APPENDICES F

HYDRAULIC MEMO

06-29-2020

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Memo

Date:	06/29/2020
Project:	Pleasant Valley Bridge Phase 1 Preliminary Engineering Report
To:	Karl McArthur, P.E., CFM City of Austin Watershed Protection Department, Watershed Engineering Division
From:	Bryan S. Martin, PE, CFM
Subject:	**Hydrologic and Hydraulic Analysis**

Section 1 - Introduction

The primary objective of the Pleasant Valley Bridge Phase 1 Preliminary Engineering Report is to study the feasibility of a new multi-use pedestrian bridge spanning the Colorado River near Longhorn Dam. This technical memorandum describes the findings of the supporting hydrologic and hydraulic analysis. The objectives of this analysis are as follows:

- to define existing hydrologic and hydraulic conditions (Section 2);
- to analyze the impacts of the pedestrian bridge on the functionality of Longhorn Dam (Section 3);
- to determine the minimum low chord elevation (Section 4);
- to analyze proposed hydraulic upstream impacts and mitigation measures (Section 5); and
- to develop recommendations to countermeasures for scour and hydraulic loads (Section 6).

Multiple pedestrian bridge alignment alternatives were considered as shown in **Figure 1** below.

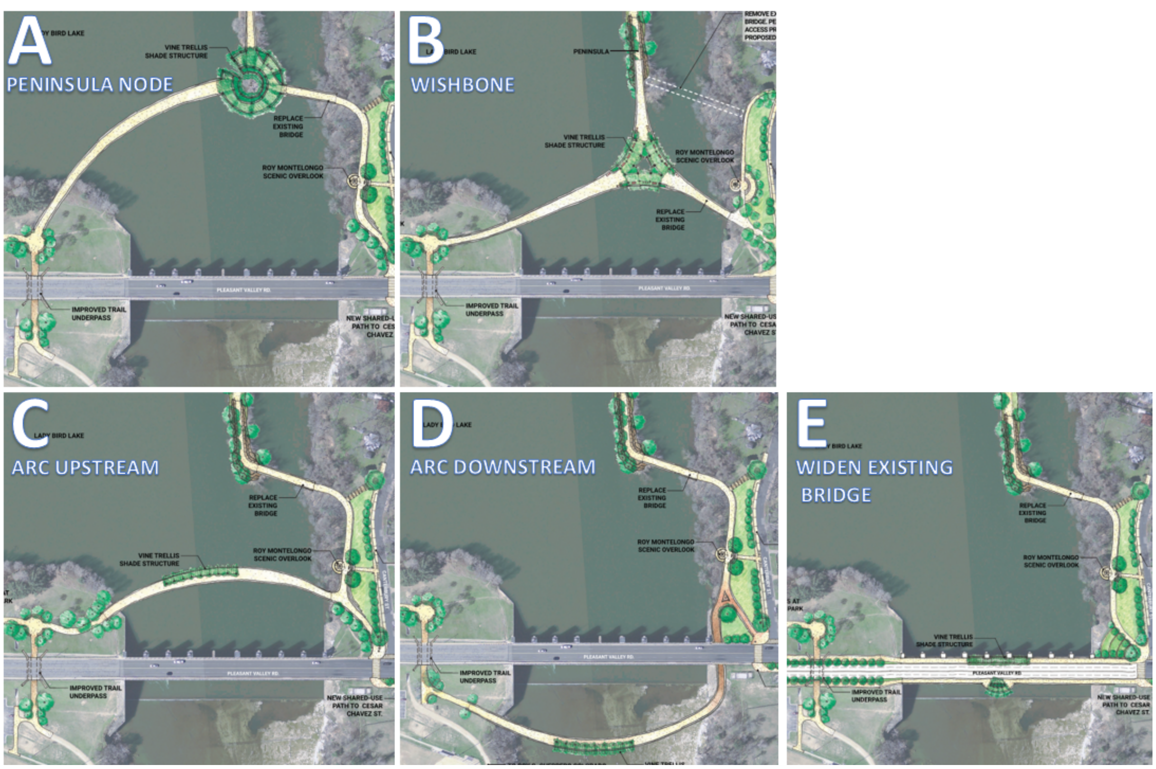

Figure 1.1 – Pleasant Valley Bridge Alternatives

Section 2 – Existing Hydrology and Hydraulic Conditions

Effective Floodplain

The project site is located in FEMA floodplain Zone AE as shown on the effective FIRM map 48453C0465J dated January 2016 (See **Figures 2.1**).

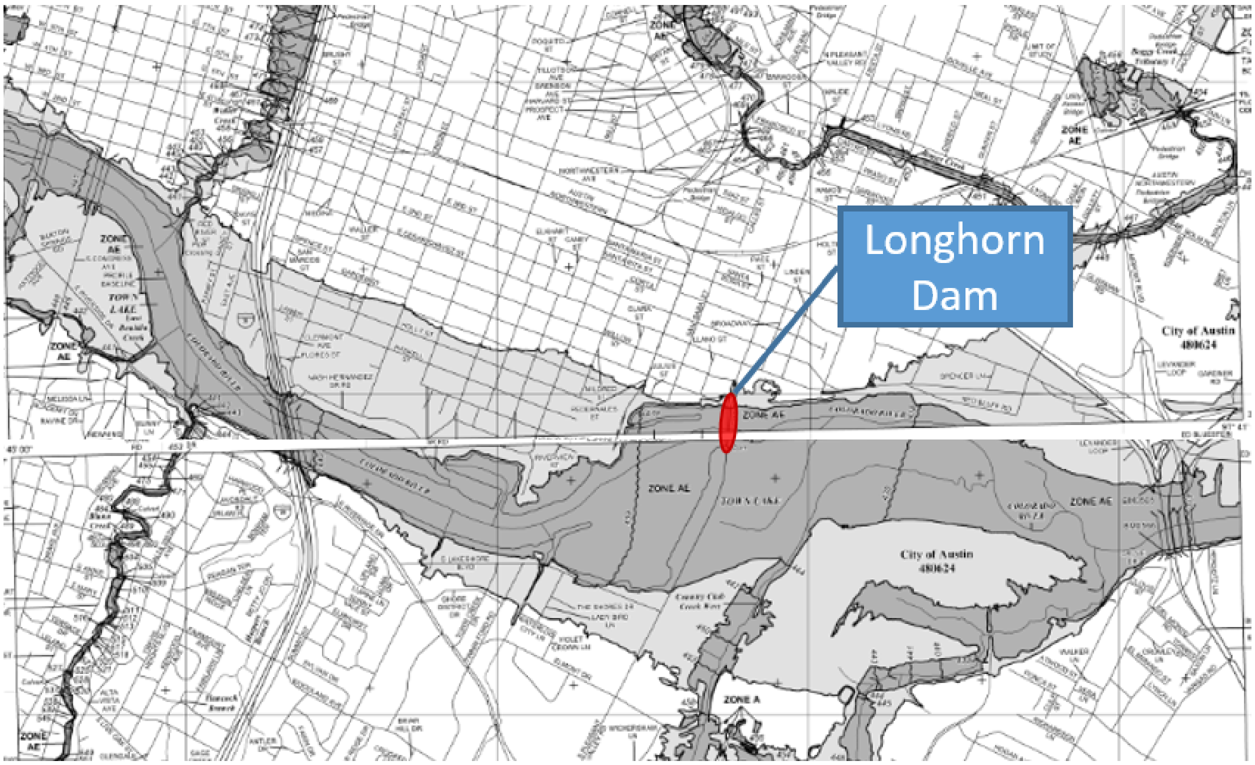

Figure 2.1 - Effective FIRM Map

Effective FIS Flood Profile

The effective FIS Flood Profile provided in **Figure 2.2** below illustrates how the Longhorn Dam spillway has limited effect on the hydraulic grade line for large storm events greater than the 50-year storm event. Further, the profile illustrates how the 50- and 100-year storm event profiles are indistinguishable.

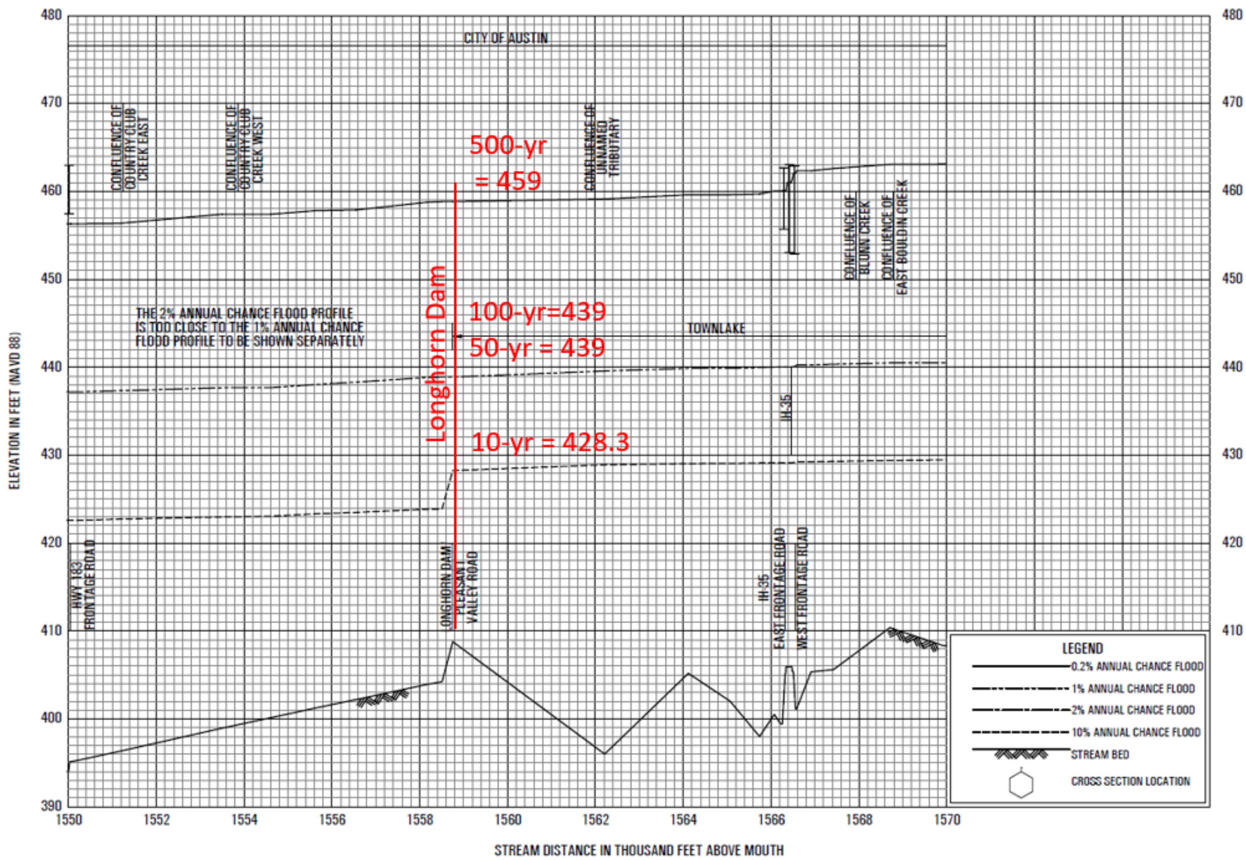

Figure 2.2 - Effective FIS Flood Profile for Colorado River

Existing Hydraulic Model

The FEMA effective Colorado hydraulic models were obtained from the City of Austin Watershed Protection Department. The hydraulic models were developed as part of the Lower Colorado River Flood Damage Evaluation Project (FDEP) prepared by Halff in 2002 for LCRA and Fort Worth District Corps of Engineers. The models are calibrated unsteady state HEC-RAS models for the Lower Colorado River with one model extending from Tom Miller Dam to Longhorn Dam and the other extending from Longhorn Dam to the Bastrop USGS Gauge 08159200. The unsteady HEC-RAS models use flow hydrographs at the upstream end from the HEC-HMS/HEC-5 results. The downstream boundary condition (stage hydrograph), as well as the upstream boundary condition (outflow hydrograph) come from the HEC-5 analysis.

