Feasibility Analysis of Adding Two 6X6 Box Culverts to Existing Stream Crossing at US-87 West of Eden, TX

Submitted by
Team ID

Member 1, Member 2, Member 3, Member 4, Member 5

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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

US highway 87 runs nearly East-West through Eden, Texas and crosses Hardin Creek just West of Eden. The crossing is currently a 2-barrel culvert system that overtops. This report examines the feasibility of adding two additional barrels to the system to reduce the frequency of overtopping and allow the highway to remain in service during specific design storms.

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.

The location of interest is a culvert system located about ½ mile West of the intersection of US 84 and US 87 in Eden, Texas.

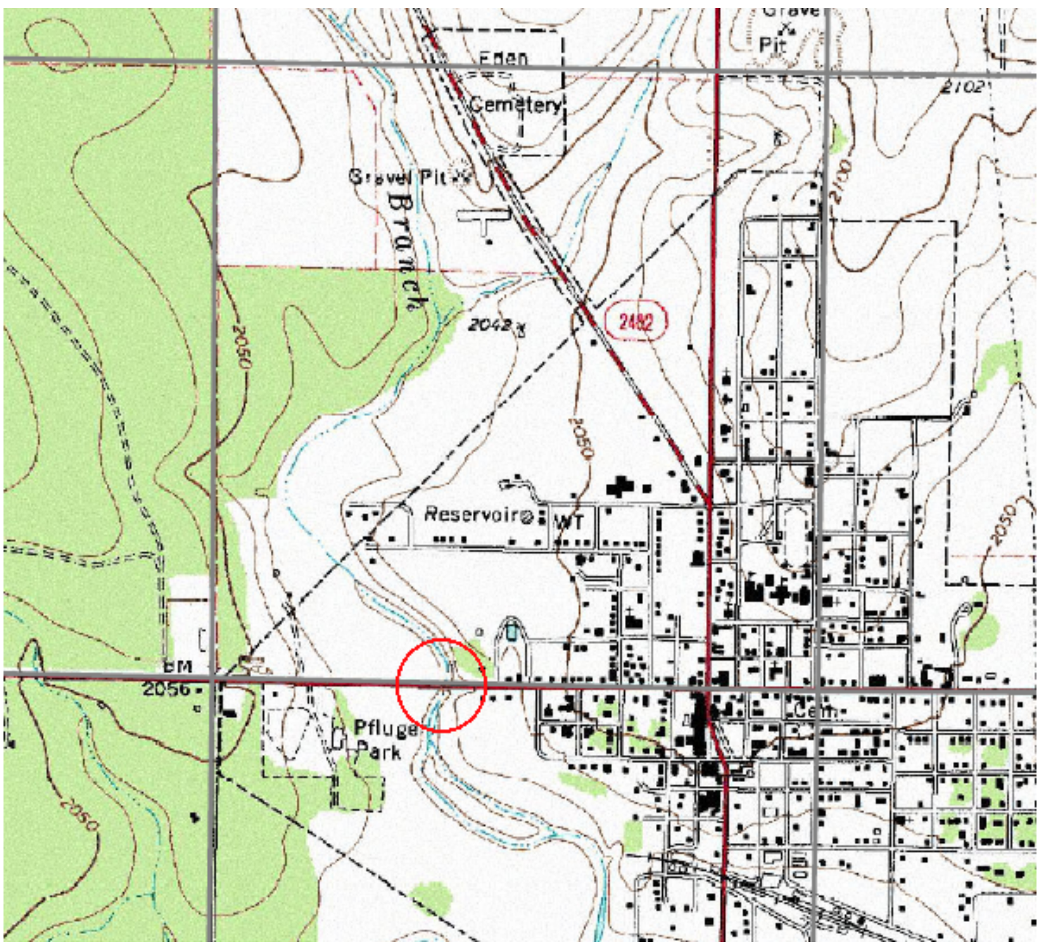


Figure 1. Culvert system located approximately 1/2 mile West of Eden, Texas.

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

The surrounding land is rolling grazing land, relatively arid with grasses and prickly pear and small oak mottes. The total area contributing runoff to the crossing is about 17 square miles, but a substantial portion of the runoff in the area is regulated by two SCS reservoirs.

DELINEATION

Figure 2 is the watershed that contributes flow to the crossing structure. The total contributing area is 16.82 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 West Catchment, and the North Catchment. The contributing area downstream of both reservoir outlets, but upstream of the point of interest is called the Eden Catchment.

The watershed delineation map in Figure 2 was also employed to estimate the travel (channel) distances for each (sub) catchment. The distances were estimated using manual opisometry (measuring length of arbitrary curved paths) as described in USAF 1985 pp. 322-326. These distances are used below to estimate time-of-concentration values to parameterize unit hydrographs for each (sub) catchment, and to estimate Muskingum-Cunge parameters for channel routing.

The watershed was delineated using the method described in McCuen, 1989; pp. 100-106. Table 1 is a list of the individual sub-catchment areas.

Table 1. Drainage Areas for Hardin Creek Watershed Study Area

Description	Value	Units
North Catchment	3.83	Square miles
West Catchment	6.04	Square miles
Eden Catchment	6.95	Square miles
Total Drainage Area	16.82	Square miles

Hardin Creek has two branches that begin downstream of either reservoir. This location will be referred to as the junction and is used as the spatial location where the flows from the two reservoirs join and continue downstream to the crossing.

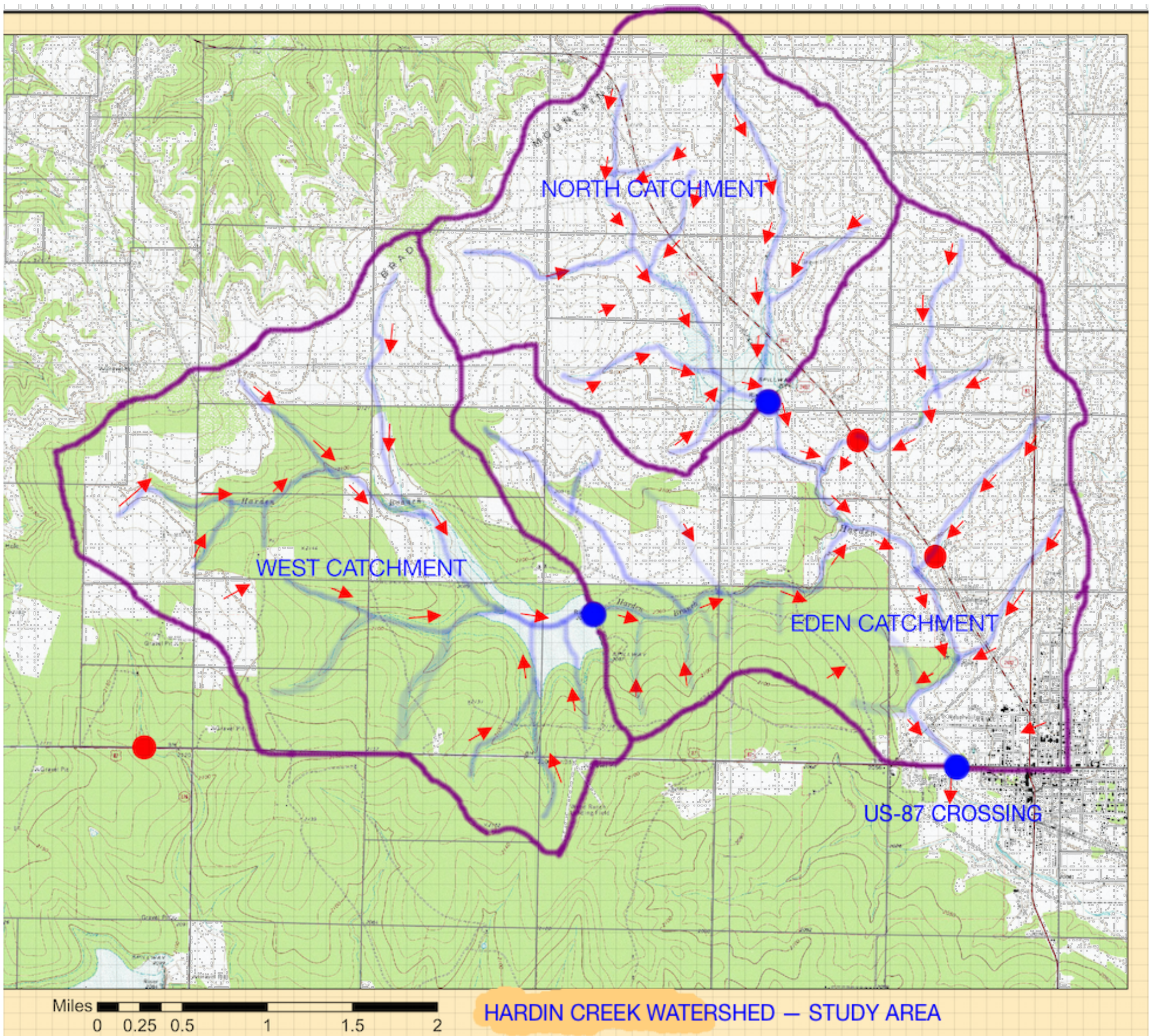


Figure 2. Hardin Creek Watershed Study Area

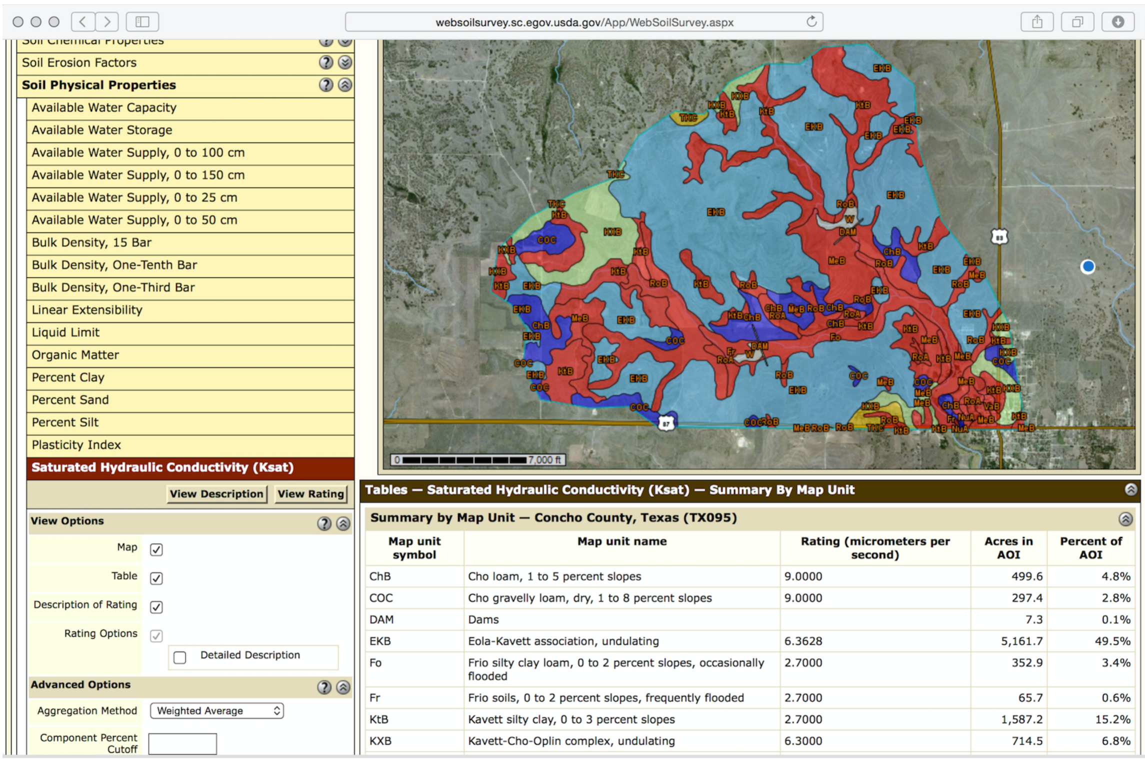
Table 2 is a list of the channel length segments for each catchment. For example, the channel length for the West Catchment to the Reservoir Outlet was estimated to be 3.44 miles. The channel length for the West Catchment Reservoir Outlet to the US-87 crossing was estimated to be 3.62 miles.

Table 2. Drainage Path Distances for Hardin Creek Watershed Study Area

Item	Value	Units
North Catchment to Reservoir Outlet	~2.74	Miles
West Catchment to Reservoir Outlet	~3.44	Miles
Eden Catchment to US 87 Crossing	~3.69	Miles
West Reservoir Outlet to US 87 Crossing	~3.62	Miles
North Reservoir Outlet to US 87 Crossing	~2.99	Miles

SOIL PROPERTIES

The USDA-ARS Web Soil Survey was used to estimate the soil properties for the study area, in particular the major soil textural descriptions and infiltration rate, both of which are used to determine a curve number. Figure 3 is a screen capture of the relevant portion of the Web Soil Survey (USDA-NRCS, 2016) map for the study area.



Map unit symbol	Map unit name	Rating (micrometers per second)	Acres in AOI	Percent of AOI
ChB	Cho loam, 1 to 5 percent slopes	9.0000	499.6	4.8%
COC	Cho gravelly loam, dry, 1 to 8 percent slopes	9.0000	297.4	2.8%
DAM	Dams		7.3	0.1%
EKB	Eola-Kavett association, undulating	6.3628	5,161.7	49.5%
Fo	Frio silty clay loam, 0 to 2 percent slopes, occasionally flooded	2.7000	352.9	3.4%
Fr	Frio soils, 0 to 2 percent slopes, frequently flooded	2.7000	65.7	0.6%
KtB	Kavett silty clay, 0 to 3 percent slopes	2.7000	1,587.2	15.2%
KXB	Kavett-Cho-Oplin complex, undulating	6.3000	714.5	6.8%

Figure 3. Web Soil Survey, Soils Properties Map of the Study Area.

The table depicted in Figure 3 is presented in its entirety below as Table 3, which is a listing of soil texture, fraction of total area, and saturated hydraulic conductivity in microns per second.

The saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

The standard Ksat class limits are:

Very low: 0.00 to 0.01;
Low: 0.01 to 0.1;
Moderately low: 0.1 to 1.0;
Moderately high: 1 to 10;
High: 10 to 100;
Very high: 100 to 705.

The properties for this study are in the Moderately High category. Numerically approximately 65% of the study area has a Ksat of 0.106 inches/hour (9 μm/sec) and the remaining 35% of the study area has a Ksat of 0.032 inches/hour (2.7 μm/sec).

Table 3. Soil Properties for Harden Creek Study Area

Summary by Map Unit — Concho County, Texas (TX095)				
Map unit symbol	Map unit name	Ksat	Acres in AOI	Percent of AOI
ChB	Cho loam, 1 to 5 percent slopes	9.0	601.0	5.4%
COC	Cho gravelly loam, dry, 1 to 8 percent slopes	9.0	555.4	5.0%
EKB	Eola-Kavett association, undulating	9.0	5,388.0	48.7%
Fo	Frio silty clay loam, 0 to 2 percent slopes, occasionally flooded	2.7	350.2	3.2%
Fr	Frio soils, 0 to 2 percent slopes, frequently flooded	2.7	64.9	0.6%
KtB	Kavett silty clay, 0 to 3 percent slopes	2.7	1,530.5	13.8%
KXB	Kavett-Cho-Oplin complex, undulating	2.7	684.5	6.2%
MeB	Mereta clay loam, 1 to 3 percent slopes	2.7	735.2	6.6%
NuA	Nuvalde silty clay loam, 0 to 1 percent slopes	2.7	11.3	0.1%
RoA	Rowena clay loam, 0 to 1 percent slopes	2.7	147.9	1.3%
RoB	Rowena clay loam, 1 to 3 percent slopes	2.7	834.8	7.5%
TKC	Tarrant-Oplin-Kavett association, undulating	2.7	72.3	0.7%
VaB	Valera silty clay, 0 to 3 percent slopes	2.7	18.4	0.2%
ChB	Cho loam, 1 to 5 percent slopes	9.0	601.0	5.4%
	Totals for Area of Interest		11,063.3	100.0%

An area weighted mean value is a Ksat of 0.08 inches/hour (6.8 μm/sec). This value will be used to represent the area and estimate a meaningful curve number from the National Engineering Handbook Chapter 630 (cite).

EXISTING CROSSING CONFIGURATION

Figure 4 is a sketch of the existing crossing hydraulic structure comprised of 2 6X6 concrete box culverts laid on the channel bottom, with backfill material supporting the roadway. The road profile is approximated in this study as a notched weir, approximately 660 feet wide, with a crest at elevation 2022 feet. The culvert invert elevations (flow line) are at elevation 2010 feet. The backfill and the roadway deck is assumed to be roughly 4 feet thick. That is the 6 foot rise + 4 foot fill and deck = 10 feet total elevation above the drainage channel.

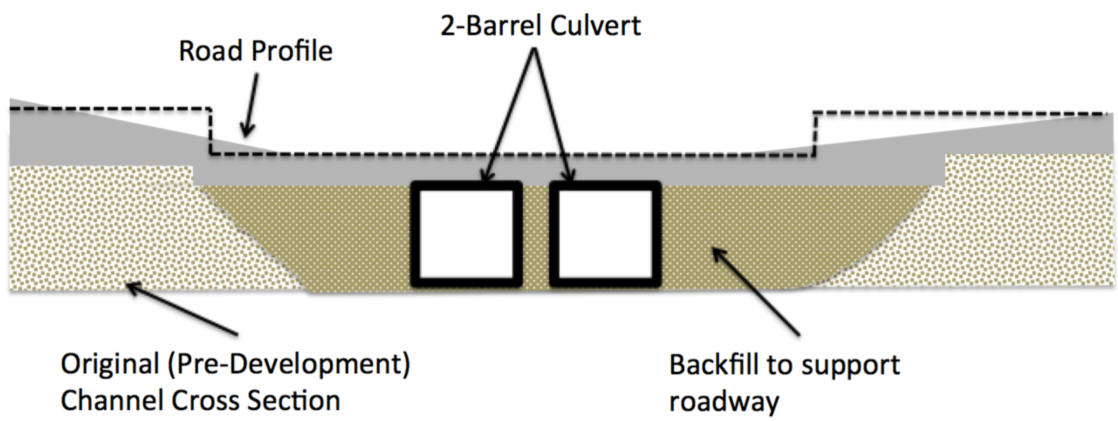


Figure 4. Existing Crossing Configuration

Figure 5 is the alternate configuration where two additional 6X6 concrete culverts are added to the existing configuration. The weir width and notch height are depicted on the figure. The other properties (crest and invert elevations) are unchanged for the alternate hydraulic structure.

