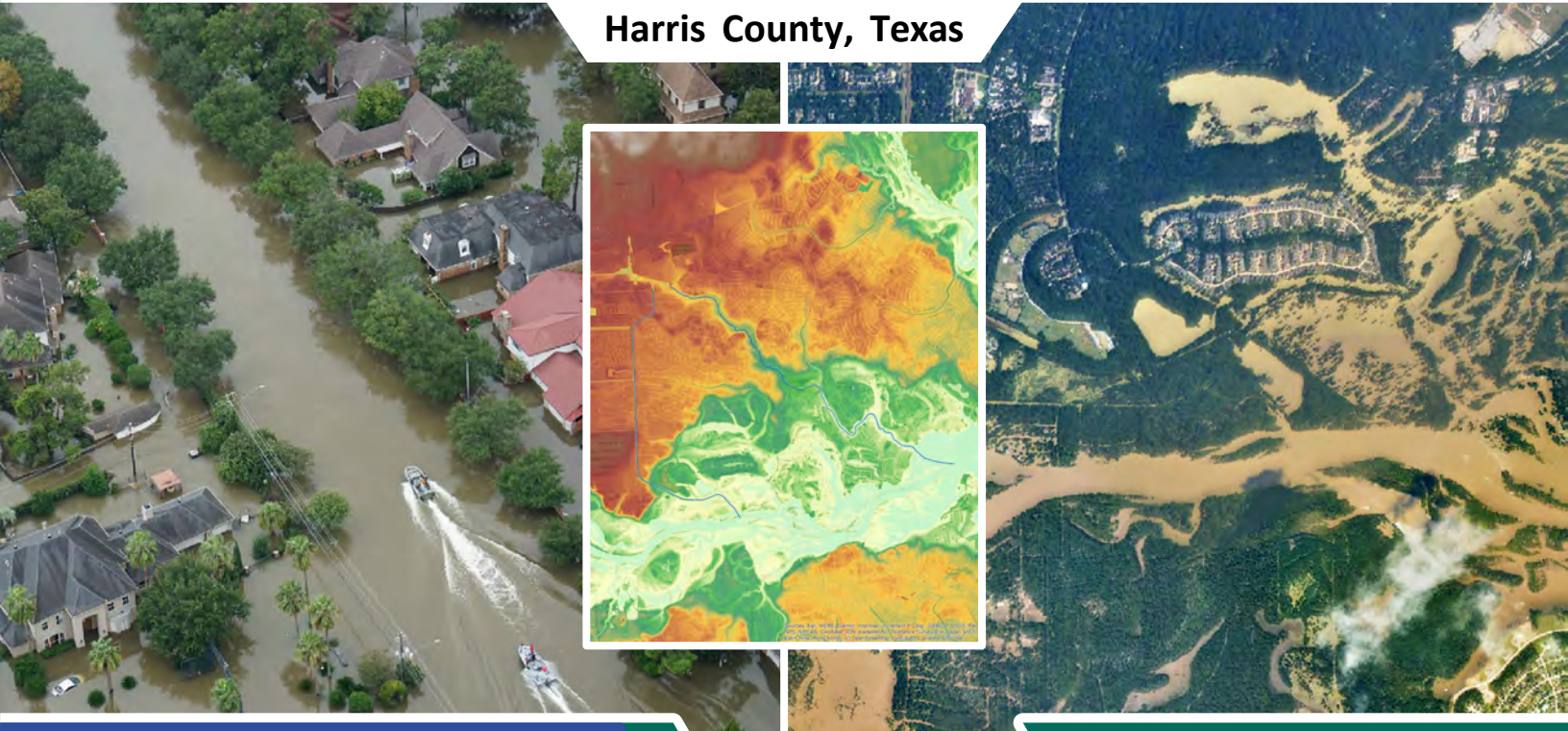


Kingwood Diversion Ditch Conveyance Improvements

Preliminary Engineering Report

HCFCF Project ID#: G103-38-00-E001

Harris County, Texas



Project No. 16532.000

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Prepared for



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Executive Summary

Neel-Schaffer, Inc. (NSI) was contracted by the Harris County Flood Control District (the Flood Control District) to provide engineering services related to the preparation of a Preliminary Engineering Report (PER) for the Kingwood Diversion Ditch (HCFCD Unit G103-38-00) Conveyance Improvements.

As demonstrated in the 2021 Kingwood Drainage Study, the purpose of the Kingwood Diversion Ditch conveyance improvement project is to provide reduced risk for structural flooding associated with development along the Bens Branch channel and provide additional capacity for future local drainage improvements within the Kingwood Diversion Ditch and Bens Branch sub-watersheds. When the Kingwood Diversion Ditch was constructed in the 1970s, additional right-of-way (ROW) was purchased to allow for channel conveyance improvements in the future when it becomes necessary to further alleviate flows along Bens Branch. The intent of this study was to show that proposed drainage improvements for the Kingwood Diversion Ditch should provide for the ability to improve stormwater conveyance within the channel while fully utilizing the existing available ROW, with minimal additional ROW acquisition needed for a new outfall into the West Fork San Jacinto River.

The scope of work for this PER includes the evaluation of existing and proposed drainage improvement conditions for project alternatives for the study area, including evaluation of existing bridges, limited channel cross-section survey of the Kingwood Diversion Ditch, geotechnical investigation for the ditch, environmental site assessments, conduct Hydrologic and Hydraulic (H&H) numerical modeling to assess these conditions, and the production of three (3) alternatives to improve the stormwater carrying capacity of the ditch in the project area.

All storm events referenced in this study were determined using NOAA Atlas 14 rainfall data. The existing and proposed models were computed using HEC-HMS version 4.2.1 and HEC-RAS version 6.2.

In accordance with the H&H scope of services, three (3) alternatives were evaluated based on the hydraulic performance, increased channel conveyance capacity, costs, and benefits in relation to the reduction in the area of inundation, environmental impacts, and construction feasibility. These alternatives include combinations of channel conveyance improvements and drainage infrastructure improvements. In each alternative, flow was restricted to Bens Branch through the use of a diversion structure located east of the Bens Branch/Kingwood Ditch confluence. The Flood Control District's guidelines allow for the use of a minimum pipe diameter of 24-inch to maintain minimum base flow downstream on Bens Branch.

These three alternatives include the following features:

- **Alternative 1** – A widened Kingwood Diversion Ditch including grass-lined trapezoidal channel, one drop structure and a new outfall of the Kingwood Diversion Ditch to West Fork San Jacinto River.
- **Alternative 2** – A widened Kingwood Diversion Ditch including a benched channel section above Ordinary High-Water Mark, two drop structures and a new outfall of the Kingwood Diversion Ditch to West Fork San Jacinto River.

- **Alternative 3** – A widened Kingwood Diversion Ditch including a Natural Stable Channel Design Sections with riffle and pools and a new outfall of the Kingwood Diversion Ditch to West Fork San Jacinto River.

The preliminary costs and benefits for each of these three alternatives are provided in the table below:

Evaluation Criteria	Alt. 1	Alt. 2	Alt. 3
Capital Cost Estimate ¹	\$37,900,000	\$33,400,000	\$40,700,000
Stormwater Detention Cost Estimate ¹	\$14,250,000		
Maintenance Costs (per 10 years)	\$2,908,000	\$3,198,500	\$1,866,200
Floodplain Reductions – Number of Parcels from which the Atlas 14 1% AEP ² Inundation Area Has Been Removed	287	189	288
Floodplain Reductions – Area (acres) from which the Atlas 14 1% AEP Inundation Area Has Been Removed	186	114	177
Floodplain Reductions – Structures from which the Atlas 14 1% AEP Inundation Area Has Been Removed	35	29	34

1. Costs include necessary ROW acquisition, see **Appendix P** for complete cost estimate.
2. 1% Annual Exceedance Probability storm event, also referred to as 100-year storm event.

It should be noted that environmental site survey with shovel testing was not performed because the majority of the shovel testing required was to be conducted in the new outfall location, which is currently private property. Harris County Flood Control District does not perform invasive surveys on private property; however, this testing will be performed during the design stage after Harris County Flood Control District has acquired the necessary ROW.

The need for stormwater detention storage volume to mitigate adverse impacts as a result of the proposed alternative channel conveyance improvements was evaluated. Both onsite and offsite stormwater detention were analyzed. The detention assessment is provided in **Section 6** of this report. The modeling shows Kingwood Diversion Ditch and the West Fork San Jacinto River have limited combined hydrologic correlation. In general, the proposed Kingwood Diversion Ditch improvements provide localized decreases in water surface elevations and inherent inline stormwater detention resulting from the additional channel volume provided. Due to the vast difference between flood volumes in the West Fork San Jacinto River and the Kingwood Diversion Ditch, the increased local flood volumes caused by the proposed diversion structure should not impact peak flood stages on the main river. Further, since all the water volume eventually drains to Lake Houston, whether flowing down Bens Branch or the Kingwood Diversion Ditch, there is no volume increase at Lake Houston due to this project. However, to confirm no adverse impacts are present, a tailwater-driven scenario of coinciding peaks was modeled to evaluate backwater of the West Fork San Jacinto River flowing into Kingwood Diversion Ditch and Bens Branch. This scenario involved utilizing a quasi-steady state 2D area boundary condition for the West Fork San Jacinto

River at the downstream boundary of Bens Branch and the Kingwood Diversion Ditch. Modeling results of this conservative scenario showed no new adverse impacts to any structures, no new adverse impacts to any parcels, along with reduction in inundation and water elevations along Bens Branch and the upper reach of Kingswood Diversion Ditch. However, small, localized increases to water surface elevations at the confluence with West Fork San Jacinto River were noted. Therefore, it is recommended to consider mitigation as part of the Kingwood Diversion Ditch channel conveyance improvements because of the potential adverse impacts resulting from coinciding extreme events. It is important to note that a coinciding peak scenario assumes that an Atlas 14 1% AEP event occurs over the West Fork San Jacinto River along with an additional Atlas 14 1% AEP event occurring over the Kingwood area, and that these two peak events occur at the same time. This scenario represents a statistical event with a much smaller chance of occurrence than an Atlas 14 1% AEP event. This probability should be considered when considering the need and volume for mitigation during the final design.

The use of an offsite detention basin as the tool to achieve this mitigation is recommended; however, since an offsite basin does not provide direct benefits to affected areas of the project, the required detention should be further examined during final design. This examination would include updating the models for the Atlas 14 1% AEP event to consider timing of hydrographs from Kingwood Diversion Ditch, Bens Branch, and the West Fork San Jacinto River in order to fully confirm potential project impacts and to optimize volume of detention required. This evaluation could also support in the consideration of other alternative tools to mitigate project impacts.

Compared to existing conditions, in **Alternative 1**, there are 186 acres (35 structures) from which the Atlas 14 1% AEP floodplain will be removed. The preliminary total project construction cost estimate for this alternative is approximately **\$37.9 million**. Similarly, **Alternative 3** has 177 acres (34 structures) from which the Atlas 14 1% AEP floodplain will be removed. Additionally, **Alternative 3** incorporates Natural Stable Channel Design features, which provide additional benefits to the environment in the form of increased habitat, improved erosion resistance, and improved filtration of suspended solids. The preliminary total project construction cost estimate for this alternative is approximately **\$40.7 million**. Although this alternative has the greatest initial construction cost, **Alternative 3** has a maintenance cost that is nearly 36% cheaper than that of **Alternative 1**, based on the existing maintenance needs of the channel. Within less than 28 years, these savings in maintenance costs would be sufficient to offset the higher initial capital cost of **Alternative 3** and provide additional benefits to the environment in the form of increased habitat, improved erosion resistance, and improved filtration of suspended solids due to the natural channel design features. For this reason, NSI recommends **Alternative 3** for the Kingwood Diversion Ditch Conveyance Improvements.

Under these alternatives, the **Alternative 3** channel has the capacity to convey the 1% AEP storm event, except at the confluence of the West Fork San Jacinto River (due to the backwater effect). A detailed alternative evaluation, along with cost estimates for all three alternatives considered is provided in **Section 8** of this report.

Based on results of this study, NSI recommends **Alternative 3** for the Kingwood Diversion Ditch Conveyance Improvements along with the proposed offsite Stormwater Detention Basin 1. The total estimated construction cost for **Alternative 3**, including stormwater detention, is approximately **\$54.95 million** (includes \$1.5 million in ROW acquisition costs). A breakdown of the cost estimate for the recommended alternative is provided in **Table 12** and **Table 20**.

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Acronyms

AEP	Annual Exceedance Probability
CMP	Corrugated Metal Pipe
DCC	Direct Construction Costs
DS	Downstream
DSS	Data Storage System
FIRM	Flood Insurance Rate Map
HCDR	Harris County District Records
HCFCDD	Harris County Flood Control District
HEC	Hydrologic Engineering Center
H-GAC	Houston-Galveston Area Council
HMS	Hydrologic Modeling System
ID	Identifier
LiDAR	Light Detection and Ranging
NAVD	North America Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
OHWM	Ordinary High-Water Mark
PCPM	Policy Criteria & Procedure Manual
QC	Quality Control
R	Storage Coefficient
RAS	River Analysis System
RCB	Reinforced Concrete Box
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
RS	River Station
SI	Structural Inventory
Tc	Time of Concentration
US	Upstream
WSE	Water Surface Elevation
XS	Cross-Section

1. Introduction

1.1 Project Background

Neel-Schaffer, Inc. was contracted by Harris County Flood Control District (Flood Control District) to provide engineering services for the preparation of the Preliminary Engineering Report (PER) for Improvements to Kingwood Diversion Channel (HCFCU Unit G103-38-00). HCFCU Unit G103-38-00 is a man-made channel that was constructed prior to 1978 and designed to divert flow from HCFCU Unit G103-33-00 (Bens Branch) by draining excess water around the Kingwood subdivision to the West Fork San Jacinto River.

1.2 Project Purpose

The purpose of this PER is to evaluate alternative channel conveyance improvement options for the Kingwood Diversion Ditch (HCFCU Unit G103-38-00) to provide an increased conveyance capacity and reduction of the Atlas 14 1% AEP floodplain for both Bens Branch (HCFCU Unit G103-33-00) and Kingwood Diversion Ditch (HCFCU Unit G103-38-00). The central and western portions of the Kingwood area were primarily developed in the 1970s and 1980s. During this time period, these areas were developed utilizing the older engineering design criteria that did not include extreme event sheet flow and detention requirements for increased runoff. This PER utilizes updated hydraulic analyses accounting for the updated and most current drainage engineering design criteria. The tasks of the PER study include performing hydrologic and hydraulic analyses and developing preliminary construction cost estimates to compare the proposed alternatives for drainage improvements. This report presents the findings from the Hydrologic and Hydraulic study and provides a recommended alternative for final design.

1.3 Project Limits

The project area is in the northeastern part of Harris County bordering Montgomery County. The project begins upstream of the confluence of Bens Branch and the Kingwood Diversion Ditch (G103-38-00) and extends downstream to the outfall into West Fork San Jacinto River (G103-00-00). The total project length is approximately 4.2 miles along the Kingwood Diversion Ditch. The Kingwood Diversion Ditch has a length of approximately 3.86 miles within Harris County and approximately 0.32 miles within Montgomery County. The project location is shown in **Exhibit 1**.



Figure 1 – Confluence of G103-33-00 (Bens Branch) and G103-38-00 (Kingwood Diversion Ditch)

1.4 Project Objectives

The objective of the Kingwood Diversion Ditch Conveyance Improvements is to reduce the risk of structural flooding associated with water surface elevations along Bens Branch and facilitate future local drainage improvements within the Kingwood Diversion Ditch and Bens Branch sub-watersheds, both located within the San Jacinto River Watershed. When the Kingwood Diversion Ditch was originally constructed in the 1970s, additional ROW was purchased to allow for channel conveyance improvements in the future when it became necessary to further alleviate flows along Bens Branch. The proposed improvements for the Kingwood Diversion Ditch will fully utilize the available ROW with minimal additional ROW acquisition needed for a new outfall into the West Fork San Jacinto River.

Therefore, the main objectives of the project are:

1. Evaluate the level of improvement to channel conveyance capacity for the existing channel and flow conditions on Bens Branch and the Kingwood Diversion Ditch.
2. Analyze three (3) alternatives to increase the channel conveyance capacity of Bens Branch and the Kingwood Diversion Ditch. Alternatives may include channel conveyance improvements, stormwater detention basins, or a combination of both. Alternatives should utilize the available ROW along the Kingwood Diversion Ditch.
3. Perform structural, economic, and environmental analyses of considered alternatives.
4. Develop an improvement alternative that is constructable, cost-effective, and would result in no adverse impacts.
5. Configure a proposed improvement configuration that would result in minimal environmental impacts.
6. Identify potential utility and pipeline conflicts associated with the improvement configurations and select a configuration that involves minimal necessary pipeline adjustments.
7. Identify and recommend the optimal alternative for final design.

The overall Scope of Services of the Preliminary Engineering Report included the following tasks:

1. Evaluation of existing site conditions,
2. Evaluation of existing bridges,
3. Development of three Flood Damage Reduction alternatives,
4. Development of a Hydrologic and Hydraulic (H&H) Analysis, including:
 - a. updating the hydrologic analysis from the July 2020 Kingwood Drainage Study,
 - b. Without Project (WOP) Conditions H&H Analysis,
 - c. Channel Improvement Analysis,
 - d. documentation of Project Results and Findings,
 - e. finalize Modeling & Project Phasing,
 - f. detention basin considerations and recommendations,
 - g. creation of a comprehensive drainage report.
5. Submittal of Findings and Recommendations,
6. Submittal of a Preliminary Engineering Report,
7. Submittal of Project vicinity map, Project Layout, Project survey control and control point detail sheets showing survey baseline, survey data tables, existing and proposed Harris County Flood

Control District right-of-way, public and private easements crossing and adjacent to Harris County Flood Control District ROW, Soil boring locations, and Typical Sections, and

8. Submittal of Preliminary Cost Estimates.

1.5 Performance Metrics

The project performance metrics were based on quantified hydraulic, economical, and environmental results. The main metrics used are:

1. Number of parcels in the inundated area for the Atlas 14 1% AEP,
2. Total estimated financial costs for improvements including ROW acquisition, earthworks for cut/fill, utility relocation, bridge construction, channel construction, structure construction, environmental mitigation, and
3. Environmental impacts.

A detailed description of the project performance metrics for the three (3) alternatives can be found in **Section 3**.

1.6 Prior Studies

The following prior studies were reviewed for pertinent information in preparing this report:

1. Neel-Schaffer, Inc. prepared the “Kingwood Drainage Study,” dated July 2020 (Project No. 15327.000) also known as “Kingwood Drainage Analysis”, which detailed the conceptual plan for streams within the Kingwood Project Area and included analysis of historical flooding, overland flow, existing levels of service for the Kingwood Area and potential improvements.
2. San Jacinto Regional Watershed—Master Drainage Plan, dated December 2020. A comprehensive study of upper San Jacinto River Watershed.
3. Northpark Drive Reconstruction Schematic Layout – HNTB, dated March 2022.
4. Northpark Drive Reconstruction Drainage – HNTB, dated March 2022.

1.7 Community Engagement

A community engagement meeting for the project was held March 6, 2024. The purpose of the meeting was to invite the public to learn about the project, provide input, and ask questions about the project. The PER was finalized after this meeting, thereby giving an opportunity to incorporate public feedback.

1.8 Data Collection

Data collected and relied upon for this PER included the following:

- Drainage Report and H&H Models of the Kingwood Drainage Study (Dated July 15, 2020) are included in Appendix A.
- FEMA Effective Hydrology Computer Models
- FEMA Effective Hydraulic Computer Models
- The Flood Control District’s Historical Flood Data
- The Flood Control District’s Watershed Master Plan Drainage Areas
- H-GAC’s 2018 LiDAR DEM

- Field Reconnaissance
- Aerial Imagery
- Other applicable GIS data for the study area, including parcels, city limits, watershed boundaries, channel rights-of-way (ROWs), Kingwood area properties, pipelines, and utilities etc.

