M-1 DITCH WATERSHED STUDY

Prepared for:

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January 2011

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1.0 INTRODUCTION

1.1 Background

The M-1 Watershed encompasses just over 9 square miles within Brazoria County. The watershed lies south of SH 6 and generally west of Mustang Bayou. The stream begins as a roadside ditch at County Road 578 and Adoue, then runs south to South Street. At South Street, the concrete-lined stream flows east towards Johnson Street where it turns south again and reverts to an earthen channel. The stream maintains its southern bearing while crossing FM 1462 and SH 35. At SH 35, the stream geometry deepens and widens and veers south and east until it outfalls to Mustang Bayou. See Exhibit 1.1 for a vicinity map.

The M-1 Ditch is a FEMA-unstudied stream. While portions of the watershed are in mapped FEMA floodplains, these are Zone AO (unstudied sheet flow) and Zone AE, resulting from the watershed's proximity to Mustang Bayou. Exhibit A.1 is a map of the FEMA zones in the vicinity (located in Appendix A). Exhibit A.3 shows the existing FEMA floodplains and the approximate floodplain as determined during this study.

The City of Alvin has experienced frequent flooding in the past, including significant repetitive losses. A recent storm event that stands out in the minds of residents and City personnel is the April 18th 2009 event, during which many residences experienced damage. Exhibit A.2 is a map showing the extent of the damages for this specific event. Much of this flooding occurred in the M-1 Ditch Watershed.

Several drainage studies have been conducted, however each addressed a specific problem area. This study provides a comprehensive analysis of the existing conditions and provides regional solutions. This study is funded by a matching grant from the Texas Water Development Board (TWDB).

1.2 Project Scope

The scope of this project includes a detailed analysis of the existing M-1 Ditch watershed to provide a comprehensive identification and review of mitigation alternatives to reduce or eliminate flooding in the watershed. Priority was given to developed portions within the City of Alvin and at the FM 1462 and SH 35 crossings, which provide access to evacuation route SH 6.

1.3 Environmental Survey

A preliminary environmental data review was performed using state and national databases to identify known jurisdictional wetland and historical preservation sites in the watershed. The preliminary data review shows no evidence of environmentally or historically sensitive areas near the existing M-1 Ditch. The proposed regional detention pond, discussed later in the report, is located on a potential environmentally sensitive area. However, the impact may be avoided by selecting a nearby property. Jurisdictional wetlands and historical preservation sites are shown on Exhibit 1.2. The electronic shapefiles of these facilities are located in Appendix A on the attached CD.

1.4 Public Meetings

Two public meetings were hosted at the City of Alvin Senior Civic Center. The public was notified of the meeting through advertisements placed in the Alvin Sun two weeks prior to the events. The meetings were also announced at the City Council meeting prior to the events. A project newsletter was also produced by Crouch Environmental which described the project area and scope and also provided common sense tips for flood preparedness. The newsletter was distributed at the City Council meetings, placed in the lobbies of City Hall and the Public Works building.

At the meetings, attendees were asked to complete attendance cards and were offered pre-addressed comment cards to fill out on-site or at a later date. A project e-mail address was also established as another avenue for public input. The e-mail address was published in the newspaper advertisement and project newsletter.

The first meeting was held on February 28, 2010, near the end of existing conditions modeling. The purpose of the meeting was to inform the citizens of the project, explain the project goals and solicit feedback regarding areas prone to flooding. A narrated presentation was displayed on a large flat screen television in the front of the room. Several rows of chairs were arranged so that people could view the looping presentation at their leisure. The narration described the scope of the project, discussed the existing conditions of the watershed and defined the goals of the project. A large roll plot aerial of the watershed was centrally located in the room. The public was invited to place yellow dots on areas known to flood. Photographs of the aerial are in Appendix B. Citizens also discussed potential solutions with project team members. 29 residents attended the meeting. Copies of the attendance and comment cards are in Appendix B, along with a tabulated summary.

In preparation for the second public meeting, the project team attended the workshops of Brazoria County Conservation & Reclamation District 3 (CR&3) and the City of Alvin City Council. The workshops were open to the public, however the primary objective was to update the elected officials on the status of the project and solicit feedback. The narrated presentation from the first public meeting was updated to incorporate the study findings and show preliminary alternatives. After the presentation, the officials asked questions and made suggestions.

The second public meeting was held on June 28, 2010, near the end of alternative development. The purpose of the meeting was to update the citizens on the status of the project and discuss alternatives. The same narrated presentation that was shown at the workshops was displayed for the public to view at their leisure, similar to the first public meeting. The roll plot aerial of the watershed was also updated with the finalized watershed boundary and the public was invited to discuss their knowledge of the watershed and suggested alternatives. 16 residents attended the meeting. Copies of the attendance and comment cards are in Appendix B, along with a tabulated summary.

The third public meeting was held on December 6, 2010. The purpose of the meeting was to inform the citizens of the planned project approach. The narrated presentation from the second public meeting was updated to include project costs and displayed on television on a continuous loop for the public to view at their leisure. A roll plot aerial of the watershed was displayed on a central table for the public to view. Seven residents attended the meeting. Copies of the attendance and comment cards are in Appendix B, along with a tabulated summary.

1.5 Problem Areas

Feedback from the first public meeting and discussions with City personnel indicated three critical areas of concern: residential flooding along Stadium Drive, head losses at the Johnson Street box culverts and overtopping at FM 1462. The city's high school fronts Stadium Drive, between Moller and Durant, and reportedly sheetflows to Stadium Drive. The sheetflow overwhelms the storm sewer system and damages residences in the area. The box culverts at Johnson Street were expanded to their current size in 2001 and are the largest crossing that could be constructed at this location. However, sizeable head losses have been observed during past storm events, forcing the water level to rise and damage the nearby church. High waters during storm events threaten to overtop the approaches at FM 1462, impeding traffic when citizens may need access to evacuation route SH 6. These problem areas are highlighted on Exhibit 1.3.

