US Army Corps of Engineers
Lower Guadalupe River Basin
Guadalupe-Blanco River Authority
Interim Feasibility Study
Technical Report Notebook (TRN)
Alternative Development

Blanco and San Marcos Rivers Confluence

Submitted to:

US Army Corps of Engineers®

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Alternatives Development
TECHNICAL REPORT NOTEBOOK

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ALTERNATIVES DEVELOPMENT
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OVERVIEW

The Guadalupe-Blanco River Authority (GBRA) Interim Feasibility Study is a detailed engineering study located in the Lower Guadalupe River Basin. The study stretches along the Guadalupe River from Canyon Lake to the Victoria County line, along the Blanco River starting in Hays County, and along the San Marcos River to its confluence with the Guadalupe River. The study is being undertaken by the United States Army Corps of Engineers (USACE), the Texas Water Development Board (TWDB), and the GBRA. This Technical Report Notebook (TRN) gives an overview of proposed flood damage reduction alternatives for the confluence of the Blanco and San Marcos Rivers.

The confluence of the Blanco and San Marcos Rivers has been the focus of repeated historical flooding. The largest recorded flood event to date on the Blanco River occurred on Memorial Day weekend in May 2015, inundating many buildings and homes in the overflow areas between the Blanco and San Marcos Rivers. The May 2015 flood event revealed the need for a better understanding of the flow dynamics and flooding extents in the neighborhoods and business centers in the overflow area to improve the floodplain permitting process and determine the impacts of recent developments.

A brief summary of recent hydraulic simulations of the Blanco / San Marcos confluence are described below.

- **GBRA/USACE/TWDB IFS:** Halff developed the initial steady-state 1D hydraulic models for the Blanco and San Marcos Rivers. From this original analysis, it was evident that the Blanco/San Marcos confluence area required a more dynamic analysis to better evaluate flood risks. The 1D hydraulic models were then converted to 1D unsteady hydraulic models.
- **San Marcos 2D Model:** After the May 2015 flood, the City wanted to develop a more sophisticated model of the Blanco / San Marcos confluence for planning purposes. To improve on the ID models of the Blanco and San Marcos Rivers recently developed for the IFS, the City of San Marcos contracted Halff to develop a 2D hydraulic analysis of the confluence and overflow areas to better model the complex multi-directional flow patterns occurring in the overflow area. The IFS 1D unsteady hydraulic models were truncated to represent the 1D portions of the Blanco River and San Marcos while the overland mesh was formed using the Hays County 2008 LiDAR. The 2D model was calibrated to surveyed and observed high water marks from the May 2015 flood event. The Innovyze Integrated Catchment Modeling (ICM) version 6.5.9 platform was utilized to complete the requested 2D simulations.
- **FEMA Physical Map Revision:** Near the completion of the City of San Marcos 2D model development, FEMA initiated the Physical Map Revision (PMR) of the Guadalupe-Blanco River Basin. The City's 2D ICM model was used to refine the 1D HEC-RAS simulations for FEMA modeling and mapping purposes. The graphic below displays the various PMR 1D HEC-RAS simulations that were used to develop the preliminary floodplains and associated water surface elevations. The main stem Blanco River and San Marcos Rivers are simulated using 1D unsteady HEC-RAS, but all other models are 1D steady-state models. The 1D conversion was conducted with the goal of achieving similar flows and resulting water surface elevations as the 2D simulation (primarily for the 1% annual chance event).

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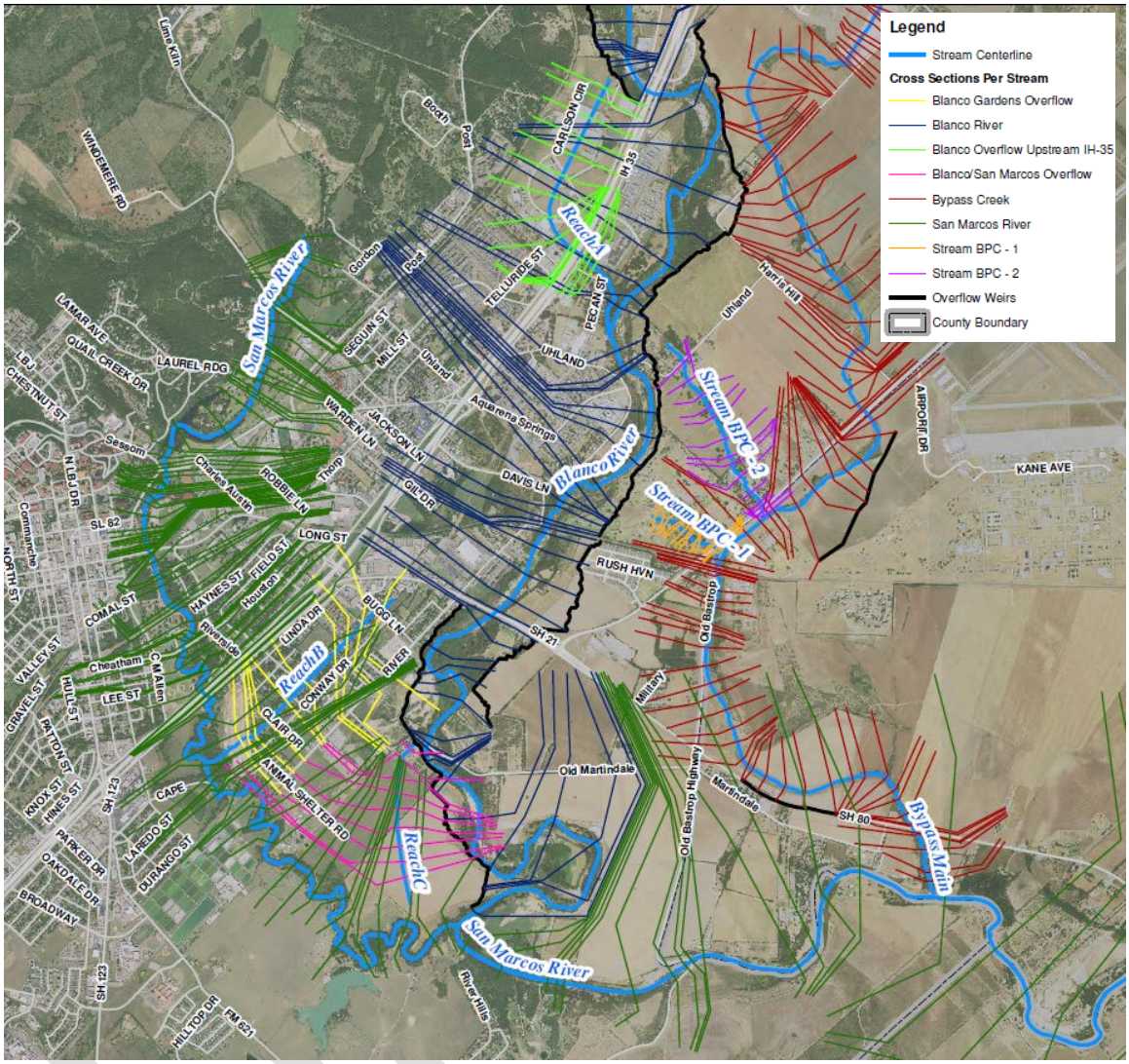

Figure 1. FEMA Physical Map Revision Hydraulics

The Infoworks ICM platform was selected for the City of San Marcos simulations. Although XPSWMM and HEC-RAS 5.0 are 2D modeling platforms that are accepted by FEMA, Infoworks ICM was selected due to the model's stability with large datasets, ability to simulate underground conveyance systems, and time efficiency to execute multiple 2D simulations. Given the USACE's need for expedited alternatives analysis of this complex area, it was recommended that the City's available Infoworks ICM model be utilized to advance the Tentatively Selected Plan (TSP) analysis. A 2D simulation is preferred rather than utilizing multiple PMR 1D HEC-RAS simulations to observe overall risk. Time constraints did not allow for the model to be converted and re-calibrated to a USACE approved platform such as HEC-RAS 5.0. Additionally, HEC-RAS 5.0 does not allow for the simulation of underground conveyance systems or complex alternatives analysis in the overland 2D mesh.

