SECTION 1

INTRODUCTION AND SUMMARY OF CONLCUSIONS

PURPOSE OF THIS REPORT

Orange County Drainage District (OCDD) authorized Dodson & Associates, Inc. to study Cow Bayou Watershed. The purpose of the study was to develop hydrologic and hydraulic computer models for the watershed in order to analyze existing conditions, develop existing conditions floodplain, establishment of drainage criteria and methodology review guidelines, and to develop a plan of improvements addressing specific problems and areas identified by Orange County Drainage District officials to be implemented within the watershed over the extended future. These efforts have been coordinated with Fittz & Shipman (F&S), who was the engineering and surveying firm originally working on the study. The following sections of the report describe the results of hydrologic and hydraulic analyses of current and proposed conditions in the Cow Bayou Watershed.

BACKGROUND INFORMATION

The Cow Bayou Watershed covers about 180 square miles in Orange, Jasper, and Newton counties. The watershed drains primarily from north to south, with the headwaters located in the community of Buna and the outfall into the Sabine Lake in Bridge City. The western and eastern limits of the watershed are roughly Vidor and Mauriceville, respectively. Exhibit 1 illustrates the location and the approximate watershed and county boundaries, major roads, and the various communities in this area. The watershed is approximately 32.5 miles long and 8 miles wide. Many areas within the watershed are frequently inundated with floodwaters. The current effective flood insurance study for this watershed is limited to computations performed for only the main channels south of I-10, which was dated in the early 1960’s. The Orange County Drainage District, and the Texas Water Development Board (TWDB) jointly fund this study.

The Orange County Drainage District should remember that this study is conceptual in nature and a preliminary engineering study will be required in order to develop a final design. Also, many of the studied stream’s tops of banks are higher than the surrounding natural ground elevations. Therefore, although the computed water surface elevations (CWSEL) may be lower than the top of bank elevations there is a possibility that the surrounding areas may not be able to drain into the system because of this situation.

STORMWATER MANAGEMENT PURPOSE and POLICY

One of the goals of this study was to develop a storm water management policy that would apply to all areas within Orange County Drainage District jurisdiction.

PURPOSE AND POLICIES

Storm water management is an essential component of community infrastructure and serves to provide both increased convenience and protection of lives and property. A properly designed system will detain and/or carry away runoff from more frequent rainfall events while allowing the movement of vehicles to homes and businesses. Such a system will also detain and/or drain storm waters from an infrequent "extreme rainfall" event so that habitable structures are not damaged and major streets are passable to public safety vehicles.

Providing Orange County Drainage District with an effective storm water management system that allows sustainable community growth is a continuing challenge. It involves setting minimum standards, planning for future detention basins and drainage channels, working with private development interests, coordinating with governmental agencies, and maintaining the efficiency of the existing system.

Recognizing that storm water system development should be guided by adopted policies and criteria the OCDD launched a planning process aimed at setting consistent standards responsive to the needs of property developers and design engineers and compliant with federal, and state regulations. Orange County Drainage District has developed a comprehensive ***Drainage Criteria Manual which*** applies to all areas within the District's jurisdiction.

"Issue Pyramid"

Organized in a "pyramid" hierarchy, this document addresses a number of important ***Issues, Goals, Objectives, and Policies.***

Each successive level of an ***"Issue Pyramid"*** supports the next. The various levels are described as follows:

Issue: A broad area of consideration that determines the community standard.

Goal: The community's aspiration on a particular issue.

Objective: A performance measure toward the achievement of a goal.

Policy: A plan or course of action, intended to influence decisions and actions.

"ISSUE PYRAMID"

Criteria:

More detailed requirements on the analysis and design of storm water system components, and operating procedures, are defined as ***Criteria*** and are provided in the District's "*Drainage Criteria Manual.*" These more detailed requirements are consistent with and support the policies herein. Therefore, criteria are defined as technical or procedural standards that implement policies.

ISSUE: DRAINAGE

GOAL 1: PRESERVE PUBLIC SAFETY

OBJECTIVE 1.1.: MINIMIZE THE POTENTIAL FOR INJURY AND LOSS OF LIFE DUE TO FLOODING

POLICY 1.1.1 MAINTAIN CONTINUITY OF CRITICAL SERVICES, INCLUDING POWER SUPPLY, WATER SUPPLY, WASTEWATER TREATMENT, AND MEDICAL CARE, DUE TO FLOODING

POLICY 1.1.2 REGULATE STANDARDS TO ENSURE THE MINIMUS DRY TRAVEL LANE FOR MAJOR THOROUGHFARES ARE ADEQUATE

OBJECTIVE 1.2.: PROVIDE ADEQUATE FLOODPLAIN STUDIES AND MAPS TO ALLOW FOR ACCURATE UNDERSTANDING OF FLOODING PROBLEMS

POLICY 1.2.1 MAINTAIN AND UPDATE DATA AND INFORMATION WITHIN THE JURISDICTION OF OCDD TO ENSURE THAT THE MOST UP-TO-DATE INFORMATION IS AVAILABLE FOR DECISION AND DESIGN CONSIDERATIONS

POLICY 1.2.2 UTILIZE AVAILABLE RESOURCES OF STUDIES, ANALYSIS, INFORMATION, AND DATA AVAILABLE THROUGH THE INTERACTION WITH CITIZENS, DEVELOPERS, AND OTHER GOVERNMENT AGENCIES

GOAL 2: REDUCE EXISTING FLOODING

OBJECTIVE 2.1.: WORK TOWARD SPECIFIC DRAINAGE IMPROVEMENTS TO REDUCE FLOODING

POLICY 2.1.1 IMPLEMENT IMPROVEMENTS IN A COST EFFECTIVE MANNER TO PROVIDE THE GREATEST REDUCTION IN FLOODING

POLICY 2.1.2 MAINTAIN EXISTING DRAINAGE SYSTEMS TO THE MAXIMUM LEVEL FEASIBLE

OBJECTIVE 2.2.: BEGIN TO IMPLEMENT LONG-TERM IMPROVEMENTS TO REDUCE FLOODING

POLICY 2.2.1 STAGE PLANNED IMPROVMENTS THROUGH PHASING TO MAXIMIZE THE BENEFITS OF EACH PLAN

POLICY 2.2.2 PROVIDE FOR CONTINUITY OF PLANNING OF FUTURE AND CURRENT STUDIES AND IMPROVEMENTS

GOAL 3: PREVENT NEW FLOODING WHENEVER POSSIBLE

OBJECTIVE 3.1.: PROVIDE FOR THE ORDERLY DEVELOPMENT OF WATERSHEDS LOCATED WHOLLY OR PARTIALLY WITHIN THE BOUNDARIES OF OCDD

POLICY 3.1.1 DEVELOP CRITERIA TO REGULATE NEW DEVELOPMENT

POLICY 3.1.2 CONSIDER THE EFFECTS ON EXISTING DRAINAGE SYSTEMS FOR ALL NEW DEVELOPMENT

OBJECTIVE 3.2.: IMPLEMENT A PROGRAM OF DRAINAGE IMPROVEMENTS

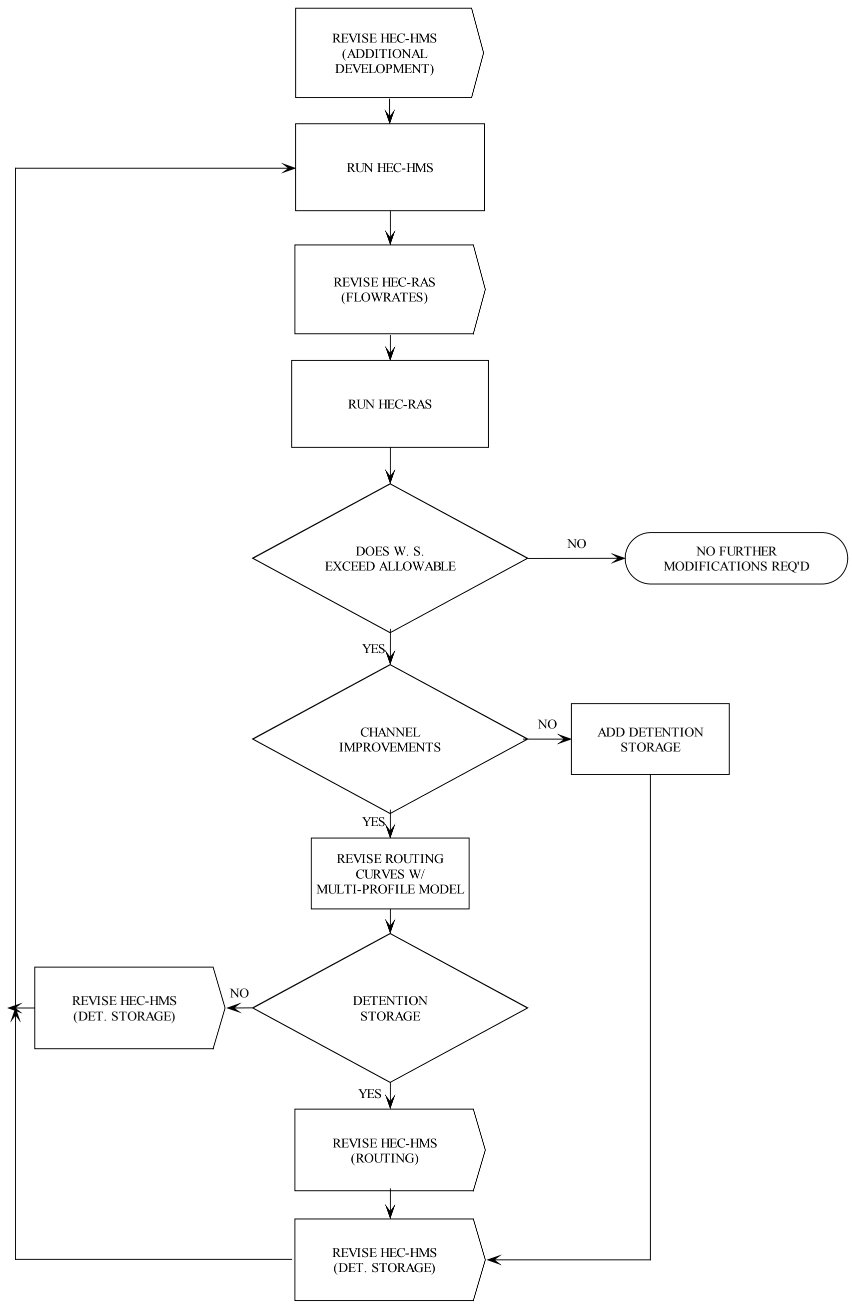
POLICY 3.2.1 NEW DRAINAGE SYSTEM COMPONENTS SHALL BE DESIGNED AND CONSTRUCTED TO MEET THE LEVELS OF PROTECTION OUTLINED BY OCDD

POLICY 3.2.2 A HIERARCHY AND PRIORITIZATION OF NEEDS, BASED UPON DRAINAGE COMPLAINTS, HISTORY OF LOCALIZED FLOODING AND ACTUAL PROPERTY DAMAGE WILL DETERMINE IMPROVEMENTS AND UPGRADE PRIORITIES AS ESTABLISHED BY OCDD

DESIGN CRITERIA

COMPUTER MODELS

Copies of the computer models developed over the course of the study will be provided to the Drainage District so that, as development occurs in the watershed, the models can be updated to reflect the revised conditions. It is recommended that the Drainage District require developers to revise the models and show the impact that the proposed development has on the allowable water surface elevations and discharges. The flow chart diagram below provides a general algorithm for making revisions to the hydrologic and hydraulic models. This algorithm was included to provide general guidelines for the more common types of watershed improvements: channel improvements and detention storage. More unusual approaches to solving drainage problems within the watershed may require additional steps.



SUMMARY OF CONCLUSIONS & RECOMMENDATIONS

The results of the hydrologic and hydraulic analysis of Cow Bayou Watershed reveal that some improvements are required to at a minimum alleviate some of the current flooding for small storm events. Based on existing conditions within the watershed and as discussed with and identified by Orange County Drainage District officials the area that we feel is of immediate importance is Terry Gully. Structural flooding has occurred and new development is expected to continue. Therefore, this area was thoroughly studied for possible improvements in this analysis.

The improvements were divided into a staged three-phase plan that is described in detail in Section 4. The 10-year storm event was the storm frequency the improvements were primarily designed to mitigate and attenuate. All three proposed improvement Phases do not adversely affect any of the storm frequencies analyzed and modeled. The CWSEL along Terry Gully and downstream of the confluence with Cow Bayou show lowered water surface elevations and smaller peak flows at many locations for the larger frequency storms. See Appendix E for complete tables comparing the Existing HEC-RAS output with the 3 Phases of improvements. The proposed improvements are stand-alone projects. This means that they must be completed in order, but implementation of all three is not necessary to achieve positive results. For example, if Phase 1 is the only phase ultimately constructed water surfaces will be lowered along Terry Gully in the I10 area without any adverse impacts downstream in the watershed.

Phase 1 provides additional protection from current flooding conditions in areas that have reported flooding (See Improvement Section for further description). It is recommended that Orange County Drainage District seek to implement this Phase as soon as economically possible. Phase 1's cost is the lowest of all three Phases (see Cost Section). It is possible that the district can qualify for monies available outlined in the possible funding sources section or could implement one of the alternative funding suggestions.

This study is conceptual in nature and is not intended to be used as a final engineering product for construction. More in depth analysis and study will need to be performed on each of the phases prior to construction of them. In addition, construction drawings, surveying, and additional environmental considerations will need to be addressed prior to the actual implementation of any improvements to the Cow Bayou Watershed.

SECTION 2

HYDROLOGIC ANALYSIS FOR THE COW BAYOU WATERSHED

Precipitation Models - HEC-HMS Frequency-based Hypothetical Storm

Rainfall data used for 10-, 50-, and 100-year storm events are developed using depth-duration-frequency data published by the National Weather Service (NWS). The table below describes rainfall depth-duration-frequency data developed through statistical analyses of recorded historical rainfall data, and published in the U.S. Weather Bureau Technical Paper No. 40 (TP40, 1961) entitled *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* and the National Weather Service Hydrometeorological Report No. 35 (HYDRO35) entitled *5- to 60-Minute Precipitation Frequency for the Eastern and Central United States*.