2.0 DATA COLLECTION

2.1 Previous Studies

The following previous studies were reviewed and key information was used to avoid duplication of effort in this study:

- "Evaluation of Flood Reduction Benefits of the M1 Bypass for Brazoria County Conservation and Reclamation District No. 3, In Cooperation with the City of Alvin – Klotz Associates, Inc. – September 2006"
- "Request to Add Hydraulic Capacity to TxDOT Crossings over M-1 Channel in Alvin – City of Alvin – September 2007"
- "Alvin Master Drainage Plan Preliminary Phase for the City of Alvin – Klotz Associates, Inc. – November 2007"
- "Letter Report for Stadium Drive Storm Sewer Feasibility Study for City of Alvin – Klotz Associates, Inc. – January 2009"

2.2 Construction Plans

Construction plans for Hunter's Cove and Mustang Crossing, Sections 1 and 2 were provided by the City of Alvin. Drawings were also obtained from TxDOT for the FM 1462 crossing at M-1 Ditch. Attempts to retrieve TxDOT plans for SH 35 were unsuccessful.

2.3 Topographic Data

The City of Alvin provided LiDAR data flown in 2002, and is on the City of Alvin's 1983 datum. The LiDAR data was used for developing hydrologic parameters and the overbank data in the hydraulic model. Survey data from previous studies was used for the channel data. This data is also on the City of Alvin datum.

The M-1 Bypass was recommended in the "Evaluation of Flood Reduction Benefits of the M1 Bypass". Several channel geometries were proposed and the benefits for each were quantified. The Bypass was constructed without plans, no as-builts or survey was conducted after construction. This study included a field survey of channel cross sections at key locations. This survey information is located in Appendix C.

3.0 METHODOLOGY

The methodology followed for this project is outlined in the Brazoria County Drainage Criteria Manual, adopted in 2003.

3.1 Rainfall Hyetograph

Flood hazard flows were developed assuming a uniform area rainfall distribution over the entire modeled watershed. The distribution of the rainfall is represented by a succession of incremental rainfall intensities over a finite storm duration. The incremental rainfall pattern is a frequency-based rainfall pattern assigned by HEC-HMS and is dependent upon the following user supplied parameters:[1]

- **Exceedence Probability –** A storm event can drop rainfall totals that have a probability of occurrence at that location within a year. A 50% exceedence event means the rainfall total has a 50% chance of occurring once in every two years. Similarly, a 1% exceedence event could occur once every hundred years. The latter is often called the 100-yr event and can occur at any moment.
- **Max Intensity Duration** – A 15-minute maximum intensity duration is used, unless any of the modeled subbasins have a time of concentration less than 15 minutes. In that case, a maximum intensity duration of 5-minutes should be used.
- **Storm Duration** – Harris County uses a 24-hour storm duration.
- **Peak Center** – The storm peak should be 67% of the storm duration.

[1] US Army Corps of Engineers – Hydrologic Engineering Center "Hydrologic Modeling System HEC-HMS Users Manual" (2001): Page 102.

- **Storm Area (mi^2)** – A storm area of 0.01 mi^2 should be used. This forces HEC-HMS to use point rainfall without depth-area reduction.

In addition to the above user-supplied parameters, partial-duration point precipitation depths that correspond to the selected exceedence frequency are needed for input into HEC-HMS. The partial-duration point precipitation depths are based upon USGS values for Brazoria County.

Figure 3.1
Point Rainfall Amount (Inches) for Varying Durations and Frequencies in Brazoria County, TX
Rainfall Frequency

Duration	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
5-minute	0.57	0.64	0.69	0.78	0.84	0.91
15-minute	1.21	1.38	1.51	1.71	1.86	2.02
60-minute	2.35	2.87	3.24	3.78	4.20	4.62
2-hour	2.85	3.75	4.35	5.00	5.6	6.20
3-hour	3.30	4.10	4.9	5.6	6.3	7.15
6-hour	3.70	5.00	5.85	6.85	7.80	8.75
12-hour	4.40	6.00	7.25	8.50	9.60	10.75
24-hour	5.10	7.00	8.55	9.95	11.50	13.00

3.2 Loss Rates

Brazoria County uses the Initial and Constant method to approximate losses in HEC-HMS.

The following values should be used:

Initial Loss	=	0.75	inches
Constant Loss	=	0.1	inches/hour

3.3 Sub-watershed Parameters

Watershed parameters are the physical characteristics that define the hydrologic properties of the watershed. They are measured and computed from topographic maps, aerial photographs, survey notes, construction drawings, etc. Brazoria County Criteria Manual uses parameters to compute the Clark's unit graph time of concentration (T_c) and storage coefficient (R) values. The Clark unit graph parameters, drainage area, and Initial and Constant rainfall loss rates of a subbasin are used by HEC-HMS to develop the runoff hydrograph for a particular subbasin.

This section will define each of Brazoria County's watershed parameters and detail how each parameter should be measured.

3.4 Drainage Area

Subdividing drainage areas allows the watershed to be studied in greater detail. When subdividing a watershed, there are two factors that must be considered. The first is the purpose of the study. This defines the areas of interest and hence the locations where subbasin boundaries and analysis points should occur. The second factor is the hydrometeorological process and basin characteristics. Each watershed is intended to have uniform parameters and should be proper shape and size to not compromise the validity of the watershed parameters.

