Engineering Analysis Report
(draft)

Houston Levee Certification - Phase II

Report prepared by

Mead & Hunt

January 4, 2016

ENGINEERING ANALYSIS REPORT

PHASE II – LEVEE CERTIFICATION

CITY OF HOUSTON, MINNESOTA

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Karen L. Wiemeri, P.E.
License No. 21122 Date: January 4, 2016

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1. Executive Summary

The City of Houston (City) retained Mead & Hunt, Inc. (Mead & Hunt) to provide coordination, research and evaluation to certify that the existing levee system will meet minimum design, operation and maintenance standards as specified by the requirements of Title 44, Chapter 1 of the Code of Federal Regulations, Section 65.10 (44 CFR 65.10).

A certification would signify that the Houston Levee System has met all of the requirements established by the Department of Homeland Security, Federal Emergency Management Agency (FEMA) for determining that the flood protection system can be reasonably expected to protect against a flood event with 1% or less probability of being exceeded in any given year, defined as the base flood. This Engineering Analysis Report presents the investigation and analysis of the City's levee system.

FEMA advised the City that they would be updating flood maps and that the land behind the levees would be protected by Provisionally Accredited Levee, or PAL, designation on the Digital Flood Insurance Rate Map (DFIRM) on October 7,2014. The City is required to submit data and documentation demonstrating to FEMA that all the levee components were still functioning and have met all of the regulations set forth in 44 CFR Section 65.10. Once compliance with 44 CFR Section 65.10 is demonstrated, the levee system will be accredited by FEMA and shown on National Flood Insurance Program (NFIP) maps, reflecting the appropriate risk zones for levee-impacted areas.

Accreditation is not a guarantee of performance during a flooding event. No levee system eliminates all flood hazards that can affect the landward of the levee system. Some level of flood hazard exists in all areas within and surrounding levee systems.

As part of the engineering analysis a subsurface exploration and field testing program was completed by Braun Intertec in August of 2015. This was necessary to verify the condition of the levee embankment and foundation soils immediately beneath the levee.

The Flood Insurance Study (FIS) for City of Houston, Minnesota dated August 23, 2000 and Houston County dated June 6, 2001, were utilized for the levee assessment of the base flood condition. Also used were the current design standards from the United States Army Corps of Engineers (USACE) and FEMA for the analysis.

As outlined in 44 CFR 65.10, FEMA requires that levee systems meet and continue to meet or exceed the following requirements:

(1) Freeboard

The surveyed elevations, base flood, and calculated freeboard are presented in **Table 3.1 – Levee Freeboard** represents current conditions. Surveyed elevation and the base flood profile from Sta. 62+60 to Sta. 64+00, Sta. 71+75 to Sta.114+00 and from Sta. 118+00 to Sta.121+00 indicates that the levee ***freeboard is not in compliance*** with 44 CFR 65.10(b)(1)(i) – Freeboard.

(2) Closures

Analysis of the closures and supporting documentation indicates that all openings that are structural parts of the system are in compliance with 44 CFR 65.10(b)(2) – Closures.

(3) Embankment Protection

The embankment is protected by vegetation. Analysis of the embankment protection and supporting documentation received indicates that the embankment protection is in compliance with 44 CFR 65.10(b)(3) – Embankment Protection.

(4) Embankment and Foundation Stability

Assessments of current and historical geotechnical exploration as well as seepage and stability analyses were performed to evaluate the levee stability. Analysis of the embankment and supporting documentation indicates that the embankment and foundation stability is in compliance with 44 CFR 65.10(b)(4) – Embankment and Foundation Stability.

(5) Settlement

Assessment of the analysis of the potential and magnitude of losses of freeboard as a result of levee settlement was performed. Analysis of the embankment and supporting documentation indicates that the embankment *settlement is not in compliance* with 44 CFR 65.10(b)(5) – Settlement because there has been a loss of freeboard.

(6) Interior Drainage

The assessment of the interior drainage utilizing updated hydrology and updated ground surface elevation data indicates that the pumping station will sufficiently convey the100-year storm event through the levee when the Root River is at the base flood elevation. The analysis of the interior drainage indicates that the pumping plant and ponding areas are in compliance with 44 CFR 65.10(b)(6) – Interior Drainage.

(7) Operation and Maintenance Plan (O&M Manual)

The O&M Manual is to document the procedures for monitoring, inspection, operation and maintenance of the levee system. The manual serves as a guide for operating procedures before, during, and after a flood emergency as well as for regularly scheduled maintenance. The existing O&M Manual is in compliance with 44 CFR 65.10(b).

(8) Other Design Criteria

No other design criteria have been requested by FEMA at this time.

A Capital Improvement Plan contained in Section 10 identifies the City's capital expenditures for the levee system. Mead & Hunt will work with the City public works to determine the exact costs to raise the levee to meet FEMA Freeboard requirements.

Based on its current condition Mead & Hunt will certify the Houston Levee System as part of Phase III – 44 CFR65.10(b) *Design Criteria Certification Materials Submittal* once the levee freeboard complies with 44 CFR 65.10(b)(1)(i) Freeboard. Phase III consists of the completion for the certification materials for submission by the City to FEMA.

2. Introduction

The City received PAL designation on the DFIRM on October 7, 2014. A PAL is shown on the DFIRM to provide probable protection against the base flood. The area landward of the levee is shown as Zone X (shaded) on a flood map except for areas of residual flooding such as ponding areas, which are shown as Special Flood Hazard Areas.

This Engineering Analysis Report is a consolidated document for Levee System Certification Determination in support of NFIP as administered by FEMA. The findings of this report is used to determine whether the levee system has met specific structural, operational, and maintenance requirement for certifying that the levee system will protect the City from a flood less than or equal to the annual one-percent (100-year or base flood) exceedance flood level.

FEMA uses levee accreditation to show a levee system provides protection from a base flood for its Flood Insurance Rate Maps (FIRMs). FIRMs are the official maps for communities where FEMA has delineated the flood hazard areas.

If the levee cannot be certified to provide protection from the base flood, FEMA will remap the levee-protected area as high-risk areas. Flood insurance will be required in high-risk areas for any mortgage that is federally backed, regulated, or insured. It is important to note that certification and accreditation correlate to the base or lower flood and that the possibility of greater floods that overtops or fails the levee exists.

Projects built to the base flood event do not entirely eliminate the risk of flooding. The base flood as it relates to the NFIP, is used to determine flood insurance requirements and is not a safety standard.

FEMA guidelines for assessing the eligibility of a levee system are based on established criteria. For the purposes of the NFIP, FEMA established levee certification criteria for:

- Design (freeboard, closures, embankment protection, embankment and foundation stability, settlement, and interior drainage)
- Operation plans and criteria
- Maintenance plans and criteria
- Actual certification requirements (as-built drawings, forms, documentation, data)

The evaluations were done to identify design issues in features specifically addressed in the FEMA requirements and validate effective design parameters based on the performance of the levee system. As part of this study, current design standards from the USACE and FEMA were used for the analyses.

A. System description

(1) Location

The Houston River Levee System as shown on **Exhibit 2.1 – Location Map,** is located in the City of Houston, Minnesota. The levee system is located on the Root River, 17 miles upstream of its confluence with the Mississippi River near La Crescent, Minnesota. The levee begins near the base of the bluff at the southwestern edge of the City, crossing CSAH 13 and US Hwy 16. The levee then turns to the northeast, and runs for a further 1400 feet. The levee then turns east, for approximately 1,200 feet to where it intersections Minnesota Hwy 76. On the east side of Minnesota Hwy 76, the levee extends 2,100 feet further in a generally eastward direction until it intersects Henderson Street. The levee then turns to the south, overlapping Henderson Street for 400 feet before turning to the southeast. The levee runs southeast for 700 feet, then turns east. The levee runs east for 2,000 feet, then turns south. The levee extends south for 400 feet, terminating at the intersection of Minnesota Hwy 76 and US Hwy 16.

(2) Project authorization

Construction of the flood barrier project was authorized by Section 205 of the 1948 Flood Control Act, as amended. The Levee System was constructed by the USACE in 1996-1998 and operations and maintenance were transferred to the City on October 6, 2003.

(3) Public sponsor

The local sponsor for the Houston Levee System is the City of Houston, Minnesota. The current point of contact is Christina Peterson, City Administrator.

(4) Principal features

The project protects a 0.65 square mile area in and around the City. The principal features include two miles of levee, a high-flow channel on the Root River, a flood warning system, pumping station, ponding areas, interior ditches, three gravity outlets and two relief wells.

(5) Datum

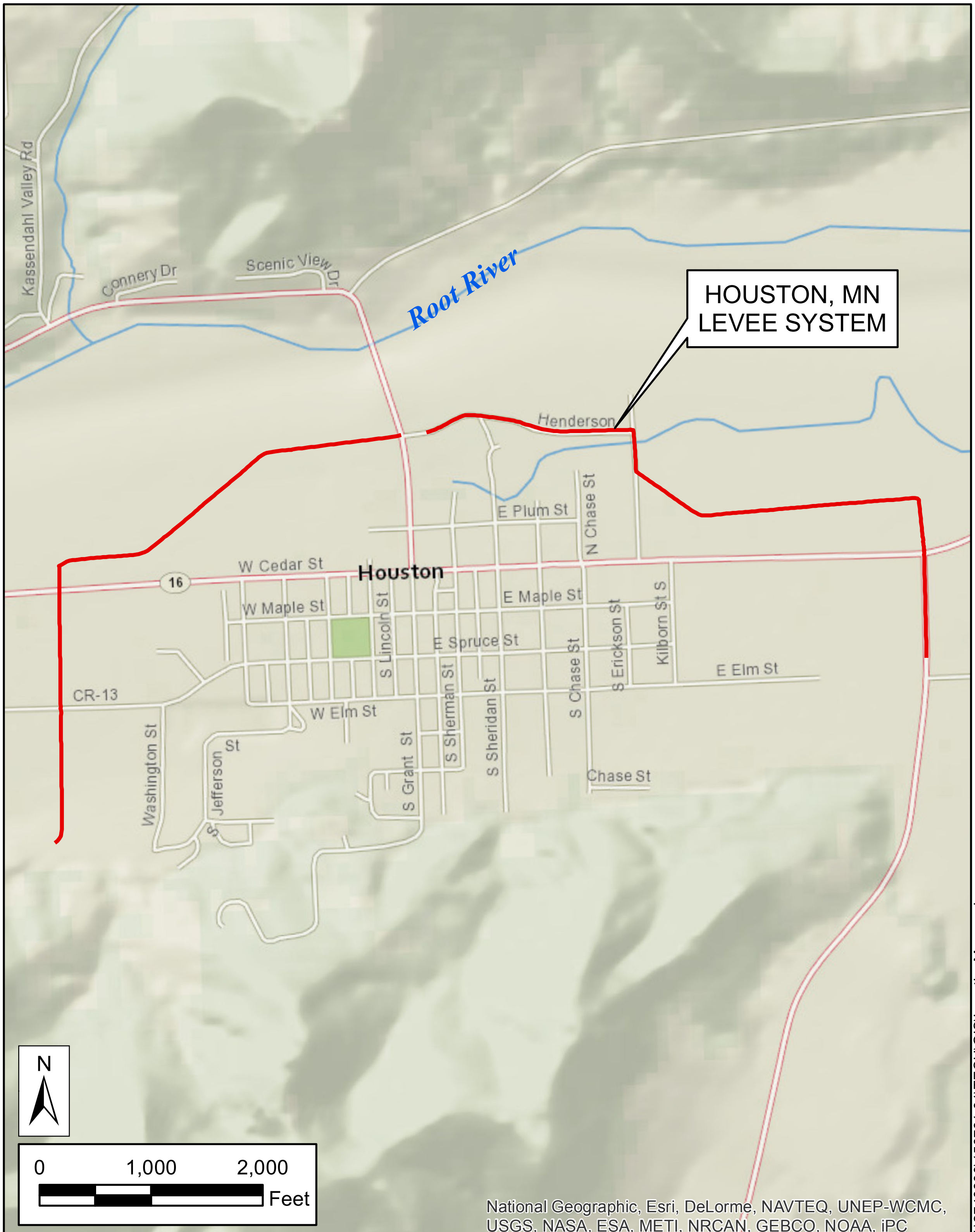
The elevation datum used in the design documents and as-built drawings is the National Geodetic Vertical Datum of 1929 (NGVD29) datum. The datum used in the Flood Insurance Study is North American Vertical Datum 1988 (NAVD88). The NAVD88 datum is the current standard that is and will be used for analyses of the levee system.

The conversion from NGVD29 datum to NAVD88 is:

NAVD88 = NGVD29 + 0.002.

(6) Minnesota State Highway 76

A portion of the levee system utilizes Minnesota State Highway 76 for protection. The City does not have access for this levee segment. The City met with FEMA and Minnesota Department of Transportation (MNDOT) to discuss how to proceed with the certification process since the highway is part of the levee system. **The City will need to continue to work with USACE, MNDOT and FEMA to determine who will certify Minnesota State Highway 76 as being part of the levee system.** FEMA may not accredit the City's levee system without Minnesota State Highway 76.



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City of Houston, MN Levee Certification 2740800-150761.01 June 2015	Location Map	Exhibit 2.1	Mead & Hunt

(7) Overall performance history

The United States Geological Survey (USGS) maintains River Gage No. 05385500, South Fork Root River near Houston, MN (drainage area 1,270 square miles). The gage datum is 667.0 feet (NGVD 29) 667.002 feet (NAVD88). The Houston gage has been in operation for the years 1909-1917; 1930-1983; and 1985- present. Flood stage at this location is 15 feet or Elevation 682.0 (NGVD 29) 682.002 (NAVD88). Major flood stage is 18 feet or Elevation 685.0(NGVD 29) 685.002 (NAVD88).

The past flood history for the Root River at Houston is shown in **Table 2.1 – Past Flood History at USGS No. 05385500.**

Table 2.1 - Past Flood History at USGS No. 05385500		
Flood Year	**Peak Gage Height (ft.)**	**Elev. (NAVD88)**
Top of levee	**24.54**	**691.54**
03/02/1965	18.32	685.32
08/19/2007	18.15	685.15
06/02/2000	17.59	684.59
09/17/2004	16.56	683.56
03/27/1950	16.56	683.56
02/23/1985	16.50	683.50
05/21/2013	16.42	703.42
03/15/2007	16.18	683.18
04/02/1993	16.14	683.14
06/10/2008	16.13	683.13

The project design flood frequency was 1 percent based on HECWRC a statistical method for computing the flood frequency given the stream gage record. The design flood discharge is 37,900 cubic feet per second (cfs), measured at the gauging station near Houston, MN. The top of levee profile was computed with a discharge of 92,000 cfs. This discharge is for the top of levee which is at 3 feet above the design elevation.

Flooding on the Root River can occur during all seasons of the year; however major floods generally occurred in early spring.

Based on the flood history, as given in **Table 2.2 – Flooding Duration**, flood stages would be expected to last approximately 2.5 days, with major flood stages may be expected to last 1 day. Water year periods have been omitted in the table because flood stage was not reached.

Table 2.2 - Flooding Duration							
Water Year	**Date of Peak**	**Peak Gage Height**	**Date Start of Flood Stage***	**Days Above Flood Stage**	**Days Above Major Flood Stage****	**Days to Major Flood Stage**	**Days to Peak Flood Stage**
1950	3/27	16.56	3/26	3	-		1
1961	3/27	15.10	3/25	4	-		2
1965	3/2	18.32	3/1	3	1	1	1
1980	9/21	15.29	9/21	1	-		1
1985	2/23	16.5			-		
1993	4/2	16.14	3/31	2	-		1
2000	6/2	17.59	6/1	2	-		1
2000	7/12	16.0	7/10	2	-		1
2001	4/13	15.51	No data		-		
2004	9/17	16.56	9/16	2	-		1
2007	3/15	16.18	3/14	2	-		1
2007	8/19	18.15	8/18	3	1		1
2008	6/10	16.13	6/8	6	-		2
2010	9/27	15.54	No data		-		
2013	5/21	16.42	5/20	2	-		1

*flood stage = 15 feet; **major flood stage = 18 feet

3. Freeboard

Levee freeboard, as defined by FEMA, is the height distance between the top of a levee and the water surface elevation of the base flood. The levee system is a riverine levee. Therefore for a riverine levee a minimum of 3 feet of freeboard above the base flood is required.

In addition to the minimum 3 feet, 44 CFR 65.10(b)(1) requires that an additional one foot is required within 100 feet of either side of structures riverward of the levee or where flow is constricted. A 3.5 foot freeboard is required along the length of the upstream tieback levee and at the upstream end of the main levee and tapers to 3 feet at the downstream end of the levee.

The Flood Insurance Study (FIS) for City of Houston, Minnesota dated August 23, 2000 and for Houston County dated June 6, 2001, were used to establish the base flood elevations. The panels used to determine the base flood elevations were 2701900065C, 2701930001D, 27019000105C and 2701900070C. To determine the base flood elevations cross sections were AC, AD, AE, AF, AG, AH, AI, AJ, AK, AL, A, B, C, D, and E and from the South Fork Root River A, B, C, D, E were used to determine "with floodway" base flood water surface elevations along the Root River.

The surveyed top of levee was taken from the survey performed by the USACE in 2008 and a portion of the levee from Highway 76 east to the end of levee by Mead & Hunt during August 2015. The freeboard was determined by subtracting the base flood elevation from the surveyed top of levee elevation. Based on the field survey information, the levee sections that do not meet freeboard requirements are:

- Sta. 62+60 to Sta. 64+00,
- Sta. 71+75 to Sta.114+00 and
- Sta. 118+00 to Sta.121+00.

Table 3.1 - Levee Freeboard summarizes the findings of the freeboard analysis, referenced to the NAVD88. The profile of the surveyed top of levee is plotted against the base flood and is shown on **Exhibits 3.1 – 3.6 Levee Freeboard**.

To raise the levee at these station to meet FEMA's freeboard requirement is to raise the levee by placing gravel or topsoil. The estimated cost for this work is found in Section 10 and in Appendix C.

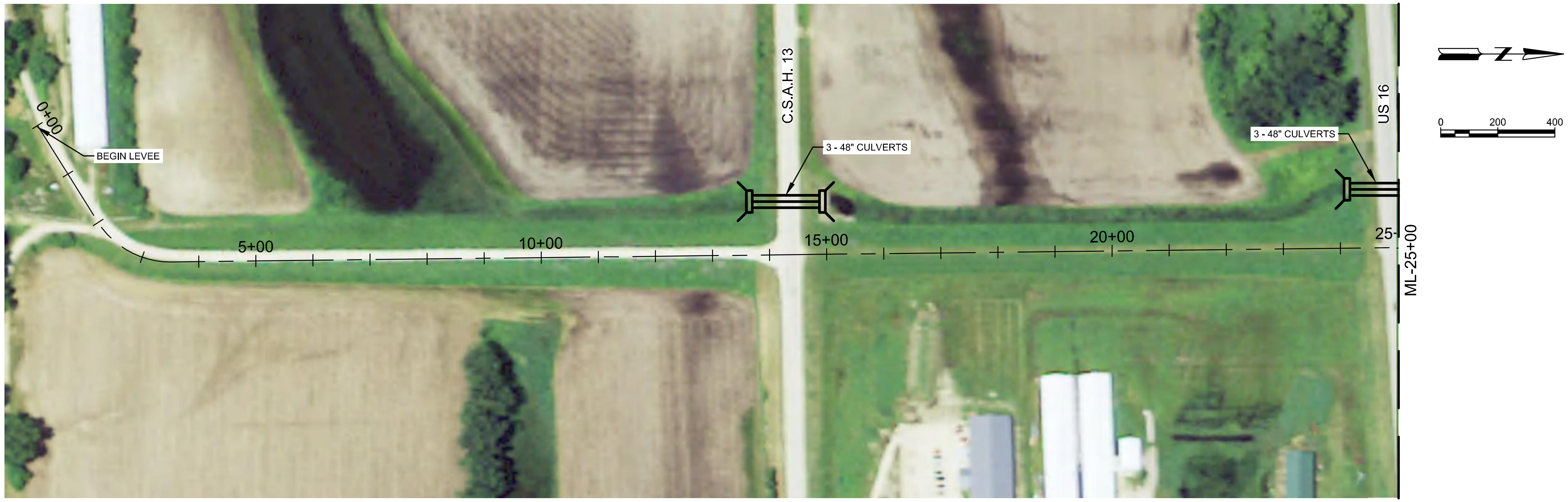
Table 3.1 – Levee Freeboard

STATION	Surveyed Cl. Elevation	base flood elevation	freeboard	req'd freeboard	Raise levee (inches)
2+11	695.177	686.3	8.88	3.5	
4+06	694.416	686.3	8.12	3.5	
8+20	694.5	686.3	8.20	3.5	
12+26	694.497	686.3	8.20	3.5	
16+16	694.048	686.3	7.75	3.5	
20+22	693.937	686.3	7.64	3.5	
24+23	693.728	686.3	7.43	3.5	
28+00	*End tie-back levee*				
28+58		686.3		Section E	
30+08	694.821	686.3	8.52	3.49	
32+26	694.426	686.3	8.13	3.48	
35+00		686.3		Section D	
35+27	694.056	686.28	7.78	3.47	
36+09	694.06	686.21	7.85	3.46	
40+18	693.907	685.88	8.03	3.45	
42+22	692.977	685.71	7.27	3.44	
44+10	693.158	685.56	7.60	3.43	
45+80	692.821	685.42	7.40	3.42	
46+00		685.4		Section C	
48+02	692.673	685.31	7.36	3.41	
48+30	692.609	685.30	7.31	3.41	
50+49	691.712	685.20	6.51	3.40	
52+28	691.466	685.12	6.35	3.39	
54+59	691.214	685.02	6.20	3.38	
55+00		685.0		Section B	
58+07	691.304	684.69	6.61	3.37	
59+50	691.498	684.55	6.95	3.36	
60+07	691.103	684.49	6.61	4	
61+09	693.159	684.39	8.77	4	
61+28	694.119	684.37	9.75	4	
62+00	690.16	684.30	5.86	4	
62+58	688.55	684.24	4.31	4	
63+00	687.38	684.20	3.18	3.35	2.04
64+00	687.56	684.10	3.46	3.34	
65+00	687.55	684.0	3.55	3.34	
70+00	687.05	683.5	3.55	3.31	
71+75	686.56	683.33	3.24	3.31	0.84
72+00	686.25	683.30	2.95	3.31	4.32
75+00	685.86	683.00	2.86	3.29	5.16
77+00				Section A	
80+00	685.54	682.64	2.90	3.27	4.44
85+00	685.22	682.38	2.94	3.25	3.72
90+00	684.96	682.11	2.85	3.23	4.56
95+00	684.44	681.85	2.59	3.20	7.32
100+00	684.36	681.59	2.77	3.18	4.92

Table 3.1 – Levee Freeboard

STATION	Surveyed Cl. Elevation	base flood elevation	freeboard	req'd freeboard	Raise levee (inches)
102+00	684.28	681.48	2.80	3.17	4.44
103+00	684.28	681.43	2.85	3.17	3.84
104+00	684.31	681.38	2.93	3.16	2.76
105+00	684.30	681.32	2.98	3.16	2.16
106+00	684.27	681.27	3.00	3.15	1.80
108+00	684.14	681.16	2.98	3.15	2.04
110+00	684.01	681.06	2.95	3.14	2.28
112+00	683.63	680.95	2.68	3.13	5.40
113+00	*Begin levee tieback*				
113+00	683.62	680.90	2.72	3.00	3.36
114+00	683.72	680.90	2.82	3.00	2.16
115+00	683.92	680.90	3.02	3.00	
116+00	684.15	680.90	3.25	3.00	
118+00	682.97	680.40	2.57	3.00	5.16
119+00	683.04	680.47	2.57	3.03	5.52
120+00	683.54	680.54	3.00	3.06	0.72
121+00	683.65	680.60	3.05	3.09	0.48
122+00	683.75	680.63	3.12	3.12	
125+00	684.14	680.72	3.42	3.21	
128+86	684.86	681.11	3.75	3.32	
134+84	685.1	681.40	3.70	3.5	
135+00	*End levee as shown on FIRM*				

Note: gray area indicates levee does not meet freeboard.