Duplicate Effective Model Results

The FEMA effective models were re-ran to create duplicate effective models in HEC-RAS v 5.0.6. The following tables summarize peak flow rates, water surface elevations, and velocities for HEC-RAS cross-sections just upstream and downstream of Longhorn Dam. Note that Longhorn Dam is located between two unsteady HEC-RAS models, which results in a modeling anomaly with higher water surface elevations downstream of the dam than upstream for the 25-year storm event through the 500-year storm event.

Table 2.1 – Duplicate effective 'Town Lake Reach' hydraulic model results just upstream of Longhorn Dam (RS1558754)

Storm Event	Q (cfs)	WSE (ft)	EGL (ft)	Vel (fps)
10-yr	-	428.25	428.25	-
25-yr	48,109	430.31	430.82	5.74
50-yr	90,210	438.60	439.35	7.03
100-yr	90,352	438.61	439.36	7.03
500-yr	366,558	458.23	459.63	11.32

Table 2.2 – Duplicate effective 'Bastrop Reach' hydraulic model results just downstream of Longhorn Dam (RS1558511)

Storm Event	Q (cfs)	WSE (ft)	EGL (ft)	Vel (fps)
10-yr	27,736.95	423.88	424.08	3.06
25-yr	49,794.29	431.54	431.82	4.32
50-yr	89,641.30	441.01	441.46	5.44
100-yr	90,048.86	441.03	441.48	5.46
500-yr	66,459.60	459.86	461.00	10.12

Existing Flood Hazards and No Adverse Impact

The City of Austin Land Development Code states proposed developments will not result in additional adverse flooding impact on other property (LDC §25-7-61). A review of prior reports indicates existing roadways and building finish floor elevations are located within the floodplain (see **Figure 2.3**). Small adverse impacts to upstream water surface elevations are anticipated with the proposed placement of bridge piers and abutments in the 100-year floodplain. Any rise in upstream water surface elevations would require a City Council variance, a notification letter to all properties impacted by the rise, a Conditional Letter of Map Revision (CLOMR), and a Letter of Map Revision (LOMR) with requirements of FEMA acknowledgement of a complete LOMR application prior to final acceptance by City.

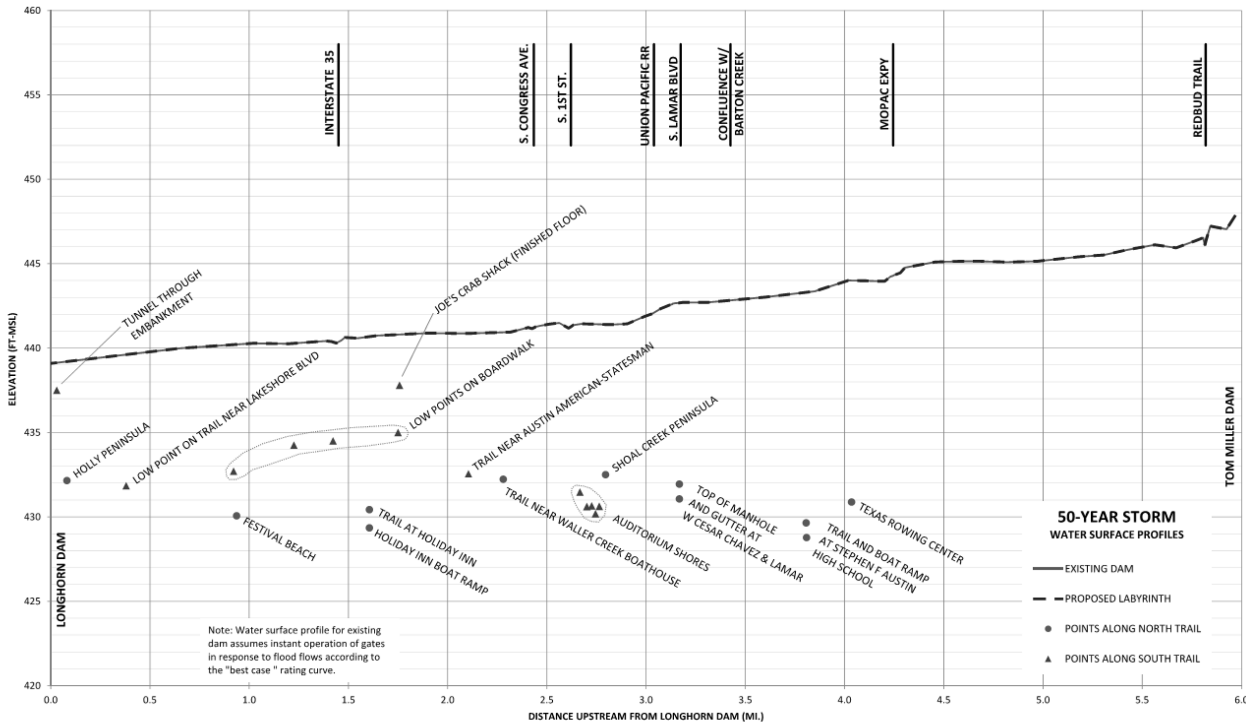

Figure 2.3 – Existing flood hazards (source: Longhorn Dam Labyrinth Weir Eval, FNI 2013)

Section 3 - Impacts to Functionality of Longhorn Dam

The objective of this section is to analyze the impacts of the pedestrian bridge alternatives on the functionality of Longhorn Dam.

Dam Description

The Longhorn Dam was constructed in 1960 by Austin Energy to create a cooling reservoir for Holly Power Plant. In 2007, Holly Power Plant was closed. As a result, the primary purpose of the dam today is to maintain Lady Bird Lake permanent pool elevation. The dam is 1,240 feet long and consists of a 506-foot wide gated spillway with earthen embankments on either side. The gated spillway consists of seven (7) 50-foot wide by 13-foot tall manually operated lift gates and two (2) 50-foot wide by 9-foot tall bascule gates. The spillway discharges into an 85-foot long concrete bottomed stilling basin that maintains seven (7) feet of water behind the gates to dissipate energy. The gated spillway supports a four lane bridge for Pleasant Valley Road and the hike and bike trail (see **Figure 3.1** below for existing site plan).

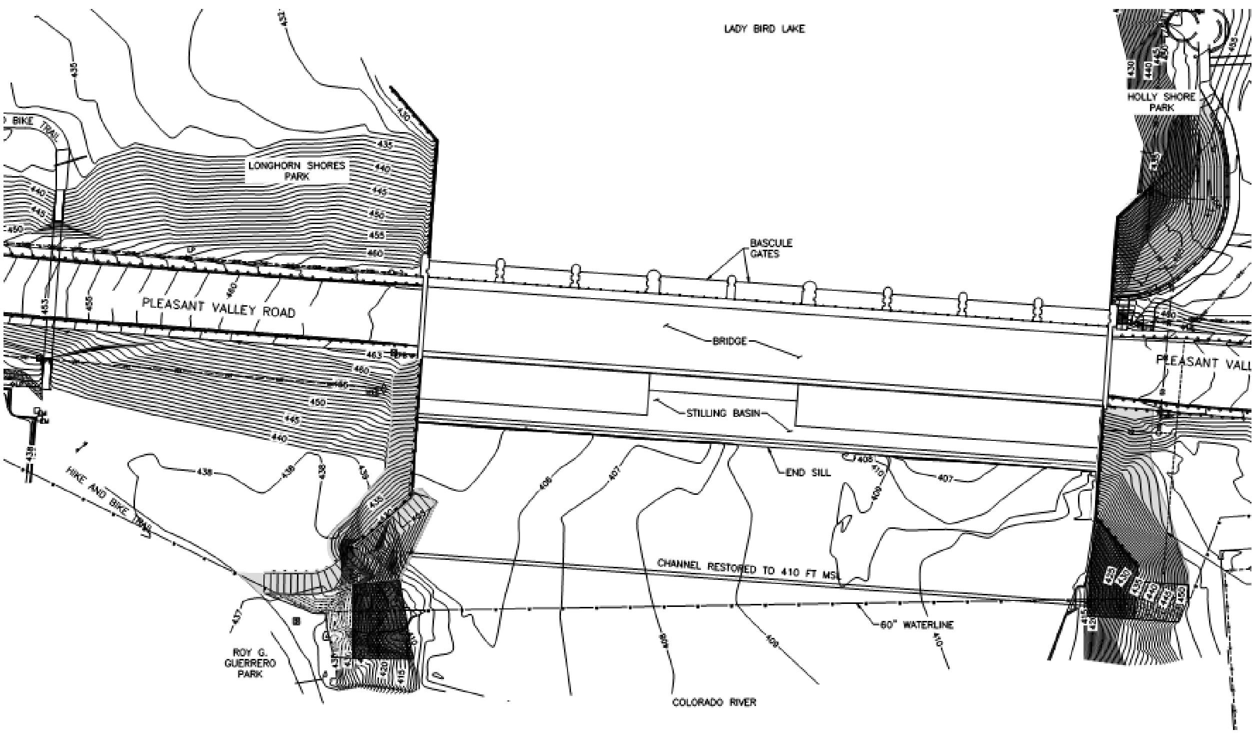

Figure 3.1 – Existing Site Plan of Longhorn Dam (source FNI 2012)

Dam Operation and Maintenance

The Longhorn Dam is currently operated and maintained by Austin Water. Austin Energy relinquished this responsibility recently to Austin Water in April 2018. Operators are sent out to the dam if a gate needs to be opened during a flood. Operators stage curb side along Pleasant Valley Road. Operators use a push button pendent to raise and lower the gates.