The recently refined Infoworks ICM 2D model extends from just west of I-35 down to the confluence of the San Marcos River and Bypass Creek and can be seen in the figure below. The red line represents the 2D modeling extents and the blue shaded area is the preliminary FEMA 1% annual chance event (ACE) floodplain.

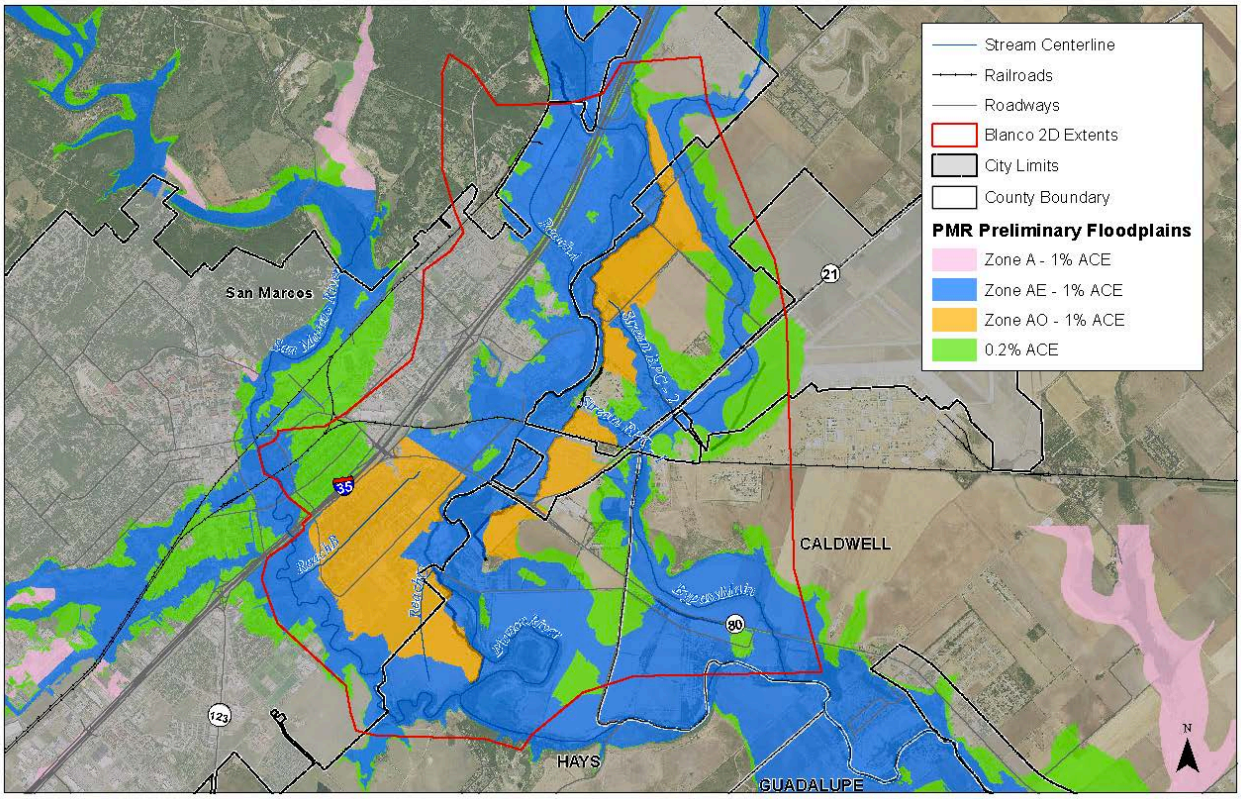

Figure 2. 2D Model Extents

A calibration of the ICM model was performed to the May 2015 flood event. The model was calibrated to surveyed high water marks (provided by GBRA), a stage hydrograph, and estimated high water marks in the Blanco Gardens neighborhood. Ten surveyed high water marks were collected throughout the study region and compared to the results of the hydraulic model. The stage hydrograph for the Blanco River located at State Highway 80 was obtained from the USGS website and compared to the stage hydrograph from the ICM model. The vertical datum of the USGS gage was adjusted to match the vertical datum of the surveyed high water mark at HWY 80. The peak stage of the model results are within 0.1 feet of the observed stage.

A validation of the calibrated model results was also performed to hand measured high water marks along Conway Street in the Blanco Gardens neighborhood. City staff provided high water marks taken at several addresses throughout the Blanco Gardens neighborhood. More than half of the measured high water marks were within 1 foot of the model results despite known inconsistencies in the determination of the measured depths. In summary, the computed results of the 2D compared favorably to the May 2015 high water marks.

HYDROLOGY

The primary hydrology utilized for this analysis was the Interagency Flood Risk Management (InFRM) San Marcos River Basin Hydrology prepared by the USACE Fort Worth District. The secondary hydrology utilized for this analysis was the FEMA PRM Bypass Creek Hydrology prepared by Halff Associates. Both hydrologic simulations utilized Hydraulic Engineering Center's Hydrologic Modeling System (HEC-HMS) version 3.5. The baseline hydrology was provided by the USACE dated July 2017. This new simulation had

been slightly modified since the PMR analysis, resulting in discharge differences less than 10 cubic feet per second (cfs).

In addition to the updated USACE hydrology model, the PMR Bypass Creek hydrology model was utilized at various nodes along Bypass Creek in the ICM model. Bypass Creek was modeled with a 2D zone in the original model and is modeled as a 1D river reach for this analysis. The frequency storm events analyzed included the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year storms. Application of the hydrologic results into the 2D model are described in Table 1 below.

Table 1. Application of Hydrology

River	Cross Section	HMS Model	HMS Element Name	Boundary Condition
San Marcos River	437930	July 2017 USACE San Marcos Basin HMS	J_USM0650	Flow Hydrograph
	434563		USM0660	Uniform Lateral Inflow
	430570		J_USM0700	Lateral Inflow Hydrograph
	429361		USM0710	Uniform Lateral Inflow
	428075		USM0720	
	427505		J_USM0320[A]	Lateral Inflow Hydrograph
	427343		USM0730	Uniform Lateral Inflow
	426620		USM0740	
	426196		USM0750	
	425437		USM0760	
	423396		USM0770	
	420755		J_USM1000_DIV_USM0910	
	419476		USM1010	
	415578		USM1020	
	412077		USM1030	
	410041		USM1040	
Blanco River	51519	July 2017 USACE San Marcos Basin HMS	Blanco_nr_Kyle_Gage & Blanco_S160[B]	Flow Hydrograph
	49825		Blanco_S160[C]	Uniform Lateral Inflow
	32463		Blanco_S170	
Bypass Creek	28960	April 2017 PMR HMS	J_BC030	Flow Hydrograph
	28067		BC040	Uniform Lateral Inflow
	24227		BC050	
	18904		BC060	
	17126		J_BC080	Lateral Inflow Hydrograph
	16962		BC090	Uniform Lateral Inflow
	13241		BC110	
	11399		BC130	
	9833		BC140	
			BC150	
			BC160	
	1552		BC170	

[A] Hydrograph for this element utilized an already reduced discharge assuming a 16.74mi^2 between 10 and 20 mi^2.
[B] Hydrograph for this element utilized an already reduced junction discharge combined with 59% of the subbasin.
[C] Hydrograph for this element utilized 41% of the subbasin.

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2D MODEL DEVELOPMENT

As noted previously, the 2D Blanco / San Marcos ICM model prepared for the City of San Marcos was utilized for this analysis. The 2D hydraulic model consisted of two types of flow regimes: 1D and 2D. The main stems of the Blanco River, San Marcos River, and Bypass Creek were modeled as 1D channel flow between channel bank stations. Overflow from each of these creeks was modeled as 2D overland flow which allows the flow to travel in multiple directions between mesh points.

