NewFields
Perspective. Vision. Solutions.

TECHNICAL MEMORANDUM

DATE:	November 3, 2022
TO:	Mr. J. Grant Lincoln Lincoln Capital Group, LLC 3101 S Russell St. Missoula, MT 59801 Cassie Tripard City of Missoula Floodplain Administrator 435 Ryman St. Missoula, MT 59802
FROM:	Matthew Peterson, PE; NewFields
REVIEWED BY:	Dan Hoffman, CFM; NewFields
SUBJECT:	**Expressway-Grant Creek Floodplain Analysis**
ATTACHMENTS:	A - FEMA 2022 Letter of Map Revision B - Hydrologic Analysis Supplementary Information C - Hydraulics Analysis Supplementary Information

INTRODUCTION

A proposed development is being planned at 200 and 220 Expressway Blvd (the Property) in the City of Missoula, Montana (**Figure 1**). A portion of the Property is designated as a Special Flood Hazard Area (SFHA) by the Federal Emergency Management Agency (FEMA), thereby restricting development opportunities in accordance with the City of Missoula Floodplain Hazard Management Regulations. The SFHA is associated with Grant Creek (**Figure 1**), which flows along the eastern boundary of the Property.

The southern portion of the SFHA that borders the property is designated as an Approximate Zone A. The City of Missoula requires a floodplain analysis for proposed developments that encroach on or border Approximate Zone A floodplain areas. NewFields has conducted a hydrologic and hydraulics analysis to predict the flood inundation area associated with the 1-percent annual chance flood (i.e., 100-year flood[1]) of Grant Creek. All elevations presented throughout this memorandum are based on the North American Vertical Datum 1988 (NAVD88). The study area is limited to the Property and adjacent areas, as shown in **Figure 1**. This technical memorandum presents the methodology and results of the analysis.

1 The term 100-year flood means there is a 1-percent chance that this flood would occur during any given year.

HYDROLOGIC ANALYSIS METHODOLOGY AND RESULTS

Grant Creek is a perennial stream that flows north to south into the Missoula Valley from the foothills of the Rattlesnake mountains northwest of the City of Missoula and eventually discharges into the Clark Fork River, west of the City of Missoula. The objective of the hydrologic analysis was to determine the peak flow rate associated with the Grant Creek 100-year flood for use in the hydraulics analysis.

A FEMA Letter of Map Revision (LOMR) published in April 2022 for Middle Grant Creek encompasses the north-east corner of the Property (**Attachment A**). The LOMR reports a 1% annual chance peak discharge of 623 cubic feet per second (cfs) for Middle Grant Creek. NewFields confirmed this peak discharge rate using the US Geological Survey StreamStats web-based application and associated regional regression equations for Grant Creek (**Attachment B**). As determined by the recent LOMR and confirmed using regional regression equations, the calculated Grant Creek 100-year flood discharge at the Property is 623 cfs.

HYDRAULICS ANALYSIS METHODOLOGY AND RESULTS

A hydraulics analysis was conducted to simulate the Grant Creek 100-year flood (a flow of 623 cfs) through the study area and to predict the 100-year flood inundation area.

Hydraulic Analysis Methodology

The most commonly used hydraulics analysis method for predicting a flood inundation area associated with a river or creek is to develop a one-dimensional (1D) hydraulic model using the U.S. Army Corps of Engineers (USACE) HEC-RAS software program. 1D models are appropriate for streams with well-defined open channels (FEMA, 2016). To be consistent with the current FEMA effective model for Grant Creek (April 2022 LOMR, **Attachment A**), a 1D HEC-RAS model was selected as the modeling tool for this application.

Hydraulics Analysis Overview and Results

The HEC-RAS model geometry was developed based on analyzing reach characteristics such as cross-sectional geometry, slope, roughness, and bridge geometry. Channel and floodplain cross-sections were surveyed along Grant Creek throughout the Property, as well as downstream of the Expressway Blvd bridge to develop the model terrain (IMEG, 2020). The upstream end of the modeled reach matches the downstream boundary of the April 2022 LOMR.

The model geometry was developed from the model terrain and surveyed bridge elevations. The Expressway Blvd bridge was modeled using the Pressure method because initial model runs indicated the bridge low-chord would be submerged during the 100-year flood event. Ineffective flow areas were assumed as a 1:1 contraction rate and a 2:1 expansion rate in the vicinity of the bridge in accordance with standard industry practice.

Manning's roughness coefficients were estimated based on reach characteristics observed during site visits completed in February and April 2022. Due to the steepness of the reach (average slope of 1.4%), additional cross-sections were interpolated, and roughness coefficients were slightly increased in areas to reduce model errors in accordance with U.S. Geological Survey Water-Resources Investigations Report 85-4004. **Attachment C** summarizes the Manning's roughness coefficients applied to the overbanks and main channel at each cross-section.

The model was run as a steady flow analysis and the upstream flow was set to 623 cfs to simulate the Grant Creek 100-year flood event. The downstream boundary condition was set to normal depth and was determined by calculating the slope of the reach.

The model results predict a base flood elevation (BFE) of 3222.7' at the upstream cross-section, which matches the FEMA effective BFE shown on the 2022 LOMR (**Attachment A**). The analysis also predicts the 100-year flows will be contained within the Grant Creek channel banks through the length of the Property. Model results are shown on **Figure 2,** which also shows the following flood insurance rate map data obtained from the FEMA national flood hazard layer for comparison:

- Approximate Zone A floodplain boundary (associated with Grant Creek, downstream of the LOMR boundary)[1]
- Zone AE floodplain boundary (associated with Grant Creek)[1]
- Cross-sections and base flood elevations included in April 2022 LOMR (**Attachment A**)

Supplementary hydraulics analysis information is provided in **Attachment C**.

CONCLUSION

Results of the hydrologic and hydraulics analysis show that the predicted Grant Creek BFE at the modeled upstream cross-section is consistent with the FEMA effective BFE, as shown in **Figure 2** and **Attachment A**. Results of the analysis also show that the predicted Grant Creek 100-year flood inundation area is slightly larger than the FEMA Approximate Zone A floodplain boundary, though the predicted inundation area is still contained within the Grant Creek channel banks. The reason for the difference is because a detailed hydraulic model was probably not developed to determine the FEMA Approximate Zone A boundary; rather, the boundary was likely approximated based on limited topographic data of Grant Creek.

