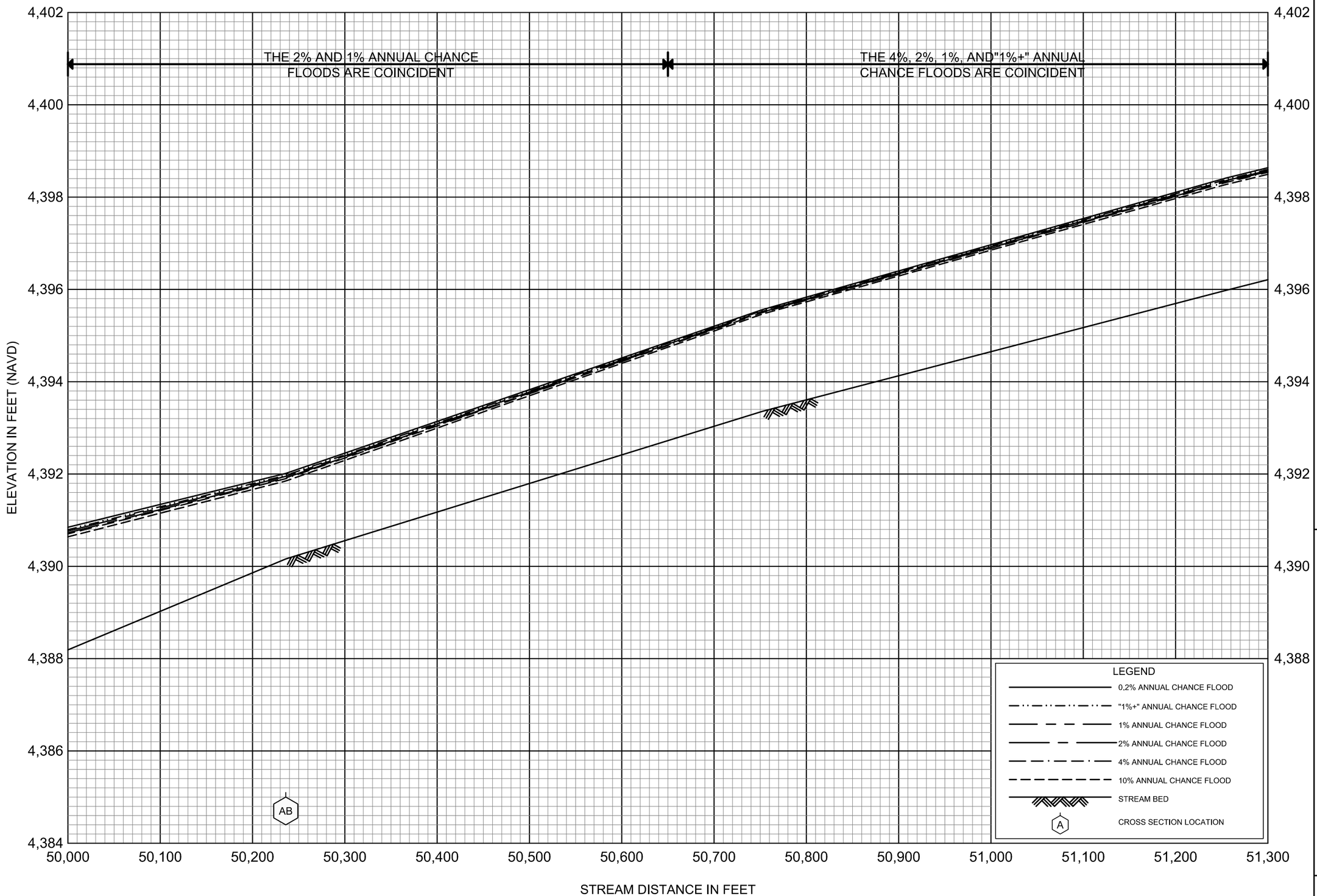
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

035P



FLOOD PROFILES

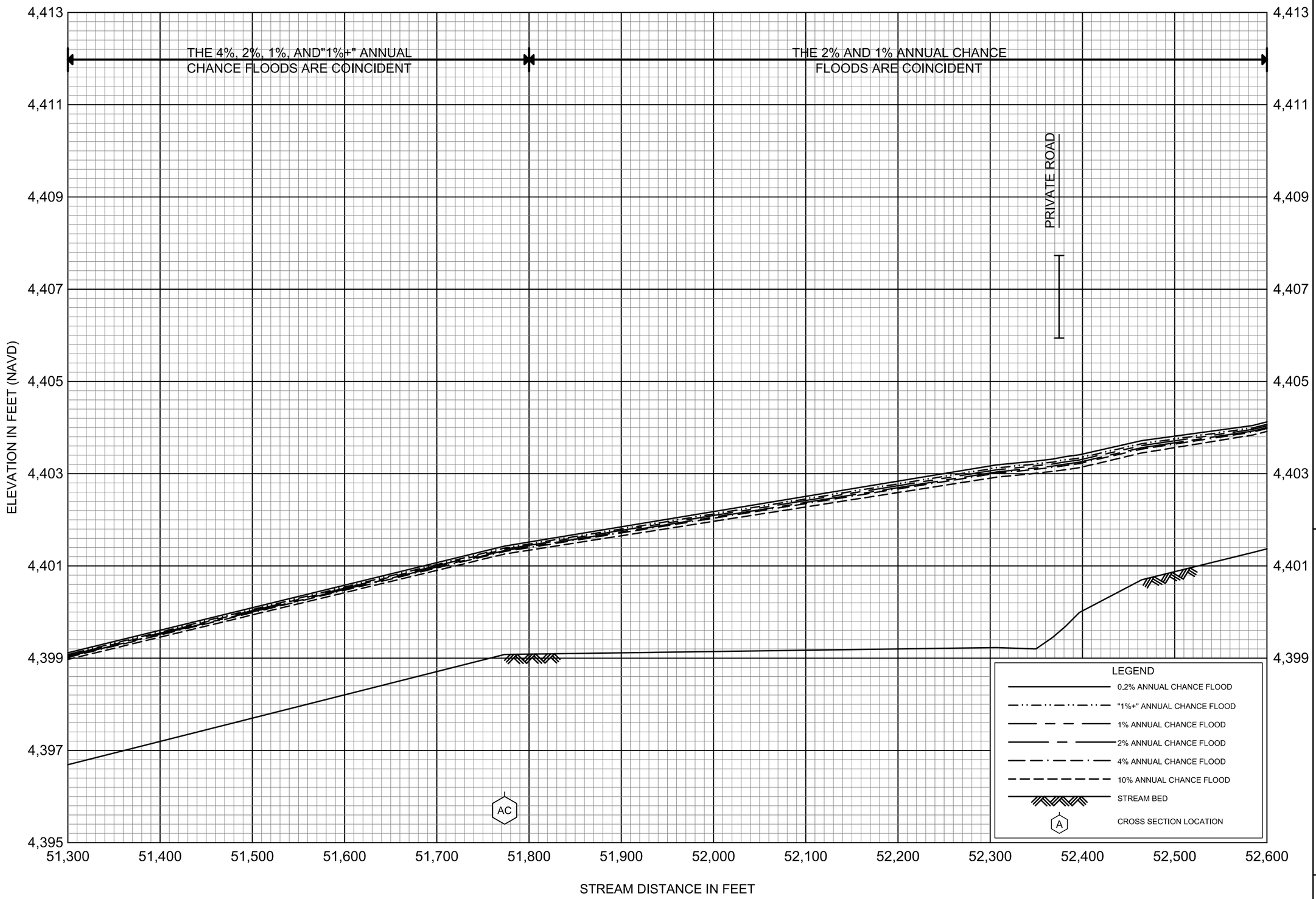
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

036P



FLOOD PROFILES

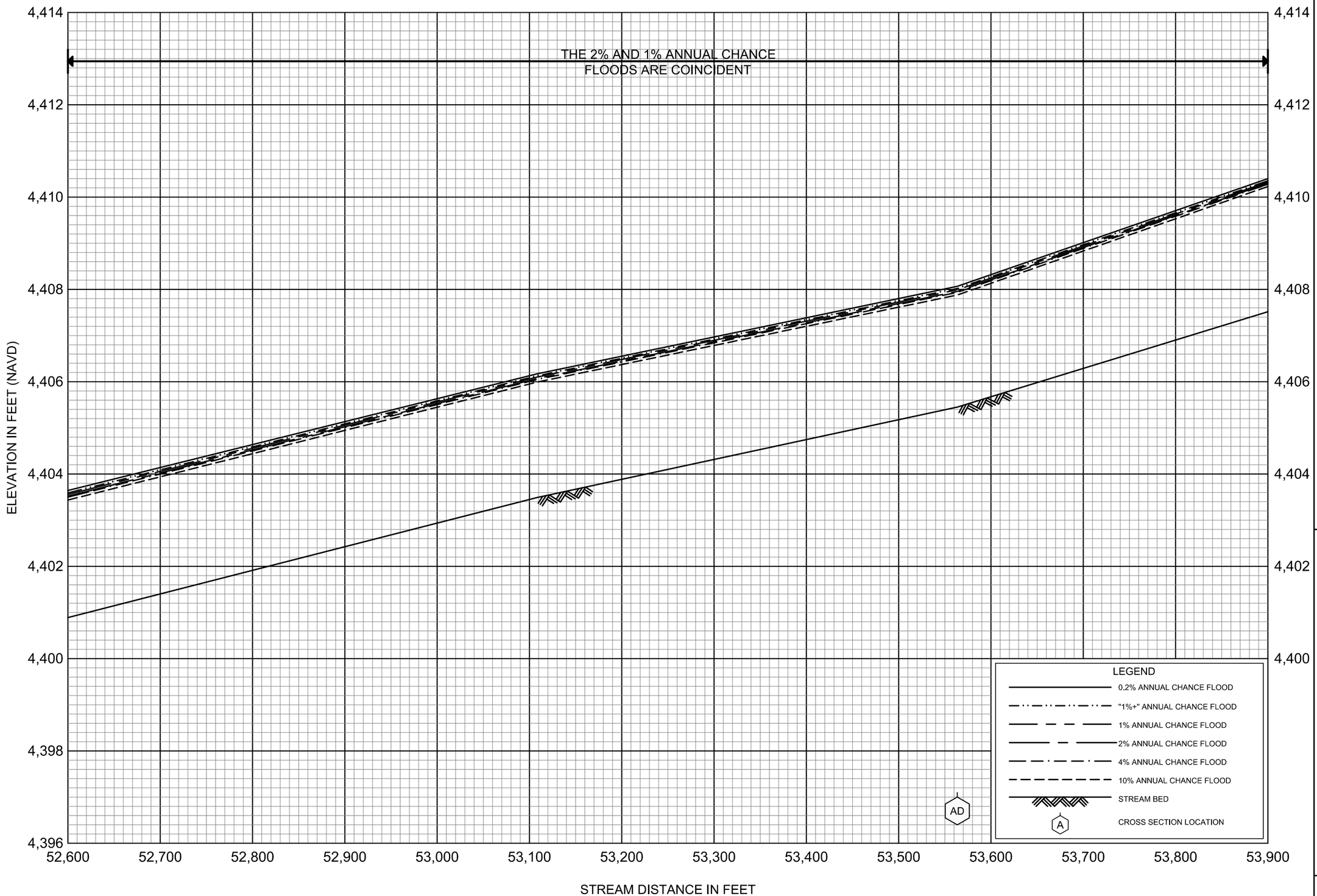
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

037P



FLOOD PROFILES

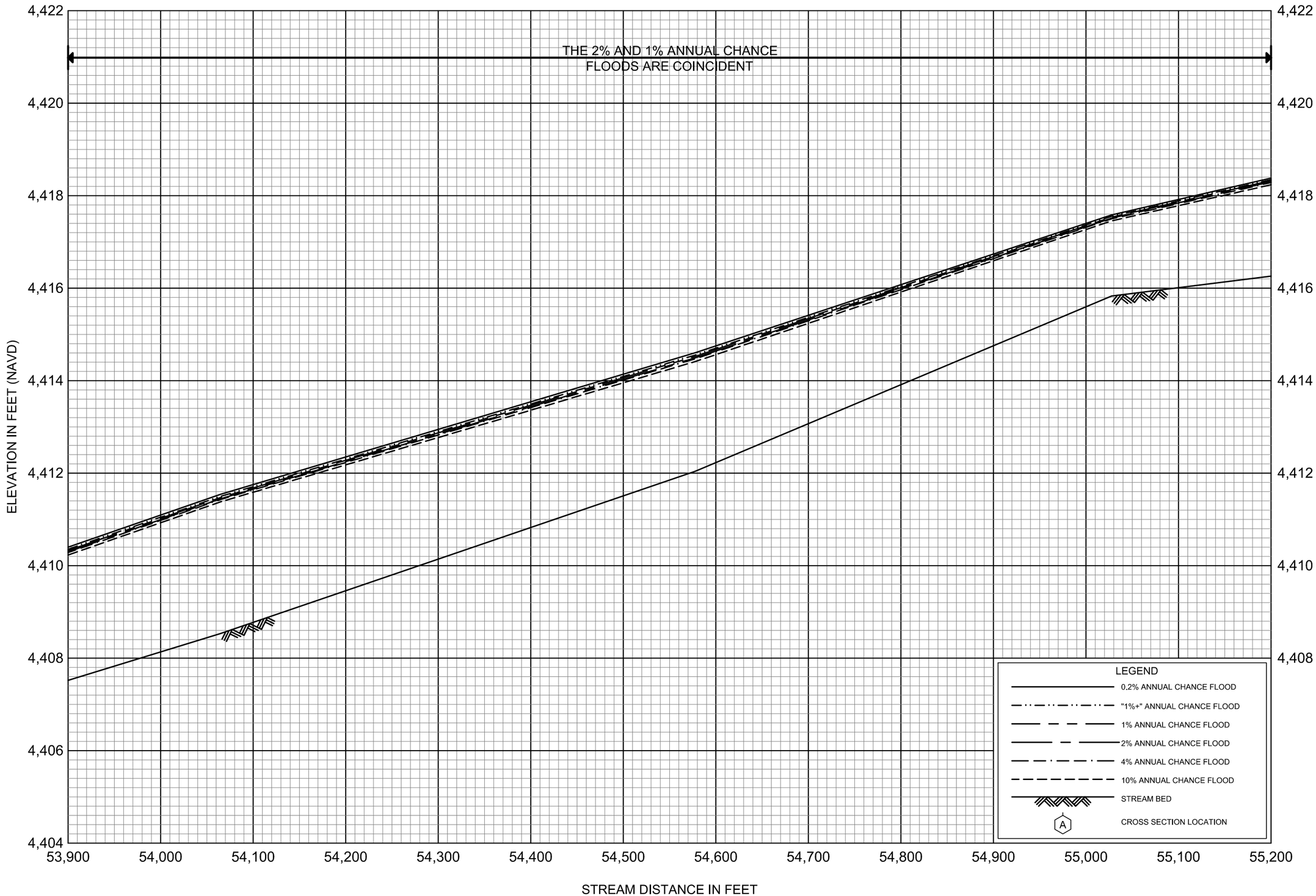
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

038P



FLOOD PROFILES

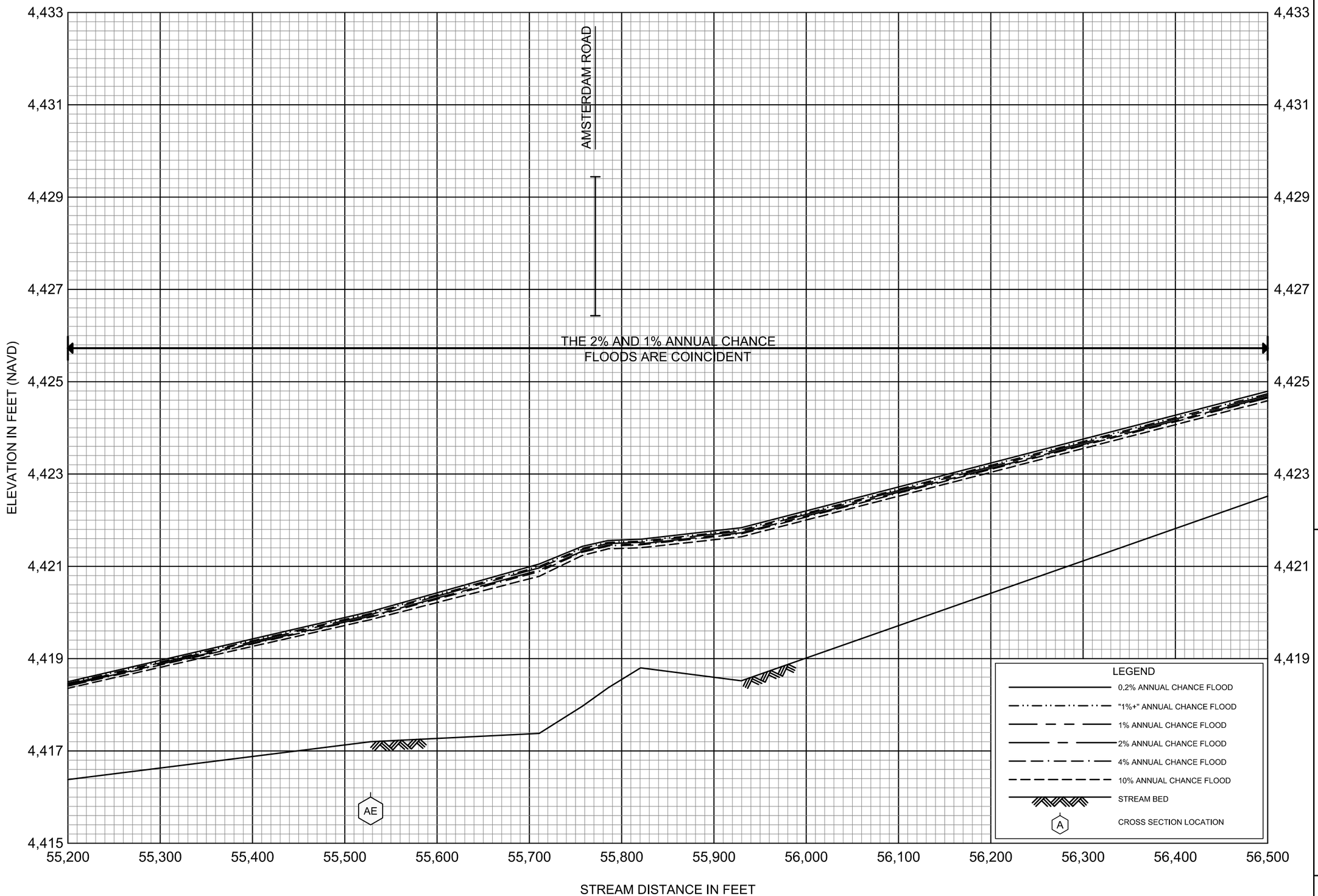
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

039P



FLOOD PROFILES

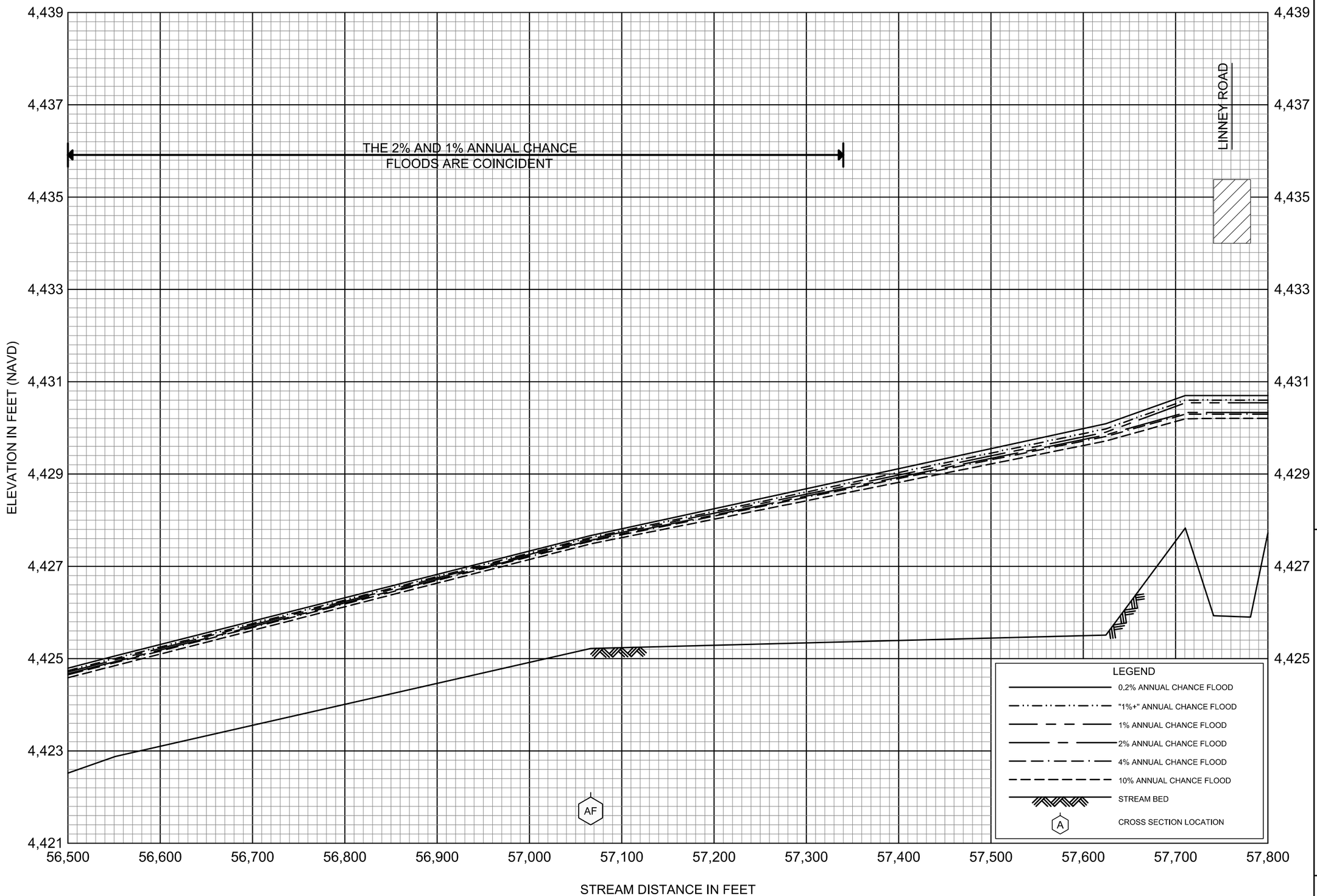
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

040P



FLOOD PROFILES

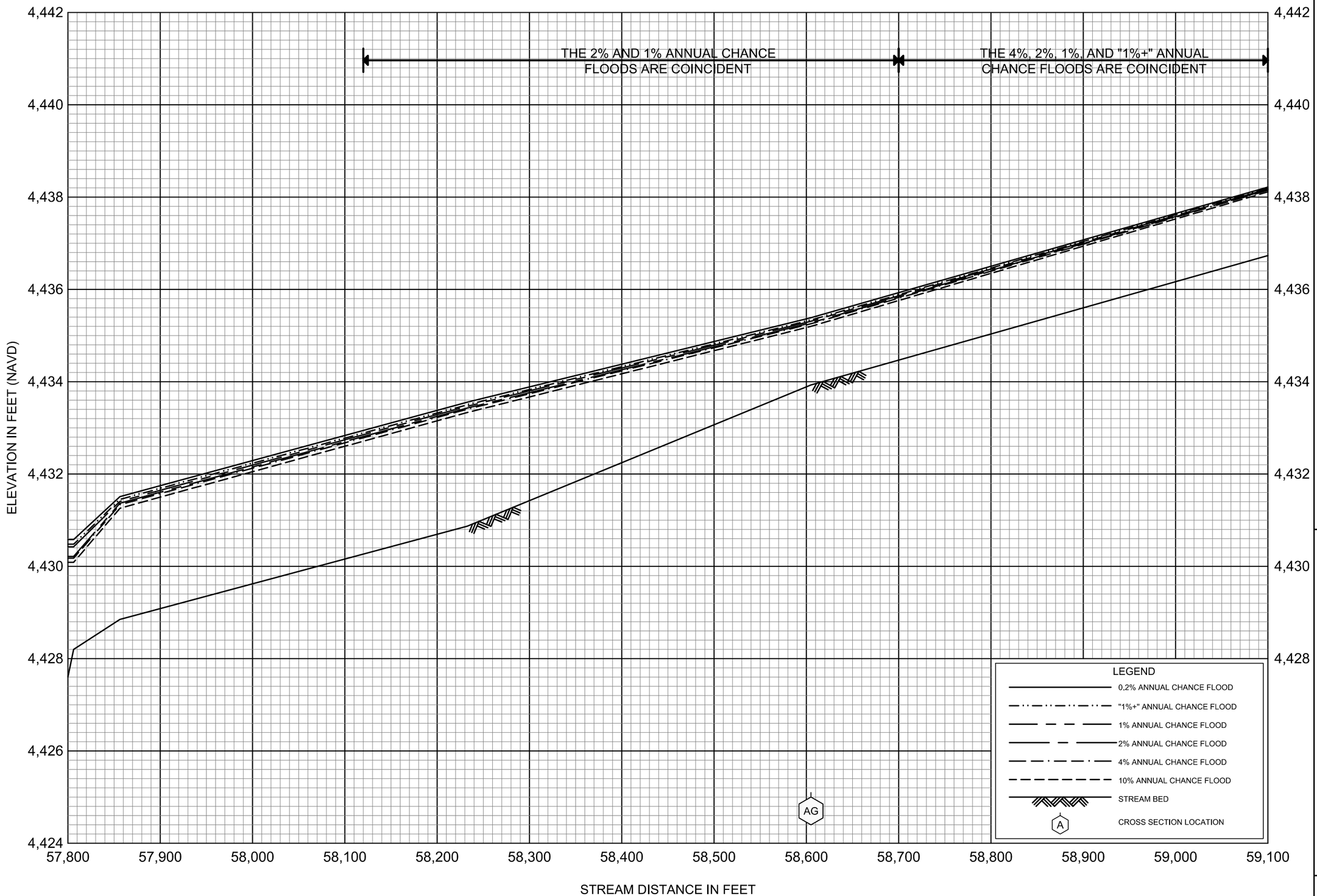
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

041P



FLOOD PROFILES

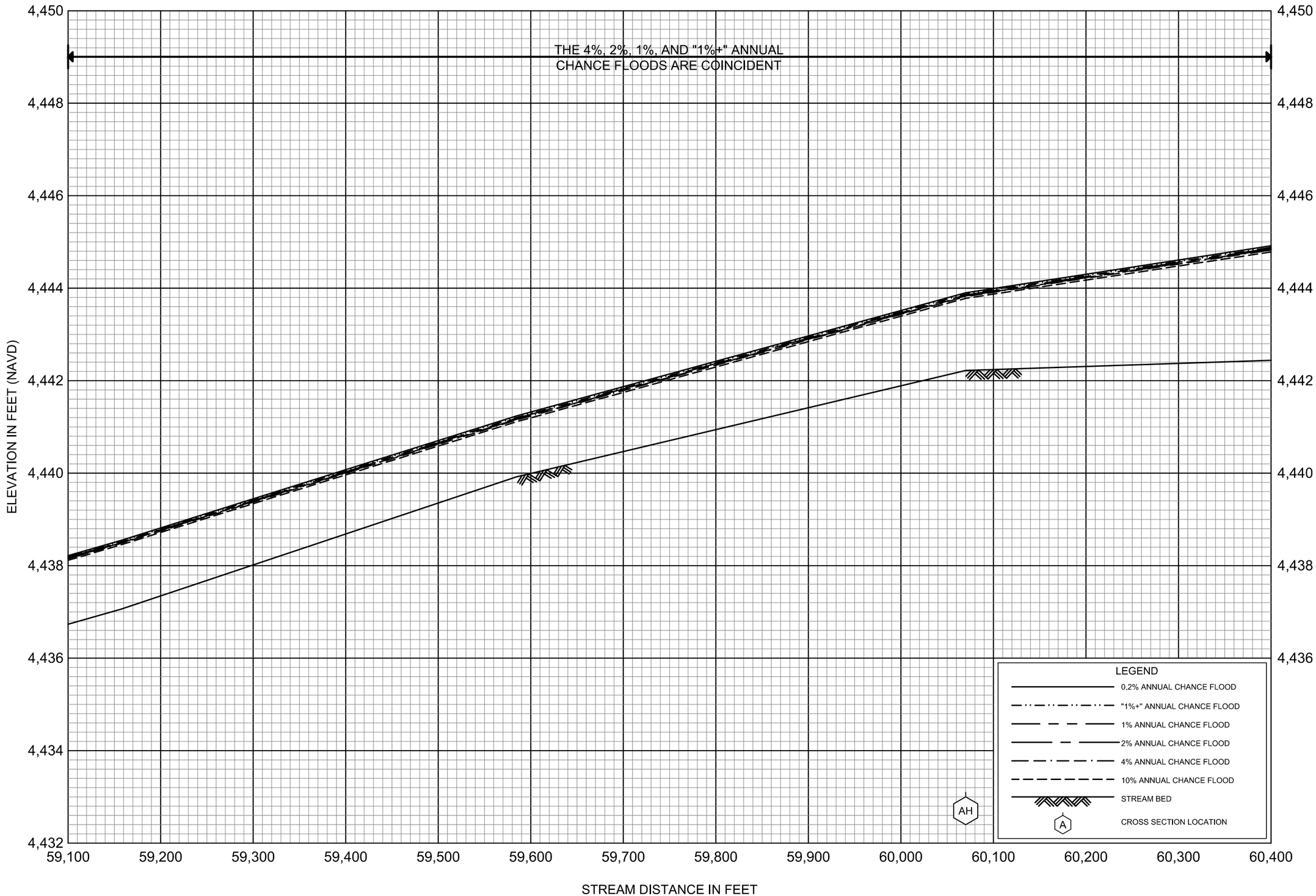
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

042P



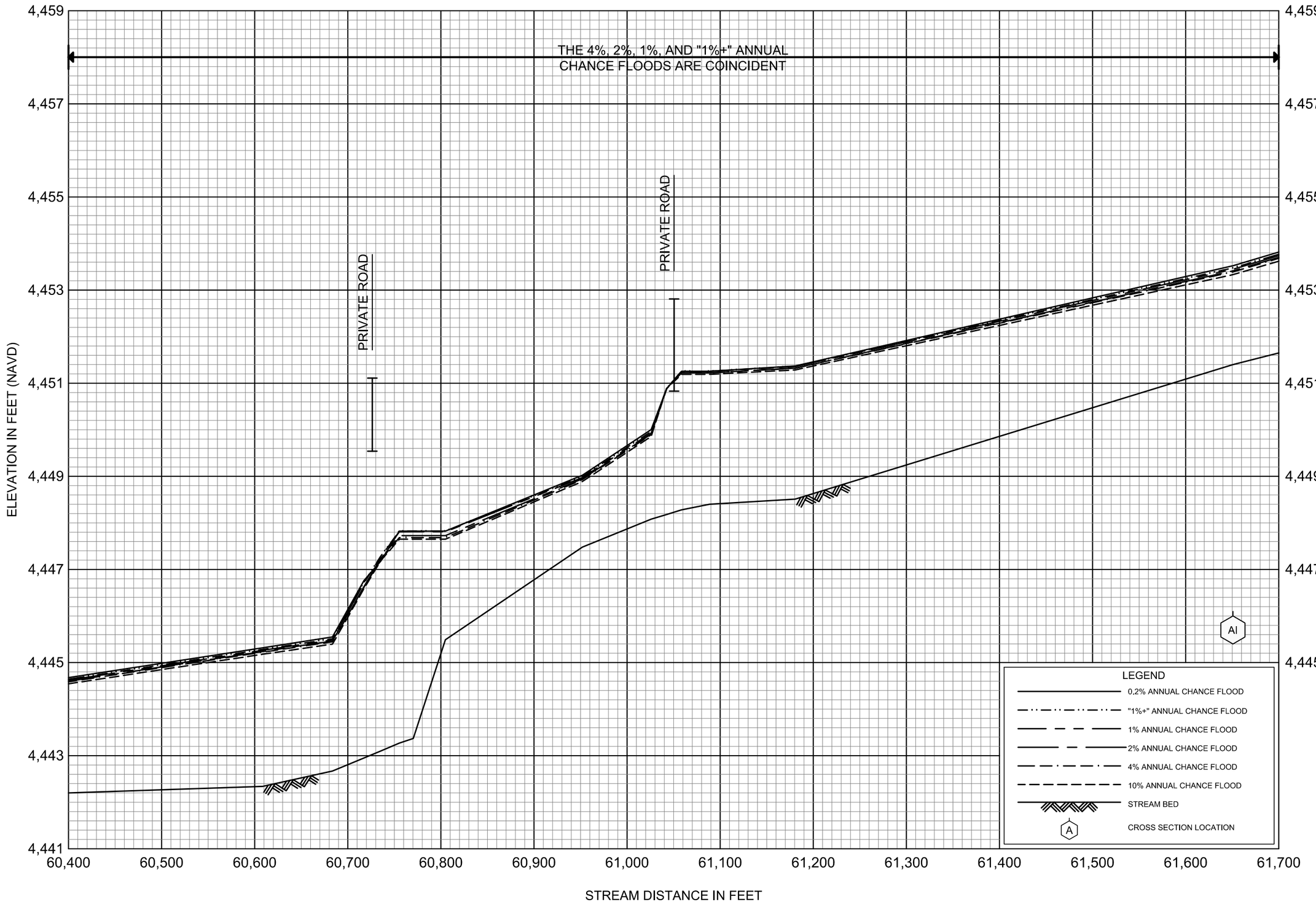
FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

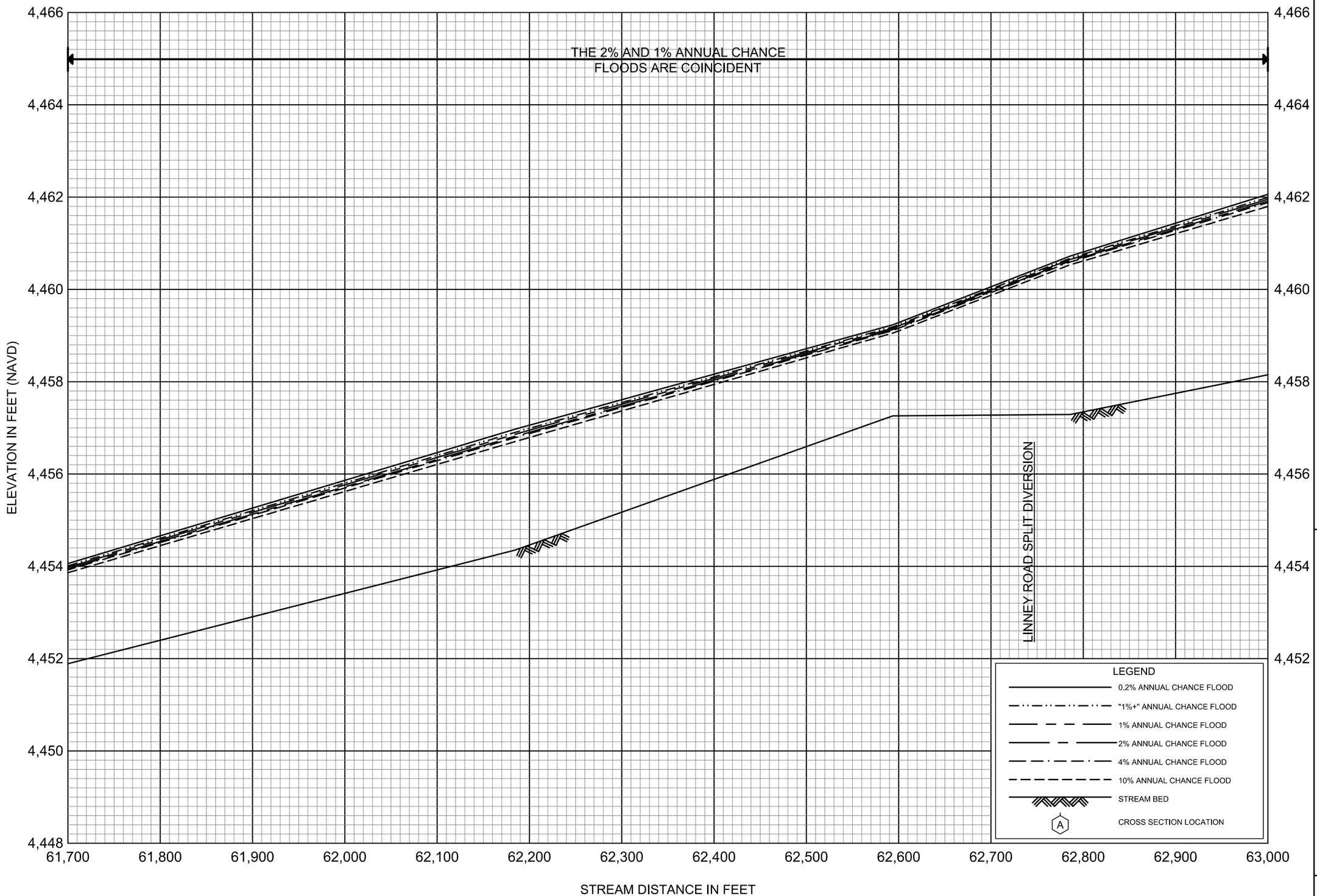
BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

044P



FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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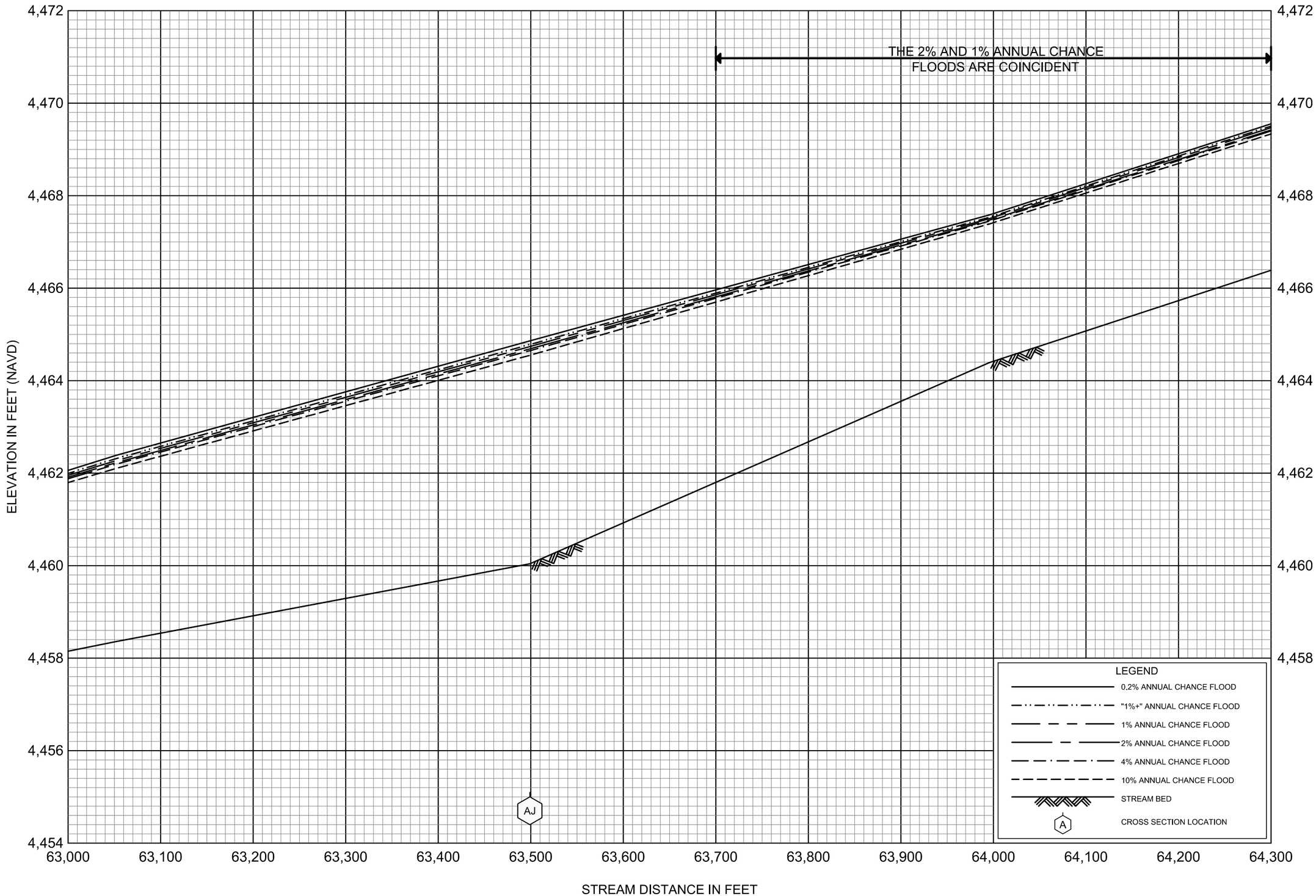


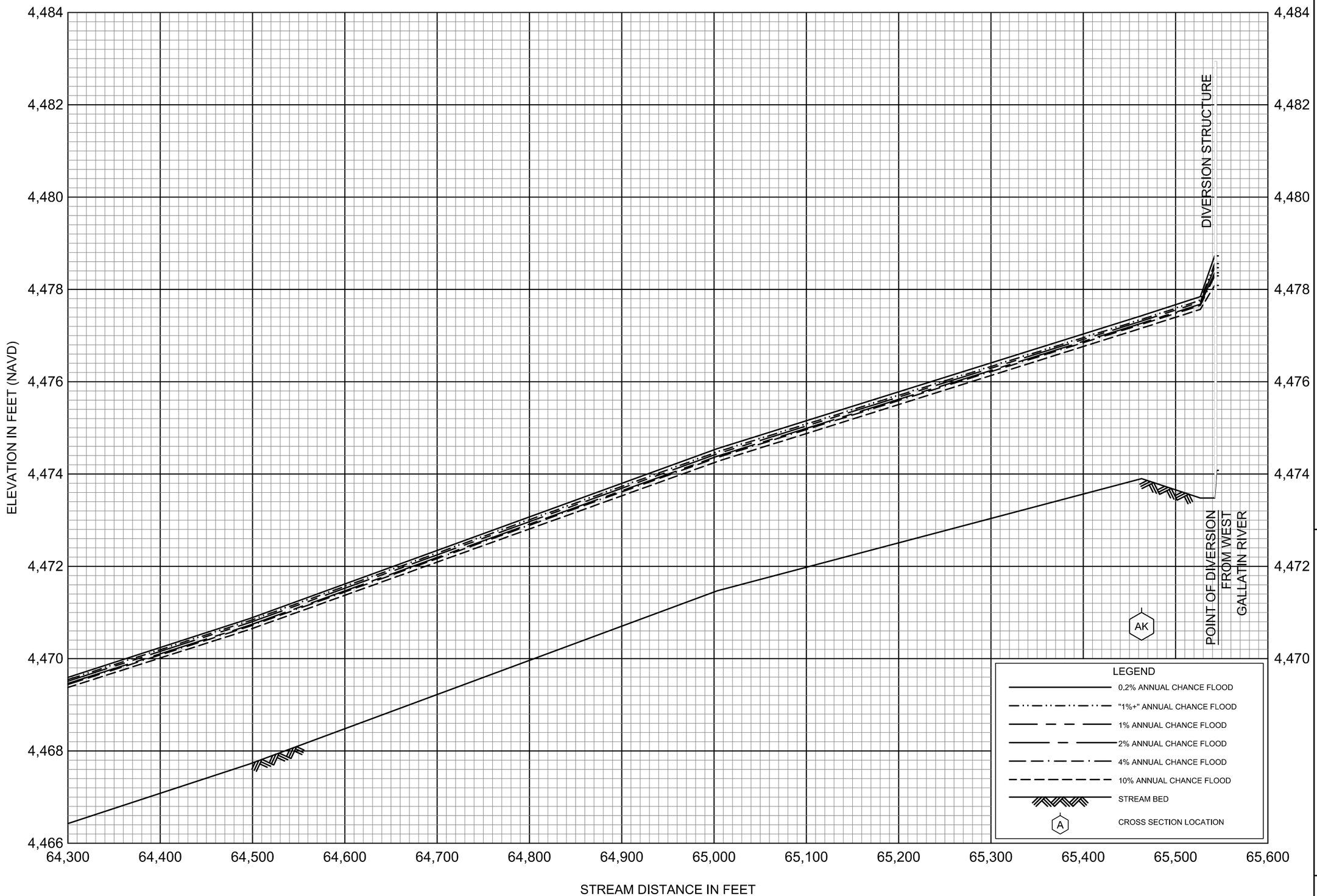
FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



