[COVER PAGE]

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Add Narrative Here – the executive summary is usually written last, however except for results, you can write most of it using the skeleton report here

INTRODUCTION

Add Narrative Here

SITE LOCATION

Figure 1 is a map of a portion of Concho County, Texas. In the Southeast corner of the map is Eden, Texas. A US highway runs nearly East-West through Eden and another US highway runs North-South.

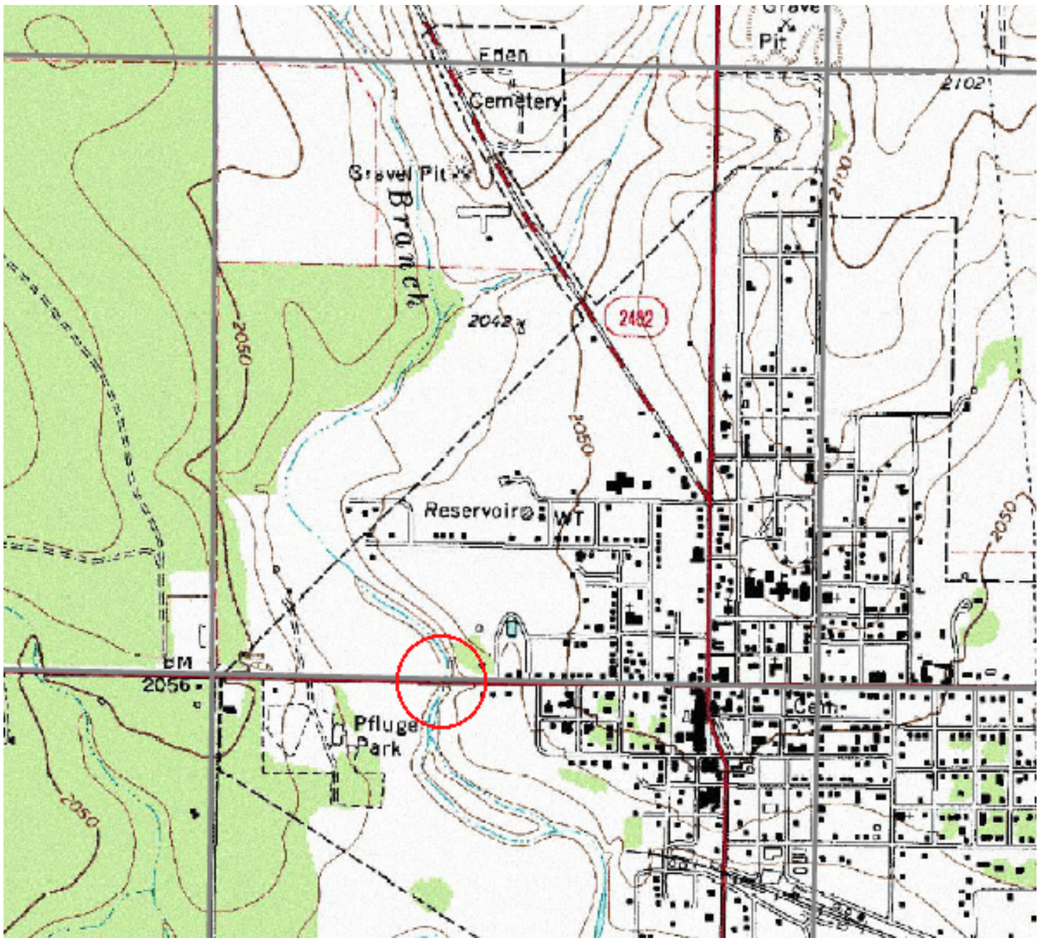

Figure 1. Location of interest, a multi-barrel culvert system located XXXX of Eden, Texas.

STUDY PURPOSE

The existing culvert system is a 2-barrel 6X6 box-culvert system. This report presents an hydrologic analysis of the existing system at an appropriate risk level to determine the depth of water at the structure (or overtopping depth), and a determination of the depth of flow if the culvert system is modified by the addition of two more barrels to a total of 4-barrel 6X6 box-culvert system.

WATERSHED DESCRIPTION

<Brief overview of the watershed as it pertains to the study – details are presented in sub-sections that follow>

DELINEATION

Figure 2 is the watershed that contributes flow to the crossing structure. The total contributing area is XX.X square miles. Two SCS reservoirs regulate flow in the upper reach of the watershed. The sub-areas regulated by these two reservoirs are called the XXXX Catchment, and the XXXX Catchment. The contributing area downstream of both reservoir outlets, but upstream of the point of interest is called the XXXX Catchment.

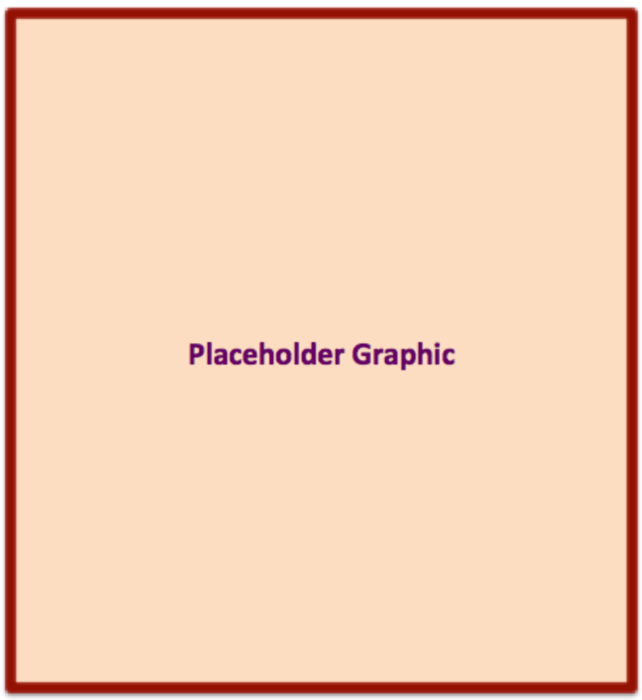

Figure 2. Caption The Figure

<Explain method(s) used to estimate sub-catchment areas>

Table XX is a list of the individual sub-catchment areas as determined by the method above.

Table 1. CAPTION THE TABLE

Item	Value	Units
XXXX Catchment	XX.XX	Square miles
XXXX Catchment	XX.XX	Square miles

XXXX Catchment	XX.XX	Square miles
Total Drainage Area	XX.XX	Square miles

The watershed delineation map in Figure 2 was also employed to estimate the travel (channel) distances for each catchment. < Explain method(s) used to estimate channel distances>

These distances are used below to estimate time-of-concentration values to parameterize unit hydrographs for each catchment. Table 2 is a list of the channel length segments for each catchment. For example, the channel length for the West Catchment was estimated to be XX.XX miles. The channel length for the West Catchment to the US-87 crossing was estimated to be XX.XX miles. The methods described above were used to populate Table 2.

Table 2. CAPTION THE TABLE

Item	Value	Units
XXXX Catchment to Reservoir Outlet	XX.XX	Miles
XXXX Catchment to Reservoir Outlet	XX.XX	Miles
XXXX Catchment to US 87 Crossing	XX.XX	Miles
XXXX Reservoir Outlet to US 87 Crossing	XX.XX	Miles
XXXX Reservoir Outlet to US 87 Crossing	XX.XX	Miles

SOIL PROPERTIES

Figure 3 is a screen capture of the relevant portion of the Web Soil Survey (CITE) map for the study area.