This report presents the results of a hydrologic and hydraulics analysis conducted to predict the Grant Creek 100-year flood inundation area. The analysis was conducted using methodologies accepted by FEMA and guidance developed by FEMA, U.S. Geological Survey, and USACE. The results do not guarantee that areas outside of the predicted inundation area will never flood. The analysis was conducted using the best available topographic data at the time of study, the predicted flood inundation area could change in the future if ground elevations within the predicted inundation area are modified.

[1] A FEMA Zone A designation represents areas subject to inundation by the 100-year flood event; Zone A areas have been determined using approximate methodologies. A FEMA Zone AE designation also represents areas subject to inundation by the 100-year flood event; however, these areas include predicted flood water surface elevations and have been determined using detailed methods (such as a hydrologic and hydraulics analysis). In the case of this study area, the FEMA Zone AE boundary was determined from the recent April 2022 LOMR (**Attachment A**).

Please contact me at mpeterson@newfields.com if you have any questions.

Sincerely,
NewFields

Matthew Peterson, PE
Civil Engineer

REFERENCES

FEMA. (2016). Guidance for Flood Risk Analysis and Mapping: Hydraulics - One-Dimensional Analysis.

FEMA. (2022). Letter of Map Revision Determination Document: Case Number 21-08-0878P, Community Number 300048.

FEMA. (2022). National Flood Hazard Layer Viewer. https://hazards-fema.maps.arcgis.com/apps/webappviewer/index.html?id=8b0adb51996444d4879338b5529aa9cd. Accessed October 2022.

IMEG. (2020). Topographic survey completed on April 21, 2022.

Jarret, Robert D. (1985). Determination of Roughness Coefficients for Streams in Colorado. U.S. Geological Survey.

Sando, R., Sando, S., McCarthy, P., & Dutton, D. (2016). Scientific Investigations Report 2015 -5019 -F: Methods for Estimating Peak-Flow Frequencies at Ungaged Sites in Montana Based on Data through Water Year 2011. U.S. Geological Survey.

U.S. Army Corps of Engineers – Hydrologic Engineering Center. (2022, March). HEC-RAS 6.2. Davis, CA.

U.S. Geological Survey. (2016). The StreamStats program, online at http://streamstats.usgs.gov, accessed on April 28, 2022 (Location: 46.90785, -114.03995).

Figures

Study Area
Expressway-Grant Creek Floodplain Analysis
Missoula, Montana
FIGURE 1

NewFields

Document Path: P:\350.00737.000 Lincoln Capitol_Express Way floodplain\05 GIS\Projects\FIGURE 1 - Study Area.mxd

Hydraulic Results - 100-Year Flood
Expressway-Grant Creek Floodplain Analysis
Missoula, Montana
FIGURE 2

NewFields

Document Path: P:\350.00737.000 Lincoln Capitol_Express Way floodplain\05 GIS\Projects\FIGURE 2 - Hydraulics Results.mxd

Attachment A

FEMA 2022 Letter of Map Revision

Federal Emergency Management Agency
Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT

COMMUNITY AND REVISION INFORMATION		PROJECT DESCRIPTION	BASIS OF REQUEST
COMMUNITY	**Missoula County** **Montana** **(Unincorporated Areas)**	**NO PROJECT**	**FLOODWAY** **1D HYDRAULIC ANALYSIS** **HYDROLOGIC ANALYSIS** **UPDATED TOPOGRAPHIC DATA**
	COMMUNITY NO.: 300048		
IDENTIFIER	Middle Grant Creek LOMR	**APPROXIMATE LATITUDE & LONGITUDE: 46.912, -114.037** **SOURCE:** Other **DATUM:** NAD 83	

ANNOTATED MAPPING ENCLOSURES	ANNOTATED STUDY ENCLOSURES
TYPE: FIRM* NO.: 30063C1195E DATE: July 6, 2015	DATE OF EFFECTIVE FLOOD INSURANCE STUDY: March 7, 2019 PROFILE: 183P-184P (NEW) SUMMARY OF DISCHARGE TABLE: 10 FLOODWAY DATA TABLE: 24

Enclosures reflect changes to flooding sources affected by this revision.
* FIRM - Flood Insurance Rate Map

FLOODING SOURCE AND REVISED REACH

Middle Grant Creek - From approximately 460 feet downstream of Schramm Street to approximately 160 feet downstream of Interstate 90 East Bound Exit Ramp

SUMMARY OF REVISIONS

Flooding Source	Effective Flooding	Revised Flooding	Increases	Decreases
Middle Grant Creek	No BFEs*	BFEs	YES	NONE
	No Floodway	Floodway	YES	NONE
	Zone A	Zone AE	YES	YES
	Zone A	Zone A	YES	NONE

* BFEs - Base Flood Elevations

DETERMINATION

This document provides the determination from the Department of Homeland Security's Federal Emergency Management Agency (FEMA) regarding a request for a Letter of Map Revision (LOMR) for the area described above. Using the information submitted, we have determined that a revision to the flood hazards depicted in the Flood Insurance Study (FIS) report and/or National Flood Insurance Program (NFIP) map is warranted. This document revises the effective NFIP map, as indicated in the attached documentation. Please use the enclosed annotated map panels revised by this LOMR for floodplain management purposes and for all flood insurance policies and renewals in your community.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Mapping and Insurance eXchange toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 3601 Eisenhower Avenue, Suite 500, Alexandria, VA 22304-6426. Additional Information about the NFIP is available on our website at https://www.fema.gov/flood-insurance.

Patrick "Rick" F. Sacbibit, P.E., Branch Chief
Engineering Services Branch
Federal Insurance and Mitigation Administration

Federal Emergency Management Agency

Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT (CONTINUED)

OTHER COMMUNITIES AFFECTED BY THIS REVISION

CID Number: 300049 **Name:** City of Missoula, Montana

AFFECTED MAP PANELS	AFFECTED PORTIONS OF THE FLOOD INSURANCE STUDY REPORT
TYPE: FIRM* NO.: 30063C1195E DATE: July 6, 2015	DATE OF EFFECTIVE FLOOD INSURANCE STUDY: March 7, 2019 PROFILE: 183P-184P (NEW) FLOODWAY DATA TABLE: 24 SUMMARY OF DISCHARGES TABLE: 10

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LETTER OF MAP REVISION
DETERMINATION DOCUMENT (CONTINUED)

COMMUNITY INFORMATION

APPLICABLE NFIP REGULATIONS/COMMUNITY OBLIGATION

We have made this determination pursuant to Section 206 of the Flood Disaster Protection Act of 1973 (P.L. 93-234) and in accordance with the National Flood Insurance Act of 1968, as amended (Title XIII of the Housing and Urban Development Act of 1968, P.L. 90-448), 42 U.S.C. 4001-4128, and 44 CFR Part 65. Pursuant to Section 1361 of the National Flood Insurance Act of 1968, as amended, communities participating in the NFIP are required to adopt and enforce floodplain management regulations that meet or exceed NFIP criteria. These criteria, including adoption of the FIS report and FIRM, and the modifications made by this LOMR, are the minimum requirements for continued NFIP participation and do not supersede more stringent State/Commonwealth or local requirements to which the regulations apply.