Bascule Gates

The two bascules gates automatically regulate lake levels during normal flow conditions. The bascule gates are operated automatically by valves, cables, and pulleys located within adjacent concrete piers. The bascule gates were designed to allow the dam to pass more than 7,500 cfs with the lake at the normal pool elevation of 428.25 ft-msl.

Lift Gates

The seven lift gates are manually opened to pass higher flows during large flood or upstream reservoir releases. The manual lift gates must be opened to prevent the lake from rising if flow rates exceed roughly 7,500 cfs (≈10-yr). The lift gates are operated with controls located at each pier. To access the piers the adjacent sidewalk must be closed as the access doors when open block the sidewalk. The concrete barrier and chain-link fence installed along the sidewalk provides protection to operators from motorist. The bascule and lift gates together have the discharge capacity to maintain a constant level up to approximately 42,000 cfs (<25-yr). Above this flow rate, the spillway no longer maintains control and gives way to downstream river backwater conditions for controlling water surface elevations in Lady Bird Lake.

Dam Maintenance

For operators to maintain the gates properly, 50-foot long, 15,000-lb stop logs must be installed upstream of the gates. These stop logs require installation by a crane and flatbed trailer with traffic restricted on Pleasant Valley. The City uses a 60 ton crane positioned on top of the dam to perform maintenance on the spillway gates. This operation occupies 1-1/4 lanes of Pleasant Valley Road. The City has to provide pedestrian traffic control if pedestrian access across the dam is changed for any reason.

Austin Water operators also require access to the spillway gates from the water side to lubricate gate wheels and to operate the low flow bascule key-hole gate valves. The maintenance boat used for access has a canopy in which personnel tie-off to during maintenance operations. Operators desire access to the dam via the boat during normal water levels on Lady Bird Lake. Austin Water provided maintenance boat specifications for a ReconCraft RC18 Vessel Package with a boat tower option. A design calculation length of 24 feet and height of 8’-2” were derived from these specifications. Thus, if the boat was operating during normal water surface elevations then a minimum clearance of roughly 437 ft-msl would be required. The boat can also be turned within its own length. Thus a length of 30 feet was assumed required between the dam spillway and any upstream obstructions to allow enough room for a maintenance boat to maneuver.

Future Dam Improvements

Plans to rehab the dam are in the works. A ‘Longhorn Dam Modernization Conceptual Design Report’ and ‘Supplemental Memorandum’ was prepared for Austin Energy in 2012. The study resulted in recommended repairs for the spillway gates (see **Figure 3.2**). Subsequently, a ‘Longhorn Dam Labyrinth Weir Conceptual Evaluation’ was prepared for Austin Energy in 2013 to provide an alternative to the earlier recommended spillway repairs (see **Figure 3.3**).

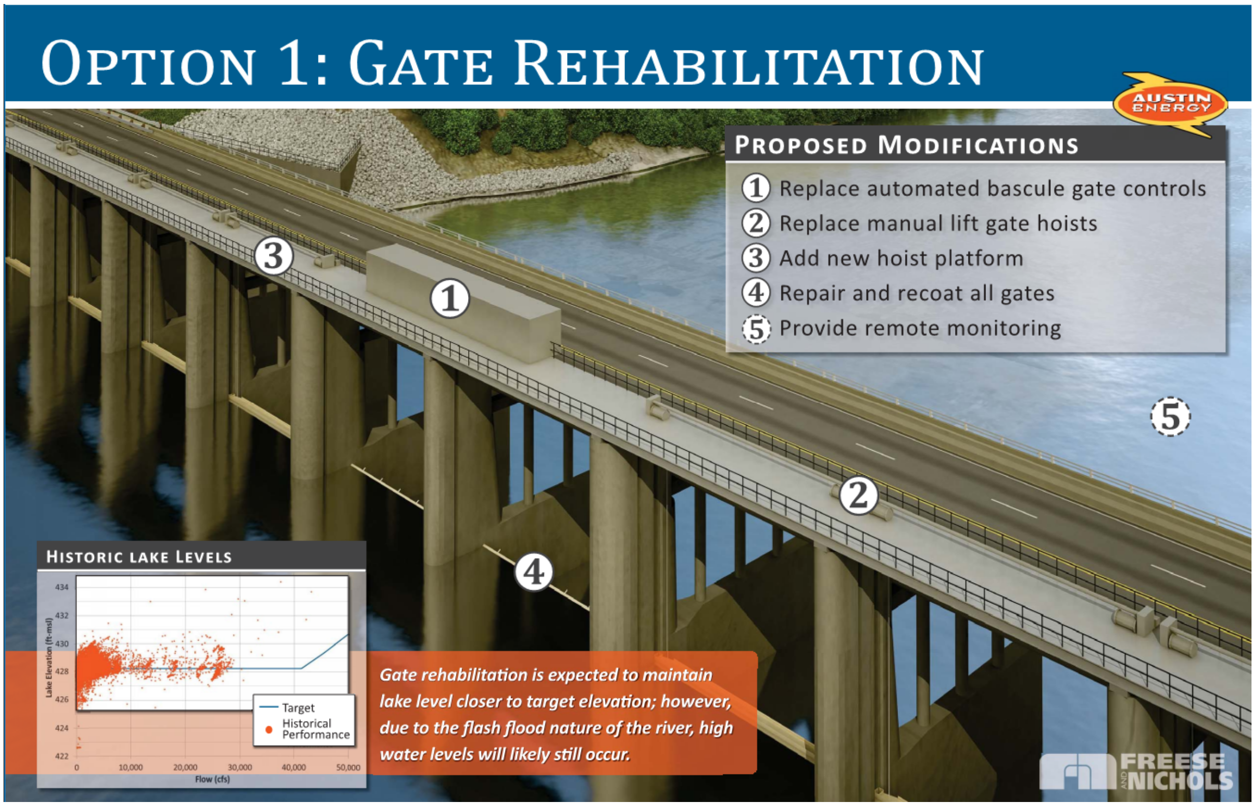

Figure 3.2 – Longhorn Dam Improvements – Gate Rehab (source: FNI and Austin Energy)

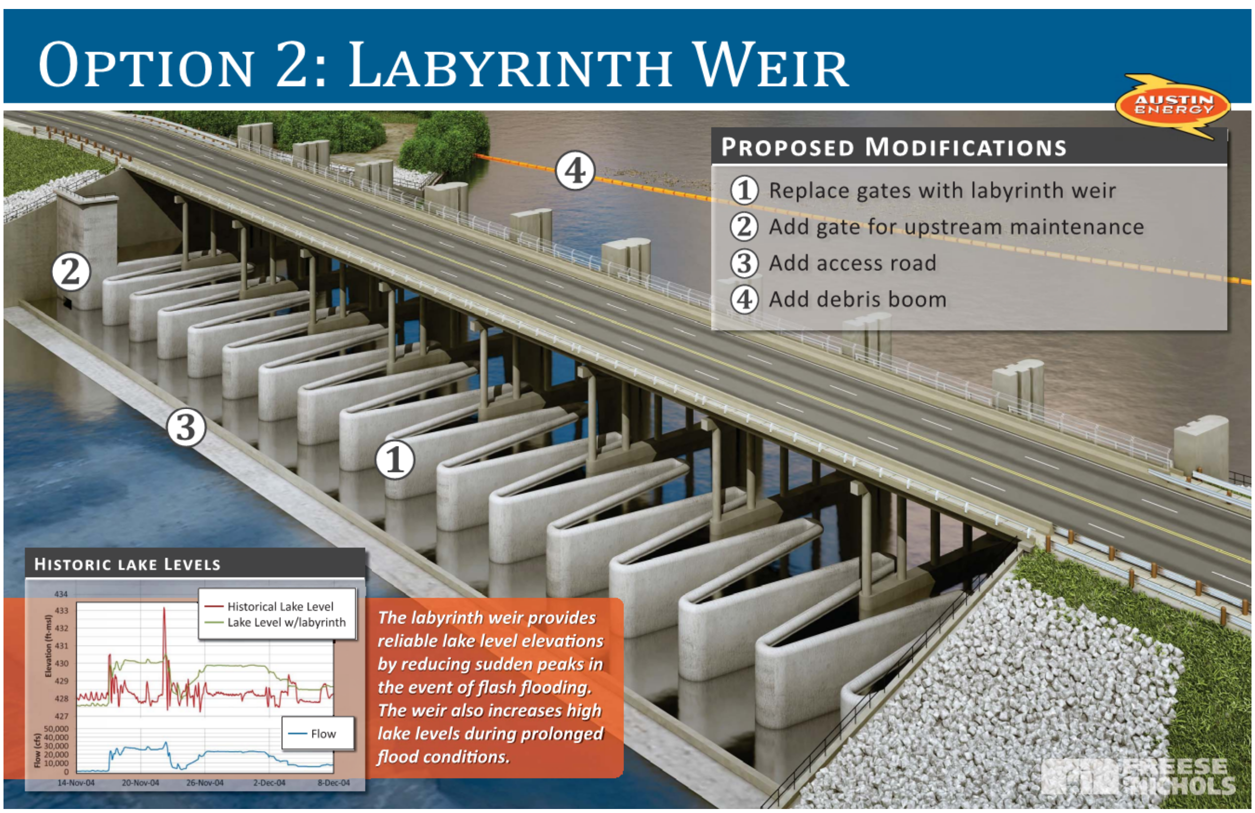

Figure 3.3 – Longhorn Dam Improvements – Labyrinth Weir (source: FNI & Austin Energy)

The replacement of the gates with a labyrinth spillway was proposed to reduce maintenance requirements, to provide more predictable and less fluctuation in lake levels, and to reduce water waste. Drawbacks of this alternative included higher flood elevations for 2- to 25-year storm events, and increased debris capture and removal requirements.

The 2012 Longhorn Conceptual Design Report also included lower priority repairs that could impact the use of the dam site. These improvements included: downstream slope repair; repair of downstream riverbed scour; training wall and embankment handrails; northwest slope improvements; a trail on the southeast slope; and a stop log deployment system.

Austin Water stated in a September 2019 progress meeting for the Pleasant Valley Bridge project that there are no short term plans to install the labyrinth spillway and that a dam rehabilitation project is planned to start in 2020 to implement most of the items under the gate rehabilitation repair option.