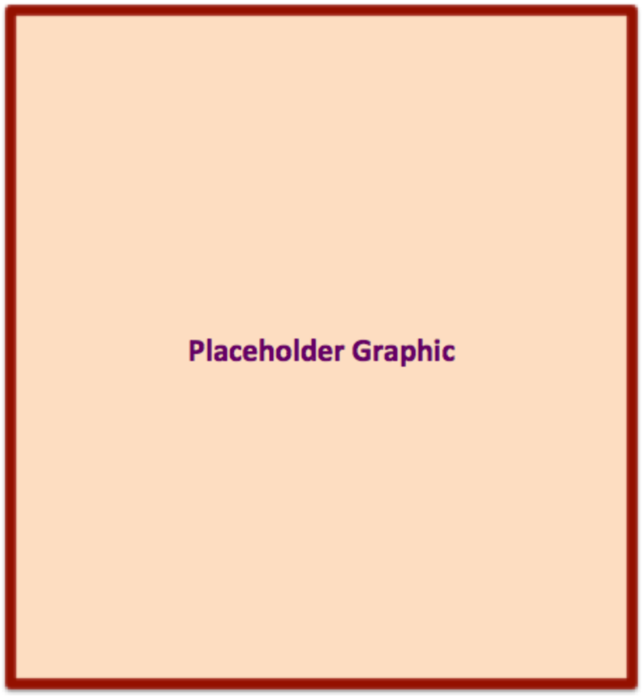

Figure 3. WSS Map of the Study Area.

< Interpet the figure in the context of the study – why do soils matter? >

EXISTING CROSSING CONFIGURATION

Describe the existing crossing.

Figure 4 is a sketch

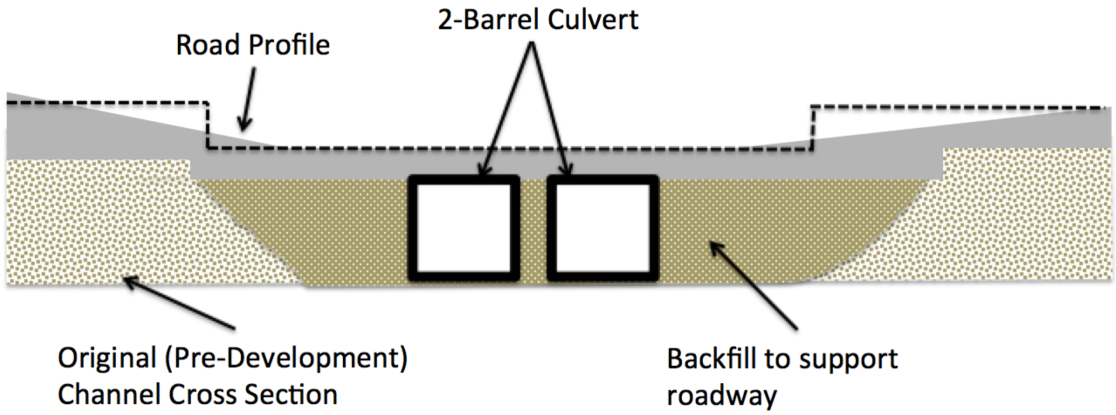

Figure 4. Existing Crossing Configuration

Figure 5 is the proposed.

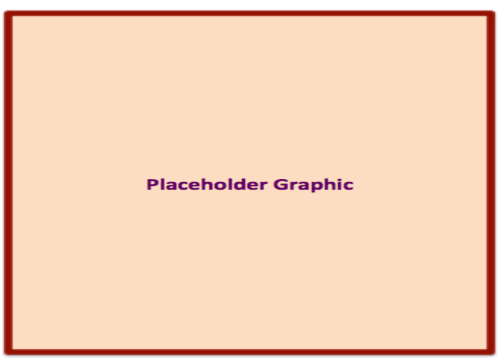

Figure 5. Here is the proposed -- you draw the 4-barrel system.

Determine and report the bottom (invert) elevation of the culverts – it determines the bottom of the system.

HYDROLOGIC ANALYSIS

Brief overview of this section. Details in the following subsections.

DESIGN RISK LEVEL

The design risk level was determined using Table 4-2 from the TxDOT Hydraulic Design Manual (CITE). The relevant portions of the table are reproduced as Figures 3 and 4.

Chapter 4 — Hydrology *Section 6 — Design Flood and Check Flood Standards*

Section 6 — Design Flood and Check Flood Standards

TxDOT's approach to selecting the design standard for a drainage facility is to use a reference table that specifies a range of design AEPs for different types of facilities. Table 4-2 provides the design frequencies for TxDOT projects. For most types of facilities a range of design frequencies is presented. For those types of facilities with a range of possible design frequencies, usually one design frequency in the range is recommended (indicated by an X with square brackets in Table 4-2). Structures and roadways should be serviceable (not inundated) up to the design standard.

Table 4-2: Recommended Design Standards for Various Drainage Facilities

Functional classification and structure type	Design AEP (Design ARI) 50% (2-yr)	20% (5-yr)	10% (10-yr)	4% (25-yr)	2% (50-yr)
Freeways (main lanes):					
Culverts					X
Bridges					X
Principal arterials:					
Culverts			X	[X]	X
Small bridges			X	[X]	X
Major river crossings					[X]
Minor arterials and collectors (including frontage roads):					
Culverts		X	[X]	X	
Small bridges			X	[X]	X
Major river crossings				X	[X]
Local roads and streets:					
Culverts	X	X	X		
Small bridges	X	X	X		
Off-system projects:					
Culverts	FHWA policy is "same or slightly better" than existing.				X
Small bridges					X
Storm drain systems on interstates and controlled access highways (main lanes):					
Inlets and drain pipe			X		
Inlets for depressed roadways*					X

Hydraulic Design Manual 4-13 *TxDOT 10/2011*

Figure 6. CAPTION THE FIGURE

Chapter 4 — Hydrology *Section 6 — Design Flood and Check Flood Standards*

Table 4-2: Recommended Design Standards for Various Drainage Facilities

Functional classification and structure type	Design AEP (Design ARI)				
	50% (2-yr)	20% (5-yr)	10% (10-yr)	4% (25-yr)	2% (50-yr)
Storm drain systems on other highways and frontage roads:					
Inlets and drain pipe	X	[X]	X		
Inlets for depressed roadways*				[X]	X

Table 4-2 notes: * A depressed roadway provides nowhere for water to drain even when the curb height is exceeded. [ ] Brackets indicate recommended AEP. Federal directives require interstate highways, bridges, and culverts be designed for the 2% AEP flood event. Storm drains on facilities such as underpasses, depressed roadways, etc., where no overflow relief is available should be designed for the 2% AEP event.

All facilities must be evaluated to the 1% AEP flood event.

Selecting a design flood is a matter of judgment; it requires balancing the flood risk with budgetary constraints. When considering the standard for a drainage facility, the designer should follow these guidelines:

- Decide on the design standard by considering the importance of the highway, the level of service, potential hazard to adjacent property, future development, and budgetary constraints.
- Develop alternative solutions that satisfy design considerations to varying degrees.
- After evaluating each alternative, select the design that best satisfies the requirements of the structure.
- Consider additional factors such as the design standards of other structures along the same highway corridor to ensure that the new structure is compatible with the rest of the roadway. Also assess the probability of any part of a link of roadway being cut off due to flooding.