Subbasin drainage area is measured in square miles. Drainage area should not be less than one square mile since the Flood Hazard Study may not be valid for subbasins with areas less than this limit. If it is necessary to have a subbasin with a drainage area less than one square mile, the subbasin's resultant peak flows should be checked for reasonableness.

In lightly developed areas, topographic maps or LiDAR data may be used to delineate drainage boundaries. In areas of higher development, roads, railroads or lot grading typically forms drainage boundaries. Storm sewer systems do not usually define drainage boundaries, as they only carry a fraction of the 100-year storm event.

3.5 Watershed Length

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of the watershed length (L):

… the length of the longest watercourse for the subarea. It is defined as the length from the outflow point to the upstream subarea watershed boundary, and is measured in miles.

3.6 Watershed Length to Centroid

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of the watershed length (L_{ca}):

… the length along the longest watercourse (L) from the outflow point to a point perpendicular to the computer centroid of the drainage area and is measured in miles. The length to centroid represents the average distance a particle of runoff water will travel before reaching the outflow point and is used in determining the Clark's time of concentration (T_c) of the subbasin.

3.7 Channel Slope

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of Channel Slope (S):

The channel slope (S) is the weighted average slope of the middle 75% of the longest watercourse of a watershed. It is representative of how fast the runoff moves through a subbasin watercourse. The average channel slope is the divisor in the hydrologic equations that calculate the time of concentration (T_c) and storage coefficient (R) of a subbasin. It is measured from stream profile plots, construction drawings, and topographic maps, and is computed in feet per mile. Abrupt changes in channel slope (such as occurs at control structures, dams drop structures) should not be considered in the calculation.

3.8 Watershed Slope

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of Watershed Slope (S_o):

The watershed slope (S_o) is the average overland slope of a subbasin. It is measured from topographic maps at several representative overland flow paths, averaged, and computed in feet per mile. Similar to S, the watershed slope helps represent the speed that runoff drains overland from the drainage boundary to a subbasin watercourse.

3.9 Percent Land Urbanization

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of Percent Land Urbanization (DLU):

Percent land urbanization (DLU) is the portion of a drainage area that is used for residential, industrial, commercial and institutional purposes. Urban development reduces the infiltration area of a watershed thereby creating more excess runoff and increasing the speed that overland runoff will travel to a watercourse. It is used in the interpolation between undeveloped and fully developed values for the time of concentration (T_c) and storage coefficient (R) of a subbasin and is expressed as a percent of the total drainage area.

Percent impervious is calculated in the same manner as DLU. Using the land use area measurements, a weighted impervious percentage can be computed for each sub-watershed using the land use – impervious percentage relationship shown in Figure 3.2.

Figure 3.2
Impervious and Development Values

Landuse	Code	% Land Urbanization	% Impervious
High Density	HD	100%	85%
Undeveloped	U	0%	0%
Developed Green Areas	GA	50%	15%
Residential – Small Lot	RS	100%	40%
Residential - Large Lot	RL	50%	20%
Residential - Rural Lot	RR	0%	5%
Isolated Transportation	T	100%	90%
Water	W	0%	100%
Light Industrial	IC	100%	60%
Unknown		0%	0%
Airport	Air	100%	50%

3.10 Percent Channel Improvement

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of Percent Channel Improvement (DCI):

Percent channel improvement (DCI) is the portion of the longest watercourse which has an improved channel. It is expressed as a percent of the longest definable channel. An improved channel section is defined as a section which has been significantly altered from its natural state by a construction project for the purpose of providing storm flow capacity for existing or proposed urban development. It is interpolation between undeveloped and fully developed values of time of concentration (T_c) for a subbasin. Aerial photographs, construction plans, and field investigation are used to determine the extent of channel improvements.

3.11 Percent Channel Conveyance

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of Percent Channel Conveyance (DCC):

Percent channel conveyance (DCC) is the ration of discharge carried between the channel banks to the total expected discharge. The conveyance of a channel is interpreted to be the capability of the channel to carry runoff in an area of uniform high velocity. DCC is a factor in the T_c+R equation, but only affects the storage coefficient (R).

3.12 Percent Ponding

The following excerpt was taken from the "Brazoria County Drainage Criteria Manual" discussion of Percent Ponding (DPP):

Percent ponding (DPP) is the portion of a subarea where runoff is retarded from reaching a watercourse due to obstructions or natural storage. Such obstructions include leveed field (rice farms), swamps, etc. It is expressed as a percent of the total drainage area.

Percent ponding is used to increase Clark's storage coefficient (R) after its value has been calculated through the unit graph parameter equations and after the on-site detention adjustment factor has been applied. The adjustment of R due to the percent ponding should only be used when the ponded areas cover at least 20% of the watershed and is dependent upon the storm frequency being analyzed, as shown below:

Exceedence Event	Pond Adjustment Factor (RM)	
20%	$RM = 1.31\ DPP^{0.214}$	(Eq. 3.1)
10%	$RM = 1.28\ DPP^{0.199}$	(Eq. 3.2)
4%	$RM = 1.25\ DPP^{0.171}$	(Eq. 3.3)
2%	$RM = 1.23\ DPP^{0.153}$	(Eq. 3.4)
1%	$RM = 1.21\ DPP^{0.132}$	(Eq. 3.5)
0.2%	$RM = 1.17\ DPP^{0.086}$	(Eq. 3.6)

The flooded portion of a reservoir should not be considered a ponding area since its runoff will not be delayed from reaching a watercourse. Reservoir attenuation should be accounted for in storage routing computations or should be modeled directly in HEC-HMS.