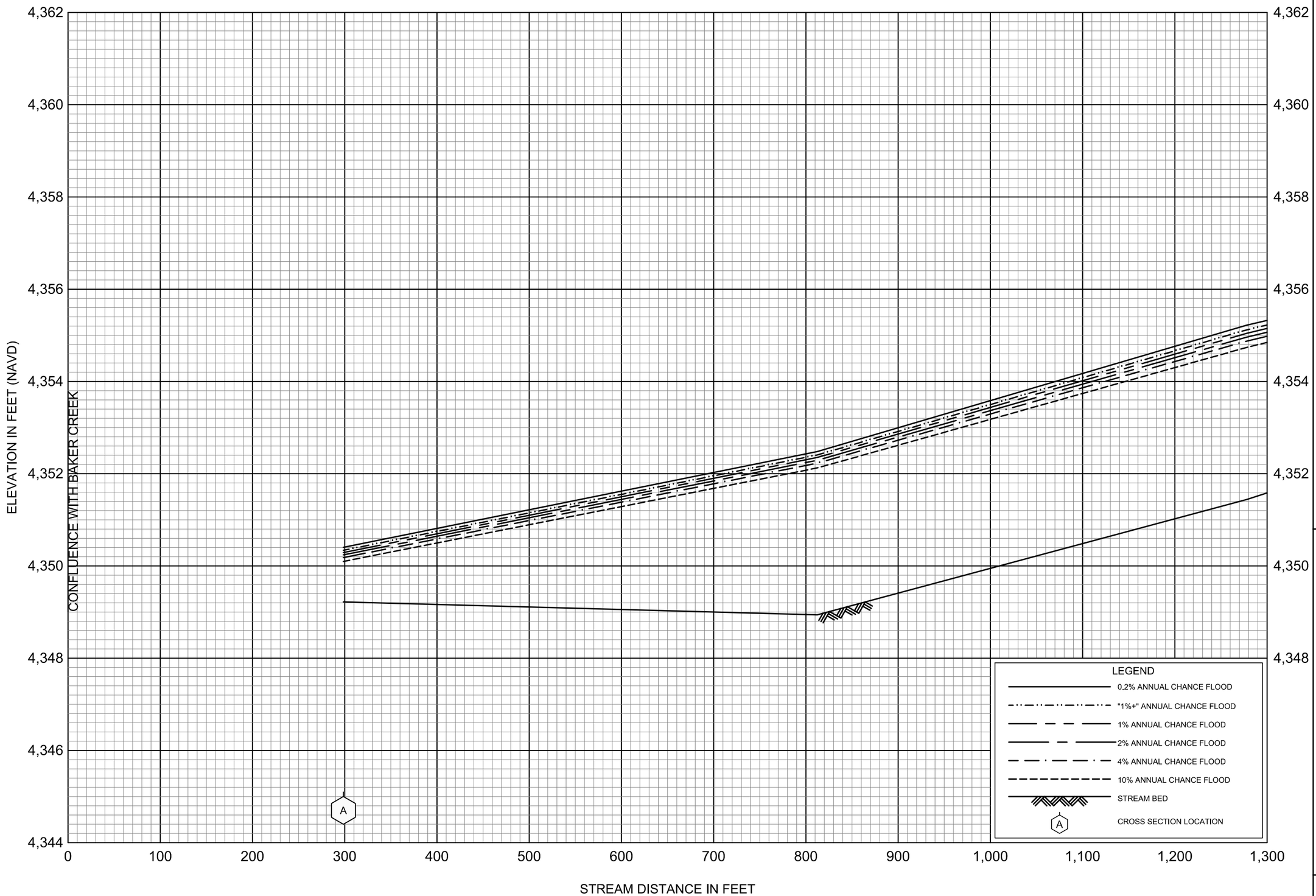
FLOOD PROFILES

BAKER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



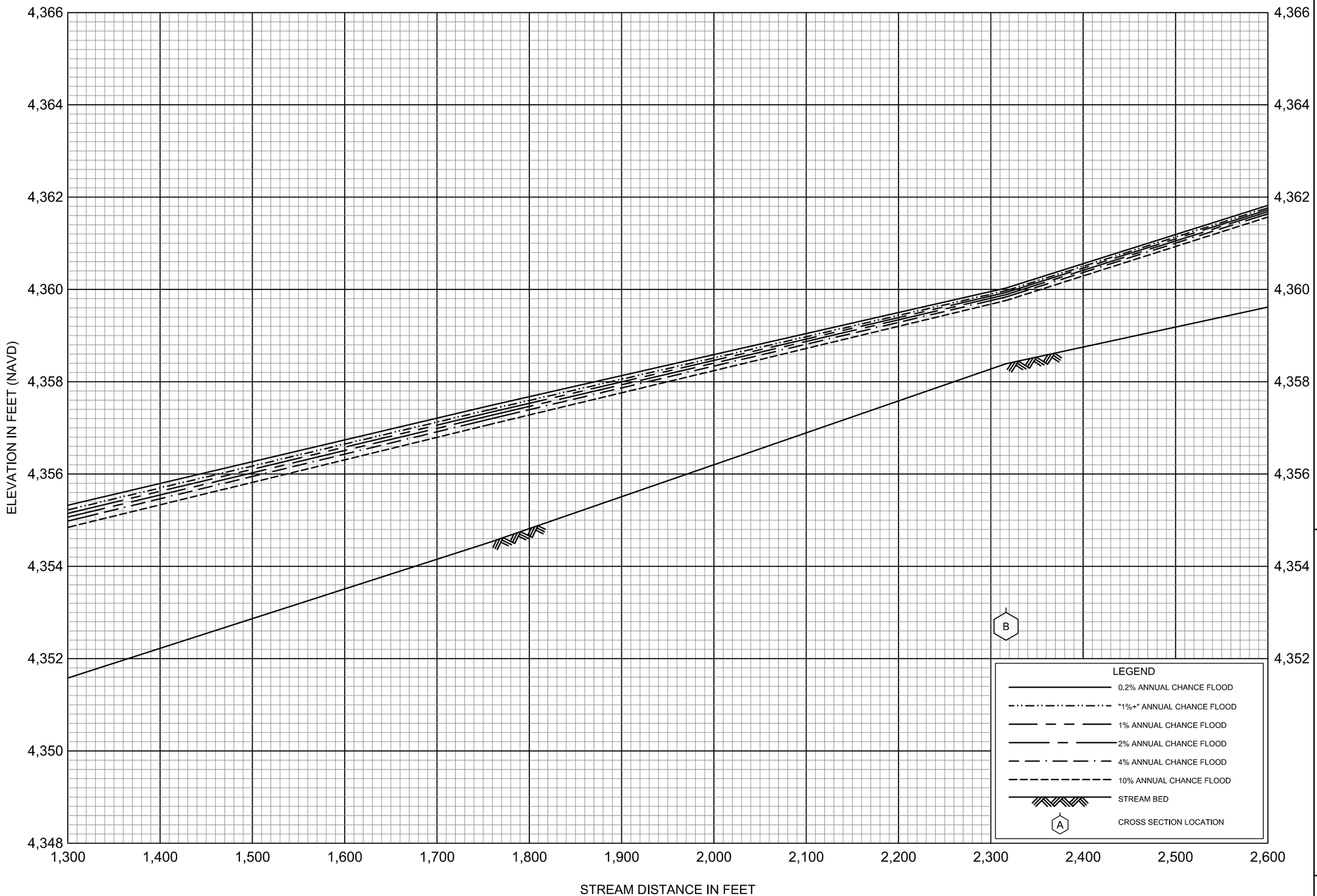
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



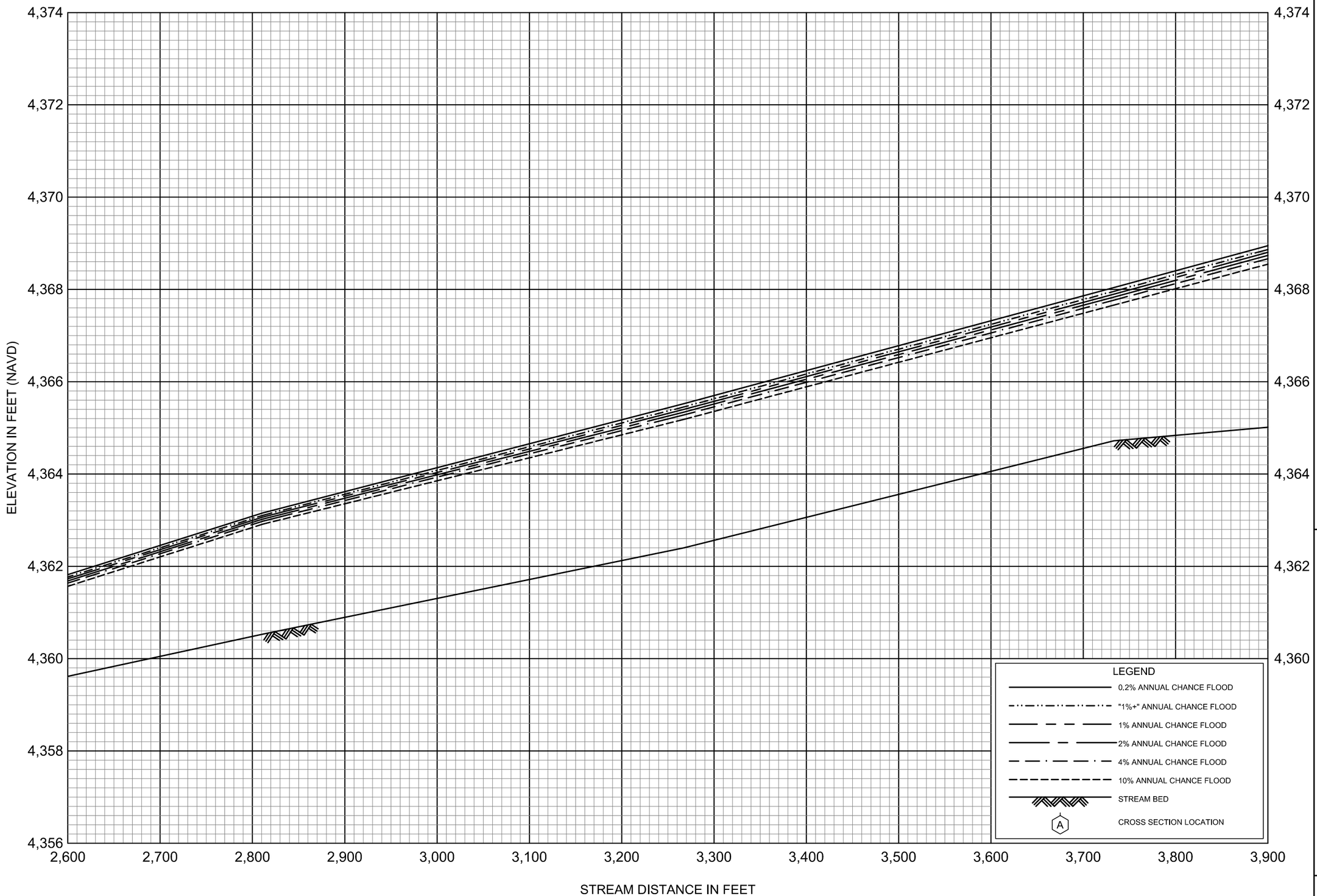
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



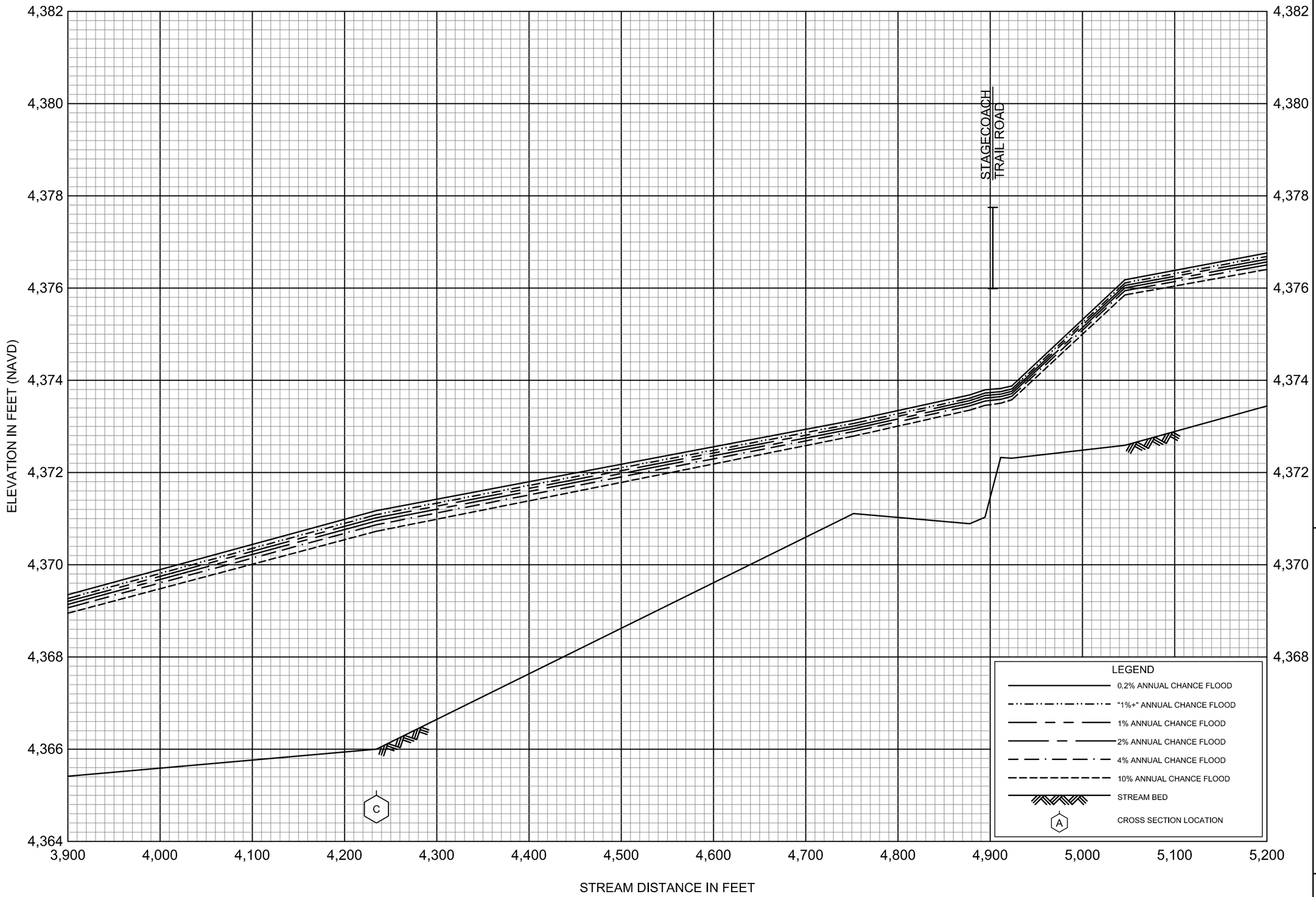
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

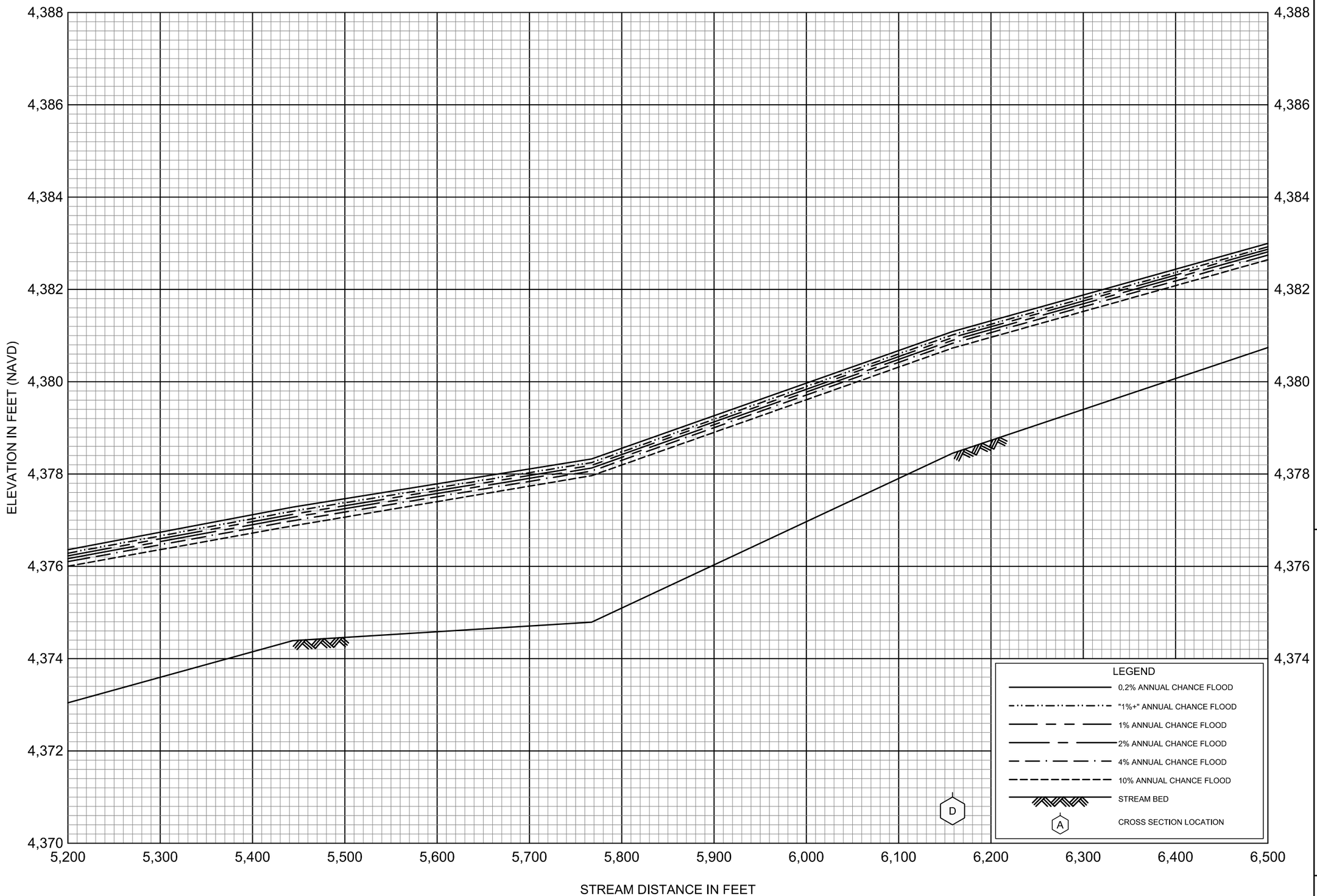
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

051P



FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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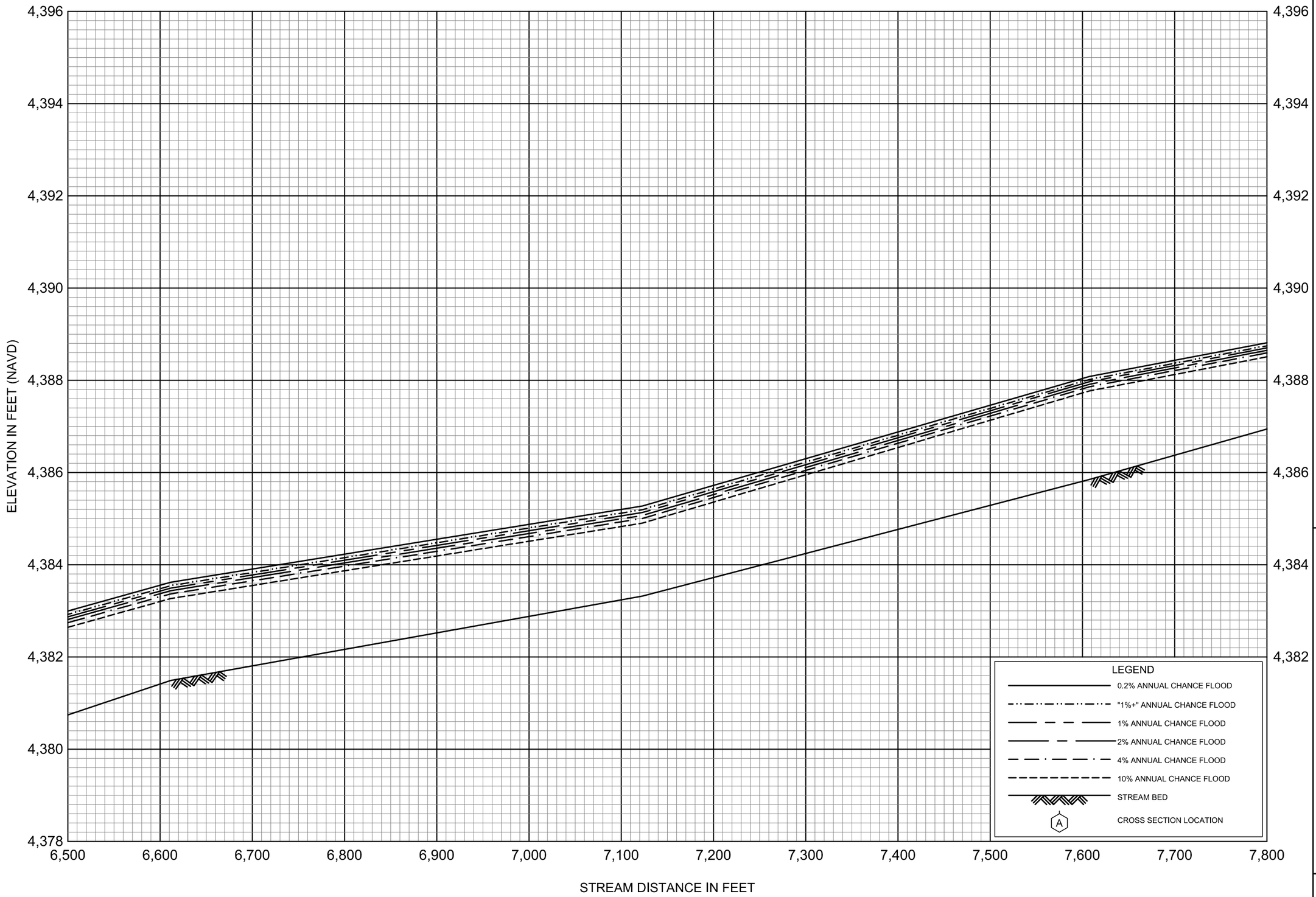


FLOOD PROFILES

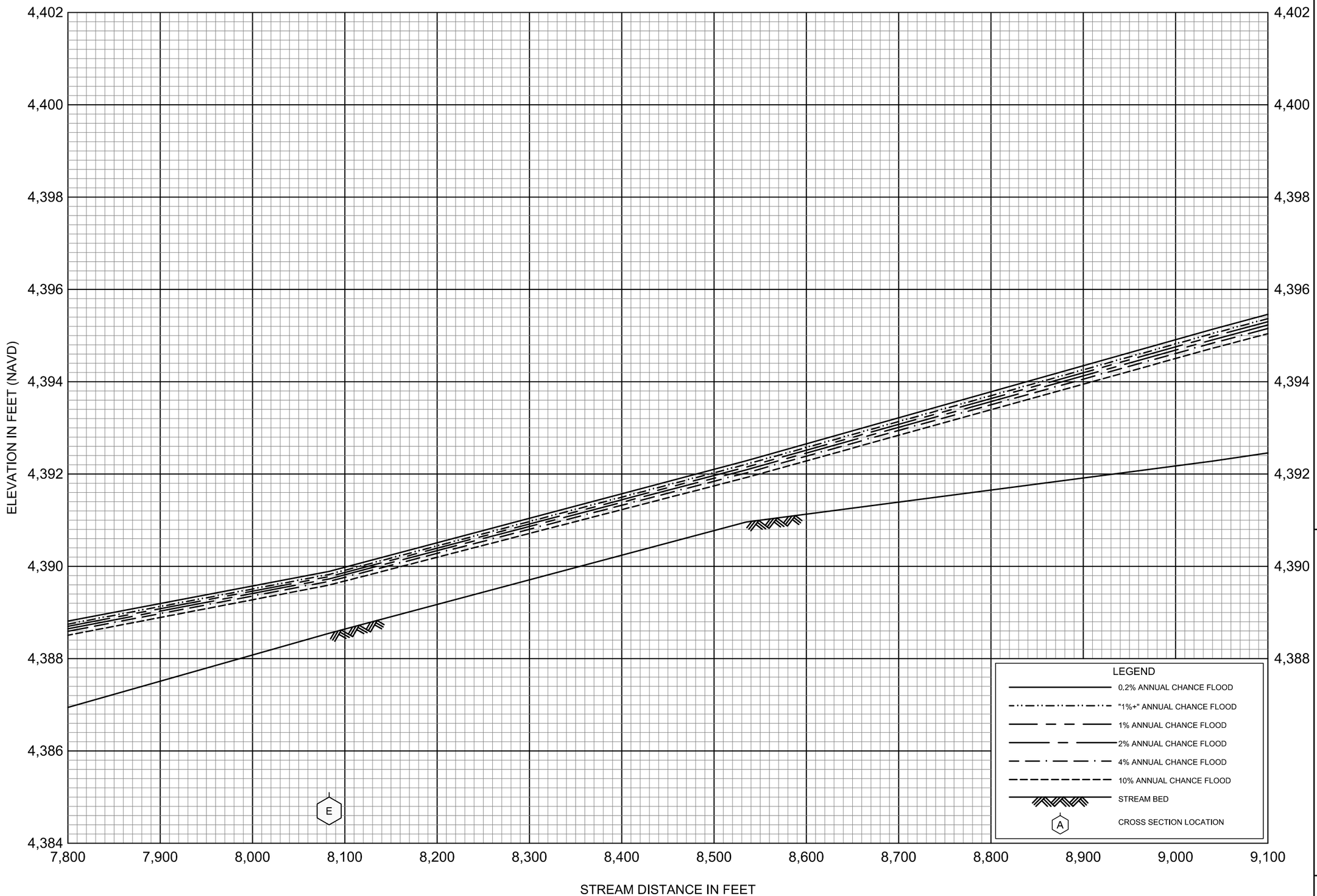
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

053P



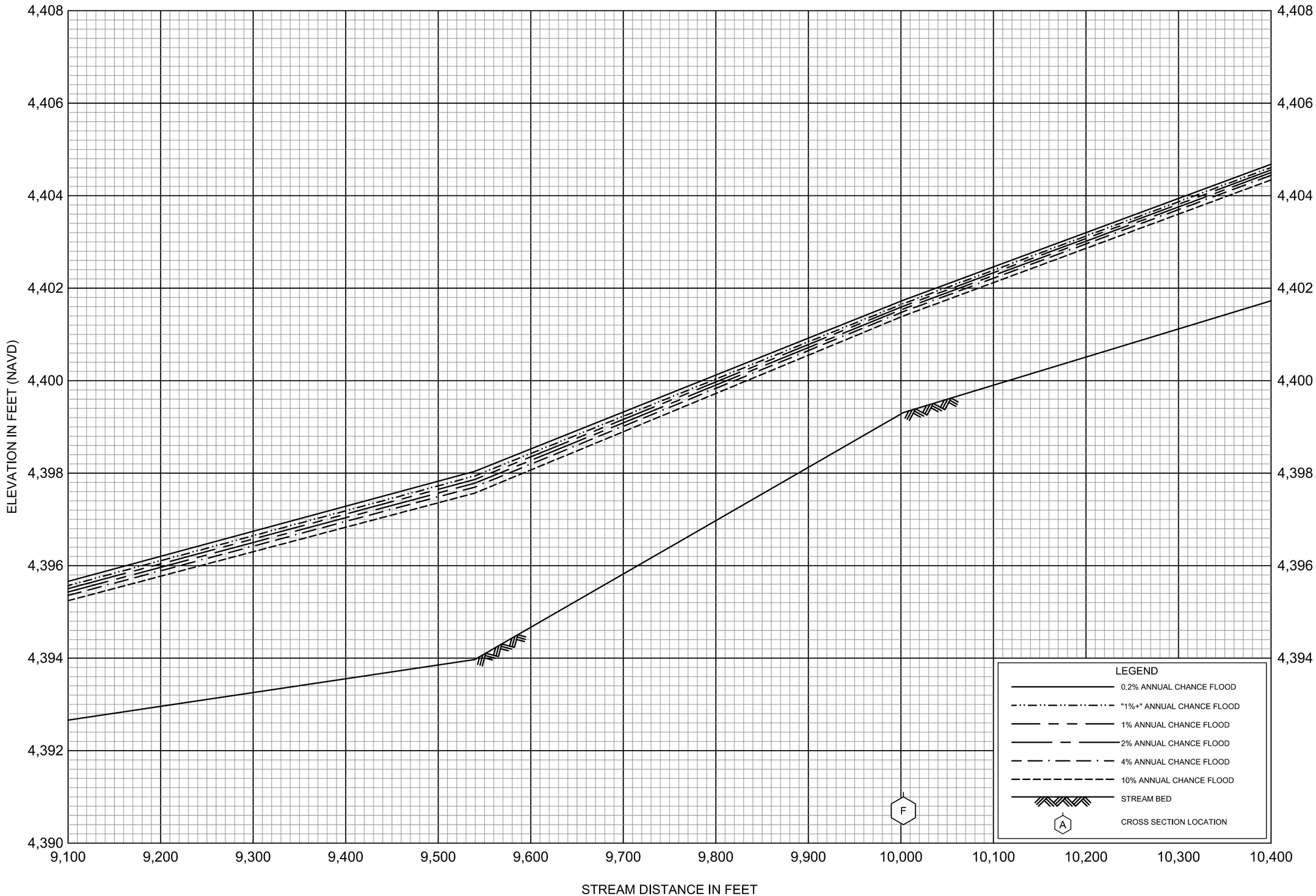
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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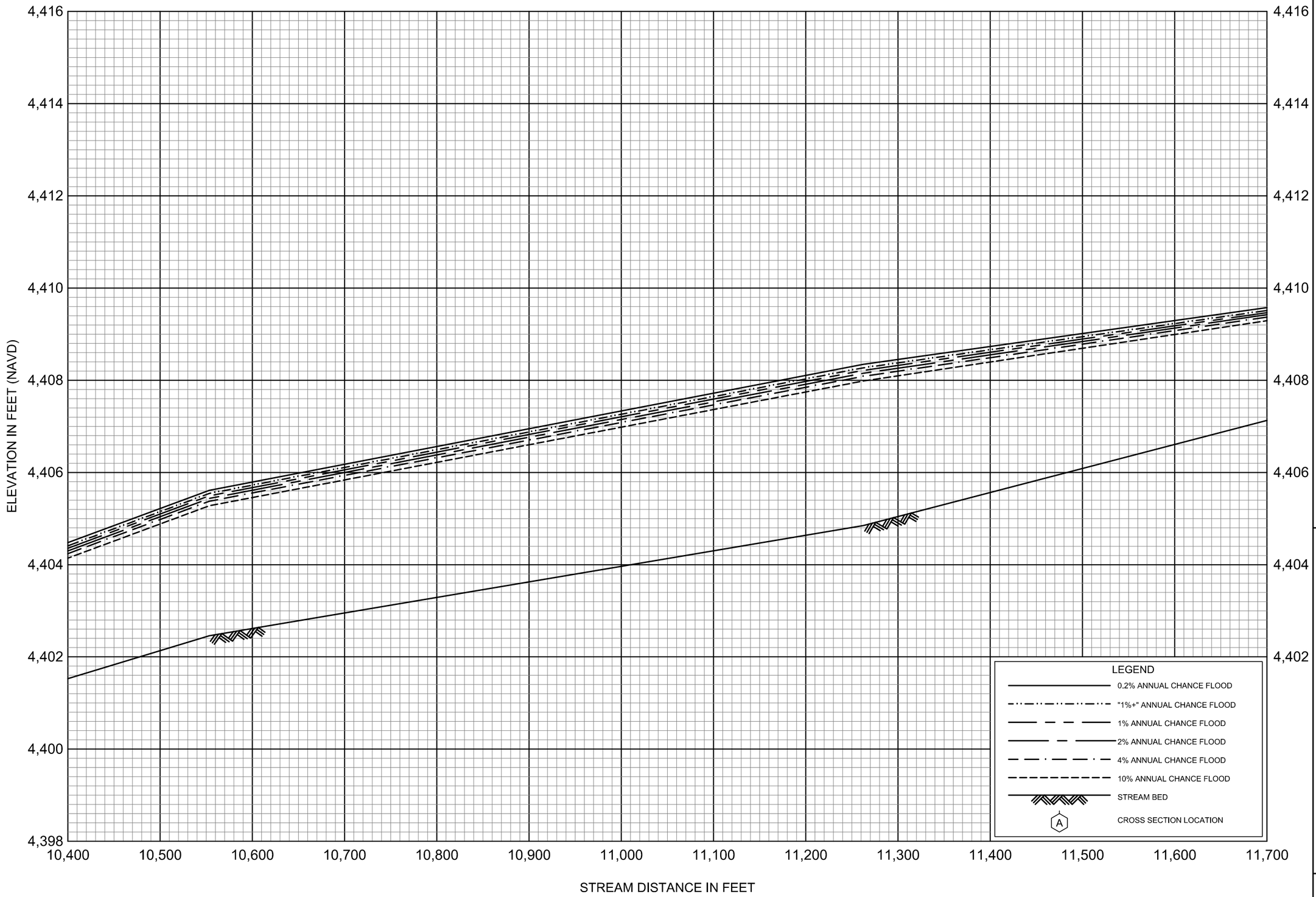

FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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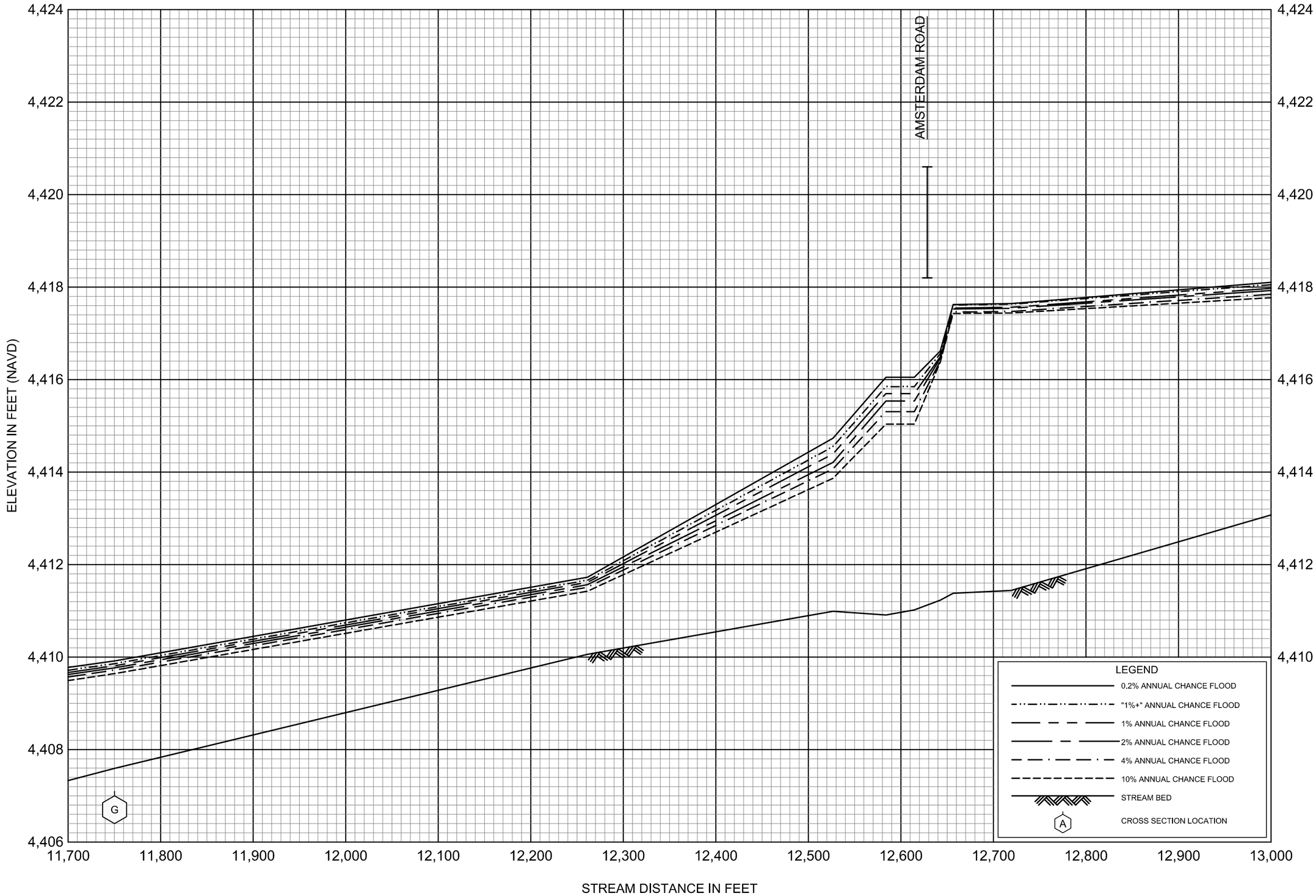

FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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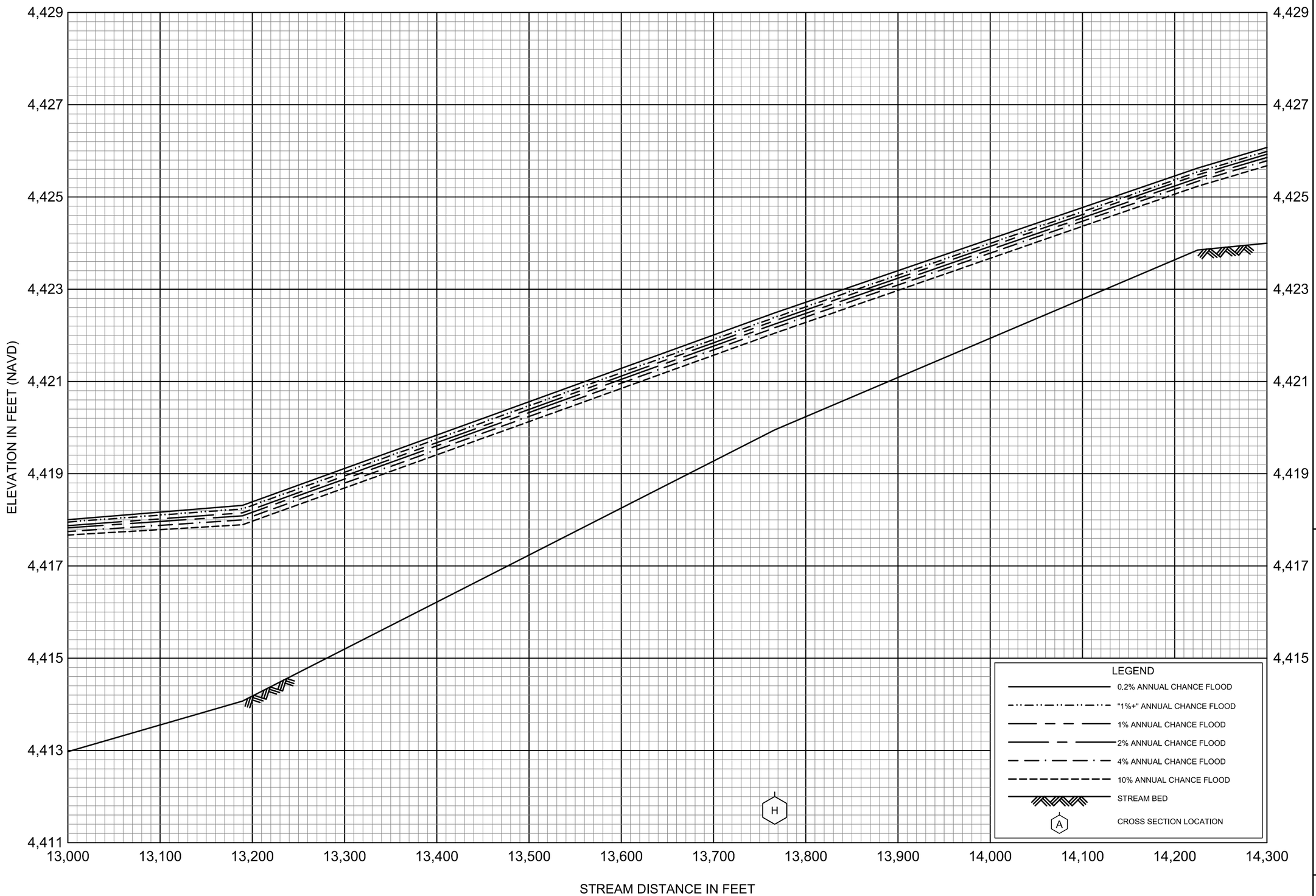


FLOOD PROFILES

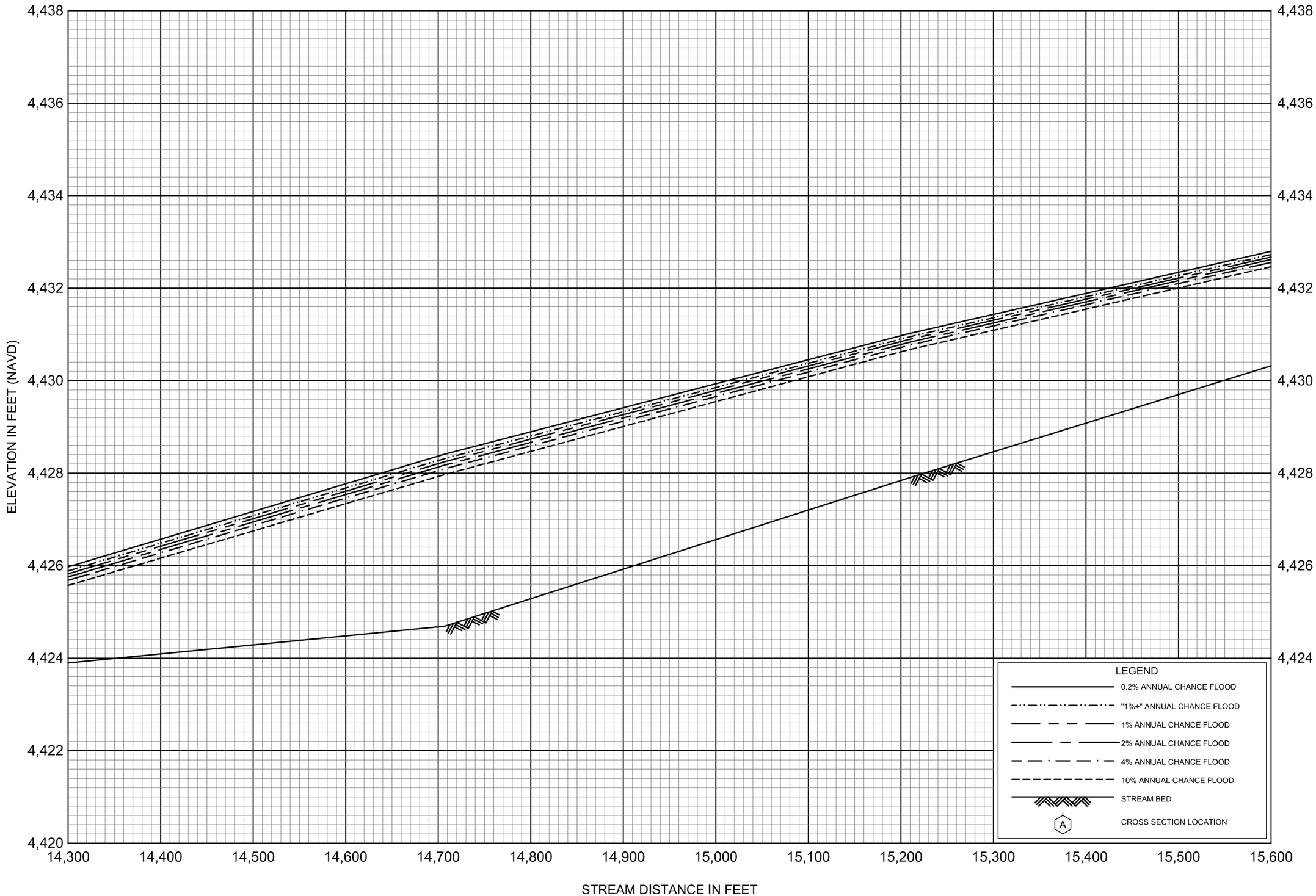
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

