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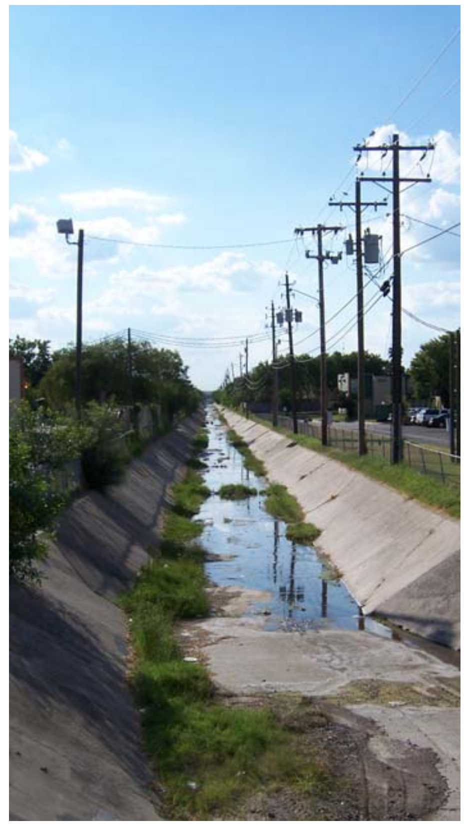
ZACATE CREEK
FLOOD PROTECTION PLAN



City of Laredo, Texas

In Association With:
City of Laredo
Texas Water Development Board
Webb County
Webb County Appraisal District
Laredo Metropolitan Planning Organization
United Independent School District
Laredo Independent School District

March 19, 2010

Project No. 7077.01

ZACATE CREEK FLOOD PROTECTION PLAN

Prepared for:

City of Laredo
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EXECUTIVE SUMMARY

The Zacate Creek Flood Protection Plan is an engineering analysis of the flooding risks facing the City of Laredo, Texas by Zacate Creek, and a planning analysis of structural and non-structural alternatives to mitigate these risks. This project was funded by the Texas Water Development Board (TWDB) and the City of Laredo, with participation from the Webb County, Webb County Appraisal District, Laredo Metropolitan Planning Organization, United Independent School District, and the Laredo Independent School District.

The purpose of this Flood Protection Plan (FPP) is to evaluate the relative costs and benefits of the mitigation strategies to guide the City of Laredo in selecting, prioritizing and implementing an optimized combination of strategies. The FPP focuses on maximizing flood conveyance within existing drainage easements to minimize the need for property acquisition. This study also focuses efforts and resources on the flood problem areas with the most significant potential flood damages. It is understood that it may not be possible to alleviate flood risks for the entire study area or for all storm events; therefore this study examines the benefits of individual flood mitigation alternatives identified within each problem area. The study employs an iterative and incremental approach to determine the most cost-effective level of service based on improvement costs and expected benefits.

To assist the City of Laredo in prioritizing the funding of projects, the alternatives are assessed by comparing the cost of implementation with associated benefits. Costs presented are planning level, and do not include right-of-way acquisition or utility relocation. To estimate the risk associated with a given magnitude flood event, HAZUS-MH software is employed. This software, developed by FEMA Hazard Mitigation Division is integrated with ArcGIS 9.3 (the platform utilized for spatial data management and analysis in the overall study). HAZUS is a widely-accepted methodology for flood damage estimation. Benefits are calculated by comparing the existing conditions damages with the expected damages assuming that the structural improvements are in place.

Structural flood control alternatives are developed with the goal to reduce flooding in problem areas or zones. Alternatives are selected to provide the best level of service, minimize the disturbance of existing channels and areas outside of existing right- of-ways, and extend or build on current city projects, including Phase 1 of the Canal Street drainage improvements and the Upper Zacate Creek Multi-Purpose Detention Basin. The figure below provides the general location of the flood control zones within the watershed. Eight zones are identified and improvements have been optimized within each zone. The locations of these zones are shown on Figure E.1, below.

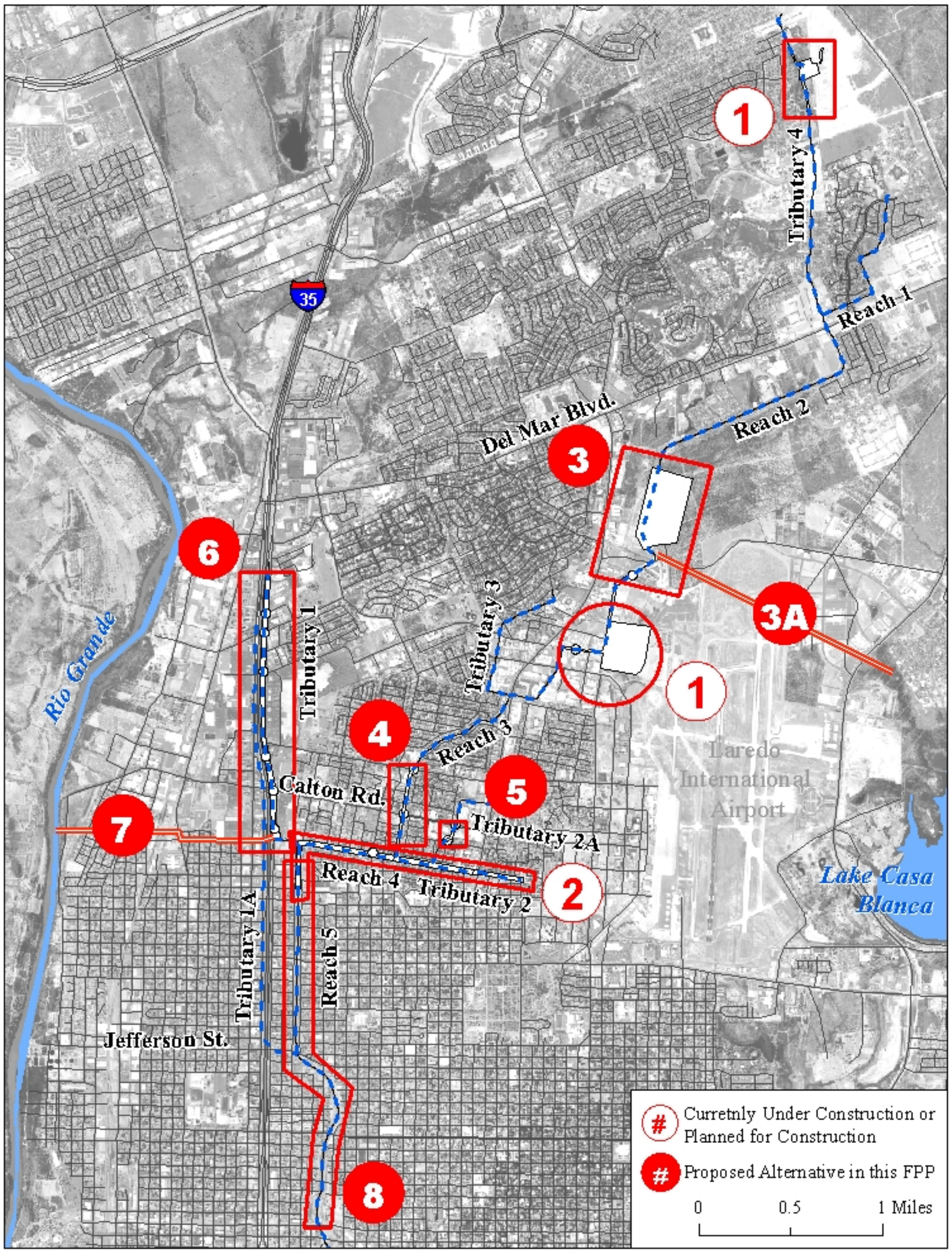

Figure E.1. Location Map of Zacate Creek Zones/Alternatives

The specific zone locations and improvements are summarized below:

Zone 1. Current City Projects (Currently Under Construction)
This includes the Shiloh Detention Basin and the Upper Zacate Creek Multi-Purpose Detention Basin. These projects are under construction and are assumed to be in place for all FPP analyses.

Zone 2. Canal Street Improvements (Phase 1 Under Construction)
This includes all five phases of the proposed Canal Street drainage improvements. Phase 1 is under construction (Fall 2009). Proposed improvements are on Zacate Creek Reach 4, and Tributary 2.

Zone 3. Alexander Ranch Detention Basin (New)
This includes expanded detention within the proposed Alexander Ranch development and assumes increased capacity at Jacaman Road within Zacate Creek Reach 2. Alternative 3A assumes the diversion of all Zacate Creek flows north of the Jacaman Blvd. culverts to Lake Casa Blanca.

Zone 4. Lower Zacate Creek Reach 3 Improvements (New)
This proposes increasing the channel size of Zacate Creel Reach 3 from Hillside Road to Canal Street and upgrading the existing Calton Road culverts to a clear-span bridge. This zone is analyzed assuming the improvements proposed for Zones 2 and 3 are in place.

Zone 5. Tributary 2A Improvements (New)
Proposed improvements on Tributary 2A include the installation of a concrete lined trapezoidal channel between Calton Road and Chaparral Street. Improvements in this area would also include increasing the size of the bridges at Calton Road and Chaparral Street.

Zone 6. Tributary 1 Improvements (New)
The proposed improvements for Tributary 1 include maximizing the channel size within the existing right-of-way (including lowering the channel invert in the downstream section) and upsizing most of the roadway crossings.

Zone 7. Diversion to the Rio Grande (New)
The proposed improvements within this zone would divert all flows upstream of Canal Street from Tributary 1 and 1A (east and west sides of IH-35) to the Rio Grande by way of three 10x10 box culverts. This would also include the improvements proposed in Zone 6 to reduce flooding along Tributary 1 to the proposed tunnel inlet.

Zone 8. Downstream Zacate Creek Option (Preliminary Analysis)
While Zacate Creek, downstream of the confluence with Tributary 1, generally contains the 100-Year event, significant benefits could be realized upstream of this area if the tailwater elevation could be lowered. This structural improvement proposes lowering the channel invert by five feet in Zacate Creek from the confluence with Tributary 1 to just upstream of the Tex-Mex Railroad Bridge. Five bridges would need to be replaced in this zone, but further study would be needed to determine the full extent of infrastructure changes required. It is assumed that many of the existing bridges would be able to accommodate the proposed deeper channel section with only minor structural changes. Bedrock can be found at the channel invert for the lower portions of Zacate Creek and it is not known how much rock excavation would be required to implement this alternative. It is expected that these changes would have substantial utility conflicts, and it is beyond the scope of this study to estimate potential utility relocation costs.

Combination Alternatives

Each of the improvement zones analyzed is examined individually; however, Zone 8 improvements have very little benefit on their own since the channel in this region generally contains the 100-Year event. The most promising aspect of the Zone 8 improvements is the potential capacity offered upstream within Zone 2 and Zone 6 (Tributary 1) if the tailwater elevation on Zacate Creek can be lowered. It also appears that Zone 8 could be implemented at a lower cost than a diversion to the Rio Grande (Zone 7) and the potential benefits could be far greater. However, uncertainties in the total Zone 8 cost, and the large number of possible configuration of a combination alternative merit additional study to provide a more reliable and detailed cost and benefit assessment. Two combination alternatives were examined. Table E.1, below, contains the cost/benefit analysis results.

Zone/Alternative	Total Benefits ($ Millions)		Cost Estimate ($ Millions)
	10-year event	100-year event	
Zone 1	$3.1	$10.8	Funding in Place
Zone 2	$19.5	$30.7	$7.8
Zone 3	$6.9	$19.9	$20.5
Alternative 3A	$14.4	$27.5	N/A
Zone 4	$24.5	$42.6	$31.0
Zone 5	$3.7	$10.7	$0.5
Zone 6	$7.1	$16.6	$16.6
Zone 7	$25.6	$60.9	$54.7
Zone 8	N/A	N/A	$28.7
Combined Improvements			
Zones 2,3,4,5,6,7	$46.6	$89.9	$86.3
Zones 2,3,4,5,6,8	N/A	N/A	$76.9

Table E.1. Cost/Benefit Analysis Results

Recommendations and Implementation

Improvements in Zone 2 (the Canal Street project) showed the "best bang for the buck" and therefore the highest priority due to the high density of residential structures and the expected flood reductions possible with the proposed channel improvements. It is recommended that the City continue with the additional phases of the Canal Street drainage improvements beyond Phase One that is currently under construction. The following discussion of Zone 8 recommendations may impact the priority of this recommendation.

As a second priority, it is also recommended that the City pursue expansion of Alexander Ranch Detention Basin and the Jacaman Road culvert improvements included in the Zone 3 proposed improvements. This is the last remaining large area with the potential to provide significant stormwater storage. Even though the proposed improvements have a small impact south of the McPherson Road Bridge, they do show significant reduction of flood potential road closing frequency in the Zone 3 vicinity.

The remaining proposed Zone improvement recommendations are prioritized, in order, as follows: Zone 6 (Tributary 1), Zone 4 (main channel between Canal Street and McPherson Blvd.), Zone 5 (Tributary 2A), and Zone 7 (Tributary 1A, the IH-35 West Frontage Road). These recommended improvements have a lower priority because improvements in these zones do not provide significant improvements in stormwater capacity or reductions in water surface elevations due to existing downstream restrictions. Zone 6 and 7 are important because flooding in these areas significantly impairs traffic in the vital IH-35 corridor even in minor rainfall events. However, any proposed improvements will require coordination, cooperation, analysis, and funding by the Texas Department of Transportation. Zone 7 improvements, though potentially very beneficial, have a very high cost. In addition permitting is uncertain and disruption of traffic during construction may be significant. It is recommended that the City begin discussions with the Texas

Department of Transportation about these improvement options as coordination and potential cost sharing is likely to require significant time and coordination.

The Zone 8 (Downstream ZC Channel) is analyzed not because of extensive existing flooding but because the tailwater from this section of the channel influences the flooding potential in the main channel and tributary channels zones upstream to McPherson Blvd. Even though further examination of Zone 8 improvements may well change the specifics of the preliminary analysis, it is known that drainage improvements will need to be made along the IH-35 corridor to alleviate flooding along Tributary 1 and 1A. The Zone 8 proposed improvements provide the only potentially cost-effective method to begin to contain major flood events within the Zacate Creek channel system. **It is the recommendation of this report that a preliminary design study be conducted by the City on the proposed Zone 8 improvements**.

The preliminary design study should concentrate on three factors critical to the design; 1) the location, elevation and relative density of the underlying rock layer that outcrops to the surface just north of the railroad bridge at the downstream end of study Zone 8, 2) the location and depth of ALL underground utilities in the Zone 8 study area (including those in Zones 2, 4, 5, 6, and 7), and 3) the optimum depth of channel cut to maximize the benefits in upstream reaches or zones. The sum of these critical factors will determine the ultimate cost and viability for the proposed improvements. Should the preliminary design study result show the project is feasible and cost-effective; the next step for the City should be to initiate Waters of the U.S. permitting. The nature and length of the channel and proposed improvements will likely require an Individual Section 404 permit from the U.S. Army Corps of Engineers, a process that may take two years or more.

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LIST OF APPENDICES

1.0 INTRODUCTION

The Zacate Creek Flood Protection Plan is an engineering analysis of the flooding risks facing the City of Laredo, Texas by Zacate Creek, and a planning analysis of structural and non-structural alternatives to mitigate these risks. This project was funded by the Texas Water Development Board (TWDB) and the City of Laredo, with participation from the Webb County, Webb County Appraisal District, Laredo Metropolitan Planning Organization, United Independent School District, and the Laredo Independent School District. The general project location is found in Figure 1. The following sections of this report describe the methods, data, and assumptions used in the analyses, as well as the results obtained.

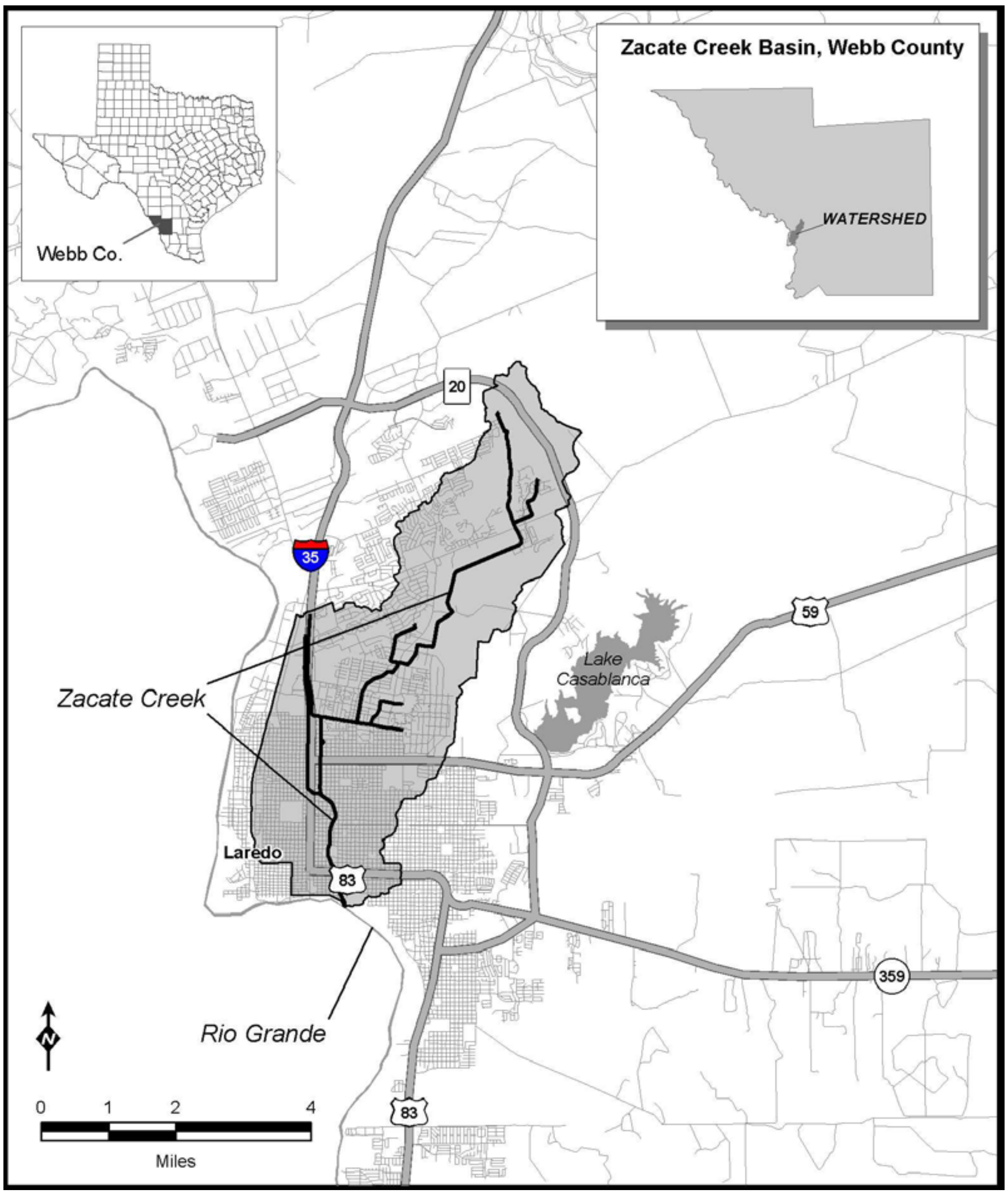


Figure 1. Zacate Creek Watershed Location Map

1.1 BACKGROUND

The risk of flooding is known to be extensive throughout the Zacate Creek watershed, and the history of flood damage in Laredo extends back to its roots as a city. The topography of the Zacate Creek watershed, the character of the soils, intensity of development, concrete-lined channels, and nature of rainfall in the area are conducive to rapid runoff and sharp-crested flood hydrographs. Flooding can occur frequently and at almost any time of the year.

Figure 2. Zacate Creek watershed in 1978, approximately the time of the effective FIS.

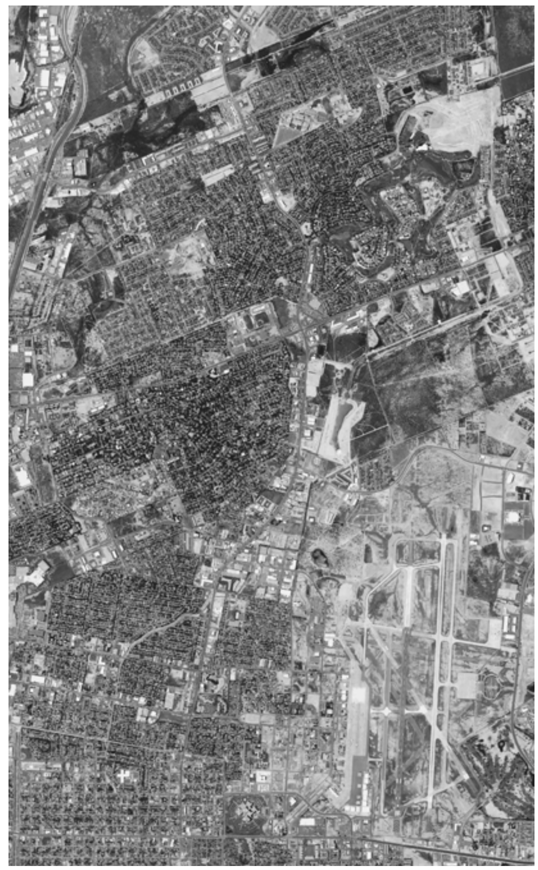


Figure 3. Zacate Creek watershed in 2006 showing significant development in the upper reaches.

Figure 2, above, shows the aerial photograph of the upper Zacate Creek watershed at roughly the time of the effective 1981 FEMA study. The more recent, 2006, photograph (Figure 3) shown of the same area shows the intense development that has occurred over the last 40 years. This study will not only examine the changes in the flooding potential but will approximate future changes and examine flood mitigation alternatives.

The previous flood studies of Zacate Creek are described in some detail in Section 1.4. The two other comprehensive studies performed in this area were the FEMA Flood Insurance Study (FIS) in 1981 and the KBR Stormwater Master Plan in 2001. The extent of the FIS detailed study was from the Rio Grande to just upstream of McPherson Road. The KBR study included an additional 2.5 miles of Zacate Creek, up to Del

Mar Boulevard. This FPP study includes detailed hydraulic analysis of the entire length of Zacate Creek, from the Rio Grande to the Bob Bullock Loop.

This FPP also differs in the formulation methodology for flood control alternatives. The intent of the KBR study was to provide a 100-Year level of service. It appears more appropriate to employ an iterative and incremental approach to determine the most cost-effective level of service based on improvement costs and expected benefits. This FPP study will focus on maximizing flood conveyance within existing drainage easements and areas that minimize the need for property acquisition. This study will also focus efforts and resource on the flood problem areas with the most significant potential flood damages. It is understood that it may not be possible to alleviate flood risks for the entire study area and this study examines the benefits of individual flood mitigation alternatives within specific problem areas.

1.2 OVERVIEW OF FLOODING PROBLEM

Flooding has been a part of Laredo's history since its founding in 1755. Historic place names in the Zacate Creek watershed suggest that earlier residents knew the creek and adjacent areas to be susceptible to flooding. Such names include: Canta Rana ("Singing Frogs") and Sal Si Puedes ("Get out while you can").

While the Rio Grande, which borders Laredo to the south and west, has produced some of the most significant flooding events in the City's history, the flashy response of the City's urban watersheds, such as Zacate Creek, can produce disastrous flooding regardless of the stage of the Rio Grande. The following table shows a partial history of flooding in the City, with some additional information related to Federal Disaster Declaration and flood stage at the Rio Grande, if known:

Table 1. Partial Flood History

DATE	DAMAGE	STAGE OF RIO GRANDE (ft)
9/11/1921		(Zacate Creek already flooding when Rio Grande above 30')
1/20/1922		
9/4/1932	15 lost lives	
6/26/1948		
2/28/1949		
6/30/1954	Federal Disaster No. 18	61.35
1/1/1965		62.48
9/29/1967		
6/30/1971		38.98
10/6/1971		31.63
9/27/1974		27.66
7/21/1975		32.05
7/19/1976		20.34
6/5/1979		21.23

8/27/1998	$2.2M in damages	35.02
8/25/1999	DR-1287-TX	Hurricane Bret
10/11/2002	DR-1434-TX	Tropical Storm Fay
10/12/2003		
6/17/2007 -	DR-1709-TX clean-up est. $820,000 in labor costs alone	
7/3/2007	14 year-old girl drowned	

The recent June 2007 floods exceeded the service limits of the Zacate Creek system. During this event, concrete-lined portions of the channel were ripped apart, and homes and businesses were inundated. Unfortunately, the summer floods of 2007 also claimed the life of a 14 year-old girl. Tropical Storm Charley dropped up to 18 inches of rainfall in the area in 1998. According to local residents, flooding also occurred in 1954, 1959, 1962, 1967, 1971, and 1972.

1.3 PROJECT SCOPE

The primary purpose of this project is to identify flooding issues and possible mitigation alternatives for Zacate Creek. The following tasks were performed in this study:

- Conduct an initial kick-off meeting with an appointed Advisory Committee

The Advisory Committee consisting of representatives of the participating entities and local public agencies, including the City of Laredo, Web County, Webb County Appraisal District, Laredo Metropolitan Planning Organization, Laredo Independent School District, and the United Independent School District, met on October 30, 2008. The project schedule and responsibilities of participants were set at this time.

- Collect data and review flood and drainage problem areas

Flood-prone areas were identified based on citizen input and records. Available GIS datasets, current and future land use maps, soil maps, cultural resource maps and materials, environmental resource maps and materials, LIDAR topography, digital orthophotography, cross-section data, detention basin data, existing FEMA information, and previous drainage, engineering, and geotechnical studies were assembled by the City of Laredo and Espey Consultants (EC) for base map creation. Information on previously identified critical environmental features was also obtained. The gathered information was reviewed and flood prone areas were identified. Environmental constraints were researched and reviewed to identify possible critical environmental features that may need to be considered during alternative development.

- Collect field survey

A list of required field survey data was compiled identifying critical structures and channel cross-sections. A total of 23 culverts and bridges, as well as channel cross sections immediately upstream and downstream of these structures, were surveyed for this study. Details on structures not surveyed were obtained from the KBR 2001 Stormwater Management Master Plan's hydraulic study and model.

- Develop hydrologic models

The hydrologic analysis encompasses the complete drainage areas of Zacate Creek. Utilizing and expanding existing hydrologic model data from the FEMA and Brown and Root Services (also known as KBR) study of Zacate Creek, an updated geo-referenced hydrologic model of the watersheds was developed using hydrologic software HEC-HMS 3.3. The model includes existing, platted, and ultimate land use assumptions, and utilizes existing City of Laredo and Webb County GIS data. Calculated peak discharges were compared to the current FIS flow rates and KBR analysis. The analysis includes an evaluation of the existing and ultimate conditions 20%, 10%, 4%, 2% and 1% (5, 10-, 25-, 50-, and 100-year) average recurrence interval storm events.

- Develop hydraulic model

The hydraulic analysis of Zacate Creek includes 16.9 miles of channel, including the main stem of Zacate Creek and five tributaries. Using recent (2006) LIDAR topographic data, the detailed hydraulic model was created using HEC-GeoRAS. This model was modified using field survey data and information from construction plans. The resulting HEC-RAS model is geo-referenced for correlation with the City Laredo GIS database. Flood profiles and floodplain maps for the existing conditions 20%, 10%, 4%, 2% and 1% (5, 10-, 25-, 50-, and 100-year) annual chance storm events were developed. The platted 2008 and ultimate conditions 1% (100-year) annual chance event were also analyzed for comparison and reference.

- Review flood protection criteria and develop, analyze, and prioritize mitigation alternatives

After review of hydraulic modeling results and the previous study of the Zacate Creek watershed recommended alternatives (KBR's 2001 Master Drainage Plan), current flood prone areas were identified and mitigation alternatives were developed. Development of alternatives focused on extending infrastructure currently in place and on minimizing disturbance of areas outside of existing drainage easements and channels. The development of the models and alternatives were presented at advisory committee meetings held on February 18, 2009 and June 4, 2009. Alternatives were finalized and a cost-benefit analysis was performed for each alternative. Results of the Benefit-Cost Analysis were discussed and alternatives prioritized at a final advisory committee meeting on August 13, 2009.

- Present initial findings at public meetings

Based on review of the gathered information and initial modeling efforts, a preliminary summary of methodology and modeling approach was prepared and presented at the public meeting held on November 13, 2008. Project results, alternatives and recommendations were presented at the second public meeting on August 13, 2009.

- Develop plan for implementation and phasing

This plan includes recommendations for the implementation and phasing of the improvements was developed. This planning effort identifies and quantifies the nature of the flooding risk, and makes this information available to the public. This effort also identifies possible capital improvements (dependant upon approval/availability of funds) that could potentially mitigate the risk, or a portion thereof, and prioritizes the recommendations in relation to public safety and welfare. The planning effort considers the hydrologic characteristics and hydraulic performance of the watershed in terms of both the existing and ultimate watershed condition.

- Prepare final flood protection plan

After staff review, this Flood Protection Plan was presented to and accepted by the Laredo City Council on December 21, 2009. This document and attachments represent the final deliverables. The deliverables include maps, technical analysis and supporting documentation, and the implementation and phasing plan.

An analysis of the effects of several structural improvements and resulting level of flood protection was performed. Structural flood protection measures include: channelization, bridge and culvert upgrades, dual-purpose flood control / water quality reservoirs, and detention facilities. Non-structural flood protection measures would likely also result in some flood reduction benefits. Potential non-structural measures include: revisions to current drainage policies, purchases of flood prone property, modification of creek maintenance programs, and a flood early warning system in cooperation with related technical partners. The City of Laredo has purchased flood prone properties in the past and is assessing potential future acquisitions. The City is also reviewing its drainage policies and looking to implement a flood early warning system. These were not further analyzed as part of this project.

The benefit of each alternative in terms of level of protection/reduction of flood damages, impacts, right-of-way requirements, environmental impacts, etc. were made in comparison to the associated cost of each improvement. The implementation discussion identifies potential funding sources for improvements. The City of Laredo's current Capital Improvements Plan and the Comprehensive Plan were considered such that the recommended flood protection strategies are coordinated and consistent with the broad objectives of the City.

The study is not a FEMA restudy (i.e., the FEMA floodplains will remain unchanged as a result of this study); however, the analyses from this study may be used in a subsequent project to revise the FEMA floodplains and creek profiles, if so desired.

1.4 PREVIOUS FLOOD STUDIES

1.4.1 FEMA Effective Model

The effective hydrologic model for the Zacate Creek watershed was created by the U.S. Army Corps of Engineers (USACE) in August 1973 as part of the *Detailed Project Report for Flood Control Zacate Creek*.

For Zacate Creek Tributary No. 1 and No. 2 the U.S. Department of Agriculture Natural Resource Conservation Service (NRCS, formerly the Soil Conservation, SCS) has developed a rainfall runoff index called the runoff curve number (CN), which takes into account such factors as soil characteristics, land use/land condition, and antecedent soil moisture condition to derive a generalized rainfall/runoff relationship for a given area. The results of the effective hydrologic analysis were published in the Federal Emergency Management Agency Flood Insurance Study (FIS), dated November 17, 1981. The most recent Webb County FIS, dated April 2, 2008, did not update hydrologic data for the Zacate Creek watershed thus making results published in the 1981 FIS the current effective hydrologic data. The 2008 restudy did remap the effective flood elevations based on more recent aerial topography.

1.4.2 KBR Zacate Creek Watershed Stormwater Management Master Plan

In March of 2001, Brown and Root Services (also known as KBR) published Zacate Creek Stormwater Management Master Plan. Brown and Root Services also submitted a request for a Letter of Map Revision (LOMR) for the Zacate Creek in December of 2000. The LOMR request was subsequently withdrawn by the City for various reasons including continued development within the upper reaches of the watershed. In their report KBR divided the Zacate Creek watershed into 19 subbasins. The subbasin areas ranged in size from 0.42 square miles to 1.49 square miles.

For the purpose of the hydrologic analysis, KBR utilized the U.S. Army Corps of Engineers (USACE) HEC-1 Flood Hydrograph Package (HEC-1) to determine peak discharges. Rainfall depths taken from Technical Paper No. 40 – Rainfall Frequency Atlas of the United States along with watershed data, and soil properties data were the hydrologic parameters utilized in determining peak discharges.

The following table compares KBR hydrologic results with those published in the 1981 Webb County FIS.

Table 2. KBR/FIS Discharge Comparison

Flooding Source and Location	Drainage Area (square miles)	Peak Discharges (cfs)					
		10% Annual Chance Event		2% Annual Chance Event		1% Annual Chance Event	
		2000 KBR	1981 FIS	2000 KBR	1981 FIS	2000 KBR	1981 FIS
Zacate Creek Main Stem (confluence with Rio Grande)	16.44	7,544	4,300	9,058	8,200	11,744	10,400
Tributary 1 (confluence with Main Stem)	1.92	1,729	1,090	2,100	1,525	2,100	1,780
Tributary 2 (confluence with Main Stem)	1.46	1,231	1,710	1,825	2,380	2,073	2,740

The discharge produced at Tributary 1 does not increase for events greater than the 2% annual chance events. The hydrology models prepared by KBR take into account any flow breaking away from the primary channel and being routed either though side channels or streets until rejoining the primary channel further downstream. The increased flow within the Zacate Creek main stem can be largely attributed to the increased urbanization that took place within Webb County, specifically the City of Laredo, between 1981 and 1994. However, it should also be noted that the KBR existing conditions model assumes undeveloped conditions for almost all of the watershed area upstream of Del Mar Boulevard, a condition which has now changed.

The Zacate Creek Stormwater Management Master Plan examined ten alternatives. The alternatives included “Buy-Out” (purchase of flood-prone property), channel and bridge improvements, detention, and diversions to the Rio Grande or Lake Casablanca. The recommended alternative was Alternative 3, Channel Improvements, at a total estimated cost of $89.7 million. This alternative called for enlarging and lowering Zacate Creek, Tributary 1 and Tributary 2 to contain the 100-Year event. The proposed channel was concrete lined and required the acquisition of an additional 88 acres of right-of-way.

1.4.3 LOMR for Unnamed Tributaries

The extents of the 100-year event flooding along Zacate Creek and two small branches between Jacaman Road and Del Mar Boulevard have been revised by FEMA Letter of Map Revisions (LOMR) in late 2008 and early 2009. These revisions are shown on the Flood Insurance Rate Map (FIRM) panel No. 48479C1205 C.

The two branches, identified as Unnamed Tributary to Zacate Creek and Unnamed Tributary 2 to Zacate Creek, were not studied in this flood protection plan. Both tributaries are categorized as approximate studies, FEMA Zone A. From Del Mar Blvd to McPherson Rd, Unnamed Tributary is channelized and contains the 100-yr event. Unnamed Tributary 2 is an engineered channel consisting of a narrow ditch that turns into shallow, wide ponds before its confluence with Zacate Creek, upstream of Alexander Ranch Detention Pond.

1.5 LOCATION AND DESCRIPTION OF WATERSHED

The Zacate Creek watershed is 16.8 square miles located within the city limits of Laredo in Webb County, Texas, as shown in Figure 1. The watershed is also bounded by the Rio Grande on the west and on the south. The watershed is bounded by the Bob Bullock Loop on the east. The northern limit of the watershed extends past the Bob Bullock Loop by approximately a half mile. The Zacate Creek watershed is located on the west end of the topographical feature known as the Rio Grande Plains, with topography dominated by flat land covered with brush, and few hills. Generally, the watershed drains towards the southwest where it outfalls to the Rio Grande. Elevations vary from 675 ft in the most northern end of the watershed to 350 ft at the outfall. The terrain slopes at an approximate rate of 0.7 percent (36 ft per mile). The primary drainage is provided by Zacate Creek and its tributaries, of which the majority of existing channels consists of engineered, concrete-lined, trapezoidal channels.

2.0 HYDROLOGIC ANALYSIS

The scope of this project includes a hydrologic study of Zacate Creek watershed performed using the United States Army Corps of Engineers (USACE) HEC-HMS software version 3.3. The hydrologic analysis includes the evaluation of the existing conditions 20%, 10%, 4%, 2% and 1% (2-, 5-, 10-, 25-, 50- and 100-year) annual chance storm events. The hydrologic analysis also evaluates the platted 2008 and ultimate conditions 1% annual chance events. The results and input parameters are compared to previous studies, but a new model was required since all previous studies were carried out using HEC-1. In addition, this study employs more recent rainfall data and impervious cover assumptions, as further discussed below.

2.1 DRAINAGE AREA DELINEATION

The United States Section of the International Boundary and Water Commission (USIBWC) is in the process of gathering data necessary for hydrologic and hydraulic modeling of the Rio Grande, levee analysis, and the creation of flood inundation maps. The USIBWC requires current detailed elevation data and digital terrain models (DTM) in order to support the afore-mentioned activities. LIDAR (Light Detection and Ranging) data in the form of 3-dimensional positions of a dense set of mass points was collected within Webb County by Sanborn Map Company, Inc. The LIDAR survey for this study was accomplished between December 13, 2005 and July 21, 2006 on multiple mobilizations. Final coordinates were delivered in Texas State Plane Coordinate System, in NAD83 horizontal datum and NAVD88 vertical datum with the units of a US survey foot.

The LIDAR data was used to generate 2-foot contours and these contours were used to delineate the watershed and sub-basin boundaries for the Zacate Creek Flood Protection Plan. The sub-basin boundary limits were field verified and modified as appropriate. A map of the drainage areas is included as Exhibit 1 in Appendix A.

2.2 PRECIPITATION

The 24-hour precipitation depths used in this study are taken from the City of Laredo Storm Water Guidance Manual. This manual does not list a 500-Year rainfall depth, so this depth was taken from a USGS publication by Asquith and Roussel, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004. The precipitation depths are shown in Table 3. Table 3 shows both the Recurrence Interval and the Exceedance Probability. The recurrence interval and the exceedance probability are both a measure of the rarity of a rainfall event. An annual maximum event has a recurrence interval of *T* years if its magnitude is met or exceeded, on average, every *T* years. The reciprocal of *T* is the exceedance probability, or the probability that the event is equaled or exceeded in any one year.

Use of the terms "recurrence interval" and "return period" can lead to confusion in the minds of some decision makers and members of public. They are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance. Specifying the annual exceedance probability makes it clearer that these rare events have a chance of occurring in any given year.

Table 3. City of Laredo 24-Hour Rainfall Depths

Recurrence Interval	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
Exceedance Probability	50%	20%	10%	4%	2%	1%	0.2%
Depth (inches)	3.8	5.3	6.5	7.6	8.6	9.8	12.0*

Source: City of Laredo Storm Water Management Guidance Manual
* Asquith and Roussel, Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas, 2004

2.3 INFILTRATION LOSSES

The U.S. Department of Agriculture Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service, SCS) has developed a rainfall runoff index called the runoff curve number (CN). The runoff curve number takes into account such factors as soil characteristics, land use/land condition, and antecedent soil moisture. This number is used to derive a generalized rainfall/runoff relationship for a given area. A description of these components and the equations for calculating runoff depth from rainfall are provided below.

The NRCS classifies soils into four hydrologic soil groups: A, B, C, and D. These groups indicate the runoff potential of a soil, ranging from a low runoff potential (group A) to a high runoff potential (group D). Digital soil data is available from the Texas Natural Resource Information System (TNRIS) post-processed from the US Department of Agriculture Soil Survey Geographic (SSURGO) database into the Texas statewide mapping system. A map of the soils found in the Zacate Creek Watershed is included as Exhibit 2 in Appendix A.

The NRCS provides runoff curve numbers for three Antecedent Moisture Conditions (AMC): I, II and III. AMC I represents dry soil conditions and AMC III represents saturated soil conditions. AMC I is used for areas that have the lowest runoff potential. In general, AMC II is considered to be the typical soil condition; however, studies have indicated that AMC II is not appropriate in all parts of Texas. Investigations have shown that the average condition ranges from AMC I in west Texas to between AMC II and III for east Texas. Runoff curve numbers vary from 0 to 100, with the smaller values representing soils with lower runoff potential and the larger values representing soils with higher runoff potential. This study assumes an AMC II to represent average condition.

Curve numbers were evaluated independent of impervious cover (i.e., these curve numbers reflect fair conditions, open spaces, brush cover) for this analysis. The table below lists the CN values for Zacate Creek.

Table 4. NRCS Curve Number Table

Soil Groups	AMC I	AMC II	AMC III
A	18	35	55
B	35	56	75
C	49	70	84
D	58	77	89

Key Assumptions: brush cover type, fair hydrologic condition
Source: TR-55

A composite CN is computed based on area weighting of each hydrologic soil group within each subbasin. Impervious cover values are entered separately from CN values into the HEC-HMS model. Calculations of the weighted curve number values for each subbasin are included in Appendix B.

HEC-HMS computes 100 percent runoff from impervious areas, while runoff from pervious areas is computed using the selected CN value and the following equations:

$$Q = (P - 0.2\times S)^2 / (P + 0.8\times S) \qquad \text{Equation 1}$$

And

$$CN = 1000 / (10 + S) \qquad \text{Equation 2}$$

Where:

Q	=	depth of runoff (in),
P	=	depth of precipitation (in),
S	=	potential maximum retention after runoff begins (in), and
CN	=	runoff curve number.

2.3.1 Existing Impervious Cover Determination

Impervious cover was determined using existing land uses in 2008 obtained from the City of Laredo Land Use and Zoning information and the 2008 NAIP one-meter resolution aerial photography. Seven major land uses were identified and assigned an impervious cover percentage, as shown in the table below.

Table 5. Impervious Cover Assumptions

Land Use	Impervious Cover
Vacant	0%
Park	10%
Residential	60%
Multifamily	80%
Commercial	85%
Industrial	90%
ROW/ Water	98%

Commercial development, industrial development, road and water are expected to provide the greatest amounts of rainfall runoff. Residential areas are categorized as single family or multifamily. Single family areas are categorized by the number of units per acre. The existing land use map is included in Appendix A as Exhibit 3.

2.3.2 Future Impervious Cover Determination

The impervious cover values for each subbasin of the Zacate Creek watershed were modified to reflect the platted 2008 (near future) and ultimate land uses. Most of the remaining large open tracts of land within this watershed can be found north of Jacaman Road and east of McPherson Road. The majority of these areas is currently under development or has been fully platted as of 2008 for development in the near future. The ultimate land use assumption simply adds the reminder of land designated as “vacant” to be developed based on zoning or adjacent land uses. The platted and ultimate land use maps are included in Appendix A as Exhibits 4 and 5. A summary comparing existing, platted and ultimate conditions impervious cover/land use is included in Appendix C.

2.3.3 Unit Hydrograph

A rainfall-runoff transformation is required to convert excess rainfall (total rainfall minus infiltration losses) into runoff from a particular sub-basin. The NRCS unit hydrograph option in HEC-HMS is used in this analysis to generate runoff hydrographs for each defined sub-basin within the studied watershed. The unit hydrograph method represents a hydrograph for one unit (one inch) of direct runoff, which is standard engineering practice.

The dimensionless unit hydrograph developed by the NRCS (see Figure 4) was developed by Victor Mockus and presented in *National Engineering Handbook, Section 4, Hydrology*. The dimensionless unit hydrograph has its ordinate values expressed in a dimensionless ratio, of discharge relative to peak discharge, q/qp, and its abscissa values as time relative to time to peak, t/Tp. This unit hydrograph has a point of inflection approximately 1.7 times the time to peak (Tp), and the time-to-peak 0.2 of the time-of-base (Tb) (NRCS 1985).

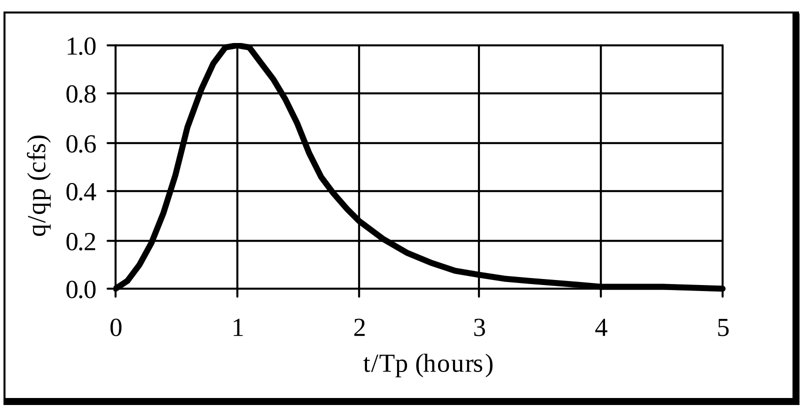


Figure 4: NRCS Unit Graph

In HEC-HMS, input data for this method consists of a single input parameter, T_{LAG}, which is equal to the time (hours) between the center of mass of rainfall excess and the peak of the unit hydrograph (NRCS 1985). In other words, there is a delay in time after a rain event begins before the runoff reaches it maximum peak. This delay is known as lag. The lag is determined based on the time of concentration, as discussed in Section 2.4.

The time to peak is computed using the following equation:

$$T_{PEAK} = \Delta t/2 + T_{LAG} \qquad \text{Equation 3}$$

Where:

T_{PEAK} = time to peak of the unit graph (hours),
Δt = computation interval or duration of unit excess (hours), and
T_{LAG} = watershed lag (hours).

The peak flow rate of the unit graph is computed using the following equation:

$$qp = 484A/T_{PEAK} \qquad \text{Equation 4}$$

Where:

qp = peak flow rate of the unit graph (cubic feet per second [cfs] / inch) and
A = watershed area (square miles).
484 = peak rate factor (dimensionless)

Note: The peak rate factor of 484 has been known to vary from 600 in steep terrain to less than 300 in very flat, swampy terrain. The 484 value is standard engineering practice and is used in this analysis.

2.4 TIME OF CONCENTRATION

The methods described in the NRCS method assume that the lag time of a watershed is 60 percent of the watershed's time of concentration. The time of concentration (Tc) is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed (NRCS, 1985). The time of concentration may be estimated by calculating and summing the travel time for each sub-reach defined by the flow type: sheet flow, shallow concentrated flow, and channelized flow (including roadways, storm sewers, and channels). The methods prescribed in NRCS Technical Release 55 (TR-55) are used to determine the times of concentration for each flow segment in this analysis. Adjustments are made to the time of concentration calculations in the platted and ultimate conditions analyses to reflect faster watershed response times, specifically in the uplands of the watershed. Time of concentration calculations can be found in Appendix D, utilizing each typical flow segment presented below.

2.4.1 Sheet Flow (≤ 300 feet)

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact, drag over the plane surface and obstacles such as litter, crop ridges, and rocks, and of erosion and transportation of sediment. These n values are for very shallow flow depths of approximately 0.1 feet. A maximum sheet flow length of 300 feet is assumed for undeveloped conditions, and 150 feet is assumed for developed conditions. Travel time is computed as follows:

$$Tt = (0.007 \times (n \times L)^{0.8}) / (P_2^{0.5} \times s^{0.4}) \qquad \text{Equation 5}$$

Where:

- Tt = travel time (hr),
- n = Manning's roughness coefficient,
- L = flow length (ft),
- P_2 = 2-year, 24-hour rainfall (in), and
- s = slope of hydraulic grade line (land slope, ft/ft).

2.4.2 Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from the following figure in which average velocity is a function of watercourse slope and type of channel (TR-55). The flow is still considered shallow in depth and flows in a swale or gutter instead of a channel, which would have greater depth.

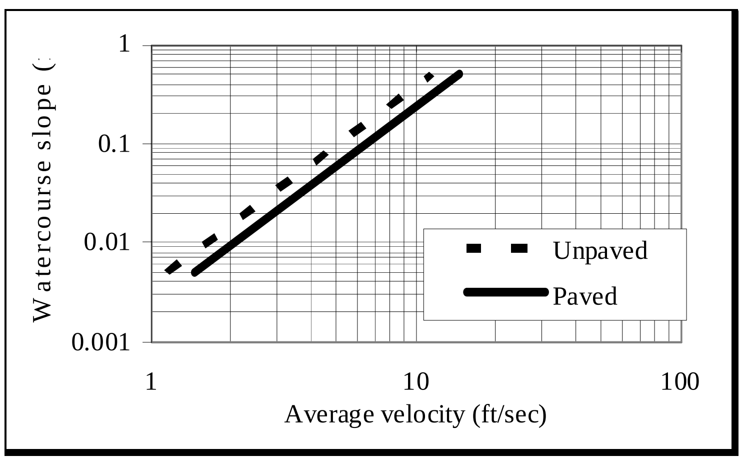


Figure 5: Avg. Velocities for Estimating Travel Time in Shallow Concentrated Flow Segments

After determining the average velocity, the following equation is used to compute travel time:

$$Tt = L / (3600 \times V) \qquad \text{Equation 6}$$

Where:

- Tt = travel time (hr),
- L = flow length (ft),
- V = average velocity (ft/sec), and
- 3,600 = conversion factor from seconds to hours.

2.4.3 Channelized Flow

As the depth of concentrated flow increases, the shallow concentrated flow evolves into channelized flow. Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States

Geological Survey (USGS) quadrangle maps. In the case of this analysis, channel flow either involves flow in man-made storm sewer infrastructure or flow in the natural channel. Manning's equation or water surface profile information (available from HEC-2 or HEC-RAS) can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevations. Both open channel and closed conduit systems can be included.

Manning's equation is:

$$V = 1.49 \times r^{2/3} \times s^{0.5} / n \qquad \text{Equation 7}$$

Where:

V = average velocity (ft/sec),
r = hydraulic radius (ft), equal to flow area divided by wetted perimeter,
s = slope of the hydraulic grade line (channel slope, ft/ft), and
n = Manning's roughness coefficient.

2.5 HYDROGRAPH ROUTING

2.5.1 Modified Puls

Channel routing simulates the movement of a flood wave through a reach, allowing for the prediction of variation in time and space. Hydrologic routing allows runoff hydrographs from multiple subbasins to be combined and routed to a point of interest. The majority of the Zacate Creek hydrologic model uses modified Puls methodology for routing. The modified Puls routing method is classified as a hydrologic method of routing, which uses the continuity equation and a relationship between reach storage and discharge at the outlet. Hydrologic routing techniques are recommended when backwater effects are significant and/or flow is out of banks.

The modified Puls method relates storage, outflow, and water surface slope in a river reach using results from HEC-RAS. In a natural river, storage is a function of outflow and a function of water surface elevation. To define a unique storage-discharge relationship, the routing reach is broken into several segments, or routing steps, with each segment treated as a level pool reservoir. The routing steps are referred to as "subreaches" in HEC-HMS. The number of routing steps is defined as the wave travel time divided by the time step (HEC-HMS computation interval). Travel time is defined as the reach length divided by average wave celerity. Wave celerity can be estimated as the slope of the discharge rating curve divided by the top width of the water surface. As a rule of thumb this value of celerity can be approximated by multiplying 1.5 times the average flow velocity, for natural channels. As number of routing steps increases, attenuation decreases. Therefore, longer routing reaches or slower velocities will increase routing steps, and reduce attenuation.

