Levee Improvement District No. 19 System Review – Phase 1 Fort Bend County, Texas

Prepared for:

Fort Bend County Levee Improvement District No. 19
202 Century Square Blvd.
Sugar Land, Texas 77478

Submitted by:

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Abbreviations & Acronyms

CFS	Cubic Feet per Second
CLOMR	Conditional Letter of Map Revision
DCM	Drainage Criteria Manual
EL	Elevation
FBC	Fort Bend County
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GPM	Gallon per Minute
HEC-HMS	(USACE) Hydrologic Engineering Center Hydrologic Modeling System
ICPR	Inter-Connected Pond Routing (software)
LID	Levee Improvement District
MGD	Million Gallons per Day
MSL	Mean Sea Level
MUD	Municipal Utility District
NAVD 88	North American Vertical Datum of 1988, Adjusted 2001
NFIP	National Flood Insurance Program
NGVD 29	National Geodetic Vertical Datum of 1929, Adjusted 1973
RCB	Reinforced Concrete Box
SFHA	Special Flood Hazard Area
TCEQ	Texas Commission on Environmental Quality
TDH	Total Dynamic Head
USACE	United States Army Corps of Engineers
WWTP	Waste Water Treatment Plants

EXECUTIVE SUMMARY

Aptim Environmental & Infrastructure (APTIM) was authorized by Levee Improvement District No. 19 (LID 19) of Fort Bend County, Texas, to perform an independent system review of the existing LID 19 facilities. The objective of the review was to determine whether the district's facilities were designed and constructed in compliance with all applicable standards and whether these facilities are presently in compliance with current applicable standards.

Levee Improvement District 19 Facilities

LID 19 encompasses approximately 780 acres and maintains a 5-mile levee system, providing flood protection from the Brazos River floodplain. The levees range in elevations from 71.0' NAVD 88 in the eastern portion, to 73.0' NAVD 88 in the western portion. The drainage outfall structure consists of four (4) 10' x 10' reinforced concrete box (RCB) culverts that run through the levee at Steep Bank Creek. In this same location there is a 60,000 gpm pump station that discharges into the Brazos River floodplain to remove water from the drainage system when gravity flow is restricted by high waters in the Brazos River. LID 19 also includes multiple detention ponds strategically placed throughout its system to assist in managing rainwater runoff. In addition to its own drainage area, LID 19 also receives rainwater from an additional 2,080 acres through Steep Bank Creek which includes several other LIDs and Municipal Utility Districts (MUDs).

Methodology & Analysis of System Review

APTIM reviewed all available design and construction documentation for LID 19 facilities while referencing applicable standards, analyzed the hydrologic and hydraulic models, and conducted a field investigation to determine whether the system was designed, was built, and is currently still in compliance with applicable standards.

Findings & Conclusions

After completing the review of all provided information and criteria associated with LID 19 facilities, APTIM provides the following information as observations throughout this process.

Levees - It was observed and confirmed that the data included in the Flood Insurance Study (released in 2014) was incorporated into the design and construction of the levees. As a result, the levee elevations were confirmed to be within compliance of the 3.0' freeboard required by FEMA and the NFIP and were also confirmed to be within compliance of the additional 1.0' of freeboard required by FBC-DCM at the time of design. Additionally, the levees were observed to be geotechnically sound, and the typical levee section was designed in compliance with applicable criteria.

Drainage and Storage Areas – Based on the current ICPR model operations, all drainage and storage areas were found to meet design criteria at the time of design, as well as the current revised 2011 FBC-DCM for both the 25-year and the 100-year requirements. It was also observed

that two WWTP effluent discharge flows were not included in the ICPR models. The design engineers felt that these flows were insignificant to affect both 25-year and 100-year gravity flows.

Pump Station – LID 19 authorized the design of Steep Bank Creek Pump Station in August 2011 in which the 2011 FBC-DCM was the latest criteria requirement. After review, the designed pumping capacity of 60,000 gpm was determined to be undersized when using the provided maximum pool elevation of 61.87' NGVD 29 and the 2011 FBC-DCM criteria. Based on the current ICPR model operations, this maximum pool elevation resulted in a larger pumping capacity requirement of approximately 100,000 gpm. It is important to note that this does not include the spare pump requirement. Also, as previously mentioned, the WWTP effluent discharges were not accounted for in the ICPR models. It is recommended that the WWTP effluent be accounted for in modeling efforts due to their potential discharge volumes based on their permitted amounts.

1.0 INTRODUCTION

Aptim Environmental & Infrastructure (APTIM) was selected by Levee Improvement District No. 19 (LID 19) of Fort Bend County, Texas, to provide a System Review of the existing LID 19 facilities. This review includes reporting on the design, construction, and operation of the facilities relative to all applicable standards and best practices within the industry. This report provides the findings of APTIM's engineering investigation performed in accordance with the services outlined in Job Order No. 01 (dated January 24, 2018) to the Master Service Agreement between APTIM and Fort Bend County Levee Improvement District No. 19, dated December 19, 2017. The objective of this Phase I – Design and Construction System Review report is to determine whether these facilities were designed and constructed within compliance of all applicable Federal, State, County, and City standards at the time of implementation and to determine whether these facilities are currently within compliance.

2.0 AREA OF STUDY

LID 19 resides in Fort Bend County (FBC), which is located in the coastal plains of southeast Texas. FBC encompasses 869 square miles of level to slightly rolling terrain with elevations ranging from elevations of 60.0' to 250.0' MSL (Mean Sea Level). The Brazos River flows diagonally northwest to southeast through the county and drains the broad central valley via a network of creeks and bayous. The largest municipality in FBC is the city of Sugar Land, located along the northeastern edge of the county. A boundary map of the County is shown in Figure 1.

Figure 1 - Fort Bend County Location

LID19 is positioned approximately 7 miles southeast of Sugar Land and encompasses approximately 780 acres. The land use of the LID 19 jurisdictional area is predominately residential with some light commercial development. The district is bounded by FBC Levee Improvement District 15 on the west, Fort Bend County Municipal Utility District (MUD) No. 46 to the north, Flat Bank Creek on the east, and the floodplain of the Brazos River to the south. The boundary of LID 19 is shown in Figure 2.

