

Las Animas Preliminary Levee Assessment

Phase - II Field Collection and Alternatives Analysis

Levee Freeboard Analysis

Arkansas River Conservancy District

Project number: 60703549

February 29, 2024

Quality information

Prepared by	Checked by	Verified by	Approved by
Andy Steininger	Leylin Marroquin	Rich Millet	Aaron Humphrey, P.E.

Revision History

Revision	Revision date	Details	Authorized	Name	Position

Distribution List

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N	Y	Arkansas River Conservancy District

Prepared for:

Arkansas River Conservancy District

Prepared by:

AECOM
804 Colorado Avenue
Glenwood Springs, CO 81601
aecom.com

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1. Introduction

As part of the Las Animas levee certification, the levee must meet a minimum existing freeboard condition as stated in Title 44 Chapter 1 Section 65.10(b)(1) of the Code of Federal Regulations (44 CFR § 65.10(b)(1)). AECOM performed a comparison of current existing levee crest elevations based on obtained survey data with hydraulic model simulated Water Surface Elevations (WSEL) to elevate this requirement. This work expands on the levee freeboard analysis incorporated in the 2021 *Preliminary Levee Assessment Report, Arkansas River Levee, Las Animas Colorado* prepared for the City of Las Animas by Wood Environment & Infrastructure Solutions, Inc. (Wood).

2. Freeboard Analysis

2.1 Requirement

The existing levee freeboard requirement for riverine levee certification under 44 CFR (Federal Code of Regulations) § 65.10(b)(1), recognized by the Federal Emergency Management Agency (FEMA), establishes the following minimum levee freeboard height above the 1%-annual-chance (100-year) water surface elevation:

44 CFR § 65.10 - Mapping of areas protected by levee systems

(b) Design criteria. For levees to be recognized by FEMA, evidence that adequate design and operation and maintenance systems are in place to provide reasonable assurance that protection from the base flood exists must be provided. The following requirements must be met:

(1) Freeboard.

(i) Riverine levees must provide a minimum freeboard of three feet above the water-surface level of the base flood. An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted. An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.

Freeboard is defined in the in the CFR as:

Freeboard means a factor of safety usually expressed in feet above a flood level for purposes of flood plain management. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as wave action, bridge openings, and the hydrological effect of urbanization of the watershed.

2.2 Data Sources and Analysis Methods

2.2.1 Levee Survey and Digital Terrain Model

Topographic survey of the levee was completed by AECOM in April and September of 2023 to establish current levee crest elevations. The levee was surveyed at approximately 100-foot point spacing along the crest, each shoulder and each toe of the levee. The Trimble Centerpoint RTX virtual network was used in conjunction with Trimble R-10 receivers to collect approximately 9,400 points. The published accuracies of the Centerpoint RTX network are 2 cm horizontally and 7 cm vertically. The virtual network was confirmed against existing published National Geodetic Database (NGS) data on 3 control points throughout the project as detailed in Appendix A.5. The estimated vertical tolerance for the survey was 0.23 feet (7 cm).

Two-foot resolution Light Imaging and Detecting Radar (LiDAR) contours were obtained from the Colorado Water Conservation Board (CWCB) Colorado Hazard Mapping and Risk MAP Portal and used to develop a terrain surface to represent floodplain elevations and tie-in areas proximal to the levee. The most recent LiDAR data available for the analysis area was from the following:

2016 Arkansas (Partial Pueblo, Crowley, Otero, Bent, & Prowers)

Published: 7/1/2016

Collected By: Merrick & Co

Collected For: CWCB

Collected From: 4/21/2016 To 5/22/2016

Quality: QL2

Coordinate System: NAD83(2011) Colorado South

These data were compiled and processed in Auto CAD Civil 3D (2023). A composite existing condition digital terrain model (DTM) of the levee and surrounding floodplain was produced representing the surveyed levee and LiDAR floodplain elevations.

The centerline alignment and stationing convention used for this analysis was kept consistent with the original 1976 levee construction plans and the 2021 *Preliminary Levee Assessment Report* (Wood 2021). The stationing increases in the downstream direction and the levee ends at Station 496+09. See Figures 2 and 3.

2.2.2 Hydraulic Modeling

The current effective Federal Insurance Rate Map (FIRM) for Bent County, Colorado and Unincorporated Areas defines the reach of the Arkansas River adjacent to the levee as Zone A, Special Flood hazard Area (SFHA), and no detailed hydraulic study has been adopted for the reach to date. The most current preliminary 1-Dimensional hydraulic models of the Arkansas River Reach adjacent to the levee was obtained from FEMA Mapping Information Platform (MIP) for use in the freeboard analysis. This model is the result of ongoing FEMA map updates administered through CWCB. The updates provide terrain, hydraulic parameter and hydrologic parameter updates based on improved modeling practices and existing conditions data. This model is projected to be adopted by CWCB and FEMA as the effective floodplain model and was thusly used herein. Therefore, the current effective regulatory flood elevations were not compared or used for this analysis. The preliminary hydraulic model used for this analysis is assumed to be comprehensive and complete. No verification or validation of the model set-up, parameters or results was performed.