3.13 Unit Hydrograph

Unit hydrograph parameters are calculated from the subbasin characteristics previously outlined. Utilizing the calculated unit hydrograph parameters in the Clark's Unit Hydrograph method allows for development of an estimated runoff hydrograph for a subbasin. Harris County utilizes the Clark's Unit Hydrograph technique due to its wide acceptance and the large number of storm hydrographs that have already been correlated to Clark's Unit Hydrograph parameters.

The HEC-HMS model requires three (3) parameters to predict runoff hydrographs using Clark's methodology:

1. Time of Concentration (T_C) - The time required for rainfall excess to travel the entire length of the longest watercourse (L).

2. Storage Coefficient (R) - Attenuates the hydrograph at the outflow point to account for storage in the subbasin.

3. Time-Area Curve - Defines the cumulative area of the subbasin as a function of time. The default curve in HEC-HMS is used.

"Brazoria County Criteria Manual" states the following concerning the equations:

The process is, calculate T_c using Equation 3.7, calculate T_c + R using either Equation 3.8 or 3.9, depending on the value of DLU. Then R = (T_c + R) – Tc. The minimum R values shall be 0.5.

As directed by the "Brazoria County Manual", the HCFCD unit hydrograph equations are as follows:[2]

$T_C = D[1 - (0.0062)(0.7\ DCI + 0.3\ DLU)](L_{ca}/ S^{1/2})^{1.06}$ (Eq. 3.7)
$T_C+R = 7.25(L/ S^{1/2})^{0.706}$ (if DLU < 18%) (Eq. 3.8)
or
$T_C+R = 4295\ (DLU)^{-0.678}\ (DCC)^{-0.967}\ (L/ S^{1/2})^{0.706}$ (if DLU>18%) (Eq. 3.9)

where:

L	=	watershed length, in miles
L_{ca}	=	length to centroid, in miles
S	=	channel slope, in feet per mile
DLU	=	percent urban development*
DLU	=	percent land urbanization*
DCI	=	percent channel improvement*
DCC	=	percent channel conveyance*
D	=	2.46 (if $S_o \leq 20$ feet/mile)
D	=	3.79 (if 20 feet/mile $< S_o \leq 40$ feet/mile)
D	=	5.12 (if $S_o > 40$ feet/mile)
S_o	=	watershed slope, in feet per mile

*Note: The values for DLU, DLU_{MIN}, DLU_{DET}, DCI, and DCC should be whole numbers (i.e., 50% would be represented by the number 50).

[2] Harris County Flood Control District "Hydrology for Harris County" March 3, 1988, Page E-8.

3.14 Stream Reach Routing

The Brazoria County Drainage Manual recommended the Modified Puls method for channel routing. This method is based on the continuity equation and a relationship between flow and storage or state. The routing is modeled on an independent-reach basis from upstream to downstream.

The Modified Puls method of routing requires three parameters to function:

- Storage –Outflow Relationship
- Number of Subreaches
- Initial Conditions

The storage-outflow relationship for a reach is determined from HEC-RAS by executing a multiple profile run of predetermined flow rates. The flow rates should encompass the expected 0.2% exceedence event discharge. Flows in the storage-outflow HEC-RAS model should be kept constant between HEC-HMS routing reaches.

The number of subreaches for a routing reach is calculated from the multiple profile run used to develop the reach's storage-outflow relationship. The average of all the profiles' travel time through a routing reach should be determined. Dividing the average travel time by the HEC-HMS model's time increment yields the number of subreaches for a given routing reach. The number of subreaches should be rounded to the nearest whole number.

If during the travel time calculations, the average velocity in the reach is found to be less than 1.0 feet per second and the reach's energy grade is relatively flat, it may be reasonable to assume that the reach is functioning as a linear reservoir. Therefore, instead of a high number of routing steps produced by the low velocity, the number of routing steps should be set to one (i.e. reservoir routing).

Initial conditions for all routing reaches should be set to "Inflow = Outflow".

4.0 HYDROLOGIC AND HYDRAULIC ANALYSIS

4.1 Hydrology

4.1.1 Clark Unit Hydrograph

The drainage areas were delineated based on overland flow patterns, as shown in the LiDAR. In some areas, notably M1_A3 and M1_A4, modifications to the drainage areas were made to account for the storm sewer system. While the LiDAR suggests that the northern portion of M1_A4 (North of Stadium Dr) drains into Mustang Bayou, the roadside ditches are graded toward South St. The drainage area delineated uses the high point of the ditch as the drainage divide. Similarly, the eastern portion of M1_A3 (east of Hill St) is drained via storm sewer into nearby Mustang Bayou. However, LiDAR strongly indicates that this area drains into M-1 Ditch. This is supported by City accounts of sheetflow cascading down Johnson St towards M-1. The drainage area accounts for this drainage pattern by reducing the bottom 224 cfs of the HEC-HMS runoff hydrograph by the capacity of the storm sewer system discharging to Mustang Bayou. Exhibit 4.1 is a drainage area map. T_c & R parameters can be seen in Appendix D. Standard storage routing was performed to define the attenuation and lag capacity of the M-1 Ditch. The routing used is in Appendix D.

4.1.2 Rational Method

The Rational Method was used to calculate peak flows for the small (less than 200 acres) drainage areas served by storm sewers. The time of concentration, T_c, was calculated using flow paths calculated for sheet flow, shallow concentrated flow, and flow through storm sewer. The rainfall intensity was calculated using Intensity-Duration-Frequency curves from the City of Alvin Criteria Manual. The C-values used were based on residential land use. The resulting peak flows were used to size the storm sewer system along Stadium Drive, Moller Road and Durant Street.