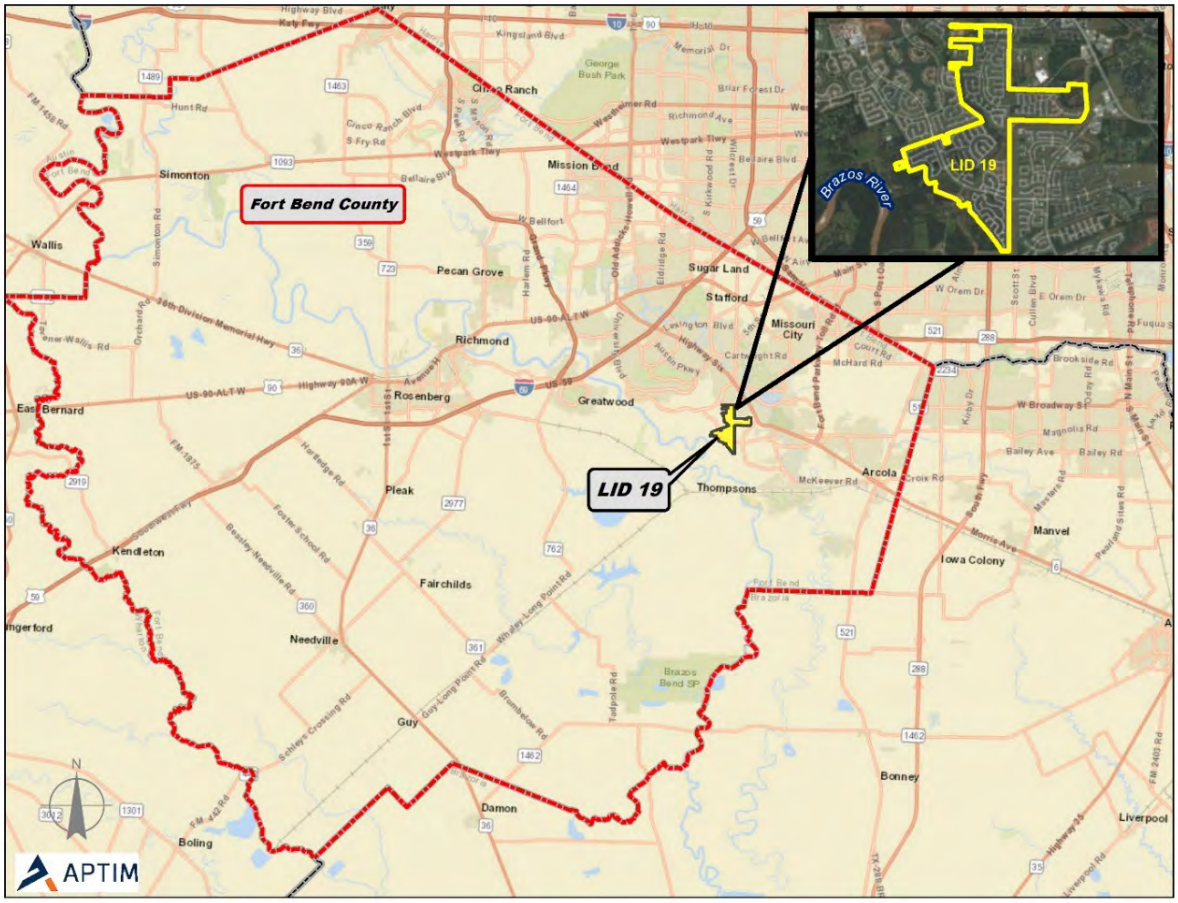

Figure 2 - Boundary of Fort Bend County Levee Improvement District No. 19

2.1 LID 19 Facilities

LID 19 has 5 miles of levees providing flood protection from the Brazos River floodplain. The levees range in elevations from 71.0' NAVD 88 in the eastern portion, to 73.0' NAVD 88 in the western portion. The northeastern levee tie-in begins approximately 1,000 feet from the intersection of Thompson Ferry Road and Oilfield Road. It continues southward and eventually parallels Flat Bank Creek until Flat Bank Creek turns west approaching its confluence with Steep Bank Creek. From this point, LID 19 levees continue northwest, crossing Steep Bank Creek and eventually tie into the existing LID 15 levee system. At the crossing of Steep Bank Creek, there are four (4) 10' x 10' reinforced concrete box (RCB) culverts for the gravity drainage outfall structure, which is part of the 100-year drainage system along with multiple detention ponds strategically placed throughout LID 19. Additionally, there is a 60,000 gpm pump station that discharges on the flood side of the levee into the Brazos floodplain to remove water from the drainage area when gravity flow is restricted by high waters in the Brazos River.

2.2 Drainage Areas

LID 19 lies within the southernmost portion of the 2,900 acres of the Steep Bank Creek drainage area. This drainage area also includes a small southeast portion of LID 2 (141 acres), the entirety of the First Colony Levee Improvement District (656 acres), Fort Bend County MUD 115 (333 acres), MUD 46 (53 acres), and the eastern portion of Fort Bend County LID 15 (940 acres). In addition to these areas, there are two wastewater treatment plants (WWTP) that discharge effluent into Steep Bank Creek. The Sugar Land South WWTP has a daily average discharge of 4.48 MGD (7.5 MGD annual average permitted flow) which is located in Maranatha Farms, northwest of Steep Bank Creek. The Missouri City WWTP has a daily average discharge of 1.9 MGD (12 MGD annual average permitted flow) and is situated south of MUD 46. All of these drainage areas and inflows are routed to various locations along Steep Bank Creek, which ultimately flow southward into the Brazos River through the LID 19 outfall structure as shown in Figure 3.

