Espey Consultants, Inc.

SAN MARCOS
FLOOD PROTECTION PLAN
VOLUME I OF II
REPORT AND APPENDICES A-F

City of San Marcos

In Association With:

Delta Survey Group, Inc.
Edwards Aquifer Authority
Guadalupe Blanco River Authority
Hays County
Texas Water Development Board
Upper San Marcos Watershed RFCD

October 2007

Project No. 5045.116

SAN MARCOS
FLOOD PROTECTION PLAN

Volume I of II

Volume I Report and Appendices A-F
Volume II Appendices G-S

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EXECUTIVE SUMMARY

This document is a Flood Protection Plan for the City of San Marcos located in Hays County, Texas. In response to concerns over major flooding events and drainage problems, the City of San Marcos and its supporting partners (Hays County, Upper San Marcos Watershed District, Guadalupe-Blanco River Authority, and Edwards Aquifer Authority) applied for funding assistance through the Flood Protection Planning Program of the Texas Water Development Board. The project contracts were executed on July 6, 2005.

The purpose of the project was to develop comprehensive hydrologic and hydraulic models of watersheds within and upstream of the City of San Marcos and its ETJ to be utilized in developing flood protection alternatives (both structural and non-structural). The study includes the watersheds of Blanco River, San Marcos River, Bypass Creek, Cottonwood Creek, Purgatory Creek, Sessom Creek, Sink Creek, and Willow Springs Creek. The study follows the natural course of the watershed, and therefore, evaluates the creeks as a system independent of political boundaries.

Major elements of the San Marcos Flood Protection Plan include: comprehensive hydrologic and hydraulic analysis, flood mitigation recommendations, and preliminary phasing and implementation recommendations to implement the flood mitigation alternatives.

1.0 INTRODUCTION

This report includes a hydrologic and hydraulic analysis of the watersheds within and near the City of San Marcos, Texas, as part of the San Marcos Flood Protection Plan prepared for the City of San Marcos. The San Marcos Flood Protection Plan is a grant project primarily funded by the Texas Water Development Board (TWDB) and the City of San Marcos (COSM). In-kind services are also provided by Hays County, the Guadalupe-Blanco River Authority (GBRA), the Edwards Aquifer Authority (EAA), and the Upper San Marcos Watershed District (USMWD). The following sections of this report describe the methods, data, and assumptions used in the analyses, as well as the results obtained.

The City of San Marcos is a rapidly growing community in central Texas located along Interstate Highway 35 (IH 35) between San Antonio and Austin. The San Marcos and Blanco Rivers and their respective creeks and tributaries run through the city, providing a source of drinking water, recreational opportunities, and miles of unique riparian corridor habitat. Nestled against the Balcones Escarpment, San Marcos also lies in a region known as "Flash Flood Alley". This area of central Texas is prone to intense rainfall events that have been known to deposit enormous volumes of water in relatively short timeframes. Coupled with steep-gradient topography and hard surface geology, runoff from intense storms frequently causes flash floods. These flooding problems are further exacerbated by urbanization. While flash flooding can be simply a nuisance in some smaller storms, since 1998, the San Marcos area has been hit with four major storm and flood events, resulting in loss of life and extensive damage to property and infrastructure.

Hays County and the San Marcos area was last studied as part of the September 2, 2005, Flood Insurance Study (FIS). It is important to note that this study was a re-delineation of floodplains; no new hydrologic or hydraulic data was generated.

The City of San Marcos is resolved to undertake a comprehensive view of its flooding risk and to implement a series of solutions that provide the most effective and sustainable approach to mitigating this risk to public health and safety. The San Marcos Flood Protection Plan is intended to guide the City in that endeavor.

1.1 SCOPE OF SERVICES

The primary purpose of this project is to identify flooding issues and possible mitigation alternatives for the City. To that end, the scope of this project includes a hydrologic and hydraulic analysis for riverine areas within the City of San Marcos. These analyses are used to determine where the riverine flood problems are located. Subsequently, mitigation alternatives are evaluated based on these analyses. Most of the mitigation alternatives have an associated cost-benefit analysis that may be used by the City to rank or prioritize possible future mitigation projects.

The scope of this project includes the hydrologic study of the seven major watersheds totaling approximately 540 square miles in San Marcos and areas upstream. The hydrologic analysis includes the evaluation of the existing conditions 50%, 10%, 4%, and 1% (2-, 10-, 25-, and 100-year) annual chance storm events. The hydrologic analysis also evaluates the ultimate conditions 1% annual chance event. The seven major watersheds that drain the City include the following:

1) Blanco River;
2) Bypass Creek;
3) Cottonwood Creek;
4) Purgatory Creek;
5) San Marcos River;
6) Sink Creek; and
7) Willow Springs Creek.

For the 42.7 miles of stream scoped for detail study, the hydraulic analysis evaluates the existing conditions 50%, 10%, 4%, and 1% annual chance storm events. The hydrologic analysis also evaluates the ultimate conditions 1% annual chance event. The hydraulic analysis includes the delineation of the 1% annual chance existing conditions floodplain as well as the 1% ultimate conditions floodplain. The table below lists the streams included in the study.

Table 1. Studied Streams Table

Flooding Source	**Reach Limits**	**Number of Hydraulic Reaches**	**Reach Length (ft)**	**Number of Structures**
Blanco River	From confluence with San Marcos River to 3,200 feet upstream of IH 35	1	35,547	5
Bypass Creek	From confluence with Blanco River to Blanco River Diversion 1	3	35,423	6
Cottonwood Creek	From NRCS Reservoir No. 13 to Centerpoint Road	4	47,767	9
Purgatory Creek	From confluence with San Marcos River to confluence with Franklin Square Tributary	3	28,470	11
Rio Vista	From confluence with San Marcos River to State Hwy 80	1	3,353	1
San Marcos River	From confluence with Bypass Creek to confluence with Sessom Creek	2	36,815	9
Schulle Canyon	From confluence with Sink Creek to Owen Street	1	6,972	2
Sessom Creek	From confluence with San Marcos River to 2,800 feet upstream of LBJ Drive	1	5,762	5
Willow Springs Creek	From confluence with San Marcos River to 2,100 feet upstream of Hunter Road	5	25,443	15
	Total	*21*	*225,552*	*63*
	Total Reach Length (miles)		*42.7*	

1.2 ADVISORY COMMITTEE

The Advisory Committee consists of representatives of the participating entities. These entities include the City of San Marcos, Hays County, GBRA, EAA, USMWD, and Texas State University. The Advisory Committee was created for the purpose of formulating a comprehensive view of the City of San Marcos flooding risk, and review and implementation of a series of alternatives that provide the most effective and sustainable approach to mitigating this risk to public health and safety. The following is a summary of the in-kind services provided by the primary participating entities within the Advisory Committee.

The City of San Marcos contributed staff time in the following areas: data collection (compilation of existing reports, geographic information system (GIS) data, field survey of slab elevations, inventory and assessment of environmental features), data preparation in GIS format, review of hydrologic and hydraulic models, coordination with other participating entities, review and prioritization of proposed flood mitigation alternatives.

In addition, the City of San Marcos provides FEMA elevation certificates as a service to residents located in Special Flood Hazard Areas.

Hays County provides in-kind services for technical assistance in the form of planning, development and review of alternatives, provision of GIS data, and other services as needed for an amount of $5,000.

The EAA provides in-kind services for technical assistance in the form of planning, development and review of alternatives, provision of GIS data, environmental data, and any available hydrogeologic data or other services which may be needed, for an amount of $5,000.

The GBRA provides in-kind technical assistance in the form of planning, development and review of alternatives, and special technical assistance in flood forecasting, for an amount of $5,000.

The USMWD provides in-kind technical assistance and coordination with the NRCS, in the form of planning, development and review of alternatives, and special technical assistance in brush management strategies.

Public meetings were held three times to present to the public the purpose of the project, scope of services, and to solicit resident input. Residence and business owners were encouraged to fill out Property Flood Survey Forms that were distributed at this meeting. Public meeting minutes and notes can be referenced in Appendix Q.

Advisory Committee meetings were held twice to submit a summary of progress and to further discuss the preliminary flood mitigation alternatives. Advisory Committee meeting minutes and notes can be referenced in Appendix Q.

1.3 LOCATION AND DESCRIPTION OF WATERSHED

The watersheds that drain to and through the City of San Marcos are known for flash flooding. These watersheds are highly urbanized, steep watersheds flowing primarily from west to east through the City. The meteorological characteristics of central Texas, along with a geographic influence caused by the Balcones Escarpment, produce conditions conducive to large rainstorms in the area. Many of the highest rainfall intensities in the world have occurred in central Texas—a 1921 storm in Thrall, Texas, produced 32 inches of rain in 12 hours, and a 1935 storm near D'Hanis, Texas, produced 22 inches of rain in 2 hours 45 minutes (Slade 1986). The most notable event to strike the San Marcos was the October 1998 event where 15 inches of rain fell in a 24-hour period causing substantial damage to the downtown area. The figure below illustrates the location of San Marcos area relative to the Balcones escarpment as well as the locations, dates, and depths for selected large rainstorms in central Texas.

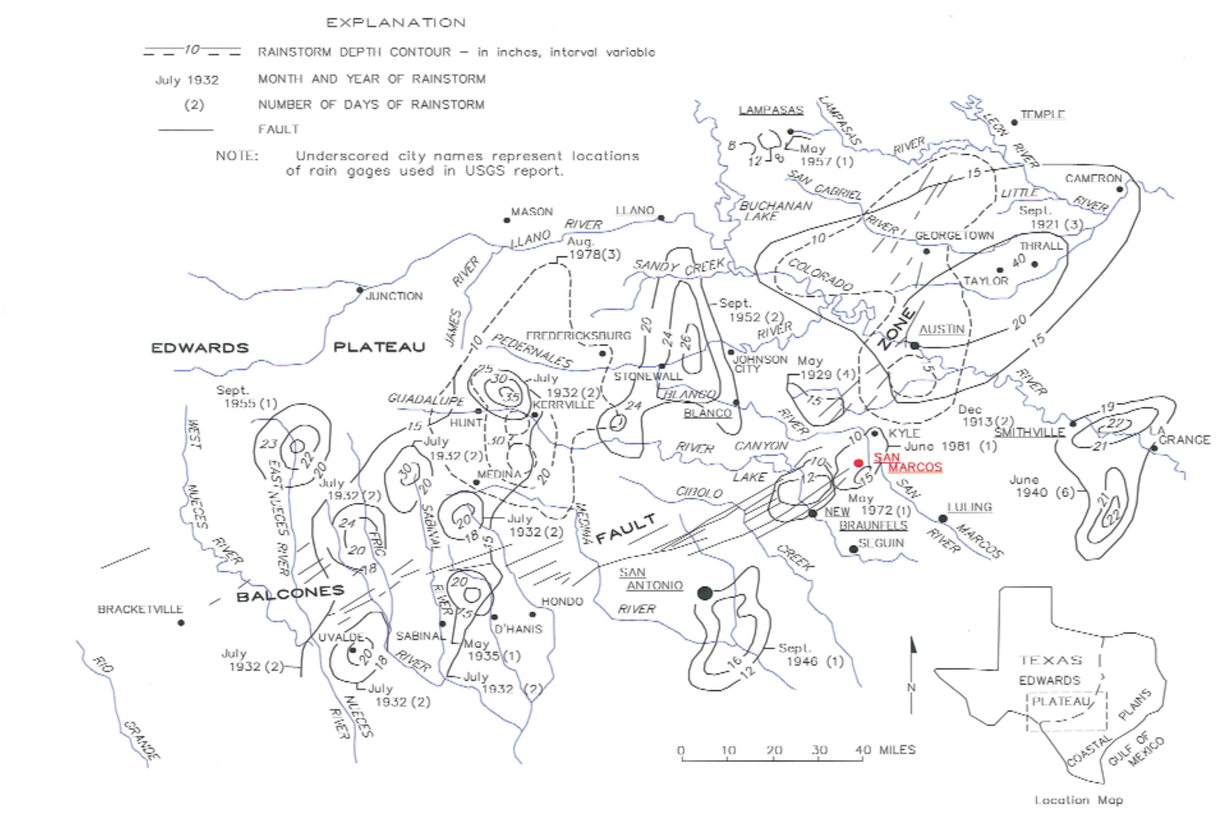

Figure 1. Balcones Escarpment and San Marcos, Texas

1.4 PURPOSE OF THE FLOOD PROTECTION PLAN

The existing flood hazard faced by the City of San Marcos is a combination of flooding and erosion issues in known special flood hazard areas, out-of-bank flooding and erosion in unstudied tributaries, and surcharge in secondary drainage systems. The potential for further flood hazard exists as currently undeveloped areas, both in and outside of the City of San Marcos' jurisdiction, become developed. The proposed planning effort will consider the hydrologic characteristics and hydraulic performance of each watershed in terms of both the existing and ultimate watershed condition. All alternatives are evaluated in light of known environmental constraints. An environmental constraints map is included in this report as Exhibit 6 in Appendix A.

One goal of the planning effort is to help not only identify alternative solutions but also prioritize them for implementation. Structural flood protection measures may include any combination of channelization, bridge and culvert upgrades, dual purpose flood control / water supply reservoirs, and detention facilities. Non-structural flood protection measures may include recommendations for revisions to current drainage policies, buy-out of floodprone property, a creek maintenance program, and a coordinated early warning system in cooperation with GBRA, Hays County, and other technical partners.

A second goal of the planning effort is to reduce the flooding risk that is borne disproportionately by the City's lower income residents. Mitigation measures, which can reduce this risk, will directly benefit those who are least able to recover from losses incurred in a flood event. In addition, the protection offered by the proposed improvements will protect property values, thereby strengthening the City's tax base and promoting reinvestment in these areas of the community. Furthermore, as a byproduct of this planning effort, elevation certificates will be prepared, as appropriate, at no cost to residents. These elevation certificates will directly benefit these policyholders under the National Flood Insurance Program (NFIP).

Byproducts of the planning effort will also contribute to the mission of minimizing the exposure of lives and property. A public meeting will be scheduled to both solicit input from the public and educate the public on flood hazard risks identified in the planning. The maps of the existing and ultimate 1% annual chance floodplain, with and without recommended improvements, will further serve to educate the public about the nature of the flood hazard risk. The project deliverables have also been provided in a format to enhance the City's Geographic Information System (GIS) database.

This study is not intended to be 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.

1.5 BASELINE DATA ACQUISITION

The completion of the hydrologic and hydraulic analysis to support the San Marcos Flood Protection Plan required baseline data acquisition of geospatial data to accurately model flooding conditions in San Marcos. The primary data sources for the creation of hydrologic and hydraulic models included:

<u>Aerial Imagery</u>
The aerial imagery used with the analysis was public domain data obtained from the Capital Area Council of Governments (CAPCOG). The aerial images used in the modeling effort are not included in Appendix S – Digital Data; however, they are readily available from CAPCOG or the City of San Marcos. The imagery was captured in February 2002 by The Sanborn Map Company Incorporated. The pixel resolution is one pixel equals two feet, and the data is horizontally referenced to the North American Datum of 1983 (NAD 83), Texas State Plane, Central Zone coordinate system.

<u>Field Survey</u>
The field survey of channel cross sections, bridges, culverts, and inline structures was performed between August 2005 and May 2006 by Delta Survey Incorporated. The field survey data is horizontally referenced to the NAD 83, Texas State Plane, South Central Zone coordinate system, and is vertically referenced to North American Vertical Datum of 1988 (NAVD 88). The raw survey data and formatted ESRI Shapefile data are included in Appendix S, Digital Data.

<u>LIDAR and Topographic Mapping</u>

The LIDAR data collection was performed by The Sanborn Map Company Incorporated in 2003 for the City of San Marcos. The raw LIDAR data was processed into contour intervals of two-feet and delivered to the City of San Marcos in shapefile format. The raw LIDAR data was not delivered to the City of San Marcos, only the processed contour information. The floodplain mapping associated with the San Marcos Flood Protection Plan was mapped onto a digital terrain model derived from the two-foot contour data set. The contour data is horizontally referenced to the NAD 83, Texas State Plane, South Central Zone coordinate system, and is vertically referenced to NAVD 88. The contour data formatted into shapefile format are included in Appendix S, Digital Data.

1.6 SUMMARY AND CONCLUSIONS

Several flood mitigation alternatives are considered as part of this flood protection plan. Both structural and non-structural alternatives were evaluated. All options are evaluated based on hydrologic and hydraulic benefit, environmental impact, cost-benefit ratio, etc. Alternatives evaluated and discussed further in this report include the following:

- Blanco River Watershed
  - Channel and overbank maintenance for Blanco River
  - Peak flow diversion to Bypass Creek
- Cottonwood Creek
  - “Detention Plus” upstream of IH 35
  - Floodplain ordinances and regulations
- Purgatory Creek
  - Channel maintenance and Hopkins Street culvert improvement
  - Castle Creek Drive culvert improvement
  - Expansion of NRCS Reservoir No. 5 flood storage volume
- Schulle Canyon
  - Culvert improvement
- Sessom Creek
  - Culvert improvement
- Willow Springs Creek
  - Downstream regional detention pond
  - Upstream regional detention pond
  - Channel maintenance

2.0 HYDROLOGIC ANALYSIS

The scope of this project includes a hydrologic study of the seven major watersheds totaling approximately 540 square miles in San Marcos and areas upstream. The hydrologic analysis includes the evaluation of the existing conditions 50%, 10%, 4%, and 1% (2-, 10-, 25-, and 100-year) annual chance storm events. The hydrologic analysis also evaluates the ultimate conditions 1% annual chance event. The seven major watersheds that drain the City include the following:

1) Blanco River 436.0 square miles at San Marcos River;
2) Bypass Creek 6.8 square miles at San Marcos River;
3) Cottonwood Creek 9.8 square miles at San Marcos River;
4) Purgatory Creek 37.0 square miles at San Marcos River;
5) San Marcos River 541.0 square miles at Bypass Creek;
6) Sink Creek 47.6 square miles at San Marcos River; and
7) Willow Springs Ck 4.5 square miles at San Marcos River.

Version 3.0.1 of the HEC-HMS computer program developed by the Hydrologic Engineering Center of the U. S. Army Corps of Engineers (USACE) is used in this analysis to estimate peak flow rates along each reach. Peak flow rates are computed along the watercourses for the 50%, 10%, 4%, 1%, and ultimate 1% annual chance storm events. This hydrology section describes the input parameters used in this analysis, the calibration efforts, the correlation with frequency analyses, and the recommended peak flow rates to be used in the floodplain analysis.

2.1 DRAINAGE AREA DELINEATION

The watersheds are delineated using United States Geological Survey (USGS) topographical survey data, City of San Marcos LIDAR data, and available site or highway record drawings. The watersheds are further divided into subareas at points of critical interest (i.e., confluence of large tributaries, floodwater retarding dams, etc.). All delineations are verified by field investigations. The rural watersheds such as the Blanco River and upstream sections of Sink Creek and Purgatory Creek contain large subareas. The portions of the watersheds that are located within the City are further subdivided to aid in the analyses. A drainage area map showing the watershed delineation and subarea nomenclature is included in Appendix A as Exhibit 1.

2.2 PRECIPITATION

The precipitation depths are taken from a USGS publication by Asquith and Roussel, *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas*, 2004. The Blanco River has one set of precipitation depths; the remaining watersheds have another set of precipitation depths. The variation in precipitation is due to the size of the Blanco River watershed and the fact that the geographic centroid is significantly different than that of the other watersheds. The table below shows the precipitation depths for various durations for the studied events.

Table 2. USGS Storm Depths for the San Marcos Flood Protection Plan

		USGS Cummulative Depth (in)							
		Blanco Watershed				Other San Marcos Watersheds			
Time	Time (min)	50%	10%	4%	1%	50%	10%	4%	1%
15 minutes	15	1.00	1.40	1.70	2.20	1.00	1.50	1.75	2.30
1 hour	60	1.75	2.70	3.20	4.30	1.80	2.75	3.30	4.40
2 hours	120	2.20	3.40	4.10	5.40	2.20	3.50	4.20	5.50
3 hours	180	2.40	3.70	4.60	6.10	2.40	3.80	4.70	6.30
6 hours	360	2.70	4.25	5.20	7.00	2.80	4.30	5.40	7.00
12 hours	720	3.10	4.70	6.00	8.20	3.10	4.95	6.00	8.20
24 hours	1440	3.50	6.10	7.50	10.00	3.55	6.20	7.60	10.20
48 hours	2880	4.00	7.00	8.70	11.50	4.00	7.00	9.00	12.00

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), which takes into account such factors as soil characteristics, land use/land condition, and antecedent soil moisture 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.

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 II is normally considered to be the average soil condition; however, studies have indicated that AMC II is not the average throughout 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 conditions.

Curve numbers were evaluated independently of imperious cover (i.e., these curve numbers reflect fair condition open spaces) for this analysis. A composite CN is computed based on area weighting of each hydrologic soil group within each subarea. Impervious cover values are entered separately from CN values into the HEC-HMS model. Tables listing the assumed CN values and the resulting range of CN values are shown below. A table describing the weighted CN values for each subarea is 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)[1], and
CN = runoff curve number.

Table 3. NRCS Curve Number Assumption Table

Group	AMC I	AMC II	AMC III
A	21	39	59
B	41	61	78
C	55	74	88
D	63	80	91

Key Assumption: Undeveloped grassland or range land.
Reference: National Engineering Handbook 4 (NEH-4)

Table 4. NRCS Curve Number Summary Table

Watershed	AMC II CN Range		Comment
	Minimum	Maximum	
Blanco River	72	77	Mostly Group C soils; large amount of Group D soil
Bypass Creek	61	73	Mostly Group B soil with some Group D
Cottonwood Creek	80	80	Almost exclusively Group D soils
Purgatory Creek	69	80	Mostly Group D with some Group C
San Marcos River	66	80	Mostly Group D with some Group B
Sink Creek	76	80	Mostly Group C soils; large amount of Group D soil
Willow Springs Creek	78	80	Mostly Group D soils with little Group C

Land use data is provided by the Texas Natural Resource Information System (TNRIS) and the City of San Marcos. The City's land use map is merged with the national land use map[2] from TNRIS to create a composite—in the areas of overlap, the City's land use map controls. This data reflects land use for the year 1992 for the national map and reflects land use for the year 2005 for the City's map. Impervious cover values are assigned to the various land use types. Land use types are based on nationally accepted land use categories for the rural portion of the map and based on City land use categories for the urban portion of the map.

The hydrologic model utilizes weighted impervious cover values calculated for each watershed subarea. A table listing the assumed impervious cover values for the various land types is shown below. All assumed impervious cover values are based on City of San Marcos criteria as well as previous watershed studies. The complete list of land use categories utilized and representative impervious cover values are shown in the figure below.

[1] Solve for S based on known CN
[2] The national land use map dataset was obtained from the United States Environmental Protection Agency (EPA) and was projected by TNRIS to the Texas State Mapping System Lambert Projection.

Table 5. Land Use Impervious Cover Assumption Table

LU Code	Description	I.C. %
COSM01	Vacant	0%
COSM03	Single Family Res	60%
COSM04	Mobile Home	50%
COSM04	Two Family Res	75%
COSM05	Multi-Family Res	75%
COSM06	Commercial	80%
COSM07	Public & Inst	80%
COSM08	Industrial	85%
COSM09	Open Space	0%
11	Residental	60%
12	Commercial and services	80%
13	Industrial	80%
14	Transportation, communication, utilities	80%
16	Mixed urban or built-up land	60%

LU Code	Description	I.C. %
17	Other urban or built-up land	60%
21	Cropland and pasture	0%
23	Confined feeding operations	0%
24	Other agricultural land	0%
31	Herbaceous rangeland	0%
32	Shrub and brush rangeland	0%
33	Mixed rangeland	0%
41	Deciduous forest land	0%
42	Evergreen forest land	0%
43	Mixed forest land	0%
53	Reservoirs	100%
75	Strip mines, quarries, gravel pits	0%
76	Transitional areas	0%

Notes: COSM denotes City of San Marcos land use categories.
All others are from the national dataset.

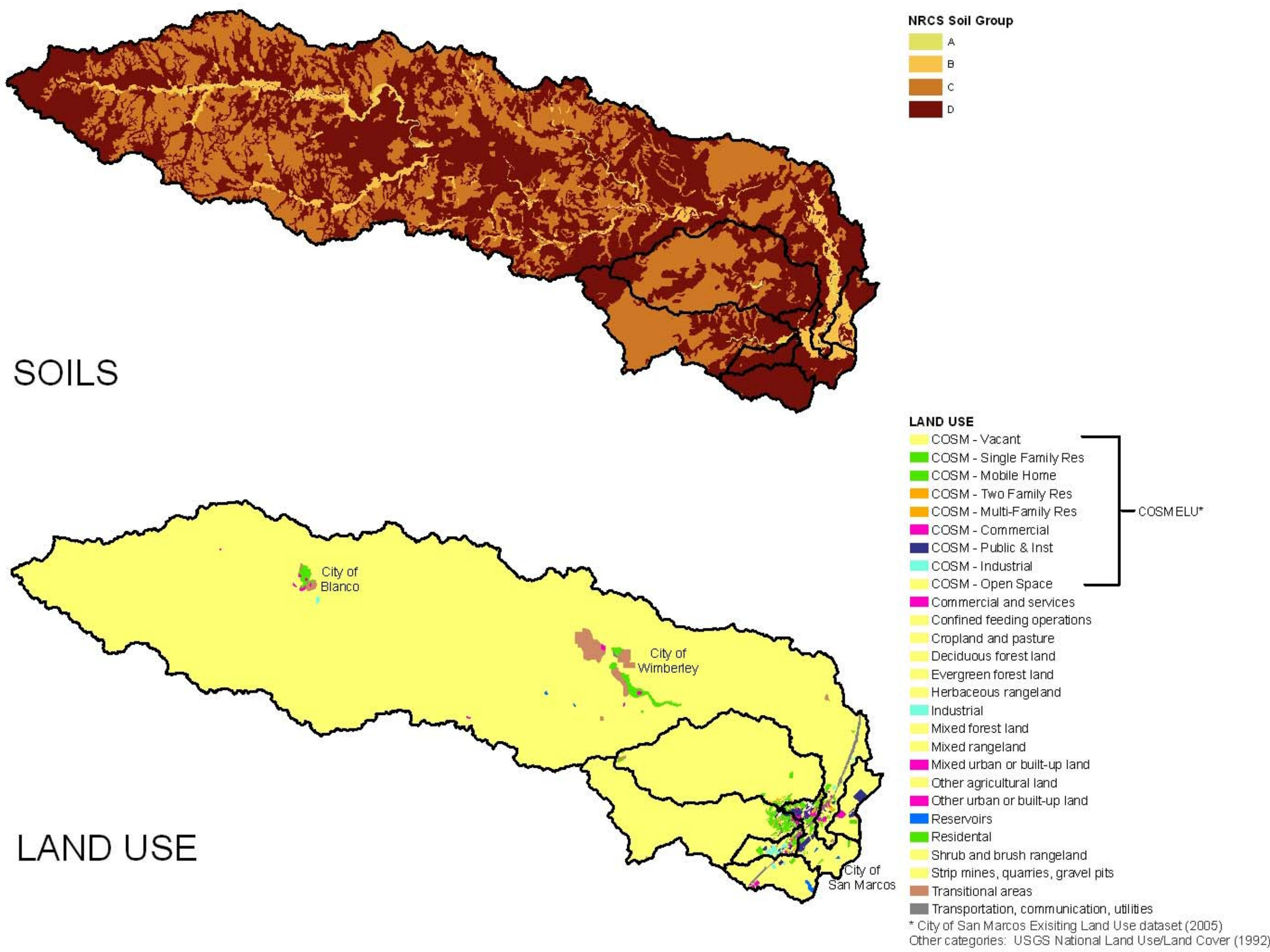

Figure 2. Soil and Land Use Maps

2.4 UNIT HYDROGRAPH METHOD

2.4.1 Background

A rainfall/runoff transformation is required to convert rainfall excess (total rainfall minus infiltration losses) into runoff from a particular subarea. The NRCS unit hydrograph option in HEC-HMS is used in this analysis to generate runoff hydrographs for each defined subarea within the studied watersheds. The unit hydrograph method represents a hydrograph for one unit [inch] of direct runoff and is a nationally accepted, standard engineering practice approach.

The dimensionless unit hydrograph developed by the NRCS (figure below) 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, q/qp, and its abscissa values as 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).

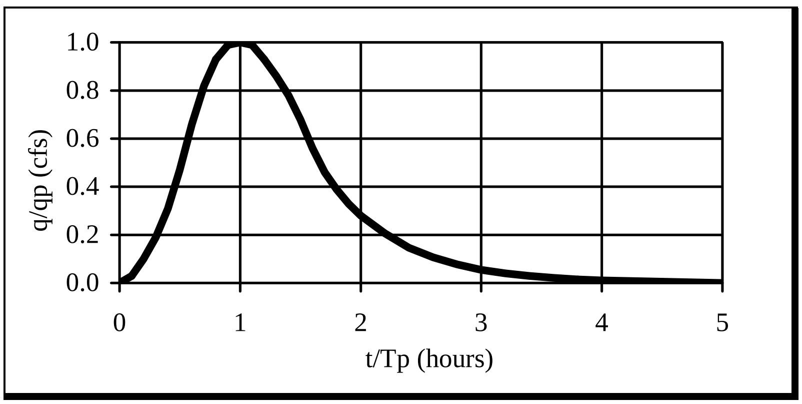

Figure 3. NRCS Unit Graph

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 before the runoff reaches it maximum peak. This delay is known as lag.

The time to peak is computed using the following equation:

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

Where:

T_{PEAK} = time to peak of the unitgraph (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:

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

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)[3]

2.4.2 Time of Concentration

The NRCS method assumes that the lag time of a watershed is 60 percent of the watershed's time of concentration. The time of concentration 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 subreach defined by the flow type: sheet flow, shallow concentrated flow, and channelized flow (including roadways, storm sewers, and natural/manmade channels). The methods prescribed in the NRCS' Technical Release 55 (TR-55) are used to determine the times of concentration for each flow segment in this analysis. Appendix D shows the results of the calculations for this analysis utilizing each typical flow segment presented below.

2.4.2.1 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, of 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 foot. Assuming sheet flow of less than or equal to 300 feet, travel time is computed as follows:

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

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).

[3] The peak rate factor of 484 has been known to vary from 600 in steep terrain to 300 in very flat, swampy terrain. The 484 value is standard engineering practice and is utilized in this analysis.

2.4.2.2 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 has greater depth.

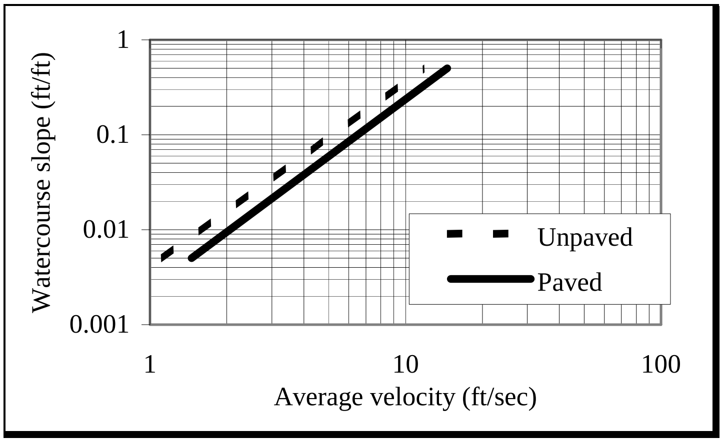

Figure 4. Avg. Velocities for Estimating Travel Time in Shallow Concentrated Flow Segments

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.

2.4.2.3 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 Stream Flow Routing

The Muskingum-Cunge method of stream flow routing is used in this analysis to modify hydrographs to reflect the effects of translation and attenuation within a channel reach. The required input for this method includes: channel length, channel slope, Manning's roughness coefficients, and an estimate of the hydraulic grade line slope. A trapezoidal channel shape is used to represent a typical channel section through each stream routing reach. A composite roughness coefficient is estimated in each routing reach based on a channel roughness coefficient ranging from 0.04 to 0.06 and an overbank roughness coefficient of 0.12. It is assumed that a composite Manning's n-value for a typical channel cross section in this study might range from 0.06 to 0.08.

Muskingum-Cunge routing is utilized as opposed to the commonly accepted Modified Puls routing technique. Muskingum-Cunge is a channel routing technique that does not take riverine valley storage (overbank storage) inot account. Modified Puls is a backwater routing technique that does take valley storage (overbank storage) into account. In steep areas such as the Texas Hill Country, channels are more incised and overbank storage is not appreciable. As shown later in this report, the Muskingum-Cunge technique generates acceptable results with a certain level of effort. A greater level of effort would be required with minimal change to the translation and attenuation of the peak flow rate in order to utilize the Modified Puls method.

2.5.2 Detention Basin Routing

Reservoir routing is performed using the Modified Puls method. Only large, regional detention structures are included in the hydrologic model. Smaller, local detention structures such as site detention ponds are not included in the hydrologic model. There are five independently modeled detention pond systems within this hydrologic model, which include:

1) NRCS Reservoir No. 1 (9,700 acre-foot reservoir on Sink Creek for 1% event);
2) NRCS Reservoir No. 2 (1,400 acre-foot reservoir on Sink Creek for 1% event);
3) NRCS Reservoir No. 3 (1,300 acre-foot reservoir on Sink Creek for 1% event);
4) NRCS Reservoir No. 4 (5,200 acre-foot reservoir on Purgatory Creek for 1% event); and
5) NRCS Reservoir No. 5 (3,700 acre-foot reservoir on Purgatory Creek for 1% event).

Each of these ponds has a typical primary outlet as well as an emergency spillway. A picture of the NRCS No. 5 primary outlet structure, which is typical of all five modeled reservoirs, is shown on the right. An elevation-storage rating curve and a storage-discharge rating curve is developed for each reservoir. The elevation-storage rating curves are developed using the 2003 LIDAR contour information utilizing the conical method to compute storage. The storage-discharge curves are developed using culvert and weir computation options in HEC-RAS. Each of the rating curves is compared to available design elevations shown in the NRCS construction drawings. The elevation-storage-discharge rating curves for all five reservoirs can be found in Appendix E.

Figure 5. NRCS No. 5 Primary Outlet (typical of all five NRCS reservoirs)

2.5.3 Diversion Routing

There are numerous locations throughout the study area where flow is diverted from one stream to another. The diversions modeled for this study include:

1) Blanco River diversion to Bypass Creek;
2) Blanco River diversion to Bypass Creek Tributary 1;
3) Blanco River diversion to Bypass Creek Tributary 2;
4) Cottonwood Creek diversion to Cottonwood Creek Tributary 3;
5) Cottonwood Creek Tributary 3 diversion to Cottonwood Creek Tributary 2; and
6) Cottonwood Creek Tributary 2 diversion to Cottonwood Creek Tributary 1.
7) Purgatory Creek Diversion No. 1 to Purgatory Creek;
8) Purgatory Creek Diversion No. 2 to Willow Springs Creek;

The **Blanco River diversions** represent overflow areas along the left overbank of the Blanco River downstream of IH 35. There are three primary areas where the Blanco River overtops its left overbank and flows into the Bypass Creek system. This is a natural occurrence due to low sections in the left overbank that act as a lateral weir. The three diversion relationships are developed by utilizing the lateral weir option in HEC-RAS. A theoretical lateral weir is programmed into the Blanco River model for cross sections that overtop the left overbank in these three areas. This lateral weir is set to balance the hydraulic grade line between the Blanco River cross sections and the weir. A certain amount of flow is removed from the Blanco River between each of the overtopping cross sections yielding a diversion rating curve for that overtopping location. The figure shown below shows the location of the three diversions. Appendix P included in this report describes the three diversion rating curves in graphical and tabular format.

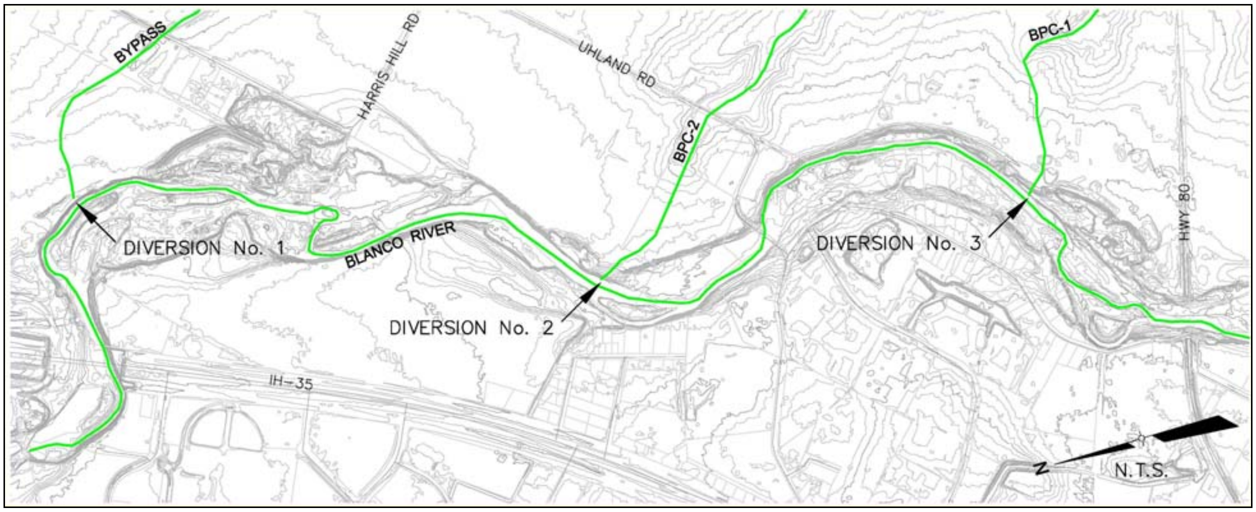

Figure 6. Blanco River – Bypass Creek Diversion Schematic

The **Cottonwood Creek diversions** represent overflow areas along Cottonwood Creek and its tributaries upstream of IH 35. There are a series of culverts that convey flow underneath IH 35 for Cottonwood Creek, Cottonwood Creek Tributary 1, Cottonwood Creek Tributary 2, and Cottonwood Creek Tributary 3. Due to the flat topography and the size of the existing IH 35 culverts, portions of high flow rates will flow north along the IH 35 southbound frontage road from one hydraulic reach to the adjacent hydraulic reach. This is a "daisy chain" diversion effect in that flow will divert from Cottonwood Creek main stem to Tributary 3, from Tributary 3 to Tributary 2, and from Tributary 2 to Tributary 1. The figure shown below is a graphical representation of the three parallel diversions. The three diversion relationships are developed from an Espey Consultants drainage impact study in 2001 titled *Drainage Impacts for the 140-Acre CC-1 Tract*. This 2001 study relates the hydraulic grade line relationship of Cottonwood Creek to the IH 35 frontage road ditch, Tributary 3 to the IH 35 roadside ditch, and Tributary 2 to the IH 35 roadside ditch. Appendix P included in this report describes the three diversion rating curves in graphical and tabular format.

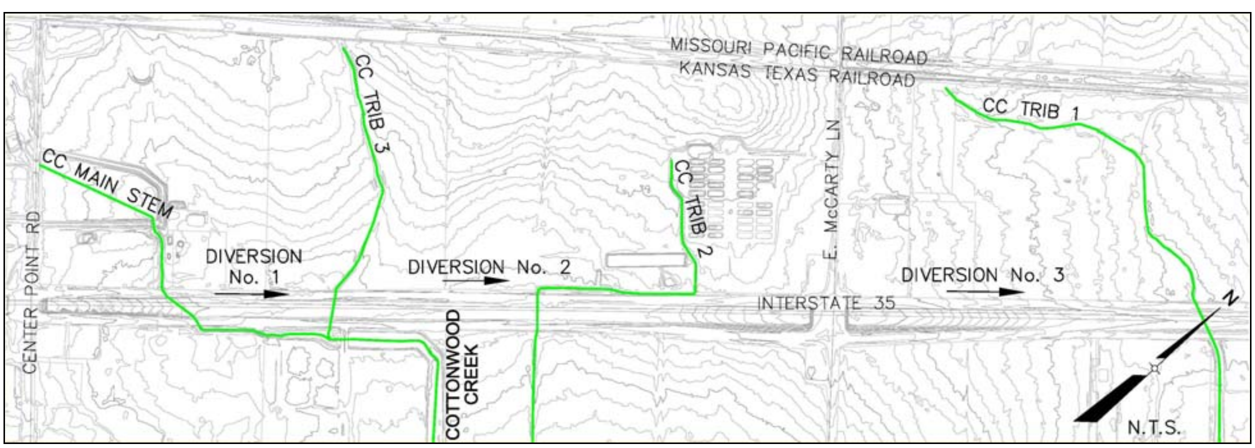

Figure 7. Cottonwood Creek Diversion Schematic

There are two **Purgatory Creek diversions** downstream of the NRCS Reservoir No. 5 and upstream of the Missouri-Pacific Railroad. Downstream of NRCS Reservoir No. 5, Purgatory Creek Diversion No. 1 diverts flow from the main stem into a side channel and reconnects with the main stem further downstream. This diversion relationship is developed by relating the hydraulic grade line (stage) of Purgatory Creek to the hydraulic grade line of the Diversion No. 1 channel. A hydraulic model of Purgatory Creek is created using cross sections that span both the main stem and the diversion channel. The hydraulic model is run to determine where the two reaches become hydraulically independent, which yields a rating curve of flow in the main channel to that in the diversion. This rating curve ratio of flow is assumed to apply along the length of each individual reach. Along the main stem of Purgatory Creek, Purgatory Creek Diversion No. 2 diverts flow from the main stem into Willow Springs Creek. This diversion relationship is developed by relating the hydraulic grade line of Purgatory Creek to the hydraulic grade line in the Diversion No. 2 channel. The stage-discharge rating curve of the uppermost cross section of Diversion No. 2 relates to the stage-discharge relationship of the nearest cross section along Purgatory Creek. Subtracting the two rating curves yields a diversion rating curve for that overtopping location. This is an iterative procedure between the hydrologic model development and the hydraulic model development. The figure shown below is a graphical representation of the two Purgatory Creek diversions. Appendix P included in this report describes the two diversion rating curves in graphical and tabular format.

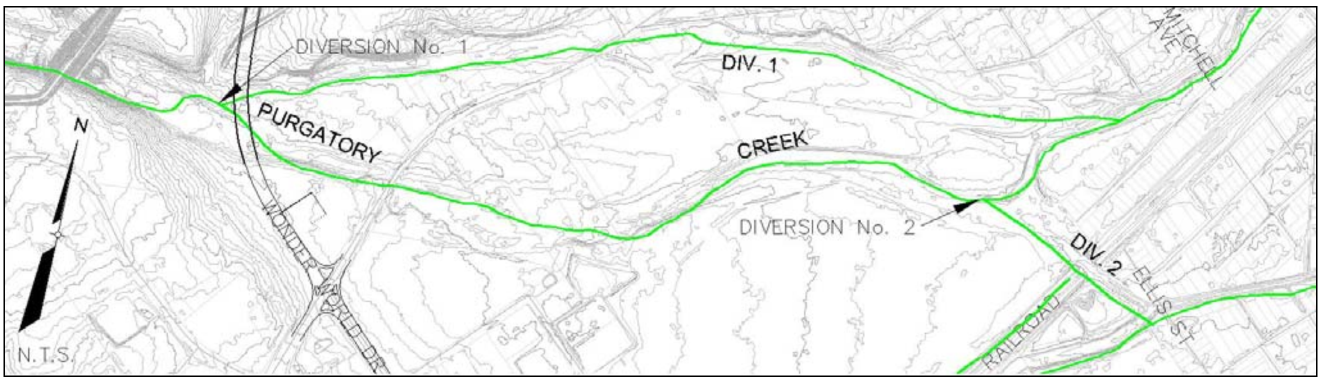

Figure 8. Purgatory Creek Diversion Schematic

2.6 HYDROLOGIC MODEL VALIDATION

2.6.1 Background

There is limited historical flow data available for the San Marcos watersheds. The October 1998 event is the defining flood event in recent history for this area; therefore, the validation exercise focuses on this event. The sources of historical data include the USGS streamflow gage on the Blanco River (#08171000) at Wimberley, the USGS streamflow gage on the Blanco River (#08171300) at Kyle, the USGS streamflow gage on the San Marcos River (#08170500) at Aquarena Springs Drive, and an estimated high water mark on NRCS Reservoir No. 5. For the San Marcos and Kyle USGS streamflow gages, peak flow rates are the only available data for the October 1998 event; therefore, this validation effort cannot evaluate hydrograph timing or runoff volume at these locations. The USGS states that records are of poor quality for the San Marcos streamflow gage during the October 1998 event, thus this data is of limited value. The USGS also states that the Kyle streamflow gage failed during the October 1998 event at a gage height of 28.3 feet; therefore, this data also is of limited value[4].

Gage-adjusted radar rainfall estimates are available for the October 1998 flood event. The figure below illustrates the radar coverage for the October 1998 event within the studied watershed. Each of the shown pixels serves as a "rainfall gage" that can be area weighted and applied to the appropriate subarea within the watershed hydrologic model. A map showing the variation in precipitation depths for the 1998 storm can be found as Exhibit 7 of Appendix A. The spatial dataset of precipitation depths in ArcGIS 9.0 format can be found in Appendix Q. There are two primary points of validation:

1) Computed v. Observed Hydrographs on the Blanco River at Wimberley in Oct. 1998, and
2) Computed v. Observed High Water Mark on NRCS No. 5 in Oct. 1998.