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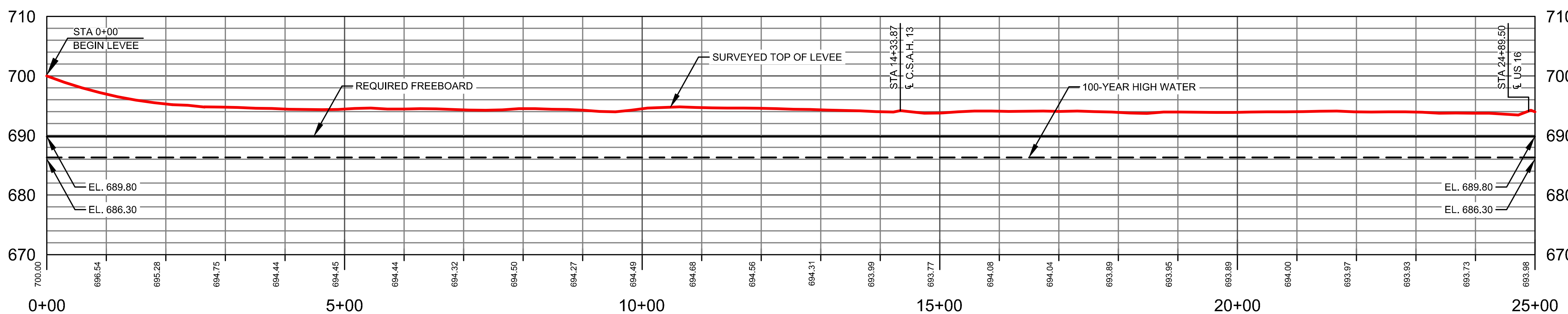

PROFILE

CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

LEVEE FREEBOARD - STA 0+00 TO STA 25+00

Mead & Hunt

EXHIBIT 3.1

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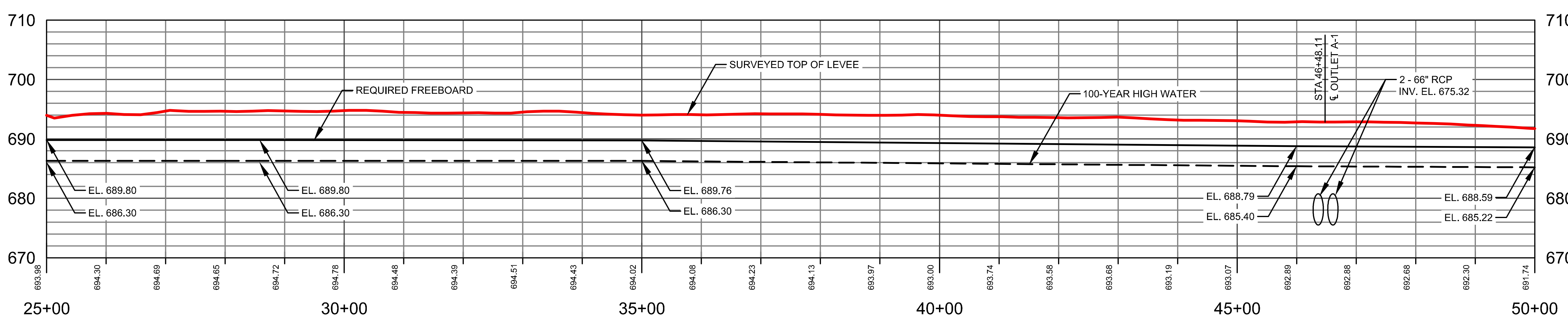

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CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

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LEVEE FREEBOARD - STA 25+00 TO STA 50+00

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EXHIBIT 3.2

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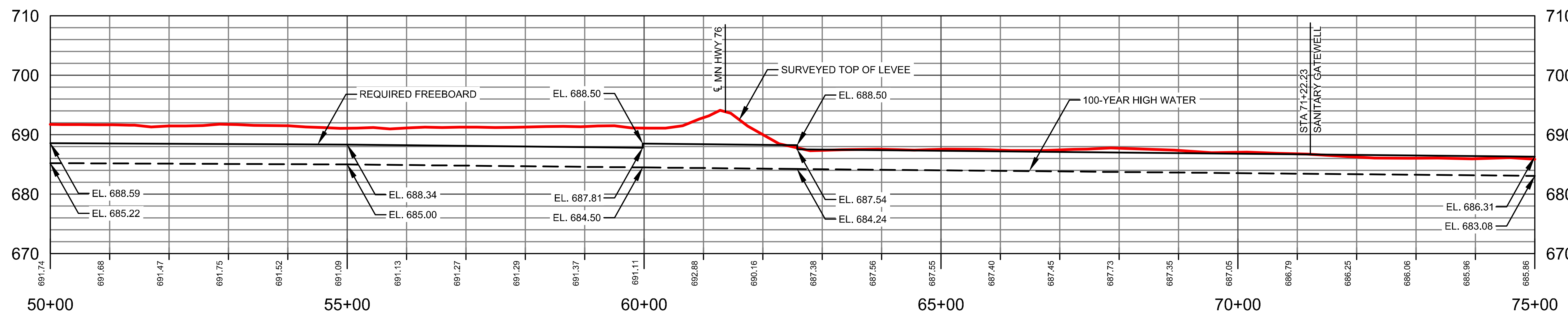

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CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

LEVEE FREEBOARD - STA 50+00 TO STA 75+00

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EXHIBIT 3.3

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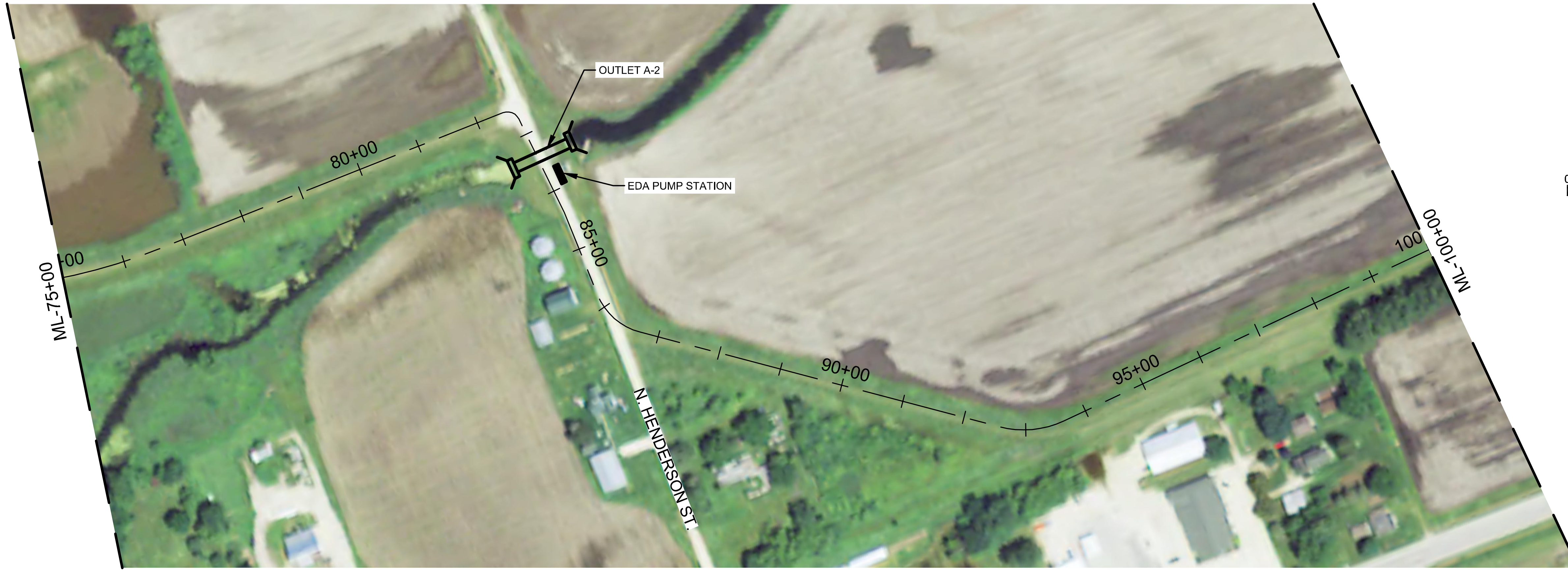

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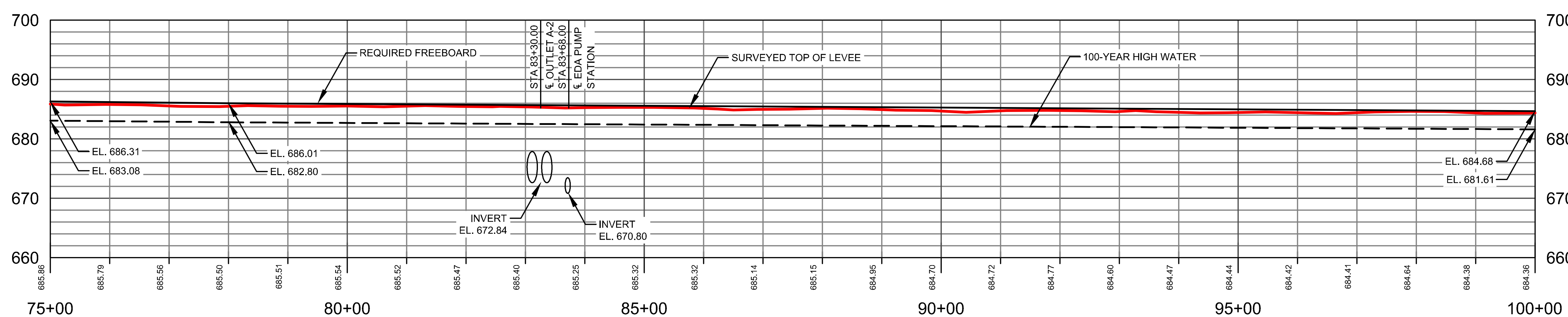

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CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

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SEPT 2015

LEVEE FREEBOARD - STA 75+00 TO STA 100+00

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EXHIBIT 3.4

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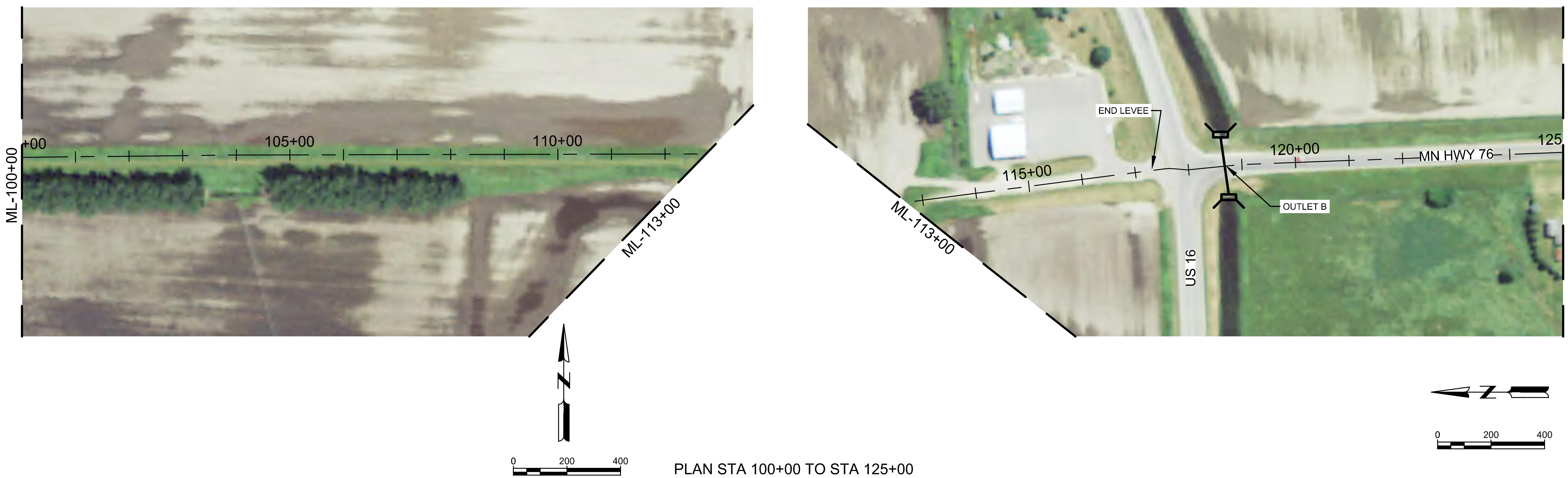

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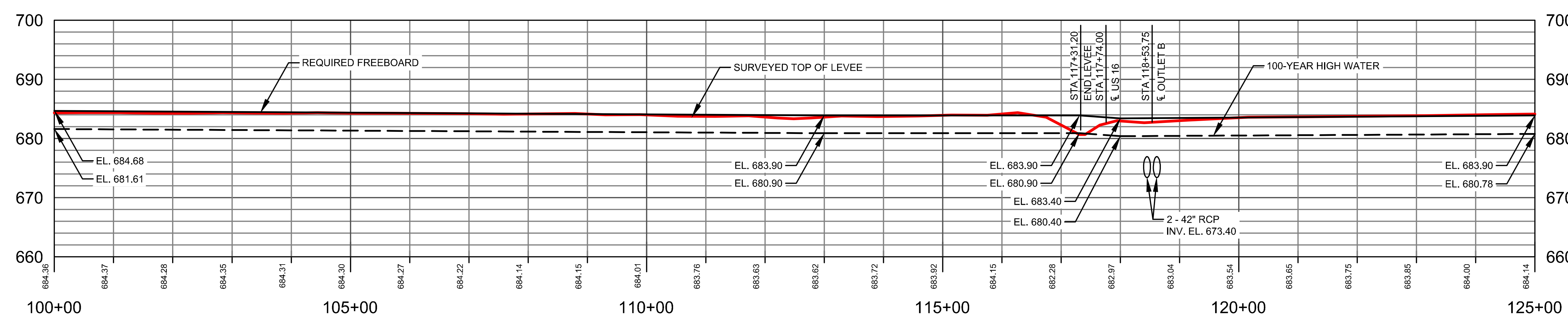

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CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

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SEPT 2015

LEVEE FREEBOARD- STA 100+00 TO STA 125+00

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EXHIBIT 3.5

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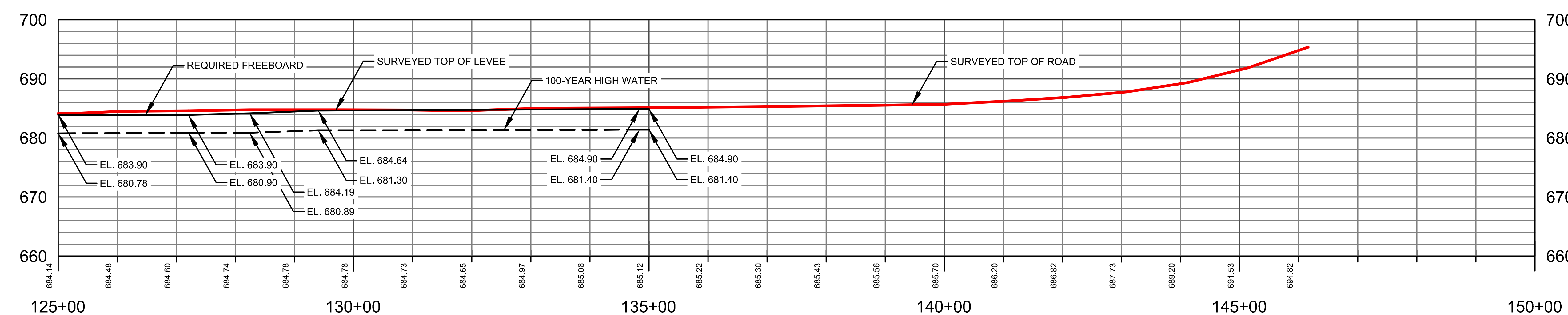

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CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

4158900-121186.01
SEPT 2015

LEVEE FREEBOARD - STA 125+00 TO STA 146+16

Mead & Hunt

EXHIBIT 3.6

4. Closures

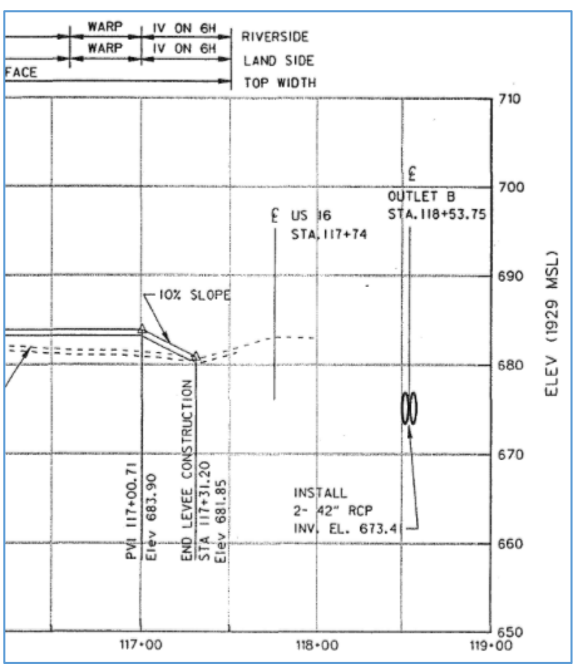
Closures refer to openings within the flood protection system that are placed or erected at various openings in the levee during a flood event. 44 CFR 65.10(b)(2) requires that all openings contain closure devices that are structural parts of the system.

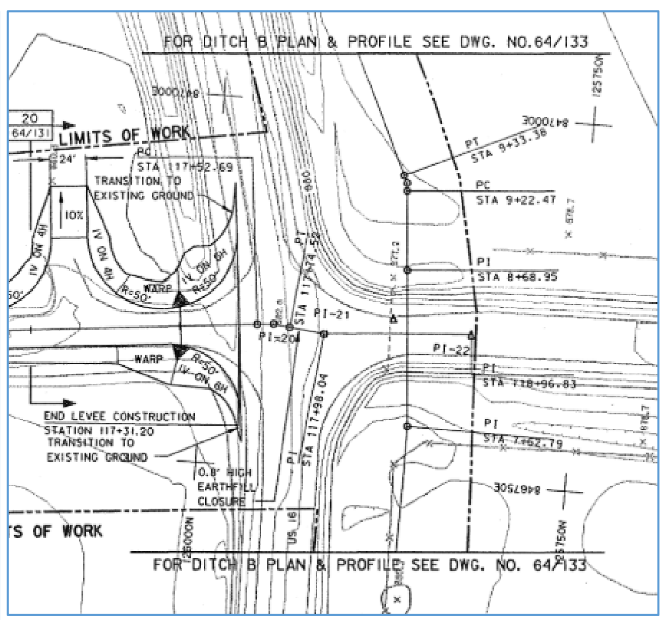
A. Engineering analysis

(1) Sandbag closure

As stated in the Operation and Maintenance Manual, in order to attain the base flood level of protection at Highway 16, the crown of the road is one foot lower than the levee therefore a sandbag closure or earthfill closure is required. The sandbags are installed when the river elevation is at Elevation 681.85 feet.

Sandbag Closure





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(2) Outlet structures

Three outlet structures carry interior storm drainage out of the protected area through the levee system. Each outlet pipe is equipped with a flap gate. During a flood event, the pressure from water on the outside of the gates seals the gate closed. In case the flap gates don't operate properly during a flood, or when a secondary means of closure is needed outlets A-1, A-2, and B are equipped with reinforced concrete gatewells with heavy-duty rising stem sluice gates. These structures are listed in **Table 4.1 – Outlet Structures**.

The fourth structure to carry interior storm drainage out of the projected area is a box culvert. The structure is equipped with a flap gate. If the flap gate does not operate properly during a flood the structure is equipped with stop logs. It appears that the stop logs are permanently in-place.

Table 4.1 - Outlet Structures

Location	Station	Size & Type	Invert Elev.*
Outlet A-1	46+48.11	2 - 66-inch RCP inlet 3 - 48-inch RCP outlet	675.20
Outlet A-2	83+30	2 - 66-inch RCP inlet 3 - 48-inch RCP outlet	672.65
Outlet B	118+53.75	2 - 42-inch RCP	673.34
Box culvert	2000 ft. south of Hwy 16 under Hwy 76	4 ft X 8 ft Conc. box culvert	643.7

* taken from Record Drawing (not converted to NAVD88)

Outlet A-1

Outlet A-2

Outlet B

Box Culvert

(3) Miscellaneous Structures

A shut off valve at Station 71+22.08, is located in the gravity outlet from the wastewater treatment plant. The shut-off valve prevents floodwaters from backing into the City. The valve is to be closed when the river is at Elevation 682.0 feet.

5. Embankment protection

44 CFR 65.10(b)(3) requires engineering analyses that demonstrates that no appreciable erosion of the levee embankment should be expected during the base flood, resulting from currents or waves. Further, anticipated erosion will not result in failure of the levee embankment or foundation directly or indirectly by seepage, piping or sand boils.

Levee embankments should be protected against erosion and scour associated with a base flood event. The following is a list of the general factors that are to be addressed as part of the analysis of embankment protection: flow velocities; channel migration; Ice and debris loading; embankment and foundation materials; duration and depth of flooding; embankment alignments; transitions and bends and embankment condition.

B. Engineering analysis

(1) Existing earthen levee section

The levee was constructed having a minimum top width of 10 feet and symmetrical riverside and landside minimum slopes at 3 horizontal to 1 vertical (3H:1V) The slopes of the levee are generally covered with grass on the land and river side.

(2) Embankment and foundation materials

The levee embankment is composed of sandy to silty clays. The foundation materials consist of natural alluvial deposits and fills.