We provide the floodway designation to your community as a tool to regulate floodplain development. Therefore, the floodway revision we have described in this letter, while acceptable to us, must also be acceptable to your community and adopted by appropriate community action, as specified in Paragraph 60.3(d) of the NFIP regulations.

COMMUNITY REMINDERS

We based this determination on the 1-percent-annual-chance discharges computed in the submitted hydrologic model. Future development of projects upstream could cause increased discharges, which could cause increased flood hazards. A comprehensive restudy of your community's flood hazards would consider the cumulative effects of development on discharges and could, therefore, indicate that greater flood hazards exist in this area.

Your community must regulate all proposed floodplain development and ensure that permits required by Federal and/or State/Commonwealth law have been obtained. State/Commonwealth or community officials, based on knowledge of local conditions and in the interest of safety, may set higher standards for construction or may limit development in floodplain areas. If your State/Commonwealth or community has adopted more restrictive or comprehensive floodplain management criteria, those criteria take precedence over the minimum NFIP requirements.

We will not print and distribute this LOMR to primary users, such as local insurance agents or mortgage lenders; instead, the community will serve as a repository for the new data. We encourage you to disseminate the information in this LOMR by preparing a news release for publication in your community's newspaper that describes the revision and explains how your community will provide the data and help interpret the NFIP maps. In that way, interested persons, such as property owners, insurance agents, and mortgage lenders, can benefit from the information.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Mapping and Insurance eXchange toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 3601 Eisenhower Avenue, Suite 500, Alexandria, VA 22304-6426. Additional Information about the NFIP is available on our website at https://www.fema.gov/flood-insurance.

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Federal Insurance and Mitigation Administration

Federal Emergency Management Agency
Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT (CONTINUED)

We have designated a Consultation Coordination Officer (CCO) to assist your community. The CCO will be the primary liaison between your community and FEMA. For information regarding your CCO, please contact:

Ms. Jeanine D. Petterson
Director, Mitigation Division
Federal Emergency Management Agency, Region VIII
Denver Federal Center, Building 710
P.O. Box 25267
Denver, CO 80225-0267
(303) 235 4830

STATUS OF THE COMMUNITY NFIP MAPS

We will not physically revise and republish the FIRM and FIS report for your community to reflect the modifications made by this LOMR at this time. When changes to the previously cited FIRM panel(s) and FIS report warrant physical revision and republication in the future, we will incorporate the modifications made by this LOMR at that time.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Mapping and Insurance eXchange toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 3601 Eisenhower Avenue, Suite 500, Alexandria, VA 22304-6426. Additional Information about the NFIP is available on our website at https://www.fema.gov/flood-insurance.

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Federal Emergency Management Agency

Washington, D.C. 20472

LETTER OF MAP REVISION
DETERMINATION DOCUMENT (CONTINUED)

PUBLIC NOTIFICATION OF REVISION

A notice of changes will be published in the *Federal Register*. This information also will be published in your local newspaper on or about the dates listed below, and through FEMA's Flood Hazard Mapping website at https://www.floodmaps.fema.gov/fhm/bfe_status/bfe_main.asp

LOCAL NEWSPAPER

Name: *The Missoulian*

Dates: December 21, 2021 and December 28, 2021

Within 90 days of the second publication in the local newspaper, any interested party may request that we reconsider this determination. Any request for reconsideration must be based on scientific or technical data. Therefore, this letter will be effective only after the 90-day appeal period has elapsed and we have resolved any appeals that we receive during this appeal period. Until this LOMR is effective, the revised flood hazard determination presented in this LOMR may be changed.

This determination is based on the flood data presently available. The enclosed documents provide additional information regarding this determination. If you have any questions about this document, please contact the FEMA Mapping and Insurance eXchange toll free at 1-877-336-2627 (1-877-FEMA MAP) or by letter addressed to the LOMC Clearinghouse, 3601 Eisenhower Avenue, Suite 500, Alexandria, VA 22304-6426. Additional Information about the NFIP is available on our website at https://www.fema.gov/flood-insurance.

Patrick "Rick" F. Sacbibit, P.E., Branch Chief
Engineering Services Branch
Federal Insurance and Mitigation Administration

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Honeysuckle Drainage Swale	100 Feet East of Reserve Street	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]
La Valle Creek	At Mullan Road Crossing	27	448	*	778	943	1,381
Lolo Creek	At confluence with Bitterroot River	270	2,300	*	2,900	3,300	3,800
Lolo Creek	At USGS Gage No. 3520	250	2,100	*	2,700	3,000	3,500
Lower Grant Creek	At confluence with Clark Fork	29.6	170	*	358	629	864
Middle Grant Creek	Approximately 430 feet downstream of Schramm Street	24.9	*	*	*	623	*
Miller Creek	At confluence with Bitterroot River	48	350	*	550	675	1,150
Pattee Creek	At confluence with Bitterroot River	16	109	*	250	348	780
Pattee Creek	At South Higgins Avenue in the City of Missoula, Total Drainage	9.8	105	*	165	195	265
Rattlesnake Creek	At USGS Gage No. 3410 in the City of Missoula	80	1,905	*	2,690	3,000	3,750
Rock Creek	At confluence with Clark Fork	885	6,200	*	8,300	9,200	11,200
South Drainage East	At South Higgins Avenue in the City of Missoula, Total Drainage	1.3	45	*	70	80	105
South Drainage West	At Miller Creek Road in the City of Missoula, Total Drainage	1.7	25	*	40	50	65

REVISED DATA

REVISED TO REFLECT LOMR EFFECTIVE: April 27, 2022

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
W	-234	28	70	9.0	3,225.9	3,225.9	3,225.9	0.0
X	758	32	73	8.5	3,241.9	3,241.9	3,241.9	0.0
Y	1,574	24	67	9.4	3,253.9	3,253.9	3,253.9	0.0
Z	2,270	30	71	8.7	3,266.3	3,266.3	3,266.3	0.0