4.2 Hydraulics

Stream Hydraulics

A HEC-RAS model was developed using the tools available through ArcGIS. Field surveys were used to define channel geometry while LiDAR data was used for the overbank areas. A cross section layout is shown on Exhibit 4.2. TxDOT bridge FM 1462 was added with the aid of construction plans, while the remainder of the bridges were taken from a HEC-RAS model created by Klotz and Associates. Manning's n-values were assigned using standard practices and engineering judgment based on aerial photos and field observations. Existing high-density subdivisions were given an n-value of 0.99 to allow floodplain storage, while preventing floodplain conveyance through the developments.

Calibration of the HEC-RAS model is difficult due to the lack of high water data available along the M-1 Ditch. An effort was made to ensure that the headlosses and overtopping at major crossings (Johnson and South Streets, FM 1462 and SH 35) shown in the model are commiserate with the stages witnessed by City officials and residents. Witnesses indicate seeing major headlosses and flooding of the Baptist Church parking lot at the intersection of Johnson and South Streets. Flooding in the approaches of FM 1462 and SH 35 have made it difficult for citizens and emergency vehicles to pass during storm events.

Storm Sewer Hydraulics

The Evironmental Protection Agency (EPA) Storm Water Management Model (SWMM) is a dynamic model used for simulation of rainfall runoff in urban areas dominated by storm sewer systems. For this study, input hydrographs were routed through the storm sewer conduits, roadside ditches and overland components. The model utilizes the storage capacity of the system to calculate WSELs.

5.0 EXISTING CONDITIONS

The node and basin flows are summarized in Table 5.1, with the basin flows listed first and the routed node flows second. The routed node flows include the storm sewer system east of Hill Street draining away from the watershed and into Mustang Bayou. The WSEL summary along the M-1 Ditch is in Table 5.2. The headlosses through the bridges along M-1 Ditch are in Table 5.3.

The existing conditions model confirmed some of the problem areas described by the City and residents, in addition to exposing a few other locations. Much of the channel upstream of SH 35 has less than a 5-year Level of Service (LOS), as seen in Exhibit 5.1. The following crossings show considerable headlosses in the HEC-RAS model (see Table 5.3): Entrance to Calloway Crossing Subdivsion, Dumble St, Kost Rd and the Park Box Structure. These headlosses indicate that the culvert crossings are undersized and reduce the level of service of the M-1 Ditch. The culverts at the South and Johnson Street intersection are overtopped at the 5-year event, which is consistent with citizen feedback.

After receiving feedback from the City and its residents, it is apparent that street flooding in the vicinity of the high school is an important priority. The results from the HEC-HMS and HEC-RAS models indicate that this flooding is not solely caused by insufficient capacity within the M-1 Ditch. Further analysis indicates that the storm sewer system is not sized for the 5-year event, as specified in the City of Alvin Design Manual. The 5-year peak flow for drainage area M1_A2 is 113 cfs, which exceeds the combined 42" RCP and roadside ditch capacity of 99 cfs along Moller Street. M1_A4 has a 5-year peak flow of 73 cfs and has the same conveyance capacity of 99 cfs along Durant, however sheet flow from M1_A2 is likely due to the flat topography and the degree to which the storm sewer along Moller is undersized. The capacity of the storm sewer and roadside ditches are based Manning's equation using the standard minimum slopes. The lack of storm sewer conveyance is compounded by the high water surface elevation (WSEL) of the M-1 Ditch.

As previously discussed, FM 1462 and SH 35 are two major thoroughfares that provide access to evacuation route SH 6. The outside lane of FM 1462 is under 3" of water for the 10-year event, and is overtopped at the 50-year event. The stream does not encroach on the travel lanes or the shoulder of SH 35 during the 100-year event.

The limits of the floodplain and base flood elevations (BFEs) shown were drawn using the resulting WSELs from the hydraulic model and comparing it to the LiDAR. This is not sufficient to submit to FEMA for official mapping, however it is useful for highlighting problem areas in the watershed. The approximate existing floodplain is shown on Exhibit 5.2.

Pre-Mustang Crossing Subdivision Sections 1 & 2

Sections 1 and 2 of the Mustang Crossing Subdivision were constructed in 2004. The subdivision is located north of FM 1462 and west the M-1 Ditch, refer to Exhibit 1.2. Per the City of Alvin design criteria, an on-site detention pond was designed to provide mitigation for the increased imperviousness of the development for the 100-year event. Because the subdivision is not in a FEMA-mapped flood zone, there was no consideration of impacts to the flooplain created by this development. However, it is clear from the approximate floodplain shown in Exhibit 5.2 that the M-1 Ditch floodplain extended into the subdivision and reductions in floodplain conveyance and storage should have been considered in the mitigation requirements.

To quantify the impacts to the floodplain, a pre-Mustang Crossing Subdivision model was created. This required showing the tract as undeveloped in the hydrologic (changing the Tc & R for M1_B) and hydraulic model (Manning's n of 0.08 in the overbank). The resulting comparison shows increases in WSEL of up to 0.30' at the South Street culvert. The subdivision removed approximately 9.1 acre-feet of floodplain storage from the watershed, calculated using the LiDAR topographic surface subtracted from the HEC-RAS WSEL. The subdivision may be expanded at a later date, so the City may require proper mitigation in the future. The flows and WSEL calculations are in Appendix D.