(3) River velocities

The FIS was used to determine the mean velocity of the floodway at each established cross section. From the FIS, the floodway mean velocities at certain cross sections in feet per second (fps) along the Root River are:

Table 5.1 - Floodway velocity

Cross Section	Floodway Mean Velocity (fps)
A	4.4
B	5.2
C	4.7
D	3.1
E	0.2
AM	4.2
AL	3.1
AK	4.7
AJ	5.2
AI	7.5
AH	8.2
AG	7.1
AF	4.4
AE	4.7
AD	4.3
AC	3.0

The hydrologic and hydraulic analyses were prepared by the USACE, St. Paul District, for FEMA. The USACE design velocities from the *Design Memorandum and Environmental Assessment*, May 1991 lists the base flood left bank velocities as:

Table 5.2 - Design velocity	
Cross Section	**Left Bank Velocity (fps)**
7	1.9
8	1.5
9	2.1
10	1.7
11	1.5
12	3.2
13	3.2
13.5	3.1
14	2.6
15	2.1
16	2.4
17	2.7

The permissible velocity for the embankment material, as found in EM 1110-2-1601, Hydraulic Design of Flood Control Channels, U.S. Army Corps of Engineers, Table 2-5, for grass-lined earth, silt clay, is 8.0 fps. Therefore, the embankment protection currently existing on the levee system meets the requirements.

(4) Slope protection techniques

During the design phase of the project USACE proposed that no erosion protection be placed along the levee. The levee alignment was determined to be far enough away from the river so that erosion will not jeopardize the levee. The levee slope is grass covered.

(5) Expected wind and wave action

Wave height for wind fetch and wave run-up heights are important consideration in determining the adequacy of the freeboard of the river levee system. Wave height from wind fetch is the vertical distance above the river level that is the result of the horizontal tractive stress exerted by wind blowing over a water surface and the distance of unobstructed water surface over which the winds blow.

The methodology contained in EM 1110-2-1100, Part II Chapter 2, was used for the analysis for the expected height during the base flood event. The National Climatic Data Center (NCDC) publication "Climatic Wind Data for the United States" (1988) was used as a reference for observed wind data in La Crosse, WI which is close to Houston, MN. The prevailing wind direction for the area is from the northwest during spring flood season and from the south during summer flood season. The peak wind gust during summer flood season is 63 mph (fps) and 53 mph (fps) during spring flood season. The maximum wave height was calculated to be 1.58 feet for summer flood season and 1.48 feet for spring flood season.

The base flood water surface elevation plus the wave height is:

Station	Top of Levee Elevation	Wave Height + Base Flood
64+00	687.6 feet	685.68 feet
107+00	684.2 feet	682.81 feet

Therefore, adding the wave heights to the expected base flood profile does not top the levee.

(6) Ice and debris loading

Obstruction of flow caused by either ice or debris loading can significantly increase the water stage elevation upstream of the obstruction. The City is not subject to flooding from ice jams. Ice loads are not considered to be significant since the major structures are above the spring floods.

(7) Levee alignment

The levee begins near the base of the bluff at the southwestern edge of the City, crossing CSAH 13 and US Hwy 16. The levee then turns to the northeast, and runs for a further 1400 feet. The levee then turns east, running 1,200 feet to where it intersections Minnesota Hwy 76. On the east side of Minnesota Hwy 76, the levee runs a further 2,100 feet in a generally eastward direction until it intersects Henderson Street. The levee then turns to the south, overlapping Henderson Street for 400 feet before turning to the southeast. The levee runs southeast for 700 feet, then turns east. The levee runs east for 2,000 feet, then turns south. The levee runs south for 400 feet, terminating at the intersection of Minnesota Hwy 76 and US Hwy 16.

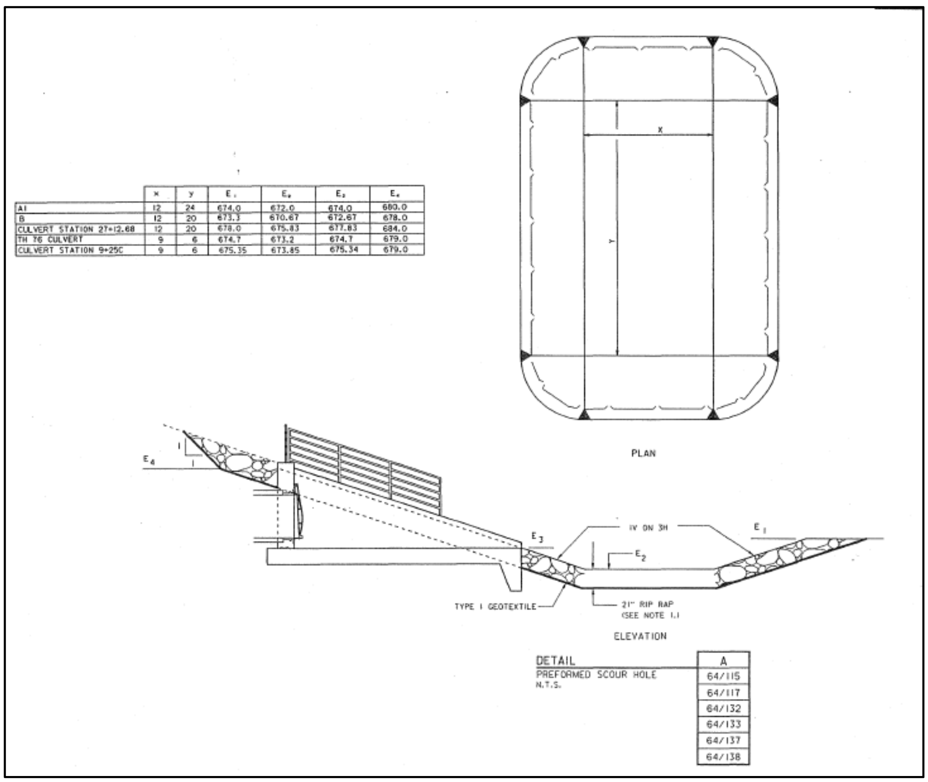
(8) Outlet design

Erosion at pipe or channel outlets is common. The flow condition, scour potential and channel erosion was reviewed. The site conditions for the culvert outfalls do not allow for use of a stilling basin.

Table 5.3 – Outlet Condition for low flow in the river conditions, lists the discharge for the 100-year storm in cubic feet per second (cfs) and associated velocity in feet per second (fps). The outlet conditions are based on NOAA Atlas 14 100-year rainfall event.

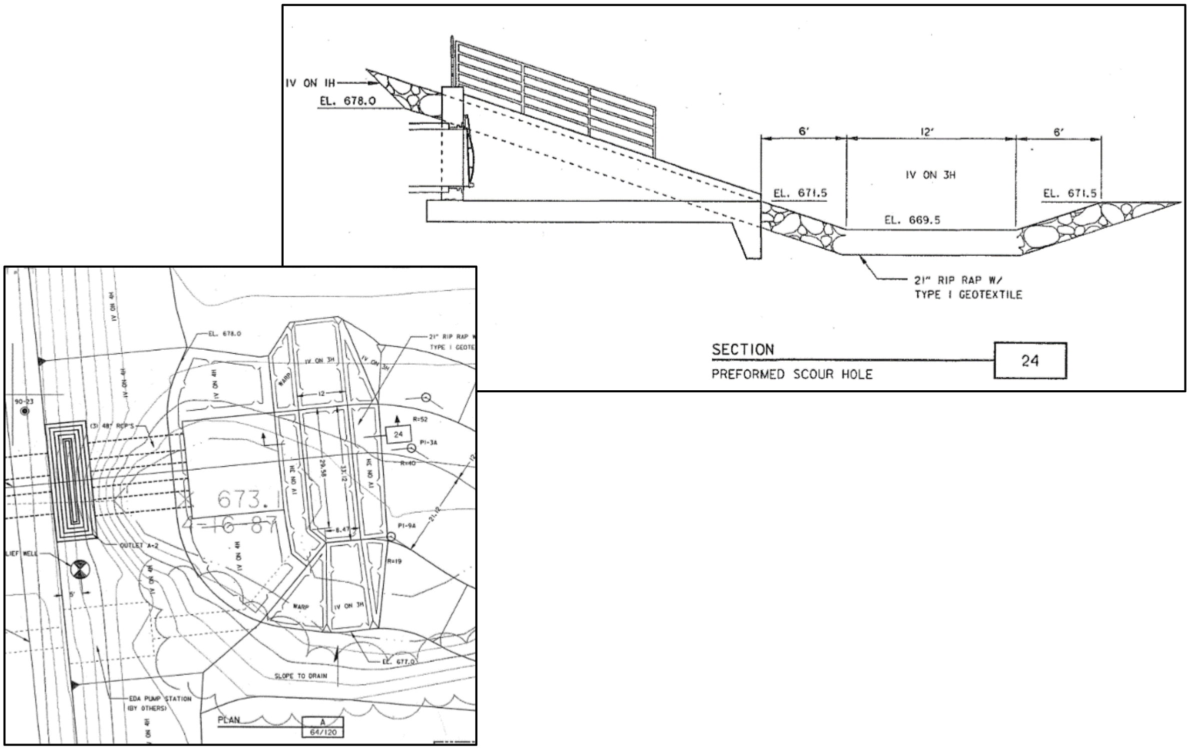
Table 5.3 - Outlet condition				
Culvert	**Station**	**Size and Type**	**100-year Discharge (cfs)**	**100-year Velocity (fps)**
Outlet A-1	46+48.11	2 - 66-inch RCP inlet 3 - 48-inch RCP outlet	31	1.9
Outlet A-2	83+30	2 - 66-inch RCP inlet 3 - 48-inch RCP outlet	181	6.0
Outlet B	118+53.75	2 - 42-inch RCP	95	4.8
Box culvert	2000 ft. south of Hwy 16 under Hwy 76	4 ft X 8 ft Conc. box culvert		

The USACE design for the outlets preformed riprap scour holes, or riprap basin, was based on criteria in WES Miscellaneous Paper H-72-5, “Practical Guidance for Estimating and Controlling Erosion at Culvert Outlets”, May 1072 and the riprap gradation from ETL 1110-2-120.



At Outlet A-1 there is a preformed riprap scour hole with a 12-foot by 24-foot base with 1 on 3 side slopes. The riprap was designed to be 12-inch thick of Type A gradation, as shown in **Table 5.4 – USACE Design Riprap Gradation**, placed on a 21-inch thickness of Type B gradation. Riprap was to be placed along the ditch bottom and 10 feet up the side slopes on the downstream end of the ditch.

At Outlet A-2 there is a preformed riprap scour hole with a 12-foot by 24-foot base with 1 on 3 side slopes. The riprap was designed to be 12-inch thick of Type A gradation placed on a 21-inch thickness of Type B gradation. Riprap was to be placed along the ditch bottom and 10 feet up the side slopes on the downstream end of the ditch.



At Outlet B there is a preformed riprap scour hole with a 10.5-foot by 20-foot base with 1 on 3 side slopes. The riprap was designed to be 12-inch thick of Type A gradation placed on a 21-inch thickness of Type B gradation. Riprap was to be placed along the ditch bottom and 10 feet up the side slopes on the downstream end of the ditch.

Table 5.4 - USACE Design Riprap Gradation			
Type A Riprap		**Type B Riprap**	
% Lighter By Weight	**Limit of Stone Weight In Pounds**	**% Lighter By Weight**	**Limit of Stone Weight In Pounds**
100	86 35	100	137 55
50	36 17	50	58 27
15	18 5	15	29 9

6. Embankment and foundation stability

44 CFR 65.10(b)(4) requires an analysis that evaluates levee embankment stability. The analyses shall evaluate the expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the levee foundation and embankment will not jeopardize embankment or foundation stability.

Embankment and foundation stability was analyzed to determine the global slope stability of the levee for several cross sections. The analysis focuses on embankment failures which could lead to breaching of the levee during base flood and rapid drawdown loading conditions.

Information and data utilized for the analysis included a review of the record drawings, soil boring logs, design calculations and inspection reports conducted by the USACE. A visual inspection consisting of traversing the levee embankment along the entire length was also completed by Mead & Hunt during May 2015. The general evaluation criteria used follows USACE guidelines. The geotechnical evaluation of the levee is based on geotechnical exploration and tests performed by Braun Intertec and the work previously conducted for the USACE during the design phase of the levee project.

A. Subsurface exploration

(1) Field exploration

The field exploration was completed by Braun Intertec (Braun) during August, 2015. Mead & Hunt selected the boring locations based upon levee geometry and from data from historic soil borings. Mead & Hunt marked with paint and/or staked the boring locations in the field and also performed the horizontal and vertical survey control. The ground surface elevations are included on the boring logs.

The exploration consisted of standard penetration test borings at 23 locations. Soil sampling was general conducted at 2-foot intervals. If groundwater was encountered, the depth was observed and recorded.

Borings were conducted primarily to assess the condition of the levee fill materials and the soils immediately underlying the levee fill. The subsurface exploration report dated September 30, 2015 prepared by Braun can be found in Appendix B.

(2) Laboratory testing

Samples obtained from the field investigation were retained at the laboratory of Braun. Testing included moisture content, grain size analysis, plastic and liquid limits, Consolidated Undrained (CU) triaxial with pore pressure measurements, direct shear and hydraulic conductivity laboratory testing.

Moisture contents were determined from the retained cohesive samples in accordance with ASTM D2216. To determine the plasticity of the cohesive soils, Atterberg Limits (ASTM D4318) were determined from the samples (ASTM D4318). Samples obtained from the thin-wall tubes were tested for unconfined compressive strength test in accordance with ASTM D2166 and dry density in accordance with ASTM D7263. The report dated September 30, 2015 summarizing the laboratory results and is included in Appendix B.

B. Engineering analysis

(1) Subsurface characterization and foundation conditions

The soils encountered in the 23 borings reflected conditions typical of the flood plain environment. Borings drilled at the levee crest encountered fill that was between 13 to 18 feet thick. The fill generally consisted of medium dense to dense, sand, silty sand to clayey sand, and medium to stiff silt and clay with sand. More detailed descriptions of the subsurface conditions encountered at each boring location are presented on the individual boring logs included in Appendix B.

(2) Seismic issues

According to the United States Geological Survey, the peak ground acceleration (PGA) for the Houston area is 0.003g for a mean return time of 108 years. EC 1110-2-6067 indicates if the PGA for the 100-year earthquake is less than 0.10g, no evaluation is required. The USGS site used to obtain this information was: https://geohazards.usgs.gov/deaggint/2002/. Since the USGS did not have a specific 100-year earthquake a 50% return period in 75 years was used to obtain information for the 108-year earthquake. The evaluation information is found in Appendix A.

(3) Depth of flooding

The depth of flooding is defined by the elevation difference between the base flood and the ground surface elevation at the landside toe of the levee. When these elevations were compared, there was an average of X feet of water against the levee. Levee sections were reviewed to determine crown and base widths and to compare base flood and landside toe elevations. **Table 6.1 - Depth of Flooding** provides an overview of the data from the review.

Table 6.1 - Depth of Flooding

Station	Approximate Crown Width (feet)	Base Flood Elev. (feet)	Landside Toe Elev. (feet)	Depth of Flooding (feet)
9+50	20	686.30	683.05	3.25
18+87	10	686.30	684.42	1.88
30+64	10	686.30	682.23	4.07
38+74	10	685.99	680.12	5.87
45+50	10	685.44	678.13	7.31
56+70	10	684.83	681.12	3.71
65+85	10	683.92	685.01	1.09
78+70	10	682.71	677.22	5.49
94+80	10	681.86	680.84	1.02
110+10	10	681.05	677.74	3.31

(4) Duration of flooding

Historical river flow data were reviewed to determine the duration of flooding. **Table 6.2 - Duration of Flooding** is presented below. Water years from that period omitted in the table did not reach flood stage.

Table 6.2 – Duration of Flooding							
Water Year	**Date of Peak**	**Peak Gage Height**	**Date Start of Flood Stage***	**Days Above Flood Stage**	**Days Above Major Flood Stage****	**Days to Major Flood Stage**	**Days to Peak Flood Stage**
1950	3/27	16.56	3/26	3	-		1
1961	3/27	15.10	3/25	4	-		2
1965	3/2	18.32	3/1	3	1	1	1
1980	9/21	15.29	9/21	1	-		1
1985	2/23	16.5			-		
1993	4/2	16.14	3/31	2	-		1
2000	6/2	17.59	6/1	2	-		1
2000	7/12	16.0	7/10	2	-		1
2001	4/13	15.51	No data		-		
2004	9/17	16.56	9/16	2	-		1
2007	3/15	16.18	3/14	2	-		1
2007	8/19	18.15	8/18	3	1		1
2008	6/10	16.13	6/8	6	-		2
2010	9/27	15.54	No data		-		
2013	5/21	16.42	5/20	2	-		1

*flood stage = 15 feet; **major flood stage = 18 feet

(5) Seepage

Under seepage below the embankment and seepage through the embankment is likely. Under seepage in pervious foundations soils may result in excessive hydrostatic pressures beneath an impervious top stratum on the land side, potentially resulting in sand boils and piping. Seepage through an embankment can emerge on the land side of the levee. This seepage can result in softening of the land side toe, sloughing of the slope, internal piping and/or decreased slope stability.

Seepage is dependent upon the levee embankment composition, levee geometry, foundation soils and duration of the high river stage. The phreatic surface and seepage affects slope stability and erosion of the levee through piping.

The USACE's calculations for underseepage quantities/rates used for the design are given below.

Levee Reach by Station	Average Levee Underseepage Quantity (gpm/ft. length/ft. height)
0+00 - 24+50	0.05
25+50 - 45+50	0.07
45+50 - 46+50	0.06
46+50 - 60+50	0.09
61+50 - 67+00	0.02 (est.)
67+00 - 75+00	0.04 (est.)
75+00 - 82+50	0.07
82+50 - 110+00	0.06
110+00 - 113+50	0.11
113+50 - 117+50	0.08
118+50 - 126+00	0.05
0+00T - 6+00T	0.07 (est.)

The purpose of the seepage analysis is to estimate where the phreatic surface may daylight on the landside toe of the levee, the flow gradient at that location, and the potential rate of seepage flowing to the surface. ETL 1110-2-569 was used as a general guideline for the seepage analysis.

The computer program SEEP2D, developed by the USACE, was used to evaluate the seepage characteristics of the levee at select locations. The hydraulic conductivities (K) used for the levee and foundation soils are presented in **Table 6.3 - Seepage Analysis Input**.

The allowable factor of safety, found in USACE in ETL 1110-2-569, for use in evaluation of seepage measures should correspond to a maximum exit gradient (i) at the toe of the levee of 0.5. In general, this would provide a factor of safety greater than 1.5 for internal erosion. Landside drainage ditches (along the toe of the levee), seepage berms and relief wells should have the same maximum exit gradient of 0.5.

Assumptions used in the seepage analyses included the following:

- Soil properties
- Steady-state flow conditions.
- Base flood elevation for the water level on the riverside of the levee.
- Landside ground surface profile is the exit face.
- Perforated pipes are not functional.

Table 6.3 - Seepage Analysis Input

Material	Hydraulic Conductivity K_H (cm/sec)	Hydraulic Conductivity K_V (cm/sec)
Sta. 9+50		
Sand embankment fill	1×10^{-2}	5×10^{-3}
Clay embankment fill	9×10^{-6}	9×10^{-7}
Organic clay	7×10^{-7}	7×10^{-8}
Sand (SP)	1×10^{-2}	1×10^{-3}
Silt	1×10^{-4}	5×10^{-4}
Sta. 30+64		
Silt embankment fill	1×10^{-4}	5×10^{-4}
Sand embankment fill	1×10^{-2}	1×10^{-3}
Sand (SP-SM)	5×10^{-3}	5×10^{-2}
Silty sand toe berm (SM)	1×10^{-3}	1×10^{-4}
Sand (SP)	1×10^{-2}	1×10^{-3}

The estimated critical gradient for each selected cross section and results from the modeling are attached in Appendix A. The SEEP2D analysis results for the exit gradient and seepage flow in cubic feet per day per foot of levee (ft.^{3}/day per ft.) are summarized in **Table 6.4 - Seepage Analysis Results – 100 year event**.

Table 6.4 - Seepage Analysis Results – 100 year event					
Station	Waterside Slope (H:V)	Landside Slope (H:V)	Length of Seepage Path (ft.)	Exit gradient at Landside Toe (i)	Seepage Flow (Q) ($ft.^3$/day per ft.)
9+50	4:1	4:1	88	.11	21.19
30+64	3:1	3:1	60	.22	3.82

The largest exit gradient determined during the base flood event at the landside toe of the levee is at Station 30+64, which is below the maximum allowable exit gradient of 0.5 specified by the USACE. The exit gradients at the landside toe of the levee meet USACE design guidelines.

The output of the analyses and other relative calculations can be found in Appendix A.

(6) Stability and strength requirements

The stability of levee landside slopes is primarily a function of the levee geometry, soil characteristics, river stage, pore water pressures and external loads applied to the levee.

The objective of the slope stability analysis is to determine the global slope stability of the levee at its most critical sections. The data used for the analysis is from recent LiDAR and crest survey along with current and historical subsurface explorations. Levee configurations were taken from record drawings. Engineering guidance for the evaluation of stability is found in EM 1110-2-1902.

The stability of the levee was analyzed for the conditions outlined in in EM 1110-2-1913, Chapter 6, Section II, 6-5. These conditions are:

- Case I, end of construction
  - Not Applicable due to age of the levee system, consolidation and settlement having already occurred. The cross section of the levee has not been recently modified.
- Case II, sudden drawdown from full flood stage
  - Test failure of the out-slope (river side) of the embankment, simulating a rapid decline in flood water level from the base flood elevation to the ground surface, leaving the levee materials saturated.
- Case III, steady seepage from full flood stage, fully develop phreatic surface
  - Test failure of the inside slope (land side) of the embankment, with the water level representing the river at base flood elevation and the levee saturated to flood conditions.
- Case IV, earthquake.
  - The earthquake case was not analyzed because of the low seismicity of the area.

For global stability of a slope, the minimum required factors of safety for stability of levees are found in EM 1110-2-1913 and are summarized in **Table 6.5 - Stability Criteria**. These theoretical factors of safety assist in evaluating the embankment section.

Table 6.5 - Stability Criteria	
Stability Condition	**Required Minimum Factor of Safety**
Case I - End-of-Construction	1.3
Case II - Rapid Drawdown following infrequent loading	1.0 – 1.2
Case III - Long-Term Steady State Seepage	1.4
Case IV - Earthquake	Not specified

(7) Slope stability analysis

The slope stability was modeled using the computer program UTEXAS4. This program is several generations removed from the original UTEXAS program developed for the USACE. The procedure used was Spencer's method of limited equilibrium to determine the lowest factor of safety (FS) through circular failure surfaces under static loading. Catastrophic failure of the cross sections were considered to be those failure surfaces having the lowest factors of safety which did appear to lead to a breach in the levee, thus eliminating near-surface and shallow bank failures.

The shear strengths used in the program were determined from correlations to index properties of the soils, such as Atterberg Limits, N-values and unconfined compressive strengths, direct shear tests and triaxial tests results. The soil unit weights used is either representative or their measured densities. The phreatic surfaces used for the slope stability analyses were generated in the SEEP2D model. **Table 6.6 - Material Strength Properties** presents the parameters used in the stability models. Total stress parameters were used to reflect the relatively rapid loading effect from the flood event. The pore water pressures used for the rapid drawdown analysis assumed a complete drawdown from the base flood elevation.

