Willow Creek Tributary M124-00-00 Feasibility Study for Extension Improvements

Prepared for:
The City of Tomball

Prepared by:

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

2925 Briarpark
Houston, Texas 77042
November, 2008

WILLOW CREEK TRIBUTARY M124-00-00
FEASIBILITY STUDY
FOR
EXTENSION IMPROVEMENTS

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CITY OF TOMBALL
ENGINEERING & PLANNING DEPARTMENT

SUMMARY OF
TECHNICAL REVIEW COMMITTEE MEETING
AND RECORD OF DECISIONS AND ACTION ITEMS

Date:	November 5, 2008
Project Title:	Willow Creek Tributary M124-00-00 Feasibility Study for Extension Improvements
Design Consultant:	Lockwood, Andrews & Newnam, Inc.
Managing Engineer:	Mike Vandewater, P.E.
TRC Date:	October 14, 2008

Attendees:

City of Tomball:
Jan Belcher
Mary Coker
Mark McClure, P.E.
Lori Lakatos, P.E.
Bobby Sanders

Lockwood, Andrews & Newnam, Inc.:
Mike Vandewater, P.E.
Derek St. John, P.E.
Patrick W. Phillips, P.E.

N/A
Jan Belcher
City of Tomball
City Manager

Mark McClure
City of Tomball
Director of Engineering and Planning

Mary Coker
Mary Coker
City of Tomball
Assistant City manager

Mike Vandewater, P.E.
Lockwood, Andrews, & Newnam, Inc.
Project Manager

Willow Creek Tributary M124-00-00 Improvements
Summary of Project Recommendations

Statement of the Problem

Channel M124 does not provide adequate capacity for the area of the City west of the Tomball Expressway. For all intensive purposes, the channel is non-existent north of FM 2920 up to the TxDOT detention facilities by the Expressway. Poor drainage conditions in the region causes problems for traffic on FM 2920, the private property and residents of the area, and for the existing commercial developments. Additionally, channel M124 does not provide sufficient depth to accommodate storm sewer outfall.

Alternative Selected

The report documents the numerous alternatives evaluated for channel routes, detention pond locations, development alternatives, and storm event sizes. A meeting was held on August 4th with City Staff from several departments to review the numerous alternatives evaluated in the report.

After a period of deliberation, the alternative selected by the City was channel route Alignment A, using a 1% Storm Frequency Design to size the channel and detention facilities using Mitigation Option 3 which mitigates the channel improvements and future loss of floodplain storage by development.

Construction Cost

The estimated construction cost of the channel and detention basin, *without adjustments for pipelines and oil wells,* is $20.3 Million. This cost does include Right-of-Way and miscellaneous construction costs, but does not include engineering effort.

Pipelines and Oil wells

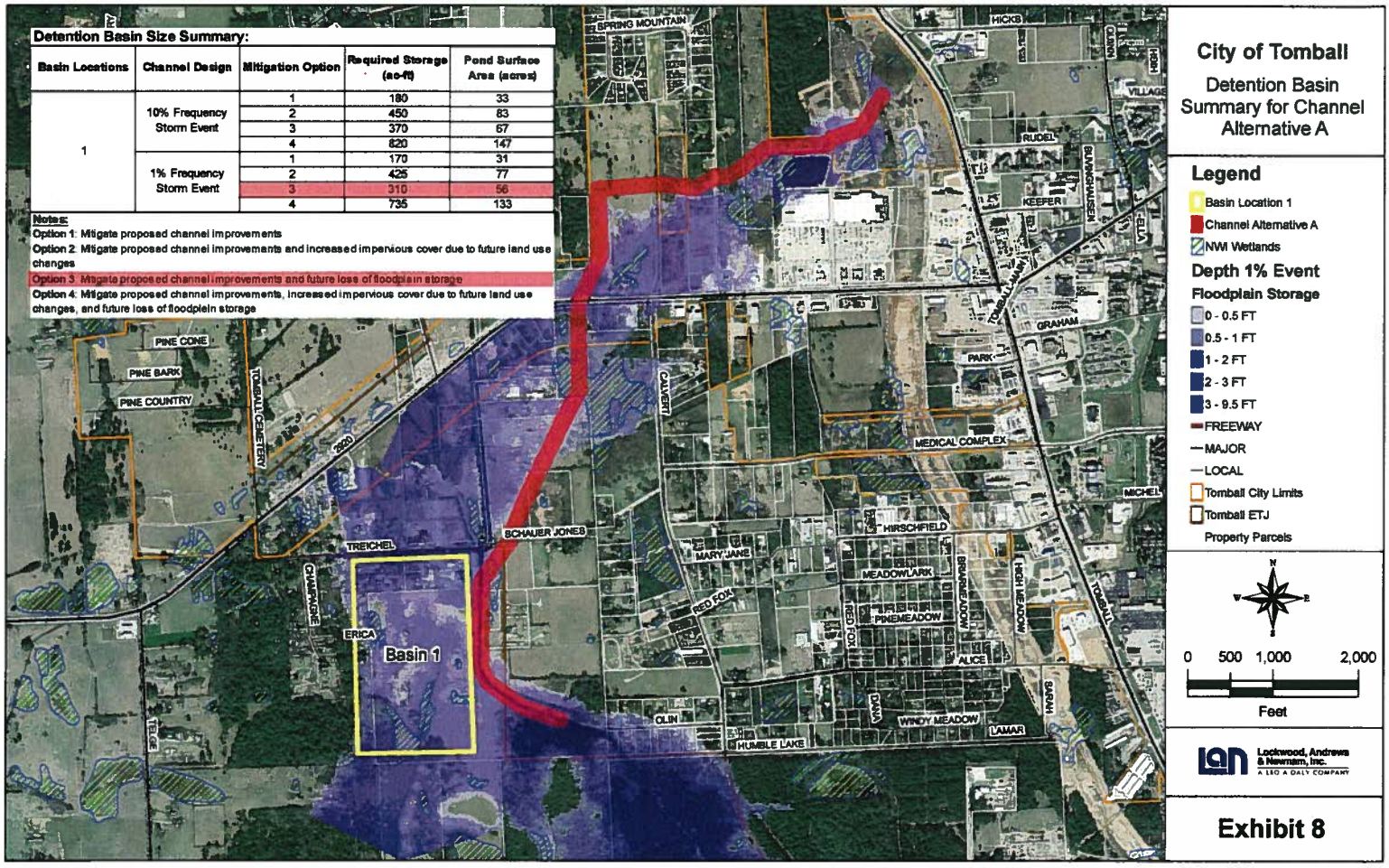
There are approximately 71 pipeline crossings that were identified from the State's GIS maps and previous studies. There are also 6 oil wells along the reroutes. It was beyond the scope of this report to accurately locate each pipeline and negotiate adjustment costs with each pipeline company. Determining a reasonable cost for dealing with these issues will be a significant task and unfortunately could cost millions to resolve. Identifying the costs associated with these facilities should be given high priority.

Next Steps

- Meet with Harris County Flood Control District (HCFCD) and Harris County Precinct 4 to review the project objectives and determine if they approve of the project in concept

- Identify and assess costs associated with the pipeline conflicts

- Perform Environmental studies along the route
- Survey the selected route
- Perform the preliminary engineering design phase and refine construction costs
- Meet with HCFCD and Harris County to formalize agreements
- Purchase ROW once the channel and pond limits are identified
- Perform the final design phase
- Begin construction



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Introduction and Background

Storm water runoff in the City of Tomball drains to one of two primary channels. These channels then route the flow across Harris County to the east. Spring Creek receives flow from the northern portions of Tomball and Willow Creek receives flow from the southern portions of the City. This report will focus on a tributary of Willow Creek that has been designated as Channel M124-00-00 (abbreviated as M124) by the Harris County Flood Control District (HCFCD). M124 extends north and west from its confluence with Willow Creek along the southwest corner of Tomball's Extraterritorial Jurisdiction (ETJ) up to Treichel Road and terminates at the south side of FM 2920.

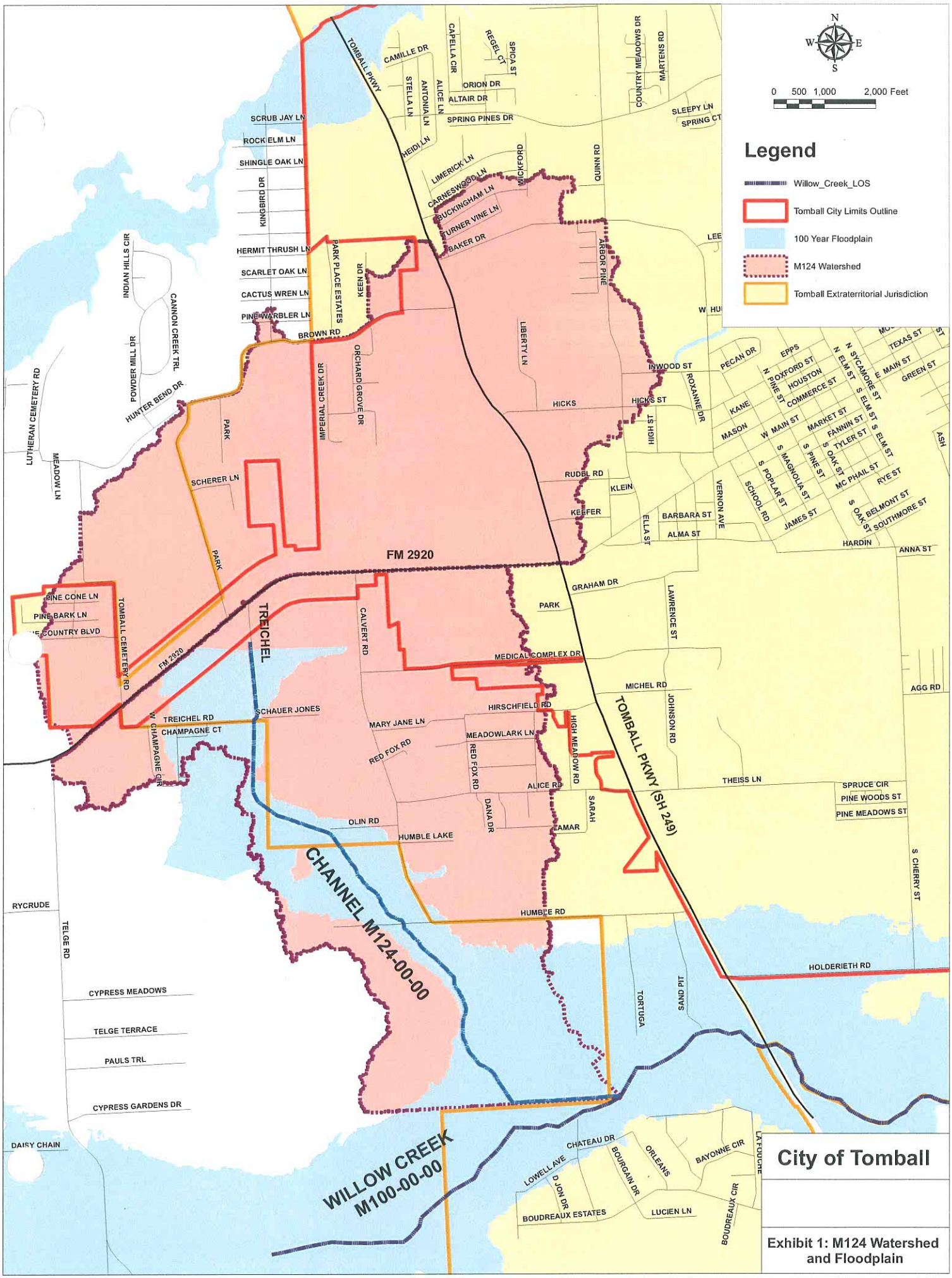
Channel M124 has been studied by the Federal Emergency Management Agency (FEMA) as part of the National Flood Insurance Program (NFIP) and a Flood Insurance Rate Map (FIRM) has been issued that shows the 100 year floodplain along the channel. The floodplain is shown on Exhibit 1 along with a delineation of the drainage area for M124. This drainage area map shows the portions of Tomball that drain to the channel.

The M124 watershed is 4.47 square miles and, as shown in Exhibit 2, there is approximately 996 acres within Tomball City Limits that drain into M124 from the north side of FM 2920. The Exhibit labels three regions within the drainage area that have different drainage characteristics. The flow from Region A is routed west across the new Tomball Expressway (SH 249). The current plan for this Region calls for detention facilities to be constructed along with new development that will maintain the existing flow rates across SH 249.

Region B is the "problem" area for the City. Currently there is not a channel in Region B that connects the flow coming from the east side of SH 249 to M124 south of FM 2920. Flow entering Region B from the box culverts under the new Expressway collects and ponds across the surrounding property until it begins to sheet flow south and west to find its way to FM 2920 where there are more drainage problems. This condition makes it difficult, if not impossible, to allow development of the approximately 588 acres in Region B without causing a negative impact in the area.

Drainage along FM 2920 within the M124 drainage area poses a significant roadway hazard to motorists traveling during a heavy rainfall. Storm water frequently ponds on segments of FM 2920 blocking portions of the traffic lanes. During heavier storms the roadway can be completely under water. The worst case scenario is traveling at night during a storm when drivers can not see the water in the roadway in time to react. Senior staff members of Tomball recall that this has been an ongoing problem for more than 20 years.