The summary of data collected for the project with the source and use is provided below in **Table 1**.

Table 1 – Data Collection Summary

Data	Source	Use
2021 Aquatic Resources Survey	Hollaway Environmental Comms., Inc.	Water/Wetland Classification
Photographs/Field Reconnaissance (April 2021)	NSI Field Survey	Preliminary Impact Analysis
Kingwood Drainage Study (July 2020)	Harris County Flood Control District	H&H Analysis
Effective FEMA Hydraulic/Hydrology Computer Models	FEMA	H&H Analysis
Historical Flood Data	Harris County Flood Control District	H&H Analysis
Watershed Master Plan Drainage Areas	Harris County Flood Control District	H&H Analysis
Survey Data (May 2022)	MBCO	Model Geometry
Geotechnical Report (September 2022)	Raba Kistner	Channel Geometry
2018 LiDAR	H-GAC	Model Terrain

2. Existing Conditions

2.1 Project Area

The project is located within the San Jacinto River watershed. Most of the project limits are located within Harris County, except for a small portion at the northern end of the Kingwood Diversion Ditch that is in Montgomery County.

The study area for the project encompasses the sub-watershed for both Bens Branch (HCFCD Unit G103-33-00) and Kingwood Diversion Ditch (HCFCD Unit G103-38-00) from their confluence to their respective outfalls into West Fork San Jacinto River. The project limits begin at the confluence of Bens Branch and Kingwood Diversion Ditch and extends along the Kingwood Diversion Ditch to the outfall into West Fork San Jacinto River (G103-00-00). Total project length is approximately 4.2 miles. Within Harris County, the channel has a length of approximately 3.86 miles and traverses from the Montgomery County boundary south towards the outfall into West Fork San Jacinto River. An additional 0.32 miles extends upstream into Montgomery County to the connection with Bens Branch.

The Kingwood Diversion Ditch (HCFCD Unit G103-38-00) is located within the San Jacinto River watershed and is a tributary to the West Fork San Jacinto River. HCFCD Unit G103-38-00 is a man-made channel that was constructed prior to 1978 and originally designed to alleviate stormwater flow along Bens Branch (HCFCD Unit G103-33-00) by draining excess stormwater in the area more efficiently to the West Fork San Jacinto River. The Kingwood Diversion Ditch has its own 2.1 sq. mile drainage area or sub-watershed.

Historical USGS topographic maps from 1916 show that Bens Branch (HCFCD Unit G103-33-00) was originally a natural channel identified as Lost Creek from within Montgomery County to the outfall into the West Fork San Jacinto River. Man-made channel improvements were constructed on Bens Branch over the years with the only remaining natural portion of the channel being located between Woodland Hills Drive and approximately 2,600 feet downstream of Tree Lane.

Historical aerials show the portion of the Kingwood Diversion Ditch watershed within Harris County east of the channel was developed prior to 1978, while the western portion of the watershed was developed after construction of the diversion ditch. Some of the most recent developments in Harris County within the study area occurred along the Harris County border with Montgomery County. Additional development in the watershed has occurred since then in Montgomery County. Most of the development within the Kingwood Diversion Ditch watershed was constructed without any detention mitigation, except for developments constructed after 1980. For the Bens Branch sub-watershed, historical aerials show that much of the development within Harris County had occurred prior to 1980. Most of the development within Bens Branch sub-watershed was constructed near the channels and floodplain. These developments did not take into consideration the extreme event inundation area.

2.1.1 Flooding History and FEMA Flood Hazard Areas

Exhibit 2 shows the FEMA Flood Insurance Rate Map (FIRM) for Harris County, Texas and Incorporated Areas, Map Number 48201C0305L, 48201C0315L, and 48201C0320L, with the Effective Date of June 18, 2007, within the study area. The Kingwood Diversion Ditch (HCFCD Unit G103-38-00) is an unstudied stream with no associated floodplains or base flood elevations; however, the downstream

portion of the channel is located within the floodplains associated within the West Fork San Jacinto River. Bens Branch (HCFCU Unit G103-33-00) is a FEMA studied stream with a Atlas 14 1% AEP regulatory floodplain. For Bens Branch, the mapped floodplains south of Kingwood Drive are associated with the backwater from the West Fork San Jacinto River floodplain.

Historic structural flooding within the study area was documented for recent federally-declared disasters. The approximate number of flooded structures for the Kingwood Diversion Ditch (HCFCU Unit G103-38-00) and Bens Branch (HCFCU Unit G103-33-00) for each storm event is listed below:

- Significant areas were flooded during Hurricane Harvey (2017) along Bens Branch (HCFCU Unit G103-33-00), while 486 structures reported flooding during Hurricane Harvey (2017) along Kingwood Diversion Ditch (HCFCU Unit G103-38-00), and
- 215 structures estimated to flood during Tropical Storm Imelda (2019) along Bens Branch (HCFCU Unit G103-33-00), while 122 structures estimated to flood during Tropical Storm Imelda (2019) along Kingwood Diversion Ditch (HCFCU Unit G103-38-00)

These structures are discussed in detail in **Exhibit 3**. The primary focus of this study is to develop conveyance solutions to reduce inundation limits while simultaneously providing capacity for improvements to the local drainage systems.

2.1.2 Survey and Datum

Field survey for the project was performed by MBCO Engineering, LLC (MBCO) in August 2021. The survey includes Kingwood Diversion cross section survey in the study area (every 600 feet) and detail bridge surveys of Northpark Drive, Kingwood Drive, Walnut Lane, and Deer Ridge Estates Boulevard. The survey data are presented as an AutoCAD dwg file. The existing channel cross-sections are attached as **Appendix B**, while the existing topography survey is attached as **Appendix C**. The project survey is referenced to North American Horizontal Datum of 1983 (NAD83) and the North American Vertical Datum (NAVD) 1988, 2001 adjustment, which is consistent with the datums used by the H&H models and the GIS mapping in this study. All elevations referenced in this report are tied to NAVD 1988, 2001 adjustment. It is noted that no topographic survey was performed beyond the existing tree line and the new outfall shown in **Appendix C** since it is located on private property. The latest LiDAR data (2018) is being used for the areas for which there was no field survey. Hence, the plans for the new outfall utilized LiDAR to determine elevations for this property. Based on recent 2021 survey, the flowline elevations for the Kingwood Diversion Ditch ranges from 39 to 64 feet – NAVD88, from the new outfall area at Woodlands Hill Drive to the confluence at Bens Branch, respectively. **Exhibit 4** shows the topographic map for the area.

2.1.3 Project Area Topography

The topography along the Kingwood Diversion Ditch drains south and southeast towards the West Fork San Jacinto River as shown on **Exhibit 4**. The Kingwood Diversion Ditch (HCFCU Unit G103-38-00) is mostly converted uplands and was constructed counter to the existing topography and runs north to south paralleling the contours. The topography of the project area is generally flat for most of the project's length, with little variation of longitudinal slope elevations until reaching its later third of the project length, which shows a steep drop of about 12 feet in less than 2,000 feet of channel length as

shown in **Figure 2**. The project area exhibits overland slopes ranging from a mild slope of 4.1 feet/mile to steep slopes of 70.4 feet/mile, with an average slope of 21.7 feet/mile.

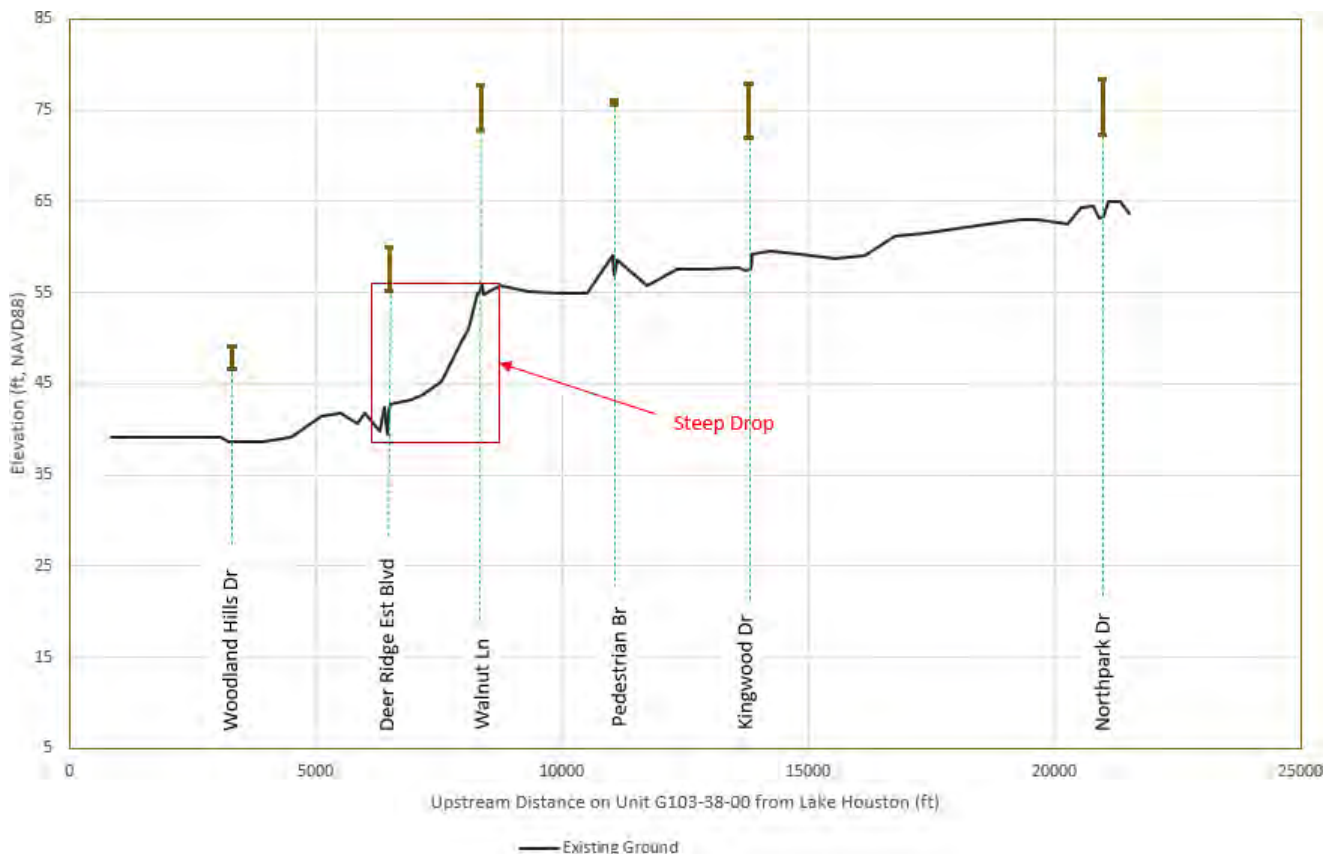


Figure 2 - Existing Ground Elevation Profile (Kingwood Diversion Ditch)

2.1.4 Land Use

The Kingwood Area is mostly developed with residential lots, with western areas constructed prior to 1984 and eastern areas post 1984, with some industrial, commercial, schools, and developed green areas such as golf courses and parks. The land use along Bens Branch and Kingwood Diversion Ditch is a mix of single-family residential, commercial, and undeveloped land. **Exhibit 5** shows the land use of the project area.

2.2 Harris County Flood Control District Facilities and Unit Numbers

2.2.1 HCFCU Unit G103-33-00 (Bens Branch)

Bens Branch (HCFCU Unit G103-33-00) is a tributary to West Fork San Jacinto River (HCFCU Unit G103-00-00). Inside Harris County, the channel has a length of approximately 4.7 miles from the Montgomery County boundary draining southeast towards the outfall into West Fork San Jacinto River (HCFCU Unit G103-00-00). An additional 1.3 miles extends into Montgomery County.

Historical aerials show that much of the development within the Bens Branch watershed within Harris County occurred prior to 1980. Most of the development within Bens Branch watershed was

constructed without detention mitigation or consideration of extreme event flow paths. Based on available aeriels, Bens Branch was originally a natural channel with some improvements such as the clearing of trees and channel conveyance improvements constructed along with the development within the watershed. A portion of the channel from downstream of Woodland Hills Drive to Rocky Woods Drive was left in its natural condition. Flooding within the Bens Branch watershed has been substantial over the last decade. **Exhibit 5** indicates historical flooding records for both Hurricane Harvey and Tropical Storm Imelda in this region.

2.2.2 Harris County Flood Control District Unit G103-38-00 (Kingwood Diversion Ditch)

The Kingwood Diversion Ditch (HCFCD Unit G103-38-00) is a man-made channel that was constructed prior to 1978, designed to alleviate flooding along HCFCD Unit G103-33-00 (Bens Branch) by diverting flow from Bens Branch to the Kingwood Diversion Ditch. Inside Harris County, the channel has a length of approximately 3.86 miles from the Montgomery County boundary south towards the outfall into West Fork San Jacinto River. An additional 0.32 miles extends into Montgomery County to the connection with Bens Branch.

Historical aeriels show that the portion of the Kingwood Diversion Ditch watershed within Harris County east of the channel was developed prior to 1978, while the western portion of the watershed was developed after construction of the diversion ditch. Some of the newest developments in the Harris County portion of the study area occurred along the Harris County border with Montgomery County with construction completed approximately 10 years ago. Additional development in the watershed has occurred since then in Montgomery County. Most of the development within the Kingwood Diversion Ditch sub-watershed, which is located within the San Jacinto River watershed, was constructed without any detention mitigation, with the exception of the more recent developments.

2.3 Right-of-Way

The existing streams within the Kingwood Area are located within right-of-way (ROW) owned by either the Harris County Flood Control District, the City of Houston, the public, and other public entities (e.g., Harris County, utility districts, neighborhood associations and communities). The width of ROW for the Kingwood Diversion Ditch varies from approximately 190 feet to 300 feet. ROW owned by Harris County within the project area is a 50-foot drainage easement (Volume 5872, Page 78, HCDR) south of G103-38-01 along the alignment of the Kingwood Diversion Ditch to San Jacinto River tributary G103-39-00. For Bens Branch, the ROW width ranges from 60 feet to 200 feet. Additional ROW must be acquired in order to construct the proposed improvements as described in **Section 3.3**. Approximate and additional ROW are shown in **Exhibit 6**.

2.4 Existing Pipelines and Utilities

Utilities within the project area that could potentially impact the project include telecommunication, electric, water, sanitary, and gas facilities owned by one of the following utility companies: City of Houston Water (**Exhibit 7**), City of Houston Sanitary Sewer (**Exhibit 8**), CenterPoint Energy Gas, Comcast, Suddenlink, MCI, Century Link, AT&T, and Crown Castle. No major pipelines (**Exhibit 9**) were identified within the project area. Overhead utility lines, and their potential conflicts, are shown in **Exhibit 10**.

Due to the changes in the Navigable Waters Protection Rule (NWPR) during the development of the Preliminary Engineering Report, Flood Control District decided to postpone Level A and B SUE until the Design Stage. NSI was authorized to perform the following utility services:

- Performing Texas One Call “811” requests for underground utility locations within the project area,
- Surveying underground utility marks placed by Texas 811 locators,
- Researching and placing available record drawings for water, CenterPoint Energy and AT&T into the drawing, and
- Surveying the sanitary sewer system from the pedestrian bridge to the south for approximately 3,600 feet including inverts of accessible manholes.

The located utilities are shown on **Exhibit 10**. The Utility Conflict Table and available Utility Record drawings are included as **Appendix D**.

2.4.1 COH Waterlines

There are several waterlines within the project area, as shown in the City of Houston Public Works Geohub. The main water line sizes for the project range from 2” to 16”. **Exhibit 7** shows the waterlines in the project area. The survey identifies waterline crossings at the following bridges:

- Northpark Drive – 16” waterline,
- Kingwood Drive – 16” waterline, and
- Walnut Lane – 12” waterline

2.4.2 COH Wastewater Lines

There are several wastewater lines within the project area as shown in the City of Houston Public Works Geohub. The wastewater line sizes for the project range from 6” to 30”. **Exhibit 8** shows the wastewater lines in the project area. The survey identifies an 8” steel wastewater line that crosses the Kingwood Diversion Ditch just north of the Green Belt Pedestrian Bridge and a 12” PVC wastewater line spanning along the west side of the Kingwood Diversion Ditch from approximately 850 LF south of Walnut Lane Bridge to 780 LF north of Walnut Lane Bridge.

2.4.3 COH Stormwater Lines

There are a few stormwater lines within the project area as shown in the City of Houston Public Works Geohub. The main stormwater line sizes for the project range from 12” to 84”. **Exhibit 11** shows the stormwater lines in the project area.

2.4.4 COH Water Tower

A COH water tower located approximately 550 feet north of Kingwood Drive and Kingwood Diversion Ditch on the east side appears to have an access road within Harris County Flood Control District ROW. The Harris County Flood Control District will need to coordinate with the COH during design and construction to maintain access to the water tower.

2.5 Environmental Conditions

Neel-Schaffer Inc. contracted with HVJ Associates, Inc. to perform a Phase I Environmental Site Assessment (ESA), Wetlands Delineation, Threatened and Endangered Species Assessment, and

Cultural Resource Analysis for the Kingwood Diversion Ditch Conveyance Improvement project (HCFCF Project ID G103-38-00-E001.)

2.5.1 Phase I ESA

Neel-Schaffer Inc. contracted HVJ Associates, Inc. to conduct a Phase I Environmental Site Assessment (ESA) in accordance with the American Society of Testing Materials (ASTM) in the standard ASTM E 1527-13 for the proposed Kingwood Diversion Ditch project. The purpose of the Phase I ESA is to identify recognized environmental conditions (RECs) in connection with the project area. ASTM E 1527-13 defines RECs as “the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property or into the ground, groundwater or surface water of the property.”

The scope of this assessment included:

- A database search of environmental records to identify any regulated environmental sites for the project area and adjoining properties,
- A review of available historical topographic maps, aerial photographs, wells and pipeline data, and city directories to assess past uses of the project area and adjoining properties,
- An on-site reconnaissance of the project area and the adjoining properties to visually inspect for the presence and management of hazardous substances and petroleum products and any signs of environmental releases or impacts,
- Interviews to obtain information relevant to the project area and adjoining properties, and
- Identification of the current uses and status of properties adjoining the project area to evaluate their potential as sources of contamination.

The assessment identified no new REC sites in connection with the project area to have a negative impact. There were seven known, suspected, and historical RECs that were further assessed. Of the seven facilities, two were listed within the project area and five listed outside the project area. These facilities were determined not to be RECs, Historically Recognized Environmental Conditions (HRECs), or Controlled Recognized Environmental Conditions (CRECs). There is no known potential for environmental contamination to the project area and no further environmental assessment of this area is needed.

The ESA Report (Date: December 2021) is included as **Appendix E**.

2.5.2 Wetland Delineation Report

Hollaway Environmental + Communications Services, Inc. (Hollaway) was contracted to complete a Waters of the United States (WOTUS) delineation for the proposed Kingwood Diversion Ditch Conveyance Improvements project. Biologists conducted field surveys within the project area on August 17, 18, 24, and 25 and September 27, 2021.

The purpose of the delineation was to evaluate the presence of jurisdictional WOTUS and determine their boundaries within the project area. The WOTUS delineation report will support the jurisdictional determination process for on-site aquatic resources. If the project is anticipated to impact

jurisdictional resources, the delineation report will support applications for regulatory permits required from the USACE for the construction activities.

The results from the delineation identified two perennial streams (G103-38-00 and West Fork San Jacinto River), one perennial and intermittent stream (Bens Branch), one ephemeral stream (WC 1), three palustrine forested (PFO) wetlands (WET 1, WET 2/3, and WET 4), and four palustrine emergent (PEM) wetlands (WET 5, WET 6, WET 7, and WET 8) that are potentially jurisdictional under the CWA. Impacts to jurisdictional WOTUS require a permit from USACE. The delineation also identified four upland-cut drainage ditches (Ditch 1, Ditch 2, Ditch 3, and Ditch 4) with ephemeral flow regimes that do not share a significant nexus with any jurisdictional feature. These features are likely non-jurisdictional under the CWA.

