INUNDATION MAPPING REPORT

TERRACE DAM AND RESERVOIR

WATER DIVISION 3, WATER DISTRICT 21
CONEJOS COUNTY, COLORADO
DAMID: 210102

Prepared for:

TERRACE IRRIGATION COMPANY
P.O. Box 109
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Prepared by:

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May 30, 2013

DRAFT

INUNDATION MAPPING REPORT
FOR
TERRACE DAM AND RESERVOIR

CERTIFICATION

I hereby certify that this Inundation Mapping Report was prepared by me (or under my direct supervision) in accordance with the provisions of the Dam Safety Branch, Colorado Division of Water Resources, Office of the State Engineer for the owners thereof.

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Mark A. Severin
Registered Professional Engineer
State of Colorado No. 28907

(seal)

DRAFT

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1.0 INTRODUCTION

Deere & Ault Consultants, Inc. (D&A) has prepared this Inundation Mapping Report at the request of the Terrace Irrigation Company. This report documents the procedure of modeling a clear-day breach of the dam at Terrace Reservoir and the development of the resulting inundation maps downstream of the dam. The inundation maps will be used to update the existing Emergency Action Plan (EAP) and to assist those involved with emergency preparedness planning and response. The hydraulic models and inundation maps contained in this report were prepared using the NAVD 88 vertical datum. The report and all associated models have been prepared in accordance with the regulations and guidelines set forth by the Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer (SEO).

1.1 Location and Background

The dam at Terrace Reservoir is located in unincorporated Conejos County approximately 11 miles northwest of the town of Capulin, Colorado in Section 23 of Township 36 North, Range 6 East of the New Mexico P.M. Terrace Dam is an earthen compacted embankment that was completed in 1912. It has a height of approximately 165 feet at the dam centerline and an active storage capacity of 15,182 acre-feet with the water surface at the emergency spillway crest.

2.0 DAM BREACH ANALYSIS

2.1 Breach Parameter Estimation

The dam dimensions, emergency spillway crest elevation, and other relevant data were taken from the following sources which are provided in **Appendix A**:

- July 1911 construction plans for Terrace Dam and Reservoir by Field, Fellows, and Hinderlider Engineering Co.
- 1996 plan sheet: Bathymetric Surface and Storage Capacity of Terrace Reservoir, from Water Resources Investigations Report 96-4027 by Kenneth R. Watts.
- Elevation-capacity table (active storage only) for Terrace Reservoir provided by SEO, which corresponds with the storage values reported by Davis Engineering (1981).
- Elevation-area-capacity curves (including dead storage) from USACE Phase I inspection reports (circa 1978).

The average upstream and downstream embankment slopes were estimated from the July 1911 construction plans for Terrace Dam. The downstream slope of 2:1 H:V was read directly from the dam profile on the plan sheet. The upstream dam face consists of several varying slopes, so an average slope of 4:1 H:V was estimated from the profile. A dam crest width of 20 feet was taken from the dam crest detail shown on the same plan sheet.

Each of the four data sources described previously uses a different vertical datum. The datums were matched up using the spillway crest elevation as a reference. A summary of the elevation data is shown in **Table 1**.

Table 1. Terrace Reservoir Dam Failure Summary of Elevation Data

Description	1911 Plans (feet, unknown datum)	1978 El-Area-Capacity Curve (feet, unknown datum)	1996 Plans (feet, NGVD 29)	SEO El-Capacity Table (feet, gage height)
Dam Crest	502	8577*	8583	136
Emergency Spillway Crest	490	8567	8571	124
Upstream Toe (Est.)	345	8422	8426	-21
Downstream Toe (Est.)	335	8412	8416	-31
Outlet Pipe (Upstream Invert)	366	8443	8447	0

* 1978 Elevation-Area-Capacity Curve defined 10 feet between spillway crest and dam crest. The freeboard is defined as 12 feet in the other three references.

The elevations cited in the remainder of this memo are in reference to the 1911 plan set datum.

The 1978 elevation-area-capacity curve defined approximately 2,300 acre-feet of storage below the upstream invert of the outlet pipe (El. 366 feet) which is not accounted for in the SEO elevation-capacity table. This extra storage volume was not considered in the breach analysis for Terrace Dam because the surface area of the reservoir that was calculated from the SEO elevation-capacity table approached zero at the upstream invert of the outlet pipe (El. 366 feet). Additionally, the 1978 elevation-area-capacity relationship was estimated by the USACE based on historical records and on USGS quadrangle maps, while the SEO elevation-capacity table was developed based on a much more precise bathymetric survey by Davis Engineering in 1981. For these reasons the storage below elevation 366 feet was deemed negligible and was not considered. A plot of the SEO elevation-capacity data, the surface area calculated from this data, and the 1978 elevation-area-capacity curves is provided in **Appendix B** to compare the two sources.

Two empirical methods for predicting the average breach width and failure time were compared. The methods, which are included as spreadsheets in **Appendix C** are the Froehlich (2008) equations and the MacDonald & Langridge – Monopolis/Washington State (MLM-WA, 2007) equations (collectively referred to as the “empirical equations”). The empirical equations predict the average breach width and failure time as a function of depth of water, dam height, and volume of water stored. The MLM-WA method also takes into consideration the estimated volume of embankment eroded.

The Froehlich method resulted in predicted bottom and average breach widths of 123 and 218 feet, respectively, and a breach formation time of 0.59 hours. These breach widths were compared to the dimensions of the canyon at the dam, which were estimated from the 1911 plan set. The widths of the canyon at both the bottom and midpoint of the final breach were nearly identical to the bottom and average breach widths predicted by the Froehlich method.

The MLM-WA method resulted in a predicted average breach width of 103 feet and a formation time of 3.02 hours. The "Results Check" section of the MLM-WA spreadsheet also predicted that the erosion rate calculated by the equations was much slower that what can be reasonably expected. For this reason the breach parameters predicted by the MLM-WA method were not considered for use in the breach simulation of Terrace Dam.

2.2 Dam Breach Simulation in HEC-HMS

The U.S. Army Corps of Engineers' (USACE) hydrologic modeling computer program HEC-HMS was used to simulate a clear-day piping failure of Terrace Dam using the breach parameters estimated by the Froehlich empirical equations. For the HEC-HMS simulation the water surface was set at the emergency spillway crest (El. 490 feet) at the onset of the breach. The assumption was made that the breach would extend from the dam crest (El. 502 feet) to the elevation of the upstream invert of the outlet pipe (El. 366 feet), and all 15,182 acre-feet of water was assumed to drain completely. The maximum breach bottom width was set at 123 feet, and the breach side slopes were set to 0.7:1 (horizontal:vertical). As recommended in the *Guidelines for Dam Breach Analysis* the piping failure was set to start at the midpoint of the final breach height, and both linear and sine wave breach progressions were simulated. The capacity table provided by the SEO was used to model the reservoir storage. The dam breach parameters and resulting peak outflows are summarized in **Table 2**.

Table 2. Terrace Reservoir Dam Failure
Comparison of Dam Breach Parameters and Estimated Peak Outflows

	Water Height* (ft)	Dam Height* (ft)	Vol. of Water* (ac-ft)	Avg. Breach Width (ft)	Breach Development Time	Linear Progression		Sine Wave Progression	
						Time to Peak Outflow	Peak (cfs)	Time to Peak Outflow	Peak (cfs)
Froehlich	124	136	15,182	218	0 hr 35 min	0 hr 35 min	429,700	0 hr 27 min	399,700

*Height of water, height of dam, and volume of water are measured relative to the breach invert elevation.

The linear breach progression resulted in the greatest predicted peak outflow of 429,700 cfs with a time to peak of 35 minutes. This hydrograph was routed downstream through representative reaches using the Muskingum-Cunge method in HEC-HMS. A trapezoidal channel with 1:1 side slopes was assumed. The reach lengths, Manning's n-values, and bottom width input parameters for the Muskingum-Cunge method were estimated in ArcMap using aerial photos, and the elevations used to compute the routing reach slopes were taken from the USGS 10-meter digital elevation model (DEM). The Manning's n-values and bottom widths were calibrated and fine-tuned through several iterations between this HEC-HMS model and a steady-state HEC-RAS model of the routing reaches. The reach descriptions, routing times, and predicted flow rates are summarized in **Table 3**. The HEC-HMS output is attached in **Appendix D**, and the full HEC-HMS model is included on the Project CD.

Table 3. Terrace Reservoir Dam Failure
Summary of HEC-HMS Results Downstream of Terrace Dam

Location	Estimated Time of Arrival from Start of Breach Development	Estimated Time to Peak from Start of Breach Development	Estimated Peak Flow Rate (cfs)
Terrace Dam	0 hr 0 min	0 hr 35 min	429,700
Alluvial Fan	0 hr 27 min	0 hr 51 min	375,300
County Rd. Z	0 hr 51 min	1 hr 5 min	352,400
County Rd. 6	1 hr 20 min	1 hr 26 min	309,900
Capulin	1 hr 50 min	1 hr 54 min	255,300
East Capulin	2 hr 29 min	2 hr 33 min	189,900
US 285	6 hr 27 min	6 hr 44 min	77,500
County Rd. 14S	11 hr 41 min	12 hr 16 min	36,900
Conejos/Costilla County Line	16 hr 44 min	17 hr 32 min	34,800
Lasauses	1 d 0 hr 5 min	1 d 5 hr 51 min	11,600
CO/NM State Line	1 d 8 hr 1 min	1 d 14 hr 34 min	7,900

At the Colorado-New Mexico state line the estimated peak flow rate due to a clear-day breach of Terrace Dam (7,900 cfs) is less than the estimated 100-year flood (8,300 cfs). The 100-year flood peak was estimated using a Log-Pearson Type III distribution analysis because there was no flood study available on the Rio Grande near the Colorado-New Mexico state line. Maximum monthly stream flow data for the USGS gaging station "Rio Grande at Colorado-New Mexico State Line" from 1953 to 1982 was downloaded from the DWR's CDSS website[1]. Using this data to approximate maximum annual stream flows, a Log-Pearson Type III analysis estimated the 100-year flood to be 8,300 cfs. The Log-Pearson spreadsheet is provided in **Appendix E**.

2.3 Hydraulic Modeling in HEC-RAS

The USACE's water surface profile modeling computer program HEC-RAS was used to create a steady-state hydraulic model of the area downstream of Terrace Dam using the flow rates and locations shown in **Table 3**. Cross-sections of the flow path were developed from the best available USGS 10-meter DEM using the HEC-GeoRAS extension in ArcGIS. The average cross section spacing over the 75-mile modeled reach was roughly 0.5 miles, with critical areas such as towns having a closer spacing, and less-critical uninhabited areas having a farther spacing. Cross sections were cut perpendicular to the direction of flow in the channel and in the left and right overbanks. Manning's n-values were estimated from aerial photography and adjusted according to the depth of overbank flow.

No bridges in the study reach were modeled and all were assumed to be overtopped.

A summary of the HEC-RAS results at critical sections is shown in **Table 4**, and a summary of the full HEC-RAS model results is attached in **Appendix F**. The HEC-RAS model is included on the Project CD.

[1] The maximum monthly stream flow data is the maximum daily average stream flow during each given month.

Table 4. Terrace Reservoir Dam Failure
Summary of HEC-RAS Results at Critical Sections

Critical Section	HEC-RAS Station (miles)	WSEL (ft) NAVD 88	Flow Rate (cfs)	Avg Vel (ft/s)	Chan Vel (ft/s)	Top Width (ft)
Downstream of Terrace Dam	75.40	8543.5	429,700	24.9	45.0	500
Alluvial Fan	69.48	8189.7	375,300	17.6	26.8	1,300
County Rd. Z	66.95	8065.9	352,400	10.2	7.8	4,300
County Rd. 6	64.80	7952.5	309,900	6.4	4.6	13,300
County Rd. 8 in Capulin	62.49	7834.2	255,300	5.9	4.0	14,500
US 285	51.94	7591.4	77,500	1.7	2.3	26,600
County Rd. 14S	45.44	7550.6	36,900	1.3	1.4	14,400
Conejos/Costilla County Line	33.31	7513.9	34,800	1.2	1.3	8,200
Lasauses	21.77	7482.7	11,600	0.8	1.1	3,200
CO/NM State Line	0.00	7392.4	7,900	9.8	10.4	200

3.0 INUNDATION EXTENTS

3.1 Detail of Mapping

The water surface profile from the HEC-RAS hydraulic modeling was exported to ArcGIS, and the inundation extent was delineated using the USGS 10-meter DEM.

All bridge crossings in the study reach were assumed to be significantly overtopped. For this reason, ground surveys were not necessary at bridge crossings or roadway embankments.

The inundation maps associated with this report are provided in **Appendix G**.

3.2 Description of Inundation Area

A clear-day failure of Terrace Dam with the water surface at the emergency spillway crest will result in a peak outflow of approximately 429,700 cfs. The time it takes to achieve this peak outflow will be 35 minutes from the onset of the breach. From the dam the flood wave will travel southeast for about 6 miles along the Alamosa River through a deep canyon where the average channel flow depth will be about 60 feet, and the channel velocity will reach up to 53 feet per second. The structures and roads located within the canyon are expected to be significantly overtopped due to a clear-day breach of Terrace Dam.

At the mouth of the canyon is an alluvial fan where the floodplain opens up to very flat and open terrain. The flood wave will follow the main channel of the Alamosa River southeast, and it will spread out considerably as it approaches the Town of Capulin. Peak flooding depths and velocities are expected to remain high in this reach. Between the canyon and the Town of Capulin the average flow velocity will be approximately 9 feet per second, and the average flow depth in the Alamosa River main channel will be about 21 feet. Several structures in this reach are expected to be inundated.

Approximately 2 hours after the onset of the breach, the flood peak will reach Capulin with an attenuated flow rate of 255,300 cfs. The flooding will be roughly 3 miles across as it flows to the east through the town. Despite the wide flood extents, the majority of the flow is expected to be conveyed along the southern portion of the floodplain through the Town of Capulin. The greatest flood depths will be near the Alamosa River which runs through the northern part of the town, and near La Jara Creek which runs through the southern part of the town. Maximum depths in these drainages are expected to reach up to 12 feet, and channel velocities will range from 3 to 11 feet per second. The maximum overbank flood depth through the town along Highway 15 is expected to be approximately 5 feet, and the overbank velocity will reach 11 feet per second. Flooding north of County Road Y in the Capulin vicinity is not expected to exceed 4 feet in depth, and will mostly be 1 foot or less with a peak velocity of about 6 feet per second.

Between Capulin and the Town of La Jara the flood will likely spread across a vast network of small alluvial drainages that generally parallel the Alamosa River. The flooding extents in this reach will be about 5 to 6 miles across, with most of the overbank flooding 3 feet or less in depth. The average overbank velocity through this reach will be approximately 4 feet per second. However, the flow velocities and depths in the vicinity of the drainage channels in this reach are expected to be greater than these average overbank depths and velocities. Numerous structures, roads, and farms in this sparsely populated reach will be inundated due to a clear-day breach of Terrace Dam.

At U.S. Highway 285 the Alamosa River, La Jara Creek, and the parallel alluvial drainages flow northeast toward their confluences with the Rio Grande. The Terrace Dam breach flood wave is expected to continue to follow these drainages with maximum flood extents ranging from 3 to 5 miles across. Most of the overbank flooding in this reach will be 3 feet deep or less, while maximum depths near channels are expected to exceed 6 feet. The Town of La Jara will be inundated by overbank flows of up to 3 feet deep, but mostly by overbank flooding that is 1 foot deep or less. The overbank velocity in the vicinity of La Jara is expected to be 3 feet per second or less. The average overbank velocity downstream of La Jara to the confluence with the Rio Grande will be approximately 1.5 feet per second.

The flood wave will flow south along the Conejos-Costilla county line shortly after converging with the Rio Grande. Downstream of this confluence to the Town of Lasauses, the Rio Grande has a clearly defined floodplain limiting inundation widths from 0.5 to 1.5 miles across. No habitable structures in Lasauses are expected to be inundated. The maximum depths in the Rio Grande main channel will range from approximately 9 to 15 feet, and the peak channel velocity will be nearly 12 feet per second. When the flood peak reaches Lasauses approximately 30 hours after the breach initiation it will have attenuated to a flow rate of 11,600 cfs.

South of Lasauses the Rio Grande and the flood wave will be contained by a very narrow and deep floodplain that is approximately the width of the Rio Grande main channel itself. The flood wave will be conveyed south for approximately 22 miles to the Colorado-New Mexico state line. Habitable structures are not apparent in this reach, but two bridges (CO 142 and County Road G) over the Rio Grande may be overtopped by the peak flood wave. Maximum channel flow depths from Lasauses to the Colorado-New Mexico state line will exceed 15 feet, and peak channel velocities will reach approximately 10 feet per second. The modeling and the delineation of the inundation extents were terminated at the state line because the attenuated flow rate due to a clear-day breach of Terrace Dam (7,900 cfs) is less than the computed 100-year flow rate (8,300 cfs).

4.0 REFERENCES

Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer, Dam Safety Branch. *Guidelines for Dam Breach Analysis*. Denver, CO. 2010.

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U.S. Army Corps of Engineers. *HEC-GeoRAS*. Version 10.0.25. Geospatial data processing extension for ArcGIS software. Davis, CA. 2011. Retrieved from: http://www.hec.usace.army.mil/

Appendix A
Data Sources

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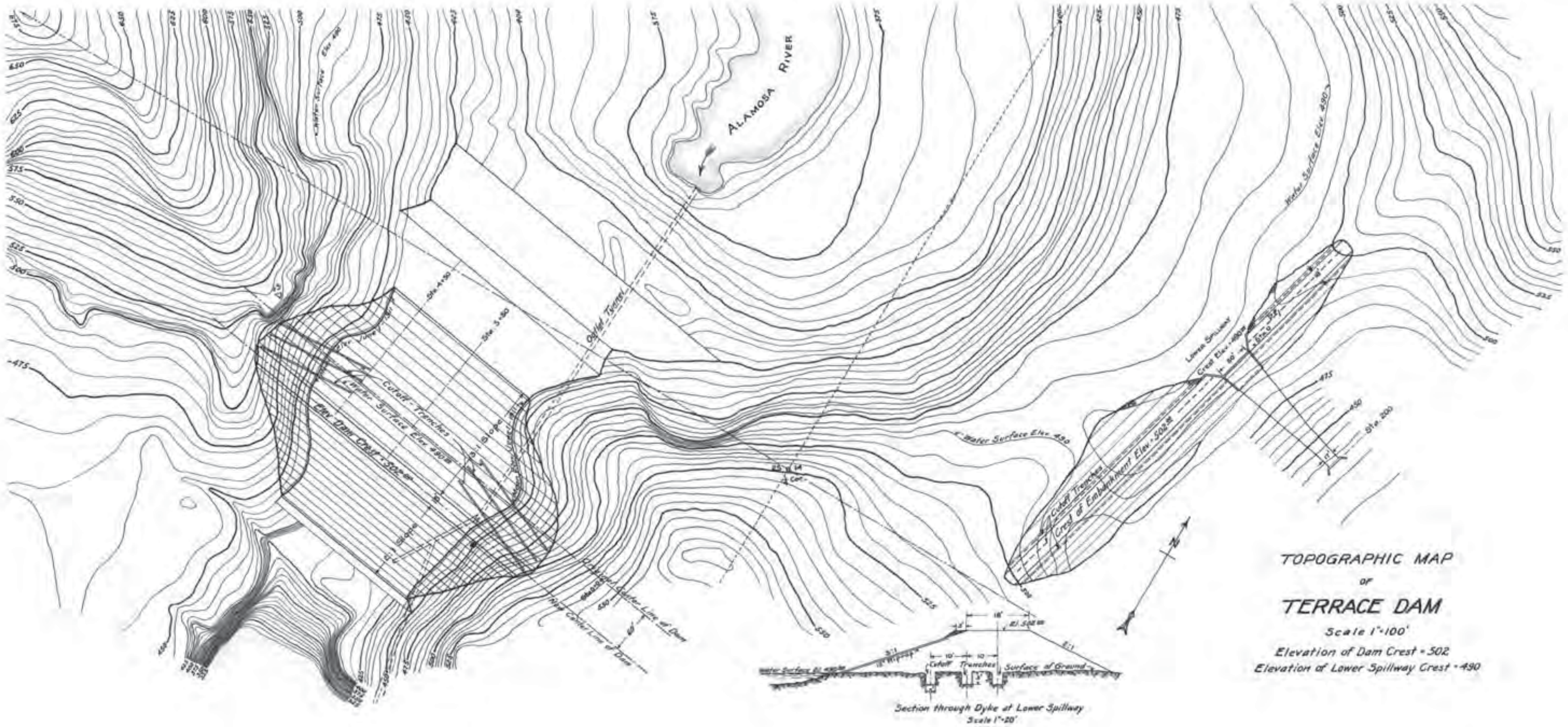
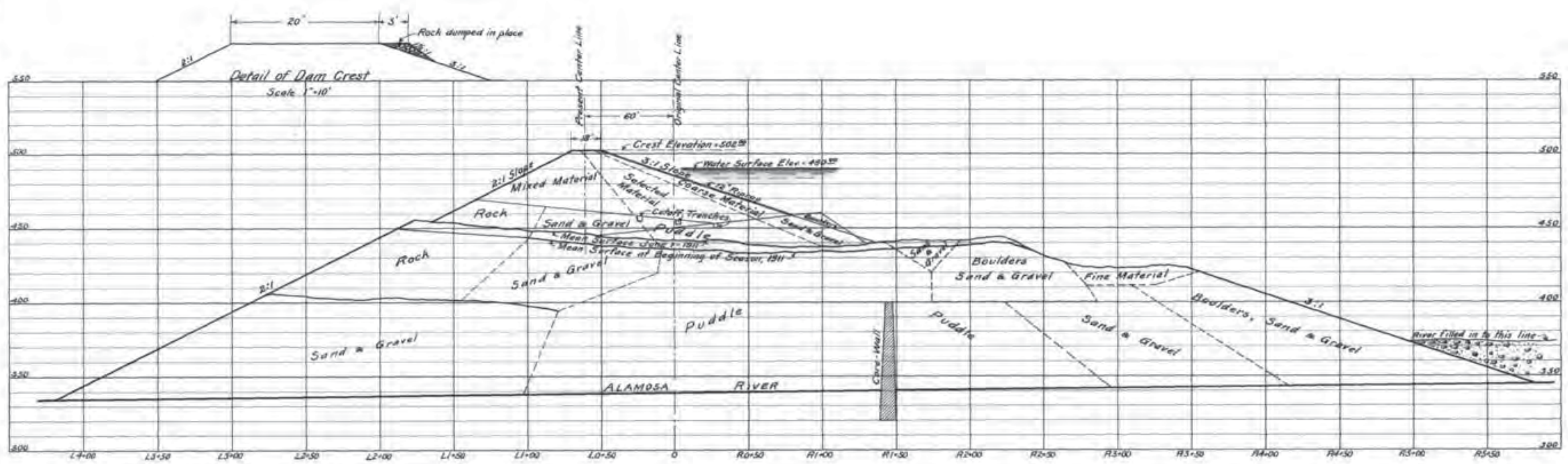


TOPOGRAPHIC MAP
of
TERRACE DAM
Scale 1"=100'
Elevation of Dam Crest = 502
Elevation of Lower Spillway Crest = 490



Tabulation showing Yardage

Contour	Between Contours Cu. yds.	Total Cu. yds.	Contour	Between Contours Cu. yds.	Total Cu. yds.
435			470		
	3421			12035	
440		3421	475		113224
	17159			11569	
445		20620	480		124733
	17142			9888	
450		37762	485		134688
	16701			8007	
455		54463	490		142696
	18170			5977	
460		70633	495		148673
	15281			3872	
465		85914	500		152545
	14275			2314	
470		100189	502		154855

PLAN
FOR COMPLETION OF
TERRACE DAM
TO LOWER SPILLWAY CREST
Scale 1"=50'

Approved July 1st, 1911
Charles W. Comstock
State Engineer.