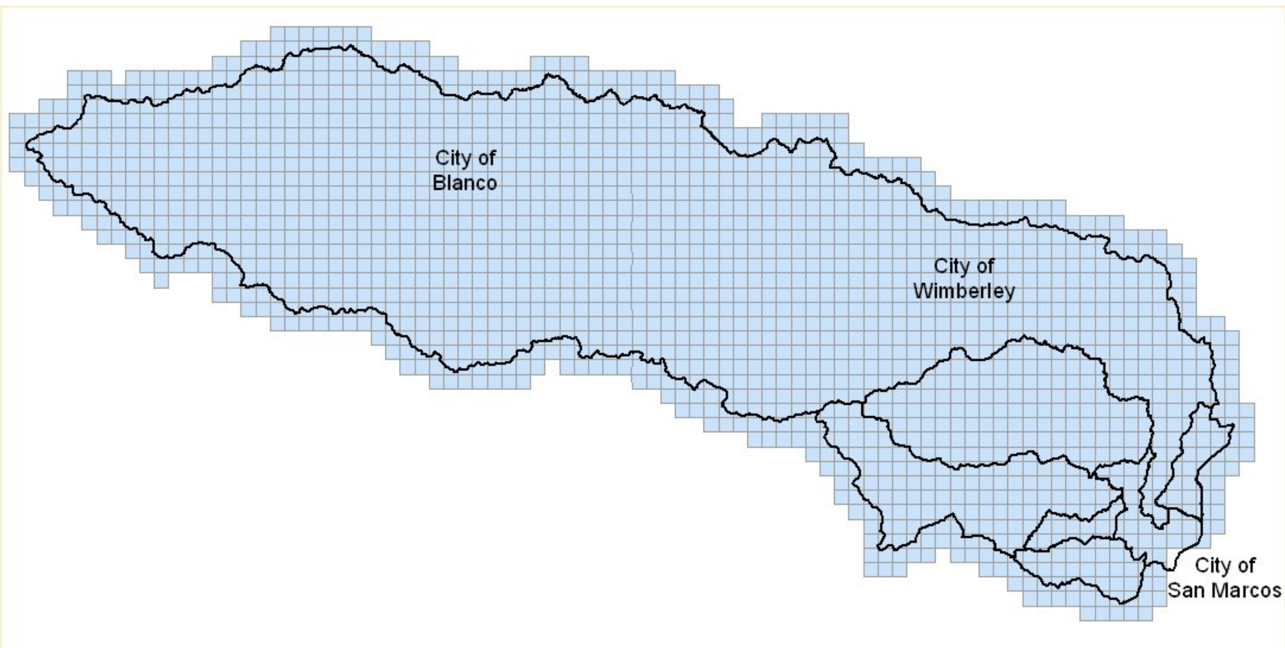

Figure 9. Rainfall Pixel Coverage for San Marcos FFP Watersheds (1 km X 1 km resolution)

The hydrologic model constructed in this restudy includes both fixed and subjective input parameters for drainage areas and hydrograph translation (routing). More subjective input parameters are adjusted in this validation exercise in an attempt to simulate actual storm events. The following is a brief summary of the various input parameters required for each major hydrologic component.

1) **Drainage area** input parameters include surface area, curve number, impervious cover, and lag time. Surface area and impervious cover are easily quantified or estimated;

[4] As a result of the Kyle gage failure during the October 1998 event, a peak flow rate for this location was estimated by indirect measurement.

however, CN and lag time calculations are somewhat subjective and require engineering judgment.

2) Input parameters for **stream routing** based on the Muskingum-Cunge method include channel length, slope, roughness, bottom width, and side slope. While several of these parameters may be easily estimated (e.g., length, slope, bottom width, and side slope), channel roughness is a more subjective parameter. This parameter primarily affects hydrograph timing with limited attenuation. This parameter cannot effectively be evaluated and validated due to the lack of historical time-series data.

3) Input parameters used in **pond routing** typically include storage rating curves and outflow rating curves derived from aerial or topographic surveys and standard engineering equations, respectively. The NRCS reservoirs in this hydrologic model have a significant impact on computed peak flow rates downstream. Limited validation of pond routing can be achieved for this analysis based on the single high water mark on NRCS Reservoir No. 5—high water marks from the other reservoirs are unavailable for this event.

Validation of the basin model includes three target objectives: peak, volume, and time. The computed peak of the watershed is driven by 1) timing of subarea hydrograph computations, 2) hydrograph translation and attenuation due to routing, and 3) runoff volume. On the other hand, volume is independent of the timing or the peak and is instead driven by assumptions regarding the initial abstraction and CN. The timing of the peak is dictated by the synchronization of the individual subarea peaks and the "lagging" influences from routing computations (e.g., reservoir and stream routing).

2.6.2 Comparison to USGS Wimberley Gage during October 1998 Event

The table and figure below show the results of the validation effort for the October 1998 storm event by comparison to measured flow rates at the Blanco River USGS streamflow gage at Wimberley. The October 1998 storm includes the fifth (5^{th}) largest recorded peak flow rate on the Blanco River at this gage (period of record dating back to water year 1925). The USGS records a peak flow rate of 88,500 cfs at this location. Based on the frequency analysis discussed later in this report, this flow rate has a return period of between 20 and 50 years[5].

As shown in the figure, the peak flow overall hydrograph volumes are significantly different. The computed peak flow rate is 41% less than the observed peak flow rate. The width of the calculated hydrograph is greater than the width of the observed hydrograph, which accounts for the volumetric difference of 52%. The rising limb of both hydrographs is coincident in time and similar in slope. The time differential between each time to peak is approximately 30 minutes.

[5] This return period is only representative of areas upstream of the Wimberley gage. The October 1998 event may have different return periods for other locations in the watersheds.

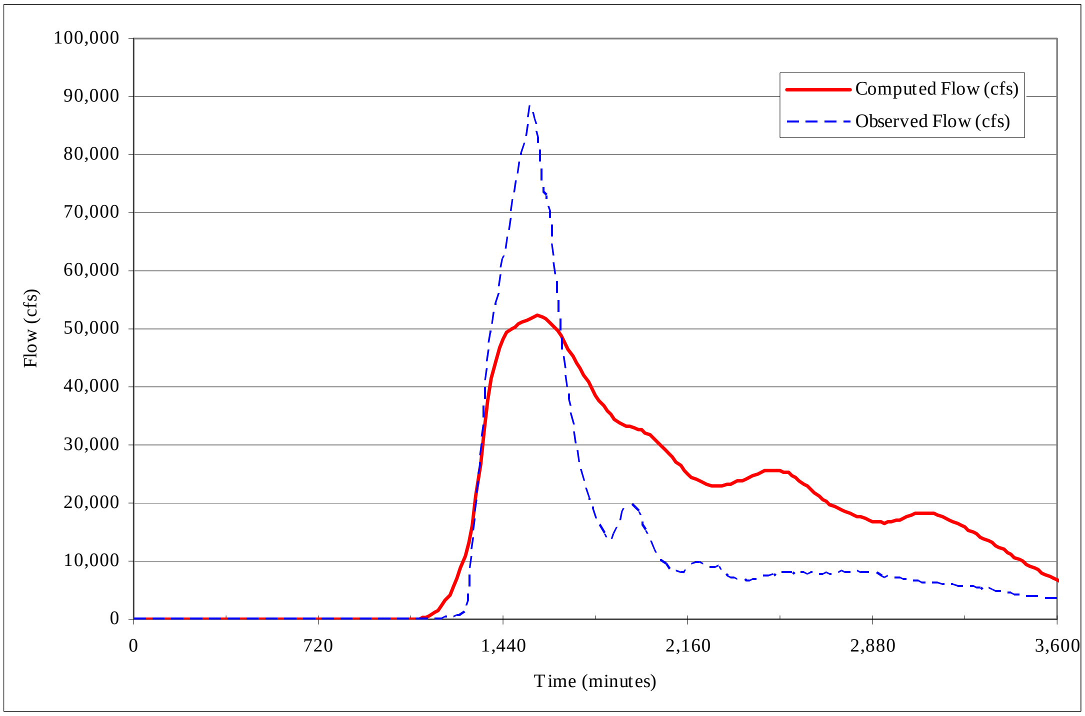

Figure 10. Validation Hydrographs for October 1998 Event

Table 6. Validation Hydrograph Summary Table for October 1998 Event at Wimberley, Texas

Peak Flow Rate (cfs)			Volume (AC-FT)			Time of Peak		
Observed	Computed	% Diff	Observed	Computed	% Diff	Observed	Computed	Diff (min)
88,500	52,263	-41%	55,723	84,746	52%	Oct. 17, '98, 14:15	Oct. 17, '98, 14:45	30

A pixel hyetograph for October 1998 storm event is shown in the figure below. In this graph, each color or line represents a different pixel gage. For this event, there is significant variability between each gage (i.e., the hyetograph peaks are not coincident in time). This causes the calculated hydrograph to “flatten out”. In other words, the hydrograph is more spread out, and consequently, the computed peak flow rate is less than the observed peak flow rate. For this reason, the October 1998 storm is believed to have limited validation value—the hydrologic model is not adjusted based on the results of this comparison.

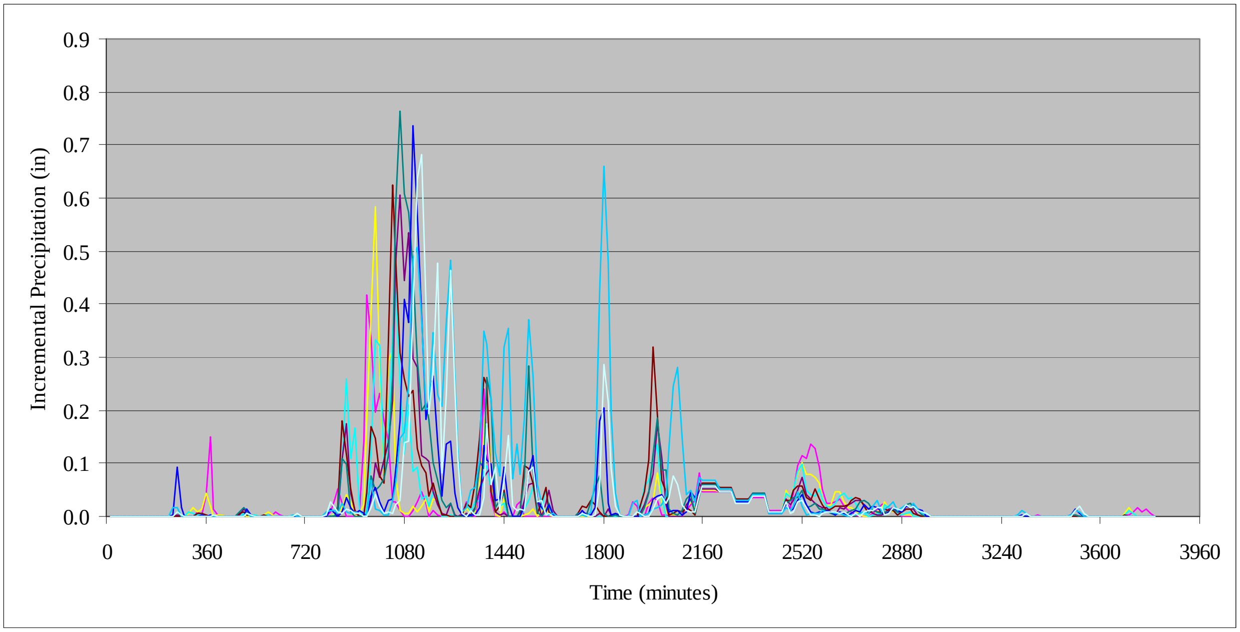

Figure 11. Pixel (Precipitation Gage) Distribution for October 1998 Storm

2.6.3 Comparison to High Water Mark during the October 1998 Event

The Upper San Marcos Watershed Reclamation and Flood Control District operates and maintains NRCS Reservoir No. 5. During the October 1998 storm event, flood waters from the upstream areas of the Purgatory Creek watershed filled the pond and engaged the emergency spillway. District officials estimate that there was approximately six (6) feet of water flowing through the broadcrested weir style spillway; however, no exact survey measurement is available. The emergency spillway has a flowline elevation of approximately 652 feet above mean sea level. Based on this information, the October 1998 event resulted in an estimated observed high water elevation of 658 feet above mean sea level for NRCS No. 5. Applying the available radar rainfall data to the hydrologic model yields a computed high water mark of 658.83 feet above mean sea level, which is 0.83 feet above the estimated observed high water mark. Given the approximation of the data, this difference is statistically insignificant. Therefore, this comparison is a reasonable validation of the hydrologic model.

2.6.4 Validation Summary

There is limited historical data available for San Marcos watersheds; therefore the calibration effort is significantly limited. The effort presented in the Engineering Report is more of a validation effort. The October 1998 event is the defining flood event of recent history for this area; therefore, the validation exercise focuses on this event. Even within this event, however, there is significant variability between each pixel hyetograph. In other words, the storm is not uniform, which causes the calculated hydrograph to "flatten out". Consequently, the computed peak flow rate is less than the observed peak flow rate. For this reason, the October 1998 event is deemed to have limited validation value. However, there is great deal of historical peak flow rate information with a long period of record for the USGS gages at Wimberley and Kyle.

Therefore, more emphasis is placed on the flood frequency analysis. The flood frequency analysis adequately validates the computed peak flow rates.

2.7 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. The following subsections describe the analysis and selection of storm duration and distribution.

2.7.1 Design Storm Duration

Design storm duration is a significant consideration for hydrologic modeling. A check must be performed to ensure that the peak flow of any given event has reached the mouth of the studied basin prior to the end of the rainfall duration. The purpose of this check is to ensure that the entire watershed area is contributing to the peak of the computed hydrograph. As shown in Figure 12 of the report, a short storm duration may artificially lower the computed peak flow rate for a large watershed such as the Blanco River. In this example, the computed hydrograph along the main stem has not had enough time to propagate downstream before the end of the storm, and as a result, hydrograph computations in the lower sections of the watershed are erroneously decreased. The time of concentration for all watersheds except the Blanco is less than 24 hours, which suggests a 24-hour duration for these watersheds is appropriate. The time of concentration for the Blanco River watershed is approximately 29 hours, which suggests a duration longer than 24 hours would be more appropriate for this watershed. The figure below shows how the peak flow rate at various locations within the Blanco River watershed vary with durations of an assumed frequency-based hypothetical rainfall distribution (balanced distribution). As shown in the figure, the peak flow rate curve begins to level off for storm durations greater than 48 hours for this watershed. Therefore, this hydrologic analysis assumes a 48-hour storm duration for the Blanco River, Bypass Creek, and all points downstream of the Blanco River – San Marcos River confluence.

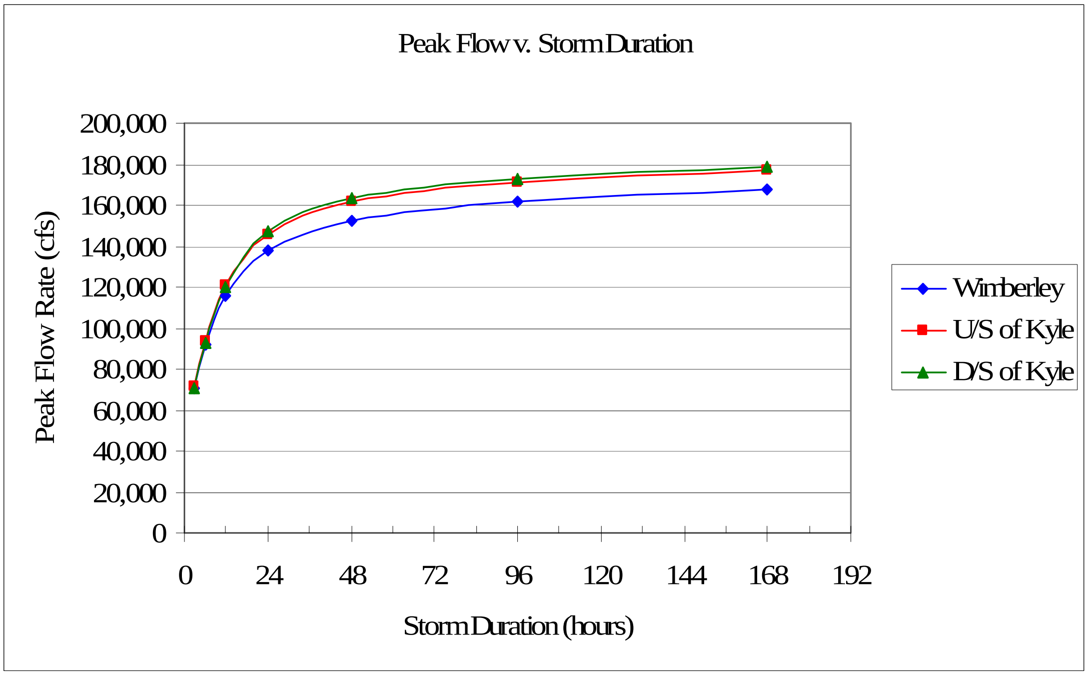

Figure 12. Computed Peak Flow v. Storm Duration for the Blanco River

2.7.2 Design Storm Distribution

A balanced and nested distribution is assumed for this analysis due to its flexibility with regard to storm duration. The distribution is balanced in that the precipitation is centered about the center of the duration. The distribution is nested in that the precipitation depths from the USGS publication are applied in an alternating block format (i.e., the 15-minute depth is applied as the hyetograph peak, the 30-minute depth is applied such that the peak 15-minute block and the adjacent 15-minute block sum to be the 30-minute depth).

2.8 FLOOD FREQUENCY ANALYSIS

Flood frequency analysis refers to the application of frequency analysis to study the occurrence of floods. Historically, various probability distributions have been used for this purpose: normal, gamma, Pearson, and Gumbel. The procedure federal agencies, including FEMA, have developed when computing a frequency curve of annual peaks was published in *Guidelines for Determining Flood Flow Frequency, Bulletin 17B* (US Department of the Interior, 1981). This procedure includes the application of the logarithmic Pearson Type III distribution. A flood frequency analysis for this study is performed for the Blanco River using data from the two historical USGS gages at Kyle and Wimberley. There is a USGS gage on the San Marcos River; however, its period of record is insufficient to perform an adequate frequency analysis.

2.8.1 Log Pearson Type III Distribution

This distribution requires three parameters for complete mathematical specification, which include: 1) the mean, or first moment (estimated by the sample mean, X); 2) the variance, or second moment (estimated by the sample variance, S^2); and 3) the skew, or third moment (estimated by the sample skew, G). Since the distribution is a logarithmic distribution, all parameters are estimated from logarithms of the observations rather than from the observations themselves. The log Pearson Type III distribution is particularly useful for hydrologic investigations because the third parameter, the skew, permits the fitting of non-normal samples to the distribution. When the skew is zero, the log Pearson Type III distribution becomes a two-parameter distribution that is identical to the logarithmic normal (log-normal) distribution.

The log Pearson Type III distribution is fitted to a data set by calculating the sample mean, variance, and skew from the following equations:

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \qquad \text{Equation 8}$$

$$S^2 = \frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1} \qquad \text{Equation 9}$$

$$G = \frac{n}{(n-1)(n-2)(S^3)} \sum_{i=1}^{n} (X_i - \overline{X})^3 \qquad \text{Equation 10}$$

Where:

- n = number of events in the data set,
- X_i = logarithm of the magnitude of the annual event,
- $\overline{X}$ = mean of logarithm,
- S = standard deviation,
- S^2 = unbiased estimate of the variance of logarithms, and
- G = unbiased estimate of the skew coefficient of logarithms.

The logarithms of the event magnitudes corresponding to each of the selected percent chance exceedance values are computed by the following equation:

$$\log Q = \overline{X} + K \times S \qquad \text{Equation 11}$$

Where:

- log Q = logarithm of the flow corresponding to a specified value of percent chance exceedance, and
- K = Pearson Type III deviate that is a function of the percent chance exceedance and the skew coefficient.

2.8.2 Expected Versus Computed Probability

A computed frequency curve is based in relation to average future expectation because of uncertainty as to the true mean and standard deviation. The effect of this bias for the normal distribution can be eliminated by an adjustment termed the “expected probability adjustment” that accounts for the actual sample size. The computation of a frequency curve by the use of the sample's statistics as an estimate of the distribution parameters provides an estimate of the true frequency curve; however, the location of the true frequency curve is uncertain. For the normal distribution, the sampling errors for the mean are defined by the t-distribution, and the sampling errors for the variance are defined by the chi-squared distribution (χ^2 distribution). These two error distributions are combined in the formation of the non-central t-distribution. The non-central t-distribution can be used to construct curves that, with a specified confidence (probability), encompass the true frequency curve.

The concept of "expected probability" is described in an earlier version of *Guidelines for Determining Flood Flow Frequency, Bulletin 17*, published in 1976[6]. However, *Bulletin 17* made no recommendation about whether the concept should be used, leaving the decision to be made independently by the federal agencies needing to estimate flood flow frequencies. A study by the National Academy of Science in 1978 commissioned by the Federal Insurance Administration concluded that the "computed" log Pearson Type III distribution be used. This task force recommended "that the FIA not use the expected probability adjustment presented in *Bulletin 17* for estimating peak flows at various probabilities of annual occurrence for the FIS's of communities located in riverine area and that it continue to use the unadjusted frequency distribution method recommended in *Bulletin 17* until that method is changed by the Water Resource Council."

2.8.3 Blanco River Flood Frequency Analysis

The USGS has published flow gage records at Wimberley since 1925 and at Kyle since 1957. The maximum stage on the Wimberley gage since at least 1869 was that of May 1929. The maximum stage on the Kyle gage since at least 1882 was also that of May 1929. Both gages are regarded as having good or reliable systematic records. The largest recorded annual events (by water year) in the Blanco River watershed at these gages are shown in the table below.

Table 7. Largest Recorded Events (Blanco River at Wimberley and Kyle)

Wimberley Gage (USGS Gage 08171000)			Kyle Gage (USGS Gage 08171300)		
Date	Peak Flow (cfs)	Rank	Date	Peak Flow (cfs)	Rank
May-29	113,000	1	May-29*	139,000	1
Nov-01	108,000	2	Sep-52*	115,000	2
May-58	96,400	3	Oct-98	105,000	3
Sep-52	95,000	4	May-58	98,000	4
Oct-98	88,500	5	Nov-01	87,300	5
Apr-57	62,600	6	Apr-57	75,400	6

* indicates historic peak (estimated stage heights provided by local residents before gage was active)

The figure below is a graphical plot of the recorded peak flow rates at the USGS gage at Wimberley and the computed frequency curve. For comparison, it also includes the current FIS values as well as the computed results from HEC-HMS (Computed 48-Hour Bal.). The

[6] *Bulletin 17* was issued to the Water Resources Council in March of 1976 as an extension and update of *Bulletin No. 15, A Uniform Technique for Determining Flood Flow Frequencies*, December 1967. The guidelines were revised and reissued in June 1977 as *Bulletin 17A*. *Bulletin 17B* is the latest effort to improve and expand upon the earlier publication.

frequency curve is generated using the HEC-FFA program. A copy of the frequency analysis output may be found in Appendix F of this report. The FIS values are reported just upstream of the confluence with Halifax Creek, which is downstream of Wimberley. The drainage area at Wimberley is approximately 355 square miles; the drainage area just upstream of Halifax Creek is 392 square miles.

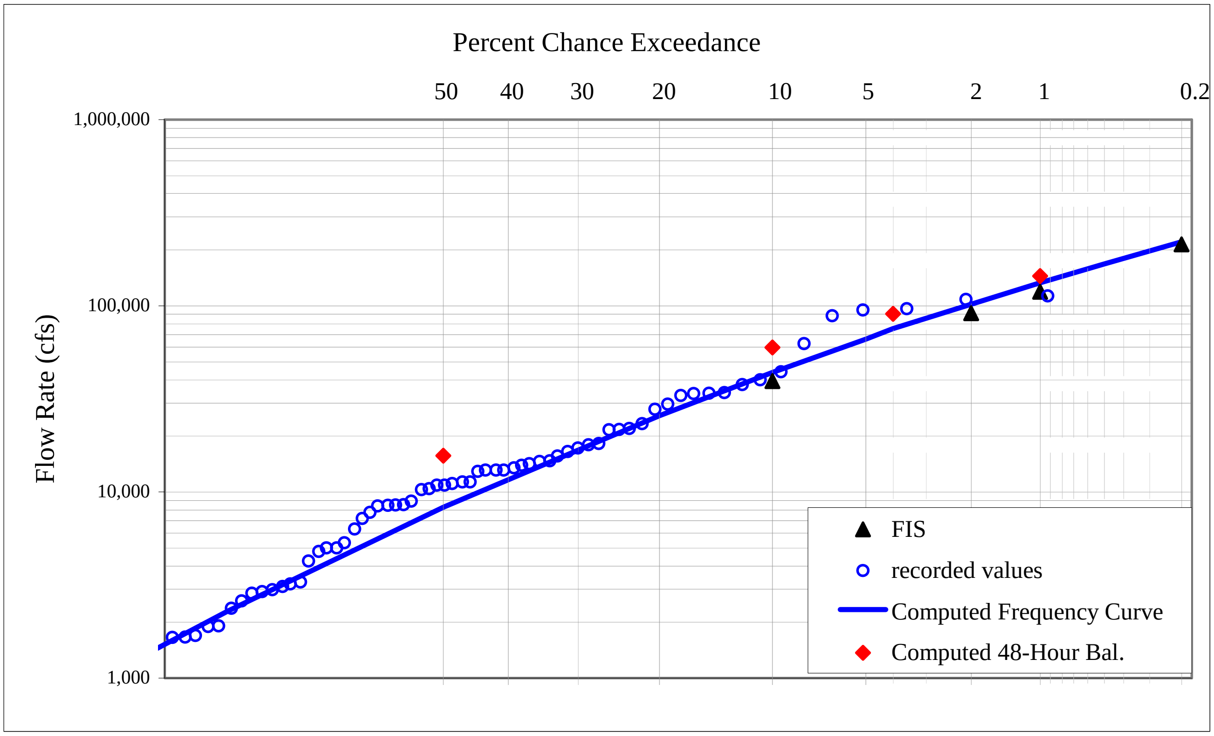

Figure 13. Computed Flood Frequency Curve at Wimberley

The results of the frequency analysis are higher than the values published in the effective FIS. The current FIS published value for the 1% annual chance flood is 118,950 cfs while the flood frequency analysis yields a computed value of 133,000 cfs. The hydrologic model shows a computed 1% annual chance peak flow rate of 144,470 cfs.

The figure below is a graphical plot of the recorded peak flow rates at the USGS gage at Kyle and the computed frequency curve. For comparison, it also includes the current FIS values as well as the computed results from HEC-HMS (Computed 48-Hr Bal.). A copy of the frequency analysis output may be found in Appendix F of this report. The FIS values are reported just downstream of IH 35.

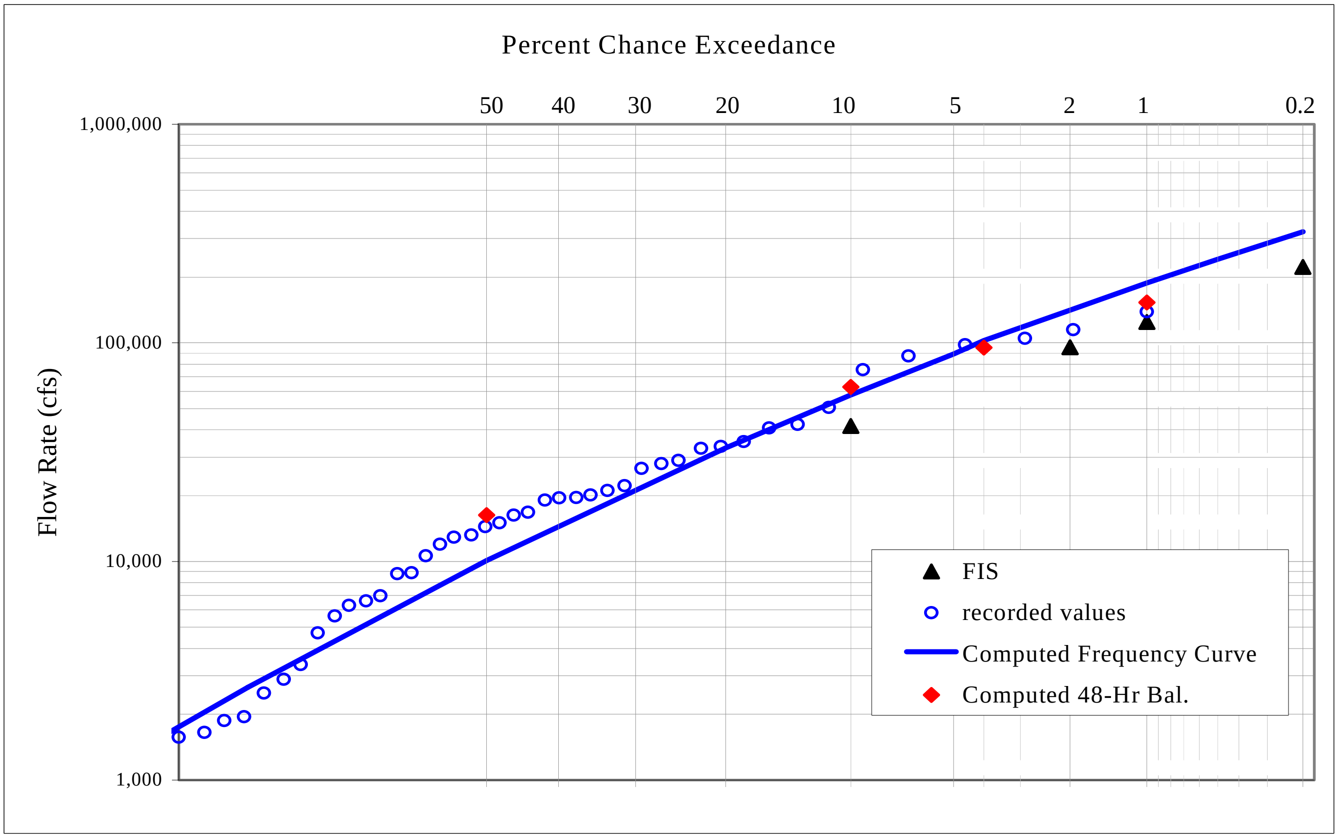

Figure 14. Computed Flood Frequency Curve at Kyle

The results of the frequency analysis are higher than the values published in the effective FIS. The current FIS published value for the 1% annual chance flood is 124,680 cfs while the flood frequency analysis yields a computed value of 188,000 cfs. The hydrologic model shows a computed 1% annual chance peak flow rate of 152,990cfs.

The table below summarizes the comparison of the peak flow rates discussed above for the Wimberley and Kyle gages relative to the computed HEC-HMS results.

Table 8. 1% Annual Chance Peak Flow Rate Comparison Table for Blanco River

HEC-HMS Node	Peak Flow Rate (cfs)					Description
	HEC-HMS	FIS	% Diff	HEC-FFA	% Diff	
J-BR10	144,470	118,950	-18%	133,000	-8%	Wimberley
J-BR11	152,990	124,680	-19%	188,000	23%	Kyle
J-SM09	127,930	109,550	-14%	-	N/A	Confl. w/SMR

% Diff: percent different from HEC-HMS computed flows

The figure below is a graphical representation of the computed flow rates from various sources including the effective FIS, the computed 48-hour balanced hydrologic model, the computed flood frequency analysis and values computed from the 2001 USGS regression equations. The USGS regression equations were derived by Asquith and Slade in 2001 and are used to analyze the flow rates at each hydrologic model node for comparison. The two vertical lines on the figure represent the locations of the Kyle and Wimberley USGS gages.

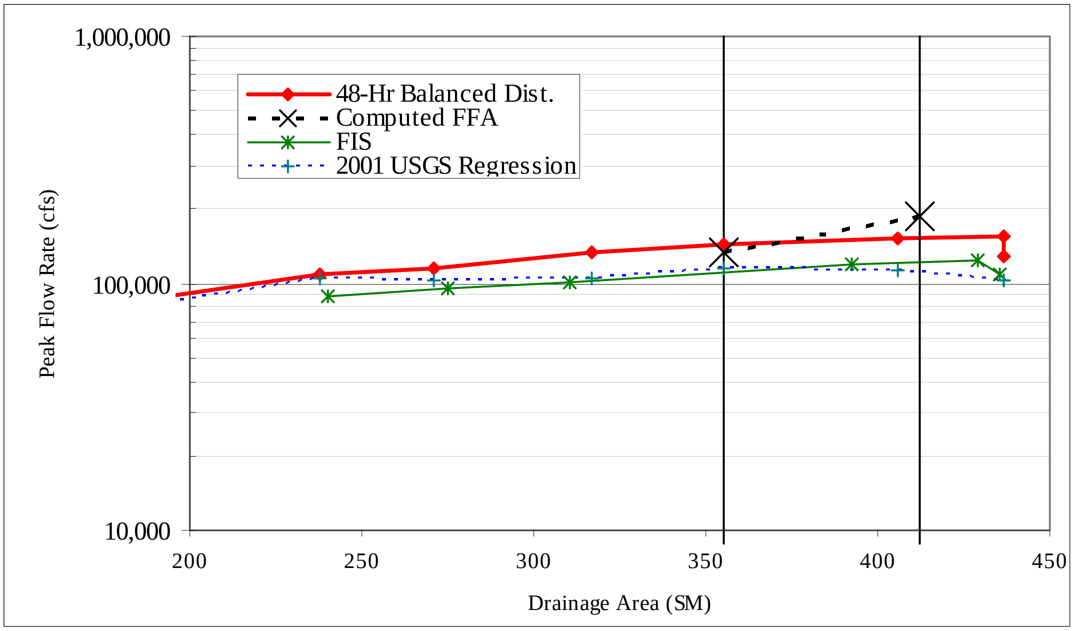

Figure 15. 1% Annual Chance Flow Rates v. Drainage Area for Blanco River

The 48-hour balanced and nested distribution generates peak flow rates that are slightly higher than the effective FIS and slightly lower than the computed frequency curve for the 1% annual chance event. The decrease in peak flow rate at the downstream end of the curve is caused by the three natural diversion areas on the Blanco River just downstream of IH 35.

2.9 ULTIMATE CONDITIONS ANALYSIS

The ultimate development conditions (fully developed conditions) analysis includes the use of the validated existing conditions basin model and the balanced and nested distribution to determine the flow rates for the watersheds at full development. For the purposes of this analysis, full development is equivalent to a 25-year time horizon (i.e., the development status in the year 2031). There are several available datasets from which to extrapolate development conditions for this future date including the City of San Marcos Future Land Use Map, the Envision Central Texas Future Land Use Map, and the Texas Department of Transportation (TxDOT) Future Density Map. Of these three, the City's map and the Envision Central Texas map are believed to be the most useful in developing projected impervious cover values; therefore, the TxDOT map is not used in this analysis.

The impervious cover for each subarea is modified to reflect the projected land use based on a merged dataset including the City of San Marcos Future Land Use Map and the Envision Central Texas Future Land Use Map. Adjustments are also made to the time of concentration calculations to reflect shorter watershed response times, specifically in the uplands of the watershed. The figure shown below is the composite future land use map for the San Marcos Flood Protection Plan watersheds. A larger scale future land use map is included with this report as Exhibit 4 in Appendix A. Assumptions for the assigned impervious cover values for each future land use category and the resulting weighted impervious cover value for each subarea are included in Appendix C. Areas that are already developed are not necessarily developed to their maximum potential; therefore, this analysis does not limit the impervious cover in any one subarea to the existing impervious cover percentage even if that area is currently developed. Note that large sections of the Blanco River, Sink Creek, and Purgatory Creek watershed extend into rural areas that are not projected to be developed within the next 25 years. This ultimate watershed conditions analysis includes flow rates for the 1% annual chance (100-year) only. These ultimate conditions flow rates will be used to determine the ultimate conditions floodplain for the 1% annual chance event.

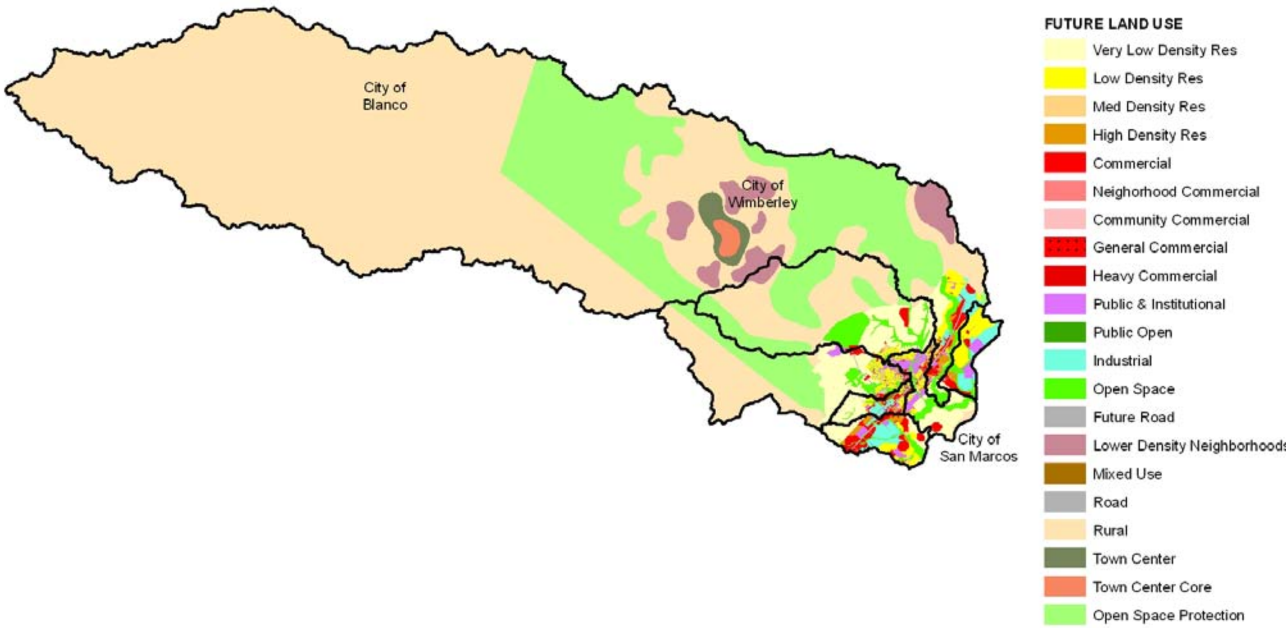

Figure 16. Composite Future Land Use Map

2.10 HYDROLOGIC ANALYSIS SUMMARY AND CONCLUSIONS

This hydrologic analysis comprehensively evaluates the watersheds that affect the City of San Marcos. Based on the results of this analysis, the most appropriate design storm for this study is the balanced and nested distribution. A 48-hour duration is used for the Blanco River and Bypass Creek watersheds as well as all points downstream of the Blanco River – San Marcos River confluence. A 24-hour duration is assumed for all other watersheds. The nested USGS precipitation depths are applied to this distribution. The most appropriate basin model for this analysis is the validated model discussed earlier in the text. For ultimate watershed conditions, the existing conditions basin model is revised to reflect projected future impervious cover based on the composite future land use map. A table listing the computed peak flow rates for the various watersheds at key points along each modeled hydraulic reach is included below. Results of this hydrologic analysis will be used to delineate the floodplains discussed later in this report.

Table 9. Computed Peak Flow Rates Summary Table – 1% Annual Chance Storm

Stream	Area (sq mi)	Peak Flow Rate (cfs)		% Diff.	Location
		FIS	1% Balanced		
Blanco River					
	436.4	109,550	127,930	17%	At confluence with San Marcos River
	429.2	124,680	154,890	24%	Downstream of Halifax Creek
San Marcos River					
	531.7	129,640	140,470	8%	Upstream of confluence with Bypass Creek
	95.3	14,850	22,520	52%	Upstream of confluence with Blanco River
	88.0	10,780	16,490	53%	Upstream of confluence with Willow Spgs. Ck
	47.6	6,920	9,033	30%	Downstream of Spring Lake
Cottonwood Creek					
	1.1	1,075	1,090	1%	Upstream of confluence with CC Tributary 2
Purgatory Creek					
	37.0	4,920	5,540	13%	At confluence with San Marcos River
	34.5	2,610	4,930	89%	Outflow from NRCS No. 5
	34.5	13,020	14,840	14%	Inflow into NRCS No. 5
Willow Springs Creek					
	4.5	4,970	6,370	28%	At confluence with San Marcos River
	3.4	3,350	4,660	39%	Upstream of confluence with Purgatory Ck Div. No. 2

Computed peak flow rates are compared to various other data to respect the historical work done as well as bolster credibility to the model. Blanco River computed peak flows are approximately 15% higher than published flow rates from the effective flood insurance study (FIS). Blanco River computed peak flow rates also compare well with a frequency analysis of available historical flow data available from USGS gages along the reach. San Marcos River flow rates are generally 10% to 50% higher than the published FIS. Cottonwood Creek peak flows are consistent with published FIS values. Computed peak flow rates fell within 20% of FIS flow rates for Purgatory Creek and within 40% for Willow Springs Creek. The resulting flow rates are used in the hydraulic analysis to calculate and delineate the floodplains for those various storm events.

3.0 HYDRAULIC ANALYSIS

The hydraulic analysis is conducted on various reaches within the San Marcos Flood Protection Plan watersheds. There are 42.7 miles of stream included with this hydraulic analysis, which computes water surface elevations for the 50%, 10%, 4%, 1%, and ultimate 1% annual chance (2-, 10-, 25-, 100-, and ultimate 100-year, respectively) storm events. The hydraulic analysis includes the delineation of the 1% annual chance as well as the ultimate 1% annual chance floodplains. The studied streams include the following reaches:

1) Blanco River;
2) Bypass Creek;
3) Cottonwood Creek;
4) Purgatory Creek;
5) Rio Vista;
6) San Marcos River;
7) Schulle Canyon;
8) Sessom Creek; and
9) Willow Springs Creek.

An overall map showing the extents of the studied reaches is included in Appendix A of this report as Exhibit 1. Several of these streams have tributaries that are modeled as independent reaches. In total, there are 21 hydraulic reaches that include 63 modeled structures. There are effective FEMA models available for the Blanco River and the San Marcos River that adequately represent existing stream geometry. The effective HEC-2 models were converted to HEC-RAS and geo-referenced, flow rates were updated, and other minor revisions were made; however, the models are generally left intact. New hydraulic models are developed for the remaining reaches.

The USACE HEC-RAS software version 3.1.3 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 HYDRAULIC MODEL DEVELOPMENT

3.1.1 Processing

For reaches other than the Blanco River and San Marcos River, the detailed study methodology incorporated using the Watershed Information System (WISE) software as a preprocessor to HEC-RAS. WISE utilizes geographically referenced data sets as well as a three-dimensional terrain model to create the input data files for HEC-RAS. HEC-RAS is then executed to determine the flood elevation at each cross section of the modeled stream. The resulting elevations are then imported back into WISE for creation of the flood boundaries.

3.1.2 Cross Section

Model cross sections are placed along the study streams using the available contour data. Where roads or other structures are encountered, supplemental cross sections are required to meet HEC-RAS data input needs. An extensive field survey of important hydraulic structures was conducted to help enhance the accuracy of the hydraulic model. In addition to hydraulically significant structures, natural cross sections are captured. These detailed cross sections are used to enhance the channel portions of the cross sections derived from the terrain model. The HEC-RAS model generated from WISE then receives an extensive quality check / quality assurance to ensure that LIDAR and Field Survey data are merged correctly. Raw survey data including the cross section and structure points in text file format (.txt) are included in Appendix Q. Additionally, ArcGIS 9.0 format shapefiles (.shp) of the surveyed cross section and structure points are included.

3.1.3 Parameter Estimation

The tables below show the various hydraulic parameters used to analyze the detailed reaches of the San Marcos Flood Protection Plan. These tables are not reach specific, but rather, they apply to the project as a whole. Note that the Blanco River and San Marcos River models are conversions of the effective models—these tables do **not** apply to the Blanco River or San Marcos River.

Table 10. Channel Manning's n Table (between overbanks)

Type	Value
Concrete	0.015
Asphalt (street)	0.02
Improved channel at bridges/culverts, uniform cross section, no vegetation	0.035
Improved channel, uniform cross section, straight, light vegetation	0.04
Improved channel, uniform cross section and straight	0.05
Natural channel, irregular cross section, meandering, brush	0.06
Natural channel, irregular cross section, meandering, heavier brush with medium trees	0.08
Medium tree coverage (50%)	0.1
Residential areas with privacy fences typical	0.99

Table 11. Overbank Manning's n Table (outside overbanks)

Type	Value
Concrete	0.015
Asphalt (parking lot with more obstacles)	0.035
Improved area, uniform cross section, straight, light vegetation	0.04
Natural area, uniform cross section, light brush	0.05
Natural area, irregular cross section, medium brush	0.06
Natural area, irregular cross section, meandering, heavier brush	0.065
Natural channel, irregular cross section, meandering, heavier brush with medium trees	0.08
Light tree coverage, scattered tree clusters (10% - 25%)	0.1
Medium tree coverage (50%)	0.12
Heavy tree cover (>75%), commercial and residential areas (privacy fences not typical)	0.15
Residential areas with privacy fences typical	0.99

Table 12. Miscellaneous Hydraulic Coefficients Table

Coefficient Type	Value or Range
Bridge pier drag coefficient for momentum equation applications, Cd	2
Pressure and weir flow coefficient (submerged inlet and outlet), Cd	0.8
Expansion coefficients for bridges / culverts / in-line structures	0.3 to 0.5
Expansion coefficients for channels	0.3
Contraction coefficients for bridges / culverts / in-line structures	0.1 to 0.3
Contraction coefficients for channels	0.1
Weir coefficients (road deck)	2.6 to 3.0
Culvert entrance loss coefficient	0.4
Culvert exit loss coefficient	1

Table 13. Range of Manning's n Values Table

	Range of Manning's n Values	
Reach	Channel	Overbanks
Bypass Creek	0.035 to 0.05	0.035 to 0.08
Bypass Creek Trib 1	0.05	0.06
Bypass Creek Trib 2	0.05	0.06
Cottonwood Creek	0.035 to 0.05	0.035 to 0.1
Cottonwood Creek Trib 1	0.035 to 0.05	0.035 to 0.06
Cottonwood Creek Trib 2	0.035 to 0.05	0.035 to 0.06
Cottonwood Creek Trib 3	0.05	0.06
Purgatory Creek	0.035 to 0.08	0.035 to 0.1
Purgatory Creek Trib 2	0.04	0.12
Franklin Square	0.035 to 0.99	0.035 to 0.99
Rio Vista	0.035 to 0.05	0.035 to 0.08
Schulle Canyon	0.035 to 0.05	0.035 to 0.1
Sessom Creek	0.015 to 0.06	0.035 to 0.1
Willow Springs Ck	0.035 to 0.05	0.035 to 0.1
Willow Springs Ck Trib 1	0.05	0.08
Willow Springs Ck Trib 2	0.015 to 0.06	0.035 to 0.99
Willow Springs Ck Trib 1 to Trib 2	0.05	0.08
Willow Springs Ck Trib 2 to Trib 2	0.035 to 0.5	0.035 to 0.8

3.1.4 Modeling Considerations

Various considerations are taken into account when evaluating each hydraulic reach. These considerations include, but are not limited to, starting water surface elevations, structure crossings, islands and flow splits, ineffective flow areas, supercritical versus subcritical flow regimes, hydraulic calibration, etc. The sections below describe the various considerations taken into account for each reach except the Blanco River and San Marcos River, whose descriptions are found later in this report.