[1]Feet above Schramm Street

TABLE 24

FEDERAL EMERGENCY MANAGEMENT AGENCY

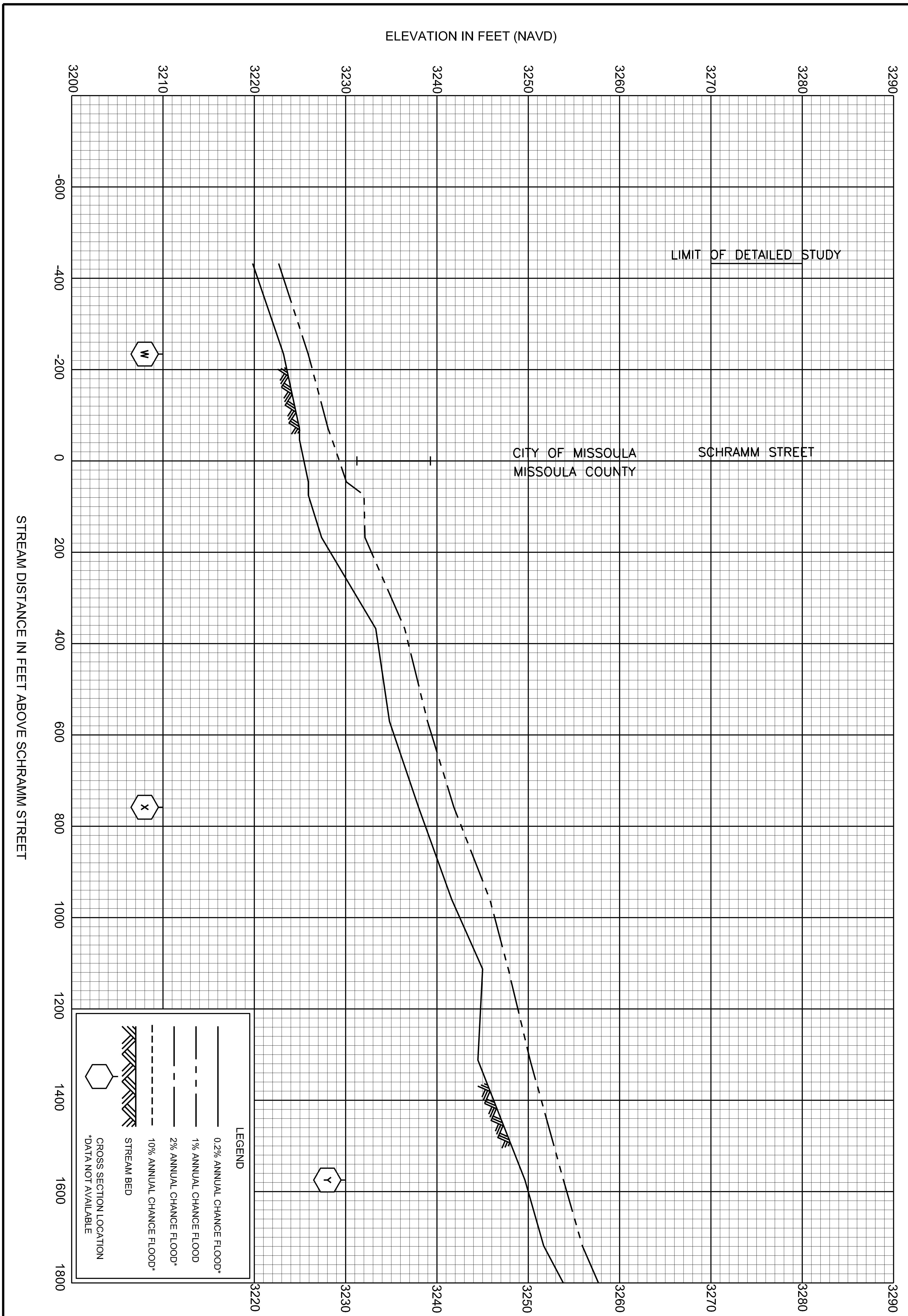
MISSOULA COUNTY, MONTANA

AND INCORPORATED AREAS

FLOODWAY DATA

REVISED TO REFLECT LOMR EFFECTIVE: April 27, 2022

FLOODING SOURCE: MIDDLE GRANT CREEK



183P

FEDERAL EMERGENCY MANAGEMENT AGENCY

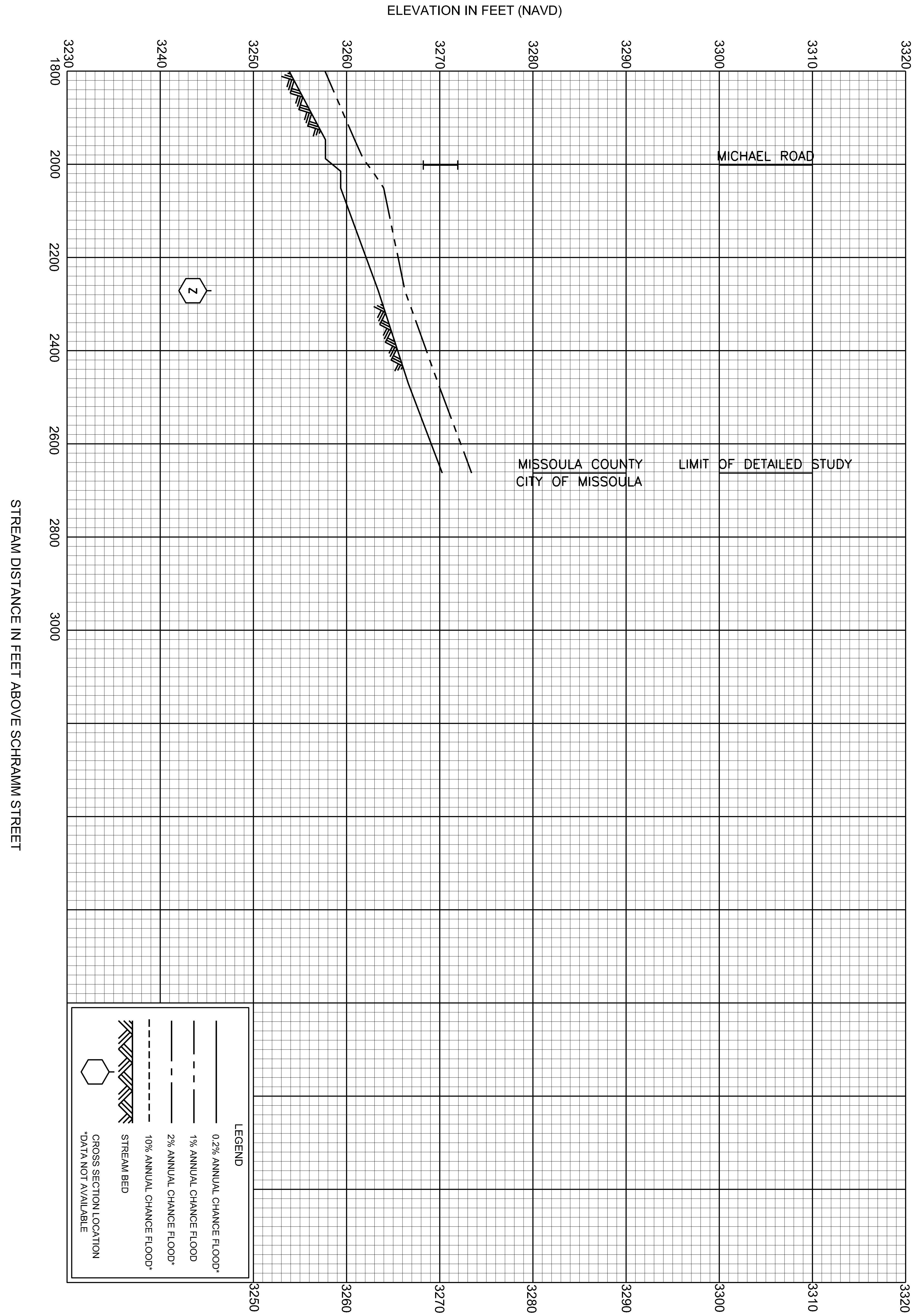
MISSOULA COUNTY, MT

AND INCORPORATED AREAS

FLOOD PROFILES

REVISED TO REFLECT LOMR EFFECTIVE: April 27, 2022

MIDDLE GRANT GREEK



184P

FEDERAL EMERGENCY MANAGEMENT AGENCY

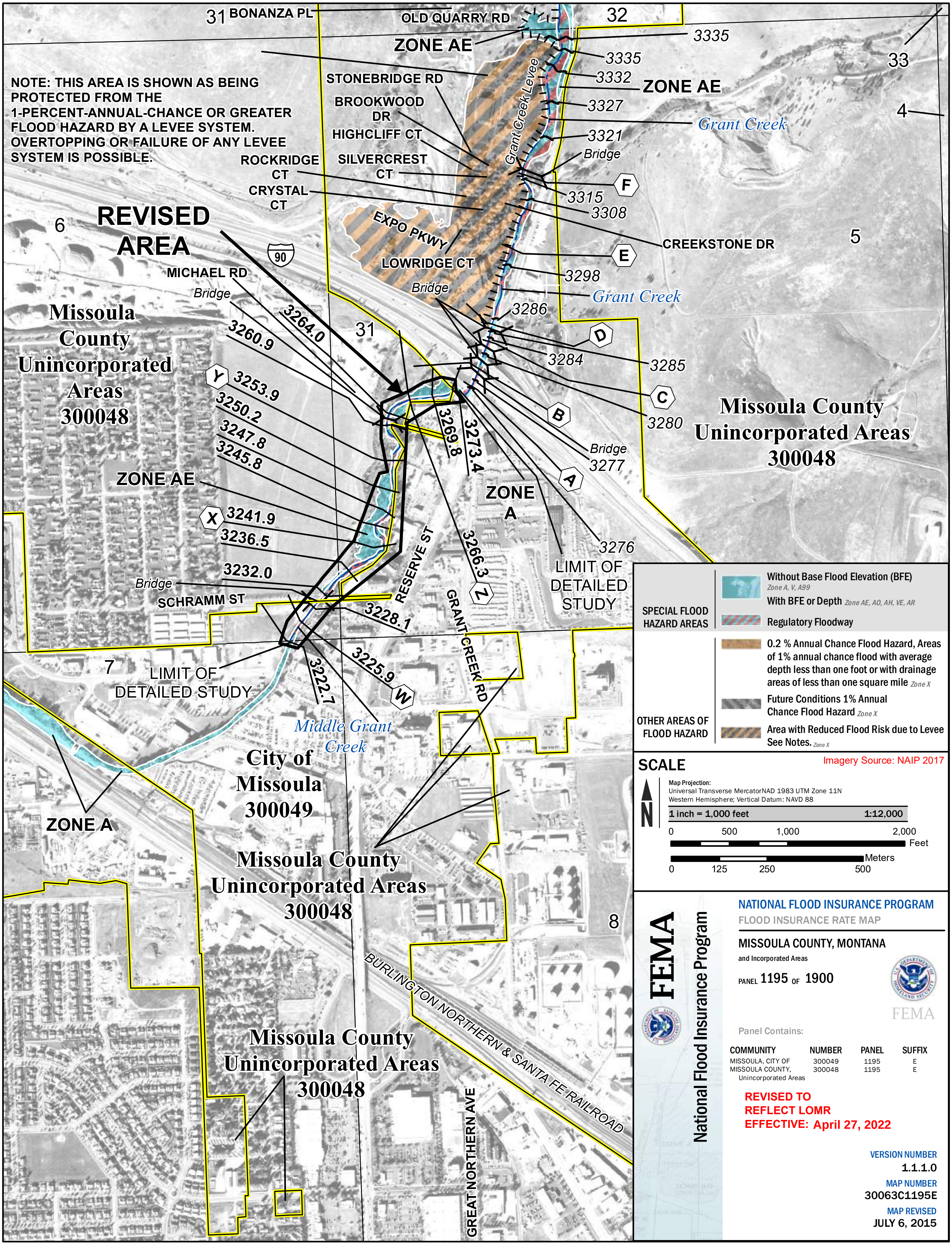
MISSOULA COUNTY, MT

AND INCORPORATED AREAS

FLOOD PROFILES

REVISED TO
REFLECT LOMR
EFFECTIVE: April 27, 2022

MIDDLE GRANT GREEK

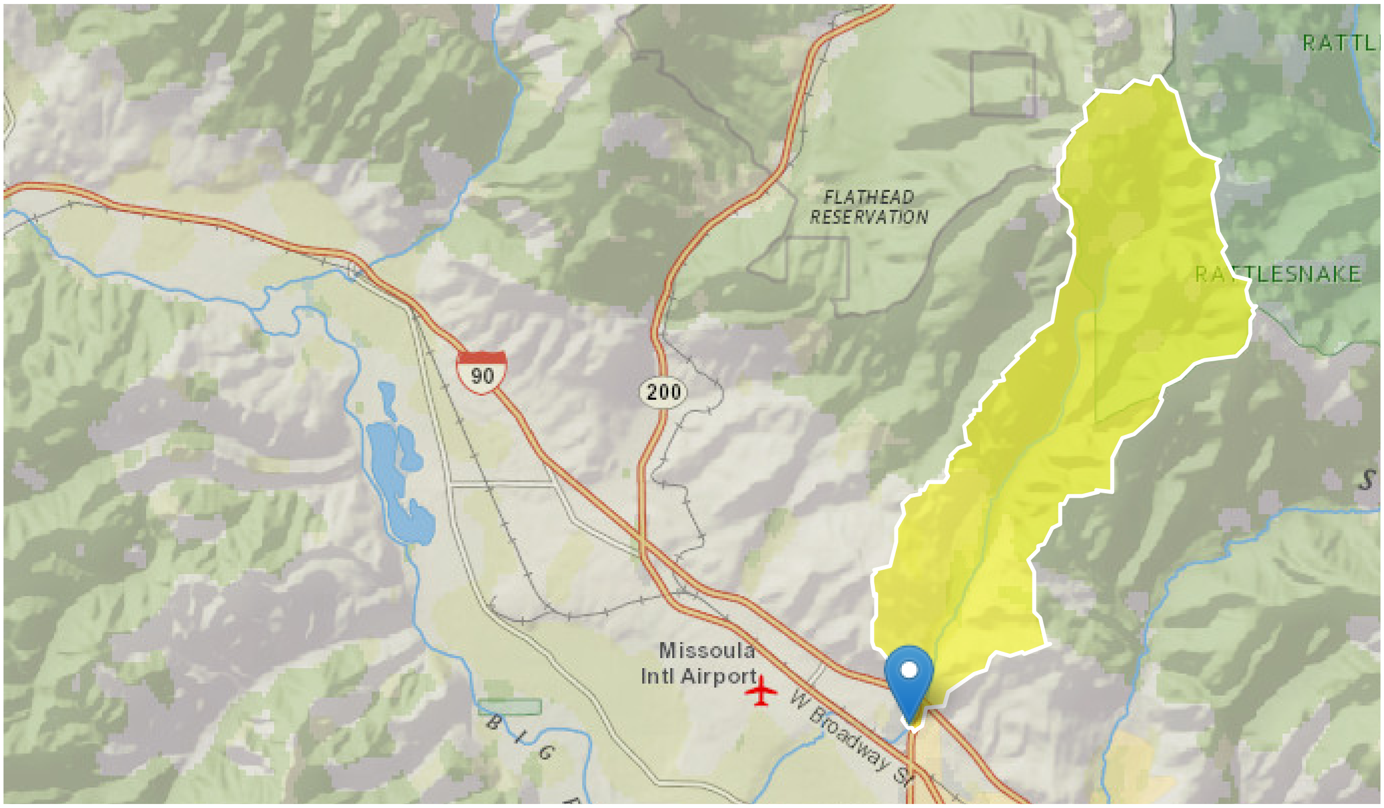

NOTE: THIS AREA IS SHOWN AS BEING PROTECTED FROM THE 1-PERCENT-ANNUAL-CHANCE OR GREATER FLOOD HAZARD BY A LEVEE SYSTEM. OVERTOPPING OR FAILURE OF ANY LEVEE SYSTEM IS POSSIBLE.
REVISED AREA
BONANZA PL