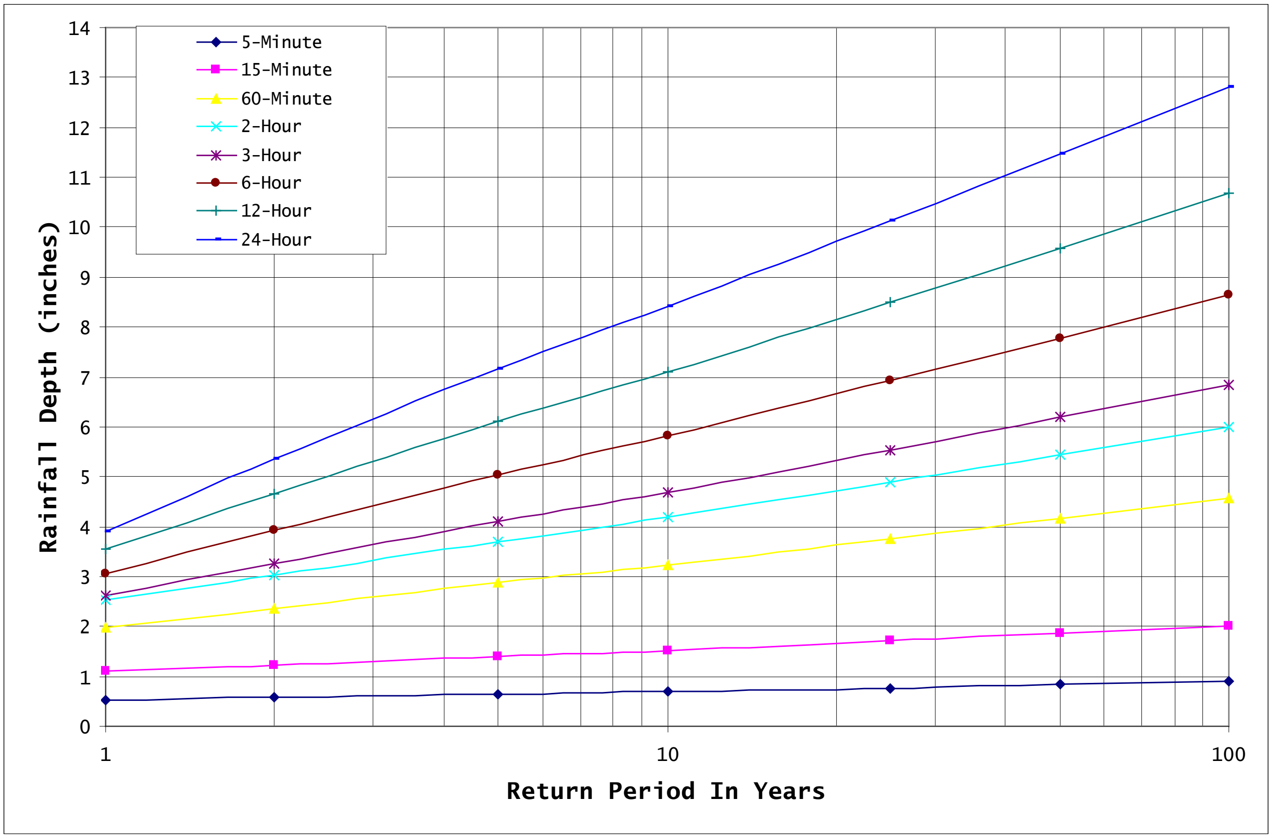
This information represents rainfall data that may be used to generate design storm events for drainage analyses and design studies. As indicated in the table, the 100-year, 24-hour rainfall depth for the Cow Bayou Watershed is about 12.8 inches.

The HEC-HMS Frequency Storm Method is used to create a balanced, synthetic storm with a known exceedance probability. Automatic adjustments for storm area and series type are based on the exceedance probability. The HEC-HMS program performs the temporal distribution of the rainfall data over specified storm duration internally. That is, it places the most intense rainfall at the center of the storm duration with decreasing rainfall amounts to either side of the period of maximum intensity. The depth of the rainfall occurring before and after the period of maximum intensity is approximately equal. 24-hour storm duration is used for all analyses of the Cow Bayou watershed.

Rainfall Data for the Cow Bayou Watershed

	Rainfall Depth in Inches							
Storm Events	5-Minute	15-Minute	60-Minute	2-Hour	3-Hour	6-Hour	12-Hour	24-Hour
2 year	0.57	1.22	2.37	3.02	3.25	3.92	4.65	5.35
5-year	0.63	1.38	2.87	3.70	4.09	5.04	6.10	7.16
10-year	0.69	1.51	3.23	4.19	4.69	5.82	7.10	8.40
25-year	0.77	1.71	3.76	4.90	5.53	6.92	8.50	10.13
50-year	0.83	1.86	4.17	5.45	6.19	7.78	9.59	11.47
100-year	0.90	2.02	4.58	6.00	6.85	8.63	10.67	12.80

Rainfall Data for the Cow Bayou Watershed



The objective of the frequency-based hypothetical storm that is included in HEC-HMS is to define an event for which the precipitation depths for various durations within the storm have a consistent exceedance probability. To develop the storm with HEC-HMS:

The user specifies the total point-precipitation depths for the selected exceedance probability for durations from 5 minutes through the desired total duration of the hypothetical storm (but no longer than 10 days). Depths for durations less than the time interval selected for runoff modeling are not necessary. For example, if the analysis requires a 24-hour storm, and the runoff from a 0.01-AEP event is sought, the user must specify the 0.01-AEP depths for durations from 5 minutes to 24 hours. In the US, depths for various durations for a specified exceedance probability may be obtained by consulting locally-developed depth-duration-frequency functions, NOAA Atlas 2 for the western US (Miller, et al., 1973) or NWS TP-40 (Herschfield, 1961) and TP-49 Miller, 1964) for the eastern US. If the depths are found from isopluvial maps in one of these sources, the values should be plotted and smoothed by the user prior to input to ensure that the storm hyetograph is reasonably shaped.

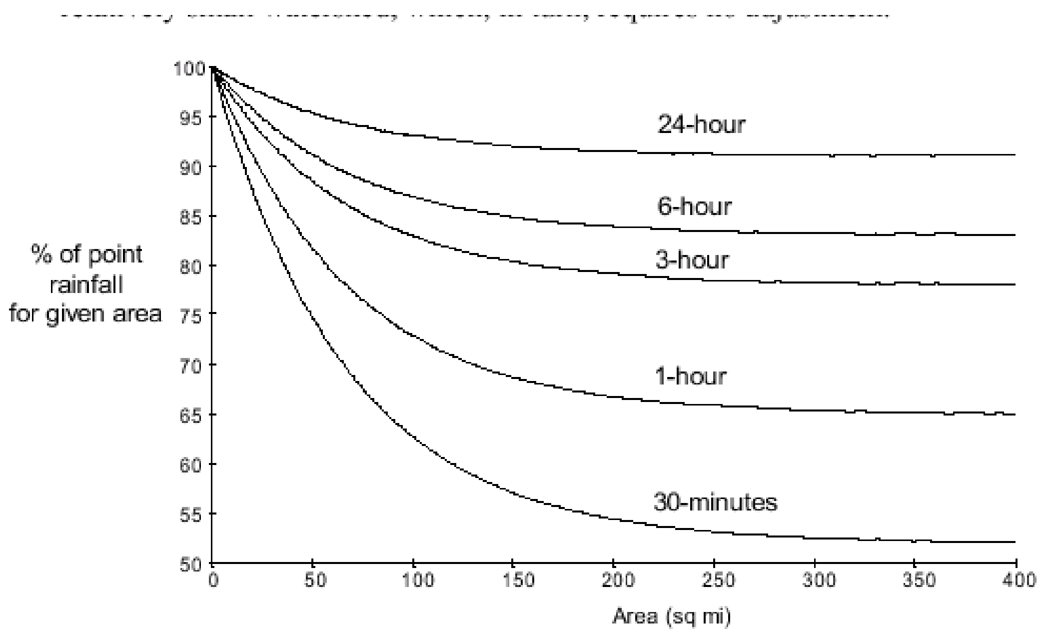


Figure 4-9. Point depth reduction factors

1. HEC-HMS applies an area correction factor to the specified depths. Precipitation estimates from depth-duration-frequency studies, such as those presented in NOAA Atlas 2 or TP-40, commonly are point estimates. However, intense rainfall is unlikely to be distributed uniformly over a large watershed. For a specified frequency and duration, the average rainfall depth over an area is less than the depth at a point. To account for this, the U.S. Weather Bureau (1958) derived, from averages of annual series of point and areal values for several dense, recording-raingage networks, factors by which point depths are to be reduced to yield areal-average depths. The factors, expressed as a percentage of point depth, are a function of area and duration, as shown in Figure 4-9. In accordance with the recommendation of the World Meteorological Organization (1994), point values should be used without reduction for areas up to 9.6 sq. mi. Furthermore, in accordance with the recommendation of HEC (USACE, 1982), no adjustment should be made for durations less than 30 minutes. A short duration is appropriate for a watershed with a short time of concentration. A short time of concentration, in turn, is indicative of a relatively small watershed, which, in turn, requires no adjustment.
2. HEC-HMS interpolates to find depths for durations that are integer multiples of the time interval selected for runoff modeling. HEC-HMS uses linear interpolation, with logarithmically transformed values of depth and duration specified in Step 1.
3. Find successive differences in the cumulative depths from Step 3, thus computing a set of incremental precipitation depths, each of duration equal to the selected computation interval.
4. Use the alternating block method (Chow, Maidment, Mays, 1988) to develop a hyetograph from the incremental precipitation values (blocks). This method positions the block of maximum incremental depth at the middle of the required duration. The remaining blocks are arranged then in descending order, alternately before and after the central block.

WATERSHED DELINIATION

Digital terrain model serves the purposes of providing additional topographic data in addition to the ground survey and as a base map for automatic floodplain delineation. The options of using Surdex TIN, USGS HYPSO in DLG-O, and USGS DEM were investigated. Surdex TIN was created in 1998 during the production of the digital orthophotos at 1" = 200' scale that covers the whole Orange County. As we understand, due to budget constraints, the TIN model does not intend to meet any established vertical accuracy mapping standards. USGS HYPSO and DEM are authoritative data sources for the digital terrain modeling. However, HYPSO and DEM are provided in a vertical datum of NGVD 1929, which makes it difficult to convert to the vertical datum of NVAD 1988, due to limited publications that document the benchmarks used for the datasets.

USGS National Elevation Dataset (NED)

The National Elevation Dataset is a new raster product assembled by the U.S. Geological Survey (USGS). The NED is designed to provide national elevation data in a seamless form with a consistent datum, elevation unit, and projection. Data corrections were made in the NED assembly process to minimize artifacts, permit edge matching, and fill sliver areas of missing data. The 7.5-minute elevation data for the conterminous United States are the primary initial source data. As higher-resolution or higher-quality data become available, the NED is periodically updated to incorporate best-available coverage.

NED is provided in a geographic projection (decimal degrees) with North American Datum of 1983 (NAD 83) horizontal datum. The cell size is one arc-second (approximately 30 meters). The vertical datum for NED is North American Vertical Datum of 1988 (NAVD 88) in decimal meters. In order to use it with the ground survey data, the obtained NED for the Cow Bayou watershed has been converted to a horizontal projection of Texas State Plane – Central (NAD83) in feet, and a vertical datum that is in feet.

NED Accuracy

It is known that USGS is in the process of developing a plan for assessing the overall accuracy of the NED based on independent high-accuracy geodetic control. Until an independent overall assessment of the accuracy of NED is completed, it is best to refer to published information on the accuracy of the source digital elevation models (DEMs) from which NED was assembled.

The USGS 7.5-minute DEMs that cover the Cow Bayou Watershed are Franklin Lake, Buna, Evadale, Gist, Harthburg, Pine Forest, Texla, Mauriceville, Beaumont East, Terry, Orangefield, Orange, and West of Green Bayou. They are all level 2 DEMs. Level 2 DEMs are elevation data sets that have been processed or smoothed for consistency and edited to remove identifiable systematic errors. DEM data derived from hyposographic and hydrographic data digitizing, either photogrammetrically or from existing maps, are entered into the Level-2 category. A root-mean-square error (RMSE) of 2.5 feet, which is one-half contour interval of 5 feet, is the maximum permitted. Therefore, theoretically, comparing to the ground survey, the anticipated RMSE for NED is about 2.5 feet.

Analysis to determine the accuracy of USGS NED was also performed independently by extracting NED (linearly interpolated) elevations at locations of about 902 (natural) ground survey points in Jasper County and Orange County, and comparing the elevations. Results indicate a RMSE of 2.69 feet for those well-distributed points. Therefore, this NED meets

ASPRS 90 Class 2 vertical accuracy mapping standards (American Society for Photogrammetry and Remote Sensing 1990 Standards). ASPRS 90 Class 1 standards are normally mandatory for FEMA contracts; however, the Regional Project Officer can specify Class 2 or Class 3 standards if additional costs for Class 1 products are determined to be excessive.

By comparing USGS DLG-HYPSO, DEM, NED and Surdex TIN with the survey data, we identified the USGS NED as the best dataset to produce the digital terrain model for this study.

Watershed Boundary

HEC-GeoHMS. Watershed boundaries were delineated using Terrain Preprocessing capability of HEC-GeoHMS. Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) is a new is a software package released in 2000 by US Army Corps of Engineers Hydrologic Engineering Center (HEC) for use with the ArcView Geographic Information System (GIS). HEC-GeoHMS uses ArcView and Spatial Analyst to develop a number of hydrologic modeling inputs. Analyzing the digital terrain information, HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation. Capabilities include the development of HEC-HMS basin model, physical watershed and stream characteristics, and background map file.

Watershed Delieantion. The 30-meter resolution DEM appears too coarse to support detailed subbasin and stream delineation. Although the Surdex TIN provides a better resolution, due the low topographic relief, the elevation inaccuary of the TIN has made it diffcult for the task. The Surdex TIN is also not detailed enough to identify some man-made barriers such as water canals. The delineated watershed boundary is based the use of USGS DRG, Surdex TIN for Orange County, USGS DEM for Jasper County, and USGS NED for Jasper and Orange County, TxDOT map for surface features (such as roadways and streams) and Surdex Aerial Photo for Orange County and TNRIS DOQQs for Jasper County. Exhibit 4 shows the watershed and sub-area boundaries.

LOSS COMPUTATIONS

USGS Curve Numbers for precipitation losses were determined by the use of SSURGO soil data and USGS Landuse/Landcover datasets. The precipitation losses represent decreases in volume from precipitation to runoff due to infiltration and storage.