The model obtained from the MIP, Case # 19-08-0035S was:

ARKANSAS RIVER REACH 3 (Reach 3)

Figure 1 shows the ancillary files used for the Reach 3 model.

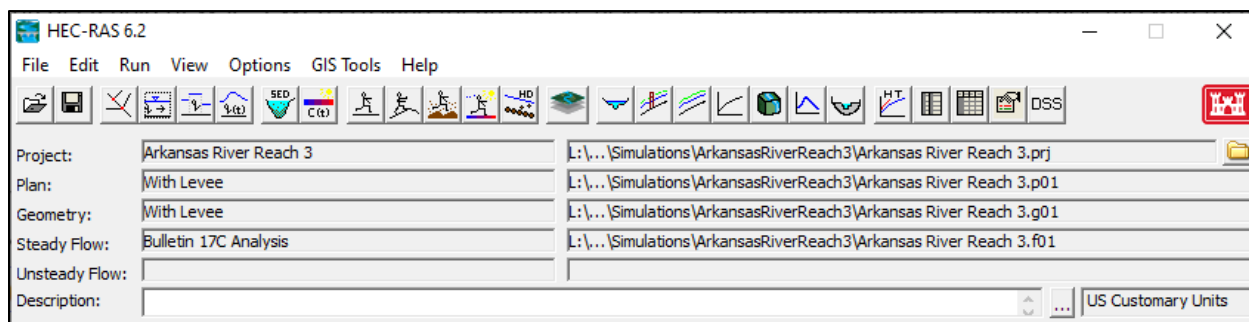


Figure 1 Arkansas River Reach 3 HEC RAS Model

The Reach 3 model fully covers a reach of the Arkansas River adjacent to the levee. The model extends downstream of the levee terminus by approximately 6,000 feet to model station 552+01.8, and beyond the levee upstream extent by approximately 2,000 feet to model station 1235+18.3 (proposed FEMA XS AA). The model is a detailed study and

includes Zone AE (1%-annual-chance), Zone AE floodway, and shaded Zone X (0.2%-annual-chance). The model includes 73 total cross sections with 63 covering the active Arkansas River floodplain as well as the levee-protected historical floodplain extent to the south. Cross sections generally cross perpendicular to the levee. 4 cross-sections define the highway 50 bridge crossing hydraulics at model station 806+99.2. The 10 model cross-section upstream and downstream of the levee extent provide adequate model domain space to capture the upstream and downstream river corridor hydraulic influence on the levee reach, minimize boundary condition influence on simulated WSEL solutions surrounding the levee, and provide a continuous model solution along the full levee extent.

As shown in Figure 2, the confluence of the Purgatorie River and the Arkansas River is approximately 2,500 feet east of the downstream extent of the levee. As the Purgatorie River alignment and floodplain is adjacent to the east end of the levee, flood water surface elevations were analyzed to confirm that the Purgatorie River does not encroach on required levee freeboard. A detailed hydraulic study of the Purgatorie River is currently being conducted as part of the aforementioned FEMA/CWCB Risk Map Study efforts. The preliminary hydraulic model for the Purgatorie River was obtained from the MIP and used to extract 1%-annual-chance water surface elevations adjacent to the levee.

MIP Case # 19-08-0035S:

PURGATOIRE RIVER REACH 1 (Reach 1)

1.0%-annual-chance water surface elevations were extracted at the 3 furthest downstream model cross-sections to compare with levee crest elevations. These cross-sections were located downstream of the modeled railroad bridge crossing and upstream of the confluence with the Arkansas River.