PLANS
OF
TERRACE RESERVOIR DAM
CONEJOS COUNTY, COLORADO
IRRIGATION DIVISION No. 3. WATER DISTRICT No. 21
SCALES AS INDICATED

C-32

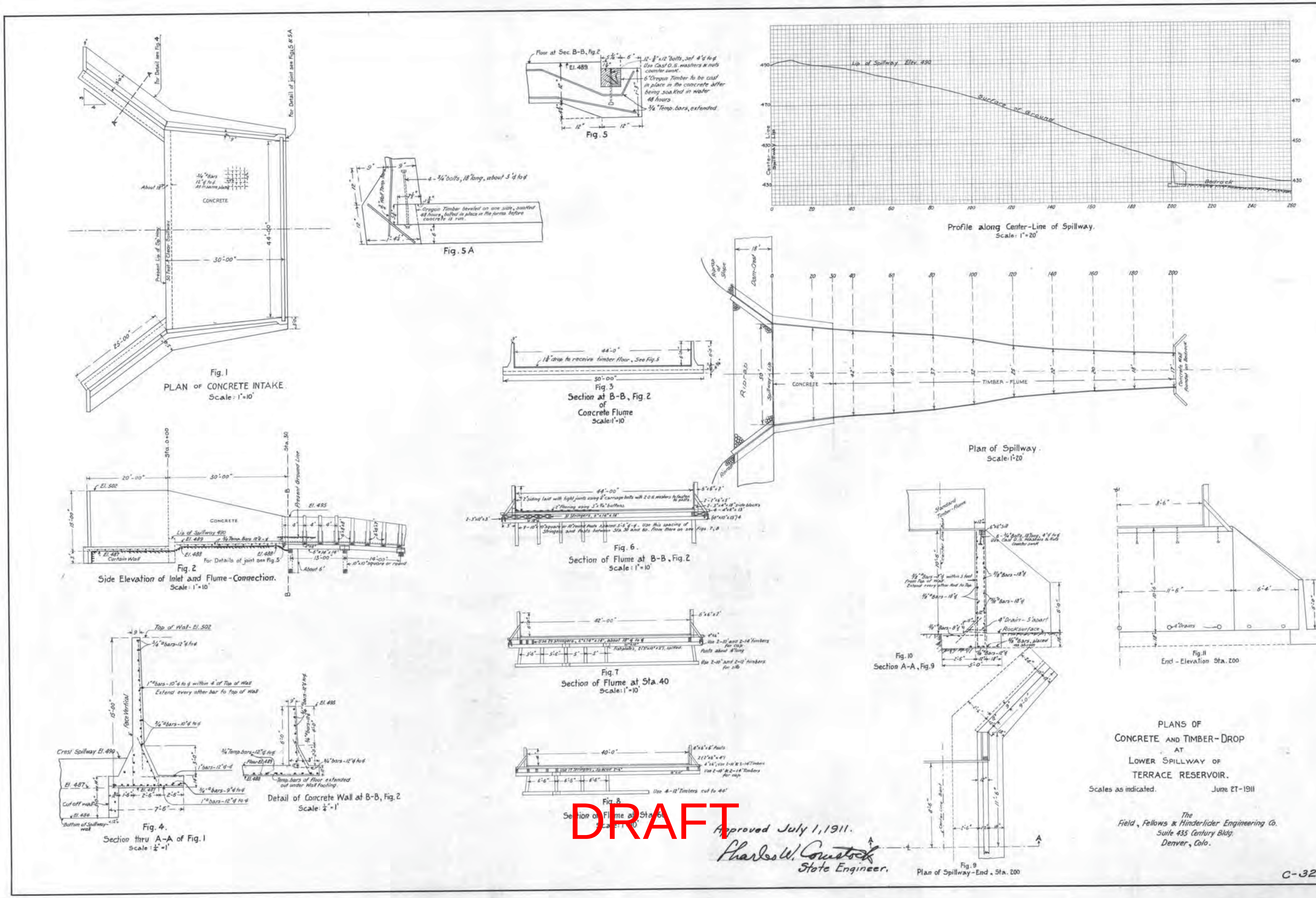


Fig. 1
PLAN OF CONCRETE INTAKE
Scale: 1"=10'
Fig. 5
Fig. 5 A
Profile along Center-Line of Spillway.
Scale: 1"=20'
Fig. 3
Section at B-B, Fig. 2
of
Concrete Flume
Scale: 1"=10'
Plan of Spillway
Scale: 1"=20'
Fig. 2
Side Elevation of Inlet and Flume-Connection.
Scale: 1"=10'
Fig. 6.
Section of Flume at B-B, Fig. 2
Scale: 1"=10'
Fig. 10
Section A-A, Fig. 9
Fig. 11
End-Elevation Sta. 200
Fig. 7
Section of Flume at Sta. 40
Scale: 1"=10'
Fig. 4.
Section thru A-A of Fig. 1
Scale: ½"=1'
Detail of Concrete Wall at B-B, Fig. 2
Scale: ½"=1'
Fig. 8
Fig. 9
Plan of Spillway-End, Sta. 200
PLANS OF
CONCRETE AND TIMBER-DROP
AT
LOWER SPILLWAY OF
TERRACE RESERVOIR.
Scales as indicated.
June 27-1911
The
Field, Fellows & Hinderlider Engineering Co.
Suite 435 Century Bldg.
Denver, Colo.
Approved July 1, 1911.
Charles W. Comstock
State Engineer.
C-32
DRAFT

PREPARED IN COOPERATION WITH THE
U.S. ENVIRONMENTAL PROTECTION AGENCY

WATER-RESOURCES INVESTIGATIONS REPORT 96-4027

Abstract

Sediments deposited in Terrace Reservoir contain large concentrations of trace metals. A study was done by the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, to map the current (1994) bathymetric (bottom) surface to estimate the current storage capacity of Terrace Reservoir and the volume of sediment deposited in the reservoir during 1981–94. A better understanding of the bathymetric surface and changes in that surface caused by deposition of trace-metal-enriched sediments will allow the U.S. Environmental Protection Agency to choose appropriate remediation plans for Terrace Reservoir. The 1994 bathymetric-surface map of Terrace Reservoir was machine contoured from 21,944 depth soundings. Depth soundings were made with an echo sounder during July and August 1994. A storage-capacity table of the reservoir was estimated from the 1994 bathymetric-surface map. Comparison of the July–August 1994 storage capacity with estimated 1981 storage capacity indicated a decrease in storage capacity of about 580 acre-feet, below a stage of 8,545 feet. Average annual deposition of sediments in Terrace Reservoir during 1981–94, below a stage of 8,545 feet, was assumed to equal the average annual decrease in storage capacity and was an estimated 41 acre-feet. The thickness of sediment deposited in Terrace Reservoir during 1981–94, below a stage of 8,545 feet, averaged about 2.7 feet.

INTRODUCTION

Sediment deposited in Terrace Reservoir, Conejos County, Colorado, contains large concentrations of trace metals (A.J. Horowitz and others, U.S. Geological Survey, written commun., 1995). The volume of trace-metal-bearing sediment stored in Terrace Reservoir had not been determined previously. However, the bathymetric surface was mapped from aerial photographs taken when the reservoir was drained for maintenance in 1981, and the storage capacity was estimated from that map (Davis Engineering Services, Inc., 1981).

Sources of trace metals in the Alamosa River Basin, upstream from Terrace Reservoir, include outcrops of mineralized rocks and mined areas. Mining of gold in the Alamosa River Basin began with the discovery of gold at Summitville in 1870. The Summitville Mine was operated as a large-tonnage, open-pit, heap-leach gold mine during 1986–92. On December 6, 1992, the operators of the Summitville Mine declared bankruptcy and abandoned the site, and the U.S. Environmental Protection Agency (EPA) assumed operation of the site and increased water-treatment capacity at the site to minimize discharge of low-quality water to the Wightman Fork, a tributary of the Alamosa River (fig. 1). Mining activities have affected concentrations of trace metals in surface water in the basin. Comparison of pre-1985 and post-1985 data indicate that pH decreased and concentrations of dissolved and total or total-recoverable trace metals (copper, iron, and possibly zinc) increased in the Alamosa River downstream from its confluence with the Wightman Fork (Cain, 1995).

Detailed studies of the water quality, limnology, sediment deposition and geochemistry, and movement of metals into, within, and through Terrace Reservoir began in 1994 by the U.S. Geological Survey, in cooperation with the EPA (Cain, 1995). A current definition of the bathymetric surface and of the volume of trace-metal-bearing sediments deposited in the reservoir can be used by the EPA in selection of appropriate actions for remediation of Terrace Reservoir. This report presents the results from a study that was done to map the current (July–August 1994) configuration of the bathymetric surface to estimate the current storage capacity of Terrace Reservoir and the volume of sediment deposited in Terrace Reservoir during 1981–94. Field work for the study was done in July and August 1994.

Location and Description of Terrace Reservoir

Terrace Reservoir is located in Conejos County, Colorado, about 16 mi south-southwest of Monte Vista and about 12 mi downstream from the confluence of the Alamosa River and the Wightman Fork (fig. 1). Water released from Terrace Reservoir is used to irrigate about 45,000 acres of farmland in the San Luis Valley of south-central Colorado (U.S. Environmental Protection Agency, 1993).

Terrace Reservoir is impounded behind an earth-fill dam that was completed across the Alamosa River Canyon during 1912. The sides of the reservoir are rocky and steep. The crest of the overflow spillway of Terrace Reservoir is at an approximate altitude of 8,571 ft above NGVD of 1929. At maximum stage (8,571 ft above NGVD of 1929), the reservoir is about 14,000 ft long; ranges from a few feet to about 1,500 ft wide; and has a surface area of about 299 acres. The storage capacity of Terrace Reservoir at maximum stage was reportedly about 15,182 acre-ft in 1981 (Davis Engineering Services, Inc., 1981). Based on high-water marks, reservoir stage generally is less than about 8,564 ft above NGVD of 1929.

The storage and release of water from Terrace Reservoir for irrigation affects the distribution of sediments within the reservoir. During the fall through late spring, when water is stored for later release, sediments are deposited in the upstream one-third of the reservoir. During the summer, when water is released for irrigation, reservoir stage drops rapidly and much of the sediment, which previously was deposited in the upstream one-third of the reservoir, is transported to and deposited in the downstream two-thirds of the reservoir. Between June 28 and August 12, 1994, the reservoir stage dropped about 30 ft and much of the sediment in the upstream one-third of the reservoir was eroded and transported farther downstream in the reservoir.

Data Collection

The bathymetric surface of Terrace Reservoir was surveyed during July and August 1994, using an echo sounder (ODECO TDS–1000) mounted on a boat. Soundings were made on a fixed time interval while the boat traveled at a relatively constant speed of about 2 to 3 mi/h. The location of each sounding was computed from the distance and azimuth from a known position on the shore (navigation station) to a target mounted on the boat about 6 ft above the echo sounder's transducer. Distance and azimuth were determined with a HYDRO2 navigation system. Distance from the navigation station to the target was measured using an infrared range finder. Azimuth from the navigation station to the target was measured with an electronic surveying instrument (total data station). Data from the echo sounder, the range finder, and the total data station were stored and processed in the field on a laptop computer, using a hydrographic-surveying software package (Coastal Oceanographics, 1994). [The use of trade, product, industry, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.]

Each sounding depth (depth to reservoir bottom) was converted to a bottom altitude by subtracting the sounding depth from the reservoir stage. Reservoir stage was determined twice daily, using temporary staff gages. When necessary, the stage was interpolated to estimate the stage at the time the depth sounding was made. Temporary staff gages were used because the stage recorder for the reservoir was inoperative during July and August 1994. Datum for the temporary staff gages was a mark on the crest of the overflow spillway of Terrace Reservoir (BM–1, fig. 2), which is approximately 8,571 ft above NGVD of 1929.

Soundings were not made in the upstream one-third of the reservoir, upstream from navigation station TP–6 (fig. 2), because the boat was difficult to handle in the shallow and relatively narrow channel. Because no soundings were made west of navigation station TP–6, the bathymetric surface of the reservoir upstream from TP–6 and above a stage of about 8,550 ft was not surveyed. Soundings in the middle one-third of the reservoir, between navigation stations TP–6 and TP–4, were made on July 1, 1994, when reservoir stage was 8,559.1 ft, and in the lower one-third of the reservoir, downstream from navigation station TP–4, during August 10–12, 1994, when reservoir stage was between 8,533.8 and 8,534.0 ft. Traces along which soundings were taken are shown in figure 2. Horizontal coordinates of the depth soundings used in this report are given as easting (distance east) and northing (distance north) from the datum that was used for a previous (1981) survey of the bathymetric surface of Terrace Reservoir (Davis Engineering Services, Inc., 1981). The locations of two prominent features (BM–1 and HUB–1, fig. 2) were used to register the coordinate locations from this survey with the coordinate locations from the survey by Davis Engineering Services, Inc. (1981). BM–1 (fig. 2) is a mark on the crest of the overflow spillway adjacent to the north wingwall. HUB–1 (fig. 2) is a 2-ft-long iron rod, near a boulder on a prominent point of rock, north of the east end of the earth-fill dam. After editing to remove spurious and duplicate data points, a total of 21,944 bottom altitudes were used to define the July–August 1994 bathymetric surface of Terrace Reservoir.

Acknowledgments

The following individuals and organizations are acknowledged for providing information and access to private property. Paul Prickett of the Terrace Reservoir Irrigation Company provided unpublished stage measurements for the reservoir, and the Terrace Reservoir Irrigation Company allowed access to the reservoir for the bathymetric survey. Davis Engineering Services, Inc., of Del Norte, Colorado, provided a base-stable copy of the 1981 bathymetric-surface map and a copy of the 1981 storage-capacity table for Terrace Reservoir. The State Engineer's Office, Irrigation Division 3, Alamosa, Colorado, provided data on monthly storage in the reservoir. David S. Mueller, U.S. Geological Survey, provided training in use of the navigation system and hydrographic software.

BATHYMETRIC SURFACE

The altitude and configuration of the bathymetric surface of Terrace Reservoir during July–August 1994 (fig. 3) were machine contoured, using ARC/INFO (Environmental Systems Research Institute, Inc., 1994). Selected machine-drawn contours were revised because of insufficient data spacing in some areas and because of inherent limitations of the contouring program. The coordinates used on the 1994 bathymetric-surface map (fig. 3) are in feet east (easting) and feet north (northing) of the datum that was used by Davis Engineering Services, Inc. (1981). Although the coordinate system is based on the State-Plane Coordinate System for southern Colorado, the locations have not been determined precisely. Therefore, the local coordinate system used by Davis Engineering Services, Inc. (1981), was maintained for comparative purposes. Because no new data were collected in the upstream one-third of the reservoir west of TP–6 (fig. 3), the 1994 bathymetric surface was not contoured in this area. Contours also are not shown where altitude of the surface is greater than 8,550 ft in the lower two-thirds of the reservoir because little data were collected when the stage of the reservoir was greater than 8,550 ft. Changes in the configuration of the bathymetric surface between altitudes of 8,550 and 8,571 ft have not been determined. However, substantial quantities of sediments are not likely to accumulate above an altitude of about 8,550 ft in the upstream one-third of the reservoir west of TP–6 (fig. 3) because of erosion during periods when the reservoir stage drops rapidly and in the downstream two-thirds of the reservoir because the sides of the reservoir are very steep.

The 1981 and 1994 bathymetric-surface maps were similar in most areas. Differences between the bathymetric surfaces, in part, quantified the accumulation of sediments in the reservoir between 1981 and 1994 and also indicated some areas in which errors in contouring probably resulted from insufficient data. Some differences between the 1981 and 1994 bathymetric-surface maps also resulted from the types of data used to prepare the maps. The 1981 bathymetric-surface map (Davis Engineering Service, Inc., 1981) was prepared from aerial photographs taken when the reservoir was drained for maintenance and essentially constituted a continuous data set. The 1994 bathymetric-surface map was prepared from a finite number of depth soundings (21,944) and constituted a discontinuous data set. Differences between the 1981 and 1994 bathymetric-surface maps also might have resulted from errors in determining locations of the navigation stations and soundings and in the measurement of depth and reservoir stage. The use of different contouring methods also could introduce differences because the methods are interpretive.

Errors in depth measurement probably resulted from the vertical motion of the boat due to waves or changes in velocity of the boat, but likely would have a mean error of zero and range from about –0.5 to 0.5 ft. Errors in sounding locations are likely to have resulted from slight errors in the measurement of the azimuth from the navigation station to the target mounted above the transducer of the echo sounder. Errors in measuring the azimuth probably were less than 1 degree. At a distance of 1,000 ft, an error of 1 degree in the azimuth would result in an error in location of the sounding of about 17.5 ft. Although the accuracy of sounding locations cannot be determined with the available data, it was assumed likely location errors were less than 1 to 2 ft. Errors in stage measurement included measurement of the stage on the temporary staff gages (–0.05 to 0.05 ft) and datum error (–0.02 to 0.02 ft) and are not a substantial source of error.

STORAGE CAPACITY

The storage capacity of Terrace Reservoir during July–August 1994 (table 1) was estimated from the 1994 bathymetric-surface map (fig. 3), using ARC/INFO. Although the storage capacity of Terrace Reservoir during 1981 (table 1) was reported by Davis Engineering Services, Inc. (1981), for purposes of comparison, the 1981 storage capacity was estimated from the digitized 1981 bathymetric-surface map, using ARC/INFO.

The difference between the 1981 reported and estimated storage capacity of Terrace Reservoir at a stage of 8,545 ft (table 1), calculated as the reported 1981 storage capacity minus the estimated 1981 storage capacity, was –130 acre-ft. The 1981 estimated storage capacity was about 1.5 percent larger than the 1981 reported storage capacity. The difference between the 1981 and the 1994 estimated storage capacity of Terrace Reservoir at a stage of 8,545 ft (table 1), calculated as 1981 estimated minus 1994 estimated storage capacity, was 580 acre-ft. The 1994 estimated storage capacity was about 6.7 percent smaller than the 1981 estimated storage capacity and was assumed equivalent to the cumulative deposition of sediments in Terrace Reservoir during 1981–94. Although the estimated change in storage capacity during 1981–94 was assumed to approximate the cumulative 1981–94 deposition of sediment, the difference in storage capacity also includes errors in data collection, in contouring the bathymetric data, and in calculating the storage capacity from the bathymetric surface. The average annual decrease in storage capacity of Terrace Reservoir at a stage of 8,545 ft, during 1981–94, was less than or equal to about 41 acre-ft, or an annual decrease of about 0.5 percent of the estimated 1981 storage capacity at a stage of 8,545 ft (table 1). Although sediment deposition was not assumed to be of uniform thickness within the reservoir at a stage of 8,545 ft, the ratio of cumulative decrease in storage capacity of the reservoir (580 acre-ft) to the estimated 1981 surface area of the reservoir (215 acres) was about 2.7 ft and was assumed to be equivalent to the average thickness of sediment deposited in Terrace Reservoir during 1981–94.

A preliminary review of the differences between the digitized 1981 bathymetric-surface map (Davis Engineering Services, Inc., 1981) and the 1994 bathymetric-surface map (fig. 3) showed an irregular pattern of positive differences (deposition) and negative differences (erosion). Most of the positive difference (deposition) was in the middle one-third of the reservoir between 1,500 and 6,000 ft easting. An apparent irregular pattern of positive and negative differences in the downstream one-third of the reservoir was assumed to primarily result from data and contouring errors.

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Table 1. Storage capacity of Terrace Reservoir, 1981 and 1994

Altitude of water surface (feet)	1981 reported[1] Surface area (acres)	1981 reported[1] Storage capacity (acre-feet)	1981 estimated[2] Surface area (acres)	1981 estimated[2] Storage capacity (acre-feet)	Difference between 1981 reported and 1981 estimated storage capacity (acre-feet)	1994 estimated[2] Surface area (acres)	1994 estimated[2] Storage capacity (acre-feet)	Difference[3] between 1981 and 1994 estimated storage capacity (acre-feet)
8,450	0.7	1.0	0.8	1.9	-0.9	0.7	1.7	0.2
8,455	2.7	9.4	2.6	10.4	-1.0	4.0	13.5	-3.1
8,460	7.0	33.5	7.1	34.6	-1.1	8.5	44.8	-10.2
8,465	14.7	87.7	14.8	88.7	-1.0	18.0	103	[illegible]
8,470	20.6	176	21.3	178	-2.0	20.6	190	-12.0
8,475	22.5	284	25.4	306	-22.0	28.2	308	-2.0
8,480	37.4	434	38.8	476	-42.0	33.5	457	19.0
8,485	46.3	561	49.9	608	-47.0	43.0	567	41.0
8,490	58.4	921	60.0	972	-51.0	49.2	878	94.0
8,495	71.3	1,250	74.0	1,310	-60.0	65.0	1,160	150
8,500	94.0	1,660	96.2	1,730	-70.0	88.1	1,550	180
8,505	108	2,160	112	2,250	-90.0	106	2,030	220
8,510	126	2,750	127	2,850	-100	120	2,600	250
8,515	136	3,400	137	3,510	-110	130	3,220	290
8,520	145	4,110	147	4,220	-110	139	3,890	330
8,525	159	4,870	161	4,990	-120	158	4,610	380
8,530	172	5,700	173	5,820	-120	162	5,390	430
8,535	183	6,590	184	6,710	-120	174	6,240	470
8,540	197	7,540	198	7,660	-120	187	7,140	520
8,545	211	8,360	215	8,490	-130	200	7,910	580

[1] Davis Engineering Services, Inc. (1981).
[2] Surface area and storage capacity estimated from digitized map of the bathymetric surface of Davis Engineering Services, Inc. (1981) using ARC/INFO.
Area and cumulative capacity estimated from 1994 bathymetric surface, using ARC/INFO.
[3] Difference calculated as 1981 estimated storage capacity minus 1994 estimated storage capacity.

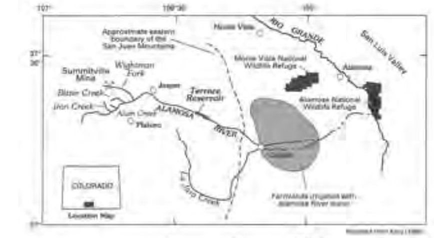
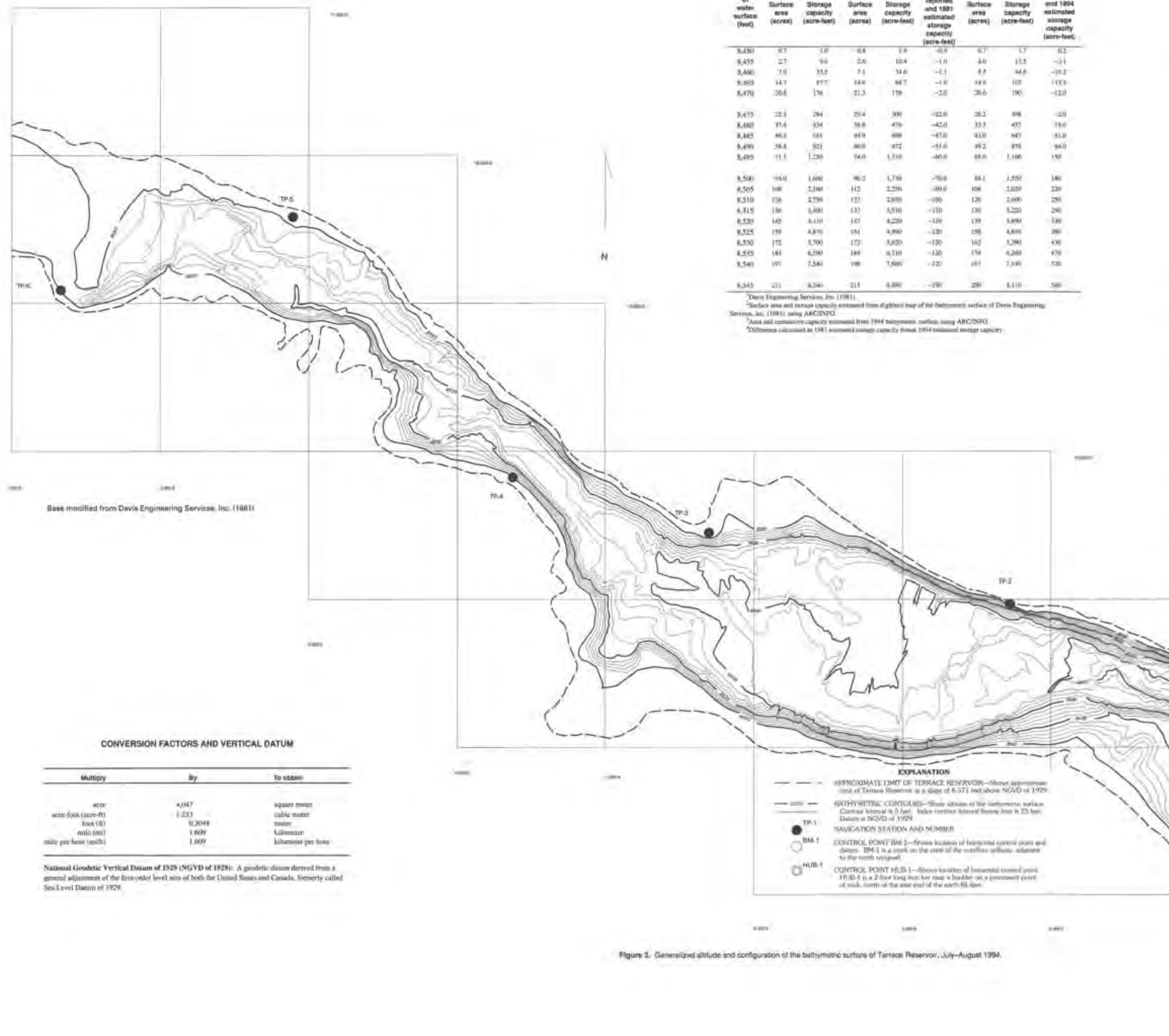
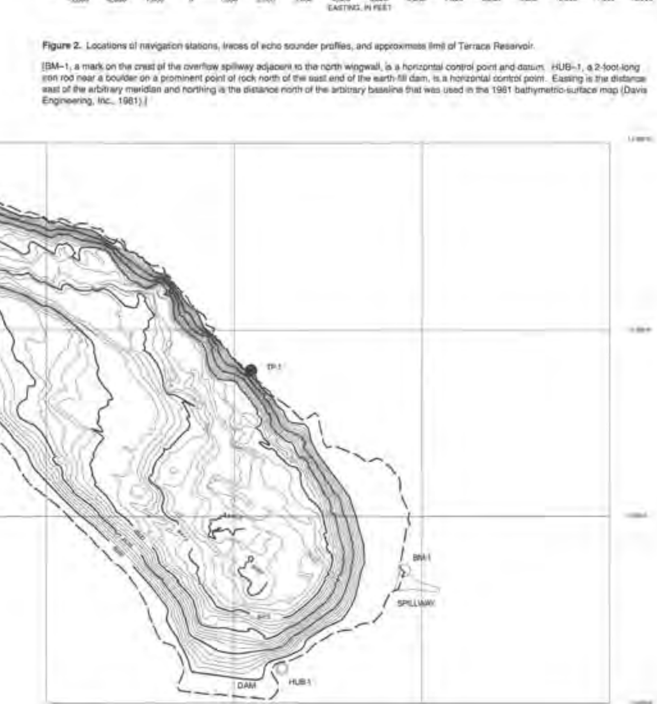


Figure 1. Location of Terrace Reservoir.