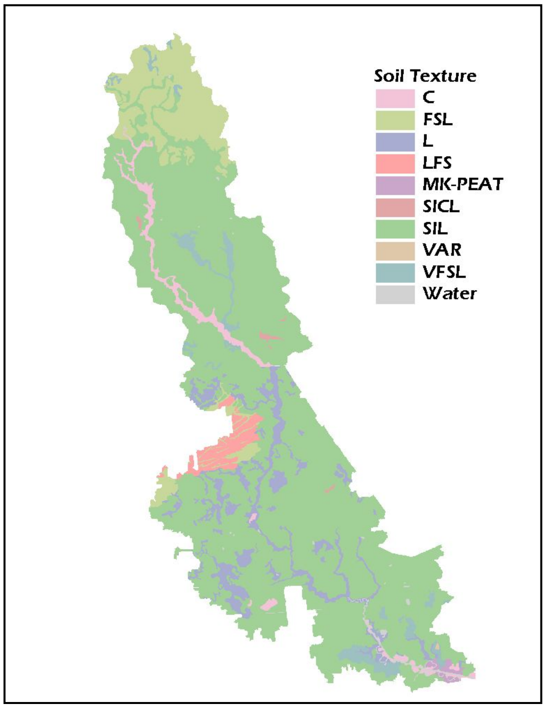
GIS Datasets

SSURGO Soil Data: The Soil Survey Geographic (SSURGO) is one of the three soil geographic datasets offered by The U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS), formerly Soil Conservation Service (SCS). The SSURGO dataset provides the most detailed level of information and was designed primarily for farm and ranch, landowner/user, township, county, or parish natural resource planning and management. Using the soil attributes, this dataset serves as an excellent source for precipitation loss computations.

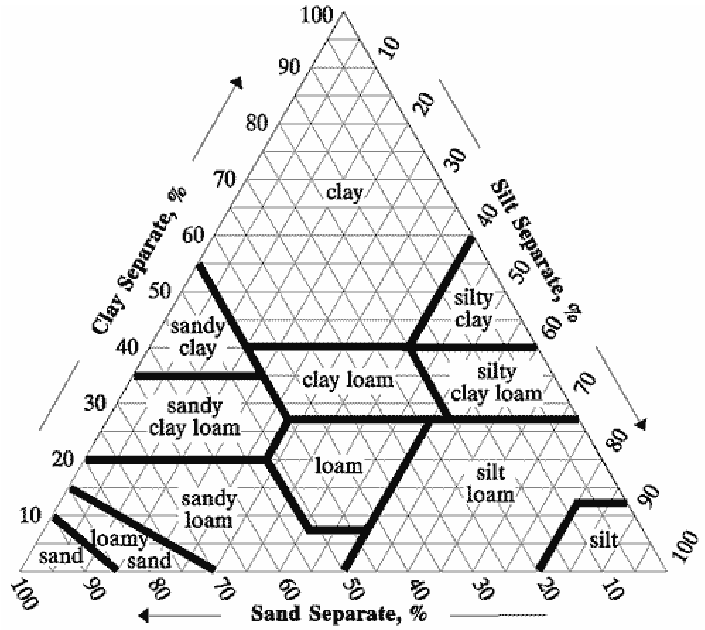
The SSURGO is provided in a geographic projection (decimal degrees) with NAD 83 horizontal datum. The obtained SSURGO that covers the Cow Bayou watershed has been converted to a horizontal projection of Texas State Plane – Central (NAD83) in feet.

Table above summarizes the types of soil in the watershed. Silt Loam is the dominant type. Fine Sandy Loam dominates the most upper part of the watershed in Jasper County (see image Exhibit 2).

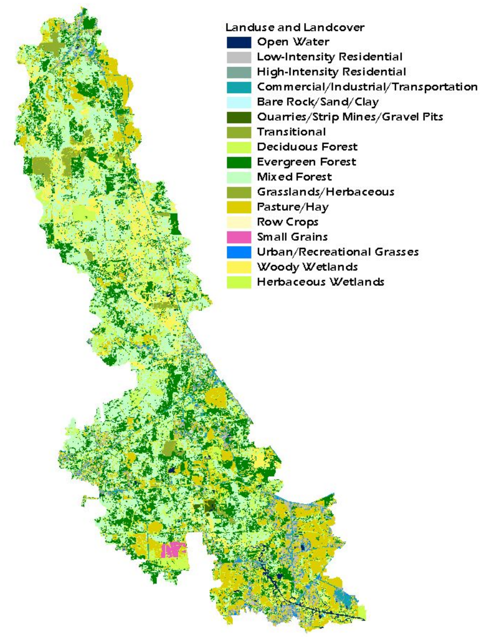
Soil Code	Soil Name	Area (sq. mi.)	Percentage Area
SIL	Silt Loam	134.04	73.12
FSL	Fine Sandy Loam	19.23	10.49
L	Loam	13.69	7.47
VFSL	Very Fine Sandy Loam	5.57	3.04
C	Clay	4.64	2.53
LFS	Loamy Fine Sand	3.83	2.09
Water	Water	1.16	0.63
MK-PEAT	Mucky-Peat	0.72	0.39
SICL	Silty Clay Loam	0.38	0.21
VAR	Variable	0.04	0.02



Loam is a soil with a combination of clay and enough sand to counteract the cohering property of the clay. Silt loam has low to moderate infiltration rates, and produce a moderate to high runoff potential. Exhibit 2 shows the soil types for Cow Bayou Watershed.



USGS Land Cover Data: This land cover dataset was produced by the USGS as part of a cooperative project between the USGS and the U.S. Environmental Protection Agency (USEPA) to produce a consistent, land cover data layer for the conterminous U.S. based on 30-meter Landsat thematic mapper (TM) data. The base data for this dataset was leaves-off Landsat TM data, nominal-1992 acquisitions. Other ancillary data layers included leaves-on TM, USGS 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief, Bureau of the Census population and housing density data, USGS land use and land cover (LUDA), and National Wetlands Inventory (NWI) data if available. This dataset serves as an excellent source for identifying the land use and land cover within the watershed. This land cover dataset is provided in an image format in an Albers Conical Equal Area projection with NAD 83 datum, GRS80 spheroid, standard parallels at 29.5 degrees north latitude and 45.5 degrees north latitude, central meridian at 96 degrees west longitude, origin of the projection at 23 degrees north latitude, and false easting and false northing being 0 meters. The obtained dataset that covers the Cow Bayou watershed has been converted to ArcView shapefile format with a horizontal projection of Texas State Plane – Central (NAD83) in feet. Exhibit 3 shows that land use.



The table below summarizes the types of land cover in the watershed. Dominant land cover is forest at about 65%. Pasture/hay is second at about 16% (see image and Exhibit 3).

Code	Decription	Area (sq. mi.)	Percentage Area
43	Mixed Forest	61.20	33.38
42	Evergreen Forest	39.96	21.80
81	Pasture/Hay	29.28	15.97
41	Deciduous Forest	19.57	10.68
91	Woody Wetlands	12.17	6.64
21	Low-Intensity Residential	4.52	2.46
33	Transitional	3.76	2.05
92	Emergent Herbaceous Wetlands	3.32	1.81
23	Commercial/Industrial/Transportation	3.03	1.65
22	High-Intensity Residential	2.47	1.35
11	Open Water	1.45	0.79
85	Urban/Recreational Grasses	1.42	0.77
83	Small Grains	0.57	0.31
32	Quarries/Strip Mines/Gravel Pits	0.33	0.18
31	Bare Rock/Sand/Clay	0.24	0.13
82	Row Crops	0.02	0.01
71	Grasslands/Herbaceous	0.00	0.00

Surdex Orthophotos for Orange County: Digital orhtophoto was acquired and produced at a scale of 1” =200’ by Surdex in 1998 for the area of Orange County.

TNRIS DOQs for Japser County: Digital orthophoto images for Jasper County areproduced for the Texas Orthoimagery Program (TOP), which is administered by the Texas Department of Information Resources (DIR) The DOQ is a 1-meter ground resolution quarter-quadrangle (3.75-minutes of latitude by 3.75-minutes of longitude) image cast on the Universal Transverse Mercator Projection (UTM) on the North American Datum of 1983(NAD83). The geographic extent of the DOQ is equivalent to a quarter-quad plus approximately 300 meters of overedge. The data was collected at the beiginning of 1996.

Loss Computations

Initial Abstratcion: Initial abstraction was estimated by estimating SCS Curve Numbers for each subwatershed. The Soil Conservation Service (SCS), now known as the Natural Resources Conservation Service, developed the empirical curve number method to estimate total excess precipitation for a storm based on cumulative precipitation, soil cover, land use, and antecedent moisture. Curve number can range from 0 to 99 but practically must be above 40.

The table below lists Runoff Curve Numbers for Land Cover Categories

Code	Land Cover Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	100	100	100	100
21	Low-Intensity Residential	51	68	79	84
22	High-Intensity Residential	62	76	84	88
23	Commercial/Industrial/Transportation	85	90	93	94
33	Transitional	75	80	85	90
41	Deciduous Forest	55	66	74	79
42	Evergreen Forest	60	75	85	89
43	Mixed Forest	57	73	82	86
81	Pasture/Hay	54	70	80	85
83	Small Grains	61	73	81	84
85	Urban/Recreational Grasses	55	69	78	83
91	Woody Wetlands	100	100	100	100
92	Emergent Herbaceous Wetlands	100	100	100	100

$$S = (1000 / CN) - 10$$

Where S is the amount of rainfall that totally infiltrates before runoff begins in inches, and CN is the SCS curve number. Initial abstraction was estimated by using 0.2xS for each subwatershed. The table included in the Green and Ampt section lists all the hydrologic parameters used for each of the individual sub-areas for this study.

Green and Ampt: The Green and Ampt method models infiltration by combining an unsaturated flow form of Darcy's law with requirements of mass conservation. An initial loss is included to model interception and depression storage. Excess precipitation is computed using the Green and Ampt equations after the initial loss is satisfied. Required parameters are the initial loss, volumetric moisture deficit, wetting front suction, and conductivity. Volumetric moisture deficit must be in the range 0 to 1. The percent imperviousness has a default value of zero and can optionally be increased. Table below lists the parameters used for each subwatershed.

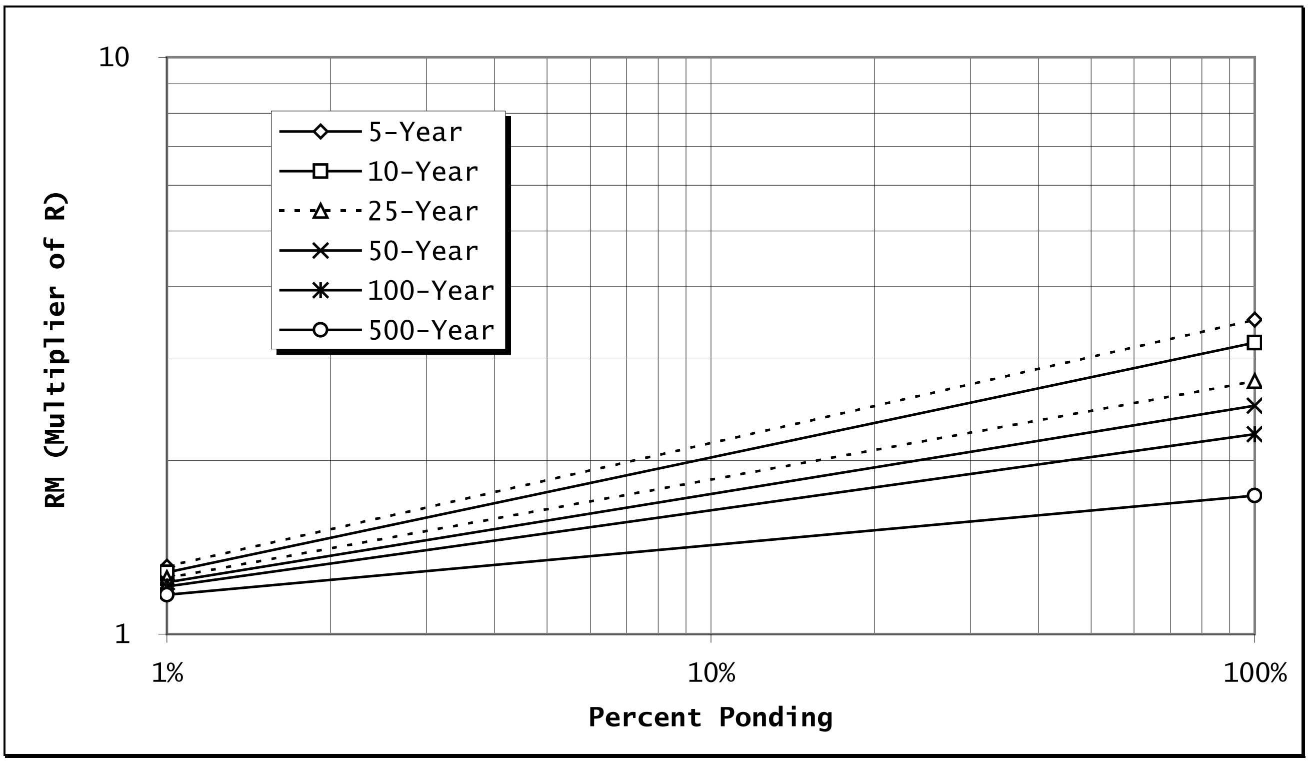
Name	Initial Abstraction (in)	Volume Moisture Deficit	Wet Front Suction (in)	Hydraulic Conductivity (in/hr)	Impervious (%)
Cole-A	0.33	0.484	6.43	0.25	11
Cole-B	0.30	0.483	6.46	0.25	7
Cole-C	0.33	0.477	6.02	0.24	0
Coon-A	0.33	0.482	6.45	0.27	16
Coon-B	0.33	0.464	5.99	0.27	17
Cow-A1	0.60	0.426	4.78	0.40	9
Cow-A2	0.60	0.432	4.92	0.38	4
Cow-B1	0.27	0.470	7.18	0.24	0
Cow-B2	0.25	0.479	6.35	0.28	1
Cow-C	0.30	0.470	6.22	0.27	3
Cow-D	0.41	0.451	4.90	0.46	4
Cow-E	0.35	0.474	5.86	0.23	6
Cow-F	0.33	0.475	5.90	0.23	7
Cow-G	0.35	0.458	5.81	0.19	0
Cow-H	0.38	0.480	6.23	0.25	3
Cow-I	0.33	0.475	5.91	0.23	6
Cow-J	0.30	0.479	6.16	0.24	4
Cow-K	0.27	0.486	6.55	0.26	23
Cow-L	0.33	0.471	6.10	0.27	12
Cow-M	0.27	0.454	6.57	0.26	30
Cow-N	0.25	0.350	5.47	0.17	29
NWVidor1-A	0.33	0.477	6.15	0.31	14
NWVidor1-B	0.33	0.474	5.97	0.23	4
NWVidor2	0.38	0.455	4.99	0.43	4
NWVidor3	0.47	0.432	4.06	0.62	1
Sandy-A	0.27	0.484	6.47	0.26	4
Sandy-B	0.35	0.484	6.43	0.25	19
Sandy-C	0.33	0.481	6.34	0.26	18
Terry-A	0.33	0.464	5.76	0.31	14
Terry-B	0.33	0.474	5.86	0.23	5
Terry-C	0.33	0.473	6.19	0.23	2

PONDING AREA COMPUTATIONS

Ponding areas are digitized from the Surdex aerial photos (see image below). Water canal is included as part of ponding areas. The area is extremely flat and will cause excessive ponding during flood. From the field trip, it seems that the area has a lot of cattle ranches (pasture/hay in LULC dataset). From the aerial photo, a lot of “cattle ranches” look like rice farms. Those “rice farms” are considered to be pasture.