Compounding these problems is the fact that currently M124 and Willow Creek only provide a level of service for a 2 year frequency storm. This means that it only takes a 2 year storm event to fill M124 and Willow Creek to the top of its banks. It is more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Legend
Willow_Creek_LOS
Tomball City Limits Outline
100 Year Floodplain
M124 Watershed
Tomball Extraterritorial Jurisdiction
FM 2920
TREICHEL
TOMBALL PKWY (SH 249)
CHANNEL M124-00-00
WILLOW CREEK M100-00-00
TOMBALL PKWY
CAMILLE DR
CAPELLA CIR
REGEL CT
SPICA ST
ORION DR
ALTAIR DR
SPRING PINES DR
COUNTRY MEADOWS DR
MARTENS RD
SLEEPY LN
SPRING CT
STELLA LN
ANTONIA LN
ALICE LN
HEIDI LN
SCRUB JAY LN
ROCK ELM LN
SHINGLE OAK LN
KINGBIRD DR
HERMIT THRUSH LN
SCARLET OAK LN
CACTUS WREN LN
PINE WARBLER LN
BROWN RD
LIMERICK LN
CARNESWOOD LN
BUCKINGHAM LN
TURNER VINE LN
BAKER DR
WICKFORD
QUINN RD
ARBOR PINE
PARK PLACE ESTATES
KERN DR
INDIAN HILLS CIR
CANNON CREEK TRL
POWDER MILL DR
HUNTER BEND DR
LUTHERAN CEMETERY RD
MEADOW LN
PARK
IMPERIAL CREEK DR
ORCHARD GROVE DR
LIBERTY LN
INWOOD ST
HICKS
HICKS ST
HIGH ST
ROXANNE DR
PECAN DR
EPPS
N OXFORD ST
HOUSTON
COMMERCE ST
N PINE ST
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N SYCAMORE ST
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KANE
MASON
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MARKET ST
FANNIN ST
S TYLER ST
S ELM ST
S OAK ST
S PINE ST
S MAGNOLIA ST
S POPLAR ST
SCHOOL RD
MC PHAIL ST
RYE ST
S OAK BELMONT ST
S OAK SOUTHMORE ST
JAMES ST
HARDIN
ANNA ST
ASH
SCHERER LN
RUDEL RD
KLEIN
KEEFER
ELLA ST
BARBARA ST
ALMA ST
VERNON AVE
GRAHAM DR
LAWRENCE ST
PINE CONE LN
PINE BARK LN
COUNTRY BLVD
TOMBALL CEMETERY RD
FM 2920
CALVERT RD
MEDICAL COMPLEX DR
MICHEL RD
AGG RD
JOHNSON RD
TREICHEL RD
CHAMPAGNE CT
W CHAMPAGNE CIR
SCHAUER JONES
HIRSCHFIELD RD
MARY JANE LN
MEADOWLARK LN
RED FOX RD
HIGH MEADOW RD
ALICE RD
THEISS LN
SPRUCE CIR
PINE WOODS ST
PINE MEADOWS ST
DANA DR
SARAH
LAMAR
OLIN RD
HUMBLE LAKE
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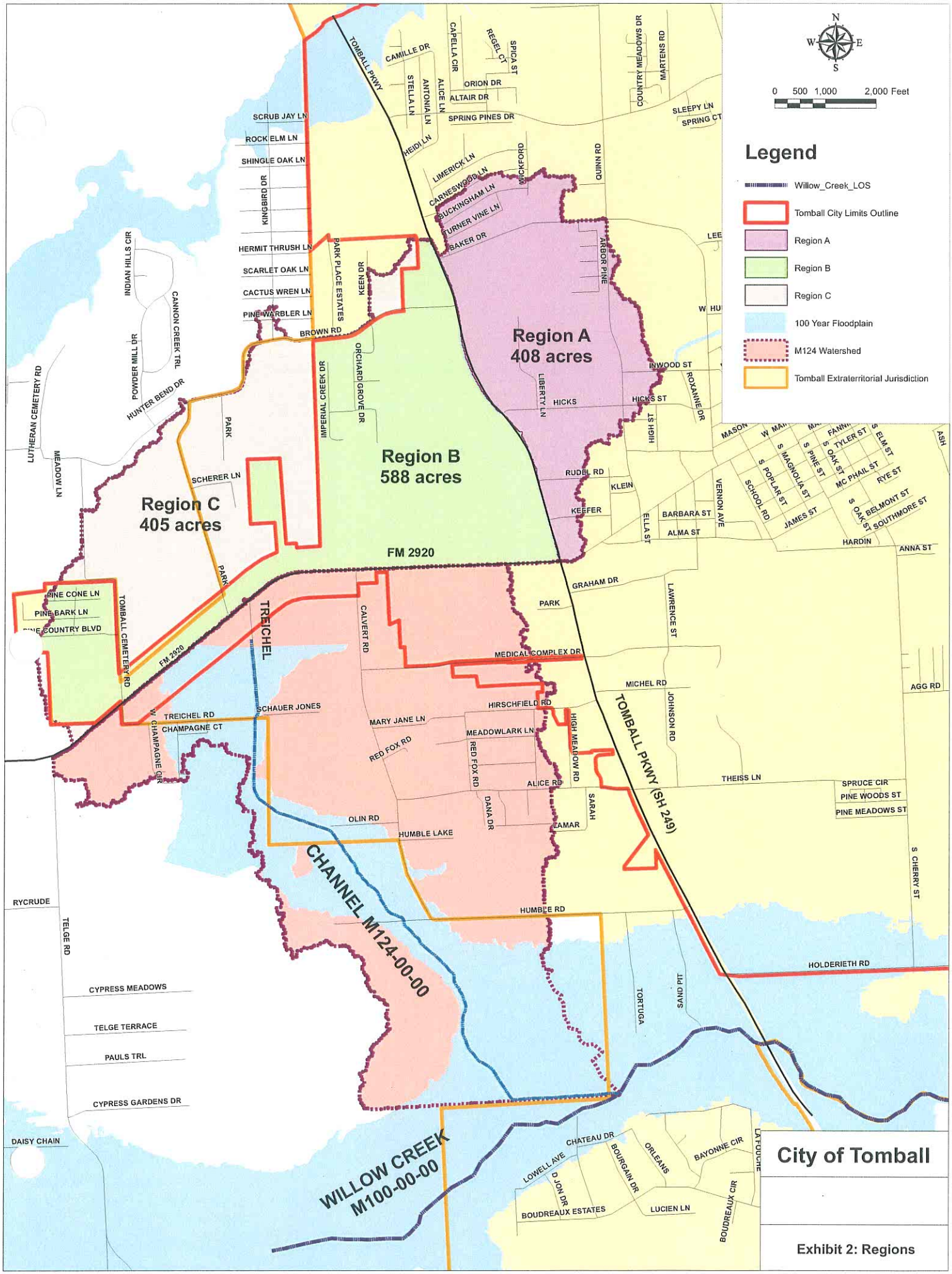
RYCRUDE
TELGE RD
HUMBLE RD
HOLDERIETH RD
CYPRESS MEADOWS
TELGE TERRACE
PAULS TRL
CYPRESS GARDENS DR
DAISY CHAIN
TORTUGA
SAND PIT
CHATEAU DR
LOWELL AVE
D JON DR
BOUDREAUX ESTATES
BOURGAIN DR
ORLEANS
BAYONNE CIR
LUCIEN LN
BOUDREAUX CIR
LA FOUCHE
City of Tomball
Exhibit 1: M124 Watershed and Floodplain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Legend
Willow_Creek_LOS
Tomball City Limits Outline
Region A
Region B
Region C
100 Year Floodplain
M124 Watershed
Tomball Extraterritorial Jurisdiction
Region A
408 acres
Region B
588 acres
Region C
405 acres
FM 2920
TOMBALL PKWY (SH 249)
TREICHEL
CHANNEL M124-00-00
WILLOW CREEK
M100-00-00
TOMBALL PKWY
CAMILLE DR
CAPELLA CIR
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SCARLET OAK LN
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HIGH ST
MASON
W MAIN
FANNIN
S TYLER ST
S ELM ST
S MAGNOLIA ST
S PINE ST
S OAK ST
MC PHAIL ST
RYE ST
S POPLAR ST
SCHOOL RD
JAMES ST
S OAK ST
BELMONT ST
SOUTHMORE ST
ASH
RUDEL RD
KLEIN
KEEFER
VERNON AVE
BARBARA ST
ELLA ST
ALMA ST
HARDIN
ANNA ST
GRAHAM DR
PARK
LAWRENCE ST
PINE CONE LN
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HUMBLE RD
TELGE RD
HOLDERIETH RD
CYPRESS MEADOWS
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TORTUGA
SANDPIPER
DAISY CHAIN
CHATEAU DR
LOWELL AVE
BOURGAIN DR
ORLEANS
BAYONNE CIR
LAFOURCHE
D JON DR
BOUDREAUX ESTATES
LUCIEN LN
BOUDREAUX CIR
City of Tomball
Exhibit 2: Regions

difficult to improve drainage for an area when the receiving streams have such a limited capacity.

The City of Tomball has contracted Lockwood, Andrews & Newnam, Inc. (LAN) to determine how to extend channel M124 north and east to SH 249. Such a project would provide the drainage infrastructure that will allow the drainage problems identified to be addressed. It should be noted that there are two components required to implement the complete project. The first component is to construct the appropriate infrastructure in the form of a channel that will accept the flow from the surrounding area. The second component is to construct the secondary collection systems to deliver the flow to the channel. This report will focus on the first component only.

Improving the conveyance capacity of Willow Creek or M124 downstream of the City's ETJ is beyond the scope of this study. Furthermore, such extensive improvements are not financially or politically practical.

Evaluate the Existing Conditions

The first step in the study phase is to assess the existing drainage conditions for Channel M124 and the watershed. Exhibit 3 presents a partial map of the area that drains to M124 and the key hydraulic elements that are the focus of this study.

There are two components in the assessment of existing conditions: 1) the determination of how much rainfall runoff will make it to the channel and 2) the determination of how much flow the channel can actually convey. The following section on Hydrology describes the process used to quantify the amount of rainfall runoff generated under various conditions. The section on Hydraulics describes the process used to estimate the flow carrying capacity for various reaches of the channel. Both components must be considered when assessing the existing conditions.

Hydrology

The methods prescribed in the Harris County Flood Control District Policy Criteria and Procedure Manual were used to estimate peak discharges and routing flow hydrographs. Because the M124 watershed is larger than 640 acres, the computer program HEC-HMS was used to simulate the storm water runoff conditions of the watershed. The Site Runoff Curves were used for estimating flows to the ditch on FM 2920.

The HEC-HMS hydrologic models obtained from HCFCD were updated to reflect the current land use and other watershed parameters. The models were run for various storm frequencies to quantify the peak flows for the existing condition at various analysis points.

The City of Tomball Master Plan 2007 - 2017 contains a projected land use map for planning water and sewer utilities. The land use map from this report showing the projection of future development was used as the ultimate development condition for the M124 watershed. The hydrologic models were then updated to reflect the ultimate development condition. The models generated flows that could be used to size the ditches and culverts for the ultimate condition.

The resulting peak flows generated for both existing and proposed conditions are presented in Exhibit 4.

A more detailed technical explanation of the modeling process is presented in the Appendix.

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Feet

Legend

- HCFCD Channels
- Region A
- Region B
- Region C

TOMBALL PKWY (SH 249)

Brown Rd

Region A
408 acres

Region B
588 acres

Hicks St

Sheet flow and ponding

Box culverts deliver flow to Region B

Region C
405 acres

Ponding problems on roadway

Existing box culverts 4 ~ 7x3

Existing box culverts 4 ~ 7x3

FM 2920 ditches have limited capacity

Calvert Rd

Treichel Rd

FM 2920

TOMBALL PKWY (SH 249)

Bridge to M124-00-00

M124 - Roadside ditches along Treichel have limited capacity

City of Tomball

Exhibit 3: Drainage Features

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Feet

Legend

- HEC-HMS Junctions
- Proposed Channel Route A
- M124 Drainage Subareas
- HCFCD Channels
- Freeway
- Major
- Local
- Tomball City Limits
- Tomball ETJ

ZION RD
QUINN RD
ULRICH RD
J231-00-00
E HUFSMITH RD
J131-04-00
W HUFSMITH
BAKER DR
J131-00-00
M124A1
M124A2
M124A3
Junction 1
M124B1
Junction 2
M124-00-00
M124B2
Junction 3
M124B3
FM 2920
TELGE RD
M125-00-00
Junction 4
TOMBALL PKWY
HOLDERIETH RD
M100-00-00
M123-00-00
M121-00-00
M122-00-00
M116-00-00

M124 Drainage Subarea Peak Flows Comparison Table:

HEC-HMS Hydrologic Element	Revised Existing Model - Peak Flows (cfs)		Land Use Option 1 and 3 Models - Peak Flows (cfs)		Land Use Option 2 and 4 Models - Peak Flows (cfs)	
	10% Frequency Storm Event	1% Frequency Storm Event	10% Frequency Storm Event	1% Frequency Storm Event	10% Frequency Storm Event	1% Frequency Storm Event
M124A1	435	751	435	751	435	751
M124A2	469	853	459	824	808	1,333
M124A3	719	1,209	719	1,209	835	1,376
M124B1	289	533	289	533	578	992
M124B2	96	172	96	172	220	358
M124B3	430	810	430	810	448	827

M124 Junction Peak Flows Comparison Table:

HEC-HMS Hydrologic Element	Revised Existing Model - Peak Flows (cfs)		10-Year Channel Improvements With Mitigation				100-Year Channel Improvements With Mitigation			
			Option 1 Model - Peak Flows (cfs)		Option 2 Model - Peak Flows (cfs)		Option 1 Model - Peak Flows (cfs)		Option 2 Model - Peak Flows (cfs)	
	10% Frequency Storm Event	1% Frequency Storm Event	10% Frequency Storm Event	1% Frequency Storm Event	10% Frequency Storm Event	1% Frequency Storm Event	10% Frequency Storm Event	1% Frequency Storm Event	10% Frequency Storm Event	1% Frequency Storm Event
Junction 1	790	1,463	761	1,258	1,016	1,663	761	1,307	974	1,685
Junction 2	1,145	2,337	1,128	2,077	1,459	2,639	1,112	2,124	1,391	2,573
Junction 3	1,034	2,256	716	1,748	724	1,747	729	1,835	706	1,899
Junction 4	1,032	2,564	783	2,089	818	2,152	785	2,157	801	2,279

City of Tomball

Exhibit 4: M124 Peak Flows

Hydraulics

The primary hydraulic elements such as ditches and culverts were evaluated to determine their existing flow carrying capacity. A level of service can be assessed for each hydraulic element by comparing the flow carrying capacity of the element to the amount of flow directed to the element. Problems can be identified by finding the structures that have more incoming flow than it has capacity to carry.