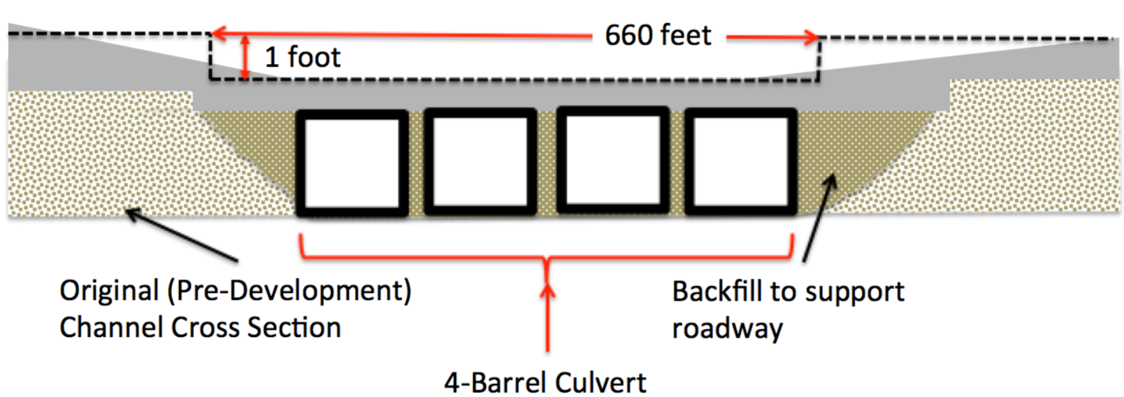


Figure 5. Alternative Crossing Configuration (4-barrel culvert system).

HYDROLOGIC ANALYSIS

The system was subjected to a hydrologic analysis that is comprised of selecting several appropriate design storms based on the recommended risk level in the Texas Hydraulic Design Manual (CITE). Once these storms are specified a HEC-HMS model of the watershed(s) and hydraulic structures was built and run with existing and proposed geometries at the crossing to assess the benefit of adding two barrels.

DESIGN RISK LEVEL

The design risk level (ARI for estimating rainfall and subsequent discharge at the water crossing) was determined using Table 4-2 from the TxDOT Hydraulic Design Manual (CITE) in conjunction with the Statewide Planning Map (CITE).

The statewide planning map is used to determine the functional classification of the highway in the vicinity of the hydraulic structure. Table 4-2 is then consulted to determine the recommended design frequency.

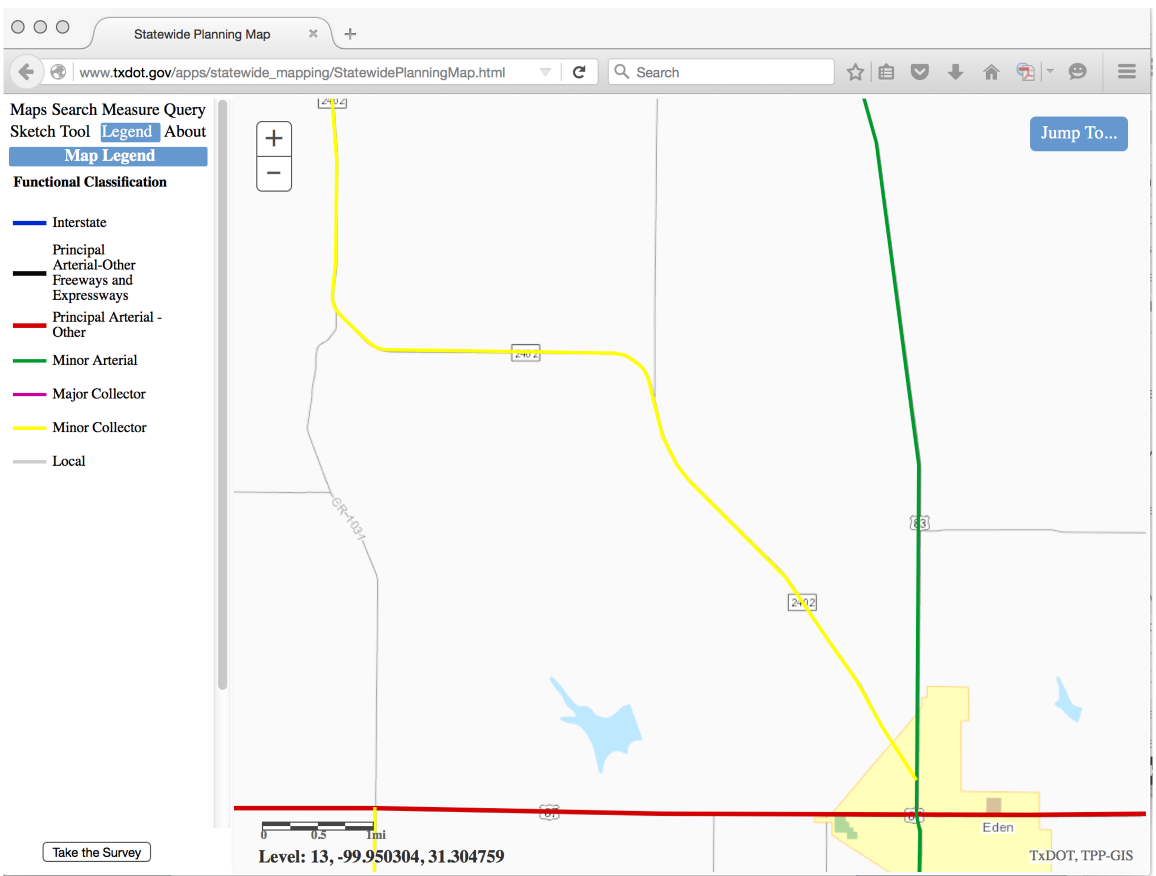
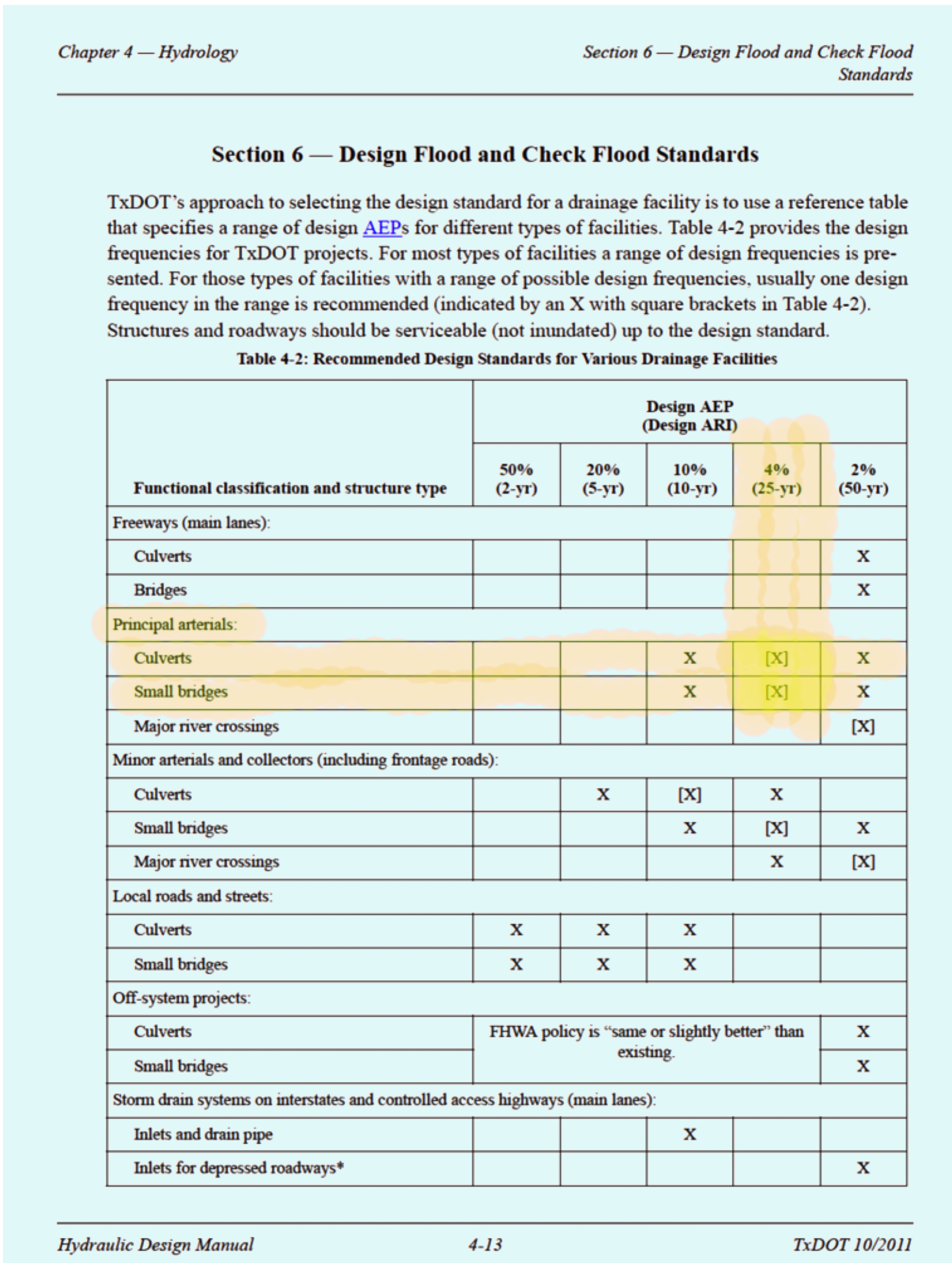


Figure 6. Statewide Planning Map in Vicinity of Hardin Creek – US87 crossing. The functional classification of the highway is "Principal Arterial – Other"

Figure 6 is a screen capture of the relevant portion of the statewide planning map. From the figure and its legend, the functional classification of US 87 in the vicinity of the water crossing is “Principal Arterial – Other.”

Table 4-2 from the TxDOT Hydraulic Design Manual (cite) is reproduced below as Figures 7 and 8.



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 7. Design AEP/ARI Standards from TxDOT (cite) (Page 1 of 2)

Figures 7 above shows the intersection of the functional classification, hydraulic structure type and the recommended AEP/ARI (4%/25-year).

The relevant portions of Figure 8 are highlighted. The requirement that all facilities should be evaluated for the 1% AEP (100-yr ARI) to establish where flooding may occur when such an event occurs will also be applied in this study.

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 8. Design AEP/ARI Standards from TxDOT (cite) (Page 2 of 2)

DESIGN STORMS

The risk level determined above was used to create several design storms for estimating the hydrologic and hydraulic performance of the US-87 culvert system. Multiple storm types were examined because the watershed system is too large for application of the Rational Method, and the critical storm duration was unknown a-priori. The watershed is about 16 square miles and the response time based on a rule-of-thumb (CITE) is about 4 hours. A 6-hour storm was selected because the 6-hr SCS storm could be investigated along with various Texas-specific storms.

25-YR, 24-HR SCS TYPE-2

The 25-yr, 24-hr SCS Type 2 was selected as one of the design storms to evaluate the US-87 crossing.

54 Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas

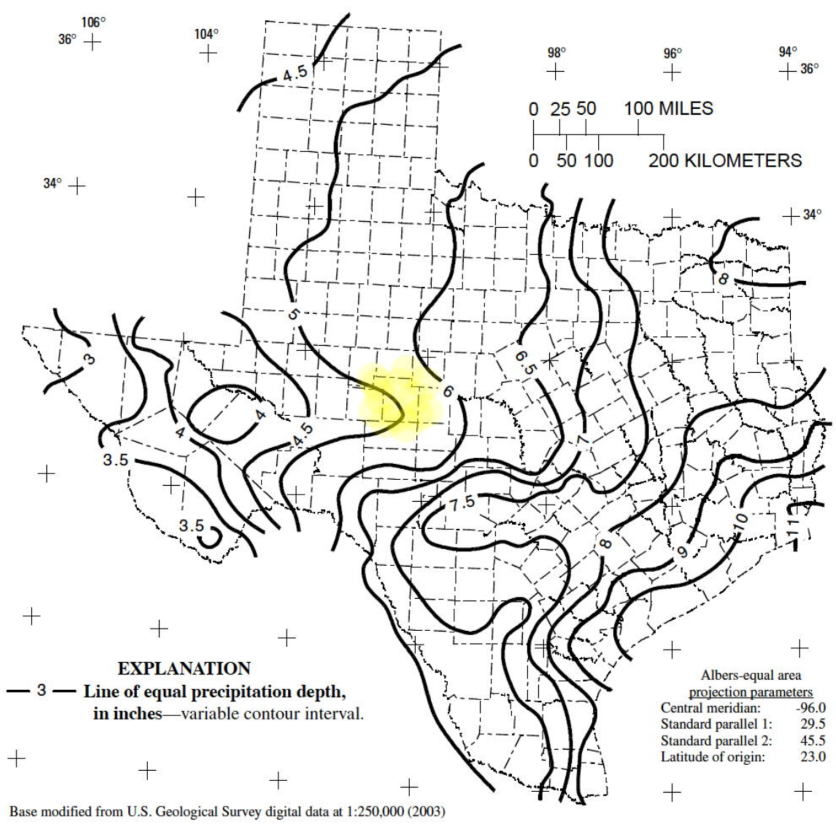


Figure 47. Depth of precipitation for 25-year storm for 1-day duration in Texas.

Figure 9. 25-YR, 24-HR Texas DDF Map. Concho County is the shaded area.

The total storm depth was determined using the Texas DDF Atlas (Asquith and Roussel, 2004) for Concho County. Figure 9 is the relevant map from the DDF Atlas; Concho County is the yellow shaded area shown in Figure 6. The 25-yr, 24-hr storm depth from the map is approximately 5.0 inches.

The depth from the Texas DDF map was entered into HEC-HMS to generate an SCS Type 2 Design Storm. Figure 10 is a plot of the SCS Storm for Concho County. The peak precipitation rate, in inches-per-hour is 2.14 inches/hour. The peak rate occurs at an elapsed time of 12 hours.

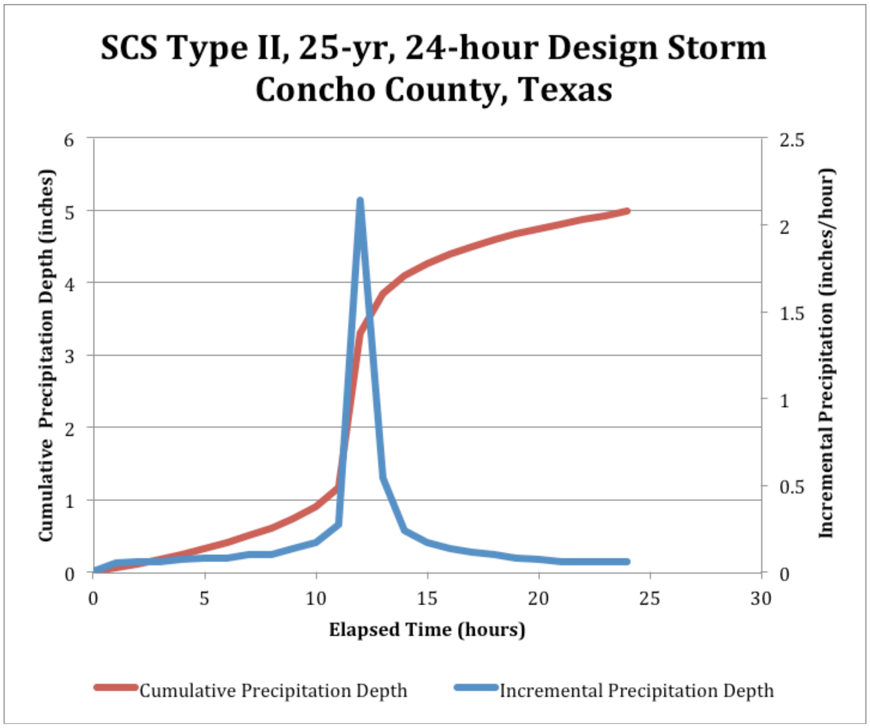
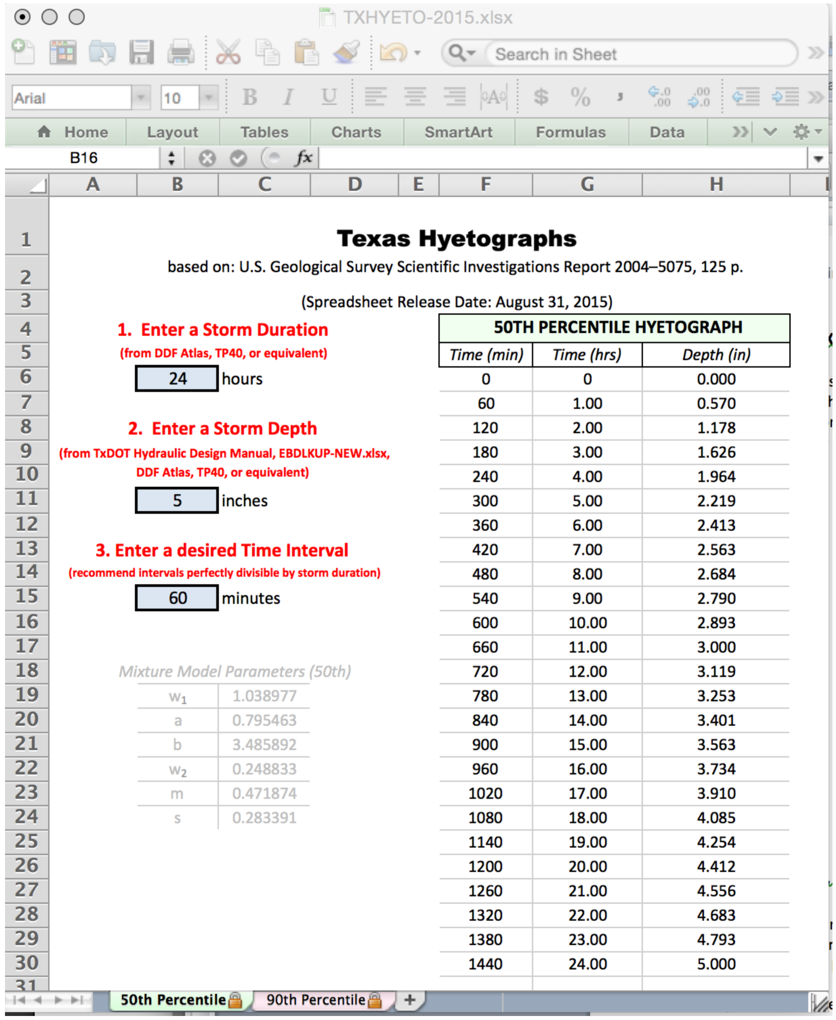


Figure 10. 25-YR, 24-HR SCS Type 2 Design Storm for Concho County, Texas.