OLD QUARRY RD
ZONE AE
STONEBRIDGE RD
BROOKWOOD DR
HIGHCLIFF CT
ROCKRIDGE CT
SILVERCREST CT
CRYSTAL CT
EXPO PKWY
LOWRIDGE CT
CREEKSTONE DR
MICHAEL RD
Grant Creek Levee
Grant Creek
Bridge
3335
3332
3327
3321
3315
3308
3298
3286
3285
3284
3280
3277
3276
3273.4
3269.8
3266.3
3264.0
3260.9
3253.9
3250.2
3247.8
3245.8
3241.9
3236.5
3232.0
3228.1
3225.9
3222.7
A
B
C
D
E
F
W
X
Y
Z
31
32
33
4
5
6
7
8
90
Missoula County Unincorporated Areas 300048
ZONE A
LIMIT OF DETAILED STUDY
RESERVE ST
GRANT CREEK RD
SCHRAMM ST
Middle Grant Creek
City of Missoula 300049
BURLINGTON NORTHERN & SANTA FE RAILROAD
GREAT NORTHERN AVE
SPECIAL FLOOD HAZARD AREAS
Without Base Flood Elevation (BFE) Zone A, V, A99
With BFE or Depth Zone AE, AO, AH, VE, AR
Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD
0.2 % Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
Future Conditions 1% Annual Chance Flood Hazard Zone X
Area with Reduced Flood Risk due to Levee See Notes. Zone X
SCALE
Imagery Source: NAIP 2017
Map Projection: Universal Transverse MercatorNAD 1983 UTM Zone 11N
Western Hemisphere; Vertical Datum: NAVD 88
1 inch = 1,000 feet
1:12,000
0
500
1,000
2,000
Feet
0
125
250
500
Meters
N
FEMA
National Flood Insurance Program
NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP
MISSOULA COUNTY, MONTANA
and Incorporated Areas
PANEL 1195 OF 1900
Panel Contains:
COMMUNITY NUMBER PANEL SUFFIX
MISSOULA, CITY OF 300049 1195 E
MISSOULA COUNTY, Unincorporated Areas 300048 1195 E
REVISED TO REFLECT LOMR
EFFECTIVE: April 27, 2022
VERSION NUMBER
1.1.1.0
MAP NUMBER
30063C1195E
MAP REVISED
JULY 6, 2015

Attachment B

Hydrologic Analysis Supplementary Information

Grant Creek StreamStats Report

Region ID: MT
Workspace ID: MT20220428165955994000
Clicked Point (Latitude, Longitude): 46.90785, -114.03995
Time: 2022-04-28 11:00:28 -0600



General Disclaimers

Upstream regulation was checked for this watershed.