Figure 2. Locations of navigation stations, traces of echo sounder profiles, and approximate limit of Terrace Reservoir.

[BM–1, a mark on the crest of the overflow spillway adjacent to the north wingwall, is a horizontal control point and datum. HUB–1, a 2-foot-long iron rod near a boulder on a prominent point of rock north of the east end of the earth-fill dam, is a horizontal control point. Easting is the distance east of the arbitrary meridian and northing is the distance north of the arbitrary baseline that was used in the 1981 bathymetric-surface map (Davis Engineering, Inc., 1981).]

Base modified from Davis Engineering Services, Inc. (1981)

Figure 3. Generalized altitude and configuration of the bathymetric surface of Terrace Reservoir, July–August 1994.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
mile per hour (mi/h)	1.609	kilometer per hour

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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BATHYMETRIC SURFACE AND STORAGE CAPACITY OF TERRACE RESERVOIR, CONEJOS COUNTY, COLORADO, JULY–AUGUST 1994

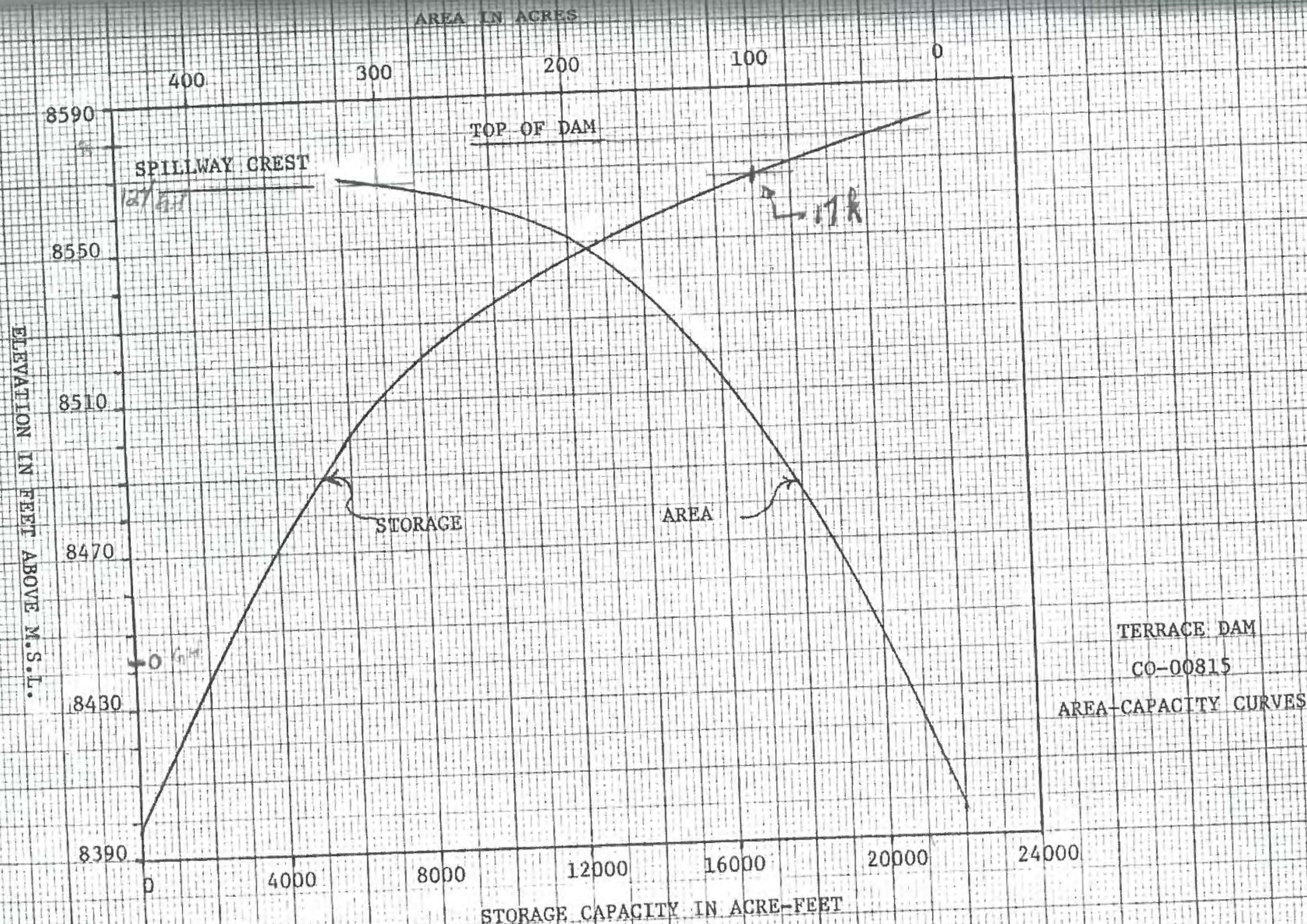
By
Kenneth R. Watts

1996

Terrace Reservoir Elevation Capacity Table*

Gage Height (Feet)	Active Storage (Acre-Feet)
0	0
1	0.1
2	0.5
3	1
4	1.9
5	3.2
6	4.9
7	6.9
8	9.4
9	12.5
10	16.4
11	21.2
12	26.9
13	33.5
14	41.3
15	50.6
16	61.4
17	73.8
18	87.7
19	103
20	120
21	137
22	156
23	176
24	197
25	219
26	240
27	262
28	284
29	308
30	335
31	365
32	398
33	434
34	472
35	513
36	557
37	602
38	651
39	701
40	753
41	808
42	864
43	921
44	981
45	1044
46	1109
47	1176
48	1246
49	1320
50	1398
51	1480
52	1567
53	1659
54	1755
55	1853
56	1954
57	2058
58	2164
59	2274
60	2388
61	2504
62	2625
63	2749
64	2876
65	3005
66	3136
67	3269
68	3404
69	3541
70	3680
71	3820
72	3963
73	4107
74	4254
75	4404
76	4556
77	4711
78	4869
79	5030
80	5193
81	5359
82	5528
83	5699
84	5872
85	6048
86	6226
87	6405
88	6588
89	6772
90	6959
91	7149
92	7342
93	7538
94	7736
95	7937
96	8141
97	8348
98	8557
99	8770
100	8986
101	9205
102	9428
103	9654
104	9883
105	10116
106	10354
107	10594
108	10838
109	11086
110	11337
111	11591
112	11849
113	12110
114	12373
115	12640
116	12909
117	13181
118	13456
119	13734
120	14016
121	14302
122	14591
123	14885
124	15182

* Table has been modified to only include 1-foot increments. The original table provided by the SEO showed stage in 0.01-foot increments.



GRJ Note: from USACE Phase I Inspection Reports, circa 1978

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APPENDIX B
TERRACE RESERVOIR ELEVATION-AREA-CAPACITY CURVE

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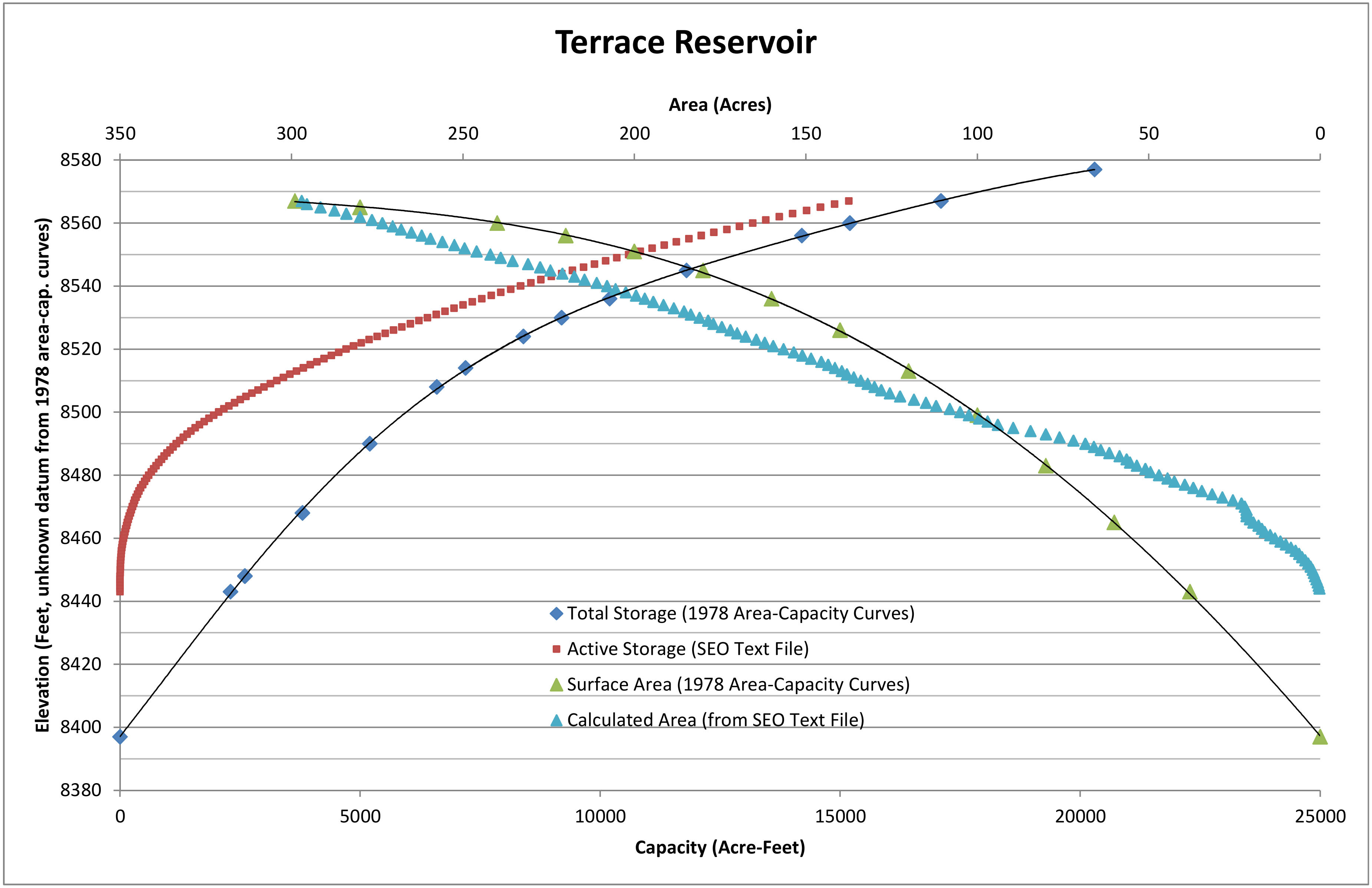
Terrace Reservoir
Area (Acres)
350
300
250
200
150
100
50
0
Elevation (Feet, unknown datum from 1978 area-cap. curves)
8580
8560
8540
8520
8500
8480
8460
8440
8420
8400
8380
Total Storage (1978 Area-Capacity Curves)
Active Storage (SEO Text File)
Surface Area (1978 Area-Capacity Curves)
Calculated Area (from SEO Text File)
0
5000
10000
15000
20000
25000
Capacity (Acre-Feet)

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APPENDIX C
EMPIRICAL METHODS FOR PREDICTING BREACH PARAMETERS

ESTIMATION OF DAM BREACH PARAMETERS
USING THE FROEHLICH 2008 METHOD

PROJECT: Terrace Reservoir - Breach to Upstream Invert of Outlet Pipe

BREACH INPUT PARAMETERS:

Select Failure Mode From Drop-Down Menu:	PIPING	
Height of water over base elevation of breach (H_w) =	124.0	Feet
Volume of water in the reservoir at the time of failure (V_w) =	15,182.0	Acre-Feet
Reservoir Surface Area at Hw (A_s) =	299.0	Acres
Height of breach (H_b) =	136.0	Feet
Failure Mode Factor (K_o) =	1	
Breach Side-Slope Ratio (Z_b) =	0.7	Z(H):1(V)
Dam Size Class:	Large	Assumes Full Reservoir At Time of Breach.

CALCULATED BREACH CHARACTERISTICS:

Average Breach Width (B_{avg}) =	218.4	Feet
Bottom Width of Breach (B_b) =	123.2	Feet
Breach Formation Time (T_f) =	0.59	Hours
Storage Intensity (SI) =	122.4	Acre Feet/Foot
Predicted Peak Flow (Q_p) =	536500	Cubic Feet per Second

RESULTS CHECK:

Average Breach Width Divided by Height of Breach (B_{avg}/H_b) =	1.61	If (B_{avg}/H_b) > 0.6, Full Breach Devlopment is Anticipated
Erosion Rate (ER), Calculated as (B_{avg}/T_f) =	373.3	
Erosion Rate Divided by Height of Water Over Base of Breach (ER/H_w) =	3.0	If 1.6 < (ER/H_w) < 21, Erosion Rate is Assumed Reasonable

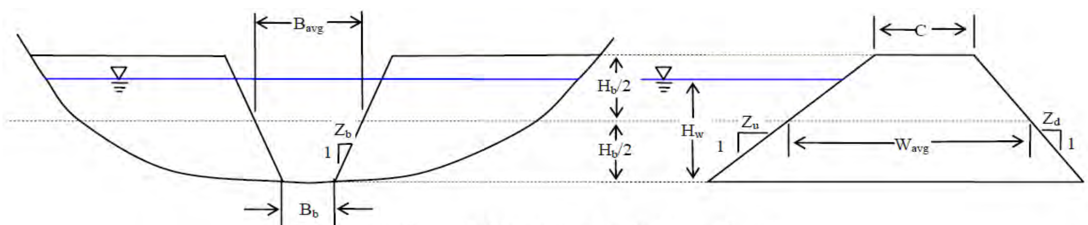

Figure 1- Breach Variable Definition Sketch

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ESTIMATION OF DAM BREACH PARAMETERS
USING THE MACDONALD & LANGRIDGE-MONOPOLIS OR WASHINGTON STATE METHODS
WITH ALL FAILURE TIMES ESTIMATED BY WASHINGTON STATE METHOD

PROJECT: Terrace Reservoir - Breach to Upstream Invert of Outlet Pipe

BREACH INPUT PARAMETERS:

Select Embankment Type From Drop-Down Menu: EARTHEN (COHESIVE)

Height of water over base elevation of breach (H_w) =	124.0	Feet
Volume of water stored in reservoir at time of failure (V_w) =	15182.0	Acre-Feet
Reservoir Surface Area at H_w (A_s) =	299.0	Acres
Crest width of dam (C) =	20.0	Feet
Height of breach from dam crest to base elevation of breach (H_b) =	136.0	Feet
Slope of upstream dam face (Z_u) =	4.0	Z(H):1(V)
Slope of downstream dam face (Z_d) =	2.0	Z(H):1(V)
Breach side-slope ratio (Z_b) =	0.5	Z(H):1(V)
Piping Orifice Coefficient (C_p) =	0.77	Used To Calculate Peak Discharge Through Piping Hole
Dam Size Class:	Large	Assumes Full Reservoir At Time of Breach

CALCULATED BREACH CHARACTERISTICS:

Breach Formation Factor (BFF) =	1882568	
Embankment Volume Eroded (V_{er}) =	221466.6	Cubic Yards
Average Dam Width (W_{avg}) =	428.0	Feet (In Direction of Flow)
Average Breach Width (B_{avg}) =	102.7	Feet
Bottom Width of Breach (B_b) =	34.7	Feet
Breach Formation Time (T_f) =	3.02	Hours
Storage Intensity (SI) =	122.4	Acre Feet/Foot
Peak Breach Discharge (Q_p) =	131745	Cubic Feet per Second

RESULTS CHECK:

Average Breach Width Divided by Height of Breach (Bavg/Hb) =	0.76	If (Bavg/Hb) > 0.6, Full Breach Development is Anticipated
Erosion Rate (ER), Calculated as (Bavg/Tf) =	34.0	
Erosion Rate Divided by Height of Water Over Base of Breach (ER/Hw) =	0.3	If 1.6 < (ER/Hw) < 21, Erosion Rate is Assumed Reasonable

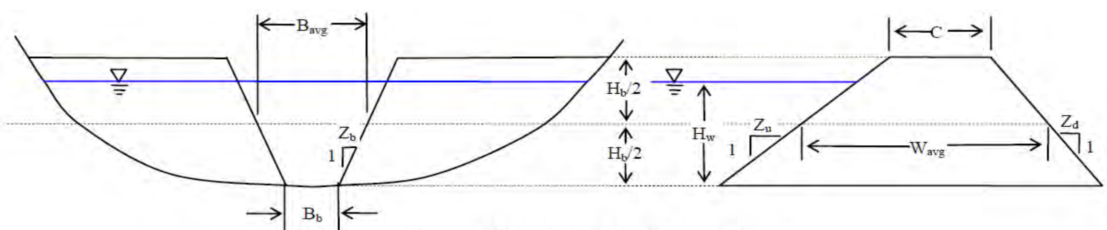

Figure 1- Breach Variable Definition Sketch

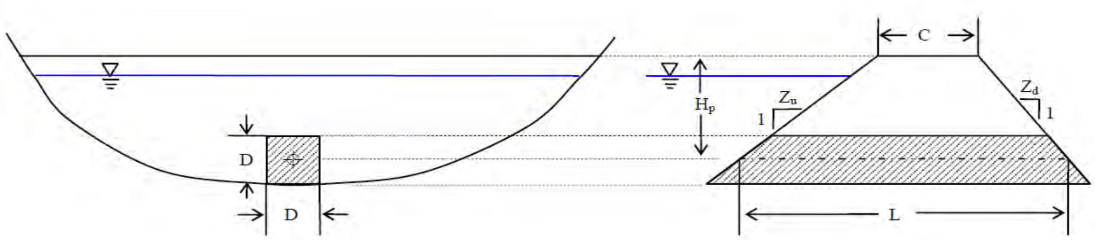

Figure 2 – Piping Hole Variable Definition Sketch

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APPENDIX D
HEC-HMS OUTPUT

Project: Terrace Reservoir Simulation Run: Froehlich Constrained Linear

Start of Run:	01Jan2013, 00:00	Basin Model:	Froehlich Constrained
End of Run:	03Jan2013, 23:59	Meteorologic Model:	Clear-Day
Compute Time:	15May2013, 13:58:12	Control Specifications:	3 Days

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
Terrace Reservoir	0	429733.2	01Jan2013, 00:35	15185.5
Dam to alluvial fan	0	375285.1	01Jan2013, 00:51	14998.8
alluvial fan to CR Z	0	352431.3	01Jan2013, 01:05	14778.9
CR Z to CR 6	0	309913.3	01Jan2013, 01:26	14514.5
CR 6 to Capulin	0	255340.8	01Jan2013, 01:54	14151.5
Capulin to E. Capulin	0	189933.2	01Jan2013, 02:33	13495.2
E. Capulin to US 285	0	77549.9	01Jan2013, 06:44	11989.0
US 285 to CR 14S	0	36930.1	01Jan2013, 12:16	9923.8
CR 14S to Conejos/Costilla	0	34768.9	01Jan2013, 17:32	9978.6
Conejos/Costilla to Lasauses	0	11643.2	02Jan2013, 05:51	7446.7
Lasauses to NM	0	7912.2	02Jan2013, 14:34	6658.1

Project: Terrace Reservoir

Simulation Run: Froehlich Constrained Linear Reservoir: Terrace Reservoir

Start of Run:	01Jan2013, 00:00	Basin Model:	Froehlich Constrained Linear
End of Run:	03Jan2013, 23:59	Meteorologic Model:	Clear-Day
Compute Time:	15May2013, 13:58:12	Control Specifications:	3 Days

Volume Units: AC-FT

Computed Results

Peak Inflow :	0.0 (CFS)	Date/Time of Peak Inflow :	01Jan2013, 00:00
Peak Outflow :	429733.2 (CFS)	Date/Time of Peak Outflow :	01Jan2013, 00:35
Total Inflow :	0.0 (AC-FT)	Peak Storage :	15182.0 (AC-FT)
Total Outflow :	15185.5 (AC-FT)	Peak Elevation :	490.00 (FT)