058P



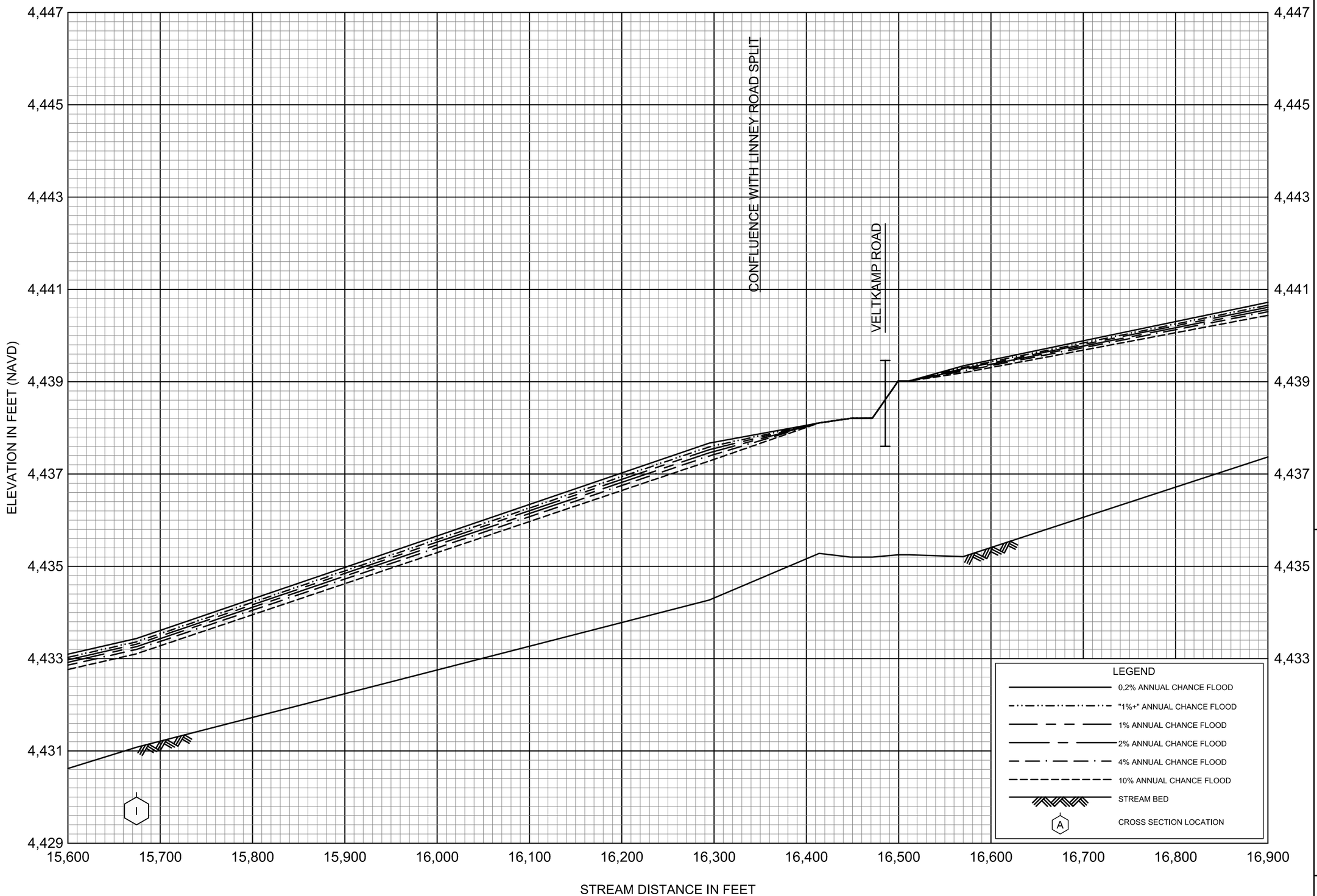
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



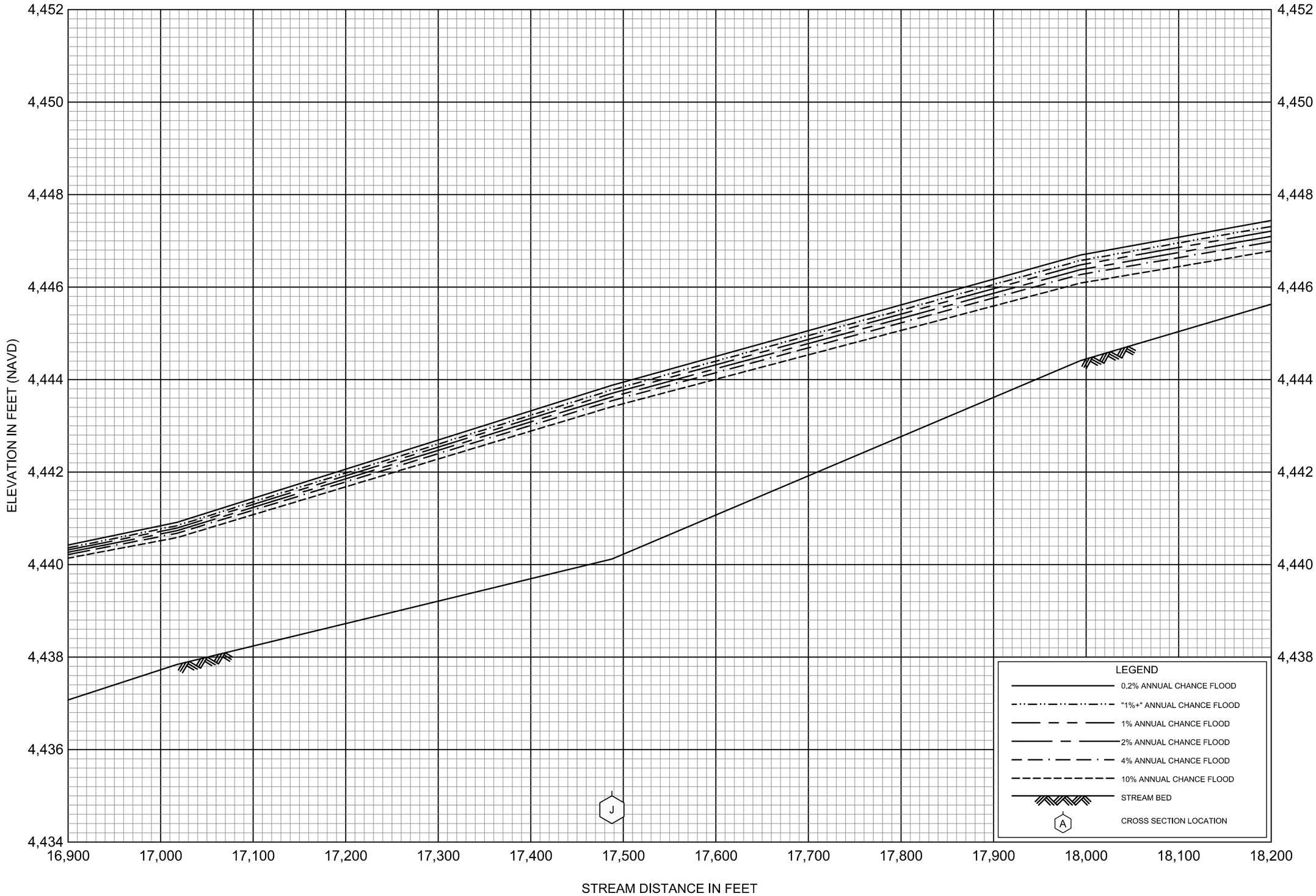
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



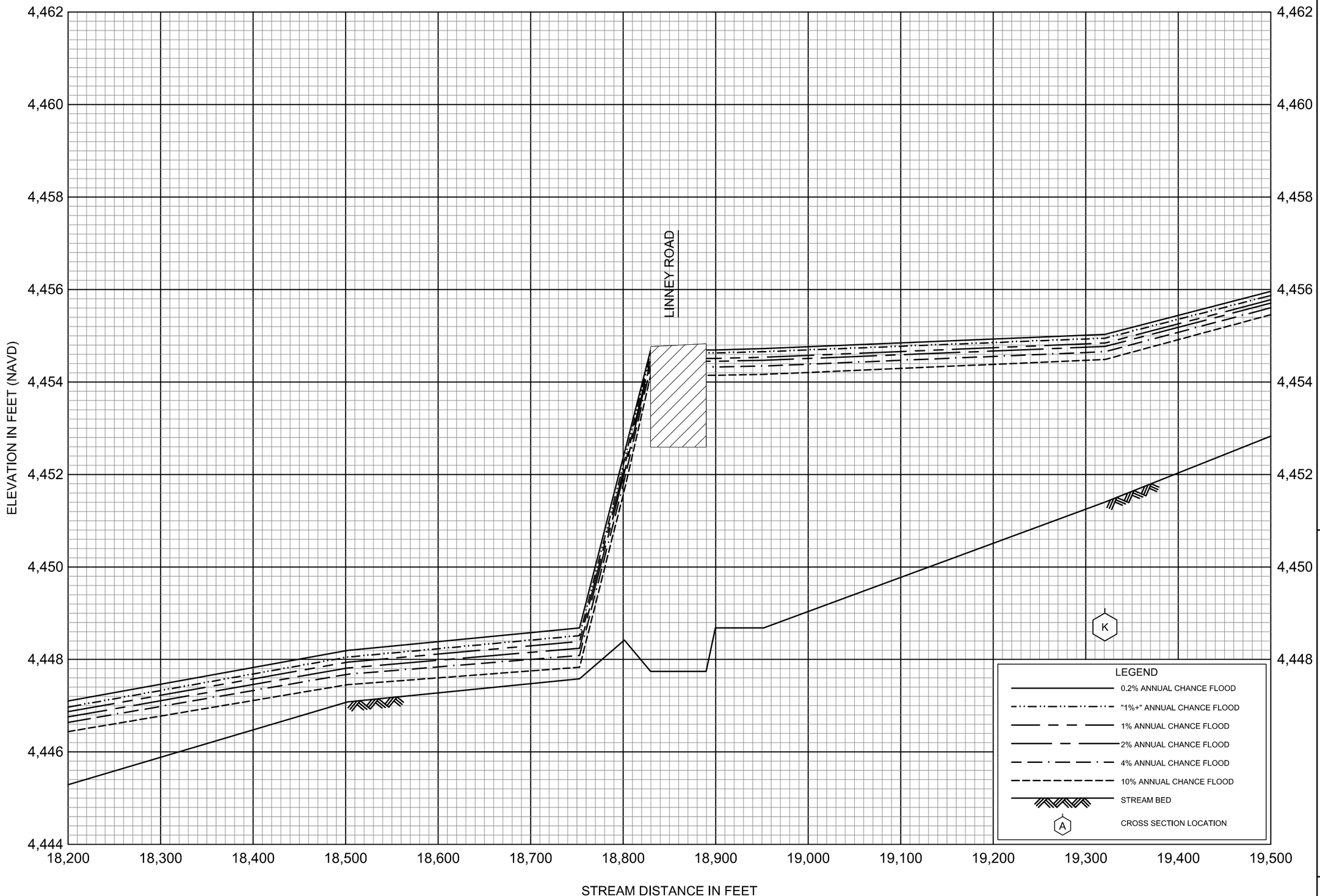
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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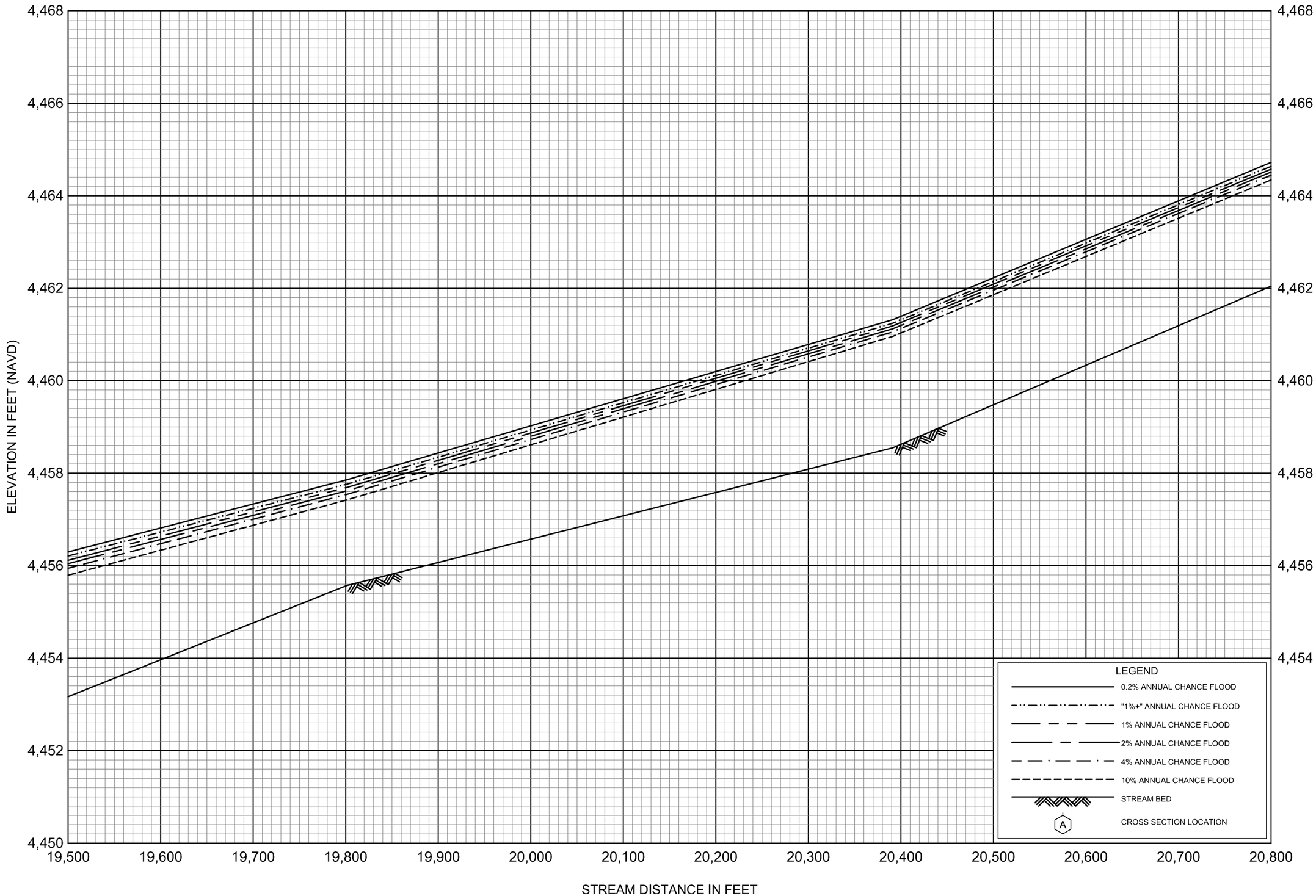

FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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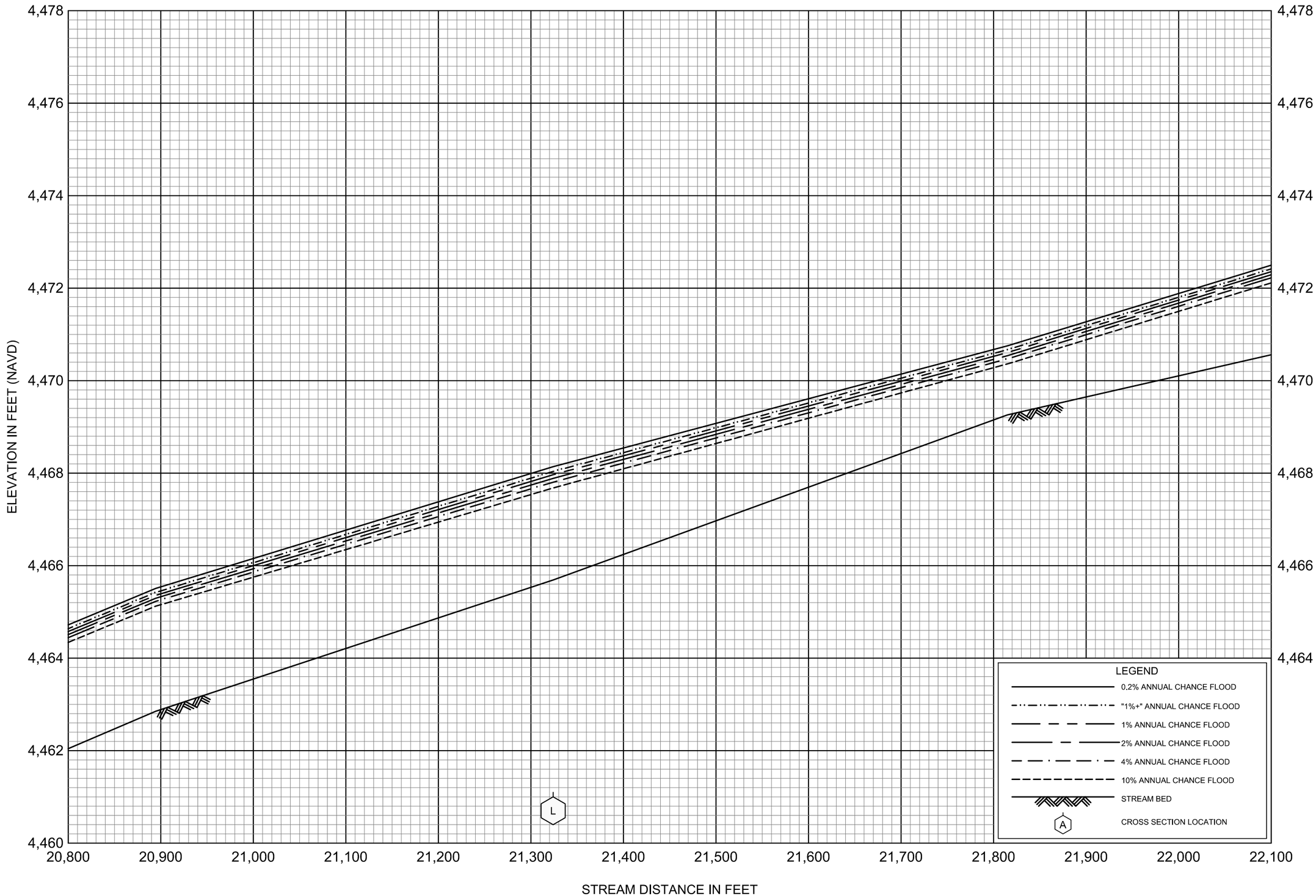

FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

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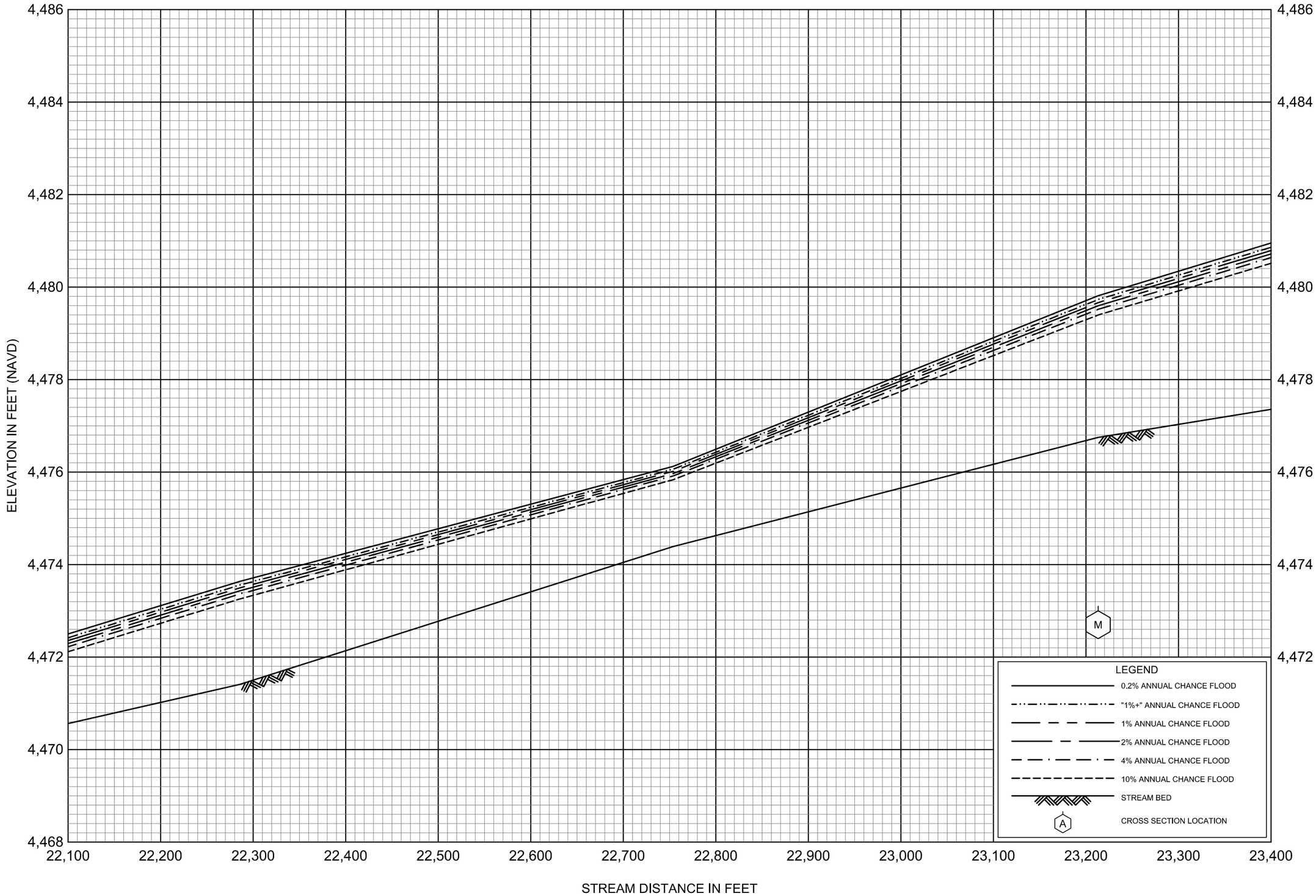
AND INCORPORATED AREAS

064P



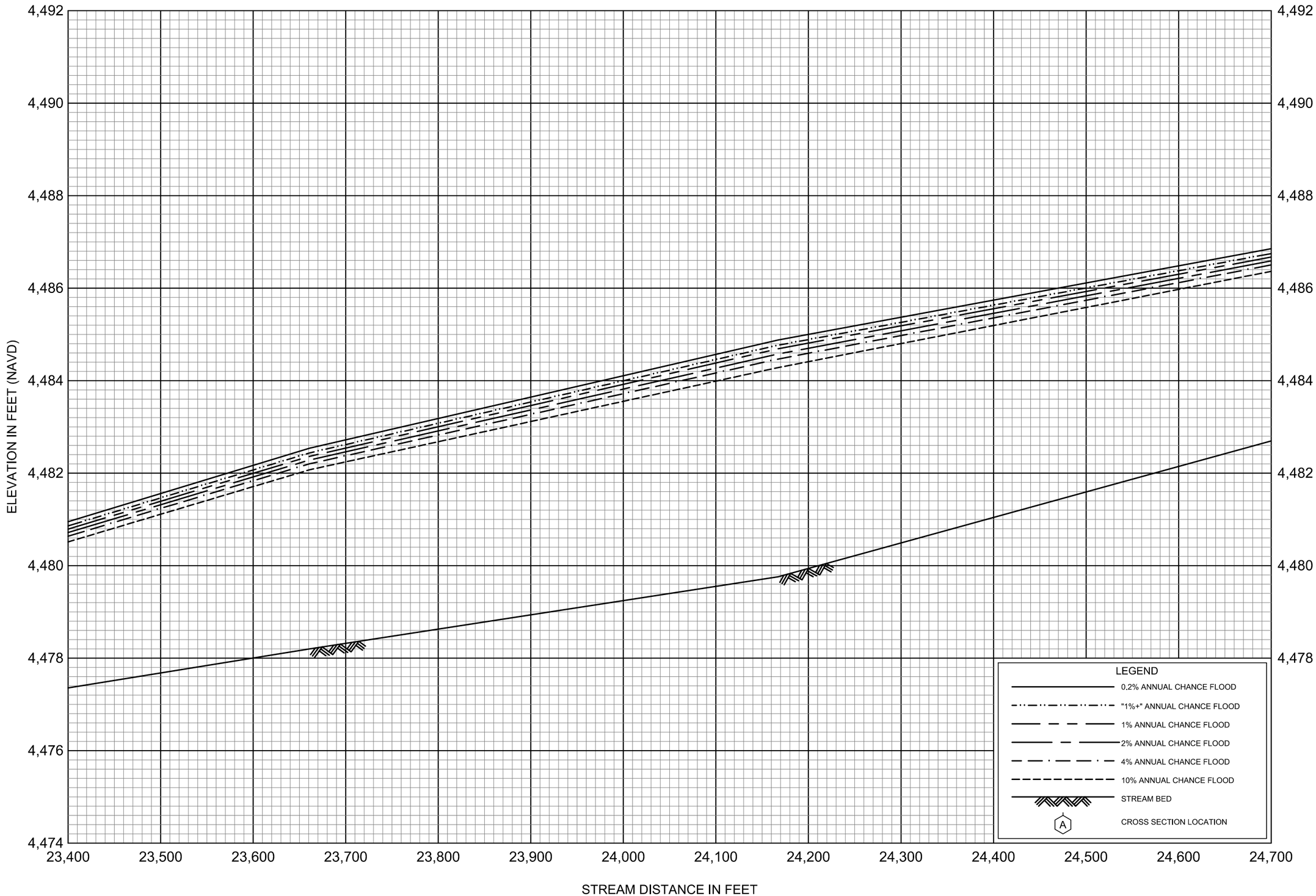
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

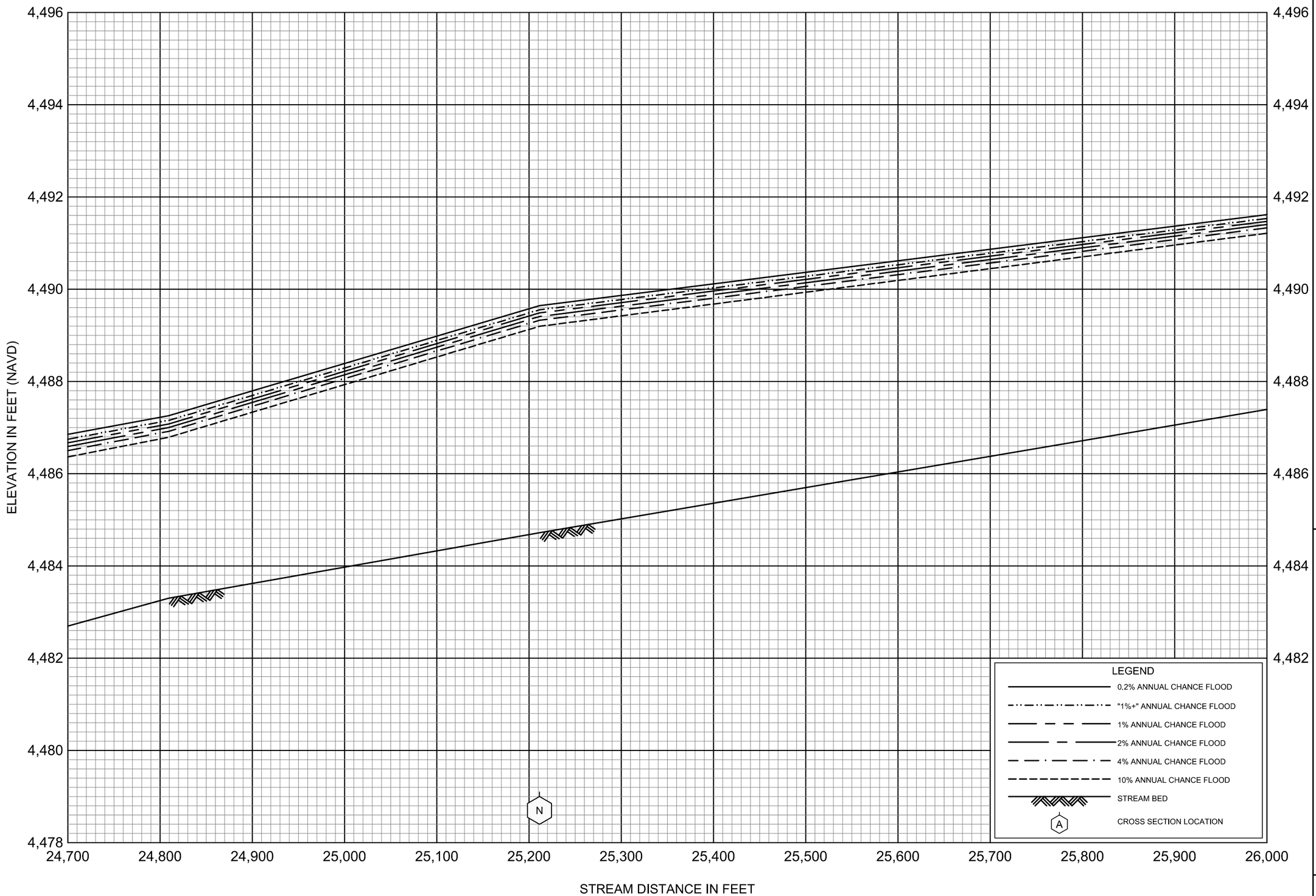
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

066P



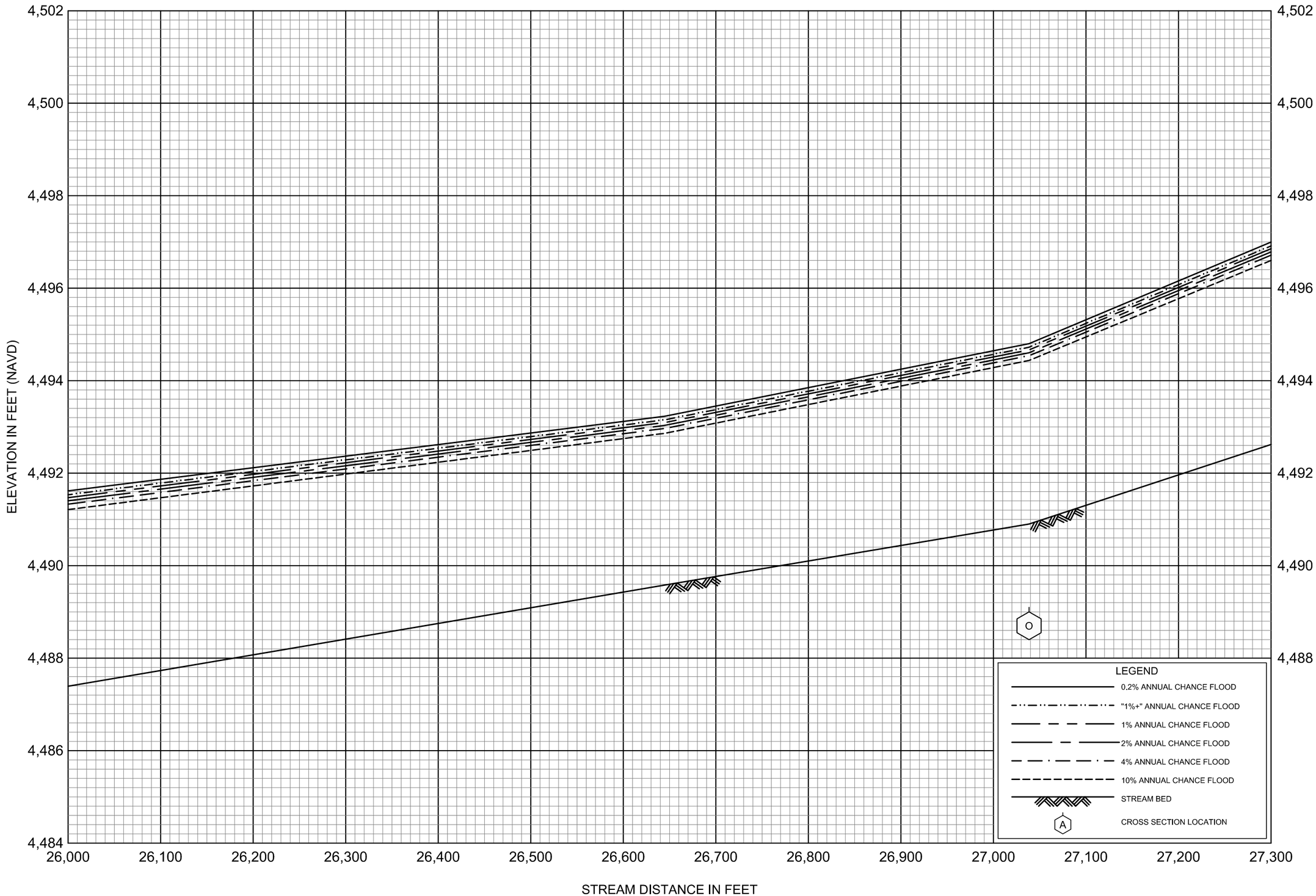
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

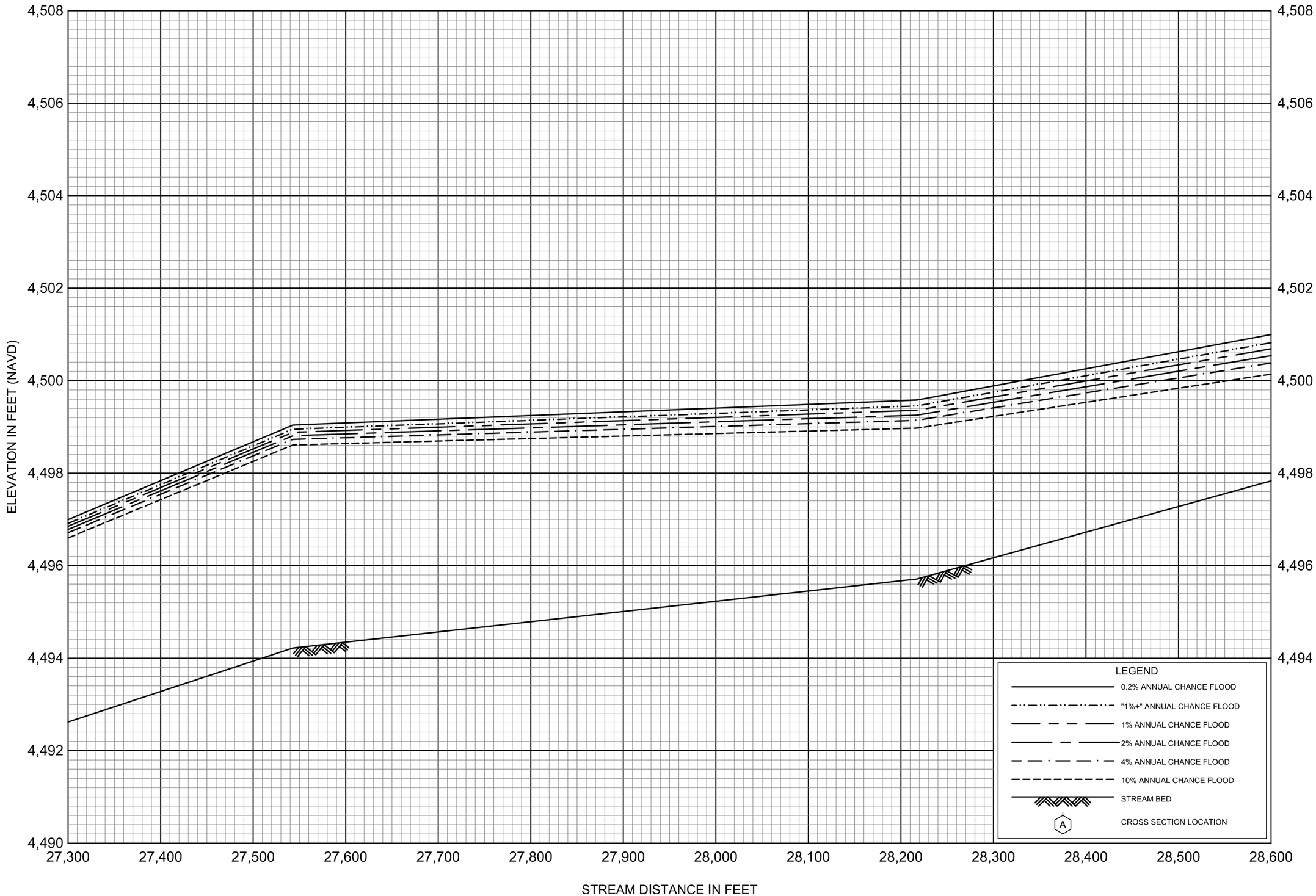
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

068P



FLOOD PROFILES

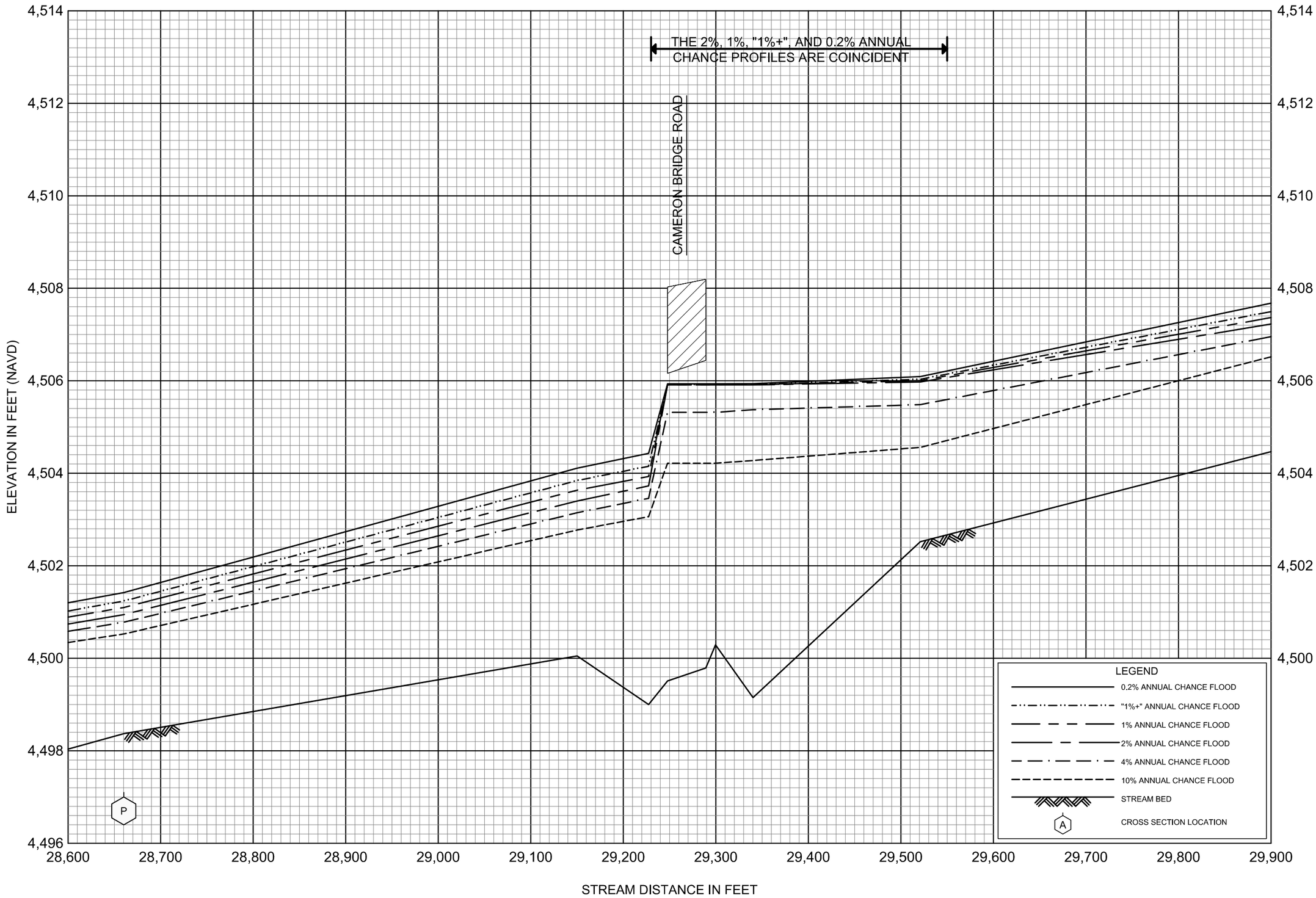
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

069P



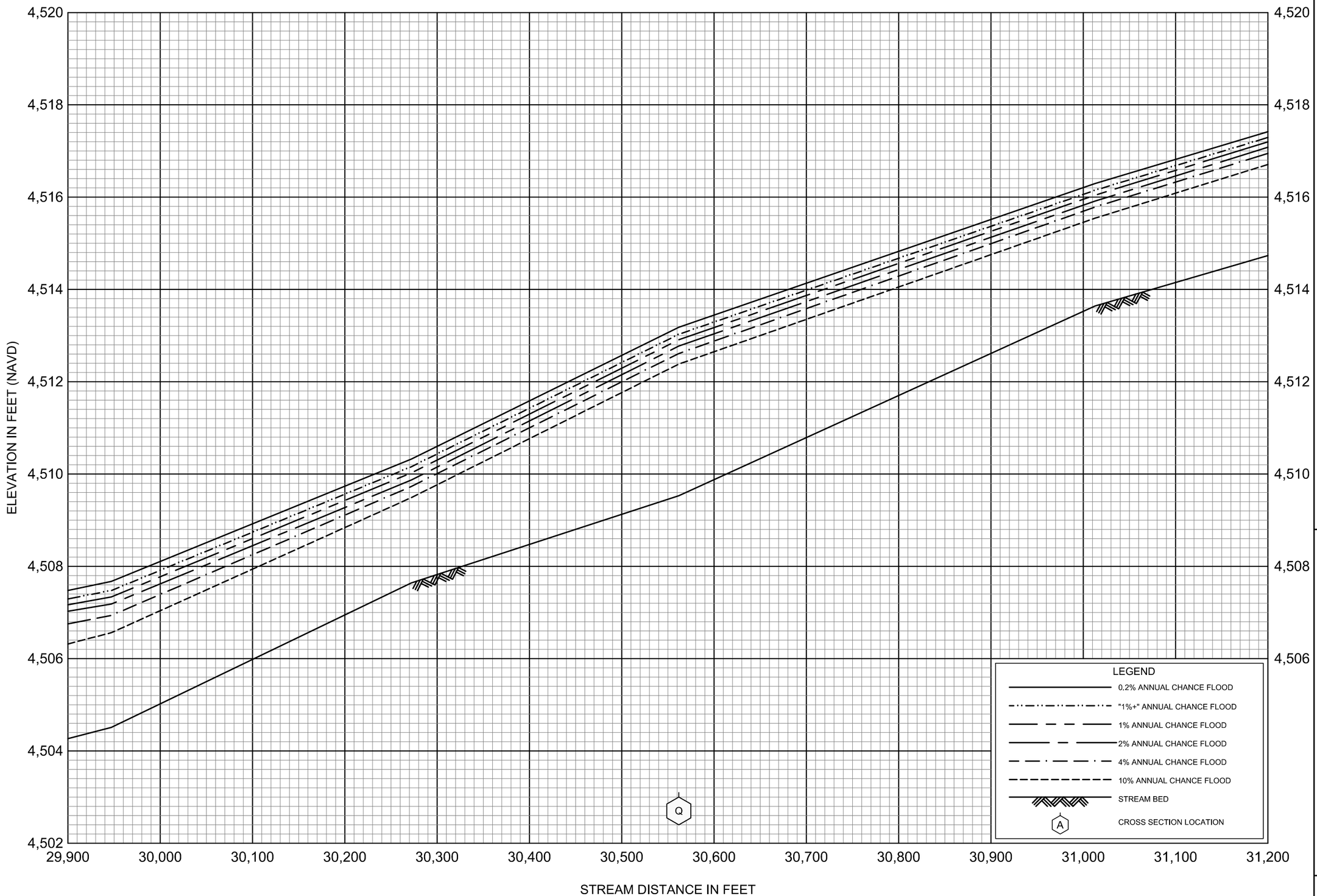
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