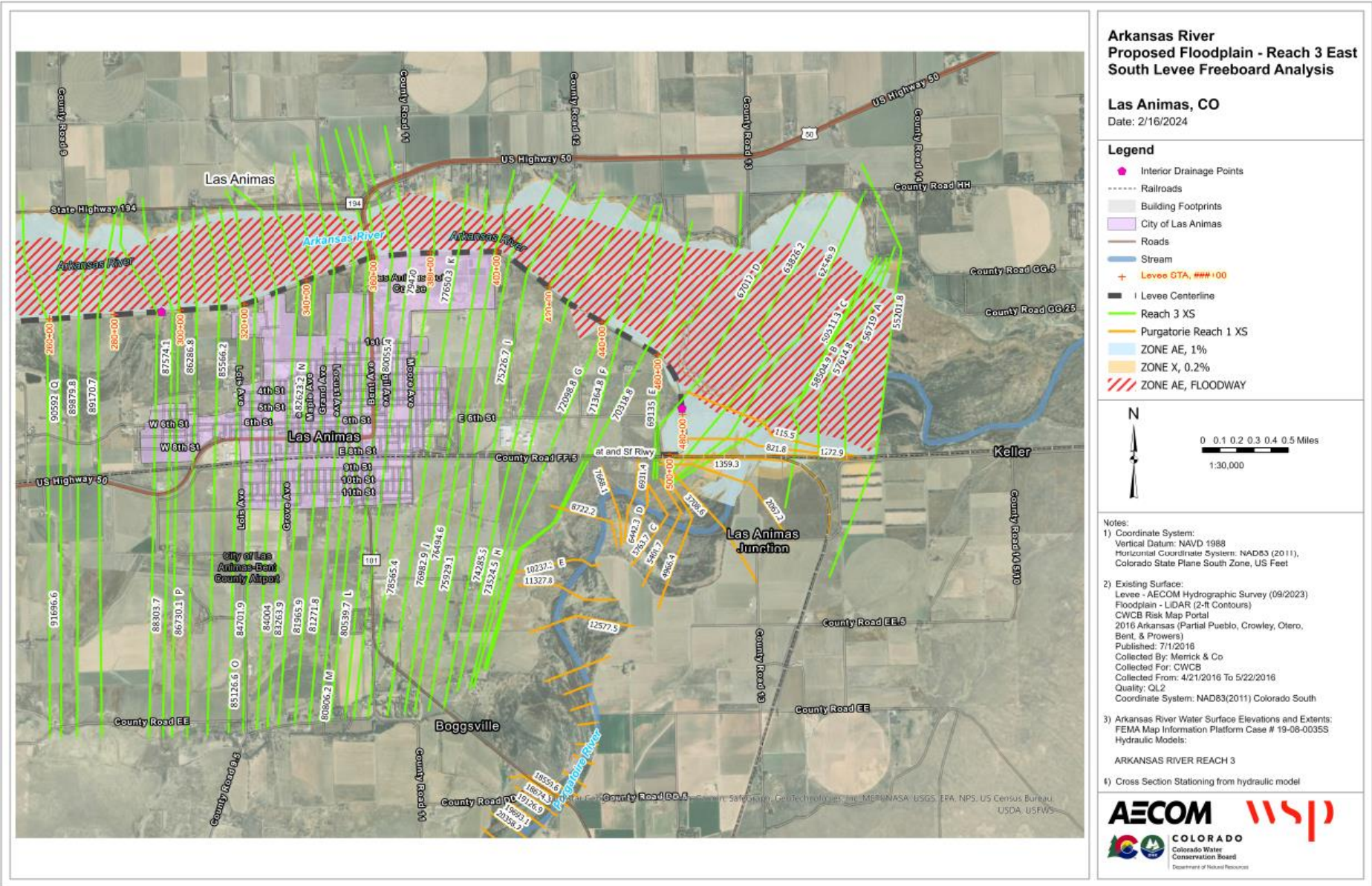


Figure 2 Arkansas River Reach 3 East Proposed Floodplain Map

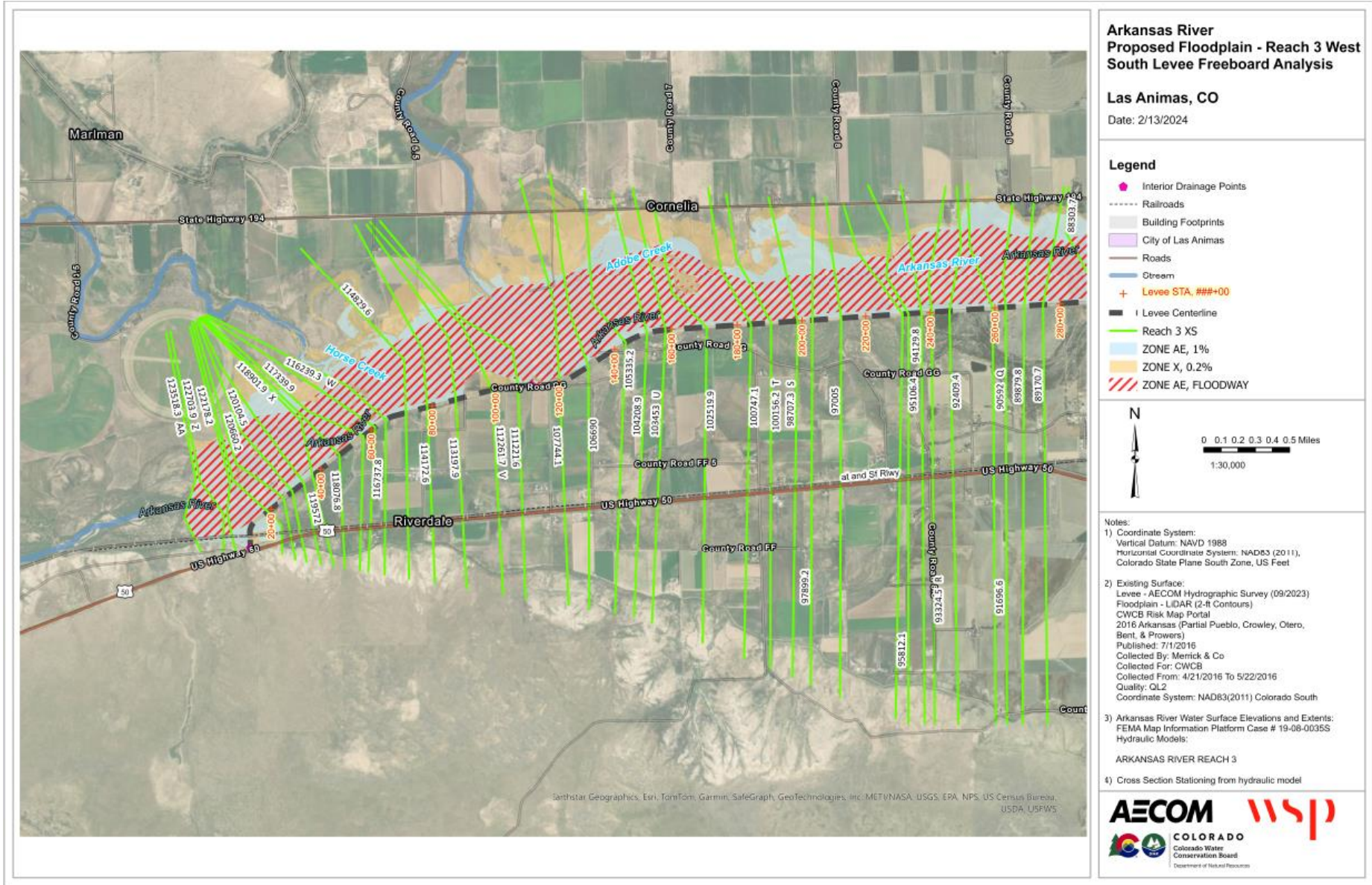


Figure 3 Arkansas River Reach 3 West Proposed Floodplain Map

The United States Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) (version 6.2) was used to extract simulated 100-yr WSEL at the model cross section locations shown in Figure 2. Flow rates included in the *Bulletin 17C Analysis* flow files accompanying the models were the following:

Table 1 HEC RAS Model Profile Names and Steady Flow Rates (cfs)

River	Reach	Model River STA	P100yr	Floodway	P10yr	P25yr	P50yr	P101yr	P500yr
Arkansas	3	1235+18.3	38600	38600	10500	18000	26600	65200	88400
Arkansas	3	867+30.1	39100	39100	10900	18700	27200	63900	86400
Arkansas	3	567+19.0	36600	36600	9510	16800	25100	48200	83400

RAS Mapper (version 2.0.0) was used to extract inundation boundaries relative to the associated DTM which were exported for mapping and surface creation. The 1%-annual-chance WSELs and inundation boundary were projected onto profile view in Auto CAD Civil 3D to produce WSEL and freeboard profiles along the levee alignment. Additionally, ground elevations were extracted from the DTM at the hydraulic model cross-section locations for direct comparison with the simulated 1%-annual-chance WSEL with the levee crest elevation. To determine freeboard height per **44 CFR § 65.10(1)(i)** a required freeboard profile was developed which incorporates all 3 criteria.

1. Minimum height of 3.0-feet for entirety of levee crest.
2. Minimum height of 3.5-feet at the upstream end of the levee linearly decreasing to 3.0-feet at the downstream extent of the levee.