Original Model Development

Hydraulic model data for the 1D channels were extracted from the 1D HEC-RAS hydraulic simulations. Data included the channel cross-sections, bank stations, roughness values, and bridge crossing information. ICM utilizes mesh triangles to distribute flow through the overland 2D extents. The mesh triangles are assigned elevations from the 2008 LiDAR that was confirmed with 2016 field survey spot shots in Blanco Gardens area. Roughness values are based on the assigned land use type. Manning's roughness values used for the 2D mesh ranged from 0.03 - 0.08 with buildings and homes being modeled as voids in the mesh. These values are consistent with standard modeling procedures as published in a document by W. J. Syme (2008) entitled "*Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences*." Roughness values as identified in Table 1 of the *FLO 2D Manual* are intended for shallow (<0.5 foot) overland flows. The roughness values in the Blanco / San Marcos ICM were selected for overland flows with 1 to 3 feet of depth. They were also selected as to not double count the assumed roughness through the neighborhood by using a high roughness value combined with voids in the mesh. Existing storm drain plans received from the City of San Marcos were also used to enhance the 2D section within the Blanco Gardens area. Finally, as-built plans were used to model the storm drain system under the Woodlands apartments. For more information on the original 2D model development, please see the *Blanco/San Marcos Confluence 2D Modeling Technical Memorandum* dated March 2016.

Model Refinement

With subsequent analysis in the Blanco / San Marcos confluence area since the development of the original 2D model, a few modifications were warranted. The modifications to the original 2D model are described below.

- **1D/2D Weir Locations:** The USACE provided a structure inventory point shapefile that represented structures (homes and businesses) that are potentially impacted by flood waters. These points were added into the 2D model to allows for a graphical representation and understanding of where impacted structures were located within the 2D model extents. Using the added structures (houses), the 1D river extents were trimmed (modified weir locations) such that most structures would be located in the overland 2D mesh. This weir relocation was performed such that water surface elevations for the impacted structures were consistently identified for the USACE benefit estimation.
- **Model Extents:** The 2D mesh extents on the upstream side of IH-35 were extended to identify additional impacted structures. It should be noted that the IH-35 configuration was raised to account for the existing concrete barrier between the northbound and southbound lanes.
- **Hydrologic Flows:** As noted above the USACE refined the InFRM San Marcos River Basin Hydrology in July 2017. This updated simulation was utilized for this analysis and applied to the 2D model as noted in Table 1 above.
- **Bypass Creek Flow Regime:** The original model simulated Bypass Creek as an overland 2D mesh. For this analysis, Bypass Creek was added as a 1D segment in order to best define the Bypass

Creek crossings and constrictions. This transition was also beneficial for the evaluation of Bypass Creek alternatives. The FEMA PMR 1D Bypass Creek hydraulic model (HEC-RAS version 4.1) was modified and imported into ICM. Cross sections in the HEC-RAS model were truncated on both the left and right overbanks to keep the 1D analysis to just outside the channel and to keep structures/voids outside of the 1D boundary. Once the cross sections were truncated, the updated geometry was imported into ICM and was finalized by checking the 1D cross sections to ensure the geometry and roughness values were imported correctly.

Crossings along Bypass Creek were input into the 1D river reach per the structure information provided in the unsteady HEC-RAS model. Bridges were input into the model in accordance to ICM practices and were separated by break nodes in between 1D river reaches. Culverts were modeled using conduits separated by break nodes in between 1D river reaches. Once the structures were added into the model, bank lines were created from the cross section extents and updated from the terrain in the ICM model. 1D/2D weir coefficients were set to 0.5 and the modular limit set to 0.9 for all the bank lines along Bypass Creek to maintain stability between the 1D/2D interaction.

- **Downstream Boundary Conditions:** In accordance with the FEMA PMR simulations, the downstream boundary conditions of the 2D model were refined. The boundary conditions of each frequency simulation were updated to match the San Marcos River PMR unsteady HEC-RAS simulations.
- **Recalibration:** With all the modifications listed above, it was necessary to recalibrate the model to the May 2015 historical event. Recalibration was conducted by using discharges from the May 2015 hydrologic simulation as provided by the USACE. Consistent with the original calibration, the updated model was calibrated to surveyed high water marks (provided by GBRA), a stage hydrograph, and estimated high water marks in the Blanco Gardens neighborhood. In order to replicate high water marks, 1D/2D weir coefficients were adjusted upstream of the Railroad and near the overflow at Bypass Creek. Coefficients were reduced from 0.5 to 0.4 and 0.3 depending on the location of the overflow. The peak stage of the updated historical simulation was within 0.1 feet of the observed stage and more than half of the measured high water marks were within 1 foot of the model results despite known inconsistencies in the determination of the measured depths. In summary, the computed results of the refined 2D model compared favorably to the May 2015 high water marks.

Existing Condition Results

Once the recalibration was completed in the ICM model, an updated existing conditions analysis was run for all storm events. Once all of the storm events were simulated, areas of interest were chosen to examine and compare results. For the 10-yr and smaller storm events, there was no ponding in the areas of interest. For the 25-yr and larger storm events, water from the Blanco River spilled outside of the banks downstream of the Highway 80 bridge, inundating the Blanco Gardens area and overflowed just upstream of West Uhland Road into a low lying area through Bogie St. The large storm events such as the 100-yr and higher show more inundation upstream of Highway 80 and begin to flood the apartment complexes located along the Blanco River. Results for the areas of interest for all the studied storm events is shown below in Table 2.

Table 2: Existing Conditions Results

Existing Conditions								
Location	**2-YR**	**5-YR**	**10-YR**	**25-YR**	**50-YR**	**100-YR**	**250-YR**	**500-YR**
Bypass Flow (cfs)	520	1,410	1,920	2,550	3,080	3,700	11,000	17,600
Bypass Outflow (cfs)	970	2,570	3,800	5,050	6,010	16,000	26,600	32,600
Flow D/S of HWY 80 (cfs)	9,650	31,600	51,450	87,800	109,700	129,500	130,600	151,400
WSEL D/S of HWY 80 (ft)	563.2	571.4	576.9	583.9	586.0	586.2	587.5	588.1
WSEL San Marcos Substation (ft)	-	-	-	581.6	583.3	584.5	584.8	585.3
WSEL Barbara Drive (ft)	-	-	-	576.0	578.1	578.9	579.5	579.9
WSEL Wal-Mart Parking Lot (ft)	-	-	-	-	-	587.5	588.2	589.0
WSEL Aspen Apartments (ft)	-	-	-	-	595.7	597.2	598.4	599.7
WSEL The Grove Apartments (ft)	-	-	-	-	600.3	602.5	604.9	606.7
WSEL Bogie St (ft)	-	-	-	570.2	574.7	579.3	582.9	584.5

(-) Indicates no ponding occurs

ALTERNATIVES ANALYSIS

The purpose of this flood risk management study is to identify areas of flood risk in the Blanco / San Marcos confluence area in order to protect life, property, and the environment. By identifying these areas early, the local communities may more easily and efficiently plan and construct flood management projects which will benefit the communities within the watershed.

The goals of this analysis are to 1) identify water resource related problems, needs and opportunities specifically related to flood risk management, 2) develop and evaluate alternative solutions to reduce flood damages, 3) use sustainable design methodologies, and 4) provide recommendations for flood reduction that the GBRA can prioritize and implement to reduce flood risks to people and the environment. Each of the alternatives presented a different set of hydrologic and hydraulic challenges. As potential alternatives were initially considered, some of them were intuitively not feasible and were not advanced. Generally, as the various alternatives were screened, plans were considered not viable if the plan required substantial activity by others or were not effective in solving the problem. The two main components leading toward an alternative's acceptability relate to implementation and satisfaction by the stakeholders. The proposed alternative must be viable.

The flood mitigation concepts discussed within this report are conceptual evaluations of potential flood mitigation solutions. They are high-level feasibility concepts that may be refined through subsequent preliminary engineering analysis and coordination with project stakeholders. Both structural and non-structural alternatives were considered by the USACE. Halff's analysis only included structural alternatives in the Blanco / San Marcos confluence area. As the hydrologic and hydraulics area of risk were evaluated, the alternatives were evaluated for environmental constraints that would affect compliance capability. Flood risk damages were identified, and general benefits were associated with each alternative (e.g., homes removed from flooding, structures removed, reduced floodplain area, etc.) This task was completed by the USACE. Conceptual design level estimates of project cost were also generated.