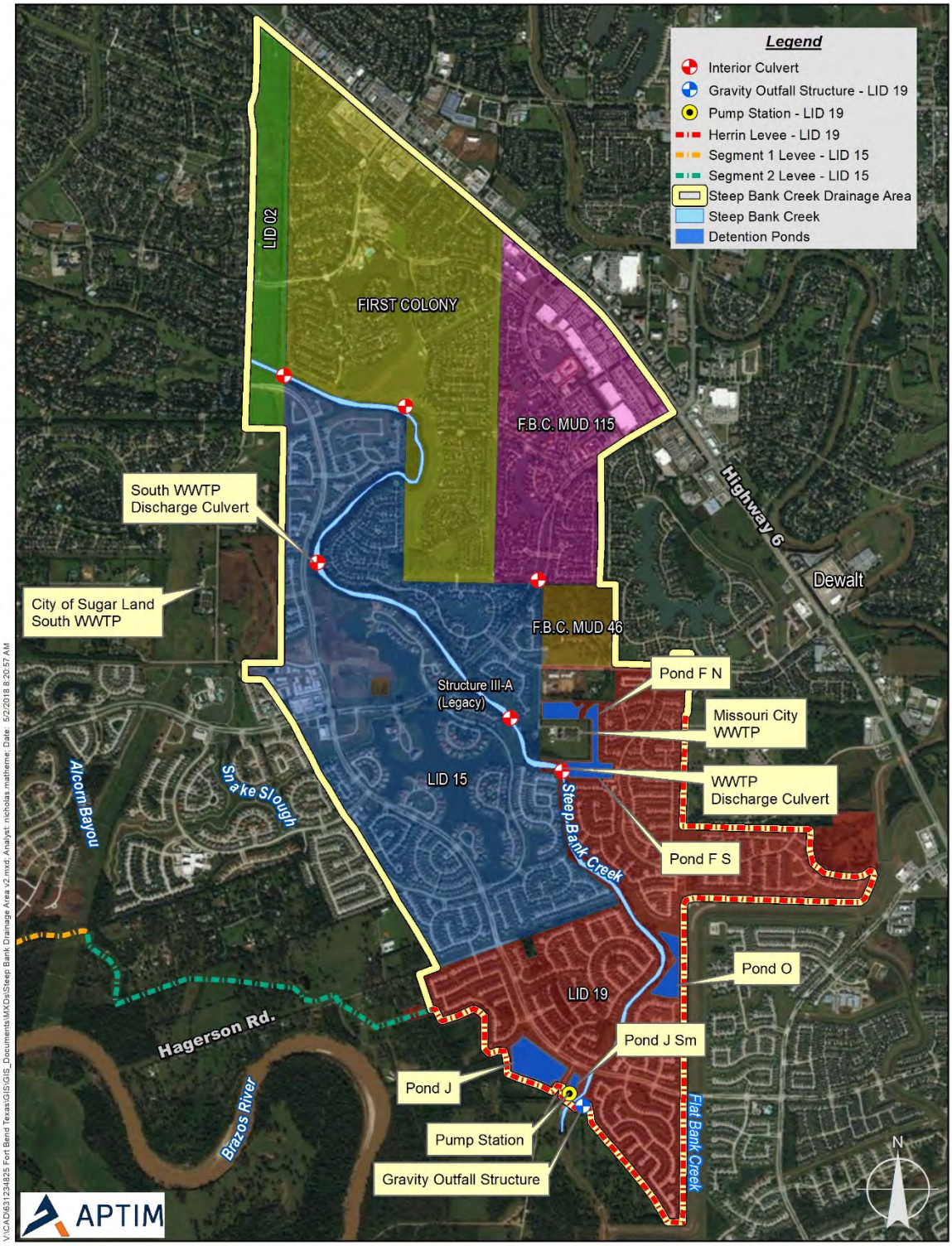

Figure 3 - Steep Bank Creek Drainage Area

3.0 FACILITIES REVIEW

3.1 Levees

In reviewing the provided information, it was observed and confirmed that the updated FEMA data provided in the Flood Insurance Study released in 2014 was obtained and incorporated in the design of the levees. In accordance with applicable standards at the time of design, the levees were designed with a minimum slope of 1 vertical to 3 horizontal and a crest width of at least 10'. The right-of-way for levee construction cross-sections measured 110', with a minimum easement of 10' beyond the toe of the levee to be kept clear of obstructions such as structures and woody vegetation, though this easement exceeds the minimum 10' width in many cases. A typical cross section taken from the Record Drawings is shown in Figure 4.