Hydraulic calculations and modeling were performed using Manning's Formula and the United States Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS). Manning's Formula was used to establish the initial estimates of capacity for channels and culverts. HEC-RAS was used to calculate the water surface profiles based on various flow conditions in the channel.

The survey datum used for elevations referenced in this report is based on the NAVD 1988, 2000 Adjustment. Profiles and cross sections in this report show elevations that are based on this datum and adjustment.

Problem Evaluation

After evaluating the existing conditions of M124, the next step was to identify the problem areas. The types of problems identified are channel reaches that demonstrate less than the desired capacity, hydraulic structures that restrict flow, and areas with limited right-of-way. Exhibit 3 shows a summary of the problem areas that have been identified after evaluating the existing conditions.

The fist problem identified is the absence of a ditch to convey flow from the culverts at the SH 249 Expressway across Region B to M124. As described in the Introduction, this condition causes water to sheet flow and pond across a large swath of land until the flow can make its way to FM 2920. This has caused considerable trouble recently with the construction of TxDOT's drainage and detention system for the SH 249 Expressway. TxDOT had months of very poor drainage conditions that kept their site muddy and made difficult conditions for construction. But worse than that, the drainage system that they constructed literally has nothing downstream to receive the flow.

This condition makes it difficult, if not impossible to develop in Region B without having a negative impact on the surrounding property. Development in this area would either remove badly needed storage that is currently provided on the property or will increase the impervious area and therefore increase the peak flows to the surrounding area. This highly unusual situation should be remedied as soon as possible.

The second problem is the FM 2920 drainage system does not have the capacity to convey the flow that it receives. A 2 year storm event causes storm water to pond on the roadway. There are 587 acres that drain to the roadside ditch along FM2920 and to the culvert just west of Calvert Road. It is estimated that a 2 year storm event would send in excess of 400 cfs to the ditches and culverts along the north side of the roadway. The capacity of the roadside ditches with the driveway culverts is less than 50 cfs. Even though some of the 400 cfs would be dissipated by the large volume of storage in Region B, the vast difference in flow versus available capacity illustrates the severity of the problem along FM 2920.

There are two culvert crossings that route flow from the north side of FM 2920 to the south side. Culvert A is located just west of Calvert and Culvert B is located at Treichel. Both culvert crossings consist of four 7 x 3 concrete box culverts. These culverts are relatively shallow and any future improvement to move water from the north side of FM 2920 to the south will require the construction of new crossings. Culvert A does not have the conveyance capacity to accommodate the flow coming to it from the east.

The third problem can not be solved by the City of Tomball but has been identified primarily to highlight the difficulty that it poses for any proposed drainage improvements. Each of the two streams M124 and Willow Creek (M100) has at most a 2 year level of service and therefore is not capable of accommodating any increase in flow from upstream channel improvements. This limitation will require mitigation of

downstream impacts caused by most any proposed drainage improvements. The mitigation will need to offset increased flows for all events from the 2 year up to the 100 year event.

Development of Alternatives

This phase of the study analyzes several design alternatives to improve the level of service of M124-00-00 to improve the existing drainage conditions and consider how future development can take place both in the Tomball City Limits and the Tomball Extra-Territorial Jurisdiction (ETJ) without adverse downstream impacts to Willow Creek.

Different design alternatives were investigated for M124-00-00 including different alignments for the channel, different channel sizes, and different regional detention basin locations and sizes. Two channel sizes were investigated and sized to provide the 10 year or the 100 year level of service. Various regional detention basins were sized for both mitigation of increased impervious cover due to future development and for mitigation of lost floodplain storage by filling in the floodplain. This report also estimates the right-of-way needed for the channel having a 10 year or 100 year level of service and estimates the costs associated with each of these options.

Channel Routes

The investigation of channel routes analyzed 7 different options that were reduced down to the 2 most feasible routes A and B. The analysis of all the routes can be explored in more detail in the technical report in the appendix. Exhibit 5 of the appendix shows the location of the routes considered. The table below shows the pros and cons of the two selected routes.

Summary of the Feasible Routes

Alignment	Pros	Cons
A	The channel is set back approximately 900' north of FM 2920 to allow for development Alignment travels through an existing HCFCD property south of FM 2920	Reconnects to the existing M124-00-00 channel south of Treichel Road which results in two channels requiring maintenance (Ultimate M124-00-00 Channel and existing channel along Treichel Road) Alignment does not travel along/through the lowest terrain north or south of FM 2920 where storm water currently ponds.
B	The channel is set back approximately 900' north of FM 2920 to allow for development Alignment travels through an existing HCFCD property south of FM 2920 and then connects to the Treichel roadside ditches eliminating Treichel Road and creating only one channel that requires maintenance Alignment travels along/through the lowest terrain south of FM2920 where the storm water ponding currently exists.	Alignment travels along FM 2920 south of the roadway restricting commercial development south of FM 2920 Alignment does not travel along/through the lowest terrain north of FM 2920 creating ponding areas outside the channel banks

Determination of Impacts/Mitigation

An integral part of any drainage project is the evaluation of adverse impacts and the recommended mitigation. If an adverse impact is calculated, a mitigation plan should be implemented.

One method for evaluating the impact of a project is to prepare hydrographs comparing the existing flow of stormwater over time to the proposed flow conditions over time. If there is an adverse impact, the proposed conditions hydrograph will have a higher peak flow than the existing conditions hydrograph. By comparing the hydrographs for the existing and proposed conditions, they can also be used to estimate the volume of stormwater that could be stored in a stormwater detention basin to offset the increase in flow over existing conditions.

A stormwater detention basin is a common way to mitigate the adverse impact, or increased stormwater flow, of a project. Stormwater detention basins are designed to receive and hold stormwater temporarily, until the peak flow passes, and then allow the detained water to drain out slowly over time. In this case, the increased flow from an improved M124 would be "held" in a stormwater detention basin so that there is no adverse impact downstream of the improvements on M124 or on Willow Creek.

There are various properties of a detention pond that affect its' performance such as volume, location, release rate, and tail water conditions. As a result, 6 alternative locations and sizes were evaluated. These alternatives are shown in Exhibit 7 of the appendix. Further study eliminated 4 of the pond locations leaving the 2 ponds shown in Exhibits 8 and 9 (appendix). Only one pond location works with Alignment A and 2 pond locations work with alignment B.

Permutation of Options for Alternatives

There is large number of options for the City to consider for addressing the drainage issues presented in this report. The variations of pond locations and alignments help proliferate a number of options to be explored. In order to provide the City with as much information as possible to make an informed selection, LAN had to evaluate multiple components that impacted each alternative that was considered.

Ultimately the City will want to answer the following questions:

1. How does the City want to deal with the impervious cover of future development? Do you want to require on site detention or size a regional pond for the future development?
2. What size design storm, or design storm frequency, is appropriate for the community and in this area of the community?
3. How will the City deal with the potential loss of floodplain storage from future development located in the floodplain?

These questions were classified as mitigation options for development, and sizing options for the pond and channel based on design frequency. In order to answer these questions, the investigation had to consider the following options for each alternative:

Mitigation Options for Future Development Conditions

1. Mitigate existing land use conditions and channel only
2. Mitigate ultimate development conditions and channel
3. Mitigate existing land use conditions, channel, and future elimination of floodplain storage
4. Mitigate ultimate development conditions, channel, and future elimination of floodplain storage

Sizing Options for Pond and Channel

1. Size for 10 year design frequency
2. Size for 100 year design frequency

Thus each of the four mitigation options, the two alignments A and B, and the 10 year or 100 year channel sizes required a separate regional detention basin configuration. For alignments A and B, the regional detention basin locations that demonstrated no downstream impacts are shown on Exhibits 8 and 9. Alignment A has one regional detention basin location that works and alignment B has two regional detention basin locations that work. With all of these options, 25 different regional detention basin configurations were evaluated. All of the alternatives were sufficiently sized to eliminate any negative downstream impacts.

The following table was prepared to summarize and make sense of all the options for each alternative. Study the table to put each of the options in perspective.

City of Tomball - M124-00-00 Channel Improvements

Summary of Alternatives ,Options and Estimated Costs (Exclusive of Pipeline Adjustment Costs)

Channel Alignment Alternative	Detention Basin Alternative	Channel Design (Frequency Storm Event)	Mitigation Option	Requires Det. For Future Dev. For Imp. Cover	Requires Det. For Future Dev. For Floodplain Storage	Requires Additional Infrastructure For Future Dev.	Average Right-of-Way Width (ft)	Right-of-Way Needs (acres)	Right-of-Way Costs ($Mil)	Channel Costs ($Mil)	Mitigation Needs (acre-feet)	Basin Surface Area (acres)	Detention Basin Costs ($Mil)	Major Roadway Crossing Costs ($Mil)	Cost of Channel and Basin (without pipelines) ($Mil)
A	1	10%	1	•	•		140	36.7	3.67	5.40	180	33	5.98	2.31	$13.7
			2		•	•					450	83	15.01	2.31	**$22.7**
			3	•			173	45.3	4.53	6.43	370	67	12.19	2.31	**$20.9**
			4			•					820	147	26.84	2.31	**$35.6**
		1%	1	•	•		170	44.6	4.46	6.73	170	31	5.63	2.31	**$14.7**
			2		•	•					425	77	14.01	2.31	**$23.1**
			3	•	•		203	53.2	5.32	7.77	310	56	10.20	2.31	**$20.3**
			4			•					735	133	24.21	2.31	**$34.3**
B	1	10%	1	•	•		140	38.3	3.83	5.63	180	33	5.98	2.40	**$14.0**
			2		•	•					450	83	14.77	2.40	**$22.8**
			3	•			173	47.4	4.74	6.71	370	67	12.19	2.40	**$21.3**
			4			•					820	147	26.84	2.40	**$36.0**
		1%	1	•	•		170	46.5	4.65	7.03	170	31	5.63	2.40	**$15.1**
			2		•	•					425	77	14.01	2.40	**$23.4**
			3	•			203	55.6	5.56	8.11	310	56	10.20	2.40	**$20.7**
			4			•					735	133	24.21	2.40	**$34.7**
	2	10%	1	•	•		140	38.3	3.83	5.63	180	33	5.98	2.40	**$14.0**
			2		•	•					450	83	14.77	2.40	**$22.8**
			3	•			173	47.4	4.74	6.71	370	67	12.19	2.40	**$21.3**
			4			•					820	147	26.84	2.40	**$36.0**
		1%	1	•	•		170	46.5	4.65	7.03	170	31	5.63	2.40	**$15.1**
			2		•	•					425	77	14.01	2.40	**$23.4**
			3	•			203	55.6	5.56	8.11	310	56	10.20	2.40	**$20.7**
			4			•					735	133	24.21	2.40	**$34.7**

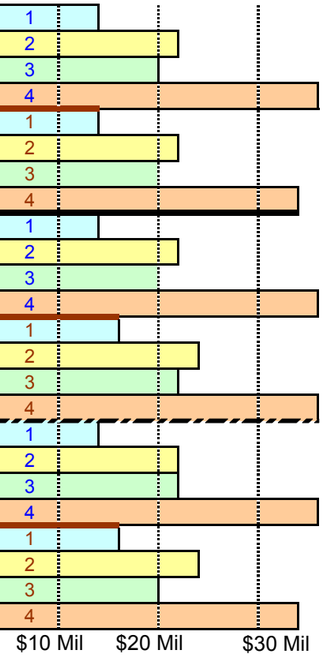


Chart of Costs

Mitigation Options

Option 1: Existing development conditions and channel only

Option 2: Mitigate channel improvements and increased impervious cover due to future development

Option 3: Mitigate channel improvements and future loss of floodplain storage by development

Option 4: Mitigate channel improvements, increased impervious cover due to future development, and future loss of floodplain storage

Observations About the Results

After reviewing the summary table to understand the 4 mitigation options, look at the bar chart on the right edge of the table graphing the costs of all the options. The following observations can be made:

Mitigation Option	**Rank by Cost (1 low 4 high)**	**Observations**
1) Mitigate existing conditions and channel only	1st	Option 1 costs are at least 20% less than Option 3 and 40% less than Option 2 and 60% less than Option 4 This may be the most practical option. Future development would be required to provide on site detention and possibly be required to compensate for lost floodplain storage. The difference in cost between the 10 year and 100 year is minimal so selecting the 100 year for this option is more practical. There is little difference in cost between channel alignment A and B
2) Mitigate ultimate development conditions and channel	3rd	Option 2 costs are significantly higher than Option 1. Even though detention will be provided for future development, a significant amount of infrastructure remains to be built to extend service to the new development locations. Compensation for floodplain storage is still required for this option.
3) Mitigate existing conditions, channel, and future elimination of floodplain storage	2nd	Option 3 is more costly than Option 1 but within an affordable range if the ability to develop without having to compensate for lost storage in the floodplain is highly desirable. There could be complications for this option if the fill material placed for a development blocks the existing drainage pattern for another property owner. Perhaps this could be worked out by careful planning.
4) Mitigate ultimate development conditions, channel, and future elimination of floodplain storage	4th	Option 4 is the most expensive alternative and does not provide significant benefit over Option 3 since this option would also have to construct additional infrastructure to accommodate the new development as discussed for Option 2.