The rice farming areas and natural storage appear to attenuate peak flows in the storm hydrograph. The U.S. Soil Conservation Service (SCS) developed a relationship between peak attenuation and percent of ponding in a watershed [SCS, 1986].

Storage Adjustment Factor for Watershed Ponding

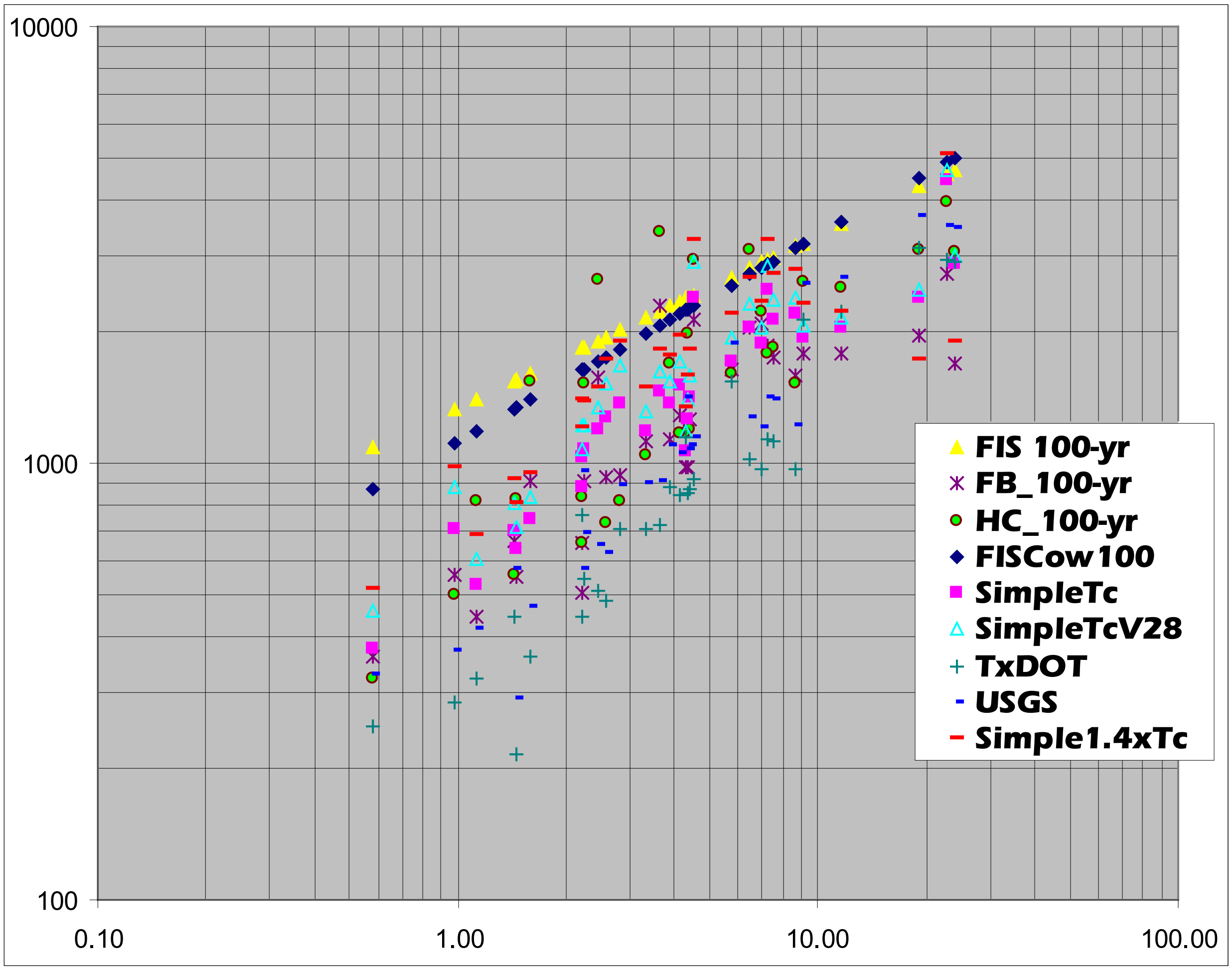


Because of the impact ponding has on the storage coefficient, it generally should not be considered unless ponding covers at least twenty percent (20%) of the sub-area. Therefore, ponding was not a parameter used in the development of the models. See table below for ponding parameters calculated for drainage areas.

Name	Area (acre)	Area (%)
Cole-A	12.43	0.50
Cole-B	43.33	0.91
Cole-C	7.57	0.27
Coon-A	17.27	1.20
Coon-B	63.83	1.55
Cow-A1	8.96	0.15
Cow-A2	2.98	0.04
Cow-B1	22.48	0.15
Cow-B2	24.60	0.20
Cow-C	84.68	0.58
Cow-D	13.14	0.36
Cow-E	2.30	0.25
Cow-F	15.95	0.75
Cow-H	101.41	2.20
Cow-I	17.83	1.09
Cow-K	28.81	2.85
Cow-L	96.99	2.18
Cow-M	15.19	0.65
Cow-N	25.39	1.63
NWVidor1-A	2.05	0.28
NWVidor1-B	16.77	0.93
NWVidor2	9.61	0.35
NWVidor3	9.11	0.64
Sandy-A	9.12	0.65
Sandy-B	18.84	0.65
Sandy-C	32.00	3.42
Terry-A	7.96	0.29
Terry-B	25.76	0.97
Terry-C	52.74	0.95
Total	789.07	0.67

RUNOFF

Runoff from the sub-areas in the Cow Bayou watershed was determined using the Clark Unit Hydrograph Method. Values for the time of concentration (TC) and Clark's runoff coefficient ® were developed using the existing available data from the current FIS study and comparisons to areas with similar conditions and established methods. Below is a graph that helped in establishing a relationship and calibration of R=1.4*TC.



Flow velocities for overland sheet flow and concentrated flow conditions were estimated using the Uplands Method developed by the U.S. Department of Agriculture Soil Conservation Service (SCS). The Uplands Method relates flow velocity to slope and land use. Below are the parameters input into the HEC-HMS model. These values where calculated with the assistance of the GEO-HMS capabilities in conjunction with ArcView. The software calculated the longest flow path and then determines the length of channel for that path. Engineering judgment and manual measuring were used to determine the shallow concentrated flow lengths. The aerial photos were of great use in this task.

Name	L (mi)	Length (ft) Overland	ShallowConcentrated	Channel	Tc (hr)	R (hr)
Cow-A1	8.63	300	4707	40563	6.83	9.57
Cow-B1	12.92	300	28544	39392	12.75	17.84
Cow-A2	7.76	300	21213	19467	8.11	11.35
Cow-B2	10.19	300	39173	14324	11.97	16.76
Cow-C	7.74	300	17588	22973	7.67	10.74
Cow-G	2.02	300	6988	3361.1	2.02	2.83
Cole-C	4.52	300	16009	7530.6	4.61	6.46
Sandy-C	3.47	300	12289	5712.8	3.54	4.95
Cow-L	5.73	300	20708	9228.5	5.92	8.28
Cow-N	3.91	300	11917	8418	3.71	5.20
Cow-E	3.30	300	8537	8605	2.92	4.08
Terry-A	5.87	300	15976	14703	5.32	7.44
NWVidor1-A	2.64	300	11288	2341	2.96	4.14
Cow-F	4.12	300	16226	5230.7	4.44	6.21
Cow-D	4.26	300	13157	9016.8	4.07	5.70
NWVidor2	5.01	300	18896	7267.1	5.29	7.40
NWVidor3	2.83	300	7329	7321.7	2.50	3.50
Cow-H	4.80	300	11408	13641	4.11	5.75
Cow-I	3.81	300	5477	14363	2.75	3.85
Terry-C	5.89	300	21900	8910.3	6.17	8.64
NWVidor1-B	4.23	300	3659	18373	2.71	3.79
Terry-B	4.73	300	11795	12898	4.13	5.78
Sandy-A	3.27	300	7860	9103.5	2.80	3.92
Coon-A	2.67	300	11665	2129	3.03	4.24
Sandy-B	3.65	300	4701	14266	2.55	3.57
Cow-J	1.55	300	5879	2031.2	1.62	2.27
Cow-K	2.77	300	13268	1049.6	3.31	4.63
Cow-M	4.11	300	15101	6311.2	4.27	5.98
Coon-B	6.31	300	11416	21598	4.90	6.86
Cole-B	5.64	300	17125	12338	5.36	7.50
Cole-A	4.83	300	12498	12699	4.28	5.99

RESULTS OF FIELD INVESTIGATION

Field investigations were performed over the course of several days by Dodson & Associates, Inc. staff members. The survey data was incomplete and incompatible for use in the hydraulic modeling of bridges and crossing structures. Extensive hand measuring was necessary to complete the minimum requirements to accurately compile the existing conditions hydraulic HEC-RAS modeling project. Appendix A contains many of the pictures of crossing structures and conditions present in the field. In addition to survey supplementation observations made during field investigations and reconnaissance were used in an effort to verify existing drainage patterns within the watershed.

SECTION 3

HYDRAULIC ANALYSIS

Several major roads, railroads, and canals cross the Cow Bayou Watershed. These crossing are important in that the flow of flood waters is often retarded, with the road, rail, or pipeline surface in some cases being overtopped by the flood waters. The impacts of the crossing in flood levels within the watershed are evaluated by including the crossing structures in the HEC-RAS hydraulic models of Cow Bayou and the major tributaries analyzed for this study. The table at the end of this section lists the HEC-RAS reach name, river station and crossing name if known.

The hydraulic model was prepared using HEC-RAS. HEC-RAS requires geometric and flow data and calculates water surface elevation in open channels. A copy of the HEC-RAS project files for the existing and the proposed have been included on CD with this report.

Geometry Data

Cross section data from the current FEMA HEC-2 models, BRINSAP data from TxDOT (for bridges), current survey, and field investigations were combined with the electronic topographic data developed in the hydrologic modeling to give the most accurate model possible.
Roughness coefficients (Manning's n values) were calculated initially within the GIS environment utilizing the ground cover theme. These values were then checked, verified, and adjusted where necessary by comparing conditions using the aerial photographs, previous studies and models and were largely based on the field reconnaissance visits. A table containing the 'n' values used is included at the end of this Section. A cross section location map is presented on Exhibit 5

Station and elevation relationships describe the physical shape of the stream and its overbanks. In many cases, cross sections from existing models as well as field survey were extended to model flood flow that was not contained with the original extend of the cross sections. This additional topographic information came from the topographic map produced in the ArcView GIS model as previously discussed in the hydrology section.

Initial the starting water surface elevation was determined from the existing FIS study. Upon further investigation it was decided that a slope/area or normal depth calculation was more representative of the storm frequencies being analyzed.

The model uses the upstream CWSEL from the downstream reach as the backwater conditions for the initial calculations on each subsequent upstream reach. This method insures continuity along the entire watershed.

Appendix B includes the existing model cross-section results and Appendix C has the existing conditions model profiles. Appendix D compares results from the existing model profiles with the three phases of proposed improvements.

Flow Data

The flow data used to model actual stream conditions are flowrates calculated by the HEC-HMS model for different storm events. Flowrates for the 10, 50, and 100-year storms as well as the 3 Phases of improvements were entered into the HEC-RAS model and water surface profiles computed. These profiles are included in Appendix C for the entire existing model and Terry Gully for the improvement Phases. The tables below show the flowrates used in the HEC-RAS model for the different scenarios. All quantities are in cubic feet per second.