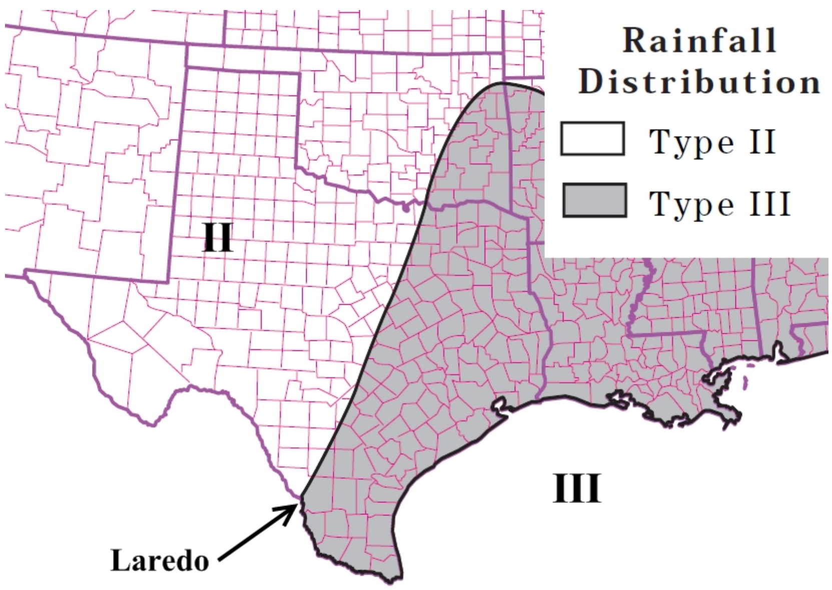
2.5.2 Muskingum Cunge

Muskingum Cunge routing is based on the conservation of mass and the diffusion representation of the conservation of momentum. While Muskingum Cunge methodology does represent the attenuation of the flood wave, no tailwater impacts are modeled in this method. Routing reaches are described using a length, channel shape, slope and roughness coefficient. Muskingum Cunge routing was used only in select areas of Zacate Creek where HEC-RAS modeling was not available, or where tailwater impacts are not expected to be significant.

2.6 DESIGN STORM ANALYSIS

The application of a design storm in the HEC-HMS model is used to generate runoff hydrographs and estimate peak flow rates along the watercourse for various storm frequencies. There are three major components to the design storm: depth, duration, and distribution. Precipitation depths that have been selected for this impact study are included in Section 2.2.

Design storm duration is a significant consideration for hydrologic modeling. The peak flow of any given event must reach the mouth of the studied basin prior to the end of the rainfall duration. The intensity of rainfall varies considerably during a storm as well as geographic regions. The NRCS has developed four synthetic 24-hour rainfall distributions for the United States using duration-frequency data, two of which are found in Texas. For this study, the NRCS Type III storm was used.



Source: NRCS, TR-55, 1989

Figure 6. NRCS Rainfall Distribution Map

2.7 SPLIT FLOW RELATIONSHIPS

Due to the extent of overland flooding within the watershed, there are many opportunities for flows to travel from one creek to another in the event of overflow. Detailed analysis of the shallow overbank flooding was beyond the scope of this study, with the exception of flooding caused by the overtopping of two of the studied channels, Tributary 1 and Tributary 2A. Two known diversions were included within the model, as further discussed below. Please note that the split flow locations included in this study differ from those modeled in the KBR study. The KBR study did not include the diversion from Tributary 2A to Zacate Creek, as this area was not included in their study. The KBR study included several diversions in the vicinity of Canal Street that are not included in this study. While it is known that flows may exit the main channel of Zacate Creek in the vicinity of Hillside Road and flow south and west to the north of Canal Street, it was not felt that these flows were hydraulically disconnected from the main channel flows. To accommodate this condition, fewer ineffective limits were included in the overbanks for this region, but no diversion is assumed.

2.7.1 Tributary 1 Diversion

Tributary 1 is situated between the IH-35 and the north-bound frontage road, and extends from the confluence with Zacate Creek to just north of Mann Road. There are significant flooding problems along the IH-35 corridor. Review of historic aerial photographs show that the IH-35 alignment is roughly in an area that had been a major tributary to Zacate Creek. The result is that IH-35 lies in a locally low area with water flowing toward the freeway and then to the south from both sides. Tributary 1 is a trapezoidal concrete channel that was built in conjunction with the freeway. This channel was sized to accommodate the 10-Year flood at the time of construction (construction plans are dated 1960). This area was undeveloped at the time, and has since been developed to include some of the densest commercial and industrial areas found within the City of Laredo. These flooding issues are further exacerbated by the fact that Tributary 1 lies at a very flat slope relative to Zacate Creek. The channel banks on Zacate Creek, upstream of the confluence with Tributary 1 are several feet higher than the IH-35 frontage road elevation. The result is that bank-full flows on Zacate Creek results in significant flooding on Tributary 1 even in the absence of local runoff.

The IH-35 roadway is generally elevated in this area with overpasses at Mann Road and Calton Road. The significant tailwater effects from Zacate Creek causes water to back-up and flow to the west at Mann and Calton Road. Flows then turn to the south, and do not re-enter Tributary 1 since IH-35 is elevated in this area. There are stormdrain connections between Tributary 1 and the west side of IH-35, but these are likely ineffective due to their small size and the tailwater elevation of Zacate Creek on the east side of IH-35. The channel and culverts on Tributary 1 are overwhelmed for all events studied. It is known that significant flows exit Tributary 1 and flow to west of IH-35 at Mann Road and Calton Road. These diversions are modeled within the HEC-HMS model. Once flows leave Tributary 1, it is assumed that they generally follow the alignment of IH-35 to the south before re-entering Zacate Creek at the channel at Jefferson Street. This flowpath is referred to as Tributary 1A in this study. There is no channel in this location until you reach Jefferson Street, so flows are generally in the streets. The area of Tributary 1A is included in the FEMA study as a Zone AO (Area of Shallow Flooding).

2.7.2 Tributary 2A Diversion

Tributary 2A is a tributary to Tributary 2. This channel enters Tributary 2 roughly halfway between the confluence of Tributary 2 and Zacate Creek and McPherson Road. Tributary 2A collects flows from areas north of Tributary 2 and west the airport and drains generally to the west and south. Tributary 2A is a natural channel upstream of McPherson and between Calton Road and Chaparral Street. The tributary is a trapezoidal concrete-lined channel between McPherson Road and Calton Road and downstream of Chaparral Street to the confluence with Tributary 2. Tributary 2A has limited capacity. Overbank flooding typically travels from Tributary 2A to Zacate Creek through the adjacent neighborhood downstream of Calton Road. This scenario is modeled as a lateral weir within HEC-RAS.

2.8 FUTURE CONDITIONS ANALYSIS

The platted and ultimate development conditions (fully developed conditions) analyses use the existing conditions basin model with the addition of current city projects in place and the NRCS Type III distribution frequency storm to determine the flow rates for the sub-basins at platted (near-future) and full (ultimate) development.

The platted conditions model includes land use assumptions to reflect development platted or master planned though not fully developed in 2008. The full (ultimate) development model includes land use assumptions to reflect all projected development according to the City Zoning overlay. The change in land use increases the impervious cover assumptions, as discussed in Section 2.3.2, and sometimes results in a change in the time of concentration, which is adjusted accordingly to reflect shorter watershed response times. These land use changes are generally located in the uplands of the watershed north and east of McPherson and alter the sheet and shallow concentrated flow assumptions.

The platted 2008 and ultimate watershed conditions analyses include flow rates for the 1% (100-year) annual chance only. These platted and ultimate conditions flow rates are used to determine the future floodplain for the 1% annual chance event.

2.9 COMPARISON WITH PREVIOUS STUDIES

Comparison with the KBR 2001 Zacate Creek Watershed Stormwater Management Master Plan shows a slight variation of the watershed boundary and basin delineation. The KBR model has a total drainage area of 16.4 square miles; the FPP model has a total drainage area of 16.8 square miles. The FPP watershed extends slightly further (several hundred feet) in several locations along the east boundary. The KBR basin extends 0.25 miles further north for Tributary 1. The KBR model subdivides the watershed into 21 basins; the FPP model subdivides the watershed into 35 basins. The FPP basin delineations for Tributaries 1, 2, 3 and 4 is more subdivided compared to the KBR model. The basin delineation is similar for both models for the Zacate Creek reach south of Canal Street. Subbasin delineation in the Alexander Ranch detention pond area varies slightly.

The FPP model includes eight detention basins: San Isidro-Bougainvilla detention basin, the proposed North Laredo City (Shiloh) detention basin, Alexander Ranch detention basin, three detention basins between Del Mar Boulevard and Alexander Ranch detention basin, the proposed Multi-Purpose City detention basin, and the Winfield Pond. Several of these basins were not present at the time of the KBR study.

Both models include diversions for Tributary 1 and Tributary 2A. The KBR study analyzed the spit flow relationship between Zacate Creek Reaches 3 and 4. This diversion is excluded from this study because two-dimensional modeling showed flow returning to the Zacate Creek channel.

FPP study uses the SCS unit hydrograph method. KBR uses the Synder's unit hydrograph. Both models employ mainly modified Puls storage routing.

The FPP study shows increased flows in all areas when compared to the KBR model. The specific flow rates used in each model for the 100-yr event are shown in Table 8. Reduced flow rates are shown to exist in Tributary 1 and Tributary 2, but this is due to different diversion assumptions. The increase in runoff is primarily due to differences in land use assumptions and time of concentration. Most of the area upstream of upstream of Del Mar Boulevard is assumed to be undeveloped in the KBR model, a condition which has now changed. Significant increases in impervious cover have occurred within this area, and this has increased flow rates. The time of concentration (Tc) in the KBR study also appears consistently longer than the FPP. Recent development would have the effect of shortening Tc, but differences exist between the models even in areas where development patterns have not significantly changed. Peak discharge varies inversely with Tc, so a shorter Tc translates to a higher peak discharge. The details of how the Tc was calculated for the KBR study are not known. The Tc calculation for the FPP was reviewed in detail when this difference became apparent, and the longer Tc assumptions used in the KBR model can no longer be justified.

Table 6. Comparison of Flows

	Existing Conditions 1% Peak Flow (cfs)		
Location	2001 KBR HEC-1 Model	Zacate Creek FPP HEC-HMS Model	Percent Change (%)
Zacate Creek			
Del Mar Boulevard	2,599	3,524	36%
Jacaman Road	4,576	6,522	43%
McPherson Road	5,257	5,679	8%
Hillside Road	5,334	5,542	4%
Springfield Avenue	4,631*	6,565	42%
Confluence with Tributary 1	4,611*	7,580	64%
Jefferson Street	10,184	13,336	31%
Outlet at Rio Grande River	11,774	15,488	32%
Tributary 1 at confluence with ZC	2,100*	1,644*	-22%
Tributary 2 at confluence with ZC	2,073*	1,610*	-22%
Tributary 3 at confluence with ZC	1,521	1,782	17%
Tributary 4 at confluence with ZC	1,414	2,081	47%

*Discharges modeled with diversions

There is not sufficient historical rainfall or streamflow data available for Zacate Creek to perform a comprehensive calibration of the hydrologic model. A model validation was performed as a part of the 2008 Canal Street Drainage Improvement Project by EC where observed water surface elevations for a rainfall event of a known frequency was compared to model results for a similar frequency. Observed water surface elevations were very similar to modeled results. The USGS Office of Surface Water regression equations for urban areas were also used as a basis of comparison. The FPP flow rates calculated were similar but lower than those calculated with regression equations in all cases. It is likely that the flow rates for the FPP were lower due to the significant effects of the storage routing (modified Puls) in HEC-HMS.

3.0 HYDRAULIC ANALYSIS

The hydraulic analysis conducted for Zacate Creek and its tributaries computes water surface elevations for the existing conditions 20%, 10%, 4%, 2% and 1% (5, 10-, 25-, 50-, and 100-year), and platted 2008 and ultimate conditions 1% (100-year) annual chance storm events as discussed in Chapter 2. The hydraulic analysis includes the delineation of the 10% and 1% annual chance floodplains. The studied channels include the following:

- Zacate Creek
- Tributary 1
- Tributary 1A
- Tributary 2
- Tributary 2A
- Tributary 3
- Tributary 4

Tributary 1A, Tributary 2A and Tributary 3 were not included in the detailed hydraulic analysis in previous studies. Please note that two unnamed tributaries that extend north from Zacate Creek in the vicinity of the Alexander Ranch detention pond that were included in the FEMA study have not been included in this study. These are minor tributaries and no modifications are proposed by this study that would impact these floodplains. An overall drainage map showing the extents of the studied reaches is included as Exhibit 1 in Appendix A of this report. In total, there are 13 hydraulic reaches that include 50 modeled structures. The specific studied reaches and cross-section locations are included as Exhibits 6 through 9 in Appendix A.

The hydraulic analysis performed in this study does not assume any backwater effects from the Rio Grande, as peak flows of the Rio Grande and Zacate Creek are not expected to coincide. The FEMA effective floodplain shown in Exhibit 10 in Appendix A for comparison purposes includes flooding impacts at the confluence with the Rio Grande. In other words, the Rio Grande Floodplain is mapped in addition to the Zacate Creek floodplain on the effective FEMA map. The FPP floodplain, as shown, represents only the Zacate Creek floodplain. Exhibit 10 also includes the floodplain as delineated in the 2001 KBR study.

The USACE HEC-RAS software version 4.0 is used for the hydraulic analyses. All modeling is one dimensional and steady state. The sections that follow describe the development of the hydraulic models both in general terms and specifics that apply to certain reaches.

3.1 DESCRIPTION OF HYDRAULIC MODEL GENERATION

A HEC-RAS hydraulic model was generated for the entire Zacate Creek watershed included in this study. The hydraulic model was generated using 2006 IBWC LIDAR data, field-surveyed cross sections, field-surveyed structures, and construction plans for selected projects within the Zacate Creek watershed. The Zacate Creek network consists predominately of engineered, trapezoidal channels that are either entirely concrete-lined or grass-lined with a concrete pilot channel. However, there are a few short reaches of natural channel with no pilot channel. Stream centerlines and cross sections were created with ESRI's ArcMap GIS software and imported into HEC-RAS using HEC-GeoRAS software.

The Zacate Creek network is modeled under a mixed flow regime. The watershed slope and presence of concrete-lined channels warrant allowing supercritical flows, as the concrete-lined channels are designed to accommodate these high flow velocities. Downstream boundary conditions at the Rio Grande were assumed to be normal depth with a slope of 0.09 percent. Table 6 below lists the stream location, length, and number of reaches and structures. A total length of 16.9 miles of stream, 13 hydraulic reaches, and 50 structures were modeled for this study.

Table 7. Zacate Creek FPP Studied Channel Summary

Stream Name	Reach Limits	Stream Length (mi)	Number of Hydraulic Reaches	Number of Structures
Zacate Creek (ZC)	Zacate Creek from the Winfield Detention Pond near the intersection of Winfield Pkwy and Loop 20 to the confluence with the Rio Grande.	9.0	6	26
ZC Tributary 1	Concrete channel running south on the east side if IH-35 from north of Mann Road to Zacate Creek south of Canal Street.	1.6	1	7
ZC Tributary 1A	Undefined channel running along streets west of IH-35 (parallel to Tributary 1) to Zacate Creek south of Jefferson Street.	2.5	1	3
ZC Tributary 2	Concrete channel flowing to the west from just north of the intersection of Meadow Avenue and Taylor Street to Zacate Creek.	0.7	2	1
ZC Tributary 2A	Channel flowing south from north of Calton Road to Tributary 2.	0.5	1	3
ZC Tributary 3	Channel flowing generally south from the intersection of Conrad Drive and Avon Court to Zacate Creek downstream of McPherson Road.	0.9	1	2
ZC Tributary 4	Channel flowing generally south from the San Isidro - Bouganvillas Detention Pond to Zacate Creek upstream of Del Mar Boulevard.	1.7	1	8
	Total	**16.9**	**13**	**50**

3.2 HYDRAULIC MODEL DEVELOPMENT

3.2.1 Streamlines and Cross Section

Study streamlines and cross sections were delineated using ArcGIS 9.3 and LIDAR. Cross sections along the streamlines were placed to capture natural cross sections and data for hydraulically significant structures, including bridges, culverts, and roads. A map of cross section location for each model is included in Appendix A as Exhibits 6 through 9. All cross sections are modeled from left to right looking downstream and do not necessarily coincide with cross-section locations shown in the previous study models. An extensive field survey of important hydraulic structures was conducted to help enhance the accuracy of the hydraulic model. Cross-section data was imported into HEC-RAS software using HEC-GeoRAS tools.

3.2.2 Parameter Estimation

Hydraulic models require several estimated parameters, including the Manning's roughness coefficients for channels and overbanks, contraction and expansion coefficients, and ineffective limits.

Manning roughness coefficient, n, is a measure of the roughness of channels and overbanks. The value n varies with flow depth, alignment, amount and type of vegetation, and flow obstructions. The table below lists typical values for Manning's n.

Table 8. Manning Roughness coefficients for various open channel surfaces

Material	Typical Manning roughness coefficient
Concrete	0.012
Gravel bottom with sides	
concrete	0.020
mortared stone	0.023
riprap	0.033
Natural stream channels	
Clean, straight stream	0.030
Clean, winding stream	0.040
Winding with weeds and pools	0.050
With heavy brush and timber	0.100
Flood Plains	
Pasture	0.035
Field crops	0.045
Light brush and weeds	0.050
Dense brush	0.070
Dense trees	0.100

Source: Chow, et al. 1988

In this study, areas with maintained grass channels were modeled with a Manning's n of 0.035, areas with concrete surfaces were modeled with 0.015 and areas of natural range lands were modeled with 0.045. Residential development in the overbanks, which consists of a mixture of streets, homes, fences, and grassy areas, was modeled with a Manning's n of 0.08. Overbank areas along the IH-35 corridor, which consists mainly of paved streets, parking lots, buildings and minimal grassy areas were modeled with a Manning's n of 0.05.

Contraction and expansion coefficients are applied upstream and downstream, respectively, of culverts and bridges to model the contraction and expansion of flow. In this study, contraction and expansion coefficients of cross sections bounding bridges with abutments and culverts are 0.3 and 0.5, respectively. All other cross sections and cross sections bounding clear span bridges use the default contraction and expansion coefficients of 0.1 and 0.3, respectively.

Ineffective flow limits are added to cross sections to accurately model any given section's inability to convey flow, such as cross sections that bound bridges and culverts. Ineffective limits were also set at the top of the channel banks to account for storage in overbanks that do not contribute to channel conveyance. Blocked obstructions are placed on areas within cross sections where conveyance is not expected to occur or in areas that should not be included as storage. Storage must be accounted to accurately model with modified Puls routing.

3.3 COMPARISON WITH PREVIOUS STUDIES

Several modeling differences exist between the FPP study and the KBR Zacate Creek Watershed Stormwater Management Master Plan study and the 1981 FEMA effective model. The difference in modeling extents follows:

- The FPP study models Tributary 1 from the confluence with Zacate Creek to approximately 1,500 ft upstream of Mann Road. The FPP study extends hydraulic modeling approximately 1,800 ft further upstream of the KBR model limits and 3,000 ft upstream of the FEMA effective model limits.
- The FPP study models the flooding along the streets west of IH-35 with Tributary 1A, which is not included in the other studies
- The FPP study models Tributary 2 300 ft further upstream of KBR model limits and 2,500 ft further upstream than the FEMA effective model limits.
- FPP study models Tributary 2A 1,200 ft further upstream than KBR model limits. The FEMA effective does not model Tributary 2A.
- Tributary 3 is modeled by the FEMA and KBR with cross sections extending from Zacate Creek. The FPP study assigns separate cross sections to Tributary 3. The FPP study models this tributary in as a separate reach and extends 1,000 ft further upstream than the KBR study and 2,500 feet upstream of the FEMA effective model.
- The FFP study models Tributary 4 from the Del Mar Boulevard up to the Bougainvilla detention basin. The effective FEMA model extends 1,000 ft beyond the Bougainvilla detention basin. Tributary 4 is not modeled in the KBR study, as the KBR model's upper limit of detailed study is Del Mar Boulevard. The effective model also extends 800 ft upstream of the proposed North City Multi-Purpose (Shiloh) detention basin toward the Bob Bullock Loop. This branch is not modeled in the FPP study.
- ZC Reach 1 is modeled in the FPP study and the effective FEMA study, but not in the KBR model. The effective FEMA model extends 1000 ft upstream of the Winfield Detention Pond.
- The effective FEMA study also models the two branches on the ZC Reach 2, identified as Unnamed Tributary to Zacate Creek and Unnamed Tributary 2 to Zacate Creek, and mapped in the FEMA Letter of Map Revisions (LOMR) in late 2008 and early 2009 were not modeled in the FPP study nor the KBR study.

As expected with increased flows shown above in Table 6, the FPP study has higher water surface elevations than the KBR model. Table 9 shows the 1 percent water surface elevations determined in the FPP study and KBR study for various locations along Zacate Creek and its tributaries. Please note that the FEMA effective floodplain includes flooding impacts at the confluence with the Rio Grande. In other words, the Rio Grande

Floodplain is mapped in addition to the Zacate Creek floodplain on the effective FEMA map. The KBR and FPP floodplains, as shown, represent only the Zacate Creek floodplain. The 100-Year effective FEMA floodplain, the 100-Year KBR floodplain and the existing conditions 100-Year FPP floodplains are shown in Appendix A, Exhibit 10.

Table 9. Comparison of Water Surface Elevations

Location	Existing Conditions 1% Water Surface Elevation (ft)		Percent Change (%)
	2001 KBR HEC-2 Model	Zacate Creek FPP HEC-RAS Model	
Zacate Creek			
Del Mar Boulevard	502.3	506.5	53.9%
Jacaman Road	470.3	471.4	6.5%
McPherson Road	450.6	451.3	4.7%
Hillside Road	437.6	440.6	21.3%
Springfield Avenue	434.0	434.3	1.8%
Confluence with Tributary 1	418.89	420.6	14.5%
Jefferson Street	408.6	415.2	53.4%
Outlet at Rio Grande River	362.7	375.6	101.1%
Tributary 1 at confluence with ZC	420.0	423.3	33.5%
Tributary 2 at confluence with ZC	433.8	434.6	11.1%
Tributary 3 at confluence with ZC	450.6	452.3	10.9%
Tributary 4 at confluence with ZC	N/A	507.5	NA

The water surface elevation of Tributary 3 at the confluence with Zacate Creek approximately corresponds with elevations at McPherson Road. Upstream of Del Mar Boulevard (Tributary 4 and ZC Reach 1) is beyond the study limit of KBR model so no comparison is available for this study.

The increased water surface elevations are due to many factors including: 1) increased flow rates; 2) new topographic data, 3) new survey data, 4) modeling differences (HEC-2 vs. HEC-RAS), and diversion assumptions. The floodplain analysis is used to focus efforts in alternative development to find sections of channel and culverts with limited conveyance capacity and to look for opportunities to add storage or diversions.

4.0 FLOODING ANALYSIS OF ZACATE CREEK

The hydrologic and hydraulic models were used to evaluate the existing conditions of Zacate Creek and tributaries. Water surface elevations for the 20%, 10%, 4%, 2% and 1% (5-, 10-, 25-, 50- and 100-year) annual chance storm events under existing conditions (current land use) are calculated with HEC-RAS 4.0, and processed with HEC-GeoRAS using GIS software (ESRI ArcMap 9.3) to identify out-of-bank flooding limits and flood depths. The results of the existing conditions analysis are summarized in the following sections in terms of level of service provided by the channels. The level of service of each reach is a measure of the magnitude of the storm event, in terms of frequency, that the channel can generally contain without overbank flooding. The existing conditions floodplain maps for each watershed for the 10% and 1% storm events (10-year and 100-year, respectively) are included in Appendix A as Exhibits 6 through 9.

4.1 MAIN STEM OF ZACATE CREEK

The hydraulic capacity of Zacate Creek varies widely within its six reaches, as modeled. The highest level of service (the 100-yr event) in the channel is achieved along Reach 2, from the confluence with Tributary 4 to upstream of the Alexander Ranch Detention Basin, and along Reach 5, from the confluence with Tributary 1 to US Hwy 59. Reach 2 was recently improved in conjunction with adjacent land development and has increased capacity. The downstream portion of Zacate Creek (Reaches 5 and 6) generally has 100-yr capacity, but the channel is bankfull and even minor future increases in discharge could dramatically increase flooding in this area.

The lowest level of service (less than the 5-yr event) occurs in the lower section of Reach 2, Reach 3 and Reach 4, which extends from the confluence of Zacate Creek with Tributary 1 to just upstream of Alexander Ranch Detention Pond. The convergence of flow from several basins and resulting backwater make the area along Zacate Creek from the confluence with Tributary 1 to the confluence with Tributary 2 prone to flooding. The specific problem areas are discussed in detail in the Alternative Analysis in Chapter 5.

4.2 ZACATE CREEK TRIBUTARIES

Tributary 1 is an engineered, concrete-lined, trapezoidal channel running parallel to IH-35. The channel was designed and constructed by TxDOT to convey the 10-year event based on the existing (undeveloped) conditions in 1960. The channel, which runs north to south on the east side of IH-35, was built prior to most of the commercial, industrial, and residential development currently found in this portion of the watershed. These flooding issues are further exacerbated by the fact that Tributary 1 lies at a very flat slope relative to Zacate Creek. Tributary 1 provides less than a 5-year level of service in the existing condition.

Tributary 1A is an undefined channel that models the flow path of overland and street flow west of IH-35 as it travels south and flows into Zacate Creek near Jefferson Street. Flooding on Tributary 1 at Mann Road and Calton Road tends to flow into Tributary 1A. This is further discussed above in Section 2.7.1. It appears that IH-35 was constructed generally in the alignment of a tributary of Zacate Creek that is visible in aerial photos prior to 1959. No flood water conveyance has been provided south or west of Tributary 1 beyond minor storm drain systems. Tributary 1A provides a level of service less than the 5-year event as all primary flood conveyance is within the existing streets.

Figure 7. Wastewater Line Crossing and Wall Obstruction Upstream of McPherson Avenue

The Tributary 2 channel has a 100-year level of service (LOS) except at McPherson Road (10-yr LOS) and from the confluence at Tributary 2A to the confluence at Zacate Creek (5-yr LOS). The McPherson Avenue culverts on Tributary 2 consist of three 10x5 ft concrete box culverts. Figure 7 shows the upstream face of the McPherson Avenue culverts. The existing conditions hydraulic model shows that the culverts themselves are sufficiently sized to convey the 100-year design storm discharge. However, the culverts are largely ineffective due to obstructions on both sides of the roadway. On the upstream side of this bridge crossing the back wall of the adjacent strip mall blocks effective flow to two of the culverts. In addition the there is a 12-inch wastewater line encasement crossing along the face of the culvert openings approximately 18 inches above the channel flowline. These upstream obstructions combine to severely decrease the conveyance capacity of the existing culverts. Alternative configurations to increase flood conveyance in this location is further discussed in Section 5.2.2 and in the report entitled Canal Street Drainage Improvements Project, Preliminary Design Report prepared by Espey Consultants in 2008. The limited channel capacity on Tributary 2 downstream of McPherson Road is due primarily to flood elevations (tailwater) on Zacate Creek.

Tributary 2A conveys the 5-year event from the confluence with Tributary 2 to Calton Road. The culvert at Calton Road is overtopped by all events because it has significantly less capacity than the upstream and downstream channel sections. From Calton Road to McPherson Road, the channel conveys less than the 5-year event due primarily to tailwater impacts from Tributary 2 and Zacate Creek. The culvert at Chaparral Street conveys all but the 100-yr event. The grass-lined section of channel from Chaparral Street to Calton Road is scheduled to be concrete lined in the fall of 2009.

Tributary 3 is a small channel that flows generally south before confluencing with Zacate Creek near the intersection of McPherson Road and Los Ebanos Drive. This channel is grass lined in the upper reaches and concrete lined from approximately 300 feet upstream of Calle del Norte to the confluence. Tributary 3 provides a 10-year level of service in the concrete channel from Calle del Norte to the confluence with Zacate Creek. The level-of0service appears limited due to conveyance limitations at the roadway crossings (Calle del Norte and Gale Street) and from tailwater elevations on Zacate Creek. The grass-lined channel upstream of Calle del Norte provides less than a 5-year level of service.

Tributary 4 generally provides a 100-yr level of service since it has been recently modified in conjunction with adjacent development. A Letter of Map Revision was recently approved in the area upstream of Del Mar Boulevard to show the impacts of recent channel improvements. There is an approximately 2,000 foot length of Tributary 4 between Yukon Lane to Fishers Hill Loop that is unimproved and poorly defined. This segment achieves less than a 5-year level of service. This segment of channel will be improved in conjunction with the Shiloh (North City) Detention Basin that is currently under construction. This basin is further discussed below in Section 5.2.1.

4.3 PLATTED AND ULTIMATE CONDITIONS FLOODING ANALYSIS

In addition to the existing conditions, the hydrologic and hydraulic models were also used to evaluate the platted and ultimate conditions of the Zacate Creek watershed. While the platted conditions watershed represents the watershed with developments platted and/or master planned in 2008, ultimate conditions represents a fully developed watershed and is intended to represent maximum peak discharges that could be realized in the future based on the current City of Laredo Zoning Overlay. The land use and impervious cover assumptions are further discussed in Section 2.3, above. The Zacate Creek watershed is approximately 90% developed, therefore flooding under platted and ultimate conditions is expected to increase only slightly compared to existing land use conditions. Under existing conditions, the majority of the undeveloped land in the Zacate Creek watershed is situated in the upper watershed, specifically along and upstream of the Bob Bullock Loop and north of and along Jacaman Road. The platted and ultimate conditions analysis modifies the impervious area of the watershed to correlate with expected development. The analysis also includes modifications to individual subbasin time of concentration (Tc) calculations, if the expected development will significantly modify the expected timing of conveyance for the system.

The comparison of discharge and water surface elevations for the platted and ultimate land use conditions to the existing condition is shown in the Table 10, below. In addition to changes in the impervious cover and Tc parameters within the hydrologic model, two detention basins were included as well for the Platted and Ultimate Conditions models. These basins are the Shiloh (North City) Detention Basin and the Upper Zacate Creek Multi-Purpose Detention Basin, which are both currently under construction. It did not appear appropriate to include these basins in the existing conditions model, but they are expected to be fully functioning in the near future. While these basins do lessen the impacts of the proposed future development, they do not produce any significant changes to the expected peak discharge flows. The impacts of the increase in impervious cover are generally confined to the upper extents of the watershed, specifically in Zacate Creek Reaches 1 and Tributary 4. These areas represent the only remaining areas of the city with large tracts of undeveloped land in the existing condition. Downstream of these reaches, the future conditions expected peak flowrates return to levels very close to existing conditions.

Table 10. Platted 2008 and Ultimate Conditions Flooding Impacts

Location	Maximum Increase for 1% Peak Discharge (cfs)		Average Increase for 1% Water Surface Elevation (ft)	
	Platted -Existing	Ultimate-Existing	Platted -Existing	Ultimate-Existing
ZC Reach 1	50%	50%	1.0	1.0
ZC Reach 2	0%	0%	0.5	0.5
ZC Reach 3	0%	0%	0.2	0.3
ZC Reach 4	2%	6%	0.1	0.6
ZC Reach 5	2%	5%	0.0	0.3
ZC Reach 6	1%	4%	0.1	0.2
Tributary 1	2%	7%	0.1	0.3
Tributary 1A	1%	6%	0.0	0.1
Tributary 2	0%	5%	0.0	0.0
Tributary 2A	0%	8%	0.0	0.1
Tributary 3	0%	2%	0.0	0.1
Tributary 4	25%	25%	0.4	0.5

The floodplain maps for the three land use conditions vary only slightly. Floodplain delineation reveals three primary areas of difference. The extent of flooding along Reach 1 approximately 2,000 feet upstream of Winfield Parkway increases under platted and ultimate conditions. Flooding on Reaches 2 and 3, between Hillside Road and the Alexander Ranch area, extends slightly further. Flooding along Canal Street (Reach 4) extends further under ultimate conditions. Along Tributary 4 the one percent peak discharges increase by as much as 25% and the average water surface elevations increase by 0.5 ft between future and existing conditions, but floodplain maps reveal minimal increase in flooding extents along this reach. The City should monitor closely development in these reaches to ensure that proposed improvements will not adversely impact the channel system and floodplain.

5.0 ALTERNATIVES ANALYSIS

The purpose of the Flood Protection Plan is to evaluate the relative benefits of the mitigation strategies developed herein, in order to guide the City of Laredo in selecting, prioritizing and implementing an optimized combination of strategies. Costs presented herein are for comparison of potential capital improvement projects. To assist the City of Laredo in prioritizing which projects should be funded, the alternatives are assessed with a combination of cost of implementation and associated benefits. As mentioned above, the intent of the 2001 KBR study was to provide a 100-Year level of service within this study reach. It appears more appropriate to employ an iterative and incremental approach to determine the most cost-effective level of service based on improvement costs and expected benefits. This FPP study will focus on maximizing flood conveyance within existing drainage easements and areas that minimize the need for property acquisition. This study will also focus efforts and resource on the flood problem areas with the most significant potential flood damages. It is understood that it may not be possible to alleviate flood risks for the entire study area and this study examines the benefits of individual flood mitigation alternatives within specific areas.

Structural flood control alternatives are potential construction projects that could be built in an effort to alter the flooding condition of a watershed. Examples of structural controls include culvert improvements, channel improvements, construction of detention ponds, and diversions. Structural controls mitigate flooding by rerouting, detaining, or altering the hydraulics of flow. These controls typically incur significant construction expenses, and costs associated with right-of-way acquisition. Structural improvements that increase conveyance capacity (increased channel/culvert size) will typically reduce the amount of storage in the system by reducing ponding and overbank flooding. Changes to system storage typically reduce the amount of peak flood attenuation and may dramatically increase flow rates downstream of improvements.

Non-structural flood control measures, typically in the form of community-based initiatives and programs, may prevent the worsening of flood problems and aim to prevent flood-induced hazards. Examples of non-structural flood control measures include flood alert systems and buy-outs in flood prone areas. Non-structural controls aim to control the land use of flood-prone areas and to restrict timing and reduce runoff. The Zacate Creek watershed is almost entirely developed or platted for development, which leaves limited options for land use control other than buy-outs and/or a flood early warning system.

Implementing both types of controls typically provides the best results. Structural controls are designed to optimize conveyance of peak flows. Non-structural controls often prevent an increase in runoff, maintaining the peak discharge, so that structural controls will continue to be effective; or, these controls seek solutions to other dimensions of the flooding problem, such as public awareness and response time.

5.1 COST BENEFIT ANALYSIS

The viability of alternatives, including eligibility for state and federal grants and/or funding assistance, is primarily measured through a comparison of the relative costs and benefits. A project must demonstrate that the expected costs do not outweigh the expected benefits. While there are numerous methods for comparing costs and benefits, for this project a comparison of benefits relative to the 10-Year and 100-Year events is performed to demonstrate the viability of a project. This methodology compares the estimated cost of the proposed project improvements with the “value” of the associated reduction in expected flooding damages. The HAZUS model was used to determine this value as the difference between expected flood damages with existing and proposed water surface elevations, as described below.

5.1.1 Cost Analysis

The estimated costs for each alternative include materials and construction costs, which are based on recent bid tabulations and unit prices for similar regional construction projects, as well as soft costs, assumed to be as follows:

- General Conditions & Overhead: 10 %
- Engineering – Design & Construction Phase Services: 25 %
- Contingency: 15 %.

In addition to recent bid tabulations for City of Laredo projects, bid tabulations from the Texas Department of Transportation (Laredo District) were evaluated to determine the most appropriate unit prices for construction items. A summary of costs for each of the structural alternatives is discussed below in Chapter 5 and in Appendix G.

5.1.2 Benefit Analysis

The benefit of the alternative is the relative monetary savings of a given improvement being in-place, compared to it “not being in-place”. This value is determined from the difference between estimated damages for existing condition and estimated damage with alternative in-place for the 10-year and 100-year events. The 10-year event was selected to represent a severe flood much more frequent than the 100-Yyear event. Many of the flood problem areas do not have a 10-year level of service in the existing conditions, so system improvements that do not provide a 100-year level of service will still show significant benefits in these areas for the 10-year event. The 100-year event is also analyzed, as this is the primary return interval used by the NFIP.

To estimate the risk associated with a given magnitude flood event, HAZUS-MH software was employed. This software, developed by FEMA Hazard Mitigation Division under a contract with the National Institute of Building Sciences, integrates with ArcGIS 9.3 (the platform utilized for spatial data management and analysis in the overall study). HAZUS is a widely-accepted methodology for flood damage estimation. HAZUS provides an estimate of damages by taking spatial information about the depth of flooding, and correlating that information in an “overlay” analysis to data about the built environment and regional assumptions about the relationship between depth of inundation and damages. In addition to this information, HAZUS provides other useful emergency management data such as estimates of displaced households, disrupted critical facilities, and business use loss.

For the City's purposes, HAZUS was used to generate estimates of the relative benefit of the flood protection measures proposed. The results of the hydraulic analysis from HEC-RAS (see Section 3.0) are processed in HEC-GeoRAS into inundation depth grids for each event ("depth grid"). For each alternative, the resulting depth grid is evaluated in HAZUS to produce an estimate of damages. These damages "with the selected improvement in place" are then compared to an estimate of damages in the existing condition, for the same storm event. The difference in damages is then the relative benefit for that particular flood control measure. Relative benefit is calculated for the 10% (10-year) and 1% (100-year) annual chance events in this study.

For each HAZUS model run, the default Census and housing inventory databases are used. The USACE-Galveston District depth-damage curves are applied in deriving damage totals. Appendix H summarizes the 10% annual chance and 1% annual chance benefits for each alternative.

5.2 STRUCTURAL IMPROVEMENTS

This section provides a description and summary of estimated benefits and costs of the proposed structural alternatives to mitigate drainage and flooding issues in the Zacate Creek watershed. Alternatives were developed to address the identified flood prone areas or zones. Alternative development was guided by the effort to provide the best level of service, minimize the disturbance of existing channels and areas outside of existing right- of-ways, and extend or build on current city projects, including Phase 1 of the Canal Street drainage improvements and the Upper Zacate Creek Multi-Purpose Detention Basin. The figure below provides the general location of the flood control zones within the watershed. Eight zones are identified.

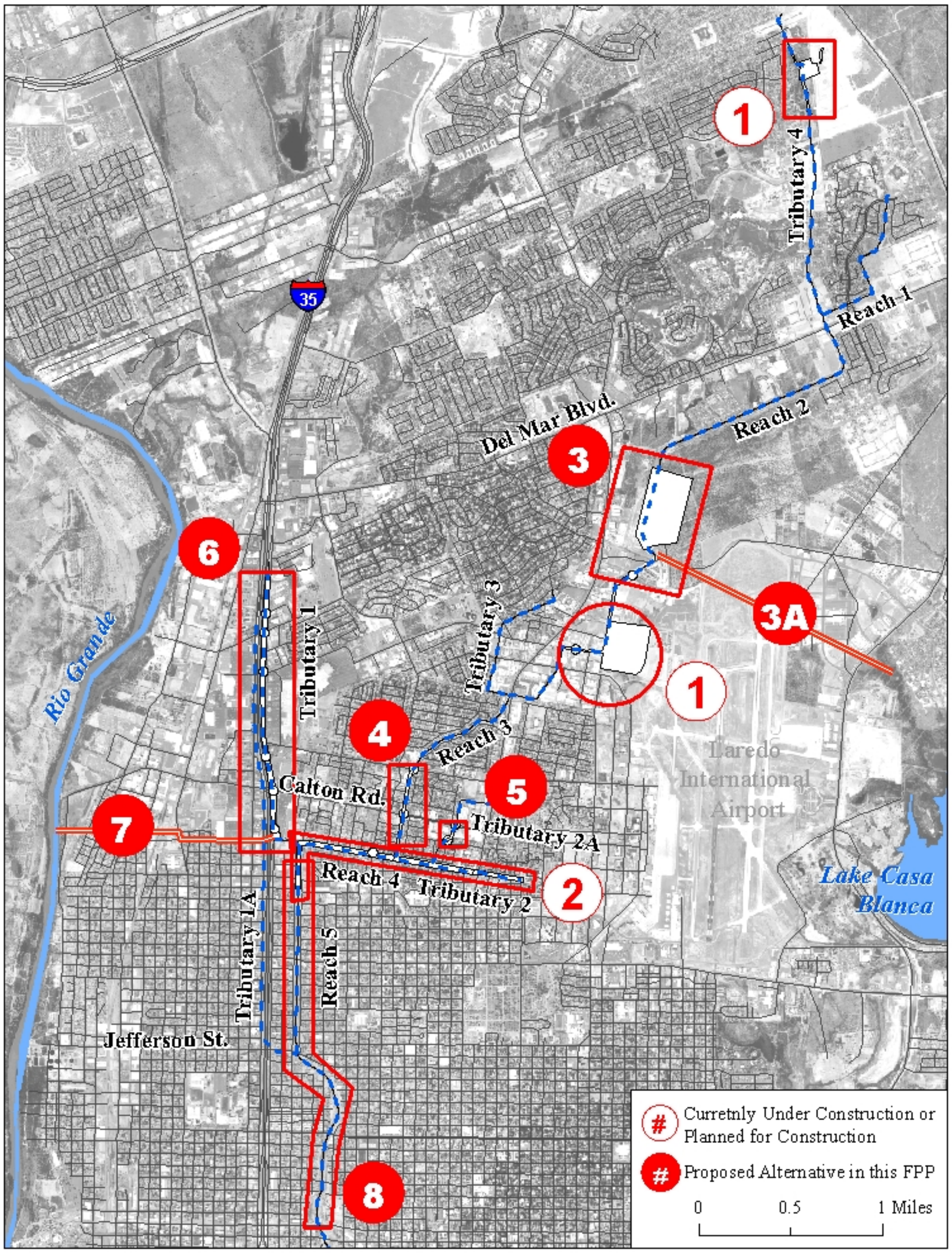


Figure 8. Location Map of Zacate Creek Zones/Alternatives

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5.2.1 Zone 1: Current City Projects

Zone 1 improvements consist of the City of Laredo projects currently or soon to be under construction, including the Shiloh Detention Basin, the Upper Zacate Creek Multi-Purpose Detention Pond, and Phase 1 of the Canal Street drainage improvements. The Shiloh Detention Basin, situated in the upper watershed along Tributary 4, mitigates the expected increased runoff resulting from the Shiloh Crossing Subdivision development and provides limited additional storage capacity. The detention basin has a storage volume of 49.6 acre-feet and is slated for construction by the end of 2009. Construction also includes channel improvements upstream and downstream of the pond. The existing channel immediately upstream and downstream of the pond is natural ground without a well defined channel. The proposed concrete-lined channel, which extends 625 feet upstream of the pond inlet to the pond inlet, has a trapezoidal shape with a bottom width of 15 feet, a top width of 35 feet, a depth of 5 feet, and 2:1 side slopes (H:V). The proposed concrete-lined channel, which extends from the pond outlet to approximately 1,000 feet downstream, has a trapezoidal shape with a bottom width 23 feet, a top width of 75 feet, a depth of 6.5 feet, and 4:1 side slopes (H:V) and ties to an existing concrete-lined channel. The location of the Zone 1 improvements can be seen on Exhibit 11 in Appendix A.

Under existing conditions the level of service along Tributary 4 downstream of Yukon Lane to Country Club Drive was determined to be less than the 5-year event. Zone 1 improvements will provide a 100-year level of service along this 2,000 ft segment of channel, which is adjacent to the Shiloh Subdivision. The channel downstream of Country Club Drive has already been improved to provide a 100-year level of service under existing conditions. The effects of flow attenuation due to the Shiloh Detention Basin will have minimal impact along Tributary 4 downstream of Country Club Drive, decreasing the water surface elevation approximately 0.5 ft to 1 ft for the 100-yr event.

Extensive flooding occurs along ZC Reach 2 between Jacaman Road and Gale Street. The Multi-Purpose Detention Basin is a 33-acre pond built by the City of Laredo in 2009 and is situated along ZC Reach 2, east of McPherson Road, between Jacaman Road and Gale Street. Basin construction includes a concrete channel outlet channel improvements from the basin to Jacaman Road. This improvement provides an l0-year level of service along ZC Reach 2 between Jacaman Road and the confluence with Tributary 3. The level of service of Gale Street improves to a 5-year level of service. The level of service of Jacaman Road culvert remains at less than a 5-year level of service.

A cost was not estimated in Zone 1 for this study as funding is already in place and both projects should be completed in 2009. The calculated benefit is \$3.1 million and \$10.8 million for the 10-year and 100-year events, respectively.

Because these projects are in progress, all subsequent improvements in other zones detailed below will include geometry and flow modifications provided in Zone 1. In other words, the existing conditions model for comparison to all subsequent proposed improvements will be the "Existing plus Zone 1" model.

5.2.2 Zone 2: Canal Street Drainage Improvements

Zone 2 improvements consist of channel and culvert improvements along ZC Reach 4 (from the confluence of Zacate Creek with Tributary 1 to the confluence with Tributary 2) and along Tributary 2 to improve channel and structure capacity. These improvements are described as Phases 2B through 5B in the report *Canal Street Drainage Improvements Project*, prepared by Espey Consultants (EC) in July 2008 for the City of Laredo. As of July 2009 construction of the Phase 1B channel and structure changes are underway. Zone 2 proposed improvements consist of the completion of the Canal Street report proposed improvements.

These improvements did not incorporate any significant downstream channel changes. All upstream improvements in other zones are on this same principal and this does limit potential benefits because of the Zacate Creek tailwater elevation at the downstream limit of Zone 2. The location of the Zone 2 improvements can be seen on Exhibit 12 in Appendix A.

Table 11. Zone 2 Improvements taken from the EC Canal Street Drainage Improvements Project

Phase	Stream	Location	Improvements	Estimated Cost
1	Zacate Creek Reach 4 and 5	From just downstream of the confluence of Zacate Creek and Tributary 1 to San Francisco Ave and Canal St intersection	Concrete channel with 40' BW, 50' TW, 0.5:1 SS To be completed in Fall 2009.	Funding in Place
2	Zacate Creek Reach 4	From San Francisco Ave to confluence of Zacate Creek and Tributary 2	Concrete channel with 40' BW, 50' TW, 0.5:1 SS Replace bridge at Marcella Ave. Rebuild maintenance ramp at Springfield Ave to east of conflucence of ZC Reach 5 and Tributary 2	$4.6 million
3	Tributary 2	From confluence of Zacate Creek and Tributary 2 to downstream face of McPherson Ave	Concrete channel with 27' BW, 40' TW, 1:1 SS	$2.8 million
4	Tributary 2	McPherson Ave	Install 2 additional 10'x5' box culverts with the existing 3-10'x5' box culverts	$875,000
5	Tributary 2	Upstream face of McPherson Ave to upstream end of Tributary 2	Concrete channel with 27' BW, 35' TW, 1:1 SS	$1.4 million

Zone 2 improvements provide an increased level of service for both channel and structures along ZC Reach 4 and Tributary 2. The table below summarizes the improved level of service.

Table 12. Zone 2 Comparative Level of Service

		Level of Service	
ZC Reach 5	Location	Existing + Zone 1	Zone 2
Channel	From Chicago/Taylor St to the Tributary 1 confluence	25-yr	100-yr
Structures	Chicago/Taylor St	50-yr	100-yr
	Pedestrian Bridge near Pace St	100-yr	100-yr
ZC Reach 4			
Channel	From the Trib 1 confluence to the Trib 2 confluence	5-yr	100-yr
Structures	Springfield Ave	<5-yr	100-yr
	Marcella Ave	5-yr	100-yr
Tributary 2			
Channel	Meadow Ave to McPherson Rd	5-yr	100-yr
	McPherson Rd to confluence with Tributary 2A	100-yr	100-yr
	From confluence with Trib 2A to Zacate Creek	<5-yr	5-yr
Structures	McPherson Rd	10-yr	100-yr

The estimated cost is $7.8 million. The calculated benefit is $19.5 million and $30.7 million for the 10-year and 100-year event, respectively. Detailed cost estimates and benefit results can be found in Appendices G and H respectively.

5.2.3 Zone 3: Alexander Ranch Detention Basin Improvements

The Zacate Creek watershed has few remaining undeveloped or unplatted areas, leaving limited available land for providing additional detention to attenuate flood flows. Alexander Ranch is a large tract of land, partly undeveloped, that is part of a master development plan. Alexander Ranch Detention Basin is the onsite wet pond located along ZC Reach 2 with a storage capacity of 150 acre-ft. Zone 3 improvements explore the possibility of expanding the basin to provide detention not just to mitigate existing and future development on Alexander Ranch, but to also attenuate flows from other areas of Zacate Creek and significantly reduce peak flows downstream of the development where flooding now occurs in 5-Year events and larger. Zone 3 improvements propose to increase the detention basin's storage capacity and also replace the Jacaman Road culvert which is significantly undersized for existing flow conditions. Proposed improvements would increase the detention basin's storage capacity to 835 acre-ft, requiring approximately 972,000 cubic-yards of excavation. In this scenario, the outlet structure would remain as nine 93" corrugated metal pipe. The location of the Zone 3 improvements can be seen on Exhibit 13 in Appendix A.

Under Zone 3 improvements, the existing culverts and pipe at Jacaman Road will be replaced with a 40' CrownSpan type culvert. This is essentially a three-sided box culvert that is open to the bottom. This represents only one possible configuration, but is included in this study due to available size, conveyance capacity, cost and ease of installation relative to other culvert or bridge configurations. The level of service at Jacaman Road would increase from less than the 5-year event to the 50-year event.

The potential benefits from the proposed Zone 2 improvements can be seen from the basin outlet to Hillside Road with a reduction of water surface elevations of 0.5 feet to 2 feet or more (compared to existing land use conditions with Zone 1 improvements) along this segment of ZC Reach 2 and ZC Reach 3 for the 100-year event. The level of service improves at Gale Street and Jacaman Road, as shown in the table below.

Table 13. Zone 3 Comparative Level of Service

		Level of Service	
ZC Reach 2	Location	Existing + Zone 1	Zone 3
Channel	AlexanderRanch Basin to Jacaman Rd	< 5-yr	10-yr
	Jacaman Rd to McPherson Rd *	10-yr	25-yr
	McPherson Rd to Hillside Rd	<5-yr	5-yr
	Hillside Rd to Calton Rd	<5-yr	<5-yr
Structures	Jacaman Rd	< 5-yr	50-yr
	Gale Street *	5-yr	10-yr
	McPherson Rd	100-yr	100-yr

* Level of Service limited by channel capacity between Gale St. and McPherson Rd.

The estimated cost the proposed Zone 2 improvements is $20.5 million. An opportunity to cost share some of these improvements with the developer for a mutually beneficial flood control structure may be explored. The calculated benefit is $6.9 million and $19.9 million for the 10-year and 100-year event, respectively. This represents a significant reduction in flood damages and these favorable results show that this plan merits further consideration. Also, the reductions in flow rates that are seen downstream further increase the benefit of more modest channel improvements. This is further explored below in Zone 4. Detailed cost estimates and benefit results can be found in Appendices G and H, respectively.