Impact of Alternatives on Longhorn Dam Functionality

All of the alternatives as summarized in the table below, except Alt 5 – Bridge Widening, are located a sufficient distance from Longhorn Dam to not impact all known existing and future operation and maintenance activities. Widening the existing bridge would place the future hike and bike trail in close proximity to dam operations where some impacts to both the trail and the operators during flood and maintenance events are anticipated. **Figures 3.4** through **3.8** depict the various alternatives in relation to Longhorn dam and potential future dam improvements.

Table 3.1 – Distance of Proposed Pedestrian Bridge Alternatives to Longhorn Dam (feet)

Longhorn Dam	Alt A Peninsula	Alt B Wishbone	Alt C Upstream	Alt D Downstream	Alt E Bridge Widening
South End	329	105	108	98	-
Center	391	209	177	140	-
North End	392	130	134	59	-

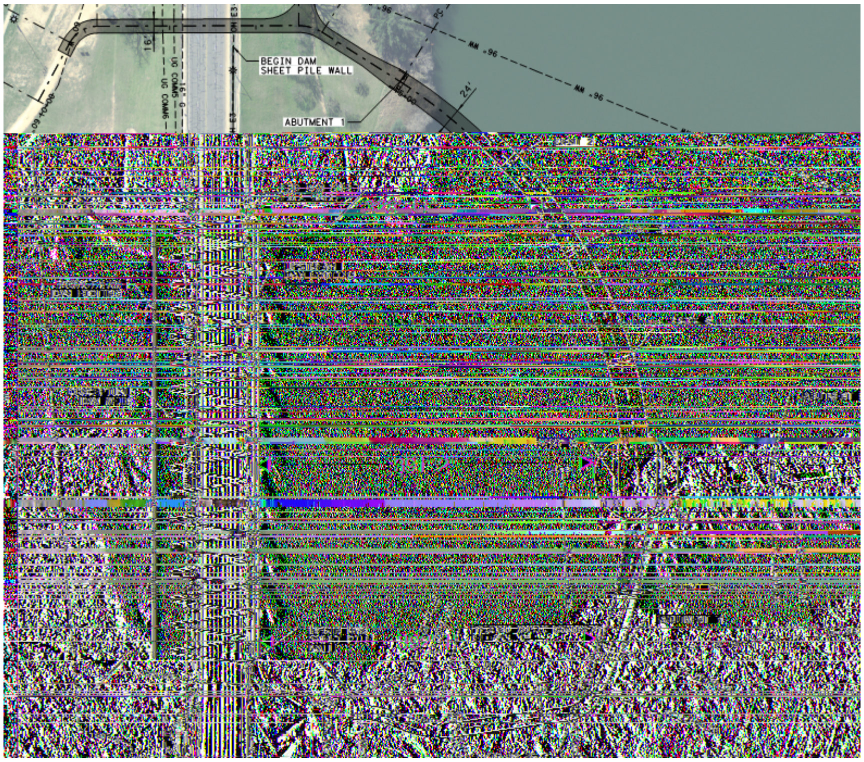

Figure 3.4 – Alternative A – Peninsula Plan View

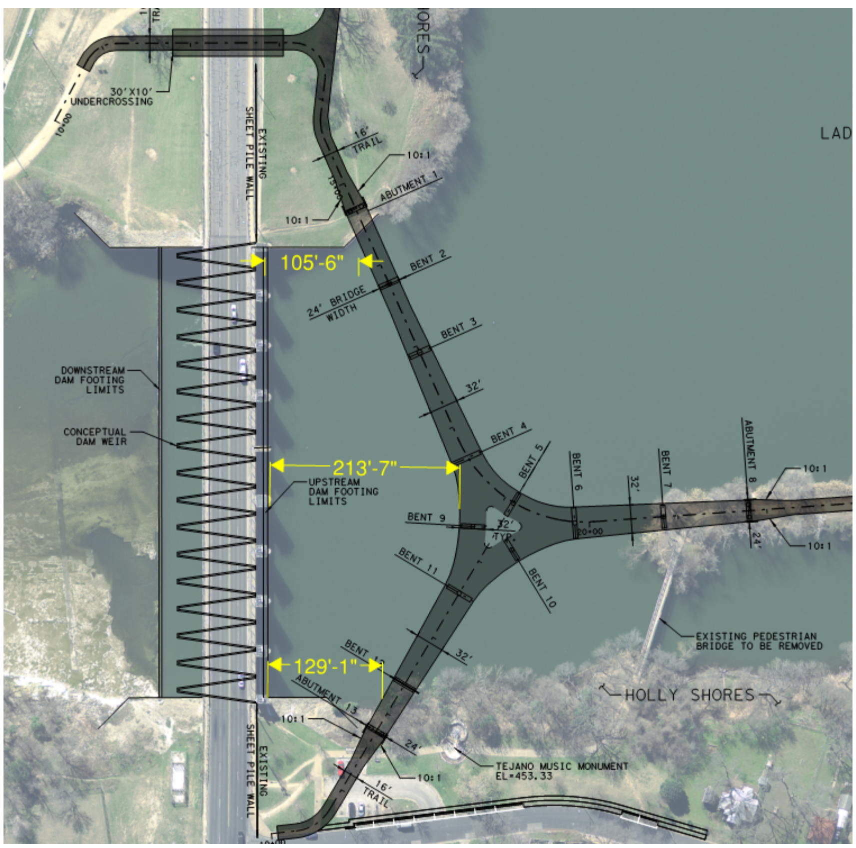

Figure 3.5 – Alternative B – Wishbone Plan View

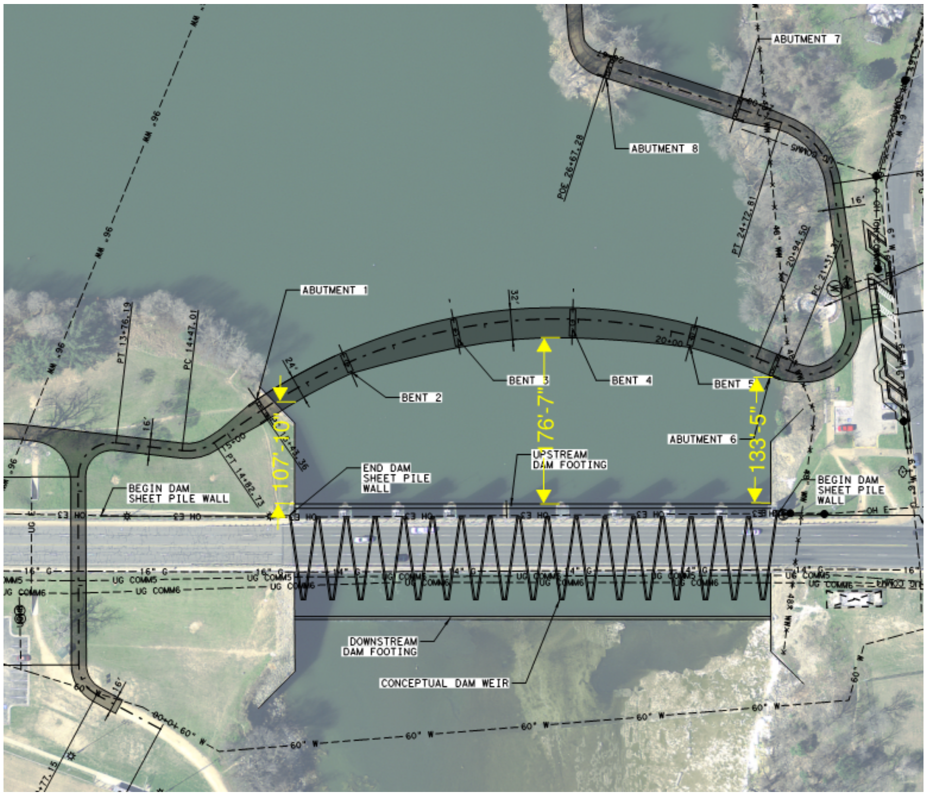

Figure 3.6 – Alternative C – Upstream Plan View

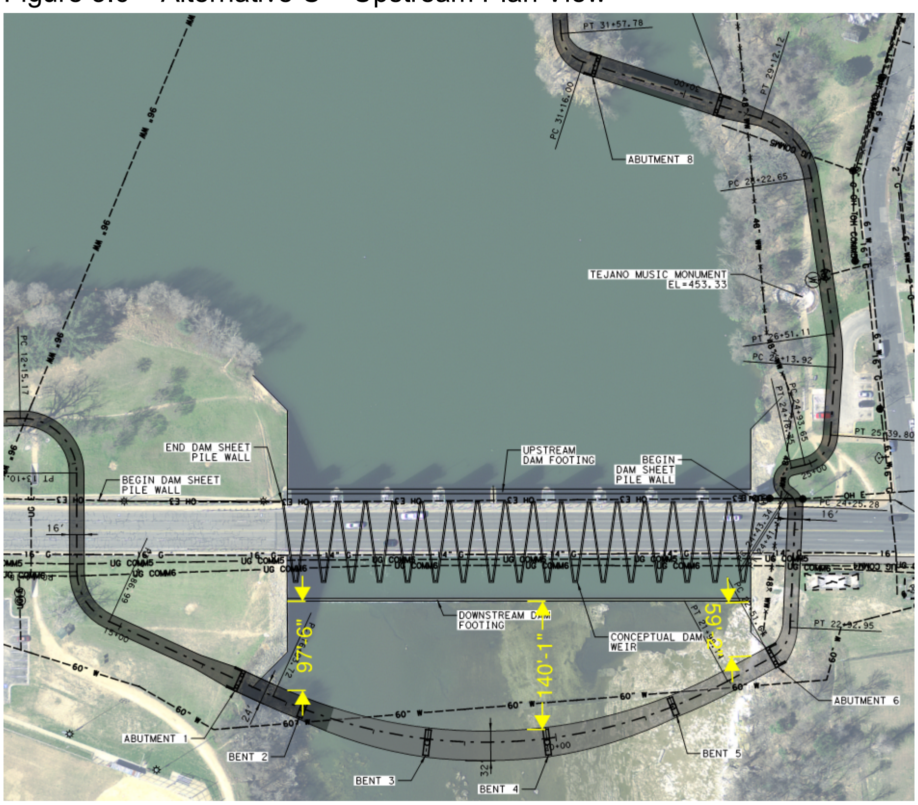

Figure 3.7 – Alternative D – Downstream Plan View

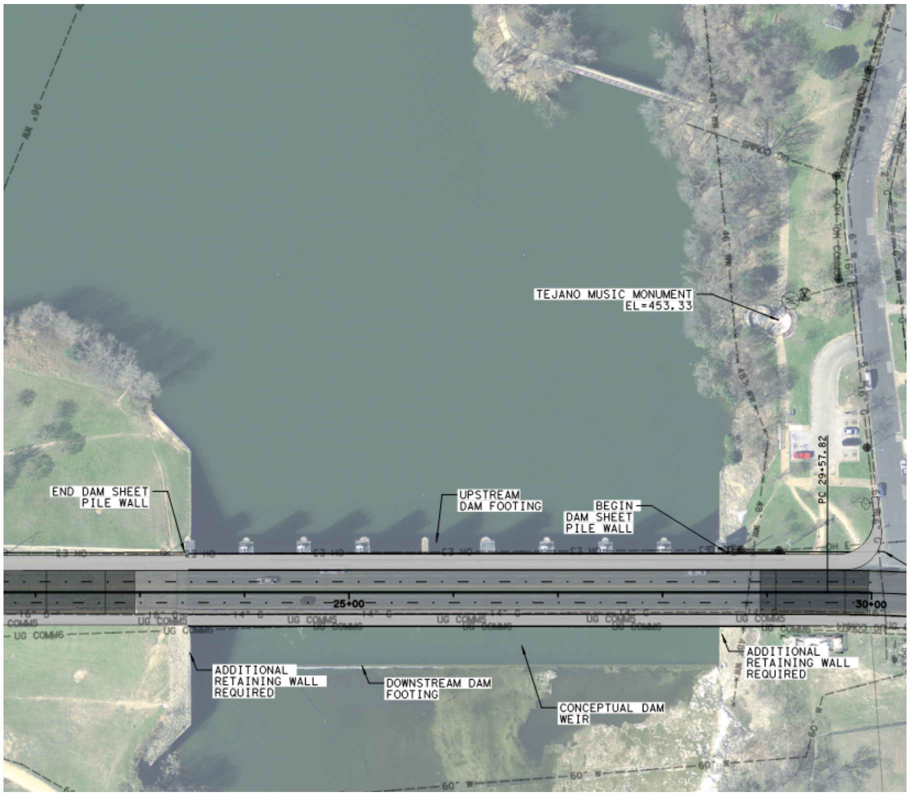

Figure 3.8 – Alternative E – Bridge Widening Plan View

Section 4 - Minimum Low Chord

The City requested that the minimum low chord be the higher of the 100-year Energy Grade Line (EGL) or the clearance required for boat maintenance access. The following table summarizes the pre-project 100-year EGL.

Table 4.1 – *Duplicate Effective* 100-year energy grade line elevations upstream and downstream of Longhorn Dam

Location	WSE (ft)	Velocity Head (ft)	EGL (ft)
Upstream of Longhorn Dam (RS1558754)	438.61	0.75	439.36
Downstream of Longhorn Dam (RS1558511)	441.03	0.45	441.48

The energy gradient elevation upstream of the dam is above the required maintenance boat clearance elevation of 437 feet. Thus the 100-year energy gradient elevation was used to initially set the minimum bridge low chord upstream of the dam. The proposed model results will be rechecked to verify the bridge low chord is above the energy gradient line elevation.

Note the City does not anticipate and near term changes to the effective Colorado River hydrologic and hydraulic models due to Atlas 14.

Section 5 - Hydraulic Impacts on Water Surface Elevations