Pre-Bypass

In "Evaluation of Flood Reduction Benefits of the M1 Bypass", Klotz Associates evaluated several bypass channel geometries from the Briscoe Canal, crossing under the Union Pacific Railroad and outfalling directly to Mustang Bayou. The bypass channel was undertaken to alleviate some of the flooding that occurred in the M-1 Ditch watershed. Several channel geometries were proposed and the benefits quantified.

The channel that was constructed did not conform to any of the proposed geometries. As constructed, the bypass channel is elevated above the flow line of the M-1 Ditch, and so provides relief to the M-1 Ditch for the less frequent storms. These benefits are quantified in Appendix D. The bypass decreases the WSEL on M-1 Ditch by approximately one foot at the Canal Siphon and the benefits dissipate by County Road 160.

6.0 PROPOSED CONDITIONS

The following flood improvement components were considered as part of the ultimate plan for improving the drainage in the watershed. The costs for each component are located in Appendix E.

6.1 Flood Improvement Components

6.1.1 Storm Sewer Improvements

Storm sewer improvements are proposed for Stadium Drive, Moller Road and Durant Street to provide the capacity for the 5-year event, the City of Alvin design event. The proposed improvements can be seen in Exhibit 6.1. The proposed improvements assume that the existing underground and ditch system will remain in place. Due to the size of the proposed boxes and right-of-way limitations, the proposed boxes will be constructed under the pavement. The preliminary engineer's estimate for these improvements is $4,814,668 and includes complete removal and replacement of the affected streets and sidewalks and installation of the storm sewer and inlets.

The proposed configuration will need to be refined at the next planning stage to account for constructability and other obstructions. Detailed dynamic modeling of the existing and proposed system (such as SWMM) should be completed to optimize the size of the storm sewers and ensure no interim downstream impacts on M-1 Ditch. In addition, the model should include enhancements to the lateral side streets to provide additional relief for residents who have experienced past flooding.

The additional conveyance provided by the proposed storm sewers need to be mitigated prior to construction of the proposed storm sewers. Mitigation can be provided via storm sewers sized for more than just conveyance, detention ponds located along M-1 Ditch or a diversion channel to provide an alternate route. Since the proposed boxes are already large and expensive and open land is available for detention, underground detention was not considered in this project. This option can be revisited if the land use of the watershed changes drastically prior to construction. The detention ponds and diversion channel options are discussed below.

6.1.2 Kost, Moller & Durant Detention Ponds

Three ponds are required to mitigate for the previously discussed storm sewer improvements and are located along M-1 Ditch at Kost Street, Moller Road and Durant Street. These ponds encompass 22 acres will provide a combined 75.85 acre-feet of storage and should be constructed prior to the storm sewer improvements.

The Durant Street pond, approximately 8 acres and 29.7 acre-feet, serves a drainage area of 68 acres and mitigates for the storm sewer improvements on Durant Street, with excess volume to be used for the improvements on Stadium and Moller. Therefore, this system can be isolated and constructed prior to the improvements on Stadium and Moller. The detention pond will be in-line, with the proposed storm sewer outfalling directly into the pond and then an outlet structure from the pond outfalling into the M-1 Ditch. In the next planning stage, optimization of the improvements should be include diverting some water from Moller to Durant to maximize the pond capacity and reap the most benefits with construction of this pond.

At 7 acres and a volume of 25.4 acre-feet, the pond at Moller Road is not large enough to mitigate for the storm sewer improvements required along Stadium and Moller. An existing antenna tower and support occupies a large section of land right at the corner of Moller and South Street and cannot be used for detention. The edge of proposed pond is 50' away from the support, with an additional 30 feet used for a maintenance berm. This is compounded by the storm sewer system that services a drainage area of 98 acres. The detention pond will be in-line, with the proposed storm sewer outfalling directly into the pond and then an outlet structure from the pond outfalling into the M-1 Ditch.

To completely mitigate for the storm sewer improvements along Moller Road, a smaller pond at Kost Street, upstream of the Moller pond, is required to have no adverse impact. This 6.6 acre pond will be off-line, with an outlet structure, and provides 20.75 acre-feet of additional storage. The suggested pond locations are shown in Exhibit 6.1.

6.1.3 School Parking Lot Pond

There is a possibility of using the school parking lot at the corner of Stadium Drive and Johnson Street for a detention pond. This 1.7 acre pond (volume of 5.5 acre-feet) will have limited use as a gravity system due to depth restrictions. However, if the land is readily available, then it may be used to phase in improvements along Stadium.

6.1.4 Diversion Channels

Since the above mentioned detention ponds are mostly used for mitigation, further improvements would be required to alleviate the overtopping and flooding that is occurring at several bridges along the M-1 Ditch. Three diversion routes were considered in this study: a diversion including the above-mentioned Kost-Moller-Durant ponds, a diversion-only within M-1 and diversion to C-1-B.

<u>Diversion with Detention at Kost-Moller-Durant</u>

This proposed diversion channel diverts flow from the M-1 Ditch at Moller Rd, and empties into an on-line detention pond, which outfalls to the M-1 Ditch just upstream of the crossing under Johnson Street. The channel has a 10' bottom width, with 4:1 side slopes and is approximately 6 feet deep. The channel requires new bridges at Rosharon Road and FM 1462 and at least two utility relocations.

The pond at the downstream end of the channel is required to mitigate for the increased conveyance in the watershed and is approximately 25.2 acres and 165 acre-feet. This diversion and pond would reduce flows in the M-1 Ditch downstream of Moller Road and alleviates the overtopping and flooding of the bridges, including the culvert at South Street. The proposed layout can be seen in Exhibit 6.1. The cost for this component is $7,853,300

Diversion Only

This diversion and downstream detention pond does not include detention ponds at Kost Road, Moller Road or Durant Street. The diversion channel follows the previously described alignment. The channel has a 30' bottom width, with 4:1 side slopes and is approximately 6 feet deep. This channel also requires new bridges at Rosharon Road and FM 1462 and at least two utility relocations.