Modifications to the existing detention basin in Zone 3 appears to be the simplest and most efficient method of increasing detention storage in this area. This configuration does not represent the only way to provide storage volume and this configuration is intended as a planning tool and does not limit the owner's options for this property. This analysis is intended to provide a basis for discussion between the City and the Alexander Ranch owner/developer to expand detention capacity for the overall benefits to the watershed and community.

5.2.4 Alternative 3A: Diversion to Lake Casa Blanca

The KBR Stormwater Master Plan included an alternative that proposed to divert flows to Lake Casa Blanca from the general Alexander Ranch area. It was determined that a similar alternative should be compared with increased detention to determine relative merits. Alternative 3A diverts all flows collected in the existing Alexander Ranch Detention Basin to Lake Casa Blanca in the Chacon Watershed, approximately 2 to 2.5 miles away. Six 10' x 10' box culverts would be required to divert all flow from Zacate Creek captured in the Alexander Ranch detention basin. The diversion, as modeled, is sized to carry 6366 cfs, the 100-year peak discharge. The outlet invert elevation of the detention basin is 460 ft. The permanent pool elevation of Lake Casa Blanca is 444 ft. The culvert will require extensive excavation and be subject to regulatory review and permitting as this culvert would cross the watershed divide, which is of higher elevation (up to 524 ft). The diversion route is constrained by existing adjacent development, including the Laredo International Airport.

The benefits of Alternative 3A extend from the outlet of Alexander Ranch Detention Basin to Calton Road. The table below shows the reduction in water surface elevations for the events 5-yr, 10-yr, 25-yr, 50-yr and 100-yr under Alternative 3A.

Table 14. Alternative 3A Water Surface Reduction

Location	WSEL Reduction (ft)
Alexander Pond to Jacaman Rd	6 to 8
Jacaman Rd to Gale St	4 to 5
Gale St to McPherson Ave	1 to 5
McPherson Ave to Calton Rd	0.5 to 2

The level of service is improved for Reach 2 and associated structures.

Table 15. Alternative 3A Comparative Level of Service

ZC Reach 2	Location	Level of Service: Existing + Zone 1	Level of Service: Alt 3A+1
Channel	Alexander Ranch Basin to Jacaman Rd	< 5-yr	100-yr
	Jacaman Rd to McPherson Rd	10-yr	100-yr
	McPherson Rd to Hillside Rd	<5-yr	5-yr
	Hillside Rd to Calton Rd	<5-yr	< 5-yr
Structure	Jacaman Rd	< 5-yr	100-yr
	Gale St	5-yr	100-yr
	McPherson Rd	100-yr	100-yr

A cost estimate was not provided as this alternative does not provide enough benefit to downstream properties to warrant the cost of the required extensive excavation and materials. Impacts from this diversion generally only extend to McPherson Road. The overall shape of the watershed and timing and size of flows from watersheds downstream of Alexander Ranch produce a scenario where the peak discharge within Zacate Creek returns very close to the existing conditions flows relatively quickly (even with the diversion of a large area). The extent of benefits does not appear to merit the complicated and expensive design, construction, and permitting anticipated for this alternative.

5.2.5 Zone 4: Channel and Culvert Improvements along Reach 3

Zone 4 improvements address flooding along ZC Reach 3 from the confluence with Tributary 2 to upstream of Hillside Road by combining improvements in Zone 2 and Zone 3 with ZC Reach 3 channel and culvert improvements. ZC Reach 3 has limited available right-of-way for channel expansion and several bridges with limited capacity. The improvements in Zone 3 facilitate improvements in this area because they reduce the overall peak flow rates. Similarly, the proposed Zone 2 improvements would lower both the channel invert and tailwater elevation at the downstream end of ZC Reach 3. No cost effective benefit to flooding could be found within this reach in the absence of changes in Zone 2 and 3. Zone 4 improvements include replacing the culvert at Calton Road and widening and deepening the channel from 575 ft upstream of Hillside Road to the confluence with Tributary 2. ZC Reach 3 improvements increase the channel capacity. Zone 2 improvements reduce the tailwater at the confluence of ZC Reach 4 and ZC Reach 3. Zone 3 improvements reduce ZC Reach 2 discharges. These improvements combine to provide appreciable capacity.

The limited space between the channel and residential developments restricts the potential to widen the channel without resorting to buyouts. Zone 4 improvements propose to widen the top width of the segment of channel from Hillside Road to the Tributary 2 confluence to the maximum extents allowable based on 2007 aerial photography while still allowing for limited maintenance access. Top widths are generally increased from 10 to 25 feet with a side slope of 0.5:1 (H:V). To further increase capacity, the channel slope is increased by grading the channel to tie into elevations at a location 575 ft upstream of Hillside Road to the

Calton Road and from the Calton Road to the confluence with Tributary 2, which requires the lower invert elevation at the confluence as called for in the Zone 2 improvements. Initially the top widths of the channel at the faces of the Calton Road were not widened in an attempt to avoid replacing the culverts, but capacity at Calton Road was not met with only channel improvements. Consequently, Zone 4 improvements proposes to remove and replace the Calton culverts with a clear span bridge and to regrade the channel to tie into the elevation 600 ft upstream of Hillside Road and the confluence with Tributary 2, increasing the channel slope from 0.21% to 0.31%. The location of the Zone 4 improvements can be seen on Exhibit 14 in Appendix A.

Table 16. Zone 4, ZC Reach 3 Modifications

		Existing Conditions			Proposed Conditions		
Location along Reach 3	XS	Top Width (ft)	Bottom Width (ft)	Side Slope (H:1)	Top Width (ft)	Bottom Width (ft)	Side Slope (H:1)
	21376	55	14	3	55	14.2	3
Upstream of Hillside Rd	21326	86	57	2	86	56.3	2
Downstream of Hillside Rd	21268	86	56	2	86	78.5	0.5
	21218	40	18	2	50	42.5	0.5
	21196	40	14	2	50	42.5	0.5
	20902	40	14	2	65	57.5	0.5
	20619	40	11	2	65	57.5	0.5
	20179	40	14	2	65	57.5	0.5
Upstream of Calton Rd	19992	50	14	2	50	42.5	0.5
Downstream of Calton Rd	19916	50	14	2	50	42.5	0.5
	19865	40	11	2	65	57.5	0.5
	19401	40	12	2	65	57.5	0.5
Confluence with Tributary 2	18747	40	12	2	65	57.5	0.5

Zone 4 improvements increase the level of service for the channel and structures along ZC Reach 3 to ZC Reach 5 from Alexander Pond to Chicago Street.

Table 17. Zone 4 Comparative Level of Service

		Level of Service	
ZC Reach 2	Location	Existing + Zone 1	Zone 4
Channel	Alexander Pond to Jacaman Rd	< 5-yr	10-yr
	Jacaman Rd to McPherson Rd	10-yr	25-yr
Structures	Jacaman Rd	< 5-yr	50-yr
	Gale St	5-yr	10-yr
	McPherson Rd	100-yr	100-yr
ZC Reach 3			
Channel	McPherson Rd to Hillside	<5-yr	< 5-yr
	Hillside Rd to Tributary 2 Confluence	<5-yr	10-yr
Structures	Pedestrian Bridge d/s of McPherson Rd.	< 5-yr	5-yr
	Hillside Rd	< 5-yr	25-yr
	Calton Rd	< 5-yr	100-yr

The estimated cost for Zone 4 improvements is $31.0 million. The calculated benefit is $24.5 million and $42.6 million for the 10-year and 100-year event, respectively. Detailed cost estimates and benefit results can be found in Appendices G and H, respectively.

5.2.6 Zone 5: Channel and Culvert Improvements along Tributary 2A

Zone 5 improvements attempt to address the out-of-bank flooding issues occurring along Tributary 2A. Tributary 2A runs roughly west and south from the vicinity of the airport before it confluences with Tributary 2. This reach can be broken into three segments; 1) a trapezoidal concrete channel upstream of Calton Road, 2) an unimproved (natural) section from Calton Road to Chaparral Street, and 3) grass lined (maintained) trapezoidal channel with a concrete pilot channel from Calton Road to the confluence with Tributary 2. The City of Laredo has a construction project underway in the near future to line the natural section with concrete. The general configuration of this planned project was assumed for the Zone 5 improvements. The location of the Zone 5 improvements can be seen on Exhibit 15 in Appendix A.

Overbank flooding in this area is conveyed in the streets to the south-west corner cul-de-sac at the intersection of Pita Drive and Lariat Loop. The City of Laredo purchased and removed the house in the corner lot at this location after it received extensive damage in the 2007 flood. The Canal Street project (Zone 2) proposes to relocate the channel maintenance ramp from Springfield Road to this location. During flood events, the ramp would also act as a discharge channel for street flooding.

Tributary 2A was modeled in HEC-RAS with a lateral weir connecting this reach to Zacate Creek at Canal Street. For every event modeled, water surface elevations were higher in Tributary 2A than in Zacate Creek, so flows were assume to go from Tributary 2A toward Zacate Creek in all cases. While improvement alternatives were examined for Tributary 2A, it was discovered that significant increases in conveyance capacity did not produce significant reductions in water surface elevation, but did reduce the assumed discharge across the lateral weir. In addition to limited conveyance capacity, one of the primary issues faced in Tributary 2A is the tailwater condition at the confluence with Tributary 2.

The proposed improvement for Zone 5 increases channel capacity by replacing the natural channel segment with a concrete-lined trapezoidal channel with a 30 ft bottom width, 40 ft top width, 1:1 side slopes (H:V) and 5 ft depth. Zone 5 improvements also propose to replace structures at Calton Road and Chaparral Street, as shown in table below.

Table 18. Zone 5 Structure Improvements

Sta	Description	Existing Structure	Proposed Structure	Culvert Length (ft)
1400	Calton Rd	2-6'x4' mbc	3-8'x4' mbc	70
800	Chaparral St	2-6'x4' mbc, 1-8'x4' mbc	3-8'x4' mbc	55

Under improvements in Zone 5, the level of service improves slightly for Tributary 2A upstream of Chaparral Street. The water surface elevation in the channel downstream of Chaparral Street slightly increases, rather than decreases, as a result of the HEC-RAS diversion modeling. Less water was determined to be lost to the lateral weir in this section, resulting in higher flood elevations downstream of the lateral weir (as modeled).

Table 19. Zone 5 Comparative Level of Service

Location along Tributary 2A	Level of Service	
	Existing + Zone 1	Zone 5
Channel		
McPherson Rd to Calton Rd	< 5-yr	5-yr
Calton Rd to Chaparral St	< 5-yr	5-yr
Pedestrian Bridge to Tributary 2 confluence	< 5-yr	< 5-yr
Structures		
Calton Rd	< 5-yr	5-yr
Chaparral St	50-yr	5-yr
Pedestrain Bridge 300' upstream of Trib 2 confluence	5-yr	< 5-yr

Tributary 2A is dominated by backwater from Tributary 2. Zone 5 improvements do not significantly improve flooding issues on Tributary 2A; this alternative is not recommended unless the backwater from Tributary 2 is addressed.

The estimated cost for Zone 5 improvements is $500,000. The benefit is $3.7 million and $10.7 million for the 10-year and 100-year event, respectively. Detailed cost estimates and benefit results can be found in Appendices G and H, respectively

5.2.7 Zone 6: Channel and Culvert Improvements along Tributary 1

Zone 6 improvements attempt to address flooding on Tributary 1. Tributary 1 is situated between the IH-35 and the north-bound frontage road, and extends from the confluence with Zacate Creek to just north of Mann Road. As described above, in section 2.7.1, there are significant flooding problems along the IH-35 corridor. IH-35 is elevated in most area, but the alignment lies in a locally low area with water flowing toward the freeway and then to the south from both sides. Tributary 1 is a trapezoidal concrete channel that was built in conjunction with the freeway. This channel was sized to accommodate the 10-Year flood at the time of construction (construction plans are dated 1960). These flooding issues are further exacerbated by the fact that Tributary 1 lies at a very flat slope relative to Zacate Creek. It is known that significant flows exit Tributary 1 and flow to west of IH-35 at Mann Road and Calton Road. Once flows leave Tributary 1, it is assumed that they generally follow the alignment of IH-35 to the south before re-entering Zacate Creek at the channel at Jefferson Street. This flowpath is referred to as Tributary 1A in this study. The location of the Zone 6 improvements can be seen on Exhibit 16 in Appendix A.

Channel capacity is increased by improving the channel side slopes from 1:1 to 0.5:1 (H:V), which in turn increases the channel bottom width varying from 10 ft to 30 ft to a bottom width varying from 40 ft to 60 ft. The channel bottom is proposed to be lowered beginning downstream of the culvert under the IH-35 off ramp at Mall del Norte (Sta 5700) to the confluence of Tributary 1 with Zacate Creek, increasing the channel bottom slope from 0.08% to 0.1%. The existing channel depth of 3 ft to 7ft is maintained under proposed conditions. The following culvert replacements are proposed, as shown in table. The culverts and roadway at the abandoned off ramp at Sta 1000 would be removed.

Table 20. Zone 6 Structure Replacement

Sta	Location	Existing	Proposed	Culvert Length (ft)
7300	IH-35 on ramp	2-5'x3' MBC	8-5'x3' MBC	166
6700	Mann Rd	3-7'x3' MBC	2-5'x3', 4-7'x3' MBC	240
5700	IH-35 off ramp	2-7'x3' MBC	6-7'x3' MBC	205
3150	IH-35 on ramp	4-5'x5' MBC	5-10'x6' MBC	150
2200	Calton Rd	4-5'x5' MBC	5-10'x6' MBC	156
1000	Abandoned off-ramp	4-5'x5 'MBC	Open Channel	156
800	IH-35 northbound frontage	3-10'x4' MBC	6-10'x6' MBC	80

Table 21. Zone 6 Proposed Tributary 1 Channel Geometry

From	To	Length (ft)	Bottom Width (ft)	Side Slopes (H:V)
IH-35 on ramp (400' upstream of Mann Rd)	IH-35 off ramp (near Mall del Norte)	2,307	40	0.5:1
IH-35 off ramp (near Mall del Norte) culvert Faces		232	46	0.5:1
IH-35 off ramp (near Mall del Norte)	Hillside Rd	2,268	48	0.5:1
Hillside Rd	Abandoned Off-Ramp (200' upstream of NB frontage road)	2,099	50	0.5:1
Abandoned off-ramp (200' upstream of NB frontage road)	Confluence with Zacate Creek	756	60	0.5:1

Although the level of service in the channel remains less than the 5-year event under the proposed Zone 6 improvements, the water surface elevation drops 1 ft to 3 ft along Tributary 1 from upstream of the IH-35 on ramp near Hillside Road to the top of the reach. This represents a significant reduction if flood elevations, but underscores the limited capacity of the chancel and culverts in this location. The ultimate level of service is also limited due to the fact that the 25-year flood elevation on Zacate Creek is higher than the north-bound frontage road along most of Tributary 1.

Table 22. Zone 6 Comparative Level of Service

Sta	Location along Tributary 1	Level of Service	
		Existing + Zone 1	Zone 6
7300	IH-35 on ramp (400' upstream of Mann Rd)	< 5-yr	5-yr
6700	Mann Rd	< 5-yr	5-yr
5700	IH-35 off ramp (near Mall del Norte)	< 5-yr	< 5-yr
3150	IH-35 on ramp (350' downstream of Hillside Rd)	< 5-yr	5-yr
2200	Calton Rd	< 5-yr	< 5-yr
1000	Abandoned off-ramp (200' upstream of NB frontage road)	< 5-yr	N/A
800	IH-35 northbound frontage road	< 5-yr	< 5-yr

The estimated cost for Zone 6 improvements is $16.6 million. The benefit is $7.1 million and $16.6 million for the 10-year and 100-year event, respectively. Detailed cost estimates and benefit results can be found in Appendices G and H, respectively.

5.2.8 Zone 7: Diversion to Rio Grande

Zone 7 improvements propose a diversion of flow from Tributary 1 and from Tributary 1A upstream of Canal Street away from Zacate Creek and towards the Rio Grande. A similar alternative was considered in the 2001 KBR study. The KBR alternative included an extension of this diversion tunnel to Zacate Creek at Hillside Street. It appears that channel improvements on Zacate Creek, such as those proposed in Zone 2, would be more cost effective and make this extension unnecessary. The proposed improvements in Zone 7 would be to divert all flows in Tributary 1 and 1A to the Rio Grande at Farias Street. Since there is no channel or other conveyance provided on the west side of IH-35 (Tributary 1A), it is proposed that the diversion culverts be extended to the north from Farias Street to collect flows and convey them underground. Zone 6 improvements are proposed to increase the conveyance capacity of Tributary 1, but periodic diversions of flows from Tributary 1 to the proposed tunnel along Tributary 1A would still be needed to achieve a level of service greater than a 5-Year. In addition, Tributary 1 would be disconnected from Zacate Creek. This would allow the lowering of the channel at the downstream end of Tributary 1 and remove the tailwater impacts from Zacate Creek to this area. The location of the Zone 7 improvements can be seen on Exhibit 17 in Appendix A.

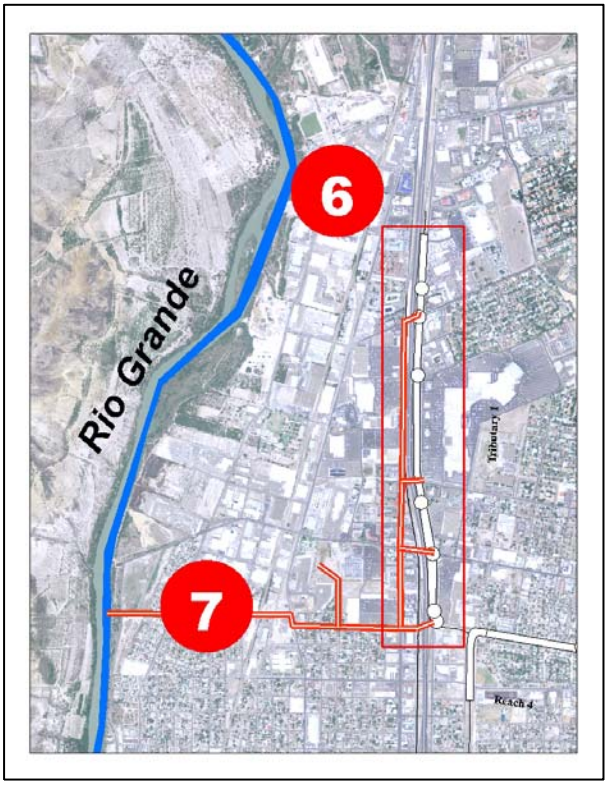

Figure 9. Location Map of Zone 7 Improvements (Includes Zone 6)

Improvements proposed in this zone include a 6,000 ft storm drain culvert along San Bernardo Avenue (along Tributary 1A), beginning at Mann Road and continuing down to Farias Street, which will collect water draining from the west and the east sides of IH-35. The Tributary 1 channel (with proposed Zone 6 improvements) would remain the primary conveyance path for flows east of IH-35, but these flows would be diverted to the culvert under San Bernardo Avenue in four locations. Figure 9 shows the general schematic layout.

There is an existing storm drain system in this vicinity that was designed to convey the 5-Year flood flows from areas west of IH-35 to Tributary 1. Analysis showed that these systems do not function as designed because the water surface elevation during flood events is higher in Tributary 1 than streets elevations west of IH-35. It is possible that flows are even reversing in these locations, i.e. flows are actually transferring from Tributary 1 to Tributary 1A. It is expected that the largest impact of the existing system is to drain remaining floodwaters after the flood elevations have dropped sufficiently after the peak of the event. With the Zone 7 diversion and culvert system in place, the tailwater issues can be addressed and these existing systems would begin to function as designed. This assumption would further reduce flood elevations by assuming that the 5-Year event is fully contained in the existing system.

Flow in Tributary 1 will be completely diverted before reaching Zacate Creek (before San Dario Ave.) via 3-10’x10’ box culverts, which will run along Farias St and converge with the culvert collecting flows along San Bernardo Avenue from Tributary 1A. From Farias Street, the system will run west along Markley Lane, and discharge at the Rio Grande. The distance of the diversion culvert from San Dario Ave. to the Rio Grande is approximately 6,500 ft.

Zone 7 improvements add to the Tributary 1 channel improvements of Zone 6, further improving the Tributary 1 capacity between Calton Rd to San Dario Ave by widening the channel bottom to 50 ft and increasing the channel bottom slope from 0.1% (Zone 6) to 0.61% by lowering the channel invert at the tunnel inlet.

Zone 7 improvements also require a floodwall at the junction at Tributary 1 and Zacate Creek to prevent flooding from Zacate Creek into the Tributary 1 diversion. A reinforced concrete floodwall is recommended. The proposed flood wall is approximately 400’ long with a top elevation of 425 ft, approximately 5 ft above natural ground and 15 ft above the existing Tributary 1 channel invert. The wall will begin at the west side of the confluence of Tributary 1 and Zacate Creek, extend across Tributary 1, and continue along the east side of Canal Street. The proposed wall must be at least three feet above the calculated 100-yr water surface elevations for Zone 7 and Zacate Creek.

Proposed Zone 7 improvements would increase the level of service along Tributary 1. Flooding is reduced along Tributary 1, Tributary 1A, and along west and east of I-35 upstream of Canal Street and Farias Street. The diversion also helps reduce out of bank flooding along Zacate Creek near the confluence with Tributary 1A, from Elm Street to Victoria Street.

Table 23. Zone 7 Comparative Level of Service

Location along Tribuary 1	Level of Service	
	Existing + Zone 1	Zone 7
Channel		
1500 ft upstream of Mann Rd to IH-35 off ramp (near mall)	< 5-yr	10-yr
IH-35 off ramp (near Mall del Norte) to IH-35 on ramp	< 5-yr	50-yr
IH-35 on ramp (350' downstream of Hillside Rd) to	< 5-yr	25-yr
Structures		
IH-35 on ramp (400' upstream of Mann Rd)	< 5-yr	10-yr
Mann Rd	< 5-yr	10-yr
IH-35 off ramp (near Mall del Norte)	< 5-yr	25-yr
IH-35 on ramp (350' downstream of Hillside Rd)	< 5-yr	100-yr
Calton Rd	< 5-yr	50-yr
Abandoned off-ramp (200' upstream of NB frontage road)	< 5-yr	N/A
IH-35 northbound frontage road	< 5-yr	N/A
Diversion near San Dario Ave	N/A	50-yr

Costs included in the Zone 7 improvements include:

1. 1,400 linear feet of improvements along the lower end of Tributary 1 (in addition to those improvements proposed in Zone 6);
2. 1 – 10x10 BC (with inlets) from Mann Road to Hillside Street, carrying flows to the south just west of IH-35;
3. 2 – 10x10 MBC (with inlets) from Hillside Street to Farias Street, carrying flows to the south just west of IH-35;
4. 3 – 10x10 MBC (with Tributary 1 main inlet) from Tributary 1 to the Rio Grande;
5. and a floodwall at the junction of Tributary 1 and Zacate Creek.

The estimated cost for Zone 7 improvements is $54.7 million. The benefit is $25.6 million and $60.9 million for the 10-year and 100-year event, respectively. Detailed cost estimates and benefit results can be found in Appendices G and H, respectively. The proposed diversion shows to be cost effective; however the final cost and viability of the project may depend heavily on acquiring permission to tunnel beneath IH-35 and the railroad, construct a major culvert outlet at the Rio Grande, and cause significant traffic disruptions on the southbound IH-35 frontage road. More detailed preliminary engineering and cost estimating is warranted to justify this approach to providing Tributary 1 and 1A flood relief. It is also important to note that even if all flows are captured along Tributary 1A at Farias Street, there would still be significant flooding experienced west of IH-35 between this location and Jefferson Street. The only effective flood conveyance within this area remains in the streets, and significant damage can be expected from flood events.

5.2.9 Zone 8: Downstream Zacate Creek Channel Improvement Alternative

During the detailed flood mitigation investigation of Zones 4, 5, and 6, it was discovered that the tailwater elevation on Zacate Creek was severely limiting potential benefits of any proposed channel improvements. For each reach (Zacate Creek Reach 3, Tributary 2A, and Tributary 1, respectively) only limited benefits could be achieved even with significant improvements to conveyance capacity because of flooding caused by Zacate Creek water surface elevations downstream of the proposed improvements. This is especially evident on Tributary 1, where the 25-Year water surface elevation at the confluence with Zacate Creek is higher than the frontage road for most of the entire studied length of Tributary 1. This prompted further investigation of the benefits of increasing the conveyance capacity (and reducing associated water surface elevations) on the Zacate Creek main channel in the most downstream sections (Reaches 5 and 6). This area generally has a 100-Year level-of-service and had not been considered a flood problem area. Improvements in Zone 8 would not produce significant benefits adjacent to the proposed improvements, but creates the opportunity for more benefits (and greater levels-of-service) in upstream reaches and tributaries. The location of the Zone 8 improvements can be seen on Exhibit 18 in Appendix A.

Zone 8 improvements are intended as an alternative to the diversion to the Rio Grande (Zone 7) and would allow additional improvement in the upstream Zones. The 2001 KBR study proposed both a diversion to the Rio Grande and lowering the channel invert within this section of Zacate Creek. The KBR study went further to proposing that the Zacate Creek channel be fully lined with concrete. It was thought that environmental limitations would make concrete channel lining of this scale impossible. The fact that the Zone 7 improvements offered only minor relief to flooding along Tributary 1A was further argument for directing the effort and project cost toward improvements that could provide additional benefits to Zacate Creek. Zone 8 improvements propose to lower the channel invert along Zacate Creek Reaches 5 and 6, and also include and expand on improvements in Zones 2, 3, 4, 5 and 6 by lowering channel inverts in Tributary 1, ZC Reach 4, ZC Reach 3, Tributary 2, and Tributary 2A. The proposed modifications are intended to maximize benefits without the acquisition of significant rights-of-way.

It should be noted that there are significant construction and utility relocation costs that are beyond the scope of this study. Bedrock can be found at the channel invert for the lower portions of Zacate Creek and it is not known how much rock excavation would be required to implement this alternative. It is expected that these changes would have substantial utility conflicts, and it is beyond the scope of this study to estimate potential utility relocation costs. An example of potential utility relocations is the extensive wastewater infrastructure known to exist in this area. There is an existing water treatment plant near the confluence of Zacate Creek and the Rio Grande. There are expected to be wastewater utilities adjacent to Zacate Creek that drain by gravity to this plant. Improvements within Zone 2 were limited by the proximity (and elevation) of existing wastewater lines. Relocating these pipes or the addition of siphons and lift stations could represent a significant project cost.

Zacate Creek Reach 5 and 6 channels are proposed to be lowered by five feet, beginning just upstream of the Tex Mex railroad bridge to the confluence with Tributary 1. A more detailed preliminary design study (with relevant geotechnical boring information) could alter the recommended depth of the modifications. In an effort to minimize construction costs, the channel would be a grass-lined channel with a concrete pilot channel and 3:1 (H:V) side slopes. This configuration would result in no significant increase in channel top-width. Bridge replacements will also be avoided if possible. The pedestrian bridges in this area are typically clear-span, and since the channel top-width is not expected to change, these brides would remain as they are. Five bridges were identified as requiring replacement due to the channel deepening. These bridges are located at Sanchez Street/W.Gustavus Street, Park Street/Clark Boulevard, Jefferson Street/W. Lyon Street, US Hwy 59 and the pedestrian bridge near Pace Street.

With the channel invert at the confluence with Tributary 1 lowered by five feet, Tributary 1 could also be lowered four to five feet keeping the channel top width described in the Zone 6 improvements. Culvert replacements as described for Zone 6 improvements will also be required, but with the culverts' height would increase by four to five feet to accommodate the deepened channel. The deeper channel, larger culverts and steeper channel slope would significantly increase the Tributary 1 channel capacity, potentially producing a level-of-service within Tributary 1 similar to the Zone 7 (diversion) improvements.

With the downstream channel invert changes, the Zacate Creek Reach 4 channel could also lowered by an additional four feet (Zone 2 improvements already include a two foot reduction) with channel and bridge modifications applied as described in Zone 2 improvements. No structures are expected to need further modification beyond what was described for the Zone 2 improvements.

The Tributary 2 (Reach 2) channel could also be lowered by four feet if the lowering of the channel invert were extended up the length of Zacate Cree Reach 4. No structures are expected to need further modification beyond what was described for the Zone 2 improvements.

Modification of the channel invert in Tributary 2 would enable further improvements in Zone 5. The Tributary 2A channel could be dropped four feet near the confluence with Tributary 2 and graded from the confluence at a 0.7 percent slope. Channel improvements (in addition to those proposed with Zone 5) would extend 1,650 ft upstream from the confluence with Tributary 2. The culverts at Calton Road and Chaparral Street would require additional improvement than those described with Zone 5 to accommodate the lowered channel.

Lastly, if the lowering of the channel invert were extended up the length of Zacate Cree Reach 4, then Reach 3 could be lowered beyond the flowline changes already included in the Zone 4 improvements. The channel could be lowered four feet from the confluence with Tributary 2 to the pedestrian bridge between Montana Street and E. Dakota Street. No structures are expected to need further modification beyond what was described for the Zone 4 improvements.

Zone 8 channel improvements and the potential upstream improvements described above would significantly increase the level of service along Zacate Creek Reaches 3, 4, 5 and 6, Tributary 1, Tributary 2 and Tributary

2A. This channel work would provide a 100-year level of service, except at McPherson Road on Tributary 2 and the Calton Road area on Tributary 1. ZC Reach 2 also evidences reduced flooding for the 100-year event from the confluence with Tributary 3 to the Alexander Ranch area.

The Zone 8 improvements on Zacate Creek Reaches 5 and 6 only are estimate to cost approximately $28.7 million. The estimated cost for combined improvements noted above is $56.5 million. This cost includes improvements within Zones 2, 4, 5, and 6 plus additional costs associated with the deeper channel invert, as described above. The combined alternative cost including improvements in Zone 3 bring the total cost to $76.9 million. The cost of the combined alternative excluding Zone 3 is comparable to the Rio Grande tunnel/culvert option (Zone 7) with significantly improved hydraulic benefits and fewer permitting issues. Zone 7 offered benefits only for Tributary 1 and Tributary 1A, while this combined alternative would provide benefits for a much larger area. The full benefit analysis is beyond the scope of this planning study but it can be assumed that benefits would exceed expected costs based on individual Zone analyses listed above. It is recommended that additional study be authorized to fully this option and benefits. Detailed cost estimates can be found in Appendices G.

5.3 ALTERNATIVE COST/BENEFIT SUMMARY

Table 24, below, includes a summary of the estimated cost and benefit for the alternative flood mitigation structural improvements detailed in the sections above. A detailed cost was not developed for Alternative 3A because the associated benefits and construction challenges did not merit further investigation. Zone 8 benefits were not calculated at this time. This area of improvement appears to offer the greatest potential for system-wide flood improvements. However, the details of what would be included in this plan and the construction costs require a more detailed examination than can be performed at this time. Recommendations are provided in Chapter 6.

Table 24. Summary of Costs and Benefits

Zone/Alternative	Total Benefits ($ Millions)		Cost Estimate ($ Millions)
	10-year event	100-year event	
Zone 1	$3.1	$10.8	Funding in Place
Zone 2	$19.5	$30.7	$7.8
Zone 3	$6.9	$19.9	$20.5
Alternative 3A	$14.4	$27.5	N/A
Zone 4	$24.5	$42.6	$31.0
Zone 5	$3.7	$10.7	$0.5
Zone 6	$7.1	$16.6	$16.6
Zone 7	$25.6	$60.9	$54.7
Zone 8	N/A	N/A	$28.7
Combined Improvements			
Zones 2,3,4,5,6,7	$46.6	$89.9	$86.3
Zones 2,3,4,5,6,8	N/A	N/A	$76.9

5.4 NON-STRUCTURAL FLOOD PROTECTION MEASURES

With the channel improvements, culvert/bridge upgrades and detention pond construction alternatives discussed above, the City can cost-effectively implement a series of non-structural measures as part of its overall flood protection planning efforts. These include: further developing the City's rainfall and streamflow gauging network, establishing coordinated stormwater runoff control policies among jurisdictions, and acquisition of flood prone properties. Each is discussed in more detail in the sections below.

5.4.1 Install Rainfall, Streamflow Gauging Network

The City should consider expanding the network of automated rainfall and streamflow depth gauges along Zacate Creek and tributaries. There are currently several rainfall gauges and streamflow depth gauges within the vicinity. Data collected from the rainfall and streamflow gauges may be used to monitor real-time flooding conditions for a flood early warning system. This information serves two purposes. First, it can bring critical information to Emergency Management personnel about potential problems, and allows the City to see the problems in one central location simultaneously, as the issues develop. Second, the data collected from this network creates a record to monitor the behavior of the system in correlation with rainfall. This would then enable the City to continually calibrate and refine its models for Zacate Creek.

5.4.2 Coordinated Stormwater Management Policy

The City of Laredo area has experienced tremendous growth in recent years, straining the ability of the Zacate Creek system to deal with large storm events. Without management practices, development increases impervious cover, which increases rainfall runoff, raises water surface elevations and increases flooding. Coordination between City of Laredo departments (Environmental Services, Public Works, Planning, Engineering, and Utilities) is necessary to develop practical and enforceable policy. Stormwater policy and guidelines should be periodically reviewed to ensure that development is not increasing flooding. As an example, it may be useful for the City to consider adding ordinances to require mitigation for multiple return period events when considering new construction, or events other than the 50-Year in impaired areas.

5.4.3 Voluntary Acquisition of Flood Prone Areas

Removing residents from flood-prone areas through the purchase of such properties reduces flooding risk. Buying flood prone structures through a voluntary acquisition or relocation program is a common practice among communities. The estimated cost of this solution will vary according to property value and cost of demolition. This alternative will potentially reduce the amount of property damage caused by flooding. Also, as undeveloped City-owned property, this land may serve as minor detention, recreational areas, and wildlife habitat. Funding may be available through the Flood Mitigation Assistance Program (FMA) for a targeted, voluntary acquisition and relocation program. The City of Laredo has already purchased some properties within the Zacate Creek watershed and future acquisition opportunities will be examined on a case-by-case basis.

6.0 FUNDING SOURCES

An important aspect of implementing any of the recommended alternatives is the funding mechanism. The mechanisms for funding of the recommended actions vary and in some instances are specific to the action. The intent of this section is to identify funding sources, as well as strategies to leverage funding mechanisms. The summary below provides a description of the possible funding sources for the District to construct a project.

6.1 LOCAL ENTITY FUNDING SOURCES

There are several local funding sources available to municipalities, as empowered by the State Legislature. These are as follows:

Capital Improvements Plan (CIP) - a long-range plan, usually four to six years, which identifies capital projects and equipment purchases, provides a planning schedule and identifies options for financing the plan. The City prepares/updates a CIP each year during its budget cycle.

Drainage Utility Fees - Municipal stormwater projects can be funded by the assessment of a drainage utility fee for all developed projects based on amount of impervious cover, number of living units, or site area. The City of Laredo currently imposes a Drainage Utility Fee on all real property within the corporate limits. These funds are used for stormwater and drainage programs.

Development Impact Fees – In accordance with Chapter 395 of Texas Local Government Code, municipalities may impose an impact fee to cover the cost of improvements that are necessitated by new development.

General Fund – The primary operating fund of a governmental entity.

General Obligation Bond (GO) - A municipal bond that is backed by the credit and "taxing power" of the issuing jurisdiction, rather than the revenue from a given project. General obligation bonds are issued with the belief that a municipality will be able to repay its debt obligation through taxation or revenue from projects. No assets are used as collateral. These bonds are typically considered the most secure type of municipal bond, and therefore carry the lowest interest rate.

Revenue Bond - A municipal bond supported by a specified stream of future income, such as income generated by a water utility from payments by customers. This differs from general-obligation bonds, which can be repaid through a variety of tax sources. Revenue bonds are only payable from specified revenues. A main reason for using revenue bonds is that they allow the municipality to avoid reaching legislated debt limits.

Special Assessment Bond - A special type of municipal bond used to fund a development project based on property tax assessments of properties located within the issuer's boundaries.

Tax Increment Bond – A bond (also known as a “tax allocation bond”) payable from the incremental increase in tax revenues realized from any increase in property value resulting from capital improvements benefiting the properties that are financed with bond proceeds. Tax increment bonds often are used to finance the redevelopment of blighted areas.

6.2 STATE FUNDING ASSISTANCE SOURCES

TWDB (Texas Water Development Board)

- Clean Water State Revolving Fund - Provides perpetual funds to provide low interest loan assistance for the planning, design, and construction of stormwater pollution control projects.
- Research and Planning Fund Grants – The purpose is to provide financial assistance for research and feasibility studies into practical solutions to water-related problems.
- State Participation and Storage Acquisition Program – The purpose is to help finance regional water projects including water storage facilities and flood retention basins; and to allow for “right sizing” of projects in consideration of future growth.
- Texas Water Development Fund – The purpose is to provide loans for the planning, design, and construction of water supply, wastewater, and flood control projects.
- Texas Department of Rural Affairs (TDRA) – The TDRA (formerly ORCA) dispenses federal funds from EDA for projects previously identified in the approved City Emergency Management Plan.

TCEQ (Texas Commission on Environmental Quality)

- Texas Clean Rivers Program (CRP) – The purpose of these funds are to maintain and improve the quality of surface water resources within each river basin in Texas.

6.3 FEDERAL ASSISTANCE SOURCES

FEMA (Federal Emergency Management Agency)

- Flood Hazard Mapping Program – Department of Homeland Security (DHS) funds are administered through FEMA to identify, publish, and update information on all flood-prone areas of the U.S. in order to inform the public on flooding risks, support sound floodplain management, and set flood insurance premium rates.
- Flood Mitigation Assistance Grants (FMA) – The purpose is to assist states and communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured through the National Flood Insurance Program (NFIP).
- Hazard Mitigation Grant Program (HMGP) – The purpose is to provide states and local governments financial assistance to permanently reduce or eliminate future damages and losses from natural hazards through safer building practices and improving existing structures and supporting infrastructure.
- Pre-Disaster Mitigation Grant Program (PDM) – The purpose is to provide funding for states and communities for cost-effective hazard mitigation activities that complement a comprehensive hazard mitigation program and reduce injuries, loss of life, and dame and destruction of property.

HUD (U.S. Department of Housing and Urban Development)

- Disaster Relief/ Urgent Needs Fund of Texas - To rebuild viable communities impacted by a natural disaster or urgent, unanticipated needs posing serious threats to health and safety by providing decent housing, suitable living environments and economic opportunities.

- Texas Community Development Program – The purpose is to build viable communities that meet "basic human needs" such as safe and sanitary sewer systems, clean drinking water, disaster relief and urgent needs, housing, drainage and flood control, passable streets, and economic development.

NRCS (Natural Resources Conservation Service)

- Watershed Protection and Flood Prevention Program – To protect, develop, and utilize the land and water resources in small watersheds of 250,000 acres or less. The program is Federally assisted and locally led.
- Watershed Surveys and Planning – Provides planning assistance to Federal, State, and local agencies for the development of coordinated water and related land resources programs in watersheds and river basins. Emphasis on flood damage reduction, erosion control, water conservation, preservation of wetlands, and water quality improvements.
- Wetlands Reserve Program – To protect and restore wetlands by enabling landowners to sell easements which take wetlands out of production.
- Emergency Watershed Protection Program – The purpose is to provide relief from imminent hazards and reduce the threat to life and property in the watersheds damaged by severe natural events. Hazards include floods and the products of erosion created by floods, fire, windstorms, earthquakes, drought, or other natural disasters.

USACE (United States Army Corps of Engineers)

- Emergency Advance Measures for Flood Prevention – The purpose is to protect against the loss of life or damages to property given an immediate threat of unusual flooding.
- Emergency Rehabilitation of Flood Control Works – The purpose of this program is to assist in the repair or restoration of flood control works damaged by flood.
- Emergency Streambank and Shoreline Protection – The purpose is to prevent erosion damages to public facilities by the emergency construction or repair of streambank and shoreline protection works.
- Floodplain Management Services – The purpose is to promote appropriate recognition of flood hazards in land and water use planning and development through the provision of flood and floodplain related data, technical services, and guidance.
- Nonstructural Alternatives to Structural Rehabilitation of Damaged Flood Control Works – This program provides a nonstructural alternative to the structural rehabilitation of flood control works damaged in floods or coastal storms.
- Planning Assistance to States – The purpose is to assist states, local governments and other non-Federal entities in the preparation of comprehensive plans for the development, utilization, and conservation of water and related land resources.
- Small Flood Control Projects – The purpose is to reduce flood damages through small flood control projects not specifically authorized by Congress.

7.0 REGULATORY COMPLIANCE

Prior to commencement of construction, it will be necessary to submit the project and appropriate permit applications to regulatory agencies. A detailed review and acquisition of the necessary permits for the construction of these project(s) exceeds the scope of this contract. However, a partial list and brief discussion of permits is included in the following subsections. This following list of agencies and corresponding permit activities is intended to be general in nature and is not intended to represent a definitive list of required permit acquisitions and agency coordination.

7.1 FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

The National Flood Insurance Act of 1968 was enacted by Title XIII of the Housing and Urban Development Act of 1968 (Public Law 90-448, August 1, 1968) to provide previously unavailable flood insurance protection to property owners in flood prone areas. FEMA administers the National Flood Insurance Program (NFIP); however, if a local community elects to participate in the NFIP, the local government is primarily responsible for enforcement. Participating communities are typically covered by FIS which define water surface profiles and floodplain boundaries through their communities.

The recommended drainage improvement projects summarized in this report are intended to reduce floodplain limits. However, if changes to the current effective FEMA floodplain elevations are desirable based on the results of this study, or from the proposed improvements, a request for a Letter of Map Revision (LOMR) from FEMA will be required. The City of Laredo normally requires a CLOMR approval prior to final design approval followed by a LOMR of the completed as-built improvements.

7.2 U. S. ARMY CORPS OF ENGINEERS (USACE)

Pursuant to Section 404 of the Clean Water Act and the Rules and Regulations promulgated there under by the United States Environmental Protection Agency (USEPA) and the United States Army Corps of Engineers (USACE), the filling or excavation of waters of the United States, including wetlands, with dredged or fill material, requires the issuance of a permit from the USACE (33 CFR Parts 320-330). For purposes of administering the Section 404 permit program, the USACE defines wetlands as follows:

> *Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. (33 CFR 328.3)*

The *Corps of Engineers Wetlands Delineation Manual (Technical Report Y-87-1)*, issued by the USACE in 1987 states that wetlands must possess three essential characteristics. These characteristics include, under normal circumstances: 1) the presence of hydrophytic vegetation, 2) hydric soils, and 3) wetland hydrology. If all three of these criteria are present on a particular property in areas larger than one-third acre in size, then a permit (general permit or nationwide permit) must be issued by the USACE in order to fill all or a portion of those areas.

Section 404 (b)(1) guidelines (40 CFR Part 230), established by the USEPA, constitute the substantive environmental criteria used in the evaluating activities regulated under Section 404 of the Clear Water Act. The purpose of these guidelines is to restore and maintain the chemical physical and biological integrity of waters of the United States through the control of discharge of dredged or fill material.

All property owners within the United States and its territories must adhere to the provisions of the Clean Water Act. If any contemplated activity might impact waters of the United States, including adjacent or isolated wetlands a permit application must be made. If jurisdictional waters and/or wetlands are found to exist, then any activity which would involve filling, excavating, or dredging these wetlands would require the issuance of a permit. The final authority to determine whether or not jurisdictional waters exist lies with USACE.

7.3 U.S. FISH AND WILDLIFE SERVICE (USFWS)

The U.S. Fish and Wildlife Service (USFWS), in the Department of the Interior, and the National Marine Fisheries Service (NMFS), in the Department of Commerce, share responsibility for administration of the Endangered Species Act (ESA). Generally, the USFWS is responsible for terrestrial and freshwater species and migratory birds, while the NMFS deals with those species occurring in marine environments and anadromous fish.

Section 9 of the ESA prohibits take of federally listed endangered or threatened species without appropriate authorization. Take is defined in the ESA, in part as “killing, harming, or harassment” of a federally listed species, while incidental take is take that is “incidental to, and not the purpose of, otherwise lawful activities”.

Section 10 of the ESA provides a means for non-Federal projects resulting in take of listed species to be permitted subject to carefully prescribed conditions. Application for an incidental take permit is subject to a number of requirements, including preparation of a Habitat Conservation Plan by the applicant. In processing an incidental take permit application, the USFWS must comply with appropriate environmental laws, including the National Environmental Policy Act. Review of the application under Section 7 of the ESA is also required to ensure that permit issuance is not likely to jeopardize listed species. Section 10 issuance criteria require the USFWS to issue and incidental take permit if, after opportunity for public comment, it finds that:

> (1) the taking will be incidental; (2) the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of the taking; (3) the applicant will ensure that adequate funding and means to deal with unforeseen circumstances will be provided; (4) the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; and (5) the applicant will ensure that other measures that the USFWS may require as being necessary or appropriate will be provided.

The U.S. Fish and Wildlife Service should be contacted to determine the potential occurrence of and consequent impacts to any federal threatened and endangered species. In addition, the Corps of Engineers will require USFWS review of the project to ensure the project is in compliance with the Endangered Species Act prior to the issuance of a Section 404 permit.

7.4 TEXAS COMMISSION ON ENVIRONMENTAL QUALITY (TCEQ)

The Texas Commission on Environmental Quality (TCEQ) has regulatory authority over: dam safety, the Edwards Aquifer, water rights, Texas Pollutant Discharge Elimination System and Section 404(b)(1) guidelines for specification of disposal sites for dredged or fill material. The following sections briefly describe these regulations.

- Texas Pollutant Discharge Elimination System (TPDES)

On September 14, 1998, the USEPA authorized Texas to implement its Texas Pollutant Discharge Elimination System (TPDES) program. TPDES is the state program to carry out the National Pollutant Discharge Elimination System (NPDES), a federal regulatory program to control discharges of pollutants to surface waters of the United States. The TCEQ administers the program, and a permit is required for any construction activity that disturbs one acre or more.

- Section 401 Water Quality Certification

Any activity requiring authorization under Section 404 of the Clean Water Act will also require a Section 401 water quality certification from the TCEQ. In Texas, these regulations are administered by the TCEQ.

- Water Rights Permit

Any proposal to impound surface water may require a Water Rights Permit. In Texas, these permits are administered by the TCEQ.

- Dam Safety Review

The Dam Safety Program monitors and regulates both private and public dams in Texas. The program periodically inspects dams that pose a high or significant hazard and makes recommendations and reports to dam owners to help them maintain safe facilities.

7.5 TEXAS HISTORICAL COMMISSION

The Division of Antiquities Protection of the Texas Historical Commission coordinates the program by identifying and protecting important archeological and historic sites that may be threatened by public construction projects. This department coordinates the nomination of numerous sites as State Archeological Landmarks or for listing in the *National Register of Historic Places*. Designation is often sought by interested parties as the most effective way to protect archeological sites threatened by new development or vandalism. Applicable rules are found in the Texas Administrative Code, Title 13-Cultural Resources, Part II-Texas Historical Commission, Chapters 24-28.

The Corps of Engineers will require that the State Historical Preservation Officer (SHPO) review the project to ensure the project is in compliance with the National Historic Act prior to issuance of a Section 404 permit.

7.6 CULTURAL RESOURCES

A review of the Texas Historical Commission's (THC) on-line Texas Archeological Sites Atlas revealed eight prehistoric (41WB53, 41WB54, 41WB55, 41WB64, 41WB346, 41WB348, 41WB349, and 41WB360) previously recorded archeological sites within the 100-YR floodplain of Zacate Creek, Laredo, Texas. The records search indicates no previously recorded historic archeological sites are located within the 100-YR floodplain. A review of the National Register of Historic Places on-line database and THC's site atlas revealed the Barrio Azteca Historic District located within the 100-YR floodplain of Zacate Creek. The Barrio Azteca Historic District is also known as El Ranchero and is roughly bounded by IH-35, Matamoros Street, Zacate Creek, and the Rio Grande. The historic district was listed in the National Register of Historic Places (NRHP) in 2003. None of the proposed flood improvements would impact this area beyond the existing channel right-of-way.

7.7 ENVIRONMENTAL INVENTORY

The environmental issues of this report have been developed by reference to existing information in published reports, maps, aerial photography, unpublished documents and communications from government agencies, individuals, and private organizations. These issues have been summarized to provide a general review level area studied. Generally, this discussion presents a cursory, screening level perspective on the environmental issues that may affect the study area.

7.8 ENDANGERED AND THREATENED SPECIES

Important species that may be considered include the local dominant (most abundant) species, species having some economic or recreational importance, those exhibiting disproportionate habitat impacts (habitat formers) as well as species listed, or proposed for listing, by either the State of Texas or the federal government (protected species) or Texas Organization for Endangered Species (TOES). There are numerous unlisted species which are still of concern (due to their rarity, restricted distribution, direct exploitation, or habitat vulnerability), yet have not been included in this discussion. Typically, the level of detail required to obtain the distribution and life history of these species, so as to produce a substantive evaluation, would be beyond the scope of this screening level survey. A map showing threatened and endangered species found within the study area, according to Texas parks and Wildlife, is shown on Exhibit 19 in Appendix A.

Located along the Mexico-US border, Laredo is in the Tamaulipan brushland, an ecosystem that has historically been home to more than 600 vertebrate species and more than 1,100 species of plants. Of these, approximately 70 are considered endangered or threatened by the FWS. (White, 2000) Urban development and the environmental pressure it exerts have, in fact, directly and significantly encroached on the range of habitats for these species, “spelling disaster for biodiversity” (CEC 1999, 91–93). While many of the area’s native species have been entirely displaced, some remnant native species remain, able to sustain their nesting and/or migration requirements despite the fragmentation of their habitat. Two species, designated as “endangered” or “threatened,” amply demonstrate the impact urbanization has had on the area’s wildlife and their habitat—these species are the Ocelot and the Interior Least Tern.

The Ocelot has been almost entirely displaced in the region as it now ranges only in several small areas of dense thicket in South Texas. A small to medium-sized field mammal associated with the native thornbrush habitat that once dominated South Texas, it finds its survival compromised by the encroachment of urban development. Recent annexations by Laredo between the city center and the Columbia/ Solidarity Bridge have brought about increased growth and development that has irrevocably fractured the once nearly impenetrable thornbrush habitat that has traditionally secluded the ocelot. (White, 2000)

The interior least tern breeds during the spring in Texas along sandbars of the Rio Grande, Canadian, Pecos, and Red Rivers. Terns construct their nests by scraping a depression in the surface of sandbars along riverbanks or reservoirs, including those alluvial islands found in Lake Casa Blanco near Laredo. Important characteristics of its breeding habitat include: the presence of bare or nearly bare ground particularly along sandbars for nesting, the availability of food (primarily small fish), and the existence of favorable water levels during the nesting, so nests remain above water. (White, 2000)

Exhibit 19 in Appendix A shows the possible range of the endangered and threatened species known to occur within and around the Zacate Creek planning area. There is one threatened species known to occur within the Zacate Creek watershed area, the Reticulate Collared Lizard. In connection with implementation of any structural alternative, a more detailed environmental analysis should be performed, to determine the presence of this species and an appropriate plan of action.