The objective of this section is to analyze the hydraulic impacts that the proposed alternatives have on water surface elevations of the Colorado River and to identify any potential mitigation measures to remove any adverse impacts. Note, Alternative D – Widening Bridge, does not propose any improvements that impact the floodplain and thus is not included in this section.

Revised Existing Model

The *Duplicate Effective* model was updated to create a *Corrected Effective* model to more accurately evaluate the impacts of the various bridge alternatives. The update added the existing Holly peninsula and pedestrian bridge (see **Figures 5.1** and **5.2** below). The existing pedestrian bridge is roughly 130 feet long, 7 feet wide, includes a 42 inch tall railing on both sides, and is located approximately 10.5 feet above the permanent water surface elevation of 428.5 ft-msl. The top of bridge elevation of roughly 439 ft-msl is located beneath the 50-year water surface elevation. The existing pedestrian bridge connects the north shore of Lady Bird Lake to an existing earthen peninsula that runs 1,100 linear feet along the north embankment with a high bank elevation of roughly 432 ft-msl.

Figure 5.1 – 2018 Google Earth aerial view of Holly Peninsula and existing pedestrian bridge

Figure 5.2 – Picture of existing pedestrian bridge during HDR field survey

Figure 5.3 below depicts the HEC-RAS cross-section view of the existing pedestrian bridge. This *Corrected Effective* model forms the basis for determining hydraulic impacts.

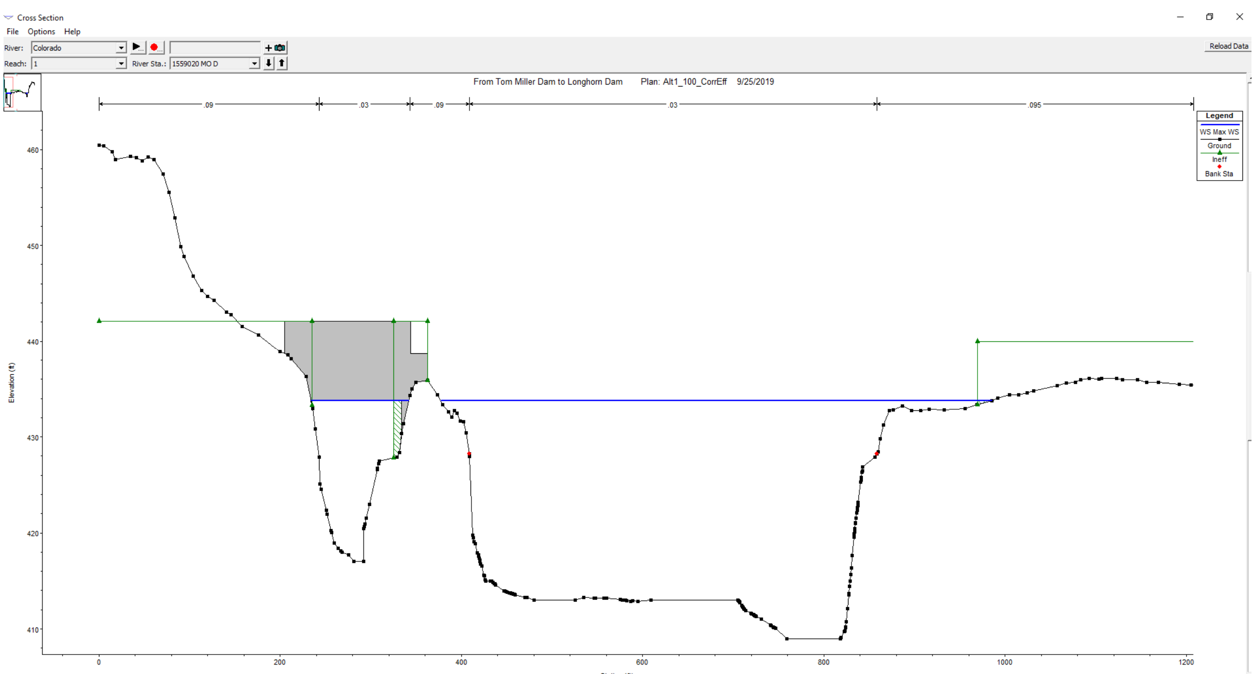

Figure 5.3 – *Corrected Effective* Model - HEC-RAS 100-year cross-section of exist pedestrian bridge

Alternative A – Peninsula Hydraulic Impacts on Water Surface Elevations

The 'peninsula' alternative hydraulic profile includes eight (8), five (5) foot diameter piers and the south abutment in the floodplain (see **Figure 5.4**). The piers are generally spanned 130 feet apart. The abutment landing along Holly peninsula is represented using a blocked obstruction. This alternative replaces the existing pedestrian bridge connected to the Holly peninsula and also recesses the pier caps to remove them from the 100-year floodplain. The above improvements resulted in upstream impacts as summarized in **Table 5.1**. The number of piers would need to be reduced further to remove all impacts under this alternative, however it was not explicitly modeled. Given the upstream impacts are only 0.03 feet this may be feasible if this alternative was moved forward in design.

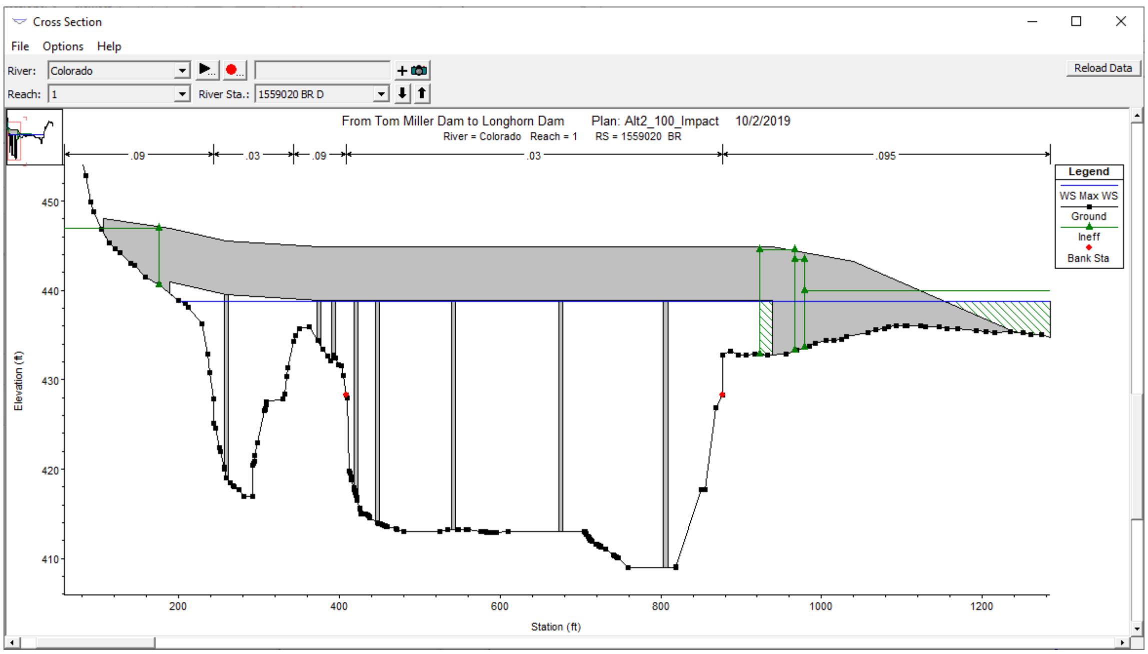

Figure 5.4 – Alternative A – Peninsula – Impact Analysis - HEC-RAS 100-year Profile View