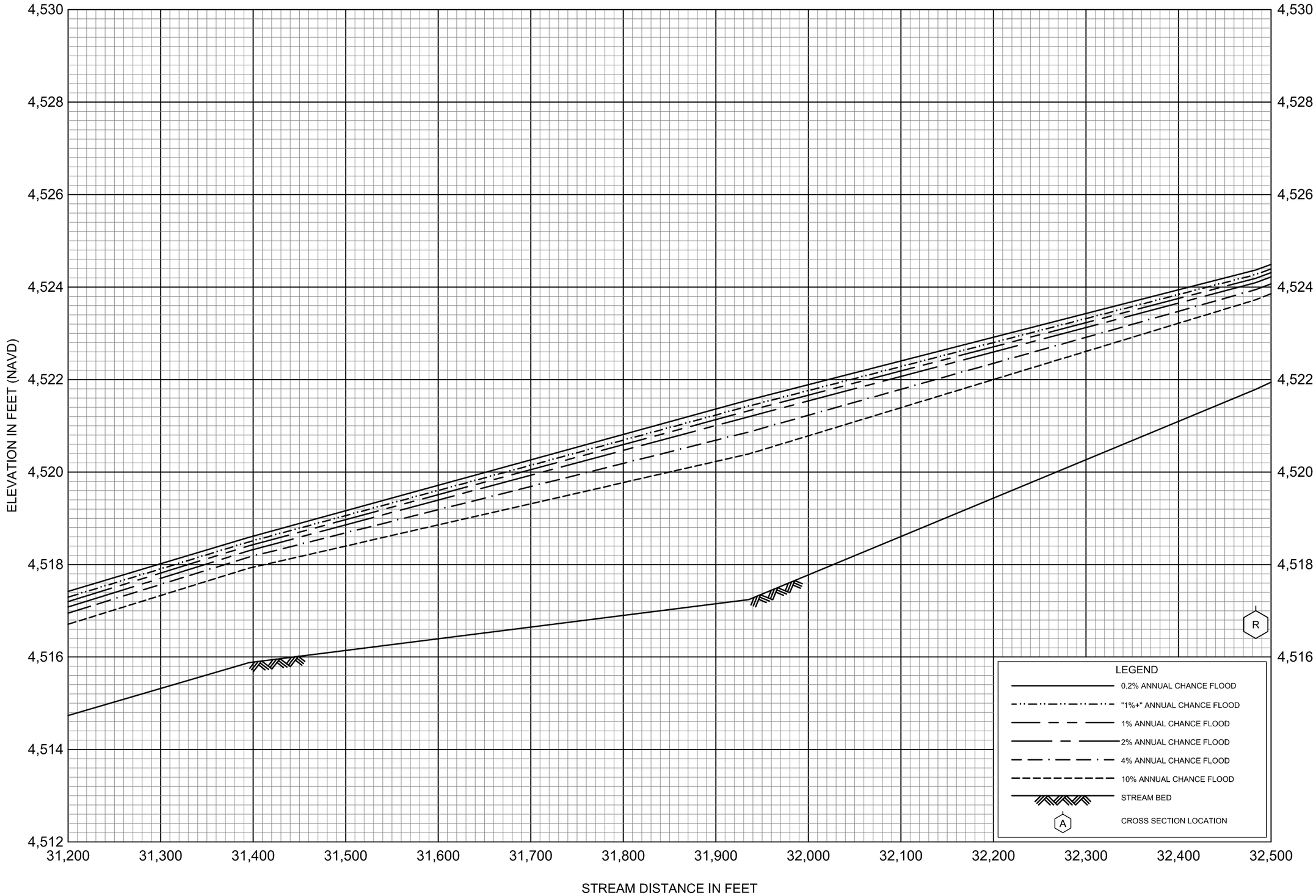
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

071P



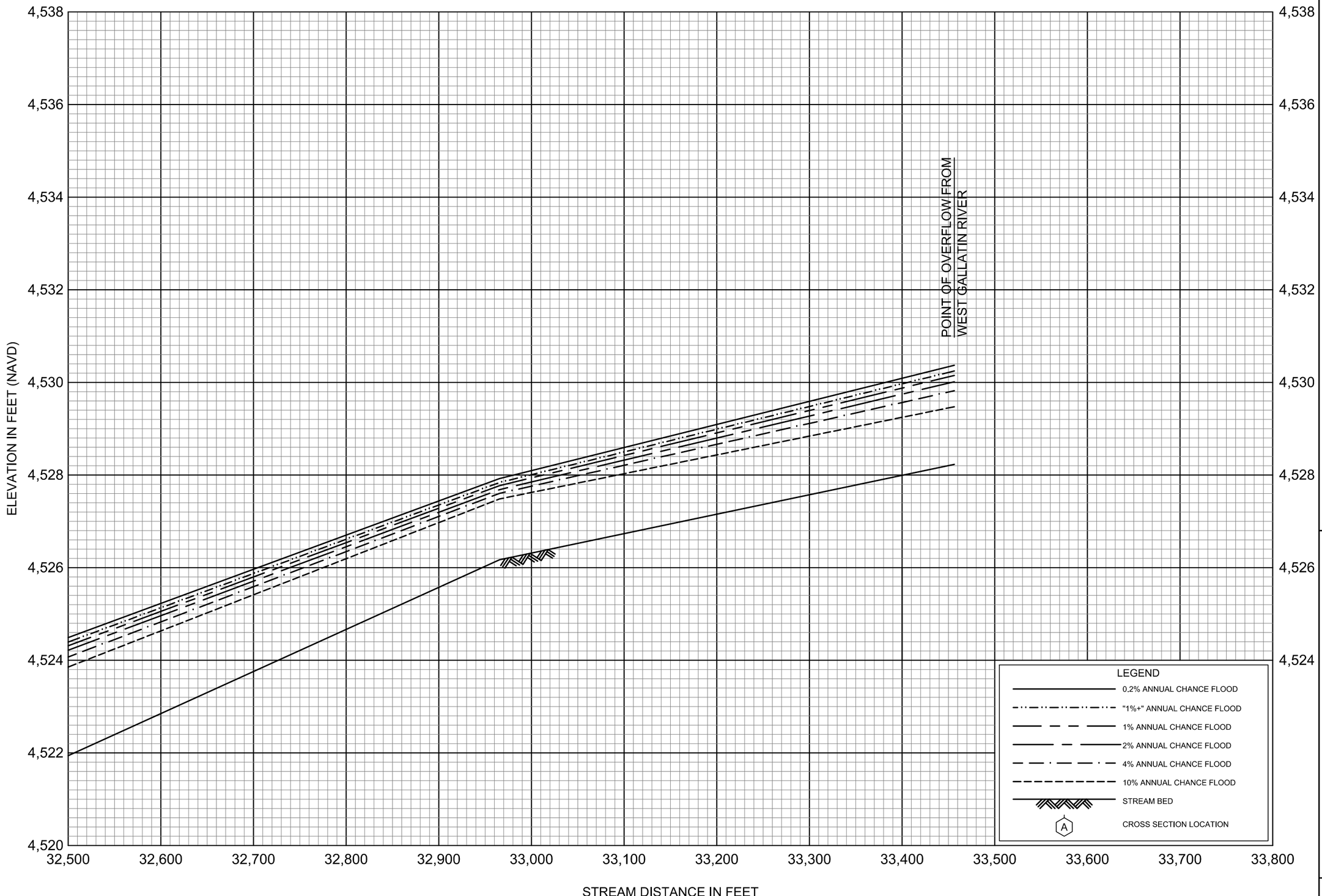
FLOOD PROFILES

BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

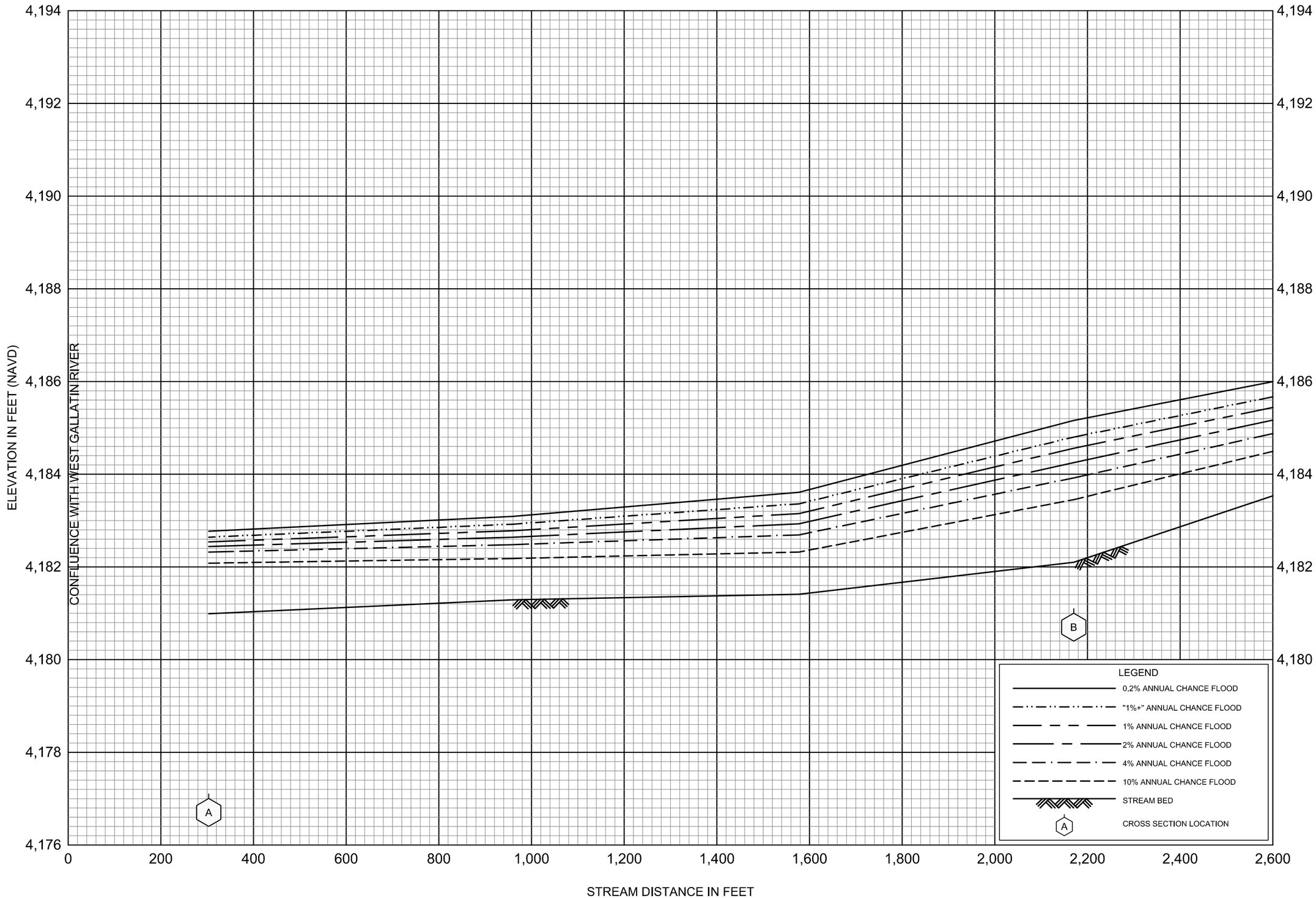
BAKER CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

073P



FLOOD PROFILES

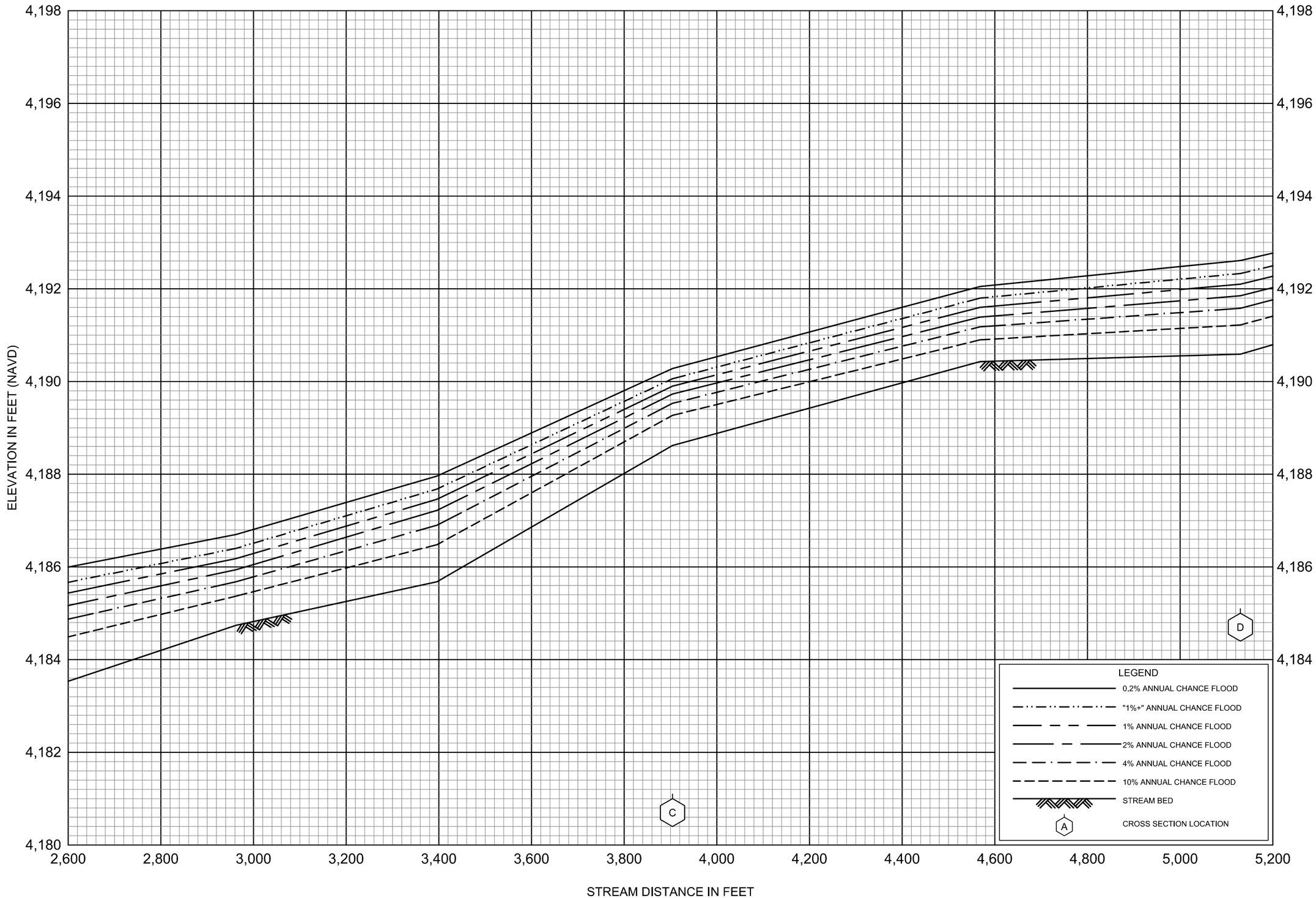
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

074P



FLOOD PROFILES

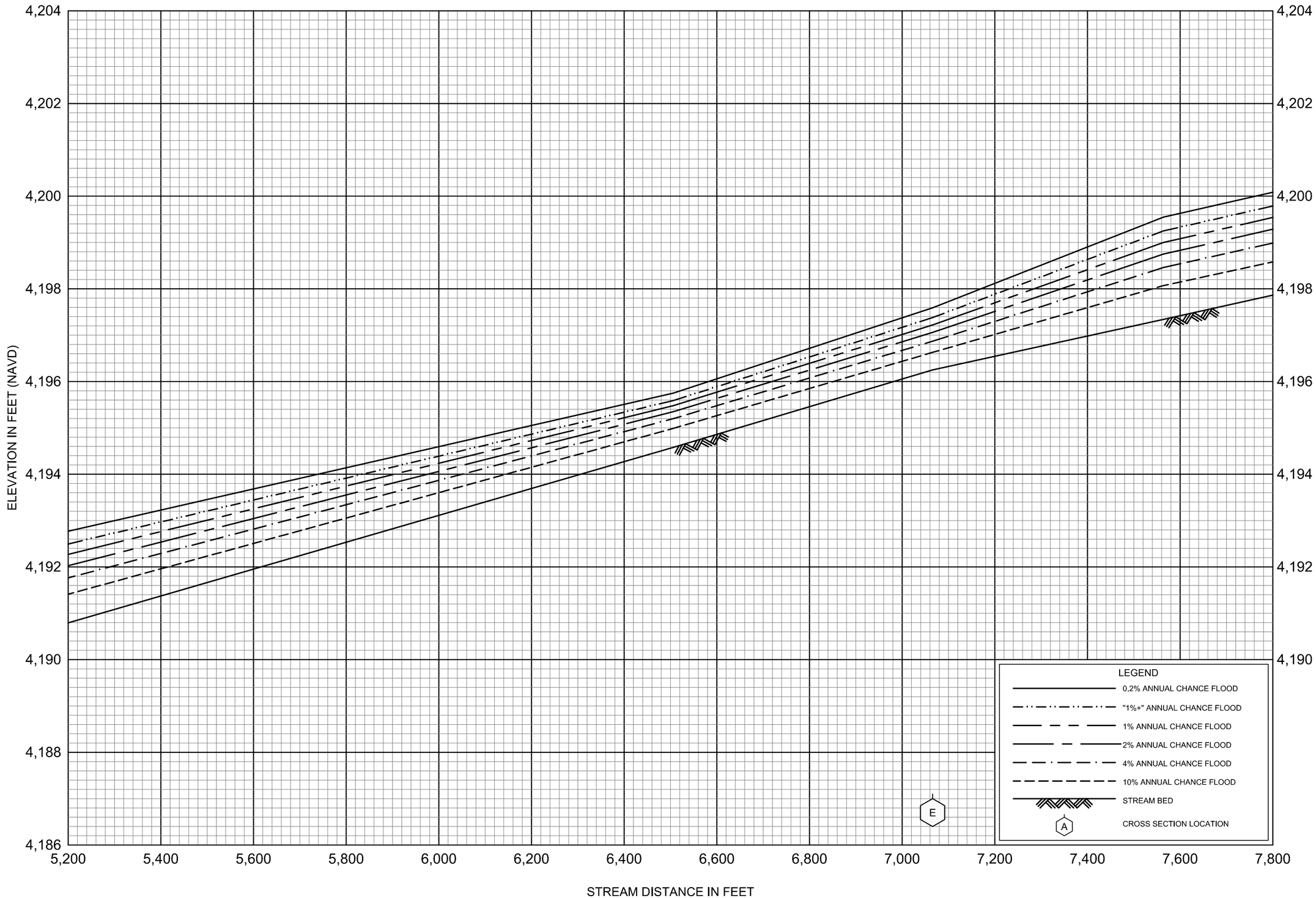
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

075P



FLOOD PROFILES

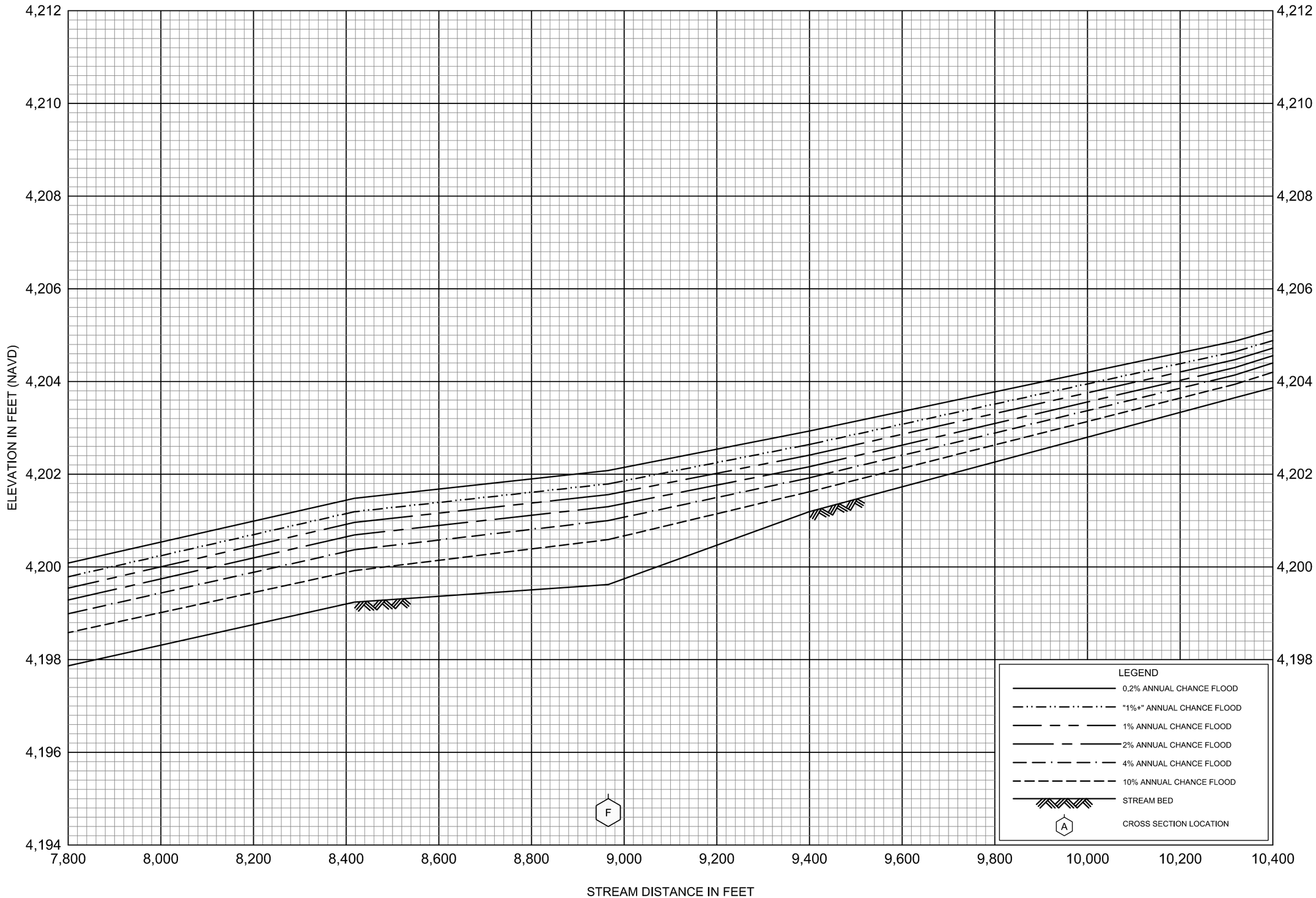
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

076P



FLOOD PROFILES

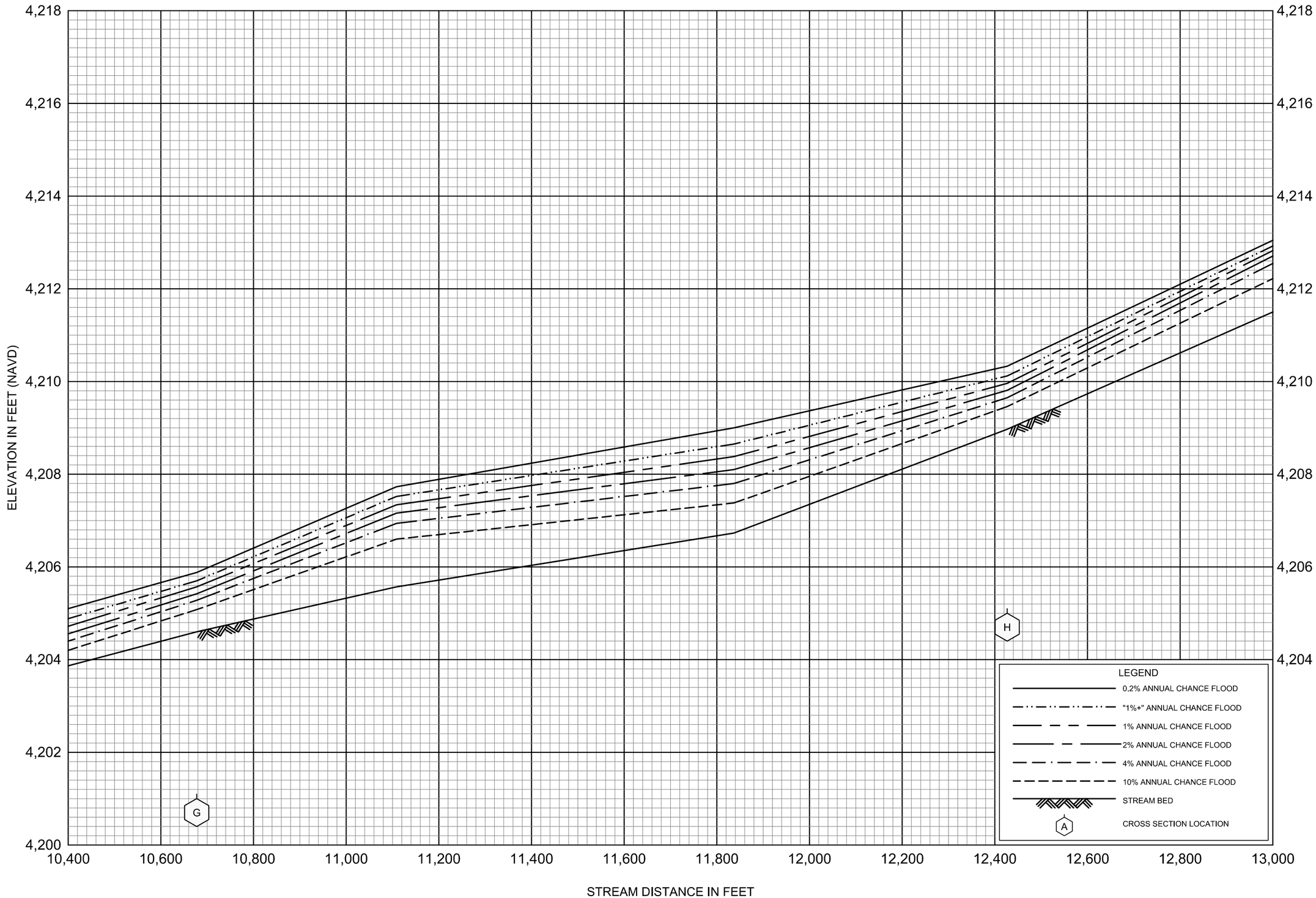
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

077P



FLOOD PROFILES

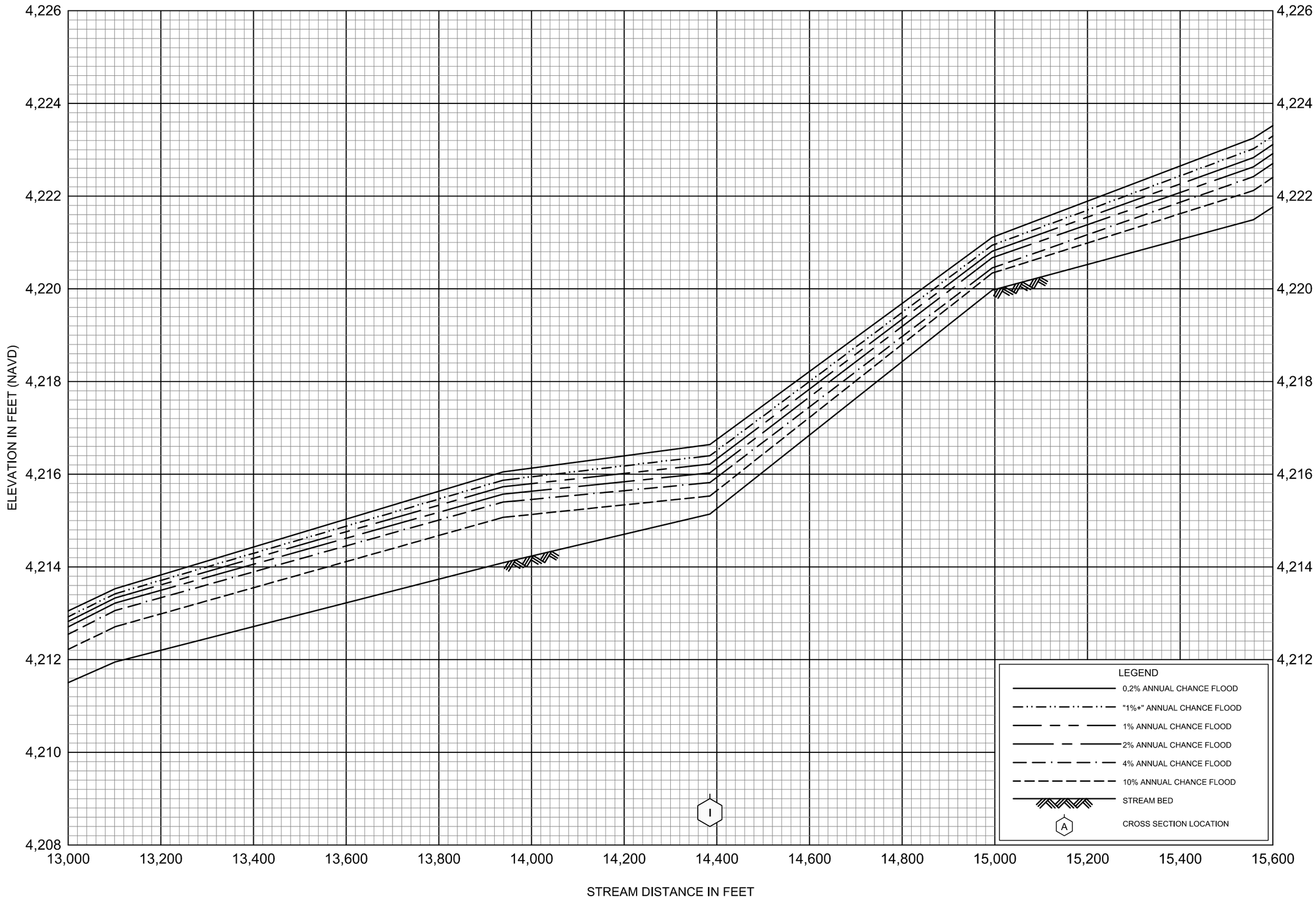
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

078P



FLOOD PROFILES

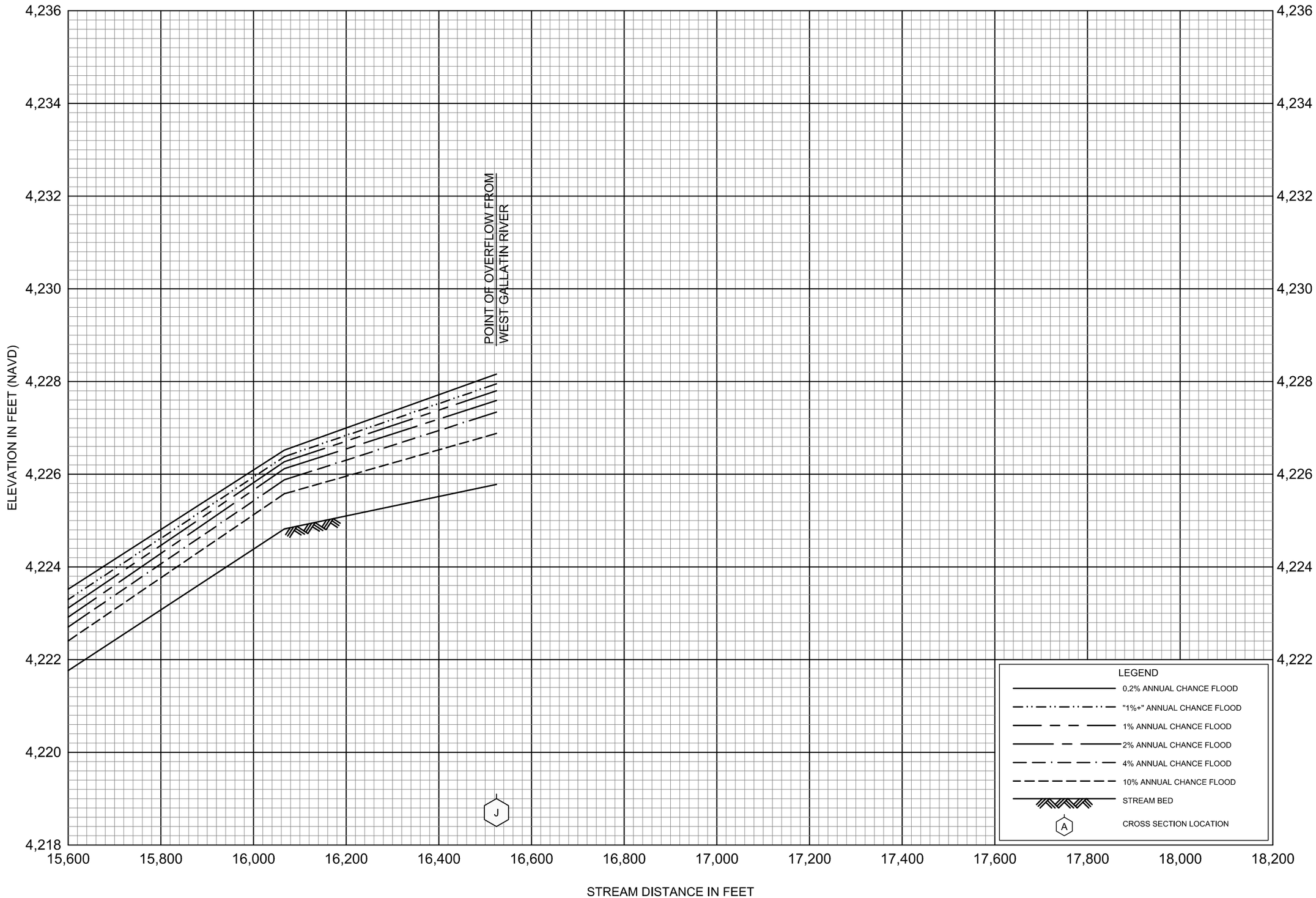
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

079P



FLOOD PROFILES

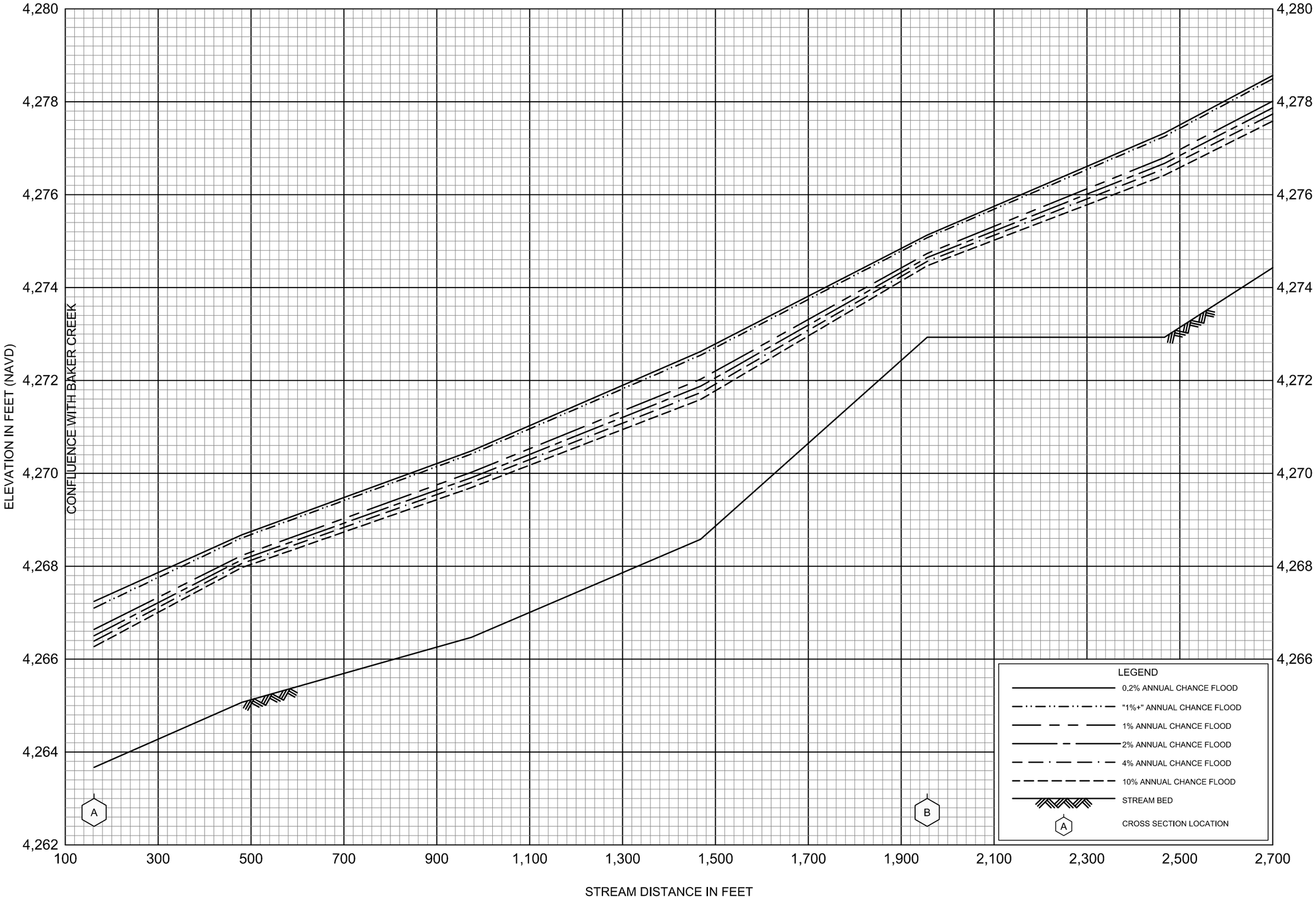
EAST OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