Peak-Flow Statistics Parameters [W Region BasinC 2015 5019F]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	24.9	square miles	0.6	2470
PRECIP	Mean Annual Precipitation	33.16	inches	14.6	62.1
FOREST	Percent Forest	69.5	percent	20.4	99.1

Peak-Flow Statistics Parameters [W Region Active Channel SIR 2020 5142]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
WACTCH	Width Of Active Channel	0	feet	3	213

Peak-Flow Statistics Parameters [W Region Bankfull SIR 2020 5142]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
WBANKFULL	Width Of Bankfull Channel	0	feet	5	246

Peak-Flow Statistics Parameters [W Region Aerial Photo SIR 2020 5142]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CHANWD_RS	Channel_Width_remotely_sensed	0	feet	2.3	203.8

Peak-Flow Statistics Flow Report [W Region BasinC 2015 5019F]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	ASEp
66.7-percent AEP flood	140	ft^3/s	57.1	343	59.4
50-percent AEP flood	176	ft^3/s	74.2	417	56.5
42.9-percent AEP flood	194	ft^3/s	82.5	456	55.7
20-percent AEP flood	277	ft^3/s	122	629	53.4
10-percent AEP flood	364	ft^3/s	162	820	52.8
4-percent AEP flood	459	ft^3/s	203	1040	53.2
2-percent AEP flood	539	ft^3/s	234	1240	54.2
1-percent AEP flood	623	ft^3/s	266	1460	56
0.5-percent AEP flood	708	ft^3/s	294	1700	58
0.2-percent AEP flood	809	ft^3/s	322	2030	61.4

Peak-Flow Statistics Disclaimers [W Region Active Channel SIR 2020 5142]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [W Region Active Channel SIR 2020 5142]

Statistic	Value	Unit
Active Channel Width 10-percent AEP flood	0	ft^3/s
Active Channel Width 20-percent AEP flood	0	ft^3/s
Active chan width 42.9 percent AEP flood	0	ft^3/s
Active Channel Width 2-percent AEP flood	0	ft^3/s
Active Channel Width 1-percent AEP flood	0	ft^3/s
Active Channel Width 4-percent AEP flood	0	ft^3/s
Active Channel Width 0.2-percent AEP flood	0	ft^3/s
Active Channel Width 0.5-percent AEP flood	0	ft^3/s
Active Channel Width 50-percent AEP flood	0	ft^3/s
Active chan width 66.7 percent AEP flood	0	ft^3/s

Peak-Flow Statistics Disclaimers [W Region Bankfull SIR 2020 5142]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [W Region Bankfull SIR 2020 5142]

Statistic	Value	Unit
Bankfull width 66.7 percent AEP flood	0	ft^3/s
Bankfull Width 50-percent AEP flood	0	ft^3/s
Bankfull width 42.9 percent AEP flood	0	ft^3/s
Bankfull Width 1-percent AEP flood	0	ft^3/s
Bankfull Width 10-percent AEP flood	0	ft^3/s
Bankfull Width 0.5-percent AEP flood	0	ft^3/s
Bankfull Width 2-percent AEP flood	0	ft^3/s
Bankfull Width 0.2-percent AEP flood	0	ft^3/s
Bankfull Width 4-percent AEP flood	0	ft^3/s
Bankfull Width 20-percent AEP flood	0	ft^3/s

Peak-Flow Statistics Disclaimers [W Region Aerial Photo SIR 2020 5142]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [W Region Aerial Photo SIR 2020 5142]

Statistic	Value	Unit
Rem_sens_chan_width_0_2_pct_AEP_flood	0	ft^3/s
Rem_sens_chan_width_0_5_pct_AEP_flood	0	ft^3/s
Rem_sens_chan_width_4_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_1_percent_AEP_flood	0	ft^3/s
Rem sens chan width 66.7 percent AEP fld	0	ft^3/s
Rem_sens_chan_width_2_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_50_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_10_percent_AEP_flood	0	ft^3/s
Rem sens chan width 42.9 percent AEP fld	0	ft^3/s
Rem_sens_chan_width_20_percent_AEP_flood	0	ft^3/s

Peak-Flow Statistics Flow Report [Area-Averaged]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	ASEp
66.7-percent AEP flood	140	ft^3/s	57.1	343	59.4
50-percent AEP flood	176	ft^3/s	74.2	417	56.5
42.9-percent AEP flood	194	ft^3/s	82.5	456	55.7
20-percent AEP flood	277	ft^3/s	122	629	53.4
10-percent AEP flood	364	ft^3/s	162	820	52.8
4-percent AEP flood	459	ft^3/s	203	1040	53.2
2-percent AEP flood	539	ft^3/s	234	1240	54.2
1-percent AEP flood	623	ft^3/s	266	1460	56
0.5-percent AEP flood	708	ft^3/s	294	1700	58
0.2-percent AEP flood	809	ft^3/s	322	2030	61.4
Active Channel Width 10-percent AEP flood	0	ft^3/s			
Active Channel Width 20-percent AEP flood	0	ft^3/s			
Active chan width 42.9 percent AEP flood	0	ft^3/s			
Active Channel Width 2-percent AEP flood	0	ft^3/s			

Statistic	Value	Unit	PIl	PIu	ASEp
Active Channel Width 1-percent AEP flood	0	ft^3/s			
Active Channel Width 4-percent AEP flood	0	ft^3/s			
Active Channel Width 0.2-percent AEP flood	0	ft^3/s			
Active Channel Width 0.5-percent AEP flood	0	ft^3/s			
Active Channel Width 50-percent AEP flood	0	ft^3/s			
Active chan width 66.7 percent AEP flood	0	ft^3/s			
Bankfull width 66.7 percent AEP flood	0	ft^3/s			
Bankfull Width 50-percent AEP flood	0	ft^3/s			
Bankfull width 42.9 percent AEP flood	0	ft^3/s			
Bankfull Width 1-percent AEP flood	0	ft^3/s			
Bankfull Width 10-percent AEP flood	0	ft^3/s			
Bankfull Width 0.5-percent AEP flood	0	ft^3/s			
Bankfull Width 2-percent AEP flood	0	ft^3/s			
Bankfull Width 0.2-percent AEP flood	0	ft^3/s			
Bankfull Width 4-percent AEP flood	0	ft^3/s			
Bankfull Width 20-percent AEP flood	0	ft^3/s			
Rem_sens_chan_width_0_2_pct_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_0_5_pct_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_4_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_1_percent_AEP_flood	0	ft^3/s			
Rem sens chan width 66.7 percent AEP fld	0	ft^3/s			
Rem_sens_chan_width_2_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_50_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_10_percent_AEP_flood	0	ft^3/s			
Rem sens chan width 42.9 percent AEP fld	0	ft^3/s			
Rem_sens_chan_width_20_percent_AEP_flood	0	ft^3/s			

Peak-Flow Statistics Citations

Sando, Roy, Sando, S.K., McCarthy, P.M., and Dutton, D.M.,2016, Methods for estimating peak-flow frequencies at ungaged sites in Montana based on data through water year 2011:

U.S. Geological Survey Scientific Investigations Report 2015–5019–F, 30 p. (https://doi.org/10.3133/sir20155019)
Chase, K.J., Sando, R., Armstrong, D.W., and McCarthy, P., 2021, Regional regression equations based on channel-width characteristics to estimate peak-flow frequencies at ungaged sites in Montana using peak-flow frequency data through water year 2011 (ver. 1.1, September 2021): U.S. Geological Survey Scientific Investigations Report 2020–5142, 49 p. (https://doi.org/10.3133/sir20205142)

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Application Version: 4.8.1
StreamStats Services Version: 1.2.22
NSS Services Version: 2.1.2

Attachment C

Hydraulics Analysis Supplementary Information

HYDRAULICS ANALYSIS SUPPLEMENTARY INFORMATION

SUBJECT: Expressway-Grant Creek Floodplain Analysis **Date: November 3, 2022**

OBJECTIVE

The objective of the hydraulics analysis was to determine the predicted flood inundation area associated with the Grant Creek 100-year flood.