It should be noted that the observations above did not consider the costs that may be incurred for pipeline relocation and dealing with existing or abandoned oil wells that are along the routes presented. There are approximately 71 pipeline crossings that were identified from the State's GIS maps and previous studies. There are also 6 oil wells along the reroutes. It was beyond the scope of this report to accurately locate each pipeline and negotiate adjustment costs with each pipeline company. Determining a reasonable cost for dealing with these issues will be a significant task and unfortunately could cost millions to resolve. Identifying the costs associated with these facilities should be given high priority.

Conclusion

The issues highlighted by this report will require planning and policy meetings to establish a consensus for dealing with future development in this area of the City.

This phase of the engineering was a conceptual and feasibility investigation. The next phase will select the channel alignment and determine which option fits the City's financial outlook and desires for this area of the community.

LAN would be happy to facilitate a series of meetings with Council, staff, and other stakeholders to begin the planning and decision making process. The Preliminary Engineering phase can begin on this project when the route is selected. The identification and assessment of the pipeline crossings will be an important component to complete so that a reasonably accurate cost can be determined. Since the pipeline adjustment costs could eliminate the feasibility of the project, it is suggested that this task be given a high priority.

Since the scope of construction for this project does not lie entirely within the City Limits, Harris County will have jurisdiction regarding the approval of this potential project. A meeting with the Harris County Flood Control District should be held when a more definitive course of action has been identified.

What's Next

The following is a list of key tasks that need to be performed in the next phase:

- City should hold meetings to determine planning and policy objectives
- City decides on scope and project route
- Meet with Harris County Flood Control District (HCFCD) and Harris County Precinct 4 to review the project objectives and determine if they approve of the project in concept
- Identify and assess costs associated with the pipeline conflicts
- Survey the selected route
- Perform the preliminary engineering design phase and refine construction costs
- Meet with HCFCD and Harris County to formalize agreements
- Purchase ROW once the channel and pond limits are identified
- Perform the final design phase
- Begin construction

TECHNICAL APPENDIX

WILLOW CREEK TRIBUTARY M124-00-00
FEASIBILITY STUDY
FOR
EXTENSION IMPROVEMENTS

Prepared for

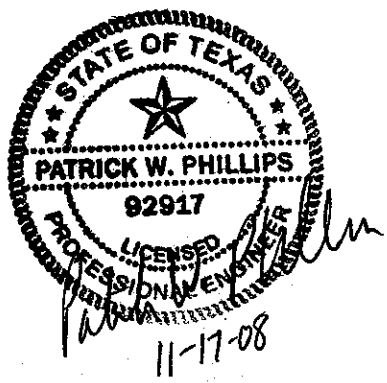
CITY OF TOMBALL

prepared by

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

2925 Briarpark
Houston, Texas 77042

November 2008



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1. PROJECT OVERVIEW

1.1. Introduction

Lockwood, Andrews and Newnam, Inc. (LAN) was authorized by the City of Tomball to prepare a Conceptual Engineering Report for a channel extension and improvements to Willow Creek Tributary M124-00-00. The intent of this M124-00-00 drainage study is to analyze and recommend several design alternatives to improve the level of service of M124-00-00 so that future development can take place both in the Tomball City Limits and the Tomball Extra-Territorial Jurisdiction (ETJ) without adverse downstream impacts to Willow Creek.

This Conceptual Engineering Report investigates different design alternatives studied for M124-00-00 including different alignments for the channel, different channel sizes, and different regional detention basin locations and sizes. Two channel sizes will be investigated and will be sized to provide the 10 year or the 100 year level of service. Various regional detention basins will be sized for both mitigation of increased impervious cover due to future development and for mitigation of lost floodplain storage by filling in the floodplain. This report also estimates the right-of-way needed for the channel having a 10 year or 100 year level of service and estimates the costs associated with each of these options.

1.2. Project Location

The project limits are shown on Exhibit 1. Willow Creek Tributary M124-00-00 is located within Harris County and the City of Tomball. The project area can be contained on Key Map pages 288E, 288F, 288J and 288K. Willow Creek Tributary M124-00-00 outfalls into Willow Creek, which in turn outfalls into Spring Creek and ultimately to Lake Houston.

1.3. Methodology

LiDAR generated during the Tropical Storm Allison Recovery Project was used to develop computer models to simulate the channel and detention basin alternatives. In particular, Harris County LiDAR data, aerial photography, ARC-GIS, and ARC-Hydro were utilized to delineate the drainage areas, time of concentrations, and other TC&R parameters that determine how fast and the quantity of runoff that enters the channel.

The analysis methods and procedures were taken from three publications. The first is a seminar manual prepared by Harris County Flood Control District (HCFCD), Hydrology for Harris County, prepared in March 1988. The second is the 2004 HCFCD Policy, Criteria, and Procedure Manual. The third publication is the TSARP Technical White Papers, prepared for HCFCD.

The hydrologic analysis was performed using HEC-HMS, version 3.1.0, developed by the U.S. Army Corps of Engineers, to develop runoff hydrographs for peak discharge estimation. The existing FEMA Effective HEC-HMS model was used to establish a base for hydrologic comparisons.

The hydraulic model was studied using U.S. Army Corp of Engineers' HEC-RAS software, version 3.1.3, to calculate the water surface profiles for steady-state flow in Willow Creek Tributary M124-00-00. The FEMA Effective HEC-RAS hydraulic model for Willow Creek Tributary M124-00-00, denoted as M124-00-00, begins south of FM 2920 and flows to the south boundary of sub-basin M124B_C at the confluence with Willow Creek, as shown on Exhibit 2.

Detention basin sizing and methodology was analyzed using the methods outlined in the research manual by Lee, Ka-Leung and Holler, E.R., Physical Modeling for Side-Channel Weirs, the Center for Research in Water Resources, University of Texas at Austin, prepared for the HCFCD in April 2002. Two methods are outlined in the report and this report uses Method A. This method analyzes a side discharge weir detention basin with variable tailwater and a weir and outfall pipe that can have forward or reverse flow.

1.4. Topographic Survey and Datum

The LiDAR data used in the analysis is referenced to the TSARP Benchmark Network based on the NAV Datum 1988 with the 2001 Adjustment. Both the hydrological and hydraulic models and all exhibits show elevations using this datum.

2. EXISTING CONDITIONS

2.1. Introduction

This section describes the modeling of existing conditions for Willow Creek Tributary M124-00-00. Once the FEMA Effective models were obtained, the modeling parameters were updated to reflect the current conditions of the watershed. A comparison of the FEMA Effective model and the revised existing conditions are provided in Table 1 of this section. Below is a summary of the hydrological and hydraulic existing conditions models for M124-00-00.

2.2. Hydrology

The purpose of the hydrologic analysis is to develop runoff hydrographs for peak discharge estimation for Willow Creek Tributary M124-00-00. The establishment of the revised existing conditions will serve as a baseline condition used to estimate the impacts of the proposed conditions model. The hydraulic modeling will be used to verify that there are no downstream impacts for the ultimate conditions.

2.2.1. FEMA Effective Hydrologic Model

The FEMA Effective model for Willow Creek Tributary M124-00-00 was obtained from Harris County Flood Control District (HCFCD). The study area, shown on Exhibit 2, consists of sub-basins M124A and M124B_C. Per FEMA Effective, M124A has a contributing drainage area (A) of 1.97 square miles, a channel slope (S) of approximately 13.3% from the upper to lower extent of the contributing drainage area, and is considered partially developed with an impervious coverage of 14%. Per FEMA Effective, M124B_C has a contributing drainage area (A) of 2.24 square miles, a channel slope (S) of approximately 7.0% from the upper to lower extent of the contributing drainage area, and is considered partially developed with an impervious coverage of 12%. These parameters can be seen in the TC and R values in Appendix A-1.

Exhibit 2 shows the existing level of service for the channel. The channel has a 2 year level of service or less for the area south of FM 2920. The area north of FM 2920 is not studied. North of FM 2920, the runoff sheet flows to the FM 2920 roadside ditch and then to the M124-00-00 ditch south of FM 2920 through 4-7'x3' RCB culverts.

The FEMA Effective model was based on the 2002 land use conditions. Additional development in the sub-basins has occurred since 2002 which adds more impervious coverage to the sub-basins, as shown on Exhibit 3.

2.2.2. Revised Existing Hydrologic Model

FEMA Effective model had M124-00-00 split into two contributing drainage areas using FM 2920 as the divide. To gain a better understanding of the flow rates within the M124-00-00 watershed and to model different channel improvements and detention basin locations, the

watershed was split into 6 subareas, as shown in Exhibit 4. M124A was split into 3 subareas and M124B_C was split in 3 subareas. The input parameters for the TC and R values were produced for the new subareas to reflect the current conditions. These parameters can be seen in the TC and R values in Appendix A-2.

Catchments were delineated from the 2002 LiDAR elevation data for overland sheet flow using ArcGIS along with the ArcHydro extension. These revised catchments were used to re-delineate the subareas. The revised delineations were compared to the FEMA Effective and presented in Exhibit 3. The drainage area (A) increased for sub-basin M124A by 165.6 acres and decreased for sub-basin M124B_C by 32.3 acres. The watershed length (L), centroid and length to centroid (L_{ca}) were recalculated for the revised sub-watershed boundaries and are shown in Exhibit 4. The channel slope (S) and overland slope (S_o) were calculated for the revised sub-watershed boundaries and can be found in the TC and R Table in Appendix A-2.

The revised sub-basin boundary and the revised sub-basin parameters for M124A varied considerably from the FEMA Effective model. This revised existing conditions model now becomes the baseline condition for comparing all other models developed.

Appendix B-1 shows the comparison of the FEMA Effective and the Revised Existing peak flows for the 100-year recurrence interval storm.

Differences from the FEMA Effective model were incurred while modeling the Revised Existing conditions. The key TC and R parameters for the Revised Existing conditions for the area north of FM 2920 (FEMA M124A) and south of FM 2920 (FEMA M124B_C) were averaged to match the drainage areas for the FEMA Effective model to allow for comparisons of approximately equal areas. The following table and discussion summarizes the differences in the two models.

Table 1: TC and R Comparison of FEMA Effective and Revised Existing

FEMA Drainage Subarea	Model	Channel Slope (ft/mi)	Overland Slope (ft/mi)	Percent Channel Conveyance (DCC)	Percent Urban Development (DLU)	DLU Detention (DET)	Percent Impervious	TC&R (Max)
M124A	FEMA Effective	13.3	89	20	35.5	14	14	4.09
	Revised Existing	34.8	79	70	47	25	25	4.24
M124B_C	FEMA Effective	7	43	20	32.6	12	12	7.4
	Revised Existing	11	18.5	50	29	15	15	0.3

- *Watershed Area*
  - The overall drainage area changed from 4.21 square miles to 4.43 square miles, or an increase of 0.22 square miles. This change reflects the northwest area, M124A_1, on Exhibit 3, that was not included in the original model, but drains to

the M124 watershed through 7-6'x3' RCB culverts under State Highway 249 and through 8-6'x4' RCB culverts under State Highway 249 Bypass.

- Channel Slope
  - The Revised Existing model for FEMA M124A utilized the entire weighted average slope of the longest watercourse of the watershed which was extended because the increased watershed area located in the northeast corner.
  - The Revised Existing model for FEMA M124B_C utilized the entire weighted average slope of the longest watercourse of the watershed, not just the M124-00-00 channel south of FM 2920.
  - The weighted average was computed as the 10% and 85% of the longest flowpath slope.
  - The Revised Existing model was nearly three times that of FEMA for M124A and the Revised Existing model was 57 percent greater than the FEMA model for M124B_C.

- Overland Slope
  - The FEMA watersheds were divided into more sub-drainage areas that affected the way the overland slopes were calculated originally. The smaller watersheds for FEMA M124A created more overland slopes to be averaged resulting in a more precise overland slope. The smaller watersheds for FEMA M124B_C created less area (length) for overland slopes to be computed.
  - The Revised Existing model was less than that of FEMA for M124A and the Revised Existing model was 57 less than the FEMA model for M124B_C.

- Percent Channel Conveyance
  - The FEMA model showed a 20 percent channel conveyance. The Revised Existing model averaged much higher for channel conveyance than FEMA Effective. The Revised Existing model followed the HCFCD White Paper for channel conveyance.

- DLU and Percent Impervious
  - Since the FEMA Effective model was developed, recent commercial and residential developments have been constructed. See Exhibit 3 for the changes in the development since 2002.

- DLU Detention
  - DLU detention is greater for the Revised Existing model to reflect the detention that was provided with the recent commercial and residential developments that have been constructed since 2002.

- Time of Concentration
  - The parameters above were used to calculate the TC and R values and resulted in the differences presented in Table 1.

2.3. Hydraulics

The purpose of the hydraulic analysis is to establish the revised 100-year water surface elevations (WSEL) using the hydrologic analysis and the geometric cross sectional properties that pertain to the Willow Creek Tributary M124-00-00 (M124A and M124B_C). The establishment of the revised existing conditions will allow for a comparison of the hydraulic model for the proposed channel design alternatives to ensure that the downstream water surface elevations for the 10 year and 100 year event do not increase. Also, a comparison is needed to issue a future CLOMR or LOMR for water surface elevation impact comparisons.

2.3.1. FEMA Effective Hydraulic Model

Willow Creek Tributary M124-00-00 is an improved channel south of FM 2920. The channel meanders within M124B_C and is generally a V-ditch in shape. The channel overbanks are primarily undeveloped with a few areas of development adjacent to the northern portion of the channel. The existing model shows the water surface elevation below FM 2920 by 0.3 feet for the 10 year event and above FM 2920 by 0.2 feet for the 100 year event.