3. Minimum height of 4.0-feet applied at STA 34+621, 35+276.4, 35+747.3 (Bridge XS), 36+025.8 and 36+497.4 resulting in approximately 644-linear-feet upstream of the bridge model cross-section and 575-linear-feet downstream of the bridge model cross-section.

These calculations resulted in a table of estimated existing freeboard and surplus above the minimum requirements.

Table 2 Arkansas River Existing Freeboard

Levee Station (ft)	FEMA Station (ft)	FEMA XS	Levee Crest Elevation (ft)	Modeled WSEL (ft)	Required Freeboard (ft)	Freeboard (ft)	Surplus (ft)
1+521.2	1212+90.8	Y	3,964.63	3,952.47	3.50	12.16	8.66
2+196.4	1206+60.2		3,963.96	3,951.32	3.49	12.64	9.15
2+529.5	1201+04.5		3,963.54	3,951.47	3.48	12.07	8.59
2+973.5	1195+72.		3,963.39	3,951.06	3.48	12.33	8.85
3+318.7	1189+01.9	X	3,963.00	3,950.26	3.47	12.74	9.27
4+363.8	1180+76.8		3,961.24	3,948.37	3.46	12.87	9.41
5+303.3	1173+39.9		3,959.05	3,947.60	3.45	11.45	8.00
5+755.6	1167+37.8		3,957.81	3,945.98	3.45	11.83	8.38
6+164.6	1162+39.3	W	3,956.84	3,945.97	3.44	10.87	7.43
6+819.7	1148+29.6		3,955.30	3,943.23	3.43	12.07	8.64
7+501.8	1141+72.6		3,953.43	3,942.33	3.42	11.10	7.68
8+414.6	1131+97.9		3,951.49	3,941.41	3.42	10.08	6.66
9+565.3	1122+61.7	V	3,948.76	3,939.52	3.41	9.24	5.83
10+383.7	1112+21.6		3,947.23	3,938.50	3.40	8.73	5.33
11+705.8	1077+44.1		3,944.86	3,934.54	3.39	10.32	6.93
12+718.6	1066+90.		3,943.36	3,933.62	3.39	9.74	6.35
14+086.8	1053+35.2		3,941.54	3,932.28	3.38	9.26	5.88
14+807.5	1042+08.9		3,940.31	3,931.18	3.37	9.13	5.76
15+388.5	1034+53.	U	3,939.56	3,930.06	3.36	9.50	6.14