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

The 25-yr, 24-hr storm depth from the DDF Atlas was also used to parameterize the Texas Hydrograph using the TXHYETO-2015 tool (Neale, et. al. 2015). The 50th-percentile dimensionless hyetograph was chosen and parameterized for 60-minute time intervals for use in HEC-HMS as an alternative storm to evaluate the performance of the hydraulic structures.



Texas Hyetographs

based on: U.S. Geological Survey Scientific Investigations Report 2004–5075, 125 p.

(Spreadsheet Release Date: August 31, 2015)

1. Enter a Storm Duration
(from DDF Atlas, TP40, or equivalent)
24 hours

2. Enter a Storm Depth
(from TxDOT Hydraulic Design Manual, EBDLKUP-NEW.xlsx, DDF Atlas, TP40, or equivalent)
5 inches

3. Enter a desired Time Interval
(recommend intervals perfectly divisible by storm duration)
60 minutes

Mixture Model Parameters (50th)

w_1	1.038977
a	0.795463
b	3.485892
w_2	0.248833
m	0.471874
s	0.283391

50TH PERCENTILE HYETOGRAPH

Time (min)	*Time (hrs)*	*Depth (in)*
0	0	0.000
60	1.00	0.570
120	2.00	1.178
180	3.00	1.626
240	4.00	1.964
300	5.00	2.219
360	6.00	2.413
420	7.00	2.563
480	8.00	2.684
540	9.00	2.790
600	10.00	2.893
660	11.00	3.000
720	12.00	3.119
780	13.00	3.253
840	14.00	3.401
900	15.00	3.563
960	16.00	3.734
1020	17.00	3.910
1080	18.00	4.085
1140	19.00	4.254
1200	20.00	4.412
1260	21.00	4.556
1320	22.00	4.683
1380	23.00	4.793
1440	24.00	5.000

Figure 11. 25-YR, 24-HR TXHYETO-2015.xlsm Design Storm for Concho County, Texas.

Figure 11 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 0.608 inches/hour. The peak rate occurs at an elapsed time of 2 hours.

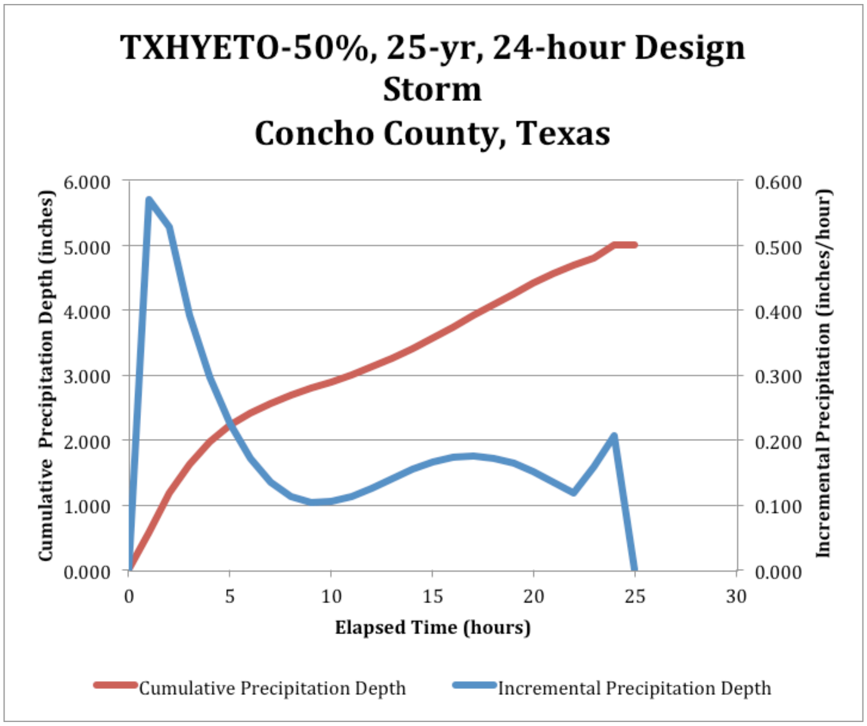


Figure 12. 25-YR, 24-HR Design Storm (TXHYETO-2015 50%) for Concho County, Texas.

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

25-YR, 6-HR SCS

The 25-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 13 is the relevant map from the DDF Atlas. Concho County is the yellow shaded area shown in Figure 13. The 25-yr, 6-hr storm depth from the map is about 4.1 inches.

The 6-hour SCS spreadsheet (Chow et. al. 1988) was used to generate a user-supplied hyetograph, based on the DDF Atlas storm depth.

Figure 14 is a screen capture of the spreadsheet tool with the 6-hr storm parameterized based upon the value in the DDF Atlas. The shaded area was added to accomplish the necessary dimensionalization (converting the dimensionless time and depth into dimensional time and depth). The check sums at the bottom of the shaded area are the total depth (actually in input value) and the maximum incremental depth reported into inches per hour.

The estimated intensity does not last for an entire hour, but is reported to provide some common comparison of input intensities for the different design storms.

Figure 15 is a plot of the SCS Storm for Concho County. The peak precipitation rate, in inches-per-hour is 2.96 inches/hour. The peak rate occurs at simulation time 2.28 hours.

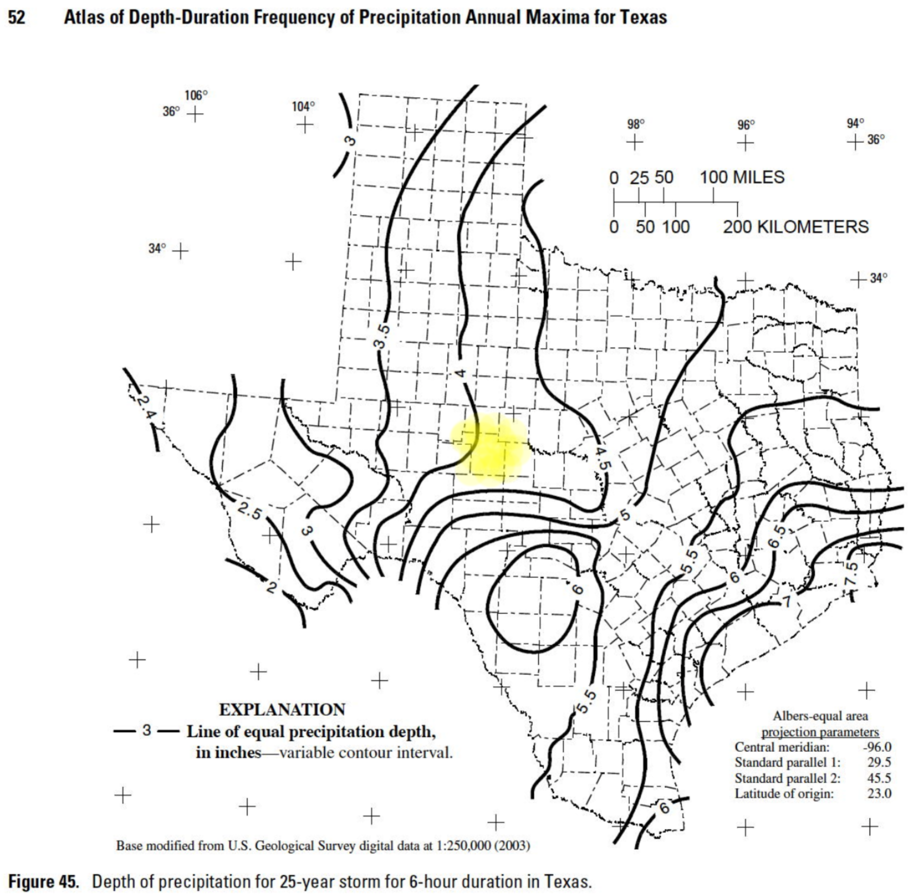
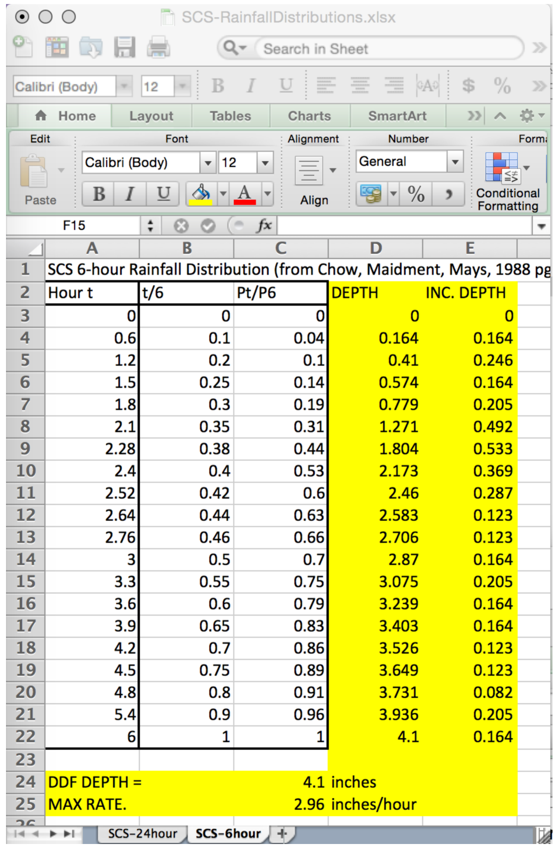


Figure 13. 25-YR, 6-HR Texas DDF Map. Concho County is the shaded area.



	A	B	C	D	E
1	SCS 6-hour Rainfall Distribution (from Chow, Maidment, Mays, 1988 pg				
2	Hour t	t/6	Pt/P6	DEPTH	INC. DEPTH
3	0	0	0	0	0
4	0.6	0.1	0.04	0.164	0.164
5	1.2	0.2	0.1	0.41	0.246
6	1.5	0.25	0.14	0.574	0.164
7	1.8	0.3	0.19	0.779	0.205
8	2.1	0.35	0.31	1.271	0.492
9	2.28	0.38	0.44	1.804	0.533
10	2.4	0.4	0.53	2.173	0.369
11	2.52	0.42	0.6	2.46	0.287
12	2.64	0.44	0.63	2.583	0.123
13	2.76	0.46	0.66	2.706	0.123
14	3	0.5	0.7	2.87	0.164
15	3.3	0.55	0.75	3.075	0.205
16	3.6	0.6	0.79	3.239	0.164
17	3.9	0.65	0.83	3.403	0.164
18	4.2	0.7	0.86	3.526	0.123
19	4.5	0.75	0.89	3.649	0.123
20	4.8	0.8	0.91	3.731	0.082
21	5.4	0.9	0.96	3.936	0.205
22	6	1	1	4.1	0.164
23					
24	DDF DEPTH =		4.1	inches	
25	MAX RATE.		2.96	inches/hour	

Figure 14. 25-YR, 6-HR SCS Design Storm for Concho County, Texas.

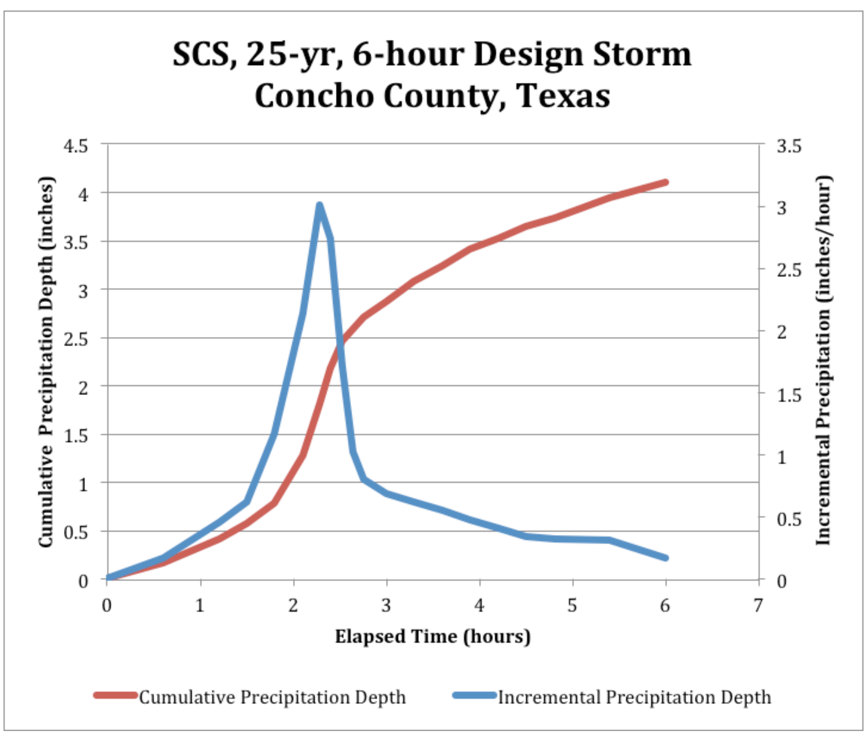
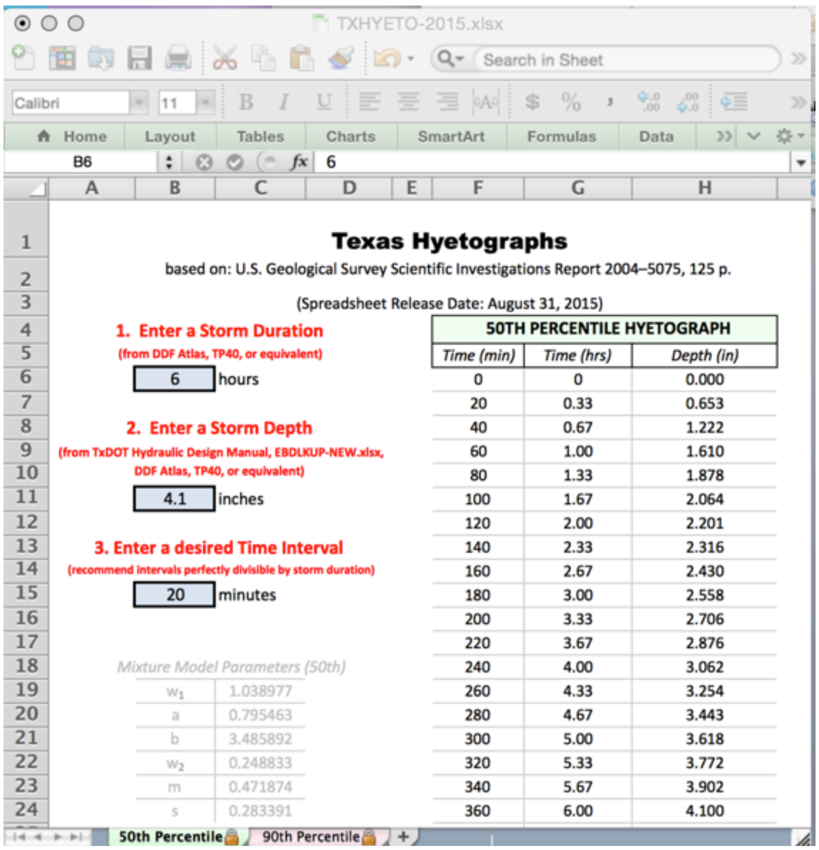


Figure 15. SCS 25-yr, 6-hr Design Storm for Concho County, Texas

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

The 25-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 20-minute time intervals for use in HEC-HMS as an additional design storm to evaluate the performance of the hydraulic structures.



TXHYETO-2015.xlsx

Texas Hyetographs

based on: U.S. Geological Survey Scientific Investigations Report 2004–5075, 125 p.