The designer should design a facility that will operate:

- Efficiently for floods smaller than the design flood.
- Adequately for the design flood.
- Acceptably for greater floods.

In addition, for all drainage facilities, including storm drain systems, the designer must evaluate the performance for the check flood (1% AEP event). The purpose of the check flood standard is to ensure the safety of the drainage structure and downstream development by identifying significant risk to life or property in the event of capacity exceedance.

The intent of the check flood is not to force the 1% AEP through the storm drain, but to examine where the overflow would travel when this major storm does occur. For example, the water may

Hydraulic Design Manual *4-14* *TxDOT 10/2011*

Figure 7. CAPTION THE FIGURE

<highlight the appropriate rows of the table(s)>
<Justify selection using next tool below>

The functional classification for the structure was determined by using the Statewide Planning Map (CITE), the relevant portion of which is presented in Figure 4.

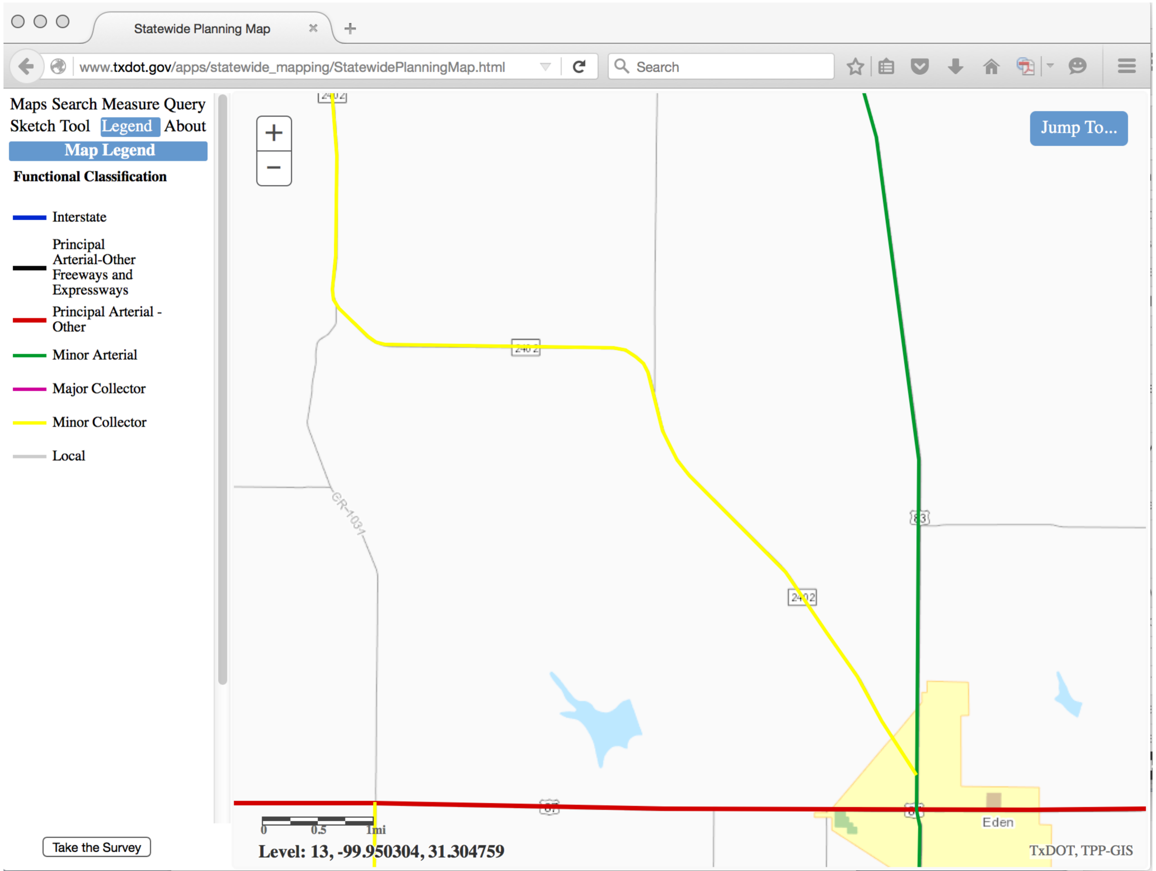

Figure 8. CAPTION THE FIGURE

<summarize and interpret the selection of frequency of interest>

The functional classification at the US-87 crossing location is XXXXXXX. The recommended design frequency (ARI) is XXXX percent (YYY-Year).

DESIGN STORMS

The risk level determined above were to create several design storms for estimating the hydrologic and hydraulic performance of the US-87 culvert system. Multiple storm types were examined because …. <provide reasoning>

X-YR, 24-HR SCS TYPE-2

The X-yr, 24-hr SCS Type 2 was selected as one of the design storms to evaluate the US-87 crossing. The total storm depth was determined using the Texas DDF Atlas (CITE) for Concho County. Figure 6 is the relevant map from the DDF Atlas.

Concho county is the COLOR shaded area shown in Figure 6. The X-yr, 24-hr storm depth from the map is XX.X inches.

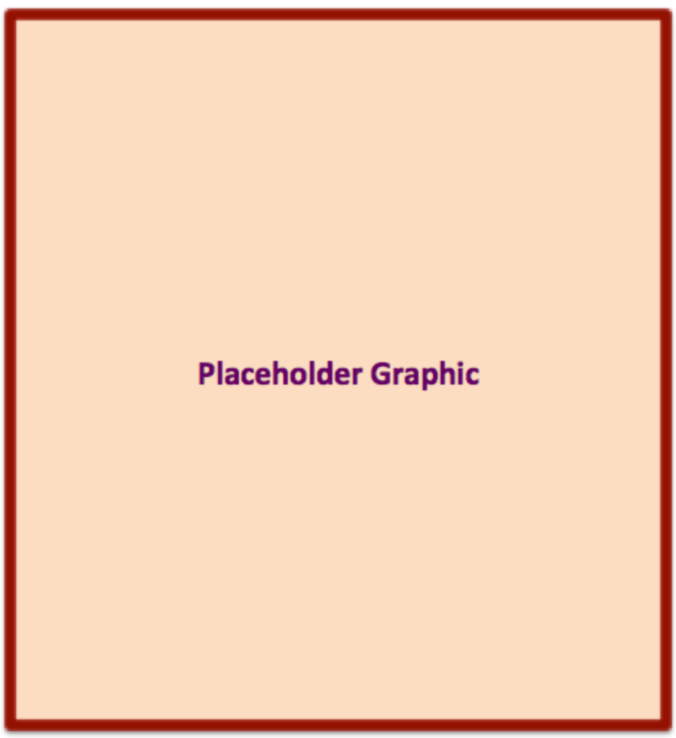

Figure 9. X-YR, 24-HR Texas DDF Map.
The COLOR shaded area is Concho County, Texas.

The depth from the Texas DDF map was entered into HEC-HMS to generate an SCS Type 2 Design Storm.