Levee Station (ft)	FEMA Station (ft)	FEMA XS	Levee Crest Elevation (ft)	Modeled WSEL (ft)	Required Freeboard (ft)	Freeboard (ft)	Surplus (ft)
16+651.9	1025+19.9		3,938.22	3,927.69	3.36	10.53	7.17
18+025.0	1007+47.1		3,936.18	3,925.56	3.35	10.62	7.27
18+644.2	1001+56.2	T	3,934.82	3,924.69	3.34	10.13	6.79
19+469.4	987+07.3	S	3,934.31	3,923.65	3.33	10.66	7.33
19+928.7	978+99.2		3,933.80	3,923.14	3.33	10.66	7.33
20+848.3	970+05.		3,932.11	3,921.80	3.32	10.31	6.99
22+739.6	958+12.1		3,928.24	3,920.66	3.31	7.58	4.27
22+923.3	951+06.4		3,928.17	3,920.41	3.30	7.76	4.46
23+325.4	941+29.8		3,927.59	3,917.82	3.30	9.77	6.47
23+644.0	933+24.5	R	3,927.01	3,917.39	3.29	9.62	6.33
24+196.8	924+09.4		3,925.83	3,916.11	3.28	9.72	6.44
25+524.8	916+96.6		3,922.59	3,915.49	3.27	7.10	3.83
25+930.6	905+92.	Q	3,921.42	3,912.93	3.27	8.49	5.22
26+500.0	898+79.8		3,920.58	3,911.78	3.26	8.80	5.54
27+086.6	891+70.7		3,919.39	3,910.34	3.25	9.05	5.80
28+933.4	883+03.7		3,916.10	3,908.52	3.24	7.58	4.34
29+411.4	875+74.1		3,916.25	3,907.51	3.23	8.74	5.51
29+591.9	867+30.1	P	3,915.95	3,906.69	3.23	9.26	6.03
30+165.7	862+86.8		3,915.94	3,906.10	3.22	9.84	6.62
30+849.5	855+66.2		3,915.48	3,905.40	3.21	10.08	6.87
31+503.3	851+26.6	O	3,915.04	3,905.01	3.20	10.03	6.83
32+002.2	847+01.9		3,914.87	3,904.74	3.20	10.13	6.93
32+732.5	840+04.		3,913.98	3,904.39	3.19	9.59	6.40
33+449.7	832+63.9		3,913.84	3,903.97	4.00	9.87	5.87
33+999.3	826+23.2	N	3,913.52	3,903.48	4.00	10.04	6.04
34+621.8	819+65.9		3,913.46	3,903.11	4.00	10.35	6.35
35+276.4	812+71.8		3,912.80	3,902.80	4.00	10.00	6.00
35+747.3	808+06.2	M	3,912.42	3,901.96	4.00	10.46	6.46
36+132.8	806+99.2	BRIDGE	3,909.17	3,899.83	4.00	9.35	5.35
36+025.8	805+39.7	L	3,907.14	3,900.42	4.00	6.72	2.72
36+497.4	800+55.4		3,906.12	3,899.65	3.13	6.47	3.34
37+051.2	794+70.		3,905.70	3,899.06	3.12	6.64	3.52
37+765.2	785+65.4		3,904.95	3,898.36	3.11	6.59	3.48
38+526.7	776+50.3	K	3,903.03	3,897.39	3.11	5.64	2.53
39+218.7	769+82.9	J	3,901.34	3,895.73	3.10	5.61	2.51
39+647.7	764+94.6		3,900.49	3,894.29	3.09	6.20	3.11
40+138.6	759+29.1		3,899.33	3,892.80	3.08	6.53	3.45
40+844.1	752+26.7	I	3,897.54	3,891.19	3.08	6.35	3.27
41+706.1	742+85.5		3,895.66	3,889.43	3.07	6.23	3.16
42+455.2	735+24.5	H	3,893.72	3,888.20	3.06	5.52	2.46
43+792.5	720+98.8	G	3,890.73	3,886.62	3.05	4.11	1.06
44+304.0	713+64.8	F	3,889.45	3,885.43	3.05	4.02	0.97