EXISTING				
Reach	**Station**	**100-yr**	**50-yr**	**10-yr**
Reach 8	250421	567	485	310
Reach 8	232376	1134	970	621
Reach 8	208428	4559	3883	2459
Reach 8	151416	6591	5555	3398
Reach 8	125587	6158	5207	3215
Reach 8	112138	5807	4948	3006
NW Vidor #3	6426	593	508	316
NW Vidor #3	1269	1186	1015	632
Reach 7	102436	5680	4796	2963
NW Vidor #2	15260	432	369	234
NW Vidor #2	10446	866	739	468
NW Vidor #2	840	1299	1109	702
Reach 6	97172	5720	4838	3083
NW Vidor #1	20114	666	578	382
Reach 5	90944	5714	4849	3094
Terry Gully	47737	384	331	216
Terry Gully	39999	768	661	432
Terry Gully	31637	1536	1323	865
Terry Gully	16216	2348	2068	1359
Reach 4	71073	7622	6511	4112
Cole Creek	53002	425	367	238
Cole Creek	45524	850	734	477
Cole Creek	38552	1700	1467	953
Cole Creek	23355	3203	2763	1781
Reach 3	50009	8135	6870	4242
Sandy Creek	19194	1350	1169	762
Sandy Creek	6337	3608	3158	2112
Reach 2	41598	9007	7506	4462
Reach 2	37815	9118	7570	4484

PHASE 1				
Reach	**Station**	**100-yr**	**50-yr**	**10-yr**
Reach 8	250421	567	485	310
Reach 8	232376	1134	970	621
Reach 8	208428	4559	3883	2459
Reach 8	151416	6591	5555	3398
Reach 8	125587	6157	5206	3215
Reach 8	112138	5762	4871	3007
NW Vidor #3	6426	593	508	316
NW Vidor #3	1269	1186	1015	632
Reach 7	102436	5645	4775	2986
NW Vidor #2	15260	432	369	234
NW Vidor #2	10446	866	739	468
NW Vidor #2	840	1299	1109	702
Reach 6	97172	5705	4860	3130
NW Vidor #1	20114	666	578	382
Reach 5	90944	5711	4882	3136
Terry Gully	47737	384	331	216
Terry Gully	39999	768	661	432
Terry Gully	31637	1536	1323	865
Terry Gully	16216	2285	2054	840
Reach 4	71073	7270	6194	3924
Cole Creek	53002	425	367	238
Cole Creek	45524	850	734	477
Cole Creek	38552	1700	1467	953
Cole Creek	23355	3225	2790	1823
Reach 3	50009	8066	6811	4192
Sandy Creek	19194	1350	1169	762
Sandy Creek	6337	3615	3165	2117
Reach 2	41598	8801	7342	4343
Reach 2	37815	8896	7406	4371

PHASE 2				
Reach	**Station**	**100-yr**	**50-yr**	**10-yr**
Reach 8	250421	567	485	310
Reach 8	232376	1134	970	621
Reach 8	208428	4559	3883	2459
Reach 8	151416	6590	5555	3398
Reach 8	125587	6157	5206	3215
Reach 8	112138	5762	4872	3007
NW Vidor #3	6426	593	508	316
NW Vidor #3	1269	1186	1015	632
Reach 7	102436	5649	4776	2986
NW Vidor #2	15260	432	369	234
NW Vidor #2	10446	866	739	468
NW Vidor #2	840	1299	1109	702
Reach 6	97172	5713	4862	3131
NW Vidor #1	20114	666	578	382
Reach 5	90944	5721	4884	3139
Terry Gully	47737	384	331	216
Terry Gully	39999	768	661	432
Terry Gully	31637	1536	1323	865
Terry Gully	16216	2269	2034	840
Reach 4	71073	7281	6026	3695
Cole Creek	53002	425	367	238
Cole Creek	45524	850	734	477
Cole Creek	38552	1700	1467	953
Cole Creek	23355	3225	2790	1823
Reach 3	50009	7959	6703	4032
Sandy Creek	19194	1350	1169	762
Sandy Creek	6337	3615	3165	2117
Reach 2	41598	8464	7022	4059
Reach 2	37815	8519	7051	4061

PHASE 3				
Reach	**Station**	**100-yr**	**50-yr**	**10-yr**
Reach 8	250421	567	485	310
Reach 8	232376	1134	970	621
Reach 8	208428	4559	3883	2459
Reach 8	151416	6590	5555	3398
Reach 8	125587	6157	5206	3215
Reach 8	112138	5762	4872	3007
NW Vidor #3	6426	593	508	316
NW Vidor #3	1269	1186	1015	632
Reach 7	102436	5649	4776	2986
NW Vidor #2	15260	432	369	234
NW Vidor #2	10446	866	739	468
NW Vidor #2	840	1299	1109	702
Reach 6	97172	5713	4862	3131
NW Vidor #1	20114	666	578	382
Reach 5	90944	5717	4884	3139
Terry Gully	47737	384	331	216
Terry Gully	39999	768	661	432
Terry Gully	31637	1536	1323	865
Terry Gully	16216	2348	2068	990
Reach 4	71073	7248	6052	3975
Cole Creek	53002	425	367	238
Cole Creek	45524	850	734	477
Cole Creek	38552	1700	1467	953
Cole Creek	23355	3225	2790	1823
Reach 3	50009	7929	6652	4183
Sandy Creek	19194	1350	1169	762
Sandy Creek	6337	3615	3165	2117
Reach 2	41598	8370	6903	4163
Reach 2	37815	8406	6922	4149

Cow Bayou Project -- Bridge Catalog

Reach	River Station	Description
Cow Bayou Reach 8	250346	CR 835?
Cow Bayou Reach 8	249162	US 96 #5
Cow Bayou Reach 8	245904	US 96 #4 Survey 1 Box FL (Assume all boxes have the same FL) Survey 5' RCP FL
Cow Bayou Reach 8	244065	FM 1004
Cow Bayou Reach 8	241843	US 96 #3
Cow Bayou Reach 8	238642	CR 773
Cow Bayou Reach 8	236151	US 96 #2
Cow Bayou Reach 8	233813	CR 722
Cow Bayou Reach 8	228752	US 96 #1
Cow Bayou Reach 8	228646	Railroad #4? (Just S US 6 #1)
Cow Bayou Reach 8	220378	CR 784 Bunker Hill Road
Cow Bayou Reach 8	213340	CR 777
Cow Bayou Reach 8	196000	RR Survey From OCDD Dec 14, 2001
Cow Bayou Reach 8	193633	FM 2246
Cow Bayou Reach 8	174477	Unnamed Crossing #6
Cow Bayou Reach 8	162014	Unnamed Crossing #5
Cow Bayou Reach 8	157746	CR 826
Cow Bayou Reach 8	145767	Unnamed Crossing #4
Cow Bayou Reach 8	142447	Unnamed Crossing #3
Cow Bayou Reach 8	131730	Northridge
Cow Bayou Reach 8	128221	FM 2802 (Old Texla Mill Road)
Cow Bayou Reach 8	122829	Pipeline Crossing #3 (Pipe Size?)
Cow Bayou Reach 8	115816	Unnamed Crossing #2 SHELL DRIVE
Cow Bayou Reach 8	113140	SH 12
Cow Bayou Reach 8	110696	Railroad #2
NW Vidor #3	6259	SH 12
NW Vidor #3	4152	Railroad
Cow Bayou Reach 7	102354	Wood Bridge (Unnamed Bridge #1)
NW Vidor #2	15167	Sweetwater
NW Vidor #2	12866	SH 12 4' x 4' US VS. 4'x 6' DS?
NW Vidor #2	12479	5580 SH 12 Driveway
NW Vidor #2	10627	Linscomb
NW Vidor #2	9962	Railroad
NW Vidor #2	9267	Unnamed Crossing #2 (just south of Railroad) (Hunting Club Road)
NW Vidor #2	4831	Unnamed Crossing #1
Cow Bayou Reach 6	NO BRIDGES	
NW Vidor #1	19007	SH 12
NW Vidor #1	17081	Linscomb
NW Vidor #1	17022	Railroad
NW Vidor #1	8496	Bridges added 2/5/02 from OCDD & F&S survey data
Cow Bayou Reach 5	89755	Pipeline Crossing (Not survey, No record)
Cow Bayou Reach 5	88050	Pipeline Crossing (Just North of IH-10)

Reach	River Station	Description
Cow Bayou Reach 5	87901	IH 10 West Bound Frtg
Cow Bayou Reach 5	87777	IH 10 Main Lanes (Modeled as one continuous bridge)
Cow Bayou Reach 5	73847	FM 1442
Terry Gully	41446	SH 12
Terry Gully	38954	Linscomb
Terry Gully	38872	Railroad #3
Terry Gully	38812	E RR St (S of RR)
Terry Gully	31517	IH 10 N. Frtg
Terry Gully	31408	IH 10 Main Lane
Terry Gully	31298	IH 10 S. Frtg
Terry Gully	16059	Railroad #2
Terry Gully	15270	FM 1135 (Doty-Terry)
Terry Gully	8565	Railroad #1
Terry Gully	8496	Terry Road (Just North of RR)
Terry Gully	6126	Liston
Terry Gully	4591	FM 1442
Cow Bayou Reach #4	66672	Railroad #1
Cole Creek	52805	SH 12
Cole Creek	49902	FM 1130
Cole Creek	49829	Railroad #2
Cole Creek	49443	Wood Bridge (Cohenour)
Cole Creek	45634	Wood Bridge (Unnamed Crossing #3)
Cole Creek	43427	Wood Bridge (Unnamed Crossing #2)
Cole Creek	43352	Wood Bridge (Unnamed Crossing #1)
Cole Creek	41057	Pipeline Crossing
Cole Creek	39619	Arledge Road
Cole Creek	37164	FM 1136 (Old Buna Road)
Cole Creek	29065	Pipeline Crossing
Cole Creek	20340	IH-10 N Frtg
Cole Creek	20248	IH-10 N Main Lane
Cole Creek	20148	IH-10 S Main Lane
Cole Creek	20060	IH-10 S Frtg
Cole Creek	3386	Railroad #1
Cow Bayou Reach #3	NO BRIDGES	
Sandy Creek	19028	IH-10 N Frtg
Sandy Creek	18911	IH-10 Main Lanes
Sandy Creek	18820	IH-10 S Frtg
Sandy Creek	18690	Unnamed Crossing #8 (Just S of IH-10)
Sandy Creek	11623	Burton
Sandy Creek	10161	JB Arrington
Sandy Creek	9331	Unnamed Crossing #7
Sandy Creek	9097	Unnamed Crossing #6
Sandy Creek	8813	Unnamed Crossing #5
Sandy Creek	8442	Unnamed Crossing #4
Sandy Creek	6447	Unnamed Crossing #3
Sandy Creek	5838	Railroad
Sandy Creek	5682	Unnamed Crossing #2
Sandy Creek	176	Unnamed Crossing #1 (Cattle Crossing Rd)
Cow Bayou Reach #2	38305	FM 105 (TxDOT 0689-02-004)

SECTION 4

IMPROVEMENTS

INTRODUCTION TO IMPROVEMENTS

Development of Orange County is projected to occur primarily adjacent to and in the vicinity of Terry Gully, south of Interstate 10 and east of Cow Bayou. These projections are based on the opinions expressed by OCDD officials at project meetings. The Terry Gully tributary of Cow Bayou does experience flood protection problems. A three phase proposed improvement plan was identified and modeled to maximize the flood protection to existing development, to offset increased flows created by existing development, and to comply with restrictions placed on the area by both FEMA and the U.S. Army Corps of Engineers (through the OCDD).

Watershed improvements were identified during the brainstorming phase of this study. After preliminary modeling of possible alternative improvements were completed a meeting with drainage personnel was held to determine the direction to proceed. It was determined that achieving 100-year protection would not be a viable goal. The topology of the area and available funding sources and economic climate in the community could not support the construction of the necessary drainage improvements for the larger events. It was determined that a 10-year event would be the most realistic frequency to design for. The available resources that OCDD has the greatest quantity of is heavy equipment and manpower, therefore unless no alternative solutions could be innovatively designed for it was deemed best to attempt to model improvements that did not involve modifications to existing crossing structures. The improvements consist of a combination of detention basins and channel improvements. Items considered in the evaluation of each phase included technical feasibility, effectiveness, and economic concerns.

Project meetings with Orange County officials identified a problem area between Interstate 10 and State Highway 12 along Terry Gully. This same area has limited R.O.W. availability so the improvement plan needed to take that into consideration. SH 12 is located at cross section 41446 and I10 is at 31408. The district officials also identified the area along the northern side of Terry Gully as an area that has recently seen new development and will probably continue to grow if possible.

Flows in Cow Bayou are such that attenuation, detention, or retention of a substantial portion would not be technically, or economically feasible for the area. Based on these observations and model results the proposed improvements focus on Terry Gully for the improvements.

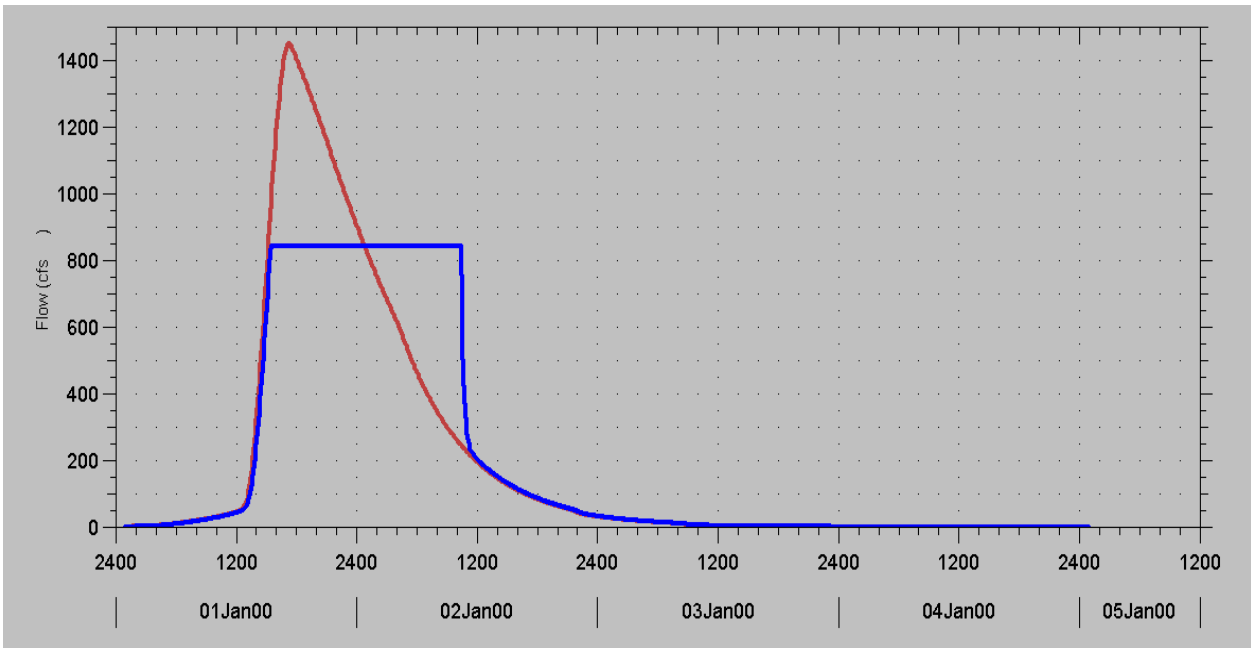
The three-phase plan is as follows:

Phase 1

The objective of Phase 1 of the improvements is to lower the water surface elevation for the 10-year frequency storm between I10 and SH12 on Terry Gully through channel improvements and a regional detention facility to mitigate improvement impacts. Exhibits 7 & 8 show the detention locations and Exhibit 5 has cross-section locations noted. No structures, bridges, pipelines, or canal crossings need to be modified or improved to implement this phase. Improving and widening the channel as shown below with all side slopes of 3:1:

CROSS SECTION	BOTTOM WIDTH
47737-41492	20
41401-39000	30
38920-23366	30

These improved channels will operate somewhat like inline detention. They will allow excess flows to be temporarily stored within the banks until available capacity is available to drain the water. In addition to the channel improvements Phase 1 also includes the excavation of a large detention facility that will also perform the task of inline detention primarily for the 10-year event.
In the graph, exported directly from the HEC-HMS model for Phase 1, below it can be seen that the detention facility will attenuate the peak inflow from over 1400 cfs to the 800 cfs range. This is a significant decrease in the flows with a minimum of land required.