The FEMA Effective peak discharges were provided as input at their respective cross sections in the hydraulic model to determine the FEMA Effective Level of Service of the channel along sub-basin M124B_C. The Level of Service of a channel is determined by which recurrence interval storm is held within the channel banks without spilling into the overbank areas. Exhibit 2 is a map of the channel for sub-basin M124B_C that shows the Level of Service provided along the channel reach. The channel was determined to have portions where the level of service is the 2-year recurrence interval storm and the remaining portions can only provide a level of service less than the 2-year recurrence interval storm.

The FEMA Effective 100-year WSELs are compared to the revised existing 100-year WSELs in Appendix C-1.

2.3.2. Revised Existing Hydraulic Model

Described in TSARP Technical White Paper "*Recommendations for Developing Station-Discharge Relationship with HEC-HMS and HEC-RAS,*" is a procedure to define how computed discharges from HEC-HMS should be placed in HEC-RAS for the hydraulic analysis. The FEMA Effective results for Station-Discharge calculations were modified to reflect the revised existing conditions by utilizing the procedure described in the White Papers.

The Revised Existing model shows the water surface elevation below FM 2920 by 0.2 feet for the 10 year event and above FM 2920 by 0.35 feet for the 100 year event.

The revised existing 100-year WSELs were observed to increase over the FEMA Effective model by a range of approximately one-tenth of a foot to two-tenths of a foot. Appendix C-1 shows a comparison of 100-year WSELs and top widths for the revised existing model and the FEMA Effective model.

2.4. Conditional Letter of Map Revision

A Conditional Letter of Map Revision (CLOMR) will be issued to the HCFCD and FEMA after the draft report is approved, a channel alignment and detention location is chosen and the City of Tomball approves funding for this task. The model will be loaded into HCFCD's database for future reference. This project's revised existing conditions raises the 100 year water surface elevations between one-tenth of a foot to two- tenths of a foot and the proposed conditions either lowers or keeps the same revised existing 100 year water surface elevations. A new map and flood plain will need to be established for M124-00-00 and Willow Creek.

ULTIMATE CONDITIONS

3.1. Introduction

The objective of this study is to increase the conveyance of Willow Creek Tributary M124-00-00 by providing a channel extension and improvements. The proposed drainage alternatives include various channel and detention basin sizes and locations. The proposed channel extension and improvements were sized for 2 different storm events (100-year and 10-year) and initially 7 channel alignments were considered. The detention basins were sized for 4 different mitigation options that provided mitigation for the proposed channel improvements, increased impervious cover due to future land use changes and/or for lost floodplain storage. Initially 6 detention basin locations were considered. The following discussion will summarize the channel alignments considered, land uses considered, channel sizing, mitigation alternatives, right-of-way requirements, pipeline and utility conflicts, and environmental impacts.

3.2. Channel Alignments

The proposed channel extension and improvements will extend north of the existing channel, across FM 2920 and bend around and terminate near SR 249 west of Hicks Road. Seven channel alternative alignments were identified and compared. The 7 alignment alternatives were lettered alphabetically from A to G and are shown in Exhibit 5. Alignment alternatives A and B were determined to be the most feasible alignments and were analyzed further. The primary reason the other alignments were not considered for further analysis was because they traveled through higher elevation ground and would limit the benefit of the channel to the lower surrounding areas. Other reasons included additional roadway crossings, too close to FM 2920, and increased channel length. The following bullets detail the differences and strengths of each alignment considered:

- **Alignment A:**
  - *Strengths*:
    - Provides approximately 900’ for commercial development north of FM 2920
    - Alignment travels through an existing HCFCD property south of FM 2920
  - *Weaknesses*:
    - Reconnects to the existing M124-00-00 channel south of Treichel Road which results in two channels requiring maintenance (Ultimate M124-00-00 Channel and existing channel along Treichel Road)
    - Alignment does not travel along/through the lowest terrain north or south of FM 2920 creating ponding areas outside the channel banks
- **Alignment B:**
  - *Strengths*:
    - Provides approximately 900’ for commercial development north of FM 2920

        - Alignment travels through an existing HCFCD property south of FM 2920 and then connects to the Treichel Road roadside ditches (removal of Treichel Road) creating one channel that requires maintenance
        - Alignment travels along/through the lowest terrain south of FM2920 limiting the ponding areas outside the channel bank
    - *Weaknesses*:
        - Alignment travels along FM 2920 south of the roadway restricting commercial development south of FM 2920
        - Alignment does not travel along/through the lowest terrain north of FM 2920 creating ponding areas outside the channel banks
- **Alignment C:**
    - *Strengths*:
        - Provides approximately 1200' for commercial development north of FM 2920
        - Alignment travels through an existing HCFCD property south of FM 2920
    - *Weaknesses*:
        - Reconnects to the existing M124-00-00 channel south of Treichel Road which results in two channels requiring maintenance (Ultimate M124-00-00 Channel and existing channel along Treichel Road)
        - Alignment travel through natural ground 4 feet higher than Alignment A (north of FM 2920) resulting in a wider channel cross section and increased ponding area outside the channel banks
        - Alignment does not travel along/through the lowest terrain south of FM 2920 creating ponding areas outside the channel banks
- **Alignment D:**
    - *Strengths*:
        - Alignment travels along/through the lowest terrain north of FM 2920 limiting the ponding areas outside the channel banks
        - Alignment travels through an existing HCFCD property south of FM 2920
    - *Weaknesses*:
        - Reconnects to the existing M124-00-00 channel south of Treichel Road which results in two channels requiring maintenance (Ultimate M124-00-00 Channel and existing channel along Treichel Road)
        - Alignment travels near FM 2920 north of the roadway restricting commercial development north of FM 2920
- **Alignment E:**
    - *Strengths*:
        - Provides for commercial development north of FM 2920
        - Alignment travels along/through the lowest terrain north of FM 2920 limiting the ponding areas outside the channel banks
    - *Weaknesses*:
        - Alignment travels along FM 2920 south of the roadway restricting commercial development south of FM 2920
        - Alignment does not travel along/through the lowest terrain south of FM 2920 creating ponding areas outside the channel banks

        - Alignment travels across Calvert Road, necessitating an additional culvert crossing
- **Alignment F:**
    - *Strengths*:
        - Provides approximately 900' for commercial development north of FM 2920
        - Alignment travels through an existing HCFCD property south of FM 2920
    - *Weaknesses*:
        - Reconnects to the existing M124-00-00 channel south of Treichel Road which results in two channels requiring maintenance (Ultimate M124-00-00 Channel and existing channel along Treichel Road)
        - Alignment does not travel along/through the lowest terrain north or south of FM 2920 creating ponding areas outside the channel banks
        - Alignment is similar to Alignment A, but has an increased channel length and two additional large bends along the channel increasing the cost of the channel improvements
- **Alignment G:**
    - *Strengths*:
        - Provides approximately 900' for commercial development north of FM 2920
        - Alignment travels through an existing HCFCD property south of FM 2920
    - *Weaknesses*:
        - Reconnects to the existing M124-00-00 channel near the end of the proposed improvements which results in two channels requiring maintenance (Ultimate M124-00-00 Channel and existing channel along Treichel Road)
        - Alignment does not travel along/through the lowest terrain north of FM 2920 creating ponding areas outside the channel banks
        - Alignment travel through natural ground 14 feet higher than existing M124-00-00 channel resulting in increased ponding area outside the channel banks a either a wider channel cross section or underground culverts along the alignment (negates the benefits to the land south of FM 2920)

Alignments A and B were selected for analysis and presented in the remaining sections of this report.

3.3. Mitigation Options

The hydrologic analysis performed for the proposed drainage conditions uses the same methods and procedures as described in the Revised Existing section of the report. The 6 subareas that were generated previously for the revised existing conditions were used during the proposed drainage alternatives analysis. The input parameters for the TC and R values were modified to reflect the proposed channel extension and improvements and the various mitigation options considered. The values can be found in Appendices A-3 and A-4.

The proposed conditions analysis evaluated four different mitigation conditions:

- Mitigation Option 1: Mitigation will be provided for the proposed channel extension and improvements. No mitigation will be provided for increased impervious cover due to future land use changes in the Tomball City Limits and ETJ within M124-00-00 or for lost floodplain storage along the channel. This option will require development to compensate a 1:1 ratio of fill in the floodplain along the channel in addition to mitigation of increased impervious cover.
- Mitigation Option 2: Mitigation will be provided for the proposed channel extension and improvements and for increased impervious cover due to future land use changes in the Tomball City Limits and ETJ within M124-00-00. The increased runoff can only be conveyed to the proposed channel extension and improvements as long as the storm sewer or ditch systems leading to the proposed channel can handle the proposed flows without causing unwanted impacts to adjacent landowners. If the existing drainage infrastructure is incapable of handling the increased runoff, all increased impervious cover will require mitigation. This option is much like the current City of Houston policy. This option will also require the developer to compensate a 1:1 ratio of fill in the floodplain along the channel.
- Mitigation Option 3: Mitigation will be provided for the proposed channel extension and improvements and for future lost floodplain storage along the channel. A regional detention basin will be provided that allows developers to fill the floodplain along the channel. Mitigation must still be provided by the developer for increased impervious cover.
- Mitigation Option 4: Mitigation will be provided for the proposed channel extension and improvements, for increased impervious cover sue to future land use changes, and for future lost floodplain storage along the channel.

The future land use conditions were based on the City of Tomball's Master Plan Map that projected future development.

Using the modified TC and R values, hydrographs were generated for each of these mitigation options and compared to the revised existing conditions. The hydrograph comparisons were then used to determine the detention basin size.

3.4. Channel Sizing

Detailed hydraulic modeling was completed for each design alternative using HEC-RAS version 3.1.3. The Revised Existing model of Willow Creek Tributary M124-00-00 was used as the base model in order to add the proposed channel extension and improvements. For each design alternative, the HEC-RAS model was modified to reflect the differences. These changes include the channel geometry necessary to convey the design storm event and were preformed using the HEC-RAS channel modification tools. The channel alternatives were designed assuming grass lined channels and a Manning's roughness coefficient of 0.04 was used to reflect the mature state

of the channel. The Manning's roughness coefficients used comply with Section 4.3 of HCFCD's Policy, Criteria and Procedure Manual.

Two channel alternatives were developed based on conveyance of the 10-year storm event and conveyance of the 100-year storm event. Both channels were designed with a minimum bottom width of 6 feet and a minimum side slope of 4 to 1, the minimums recommended by HCFCD. The 10-year channel was designed with a minimum channel slope of 0.05% south of FM 2920 and a minimum channel slope of 0.1% north of FM 2920. The channel geometry for the 10-year channel was a simple trapezoidal channel that met the HCFCD requirements. The 100-year channel was designed with a minimum channel slope of 0.05% with the geometry of a trapezoidal channel with a 10-foot bench located 5 feet above the channel bottom.

The channel size varies based on the level of service provided. North of FM 2920, the 10 or 100 year water surface elevation can be contained within the top bank, depending on the width of the channel provided. The 10 year channel size contains the 10-year water surface elevation within the banks and the 100 year channel size contains the 100-year water surface elevation within the banks. This means that the 10 year and 100 year channels provide a 10-year and 100-year level of service, respectively. South of FM 2920, the 100-year water surface elevation of Willow Creek is higher than the natural ground of the proposed channel alignment. This means that the water surface elevation can not be contained within the proposed channel banks south of FM 2920. For this study, the channel size north of FM 2920 was used south of FM 2920. Table 2 in Section 3.6 lists the right-of-way needed for each channel size.

3.5. Mitigation Alternatives

Each of the four mitigation options, the two alignments A and B, and the 10 year or 100 year channel sizes required a separate regional detention basin configuration. For alignments A and B, the regional detention basin locations that demonstrated no downstream impacts are shown on Exhibits 8 and 9. Alignment A has one regional detention basin location that works and alignment B has two regional detention basin locations that work. With all of these options, 25 different regional detention basin configurations were evaluated. The right-of-way needed for the detention basins are presented in Table 3 of Section 3.6. All of the alternatives were sufficiently sized to eliminate any negative downstream impacts.

To model the detention basins, a detailed storage-outflow relationship was developed for the basin using a spreadsheet that related channel tailwater, forward and reverse flow through the proposed detention basin from the side flow weir and flow out of the basin through the outfall culvert. The spreadsheet was used to calculate the discharge (cfs) for each time step used in the rainfall event in HMS based on the inflow from the channel into the basin and the outflow rate from the basin into the channel.

The side weir hydraulics was modeled with a 2002 report from the Center of Research in Water Resources (CRWR), Physical Modeling For Side Channel Weirs, (Report 02-2). The report's Method A was easily adapted into spreadsheet calculations. The spreadsheet was used to

quantify flow into the basin and reverse flow into the channel after the channel water surface elevation succeeded.

Results from the spreadsheet were inserted back into the HMS model as a discharge gage. The discharge gage modeled the water in the channel being removed and sent back to the channel at the rates calculated in the spreadsheet.

The peak flow results from the proposed conditions in the HEC-HMS model were input into the HEC-RAS model to verify no immediate downstream impacts. Cross sections were evaluated along Willow Creek Tributary M124-00-00 and no increases in water surface elevations were observed. Along Willow Creek it was verified that the peak flows did not increase.

3.6. Right-of-Way Requirements

The right of way and surface area requirements are summarized below for the two channel alignments, channel conveyance size, and level of mitigation provided.