The pond at the downstream end of the channel is required to mitigate for the increased conveyance in the watershed and is approximately 41.5 acres and 287 acre-feet. This diversion and pond would reduce flows in the M-1 Ditch downstream of Moller Road and alleviates the overtopping and flooding of the bridges, including the culvert at South Street. The proposed layout can be seen in Exhibit 6.1. The cost for this component is $14,752,900. This option is not included in the final recommendations because it is not easily phased into an overall watershed plan.

Diversion to C-1-B

This diversion begins at Kost and South Streets and diverted the 104 cfs from M-1 Ditch into a small tributary to C-1-B via 9'x4' RCB under Kost Street. C&R 3, responsible for C-1-B and its receiving channel, Chocolate Bayou, maintains that this tributary, C-1-B and Chocolate Bayou all have sufficient capacity to accept this flow. Assuming that this diversion will not affect residents in Chocolate Bayou, the tributary to C-1-B and C-1-B will need to be improved to daylight at Chocolate Bayou. This diversion is estimated to cost $5,283,800 and has minimal benefits to M-1 Ditch due to the small amount of water being diverted out of the watershed.

6.1.5 Bridge Improvements

FM 1462

Improving the FM 1462 crossing with two additional 6' X 6' RCBs, lowers the WSEL to half of the shoulder width for the 100-year event. Mitigation for the improved conveyance will be provided in the regional detention pond upstream of Johnson Street. Construction will be challenging with the heavy traffic on FM 1462 and the need for coffer dams or sheet piling to protect the construction area from unwanted waters during construction. The cost for this improvement is estimated to be $371,100.

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The existing bridge experiences headlosses, but no overtopping, therefore no improvement options were explored.

6.1.6 Culvert Improvements

The following culverts are undersized: Entrance to Calloway Crossing, Dumble St, Kost Rd and the Park Box Structure. The Coombs Street culvert should be increased to a 5'x5' box. An additional 48" RCP should be installed at the Dumble Street culvert. Two additional 60" RCP culverts should be installed at the Kost Street crossing. An additional 6'x6' RCB should be installed at the Park Street crossing. These culvert upgrades are estimated to cost $138,800 and will eliminate the floodplain in the upper reach of the watershed.

6.1.7 Concrete Channel Lining

If the proposed diversion channel becomes a less desirable solution, i.e. the land becomes unavailable or more private utility crossings are discovered, another alternative is concrete lining the earthen channel downstream of the South Street culvert to the Johnson Street bridge. A field visit indicates that private utilities may run parallel to the existing M-1 Ditch and may need to be relocated for construction. An off-line detention pond to mitigate for the increase in conveyance will be provided just upstream of Johnson Street. The cost for this improvement is estimated to be $11,773,400.

6.2 Combined Plans

6.2.1 Plan A

The preferred alternative of proposed improvements consists of:

- Detention ponds at Kost, Moller and Durant
- Storm sewer improvements along Stadium, Moller and Durant
- Regional detention pond at Johnson Street
- 10' bottom width diversion channel from Moller to Johnson Street
- M-1 Ditch culvert improvements at Coombs St, Dumble St, Kost Rd and the Park Box Structure and
- 2 additional 6'x6' box culverts at FM 1462.

Exhibit 6.1 shows the extent and route of the proposed improvements. This plan alleviates all the problem areas within the M-1 Ditch watershed (see Exhibit 6.2 for the improved LOS), while providing potential drainage outfalls for future development. Exhibit 6.3 compares the existing and residual floodplains. Further study could also size the channel and regional detention pond to mitigate for future development. The resulting flow and WSEL comparisions are in Tables 6.1 and 6.2, respectively. The total estimated construction costs for Plan A are $15,667,400. Back up calculations for Plan A are located in Appendix F.

6.2.2 Plan B

An alternative combination of proposed improvements consists of:

- Detention ponds at Kost, Moller and Durant
- Storm sewer improvements along Stadium, Moller and Durant
- Regional detention pond at Johnson Street
- Concrete channel lining from South to Johnson Street
- M-1 Ditch culvert improvements at Coombs St, Dumble St, Kost Rd and the Park Box Structure and
- 2 additional 6'x6' box culverts at FM 1462.

Exhibit 6.4 shows the extent and route of the proposed improvements. This plan alleviates all the problem areas within the M-1 Ditch watershed, but does provide potential drainage outfalls for future development. The M-1 Ditch along Johnson Street is at its maximum size and cannot easily be widened. The resulting WSELs are similar to those in Plan A, see Appendix G. The total estimated construction costs for Plan B are $16,466,400.

7.0 IMPLEMENTATION

Since the funds are not available to complete all components of the plan immediately, the project has been phased. In developing the phasing plan, higher priority is placed on areas of known structural flooding. All conveyance improvements are preceded or accompanied by detention, to avoid interim WSEL impacts upstream and downstream. The phases are designed to fit within the City's Capital Improvements Program.

7.1 Plan A

Phase 1 – consists of completing the storm sewer improvements along Durant Street system and constructing the Durant pond. This is one of the lower cost phases and will help solve a frequent problem of flooding due to inadequate storm sewer. A preliminary SWMM model shows that system can be sized for a 5-year event and reduce the structural flooding for the frequent storm events. Comparisons between Existing Conditions and Phase 1 flows and WSEL can be seen in Tables 7.1 and 7.2 respectively. This phase has a slight flow impact far downstream of the project, but this does not correspond to WSEL impacts. The SWMM model is in Appendix H. The cost of this phase is $986,600.