080P



FLOOD PROFILES

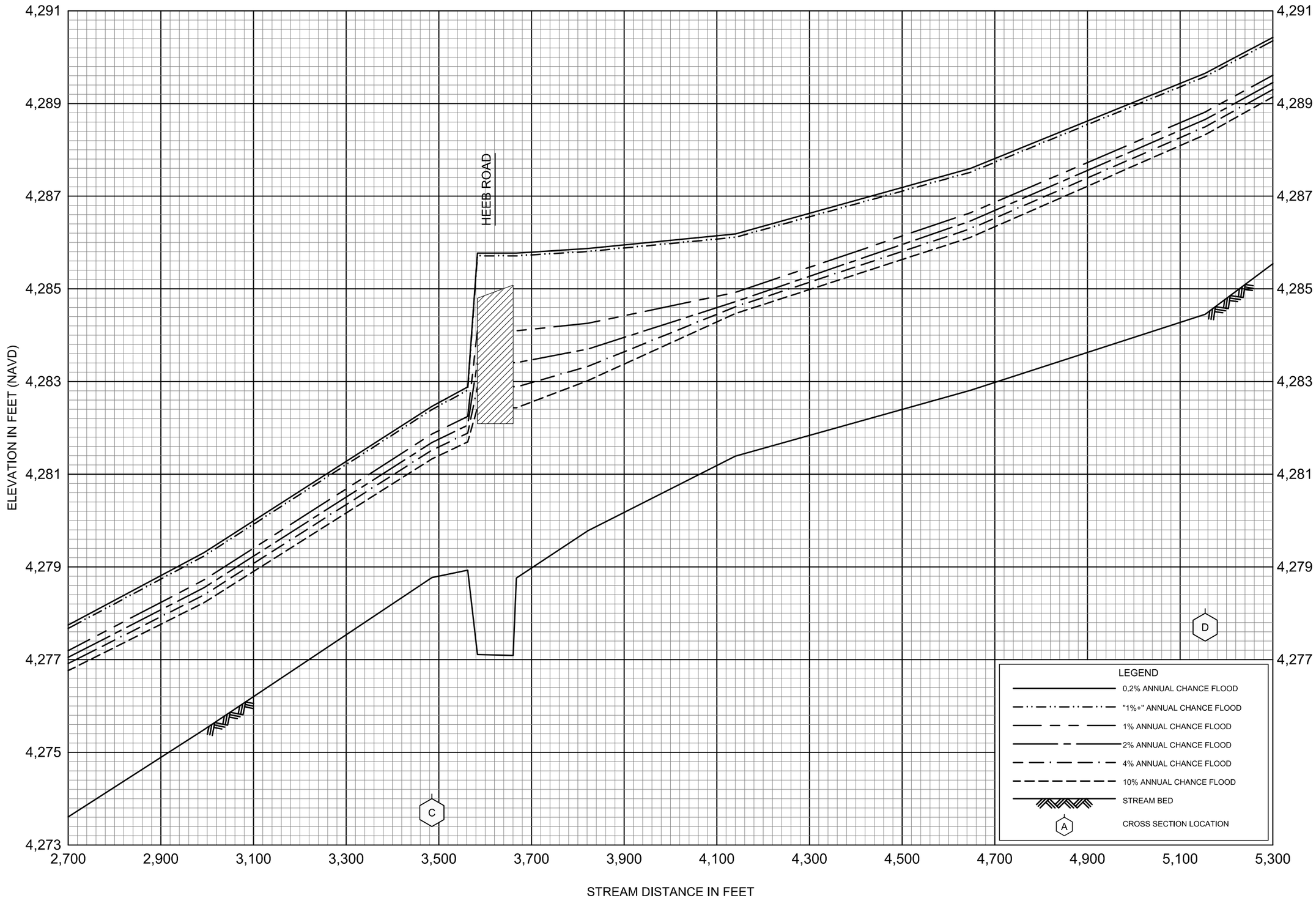
I90 DIVERSION

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

081P



FLOOD PROFILES

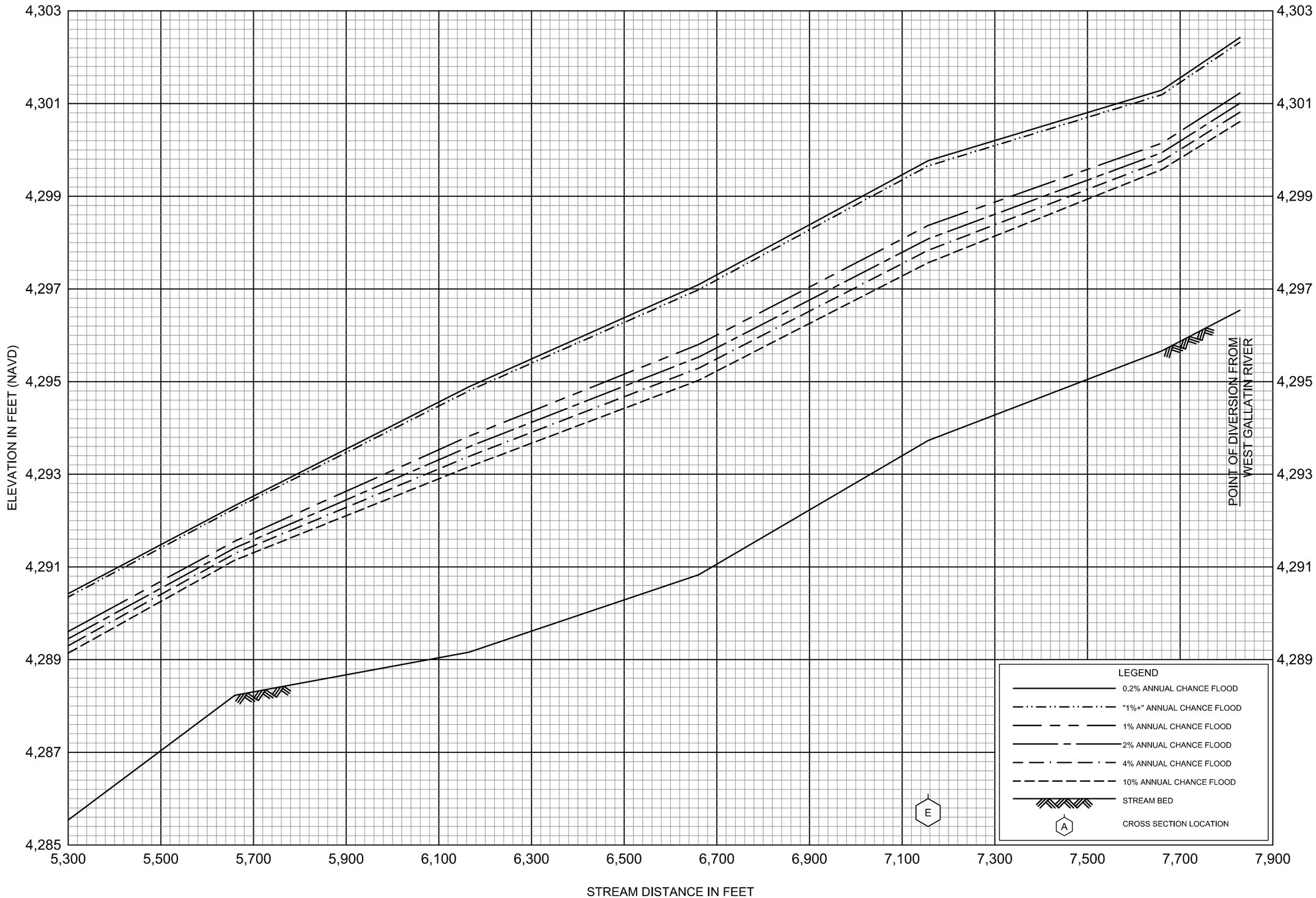
I90 DIVERSION

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

082P



FLOOD PROFILES

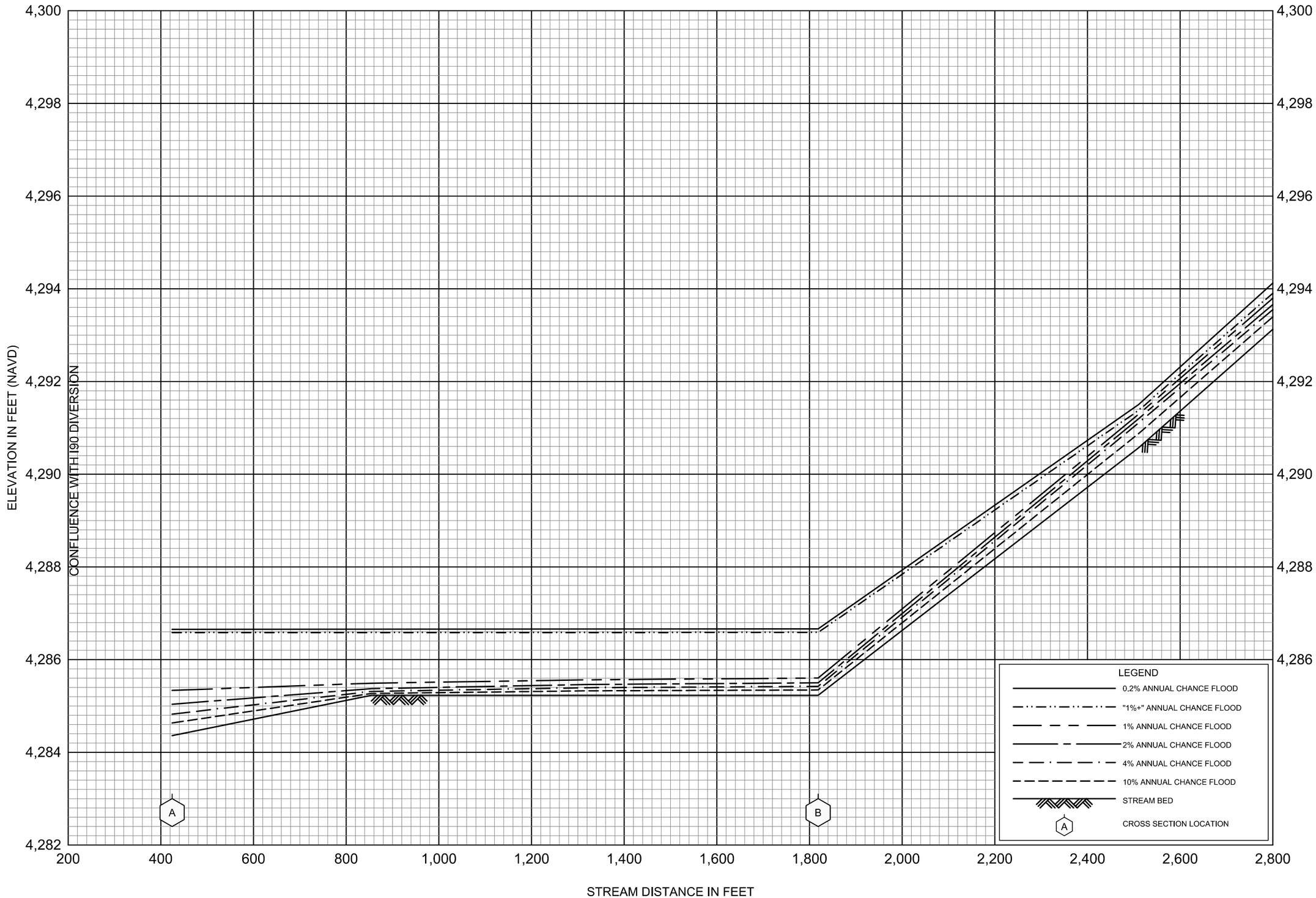
I90 DIVERSION

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

083P



FLOOD PROFILES

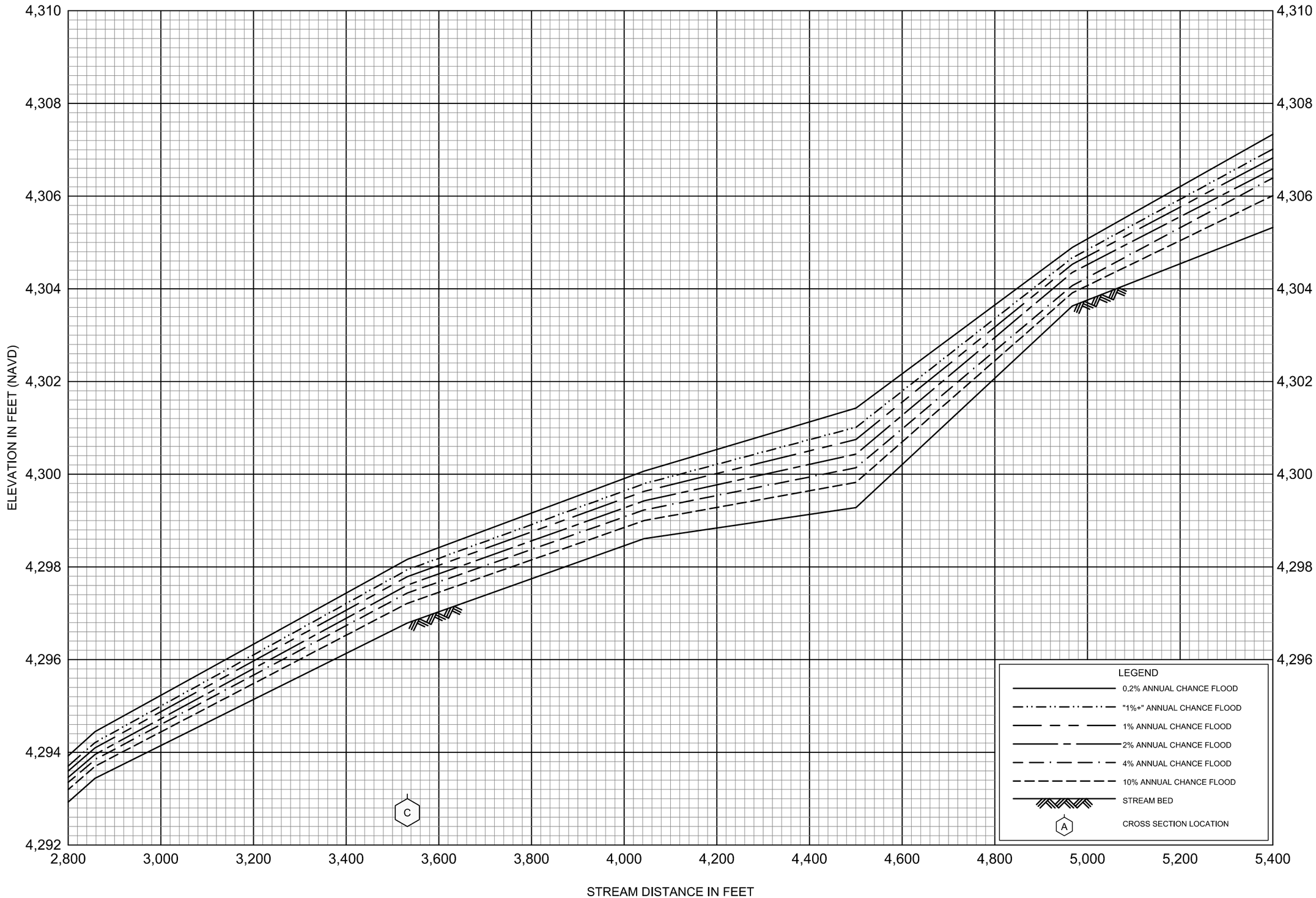
I90 LATERAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

084P



FLOOD PROFILES

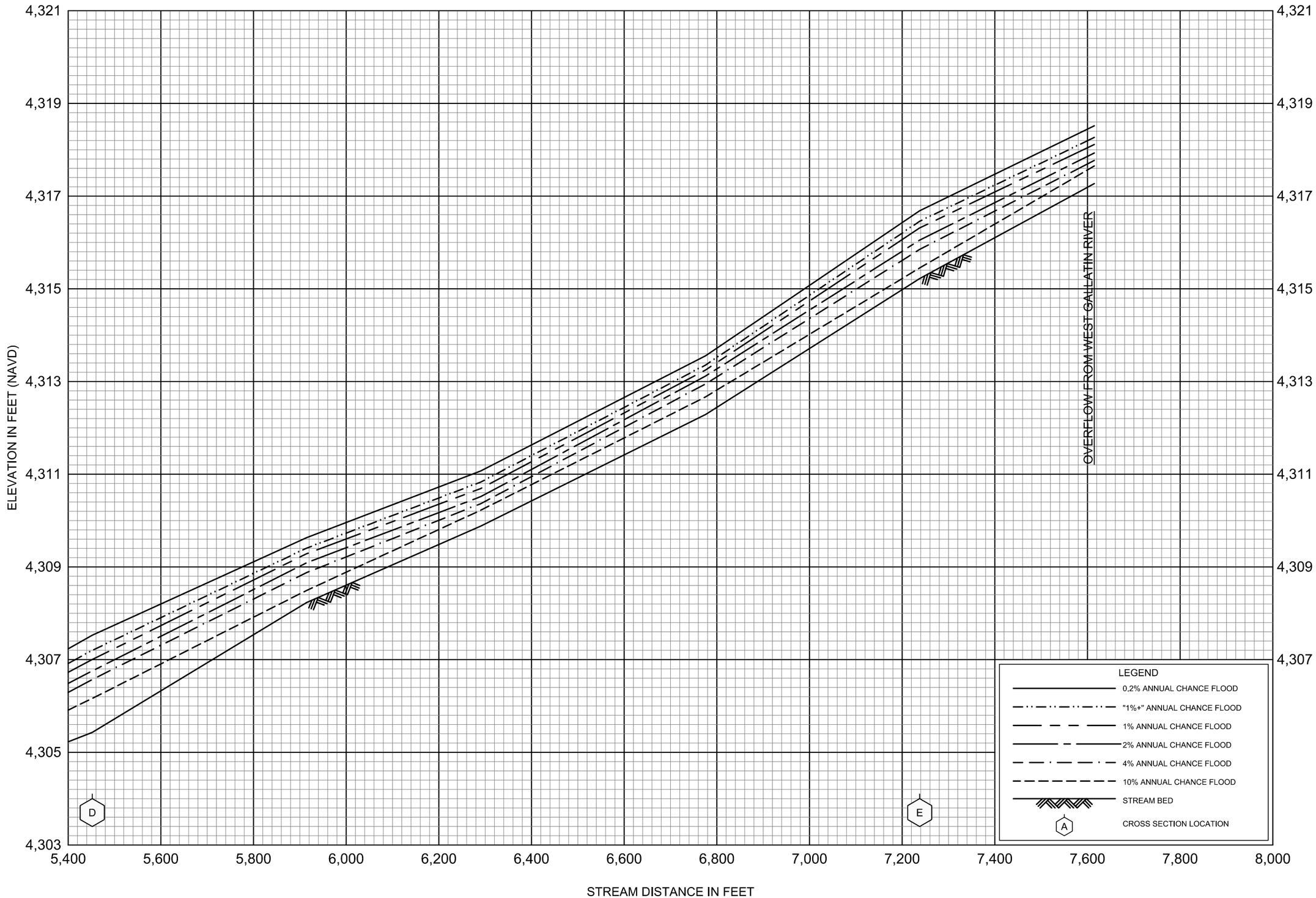
I90 LATERAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

085P



FLOOD PROFILES

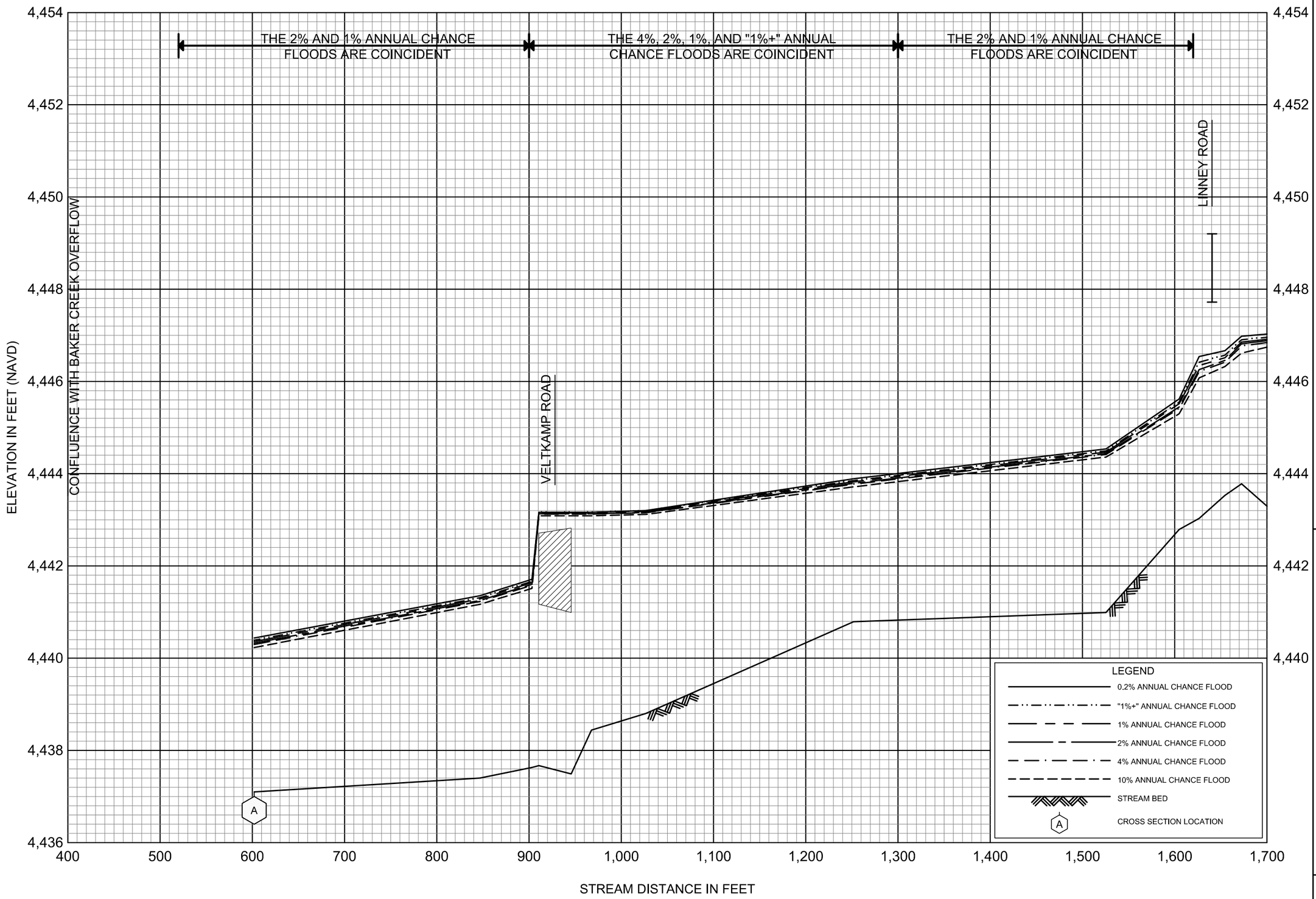
I90 LATERAL

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

086P



FLOOD PROFILES

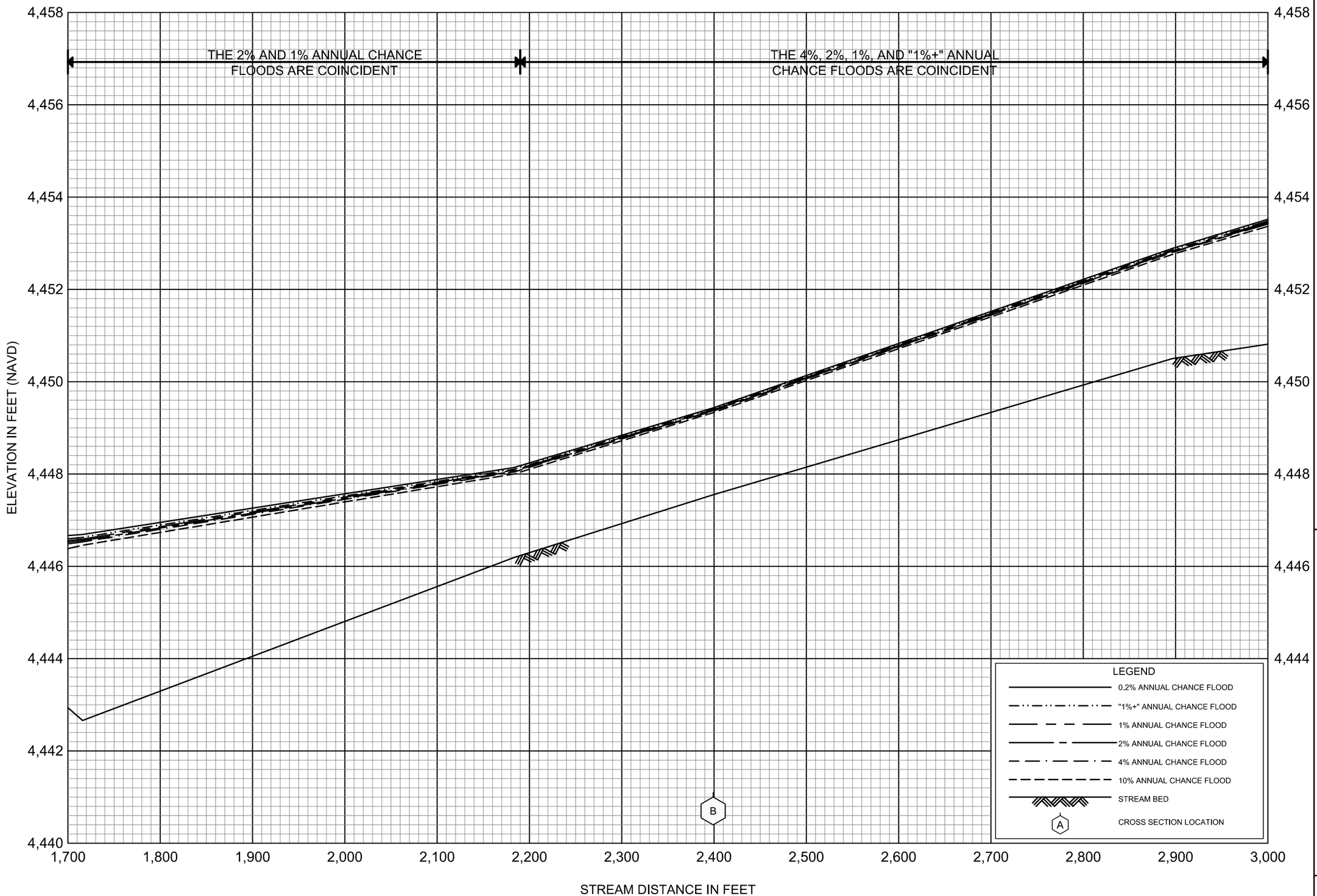
LINNEY ROAD SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

087P



FLOOD PROFILES

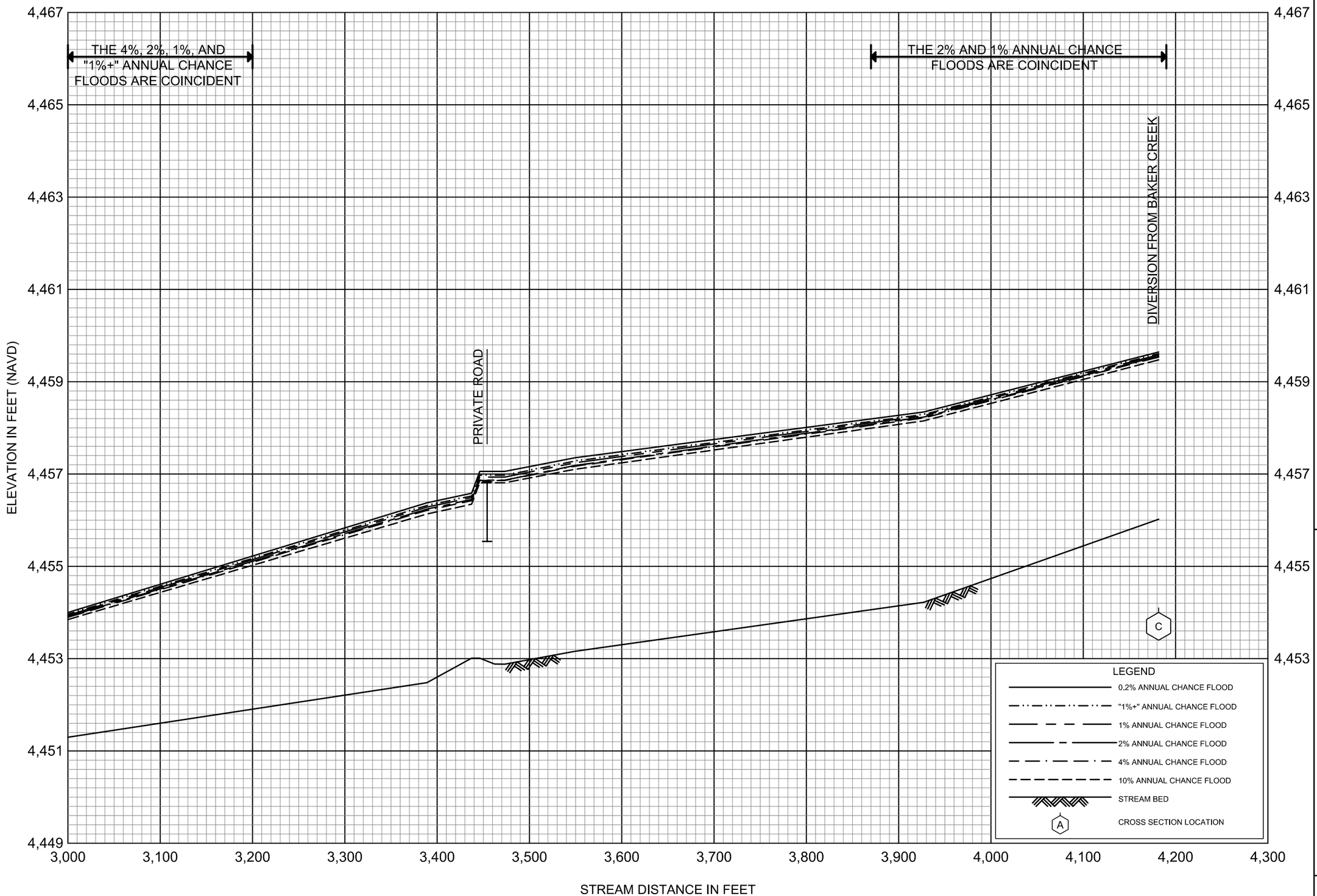
LINNEY ROAD SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

088P



FLOOD PROFILES

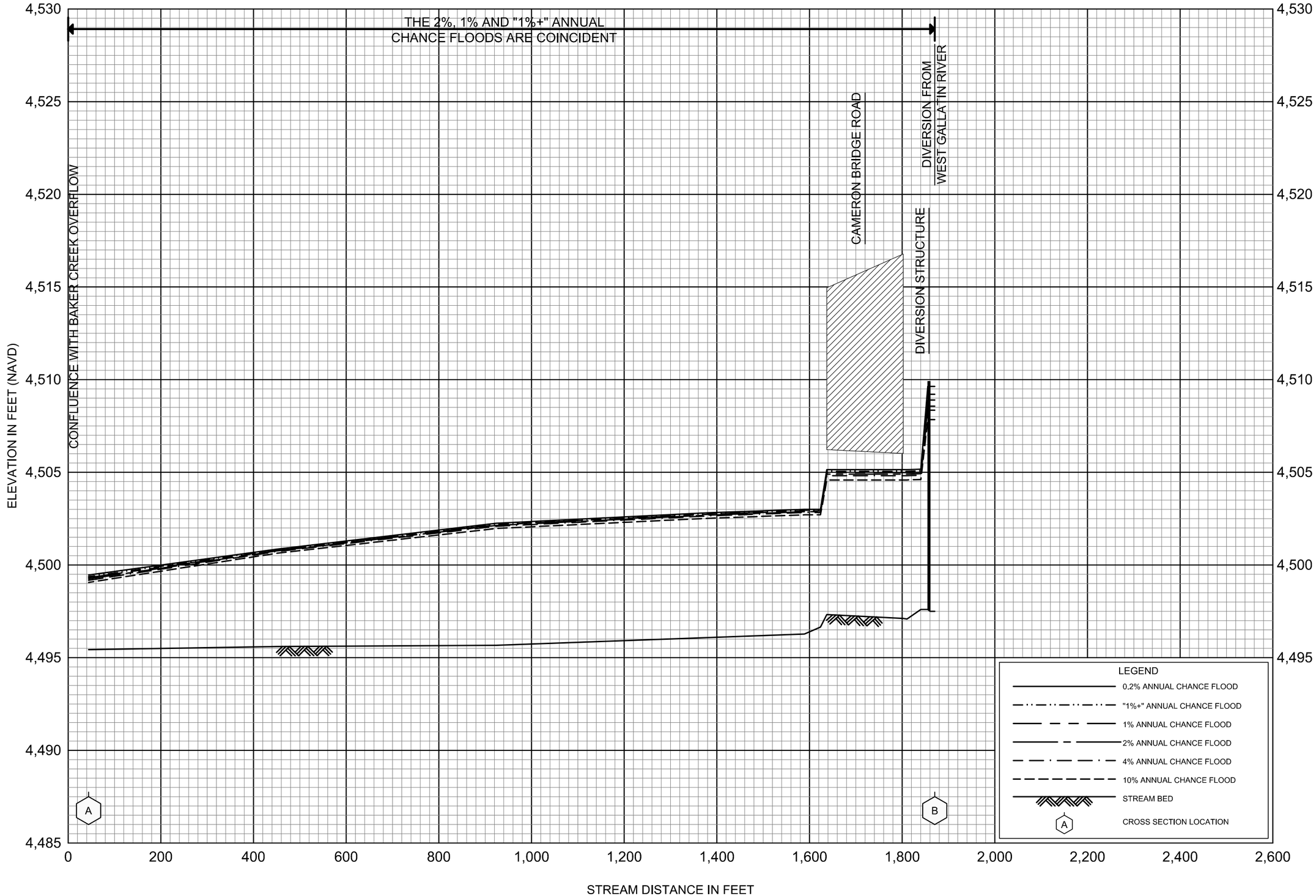
LINNEY ROAD SPLIT

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

089P



FLOOD PROFILES

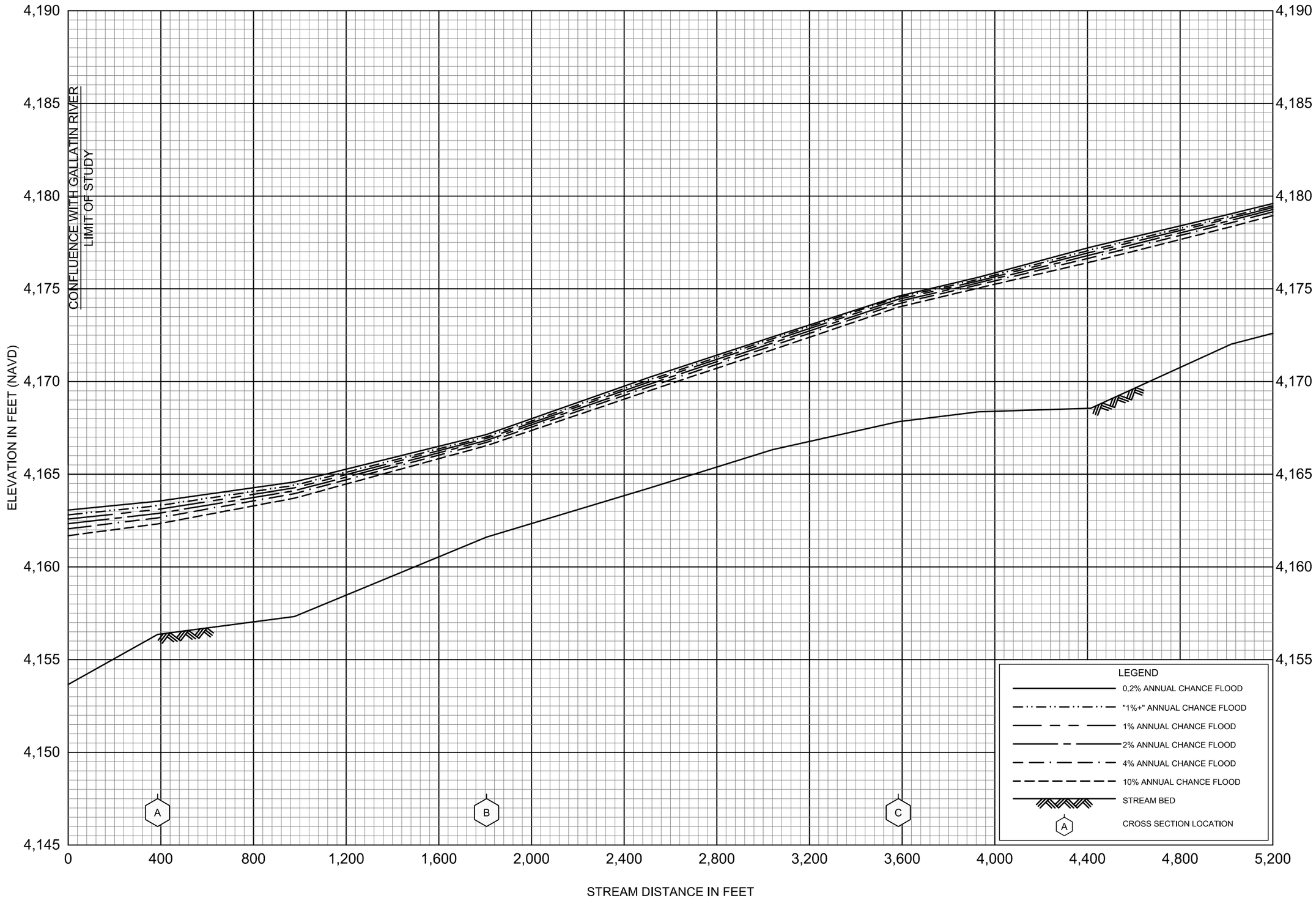
MORELAND DITCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

090P



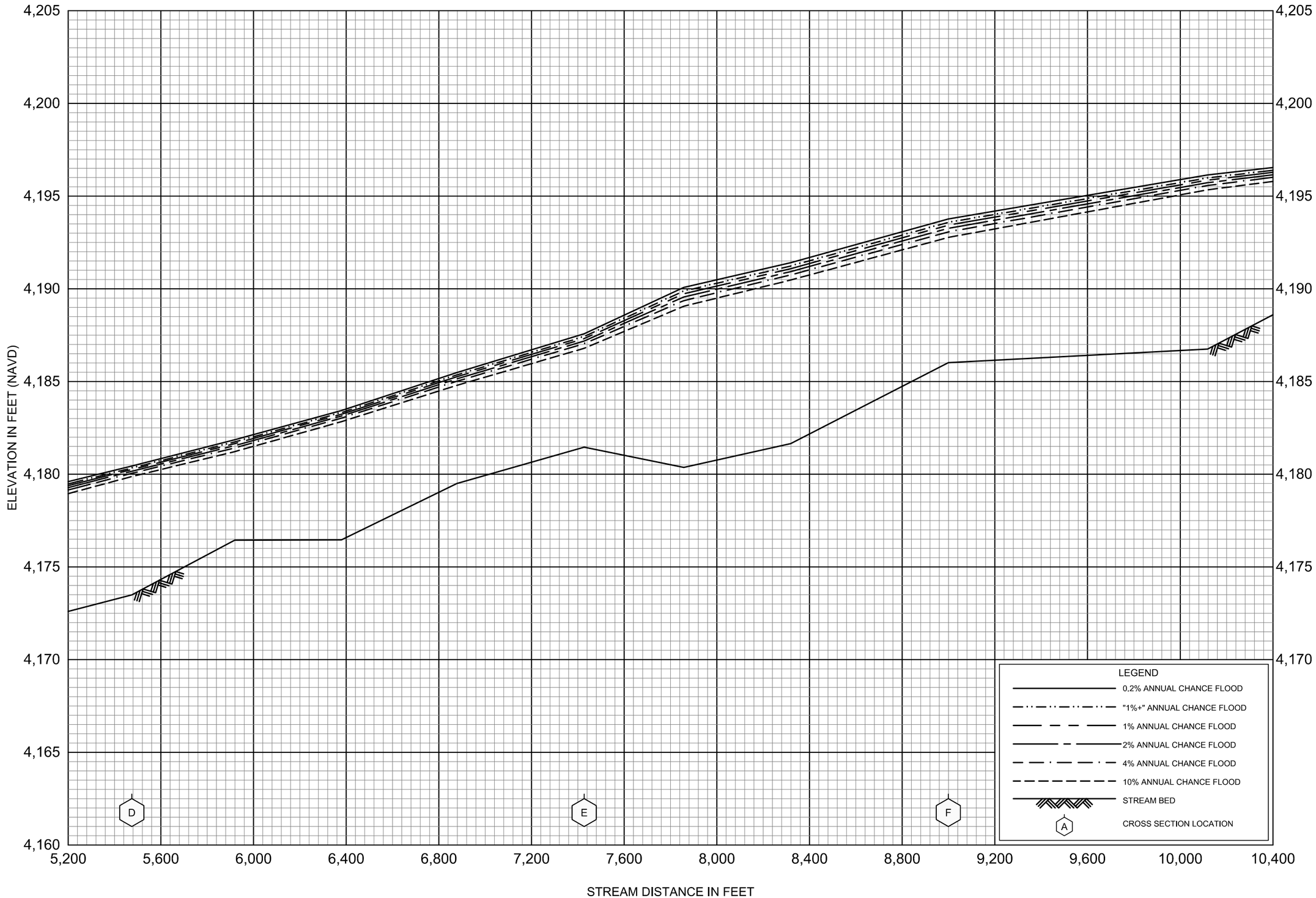
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

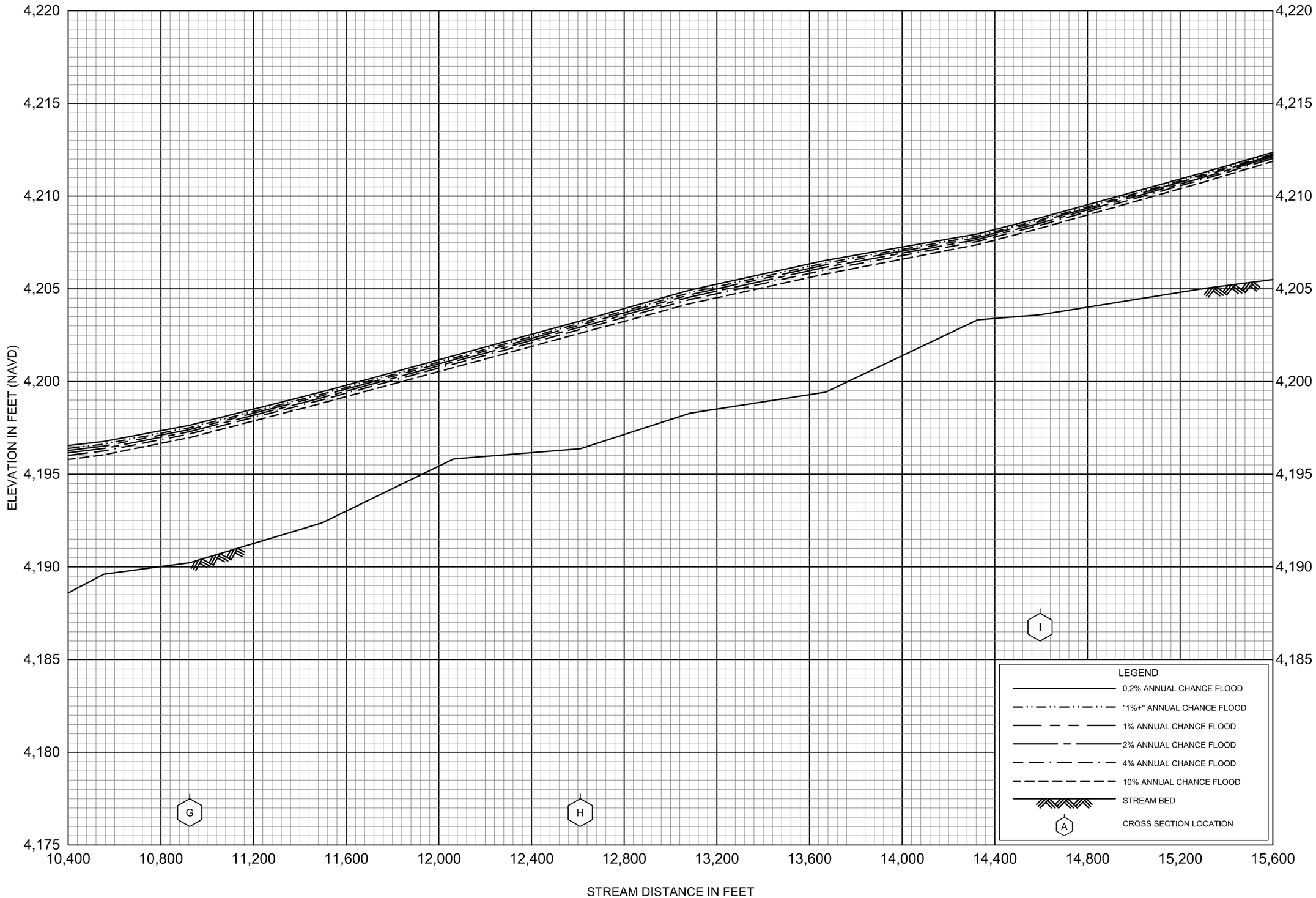
WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

092P



FLOOD PROFILES

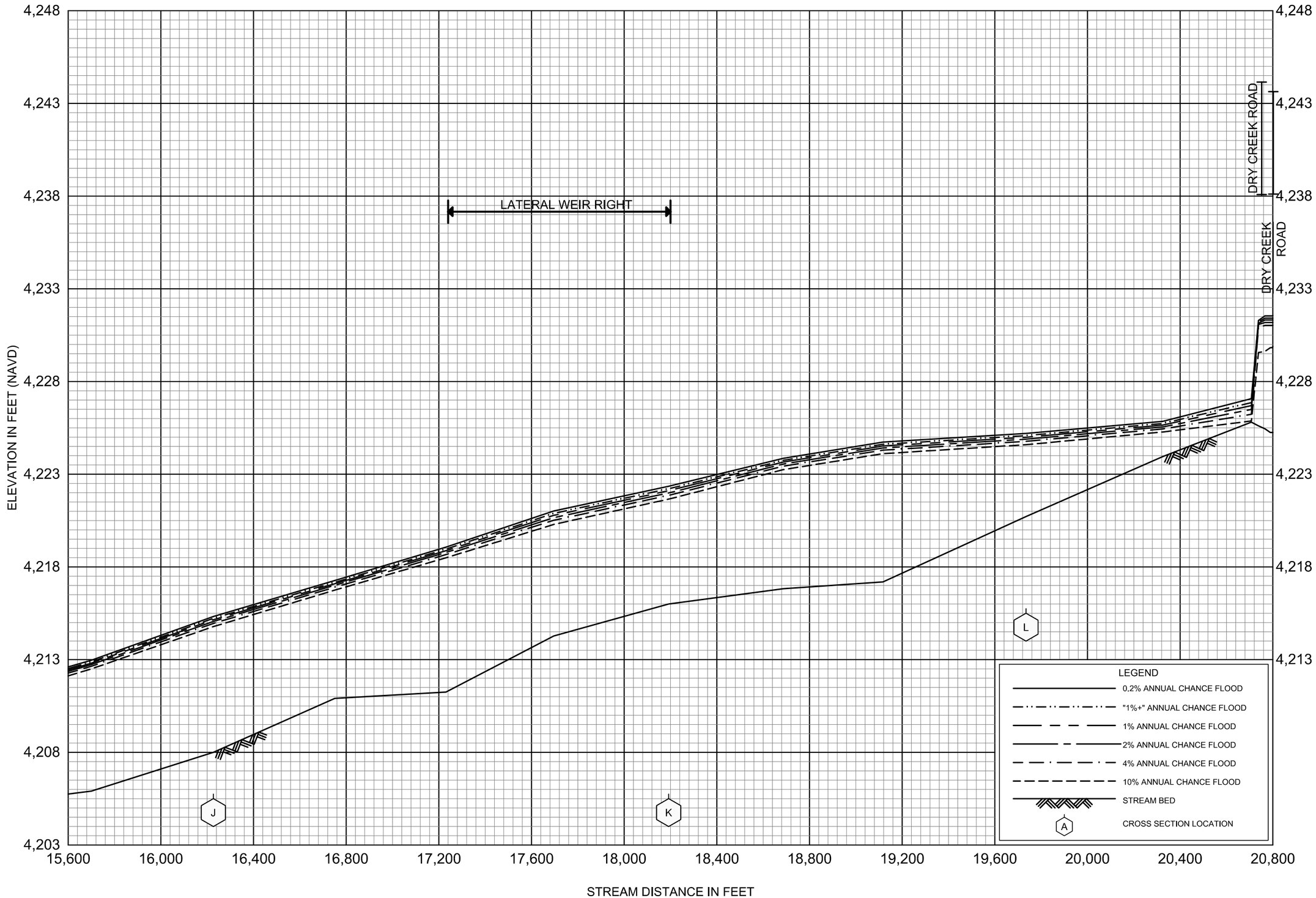
WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

093P



FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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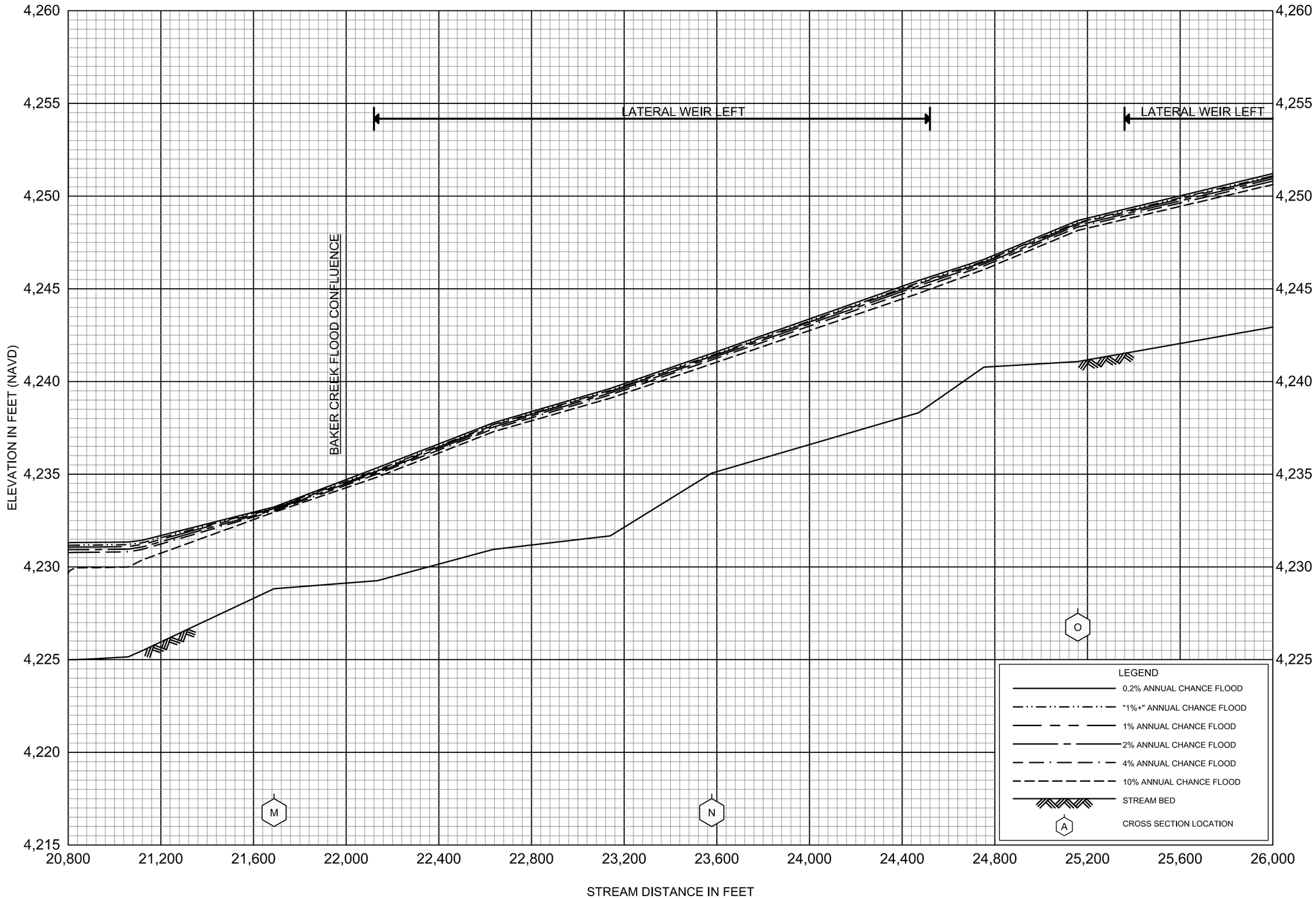

FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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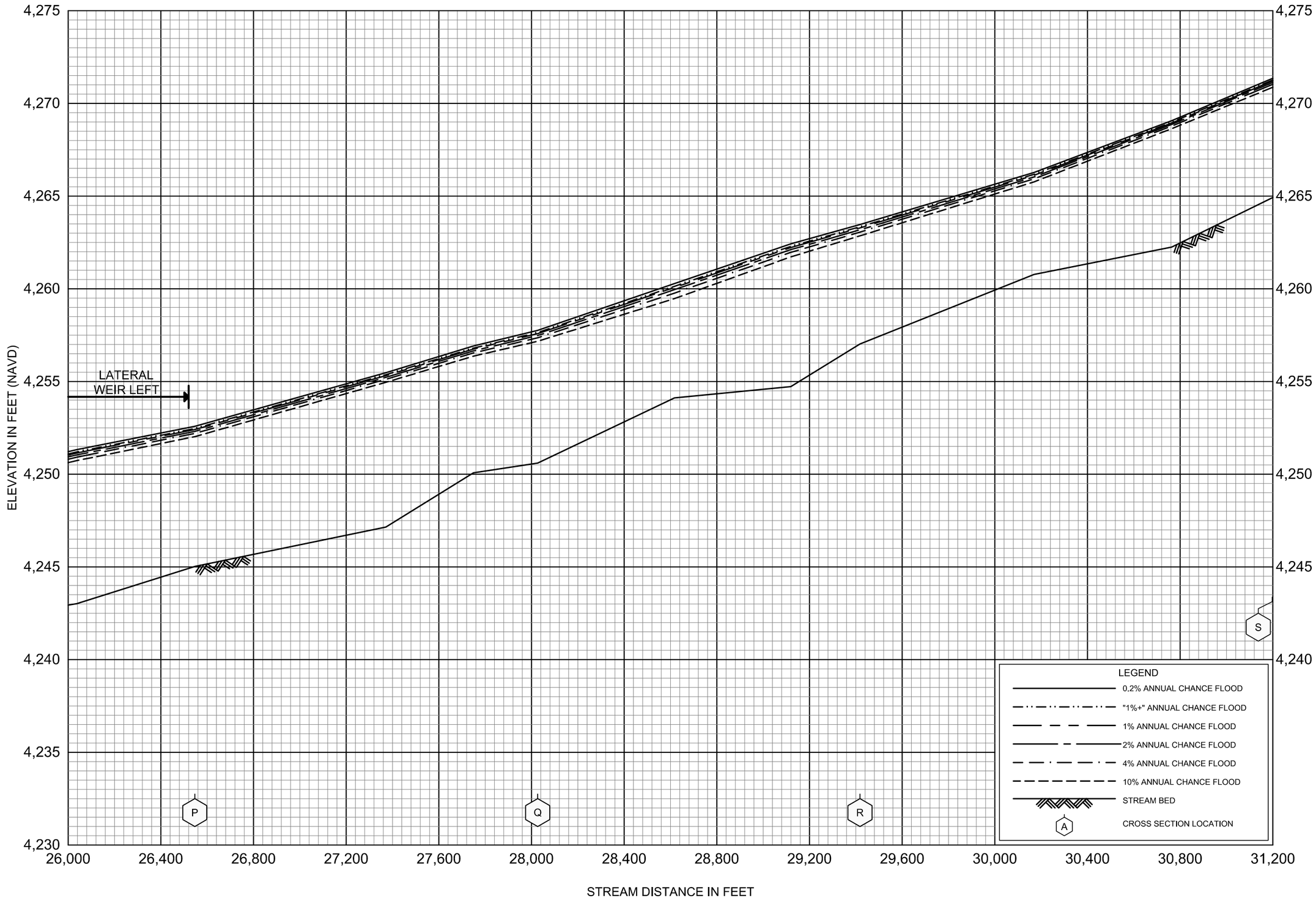

FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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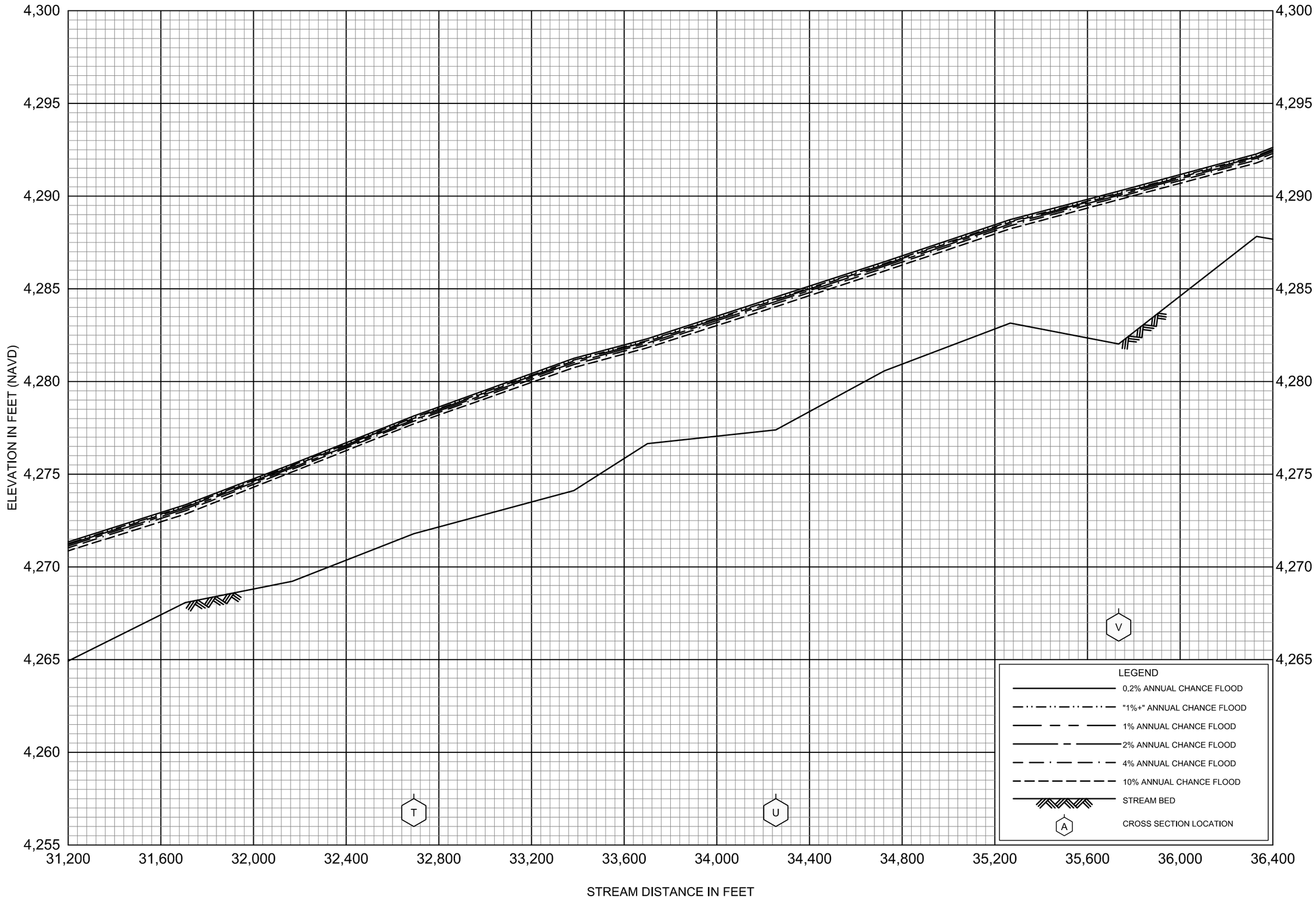

FLOOD PROFILES

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FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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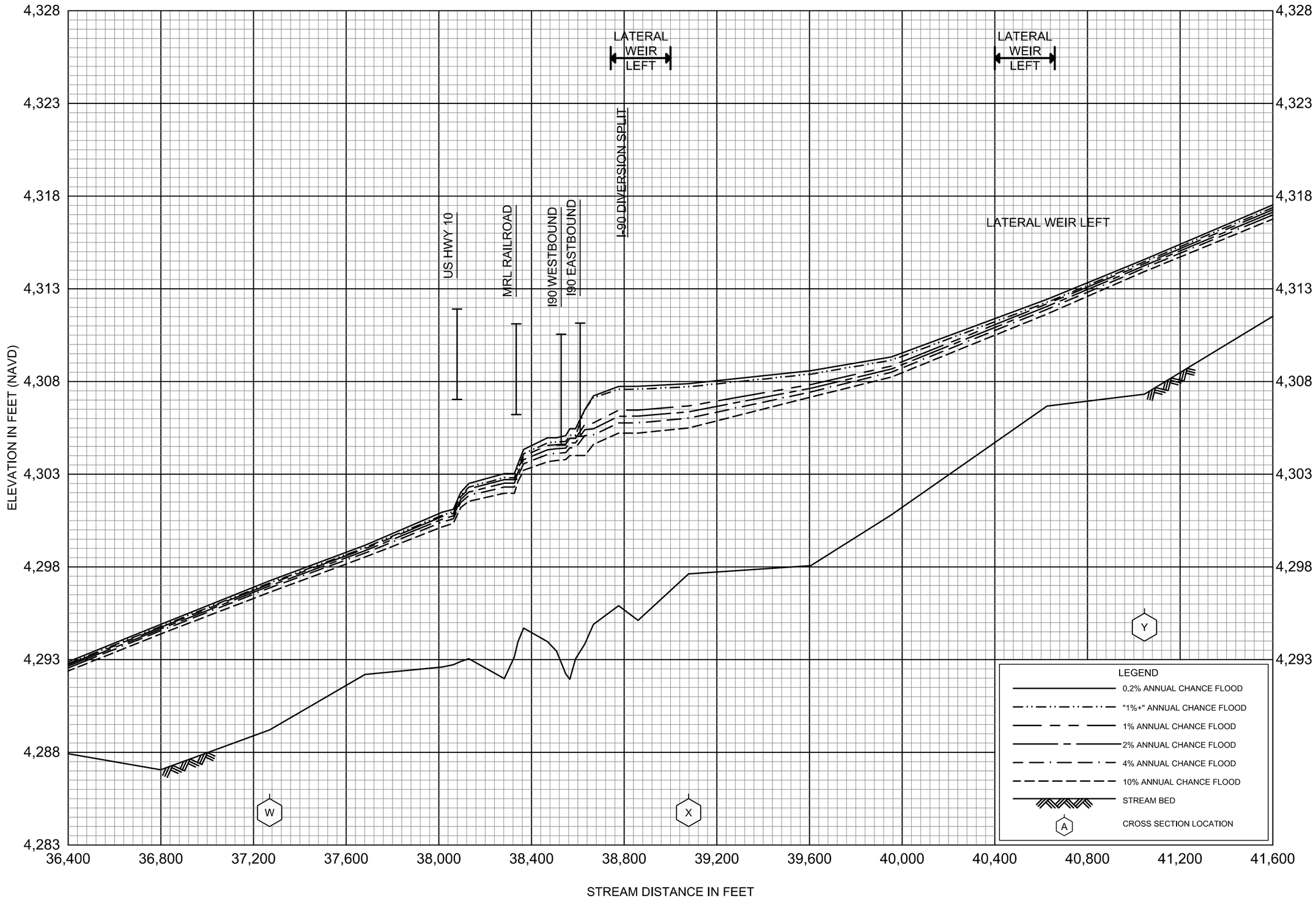

FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

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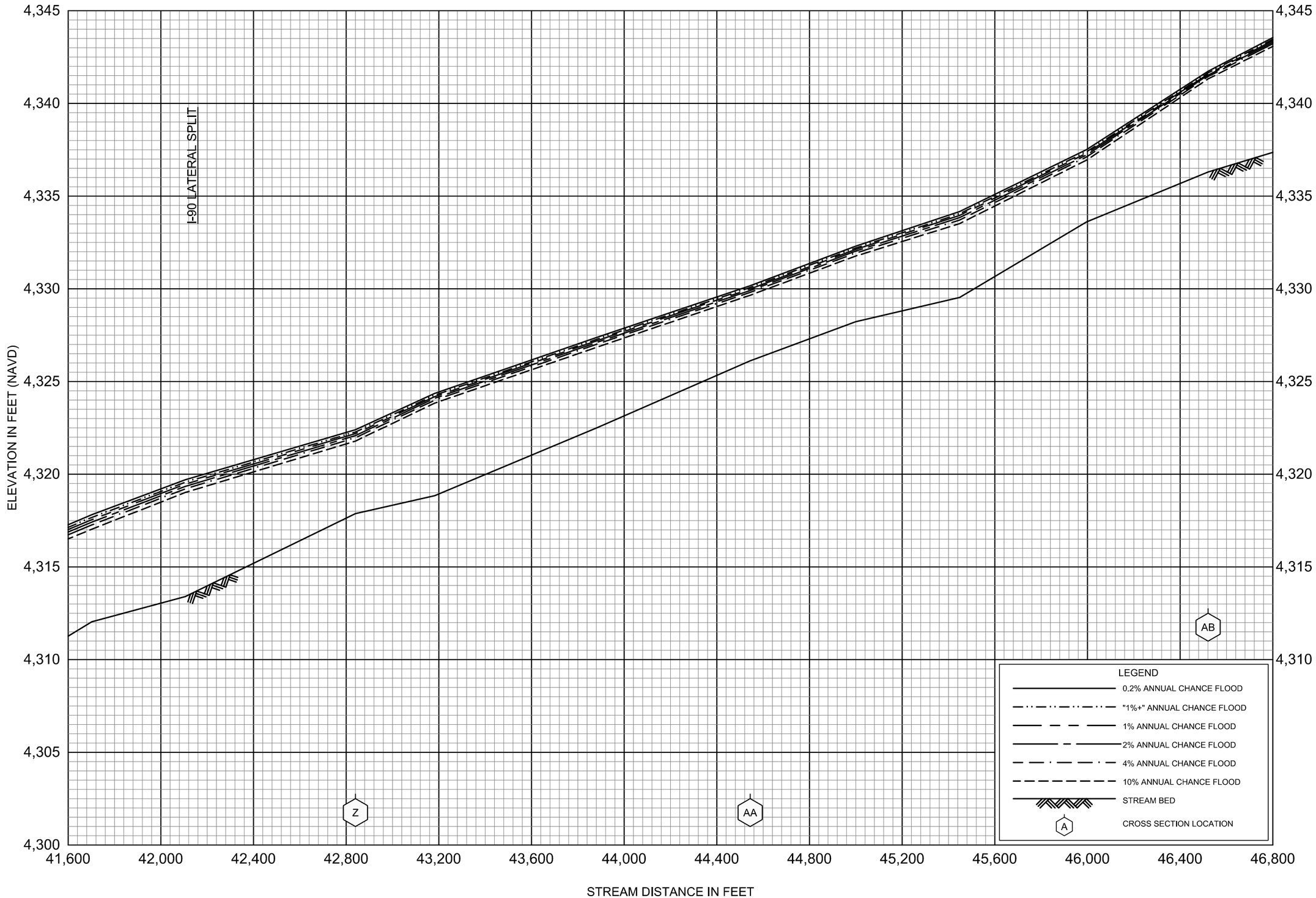

FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

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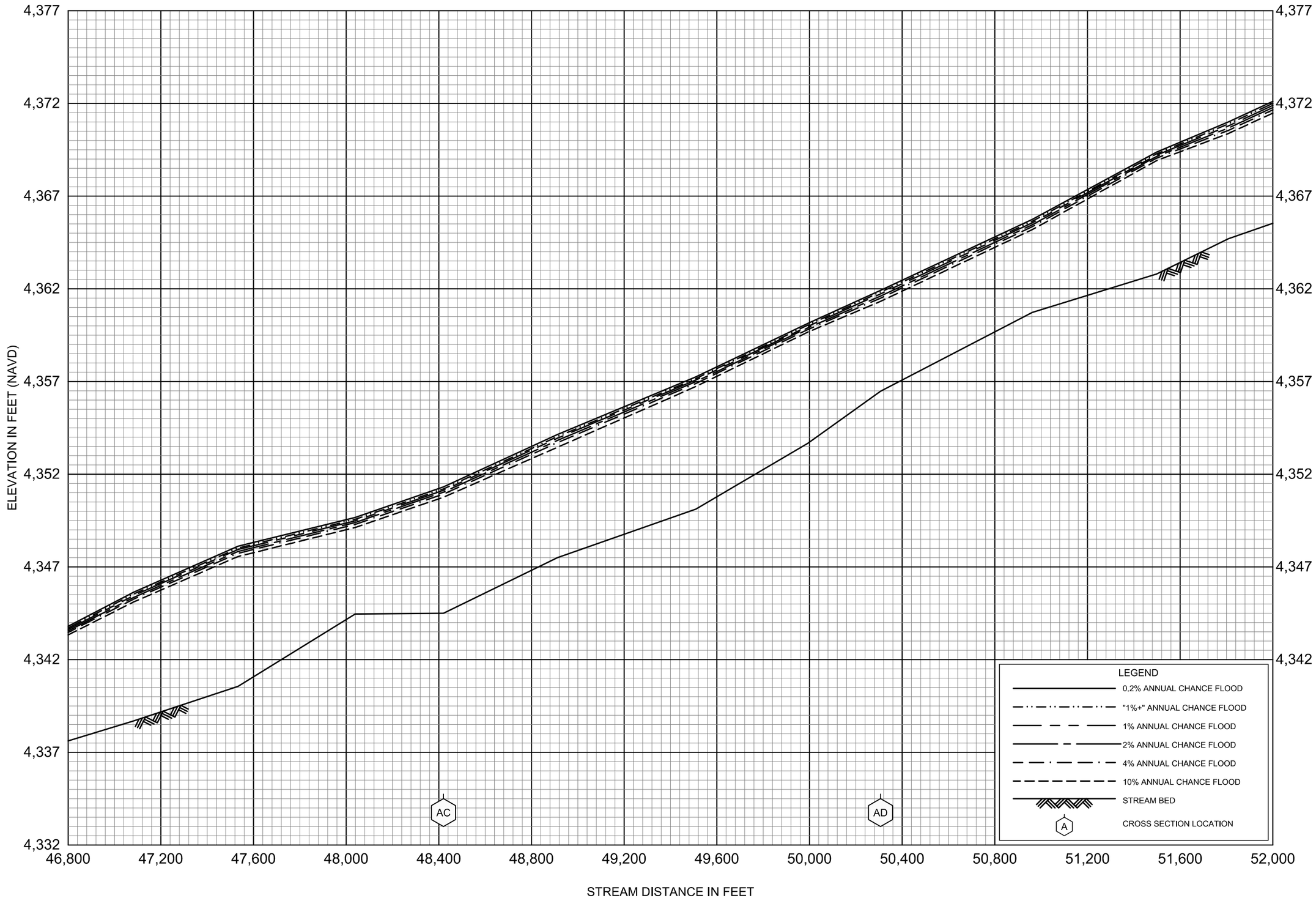


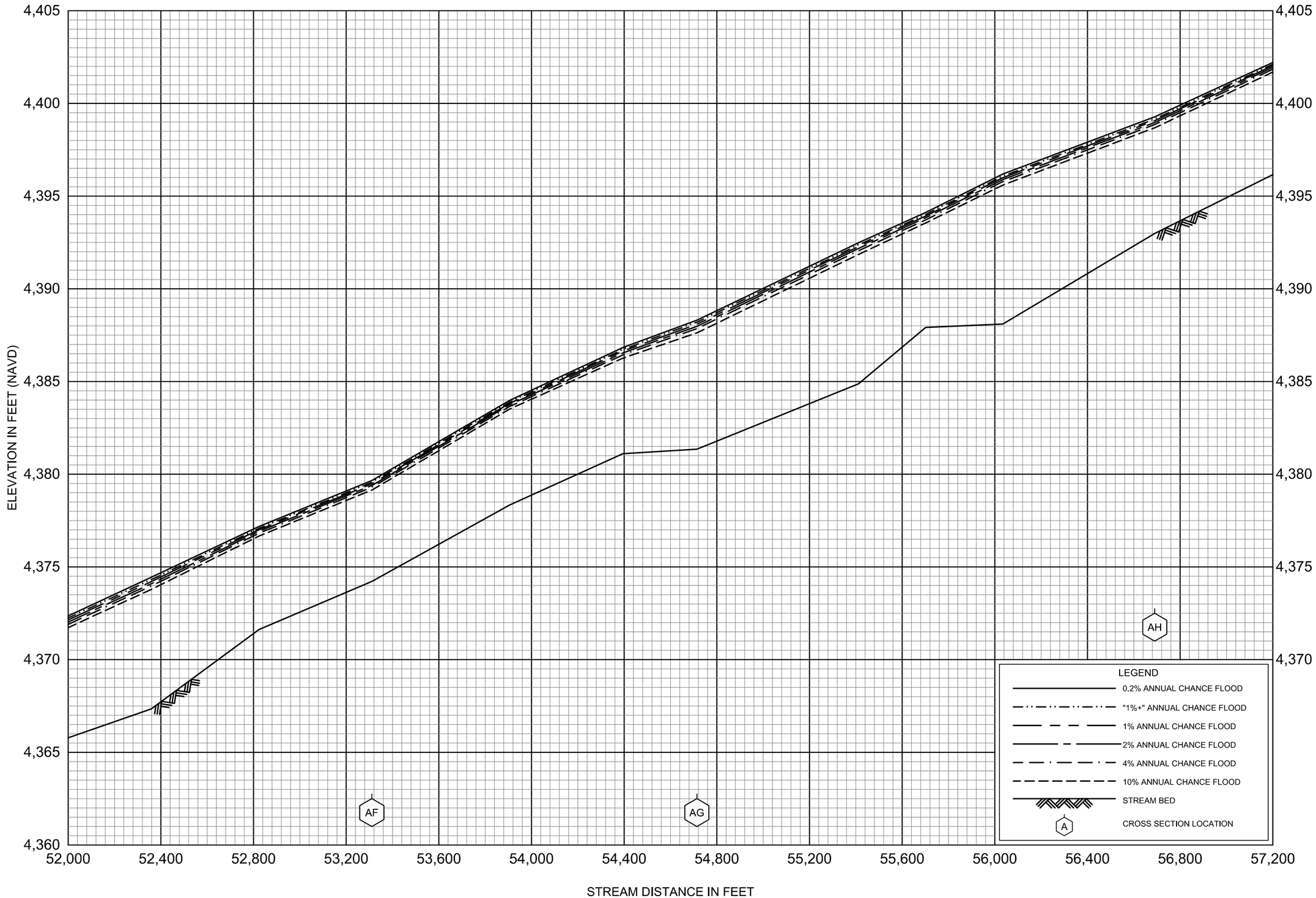
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



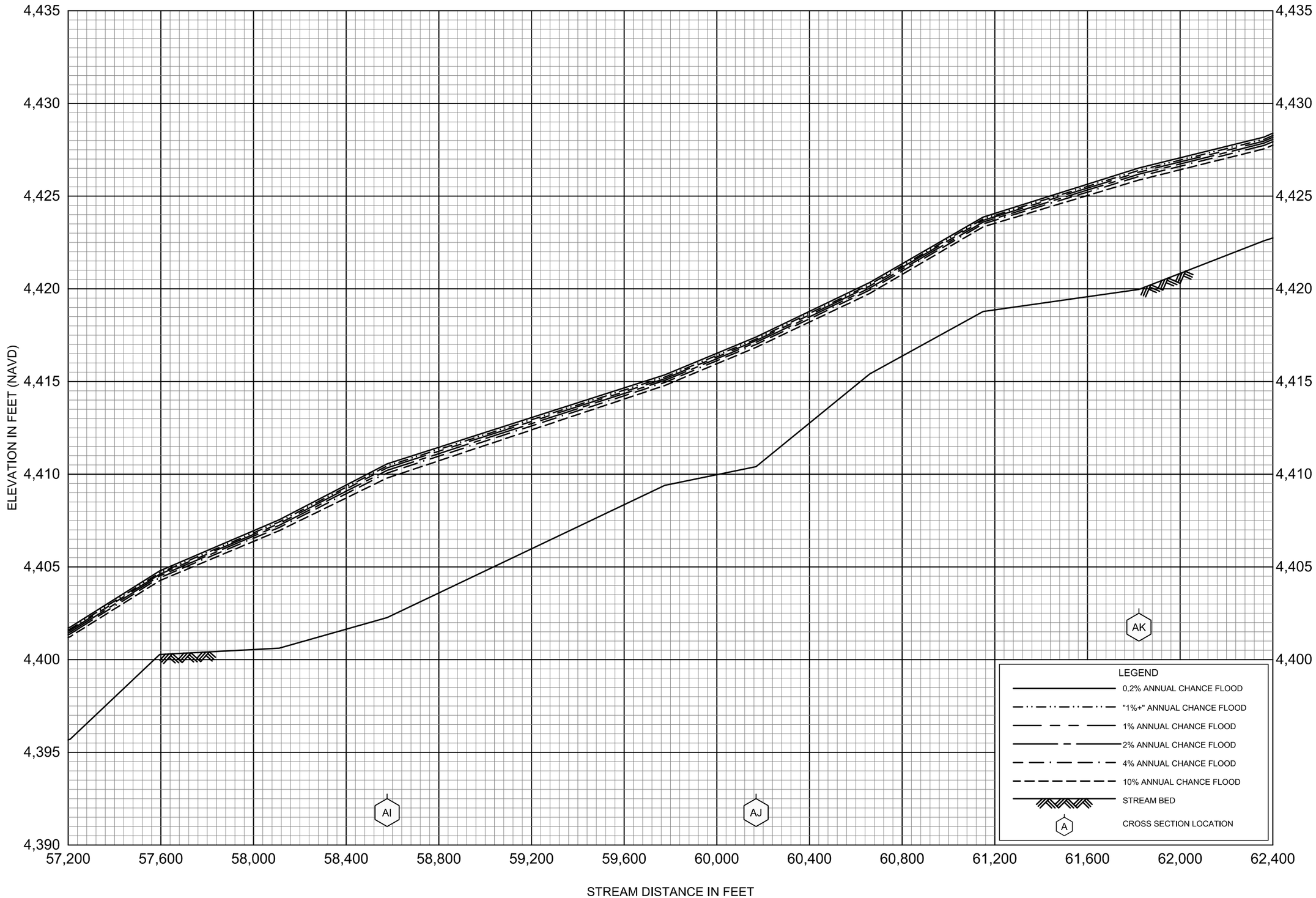
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



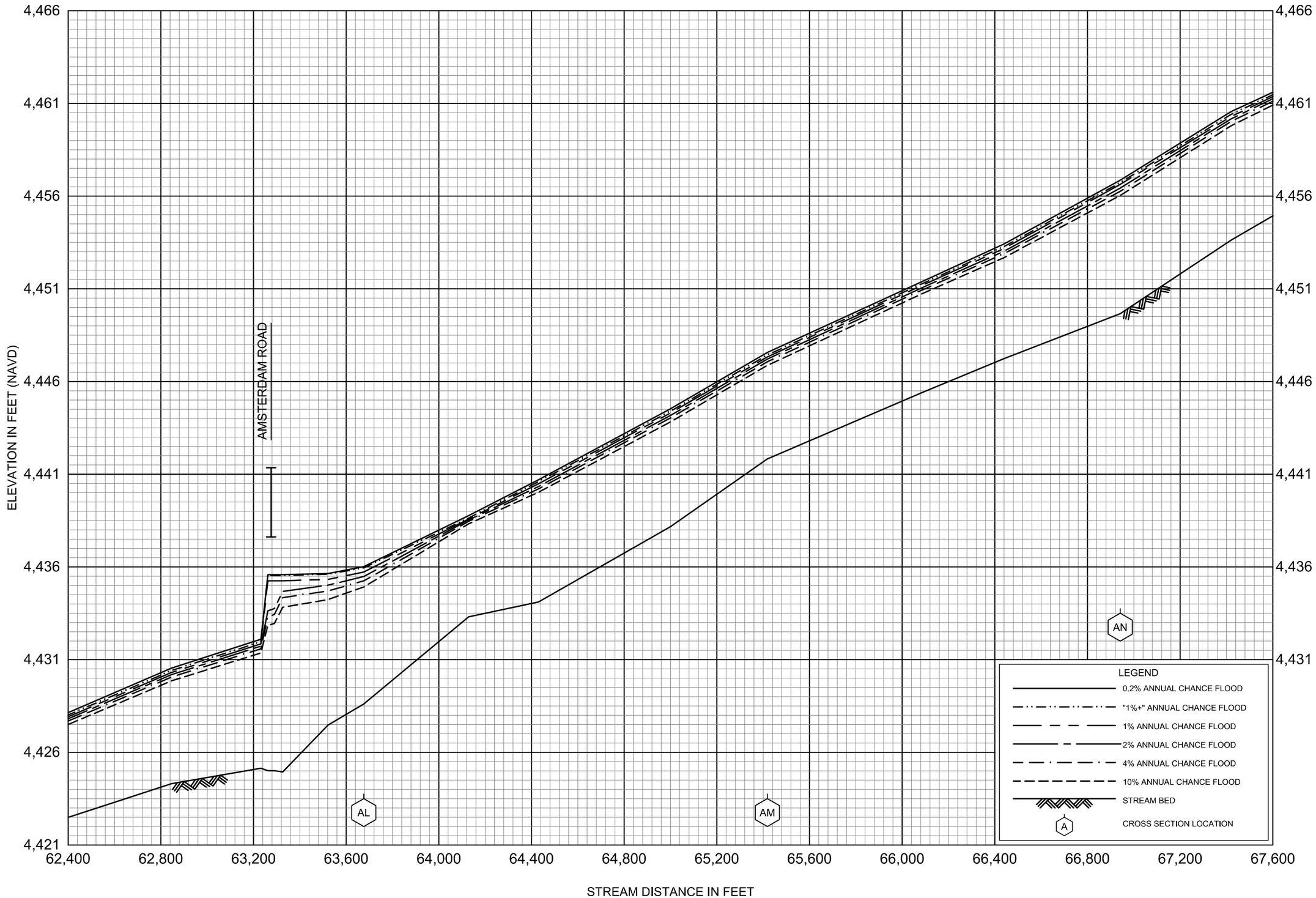
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



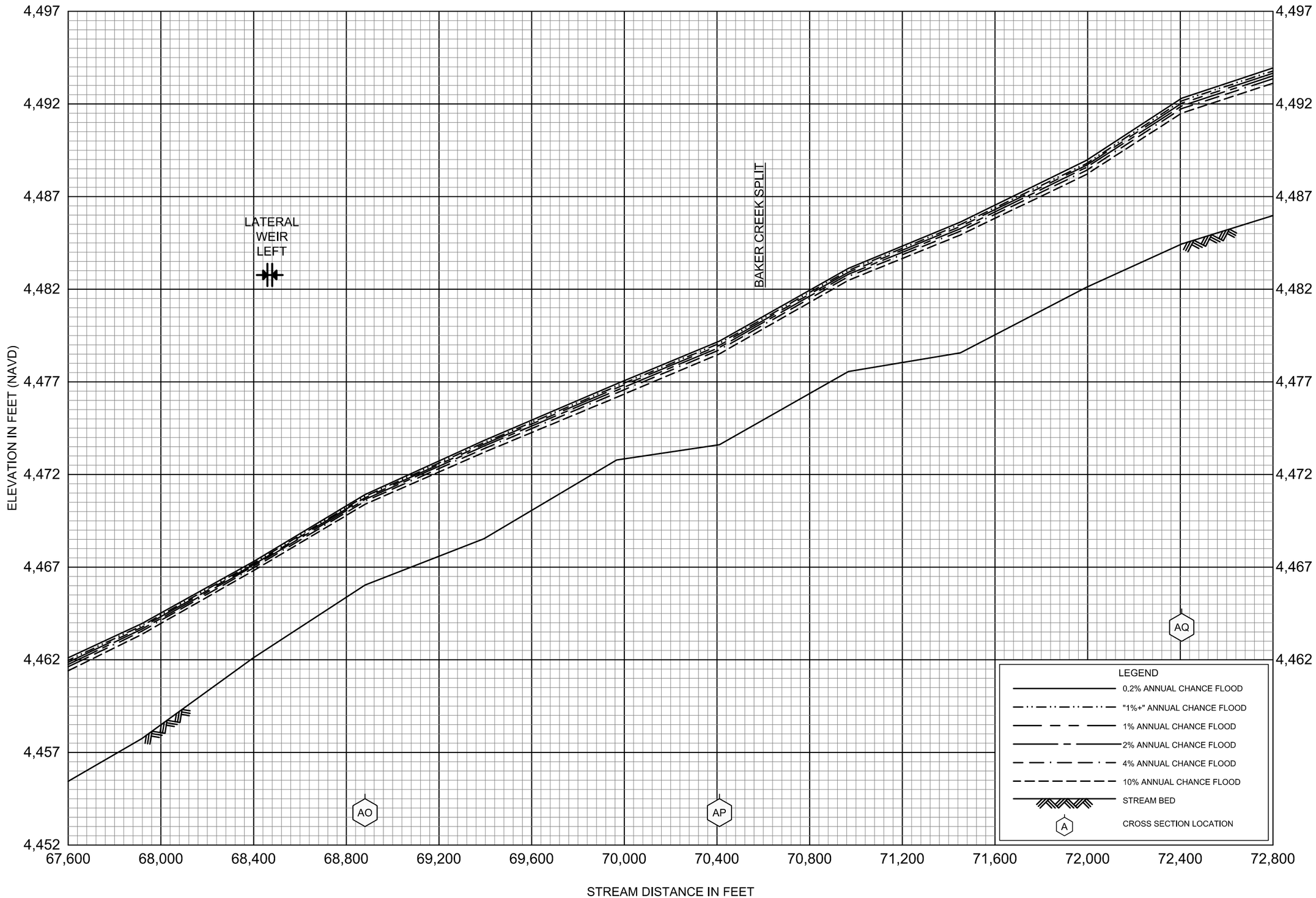
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



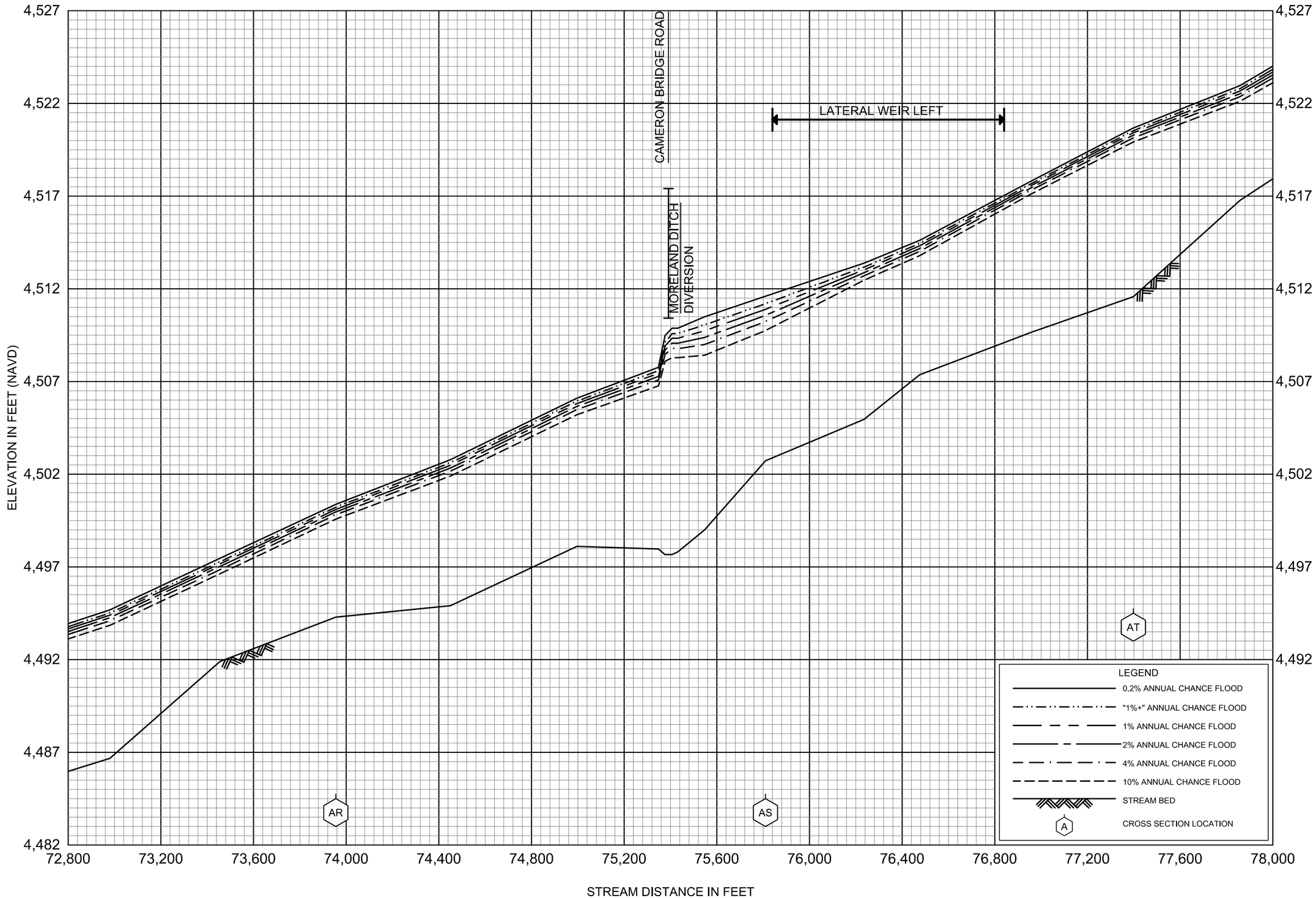
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



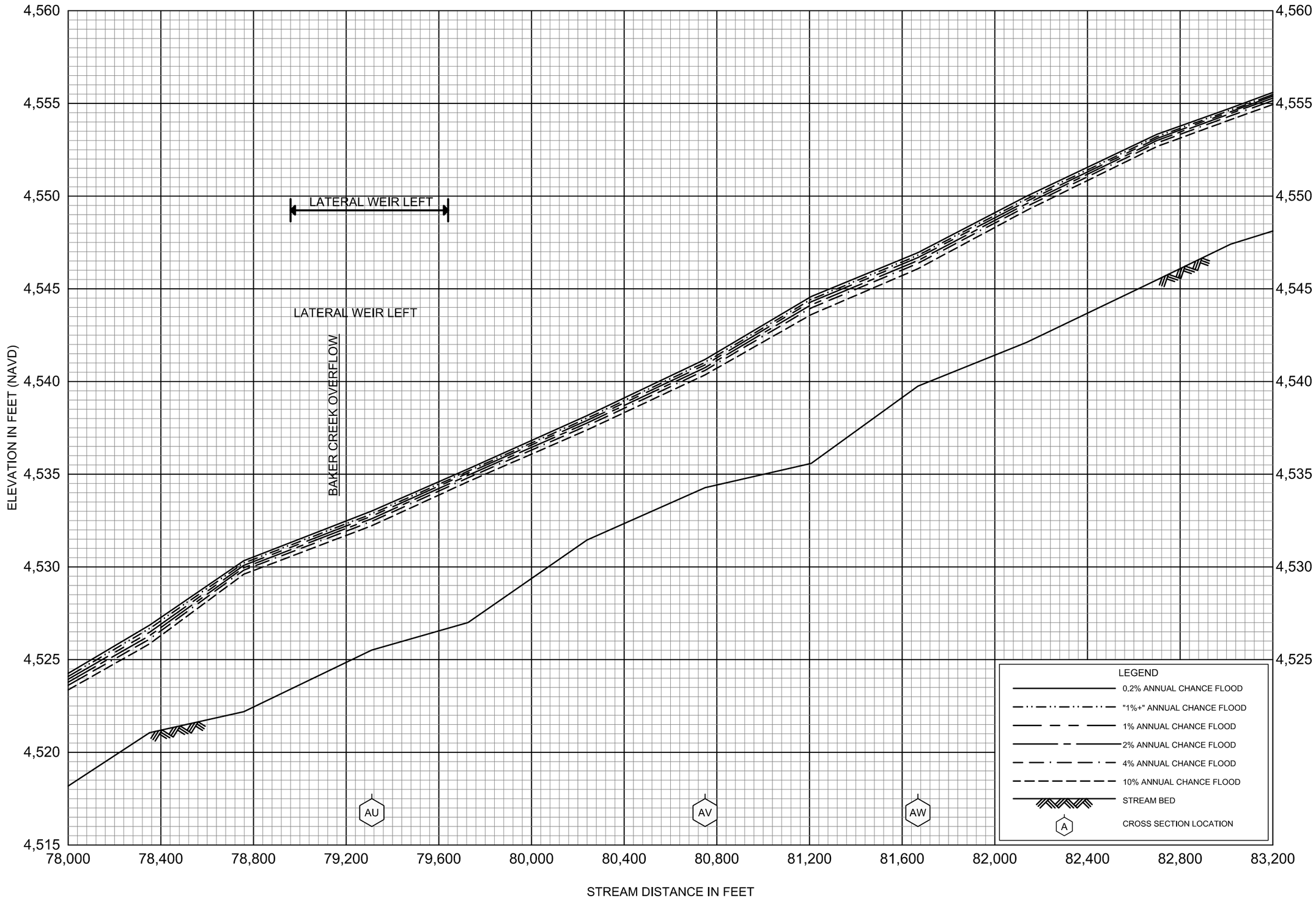
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



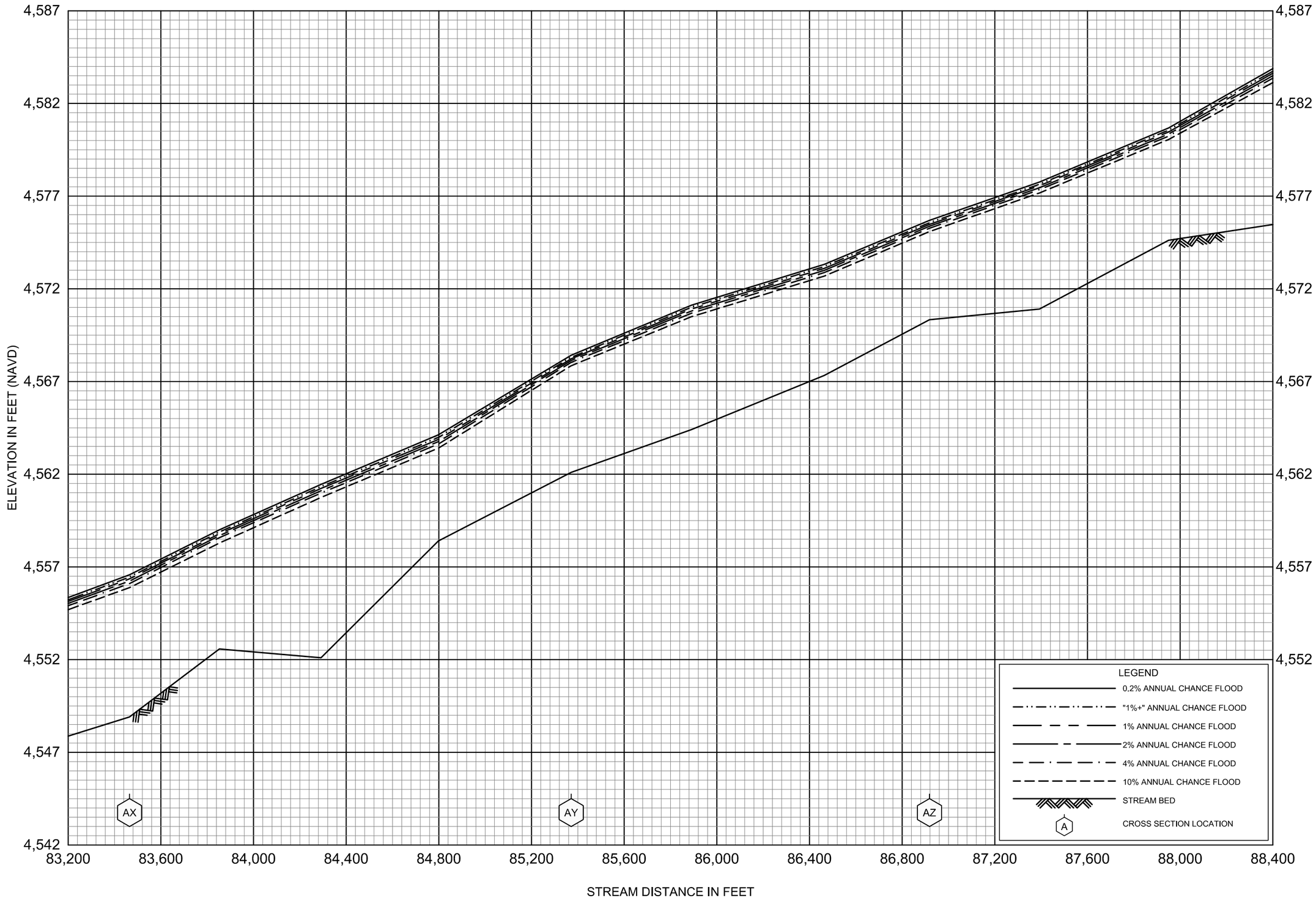
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