A jurisdictional WOTUS under the Clean Water Act (CWA) exhibits a surface water connection and/or contributes a significant nexus to a traditionally navigable water (TNW). G103-38-00 is a man-made channel with a perennial flow regime. It is a relatively permanent water (RPW) and contributes surface water flow to the West Fork San Jacinto River, a TNW. West Fork San Jacinto River is a manipulated river with a perennial flow regime. It is a TNW and contributes surface water flow to Lake Houston, also a TNW. Bens Branch is a manipulated stream with a perennial flow regime west of the confluence with G103-38-00 and an intermittent flow regime east of the confluence with G103-38-00. It contributes surface water flow to G103-38-00 and West Fork San Jacinto River, a TNW, and is an RPW. WC 1 is an ephemeral stream that contributes surface water flow to and has a significant nexus with G103-38-00, an RPW. WET 1, WET 2/3, and WET 4 are wetlands located with sheet flow connectivity to the West Fork San Jacinto River through floodway. WET 5 is likely jurisdictional as it is an adjacent wetland located on the banks of G103-38-00. WET 6 is located along West Fork San Jacinto River as a fringe wetland. WET 7, and WET 8 are located along G103-38-00 as fringe wetland areas.

The Waters of the United States Report (Date: December 2021) is included as **Appendix F**. The delineation report provides best professional judgment. Only the United States Army Corps of Engineers (USACE) can make the final determination on the location of waterbody and wetland boundaries and their jurisdictional status. An official jurisdictional determination (JD) from the USACE, the delineation report and JD request form were submitted to the USACE Galveston District Office in January of 2022. The USACE Galveston District Office provided an approved JD on December 6, 2022. The USACE “SWG-2022-00061; Approved Jurisdictional Determination (AJD), Kingwood Diversion Ditch, G103-38-00-E001, Harris and Montgomery Counties, Texas” correspondence is included in **Appendix F**. Based on federal regulations and coordination with EPA and Corps’ Headquarters, the USACE has determined that G103-38-00 (18,253.68 LF), Bens Branch East (343.18 LF), Bens Branch West (339.61 LF), West Fork San Jacinto River (379.83 LF), Wet 1 (0.52 ac), Wet 2/3 (8.51 ac), Wet 4 (1.45 ac), Wet 5 (0.03 ac), Wet 6 (0.05 ac), Wet 7 (0.03 ac) and Wet 8 (0.03 ac) are waters of the United States subject to USACE jurisdiction pursuant to 33 CFR 328.

Any discharge of dredged or fill material into these areas will require a Department of the Army (DOA) permit prior to discharge or work. Also, WC 1 and Drainage Ditches 1-4 are not considered waters of the United States and are not subject to USACE jurisdiction. The discharge of dredged and/or fill material into these areas does not require a DOA permit, prior to any discharge. The approved

jurisdictional determination is valid for 5 years unless new information warrants a revision of the determination prior to the expiration date.

2.5.3 Threatened and Endangered Species Assessment

Hollaway was contracted to complete a Threatened and Endangered Species Assessment for the proposed Kingwood Diversion Ditch project. Biologists conducted field surveys within the project area on August 17, 18, 24, and 25, and September 27, 2021. A desktop analysis was also completed.

The purpose of this assessment was to identify federally listed or state listed threatened and endangered species or protected habitats. This assessment was completed by identifying the habitats within the project area and comparing the specific habitat requirements for the species identified on the United States Fish and Wildlife Service (USFWS) or Texas Parks and Wildlife Department (TPWD) list as having potential to utilize these habitats. The purpose of these assessments is to determine the potential impact to threatened and endangered species or their critical habitats as a result of the proposed project.

Based on the threatened and endangered species assessment, no federally or state listed species were observed within the project area. One federally and state listed species (eastern black rail), one federally protected species (bald eagle), one candidate species for federal listing (monarch butterfly), and six state listed species (swallow-tailed kite, white-tailed hawk, chub shiner, Rafinesque's big-eared bat, sandbank pocketbook, and alligator snapping turtle) may be temporarily impacted by the construction activities associated with the proposed project activities. The project area has potential to support protected breeding, wintering, and transitory migratory birds. Consultation with the USFWS is required prior to construction activities.

The Threatened and Endangered Species Assessment Report (Date: February 2022) is included as **Appendix G**.

2.5.4 Stream Condition Assessment

Hollaway was contracted by HVJ associates to conduct a Level II Stream Condition Assessment (SCA) for the proposed Kingwood Diversion Ditch project. The Project Area consists of approximately 3.5 miles (mi) of G103-38-00 from its upstream confluence with Bens Branch (G103-33-00) to Woodland Hills Drive, the surrounding right-of-way (ROW), and an approximately 46-acre (ac) parcel of forested land adjacent to the West Fork San Jacinto River (G103-00-00). The nearest cross streets on the northern terminus are Russell Palmer at Northpark Drive and Woodland Hills Drive at Soccer/Lacrosse Road on the southern terminus. The Flood Control District proposes to improve channel conveyance from the confluence of Bens Branch and G103-38-00 to a proposed outfall into the West Fork San Jacinto River.

2.5.4.1 Methodology

A data form was completed for each transect along the survey reach and included data collected from the stream, riparian buffers, observations of alterations made to the channel, and summaries of macroinvertebrates and fish identified within the channel.

Per the SCA guidance document for intermittent streams with perennial pools and/or perennial streams or wadeable rivers with impacts greater than 500 linear feet, the following five parameters

were assessed in the field to evaluate the baseline stream condition of the survey reach being impacted:

- 1) Channel Condition,
- 2) Riparian Buffer,
- 3) Visual Channel Alteration,
- 4) In-Stream Macroinvertebrate Observation, and
- 5) Regionalized Index of Biotic Integrity for Fish.

The above five parameters were evaluated at transects spaced 350 feet apart. The results of the parameter assessments were then scored, expressed as channel condition variable (CV); riparian buffer variable (BV); channel alteration variable (AV); macroinvertebrate variable (MV); and fish variable (FV). Final scores of the five parameters were then averaged to determine the condition index (CI). The CI value for each transect was then averaged to calculate the RCI for G103-38-00 within the Project Area.

2.5.4.2 Field Conditions

Land use surrounding the survey reach of G103-38-00 consists primarily of residential development. An institutional facility and commercial development are located along the northern terminus with some commercial development dispersed along the remainder of the survey reach. During the WOTUS delineation and determination field reconnaissance, four vegetative communities were observed within the Project Area: Herbaceous Upland, Forested Upland, Palustrine Emergent (PEM) Wetland, and Palustrine Forested (PFO) Wetland.

The surveyed reaches of G103-38-00 within the Project Area displayed a perennial flow regime and starts at its confluence with Bens Branch moving in a generally southern direction before it confluences with the West Fork San Jacinto River. G103-38-00 is a man-made channel, excavated in the 1970s to divert flow from Bens Branch to the West Fork San Jacinto River.

Overall, the habitat complex of G103-38-00 consisted mostly of runs at depths of 3 feet to approximately 10 feet with clayey silty substrates. The low-flow locations exhibited riffle-pool sequences located near roadway crossings. Water depth along the low-flow locations were approximately 1-foot in depth and contained rock riprap. The surveyed reaches of G103-38-00 exhibited low to moderately incised banks with the southern terminus displaying significant bank erosion.

2.5.4.3 Results

Hollaway conducted the Level II SCA of the survey reach on August 29 through September 1, 2022.

The CV score values for the survey reach ranged from 5 to 6, between 'very low' and 'low'. Minimal bank erosion was noted throughout the Project Area, with a majority of the observed erosion concentrated between Deer Springs Drive and Walnut Drive.

The riparian buffer cover types and percentages were calculated based on Hollaway's WOTUS delineation and determination, field reconnaissance, threatened and endangered species habitat assessment, and historical aerials and topographic maps. The BV averages at a value of 2.62, between 'high suboptimal' and 'severe'.

A review of historical aerials indicates that G103-38-00 was excavated between 1969 and 1977. The Project Area is surrounded by residential development and commercial developments. Based on field observations, the straight channel appears to have stabilized and displays natural flow since it was excavated; however, the majority of the survey reach contained low to moderately incised banks with some evidence of erosion present along the southern terminus. Typical bank armaments, such as rock riprap, and straightened channelization were observed along the survey reach. The average AV score along the survey reach was 1. The AV score and site-specific observations for each transect are provided in the full Stream Condition Assessment Report.

A total of 3,158 benthic organisms representing a minimum of 22 taxa were identified during the assessment. Dominant taxa within the project reach included mayfly species (*Ephemeroptera spp.*) and midges (*Chironomidae spp.*). The HBI scores ranged from 4.24 to 5.82, with a mean HBI value of 5.20, corresponding to an 'optimal' score.

Thirteen species of fish were collected within the survey reach. Blackstripe topminnow (*Fundulus notatus*) and western mosquitofish (*Gambusia affinis*) were the dominant species. While not captured during fish sampling, longnose/spotted gar (*Lepisosteus osseus/oculatus*) were viewed within the Project Area and banded pygmy sunfish (*Elassoma zonatum*) were captured during benthic macroinvertebrate sampling. The ALU score for the entire survey reach was 'limited', with an FV score of 2.

2.5.4.4 Condition Index

The five assessed parameters (channel condition, riparian buffer, visual channel alteration, in-stream macroinvertebrate observation, and regionalized index of biotic integrity for fish) were further evaluated to calculate the CI for each transect, which determines the relative ability of an aquatic resource to support and maintain a community of organisms with composition, diversity, and function compared to other aquatic resources within the region. The CI value for each transect is calculated by averaging the final scores of the five parameters (CV, BV, AV, MV, and FV). The CI value was then averaged to determine the RCI, which evaluates the entire survey reach of a stream, whereas the CI evaluates each individual transect within the survey reach. **Table 2** provides the CI value for each transect and the overall RCI for G103-38-00 within the Project Area.

Table 2 - Summary of Condition Index Results

Transect #	Channel Condition Variable (CV)	Riparian Buffer Value (BV)	Channel Alteration Variable (AV)	Macroinvertebrate Variable (MV)	Fish Variable (FV)	Condition Index (CI)
1	5	3.84	1	4	1	2.97
2	5	4.25	1	3	1	2.85
3	5	2.46	1	3	1	2.49
4	5	2.61	1	3	1	2.52
5	5	2.95	1	3	1	2.59
6	5	2.15	1	3	2	2.63
7	5	2.33	1	3	3	2.87
8	4	2.21	1	3	3	2.64
9	5	2.16	1	3	3	2.83
10	5	2.41	1	2	2	2.48
11	5	2.4	1	2	3	2.68
12	5	2.2	1	3	2	2.64
13	5	2.5	1	2	3	2.70
14	5	2.39	1	2	2	2.48
15	5	2.32	1	2	3	2.66
16	5	2.85	1	2	2	2.57
17	5	2.9	1	2	3	2.78
18	5	1.96	1	3	2	2.59
19	5	2.93	1	2	2	2.59
RCI						2.66

2.5.4.5 Conclusion and Recommendations

Based on the site reconnaissance conducted for the study area, G103-38-00 is a straight, man-made, perennial stream that exhibits stable banks with low erosion and low-quality habitat as determined by the biotic indices for macroinvertebrates and fish. A stream assessment was conducted according to the USACE Galveston District Level II SCA Procedures (USACE, 2014) with approved modifications to the transect length and placement to determine the existing stream function conditions. Based on the field and desktop investigations, G103-38-00 was observed as a man-made channel with low levels of erosion throughout its reach within the Project Area. The southern portion of the channel is buffered by wooded upland and wetland communities and the remainder of the channel is buffered by maintained ROW. The CI scores were slightly higher in the southern portion of the reach but were otherwise consistent throughout the Project Area. The calculated existing condition RCI score for the surveyed reach of G103-38-00 equals 2.66.

In order to reduce potential mitigation costs, Hollaway recommended considering construction elements that preserve, maintain, or improve the quality and function of the stream, such as

incorporating natural stream design into any modifications made to the channel, including stabilizing banks with natural vegetation where practicable. Additionally, Hollaway recommended designing improvements to the channel that will heighten, intensify, or improve specific functions of the channel as described in the SCA report.

During construction, Hollaway recommends maintaining channel flow so that the function of the channel is not significantly impaired. Additionally, water quality BMPs should be utilized to minimize impacts to the channel and downstream habitats. These BMPs include, but are not limited to:

- Minimizing the use of equipment in the channel and riparian areas during construction,
- When possible, equipment access should be from banks or bridge decks,
- When temporary stream crossings are unavoidable, remove stream crossings once they are no longer needed and stabilize banks and soils around the crossing,
- Utilize biotechnical bank stabilization methods, including live native vegetation where practicable, or a combination of vegetative and structural material, and
- Reducing erosion through the use of temporary vegetation, blankets/matting, silt fencing, or other similar methods.

Post construction, Hollaway recommends incorporating permanent BMPs to reduce total suspended solids within the channel. These BMPs include, but are not limited to:

- Vegetative filter strips,
- Constructed wetlands,
- Wet-bottomed basins, and
- Mulch filter socks.

The Level II Stream Condition Assessment Report (Date: October 2022) is included as **Appendix H**.

2.5.5 Cultural Resources

Moore Archaeological Consulting, Inc. was contracted to conduct a cultural resources assessment for the Kingwood Diversion Ditch project. The assessment included a desk-based analysis of available data within the project's Area of Potential Effects (APE). The APE included an estimated 142 acres that are anticipated to be directly impacted by the proposed project.

The purpose of the cultural resources assessment was to review available data of previously recorded cultural resources surveys, archaeological sites, and historic resources within the project area. The assessment also provides the potential to identify new cultural resources. This information will inform project planning and identify potential requirements for regulatory compliance.

A review of the archival documentation revealed alterations to the landforms immediately adjacent to the APE. Major alterations include the development of the Lake Houston, Kingwood, and North Shore neighborhoods, oil and gas development, and installation of the dam on San Jacinto River. The dam resulted in the creation of Lake Houston that caused the West Fork to expand into low lying areas.

Based on the cultural resources assessment, no previously recorded cultural resources investigations were completed within the project's area of potential effects (APE). One archaeological site

(41HR1176) was identified within the APE. Four cultural resources surveys and three archaeological sites were identified outside the APE but within a one-mile radius of the APE.

The underlying soils within the project area and its proximity to the Bens Branch and the West Fork San Jacinto River indicate a high potential to encounter buried prehistoric resources within the APE. The probability decreases northward of the San Jacinto River. There is a moderate potential to encounter cultural resources along the northern portion of Bens Branch. Construction activities have the potential to adversely impact cultural resources. Consultation with the USACE-Galveston District and Texas Historical Commission (THC) is required prior to construction activities.

Staff archeologists at the THC reviewed the desk-based assessment produced by Moore Archeological Consulting (MAC) and submitted their response on January 3, 2022 (THC Tracking #202204392). The THC concurred with the findings and recommendations made in the assessment. These included the recommendation for an archeological survey and, specifically, the need to archeologically test the previously recorded prehistoric site 41HR1176 to assess its potential for inclusion on the National Register of Historic Places (NRHP).

As a result of the THC's response, MAC submitted a proposal for field investigations to be conducted within the APE of the Kingwood Diversion Ditch project prior to the onset of construction. This work will fall under the Antiquities Code of Texas, which will require MAC to apply for and receive a Texas Antiquities Commission (TAC) permit. The THC specifically recommended that the general investigation be conducted under one permit and the site evaluation of 41HR1176 under another permit. The first phase will focus on the general APE study and MAC will submit an application for the TAC permit for that work. Once the TAC permit is obtained, MAC will proceed to conduct the following investigations within the APE.

2.5.5.1 Phase 1

The approximately 71.04-acre area between the West Fork San Jacinto River and the pedestrian bridge at Walnut Lane has a high probability of containing buried archeological deposits. The investigations will include:

- An assessment of shallowly and potentially deeply buried deposits. Deeply buried deposits along the San Jacinto River should be assessed using shovel testing and hand-excavated augers,
- Backhoe trenches placed in accessible and open areas, and
- Shovel testing focused on relatively undisturbed areas of an approximately 974 m (3,195 ft) long segment between Deer Ridge Boulevard and Walnut Lane.

The northernmost portion of the project area, approximately 6.83 acres north of Northpark Drive, will be investigated for shallowly buried deposits using shovel tests.

The THC concurred with MAC's findings that the area identified in the Figure shown in **Exhibit 01 in Appendix I** as "C" be excluded from field investigations, so no work will be done there.

This investigation will have a no-collect policy with all finds being mapped, photographed, and documented (including simple analysis) in the field before being reburied in place.

Following completion of the fieldwork, a report will be written compiling the findings of the investigation and making recommendations for any additional investigation (if needed), as well as an assessment of any previously unrecorded sites found during the investigation. This report will be submitted to the THC for review and approval of the recommendations made. A final report addressing any changes requested by the THC will be submitted and curation requirements completed in order to close out the TAC permit.

2.5.5.2 Phase 2

For the second phase of the project, which comprises the NRHP eligibility testing of site 41HR1176, MAC will obtain a second TAC permit from the THC. The work at the site will involve the excavation of approximately 6 excavation units distributed across the site using professional judgement and best practices in order to obtain the best sampling possible and to reach as deep as necessary. The collection policy of this part of the investigation will be to collect all artifacts.

Once the fieldwork at 41HR1176 is completed, MAC will analyze all artifacts and field data to assess the site's NRHP eligibility and write a report compiling the findings of the investigation. The draft of this report will be submitted to the THC for review and concurrence of any recommendations made. A final report will be submitted addressing any changes requested by the THC and submitted to all parties. All artifacts and other requisite materials will be curated, and the permit will be closed out as soon as all final deliverables are submitted.

The complete scope of work is attached as **Exhibit 01** in **Appendix I**.

The Cultural Resources Assessment Report (Date: December 2021) is included in **Appendix I**.

2.6 Geotechnical Exploration

Neel-Schaffer, Inc. contracted with Raba Kistner Consultants, Inc. to prepare a Geotechnical Engineering Study for the project, HCFC Unit No. G103-38-00.

The scope of geotechnical study included:

- Drilling and sampling 20 borings within the existing Kingwood Diversion Ditch to determine subsurface conditions,
- Performing laboratory tests on selected soil samples,
- Performing a slope stability analysis for the proposed six channel segments geometries,
- An evaluation of erosion potential and recommendations to minimize erosion,
- Analyzing global stability of the proposed diversion structure to develop sizing requirements, and
- Preparing a geotechnical report.

Subsurface sampling along the proposed project corridor indicates that a variety of soil conditions underlie it. Principally, the project rests on the Beaumont formation, whose soils mostly consist of clay-sand and silt of moderate permeability and drainage, displaying low to moderate compressibility and potential for shrink or swell. Several of the borings in the Southern portion of the project pass through alluvial deposits that display highly variable characteristics, including alternating and overlain

layers of cohesive and cohesionless soils with high plasticity and the presence of high groundwater including deposits of silts and fat clays.

Harris County Flood Control District requires a minimum factor of safety of 1.3, 1.25 and 1.5 for end of construction, rapid drawdown, and long-term conditions, respectively. Based on the slope stability analyses, it appears that proposed Channel Segment 3 does not meet the minimum requirements for factors of safety against slope failures for rapid drawdown and long-term conditions. Slickensided structures were observed in the underlying cohesive material and therefore, the residual drained strength was measured based on the CU test result shown in Boring B-13 at a depth of 23 feet to 25 feet. Based on information provided, it is understood that this segment cannot be flattened to improve its performance. Therefore, slope stability analyses results of Segment 3 will be included with soil improvement using select fill and toe rip rap.

Based on the laboratory results of the crumb tests, the cohesive soils sampled in the project borings ranged from non-dispersive to highly dispersive. Therefore, construction of backslope swales to intercept runoff is recommended. Also, if any eroded areas occur, then those areas should be repaired and backfilled with non-dispersive sandy lean clay soils. All slopes should be permanently vegetated by turf grass establishment. An established permanent turf grass stand is an effective and economical method to stabilize slopes and minimize erosion caused by overbank flow and high velocities in channels.