Table 5.1 – Alt A – Peninsula - 100-Year Water Surface Elevation Analysis				
Cross Section	Description	WSE Corrected Effective	WSE Proposed – Alt2	Impact Delta (feet)
1558754	Longhorn Dam	438.61	438.61	0.00
1559327	Upstream Project	439.33	439.36	0.03
1566218	IH-35	439.70	439.73	0.03
1571555	Congress Ave.	440.83	440.85	0.02
1572530	First St.	440.86	440.89	0.03
1574746	UPRR	441.75	441.77	0.02
1575242	Lamar Ped/Bike	442.31	442.33	0.02
1575457	Lamar Blvd	442.42	442.44	0.02
1576840	Barton Creek	442.58	442.60	0.02
1581093	Mopac	444.04	444.05	0.01
1589459	Redbud Trail	445.92	445.93	0.01
1590256	Tom Miller Dam	448.27	448.28	0.01

Alternative B – Wishbone Hydraulic Impacts on Water Surface Elevations

Wishbone – Mitigation Model 1

The ‘wishbone’ alternative modeling approach includes a traditional bridge structure to represent the bridge deck, abutments, and piers perpendicular to the flow and blocked obstructions to represent the bridge deck, abutments, and piers parallel to the flow. The hydraulic profile for the traditional bridge structure includes eight, five foot diameter piers and its south abutment in the 100-year floodplain (see **Figure 5.5**). In the hydraulic profile, the pier span range from 30 to 130 feet apart. The two remaining piers were modeled as obstructions, each five feet wide at cross-sections just upstream of their locations. The abutment landing on Holly Peninsula was modeled using a 24 foot wide blocked obstruction. To mitigation upstream impacts for this alternative the pier caps were recessed to remove them from impacting the floodplain and the existing pedestrian bridge connected to the Holly peninsula was removed. These mitigation measure resulted in a significant reduction in the amount of upstream impact but did not remove all the impacts as shown in **Table 5.2** below.

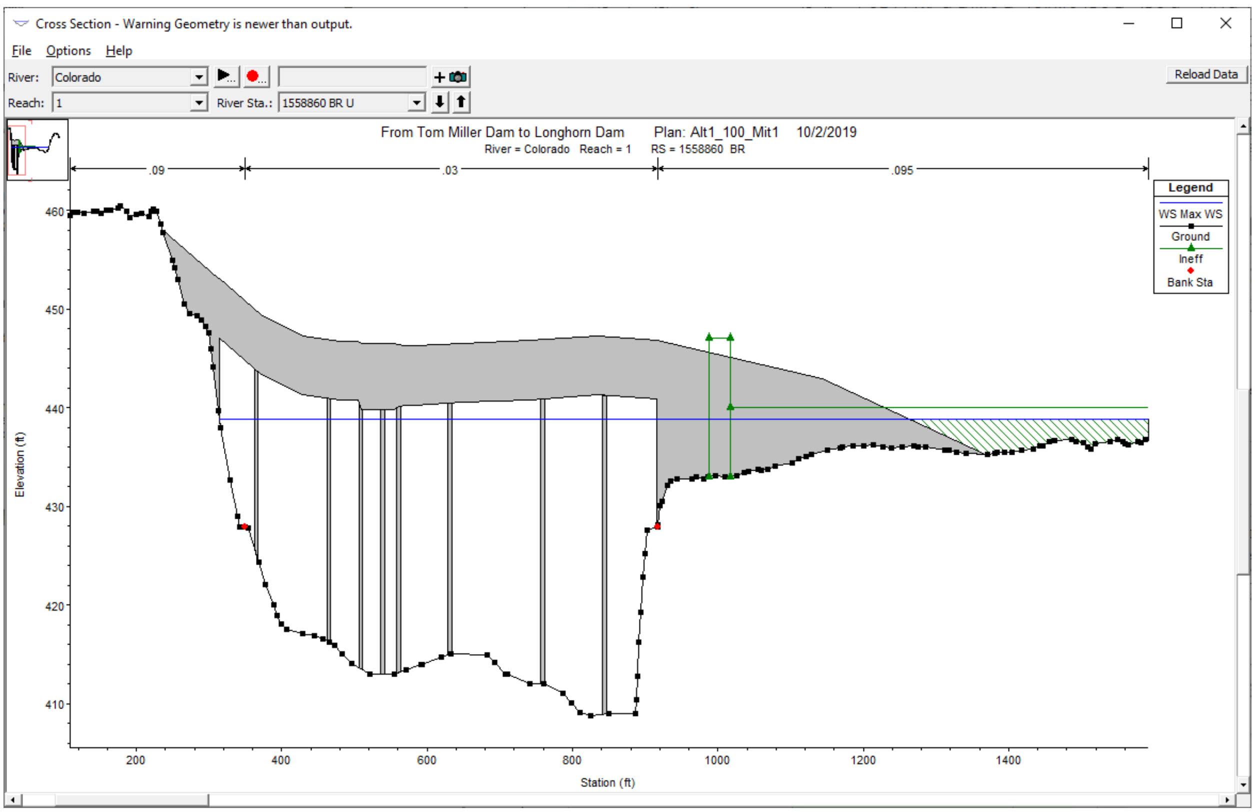

Figure 5.5 – Alternative B – Wishbone – Impact - HEC-RAS 100-year Profile View

Table 5.2 – Alternative B – Wishbone – Mitigation 1 - 100-Year Water Surface Elevation Analysis						
Cross Section	Description	WSE Corrected Effective	WSE Impact	Impact Delta (feet)	Proposed - Mit1	
					WSE (ft)	Impact (ft)
1558754	Longhorn Dam	438.61	438.61	0.00	438.61	0.00
1559327	Upstream Project	439.32	439.46	0.14	439.39	0.07
1566218	IH-35	439.69	439.82	0.13	439.75	0.06
1571555	Congress Ave.	440.82	440.94	0.12	440.87	0.05
1572530	First St.	440.86	440.97	0.11	440.91	0.05
1574746	UPRR	441.75	441.85	0.10	441.79	0.04
1575242	Lamar Ped/Bike	442.31	442.4	0.09	442.35	0.04
1575457	Lamar Blvd	442.42	442.51	0.09	442.46	0.04
1576840	Barton Creek	442.58	442.67	0.09	442.62	0.04
1581093	Mopac	444.04	444.11	0.07	444.07	0.03
1589459	Redbud Trail	445.92	445.98	0.06	445.95	0.03
1590256	Tom Miller Dam	448.27	448.31	0.04	448.29	0.02

Wishbone - Mitigation Model 2

Additional mitigation measures were applied to the wishbone alternative by moving the south abutment south approximately 65 feet to be contained within the existing ineffective flow boundary of Longhorn Dam (see **Figure 5.6**). This additional measure resulted in an additional reduction in the amount of upstream impact, but did not remove all the impacts as shown in **Table 5.3** below.

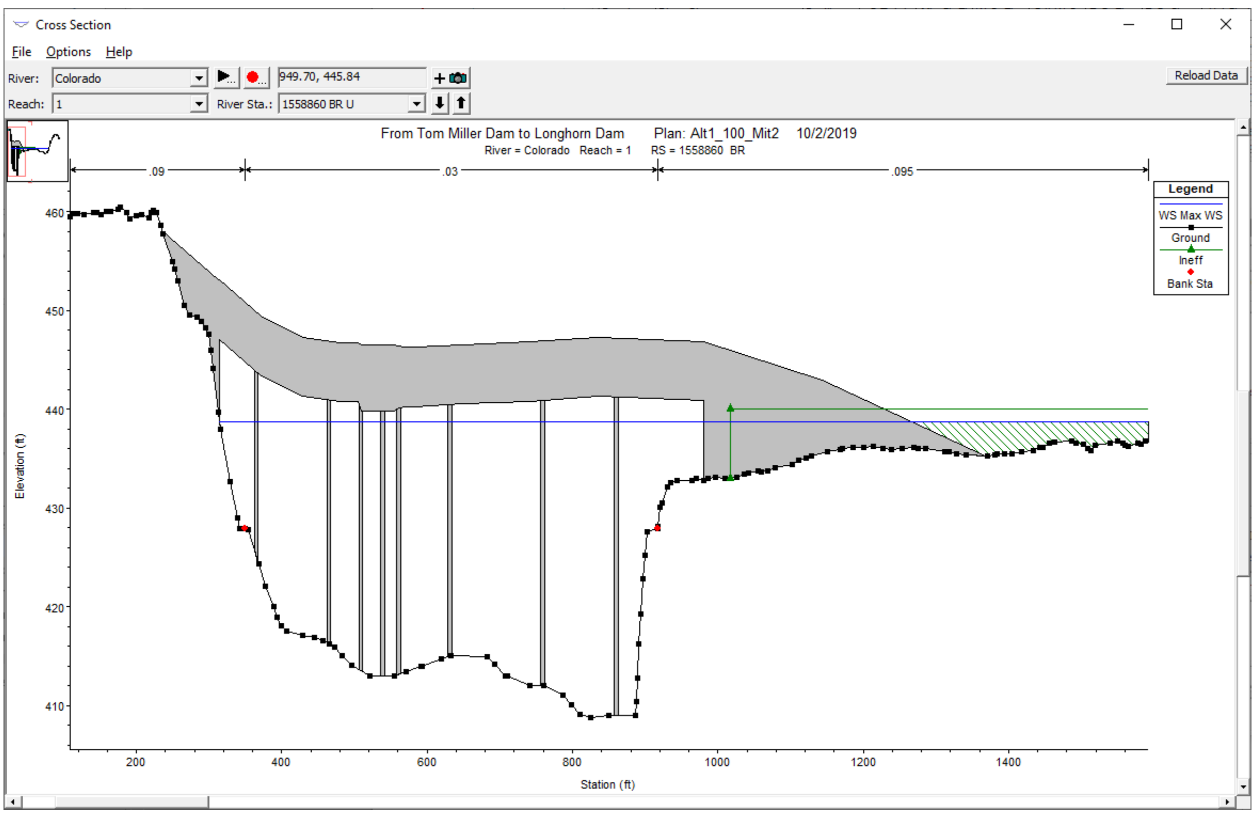

Figure 5.6 – Alternative B – Wishbone – Mitigation 2 - HEC-RAS 100-year Profile View

Table 5.3 – Alternative B – Wishbone – Mitigation 2 - 100-Year Water Surface Elevation Analysis						
Cross Section	Description	WSE Corrected Effective	WSE Impact	Impact Delta (feet)	Proposed - Mit2	
					WSE (ft)	Impact (ft)
1558754	Longhorn Dam	438.61	438.61	0.00	438.61	0.00
1559327	Upstream Project	439.32	439.46	0.14	439.37	0.05
1566218	IH-35	439.69	439.82	0.13	439.73	0.04
1571555	Congress Ave.	440.82	440.94	0.12	440.86	0.04
1572530	First St.	440.86	440.97	0.11	440.89	0.03
1574746	UPRR	441.75	441.85	0.10	441.78	0.03
1575242	Lamar Ped/Bike	442.31	442.4	0.09	442.34	0.03
1575457	Lamar Blvd	442.42	442.51	0.09	442.45	0.03
1576840	Barton Creek	442.58	442.67	0.09	442.60	0.02
1581093	Mopac	444.04	444.11	0.07	444.06	0.02
1589459	Redbud Trail	445.92	445.98	0.06	445.94	0.02
1590256	Tom Miller Dam	448.27	448.31	0.04	448.28	0.01

Wishbone - Mitigation Model 3

To further reduce impacts, mitigation model 3 reduces the number of piers from ten to seven with spans increased to a minimum of 50 feet hydraulically, as shown in **Figure 5.7**, in addition to the mitigation strategies already discussed in mitigation model 1 and 2. To achieve this the structural beams for the center landing pad of the 'wishbone' alternative would need to be changed from concrete to steel which would negate the three center piers (bents 5, 9, and 10 in **Figure 5.8**). An additional strategy for reducing impacts upstream included removing part of the Holly Peninsula to compensate for the lost flow area, but this proved to be ineffective. This alternative is likely to have upstream impacts, as shown in **Table 5.4**, and thus requiring a floodplain variance.