Levee Station (ft)	FEMA Station (ft)	FEMA XS	Levee Crest Elevation (ft)	Modeled WSEL (ft)	Required Freeboard (ft)	Freeboard (ft)	Surplus (ft)
45+257.4	703+18.8		3,887.33	3,883.09	3.04	4.24	1.20
45+753.4	691+35.	E	3,886.13	3,880.24	3.03	5.89	2.86
47+298.8	670+17.	D	3,882.30	3,877.38	3.02	4.92	1.90

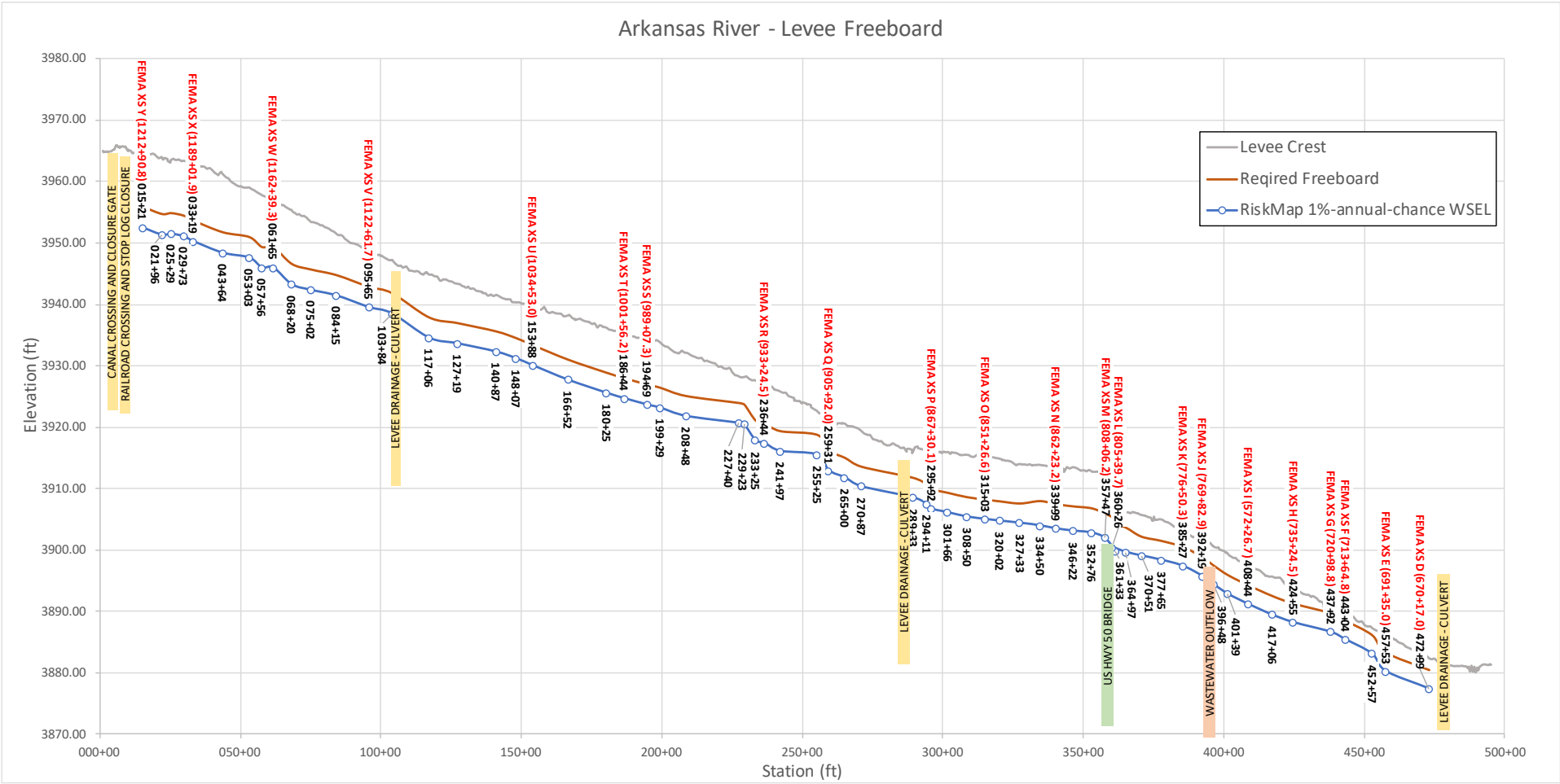


Figure 4 Arkansas River Simulated 1%-annual-chance Flood Profile and Existing Freeboard

Water surface elevations were extracted from the Purgatorie River Reach 1 model to compare with levee crest elevations on the east end of the levee.