There could be actual variations of the subsurface conditions across the site which the extent of variations may not become evident until construction commences. In addition, the construction process itself may also alter subsurface conditions. If variations appear evident at the time of construction, it may be necessary to reevaluate the geotechnical recommendations after performing on-site observations and tests to establish the impact of the variations.

To meet the Flood Control District's minimum factor of safety and to maintain a 3:1 side slope in order to not encroach onto private property, Segments 3 will require structural excavation (benching), to replace the existing soil with select fill material, with a riprap wedge. See Typical Benching Details in **Appendix J** for details. Due to the reduced surveyed cross-sections, it is recommended to reanalyze the slope analysis with the complete topographic survey during the Design Stage which could result in a reduction in construction cost.

The Geotechnical Engineering Study (Date: June 23, 2023) is included as **Appendix J**.

2.7 Existing Bridge Study

Neel-Schaffer, Inc. completed a Bridge Evaluation Report for structures crossing the Kingwood Diversion Ditch dated February 7, 2022.

There are seven existing bridges that are impacted by improvements to the Kingwood Diversion Ditch:

- Northpark Drive (west bound) – TIRZ 10 currently reconstructing,
- Northpark Drive (east bound) – TIRZ 10 currently reconstructing,
- Kingwood Drive (west bound),
- Kingwood Drive (east bound),

- Greenbelt Trails Pedestrian Bridge,
- Walnut Lane, and
- Deer Ridge Estates Blvd.

The evaluation relied heavily on existing Federal Highway Administration’s (FHWA) National Bridge Inventory (NBI) inspection reports and a field evaluation, due to lack of availability of the existing bridge drawings and inspection and maintenance reports. Site visits were made on March 1 and October 8, 2021.

The sufficiency rating of these bridges varies from 64.3 to 89.8 with each being structurally sound, although channel conditions around several of the bridges were poor, with failed concrete revetment and bank erosion present.

The necessary maintenance for each bridge should be completed to ensure safe conditions. An overall review of channel conditions and proposed improvements may require changes to the existing channel and banks that exceed the current limits of the existing bridges. The bridges are owned and maintained by others.

The following are the results of the General Condition of the four bridges:

- Kingwood Drive Bridges General Condition – **Fair**
 - General Condition of the slope paving is **Poor**
 - NBI Sufficiency Rating – **64.3** dated August of 2017
 - Owned by City of Houston
- Walnut Lane Bridge General Condition – **Fair**
 - NBI Sufficiency Rating – **81.3** dated August of 2017
 - Owned by City of Houston
- Deer Ridge Estates Boulevard Bridge General Condition – **Good**
 - NBI Sufficiency Rating – **89.8** dated August of 2017
 - Owned by City of Houston
- Greenbelt Trails Pedestrian Bridge General Condition – **Good**
 - No NBI Sufficiency Rating
 - (*) Owned by Kingwood, Houston (master planned community)

(*) Kingwood has over 75 miles of hike and bicycle trails called Greenbelt Trails. The parks and trails are owned by the Kingwood community. Greenbelt Trails maintenance is the responsibility of the trail association in each village except for Trailwood Village.

Bridge replacement costs are based on the following resources:

1. Texas Department of Transportation (TxDOT)
 - a. Table 1. State FY 20 Average Unit Cost (Low Bid Average for New and Replaced Bridges with DCIS Estimate)
 - b. Table 2. State FY 20 Average Unit Cost (Low Bid Average for New and Replaced Bridges with DCIS Estimate, On and Off System)
2. U.S. Department of Transportation / Federal Highway Administration (Bridges & Structures) Bridge Replacement Cost Data

a. Non-National Highway System Bridges (2018, 2019, 2020)

2020 cost data was the most recent available at the time of the bridge evaluation and bridge replacement cost estimate. A blended average for similar bridges (types, span lengths, etc.) was used along with an applied inflation factor for current cost.

The Bridge Evaluation Report (Date: February 7, 2022) is included as **Appendix K**.

3. Methods of Analysis

Harris County Flood Control District and FEMA criteria were used in this analysis, including potential mitigation for any adverse impacts. Flows were diverted to Kingwood Diversion Ditch (maximum capacity) from Bens Branch and measures were taken to avoid additional flooding of properties along Kingwood Ditch from Bens Branch.

3.1 Data Collection

The following data were collected for the hydraulic impact analysis:

- FEMA-Effective Models (HEC-HMS and HEC-RAS) for the Bens Branch sub-watershed and San Jacinto River watershed,
- LiDAR data for the project area,
- Atlas-14 Rainfall data (Table 3),
- Topographic Field Survey data,
- As-Builts for existing channel crossings, and
- Parcel data from Harris County and Montgomery County Appraisal Districts.

Table 3 - Atlas-14 Rainfall Data

Storm Event	Duration							
	5-min	15-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
50% AEP	0.58	1.17	2.22	2.8	3.15	3.78	4.44	5.15
10% AEP	0.85	1.69	3.22	4.27	4.97	6.21	7.46	8.79
1% AEP	1.27	2.52	4.82	6.94	8.53	11.4	14.1	17.1
0.2% AEP	1.59	3.15	6.28	9.59	12.2	16.7	21	25.4

3.2 Tools and Programs Used

The following tools and programs were used in this analysis:

- ArcGIS for LiDAR/Survey data processing, model development and inundation mapping,
- Civil3D for survey data review,
- HEC-HMS to compute flows for the drainage areas, and
- HEC-RAS for hydraulic analysis.

3.3 Existing and Alternative Condition Analysis

Three feasible Alternatives were analyzed, along with an analysis of existing conditions. In each alternative, flow was restricted to Bens Branch through use of a 24-inch RCP (just on the east side of Bens Branch/Kingwood Diversion Ditch confluence), with an overflow weir set to the elevation of the Atlas 14 1% AEP event, rather than allowing free flow to Bens Branch. The Flood Control District's guidelines to use a pipe diameter of 24 inches were adopted to maintain minimum flow on Bens Branch (downstream of the confluence of Bens Branch and the Kingwood Diversion Ditch). Alternative conditions have been described below.

The Without Project Conditions Memorandum (Date: July 19, 2022) is included as **Appendix L**.

3.3.1 Alternative 1 – Trapezoidal Channel Section

In Alternative 1 (**Figure 3**), the proposed channel is a widened trapezoidal channel along the Kingwood Diversion Ditch with lowered inverts to obtain a consistent slope of 0.1% to Walnut Lane and 0.08% downstream of the proposed drop structure to the new outfall into the West Fork San Jacinto River. Upstream of Woodland Hills Drive, a new outfall channel will be constructed to the West Fork San Jacinto River while maintaining the existing channel and outfall east of Woodland Hills Drive.

The proposed channel is a grass-lined trapezoidal channel with minimum side slopes of 3H:1V, with a bottom width ranging from 10 feet to 80 feet and a top width of 150 feet to 195 feet. See **Appendix M** for typical sections.

Along the existing channel alignment, the channel modifications were limited to the existing Right-of-Way (ROW). The new proposed outfall channel running parallel to Woodland Hills Drive would require a new culvert crossing at Hamblen Road (eight 12-ft by 7-ft concrete box culverts), along with additional ROW of currently vacant land that is located inside the existing floodplain of West Fork San Jacinto River.

The lowered invert elevations along the channel upstream of the steep section will reduce the potential slope from Walnut Lane to Deer Ridge Estates Boulevard; however, to reduce the channel velocities and to help protect against erosion, this alternative proposes a single 6-foot drop structure with concrete lining upstream and downstream of the structure.

For Alternative 1, a drop structure is proposed at RS 7550. At this location, the Atlas 14 1% AEP flow is 6,423 cubic feet per second (cfs). The drop structure was designed based on the Atlas 14 1% AEP discharge. A straight drop structure was selected over sloped drop and baffle chute structures based on the drop height, channel bottom width, and channel condition. Since the channel width near the proposed drop structure is greater than 10 feet, the sloped drop was excluded. Similarly, the use of a baffle chute was excluded since the change in elevation is not abrupt, and there is no lateral flow joining the main channel. The calculation followed the procedures provided in '*A.14 Transition Control Structural Examples*' of *HCFCDC Interim Policy Criteria and Procedures Manual, July 2019*.

The dimensions of the drop structure were calculated using a longitudinal slope of 0.08% and a trapezoidal channel with a bottom width of 60 feet and side slopes of 3.5:1 (H:V).

The length of protection required was also calculated using the selected final practical widths and a drop of 6.3 feet. Based on the hydraulic analysis, no hydraulic jump is formed downstream of the drop structure. As a result, the protection length is calculated based only on the drop depth. The calculations resulted in a drop length of 38 feet for the Atlas 14 1% AEP flow, which will be the required length of protection at the drop structure. Downstream of the concrete protection, riprap is proposed, extending a minimum of 20 feet beyond the concrete section.

As a result of the expanded cross sections, several of the bridges along the Kingwood Diversion Ditch will need to be replaced. Due to the new channel configuration and invert elevations, the bridge crossings at Kingwood Drive, Walnut Lane, Deer Ridge Estates Boulevard, and the pedestrian bridge near Lake Village Drive will need to be replaced. The bridge crossing for Northpark Drive is currently in the process of reconstruction by the Lake Houston Redevelopment Authority TIRZ Number 10

Northpark Drive Overpass Project. A comparison of the bridge spans and low chord elevations is shown in **Table 4** below.

Table 4 - Alternative 1 - Existing and Proposed Bridges

Road	Length (ft)		Low Chord (ft)	
	Existing	Proposed	Existing	Proposed
Northpark Dr	TIRZ 10 CURRENTLY RECONSTRUCTING			
Kingwood Dr	145	160	71.90	71.90
Lake Village Pedestrian Bridge	220	220	75.50	75.50
Walnut Ln	119	180	72.83	72.83
Deer Ridge Estates Blvd	120	160	55.12	55.12

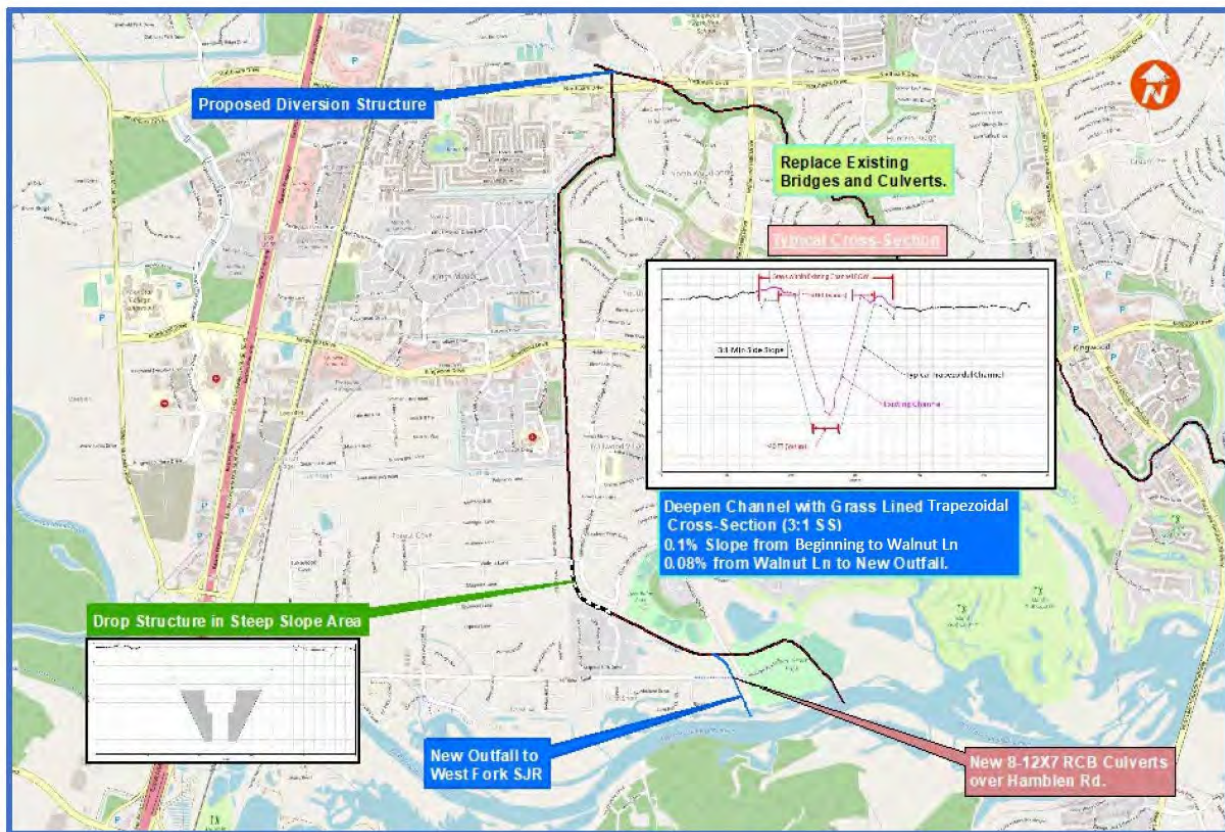


Figure 3 - Alternative 1 - Trapezoidal Benched Cross-Section

3.3.2 Alternative 2 – Trapezoidal Benched Cross-Section above the Ordinary High-Water Mark (OHWM)

Alternative 2 includes a benched channel section (**Figure 4**), which has the same alignment as the trapezoidal channel alternative and the same proposed outfall channel alignment. The primary difference compared to Alternative 1 is that instead of lowering the channel and placing a fully

trapezoidal section, the existing channel was maintained below the Ordinary High Water Mark (OHWM), with a trapezoidal benched section placed 1 foot above the OHWM. The benched section maintains the same general side slopes and top width as the trapezoidal channel alternative to maintain the improvements within the existing ROW through the fully developed portion of the channel. See **Appendix M** for typical sections.

It would not be practical to construct a benched channel section through the steep section between Walnut Lane and Deer Ridge Estates Boulevard, as the high velocities would erode the proposed/existing portions of the channel section; therefore, trapezoidal channel sections with two drop structures are proposed through the steep section. These trapezoidal sections result in the need for stream mitigation credits, as they include construction within the Waters of the U.S. (WOTUS).

Along the existing channel alignment, the channel modifications were limited to the existing ROW. Similar to Alternative 1, the new proposed outfall channel running parallel to Woodland Hills Drive would require a new culvert crossing at Hamblen Road (eight 12-ft by 7-ft concrete box culverts), along with additional ROW of currently vacant land that is located inside the existing West Fork San Jacinto River floodplain.

As with the trapezoidal channel section, no changes to the channel configuration are proposed along Bens Branch or along the portion of the Kingwood Diversion Ditch downstream of Woodland Hills Drive.

Two drop structures are proposed between Walnut Lane and Deer Ridge Estates Boulevard to minimize the proposed fill within the existing channel and contain the channel conveyance improvements within the existing ROW. A three-foot drop structure, followed by a four-foot drop structure will be placed between Walnut Lane and Deer Ridge Estates Boulevard.

Design for the drop structure for Alternative 2 used similar procedures to those used to calculate the drop structure dimensions for Alternative 1. The calculation followed the procedures provided in '*A.14 Transition Control Structural Examples*' of *HCFCD Interim Policy Criteria and Procedures Manual, July 2019*.

The length of protection required was also calculated using the selected final practical widths and a drop of 3.5 feet and 4 feet at RS 8116 and RS 7550, respectively. Based on the hydraulic analysis, no hydraulic jump was formed downstream of both drop structures. As a result, the protection length was calculated based only on the drop depths. The calculations resulted in a drop length of 35 feet and 38 feet for the Atlas 14 1% AEP flow, which will be the required length of protection for the drop structure at RS 8116 and RS 7550, respectively.

As a result of the expanded cross sections, several of the bridges along the Kingwood Diversion Ditch will need to be replaced. Due to the new channel configuration and invert elevations, the bridge crossings at Kingwood Drive, Walnut Lane, Deer Ridge Estates Boulevard, and the pedestrian bridge near Lake Village Drive will need to be replaced. The bridge crossing for Northpark Drive is currently in the process of reconstruction by the Lake Houston Redevelopment Authority TIRZ Number 10 Northpark Drive Overpass Project. A comparison of the bridge spans and low chord elevations is shown in **Table 5**.

Table 5 - Alternative 2 - Existing and Proposed Bridges

Road	Length (ft)		Low Chord (ft)	
	Existing	Proposed	Existing	Proposed
Northpark Dr	TIRZ 10 CURRENTLY RECONSTRUCTING			
Kingwood Dr	145	160	71.90	73.88
Lake Village Pedestrian Bridge	220	220	75.50	75.50
Walnut Ln	119	180	72.83	72.83
Deer Ridge Estates Blvd	120	160	55.12	55.89

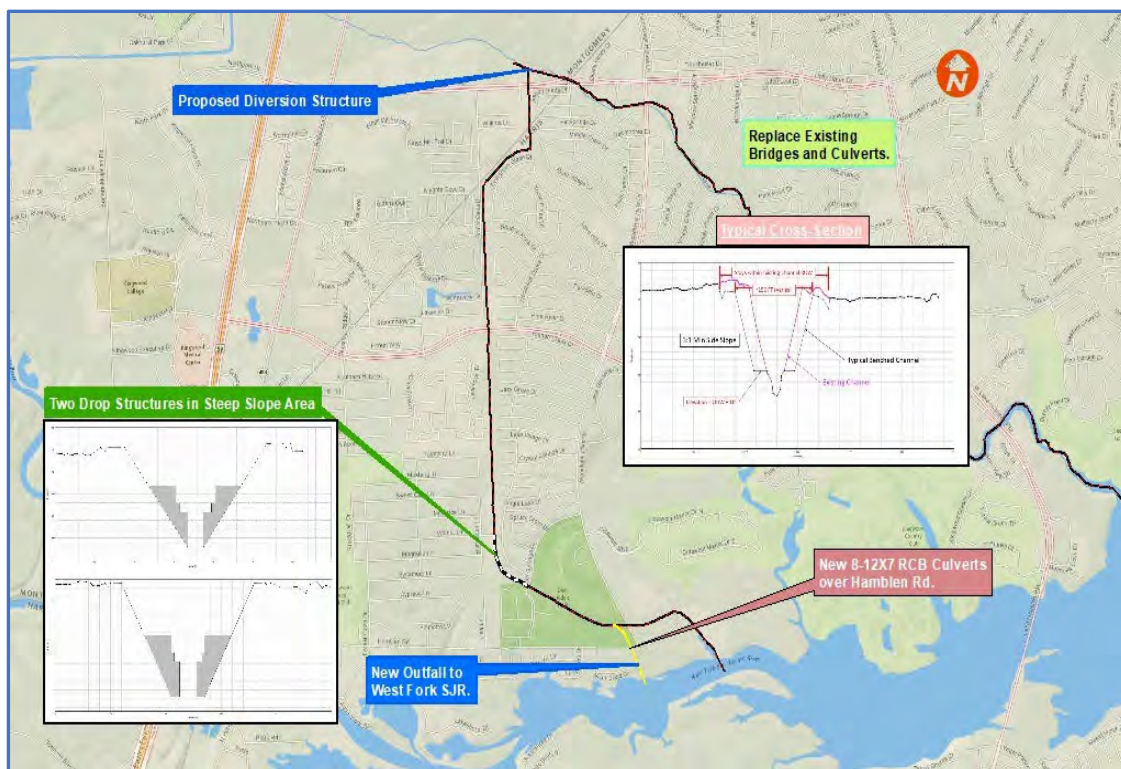


Figure 4 - Alternative 2 - Trapezoidal Benched Cross-Section above OHWM

3.3.3 Alternative 3 – Natural Stable Channel Design Features Section

Alternative 3 (Figure 5) included a natural stable channel design section with a low-flow section. The intent is to utilize the natural stable channel design features to offset/reduce impacts to the WOTUS. Design of the typical sections and drop structures for the section using natural stable channel design features was performed by Freese & Nichols, and has been documented in a separate report. This report analyzed the hydraulic results of the Freese & Nichols design.