The assumptions used in the stability analyses:

- The embankment contains zones of upstream and downstream pervious soils that are expected to be somewhat free draining. However in the rapid draw down analysis, the shell soils were assumed to remain saturated to the level of the phreatic surface prior to the drawdown occurring.
- The phreatic surface within the embankment during flood stage and rapid draw down was assumed to saturate the entire levee and reach steady state conditions even though the short duration of a flood event may not reach this stage.

Table 6.6 - Material Strength Properties			
Material	Unit Weight (γ, pcf)	Friction Angle (Φ, degrees)	Cohesion (c, psf)
Station 9+50			
Sand embankment fill	120	30	0
Clay embankment fill	115	25	750
Organic clay	110	6	820
Base course	138	40	0
Poorly graded sand	120	33	0
Silt	115	25	0
Station 30+64			
Silt embankment fill	115	25	0
Sand (SP-SM)	120	30	0
Sand embankment fill	115	39	0
Poorly graded sand (SP)	120	33	0
Silty sand (SM)	120	33	0
Base course	138	40	0
Sand (SP-SM)	120	33	0

(a) Results

The results from the analyses are presented in **Table 6.7 - Stability Results – Factor of Safeties**. Graphical presentations of the analyses are included in Appendix A. Based on the results of the analysis the global stability for the levee meets the allowable factors of safety specified by the USACE in EM 1110-2-1913.

Table 6.7 - Stability Results – Factor of Safeties						
	Base Flood – river level 686.3		Rapid Drawdown from Base Flood		Unusual Event – river level 684.7	
Station	Calculated Circular Failure Surface	USACE Specified	Calculated Circular Failure Surface	USACE Specified	Calculated Circular Failure Surface	USACE Specified
9+50	4.31	1.4	3.78	1.2	2.28	none
30+64	2.27	1.4	1.73	1.2	1.78	none

Based on the results of the stability analyses for the conditions evaluated and the base flood elevation, the resulting safety factors meet the required global factors of safety.

7. Settlement

44 CFR 65.10(b)(5) requires that engineering analyses be submitted that assess the potential and magnitude of future losses of freeboard as a result of settlement and demonstrate that freeboard will be maintained within the minimum standards for the duration of the levee service period. The analysis must address embankment loads, compressibility of embankment soils, compressibility of foundation soils, age of the levee system, and construction methods.

A. Engineering Analysis

(1) USACE Design

When the levee system was upgraded in 1991, settlement was evaluated based upon soil borings and laboratory test results. Some settlement was expected due to the presence of clay deposits. The levee was overbuilt along some sections, as shown below:

Table E-4: Proposed Levee Overbuild for Settlement

Levee Reach by Station	Levee Overbuild for Settlement (ft.)
2+00	0.0
7+00 - 10+50	0.6
11+00 - 22+00	0.4
23+00 - 24+25	0.5
24+50 - 25+00	0.0
25+25 - 27+00	0.2
27+50 - 58+50	0.0
59+00 - 60+50	0.2
61+00 - 79+00	0.0
80+00 - 86+25	0.1
86+50 - 92+50	0.3
93+00 - 112+50	0.1
113+00 - 118+50	0.0
119+00 - 136+00	0.2
136+20 - 136+60	0.0
136+80 - 142+00	0.4
142+30	0.0

(2) Embankment geometry

The existing levee has a 10-24 foot crest width. The wider width is to accommodate roadway traffic. The riverside slopes range between 4H:1V from Station 0+00 to 13+70 3H:1V from Station 13+70 to 117+69. The riverside slope also contains an impervious blanket. The landside slopes range between 3H:1V to 6H:1V, which varies from station to station. A thirty foot long seepage berm was also placed along the landside of the levee at isolated areas to control seepage.

(3) Embankment and foundation loads

The expected live loads on the embankments are pedestrians, police cars, light city trucks and heavier equipment for levee maintenance. All of these applied loads are transmit to relatively shallow depths and are transient with little if any effect on embankment settlement. The foundation is primarily subject to the load of the embankment.

(4) Embankment and foundation materials

The boring logs indicated the core of the embankment consists of sand, silty to clayey sands, silt and lean clay soils. Foundation soils generally consist of clean sands to silty sand. Some areas of the levee contain a silt or clay layer above the sands. Some organic material was found in the overlying cohesive soils.

(5) Compressibility of embankment and foundation soils

Topsoil along with other unsuitable soils were removed prior placing fill for the levee. The technical specifications for the embankment construction required a maximum 6-12 inch loose lift thickness and 92-100 percent compaction for embankment materials. Assuming these requirements were achieved during construction, on negligible settlement of embankment soils is expected, and would have occurred within the first couple years after construction.

Only minor settlement within the granular foundations soils would expected based upon soil boring information. This settlement would have likely occurred shortly after embankment construction. The clay and silt foundation soils would be susceptible to greater settlement. The majority of this primary consolidation would have likely already occurred, however some minor additional consolidation settlement is likely to occur.

(6) Settlement evaluation

The original design calculations for settlement were made available to the City. Therefore, it was necessary to confirm that the calculations completed in 1993 conform to current USACE standards.. As mentioned previously, the majority of the settlement likely occurred early after construction. Calculations were more intended to analyze settlement during the next 50 years. The future settlement is considered to be around a maximum of 1.5 inches, where the cohesive soils are the thickest. The settlement calculations are presented in Appendix A.

(7) Design elevation verses surveyed elevation

Comparing design elevation to current survey information provides the basis to evaluate historical settlement. The surveyed crest of the levee was compared to the design elevations shown in the record drawings.

Observed settlement was calculated by subtracting surveyed top of levee from the adjusted design elevation. The record drawings were based on National Geodetic Vertical Datum of 1929 (NGVD29). The record drawings were converted to the NAVD88 datum.

The observed settlement ranged from 0.0 feet to 1.34 feet and averaged 0.34 (4-inches) feet**. Table 7.1 - Settlement** provides an overview of the data from the analysis.

Table 7.1 - Settlement

STATION	Surveyed Elevation	Design Elevation	Observed Settlement (ft)	Req'd Freeboard Elevation
13+66	694.14	694.2	0.06	689.80
16+74	694.12	694.2	0.08	689.80
19+64	693.87	694.2	0.33	689.80
22+54	693.99	694.2	0.21	689.80
25+13	693.51	694.2	0.69	689.80
26+58	694.08	694.2	0.12	689.80
49+92	691.76	692.06	0.29	688.63
51+70	691.30	691.84	0.54	688.54
54+88	691.07	691.56	0.48	688.39
55+16	691.12	691.53	0.41	688.36
55+72	690.99	691.48	0.49	688.31
56+01	691.13	691.45	0.32	688.28
57+78	691.23	691.30	0.07	688.09
60+65	691.52	692.86	1.34	688.44
60+93	692.65	693.8	1.15	688.41
63+00	**687.38**	687.63	0.25	**687.55**
64+00	687.56	687.63	0.07	687.44
65+00	687.55	687.63	0.08	687.34
71+75	**686.56**	686.72	0.16	**686.63**
72+00	**686.25**	686.69	0.44	**686.60**
73+00	**686.05**	686.60	0.54	**686.50**
74+00	**685.96**	686.52	0.56	**686.39**
75+00	**685.86**	686.43	0.57	**686.29**
76+00	**685.79**	686.26	0.56	**686.19**
77+00	686.56	686.26	0.70	686.09
78+00	**685.50**	686.17	0.67	**686.08**
79+00	**685.51**	686.09	0.58	**685.97**
80+00	**685.54**	686.00	0.46	**685.91**
81+00	**685.52**	685.84	0.32	**685.85**
82+00	**685.47**	685.68	0.21	**685.80**
83+00	**685.40**	685.52	0.12	**685.74**
84+00	**685.25**	685.36	0.11	**685.68**
85+00	**685.32**	685.20	-0.12	**685.63**
86+48	**685.06**	685.14	0.08	**685.54**
87+04	**685.07**	685.12	0.04	**685.51**
88+76	**685.00**	685.05	0.05	**685.41**
89+00	**684.95**	685.04	0.09	**685.40**
90+00	**684.70**	685.00	0.30	**685.34**
91+00	**684.72**	684.96	0.24	**685.28**
92+00	**684.77**	684.92	0.15	**685.22**
93+00	**684.60**	684.88	0.28	**685.17**
94+00	**684.47**	684.84	0.37	**685.11**
95+00	**684.44**	684.80	0.36	**685.05**
96+00	**684.42**	684.76	0.34	**685.00**

Table 7.1 - Settlement				
STATION	**Surveyed Elevation**	**Design Elevation**	**Observed Settlement (ft)**	**Req'd Freeboard Elevation**
97+00	**684.41**	684.73	0.32	**684.94**
98+00	**684.64**	684.69	0.05	**684.88**
99+00	**684.38**	684.66	0.28	**684.82**
100+00	**684.36**	684.62	0.26	**684.77**
101+00	**684.37**	684.59	0.22	**684.71**
102+00	**684.28**	684.55	0.27	**684.65**
105+00	**684.30**	684.44	0.14	**684.48**
113+00	**683.62**	683.90	0.28	**683.9**
114+00	**683.72**	683.90	0.18	**683.9**
116+00	684.15	683.90	-0.25	683.9

Note: grey indicates freeboard not met.

In evaluating settlement as a potential failure mode, there are areas along the levee embankment that identified settlement sufficient to place the crest of the levee below the freeboard criteria.

(8) Settlement conclusion

Future settlement is considered negligible and only along sections of the levee that contain thicker layers of cohesive soils. In order to meet levee freeboard the levee crown will need to be raised to maintain the base flood protection. Routine maintenance should include routine surveys of the elevation of the top of the levee to monitor the gradual long-term settlement of the levee.

8. Interior drainage

44 CFR 65.10(b)(6) requires an analysis that identifies the sources, extent and depth of interior flooding. The required analysis is to be based on the joint probability of interior and exterior flooding and the capacity of facilities for draining interior floodwater.

FEMA requires an analysis that identifies the sources, extent and depth of interior flooding. The required analysis is to be based on the joint probability of interior and exterior flooding and the capacity of facilities for draining interior floodwater.

The interior drainage system is the system of culverts, ditches, storm sewers, outfalls, and structures which conveys interior water from rainfall or groundwater seepage by gravity to outside of the levee or through a pump station conveying the storm water to the river when flood levels are greater than the gravity outfalls.

A. Engineering Analysis

This analysis looks at both the impacts of rainfall within the interior area behind the levee and flood stage on the Root River and the interaction between the interior and exterior conditions.

(1) USACE Design

The USACE design considered that while the intense summer rainfalls which occur over the Root River basin and the interior area generally causes intermediate discharges and stages on the Root River, the peak discharges on the river do not coincide with peak discharges from the interior area. Since the time of concentration for the interior areas is so much shorter than for the Root River basin, the peak discharge from the interior area occurs before the Root River rises enough to prevent outflow from the ponding areas and outlets. The maximum pond elevations generally result from routing the peak discharge through the ponding areas and outlets rather than from the need to store runoff during a period of blocked gravity.

The Unit hydrographs for hypothetical storms were developed using the Soil Conservation Service unit hydrograph method in the HEC-1 program. The theoretical rainfall events were developed from the National Weather Service publications HYDRO 35, TP-20 and TP-49. The theoretical rainfall amounts used were:

Rainfall Duration	Rainfall Frequency in Percent						
	100	50	20	10	4	2	1
5-min	1.39	0.43	0.52	0.58	0.67	0.75	0.82
10-min	0.55	0.67	0.83	0.95	1.11	1.24	1.36
15-min	0.67	0.84	1.05	1.20	1.41	1.58	1.74
30-min	0.91	1.18	1.47	1.68	1.98	2.21	2.44
60-min	1.28	1.54	1.92	2.18	2.57	2.86	3.16
2-hr	1.36	1.69	2.12	2.42	2.82	3.15	3.49
3-hr	1.49	1.84	2.32	2.65	3.08	3.43	3.82
6-hr	1.80	2.22	2.83	3.25	3.74	4.16	4.64
12-hr	2.03	2.55	3.29	3.79	4.33	4.80	5.40
24-hr	2.30	2.89	3.75	4.32	4.92	5.45	6.14
48-hr	2.72	3.40	4.30	5.10	5.75	6.50	7.20
72-hr	2.98	3.71	4.80	5.51	6.40	7.06	7.89
96-hr	3.29	4.10	5.15	5.90	6.95	7.78	8.60

The USACE designed the ponding areas for the 1% annual chance event (100-year) under gravity flow conditions. The designed maximum ponding levels for the 1% annual event are given in **Table 8.1 – USACE Designed Ponding (gravity flow)** below.

Table 8.1 – USACE Designed Ponding (gravity flow)

Ponding Area	Storage (Acre-Feet)	Elevation (Feet)	Peak Inflow (1% Event) (cfs)	Peak Outflow (1% Event) (cfs)
A-1	32.5	681.0	526	240
A-2	35.0	680.5	860	408
B	36.5	679.0	428	121

For ponding area A-1 there are a series of ponds located in the southwest area of the City which are an integral part of the interior drainage plan and are designed to pond at Elevation 682.0 feet.

(2) Land and water resource inventory

(a) Flooding sources

Sources of interior flooding of the area behind the levee are from local runoff and by seepage from the river under or through the levee.

(b) Topography

The topography of the area behind the levee consists of generally flat land within the City limits along the Root River valley floor. South of the City limits, relatively steep foothills rise more than 500 feet above the valley floor. As such, the interior area generally drains from south to north.

(c) Land uses

The existing developed areas consists of buildings, streets, parking lots and other urban structures in residential, commercial and industrial areas. The undeveloped areas consist of agricultural land along the valley floor, and heavily wooded lands within the foothills.

(d) Soils information

As classified by the Soil Survey of Houston County, Minnesota, the site soils are generally classified as silty loam.

The nature of soils comprising the top layer of unconsolidated material in a watershed is important because soil properties are the primary factor in determining the volume of runoff associated with a given rainfall event. The Soil Survey assigns soil types to a hydrologic group depending on the soils ability to infiltrate water during long-duration storms. The four hydrologic soil groups are: Group A- high infiltration, Group B – moderate infiltration, Group C – slow infiltration and Group D – very slow infiltration.

The Soil Survey indicates that the interior area is comprised of all four hydrologic soil groups.

(3) Hydrologic analyses and results

The hydrologic assessment of the area behind the levee is based on land use, soil type, and topography of the site.

(a) Methodology

A hydrologic computer model was developed using XPSWMM to facilitate assessment of the capacity of the system. This program was used because it is capable of analyzing both the hydrologic response of the interior subwatersheds to a synthetic rainfall event, and the hydraulics associated with routing the runoff hydrographs through the interior drainage system. The hydrologic component of the model generates flows based on the physical features and rainfall events entered by the user, including: drainage areas, runoff curve numbers (CN), time of concentration (T_c), seepage data and design storm events.

(b) Drainage areas

The 1,022 acre watershed behind the levee was separated into 14 subwatershed areas to define the volume of runoff to the line of protection as shown on **Exhibit 8.1 - Interior drainage**. A sub-watershed is a region defined by a divide that drains all to one location. The subwatersheds were delineated using 2-foot contours and a digital elevation model (DEM) developed from LiDAR data for Houston County. In addition, drainage maps from the USACE Design Memorandums were used as a basis for the subwatershed boundaries.

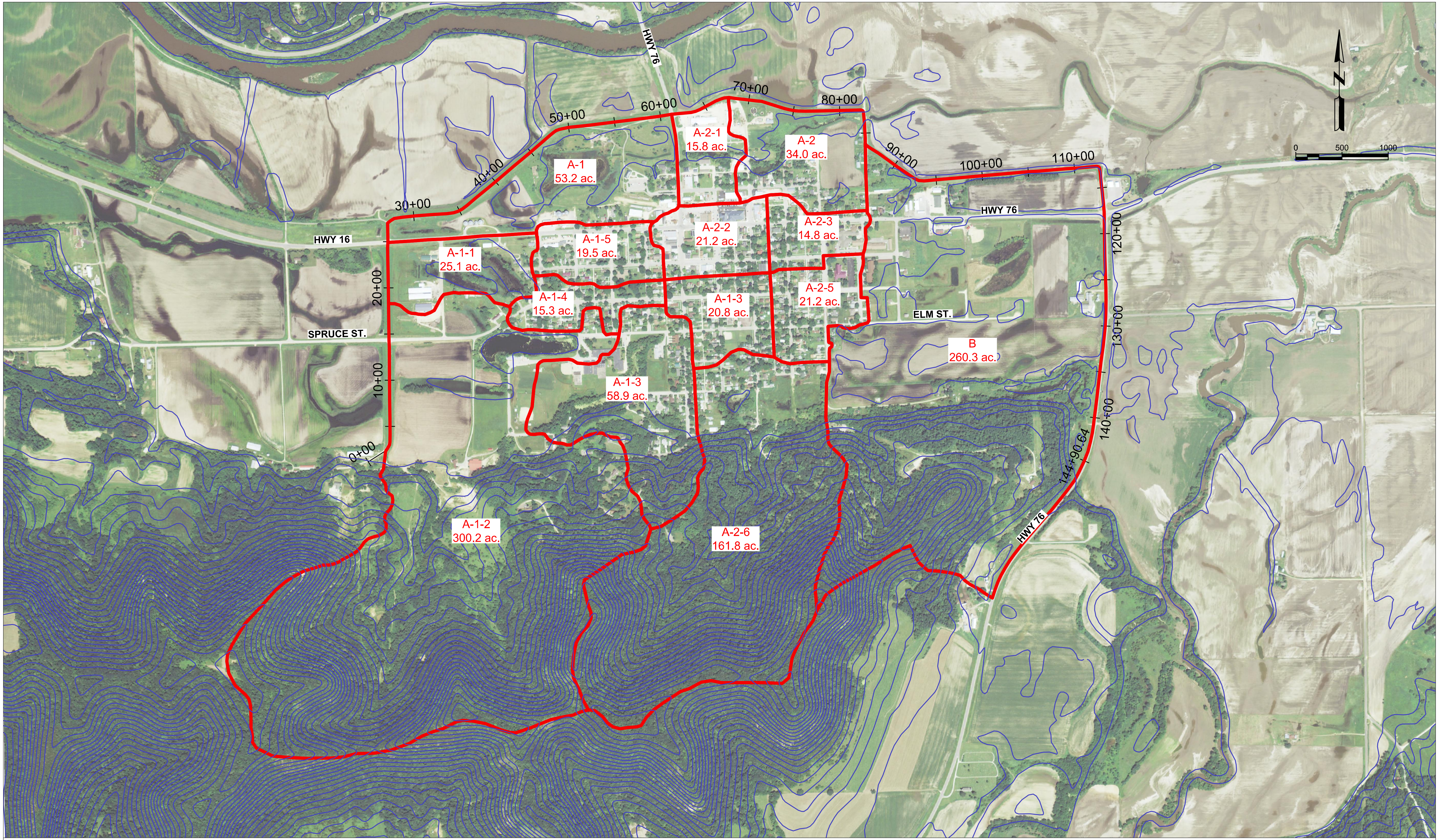
Within the urban areas of the watershed, stormwater is picked up by catch basins distributed throughout the system. The subwatershed boundaries within the urban areas were developed using a combination of the LiDAR data and a utility map of the City showing the storm sewer network.

(c) Runoff curve number

The runoff curve number (CN) is a composite number assigned to a combination of soil types and land uses. The CN is affected by the infiltration characteristics of the soil and ground cover. Attributes associated with each of the subareas are summarized in the modeling data included in Appendix A. High CN's typical of commercial settings, have high rates of runoff, while low CN's, typical of wooded, well drained soils have low rates of runoff. Soil curve numbers range between 0 and 100, with higher numbers corresponding to impervious soils and surfaces with higher runoff rates.

Aerial photographs were used to assign composite curve numbers to each subarea based on land classification. The curve number subareas were then merged with hydrologic soil group subareas obtained from the Soil Survey Geographic Database (SSURGO) in order to compute the curve numbers based on the different hydrologic soil groups present throughout the basin. The weighted composite curve numbers for each subwatershed are presented in **Table 8.2 - Weighted Composite Runoff Curve Number** below.

Table 8.2 - Weighted Composite Runoff Curve Number		
Subwatershed	Total Area (acres)	Weighted Composite Curve Number
A-1	53.15	86.5
A-1-1	25.13	86.5
A-1-2	300.2	60.5
A-1-3	58.85	66.7
A-1-4	15.26	82.2
A-1-5	19.52	77.6
A-2	34.02	81.7
A-2-1	15.83	88.3
A-2-2	21.19	85.0
A-2-3	14.76	82.5
A-2-4	20.83	83.0
A-2-5	21.15	84.4
A-2-6	161.78	52.2
B	260.31	66.4



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CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

4158900-121186.01
SEPT 2015

DRAINAGE BASIN MAP

Mead & Hunt

EXHIBIT 8.1

(d) Time of concentration (Tc)

The time of concentration (Tc) is used to define the shape of the runoff hydrograph. It is defined as the time it takes stormwater from the hydrologically most distant point of the watershed to reach its point of collection. The T_C has a significant effect on peak flows, where a shorter time of concentration will increase the peak runoff rate. For this study, the T_C for each of the subarea has been calculated utilizing the SCS TR-55 flow path methodology and converted to a lag time (TL) using the relationship of TL = 0.6TC. The T_C is listed in **Table 8.3 - T_C**.

Table 8.3 - T_C	
Subwatershed	**T_C (Min.)**
A-1	29.0
A-1-1	15.0
A-1-2	46.0
A-1-3	62.9
A-1-4	15.0
A-1-5	15.0
A-2	44.5
A-2-1	15.0
A-2-2	15.0
A-2-3	15.0
A-2-4	15.0
A-2-5	15.0
A-2-6	30.0
B	90.6

The hydraulic flow path for each of the subwatersheds was determined by several manual delineations and iterations to determine the longest hydraulic flow path for the subwatershed. The hydraulic flow path was separated and classified for each flow segment (sheet flow, shallow concentrated flow, open channel flow, or pipe flow). The surface description, flow length and slope were determined for each of the identified flow segment using aerial photos, topographic maps and storm sewer maps. Storm sewer pipes were assumed to be flowing full. Each of these properties was used to compute the time of concentration for each subwatershed. The times of concentration for the urban subwatersheds were not calculated and instead were assumed to be equal to 15 minutes.

(e) Rainfall data

Rainfall depths for the 10- and 100-year, 24-hour events were obtained from NOAA Atlas 14. The temporal distribution of the rainfall was established using an SCS Type II distribution.

(f) Hydrology model runoff quantities

Calculations for the runoff quantities were based on the 100-year, 24 hour frequency storm developed using NOAA Atlas 14, A summary of the peak inflow and total runoff volumes listed in acre-feet (ac-ft) for the selected design storm are presented in **Table 8.4 - Hydrology Results**.