(Spreadsheet Release Date: August 31, 2015)

1. Enter a Storm Duration (from DDF Atlas, TP40, or equivalent): 6 hours

2. Enter a Storm Depth (from TxDOT Hydraulic Design Manual, EBDLKUP-NEW.xlsx, DDF Atlas, TP40, or equivalent): 4.1 inches

3. Enter a desired Time Interval (recommend intervals perfectly divisible by storm duration): 20 minutes

Mixture Model Parameters (50th)

w_1	1.038977
a	0.795463
b	3.485892
w_2	0.248833
m	0.471874
s	0.283391

50TH PERCENTILE HYETOGRAPH

Time (min)	Time (hrs)	Depth (in)
0	0	0.000
20	0.33	0.653
40	0.67	1.222
60	1.00	1.610
80	1.33	1.878
100	1.67	2.064
120	2.00	2.201
140	2.33	2.316
160	2.67	2.430
180	3.00	2.558
200	3.33	2.706
220	3.67	2.876
240	4.00	3.062
260	4.33	3.254
280	4.67	3.443
300	5.00	3.618
320	5.33	3.772
340	5.67	3.902
360	6.00	4.100

Figure 16. 25-YR, 6-HR TXHYETO-2015.xlsm Design Storm for Concho County, Texas.

Figure 16 is a screen capture of the TXHYETO-2015.xlsx worksheet for Concho Co., Texas.

Figure 17 is a screen capture of the design hyetograph based on the TXHYETO-2015.xlsx tool for Concho, Co., Texas. The peak discharge rate, in inches-per-hour is 1.44 inches/hour, and occurs at elapsed time 0.66 hours (40 minutes).

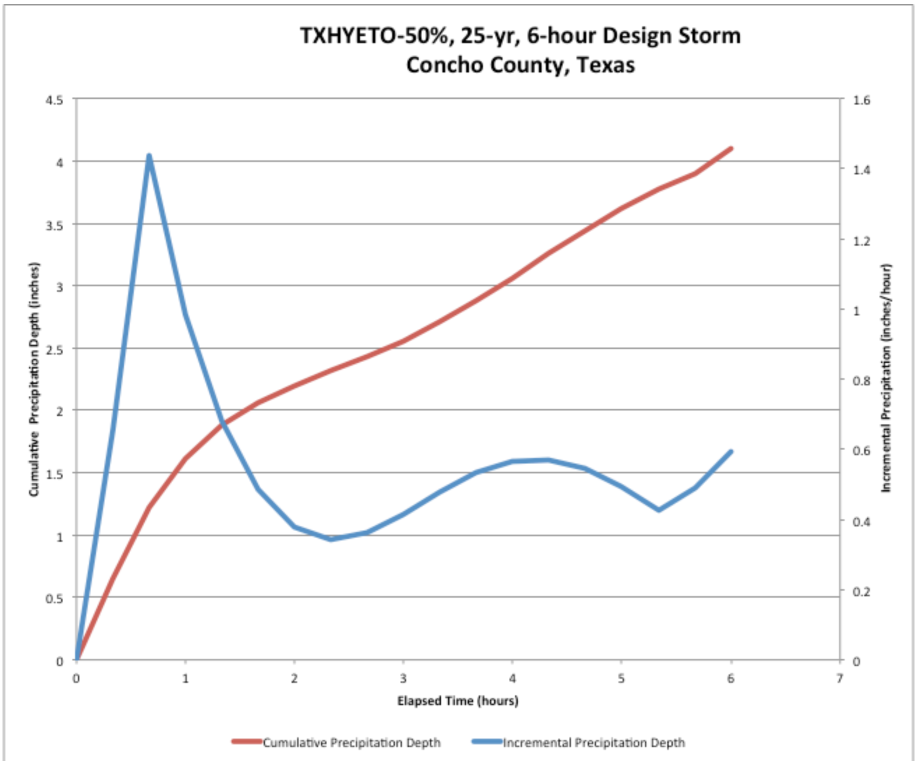


Figure 17. 25-YR, 6-HR Design Storm for Concho County, Texas.

HEC-HMS CONCEPTUALIZATION

Figure 18 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.[1]

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.

The routing elements are conceptualized as channels with width and elevation determined directly from the topographic map. The routing technique employed is the Muskingum-Cunge method and the parameters are explained in subsequent portions of the report.

[1] The crossing hydraulic structure is modeled as a reservoir with 2 or 4 culvert outlets and an overflow spillway.

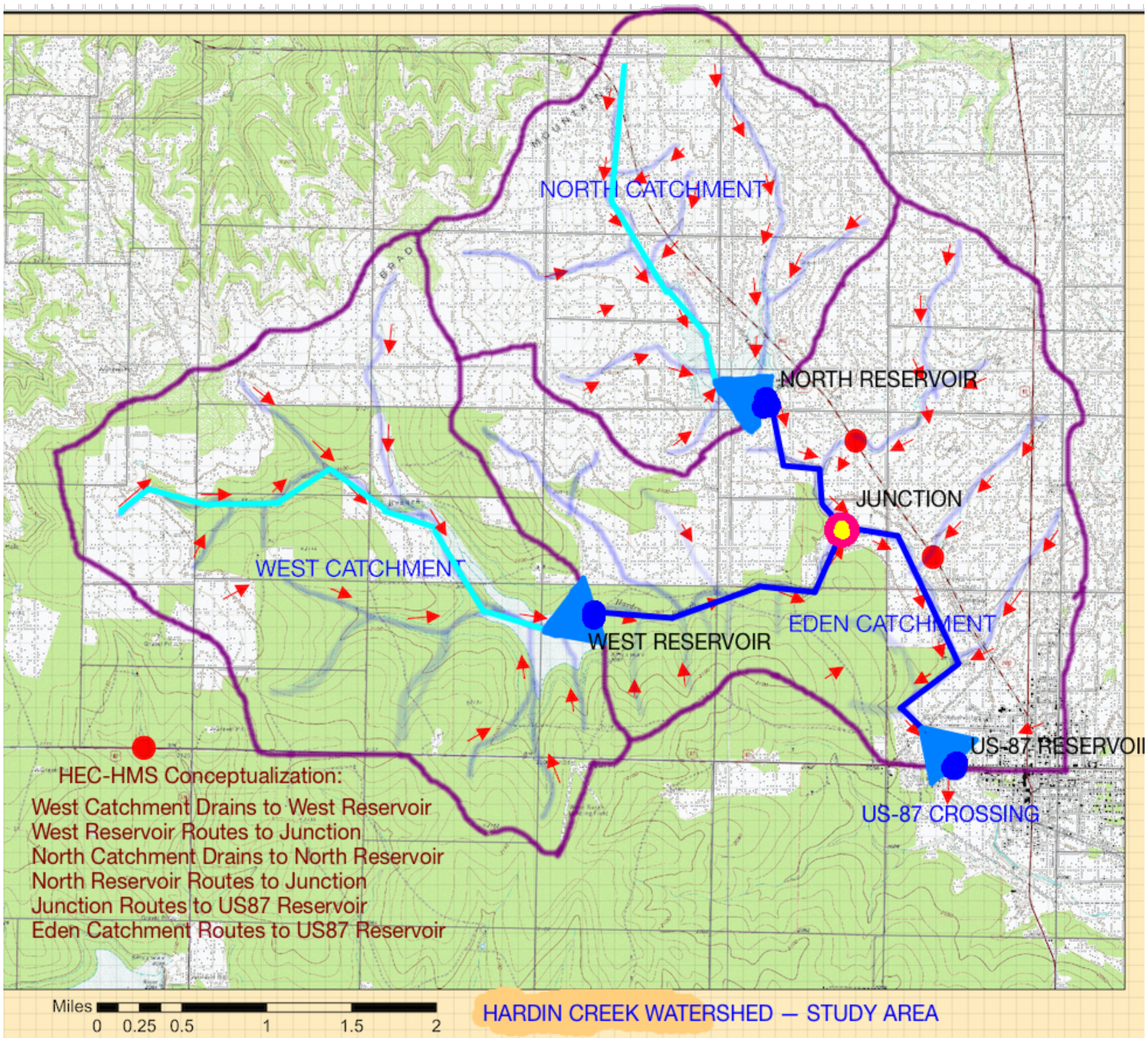


Figure 18. Hardin Creek Watershed with HEC-HMS Conceptualization Overlay

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

The West, North, and Eden catchments all have a loss model and unit hydrograph associated with them. The SCS Curve Number loss model is used, and the SCS Dimensionless Unit Hydrograph is used for the watershed response. The remaining process models available in HEC-HMS are disabled in this study.

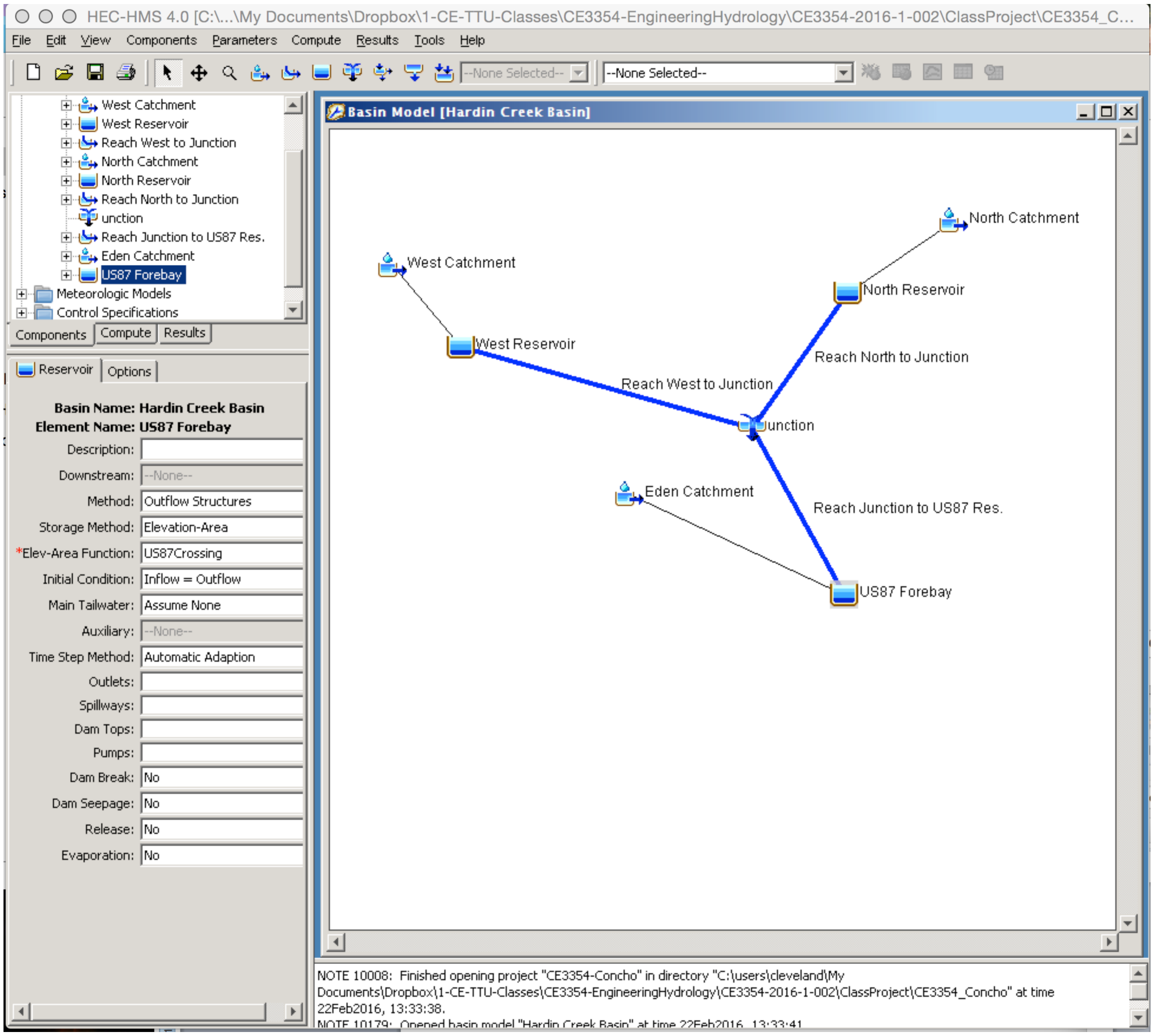


Figure 19. HEC-HMS Topology for Hardin Creek Study

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. To estimate a curve number, the hydrologic soil group type is identified, than based on land use and/or textural description the CN is estimated.

Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA 1955).

The four groups are:

1) Group A soils have low runoff potential and high infiltration rates of water transmission (greater than 0.30 in/hr).
2) Group B soils have moderate infiltration rates of water transmission (0.15- 0.30 in/hr).
3) Group C soils have low infiltration rates of water transmission (0.05-0.15 in/hr).
4) Group D soils have high runoff potential. These soils have a very low rate of water transmission (0-0.05 in/hr).

Based on the Ksat values from the Web Soil Survey results, the hydrologic soil groups for the study area are approximately 65% Group C and 35% Group D

The hydrologic condition of the study area is estimated to be GOOD. Figure 20 is an excerpt from the National Engineering Handbook relevant to the study area. The CN values for the 65% portion (Group C) of the study area is 74 and for the 35% portion (Group D) is 80.

The composite curve number for the three sub-catchments is computed using Equation 1 below:

$$CN_{comp.} = (0.65 * 74 + 0.35 * 80) = 76 \quad (1)$$

The alternate *CN* is determined using the area weighted Ksat of 0.08 inches/hour would place the entire study area as Group C soil, and the resulting value from Figure 20 is 74. The difference between the two values at the scale of the study is irrelevant; however we choose to use the larger of the two values (76) to challenge the hydraulic structure.

The Eden Catchment value was increased by considering the roughly 14% of developed area within the catchment. Its value was computed using Equation 2 below:

$$CN_{Eden} = (0.86 * 76 + 0.14 * 98) = 79 \quad (2)$$

The composite CN for each sub-basin is listed in Table 4.

Table 4. SCS Curve Numbers for Three Sub-Catchments

Sub-basin name	Area (sq. mi.)	Composite CN	Remarks
North Catchment	3.83	76	Used larger value
West Catchment	6.04	76	Used larger value
Eden Catchment	6.95	79	Reflect the developed portion.

Chapter 9 | Hydrologic Soil-Cover Complexes | Part 630 National Engineering Handbook

Table 9–1 Runoff curve numbers for agricultural lands [1] — Continued

Cover description: cover type	treatment [2]	hydrologic condition [3]	CN for hydrologic soil group: A	B	C	D
Pasture, grassland, or range-continuous forage for grazing [4]		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Meadow-continuous grass, protected from grazing and generally mowed for hay		Good	30	58	71	78
Brush-brush-forbs-grass mixture with brush the major element [5]		Poor	48	67	77	83
		Fair	35	56	70	77
		Good	30 [6]	48	65	73
Woods-grass combination (orchard or tree farm) [7]		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods [8]		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Farmstead--buildings, lanes, driveways, and surrounding lots		---	59	74	82	86
Roads (including right-of-way):						
Dirt		---	72	82	87	89
Gravel		---	76	85	89	91

Figure 20. CN Table from NEH Part 630 , Chapter 9

UNIT HYDROGRAPH MODEL

The SCS DUH was parameterized for each sub-basin: North, West and Eden, using the NRCS overland method for different cover types. The NRCS_Upland.xlsx spreadsheet 9CITE) was used to estimate the travel times for runoff in each of the three catchments.

The time from the tools is multiplied by 0.6 to produce an estimate of the basin lag time for the SCS DUH unit hydrograph model (cite source).

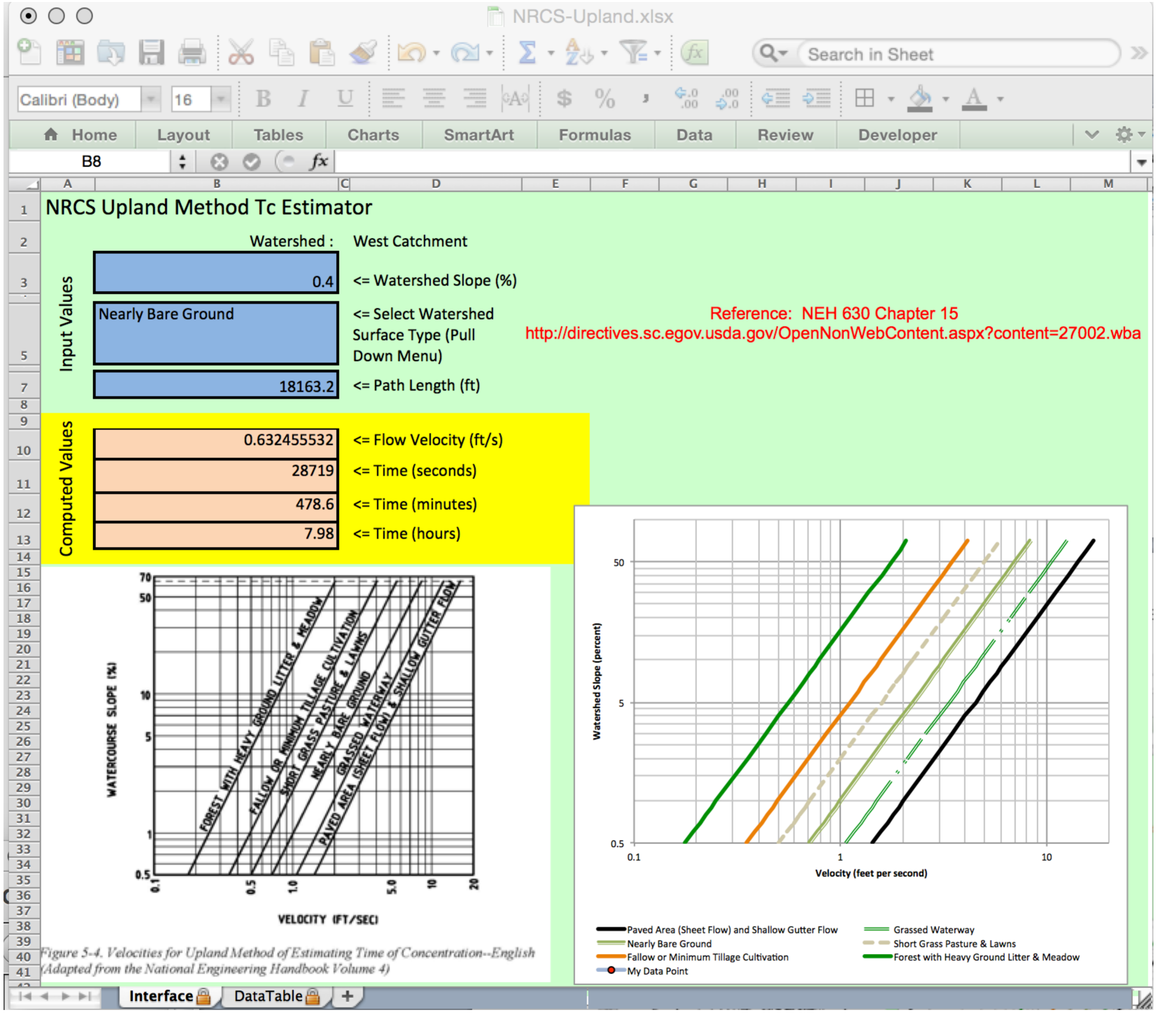


Figure 21. NRCS lag time analysis for West Catchment.