The natural stable channel alternative generally has the same overall trapezoidal section as Alternative 1. A meandering, low-flow channel with natural stable channel design features such as riffles and pools is to be constructed along the bottom of the channel section. Due to the spacing of the cross sections associated with the available project survey data as part of this analysis, only the

riffle cross sections were modeled. The riffle sections are the shallower sections that will control the conveyance capacity for the channel. The channel sections include vegetation within the channel banks and along the low flow sections in the channel. The vegetation consists of grasses and small shrubs to be planted, and some woody shrubs only along bends in the channel to provide additional protection against erosion. No trees or large woody shrubs are to be planted within the channel section. See **Appendix M** for typical sections.

A series of rock cross vane structures are recommended in lieu of drop structures to be installed in the natural channel to lower the elevation in a stable manner. For every 1 foot of elevation change, a rock cross vane structure is recommended to allow for aquatic organism passage. The elevation of the top of each structure will be set at the proposed design elevation of the end of the riffle. Cross vanes, vanes, and boulder clusters are proposed for use in the Kingwood Diversion Ditch. These structures are anticipated to be constructed using rock boulders, but hardwood logs could also be considered for some of the structures during final design. Similar to Alternatives 1 and 2, the new proposed outfall channel running parallel to Woodland Hills Drive would require a new culvert crossing at Hamblen Road (eight 12-ft by 7-ft concrete box culverts), along with additional ROW of currently vacant land that is located inside the existing West Fork San Jacinto River floodplain. As a result of the expanded cross sections, several of the bridges along the Kingwood Diversion Ditch need to be replaced. Due to the new channel configuration and invert elevations, the bridge crossings at Kingwood Drive, Walnut Lane, Deer Ridge Estates Boulevard, and the pedestrian bridge near Lake Village Drive need to be replaced. The bridge crossing for Northpark Drive is currently in the process of reconstruction by the Lake Houston Redevelopment Authority TIRZ Number 10 Northpark Drive Overpass Project. Comparison of the bridge spans and low chord elevations has been shown in **Table 6**.

Table 6 - Alternative 3- Existing and Proposed Bridges

Road	Length (ft)		Low Chord (ft)	
	Existing	Proposed	Existing	Proposed
Northpark Dr	TIRZ 10 CURRENTLY RECONSTRUCTING			
Kingwood Dr	145	160	71.90	71.90
Lake Village Pedestrian Bridge	220	220	75.50	75.50
Walnut Ln	119	180	72.83	72.83
Deer Ridge Estates Blvd	120	160	55.12	55.61

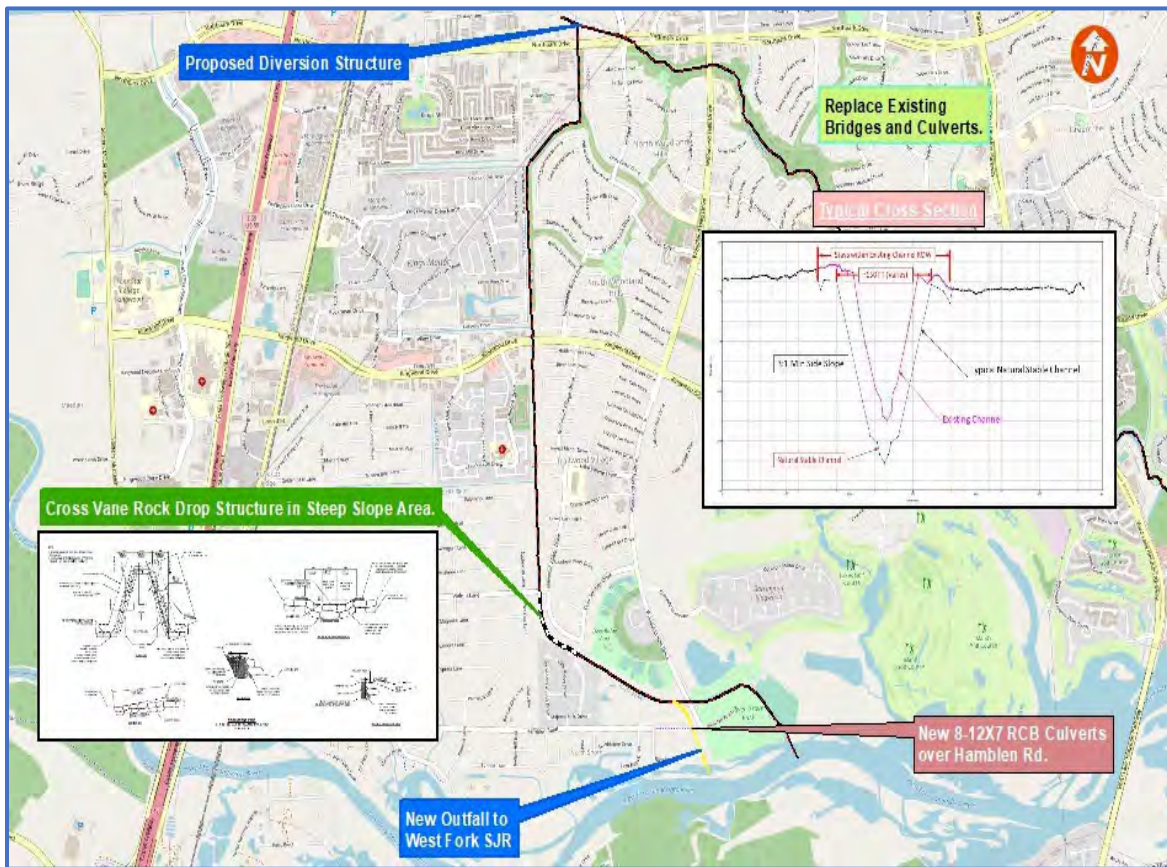


Figure 5 - Alternative 3 - Natural Stable Channel Section Design

The Natural Stable Channel Design Report (Date: November 01, 2022) is included as **Appendix N**.

4. Hydrologic and Hydraulic Analysis

4.1 Hydrologic Analysis

The Effective FEMA HEC-HMS model for the San Jacinto River watershed was used as a base model for the existing and Alternative conditions. No changes were made to the hydrologic data of the drainage areas. The following steps were taken to modify the Effective HEC-HMS model.

1. Separate model plans were created for the Existing and Three Alternative Conditions. All plans were updated with Atlas-14 Rainfall Data.
2. SV-SQ (Storage-Discharge) relationships were optimized between HEC-HMS reaches and HEC-RAS model plans.
3. Atlas 14 50% AEP, 10% AEP, 1% AEP and 0.2% AEP HEC-HMS model plans were executed for corresponding flows in the HEC-RAS Model plans.
4. A tailwater-driven simulation of coinciding peaks was modeled involving the Atlas 14 1% AEPs for both the Kingwood Diversion Ditch and West Fork San Jacinto River. This scenario assumes that an Atlas 14 1% AEP event occurs over the West Fork San Jacinto River simultaneously with an additional Atlas 14 1% AEP event occurring over the Kingwood area. This conservative scenario represents a statistical event with a much smaller chance of occurrence than a single Atlas 14 1% AEP event occurring over the watershed of Kingwood Diversion ditch.

4.2 Hydraulic Analysis

The following steps were followed for HEC-RAS model development:

1. The existing model was modified to incorporate 2D area at the Bens Branch-Kingwood Diversion Ditch diversion area and at the downstream confluence area of the Kingwood Diversion Ditch and West Fork San Jacinto River. The 1D area of the Existing Conditions model (Kingwood Diversion Ditch & Bens Branch) was connected to the 2D areas of the model. Manning's roughness values were updated for the 2D and 1D areas.
2. Using the Existing Conditions geometry file as a starting point, three new geometry files were created for the alternatives discussed above.
3. In the Alternative Condition model plans, flow restrictions to Bens Branch (east of the confluence area) and a new culvert crossing at Hamblen Rd were incorporated in the 2D areas.
4. Flow hydrographs for the Existing and Alternative Conditions were incorporated from the corresponding HEC-HMS model.
5. In most alternatives, Normal Depth (0.005 ft/ft) was used as a Boundary Condition at the downstream ends of Kingwood Diversion Ditch and Bens Branch. This was done to evaluate hydraulic performance of different alternatives with respect to the existing conditions, without the influence of the West Fork San Jacinto River.
6. For the model simulation of coinciding peaks (see 4.1.4), quasi-steady state 2D boundary conditions were applied to West Fork San Jacinto at the downstream of Kingwood Diversion Ditch and Bens Branch.

5. Hydrologic and Hydraulic Results and Discussion

5.1 Hydrologic Results

Results of the SV-SQ analysis for the Existing and Alternative Conditions have been shown in the H&H Report in **Appendix O** (Appendices 3A, 3B, 3C, 3D). These results present flows and changes in reach storages in different conditions.

Peak flows from the drainage areas for different storm events are shown below in Table 7.

Table 7 - Peak Flows of the Drainage Areas

Drainage Area Name	Drainage Area (ac)	Peak Flows for Atlas 14 Storm Events (cfs)			
		50% AEP	10% AEP	1% AEP	0.2% AEP
Bens Branch (HCFCD Unit G103-33-00)					
G1033300A	291.20	238.40	379.40	647.60	915.30
G1033303A	68.29	89.30	136.80	221.80	302.90
G1033300B	167.62	132.40	210.90	361.10	511.80
G1033302A	242.43	210.30	331.60	561.10	789.20
G1033300C	190.02	130.70	210.40	366.70	525.70
G1033300D	207.36	137.50	222.30	389.20	559.30
G1033300E	135.42	94.60	152.70	265.80	380.70
G1033300F	160.96	152.50	239.50	401.60	560.70
G1033301A	191.55	219.60	339.00	556.70	767.30
G1033301B	182.46	160.80	253.40	428.40	601.50
G1033301C	264.90	212.00	337.50	577.40	817.40
G1033301D	158.08	176.80	273.60	450.30	621.40
G1033300G	98.43	117.10	180.50	295.40	405.90
G1033300H	192.19	178.30	279.50	469.30	656.80
G1033304B	149.31	171.20	264.30	433.80	597.80
G1033304A	110.08	167.90	253.30	404.50	547.20
G1033304C	192.32	246.10	376.90	612.00	837.40
G1033304D	95.55	82.40	130.20	220.80	310.60
G1033300I	203.97	166.50	265.20	452.70	639.90
Kingwood Diversion Ditch (HCFCD Unit G103-38-00)					
G1033800A	98.05	98.80	153.90	255.90	355.50
G1033800B	94.59	88.30	138.70	232.90	325.70
G1033801B	65.73	92.20	140.70	226.60	308.10
G1033801A	274.62	219.00	349.40	598.70	847.90
G1033800C	410.05	275.60	443.00	774.10	1110.10
G1033802A	233.54	251.00	388.80	642.70	890.20
G1033802B	117.76	128.20	198.00	326.50	451.50
G10338011A	51.90	55.20	86.00	142.40	197.20
G1033800G	364.42	158.60	267.10	492.70	723.40
G1033800F	378.69	329.60	522.90	886.90	1246.80
G1033800E	280.83	233.30	369.50	629.10	888.00
G1033800D	264.96	200.20	319.70	550.70	783.50

5.2 Hydraulic Results

The results of the HEC-RAS model are shown in **Table 8** and **Table 9** (Atlas 14 1% AEP). Inundation maps for the existing and Alternative Conditions are shown in following exhibits:

- **Exhibit 12:** Inundation Map (50% AEP),
- **Exhibit 13** Inundation Map (10 % AEP),
- **Exhibit 14:** Inundation Map (1% AEP), and
- **Exhibit 15:** Inundation Map (0.2% AEP).

Table 8 - Kingwood Diversion Ditch HEC-RAS Model Results (Atlas 14 1% AEP)

Existing		Alternative 1	Alternative 2	Alternative 3	Differences in W.S. Elevation (ft)		
River Station	W.S. Elev. (ft)	W.S. Elev. (ft)	W.S. Elev. (ft)	W.S. Elev. (ft)	Alternative 1-Existing	Alternative 2-Existing	Alternative 3-Existing
21100	73.19	71.88	72.75	71.82	-1.31	-0.44	-1.37
21016	73.19	71.85	72.73	71.78	-1.34	-0.46	-1.41
20972	Northpark Dr						
20898	73.17	71.77	72.69	71.68	-1.40	-0.48	-1.49
20789	73.16	71.73	72.67	71.64	-1.43	-0.49	-1.52
20553	73.13	71.62	72.62	71.51	-1.51	-0.51	-1.62
20266	73.12	71.53	72.58	71.39	-1.59	-0.54	-1.73
19822	73.09	71.3	72.52	71.21	-1.79	-0.57	-1.88
19649	73.08	71.26	72.49	71.15	-1.82	-0.59	-1.93
19316	73.05	71.16	72.44	71.05	-1.89	-0.61	-2.00
18655	73.06	70.97	72.34	70.84	-2.09	-0.72	-2.22
18020	73.05	70.68	72.24	70.53	-2.37	-0.81	-2.52
17398	73.05	70.42	72.18	70.27	-2.63	-0.87	-2.78
16769	72.94	69.92	71.94	69.75	-3.02	-1.00	-3.19
16159	72.84	69.65	71.82	69.47	-3.19	-1.02	-3.37
15547	72.76	69.31	71.68	69.11	-3.45	-1.08	-3.65
14816	72.66	69.00	71.48	68.80	-3.66	-1.18	-3.86
14229	72.56	68.78	71.34	68.59	-3.78	-1.22	-3.97
13880	72.52	68.67	71.28	68.49	-3.85	-1.24	-4.03
13827	72.44	68.46	71.11	68.28	-3.98	-1.33	-4.16
13792	Kingwood Dr						
13700	72.35	68.41	71.07	68.22	-3.94	-1.28	-4.13
13593	72.25	68.36	71.04	68.17	-3.89	-1.21	-4.08
12985	72.02	68.09	70.83	67.90	-3.93	-1.19	-4.12
12342	71.69	67.81	70.59	67.63	-3.88	-1.10	-4.06
11734	71.36	67.56	70.34	67.37	-3.80	-1.02	-3.99
11117	71.04	67.32	70.06	67.10	-3.72	-0.98	-3.94
11087	71.02	67.31	70.05	67.09	-3.71	-0.97	-3.93
11071	Lake Village Dr						
11058	70.92	67.28	70.02	67.07	-3.64	-0.90	-3.85
11022	70.86	67.27	69.99	67.06	-3.59	-0.87	-3.80
10527	70.67	66.87	69.74	66.68	-3.80	-0.93	-3.99
9921	69.95	65.55	68.76	65.34	-4.40	-1.19	-4.61
9329	69.23	64.38	67.82	64.22	-4.85	-1.41	-5.01
8734	67.93	63.18	66.53	63.05	-4.75	-1.40	-4.88
8406	66.67	62.35	65.44	62.04	-4.32	-1.23	-4.63

Existing		Alternative 1	Alternative 2	Alternative 3	Differences in W.S. Elevation (ft)		
River Station	W.S. Elev. (ft)	W.S. Elev. (ft)	W.S. Elev. (ft)	W.S. Elev. (ft)	Alternative 1- Existing	Alternative 2- Existing	Alternative 3- Existing
8383	66.46	62.25	65.37	61.94	-4.21	-1.09	-4.52
8352	Walnut Ln						
8324	63.18	60.71	63.49	60.22	-2.47	0.31	-2.96
8287	62.57	60.51	63.08	59.99	-2.06	0.51	-2.58
8116	60.51	59.50	60.82	58.75	-1.01	0.31	-1.76
7550	57.28	55.95	55.84	55.28	-1.33	-1.44	-2.00
6942	56.14	54.14	54.00	53.84	-2.00	-2.14	-2.30

The results of the HEC-RAS model show significant diversion (**Table 10**) of flow from Bens Branch to Kingwood Ditch under the alternative conditions. In the case of a 1% AEP storm event, Alternative 3 achieves the most flow diversion, followed by Alternative 1, and then followed by Alternative 2. Water surface elevations drop significantly in Bens Branch, while the Kingwood Diversion Ditch water surface elevations indicate mixed results. Alternative 3 provides the most reduction in water surface elevation, followed by Alternative 1, and then followed by Alternative 2.

For the coinciding peaks model, results showed no new adverse impacts to any structures, no new adverse impacts to any parcels, along with reduction in inundation and water elevations along Bens Branch and the upper reach of Kingwood Diversion Ditch. However, small, localized increases to water surface elevations at the confluence with West Fork San Jacinto River were noted. These results along with NSI’s H&H Analysis (**Appendix O**), indicate that the West Fork San Jacinto River and Kingwood Diversion Ditch improvements have limited hydrologic correlation. This is due to the vast difference between flood volumes and watersheds represented in the West Fork San Jacinto River and the Kingwood Diversion Ditch. Further, since all the water volume eventually drains to Lake Houston, whether flowing down Bens Branch or the Kingwood Diversion Ditch, there is no volume increase at Lake Houston due to this project.

The number of parcels flooded under each alternative condition are shown in **Table 11**. For the 1% AEP, a nearly equal number of parcels are flooded for Alternative 1 and Alternative 3. However, a smaller number of properties are flooded during the 0.2% AEP in Alternative 3 than in Alternative 1.

Table 9 - Bens Branch HEC-RAS Results (Atlas 14 1% AEP)

Existing		Alternative 1	Alternative 2	Alternative 3	Differences in W.S. Elevation (ft)		
River Station	W.S. Elev.(ft)	W.S. Elev. (ft)	W.S. Elev. (ft)	W.S. Elev. (ft)	Alternative 1- Existing	Alternative 2- Existing	Alternative 3- Existing
28178	72.78	72.01	72.59	71.98	-0.77	-0.19	-0.80
28146.3	72.77	72.01	72.59	71.98	-0.76	-0.18	-0.79
28114.66	72.71	71.99	72.55	71.96	-0.72	-0.16	-0.75
27951.87	Woodridge Pkwy						
27861.8	72.67	71.71	72.33	71.66	-0.96	-0.34	-1.01
27797.29	72.65	71.71	72.32	71.66	-0.94	-0.33	-0.99
27756	72.61	71.69	72.29	71.65	-0.92	-0.32	-0.96
27730	Northpark Dr						
27706	72.57	71.68	72.26	71.63	-0.89	-0.31	-0.94
27632.55	72.55	71.67	72.24	71.63	-0.88	-0.31	-0.92

Existing	Existing	Alternative 1	Alternative 2	Alternative 3	Differences in W.S. Elevation (ft)		
River Station	W.S. Elevation (ft)	W.S. Elevation (ft)	W.S. Elevation (ft)	W.S. Elevation (ft)	Alternative 1- Existing	Alternative 2- Existing	Alternative 3- Existing
27608.98	72.54	71.67	72.24	71.63	-0.87	-0.30	-0.91
27561.33	Northpark Dr						
27513.68	71.55	68.80	70.55	68.71	-2.75	-1.00	-2.84
27441.69	71.52	68.82	70.51	68.73	-2.70	-1.01	-2.79
26458.74	70.91	68.21	69.84	68.12	-2.70	-1.07	-2.79
25496.43	70.41	67.85	69.33	67.77	-2.42	-1.01	-2.49
25438.45	70.24	67.82	69.23	67.75	-2.75	-1.00	-2.84
25381.46	Woodland Hills Dr						
25324.46	69.97	67.77	69.07	67.70	-2.20	-0.90	-2.27
25279.51	70.07	67.78	69.12	67.71	-2.29	-0.95	-2.36
24159.5	69.61	67.36	68.66	67.29	-2.25	-0.95	-2.32
23234.05	69.00	66.66	67.96	66.61	-2.34	-1.04	-2.39
21847.04	67.95	65.28	66.56	65.26	-2.67	-1.39	-2.69
21221.31	67.55	64.58	65.91	64.56	-2.97	-1.64	-2.99
21087.61	67.46	64.38	65.74	64.36	-3.08	-1.72	-3.10
21058.2	Park Point Dr						
21020.31	67.43	64.39	65.71	64.37	-3.04	-1.72	-3.06
20932.01	67.40	64.34	65.66	64.32	-3.06	-1.74	-3.08
20347	67.09	64.11	65.44	64.09	-3.86	-2.58	-3.87
19548.24	67.43	63.7	65.07	63.69	-3.04	-1.72	-3.06
19504.82	67.40	63.54	64.82	63.53	-3.06	-1.74	-3.08
19468.8	Tree Ln						
19400.18	61.51	60.27	61.08	60.26	-1.24	-0.43	-1.25
19362.84	61.69	60.34	61.21	60.33	-1.35	-0.48	-1.36
18617.86	61.24	60.06	60.84	60.05	-1.18	-0.40	-1.19
18068	60.51	59.47	60.26	59.45	-1.04	-0.25	-1.06
18060	Trail Lodge Dr						
18057	60.07	58.78	59.58	58.77	-1.29	-0.49	-1.30
17483.99	59.21	57.91	58.72	57.89	-1.30	-0.49	-1.32
16519.62	58.28	57.11	57.84	57.10	-1.17	-0.44	-1.18
16354.02	57.93	56.82	57.51	56.80	-1.11	-0.42	-1.13
15455.73	56.28	55.52	55.99	55.51	-0.76	-0.29	-0.77

Table 10 - Flow Diversion at Existing and Alternative Conditions

Storm Event	Existing		Alternative 1		Alternative 2		Alternative 3	
	Bens Branch	Kingwood	Bens Branch	Kingwood	Bens Branch	Kingwood	Bens Branch	Kingwood
50% AEP	442	443	60	799	287	573	57	801
10% AEP	941	620	189	1302	570	915	187	1302
1% AEP	5940	776	1462	2654	3987	1495	1350	2679

Table 11 - Number of Parcels Flooded at Existing and Alternative Conditions

Condition	Number of Properties Inundated			Number of Structures Inundated		
	50% AEP	10% AEP	1% AEP	50% AEP	10% AEP	1% AEP
Existing	179	266	685	4	20	72
Alternative-1	150	208	398	2	10	37
Alternative-2	166	241	496	2	11	43
Alternative-3	146	203	397	2	10	38

5.3 Hydrologic and Hydraulic Conclusions

This hydraulic analysis was performed to check the hydraulic performance of different alternatives for conveyance improvements along the Kingwood Diversion Ditch, in order to reduce flooding in the Bens Branch drainage area. These alternatives include flow restriction to Bens Branch by a diversion structure at the east of the confluence of the Kingwood Diversion Ditch & Bens Branch, channel conveyance improvements, velocity reduction by drop structures, and a new Kingwood Diversion Ditch outfall. Refer to **Appendix P** for cost estimates. Based on the hydraulic results, Neel-Schaffer presents the following findings.