Table 2: Channel Right-of-Way Requirements

Alternative	Total Channel Length (ft)	Channel Design (Frequency Storm Event)	Mitigation Option	Average Right-of-Way Width (ft)	Average Depth of Channel (ft)	Channel ROW Area (acres)
A	11417	10%	1, 2	140	8.5	36.7
			3, 4	173	8.5	45.3
		1%	1, 2	170	9.0	44.6
			3, 4	203	9.0	53.2
B	11923	10%	1, 2	140	8.5	38.3
			3, 4	173	8.5	47.4
		1%	1, 2	170	9.0	46.5
			3, 4	203	9.0	55.6

The right of way and surface area requirements are summarized below for the detention basin sizes required to provide mitigation for the different channel and mitigation options.

Table 3: Detention Basin Right-of-Way Requirements

Preferred Detention Basin Alternative	Channel Design (Frequency Storm Event)	Mitigation Option	Required Storage (ac-ft)	Basin Surface Area (acres)
1	10%	1	180	33
		2	450	83
		3	370	67
		4	820	147
	1%	1	170	31
		2	425	77
		3	310	56
		4	735	133
2	10%	1	180	33
		2	450	81
		3	370	67
		4	820	147
	1%	1	170	31
		2	425	77
		3	310	56
		4	735	133

3.7. Potential Pipeline and Utility Conflicts

A field survey preformed by SoDeep Incorporated identified several private utility crossing along the proposed channel extension and proposed detention basin sites that was done for a previous study. In addition, the Texas Railroad Commission has files of well locations and approximate pipeline locations for the project area. Exhibit 10 shows the pipeline crossings and well locations within the project watershed. There are potentially 71 pipeline crossings and 6 well locations within channel alignment A and pond location 1. The following tables summarize our findings:

Table 4: Pipeline Conflicts and Conceptual Cost

Major Pipeline Conflicts (>12")	Minor Pipeline Conflicts (<12")	Unknown Pipeline Conflicts	Water / Sewer Line Conflicts	Fiber Optic Cable Conflicts	Total Pipeline Conflicts	Pipeline Cost (Millions)
2	31	31	2	5	71	$21.7

Table 5: Well Conflicts and Conceptual Cost

Oil Well Conflicts	Abandoned Oil Well Conflicts	Service Well Conflicts	Gas Well Conflicts	Total Well Conflicts	Well Cost (Millions)
5	1	-	-	6	$1.8

The total cost of the pipeline and well relocation or abandonment could cost $23.5 million. A more detailed underground utility characterization analysis will need to be performed in order to determine the exact locations, depths, sizes, and future plans for the conflicting pipelines and wells. It is recommended that this detail analysis be performed after the ultimate channel alignment and size and the regional detention basin location is determined. This detailed analysis will allow a more accurate cost estimate of pipeline and well relocation or abandonment to be obtained. The unit costs used in Tables 4 and 5 for determining the cost of relocating or abandonment of each pipeline and well can be found in Appendix D-6.

3.8. Environmental Considerations

According to the National Wildlife Institute, by the Texas Fish and Game Department, Exhibits 8 and 9 show the registered wetlands. There are currently 26 wetlands registered that total 13.6 acres that intersect the regional detention basin and channel locations. These wetlands might not be jurisdictional wetlands registered with the Environmental Protection Agency, but a detailed environmental study will need to be performed to make a judgment on them. The following table identifies the specific proposed alternative and the approximate number of registered wetlands and approximate acreage affected.

Table 6: Wetland Conflicts

Design Component	Number of Wetland Conflicts	Impacted Wetlands (Acreage)
Channel Alternative A	7	3.5
Channel Alternative B	9	2.1
Basin Location 1	7	6.4
Basin Location 2	3	1.6

4. CONSTRUCTION COST ESTIMATES FOR ALTERNATIVES

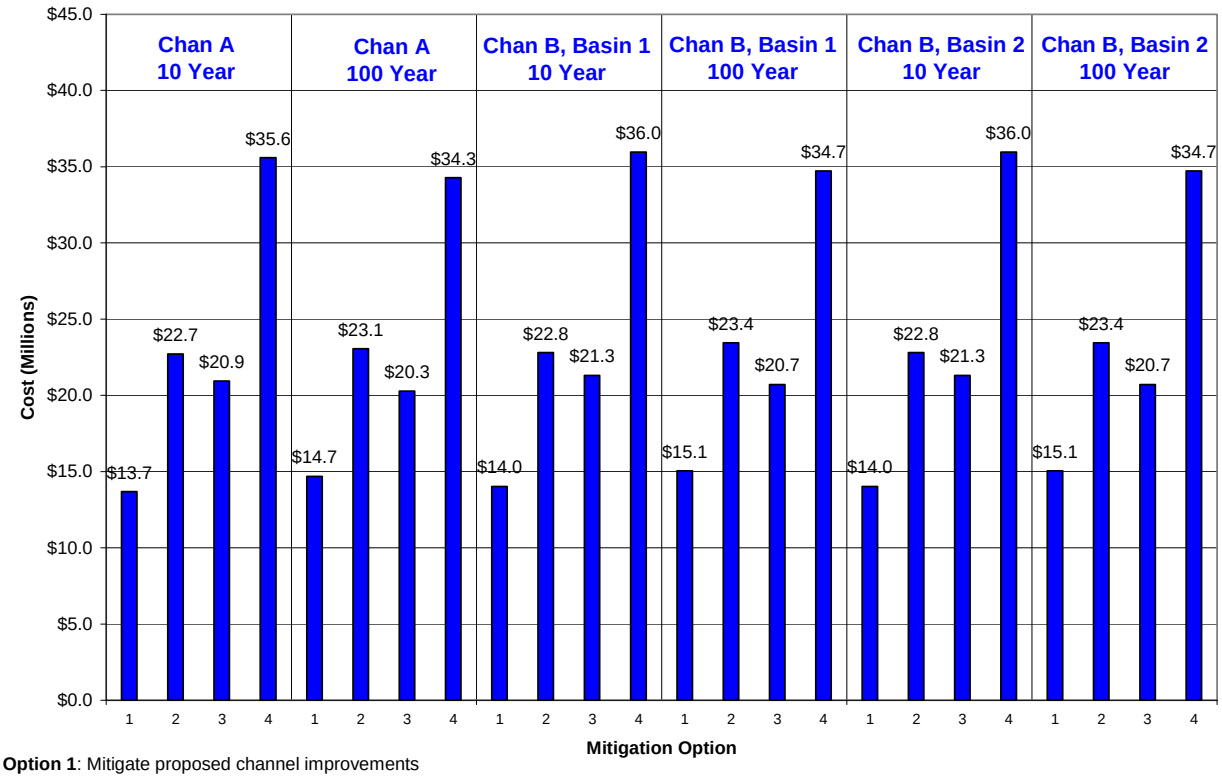
4.1. Introduction

The cost of the project was based on land values for the detention basin and channel, excavation costs, roadway replacement for FM 2920 due to raising the profile grade line, two culvert systems (one for FM 2920 and one for the future Medical Complex Drive), and the pipeline and well relocation or removal costs. The detailed itemization for the values can be found in Appendix D.

4.2. Cost Summary

Below is a chart summarizing the cost for each option discussed in Section 3.

Chart 1: Conceptual Cost of Channel & Detention <u>WITHOUT</u> Pipeline and Well Costs



Option 1: Mitigate proposed channel improvements
Option 2: Mitigate proposed channel improvements and increased impervious cover due to future land use changes
Option 3: Mitigate proposed channel improvements and future loss of floodplain storage
Option 4: Mitigate proposed channel improvements, increased impervious cover due to future land use changes, and future loss of floodplain storage

The costs range from $13.7 million to $36 million, depending on the level of service provided. It is worth noting that a 10 year channel requires a larger regional detention basin than the 100 year channel. This variation in the required regional detention basin size results in the 10 year and 100 year channels having approximately the came cost. Also, for each alignment option or pond location, the costs are approximately equal to each other. After an alignment and pond location

are chosen, the real cost question is which of the four mitigation options will be best for the City of Tomball. The price for each mitigation option provided in order of least expensive to most expensive are:

1. The least expensive solution ranges from $13.7 million to $15.1 million, depending on the channel size and alignment for Mitigation Option 1. This option provides mitigation for the proposed channel only. Mitigation for increased impervious cover due to future land use changes or future loss of floodplain storage is not provided. The developer will have to provide a 1:1 ratio of fill in the floodplain next to the channel.
2. The second least expensive solution ranges from $20.3 million to $21.3 million, depending on the channel size and alignment for Mitigation Option 3. This option provides mitigation for the proposed channel extension and improvements and lost floodplain storage along the channel through a regional detention basin. This option does not provide any mitigation for increased impervious cover due to future land use changes.
3. The third least expensive solution ranges from $22.7 million to $23.4 million, depending on the channel size and alignment for Mitigation Option 2. This option provides mitigation for the proposed channel extension and improvements and increased impervious cover due to future land use changes. Mitigation for lost floodplain storage is not provided and the developer will have to provide a 1:1 ratio of fill in the floodplain next to the channel.
4. The most expensive, but most complete service provided ranges from $34.3 million to $36.0 million, depending on the channel size and alignment for Mitigation Option 4. This option provides mitigation for the proposed channel extension and improvements, increased impervious cover due to future land use changes and lost floodplain storage along the channel through a regional detention basin.

5.0 SUMMARY OF FINDINGS

5.1. Introduction

This section summarizes the options presented and recommends two alignments for consideration by the City of Tomball as alternatives that allow development and causes no adverse downstream impacts to Willow Creek.

5.2. Channel Alignment

The two alignments A and B are shown in Exhibit 5. These alignments were selected because they allow the most development to take place and still follow reasonably the natural flow path of the watershed.

5.3. Mitigation Options

Section 3.3 presented the 4 different mitigation options that were evaluated. The City of Tomball will have to decide what level of service they are willing to provide based on available funds. The four mitigation options are:

1. Mitigation of the proposed channel extension and improvements only.
2. Mitigation of the proposed channel extension and improvements and increased impervious cover due to future land use changes.
3. Mitigation of the proposed channel extension and improvements and future lost floodplain storage.
4. Mitigation of the proposed channel extension and improvements, increased impervious cover due to future land use changes, and future lost floodplain storage.

5.4. Channel Sizing

The channel size varies based on the level of service provided. North of FM 2920, the 10 or 100 year water surface elevation can be contained with in the top bank, depending on the width of the channel provided. The 10 year channel size contains the 10-year water surface elevation within the banks and the 100 year channel size contains the 100-year water surface elevation within the banks. This means that the 10 year and 100 year channels provide a 10-year and 100-year level of service, respectively. South of FM 2920, the tailwater of Willow Creek causes the water surface to rise above the top of bank regardless of the size of the channel. For this study, the channel size south of FM 2920 remained the same as that required north of FM 2920 to provide the desired level of service. Table 2 in Section 3.6 lists the right-of-way needed for each channel size.

5.5. Mitigation

A regional detention basin was sized for each combination of the various design options. The different design options include the channel alignment (A or B), the channel size (based on level

of service desired), and the mitigation option. There are 4 mitigation options as described in Section 3.3 of this report. Alignment A has 1 possible regional detention basin location and Alignment B has two possible regional detention basin locations that are able to provide adequate mitigation of the proposed improvements. Exhibits 8 and 9 show the possible combinations of regional detention basins that will provide no adverse impacts downstream in Willow Creek.

5.6. Potential Pipeline and Utility Conflicts

Based on preliminary findings, there are numerous pipelines of various sizes and wells that will have to be relocated or removed that could cost $23.5 million. Once the channel alignment and regional detention basin location are finalized, a more detailed cost and pipeline analysis can be performed.

This cost was estimated by using the field survey preformed by SoDeep Incorporated that identified several private utility crossings for a previous study in the vicinity of the proposed project, Texas Railroad Commission file of well locations, and unit costs developed for HCFCD. These costs are simply a reminder that there could be some large costs associated with the pipelines and wells. Sufficient information is not available to provide a meaningful cost estimate.

5.7. Cost

The cost of the alternatives are presented in Chart 1 and Appendix D and range from $14 million to $36 million, depending on the level of service desired for the channel size, alignment, and mitigation option.

5.8. Conditional Letter of Map Revision

A Conditional Letter of Map Revision (CLOMR) will be issued to the HCFCD and FEMA after the draft report is approved, a channel alignment and detention location is chosen and the City of Tomball approves funding for this task. The model will be loaded into HCFCD's database for future reference. This project's revised existing conditions raises the 100 year water surface elevations and the proposed conditions either lowers or keeps the same 100 year water surface elevations. A new map and flood plain will need to be established for M124-00-00 and Willow Creek.