7.9 WETLANDS

The best publicly available wetland data for this area comes from hardcopy maps produced by the U.S. Fish and Wildlife Service in 1989. These delineations are primarily based on stereoscopic analysis of high altitude aerial photography flown November of 1983 at a scale of 1:58,000. Within the watershed of Zacate Creek 51 distinct wetlands are identified, most of which are in the upper portion of the boundary. Wetlands were indentified on the photography based on vegetation, visible hydrology, and geography in accordance with **Classification of Wetlands and Deepwater Habitats of the Unites States (FWS/OBS-79/31 December 1979)** These identifications represent a snapshot of the conditions at the time of year and season the aerial photography was flown necessitating a detailed on the ground and historical analysis of a single site if activities involving modification within or adjacent to wetland areas are intended. Federal, State, and local regulatory agencies with jurisdiction over the wetlands may define and describe wetlands in a different manner than that used in this inventory.

8.0 FLOOD PROTECTION PLAN

The response to these flooding issues is directed by a series of policy goals, analyses and actions, as formulated below. A goal is a desired end or outcome. The analysis discusses the technical basis behind the goal, and supplies the impetus to the individual actions. The actions are specific projects, programs or activities which are recommended for implementation in order to achieve the goal. Taken all together, these goals represent the long term approach that the City of Laredo and its partners in floodplain management must take in order to address the flood hazards present in the Zacate Creek Watershed. In short these goals are as follows:

Goal 1: Proactively address flood problem areas with targeted improvements that consider the entire watershed.

Goal 2: Ensure that new development does not adversely affect property downstream

Goal 3: Protect and enhance available storage in the system.

Goal 4: Actively inform the community of the risk of flooding and promote the purchase and continuance of flood insurance.

Goal 5: Update and refine the Flood Protection Plan on a bi-annual basis

The following sections describe important analyses, considerations and actions to be taken in furthering each goal.

8.1 PRIORITIZATION, IMPLEMENTATION AND PHASING

Each alternative that was studied offers specific benefits and costs, as well as specific policy implications. There are, in general, many other factors which should also be considered in prioritizing and selecting various alternatives in addition to the benefit-cost ratio. The process of scoring the various alternatives, how they were ranked, how the various factors were weighted, and the proposed Implementation Plan is described in the following sections.

Beyond the project cost and calculated benefit, many factors can be included in assessing the budgetary priority of the project. Table 25, below, includes many of the considerations and ranking factors that the City could use to set project priorities.

Table 25: Prioritization Ranking Factors

Prioritization Ranking Factors
Benefits Existing Taxpayers
Keeps Flood Water off of Critical Public Facilities (Hospital, Fire Station, etc.)
Shortens Flood Duration
Potential for Leveraged Funds
Damage Reduction (Relative Dollar Benefit)
Maximizes Conveyance
Benefits Future Development
Provides at Least a 25-Year Level of Service
Low O&M Costs
Enchances Water Quality
Promote Orderly Development or Improve Economic Dev./Redev. Potential
Can Be Implemented Independent of Other Projects
Permitting Resistance or Difficulty
Time To Implement / Construct
Environmental or Habitat Enchancement
Potential for Recreational Use

8.2 IMPLEMENTATION RECOMMENDATIONS

Utilizing the above ranking factors, the improvements recommended for each zone can be prioritized. Improvements in Zone 2 (the Canal Street project) showed the "best bang for the buck" and therefore the highest priority due to the high density of residential structures and the expected flood reductions possible with the proposed channel improvements. It is recommended that the City continue with the additional phases of the Canal Street drainage improvements beyond Phase One that is currently under construction. Note that the discussion on Zone 8 recommendations below may impact the priority of this recommendation.

As a second priority, it is also recommended that the City pursue expansion of Alexander Ranch Detention Basin and the Jacaman Road culvert improvements included in the Zone 3 proposed improvements. This is the last remaining large area with the potential to provide significant stormwater storage. Even though the proposed improvements have a small impact south of the McPherson Road Bridge, they do show significant reduction of flood potential road closing frequency in the Zone 3 vicinity.

The remaining proposed Zone improvement recommendations are prioritized, in order, as follows: Zone 6 (Tributary 1), Zone 4 (main channel between Canal Street and McPherson Blvd.), Zone 5 (Tributary 2A), and Zone 7 (Tributary 1A, the IH-35 West Frontage Road). These recommended improvements have a lower priority because improvements in these zones do not provide significant improvements in stormwater capacity or reductions in water surface elevations due to existing downstream restrictions. Zone 6 and 7 are important because flooding in these areas significantly impairs traffic in the vital IH-35 corridor even in minor rainfall events. However, any proposed improvements will require coordination, cooperation, analysis, and funding by the Texas Department of Transportation. Zone 7 improvements, though potentially very beneficial, have a very high cost. In addition permitting is uncertain and disruption of traffic during construction may be significant. It is recommended that the City begin discussions with the Texas

Department of Transportation about these improvement options as coordination and potential cost sharing is likely to require significant time and coordination.

The Zone 8 (Downstream ZC Channel) was analyzed not because of extensive existing flooding but because the tailwater from this section of the channel influences the flooding potential in the main channel and tributary channels zones upstream to McPherson Blvd. Even though further examination of Zone 8 improvements may well change the specifics of the preliminary analysis, it is known that drainage improvements will need to be made along the IH-35 corridor to alleviate flooding along Tributary 1 and 1A. The Zone 8 proposed improvements provide the only potentially cost-effective method to begin to contain major flood events within the Zacate Creek channel system. **It is the recommendation of this report that a preliminary design study be conducted by the City on the proposed Zone 8 improvements**.

The preliminary design study should concentrate on three critical factors to the design; 1) the location, elevation and relative density of the underlying rock layer that outcrops to the surface just north of the railroad bridge at the downstream end of study Zone 8, 2) the location and depth of ALL underground utilities in the Zone 8 study area (including those in Zones 2, 4, 5, 6, and 7), and 3) the optimum depth of channel cut to maximize the benefits in upstream reaches or zones. The sum of these critical factors will determine the ultimate cost and viability for the proposed improvements. Should the preliminary design study result show the project is feasible and cost-effective; the next step for the City should be to initiate Waters of the U.S. permitting. The nature and length of the channel and proposed improvements will likely require an Individual Section 404 permit from the U.S. Army Corps of Engineers, a process that may take two years or more.

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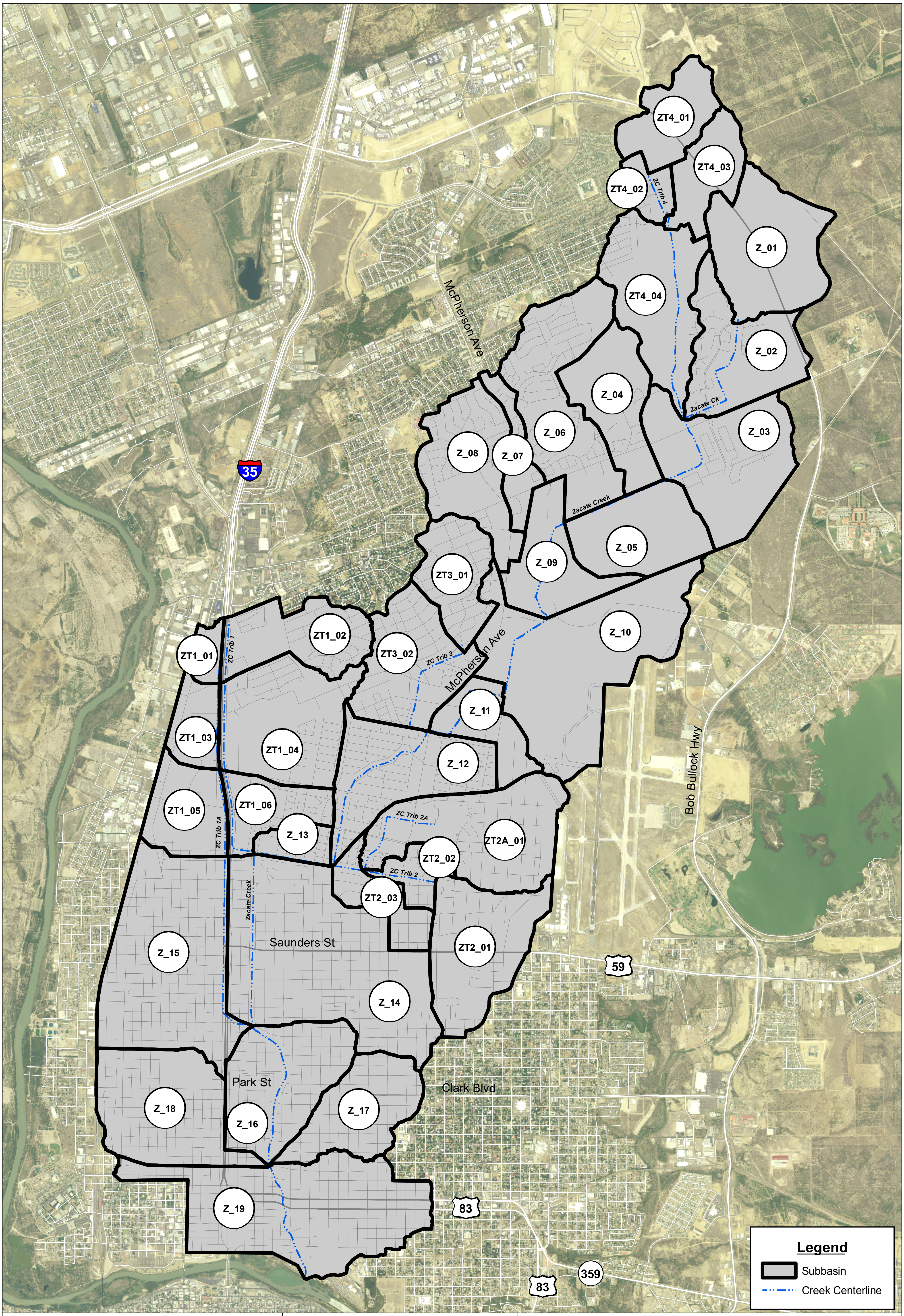
APPENDIX A
EXHIBITS



Espey Consultants, Inc.

Environmental & Engineering Services

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EXHIBIT 1
DRAINAGE AREA MAP
ZACATE CREEK FLOOD PROTECTION PLAN

LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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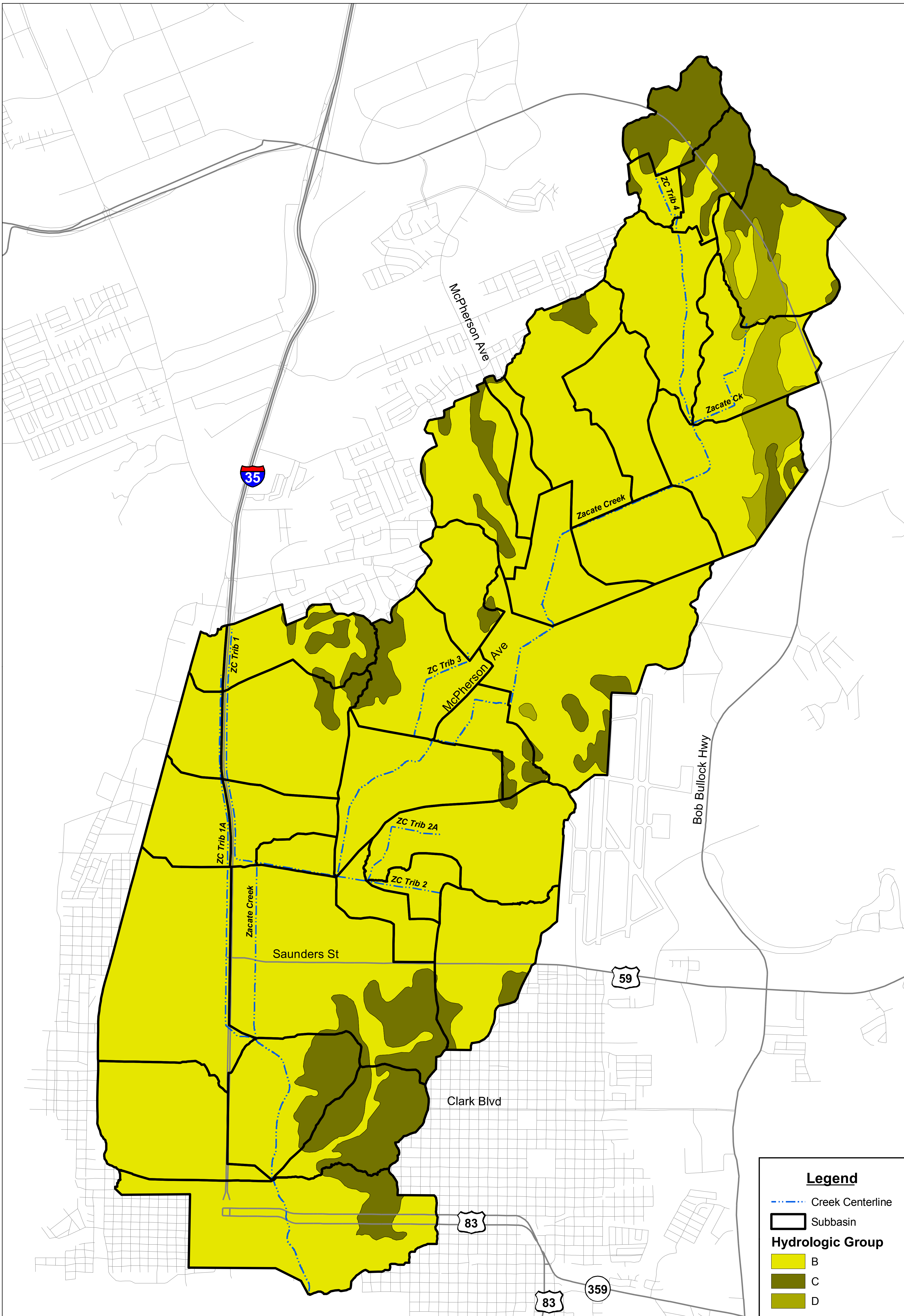

Espey Consultants, Inc.
Environmental & Engineering Services

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EXHIBIT 2
SOILS MAP
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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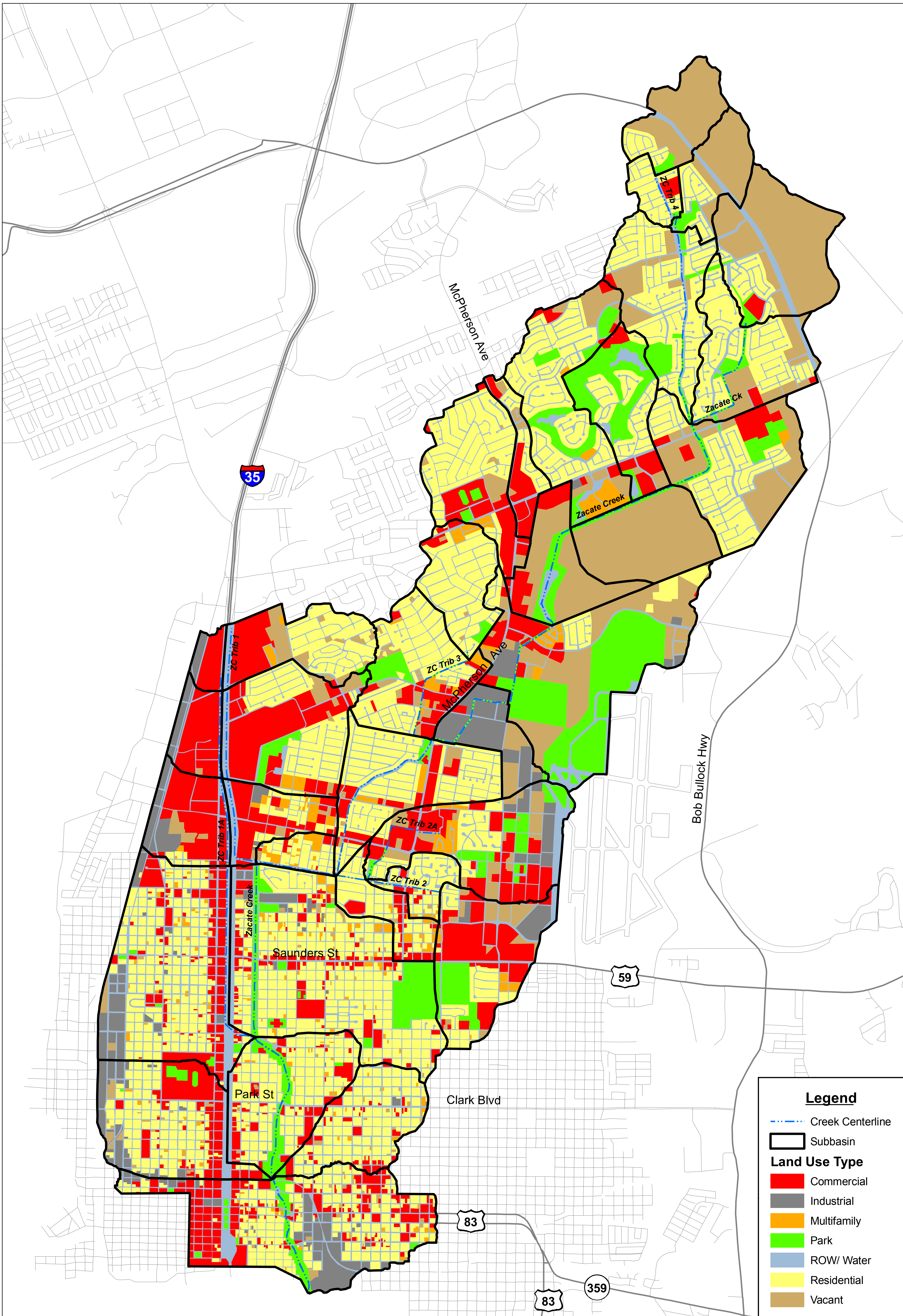

Espey Consultants, Inc.
Environmental & Engineering Services

0 1,500 3,000 6,000
Feet

N

EXHIBIT 3
EXISTING 2008 LAND USE MAP
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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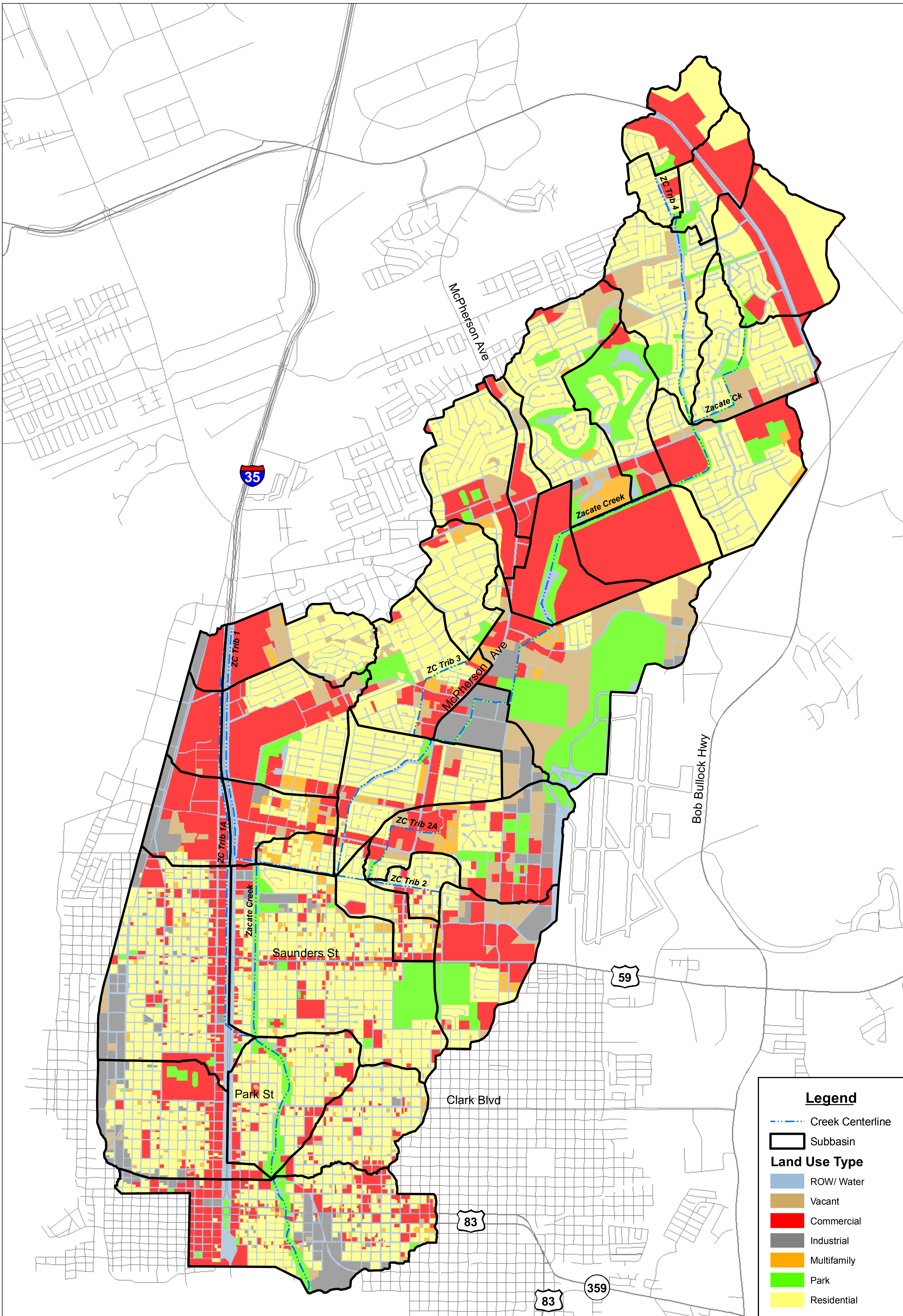

Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 4
PLATTED 2008 LAND USE MAP
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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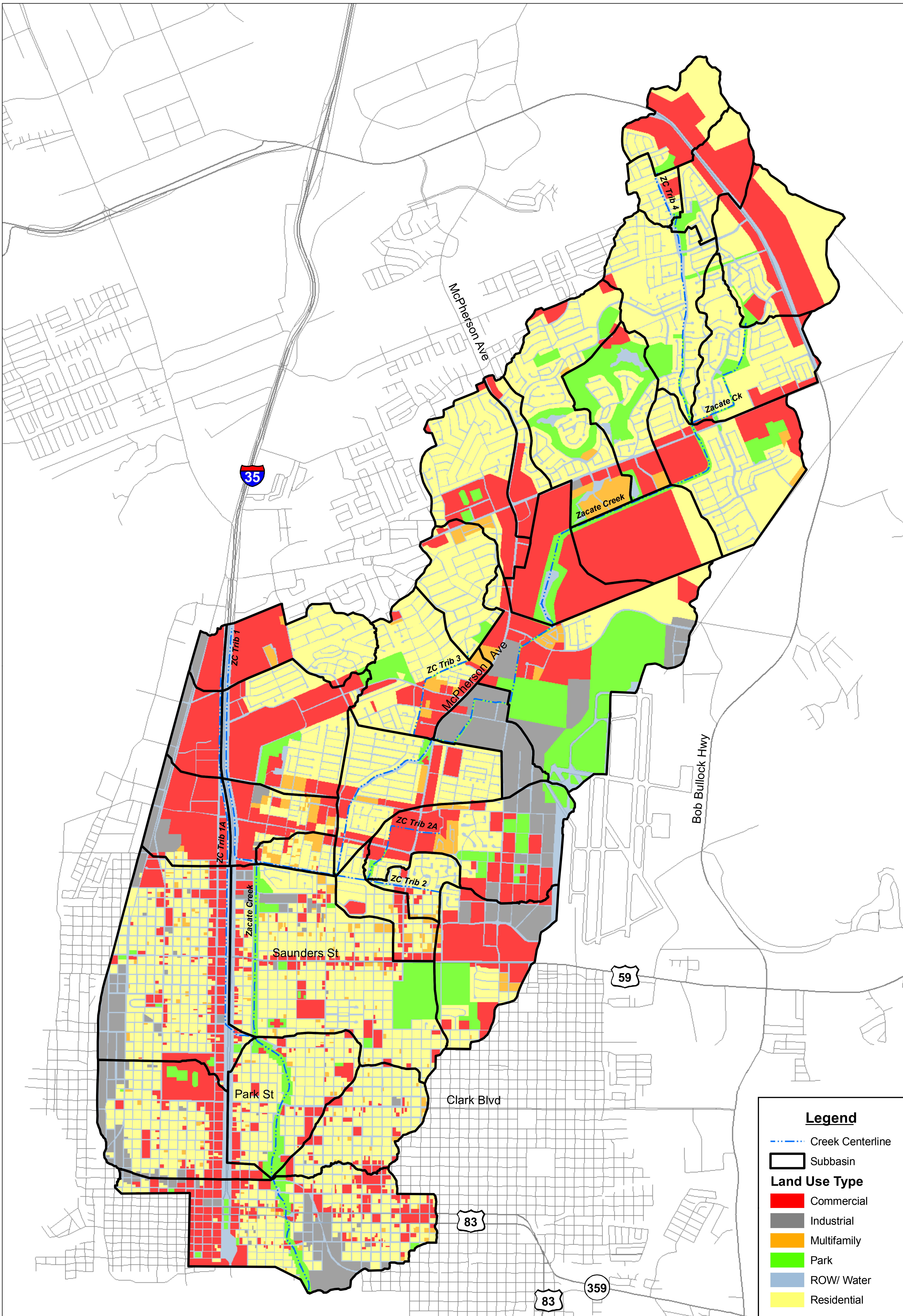

Espey Consultants, Inc.

Environmental & Engineering Services

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Feet

N

EXHIBIT 5

ULTIMATE LAND USE MAP

ZACATE CREEK FLOOD PROTECTION PLAN

LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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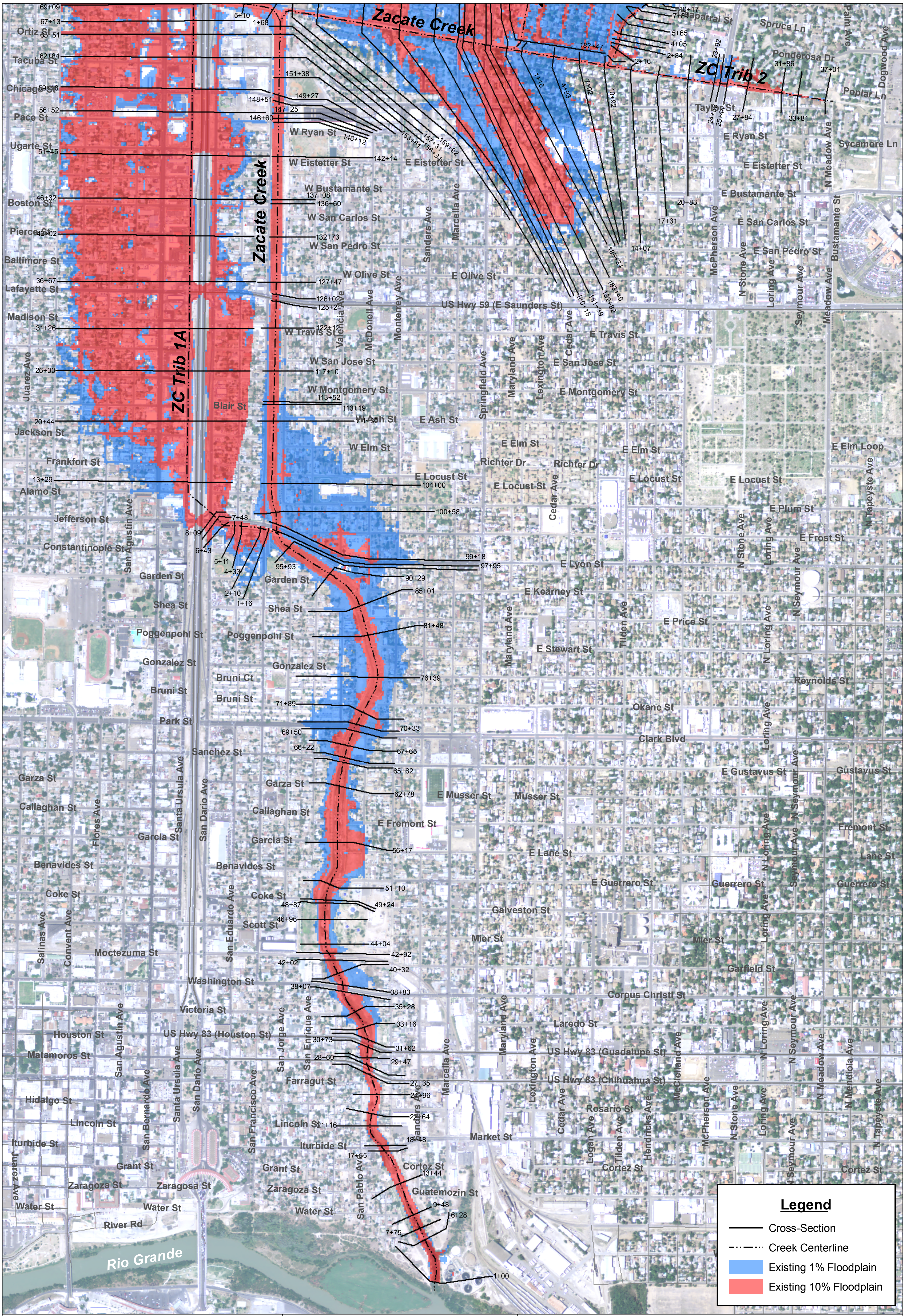

Espey Consultants, Inc.

Environmental & Engineering Services

0 500 1,000 2,000

Feet

N

EXHIBIT 6

CROSS-SECTION LOCATION AND FLOODPLAIN MAP

1 OF 4

ZACATE CREEK FLOOD PROTECTION PLAN

NOVEMBER 2009 LAREDO, TEXAS PROJECT NO. 7077.01

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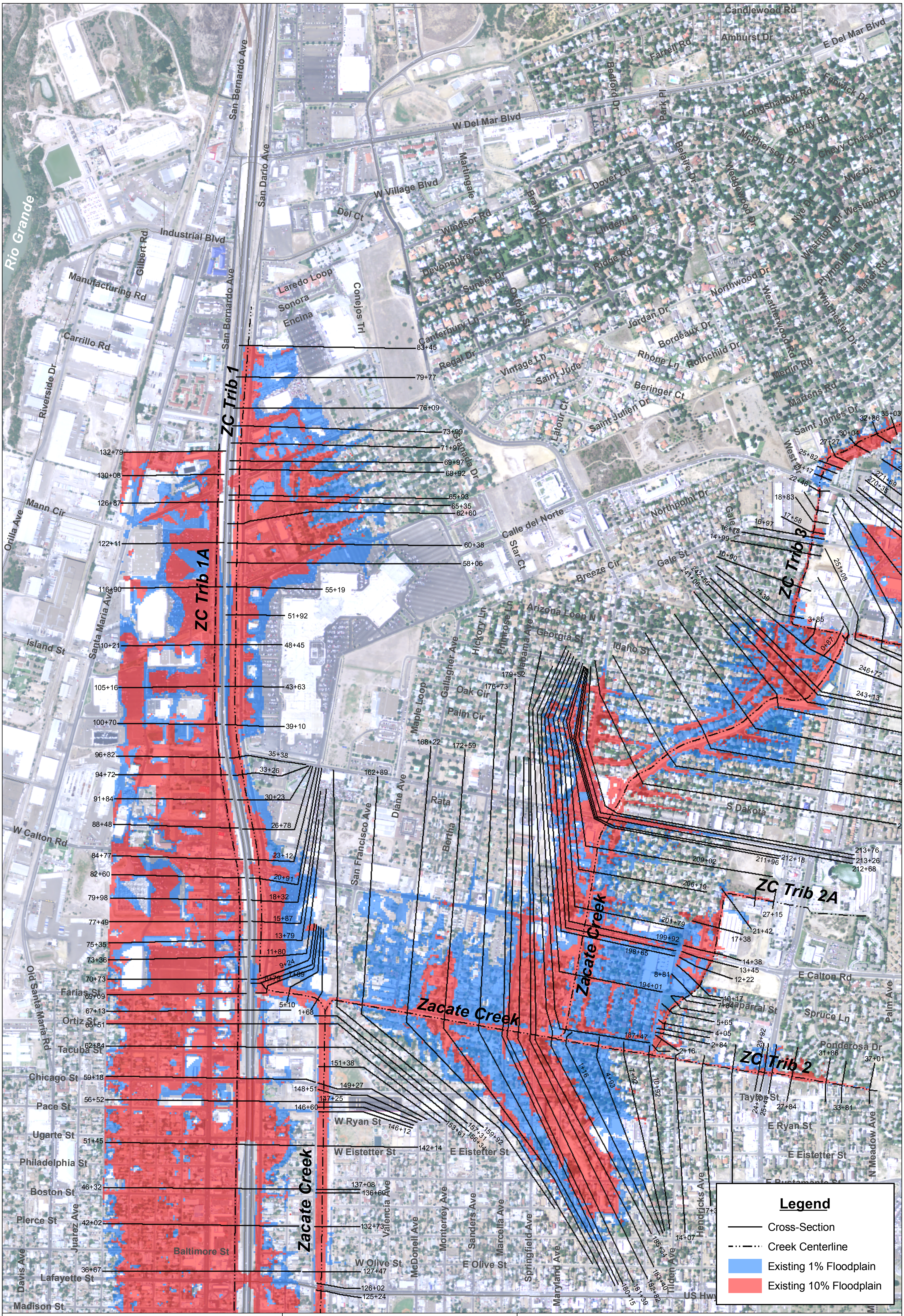

Espey Consultants, Inc.
Environmental & Engineering Services

0 500 1,000 2,000
Feet

N

EXHIBIT 7

CROSS-SECTION LOCATION AND FLOODPLAIN MAP
2 OF 4
ZACATE CREEK FLOOD PROTECTION PLAN

NOVEMBER 2009 LAREDO, TEXAS PROJECT NO. 7077.01

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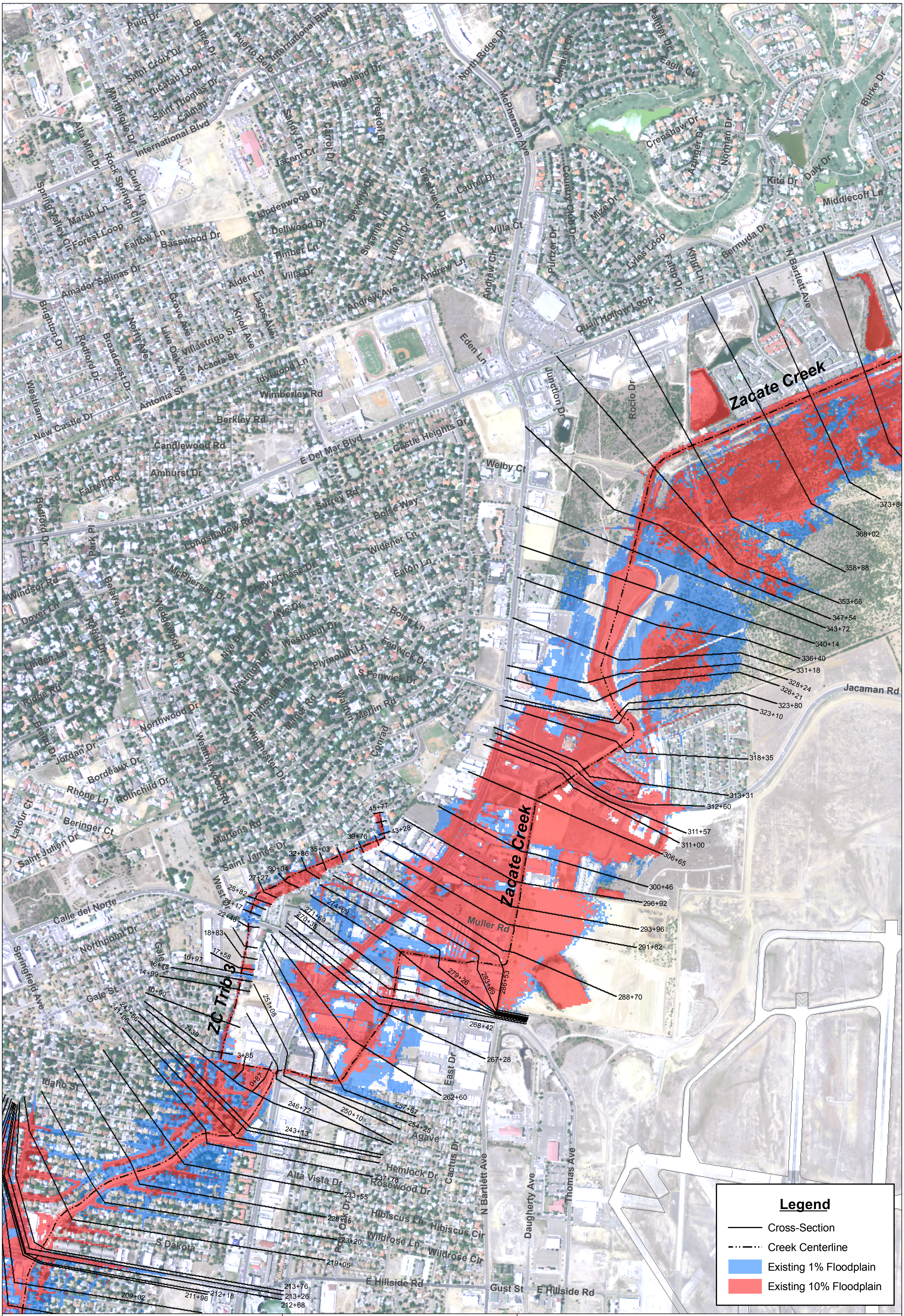

Espey Consultants, Inc.

Environmental & Engineering Services

0 500 1,000 2,000

Feet

N

EXHIBIT 8

CROSS-SECTION LOCATION AND FLOODPLAIN MAP

3 OF 4

ZACATE CREEK FLOOD PROTECTION PLAN

NOVEMBER 2009 LAREDO, TEXAS PROJECT NO. 7077.01

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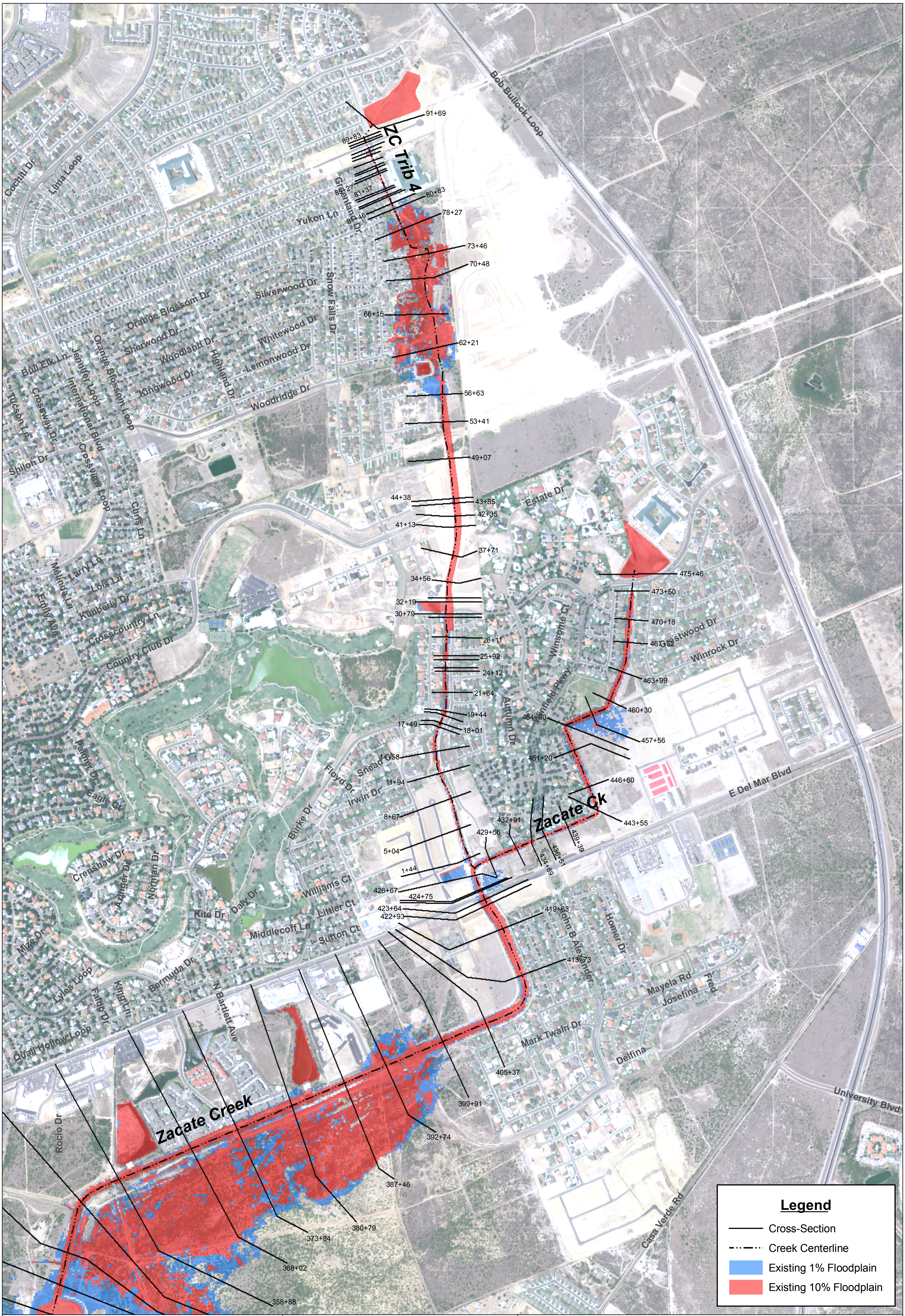

Espey Consultants, Inc.

Environmental & Engineering Services

0 500 1,000 2,000

Feet

N

EXHIBIT 9

CROSS-SECTION LOCATION AND FLOODPLAIN MAP

4 OF 4

ZACATE CREEK FLOOD PROTECTION PLAN

NOVEMBER 2009 LAREDO, TEXAS PROJECT NO. 7077.01

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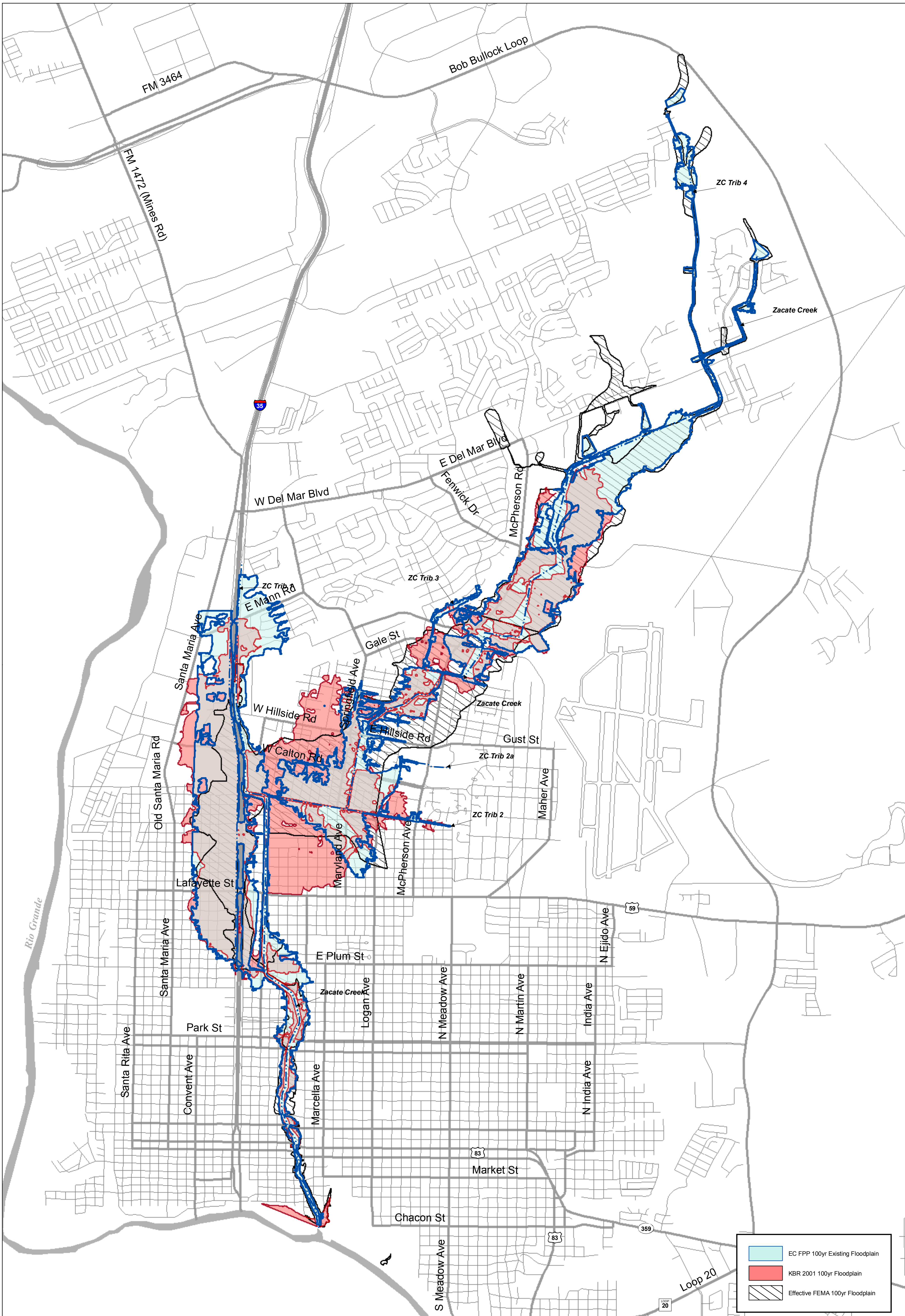

Espey Consultants, Inc.