Figure 21 is a screen capture of the analysis for the West Catchment.

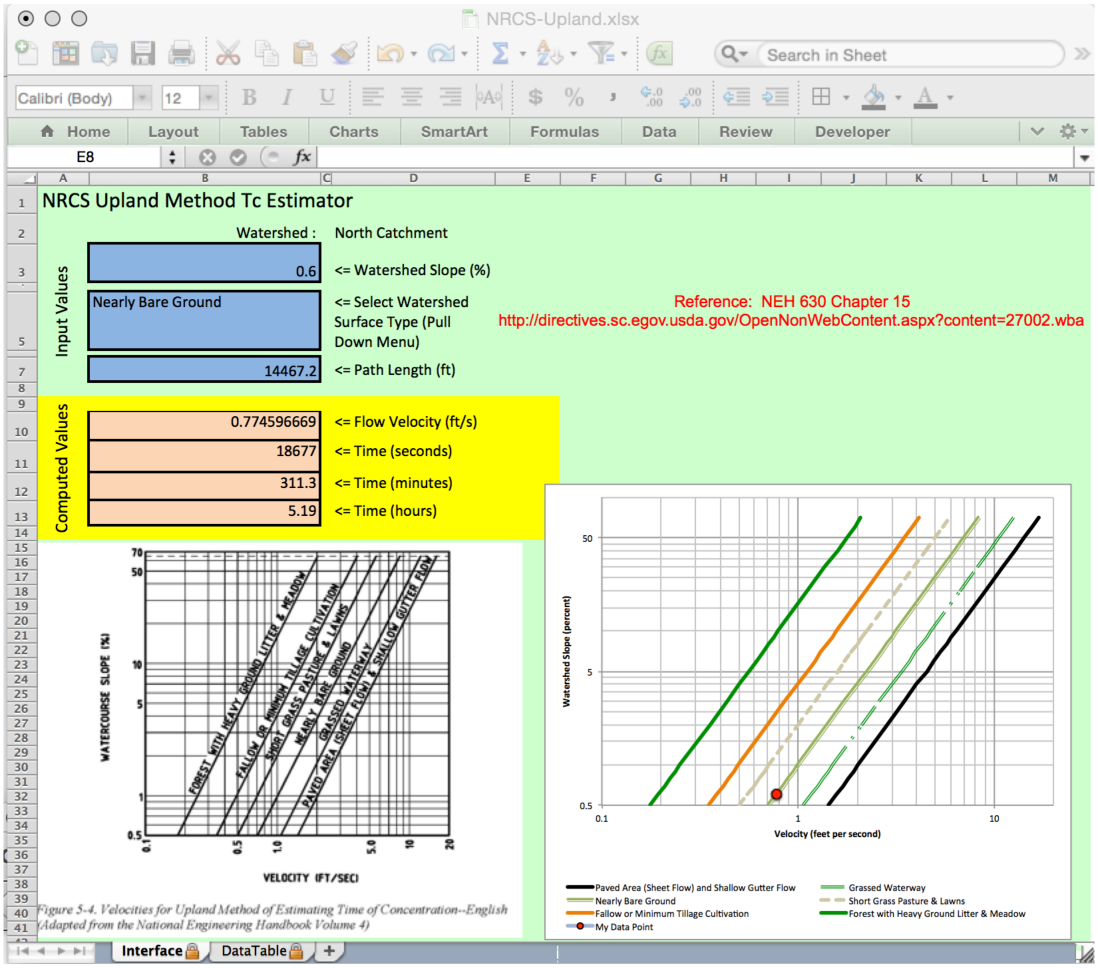


Figure 22. NRCS lag time analysis for North Catchment.

Figure 22 is a screen capture of the analysis for the North Catchment.

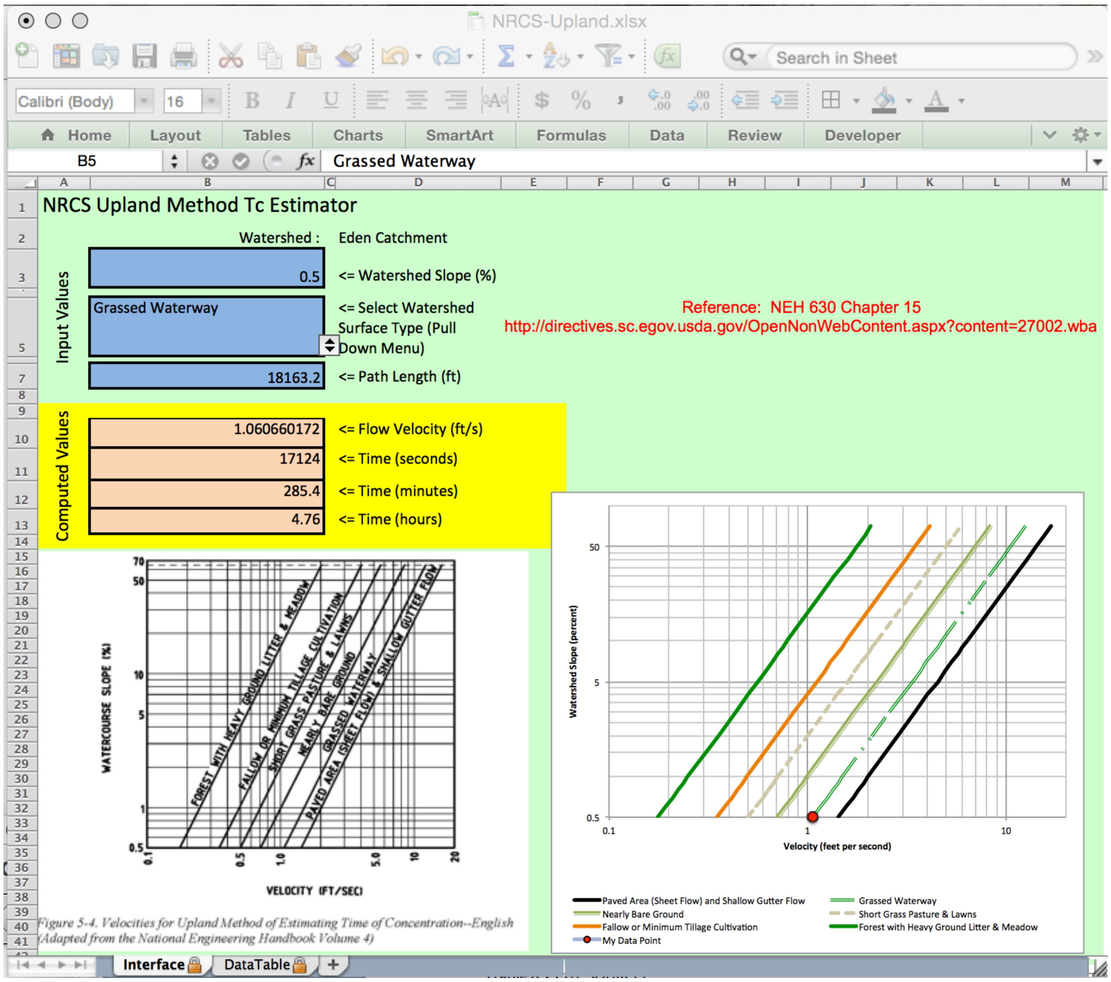


Figure 23. NRCS lag time analysis for Eden Catchment.

Figure 23 is a screen capture of the analysis for the Eden Catchment.

Table 5 is a list of the three catchments and the DUH parameters for use in the HEC-HMS program.

Table 5. Unit Hydrograph Parameters for 3 Catchments

Sub-basin name	Area (sq. mi.)	Path Length (miles)	Slope	Tc (hours)	Basin Lag (0.6*Tc) (hours)
North Catchment	3.83	2.74	~0.006	5.19	3.11
West Catchment	6.04	3.44	~0.004	7.98	4.78
Eden Catchment	6.95	3.69	~0.005	4.76	2.85

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 (CITE HEC-HMS PAGES). The three channel sections are North-to-Junction, West-to-Junction, and Junction-to-US87.

Figure 24 is a map showing the locations of cross sections used to approximate the channel geometry for three channel elements: North to the Junction, West to the Junction, and the Junction to the US 87 crossing. The junction is shown on the figure as the magenta circle – it is a modeling construct only (it is a real junction, but in HMS is simply used to hydrologicaly connect the three routing elements.

Next to each cross section are the actual measurements of elevation and distance along the cross section corresponding to each elevation. These measurements are used in HEC-HMS to construct the channel geometry for the three routing elements.

Figure 24. Cross section locations used to approximate channel geometry for Muskingum-Cunge routing in HEC-HMS

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

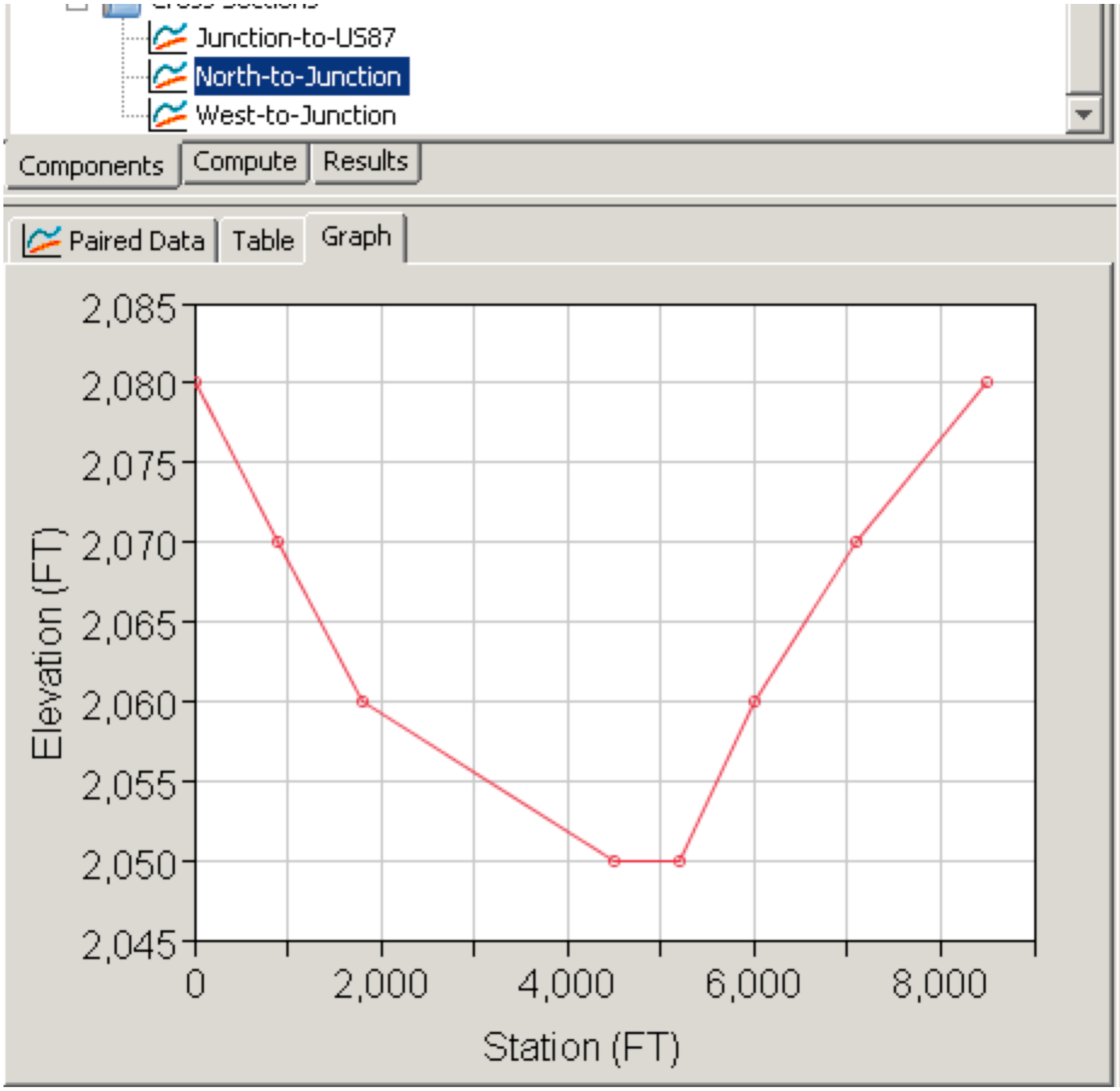


Figure 25. Cross Section for North to Junction

Section North-to-Junction is shown on Figure 25 The channel is treated as a grass-lined channel; Manning's n for the section is 0.035. The average channel slope is 0.6%. The length of the channel is XXXX feet.

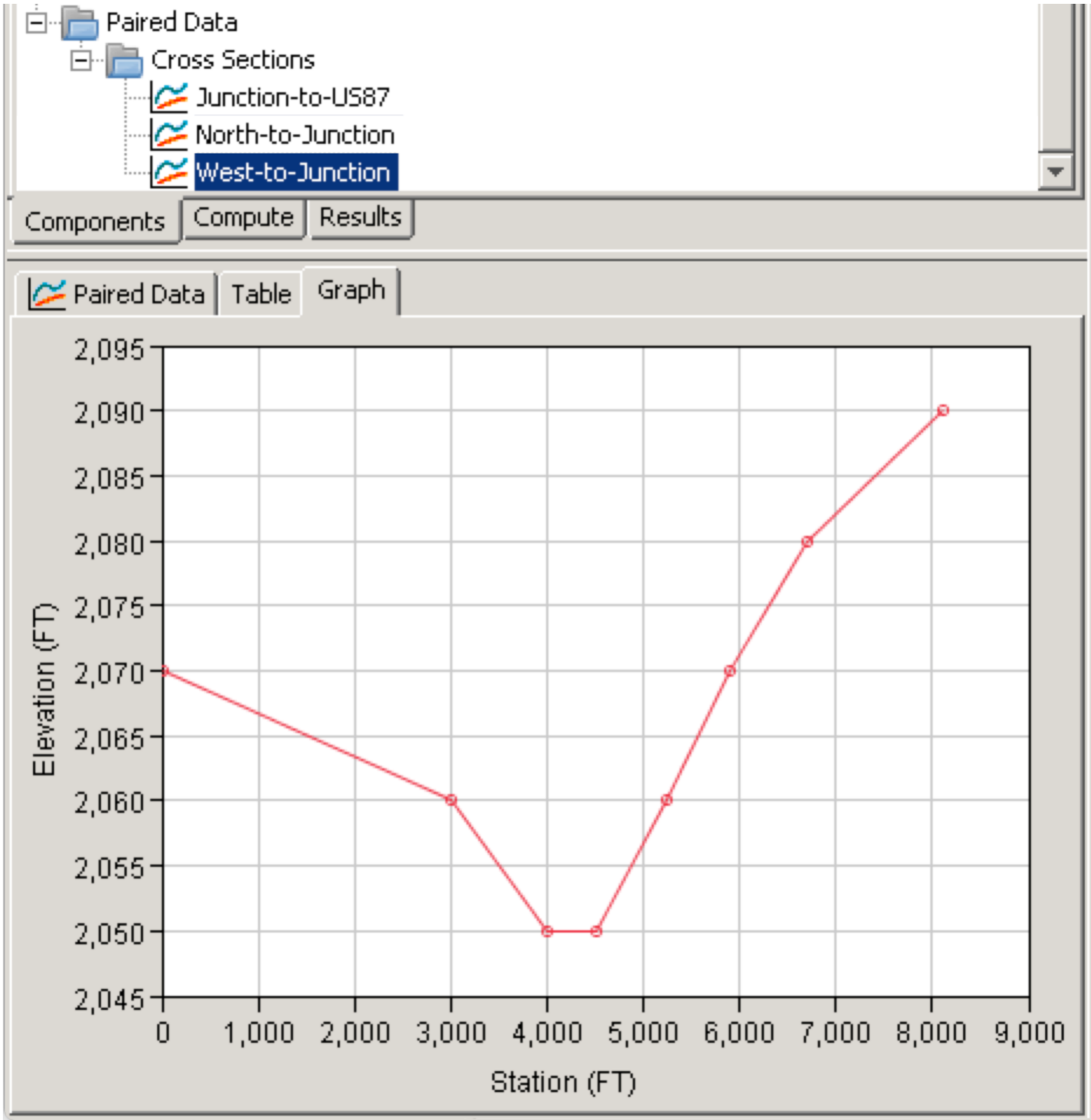


Figure 26. Cross Section for West-to-Junction

Section West-to-Junction is shown on Figure 26. The channel is treated as a grass-lined channel; Manning's n for the section is 0.035. The average channel slope is 0.4%. The length of the channel is XXXX feet.