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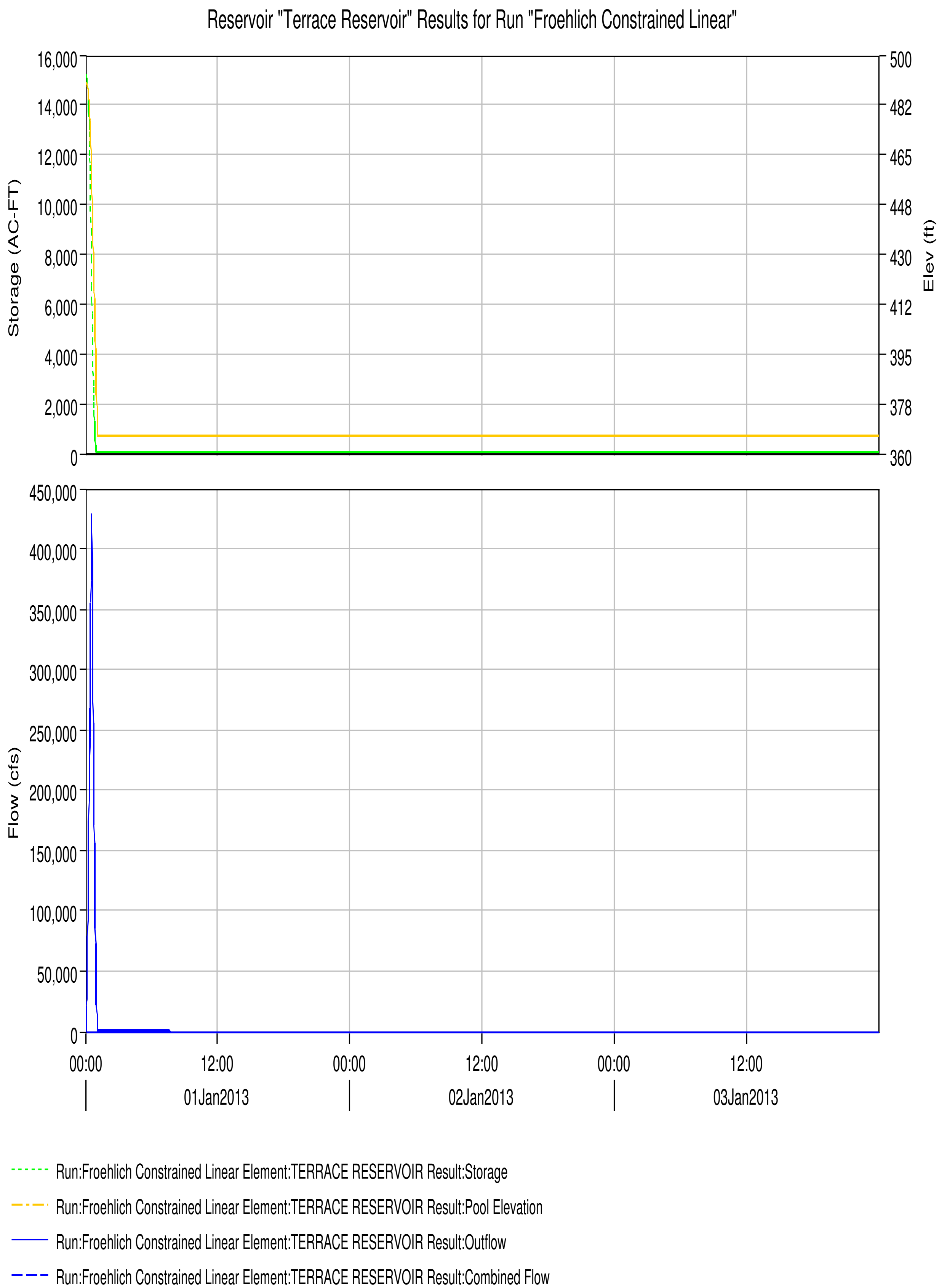
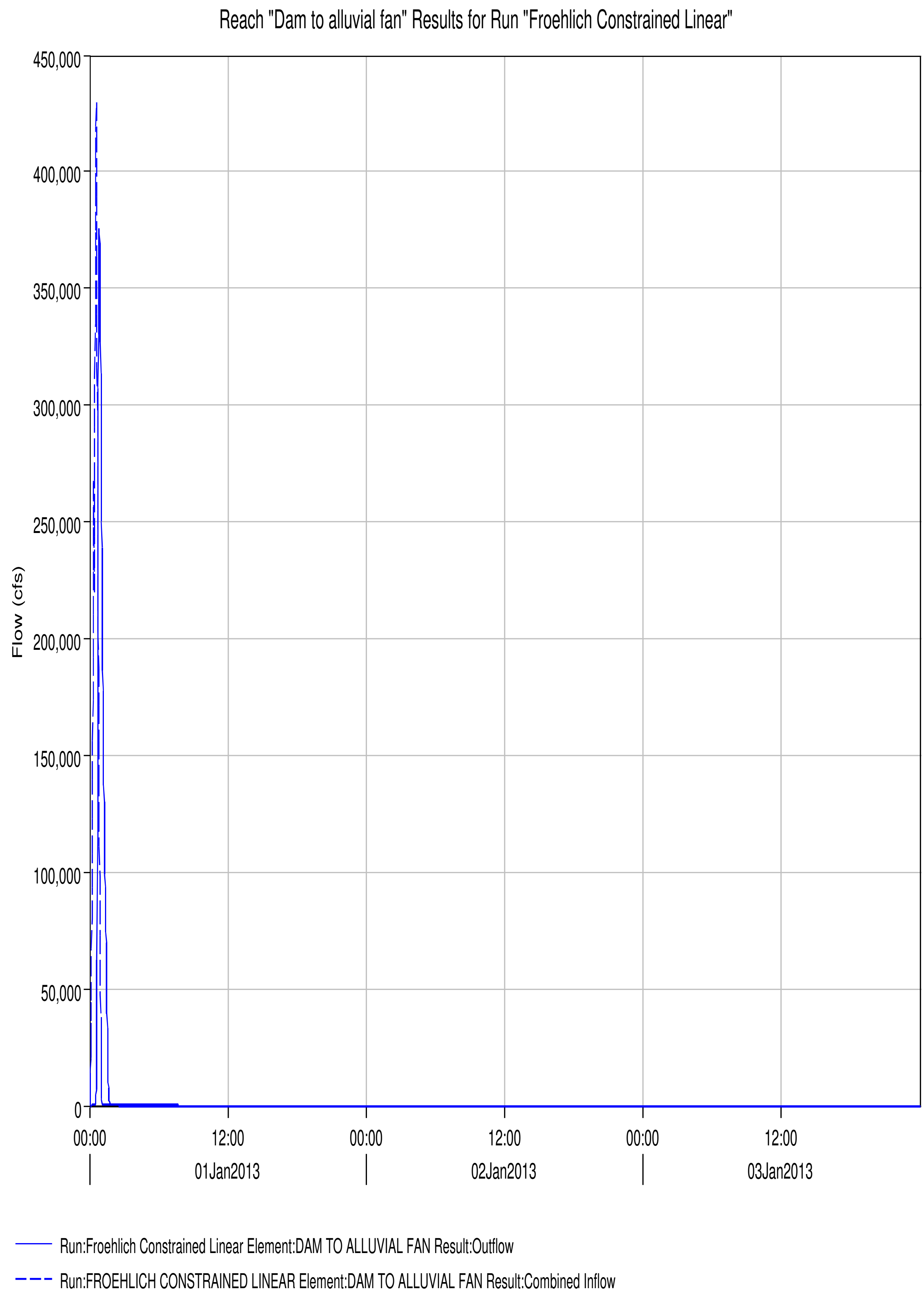

Reservoir "Terrace Reservoir" Results for Run "Froehlich Constrained Linear"
Storage (AC-FT)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Elev (ft)
500
482
465
448
430
412
395
378
360
Flow (cfs)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:TERRACE RESERVOIR Result:Storage
Run:Froehlich Constrained Linear Element:TERRACE RESERVOIR Result:Pool Elevation
Run:Froehlich Constrained Linear Element:TERRACE RESERVOIR Result:Outflow
Run:Froehlich Constrained Linear Element:TERRACE RESERVOIR Result:Combined Flow


Reach "Dam to alluvial fan" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:DAM TO ALLUVIAL FAN Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:DAM TO ALLUVIAL FAN Result:Combined Inflow

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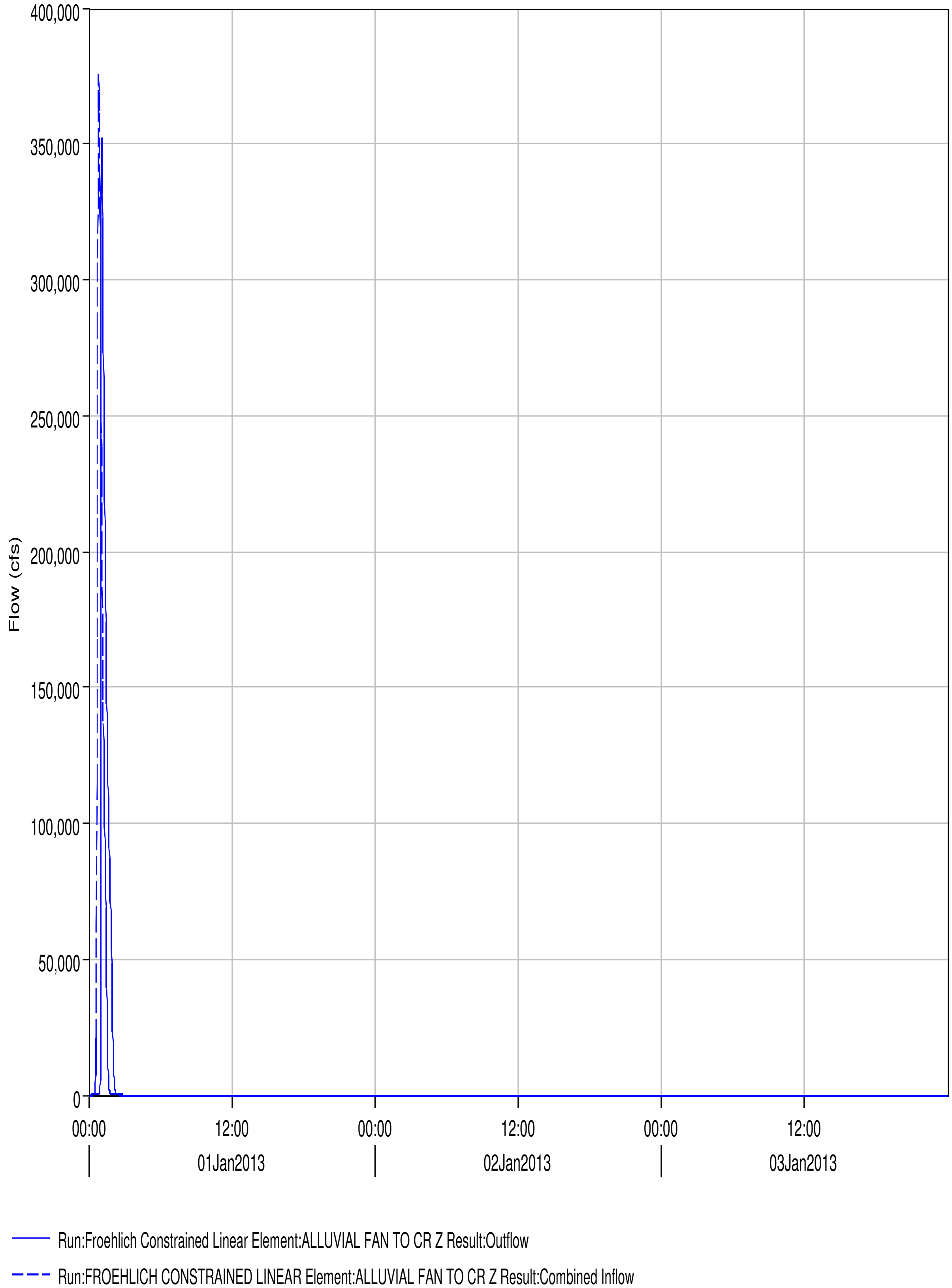
Reach "alluvial fan to CR Z" Results for Run "Froehlich Constrained Linear"



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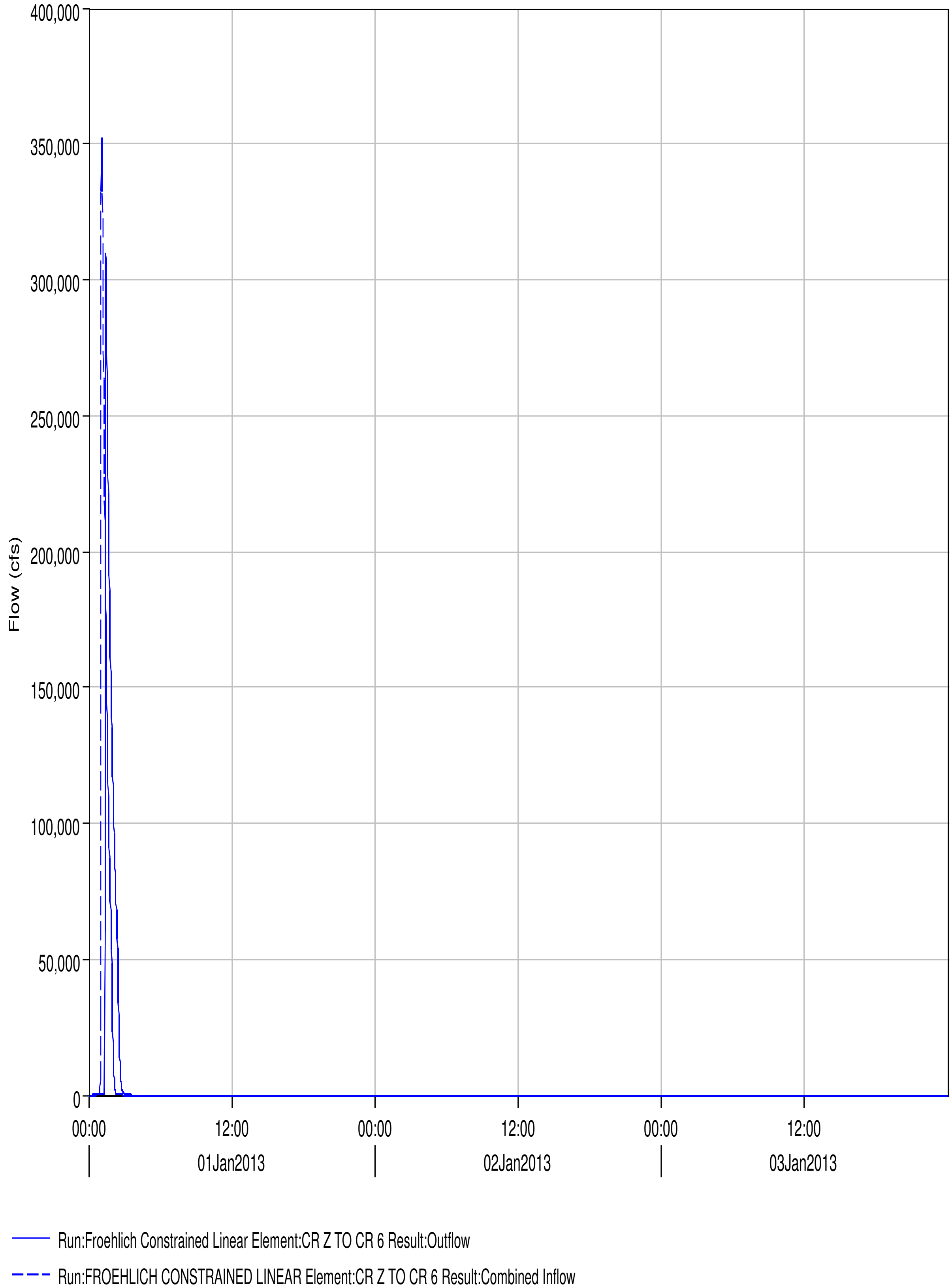
Reach "CR Z to CR 6" Results for Run "Froehlich Constrained Linear"



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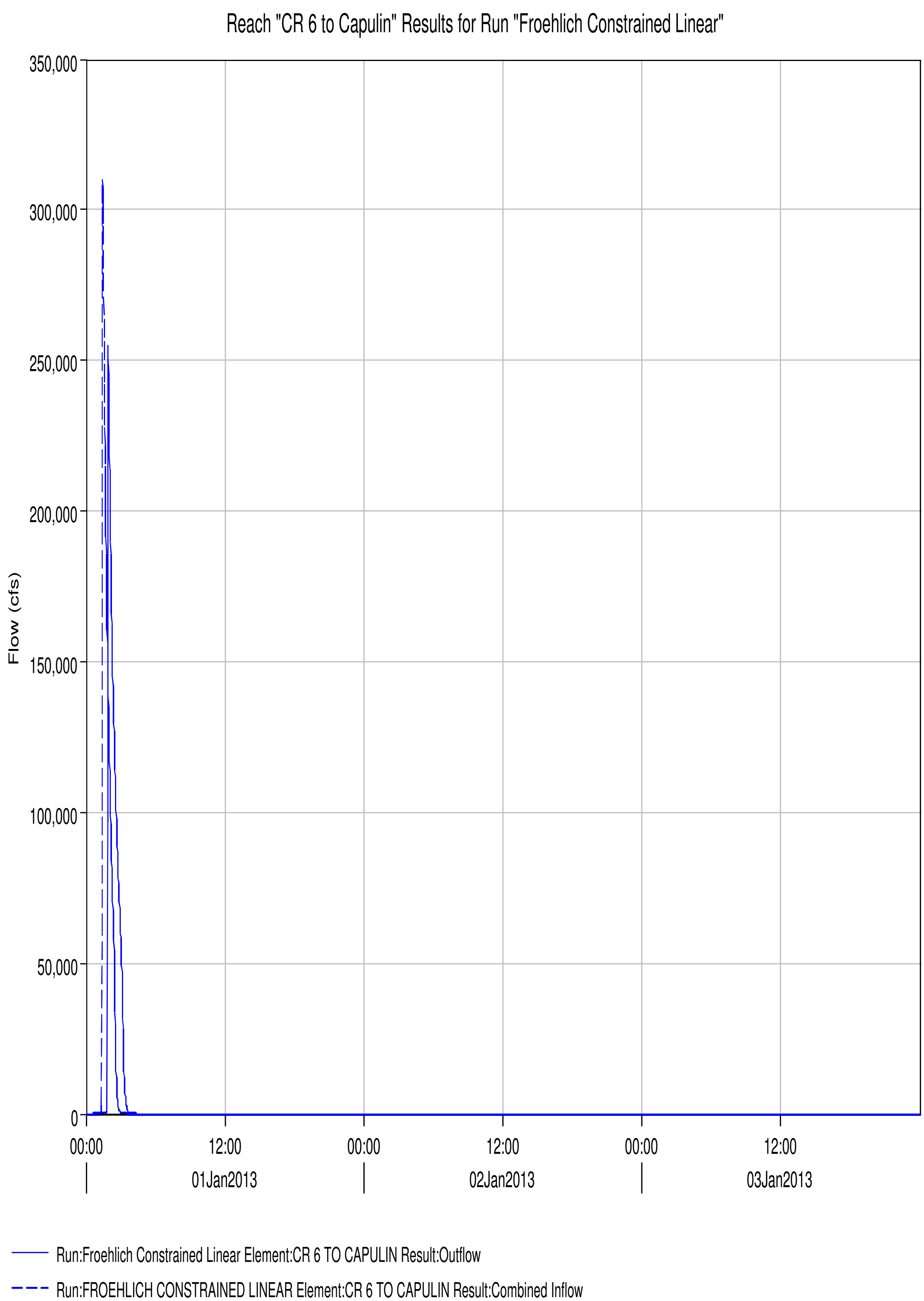
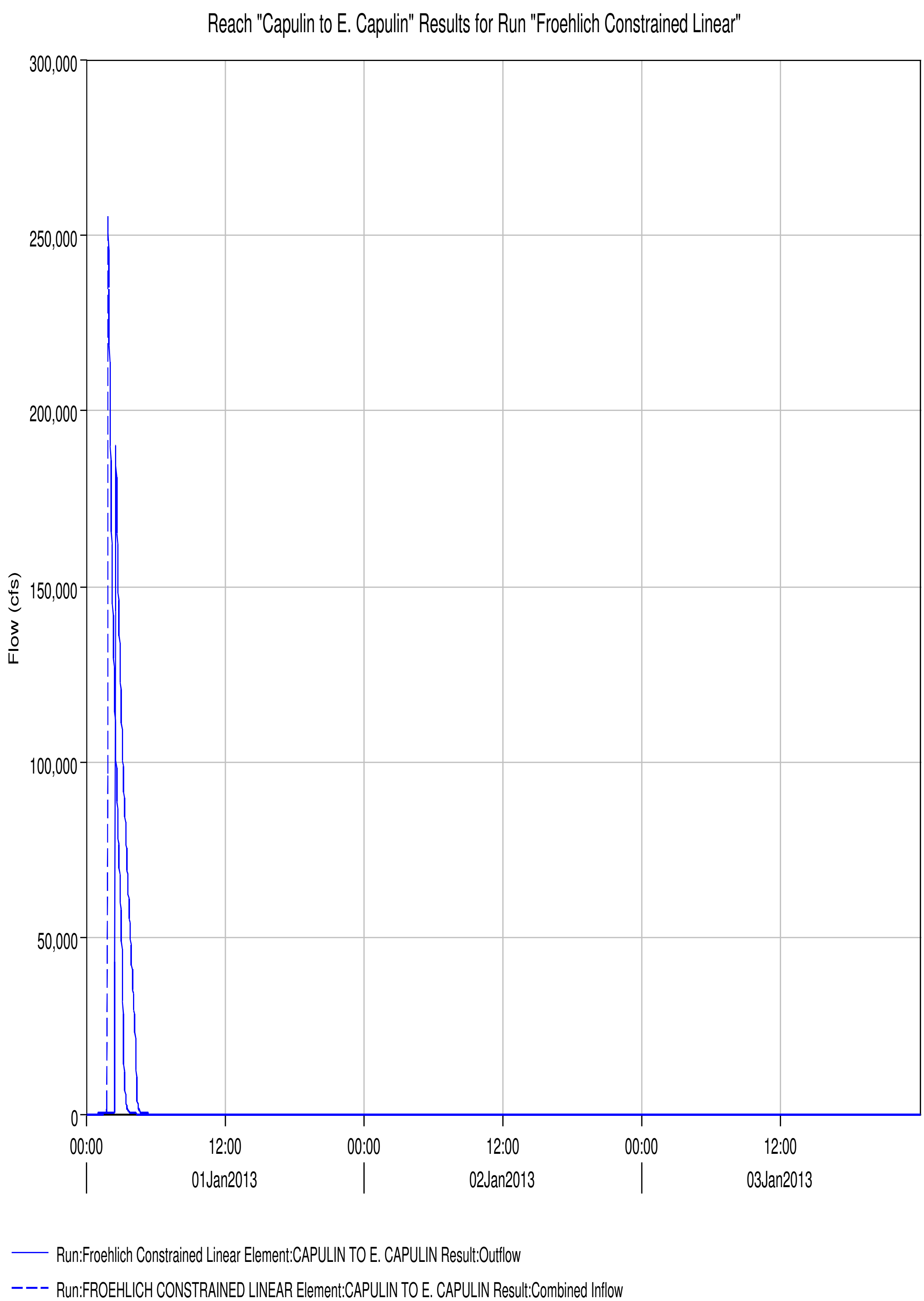
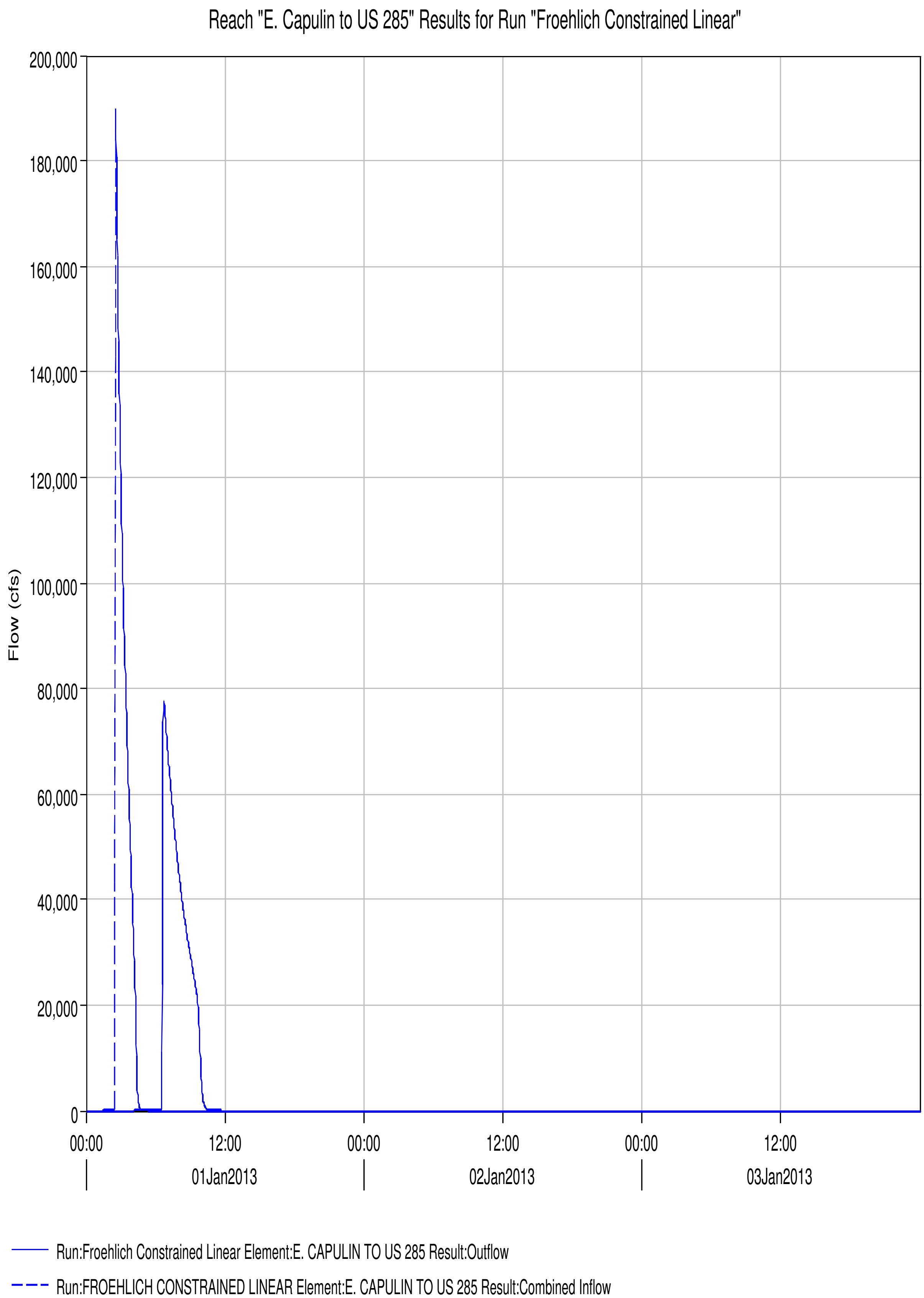


Reach "CR 6 to Capulin" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:CR 6 TO CAPULIN Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:CR 6 TO CAPULIN Result:Combined Inflow