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Conceptual Alternatives

For this study, seven alternative concepts were analyzed to mitigate the flooding impacts in the Blanco / San Marcos confluence area. The modeled alternative results were compared with the existing condition results to determine the preferred alternative based on feasibility of implementation and flood reduction benefits to the community. The location of these alternatives are displayed in Figure 3. Each alternative concepts consisted of a combination of improvements including:

- **Channelization of Bypass Creek:** Channelizing Bypass Creek from the Blanco overflow near IH-35 to the confluence with the San Marcos River increases the capacity of Bypass Creek allowing more overflow from the Blanco River into the improved channel while avoiding heavily populated areas. The conceptual diversion consisted of a 125-foot, 20-feet deep channel. In addition to the channel improvements, this alternative also requires lowering the topography between the Blanco River and Bypass Creek upstream of County Road 160 to allow more flow to divert into Bypass Creek. Channel improvements will also require each of the crossing structures to be removed and reconstructed as bridges that span the channel. The bridges were not included in the hydraulic modeling as it was assumed the bridges would be designed to generate minimal headloss.
- **Bypass of Bypass Creek:** Channelization of Bypass Creek from the Blanco overflow near IH-35 and rerouting the channel to the confluence with the San Marcos River increases the capacity of Bypass Creek and the Bypass of Bypass Creek allowing more overflow from the Blanco River into the improved channel while avoiding heavily populated areas. This alternative reroutes Bypass Creek between Airport Highway and Highway 80 creating a shorter channel with less crossings, development, and constraints. Two conceptual channel options were investigated: 1) 125-foot, 20-feet deep channel and 2) 200-ft, 20-feet deep channel. Similar to channelization of Bypass Creek, this alternative also requires lowering the topography between the Blanco River and Bypass Creek and construction of bridges.
- **Diversion 1:** Diverting water from the Blanco River downstream of the Highway 80 bridge crossing to the San Marcos River downstream of the Old Bastrop Highway efficiently transfers flow to the San Marcos River allowing for water surface elevation reductions along the Blanco River downstream of the Highway 80. The conceptual diversion consisted of a 125-foot, 20-feet deep channel. Similar to channelization of Bypass Creek, this alternative also requires each of the roadway crossings to be constructed as bridges that span the channel generating minimal headloss.
- **Diversion 2:** Diverting water from the Blanco River near Old Martindale Road to the San Marcos River between Cape Street and Scrutchin Lake efficiently transfers flow to the San Marcos River allowing for water surface elevation reductions along the Blanco River downstream of the Highway 80. This diversion is primarily located on the City of San Marcos property in between the Blanco and San Marcos Rivers. The conceptual diversion consisted of a 300-foot, 10-feet deep channel. Similar to channelization of Bypass Creek, this alternative also requires each of the roadway crossings to be constructed as bridges that span the channel generating minimal headloss.
- **Blanco Gardens Berm:** A berm located on the west side of the Blanco River near the Blanco Gardens Neighborhood decreases overflows from the Blanco River. A berm with an elevation of the 50-year existing condition Blanco River water surface elevations is used to reduce the neighborhood's flood risk for more frequent storm events.

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- **Upstream Detention:** The USACE provided the hydrologic results from the simulated Blanco2 regional detention site in Blanco County. The post-detention flow rates were applied to the 2D model to evaluate flood mitigation benefit. The detention as proposed by the USACE conceptually reduced the flow in the Blanco River to near the 50-year storm event.

These alternatives include the construction of diversion channels, detention and berms in order to reduce the computed 100-year water surface elevations. Any downstream adverse impacts or increases in water surface elevation associated with hydraulic alternative options would be evaluated and mitigated should any of the projects mentioned in this analysis be recommended for further evaluation. All of the alternatives were evaluated for locations to dissipate flood waters prior to release into the San Marcos River. Although not included in the conceptual simulations, each diversion alternative has adequate locations for energy dissipation outside the banks of the San Marcos River. The flood mitigation concepts were simulated using the boundary condition of the existing conditions analysis for the alternative analysis with the exception of Bypass Creek. For alternatives with the channelized or rerouted Bypass Creek, additional tailwater hydrographs were developed to include the downstream boundary condition of the San Marcos River since the model was altered from existing condition. Tailwater hydrographs were established using a rating curve of the hydraulic cross section nearest to the outfall from the PMR San Marcos River HEC-RAS model and the flow hydrograph from the junction at the Blanco and San Marcos River confluence in the USACE's HEC-HMS model. These tailwater conditions were derived for each simulated storm event.

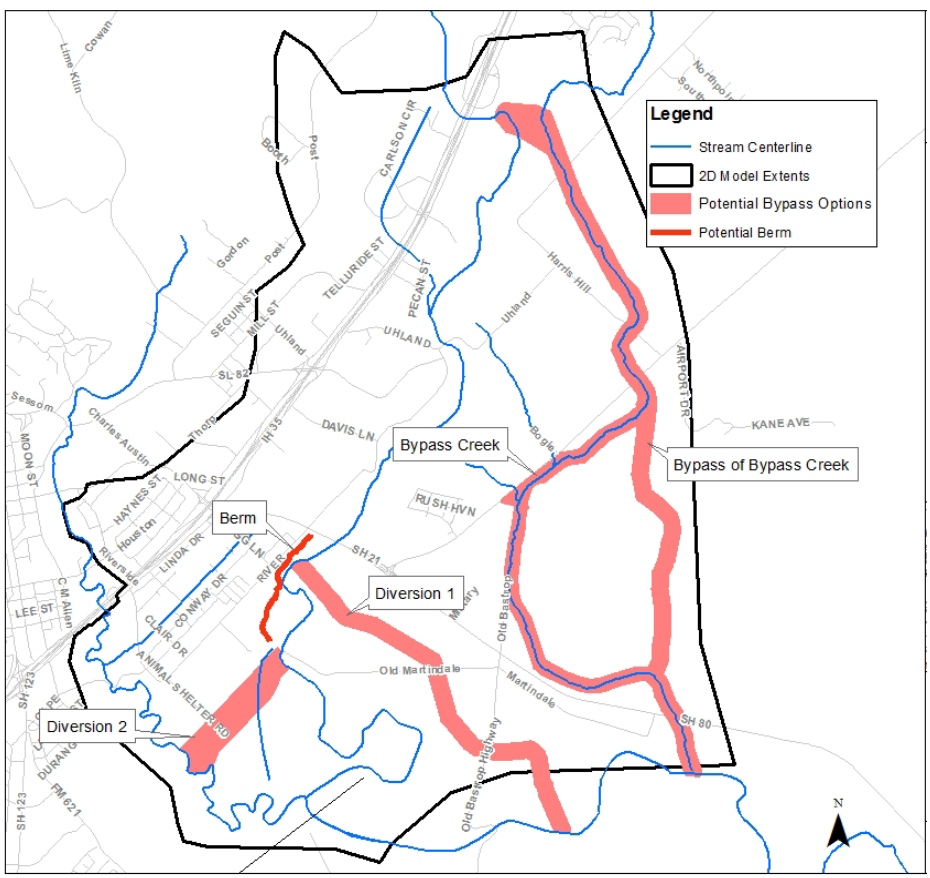

Figure 3. Potential Mitigation Options

The conceptual alternatives were evaluated independent of other flood mitigation alternatives to observe mitigation benefits. Using the results from the initial analysis, the study team was able to identify favorable alternatives for combined evaluation. Table 3 includes each alternative combination simulated for this analysis. Each combined alternative was simulated for the 100-year storm event to determine the impacts to the existing floodplain.

Table 3: Alternative Summary Chart

Alternative	Bypass Creek Channel	Rerouted Bypass Creek Channel	Diversion 1 Channel	Diversion 2 Channel	Larger Rerouted Bypass Creek Channel	Blanco Gardens Berm	Upstream Detention
Alternative 1	✓						
Alternative 1A	✓			✓			
Alternative 2		✓					
Alternative 2A		✓		✓			
Alternative 2B		✓	✓				
Alternative 2C		✓	✓			✓	
Alternative 2D		✓				✓	
Alternative 3			✓				
Alternative 3A			✓	✓			
Alternative 4					✓		
Alternative 4A					✓	✓	
Alternative 5						✓	✓
Alternative 6				✓		✓	

Alternatives Results

Once all of the alternatives were developed in the Infoworks ICM model, each alternative was simulated to observe the 100-year storm event impacts. Results were collected at the areas of interest that were analyzed in the existing conditions as follows. Figure 4 provides a graphical location of these analysis points in relation to the May 2015 resulting floodplain extents.