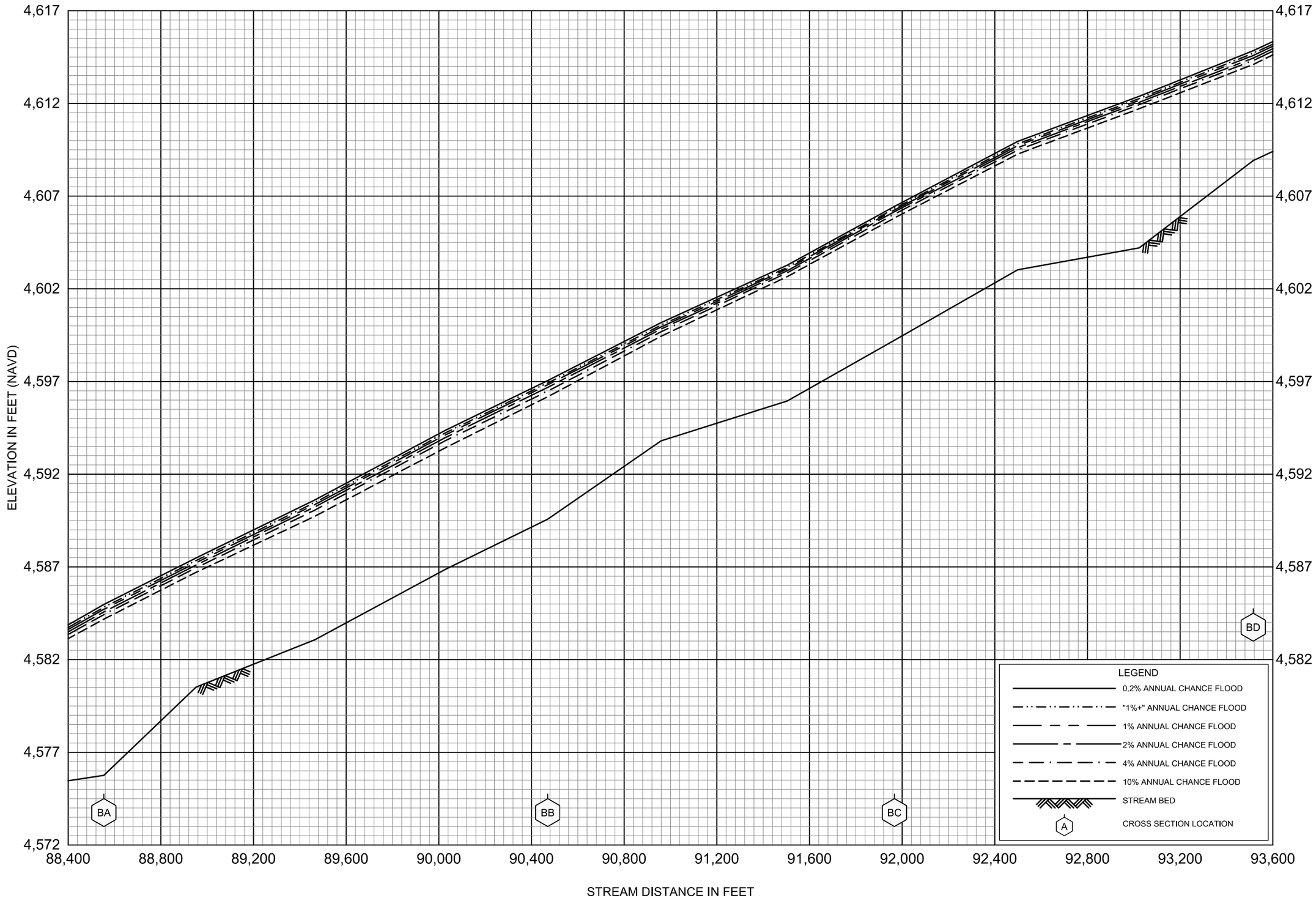
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



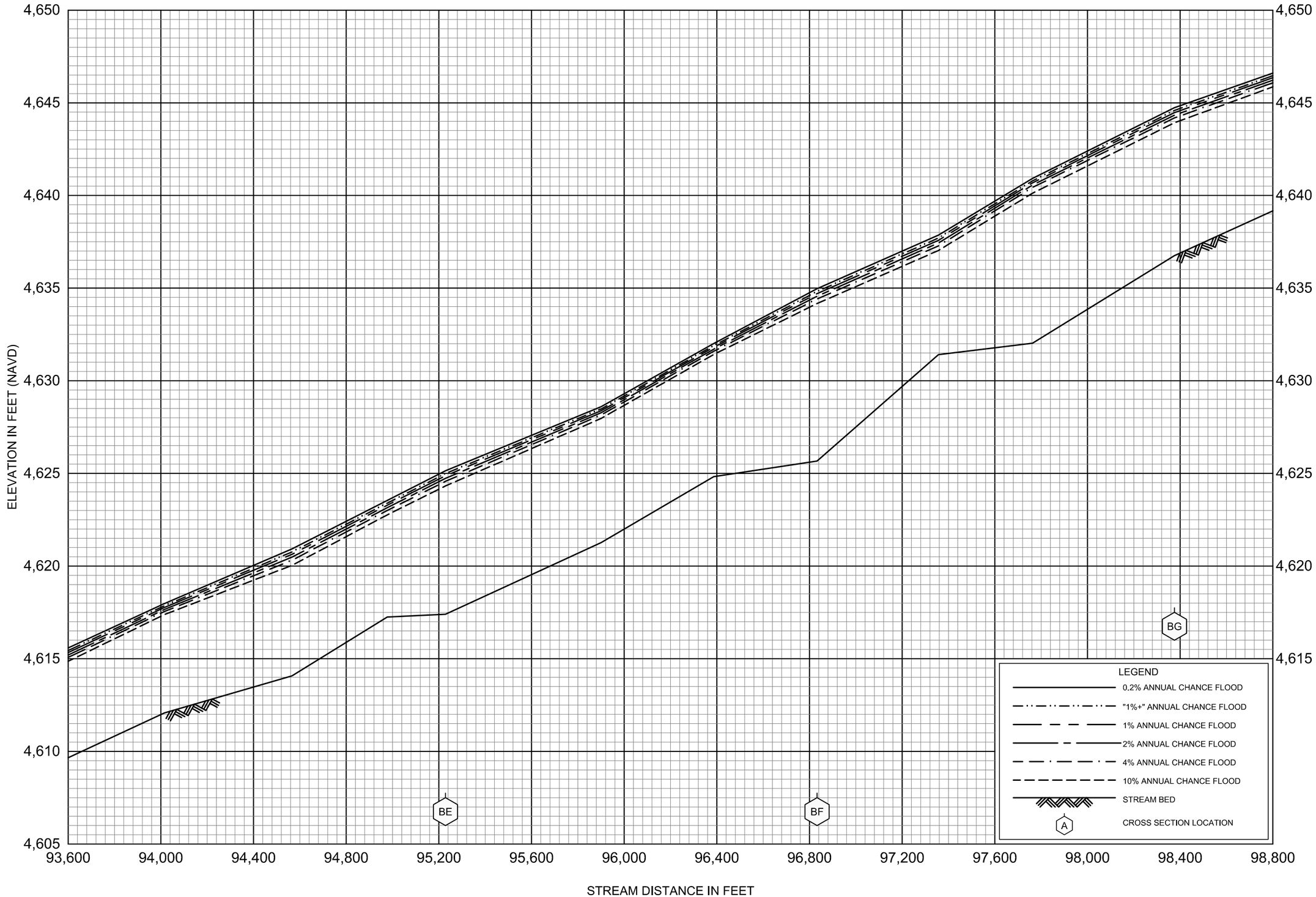
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



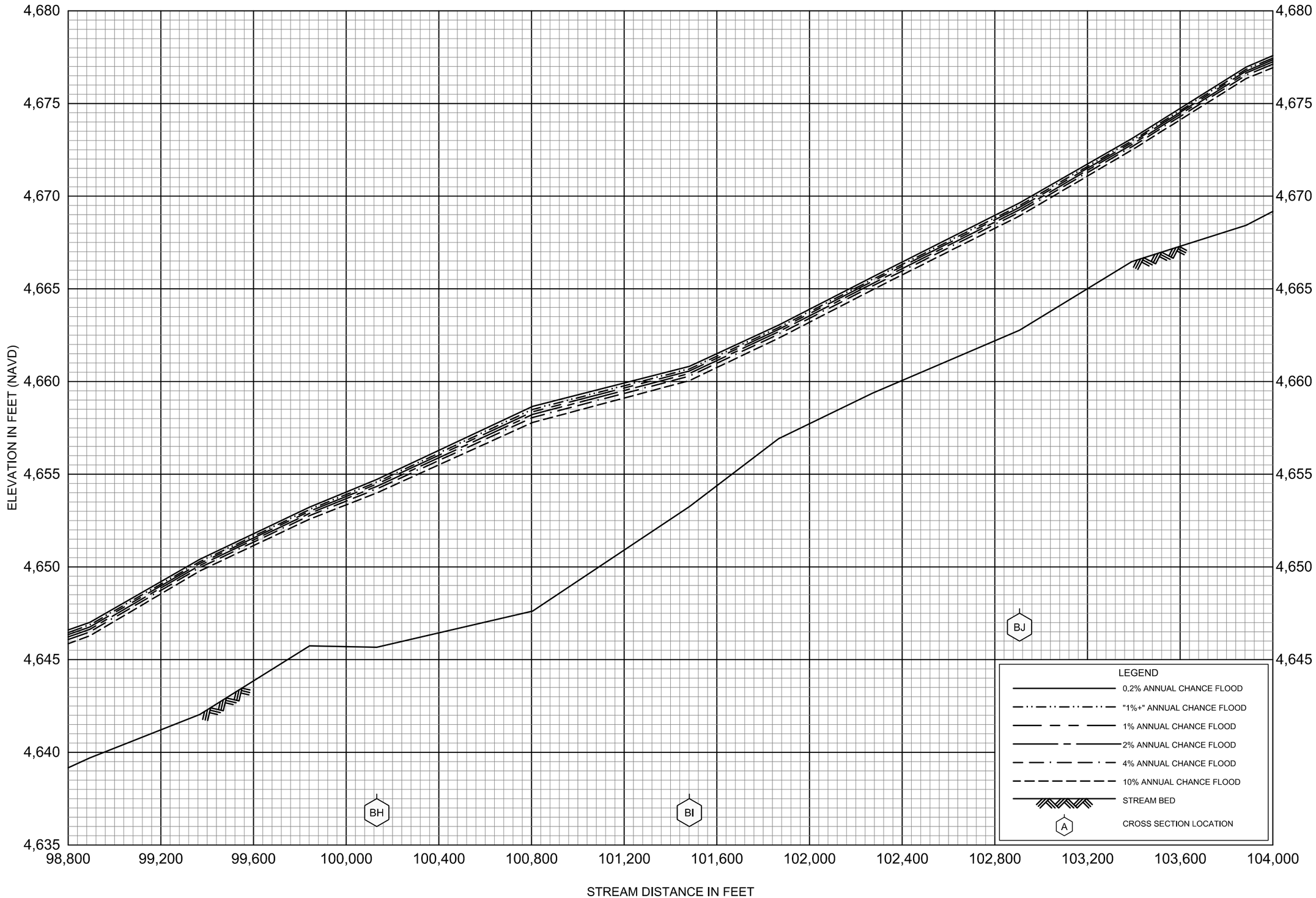
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



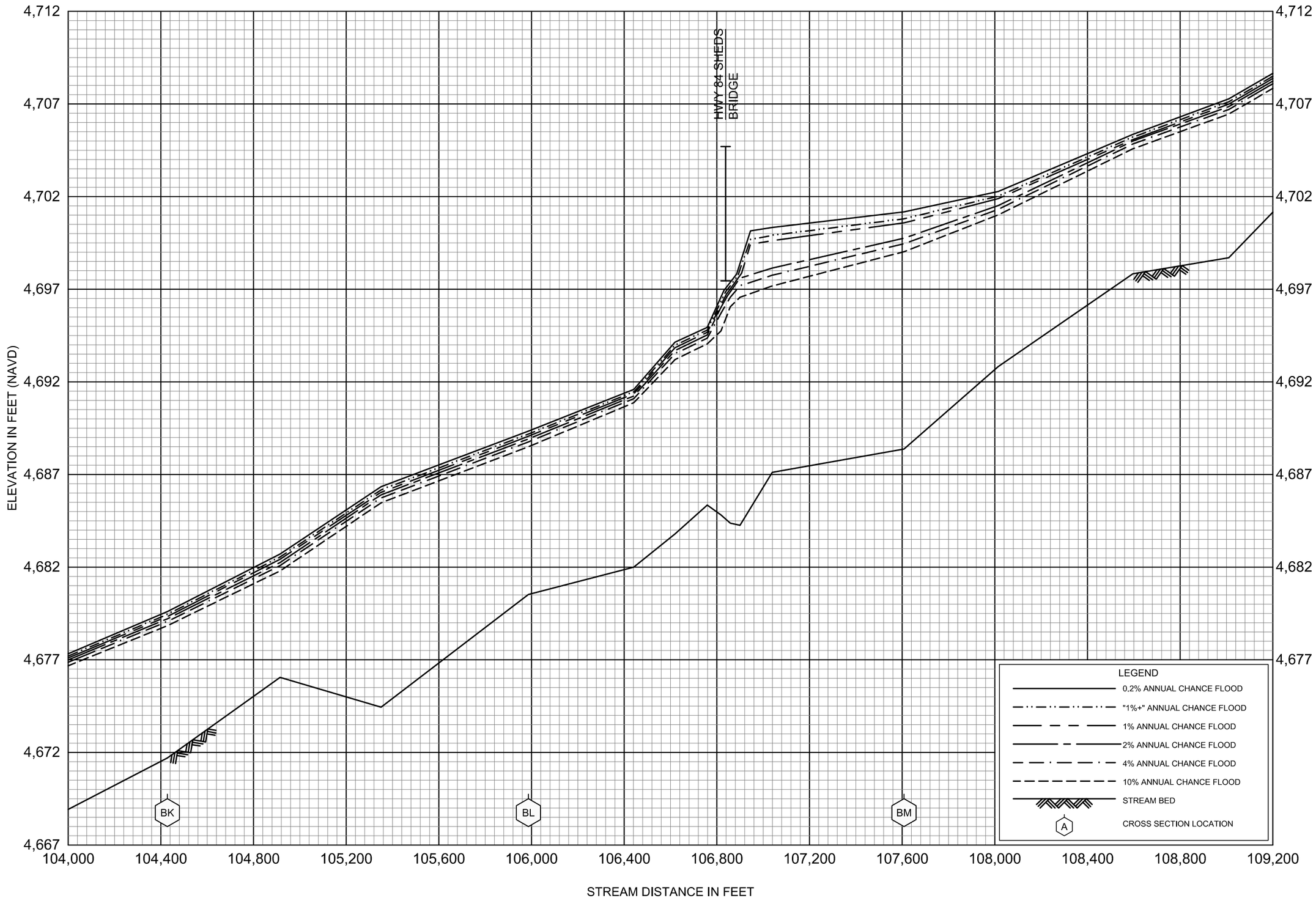
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



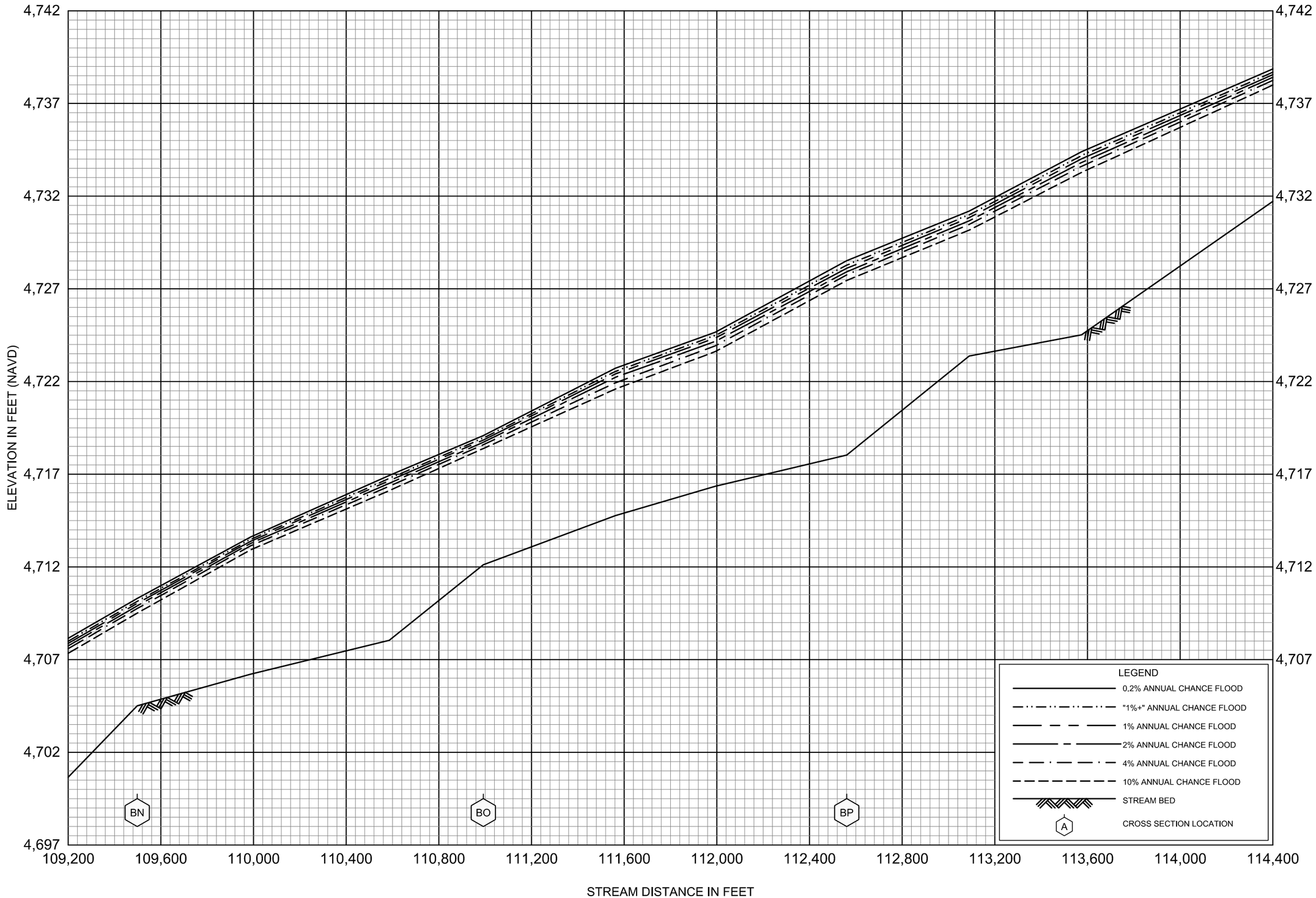
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



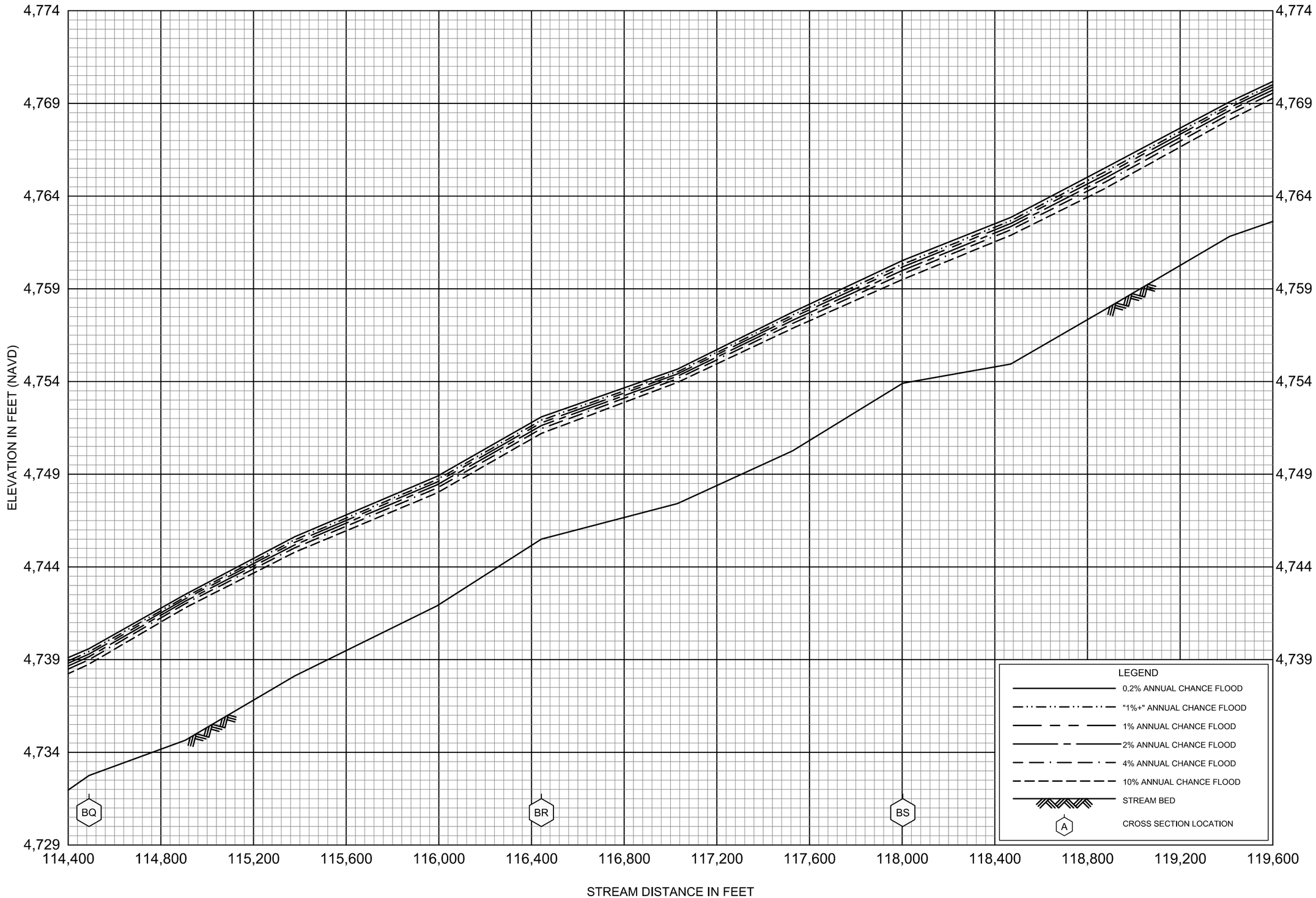
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



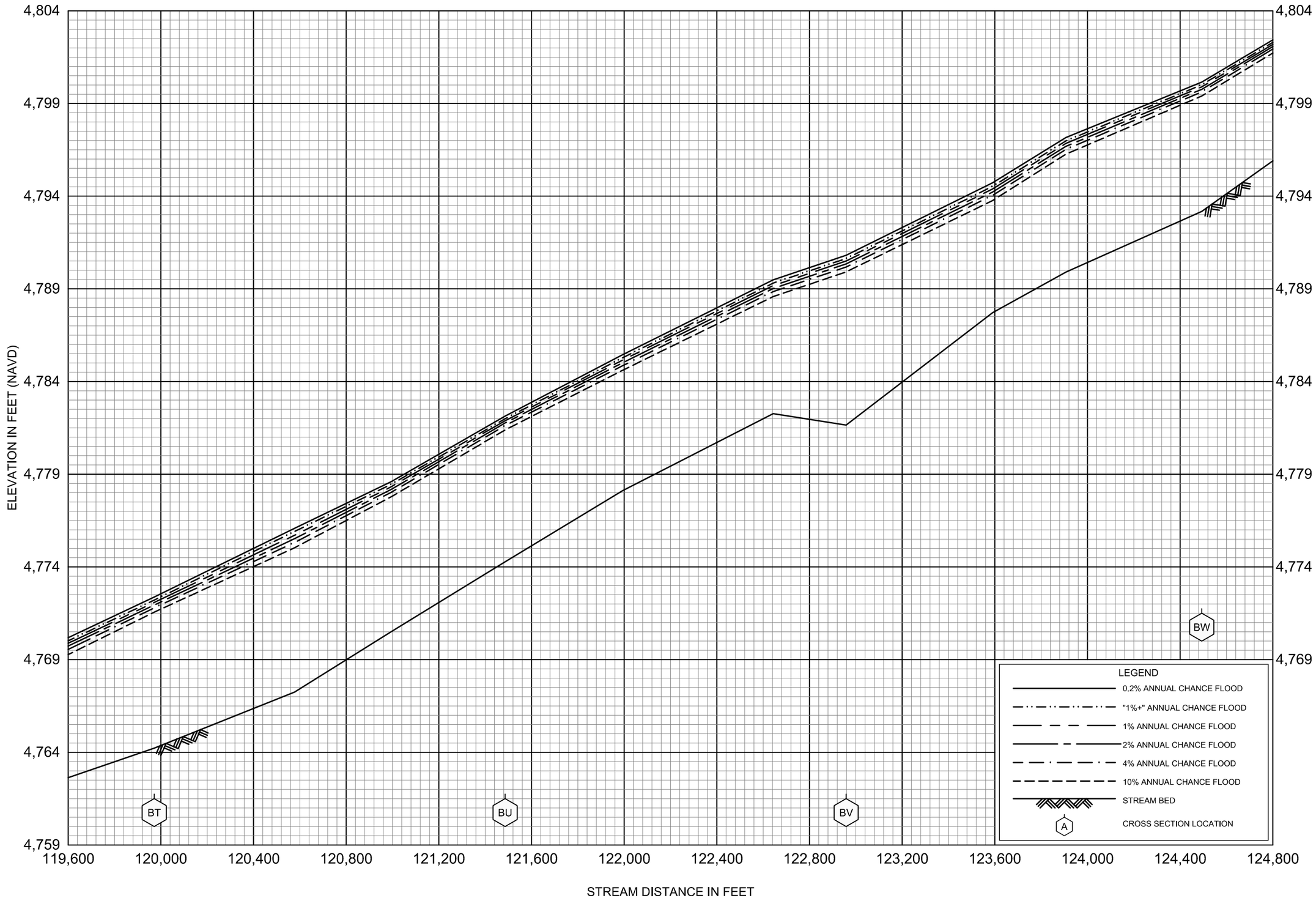
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



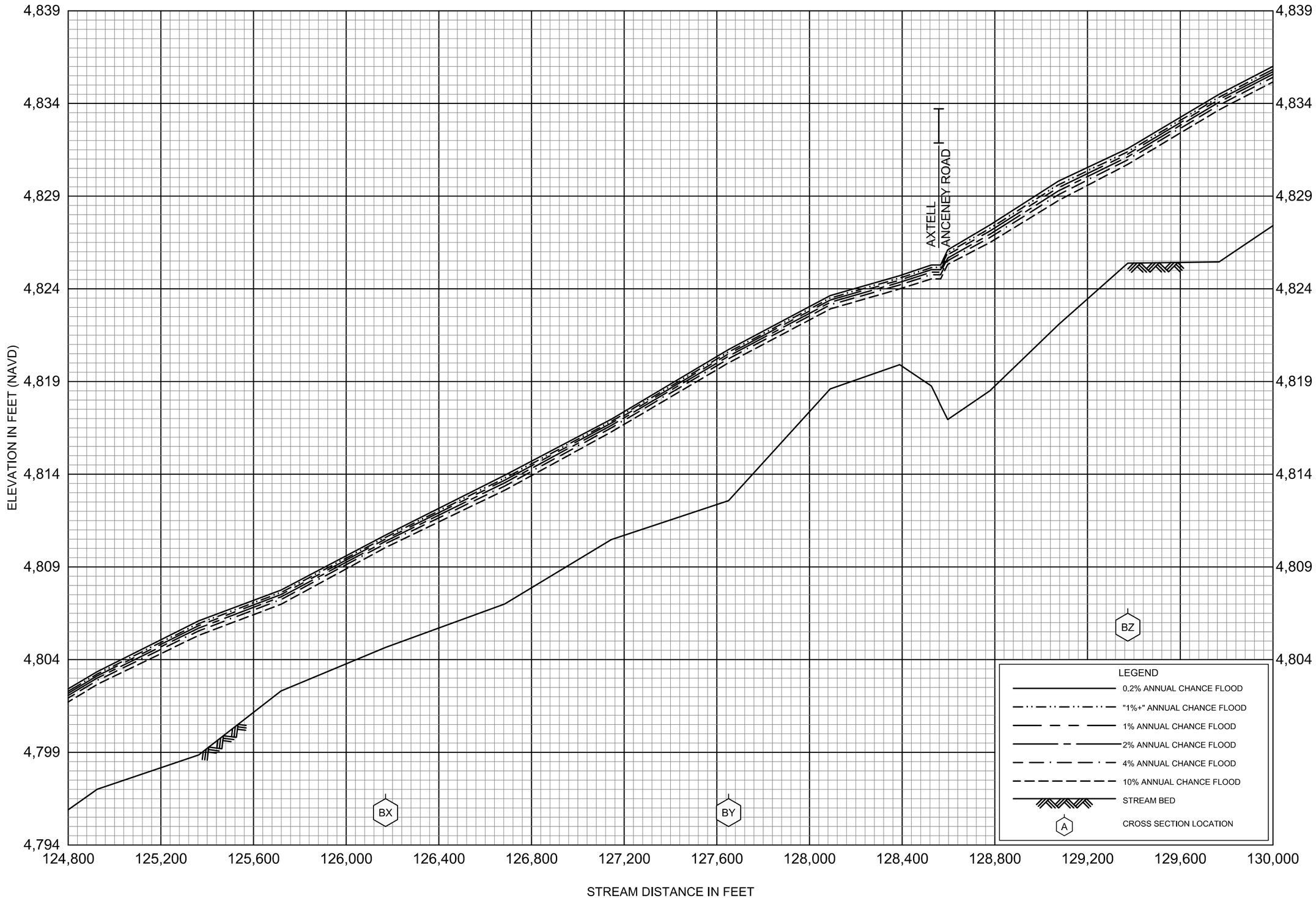
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



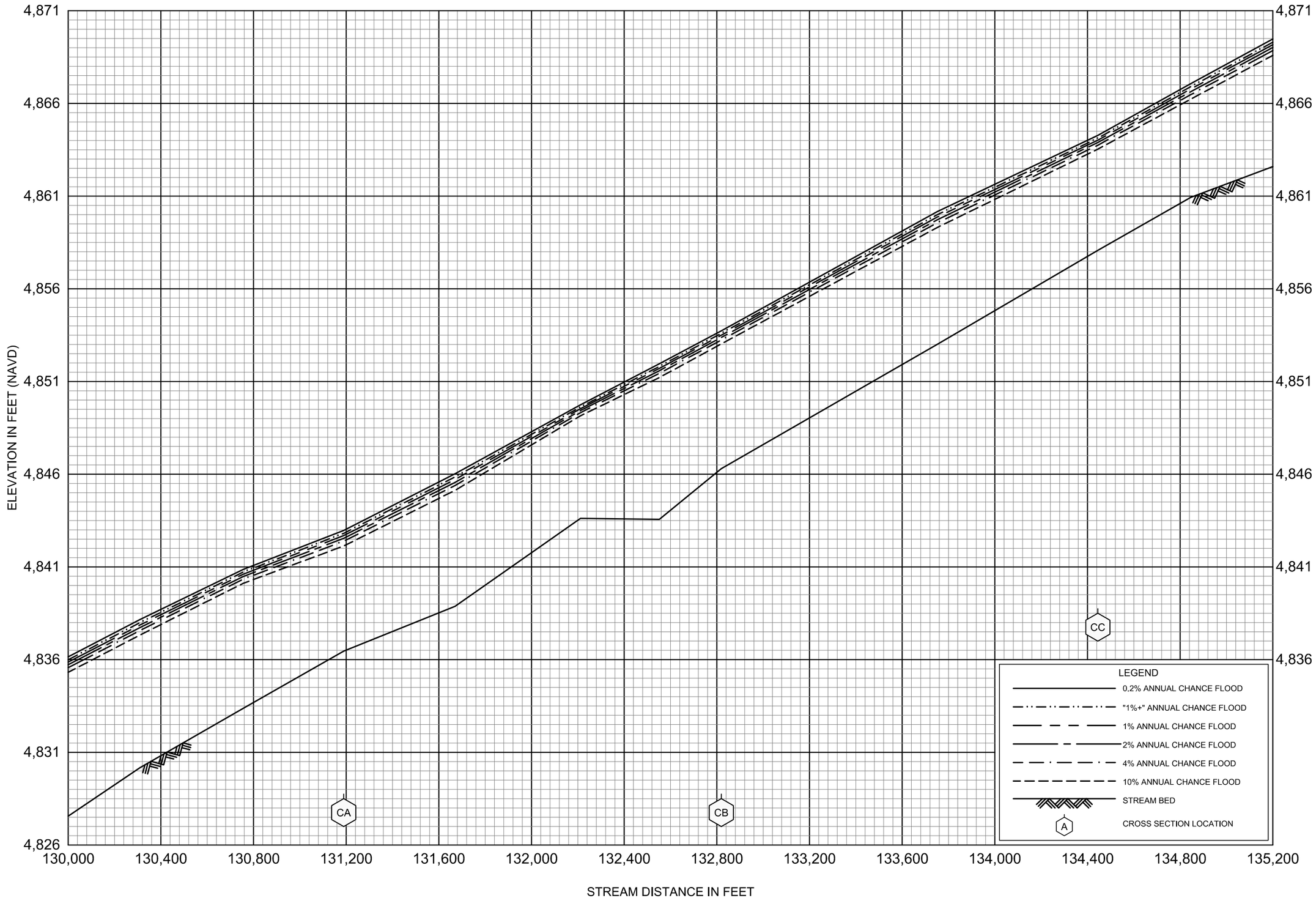
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



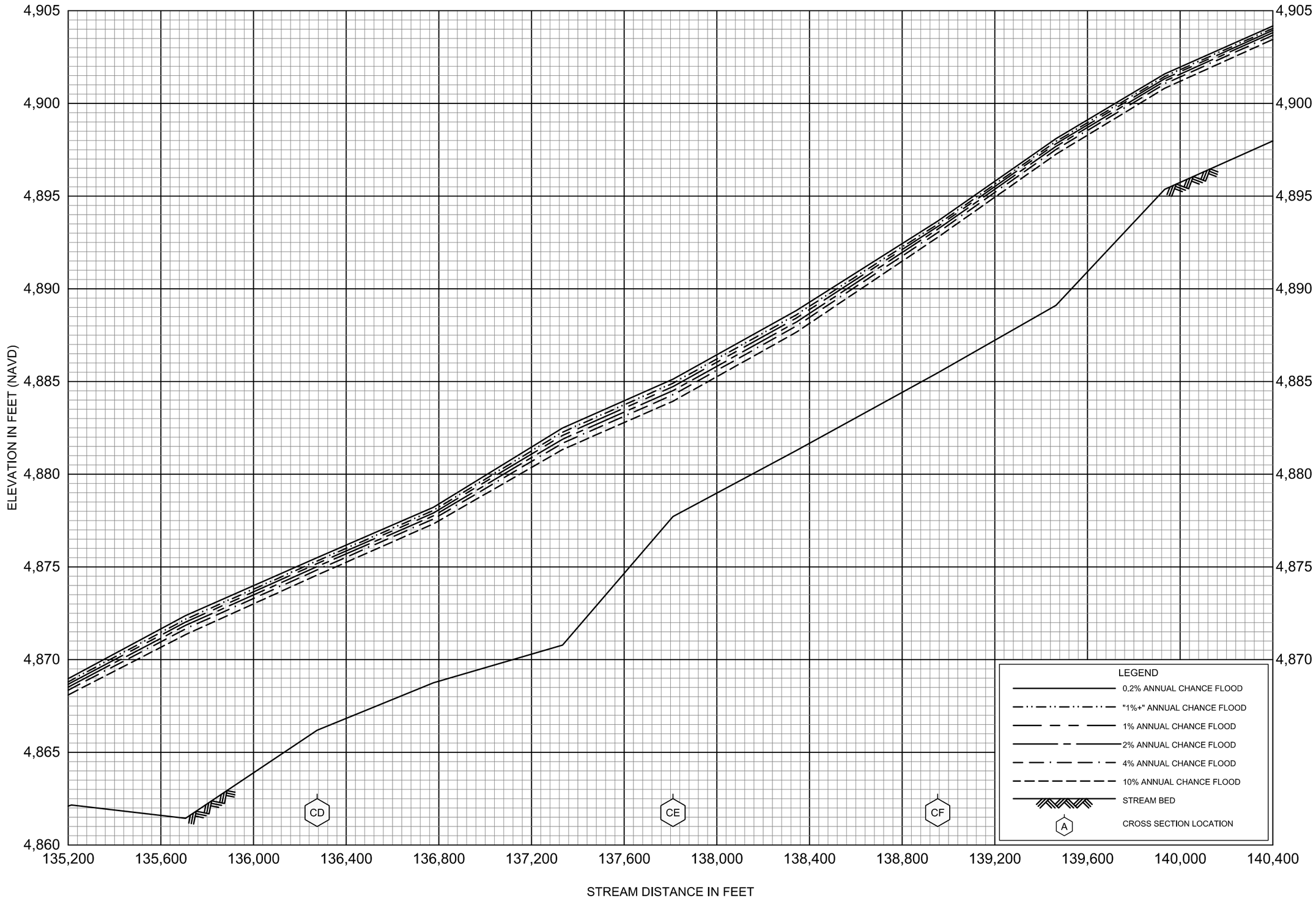
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



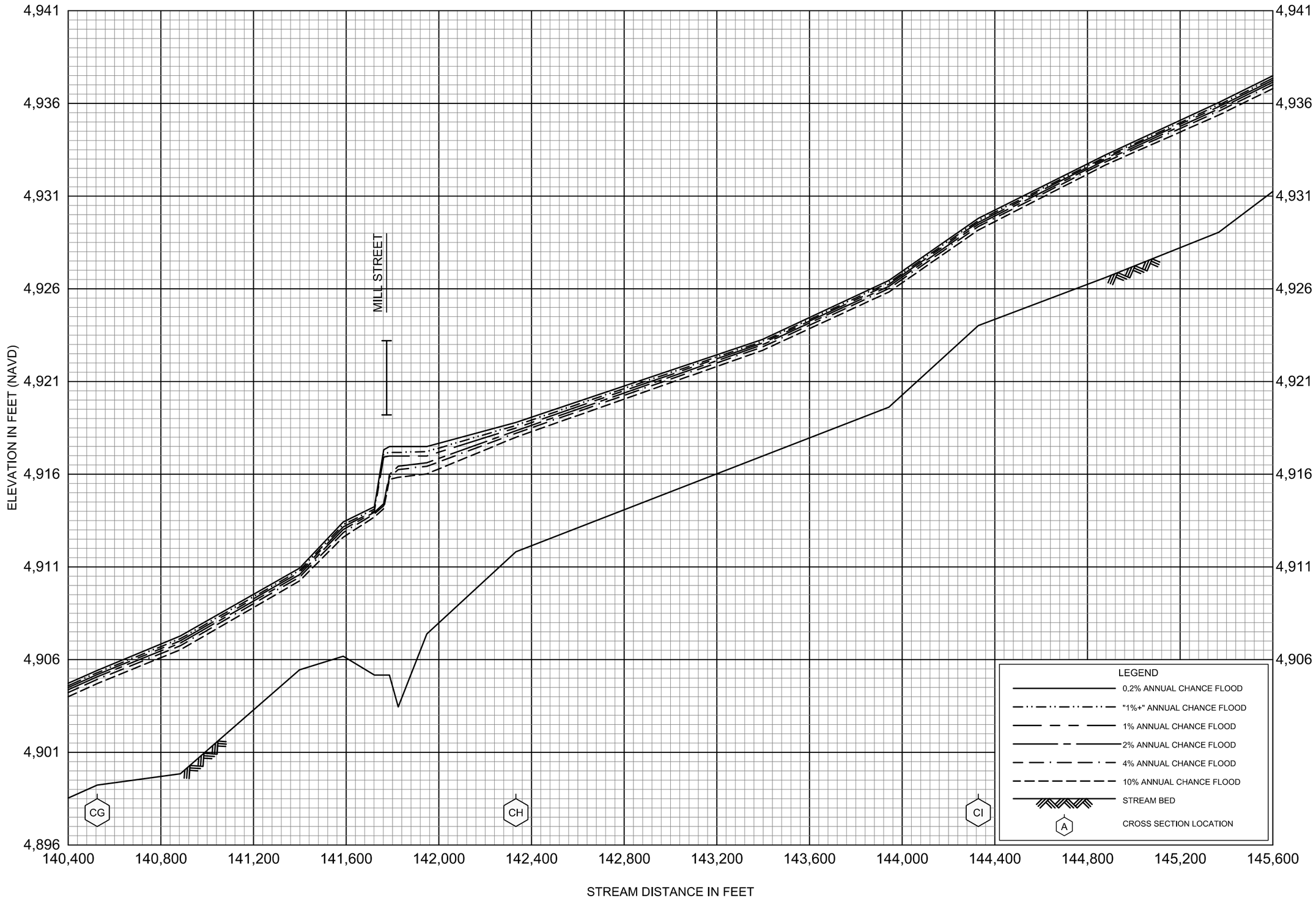
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



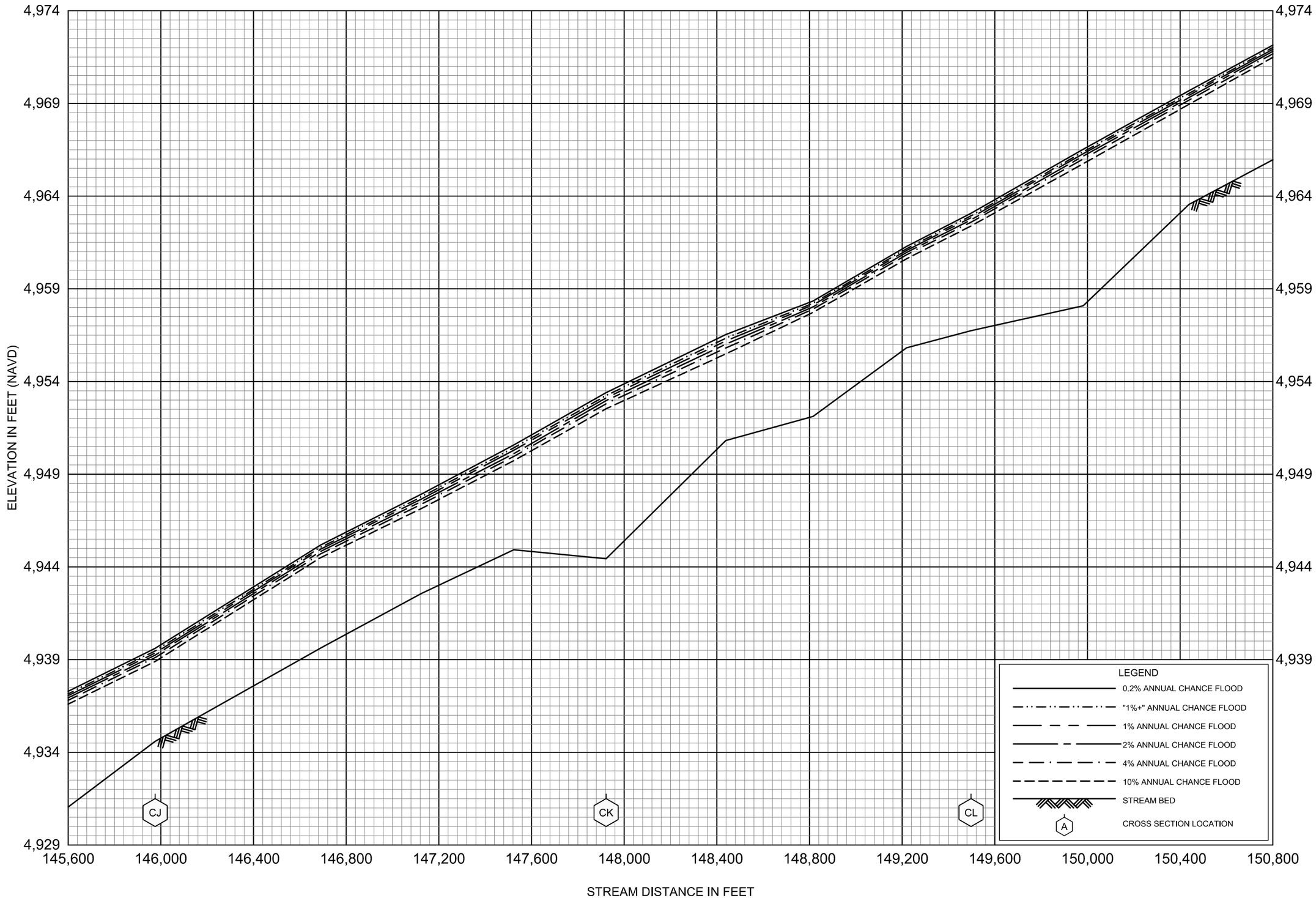
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