Table 8.4 - Hydrology Results				
Subwatershed	**10-year Peak Inflow (cfs)**	**10-year Total Volume (ac-ft)**	**100-year Peak Inflow (cfs)**	**100-year Total Volume (ac-ft)**
A-1	146	13.77	286	27.90
A-1-1	93	6.25	181	12.66
A-1-2	166	25.14	592	77.63
A-1-3	40	6.96	117	18.90
A-1-4	49	3.30	103	7.06
A-1-5	53	3.59	121	8.18
A-2	60	7.48	128	16.13
A-2-1	61	4.16	117	8.25
A-2-2	75	5.02	149	10.37
A-2-3	48	3.22	100	6.87
A-2-4	69	4.62	142	9.80
A-2-5	73	4.92	148	10.23
A-2-6	52	7.93	297	31.06
B	131	30.02	389	81.95

(4) Pumping Station

The drainage from the interior is passed through the levee during flood periods with one pumping station located at Station 83+68. The pumping station is provided with a sluice-gated gravity outlet. The pump station is reinforced concrete containing two submersible pumps, one 5,000 gpm and one 15,000 gpm. Pump operation is triggered by floats. The pump station includes a 60-inch RCP inlet pipe with a trash rack and a 60-inch reinforced concrete outlet pipe.

Power to operate the pumping stations comes from a 3-phase 277/480 volt electric service which is supplied by Tri-County Electric Cooperative. Overall, the City does not experience any critical, ongoing issues with its pumping station and pump station failure has not been a cause for concern. The City's emergency response plan for power failure is to connect the dedicated pumping station generator to the pumping station.

The first pump (5,000 gpm) will begin operating at Elevation 675.0 and shut off at Elevation 674.0. The second pump (15,000 gpm) will begin operating at Elevation 678.0 and will shut off at elevation 675.5.

Pump curves were developed for each pump in the hydraulic model based on pump curves found in the Pump Station Operation and Maintenance Manual. The curves developed can be found in Appendix A.

(5) Structural Analysis for Pump Station, Gatewells and Headwalls

The design criteria used by the USACE to design the structures was:

Reinforced Concrete Structures

Specified Compressive Strength of Concrete: f'c = 4000 psi

Steel Reinforcement Bars: Grade 60

Minimum reinforcement cover for cast-in-place Hydraulic Structures:

Any surface – 2 inches

Concrete surfaces cast against earth or in contact with flowing water – 3 inches

Material Properties

Unit Weights: pcf

Concrete – 150

Water – 62.5

Soil Unit Weights: pcf

Moist	Saturated	Submerged
120	130	67.5

Soil Properties

	phi (degrees)	c (psf)
Pervious Backfill for All Structures	24	250

Live Loads

For the purposes of drainage pipe design, two live loading types were considered:

a. A construction load of 50,000 lbs for all pipes, and
b. AASHTO HS20 loading for all pipes that cross under roadways.

Today's design methods HS25 (40,000 lbs axle loading) is typically used for underground hydraulic structures as opposed to AASHTO HS20 (32,000 lbs) but construction load still controls so the live loads used by the USACE design would not change.

Uplift

Uplift head elevation was taken as the full hydrostatic head uniformly distributed beneath the structure.

(a) Pump Station

The pump station is built into the levee. The pump station inlet and outlet consists of a 60-inch reinforced concrete class III pipe (RCP). The structure is comprised of two bays, one containing a gatewell and the second bay containing two pumps and floats. The structure is constructed of reinforced concrete walls resting on a reinforced concrete slab. The top elevation of the structure is at the top of levee elevation. A grated hatch provided at the top of the structure allows access to the pump station. Pump removal is facilitated through openings in the slab above the pump bay. The pump station was analyzed for stability against flotation and under full hydrostatic head. Wall thicknesses were sized based upon applied soil and water loadings.

(b) Gatewells

The three gatewells are located in approximately the riverward third of the levee with the top elevation of the gatewell at the top of levee elevation. The main features of these outlets are gravity inlet and outlet pipes, a gatewell, and headwalls with flap gates at the end of the outlet pipes.

Gatewell wall thicknesses were sized based on applied soil and water loadings. Stability evaluations were the same as those undertaken for the pump station. Since the outlets are expected not to be in operation during freezing conditions, ice was determined not to be a problem.

The structural design completed by the USACE for the gatewells can be found in Appendix A. Design is still applicable and the worst case loading was taken.

(c) Headwalls

Headwalls are provided at the end of outlet pipes at each outlet to accommodate the flapgates at the end of the pipes. The headwalls consist of reinforced concrete headwall and sidewalls to retain the levee behind the headwall. The sidewalls descent at a 1V on 3H slope to the toe of the levee. The walls are constructed on top of a reinforced concrete slab. Wall and slab thicknesses are based on applied soil and water loads. Sliding stability was evaluated using CSlide.

The load factors used in original design are conservatively higher than what would typically be used for design today.

Original Load Factored Equation: 1.4DL + 1.3Hf + 1.7L
Updated Load Factored Equation: 1.2(D+Hf) + 1.6L

The structural design completed by the USACE for the headwalls can be found in Appendix A.

(6) Hydraulic analyses and results

The hydraulic modeling component of XP-SWMM was used to quantify inflow and outflow rates as well as ponding elevations, volumes and durations. The XP-SWMM model is on a disc, found in Appendix A.

Hydraulic modeling for four scenarios were performed. The four scenarios are the 10-year and 100-year 24 hour storm for both the (1) low river condition in which there would be gravity flow, and (2) for the base flood condition in which the pumps in the pumping station would be in operation for the entire duration of the rainfall event.

(a) Methodology

<u>Assumptions</u>

- Tailwater rating curves were used to represent the tailwater conditions at each outlet during gravity flow conditions and were developed from the head-discharge curves presented in the USACE's *Design Memorandum*.
- Base flow into the pumping station prior to the 100-year storm event were assumed to be negligible; therefore ignored.

(b) Seepage

The estimated rate of seepage through the flood barrier that would drain to each subwatershed adjacent to the levee during the base flood is listed in the **Table 8.5 - Seepage**.

Table 8.5 - Seepage		
Location	Estimated seepage (cfs)	Station to Station
A-1-1	0.06	0+00 to 14.00
A-1	0.21	14+00 to 61+00
A-2	0.02	61+00 to 85+77
B	0.14	85+77 to 117+50

The seepage through the flood barrier during base flood was found to be negligible. Therefore seepage is not accounted for in the interior drainage analysis.

(c) Pipe Network

Stormwater is conveyed through the urban areas of the City via a storm sewer network. Several of the storm sewer pipes outfall to the various designated ponding areas around the City. In fact, the only means for water to be transferred from the ponding areas on the south side of the City to the ponding areas on the north side of the City (near the levee) is through the storm sewer network. Therefore it was important to model the pipe connections between the ponds in order to perform an accurate analysis of the ponding around the City.

Only the main pipes used to transfer flows between the north and south ponds and shown on Plate D-2 of the 1992 USACE *Design Memorandum* were included in the model. Pipe sizes and invert elevations were obtained from Plate D-2. In addition to the pipes within the urban area of the City, two culverts located under State Highway 76 and N Sheridan Street are used to convey flows from the ponding area at Outlet A-1 to the ponding area at Outlet A-2. The culvert sizes, lengths and invert elevations were obtained from the field survey data.

(d) Ponding

Designated ponding areas are located along the north side of the City near the levee and outlet structures, and also along the south side of the City. To account for the storage area at each ponding area, elevation-area curves were developed using the LiDAR DEM. The elevation-area curves were then assigned to storage nodes within the hydraulic model. The elevation-area curves are included in Appendix A.

During large flood events, flow would be transferred between some of the ponding areas along the south side of the City via overland flow. These overland flow connections were represented within the XPSWMM model as weirs. The weir lengths, elevations and discharge coefficients were approximated using the LiDAR DEM.

(e) Results

Table 8.6 - 100-year Storm – Low River Condition and **Table 8.7 - 100-year Storm – High River Condition** summarizes the results of the hydraulic modeling for both the 10-year and 100-year storm events occurring during a low river condition and high river (base flood level) condition.

Table 8.6 - Outlet Results 10-year Storm – Low River Conditions			
Location	**Peak Discharge (cfs)**	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
Outlet A-1	1	676.1	11.37
Outlet A-2	116	675.4	2.81
Outlet B	34	675.8	14.22

Table 8.7 - Outlet Results 100-year Storm – Low River Conditions			
Location	**Peak Discharge (cfs)**	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
Outlet A-1	31	677.0	19.69
Outlet A-2	181	676.2	5.51
Outlet B	95	677.3	40.32

Table 8.8 - Interior Ponding Area Results – 10-year Storm – Low River Conditions and **Table 8.9 - Interior Ponding Area Results –100-year Storm – Low River Conditions** summarizes the results of hydraulic modeling for the area south of the levee with low river conditions.

Table 8.8 - Interior Ponding Area Results 10-year Storm – Low River Conditions		
Location	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
A-1-1 (Interior Pond, Flow Area 3)	679.0	6.4
A-1-2 (Interior Pond, Flow Area 2)	680.1	34.4
A-1-3 (Interior Pond, Flow Area 1)	681.9	7.9
A-2-1 (Flow Area 5, between Hwy 76 and Sheridan St.)	675.7	2.3
A-2-6 (South side of City between Sheridan St. and Sherman St.)	681.9	8.1
A-2-6-2 (South side of City between Ellsworth St. and Sheridan St.)	680.0	0.0
A-2-6-3 (South side of City between Chase St. and Ellsworth St.)	677.0	0.0

Table 8.9 - Interior Ponding Area Results 100-year Storm – Low River Conditions		
Location	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
A-1-1 (Interior Pond, Flow Area 3)	681.3	30.94
A-1-2 (Interior Pond, Flow Area 2)	682.1	72.85
A-1-3 (Interior Pond, Flow Area 1)	683.1	19.50
A-2-1 (Flow Area 5, between Hwy 76 and Sheridan St.)	676.9	4.18
A-2-6 (South side of City between Sheridan St. and Sherman St.)	682.6	12.93
A-2-6-2 (South side of City between Ellsworth St. and Sheridan St.)	682.3	7.00
A-2-6-3 (South side of City between Chase St. and Ellsworth St.)	682.1	11.69

Tables 8.10 Pumping Plant Results – 100-year River Conditions through **Table 8.12 Outlet Results – 100-year Storm – 100-year River Conditions** summarizes the results of hydraulic for high river results (base flood).

Table 8.10 – Pumping Plant Results 100-year River Conditions		
Storm Event	**Peak Total Pumping Rate (GPM)**	**Max No. of Pumps Used**
10-year	6,950	1
100-year	22,060	2

Table 8.11 – Outlet Results 10-year Storm – 100-year River Conditions			
Location	**Peak Discharge (cfs)**	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
Outlet A-1	N/A	677.0	19.1
Outlet A-2	pumping	677.5	12.0
Outlet B	N/A	676.8	30.3

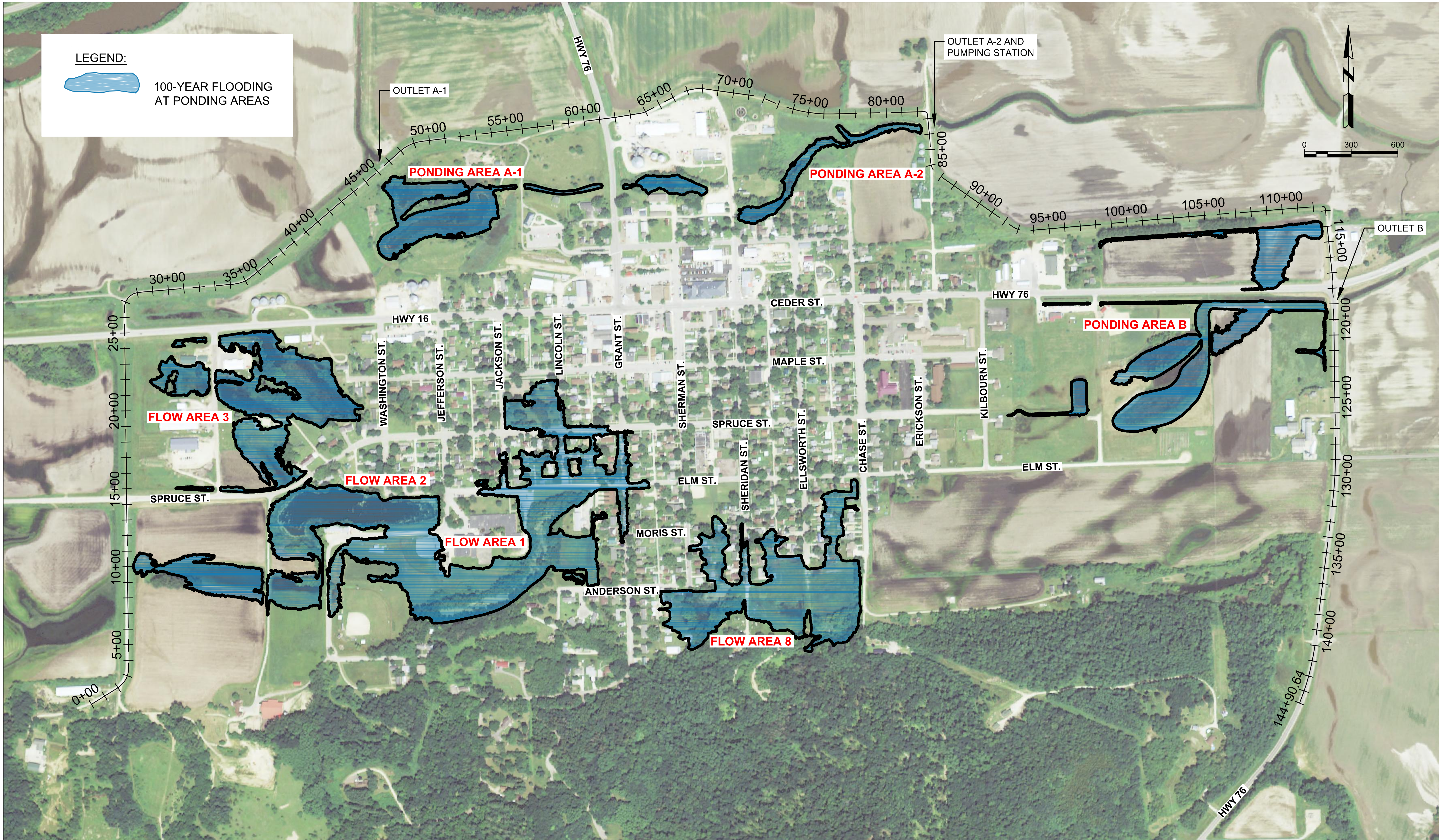
Table 8.12 – Outlet Results 100-year Storm – 100-year River Conditions			
Location	**Peak Discharge (cfs)**	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
Outlet A-1	N/A	678.3	37.6
Outlet A-2	pumping	678.5	19.8
Outlet B	N/A	678.4	84.6

Tables 8.13 Interior Ponding Area Results – 10-year Storm – 100-year River Conditions and **Table 8.14 Interior Ponding Area Results – 100-year Storm – 100-year River Conditions** summarizes the results for the area south of the levee.

Table 8.13 – Interior Ponding Area Results 10-year Storm – 100-year River Conditions		
Location	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
A-1-1 (Interior Pond, Flow Area 3)	679.0	6.3
A-1-2 (Interior Pond, Flow Area 2)	680.1	33.7
A-1-3 (Interior Pond, Flow Area 1)	681.9	7.7
A-2-1 (Flow Area 5, between Hwy 76 and Sheridan St.)	677.0	4.3
A-2-6 (South side of City between Sheridan St. and Sherman St.)	681.9	8.0
A-2-6-2 (South side of City between Ellsworth St. and Sheridan St.)	680.0	0.02
A-2-6-3 (South side of City between Chase St. and Ellsworth St.)	677.0	0.0

Table 8.14 – Interior Ponding Area Results 100-year Storm – 100-year River Conditions		
Location	**Peak Ponding Elev. (ft)**	**Peak Ponding Vol. (ac-ft)**
A-1-1 (Interior Pond, Flow Area 3)	681.3	31.0
A-1-2 (Interior Pond, Flow Area 2)	682.1	72.9
A-1-3 (Interior Pond, Flow Area 1)	683.5	19.5
A-2-1 (Flow Area 5, between Hwy 76 and Sheridan St.)	678.2	7.0
A-2-6 (South side of City between Sheridan St. and Sherman St.)	682.6	12.9
A-2-6-2 (South side of City between Ellsworth St. and Sheridan St.)	682.3	7.0
A-2-6-3 (South side of City between Chase St. and Ellsworth St.)	682.1	11.7

Exhibit 8.2 - Ponding shows the peak ponding areas for the 100-year storm – Low River Conditions.



CITY OF HOUSTON, MINNESOTA
HOUSTON LEVEE CERTIFICATION

4158900-121186.01
SEPT 2015

GRAVITY FLOW CONDITION
100 - YEAR, 24 HOUR STORM EVENT TEMPORARY FLOODING

Mead & Hunt

EXHIBIT 8.2

X:\2740800\150761.01\TECH\CAD\100yr_Ponding_Limits.dwg
Oct 02, 2015 - 8:37am

9. Operation and maintenance systems

Levee systems are to be operated and maintained in accordance with an officially adopted plan. 44 CFR 65.10(b) requires that Operation and Maintenance Plans are to be submitted to FEMA that detail how the flood protection system will be maintained and operated during its service period.

A. Levee as-built plans

The as-built plans that are missing are:

B. Official operation and maintenance manuals

The Final Operation and Maintenance Manual for Section 205 Flood Control Project, August 22, 2003 was used for the review.

(1) Recommendations to modify O&M manual

The O&M Manual is based on the condition of the levee system immediately after construction of the levee. The O&M Manual will need to be reviewed for the pumping station to determine that the operation of the pumping station is the same or if changes to the operation have been made. The items to review include:

- Part 1, Page 9- paragraph 6.10 Flood Warning System, review that the flood warning system used by the City. A new gage with provisional station name of "Root River above Rushford" ID 05384330 was established in 2007.
- Part 2, Page 4 – paragraph 2.10 Flood Warning system has the emergency contact information changed?
- Part 3, Page 1– paragraph 2.3, Figure 3-1, should list the most current Emergency Contacts with their phone numbers.
- Part 3, Page 2- paragraph 2.4 are the flood alerts the most current? and structure flood figures 3-2 – 3-7.
- Part 3, Page 8, paragraph 6.2, verify the mailing address for the USACE. The street address is 180 5th Street East, Suite 700.
- Page C-3, verify phone numbers listed for the telephone dialer.
- Page C-15, Table 4 verify that Ace Telephone Company is the provider and the local contact is Brian Jerviss. Ace Telephone Company is now AcenTek.

(2) Recommendations to modify Emergency Flood Plan

The Houston Minnesota Emergency flood plan, dated February 2009 was used for the review. The following items are recommended to be added:

- List the specific river stages for early recognition of floods and dissemination of warnings.
- List of how the information to the community to the flood hazard is given.
- Information given to the volunteers who will be watching the flood levels
- Information that is given to flood fighters.
- Lists of project supervisors, inspectors and other personnel, including their detailed contact information. The list should indicate which people would be contacted during a flood emergency. Additionally this list should include the telephone number for the USACE emergency operation center, flood fight supply and equipment vendors.
- A list or annotate on a map the important project features and areas of concern during a flood event.

(3) Training

The City is responsible for training personal to operate, maintain and patrol the levee. Flood control exercises should be held once per year. This should be done to show new personnel how to do things like how to operate the closure structures, respond to sand boils and patrol the levee during a flood. Training also provides how much time and manpower is necessary to complete certain tasks. The training should include:

- Physical operation of the project features (e.g. sluice gates, pumping stations, closure structures);
- Notification of emergency response personnel;
- Testing communication systems;
- Mobilization of monitoring teams and monitoring project features;
- Basic flood fighting techniques, such as how to prepare the sandbag closure structure;
- Coordination between volunteers, WVDOT, etc.; and
- Dissemination of information to the public.

Documentation of any levee maintenance-related training conducted (e.g. agenda, attendee sign in sheets, etc.) should be submitted with the final submittal to FEMA.

(4) Maintenance and inspection reports

In addition to the O&M manual, copies of maintenance and inspection reports and verification that deficiencies that were noted during the United States Army Corps of Engineers (USACE) periodic inspection have been corrected will need to be submitted to FEMA.

(5) Additional recommendations

(a) Emergency action procedure

As part of the O&M Manual a Flood Emergency Action Procedure should be included, although this is not a requirement of FEMA. The City must be prepared to act promptly and effectively during high water events or when a flood protection structure begins to show signs of failure. The plan should identify proactive remediation measures, coordinate City departments and resources, and serve to inform all responsible and affected parties to the possibility of this type of event. The purpose of this plan is to:

- Specify methods for early recognition floods and dissemination of warnings;
- Prevent injury and loss of life due to flooding and flood related causes;
- Reduce public and private property damages from flooding;
- Initiate post flood actions and develop community awareness of the flood hazard and
- Prepare for the accurate and timely provision of information during flood emergencies.

The plan should be concise and easily understood to reduce reliance on the personal knowledge of a few people.

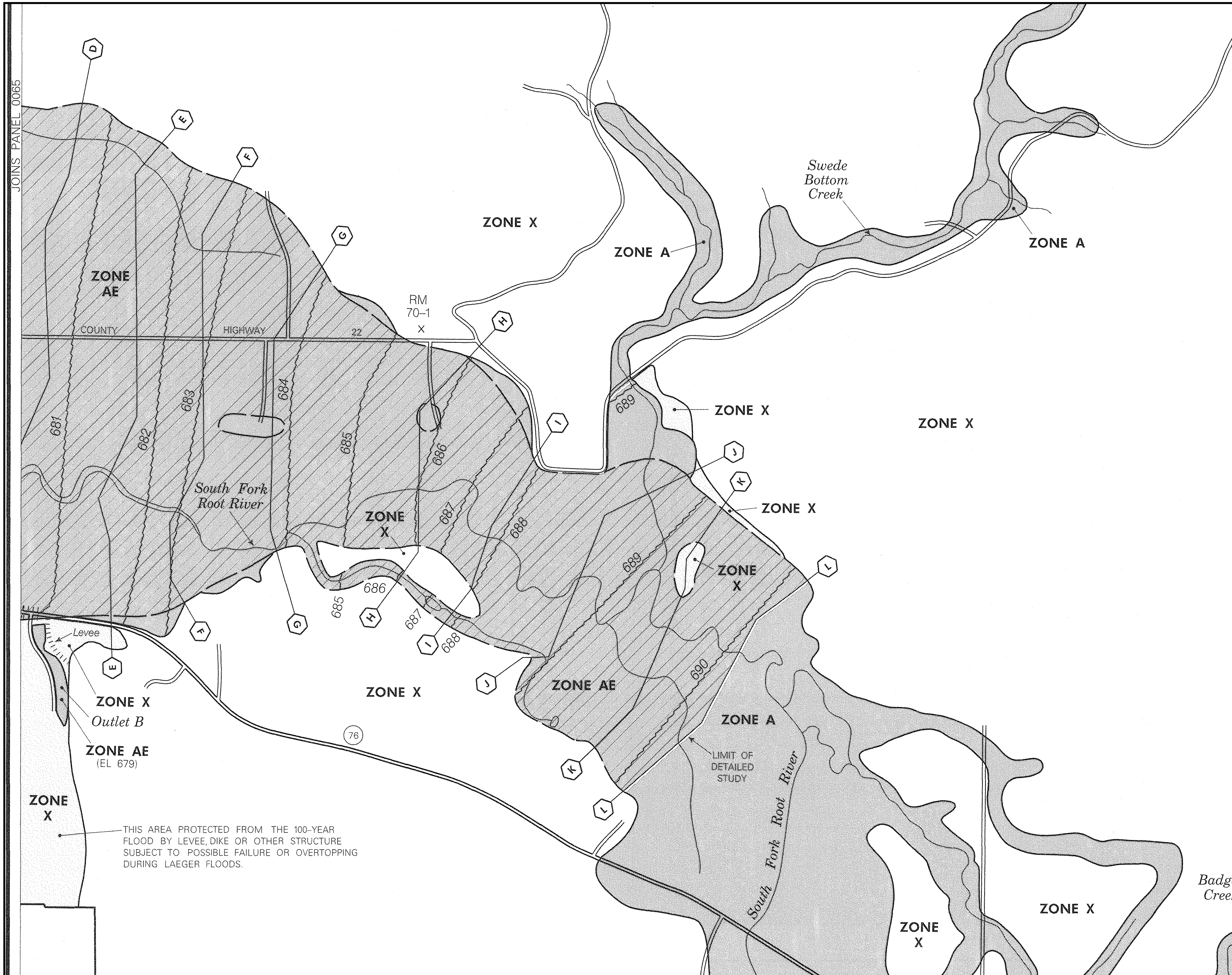
Because floods may occur decades apart, it is important that information be recorded for future use. Lessons learned are an important part of the flood response and should be incorporated into the plan.