Environmental & Engineering Services

0 1,500 3,000 6,000

Feet

N

EXHIBIT 10

FLOODPLAIN COMPARISON MAP

ZACATE CREEK FLOOD PROTECTION PLAN

LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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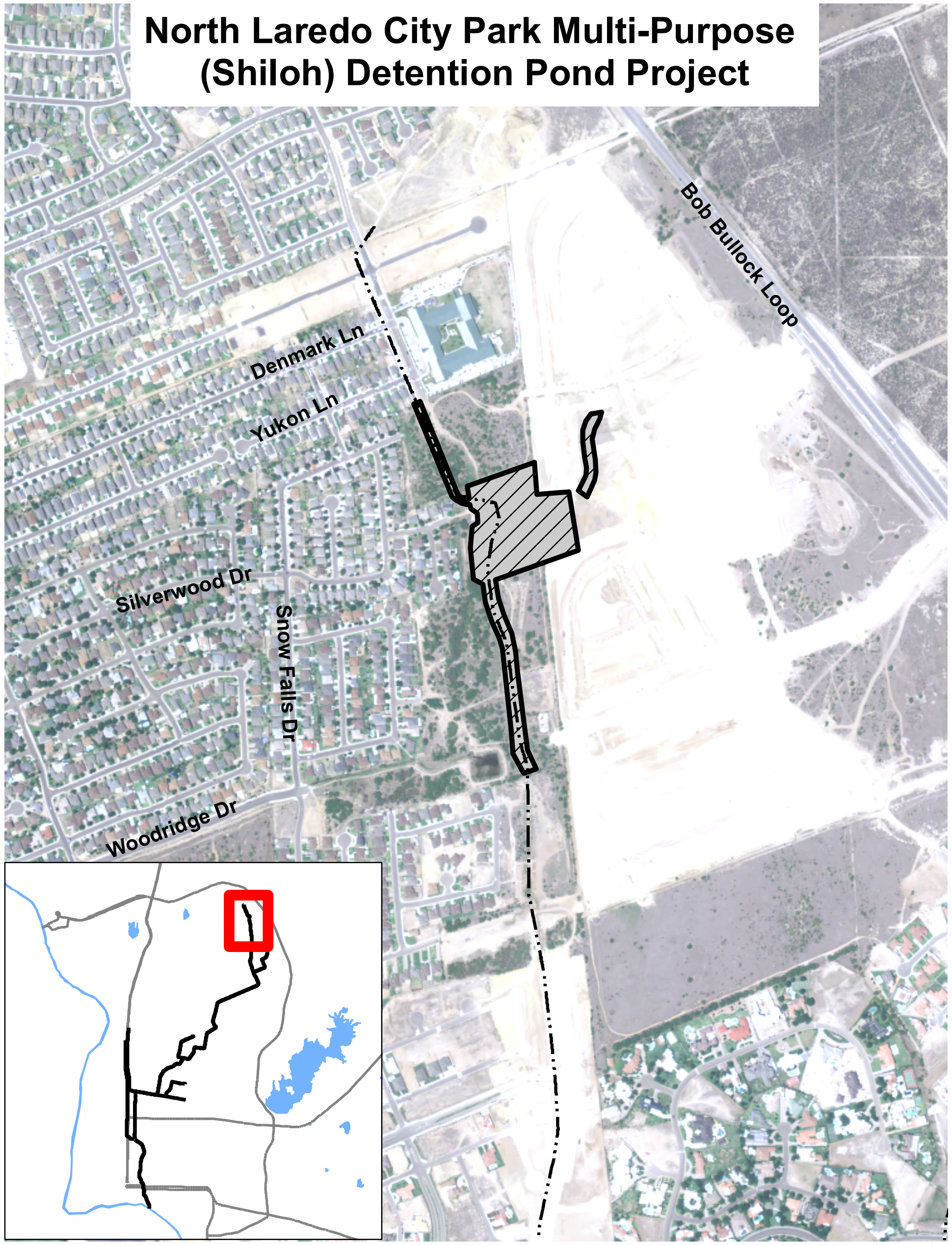

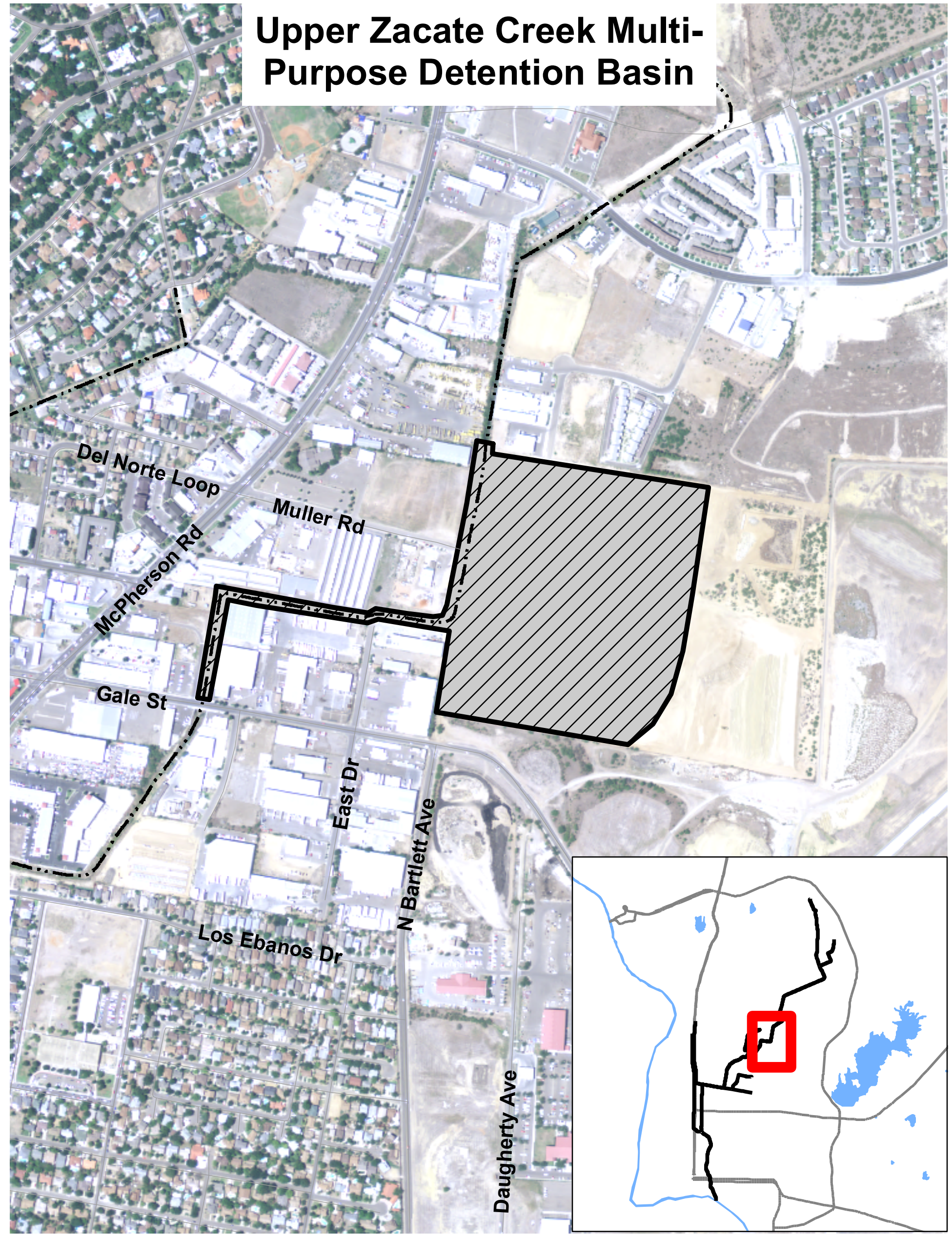

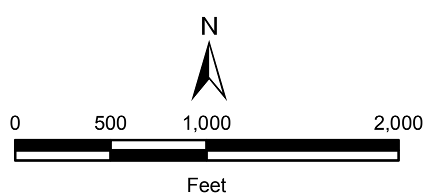

Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 11
ZONE 1 MAP
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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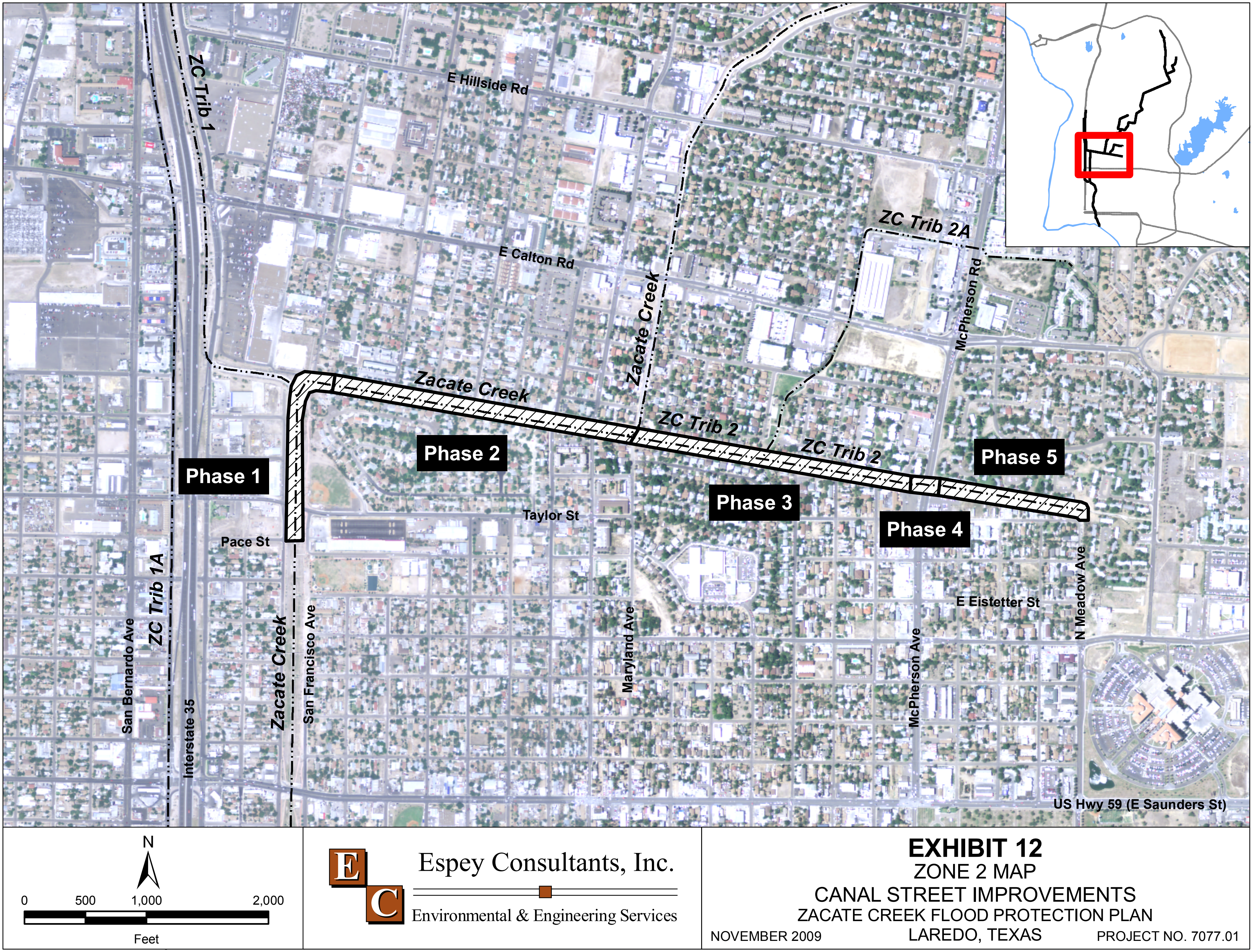


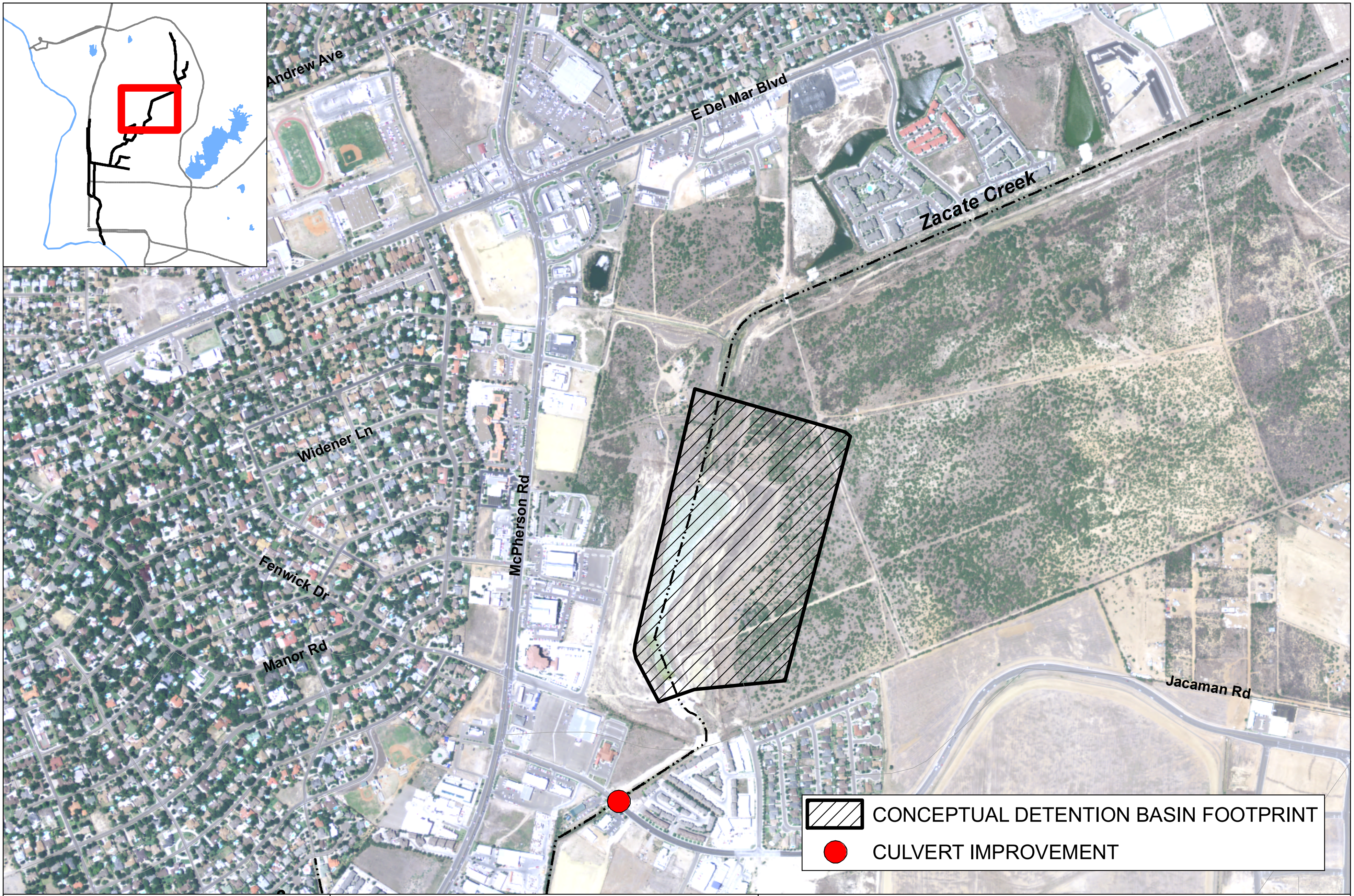
Espey Consultants, Inc.
Environmental & Engineering Services

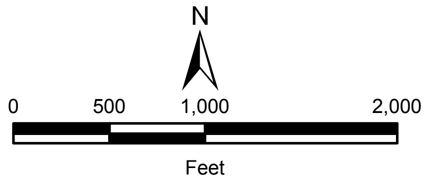
EXHIBIT 12
ZONE 2 MAP
CANAL STREET IMPROVEMENTS
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

P:\Active\7077.01 Zacate Creek FPP\GIS\Exhibits\REPORT\7077-01exh-Zone_2_Map.mxd





Espey Consultants, Inc.

Environmental & Engineering Services

EXHIBIT 13

ZONE 3 MAP

ALEXANDER RANCH BASIN EXPANSION + JACAMAN RD

ZACATE CREEK FLOOD PROTECTION PLAN

NOVEMBER 2009 LAREDO, TEXAS PROJECT NO. 7077.01

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Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 14
ZONE 4 MAP
CHANNEL AND CULVERT IMPROVEMENTS
ZACATE CREEK FLOOD PROTECTION PLAN
LARADO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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0 500 1,000 2,000

Feet

Espey Consultants, Inc.

Environmental & Engineering Services

EXHIBIT 15

ZONE 5 MAP

CHANNEL AND CULVERT IMPROVEMENTS

ZACATE CREEK FLOOD PROTECTION PLAN

NOVEMBER 2009 LAREDO, TEXAS PROJECT NO. 7077.01

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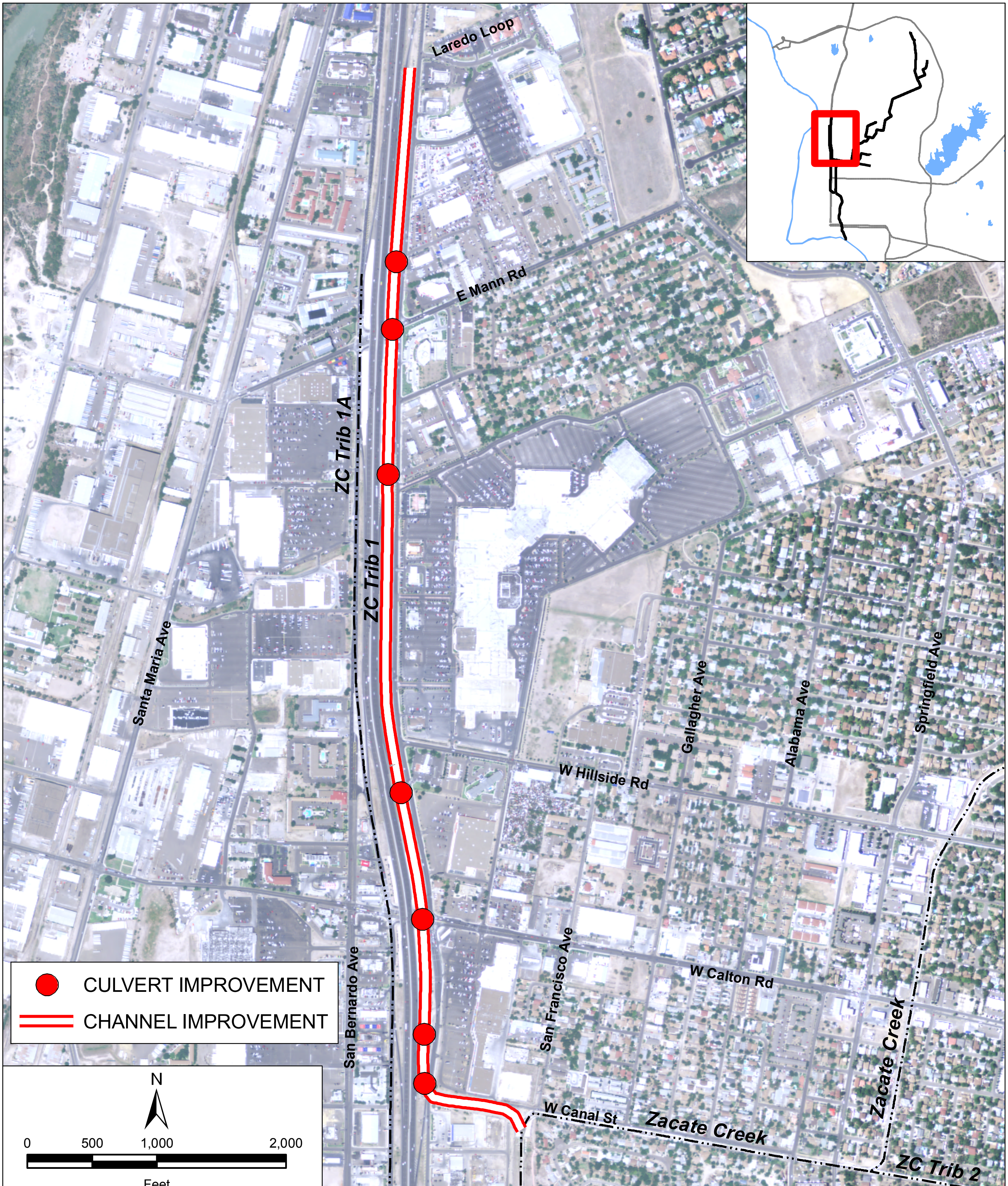

Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 16
ZONE 6 MAP
CHANNEL AND CULVERT IMPROVEMENTS
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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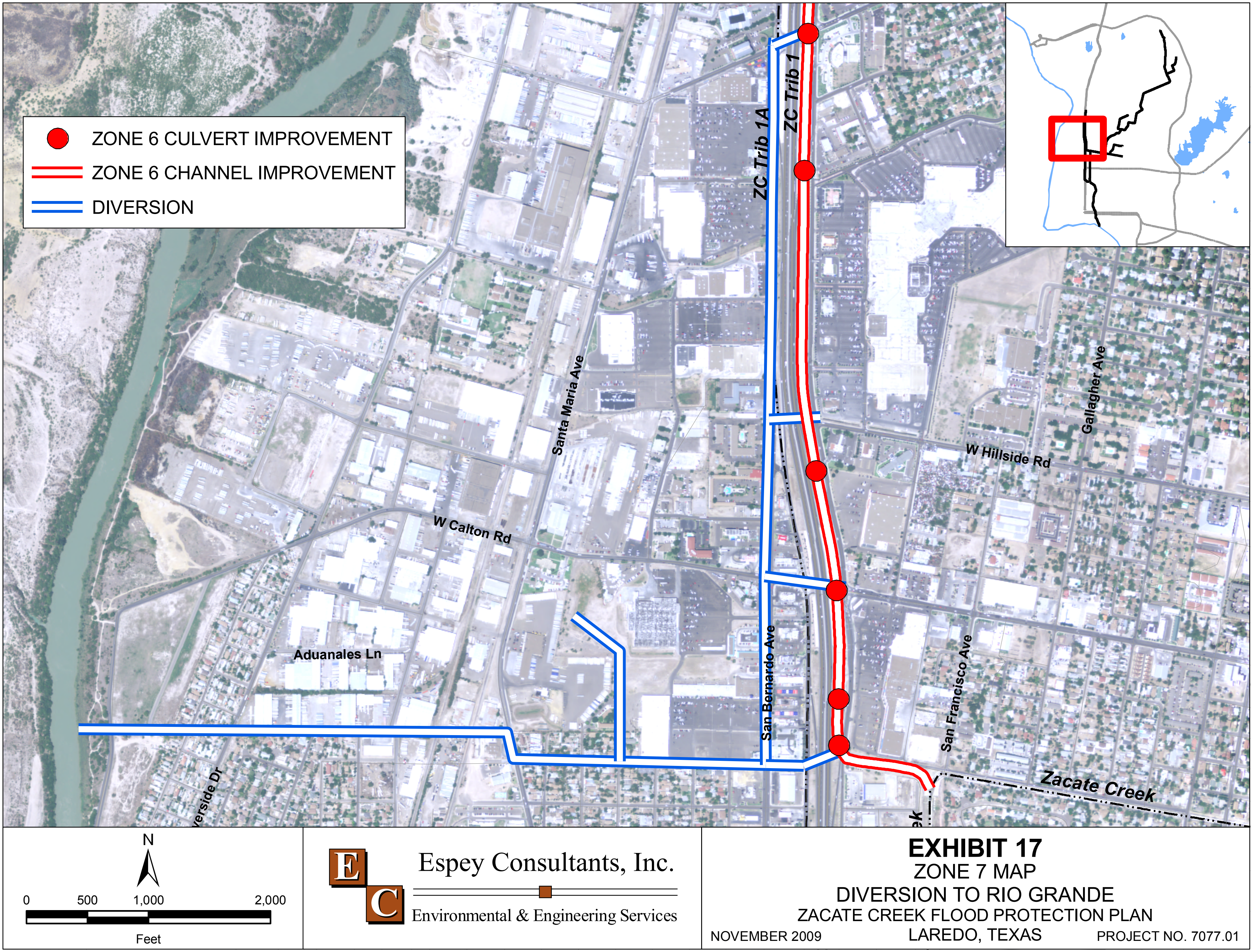


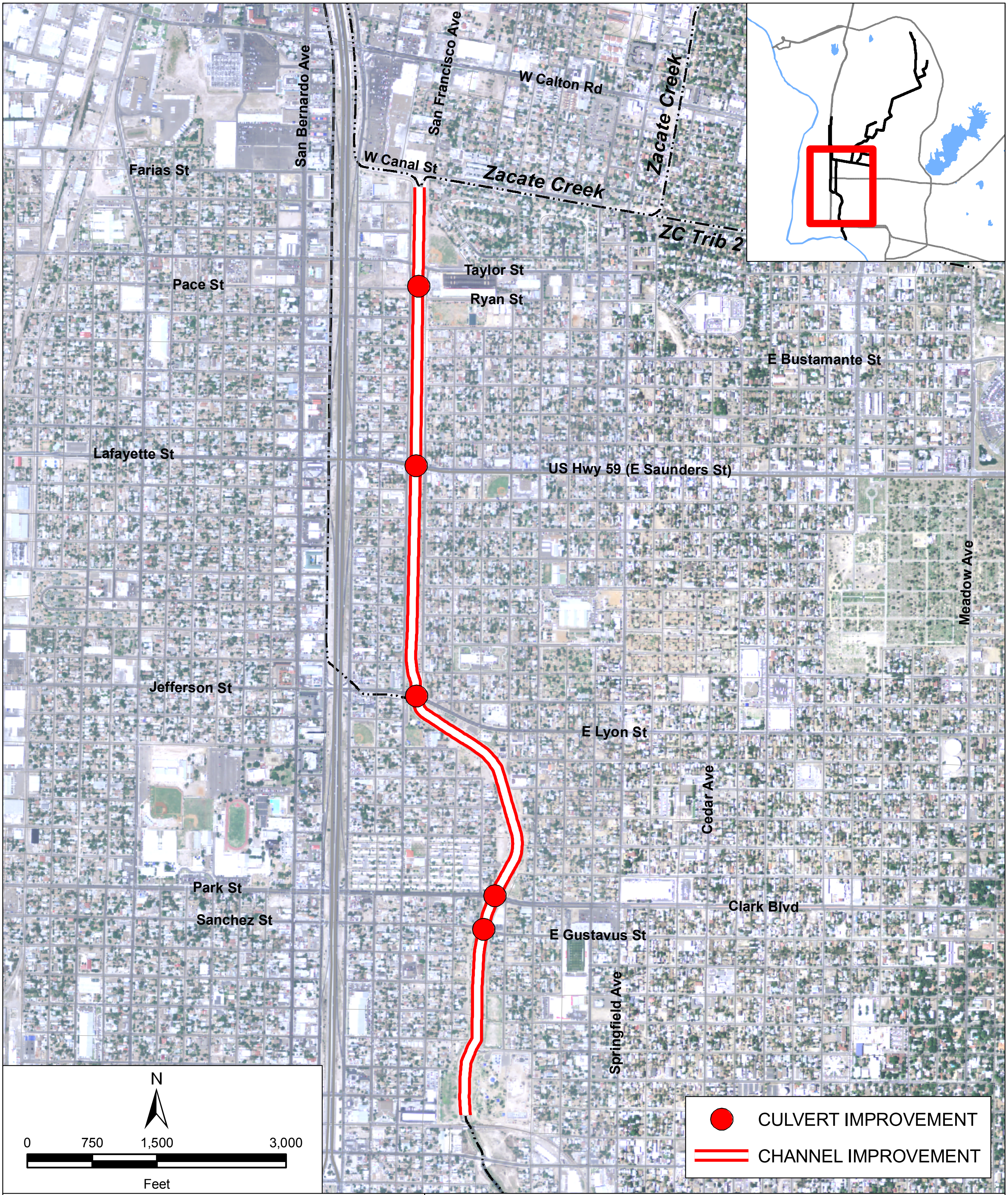
Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 17
ZONE 7 MAP
DIVERSION TO RIO GRANDE
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

P:\Active\7077.01 Zacate Creek FPP\GIS\Exhibits\REPORT\7077-01exh-Zone_7_Map.mxd



Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 18

ZONE 8 MAP

DOWNSTREAM CHANNEL IMPROVEMENTS

ZACATE CREEK FLOOD PROTECTION PLAN

LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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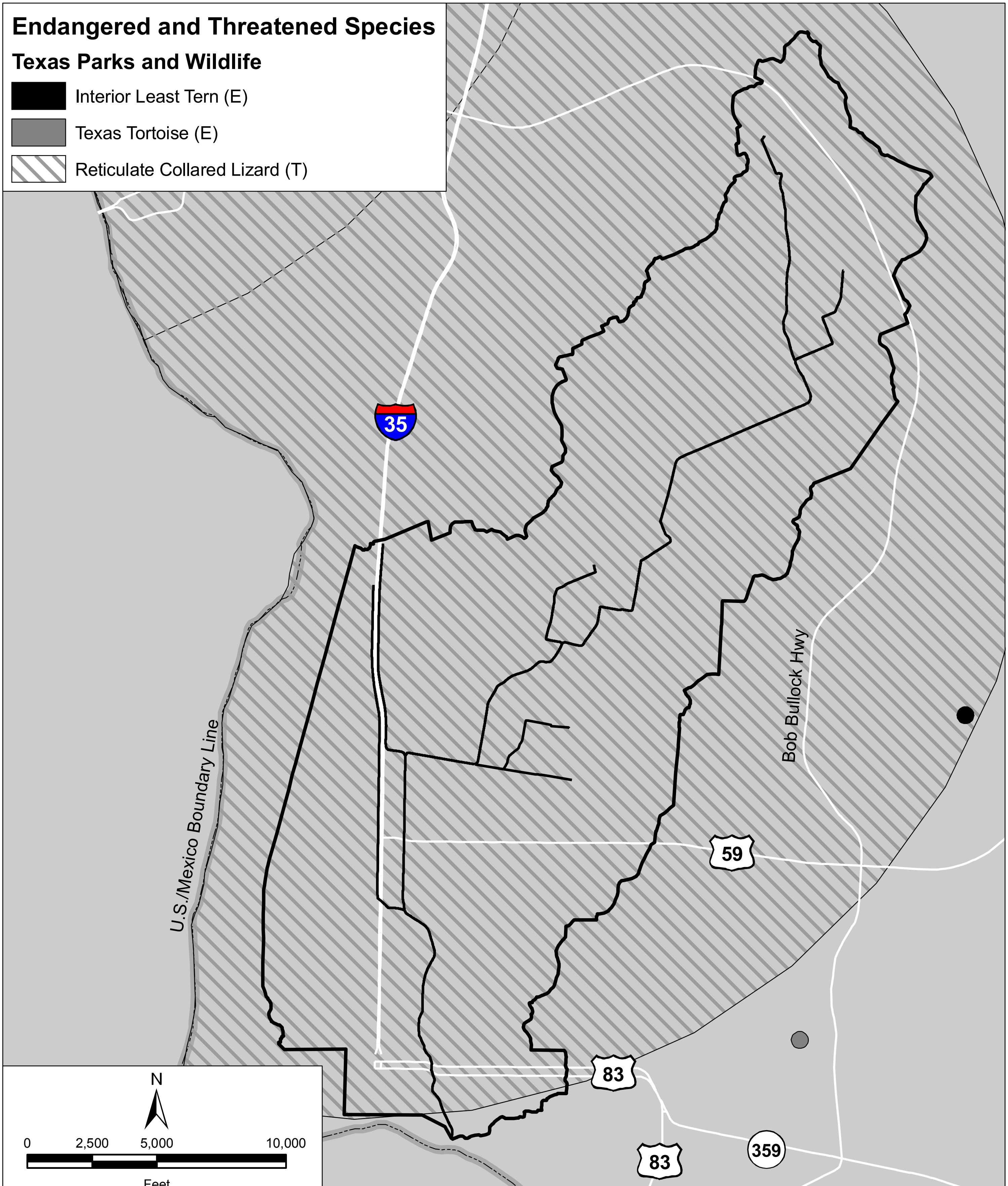

Espey Consultants, Inc.
Environmental & Engineering Services

EXHIBIT 19
ENDANGERED AND THREATENED SPECIES
ZACATE CREEK FLOOD PROTECTION PLAN
LAREDO, TEXAS

NOVEMBER 2009

PROJECT NO. 7077.01

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APPENDIX B
CURVE NUMBER CALCULATIONS

Curve Number Calculations

	Subbasin	Area of NRCS Group (Acres) A	B	C	D	Total Area (Acres)	Percent of Soil Type %A	%B	%C	%D	Weighted Curve Number (AMC II)
Main Drain A and Tributaries	Z_01		195.65	98.59	86.22	380.47	0%	51%	26%	23%	64
	Z_02		234.12		82.27	316.39	0%	74%	0%	26%	61
	Z_03		292.86	37.08	96.03	425.97	0%	69%	9%	23%	62
	Z_04		254.02			254.02	0%	100%	0%	0%	56
	Z_05		277.24			277.24	0%	100%	0%	0%	56
	Z_06		412.76	27.17		439.93	0%	94%	6%	0%	57
	Z_07		94.74	2.91		97.64	0%	97%	3%	0%	56
	Z_08		254.36	70.19		324.55	0%	78%	22%	0%	59
	Z_09		229.06			229.06	0%	100%	0%	0%	56
	Z_10		626.53	68.02	5.60	700.15	0%	89%	10%	1%	58
	Z_11		125.31	27.78		153.09	0%	82%	18%	0%	59
	Z_12		357.06	3.66		360.72	0%	99%	1%	0%	56
	Z_13		70.98			70.98	0%	100%	0%	0%	56
	Z_14		663.93	170.39		834.32	0%	80%	20%	0%	59
	Z_15		670.72			670.72	0%	100%	0%	0%	56
	Z_16		252.41	113.07		365.49	0%	69%	31%	0%	60
	Z_17		51.73	215.01		266.73	0%	19%	81%	0%	67
	Z_18		406.87			406.87	0%	100%	0%	0%	56
	Z_19		578.90	82.66		661.55	0%	88%	12%	0%	58
	ZT1_01		48.85			48.85	0%	100%	0%	0%	56
	ZT1_02		177.81	72.89		250.70	0%	71%	29%	0%	60
	ZT1_03		112.64			112.64	0%	100%	0%	0%	56
	ZT1_04		367.54	37.91		405.45	0%	91%	9%	0%	57
	ZT1_05		195.01			195.01	0%	100%	0%	0%	56
	ZT1_06		161.79			161.79	0%	100%	0%	0%	56
	ZT2_01		322.27	37.27		359.54	0%	90%	10%	0%	57
	ZT2_02		89.70			89.70	0%	100%	0%	0%	56
	ZT2_03		131.05			131.05	0%	100%	0%	0%	56
	ZT2A_01		424.21	4.33		428.55	0%	99%	1%	0%	56
	ZT3_01		193.76	10.20		203.95	0%	95%	5%	0%	57
	ZT3_02		259.85	63.08		322.93	0%	80%	20%	0%	59
	ZT4_01		20.54	167.66		188.20	0%	11%	89%	0%	68
	ZT4_02		60.61	12.01		72.62	0%	83%	17%	0%	58
	ZT4_03		51.22	115.12		166.34	0%	31%	69%	0%	66
	ZT4_04		363.94			363.94	0%	100%	0%	0%	56

Soil Groups	AMC I	AMC II	AMC III
A	18	35	55
B	35	56	75
C	49	70	84
D	58	77	89

Assumption: Brush cover type; Fair condition
Source: TR-55

APPENDIX C
EXISTING 2008, PLATTED 2008 AND ULTIMATE CONDITIONS IMPERVIOUS COVER PERCENTAGES

Existing Conditions 2008
Impervious Cover Calculations

	Drainage Area by Land Use Type (SF)									
Drainage Basin	Commercial (IC=85%)	Industrial (IC=90%)	Multifamily (IC=80%)	Park (IC=10%)	Single Family (IC=60%)	Transportation/Water (IC=98%)	Vacant (IC=0%)	Total Drainage Basin Area (SF)	Impervious Area (SF)	Impervious Cover Percent
Z_01	383,219	0	0	361,886	1,874,498	1,725,392	12,228,127	16,573,123	3,177,508	19%
Z_02	271,309	0	0	863,032	7,467,172	2,339,669	2,840,584	13,781,766	7,090,095	51%
Z_03	1,502,926	0	139,743	1,434,089	7,161,074	2,217,771	6,099,555	18,555,158	8,002,750	43%
Z_04	1,436,046	0	35	4,432,381	3,179,548	1,651,446	365,537	11,064,993	5,190,051	47%
Z_05	0	0	0	537,841	2,108	486	11,536,206	12,076,641	55,526	0%
Z_06	757,731	100,865	1,345,208	2,711,110	9,052,846	3,077,054	2,118,613	19,163,428	10,529,349	55%
Z_07	1,872,425	0	0	0	1,126,825	893,348	360,782	4,253,380	3,143,137	74%
Z_08	3,036,153	0	197,153	379,151	7,764,870	1,871,697	888,458	14,137,483	9,269,553	66%
Z_09	1,563,504	0	0	1,423,431	0	623,073	6,367,954	9,977,962	2,081,933	21%
Z_10	2,168,925	1,146,135	591,521	12,440,728	2,437,445	2,679,128	9,034,860	30,498,741	8,680,410	28%
Z_11	127,462	4,556,927	0	243,087	12,855	511,191	1,216,876	6,668,398	4,742,567	71%
Z_12	2,008,362	497	368,397	211,104	9,685,833	2,918,481	520,199	15,712,873	10,694,994	68%
Z_13	228,445	19,927	589,475	1,113	1,629,020	560,967	62,987	3,091,934	2,210,963	72%
Z_14	3,768,208	931,902	1,082,020	4,607,245	18,339,268	7,175,210	439,176	36,343,030	23,403,296	64%
Z_15	5,308,033	2,554,826	426,641	243,595	11,843,959	8,471,844	367,453	29,216,352	22,585,627	77%
Z_16	2,054,022	23,953	165,194	1,811,525	8,363,795	3,362,573	139,578	15,920,640	10,394,383	65%
Z_17	1,181,715	107,257	257,798	100,621	7,146,265	2,699,817	125,393	11,618,867	8,250,869	71%
Z_18	4,250,954	1,944,371	162,198	434,681	6,501,312	3,868,562	561,049	17,723,127	13,228,449	75%
Z_19	6,911,263	3,763,364	352,897	1,493,104	9,289,528	6,584,236	422,867	28,817,259	21,719,497	75%
ZT1_01	4,730,522	1,151,417	0	0	0	1,102,370	50,062	7,034,370	6,137,541	87%
ZT1_02	9,369,799	10,762	629,401	966,261	10,404,849	4,521,096	2,679,584	28,581,750	19,247,744	67%
ZT1_03	4,646,459	1,612,869	62,986	0	360,293	1,271,092	540,947	8,494,646	6,913,307	81%
ZT1_04	3,027,587	326,462	679,996	550	1,306,558	1,428,125	278,388	7,047,666	5,594,814	79%
ZT2_01	5,615,211	1,082,936	393,724	2,075,949	2,734,029	2,234,462	1,525,420	15,661,729	10,100,335	64%
ZT2_02	283,141	0	129,027	5,965	2,441,654	971,840	75,684	3,907,310	2,761,883	71%
ZT2_03	1,162,632	0	416,514	27	2,958,957	1,115,233	55,222	5,708,585	4,189,754	73%
ZT2A_01	5,619,130	1,638,815	754,067	2,089,899	2,687,291	3,393,142	2,485,098	18,667,442	12,001,092	64%
ZT3_01	375,667	0	354,200	274,322	6,534,250	1,261,750	84,049	8,884,238	5,787,175	65%
ZT3_02	2,088,633	4,231	564,593	1,170,726	7,458,435	1,812,711	967,485	14,066,815	8,599,411	61%
ZT4_01	0	0	0	273,013	1,051,723	539,132	6,333,993	8,197,860	1,186,685	14%
ZT4_02	373,089	0	0	55,709	2,181,203	553,517	0	3,163,518	2,173,865	69%
ZT4_03	27	0	0	430,814	1,416,894	928,124	4,469,893	7,245,751	1,802,802	25%
ZT4_04	133,104	0	0	1,452,688	9,211,219	2,821,151	2,235,097	15,853,260	8,549,867	54%
									Total Weighted IC	**58%**

Platted Conditions 2008
Impervious Cover Calculations

Drainage Basin	Drainage Area by Land Use Type (SF) Commercial (IC=85%)	Industrial (IC=90%)	Multifamily (IC=80%)	Park (IC=10%)	Single Family (IC=60%)	Transportation/Water (IC=98%)	Vacant (IC=0%)	Total Drainage Basin Area (SF)	Impervious Area (SF)	Impervious Cover Percent
Z_01	6,391,976	0	0	412,747	8,043,007	1,725,393	0	16,573,123	11,991,144	72%
Z_02	860,807	0	0	863,032	7,874,961	2,339,669	1,843,296	13,781,766	7,835,842	57%
Z_03	4,182,255	0	331,585	1,434,089	10,018,772	2,217,771	370,686	18,555,158	12,148,273	65%
Z_04	1,445,160	0	1,172	4,432,381	3,179,548	1,651,446	355,286	11,064,993	5,198,708	47%
Z_05	9,586,107	0	0	537,841	1,952,207	486	0	12,076,641	9,373,776	78%
Z_06	758,735	100,865	1,702,715	2,711,110	9,052,846	3,077,054	1,760,103	19,163,428	10,816,207	56%
Z_07	1,872,425	0	0	0	1,126,825	893,348	360,782	4,253,380	3,143,137	74%
Z_08	3,196,147	0	197,153	379,151	7,764,870	1,871,697	728,465	14,137,483	9,405,547	67%
Z_09	7,923,420	0	0	1,425,740	0	623,073	5,730	9,977,962	7,488,092	75%
Z_10	2,276,587	1,146,135	591,521	12,440,728	3,108,974	2,679,154	8,255,643	30,498,741	9,174,865	30%
Z_11	127,462	4,556,927	0	243,087	12,855	511,191	1,216,876	6,668,398	4,742,567	71%
Z_12	2,008,362	497	368,397	211,104	9,685,833	2,918,600	520,080	15,712,873	10,695,111	68%
Z_13	228,445	19,927	589,475	1,113	1,629,020	561,203	62,750	3,091,934	2,211,195	72%
Z_14	3,768,208	931,902	1,082,020	4,607,245	18,339,268	7,175,210	439,176	36,343,030	23,403,296	64%
Z_15	5,308,033	2,554,826	426,641	243,595	11,843,959	8,471,844	367,453	29,216,352	22,585,627	77%
Z_16	2,054,022	23,953	165,194	1,811,525	8,363,795	3,362,573	139,578	15,920,640	10,394,383	65%
Z_17	1,181,715	107,257	257,798	100,621	7,146,265	2,699,817	125,393	11,618,867	8,250,869	71%
Z_18	4,250,954	1,944,371	162,198	434,681	6,501,312	3,868,562	561,048	17,723,127	13,228,450	75%
Z_19	6,911,263	3,763,364	352,897	1,493,104	9,289,528	6,584,236	422,867	28,817,259	21,719,497	75%
ZT1_01	4,730,522	1,151,417	0	0	0	1,102,370	50,062	7,034,370	6,137,541	87%
ZT1_02	9,369,799	10,762	629,401	966,261	10,404,849	4,521,096	2,679,584	28,581,750	19,247,744	67%
ZT1_03	4,646,459	1,612,869	62,986	0	360,293	1,271,092	540,947	8,494,646	6,913,307	81%
ZT1_04	3,027,587	326,462	679,996	550	1,306,558	1,428,125	278,388	7,047,666	5,594,814	79%
ZT2_01	5,615,211	1,082,936	393,724	2,075,949	2,734,029	2,234,462	1,525,420	15,661,729	10,100,335	64%
ZT2_02	283,141	0	129,027	1,608	2,446,011	971,840	75,684	3,907,310	2,764,062	71%
ZT2_03	1,162,632	0	416,514	27	2,958,957	1,115,233	55,222	5,708,585	4,189,754	73%
ZT2A_01	5,619,130	1,638,815	754,067	2,089,899	2,687,291	3,393,142	2,485,098	18,667,442	12,001,092	64%
ZT3_01	375,667	0	354,200	274,322	6,534,250	1,261,750	84,049	8,884,238	5,787,175	65%
ZT3_02	2,088,633	4,231	564,593	1,170,726	7,458,435	1,812,711	967,485	14,066,815	8,599,411	61%
ZT4_01	3,456,516	0	0	273,013	3,929,199	539,132	0	8,197,860	5,851,209	71%
ZT4_02	373,089	0	0	55,709	2,181,203	553,517	0	3,163,518	2,173,865	69%
ZT4_03	2,885,584	0	0	430,814	2,999,323	928,124	1,906	7,245,751	5,204,983	72%
ZT4_04	133,104	0	0	1,452,688	9,211,219	2,821,151	2,235,097	15,853,260	8,549,867	54%
									Total Weighted IC	**66%**

Ultimate Conditions
Impervious Cover Calculations

	Drainage Area by Land Use (SF)								
Drainage Basin	Commercial (IC=85%)	Industrial (IC=90%)	Multifamily (IC=80%)	Park (IC=10%)	Single Family (IC=60%)	Transportation/Water (IC=98%)	Total Drainage Basin Area (SF)	Impervious Area (SF)	Impervious Cover Percent
Z_01	6,391,976	0	0	412,747	8,043,007	1,725,393	16,573,123	11,991,144	72%
Z_02	1,434,281	0	0	863,032	9,144,647	2,339,805	13,781,766	9,085,240	66%
Z_03	4,546,229	0	337,720	1,434,089	10,019,349	2,217,771	18,555,158	12,462,905	67%
Z_04	1,508,440	0	267,905	4,432,381	3,204,821	1,651,446	11,064,993	5,481,046	50%
Z_05	9,586,107	0	0	537,841	1,952,207	486	12,076,641	9,373,776	78%
Z_06	1,104,463	100,865	1,907,450	2,711,110	10,262,456	3,077,083	19,163,428	11,999,659	63%
Z_07	1,919,470	0	0	0	1,440,516	893,394	4,253,380	3,371,385	79%
Z_08	3,775,686	0	200,305	379,151	7,910,645	1,871,697	14,137,483	9,988,141	71%
Z_09	7,929,149	0	0	1,425,740	0	623,073	9,977,962	7,492,963	75%
Z_10	5,119,911	4,554,008	773,754	12,447,314	4,924,464	2,679,290	30,498,741	15,894,649	52%
Z_11	127,462	5,773,803	0	243,087	12,855	511,191	6,668,398	5,837,755	88%
Z_12	2,490,646	497	368,397	215,561	9,718,822	2,918,950	15,712,873	11,125,634	71%
Z_13	279,384	19,927	589,542	5,049	1,637,061	560,971	3,091,934	2,259,537	73%
Z_14	3,775,646	1,080,402	1,101,844	4,607,842	18,602,030	7,175,267	36,343,030	23,716,899	65%
Z_15	5,346,302	2,829,963	426,641	243,595	11,898,007	8,471,844	29,216,352	22,898,207	78%
Z_16	2,106,084	23,953	168,807	1,811,525	8,447,699	3,362,573	15,920,640	10,491,868	66%
Z_17	1,234,329	107,257	257,798	100,621	7,218,821	2,700,041	11,618,867	8,339,344	72%
Z_18	4,327,884	2,285,870	162,198	434,681	6,643,907	3,868,586	17,723,127	13,686,770	77%
Z_19	7,005,515	3,883,494	366,783	1,493,104	9,482,196	6,586,167	28,817,259	22,036,331	76%
ZT1_01	4,780,584	1,151,417	0	0	0	1,102,370	7,034,370	6,180,094	88%
ZT1_02	11,293,307	10,762	637,750	966,260	11,152,576	4,521,096	28,581,750	21,338,042	75%
ZT1_03	5,187,406	1,612,869	62,986	0	360,293	1,271,092	8,494,646	7,373,112	87%
ZT1_04	3,259,115	326,462	689,117	550	1,344,296	1,428,125	7,047,666	5,821,553	83%
ZT2_01	6,094,115	2,122,911	393,724	2,075,949	2,740,570	2,234,462	15,661,729	11,447,306	73%
ZT2_02	283,963	0	129,027	19,781	2,488,397	986,142	3,907,310	2,806,026	72%
ZT2_03	1,173,454	0	416,514	27	3,003,282	1,115,308	5,708,585	4,225,621	74%
ZT2A_01	7,005,327	2,719,469	754,067	2,107,554	2,687,827	3,393,199	18,667,442	14,154,090	76%
ZT3_01	412,397	0	357,652	274,322	6,578,117	1,261,750	8,884,238	5,847,477	66%
ZT3_02	2,566,137	4,231	756,481	1,170,945	7,755,418	1,813,603	14,066,815	9,337,886	66%
ZT4_01	3,456,516	0	0	273,013	3,929,199	539,132	8,197,860	5,851,209	71%
ZT4_02	373,089	0	0	55,709	2,181,203	553,517	3,163,518	2,173,865	69%
ZT4_03	2,885,584	0	0	430,814	3,001,229	928,124	7,245,751	5,206,127	72%
ZT4_04	133,105	0	0	1,452,688	11,446,317	2,821,151	15,853,260	9,890,925	62%
								Total Weighted IC	**70%**

APPENDIX D
TIME OF CONCENTRATION CALCULATIONS

EXISTING 2008 CONDITIONS
TR-55 Method of Computing the Time of Concentration

	variable	units	Z_01	Z_02	Z_03	Z_04	Z_05	Z_06	Z_07	Z_08	Z_09	Z_10
Sheet Flow	variable	units										
Manning's roughness coefficient	n	n/a	0.130	0.240	0.130	0.130	0.130	0.130	0.240	0.240	0.130	0.130
Flow Length	L	feet	300	100	300	150	300	300	100	75	150	300
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0205	0.0200	0.0072	0.0255	0.0444	0.0333	0.0107	0.0376	0.0041	0.0084
Travel time	Tt	hours	0.359	0.246	0.545	0.189	0.263	0.295	0.315	0.152	0.391	0.513
Shallow Concentrated Flow		min.	21.5	14.7	32.7	11.3	15.8	17.7	18.9	9.1	23.5	30.8
Flow Length	L	feet	1,000	1,000	1,000	410	1,000	1,000	680	1,000	665	1,000
Slope	s	ft/ft	0.026	0.015	0.017	0.035	0.019	0.025	0.015	0.015	0.008	0.018
Surface (1=paved or 2=unpaved)		n/a	2	2	2	1	2	2	2	1	1	2
Velocity	V	ft/sec	2.63	1.97	2.09	3.85	2.22	2.55	1.97	2.51	1.81	2.19
Travel time	Tt	hours	0.105	0.141	0.133	0.030	0.125	0.109	0.096	0.111	0.102	0.127
Manning's Equation		min.	6.3	8.5	8.0	1.8	7.5	6.5	5.7	6.7	6.1	7.6
1 Flow Length	L	feet	2,150	2,450	1,300	3,385	1,200	1,695	1,873	1,425	860	575
Slope	S	ft/ft	0.0170	0.0111	0.0061	0.0134	0.0120	0.0104	0.0080	0.0071	0.0145	0.0214
roughness	n	n/a	0.05	0.022	0.03	0.035	0.05	0.022	0.03	0.022	0.05	0.022
Open Channel												
Bottom Width	BW	feet	5	3	3	3	3	3	5	3	4	3
Side Slopes (H:1)	H	feet	2.5	1.5	1.5	3	2	3	3	1.5	3	1.5
Depth	d	feet	1	0.5	1.5	0.75	0.5	0.5	1	0.5	0.75	0.25
Cross-Sectional Area	X-A	feet^2	7.50	1.88	7.88	3.94	2.00	2.25	8.00	1.88	4.69	0.84
Flow Rate	Q	cfs	0.72	0.39	0.94	0.51	0.38	0.37	0.71	0.39	0.54	0.22
Velocity	V	ft/sec	23.44	7.15	29.22	12.36	3.44	7.94	28.19	5.73	11.12	3.01
Travel time	Tt	hours	0.191	0.178	0.097	0.300	0.194	0.133	0.148	0.130	0.101	0.045
2 Flow Length	L	feet	2,250	2,404	3,040	2,055	1,300	2,005	1,847	2,360	1,510	4,575
Slope	S	ft/ft	0.0094	0.0031	0.0065	0.0060	0.0092	0.0029	0.0089	0.0041	0.0067	0.0076
roughness	n	n/a	0.05	0.05	0.022	0.05	0.05	0.022	0.03	0.022	0.05	0.022
Open Channel												
Bottom Width	BW	feet	20	20	4	3	3	3	5	3	6	3
Side Slopes (H:1)	H	feet	3	4	1.5	3	2	1.5	3	1.5	2	1.5
Depth	d	feet	1.5	5	0.5	3	1	1.4	1	1	1.5	0.5
Cross-Sectional Area	X-A	feet^2	36.75	200.00	2.38	36.00	5.00	7.14	8.00	4.50	13.50	1.88
Flow Rate	Q	cfs	1.25	3.27	0.41	1.64	0.67	0.89	0.71	0.68	1.06	0.39
Velocity	V	ft/sec	123.23	728.74	7.13	115.04	10.91	24.14	29.68	15.16	34.36	5.91
Travel time	Tt	hours	0.186	0.183	0.281	0.179	0.166	0.165	0.138	0.195	0.165	0.403
3 Flow Length	L	feet	665	1,908	394	943	1,675	5,618	1,375	3,466	2,188	2,451
Slope	S	ft/ft	0.0133	0.0042	0.0047	0.0036	0.0023	0.0069	0.0065	0.0025	0.0024	0.0012
roughness	n	n/a	0.05	0.05	0.05	0.05	0.05	0.05	0.016	0.03	0.05	0.05
Open Channel												
Bottom Width	BW	feet	20	20	75	50	10	15	10	20	40	15
Side Slopes (H:1)	H	feet	3	4	4	6	4	3	5	5	4	3
Depth	d	feet	1.5	5	3	3	4	3	0.5	2	3	5
Cross-Sectional Area	X-A	feet^2	36.75	200.00	261.00	204.00	104.00	72.00	6.25	60.00	156.00	150.00
Flow Rate	Q	cfs	1.25	3.27	2.62	2.36	2.42	2.12	0.41	1.49	2.41	3.22
Velocity	V	ft/sec	146.33	853.70	1015.25	647.12	267.27	293.91	26.07	194.12	405.22	342.06
Travel time	Tt	hours	0.046	0.124	0.028	0.083	0.181	0.382	0.092	0.298	0.234	0.299
Total Travel Time	TC	hours	0.888	0.872	1.084	0.779	0.929	1.084	0.789	0.884	0.993	1.386
	TC	min.	53.3	52.3	65.1	46.7	55.7	65.1	47.3	53.0	59.6	83.2
Lag Time	TL	hours	0.5330	0.5234	0.6507	0.4675	0.5572	0.6507	0.4732	0.5305	0.5956	0.8315
	TL	min.	32.0	31.4	39.0	28.0	33.4	39.0	28.4	31.8	35.7	49.9