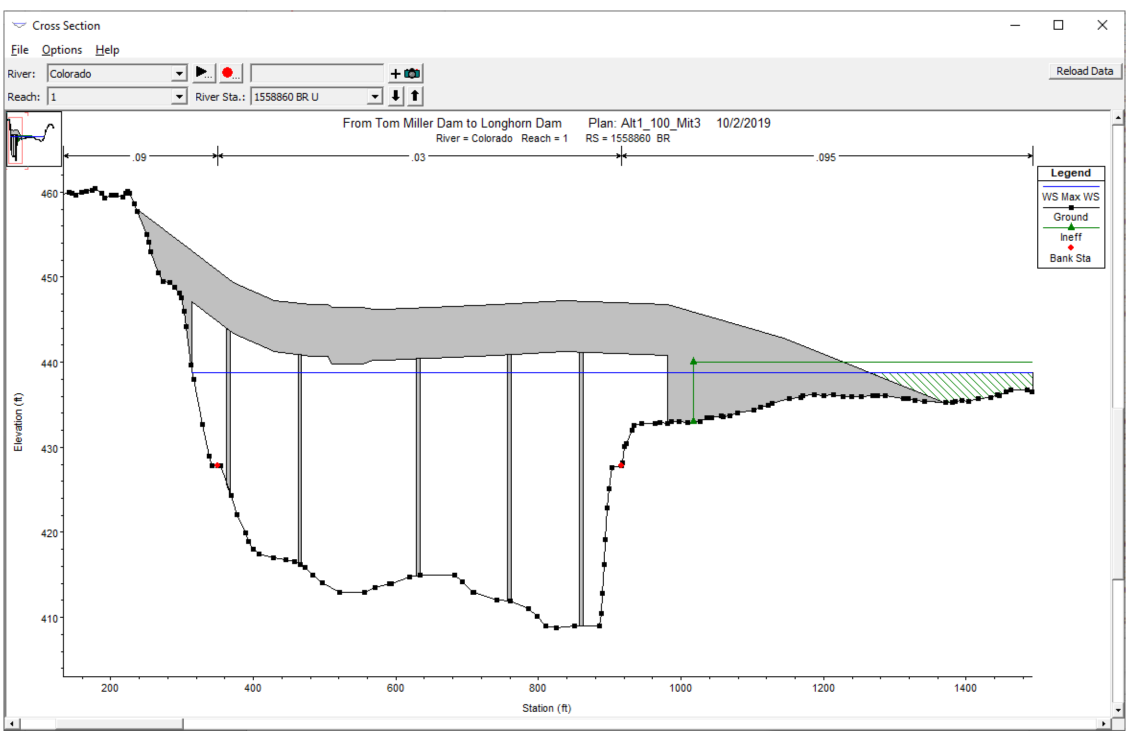

Figure 5.7 – Alternative B – Wishbone – Mitigation 3 - HEC-RAS 100-year Profile View

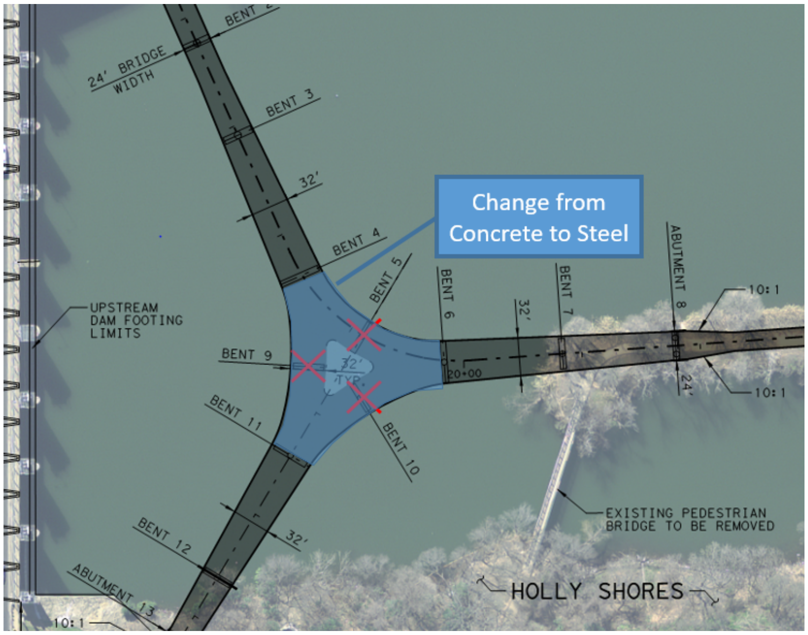

Figure 5.8 – Alternative B – Wishbone – Mitigation 3 – Removal of Center Piers

Table 5.4 – Alternative B – Wishbone – Mitigation 3 - 100-Year Water Surface Elevation Analysis

Cross Section	Description	WSE Corrected Effective	WSE Impact	Impact Delta (feet)	Proposed - Mit3	
					WSE (ft)	Impact (ft)
1558754	Longhorn Dam	438.61	438.61	0.00	438.61	0.00
1559327	Upstream Project	439.32	439.46	0.14	439.34	0.02
1566218	IH-35	439.69	439.82	0.13	439.71	0.02
1571555	Congress Ave.	440.82	440.94	0.12	440.84	0.02
1572530	First St.	440.86	440.97	0.11	440.87	0.01
1574746	UPRR	441.75	441.85	0.10	441.76	0.01
1575242	Lamar Ped/Bike	442.31	442.4	0.09	442.32	0.01
1575457	Lamar Blvd	442.42	442.51	0.09	442.43	0.01
1576840	Barton Creek	442.58	442.67	0.09	442.59	0.01
1581093	Mopac	444.04	444.11	0.07	444.05	0.01
1589459	Redbud Trail	445.92	445.98	0.06	445.93	0.01
1590256	Tom Miller Dam	448.27	448.31	0.04	448.27	0.00

Alternative C – Upstream Hydraulic Impacts on Water Surface Elevations

The 'upstream' alternative hydraulic profile includes four, five foot diameter piers and north and south abutments in the floodplain (see **Figure 5.9**). The piers are generally spanned 125 feet apart. This alternative replaces the existing pedestrian bridge connected to the Holly peninsula but does not raise it out of the floodplain. This alternative also recesses the pier caps to remove them from the 100-year floodplain. The above improvements resulted in upstream impacts as summarized in **Table 5.5** below. The upstream impacts for this alternative are higher due to the existing pedestrian bridge connection to the Holly peninsula remaining. This alternative is likely to have upstream impacts and thus requiring a floodplain variance.

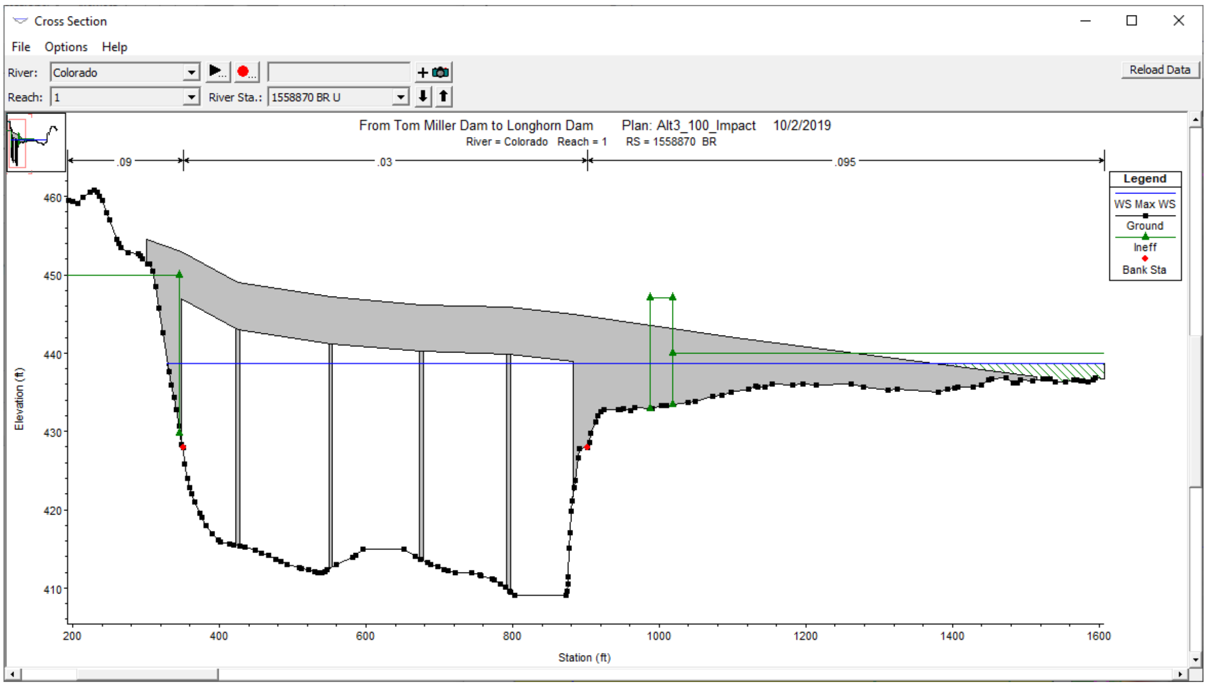

Figure 5.9 – Alternative C – Upstream – Impact Analysis - HEC-RAS 100-year Profile View