Table 3 Purgatorie River Existing Freeboard

Levee Station (ft)	FEMA Station (ft)	FEMA XS	Levee Crest Elevation (ft)	Modeled WSEL (ft)	Required Freeboard (ft)	Freeboard (ft)	Surplus (ft)
469+07.2	1+15.5		3,882.3	3,870.78	3.02	11.52	8.50
484+55.8	8+21.8		3,879.9	3,871.50	3.01	8.40	5.39
491+07.0	12+72.9		3,880.9	3,872.08	3.01	8.82	5.81

When Purgatorie River 1%-annual-chance water surface elevations are compared with levee crest elevations surplus freeboard in excess of 5.0-feet is exhibited along the potentially affected levee segment. Additionally, the 1%-annual-chance flood inundation boundary was extracted from the Reach 1 model. This boundary reveals that topography including the railroad grade preclude the 1%-annual-chance flood from reaching the toe of the levee.

2.3 Freeboard Analysis Results

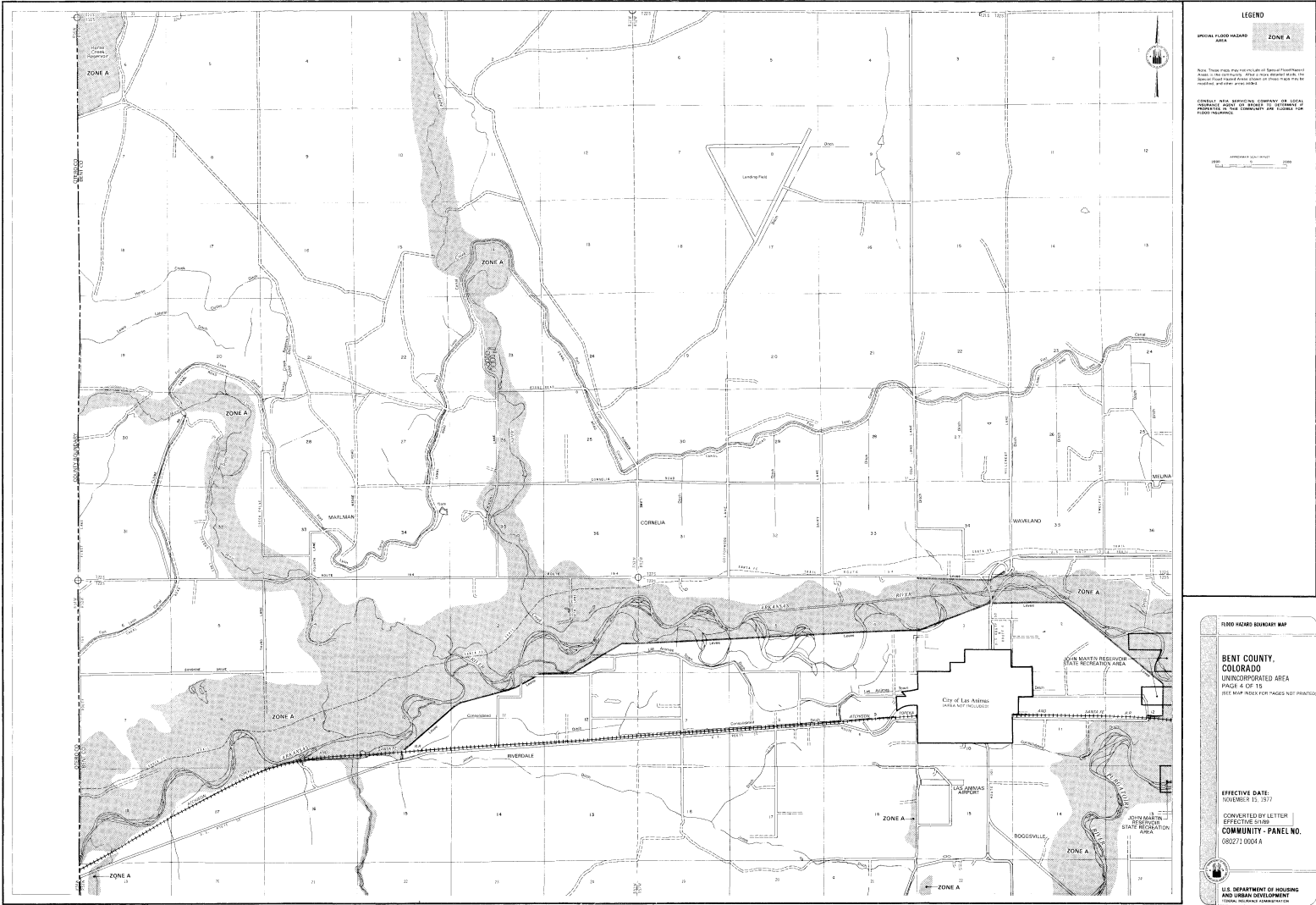
The DTM and Hydraulic Model output used for this analysis provide a comparison of the existing levee crest elevation and the simulated 1%-annual-chance WSEL to define the existing levee freeboard available relative to the minimum criteria set forth in 44 CFR § 65.10 - *Mapping of areas protected by levee systems*. The entire extent of the levee crest currently allows the required minimum freeboard with surplus. The levee shows an average surplus freeboard of 5.65-feet above the minimum requirement. Levee station 44+304.0, model station 713+64.8 (Proposed FEMA XS F), shows the least freeboard surplus with 0.97-feet. The estimated possible vertical error in the levee survey is determined to be 0.23-feet. If the freeboard surplus values are conservatively reduced by the maximum estimated survey vertical error the minimum surplus value is 0.74-feet. Purgatorie River freeboard on the levee was found to exceed the required minimum value towards the east end of the levee by more than 5.0-feet. The surplus values establish a factor of safety to the existing available freeboard.