EXISTING 2008 CONDITIONS
TR-55 Method of Computing the Time of Concentration

			Z_11	Z_12	Z_13	Z_14	Z_15	Z_16	Z_17	Z_18	Z_19	ZT1_01
Sheet Flow	variable	units										
Manning's roughness coefficient	n	n/a	0.130	0.240	0.240	0.240	0.011	0.240	0.240	0.011	0.240	0.011
Flow Length	L	feet	250	100	75	150	100	100	100	100	150	100
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0309	0.0196	0.0324	0.0349	0.0063	0.0622	0.0489	0.0026	0.0099	0.0008
Travel time	Tt	hours	0.263	0.248	0.161	0.272	0.033	0.156	0.172	0.047	0.451	0.074
Shallow Concentrated Flow		min.	15.8	14.9	9.7	16.3	2.0	9.4	10.3	2.8	27.0	4.4
Flow Length	L	feet	800	1,000	475	1,150	1,000	1,000	1,000	1,000	1,000	310
Slope	s	ft/ft	0.022	0.014	0.004	0.041	0.002	0.045	0.034	0.004	0.002	0.009
Surface (1=paved or 2=unpaved)		n/a	2	1	1	2	1	1	1	1	1	2
Velocity	V	ft/sec	2.38	2.42	1.35	3.26	0.90	4.36	3.82	1.26	0.98	1.56
Travel time	Tt	hours	0.093	0.115	0.097	0.098	0.307	0.064	0.073	0.221	0.283	0.055
Manning's Equation		min.	5.6	6.9	5.8	5.9	18.4	3.8	4.4	13.2	17.0	3.3
1 Flow Length	L	feet	510	3,250	550	3,700	2,300	830	900	4,300	2,150	616
Slope	S	ft/ft	0.0120	0.0029	0.0029	0.0104	0.0025	0.0346	0.0218	0.0005	0.0013	0.0041
roughness	n	n/a	0.05	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.035
Open Channel												
Bottom Width	BW	feet	5	3	3	3	3	3	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	1.5	3	1.5	3	1.5	3
Depth	d	feet	1	1.5	1	0.5	2	0.2	0.3	4	2	1
Cross-Sectional Area	X-A	feet^2	6.50	7.88	4.50	1.88	12.00	0.72	1.04	68.00	12.00	6.00
Flow Rate	Q	cfs	0.76	0.94	0.68	0.39	1.18	0.17	0.25	2.24	1.18	0.64
Velocity	V	ft/sec	17.60	27.64	12.61	6.92	45.42	2.77	4.15	170.27	32.13	12.16
Travel time	Tt	hours	0.052	0.257	0.055	0.279	0.169	0.060	0.062	0.477	0.223	0.084
2 Flow Length	L	feet	2,170	1,650	350	3,275	5,640	980	5,000	3,650	4,150	861
Slope	S	ft/ft	0.0118	0.0041	0.0017	0.0058	0.0011	0.0119	0.0106	0.0006	0.0012	0.0005
roughness	n	n/a	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.035
Open Channel												
Bottom Width	BW	feet	3	3	3	3	5	3	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	3	1.5	1.5	3	1.5	3
Depth	d	feet	0.5	1.5	1.5	1	3	0.5	0.5	4	3	5
Cross-Sectional Area	X-A	feet^2	1.88	7.88	7.88	4.50	42.00	1.88	1.88	68.00	22.50	90.00
Flow Rate	Q	cfs	0.39	0.94	0.94	0.68	1.75	0.39	0.39	2.24	1.63	2.60
Velocity	V	ft/sec	7.36	32.50	20.86	17.92	138.70	7.40	7.00	200.95	72.96	158.62
Travel time	Tt	hours	0.154	0.111	0.037	0.228	0.474	0.069	0.372	0.343	0.355	0.136
3 Flow Length	L	feet	1,115	3,434	2,101	2,054	804	4,419	897	525	2,113	224
Slope	S	ft/ft	0.0029	0.0024	0.0037	0.0023	0.0062	0.0038	0.0185	0.0585	0.0087	0.0058
roughness	n	n/a	0.05	0.016	0.016	0.035	0.016	0.035	0.035	0.03	0.035	0.035
Open Channel												
Bottom Width	BW	feet	20	20	40	50	15	100	10	10	10	3
Side Slopes (H:1)	H	feet	2	1.5	0.5	1.5	1.5	3.5	3	3	3	3
Depth	d	feet	5	1	0.5	2.5	0.5	1.5	1	0.25	1	1
Cross-Sectional Area	X-A	feet^2	150.00	21.50	20.13	134.38	7.88	157.88	13.00	2.69	13.00	6.00
Flow Rate	Q	cfs	3.54	0.91	0.49	2.28	0.47	1.42	0.80	0.23	0.80	0.64
Velocity	V	ft/sec	563.21	92.80	70.60	472.66	34.84	524.85	64.72	12.19	44.38	14.48
Travel time	Tt	hours	0.082	0.221	0.166	0.162	0.050	0.369	0.050	0.032	0.172	0.026
Total Travel Time	TC	hours	0.645	0.952	0.516	1.039	1.034	0.718	0.729	1.120	1.485	0.375
	TC	min.	38.7	57.1	31.0	62.4	62.0	43.1	43.7	67.2	89.1	22.5
Lag Time	TL	hours	0.3870	0.5710	0.3096	0.6235	0.6203	0.4307	0.4374	0.6719	0.8908	0.2251
	TL	min.	23.2	34.3	18.6	37.4	37.2	25.8	26.2	40.3	53.4	13.5

EXISTING 2008 CONDITIONS
TR-55 Method of Computing the Time of Concentration

			ZT1_02	ZT1_03	ZT1_04	ZT1_05	ZT1_06	ZT2_01	ZT2_02	ZT2_03	ZT2A_01	ZT3_01
Sheet Flow	variable	units										
Manning's roughness coefficient	n	n/a	0.240	0.011	0.130	0.011	0.011	0.240	0.240	0.011	0.130	0.240
Flow Length	L	feet	130	100	300	150	100	100	100	100	100	150
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0404	0.0142	0.0373	0.0035	0.0261	0.1160	0.0048	0.0195	0.0113	0.0201
Travel time	Tt	hours	0.229	0.024	0.282	0.058	0.019	0.122	0.435	0.021	0.189	0.339
Shallow Concentrated Flow		min.	13.7	1.4	16.9	3.5	1.1	7.3	26.1	1.3	11.4	20.3
Flow Length	L	feet	1,000	1,000	650	900	1,100	1,000	1,000	1,000	1,000	600
Slope	s	ft/ft	0.028	0.002	0.040	0.001	0.005	0.021	0.006	0.014	0.015	0.032
Surface (1=paved or 2=unpaved)		n/a	1	1	2	1	1	1	1	1	2	1
Velocity	V	ft/sec	3.45	0.92	3.23	0.53	1.45	2.99	1.56	2.44	2.01	3.70
Travel time	Tt	hours	0.081	0.302	0.056	0.468	0.211	0.093	0.179	0.114	0.138	0.045
Manning's Equation		min.	4.8	18.1	3.4	28.1	12.7	5.6	10.7	6.8	8.3	2.7
1 Flow Length	L	feet	870	1,550	1,550	750	1,800	2,500	700	900	1,900	750
Slope	S	ft/ft	0.0157	0.0010	0.0203	0.0048	0.0029	0.0113	0.0039	0.0103	0.0106	0.0128
roughness	n	n/a	0.022	0.022	0.022	0.022	0.022	0.04	0.022	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	3	3	3	3	1	3	3	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	3	1.5	1.5	5	3	1.5	1.5	1.5
Depth	d	feet	0.25	3	0.3	0.5	1	0.5	0.5	0.25	0.25	0.4
Cross-Sectional Area	X-A	feet^2	0.84	22.50	1.17	1.88	4.50	1.75	2.25	0.84	0.84	1.44
Flow Rate	Q	cfs	0.22	1.63	0.24	0.39	0.68	0.29	0.37	0.22	0.22	0.32
Velocity	V	ft/sec	2.58	67.54	4.34	4.70	12.68	3.01	4.84	2.09	2.12	5.21
Travel time	Tt	hours	0.079	0.143	0.116	0.083	0.177	0.403	0.090	0.101	0.210	0.058
2 Flow Length	L	feet	2,200	1,720	2,600	2,127	1,180	1,730	990	1,650	4,775	1,180
Slope	S	ft/ft	0.0130	0.0021	0.0049	0.0009	0.0060	0.0061	0.0066	0.0039	0.0077	0.0143
roughness	n	n/a	0.022	0.035	0.022	0.05	0.022	0.015	0.022	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	10	3	15	3	1	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1	3	2	1.5	5	4	1.5	1.5	1.5
Depth	d	feet	0.5	3	1	3	0.5	0.5	0.5	0.5	0.5	0.3
Cross-Sectional Area	X-A	feet^2	1.88	39.00	6.00	63.00	1.88	1.75	2.50	2.88	1.88	1.04
Flow Rate	Q	cfs	0.39	2.11	0.64	2.22	0.39	0.29	0.35	0.42	0.39	0.25
Velocity	V	ft/sec	7.73	125.11	21.18	94.87	5.24	5.89	6.84	6.82	5.95	3.35
Travel time	Tt	hours	0.148	0.149	0.205	0.392	0.117	0.143	0.101	0.193	0.418	0.101
3 Flow Length	L	feet	1,918	1,720	2,742	1,303	2,047	1,184	1,299	2,351	1,343	3,048
Slope	S	ft/ft	0.0030	0.0013	0.0020	0.0003	0.0034	0.0077	0.0062	0.0034	0.0035	0.0035
roughness	n	n/a	0.022	0.016	0.016	0.016	0.016	0.022	0.015	0.022	0.016	0.022
Open Channel												
Bottom Width	BW	feet	3	3	20	5	28	15	15	5	15	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	1	1	2	1.5	1.5	1.5
Depth	d	feet	2	2	1	4	0.5	0.25	0.5	1	0.5	1.5
Cross-Sectional Area	X-A	feet^2	12.00	12.00	21.50	44.00	14.25	3.81	8.00	6.50	7.88	7.88
Flow Rate	Q	cfs	1.18	1.18	0.91	2.27	0.48	0.24	0.46	0.76	0.47	0.94
Velocity	V	ft/sec	49.46	44.36	84.11	119.73	47.88	8.82	37.64	21.17	26.14	30.04
Travel time	Tt	hours	0.129	0.129	0.195	0.133	0.169	0.142	0.077	0.201	0.112	0.222
Total Travel Time	TC	hours	0.666	0.747	0.854	1.135	0.694	0.903	0.881	0.630	1.067	0.765
	TC	min.	39.9	44.8	51.2	68.1	41.6	54.2	52.9	37.8	64.0	45.9
Lag Time	TL	hours	0.3995	0.4482	0.5122	0.6807	0.4163	0.5416	0.5287	0.3779	0.6401	0.4588
	TL	min.	24.0	26.9	30.7	40.8	25.0	32.5	31.7	22.7	38.4	27.5

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			Z_01	Z_02	Z_03	Z_04	Z_05	Z_06	Z_07	Z_08	Z_09	Z_10
Sheet Flow	variable	units										
Manning's roughness coef.	n	n/a	0.240	0.240	0.240	0.130	0.240	0.130	0.240	0.240	0.011	0.130
Flow Length	L	feet	100	100	100	150	100	300	100	75	150	300
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0127	0.0200	0.0101	0.0255	0.0512	0.0333	0.0107	0.0376	0.0041	0.0084
Travel time	Tt	hours	0.295	0.246	0.323	0.189	0.169	0.295	0.315	0.152	0.054	0.513
Shallow Concentrated Flow		min.	17.7	14.7	19.4	11.3	10.1	17.7	18.9	9.1	3.3	30.8
Flow Length	L	feet	1,000	1,000	820	410	1,000	1,000	680	1,000	1,000	1,000
Slope	s	ft/ft	0.026	0.015	0.017	0.035	0.024	0.025	0.015	0.015	0.008	0.018
Surface (1=paved or 2=unpaved)		n/a	1	2	1	1	1	2	2	1	1	2
Velocity	V	ft/sec	3.33	1.97	2.71	3.85	3.21	2.55	1.97	2.51	1.83	2.19
Travel time	Tt	hours	0.083	0.141	0.084	0.030	0.086	0.109	0.096	0.111	0.152	0.127
Manning's Equation		min.	5.0	8.5	5.0	1.8	5.2	6.5	5.7	6.7	9.1	7.6
1 Flow Length	L	feet	2,350	2,450	1,680	3,385	900	1,695	1,873	1,425	525	575
Slope	S	ft/ft	0.0177	0.0111	0.0069	0.0134	0.0140	0.0104	0.0080	0.0071	0.0186	0.0214
roughness	n	n/a	0.022	0.022	0.03	0.035	0.022	0.022	0.03	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	3	3	3	5	3	5	3	4	3
Side Slopes (H:1)	H	feet	2.5	1.5	1.5	3	3	3	3	1.5	3	1.5
Depth	d	feet	0.25	0.5	1.5	0.75	0.25	0.5	1	0.5	0.75	0.25
Cross-Sectional Area	X-A	feet^2	0.91	1.88	7.88	3.94	1.44	2.25	8.00	1.88	4.69	0.84
Flow Rate	Q	cfs	2.87	7.15	31.11	12.36	4.18	7.94	28.19	5.73	28.55	3.01
Velocity	V	ft/sec	3.17	3.81	3.95	3.14	2.91	3.53	3.52	3.06	6.09	3.57
Travel time	Tt	hours	0.206	0.178	0.118	0.300	0.086	0.133	0.148	0.130	0.024	0.045
2 Flow Length	L	feet	2,250	2,404	3,040	2,055	1,800	2,005	1,847	2,360	1,510	4,575
Slope	S	ft/ft	0.0094	0.0031	0.0065	0.0060	0.0091	0.0029	0.0089	0.0041	0.0067	0.0076
roughness	n	n/a	0.022	0.05	0.022	0.05	0.022	0.022	0.03	0.022	0.05	0.022
Open Channel												
Bottom Width	BW	feet	20	20	4	3	3	3	5	3	6	3
Side Slopes (H:1)	H	feet	3	4	1.5	3	3	1.5	3	1.5	2	1.5
Depth	d	feet	0.4	5	0.5	3	0.5	1.4	1	1	1.5	0.5
Cross-Sectional Area	X-A	feet^2	8.48	200.00	2.38	36.00	2.25	7.14	8.00	4.50	13.50	1.88
Flow Rate	Q	cfs	29.09	728.74	7.13	115.04	7.42	24.14	29.68	15.16	34.36	5.91
Velocity	V	ft/sec	3.43	3.64	3.00	3.20	3.30	3.38	3.71	3.37	2.54	3.15
Travel time	Tt	hours	0.182	0.183	0.281	0.179	0.152	0.165	0.138	0.195	0.165	0.403
3 Flow Length	L	feet	665	1,908	394	943	1,675	5,618	1,375	3,466	2,188	2,451
Slope	S	ft/ft	0.0133	0.0042	0.0047	0.0036	0.0023	0.0069	0.0065	0.0025	0.0024	0.0012
roughness	n	n/a	0.015	0.05	0.05	0.05	0.022	0.05	0.016	0.03	0.05	0.05
Open Channel												
Bottom Width	BW	feet	20	20	75	50	10	15	10	20	40	15
Side Slopes (H:1)	H	feet	5	4	4	6	4	3	5	5	4	3
Depth	d	feet	0.2	5	3	3	1.5	3	0.5	2	3	5
Cross-Sectional Area	X-A	feet^2	4.20	200.00	261.00	204.00	24.00	72.00	6.25	60.00	156.00	150.00
Flow Rate	Q	cfs	15.94	853.70	1015.25	647.12	81.51	293.91	26.07	194.12	405.22	342.06
Velocity	V	ft/sec	3.79	4.27	3.89	3.17	3.40	4.08	4.17	3.24	2.60	2.28
Travel time	Tt	hours	0.049	0.124	0.028	0.083	0.137	0.382	0.092	0.298	0.234	0.299
Total Travel Time	TC	hours	0.815	0.872	0.835	0.779	0.630	1.084	0.789	0.884	0.629	1.386
	TC	min.	48.9	52.3	50.1	46.7	37.8	65.1	47.3	53.0	37.7	83.2
Lag Time	TL	hours	0.4890	0.5234	0.5011	0.4675	0.3777	0.6507	0.4732	0.5305	0.3773	0.8315
	TL	min.	29.3	31.4	30.1	28.0	22.7	39.0	28.4	31.8	22.6	49.9

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	variable	units	Z_11	Z_12	Z_13	Z_14	Z_15	Z_16	Z_17	Z_18	Z_19	ZT1_01
Sheet Flow	variable	units										
Manning's roughness coef.	n	n/a	0.130	0.240	0.240	0.240	0.011	0.240	0.240	0.011	0.240	0.011
Flow Length	L	feet	250	100	75	150	100	100	100	100	150	100
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0309	0.0196	0.0324	0.0349	0.0063	0.0622	0.0489	0.0026	0.0099	0.0008
Travel time	Tt	hours	0.263	0.248	0.161	0.272	0.033	0.156	0.172	0.047	0.451	0.074
Shallow Concentrated Flow		min.	15.8	14.9	9.7	16.3	2.0	9.4	10.3	2.8	27.0	4.4
Flow Length	L	feet	800	1,000	475	1,150	1,000	1,000	1,000	1,000	1,000	310
Slope	s	ft/ft	0.022	0.014	0.004	0.041	0.002	0.045	0.034	0.004	0.002	0.009
Surface (1=paved or 2=unpaved)		n/a	2	1	1	2	1	1	1	1	1	2
Velocity	V	ft/sec	2.38	2.42	1.35	3.26	0.90	4.36	3.82	1.26	0.98	1.56
Travel time	Tt	hours	0.093	0.115	0.097	0.098	0.307	0.064	0.073	0.221	0.283	0.055
Manning's Equation		min.	5.6	6.9	5.8	5.9	18.4	3.8	4.4	13.2	17.0	3.3
1 Flow Length	L	feet	510	3,250	550	3,700	2,300	830	900	4,300	2,150	616
Slope	S	ft/ft	0.0120	0.0029	0.0029	0.0104	0.0025	0.0346	0.0218	0.0005	0.0013	0.0041
roughness	n	n/a	0.05	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.035
Open Channel												
Bottom Width	BW	feet	5	3	3	3	3	3	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	1.5	3	1.5	3	1.5	1.5
Depth	d	feet	1	1.5	1	0.5	2	0.2	0.3	4	2	3
Cross-Sectional Area	X-A	feet^2	6.50	7.88	4.50	1.88	12.00	0.72	1.04	68.00	12.00	22.50
Flow Rate	Q	cfs	17.60	27.64	12.61	6.92	45.42	2.77	4.15	170.27	32.13	84.68
Velocity	V	ft/sec	2.71	3.51	2.80	3.69	3.79	3.85	4.01	2.50	2.68	3.76
Travel time	Tt	hours	0.052	0.257	0.055	0.279	0.169	0.060	0.062	0.477	0.223	0.045
2 Flow Length	L	feet	2,170	1,650	350	3,275	5,640	980	5,000	3,650	4,150	861
Slope	S	ft/ft	0.0118	0.0041	0.0017	0.0058	0.0011	0.0119	0.0106	0.0006	0.0012	0.0005
roughness	n	n/a	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.035
Open Channel												
Bottom Width	BW	feet	3	3	3	3	5	3	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	3	1.5	1.5	3	1.5	3
Depth	d	feet	0.5	1.5	1.5	1	3	0.5	0.5	4	3	3
Cross-Sectional Area	X-A	feet^2	1.88	7.88	7.88	4.50	42.00	1.88	1.88	68.00	22.50	36.00
Flow Rate	Q	cfs	7.36	32.50	20.86	17.92	138.70	7.40	7.00	200.95	72.96	46.64
Velocity	V	ft/sec	3.93	4.13	2.65	3.98	3.30	3.95	3.73	2.96	3.24	1.30
Travel time	Tt	hours	0.154	0.111	0.037	0.228	0.474	0.069	0.372	0.343	0.355	0.185
3 Flow Length	L	feet	1,115	3,434	2,101	2,054	804	4,419	897	525	2,113	224
Slope	S	ft/ft	0.0029	0.0024	0.0037	0.0023	0.0062	0.0038	0.0185	0.0585	0.0087	0.0058
roughness	n	n/a	0.05	0.016	0.016	0.035	0.016	0.035	0.035	0.03	0.035	0.035
Open Channel												
Bottom Width	BW	feet	20	20	40	50	15	100	10	10	10	3
Side Slopes (H:1)	H	feet	2	1.5	0.5	1.5	1.5	3.5	3	3	3	3
Depth	d	feet	5	1	0.5	2.5	0.5	1.5	1	0.25	1	2
Cross-Sectional Area	X-A	feet^2	150.00	21.50	20.13	134.38	7.88	157.88	13.00	2.69	13.00	18.00
Flow Rate	Q	cfs	563.21	92.80	70.60	472.66	34.84	524.85	64.72	12.19	44.38	63.97
Velocity	V	ft/sec	3.75	4.32	3.51	3.52	4.42	3.32	4.98	4.54	3.41	3.55
Travel time	Tt	hours	0.082	0.221	0.166	0.162	0.050	0.369	0.050	0.032	0.172	0.018
Total Travel Time	TC	hours	0.645	0.952	0.516	1.039	1.034	0.718	0.729	1.120	1.485	0.377
	TC	min.	38.7	57.1	31.0	62.4	62.0	43.1	43.7	67.2	89.1	22.6
Lag Time	TL	hours	0.3870	0.5710	0.3096	0.6235	0.6203	0.4307	0.4374	0.6719	0.8908	0.2261
	TL	min.	23.2	34.3	18.6	37.4	37.2	25.8	26.2	40.3	53.4	13.6

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			ZT1_02	ZT1_03	ZT1_04	ZT1_05	ZT1_06	ZT2_01	ZT2_02	ZT2_03	ZT2A_01	ZT3_01
Sheet Flow	variable	units										
Manning's roughness coef.	n	n/a	0.240	0.011	0.240	0.011	0.011	0.240	0.240	0.011	0.130	0.240
Flow Length	L	feet	130	100	50	150	100	100	100	100	100	150
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0404	0.0142	0.0054	0.0035	0.0261	0.1160	0.0048	0.0195	0.0113	0.0201
Travel time	Tt	hours	0.229	0.024	0.239	0.058	0.019	0.122	0.435	0.021	0.189	0.339
Shallow Concentrated Flow		min.	13.7	1.4	14.3	3.5	1.1	7.3	26.1	1.3	11.4	20.3
Flow Length	L	feet	1,000	1,000	900	900	1,100	1,000	1,000	1,000	1,000	600
Slope	s	ft/ft	0.028	0.002	0.041	0.001	0.005	0.021	0.006	0.014	0.015	0.032
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1	1	1	1	2	1
Velocity	V	ft/sec	3.45	0.92	4.16	0.53	1.45	2.99	1.56	2.44	2.01	3.70
Travel time	Tt	hours	0.081	0.302	0.060	0.468	0.211	0.093	0.179	0.114	0.138	0.045
Manning's Equation		min.	4.8	18.1	3.6	28.1	12.7	5.6	10.7	6.8	8.3	2.7
1 Flow Length	L	feet	870	1,550	1,550	750	1,800	2,500	700	900	1,900	750
Slope	S	ft/ft	0.0157	0.0010	0.0203	0.0048	0.0029	0.0113	0.0039	0.0103	0.0106	0.0128
roughness	n	n/a	0.022	0.022	0.022	0.022	0.022	0.04	0.022	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	3	3	3	3	1	3	3	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	3	1.5	1.5	5	3	1.5	1.5	1.5
Depth	d	feet	0.25	3	0.3	0.5	1	0.5	0.5	0.25	0.25	0.4
Cross-Sectional Area	X-A	feet^2	0.84	22.50	1.17	1.88	4.50	1.75	2.25	0.84	0.84	1.44
Flow Rate	Q	cfs	2.58	67.54	4.34	0.39	0.68	3.01	4.84	2.09	2.12	5.21
Velocity	V	ft/sec	3.06	3.00	3.71	4.70	12.68	1.72	2.15	2.47	2.52	3.62
Travel time	Tt	hours	0.079	0.143	0.116	0.083	0.177	0.403	0.090	0.101	0.210	0.058
2 Flow Length	L	feet	2,200	1,720	2,600	2,127	1,180	1,730	990	1,650	4,775	1,180
Slope	S	ft/ft	0.0130	0.0021	0.0049	0.0009	0.0060	0.0061	0.0066	0.0039	0.0077	0.0143
roughness	n	n/a	0.022	0.035	0.022	0.05	0.022	0.015	0.022	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	10	3	15	3	1	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1	3	2	1.5	5	4	1.5	1.5	1.5
Depth	d	feet	0.5	3	1	3	0.5	0.5	0.5	0.5	0.5	0.3
Cross-Sectional Area	X-A	feet^2	1.88	39.00	6.00	63.00	1.88	1.75	2.50	2.88	1.88	1.04
Flow Rate	Q	cfs	7.73	125.11	21.18	2.22	0.39	5.89	6.84	6.82	5.95	3.35
Velocity	V	ft/sec	4.12	3.21	3.53	94.87	5.24	3.37	2.74	2.37	3.18	3.24
Travel time	Tt	hours	0.148	0.149	0.205	0.392	0.117	0.143	0.101	0.193	0.418	0.101
3 Flow Length	L	feet	1,918	1,720	2,742	1,303	2,047	1,184	1,299	2,351	1,343	3,048
Slope	S	ft/ft	0.0030	0.0013	0.0020	0.0003	0.0034	0.0077	0.0062	0.0034	0.0035	0.0035
roughness	n	n/a	0.022	0.016	0.016	0.016	0.016	0.022	0.015	0.022	0.016	0.022
Open Channel												
Bottom Width	BW	feet	3	3	20	5	28	15	15	5	15	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	1	1	2	1.5	1.5	1.5
Depth	d	feet	2	2	1	4	0.5	0.25	0.5	1	0.5	1.5
Cross-Sectional Area	X-A	feet^2	12.00	12.00	21.50	44.00	14.25	3.81	8.00	6.50	7.88	7.88
Flow Rate	Q	cfs	49.46	44.36	84.11	2.27	0.48	8.82	37.64	21.17	26.14	30.04
Velocity	V	ft/sec	4.12	3.70	3.91	119.73	47.88	2.31	4.70	3.26	3.32	3.81
Travel time	Tt	hours	0.129	0.129	0.195	0.133	0.169	0.142	0.077	0.201	0.112	0.222
Total Travel Time	TC	hours	0.666	0.747	0.814	1.135	0.694	0.903	0.881	0.630	1.067	0.765
	TC	min.	39.9	44.8	48.9	68.1	41.6	54.2	52.9	37.8	64.0	45.9
Lag Time	TL	hours	0.3995	0.4482	0.4886	0.6807	0.4163	0.5416	0.5287	0.3779	0.6401	0.4588
	TL	min.	24.0	26.9	29.3	40.8	25.0	32.5	31.7	22.7	38.4	27.5

ULTIMATE CONDITIONS
TR-55 Method of Computing the Time of Concentration

			Z_01	Z_02	Z_03	Z_04	Z_05	Z_06	Z_07	Z_08	Z_09	Z_10
Sheet Flow	variable	units										
Manning's roughness coef.	n	n/a	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.240	0.011	0.240
Flow Length	L	feet	100	100	100	75	100	100	100	75	150	100
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0127	0.0200	0.0101	0.0282	0.0512	0.0240	0.0107	0.0376	0.0041	0.0069
Travel time	Tt	hours	0.295	0.246	0.323	0.170	0.169	0.228	0.315	0.152	0.054	0.377
Shallow Concentrated Flow		min.	17.7	14.7	19.4	10.2	10.1	13.7	18.9	9.1	3.3	22.6
Flow Length	L	feet	1,000	1,000	820	485	1,000	1,000	680	1,000	1,000	1,000
Slope	s	ft/ft	0.026	0.015	0.017	0.033	0.024	0.030	0.015	0.015	0.008	0.015
Surface (1=paved or 2=unpaved)		n/a	1	2	1	1	1	1	2	1	1	1
Velocity	V	ft/sec	3.33	1.97	2.71	3.75	3.21	3.54	1.97	2.51	1.83	2.48
Travel time	Tt	hours	0.083	0.141	0.084	0.036	0.086	0.078	0.096	0.111	0.152	0.112
Manning's Equation		min.	5.0	8.5	5.0	2.2	5.2	4.7	5.7	6.7	9.1	6.7
1 Flow Length	L	feet	2,350	2,450	1,680	3,385	900	1,895	1,873	1,425	525	775
Slope	S	ft/ft	0.0177	0.0111	0.0069	0.0134	0.0140	0.0108	0.0080	0.0071	0.0186	0.0230
roughness	n	n/a	0.022	0.022	0.03	0.035	0.022	0.022	0.03	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	3	3	3	5	3	5	3	4	3
Side Slopes (H:1)	H	feet	2.5	1.5	1.5	3	3	3	3	1.5	3	1.5
Depth	d	feet	0.25	0.5	1.5	0.75	0.25	0.5	1	0.5	0.75	0.25
Cross-Sectional Area	X-A	feet^2	0.91	1.88	7.88	3.94	1.44	2.25	8.00	1.88	4.69	0.84
Flow Rate	Q	cfs	2.87	7.15	31.11	12.36	4.18	8.10	28.19	5.73	28.55	3.12
Velocity	V	ft/sec	3.17	3.81	3.95	3.14	2.91	3.60	3.52	3.06	6.09	3.70
Travel time	Tt	hours	0.206	0.178	0.118	0.300	0.086	0.146	0.148	0.130	0.024	0.058
2 Flow Length	L	feet	2,300	2,404	3,040	2,055	1,800	2,005	1,847	2,360	1,510	4,575
Slope	S	ft/ft	0.0105	0.0031	0.0065	0.0060	0.0091	0.0029	0.0089	0.0041	0.0067	0.0076
roughness	n	n/a	0.022	0.05	0.022	0.05	0.022	0.022	0.03	0.022	0.05	0.022
Open Channel												
Bottom Width	BW	feet	20	20	4	3	3	3	5	3	6	3
Side Slopes (H:1)	H	feet	3	4	1.5	3	3	1.5	3	1.5	2	1.5
Depth	d	feet	0.4	5	0.5	3	0.5	1.4	1	1	1.5	0.5
Cross-Sectional Area	X-A	feet^2	8.48	200.00	2.38	36.00	2.25	7.14	8.00	4.50	13.50	1.88
Flow Rate	Q	cfs	30.65	728.74	7.13	115.04	7.42	24.14	29.68	15.16	34.36	5.91
Velocity	V	ft/sec	3.61	3.64	3.00	3.20	3.30	3.38	3.71	3.37	2.54	3.15
Travel time	Tt	hours	0.177	0.183	0.281	0.179	0.152	0.165	0.138	0.195	0.165	0.403
3 Flow Length	L	feet	615	1,908	394	943	1,675	5,618	1,375	3,466	2,188	2,451
Slope	S	ft/ft	0.0097	0.0042	0.0047	0.0036	0.0023	0.0069	0.0065	0.0025	0.0024	0.0012
roughness	n	n/a	0.015	0.05	0.05	0.05	0.022	0.05	0.016	0.03	0.05	0.05
Open Channel												
Bottom Width	BW	feet	20	20	75	50	10	15	10	20	40	15
Side Slopes (H:1)	H	feet	5	4	4	6	4	3	5	5	4	3
Depth	d	feet	0.2	5	3	3	1.5	3	0.5	2	3	5
Cross-Sectional Area	X-A	feet^2	4.20	200.00	261.00	204.00	24.00	72.00	6.25	60.00	156.00	150.00
Flow Rate	Q	cfs	13.64	853.70	1015.25	647.12	81.51	293.91	26.07	194.12	405.22	342.06
Velocity	V	ft/sec	3.25	4.27	3.89	3.17	3.40	4.08	4.17	3.24	2.60	2.28
Travel time	Tt	hours	0.053	0.124	0.028	0.083	0.137	0.382	0.092	0.298	0.234	0.299
Total Travel Time	TC	hours	0.813	0.872	0.835	0.767	0.630	1.000	0.789	0.884	0.629	1.248
	TC	min.	48.8	52.3	50.1	46.0	37.8	60.0	47.3	53.0	37.7	74.9
Lag Time	TL	hours	0.4881	0.5234	0.5011	0.4602	0.3777	0.5999	0.4732	0.5305	0.3773	0.7489
	TL	min.	29.3	31.4	30.1	27.6	22.7	36.0	28.4	31.8	22.6	44.9

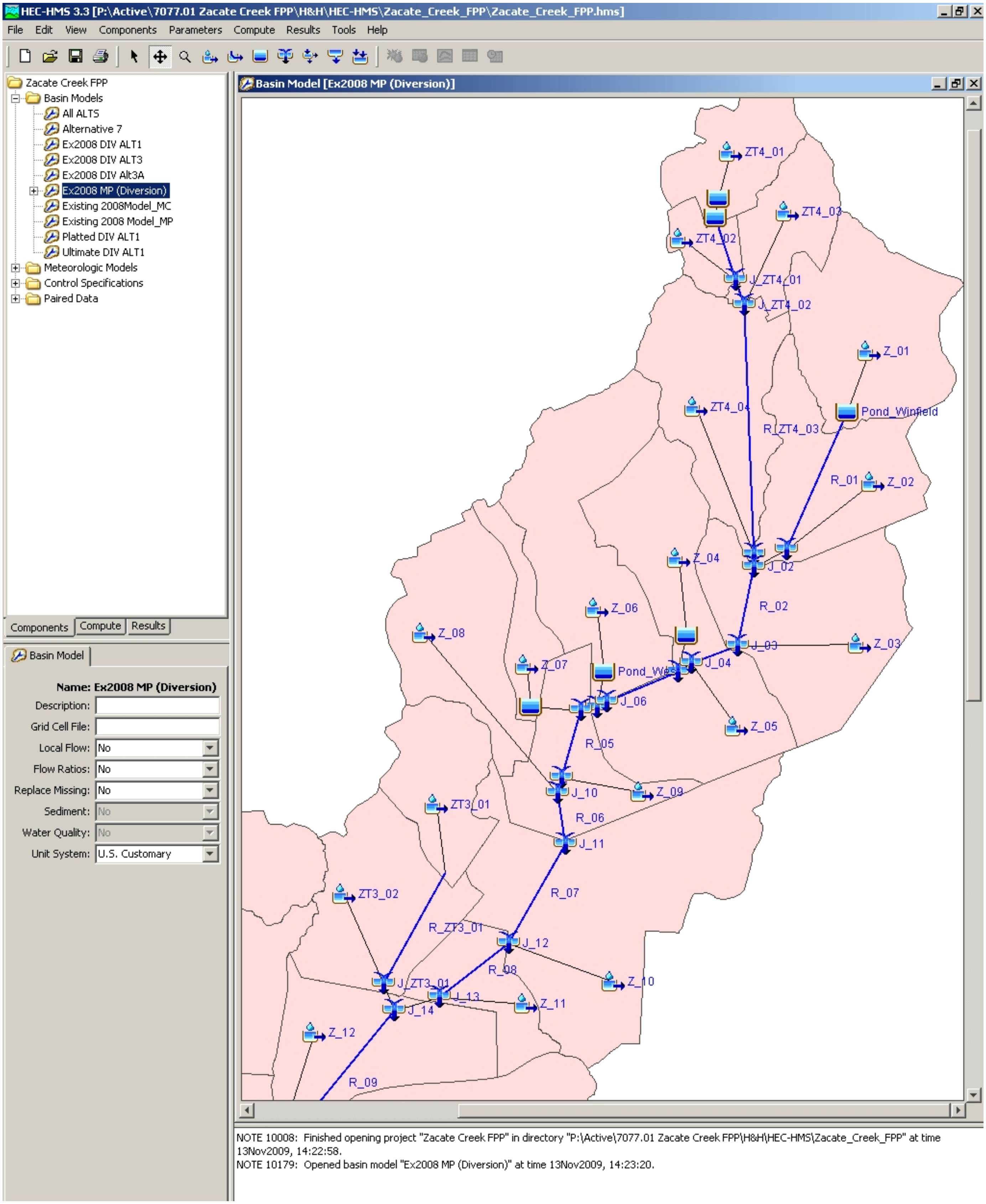
ULTIMATE CONDITIONS
TR-55 Method of Computing the Time of Concentration

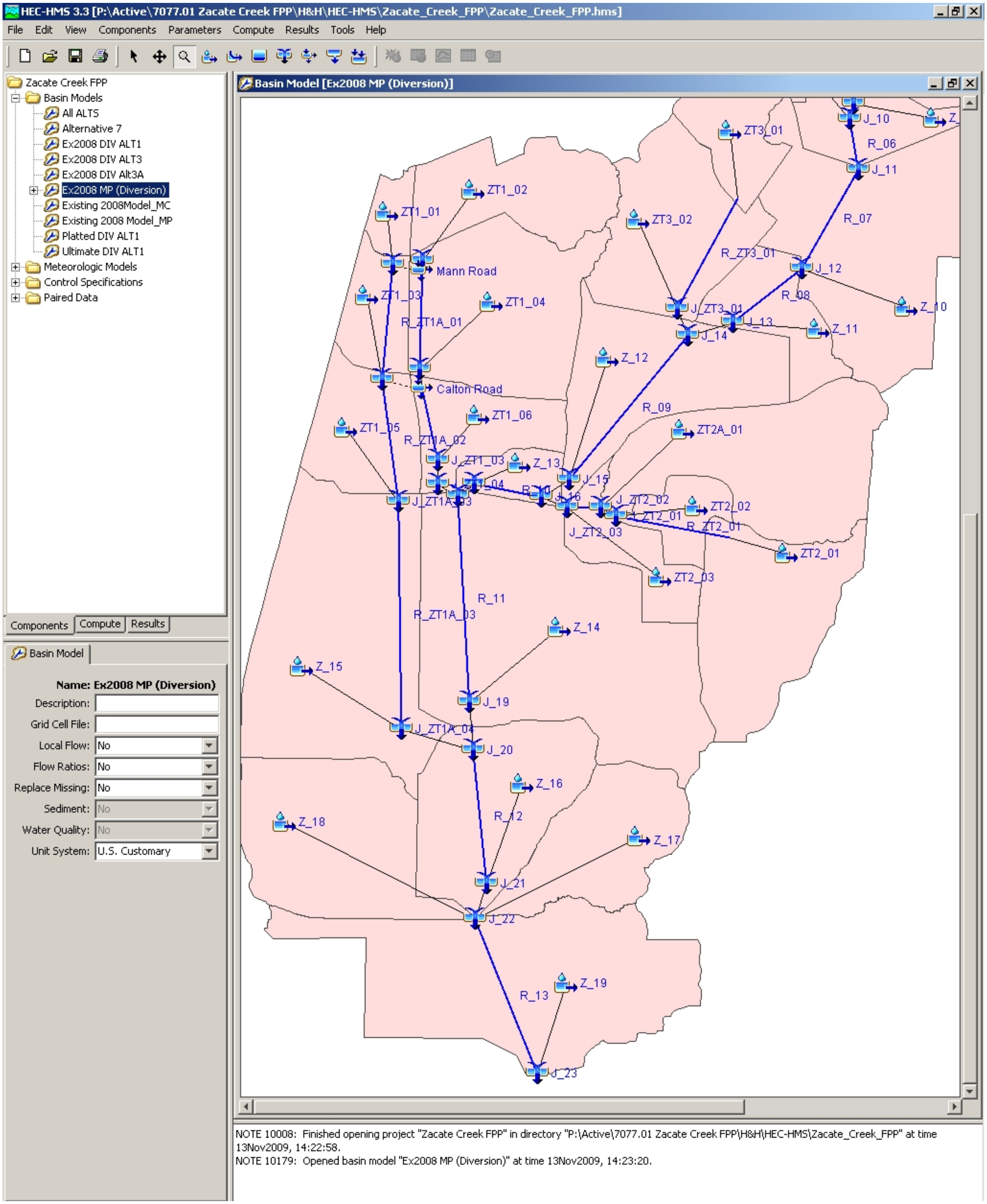
			Z_11	**Z_12**	**Z_13**	**Z_14**	**Z_15**	**Z_16**	**Z_17**	**Z_18**	**Z_19**	**ZT1_01**
Sheet Flow	variable	units										
Manning's roughness coef.	n	n/a	0.130	0.240	0.240	0.240	0.011	0.240	0.240	0.011	0.240	0.011
Flow Length	L	feet	250	100	75	150	100	100	100	100	150	100
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0309	0.0196	0.0324	0.0349	0.0063	0.0622	0.0489	0.0026	0.0099	0.0008
Travel time	Tt	hours	0.263	0.248	0.161	0.272	0.033	0.156	0.172	0.047	0.451	0.074
Shallow Concentrated Flow		min.	15.8	14.9	9.7	16.3	2.0	9.4	10.3	2.8	27.0	4.4
Flow Length	L	feet	800	1,000	475	1,150	1,000	1,000	1,000	1,000	1,000	310
Slope	s	ft/ft	0.022	0.014	0.004	0.041	0.002	0.045	0.034	0.004	0.002	0.009
Surface (1=paved or 2=unpaved)		n/a	2	1	1	2	1	1	1	1	1	2
Velocity	V	ft/sec	2.38	2.42	1.35	3.26	0.90	4.36	3.82	1.26	0.98	1.56
Travel time	Tt	hours	0.093	0.115	0.097	0.098	0.307	0.064	0.073	0.221	0.283	0.055
Manning's Equation		min.	5.6	6.9	5.8	5.9	18.4	3.8	4.4	13.2	17.0	3.3
1 Flow Length	L	feet	510	3,250	550	3,700	2,300	830	900	4,300	2,150	616
Slope	S	ft/ft	0.0120	0.0029	0.0029	0.0104	0.0025	0.0346	0.0218	0.0005	0.0013	0.0041
roughness	n	n/a	0.05	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.035
Open Channel												
Bottom Width	BW	feet	5	3	3	3	3	3	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	1.5	3	1.5	3	1.5	1.5
Depth	d	feet	1	1.5	1	0.5	2	0.2	0.3	4	2	3
Cross-Sectional Area	X-A	feet^2	6.50	7.88	4.50	1.88	12.00	0.72	1.04	68.00	12.00	22.50
Flow Rate	Q	cfs	17.60	27.64	12.61	6.92	45.42	2.77	4.15	170.27	32.13	84.68
Velocity	V	ft/sec	2.71	3.51	2.80	3.69	3.79	3.85	4.01	2.50	2.68	3.76
Travel time	Tt	hours	0.052	0.257	0.055	0.279	0.169	0.060	0.062	0.477	0.223	0.045
2 Flow Length	L	feet	2,170	1,650	350	3,275	5,640	980	5,000	3,650	4,150	861
Slope	S	ft/ft	0.0118	0.0041	0.0017	0.0058	0.0011	0.0119	0.0106	0.0006	0.0012	0.0005
roughness	n	n/a	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.035
Open Channel												
Bottom Width	BW	feet	3	3	3	3	5	3	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	3	1.5	1.5	3	1.5	3
Depth	d	feet	0.5	1.5	1.5	1	3	0.5	0.5	4	3	3
Cross-Sectional Area	X-A	feet^2	1.88	7.88	7.88	4.50	42.00	1.88	1.88	68.00	22.50	36.00
Flow Rate	Q	cfs	7.36	32.50	20.86	17.92	138.70	7.40	7.00	200.95	72.96	46.64
Velocity	V	ft/sec	3.93	4.13	2.65	3.98	3.30	3.95	3.73	2.96	3.24	1.30
Travel time	Tt	hours	0.154	0.111	0.037	0.228	0.474	0.069	0.372	0.343	0.355	0.185
3 Flow Length	L	feet	1,115	3,434	2,101	2,054	804	4,419	897	525	2,113	224
Slope	S	ft/ft	0.0029	0.0024	0.0037	0.0023	0.0062	0.0038	0.0185	0.0585	0.0087	0.0058
roughness	n	n/a	0.05	0.016	0.016	0.035	0.016	0.035	0.035	0.03	0.035	0.035
Open Channel												
Bottom Width	BW	feet	20	20	40	50	15	100	10	10	10	3
Side Slopes (H:1)	H	feet	2	1.5	0.5	1.5	1.5	3.5	3	3	3	3
Depth	d	feet	5	1	0.5	2.5	0.5	1.5	1	0.25	1	2
Cross-Sectional Area	X-A	feet^2	150.00	21.50	20.13	134.38	7.88	157.88	13.00	2.69	13.00	18.00
Flow Rate	Q	cfs	563.21	92.80	70.60	472.66	34.84	524.85	64.72	12.19	44.38	63.97
Velocity	V	ft/sec	3.75	4.32	3.51	3.52	4.42	3.32	4.98	4.54	3.41	3.55
Travel time	Tt	hours	0.082	0.221	0.166	0.162	0.050	0.369	0.050	0.032	0.172	0.018
Total Travel Time	TC	hours	0.645	0.952	0.516	1.039	1.034	0.718	0.729	1.120	1.485	0.377
	TC	min.	38.7	57.1	31.0	62.4	62.0	43.1	43.7	67.2	89.1	22.6
Lag Time	TL	hours	0.3870	0.5710	0.3096	0.6235	0.6203	0.4307	0.4374	0.6719	0.8908	0.2261
	TL	min.	23.2	34.3	18.6	37.4	37.2	25.8	26.2	40.3	53.4	13.6

ULTIMATE CONDITIONS
TR-55 Method of Computing the Time of Concentration

			ZT1_02	ZT1_03	ZT1_04	ZT1_05	ZT1_06	ZT2_01	ZT2_02	ZT2_03	ZT2A_01	ZT3_01
Sheet Flow	variable	units										
Manning's roughness coef.	n	n/a	0.240	0.011	0.240	0.011	0.011	0.240	0.240	0.011	0.130	0.240
Flow Length	L	feet	130	100	50	150	100	100	100	100	100	150
2-year, 24-hour rainfall	P2	inches	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Slope	s	ft/ft	0.0404	0.0142	0.0054	0.0035	0.0261	0.1160	0.0048	0.0195	0.0113	0.0201
Travel time	Tt	hours	0.229	0.024	0.239	0.058	0.019	0.122	0.435	0.021	0.189	0.339
Shallow Concentrated Flow		min.	13.7	1.4	14.3	3.5	1.1	7.3	26.1	1.3	11.4	20.3
Flow Length	L	feet	1,000	1,000	900	900	1,100	1,000	1,000	1,000	1,000	600
Slope	s	ft/ft	0.028	0.002	0.041	0.001	0.005	0.021	0.006	0.014	0.015	0.032
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1	1	1	1	2	1
Velocity	V	ft/sec	3.45	0.92	4.16	0.53	1.45	2.99	1.56	2.44	2.01	3.70
Travel time	Tt	hours	0.081	0.302	0.060	0.468	0.211	0.093	0.179	0.114	0.138	0.045
Manning's Equation		min.	4.8	18.1	3.6	28.1	12.7	5.6	10.7	6.8	8.3	2.7
1 Flow Length	L	feet	870	1,550	1,550	750	1,800	2,500	700	900	1,900	750
Slope	S	ft/ft	0.0157	0.0010	0.0203	0.0048	0.0029	0.0113	0.0039	0.0103	0.0106	0.0128
roughness	n	n/a	0.022	0.022	0.022	0.022	0.022	0.04	0.022	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	3	3	3	3	1	3	3	3	3
Side Slopes (H:1)	H	feet	1.5	1.5	3	1.5	1.5	5	3	1.5	1.5	1.5
Depth	d	feet	0.25	3	0.3	0.5	1	0.5	0.5	0.25	0.25	0.4
Cross-Sectional Area	X-A	feet^2	0.84	22.50	1.17	1.88	4.50	1.75	2.25	0.84	0.84	1.44
Flow Rate	Q	cfs	2.58	67.54	4.34	0.39	0.68	3.01	4.84	2.09	2.12	5.21
Velocity	V	ft/sec	3.06	3.00	3.71	4.70	12.68	1.72	2.15	2.47	2.52	3.62
Travel time	Tt	hours	0.079	0.143	0.116	0.083	0.177	0.403	0.090	0.101	0.210	0.058
2 Flow Length	L	feet	2,200	1,720	2,600	2,127	1,180	1,730	990	1,650	4,775	1,180
Slope	S	ft/ft	0.0130	0.0021	0.0049	0.0009	0.0060	0.0061	0.0066	0.0039	0.0077	0.0143
roughness	n	n/a	0.022	0.035	0.022	0.05	0.022	0.015	0.022	0.022	0.022	0.022
Open Channel												
Bottom Width	BW	feet	3	10	3	15	3	1	3	5	3	3
Side Slopes (H:1)	H	feet	1.5	1	3	2	1.5	5	4	1.5	1.5	1.5
Depth	d	feet	0.5	3	1	3	0.5	0.5	0.5	0.5	0.5	0.3
Cross-Sectional Area	X-A	feet^2	1.88	39.00	6.00	63.00	1.88	1.75	2.50	2.88	1.88	1.04
Flow Rate	Q	cfs	7.73	125.11	21.18	2.22	0.39	5.89	6.84	6.82	5.95	3.35
Velocity	V	ft/sec	4.12	3.21	3.53	94.87	5.24	3.37	2.74	2.37	3.18	3.24
Travel time	Tt	hours	0.148	0.149	0.205	0.392	0.117	0.143	0.101	0.193	0.418	0.101
3 Flow Length	L	feet	1,918	1,720	2,742	1,303	2,047	1,184	1,299	2,351	1,343	3,048
Slope	S	ft/ft	0.0030	0.0013	0.0020	0.0003	0.0034	0.0077	0.0062	0.0034	0.0035	0.0035
roughness	n	n/a	0.022	0.016	0.016	0.016	0.016	0.022	0.015	0.022	0.016	0.022
Open Channel												
Bottom Width	BW	feet	3	3	20	5	28	15	15	5	15	3
Side Slopes (H:1)	H	feet	1.5	1.5	1.5	1.5	1	1	2	1.5	1.5	1.5
Depth	d	feet	2	2	1	4	0.5	0.25	0.5	1	0.5	1.5
Cross-Sectional Area	X-A	feet^2	12.00	12.00	21.50	44.00	14.25	3.81	8.00	6.50	7.88	7.88
Flow Rate	Q	cfs	49.46	44.36	84.11	2.27	0.48	8.82	37.64	21.17	26.14	30.04
Velocity	V	ft/sec	4.12	3.70	3.91	119.73	47.88	2.31	4.70	3.26	3.32	3.81
Travel time	Tt	hours	0.129	0.129	0.195	0.133	0.169	0.142	0.077	0.201	0.112	0.222
Total Travel Time	TC	hours	0.666	0.747	0.814	1.135	0.694	0.903	0.881	0.630	1.067	0.765
	TC	min.	39.9	44.8	48.9	68.1	41.6	54.2	52.9	37.8	64.0	45.9
Lag Time	TL	hours	0.3995	0.4482	0.4886	0.6807	0.4163	0.5416	0.5287	0.3779	0.6401	0.4588
	TL	min.	24.0	26.9	29.3	40.8	25.0	32.5	31.7	22.7	38.4	27.5

APPENDIX E
HEC-HMS OUTPUT REPORT


HEC-HMS 3.3 [P:\Active\7077.01 Zacate Creek FPP\H&H\HEC-HMS\Zacate_Creek_FPP\Zacate_Creek_FPP.hms]
File Edit View Components Parameters Compute Results Tools Help
Zacate Creek FPP
Basin Models
All ALTS
Alternative 7
Ex2008 DIV ALT1
Ex2008 DIV ALT3
Ex2008 DIV Alt3A
Ex2008 MP (Diversion)
Existing 2008Model_MC
Existing 2008 Model_MP
Platted DIV ALT1
Ultimate DIV ALT1
Meteorologic Models
Control Specifications
Paired Data
Components Compute Results
Basin Model
Name: Ex2008 MP (Diversion)
Description:
Grid Cell File:
Local Flow: No
Flow Ratios: No
Replace Missing: No
Sediment: No
Water Quality: No
Unit System: U.S. Customary
Basin Model [Ex2008 MP (Diversion)]
ZT4_01
ZT4_03
ZT4_02
J_ZT4_01
J_ZT4_02
Z_01
ZT4_04
Pond_Winfield
R_ZT4_03
R_01
Z_02
Z_04
J_02
R_02
Z_06
Z_08
J_03
Z_03
Z_07
Pond_We
J_04
J_06
Z_05
R_05
J_10
Z_09
ZT3_01
R_06
J_11
ZT3_02
R_07
R_ZT3_01
J_12
R_08
Z_10
J_ZT3_01
J_13
J_14
Z_11
Z_12
R_09
NOTE 10008: Finished opening project "Zacate Creek FPP" in directory "P:\Active\7077.01 Zacate Creek FPP\H&H\HEC-HMS\Zacate_Creek_FPP" at time 13Nov2009, 14:22:58.
NOTE 10179: Opened basin model "Ex2008 MP (Diversion)" at time 13Nov2009, 14:23:20.