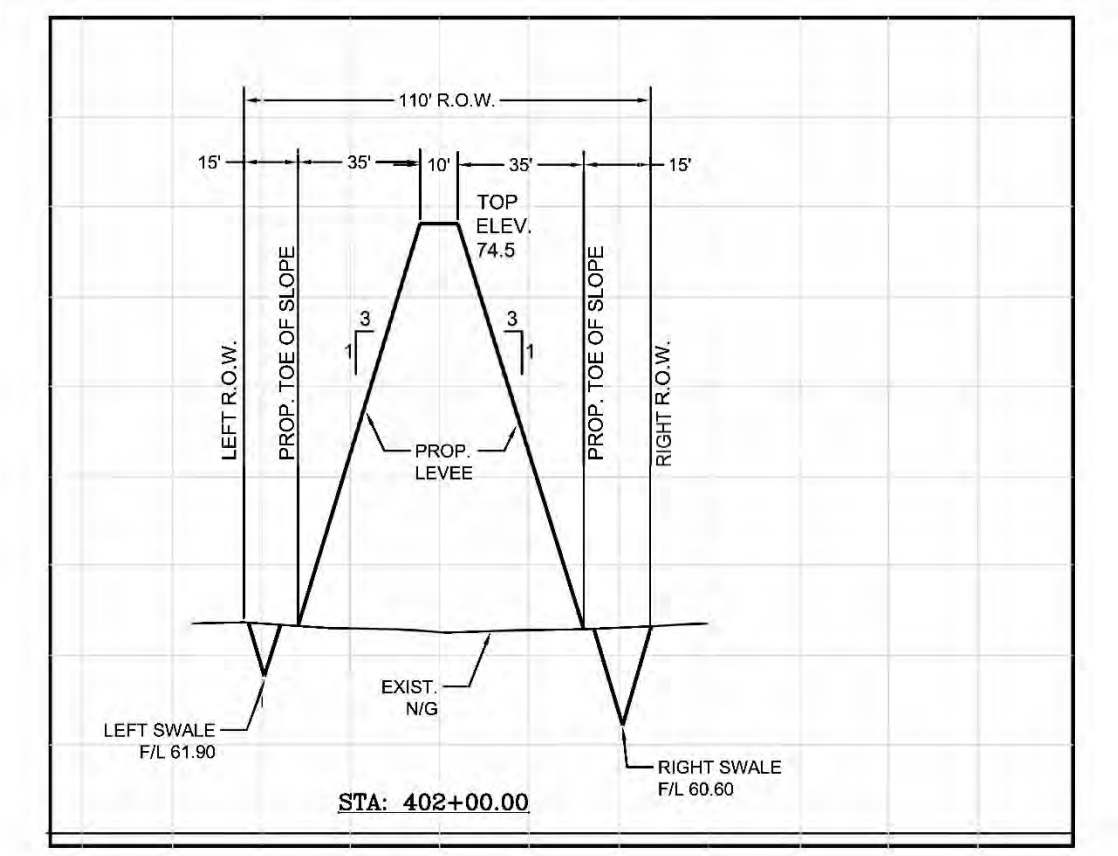

Figure 4 - Typical Levee Cross Section

A geotechnical study was conducted by Paradigm Consultants to determine the suitability of the subgrade soils for construction of the levee. Their initial field investigation was conducted in accordance with recommendations as outlined in EM 1110-2-1913 (USACE)

and the design criteria with regards to configuration, construction, and stability were as outlined in 44 CFR 65.10, the Fort Bend County Drainage Criteria Manual (FBC-DCM), and Texas Administrative Code 30 301.34. Major details of the investigation, engineering analyses, final design, and construction of the levee system are as follows:

1. Soil borings were conducted at intervals less than 1,000 feet and to depths at least twice the height of the levee.
2. Engineering studies and analyses conducted by Paradigm were adequate to demonstrate the stability of the levee. Slope stability analyses were conducted for all four cases as recommended by EM-1110-2-1913. A seepage analysis using flow net methodology was also performed to provide assurance that excessive seepage would not result in liquefaction and piping erosion of the embankment.
3. The minimum levee freeboard is specified by FEMA as no less than 3' above the Base Flood Elevation (BFE). The FBC-DCM requires an additional foot of freeboard as a safety margin. The design freeboard was determined by noting the minimum surveyed elevation of the crest in each levee section of the Record Drawings and subtracting the BFE for that individual section. Minimum levee freeboard was found to be sufficient throughout the levee alignment based on the differences between the as-built survey and the BFEs in the 2014 Flood Insurance Study, as shown in Table 1.
4. According to the field test reports, the levee fill was compacted to 95% of its maximum dry density (Standard Proctor) in accordance with the plans and specifications.
5. Based on reports from the testing laboratory, the embankment material was a clay soil of varying plasticity (CH, CL) with Liquid Limits in excess of 30 and Plasticity Indices greater than 15. No data was available on the fine content; however, the fact that these soils were classified as clays would indicate that percent passing the #200 sieve was in excess of 50%.
6. The levee slopes are well vegetated and are therefore resistant to erosion from runoff and minor flow velocity. The flood side of the levee is a distance of 2,300 feet from the Brazos River through a wooded floodplain; therefore, erosion from high velocity river flow and damage from debris would not be of concern.
7. A settlement analysis conducted as part of the geotechnical design indicated that total settlement of the levee would be between 2.1 to 4.2 inches, and it would occur primarily during construction.

Table 1 - Minimum Levee Freeboard

Levee Section from Drawings	*Lowest Elevation (ft) (NGVD 29)*	*Lowest Elevation (ft) (NAVD 88*)*	*Approximate Station*	*BFE (ft) (NGVD 29)*	*BFE (ft) (NAVD 88)*	*Levee Freeboard (ft)*
5	74.16	72.88	404+80	69.3	68.02	4.86
6	74.50	73.22	404+60	68.9	67.62	5.60
7	74.50	73.22	429+00	68.5	67.22	6.00
7a	73.50	72.22	438+00	68.3	67.02	5.20
8	73.45	72.17	447+20	68.1	66.82	5.35
9	71.95	70.67	462+70	67.7	66.42	4.25
10	72.49	71.21	479+00	67.5	66.22	4.99
11	72.11	70.83	483+00	67.5	66.22	4.61
12	72.44	71.16	505+00	67.7	66.42	4.74
13	72.40	71.12	515+00	67.7	66.42	4.70
14	72.46	71.18	534+85	67.7	66.42	4.76
15	72.39	71.11	538+80	67.7	66.42	4.69
16	72.45	71.17	563+70	67.7	66.42	4.75
17	72.75	71.47	565+75	67.7	66.42	5.05
18	72.69	71.41	644+65	67.7	66.42	4.99
19	72.95	71.67	610+40	67.7	66.42	5.25
20	72.64	71.36	626+45	67.7	66.42	4.94
21	72.50	71.22	628+90	67.7	66.42	4.80
22	72.49	71.21	707+20	67.7	66.42	4.79
23	72.68	71.40	717+10	67.7	66.42	4.98

*Note: (NAVD 88 = NGVD 29 – 1.28')

Based on these conditions, it is our opinion the levee was designed and constructed in accordance with the aforementioned applicable standards in effect at the time of LID 19 creation. With respect to levee design and construction, Tables 2 through 4 summarize the compliance with individual requirements.