1. Blanco River just downstream of Highway 80
2. Blanco overflow near the San Marcos Substation
3. Blanco overflow along Barbra Drive in the Blanco Gardens neighborhood
4. Blanco overflow in the Wal-Mart parking lot just north of Highway 80
5. Blanco overflow at the Aspen Heights Apartments
6. Blanco overflow at the Grove Apartments
7. Bypass Creek 1 along Bogie Drive

These results of the alternatives analysis are listed below in Table 4. This table provides a comparison of computed flows in three locations as well as the computed water surface elevations in the locations listed above.

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Table 4: Alternative Summary Results

Alternative	Flow Rate (cfs)			Analysis Point Computed 100-yr Water Surface Elevation (ft)						
	Diverted (Bypass) Flow	Bypass Creek Outflow	Blanco River D/S Hwy 80	1	2	3	4	5	6	7
Existing	3,700	16,000	129,500	586.2	584.5	578.9	587.5	597.2	602.5	579.3
Alternative 1	35,700	34,200	116,000	586.1	583.4	578.2	585.4	595.8	600.5	575.3
Alternative 1A	36,000	33,900	116,700	585.9	583.1	577.8	-	595.9	600.6	575.4
Alternative 2	36,400	28,900	116,400	586.1	583.4	578.2	-	595.9	600.8	575.5
Alternative 2A	36,100	28,600	116,200	585.9	583.0	577.8	-	595.8	600.8	575.3
Alternative 2B	36,000	21,900	116,300	585.0	582.2	576.6	-	595.7	600.7	575.0
Alternative 2C	35,900	21,900	116,200	585.1	-	-	-	595.7	600.7	575.0
Alternative 2D	36,600	29,500	114,600	586.7	582.6	577.1	586.2	595.9	600.5	575.3
Alternative 3	3,700	12,400	131,000	586.3	583	577.5	587.3	597.1	602.5	579.3
Alternative 3A	3,700	12,400	131,100	586.2	582.9	577.4	587.3	597.1	602.5	579.3
Alternative 4	50,600	48,900	106,300	585.5	582.9	577.7	-	595.0	-	571.4
Alternative 4A	52,000	50,000	103,000	585.9	581.2	-	-	594.8	-	570.4
Alternative 5	3,700	5,700	112,500	586.7	582.6	577.2	586.4	595.9	600.6	575.5
Alternative 6	3,700	16,000	128,600	586.5	583.1	577.6	587.6	597.2	602.5	579.3

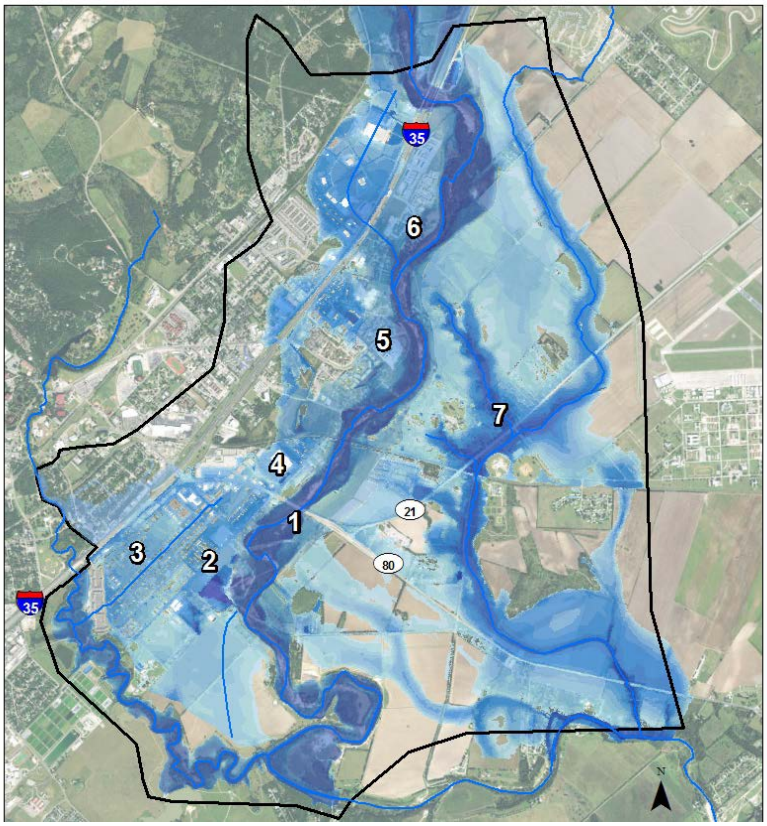

Figure 4. Analysis Locations

Based on the results in Table 4, flow rates and water surface elevations vary depending on what improvements are used for the specific alternative. Certain improvements have more hydraulic impact based on the location of the improvement relative to the watershed, the size of the proposed channels, and the reduction in flow through the Blanco River. The alternative results reveal the following hydraulic conclusions regarding the proposed improvements.

- **Channelization of Bypass Creek:** Channelization of Bypass Creek provides reduction in flood risk for all analysis points since flows in the Blanco River are decreased from near IH-35 to the confluence with the San Marcos River. Due to the constriction limitations along Bypass Creek, a larger channel was not feasible to further reduce flood risk. Alternative 1 flood risk reduction benefits average approximately 1.8 feet upstream of Highway 80 and approximately 0.6 feet in the Blanco Gardens area.
- **Bypass of Bypass Creek:** Similar to the channelization of Bypass Creek, the channelization and relocation of Bypass Creek provides reduction in flood risk for all analysis points since flows in the Blanco River are decreased from near IH-35 to the confluence with the San Marcos River. Since two channel dimensions were evaluated for this option, it was evident that a larger channel provides greater benefits. Alternative 2 simulates the impacts of the smaller channel while Alternative 4 simulates the benefits of the larger channel. Alternative 2 flood risk reduction benefits average approximately 1.5 feet upstream of Highway 80 and approximately 0.6 feet in the Blanco Gardens area. Alternative 4 flood risk reduction benefits average approximately 2.2 feet upstream of Highway 80 and approximately 1.2 feet in the Blanco Gardens area.
- **Diversion 1:** The diversion channel located downstream of Highway 80 provides reduction in flood risk for only areas downstream of Highway 80 through the Blanco Gardens neighborhood. Since the flow is diverted downstream of the road crossing, this improvement only impacts structures downstream of the highway. The diversion channel in Alternative 3 flood risk reduction benefits average approximately 0.9 feet in the Blanco Gardens area. This improvement alone does not provide benefits for all at risk structures in the Blanco / San Marcos confluence area. However, the channel could be combined with other options to provide a comprehensive flood risk reduction.
- **Diversion 2:** The Diversion 2 channel from Old Martindale Road to the San Marcos River does not provide benefit for the Blanco / San Marcos confluence area as an independent alternative. Therefore, Diversion 2 was simulated in combination with other improvements though Alternatives 1A, 2A, 3A, and 6. Majority of these simulations did not gain additional benefits with the addition of Diversion 2 with the exception of Alternative 6. In Alternative 6, the Diversion 2 channel is used to mitigate some of the rise caused by the Blanco Gardens Berm. Simulation of the berm increases flow in the Blanco River disconnecting the overflow for the more frequent storm events. The diversion channel reduces that impact by adding additional storage volume and conveyance to the San Marcos River.
- **Blanco Gardens Berm:** The Blanco Gardens berm provides reduction in flood risk for most storm events and prevents overflow into the Blanco Gardens neighborhood for storm events lower than the 50-year event. The berm's reduction benefit is limited only to the Blanco Gardens neighborhood and slightly increases flow and water surface elevation downstream along the Blanco River. As mentioned above, this alternative combined with Diversion 2 mitigates the potential adverse impact.