HEC-HMS 3.3 [P:\Active\7077.01 Zacate Creek FPP\H&H\HEC-HMS\Zacate_Creek_FPP\Zacate_Creek_FPP.hms]
File Edit View Components Parameters Compute Results Tools Help
Zacate Creek FPP
Basin Models
All ALTS
Alternative 7
Ex2008 DIV ALT1
Ex2008 DIV ALT3
Ex2008 DIV Alt3A
Ex2008 MP (Diversion)
Existing 2008Model_MC
Existing 2008 Model_MP
Platted DIV ALT1
Ultimate DIV ALT1
Meteorologic Models
Control Specifications
Paired Data
Components Compute Results
Basin Model
Name: Ex2008 MP (Diversion)
Description:
Grid Cell File:
Local Flow: No
Flow Ratios: No
Replace Missing: No
Sediment: No
Water Quality: No
Unit System: U.S. Customary
Basin Model [Ex2008 MP (Diversion)]
NOTE 10008: Finished opening project "Zacate Creek FPP" in directory "P:\Active\7077.01 Zacate Creek FPP\H&H\HEC-HMS\Zacate_Creek_FPP" at time 13Nov2009, 14:22:58.
NOTE 10179: Opened basin model "Ex2008 MP (Diversion)" at time 13Nov2009, 14:23:20.

NODE	DA (sq mi)	20% Event	10% Event	4% Event	2% Event	1% Event
Calton Road	1.026	994	996	989	1074	1157
J_01	1.088	619	839	1036	1218	1520
J_02	2.324	1522	2046	2539	2984	3524
J_03	2.99	1980	2696	3389	3992	4730
J_04	3.423	2109	2899	3668	4357	5205
J_05	3.82	2237	3109	3948	4856	5881
J_06	3.82	2109	2840	3554	4336	5319
J_07	4.507	2409	3221	4158	5134	6260
J_08	4.66	2525	3371	4335	5332	6493
J_09	5.018	2490	3274	4155	5038	6157
J_10	5.525	2754	3583	4515	5469	6657
J_11	5.525	2607	3441	4392	5347	6522
J_12	6.619	2508	3280	4080	4782	5680
J_13	6.858	2522	3292	4065	4634	5445
J_14	7.682	2675	3470	4280	4839	5679
J_15	8.246	2581	3298	4040	4750	5542
J_16	9.823	3874	4673	5302	5835	6565
J_17	9.934	3459	4168	4906	5549	6288
J_18	11.213	4537	5327	6096	6771	7580
J_19	12.517	5434	6470	7481	8271	9285
J_20	14.122	6633	8295	10097	11523	13336
J_21	14.693	6883	8472	10172	11372	13015
J_22	15.746	7714	9436	11072	12310	14082
J_23	16.78	8564	10526	12228	13683	15488
J_ZT1_01	0.392	483	620	749	869	1015
J_ZT1_02	1.026	1082	1249	1492	1753	2016
J_ZT1_03	1.279	1172	1279	1374	1494	1644
J_ZT1_04	1.279	1172	1279	1374	1494	1644
J_ZT1A_01	0.076	250	438	544	597	703
J_ZT1A_02	0.252	475	927	1355	1645	1994
J_ZT1A_03	0.557	753	1265	1743	2117	2547
J_ZT1A_04	1.605	1280	1958	2673	3300	4051
J_ZT2_01	0.702	736	942	1137	1302	1489
J_ZT2_02	1.372	1374	1760	2127	2451	2833
J_ZT2_03	1.577	1585	2028	2386	2609	2953
J_ZT3_01	0.824	832	1077	1310	1526	1782
J_ZT4_01	0.407	210	277	339	401	473
J_ZT4_02	0.667	444	598	744	880	1049
J_ZT4_03	1.236	904	1219	1503	1766	2081
Mann Road	0.392	400	396	393	485	536
Pond_Basin7	0.153	147	205	262	310	362
Pond_Bougainvilla 1	0.294	177	249	322	391	480
Pond_Bougainvilla 2	0.294	156	220	281	328	384
Pond_East	0.397	151	233	299	499	688
Pond_West	0.687	317	398	623	798	941
Pond_Winfield	0.594	305	392	490	586	974
R_01	0.594	294	382	478	573	837
R_02	2.324	1454	1988	2502	2946	3491
R_03	2.99	1974	2673	3350	3949	4686
R_04	3.82	2109	2840	3554	4336	5319
R_05	4.66	2383	3129	3967	4811	5881
R_06	5.525	2607	3441	4392	5347	6522

NODE	DA (sq mi)	20% Event	10% Event	4% Event	2% Event	1% Event
R_07	5.525	2276	2987	3714	4352	5173
R_08	6.619	2485	3246	4013	4579	5383
R_09	7.682	2507	3210	3936	4636	5414
R_10	9.823	3417	4111	4833	5476	6214
R_11	11.213	4493	5271	6022	6694	7492
R_12	14.122	6611	8203	9859	11054	12643
R_13	15.746	7676	9404	11040	12286	14036
R_ZT1_01	0.392	378	364	382	472	527
R_ZT1_02	1.026	945	958	958	1007	1096
R_ZT1A_01	0.076	208	399	505	561	668
R_ZT1A_02	0.252	443	857	1259	1550	1892
R_ZT1A_03	0.557	702	1143	1580	1942	2351
R_ZT2_01	0.562	581	745	901	1030	1180
R_ZT2_02	1.372	1370	1756	2061	2313	2635
R_ZT3_01	0.319	320	412	502	583	673
R_ZT4_01	0.294	153	216	278	326	381
R_ZT4_02	0.407	209	276	339	401	473
R_ZT4_03	0.667	396	547	681	805	955
Z_01	0.594	422	596	765	923	1118
Z_02	0.494	482	632	774	906	1068
Z_03	0.666	540	718	888	1046	1240
Z_04	0.397	361	480	595	703	836
Z_05	0.433	139	237	340	439	564
Z_06	0.687	591	770	941	1101	1298
Z_07	0.153	189	239	285	328	381
Z_08	0.507	559	715	861	996	1161
Z_09	0.358	188	275	361	443	546
Z_10	1.094	576	807	1033	1249	1515
Z_11	0.239	320	406	487	562	652
Z_12	0.564	594	757	911	1054	1228
Z_13	0.111	162	205	245	283	329
Z_14	1.304	1296	1662	2006	2326	2715
Z_15	1.048	1163	1462	1743	2002	2315
Z_16	0.571	695	888	1071	1240	1445
Z_17	0.417	559	707	844	970	1123
Z_18	0.636	661	833	995	1144	1325
Z_19	1.034	925	1166	1392	1600	1853
ZT1_01	0.076	145	180	212	242	277
ZT1_02	0.392	483	620	749	869	1015
ZT1_03	0.176	252	313	369	421	484
ZT1_04	0.634	728	925	1110	1281	1489
ZT1_05	0.305	334	417	496	567	654
ZT1_06	0.253	346	434	517	593	685
ZT2_01	0.562	591	757	915	1062	1241
ZT2_02	0.14	159	202	242	279	324
ZT2_03	0.205	278	351	421	485	562
ZT2A_01	0.67	638	819	990	1149	1343
ZT3_01	0.319	368	471	568	659	769
ZT3_02	0.505	563	725	879	1021	1195
ZT4_01	0.294	262	368	469	563	679
ZT4_02	0.113	163	208	249	288	335
ZT4_03	0.26	236	324	408	486	582
ZT4_04	0.569	531	694	850	996	1176

APPENDIX F
HEC-RAS OUTPUT REPORT

```
                    HEC-RAS Version 4.0.0 March 2008
                      U.S. Army Corps of Engineers
                     Hydrologic Engineering Center
                           609 Second Street
                           Davis, California

         X     X  XXXXXX    XXXX        XXXX       XX      XXXX
         X     X  X        X    X       X   X     X  X    X
         X     X  X        X            X   X    X    X   X
         XXXXXXX  XXXX     X       XXX  XXXX     XXXXXX    XXXX
         X     X  X        X            X  X     X    X        X
         X     X  X        X    X       X   X    X    X        X
         X     X  XXXXXX    XXXX        X    X   X    X   XXXXX
```

```
PROJECT DATA
Project Title: Zacate_Creek_FPP_7077.01
Project File : Zacate_Creek_FPP.prj
Run Date and Time: 9/1/2009 4:01:16 PM

Project in English units

Project Description:



PLAN DATA

Plan Title: EXISTING W/DIVERSIONS
Plan File : p:\Active\7077.01 Zacate Creek FPP\Report\Digital Data\HEC-RAS\Zacate_Creek_FPP.p08

           Geometry Title: EXISTING CONDITIONS (w/diversions)
           Geometry File : p:\Active\7077.01 Zacate Creek FPP\Report\Digital Data\HEC-RAS\Zacate_Creek_FPP.g01

           Flow Title    : EXISTING CONDITIONS (W/DIV)
           Flow File     : p:\Active\7077.01 Zacate Creek FPP\Report\Digital Data\HEC-RAS\Zacate_Creek_FPP.f10

Plan Description:
Trib 2A Optimization on.


Plan Summary Information:
Number of:  Cross Sections =  342    Multiple Openings  =    0
            Culverts       =   29    Inline Structures  =    0
            Bridges        =   21    Lateral Structures =    4
```

Computational Information
    Water surface calculation tolerance = 0.01
    Critical depth calculation tolerance = 0.01
    Maximum number of iterations   = 20
    Maximum difference tolerance   = 0.3
    Flow tolerance factor   = 0.001

Computation Options
    Critical depth computed only where necessary
    Conveyance Calculation Method: At breaks in n values only
    Friction Slope Method: Average Conveyance
    Computational Flow Regime: Mixed Flow

FLOW DATA

Flow Title: EXISTING CONDITIONS (W/DIV)
Flow File : p:\Active\7077.01 Zacate Creek FPP\Report\Digital Data\HEC-RAS\Zacate_Creek_FPP.f10

Flow Data (cfs)

River	Reach	RS	Ex2008 20%	Ex2008 10%	Ex2008 4%	Ex2008 2%	Ex2008 1%
Zacate Creek	1	47546	305	392	490	586	974
Zacate Creek	1	46399	619	839	1036	1218	1520
Zacate Creek	2	42667	1522	2046	2539	2984	3524
Zacate Creek	2	41963	1980	2696	3389	3992	4730
Zacate Creek	2	39274	2109	2899	3668	4357	5205
Zacate Creek	2	38079	2237	3109	3948	4856	5881
Zacate Creek	2	35888	2409	3221	4158	5134	6260
Zacate Creek	2	34754	2525	3371	4335	5332	6493
Zacate Creek	2	33640	2754	3583	4515	5469	6657
Zacate Creek	2	32621	2607	3441	4392	5347	6522
Zacate Creek	2	28653	2508	3280	4080	4782	5680
Zacate Creek	2	26728	2522	3292	4065	4634	5445
Zacate Creek	3	24672	2675	3470	4280	4839	5679
Zacate Creek	3	22815	2581	3298	4040	4750	5542
Zacate Creek	4	18534	3874	4673	5302	5835	6565
Zacate Creek	5	15731	4537	5327	6096	6771	7580
Zacate Creek	5	14214	5434	6470	7481	8271	9285
Zacate Creek	6	9593	6633	8295	10097	11523	13336
Zacate Creek	6	4202	7714	9436	11072	12310	14082
Zacate Creek	6	3316	8564	10526	12228	13683	15488
ZC Trib 1	1	8345	121	155	187	217	254
ZC Trib 1	1	7977	241	310	375	435	507
ZC Trib 1	1	7197	483	620	749	869	1015
ZC Trib 1	1	5519	1082	1249	1492	1753	2016
ZC Trib 1	1	2678	1172	1279	1374	1494	1644
ZC Trib 1	1	769	1172	1279	1374	1494	1644

ZC Trib 1A	1	13279	250	438	544	597	703
ZC Trib 1A	1	11690	475	927	1355	1645	1994
ZC Trib 1A	1	8848	753	1265	1743	2117	2547
ZC Trib 1A	1	4202	1280	1958	2673	3300	4051
ZC Trib 2	1	3701	591	757	915	1062	1241
ZC Trib 2	1	3186	736	942	1137	1302	1489
ZC Trib 2	2	1092	1374	1760	2127	2451	2833
ZC Trib 2	2	792	1585	2028	2386	2609	2953
ZC Trib 2A	1	2715	319	409	495	575	672
ZC Trib 2A	1	1738	638	819	990	1149	1343
ZC Trib 3	1	4577	368	471	568	659	769
ZC Trib 3	1	3004	416	538	655	763	891
ZC Trib 3	1	2582	624	807	982	1144	1337
ZC Trib 3	1	385	832	1077	1310	1526	1782
ZC Trib 4	1	9169	156	220	281	328	384
ZC Trib 4	1	8695	210	277	339	401	473
ZC Trib 4	1	7346	444	598	744	880	1049
ZC Trib 4	1	5663	904	1219	1503	1766	2081

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Zacate Creek	1	Ex2008 20%	Critical	
Zacate Creek	1	Ex2008 10%	Critical	
Zacate Creek	1	Ex2008 4%	Critical	
Zacate Creek	1	Ex2008 2%	Critical	
Zacate Creek	1	Ex2008 1%	Critical	
Zacate Creek	6	Ex2008 20%		Normal S = 0.0009
Zacate Creek	6	Ex2008 10%		Normal S = 0.0009
Zacate Creek	6	Ex2008 4%		Normal S = 0.0009
Zacate Creek	6	Ex2008 2%		Normal S = 0.0009
Zacate Creek	6	Ex2008 1%		Normal S = 0.0009
ZC Trib 1	1	Ex2008 20%	Critical	
ZC Trib 1	1	Ex2008 10%	Critical	
ZC Trib 1	1	Ex2008 4%	Critical	
ZC Trib 1	1	Ex2008 2%	Critical	
ZC Trib 1	1	Ex2008 1%	Critical	
ZC Trib 1A	1	Ex2008 20%	Critical	
ZC Trib 1A	1	Ex2008 10%	Critical	
ZC Trib 1A	1	Ex2008 4%	Critical	
ZC Trib 1A	1	Ex2008 2%	Critical	
ZC Trib 1A	1	Ex2008 1%	Critical	
ZC Trib 2	1	Ex2008 20%	Critical	
ZC Trib 2	1	Ex2008 10%	Critical	
ZC Trib 2	1	Ex2008 4%	Critical	
ZC Trib 2	1	Ex2008 2%	Critical	
ZC Trib 2	1	Ex2008 1%	Critical	
ZC Trib 2A	1	Ex2008 20%	Critical	

ZC Trib 2A	1	Ex2008 10%	Critical
ZC Trib 2A	1	Ex2008 4%	Critical
ZC Trib 2A	1	Ex2008 2%	Critical
ZC Trib 2A	1	Ex2008 1%	Critical
ZC Trib 3	1	Ex2008 20%	Critical
ZC Trib 3	1	Ex2008 10%	Critical
ZC Trib 3	1	Ex2008 4%	Critical
ZC Trib 3	1	Ex2008 2%	Critical
ZC Trib 3	1	Ex2008 1%	Critical
ZC Trib 4	1	Ex2008 20%	Critical
ZC Trib 4	1	Ex2008 10%	Critical
ZC Trib 4	1	Ex2008 4%	Critical
ZC Trib 4	1	Ex2008 2%	Critical
ZC Trib 4	1	Ex2008 1%	Critical

Profile Output Table - Standard Table 1

River	Reach	River Sta		Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
ZC Trib 4	1	9169		Ex2008 1%	384.00	562.15	567.47	565.31	567.60	0.000511	2.86	134.26	108.38	0.26
ZC Trib 4	1	9000	Backwoods St		Culvert									
ZC Trib 4	1	8983		Ex2008 1%	384.00	561.65	565.31	564.66	566.32	0.001178	8.07	47.56	26.12	0.74
ZC Trib 4	1	8951		Ex2008 1%	384.00	561.20	565.68	563.68	565.91	0.000330	3.83	100.18	41.20	0.37
ZC Trib 4	1	8923		Ex2008 1%	384.00	560.80	565.37	563.59	565.87	0.000447	5.70	67.40	102.97	0.47
ZC Trib 4	1	8900	Stonefield Dr		Culvert									
ZC Trib 4	1	8852		Ex2008 1%	384.00	560.00	564.85	562.75	565.29	0.000351	5.29	72.64	107.51	0.42
ZC Trib 4	1	8811		Ex2008 1%	384.00	559.60	565.00	562.04	565.12	0.000138	2.78	145.53	147.27	0.25
ZC Trib 4	1	8770		Ex2008 1%	384.00	559.30	565.02	562.51	565.11	0.000106	2.47	155.69	200.24	0.22
ZC Trib 4	1	8700	Utility Crossing		Culvert									
ZC Trib 4	1	8695		Ex2008 1%	473.00	558.60	561.36	561.36	562.44	0.002697	8.36	56.60	26.03	1.00
ZC Trib 4	1	8630		Ex2008 1%	473.00	558.00	560.30	560.75	562.01	0.005197	10.50	45.06	24.20	1.36
ZC Trib 4	1	8604		Ex2008 1%	473.00	557.80	561.40	560.04	561.83	0.000511	5.26	89.93	32.71	0.49
ZC Trib 4	1	8600	Denmark Ln.		Culvert									
ZC Trib 4	1	8553		Ex2008 1%	473.00	557.60	560.83	559.89	561.38	0.000777	5.95	79.49	31.55	0.59
ZC Trib 4	1	8527		Ex2008 1%	473.00	557.40	560.36	560.16	561.25	0.002093	7.55	62.68	27.91	0.89
ZC Trib 4	1	8337		Ex2008 1%	473.00	556.70	560.35	559.46	560.88	0.000980	5.87	80.62	29.23	0.62
ZC Trib 4	1	8313		Ex2008 1%	473.00	556.60	560.51	558.67	560.79	0.000310	4.22	112.01	35.96	0.38
ZC Trib 4	1	8300	Yukon Ln.		Culvert									
ZC Trib 4	1	8261		Ex2008 1%	473.00	556.40	560.27	558.63	560.58	0.000374	4.47	105.73	35.88	0.41
ZC Trib 4	1	8235		Ex2008 1%	473.00	556.60	559.48	559.29	560.38	0.002133	7.64	61.94	27.39	0.89
ZC Trib 4	1	8146		Ex2008 1%	473.00	556.10	559.54	558.87	560.15	0.001212	6.30	75.06	28.78	0.69
ZC Trib 4	1	8083		Ex2008 1%	473.00	556.27	558.95	558.95	559.92	0.024674	7.90	59.87	79.71	1.00
ZC Trib 4	1	7827		Ex2008 1%	473.00	554.66	559.12	557.52	559.13	0.000226	1.05	648.02	523.62	0.10
ZC Trib 4	1	7346		Ex2008 1%	1049.00	553.42	557.73	557.73	558.32	0.024735	6.41	190.15	423.77	0.96
ZC Trib 4	1	7048		Ex2008 1%	1049.00	551.79	555.58	555.58	556.21	0.024516	6.64	169.09	374.87	0.97
ZC Trib 4	1	6615		Ex2008 1%	1049.00	547.21	551.25	550.92	551.55	0.011542	4.43	238.51	461.73	0.67
ZC Trib 4	1	6221		Ex2008 1%	1049.00	545.37	547.74	547.35	547.92	0.007360	3.50	331.66	700.81	0.53
ZC Trib 4	1	5663		Ex2008 1%	2081.00	536.38	542.96	542.73	543.80	0.007222	7.83	347.36	212.57	0.63
ZC Trib 4	1	5341		Ex2008 1%	2081.00	531.20	538.04	538.04	540.04	0.020220	11.35	183.40	45.84	1.00
ZC Trib 4	1	4907		Ex2008 1%	2081.00	527.20	531.70	532.90	535.86	0.005177	16.37	127.15	32.89	1.47
ZC Trib 4	1	4438		Ex2008 1%	2081.00	525.10	532.72	530.77	533.86	0.000811	8.56	243.01	93.15	0.61
ZC Trib 4	1	4385		Ex2008 1%	2081.00	524.50	532.74	529.75	533.79	0.000414	8.19	254.01	171.69	0.50
ZC Trib 4	1	4300	Country Club		Culvert									
ZC Trib 4	1	4235		Ex2008 1%	2081.00	523.60	528.43	528.78	531.43	0.002445	13.91	149.60	37.16	1.12
ZC Trib 4	1	4113		Ex2008 1%	2081.00	523.00	528.08	528.66	531.17	0.003386	14.11	147.49	34.55	1.20
ZC Trib 4	1	3771		Ex2008 1%	2081.00	520.80	525.35	526.61	529.62	0.005278	16.58	125.50	32.11	1.48

ZC Trib 4	1	3456		Ex2008 1%	2081.00	518.50	522.86	524.36	527.75	0.006327	17.75	117.27	30.80	1.60
ZC Trib 4	1	3263		Ex2008 1%	2081.00	517.60	521.96	523.29	526.47	0.005805	17.04	122.14	32.44	1.55
ZC Trib 4	1	3219		Ex2008 1%	2081.00	516.80	521.07	522.61	526.13	0.006685	18.06	115.20	30.19	1.63
ZC Trib 4	1	3079		Ex2008 1%	2081.00	515.60	518.16	519.82	523.93	0.063420	19.28	107.91	49.26	2.30
ZC Trib 4	1	3041		Ex2008 1%	2081.00	515.60	521.76	519.85	522.45	0.002808	6.64	313.29	64.86	0.53
ZC Trib 4	1	2811		Ex2008 1%	2081.00	514.80	521.20		521.82	0.002496	6.33	328.60	66.88	0.50
ZC Trib 4	1	2592		Ex2008 1%	2081.00	514.20	520.72	518.46	521.28	0.002250	6.02	345.83	70.33	0.48
ZC Trib 4	1	2547		Ex2008 1%	2081.00	514.00	520.86	517.21	521.19	0.000175	4.61	451.07	74.64	0.31
ZC Trib 4	1	2500	Links Dr.		Culvert									
ZC Trib 4	1	2451		Ex2008 1%	2081.00	513.70	519.59	517.03	520.06	0.000312	5.53	376.38	73.04	0.41
ZC Trib 4	1	2412		Ex2008 1%	2081.00	513.60	519.58	516.98	520.02	0.001642	5.33	390.49	71.37	0.40
ZC Trib 4	1	2164		Ex2008 1%	2081.00	513.10	518.43	517.35	519.36	0.004098	7.75	268.68	65.51	0.67
ZC Trib 4	1	1944		Ex2008 1%	2081.00	511.70	517.89		518.54	0.002784	6.45	322.82	69.78	0.53
ZC Trib 4	1	1898		Ex2008 1%	2081.00	511.60	518.04	514.81	518.44	0.000218	5.07	410.80	72.96	0.35
ZC Trib 4	1	1850	Burke Dr.		Culvert									
ZC Trib 4	1	1801		Ex2008 1%	2081.00	511.40	516.55	514.61	517.18	0.000459	6.33	328.80	77.07	0.49
ZC Trib 4	1	1749		Ex2008 1%	2081.00	511.40	515.34	515.28	516.85	0.008147	9.87	210.87	67.17	0.98
ZC Trib 4	1	1458		Ex2008 1%	2081.00	509.00	514.39		515.28	0.003099	7.54	276.12	67.33	0.66
ZC Trib 4	1	1194		Ex2008 1%	2081.00	508.00	512.04	512.04	513.65	0.015235	10.18	204.49	64.02	1.00
ZC Trib 4	1	867		Ex2008 1%	2081.00	505.00	509.21	508.83	510.42	0.005853	8.83	235.76	70.62	0.85
ZC Trib 4	1	504		Ex2008 1%	2081.00	503.00	506.83	506.78	508.31	0.005618	9.74	213.65	69.13	0.98
ZC Trib 4	1	144		Ex2008 1%	2081.00	501.00	507.49		507.58	0.000332	2.52	1072.16	725.30	0.20
ZC Trib 3	1	4577		Ex2008 1%	769.00	466.09	471.61	470.89	471.96	0.003202	5.50	251.29	118.55	0.51
ZC Trib 3	1	4466		Ex2008 1%	769.00	465.11	470.72	470.14	471.49	0.004735	7.47	156.77	79.04	0.62
ZC Trib 3	1	4328		Ex2008 1%	769.00	463.76	470.08	469.89	470.79	0.005115	7.42	191.54	133.30	0.64
ZC Trib 3	1	4177		Ex2008 1%	769.00	463.07	470.21	467.85	470.36	0.000842	3.69	373.62	127.70	0.28
ZC Trib 3	1	3976		Ex2008 1%	769.00	463.41	468.16	468.16	469.79	0.012479	10.34	83.62	51.27	0.95
ZC Trib 3	1	3718		Ex2008 1%	769.00	461.20	467.49	466.71	467.82	0.002512	5.39	299.45	176.12	0.45
ZC Trib 3	1	3503		Ex2008 1%	769.00	460.12	466.79	466.17	467.21	0.003174	6.39	267.38	130.35	0.49
ZC Trib 3	1	3286		Ex2008 1%	769.00	460.00	466.46	465.63	466.61	0.001921	4.30	439.85	254.46	0.37
ZC Trib 3	1	3004		Ex2008 1%	891.00	459.59	465.99	464.13	466.15	0.001435	4.27	480.85	270.26	0.35
ZC Trib 3	1	2727		Ex2008 1%	891.00	459.16	465.73	464.05	465.81	0.000915	3.37	581.06	223.01	0.28
ZC Trib 3	1	2582		Ex2008 1%	1337.00	459.11	464.46	464.46	465.54	0.001591	9.25	386.31	217.18	0.85
ZC Trib 3	1	2511		Ex2008 1%	1337.00	454.57	461.89	459.02	462.17	0.000269	4.23	322.59	107.79	0.36
ZC Trib 3	1	2417		Ex2008 1%	1337.00	453.43	461.67	459.92	462.12	0.000418	5.44	307.94	187.99	0.45
ZC Trib 3	1	2350	Calle del Norte		Culvert									
ZC Trib 3	1	2246		Ex2008 1%	1337.00	452.30	458.52	458.52	461.30	0.001966	13.37	99.99	39.18	1.00
ZC Trib 3	1	2019		Ex2008 1%	1337.00	450.62	454.59	456.21	459.73	0.010410	18.19	73.49	28.81	2.01
ZC Trib 3	1	1883		Ex2008 1%	1337.00	450.22	454.73	455.81	458.18	0.005782	14.90	89.71	30.05	1.52
ZC Trib 3	1	1758		Ex2008 1%	1337.00	449.98	456.86	455.40	457.42	0.000580	6.22	357.39	226.81	0.52
ZC Trib 3	1	1697		Ex2008 1%	1337.00	449.27	456.75	455.36	457.38	0.000556	6.43	287.74	259.47	0.51
ZC Trib 3	1	1650	Gale St.		Culvert									
ZC Trib 3	1	1618		Ex2008 1%	1337.00	447.80	454.08	454.08	456.87	0.001911	13.40	99.81	48.28	1.00
ZC Trib 3	1	1499		Ex2008 1%	1337.00	447.80	450.83	452.34	455.76	0.011758	17.81	75.05	34.23	2.12
ZC Trib 3	1	1090		Ex2008 1%	1337.00	446.35	452.93	452.16	454.12	0.001489	8.75	152.85	70.20	0.80
ZC Trib 3	1	739		Ex2008 1%	1337.00	445.33	453.45	450.54	453.67	0.000205	4.04	846.36	719.16	0.32
ZC Trib 3	1	385		Ex2008 1%	1782.00	445.05	451.87	451.87	453.36	0.001412	10.03	317.92	231.08	0.81
ZC Trib 3	1	87		Ex2008 1%	1782.00	443.29	452.31	451.11	452.81	0.000478	6.22	729.92	347.25	0.48
ZC Trib 2A	1	2715		Ex2008 1%	672.00	437.95	441.72	440.86	442.34	0.001034	6.32	106.35	36.41	0.65
ZC Trib 2A	1	2492		Ex2008 1%	672.00	437.20	441.65		442.07	0.000585	5.23	128.52	37.79	0.50
ZC Trib 2A	1	2142		Ex2008 1%	672.00	436.20	441.64		441.89	0.000258	3.98	195.17	124.28	0.34
ZC Trib 2A	1	1738		Ex2008 1%	1343.00	435.25	440.47	439.68	441.55	0.001229	8.38	187.45	91.59	0.74
ZC Trib 2A	1	1438		Ex2008 1%	1343.00	434.50	440.40	439.85	441.19	0.000726	7.16	258.16	402.34	0.58
ZC Trib 2A	1	1400	Calton Rd.		Culvert									
ZC Trib 2A	1	1345		Ex2008 1%	1343.00	434.09	439.82	439.42	440.77	0.007561	7.90	231.24	400.19	0.78
ZC Trib 2A	1	1250			Lat Struct									
ZC Trib 2A	1	1222		Ex2008 1%	594.85	433.62	439.49	437.79	439.85	0.002623	4.85	136.68	138.45	0.46
ZC Trib 2A	1	1017		Ex2008 1%	561.10	433.93	438.92	438.06	439.23	0.003397	4.73	201.68	405.15	0.51
ZC Trib 2A	1	881		Ex2008 1%	561.10	433.57	437.26	437.02	438.40	0.009833	8.60	65.26	50.19	0.88
ZC Trib 2A	1	800	Chaparral St.		Culvert									
ZC Trib 2A	1	784		Ex2008 1%	561.10	432.67	436.52	435.75	437.35	0.002307	7.28	77.08	57.85	0.69
ZC Trib 2A	1	750			Lat Struct									

ZC Trib 2A	1	682		Ex2008 1%	514.11	432.18	436.63	434.98	436.86	0.001464	3.79	136.12	90.36	0.40
ZC Trib 2A	1	565		Ex2008 1%	417.52	431.58	436.62	434.10	436.71	0.000569	2.52	180.59	182.50	0.25
ZC Trib 2A	1	405		Ex2008 1%	1.34	430.89	436.67	431.05	436.67	0.000000	0.01	254.66	155.03	0.00
ZC Trib 2A	1	335		Ex2008 1%	1.34	430.58	436.67	430.74	436.67	0.000000	0.01	225.74	147.63	0.00
ZC Trib 2A	1	300	Pedestrian Bridg		Bridge									
ZC Trib 2A	1	284		Ex2008 1%	1.34	430.36	436.67	430.53	436.67	0.000000	0.01	251.64	171.98	0.00
ZC Trib 2A	1	216		Ex2008 1%	1.34	430.06	436.67		436.67	0.000000	0.00	475.79	266.57	0.00
ZC Trib 2A	1	91		Ex2008 1%	1.34	429.52	436.67	429.68	436.67	0.000000	0.00	324.74	95.55	0.00
ZC Trib 2	1	3701		Ex2008 1%	1241.00	445.42	450.34	450.34	452.08	0.002360	10.58	117.33	33.68	1.00
ZC Trib 2	1	3381		Ex2008 1%	1241.00	442.98	446.62	447.90	450.61	0.007486	16.03	77.42	28.55	1.72
ZC Trib 2	1	3186		Ex2008 1%	1489.00	441.90	447.00	447.50	449.26	0.002946	12.05	123.57	34.42	1.12
ZC Trib 2	1	2784		Ex2008 1%	1489.00	440.38	445.16	445.92	447.87	0.003801	13.22	112.65	53.22	1.26
ZC Trib 2	1	2544		Ex2008 1%	1489.00	439.51	446.48	445.60	446.84	0.000249	4.99	672.98	574.88	0.35
ZC Trib 2	1	2500			Culvert									
ZC Trib 2	1	2456		Ex2008 1%	1489.00	439.12	445.69	443.18	445.96	0.000233	4.62	948.95	439.27	0.34
ZC Trib 2	1	2392		Ex2008 1%	1489.00	438.46	444.39	444.39	445.64	0.001336	9.23	335.50	377.54	0.78
ZC Trib 2	1	2083		Ex2008 1%	1489.00	435.18	439.11	440.99	443.78	0.008065	17.34	85.89	29.72	1.80
ZC Trib 2	1	1731		Ex2008 1%	1489.00	433.10	437.38	438.64	441.08	0.005841	15.44	96.46	48.73	1.54
ZC Trib 2	1	1407		Ex2008 1%	1489.00	431.36	435.74	436.98	439.20	0.005330	14.94	99.69	151.44	1.48
ZC Trib 2	2	1092		Ex2008 1%	1490.00	429.68	433.38	434.64	437.28	0.006724	15.84	94.08	125.16	1.65
ZC Trib 2	2	792		Ex2008 1%	1610.00	428.17	432.60	433.33	435.44	0.004031	13.51	119.14	48.14	1.30
ZC Trib 2	2	493		Ex2008 1%	1610.00	426.57	434.54	431.72	434.69	0.000150	3.90	2097.40	1512.88	0.28
ZC Trib 2	2	116		Ex2008 1%	1610.00	424.46	434.58	429.62	434.64	0.000048	2.53	3277.57	2157.02	0.16
ZC Trib 1A	1	13279		Ex2008 1%	703.00	423.78	427.36	426.16	427.38	0.003470	1.14	614.57	1162.56	0.28
ZC Trib 1A	1	13008		Ex2008 1%	703.00	422.05	426.43		426.50	0.003037	2.03	346.25	249.75	0.30
ZC Trib 1A	1	12687		Ex2008 1%	703.00	423.77	426.26		426.27	0.000284	0.66	1069.55	711.12	0.09
ZC Trib 1A	1	12211		Ex2008 1%	703.00	421.88	426.16		426.16	0.000175	0.58	1205.34	665.61	0.08
ZC Trib 1A	1	11690		Ex2008 1%	1994.00	421.33	425.97		425.99	0.000419	1.20	1660.78	597.80	0.13
ZC Trib 1A	1	11021		Ex2008 1%	1994.00	420.85	425.15		425.23	0.009108	2.30	868.30	1191.02	0.47
ZC Trib 1A	1	10516		Ex2008 1%	1994.00	420.53	424.34		424.36	0.000684	1.52	1648.02	868.09	0.16
ZC Trib 1A	1	10070		Ex2008 1%	1994.00	419.37	423.65		423.71	0.004918	1.93	1031.63	1154.43	0.36
ZC Trib 1A	1	9682		Ex2008 1%	1994.00	418.43	422.58		422.62	0.001831	1.42	1405.45	1191.48	0.23
ZC Trib 1A	1	9472		Ex2008 1%	1994.00	418.50	422.44		422.45	0.000406	0.94	2127.92	1085.67	0.12
ZC Trib 1A	1	9184		Ex2008 1%	1994.00	418.47	422.32		422.34	0.000372	1.00	2003.84	875.84	0.12
ZC Trib 1A	1	8848		Ex2008 1%	2547.00	418.89	422.09		422.12	0.001147	1.47	1732.68	980.93	0.19
ZC Trib 1A	1	8477		Ex2008 1%	2547.00	417.80	421.85		421.87	0.000430	1.14	2233.34	886.41	0.13
ZC Trib 1A	1	8260		Ex2008 1%	2547.00	417.42	421.75		421.76	0.000540	1.00	2558.25	1473.77	0.13
ZC Trib 1A	1	7998		Ex2008 1%	2547.00	417.76	421.34		421.42	0.006503	2.19	1165.09	1332.70	0.41
ZC Trib 1A	1	7749		Ex2008 1%	2547.00	417.58	421.11		421.12	0.000442	0.91	2785.86	1570.50	0.12
ZC Trib 1A	1	7535		Ex2008 1%	2547.00	418.54	420.82		420.89	0.005676	2.03	1257.71	1460.59	0.38
ZC Trib 1A	1	7336		Ex2008 1%	2547.00	417.79	420.44		420.47	0.001039	1.24	2051.30	1389.73	0.18
ZC Trib 1A	1	7073		Ex2008 1%	2547.00	417.61	420.01		420.06	0.002576	1.74	1464.14	1180.59	0.28
ZC Trib 1A	1	6909		Ex2008 1%	2547.00	417.29	419.86		419.88	0.000573	0.98	2590.63	1594.20	0.14
ZC Trib 1A	1	6713		Ex2008 1%	2547.00	416.73	419.60		419.65	0.003031	1.76	1447.28	1294.99	0.29
ZC Trib 1A	1	6551		Ex2008 1%	2547.00	416.78	419.43		419.45	0.000649	0.95	2668.94	1884.66	0.14
ZC Trib 1A	1	6284		Ex2008 1%	2547.00	416.79	419.12		419.15	0.002211	1.53	1666.11	1454.70	0.25
ZC Trib 1A	1	5918		Ex2008 1%	2547.00	416.01	418.64		418.66	0.000905	1.02	2498.06	2048.39	0.16
ZC Trib 1A	1	5652		Ex2008 1%	2547.00	415.91	418.22		418.27	0.002709	1.77	1437.49	1171.47	0.28
ZC Trib 1A	1	5145		Ex2008 1%	2547.00	414.41	417.80		417.81	0.000431	0.83	3084.80	1986.63	0.12
ZC Trib 1A	1	4632		Ex2008 1%	2547.00	413.36	417.54		417.56	0.000556	0.96	2657.53	1657.80	0.13
ZC Trib 1A	1	4202		Ex2008 1%	4051.00	413.07	417.32		417.33	0.000504	1.08	3763.03	1833.41	0.13
ZC Trib 1A	1	3667		Ex2008 1%	4051.00	412.76	416.96		416.99	0.000844	1.29	3152.46	1729.69	0.17
ZC Trib 1A	1	3126		Ex2008 1%	4051.00	412.41	416.47		416.50	0.000976	1.28	3161.41	1946.83	0.18
ZC Trib 1A	1	2630		Ex2008 1%	4051.00	411.47	415.88		415.92	0.001456	1.43	2840.59	2010.60	0.21
ZC Trib 1A	1	2044		Ex2008 1%	4051.00	411.01	415.26		415.29	0.000807	1.25	3236.10	1790.04	0.16
ZC Trib 1A	1	1329		Ex2008 1%	4051.00	409.64	414.24		414.33	0.002637	2.29	1765.30	955.76	0.30
ZC Trib 1A	1	809		Ex2008 1%	4051.00	403.63	412.41		413.51	0.000840	9.88	1034.17	352.49	0.67
ZC Trib 1A	1	748		Ex2008 1%	4051.00	403.43	412.09	412.09	413.43	0.001153	10.96	968.52	374.61	0.76
ZC Trib 1A	1	700			Culvert									
ZC Trib 1A	1	643		Ex2008 1%	4051.00	403.04	411.47	410.55	413.11	0.000992	10.66	567.72	283.68	0.73
ZC Trib 1A	1	511		Ex2008 1%	4051.00	401.74	411.61	409.62	412.76	0.000634	8.96	684.76	225.50	0.58
ZC Trib 1A	1	450			Culvert									

ZC Trib 1A	1	433		Ex2008 1%	4051.00	401.57	411.92		412.67	0.000391	7.39	1068.37	426.26	0.46
ZC Trib 1A	1	210		Ex2008 1%	4051.00	401.09	411.85	409.03	412.56	0.000448	6.93	895.58	492.98	0.48
ZC Trib 1A	1	150			Culvert									
ZC Trib 1A	1	116		Ex2008 1%	4051.00	400.27	411.95		412.11	0.001095	4.06	1580.81	650.20	0.23
ZC Trib 1	1	8345		Ex2008 1%	254.00	419.80	425.73	422.28	425.75	0.000029	1.42	367.72	241.51	0.11
ZC Trib 1	1	7977		Ex2008 1%	507.00	419.30	425.56	423.14	425.70	0.000168	3.72	275.00	497.19	0.27
ZC Trib 1	1	7609		Ex2008 1%	507.00	418.80	425.58	422.90	425.64	0.000067	2.49	415.01	732.63	0.18
ZC Trib 1	1	7399		Ex2008 1%	507.00	418.60	425.61	423.36	425.62	0.000019	1.28	1335.85	1053.12	0.09
ZC Trib 1	1	7300	I-35 OnRamp		Culvert									
ZC Trib 1	1	7197		Ex2008 1%	1015.00	418.30	425.57	423.97	425.61	0.000075	2.63	1240.25	1155.23	0.18
ZC Trib 1	1	7000			Lat Struct									
ZC Trib 1	1	6997		Ex2008 1%	1015.00	418.00	425.57	423.92	425.59	0.000049	2.19	2326.41	1303.18	0.15
ZC Trib 1	1	6892		Ex2008 1%	1015.00	417.90	425.57	423.04	425.58	0.000025	1.68	2283.27	1406.36	0.11
ZC Trib 1	1	6700	Mann Road		Culvert									
ZC Trib 1	1	6593		Ex2008 1%	1015.00	417.70	425.57	422.75	425.58	0.000024	1.67	2440.77	1499.50	0.11
ZC Trib 1	1	6535		Ex2008 1%	1015.00	417.60	425.57	422.98	425.58	0.000020	1.48	2659.29	1574.23	0.10
ZC Trib 1	1	6260		Ex2008 1%	1015.00	417.30	425.57	422.53	425.57	0.000011	1.18	3305.53	1714.98	0.08
ZC Trib 1	1	6038		Ex2008 1%	1015.00	417.00	425.56	421.82	425.57	0.000009	1.06	3577.73	1783.44	0.07
ZC Trib 1	1	5806		Ex2008 1%	1015.00	416.70	425.56	421.51	425.57	0.000012	1.29	2844.59	1617.61	0.08
ZC Trib 1	1	5700	I-35 OffRamp		Culvert									
ZC Trib 1	1	5519		Ex2008 1%	2016.00	416.30	425.45	422.89	425.56	0.000108	3.97	1332.70	587.49	0.24
ZC Trib 1	1	5192		Ex2008 1%	2016.00	416.00	425.33	422.96	425.50	0.000141	4.60	1211.63	497.26	0.27
ZC Trib 1	1	4845		Ex2008 1%	2016.00	415.80	424.95		425.41	0.000278	6.37	623.49	242.99	0.38
ZC Trib 1	1	4363		Ex2008 1%	2016.00	415.40	425.02	422.81	425.24	0.000151	4.87	1005.97	437.46	0.29
ZC Trib 1	1	3910		Ex2008 1%	2016.00	415.00	424.82		425.15	0.000194	5.60	891.77	441.44	0.33
ZC Trib 1	1	3538		Ex2008 1%	2016.00	414.70	424.41		425.03	0.000305	6.96	515.32	151.66	0.41
ZC Trib 1	1	3326		Ex2008 1%	2016.00	414.50	424.35	420.99	424.97	0.000279	6.78	502.49	195.89	0.39
ZC Trib 1	1	3150	I-35 OnRamp		Culvert									
ZC Trib 1	1	3023		Ex2008 1%	2016.00	414.30	423.27	420.82	423.82	0.000311	6.70	541.44	267.29	0.41
ZC Trib 1	1	2678		Ex2008 1%	1644.00	414.00	423.38	419.50	423.58	0.000124	4.37	761.79	263.71	0.26
ZC Trib 1	1	2400			Lat Struct									
ZC Trib 1	1	2312		Ex2008 1%	1644.00	413.74	423.38	419.43	423.52	0.000091	3.82	1024.45	446.01	0.22
ZC Trib 1	1	2200	Calton Road		Culvert									
ZC Trib 1	1	2091		Ex2008 1%	1644.00	413.56	423.43	419.22	423.50	0.000053	2.96	1818.28	890.65	0.17
ZC Trib 1	1	1832		Ex2008 1%	1644.00	413.40	423.43	419.68	423.48	0.000039	2.56	2008.66	821.20	0.15
ZC Trib 1	1	1587		Ex2008 1%	1644.00	413.20	423.39	418.75	423.46	0.000052	3.01	1456.75	1020.91	0.17
ZC Trib 1	1	1379		Ex2008 1%	1644.00	413.00	423.38	418.76	423.45	0.000050	2.91	1437.00	1222.14	0.17
ZC Trib 1	1	1180		Ex2008 1%	1644.00	412.83	423.38	418.48	423.44	0.000047	2.85	1520.36	1336.03	0.16
ZC Trib 1	1	1000	Abandoned Off-Ra		Culvert									
ZC Trib 1	1	924		Ex2008 1%	1644.00	412.63	423.35	418.24	423.43	0.000049	2.91	1608.15	989.83	0.16
ZC Trib 1	1	879		Ex2008 1%	1644.00	412.60	423.35	416.94	423.42	0.000033	2.44	1830.06	1219.16	0.14
ZC Trib 1	1	800	I-35 NB FR		Culvert									
ZC Trib 1	1	769		Ex2008 1%	1644.00	412.30	423.37	416.64	423.41	0.000023	2.02	2087.50	1287.63	0.12
ZC Trib 1	1	510		Ex2008 1%	1644.00	411.90	423.27		423.39	0.000044	2.94	791.86	200.95	0.16
ZC Trib 1	1	168		Ex2008 1%	1644.00	410.70	423.28	414.90	423.36	0.000028	2.50	1026.06	252.29	0.13
Zacate Creek	1	47546		Ex2008 1%	974.00	520.06	525.22	523.20	525.24	0.000272	1.24	785.29	332.25	0.14
Zacate Creek	1	47350		Ex2008 1%	974.00	521.10	524.17		525.02	0.005788	7.37	132.19	55.27	0.84
Zacate Creek	1	47018		Ex2008 1%	974.00	518.76	523.73		523.95	0.001513	3.76	259.16	74.36	0.35
Zacate Creek	1	46752		Ex2008 1%	974.00	517.73	523.38		523.58	0.001243	3.55	274.48	73.77	0.32
Zacate Creek	1	46399		Ex2008 1%	1520.00	517.06	522.34		522.82	0.003148	5.56	273.17	75.28	0.51
Zacate Creek	1	46030		Ex2008 1%	1520.00	515.33	521.66		521.95	0.001629	4.32	352.49	91.74	0.38
Zacate Creek	1	45756		Ex2008 1%	1520.00	514.05	521.19	518.57	521.36	0.002450	3.68	573.44	402.13	0.30
Zacate Creek	1	45430		Ex2008 1%	1520.00	514.84	519.14	518.80	520.14	0.005518	8.07	196.53	160.59	0.83
Zacate Creek	1	45120		Ex2008 1%	1520.00	512.08	518.28	516.77	518.77	0.002937	5.66	270.18	88.06	0.53
Zacate Creek	1	44660		Ex2008 1%	1520.00	510.85	515.47	515.47	516.68	0.007336	8.85	177.80	86.08	0.96
Zacate Creek	1	44355		Ex2008 1%	1520.00	507.57	512.50	513.14	514.69	0.005299	11.87	128.07	59.33	1.42
Zacate Creek	1	43939		Ex2008 1%	1520.00	505.86	511.33	511.33	512.78	0.011597	9.68	156.95	54.97	1.01
Zacate Creek	1	43651		Ex2008 1%	1520.00	504.58	510.96	507.78	511.32	0.000209	4.84	314.13	70.58	0.34
Zacate Creek	1	43550	Winfield Pkwy.		Culvert									
Zacate Creek	1	43489		Ex2008 1%	1520.00	504.26	509.35	507.41	509.92	0.000442	6.03	251.95	65.12	0.48
Zacate Creek	1	43291		Ex2008 1%	1520.00	504.00	508.80	508.24	509.64	0.004018	7.36	206.52	71.68	0.76
Zacate Creek	1	42956		Ex2008 1%	1520.00	502.33	507.08		507.89	0.006984	7.23	210.13	71.30	0.74