DRAFT

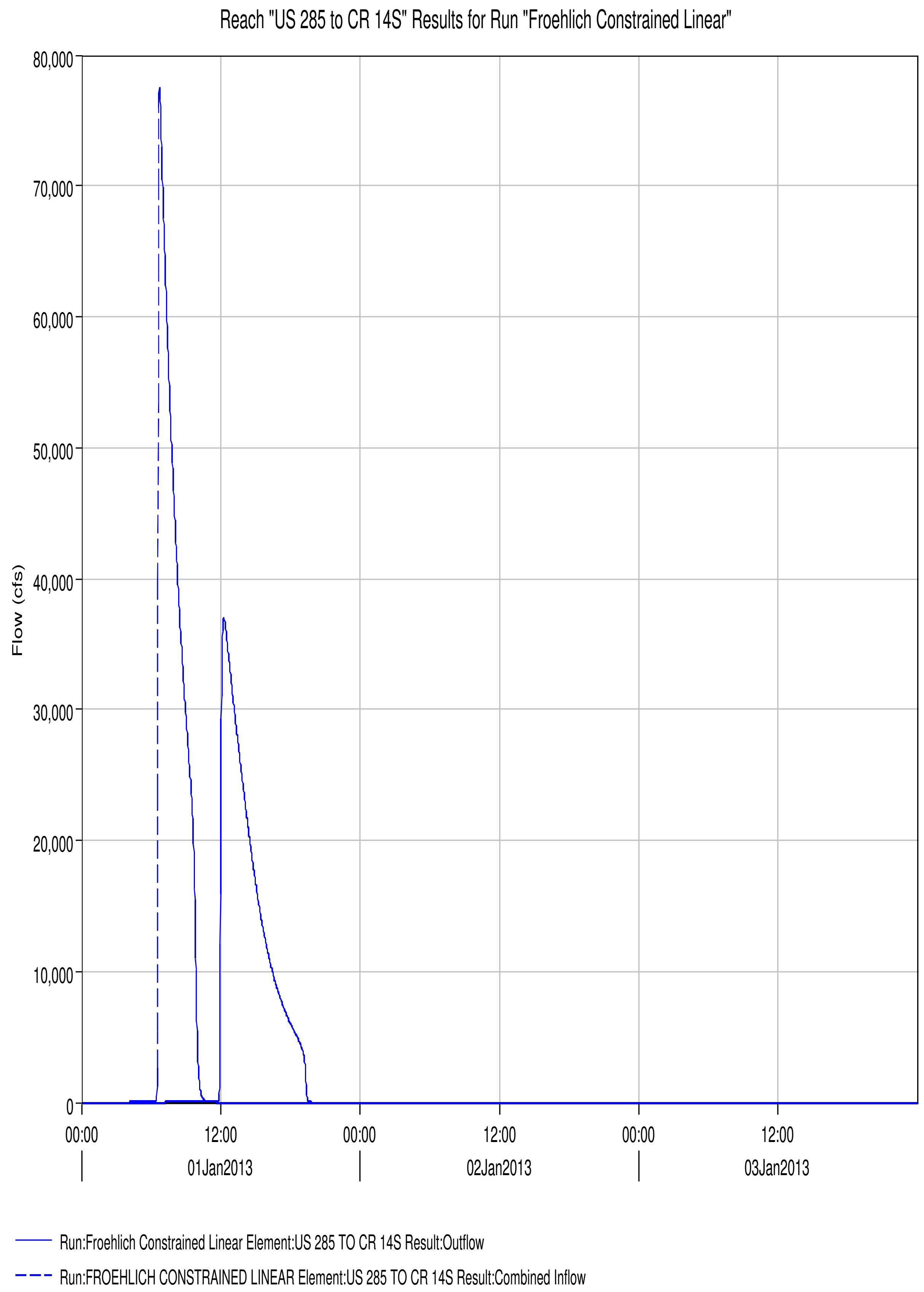

Reach "Capulin to E. Capulin" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
300,000
250,000
200,000
150,000
100,000
50,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:CAPULIN TO E. CAPULIN Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:CAPULIN TO E. CAPULIN Result:Combined Inflow

DRAFT



Reach "E. Capulin to US 285" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:E. CAPULIN TO US 285 Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:E. CAPULIN TO US 285 Result:Combined Inflow

DRAFT


Reach "US 285 to CR 14S" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:US 285 TO CR 14S Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:US 285 TO CR 14S Result:Combined Inflow

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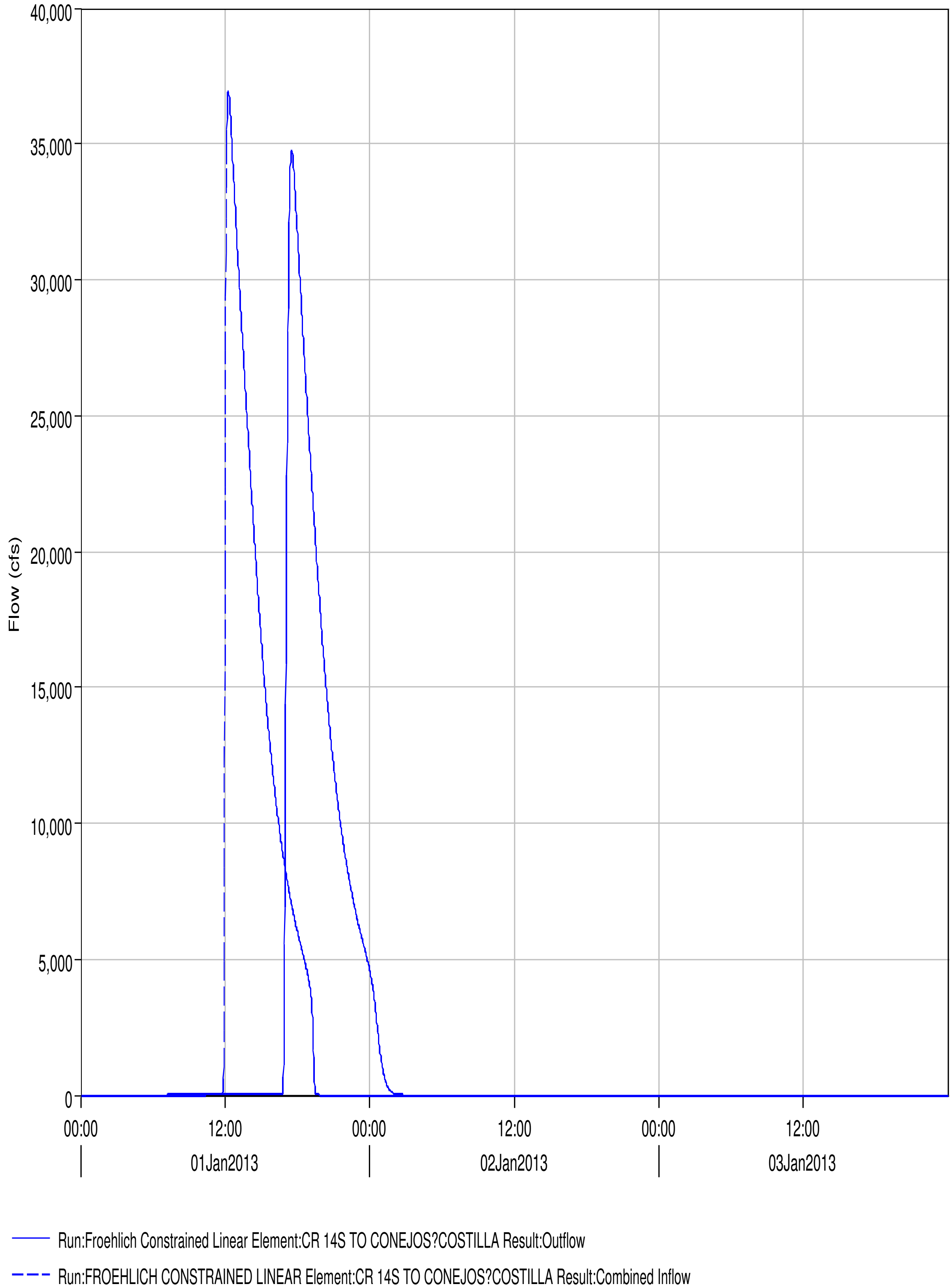
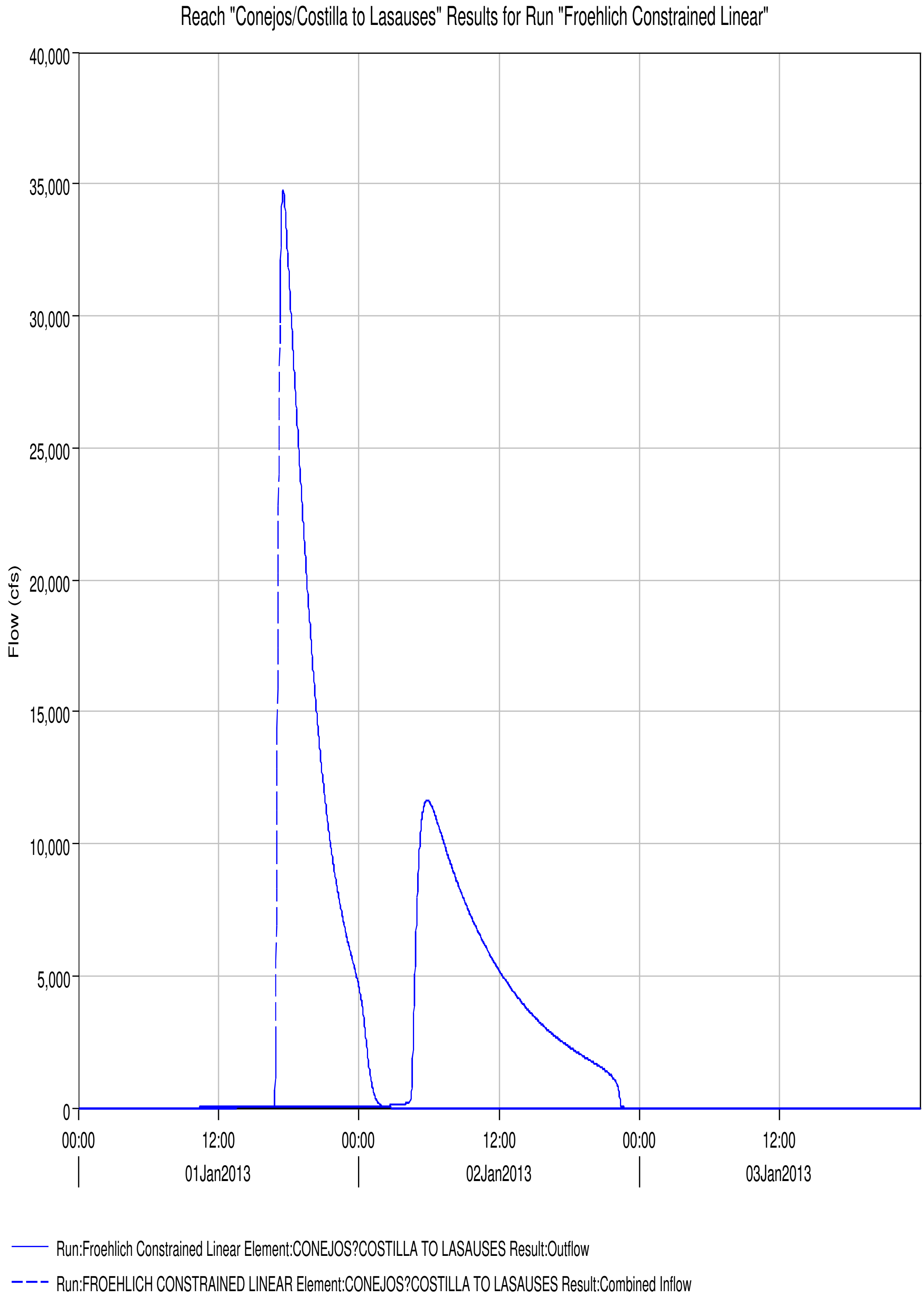
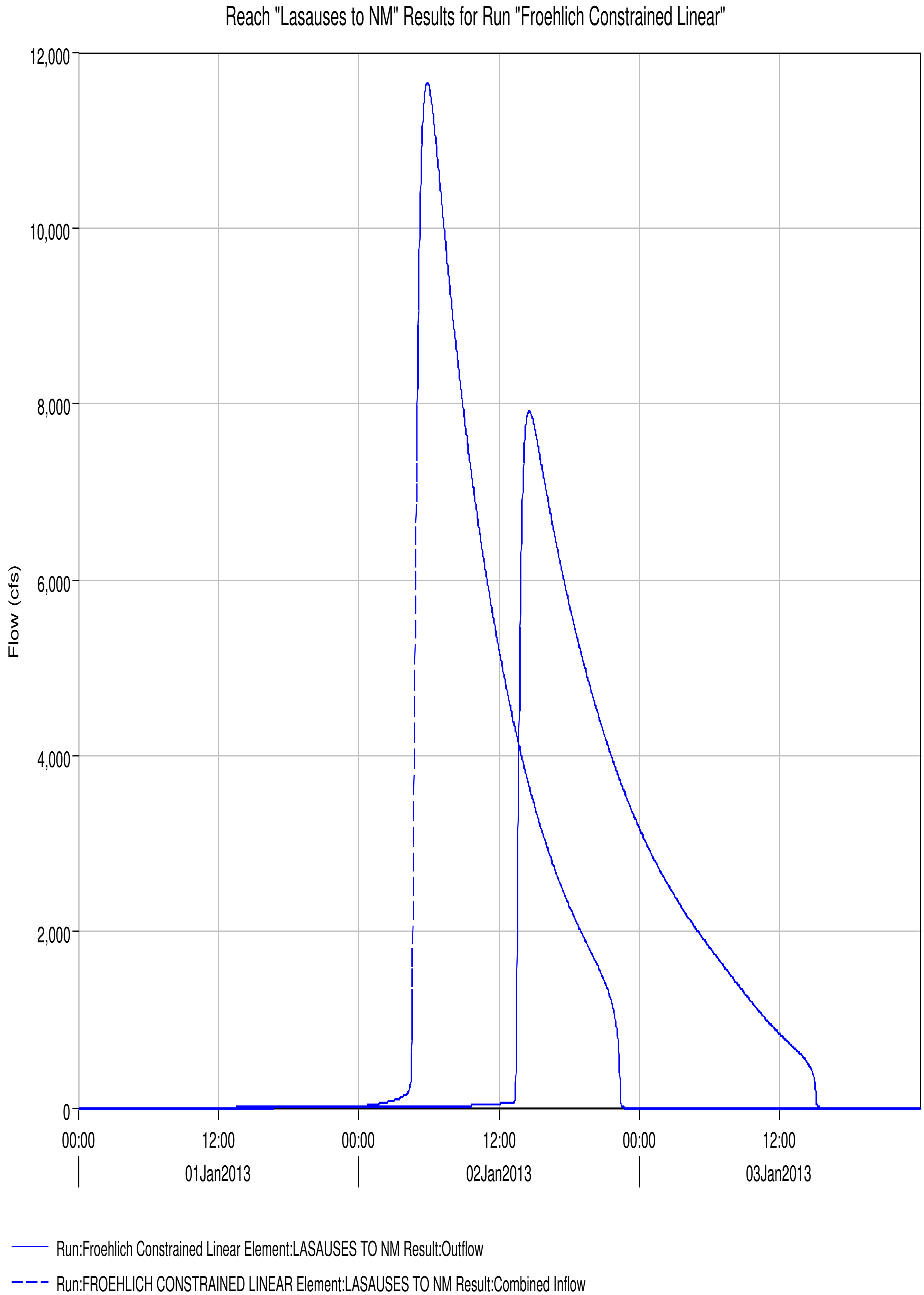
Reach "CR 14S to Conejos/Costilla" Results for Run "Froehlich Constrained Linear"



DRAFT


Reach "Conejos/Costilla to Lasauses" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:CONEJOS?COSTILLA TO LASAUSES Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:CONEJOS?COSTILLA TO LASAUSES Result:Combined Inflow

DRAFT



Reach "Lasauses to NM" Results for Run "Froehlich Constrained Linear"
Flow (cfs)
12,000
10,000
8,000
6,000
4,000
2,000
0
00:00
12:00
00:00
12:00
00:00
12:00
01Jan2013
02Jan2013
03Jan2013
Run:Froehlich Constrained Linear Element:LASAUSES TO NM Result:Outflow
Run:FROEHLICH CONSTRAINED LINEAR Element:LASAUSES TO NM Result:Combined Inflow

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Appendix E
Log-Pearson Type III Spreadsheet

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Flood Frequency Analysis Calculator: Log-Pearson Type III Distribution

NOTE: Only enter data/edit yellow cells; do not alter white or blue cells

USGS Gaging Station Name: RIO GRANDE AT CO-NM STATE LINE **USGS Site ID:** 8252000

Step 1: On separate sheet, sort PeakQ with date, from highest to lowest; Step 2: Paste sorted dates and Qpeak into Col B and C, respectively

RANK	YEAR OF PEAK FLOW	PEAK_FLOW_ VALUE_Q(cfs)	LOGQ_cfs	(log Q – avg(logQ))^2	(log Q – avg(logQ))^3	Return Period (n+1)/m	Exceedence Probability (1/Tr)
1	1979	4860	3.687	0.3612	0.2171	31.00	0.032
2	1958	4030	3.605	0.2701	0.1404	15.50	0.065
3	1957	3630	3.560	0.2250	0.1067	10.33	0.097
4	1965	3540	3.549	0.2147	0.0995	7.75	0.129
5	1973	3460	3.539	0.2056	0.0933	6.20	0.161
6	1980	3040	3.483	0.1578	0.0627	5.17	0.194
7	1975	2440	3.387	0.0911	0.0275	4.43	0.226
8	1969	2400	3.380	0.0868	0.0256	3.88	0.258
9	1962	2300	3.362	0.0762	0.0211	3.44	0.290
10	1968	2270	3.356	0.0731	0.0198	3.10	0.323
11	1970	2080	3.318	0.0540	0.0126	2.82	0.355
12	1982	1890	3.276	0.0364	0.0070	2.58	0.387
13	1971	1650	3.217	0.0174	0.0023	2.38	0.419
14	1960	1590	3.201	0.0134	0.0016	2.21	0.452
15	1976	1350	3.130	0.0020	0.0001	2.07	0.484
16	1966	1270	3.104	0.0003	0.0000	1.94	0.516
17	1961	1260	3.100	0.0002	0.0000	1.82	0.548
18	1967	905	2.957	0.0166	-0.0021	1.72	0.581
19	1978	**885**	2.947	0.0192	-0.0027	1.63	0.613
20	1972	820	2.914	0.0295	-0.0051	1.55	0.645
21	1974	780	2.892	0.0374	-0.0072	1.48	0.677
22	1956	644	2.809	0.0766	-0.0212	1.41	0.710
23	1981	563	2.751	0.1123	-0.0376	1.35	0.742
24	1964	539	2.732	0.1253	-0.0444	1.29	0.774
25	1977	415	2.618	0.2186	-0.1022	1.24	0.806
26	1963	391	2.592	0.2435	-0.1201	1.19	0.839
27	1954	380	2.580	0.2559	-0.1294	1.15	0.871
28	1959	362	2.559	0.2776	-0.1463	1.11	0.903
29	1955	306	2.486	0.3599	-0.2159	1.07	0.935
30	1953	300	2.477	0.3703	-0.2253	1.03	0.968
31			no data	no data	no data	no data	no data
32			no data	no data	no data	no data	no data

No. Years in Record	30.00	
Avg_Qpeak_cfs	1678.33	
Avg_LogQ_cfs	3.086	
Sum {(log Q – avg(logQ))^2}	4.028	
Sum {(log Q – avg(logQ))^3	-0.223	
Variance_LogQ_cfs	0.1389	
Stdev_LogQ_cfs	0.3727	
Skewness (Cs)	-0.1588	
Skew Coefficient (Cm)	-0.08	**Determine from skew coefficient Map of US
Variance of Regional Skewness V(Cm)	0.302	**Constant for U.S. = 0.302
Variance of Station Skewness (V(Cs):	0.17944	**V(Cs)=$10^{[A-B*(\log(n/10))]}$
A value	-0.3173	
B value	0.89871	
Weighting Factor (W)	0.62729	**W=V(Cm)/[V(Cs)+V(Cm)]
Weighted Skewness (Cw)	-0.1276	**Cw = [W*Cs] + [(1-W)*Cm]
Table Cw upper	-0.1	**Paste value here from K factor table below
Table Cw lower	-0.2	**Paste value here from K factor table below
Calculated Cw Value	-0.1276	

Tr	K lower	K upper	Slope	K calculated	$LogQ_{Tr}$_cfs	Q_{Tr}_cfs
2	0.033	0.017	-0.16	0.021	3.094	1240.5
5	0.850	0.846	-0.04	0.847	3.401	2519.5
10	1.258	1.270	0.12	1.267	3.558	3611.6
25	1.680	1.716	0.36	1.706	3.721	5265.7
50	1.945	2.000	0.55	1.985	3.825	6688.8
100	2.178	2.252	0.74	2.232	3.917	8266.4
200	2.388	2.482	0.94	2.456	4.001	10023

*Note: paste K lower and upper values from K factor table below

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APPENDIX F
HEC-RAS OUTPUT

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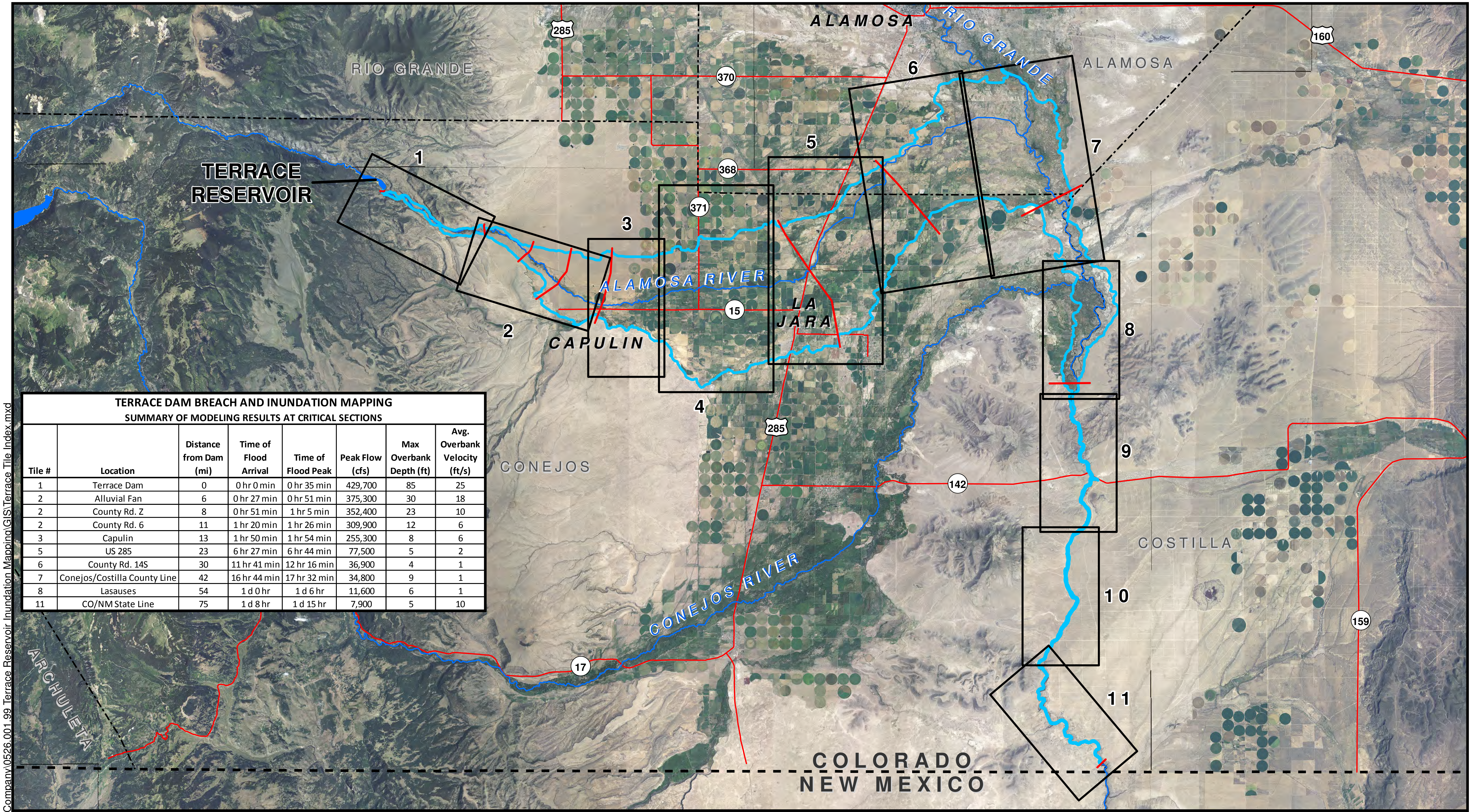
HEC-RAS Plan: Run 8 River: Alamosa and RG Reach: Terrace Profile: Terrace Run 8