10. Capital Improvement Plan (CIP)

The Capital Improvement Plan (CIP) identifies the City's capital expenditures for the levee system. The CIP only contains projects which are realistic from a financial, engineering, and environmental point of view. Maintenance type projects have not been included in this plan.

The cost to raise the levee was based on 2015 construction costs. A contingency value of 15 percent was applied to the total construction costs for the project. The value is justified due to the reconnaissance assessment for this study. Planning, engineering and design is assumed to represent 15 percent of the total construction cost for each project. Supervision and administration is assumed to represent 10 percent of the total construction cost. These costs do not take into account inflation. A detailed breakdown of the cost is found in Appendix C.

Appendix A – Supporting Calculations



NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

COUNTY OF
HOUSTON,
MINNESOTA
(UNINCORPORATED AREAS)

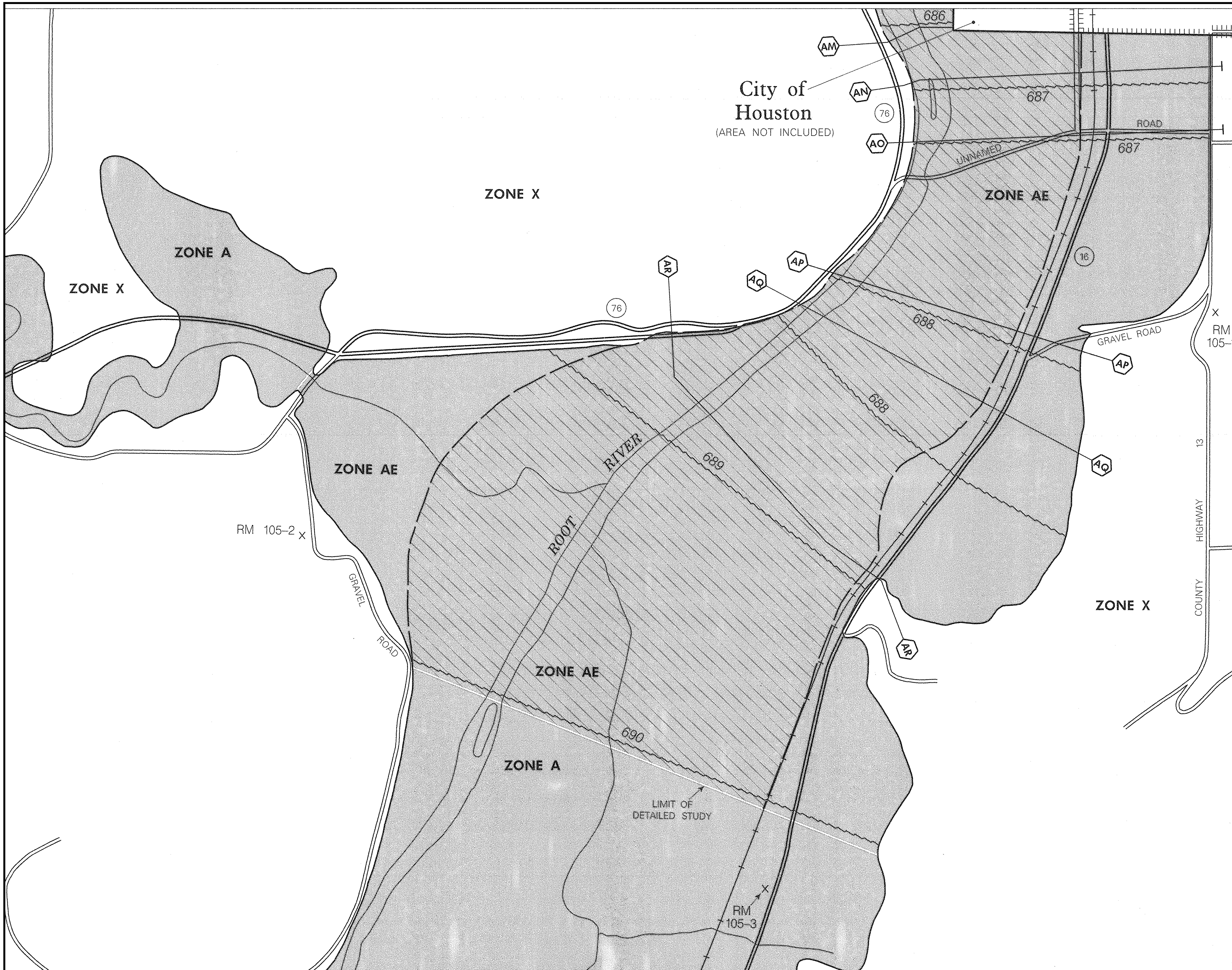
PANEL 70 OF 150

(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY - PANEL NUMBER
270190 0070 C

MAP REVISED:
JUNE 6, 2001

Federal Emergency Management Agency



APPROXIMATE SCALE

1000 0 1000 FEE

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

COUNTY OF
HOUSTON,
MINNESOTA
(UNINCORPORATED AREAS)

PANEL 105 OF 150

(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY - PANEL NUMBER
270190 0105 C

MAP REVISED:
JUNE 6, 2001

Federal Emergency Management Agency

TO USERS

n in areas where Base Flood Elevations
etermined, users are encouraged to consult
Data tables contained within the Flood
companies this FIRM. Users should be
M represent rounded whole-foot elevations
ct the flood elevation data presented in
/or floodplain management purposes, users
vation data presented in the FIS report in
n this FIRM.

vations listed on this map were obtained
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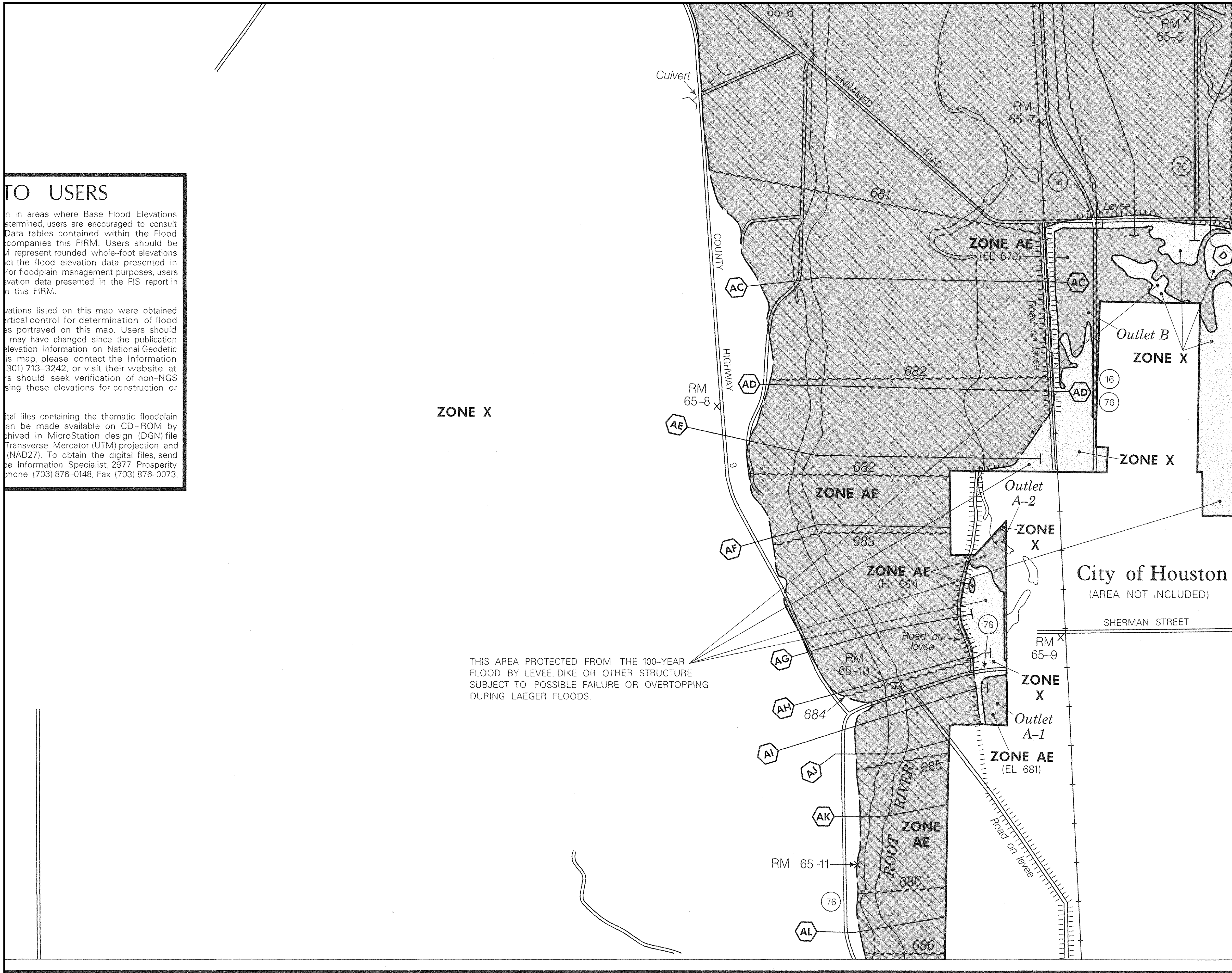
s portrayed on this map. Users should
may have changed since the publication
elevation information on National Geodetic
is map, please contact the Information
301) 713-3242, or visit their website at
rs should seek verification of non-NGS
sing these elevations for construction or

ital files containing the thematic floodplain
an be made available on CD-ROM by
chived in MicroStation design (DGN) file
Transverse Mercator (UTM) projection and
(NAD27). To obtain the digital files, send
e Information Specialist, 2977 Prosperity
phone (703) 876-0148, Fax (703) 876-0073.



APPROXIMATE SCALE

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NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

COUNTY OF
HOUSTON,
MINNESOTA
(UNINCORPORATED AREAS)

PANEL 65 OF 150

(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY - PANEL NUMBER
270190 0065 C

MAP REVISED:
JUNE 6, 2001

Federal Emergency Management Agency

D USERS

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hould seek verification of non–NGS
these elevations for construction or

files containing the thematic floodplain

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

COUNTY OF
HOUSTON,
MINNESOTA
(UNINCORPORATED AREAS)

PANEL 65 OF 150

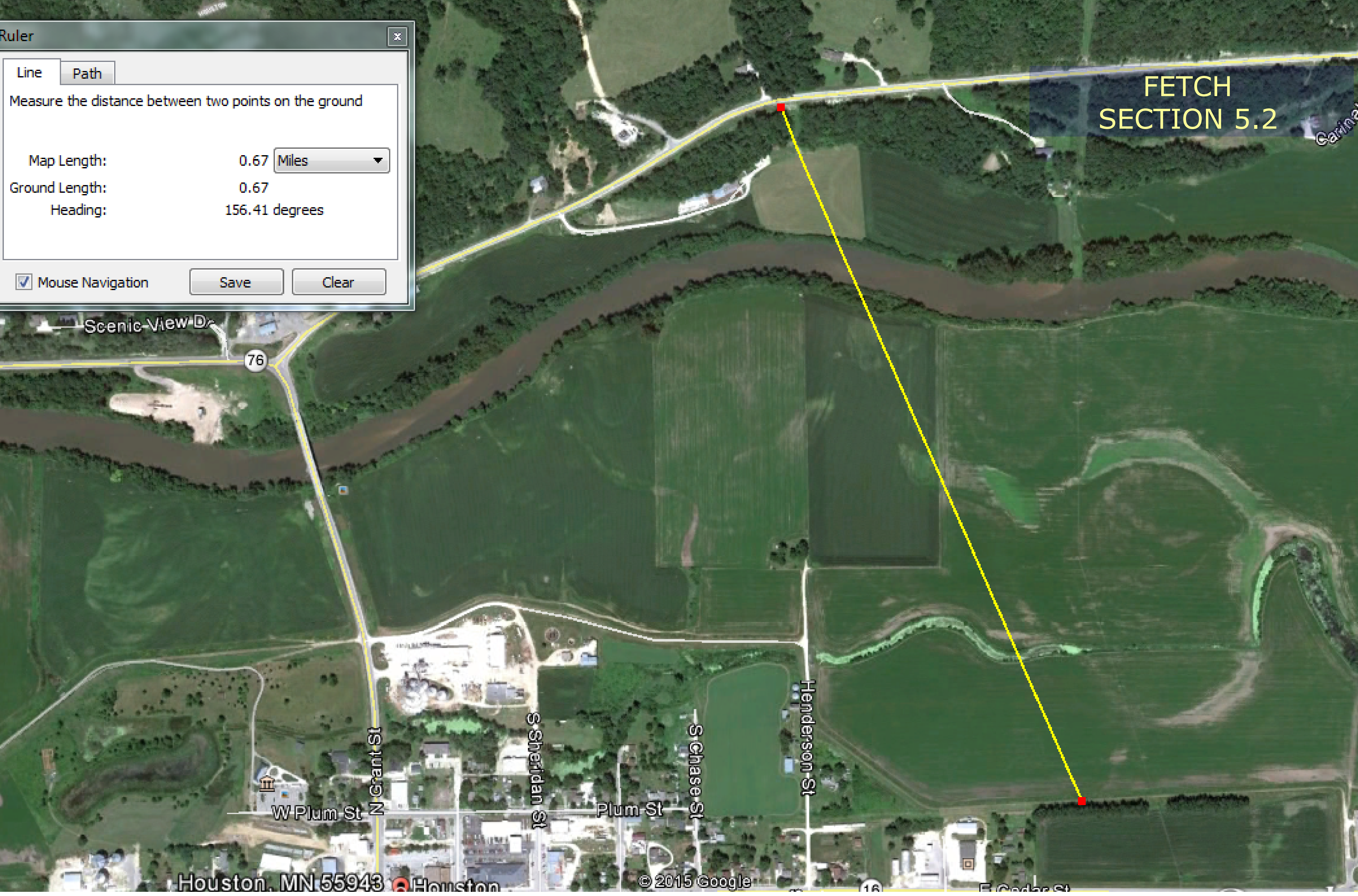
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY - PANEL NUMBER
270190 0065 C

MAP REVISED:
JUNE 6, 2001

Federal Emergency Management Agency

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Seattle City Office	DIR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SPD	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	PGU	51	49	54	44	46	37	39	33	33	41	63	46	63
Spokane	DIR	NE	NE	ENE	ENE	SW	SW	SW	SW	SW	SW	SW	SW	SW
	SPD	9	9	10	10	9	9	9	8	8	8	9	8	9
	PGU	56	51	52	62	53	49	51	47	47	62	56	63	63
Walla Walla	DIR	S	S	S	S	S	S	S	S	S	S	S	S	S
	SPD	5	6	6	6	6	6	5	5	5	5	5	5	5
	$PGU	49	47	62	41	37	37	36	35	51	54	67	47	67
Whidbey Island NAS	DIR	ESE	SE	SSE	W	W	W	W	W	W	SE	ESE	SE	W
	SPD	7	8	8	7	6	6	5	5	5	6	8	8	6
	PGU	69	67	62	61	54	45	53	51	59	70	70	69	70
Yakima	DIR	W	W	W	W	W	W	W	W	W	W	W	W	W
	SPD	6	6	8	9	8	8	8	8	7	7	6	5	7
	PGU	55	56	51	52	69	51	59	44	55	54	58	61	69
WEST VIRGINIA														
Beckley	DIR	WNW	WNW	SE	WNW	SE	WSW	WSW	SE	SE	SE	SE	SE	SE
	SPD	10	10	10	10	8	7	7	7	7	8	9	10	9
	PGU	51	62	48	48	56	53	51	46	48	43	60	53	62
Charleston	DIR	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW
	SPD	7	7	8	7	6	5	5	4	5	5	6	7	6
	#PGU	46	32	38	43	41	37	46	21	30	39	37	29	46
Elkins	DIR	WNW	WNW	WNW	NW	NW	WNW	WNW	WNW	WNW	WNW	WNW	W	WNW
	SPD	7	8	8	8	6	5	4	4	4	5	7	8	6
	PGU	56	49	48	69	60	69	47	46	44	46	59	52	69
Huntington	DIR	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	WSW	SW	SW	WSW
	SPD	8	8	8	8	6	6	5	5	5	6	7	8	7
	PGU	51	53	54	52	55	56	56	49	41	44	55	51	56
WISCONSIN														
Green Bay	DIR	W	W	SSW	SSW	NNE	NNE	NNE	NNE	NNE	NNE	SSW	SSW	SSW
	SPD	11	10	11	11	10	9	8	8	9	10	11	10	10
	PGU	46	46	55	49	81	49	56	54	47	44	49	53	81
La Crosse	DIR	NW	NW	NW	S	S	S	S	S	S	S	S	S	S
	SPD	9	9	10	11	10	9	8	7	8	9	10	9	9
	PGU	45	37	40	53	58	63	52	63	40	39	46	43	63
Madison	DIR	WNW	WNW	WNW	S	S	S	S	S	S	S	S	WNW	S
	SPD	11	10	11	12	10	9	8	8	9	10	11	10	10
	PGU	46	62	67	63	63	70	83	64	64	62	52	58	83
Milwaukee	DIR	WNW	WNW	WNW	N	NNE	NNE	SW	SW	SSW	SSW	WNW	WNW	WSW
	SPD	13	12	13	13	12	10	10	10	10	11	12	12	12
	PGU	54	46	77	64	54	56	81	69	58	53	56	59	81
WYOMING														
Casper	DIR	SW	SW	SW	WSW	WSW	WSW	WSW	WSW	WSW	SW	SW	SW	SW
	SPD	17	15	14	12	12	11	10	10	11	12	15	16	13
	PGU	67	64	63	64	64	64	62	62	63	62	60	66	67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Path
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Ground Length: 0.67
Heading: 156.41 degrees
Mouse Navigation
Save
Clear
FETCH
SECTION 5.2
Scenic View Dr
76
N Grant St
S Sheridan St
S Chase St
Henderson St
W Plum St
Plum St
Houston, MN 55943
Houston
© 2015 Google

HOUSTON, MN LEVEE CERTIFICATION
EMBANKMENT PROTECTION - WIND WAVE ACTION

INPUT

g =	32.2	ft/sec^2	acceleration of gravity
F_e =	0.5	miles	Fetch length (use 0.5 miles minimum)
U_{10} =	92.4	fps	Windspeed
Ø =	0	degrees	Angle between wind and wave direction

EM 1110-2-1100 (PART II-2)

g =	9.81456	m/sec^2	
F_e =	804.65	meters	Straight line Fetch distance
U_{10} =	28.16352	m/s	Wind speed at 10m elevation
C_D =	0.002086	-	Drag coefficient
u_* =	1.28622	m/s	friction velocity
H_{m0} =	0.48	meters	Significant wave height
T_p =	1.66	sec	

WIND-WAVE GENERATION ON RESTRICTED FETCHES

U cos Ø =	92.4		
X =	9.95671		
H =	0.00		
F =	1.37		
f_s =	0.48	Hz	peak frequency
H_s =	1.25	ft	Significant wave height
T_p =	2.10	sec	

SLOPE PROTECTION FOR DAMS AND LAKESHORES

H_0 =	2	ft	use 2' minimum for boats
w_r =	150	lbs/ft	riprap unit weight
w_w =	62.4	lbs/ft	water unit weight
S_r =	2.40	-	specific gravity
D_F =	1	-	Safety factor
a =	0.30	ft/ft	riverside slope
K_{rr} =	2.5		Stability coefficient
W_{50} =	52.48	lbs	
d_{50} =	10	inch	

EM 1110-2-1100 (PART VI-5.2) / ERDC/CHL CHETN-III-77

H_0 =	1.58	ft	Wave HEIGHT
T =	1.66	sec	Wave period
a =	0.30	ft/ft	riverside slope
R_c =	3.25	ft	freeboard
L_0 =	14.07	ft	deepwater wave length
s_0 =	0.112	ft/ft	deepwater wave steepness
γ =	1.000	-	$\gamma_r * \gamma_b * \gamma_h * \gamma_\beta$
ξ =	0.90		Iribarren number
R_u =	2.12	Run-up	$\xi \leq 2$
q_w =	7.1E-06	cfs/ft	Average wave flow over levee

RUNUP
SECTION 5.3

A-1							
		Total Area =		53.15 acres		53.13	
			Composite CN =	86.5			
OBJECTID	Subbasin_N	CN_Class	HydSoilGrp	Area_Ac	CN	% Area	CN x % Area
180	A-1	URB_C	B	7.804	92	0.147	13.51
197	A-1	OPEN_W	B	0.003	98	0.000	0.00
201	A-1	URB_I	B	0.065	88	0.001	0.11
205	A-1	URB_I	B/D	0.071	93	0.001	0.13
208	A-1	OPEN_W	B	2.012	98	0.038	3.71
209	A-1	OPEN_W		1.876	98	0.035	3.46
210	A-1	OPEN_W	C	3.590	98	0.068	6.62
211	A-1	OPEN_W	B/D	2.468	98	0.046	4.55
212	A-1	Open_FC	B	3.448	69	0.065	4.48
214	A-1	Open_FC	C	5.286	79	0.099	7.86
215	A-1	Open_FC	B/D	3.295	84	0.062	5.21
216	A-1	Row_Crops_SR_G	B	3.841	78	0.072	5.64
217	A-1	Row_Crops_SR_G	A	0.873	67	0.016	1.10
218	A-1	Row_Crops_SR_G	C	3.526	85	0.066	5.64
219	A-1	Row_Crops_SR_G	B/D	0.767	89	0.014	1.28
220	A-1	Row_Crops_SR_G	B/D	3.814	89	0.072	6.39
221	A-1	Row_Crops_SR_G	B/D	3.484	89	0.066	5.83
222	A-1	Row_Crops_SR_G	C	1.617	85	0.030	2.59
223	A-1	URB_I	B	1.317	88	0.025	2.18
226	A-1	URB_I	C	0.257	91	0.005	0.44
227	A-1	URB_I	B/D	0.000	93	0.000	0.00
228	A-1	URB_I	B/D	0.010	93	0.000	0.02
229	A-1	URB_I	C	0.006	91	0.000	0.01
231	A-1	RES_1/4	B	2.045	75	0.038	2.89
247	A-1	RES_1/4	B/D	0.057	87	0.001	0.09
312	A-1	IMP_ST_OD	B/D	0.111	93	0.002	0.19
313	A-1	IMP_ST_OD	B/D	0.836	93	0.016	1.46
315	A-1	IMP_ST_OD	C	0.594	92	0.011	1.03
354	A-1	OPEN_W	B	0.016	98	0.000	0.03
355	A-1	Row_Crops_SR_G	B	0.016	78	0.000	0.02
356	A-1	OPEN_W	C	0.012	98	0.000	0.02
357	A-1	Row_Crops_SR_G	C	0.012	85	0.000	0.02