Ineffective flow areas are added to portions of various cross sections to accurately model any given section's ability to convey flow. Ineffective flow areas are typically modeled by

1) applying an ineffective flow area boundary in HEC-RAS with a test elevation that, if exceeded, would offer some level of conveyance,
2) applying a permanent ineffective flow area boundary in HEC-RAS, which will permanently prevent that portion of the cross section from conveying flow,
3) applying a high Manning's n value such as 0.99, which significantly limits the conveyance capability of any given area of a cross section, and
4) applying a blocked obstruction boundary in HEC-RAS, which will permanently prevent that portion of the cross section from conveying flow and removes storage capacity of the stream.

Examples of temporary ineffective flow areas include 1) minor swales parallel to the reach that eventually outfall into the reach or 2) cross sections immediately upstream or downstream of an in-line structure. Examples of permanent ineffective flow areas include 1) minor swales parallel to the reach, which do not outfall into the reach or 2) off-line water quality / detention ponds. Streets are also evaluated on a case-by-case basis to determine whether or not that street offers flow conveyance to the system.

3.2 DETAILED DESCRIPTION OF HYDRAULIC MODEL GENERATION

3.2.1 Bypass Creek and Tributaries

Bypass Creek along with its two tributaries drains approximately 6.80 square miles as it flows into the San Marcos River. Each of the three reaches is modeled as a separate HEC-RAS project. This creek was last studied as part of the 1995 Hays County FIS. Bypass Creek and its two tributaries present significant flooding risks to adjacent properties due to a series of three overflows from the Blanco River. Generally, the Blanco River is contained within its banks for the 4% annual chance storm event; however, for more extreme events, the Blanco River overtops its left overbank and overflows naturally into Bypass Creek and its two tributaries. Thus, the Bypass Creek 1% annual chance flow rate is governed by the Blanco River. The limits of this study correspond to the limits of the effective FIS, which extend from the confluence with the San Marcos River near Martindale Road upstream to a point approximately 460 feet upstream of Harris Hill Road. The upper section of the hydraulic model was generated using two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. The lower

6,500 feet of Bypass Creek was generated on USGS ten-foot contours. There are 84 cross sections, 5 culverts, and 1 bridge modeled in Bypass Creek and its tributaries. Most of Bypass Creek includes an unimproved natural channel with mostly grass bottom and grass side slopes. Bypass Creek Tributaries 1 and 2 include an unimproved, poorly-defined swale with mostly grass bottom and side slopes. The downstream portion of the Bypass Creek Tributary 2 swale has been paved as Bogey Drive before being diverted into a culvert under State Highway 21. These three models represent a total reach length of 35,400 feet. All cross sections are modeled from left to right looking downstream.

The peak flow rate for the 1% and ultimate 1% annual chance events along Bypass Creek and its tributaries is dominated by the overtopping of the Blanco River. However, the peak flow rate for the 50%, 10%, and 4% events is dominated by the contributing drainage area to Bypass Creek rather than any overtopping from the Blanco River. Thus, each of the three models is built on the assumption that the downstream reach has a coincident hydrograph peak condition for the extreme events (larger streams are tailwater controlled). Furthermore, each of the three models is built on the assumption that the downstream reach does not have a coincident hydrograph peak for the lesser events. Based on these unique circumstances, the 1% and ultimate 1% annual chance downstream boundary conditions are set as known water surface elevations of Bypass Creek and its tributaries based on the computed water surface elevation of the downstream reach at the time of the modeled reach's hydrograph peak. To cite an example, the downstream water surface elevation of Bypass Creek is based on the flow rate in the San Marcos River at the time of the Bypass Creek hydrograph peak. The 50%, 10%, and 4% annual chance downstream boundary conditions are set as normal depth elevations for each of the reaches.

The side overflows from the Blanco River to Bypass Creek and Tributaries are further discussed in §3.3.1.3, and the inflow-diversion relationships are included in Appendix P.

Bypass Creek and its tributaries are modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Bypass Creek or its tributaries with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis.

3.2.2 Cottonwood Creek and Tributaries

Cottonwood Creek and its three tributaries drain approximately 9.63 square miles. Each of the four reaches is modeled as a separate HEC-RAS project. Cottonwood Creek was last studied as part of the 1995 Hays County FIS. Cottonwood Creek and its three tributaries present significant flooding risk downstream of the Missouri Pacific / Kansas Texas Railroads and upstream of Interstate Highway 35. Additionally, Cottonwood Creek presents a significant flooding risk to the rapidly developing areas downstream of Interstate Highway 35. The limits of this study extend from the bridge at State Highway 123 upstream to a point approximately 1,330 feet downstream of Centerpoint Road. The model was generated from two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. There are 102 cross sections, 8 culverts, and 1 bridge modeled in Cottonwood Creek and its tributaries. Most of Cottonwood Creek and its tributaries consist of a narrowly defined natural channel with mostly grass bottom and grass side slopes. Extensive modification to the natural channel has occurred in the areas near Centerpoint Road and Interstate Highway 35. These four models represent a total reach length of 47,800 feet. All cross sections are modeled from left to right looking downstream.

The downstream starting water surface elevation for Cottonwood Creek and Cottonwood Creek Tributary 2 is based on a normal depth assumption. The downstream starting water surface elevation for Cottonwood Creek Tributaries 1 and 3 are based a known water surface elevation. Thus, Cottonwood Creek Tributaries 1 and 3 are built on the assumption that the downstream reach has a coincident hydrograph peak condition with the main stem of Cottonwood Creek.

Cottonwood Creek and its tributaries are modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Cottonwood Creek or its tributaries with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis.

3.2.3 Purgatory Creek and Tributaries

Purgatory Creek and its tributaries drain approximately 37.0 square miles as it flows into the San Marcos River. Each of the four reaches is modeled as a separate HEC-RAS project. Purgatory Creek was last studied as part of the 1995 Hays County FIS. Purgatory Creek and its tributaries present significant flooding risk to western and central San Marcos. Extensive modification to the natural drainage system has occurred due to the placement of NRCS Reservoirs No. 4 and 5. Approximately 34.5 square miles of contributing drainage area are controlled by these flood control structures, which amounts to 93% of the total watershed area. Purgatory Creek presents a significant flooding risk for areas downstream of NRCS Reservoir No. 5. The limits of this study extend from the confluence with the San Marcos River upstream to a point 100 feet downstream of Craddock Avenue. The model was generated from two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. There are 116 cross sections, 7 culverts, 5 bridges, and 1 dam modeled in Purgatory Creek and its tributaries. Most of Purgatory Creek and its tributaries consist of a defined natural channel with mostly grass bottom, grass side slopes, and brushy/woody overbank areas. The downstream segments of Purgatory Creek pass through an urbanized section of San Marcos that receives regular mowing and maintenance by the City of San Marcos. These four models represent a total reach length of 28,500 feet. All cross sections are modeled from left to right looking downstream.

The downstream boundary conditions for Purgatory Creek, Purgatory Creek Tributary 2, Purgatory Creek Tributary 3, and Purgatory Creek Diversion No. 2 are based on a normal depth assumption. The downstream boundary condition for Purgatory Creek Diversion No. 1 is based on a known water surface elevation. Thus, Purgatory Creek Diversion No. 1 is built on the assumption that the downstream reach has a coincident hydrograph peak condition with Purgatory Creek.

An important hydraulic characteristic of Purgatory Creek is that it has two flow diversions, Diversion No. 1 splits from the main stem and then rejoins downstream, and Diversion No. 2

diverts water to the main stem of Willow Springs Creek. An inflow-diversion relationship for Purgatory Creek Diversion No. 1 was developed after assessing the topography where water no longer flows in one watercourse, but in two separate and distinct channels. The cross section chosen to develop the inflow-diversion relationship is the first cross section downstream of the split that clearly contains the range of flows in the diversion channel or main stem. An inflow-diversion relationship for Purgatory Creek Diversion No. 2 was developed by applying a range of flow rates in the main stem of Purgatory Creek and then correlating the water surface elevation in the main stem to a flow rate in the Diversion No. 2. Graphical and tabular descriptions of the inflow-diversion relationships for Purgatory Creek Diversions can be found in Appendix P.

Purgatory Creek and its tributaries are modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Purgatory Creek or its tributaries with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis.

3.2.4 Rio Vista Creek

Rio Vista Creek drains approximately 0.18 square miles as it flows into the San Marcos River. Rio Vista Creek was last studied as part of the 1994 City of San Marcos Drainage Master Plan performed by Camp, Dresser, & Mckee (CDM) and is not a studied stream in the effective FIS. The reach is modeled as one HEC-RAS project. Rio Vista Creek presents significant flooding risk to the adjacent neighborhood during more extreme events when flow is not contained within the channel banks. The adjacent railroad embankment coupled with a lack of downstream conveyance causes the flat terrain in the adjacent neighborhood to pond water and flood. The limits of this study extend from the confluence with the San Marcos River upstream to a point approximately 20 feet downstream of Hopkins Street. The model was generated from two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. There are 13 cross sections and 1 culvert modeled in Rio Vista Creek. Rio Vista Creek consists of a narrowly defined natural channel with mostly grass bottom and grass side slopes. This model represents a total reach length of 3,400 feet. All cross sections are modeled from left to right looking downstream.

The downstream boundary condition for the Rio Vista Creek model is based on a normal depth assumption.

Rio Vista Creek is modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Rio Vista Creek with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis.

3.2.5 Schulle Canyon Creek

Schulle Canyon Creek drains approximately 0.40 square miles as it flows into Sink Creek. Schulle Canyon Creek was last studied as part of the 1994 City of San Marcos Drainage Master

Plan performed by CDM and is not a studied stream in the effective FIS. Schulle Canyon Creek presents flooding risks to the adjacent neighborhood and street crossings during more extreme events when flow is not contained within the channel banks. The limits of this study extend from the confluence with Sink Creek upstream to a point approximately 175 feet downstream of Owens Street. The model was generated from two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. There are 26 cross sections and 2 culverts modeled in Schulle Canyon Creek. Schulle Canyon Creek consists of an incised natural channel with a grass channel bottom and grass side slopes. This model represents a total reach length of 6,972 feet. All cross sections are currently modeled from left to right looking downstream.

The downstream boundary condition for the Schulle Canyon Creek model is based on a normal depth assumption.

Schulle Canyon Creek is modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Schulle Canyon Creek with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis.

3.2.6 Sessom Creek

Sessom Creek drains approximately 0.63 square miles as it flows into the San Marcos River. Sessom Creek was last studied as part of the 1994 City of San Marcos Drainage Master Plan performed by CDM and is not a studied stream in the effective FIS. Sessom Creek presents significant flooding risk to the areas adjacent to Sessom Drive and Texas State University during more extreme events when flow is not contained within the channel banks. The large amount of impervious cover, steep slopes, and lack of conveyance capacity causes significant flash flooding in the Texas State University / Sessom Drive area. The limits of this study extend from the confluence with the San Marcos River upstream to a point approximately 75 feet downstream of Canyon Fork. The model was generated from two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. There are 37 cross sections and 5 culverts modeled in Sessom Creek. The upper portion of Sessom Creek consists of an incised natural channel with a grass/rock bottom and heavy brush on the side slopes. The lower portion of Sessom Creek is highly urbanized with a system of culverts, bridges, and concrete channels. This model represents a total reach length of 5,800 feet. All cross sections are modeled from left to right looking downstream.

The downstream boundary condition for the Sessom Creek model is based on a normal depth assumption.

Sessom Creek is modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Sessom Creek with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis

3.2.7 Willow Springs Creek and Tributaries

Willow Springs Creek and its four tributaries drain approximately 4.51 square miles as it flows into the San Marcos River. Willow Springs Creek and its tributaries were last studied as part of the 1995 Hays County FIS. Willow Springs Creek presents a significant flooding risk near Stagecoach Trail as well as in the urbanized sections in central San Marcos downstream of Missouri Pacific / Kansas Texas Railroad tracks. The limits of this study extend from the confluence with the San Marcos River upstream to a point 2,250 feet upstream of Hunter Road. The model was generated from two-foot, 2003 LIDAR contour data, field-surveyed cross sections, and field-surveyed structures. There are 98 cross sections, 9 culverts, and 8 bridges modeled in Willow Springs Creek and its tributaries. Most of Willow Springs Creek and its tributaries consist of a defined natural channel with mostly grass bottom, grass side slopes, and brushy overbank areas. The downstream segments of Willow Springs Creek pass through an urbanized section of San Marcos that receives regular mowing and maintenance by the City of San Marcos. Tributaries to Willow Springs Creek are fully channelized with concrete in the area near Wonder World Drive at IH 35. Additionally, there is a concrete trickle channel in the main stem of Willow Springs Creek between Ellis Street and McKie Street. These five models represent a total reach length of 25,400 feet. All cross sections are modeled from left to right looking downstream.

The downstream boundary conditions for Willow Springs Creek main stem, as well as all of its tributaries are based on a normal depth assumption.
An important hydraulic characteristic of Willow Springs Creek is that it has receives flow diversion from the adjacent Purgatory Creek watershed. Purgatory Creek Diversion No. 2 splits from the main stem of Purgatory Creek and flows into the main stem of Willow Springs Creek. Further discussion regarding the flow diversion can be found in §2.5.3 of this report.

Willow Springs Creek and its tributaries are modeled assuming a subcritical flow regime, which is consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix C.3.4.4. There are no existing stream gages on Willow Springs Creek or its tributaries with which to perform any hydraulic model calibration; therefore, no calibration of this reach is performed as part of this analysis.

3.3 MODEL DEVELOPMENT – BLANCO RIVER AND SAN MARCOS RIVER

The Blanco River and San Marcos River hydraulic models are derived from the FEMA effective hydraulic model for each reach. The development of each of these models is discussed in the sections that follow. The Blanco River extends from its confluence with the San Marcos River to the west of the City of Blanco, Texas.

3.3.1 Blanco River

The Blanco River is a large watershed and the source of many flooding problems in the San Marcos community. The cumulative drainage area of the Blanco River at the confluence with the San Marcos River is approximately 436 square miles. It was last studied as part of the 1995 Hays County FIS.

3.3.1.1 Identification of the Effective Model

On November 21, 2005, Espey Consultants (EC) submitted a Category 1 Data Request to the FEMA Project Library in care of Michael Baker, Jr., Inc. On December 28, 2005, FEMA notified EC that all available electronic data for Hays County, Texas, was available for download from the Michael Baker FTP site. This download included a HEC-2 electronic output file of the Blanco River Reaches A and B. These models referenced an old (FIS) dated February 18, 1998. The effective Hays County FIS is dated September 2, 2005; however, no revisions were made to the Blanco River hydrologic or hydraulic models. The updated FIS only changed the Blanco River with respect to a datum conversion from NGVD 1929 to NAVD 1988. As of the 2005 FIS, the hydraulic model is still referenced to the NGVD 1929. The hydraulic model reaches A and B are described by the table shown below.

Table 14. Blanco River HEC-2 Reach Limits and Descriptions

Reach	Beginning Station	Ending Station	Description (D/S limit to U/S limit)
A	5+30	374+10	Confluence with San Marcos River to San Marcos corporate limits*
B	374+10	1200+20	San Marcos corporate limits to Loneman Creek

* corporate limits as defined at time of original study circa 1995

With respect to the Blanco River, the scope of this flood protection plan includes an analysis of the Blanco River from its confluence with the San Marcos River (HEC-2 Station 5+30) to approximately 1,000 feet upstream of Interstate Highway 35 (IH 35) (HEC-2 Station 351+40). Thus, the scope of this flood protection plan only includes Reach A.

The 1% annual chance computed water surface elevations (CWSELs) from the provided electronic output file for Reach A satisfactorily matches the 1998 FIS. The differences in CWSELs are shown in the table below.

Table 15. Blanco River Verification of Water Surface Elevations for the Effective Model

	FIS		HEC-2		
XS Letter	Station	Published 1% WSE*	Station	Computed 1% WSE	Difference
A	104+80	580.4	104+80	580.5	0.1
B	188+00	588.3	188+00	589.3	1.0
C	234+70	594.5	234+70	594.9	0.4
D	319+60	605.1	319+60	605.1	0.0

* 1% WSE refers to the 1% annual chance water surface elevation

Although there are discrepancies as shown above, this HEC-2 model was provided by FEMA and matches the published FIS to an acceptable degree. This HEC-2 model is considered the **effective model** for Reach A of the Blanco River. A table showing the comparison of the published and computed water surface elevations as well as the published model output is included in the Blanco River Technical Memorandum dated November 3, 2006.

3.3.1.2 Creation of the Duplicate Effective Model

An input file representing a duplication of the input file of the effective model was created using HEC-2. CWSELs for the 1% annual chance event match at each cross section within Reach A. This HEC-2 model is considered the **duplicate effective model** for Reach A of the Blanco River.

3.3.1.3 Corrections to Create the Corrected Model

The duplicate effective HEC-2 model was imported into HEC-RAS. The duplicate effective model was checked for any records that HEC-RAS v3.1.3 is not capable of converting. These include the channel improvement record (CI) and the additional ground points record (X4)—neither were present. The Bridge Culvert Data option “distance to upstream cross section” was adjusted from zero feet to one foot in order to allow HEC-RAS to run. In exchange, all road decks were shortened by one foot. The duplicate effective model also contained several cross sections with duplicate points. These points were removed to allow HEC-RAS to run.

The HEC-RAS model was then computed using the HEC-2 style conveyance calculation option. CWSELs were compared to verify accuracy of the HEC-2 to HEC-RAS conversion. For the most part, the conversion ran smoothly resulting in minimal differences in CWSELs; however, in the vicinity of bridges, water surface elevations did decrease by as much as 1.1 feet (specifically at State Highway 80).

Cross sections and the stream centerline were geographically referenced by drawing the cross sections in AutoCAD. A shapefile of the lettered cross sections was provided by Halff Associates who performed the 2005 revision to the Hays County FIS. Lettered cross sections and bridges were used as landmarks to re-station and geo-reference all cross sections including interpolated cross sections of the effective model. Coordinates were copied into the HEC-RAS geometry file. River stations were renamed using their new channel downstream reach lengths.

Once a working model was created, a draft 1% annual chance floodplain was created and delineated using ArcView and HEC-GeoRAS. Overbank reach lengths were measured by estimating the centroid of the floodplain fringe on each overbank and measuring the length of the flowpath between cross sections.

Other corrections include the following:

1) Flow rates are revised to reflect the hydrologic model developed as part of the San Marcos Flood Protection Plan. Note that the flow rates from the effective model included the 10%, 2%, 1%, and the 0.2% annual chance events. The new flow rates added for the San Marcos Flood Protection Plan are the 50%, 10%, 4%, 1%, and the ultimate 1% annual chance events.
2) Conveyance calculation methodology was changed from HEC-2 style, which computes conveyance between every coordinate point, to HEC-RAS style, which computes conveyance between changes in n value only.
3) All elevations were vertically adjusted from the National Geodetic Vertical Datum (NGVD) of 1929 to the North American Vertical Datum (NAVD) of 1988. The US Army Corps of Engineers Corpscon v6.0.1 software was used to derive the appropriate vertical adjustment. Adjustments were computed at three locations, the downstream end of the reach, the middle of the reach, and the upstream end of the reach. The adjustments were +0.27 feet, +0.28 feet, and +0.34 feet. The resulting average adjustment, which is applied along the length of the

reach, is +0.30 feet (i.e., NAVD 88 is an average of 0.30 feet higher than NGVD 29 for this reach).

4) Test elevations for ineffective flow areas required no adjustment.
5) Certain cross sections are exceeded by the extreme events; however, these cross sections were also exceeded by the FIS extreme events. The floodplain elevation will be mapped rather than the floodplain top width. No adjustment is required.
6) The downstream boundary condition is set as known water surface elevations for each profile. Assumed water surface elevations are based on CWSELs from the corrected San Marcos River Reach A hydraulic model. The San Marcos model is run assuming the Blanco River flow rates. This implies non-coincident peaks between the San Marcos and Blanco Rivers; however, the flow in the Blanco River causes a water surface elevation greater than normal depth for each computed flow rate.
7) The Blanco River hydrologic model previously utilized inflow-diversion rating curves to simulate the diversion of flood waters to Bypass Creek and its tributaries. The EC existing conditions 1% storm event flow rate exceeds all points on the FIS inflow-diversion rating curves. An appropriate method to simulate these diversions is to place a lateral weir on the left overbanks, and let HEC-RAS calculate the amount of flow diverted. HEC-RAS Hydraulic Reference Manual (Chapter 8, Page 8-15) discusses the merits of computing the flow with the energy grade line or water surface elevation. In this circumstance the momentum is in the downstream direction, therefore the water surface elevation option was utilized. The weir type option is broadcrested, and the weir coefficient is 2.6. The inflow-diversion rating curves developed for the side overflows to Bypass Creeks are included in Appendix P.

This concludes the development of the **corrected hydraulic model** for the Blanco River.

3.3.2 San Marcos River

The San Marcos River extends from its confluence with the Guadalupe River located in Gonzales County, Texas, to San Marcos Springs and Spring Lake located in the City of San Marcos, Texas. The San Marcos River is unique in that it is fed by a large tributary at its upstream end known as Sink Creek and that it is fed by the larger Blanco River at the downstream end of the City of San Marcos. A baseflow condition is created by San Marcos Springs; however, this baseflow is insignificant when compared to the larger peak flow rates generated by intense storm events on Sink Creek and the Blanco River. The average baseflow in the San Marcos River downstream of San Marcos Springs is 175[7] cfs, which is approximately 2% of the 1% annual chance peak flow rate. Therefore, the San Marcos hydraulic model does not include the spring baseflow. The figure shown on the right is a typical view of flow from San Marcos Springs over the Spring Lake Dam. It was last studied as part of

Figure 17. Typical Spring Lake Spillway Discharge

[7] Average derived from measured USGS daily mean data between 1957 and 2006

the 1998 Hays County FIS. The cumulative drainage area of the San Marcos River is described as follows:

- 48.9 square miles at Spring Lake (headwaters of San Marcos River);
- 95.3 square miles just upstream of confluence with Blanco River;
- 531.7 square miles just downstream of confluence with Blanco River; and
- 541.0 square miles just downstream of confluence with Bypass Creek.

The scope of this project includes a conversion of the effective hydraulic model of the San Marcos River from its confluence with Bypass Creek to its headwaters at Spring Lake Dam.

3.3.2.1 Identification of the Effective Model

On November 21, 2005, Espey Consultants (EC) submitted a Category 1 Data Request to the FEMA Project Library in care of Michael Baker, Jr., Inc. On December 28, 2005, FEMA notified EC that all available electronic data for Hays County, Texas, was available for download from the Michael Baker FTP site. This download included an HEC-2 electronic output file of the San Marcos River Reach A-B and the San Marcos River Reach B-K. These models referenced an old Flood Insurance Study (FIS) dated February 18, 1998. The effective Hays County FIS is dated September 2, 2005; however, no revisions were made to the San Marcos River hydrologic or hydraulic models. The updated FIS only changed the San Marcos River mapping and profiling with respect to a datum conversion from NGVD 1929 to NAVD 1988. As of the 2005 FIS, the hydraulic model is still referenced to the NGVD 1929. The hydraulic model reaches A-B and B-K are described by the table shown below.

With respect to the San Marcos River, the scope of this flood protection plan includes an analysis of the river from its confluence with the Bypass Creek (HEC-2 Station 3779+00) to its confluence with Sessom Creek (HEC-2 Station 4162+30). Thus, the scope of this flood protection plan only includes a portion of Reach A and a portion of Reach B.

The 1% annual chance CWSELs from the provided electronic output file for Reach A and Reach B satisfactorily matches the 1998 FIS. The differences in CWSELs are shown in the table below.

Table 16. San Marcos River HEC-2 Reach Limits and Descriptions

Reach	Beginning Station	Ending Station	Description (D/S limit to U/S limit)
A	3732+80	3923+10	Confluence w/ Bypass Creek to Confluence w/ Blanco River
B	3920+30	4176+80	Confluence w/ Blanco River to Confluence w/ Sessom Creek

This HEC-2 model is considered the **effective model** for Reach A and B of the San Marcos River. The published model output is included in this report as Appendix L.

Table 17. San Marcos River Verification of Water Surface Elevations for the Effective Model

FEMA XS Letter	River Station	Published Water Surface Elevations FIS	Computed Water Surface Elevations HEC-2	Difference
A	3765+40	552.0	552.0	0.0
B	3852+10	563.8	563.8	0.0
C	3943+50	565.6	565.6	0.0
D	4005+80	566.1	566.1	0.0
E	4058+50	566.7	566.7	0.0
F	4085+50	566.9	566.9	0.0
G	4127+00	569.3	569.3	0.0
H	4140+40	570.2	570.2	0.0
I	4147+80	571.3	571.3	0.0
J	4159+60	572.6	572.6	0.0
K	4171+80	576.8	576.8	0.0

3.3.2.2 Creation of the Duplicate Effective Model

An input file representing a duplication of the output file of the effective model was created using HEC-2. Computed water surface elevations for the 1% annual chance event match at each cross section within Reach A and B. This HEC-2 model is considered the **duplicate effective model** for Reach A and B of the San Marcos River. The comparison of the effective and duplicate effective water surface elevations are shown in the table below. The differences between the HEC-2 and HEC-RAS CWSELs are insignificant.

Table 18. Effective versus Duplicate Effective CWSELs for the San Marcos River

FEMA XS Letter	River Station	Computed Water Surface Elevations		Difference
		HEC-2	HEC-RAS	
A	3765+40	552.03	552.03	0.00
B	3852+10	563.78	563.78	0.00
C	3943+50	565.61	565.61	0.00
D	4005+80	566.11	566.11	0.00
E	4058+50	566.72	566.72	0.00
F	4085+50	566.89	566.89	0.00
G	4127+00	569.30	569.43	0.13
H	4140+40	570.18	570.31	0.13
I	4147+80	571.29	571.40	0.11
J	4159+60	572.56	572.63	0.07
K	4171+80	576.81	576.81	0.00

3.3.2.3 Corrections to Create the Corrected Model

The duplicate effective model was checked for any records that HEC-RAS v3.1.3 is not capable of converting. These include the channel improvement record (CI) and the additional ground points record (X4)—neither were present. The Bridge Culvert Data option “distance to upstream cross section” was adjusted from zero feet to one foot in order to allow HEC-RAS to run. In exchange, all road decks were shortened by one foot. The duplicate effective model also contained several cross sections with duplicate points. These points were removed to allow HEC-RAS to run.

The HEC-RAS model was then run using the HEC-2 style conveyance calculation option. CWSELs were compared to verify accuracy of the HEC-2 to HEC-RAS conversion. For the most part the conversion run smoothly resulting in minimal differences in CWSELs; however, in the vicinity of bridges, water surface elevations did increase by as much as 0.2 feet.

Cross sections and the stream centerline were geographically referenced by drawing the cross sections in AutoCAD. A shapefile of the lettered cross sections was provided by Halff Associates who performed the 2005 revision to the Hays County FIS. Lettered cross sections and bridges were used as landmarks to re-station and geo-reference all cross sections including interpolated cross sections of the effective model. Coordinates were copied into the HEC-RAS geometry file. River stations were renamed according to their new channel downstream reach lengths.

Once a working model was created, a draft 1% annual chance floodplain was created and delineated using ArcView and HEC-GeoRAS. Overbank reach lengths were measured by estimating the centroid of the floodplain fringe on each overbank and measuring the length of the flowpath between cross sections.

Other corrections include the following:

1) Flow rates are revised to reflect the hydrologic model developed as part of the San Marcos Flood Protection Plan. Note that the flow rates from the effective model included the 10%, 2%, 1%, and the 0.2% annual chance events. The new flow rates modeled for the San Marcos Flood Protection Plan are the 50%, 10%, 4%, 1%, and the ultimate 1% annual chance events.
2) Conveyance calculation methodology was changed from HEC-2 style, which computes conveyance between every coordinate point, to HEC-RAS style, which computes conveyance between changes in n value only.
3) All elevations were vertically adjusted from the National Geodetic Vertical Datum (NGVD) of 1929 to the North American Vertical Datum (NAVD) of 1988. The US Army Corps of Engineers Corpscon v6.0.1 software was used to derive the appropriate vertical adjustment. Adjustments were computed at three locations, the downstream end of the reach, the middle of the reach, and the upstream end of the reach. The adjustments were +0.26 feet, +0.26 feet, and +0.28 feet. The resulting average adjustment, which is applied along the length of the reach, is +0.27 feet (i.e., NAVD 88 is an average of 0.27 feet higher than NGVD 29 for this reach).
4) Test elevations for ineffective flow areas required no adjustment.
5) Certain cross sections are exceeded by the extreme events; however, these cross sections were also exceeded by the FIS extreme events. The floodplain elevation will be mapped rather than the floodplain top width. No adjustment is required.
6) The downstream boundary condition is set as a known water surface elevation for each profile in Reach B of the hydraulic model. The assumed water surface elevations in the Reach B hydraulic model are based on CWSELs from the Reach A hydraulic model. The Reach A hydraulic model is run assuming the Blanco River is not at flood stage. This

implies non-coincident peaks between the San Marcos and Blanco Rivers. The downstream boundary condition is set to normal depth for Reach A of the hydraulic model.

7) Cross sections were obtained from the Halff & Associates hydraulic study related to the rehabilitation of the Rio Vista Dam. The hydraulic models from Halff Associates contain cross sections with as-built survey data included, and are incorporated into the Reach B hydraulic model.

This concludes the development of the **corrected hydraulic model** for the San Marcos River.

3.4 HYDRAULIC MODEL VALIDATION

The October 1998 event is the defining flood event in recent history for this area; therefore, the validation exercise focuses on this event. There is limited historical high water mark (HWM) data available for the San Marcos watersheds. The source of high water elevation data for the 1998 flood is the U.S. Army Corps of Engineers (USACE) Fort Worth District Office post-flood observations. The photos of HWMs were coupled by a written description of the location and corresponding elevation (usually stated in height above ground or top of road).

As discussed in §2.6.1, the NEXRAD rainfall data for the October 1998 storm is input to the hydrologic model and peak flow rates are computed. The computed flow rates can then be evaluated in the hydraulic model to generate CWSELs. The interpreted HWMs are then compared to CWSELs for the 1998 storm event. It is important to note that the accuracy of the HWMs may exceed ±1.0 feet given the in manner which they are collected. Generally, the differences between the HWMs and CWSELs are within a tolerable range, thereby providing validation to the hydraulic model. The table below provides a comparison of the measured versus computed HWMs for the 1998 storm event at key locations.

Table 19. Hydraulic Model Validation for the 1998 Storm Event

Stream	Location	Measured HWM	Computed HWM	Diff
Blanco River	IH-35 Bridge	607.3	606.1	-1.2
Blanco River	SH-80 Bridge	587.0	584.4	-2.6
Purgatory Creek	Mitchell Rd Culvert	585.9	586.8	0.9
Purgatory Creek	Guadalupe St Culvert	583.0	583.3	0.3
San Marcos River	Union Pacific RR Bridge near Hopkins St	576.0	579.1	3.1
San Marcos River	Tree near CM Allen Pkwy at Hopkins Rd	577.7	580.6	3.0

% Diff: percent different from measured HWM

3.5 HYDRAULIC ANALYSIS SUMMARY AND CONCLUSIONS

The comprehensive hydraulic analysis of San Marcos area watersheds Bypass Creek, Cottonwood Creek, Purgatory Creek, Rio Vista Creek, Schulle Canyon Creek, Sessom Creek, and Willow Springs Creek includes LIDAR topographic data, field surveyed structure data, and construction records data. The hydraulic analysis of Blanco River and San Marcos River included a conversion from HEC-2 to HEC-RAS, new flow rates, and construction records data. In general, 1% annual chance CWSELs increased in reaches that were previously studied in the FIS.

Computed water surface elevations and floodplain delineations are compared to various other data to respect the historical work done as well as bolster credibility to the model. The Blanco River and San Marcos River hydraulic models are conversions of the effective Federal Emergency Management Agency (FEMA) hydraulic models. Minor revisions have been made to these hydraulic models; however, the new computed water surface elevations are relatively consistent with FIS elevations. New hydraulic models were created for the remaining reaches of this study. Published peak flow rates from the FIS were input into the newly created hydraulic models to compare floodplains. The resulting delineation shows that the new hydraulic model floodplains assuming FEMA peak flows are consistent with the effective FEMA floodplains. The floodplains assuming new computed peak flow rates are generally wider that the published FEMA floodplain data.

Cross sections used in this hydraulic analysis are geographically referenced (horizontally) in the North American Datum (NAD) of 1983 – State Plane, South Central Texas Zone, US feet. Water surface elevations for each cross section are mapped onto the City's 2003 LIDAR data, which is referenced (vertically) to the NAVD of 1988. The San Marcos River hydraulic model deviates from the horizontal geographic reference, and is in North American Datum (NAD) of 1983 – Texas State Plane, Central Zone, US feet. The existing conditions and ultimate conditions floodplain map for Blanco River, Bypass Creek, Cottonwood Creek, Purgatory Creek, San Marcos River, Schulle Canyon Creek, Sessom Creek, and Willow Springs Creek are included in this report as Exhibit 5 of Appendix A.

The City of San Marcos can use the results of this hydraulic analysis and the floodplains delineated on Exhibit 5 to assist in the regulation of development within the watershed. Exhibit 5 shows where the floodprone areas are and how these floodprone areas are likely to change as development progresses. The City can use this information to evaluate flood control projects, write floodplain/stormwater ordinances regulating development, etc. As shown in Exhibit 5, there are several flood prone areas within the City. There are also areas where the ultimate conditions floodplain is projected to be significantly different from the existing conditions floodplain. In areas such as the Blanco River and San Marcos River, the ultimate conditions floodplain is indistinguishable from the existing conditions floodplain due to the development and hydrologic characteristics of the watershed. The lower sections of Purgatory Creek and Willow Springs Creek will be subject to significant changes in floodplain delineation from existing to ultimate conditions. The Franklin Square and Cottonwood Creek will be subject to moderate changes in floodplain delineation as development approaches ultimate conditions.

4.0 FLOOD MITIGATION ALTERNATIVES

The San Marcos Flood Protection Plan provides numerous solutions to mitigate against flooding issues and helps the city assess which projects provide the greatest benefit in relation to the cost. Given the expense of infrastructure, the cost if implementation is a significant limitation on which projects may be realized. To assist the City in prioritizing which projects should be funded, the alternatives are assessed with a combination of cost of implementation and associated benefits. Evaluated projects include structural flood controls, prediction tools and flood early warning systems, and community initiatives. Each of these alternatives are discussed in the sections that follow. Detailed cost estimates of the mitigation alternatives are included in Appendix R of this report.

4.1 STRUCTURAL FLOOD CONTROLS

Structural flood controls such as creek maintenance, detention ponds, etc., are potential construction projects that could be built in an effort to alter the flood condition of a watershed. These projects have a high variability in complexity and cost. Channel maintenance and overbank maintenance could consist of any combination of sediment deposit removal, brush removal, or enhancements to conveyance capacity. A peak flow diversion consists of increasing the flood conveyance capacity of naturally occurring flow diversions in an effort to redirect floodwaters away from the main source of flooding. Regional detention ponds are large impoundments of floodwater that reduces peak flow rates downstream. Specific potential projects for various hydraulic reaches are described in this section. Alternatives evaluated and discussed further in this section include the following:

- Blanco River Watershed
  - Channel and overbank maintenance for Blanco River
  - Peak flow diversion to Bypass Creek
- Cottonwood Creek
  - “Detention Plus” upstream of IH 35
  - Floodplain ordinances and regulations
- Purgatory Creek
  - Channel maintenance and Hopkins Street culvert improvement
  - Castle Creek Drive culvert improvement
  - Expansion of NRCS Reservoir No. 5 flood storage volume
- Schulle Canyon
  - Culvert improvement
- Sessom Creek
  - Culvert improvement
- Willow Springs Creek
  - Downstream regional detention pond
  - Upstream regional detention pond
  - Channel maintenance

4.1.1 Blanco River

Mitigation Alternative 1A – Channel and Overbank Maintenance

Routine maintenance is one alternative that can be utilized in reducing flood risks along the Blanco River. A routine channel maintenance program would include regularly scheduled mowing and debris removal. The level of channel maintenance can be adjusted to meet the specific riparian characteristics of the Blanco River. Hydraulically, routine maintenance along the Blanco River would eliminate sediment deposits and promote flow with a "smoother", more hydraulically efficient channel surface.

i) Methodology

To simulate the channel maintenance, certain parameters are modified within the hydraulic model. Channel Manning's n-values in the Blanco River hydraulic model range from 0.04 to 0.05, and overbank n-values range from 0.065 to 0.08. The n-values are globally reduced by 0.005 in the Mitigation Alternative 1A hydraulic model in order to quantify a potential benefit.

ii) Cost of Implementation

The logistics of maintenance on a major river complicates the implementation of an effective maintenance program. The channel width averages 300 feet wide and the floodplain is as much as 9,000 feet wide in some locations. The maintenance area would extend onto numerous private properties; therefore, the City would need to obtain access easements in order to perform maintenance activities on those properties. The costs associated with the program would be primarily dominated by manpower and equipment costs. The intensity (level of service) of the maintenance program would dictate cost.

iii) Benefit

The average reduction in CWSELs is 0.4 feet for the 1% annual chance event and 0.8 feet for the 4% annual chance event. Due to environmental impacts and the marginal reduction in CWSELs, this project is not recommended as a viable improvement alternative at this time.

Mitigation Alternative 1B – Peak Flow Diversion to Bypass Creek

Blanco River and its Bypass Creek system present significant flooding risk to adjacent properties along the Blanco River, Bypass Creek and its two tributaries. Currently, the Blanco River is contained within its banks in most locations for the 4% annual chance storm event. Storm events greater than the 4% event overtop the Blanco River left bank and overflow naturally into Bypass Creek and its two tributaries. These storm events also overtop the right overbank and flood significant areas of the City. One proposed alternative for reducing flood risk involves increasing the peak flow diversion from Blanco River to Bypass Creek with structural improvements. The intent of this improvement would be to reduce the peak flow rate of the Blanco River such that flow is contained in the overbanks (i.e., the 4% event). The excess flow would be diverted to an improved Bypass Creek channel. A schematic of the Bypass Creek system can be found as Exhibit 8 of Appendix A.

i) Methodology

Improvements to Bypass Creek would require the construction of a "perched" channel that is partially sunken into the ground and partially above ground with bermed sides. The berm would be required along the entire length of Bypass Creek. Reduction of the 1% annual chance peak flow rate to the 4% annual chance peak flow rate provides significant reduction in flooding depths to areas effected by the Blanco River floodplain. The peak flow rate for the 1% annual chance storm in the Blanco River is approximately 155,000 cfs. The peak flow rate for the 4% annual chance storm is approximately 97,000 cfs. The difference between the two peak flows is approximately 58,000 cfs. To convey a diverted flow of 58,000 cfs, the required channel dimensions would be 150 feet of bottom width, 3:1 side slopes, and 20 feet of depth.

ii) Cost of Implementation

This improvement alternative involves extensive earthwork to remove and/or reuse 1.67 million cubic yards of earthen material. Assuming a unit cost of $30 per cubic yard of excavation to be removed from site and $20 per cubic yard of excavation to be reused on site, the cost of implementation for this project is approximately $64 million. An itemized cost estimate can be found in Appendix S.

iii) Benefit

The Bypass Creek peak flow diversion removes approximately 570 residential properties from the 1% annual chance floodplain. Exhibit 8 in Appendix A shows the location of the proposed Bypass Creek channel improvement and the projected floodplain benefit. The total value of all residential property in the Blanco River and Bypass Creek 1% annual chance storm event floodplain is approximately $40 million. This value is based on a median property value of approximately $70,000 per property, which is calculated using a 10% sample of all affected residential properties. All property value data is obtained from Hays Central Appraisal District for the 2006 tax year. In terms of direct floodplain reduction, this proposed mitigation project is highly beneficial. Potential environmental impacts would be confined to Bypass Creek while leaving the Blanco River in a natural state. The City must weigh the cost of the project versus the floodplain benefit to determine the feasibility of the project.

4.1.2 Cottonwood Creek

Mitigation Alternative 2A – Detention Plus

The upper Cottonwood Creek watershed conveyance is significantly restricted by conveyance structures at I-35, resulting in lateral flow across sub-watersheds. This condition significantly affects the development potential in this desirable development corridor. Structural improvements, such as upgrading the conveyance structures, adding new conveyance structures, tunneling, among others, are considered to be cost prohibitive. At the same time, implementation of a regional detention program in the Cottonwood Creek watershed may be limited, due to a select number of sites that are able to meet the desired volume criterion.

i) Methodology

One approach to handle this need may be through distributing the required volume across a number of new development projects. A program, titled for instance "Detention Plus", may be established in a manner similar to a cost "oversize" program typically applicable with water and wastewater infrastructure. Applicants would be responsible for providing detention storage to offset the increase in runoff attributable to their development, as well as additional prorated storage (either in detention or retention) that serves to meet the regional (Upper Cottonwood Creek) need. This additional regional need is defined as the storage volume necessary to enable full conveyance through the existing structures crossing under I-35. Additional analysis would be required to quantify the oversize responsibility of land development in this area.

ii) Cost of Implementation

The cost associated with this additional prorated storage represents the "oversize" component, and may be financed through impact fees or an impact fee waiver/credit, or other funding mechanisms. The applicant's development area and land use classification would be used to determine the required storage volume in addition to the volume required to mitigate the effects of the development.

iii) Benefit

Traditional strategies of detaining stormwater and discharging the existing conditions peak flow rate will not alleviate flooding on Cottonwood Creek upstream of IH-35. The cost-sharing mechanism allows for development of the property with minimal expense to the city. The implementation of the Detention Plus ordinance in the upper Cottonwood Creek watershed could demonstrate the City's foresight and commitment to minimize the risk to life and property associated with flooding.

4.1.3 Purgatory Creek

Purgatory Creek and its tributaries present a significant risk to life and property downstream of NRCS Reservoir No. 5 due to flooding. Flooding adversely impacts vital transportation links and many properties adjacent to the creek. Hopkins Street is an important road that is utilized by many western and central San Marcos districts and serves as a link to downtown, IH-35 (via Wonder World Drive), and the Central Texas Medical Center (via Wonder World Drive). Transportation use at the culvert crossings on Hopkins Road at Purgatory Creek and the Purgatory Creek Diversion No. 1 is dangerous and impassable when overtopped by floodwaters.

There are several recommended solutions to reduce the flooding risk caused by Purgatory Creek and its tributaries, including Purgatory Creek Diversion No. 1.

Mitigation Alternative 3A – Culvert Improvement and Channel Maintenance

Currently, Purgatory Diversion No. 1 diverts flow from the main channel immediately downstream of the NRCS Reservoir No. 5 spillway and reconnects with the main stem of Purgatory Creek approximately 1.2 miles downstream. After the flow diversion, both the main stem and diversion cross culverts at Hopkins Street. Both culverts are overtopped in the 50% annual chance storm.

i) Methodology

Routine channel maintenance is one alternative that can be utilized in reducing flood risks along Purgatory Creek and its tributaries. The channel maintenance program provides regular mowing and brush removal on the lower segment on Purgatory Creek, but there is no observed maintenance upstream of Hopkins Street. The flooding events from 1998 to present date have deposited a large amount of sediment downstream of NRCS Reservoir No. 5. Observation of the 2002 aerial imagery shows large amounts of scour from the emergency spillway. Discussions with the Upper San Marcos Watershed District indicate that 6 to 10 feet of sediment deposition has occurred on the main stem of Purgatory Creek near Purgatory Creek Diversion No. 1. Exhibit 9 of Appendix A shows the existing creek flowline and areas of severe sedimentation. The restoration of channel conveyance capacity requires sediment removal and restoration of original channel characteristics (i.e., flow line, channel banks, and vegetation). A schematic of the Lower Purgatory Creek system can be found in Exhibit 9 of Appendix A. The length of channel excavation is 3,450 feet, the channel depth is 4 feet, and the channel bottom width is 30 feet.

ii) Cost of Implementation

Culvert improvements are proposed at Purgatory Creek main stem at Hopkins Street. The proposed culvert crossing consists of four 8’ x 6’ box culverts in order to convey the 4% annual chance peak flow rate (1,450 cfs). The estimated cost of these improvements is $139,000. This estimate includes the cost of culverts, headwall, excavation, and roadway work. An itemized cost estimate can be found in Appendix S.

iii) Benefit

Maintaining roadway accessibility on Hopkins Street crossing Purgatory Creek is of vital importance. As mentioned earlier, this important transportation artery links many western and central San Marcos residential districts to downtown San Marcos, IH-35 (via Wonder World Drive), and the Central Texas Medical Center (via Wonder World Drive). The major benefits from this proposed project include the provision of accessible routes during storm events and reduction of risk to life and property associated with flooding. The improvements to Purgatory Creek would remove 67 acres from the 1% annual chance floodplain.