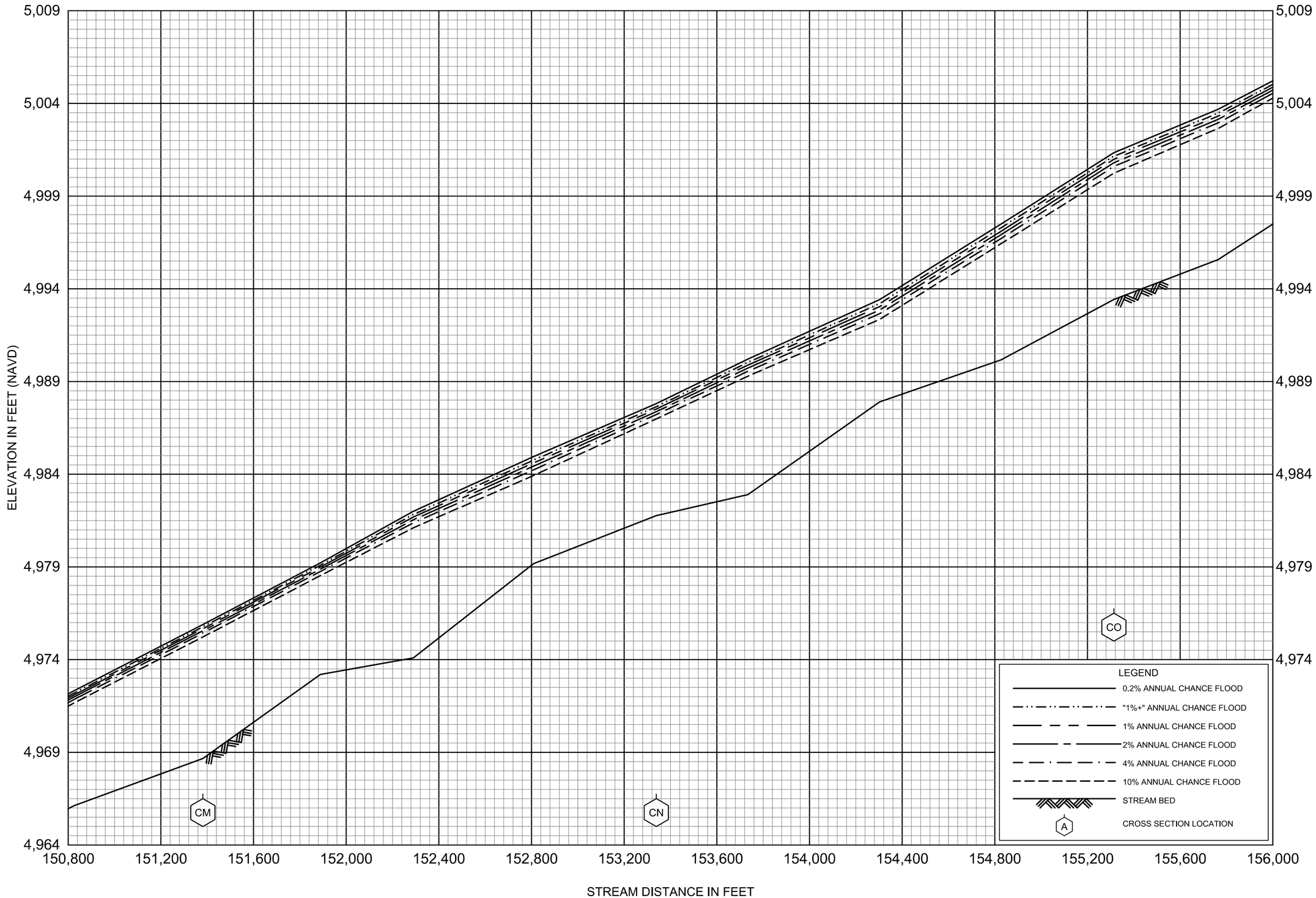
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



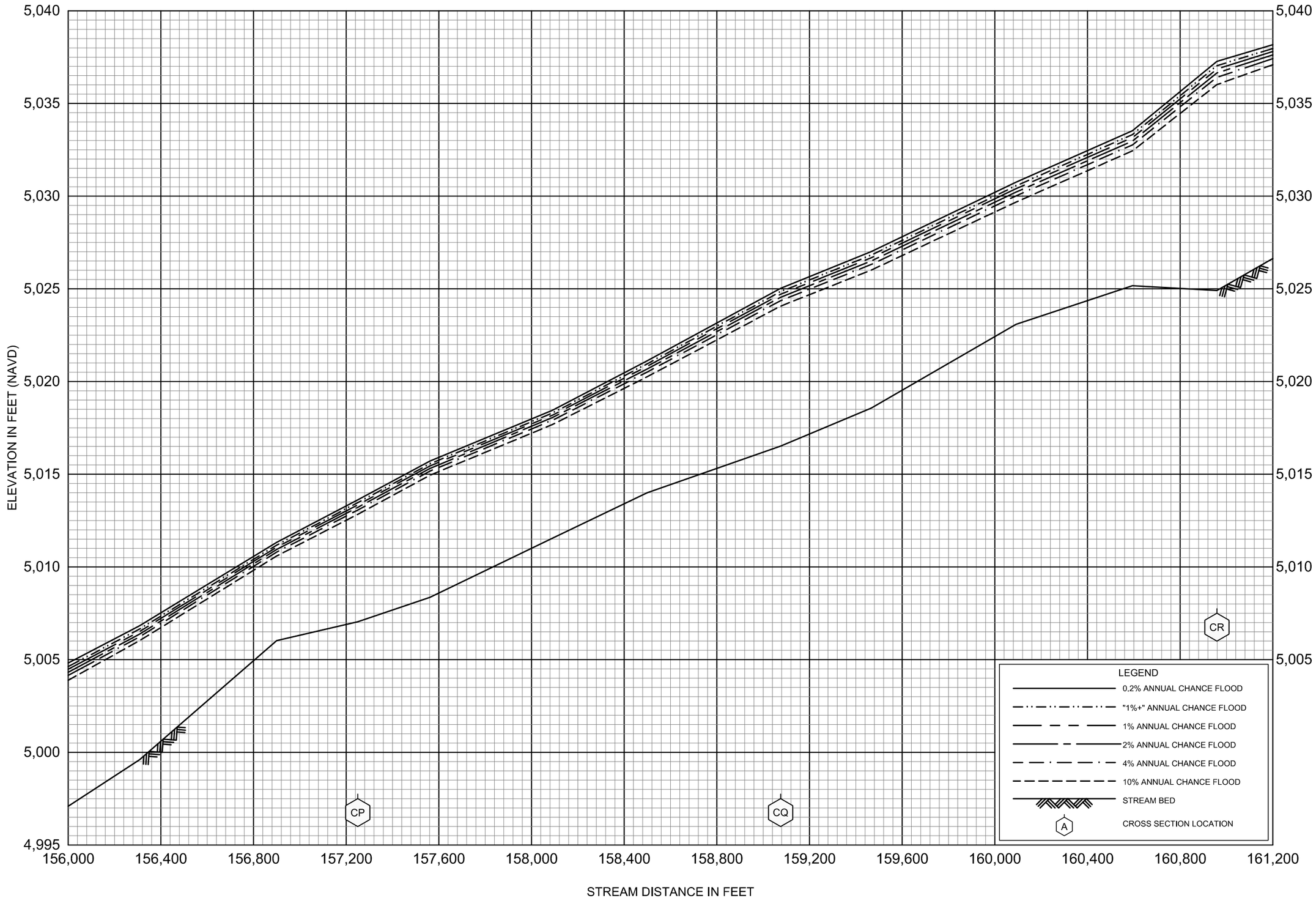
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



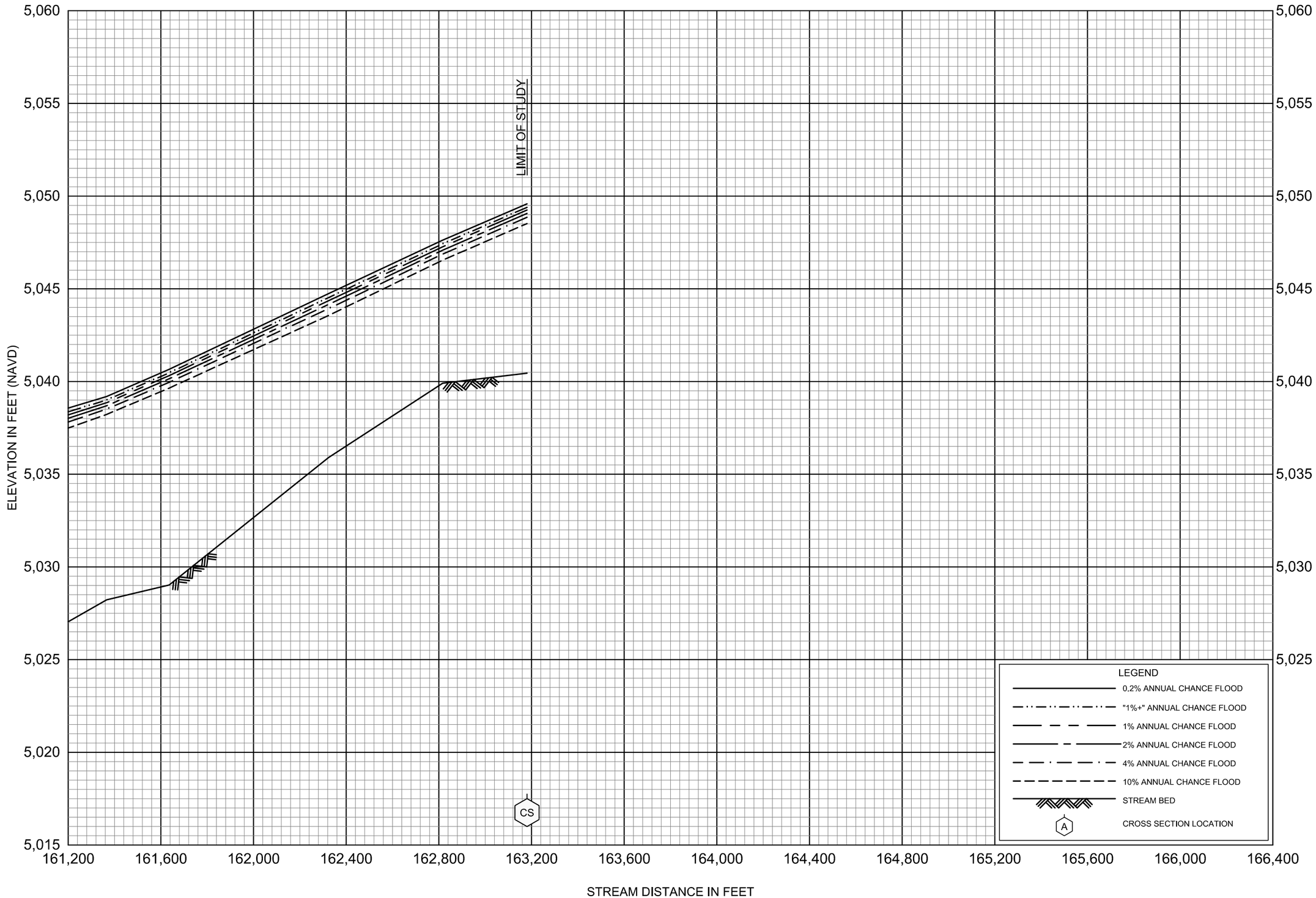
FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

WEST GALLATIN RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

Appendix C – Structure Photos

Structure Photograph Reference Table:

Location	ID	Type	Reach	RS	Page
Nixon Gulch Rd.	1	Bridge	Gallatin River	-516	1
Dry Creek Rd.	4	Culvert	West Gallatin River	20764	2
Dry Creek Rd.	8	Bridge	West Gallatin Side Channel	20764	3
Pedestrian Path	8	Bridge	West Gallatin Side Channel	20800	3
Dry Creek Rd.	10	Culvert	West Gallatin Side Channel	20764	4
Dry Creek Rd.	11	Bridge	West Gallatin River	20764	5
Pedestrian Path	11	Bridge	West Gallatin River	20800	5
Highway 10	15	Bridge	Baker Creek Side Channel	15017	6
Highway 10	16	Bridge	Baker Creek	15017	7
I-90 Westbound	17	Bridge	Baker Creek	15441	8
Highway 10	18	Bridge	Baker Creek	15017	9
I-90 Eastbound	19	Bridge	Baker Creek	15508	10
MRL Railroad	22	Bridge	Baker Creek	15252	11
I-90 Eastbound	24	Bridge	Baker Creek	15508	12
I-90 Westbound	25	Bridge	Baker Creek	15441	13
MRL Railroad	28	Bridge	Baker Creek	15252	14
Heeb Rd	35	Culvert	I-90 Diversion	3617	15
Highway 10	36	Bridge	West Gallatin River	39076	16
MRL Railroad	37	Bridge	West Gallatin River	38331	17
I-90 Westbound	38	Bridge	West Gallatin River	38529	18
I-90 Eastbound	39	Bridge	West Gallatin River	38604	19
Private Rd.	52	Bridge	Baker Creek	42651	20
Stage Coach Trail	57	Bridge	Baker Creek	47932	21
Stage Coach Trail	58	Bridge	Baker Creek Overflow	4904	22
Private Rd.	61	Bridge	Baker Creek	52373	23
Amsterdam Rd.	66	Bridge	Baker Creek Overflow	12627	24
Amsterdam Rd.	73	Bridge	Baker Creek	55758	25
Linney Rd.	74	Culvert	Baker Creek	57766	26
Amsterdam Rd.	75	Bridge	West Gallatin Side Channel	63279	27
Amsterdam Rd.	77	Bridge	West Gallatin Side Channel	63279	28
Amsterdam Rd.	78	Bridge	West Gallatin River	63279	29
Veltkamp Rd.	80	Bridge	Baker Creek Overflow	16480	30
Linney Rd.	82	Bridge	Linney Rd. Split Flow Channel	1640	31
Veltkamp Rd.	83	Culvert	Linney Rd. Split Flow Channel	926	32
Heidner Lane	84	Bridge	Baker Creek	60727	33
Heidner Lane	87	Bridge	Baker Creek	60727	34
Private Rd.	88	Bridge	Baker Creek	61053	35
Private Rd.	89	Bridge	Linney Rd. Split Flow Channel	3455	36
Linney Rd.	92	Culvert	Baker Creek Overflow	18863	37

Location	ID	Type	Reach	RS	Page
West Gallatin	96	Diversion	Baker Creek	65545	38
Cameron Bridge Rd.	101	Culvert	Baker Creek Overflow	29269	39
Cameron Bridge Rd.	102	Culvert	Moreland Ditch	1723	40
West Gallatin	103	Diversion	Moreland Ditch	1860	41
Cameron Bridge Rd.	104	Bridge	West Gallatin River	75399	42
Cameron Bridge Rd.	106	Culvert	West Gallatin River Ditch	75399	43
Highway 84	128	Bridge	West Gallatin River	106835	44
Highway 84	129	Culvert	West Gallatin Side Channel	106835	45
Axtell Anceney Rd.	151	Bridge	West Gallatin Side Channel	128558	46
Axtell Anceney Rd.	152	Bridge	West Gallatin River	128558	47
Mill Street	157	Culvert	West Gallatin Side Channel	141776	48
Mill Street	158	Bridge	West Gallatin River	141776	49
Mill Street	159	Culvert	West Gallatin Side Channel	141776	50
Mill Street	160	Bridge	West Gallatin River	141776	51
Dry Creek Rd.	163	Culvert	West Gallatin Side Channel	20764	52
Dry Creek Rd.	165	Culvert	West Gallatin River Channel	20764	53

Nixon Gulch Rd., Structure ID1 – Gallatin River RS: -516

Upstream face of bridge.

Downstream face of bridge.

Dry Creek Rd, Structure ID4 – West Gallatin River Side Channel RS: 20764

Upstream face of culvert.

Downstream face of culvert.

Dry Creek Rd, Structure ID8 – West Gallatin Side Channel RS 20764

Pedestrian Path, Structure ID8 – West Gallatin Side Channel RS 20800

Upstream face of bridges.

Downstream face of bridges.

Dry Creek Rd, Structure ID10 – West Gallatin River Side Channel RS: 20764

Upstream face of culvert.

Downstream face of culvert.

Dry Creek Rd, Structure ID11 – West Gallatin RS 20764

Pedestrian Path, Structure ID11 – West Gallatin RS 20800

Upstream face of bridges.

Downstream face of bridges.

Highway 10, Structure ID15 – Baker Creek Side Channel RS: 15017

Upstream face of culvert.

Downstream face of culvert.

Highway 10, Structure ID16 – Baker Creek RS: 15017

Upstream face of bridge.

Downstream face of bridge.

I-90 Westbound, Structure ID17 – Baker Creek RS: 15441

Upstream face of bridge.

Downstream face of bridge.

Highway 10, Structure ID18 – Baker Creek RS: 15017

Upstream face of bridge.

Downstream face of bridge.

I-90 Eastbound, Structure ID19 – Baker Creek RS: 15508

Upstream face of bridge.

Downstream face of bridge.

MRL Railroad, Structure ID22 – Baker Creek RS: 15252

Upstream face of bridge.

Downstream face of bridge.

I-90 Eastbound, Structure ID24 – Baker Creek RS: 15508

Upstream face of bridge.

Downstream face of bridge.

I-90 Westbound, Structure ID25 – Baker Creek RS: 15441

Upstream face of bridge.

Downstream face of bridge.

MRL Railroad, Structure ID28 – Baker Creek RS 15252

Upstream face of bridge.

Downstream face of bridge.

Heeb Rd., Structure ID35 – I-90 Diversion RS: 3617

Upstream face of culverts.

Downstream face of culverts.

Highway 10, Structure ID36 – West Gallatin River RS: 38076

Upstream face of bridge.

Downstream face of bridge.

MRL Railroad, Structure ID37 – West Gallatin River RS: 38331

Upstream face of bridge.

Downstream face of bridge.

I-90 Westbound, Structure ID38 – West Gallatin River RS: 38529

Upstream face of bridge.

Downstream face of bridge.

I-90 Eastbound, Structure ID39 – West Gallatin River RS: 38604

Upstream face of bridge.

Downstream face of bridge.

Private Rd., Structure ID52 – Baker Creek RS: 42651

Upstream face of bridge.

Downstream face of bridge.

Stage Coach Trail, Structure ID57 – Baker Creek RS: 47932

Upstream face of bridge.

Downstream face of bridge.

Stage Coach Trail, Structure ID58 – Baker Creek Overflow RS: 4904

Upstream face of bridge.

Downstream face of bridge.

Private Rd., Structure ID61 – Baker Creek RS: 52373

Upstream face of bridge.

Downstream face of bridge.

Amsterdam Rd., Structure ID66 – Baker Creek Overflow RS: 12627

Upstream face of bridge.

Downstream face of bridge.

Amsterdam Rd. ID73 – Baker Creek RS: 55758

Upstream face of bridge.

Downstream face of bridge.

Linney Rd. ID74 – Baker Creek RS: 57766

Upstream face of culvert.

Downstream face of culvert.

Amsterdam Rd. ID75 – West Gallatin River Side Channel RS: 63279

Upstream face of bridge.

Downstream face of bridge.

Amsterdam Rd. Structure ID77 – West Gallatin River Side Channel RS: 63279

Upstream face of bridge.

Downstream face of bridge.

Amsterdam Rd. Structure ID78 – West Gallatin River RS: 63279

Upstream face of bridge.

Downstream face of bridge.

Veltkamp Rd. Structure ID80 – Baker Creek Overflow RS: 16480

Upstream face of bridge.

Downstream face of bridge.

Linney Rd. Structure ID82 – Linney Rd. Split Flow Channel RS: 1640

Upstream face of bridge.

Downstream face of bridge.

Veltkamp Rd. Structure ID83 – Linney Rd. Split Flow Channel RS: 926

Upstream face of culvert.

Downstream face of culvert.

Heidner Lane Structure ID84 Baker Creek RS: 60727

Upstream face of bridge.

Upstream face of bridge.

Heidner Lane Structure ID87 Baker Creek RS: 60727

Upstream face of bridge.

Downstream face of bridge.

Private Rd. Structure ID88 Baker Creek RS: 61053

Upstream face of bridge.

Downstream face of bridge.

Private Rd. Structure ID89 Linney Rd. Split RS: 3455

Upstream face of bridge.

Downstream face of bridge.

Linney Rd. Structure ID92 Baker Creek Overflow RS: 18863

Upstream face of culverts.

Downstream face of culverts.

West Gallatin River Diversion Structure ID96 Baker Creek RS: 65545

Upstream face of Baker Creek diversion structure.

Downstream face of Baker Creek diversion structure.

Cameron Bridge Rd. Structure ID101 – Baker Creek Overflow RS: 29269

Upstream face of culvert.

Downstream face of culvert.

Cameron Bridge Rd. Structure ID102 – Moreland Ditch RS: 1723

Upstream face of culvert.

Downstream face of culvert.

West Gallatin River Diversion Structure ID103 – Moreland Ditch RS: 1860

Upstream face of diversion structure.

Downstream face of diversion structure.

Cameron Bridge Rd. Structure ID104 – West Gallatin River RS: 75399

Upstream face of bridge.

Downstream face of bridge.

Cameron Bridge Rd. Structure ID106 – West Gallatin River Ditch RS: 75399

Upstream face of culvert.

Downstream face of culvert.

Highway 84 Structure ID128 – West Gallatin River RS: 106835

Upstream face of bridge.

Downstream face of bridge.

Highway 84 Structure ID129 – West Gallatin River Side Channel RS: 106835

Upstream face of culverts.

Downstream face of culverts.

Axtell Anceney Rd. Structure ID151 – West Gallatin River Side Channel RS: 128558

Upstream face of bridge.

Downstream face of bridge.

Axtell Anceney Rd Structure ID152 – West Gallatin River RS: 128558

Upstream face of bridge.

Downstream face of bridge.

Mill Street Structure ID157 – West Gallatin River Side Channel RS: 141776

Upstream face of culvert.

Downstream face of culvert.

Mill Street Structure ID158 – West Gallatin River RS: 141776

Upstream face of bridge.

Downstream face of bridge.

Mill Street Structure ID159 – West Gallatin River Side Channel RS: 141776

Upstream face of culverts.

Downstream face of culverts.

Mill Street Structure ID160 – West Gallatin River RS: 141776

Upstream face of bridge.

Downstream face of bridge.

Dry Creek Rd, Structure ID163 – West Gallatin River Side Channel RS: 20764

Upstream face of culverts

Downstream face of culverts.

Dry Creek Rd, Structure ID165 – West Gallatin River Side Channel RS: 20764

Upstream face of culvert

Downstream face of culvert.

Appendix D – Floodway Data Table

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
WEST GALLATIN RIVER								
A	386	895[2]	2860	3.6	4163.1	4163.1	4163.2	0.1
B	1,806	800	2021	5.1	4166.9	4166.9	4167.4	0.5
C	3,583	871[2]	2095	4.9	4174.4	4174.4	4174.7	0.3
D	5,474	840[2]	2034	5.0	4180.3	4180.3	4180.6	0.3
E	7,427	632[2]	1448	7.1	4187.3	4187.3	4187.5	0.2
F	8,999	779	2316	4.4	4193.4	4193.4	4193.5	0.1
G	10,924	1100	3063	3.3	4197.4	4197.4	4197.8	0.4
H	12,610	1146[2]	2502	4.1	4203.1	4203.1	4203.4	0.3
I	14,595	1036[2]	1793	5.7	4208.6	4208.6	4209.0	0.4
J	16,226	2168[2]	2920	3.5	4214.9	4214.9	4215.3	0.4
K	18,192	3007[2]	3109	3.3	4221.9	4221.9	4221.9	0.0
L	19,735	3961[2]	4695	2.2	4224.8	4224.8	4225.1	0.3
M	21,689	2802[2]	3593	2.9	4233.2	4233.2	4233.7	0.5
N	23,578	1151[2]	1496	6.0	4241.4	4241.4	4241.8	0.4
O	25,158	985[2]	2075	4.5	4248.5	4248.5	4248.9	0.4
P	26,546	825[2]	2348	4.0	4252.4	4252.4	4252.7	0.3
Q	28,027	904[2]	2425	3.9	4257.6	4257.6	4257.9	0.3
R	29,418	1362[2]	2035	4.7	4263.3	4263.3	4263.6	0.3
S	31,197	1180[2]	2237	4.3	4271.2	4271.2	4271.4	0.2
T	32,692	1054	1902	5.0	4278.0	4278.0	4278.4	0.4
U	34,255	880	2160	4.4	4284.4	4284.4	4284.6	0.2
V	35,735	1219[2]	2328	4.1	4290.1	4290.1	4290.4	0.3

[1]Feet above confluence with Gallatin River

[2]Floodway topwidth includes width of high ground area

TABLE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

FLOODWAY DATA

WEST GALLATIN RIVER

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
WEST GALLATIN RIVER								
W	37,269	1113[2]	2890	3.3	4296.8	4296.8	4297.3	0.5
X	39,078	797	2875	3.4	4306.4	4306.4	4306.4	0.0
Y	41,046	619[2]	1511	6.5	4314.1	4314.1	4314.4	0.3
Z	42,840	1415	3552	2.8	4322.2	4322.2	4322.6	0.4
AA	44,544	1532[2]	2084	4.7	4330.0	4330.0	4330.2	0.2
AB	46,521	1493[2]	2435	4.0	4341.6	4341.6	4342.0	0.4
AC	48,420	998[2]	1952	5.0	4350.9	4350.9	4351.3	0.4
AD	50,306	1045[2]	2140	4.6	4361.5	4361.5	4361.7	0.2
AF	53,311	789[2]	1800	5.4	4379.0	4379.0	4379.3	0.3
AG	54,714	821[2]	1693	5.8	4387.6	4387.6	4388.0	0.4
AH	56,690	925	2353	4.2	4398.6	4398.6	4398.7	0.1
AI	58,576	802[2]	1465	6.7	4410.3	4410.3	4410.5	0.2
AJ	60,169	749[2]	1689	5.8	4417.2	4417.2	4417.6	0.4
AK	61,822	762	2695	3.6	4426.3	4426.3	4426.8	0.5
AL	63,676	1257[2]	1923	5.1	4436.0	4436.0	4436.1	0.1
AM	65,418	726[2]	1638	6.0	4447.6	4447.6	4447.8	0.2
AN	66,941	980[2]	1346	7.3	4456.9	4456.9	4457.2	0.3
AO	68,881	1466[2]	2096	4.7	4470.5	4470.5	4470.8	0.3
AP	70,411	1411[2]	2205	4.5	4478.7	4478.7	4479.1	0.4
AQ	72,407	770	1701	5.8	4491.8	4491.8	4492.0	0.2
AR	73,955	769[2]	1968	5.0	4499.9	4499.9	4500.0	0.1
AS	75,810	328	1445	6.8	4510.7	4510.7	4510.7	0.0

[1]Feet above confluence with Gallatin River
[2]Floodway topwidth includes width of high ground area

TABLE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

FLOODWAY DATA

WEST GALLATIN RIVER

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
WEST GALLATIN RIVER								
AT	77,398	804[2]	2224	4.5	4520.2	4520.2	4520.4	0.2
AU	79,311	1020[2]	2858	3.6	4532.2	4532.2	4532.5	0.3
AV	80,749	645[2]	1434	7.2	4540.4	4540.4	4540.8	0.4
AW	81,668	744[2]	1905	5.4	4546.2	4546.2	4546.3	0.1
AX	83,465	1402[2]	2726	3.8	4556.1	4556.1	4556.3	0.2
AY	85,371	1267[2]	2166	4.7	4568.0	4568.0	4568.2	0.2
AZ	86,918	1953[2]	3130	3.3	4575.2	4575.2	4575.3	0.1
BA	88,554	1104[2]	1851	5.6	4584.5	4584.5	4584.8	0.3
BB	90,470	782[2]	1832	5.6	4596.6	4596.6	4596.6	0.0
BC	91,967	847[2]	1627	6.3	4606.0	4606.0	4606.3	0.3
BD	93,515	1586[2]	3325	3.1	4614.3	4614.3	4614.8	0.5
BE	95,229	914[2]	1989	5.2	4624.4	4624.4	4624.6	0.2
BF	96,833	971[2]	1912	5.4	4634.2	4634.2	4634.7	0.5
BG	98,375	1161[2]	2438	4.2	4644.0	4644.0	4644.5	0.5
BH	100,132	1092[2]	1920	5.4	4654.0	4654.0	4654.3	0.3
BI	101,481	1293	3555	2.9	4660.1	4660.1	4660.6	0.5
BJ	102,907	1356[2]	3063	3.4	4668.9	4668.9	4669.3	0.4
BK	104,428	1113[2]	2984	3.4	4679.1	4679.1	4679.6	0.5
BL	105,987	1177[2]	2296	4.5	4688.8	4688.8	4689.2	0.4
BM	107,608	892[2]	2736	3.9	4700.3	4700.3	4700.4	0.1
BN	109,498	871[2]	1855	5.5	4710.3	4710.3	4710.6	0.3
BO	110,992	673[2]	1596	6.4	4719.1	4719.1	4719.3	0.2

[1]Feet above confluence with Gallatin River
[2]Floodway topwidth includes width of high ground area

TABLE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

FLOODWAY DATA

WEST GALLATIN RIVER

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
WEST GALLATIN RIVER								
BP	112,560	481[2]	1244	8.3	4728.4	4728.4	4728.5	0.1
BQ	114,490	1325[2]	1615	6.4	4739.3	4739.3	4739.6	0.3
BR	116,442	779[2]	1865	5.5	4751.8	4751.8	4752.2	0.4
BS	118,003	773[2]	1736	5.9	4760.2	4760.2	4760.7	0.5
BT	119,971	744[2]	1458	7.0	4772.1	4772.1	4772.1	0.0
BU	121,486	515[2]	1511	6.8	4781.9	4781.9	4781.9	0.0
BV	122,958	440	1381	7.4	4790.5	4790.5	4790.6	0.1
BW	124,493	1154[2]	2238	4.6	4799.9	4799.9	4800.2	0.3
BX	126,170	1425[2]	2039	5.0	4810.5	4810.5	4810.9	0.4
BY	127,650	815[2]	1589	6.5	4820.5	4820.5	4820.6	0.1
BZ	129,374	651[2]	1587	6.5	4831.3	4831.3	4831.5	0.2
CA	131,189	754[2]	1717	6.0	4842.5	4842.5	4843.0	0.5
CB	132,819	597[2]	1435	7.2	4853.4	4853.4	4853.8	0.4
CC	134,444	590[2]	1498	6.9	4863.9	4863.9	4864.0	0.1
CD	136,275	734[2]	2254	4.6	4875.5	4875.5	4875.9	0.4
CE	137,811	225[2]	1117	9.2	4885.1	4885.1	4885.1	0.0
CF	138,953	1226[2]	2054	5.0	4893.7	4893.7	4893.8	0.1
CG	140,525	1330[2]	3114	3.3	4905.0	4905.0	4905.2	0.2
CH	142,333	1982[2]	2500	4.1	4918.3	4918.3	4918.3	0.0
CI	144,328	1751[2]	2233	4.6	4929.4	4929.4	4929.8	0.4
CJ	145,975	1396[2]	1861	5.5	4939.4	4939.4	4939.9	0.5
CK	147,922	1030[2]	1202	8.5	4953.1	4953.1	4953.2	0.1

[1]Feet above confluence with Gallatin River
[2]Floodway topwidth includes width of high ground area

TABLE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

FLOODWAY DATA

WEST GALLATIN RIVER

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
WEST GALLATIN RIVER								
CL	149,498	1192[2]	1882	5.5	4962.8	4962.8	4963.3	0.5
CM	151,381	1419[2]	2057	5.0	4975.7	4975.7	4976.2	0.5
CN	153,339	714[2]	1511	6.8	4987.5	4987.5	4987.7	0.2
CO	155,314	378[2]	1388	7.4	5001.0	5001.0	5001.1	0.1
CP	157,250	729[2]	1344	7.6	5013.8	5013.8	5014.0	0.2
CQ	159,075	324	1325	7.8	5025.1	5025.1	5025.4	0.3
CR	160,959	445	2125	4.8	5037.3	5037.3	5037.7	0.4
CS	163,181	200[2]	1134	9.1	5049.3	5049.3	5049.7	0.4

[1]Feet above confluence with Gallatin River
[2]Floodway topwidth includes width of high ground area

TABLE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

GALLATIN COUNTY, MT

AND INCORPORATED AREAS

FLOODWAY DATA

WEST GALLATIN RIVER

Appendix E – QA/QC Checklists

MORRISON MAIERLE, INC.
ENGINEERS • SURVEYORS • PLANNERS • SCIENTISTS

Hydraulic Data

Quality Control Tracking

Project Name: West Gallatin Flood Study

Mapping Activity Statement No.: 2014-02

Task Completed: 12/01/2015

Submission Date: 12/08/2015

QC Review Activity		
1. Ready for QC	LTP: Mark Franchi	Date: 10/13/2015
2. QC Review	QCR: Luke Carlson	Date: 10/28/2015
3. Concurrence	LTP: Mark Franchi	Date: 10/22/2015
4. Changes Made	LTP: Mark Franchi	Date: 12/01/2015
5. Changes Verified	QCR: Luke Carlson	Date: 12/08/2015

LTP – Lead Technical Professional: Mark Franchi − MAF

QCR – Quality Control Reviewers: Luke Carson − LC

Individual − Initials

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
01	Is the computer program used for hydraulic modeling approved by FEMA, and is it a current model version?	The list of models approved by FEMA can be found at www.fema.gov/fhm/en_modl.shtm	Pass ☒ Fail ☐ N/A ☐	HEC-RAS v4.1.0
02	Does the model cover the reach of detailed study shown on the workmap?		Pass ☒ Fail ☐ N/A ☐	
03	Were both Multiple and Floodway models run?		Pass ☒ Fail ☐ N/A ☐	
04	Does the flow used in the hydraulic model match with the Summary of Discharges table?		Pass ☒ Fail ☐ N/A ☐	
05	Do split flow reaches check with master flow diagram and table and check for continuity with hydrology?		Pass ☒ Fail ☐ N/A ☐	
06	Are the 1% AC flows identical for both multiple & floodway models?		Pass ☒ Fail ☐ N/A ☐	
07	Is the starting water surface boundary condition of the model appropriate?		Pass ☒ Fail ☐ N/A ☐	
08	Is the Starting Water Surface Elevation for floodway run within 0.5 foot surcharge limit?		Pass ☒ Fail ☐ N/A ☐	
09	Are all floodway surcharges less than or equal to 0.5 foot?		Pass ☒ Fail ☐ N/A ☐	
10	Are all bridges visible on the workmap modeled or is a reason for not modeling provided?		Pass ☒ Fail ☐ N/A ☐	
11	Are bridges/culverts correctly modeled with high and low flow methods selection?		Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
12	Are bridges/culverts coded with correct low chord, high chord, pier widths, coefficients and centerline stations?		Pass ☒ Fail ☐ N/A ☐	
13	Have ineffective flow areas, if any, been identified and blocked?		Pass ☒ Fail ☐ N/A ☐	
14	Does the model's stationing as represented on the profile, match the stream distances shown on the map?		Pass ☒ Fail ☐ N/A ☐	
15	Are the left and right overbank distances adjusted for flow around curves?		Pass ☒ Fail ☐ N/A ☐	
16	Are cross-sections placed perpendicular to channel?		Pass ☒ Fail ☐ N/A ☐	
17	Are cross-section bank stations set at top of main channel bank?		Pass ☒ Fail ☐ N/A ☐	
18	Do cross-sections extend beyond the 0.2% AC floodplain?		Pass ☒ Fail ☐ N/A ☐	
19	Are cross-sections spaced correctly for general criteria of 500-600 feet maximum between cross-sections?		Pass ☒ Fail ☐ N/A ☐	
20	Are split flow paths unencroached and identified?		Pass ☒ Fail ☐ N/A ☐	
21	Are all Check-RAS error messages resolved?		Pass ☒ Fail ☐ N/A ☐	
22	Are the Manning's n values used in the model within reasonable ranges?		Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
23	Are Levees, if present, modeled appropriately based on whether they are certified according to NFIP (65.10)?		Pass ☐ Fail ☐ N/A ☒	
24	Are expansion/contraction coefficients set at 0.3 and 0.5 at correct river stations for bridge/culvert crossings?		Pass ☒ Fail ☐ N/A ☐	
25	For areas where non-certified levees are shown on the workmap has analysis been provided for With & Without Levee conditions?		Pass ☐ Fail ☐ N/A ☒	
26	Have sufficient backup hydraulic analysis been provided for any shallow flooding, or coastal areas, if any?		Pass ☐ Fail ☐ N/A ☒	
27	Metadata file is submitted?		Pass ☒ Fail ☐ N/A ☐	
28	Hydraulic model is calibrated to available high water?		Pass ☒ Fail ☐ N/A ☐	
Profiles:				
29	Do the profiles meet FEMA format & font criteria?		Pass ☒ Fail ☐ N/A ☐	
30	Have appropriate vertical and horizontal scales been chosen?		Pass ☒ Fail ☐ N/A ☐	
31	Are elevations referenced to NAVD88 and shown?		Pass ☒ Fail ☐ N/A ☐	
32	Does the title block show the correct community or county and State names?		Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
33	Does the beginning station reference match the labeling of the left side of the first profile for each flooding source?		Pass ☒ Fail ☐ N/A ☐	
34	Is the backwater or influence from the receiving stream shown on the profile?		Pass ☐ Fail ☐ N/A ☒	
35	Do the profiles have appropriately spaced lettered cross-sections?		Pass ☒ Fail ☐ N/A ☐	
36	Are all the corporate limits and confluences shown on the profile?		Pass ☒ Fail ☐ N/A ☐	
37	Do the bridge and culvert labels match with the labels shown on the base map?		Pass ☒ Fail ☐ N/A ☐	
38	Do bridge low chord, high chord, and river station match HEC-RAS model?		Pass ☒ Fail ☐ N/A ☐	
39	Do the locations of the lettered cross sections with respect to bridges and confluences match with the mapped locations?		Pass ☒ Fail ☐ N/A ☐	
Floodway Data Tables:				
40	Do the overall font & formatting meet FEMA criteria?		Pass ☒ Fail ☐ N/A ☐	
41	Is the proper community name and stream name shown?		Pass ☒ Fail ☐ N/A ☐	
42	Do the beginning station and measurement units match the profile?		Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
43	Do the Cross Section Letter distances match the stations shown on the Profile?	(rounded to nearest foot)	Pass ☒ Fail ☐ N/A ☐	
44	Are the WIDTH and SECTION AREA in FDT exactly the same as the model output?	(rounded to nearest foot)	Pass ☒ Fail ☐ N/A ☐	
45	Do the Velocity numbers match the Mean Velocity output?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	
46	Are backwater elevations or influence elevations from the profile, if any, shown in the Regulatory Column?	(rounded to one decimal point)	Pass ☐ Fail ☐ N/A ☒	
47	Are the With and Without Floodway WSELs shown "without consideration of backwater", and do they match the model output?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	
48	Is the correct Datum shown?	Must match Profile and FIRM	Pass ☒ Fail ☐ N/A ☐	
49	Does the INCREASE column, equal the difference between WITH & WITHOUT columns?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	

HEC-RAS
Review Checklist

Project Name: West Gallatin River Flood Study
Project Number: 1447.037
Completed By: Luke Carlson Date: 12/01/2015

HEC-RAS Model Items:
Check appropriate box: *(If "NA" is checked, an explanation should be entered below item.)*

Yes	No	N/A	
☐	☒	☐	Does the model go through Critical Depth for any of the flows? If no, then go to next item. If yes, is this reasonable? If so, go to errors and check whether critical depth was calculated or assumed. If critical depth was calculated, run under mixed flow. If critical depth was assumed, model should be revised.
☒	☐	☐	Model has been calibrated (if possible).
☐	☐	☒	2-year (50% Annual-Chance) event water surface is within channel.
☒	☐	☐	Multiple Critical Depth Search has been set.
☒	☐	☐	Energy Grade Line decreases is in downstream direction.
☒	☐	☐	Ineffective flows overtopping at correct elevation (roadway and other sections).
☒	☐	☐	Continuity between X-SECs, especially when overtopping occurs.
☒	☐	☐	Flow widths are appropriate and/or calibrated.
☒	☐	☐	Right overbank flow at an acceptable event.
☒	☐	☐	Flow in channel.
☒	☐	☐	Left overbank flow at an acceptable event?
☒	☐	☐	Ineffective flow locations & elevations entered and checked.
☒	☐	☐	Contraction/Expansion coefficients checked.
☒	☐	☐	Entrance loss coefficients checked.
☒	☐	☐	Structure X-SECs located at 1:1 upstream and 2:1 downstream and are fully expanded.
☒	☐	☐	Reach distances between X-SECs checked. (Use an aerial photograph with surveyed X-SEC locations for reference. The X-SECs should be labeled with stations used in HEC-RAS and/or the U/S and D/S distances).

HEC-RAS
Review Checklist

HEC-RAS Model Items:
Check appropriate box: (If "NA" is checked, an explanation should be entered below item.)

Yes	No	N/A	
☒	☐	☐	Manning's "n" values checked and at each cross-section.
☒	☐	☐	Bank stations checked and are appropriate for each cross-section.
☒	☐	☐	Energy Method set for bridges in pressure flow or if ratio of EGL to Existing ground/Low chord to Existing Ground is less than or equal to 1.2. If ratio is greater than 1.2, use Pressure/Weir Method. If overtopping of the roadway is occurring, Pressure/Weir may need to be selected to calculate the weir flow over the road even if the bridge is not in pressure flow.
☒	☐	☐	Culvert calculation method set at highest "Upstream EG" or explain otherwise.
☐	☐	☒	Scour calculations have been checked. *(HEC-RAS often assumes an incorrect value or may not pick the correct method (Live Bed vs. Clear Water) for Contraction Scour. See HEC-RAS errata).*
☐	☐	☒	Contraction Scour bank points are set outside of Bridge Opening. (This make HEC-RAS determine flows, depths, widths, etc).
☐	☐	☒	Pier Scour K2 Coefficient set at 1, if angle of attack of the flow is 0 degrees and bridge is not skewed or flow is parallel with the pier. Otherwise check HEC-18 for K2 based on L/a ratio.
☐	☐	☒	HEC-RAS error for Abutment Scour been accounted for by entering all of the data for the Abutment Scour calculation.
☐	☐	☒	Independent check of HEC-RAS scour calculations using Excel spreadsheets.
☐	☐	☒	Plot toes and tops of slope for proposed bridge on the topographic mapping for project to check for skew, channel centerline, and overall layout. Show skew of bridge and the roadway stationing (if available).
☒	☐	☐	Multiple opening crossings set with conveyances only at the left and right extents of cross section.
☒	☐	☐	Check HEC-RAS output Errors, Warnings and Notes.

HEC-RAS
Review Checklist

Hydraulics Report Items:
Check appropriate box: *(If "NA" is checked, an explanation should be entered below item.)*

Yes	No	N/A	
☐	☐	☒	Included caveat: *This hydraulic evaluations summarized in this report were performed as part of a MDT road reconstruction project and should not be used as a floodplain study or for any other purposes.*
☒	☐	☐	Version of HEC-RAS listed in report.
☒	☐	☐	High water events and floodplain risks within project limits discussed in the report.
☐	☐	☒	Existing and proposed overtopping events discussed in the report.
☐	☐	☒	Water surface elevation(s) on the date of survey listed in report and the Bridge Rec Memo.
☐	☐	☒	Hydraulic Data Summary Sheet completed.
☐	☐	☒	Channel width modeled in HEC-RAS matches Report & Bridge Recommendation Memo.