- Alternative 1 has the least number of properties flooded compared to Existing Conditions (186 acres and 35 structures recovered from Atlas 14 1% AEP flood inundation) but has the highest impacts to Waters of the U.S. (WOTUS).
- Alternative 3 ranks second for number of properties flooded compared to Existing Conditions (177 acres and 34 structures recovered from Atlas 14 1% AEP flood inundation) but has a higher cost estimate compared to Alternative 1.
- Alternative 2 has the least benefits with respect to flooded properties compared to Existing Conditions (114 acres and 29 structures recovered from Atlas 14 1% AEP flood inundation) but has a lower cost estimate than other alternatives and fewer impacts to WOTUS.

For the model scenario utilizing coinciding peaks, results showed small, localized increases to water

surface elevations at the confluence with West Fork San Jacinto River. However, modeling results of this conservative scenario showed no new adverse impacts to any structures, no new adverse impacts to any parcels, along with reduction in inundation and water elevations along Bens Branch and the upper reach of Kingswood Diversion Ditch.

The H&H Report is included as **Appendix O**.

6. Mitigation/Detention Requirements

6.1 Stormwater Detention Basin

As described in Section 4.1, a tailwater-driven scenario reflecting coinciding peaks was modeled to evaluate potential adverse impacts of backwater of the West Fork San Jacinto River flowing upstream into Kingswood Diversion Ditch and Bens Branch. This scenario involved utilizing a quasi-steady state 2D area boundary condition for the West Fork San Jacinto River at the downstream boundary of Bens Branch and the Kingswood Diversion Ditch.

The coincident peak model illustrated localized increases to water surface elevations at the confluence between Kingswood Diversion Ditch and the West Fork San Jacinto River. The increase in water surface elevations, however small, is considered an adverse hydrologic impact, and therefore, mitigation is recommended. Because stormwater detention basins are effective tools for mitigating adverse hydrologic impacts, nine potential stormwater detention basin locations were considered as part of the analysis of alternatives.

In summary, of the nine locations reviewed, eight sites were rejected for fatal flaws, and only one site had the best potential for meeting engineering requirements for capacity, avoiding wetlands and floodways, and limiting encroachments on floodplains. See **Appendix Q** for the locations of the nine stormwater detention basins that were considered. Below is a brief summary of NSI's findings:

- **Detention Basin 1** is the proposed location described in the PER report. NSI determined the required detention volume is obtained above/outside of the 100-year floodplain boundary. A small portion of the basin's perimeter footprint is within Zone AE, but will have minimal impacts to the floodplain.
- **Detention Basins 2, 3, 5, 6, 7, 8 and 9** were not considered due to negative impacts to floodway, floodplain, and wetlands.
- **Detention Basin 4** was rejected for insufficient storage capacity due to the lack of acreage within the property tract.

The proposed alternative channel conveyance improvements developed for the PER provide additional capacity for stormwater conveyance and storage within the limits of the Kingswood Diversion Ditch and existing channel ROW. As described in **Section 5**, the proposed Kingswood Diversion Ditch improvements and the West Fork San Jacinto River have limited combined hydrologic correlation. The peak flow volumes between the West Fork San Jacinto River and the Kingswood Diversion Ditch differ significantly. Since all flow ultimately drains into Lake Houston – either through Bens Branch or the Kingswood Diversion Ditch – this project does not result in any net increase in volume at Lake Houston.

It is also important to reiterate that a coinciding peak scenario assumes that an Atlas 14 1% AEP event

occurs over the West Fork San Jacinto River along with an additional Atlas 14 1% AEP event occurring over the Kingwood area, and that these two peak events occur at the same time. This scenario represents a statistical event with a much smaller chance of occurrence than 1%. This probability should be considered when determining the need and exact volume for mitigation during the final design.

6.2 Methodology for Stormwater Detention

Based on the model simulation of coinciding peaks, there are localized increases to water surface elevations at the confluence between Kingwood Diversion Ditch and the West Fork San Jacinto River.

This project does not involve changes in the land use pattern of drainage areas, which can increase runoff. The proposed conveyance improvements for Alternative 1, Alternative 2 and Alternative 3 will create additional inline storage, resulting in lower peak flows than the flows under existing conditions. The anticipated increase in channel storage in each case results from:

- Channel widening to create additional inline storage,
- Adjusting the channel to have flatter bottom slope than the existing channel,
- The addition of an outfall at the Kingwood Diversion Ditch to create more inline storage, and
- Use of diversion and drop structures to reduce flow velocity compared to existing conditions.

NSI compared the existing and proposed Kingwood Diversion Ditch and Bens Branch outfall hydrographs to determine potential need for detention. In the proposed condition, it was observed that peak flows along the Kingwood Diversion Ditch were higher than the existing peak flows, while the peak flows in Bens Branch were lower than the existing peak flows. However, Lake Houston, which ultimately receives flow from Bens Branch and Kingwood Diversion Ditch, will not experience increased flow volumes due to the project.

6.3 Stormwater Detention for the Preferred Alternative

As noted in **Section 6.1**, onsite stormwater detention basin alternatives were quickly eliminated due to the densely populated Kingwood area surrounding the channel. A desktop study was performed to assess the potential for offsite stormwater detention locations. The stormwater detention storage volume that would be required if the diverted flood volumes were mitigated was determined to be approximately 405 acre-feet at approximately 75 acres of surface area. Refer to **Appendix O** for details supporting this determination.

The findings provided two alternative locations for the proposed stormwater detention basins. Of the two options, Stormwater Detention Basin 1 provides the preferable offsite option for achieving the aforementioned 75-acre surface area and approximately 405 acre-feet of storage for the Kingwood Diversion Ditch Conveyance Improvement Project.

NSI considered several potential locations for proposed offsite stormwater detention basin alternatives using the following criteria:

- Avoid or minimize detrimental impacts to wetlands,
- Avoid or minimize impacts to the effective FEMA regulatory floodway,
- Minimize influence on areas within the FEMA Zone AE floodplain,
- Utilize large areas/parcels adjacent to the Kingwood Diversion Ditch and the West Fork San

Jacinto River, and

- Minimize number of properties required to construct the detention basin.

The preferred offsite stormwater detention, Proposed Stormwater Detention Basin 1, is shown below in **Figure 6**. **Appendix Q** shows the offsite stormwater detention basin layout, location map, and FEMA FIRM map.

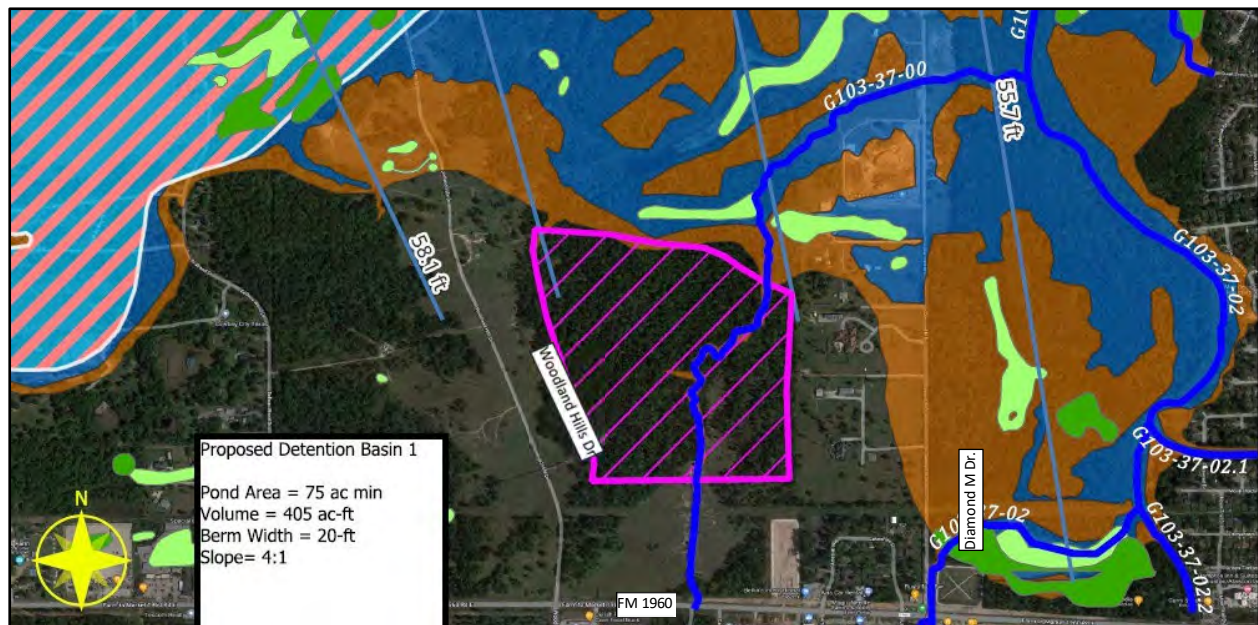


Figure 6 – Proposed Alternative Offsite Location for Stormwater Detention Basin 1

NSI performed a high-level desktop analysis for the preferred alternative which followed Harris County Flood Control PCPM criteria. The proposed 405 acre-feet of stormwater storage would require the following for detention basin design:

- Approximately 75 acres
- Average of six feet of depth
- 4:1 side slopes
- Twenty (20) feet maintenance berm

The need, size, and scope of the recommended detention should be thoroughly evaluated during final design. The models for the Atlas 14 1% AEP events should be updated to consider timing of hydrographs from Kingwood Diversion Ditch, Bens Branch, and the West Fork San Jacinto River. This type of detailed analysis is critical to fully understand potential project impacts and could reduce the required detention volume or support in the consideration of other alternative tools to mitigate project impacts in lieu of a detention basin.

No geotechnical analysis was performed at this stage and would be needed for further design after parcel acquisition. NSI assumed that the depth of the water table is deeper than six (6) feet depth. A geotechnical analysis would be needed to confirm the water table depth.

6.4 Stormwater Detention Basin Conclusion

Although an offsite stormwater detention basin is feasible, the prospective benefits are negligible. The HEC-RAS model shows increased peak flows in Kingwood Diversion Ditch due to the proposed diversion structure, which may require 405 acre-feet of stormwater detention. After investigating the potential for stormwater detention to effectively mitigate increased peak flows, it was determined that due to onsite constraints, the offsite stormwater detention basin was the most feasible option.

However, construction of an offsite stormwater detention basin would likely not have a direct positive impact on the project area since it does not directly reduce water surface elevations within the Kingwood Diversion Ditch or at the confluence of Kingwood Diversion Ditch and West Fork San Jacinto River.

If a stormwater detention basin were to be constructed, NSI explored different options for stormwater detention and identified a possible location for detention basin construction. Additional data would be required in order to design the stormwater detention basin. Based on results of this study, NSI recommends Stormwater Detention Basin 1, which represents a significant approximate total construction cost of **\$13.55 million** with a ROW acquisition cost of **\$700,000**. The detailed cost breakdown is provided in **Appendix P**. The inclusion of stormwater detention mitigation for the Kingwood Diversion Ditch Conveyance Improvement Project would significantly increase the construction cost while not providing substantial benefit to the residents and stakeholders in terms of a direct reduction in flood hazard. Due to limited effectiveness and significant cost, the recommended detention basin should be further examined during final design.

The overall stormwater detention analysis is provided in **Appendix Q**.

7. Summary of Results

In the following sections, the estimated cost of each alternative is presented. In addition, assessments of each alternative combination were made based on the criteria identified previously. The benefits were assessed based on the categories of performance metrics mentioned earlier.

7.1 Cost Estimation

The costs for the alternatives were estimated using the unit costs obtained from the Harris County Flood Control District's Standard Pay Items. **Table 12** contains a summary of preliminary costs for each of the alternatives. Contingency costs were included as a percentage of construction costs (20%). Construction costs mainly included channel excavation and fill material, bridge replacement, and excavation for stormwater detention basins. Detailed cost estimates for all the alternatives are provided in **Appendix P**.

Table 12 – Cost Estimates for Alternatives

Alternative	Description	Cost	*Total Cost	*Cost without Detention Basin
Alt. 1	Channel Conveyance Improvements	\$37,100,000	\$52,150,000	\$37,900,000
	ROW Acquisition for Conveyance Improvement	\$800,000		
	Stormwater Detention Basin	\$13,550,000		
	ROW Acquisition for Stormwater Detention Basin	\$700,000		
Alt. 2	Channel Conveyance Improvement	\$32,600,000	\$47,650,000	\$33,400,000
	ROW Acquisition for Conveyance Improvement	\$800,000		
	Stormwater Detention Basin	\$13,550,000		
	ROW Acquisition for Stormwater Detention Basin	\$700,000		
Alt. 3	Channel Conveyance Improvement	\$39,900,000	\$54,950,000	\$40,700,000
	ROW Acquisition for Conveyance Improvement	\$800,000		
	Stormwater Detention Basin	\$13,550,000		
	ROW Acquisition for Stormwater Detention Basin	\$700,000		

*Costs have been rounded and have a 20% contingency, see **Appendix P** for complete cost estimate.

7.1.1 Maintenance Costs

The recommended engineering H&H alternative will be selected based upon flood damage reduction, stream and wetland quality benefits, and the overall capital costs associated with the Kingwood Diversion Ditch improvements. In addition to the required capital outlay for each alternative, basic maintenance and operational costs (O/M costs) for the Kingwood Diversion Ditch Channel improvements were evaluated to best determine the annualized maintenance cost over a ten-year period. The results of this analysis provide further cost consideration to the wholistic approach for constructing, operating, and maintaining the conveyance channel, the configured slopes, and its required 30-foot-wide access

corridors on each side of the Kingwood Diversion Ditch.

To properly compare maintenance costs, Jason Krahn with the Harris County Flood Control District has provided actual O/M costs associated with the HCFCD Unit G103-38-00 over a 10-year period for a 57.97-acre area. This data was extrapolated to accommodate the Kingwood Diversion Ditch project's total area of 111 acres. As noted by Jason Krahn, the control data for G103-38-00 does not include costs associated with engineering evaluations, annual inspections, construction repair field inspection services, administrative management, or field supervision services. Since each of the Kingwood Alternatives are similar in size and scope, NSI assumed these excluded costs will be equal for each Alternative. Therefore, these costs were not analyzed for the maintenance comparison.

To assess the maintenance operation costs for Alternatives 1, 2, and 3, it is necessary to understand the benefits and drawbacks that each alternative provides. The chart below provides a brief summary of each Alternative's features that affect the way maintenance is performed. For instance, each Alternative includes the entirety of the 111-acre project area. However, due to its benched cross-section, Alternative 2 entails additional complexity because of access for mowing the 3:1 side slopes above and below the benched tier.

Table 13 – Maintenance Requirements per Alternative

Alternative Maintenance Features					
<i>Alternative</i>	<i>General Description</i>	<i>Mowing Required</i>	<i>Slope Repairs</i>	<i>Sediment Maintenance</i>	<i>Access Road Maintenance</i>
Alt. 1	3:1 Trapezoidal Section	Maximum – Access Roads, Slopes, and Bottom	Moderate - due to exposure	Moderate	Moderate
Alt. 2	3:1 Trapezoidal Section w/Bench	Maximum – Access Roads, Slopes, and Bottom	Moderate - due to exposure	Moderate	Moderate
Alt. 3	3:1 Trapezoidal Section with Stabilized Bottom Design	Minimal - Only Access Roads	Minimal - Strategic plantings and full coverage	Minimal – Strategic design to limit sediment drop	Moderate

Because of the distinct and defining features of each Alternative, complexity factors were assigned to each category detailed by the Flood Control District, which indicate the relative complexity of maintenance for each Alternative compared to the existing diversion channel. For simplicity, a complexity factor of 100% equates to a normal standard of care to perform the maintenance task. Complexity factors greater than 100% indicate the Alternative feature or configuration requires additional effort and time to complete the intended maintenance tasks, resulting in additional costs. Complexity factors less than 100% mean the maintenance task is less difficult and less time-consuming to complete, resulting in less cost.

These complexity factors and their impacts on each of the Alternative’s maintenance costs are presented in greater detail in **Appendix P**.

Complexity factors were developed by NSI’s engineers familiar with open channel maintenance and operations. In addition, Jason Krahn’s data provided insightful information concerning the maintenance teams required to perform the work. Various crews such as facilities mowing, construction groups, infrastructure repair teams, maintenance engineering, and disaster recovery teams were allocated for specific work directives. **Appendix P** provides specific information for each Alternative.

The comparison of quality engineering for maintenance of the Kingwood Diversion Ditch included the impacts caused by the area of maintenance, frequency required, complexity factor, and the resulting total cost.

Table 14 – Maintenance Costs per Alternative

Results of Quality Engineering Maintenance Costs					
O/M Item	Maintenance Type	Existing Ditch (\$)	Alternative 1 (\$)	Alternative 2 (\$)	Alternative 3 (\$)
001 - Facility Mowing	Contract Mowing	366,300.00	366,300.00	402,930.00	44,088.00
002 - Facility Maintenance	Pruning, tree removal, Herbicides, sod, seed, clearing, rut repairs	670,799.44	670,799.44	737,879.39	503,099.58
003 - Corrective Action Repairs	Large ruts, regrading slopes, desilts, disposal, minor erosion repairs	91,562.15	91,562.15	100,718.37	66,671.61
004 - Infrastructure Repairs	Backslope swales, major spot erosion repairs	497,850.03	497,850.03	547,635.03	373,387.52
005 - Maintenance Engineering	Rehab earthwork, design, survey, testing, and contractor costs	808,679.52	808,679.52	889,547.47	404,339.76
006 - Disaster Recovery	Post-storm repairs, water quality improvements	472,568.57	472,568.57	519,825.43	472,568.57
Totals		2,907,759.71	2,907,759.71	3,198,535.69	1,866,155.05
Percent Maintenance Cost (vs. Existing)		100%	100%	110%	64.2%

The analysis shows that **Alternative 3** has the lowest long-term maintenance costs, resulting in an overall savings of about 35.8% annually when compared to the baseline existing maintenance costs and those costs associated with **Alternative 1**. **Alternative 3** is anticipated to cost \$1,866,155 per year to maintain. **Alternative 2** is anticipated to require an additional 10% of maintenance cost when compared to the existing baseline conditions due to difficulty of mowing the tiered bench slopes. Since **Alternative 1** only differs from the existing condition by the increased width of the central channel itself, long-term

maintenance costs are anticipated to be in-line with maintenance costs currently incurred for existing conditions.