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Terrace	75.40	Terrace Run 8	429733.20	8458.05	8543.50	8543.50	8568.16	0.006246	44.97	17239.70	490.49	0.87
Terrace	75.35	Terrace Run 8	429733.20	8400.62	8522.19	8522.19	8547.34	0.005781	46.78	17826.93	386.37	0.78
Terrace	75.21	Terrace Run 8	429733.20	8393.26	8497.71	8497.71	8522.59	0.007217	48.87	18184.40	387.02	0.88
Terrace	75.11	Terrace Run 8	429733.20	8381.22	8490.51		8493.88	0.001180	22.86	44520.70	710.62	0.39
Terrace	74.99	Terrace Run 8	429733.20	8376.37	8491.39		8492.94	0.000468	15.01	63381.34	945.86	0.25
Terrace	74.86	Terrace Run 8	429733.20	8370.50	8489.53	8436.50	8492.46	0.000622	17.45	47020.69	739.21	0.29
Terrace	74.66	Terrace Run 8	429733.20	8360.65	8456.42	8456.42	8487.95	0.007935	53.38	14891.52	263.70	0.98
Terrace	74.44	Terrace Run 8	429733.20	8351.71	8412.21	8412.21	8432.86	0.010582	46.02	16342.80	407.15	1.06
Terrace	74.31	Terrace Run 8	429733.20	8348.88	8394.46	8394.46	8412.59	0.010348	37.44	15667.18	477.98	1.00
Terrace	74.16	Terrace Run 8	429733.20	8342.24	8377.76	8377.76	8391.85	0.012913	34.31	16979.91	642.90	1.06
Terrace	73.79	Terrace Run 8	429733.20	8328.08	8358.83	8357.06	8368.77	0.009111	25.84	19267.06	940.75	0.87
Terrace	73.42	Terrace Run 8	429733.20	8310.24	8343.61		8351.18	0.008635	25.97	27818.44	1293.68	0.85
Terrace	73.20	Terrace Run 8	429733.20	8301.58	8342.78		8345.77	0.001894	14.55	35576.45	1171.68	0.42
Terrace	72.88	Terrace Run 8	429733.20	8287.09	8339.19		8342.67	0.002134	17.93	34227.57	914.18	0.46
Terrace	72.55	Terrace Run 8	429733.20	8275.95	8338.33		8340.23	0.000755	12.45	46142.17	977.53	0.28
Terrace	72.23	Terrace Run 8	429733.20	8262.18	8337.75		8338.99	0.000544	11.97	58206.75	1076.84	0.25
Terrace	72.00	Terrace Run 8	429733.20	8262.36	8316.21	8316.21	8335.43	0.009051	36.03	13824.54	426.75	0.93
Terrace	71.71	Terrace Run 8	429733.20	8239.31	8280.69	8280.69	8290.06	0.009876	32.25	23522.66	1097.61	0.94
Terrace	71.64	Terrace Run 8	429733.20	8235.90	8272.59		8277.62	0.006469	22.68	29164.51	1350.20	0.73
Terrace	71.63	Terrace Run 8	429733.20	8236.00	8272.23		8276.87	0.006398	22.40	29864.95	1339.67	0.73
Terrace	71.54	Terrace Run 8	429733.20	8233.47	8266.10	8263.32	8272.41	0.010973	29.35	25331.95	1187.10	0.96
Terrace	71.27	Terrace Run 8	429733.20	8226.18	8257.03	8248.97	8260.64	0.005828	19.31	31231.77	1319.58	0.68
Terrace	70.65	Terrace Run 8	429733.20	8207.80	8227.50	8227.50	8234.73	0.020590	28.13	22702.35	1542.61	1.20
Terrace	70.16	Terrace Run 8	429733.20	8184.55	8221.95	8206.50	8223.75	0.001581	12.60	46014.67	1536.36	0.38
Terrace	69.94	Terrace Run 8	429733.20	8175.05	8215.08	8206.44	8220.65	0.005893	25.89	30972.57	1032.61	0.74
Terrace	69.70	Terrace Run 8	429733.20	8165.81	8210.72		8214.45	0.003842	22.02	46823.21	1889.59	0.60
Terrace	69.57	Terrace Run 8	429733.20	8160.11	8198.31	8198.31	8209.80	0.012747	34.99	24308.29	1038.22	1.06
Terrace	69.48	Terrace Run 8	375285.10	8157.36	8189.72	8189.72	8198.64	0.010024	26.77	21339.11	1332.42	0.91
Terrace	69.23	Terrace Run 8	375285.10	8148.38	8173.13		8177.57	0.007728	19.13	26862.17	1874.16	0.76
Terrace	69.09	Terrace Run 8	375285.10	8142.12	8167.77		8170.29	0.010419	7.39	34487.04	2307.13	0.28
Terrace	68.79	Terrace Run 8	375285.10	8130.22	8157.89		8159.48	0.008654	7.16	40719.17	2929.99	0.26
Terrace	68.6	Terrace Run 8	375285.10	8120.09	8150.33		8151.89	0.009097	7.61	40823.81	3021.58	0.27
Terrace	68.43	Terrace Run 8	375285.10	8111.99	8142.21		8144.08	0.007920	7.07	38434.75	3163.20	0.25
Terrace	68.25	Terrace Run 8	375285.10	8103.30	8134.40	8130.56	8136.59	0.008899	7.17	34277.96	2830.16	0.26
Terrace	68.09	Terrace Run 8	375285.10	8096.80	8126.30	8122.07	8128.70	0.012563	8.64	32580.86	2625.36	0.31
Terrace	67.8	Terrace Run 8	375285.10	8080.16	8108.97	8104.50	8111.14	0.010037	7.66	34650.86	2789.83	0.28
Terrace	67.52	Terrace Run 8	375285.10	8065.73	8095.05	8090.75	8097.30	0.010447	7.58	34094.29	2786.34	0.28
Terrace	67.27	Terrace Run 8	375285.10	8054.13	8081.08	8076.99	8083.35	0.011667	7.36	34954.66	3491.81	0.29
Terrace	67.14	Terrace Run 8	375285.10	8048.52	8074.86	8070.74	8076.80	0.010967	7.27	37328.57	3628.28	0.28
Terrace	66.95	Terrace Run 8	352431.30	8039.89	8065.87	8063.60	8067.64	0.013306	7.79	34443.11	4250.58	0.31
Terrace	66.78	Terrace Run 8	352431.30	8031.66	8055.52	8052.69	8056.96	0.010645	6.54	38817.28	4718.57	0.27
Terrace	66.36	Terrace Run 8	352431.30	8010.66	8033.93		8035.48	0.010096	6.33	40908.35	5499.18	0.26
Terrace	66.24	Terrace Run 8	352431.30	8004.39	8026.61		8028.35	0.012954	6.89	38309.78	5595.15	0.30
Terrace	65.95	Terrace Run 8	352431.30	7990.06	8013.74		8014.64	0.009175	6.34	47957.27	6100.64	0.26
Terrace	65.78	Terrace Run 8	352431.30	7981.68	8005.63		8006.77	0.011787	6.51	43312.99	6394.77	0.28
Terrace	65.44	Terrace Run 8	352431.30	7967.49	7985.25		7986.44	0.012241	5.60	43810.34	7528.08	0.28
Terrace	65.22	Terrace Run 8	352431.30	7958.16	7974.89	7972.76	7975.97	0.009134	4.48	46606.68	8363.74	0.23
Terrace	65.00	Terrace Run 8	352431.30	7950.24	7964.50	7963.21	7965.42	0.013605	5.68	48116.88	10964.56	0.29
Terrace	64.80	Terrace Run 8	309913.30	7936.75	7952.47	7951.29	7953.17	0.012025	4.58	48398.07	13341.10	0.26
Terrace	64.62	Terrace Run 8	309913.30	7926.89	7942.24	7941.00	7942.85	0.011309	4.36	51377.47	14017.90	0.25
Terrace	64.44	Terrace Run 8	309913.30	7917.66	7932.88	7931.76	7933.49	0.011760	4.41	50956.70	14763.08	0.26
Terrace	64.25	Terrace Run 8	309913.30	7906.97	7921.75	7920.90	7922.41	0.011271	6.77	48385.50	15431.03	0.40
Terrace	64.04	Terrace Run 8	309913.30	7896.83	7912.05	7911.03	7912.63	0.009280	6.05	51251.71	15059.66	0.36
Terrace	63.82	Terrace Run 8	309913.30	7888.31	7901.23	7900.53	7901.91	0.013035	6.63	47369.43	15352.74	0.42
Terrace	63.61	Terrace Run 8	309913.30	7877.26	7892.01	7890.99	7892.56	0.009295	5.77	53724.07	16558.61	0.36
Terrace	63.43	Terrace Run 8	309913.30	7869.26	7881.91		7882.55	0.013667	6.08	48309.24	16693.02	0.42
Terrace	63.25	Terrace Run 8	309913.30	7861.02	7872.39	7871.14	7872.85	0.007783	4.40	57540.43	16779.95	0.31
Terrace	63.05	Terrace Run 8	309913.30	7853.12	7862.14	7861.70	7863.14	0.018692	7.02	39194.02	12784.56	0.49
Terrace	62.88	Terrace Run 8	309913.30	7844.66	7853.84	7852.20	7854.21	0.004979	3.29	65010.46	18368.90	0.25
Terrace	62.82	Terrace Run 8	255340.80	7842.04	7851.69	7850.34	7852.09	0.005247	3.27	54034.02	18517.73	0.25
Terrace	62.67	Terrace Run 8	255340.80	7834.09	7845.08	7843.23	7845.56	0.003901	3.26	54252.31	16585.66	0.22
Terrace	62.57	Terrace Run 8	255340.80	7830.74	7839.43		7840.09	0.007375	4.20	44384.77	14856.25	0.30
Terrace	62.49	Terrace Run 8	255340.80	7826.24	7834.22		7834.97	0.008062	4.00	43015.22	14549.34	0.31
Terrace	62.23	Terrace Run 8	255340.80	7815.96	7822.83		7824.11	0.008895	3.86	33893.09	8617.63	0.32
Terrace	62.00	Terrace Run 8	255340.80	7806.57	7812.93		7814.17	0.009116	4.53	32212.64	8042.02	0.40
Terrace	61.77	Terrace Run 8	255340.80	7797.18	7802.95		7804.05	0.007692	3.86	33795.19	8965.83	0.36
Terrace	61.47	Terrace Run 8	255340.80	7785.45	7793.82		7794.63	0.008084	5.27	37918.01	11972.73	0.39
Terrace	61.23	Terrace Run 8	255340.80	7775.87	7783.69		7784.48	0.006125	4.20	39134.70	9121.66	0.33
Terrace	60.89	Terrace Run 8	255340.80	7762.81	7773.23	7771.95	7774.06	0.007055	4.81	37538.77	8666.42	0.36
Terrace	60.48	Terrace Run 8	255340.80	7754.50	7763.15		7763.80	0.006367	4.57	42722.95	10371.81	0.35
Terrace	60.16	Terrace Run 8	189933.20	7745.06	7752.30	7750.92	7752.68	0.007677	3.92	41601.60	14604.82	0.36
Terrace	59.50	Terrace Run 8	189933.20	7722.57	7730.79	7729.78	7731.14	0.006494	2.36	44416.50	18496.72	0.30
Terrace	59.25	Terrace Run 8	189933.20	7714.30	7722.14	7721.04	7722.42	0.006323	2.93	46982.86	17735.08	0.31
Terrace	58.58	Terrace Run 8	189933.20	7696.62	7702.92	7701.41	7703.11	0.005188	3.24	55338.45	21685.86	0.29
Terrace	57.74	Terrace Run 8	189933.20	7675.16	7680.48	7679.39	7680.65	0.005737	2.56	59072.00	27127.91	0.29
Terrace	56.99	Terrace Run 8	189933.20	7655.44	7662.01	7660.89	7662.15	0.004190	2.04	67564.16	33554.63	0.24
Terrace	56.50	Terrace Run 8	189933.20	7645.62	7651.26	7650.20	7651.41	0.004274	2.88	62520.90	30622.35	0.33
Terrace	56.02	Terrace Run 8	189933.20	7634.73	7641.69	7640.48	7641.84	0.003771	2.78	63299.98	29639.70	0.31
Terrace	55.53	Terrace Run 8	189933.20	7626.51	7631.57	7630.40	7631.70	0.003615	2.53	65717.25	29691.11	0.30
Terrace	54.91	Terrace Run 8	189933.20	7615.82	7622.18	7620.59	7622.28	0.002646	2.75	72609.48	30431.97	0.27
Terrace	54.26	Terrace Run 8	189933.20	7606.20	7611.81	7610.36	7611.93	0.002833	2.91	69386.14	28783.57	0.28

HEC-RAS Plan: Run 8 River: Alamosa and RG Reach: Terrace Profile: Terrace Run 8 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Terrace	54.02	Terrace Run 8	189933.20	7601.83	7608.31	7607.15	7608.46	0.002557	3.86	65645.15	29109.74	0.40
Terrace	53.83	Terrace Run 8	189933.20	7599.53	7605.88	7604.40	7606.02	0.002210	3.58	67049.77	28697.36	0.37
Terrace	53.56	Terrace Run 8	189933.20	7597.15	7602.95	7601.36	7603.06	0.001639	3.26	76507.62	30712.21	0.32
Terrace	53.04	Terrace Run 8	189933.20	7591.75	7599.19		7599.31	0.001898	3.33	71395.86	28572.68	0.34
Terrace	52.79	Terrace Run 8	189933.20	7592.20	7597.31	7595.47	7597.41	0.001494	3.08	77845.61	29713.95	0.31
Terrace	52.52	Terrace Run 8	189933.20	7589.37	7595.06		7595.18	0.001967	3.49	71556.17	29311.96	0.35
Terrace	51.94	Terrace Run 8	77549.90	7585.04	7591.38		7591.44	0.001087	2.34	45400.23	26550.50	0.25
Terrace	51.12	Terrace Run 8	77549.90	7579.37	7584.95	7584.07	7585.04	0.002750	2.82	33620.99	25134.16	0.38
Terrace	50.42	Terrace Run 8	77549.90	7574.30	7579.90		7579.96	0.001023	1.52	39583.01	20957.19	0.22
Terrace	49.64	Terrace Run 8	77549.90	7569.55	7575.12	7573.83	7575.20	0.001700	2.56	36776.74	20534.16	0.31
Terrace	49.18	Terrace Run 8	77549.90	7566.55	7571.58		7571.67	0.001265	2.82	36531.66	17865.57	0.28
Terrace	48.59	Terrace Run 8	77549.90	7562.27	7567.41	7565.97	7567.51	0.001553	3.09	34584.06	18480.41	0.31
Terrace	47.87	Terrace Run 8	77549.90	7557.50	7561.40	7559.94	7561.49	0.001701	2.76	33648.20	16732.54	0.31
Terrace	47.15	Terrace Run 8	77549.90	7552.52	7556.57	7554.79	7556.64	0.000994	2.43	40799.27	17724.42	0.25
Terrace	45.44	Terrace Run 8	36930.10	7544.28	7550.60	7548.79	7550.62	0.000662	1.44	28353.24	14431.37	0.16
Terrace	43.31	Terrace Run 8	36930.10	7537.83	7541.18	7539.72	7541.23	0.001362	1.82	22025.58	12024.04	0.22
Terrace	41.05	Terrace Run 8	36930.10	7528.94	7531.09	7529.71	7531.11	0.000654	0.93	34798.98	22156.75	0.14
Terrace	39.84	Terrace Run 8	36930.10	7522.58	7527.66	7526.17	7527.68	0.000727	1.31	33130.57	22214.95	0.16
Terrace	39.41	Terrace Run 8	36930.10	7520.66	7525.72	7524.28	7525.74	0.000886	1.10	31052.85	23403.24	0.16
Terrace	38.78	Terrace Run 8	36930.10	7518.54	7523.90	7522.12	7523.92	0.000444	1.04	39291.62	23786.12	0.13
Terrace	38.16	Terrace Run 8	36930.10	7512.78	7522.60	7520.66	7522.62	0.000487	1.26	35282.99	21822.20	0.14
Terrace	37.38	Terrace Run 8	36930.10	7509.19	7520.30	7518.63	7520.33	0.000761	1.79	29200.80	18329.37	0.18
Terrace	33.31	Terrace Run 8	34768.90	7503.58	7513.87	7510.00	7513.90	0.000212	1.29	30264.57	8175.19	0.12
Terrace	31.08	Terrace Run 8	34768.90	7499.26	7510.73		7510.80	0.000527	2.70	18216.59	5449.87	0.20
Terrace	29.72	Terrace Run 8	34768.90	7496.57	7506.61		7506.69	0.000723	3.27	18167.92	5671.53	0.24
Terrace	27.45	Terrace Run 8	34768.90	7489.61	7501.34	7498.76	7501.38	0.000463	2.50	24214.07	8971.01	0.19
Terrace	25.52	Terrace Run 8	34768.90	7483.18	7495.71	7492.23	7495.87	0.000741	3.67	12145.84	8742.30	0.25
Terrace	23.92	Terrace Run 8	34768.90	7478.17	7492.43	7486.24	7492.52	0.000253	2.67	15606.33	4881.61	0.15
Terrace	23.45	Terrace Run 8	34768.90	7476.54	7491.60	7486.07	7491.73	0.000395	3.37	12516.92	4161.79	0.19
Terrace	22.72	Terrace Run 8	34768.90	7475.49	7485.20	7485.20	7487.21	0.011579	11.62	3218.49	5003.92	0.92
Terrace	21.77	Terrace Run 8	11643.20	7472.65	7482.68		7482.69	0.000063	1.06	14330.14	3238.02	0.07
Terrace	21.06	Terrace Run 8	11643.20	7470.66	7482.20		7482.29	0.000256	2.75	5180.66	763.16	0.15
Terrace	20.69	Terrace Run 8	11643.20	7469.94	7481.64		7481.76	0.000300	3.07	4440.95	564.87	0.17
Terrace	20.43	Terrace Run 8	11643.20	7469.38	7481.31		7481.40	0.000230	2.80	5239.15	701.19	0.15
Terrace	20.20	Terrace Run 8	11643.20	7469.04	7480.62		7480.92	0.000799	5.01	2793.08	382.79	0.27
Terrace	19.95	Terrace Run 8	11643.20	7467.52	7479.82		7480.06	0.000542	4.44	3228.13	429.00	0.23
Terrace	19.61	Terrace Run 8	11643.20	7466.37	7478.55		7478.89	0.000762	5.33	2631.61	315.36	0.27
Terrace	19.24	Terrace Run 8	11643.20	7466.08	7477.07		7477.38	0.000795	5.15	2749.03	361.99	0.27
Terrace	18.90	Terrace Run 8	11643.20	7465.57	7475.67		7475.95	0.000798	4.73	2803.53	367.30	0.27
Terrace	18.43	Terrace Run 8	11643.20	7462.92	7474.56		7474.68	0.000334	3.26	4470.89	632.12	0.18
Terrace	18.18	Terrace Run 8	11643.20	7461.70	7473.99		7474.19	0.000457	4.11	3420.96	410.18	0.21
Terrace	17.89	Terrace Run 8	11643.20	7461.24	7473.10		7473.38	0.000622	4.67	2921.48	359.39	0.24
Terrace	17.52	Terrace Run 8	11643.20	7464.41	7472.19		7472.34	0.000435	2.81	3793.57	481.52	0.19
Terrace	17.19	Terrace Run 8	11643.20	7459.57	7471.10		7471.36	0.000744	4.57	3152.21	529.06	0.26
Terrace	16.99	Terrace Run 8	11643.20	7459.11	7470.36	7464.55	7470.63	0.000637	4.45	2978.18	401.93	0.24
Terrace	16.82	Terrace Run 8	11643.20	7459.19	7469.99	7464.52	7470.13	0.000457	3.33	3981.51	734.94	0.20
Terrace	16.72	Terrace Run 8	11643.20	7458.68	7469.70		7469.88	0.000452	3.70	3549.07	446.18	0.20
Terrace	16.51	Terrace Run 8	11643.20	7458.01	7468.98		7469.26	0.000730	4.64	2885.13	387.04	0.26
Terrace	16.27	Terrace Run 8	11643.20	7456.09	7467.97		7468.29	0.000803	5.37	2795.72	396.09	0.28
Terrace	15.81	Terrace Run 8	11643.20	7455.52	7466.14		7466.41	0.000717	4.60	2943.51	403.32	0.26
Terrace	15.42	Terrace Run 8	11643.20	7452.26	7464.88		7465.15	0.000540	4.48	2915.64	308.93	0.23
Terrace	15.05	Terrace Run 8	11643.20	7451.51	7463.86		7464.10	0.000520	4.25	3015.69	310.02	0.22
Terrace	14.78	Terrace Run 8	11643.20	7450.95	7462.13		7462.81	0.001714	7.54	2020.89	350.78	0.40
Terrace	14.41	Terrace Run 8	11643.20	7448.85	7460.43		7460.68	0.000696	4.48	3072.86	432.49	0.25
Terrace	13.86	Terrace Run 8	11643.20	7447.30	7458.55		7458.80	0.000602	4.47	3100.07	412.81	0.24
Terrace	12.89	Terrace Run 8	11643.20	7444.03	7455.71		7455.91	0.000529	4.08	3544.98	569.79	0.22
Terrace	11.81	Terrace Run 8	11643.20	7440.65	7452.37		7452.62	0.000636	4.37	3178.98	490.37	0.24
Terrace	10.83	Terrace Run 8	11643.20	7441.36	7448.84		7449.03	0.000751	3.28	3341.86	530.42	0.24
Terrace	9.85	Terrace Run 8	11643.20	7434.98	7446.32		7446.43	0.000350	3.11	4483.49	647.49	0.18
Terrace	8.48	Terrace Run 8	11643.20	7428.76	7443.11		7443.43	0.000500	4.76	2668.50	235.77	0.23
Terrace	7.46	Terrace Run 8	11643.20	7425.16	7438.57		7439.26	0.001322	7.32	1851.30	200.00	0.36
Terrace	7.14	Terrace Run 8	11643.20	7422.36	7437.67		7437.95	0.000451	4.64	2849.61	252.18	0.22
Terrace	6.92	Terrace Run 8	11643.20	7421.42	7436.67		7437.22	0.000797	6.15	2027.61	168.86	0.29
Terrace	6.77	Terrace Run 8	11643.20	7420.71	7436.08		7436.59	0.000814	6.24	2138.19	196.12	0.29
Terrace	6.48	Terrace Run 8	11643.20	7419.55	7435.20		7435.55	0.000512	5.23	2519.94	198.33	0.23
Terrace	6.25	Terrace Run 8	11643.20	7418.80	7434.22		7434.77	0.000812	6.43	2051.45	173.05	0.29
Terrace	5.96	Terrace Run 8	11643.20	7418.29	7432.60		7433.27	0.001187	7.21	1914.83	209.23	0.35
Terrace	5.69	Terrace Run 8	11643.20	7416.70	7431.14		7431.73	0.000987	6.68	1949.94	173.79	0.32
Terrace	5.33	Terrace Run 8	11643.20	7414.96	7429.18		7429.78	0.001038	6.76	1956.40	183.55	0.33
Terrace	5.04	Terrace Run 8	11643.20	7413.50	7428.22		7428.58	0.000545	5.14	2480.93	194.63	0.24
Terrace	4.35	Terrace Run 8	11643.20	7411.73	7425.45		7426.01	0.000936	6.50	2022.70	183.43	0.31
Terrace	4.06	Terrace Run 8	11643.20	7411.01	7424.05		7424.55	0.000925	6.12	2110.77	201.28	0.30
Terrace	3.48	Terrace Run 8	11643.20	7408.60	7421.29		7421.75	0.000908	5.97	2216.80	225.99	0.30
Terrace	2.97	Terrace Run 8	11643.20	7405.37	7417.99		7418.70	0.001462	7.61	1790.73	188.41	0.38
Terrace	2.59	Terrace Run 8	11643.20	7402.30	7415.64		7416.19	0.001035	6.47	2022.42	199.28	0.32
Terrace	2.21	Terrace Run 8	11643.20	7400.71	7412.85		7413.66	0.001552	7.48	1692.10	181.76	0.39
Terrace	1.35	Terrace Run 8	11643.20	7395.59	7407.41		7407.88	0.001016	6.07	2192.53	241.51	0.31
Terrace	1.07	Terrace Run 8	11643.20	7392.20	7404.44		7405.57	0.002660	9.82	1470.11	190.76	0.51
Terrace	0.82	Terrace Run 8	11643.20	7390.72	7402.85		7403.30	0.000968	6.07	2272.89	254.88	0.31
Terrace	0.57	Terrace Run 8	11643.20	7389.54	7401.00	7396.44	7401.66	0.001512	7.04	1824.74	201.55	0.38
Terrace	0.00	Terrace Run 8	7912.20	7386.45	7392.38	7391.67	7393.98	0.008001	10.39	804.33	171.06	0.78

APPENDIX G
INUNDATION MAPPING



TERRACE DAM BREACH AND INUNDATION MAPPING
SUMMARY OF MODELING RESULTS AT CRITICAL SECTIONS

Tile #	Location	Distance from Dam (mi)	Time of Flood Arrival	Time of Flood Peak	Peak Flow (cfs)	Max Overbank Depth (ft)	Avg. Overbank Velocity (ft/s)
1	Terrace Dam	0	0 hr 0 min	0 hr 35 min	429,700	85	25
2	Alluvial Fan	6	0 hr 27 min	0 hr 51 min	375,300	30	18
2	County Rd. Z	8	0 hr 51 min	1 hr 5 min	352,400	23	10
2	County Rd. 6	11	1 hr 20 min	1 hr 26 min	309,900	12	6
3	Capulin	13	1 hr 50 min	1 hr 54 min	255,300	8	6
5	US 285	23	6 hr 27 min	6 hr 44 min	77,500	5	2
6	County Rd. 14S	30	11 hr 41 min	12 hr 16 min	36,900	4	1
7	Conejos/Costilla County Line	42	16 hr 44 min	17 hr 32 min	34,800	9	1
8	Lasauses	54	1 d 0 hr	1 d 6 hr	11,600	6	1
11	CO/NM State Line	75	1 d 8 hr	1 d 15 hr	7,900	5	10

DRAFT

Legend:

Modeled Cross Section

Inundation Limit

0 2 4
Miles

N

2011 AERIAL PHOTOGRAPHY FROM USDA GEOSPATIAL DATA GATEWAY

DISCLAIMER
THE INUNDATION LIMITS AND ASSOCIATED PROPERTIES CONTAINED IN THIS MAPPING ARE BASED ON ESTIMATED PARAMETERS AND ASSUMPTIONS. THE ACTUAL PROPERTIES OF A TERRACE DAM BREACH MAY DIFFER FROM THESE VALUES.