Mitigation Alternative 3B - Culvert Improvement Castle Creek Drive

Franklin Square Creek (Purgatory Tributary 3) receives stormwater flows from mostly single family residential drainage areas in the western region of San Marcos. The culvert crossing at Castle Creek Drive causes backwater to encroach onto adjacent properties during a 10% storm event, and the crossing is overtopped during a 4% storm event. Mitigation Alternative 3B focuses on reducing the impacts of flooding at this structure. A schematic of the Franklin Square Creek can be found in Exhibit 10 of Appendix A.

i) Methodology

The existing three-barrel, five-foot diameter circular culvert at Castle Creek Drive provides a 10-year level of service. The flood depth over the lowest point of the road during the 4% annual chance event is 1.10 feet. One recommendation involves increasing the barrel diameters from five feet to six feet. This increase in capacity would provide this structure with a 25-year level of service.

ii) Cost of Implementation

The estimated cost of these culvert improvements is $64,000. This estimate includes the cost of culverts, headwall, excavation, and roadway work. An itemized cost estimate can be found in Appendix S.

iii) Benefit

Maintaining roadway accessibility is the primary benefit to culvert improvements and channel maintenance. Additionally, the properties adjacent to the upstream face of the culvert will experience a nominal reduction in stormwater inundation from Franklin Square Creek. Although there is a minimal benefit in terms of floodplain reclamation, the primary benefit of this alternative is to increase the level of service at the Castle Creek Drive culvert. In this case, the level of service was increased from 10 years to 25 years. The total value of the two impacted properties is $220,000.

Mitigation Alternative 3C - NRCS Reservoir No. 5 Volume Expansion

NRCS Reservoir No. 5 is an in-line flood control structure located along the main stem of Purgatory Creek. This structure has an emergency spillway with a flowline elevation of 650.80 feet above mean sea level (MSL). During the 1% annual chance event, this facility has a peak volume of 3,700 acre feet with a peak computed water surface elevation of 653.42 feet above MSL, which engages the emergency spillway. Recall from §2.2 that the 1% annual chance event includes a balanced and nested distribution of 10.2 inches of precipitation in 24 hours. In recent history, the emergency spillway was engaged during the October 1998 event as well as the November 2001 event. When the spillway is engaged, large flow rates are conveyed via overland flow through the spillway weir into a downstream channel that discharges into Purgatory Creek. This causes significant flooding, erosion, and sedimentation to points downstream. The objective of this expansion concept is to increase the volume of the existing reservoir to the maximum extent possible in an effort to disengage the spillway for as many storm events as possible.

i) Methodology

The existing reservoir inundates a large area during extreme events; however, areas where additional storage volume may be acquired are limited to the area north of the creek centerline on the NRCS parcel. Assuming a 1% minimum bottom cross slope and a maximum 4:1 pond side slope, an additional 700 acre feet of storage volume can be added to the reservoir below the emergency spillway elevation. Exhibit 11 of Appendix A shows a schematic of the proposed NRCS Reservoir No. 5 expansion.

ii) Cost of Implementation

This improvement alternative involves extensive earthwork to remove the 700 acre feet (1.1 million cubic yards) of earthen material. Assuming a unit cost of $30 per cubic yard of excavation, the cost of implementation for this project is approximately $40 million. An itemized cost estimate can be found in Appendix S.

iii) Benefit

The additional 700 acre feet of storage volume for the reservoir will not disengage the emergency spillway for the 1% annual chance event. This additional volume reduces the peak outflow of the reservoir by only 40 cfs. In order to disengage the emergency spillway and significantly reduce the flow rate for the 1% annual chance event, approximately 3,500 acre feet of additional storage would be required. In order to acquire this additional volume, land in addition to that shown in Exhibit 11 of Appendix A would be required. Due to the high cost and low benefit of this project, this project is not recommended as a viable improvement alternative at this time.

4.1.4 Schulle Canyon Creek

Schulle Canyon Creek presents flooding risks to the adjacent neighborhood and street crossings during more extreme events when flow is not contained within the channel banks. It is important to note that Schulle Canyon Creek has a relatively steep slope thus producing velocities that can cause possible stream bank erosion. An erosion prevention analysis would require additional study.

Mitigation Alternative 4A - Culvert Improvement LBJ Drive

i) Methodology

Currently, both culverts along Schulle Canyon Creek provide a two-year level of service. The most downstream culvert in this study area, located at North LBJ Drive, consists of four 3.5-foot diameter circular culverts. An increase in conveyance capacity can be achieved through basic channel maintenance. The downstream face of this culvert system is obstructed by sedimentation and vegetation. Basic culvert maintenance combined with regularly scheduled mowing and debris removal upstream and downstream of the culvert system is a recommended alternative for improving stormwater conveyance.

The upstream 29-foot long culvert, located at Schulle Drive, currently provides a two-year level of service. This portion of Schulle Drive is inundated by approximately one foot of water during the 4% annual chance storm event. Replacement of the existing four-foot diameter culvert with one 6' x 4' culvert is one recommendation for improving conveyance.

ii) Cost of Implementation

The estimated cost of the culvert improvement at Schulle Canyon Creek and Schulle Drive is $27,000. This estimate includes the cost of culverts, headwall, excavation, and roadway work. An itemized cost estimate can be found in Appendix S.

iii) Benefit

Maintaining roadway accessibility is the primary benefit to culvert improvements and channel maintenance.

4.1.5 Sessom Creek

When overtopped by extreme rain events, Sessom Creek poses a significant threat to vital infrastructure located within and adjacent to Texas State University. One alternative to alleviating the threat of flooding involves culvert improvements at specific points along Sessom Creek and Sessom Drive.

Mitigation Alternative 5A – Evaluation of Sessom Creek Drainage Infrastructure

i) Methodology

City of San Marcos code requires street and drainage improvements to provide a level of service that conveys a 4% annual chance event. Currently, four of the five structures along Sessom Creek fail the 4% annual chance event criterion. Culvert maintenance and upgrades can be considered as an alternative to reducing the risk of flooding at all four of these locations.

The existing 576-foot long, 4' x 8' box culvert at Sessom Drive and North LBJ fails to provide a level of service that can convey a 4% annual chance event. Currently, this culvert provides a two-year level of service. The flood depth over the lowest point of the road during the 4% annual chance event is approximately 2.5 feet. Replacement of the existing 4' x 8' box culvert with one 6' x 8' culvert is one recommendation for improving conveyance.

The next downstream structure located at Sessom Drive and Pleasant Street consists of one 4' x 8' box culvert. The flood depth over the lowest point of the road during the 4% annual chance event is 3.3 feet and 1.7 feet during the 50% annual chance event. An increase in flow area can be achieved through basic channel maintenance. Approximately 40% of the upstream face is obstructed by sediment build-up which has subsequently led to vegetation growth directly upstream of the culvert opening. Stormwater conveyance at this culvert can be vastly improved through simple sedimentation removal.

Located downstream of Pleasant Street at the intersection of Sessom Drive and an unnamed campus road is a bridge structure that is inundated by 2.5 feet of water during the 4% annual chance event. Channel maintenance through sedimentation removal is recommended for this section of drainage infrastructure. Upstream, underneath, and downstream of the bridge suffers from decreased conveyance due to vegetation growth caused by a build-up of sedimentation. Currently, this bridge structure provides a two-year level of service.

The existing 227-foot, 5’ x 10’ box culvert located at Sessom Drive and Peques Street currently provides a two-year level of service but fails to provide a level of service that conveys a 4% annual chance event. Replacement of the existing 10’ x 5’ box culvert with one 10’ x 8’ culvert is one recommendation for improving conveyance.

ii) Cost of Implementation

The estimated cost of the culvert improvements at North LBJ and Peques Street is $822,000. Individually, the estimated costs are $589,000 for culvert improvements at North LBJ, and $233,000 for culvert improvements at Peques Street. This estimate includes the cost of culverts, headwall, excavation, and roadway work. An itemized cost estimate can be found in Appendix S.

iii) Benefit

Limiting inundation of roadways will allow the City to maintain traffic flow through highly utilized transportation arteries without posing significant risk to personal safety associated with navigating overtopped roadways.

4.1.6 Willow Springs Creek

Mitigation Alternative 6A - Downstream Regional Detention

Willow Springs Creek presents a significant flood risk to the Victory Gardens neighborhood located in central San Marcos. The construction of a regional detention pond is one proposed approach to reducing the number of residential properties located in the Willow Springs 1% annual chance floodplain. The design objective of this proposed regional project is to reduce computed peak flow for locations downstream of the Union Pacific Railroad.

i) Methodology

The proposed Willow Springs Regional Detention Pond is located on approximately 110-acres of vacant, undeveloped land. The location of this site is bordered by Purgatory Creek to the north, Wonder World Drive to the southwest, and the Missouri Pacific / Kansas Texas Railroad tracks to the east. This proposed regional detention facility is located in the lower portion of Willow

Springs Creek watershed. The proposed regional detention facility will collect stormwater runoff from Willow Springs Creek main stem. The total drainage area upstream of the facilities is approximately 2.8 square miles. The total detention volume is approximately 740 acre-feet.

ii) Cost of Implementation

The total estimated cost of the proposed regional pond is approximately $9.1 million. This estimate includes land cost, cost of excavation, outlet structure, erosion and sedimentation controls, landscaping, mobilization, and miscellaneous costs such as engineering, surveying, and project management. The permanent right-of-way (ROW) land cost is approximately $1.6 million of the total cost of 149 acres. The assumption for cost of the land is determined using the current Hays Central Appraisal District (HCAD) appraised land value for the impacted parcel. An itemized cost estimate can be found in Appendix S.

iii) Benefit

The Willow Springs Creek regional detention pond benefit is quantified by the number of residential properties removed from the 1% annual chance event floodplain. The removal of residential properties from the 1% annual chance event floodplain is categorized into four different levels: completely removed (100%), substantially removed (75%), partially removed (50%), or minimally removed (25%). The median property value, $41,960, was determined using a 20% sample of all residential property in the Victory Gardens neighborhood. The financial benefit is determined by the percentage of each property removed from the floodplain along with median property value of all residential properties located within the existing floodplain. Using this methodology, the estimated value of property removed from the Willow Springs Creek floodplain is $3.6 million.

Mitigation Alternative 6B - Upstream Regional Detention

Another possible approach to reduce flooding depths on Willow Springs Creek in the City of San Marcos is to construct a regional detention facility in the upper portion of the watershed. An optimal location for such a facility would be at the McCarty Lane crossing of the eastern branch of Willow Springs Creek.

i) Methodology

The analysis discounted all contributing area upstream of McCarty Lane with input parameters adjusted in the hydrologic model accordingly. The reduced flow rates are input into the hydraulic model to evaluate new CWSELs.

ii) Cost of Implementation

No cost of implementation was calculated for this alternative.

iii) Benefit

The proposed project results in a mean reduction in CWSELs of 0.23 feet and a median reduction of 0.21 feet for the 1% annual chance storm. It is not recommended that the proposed alternative be implemented based on the minimal reduction in CWSELs.

Mitigation Alternative 6C - Channel Maintenance

Another possible mitigation approach is to perform channel maintenance and sediment removal on Willow Springs Creek to reduce flooding depths. Hydraulically, routine maintenance along the Willow Springs Creek would eliminate sediment deposits and promote flow with a "smoother", more hydraulically efficient channel surface.

1. Methodology

To simulate the channel maintenance, certain parameters are modified within the HEC-RAS model. The existing flowline of the creek is maintained, and a trapezoidal channel is cut to remove sediment and enhance conveyance capacity. The bottom width is 50 feet, which generally contains a 50% storm in the channel banks.

2. Cost of Implementation

The removal of sediment is proposed for a 6,750 foot segment of Willow Springs Creek. The average layer depth of sedimentation to be removed from this stretch of Willow Springs Creek is one foot. This channel maintenance results in the excavation and removal of 13,000 cubic yards of soil. Assuming a unit cost of $30 per cubic yard, the estimated total cost is $468,000. An itemized cost estimate can be found in Appendix S.

3. Benefit

The proposed project resulted in a mean reduction in CWSELs of 0.51 feet and a median reduction of 0.58 feet for the 1% annual chance storm.

4.2 BLANCO RIVER – FLOOD PREDICTION TOOLS AND WARNING SYSTEMS

One of the key elements in floodplain and emergency management is assessing a changing level of risk as the situation changes and being able to mobilize and take protective measures quickly. For the City of San Marcos, the Blanco River is a major flood hazard during extreme events. In a flood emergency situation, the City must be able to interpret and relate available data to a certain risk or hazard level and relay that hazard level to appropriate emergency management officials, City staff, and/or the public.

4.2.1 Blanco River Precipitation Nomograph

One of the tools that community officials can use to assess risk is precipitation data. For example, if a storm precipitates 6.0 inches of rain in six hours distributed over a significant portion of the Blanco River watershed, what flood risk or hazard is associated with that rainfall? What amount of rainfall is significant? What area of precipitation is significant?

Generally, the Blanco River overtops its banks in many locations for events of equal or greater magnitude than the 4% annual chance exceedance event. This equates to a high flood hazard event that warrants significant community action. For events between a 4% and 10% annual chance, the Blanco River overtops its banks in a few locations, thus the flood hazard level may be considered moderate requiring only targeted actions. For events with a greater than 10% annual chance exceedance, the flood risk is relatively minimal. The figure below represents the depth-duration-frequency curve for the Blanco River watershed with corresponding hazard levels indicated. The City could tabulate and plot cumulative precipitation versus duration (time) for any given storm event in real time using data from the National Weather Service. If the real time data encroached upon the nomograph areas designated as moderate hazard, public notification and closing of all low water crossing over the Blanco River would be prudent. If the precipitation was more intense and encroached upon the nomograph area designated as high hazard, public notification and evacuation of floodplain areas with the Blanco watershed would be prudent. These actions are most likely accomplished by emergency operations personnel.

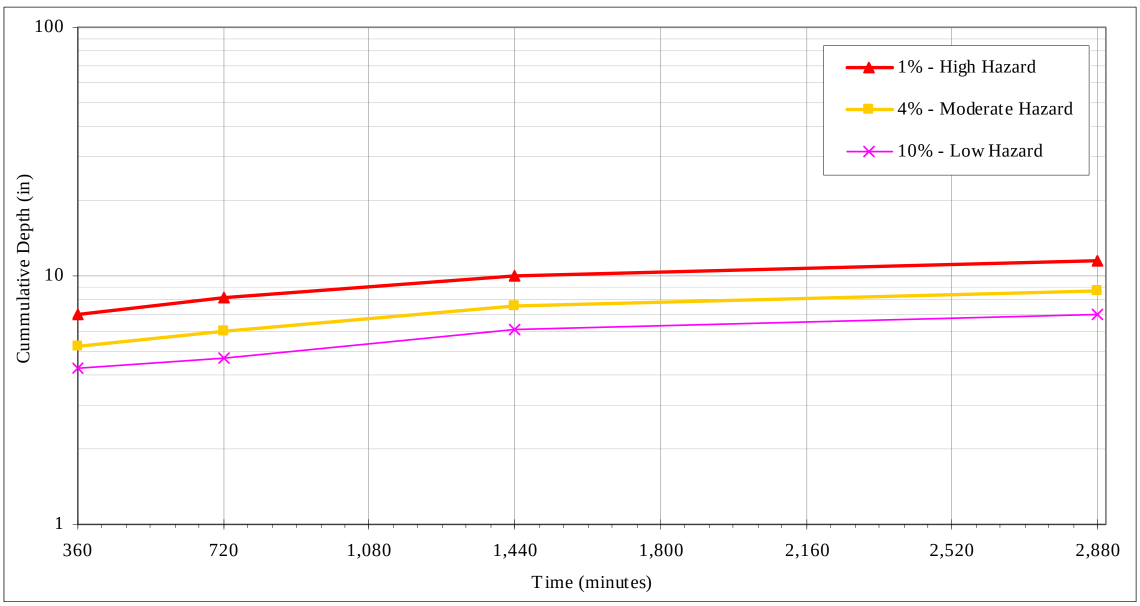

Figure 18. Precipitation Hazard Nomograph for Blanco River

The table and figure below represent an example application of this precipitation hazard nomograph shown above. As seen in the example, once the real time data encroaches upon the moderate hazard envelope, a public watch notice would be required. Furthermore, once the real time data encroaches upon the high hazard area, a public warning and an evacuation of critical areas would be required.

Table 20. Sample Real Time Precipitation Record Table

Duration (min)	Recorded Precip. Depth (in)
405	2.3
540	3.7
730	4.6
920	6.0
1,110	7.5
1,300	7.6
1,450	8.0
1,620	8.0
1,800	8.0
2,160	8.0
2,520	8.0
2,880	8.0

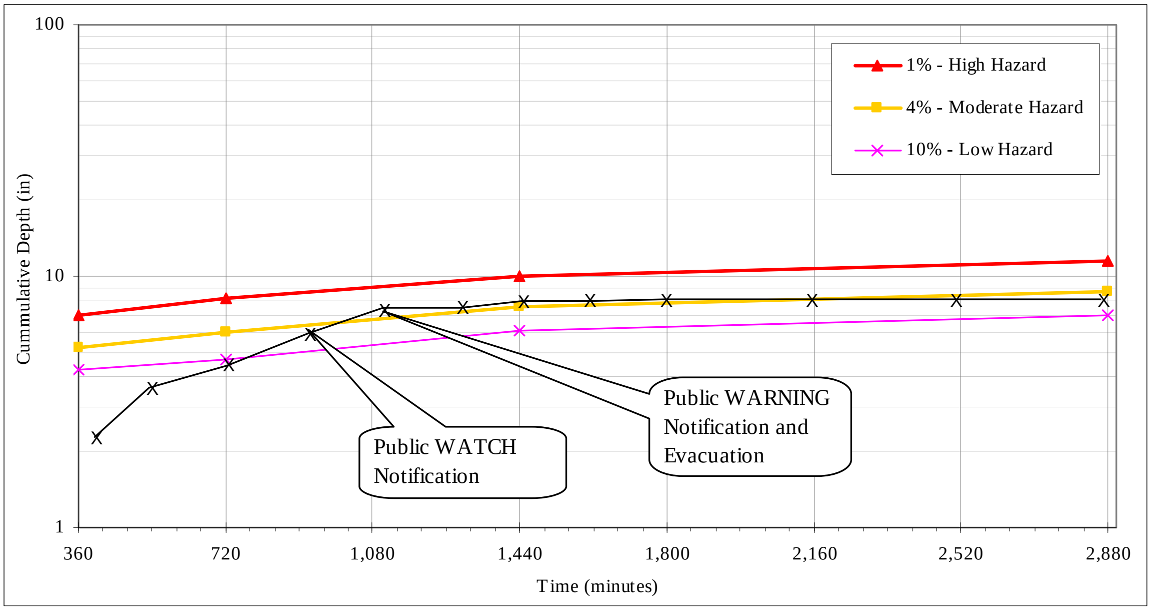

Figure 19. Sample Application of the Precipitation Hazard Nomograph for Blanco River

4.2.2 Blanco River Historical Flow Nomograph

Another tool at the community's disposal for assessing risk from the Blanco River is flow gage data from the upstream gages. As discussed in **t**2.8.3 of this report, there are two historical flow gages on the Blanco River. A recorded instantaneous flow rate at either the Wimberley or Kyle gage has a certain statistical chance of occurring in any given year. Anything more extreme than a 10% annual chance event should be considered a moderate flood threat to San Marcos citizens. Anything more extreme than a 4% annual chance event should be considered a severe threat to San Marcos citizens. The table below lists the various statistical flow rate thresholds and relates those flow rates to a risk level. The figure below represents a flow hazard nomograph for the Blanco River. Peak flow rates can be compared to values shown on this nomograph to assist the City in assessing the risk level. The user of this table and figure should note that a severe storm may strike the Blanco River watershed downstream of the Wimberley or Kyle gages, and thus, the USGS gages would not indicate a potential threat. The Kyle gage is more useful in the sense that it is located closer to the City of San Marcos. The travel time from the Kyle gage to the confluence with the San Marcos River is approximately 80 minutes.

Table 21. Peak Flow Danger Threshold Table for the Blanco River

Risk Level	Percent Chance Exceedance	Return Frequency (years)	Peak Flow Rate (cfs)	
			Wimberley Gage	Kyle Gage
Severe	0.2%	500	220,000	322,000
	0.5%	200	168,000	241,000
	1%	100	133,000	188,000
	2%	50	102,000	141,000
Moderate	5%	20	66,100	89,100
	10%	10	43,800	57,800
Low	20%	5	25,700	33,000
	50%	2	8,280	10,100
	80%	1.25	2,280	2,660
	90%	1.1	1,090	1,250
	95%	1.05	573	643
	99%	1	157	171

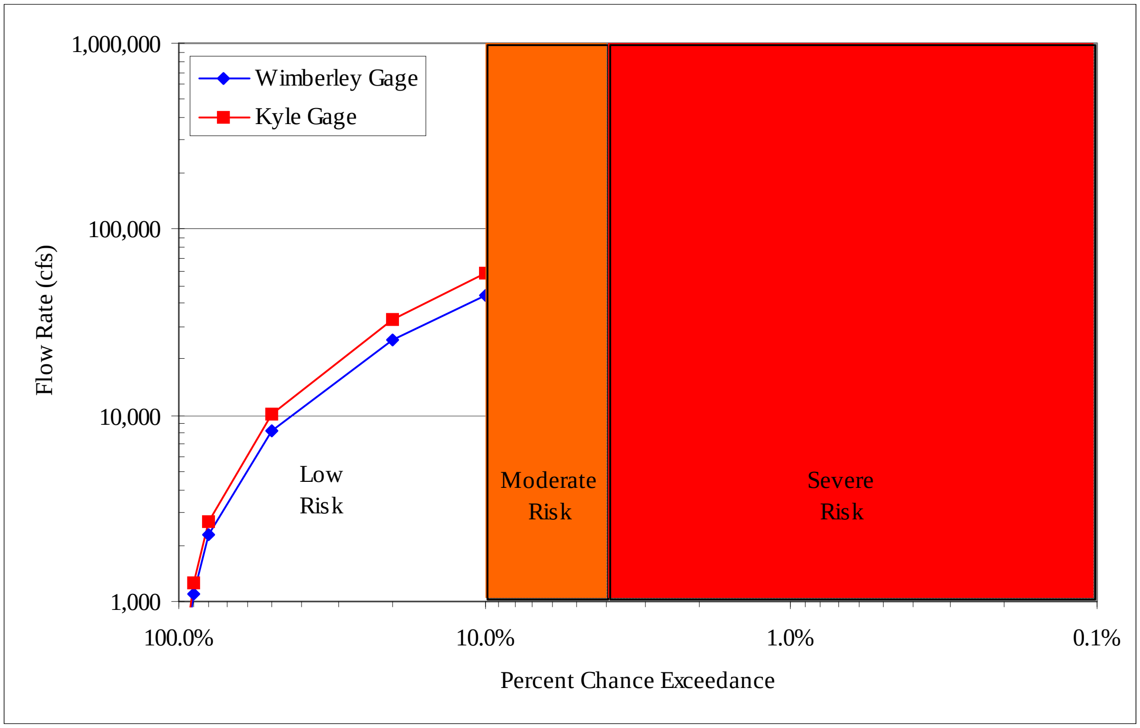

Figure 20. Flow Hazard Nomograph for the Blanco River

4.3 FLOOD EARLY WARNING SYSTEM

A Flood Early Warning System (FEWS) is a coordinated effort to reduce the risk to life and property associated with flooding before a storm strikes the community. Elements associated with a FEWS include but are not limited to: automated low water crossing safety devices, streamflow measurement devices, precipitation measurement devices, flood predictions, and communications. These elements must be integrated with pre-disaster planning organized by responsible and accountable entities. The major stakeholders in a proposed FEWS would be COSM, GBRA, Hays County, and USMRFCD. The two adjacent river authorities, Lower Colorado River Authority (LCRA) and San Antonio River Authority (SARA), operate extensive streamflow and precipitation sensors with advanced flood prediction capacity. The LCRA and SARA serve as regional anchors for the administration of their FEWS, and all cities and counties are integrated into their system.

The natural lead for an integrated FEWS would be the GBRA with support from the other stakeholders. The integration of Hays County and City of San Marcos FEWS elements or systems should be coordinated with the GBRA to ensure interoperability and maximum protection to citizens.

4.3.1 Automated Low Water Crossing Safety Devices

The leading cause of flood related deaths in Texas results from people trying to pass low water crossings in vehicles during flood events. Simple structural controls such as railroad style safety gates with flashing lights provide a physical barrier to prevent crossing a dangerous stream. Automated controls are activated by streamflow gages that trigger gate closing based on specified flow rates or stages. These controls may qualify for Pre-Disaster Mitigation (PDM) Grants though the State of Texas or FEMA. Hays County received a grant for $600,000 from FEMA in October 2006 to implement a system of automated low water crossing safety devices and associated streamflow gages. The City should investigate implementing a similar system to help minimize the risk to life and property associated with flooding events.

4.3.2 Emergency Communications

1. KTSW FM 89.9

Texas State University operates KTSW which is a valuable resource for localized information when emergencies occur. The current station has low transmitting power and cannot be received in all areas of San Marcos. News 8 Austin reported on February 9, 2007 that Texas State University has presented a proposal to erect a new transmission tower and increase the transmitting power. The City of San Marcos should coordinate further with KTSW and support the improvement of emergency communications. Public awareness about the availability of this valuable resource should be further publicized as discussed in §4.4.

2. KWED AM 1580

The GBRA broadcasts emergency warnings on KWED AM 1580 located in Seguin, Texas. Broadcasts are available even during power outages. The City of San Marcos should ensure that all available means of communication are utilized during flooding events. Public awareness about the availability of this valuable resource should be further publicized as discussed in **§**4.4.

3. NOAA All Hazards Weather Radio

NOAA operates an emergency radio system separate from the traditional AM/FM radio system. The All Hazards Weather Radio is a low cost device that can operate during blackouts and can be automatically turned on to receive emergency warnings (of great benefit during the night). The City should inform residents in floodprone areas about the benefits of these weather radios. The City could choose to subsidize a program that provides NOAA All Hazards Weather Radios at little or no cost to residents in floodprone areas. Public awareness about the availability of this valuable resource should be further publicized as discussed in **§**4.4.

4. Reverse 911

Emergency managers have a valuable tool to contact large numbers of affected residents during disasters and flood events. The system is known by many terms, but the two common names are Reverse 911 or Emergency Phone Dialer. The technology allows for directed broadcasts of emergency information from the City or County Emergency Operations Center. The emergency communications assets in place should be leveraged to disseminate vital information during critical flooding events in San Marcos.

4.3.3 NOAA AHPS Forecasting Participation

The National Oceanic and Atmospheric Administration (NOAA) operates the Advanced Hydrologic Prediction Service (AHPS) as a service to governments and citizens of the United States. The service offers many prediction products to provide guidance on risk related to future storm events. One important product is the Quantitative Prediction Forecast (QPF) that predicts future rainfall for 72 hours with the prediction being updated once per day. This tool provides guidance to emergency management officials with regards to preparedness and mobilization decisions. The City of San Marcos should request that both the Wimberley and Kyle USGS streamflow gages be added as forecast points in the AHPS system. There is no cost and the City should submit a formal request to the Senior Hydrologist at the West Gulf River Forecast Center (WGRFC), which is a part of NOAA’s Fort Worth, Texas, office. The AHPS tools will help predict flood crest levels and help protect lives of citizens through better use of available resources.

4.3.4 Streamflow Gage Network

The USGS operates two streamflow gages on the Blanco River which provide valuable information on river flow characteristics, both historical and real time. The only other active streamflow gage in the San Marcos area is the USGS gage located on the San Marcos River near the Aquarena Springs Drive bridge. The five NRCS reservoirs have significant impact on the peak flow rates that are released into the City of San Marcos. A large fraction of the contributing drainage area to Purgatory and Sink Creek is controlled by these structures. When NRCS reservoir storage capacity is exceeded excess stormwater is discharged via emergency spillways thus resulting in sharp increases in flow rate and the release of large amounts of stormwater. A gage on all five of these structures could provide valuable information that affects numerous citizens in the City. Examples of information would be stage, release flow rate, and rate of rise in elevation. Careful monitoring and use of these proposed gages would provide critical data to emergency managers in San Marcos and help mitigate against the risk to life during a flooding event.

4.4 COMMUNITY INITIATIVES

Apart from the structural mitigation alternatives that can be implemented to reduce risk, as a first line of defense, there are a number of programs that can be implemented to educate the community about the nature of risk posed and remove those areas subject to the most frequent risk. As a second line of defense, a coordinated, but leveraged and cost-effective approach will be required to provide early warning of an impending flood event. These measures are important in building a disaster resistant community, and can be viewed as a series of goals and implementation actions which complement the City's Sector Planning efforts.

Goal 1: **Leverage the efforts of various entities in keeping the citizens of San Marcos informed about the risk of flooding before disaster strikes, so that they also know how to respond in the event of a flooding event**.

Action 1.1: Provide free access to the floodplain maps, both in paper and digital form. Create an atlas of maps, which can be viewed at City Hall, downloaded in .pdf format from the City's website, and viewed or downloaded in an ArcIMS environment.

Action 1.2: Utilize educational material available through FEMA, TFMA, GBRA and others (such as the "Turn Around Don't Drown" sticker campaign, and GBRA's "Staying Safe" Flood Guide) in dissemination efforts.

Action 1.3: Identify community leaders in the most at-risk areas and develop a specific outreach campaign for these neighborhoods with their guidance.

Action 1.4: Make an initial presentation to the San Marcos Chamber of Commerce, and follow up with subsequent "annual update presentations" or contributing articles to the Chamber's newsletter with updates on various projects and action items.

Action 1.5: Work with Texas State University to develop an informational presentation to incoming students describing the nature of the flood risk and actions to be taken during a flood event. Excerpts from the PBS video "Flash Flood Alley" could be included to provide documented accounts of the destructive capacity of flooding in Central Texas. The information should utilize resources from www.floodsaftey.com including "Turn Around Don't Drown" stickers.

Action 1.6: Work with area apartment and off-campus housing managers to distribute an informational packet, such as GBRA's "Staying Safe" flood guide.

Action 1.7: Work with private industry and other stakeholders to further an existing program, or develop and implement a program to distribute NOAA All Hazards Weather Radios to the public.

Action 1.8: In any public outreach program, heighten awareness of GBRA's KWED 1580 AM radio broadcasts as a means of reaching the public even during power outages.

Goal 2: **Eliminate the leading cause of death during Texas flood events – driving through low-water crossings.**

Action 2.1: Install Low Water Crossing safety features (cross-arm or retractable fence) at low water crossings.

Action 2.2: Utilize "Turn Around Don't Drown" material available to the City, and involve the San Marcos/Hays Consolidated ISDs in an outreach program.

Goal 3: Repetitive-loss structures and improved property at-risk during a 10% annual chance event or higher should be removed from these areas of risk.

Action 3.1: Consider a relocation program to assist in the moving of manufactured or pier-and-beam foundation homes out of harm's way. This program could offer a defined percentage contribution toward the moving expenses. Potential candidates may include the lower sections of Purgatory and Willow Springs Creek.

Action 3.2: Develop a voluntary acquisition program to purchase these areas and dedicate them to open space in perpetuity.

Goal 4: **Leverage the resources of other regional stakeholders in developing a flood early warning system.**

Action 4.1: Officially request that the USGS streamflow gage at Kyle remains in service, in order to maintain continuity of record of historic flow rates. This gage provides the most effective means of calibrating streamflow to rainfall data.

Action 4.2: Officially request participation in the National Weather Service Advanced Hydrologic Prediction Service (AHPS) to receive flood forecasting services for both the

Wimberley and Kyle USGS streamflow gages. However, in order to provide meaningful data, the USGS gage at Kyle cannot be lost, as this provides the most relevant and best available source of historic data. (See Action 4.1)

Action 4.3: Continue dialogue with GBRA about the placement of additional automated gauges to enhance this network. The network data is collected and placed on a non-public internet page to allow emergency management personnel and the National Weather Service access to the data.

Goal 5: **Seek coordinated opportunities to implement multi-purpose projects, particularly with regard to water quality and erosion mitigation.**

Action 5.1: As each structural flood control measure is evaluated in a preliminary engineering stage, the viability of water quality benefit should be assessed and implemented where feasible. It is often easier to integrate water quality solutions (BMPs) into flood control projects during the initial design phase, than to retrofit at a later date at additional cost.

Action 5.2: Channel maintenance projects on Willow Springs Creek offer the opportunity for hike-and-bike or wilderness trail implementation, and should be coordinated with the Parks and Recreation Department and its planning efforts.

Goal 6: Recognizing that the City is a growing entity, identify current and future partners in floodplain management, and cultivate relationships for regional disaster resistance into the future.

Action 6.1: Continue to share information with GBRA and Hays County, the City's key partners in floodplain management.

Action 6.2: Continue to include EAA as a partner in any discussions on regional detention or retention facilities.

Action 6.3: Build upon the existing cooperative relationships at the law enforcement level with neighboring Caldwell, Comal, and Guadalupe Counties, and the communities of Wimberley and Kyle, to develop specific emergency management and forecasting communications measures that can be mutually beneficial.

Action 6.4: Review and update this plan at the same time updates are made to the Sector Plans, the Multi-Hazard Mitigation Action Plan, Emergency Action Plans, and Capital Improvements Plans.

5.0 PHASING AND IMPLEMENTATION

A priority matrix is provided in Appendix S that suggests a phasing plan based on a qualitative benefit-to-cost assessment. That is, potential projects are ranked in an order that would provide the highest level of service versus the cost to implement the structural improvements. The analysis is not a standard quantitative benefit-cost ratio due to non-quantifiable benefits associated with each alternative such as access for emergency services, nuisance flooding, or long-term streambank erosion. The priority ranking for each recommended alternative (with watershed name noted as follows):

1) **Alternative 3a -Culvert Improvement and Channel Maintenance** (Purgatory Creek)
   The placement of new box culverts combined with channel maintenance will reduce flooding on adjacent properties and provides critical emergency access during major floods.
2) **Alternative 6c – Channel Restoration** (Willow Springs Creek)
   Channel maintenance and sediment removal will facilitate flow with a more hydraulically efficient surface and reduce CWSELs by an average of 0.51 feet. It is recommended that this alternative be implemented concurrent with Alternative 6a (priority 3) to receive the maximum benefit. A nature trail option is available with this improvement but is not included in the cost estimate.
3) **Alternative 6a – Downstream Regional Detention** (Willow Springs Creek)
   The placement of a regional detention facility in the Willow Springs Creek Watershed will reduce the impacts of flooding to the Victory Gardens neighborhood. The value of homes removed from the 1% annual chance floodplain is equal to $3,600,000. The Willow Springs Watersheds projects are multi-benefit by both reducing flooding impacts and adding parkland with nature trails.
4) **Alternative 5a – Drainage Infrastructure Improvements** (Sessom Creek)
   The replacement of culverts beneath Sessom Drive will protect critical vehicular and pedestrian route between Aquarena Springs and Texas State University. Many of the culverts provide only a two-year level of service, with some culverts failing to provide even a two-year level of service. As per current City code, all new culverts must provide a 25-year level of service.
5) **Alternative 4a – Culvert Improvement LBJ Drive** (Schulle Canyon Creek)
   The placement of a new culvert at LBJ Drive near North Bishop Street would upgrade the level of service from 2-year to 25-year while maintaining an ingress/egress point to the neighborhood.
6) **Alternative 2a – Detention Plus** (Cottonwood Creek)
   The Detention Plus plan for stormwater management in the Cottonwood Creek Watershed would achieve the reduction in impacts from flooding by distributing the required detention volume across a number of new development projects. The City would share the cost of over sizing detention ponds to further the effort of a watershed based approach to reducing the impacts of flooding.
7) **Alternative 1b – Peak Flow Diversion to Bypass Creek** (Blanco River)
   The Bypass Creek peak flow diversion would divert almost 60,000 cfs of water from a flooded Blanco River and redirect it around the city in the Bypass Creek diversion channel. The project removes approximately 570 residential properties from the 1%

annual chance floodplain. The removal of properties from the 1% annual chance floodplain will have a substantial impact on property values in this area and allow future development. A parkland option is available with this improvement but is not included in the cost estimate.

8) **Alternative 3b – Culvert Improvement Castle Creek Drive** (Purgatory Creek)
The Castle Creek Drive culvert improvement will increase the level of service from 10-year to 25-year and reduce flooding risk to two adjacent properties.

Construction Phasing

Construction phasing should generally move from downstream to upstream. This is standard engineering practice to ensure that downstream areas have capacity to receive flows from any improvements upstream. For example, the Blanco River Peak Flow Diversion to Bypass Creek (Mitigation Alternative 1B) should tie into the San Marcos River downstream prior to connecting to the Blanco River upstream. This provides conveyance for the intervening drainage areas of Bypass Creek as well as not prematurely accepting flow from the Blanco River. Since these projects are not hydraulically connected, or dependant upon another for implementation, these projects could be constructed in any sequence. Time required for the acquisition of right-of-way or easements, and input from the public, and the availability of funds are more likely to influence phasing of construction.

5.1 FUNDING SOURCES

An important aspect of implementing any of the recommending alternatives is the funding mechanism. The summary below provides a description of the available funding sources for the City to construct a project. The available funding sources for each recommended alternative can be found in Appendix S.

Municipal Funding Sources

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.

Drainage Utility Fees **-** Municipal stormwater projects are 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.

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.

State Assistance

GBRA (Guadalupe-Blanco River Authority)

- The river authority for the watershed. Many State and Federal agencies stipulate that river authorities must be the arbiters for the pass-through of funds.

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.

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.

Federal Assistance

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 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.

5.2 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.

5.2.1 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.

Most streams included in this hydraulic analysis are studied streams in the current Hays County FIS dated February 18, 1998, revised September 2, 2005. The effective Flood Insurance Rate Maps (FIRM) is dated September 2, 2005. The revision to the FIS consisted of a redelineation of the 1998 FIS data.

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.

5.2.2 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.

5.2.3 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.

5.2.4 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.

- Edwards Aquifer Rules

The Edwards Rules (30 TAC Chapter 213) regulate activities having the potential for polluting the Edwards Aquifer and associated surface waters. The goals of the rules are the protection of existing and potential uses of groundwater and the maintenance of Texas Surface Water Quality Standards. The activities addressed are those that pose a threat to water quality in the recharge and transition zones. The rules apply in the Edwards Aquifer recharge, transition, and contributing zones. The limits of this project(s) may lie within the Edwards Aquifer recharge zone, and will require compliance with the Edwards Rules last published October 16, 2006.

Construction of any regulated activity will require the submission of an application to, and the approval of the TCEQ. Each application is required to include the following:

1. Name of the development;
2. A narrative description of the location of the project;
3. A technical report (includes information prepared for NPDES SWPPP, description of permanent BMP's, measured to control stream bank erosion, method of wastewater disposal from the site, measures that will be used to

contain any spill of static hydrocarbons or hazardous substances such as on a roadway or from a pipeline or temporary aboveground storage tank and indicate placement of permanent aboveground storage tank facilities (§213.24)); and

4. Any additional information needed by the executive director for plan approval.

- 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.

- 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.

5.3 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. A map showing endangered and threatened species is included as Exhibit 6 of Appendix A. The source data for habitat zones shown on this map comes from the Texas Parks and Wildlife Department (TPWD).

Important species may be considered 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) which are not evaluated or mapped on Exhibit 6 of Appendix A. 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.