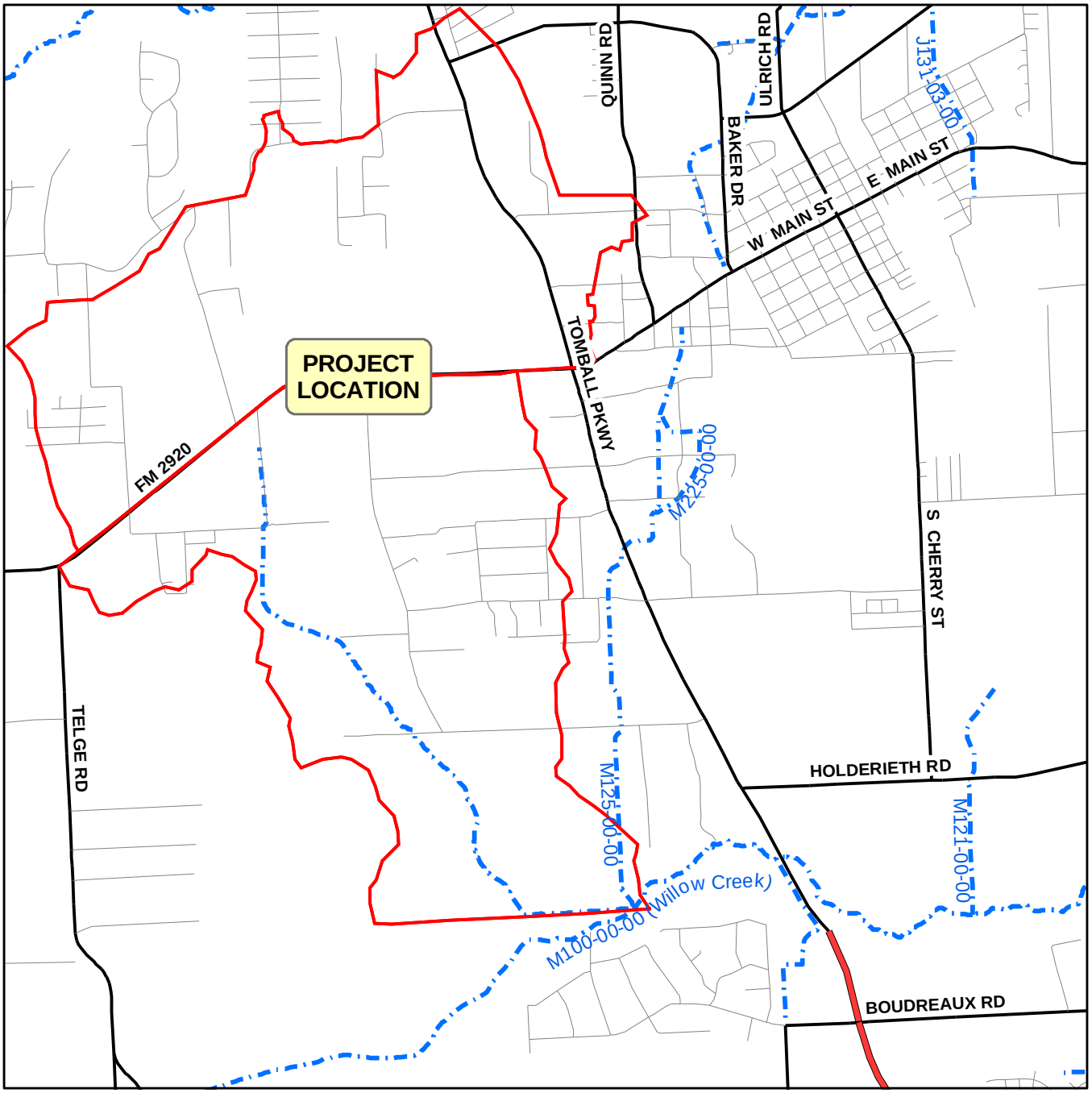
5.9. Environmental Considerations

According to the National Wildlife Institute, by the Texas Fish and Game Department, Exhibits 8 and 9 show the registered wetlands. There are currently 26 wetlands registered that total 13.6 acres that intersect the regional detention basin and channel locations. These wetlands might not be jurisdictional wetlands registered with the Environmental Protection Agency, but a detailed environmental study will need to be performed to make a judgment on them.

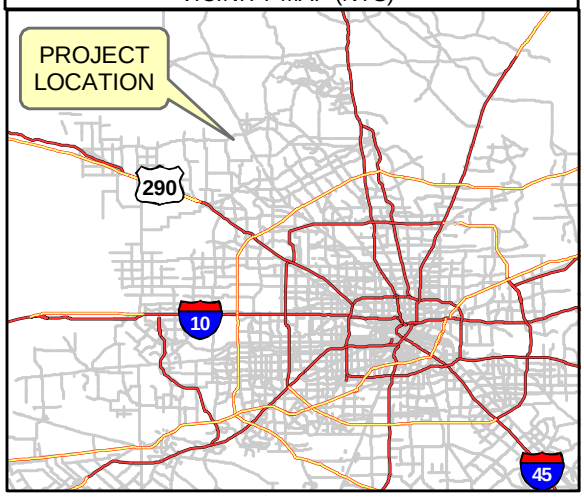
5.10. Summary

Based on this report, 24 separate options are provided for the following design options: two channel alignments, two channel widths, 2 regional detention basin locations and 4 mitigation options. The cost difference for each channel and regional detention basin option can be seen from Chart 1. The 100 year channel and the chosen regional detention basin is approximately the same cost as the 10 year channel and the equivalent regional detention basin. The regional detention basins for the two alignments (A and B) are approximately equal in cost. The real decision is this: which of the four mitigation options discussed in Section 3.3 is a good choice for future growth of the City of Tomball and is financially feasible for the City of Tomball? This narrows the 24 different options to 4 options once an alignment and regional detention basin location is chosen. To summarize, the following decisions will be necessary:

1. Which of the two alignments A or B will serve the City of Tomball best? Alignment A has one regional detention basin location available, and Alignment B has two regional detention basins locations available.
2. The level of protection (10-year or 100-year recurrence interval storm) that the proposed channel will provide for the City of Tomball will need to be determined.
3. A utility survey of the pipelines and wells are needed that summarize the cost of relocating the pipelines and wells.
4. An environmental impact study is needed to determine what wetlands are in the project vicinity and what the solutions can be provided.
5. The next choice is which of the four mitigation options are best for the City of Tomball. The cost varies significantly for each of the four mitigation options.



VICINITY MAP (NTS)



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M124-00-00
CHANNEL IMPROVEMENTS

Lockwood, Andrews & Newnam, Inc.
A LEO A DALY COMPANY

CITY OF TOMBALL
PRELIMINARY DRAINAGE REPORT

PROJECT LOCATION MAP
HARRIS COUNTY, TEXAS

EXHIBIT 1

City of Tomball

FEMA Effective Drainage Subareas And Existing Level of Service Map

Legend

Existing Level of Service

- M124-00-00, 2-YR EVENT
- M124-00-00, < 2-YR EVENT
- M100-00-00, < 2-YR EVENT
- FEMA Effective Subareas

StarMap_HC

- Freeway
- Major
- Local
- Tomball City Limits
- Tomball ETJ

N W E S

0 1,000 2,000 4,000

Feet

Exhibit 2

M124A

< 2-YR EVENT

2-YR EVENT

< 2-YR EVENT

M124B_C

M124-00-00 Channel

2-YR EVENT

Willow Creek M100-00-00

QUINN RD

ULRICH RD

E HUFSMITH RD

W HUFSMITH RD

BAKER DR

N CHERRY ST

E MAIN ST

W MAIN ST

TOMBALL PKWY

S CHERRY ST

FM 2920

TELGE RD

HOLDERIETH RD

City of Tomball

Revised Existing vs. FEMA Effective Land Use Changes Map

Legend

- Land Use Changes
- Revised Existing Subareas
- FEMA Effective Subareas
- HCFCD Channels

StarMap_HC

- Freeway
- Major
- Tomball City Limits
- Tomball ETJ

Note: This map shows the added development since the 2002 FEMA Study

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Feet

Exhibit 3

City of Tomball

Revised Existing Subareas for M124-00-00 Map

Legend

- Revised Existing Subareas
- Subarea Centroids

Longest Flow Paths

- Ultimate
- Existing

Length To Centroids

- Ultimate
- Existing
- HCFCD Channels

StarMap_HC

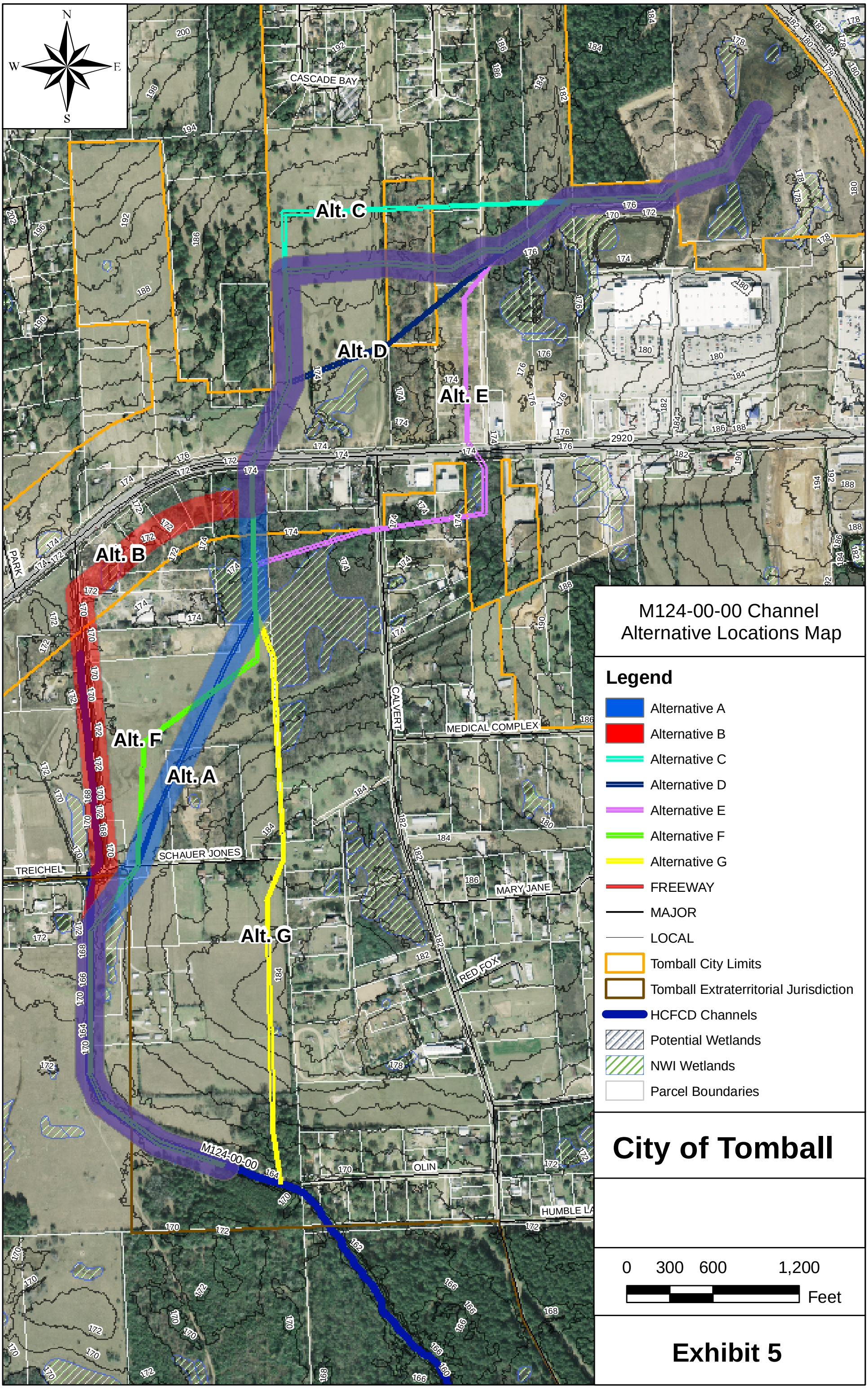
- Freeway
- Major
- Local
- Tomball City Limits
- Tomball ETJ

N W E S

0 1,000 2,000 4,000

Feet

Exhibit 4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2920
PARK
CALVERT
MEDICAL COMPLEX
SCHAUER JONES
TREICHEL
MARY JANE
RED FOX
OLIN
HUMBLE LA
M124-00-00
M124-00-00 Channel
Alternative Locations Map
Legend
Alternative A
Alternative B
Alternative C
Alternative D
Alternative E
Alternative F
Alternative G
FREEWAY
MAJOR
LOCAL
Tomball City Limits
Tomball Extraterritorial Jurisdiction
HCFCD Channels
Potential Wetlands
NWI Wetlands
Parcel Boundaries
City of Tomball
0 300 600 1,200
Feet
Exhibit 5

City of Tomball

Partial Development Land Use Map

Legend

Land Use

- High Density
- Residential Large Lot
- Water
- Channel Alternative A
- Channel Alternative B
- Revised Existing Subareas
- HCFCD Channels

StarMap_HC

- Freeway
- Major
- Tomball City Limits
- Tomball ETJ

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Feet

Exhibit 6

City of Tomball

Detention Basin Locations Considered Map

Legend

- Basin Locations
- Preferred Channel Alternative A
- Preferred Channel Alternative B

Depth 1% Event

Floodplain Storage

- 0 - 0.5 FT
- 0.5 - 1 FT
- 1 - 2 FT
- 2 - 3 FT
- 3 - 9.5 FT
- FREEWAY
- MAJOR
- LOCAL
- Tomball City Limits
- Tomball ETJ
- Property Parcels

N W E S

0 500 1,000 2,000

Feet

Exhibit 7

Detention Basin Size Summary:

Basin Locations	Channel Design	Mitigation Option	Required Storage (ac-ft)	Pond Surface Area (acres)
1	10% Frequency Storm Event	1	180	33
		2	450	83
		3	370	67
		4	820	147
	1% Frequency Storm Event	1	170	31
		2	425	77
		3	310	56
		4	735	133