JOB NO. 0526.001.00

TERRACE DAM INUNDATION MAPPING
Vicinity Map

DEERE & AULT CONSULTANTS, INC.

TILE **INDEX**

DATE: 5-28-2013

SCALE: AS NOTED

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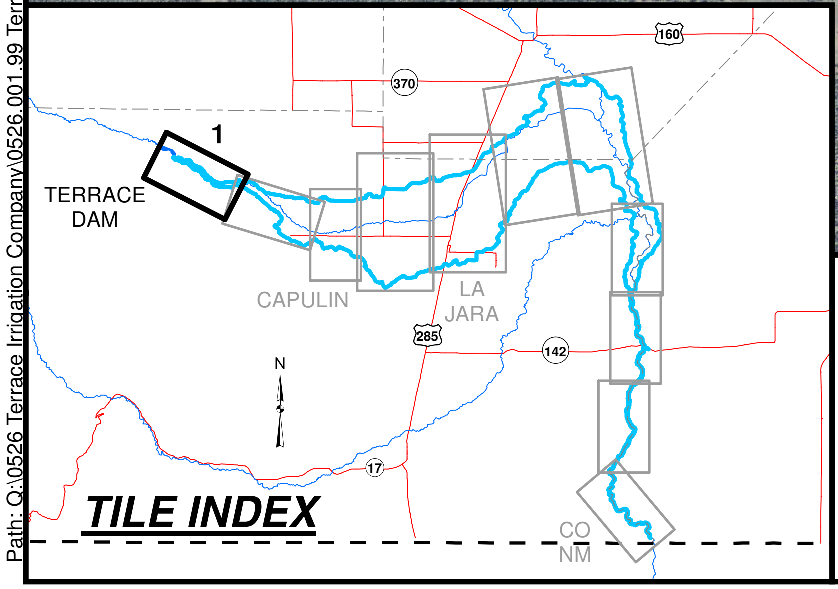

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Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

N

0 1,000 2,000
Scale in Feet

NOTE:
THE DEPTHS AND VELOCITIES SHOWN ON THESE MAPS REPRESENT OVERBANK FLOW. THE DEPTHS AND VELOCITIES IN THE MAIN CHANNEL WILL LIKELY BE SIGNIFICANTLY HIGHER.

DISCLAIMER
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JOB NO. 0526.001.00

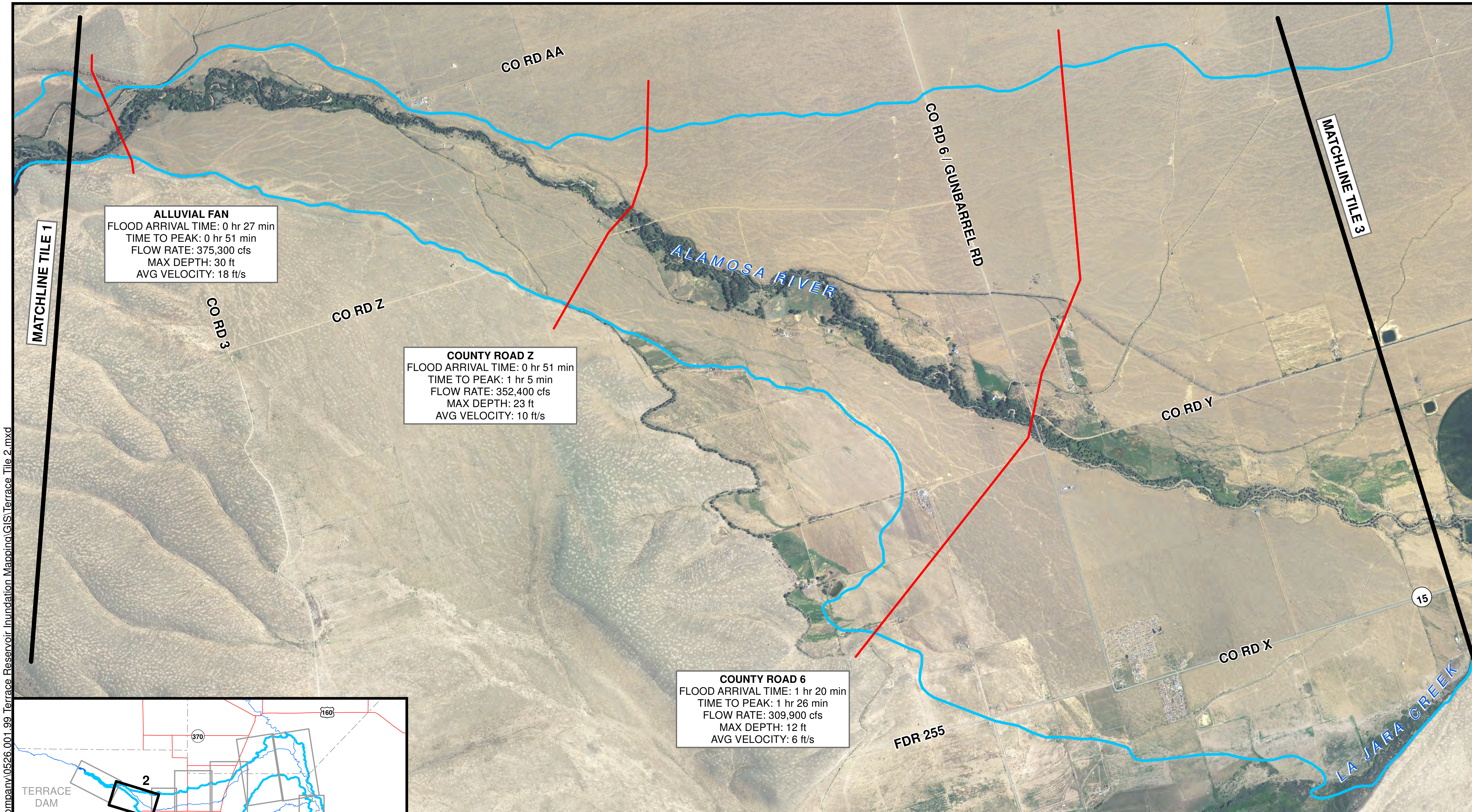
TERRACE DAM
INUNDATION MAPPING

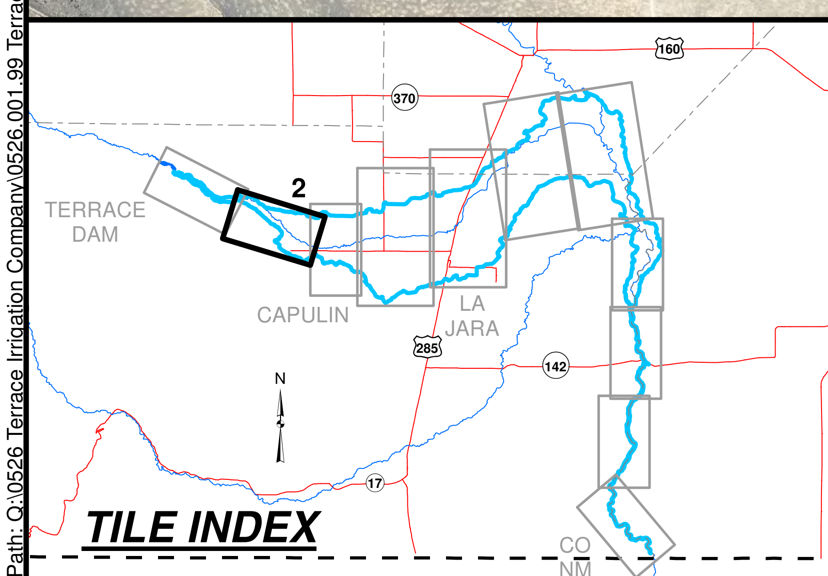
DEERE & AULT CONSULTANTS, INC.

TILE: 1

DATE: 5-28-2013

SCALE: AS NOTED





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Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

0 1,000 2,000
Scale in Feet

NOTE:
THE DEPTHS AND VELOCITIES SHOWN ON THESE MAPS REPRESENT OVERBANK FLOW. THE DEPTHS AND VELOCITIES IN THE MAIN CHANNEL WILL LIKELY BE SIGNIFICANTLY HIGHER.

DISCLAIMER
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JOB NO. 0526.001.00

TERRACE DAM INUNDATION MAPPING

DEERE & AULT CONSULTANTS, INC.

TILE 2

DATE: 5-28-2013

SCALE: AS NOTED

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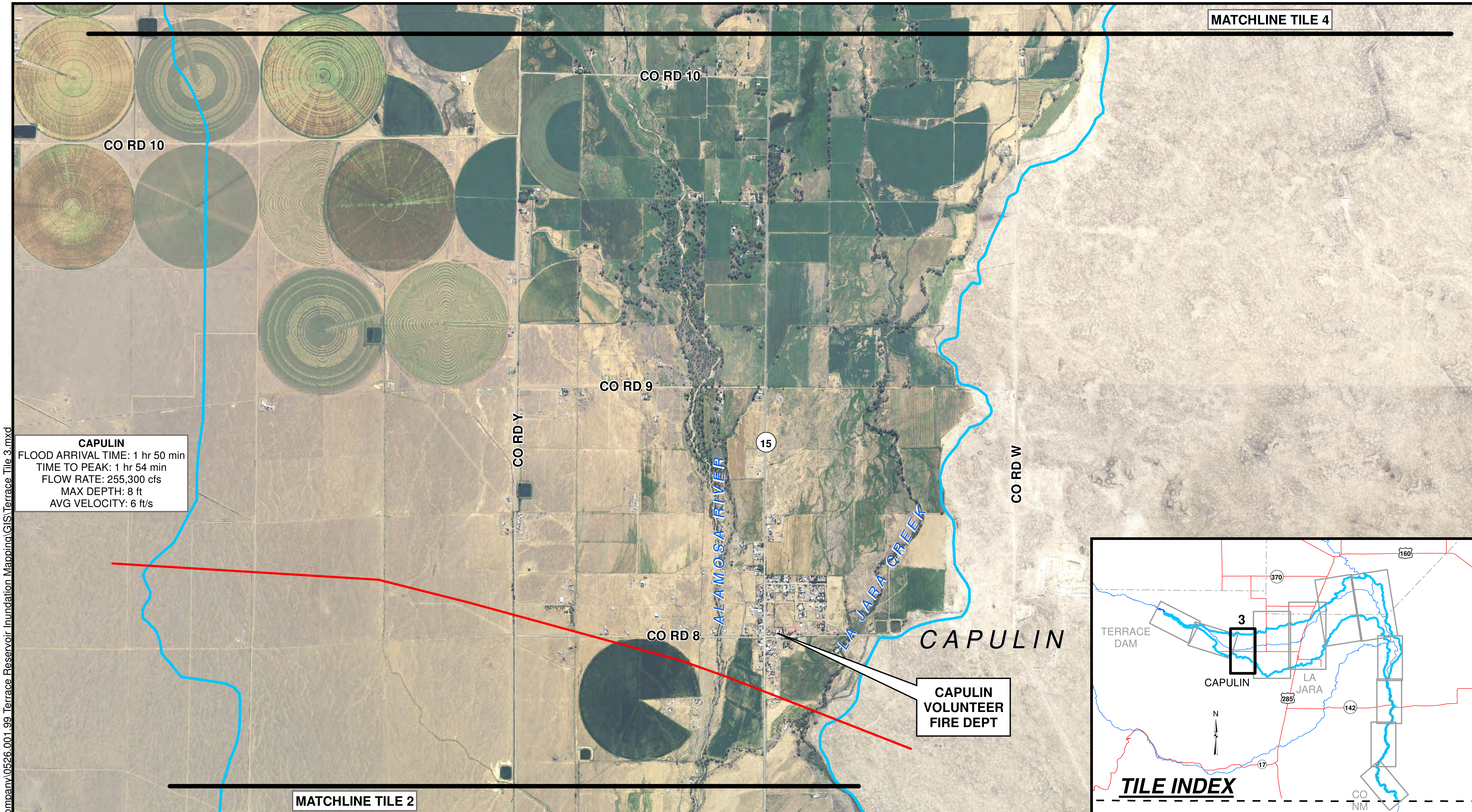


Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

N

0 1,000 2,000

Scale in Feet

NOTE:
THE DEPTHS AND VELOCITIES SHOWN ON THESE MAPS REPRESENT OVERBANK FLOW. THE DEPTHS AND VELOCITIES IN THE MAIN CHANNEL WILL LIKELY BE SIGNIFICANTLY HIGHER.

DISCLAIMER
THE INUNDATION LIMITS AND ASSOCIATED PROPERTIES CONTAINED IN THIS MAPPING ARE BASED ON ESTIMATED PARAMETERS AND ASSUMPTIONS. THE ACTUAL PROPERTIES OF A TERRACE DAM BREACH MAY DIFFER FROM THESE VALUES.

JOB NO. 0526.001.00

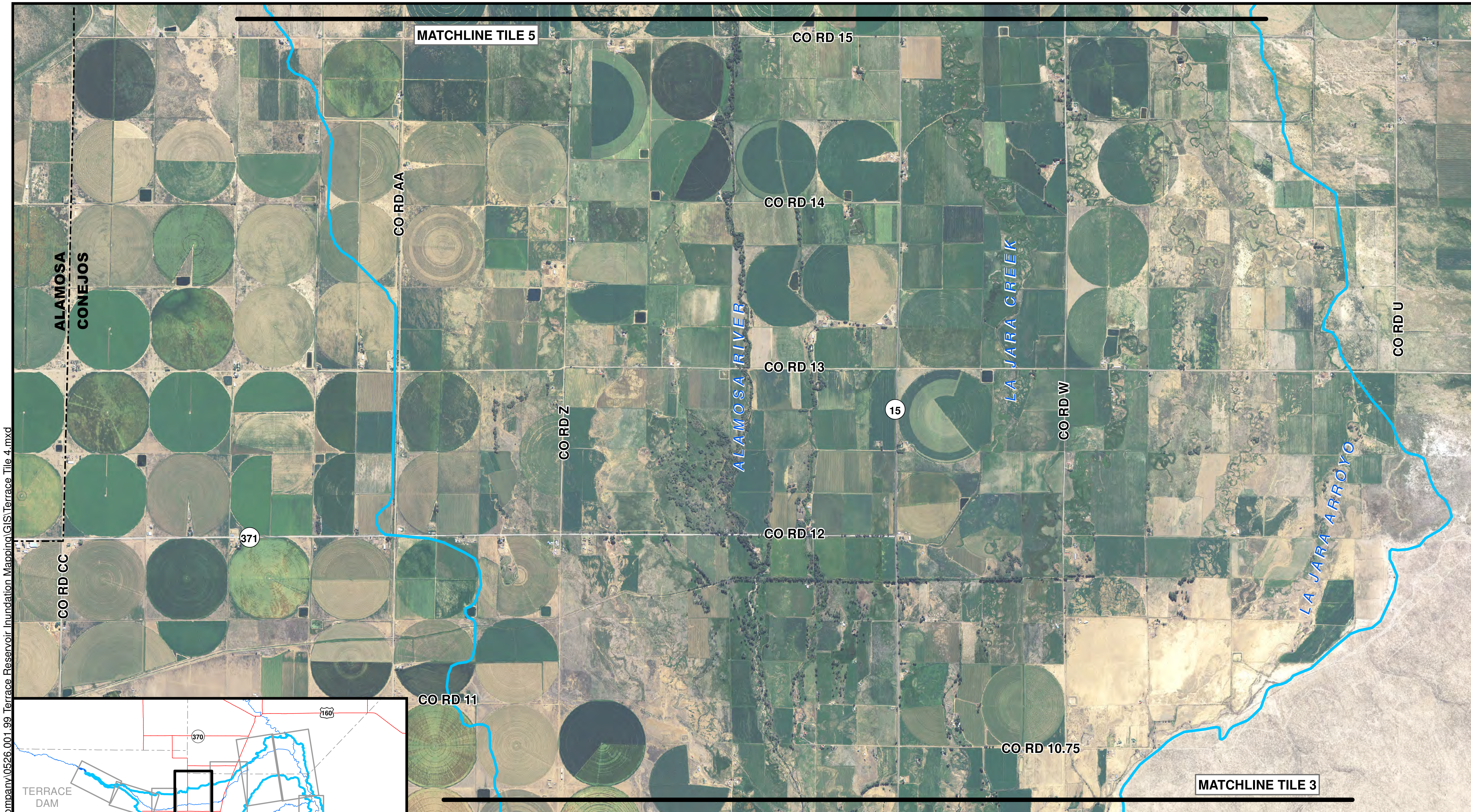
TERRACE DAM INUNDATION MAPPING

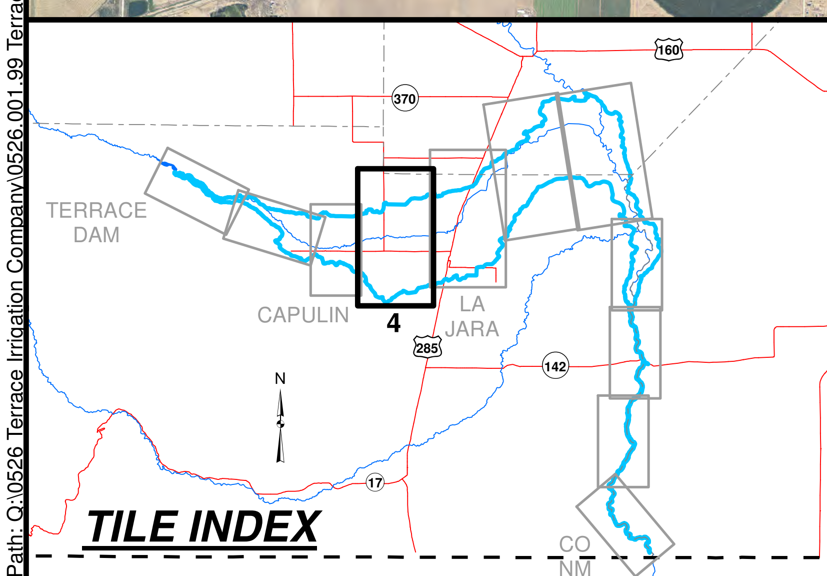
DEERE & AULT CONSULTANTS, INC.

TILE: 3

DATE: 5-28-2013

SCALE: AS NOTED





Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

N

0 1,500 3,000
Scale in Feet

NOTE:
THE DEPTHS AND VELOCITIES SHOWN ON THESE MAPS REPRESENT OVERBANK FLOW. THE DEPTHS AND VELOCITIES IN THE MAIN CHANNEL WILL LIKELY BE SIGNIFICANTLY HIGHER.

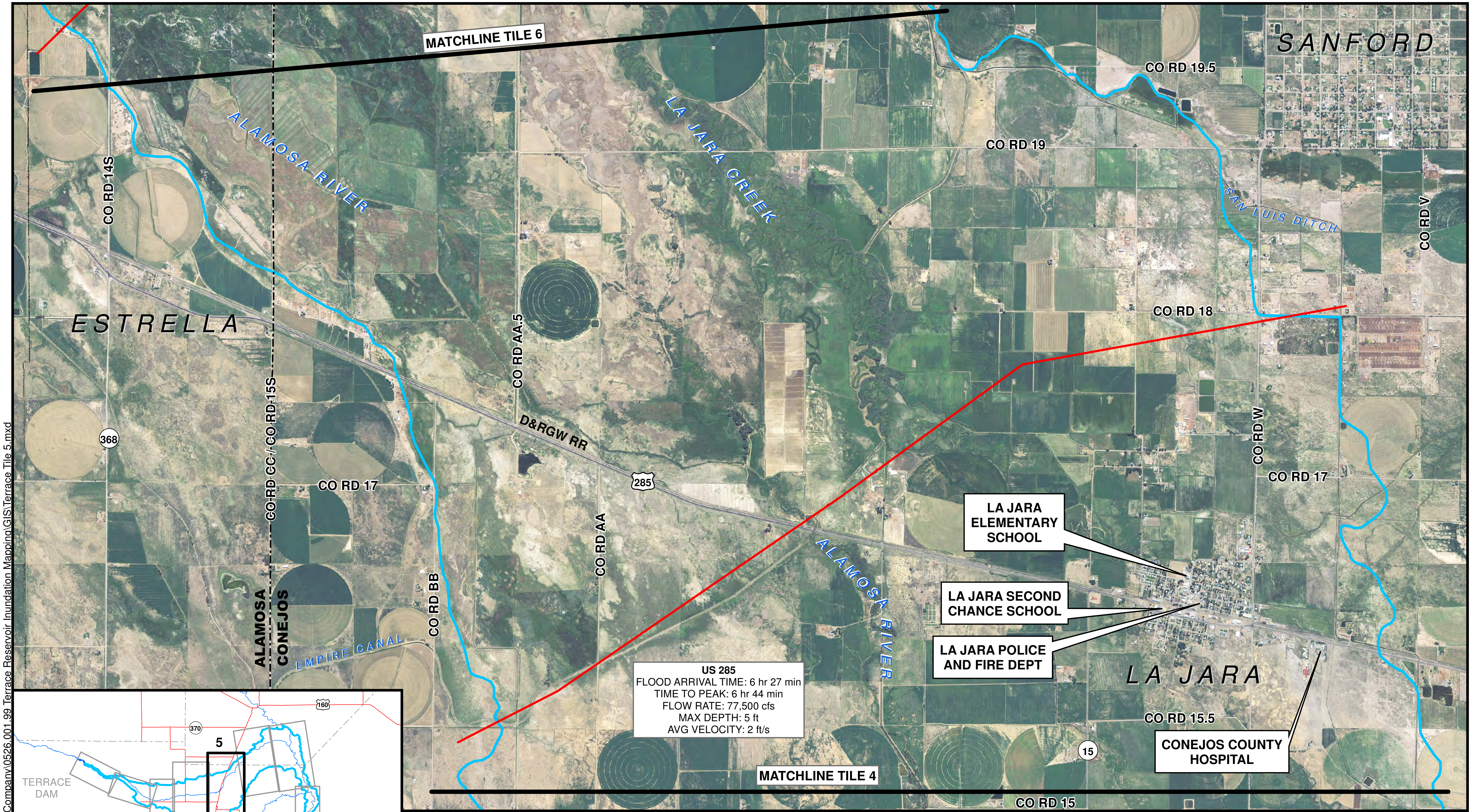
DISCLAIMER
THE INUNDATION LIMITS AND ASSOCIATED PROPERTIES CONTAINED IN THIS MAPPING ARE BASED ON ESTIMATED PARAMETERS AND ASSUMPTIONS. THE ACTUAL PROPERTIES OF A TERRACE DAM BREACH MAY DIFFER FROM THESE VALUES.