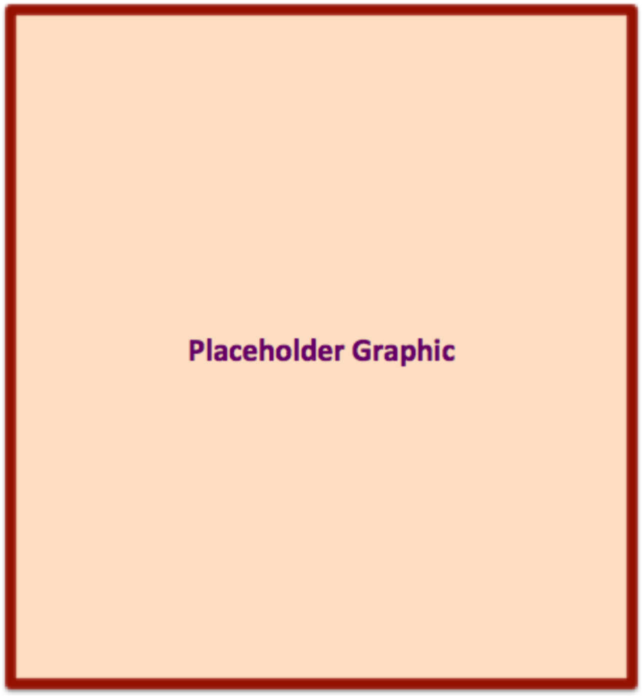

Figure 10. X-YR, 24-HR SCS Type 2 Design Storm for Concho County, Texas.

Figure 7 is a plot of the SCS Storm (from HEC-HMS) for Concho County. The peak discharge rate, in inches-per-hour is XX.X inches/hour. The peak rate occurs at simulation time XX:XX hours.

X -YR, 24-HR TXHYETO(50%)

The X-yr, 24-hr storm depth from the DDF Atlas was also used to parameterize the Texas Hydrograph. The 50th-percentile dimensionless hyetograph was chosen and parameterized for 15-minute time intervals for use in HEC-HMS as a second design storm to evaluate the performance of the hydraulic structures.

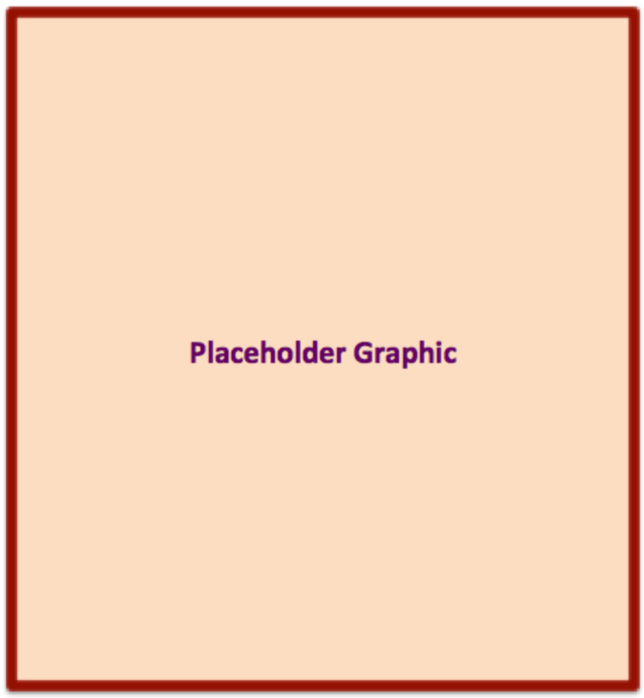

Figure 11. X-YR, 24-HR TXHYETO-2015.xlsm Design Storm for Concho County, Texas.

Figure XX is a screen capture of the design storm based on the TXHYETO-2015.xlsx worksheet for Concho Co., Texas. The peak discharge rate, in inches-per-hour is XX.X inches/hour. The peak rate occurs at simulation time XX:XX hours.

Figure 9 is a screen capture of the actual design hyetograph from HEC-HMS based on the TXHYETO-2015.xlsx tool for Concho, Co., Texas.

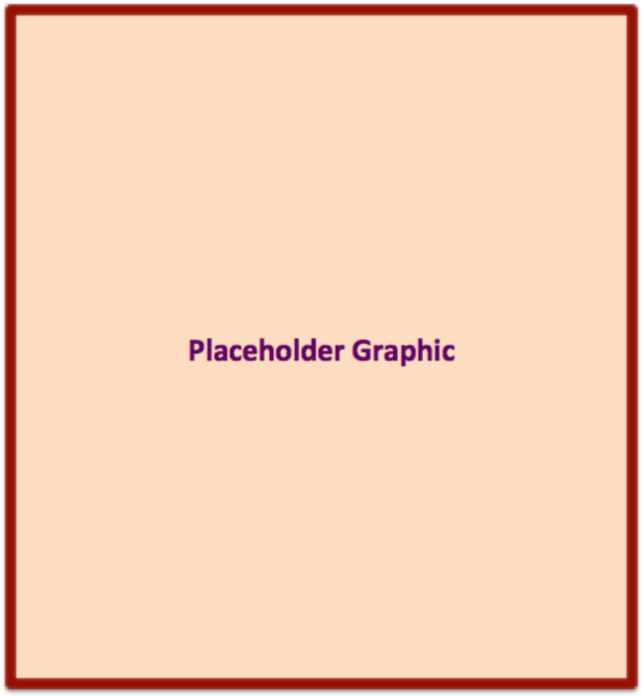

Figure 12. X-YR, 24-HR Design Storm (HEC-HMS) for Concho County, Texas.

X-YR, 6-HR SCS

The X-yr, 6-hr SCS was also examined as one of the design storms to evaluate the US-87 crossing. The total storm depth was determined using the Texas DDF Atlas (CITE) for Concho County. Figure XX is the relevant map from the DDF Atlas. Concho county is the COLOR shaded area shown in Figure XX. The X-yr, 24-hr storm depth from the map is XX.X inches.

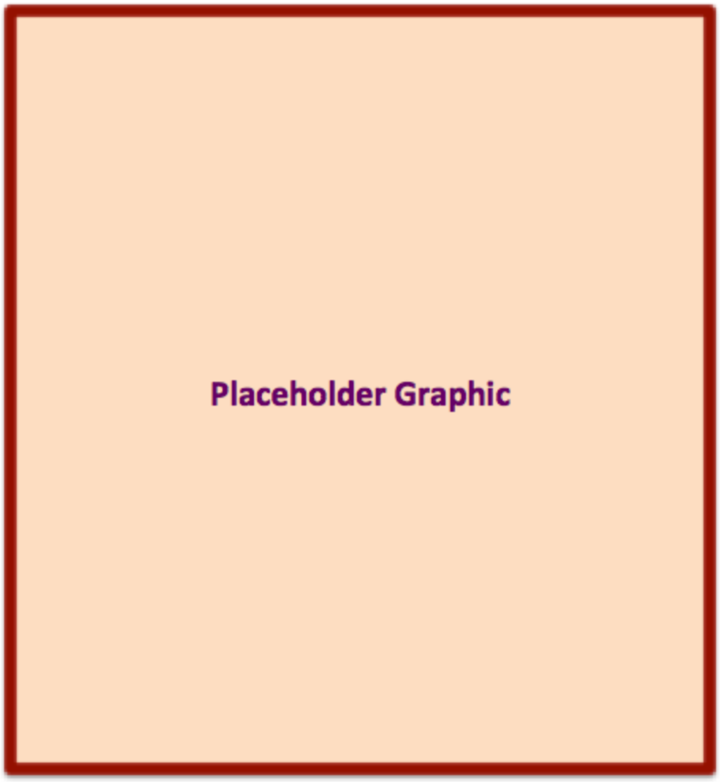

Figure 13. X-YR, 6-HR Texas DDF Map.
The COLOR shaded area is Concho County, Texas.