Many factors were considered when choosing the location of the Terry B Phase 1 detention facility and its subsequent parameters. The location is downstream of the water canal thereby eliminating the need to modify, relocate, or impact the canal and incur addition costs. Also, the canal cross section acts as a natural restrictor for flow and possibly could be advantageously used in the subsequent design of the facility and thereby reducing cost further. The length, width, side slopes modeled can be modified if necessary for the acquisition of land when final design is begun. A soil investigation and study will need to be conducted to determine the acceptable maximum side slope used in the final design. The detention pond parameters are shown in the table below:

BOTTOM WIDTH	586	SIDE SLOPE	3
BOTTOM LENGTH	2506	END SLOPE	3

DEPTH	TOP WIDTH	TOP LENGTH	VOLUME (cubic feet)	VOLUME (acre-feet)	TOP AREA (acre)
0.0	586	2506	0	0	33.7
0.5	589	2509	736577	17	33.9
1.0	592	2512	1477792	34	34.1
1.5	595	2515	2223645	51	34.4
2.0	598	2518	2974136	68	34.6
2.5	601	2521	3729265	86	34.8
3.0	604	2524	4489032	103	35.0
3.5	607	2527	5253437	121	35.2
4.0	610	2530	6022480	138	35.4
4.5	613	2533	6796161	156	35.6
5.0	616	2536	7574480	174	35.9
5.5	619	2539	8357437	192	36.1
6.0	622	2542	9145032	210	36.3
6.5	625	2545	9937265	228	36.5
7.0	628	2548	10734136	246	36.7
7.5	631	2551	11535645	265	37.0
8.0	634	2554	12341792	283	37.2
8.5	637	2557	13152577	302	37.4
9.0	640	2560	13968000	321	37.6
9.5	643	2563	14788061	339	37.8
9.7	644	2564	15117384	347	37.9
10.0	646	2566	15612760	358	38.1

The resulting storage-discharge relationships were entered into the HEC-HMS model through several iterations and the final results showed a substantial lowering of the CWSEL along the reach. The tables below show the results from this Phase as well as the Existing conditions and the subsequent Phases for sections along the entire reach of Terry Gully.

Excavation quantities for this phase will be 127,000 cubic yards for the channel improvements and 560,000 cubic yards for the detention facility for a total of 687,000 cubic yards. Possible ROW acquisition requirements were kept to a minimum with the pond requiring 38 acres of top area and an addition 30’ maintenance area around the perimeter.

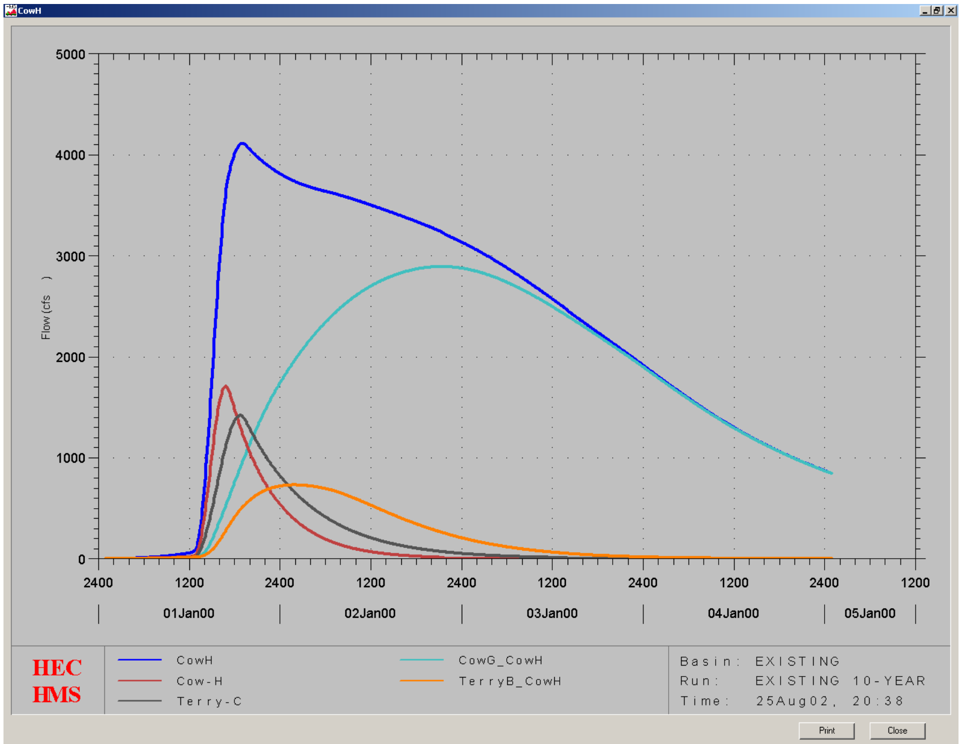
TERRY GULLY 10-YEAR EXISTING COMPARED TO PHASE 1,2, & 3

Station	W.S. Elev (ft)				Station	W.S. Elev (ft)			
	EXISTING	PHASE 1	PHASE 2	PHASE 3		EXISTING	PHASE 1	PHASE 2	PHASE 3
47737	20.82	20.30	20.30	20.25	20833	14.79	13.87	13.88	10.71
45470	20.30	19.64	19.64	19.47	18136	14.19	13.27	13.27	10.56
43482	20.15	19.46	19.46	19.23	16216	13.48	12.58	12.58	10.42
41545	20.11	19.34	19.34	19.06	16105	13.24	12.47	12.47	10.40
41492	20.10	19.34	19.34	19.05	16013	12.93	12.33	12.33	10.37
41401	19.87	19.11	19.11	18.82	15936	13.00	12.35	12.35	10.35
41298	19.87	19.10	19.10	18.82	15495	12.96	12.30	12.30	10.32
39999	19.83	19.02	19.02	18.71	15395	12.95	12.30	12.30	10.30
39047	19.74	18.87	18.87	18.54	15309	12.75	12.20	12.20	10.28
39000	19.72	18.86	18.86	18.52	15231	12.50	12.10	12.10	10.26
38920	19.64	18.78	18.78	18.45	15090	12.49	12.07	12.08	10.25
38918	19.62	18.78	18.78	18.45	14969	12.45	12.03	12.04	10.24
38838	19.56	18.74	18.74	18.40	13562	11.96	11.60	11.61	10.15
38836	19.54	18.73	18.73	18.39	9979	11.40	10.38	10.37	9.81
38788	19.39	18.48	18.48	18.07	8735	11.24	10.15	10.12	9.62
38682	19.36	18.45	18.45	18.03	8645	11.23	10.14	10.12	9.61
38467	19.30	18.36	18.36	17.92	8577	11.03	10.01	9.98	9.59
35740	18.80	17.63	17.63	17.01	8554	10.92	9.96	9.94	9.59
33942	18.37	17.20	17.20	16.54	8552	10.88	9.96	9.93	9.53
32387	17.89	16.94	16.94	16.25	8439	10.69	9.90	9.87	9.52
31637	17.38	16.68	16.68	15.90	8241	10.66	9.87	9.85	9.51
31557	17.33	16.61	16.61	15.80	6909	10.48	9.77	9.74	9.45
31477	17.21	16.44	16.44	15.58	6308	10.42	9.73	9.70	9.43
31475	17.20	16.43	16.43	15.57	6236	10.41	9.72	9.69	9.42
31339	17.06	16.23	16.23	15.30	6150	10.38	9.71	9.68	9.38
31337	17.05	16.22	16.22	15.29	6103	10.31	9.61	9.53	9.34
31257	16.95	16.02	16.02	15.00	6045	10.29	9.60	9.51	9.33
31157	16.92	16.00	16.00	14.97	5982	10.28	9.58	9.49	9.32
28430	16.46	15.22	15.22	14.05	4695	9.73	9.17	9.04	9.13
25921	16.01	14.79	14.79	13.29	4645	9.29	8.99	8.85	9.05
23366	14.98	14.18	14.18	12.65	4537	9.25	8.98	8.84	8.97
21297	14.94	14.07	14.07	11.46	4414	9.34	9.01	8.88	8.98
21195	14.94	14.07	14.07	11.15	4216	9.31	9.00	8.86	8.96
21119	14.87	13.97	13.97	10.88	1752	9.05	8.87	8.72	8.88
20999	14.79	13.87	13.87	10.46	117	8.98	8.85	8.69	8.86

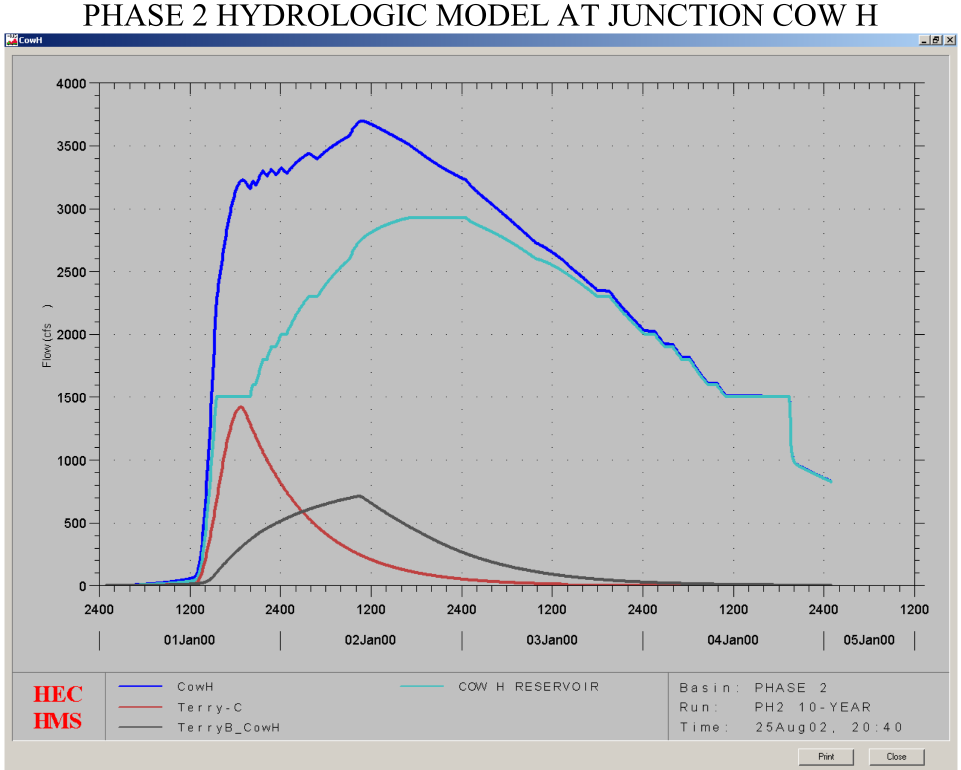
PHASE 2

Phase 2 is a 42-acre detention facility east of Cow Bayou and north of the confluence with Terry Gully. Exhibits 7 & 8 show the location. Phase 2's objective was to attenuate the peak flow for the ten-year frequency storm on Cow Bayou upstream of the confluence with Terry Gully. By achieving this, the CWSEL would be lowered at this junction and the timing of flows would peak at a later time. The resulting lag of the peak occurrence assists in the mitigation of Phase 3 impacts. Below are two graphs representing the Existing and Phase 2 flows from HEC-HMS.