Table 2 - Summary of Texas Administrative Code Requirements

TAC Criteria	*Criteria Description*	*Criteria Met*	*Comments*
30 301.34 (1)	Structural integrity	✓	Levee designed in accordance with applicable standards
30 301.34 (2)	Compatibility with existing hydraulic structures	✓	The design of the levee and drainage system does not inhibit existing drainage from adjacent tracts and is coordinated with other projects within the same hydraulic influence
30 301.34 (3)	Safety	✓	
30 301.34 (4)	Rights of third parties	✓	
30 301.34 (5)	Design with respect to existing conditions	✓	
30 301.34 (6)	Minimum freeboard	✓	The levee has adequate design freeboard (See Table 1)

Table 3 - Summary of FEMA Requirements

FEMA Criteria	*Criteria Description*	*Criteria Met*	*Comments*
44 CFR 65.10 (b) (1)	Freeboard	✓	The levee has adequate design freeboard (See Table 1)
44 CFR 65.10 (b) (2)	Closures	✓	All outlets have swing type check valves ("flap gates") on the flood side with sluice gates on the protected side as backup
44 CFR 65.10 (b) (3)	Embankment protection	✓	Since the levee is exposed to riverine flooding in a wooded floodplain, velocity is minimized, and erosion is not of concern. The levee has a well-tended vegetative cover beyond the flood side toe
44 CFR 65.10 (b) (4)	Embankment and foundation stability	✓	The geotechnical report shows that the levee design meets applicable design criteria specified in EM-1110-2-1913 with respect to global stability and seepage
44 CFR 65.10 (b) (5)	Settlement	✓	A detailed settlement analysis was conducted as part of the geotechnical study

Table 4 - Summary of Fort Bend County Drainage Criteria Manual Requirements

FBC-DCM Criteria	Criteria Description	Criteria Met	Comments
7.2.1	Frequency criteria	✓	Design of the levee utilized the 100-year flood event as outlined in the 2014 FEMA Flood Insurance Map as the base flood elevation
7.2.2.1	Geotechnical investigation	✓	Conducted by Paradigm Consultants
7.2.2.2	Foundation stripping	✓	As directed in the drawings And specifications
7.2.2.3	Embankment material	✓	Satisfactory as indicated in the laboratory and field reports from the CMT testing laboratory and geotechnical report.
7.2.2.3. a.	Liquid limit ≥ 30	✓	
7.2.2.3. b.	Plasticity index ≥ 15	✓	
7.2.2.4	Embankment compaction	✓	Satisfactory as indicated in the field reports from the CMT testing laboratory
7.2.2.5	Embankment protection	✓	As directed in the drawings and specifications and noted during site visit
7.2.2.6	Minimum levee width	✓	As directed in the drawings and specifications
7.2.2.7	Levee slope	✓	
7.2.2.8	Levee freeboard	✓	The levee has adequate design freeboard (See Table 1)
7.2.2.9	Levee coverage	✓	As directed in the drawings and specifications
7.2.2.10	Levee penetrations	✓	Discharge piping from the internal drain system penetrates the levee through a concrete headwall section. Flap gates (exterior) and sluice gates (interior) insure positive cutoff
7.2.2.10	Levee easements	✓	As directed in the drawings and specifications

3.1.1 Current Status of the Levee

On March 23, 2018, our engineers conducted a cursory field investigation of the levee alignment as part of field assessment of LID 19 for the purposes of general project area familiarization.

3.1.1.1 Existing Conditions

The levee appeared to be well maintained and monitored and was in satisfactory condition. The side slopes were well vegetated with very minor bare areas, which, in all likelihood, were merely due to seasonal conditions. Although our field

investigation team observed some rutting on the crest, crews were adding additional fill during our site visit to restore the crest. There did not appear to be any major issues with erosion, sloughing, bulging, or low areas. It is worthy of note that the levee showed no appreciable damage following the flood associated with Hurricane Harvey.

3.1.1.2 Current Freeboard

A survey of the levee is conducted every five years. Based on the latest survey, which was performed following Hurricane Harvey, the existing freeboard is shown in Table 5.

Table 5 - Current Levee Freeboard

Levee Section from Drawings	*Lowest Elevation (ft) (NGVD 29)*	*Lowest Elevation (ft) (NAVD 88)*	*Approximate Station*	*Base Flood Elevation (ft) (NGVD 29)*	*Base Flood Elevation (ft) (NAVD 88)*	*Levee Freeboard (ft)*
5	73.90	72.62	406+00	69.30	68.02	4.60
6	73.70	72.42	420+75	68.90	67.62	4.80
7	73.90	72.62	425+50	68.50	67.22	5.40
7a	73.53	72.25	435+00	68.30	67.02	5.23
8	73.51	72.23	452+00	68.10	66.82	5.41
9	73.68	72.40	466+00	67.70	66.42	5.98
10	73.52	72.24	473+00	67.50	66.22	6.02
11	72.74	71.46	488+00	67.50	66.22	5.24
12	72.10	70.82	499+00	67.70	66.42	4.40
13	72.00	70.72	518+00	67.70	66.42	4.30
14	72.30	71.02	535+00	67.70	66.42	4.60
15	72.00	70.72	538+00	67.70	66.42	4.30
16	72.20	70.92	556+00	67.70	66.42	4.50
17	72.10	70.82	573+50	67.70	66.42	4.40
18	72.10	70.82	582+00	67.70	66.42	4.40
19	72.20	70.92	607+00	67.70	66.42	4.50
20	72.10	70.82	615+00	67.70	66.42	4.40
21	72.20	70.92	640+00	67.70	66.42	4.50
22	72.10	70.82	705+00	67.70	66.42	4.40
23	72.10	70.82	726+00	67.70	66.42	4.40

3.2 Drainage and Detention

In accordance with the Fort Bend County's Drainage Criteria Manual (FBC-DCM), the internal drainage system and detention areas are designed to accommodate a localized 100-year, 24-hour rainfall event without any tail water conditions that might impede gravity flow.