3. References

- 1) Auto Desk (2023). Auto Desk Civil 3D 2023. Version 2023.0. Released April 12, 2023.
- 2) CHAMP Phase III, Bent County, CO, Hydraulic Analyses Report. Wood Environment & Infrastructure Solutions, Inc. 2019.
- 3) CHAMP Phase III, Bent County, CO, Hydraulic Analyses Report Addendum. Wood Environment & Infrastructure Solutions, Inc. 2022.
- 4) CWCB (2023). Colorado Hazard Mapping & Risk MAP Portal: LiDAR
[lidarDownload - CO Hazard Mapping & RiskMAP Portal \(coloradohazardmapping.com\)](https://coloradohazardmapping.com/lidarDownload)
- 5) Earth Science Research Institute, Inc. (2021). ArcGIS Desktop. Version 10.8.1. Released July 28, 2020.
- 6) Evolution of Channel Conveyance Capacity, Arkansas River at Las Animas, CO. US Geological Survey, 2006.
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<https://msc.fema.gov/portal/home>
- 8) Las Animas Flood Control Project, Las Animas Colorado, Periodic Inspection Report No. 1. Tetra Tech. 2012.
- 9) Mapping of Areas Protected by Levee Systems, 44 CFR § 65.10 (2011).
[eCFR :: 44 CFR 65.10 -- Mapping of areas protected by levee systems.](https://www.federalregister.gov/documents/2011/04/22/44-cfr-65-10-mapping-of-areas-protected-by-levee-systems)
- 10) Plans for Construction of Levees and Appurtenant Facilities, Las Animas Colorado, Arkansas River, Colorado. United States Army Corps of Engineers. 1976.
- 11) Preliminary Levee Assessment Report, Arkansas River Levee, Las Animas Colorado. Wood Environment & Infrastructure Solutions, Inc. 2021.
- 12) U.S. Army Corps of Engineers, Hydrologic Engineering Center (2022). River Analysis System, Version 6.2. Released March 2022.
- 13) U.S. Army Corps of Engineers, Hydrologic Engineering Center (2023). HEC-RAS Hydraulic Reference Manual.
[HEC-RAS User's Manual \(army.mil\)](https://www.army.mil/hec-ras-user-manual)
- 14) U.S. Army Corps of Engineers, Hydrologic Engineering Center (2023). HEC-RAS Mapper User's Manual.
<https://www.hec.usace.army.mil/confluence/rasdocs/rmum/latest>

Appendix A Freeboard Analysis Documents

A.1 Bent County and Unincorporated Area Effective FIRM – Community Panel No. 080271 0004 A



A.2 NGS Survey Control Point Stakeout ReportLas Animas Preliminary

Project file data		Coordinate System	
Name: Las Animas Levee NGS Control Check		Name:	United States/NAD83
Size:		Zone:	Colorado South 0503
Modified:		Datum:	NAD83(2011)
Time zone:		Global reference datum:	NAD83(2011)
Reference number:		Global reference epoch:	2010
Description:		Geoid:	GEOID18 (Conus)
Comment 1:		Vertical datum:	
Comment 2:		Calibrated site:	
Comment 3:			

Additional Coordinate System Details

Local Site Settings			
Project latitude:	?	Ground scale factor:	1
Project longitude:	?	False northing offset:	0.000
Project height:	4000.000	False easting offset:	0.000

As-Staked Report

Linear units:	US survey foot
Horizontal tolerance:	0.066
Vertical tolerance:	0.23

As-Staked Points

As-Staked Name	As-Staked Code	Design Name	Design Code	Design Northing	Design Easting	Design Elevation	ΔNorthing	ΔEasting	ΔElevation
20230502_ CK1	RTX-N 432	N 432	JJ0680	1509519.609	3612801.230	4036.016	0.076	-0.051	0.081
20230502_ CK2	RTX-PAUL	PAUL	AJ2453	1516222.283	3650870.951	3905.823	-0.020	-0.046	-0.071
20230502_ CK3	RTX-FORT	FORT	JJ0930	1530693.170	3679543.875	3900.299	-0.015	-0.052	0.067

12/21/2023 10:02:27 AM		Trimble Business Center
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A.3 Levee Assessment Plans --SEPARATE ATTACHEMENT--

A.4 CHAMP Phase III, Bent County, CO - Reach 3 Hydraulic Report Addendum --SEPARATE ATTACHMENT--