Because the 6-hr storm is not built into HEC-HMS a spreadsheet was used to generate a user-supplied hyetograph in HEC-HMS. Figure XX is a screen capture of the spreadsheet tool with the 6-hr storm parameterized based upon the value in the DDF Atlas.

Figure XX is a screen capture of the actual hyetograph as it appears in HEC-HMS

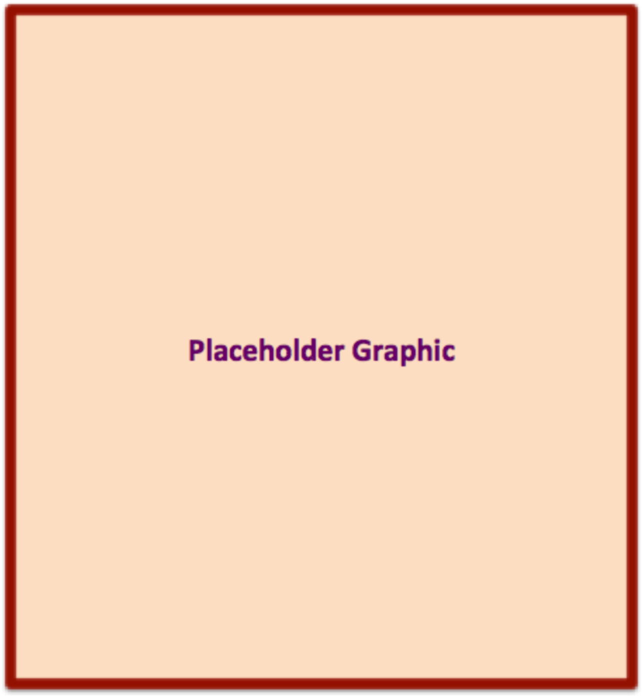

Figure 14. X-YR, 6-HR SCS Design Storm (HEC-HMS) for Concho County, Texas.

Figure 7 is a plot of the SCS Storm (from HEC-HMS) for Concho County. The peak discharge rate, in inches-per-hour is XX.X inches/hour. The peak rate occurs at simulation time XX:XX hours.

X-YR, 6-HR TXHYETO(50%)

The X-yr, 6-hr storm depth from the DDF Atlas was also used to parameterize the Texas Hydrograph. The 50th-percentile dimensionless hyetograph was chosen and parameterized for 15-minute time intervals for use in HEC-HMS as a second design storm to evaluate the performance of the hydraulic structures.

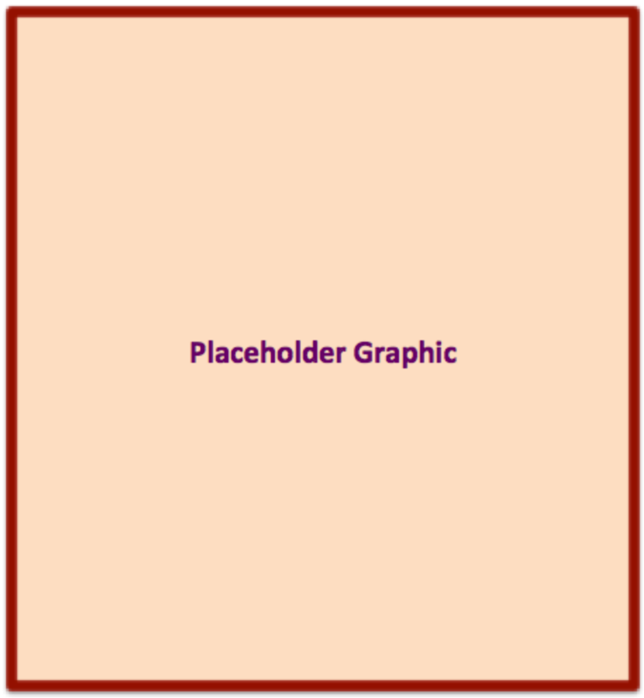

Figure 15. X-YR, 24-HR TXHYETO-2015.xlsm Design Storm for Concho County, Texas.

Figure 12 is a screen capture of the design storm based on the TXHYETO-2015.xlsx worksheet for Concho Co., Texas.

Figure 13 is a screen capture of the actual design hyetograph from HEC-HMS based on the TXHYETO-2015.xlsx tool for Concho, Co., Texas. The peak discharge rate, in inches-per-hour is XX.X inches/hour. The peak rate occurs at simulation time XX:XX hours.

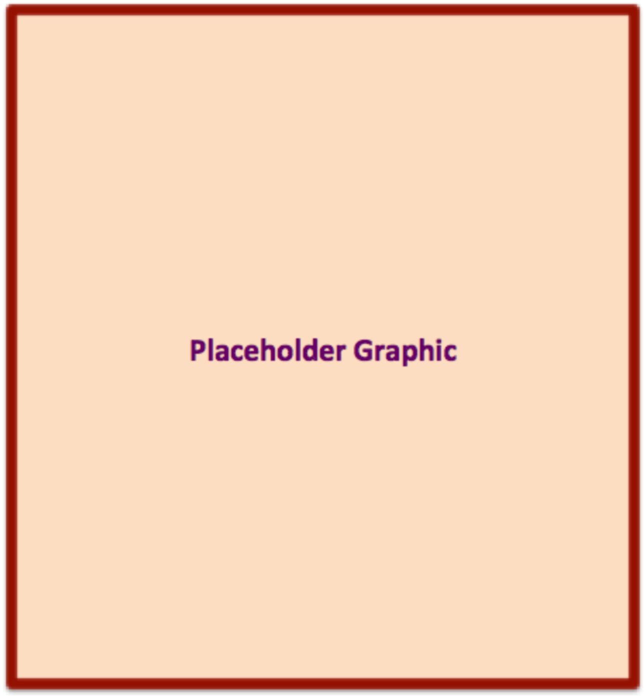

Figure 16. X-YR, 24-HR Design Storm (HEC-HMS) for Concho County, Texas.

HEC-HMS CONCEPTUALIZATION

Figure 3 is the watershed base map with the HEC-HMS conceptualization overlain on the map. The entire watershed is conceptualized as being comprised of three sub-basins (North Catchment, West Catchment, and the Eden Catchment). The North Catchment drains into the North Reservoir; the West Catchment drains into the West reservoir; and the Eden Catchment drains directly into the US-87 Reservoir.

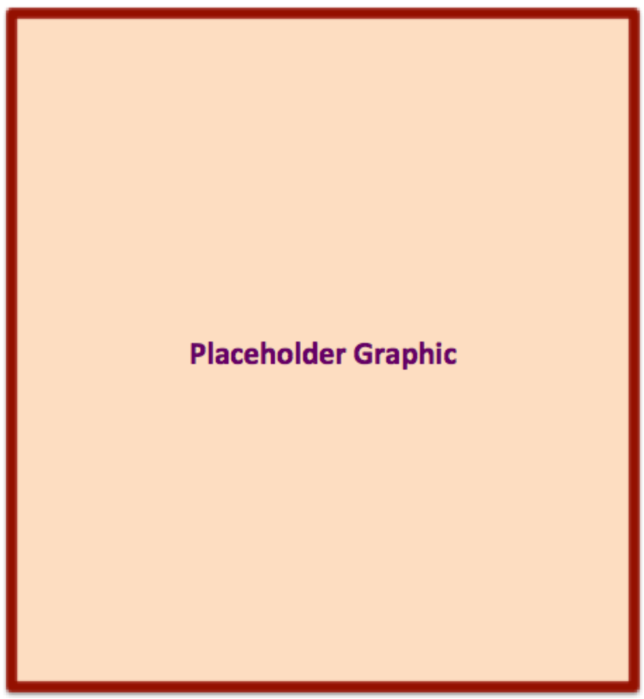

Figure 17. CAPTION THE FIGURE

The discharge from the North and West reservoirs is routed to the Junction depicted on the map. The distances, in feet of these routing elements are: West to Junction is XX.XX feet; North to Junction is XX.XX feet. The distance from the Junction to the US-87 reservoir is XX.XX feet.