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- **Upstream Detention:** Large upstream detention produces benefits to most analysis points since flows in the Blanco River are decreased to the confluence with the San Marcos River. Alternative 5 flood risk reduction benefits average approximately 1.4 feet upstream of Highway 80 and approximately 1.0 feet in the Blanco Gardens area.
- **Least Benefit:** The independent alternative with the least flood reduction benefit for the analysis points is Alternative 3. The combined alternative with the least flood reduction benefit for the analysis points is Alternative 3A. These alternatives are best used in combination with other alternatives.
- **Greatest Benefit:** The independent alternative with the greatest flood reduction benefit for the analysis points is Alternative 4. The combined alternative with the greatest flood reduction benefit for the analysis points is Alternative 4A. Although these alternatives provide the greatest benefit, they are also the most expensive options.

FINAL FLOOD MITIGATION ALTERNATIVES

An extensive set of potential flood mitigation alternatives were evaluated based upon expected flood mitigation benefits, high-level engineering feasibility, and cost effectiveness of each individual alternative. Based on the analysis, two combined alternatives were selected for further engineering analysis and consideration by the USACE. Alternatives 2D and 6 were selected for further evaluation and simulated for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year events. The results of the simulations were provided to the USACE to estimate economic benefits.

These selected alternatives were chosen considering their technical feasibility, cost, and input from project stakeholders. A structure inventory spatial file was obtained from the USACE representing a point for each structure (home or building) in the Blanco / San Marcos confluence area. Simulated water surface elevations were populated to the spatial file for the existing condition simulation, the Alternative 2D simulation, and the Alternative 6 simulation for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year storm events. This file was provided to the USACE for the estimation of economic benefit.

An opinion of probable cost was developed for each alternative. Unit prices for probable costs were developed using the Texas Department of Transportation (TxDOT) bid tabulations from projects within the Austin District within the last calendar year. For specific elements that were not listed within the TxDOT tabulation, unit prices were derived using recent land development and drainage projects in the Central Texas region. Since both of these alternatives require the excavation of a channel the unit cost associated with excavation is estimated with the assumption that material will be spread nearby rather than hauling. Property acquisition is estimated using average Hays County Appraisal District land values with an applied multiplier. It should be noted that these opinions of cost use standard practice and are only considered an estimate. These estimates should be refined should any of the projects mentioned in this analysis be recommended for further evaluation. Opinions of probable cost for each alternative can be found in Appendix A.

Alternative 2D: Bypass of Bypass Creek combined with Blanco Gardens Berm

This alternative includes the combination of the Bypass of Bypass Creek and the Blanco Gardens Berm. This alternative provides flood mitigation benefits for all analysis points since flows in the Blanco River are decreased from near IH-35 to the confluence with the San Marcos River. A schematic of the alternative is displayed in Figure 5 below.

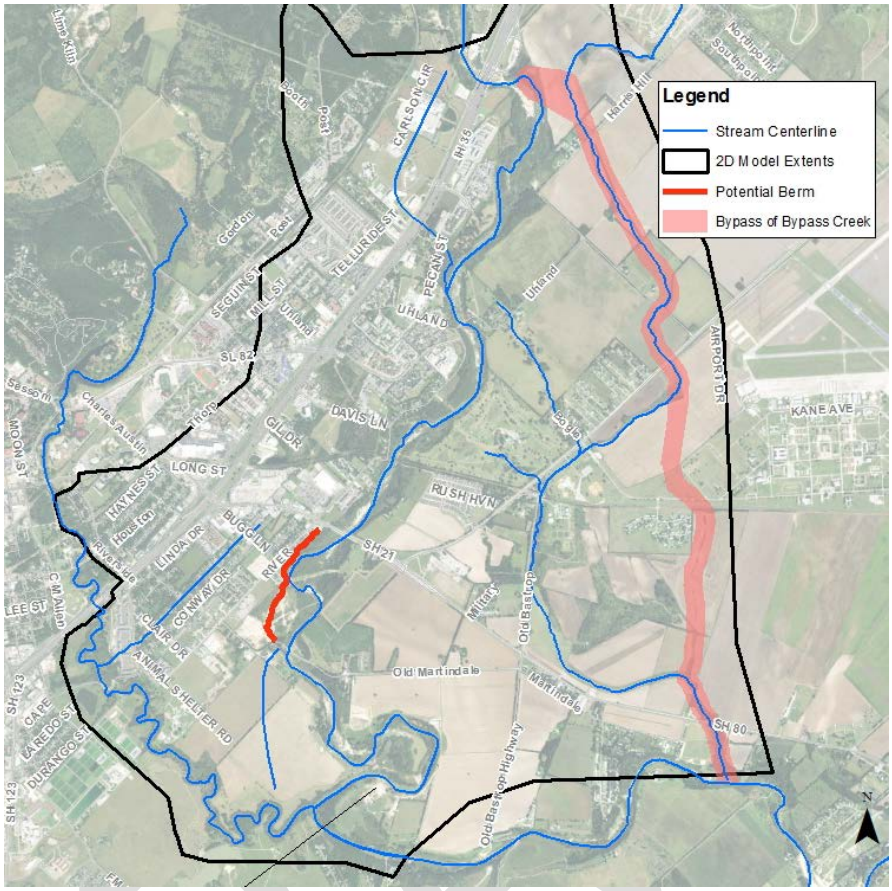

Figure 5. Alternative 2D Schematic

This alternative lowers the topography between the Blanco River and Bypass Creek upstream of County Road 160 to allow approximately 33,000 cfs to flow from the Blanco River into Bypass Creek. The conceptual diversion consists of a 125-foot, 20-feet deep channel that follows the Bypass Creek alignment to Airport Highway then flows south ultimately rejoining the Bypass Creek alignment near Highway 80. This alignment is preferred over the Bypass Creek alignment creating a shorter channel with less crossings, development, and constraints. The proposed channel improvements will require each of the crossing structures to be removed and reconstructed as bridges that span the channel. The bridges were not included in the hydraulic modeling as it was assumed the bridges would be designed to generate minimal headloss. As noted above, this the Bypass of Bypass Creek reduces flows along the mainstem of the Blanco River. The lower flow rates combined with the Blanco Gardens Berm significantly reduce overflows into the Blanco Gardens neighborhood. The conceptual berm is located on the western bank of the Blanco River downstream of Highway 80. The berm is simulated at the 50-year existing condition Blanco River water surface elevations protecting the neighborhood from the more frequent storm events.

The estimated project cost for this flood mitigation alternative is **$52,500,000**. The benefits and constraints of this alternative are listed below:

Benefits

- **Water surface mitigation benefits:** This flood mitigation alternative results in an average 100-year water surface depth reduction of approximately 1.5 feet upstream of Highway 80, 1.1 feet in the Blanco Gardens area, 4.0 feet along Bogie Drive.
- **Structural mitigation benefits:** This flood mitigation alternative reduces the computed structural flooding of approximately XX out of XX structures for the 100-year event in the Blanco / San Marcos confluence area.
- **Flood mitigation benefits:** These flood mitigation alternatives provides flood reduction benefits to in the entire 2D study area. Not only does this alternative reduce water surface elevations along the Blanco River, this alternatives significantly reduces overflows and associated flood depths from IH-35 to Highway 80 toward Bypass Creek, Blanco Gardens overflows, and overtopping if IH-35.

Constraints

- **Multi-stakeholder coordination:** Since the proposed project crosses many jurisdictional boundaries negotiations with project stakeholders would be required.
- **Perpetual channel maintenance:** Once the channel improvements are complete, great efforts would be required to maintain an effective channel.
- **Property acquisition required:** The project stakeholders do not currently own easement or property along this proposed alignment of the bypass channel or berm location. Property acquisition would be required in the areas where channel clearing is proposed.
- **Significant long-term environmental impacts:** Altering natural channels impacts water quality, creek stability, wildlife, and trees. To maintain the flood mitigation benefits of this alternative, perpetual maintenance is required prolonging the environmental impact.
- **Permitting:** A USACE 404 Individual Permit is anticipated due to the proposed channel improvements along Bypass Creek, near the Blanco River, and near the San Marcos Rivers. In addition, permitting is likely required from the City of San Marcos, Hays County, Caldwell County, TCEQ, and US Fish and Wildlife.