A-1-1							
		Total Area =		25.13 acres		25.13	
				Composite CN =	**86.5**		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
224	A-1-1	URB_I	B	0.093	88	0.004	0.33
230	A-1-1	URB_I	C	0.000	91	0.000	0.00
234	A-1-1	RES_1/4	B	0.009	75	0.000	0.03
254	A-1-1	RES_1/4	C	0.006	83	0.000	0.02
271	A-1-1	RES_1/2	B	0.024	70	0.001	0.07
275	A-1-1	RES_1/2	C	1.848	80	0.074	5.88
278	A-1-1	RES_1/2		0.364	98	0.014	1.42
285	A-1-1	OPEN_W		1.170	98	0.047	4.56
286	A-1-1	OPEN_W	B/D	0.307	98	0.012	1.20
288	A-1-1	OPEN_W	C	1.564	98	0.062	6.10
289	A-1-1	OPEN_W		2.423	98	0.096	9.45
290	A-1-1	OPEN_W	B	2.778	98	0.111	10.83
291	A-1-1	Open_FC	C	2.540	79	0.101	7.99
292	A-1-1	Open_FC		0.016	98	0.001	0.06
293	A-1-1	URB_C		0.736	98	0.029	2.87
294	A-1-1	URB_C	B/D	0.370	95	0.015	1.40
295	A-1-1	URB_C	A	0.025	89	0.001	0.09
296	A-1-1	URB_C		0.011	98	0.000	0.04
298	A-1-1	URB_C	B	3.719	92	0.148	13.62
299	A-1-1	PAST_F		0.004	98	0.000	0.02
300	A-1-1	PAST_F	B/D	0.430	84	0.017	1.44
302	A-1-1	PAST_F	C	0.222	79	0.009	0.70
303	A-1-1	PAST_F	A	0.928	49	0.037	1.81
305	A-1-1	PAST_F	B	4.089	69	0.163	11.23
311	A-1-1	IMP_ST_OD	B	0.004	89	0.000	0.01
314	A-1-1	IMP_ST_OD	B/D	0.751	93	0.030	2.78
316	A-1-1	IMP_ST_OD	C	0.699	92	0.028	2.56

A-1-2							
		Total Area =		300.2 acres	300.26		
				Composite CN =	60.5		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
60	A-1-2			0.015	98	0.000	0.00
77	A-1-2	WOOD_G	B/D	0.157	77	0.001	0.04
82	A-1-2	WOOD_G	A	38.102	30	0.127	3.81
86	A-1-2	WOOD_G	B	126.350	55	0.421	23.15
89	A-1-2	WOOD_G	C	0.480	70	0.002	0.11
90	A-1-2	WOOD_G	C	20.991	70	0.070	4.89
92	A-1-2	WOOD_G	C	14.832	70	0.049	3.46
97	A-1-2	WOOD_G	C	1.187	70	0.004	0.28
101	A-1-2	WOOD_G	C	9.829	70	0.033	2.29
103	A-1-2	PAST_G	A	3.875	39	0.013	0.50
104	A-1-2	PAST_G	B	0.364	61	0.001	0.07
105	A-1-2	PAST_F	B/D	6.431	84	0.021	1.80
106	A-1-2	PAST_F	A	8.326	49	0.028	1.36
107	A-1-2	PAST_F	B	7.881	69	0.026	1.81
108	A-1-2	PAST_F		0.193	98	0.001	0.06
109	A-1-2	Open_GC	B/D	4.457	80	0.015	1.19
111	A-1-2	Open_GC	A	2.074	39	0.007	0.27
239	A-1-2	RES_1/4	B/D	1.329	87	0.004	0.39
249	A-1-2	RES_1/4	C	0.712	83	0.002	0.20
267	A-1-2	URB_C	B/D	3.509	95	0.012	1.11
270	A-1-2	URB_C		0.188	98	0.001	0.06
272	A-1-2	RES_1/2	B/D	0.147	85	0.000	0.04
274	A-1-2	RES_1/2	C	1.253	80	0.004	0.33
280	A-1-2	OPEN_W	B/D	4.123	98	0.014	1.35
281	A-1-2	OPEN_W		2.168	98	0.007	0.71
282	A-1-2	OPEN_W		4.641	98	0.015	1.52
283	A-1-2	OPEN_W	C	1.261	98	0.004	0.41
284	A-1-2	OPEN_W	A	0.004	98	0.000	0.00
287	A-1-2	OPEN_W	C	0.060	98	0.000	0.02
297	A-1-2	URB_C	B	0.030	92	0.000	0.01
301	A-1-2	PAST_F	C	3.337	79	0.011	0.88
304	A-1-2	PAST_F	B	4.578	69	0.015	1.05
306	A-1-2	Row_Crops_SR_G	B/D	2.976	89	0.010	0.88
307	A-1-2	Row_Crops_SR_G	C	6.170	85	0.021	1.75
308	A-1-2	Row_Crops_SR_G	B/D	4.709	89	0.016	1.40
309	A-1-2	Row_Crops_SR_G	A	10.063	67	0.034	2.25
310	A-1-2	Row_Crops_SR_G		0.142	98	0.000	0.05
317	A-1-2	OPEN_W	C	1.315	98	0.004	0.43
318	A-1-2	OPEN_W	B	0.065	98	0.000	0.02
319	A-1-2	IMP_ST_OD	C	1.810	92	0.006	0.55
336	A-1-2	WOOD_G	B	0.001	55	0.000	0.00
337	A-1-2	PAST_G	B	0.001	61	0.000	0.00
358	A-1-2	OPEN_W	B/D	0.013	98	0.000	0.00
359	A-1-2	Row_Crops_SR_G	B/D	0.013	89	0.000	0.00
360	A-1-2	OPEN_W	C	0.048	98	0.000	0.02
361	A-1-2	Row_Crops_SR_G	C	0.048	85	0.000	0.01

A-1-3							
		Total Area =		58.85 acres			58.85
				Composite CN =	66.7		
OBJECTID	Subbasin_N	CN_Class	HydSoilGrp	Area_Ac	CN	% Area	CN x % Area
80	A-1-3	WOOD_G	B/D	0.007	77	0.000	0.01
85	A-1-3	WOOD_G	A	16.562	30	0.281	8.44
100	A-1-3	WOOD_G	C	1.528	70	0.026	1.82
110	A-1-3	Open_GC	B/D	7.374	80	0.125	10.02
112	A-1-3	Open_GC	A	0.156	39	0.003	0.10
242	A-1-3	RES_1/4	B/D	7.399	87	0.126	10.94
246	A-1-3	RES_1/4	A	0.191	61	0.003	0.20
253	A-1-3	RES_1/4	C	3.035	83	0.052	4.28
261	A-1-3	RES_1/3	B/D	2.596	86	0.044	3.79
262	A-1-3	RES_1/3	A	4.408	57	0.075	4.27
263	A-1-3	OPEN_W	B/D	4.251	98	0.072	7.08
264	A-1-3	OPEN_W	A	1.475	98	0.025	2.46
265	A-1-3	Open_FC	B/D	1.748	84	0.030	2.50
266	A-1-3	Open_FC	A	3.010	49	0.051	2.51
268	A-1-3	URB_C	B/D	5.115	95	0.087	8.26

A-1-4							
		Total Area =		15.26 acres			15.26
				Composite CN =	**82.2**		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
236	A-1-4	RES_1/4	B	1.128	75	0.074	5.55
243	A-1-4	RES_1/4	B/D	0.998	87	0.065	5.69
256	A-1-4	RES_1/4	C	10.015	83	0.656	54.47
269	A-1-4	URB_C	B/D	0.000	95	0.000	0.00
273	A-1-4	RES_1/2	B/D	0.012	85	0.001	0.07
277	A-1-4	RES_1/2	C	2.932	80	0.192	15.37
279	A-1-4	RES_1/2		0.171	98	0.011	1.10

A-1-5							
		Total Area =		19.52 acres			19.52
				Composite CN =	**77.6**		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
184	A-1-5	URB_C	B	0.530	92	0.027	2.50
225	A-1-5	URB_I	B	2.456	88	0.126	11.07
235	A-1-5	RES_1/4	B	15.133	75	0.775	58.14
255	A-1-5	RES_1/4	C	1.050	83	0.054	4.47
276	A-1-5	RES_1/2	C	0.355	80	0.018	1.45

A-2							
		Total Area =		34.02 acres			33.42
				Composite CN =	81.7		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
158	A-2	RES_1/2	B	3.122	70	0.092	6.424
161	A-2	BRUSH_G	B	0.203	48	0.006	0.287
163	A-2	Small_Grain_SR_G	B	9.027	75	0.265	19.900
164	A-2	Small_Grain_SR_G	B/D	1.130	87	0.033	2.890
182	A-2	URB_C	B	3.920	92	0.115	10.600
187	A-2	URB_C		0.312	98	0.009	0.900
188	A-2	RES_1/3	B	4.045	72	0.119	8.561
189	A-2	RES_1/3		0.188	98	0.006	0.541
191	A-2	Small_Grain_SR_G	B	2.389	75	0.070	5.266
192	A-2	Small_Grain_SR_G		0.110	98	0.003	0.317
193	A-2	Small_Grain_SR_G	B/D	2.222	87	0.065	5.683
194	A-2	OPEN_W	B	0.412	98	0.012	1.186
195	A-2	OPEN_W		0.894	98	0.026	2.576
196	A-2	OPEN_W	B/D	2.712	98	0.080	7.813
199	A-2	OPEN_W	B	0.012	98	0.000	0.033
203	A-2	URB_I	B	2.726	88	0.080	7.051
207	A-2	URB_I	B/D	0.598	93	0.018	1.636

A-2-1							
		Total Area =		15.83 acres			15.83
				Composite CN =	88.3		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
181	A-2-1	RES_1/8	B	7.092	85	0.448	38.083
186	A-2-1	URB_C		0.268	98	0.017	1.657
190	A-2-1	Small_Grain_SR_G	B	0.010	75	0.001	0.048
198	A-2-1	OPEN_W	B	0.926	98	0.059	5.734
200	A-2-1	OPEN_W		0.943	98	0.060	5.836
202	A-2-1	URB_I	B	5.526	88	0.349	30.719
204	A-2-1	URB_I		0.065	98	0.004	0.399
206	A-2-1	URB_I	B/D	0.993	93	0.063	5.832
213	A-2-1	Open_FC	B	0.006	69	0.000	0.025

A-2-2							
		Total Area =		21.19 acres			21.19
				Composite CN =	**85.0**		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
66	A-2-2			0.011	98	0.001	0.051
185	A-2-2	URB_C	B	12.411	92	0.586	53.886
237	A-2-2	RES_1/4	B	8.769	75	0.414	31.037

A-2-3							
		Total Area =		14.76 acres			14.76
				Composite CN =	82.5		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
63	A-2-3			0.044	98	0.003	0.290
152	A-2-3	URB_C	B	2.290	92	0.155	14.274
156	A-2-3	URB_C	C	1.868	94	0.127	11.894
160	A-2-3	RES_1/2	B	1.011	70	0.068	4.793
175	A-2-3	RES_1/3	B	3.459	72	0.234	16.873
178	A-2-3	RES_1/3	C	1.189	81	0.081	6.526
183	A-2-3	URB_C	B	2.586	92	0.175	16.121
232	A-2-3	RES_1/4	B	2.311	75	0.157	11.744
250	A-2-3	RES_1/4	C	0.002	83	0.000	0.012
338	A-2-3	URB_C	C	0.000	94	0.000	0.002
339	A-2-3	RES_1/3	C	0.000	81	0.000	0.001
346	A-2-3	RES_1/3	B	0.001	72	0.000	0.004
347	A-2-3	URB_C	B	0.001	92	0.000	0.005

A-2-4							
		Total Area =		20.83 acres			20.83
				Composite CN =	83.0		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
67	A-2-4			0.001	98	0.000	0.003
238	A-2-4	RES_1/4	B	2.231	75	0.107	8.032
244	A-2-4	RES_1/4	B/D	0.299	87	0.014	1.250
257	A-2-4	RES_1/4	C	13.246	83	0.636	52.779
258	A-2-4	URB_C	C	3.135	94	0.151	14.149
260	A-2-4	Open_GC	C	1.915	74	0.092	6.803

A-2-5							
		Total Area =		21.15 acres			21.18
				Composite CN =	84.4		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
64	A-2-5			0.053	98	0.002	0.245
115	A-2-5	Row_Crops_SR_G	B/D	0.004	89	0.000	0.018
122	A-2-5	Row_Crops_SR_G	C	0.047	85	0.002	0.187
154	A-2-5	URB_C	B/D	0.019	95	0.001	0.087
157	A-2-5	URB_C	C	3.389	94	0.160	15.061
166	A-2-5	RES_1/4	B/D	0.462	87	0.022	1.902
168	A-2-5	RES_1/4	C	3.914	83	0.185	15.359
176	A-2-5	RES_1/3	B/D	0.976	86	0.046	3.968
179	A-2-5	RES_1/3	C	8.126	81	0.384	31.122
233	A-2-5	RES_1/4	B	0.086	75	0.004	0.304
240	A-2-5	RES_1/4	B/D	0.023	87	0.001	0.094
251	A-2-5	RES_1/4	C	4.027	83	0.190	15.802
340	A-2-5	URB_C	C	0.000	94	0.000	0.002
341	A-2-5	RES_1/3	C	0.000	81	0.000	0.001
342	A-2-5	RES_1/4	B/D	0.001	87	0.000	0.003
343	A-2-5	RES_1/3	B/D	0.001	86	0.000	0.003
348	A-2-5	RES_1/3	B/D	0.002	86	0.000	0.008
349	A-2-5	RES_1/4	B/D	0.002	87	0.000	0.008
352	A-2-5	RES_1/3	C	0.025	81	0.001	0.094
353	A-2-5	RES_1/4	C	0.025	83	0.001	0.097

A-2-6							
		Total Area =		161.78 acres			161.79
				Composite CN =	52.2		
OBJECTID	**Subbasin_N**	**CN_Class**	**HydSoilGrp**	**Area_Ac**	**CN**	**% Area**	**CN x % Area**
65	A-2-6			0.010	98	0.000	0.006
79	A-2-6	WOOD_G	B/D	0.224	77	0.001	0.107
84	A-2-6	WOOD_G	A	59.373	30	0.367	11.010
88	A-2-6	WOOD_G	B	47.136	55	0.291	16.025
91	A-2-6	WOOD_G	C	17.865	70	0.110	7.730
95	A-2-6	WOOD_G	C	3.780	70	0.023	1.636
98	A-2-6	WOOD_G	C	6.423	70	0.040	2.779
99	A-2-6	WOOD_G	C	1.197	70	0.007	0.518
102	A-2-6	WOOD_G	B	4.546	55	0.028	1.546
116	A-2-6	Row_Crops_SR_G	B/D	0.022	89	0.000	0.012
170	A-2-6	Open_FC	B/D	6.544	84	0.040	3.398
171	A-2-6	Open_FC	A	1.414	49	0.009	0.428
172	A-2-6	OPEN_W	B/D	0.366	98	0.002	0.222
173	A-2-6	OPEN_W	A	0.001	98	0.000	0.000
174	A-2-6	OPEN_W		0.851	98	0.005	0.515
177	A-2-6	RES_1/3	B/D	1.275	86	0.008	0.678
241	A-2-6	RES_1/4	B/D	7.753	87	0.048	4.169
245	A-2-6	RES_1/4	A	0.847	61	0.005	0.319
248	A-2-6	RES_1/4		0.202	98	0.001	0.123
252	A-2-6	RES_1/4	C	1.804	83	0.011	0.926
259	A-2-6	Open_GC	C	0.140	74	0.001	0.064
344	A-2-6	Open_FC	B/D	0.004	84	0.000	0.002
345	A-2-6	RES_1/3	B/D	0.004	86	0.000	0.002
350	A-2-6	RES_1/3	B/D	0.005	86	0.000	0.003
351	A-2-6	RES_1/4	B/D	0.005	87	0.000	0.003

B

Total Area = 260.31 acres 260.31

Composite CN = 66.4

OBJECTID	Subbasin_N	CN_Class	HydSoilGrp	Area_Ac	CN	% Area	CN x % Area
62	B			0.006	98	0.000	0.002
68	B	IMP_ST_OD	B	5.226	89	0.020	1.787
69	B	IMP_ST_OD	B/D	0.000	93	0.000	0.000
70	B	IMP_ST_OD	A	0.840	83	0.003	0.268
71	B	IMP_ST_OD	C	2.260	92	0.009	0.799
72	B	IMP_ST_OD	A	0.861	83	0.003	0.274
73	B	IMP_ST_OD	B	0.643	89	0.002	0.220
74	B	IMP_ST_OD	A	0.017	83	0.000	0.005
75	B	›w_Crops_SR_	A	0.371	67	0.001	0.096
76	B	›w_Crops_SR_	B	3.808	78	0.015	1.141
78	B	WOOD_G	B/D	11.218	77	0.043	3.318
81	B	WOOD_G	C	0.725	70	0.003	0.195
83	B	WOOD_G	A	69.437	30	0.267	8.002
87	B	WOOD_G	B	9.110	55	0.035	1.925
93	B	WOOD_G		2.336	98	0.009	0.880
94	B	WOOD_G	C	13.391	70	0.051	3.601
96	B	WOOD_G	A	2.840	30	0.011	0.327
113	B	›w_Crops_SR_	B	0.213	78	0.001	0.064
114	B	›w_Crops_SR_	B/D	26.618	89	0.102	9.101
117	B	›w_Crops_SR_	A	3.640	67	0.014	0.937
118	B	›w_Crops_SR_	C	9.334	85	0.036	3.048
119	B	›w_Crops_SR_	A	1.257	67	0.005	0.324
120	B	›w_Crops_SR_	C	9.747	85	0.037	3.183
121	B	›w_Crops_SR_	C	5.438	85	0.021	1.776
123	B	›w_Crops_SR_	B/D	0.000	89	0.000	0.000
124	B	URB_I	B	2.203	88	0.008	0.745
125	B	URB_I	B/D	0.053	93	0.000	0.019
126	B	URB_I	C	1.047	91	0.004	0.366
127	B	URB_I	C	0.063	91	0.000	0.022
128	B	OPEN_W	B	0.583	98	0.002	0.220
129	B	OPEN_W	A	0.753	98	0.003	0.284
130	B	OPEN_W	C	3.833	98	0.015	1.443
131	B	OPEN_W		2.540	98	0.010	0.956
132	B	OPEN_W	B/D	1.122	98	0.004	0.423
133	B	ıall_Grain_SR	B	3.519	75	0.014	1.014
134	B	ıall_Grain_SR	A	1.044	63	0.004	0.253
135	B	ıall_Grain_SR	C	0.087	83	0.000	0.028
136	B	ıall_Grain_SR	B	11.518	75	0.044	3.319
137	B	ıall_Grain_SR	A	2.760	63	0.011	0.668
138	B	Open_FC	B	7.495	69	0.029	1.987
139	B	Open_FC	B/D	2.497	84	0.010	0.806
140	B	Open_FC	C	8.133	79	0.031	2.468
141	B	Open_FC	C	0.018	79	0.000	0.006
142	B	Open_FC		0.599	98	0.002	0.225
143	B	Open_FC	B/D	3.888	84	0.015	1.255
144	B	URB_C	B	5.758	92	0.022	2.035
145	B	IMP_ST_G	B/D	0.700	91	0.003	0.245
146	B	IMP_ST_G	C	1.235	89	0.005	0.422
147	B	IMP_ST_G	C	0.350	89	0.001	0.120
148	B	RES_1	B	0.852	68	0.003	0.223
149	B	RES_1	B/D	1.916	84	0.007	0.618
150	B	RES_1	C	2.112	79	0.008	0.641
151	B	URB_C	B	0.747	92	0.003	0.264
153	B	URB_C	B/D	2.166	95	0.008	0.791
155	B	URB_C	C	3.443	94	0.013	1.243