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APPENDIX A
EXHIBITS

Exhibit 1 – Drainage Area Map
Exhibit 2 – Soils Map
Exhibit 3 – Current Land Use Map
Exhibit 4 – Future Land Use Map
Exhibit 5 – Existing and Ultimate Conditions 1% Annual Chance Floodplains
Exhibit 6 – Environmental Constraints Map
Exhibit 7 – Precipitation Depths Map October 1998 Storm
Exhibit 8 – Blanco River Alternatives
Exhibit 9 – Cottonwood Creek Alternatives
Exhibit 10 – Lower Purgatory Creek Alternatives
Exhibit 11 – Franklin Square Creek Alternatives
Exhibit 12 – Upper Purgatory Creek Alternatives
Exhibit 13 – Schulle Canyon Creek Alternatives
Exhibit 14 – Willow Springs Creek Alternatives

Exhibit 1
Drainage Area Map

Exhibit 2
Soils Map

Exhibit 3
Current Land Use Map

Exhibit 4
Future Land Use Map

Exhibit 5
Existing and Ultimate Conditions 1% Annual Chance Floodplains

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Precipitation Depths Map for the October 1998 Storm

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Upper Purgatory Creek Alternatives

Exhibit 12
Schulle Canyon Creek Alternatives

Exhibit 13
Sessom Creek Alternatives

Exhibit 14
Willow Springs Creek Alternatives

APPENDIX B
WEIGHTED CURVE NUMBER TABLE

SUBBASIN SOIL AND WEIGHED CURVE NUMBER SUMMARY

		Area of NRCS Group (SF)				Total Area	Percent of Soil Type				Weighted Curve Number
	Subbasin	A	B	C	D	(sq. mi.)	%A	%B	%C	%D	AMC II
BLANCO RIVER	B01	34,740,936	8,710,556	439,932,777	839,693,043	47.46	3%	1%	33%	63%	77
	B02	4,067,838	56,463,585	699,377,649	354,338,314	39.97	0%	5%	63%	32%	75
	B03		65,774,941	536,642,265	369,271,964	34.85	0%	7%	55%	38%	75
	B04		51,496,784	520,803,148	734,498,492	46.87	0%	4%	40%	56%	77
	B05	4,110,181	51,677,943	742,219,859	324,157,129	40.25	0%	5%	66%	29%	75
	B06		53,179,208	359,798,213	381,018,840	28.48	0%	7%	45%	48%	76
	B07	1,381,826	26,915,819	403,252,701	489,270,236	33.03	0%	3%	44%	53%	77
	B08	791,859	75,380,038	849,544,818	359,542,798	46.10	0%	6%	66%	28%	75
	B09	10,922,588	23,443,360	698,239,178	326,423,033	37.99	1%	2%	66%	31%	75
	B10		50,956,592	892,499,957	468,750,075	50.66	0%	4%	63%	33%	76
	B11	18,247,560	139,833,439	156,786,361	540,588,552	30.69	2%	16%	18%	63%	75
	BC01	0	82,548,456	3,520,167	102,063,617	6.75	0%	44%	2%	54%	72
BYPASS	BP01	0	114,252,676			4.10	0%	100%	0%	0%	61
	BP02				15,313,322	0.55	0%	0%	0%	100%	80
	BP03				4,205,514	0.15	0%	0%	0%	100%	80
	BP04				3,644,670	0.13	0%	0%	0%	100%	80
	BP05		18,762,992	4,778,460	28,657,757	1.87	0%	36%	9%	55%	73
COTTONWOOD	C01			432,835	30,394,311	1.11	0%	0%	1%	99%	80
	C02				20,797,438	0.75	0%	0%	0%	100%	80
	C03				6,626,209	0.24	0%	0%	0%	100%	80
	C04				22,960,294	0.82	0%	0%	0%	100%	80
	C05				62,160,995	2.23	0%	0%	0%	100%	80
	C06				40,168,871	1.44	0%	0%	0%	100%	80
	C07			7,040	80,726,170	2.90	0%	0%	0%	100%	80
PURGATORY CREEK	P01			399,820,940	162,306,642	20.16	0%	0%	71%	29%	76
	P02	5,105,779		122,756,201	144,518,438	9.77	2%	0%	45%	53%	77
	P03	58,327		29,217,982	43,280,295	2.60	0%	0%	40%	60%	78
	P04	50,565		13,341,558	17,878,782	1.12	0%	0%	43%	57%	77
	P05			135,492	4,975,971	0.18	0%	0%	3%	97%	80
	P06			2,677,542	6,263,668	0.32	0%	0%	30%	70%	78
	P07			528,579	9,311,371	0.35	0%	0%	5%	95%	80
	P08			1,269,474	9,056,896	0.37	0%	0%	12%	88%	79
	P09	58,858		123,938	5,212,338	0.19	1%	0%	2%	97%	79
	P10	3,502,334	825,681	1,571,164	9,653,009	0.56	23%	5%	10%	62%	69
	P11	323,855		1,918,120	5,693,380	0.28	4%	0%	24%	72%	77
	P12	1,271,165	2,646,293	633,067	9,537,456	0.51	9%	19%	4%	68%	72
	P13	55,749		4,017,369	7,949,271	0.43	0%	0%	33%	66%	78
	P14	764,696	336,132		3,833,365	0.18	15%	7%	0%	78%	72
SAN MARCOS RIVER	SM-01			4,435,628	6,938,331	0.41	0%	0%	39%	61%	78
	SM-02		40,775	729,326	5,389,516	0.22	0%	1%	12%	87%	79
	SM-03		1,640,804	358,687	15,384,213	0.62	0%	9%	2%	88%	78
	SM-04		155,026	233,686	5,720,378	0.22	0%	3%	4%	94%	79
	SM-05		918,827		18,095,781	0.68	0%	5%	0%	95%	79
	SM-06a		2,367,603		2,650,756	0.18	0%	47%	0%	53%	71
	SM-06b	3,927	7,079,263		3,164,160	0.37	0%	69%	0%	31%	67
	SM-07		16,497,963		22,425,001	1.40	0%	42%	0%	58%	72
	SM-08		18	995,272	30,606,345	1.13	0%	0%	3%	97%	80
	SM-09		5,887,215		2,034,461	0.28	0%	74%	0%	26%	66
	SM-10		27,447,079	1,429,247	76,746,493	3.79	0%	26%	1%	73%	75
SINK CREEK	SK-01			248,646,563	154,201,126	14.45	0%	0%	62%	38%	76
	SK-02	2,233,065		338,929,937	185,248,901	18.88	0%	0%	64%	35%	76
	SK-03			40,679,961	80,279,715	4.34	0%	0%	34%	66%	78
	SK-04	1,914,252		43,909,962	99,938,741	5.23	1%	0%	30%	69%	78
	SK-05			2,257,429	2,452,872	0.17	0%	0%	48%	52%	77
	SK-06			101,692	7,145,135	0.26	0%	0%	1%	99%	80
	SK-07		1,635,616	12,737,124	108,461,446	4.41	0%	1%	10%	88%	79
WILLOW CREEK	W-01			14,187,485	43,021,159	2.05	0%	0%	25%	75%	79
	W-02			2,399,389	3,776,689	0.22	0%	0%	39%	61%	78
	W-03			313,886	8,367,753	0.31	0%	0%	4%	96%	80
	W-04			119,581	6,480,713	0.24	0%	0%	2%	98%	80
	W-05				7,224,669	0.26	0%	0%	0%	100%	80
	W-06				9,160,514	0.33	0%	0%	0%	100%	80
	W-07		1,104,658		29,683,808	1.10	0%	4%	0%	96%	79

CURVE NUMBER ASSUMPTIONS

Group	AMC I	AMC II	AMC III
A	21	39	59
B	41	61	78
C	55	74	88
D	63	80	91

APPENDIX C
WEIGHTED LAND USE TABLE

Existing Conditions Weighted Land Use Table

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	B01	B02	B03	B04	B05
COSM01	Vacant	0%	0	0	0	0	0
COSM03	Single Family Res	60%	0	0	0	0	0
COSM04	Mobile Home	50%	0	0	0	0	0
COSM04	Two Family Res	75%	0	0	0	0	0
COSM05	Multi-Family Res	75%	0	0	0	0	0
COSM06	Commercial	80%	0	0	0	0	0
COSM07	Public & Inst	80%	0	0	0	0	0
COSM08	Industrial	85%	0	0	0	0	0
COSM09	Open Space	0%	0	0	0	0	0
1	Urban or built-up land	80%	0	0	0	0	0
11	Residental	60%	0	0	17,294,332	0	0
12	Commercial and services	80%	0	368,290	2,538,819	0	0
13	Industrial	80%	0	0	2,083,210	0	0
14	Transportation, communication, utilities	80%	0	0	0	0	0
15	Industrial and commercial complexes	80%	0	0	0	0	0
16	Mixed urban or built-up land	60%	0	0	0	0	0
17	Other urban or built-up land	60%	0	0	2,479,532	0	0
2	Agricultural land	0%	0	0	0	0	0
21	Cropland and pasture	0%	100,633,407	178,189,548	201,972,045	206,768,693	129,835,878
22	Orchards, groves, vineyards, nurseries, and ornamental	0%	0	0	0	0	0
23	Confined feeding operations	0%	0	0	0	0	0
24	Other agricultural land	0%	0	0	0	0	5,891
3	Rangeland	0%	0	0	0	0	0
31	Herbaceous rangeland	0%	0	0	0	0	0
32	Shrub and brush rangeland	0%	0	106,796	2,993,605	43,893,860	40,419,449
33	Mixed rangeland	0%	162,477,397	106,730,217	143,301,853	72,710,743	107,969,139
4	Forest land	0%	0	0	0	0	0
41	Deciduous forest land	0%	0	0	0	0	0
42	Evergreen forest land	0%	1,058,880,133	775,548,634	565,106,312	983,425,209	855,498,852
43	Mixed forest land	0%	1,089,596	53,303,701	24,428,030	0	0
5	Water	100%	0	0	0	0	0
51	Streams and canals	100%	0	0	0	0	0
52	Lakes	100%	0	0	0	0	0
53	Reservoirs	100%	0	0	0	0	0
54	Bays and estuaries	100%	0	0	0	0	0
6	Wetland	0%	0	0	0	0	0
61	Forested wetland	0%	0	0	0	0	0
62	Nonforested wetland	0%	0	0	0	0	0
7	Barren land	0%	0	0	0	0	0
71	Dry salt flats	0%	0	0	0	0	0
72	Beaches	0%	0	0	0	0	0
73	Sandy areas not beaches	0%	0	0	0	0	0
74	Bare exposed rock	100%	0	0	0	0	0
75	Strip mines, quarries, gravel pits	0%	0	0	0	0	0
76	Transitional areas	0%	0	0	9,491,494	0	0
8	Tundra	0%	0	0	0	0	0
81	Shrub and brush tundra	0%	0	0	0	0	0
82	Herbaceous tundra	0%	0	0	0	0	0
83	Bare ground	0%	0	0	0	0	0
84	Wet tundra	0%	0	0	0	0	0
85	Mixed tundra	0%	0	0	0	0	0
9	Perennial snow or ice	0%	0	0	0	0	0
91	Perennial snowfields	0%	0	0	0	0	0
92	Glaciers	100%	0	0	0	0	0
		Composite IC	0%	0%	2%	0%	0%
		Area I.C. (SF)	0	294632	15561941	0	0
		Area (SF)	1,323,080,534	1,114,247,186	971,689,232	1,306,798,505	1,133,729,210
		Area (AC)	30,374	25,580	22,307	30,000	26,027
		Area (SQ-MI)	47.459	39.968	34.855	46.875	40.667

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	B06	B07	B08	B09	B10
COSM01	Vacant	0%	0	0	0	0	0
COSM03	Single Family Res	60%	0	0	0	0	0
COSM04	Mobile Home	50%	0	0	0	0	0
COSM04	Two Family Res	75%	0	0	0	0	0
COSM05	Multi-Family Res	75%	0	0	0	0	0
COSM06	Commercial	80%	0	0	0	0	0
COSM07	Public & Inst	80%	0	0	0	0	0
COSM08	Industrial	85%	0	0	0	0	0
COSM09	Open Space	0%	0	0	0	0	0
1	Urban or built-up land	80%	0	0	0	0	0
11	Residental	60%	0	0	4,920,563	22,682,583	16,182,810
12	Commercial and services	80%	0	0	369,449	2,161,183	0
13	Industrial	80%	0	0	0	0	0
14	Transportation, communication, utilities	80%	0	0	0	1,553,710	0
15	Industrial and commercial complexes	80%	0	0	0	0	0
16	Mixed urban or built-up land	60%	0	0	1,137,861	956,441	646,560
17	Other urban or built-up land	60%	0	0	0	0	0
2	Agricultural land	0%	0	0	0	0	0
21	Cropland and pasture	0%	97,629,993	49,525,786	95,084,215	28,241,357	48,166,652
22	Orchards, groves, vineyards, nurseries, and ornamental	0%	0	0	0	0	0
23	Confined feeding operations	0%	0	0	0	0	0
24	Other agricultural land	0%	0	0	642,827	0	0
3	Rangeland	0%	0	0	0	0	0
31	Herbaceous rangeland	0%	0	0	0	0	0
32	Shrub and brush rangeland	0%	24,743,861	65,519,011	1,331,423	34,967,568	71,499,639
33	Mixed rangeland	0%	69,482,839	2,968,051	9,148,454	31,483,712	204,662,352
4	Forest land	0%	0	0	0	0	0
41	Deciduous forest land	0%	0	0	0	0	70,018,047
42	Evergreen forest land	0%	607,708,716	803,112,765	1,163,811,125	848,551,666	829,789,704
43	Mixed forest land	0%	0	0	0	0	175,122,411
5	Water	100%	0	0	0	0	0
51	Streams and canals	100%	0	0	0	0	0
52	Lakes	100%	0	0	0	0	0
53	Reservoirs	100%	0	835,486	521,996	0	0
54	Bays and estuaries	100%	0	0	0	0	0
6	Wetland	0%	0	0	0	0	0
61	Forested wetland	0%	0	0	0	0	0
62	Nonforested wetland	0%	0	0	0	0	0
7	Barren land	0%	0	0	0	0	0
71	Dry salt flats	0%	0	0	0	0	0
72	Beaches	0%	0	0	0	0	0
73	Sandy areas not beaches	0%	0	0	0	0	0
74	Bare exposed rock	100%	0	0	0	0	0
75	Strip mines, quarries, gravel pits	0%	0	0	536,335	0	0
76	Transitional areas	0%	0	0	12,531,646	88,905,409	0
8	Tundra	0%	0	0	0	0	0
81	Shrub and brush tundra	0%	0	0	0	0	0
82	Herbaceous tundra	0%	0	0	0	0	0
83	Bare ground	0%	0	0	0	0	0
84	Wet tundra	0%	0	0	0	0	0
85	Mixed tundra	0%	0	0	0	0	0
9	Perennial snow or ice	0%	0	0	0	0	0
91	Perennial snowfields	0%	0	0	0	0	0
92	Glaciers	100%	0	0	0	0	0
		Composite IC	0%	0%	0%	2%	1%
		Area I.C. (SF)	0	835486	4452610	17155329	10097622
		Area (SF)	799,565,409	921,961,099	1,290,035,894	1,059,503,630	1,416,088,176
		Area (AC)	18,355	21,165	29,615	24,323	32,509
		Area (SQ-MI)	28.680	33.071	46.274	38.004	50.795

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	B11	BP01	BP02	BP03	BP04
COSM01	Vacant	0%	27,099,329	282,891			
COSM03	Single Family Res	60%	2,534,250				
COSM04	Mobile Home	50%	2,355,171				
COSM04	Two Family Res	75%	260,743				
COSM05	Multi-Family Res	75%	4,086,607				
COSM06	Commercial	80%	5,933,671				
COSM07	Public & Inst	80%	2,359,018	15,220,998			2,861
COSM08	Industrial	85%	3,391,871				
COSM09	Open Space	0%	8,872,982	967,040	8,668	48,235	1,780,870
1	Urban or built-up land	80%	0				
11	Residental	60%	4,053,284				
12	Commercial and services	80%	96,061	414,852			199,818
13	Industrial	80%	0	956,950			80,037
14	Transportation, communication, utilities	80%	23,672,400				
15	Industrial and commercial complexes	80%	0	12,567			
16	Mixed urban or built-up land	60%	0				
17	Other urban or built-up land	60%	1,871,642				
2	Agricultural land	0%	0		2,451,370	3,384,319	3,485
21	Cropland and pasture	0%	312,288,610				
22	Orchards, groves, vineyards, nurseries, and ornamental	0%	0	96,404,751	12,853,284	772,960	1,577,603
23	Confined feeding operations	0%	2,529,565				
24	Other agricultural land	0%	1,521,901				
3	Rangeland	0%	0				
31	Herbaceous rangeland	0%	0				
32	Shrub and brush rangeland	0%	6,251,347				
33	Mixed rangeland	0%	33,066,369				
4	Forest land	0%	0				
41	Deciduous forest land	0%	220,564,950				
42	Evergreen forest land	0%	40,367,077				
43	Mixed forest land	0%	147,278,633				
5	Water	100%	0				
51	Streams and canals	100%	0				
52	Lakes	100%	0				
53	Reservoirs	100%	408,842				
54	Bays and estuaries	100%	0				
6	Wetland	0%	0				
61	Forested wetland	0%	0				
62	Nonforested wetland	0%	0				
7	Barren land	0%	0				
71	Dry salt flats	0%	0				
72	Beaches	0%	0				
73	Sandy areas not beaches	0%	0				
74	Bare exposed rock	100%	0				
75	Strip mines, quarries, gravel pits	0%	2,225,706				
76	Transitional areas	0%	3,026,643				
8	Tundra	0%	0				
81	Shrub and brush tundra	0%	0	0			
82	Herbaceous tundra	0%	0	0			
83	Bare ground	0%	0	0			
84	Wet tundra	0%	0	0			
85	Mixed tundra	0%	0	0			
9	Perennial snow or ice	0%	0	0			
91	Perennial snowfields	0%	0	0			
92	Glaciers	100%	0	0			
		Composite IC	4%	12%	0%	0%	6%
		Area I.C. (SF)	38,454,456	13,284,293	0	0	226,172
		Area (SF)	856,116,672	114,260,049	15,313,323	4,205,514	3,644,674
		Area (AC)	19,654	2,623	352	97	84
		Area (SQ-MI)	30.709	4.099	0.549	0.151	0.131

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	BP05
COSM01	Vacant	0%	
COSM03	Single Family Res	60%	
COSM04	Mobile Home	50%	
COSM04	Two Family Res	75%	
COSM05	Multi-Family Res	75%	
COSM06	Commercial	80%	
COSM07	Public & Inst	80%	
COSM08	Industrial	85%	
COSM09	Open Space	0%	46,741
1	Urban or built-up land	80%	
11	Residental	60%	
12	Commercial and services	80%	2,423,129
13	Industrial	80%	
14	Transportation, communication, utilities	80%	
15	Industrial and commercial complexes	80%	
16	Mixed urban or built-up land	60%	
17	Other urban or built-up land	60%	
2	Agricultural land	0%	
21	Cropland and pasture	0%	
22	Orchards, groves, vineyards, nurseries, and ornamental	0%	49,440,185
23	Confined feeding operations	0%	
24	Other agricultural land	0%	289,364
3	Rangeland	0%	
31	Herbaceous rangeland	0%	
32	Shrub and brush rangeland	0%	
33	Mixed rangeland	0%	
4	Forest land	0%	
41	Deciduous forest land	0%	
42	Evergreen forest land	0%	
43	Mixed forest land	0%	
5	Water	100%	
51	Streams and canals	100%	
52	Lakes	100%	
53	Reservoirs	100%	
54	Bays and estuaries	100%	
6	Wetland	0%	
61	Forested wetland	0%	
62	Nonforested wetland	0%	
7	Barren land	0%	
71	Dry salt flats	0%	
72	Beaches	0%	
73	Sandy areas not beaches	0%	
74	Bare exposed rock	100%	
75	Strip mines, quarries, gravel pits	0%	
76	Transitional areas	0%	
8	Tundra	0%	
81	Shrub and brush tundra	0%	
82	Herbaceous tundra	0%	
83	Bare ground	0%	
84	Wet tundra	0%	
85	Mixed tundra	0%	
9	Perennial snow or ice	0%	
91	Perennial snowfields	0%	
92	Glaciers	100%	
		Composite IC	4%
		Area I.C. (SF)	1,938,503
		Area (SF)	52,199,419
		Area (AC)	1,198
		Area (SQ-MI)	1.872

COTTONWOOD CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	C01	C02	C03	C04	C05
COSM01	Vacant	0%	1,471,097		6,100	4,320,496	31,582,688
COSM03	Single Family Res	60%					
COSM04	Mobile Home	50%					
COSM04	Two Family Res	75%					
COSM05	Multi-Family Res	75%					
COSM06	Commercial	80%					3,561,796
COSM07	Public & Inst	80%					
COSM08	Industrial	85%				429,206	
COSM09	Open Space	0%	7,858	103,801	212,895	1,043,865	
1	Urban or built-up land	80%					
11	Residental	60%					
12	Commercial and services	80%	564,914				
13	Industrial	80%	3,937				
14	Transportation, communication, utilities	80%	765,991	1,208,625	2,155,166	672,161	
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%					
2	Agricultural land	0%					
21	Cropland and pasture	0%	10,861,521	9,683,004	4,252,048	14,209,511	27,402,584
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%					
3	Rangeland	0%					
31	Herbaceous rangeland	0%					
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%					
4	Forest land	0%					
41	Deciduous forest land	0%	4,771,447	8,502,282		2,285,054	
42	Evergreen forest land	0%	12,677,749	1,398,723			
43	Mixed forest land	0%					
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%					
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%					
76	Transitional areas	0%					
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	3%	5%	26%	4%	5%
		Area I.C. (SF)	1,067,873	966,900	1,724,133	902,553	2,849,437
		Area (SF)	31,124,514	20,896,435	6,626,209	22,960,293	62,547,068
		Area (AC)	715	480	152	527	1,436
		Area (SQ-MI)	1.116	0.750	0.238	0.824	2.244

COTTONWOOD CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	C06	C07
COSM01	Vacant	0%	17,932,846	7,213
COSM03	Single Family Res	60%	1,839,249	
COSM04	Mobile Home	50%	91,758	
COSM04	Two Family Res	75%		
COSM05	Multi-Family Res	75%	130,476	
COSM06	Commercial	80%	778,830	
COSM07	Public & Inst	80%	2,409,642	
COSM08	Industrial	85%		
COSM09	Open Space	0%	1,209,669	
1	Urban or built-up land	80%		
11	Residental	60%		
12	Commercial and services	80%	107,542	
13	Industrial	80%	2,373,619	
14	Transportation, communication, utilities	80%	352,631	
15	Industrial and commercial complexes	80%		
16	Mixed urban or built-up land	60%		
17	Other urban or built-up land	60%		
2	Agricultural land	0%		
21	Cropland and pasture	0%	12,976,226	79,427,069
22	Orchards, groves, vineyards, nurseries, and ornamental	0%		
23	Confined feeding operations	0%		
24	Other agricultural land	0%		
3	Rangeland	0%		
31	Herbaceous rangeland	0%		
32	Shrub and brush rangeland	0%		
33	Mixed rangeland	0%		
4	Forest land	0%		
41	Deciduous forest land	0%		
42	Evergreen forest land	0%		
43	Mixed forest land	0%		
5	Water	100%		
51	Streams and canals	100%		
52	Lakes	100%		
53	Reservoirs	100%		5,219,141
54	Bays and estuaries	100%		
6	Wetland	0%		
61	Forested wetland	0%		
62	Nonforested wetland	0%		
7	Barren land	0%		
71	Dry salt flats	0%		
72	Beaches	0%		
73	Sandy areas not beaches	0%		
74	Bare exposed rock	100%		
75	Strip mines, quarries, gravel pits	0%		
76	Transitional areas	0%		
8	Tundra	0%		
81	Shrub and brush tundra	0%		
82	Herbaceous tundra	0%		
83	Bare ground	0%		
84	Wet tundra	0%		
85	Mixed tundra	0%		
9	Perennial snow or ice	0%		
91	Perennial snowfields	0%		
92	Glaciers	100%		
		Composite IC	15%	6%
		Area I.C. (SF)	6,065,097	5,219,141
		Area (SF)	40,202,487	84,653,423
		Area (AC)	923	1,943
		Area (SQ-MI)	1.442	3.037

PURGATORY CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	P-01	P-02	P-03	P-04	P-05
COSM01	Vacant	0%		801,697		179	2,218,133
COSM03	Single Family Res	60%		26,816		666,833	2,045,619
COSM04	Mobile Home	50%					
COSM04	Two Family Res	75%					
COSM05	Multi-Family Res	75%					
COSM06	Commercial	80%				152,708	67,156
COSM07	Public & Inst	80%		8,775		35,664	140,758
COSM08	Industrial	85%					
COSM09	Open Space	0%		3,991,518			71,907
1	Urban or built-up land	80%					
11	Residental	60%		30,243			360,139
12	Commercial and services	80%					
13	Industrial	80%					
14	Transportation, communication, utilities	80%					
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%					
2	Agricultural land	0%					
21	Cropland and pasture	0%	12,663,467	4,278,546	2,402,984	2,438,921	
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%	502,154	462,105			
3	Rangeland	0%					
31	Herbaceous rangeland	0%	150,010,226				
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%		12,457,700	1,678,751		
4	Forest land	0%					
41	Deciduous forest land	0%		38,973,149	37,980,470	27,976,602	214,973
42	Evergreen forest land	0%	397,958,592	209,512,095	31,256,701		
43	Mixed forest land	0%					
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%					
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%		2,549,675			
76	Transitional areas	0%	993,317				
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	0%	0%	0%	2%	31%
		Area I.C. (SF)	0	41,255	0	550,797	1,609,786
		Area (SF)	562,127,756	273,092,316	73,318,907	31,270,906	5,118,685
		Area (AC)	12,905	6,269	1,683	718	118
		Area (SQ-MI)	20.164	9.796	2.630	1.122	0.184

PURGATORY CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	P-06	P-07	P-08	P-09	P-10
COSM01	Vacant	0%	1,931,870	1,788,780	1,794,710	1,273,586	3,921,262
COSM03	Single Family Res	60%	2,883,767	301,713	4,620,649	922,930	4,681,664
COSM04	Mobile Home	50%		26,705	5,798	30,726	647,977
COSM04	Two Family Res	75%		11,028	792,826	2,852	532,118
COSM05	Multi-Family Res	75%			73,773		526,015
COSM06	Commercial	80%	162,659	2,907	30,087		643,539
COSM07	Public & Inst	80%	240		981,576	43,667	765,413
COSM08	Industrial	85%			68,303		
COSM09	Open Space	0%	223,107			2,948,252	1,955,100
1	Urban or built-up land	80%					
11	Residental	60%	77,037	299,794	1,863,736	173,952	1,189,554
12	Commercial and services	80%					
13	Industrial	80%					
14	Transportation, communication, utilities	80%					
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%			124,727		174,628
2	Agricultural land	0%					
21	Cropland and pasture	0%		2,209,339			185,851
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%					
3	Rangeland	0%					
31	Herbaceous rangeland	0%					
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%					
4	Forest land	0%					
41	Deciduous forest land	0%	3,666,521	5,199,683	411	7,832	341,983
42	Evergreen forest land	0%					
43	Mixed forest land	0%					
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%					
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%					
76	Transitional areas	0%					
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	21%	4%	53%	13%	38%
		Area I.C. (SF)	1,906,801	384,853	5,485,702	710,565	5,872,257
		Area (SF)	8,945,200	9,839,949	10,356,595	5,403,797	15,565,105
		Area (AC)	205	226	238	124	357
		Area (SQ-MI)	0.321	0.353	0.371	0.194	0.558

PURGATORY CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	P-11	P-12	P-13	P-14
COSM01	Vacant	0%	4,829,764	1,576,675	164,075	559,225
COSM03	Single Family Res	60%	365,571	7,190,836	3,081,766	155,595
COSM04	Mobile Home	50%	48,480	117,703	662	
COSM04	Two Family Res	75%		73,112	194,114	
COSM05	Multi-Family Res	75%		551,191	1,013,101	
COSM06	Commercial	80%	672,080	100,638	910,477	1,334,647
COSM07	Public & Inst	80%	131,133	399,416	4,728,582	307,653
COSM08	Industrial	85%		28,347	14,772	42,131
COSM09	Open Space	0%	1,225,383	1,323,647	915	605,844
1	Urban or built-up land	80%				
11	Residental	60%		2,704,668	1,116,334	966,654
12	Commercial and services	80%			764,315	962,608
13	Industrial	80%				
14	Transportation, communication, utilities	80%				
15	Industrial and commercial complexes	80%				
16	Mixed urban or built-up land	60%				
17	Other urban or built-up land	60%		45,024	37,189	
2	Agricultural land	0%				
21	Cropland and pasture	0%	510,029			
22	Orchards, groves, vineyards, nurseries, and ornamental	0%				
23	Confined feeding operations	0%				
24	Other agricultural land	0%				
3	Rangeland	0%				
31	Herbaceous rangeland	0%				
32	Shrub and brush rangeland	0%				
33	Mixed rangeland	0%				
4	Forest land	0%				
41	Deciduous forest land	0%	155,202		1,598	
42	Evergreen forest land	0%				
43	Mixed forest land	0%				
5	Water	100%				
51	Streams and canals	100%				
52	Lakes	100%				
53	Reservoirs	100%				
54	Bays and estuaries	100%				
6	Wetland	0%				
61	Forested wetland	0%				
62	Nonforested wetland	0%				
7	Barren land	0%				
71	Dry salt flats	0%				
72	Beaches	0%				
73	Sandy areas not beaches	0%				
74	Bare exposed rock	100%				
75	Strip mines, quarries, gravel pits	0%				
76	Transitional areas	0%				
8	Tundra	0%				
81	Shrub and brush tundra	0%				
82	Herbaceous tundra	0%				
83	Bare ground	0%				
84	Wet tundra	0%				
85	Mixed tundra	0%				
9	Perennial snow or ice	0%				
91	Perennial snowfields	0%				
92	Glaciers	100%				
		Composite IC	11%	49%	71%	57%
		Area I.C. (SF)	886,153	6,915,534	8,582,170	2,793,089
		Area (SF)	7,937,642	14,111,257	12,027,899	4,934,359
		Area (AC)	182	324	276	113
		Area (SQ-MI)	0.285	0.506	0.431	0.177

SAN MARCOS RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	SM-01	SM-02	SM-03	SM-04	SM-05
COSM01	Vacant	0%	1,453,660	618,977	2,550,987		2,637,478
COSM03	Single Family Res	60%	4,544,343	1,432,122	2,469,887	25,587	1,066,809
COSM04	Mobile Home	50%	4,149	2,128	161,811		475,428
COSM04	Two Family Res	75%	68,398	66,244			893,303
COSM05	Multi-Family Res	75%	911,151	585,893	520,234	133,781	2,090,956
COSM06	Commercial	80%	194,354	143,042	48,379	1,122,519	2,410,725
COSM07	Public & Inst	80%	2,463,120	2,556,249	3,708,624	3,188,697	4,077,028
COSM08	Industrial	85%					
COSM09	Open Space	0%		26,977	1,714,352	293,694	1,151,851
COSM10	Public Open	5%		46,264	2,422,955	14,176	892,384
1	Urban or built-up land	80%					
11	Residental	60%	1,365,115	653,757	1,214,690	198,002	1,596,255
12	Commercial and services	80%	284,835	44,236		1,132,720	
13	Industrial	80%					
14	Transportation, communication, utilities	80%					
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%			88,590		1,551,466
2	Agricultural land	0%					
21	Cropland and pasture	0%			80,749		172,299
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%					
3	Rangeland	0%					
31	Herbaceous rangeland	0%					
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%					
4	Forest land	0%					
41	Deciduous forest land	0%	102,642		3,479,101		
42	Evergreen forest land	0%					
43	Mixed forest land	0%					
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%					
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%					
76	Transitional areas	0%					
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	58%	64%	31%	75%	54%
		Area I.C. (SF)	6,636,258	3,936,515	5,740,583	4,589,638	10,194,828
		Area (SF)	11,391,767	6,175,888	18,460,357	6,109,177	19,015,983
		Area (AC)	262	142	424	140	437
		Area (SQ-MI)	0.409	0.222	0.662	0.219	0.682

SAN MARCOS RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	SM-06a	SM-06b	SM-07	SM-08	SM-09
COSM01	Vacant	0%	44,254	441,907	12,893,559	2,563,983	130,239
COSM03	Single Family Res	60%	1,897,893	1,586,899	4,120,353	740,427	
COSM04	Mobile Home	50%		84,340	155,050		
COSM04	Two Family Res	75%	405,414	104,548	34,483		
COSM05	Multi-Family Res	75%		312,422	1,050,808		
COSM06	Commercial	80%	862,268	1,021,060	952,538		
COSM07	Public & Inst	80%	159,006	811,588	11,388,101	33,682	
COSM08	Industrial	85%		15,852			
COSM09	Open Space	0%	27,048	2,625,921	3,353,038	266,212	
COSM10	Public Open	5%	926	167,766	12,912	63,382	
1	Urban or built-up land	80%					
11	Residental	60%	925,224	1,160,510	1,659,255	211,757	
12	Commercial and services	80%		2,014	149,180		
13	Industrial	80%					
14	Transportation, communication, utilities	80%	766,257	1,805,113			
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%	182,532				
2	Agricultural land	0%					
21	Cropland and pasture	0%		107,614	3,263,598	27,080,940	7,804,366
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%			16,050		
3	Rangeland	0%					
31	Herbaceous rangeland	0%					
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%					
4	Forest land	0%					
41	Deciduous forest land	0%					
42	Evergreen forest land	0%					
43	Mixed forest land	0%					
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%			71,403	681,041	6,763
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%					
76	Transitional areas	0%					
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	67%	48%	37%	4%	0%
		Area I.C. (SF)	3,537,474	4,928,637	14,422,517	1,279,297	6,763
		Area (SF)	5,270,822	10,247,553	39,120,328	31,641,425	7,941,369
		Area (AC)	121	235	898	726	182
		Area (SQ-MI)	0.189	0.368	1.403	1.135	0.285

SAN MARCOS RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	SM-10
COSM01	Vacant	0%	
COSM03	Single Family Res	60%	
COSM04	Mobile Home	50%	
COSM04	Two Family Res	75%	
COSM05	Multi-Family Res	75%	
COSM06	Commercial	80%	
COSM07	Public & Inst	80%	
COSM08	Industrial	85%	
COSM09	Open Space	0%	
COSM10	Public Open	5%	
1	Urban or built-up land	80%	
11	Residental	60%	2,589,545
12	Commercial and services	80%	
13	Industrial	80%	
14	Transportation, communication, utilities	80%	
15	Industrial and commercial complexes	80%	
16	Mixed urban or built-up land	60%	
17	Other urban or built-up land	60%	
2	Agricultural land	0%	
21	Cropland and pasture	0%	101,071,781
22	Orchards, groves, vineyards, nurseries, and ornamental	0%	
23	Confined feeding operations	0%	
24	Other agricultural land	0%	1,060,136
3	Rangeland	0%	
31	Herbaceous rangeland	0%	
32	Shrub and brush rangeland	0%	
33	Mixed rangeland	0%	
4	Forest land	0%	
41	Deciduous forest land	0%	
42	Evergreen forest land	0%	
43	Mixed forest land	0%	
5	Water	100%	
51	Streams and canals	100%	
52	Lakes	100%	
53	Reservoirs	100%	938,981
54	Bays and estuaries	100%	
6	Wetland	0%	
61	Forested wetland	0%	
62	Nonforested wetland	0%	
7	Barren land	0%	
71	Dry salt flats	0%	
72	Beaches	0%	
73	Sandy areas not beaches	0%	
74	Bare exposed rock	100%	
75	Strip mines, quarries, gravel pits	0%	
76	Transitional areas	0%	
8	Tundra	0%	
81	Shrub and brush tundra	0%	
82	Herbaceous tundra	0%	
83	Bare ground	0%	
84	Wet tundra	0%	
85	Mixed tundra	0%	
9	Perennial snow or ice	0%	
91	Perennial snowfields	0%	
92	Glaciers	100%	
		Composite IC	2%
		Area I.C. (SF)	2,492,708
		Area (SF)	105,660,442
		Area (AC)	2,426
		Area (SQ-MI)	3.790

SINK CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	SK-01	SK-02	SK-03	SK-04	SK-05
COSM01	Vacant	0%				731,775	1,161,935
COSM03	Single Family Res	60%				2,401,622	2,462,239
COSM04	Mobile Home	50%					
COSM04	Two Family Res	75%				576,927	18,969
COSM05	Multi-Family Res	75%				1,554,928	413,303
COSM06	Commercial	80%				222,870	34,072
COSM07	Public & Inst	80%				209,901	55,061
COSM08	Industrial	85%					
COSM09	Open Space	0%					
1	Urban or built-up land	80%					
11	Residental	60%	1,990,766			4,540,416	270,050
12	Commercial and services	80%					
13	Industrial	80%					
14	Transportation, communication, utilities	80%					
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%					9,381
2	Agricultural land	0%					
21	Cropland and pasture	0%		42,298,990	13,154,498	15,071,807	
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%	124,112	1,815,986			
3	Rangeland	0%					
31	Herbaceous rangeland	0%	14,983,299	5,230,424			
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%	45,868,957	56,415,263			
4	Forest land	0%					
41	Deciduous forest land	0%		95,592,503	50,748,553	120,460,615	298,761
42	Evergreen forest land	0%	337,596,384	290,170,564	56,545,191		
43	Mixed forest land	0%		36,799,544	511,435		
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%					
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%					
76	Transitional areas	0%	2,284,171				
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	0%	0%	0%	4%	43%
		Area I.C. (SF)	1,194,460	0	0	6,110,331	2,040,512
		Area (SF)	402,847,688	528,323,273	120,959,677	145,770,861	4,723,772
		Area (AC)	9,248	12,129	2,777	3,346	108
		Area (SQ-MI)	14.450	18.951	4.339	5.229	0.169

SINK CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	SK-06	SK-07
COSM01	Vacant	0%	1,213,491	1,948,623
COSM03	Single Family Res	60%	626,689	2,676,429
COSM04	Mobile Home	50%		
COSM04	Two Family Res	75%	534,072	
COSM05	Multi-Family Res	75%	73	919,420
COSM06	Commercial	80%		
COSM07	Public & Inst	80%		1,632,591
COSM08	Industrial	85%		
COSM09	Open Space	0%		47,856
1	Urban or built-up land	80%		
11	Residental	60%	6,987	915,498
12	Commercial and services	80%		
13	Industrial	80%		
14	Transportation, communication, utilities	80%		
15	Industrial and commercial complexes	80%		
16	Mixed urban or built-up land	60%		
17	Other urban or built-up land	60%		
2	Agricultural land	0%		
21	Cropland and pasture	0%	89,424	20,474,573
22	Orchards, groves, vineyards, nurseries, and ornamental	0%		
23	Confined feeding operations	0%		
24	Other agricultural land	0%		
3	Rangeland	0%		
31	Herbaceous rangeland	0%		
32	Shrub and brush rangeland	0%		
33	Mixed rangeland	0%		
4	Forest land	0%		
41	Deciduous forest land	0%	4,779,658	68,761,059
42	Evergreen forest land	0%		22,308,295
43	Mixed forest land	0%		
5	Water	100%		
51	Streams and canals	100%		
52	Lakes	100%		
53	Reservoirs	100%		
54	Bays and estuaries	100%		
6	Wetland	0%		
61	Forested wetland	0%		
62	Nonforested wetland	0%		
7	Barren land	0%		
71	Dry salt flats	0%		
72	Beaches	0%		
73	Sandy areas not beaches	0%		
74	Bare exposed rock	100%		
75	Strip mines, quarries, gravel pits	0%		3,201,114
76	Transitional areas	0%		
8	Tundra	0%		
81	Shrub and brush tundra	0%		
82	Herbaceous tundra	0%		
83	Bare ground	0%		
84	Wet tundra	0%		
85	Mixed tundra	0%		
9	Perennial snow or ice	0%		
91	Perennial snowfields	0%		
92	Glaciers	100%		
		Composite IC	11%	3%
		Area I.C. (SF)	780,815	4,150,794
		Area (SF)	7,250,394	122,885,457
		Area (AC)	166	2,821
		Area (SQ-MI)	0.260	4.408

WILLOW SPRINGS CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	W-01	W-02	W-03	W-04	W-05
COSM01	Vacant	0%	1,895,931	2,938,412	1,147,882	1,811,769	1,140,779
COSM03	Single Family Res	60%		86,307	36,101		1,812
COSM04	Mobile Home	50%					
COSM04	Two Family Res	75%					
COSM05	Multi-Family Res	75%				436,262	
COSM06	Commercial	80%			153,449	87,128	571,825
COSM07	Public & Inst	80%	941,026	968,045			600,087
COSM08	Industrial	85%			3,380,245	3,220,556	3,625,399
COSM09	Open Space	0%	370,602	1,059,287	57,119	275,011	
1	Urban or built-up land	80%					
11	Residental	60%	4,062,930				
12	Commercial and services	80%					
13	Industrial	80%					105,983
14	Transportation, communication, utilities	80%					764,169
15	Industrial and commercial complexes	80%					
16	Mixed urban or built-up land	60%					
17	Other urban or built-up land	60%					
2	Agricultural land	0%					
21	Cropland and pasture	0%	4,575,086	13,523	1,231,500	775,194	416,923
22	Orchards, groves, vineyards, nurseries, and ornamental	0%					
23	Confined feeding operations	0%					
24	Other agricultural land	0%					
3	Rangeland	0%					
31	Herbaceous rangeland	0%					
32	Shrub and brush rangeland	0%					
33	Mixed rangeland	0%					
4	Forest land	0%					
41	Deciduous forest land	0%	45,009,150	505,369			
42	Evergreen forest land	0%	3,939,275				
43	Mixed forest land	0%					
5	Water	100%					
51	Streams and canals	100%					
52	Lakes	100%					
53	Reservoirs	100%					
54	Bays and estuaries	100%					
6	Wetland	0%					
61	Forested wetland	0%					
62	Nonforested wetland	0%					
7	Barren land	0%					
71	Dry salt flats	0%					
72	Beaches	0%					
73	Sandy areas not beaches	0%					
74	Bare exposed rock	100%					
75	Strip mines, quarries, gravel pits	0%					
76	Transitional areas	0%					
8	Tundra	0%					
81	Shrub and brush tundra	0%					
82	Herbaceous tundra	0%					
83	Bare ground	0%					
84	Wet tundra	0%					
85	Mixed tundra	0%					
9	Perennial snow or ice	0%					
91	Perennial snowfields	0%					
92	Glaciers	100%					
		Composite IC	5%	15%	50%	47%	65%
		Area I.C. (SF)	3,190,579	826,220	3,017,628	3,134,372	4,716,328
		Area (SF)	60,794,001	5,570,943	6,006,296	6,605,921	7,226,977
		Area (AC)	1,396	128	138	152	166
		Area (SQ-MI)	2.181	0.200	0.215	0.237	0.259

WILLOW SPRINGS CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	W-06	W-07
COSM01	Vacant	0%	3,329,042	9,197,544
COSM03	Single Family Res	60%	236,178	6,154,397
COSM04	Mobile Home	50%		78,989
COSM04	Two Family Res	75%		
COSM05	Multi-Family Res	75%	805,502	1,556,288
COSM06	Commercial	80%	1,587,355	3,179,483
COSM07	Public & Inst	80%	898,554	1,514,009
COSM08	Industrial	85%	381,211	318,070
COSM09	Open Space	0%	252,777	2,188,416
1	Urban or built-up land	80%		
11	Residental	60%	40,916	2,556,043
12	Commercial and services	80%	3,989	1,092,664
13	Industrial	80%	14,819	204,770
14	Transportation, communication, utilities	80%	460,295	2,169,232
15	Industrial and commercial complexes	80%		
16	Mixed urban or built-up land	60%		
17	Other urban or built-up land	60%		
2	Agricultural land	0%		
21	Cropland and pasture	0%	1,158,804	583,316
22	Orchards, groves, vineyards, nurseries, and ornamental	0%		
23	Confined feeding operations	0%		
24	Other agricultural land	0%		
3	Rangeland	0%		
31	Herbaceous rangeland	0%		
32	Shrub and brush rangeland	0%		
33	Mixed rangeland	0%		
4	Forest land	0%		
41	Deciduous forest land	0%		
42	Evergreen forest land	0%		
43	Mixed forest land	0%		
5	Water	100%		
51	Streams and canals	100%		
52	Lakes	100%		
53	Reservoirs	100%		
54	Bays and estuaries	100%		
6	Wetland	0%		
61	Forested wetland	0%		
62	Nonforested wetland	0%		
7	Barren land	0%		
71	Dry salt flats	0%		
72	Beaches	0%		
73	Sandy areas not beaches	0%		
74	Bare exposed rock	100%		
75	Strip mines, quarries, gravel pits	0%		
76	Transitional areas	0%		
8	Tundra	0%		
81	Shrub and brush tundra	0%		
82	Herbaceous tundra	0%		
83	Bare ground	0%		
84	Wet tundra	0%		
85	Mixed tundra	0%		
9	Perennial snow or ice	0%		
91	Perennial snowfields	0%		
92	Glaciers	100%		
		Composite IC	38%	43%
		Area I.C. (SF)	3,466,422	13,231,461
		Area (SF)	9,169,442	30,793,222
		Area (AC)	211	707
		Area (SQ-MI)	0.329	1.105

Ultimate Conditions Weighted Land Use Table

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	B01	B02	B03	B04	B05
02	02Very Low Density Res	20%					
03	03Low Density Res	40%					
04	04Med Density Res	60%					
05	05High Density Res	75%					
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%					
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%					
07	07Public Open	5%					
08	08Industrial	85%					
09	09Open Space	0%					
	Future Road	80%					
	Lower Density Neighborhoods	20%					
	Mixed Use	60%					
	Open space protection	0%				90,247,005	
	Road	80%					
	Rural	0%	1,323,080,534	1,114,247,186	971,689,231	1,216,551,501	1,122,159,923
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	0%	0%	0%	0%	0%
		Area I.C. (SF)	0	0	0	0	0
		Area (SF)	1,323,080,534	1,114,247,186	971,689,231	1,306,798,506	1,122,159,923
		Area (AC)	30,374	25,580	22,307	30,000	25,761
		Area (SQ-MI)	47.459	39.968	34.855	46.875	40.252

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	B06	B07	B08	B09	B10
02	02Very Low Density Res	20%					
03	03Low Density Res	40%					
04	04Med Density Res	60%					
05	05High Density Res	75%					
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%					
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%					
07	07Public Open	5%					
08	08Industrial	85%					
09	09Open Space	0%					
	Future Road	80%					
	Lower Density Neighborhoods	20%			63,241,829	31,089,998	170,462,018
	Mixed Use	60%					
	Open space protection	0%	74,732,641	761,131,741	309,012,890	447,158,210	753,571,109
	Road	80%					
	Rural	0%	719,263,592	159,687,764	889,246,270	528,809,042	404,440,846
	Town Center	50%			22,164,837	42,385,377	44,494,357
	Town Center Core	60%			1,593,769	9,585,597	39,238,384
		Composite IC	0%	0%	2%	3%	6%
		Area I.C. (SF)	0	0	24687046	33162047	79882613
		Area (SF)	793,996,234	920,819,505	1,285,259,595	1,059,028,225	1,412,206,715
		Area (AC)	18,228	21,139	29,506	24,312	32,420
		Area (SQ-MI)	28.481	33.030	46.102	37.987	50.656

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	B11	BP01	BP02	BP03	BP04
02	02Very Low Density Res	20%	48,651,545				
03	03Low Density Res	40%	51,937,554	55,099,366	13,373,480		
04	04Med Density Res	60%	4,843,033				
05	05High Density Res	75%	20,710,522				
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%	36,253,087	3,703,683			
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%	5,202,966	17,283,840	16,072		1,673,534
07	07Public Open	5%					
08	08Industrial	85%	29,775,872	34,021,173			6,787
09	09Open Space	0%	54,546,051	3,153,709	1,693,072	4,027,244	1,825,123
	Future Road	80%					
	Lower Density Neighborhoods	20%	116,629,236				
	Mixed Use	60%					
	Open space protection	0%	259,929,584				
	Road	80%	12,876,027	2,041,057	230,697	178,270	139,716
	Rural	0%	1,323,080,534	1,114,247,186	971,689,231	1,216,551,501	1,122,159,923
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	7%	6%	1%	0%	0%
		Area I.C. (SF)	141045045	69380607	5546808	142616	1456369
		Area (SF)	1,964,436,011	1,229,550,013	987,002,553	1,220,757,015	1,125,805,084
		Area (AC)	45,097	28,227	22,658	28,025	25,845
		Area (SQ-MI)	70.464	44.104	35.404	43.789	40.383

BLANCO RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	BP05
02	02Very Low Density Res	20%	4,388,575
03	03Low Density Res	40%	1,551,672
04	04Med Density Res	60%	
05	05High Density Res	75%	5,720,432
06a	06aNhoodCommercial	80%	
06b	06bCommunityCommercial	80%	
06c	06cGeneralCommercial	80%	
06	06Commercial	80%	12,757,641
06d	06dHeavyCommercial	80%	
07	07Public & Inst	80%	2,519,320
07	07Public Open	5%	
08	08Industrial	85%	16,597,591
09	09Open Space	0%	7,723,839
	Future Road	80%	
	Lower Density Neighborhoods	20%	
	Mixed Use	60%	
	Open space protection	0%	
	Road	80%	1,013,420
	Rural	0%	
	Town Center	50%	
	Town Center Core	60%	
		Composite IC	63%
		Area I.C. (SF)	32928965
		Area (SF)	52,272,490
		Area (AC)	1,200
		Area (SQ-MI)	1.875

COTTONWOOD CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	C01	C02	C03	C04	C05
02	02Very Low Density Res	20%	21,215,600	11,201,542	154,240	5,828,148	
03	03Low Density Res	40%					11,252,064
04	04Med Density Res	60%					
05	05High Density Res	75%	1,630,594	2,290,201	1,209,084	5,762,812	6,797
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%	6,162,008	6,117,096	58,969	5,343,796	15,862,107
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%		663,542	4,406,197	1,502,205	307,465
07	07Public Open	5%					
08	08Industrial	85%	284,656	16,727		3,077,487	27,535,895
09	09Open Space	0%	953,459	258,748	224,009	848,064	5,707,803
	Future Road	80%					
	Lower Density Neighborhoods	20%					
	Mixed Use	60%					
	Open space protection	0%					
	Road	80%	587,929	282,182	580,058	646,164	2,024,040
	Rural	0%					
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	36%	46%	75%	61%	68%
		Area I.C. (SF)	11107972	9622433	4973840	14097334	42466324
		Area (SF)	30,834,246	20,830,038	6,632,558	23,008,676	62,696,172
		Area (AC)	708	478	152	528	1,439
		Area (SQ-MI)	1.106	0.747	0.238	0.825	2.249