Phase 2 – consists of completing the remaining storm sewer improvements along Stadium and Moller and construction of the Kost and Moller ponds. The addition of these ponds provides residual flow decreases along the M-1 Ditch, resulting in WSEL decreases for this phase. Comparisons between Existing Conditions and Phase 2 flows and WSEL can be seen in Tables 7.3 and 7.4 respectively. The cost of this phase is $6,456,500.

Phase 3 – consists of constructing the regional detention pond near Johnson Street that will be required to mitigate for the future diversion channel. This phase does not have any impacts on the flows or WSEL, because the pond will be in-line on the diversion channel. A temporary weir can be added to the pond to have interim benefits. This weir will be removed after the completion of the diversion channel. The cost of this phase is $3,593,400.

Phase 4 – consists of constructing the diversion channel. This phase introduces the largest benefits to the M-1 Ditch, due to the diversion of flow at Moller Rd and routed through a detention pond before returning to the M-1 Ditch. Also in this phase, culvert crossings at Coombs Rd, Dumble St, Kost St and the Park Box Structure Crossing, will be improved to decrease headlosses. The change in WSEL can be seen in Table 7.5. The cost of this phase is $4,121,100.

Phase 5 – consists of adding two 6'x6' RCBs at FM 1462. This is the ultimate condition, which are summarized in Tables 6.1 and 6.2. The cost of this phase is $371,100.

The models for Plan A are in Appendix F.

7.2 Plan B

Phases 1-3 and 5 are the same in Plans A and B.

Phase 4 – consists of concrete lining the M-1 Ditch from downstream of the South Street culvert to the Johnson Street bridge. Also in this phase, culvert crossings at Coombs Rd, Dumble St, Kost St and the Park Box Structure Crossing, will be improved to decrease headlosses.

The models for Plan B are in Appendix G.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The urbanized portion of the M-1 Ditch is undersized, as are many of the culvert crossings. Conveyance capacity should be added to the system to lower the WSEL in critical areas. Prior to any increases in conveyance, mitigation measures (detention) should be in place.

The City has expressed interest in reducing the residential flooding along Stadium, Moller and Durant. The proposed storm sewer improvements should be refined in a Preliminary Engineering Report (PER) that includes dynamic modeling and alternate routes. Dynamic modeling of the system will provide an avenue for taking advantage of the storage provided by the boxes. In addition, the reduction in street flooding will be quantified and can be translated into the number of houses that will benefit.

Once the City implements the proposed improvements, as previously outlined, measures should be taken to ensure that the channel capacity is not downgraded due to future development. The City can require that future developments use the models developed in this report as a baseline for future projects, although enforcement may be problematic. Alternately, the existing conditions results of this study can be used as a foundation for further developing future FEMA effective HEC-RAS and HEC-HMS models and mapping.

9.0 FUNDING

Available Grants

TWDB administers grant programs designed to reduce flooding within the state. The Flood Mitigation Assistance (FMA) Program is the most applicable for funding the implementation of the recommended plan. TWDB administers this grant program for the State of Texas on behalf of FEMA. This program provides federal funding for cost effective measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes and other structures insurable under the National Flood Insurance Program (NFIP). This program has two components: planning and project grants.

Planning grants are available to develop or update the Flood Hazard component of a previously defined Multi-Hazard Mitigation Plan. An approved Multi-Hazard Mitigation Plan (Mitigation Plan), whether single or multi-jurisdictional, is an eligibility requirement of a community in order to apply for an FMA project grant.

The Mitigation Plan is submitted to FEMA for approval through the Governor’s Division of Emergency Management (GDEM). The Mitigation Plan must assess flood risk and identify technically feasible and cost-effective options to reduce that risk. The Mitigation Plan must describe the planning process and public involvement during the planning process in developing the Mitigation Plan, and must provide proper documentation of its formal adoption by the jurisdiction

Project grants are available to implement measures to reduce flood losses. Projects that reduce the risk of flood damage to structures insurable under the NFIP are eligible. Such activities include:

- Acquisition of insured structures and real property;
- Relocation or demolition of insured structures;
- Dry flood proofing of insured structures;
- Elevation of insured structures; and,
- Minor localized flood reduction projects.

Eligible projects must meet the following criteria:

- Cost effective and beneficial to the National Flood Insurance Fund. The Benefit Cost Ratio must yield 1.0 or greater;
- Technically feasible;
- Physically located in a participating NFIP community or it must reduce future flood damages in a NFIP community;
- Meet the minimum standards of the NFIP Floodplain Management Regulations;
- Comply with the applicant's Multi-Hazard Mitigation Plan; and
- Conform with all applicable laws and regulations, such as Federal and State environmental standards or local building codes.

FEMA may contribute up to 75% of the total eligible costs. At least 25% of the total eligible costs must be provided by a non-federal source. Of the 25% from the non-federal source, no more than half (12.5%) can be provided as in-kind contributions from third parties. Funding limits for planning grants are $50,000 to any one community five year period. Funding limits for project grants are no more than $3,300,000 to any one community during any five year period.

<u>City Funds</u>
The City funds the Public Works department through a portion of the sales tax. These funds are dedicated for streets and drainage maintenance and improvements through an amendment to the City Charter and are not available for other uses. The City will use these funds to pay for their portion of the improvements, if they are able to obtain any of the above-mentioned grants. If the City is unable to obtain any of the above-mentioned grants, the projects will be paid for exclusively through their portion of the sales tax.