Alternative 6: Blanco Gardens Berm combined with Diversion 2

This alternative includes the combination of the Blanco Gardens Berm and Diversion 2 from Old Martindale Road to the San Marcos River. This alternative only provides flood mitigation benefits for the Blanco Gardens neighborhood. A schematic of the alternative is displayed in Figure 6 below.

This alternative raises the topography of the western Blanco River bank from Highway 80 to Old Martindale Road. This elevation of the bank reduces the overflow from the Blanco River into the Blanco Gardens neighborhood. The berm is simulated at the 50-year existing condition Blanco River water surface elevations protecting the neighborhood from the more frequent storm events. Reduction of overflow into the neighborhood increases flows in the Blanco River causing a slight increase in the water surface. A diversion from near Old Martindale Road to the San Marcos River is used to mitigate that rise. The conceptual diversion consists of a 300-foot, 10-feet deep channel. Additionally this alignment significantly reduces the required property acquisition because the majority of the land along this alignment is owned by the City of San Marcos. The proposed channel will require each of the crossing structures to be constructed as bridges that span the channel. The bridges were not included in the hydraulic modeling as it was assumed the bridges would be designed to generate minimal headloss.

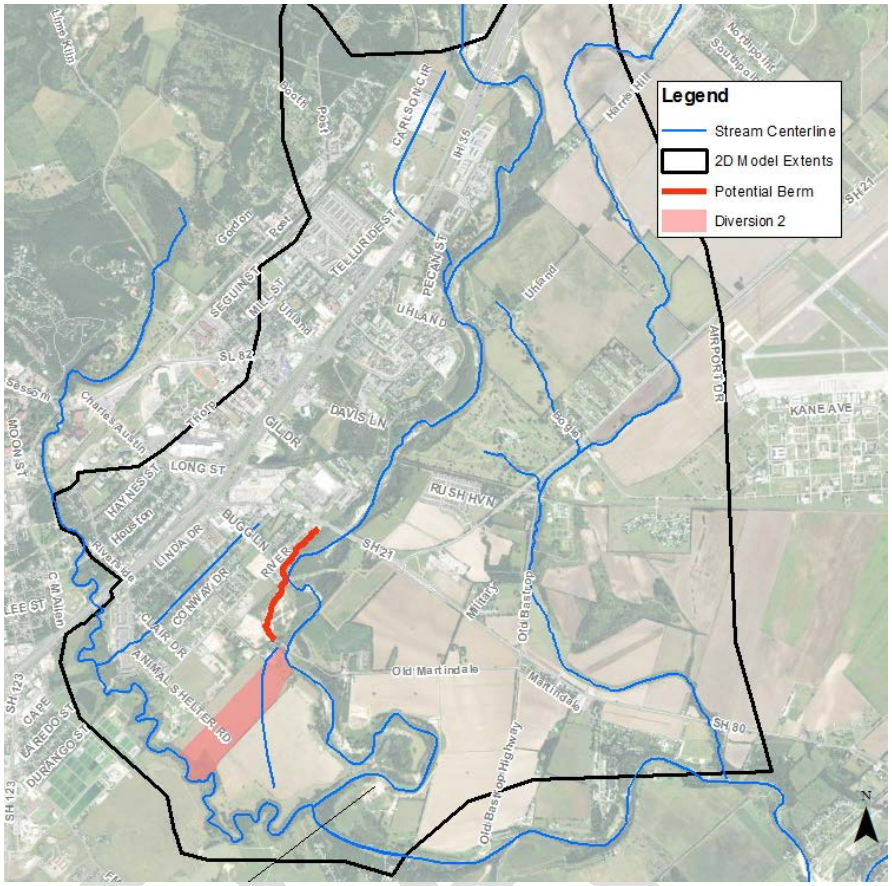

Figure 6. Alternative 6 Schematic

The estimated project cost for this flood mitigation alternative is **$9,400,000**. The benefits and constraints of this alternative are listed below:

Benefits

- **Water surface mitigation benefits:** This flood mitigation alternative results in an average 100-year water surface depth reduction of approximately 0.8 feet in the only in the Blanco Gardens area.
- **Structural mitigation benefits:** This flood mitigation alternative reduces the computed structural flooding of approximately XX out of XX structures for the 100-year event in the Blanco / San Marcos confluence area.
- **Property acquisition required:** The City of San Marcos currently owns property along the proposed alignment of the diversion channel. Ownership of property in this area reduces the required property acquisition for the project.
- **Permitting:** A USACE Nationwide Permit is anticipated due to the proposed connections to the Blanco River and San Marcos Rivers. In addition, permitting is likely required from the City of San Marcos, Hays County, TCEQ, and US Fish and Wildlife.

Constraints

- **Limited flood mitigation benefits:** Since improvements are only proposed downstream of Highway 80, this alternative only provides mitigation benefits to the Blanco Gardens neighborhood. Additionally, the elevation of the proposed berm is at the 50-year existing condition Blanco River water surface elevations. This elevation protects the neighborhood from the more frequent storm events, but does not protect the neighborhood from events greater than the 50-year event.
- **Multi-stakeholder coordination:** Since the proposed project crosses many jurisdictional boundaries negotiations with project stakeholders would be required.
- **Perpetual channel maintenance:** Once the channel construction is complete, great efforts would be required to maintain an effective channel.
- **Significant long-term environmental impacts:** Altering natural channels impacts water quality, creek stability, wildlife, and trees. To maintain the flood mitigation benefits of this alternative, perpetual maintenance is required prolonging the environmental impact.

PROJECT SUMMARY

The GBRA Interim Feasibility Study is a detailed engineering study of the Lower Guadalupe River Basin. The study is being undertaken by the USACE, the TWDB, and the GBRA. This report documents a portion of the overall study focusing on flood damage reduction alternatives for the confluence of the Blanco and San Marcos Rivers. Given the USACE's need for expedited alternatives analysis of this complex area, it was recommended that the City's available Infoworks ICM model be utilized to advance the TSP analysis.

This report documents the 2D analysis and subsequent alternatives analysis that was conducted for the Blanco / San Marcos confluence area. The study team identified two viable alternatives to reduce flood risks along the Blanco and San Marcos Rivers from IH-35 to the confluence. One alternatives provides greater flood reduction benefits over the entire study area through the construction of a channelized and rerouted Bypass Creek combined with. The other alternative provides less flood reduction benefits only providing reduction of water surface elevations in the Blanco Gardens neighborhood through the construction of a berm to elevate the western bank of the Blanco River near the Blanco Gardens neighborhood and construction of a diversion channel to mitigate the rise caused by the berm.

Although the first alternative provides the greatest flood reduction benefits, it is also the most expensive alternative. In support of the greater USACE project, Halff was contracted to conduct 2D analysis, alternatives analysis using the 2D model, computation of existing condition and proposed condition water surface elevations, and development of opinions of probable cost for the viable alternatives. This data will be utilized by the USACE to evaluate project economics and overall viability.