COTTONWOOD CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	C06	C07
02	02Very Low Density Res	20%	44,771	24,002,215
03	03Low Density Res	40%	2,735,478	18,500,026
04	04Med Density Res	60%		4,688,241
05	05High Density Res	75%	5,410,066	2,690,932
06a	06aNhoodCommercial	80%		
06b	06bCommunityCommercial	80%		
06c	06cGeneralCommercial	80%		
06	06Commercial	80%	10,359,448	14,894,350
06d	06dHeavyCommercial	80%		
07	07Public & Inst	80%	2,625,205	4,572,398
07	07Public Open	5%		
08	08Industrial	85%	14,952,693	
09	09Open Space	0%	2,230,734	15,322,650
	Future Road	80%		
	Lower Density Neighborhoods	20%		
	Mixed Use	60%		
	Open space protection	0%		
	Road	80%	1,854,999	24,331
	Rural	0%		
	Town Center	50%		
	Town Center Core	60%		
		Composite IC	74%	39%
		Area I.C. (SF)	29742205	32624461
		Area (SF)	40,213,394	84,695,145
		Area (AC)	923	1,944
		Area (SQ-MI)	1.442	3.038

PURGATORY CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	P01	P02	P03	P04	P05
02	02Very Low Density Res	20%		103,063,996	55,167,351	19,601,835	
03	03Low Density Res	40%		23,108			2,751,367
04	04Med Density Res	60%					409,254
05	05High Density Res	75%					
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%		120,869	395,903	6,672,500	832,836
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%		8,775	8,211,385		
07	07Public Open	5%				35,755	140,492
08	08Industrial	85%					
09	09Open Space	0%		10,300,427	7,757,591	4,008,688	201,161
	Future Road	80%		440,167		1,620,460	86,671
	Lower Density Neighborhoods	20%					
	Mixed Use	60%					
	Open space protection	0%	187,034,865	104,732,641			
	Road	80%		108,937	53,417	127,736	690,608
	Rural	0%	375,092,892	64,566,873	970,957		
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	0%	7%	25%	33%	52%
		Area I.C. (SF)	0	21165041	17962034	10658712	2641216
		Area (SF)	562,127,757	283,365,795	72,556,604	32,066,974	5,112,389
		Area (AC)	12,905	6,505	1,666	736	117
		Area (SQ-MI)	20.164	10.164	2.603	1.150	0.183

PURGATORY CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	P06	P07	P08	P09	P10
02	02Very Low Density Res	20%	3,150,592	6,471,585	688,885	924,327	1,228,222
03	03Low Density Res	40%	3,556,769	1,034,992	5,206,326	1,279,121	7,383,553
04	04Med Density Res	60%		11,027	824,992	2,684	710,831
05	05High Density Res	75%			56,345		404,969
06a	06aNhoodCommercial	80%					89,016
06b	06bCommunityCommercial	80%					1,273,214
06c	06cGeneralCommercial	80%					109,790
06	06Commercial	80%	942,267	1,050,818	102,121		23,472
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%			635,405	43,667	241,800
07	07Public Open	5%			410,807		381,847
08	08Industrial	85%					
09	09Open Space	0%	436,598	477,050		2,638,314	2,092,672
	Future Road	80%		494,948	243,012	344,653	142,783
	Lower Density Neighborhoods	20%					
	Mixed Use	60%	250,283	44,040	167,890		164,202
	Open space protection	0%					
	Road	80%	1,271,903	256,740	1,993,971	165,643	1,615,913
	Rural	0%					
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	41%	32%	51%	21%	43%
		Area I.C. (SF)	3974332	3183359	5258442	1141294	6843695
		Area (SF)	9,608,412	9,841,200	10,329,753	5,398,408	15,862,285
		Area (AC)	221	226	237	124	364
		Area (SQ-MI)	0.345	0.353	0.371	0.194	0.569

PURGATORY CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	P11	P12	P13	P14
02	02Very Low Density Res	20%	9,938			
03	03Low Density Res	40%	83,910	8,733,298	3,118,788	108,304
04	04Med Density Res	60%	430,317	277,674	199,822	
05	05High Density Res	75%		335,662	1,017,799	
06a	06aNhoodCommercial	80%		68,758	45,988	
06b	06bCommunityCommercial	80%	622,666			
06c	06cGeneralCommercial	80%	1,930,409	3,643	14,177	
06	06Commercial	80%	1,131,917	11,145	883,176	1,870,770
06d	06dHeavyCommercial	80%				
07	07Public & Inst	80%	517	522,138	3,648,275	303,840
07	07Public Open	5%			991,627	
08	08Industrial	85%		26,947		98,350
09	09Open Space	0%	1,453,634	1,327,262	2,515	596,327
	Future Road	80%	266,727	38,858	8,073	
	Lower Density Neighborhoods	20%				
	Mixed Use	60%	1,386,575		172,778	24,844
	Open space protection	0%				
	Road	80%	647,094	2,742,923	1,920,037	1,931,777
	Rural	0%				
	Town Center	50%				
	Town Center Core	60%				
		Composite IC	60%	47%	62%	69%
		Area I.C. (SF)	4805151	6644548	7499787	3426935
		Area (SF)	7,963,705	14,088,309	12,023,056	4,934,211
		Area (AC)	183	323	276	113
		Area (SQ-MI)	0.286	0.505	0.431	0.177

SINK CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	SK01	SK02	SK03	SK04	SK05
02	02Very Low Density Res	20%	1,764,652	4,541,481	1,471,639	98,132,353	
03	03Low Density Res	40%				2,723,380	2,653,673
04	04Med Density Res	60%				830,235	42,335
05	05High Density Res	75%				1,558,043	414,730
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%		2,975,956		3,910,698	33,354
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%		1,593,715		85,166	48,307
07	07Public Open	5%				119,090	10,390
08	08Industrial	85%					
09	09Open Space	0%	347,231	65,580,841		17,653,441	917,207
	Future Road	80%		78,435			
	Lower Density Neighborhoods	20%		32,936,955			
	Mixed Use	60%					
	Open space protection	0%	182,827,944	190,207,383	44,082,465	10,029,979	
	Road	80%	3,952	21,081		1,038,818	590,984
	Rural	0%	217,903,912	228,476,801	75,405,571	9,855,147	
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	0%	2%	0%	18%	41%
		Area I.C. (SF)	356092	11231037	294328	26416196	1936554
		Area (SF)	402,847,690	526,412,648	120,959,675	145,936,350	4,710,981
		Area (AC)	9,248	12,085	2,777	3,350	108
		Area (SQ-MI)	14.450	18.882	4.339	5.235	0.169

SINK CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	SK06	SK07
02	02Very Low Density Res	20%	3,751,089	76,277,404
03	03Low Density Res	40%	1,247,767	4,598,882
04	04Med Density Res	60%	1,248,307	365,342
05	05High Density Res	75%	91	545,558
06a	06aNhoodCommercial	80%		
06b	06bCommunityCommercial	80%		
06c	06cGeneralCommercial	80%		
06	06Commercial	80%	47,832	6,274,387
06d	06dHeavyCommercial	80%		
07	07Public & Inst	80%		1,080,799
07	07Public Open	5%		648,054
08	08Industrial	85%		
09	09Open Space	0%	570,988	26,023,237
	Future Road	80%		
	Lower Density Neighborhoods	20%		
	Mixed Use	60%		
	Open space protection	0%		1,722,481
	Road	80%	392,929	773,526
	Rural	0%		4,757,432
	Town Center	50%		
	Town Center Core	60%		
		Composite IC	32%	20%
		Area I.C. (SF)	2350987	24258779
		Area (SF)	7,259,004	123,067,100
		Area (AC)	167	2,825
		Area (SQ-MI)	0.260	4.414

SAN MARCOS RIVER - LAND USE SUMMARY

LU Code	Description	I.C. %	SM01	SM02	SM03	SM04	SM05
02	02Very Low Density Res	20%			2,864,635		
03	03Low Density Res	40%	4,155,053	2,052,286	4,662,061	25,597	1,165,492
04	04Med Density Res	60%	159,959	55,404	124,842		2,105,987
05	05High Density Res	75%	913,610	580,467	1,036,821	125,483	2,381,386
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%	213,491	144,488	37,481	1,131,227	3,003,633
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%	3,940,499	2,553,157	3,132,250	3,189,714	5,182,737
07	07Public Open	5%		46,347	2,461,688	14,210	864,569
08	08Industrial	85%					
09	09Open Space	0%	215,534	26,982	1,436,955	293,329	1,100,402
	Future Road	80%					
	Lower Density Neighborhoods	20%					
	Mixed Use	60%					
	Open space protection	0%					
	Road	80%	1,779,959	703,949	1,663,553	1,331,573	3,219,006
	Rural	0%					
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	63%	65%	42%	76%	67%
		Area I.C. (SF)	7190364	4013099	7279984	4627073	12683357
		Area (SF)	11,378,107	6,163,079	17,420,286	6,111,134	19,023,211
		Area (AC)	261	141	400	140	437
		Area (SQ-MI)	0.408	0.221	0.625	0.219	0.682

SAN MARCOS RIVERS - LAND USE SUMMARY

LU Code	Description	I.C. %	SM06A	SM06B	SM07	SM08	SM09
02	02Very Low Density Res	20%			9,982,074	17,919,979	1,212,380
03	03Low Density Res	40%	2,062,543	1,946,311	4,942,795	1,654,654	
04	04Med Density Res	60%		207,093	846,494		
05	05High Density Res	75%		307,943	2,058,163	272,435	
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%					
06	06Commercial	80%	903,895	1,209,742	2,099,962	93,330	
06d	06dHeavyCommercial	80%					
07	07Public & Inst	80%	159,433	900,819	11,485,486	30,574	
07	07Public Open	5%		29,133	12,796		
08	08Industrial	85%		15,979			
09	09Open Space	0%	27,058	2,725,473	4,861,477	11,008,565	6,735,021
	Future Road	80%					
	Lower Density Neighborhoods	20%					
	Mixed Use	60%					
	Open space protection	0%					
	Road	80%	1,867,100	2,911,078	3,067,600	722,314	
	Rural	0%					
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	63%	50%	49%	16%	3%
		Area I.C. (SF)	3169360	5166087	19348130	5127158	242476
		Area (SF)	5,020,029	10,253,571	39,356,848	31,701,851	7,947,401
		Area (AC)	115	235	904	728	182
		Area (SQ-MI)	0.180	0.368	1.412	1.137	0.285

WILLOW SPRINGS CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	W01	W02	W03	W04	W05
02	02Very Low Density Res	20%	61,862,717	240,962	3,044,828		
03	03Low Density Res	40%	1,279,540	2,900,756			
04	04Med Density Res	60%					
05	05High Density Res	75%	142,768		232,757	900,381	110,575
06a	06aNhoodCommercial	80%					
06b	06bCommunityCommercial	80%					
06c	06cGeneralCommercial	80%				5,228	
06	06Commercial	80%	13	800,624	1,589,232	1,299,565	746,272
06d	06dHeavyCommercial	80%					163,736
07	07Public & Inst	80%	949,193	1,075,809	183,274	78,557	566,954
07	07Public Open	5%					
08	08Industrial	85%			3,426,834	3,407,089	4,462,552
09	09Open Space	0%	2,920,768	1,113,046	45,803	389,302	
	Future Road	80%					
	Lower Density Neighborhoods	20%					
	Mixed Use	60%					
	Open space protection	0%					
	Road	80%	18,572	170,796	180,530	523,183	1,177,082
	Rural	0%					
	Town Center	50%					
	Town Center Core	60%					
		Composite IC	20%	45%	60%	77%	83%
		Area I.C. (SF)	13765657	2846277	5258771	5096538	5999335
		Area (SF)	67,173,570	6,301,992	8,703,258	6,603,305	7,227,170
		Area (AC)	1,542	145	200	152	166
		Area (SQ-MI)	2.410	0.226	0.312	0.237	0.259

WILLOW SPRINGS CREEK - LAND USE SUMMARY

LU Code	Description	I.C. %	W06	W07
02	02Very Low Density Res	20%		252,761
03	03Low Density Res	40%	203,524	7,370,858
04	04Med Density Res	60%	41,588	665,593
05	05High Density Res	75%	1,501,666	1,220,529
06a	06aNhoodCommercial	80%		
06b	06bCommunityCommercial	80%		
06c	06cGeneralCommercial	80%		1,510,267
06	06Commercial	80%	4,181,516	5,540,563
06d	06dHeavyCommercial	80%	33,070	
07	07Public & Inst	80%	892,874	1,505,324
07	07Public Open	5%		
08	08Industrial	85%	730,465	1,001,782
09	09Open Space	0%		2,593,352
	Future Road	80%		
	Lower Density Neighborhoods	20%		
	Mixed Use	60%		2,471,857
	Open space protection	0%		
	Road	80%	1,664,554	6,601,567
	Rural	0%		
	Town Center	50%		
	Town Center Core	60%		
		Composite IC	79%	61%
		Area I.C. (SF)	7271119	18774453
		Area (SF)	9,249,257	30,734,452
		Area (AC)	212	706
		Area (SQ-MI)	0.332	1.102

APPENDIX D
TIME OF CONCENTRATION SPREADSHEETS

Existing Conditions Time of Concentration Spreadsheets

BLANCO RIVER							
TR-55 Method of Computing the Time of Concentration							
EXISTING CONDITIONS					**SUBAREA**		
			B-01	**B-02**	**B-03**	**B-04**	**B-05**
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.017	0.030	0.030	0.067	0.020
Travel time	Tt	hours	0.879	0.701	0.701	0.508	0.824
Shallow Concentrated Flow		min.	52.8	42.0	42.0	30.5	49.4
Flow Length	L	feet	900	2,400	1,200	1,000	1,000
Slope	s	ft/ft	0.033	0.054	0.079	0.06	0.142
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	2.94	3.76	4.55	3.97	6.10
Travel time	Tt	hours	0.085	0.177	0.073	0.070	0.046
Manning's Equation		min.	5.1	10.6	4.4	4.2	2.7
Flow Length	L	feet	70,600	38,900	26,800	31,400	68,000
Slope	S	ft/ft	0.007	0.009	0.015	0.014	0.008
roughness	n	n/a	0.1	0.08	0.08	0.1	0.08
Open Channel							
Bottom Width	BW	feet	100	100	50	100	100
Side Slopes (H:1)	H	feet	10	10	10	10	5
Depth	d	feet	10	5	5	5	5
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	2000.00	750.00	500.00	750.00	625.00
Flow Rate	Q	cfs	8812.60	3193.48	2539.53	3186.38	2684.29
Velocity	V	ft/sec	4.41	4.26	5.08	4.25	4.29
Travel time	Tt	hours	4.451	2.538	1.466	2.053	4.398
Flow Length	L	feet		17,500	31,500	78,000	
Slope	S	ft/ft		0.003	0.020	0.003	
roughness	n	n/a		0.08	0.08	0.08	
Open Channel							
Bottom Width	BW	feet		100	100	100	
Side Slopes (H:1)	H	feet		5	10	10	
Depth	d	feet		10	10	15	
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2		1500.00	2000.00	3750.00	
Flow Rate	Q	cfs		5727.13	18620.02	16967.60	
Velocity	V	ft/sec		3.82	9.31	4.52	
Travel time	Tt	hours	-	1.273	0.940	4.789	-
Total Travel Time	TC	hours	5.42	4.69	3.18	7.42	5.27
	TC	min.	324.9	281.3	190.8	445.2	316.1
Lag Time	TL	hours	3.25	2.81	1.91	4.45	3.16
	TL	min.	194.9	168.8	114.5	267.1	189.6

BLANCO RIVER TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA				
			B-06	B-07	B-08	B-09	B-10
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.016	0.010	0.010	0.067	0.017
Travel time	Tt	hours	0.901	1.087	1.087	0.508	0.879
Shallow Concentrated Flow		min.	54.1	65.2	65.2	30.5	52.8
Flow Length	L	feet	2,000	1,500	2,000	2,000	2,000
Slope	s	ft/ft	0.042	0.054	0.042	0.04	0.04
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	3.32	3.76	3.32	3.24	3.24
Travel time	Tt	hours	0.167	0.111	0.167	0.171	0.171
Manning's Equation		min.	10.0	6.6	10.0	10.3	10.3
Flow Length	L	feet	58,800	38,200	53,500	77,200	52,200
Slope	S	ft/ft	0.006	0.127	0.008	0.007	0.009
roughness	n	n/a	0.08	0.08	0.08	0.08	0.08
Open Channel							
Bottom Width	BW	feet	100	50	50	80	50
Side Slopes (H:1)	H	feet	5	5	10	5	10
Depth	d	feet	10	5	5	5	5
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	1500.00	375.00	500.00	525.00	500.00
Flow Rate	Q	cfs	8237.84	5968.75	1854.61	2064.29	1967.11
Velocity	V	ft/sec	5.49	15.92	3.71	3.93	3.93
Travel time	Tt	hours	2.974	0.667	4.007	5.454	3.686
Flow Length	L	feet		33,800	38,400		28,200
Slope	S	ft/ft		0.002	0.001		0.006
roughness	n	n/a		0.06	0.06		0.05
Open Channel							
Bottom Width	BW	feet		100	125		120
Side Slopes (H:1)	H	feet		6	5		5
Depth	d	feet		10	15		25
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	0.00	1600.00	3000.00		6125.00
Flow Rate	Q	cfs	0.00	6637.33	11506.39		91031.74
Velocity	V	ft/sec	0.00	4.15	3.84		14.86
Travel time	Tt	hours	-	2.263	2.781	-	0.527
Total Travel Time	TC	hours	4.04	4.13	8.04	6.13	5.26
	TC	min.	242.5	247.7	482.5	368.0	315.8
Lag Time	TL	hours	2.43	2.48	4.83	3.68	3.16
	TL	min.	145.5	148.6	289.5	220.8	189.5

BLANCO RIVER TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA
			B-11
Sheet Flow	variable	units	
Manning's roughness coef.	n	n/a	0.4
Flow Length	L	feet	300
2-year, 24-hour rainfall	P2	inches	3.5
Slope	s	ft/ft	0.017
Travel time	Tt	hours	0.879
Shallow Concentrated Flow		min.	52.8
Flow Length	L	feet	1,400
Slope	s	ft/ft	0.036
Surface (1=paved or 2=unpaved)		n/a	2
Velocity	V	ft/sec	3.07
Travel time	Tt	hours	0.127
Manning's Equation		min.	7.6
Flow Length	L	feet	4,600
Slope	S	ft/ft	0.0180
roughness	n	n/a	0.1
Open Channel			
Bottom Width	BW	feet	50
Side Slopes (H:1)	H	feet	5
Depth	d	feet	5
...or Closed Conduit			
Rise / Diameter	R / D	feet	
Span (BLANK if circular)	S	feet	
Cross-Sectional Area	X-A	feet^2	375.00
Flow Rate	Q	cfs	1797.66
Velocity	V	ft/sec	4.79
Travel time	Tt	hours	0.267
Flow Length	L	feet	84,200
Slope	S	ft/ft	0.002
roughness	n	n/a	0.05
Open Channel			
Bottom Width	BW	feet	150
Side Slopes (H:1)	H	feet	2
Depth	d	feet	35
...or Closed Conduit			
Rise / Diameter	R / D	feet	
Span (BLANK if circular)	S	feet	
Cross-Sectional Area	X-A	feet^2	7700.00
Flow Rate	Q	cfs	88027.58
Velocity	V	ft/sec	11.43
Travel time	Tt	hours	2.046
Total Travel Time	TC	hours	3.32
	TC	min.	199.1
Lag Time	TL	hours	1.99
	TL	min.	119.5

BYPASS CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA				
			BP-01	BP-02	BP-03	BP-04	BP-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.15	0.15	0.15	0.15	0.15
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.010	0.010	0.003	0.003	0.007
Travel time	Tt	hours	0.496	0.496	0.803	0.803	0.572
Shallow Concentrated Flow		min.	29.8	29.8	48.2	48.2	34.3
Flow Length	L	feet	4,200	2,220	960	2,800	3,900
Slope	s	ft/ft	0.008	0.009	0.018	0.005	0.009
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	1.45	1.54	2.17	1.15	1.54
Travel time	Tt	hours	0.805	0.401	0.123	0.679	0.705
Manning's Equation		min.	48.3	24.1	7.4	40.7	42.3
Flow Length	L	feet	6,785	3,160	1,620	1,290	6,880
Slope	S	ft/ft	0.004	0.003	0.007	0.004	0.003
roughness	n	n/a	0.06	0.06	0.06	0.06	0.06
Open Channel							
Bottom Width	BW	feet	10	35	50	100	50
Side Slopes (H:1)	H	feet	10	30	25	4	15
Depth	d	feet	5	3	2	2	3
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	300.00	375.00	200.00	216.00	285.00
Flow Rate	Q	cfs	917.02	738.86	503.22	512.03	622.08
Velocity	V	ft/sec	3.06	1.97	2.52	2.37	2.18
Travel time	Tt	hours	0.617	0.446	0.179	0.151	0.876
Flow Length	L	feet	11,820				
Slope	S	ft/ft	0.0030				
roughness	n	n/a	0.05				
Open Channel							
Bottom Width	BW	feet	50				
Side Slopes (H:1)	H	feet	80				
Depth	d	feet	3				
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	870.00				
Flow Rate	Q	cfs	1975.96				
Velocity	V	ft/sec	2.27				
Travel time	Tt	hours	1.446	-	-	-	-
Total Travel Time	TC	hours	3.364	1.34	1.10	1.63	2.15
	TC	min.	201.8	80.6	66.3	98.0	129.2
Lag Time	TL	hours	2.02	0.81	0.66	0.98	1.29
	TL	min.	121.1	48.3	39.8	58.8	77.5

COTTONWOOD CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA				
			C-01	C-02	C-03	C-04	C-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.053	0.040	0.033	0.040	0.017
Travel time	Tt	hours	0.558	0.625	0.675	0.625	0.879
Shallow Concentrated Flow		min.	33.5	37.5	40.5	37.5	52.8
Flow Length	L	feet	1,500	1,050	2,000	1,900	2,000
Slope	s	ft/ft	0.08	0.066	0.024	0.0433	0.017
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	4.58	4.16	2.51	3.37	2.11
Travel time	Tt	hours	0.091	0.070	0.221	0.157	0.263
Manning's Equation		min.	5.5	4.2	13.3	9.4	15.8
Flow Length	L	feet	5,000	8,650	1,700	3,700	16,000
Slope	S	ft/ft	0.019	0.019	0.024	0.014	0.005
roughness	n	n/a	0.1	0.08	0.08	0.1	0.08
Open Channel							
Bottom Width	BW	feet	20	20	20	20	20
Side Slopes (H:1)	H	feet	10	10	10	10	5
Depth	d	feet	5	5	5	5	10
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	350.00	350.00	350.00	350.00	700.00
Flow Rate	Q	cfs	1444.04	1829.28	2055.93	1242.66	2895.42
Velocity	V	ft/sec	4.13	5.23	5.87	3.55	4.14
Travel time	Tt	hours	0.337	0.460	0.080	0.289	1.074
Flow Length	L	feet	4,400			2,900	
Slope	S	ft/ft	0.012			0.006	
roughness	n	n/a	0.1			0.1	
Open Channel							
Bottom Width	BW	feet	20			20	
Side Slopes (H:1)	H	feet	10			10	
Depth	d	feet	5			5	
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	350.00			350.00	
Flow Rate	Q	cfs	1158.16			842.68	
Velocity	V	ft/sec	3.31			2.41	
Travel time	Tt	hours	0.369	-	-	0.335	-
Total Travel Time	TC	hours	1.36	1.15	0.98	1.41	2.22
	TC	min.	81.3	69.3	58.6	84.3	133.0
Lag Time	TL	hours	0.81	0.69	0.59	0.84	1.33
	TL	min.	48.8	41.6	35.1	50.6	79.8

COTTONWOOD CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA	
			C-06	C-07
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.4	0.4
Flow Length	L	feet	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.0067	0.0230
Travel time	Tt	hours	1.276	0.779
Shallow Concentrated Flow		min.	76.6	46.8
Flow Length	L	feet	2,000	2,000
Slope	s	ft/ft	0.01	0.0251
Surface (1=paved or 2=unpaved)		n/a	2	2
Velocity	V	ft/sec	1.62	2.57
Travel time	Tt	hours	0.343	0.216
Manning's Equation		min.	20.6	13.0
Flow Length	L	feet	9,000	3,600
Slope	S	ft/ft	0.004	0.015
roughness	n	n/a	0.08	0.08
Open Channel				
Bottom Width	BW	feet	20	20
Side Slopes (H:1)	H	feet	5	5
Depth	d	feet	10	10
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	700.00	700.00
Flow Rate	Q	cfs	2740.48	5118.44
Velocity	V	ft/sec	3.91	7.31
Travel time	Tt	hours	0.639	0.137
Flow Length	L	feet		8,500
Slope	S	ft/ft		0.001
roughness	n	n/a		0.08
Open Channel				
Bottom Width	BW	feet		20
Side Slopes (H:1)	H	feet		5
Depth	d	feet		10
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2		700.00
Flow Rate	Q	cfs		1182.05
Velocity	V	ft/sec		1.69
Travel time	Tt	hours	-	1.398
Total Travel Time	TC	hours	2.26	2.53
	TC	min.	135.5	151.8
Lag Time	TL	hours	1.35	1.52
	TL	min.	81.3	91.1

PURGATORY CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA				
			P-01	P-02	P-03	P-04	P-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.41	0.41
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.050	0.010	0.015	0.017	0.027
Travel time	Tt	hours	0.583	1.109	0.943	0.904	0.749
Shallow Concentrated Flow		min.	35.0	66.5	56.6	54.3	45.0
Flow Length	L	feet	4,200	3,400	1,200	1,100	1,200
Slope	s	ft/ft	0.032	0.024	0.046	0.016	0.060
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	2.88	2.52	3.47	2.07	3.97
Travel time	Tt	hours	0.405	0.375	0.096	0.147	0.084
Manning's Equation		min.	24.3	22.5	5.8	8.8	5.0
Flow Length	L	feet	15,000	13,000	15,000	8,300	1,250
Slope	S	ft/ft	0.009	0.010	0.012	0.023	0.015
roughness	n	n/a	0.08	0.08	0.08	0.08	0.06
Open Channel							
Bottom Width	BW	feet	20	10	30	50	50
Side Slopes (H:1)	H	feet	5	4	4	10	25
Depth	d	feet	5	5	4	6	2
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	225.00	150.00	176.00	577.50	131.25
Flow Rate	Q	cfs	848.25	571.80	743.13	3820.63	412.26
Velocity	V	ft/sec	3.77	3.81	4.22	6.62	3.14
Travel time	Tt	hours	1.105	0.947	0.987	0.348	0.111
Flow Length	L	feet	25,000	18,000			
Slope	S	ft/ft	0.006	0.004			
roughness	n	n/a	0.08	0.06			
Open Channel							
Bottom Width	BW	feet	30	40			
Side Slopes (H:1)	H	feet	8	15			
Depth	d	feet	6	7			
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	468.00	1015.00			
Flow Rate	Q	cfs	1665.93	3995.57			
Velocity	V	ft/sec	3.56	3.94			
Travel time	Tt	hours	1.951	1.270	-	-	-
Flow Length	L	feet	18,000				
Slope	S	ft/ft	0.006				
roughness	n	n/a	0.08				
Open Channel							
Bottom Width	BW	feet	35				
Side Slopes (H:1)	H	feet	12				
Depth	d	feet	7				
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	833.00				
Flow Rate	Q	cfs	2958.44				
Velocity	V	ft/sec	3.55				
Travel time	Tt	hours	1.408	-	-	-	-
Total Travel Time	TC	hours	5.45	3.70	2.03	1.40	0.94
	TC	min.	327.1	222.1	121.6	84.0	56.6
Lag Time	TL	hours	3.27	2.22	1.22	0.84	0.57
	TL	min.	196.2	133.3	72.9	50.4	34.0

PURGATORY CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS								
				P-06	**P-07**	**P-08**	**P-09**	**P-10**
Sheet Flow		variable	units					
	Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.41	0.41
	Flow Length	L	feet	300	300	300	300	200
	2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
	Slope	s	ft/ft	0.017	0.017	0.013	0.017	0.015
	Travel time	Tt	hours	0.904	0.904	0.989	0.904	0.682
Shallow Concentrated Flow			min.	54.3	54.3	59.3	54.3	40.9
	Flow Length	L	feet	1,000	1,200	1,250	1,000	750
	Slope	s	ft/ft	0.032	0.024	0.037	0.037	0.041
	Surface (1=paved or 2=unpaved)		n/a	2	2	2	1	1
	Velocity	V	ft/sec	2.90	2.51	3.11	3.96	4.17
	Travel time	Tt	hours	0.096	0.133	0.112	0.070	0.050
Manning's Equation			min.	5.8	8.0	6.7	4.2	3.0
	Flow Length	L	feet	1,250	2,375	4,250	3,300	2,700
	Slope	S	ft/ft	0.026	0.025	0.022	0.025	0.036
	roughness	n	n/a	0.08	0.06	0.06	0.06	0.06
	Open Channel							
	Bottom Width	BW	feet	2	5	5	20	4
	Side Slopes (H:1)	H	feet	10	5	6	15	6
	Depth	d	feet	4	4	4	2	4
	...or Closed Conduit							
	Rise / Diameter	R / D	feet					
	Span (BLANK if circular)	S	feet					
	Cross-Sectional Area	X-A	feet^2	129.50	100.00	116.00	100.00	112.00
	Flow Rate	Q	cfs	568.92	660.93	714.35	455.13	872.76
	Velocity	V	ft/sec	4.39	6.61	6.16	4.55	7.79
	Travel time	Tt	hours	0.079	0.100	0.192	0.201	0.096
	Flow Length	L	feet	2,125	1,200			3,450
	Slope	S	ft/ft	0.012	0.008			0.023
	roughness	n	n/a	0.06	0.08			0.06
	Open Channel							
	Bottom Width	BW	feet	20	60			10
	Side Slopes (H:1)	H	feet	15	16			3
	Depth	d	feet	3	5			8
	...or Closed Conduit							
	Rise / Diameter	R / D	feet					
	Span (BLANK if circular)	S	feet					
	Cross-Sectional Area	X-A	feet^2	195.00	700.00			272.00
	Flow Rate	Q	cfs	783.65	2572.33			2787.64
	Velocity	V	ft/sec	4.02	3.67			10.25
	Travel time	Tt	hours	0.147	0.091	-	-	0.094
	Flow Length	L	feet					
	Slope	S	ft/ft					
	roughness	n	n/a					
	Open Channel							
	Bottom Width	BW	feet					
	Side Slopes (H:1)	H	feet					
	Depth	d	feet					
	...or Closed Conduit							
	Rise / Diameter	R / D	feet					
	Span (BLANK if circular)	S	feet					
	Cross-Sectional Area	X-A	feet^2					
	Flow Rate	Q	cfs					
	Velocity	V	ft/sec					
	Travel time	Tt	hours	-	-	-	-	-
Total Travel Time		TC	hours	1.23	1.23	1.29	1.18	0.92
		TC	min.	73.6	73.7	77.5	70.5	55.3
Lag Time		TL	hours	0.74	0.74	0.78	0.71	0.55
		TL	min.	44.1	44.2	46.5	42.3	33.2

PURGATORY CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS						
			P-11	**P-12**	**P-13**	**P-14**
Sheet Flow	variable	units				
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.15
Flow Length	L	feet	300	300	200	200
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.030	0.130	0.030	0.040
Travel time	Tt	hours	0.715	0.398	0.517	0.206
Shallow Concentrated Flow		min.	42.9	23.9	31.0	12.4
Flow Length	L	feet	1,100	900	500	400
Slope	s	ft/ft	0.012	0.045	0.050	0.050
Surface (1=paved or 2=unpaved)		n/a	2	1	1	1
Velocity	V	ft/sec	1.77	4.37	4.61	4.61
Travel time	Tt	hours	0.172	0.057	0.030	0.024
Manning's Equation		min.	10.3	3.4	1.8	1.4
Flow Length	L	feet	800.00	2400.00	2250.00	1250.00
Slope	S	ft/ft	0.025	0.028	0.053	0.022
roughness	n	n/a	0.06	0.06	0.06	0.06
Open Channel						
Bottom Width	BW	feet	10	10	1	2
Side Slopes (H:1)	H	feet	10	4	3	4
Depth	d	feet	2	4	3	4
...or Closed Conduit						
Rise / Diameter	R / D	feet				
Span (BLANK if circular)	S	feet				
Cross-Sectional Area	X-A	feet^2	60.00	104.00	30.00	72.00
Flow Rate	Q	cfs	265.33	778.88	224.94	429.10
Velocity	V	ft/sec	4.42	7.49	7.50	5.96
Travel time	Tt	hours	0.050	0.089	0.083	0.058
Flow Length	L	feet			2,200	
Slope	S	ft/ft			0.025	
roughness	n	n/a			0.06	
Open Channel						
Bottom Width	BW	feet			4	
Side Slopes (H:1)	H	feet			4	
Depth	d	feet			4	
...or Closed Conduit						
Rise / Diameter	R / D	feet				
Span (BLANK if circular)	S	feet				
Cross-Sectional Area	X-A	feet^2			80.00	
Flow Rate	Q	cfs			525.39	
Velocity	V	ft/sec			6.57	
Travel time	Tt	hours	-	-	0.093	-
Flow Length	L	feet			2,250	
Slope	S	ft/ft			0.033	
roughness	n	n/a			0.06	
Open Channel						
Bottom Width	BW	feet			5	
Side Slopes (H:1)	H	feet			5	
Depth	d	feet			5	
...or Closed Conduit						
Rise / Diameter	R / D	feet				
Span (BLANK if circular)	S	feet				
Cross-Sectional Area	X-A	feet^2			150.00	
Flow Rate	Q	cfs			1305.32	
Velocity	V	ft/sec			8.70	
Travel time	Tt	hours	-	-	0.072	-
Total Travel Time	TC	hours	0.94	0.54	0.80	0.29
	TC	min.	56.2	32.6	47.7	17.3
Lag Time	TL	hours	0.56	0.33	0.48	0.17
	TL	min.	33.7	19.6	28.6	10.4

SAN MARCOS RIVER TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS							
			SUBAREA				
			SM-01	SM-02	SM-03	SM-04	SM-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.010	0.050	0.015	0.025	0.005
Travel time	Tt	hours	0.452	0.237	0.384	0.313	0.596
Shallow Concentrated Flow		min.	27.1	14.2	23.0	18.8	35.7
Flow Length	L	feet	1,950	1,750	1,625	1,100	500
Slope	s	ft/ft	0.03	0.05	0.065	0.073	0.026
Surface (1=paved or 2=unpaved)		n/a	2	2	2	1	2
Velocity	V	ft/sec	2.81	3.62	4.13	5.57	2.61
Travel time	Tt	hours	0.193	0.134	0.109	0.055	0.053
Manning's Equation		min.	11.6	8.1	6.6	3.3	3.2
Flow Length	L	feet	2,800	1,500	2,000	1,900	8,250
Slope	S	ft/ft	0.039	0.051	0.036	0.044	0.006
roughness	n	n/a	0.1	0.05	0.1	0.013	0.05
Open Channel							
Bottom Width	BW	feet	15	5	14		8
Side Slopes (H:1)	H	feet	6	6	12		8
Depth	d	feet	4	4	3		6
...or Closed Conduit							
Rise / Diameter	R / D	feet				3.5	
Span (BLANK if circular)	S	feet				0	
Cross-Sectional Area	X-A	feet^2	156.00	116.00	150.00	9.62	336.00
Flow Rate	Q	cfs	834.36	1305.16	613.28	285.94	1629.79
Velocity	V	ft/sec	5.35	11.25	4.09	29.72	4.85
Travel time	Tt	hours	0.145	0.037	0.136	0.018	0.472
Flow Length	L	feet		1,000	3,500	2,200	
Slope	S	ft/ft		0.019	0.004	0.010	
roughness	n	n/a		0.013	0.05	0.05	
Open Channel							
Bottom Width	BW	feet			250	90	
Side Slopes (H:1)	H	feet			20	5	
Depth	d	feet			10	12	
...or Closed Conduit							
Rise / Diameter	R / D	feet		2			
Span (BLANK if circular)	S	feet		0			
Cross-Sectional Area	X-A	feet^2	0.00	3.14	4500.00	1800.00	0.00
Flow Rate	Q	cfs	0.00	42.25	29616.56	22299.60	0.00
Velocity	V	ft/sec	0.00	13.45	6.58	12.39	0.00
Travel time	Tt	hours	-	0.021	0.148	0.049	-
Total Travel Time	TC	hours	0.79	0.43	0.78	0.43	1.12
	TC	min.	47.4	25.7	46.6	26.1	67.3
Lag Time	TL	hours	0.47	0.26	0.47	0.26	0.67
	TL	min.	28.4	15.4	28.0	15.7	40.4

SAN MARCOS RIVER TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA				
			SM-06A	SM-06B	SM-06C	SM-07	SM-08
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.02	0.24	0.24	0.4	0.4
Flow Length	L	feet	25	300	25	100	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.010	0.005	0.010	0.030	0.060
Travel time	Tt	hours	0.014	0.954	0.099	0.291	0.531
Shallow Concentrated Flow		min.	0.8	57.2	5.9	17.5	31.9
Flow Length	L	feet	600	740	635	1,450	4,700
Slope	s	ft/ft	0.017	0.005	0.005	0.026	0.011
Surface (1=paved or 2=unpaved)		n/a	1	2	1	2	2
Velocity	V	ft/sec	2.69	1.15	1.46	2.61	1.70
Travel time	Tt	hours	0.062	0.179	0.121	0.154	0.768
Manning's Equation		min.	3.7	10.8	7.3	9.3	46.1
Flow Length	L	feet	805	1,120	2,590	7,250	
Slope	S	ft/ft	0.007	0.011	0.003	0.012	
roughness	n	n/a	0.035	0.02	0.013	0.1	
Open Channel							
Bottom Width	BW	feet	10	28		15	
Side Slopes (H:1)	H	feet	4	0		8	
Depth	d	feet	1	0.5		4	
...or Closed Conduit							
Rise / Diameter	R / D	feet			3		
Span (BLANK if circular)	S	feet			0		
Cross-Sectional Area	X-A	feet^2	14.00	14.00	7.07	188.00	
Flow Rate	Q	cfs	41.79	67.32	49.50	544.69	
Velocity	V	ft/sec	2.99	4.81	7.00	2.90	
Travel time	Tt	hours	0.075	0.065	0.103	0.695	-
Flow Length	L	feet	3,350			8,500	
Slope	S	ft/ft	0.0050			0.0012	
roughness	n	n/a	0.06			0.05	
Open Channel							
Bottom Width	BW	feet	6			60	
Side Slopes (H:1)	H	feet	2			5	
Depth	d	feet	5			15	
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	80.00			2025.00	
Flow Rate	Q	cfs	280.46			9382.85	
Velocity	V	ft/sec	3.51			4.63	
Travel time	Tt	hours	0.265	-	-	0.510	-
Total Travel Time	TC	hours	0.42	1.20	0.32	1.65	1.30
	TC	min.	25.0	71.9	19.4	99.0	78.0
Lag Time	TL	hours	0.25	0.72	0.19	0.99	0.78
	TL	min.	15.0	43.1	11.6	59.4	46.8

SAN MARCOS RIVER TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA	
			SM-09	SM-10
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.4	0.24
Flow Length	L	feet	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.0030	0.0200
Travel time	Tt	hours	1.760	0.548
Shallow Concentrated Flow		min.	105.6	32.9
Flow Length	L	feet	1,950	2,900
Slope	s	ft/ft	0.02	0.022
Surface (1=paved or 2=unpaved)		n/a	2	2
Velocity	V	ft/sec	2.29	2.40
Travel time	Tt	hours	0.236	0.335
Manning's Equation		min.	14.2	20.1
Flow Length	L	feet	4,750	3,490
Slope	S	ft/ft	0.0004	0.020
roughness	n	n/a	0.1	0.05
Open Channel				
Bottom Width	BW	feet	60	10
Side Slopes (H:1)	H	feet	5	10
Depth	d	feet	15	3
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	2025.00	120.00
Flow Rate	Q	cfs	2708.60	722.34
Velocity	V	ft/sec	1.34	6.02
Travel time	Tt	hours	0.986	0.161
Flow Length	L	feet		9,890
Slope	S	ft/ft		0.0010
roughness	n	n/a		0.05
Open Channel				
Bottom Width	BW	feet		50
Side Slopes (H:1)	H	feet		8
Depth	d	feet		6
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2		588.00
Flow Rate	Q	cfs		1397.93
Velocity	V	ft/sec		2.38
Travel time	Tt	hours	-	1.156
Total Travel Time	TC	hours	2.98	2.20
	TC	min.	179.0	132.0
Lag Time	TL	hours	1.79	1.32
	TL	min.	107.4	79.2

SINK CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA				
			SK-01	SK-02	SK-03	SK-04	SK-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.41	0.41
Flow Length	L	feet	300	300	300	300	150
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.036	0.067	0.050	0.067	0.053
Travel time	Tt	hours	0.662	0.519	0.583	0.519	0.326
Shallow Concentrated Flow		min.	39.7	31.2	35.0	31.2	19.6
Flow Length	L	feet	2,400	5,800	5,800	2,600	700
Slope	s	ft/ft	0.054	0.028	0.029	0.031	0.057
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	1
Velocity	V	ft/sec	3.77	2.69	2.77	2.84	4.92
Travel time	Tt	hours	0.177	0.599	0.581	0.254	0.039
Manning's Equation		min.	10.6	35.9	34.9	15.2	2.4
Flow Length	L	feet	33,000	24,000	11,000	14,000	3,000
Slope	S	ft/ft	0.008	0.009	0.009	0.009	0.027
roughness	n	n/a	0.08	0.08	0.08	0.08	0.08
Open Channel							
Bottom Width	BW	feet	10	10	5	10	5
Side Slopes (H:1)	H	feet	6	7	17	20	6
Depth	d	feet	8	7	5	8	5
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	432.00	413.00	437.50	1360.00	133.88
Flow Rate	Q	cfs	1901.54	1790.06	1457.35	6023.49	734.03
Velocity	V	ft/sec	4.40	4.33	3.33	4.43	5.48
Travel time	Tt	hours	2.083	1.538	0.917	0.878	0.152
Flow Length	L	feet	11000	15000			
Slope	S	ft/ft	0.006	0.005			
roughness	n	n/a	0.08	0.08			
Open Channel							
Bottom Width	BW	feet	10	10			
Side Slopes (H:1)	H	feet	5	11			
Depth	d	feet	8	5			
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	400.00	325.00			
Flow Rate	Q	cfs	1588.02	856.78			
Velocity	V	ft/sec	3.97	2.64			
Travel time	Tt	hours	0.770	1.581	-	-	-
Flow Length	L	feet					
Slope	S	ft/ft					
roughness	n	n/a					
Open Channel							
Bottom Width	BW	feet					
Side Slopes (H:1)	H	feet					
Depth	d	feet					
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (0 if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2					
Flow Rate	Q	cfs					
Velocity	V	ft/sec					
Travel time	Tt	hours	-	-	-	-	-
Total Travel Time	TC	hours	3.69	4.24	2.08	1.65	0.52
	TC	min.	221.5	254.2	124.8	99.1	31.1
Lag Time	TL	hours	2.21	2.54	1.25	0.99	0.31
	TL	min.	132.9	152.5	74.9	59.5	18.6

SINK CREEK TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			SUBAREA	
			SK-06	SK-07
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.41	0.41
Flow Length	L	feet	150	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.053	0.033
Travel time	Tt	hours	0.326	0.685
Shallow Concentrated Flow		min.	19.6	41.1
Flow Length	L	feet	950	2,200
Slope	s	ft/ft	0.072	0.023
Surface (1=paved or 2=unpaved)		n/a	1	2
Velocity	V	ft/sec	5.51	2.44
Travel time	Tt	hours	0.048	0.250
Manning's Equation		min.	2.9	15.0
Flow Length	L	feet	1,450	14,000
Slope	S	ft/ft	0.034	0.012
roughness	n	n/a	0.08	0.08
Open Channel				
Bottom Width	BW	feet	5	5
Side Slopes (H:1)	H	feet	10	22
Depth	d	feet	4	5
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	180.00	567.50
Flow Rate	Q	cfs	1023.44	2176.10
Velocity	V	ft/sec	5.69	3.83
Travel time	Tt	hours	0.071	1.014
Flow Length	L	feet	2,250	
Slope	S	ft/ft	0.028	
roughness	n	n/a	0.08	
Open Channel				
Bottom Width	BW	feet	5	
Side Slopes (H:1)	H	feet	6	
Depth	d	feet	5	
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	162.50	
Flow Rate	Q	cfs	982.00	
Velocity	V	ft/sec	6.04	
Travel time	Tt	hours	0.103	-
Flow Length	L	feet		
Slope	S	ft/ft		
roughness	n	n/a		
Open Channel				
Bottom Width	BW	feet		
Side Slopes (H:1)	H	feet		
Depth	d	feet		
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (0 if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2		
Flow Rate	Q	cfs		
Velocity	V	ft/sec		
Travel time	Tt	hours	-	-
Total Travel Time	TC	hours	0.55	1.95
	TC	min.	32.9	117.0
Lag Time	TL	hours	0.33	1.17
	TL	min.	19.7	70.2