Alternative 3, the Natural Stable Channel, is the most cost-effective maintenance solution over the evaluated 10-year period. Maintenance is significantly reduced because the natural woody vegetation buffer serves as a slope and bottom stabilization feature for combating erosion, which reduces the need for erosion prevention structures or slope repairs. Under **Alternative 3**, mowing is not required inside the crests of the Kingwood Ditch. The only mowing required will be along the perimeter access paths. These 30-foot wide corridors account for 13.36 acres of maintenance (12.3%) out of the total 111 acres in the project area and are flat and easier to maintain. The remaining interior 97.64 acres (87.7%) inside the top banks are designed to provide vegetation without the need for mowing. This is described as self-maintaining because of the selected grass, tree, and foliage species.

Additionally, the naturally stabilized channel design seeks Low Impact Development (LID) features for improving water quality by reducing pollutant loading. If selected, final design parameters associated with **Alternative 3** would target ways to improve pollutant removal performance for total suspended solids, thus reducing concentrations of nitrogen and phosphorus in the stream.

7.2 Comparison of Benefits

Table 15 shows a comparison of performance metrics for all proposed alternatives. In addition, **Table 16** shows the advantages and disadvantages of all alternatives.

Table 15 – Alternatives Metrics Comparison

Evaluation Criteria	Alternative 1	Alternative 2	Alternative 3
Cost Estimate*	\$37,100,000	\$32,600,000	\$39,900,000
Stream Mitigation Debits	4,158.04	455.58	-
50% AEP Flooded Parcels/Structures Removed	29/2	13/2	33/2
10% AEP Flooded Parcels/Structures Removed	58/10	25/9	63/10
1% AEP Flooded Parcels/Structures Removed	287/35	189/29	288/34

*Costs are without ROW acquisitions, see **Appendix P** for complete cost estimate.

Table 16 – Alternative Advantage Comparison

Alternative Number	Advantages	Disadvantages	Total Construction Cost without Detention
Alt. 1	<ul style="list-style-type: none"> Provides significant reduction in WSEL along Bens Branch and Kingwood Diversion Ditch. Removes the 1% AEP Inundation Area from 287 parcels and 35 structures. Provides channel capacity along Bens Branch and Kingwood Diversion Ditch to allow for improvement to the local roadway drainage systems. 	<ul style="list-style-type: none"> Alternative 1 requires a higher construction cost than Alternative 2. 	\$37,100,000*
Alt. 2	<ul style="list-style-type: none"> Provides some reduction in WSEL along Bens Branch and Kingwood Diversion Ditch. Removes the 1% AEP Inundation Area from 189 parcels and 29 structures. Provides channel capacity along Bens Branch (HCFCD Unit G103-33-00) and Kingwood Diversion Ditch (HCFCD Unit G103-38-00) to allow for improvement to the local roadway drainage systems. 	<ul style="list-style-type: none"> Alternative 2 provides the lowest flood risk reduction benefits. 	\$32,600,000*
Alt. 3	<ul style="list-style-type: none"> Provides significant reduction in WSEL along Bens Branch and Kingwood Diversion Ditch Removes the 1% AEP Inundation Area from 288 parcels and 34 structures. 	<ul style="list-style-type: none"> Alternative 3 will require costs associated with Natural Stable Channel Design. 	\$39,900,000*

*Costs are without ROW acquisitions, see **Appendix P** for complete cost estimate.

7.3 Potential Funding Sources

Due to the significant costs associated with each alternative, it is recommended that Harris County Flood Control District explores other funding to help mitigate the overall cost of the project. Below are a couple of potential funding opportunities that should be considered.

7.3.1 FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP assists states, territories, federally-recognized tribes, and local communities by:

- Significantly reducing or permanently eliminating future risk to lives and property from natural hazards,
- Providing funds to implement projects in accordance with priorities identified in state, tribal, or local hazard mitigation plans, and
- Enabling mitigation measures to be implemented during the recovery following a major disaster declaration.

Mitigation measures which may be included as part of the scope for the Kingwood Diversion Ditch project, which are eligible for this funding include:

- Mitigation projects/reconstruction,
- Property acquisition and structure demolition/relocation,
- Localized/non-localized flood risk reduction projects,
- Soil stabilization, and
- Hazard mitigation planning.

This grant funding is available after a presidentially-declared disaster. In this project area, areas impacted by Hurricane Harvey were included in a disaster declaration on August 25, 2017. As the flood damage to the Kingwood area was a specific consequence of Hurricane Harvey, this disaster declaration could render the project eligible for HMGP funding. It is possible, however, that the disaster declaration period has ended, which could potentially render the project ineligible for HMGP funding.

Individuals, businesses, and certain private nonprofits are generally ineligible to directly apply for Hazard Mitigation Assistance (HMA). Applying for HMA happens through eligible subapplicants, such as state agencies and local governments, who in turn submit a subapplication on behalf of individuals, businesses, and private nonprofit organizations. To be eligible for HMA, all applicants and subapplicants must have a FEMA-approved mitigation plan.

The amount of HMGP funding available to the applicant is based on the estimated total federal assistance, subject to the sliding scale formula that FEMA provides for disaster recovery for each disaster declaration. The formula provides for:

1. Up to 15% of the first \$2 billion of estimated aggregate amounts of disaster assistance.
2. Up to 10% for amounts between \$2 billion and \$10 billion.
3. Up to 7.5% for amounts between \$10 billion and \$35.333 billion.

In general, HMA may be used to pay up to 75% of the eligible activity costs. The remaining 25% of eligible activity costs are derived from non-federal sources. Exceptions to the 75% federal and 25% non-federal share are as follows:

- Building Resilient Infrastructure and Communities (BRIC):
 - Small, impoverished communities may be eligible for up to a 90% federal cost share.
 - FEMA provides 100% cost share for management costs.

- Flood Mitigation Assistance (FMA):
 - FEMA may contribute up to 100% federal cost share for severe repetitive loss structures.
 - FEMA may contribute up to 90% federal cost share for repetitive loss structures.

Recipients are required to submit quarterly financial and progress reports to FEMA as a condition of their award acceptance throughout the period of performance, including partial calendar quarters, as well as for periods where no award activity occurs. Future awards and fund drawdowns may be withheld if these reports are delinquent, demonstrate a lack of progress, or are insufficient in detail. Recipients are also required to submit close-out reports, which consist of the final financial and performance reports.

For states and federally recognized tribal governments with enhanced mitigation plans, the eligible assistance is up to 20% for estimated aggregate amounts of disaster assistance, not to exceed \$35.333 billion. The sliding scale does not apply to recipients with enhanced mitigation plans.

7.3.2 FEMA Flood Mitigation Assistance (FMA)

FEMA provides an additional avenue for assistance through the Flood Mitigation Assistance (FMA) program, which provides funding for similar activities on an annual basis, regardless of disaster activity. While HMGP is a post-disaster program, FMA is a pre-disaster program, which provides assistance with planning and performing projects to reduce future flood losses. These may include elevating, buying, or moving National Flood Insurance Program (NFIP)-insured structures. Though this grant could be beneficial to the funding of the diversion channel itself, FMA monies would be of particular importance to fund mitigation and protection for structures impacted by the disaster outside of the project footprint.

FMA provides funds yearly to reduce or remove the risk of flood damage to NFIP insured buildings. Properties included in a project subapplication for FMA must be insured by the National Flood Insurance Program (NFIP) prior to the opening of the application period and be maintained for the life of the structure.

Under certain circumstances, properties may be eligible for a federal cost share greater than 75%. Properties must meet one of the two definitions below to receive an increased federal cost share:

- The property is a severe repetitive loss structure. In this case, the property is eligible for a 100% federal cost share. A severe repetitive loss structure is a structure that is covered under an NFIP policy and has incurred flood-related damage:
 - For which four or more separate claims payments have been made under flood insurance coverage with the amount of each claim (including building and contents payments) exceeding \$5,000 and with the cumulative amount of such claims payments exceeding \$20,000; or
 - For which at least two separate flood insurance claims payments (building payments only) have been made, with the cumulative amount of such claims exceeding the value of the insured structure.
- The property is a repetitive loss structure. In this case, the structure is eligible for a 90% cost

share. A repetitive loss structure is a structure covered under an NFIP policy that:

- Has incurred flood-related damage on two occasions, in which the cost of repair, on average, equaled or exceeded 25% of the value of the structure at the time of each such flood event; and
- At the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage.

FMA is a competitive program. Available assistance for the program is provided for the year that the year funding is sought. For FMA, the following assistance restrictions apply:

- Individual planning awards or subawards using FMA shall not exceed a federal share of \$50,000 to any applicant or \$25,000 to any sub applicant.
- FMA planning assistance can only be used to create or update a hazard mitigation plan that meets the planning criteria outlined in 44 CFR Part 201 and provides for reduction of flood losses to structures for which NFIP coverage is available.

7.3.3 FEMA Building Resilient Infrastructure and Communities (BRIC)

BRIC supports state, local, tribal, and territorial governments as they undertake hazard mitigation activities, reducing the risks they face from disasters and natural hazards. Similarly to FMA, BRIC is intended to act as a pre-disaster program, which seeks to fund effective and innovative activities that will reduce risk, increase resilience, and serve as a catalyst to encourage the whole community to invest in and adopt mitigation policies. The BRIC program aims to categorically shift the federal focus away from reactive disaster spending and toward proactive investment in community resilience.

FEMA's priorities for the BRIC program are to:

1. Incentivize natural hazard risk reduction activities that mitigate risk to public infrastructure and disadvantaged communities as referenced in Executive Order 14008 – Tackling the Climate Crisis at Home and Abroad.
2. Incorporate nature-based solutions, including those designed to reduce carbon emissions.
3. Enhance climate resilience and adaptation.
4. Increase funding for the adoption and enforcement of the latest published editions of building codes.
5. Encourage mitigation projects that meet multiple program priorities.

In the case of the Kingwood Diversion Channel project, improvements to the channel could classify as natural hazard risk reduction activities that mitigate risk to public infrastructure. Furthermore, Natural Stable Channel design features in Alternative 3 incorporate nature-based solutions into the design of the channel and enhance climate adaptation within the channel as a result.

States and territories that have had a major disaster declaration under the Stafford Act in the seven years prior to the annual application period start date are eligible to apply for federal assistance under BRIC as applicants. Individuals, businesses, and nonprofit organizations are not eligible to apply for BRIC assistance; however, an eligible applicant or subapplicant may apply for funding on behalf of individuals, businesses, and nonprofit organizations.

The BRIC program distributes assistance annually and requires a cost share. Application must be made

no later than 180 calendar days after each major disaster is declared under the Stafford Act and subject to assistance availability,

FEMA calculates the estimated aggregate amount of grants to be made under select sections of the Stafford Act for the major disaster. FEMA may set aside up to 6% of that amount from the Disaster Relief Fund for deposit into the National Public Infrastructure Pre-Disaster Mitigation Fund to fund BRIC.

8. Recommended Alternative

8.1 Results of Analysis

The proposed flood damage reduction alternatives were evaluated using several metrics, including reduction in inundated area and water surface elevations along Bens Branch and the Kingwood Diversion Ditch. Each alternative was evaluated for existing and proposed conditions using the Atlas 14 50%, 10%, 1%, 0.2% AEP storm events. A summary of the results of the three alternatives is included in **Table 15**. The inundation areas for Alternatives 1, 2 and 3 are provided in **Exhibits 13, 14, 15, and 16**.

Table 17 – Alternatives Benefit Summary (Inundation Area rounded to the nearest Acre)

Atlas 14 Storm Event	Existing Inundation Area (Acres)	Inundation Area - Alt. 1 (Acres)	Inundation Area - Alt. 2 (Acres)	Inundation Area - Alt. 3 (Acres)
50% AEP	529	124	85	105
10% AEP	763	149	103	130
1% AEP	1152	186	114	177

Alternative 1 provides the greatest reduction in water surface elevations and inundation area in the Atlas 14 1% AEP. Alternative 1 is approximately 4.8 million dollars more than **Alternative 2** (12% increase) and removes an additional 6 flooded structures. Stream and wetlands mitigation will be needed from the confluence of Bens Branch and the Kingwood Diversion Ditch to the new outfall.

Alternative 2 provides the smallest reduction in water surface elevations and inundation area in Atlas 14 1% AEP. Stream and wetlands mitigation will be needed between Walnut Lane and Deer Ridge Estates Boulevard. **Alternative 2** has the least amount of stream mitigation and construction costs; however, given the reduction in benefits associated with this alternative without a significant reduction of cost (~12%), **Alternative 2** is not recommended.

Alternative 3 maximizes flood damage reduction benefits for the Atlas 14 1% AEP event similar to **Alternative 1** and requires the same amount of additional ROW to **Alternative 1**. Stream and wetlands mitigation will be needed from the confluence of Bens Branch and Kingwood Diversion Ditch to the new outfall. This alternative will have the highest overall project cost and only slightly more flood damage reduction benefit. Due to the lower maintenance costs over time, increased environmental benefits, and similar flood damage reduction to the first alternative, **Alternative 3** is recommended since operation and maintenance costs are recovered in the long term.

8.2 Plan Benefits

The recommended alternative, **Alternative 3**, includes the following project features:

- Installation of a new diversion structure at Bens Branch (HCFCD Unit G103-33-00),
- Installation of a series of rock cross vanes in lieu of a drop structure between Walnut Lane and Deer Ridge Estates Boulevard,
- Natural Stable Channel Design features, such as a meandering low-flow channel with riffles and pools for flow regulation and natural vegetation for erosion control,
- Bridge replacements for Kingwood Drive, Lake Village Pedestrian Bridge, Walnut Lane, and Deer Ridge Estates Boulevard,
- Additional ROW for new outfall channel section parallel to Woodland Hills Drive, and
- New bridge at Hamblen Road along new outfall into West Fork San Jacinto River.

Alternative 3 includes the following benefits:

- Provides significant reduction in water surface elevation (WSEL) along Bens Branch (HCFCD Unit G103-33-00). See **Table 9** for WSEL reduction.
- Reduces the Atlas 14 1% AEP inundation area by 177 acres compared to existing conditions.
- Offsets environmental impacts and minimizes required mitigation stream credits via Natural Stable Channel Design features.
- Maximizes the use of existing ROW along the Kingwood Diversion Ditch.
- In general, the natural stable channel is designed in a way that is self-maintaining and should provide an equilibrium condition with no long-term aggradation or degradation.

8.3 Utility Conflicts

There are several existing utilities that have the potential to affect the design and construction of the project and need to be addressed. These utilities include sanitary sewer, water, CenterPoint Gas pipelines, fiber optic cables, and overhead power lines (see **Exhibit 10** for potential conflicts). The majority of the potential utility relocations are attached to or adjacent to the bridges that are recommended to be replaced. Due to utility relocation design not being part of the scope, NSI used a lump sum pay item "*Bridge Utility Relocation*" to account for the utility relocations (approximately 8% of the total bridge replacement cost).

It is recommended that Quality Level B and Quality Level A (if necessary) be done during the design stage to determine the necessary utility relocations.

8.4 Right-Of-Way Requirements

All alternatives will require the full acquisition of MCAD Parcel No. R43989 and HCAD Parcel No. 0410470000143, and a partial acquisition of MCAD Parcel No. R505293. Partial acquisitions are needed within the 50-foot easement along G103-38-00 from G103-38-01 to the confluence of G103-39-00 and G103-38-00, consisting of the HCAD Parcel Numbers:

Table 18 – 50-foot Easement ROW Acquisition Parcel Numbers

095281000072	095281000044	095281000045
095281000071	095281000043	
095281000070	095281000042	
095281000069	095281000040	
095281000068	095281000039	
095281000067	095281000038	
095281000048	095281000037	
095281000047	095281000036	
095281000046	095281000035	

The project will also require partial acquisitions of HCAD No. 045127000029, 045127000012, and 0410470000144. The stormwater detention basin will require a partial acquisition of HCAD No. 045007000001. See **Appendix P** for ROW acquisition cost estimates. See **Figure 7** for Proposed ROW Acquisitions for the Kingwood Diversion Ditch only (does not show stormwater detention basin location).

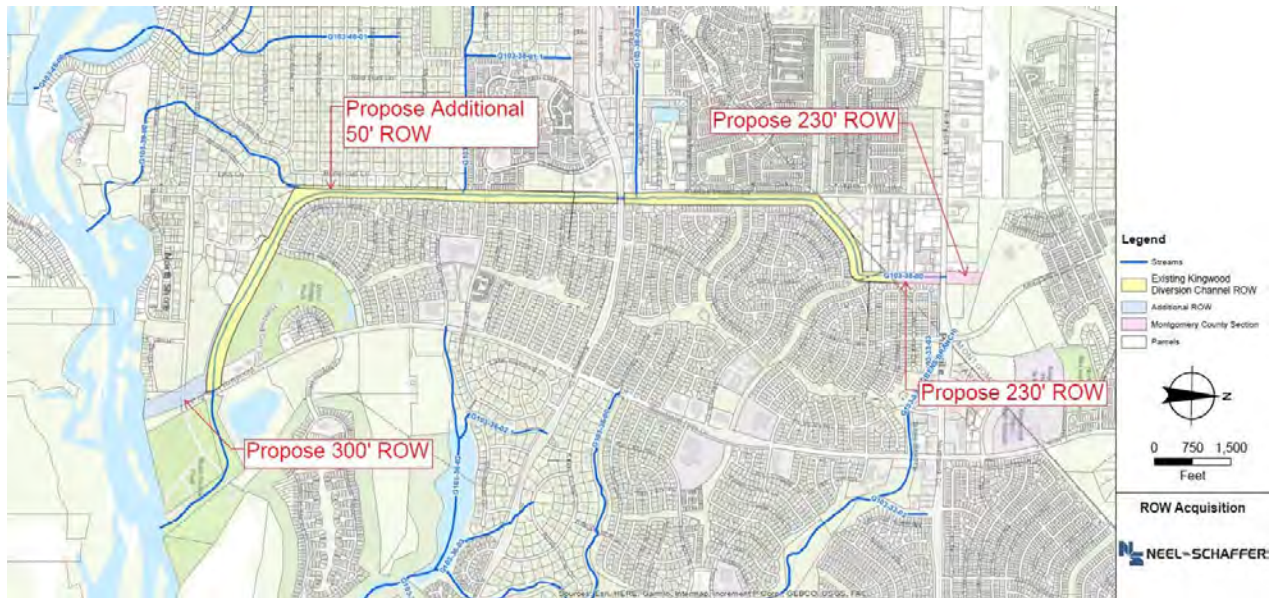


Figure 7 - Proposed ROW Acquisition

8.5 Environmental and Cultural Resource Considerations

8.5.1 Waters of the United States

Two perennial streams (G103-38-00 and West Fork San Jacinto River), one perennial and intermittent stream (Bens Branch), one ephemeral stream (WC 1), three palustrine forested (PFO) wetlands (WET 1, WET 2/3, and WET 4), four palustrine emergent (PEM) wetlands (WET 5, WET 6, WET 7, and WET 8) are potentially jurisdictional under the CWA. Impacts to jurisdictional WOTUS require a permit from USACE.