METHODOLOGY

A one-dimensional (1D) HEC-RAS model was developed to simulate the Grant Creek 100-year flood (a flow of 623 cfs) through the study area and to produce the predicted flood inundation area associated with 100-year flood.

MODEL GEOMETRY

Model geometry information is provided in **Table 1**.

Table 1. HEC-RAS Model Geometry Information

Model Element	Description	Source/Reference
Terrain	Surveyed cross-sections, bridge elevations and floodplain topography. ▪ Surveyed on April 21, 2022. ▪ Cross-section locations were determined based on change in reach characteristics such as cross-sectional geometry, slope, and roughness. ▪ Terrain built in Civil3D and exported to HEC-RAS as a 0.5-ft grid. ▪ Coordinate system: NAD83 Montana State Planes, International Foot.	IMEG (2022)
Upstream Cross-Section Location	Placed to match downstream cross-section of April 2022 LOMR.	
Downstream Cross-Section Location	Placed approximately 150-feet downstream of the Expressway Blvd bridge.	
Manning's 'n'	▪ Manning's roughness coefficients ('n') were based off observations noted during site visits completed in February and April 2022. ▪ **Table 2** summarizes the Manning's n for left overbank, main channel, and right overbank at each cross-section.	
Hydraulic Structures	Bridges: ▪ Expressway Blvd bridge is located at the downstream end of the study area. ▪ **Table 3** summarizes the bridge modeling approach and associated assumptions. ▪ No additional hydraulic structures were identified during site visits.	
Boundary Conditions	Two boundary conditions at model inflow and outflow locations. See **Table 4.**	

Table 2. Manning's n Values

Cross-Section Station	Left Overbank		Main Channel		Right Overbank	
	Manning's n	Description	Manning's n	Description	Manning's n	Description
515	0.04	Floodplain: Short Grass with Small Trees	0.04	Mountain Streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages - bottom: gravel, cobbles, and a few boulders.* *Manning's n increased from 0.04 to 0.06 at certain sections to reduce model errors (due to steep slope)	0.07	Floodplain: Light Brush with Large Trees
493	0.04	Floodplain: Short Grass with Small Trees	0.04		0.07	Floodplain: Light Brush with Large Trees
439	0.05	Floodplain: High Grass with Small Trees	0.04		0.065	Floodplain: Light Brush with Large Trees
420	0.06	Floodplain: Light Brush with Trees	0.06		0.06	Floodplain: Light Brush with Trees
375	0.04	Floodplain: Short Grass with Small Trees	0.06		0.06	Floodplain: Light Brush with Trees
304	0.05	Floodplain: High Grass with Small Trees	0.04		0.06	Floodplain: Light Brush with Trees
248	0.05	Floodplain: High Grass with Small Trees	0.04		0.06	Floodplain: Light Brush with Trees
219	0.06	Floodplain: Light Brush with Large Tree	0.04		0.06	Floodplain: Light Brush with Trees
162	0.04	Floodplain: Short Grass with Small Trees	0.06		0.06	Floodplain: Light Brush with Trees
133	0.04	Floodplain: Short Grass with Small Trees	0.06		0.06	Floodplain: Light Brush with Trees
99	0.05	Floodplain: High Grass with Small Trees	0.04		0.06	Floodplain: Light Brush with Trees
62	0.05	Floodplain: High Grass with Small Trees	0.06		0.06	Floodplain: Light Brush with Trees
6	0.07	Floodplain: Light Brush with Large Trees	0.06		0.07	Floodplain: Light Brush with Large Trees

Table 3. Bridge Modeling

Model Element	Description	Source/Reference
Bridge Modeling Approach	▪ Low Flow Method: Energy (Standard Step) ▪ High Flow Method: Pressure and/or Weir ○ Submerged Inlet + Outlet Cd = 0.8	(USACE, 2020)
Ineffective Flow Areas	Assumptions: ▪ 1:1 contraction rate upstream of bridge ▪ 2:1 expansion rate downstream of bridge	(USACE, 2020)

Contraction and Expansion Coefficients	▪ Adjusted contraction and expansion coefficients within ineffective flow areas. ▪ Within ineffective flow area: Contraction = 0.3, Expansion 0.5. ▪ Outside of ineffective flow area: Contraction = 0.1, Expansion = 0.3	(USACE, 2020)

MODEL STEADY FLOW DATA

Steady flow data was developed to simulate the Grant Creek 100-year flow of 623 cfs. Boundary conditions were placed at inflow and outflow locations. Boundary condition information is provided in **Table 4**.

Table 4. Steady Flow Data Boundary Conditions

Boundary Condition	Discussion
Upstream (Inflow)	The model was run as a steady flow analysis and the upstream cross section flow was set to 623 cfs to simulate the Grant Creek 100-year flood event.
Normal Depth	The downstream boundary condition was set to normal depth and was determined by calculating the slope of the reach at the downstream end of the model (S=0.0338) A sensitivity analysis was conducted and verified that a normal depth set to a less steep slope did not impact model results upstream of the bridge.

MODEL RUN PARAMETERS

A steady flow simulation file was developed to run the 1D flow model. Key model run parameters are presented in **Table 5**.

Table 5. Model Run Parameters

Parameter	Setting	Discussion
Friction Slope Method for Steady Flow	Average Conveyance	Default
Computing Critical Depth	Parabolic Method	Computationally faster
Method of Calculating Conveyance	At breaks in n values only	Default
Flow Regime	Subcritical	

REFERENCES

IMEG. (2020). Topographic survey completed on April 21, 2022.

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U.S. Army Corps of Engineers - Hydrologic Engineering Center. (2020). HEC-RAS Hydraulic Reference Manual, Version 6.2. Davis, CA.