WILLOW SPRINGS CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA				
			W-01	W-02	W-03	W-04	W-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.067	0.020	0.013	0.020	0.010
Travel time	Tt	hours	0.211	0.342	0.407	0.342	0.452
Shallow Concentrated Flow		min.	12.7	20.5	24.4	20.5	27.1
Flow Length	L	feet	930	1,750	2,700	1,325	900
Slope	s	ft/ft	0.043	0.026	0.02	0.019	0.014
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1
Velocity	V	ft/sec	4.27	3.32	2.91	2.84	2.44
Travel time	Tt	hours	0.060	0.146	0.257	0.130	0.103
Manning's Equation		min.	3.6	8.8	15.4	7.8	6.2
Flow Length	L	feet	13,800	1,575	4,000	4,400	4,800
Slope	S	ft/ft	0.010	0.008	0.011	0.011	0.010
roughness	n	n/a	0.1	0.1	0.1	0.1	0.1
Open Channel							
Bottom Width	BW	feet	40	60	40	4	10
Side Slopes (H:1)	H	feet	30	30	8	5	6
Depth	d	feet	3	2	3	2	4
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	390.00	240.00	192.00	28.00	136.00
Flow Rate	Q	cfs	850.92	387.38	503.32	47.97	354.97
Velocity	V	ft/sec	2.18	1.61	2.62	1.71	2.61
Travel time	Tt	hours	1.757	0.271	0.424	0.713	0.511
Flow Length	L	feet					
Slope	S	ft/ft					
roughness	n	n/a					
Open Channel							
Bottom Width	BW	feet					
Side Slopes (H:1)	H	feet					
Depth	d	feet					
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2					
Flow Rate	Q	cfs					
Velocity	V	ft/sec					
Travel time	Tt	hours	-	-	-	-	-
Total Travel Time	TC	hours	2.03	0.76	1.09	1.19	1.06
	TC	min.	121.7	45.6	65.3	71.1	63.9
Lag Time	TL	hours	1.22	0.46	0.65	0.71	0.64
	TL	min.	73.0	27.3	39.2	42.7	38.3

WILLOW SPRINGS CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA	
			W-06	W-07
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.4	0.4
Flow Length	L	feet	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.073	0.007
Travel time	Tt	hours	0.204	0.521
Shallow Concentrated Flow		min.	12.2	31.2
Flow Length	L	feet	825	3,950
Slope	s	ft/ft	0.032	0.006
Surface (1=paved or 2=unpaved)		n/a	1	1
Velocity	V	ft/sec	3.69	1.60
Travel time	Tt	hours	0.062	0.688
Manning's Equation		min.	3.7	41.3
Flow Length	L	feet	1,100	7,900
Slope	S	ft/ft	0.014	0.004
roughness	n	n/a	0.013	0.1
Open Channel				
Bottom Width	BW	feet		20
Side Slopes (H:1)	H	feet		12
Depth	d	feet		7
...or Closed Conduit				
Rise / Diameter	R / D	feet	3	
Span (BLANK if circular)	S	feet	0	
Cross-Sectional Area	X-A	feet^2	7.07	728.00
Flow Rate	Q	cfs	106.93	1688.32
Velocity	V	ft/sec	15.13	2.32
Travel time	Tt	hours	0.020	0.946
Flow Length	L	feet	2,600	
Slope	S	ft/ft	0.005	
roughness	n	n/a	0.013	
Open Channel				
Bottom Width	BW	feet	12	
Side Slopes (H:1)	H	feet	5	
Depth	d	feet	5	
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	185.00	
Flow Rate	Q	cfs	3075.02	
Velocity	V	ft/sec	16.62	
Travel time	Tt	hours	0.043	-
Total Travel Time	TC	hours	0.33	2.15
	TC	min.	19.8	129.3
Lag Time	TL	hours	0.20	1.29
	TL	min.	11.9	77.6

Ultimate Conditions Time of Concentration Spreadsheets

BLANCO RIVER							
TR-55 Method of Computing the Time of Concentration							
ULTIMATE CONDITIONS					**SUBAREA**		
			B-01	**B-02**	**B-03**	**B-04**	**B-05**
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.017	0.030	0.030	0.067	0.020
Travel time	Tt	hours	0.879	0.701	0.701	0.508	0.824
Shallow Concentrated Flow		min.	52.8	42.0	42.0	30.5	49.4
Flow Length	L	feet	900	2,400	1,200	1,000	1,000
Slope	s	ft/ft	0.033	0.054	0.079	0.06	0.142
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	2.94	3.76	4.55	3.97	6.10
Travel time	Tt	hours	0.085	0.177	0.073	0.070	0.046
Manning's Equation		min.	5.1	10.6	4.4	4.2	2.7
Flow Length	L	feet	70,600	38,900	26,800	31,400	68,000
Slope	S	ft/ft	0.007	0.009	0.015	0.014	0.008
roughness	n	n/a	0.1	0.08	0.08	0.1	0.08
Open Channel							
Bottom Width	BW	feet	100	100	50	100	100
Side Slopes (H:1)	H	feet	10	10	10	10	5
Depth	d	feet	10	5	5	5	5
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	2000.00	750.00	500.00	750.00	625.00
Flow Rate	Q	cfs	8812.60	3193.48	2539.53	3186.38	2684.29
Velocity	V	ft/sec	4.41	4.26	5.08	4.25	4.29
Travel time	Tt	hours	4.451	2.538	1.466	2.053	4.398
Flow Length	L	feet		17,500	31,500	78,000	
Slope	S	ft/ft		0.003	0.020	0.003	
roughness	n	n/a		0.08	0.08	0.08	
Open Channel							
Bottom Width	BW	feet		100	100	100	
Side Slopes (H:1)	H	feet		5	10	10	
Depth	d	feet		10	10	15	
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	0.00	1500.00	2000.00	3750.00	0.00
Flow Rate	Q	cfs	0.00	5727.13	18620.02	16967.60	0.00
Velocity	V	ft/sec	0.00	3.82	9.31	4.52	0.00
Travel time	Tt	hours	-	1.273	0.940	4.789	-
Total Travel Time	TC	hours	5.42	4.69	3.18	7.42	5.27
	TC	min.	324.9	281.3	190.8	445.2	316.1
Lag Time	TL	hours	3.25	2.81	1.91	4.45	3.16
	TL	min.	194.9	168.8	114.5	267.1	189.6

BLANCO RIVER TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS					SUBAREA		
			B-06	B-07	B-08	B-09	B-10
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	300	300	300	300	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.016	0.010	0.010	0.067	0.017
Travel time	Tt	hours	0.901	1.087	1.087	0.508	0.879
Shallow Concentrated Flow		min.	54.1	65.2	65.2	30.5	52.8
Flow Length	L	feet	2,000	1,500	2,000	2,000	2,000
Slope	s	ft/ft	0.042	0.054	0.042	0.04	0.04
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	3.32	3.76	3.32	3.24	3.24
Travel time	Tt	hours	0.167	0.111	0.167	0.171	0.171
Manning's Equation		min.	10.0	6.6	10.0	10.3	10.3
Flow Length	L	feet	58,800	38,200	53,500	77,200	52,200
Slope	S	ft/ft	0.006	0.127	0.008	0.007	0.009
roughness	n	n/a	0.08	0.08	0.08	0.08	0.08
Open Channel							
Bottom Width	BW	feet	100	50	50	80	50
Side Slopes (H:1)	H	feet	5	5	10	5	10
Depth	d	feet	10	5	5	5	5
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	1500.00	375.00	500.00	525.00	500.00
Flow Rate	Q	cfs	8237.84	5968.75	1854.61	2064.29	1967.11
Velocity	V	ft/sec	5.49	15.92	3.71	3.93	3.93
Travel time	Tt	hours	2.974	0.667	4.007	5.454	3.686
Flow Length	L	feet		33,800	38,400		28,200
Slope	S	ft/ft		0.002	0.001		0.006
roughness	n	n/a		0.06	0.06		0.05
Open Channel							
Bottom Width	BW	feet		100	125		120
Side Slopes (H:1)	H	feet		6	5		5
Depth	d	feet		10	15		25
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	0.00	1600.00	3000.00	0.00	6125.00
Flow Rate	Q	cfs	0.00	6637.33	11506.39	0.00	91031.74
Velocity	V	ft/sec	0.00	4.15	3.84	0.00	14.86
Travel time	Tt	hours	-	2.263	2.781	-	0.527
Total Travel Time	TC	hours	4.04	4.13	8.04	6.13	5.26
	TC	min.	242.5	247.7	482.5	368.0	315.8
Lag Time	TL	hours	2.43	2.48	4.83	3.68	3.16
	TL	min.	145.5	148.6	289.5	220.8	189.5

BLANCO RIVER TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA
			B-11
Sheet Flow	variable	units	
Manning's roughness coef.	n	n/a	0.4
Flow Length	L	feet	100
2-year, 24-hour rainfall	P2	inches	3.5
Slope	s	ft/ft	0.017
Travel time	Tt	hours	0.365
Shallow Concentrated Flow		min.	21.9
Flow Length	L	feet	1,600
Slope	s	ft/ft	0.036
Surface (1=paved or 2=unpaved)		n/a	1
Velocity	V	ft/sec	3.91
Travel time	Tt	hours	0.114
Manning's Equation		min.	6.8
Flow Length	L	feet	4,600
Slope	S	ft/ft	0.018
roughness	n	n/a	0.1
Open Channel			
Bottom Width	BW	feet	50
Side Slopes (H:1)	H	feet	5
Depth	d	feet	5
...or Closed Conduit			
Rise / Diameter	R / D	feet	
Span (BLANK if circular)	S	feet	
Cross-Sectional Area	X-A	feet^2	375.00
Flow Rate	Q	cfs	1797.66
Velocity	V	ft/sec	4.79
Travel time	Tt	hours	0.267
Flow Length	L	feet	84,200
Slope	S	ft/ft	0.0020
roughness	n	n/a	0.05
Open Channel			
Bottom Width	BW	feet	150
Side Slopes (H:1)	H	feet	2
Depth	d	feet	35
...or Closed Conduit			
Rise / Diameter	R / D	feet	
Span (BLANK if circular)	S	feet	
Cross-Sectional Area	X-A	feet^2	7700.00
Flow Rate	Q	cfs	88027.58
Velocity	V	ft/sec	11.43
Travel time	Tt	hours	2.046
Total Travel Time	TC	hours	2.79
	TC	min.	167.5
Lag Time	TL	hours	1.67
	TL	min.	100.5

BYPASS CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA				
			BP-01	BP-02	BP-03	BP-04	BP-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.15	0.15	0.15	0.15	0.15
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.010	0.010	0.003	0.003	0.007
Travel time	Tt	hours	0.206	0.206	0.333	0.333	0.238
Shallow Concentrated Flow		min.	12.4	12.4	20.0	20.0	14.3
Flow Length	L	feet	4,400	2,400	1,160	3,000	4,100
Slope	s	ft/ft	0.008	0.009	0.018	0.005	0.009
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1
Velocity	V	ft/sec	1.84	1.95	2.76	1.46	1.95
Travel time	Tt	hours	0.663	0.341	0.117	0.572	0.583
Manning's Equation		min.	39.8	20.5	7.0	34.3	35.0
Flow Length	L	feet	6,785	3,160	1,620	1,290	6,880
Slope	S	ft/ft	0.004	0.003	0.007	0.004	0.003
roughness	n	n/a	0.06	0.06	0.06	0.06	0.06
Open Channel							
Bottom Width	BW	feet	10	35	50	100	50
Side Slopes (H:1)	H	feet	10	30	25	4	15
Depth	d	feet	5	3	2	2	3
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	300.00	375.00	200.00	216.00	285.00
Flow Rate	Q	cfs	917.02	738.86	503.22	512.03	622.08
Velocity	V	ft/sec	3.06	1.97	2.52	2.37	2.18
Travel time	Tt	hours	0.617	0.446	0.179	0.151	0.876
Flow Length	L	feet	11,820				
Slope	S	ft/ft	0.0030				
roughness	n	n/a	0.05				
Open Channel							
Bottom Width	BW	feet	50				
Side Slopes (H:1)	H	feet	80				
Depth	d	feet	3				
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	870.00				
Flow Rate	Q	cfs	1975.96				
Velocity	V	ft/sec	2.27				
Travel time	Tt	hours	1.446	-	-	-	-
Total Travel Time	TC	hours	2.932	0.99	0.63	1.06	1.70
	TC	min.	175.9	59.6	37.7	63.4	101.8
Lag Time	TL	hours	1.76	0.60	0.38	0.63	1.02
	TL	min.	105.5	35.7	22.6	38.0	61.1

COTTONWOOD CREEK **TR-55 Method of Computing the Time of Concentration** **ULTIMATE CONDITIONS**					**SUBAREA**		
			C-01	**C-02**	**C-03**	**C-04**	**C-05**
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.053	0.040	0.033	0.040	0.017
Travel time	Tt	hours	0.232	0.259	0.280	0.259	0.365
Shallow Concentrated Flow		min.	13.9	15.6	16.8	15.6	21.9
Flow Length	L	feet	1,700	1,250	2,200	2,100	2,200
Slope	s	ft/ft	0.08	0.066	0.024	0.0433	0.017
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1
Velocity	V	ft/sec	5.83	5.29	3.19	4.29	2.69
Travel time	Tt	hours	0.081	0.066	0.191	0.136	0.228
Manning's Equation		min.	4.9	3.9	11.5	8.2	13.7
Flow Length	L	feet	5,000	8,650	1,700	3,700	16,000
Slope	S	ft/ft	0.019	0.019	0.024	0.014	0.005
roughness	n	n/a	0.1	0.08	0.08	0.1	0.08
Open Channel							
Bottom Width	BW	feet	20	20	20	20	20
Side Slopes (H:1)	H	feet	10	10	10	10	5
Depth	d	feet	5	5	5	5	10
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	350.00	350.00	350.00	350.00	700.00
Flow Rate	Q	cfs	1444.04	1829.28	2055.93	1242.66	2895.42
Velocity	V	ft/sec	4.13	5.23	5.87	3.55	4.14
Travel time	Tt	hours	0.337	0.460	0.080	0.289	1.074
Flow Length	L	feet	4,400			2,900	
Slope	S	ft/ft	0.012			0.006	
roughness	n	n/a	0.1			0.1	
Open Channel							
Bottom Width	BW	feet	20			20	
Side Slopes (H:1)	H	feet	10			10	
Depth	d	feet	5			5	
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	350.00			350.00	
Flow Rate	Q	cfs	1158.16			842.68	
Velocity	V	ft/sec	3.31			2.41	
Travel time	Tt	hours	0.369	-	-	0.335	-
Total Travel Time	TC	hours	1.02	0.78	0.55	1.02	1.67
	TC	min.	61.1	47.1	33.1	61.2	100.0
Lag Time	TL	hours	0.61	0.47	0.33	0.61	1.00
	TL	min.	36.7	28.2	19.9	36.7	60.0

COTTONWOOD CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA	
			C-06	C-07
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.4	0.4
Flow Length	L	feet	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.007	0.023
Travel time	Tt	hours	0.530	0.324
Shallow Concentrated Flow		min.	31.8	19.4
Flow Length	L	feet	2,200	2,200
Slope	s	ft/ft	0.01	0.025
Surface (1=paved or 2=unpaved)		n/a	1	1
Velocity	V	ft/sec	2.06	3.26
Travel time	Tt	hours	0.297	0.187
Manning's Equation		min.	17.8	11.2
Flow Length	L	feet	9,000	3,600
Slope	S	ft/ft	0.004	0.015
roughness	n	n/a	0.08	0.08
Open Channel				
Bottom Width	BW	feet	20	20
Side Slopes (H:1)	H	feet	5	5
Depth	d	feet	10	10
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	700.00	700.00
Flow Rate	Q	cfs	2740.48	5118.44
Velocity	V	ft/sec	3.91	7.31
Travel time	Tt	hours	0.639	0.137
Flow Length	L	feet		8,500
Slope	S	ft/ft		0.001
roughness	n	n/a		0.08
Open Channel				
Bottom Width	BW	feet		20
Side Slopes (H:1)	H	feet		5
Depth	d	feet		10
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2		700.00
Flow Rate	Q	cfs		1182.05
Velocity	V	ft/sec		1.69
Travel time	Tt	hours	-	1.398
Total Travel Time	TC	hours	1.47	2.05
	TC	min.	87.9	122.8
Lag Time	TL	hours	0.88	1.23
	TL	min.	52.7	73.7

PURGATORY CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA				
			P-01	P-02	P-03	P-04	P-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.41	0.41
Flow Length	L	feet	300	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.050	0.030	0.045	0.050	0.080
Travel time	Tt	hours	0.583	0.297	0.252	0.242	0.200
Shallow Concentrated Flow		min.	35.0	17.8	15.1	14.5	12.0
Flow Length	L	feet	4,200	3,400	1,200	1,100	1,200
Slope	s	ft/ft	0.032	0.024	0.046	0.016	0.060
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2
Velocity	V	ft/sec	2.88	2.52	3.47	2.07	3.97
Travel time	Tt	hours	0.405	0.375	0.096	0.147	0.084
Manning's Equation		min.	24.3	22.5	5.8	8.8	5.0
Flow Length	L	feet	15,000	13,000	15,000	8,300	1,250
Slope	S	ft/ft	0.009	0.010	0.012	0.023	0.015
roughness	n	n/a	0.08	0.08	0.08	0.08	0.06
Open Channel							
Bottom Width	BW	feet	20	10	30	50	50
Side Slopes (H:1)	H	feet	5	4	4	10	25
Depth	d	feet	5	5	4	6	2
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	225.00	150.00	176.00	577.50	131.25
Flow Rate	Q	cfs	848.25	571.80	743.13	3820.63	412.26
Velocity	V	ft/sec	3.77	3.81	4.22	6.62	3.14
Travel time	Tt	hours	1.105	0.947	0.987	0.348	0.111
Flow Length	L	feet	25,000	18,000			
Slope	S	ft/ft	0.006	0.004			
roughness	n	n/a	0.08	0.06			
Open Channel							
Bottom Width	BW	feet	30	40			
Side Slopes (H:1)	H	feet	8	15			
Depth	d	feet	6	7			
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	468.00	1015.00			
Flow Rate	Q	cfs	1665.93	3995.57			
Velocity	V	ft/sec	3.56	3.94			
Travel time	Tt	hours	1.951	1.270	-	-	-
Flow Length	L	feet	18,000				
Slope	S	ft/ft	0.006				
roughness	n	n/a	0.08				
Open Channel							
Bottom Width	BW	feet	35				
Side Slopes (H:1)	H	feet	12				
Depth	d	feet	7				
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	833.00				
Flow Rate	Q	cfs	2958.44				
Velocity	V	ft/sec	3.55				
Travel time	Tt	hours	1.408	-	-	-	-
Total Travel Time	TC	hours	5.45	2.89	1.34	0.74	0.40
	TC	min.	327.1	173.4	80.1	44.3	23.7
Lag Time	TL	hours	3.27	1.73	0.80	0.44	0.24
	TL	min.	196.2	104.0	48.1	26.6	14.2

PURGATORY CREEK **TR-55 Method of Computing the Time of Concentration** **ULTIMATE CONDITIONS**							
			P-06	**P-07**	**P-08**	**P-09**	**P-10**
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.41	0.41
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.050	0.050	0.040	0.050	0.030
Travel time	Tt	hours	0.242	0.242	0.265	0.242	0.297
Shallow Concentrated Flow		min.	14.5	14.5	15.9	14.5	17.8
Flow Length	L	feet	1,000	1,200	1,250	1,000	750
Slope	s	ft/ft	0.032	0.024	0.037	0.037	0.041
Surface (1=paved or 2=unpaved)		n/a	2	2	2	1	1
Velocity	V	ft/sec	2.90	2.51	3.11	3.96	4.17
Travel time	Tt	hours	0.096	0.133	0.112	0.070	0.050
Manning's Equation		min.	5.8	8.0	6.7	4.2	3.0
Flow Length	L	feet	1,250	2,375	4,250	3,300	2,700
Slope	S	ft/ft	0.026	0.025	0.022	0.025	0.036
roughness	n	n/a	0.08	0.06	0.06	0.06	0.06
Open Channel							
Bottom Width	BW	feet	2	5	5	20	4
Side Slopes (H:1)	H	feet	10	5	6	15	6
Depth	d	feet	4	4	4	2	4
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	129.50	100.00	116.00	100.00	112.00
Flow Rate	Q	cfs	568.92	660.93	714.35	455.13	872.76
Velocity	V	ft/sec	4.39	6.61	6.16	4.55	7.79
Travel time	Tt	hours	0.079	0.100	0.192	0.201	0.096
Flow Length	L	feet	2,125	1,200			3,450
Slope	S	ft/ft	0.012	0.008			0.023
roughness	n	n/a	0.06	0.08			0.06
Open Channel							
Bottom Width	BW	feet	20	60			10
Side Slopes (H:1)	H	feet	15	16			3
Depth	d	feet	3	5			8
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	195.00	700.00			272.00
Flow Rate	Q	cfs	783.65	2572.33			2787.64
Velocity	V	ft/sec	4.02	3.67			10.25
Travel time	Tt	hours	0.147	0.091	-	-	0.094
Flow Length	L	feet					
Slope	S	ft/ft					
roughness	n	n/a					
Open Channel							
Bottom Width	BW	feet					
Side Slopes (H:1)	H	feet					
Depth	d	feet					
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2					
Flow Rate	Q	cfs					
Velocity	V	ft/sec					
Travel time	Tt	hours	-	-	-	-	-
Total Travel Time	TC	hours	0.56	0.57	0.57	0.51	0.54
	TC	min.	33.8	33.9	34.1	30.8	32.2
Lag Time	TL	hours	0.34	0.34	0.34	0.31	0.32
	TL	min.	20.3	20.4	20.4	18.5	19.3

PURGATORY CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS						
			P-11	**P-12**	**P-13**	**P-14**
Sheet Flow	variable	units				
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.15
Flow Length	L	feet	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.030	0.130	0.030	0.080
Travel time	Tt	hours	0.297	0.165	0.297	0.090
Shallow Concentrated Flow		min.	17.8	9.9	17.8	5.4
Flow Length	L	feet	1,100	900	500	400
Slope	s	ft/ft	0.012	0.045	0.050	0.050
Surface (1=paved or 2=unpaved)		n/a	2	1	1	1
Velocity	V	ft/sec	1.77	4.37	4.61	4.61
Travel time	Tt	hours	0.172	0.057	0.030	0.024
Manning's Equation		min.	10.3	3.4	1.8	1.4
Flow Length	L	feet	800	2,400	2,250	1,250
Slope	S	ft/ft	0.025	0.028	0.053	0.022
roughness	n	n/a	0.06	0.06	0.06	0.06
Open Channel						
Bottom Width	BW	feet	10	10	1	2
Side Slopes (H:1)	H	feet	10	4	3	4
Depth	d	feet	2	4	3	4
...or Closed Conduit						
Rise / Diameter	R / D	feet				
Span (BLANK if circular)	S	feet				
Cross-Sectional Area	X-A	feet^2	60.00	104.00	30.00	72.00
Flow Rate	Q	cfs	265.33	778.88	224.94	429.10
Velocity	V	ft/sec	4.42	7.49	7.50	5.96
Travel time	Tt	hours	0.050	0.089	0.083	0.058
Flow Length	L	feet			2,200	
Slope	S	ft/ft			0.025	
roughness	n	n/a			0.06	
Open Channel						
Bottom Width	BW	feet			4	
Side Slopes (H:1)	H	feet			4	
Depth	d	feet			4	
...or Closed Conduit						
Rise / Diameter	R / D	feet				
Span (BLANK if circular)	S	feet				
Cross-Sectional Area	X-A	feet^2			80.00	
Flow Rate	Q	cfs			525.39	
Velocity	V	ft/sec			6.57	
Travel time	Tt	hours	-	-	0.093	-
Flow Length	L	feet			2,250	
Slope	S	ft/ft			0.033	
roughness	n	n/a			0.06	
Open Channel						
Bottom Width	BW	feet			5	
Side Slopes (H:1)	H	feet			5	
Depth	d	feet			5	
...or Closed Conduit						
Rise / Diameter	R / D	feet				
Span (BLANK if circular)	S	feet				
Cross-Sectional Area	X-A	feet^2			150.00	
Flow Rate	Q	cfs			1305.32	
Velocity	V	ft/sec			8.70	
Travel time	Tt	hours	-	-	0.072	-
Total Travel Time	TC	hours	0.52	0.31	0.58	0.17
	TC	min.	31.2	18.7	34.5	10.3
Lag Time	TL	hours	0.31	0.19	0.35	0.10
	TL	min.	18.7	11.2	20.7	6.2

SAN MARCOS RIVER TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS							
			SUBAREA				
			SM-01	SM-02	SM-03	SM-04	SM-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.010	0.050	0.015	0.025	0.005
Travel time	Tt	hours	0.452	0.237	0.384	0.313	0.596
Shallow Concentrated Flow		min.	27.1	14.2	23.0	18.8	35.7
Flow Length	L	feet	1,950	1,750	1,625	1,100	500
Slope	s	ft/ft	0.03	0.05	0.065	0.073	0.026
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1
Velocity	V	ft/sec	3.57	4.61	5.25	5.57	3.32
Travel time	Tt	hours	0.152	0.106	0.086	0.055	0.042
Manning's Equation		min.	9.1	6.3	5.2	3.3	2.5
Flow Length	L	feet	2,800	1,500	2,000	1,900	8,250
Slope	S	ft/ft	0.039	0.051	0.036	0.044	0.006
roughness	n	n/a	0.1	0.05	0.1	0.013	0.05
Open Channel							
Bottom Width	BW	feet	15	5	14		8
Side Slopes (H:1)	H	feet	6	6	12		8
Depth	d	feet	4	4	3		6
...or Closed Conduit							
Rise / Diameter	R / D	feet				3.5	
Span (BLANK if circular)	S	feet				0	
Cross-Sectional Area	X-A	feet^2	156.00	116.00	150.00	9.62	336.00
Flow Rate	Q	cfs	834.36	1305.16	613.28	285.94	1629.79
Velocity	V	ft/sec	5.35	11.25	4.09	29.72	4.85
Travel time	Tt	hours	0.145	0.037	0.136	0.018	0.472
Flow Length	L	feet		1,000	3,500	2,200	
Slope	S	ft/ft		0.019	0.004	0.010	
roughness	n	n/a		0.013	0.05	0.05	
Open Channel							
Bottom Width	BW	feet			250	90	
Side Slopes (H:1)	H	feet			20	5	
Depth	d	feet			10	12	
...or Closed Conduit							
Rise / Diameter	R / D	feet		2			
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2		3.14	4500.00	1800.00	
Flow Rate	Q	cfs		31.27	29616.56	22299.60	
Velocity	V	ft/sec		9.95	6.58	12.39	
Travel time	Tt	hours	-	0.028	0.148	0.049	-
Total Travel Time	TC	hours	0.75	0.41	0.75	0.43	1.11
	TC	min.	44.9	24.5	45.2	26.1	66.6
Lag Time	TL	hours	0.45	0.24	0.45	0.26	0.67
	TL	min.	27.0	14.7	27.1	15.7	40.0

SAN MARCOS RIVER TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA				
			SM-06A	SM-06B	SM-06C	SM-07	SM-08
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.02	0.24	0.24	0.4	0.4
Flow Length	L	feet	25	100	25	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.010	0.005	0.010	0.030	0.060
Travel time	Tt	hours	0.014	0.396	0.099	0.291	0.221
Shallow Concentrated Flow		min.	0.8	23.8	5.9	17.5	13.2
Flow Length	L	feet	600	940	635	1,450	4,900
Slope	s	ft/ft	0.017	0.005	0.005	0.026	0.011
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1
Velocity	V	ft/sec	2.69	1.46	1.46	3.32	2.16
Travel time	Tt	hours	0.062	0.179	0.121	0.121	0.630
Manning's Equation		min.	3.7	10.8	7.3	7.3	37.8
Flow Length	L	feet	805	1,120	2,590	7,250	
Slope	S	ft/ft	0.007	0.011	0.003	0.012	
roughness	n	n/a	0.035	0.02	0.013	0.1	
Open Channel							
Bottom Width	BW	feet	10	28		15	
Side Slopes (H:1)	H	feet	4	0		8	
Depth	d	feet	1	0.5		4	
...or Closed Conduit							
Rise / Diameter	R / D	feet			3		
Span (BLANK if circular)	S	feet			0		
Cross-Sectional Area	X-A	feet^2	14.00	14.00	7.07	188.00	
Flow Rate	Q	cfs	41.79	67.32	49.50	544.69	
Velocity	V	ft/sec	2.99	4.81	7.00	2.90	
Travel time	Tt	hours	0.075	0.065	0.103	0.695	-
Flow Length	L	feet	3,350			8,500	
Slope	S	ft/ft	0.005			0.001	
roughness	n	n/a	0.06			0.05	
Open Channel							
Bottom Width	BW	feet	6			60	
Side Slopes (H:1)	H	feet	2			5	
Depth	d	feet	5			15	
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	80.00	0.00	0.00	2025.00	0.00
Flow Rate	Q	cfs	280.46	0.00	0.00	9382.85	0.00
Velocity	V	ft/sec	3.51	0.00	0.00	4.63	0.00
Travel time	Tt	hours	0.265	-	-	0.510	-
Total Travel Time	TC	hours	0.42	0.64	0.32	1.62	0.85
	TC	min.	25.0	38.4	19.4	97.0	51.0
Lag Time	TL	hours	0.25	0.38	0.19	0.97	0.51
	TL	min.	15.0	23.0	11.6	58.2	30.6

SAN MARCOS RIVER TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA	
			SM-09	**SM-10**
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.4	0.24
Flow Length	L	feet	100	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.0030	0.0200
Travel time	Tt	hours	0.731	0.548
Shallow Concentrated Flow		min.	43.9	32.9
Flow Length	L	feet	2,150	2,900
Slope	s	ft/ft	0.02	0.022
Surface (1=paved or 2=unpaved)		n/a	1	2
Velocity	V	ft/sec	2.91	2.40
Travel time	Tt	hours	0.205	0.335
Manning's Equation		min.	12.3	20.1
Flow Length	L	feet	4,750	3,490
Slope	S	ft/ft	0.0004	0.020
roughness	n	n/a	0.1	0.05
Open Channel				
Bottom Width	BW	feet	60	10
Side Slopes (H:1)	H	feet	5	10
Depth	d	feet	15	3
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	2025.00	120.00
Flow Rate	Q	cfs	2708.60	722.34
Velocity	V	ft/sec	1.34	6.02
Travel time	Tt	hours	0.986	0.161
Flow Length	L	feet		9,890
Slope	S	ft/ft		0.0010
roughness	n	n/a		0.05
Open Channel				
Bottom Width	BW	feet		50
Side Slopes (H:1)	H	feet		8
Depth	d	feet		6
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	0.00	588.00
Flow Rate	Q	cfs	0.00	1397.93
Velocity	V	ft/sec	0.00	2.38
Travel time	Tt	hours	-	1.156
Total Travel Time	TC	hours	1.92	2.20
	TC	min.	115.3	132.0
Lag Time	TL	hours	1.15	1.32
	TL	min.	69.2	79.2

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

			SUBAREA				
			SK-01	**SK-02**	**SK-03**	**SK-04**	**SK-05**
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.41	0.41	0.41	0.41	0.41
Flow Length	L	feet	300	300	300	300	150
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.036	0.067	0.050	0.067	0.053
Travel time	Tt	hours	0.662	0.519	0.583	0.519	0.326
Shallow Concentrated Flow		min.	39.7	31.2	35.0	31.2	19.6
Flow Length	L	feet	2,400	5,800	5,800	2,600	700
Slope	s	ft/ft	0.054	0.028	0.029	0.031	0.057
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	1
Velocity	V	ft/sec	3.77	2.69	2.77	2.84	4.92
Travel time	Tt	hours	0.177	0.599	0.581	0.254	0.039
Manning's Equation		min.	10.6	35.9	34.9	15.2	2.4
Flow Length	L	feet	33,000	24,000	11,000	14,000	3,000
Slope	S	ft/ft	0.008	0.009	0.009	0.009	0.027
roughness	n	n/a	0.08	0.08	0.08	0.08	0.08
Open Channel							
Bottom Width	BW	feet	10	10	5	10	5
Side Slopes (H:1)	H	feet	6	7	17	20	6
Depth	d	feet	8	7	5	8	5
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	432.00	413.00	437.50	1360.00	133.88
Flow Rate	Q	cfs	1901.54	1790.06	1457.35	6023.49	734.03
Velocity	V	ft/sec	4.40	4.33	3.33	4.43	5.48
Travel time	Tt	hours	2.083	1.538	0.917	0.878	0.152
Flow Length	L	feet	11000	15000			
Slope	S	ft/ft	0.006	0.005			
roughness	n	n/a	0.08	0.08			
Open Channel							
Bottom Width	BW	feet	10	10			
Side Slopes (H:1)	H	feet	5	11			
Depth	d	feet	8	5			
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	400.00	325.00			
Flow Rate	Q	cfs	1588.02	856.78			
Velocity	V	ft/sec	3.97	2.64			
Travel time	Tt	hours	0.770	1.581	-	-	-
Flow Length	L	feet					
Slope	S	ft/ft					
roughness	n	n/a					
Open Channel							
Bottom Width	BW	feet					
Side Slopes (H:1)	H	feet					
Depth	d	feet					
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (0 if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2					
Flow Rate	Q	cfs					
Velocity	V	ft/sec					
Travel time	Tt	hours	-	-	-	-	-
Total Travel Time	TC	hours	3.69	4.24	2.08	1.65	0.52
	TC	min.	221.5	254.2	124.8	99.1	31.1
Lag Time	TL	hours	2.21	2.54	1.25	0.99	0.31
	TL	min.	132.9	152.5	74.9	59.5	18.6

SINK CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA	
			SK-06	SK-07
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.41	0.41
Flow Length	L	feet	150	300
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.053	0.033
Travel time	Tt	hours	0.326	0.685
Shallow Concentrated Flow		min.	19.6	41.1
Flow Length	L	feet	950	2,200
Slope	s	ft/ft	0.072	0.023
Surface (1=paved or 2=unpaved)		n/a	1	2
Velocity	V	ft/sec	5.51	2.44
Travel time	Tt	hours	0.048	0.250
Manning's Equation		min.	2.9	15.0
Flow Length	L	feet	1,450	14,000
Slope	S	ft/ft	0.034	0.012
roughness	n	n/a	0.08	0.08
Open Channel				
Bottom Width	BW	feet	5	5
Side Slopes (H:1)	H	feet	10	22
Depth	d	feet	4	5
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	180.00	567.50
Flow Rate	Q	cfs	1023.44	2176.10
Velocity	V	ft/sec	5.69	3.83
Travel time	Tt	hours	0.071	1.014
Flow Length	L	feet	2,250	0.00
Slope	S	ft/ft	0.028	0.000
roughness	n	n/a	0.08	0.06
Open Channel				
Bottom Width	BW	feet	5	
Side Slopes (H:1)	H	feet	6	
Depth	d	feet	5	
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	162.50	
Flow Rate	Q	cfs	982.00	
Velocity	V	ft/sec	6.04	
Travel time	Tt	hours	0.103	-
Flow Length	L	feet		
Slope	S	ft/ft		
roughness	n	n/a		
Open Channel				
Bottom Width	BW	feet		
Side Slopes (H:1)	H	feet		
Depth	d	feet		
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (0 if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2		
Flow Rate	Q	cfs		
Velocity	V	ft/sec		
Travel time	Tt	hours	-	-
Total Travel Time	TC	hours	0.55	1.95
	TC	min.	32.9	117.0
Lag Time	TL	hours	0.33	1.17
	TL	min.	19.7	70.2

WILLOW SPRINGS CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA				
			W-01	W-02	W-03	W-04	W-05
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.4	0.4	0.4	0.4	0.4
Flow Length	L	feet	100	100	100	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5	3.5	3.5	3.5
Slope	s	ft/ft	0.067	0.020	0.013	0.020	0.010
Travel time	Tt	hours	0.211	0.342	0.407	0.342	0.452
Shallow Concentrated Flow		min.	12.7	20.5	24.4	20.5	27.1
Flow Length	L	feet	930	1,750	2,700	1,325	900
Slope	s	ft/ft	0.043	0.026	0.02	0.019	0.014
Surface (1=paved or 2=unpaved)		n/a	1	1	1	1	1
Velocity	V	ft/sec	4.27	3.32	2.91	2.84	2.44
Travel time	Tt	hours	0.060	0.146	0.257	0.130	0.103
Manning's Equation		min.	3.6	8.8	15.4	7.8	6.2
Flow Length	L	feet	13,800	1,575	4,000	4,400	4,800
Slope	S	ft/ft	0.010	0.008	0.011	0.011	0.010
roughness	n	n/a	0.1	0.1	0.1	0.1	0.1
Open Channel							
Bottom Width	BW	feet	40	60	40	4	10
Side Slopes (H:1)	H	feet	30	30	8	5	6
Depth	d	feet	3	2	3	2	4
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	390.00	240.00	192.00	28.00	136.00
Flow Rate	Q	cfs	850.92	387.38	503.32	47.97	354.97
Velocity	V	ft/sec	2.18	1.61	2.62	1.71	2.61
Travel time	Tt	hours	1.757	0.271	0.424	0.713	0.511
Flow Length	L	feet					
Slope	S	ft/ft					
roughness	n	n/a					
Open Channel							
Bottom Width	BW	feet					
Side Slopes (H:1)	H	feet					
Depth	d	feet					
...or Closed Conduit							
Rise / Diameter	R / D	feet					
Span (BLANK if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2					
Flow Rate	Q	cfs					
Velocity	V	ft/sec					
Travel time	Tt	hours	-	-	-	-	-
Total Travel Time	TC	hours	2.03	0.76	1.09	1.19	1.06
	TC	min.	121.7	45.6	65.3	71.1	63.9
Lag Time	TL	hours	1.22	0.46	0.65	0.71	0.64
	TL	min.	73.0	27.3	39.2	42.7	38.3

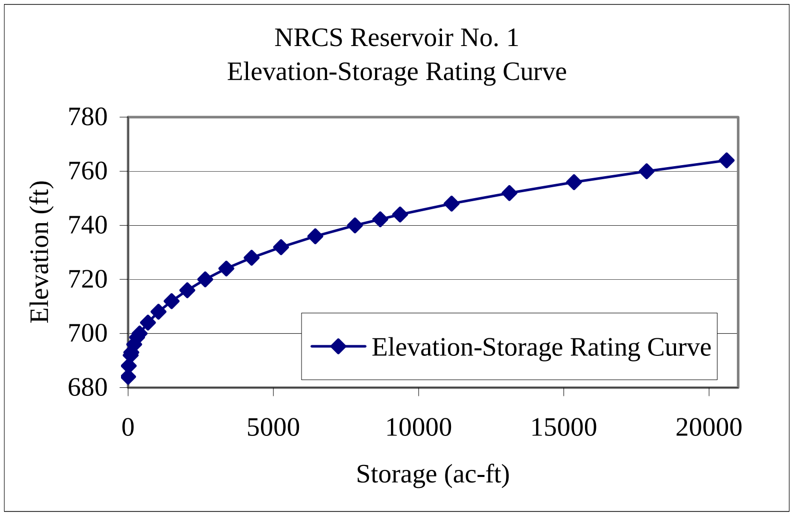
WILLOW SPRINGS CREEK TR-55 Method of Computing the Time of Concentration ULTIMATE CONDITIONS			SUBAREA	
			W-06	**W-07**
Sheet Flow	variable	units		
Manning's roughness coef.	n	n/a	0.4	0.4
Flow Length	L	feet	100	100
2-year, 24-hour rainfall	P2	inches	3.5	3.5
Slope	s	ft/ft	0.073	0.007
Travel time	Tt	hours	0.204	0.521
Shallow Concentrated Flow		min.	12.2	31.2
Flow Length	L	feet	825	3,950
Slope	s	ft/ft	0.032	0.006
Surface (1=paved or 2=unpaved)		n/a	1	1
Velocity	V	ft/sec	3.69	1.60
Travel time	Tt	hours	0.062	0.688
Manning's Equation		min.	3.7	41.3
Flow Length	L	feet	1,100	7,900
Slope	S	ft/ft	0.014	0.004
roughness	n	n/a	0.013	0.1
Open Channel				
Bottom Width	BW	feet		20
Side Slopes (H:1)	H	feet		12
Depth	d	feet		7
...or Closed Conduit				
Rise / Diameter	R / D	feet	3	
Span (BLANK if circular)	S	feet	0	
Cross-Sectional Area	X-A	feet^2	7.07	728.00
Flow Rate	Q	cfs	106.93	1688.32
Velocity	V	ft/sec	15.13	2.32
Travel time	Tt	hours	0.020	0.946
Flow Length	L	feet	2,600	
Slope	S	ft/ft	0.005	
roughness	n	n/a	0.013	
Open Channel				
Bottom Width	BW	feet	12	
Side Slopes (H:1)	H	feet	5	
Depth	d	feet	5	
...or Closed Conduit				
Rise / Diameter	R / D	feet		
Span (BLANK if circular)	S	feet		
Cross-Sectional Area	X-A	feet^2	185.00	
Flow Rate	Q	cfs	3075.02	
Velocity	V	ft/sec	16.62	
Travel time	Tt	hours	0.043	-
Total Travel Time	TC	hours	0.33	2.15
	TC	min.	19.8	129.3
Lag Time	TL	hours	0.20	1.29
	TL	min.	11.9	77.6

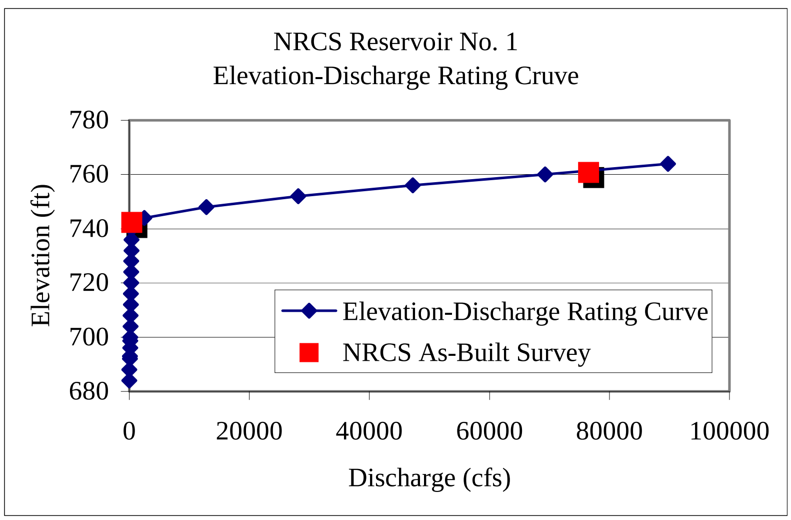
APPENDIX E
DETENTION POND ELEV-STOR-DISCHARGE RATING CURVES

NRCS Reservoir No. 1
NRCS Reservoir No. 2
NRCS Reservoir No. 3
NRCS Reservoir No. 4
NRCS Reservoir No. 5

NRCS Reservoir No. 1

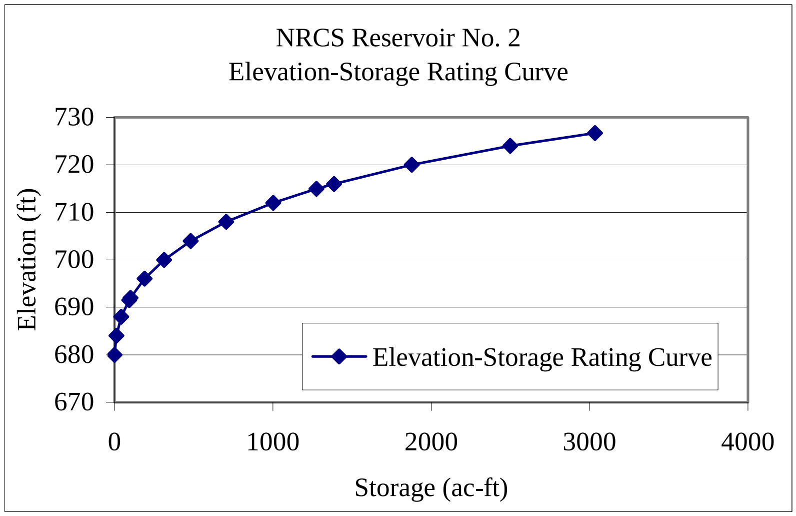
NRCS Reservoir No. 1		
Elevation (ft)	Storage (ac-ft)	Discharge (cfs)
684	4	0
688	25	5
692	86	96
693	107	111
696	206	150
698.6	304	170
700	398	180
704	678	209
708	1,047	234
712	1,498	256
716	2,032	277
720	2,654	296
724	3,384	314
728	4,249	331
732	5,267	347
736	6,447	363
740	7,806	378
742.3	8,683	399
744	9,363	2,492
748	11,133	12,839
752	13,123	28,162
756	15,356	47,245
760	17,848	69,306
764	20,602	89,770