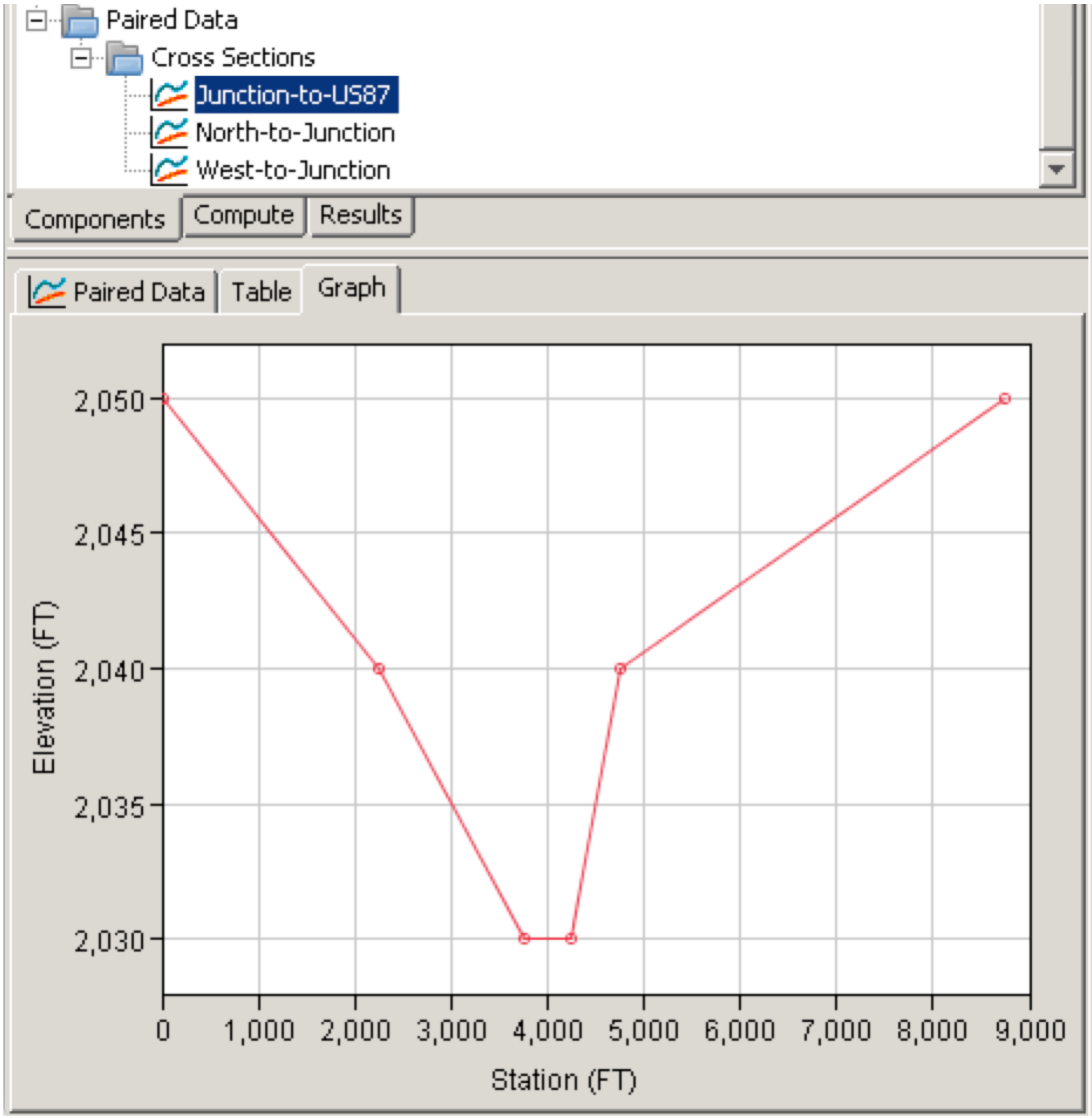


Figure 27. Cross Section for Junction-to-US87

Section Junction-to-US87 is shown on Figure 27. Section West-to-Junction is shown on Figure 26. The channel is treated as a grass-lined channel; Manning's n for the section is 0.035. The average channel slope is 0.5%. The length of the channel is XXXX feet.

RESERVOIR STORAGE ELEMENTS

The West and North Reservoirs are earth-berm type reservoirs with a riser pipe that penetrates the berm as a controlled outlet. The riser pipes are covered by a box structure with inlets. Each reservoir also has an emergency spillway about 50-feet wide that is provided to prevent overtopping at an arbitrary location possibly compromising the berm and eroding the entire structure. The emergency spillways appear on Google Earth to be earthen with large rock bottoms to resist erosion if and when they activate (carry flow).

The West reservoir has the riser inlet elevation at 2075 feet and the emergency spillway crest is at 2087 feet.

The North reservoir has the riser inlet elevation at 2065 feet and the emergency spillway crest is at 2076 feet.

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. In the HEC-HMS model this condition is specified as INFLOW=OUTFLOW initial condition.

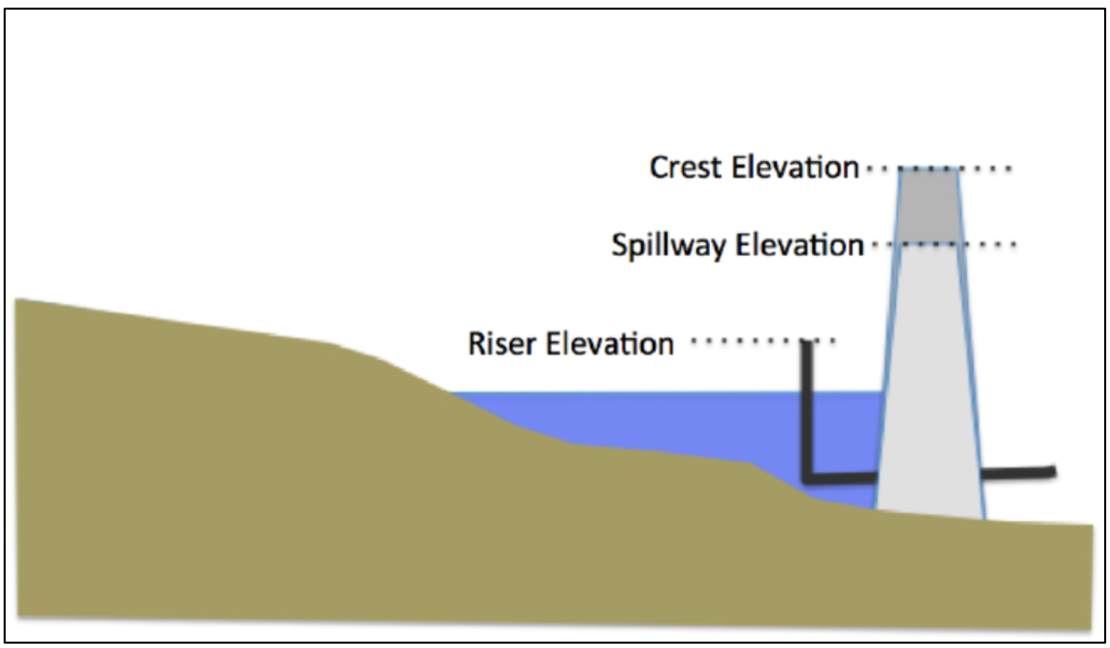


Figure 28. Schematic of Pool Depth and Outlet Features for the two SCS Reservoirs

Figure 28 is an elevation view (not to scale) sketch of the West and North reservoirs.

Elevation-area values were determined as illustrated in Figures 29-32. First a pool elevation was selected, then the surface area inundated by that elevation was determined using Acrobat Pro area measuring tools and then converted into acres. The resulting elevation-area values were then entered into HEC-HMS.

Elevation-area tables were determined for three locations: North Reservoir, West Reservoir and the US-87 Crossing (treating the roadway embankment as a dam, and the culverts as outlet structures.

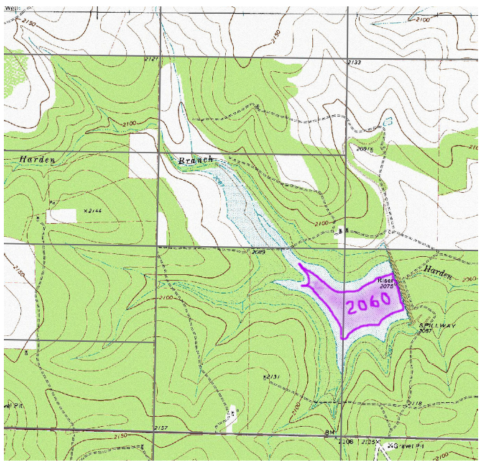


Figure 29. Pool area for West Reservoir at elevation 2060 ft.

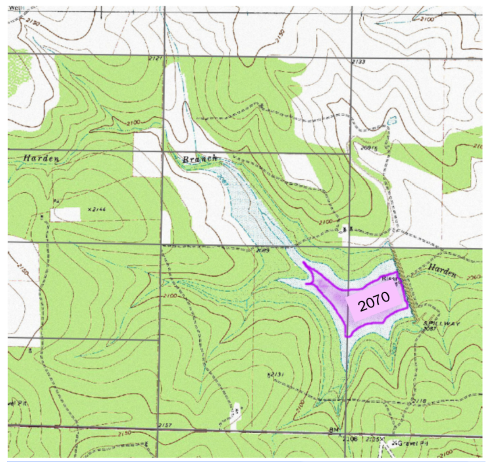


Figure 30. Pool area for West Reservoir at elevation 2070 ft.

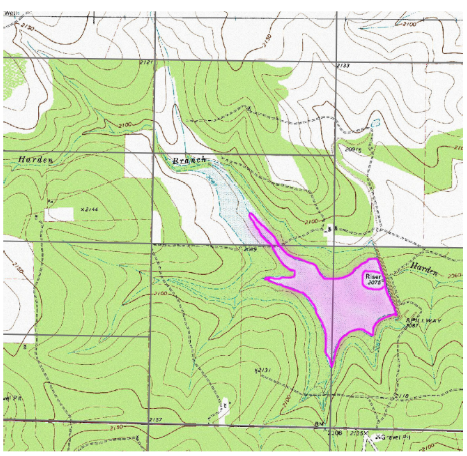


Figure 31. Pool area for West Reservoir at elevation 2075 ft.

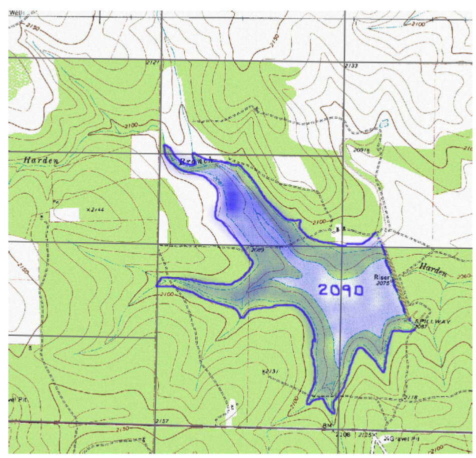


Figure 32. Pool area for West Reservoir at elevation 2090 ft.

NORTH RESERVOIR ELEVATION-AREA TABLE

The North reservoir elevation-area table was determined in a fashion described above – different elevations were selected, then the pool area behind the berm at that elevation was determined using Acrobat Pro Measuring Tools.

Table 6. North Reservoir Elevation-Area Data

North Reservoir Elevation-Area	
Pool Elevation (feet)	Surface Area (acres)
2055	0.00
2065	61.44
2070	115.2
2076	192.0

Table 6 lists the pool elevation in feet and associated inundated area in acres.

Discharge from the reservoir is computed using HEC-HMS outlet structures. The two structures are an orifice outlet and a spillway. The relevant values are shown in Figures 33 and 34.

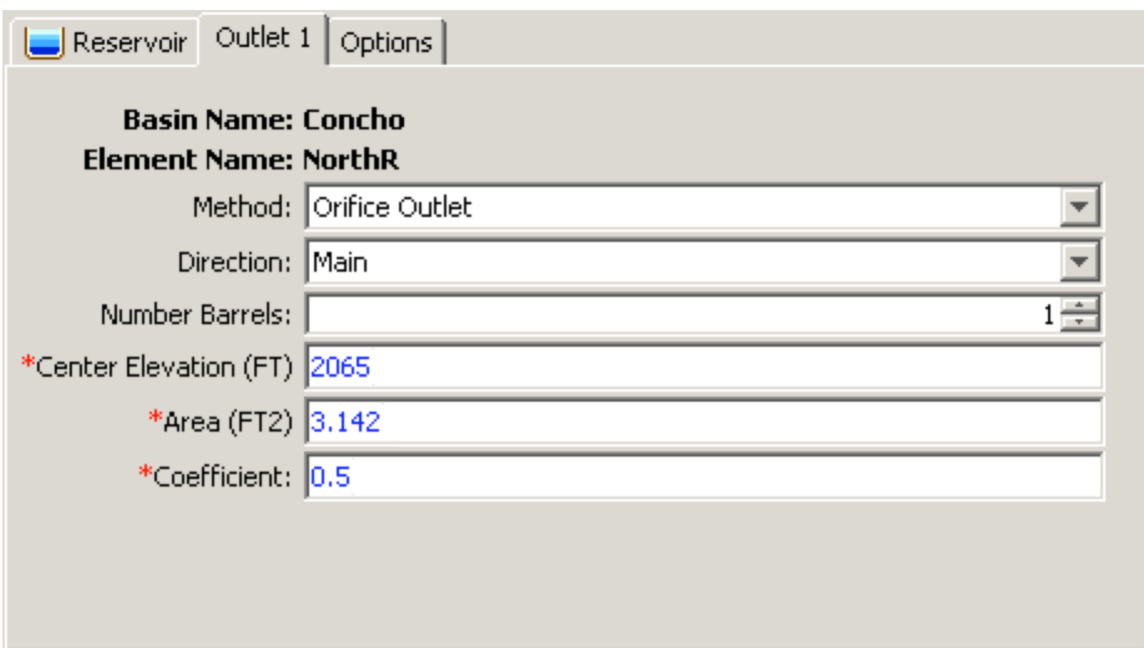


Figure 33. North Reservoir Orifice Outlet Specifications

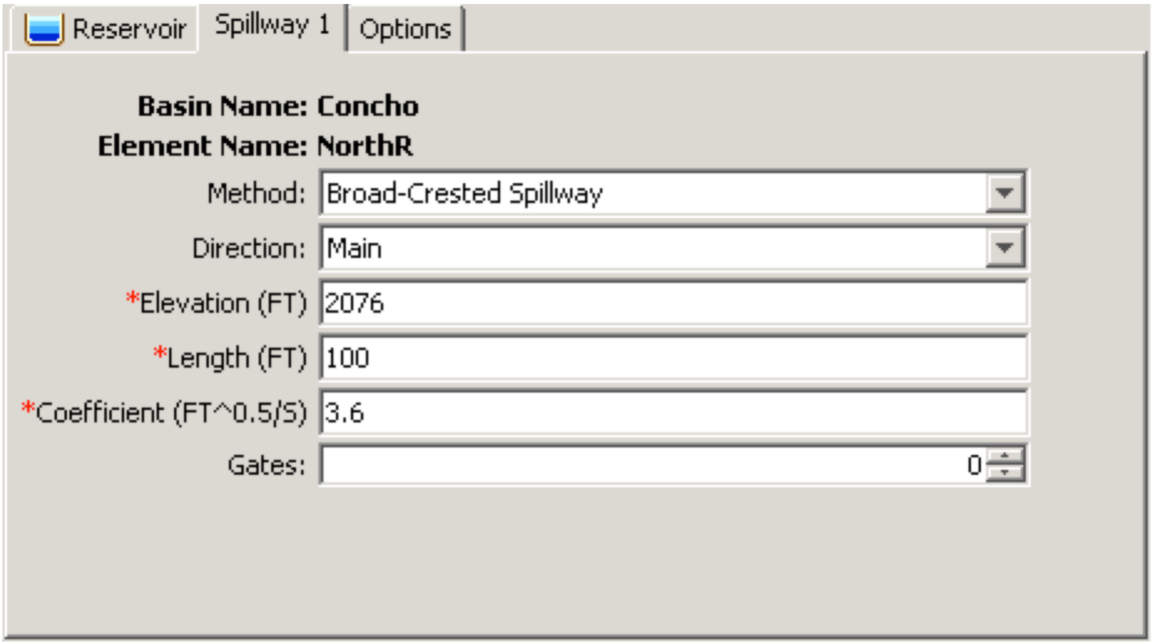


Figure 34. North Reservoir Emergency Spillway Specification

WEST RESERVOIR ELEVATION-AREA TABLE

The West reservoir elevation-area table was determined in a fashion described above – different elevations were selected, then the pool area behind the berm at that elevation was determined using Acrobat Pro Measuring Tools.

Table 7. West Reservoir Elevation-Area Data

West Reservoir Elevation-Area	
Pool Elevation (feet)	Surface Area (acres)
2065	0.00
2075	115.20
2080	235.52
2087	329.60

Table 7 lists the pool elevation in feet and associated inundated area in acres.

Discharge from the reservoir is computed using HEC-HMS outlet structures. The two structures are an orifice outlet and a spillway. The relevant values are shown in Figures 35 and 36.