The hydrologic and hydraulic model created by Costello, Inc., for LID 19 utilized the Inter-Connected Pond Routing (ICPR) software. To begin the modeling process, the entire basin was divided into smaller sub-catchment drainage areas and a maximum peak runoff rate was calculated for each area using the Rational Method. Hydrographs for each sub-catchment area were then developed using HEC-HMS software, as recommended by the FBC-DCM. Each sub-catchment hydrograph generated was incorporated into the ICPR model to simulate storm water runoff routing down Steep Bank Creek. The outfall structure and internal improvements were sized to accommodate the design storm capacity required under normal gravity conditions to maintain the 100-year water surface elevations in accordance with FBC-DCM. A 25-year storm model and a 100-year storm model were developed for the entire basin. Table 6 outlines the system's adherence to the specific requirements included in the FBC-DCM.

Table 6 - FBC-DCM Compliance Analysis

FBC Drainage Criteria	*Criteria Description*	*Criteria Met*	*Comments*
1.4	Drainage Policy – Construct & Maintain 100-year design drainage facilities.	✓	
2.1	HEC-HMS computer software used as primary tool for modeling storm runoff hydrographs.	✓	
2.1	HEC-HMS modeling required for 100-year rainfall event.	✓	
2.1	HEC-HMS modeling required for 25-year rainfall event.	✓	
2.2.1	24-hour duration storm events. Amounts listed on Table 2-1.	✓	
2.2.3.1	The Clark Unit Hydrograph shall be used and calculated as presented.	✓	
2.4	Rational Method used only for areas less than 200 acres	✓	Costello, Inc., indicated that the Rational Method used for the 459 acre sub-catchment area SB-8,

FBC Drainage Criteria	Criteria Description	Criteria Met	Comments
			was a conservative approach—an assessment with which APTIM agrees.
2.4.1	Runoff Coefficient description and coefficient adjustment per Table 2-4.	✓	The 25-year model coefficient adjustment factor used was higher than a 25-year event for 3 sub-catchment areas. This is a conservative approach in engineering design.
2.4.2	Rainfall intensity for Rational Method per Figure 2-7.	✓	
3.3.1	Open channels shall be designed to contain the runoff from a 100-year frequency 24-hour duration storm event.	✓	The ICPR model results appear to show Steep Bank Creek to be adequate to handle the 100-year storm event.
4.2.1	Culverts shall be designed to handle the 100-year flood flow for fully developed conditions.	✓	The ICPR model results appear to show that the culverts are able to handle the 100-year storm event.
6.4.3	Drainage Areas >640 Acres	✓	HEC-HMS models were performed for the 25 & 100-year storm events.
6.4.4	Design Tailwater Depth	✓	The ICPR model provided included rating curves for the ponds. For the coincidental pumping event, no gravity outflow was assumed which is a conservative approach.
6.4.6	Downstream Impact Analysis Requirements	✓	HEC-HMS models were performed and included the downstream portions of the channels.
6.4.7	Final Sizing of Pond Storage and Outflow Structure	✓	The ponds include at least one foot of freeboard.
6.4.10	Erosion Control	✓	From the as-built plans, it appears that proper re-vegetation occurred during construction.
7.4	Gravity outlet and outfall channel equipped with gate to prevent backflow from river.	✓	

The internal gravity drainage system produces a maximum flow rate at the Steep Bank Creek Outfall structure of 1,400 cfs (628,400 gpm) for a 100-year storm design. There are a total of four (4) 10'x10' (RCB) culverts installed through the levee. Each RCB has a

sluice gate on the protected side and a one-directional flow flap gate on the flood side to prevent backflow from a high Brazos River condition. The design of these box culverts appears to be adequate to handle the maximum flow conditions for a 100-year storm event.

3.3 Pump Station (coincidental events)

In the event the Brazos River water elevation rises above the inverts of the drainage culverts that penetrate through the LID 19 flood protection levee, the capacity of the internal gravity drainage system significantly diminishes. The FBC-DCM therefore recommends design and construction of pumps to remove interior drainage and requires independent analysis of all leveed areas which discharge into the Brazos River, with any required analysis using the coincidental events criteria. The coincidental events criteria presume the storm event causing a high flood stage at the Brazos River is independent of the storm event occurring over the leveed area. The steps to determine the required pump capacity are specifically listed for the coincidental events criteria in the FBC-DCM. In order to determine the required pumping capacity, the design engineer must obtain the maximum ponding elevation within the leveed area, which is normally the 100-year flood event elevation as described above. Costello, Inc. provided a maximum ponding elevation of 61.87' NGVD 29 for the system which coincides with the lowest top-of-curb within the system plus one foot of ponding as per the requirements of the FBC-DCM. Since Costello, Inc., was given authorization by the LID 19 to design this pump station in August of 2011, the 2011 FBC-DCM (Released in February 2011) will be used for this evaluation. The methodology below describes the process for determining pumping capacity for a coincidental event:

1. Find the location of the pump station outfall along the Brazos River Floodway between profiles "P" and "Q" using the updated FIRM maps (Figure 5). In this location the Brazos River crosses the Steek Bank Creek profile in two locations creating a range of flow rate values.