EXISTING HYDROLOGIC MODEL AT JUNCTION COW H



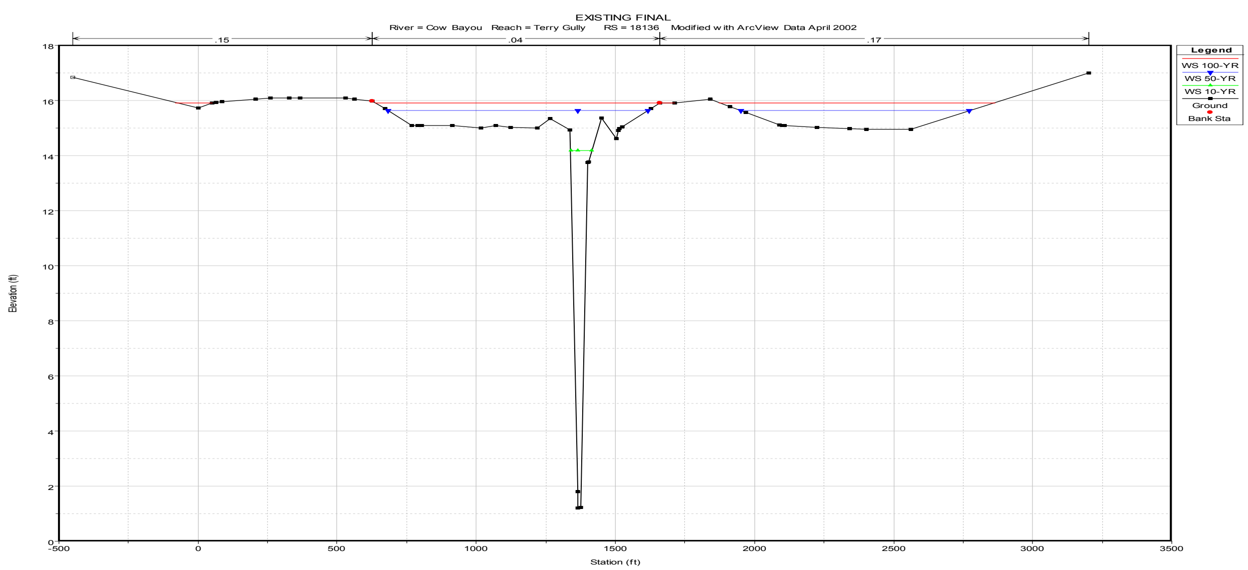
PHASE 2 HYDROLOGIC MODEL AT JUNCTION COW H

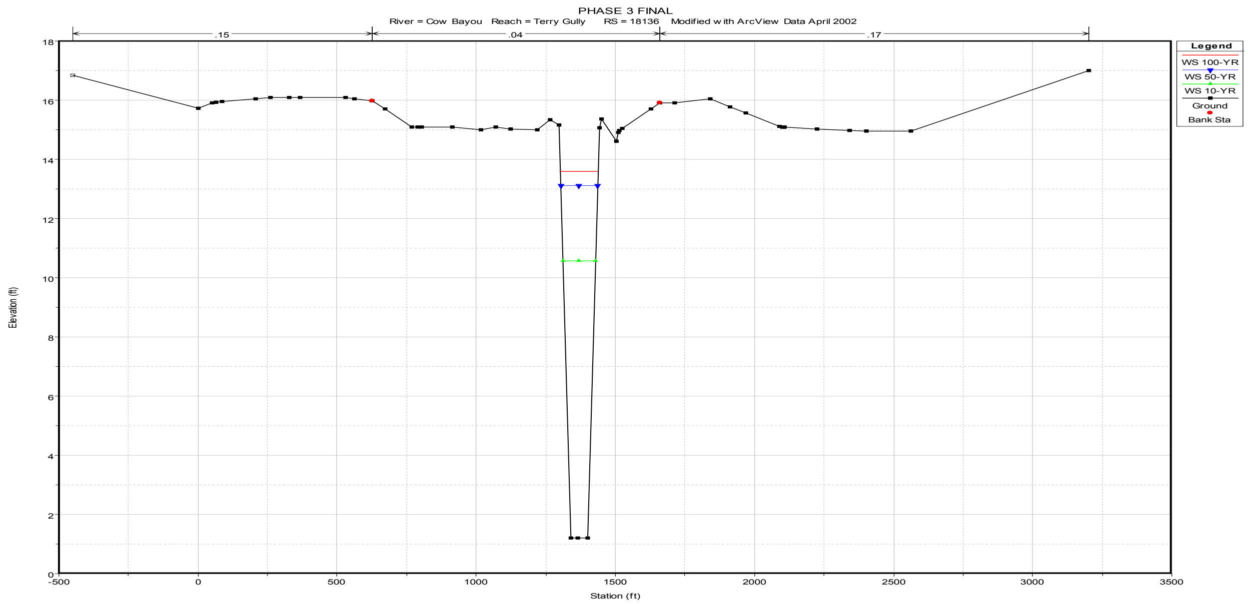


As with Phase 1, Phase 2 does not call for any improvement or modification to bridges or crossing structures. By planning these types of improvements the costs are minimized while the benefits are maximized. The volumes of excavation are as follows. 1,050,000 cubic yards for the detention facility. A maintenance access area will be required around the perimeter as noted in Phase 1. The direct benefit to Terry Gully and Cow Bayou is not readily seen through the construction of Phase 2. The benefits will be achieved when Phase 3 is completed. To achieve no adverse impacts on downstream flows and/or water surface elevations upstream or downstream it was necessary to mitigate prior to the construction of the next Phase otherwise the flows downstream for the larger events would increase and have impacts on businesses, homes, and property located further down the watershed.

Phase 3

Phase 3's objective is to lower the CWSEL along Terry Gully from the water canal crossing downstream to Cow Bayou. As in previous phases this planned improvement was achieved with no crossing structure modifications. The acquisition of additional ROW is a possibility. Phase 3 will widen Terry Gully from cross-section 18136 located downstream of the water canal crossing to a bottom width of 60 feet to the confluence of Cow Bayou. Below are a representative cross section showing the existing and then the proposed improvement to the channel.





The channel widening will require the excavation of 479,000 cubic yards of soil for the channel improvements. In addition, a detention facility is necessary to mitigate any downstream impacts. The detention pond parameters are as follows.

BOTTOM WIDTH 675 SIDE SLOPE 3

BOTTOM LENGTH 2250 END SLOPE 3

DEPTH (ft)	TOP WIDTH (ft)	TOP LENGTH (ft)	VOLUME (ft^3)	VOLUME (acre-feet)	TOP AREA (acre)
6.5	714	2289	10242619	235	38
7.0	717	2292	11061225	254	38
7.5	720	2295	11884219	273	38
8.0	723	2298	12711600	292	38
8.5	726	2301	13543369	311	38
9.0	729	2304	14379525	330	39
9.5	732	2307	15220069	349	39
10.0	735	2310	16065000	369	39
10.5	738	2313	16914319	388	39
11.0	741	2316	17768025	408	39
11.5	744	2319	18626119	428	40
12.0	747	2322	19488600	447	40
12.5	750	2325	20355469	467	40
13.0	753	2328	21226725	487	40
13.5	756	2331	22102369	507	40
14.0	759	2334	22982400	528	41
14.5	762	2337	23866819	548	41
15.0	765	2340	24755625	568	41
15.5	768	2343	25648819	589	41
16.0	771	2346	26546400	609	42
16.5	774	2349	27448369	630	42
17.0	777	2352	28354725	651	42

With the channel improvements and the detention facility completed the benefits will be achieved not only for the 10-year event but also will have advantageous impacts on the larger events as can been seen in the output tables and the above cross sections. The excavation quantity for the proposed detention facility is 620,000 cubic yards of earth. This facility will be located south of Terry Gully and west of Cow Bayou on a tract of undeveloped land. This final phase in the planned improvements along Terry Gully substantially lowers the computed water surface elevations for the 10-year frequency storm event at a maximum as compared to the existing conditions by 4.08'.

All cross sections comparing the CWSEL for the 10-, 50, 100-year events for the Existing Conditions and Phase 1, 2, & 3 are included in Appendix D. Profiles for all of the above mentioned and analyzed scenarios are also included in Appendix D.

SECTION 5

PRELIMINARY COST DATA FOR IMPROVEMENTS

The cost for the proposed improvements are based upon soil excavation. There are two sets of estimates based on in-house construction or contracted excavation.

We contacted Jefferson County Drainage District No. 6 to confirm unit prices for excavation as they have constructed several facilities recently using in-house and contracted forces.

Unit costs for Excavation are based on $1.25/C.Y. for depositing materials adjacent to channel. Costs for pond excavation are $2.25/C.Y. for in-house forces hauling the materials from the site to a nearby stockpile location. Contract forces are estimated to be $3.50/C.Y.

Phase 1 Costs

Order of Magnitude Estimate

Phase 1 Improvements

Terry Gully Channel Widening
Terry Gully Detention Facility - 38 Ac

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	AMOUNT
Construction by In-House Personnel & Equipment					
Channel Improvements - Terry Gully					
	ROW & Esmt Acquisition	Ac.	33.5	2,200.00	73,700.00
	Channel Improvements	C.Y.	127,000	1.25	158,750.00
				SUBTOTAL	232,450.00
				10% Contingency	23,250.00
				Engineering	15,100.00
				SUBTOTAL - CHANNEL IMPROVEMENTS	270,800.00
Detention Facilities - Terry Gully					
	ROW & Esmt Acquisition	Ac.	43.0	2,200.00	94,600.00
	Detention Excavation	C.Y.	560,000	2.25	1,260,000.00
				SUBTOTAL	1,354,600.00
				10% Contingency	135,500.00
				Engineering	88,000.00
				SUBTOTAL - DETENTION IMPROVEMENTS	1,578,100.00
				TOTAL CONSTRUCTION COST	$1,848,900.00

Order of Magnitude Estimate

Phase 1 Improvements

Terry Gully Channel Widening
Terry Gully Detention Facility - 38 Ac

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	AMOUNT
<u>Construction by Outside Contract</u>					
Channel Improvements - Terry Gully					
	ROW & Esmt Acquisition	Ac.	33.5	2,200.00	73,700.00
	Channel Improvements	C.Y.	127,000	1.50	190,500.00
				SUBTOTAL	264,200.00
				10% Contingency	26,400.00
				Engineering	17,200.00
		SUBTOTAL - CHANNEL IMPROVEMENTS			307,800.00
Detention Facilities - Terry Gully					
	ROW & Esmt Acquisition	Ac.	43.0	2,200.00	94,600.00
	Detention Excavation	C.Y.	560,000	3.50	1,960,000.00
				SUBTOTAL	2,054,600.00
				10% Contingency	205,500.00
				Engineering	133,500.00
		SUBTOTAL - DETENTION IMPROVEMENTS			2,393,600.00
		TOTAL CONSTRUCTION COST			**$2,701,400.00**

Phase 2 Costs

Order of Magnitude Estimate

Phase 2 Improvements

Terry Gully Detention Facility - 42 Ac

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	AMOUNT
Construction by In-House Personnel & Equipment					
Detention Facilities - Terry Gully					
	ROW & Esmt Acquisition	Ac.	49.0	2,200.00	107,800.00
	Detention Excavation	C.Y.	1,050,000	2.25	2,362,500.00
				SUBTOTAL	2,470,300.00
				10% Contingency	247,000.00
				Engineering	160,500.00
	SUBTOTAL - DETENTION IMPROVEMENTS				2,877,800.00
	TOTAL CONSTRUCTION COST				$2,877,800.00

Order of Magnitude Estimate

Phase 2 Improvements

Terry Gully Detention Facility - 42 Ac

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	AMOUNT
Construction by Outside Contract					
Detention Facilities - Terry Gully					
	ROW & Esmt Acquisition	Ac.	49.0	2,200.00	107,800.00
	Detention Excavation	C.Y.	1,050,000	3.50	3,675,000.00
				SUBTOTAL	3,782,800.00
				10% Contingency	378,000.00
				Engineering	246,000.00
	SUBTOTAL - DETENTION IMPROVEMENTS				4,406,800.00
	TOTAL CONSTRUCTION COST				$4,406,800.00

Phase 3 Costs

Order of Magnitude Estimate

Phase 3 Improvements
Terry Gully Channel Widening
Terry Gully Detention Facility - 38 Ac

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	AMOUNT
Construction by In-House Personnel & Equipment					
Channel Improvements - Terry Gully					
	ROW & Esmt Acquisition	Ac.	50.0	2,200.00	110,000.00
	Channel Improvements	C.Y.	490,000	1.25	612,500.00
				SUBTOTAL	722,500.00
				10% Contingency	72,250.00
				Engineering	47,000.00
				SUBTOTAL - CHANNEL IMPROVEMENTS	841,750.00
Detention Facilities - Terry Gully					
	ROW & Esmt Acquisition	Ac.	49.0	2,200.00	107,800.00
	Detention Excavation	C.Y.	620,000	2.25	1,395,000.00
				SUBTOTAL	1,502,800.00
				10% Contingency	150,300.00
				Engineering	98,000.00
				SUBTOTAL - DETENTION IMPROVEMENTS	1,751,100.00
				TOTAL CONSTRUCTION COST	$2,592,850.00

Order of Magnitude Estimate

Phase 3 Improvements
Terry Gully Channel Widening
Terry Gully Detention Facility - 38 Ac

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE	AMOUNT
Construction by Outside Contract					
Channel Improvements - Terry Gully					
	ROW & Esmt Acquisition	Ac.	50.0	2,200.00	110,000.00
	Channel Improvements	C.Y.	490,000	1.50	735,000.00
				SUBTOTAL	845,000.00
				10% Contingency	72,250.00
				Engineering	47,000.00
				SUBTOTAL - CHANNEL IMPROVEMENTS	964,250.00
Detention Facilities - Terry Gully					
	ROW & Esmt Acquisition	Ac.	49.0	2,200.00	107,800.00
	Detention Excavation	C.Y.	620,000	3.50	2,170,000.00
				SUBTOTAL	2,277,800.00
				10% Contingency	150,300.00
				Engineering	98,000.00
				SUBTOTAL - DETENTION IMPROVEMENTS	2,526,100.00
				TOTAL CONSTRUCTION COST	$3,490,350.00

Summary of Costs for Improvements

Summary of Costs

Construction by In-House Personnel & Equipment

	Phase 1	Phase 2	Phase 3
Channel ROW & Esmts	73,700.00		110,000.00
Channel Excavation	158,750.00		612,500.00
Contingency & Engineering	38,350.00		119,250.00
SUBTOTAL - Channel Imp.	270,800.00		841,750.00
Detention Properties	94,600.00	107,800.00	107,800.00
Detention Pond Constr.	1,260,000.00	2,362,500.00	1,395,000.00
Contingency & Engineering	223,500.00	407,500.00	248,300.00
SUBTOTAL - Detention	1,578,100.00	2,877,800.00	1,751,100.00
Total Estimated Cost	1,848,900.00	2,877,800.00	2,592,850.00

Construction by Outside Contract

	Phase 1	Phase 2	Phase 3
Channel ROW & Esmts	73,700.00		110,000.00
Channel Excavation	190,500.00		735,000.00
Contingency & Engineering	43,600.00		119,250.00
SUBTOTAL - Channel Imp.	307,800.00		964,250.00
Detention Properties	94,600.00	107,800.00	107,800.00
Detention Pond Constr.	1,960,000.00	3,675,000.00	2,170,000.00
Contingency & Engineering	339,000.00	624,000.00	248,300.00
SUBTOTAL - Detention	2,393,600.00	4,406,800.00	2,526,100.00
Total Estimated Cost	**$ 2,701,400.00**	**$ 5,248,550.00**	**$ 2,526,100.00**

SECTION 6

ANTICIPATED FLOOD DAMAGE COSTS

During October 2002 Southeast Texas experienced a rainfall event that inundated many of the waterways and caused substantial damage to numerous communities. Preliminary data from NWS indicate that Orange received a daily total of 7.05 inches on October 28. After applying that total to the nearest recorded hourly distribution (Port Arthur) it is estimated that the maximum precipitation for a one hour increment was 4.65 inches. As discussed previously in the hydrology section, the 100-year depth for a 1-hour event is 4.58 inches. Therefore, this storm is assumed to be the 100-year storm.

The flood boundaries from this event were then compared to the boundaries predicted for the 100-yr event by the models. The boundaries were consistent, confirming the 100-yr designation given to the event. Because the rainfall and flooding from this actual event so closely match the design 100-yr storm, it can also be assumed that the amount of damages incurred in the Cow Bayou watershed during this storm will emulate the damages during the 100-yr design storm.

According to data gathered by the Orange County Emergency Management Coordinator, Chuck Frazier, an estimated 608 homes were damaged by floodwaters in Orange County during the October storm. Only 20 homes, or approximately 3% of the total, experienced "major" damage.

Information gathered by the Orange County Flood Administration Administrator, Sammy Owens, of 336 homes in the County, included actual depths of flooding for 82 homes. Of those homes reporting depths, 1.2% experienced flooding between 1.5 and 2.0 feet, 8.5% experienced flooding between 1.0 and 1.5 feet, 20.7% experienced flooding between 0.5 and 1.0 foot, and the majority, 65.9% experienced flooding of less than 0.5 foot. In addition, 3.7% experienced flood damages with no measurable depth of water in their homes.