Figure 4 is a screen capture of the HEC-HMS interface showing the elements from Figure 3 in the HEC-HMS modeling environment.

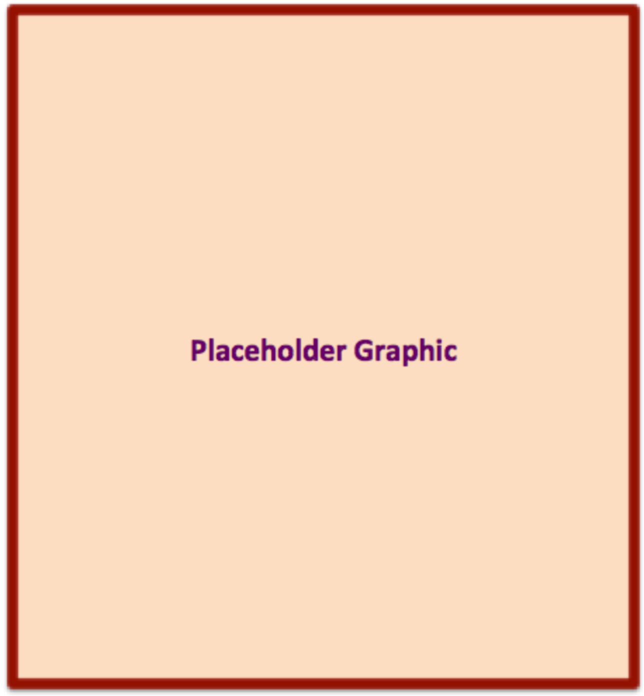

Figure 18. CAPTION THE FIGURE

RAINFALL RUNOFF MODEL

The rainfall-runoff process selected was the SCS CN loss model, and the lumped parameter transformation model selected was the SCS Dimensionless Unit Hydrograph model. These two models were parameterized using the methods described in the following subsections.

LOSS MODEL

The SCS CN was determined using the Web Soil Survey results described in the Watershed Description.

<Single example of composite CN calculation for the Eden Catchment (it is only one with any substantial urban area) here>

The composite CN for each sub-basin is listed in Table 3.

Table 3. CAPTION THE TABLE

Sub-basin name	Area (sq. mi.)	Composite CN
XXXX Catchment		
XXXX Catchment		
XXXX Catchment		

UNIT HYDROGRAPH MODEL

The SCS DUH was parameterized for each sub-basin <list their names here> using the NRCS overland method for different cover types. The <tool name .xlsm> (CITE SOURCE) was used to estimate the travel times for runoff in each of the three catchments.

Figure 16 is a screen capture of the analysis for the West Catchment.

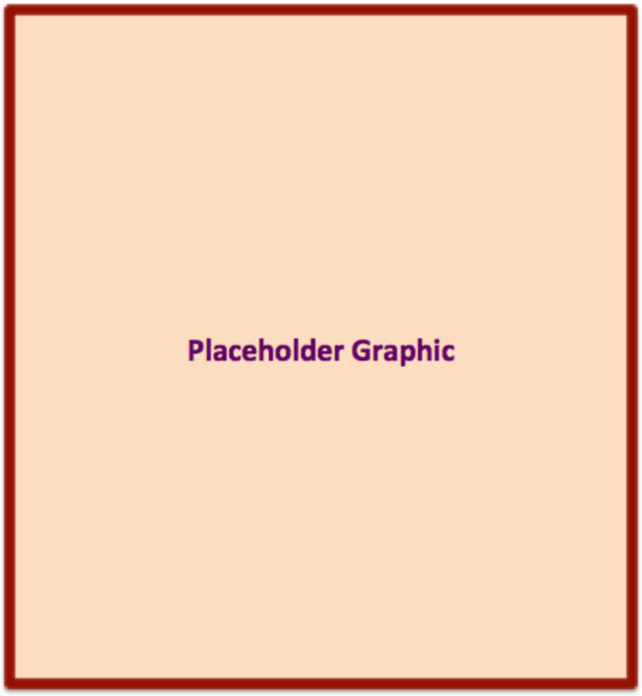

Figure 19. NRCS lag time analysis for West Catchment.

Figure 17 is a screen capture of the analysis for the North Catchment.

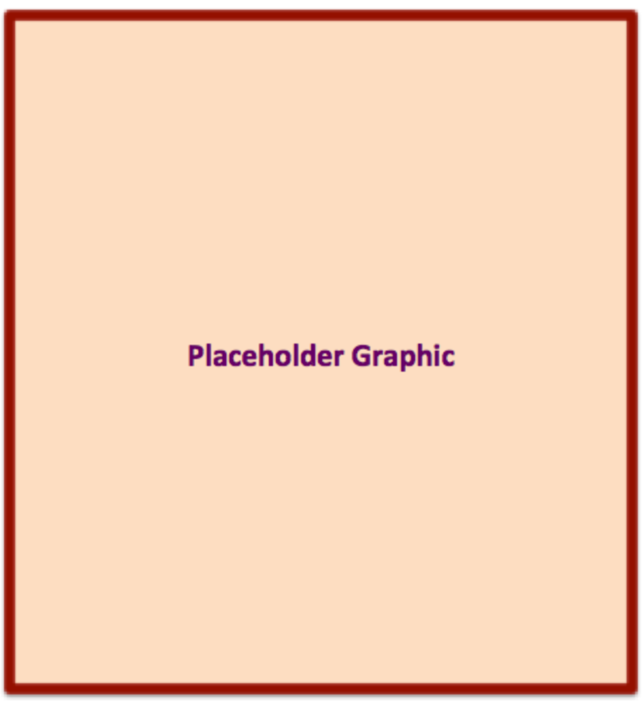

Figure 20. NRCS lag time analysis for North Catchment.

Figure 18 is a screen capture of the analysis for the Eden Catchment.

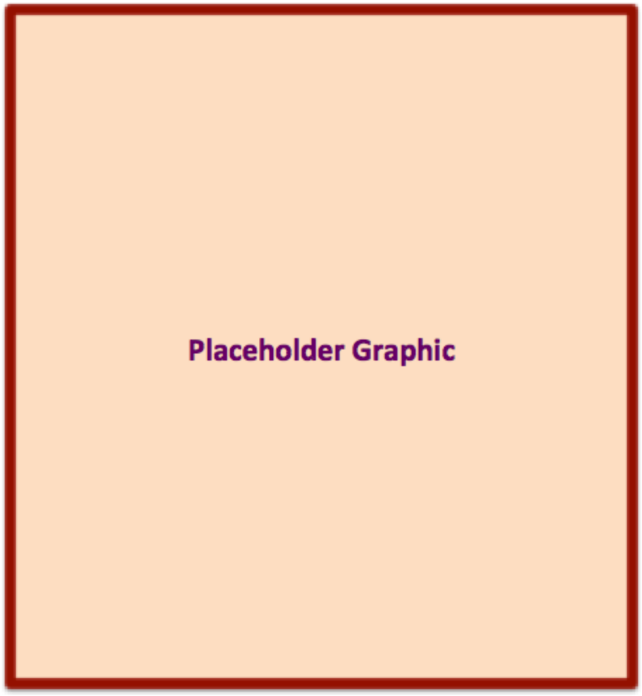

Figure 21. NRCS lag time analysis for Eden Catchment.