Table 5.5 – Alt C – Upstream - 100-Year Water Surface Elevation Analysis

Cross Section	Description	WSE Corrected Effective	WSE Proposed Alt3	Impact Delta (feet)
1558754	Longhorn Dam	438.61	438.61	0.00
1559327	Upstream Project	439.31	439.41	0.10
1566218	IH-35	439.68	439.78	0.10
1571555	Congress Ave.	440.81	440.90	0.09
1572530	First St.	440.84	440.93	0.09
1574746	UPRR	441.74	441.81	0.07
1575242	Lamar Ped/Bike	442.30	442.37	0.07
1575457	Lamar Blvd	442.41	442.48	0.07
1576840	Barton Creek	442.57	442.63	0.06
1581093	Mopac	444.03	444.08	0.05
1589459	Redbud Trail	445.91	445.96	0.05
1590256	Tom Miller Dam	448.26	448.29	0.03

Alternative D – Downstream Hydraulic Impacts on Water Surface Elevations

The 'downstream' alternative hydraulic profile includes four, five foot diameter piers and north and south abutments in the floodplain (see **Figure 5.10**). The piers are generally spanned 125 feet apart. This alternative replaces the existing pedestrian bridge connected to the Holly peninsula but does not raise it out of the floodplain. This alternative also recesses the pier caps to remove them from the 100-year floodplain. The disconnection of the City effective hydraulic model at Longhorn Dam does not allow for HDR to reasonably ascertain the impacts of the proposed structure that has components both upstream and downstream of the Dam. For the purposes of the impact analysis, a simplified steady-state model developed by City staff in fall of 2018 and obtained by HDR in March 2019 was used in lieu of the effective model. This simplified model evaluates a peak flow of 90,000 cfs which is roughly equivalent to the 100-year event simulated in the effective model. This model does not extend all the way upstream to Tom Miller Dam or downstream to the USGS gage in Bastrop instead being bound by IH-35 and US 183 crossings. The above improvements resulted in impacts surrounding Longhorn Dam and upstream of the project as summarized in **Table 5.6** below.

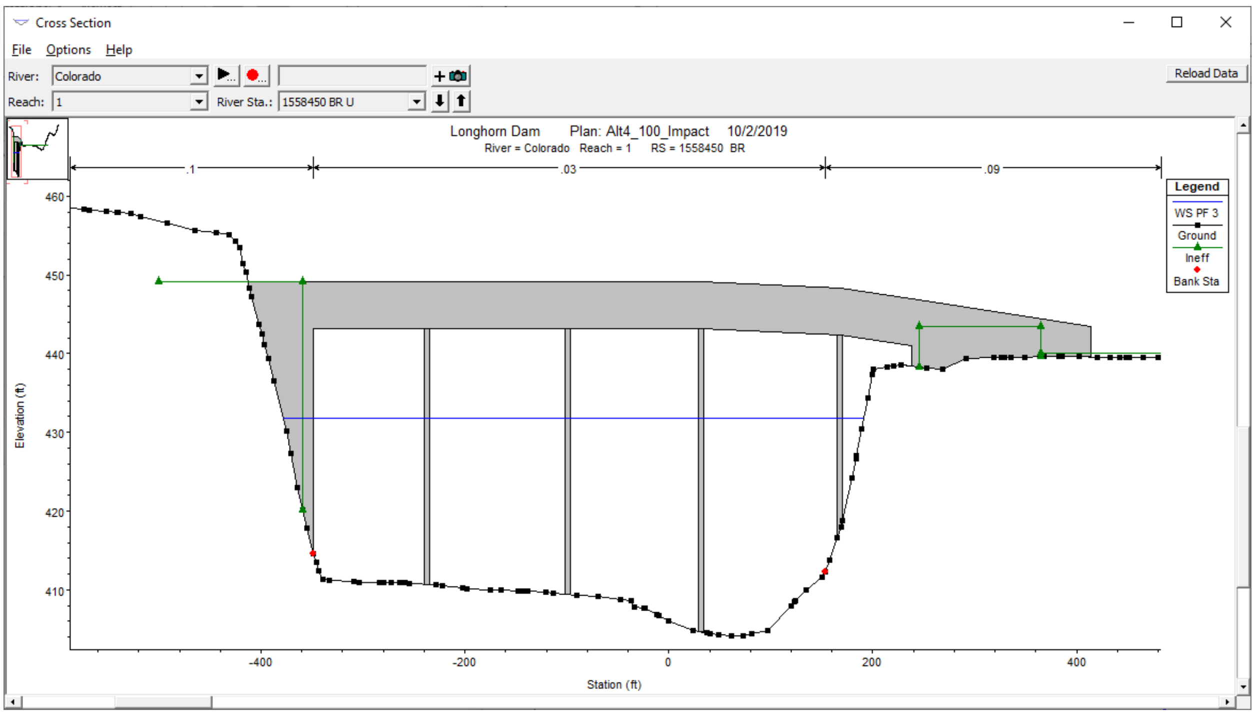

Figure 5.10 – Alternative D – Downstream – Impact Analysis – HEC-RAS 100-year Profile View

Table 5.6 – Alt D – Downstream - 100-Year Water Surface Elevation Analysis				
Cross Section	Description	WSE Corrected Effective	WSE Proposed Alt 4	Impact Delta (feet)
1550203	US 183	423.48	423.48	0.00
1558192	Downstream Project	431.75	431.75	0.00
1558511	Downstream Longhorn Dam	431.84	431.93	0.09
1558754	Upstream Longhorn Dam	437.60	437.67	0.07
1559327	Upstream Project	438.43	438.49	0.06
1566218	IH-35	438.95	439.00	0.05

The 'downstream' alternative does appear to have adverse impacts upstream of the project area as evident by increased water surface elevations upstream of the project to IH35. If this alternative was moved forward in the design a more detailed combined model would need to be developed, however, this alternative is likely to have upstream impacts and thus requiring a floodplain variance.

Alternative Impact Summary

Table 5.7 – Alternative 100-year Water Surface Elevation Impact Summary		
Alternative	Mitigation Measures	Max. Upstream Impact (feet)
Alt A – Peninsula Impact	Recess pier caps	0.03
Alt B – Wishbone Impact	Recess pier caps, Keep Holly Ped. Bridge	0.14
Alt B – Wishbone Mit 1	+ Remove Holly Ped. Bridge	0.07
Alt B – Wishbone Mit 2	+ Move south abutment to ineffective flow area	0.05
Alt B – Wishbone Mit 3	+ Remove 3 center piers	0.02
Alt C – Upstream Impact	Recess pier caps	0.10
Alt D – Downstream Impact	Recess pier caps	0.05
Alt E – Widening	N/A	0.00

Alternative A (Peninsula), Alternative C (Upstream), and Alternative D (Downstream) as currently conceived are showing adverse impacts to existing flood conditions and include impacts to PARD property. Additional mitigation measures are required or a floodplain variance, and PARD approval obtained, if these alternatives are move forward in design.

Alternative B (Wishbone) is also showing adverse impacts on existing flood conditions and to PARD property. But impacts are reduced if the following mitigation measures are implemented: recess pier caps to above the 100-year water surface elevation; remove the Holly pedestrian bridge; limit the south abutment encroachment to the ineffective flow area; and remove the three center piers.

Alternative E (Widening) does not appear to have adverse impacts on existing flood conditions. However, further detailed hydraulic modeling would be required to verify the initial no impact results for this alternative.

Section 7 - Bridge Countermeasures for Hydraulic Forces and Scour

Given the conceptual nature of this study detailed scour calculations and hydraulic load calculations were not performed. If the project moves forward in design then procedures as outlined in HEC-18, 20, and 23 should be followed to determine the scour envelop and hydraulic loads. The objective of this section is to provide preliminary recommendations for bridge countermeasures to withstand scour and hydraulic loads.

Hydraulic Forces Countermeasures for Submerged Superstructure

The proposed pedestrian bridge is anticipated to be submerged during the 500-year storm event. The following provides recommended best practices to implement when a bridge superstructure is submerged:

- Hydraulic Forces - The proposed pedestrian bridge should be designed to resist the hydraulic forces associated with a 500-year event.
- Deck Thickness - Make bridge deck as shallow as possible.
- Railing - Use slender open railing and assume railing openings blocked in analysis.
- Design for impact, hydrodynamic drag and lift, buoyant, and hydrostatic forces. Consider debris impacts and loading (reference NCHRP 653 for geometry guidance).
- Anchor superstructure and allow air to vent.
- Structure Type – Consider continuous span over simple span bridges to withstand forces due to scour and resultant foundation movement when significant.

Scour Countermeasures

Eroding bed material around bridge foundations is the most common cause of bridge failure (HDS-7). According to 1959 borings near the dam, the channel bed is anticipated to be shale with some sand and gravel present along the south channel bank. These soils are non-cohesive soils, in which scour progresses more rapidly than cohesive type soils.

A scour analysis is recommended for all new bridges. Total scour depths represent a combination of long-term degradation or aggradation, contraction scour, and local scour at piers and abutments. Given that Longhorn Dam is located immediately downstream of the proposed upstream pedestrian bridge alternatives, and acts as a grade control, greatly reduces the risk of long-term degradation of the channel for the upstream alternatives. However, the downstream alternative is susceptible to long-term degradation. All alternatives are susceptible to contraction and local scour at the proposed bridge piers and abutments. The following provides a list of best practices from HEC-18 to implement to reduce the risk of bridge failure from scour:

- Define Scour Envelop - Perform bridge foundation analysis assuming all streambed material in the scour prism has been removed and is not available for bearing or lateral support.
- Scour Design Frequency - HEC-18 recommends for Q100 design, use Q200 for scour design, and Q500 for check.
- Factor in Storm Debris – Determine if a problem and if so consider storm debris in hydraulic and scour calculations;
- Abutment Slopes - Provide sloping spill-through type abutment, as scour for this type of abutment is about 50 percent of the scour that occurs at vertical wall abutments.

- Abutment Armoring - Provide riprap or other bank protection methods on the upstream and downstream side of an abutment or approach embankment to protect against accelerating flows to protect them from erosion by flow expansions and wake vortices.
- Streamline Piers - Align bridge piers and caps with flow and provide round nosed piers;
- Understand Flood Flow Pattern - Identify bridge elements most vulnerable to overall flood flows.
- Drilled Shafts and Driven Pilings - Place the top of the footing or pile cap below the streambed at a depth equal to the estimated long-term degradation and contraction scour depth.
- Piers in Main Channel - All piers in the main channel should be designed to the same elevation. Similar consideration should be given to pier foundations in the floodplain.