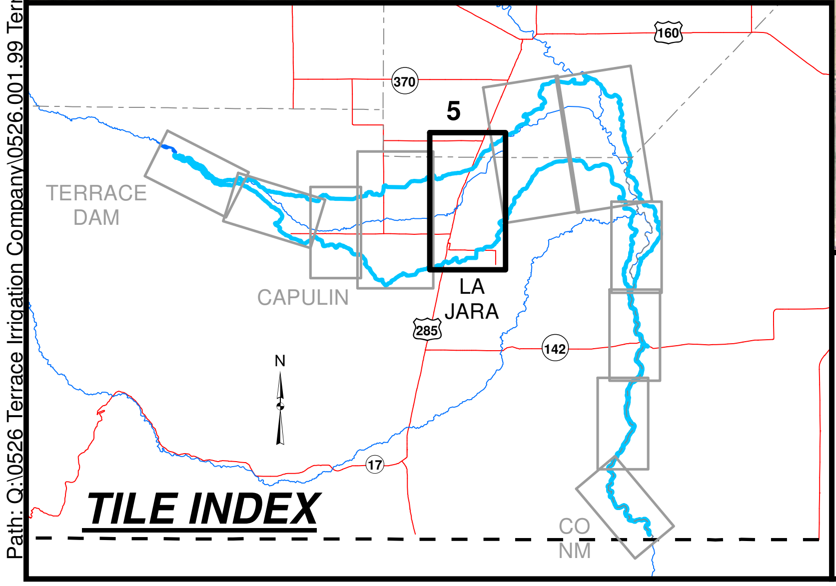
JOB NO. 0526.001.00

**TERRACE DAM
INUNDATION MAPPING**

DEERE & AULT
CONSULTANTS, INC.

TILE	4
DATE:	5-28-2013
SCALE:	AS NOTED





TILE INDEX

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Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

N

0 1,500 3,000
Scale in Feet

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JOB NO. 0526.001.00

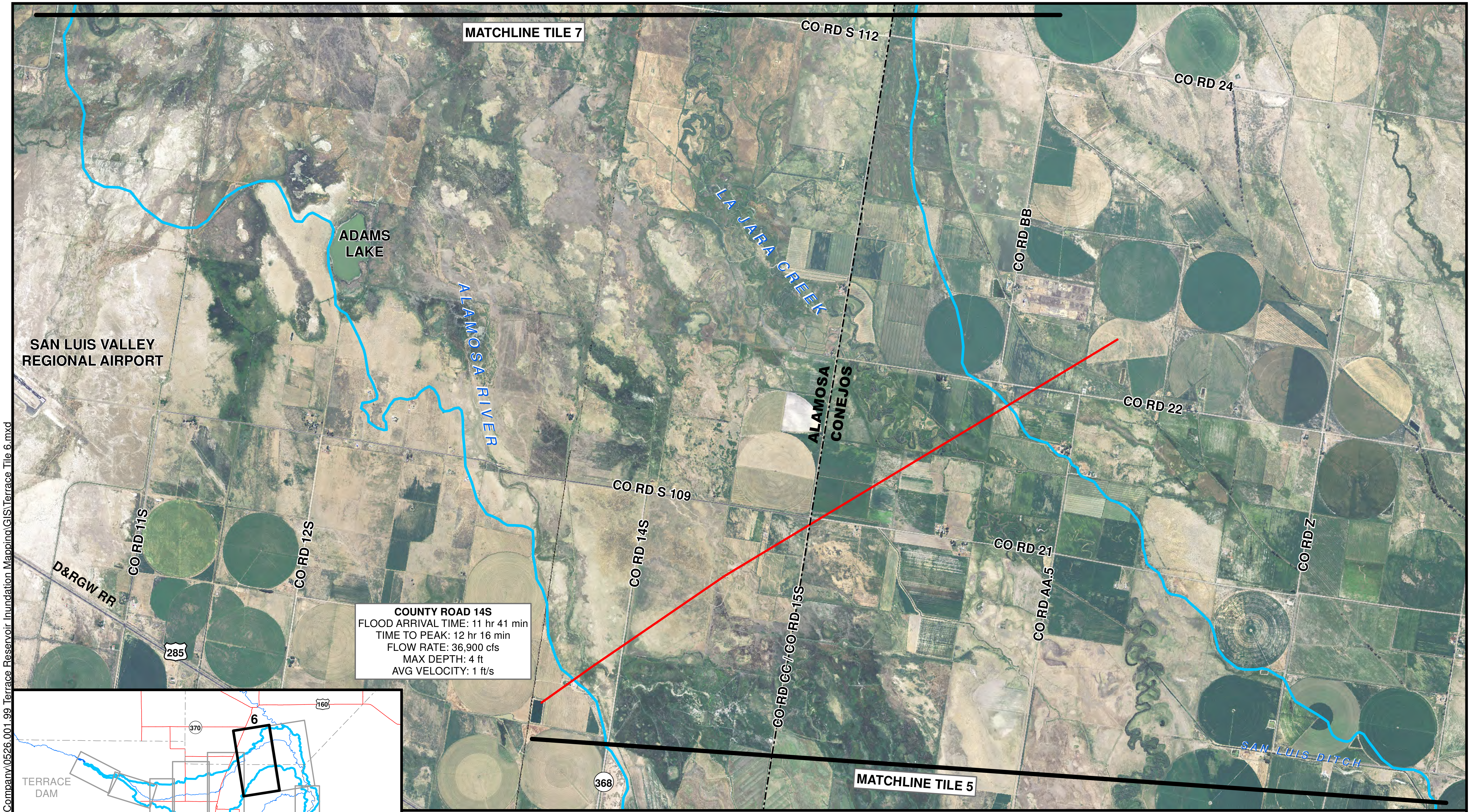
TERRACE DAM INUNDATION MAPPING

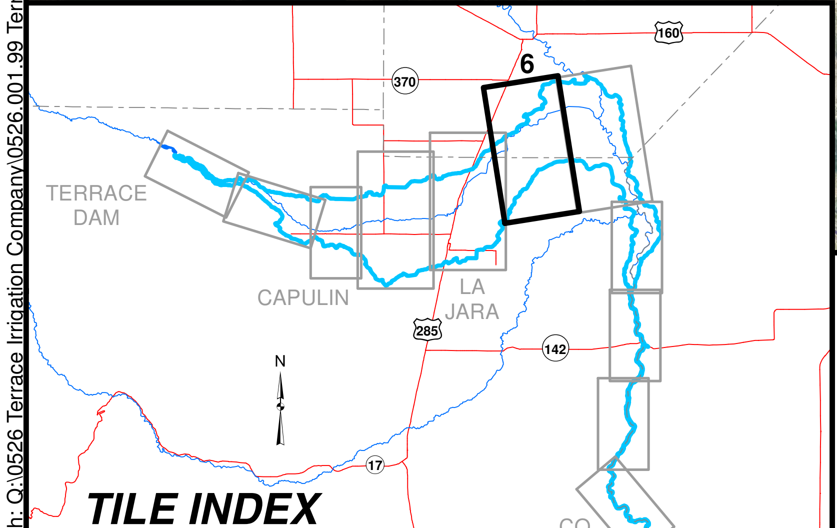
DEERE & AULT CONSULTANTS, INC.

TILE 5

DATE: 5-28-2013

SCALE: AS NOTED





TILE INDEX

Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

0 1,500 3,000
Scale in Feet

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TERRACE DAM INUNDATION MAPPING

DEERE & AULT CONSULTANTS, INC.

TILE 6

DATE: 5-28-2013

SCALE: AS NOTED

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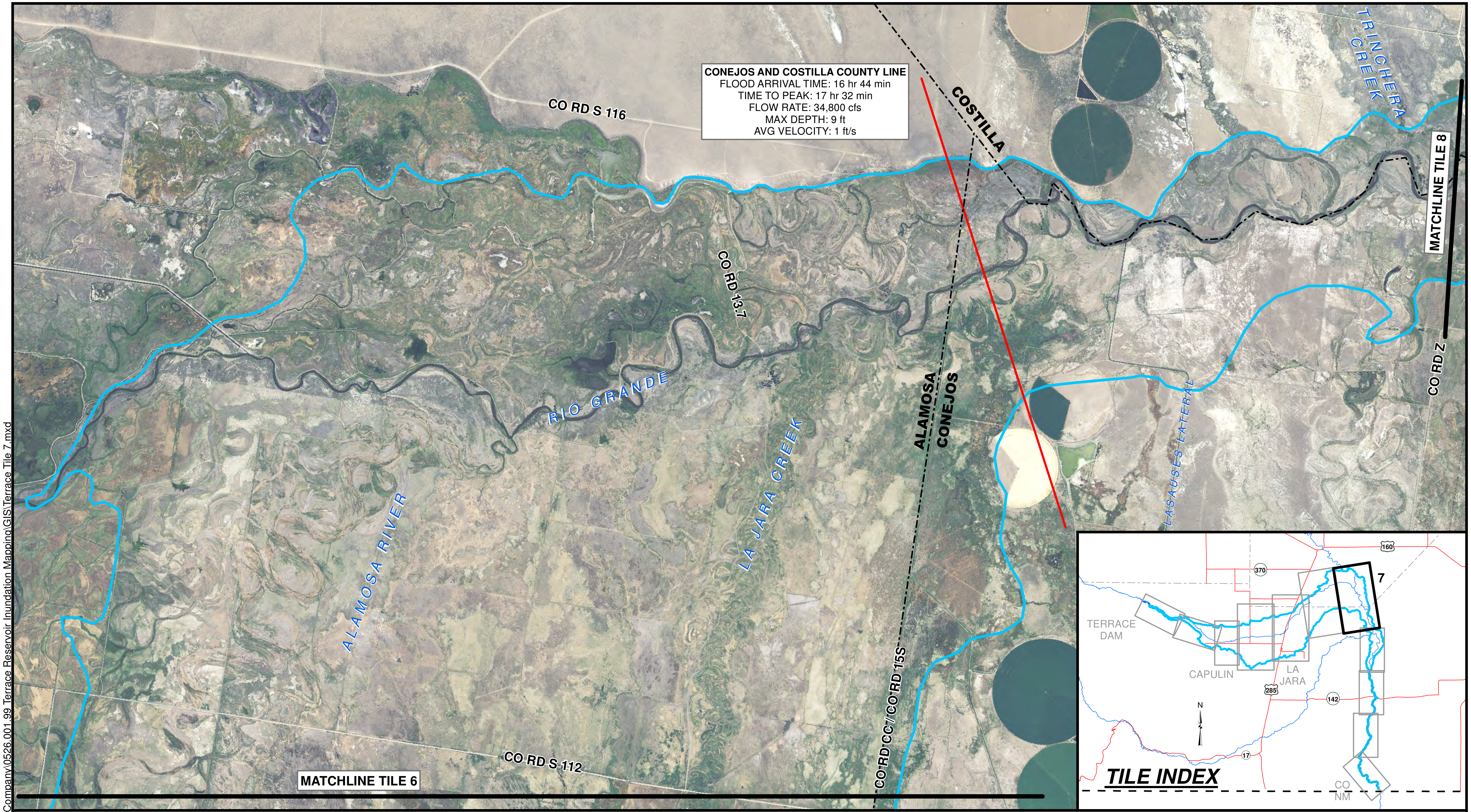

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Legend:

Modeled Cross Section

Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

0 1,500 3,000
Scale in Feet

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JOB NO. 0526.001.00

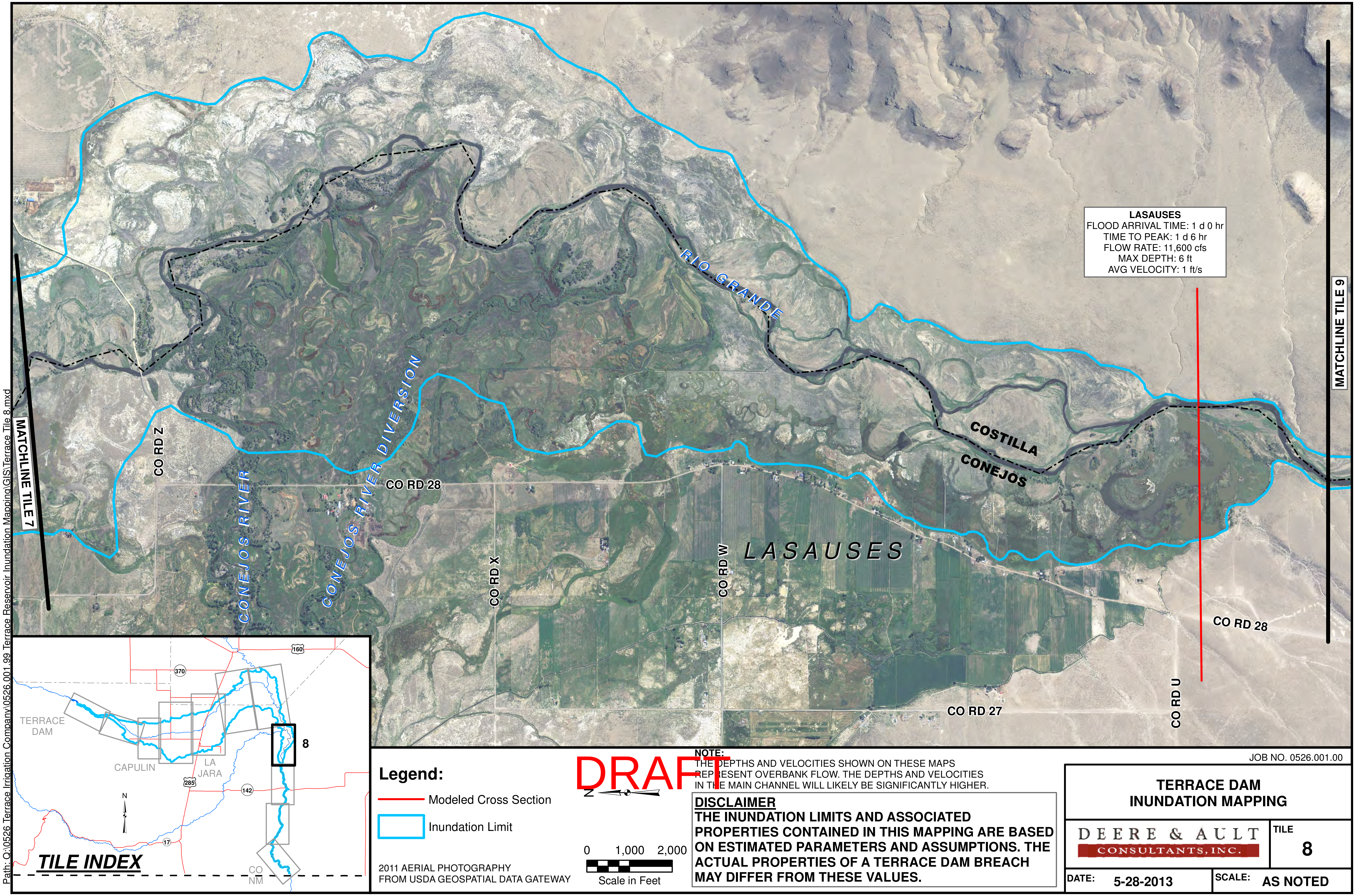
TERRACE DAM
INUNDATION MAPPING

DEERE & AULT
CONSULTANTS, INC.

TILE
7

DATE: 5-28-2013

SCALE: AS NOTED



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Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

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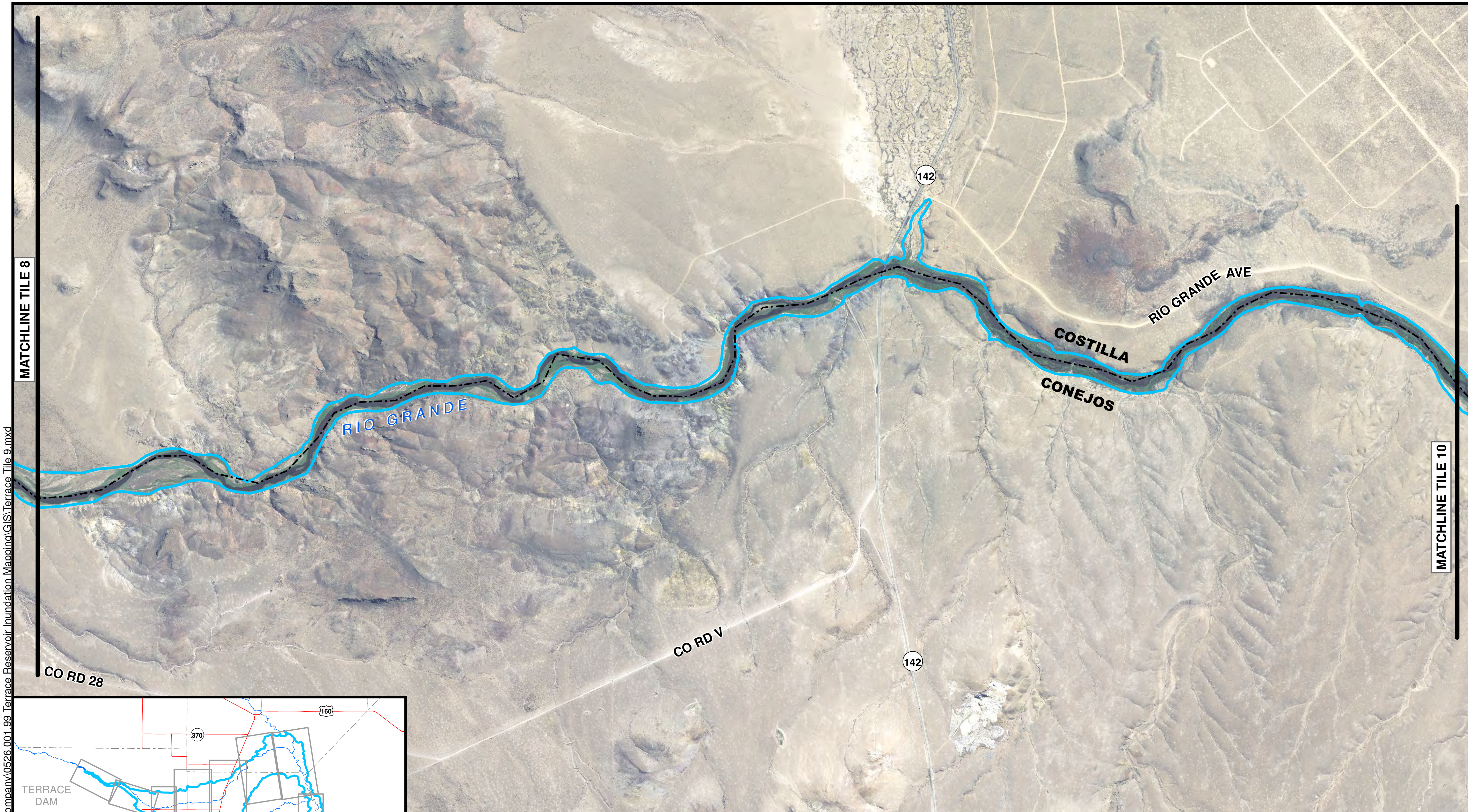
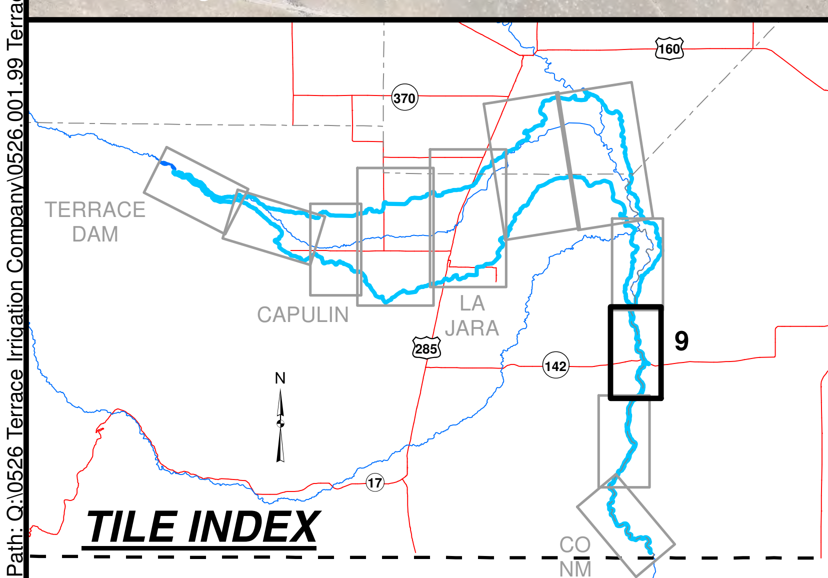
TERRACE DAM
INUNDATION MAPPING

DEERE & AULT CONSULTANTS, INC.

TILE	8
DATE: 5-28-2013	SCALE: AS NOTED





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Legend:

Modeled Cross Section

Inundation Limit

2011 AERIAL PHOTOGRAPHY FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

0 1,000 2,000

Scale in Feet

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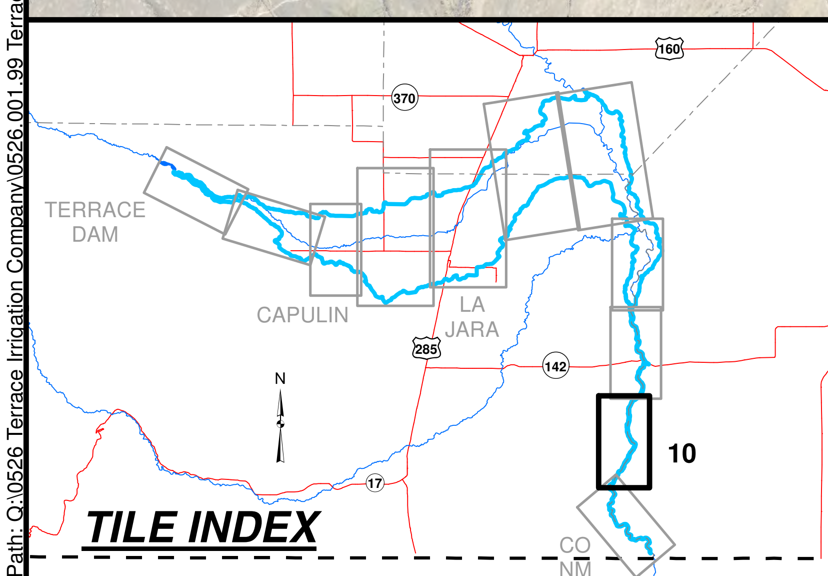
TERRACE DAM INUNDATION MAPPING

DEERE & AULT CONSULTANTS, INC.

TILE: 9

DATE: 5-28-2013

SCALE: AS NOTED



TILE INDEX

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Legend:

- Modeled Cross Section
- Inundation Limit

2011 AERIAL PHOTOGRAPHY
FROM USDA GEOSPATIAL DATA GATEWAY

DRAFT

0 1,000 2,000
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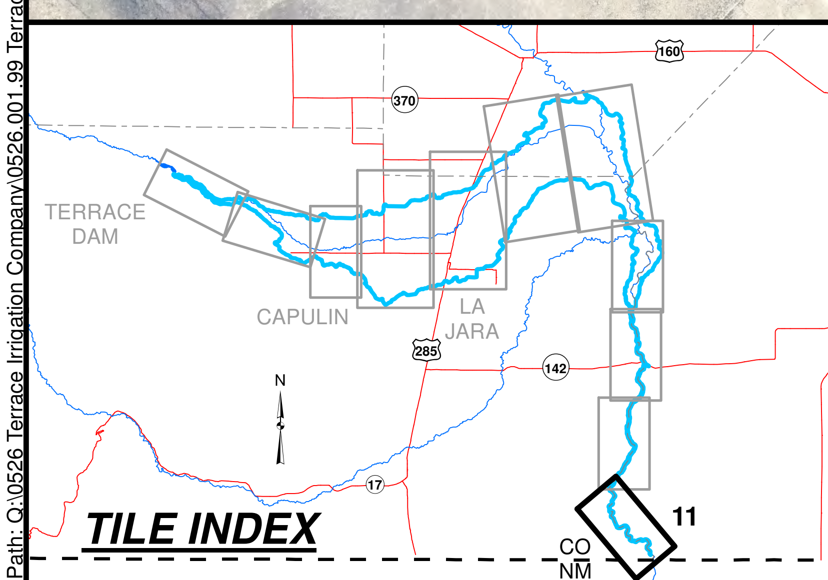
TERRACE DAM INUNDATION MAPPING

DEERE & AULT CONSULTANTS, INC.

TILE 10

DATE: 5-28-2013

SCALE: AS NOTED



TILE INDEX

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Legend:

- Modeled Cross Section
- Inundation Limit

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DRAFT

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TERRACE DAM INUNDATION MAPPING

DEERE & AULT CONSULTANTS, INC.

TILE 11

DATE: 5-28-2013

SCALE: AS NOTED