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Appendix A

Estimates of Probable Cost

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ENGINEER'S OPINION OF PROBABLE CONSTRUCITON COST

Alternative 2D

Combined Estimate of Probable Cost

BYPASS CHANNEL OF BYPASS CREEK	
Total Project Cost	$ 45,141,125
Engineering and Survey Fees	$ 4,520,000
Regulatory Permitting	$ 460,000
Property/Easement Acquisition	$ 1,161,000
PROJECT GRAND TOTAL	**$ 51,282,125**

BERM	
Total Project Cost	$ 968,500
Engineering and Survey Fees	$ 100,000
Regulatory Permitting	$ 10,000
Property/Easement Acquisition	$ 142,000
PROJECT GRAND TOTAL	**$ 1,220,500**

BYPASS CHANNEL & BERM COMBINED	
Total Project Cost	$ 46,109,625
Engineering and Survey Fees	$ 4,620,000
Regulatory Permitting	$ 470,000
Property/Easement Acquisition	$ 1,303,000
PROJECT GRAND TOTAL	**$ 52,502,625**

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ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

DATE: 10/5/2017
AVO: 32797
PROJECT: Blanco/San Marcos 2D Analysis Feasibilty
Alternative: Bypass Channel of Bypass Creek

PAY ITEM NO	DESCRIPTION	UNITS	UNIT PRICE	QUANTITY	SUB-TOTALS
1	Channel Excavation (assumes no	CY	$ 5	3,561,500	$ 17,807,500
2	Bridge Construction	SF	$ 100	84,600	$ 8,460,000
3	Railroad Improvement	SF	$ 200	19,600	$ 3,920,000
4	Clearing and grubbing	AC	$ 8,000	156	$ 1,248,000
5	Hydromulch Seeding	SY	$ 0.40	756,000	$ 302,400
6	Soil Retention Blankets	SY	$ 2	756,000	$ 1,512,000
7	Channel Outlet at San Marcos River	LS	$ 500,000	1	$ 500,000
8	Temporary Erosion and Sediment Control (2%)	LS	$ 675,000	1	$ 675,000
9	Mobilization (5%)	LS	$ 1,688,000	1	$ 1,688,000
				SUBTOTAL	**$ 36,112,900**
				CONTINGENCY (25%)	**$ 9,028,225**
				TOTAL PROJECT COST	**$ 45,141,125**
9	Engineering and Survey Fees (10%)	LS	$ 4,520,000	1	$ 4,520,000
10	Regulatory Permitting (1%)	LS	$ 460,000	1	$ 460,000
11	Property/Easement Acquisition	AC	$ 13,500	86	$ 1,161,000
				PROJECT GRAND TOTAL	**$ 51,282,125**

Note: Estimate excludes cost of protection, relocation, reconstruction of utilities.

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and the Engineer shall not be held liable to Owner or third party for any failure to accurately estimate the cost of the project, or any part thereof. Unit Prices are in current dollars and should be adjusted as required when schedule for project is determined.

HALFF

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

DATE: 10/5/2017
AVO: 32797
PROJECT: Blanco/San Marcos 2D Analysis Feasibilty
Alternative: Berm

PAY ITEM NO	DESCRIPTION	UNITS	UNIT PRICE	QUANTITY	SUB-TOTALS
1	Clearing and Grubbing	AC	$ 11,000	4	$ 44,000
2	Embankment	CY	$ 30	3,500	$ 105,000
3	Subgrade Preparation	SY	$ 15	19,400	$ 291,000
4	Soil Retention Blankets	SY	$ 5	19,400	$ 97,000
5	Placing Topsoil (4")	SY	$ 5	19,400	$ 97,000
6	Hydromulch Seeding	SY	$ 2	19,400	$ 38,800
7	Temporary Erosion and Sediment Control (5%)	LS	$ 34,000	1	$ 34,000
8	Mobilization (10%)	LS	$ 68,000	1	$ 68,000
				SUBTOTAL	**$ 774,800**
				CONTINGENCY (25%)	**$ 193,700**
				TOTAL PROJECT COST	**$ 968,500**
8	Engineering and Survey Fees (10%)	LS	$ 100,000	1	$ 100,000
9	Regulatory Permitting (1%)	LS	$ 10,000	1	$ 10,000
10	Property/Easement Acquisition	AC	$ 35,500	4	$ 142,000
				PROJECT GRAND TOTAL	**$ 1,220,500**

Note: Estimate excludes cost of protection, relocation, reconstruction of utilities. Also excludes property acquisition costs.

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and the Engineer shall not be held liable to Owner or third party for any failure to accurately estimate the cost of the project, or any part thereof. Unit Prices are in current dollars and should be adjusted as required when schedule for project is determined.

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ENGINEER'S OPINION OF PROBABLE CONSTRUCITON COST

Alternative 6

Combined Estimate of Probable Cost

DIVERSION 2 CHANNEL	
Total Project Cost	$7,241,500
Engineering and Survey Fees	$730,000
Regulatory Permitting	$80,000
Property/Easement Acquisition	$140,000
PROJECT GRAND TOTAL	**$8,191,500**
BERM	
Total Project Cost	$968,500
Engineering and Survey Fees	$100,000
Regulatory Permitting	$10,000
Property/Easement Acquisition	$142,000
PROJECT GRAND TOTAL	**$1,220,500**
DIVERSION CHANNEL & BERM COMBINED	
Total Project Cost	$8,210,000
Engineering and Survey Fees	$830,000
Regulatory Permitting	$90,000
Property/Easement Acquisition	$282,000
PROJECT GRAND TOTAL	**$9,412,000**

HALFF

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

DATE: 10/23/2017
AVO: 32797
PROJECT: Blanco/San Marcos 2D Analysis Feasibilty
Alternative: Diversion 2 from Blanco River

PAY ITEM NO	DESCRIPTION	UNITS	UNIT PRICE	QUANTITY	SUB-TOTALS
1	Channel Excavation (assumes no	CY	$ 5	530,000	$ 2,650,000
2	Bridge Construction	SF	$ 100	16,400	$ 1,640,000
4	Clearing and grubbing	AC	$ 8,000	32	$ 256,000
5	Hydromulch Seeding	SY	$ 0.40	153,000	$ 61,200
6	Soil Retention Blankets	SY	$ 2	153,000	$ 306,000
7	Channel Outlet at San Marcos River	LS	$ 500,000	1	$ 500,000
8	Temporary Erosion and Sediment Control (2%)	LS	$ 109,000	1	$ 109,000
9	Mobilization (5%)	LS	$ 271,000	1	$ 271,000
				SUBTOTAL	$ 5,793,200
				CONTINGENCY (25%)	$ 1,448,300
				TOTAL PROJECT COST	$ 7,241,500
9	Engineering and Survey Fees (10%)	LS	$ 730,000	1	$ 730,000
10	Regulatory Permitting (1%)	LS	$ 80,000	1	$ 80,000
11	Property/Easement Acquisition	AC	$ 35,000	4	$ 140,000
				PROJECT GRAND TOTAL	$ 8,191,500

Note: Estimate excludes cost of protection, relocation, reconstruction of utilities.

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and the Engineer shall not be held liable to Owner or third party for any failure to accurately estimate the cost of the project, or any part thereof. Unit Prices are in current dollars and should be adjusted as required when schedule for project is determined.

HALFF

ENGINEER'S OPINION OF PROBABLE CONSTRUCTION COST

DATE: 10/23/2017
AVO: 32797
PROJECT: Blanco/San Marcos 2D Analysis Feasibilty
Alternative: Berm

PAY ITEM NO	DESCRIPTION	UNITS	UNIT PRICE	QUANTITY	SUB-TOTALS
1	Clearing and Grubbing	AC	$ 11,000	4	$ 44,000
2	Embankment	CY	$ 30	3,500	$ 105,000
3	Subgrade Preparation	SY	$ 15	19,400	$ 291,000
4	Soil Retention Blankets	SY	$ 5	19,400	$ 97,000
5	Placing Topsoil (4")	SY	$ 5	19,400	$ 97,000
6	Hydromulch Seeding	SY	$ 2	19,400	$ 38,800
7	Temporary Erosion and Sediment Control (5%)	LS	$ 34,000	1	$ 34,000
8	Mobilization (10%)	LS	$ 68,000	1	$ 68,000
				SUBTOTAL	$ 774,800
				CONTINGENCY (25%)	$ 193,700
				TOTAL PROJECT COST	$ 968,500
8	Engineering and Survey Fees (10%)	LS	$ 100,000	1	$ 100,000
9	Regulatory Permitting (1%)	LS	$ 10,000	1	$ 10,000
10	Property/Easement Acquisition	AC	$ 35,500	4	$ 142,000
				PROJECT GRAND TOTAL	$ 1,220,500

Note: Estimate excludes cost of protection, relocation, reconstruction of utilities. Also excludes property acquisition costs.

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and the Engineer shall not be held liable to Owner or third party for any failure to accurately estimate the cost of the project, or any part thereof. Unit Prices are in current dollars and should be adjusted as required when schedule for project is determined.

Appendix B

Digital Data