A USACE Individual Permit (IP) under Section 404 of the Clean Water Act (CWA) is required for the discharge of dredged or fill material into jurisdictional WOTUS for a project of this size. The Texas Commission on Environmental Quality (TCEQ) has the authority under the CWA to regulate activities resulting in a discharge of pollutants into state waters.

If the project is anticipated to impact aquatic resources, it is recommended to submit the delineation report to the USACE Galveston District Office, along with a Jurisdictional Determination (JD) request form, to obtain an official jurisdiction determination (JD) from the USACE. Only the USACE has the authority to make an official jurisdiction determination for WOTUS. A USACE CWA permit will be required for impacts to WOTUS. The proposed activity and quantity of impacts will determine the level of permitting required.

8.5.2 Section 404 Permit

USACE Regulatory Program administers and enforces Section 404 of the Clean Water Act (CWA). Under Section 10 of the Rivers and Harbors Act (RHA), a permit is required for work or structures in, over, or under navigable waters of the United States. Under the CWA Section 404, a permit is required for the discharge of dredged or fill material into waters of the United States.

The Individual Permit (IP) application form is available on the Galveston District website¹. A completed IP application with drawings and illustrations will be submitted to the USACE Galveston District Regulatory Division. Within five business days, USACE will send an email that includes a stamped-in date, contact information for the regulator assigned to the request, and a file number. Potential applicants can request electronic pre-application consultation with the Galveston District Regulatory Division. Pre-application screening is a tool to assist applicants to ensure that all necessary requirements for the application are present for future submission. Potential applicants can submit a pre-application screening via email to CESWGRegulatoryInbox@usace.army.mil. A USACE pre-application meeting was held on January 9, 2023, to discuss the stream condition impact study and the necessary stream mitigation credits that will be needed for each alternative. The minutes from the meeting can be found in **Appendix R**.

8.5.3 Section 401 Certification

The TCEQ conducts Section 401 Water Quality Certification (WQC) reviews of projects in Texas (except oil and gas projects) requiring a Section 404 permit from the USACE for the discharge of dredged or

¹ Individual Permit application provided at <https://www.swg.usace.army.mil/Missions/Regulatory/Permits/Permit-Application.aspx>

fill material into waters of the U.S., including wetlands. The purpose of these certification reviews is to determine whether a proposed discharge will comply with Federal and state water quality standards.

Potential applicants seeking 401 WQC are required to submit a Pre-filing Meeting Request and a Certification Request. These request forms can be found on the TCEQ website². The TCEQ reviews the meeting request to determine whether it is necessary or appropriate for the proposed project. A completed Pre-filing Meeting Request form with a project location map should be submitted to 401Certs@tceq.texas.gov. If a response from TCEQ is not received within 30 days, the applicant can submit the Certification Request form. A completed Certification Request form should be submitted to the above email and the USACE regulator assigned to the project.

Additional information may be required depending on whether the proposed project is a Tier I or Tier II project. Tier I projects are those that impact less than 3 acres of wetlands or 1,500 linear feet of stream or shoreline, or any combination of the two, where 500 linear feet of stream or shoreline is equivalent to one acre of wetland. Tier II projects are those with impacts that exceed Tier I impact thresholds. For Tier I³ projects, the TCEQ requires a Tier I checklist to be attached to the Certification Request. For Tier II⁴ projects, a copy of the USACE Section 404 permit application and Tier II 401 Questionnaire and Alternatives Analysis Checklist are required.

8.5.4 USACE Coordination

Harris County Flood Control District, NSI, and Hollaway conducted a meeting on January 9th, 2023, with the USACE to discuss the Kingwood Diversion Ditch Conveyance Improvement project (G103-38-00-E001), its project alternatives, and any concerns that the USACE might have as the project heads toward permitting. This was an informal meeting with Dwayne Johnson, of USACE, to ascertain the permitting requirements for each of the proposed channel alternatives.

The purpose of the project was discussed and the three alternatives were presented to USACE. For Alternative 3, the USACE emphasized that sinuosity is critical to Natural Stable Channel Design, as this was not evident in the overhead layout. NSI indicated that meandering is achieved by meandering along the channel bottom. USACE noted that currently, the Least Environmentally Damaging Practicable Alternative (LEDPA) is Alternative 1 with mitigation.

Permitting needs are dependent on the alternative selection. USACE indicated that an individual Permit (IP) will likely be needed for any of the proposed alternatives. USACE can make no official comments until the formal permit application is received. The Harris County Flood Control District requested clarification that mitigation is taken into account when selecting the LEDPA – i.e., that Alternative 2 would not automatically be selected because it has the fewest impacts to WOTUS, but that the proposed mitigation for Alternative 1 would be factored into the analysis. USACE responded in the affirmative. The total impacts should be discussed in the application and the LEDPA should be proven through that discussion. USACE indicated that water quality coordination is initiated by the

² TCEQ request forms provided at https://www.tceq.texas.gov/permitting/401certification/401certification_definition.html

³ Tier I Checklist provided at <https://www.tceq.texas.gov/assets/public/permitting/waterquality/forms/20228.pdf>

⁴ Tier II Checklist provided at <https://www.tceq.texas.gov/assets/public/permitting/waterquality/forms/20229.pdf>

Applicant (not the USACE). The application will go out on public notice, so included documentation will need to be legible to the general public.

USACE inquired about the timeline of submittal. At the time of the meeting, the Harris County Flood Control District responded that the Preliminary Engineering Report (PER) had not yet been completed, and that they anticipate 50% designs by winter 2023. The USACE expressed concerns that if 50% design plans were used for the final permit application, then that could create issues since the USACE generally issues permits for final designs. At the meeting the USACE indicated that an Individual Permit (IP) will likely be needed for any of the proposed alternatives. No official comments can be made until the formal permit application is received. A permit application would be completed once the alternative recommendation is selected and final design is complete.

The USACE Coordination Meeting Minutes are provided in **Appendix R**.

8.5.5 Threatened and Endangered Species

Based on the threatened and endangered species assessment, no federally or state listed species were observed within the project area. One federally and state listed species (eastern black rail), one federally protected species (bald eagle), one candidate species for federal listing (monarch butterfly), and six state listed species (swallow-tailed kite, white-tailed hawk, chub shiner, Rafinesque's big-eared bat, sandbank pocketbook, and alligator snapping turtle) may be temporarily impacted by the construction activities associated with the proposed project activities.

Coordination with the Texas Coastal Ecological Service's Field Office is recommended to determine the next steps and potential conservation measures that may be implemented to avoid and minimize adverse effects to the eastern black rail within the project area. If project activities occur in suitable habitat between March 1st through September 20th, the USFWS requests that a species survey be conducted within modeled suitable black rail habitat prior to any project action. The Texas Coastal Ecological Service's Office provides survey recommendations on a project-by-project basis.

It is recommended that hollowed trees be assessed for potential bat roosts by a qualified biologist prior to the removal of the hollow trees. Vegetation clearing activities should be avoided during the Rafinesque's big-eared bat pupping periods (late May to early September).

If the proposed project is anticipated to impact G103-38-00, Bens Branch, or the West Fork San Jacinto River below the OHWM, an Aquatic Resources Relocation Plan (ARRP) obtained from the TPWD, and a freshwater mussel survey is recommended. The ARRP would enable a permitted malacologist to relocate discovered mussels to an approved location outside of construction work zones.

The project area has potential to support protected breeding, wintering, and transitory migratory birds. Migratory birds and bald eagles are protected under the Migratory Bird Treaty Act and Bald and Golden Eagle Protection Act, respectively. Consultation with U.S. Fish and Wildlife Service (USFWS) is required prior to construction activities. It is recommended that migratory birds and trees with active migratory bird nests be avoided. The Harris County Flood Control District requires bird nest surveys be conducted year-round.

Although candidate species receive no statutory protection under the ESA, in efforts to avoid potential impacts to the monarch butterfly, cooperative conservation measures are recommended such as

avoiding the use of pesticides and conducting routine maintenance outside of the monarch's migratory and egg laying season (February to October). However, this recommendation is not required.

8.5.6 Cultural Resources

The THC reviewed the desk-based cultural resources assessment produced by Moore Archeological Consulting (MAC) and submitted their response on January 3, 2022 (THC Tracking #202204392). The THC concurred with the findings and recommendations made in the assessment. These included the recommendation for an archeological survey and, specifically, the need to archeologically test the previously recorded prehistoric site 41HR1176 to assess its potential for inclusion on the National Register of Historic Places (NRHP). As a result of the THC's response, a proposal was submitted to the THC for field investigations to be conducted within the APE of the Kingwood Diversion Ditch project prior to the onset of construction. This work will fall under the Antiquities Code of Texas, which will require application for a Texas Antiquities Commission (TAC) permit. The THC specifically recommended that the general investigation be conducted under one permit and the site evaluation of 41HR1176 under another permit. The first phase will focus on the general APE study. Once the TAC permit is obtained, field investigations will be conducted within the APE. Following completion of the fieldwork, a report will be written compiling the findings of the investigation and making recommendations for any additional investigation (if needed) as well as an assessment of any previously unrecorded sites found during the investigation. This report will be submitted to the THC for review and approval of the recommendations made. A final report addressing any changes requested by the THC will be submitted and curation requirements completed in order to close out the TAC permit. For the second phase of the project, which comprises the NRHP eligibility testing of site 41HR1176, a second TAC permit will be obtained from the THC. The work at the site will involve the excavation of approximately 6 excavation units distributed across the site using professional judgement. Once the fieldwork at 41HR1176 is completed, all artifacts and field data will be analyzed to assess the site's NRHP eligibility and to make a recommendation and write a report compiling the findings of the investigation. The draft of this report will be submitted to the THC for review and concurrence of any recommendations made. A final report will be submitted addressing any changes requested by the THC and submitted to all parties. All artifacts and other requisite materials will be curated, and the permit will be closed out as soon as all final deliverables are submitted.

8.6 Construction Phasing Recommendation

To expedite the recommended alternative, NSI is recommending the following phasing to the Harris County Flood Control District for the design and construction of the Kingwood Diversion Ditch channel conveyance improvements:

Design Phase

1. Obtain necessary ROW (see **Section 8.3**), obtain USFWS approval, obtain cultural resources approval, begin the USACE permitting process, engineering and design, and remaining data collection, including SUE.
 - a. Begin shovel testing after proposed ROW acquisition has been completed.
 - b. Start the funding process that is recommended in **Section 7.3**.
2. Bid and award the Kingwood Diversion Ditch Conveyance Improvement project to the recommended bidder.

Construction Phase

1. Begin construction on detention basin.
2. Replace proposed bridges with channel improvements within the construction limits of the bridges. This can be done before or congruently with Construction Phase 1.
3. Construct new outfall section. Construction Phase 1 must be complete before beginning this phase.
4. Construct channel conveyance improvements from downstream to upstream.
5. Construct new diversion structure.
6. Ensure the client is aware of future O/M requirements.
7. Close out the project.

A maintenance access plan will be developed during the design stage. The channel will require a minimum 30-ft berm for maintenance access.

8.7 Cost Estimate

The preliminary estimated construction cost of the channel improvements for the recommended alternative, **Alternative 3**, is approximately **\$39.9 million**, which does not include other capital costs such as ROW acquisition of **\$800,000**. The total estimated construction cost for **Alternative 3**, including stormwater detention, is approximately **\$54.95 million** (includes \$1.5 million in ROW acquisition costs). A breakdown of the cost estimate for the recommended alternative is provided in **Table 12** and **Table 20**. Additionally, **Appendix P** provides a detailed Cost Estimate for **Alternative 1**, **Alternative 2**, and the Stormwater Detention Basin.

KINGWOOD DIVERSION DITCH CONVEYANCE IMPROVEMENTS — PRELIMINARY ENGINEERING REPORT

FINAL PER REPORT

JANUARY 2025

Table 19 - Alternative 3 Opinion of Probable Construction Cost Estimate

ALTERNATIVE 3 CHANNEL IMPROVEMENT - ESTIMATED CONSTRUCTION COST							
Item No.	Short Description	Unit	Quantity	Unit Bid Price	Total Bid Price	Contingency: 20%	Final Estimated Price
1	Rem. & Dis. of All Pipe	LF	180	\$20	\$3,600	\$720	\$4,320
2	Rem. & Dis. of Channel Lining	SY	70	\$15	\$1,050	\$210	\$1,260
3	Remove & Dispose of Existing Bridges	SF	19,120	\$40	\$764,800	\$152,960	\$917,760
4	Site Preparation & Restoration	EA	1	\$700,000	\$700,000	\$140,000	\$840,000
5	Clearing and Grubbing	AC	40	\$8,000	\$320,000	\$64,000	\$384,000
6	Trench Shoring System, 5 to 20 feet	LF	2,900	\$5	\$14,500	\$2,900	\$17,400
7	Excavation & Off-site Disposal	CY	859,500	\$15	\$12,892,500	\$2,578,500	\$15,471,000
8	Excavation & Fill (On-Site)	CY	99,000	\$10	\$990,000	\$198,000	\$1,188,000
9	Select Fill Material	CY	86,000	\$25	\$2,150,000	\$430,000	\$2,580,000
10	B/S Drainage System Swales	LF	38,565	\$10	\$385,650	\$77,130	\$462,780
11	Concrete Channel Lining, 6"	SY	1,700	\$90	\$153,000	\$30,600	\$183,600
12	Concrete Interceptor Structure	SY	540	\$156	\$84,240	\$16,848	\$101,088
13	Riprap, Gradation No.1	SY	46,000	\$100	\$4,600,000	\$920,000	\$5,520,000
14	24" CMP	LF	4,400	\$100	\$440,000	\$88,000	\$528,000
15	Temporary Bypass Pump	LS	1	\$60,000	\$60,000	\$12,000	\$72,000
16	Bed Material	TN	7,250	\$90	\$652,500	\$130,500	\$783,000
17	Coir Fiber Matting	SY	71,400	\$6	\$428,400	\$85,680	\$514,080
18	Rock Cross Vane	EA	8	\$10,000	\$80,000	\$16,000	\$96,000
19	Log or Rock Toe Protection	LF	8,350	\$200	\$1,670,000	\$334,000	\$2,004,000
20	Boulder Clusters	EA	6	\$400	\$2,400	\$480	\$2,880
21	Log Vane	EA	43	\$4,000	\$172,000	\$34,400	\$206,400
22	Permanent Seeding	AC	55	\$1,500	\$82,500	\$16,500	\$99,000
23	Temporary Seeding	AC	55	\$1,500	\$82,500	\$16,500	\$99,000
24	Live Stakes	EA	24,100	\$8	\$192,800	\$38,560	\$231,360
25	Bare Root Seedings	EA	24,100	\$15	\$349,450	\$69,890	\$419,340
26	Kingwood Drive Bridge	EA	2	\$775,200	\$1,550,400	\$310,080	\$1,860,480
27	Walnut Lane Bridge	EA	1	\$866,400	\$866,400	\$173,280	\$1,039,680
28	Deer Ridge Estates Blvd Bridge	EA	1	\$866,400	\$866,400	\$173,280	\$1,039,680
29	Green Trails Pedestrian Bridge	EA	1	\$531,400	\$531,400	\$106,280	\$637,680
30	Bridge Utility Relocation	LS	1	\$200,000	\$200,000	\$40,000	\$240,000
31	Concrete Diversion Structure	EA	1	\$1,062,500	\$1,062,500	\$212,500	\$1,275,000
32	RCB (12'x7')	LF	280	\$2,500	\$700,000	\$140,000	\$840,000
33	Concrete Sidewalk Removal	SY	133	\$40	\$5,333	\$1,067	\$6,400
34	Concrete Sidewalk (6")	SY	133	\$90	\$12,000	\$2,400	\$14,400
35	Anchored Sodding	SY	26,000	\$7	\$182,000	\$36,400	\$218,400
36	Stream & Wetland Mitigation	LS	1	\$0	\$0	\$0	\$0
Project Cost Subtotals					\$33,248,323	\$6,649,665	\$39,897,988
						BUDGET	\$39,900,000

9. Conclusions

The pre-project conditions in the Kingwood Diversion Ditch project area do not sufficiently divert flow down the Kingwood Diversion Ditch to reduce flows and prevent flooding along Bens Branch. To provide flood reduction along Bens Branch, three (3) channel conveyance improvement alternatives were analyzed for this study. Based on this analysis, **Alternative 3** was selected as the recommended alternative. The onsite improvements associated with **Alternative 3** utilize the existing ROW to maximize conveyance capacity along Kingwood Diversion Ditch.

Alternative 3 reduces the risk of flooding of 288 parcels and 34 structures compared to existing conditions. Although the capital construction costs of implementing **Alternative 3** are approximately \$3 million more than Alternative 1, **Alternative 3** offers similar benefits to Alternative 1, and saves a total of \$1,041,604.67 in maintenance costs over the 10-year period considered. Thus, the annual maintenance and operational savings from the Natural Stable Channel Design balances the initial implementation cost within 28 years. Additionally, **Alternative 3** incorporates Natural Stable Channel Design features, which provide additional benefits to the environment in the form of increased habitat, improved erosion resistance, and improved filtration of suspended solids. These features could potentially provide additional avenues for grant funding in the interest of environmental benefits, further reducing the time to a balanced cost.

A model simulation of coinciding peaks was developed to evaluate backwater of the West Fork San Jacinto River flowing into Kingwood Diversion Ditch and Bens Branch and determine the need for stormwater detention. Results of this conservative scenario showed small, localized increases to water surface elevations at the confluence with West Fork San Jacinto River. This impact initiated the recommendation for stormwater mitigation. The total cost to build the offsite Stormwater Detention Basin 1 would be **\$14.25 million**. The following conclusions regarding potential need for detention were drawn from results of this study:

- Offsite detention will not provide direct benefits to flows or water surface elevations in the Kingwood area.
- The recommended diversion and channel improvement project will not involve changes in the land use patterns of the Bens Branch or Kingwood Diversion Ditch drainage areas; therefore, runoff volumes will not be increased by the project.
- The recommended channel improvements and Hamblen Road bridge crossing upgrade along Kingwood Diversion Ditch will create additional inline storage capacity to mitigate the diverted flows, resulting in lower peak flows and water surface elevations along Kingwood Ditch than under existing conditions.
- Due to the vast difference in flood volumes between West Fork San Jacinto River and the Kingwood Diversion Ditch, flow from the Kingwood Diversion Ditch drainage area does not have an impact on peak flows and water surface elevations within West Fork San Jacinto River.
- Because all the water volume eventually drains to Lake Houston, whether flowing down Bens Branch or diverted down the Kingwood Diversion Ditch, there will be no volume increase at Lake Houston due to this project.

It is recommended to consider mitigation as part of the Kingwood Diversion Ditch channel conveyance improvement project because of the potential adverse impacts resulting from coinciding extreme events.

It is important to note that the coinciding peak scenario utilized for this study assumes that an Atlas 14 1% AEP event occurs over the West Fork San Jacinto River simultaneously with an additional Atlas 14 1% AEP event occurring over the Kingwood area. This scenario represents a statistical event with a much smaller chance of occurrence than an Atlas 14 1% AEP event. This probability should be considered when considering the need and volume for mitigation during the final design.

The use of an offsite detention basin as the tool to achieve this mitigation is recommended at this time; however, due to the reasons stated above, the required detention should be further examined during the final design stage. This examination would include updating the models for the Atlas 14 1% AEP event to consider timing of hydrographs from Kingwood Diversion Ditch, Bens Branch, and the West Fork San Jacinto River in order to fully confirm potential project impacts and to optimize volume of detention potentially required. This evaluation could also support in the consideration of other alternative tools to mitigate project impacts.

Based on results of this study, NSI recommends **Alternative 3** for the Kingwood Diversion Ditch Conveyance Improvements along with the proposed offsite Stormwater Detention Basin 1. The total estimated construction cost for **Alternative 3**, including stormwater detention, is approximately **\$54.95 million** (includes \$1.5 million in acquisition costs). A breakdown of the cost estimate for **Alternative 3** is provided in **Table 12** and **Table 20**. Additionally, **Appendix P** provides a detailed Cost Estimate for **Alternative 1**, **Alternative 2**, and the Stormwater Detention Basin.