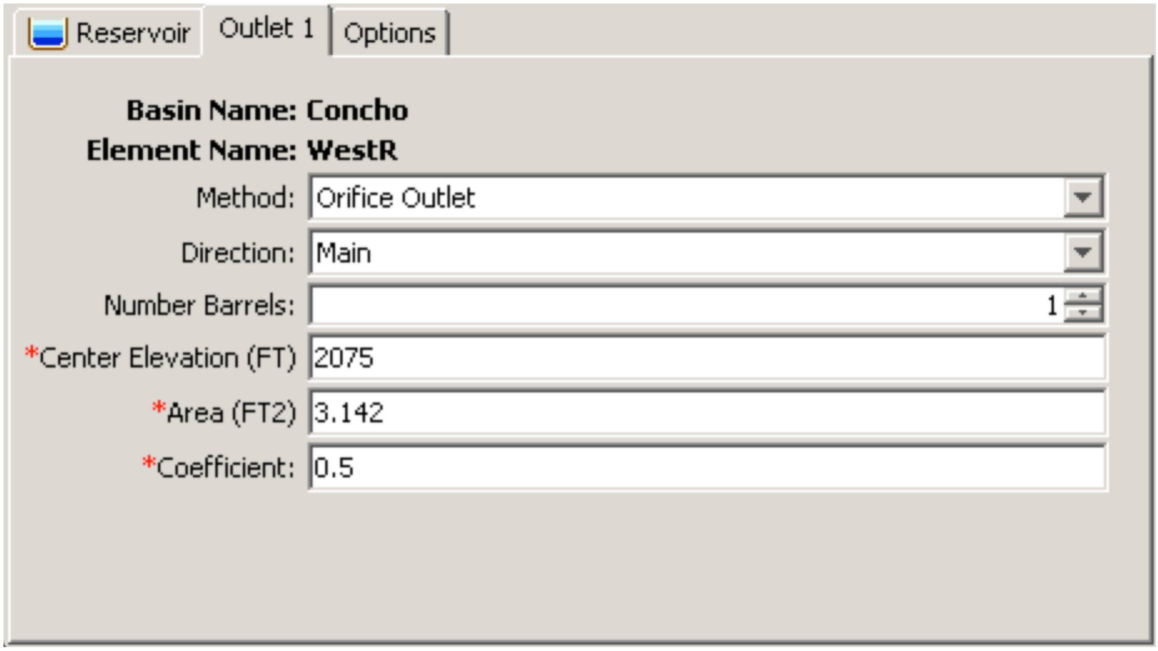


Figure 35. West Reservoir Orifice Outlet Specification

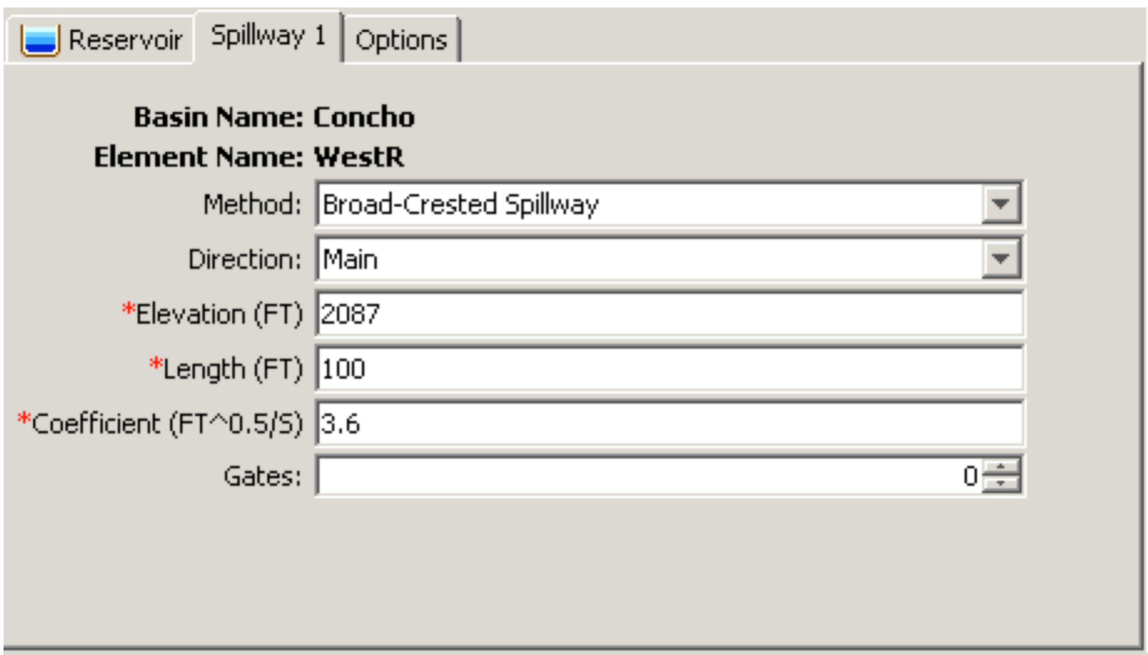


Figure 36. West Reservoir Emergency Spillway Specification

US-87 RESERVOIR ELEVATION-AREA TABLE

Figure 37 is s cross-section view looking downstream at the US-87 Crossing (US-87 Reservoir Outlet) with the existing 2-barrel system depicted. The road profile is the grey region that slopes down to the top of the culverts then back up.

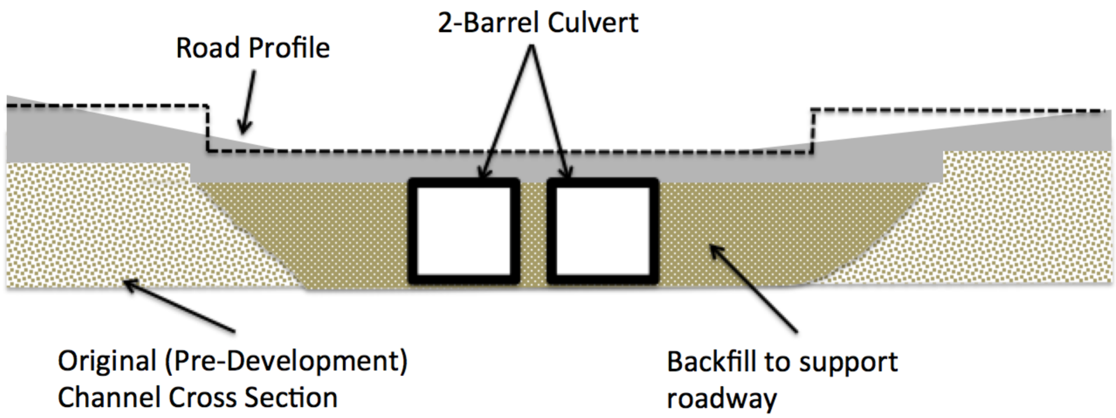


Figure 37. Existing 2-Barrel Culvert System

Figure 38 is s cross-section view looking downstream at the US-87 Crossing (US-87 Reservoir Outlet) with the proposed 4-barrel system depicted.

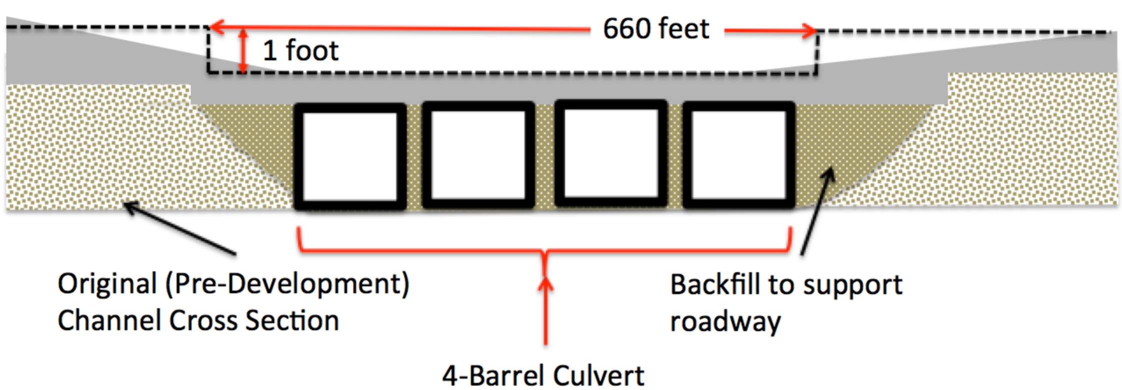


Figure 38. Proposed 4-Barrel Culvert System

Figure XX is a side –view of the roadway crossing showing the embankment and the culvert system, along with the elevations of the upstream end of the culvert, the top of the culvert, and the roadway elevation.

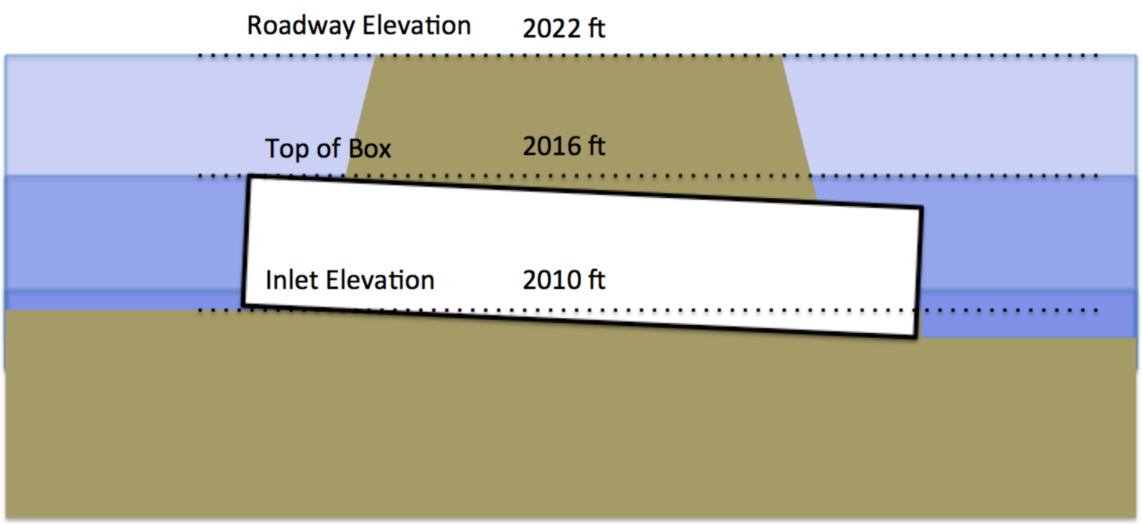


Figure 39. Elevation View of Culvert through Embankment

The US-87 Forebay reservoir elevation-area table was determined in a fashion described above – different elevations were selected, then the pool area behind the berm at that elevation was determined using Acrobat Pro Measuring Tools.

Table 8. Elevation-Area for US87 Crossing

US-87 Forebay Elevation-Area	
Pool Elevation (feet)	Surface Area (acres)
2010	0.00
2020	3.29
2030	115.00

Table 8 lists the pool elevation in feet and associated inundated area upstream of the culvert in acres.

Discharge from the culvert is computed using HEC-HMS outlet structures. The two structures are culvert outlet and a spillway. Figure XX shows the 2-barrel culvert specifications. To simulate the 4-barrel system, the number of barrels is changed and the program run again.

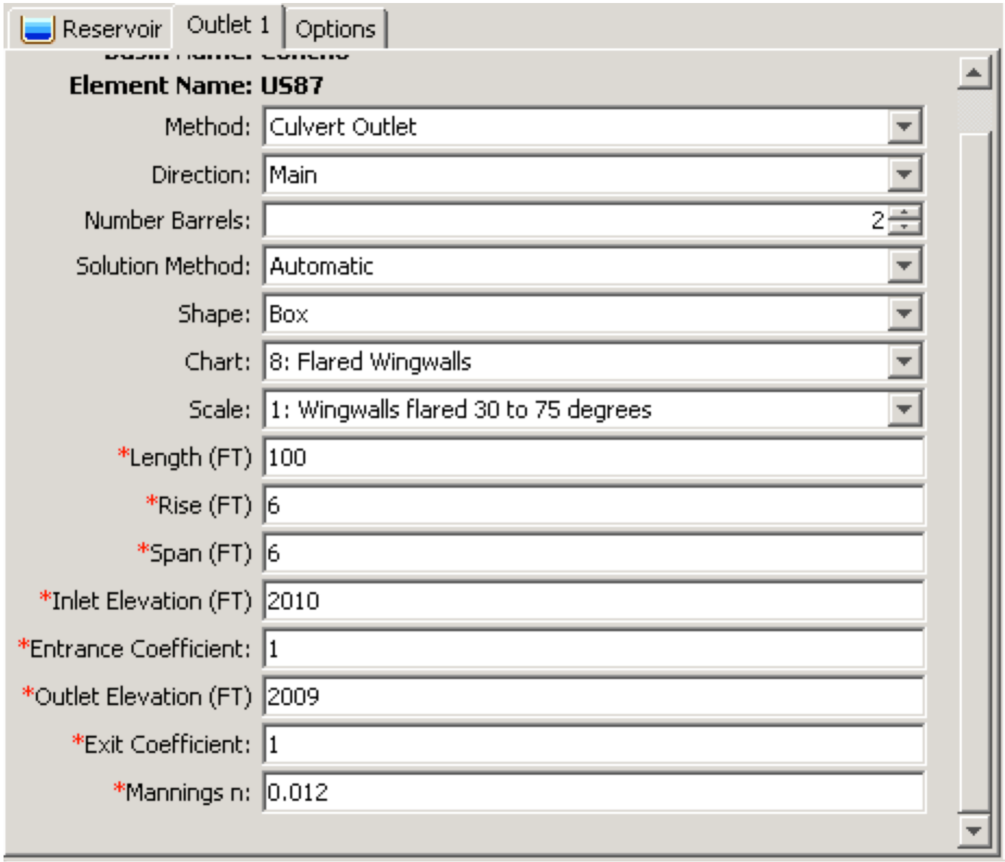


Figure 40 US-87 Outlet Culvert(s). 2-Barrel 6X6

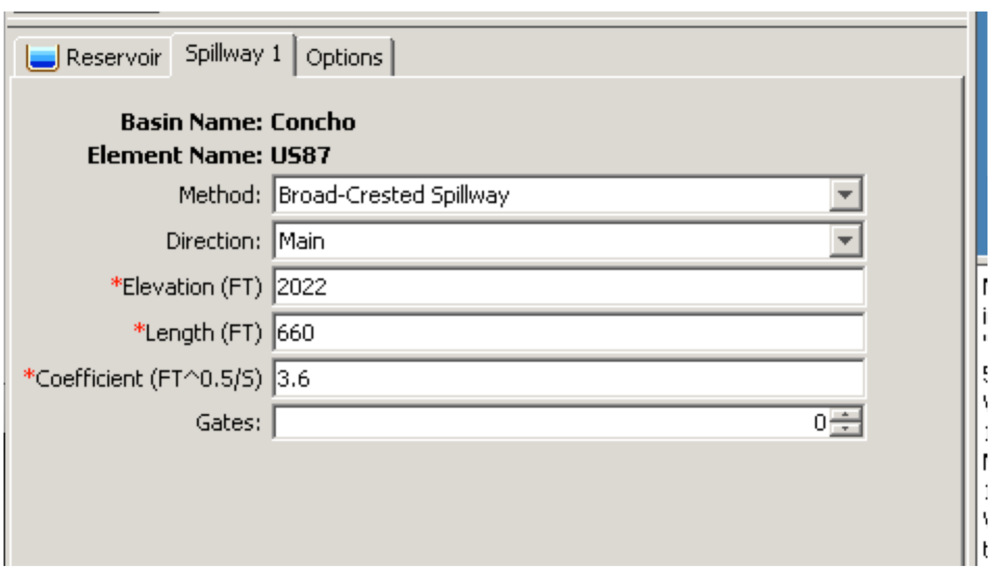


Figure 41. US-87; 660 feet treated as spillway to simulate flow over road.

RESULTS

The HEC-HMS representations of the system were run using the different design storms to determine discharge at the US-87 crossing and the pool elevation in the US-87 Forebay is used as the proxy for water surface elevation in the vicinity of the stream crossing.

EXISTING CONDITION

Figure XX is a screen capture of the HEC-HMS run for the 2-barrel system using an SCS 24 hour, Type II design storm.   The pool elevation at the peak is 2022.6 feet, which is 0.6 feet (7.2 inches) above the road – while this depth is passable for most vehicles, if the water is turbid, then vehicles would have difficulty seeing the road; if the water is moving, this is sufficient depth to present a hazard to vehicles.

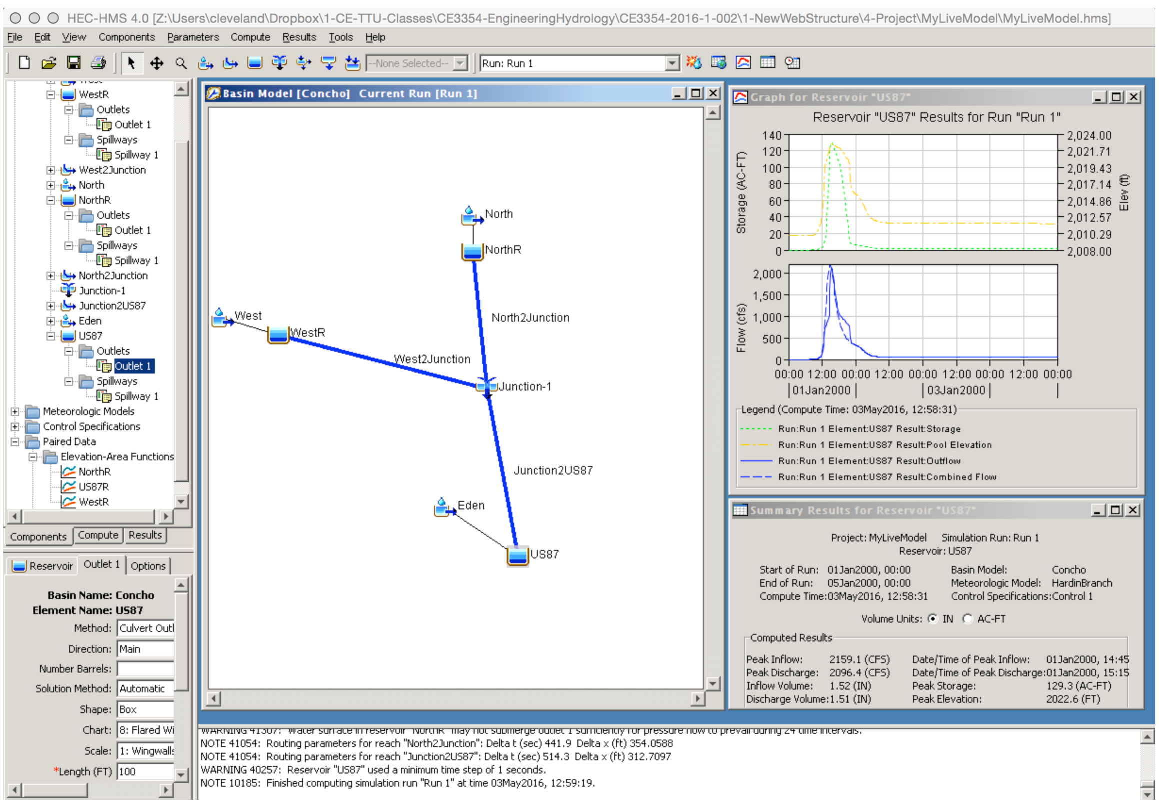


Figure 42. Screen Capture HEC-HMS Run for Existing Conditions, 24-hour SCS Type II Design Storm.