Table 4 is a list of ….

Table 4. CAPTION THE TABLE

Sub-basin name	Area (sq. mi.)	Lag Time (for DUH)
XXXX Catchment		
XXXX Catchment		
XXXX Catchment		

HYDROGRAPH ROUTING ELEMENTS

Discharge leaving the West and North Reservoirs are routed through a stream system to the US-Reservoir.

CHANNEL ELEMENTS

The channels are modeled as 8-point cross sections and the Muskingum-Cunge routing model is used. The three channel sections are <name the 3 sections>.

Values of Manning's n appropriate for the channel sections was chosen from Appendix I (Table 8.2 CITE SOURCE).

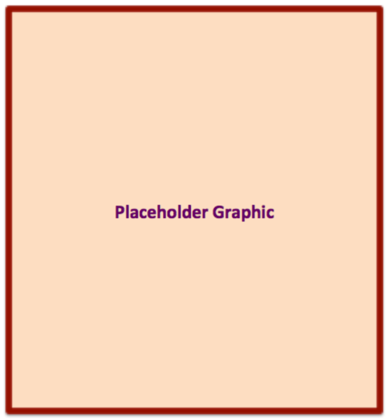

Figure 22. Typical Cross Section for <name 1>.

Section <name 1> is shown on Figure XX. <describe the channel coverage, grass lined, etc.> Manning's n for the section is ##. The average channel slope is X.XXXX. The length of the channel is XXXX feet.

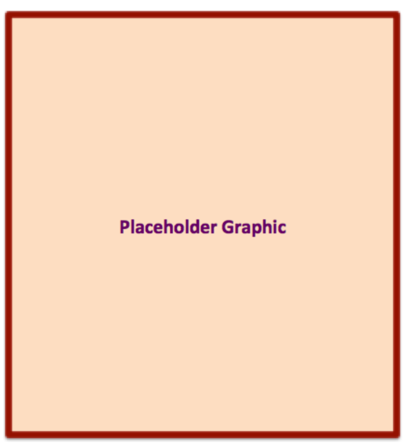

Figure 23. Typical Cross Section for <name 2>.

Section <name 2> is shown on Figure XX. <describe the channel coverage, grass lined, etc.> Manning's n for the section is ##. The average channel slope is X.XXXX. The length of the channel is XXXX feet.

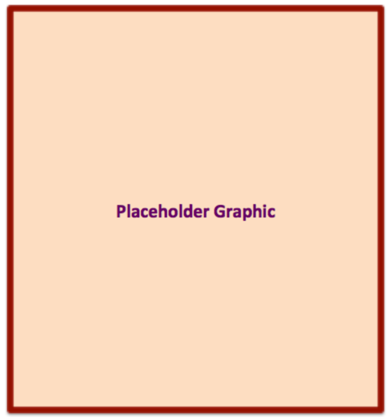

Figure 24. Typical Cross Section for <name 3>.

Section <name 3> is shown on Figure XX. <describe the channel coverage, grass lined, etc.> Manning's n for the section is ##. The average channel slope is X.XXXX. The length of the channel is XXXX feet.

RESERVOIR STORAGE ELEMENTS

The West and North Reservoirs are <describe the reservoirs – the dam crest height, the spillway height, and the riser pipe height>

The reservoirs are assumed to already contain water at pool elevation equal to the outlet riser pipe – thus any additional water added to the reservoir will immediately raise the pool elevation above the riser pipe and water will begin to flow out of the reservoir into the drainage channels.

Figure XX is an elevation view (not to scale) sketch of the West and North reservoirs.

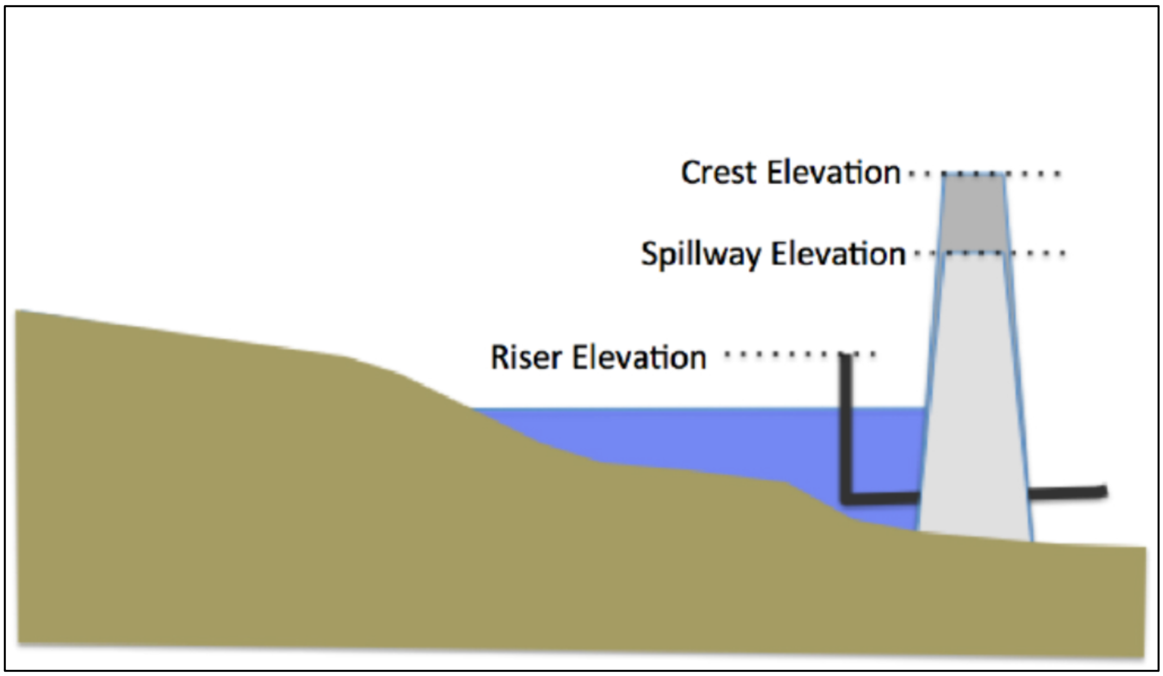

Figure 25. CAPTION THE FIGURE

NORTH RESERVOIR ELEVATION-AREA-STORAGE TABLE

<describe the elevation-area calculations Lectures 19 and 20>
<Show representative calculations/measurements>
<can assume spillways are 50 ft wide and crest height is 4 feet above spillway>
<report riser elevation, crest elevation, and spillway elevation>
<Then provide the table>

WEST RESERVOIR ELEVATION-AREA-STORAGE TABLE

<describe the elevation-area calculations Lectures 19 and 20>
<Show representative calculations/measurements>
<can assume spillways are 50 ft wide and crest height is 4 feet above spillway>
<report riser elevation, crest elevation, and spillway elevation>

<Then provide the table>

US-87 RESERVOIR ELEVATION-AREA-STORAGE TABLE

<Make a similar sketch to Figure 23, except the riser is a horizontal culvert. The spillway elevation is the roadway height>

Figure XX is an profile view looking downstream at the US-87 Crossing (US-87 Reservoir Outlet). The road profile is the grey region that slopes down to the top of the culverts then back up. The original stream channel is shown – there is sufficient space to add additional culvert barrels if indicated. The dashed line approximates the spillway/crest profile (the approximation is for simplicity in hydraulics calculations).