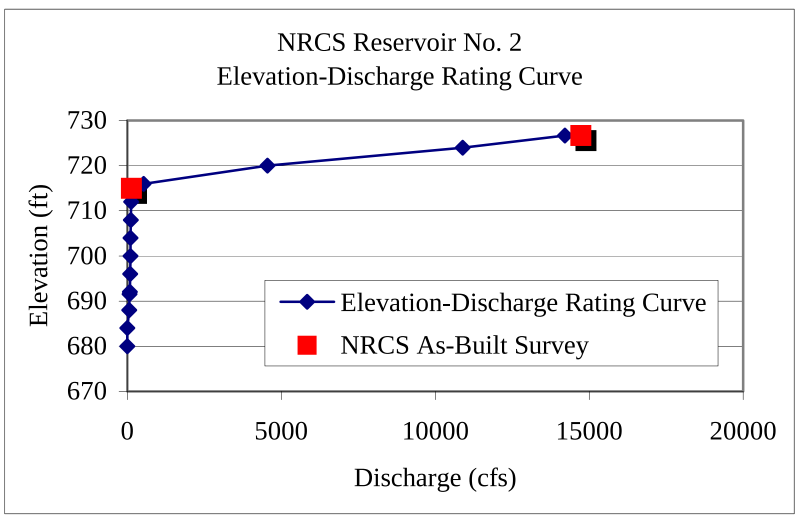




NRCS Reservoir No. 2

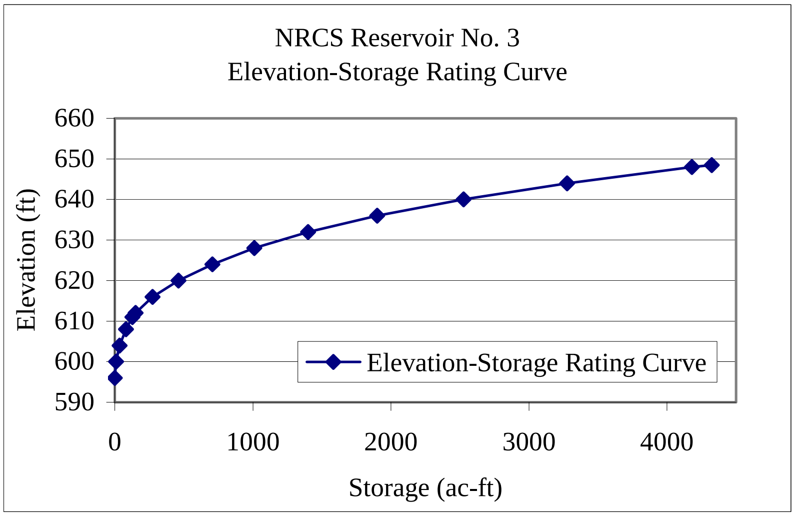
NRCS Reservoir No. 2		
Elevation (ft)	Storage (ac-ft)	Discharge (cfs)
680	1	0
684	12	5
688	43	65
691.5	93	77
692	100	78
696	189	90
700	313	100
704	480	109
708	705	117
712	1,002	125
715	1,275	139
716	1,386	527
720	1,876	4,547
724	2,499	10,893
726.7	3,034	14,215

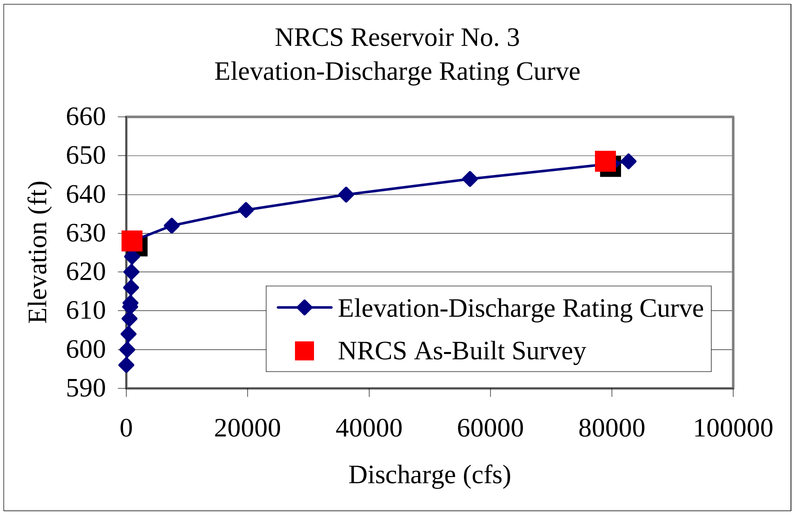




NRCS reservoir No. 3

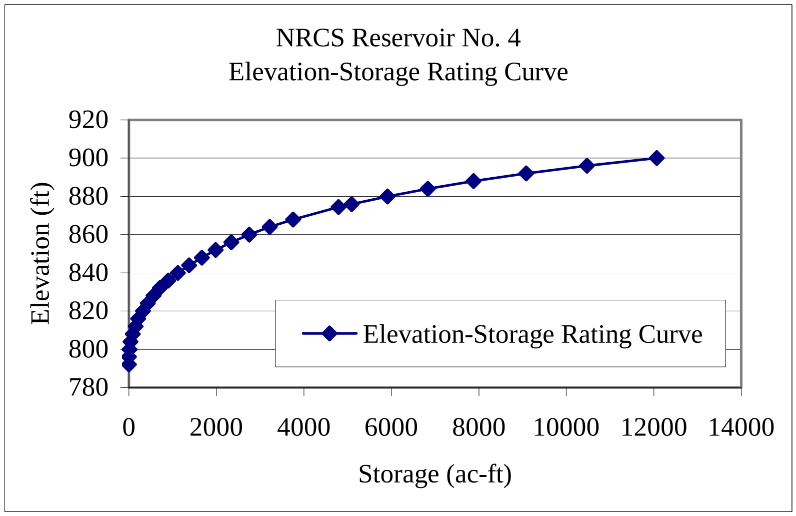
NRCS Reservoir No. 3		
Elevation (ft)	Storage (ac-ft)	Discharge (cfs)
596	1	0
600	10	165
604	35	380
608	80	541
611	127	637
612	151	665
616	273	769
620	461	861
624	706	944
628	1,011	1,021
632	1,400	7,500
636	1,901	19,722
640	2,526	36,215
644	3,276	56,629
648	4,180	80,012
648.5	4,323	82,737

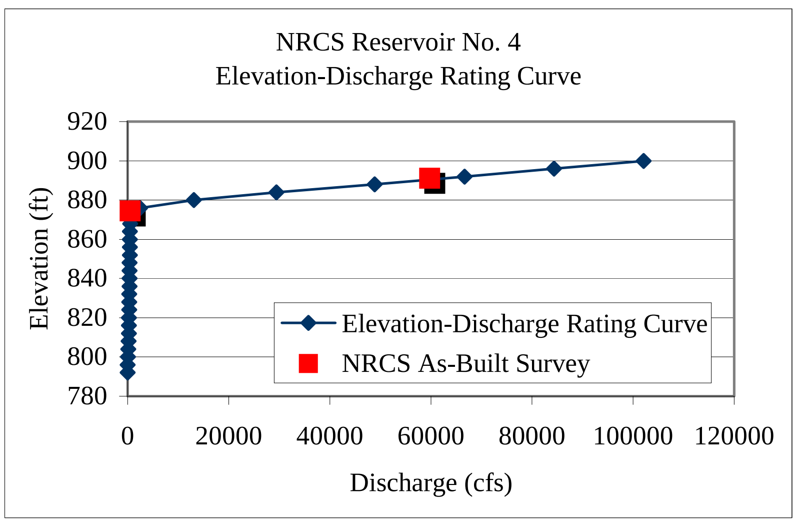




NRCS Reservoir No. 4

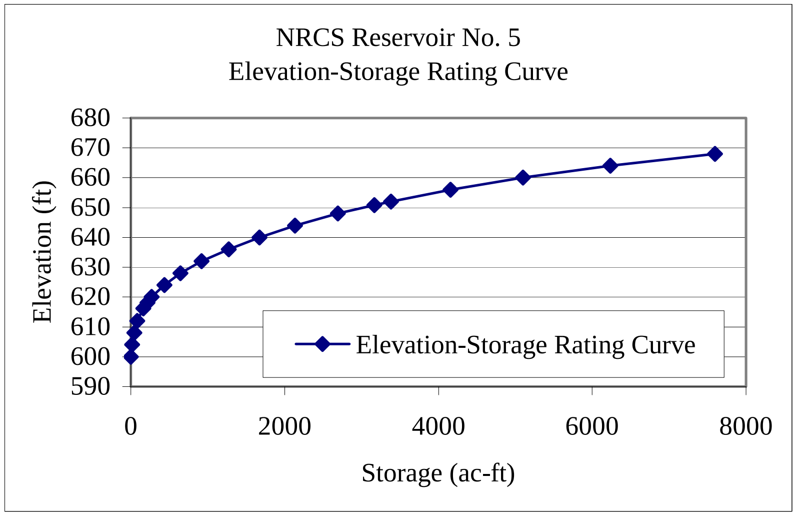
NRCS Reservoir No. 4		
Elevation (ft)	Storage (ac-ft)	Discharge (cfs)
792	0	0
796	2	5
800	11	93
804	39	157
808	89	196
812	152	226
816	215	254
820	323	278
824	434	300
828	561	321
832	712	340
836	899	359
840	1,122	376
844	1,378	393
848	1,665	409
852	1,984	425
856	2,343	440
860	2,753	454
864	3,218	468
868	3,755	482
874.4	4,788	510
876	5,093	2,496
880	5,908	13,119
884	6,830	29,462
888	7,877	48,871
892	9,087	66,616
896	10,478	84,360
900	12,067	102,105

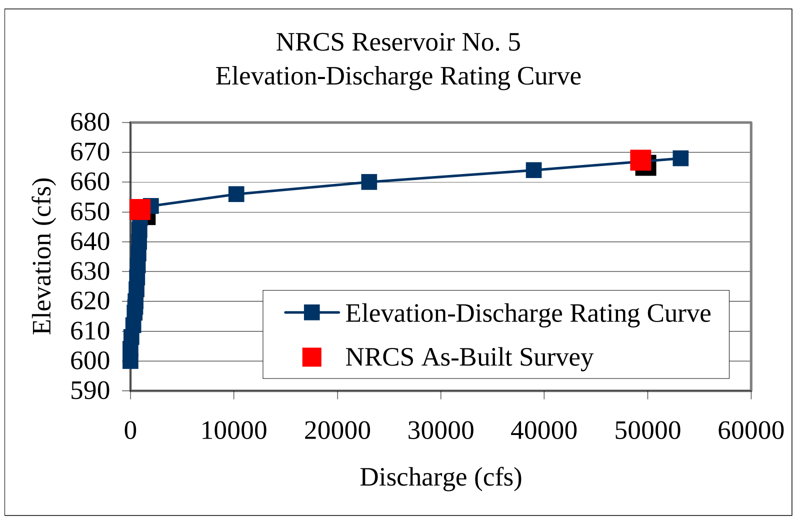




NRCS Reservoir No. 5

NRCS Reservoir No. 5		
Elevation (ft)	Storage (ac-ft)	Discharge (cfs)
600	2	0
604	16	0
608	46	104
612	84	272
616.2	161	394
618.1	215	449
620	269	503
624	435	582
628	644	652
632	921	716
636	1,271	773
640	1,672	826
644	2,134	876
648	2,691	941
650.8	3,167	997
652	3,382	1,991
656	4,154	10,250
660	5,100	23,074
664	6,238	38,987
668	7,596	53,190





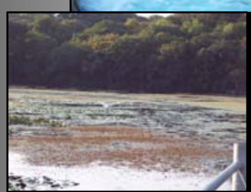
APPENDIX F
BLANCO RIVER FLOOD FREQUENCY ANALYSIS

USGS Gage at Kyle, Texas

USGS Gage at Wimberley, Texas

Espey Consultants, Inc.

SAN MARCOS
FLOOD PROTECTION PLAN
VOLUME II OF II
APPENDICES G-S


City of San Marcos

In Association With:

Delta Survey Group, Inc.
Edwards Aquifer Authority
Guadalupe Blanco River Authority
Hays County
Texas Water Development Board
Upper San Marcos Watershed RFCD

October 2007

Project No. 5045.116

SAN MARCOS
FLOOD PROTECTION PLAN

Volume II of II

Volume I Report and Appendices A-F
Volume II Appendices G-S

Prepared for:

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EC Project No. 5045.116

October 25, 2007

APPENDIX G
BLANCO RIVER HYDRAULIC MODELS

FIS Effective Hydraulic Model
Duplicate Effective Hydraulic Model
Corrected Effective Hydraulic Model

FIS Effective Hydraulic Model

Duplicate Effective Hydraulic Model

Corrected Effective Hydraulic Model

APPENDIX H
BYPASS CREEK HYDRAULIC MODELS

Bypass Creek Main Stem Hydraulic Model
Bypass Creek Tributary 1 Hydraulic Model
Bypass Creek Tributary 2 Hydraulic Model

Bypass Creek Main Stem Hydraulic Model

Bypass Creek Tributary 1 Hydraulic Model

Bypass Creek Tributary 2 Hydraulic Model

APPENDIX I
COTTONWOOD CREEK HYDRAULIC MODELS

Cottonwood Creek Main Stem Hydraulic Model
Cottonwood Creek Tributary 1 Hydraulic Model
Cottonwood Creek Tributary 2 Hydraulic Model
Cottonwood Creek Tributary 3 Hydraulic Model

Cottonwood Creek Main Stem Hydraulic Model

Cottonwood Creek Tributary 1 Hydraulic Model

Cottonwood Creek Tributary 2 Hydraulic Model

Cottonwood Creek Tributary 3 Hydraulic Model

APPENDIX J
PURGATORY CREEK HYDRAULIC MODELS

Purgatory Creek Main Stem Hydraulic Model
Purgatory Creek Diversion Hydraulic Model
Purgatory Creek Tributary 2 Hydraulic Model
Purgatory Creek Tributary 3 Hydraulic Model

Purgatory Creek Main Stem Hydraulic Model

Purgatory Creek Diversion Hydraulic Model

Purgatory Creek Tributary 2 Hydraulic Model

Purgatory Creek Tributary 3 Hydraulic Model

APPENDIX K
RIO VISTA CREEK HYDRAULIC MODEL

APPENDIX L
SAN MARCOS RIVER HYDRAULIC MODELS

FIS Effective Hydraulic Model
Duplicate Effective Hydraulic Model
Corrected Effective Hydraulic Model

FIS Effective Hydraulic Model

Duplicate Effective Hydraulic Model

Corrected Effective Hydraulic Model

APPENDIX M
SCHULLE CANYON HYDRAULIC MODEL

APPENDIX N
SESSOM CREEK HYDRAULIC MODEL

APPENDIX O
WILLOW SPRINGS CREEK HYDRAULIC MODEL

Willow Springs Creek Hydraulic Model
Willow Springs Tributary 1 Creek Hydraulic Model
Willow Springs Tributary 2 Creek Hydraulic Model
Willow Springs Creek Tributary 1 to Tributary 2 Hydraulic Model
Willow Springs Creek Tributary 2 to Tributary 2 Hydraulic Model

Willow Springs Creek Hydraulic Model

Willow Springs Tributary 1 Creek Hydraulic Model

Willow Springs Tributary 2 Creek Hydraulic Model

Willow Springs Creek Tributary 1 to Tributary 2 Hydraulic Model

Willow Springs Creek Tributary 2 to Tributary 2 Hydraulic Model

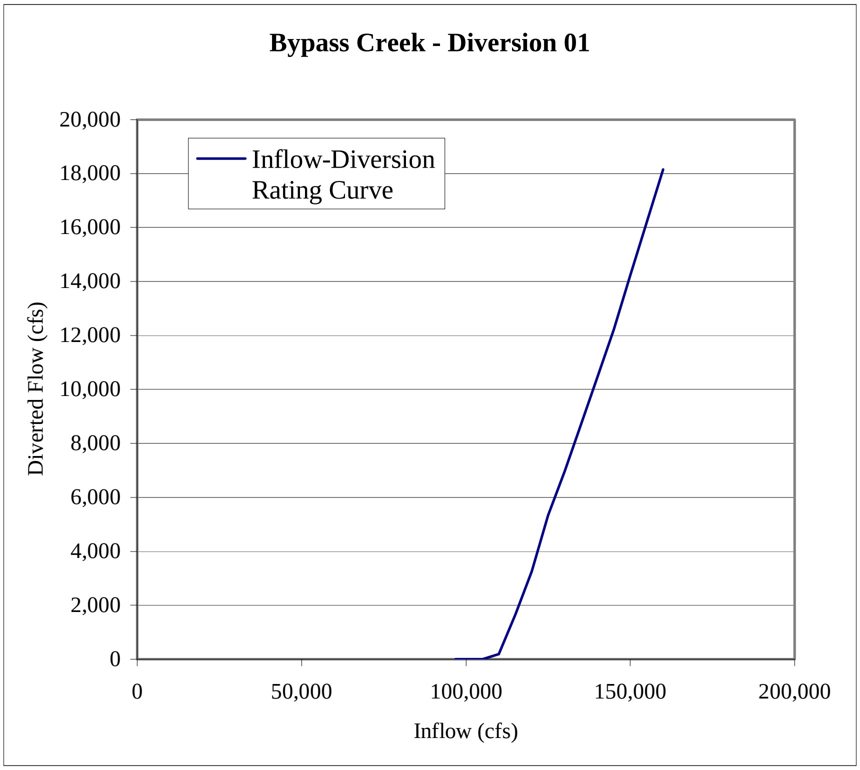
APPENDIX P
INFLOW-DIVERSION RATING CURVES

Blanco River diversion to Bypass Creek
Blanco River diversion to Bypass Creek Tributary 1
Blanco River diversion to Bypass Creek Tributary 2
Cottonwood Creek diversion to Cottonwood Creek Tributary 3
Cottonwood Creek Tributary 3 diversion to Cottonwood Creek Tributary 2
Cottonwood Creek Tributary 2 diversion to Cottonwood Creek Tributary 1
Purgatory Creek Diversion No. 1 to Purgatory Creek
Purgatory Creek Diversion No. 2 to Willow Springs Creek

Blanco River diversion to Bypass Creek

Blanco River diversion to Bypass Creek
(HMS ID: DIV-BP01)

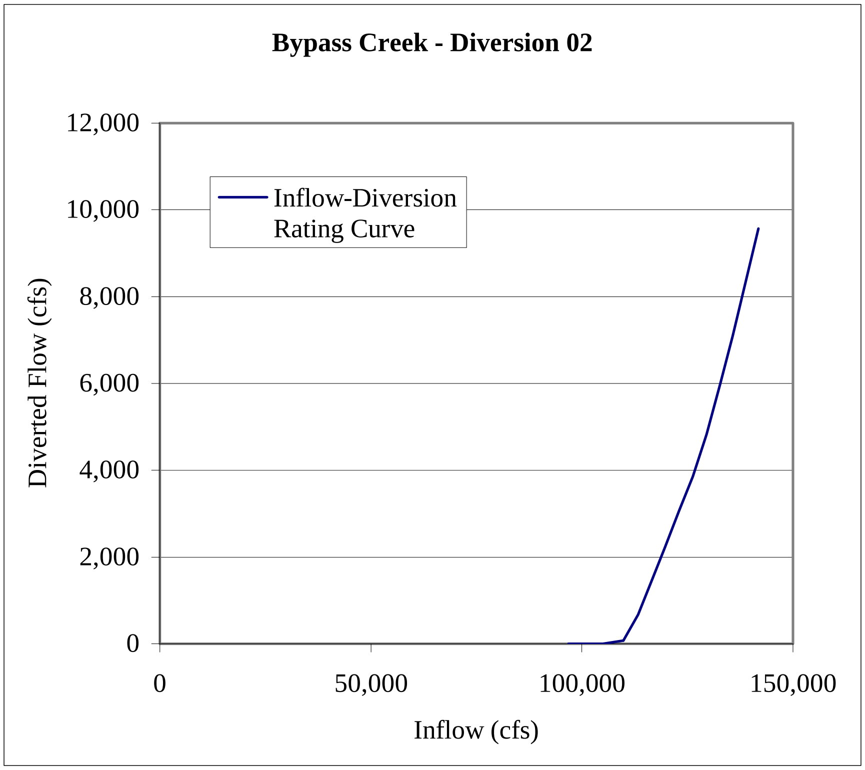
Inflow	Diversion
96,790	0
100,000	0
105,000	0
110,000	185
115,000	1,657
120,000	3,265
125,000	5,340
130,000	6,969
135,000	8,694
140,000	10,474
145,000	12,227
150,000	14,216
160,000	18,155



Blanco River diversion to Bypass Creek Tributary 1

Blanco River diversion to Bypass Creek Tributary 02
(HMS ID: DIV-BP02)

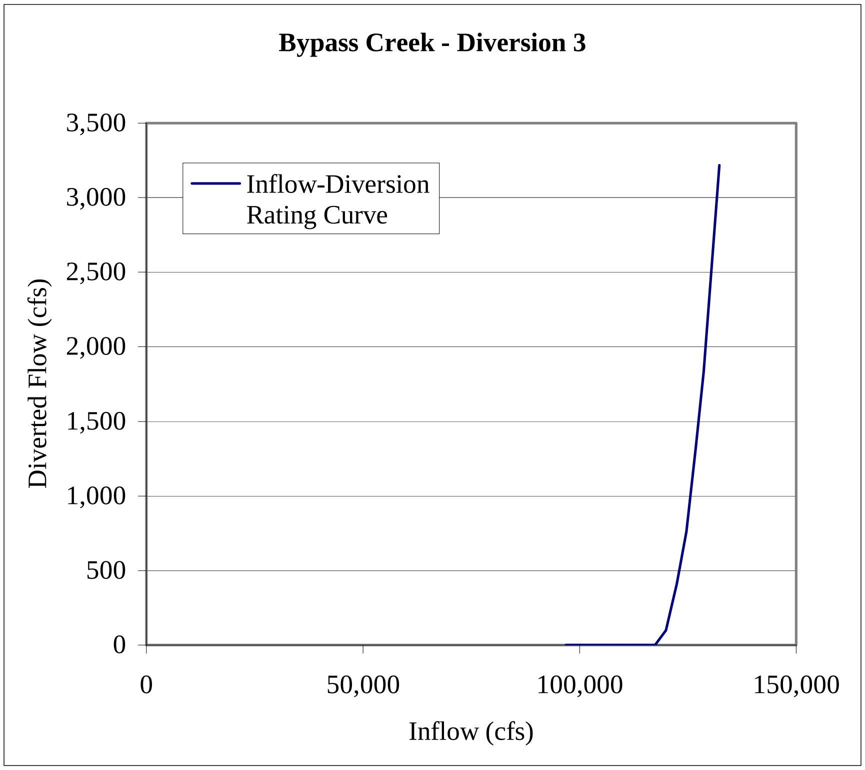
Inflow	Diversion
96,790	0
100,000	0
105,000	0
109,815	75
113,343	668
116,735	1,505
119,660	2,229
123,031	3,067
126,306	3,857
129,526	4,831
132,774	5,998
135,784	7,109
141,845	9,567



Blanco River diversion to Bypass Creek Tributary 2

Blanco River diversion to Bypass Creek Tributary 02
(HMS ID: DIV-BP03)

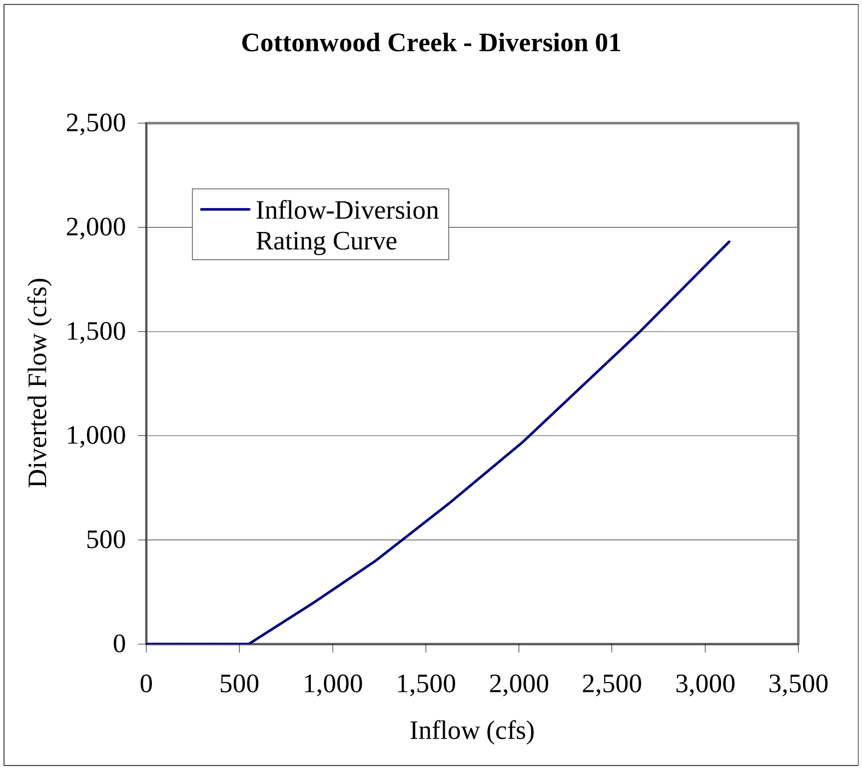
Inflow	Diversion
96,790	0
100,000	0
105,000	0
109,740	0
112,675	0
115,231	0
117,432	0
119,964	98
122,449	413
124,695	762
126,775	1,319
128,675	1,834
132,278	3,217



Cottonwood Creek diversion to Cottonwood Creek Tributary 3

Cottonwood Creek diversion to Cottonwood Creek Tributary 03
(HMS ID: DIV-CC01)

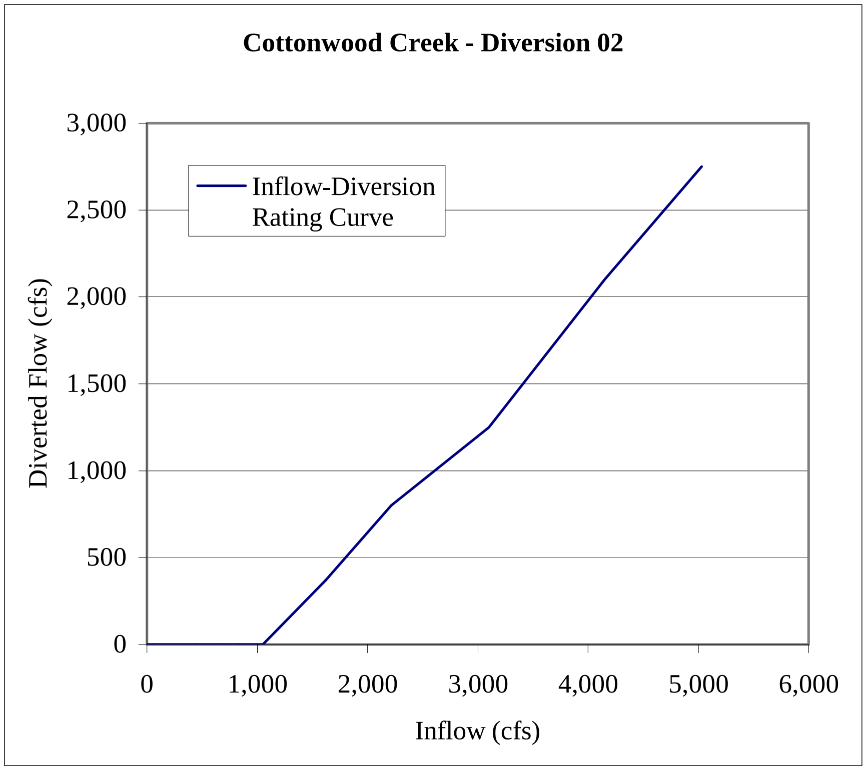
Inflow	Diversion
0	0
50	0
200	0
350	0
550	0
900	200
1,230	400
1,630	680
2,020	970
2,650	1,500
3,130	1,930



Cottonwood Creek Tributary 3 diversion to Cottonwood Creek Tributary 2

Cottonwood Creek Tributary 03 diversion to Cottonwood Creek Tributary 02
(HMS ID: DIV-CC02)

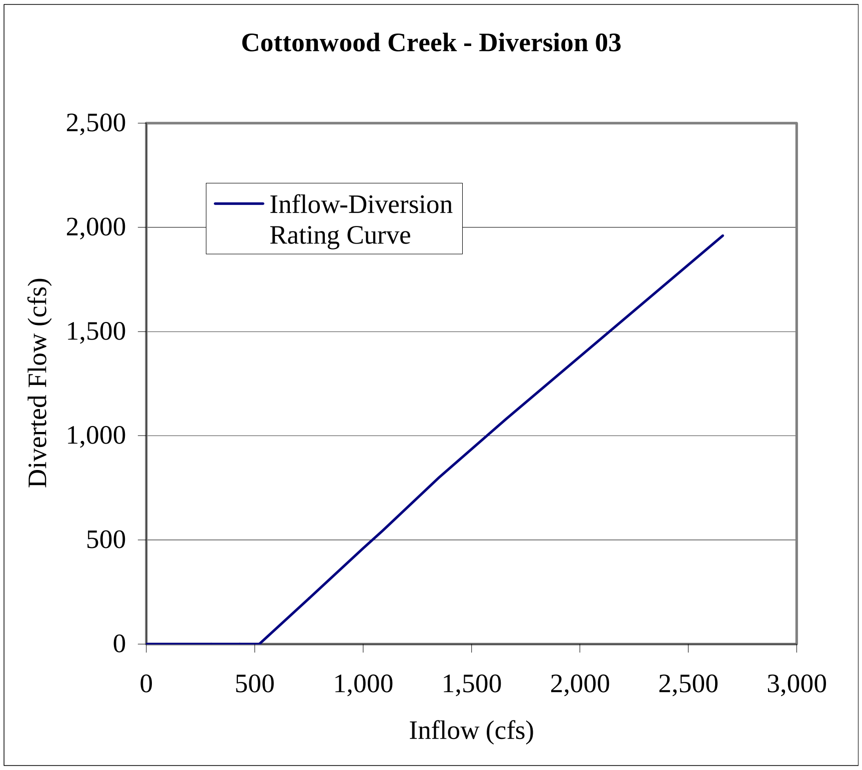
Inflow	Diversion
0	0
50	0
450	0
650	0
830	0
1,050	0
1,620	370
2,215	800
3,100	1,250
4,150	2,100
5,030	2,750



Cottonwood Creek Tributary 2 diversion to Cottonwood Creek Tributary 1

Cottonwood Creek Tributary 02 diversion to Cottonwood Creek Tributary 01
(HMS ID: DIV-CC01)

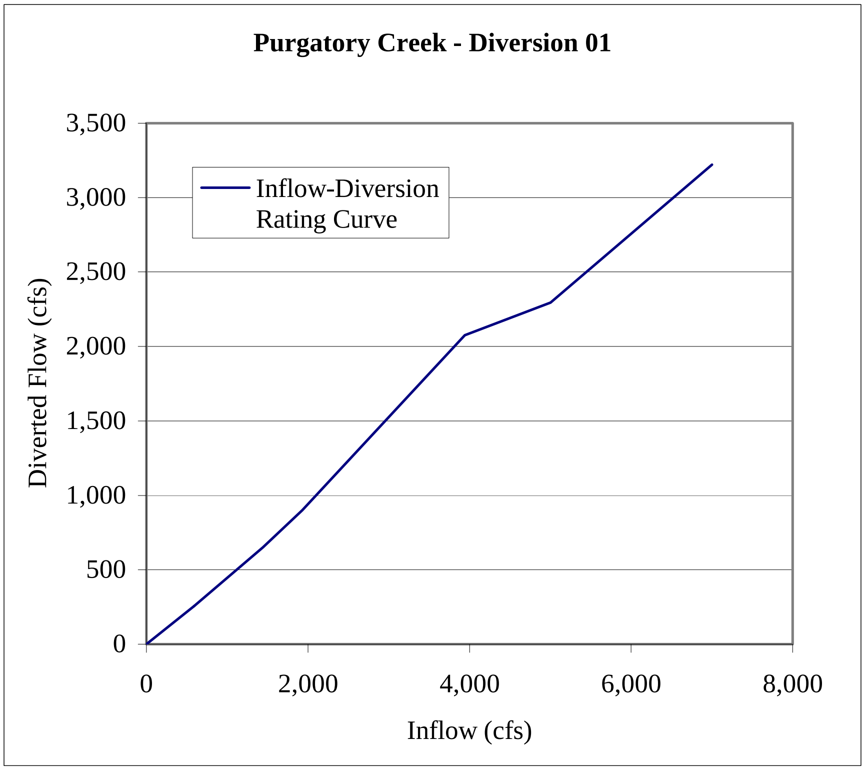
Inflow	Diversion
0	0
300	0
430	0
520	0
750	220
1,000	460
1,090	545
1,350	800
1,660	1,080
2,660	1,960



Purgatory Creek Diversion No. 1 to Purgatory Creek

Purgatory Creek Diversion No. 01 to Purgatory Creek
(HMS ID: DIV-P01)

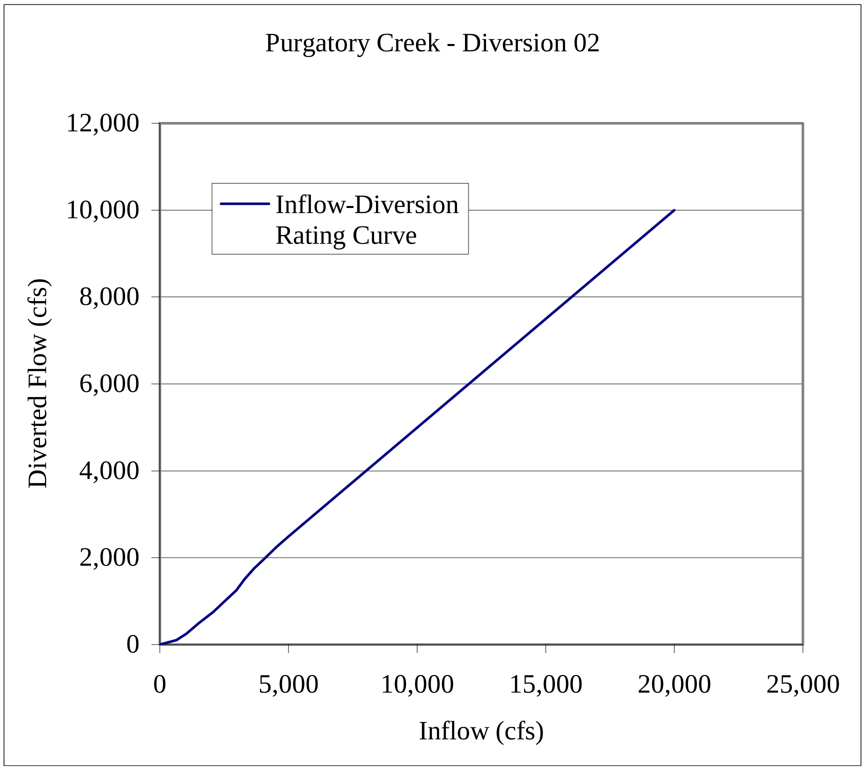
Inflow	Diversion
0	0
590	255
1,440	650
1,930	900
3,940	2,075
5,000	2,295
7,000	3,220



Purgatory Creek Diversion No. 2 to Willow Springs Creek

Purgatory Creek Diversion No. 02 to Willow Springs Creek
(HMS ID: DIV-P02)

Inflow	Diversion
0	0
645	100
1,029	250
1,534	500
2,079	750
2,530	1,000
2,975	1,250
3,285	1,500
3,656	1,750
4,099	2,000
4,536	2,250
5,027	2,500
20,000	10,000



APPENDIX Q
ADVISORY AND PUBLIC MEETING NOTES

Meeting No. 1 - September 8, 2005 (Advisory Committee Notes)
Meeting No. 2 – November 17, 2005 (Advisory Committee Notes and Public Meeting Notes)
Meeting No. 3 – January 11, 2006 (Advisory Committee Notes)
Meeting No. 4 – August 29, 2006 (Advisory Committee Notes)
Meeting No. 5 – September 12, 2006 (Advisory Committee and Public Meeting Notes Combined)

Meeting No. 1 – September 8, 2005
Advisory Committee Notes

Meeting No. 2 – November 17, 2005
Advisory Committee Notes and Public Meeting Notes

Meeting No. 3 – January 11, 2006
Advisory Committee Notes

Meeting No. 4 – August 29, 2006
Advisory Committee Notes

Meeting No. 5 – September 12, 2006
Advisory Committee and Public Meeting Notes Combined

APPENDIX R
COST ESTIMATES

Mitigation Alternative 1B – Peak Flow Diversion to Bypass Creek
Mitigation Alternative 3A – Culvert Improvement and Channel Maintenance
Mitigation Alternative 3B - Culvert Improvement Castle Creek Drive
Mitigation Alternative 3C - NRCS Reservoir No. 5 Volume Expansion
Mitigation Alternative 4A - Culvert Improvement LBJ Drive
Mitigation Alternative 5A – Sessom Creek Drainage Infrastructure
Mitigation Alternative 6A - Downstream Regional Detention
Mitigation Alternative 6C - Channel Maintenance

Mitigation Alternative 1B – Peak Flow Diversion to Bypass Creek

					Total
Item	**Item Description**	**Qty**	**Unit**	**Unit Cost**	**Amount**
Excavation/Fill					
	Excavation/On-Site Use	780,889	cy	$ 20	$ 15,617,778
	Excavation/Off-Site Disposal	892,444	cy	$ 30	$ 26,773,333
				SUBTOTAL	**$ 42,391,111**
Contingency (20%)					$ 8,478,222
				SUBTOTAL	**$ 50,869,333**
Engineering and surveying (20%)					$ 10,173,867
CoSM Project Management (2%)					$ 1,017,387
CoSM Construction Inspection (4%)					$ 2,034,773
				TOTAL ESTIMATED COST	**$ 64,095,360**

Note: Does not include relocation of any utilities

Mitigation Alternative 3A – Culvert Improvement and Channel Maintenance

Item No.	Quantity	Unit	Item Description	Unit Price	Amount
1	168	LF	Box Culverts (4 - 8' x 6')	$ 325.00	$ 54,600.00
2	1	EA	Headwall/Wingwall	$ 6,825.00	$ 6,825.00
3	168	LF	Demolition/Existing Culvert	$ 11.35	$ 1,906.80
4	229	SY	Demolish, Remove Pavement	$ 6.75	$ 1,543.50
5	146	CY	Demolish, Remove Concrete	$ 119.00	$ 17,324.55
6	2	Ton	Concrete, Base Mix	$ 41.50	$ 81.56
7	305	CY	Excavation and Removal	$ 20.00	$ 6,097.78
8	229	SY	Asphaltic Concrete Pavement	$ 9.95	$ 2,278.55
9	49	LF	Traffic Lanes and Markings	$ 1.08	$ 52.92
			Mobilization/Demobilization (5%)		$ 4,535.53
				Subtotal	**$ 95,246.19**
				Contingency (20%)	$ 19,049.24
				Subtotal	**$ 114,295.43**
			Engineering and surveying (20%)		$ 22,859
			CoSM Project Management (2%)		$ 2,286
			CoSM Construction Inspection (4%)		$ 4,572
				TOTAL ESTIMATED COST	**$ 139,440**

Mitigation Alternative 3B - Culvert Improvement Castle Creek Drive

Item No.	Quantity	Unit	Item Description	Unit Price	Amount
1	61	LF	Box Culvert (3 - 8' diameter)	$ 289.00	$ 17,629.00
2	1	EA	Headwall/Wingwall	$ 6,825.00	$ 6,825.00
3	61	LF	Demolition/Existing Culvert	$ 11.35	$ 692.35
4	140	SY	Demolish, Remove Pavement	$ 6.75	$ 947.03
5	94	CY	Demolish, Remove Concrete	$ 119.00	$ 11,130.47
6	1	Ton	Concrete, Base Mix	$ 41.50	$ 52.40
7	74	CY	Excavation and Reuse	$ 20.00	$ 1,487.18
8	140	SY	Asphaltic Concrete Pavement	$ 9.95	$ 1,395.99
9	140	LF	Traffic Lanes and Markings	$ 1.08	$ 151.52
			Mobilization/Demobilization (5%)		$ 2,015.55
				Subtotal	**$ 42,326.48**
				Contingency (20%)	$ 8,465.30
				Subtotal	**$ 50,791.78**
			Engineering and surveying (20%)		$ 10,158
			CoSM Project Management (2%)		$ 1,016
			CoSM Construction Inspection (4%)		$ 2,032
				TOTAL ESTIMATED COST	**$ 63,998**

Mitigation Alternative 3C - NRCS Reservoir No. 5 Volume Expansion

Item No.	Quantity	Unit	Item Description	Unit Price	Amount
1	1,100,000	CF	Excavation/off-site disposal	$ 30.00	$ 33,000,000.00
				Subtotal	**$ 33,000,000.00**
				Contingency (20%)	$ 6,600,000.00
				TOTAL	**$ 39,600,000.00**

Mitigation Alternative 4A - Culvert Improvement LBJ Drive

Item No.	Quantity	Unit	Item Description	Unit Price	Amount
1	29	LF	Box Culverts (1 - 6' x 4')	$ 281.00	$ 8,149.00
2	1	EA	Headwall/Wingwall	$6,825.00	$ 6,825.00
3	29	LF	Demolition/Existing Culvert	$ 17.00	$ 493.00
4	13	SY	Demolish, Remove Pavement	$ 6.75	$ 87.00
5	9	CY	Demolish, Remove Concrete	$ 119.00	$ 1,022.52
6	0	Ton	Concrete, Base Mix	$ 41.50	$ 4.81
7	30	CY	Excavation and Removal	$ 20.00	$ 601.48
8	13	SY	Asphaltic Concrete Pavement	$ 9.95	$ 129.35
9	4	LF	Traffic Lanes and Markings	$ 1.08	$ 4.32
			Mobilization/Demobilization (5%)		$ 865.82
				Subtotal	**$ 18,182.31**
				Contingency (20%)	$ 3,636.46
				TOTAL	**$ 21,818.77**
			Engineering and surveying (20%)		$ 4,364
			CoSM Project Management (2%)		$ 436
			CoSM Construction Inspection (4%)		$ 873
				TOTAL ESTIMATED COST	**$ 26,619**

Mitigation Alternative 5A – Sessom Creek Drainage Infrastructure

Item No.	Quantity	Unit	Item Description (Sessom Dr. @ Peques St.)	Unit Price	Amount
1	227	LF	Box Culvert (1 - 10' x 8')	$ 475.00	$ 107,825.00
2	1	EA	Headwall/Wingwall	$6,825.00	$ 6,825.00
3	227	LF	Demolition/Existing Culvert	$ 11.35	$ 2,576.45
4	252	SY	Demolish, Remove Pavement	$ 6.75	$ 1,702.50
5	168	CY	Demolish, Remove Concrete	$ 119.00	$ 20,009.63
6	2	Ton	Concrete, Base Mix	$ 41.50	$ 94.21
7	252	CY	Excavation and Reuse	$ 20.00	$ 5,044.44
8	252	SY	Asphaltic Concrete Pavement	$ 9.95	$ 2,507.40
9	227	LF	Traffic Lanes and Markings	$ 1.08	$ 245.16
			Mobilization/Demobilization (5%)		$ 7,341.49
				Subtotal	**$ 154,171.28**
				Contingency (20%)	$ 30,834.26
				Subtotal	**$ 185,005.53**
			Engineering and surveying (20%)		$ 37,001
			CoSM Project Management (2%)		$ 3,700
			CoSM Construction Inspection (4%)		$ 7,400
				TOTAL ESTIMATED COST	**$ 233,107**

Item No.	Quantity	Unit	Item Description (Sessom Dr. @ N. LBJ)	Unit Price	Amount
1	576	LF	Box Culvert (1 - 8' x 6')	$ 440.00	$ 253,440.00
2	1	EA	Headwall/Wingwall	$6,825.00	$ 6,825.00
3	576	LF	Demolition/Existing Culvert	$ 11.35	$ 6,537.60
4	485	SY	Demolish, Remove Pavement	$ 6.75	$ 3,276.00
5	341	CY	Demolish, Remove Concrete	$ 119.00	$ 40,618.67
6	5	Ton	Concrete, Base Mix	$ 41.50	$ 191.23
7	2,731	CY	Excavation and Reuse	$ 20.00	$ 54,613.33
8	485	SY	Asphaltic Concrete Pavement	$ 9.95	$ 4,829.07
9	576	LF	Traffic Lanes and Markings	$ 1.08	$ 622.08
			Mobilization/Demobilization (5%)		$ 18,547.65
				Subtotal	**$ 389,500.63**
				Contingency (20%)	$ 77,900.13
				Subtotal	**$ 467,400.75**
			Engineering and surveying (20%)		$ 93,480
			CoSM Project Management (2%)		$ 9,348
			CoSM Construction Inspection (4%)		$ 18,696
				TOTAL ESTIMATED COST	**$ 588,925**

Mitigation Alternative 6A - Downstream Regional Detention

Item	Item Description	Qty	Unit	Unit Cost		Total Amount	
Excavation/Fill							
	Excavation within site	166,000	cy	$	20	$	3,320,000
	Import fill	19,000	cy	$	30	$	570,000
Outlet Structure							
	Pipe (4-24" diameter RCP)	300	lf	$	100	$	30,000
	Concrete wier/Embankment armory	100	cy	$	150	$	15,000
	Low flow trickle channel	1,300	cy	$	100	$	130,000
Erosion/Sedimentation Controls							
	Erosion control blanket	2,800	sy	$	5	$	14,000
	Silt fence	9,000	lf	$	3	$	27,000
	Rock berm	500	lf	$	20	$	10,000
Landscaping							
	Maintence road/Hike & bike trail	9,230	lf	$	10	$	92,300
	Pond access	700	lf	$	10	$	7,000
Miscellaneous (5%)							
	Mobilization/Demobilization					$	210,765
	ROW Cost					$	1,600,000
				SUBTOTAL		**$**	**6,026,065**
Contingency (20%)						$	1,205,213
				SUBTOTAL		**$**	**7,231,278**
Engineering and surveying (20%)						$	1,446,256
CoSM Project Management (2%)						$	144,626
CoSM Construction Inspection (4%)						$	289,251
				TOTAL ESTIMATED COST		**$**	**9,111,410**

Mitigation Alternative 6C - Channel Maintenance

Item No.	Quantity	Unit	Item Description	Unit Price		Amount
1	13,000	CF	Excavation/off-site disposal	$ 30.00	$	390,000.00
				Subtotal	**$**	**390,000.00**
				Contingency (20%)	$	78,000.00
				TOTAL	**$**	**468,000.00**

APPENDIX S
DIGITAL DATA (ON DVD)

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