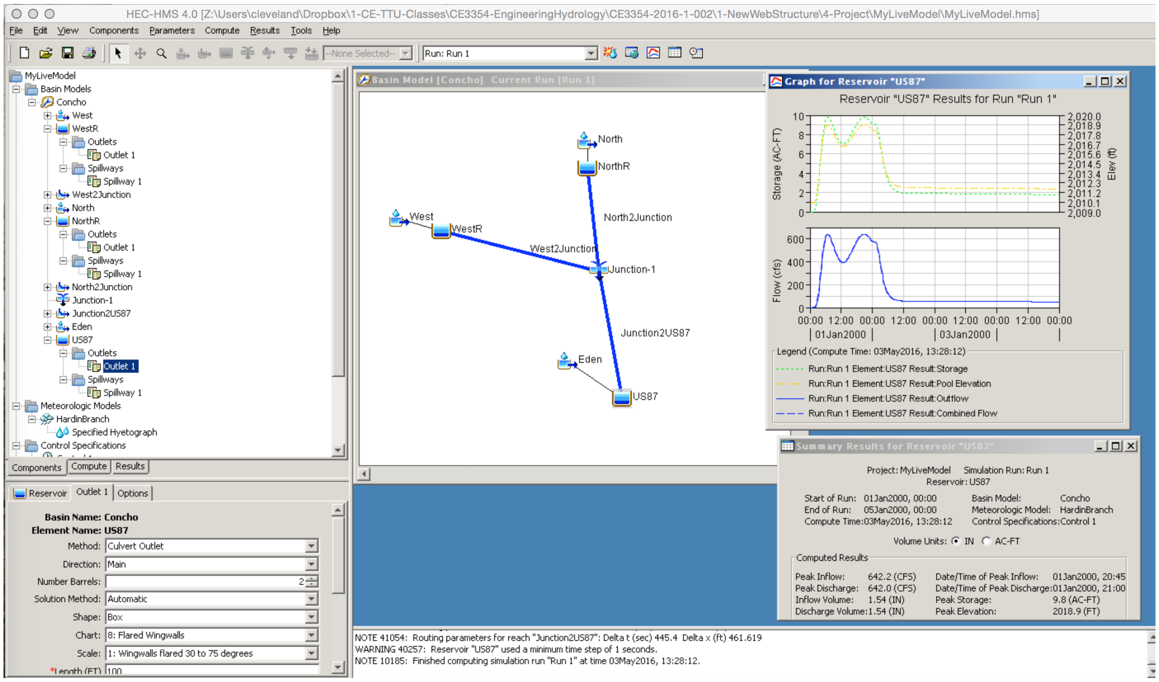


Figure 43 Screen Capture of HEC-HMS Run for Existing Conditions using TxHETO 50yr, 24hr Design Storm

Figure XX is a screen capture of the HEC-HMS run for the 2-barrel system using a TxHYETO 24 hour, design storm. The pool elevation at the peak is 2018.9 feet, which is below the road.

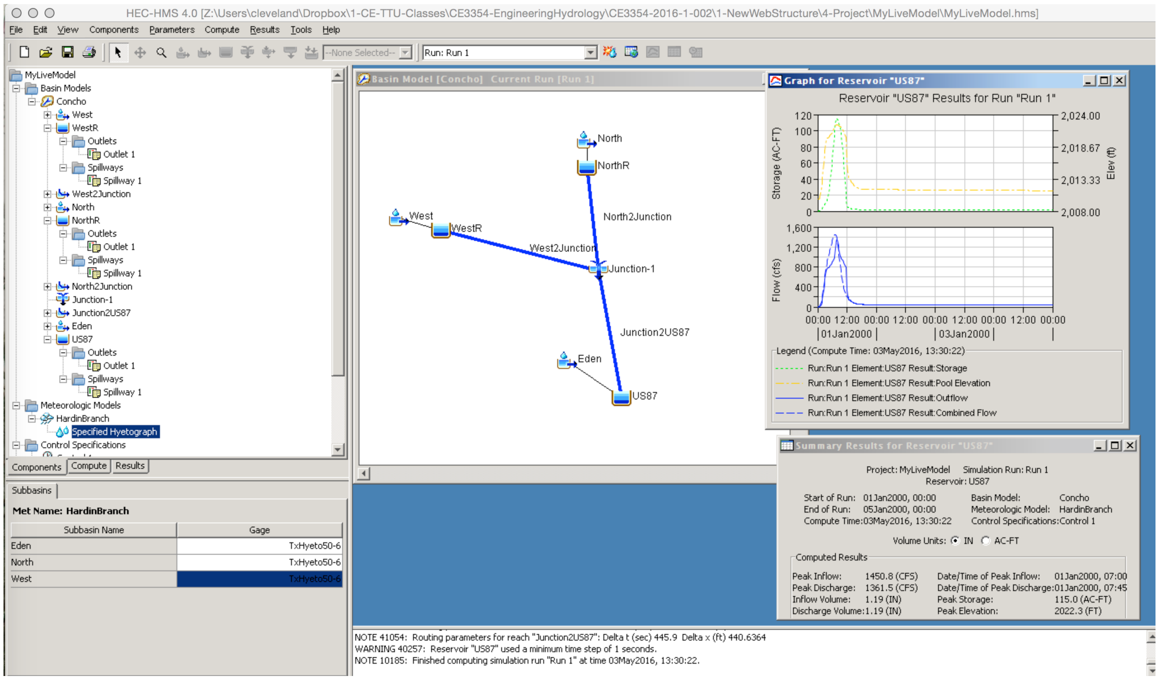


Figure 44. Screen Capture of HEC-HMS Run for Existing Conditions using TxHYETO 50yr, 6hr Design Storm.

Figure XX is a screen capture of the HEC-HMS run for the 2-barrel system using a TxHYETO 6 hour, design storm. The pool elevation at the peak is 2022.3 feet, which is 0.3 feet (3.6 inches) above the road.

PROPOSED CONDITION

Figure XX is a screen capture of the HEC-HMS run for the 4-barrel system using an SCS-24 hour Type II design storm. The pool elevation at the peak is 2021.3 feet, which is 0.7 feet (8.4 inches) below the road; hence the roadway would still be in service.

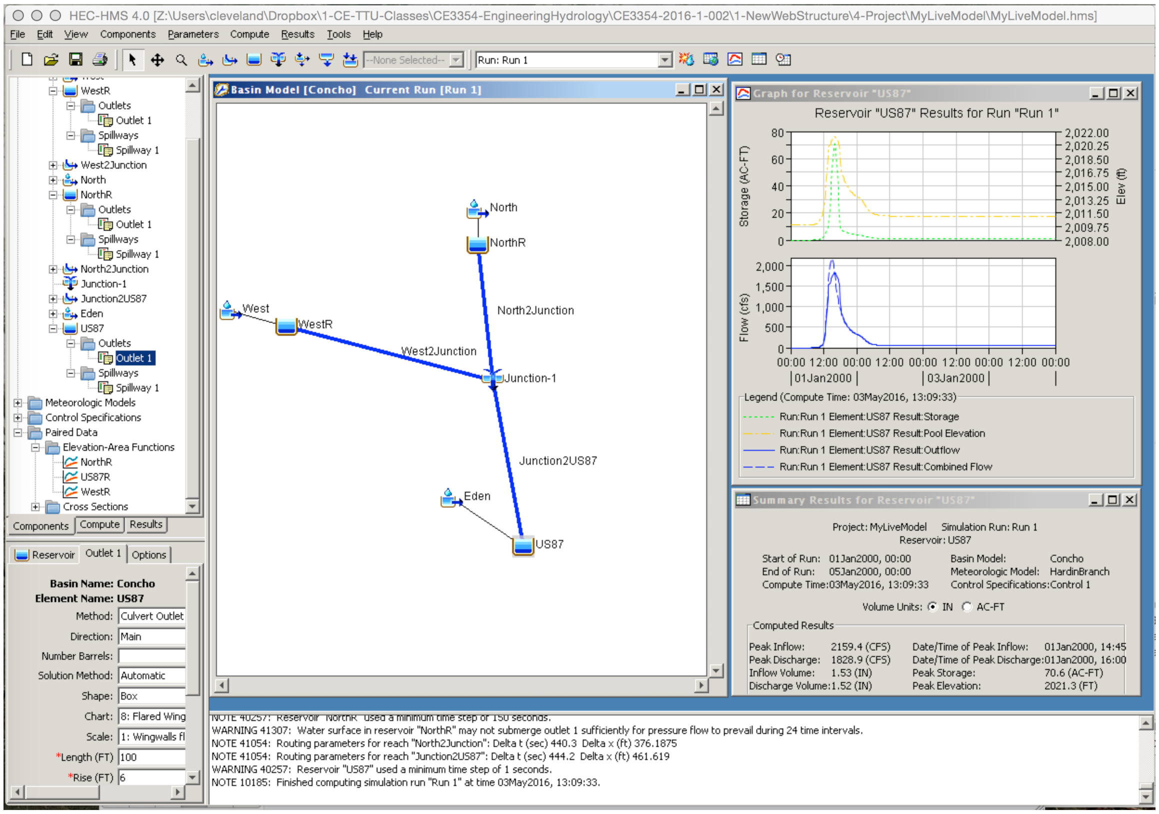


Figure 45. Screen Capture of HEC-HMS Run for Proposed Conditions 24-hour SCS Type II Design Storm

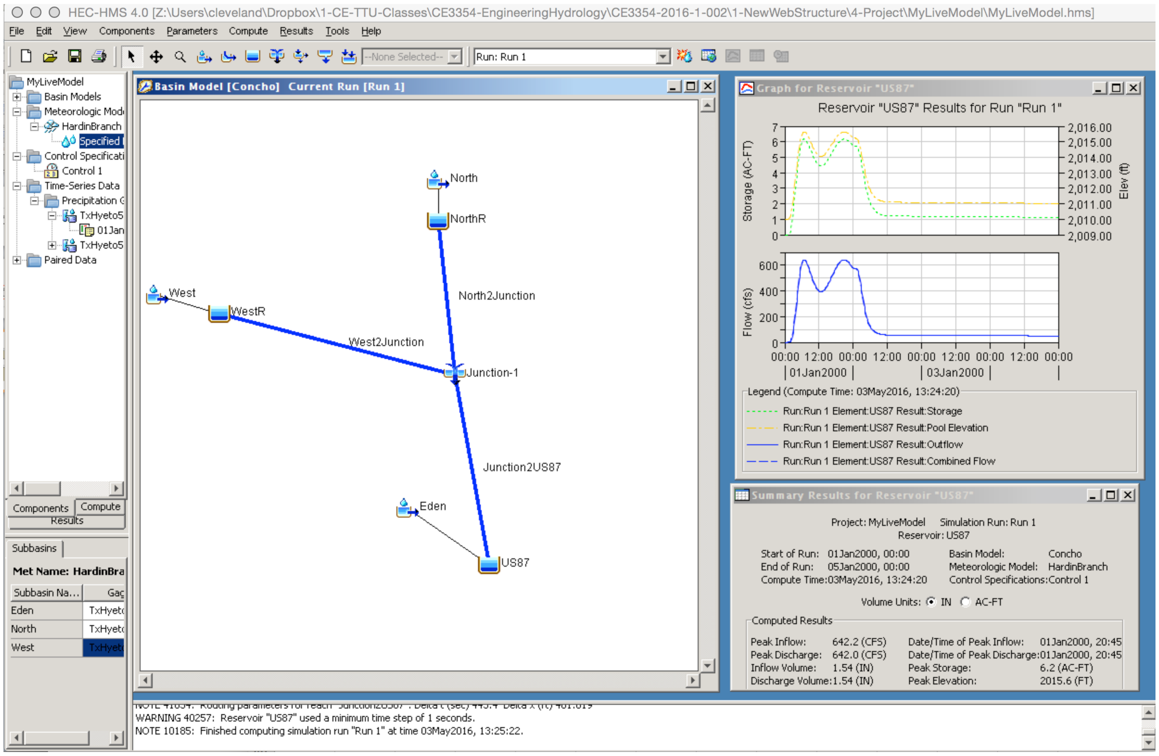


Figure 46. Screen Capture of HEC-HMS run for proposed conditions using TxHYETO 50-yr, 24-hr Design Storm

Figure XX is a screen capture of the HEC-HMS run for the 4-barrel system using an TxHYETO 50-yr, 24-hr design storm. The pool elevation at the peak is 2015.6 feet, which is well below the road; hence the roadway would still be in service.

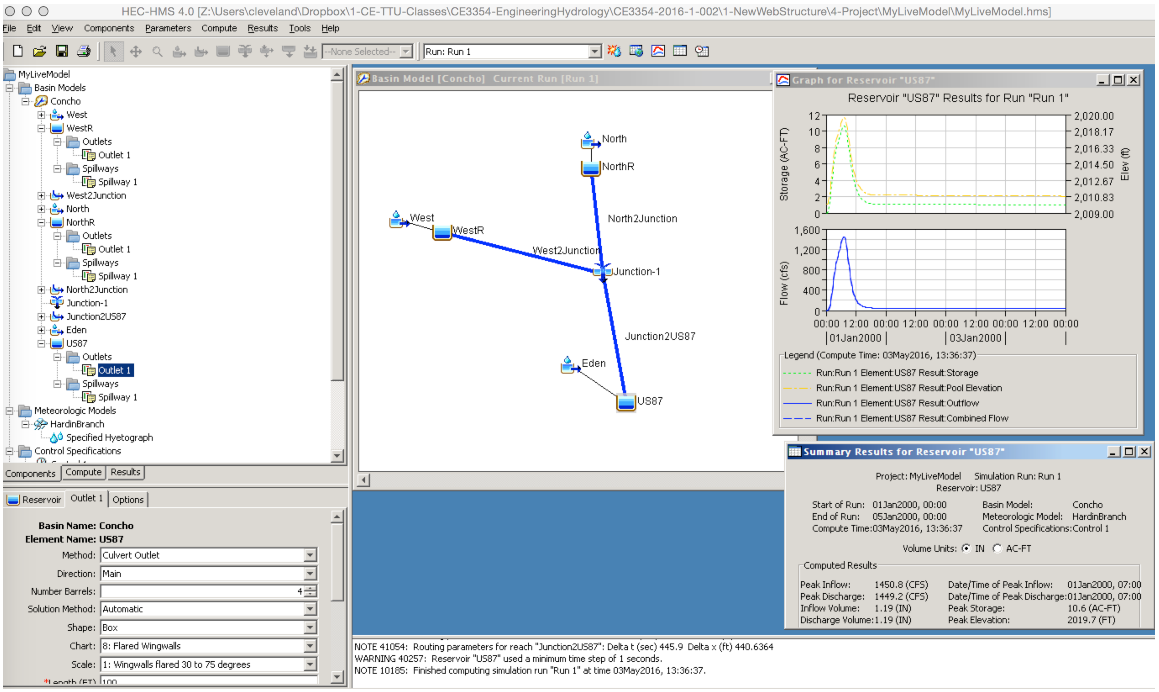


Figure 47. Screen Capture of HEC-HMS run for proposed conditions using TxHYETO 50-yr, 6-hr Design Storm

Figure XX is a screen capture of the HEC-HMS run for the 4-barrel system using an TxHYETO 50-yr, 6-hour design storm. The pool elevation at the peak is 2019.7 feet, which is below the road; hence the roadway would still be in service.

INTERPRETATION OF RESULTS

The proposed conditions convey the estimated discharge through the culvert system without inundating the road, whereas the existing system must pass water over the road to accommodate the discharges. Hence the addition of two additional barrels is justifiable in that the system will remain in service for storms of magnitudes less that the design storm.

Table 9. Peak Pool Elevations at Culvert for Different Design Storms

Condition	Storm	Peak Elevation	Flow Over Road
Existing	SCS Type II	2022.6	Yes
Existing	TxHYETO-24hr	2018.9	No
Existing	TxHYETO-6hr	2022.3	Yes
Proposed	SCS Type II	2021.3	No
Proposed	TxHYETO-24hr	2015.6	No
Proposed	TxHYETO-6hr	2019.7	No

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The existing conditions convey the estimated discharge through the culvert system only for a TxHYETO 24 hour design storm, whereas the other two design storms used require flow over the road to accommodate the discharge.

The proposed (4-barrel) system conveys the design storms without inundating the road, Hence the addition of two additional barrels is recommended so that the system will remain in service for storms of magnitudes less that the design storms.

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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 ✓

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