Zacate Creek	2	42667		Ex2008 1%	3524.00	500.00	507.24		507.47	0.000519	4.01	1289.69	598.27	0.29
Zacate Creek	2	42494		Ex2008 1%	3524.00	500.00	506.95		507.34	0.000949	5.03	701.22	153.10	0.41
Zacate Creek	2	42475		Ex2008 1%	3524.00	500.00	506.51	504.49	507.29	0.000501	7.08	497.59	147.75	0.52
Zacate Creek	2	42400	Del Mar Blvd		Culvert									
Zacate Creek	2	42364		Ex2008 1%	3524.00	498.75	505.39	502.46	505.65	0.000535	4.08	994.47	570.25	0.31
Zacate Creek	2	42293		Ex2008 1%	3524.00	498.65	505.16	502.64	505.56	0.001125	5.05	697.45	143.65	0.40
Zacate Creek	2	41963		Ex2008 1%	4730.00	498.00	504.06	502.67	504.93	0.002664	7.46	634.36	140.18	0.62
Zacate Creek	2	41373		Ex2008 1%	4730.00	496.00	500.67	500.67	502.42	0.007101	10.61	445.85	127.16	1.00
Zacate Creek	2	40537		Ex2008 1%	4730.00	491.00	496.36	495.47	497.42	0.001650	8.29	570.59	140.20	0.72
Zacate Creek	2	39991		Ex2008 1%	4730.00	488.26	495.23	493.13	495.89	0.004638	6.54	723.90	167.35	0.52
Zacate Creek	2	39274		Ex2008 1%	5205.00	485.82	494.51	492.59	494.60	0.000816	3.19	2643.68	1140.32	0.22
Zacate Creek	2	38746		Ex2008 1%	5205.00	482.74	490.49	490.49	493.18	0.017576	13.16	395.62	890.37	1.00
Zacate Creek	2	38079		Ex2008 1%	5881.00	480.02	488.90	487.64	490.42	0.006865	10.21	676.42	1281.08	0.66
Zacate Creek	2	37384		Ex2008 1%	5881.00	477.74	484.62		485.32	0.007107	8.28	1297.92	1093.81	0.64
Zacate Creek	2	36802		Ex2008 1%	5881.00	475.99	483.10	482.27	483.21	0.001927	3.75	2470.80	1397.64	0.32
Zacate Creek	2	35888		Ex2008 1%	6260.00	473.65	479.24	479.24	479.81	0.008888	8.44	1366.99	1261.82	0.69
Zacate Creek	2	35366		Ex2008 1%	6260.00	470.33	478.92	478.20	479.03	0.001422	3.92	3234.71	2227.43	0.29
Zacate Creek	2	34754		Ex2008 1%	6493.00	467.74	478.05	477.28	478.19	0.001404	4.29	3149.81	2075.40	0.29
Zacate Creek	2	34372		Ex2008 1%	6493.00	467.44	476.13	476.13	477.07	0.007419	8.73	1065.78	537.10	0.66
Zacate Creek	2	34014		Ex2008 1%	6493.00	460.47	476.17	463.50	476.18	0.000027	0.93	6993.79	625.08	0.05
Zacate Creek	2	33640		Ex2008 1%	6657.00	459.95	476.12		476.16	0.000098	1.61	4143.17	379.57	0.09
Zacate Creek	2	33118		Ex2008 1%	6657.00	460.90	475.96		476.07	0.000326	2.66	2507.34	263.87	0.15
Zacate Creek	2	32824		Ex2008 1%	6657.00	460.88	475.90		475.98	0.000241	2.28	2914.38	304.71	0.13
Zacate Creek	2	32621		Ex2008 1%	6522.00	461.41	475.75	467.26	475.91	0.000446	3.23	2024.15	213.08	0.18
Zacate Creek	2	32500	Alexander Pond O		Culvert									
Zacate Creek	2	32380		Ex2008 1%	6522.00	461.50	471.44	467.37	471.95	0.000240	5.75	1163.22	335.57	0.37
Zacate Creek	2	32310		Ex2008 1%	6522.00	461.20	471.41	467.37	471.93	0.000249	5.79	1126.39	155.23	0.38
Zacate Creek	2	31835		Ex2008 1%	6522.00	458.70	471.33	470.21	471.66	0.002053	6.07	1739.74	539.16	0.36
Zacate Creek	2	31331		Ex2008 1%	6522.00	458.50	471.05	468.61	471.12	0.000620	3.63	5285.98	1829.93	0.20
Zacate Creek	2	31260		Ex2008 1%	6522.00	457.90	471.04	468.25	471.08	0.000354	2.86	6719.13	1913.73	0.15
Zacate Creek	2	31200	Jacaman Rd.		Culvert									
Zacate Creek	2	31157		Ex2008 1%	6522.00	457.80	470.90	467.75	471.06	0.000103	4.66	8278.41	2159.15	0.25
Zacate Creek	2	31100		Ex2008 1%	6522.00	457.70	470.67	466.90	470.99	0.001406	5.81	2849.46	2097.03	0.31
Zacate Creek	2	30665		Ex2008 1%	6522.00	457.71	469.53	468.54	470.00	0.004122	7.49	1960.97	2200.32	0.42
Zacate Creek	2	30046		Ex2008 1%	6522.00	454.72	467.81	467.81	467.95	0.002454	5.05	3140.60	1815.13	0.30
Zacate Creek	2	29692		Ex2008 1%	6522.00	455.70	465.76	464.85	465.98	0.004542	6.20	2496.99	1760.10	0.41
Zacate Creek	2	29396		Ex2008 1%	6522.00	455.53	465.44	463.95	465.50	0.000723	4.03	5174.37	2473.95	0.26
Zacate Creek	2	29182		Ex2008 1%	6522.00	454.18	465.32	463.48	465.36	0.000508	3.43	6002.73	2480.41	0.22
Zacate Creek	2	28870		Ex2008 1%	6522.00	453.40	464.60	463.17	465.01	0.002873	8.21	1970.06	2410.48	0.51
Zacate Creek	2	28653		Ex2008 1%	5680.00	452.80	463.46	463.00	464.13	0.004120	9.39	1731.64	2248.96	0.61
Zacate Creek	2	28389		Ex2008 1%	5680.00	452.10	462.46	462.46	463.20	0.004861	10.63	1903.21	1897.77	0.64
Zacate Creek	2	27926		Ex2008 1%	5680.00	450.80	461.98	461.04	462.14	0.002880	5.35	2645.51	1300.06	0.33
Zacate Creek	2	27469		Ex2008 1%	5680.00	449.58	461.92	459.58	461.94	0.000314	1.97	4636.08	1780.91	0.12
Zacate Creek	2	27169		Ex2008 1%	5680.00	449.22	459.32	459.32	461.51	0.006388	12.19	627.86	1537.32	0.81
Zacate Creek	2	27035		Ex2008 1%	5680.00	448.60	453.54	455.61	460.20	0.006525	20.70	274.42	63.00	1.75
Zacate Creek	2	26922		Ex2008 1%	5680.00	447.00	457.70	453.39	458.75	0.000435	8.35	1136.93	969.30	0.45
Zacate Creek	2	26900	Gale St.		Culvert									
Zacate Creek	2	26842		Ex2008 1%	5680.00	446.80	458.09		458.72	0.000283	6.89	2542.34	1337.12	0.36
Zacate Creek	2	26728		Ex2008 1%	5445.00	447.00	457.08	454.86	458.46	0.000667	9.59	966.85	946.46	0.61
Zacate Creek	2	26260		Ex2008 1%	5445.00	445.20	457.74	455.95	457.80	0.000522	3.14	4943.76	1736.29	0.18
Zacate Creek	2	25767		Ex2008 1%	5445.00	442.50	457.09	451.94	457.40	0.001484	5.20	2149.30	1850.54	0.31
Zacate Creek	2	25425		Ex2008 1%	5445.00	442.30	452.73	452.73	456.00	0.018293	14.49	375.65	128.80	1.00
Zacate Creek	2	25108		Ex2008 1%	5445.00	442.00	451.74	449.97	453.27	0.003028	9.95	547.46	83.69	0.69
Zacate Creek	2	25100	McPherson Rd.		Bridge									
Zacate Creek	2	25010		Ex2008 1%	5445.00	442.10	451.34	449.70	453.02	0.000926	10.40	523.57	77.82	0.71
Zacate Creek	3	24672		Ex2008 1%	5679.00	440.14	451.16	451.16	452.06	0.003863	8.83	1578.30	948.48	0.58
Zacate Creek	3	24313		Ex2008 1%	5679.00	438.67	450.68	445.99	450.93	0.000952	4.63	2644.91	1132.78	0.30
Zacate Creek	3	24300	Pedestrian Bridg		Bridge									
Zacate Creek	3	24256		Ex2008 1%	5679.00	438.67	450.31	445.99	450.56	0.001453	4.69	2492.35	1139.84	0.30
Zacate Creek	3	24106		Ex2008 1%	5679.00	438.47	450.08	448.64	450.29	0.002146	5.28	2722.13	1361.93	0.36
Zacate Creek	3	23778		Ex2008 1%	5679.00	438.67	449.06	447.94	449.68	0.002160	7.65	2070.60	1192.82	0.48
Zacate Creek	3	23355		Ex2008 1%	5679.00	435.07	447.45	447.45	448.58	0.002737	9.43	1514.28	1104.89	0.56

Zacate Creek	3	22815		Ex2008 1%	5542.00	433.60	446.39	444.35	447.06	0.001523	7.60	1996.39	1206.70	0.45
Zacate Creek	3	22320		Ex2008 1%	5542.00	432.16	443.12	443.12	445.60	0.005566	13.05	632.90	468.18	0.85
Zacate Creek	3	21905		Ex2008 1%	5542.00	431.40	440.79	442.05	443.93	0.002828	15.70	1142.36	809.03	1.19
Zacate Creek	3	21376		Ex2008 1%	5542.00	430.70	438.63	440.34	442.31	0.003171	16.66	946.09	701.03	1.26
Zacate Creek	3	21326		Ex2008 1%	5542.00	430.50	440.57	436.96	440.84	0.000144	4.99	5601.60	2742.64	0.29
Zacate Creek	3	21300	HIllside Rd.		Bridge									
Zacate Creek	3	21268		Ex2008 1%	5542.00	430.30	440.48	437.00	440.69	0.000130	4.58	6252.97	2636.20	0.28
Zacate Creek	3	21218		Ex2008 1%	5542.00	430.10	439.37	439.37	440.42	0.001075	10.73	3174.61	2164.29	0.74
Zacate Creek	3	21196		Ex2008 1%	5542.00	427.90	438.84	438.65	440.24	0.000935	10.93	2015.27	2036.04	0.70
Zacate Creek	3	20902		Ex2008 1%	5542.00	427.60	438.78	438.78	439.90	0.000773	10.59	2813.31	2524.80	0.65
Zacate Creek	3	20619		Ex2008 1%	5542.00	427.20	437.63	438.32	439.55	0.001385	13.64	2212.76	2046.60	0.85
Zacate Creek	3	20179		Ex2008 1%	5542.00	426.70	437.22	437.16	438.13	0.000675	9.22	3070.52	2364.76	0.61
Zacate Creek	3	19992		Ex2008 1%	5542.00	426.50	437.46	436.63	437.89	0.000305	6.96	5172.50	3495.39	0.41
Zacate Creek	3	19950	Calton Rd.		Culvert									
Zacate Creek	3	19916		Ex2008 1%	5542.00	426.30	437.65	436.13	437.88	0.000184	5.59	6507.67	4067.17	0.32
Zacate Creek	3	19865		Ex2008 1%	5542.00	426.30	436.66	436.66	437.63	0.000932	10.54	2981.56	3113.07	0.68
Zacate Creek	3	19401		Ex2008 1%	6323.90	425.60	434.96	435.19	436.97	0.002318	13.94	2206.33	1889.32	1.07
Zacate Creek	3	18747		Ex2008 1%	6885.00	424.50	434.27	434.83	435.86	0.001582	13.58	3237.95	2339.52	0.90
Zacate Creek	4	18534		Ex2008 1%	6565.00	424.20	432.50	433.64	435.33	0.002220	15.03	1589.61	1169.44	1.07
Zacate Creek	4	18340		Ex2008 1%	6565.00	423.90	433.92	433.19	434.19	0.000290	6.54	8118.46	4241.49	0.40
Zacate Creek	4	18300	Springfield Brid		Bridge									
Zacate Creek	4	18282		Ex2008 1%	6565.00	423.60	433.88	433.03	434.08	0.000224	5.86	9344.25	4656.58	0.35
Zacate Creek	4	18139		Ex2008 1%	6565.00	422.90	432.30	432.30	433.88	0.001134	12.09	2746.15	1601.93	0.78
Zacate Creek	4	18015		Ex2008 1%	6565.00	421.40	432.72	431.79	433.44	0.000482	8.41	5031.17	4238.08	0.48
Zacate Creek	4	18000	Marcella Bridge		Bridge									
Zacate Creek	4	17952		Ex2008 1%	6565.00	421.10	432.08	432.08	433.12	0.000807	9.39	2970.80	3735.79	0.61
Zacate Creek	4	17673		Ex2008 1%	6565.00	418.60	430.79	428.75	431.45	0.000349	8.04	5550.39	3684.55	0.45
Zacate Creek	4	17259		Ex2008 1%	6565.00	418.00	428.82	428.82	431.07	0.001039	12.89	1697.47	1344.91	0.77
Zacate Creek	4	16822		Ex2008 1%	6565.00	416.40	426.58	428.14	430.34	0.001781	15.95	940.82	943.27	0.98
Zacate Creek	4	16289		Ex2008 1%	6565.00	414.70	424.25	426.39	429.13	0.002408	17.81	506.83	479.90	1.13
Zacate Creek	4	15992		Ex2008 1%	6565.00	413.20	420.56	423.93	427.90	0.004851	21.74	301.99	46.88	1.51
Zacate Creek	5	15731		Ex2008 1%	7580.03	409.60	422.80	417.47	423.28	0.000564	5.53	1439.08	241.88	0.33
Zacate Creek	5	15634		Ex2008 1%	7580.03	409.94	422.47	418.43	423.18	0.000871	6.79	1157.02	255.65	0.42
Zacate Creek	5	15361		Ex2008 1%	7580.03	409.07	422.32	417.54	422.94	0.000730	6.30	1202.44	331.09	0.39
Zacate Creek	5	15138		Ex2008 1%	7580.03	408.73	422.18	417.37	422.77	0.000681	6.19	1225.10	521.00	0.38
Zacate Creek	5	14927		Ex2008 1%	7580.03	408.02	422.17	416.40	422.60	0.000504	5.31	1428.44	546.49	0.32
Zacate Creek	5	14900	Chicago/Taylor S		Bridge									
Zacate Creek	5	14851		Ex2008 1%	7580.03	407.90	421.93	416.34	422.41	0.000786	5.55	1366.88	408.09	0.32
Zacate Creek	5	14725		Ex2008 1%	7580.03	407.74	421.74	416.23	422.28	0.000947	5.91	1287.50	146.88	0.35
Zacate Creek	5	14660		Ex2008 1%	7580.03	407.84	421.69	416.13	422.22	0.000941	5.83	1299.80	217.91	0.34
Zacate Creek	5	14650	Pedestrian Bridg		Bridge									
Zacate Creek	5	14612		Ex2008 1%	7580.03	406.60	420.56	415.36	421.18	0.001135	6.31	1201.19	137.33	0.38
Zacate Creek	5	14214		Ex2008 1%	9285.03	406.62	419.57	415.50	420.52	0.001724	7.82	1187.37	136.07	0.47
Zacate Creek	5	13708		Ex2008 1%	9285.03	405.40	418.60	414.70	419.61	0.001858	8.05	1153.88	134.48	0.48
Zacate Creek	5	13700	Pedestrian Bridg		Bridge									
Zacate Creek	5	13660		Ex2008 1%	9285.03	405.37	418.61	414.39	419.53	0.001739	7.70	1207.46	149.12	0.47
Zacate Creek	5	13273		Ex2008 1%	9285.03	404.49	418.05	413.27	418.83	0.001506	7.06	1318.74	205.57	0.43
Zacate Creek	5	12747		Ex2008 1%	9285.03	403.40	416.56	412.46	417.52	0.004628	7.89	1176.25	138.30	0.48
Zacate Creek	5	12602		Ex2008 1%	9285.03	403.18	415.18	412.20	417.20	0.000759	11.39	815.50	76.27	0.61
Zacate Creek	5	12575	LaFayette St/US		Bridge									
Zacate Creek	5	12524		Ex2008 1%	9285.03	403.25	414.46	412.10	416.73	0.000715	12.09	768.07	82.42	0.67
Zacate Creek	5	12212		Ex2008 1%	9285.03	402.18	414.65	411.36	415.81	0.002298	8.65	1077.33	146.18	0.53
Zacate Creek	5	11710		Ex2008 1%	9285.03	401.39	414.07	409.77	414.93	0.001137	7.44	1248.35	153.64	0.45
Zacate Creek	5	11352		Ex2008 1%	9285.03	400.87	413.72	409.26	414.50	0.001149	7.12	1338.11	264.77	0.48
Zacate Creek	5	11350	Pedestrian Bridg		Bridge									
Zacate Creek	5	11319		Ex2008 1%	9285.03	400.90	413.50	409.24	414.33	0.001015	7.30	1333.11	252.76	0.44
Zacate Creek	5	11130		Ex2008 1%	9285.03	400.48	413.25	408.79	414.09	0.001480	7.40	1398.77	501.69	0.43
Zacate Creek	5	10400		Ex2008 1%	9285.03	399.10	412.48	408.08	413.16	0.000809	6.83	2208.15	775.95	0.39
Zacate Creek	5	10058		Ex2008 1%	9285.03	398.49	412.54	407.52	412.79	0.000612	4.79	4563.86	1504.49	0.28
Zacate Creek	5	9918		Ex2008 1%	9285.03	399.05	412.51	406.28	412.75	0.000095	4.65	7318.57	1716.65	0.25
Zacate Creek	5	9850	Jefferson/W Lyon		Bridge									
Zacate Creek	5	9795		Ex2008 1%	9285.03	398.03	411.34	406.25	411.88	0.000191	6.39	4573.30	1655.33	0.35

Zacate Creek	6	9593		Ex2008 1%	13336.03	397.64	410.01	407.47	411.48	0.002337	9.72	1373.51	1260.22	0.64
Zacate Creek	6	9029		Ex2008 1%	13336.03	396.44	409.16	405.65	410.38	0.001469	8.92	1602.30	699.09	0.52
Zacate Creek	6	8501		Ex2008 1%	13336.03	394.89	408.57	404.22	409.52	0.001478	8.04	2326.34	658.78	0.44
Zacate Creek	6	8148		Ex2008 1%	13336.03	393.79	408.38	403.34	409.08	0.000754	7.10	3187.09	844.39	0.38
Zacate Creek	6	7639		Ex2008 1%	13336.03	392.73	408.11	402.38	408.71	0.000599	6.57	2726.32	680.43	0.34
Zacate Creek	6	7189		Ex2008 1%	13336.03	391.44	407.96	400.84	408.46	0.000429	5.90	3553.45	820.16	0.29
Zacate Creek	6	7033		Ex2008 1%	13336.03	391.13	408.05	400.23	408.34	0.000293	4.76	5283.24	1002.04	0.24
Zacate Creek	6	7000	Park/Clark St.		Bridge									
Zacate Creek	6	6950		Ex2008 1%	13336.03	390.57	405.55	400.11	406.22	0.000778	6.70	2758.90	819.00	0.37
Zacate Creek	6	6765		Ex2008 1%	13336.03	390.38	405.36	399.59	406.07	0.000670	7.05	2920.28	670.65	0.36
Zacate Creek	6	6622		Ex2008 1%	13336.03	389.98	405.16	399.79	405.96	0.000757	7.44	2662.70	606.26	0.38
Zacate Creek	6	6600	Sanchez/W. Gusta		Bridge									
Zacate Creek	6	6562		Ex2008 1%	13336.03	389.89	401.92	399.83	403.91	0.002904	11.33	1179.88	178.61	0.69
Zacate Creek	6	6278		Ex2008 1%	13336.03	389.12	401.40	398.42	402.80	0.002805	9.56	1554.27	335.67	0.56
Zacate Creek	6	5617		Ex2008 1%	13336.03	387.46	400.08	396.70	401.09	0.002101	8.45	2329.09	579.21	0.48
Zacate Creek	6	5110		Ex2008 1%	13336.03	386.58	399.03	395.69	400.03	0.002066	8.40	1951.18	428.74	0.48
Zacate Creek	6	4924		Ex2008 1%	13336.03	386.00	398.49	394.95	399.58	0.002313	8.02	1621.69	381.80	0.46
Zacate Creek	6	4900	Pedestrian Bridg		Bridge									
Zacate Creek	6	4887		Ex2008 1%	13336.03	385.79	397.40	394.96	399.00	0.004043	10.20	1356.49	293.31	0.61
Zacate Creek	6	4696		Ex2008 1%	13336.03	383.94	396.20		398.06	0.005086	10.95	1248.02	201.58	0.68
Zacate Creek	6	4404		Ex2008 1%	13336.03	382.41	395.71		396.88	0.002343	8.72	1569.59	235.95	0.47
Zacate Creek	6	4292		Ex2008 1%	13336.03	378.47	395.64	390.09	396.62	0.001464	7.94	1681.11	223.04	0.41
Zacate Creek	6	4250	Tex Mex RR Bridg		Bridge									
Zacate Creek	6	4202		Ex2008 1%	14082.03	379.15	395.24	389.01	396.24	0.001454	8.03	1753.62	159.78	0.40
Zacate Creek	6	4032		Ex2008 1%	14082.03	378.70	394.99		395.99	0.001521	8.16	1869.19	370.51	0.44
Zacate Creek	6	3883		Ex2008 1%	14082.03	379.09	394.61	389.51	395.87	0.000367	9.00	1569.18	300.79	0.48
Zacate Creek	6	3850	Washington/Corpu		Bridge									
Zacate Creek	6	3807		Ex2008 1%	14082.03	378.81	394.13	389.50	395.52	0.000590	9.46	1488.99	148.50	0.53
Zacate Creek	6	3528		Ex2008 1%	14082.03	377.66	394.07		394.99	0.002364	7.78	1992.01	416.93	0.47
Zacate Creek	6	3316		Ex2008 1%	15488.03	376.53	393.62		394.53	0.001991	7.65	2036.26	267.43	0.45
Zacate Creek	6	3162		Ex2008 1%	15488.03	375.11	393.48	386.82	394.22	0.001086	6.91	2241.56	252.35	0.36
Zacate Creek	6	3100	Houston/Guadalup		Bridge									
Zacate Creek	6	3073		Ex2008 1%	15488.03	374.70	392.97	387.54	393.96	0.001519	7.98	1940.25	173.28	0.42
Zacate Creek	6	2947		Ex2008 1%	15488.03	374.46	390.77	388.14	393.18	0.006996	12.45	1244.17	126.53	0.69
Zacate Creek	6	2900	Parking Bridge		Bridge									
Zacate Creek	6	2860		Ex2008 1%	15488.03	374.49	390.56	386.44	392.17	0.003390	10.18	1522.13	142.28	0.55
Zacate Creek	6	2800	Matamoros/Chihua		Bridge									
Zacate Creek	6	2735		Ex2008 1%	15488.03	374.57	390.19	384.73	391.14	0.001784	7.82	1979.32	189.36	0.42
Zacate Creek	6	2496		Ex2008 1%	15488.03	372.11	387.62		389.99	0.006340	12.35	1253.64	134.09	0.71
Zacate Creek	6	2264		Ex2008 1%	15488.03	369.14	385.76		388.49	0.006193	13.26	1168.21	131.67	0.78
Zacate Creek	6	2116		Ex2008 1%	15488.03	368.42	385.46		387.42	0.005232	11.23	1379.05	138.82	0.63
Zacate Creek	6	1848		Ex2008 1%	15488.03	368.04	384.81	379.41	386.28	0.002776	9.71	1595.55	137.39	0.50
Zacate Creek	6	1800	Iturbide/Market		Bridge									
Zacate Creek	6	1765		Ex2008 1%	15488.03	368.28	383.68	380.30	385.74	0.004370	11.52	1344.63	123.17	0.61
Zacate Creek	6	1344		Ex2008 1%	15488.03	364.89	382.34		383.87	0.003339	9.91	1562.78	144.48	0.53
Zacate Creek	6	948		Ex2008 1%	15488.03	364.76	380.64		382.29	0.004721	10.33	1499.00	147.63	0.57
Zacate Creek	6	775		Ex2008 1%	15488.03	364.73	376.86	376.86	380.58	0.021213	15.49	1000.07	135.63	1.01
Zacate Creek	6	628		Ex2008 1%	15488.03	352.03	375.62	365.80	376.64	0.002252	8.08	1916.10	133.28	0.38
Zacate Creek	6	100		Ex2008 1%	15488.03	350.28	375.17	362.25	375.81	0.000901	6.53	2505.03	175.08	0.26

APPENDIX G
COST ESTIMATE CALCULATIONS

Zacate Creek Floodplain Protection Plan

Cost Estimate

Zone 2

Canal Street Drainage Improvements

Phase 2	Quantity	Unit	Unit Price	Total
Remove Concrete Rip Rap	15,255	SY	$10	$152,547
Remove Bridge	1	EA	$30,000	$30,000
Remove Wasterwater Line	2,550	LF	$25	$63,750
Excavation	12,396	CY	$8	$99,167
Install Concrete Channel	5,890	CY	$400	$2,355,822
Install Bridge	2,520	SF	$90	$226,800
Install Ramp @ U/S Intersection	1	EA	$7,500	$7,500
Install Wastewater Line	2,550	LF	$40	$102,000
Install Wastewater Manholes	6	EA	$5,000	$30,000
Erosion/Sedimentation Control	1	LS	$20,000	$20,000
Traffic Control	1	LS	$10,000	$10,000
Sub-Total				**$3,097,586**

Phase 3	Quantity	Unit	Unit Price	Total
Remove Concrete Rip Rap	11,069	SY	$10	$110,693
Remove Wasterwater Line	1,200	LF	$25	$30,000
Excavation	4,572	CY	$8	$36,578
Install Concrete Channel	4,000	CY	$400	$1,600,000
Remove/Replace Wastewater Line	1,200	LF	$65	$78,000
Install Wastewater Manholes	3	EA	$5,000	$15,000
Erosion/Sedimentation Control	1	LS	$20,000	$20,000
Traffic Control	1	LS	$5,000	$5,000
Sub-Total				**$1,895,271**

Phase 4	Quantity	Unit	Unit Price	Total
Remove Concrete Rip Rap	401	SY	$10	$4,005.6
Demo Road for Culverts	1	LS	$5,000	$5,000.0
Install Concrete Channel	196	CY	$400	$78,370.4
Install Precast Concrete Box Culverts - 10x5	117	CY	$500	$58,352.8
Install HMAC/sidewalk/curb and gutter	1	LS	$7,365	$7,365.0
Remove/Replace Aerial WW Line, inc. lift station/MH/force main	1	LS	$405,000	$405,000.0
Erosion/Sedimentation Control	1	LS	$10,000	$10,000.0
Traffic Control	1	LS	$15,000	$15,000.0
Sub-Total				**$583,094**

Phase 5	Quantity	Unit	Unit Price	Total
Remove Concrete Rip Rap	4,764	SY	$10	$47,638
Excavation	1,288	CY	$8	$10,304
Install Concrete Channel	1,845	CY	$400	$738,015
Property Acquisition	13,500	SF	$7	$94,500
Erosion/Sedimentation Control	1	LS	$20,000	$20,000
Sub-Total				**$910,456**

Sub-Total for All Phases	**$6,486,407**
General Conditions and Overhead @ 5%	**$324,320**
Contigency @ 5%	**$324,320**
Engineeering - Design & Construction Phase Services @10%	**$648,641**
Total	**$7,783,688**

Zacate Creek Floodplain Protection Plan

Cost Estimate

Zone 3

Jacaman St Bridge Improvement and Alexander Pond Expansion

	Quantity	Unit	Unit Price	Total
Jacaman St Bridge Improvements				
Road Demolition	840	SY	$10	$8,400
Remove Guard Rail	80	LF	$10	$800
Remove Culverts (1-6'x5' mbc, 1-5' dia pipe, 1-6'x4' mbc)	229	CY	$10	$2,290
40' crown-span box arch (box, arch, installation)	1	EA	$195,150	$195,150
Install Guard Rail	80	LF	$75	$6,000
Concrete under bridge (cha surface 55 ft, length 100 ft, concrete depth 0.5ft)	306	CY	$400	$122,220
Install HMAC/sidewalk/curb and gutter	1	EA	$13,920	$13,920
Alexander Pond Expansion				
Clearing and Grubbing	59	Acres	$2,500	$147,500
Land Acquisition	46	Acres	$250,000	$11,500,000
Excavation (no haul)	971,792	CY	$5	$4,858,960
Berm Embankment, Compacted Fill	7,693	CY	$12	$92,320
Miscellaneous				
Erosion/Sedimentation Control (0.5% of Total)	1	LS	$84,738	$84,740
Traffic Control	2	MO	$12,000	$24,000
Sub-Total				**$17,056,300**
General Conditions and Overhead @ 5%				**$852,815**
Contigency @ 5%				**$852,815**
Engineeering - Design & Construction Phase Services @10%				**$1,705,630**
Total				**$20,467,560**

Zacate Creek Floodplain Protection Plan

Cost Estimate

Zone 4

Channel Improvements on Zacate Creek:Upstream of Hillside Rd to Canal St
and Bridge Replacement at Calton Rd

	Quantity	Unit	Unit Price	Total
Channel Improvements: Trapezoidal concrete channel (0.5:1 SS, 42.5'-57.5' bottom width, 3,370 ft length)				
Remove concrete rip rap of existing channel	17,912	SY	$10	$179,120
Channel Excavation	28,002	CY	$8	$224,020
Install concrete channel, 6" concrete depth	4,338	CY	$400	$1,735,330
Calton Rd Bridge Improvements				
Road Demolition	733	SY	$10	$7,330
Remove Guard Rail	120	LF	$10	$1,200
Remove culverts at Calton Rd (3-8'x7 boxes)	361	CY	$10	$3,610
Install bridgeat Calton Rd, 55' span, 60' length	1	EA	$125,000	$125,000
Guard Rail	120	LF	$50	$6,000
Install HMAC/sidewalk/curb and gutter	1	EA	$19,880	$19,880
Miscellaneous				
Erosion/Sedimentation Control (0.5% of Total)	1	LS	$11,507	$11,510
Traffic Control	1	MO	$12,000	$12,000
Sub-Total				**$2,325,000**
General Conditions and Overhead @ 5%				**$116,250**
Contigency @ 5%				**$116,250**
Engineeering - Design & Construction Phase Services @10%				**$232,500**
Total				**$2,790,000**
Zone 2				**$7,783,688**
Zone 3				**$20,467,560**
Zone 4 Total				**$31,041,248**

Zacate Creek Floodplain Protection Plan

Cost Estimate

Zone 5

Channel and Culvert Improvements on Tributary 2: Calton Rd to Chapparral St

	Quantity	Unit	Unit Price	Total
Culvert Improvements				
Road Demolition	1,425	SY	$10	$14,250
Remove Guard Rail	270	LF	$10	
Remove culverts at Carlton Rd (2-6'x4' boxes)	124	CY	$10	$1,240
Remove culverts at Chaparral St (2-6'x4' boxes, 1-8'x4' boxes)	163	CY	$10	$1,630
Install 3-8'x4' box culverts at Carlton Rd (70' length)	210	LF	$320	$67,200
Install 3-8'x4' box culverts at Chaparral St (55' length)	165	LF	$320	$52,800
Install Guard Rail	270	LF	$50	$13,500
Install HMAC/sidewalk/curb and gutter	1	EA	$33,090	$33,090
Channel Improvements: Trapezoidal concrete channel (1:1 SS, 30' bottom width, 655' length)				
Excavation and Haul	1,443	CY	$9	$12,990
Install concrete channel	535	CY	$400	$213,840
Miscellaneous				
Erosion/Sedimentation Control (0.5% of Total)	1	LS	$2,053	$2,050
Traffic Control	2	MO	$12,000	$24,000
Sub-Total				**$436,590**
General Conditions and Overhead @ 5%				**$21,830**
Contigency @ 5%				**$21,830**
Engineeering - Design & Construction Phase Services @10%				**$43,659**
Total				**$523,908**

Zacate Creek Floodplain Protection Plan

Cost Estimate

Zone 6

Channel Improvements and Structure Replacement on Tributary 1 along IH-35 Northbound Frontage Road

	Quantity	Unit	Unit Price	Total
Culvert Improvements				
Road Demolition	4,484	SY	$10	$44,840
Remove Guard Rail	184	LF	$10	$1,840
Remove Culvert at Sta 7300 I-35 On Ramp	184	CY	$10	$1,840
Remove Culvert at Sta 6700 Mann Rd	560	CY	$10	$5,600
Remove Culvert at Sta 5700 I-35 Off Ramp	319	CY	$10	$3,190
Remove Culvert at Sta 2200 Calton Road	556	CY	$10	$5,560
Remove Culvert at Sta 1000 Off Ramp (out of service)	578	CY	$10	$5,780
Remove Culvert at Sta 800 I-35 Northbound Frontage Road	578	CY	$10	$5,780
Install 8-5'x3' box culverts at Sta 7300 I-35 On Ramp, 166 LF ea.	1,328	CY	$150	$199,200
Install 2-5'x3' box culverts at Sta 6700 Mann Rd, 240 LF ea.	480	LF	$150	$72,000
Install 4-7'x3' box culverts at Sta 6700 Mann Rd, 240 LF ea.	960	LF	$255	$244,800
Install 6-7x3' box culverts at Sta 5700 I-35 Off Ramp, 205 LF ea	1,230	LF	$255	$313,650
Install 5-10'x6' box culverts at Sta 3150 I-35 Off Ramp, 150 LF ea	750	LF	$440	$330,000
Install 5-10'x6' box culverts at Sta 2200 Calton Road, 156 LF ea	780	LF	$440	$343,200
Install 6-10'x6' box culverts at Sta 800 I-35 Northbound Frontage Road, 80 LF ea.	936	LF	$440	$411,840
Install Guard Rail	1,780	LF	$50	$89,000
Install HMAC/sidewalk/curb and gutter	1	EA	$531,793	$531,790
Channel Improvements: Trapezoidal concrete channel (0.5:1 SS, 40'-60' bottom width, 8180' length)				
Remove concrete rip-rap	27,157	SY	$10	$271,568
Excavation and Haul	50,696	CY	$9	$456,264
Install concrete channel, assume 0.5' thickness	25,939	CY	$400	$10,375,430
Miscellaneous				
Erosion/Sedimentation Control (0.5% of Total)	1	LS	$68,566	$68,566
Traffic Control	6	MO	$12,000	$72,000
Sub-Total				**$13,853,738**
General Conditions and Overhead @ 5%				**$692,687**
Contigency @ 5%				**$692,687**
Engineeering - Design & Construction Phase Services @10%				**$1,385,374**
Total				**$16,624,486**

Zacate Creek Floodplain Protection Plan

Cost Estimate

Zone 7

Storm Drainage System in Southbound Frontage Road, Diversion to Rio Grande and Channel Improvements on Tributary 1 downstream of Calton Rd

	Quantity	Unit	Unit Price	Total
Storm Drainage System in Southbound Frontage Road				
Curb Inlets at every 500 ft along system	37	EA	$4,000	$146,260
Manholes at every 500 ft along system	31	EA	$3,400	$103,920
Excavation Roadway (assume 10' culvert rise +3' cover)	204,808	CY	$4	$819,230
Culverts				
Assume 1-10X10 mbc from Mann Dr to Hillside Rd	3510	LF	$622	$2,183,220
Assume 2-10X10 from Hillside Rd to Farias St	3923	LF	$1,244	$4,880,210
Assume 3-10X10 from IH-35 NB Fronatage Rd to Rio Grande	7847	LF	$1,866	$14,642,500
Install HMAC/curb and gutter	1	EA	$7,060,284	$7,060,280
Channel Improvements: Rectangular concrete channel from Calton Rd to IH-35 Northbound Frontage Road (less than 0.5:1 SS, 50' bottom width, 1215' length)				
Remove concrete rip-rap	9,742	SY	$10	$97,420
Excavation and Haul	7,052	CY	$9	$63,470
Install concrete channel, assume 1' thickness	2,633	CY	$400	$1,053,390
Floodwall between Tributary 1 and ZC at junction,	1	EA	$250,000	$250,000
Miscellaneous				
Erosion/Sedimentation Control (0.5% of Total)	1	LS	$156,500	$156,500
Traffic Control	24	MO	$12,000	$288,000
Sub-Total				**$31,744,400**
General Conditions and Overhead @ 5%				**$1,587,220**
Contigency @ 5%				**$1,587,220**
Engineeering - Design & Construction Phase Services @10%				**$3,174,440**
Total				**$38,093,280**
Zone 6				**$16,624,486**
Zone 7 Total				**$54,717,766**

Zacate Creek Floodplain Protection Plan
Cost Estimate

Zone 8
Structure Improvements:Reach 5 and 6 and the difference increased work for Alts 1,2,3,4, 5 and 6

	Quantity	Unit	Unit Price	Total
Structure Improvements: Reach 5 and 6				
Road Demolition (4)	4,462	SY	$10	$44,620
Remove Guardrails	1400	LF	$10	$14,000
Remove & Install bridges along Reaches 5 and 6				
Sanchez/W.Gusta	5,800	SF	$200	$1,160,000
Park/Clark St	15,900	SF	$250	$3,975,000
Jefferson/W Lyon	8,700	SF	$250	$2,175,000
US 59	9,900	SF	$250	$2,475,000
Pedestrian Bridge ds of Chicago/Taylor St	1,400	SF	$200	$280,000
Trib 2A Increased Culvert Costs				
Calton Rd	1	EA	$12,662	$12,662
Chaparral St	1	EA	$16,107	$16,107
Trib 1 Increased Culvert Costs				
I-35 On Ramp	1	EA	$224,963	$224,963
Mann Rd	1	EA	$81,312	$81,312
Mann Rd	1	EA	$141,408	$141,408
I-35 Off Ramp	1	EA	$181,179	$181,179
I-35 On Ramp	1	EA	$271,650	$271,650
Calton Rd	1	EA	$138,216	$138,216
I-35 NB FR	1	EA	$85,056	$85,056
Channel Improvements: Reach 5 and 6 and the difference increased work for Alts 1,2,3,4, and 6				
Remove concrete pilot channel (reach 5 and 6)	445	SY	$10	$4,450
Excavation and Haul (reach 5, 6 and incresase from prev alts)	329,697	CY	$9	$2,967,270
Install concrete pilot channel, assume 6" thickness (reach 5 and 6)	4,003	CY	$400	$1,601,040
Install concrete channel, assume 0.5' thickness (prev alts have increase in ch area)	18,643	CY	$400	$7,457,000
Turf Reinforcement Matting	47,752	SY	$5	$238,760
Miscellaneous				
Erosion/Sedimentation Control (0.5% of Total)	1	LS	$117,723	$117,720
Traffic Control	24	MO	$12,000	$288,000
Sub-Total				**$23,950,413**
General Conditions and Overhead @ 5%				**$1,197,521**
Contigency @ 5%				**$1,197,521**
Engineeering - Design & Construction Phase Services @10%				**$2,395,041**
Total				**$28,740,496**
Zone 2				**$7,783,688**
Zone 3				**$20,467,560**
Zone 4				**$2,790,000**
Zone 5				**$523,908**
Zone 6				**$16,624,486**
Zone 8 Total				**$76,930,137**

APPENDIX H
ALTERNATIVE BENEFIT CALCULATIONS

Zacate Creek HAZUS Loss Estimation Results Summary

Zacate FPP Alternatives	Displaced Households		Residential Property Losses ($ Millions)		Total Property Losses ($ Millions)		Business Interruptions Losses ($ Millions)		Total Damages		Total Benefits ($ Millions)		Costs ($ Millions)
	10-year event	100-year event	10-year event	100-year event	10-year event	100-year event	10-year event	100-year event	10-year event	100-year event	10-year event	100-year event	
Existing Conditions	2,198	3,579	36.54	67.61	76.05	141.24	1.5	2.42	78	144			
Zone 1	2,111	3,343	37.29	62.21	73.08	130.63	1.35	2.25	74.43	132.88	$3.1	$10.8	N/A*
Zone 2	1,472	2,530	23.63	47.85	56.81	110.96	1.22	2.01	58.03	112.97	$19.5	$30.7	$7.8
Zone 3	2,010	3,173	35.13	58.20	69.40	121.69	1.29	2.10	70.69	123.79	$6.9	$19.9	$20.5
Alternative 3A	1,844	3,001	29.34	55.27	61.96	114.21	1.22	1.91	63.18	116.12	$14.4	$27.5	N/A
Zone 4	1,292	2,250	21.27	42.73	51.98	99.28	1.11	1.78	53.09	101.06	$24.5	$42.6	$31.0
Zone 5	2,101	3,354	37.01	62.27	72.50	130.68	1.34	2.26	73.84	132.94	$3.7	$10.7	$0.5
Zone 6	2,073	3,278	36.67	60.59	69.22	124.96	1.23	2.12	70.45	127.08	$7.1	$16.6	$16.6
Zone 7	1,846	2,670	31.49	45.51	51.15	81.44	0.77	1.37	51.92	82.81	$25.6	$60.9	$54.7
Zone 8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$28.7
Combined Improvements													
Zone 7+6+5+4+3+2	1,040	1,589	15.64	26.23	30.44	52.81	0.54	0.98	30.98	53.79	$46.6	$89.9	$86.3
Zone 8+6+5+4+3+2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$76.9

*Funding in place

Quick Assessment Report

July 10, 2009

Study Region :	Webb County_HazusData
Scenario :	Existing 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,198
Short Term Shelter (# People)	5,277

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	36.54
Total Property (Capital Stock) Losses ($ Millions)	76.05
Business Interruptions (Income) Losses ($ Millions)	1.50

Disclaimer:

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Quick Assessment Report

July 13, 2009

Study Region :	Webb County_HazusData
Scenario :	Existing 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	3,579
Short Term Shelter (# People)	9,325

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	67.61
Total Property (Capital Stock) Losses ($ Millions)	141.24
Business Interruptions (Income) Losses ($ Millions)	2.42

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Quick Assessment Report

July 13, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative_1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,111
Short Term Shelter (# People)	5,057

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	37.29
Total Property (Capital Stock) Losses ($ Millions)	73.08
Business Interruptions (Income) Losses ($ Millions)	1.35

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Quick Assessment Report

July 13, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative_1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	3,343
Short Term Shelter (# People)	8,645

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	62.21
Total Property (Capital Stock) Losses ($ Millions)	130.63
Business Interruptions (Income) Losses ($ Millions)	2.25

Quick Assessment Report

July 13, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 2+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	1,472
Short Term Shelter (# People)	3,373

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	23.63
Total Property (Capital Stock) Losses ($ Millions)	56.81
Business Interruptions (Income) Losses ($ Millions)	1.22

Disclaimer:

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Quick Assessment Report

July 14, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 2+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,530
Short Term Shelter (# People)	6,347

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	47.85
Total Property (Capital Stock) Losses ($ Millions)	110.96
Business Interruptions (Income) Losses ($ Millions)	2.01

Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 3+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,010
Short Term Shelter (# People)	4,807

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	35.13
Total Property (Capital Stock) Losses ($ Millions)	69.40
Business Interruptions (Income) Losses ($ Millions)	1.29

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 3+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	3,173
Short Term Shelter (# People)	8,099

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	58.20
Total Property (Capital Stock) Losses ($ Millions)	121.69
Business Interruptions (Income) Losses ($ Millions)	2.10

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 3A+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	1,844
Short Term Shelter (# People)	4,353

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	29.34
Total Property (Capital Stock) Losses ($ Millions)	61.96
Business Interruptions (Income) Losses ($ Millions)	1.22

Disclaimer:

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 3a+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	3,001
Short Term Shelter (# People)	7,605

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	55.27
Total Property (Capital Stock) Losses ($ Millions)	114.21
Business Interruptions (Income) Losses ($ Millions)	1.91

Disclaimer:

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 4+3+2+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	1,292
Short Term Shelter (# People)	2,935

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	21.27
Total Property (Capital Stock) Losses ($ Millions)	51.98
Business Interruptions (Income) Losses ($ Millions)	1.11

Disclaimer:

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 4+3+2+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,250
Short Term Shelter (# People)	5,557

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	42.73
Total Property (Capital Stock) Losses ($ Millions)	99.28
Business Interruptions (Income) Losses ($ Millions)	1.78

Disclaimer:

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Quick Assessment Report

July 16, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 5+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,101
Short Term Shelter (# People)	5,037

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	37.01
Total Property (Capital Stock) Losses ($ Millions)	72.50
Business Interruptions (Income) Losses ($ Millions)	1.34

Disclaimer:

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The estimates of social and economic impacts contained in this report were produced using HAZUS loss estimation methodology software which is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this report and the actual social and economic losses following a specific flood. These results can be improved by using enhanced inventory data and flood hazard information.

Quick Assessment Report

July 16, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 5+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	3,354
Short Term Shelter (# People)	8,684

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	62.27
Total Property (Capital Stock) Losses ($ Millions)	130.68
Business Interruptions (Income) Losses ($ Millions)	2.26

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Quick Assessment Report

July 15, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 6+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,073
Short Term Shelter (# People)	4,974

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	36.67
Total Property (Capital Stock) Losses ($ Millions)	69.22
Business Interruptions (Income) Losses ($ Millions)	1.23

Disclaimer:

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Quick Assessment Report

July 16, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 6+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	3,278
Short Term Shelter (# People)	8,414

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	60.59
Total Property (Capital Stock) Losses ($ Millions)	124.96
Business Interruptions (Income) Losses ($ Millions)	2.12

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 7+6+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	1,846
Short Term Shelter (# People)	4,333

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	31.49
Total Property (Capital Stock) Losses ($ Millions)	51.15
Business Interruptions (Income) Losses ($ Millions)	0.77

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Quick Assessment Report

July 24, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 7+6+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	2,670
Short Term Shelter (# People)	6,683

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	45.51
Total Property (Capital Stock) Losses ($ Millions)	81.44
Business Interruptions (Income) Losses ($ Millions)	1.37

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Quick Assessment Report

July 27, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 7+6+5+4+3+2+1 10-year
Return Period:	10
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	1,040
Short Term Shelter (# People)	2,251

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	15.64
Total Property (Capital Stock) Losses ($ Millions)	30.44
Business Interruptions (Income) Losses ($ Millions)	0.54

Quick Assessment Report

July 27, 2009

Study Region :	Webb County_HazusData
Scenario :	Alternative 7+6+5+4+3+2+1 100-year
Return Period:	100
Analysis Option:	0

Regional Statistics

Area (Square Miles)	3,356
Number of Census Blocks	6,660
Number of Buildings	
Residential	57,636
Total	62,408
Number of People in the Region (x 1000)	193
Building Exposure ($ Millions)	
Residential	5,258
Total	7,831

Scenario Results

Shelter Requirements

Displaced Population (# Households)	1,589
Short Term Shelter (# People)	3,621

Economic Loss

Residential Property (Capital Stock) Losses ($Millions)	26.23
Total Property (Capital Stock) Losses ($ Millions)	52.81
Business Interruptions (Income) Losses ($ Millions)	0.98

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APPENDIX I
DIGITAL DATA

APPENDIX J
TWDB COMMENTS

March 9, 2010

Mr. Riazul Mia, P.E.
Director, Environmental Services
City of Laredo
P.O. Box 579
Laredo, Texas 78042-0579

Re: Flood Protection Planning Contract between the Texas Water Development Board (TWDB) and the City of Laredo (CITY), TWDB Contract No. 0804830837, Draft Final Report Comments

Dear Mr. Mia:

Staff members of the TWDB have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT I provides the comments resulting from this review. As stated in the TWDB contract, the CITY will consider incorporating draft report comments from the EXECUTIVE ADMINISTRATOR as well as other reviewers into the final report. In addition, the CITY will include a copy of the EXECUTIVE ADMINISTRATOR'S draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. The CITY shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

If you have any questions concerning the contract, please contact Ivan Ortiz, the TWDB's designated Contract Manager for this project at (512) 463-8184.

Sincerely,

Dan Harden
for Carolyn L. Brittin
Deputy Executive Administrator
Water Resources Planning and Information

Enclosures

c: Ivan Ortiz, TWDB

ATTACHMENT
Review of Draft Report of Contract No. 0804830837
Zacate Creek Flood Protection Study Draft

1. Page 25, Section 3.3, 2nd paragraph indicates that Table 8 refers to flood flow levels while Table 8 (page 24) shows Mannings Roughness coeficients for various open channel surfaces. The referenced flows are shown in Table 9. Please change text to match the Table.

2. Page 28, second paragraph (third paragraph of Section 4.2), states that alternative configurations to increase flood conveyance in this location is further discussed in Section 5.3.2 - while no Section 5.3.2 exists in the document. Please correct the referenced section.

3. Page 29, first paragraph (last paragraph of Section 4.2), states that additional discussion of the Shiloh Detention Basin can be found below in Sections 4.2 and 5.3.1 - while this is the last paragraph of Section 4.2 and no Section 5.3.1 is found in the document. Please correct the referenced sections.

4. Pages 29 and 30, Section 4.3 second and third paragraphs each refer to the three land use conditions included in Table 10 while Table 10 only illustrates two land use conditions - Platted 2008 and Ultimate Conditions. Please correct text to reference the appropriate land use conditions.

5. In general, all studies presented by this draft report would be appropriate as support to an application to the Board for financing as the preliminary engineering feasibility information, provided that all additional information required by Board rules, 31 TAC 363.404-404, and required to make legal findings required by Texas Water Code Chapter 17.7771-776 will be required at the time of application.

6. Please also be reminded that the eligibility of Clean Water State Revolving Funds that is considered by the draft report in order to implement the flood protection project will be determined according to 31 TAC 375, Subchapter C.

City of Laredo
Environmental Services Department
619 Reynolds St.
Laredo, Texas 78040
Ph: (956) 794-1650 Fax: (956) 727-7944

March 19, 2010

Mr. Ivan Ortiz, CFM
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

Re: Flood Protection Planning Contract between the Texas Water Development Board (TWDB) and the City of Laredo, TWDB Contract No. 0804830837, Final Report Comments

Dear Mr. Ortiz:

Thank you for your time in review of the above-referenced report, and for the TWDB's support of this City of Laredo study. Following is an itemized response (*italics*) to the comments dated March 9, 2010:

1. Page 25, Section 3.3, 2nd paragraph indicates that Table 8 refers to flood flow levels while Table 8 (page 24) shows Manning's Roughness coefficients for various open channel surfaces. The referenced flows are shown in Table 9. Please change text to match the Table. *The flow rate comparison is shown in Table 6 (not Table 8). This has been corrected in the text. Table 9 includes a comparison of computed water surface elevations and is properly referenced in this paragraph.*

2. Page 28, second paragraph (third paragraph of Section 4.2), states that alternative configurations to increase flood conveyance in the location is further discussed in Section 5.3.2 – while no Section 5.3.2 exists in the document. Please correct the referenced section. *The reference to Section 5.3.2 has been changed to read 5.2.2.*

3. Page 29, first paragraph (last paragraph of Section 4.2), states that additional discussion of the Shiloh Detention Basin can be found below in Sections 4.2 and 5.3.1 – while this is the last paragraph of Section 4.2 and no Section 5.3.1 is found in the document. Please correct the referenced sections. *The reference to Section 4.2 has been deleted in this location; 5.3.1 has been changed to 5.2.1.*

4. Pages 29 and 30, Section 4.3 second and third paragraphs each refer to the three land use conditions included in Table 10 while Table 10 only illustrates two land use conditions – Platted 2008 and Ultimate Conditions. Please correct text to reference the appropriate land use conditions. *The text in the two paragraphs before Table 10 has been modified to clarify that the three land use conditions modeled were Existing, Platted (2008), and Ultimate. The text describing the content of Table 10 has been modified to clarify that this table shows the impact of the Platted and Ultimate conditions analyses when compared to the Existing conditions.*

5. In general all studies presented by this draft report would be appropriate as support to an application to the Board for financing as the preliminary engineering feasibility information, provided that all additional information required by Board rules 31, TAC 363.404-404, and required to make legal finding required by Texas Water Code Chapter 17.7771-776 will be required at the time of application. *Noted, Thank you!*

6. Please also be reminded that the eligibility of Clean Water State Revolving Funds that is considered by the draft report in order to implement the flood protection project will be determined according to 31 TAC 375, Subchapter C. *Noted.*

Attached please find six (6) bound double-sided copies of the final report, as well as one (1) CD-ROM containing the entire Final Report and related computer models. The City of Laredo City Council accepted the Flood Protection Plan on December 21, 2009.

Please feel free to contact me if you have any questions.

Sincerly,

Riazul Mia, PE, CFM
Director

Encl.

Cc: Thomas W. Mountz, PE, D.WRE, CFM, Espey Consultants, Inc.

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