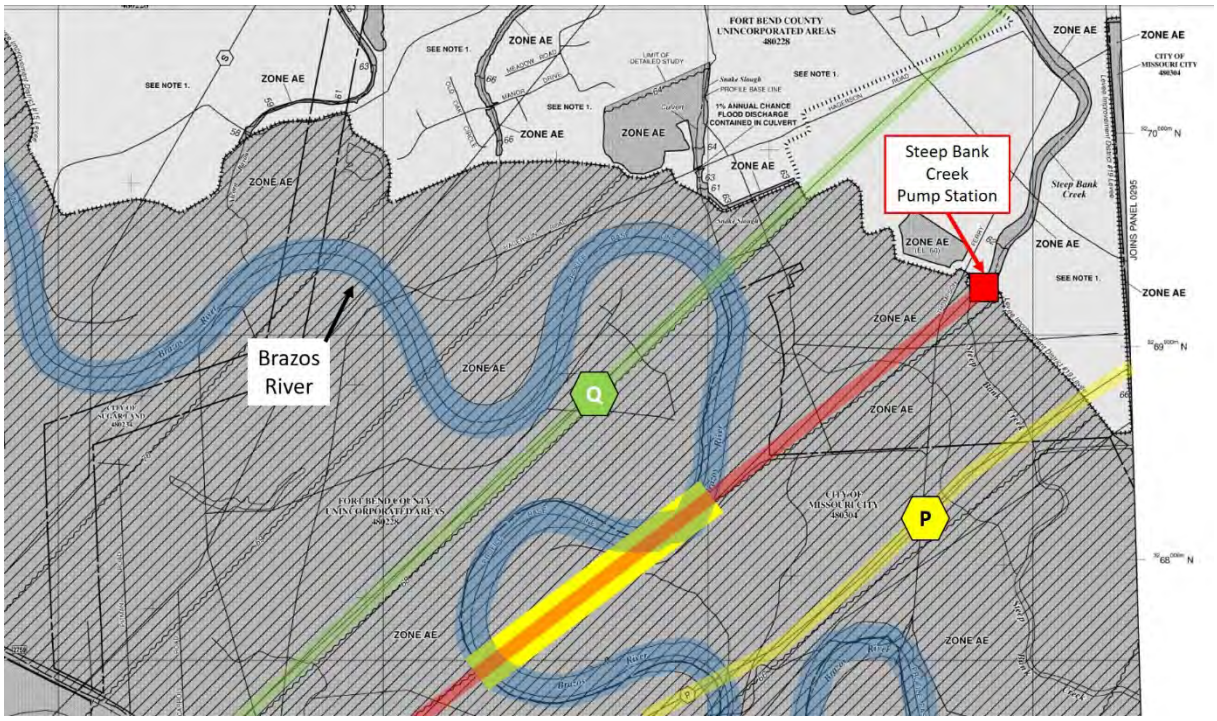

Figure 5 - Brazos River Flood Profiles from NFIP-FIRM 2014

2. To determine this range, use the system's maximum ponding elevation of 61.87' NGVD 29 which converts to 60.59' NAVD 88. Apply this elevation in the location of the pump station in Figure 7-1-3 from the 2011 FBC-DCM and the corresponding flow rate values range from approximately 70,000 cfs to 77,000 cfs with the midpoint being 73,500 cfs, as demonstrated in Figure 6.

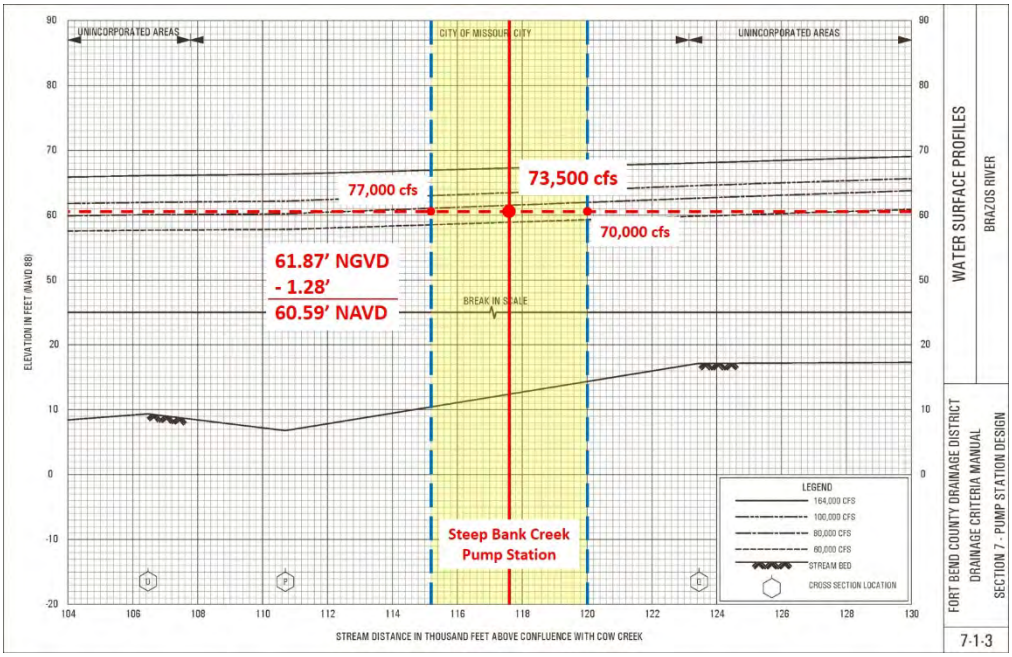

Figure 6 - FBC-DCM 2011, Figure 7-1-3

3. Using this midpoint flow rate of 73,500 cfs in the Brazos River, the frequency of rainfall over the leveed area for coincidental events is determined to be an 8.2-year event, as shown in Figure 7 below.

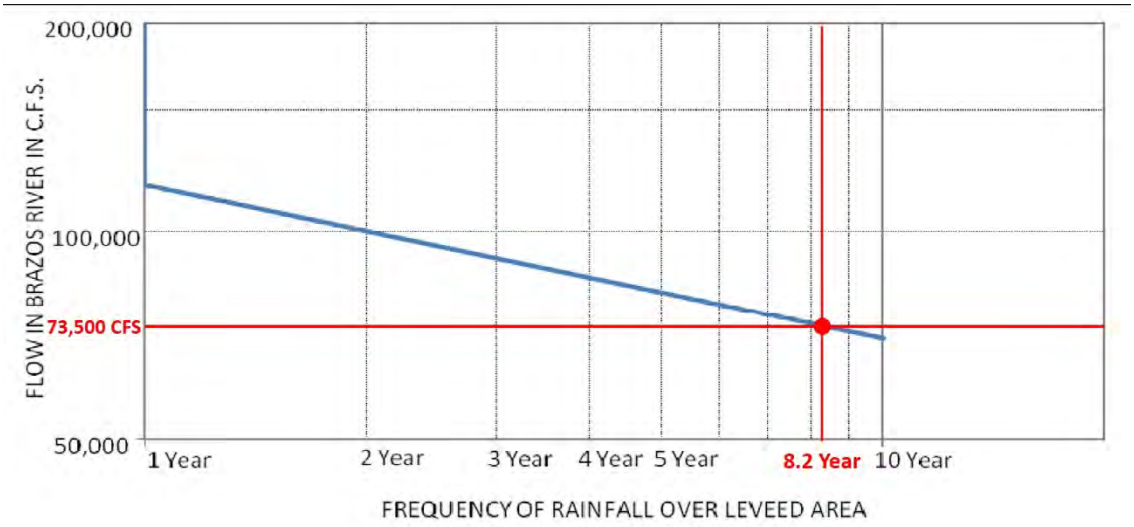

Figure 7 - FBC-DCM 2011, Figure 7-2

4. Applying this rainfall frequency to (Figure 8), the inches of rainfall in 24 hours over the leveed area is determined to be 7.7 inches.