The FIA developed generic (national) depth vs. damage curves for input into the HEC-FDA model. These curves relate the amount of damages incurred at a residence to the depth of flooding experienced and the value of the structure and its contents. The curves used for this study were derived from the FDA generic curves specifically for New Orleans, LA. It was felt that these were more applicable than the national curves due to the proximity of the study area to New Orleans. The values pertinent to the October 2002 flood are summarized in the following table:

DEPTH TO DAMAGE RATIOS

Depth of Flooding Experienced (ft)	Ratio of Damage Incurred by Structure to Cost of Structure (Percent)	Ratio of Damage Incurred by Contents to Cost of Contents (Percent)
Not measurable (0)	20.5%	0.0%
0.0 – 0.5	40.5%	28.1%
0.5 – 1.0	41.5%	41.8%
1.0 – 1.5	45.1%	49.3%
1.5 – 2.0	52.3%	62.9%

The estimated cost of a single-family residence in the area is $101,125. For this average cost of the home the contents are valued at 46.6%, which equates to $47,124. This percentage is according to the FIA, and is adjusted for New Orleans. The estimated average value of a home plus its contents in the area is therefore calculated at $148,250.

Approximately one quarter of the 608 structures (or 152 homes) damaged in the flood are assumed to be in the Cow Bayou watershed. A rough estimate of total damages to residential structures and their contents can be calculated as shown in the following table.

DAMAGES INCURRED BY SURVEYED RESIDENCES

Depth (ft)	Percent of Homes	Approximate Number of Homes	Cost of Damage to Structure	Cost of Damage to Contents	Total Cost to Individual Homeowner	Total Damages
0	3.7%	6	$ 20,731	$ -	$ 20,731	$ 116,589
0-0.5	65.9%	100	$ 40,956	$ 13,242	$ 54,197	$ 5,428,852
0.5-1.0	20.7%	31	$ 41,967	$ 19,698	$ 61,665	$ 1,940,218
1.0-1.5	8.5%	13	$ 45,607	$ 23,232	$ 68,840	$ 889,406
1.5-2.0	1.2%	2	$ 63,608	$ 29,641	$ 93,249	$ 170,085
					Total =	**$ 8,545,151**

Commercial properties also incurred damages during the October 2002 storm. Information gathered by the Orange County Flood Administration Administrator, includes reports of 11 businesses experiencing flooding. Of the 11 businesses, three report damages in dollar amounts. The total dollar amount of damages for the three businesses is estimated at $100,000, with an average of $33,333 of damage per business. Assuming this average applies to all 11 businesses, the county's businesses incurred approximately $367,000 of damage. Furthermore, assuming one quarter of these damages occurred within the Cow Bayou watershed, the approximate cost of damages due to flooded businesses within the watershed is approximately $92,000.

The Orange County Emergency Management Coordinator gathered information regarding the damages to public buildings, drainage structures and streets. Approximately $365,000 in damage was reported. Again assuming that one quarter of the damages in Orange County occurred within the Cow Bayou watershed, about $91,250 of damages was incurred there by public infrastructure.

Within the Cow Bayou watershed, the October 2002 storm caused preliminary estimated damages of $8,545,000, $92,000, and $91,250 to residences, businesses, and public infrastructure, respectively. Using the logic asserted previously, these damages are approximately the damages incurred by a 100-yr design storm. Therefore, the damages anticipated due to a 100-yr design storm could conceivably total nearly $8.73 million.

SECTION 7

POSSIBLE SOURCES OF FUNDING

One of the most important components of this study is the identification of funding sources for planning and implementation of flood control and drainage projects.

As a result of our experience with many similar studies for other local government agencies, we have developed some basic information about funding sources that should be considered. This section summarizes available information about the following funding sources for flood control planning and implementation:

- Texas Water Development Board (TWDB)
- Federal Emergency Management Agency (FEMA) Grants
- Storm water Control Districts
- Watershed Drainage Districts
- Fresh-Water Supply Corporations
- Municipal Drainage Utility System (Drainage Charge)
- Impact Fees

Texas Water Development Board (TWDB) Programs

According to the TWDB rules, there are two types of funding available for flood control planning and projects:

1. A grant program for flood protection planning, as described in Section 355 of the Texas Administrative Code. This study is partially funded through this type of grant.
2. A loan program for flood control projects, as described in Section 363 of the Texas Administrative Code. This loan program also includes a provision for making loans for the development of flood plain management plans. The general application requirements for the loan program include demonstration engineering feasibility and performing adequate environmental assessments and reviews.

Because the first grant program has been utilized in the funding of this project and is familiar to OCDD it will not be further discussed here. The Loan program for flood control projects is described in the following section.

TWDB Loan Program for Flood Control Projects

The TWDB may provide loans to political subdivisions for structural[1] and nonstructural[2] flood control projects, and for development of flood plain management plans[3]. Applicants for flood

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[1] Structural flood control – Includes but is not limited to measures such as construction of storm water retention basins, enlargement of stream channels, modification or reconstruction of bridges, control of coastal erosion, or beach nourishment

control must be located within an area in which National Flood Insurance is available at the time of application and throughout the life of the board's financial assistance.

An engineering feasibility report must be prepared, providing:

1. description and purpose of the project
2. entities to be served and current and future population;
3. the cost of the project;
4. a description of innovative and conventional alternatives considered and reasons for the selection of the project proposed;
5. sufficient information to evaluate the engineering feasibility; and
6. maps and drawings as necessary to locate and describe the project area. The executive administrator may request additional information or data as necessary to evaluate the project.

In addition, engineering data must be provided to clearly demonstrate the following:

1. the capacity of the watershed to accommodate storm water runoff;
2. the impact of the project on watershed capacity along the entire watershed and the degree to which that capacity was considered in planning the project;
3. whether the project will increase or decrease the volume or rate of storm water runoff in any channel in the watershed;
4. if the project would increase the volume or rate of storm water runoff, that adequate consideration was given to alternative approaches that would decrease or hold constant the volume or rate of storm water runoff;
5. the project will not significantly increase the peak water surface elevation of any portion of any stream within the watershed or within any downstream watershed. Potential loss of life and property will be considered in evaluating significance of peak water surface elevation impacts for flood control projects.
6. the relationship of the project to any flood plain management plan for the watershed; and
7. adequate consideration was given to the effects of the project with regard to erosion and sediment control.

A complete environmental assessment and review of the proposed flood protection project is required for approval of the TWDB loan application.

FEMA Hazard Mitigation Grant Program

The Hazard Mitigation Grant Program (HMGP) was created in November 1988, by Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP assists

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[2] Nonstructural flood control – Includes but is not limited to measures such as acquisition of flood plain land for use as public open space, acquisition and removal of buildings located in a flood plain, relocation of residents of buildings removed from a flood plain, or flood warning systems.

[3] Flood plain management plan – A comprehensive plan for flood control within a watershed, based on analysis of alternative nonstructural and structural means of reducing flood hazards, including assessments of costs, benefits, and environmental effects and may include preliminary design of structural flood control projects.

States and local communities in implementing long-term mitigation measures following a Presidential disaster declaration. The objectives of the HMGP are:

- To prevent future losses of lives and property due to disaster;
- To implement State or local mitigation plans;
- To enable mitigation measures to be implemented during a State's or community's immediate recovery from a disaster; and
- To provide funding for previously identified mitigation measures that benefit the disaster area.

To meet these objectives, FEMA can fund up to 75% of the eligible costs of each project. The State or local cost-share match does not need to be cash; in kind services or materials may also be used.

With the passage of the Hazard Mitigation and Relocation Assistance Act of 1993, Federal funding under the HMGP is now increased to 15 percent of the Federal funds spent on the Public and Individual Assistance programs (minus administrative expenses) for each disaster.

The HMGP can be used to fund projects to protect either public or private property, so long as the projects in question fit within the State and local government's overall mitigation strategy for the disaster area, and comply with program guidelines. Examples of projects that may be funded include the acquisition or relocation of structures from hazard-prone areas, the retrofitting of existing structures to protect them from future damages; and the development of State or local standards designed to protect buildings from future damages.

In order to be eligible for this program, the State or community must first develop (and have approved by FEMA) a flood mitigation plan that describes the activities to be carried out with the assistance provided under this program. The plan must be consistent with a comprehensive strategy for mitigation activities, and be adopted by the State or community following a public hearing.

Municipal Drainage Utility System

A municipality is permitted to establish a municipal drainage utility system within its established service area as codified in the Texas Local Government Code under Chapter 402 Subchapter C – Municipal Drainage Utility Systems. Chapter 402 Subchapter C is otherwise referred to as the Municipal Drainage Utility Systems Act. The act delegates to municipalities the power to declare, after a public hearing, a drainage system to be a public utility. The act prescribes bases on which a municipal drainage utility system may be funded and fees in support of the system may be assessed, levied, and collected. The municipality may assess a drainage charge to a lot or tract of benefited property for drainage services. The basis of the drainage charge must be directly related to drainage.

A Municipal Drainage System Utility (or "storm water utility") is based on the criteria that each parcel of property in the municipality benefits from a storm water management program. Storm water costs are allocated according to the benefit received, or the portion of storm water that runs off of each parcel.

Using a combination of land use runoff factors and coefficients, that percentage of runoff from representative parcels for each land use with the municipality can be calculated.

To generate the revenue needed to maintain the storm water management program, the municipality can charge residents a user fee based on the municipality's expenditures for storm water-related activities. The fee schedule is often calculated based on a "Basic Assessment Unit" (BAU) which is equivalent to the amount of impervious cover of a single-family residence. The user charge for each parcel is calculated according to the number of equivalent BAUs for that parcel, as determined by the following formula:

$$NBAU = \frac{AC}{BAU}$$

where NBAAU – Number of BAU equivalents charged to a particular parcel or land use;

A = Surface Area of Parcel or Land Use;

C = Runoff Coefficient of Parcel or Land Use;

BAU = Basic Assessment Unit = Size of Average OCDD Single-Family Residence x Runoff Coefficient of Average OCDD Single-Family Residence.

For simplicity, all single-family parcels are charged as one BAU.

The following table illustrates the typical monthly charge for a monthly storm water utility. These figures are typical averages only; they will vary according to the size and characteristics of the individual parcel.

Typical Monthly Storm Water Utility Charges

Land Use	Typical Monthly Charge
Single Family Residential	$2.00
Apartments, Condominiums, and Mobile Homes	$2.50
Commercial Property	$12.50
Industrial Property	$11.50
Private Parking	$6.00
Vacant Lots	$0.50

An additional surcharge could also be assessed on areas which directly benefit from specific flood control projects which remove them from the regulatory 100-year flood plain. The surcharge can be timed to coincide with a reduction in FEMA flood insurance rates due to improved flood protection, so that the impact of the surcharge on property owners is minimized.

By charging residents in proportion to the actual use and benefit they derive from the system, the OCDD may have a viable way to improve flood protection and reduce the discharge of pollutants to the receiving systems and watersheds.

Office of Rural Community Affairs - ORCA

- Community Development Fund

Funds are available every 2 years on a regional competition basis. Funding for drainage is eligible along with funding for water and wastewater improvements – usually large drainage projects are limited to $250,000 or regional project size limts. In addition, drainage projects are usually lower priority in regional scoring.

- Texas Capital Fund

Funding available to local communities for specific economic development projects to retain/create jobs.

- Disaster Relief / Urgent Need Fund

Funding available to local communities for response to natural disasters including flooding. This funding is only available after a disaster occurs.

Corps of Engineers Funding

Direct funding or construction by the U.S.Army Corps of Engineers

Impact Fees

Impact fees are available funding source to construct capital improvements for drainage or flood control facilities to accommodate new development. The 70th Texas Legislature enacted the nation's first comprehensive impact fee enabling statute in 1987.The statute is commonly known as "SB336". Initially codified as Tex. Civ. Rev. Stat. Art. 1269j-4.11, the bill has now been incorporated within the Texas Local Government code as Ch. 396 – Financing Capital Improvements Required By New Development in Municipalities, Counties, and Certain Other Local Governments. Ch. 395 authorizes municipalities and certain special districts to impose impact fees against new development.

An impact fee is a charge or assessment imposed by a political subdivision against new development in order to generate revenues for funding or recouping the costs of capital improvements or facility expansions necessitated by and attributable to the new development. The term includes amortized charges, lump-sum charges, capital recovery fees, contributions in aid of construction, and any other fee that functions as described by this definition. Specifically, impact fees are charges which are imposed only on "new development." New development means that subdivision of land; the construction, reconstruction, redevelopment, conversion, structural alteration, relocation, or enlargement of any structure; or any use or extension of the use of land; any of which increases the number of service units. Capital improvements include public facilities for (1) storm water, drainage, and flood control facilities; (2) water supply treatments and distribution facilities; (3) wastewater collection and treatment facilities; and, (4) roadway facilities. Facility expansion refers to the expansion of the capacity of an existing facility of one of these types of capital improvements.

The OCDD would have legislative authority to establish impact fees as the means of funding future drainage and flood protection improvements necessitated by new development. A few advantage of impact fees are described as follows:

- Impact fees represent an additional source of revenues from which to finance a portion of future capital improvement needs;
- Local governments can transfer a portion of the costs of capital improvements to serve new development to the ultimate beneficiaries;
- Existing revenue sources may be devoted to maintaining service levels and funding capital improvements to correct existing deficiencies or replace existing facilities; and,
- Impact fees represent a more equitable form of distributing the burden for financing capital improvements among various types of development.

A few potential disadvantages of impact fees are outlined below:

- Generation of revenues from impact fees are contingent on new development;
- The cost of capital improvements required to serve new development on a watershed basis may exceed the funding capability from impact fees on a timely basis;
- Impact fees may inhibit economic development in the District if impact fees are not equally assessed in other jurisdictions;
- Impact fees are costly to implement and relatively difficult to administer.

SECTION 8

Reference:

- National Weather Service (NWS), Technical Paper 40, Rainfall Frequency Atlas of the United States for Duration from 30 minutes to 24 Hours and Return Periods from 1 to 100 Years, 1961
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- Federal Emergency Management Agency (FEMA), Flood Insurance Study, Unincorporated Areas of Orange County, Texas, July 6, 1982
- Surdex, Ground Control Survey Report for the Orange County Drainage District, July 1998.
- Corps of Engineers, Galveston District, Flood Plain Information: Tiger and Caney Creeks, Meyers Bayou, Anderson and Terry Gullies, Vidor, Texas, December 1971. - The report was prepared at the request of the City Council of Vidor to aid in the solution of local flood problems and in the best utilization of land subject to overflow.
- Texas Department of Public Safety, Lake Sabine Study Area - Hurricane Storm Atlas, June 1998. – This study was prepared for the Governor's Division of Emergency Management (DEM) in Austin, Texas. It is designed to provide information on vulnerability analysis planning for the Lake Sabine Study Area.
- FEMA, Flood Insurance Study for Orange County Unincorporated Areas, Texas, July 1982.