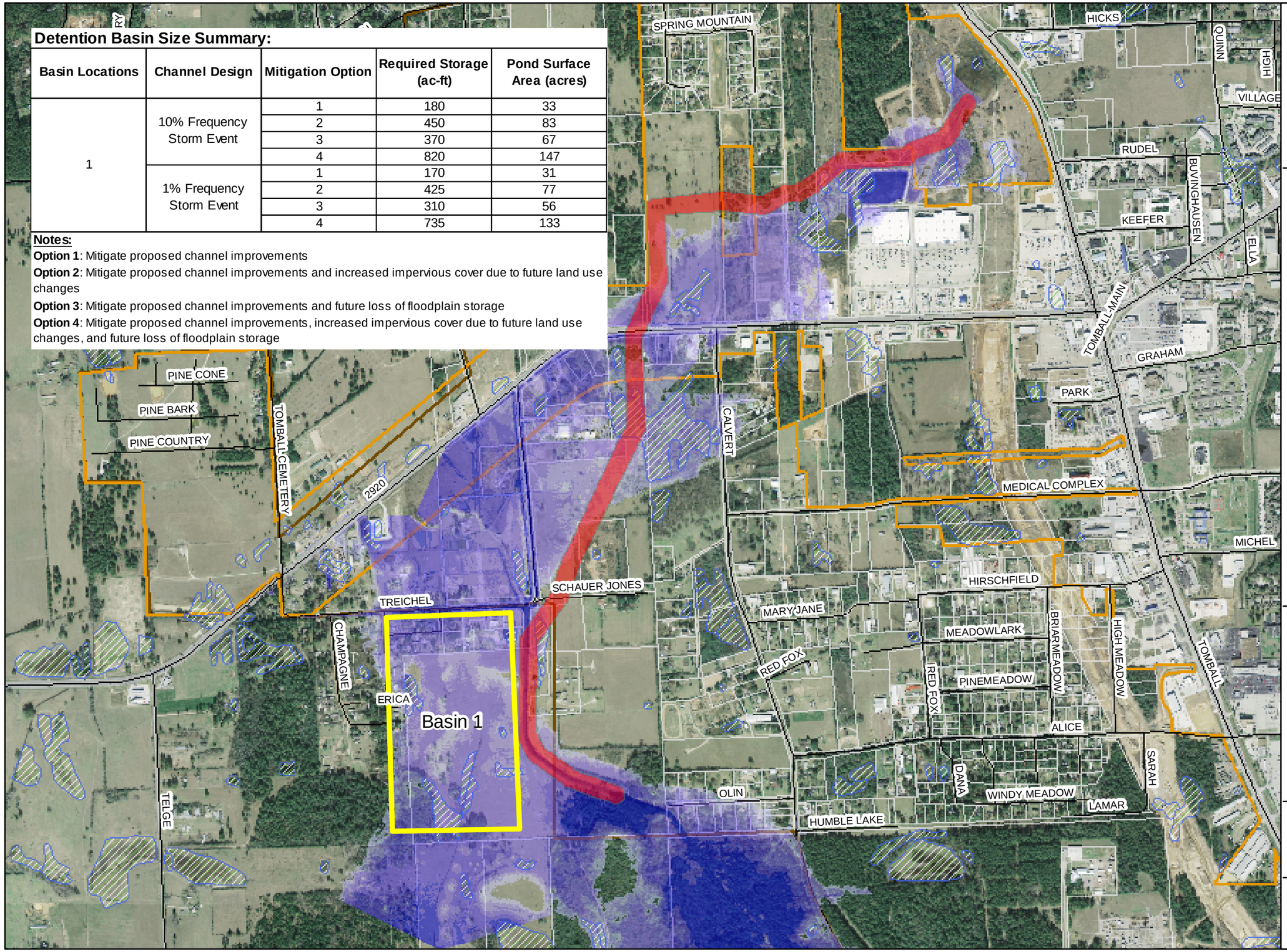
Notes:

Option 1: Mitigate proposed channel improvements

Option 2: Mitigate proposed channel improvements and increased impervious cover due to future land use changes

Option 3: Mitigate proposed channel improvements and future loss of floodplain storage

Option 4: Mitigate proposed channel improvements, increased impervious cover due to future land use changes, and future loss of floodplain storage



City of Tomball

Detention Basin Summary for Channel Alternative A

Legend

- Basin Location 1
- Channel Alternative A
- NWI Wetlands

Depth 1% Event

Floodplain Storage

- 0 - 0.5 FT
- 0.5 - 1 FT
- 1 - 2 FT
- 2 - 3 FT
- 3 - 9.5 FT
- FREEWAY
- MAJOR
- LOCAL
- Tomball City Limits
- Tomball ETJ
- Property Parcels

N W E S

0 500 1,000 2,000

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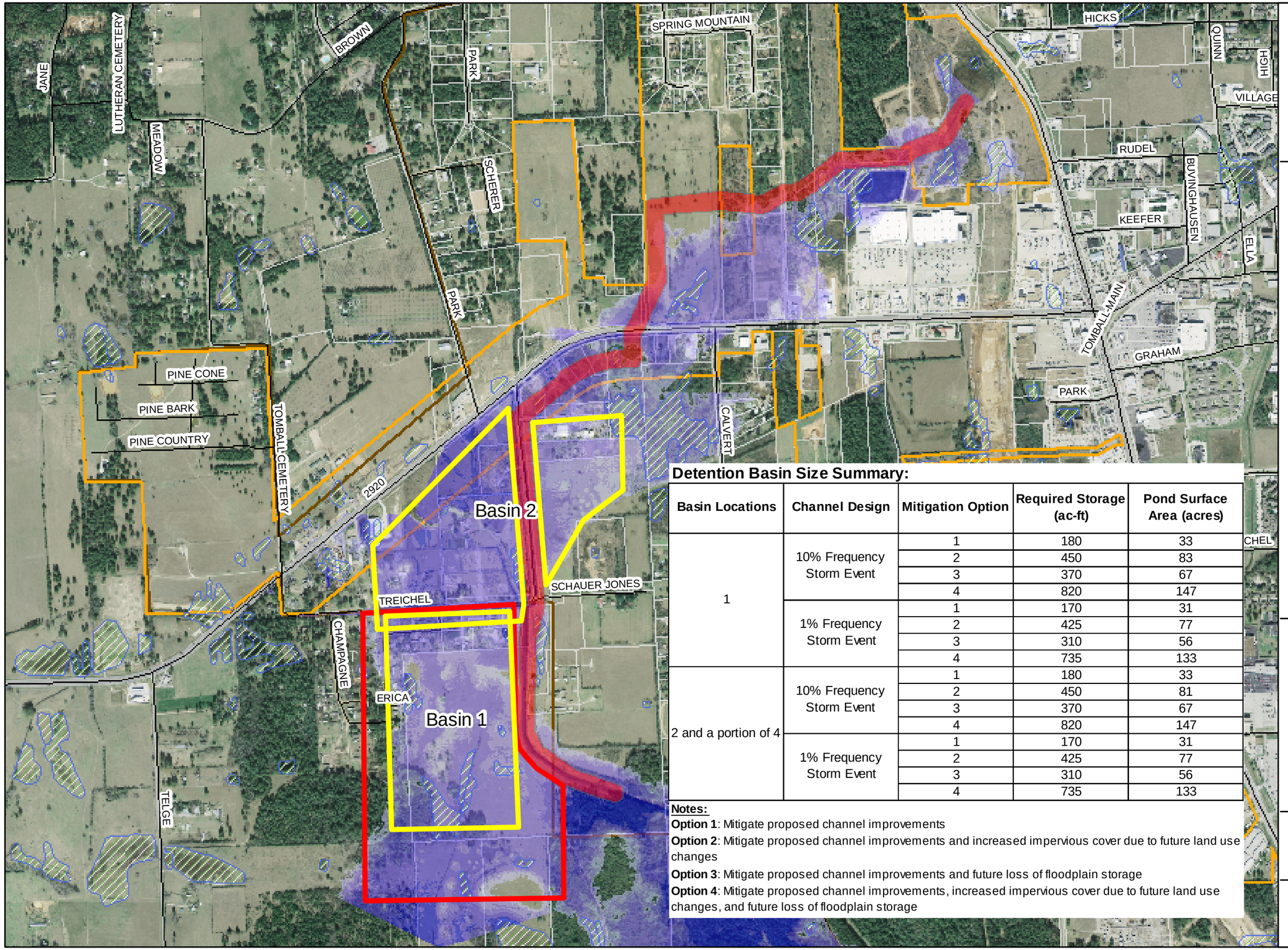
Exhibit 8

City of Tomball

Detention Basin Summary for Channel Alternative B



Detention Basin Size Summary:

Basin Locations	Channel Design	Mitigation Option	Required Storage (ac-ft)	Pond Surface Area (acres)
1	10% Frequency Storm Event	1	180	33
		2	450	83
		3	370	67
		4	820	147
	1% Frequency Storm Event	1	170	31
		2	425	77
		3	310	56
		4	735	133
2 and a portion of 4	10% Frequency Storm Event	1	180	33
		2	450	81
		3	370	67
		4	820	147
	1% Frequency Storm Event	1	170	31
		2	425	77
		3	310	56
		4	735	133

Notes:

Option 1: Mitigate proposed channel improvements

Option 2: Mitigate proposed channel improvements and increased impervious cover due to future land use changes

Option 3: Mitigate proposed channel improvements and future loss of floodplain storage

Option 4: Mitigate proposed channel improvements, increased impervious cover due to future land use changes, and future loss of floodplain storage

Legend

- Basin Locations 1 and 2
- Basin for Mitigation Option 4
- Channel Alternative B
- NWI Wetlands

Depth 1% Event

Floodplain Storage

- 0 - 0.5 FT
- 0.5 - 1 FT
- 1 - 2 FT
- 2 - 3 FT
- 3 - 9.5 FT
- FREEWAY
- MAJOR
- LOCAL
- Tomball City Limits
- Tomball ETJ
- Property Parcels

N W E S

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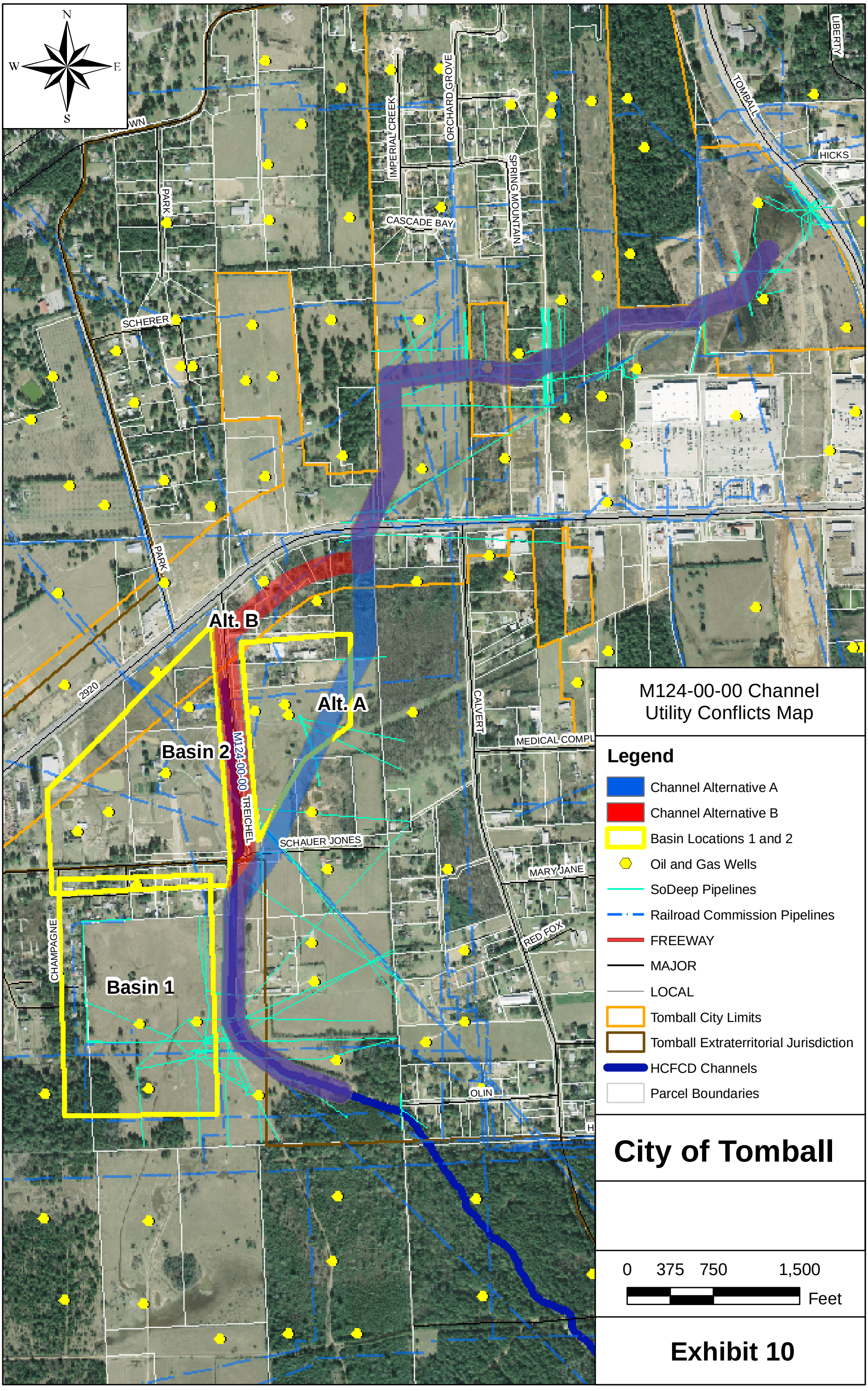
Feet

Exhibit 9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IMPERIAL CREEK
ORCHARD GROVE
SPRING MOUNTAIN
CASCADE BAY
TOMBALL
LIBERTY
HICKS
PARK
SCHERER
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Alt. B
Alt. A
Basin 2
M124-00-00
TREICHEL
SCHAUER JONES
CALVERT
MEDICAL COMPL
MARY JANE
RED FOX
CHAMPAGNE
Basin 1
OLIN
M124-00-00 Channel
Utility Conflicts Map
Legend
Channel Alternative A
Channel Alternative B
Basin Locations 1 and 2
Oil and Gas Wells
SoDeep Pipelines
Railroad Commission Pipelines
FREEWAY
MAJOR
LOCAL
Tomball City Limits
Tomball Extraterritorial Jurisdiction
HCFCD Channels
Parcel Boundaries
City of Tomball
0 375 750 1,500
Feet
Exhibit 10