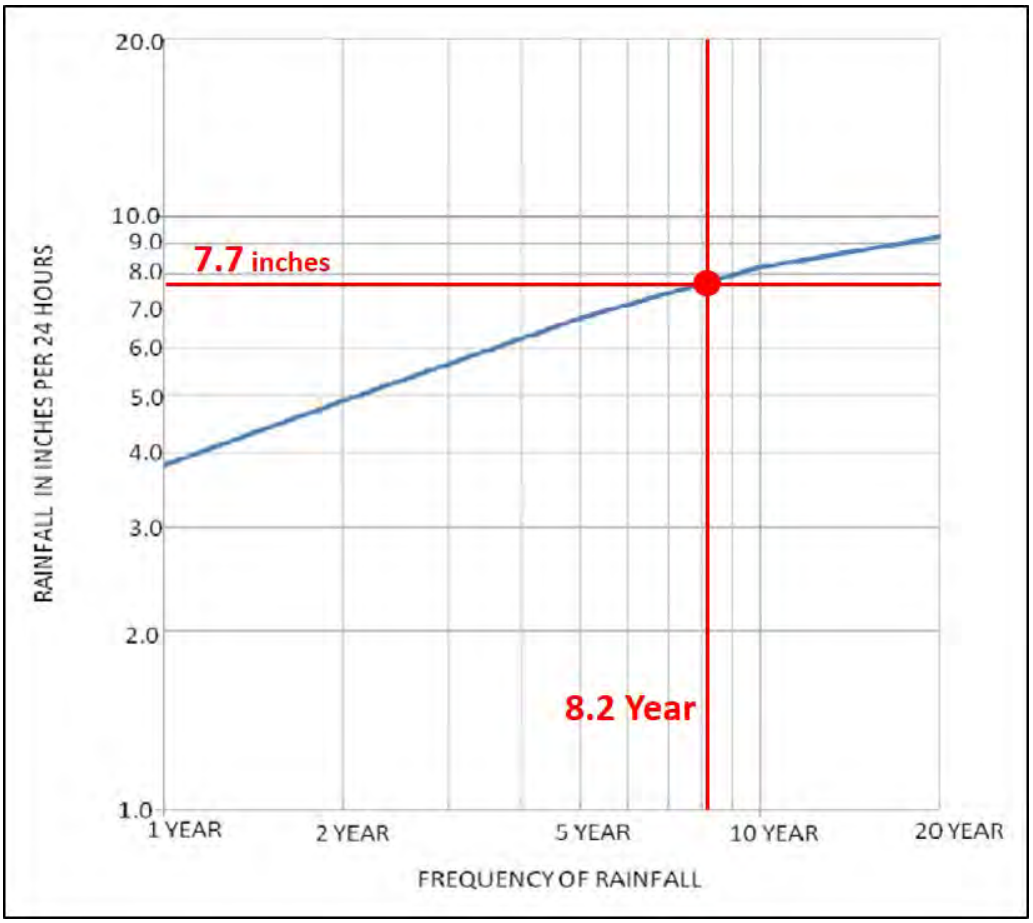

Figure 8 - FBC-DCM 2011, Figure 7-3

Using this rainfall information, new hydrographs were created representing the updated rainfall intensity and imported into the ICPR model. Several iterations were performed, adjusting the pumping needs until the maximum ponding elevation was maintained. This resulted in a pumping requirement of approximately 100,000 gpm. Consequentially, the current pump station of 60,000 gpm does not meet this requirement.

4.0 CONCLUSIONS

After completing the review of all provided information and criteria associated with LID 19 facilities, APTIM provides the following information as observations throughout this process.

Levees - It was observed and confirmed that the data included in the Flood Insurance Study (released in 2014) was incorporated into the design and construction of the levees. As a result, the levee elevations were confirmed to be within compliance of the 3.0' freeboard required by FEMA and the NFIP and were also confirmed to be within compliance of the additional 1.0' required by FBC-DCM at the time of design. Additionally, the levees were observed to be geotechnically sound, and the typical levee section was designed in compliance with applicable criteria.

Drainage and Storage Areas – Based on the current ICPR model operations, all drainage and storage areas were found to meet design criteria at the time of design, as well as the current revised 2011 FBC-DCM for both the 25-year and the 100-year requirements. It was also observed that two WWTP effluent discharge flows were not included in the ICPR models. The design engineers felt that these flows were insignificant to affect both the 25-year and 100-year gravity flows.

Pump Station – LID 19 authorized the design of Steep Bank Creek Pump Station in August of 2011 in which the 2011 FBC-DCM was the latest criteria requirement. After review, the designed pumping capacity of 60,000 gpm was determined to be undersized when using the maximum pool elevation of 61.87' NGVD 29 and the 2011 FBC-DCM criteria. Based on the current ICPR model operations, this maximum pool elevation resulted in a larger pumping capacity requirement of approximately 100,000 gpm. It is important to note that this does not include the spare pump requirement. Also, as previously mentioned, the WWTP effluent discharges were not accounted for in the ICPR models. It is recommended that the WWTP effluent be accounted for in modeling efforts due to their potential discharge volumes based on their permitted amounts.

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