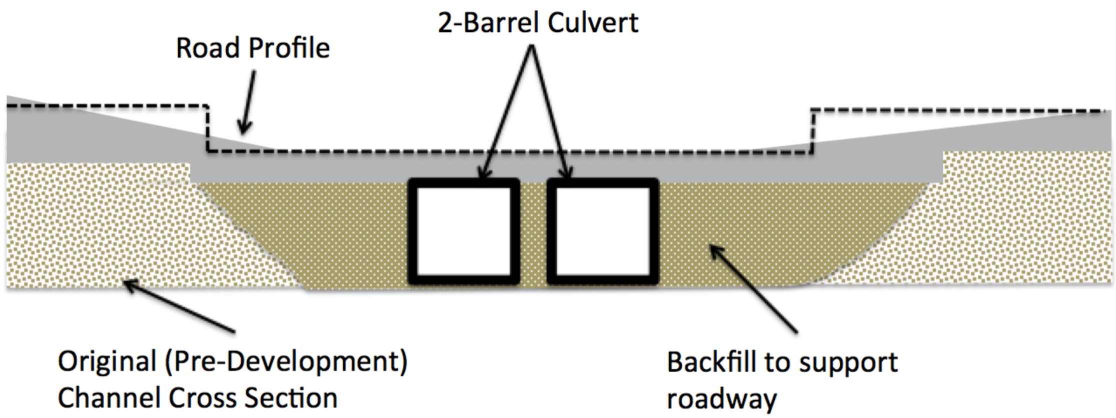

Figure 26. CAPTION THE FIGURE

<describe the elevation-area calculations Lectures 19 and 20>
<Show representative calculations/measurements>
<Use google earth to approximate spillway width and crest height is 0.5 feet above spillway>
<report culvert bottom, crest elevation, and spillway elevation>
<Then provide the table>

DISCHARGE ESTIMATES

Add Narrative Here – Naturally you need to run the model(s).

PEAK WATER SURFACE ELEVATION

Add Narrative Here – Naturally you need to run the model(s).
You get peak elevation from where? (which reservoir)

EXISTING CONDITION

Add Narrative Here – Naturally you need to run the model(s) .
Peak WSE for 4 design storms. Does the reservoir overtop (ie does the elevation go above the spillway?)

PROPOSED CONDITION

Add Narrative Here – Naturally you need to run the model(s) .
Peak WSE for 4 design storms. Does the reservoir overtop (ie does the elevation go above the spillway?)

INTERPRETATION OF RESULTS

Add Narrative Here – Naturally you need to run the model(s) .

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Add Narrative Here – Naturally you have to write this section after nearly everything else is completed.

REFERENCES

TxDOT 2016. Hydraulic Design Manual, Texas Department of Transportation, (http://url-goes-here) accessed date.

Asquith, W.H., and Roussel, M.C., 2004, Atlas of depth-duration frequency of precipitation annual maxima for Texas: U.S. Geological Survey Scientific Investigations Report 2004–5041, 106 p.

Soil Conservation Service, 1973, A method for estimating volume and rate of runoff in small watersheds: Washington, D.C., U.S. Department of Agriculture, Soil Conservation Service, SCS–TP–149, 19 p.

Chow, V.T., Maidment, D.R., and Mays, L.W., 1988, Applied hydrology: New York, McGraw-Hill Publishing Company, 572 p.

HEC-HMS, 2015. Hydrologic Modeling System HEC-HMS. U.S. Army Corps of Engineers, Hydrologic Engineering Center (CEIWR-HEC) (http://url-goes-here) accessed date.

Statewide Planning Map – find it cite the URL

NRCS Overland Method – find it, cite the NRCS document. Also cite the URL for the Spreadsheet Tool (if you use it). If you use Kerby-Kirpich, cite the source document (its not my notes!) and the spreadsheet tool if you use it (cite the uRL).

Web Soil Survey – find it; cite the URL.

APPENDIX-I MANNING'S N VALUES

TABLE 8.2 Roughness Coefficients for Open Channels

Description of Channel	n
Exceptionally smooth, straight surfaces: enameled or glazed coating; glass; lucite; brass	0.009
Very well planed and fitted lumber boards; smooth metal; pure cement plaster; smooth tar or paint coating	0.010
Planed lumber; smoothed mortar ($\frac{1}{3}$ sand) without projections, in straight alignment	0.011
Carefully fitted but unplaned boards; steel troweled concrete, in straight alignment	0.012
Reasonably straight, clean, smooth surfaces without projections; good boards; carefully built brick wall; wood troweled concrete; smooth, dressed ashlar	0.013
Good wood, metal, or concrete surfaces with some curvature, very small projections, slight moss or algae growth or gravel deposition; shot concrete surfaced with troweled mortar	0.014
Rough brick; medium quality cut stone surface; wood with algae or moss growth; rough concrete; riveted steel	0.015
Very smooth and straight earth channels, free from growth; stone rubble set in cement; shot, untroweled concrete; deteriorated brick wall; exceptionally well excavated and surfaced channel cut in natural rock	0.017
Well-built earth channels covered with thick, uniform silt deposits; metal flumes with excessive curvature, large projections, accumulated debris	0.018
Smooth, well-packed earth; rough stone walls; channels excavated in solid, soft rock; little curving channels in solid loess, gravel, or clay with silt deposits, free from growth and in average condition; deteriorating uneven metal flume with curvatures and debris; very large canals in good condition	0.020
Small, human-made earth channels in well-kept condition; straight natural streams with rather clean, uniform bottoms without pools and flow barriers, cavings, and scours of the banks	0.025
Ditches; below-average human-made channels with scattered cobbles in bed	0.028
Well-maintained large floodway; unkept artificial channels with scours, slides, considerable aquatic growth; natural stream with good alignment and fairly constant cross section	0.030
Permanent alluvial rivers with moderate changes in cross section, average stage; slightly curving intermittent streams in very good condition	0.033
Small, deteriorated artificial channels, half choked with aquatic growth; winding river with clean bed, but with pools and shallows	0.035
Irregularly curving permanent alluvial stream with smooth bed; straight natural channels with uneven bottom, sand bars, dunes, few rocks and underwater ditches; lower section of mountainous streams with well-developed channel with sediment deposits; intermittent streams in good condition; rather deteriorated artificial channels, with moss and reeds, rocks, and slides	0.040
Artificial earth channels partially obstructed with debris, roots, and weeds; irregularly meandering rivers with partly grown-in or rocky bed; developed flood plains with high grass and bushes	0.067
Mountain ravines; fully ingrown small artificial channel; flat flood plains crossed by deep ditches (slow flow)	0.080
Mountain creeks with waterfalls and steep ravines; very irregular flood plains; weedy and sluggish natural channels obstructed with trees	0.10
Very rough mountain creeks; swampy, heavily vegetated rivers with logs and driftwood on the bottom; flood plain forest with pools	0.133
Mudflows; very dense flood plain forests; watershed slopes	0.22

from: Simon, A.L., and Korom, S.F. 1997. Hydraulics 4ed., Prentice Hall, Ohio 443p.

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APPENDIX-II HEC-HMS Support Files (Excel Spreadsheets)