NOAA Atlas 14, Volume 8, Version 2
Location name: Houston, Minnesota, US*
Latitude: 43.7634°, Longitude: -91.5690°
Elevation: 685 ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.382 (0.305–0.481)	0.446 (0.356–0.562)	0.553 (0.440–0.699)	0.644 (0.509–0.817)	0.771 (0.591–1.01)	0.872 (0.653–1.16)	0.974 (0.706–1.32)	1.08 (0.752–1.51)	1.22 (0.819–1.75)	1.33 (0.871–1.94)
10-min	0.559 (0.446–0.704)	0.653 (0.521–0.824)	0.810 (0.644–1.02)	0.943 (0.746–1.20)	1.13 (0.865–1.48)	1.28 (0.956–1.70)	1.43 (1.03–1.94)	1.58 (1.10–2.21)	1.79 (1.20–2.57)	1.95 (1.28–2.84)
15-min	0.682 (0.544–0.859)	0.797 (0.636–1.00)	0.988 (0.786–1.25)	1.15 (0.909–1.46)	1.38 (1.06–1.81)	1.56 (1.17–2.07)	1.74 (1.26–2.37)	1.93 (1.34–2.69)	2.18 (1.46–3.13)	2.38 (1.56–3.46)
30-min	0.971 (0.776–1.22)	1.14 (0.908–1.44)	1.42 (1.13–1.79)	1.65 (1.30–2.09)	1.98 (1.51–2.59)	2.23 (1.67–2.96)	2.49 (1.81–3.39)	2.76 (1.92–3.85)	3.12 (2.09–4.47)	3.39 (2.22–4.94)
60-min	1.27 (1.02–1.60)	1.49 (1.19–1.88)	1.86 (1.48–2.35)	2.18 (1.72–2.76)	2.62 (2.01–3.44)	2.97 (2.23–3.96)	3.34 (2.42–4.54)	3.71 (2.59–5.19)	4.23 (2.84–6.07)	4.62 (3.02–6.73)
2-hr	1.57 (1.27–1.96)	1.85 (1.48–2.31)	2.31 (1.85–2.89)	2.70 (2.15–3.40)	3.27 (2.53–4.26)	3.72 (2.81–4.91)	4.18 (3.06–5.66)	4.67 (3.28–6.48)	5.33 (3.61–7.61)	5.85 (3.86–8.46)
3-hr	1.75 (1.42–2.18)	2.06 (1.66–2.56)	2.58 (2.08–3.21)	3.03 (2.43–3.79)	3.69 (2.87–4.80)	4.22 (3.21–5.56)	4.78 (3.51–6.44)	5.36 (3.79–7.43)	6.17 (4.20–8.78)	6.81 (4.51–9.81)
6-hr	2.04 (1.66–2.51)	2.40 (1.95–2.95)	3.02 (2.45–3.73)	3.58 (2.89–4.45)	4.42 (3.48–5.73)	5.11 (3.92–6.70)	5.84 (4.34–7.84)	6.63 (4.72–9.14)	7.73 (5.31–11.0)	8.62 (5.75–12.3)
12-hr	2.31 (1.90–2.81)	2.71 (2.22–3.30)	3.43 (2.81–4.20)	4.10 (3.34–5.04)	5.12 (4.08–6.62)	5.98 (4.64–7.81)	6.91 (5.18–9.25)	7.93 (5.70–10.9)	9.37 (6.49–13.2)	10.5 (7.08–15.0)
24-hr	2.61 (2.16–3.16)	3.03 (2.51–3.67)	3.82 (3.15–4.63)	4.56 (3.74–5.56)	5.72 (4.61–7.36)	6.72 (5.27–8.73)	7.81 (5.91–10.4)	9.02 (6.55–12.3)	10.8 (7.51–15.1)	12.2 (8.24–17.2)
2-day	3.03 (2.53–3.63)	3.44 (2.87–4.13)	4.24 (3.52–5.09)	5.00 (4.14–6.04)	6.22 (5.06–7.95)	7.28 (5.76–9.39)	8.45 (6.46–11.2)	9.76 (7.15–13.2)	11.7 (8.21–16.3)	13.2 (9.01–18.5)
3-day	3.33 (2.80–3.96)	3.76 (3.16–4.49)	4.59 (3.83–5.48)	5.37 (4.47–6.45)	6.62 (5.40–8.39)	7.70 (6.11–9.86)	8.89 (6.82–11.7)	10.2 (7.51–13.8)	12.1 (8.58–16.8)	13.7 (9.38–19.1)
4-day	3.58 (3.02–4.25)	4.05 (3.41–4.80)	4.91 (4.12–5.85)	5.73 (4.78–6.86)	7.01 (5.74–8.84)	8.12 (6.46–10.3)	9.33 (7.17–12.2)	10.7 (7.86–14.3)	12.6 (8.92–17.4)	14.2 (9.73–19.7)
7-day	4.22 (3.58–4.96)	4.78 (4.05–5.63)	5.80 (4.90–6.85)	6.73 (5.66–7.99)	8.16 (6.70–10.2)	9.36 (7.48–11.8)	10.6 (8.23–13.8)	12.1 (8.94–16.1)	14.1 (10.0–19.3)	15.7 (10.8–21.7)
10-day	4.78 (4.08–5.60)	5.43 (4.62–6.37)	6.58 (5.58–7.73)	7.61 (6.42–8.99)	9.15 (7.53–11.3)	10.4 (8.37–13.1)	11.8 (9.15–15.2)	13.3 (9.87–17.6)	15.4 (11.0–20.9)	17.0 (11.8–23.5)
20-day	6.46 (5.56–7.50)	7.32 (6.28–8.50)	8.78 (7.51–10.2)	10.0 (8.55–11.7)	11.9 (9.80–14.4)	13.3 (10.8–16.5)	14.9 (11.6–18.9)	16.5 (12.3–21.5)	18.7 (13.4–25.2)	20.4 (14.3–28.0)
30-day	7.94 (6.86–9.15)	8.97 (7.74–10.4)	10.7 (9.20–12.4)	12.2 (10.4–14.1)	14.2 (11.8–17.1)	15.8 (12.8–19.3)	17.4 (13.6–21.9)	19.1 (14.3–24.8)	21.4 (15.4–28.6)	23.1 (16.3–31.5)
45-day	9.88 (8.58–11.3)	11.2 (9.69–12.8)	13.3 (11.5–15.3)	15.0 (12.9–17.3)	17.3 (14.3–20.6)	19.1 (15.5–23.1)	20.8 (16.3–26.0)	22.6 (17.0–29.1)	24.8 (18.0–33.0)	26.5 (18.7–36.0)
60-day	11.6 (10.1–13.2)	13.1 (11.4–15.0)	15.5 (13.5–17.8)	17.5 (15.1–20.1)	20.0 (16.7–23.7)	22.0 (17.9–26.5)	23.8 (18.7–29.5)	25.6 (19.3–32.8)	27.9 (20.2–36.9)	29.5 (20.9–40.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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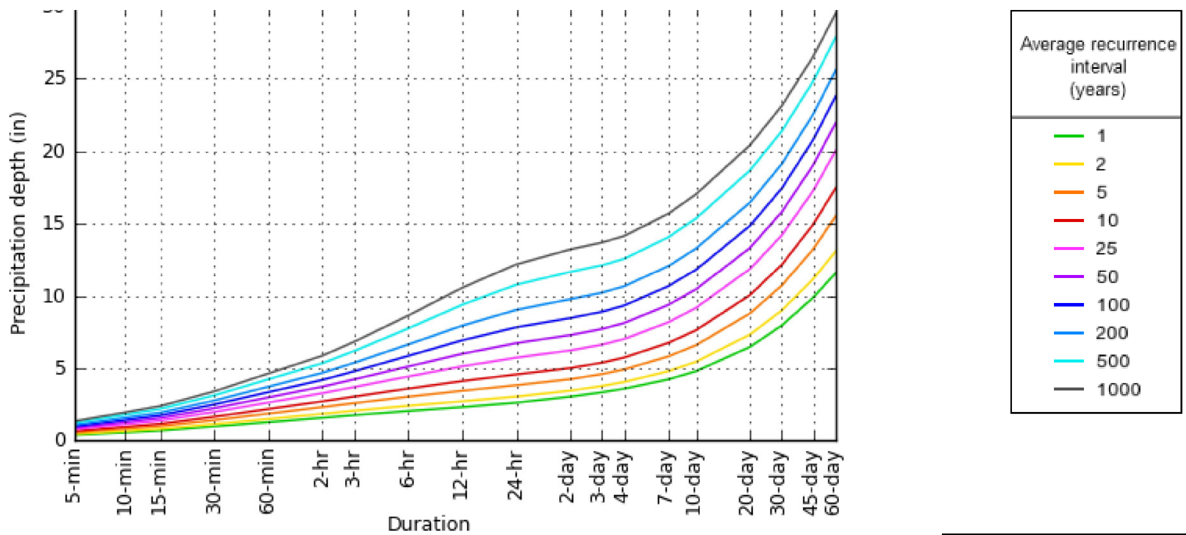
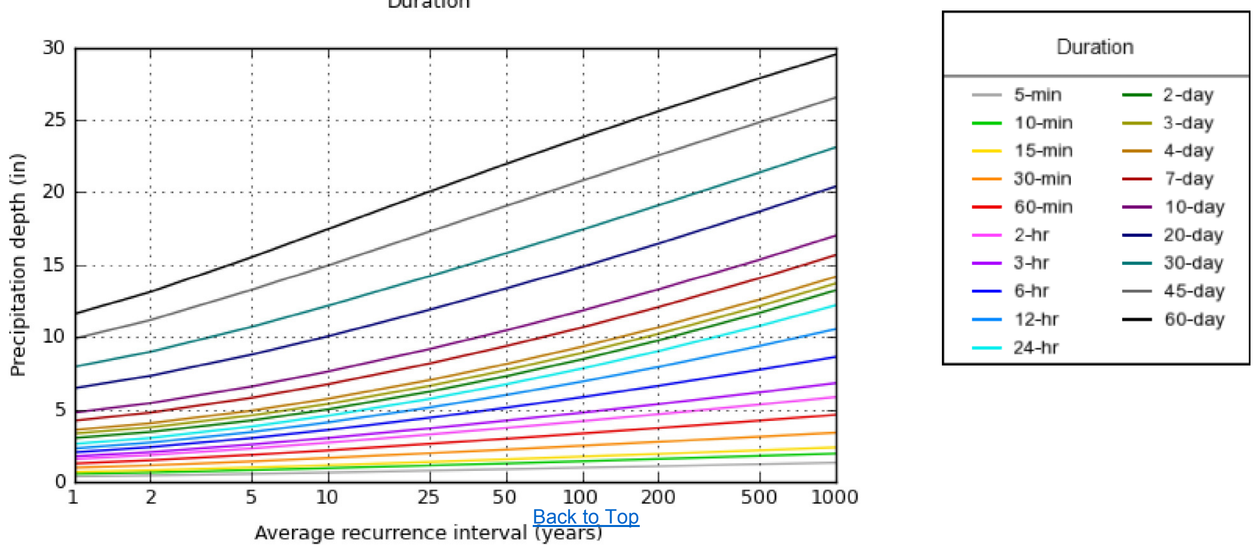
PF graphical

RAINFALL DATA

SECTION 8.2 - INTERIOR DRAINAGE





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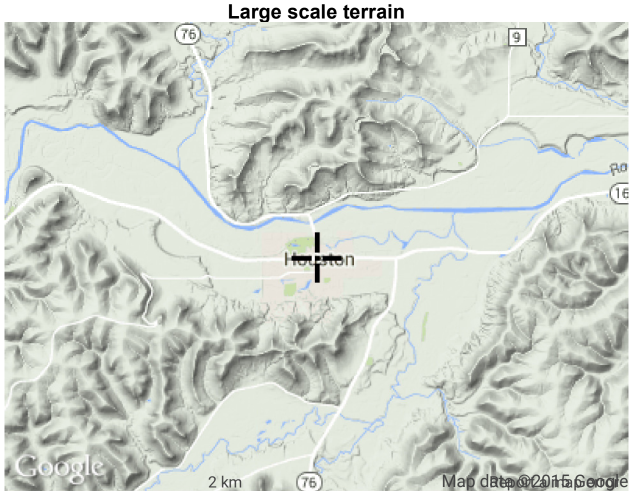
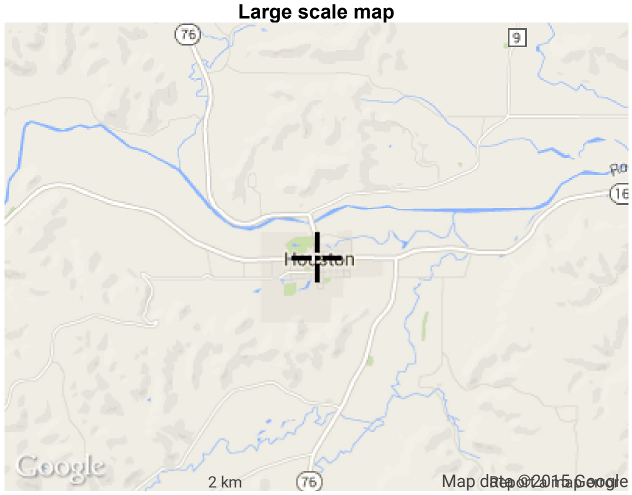
Maps & aerials

Small scale terrain

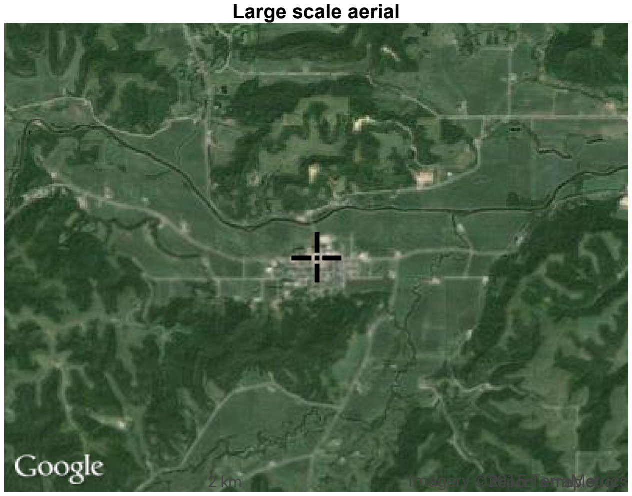
Large scale terrain



Large scale map



Large scale aerial



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[National Oceanic and Atmospheric Administration](#)
[National Weather Service](#)
[Office of Hydrologic Development](#)
1325 East West Highway
Silver Spring, MD 20910

Questions?: HDSC.Questions@noaa.gov

Disclaimer

Pump #1 (5,000 GPM)

Manufacturer's Pump Curve (for 0° vane angle)		
Flow (GPM)	Flow (cfs)	Head (ft)
3750	8.4	16.5
4000	8.9	16.2
4500	10.0	15.3
5000	11.1	14.2
5500	12.3	13.2
6000	13.4	11.9
6500	14.5	10.3
7000	15.6	8.4
7500	16.7	6.3
8000	17.8	3.4

From Davy's drawings sheet 3:

Pump 1 ON El. = 675.0

Pump 1 OFF El. = 674.0

Assumed head when pump turns off = 11.5 ft (685.5 - 674.0)

Revised Pump Curve to Prevent Cycling (for Model)		
Flow (GPM)	Flow (cfs)	Head (ft)
0	0	11.5
6281	14.0	11
6500	14.5	10.3
7000	15.6	8.4
7500	16.7	6.3
8000	17.8	3.4

Pump #2 (15,000 GPM)

Manufacturer's Pump Curve (for 0° vane angle)		
Flow (GPM)	Flow (cfs)	Head (ft)
7700	17.2	20
8000	17.8	19.8
9000	20.1	18.9
10000	22.3	17.7
11000	24.5	16.3
12000	26.7	14.9
13000	29.0	13.2
14000	31.2	11
15000	33.4	8.5
16000	35.7	5.7
16500	36.8	4

From Davy's drawings sheet 3:

Pump 2 ON El. = 678.0

Pump 2 OFF El. = 675.5

Assumed head when pump turns off = 10 ft (685.5 - 675.5)

Revised Pump Curve to Prevent Cycling (for Model)		
Flow (GPM)	Flow (cfs)	Head (ft)
0	0	10
14811	33.0	9.5
15000	33.4	8.5
16000	35.7	5.7
16500	36.8	4

ROOT RIVER AT HOUSTON, MINNESOTA
FEATURE DESIGN MEMORANDUM
FLOOD CONTROL PROJECT

APPENDIX F

STRUCTURAL

TABLE OF CONTENTS

ROOT RIVER AT HOUSTON, MINNESOTA
FEATURE DESIGN MEMORANDUM
FLOOD CONTROL PROJECT

APPENDIX F

STRUCTURAL ANALYSIS & DESIGN

PURPOSE

1. Within this appendix is a description of the methods and criteria used in the design and analysis of the structural portion of the Houston Flood Control Project at Houston, Minnesota. A summary of references, material properties, loads and design criteria are presented herein as well as a description of the design of all major structural features.

2. Structural design computations were completed to enough detail to ensure structural stability and to provide for accurate quantities. The level of overall detail on project features was minimized, but is of a sufficient level as not to hinder the cost estimate or advancement into plans and specification development.

REFERENCES

3. Loading conditions, design assumptions and design methods are based on applicable parts of the following references.

a.ACI 318-89 American Concrete Institute, "Building Code Requirements for Reinforced Concrete".
b.American Concrete Pipe Association, "Concrete Pipe Design Manual", 1978.
c.EC 1110-2-267, Strength Design for Reinforced Concrete Hydraulic Structures (31 Jan 90)
d.EM 1110-1-2101, Working Stresses for Structural Design (1 Nov 63)
e.EM 1110-2-2000, Standard Practices for Concrete (5 Sept 85)
f.EM 1110-2-2502, Retaining and Flood Walls (29 Sept 89)
g.EM 1110-2-2902, Conduits, Culverts and Pipes (March 1969)
h.EM 1110-2-256, Sliding Stability for Concrete Structures (Jun 1981)
i.ETL 1110-2-307, Flotation Stability Criteria for Concrete Hydraulic Structures (Aug 1987)

DESIGN CRITERIA

REINFORCED CONCRETE STRUCTURES

4. Specified Compressive Strength of Concrete: f'c = 4000 psi

5. Steel Reinforcing Bars: Grade 60

6. Minimum reinforcement cover for cast-in-place Hydraulic Structures:
Any surface - 2 inches
Concrete surfaces cast against earth or in contact with flowing water - 3 inches

MATERIAL PROPERTIES

7. Unit Weights: pcf
Concrete - 150
Water - 62.5

8. Soil Unit Weights: pcf

moist	saturated	submerged
120	130	67.5

9. Soil Properties

	phi (degrees)	c (psf)
a. Pervious Backfill for All Structures	24	250

LIVE LOADS

10. For the purposes of drainage pipe design, two live loading types are considered:

a. A construction load of 50,000 lbs for all pipes, and
b. AASHTO HS20 loading for all pipes that cross under roadways.

UPLIFT

11. Uplift head elevation is taken as the full hydrostatic head uniformly distributed beneath the structure unless otherwise determined by Geotechnical Engineering.

PRECAST REINFORCED CONCRETE PIPE

12. Pipe was classed according to ASTM C76 and C655 and shall meet the strength test requirements under the three-edge-bearing method for the specified D-load to produce a 0.01-inch crack. The factor of safety for pipes in the levee is 2.0 in accordance with EM 1110-2-2902.

PROJECT FEATURES

GATEWELLS

13. Interior Flood Control measures include three outlets. The main features of these outlets are gravity inlet and outlet pipes, a gatewell, and headwalls with flapgates at the end of the outlet pipes.

14. The gatewells are located on the riverward side of the levee with the top elevation of the gatewell at the top of levee elevation. The flapgates at the outlet headwalls provide the primary means of closure while a heavy duty sluice gate in the gatewell provides the secondary means of closure. Removable steel gratings on top of the gatewell provide access for the removal and maintenance of the sluice gates while a steel grating hatch provides access via a ladder to the gatewell itself. Inlet ends consist of flared end sections with trash racks. Outlet ends consist of headwalls with flapgates. Pipe joints are bell and spigot with O-rings.

15. Gatewell wall thicknesses are sized based on applied soil and water loadings. The gatewells were analyzed for flotation stability and were found to be stable under full hydrostatic head within an acceptable factor of safety. Since the outlets are not expected to be operated during freezing conditions, ice was not determined to be a problem and therefore was not used as a design load.

16. Handrails surround the perimeter of the gatewell for safety.

HEADWALLS

17. Headwalls are provided at the end of outlet pipes at each outlet to accommodate the flapgates at pipe ends. The headwalls consist of reinforced concrete headwall and sidewalls to retain the earthen levee behind them. The sidewalls descend at a 1V on 3H slope to the toe of the levee. The walls are constructed on top of a reinforced concrete slab. Wall and slab thicknesses are based on applied soil and water loads. Sliding stability was evaluated

using CSlide.

MISCELLANEOUS FEATURES

18. Two additional outlets are required and consist of a sanitary outlet pipe and a natural gas pipeline. The design consists of a gate valve closure for each pipe through the levee housed within a 60 inch manhole. For the sanitary outlet, an 18 inch DIP will replace the vitrified clay pipe currently in use through the levee. The design is based solely on comparison with past similar designs.

19. Near the down stream end of the project, two Catch Basins are provided to facilitate drainage of potential ponding between the levee and U. S. Highway 16. Feature components include 48 inch manhole risers with cone, base and casting along with extensions of existing concrete pipes. The extent of the design consists of selection of manhole sizes and classing of pipe based on experience.

DESIGN COMPUTATIONS

20. The purpose of the computations is to show loading assumptions, design methods, design criteria and level of detail used in designing the structures and to size features to provide accurate quantity estimates. Reinforcement details are not provided but will be developed in Plans and Specifications.

21. The structural computations are arranged as shown in the following table of contents. The headwall and gatewell calculations are shown for outlet A1 only.

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 1 OF 22	FILE: HCOM.WK1

NAME OF OFFICE: ED-D-ES	COMPUTATION: ELEVATIONS & STRUCTURE WEIGHT -- GATEWELL A1
SUBJECT: HOUSTON GDM -- GATEWELL DESIGN	SOURCE DATA:

COMPUTED BY: PWS	CHECKED BY:	APPROVED BY:

ELEVATIONS

TOP OF WALL EL =	692.54
INVERT EL =	675.2
TOP OF SLAB EL =	674.53
BOT OF SLAB EL =	673.03
TOP OF LOWER WALL EL =	682.53
GROUND EL @ BACK OF WALL =	692.54
MAX FLOOD EL =	692.54

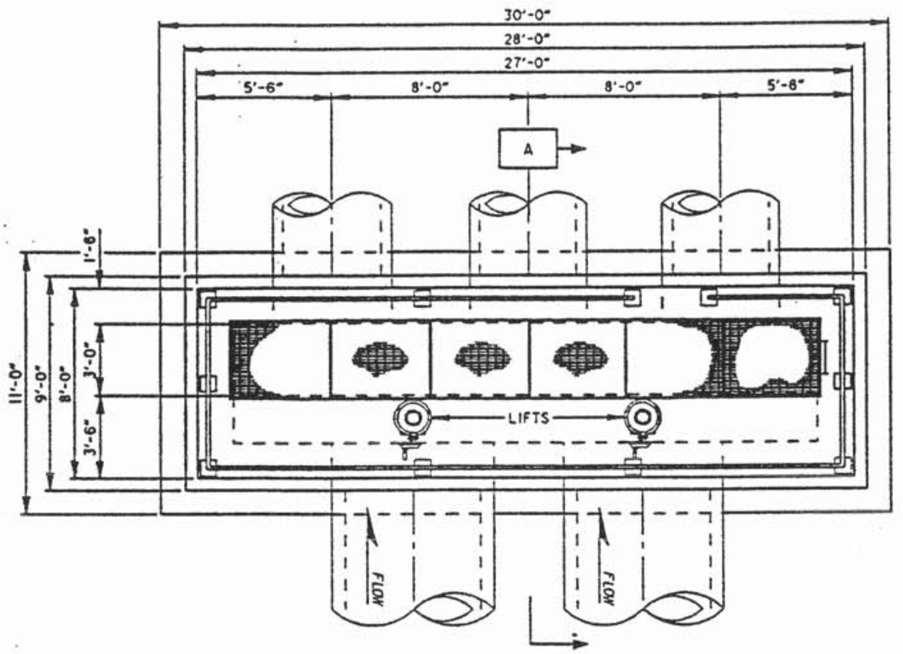
STRUCTURE WEIGHT (SEE SKETCH NEXT PAGE)

COMPONENT	X1(FT)	X2(FT)	Y(FT)	Z(FT)	VOL(FT^3)
FRONT WALL - UPPER		1.5	27	10.01	405.27
- LOWER		2	28	8	448
ACK WALL - UPPER		1.5	27	10.01	405.27
- LOWER		2	28	8	448
SIDEWALLS(2)					
- UPPER		1.5	5	10.01	150.1
- LOWER		2	5	8	160
HAUNCH	1.50	2.00	1.5	24	63
SLAB		11	30	1.5	495
CONC FILL		5	24	0.67	80
HOLES		NO	DIA	THICK.	
		3	4	2	-75.39
		2	5.5	2	-95.03

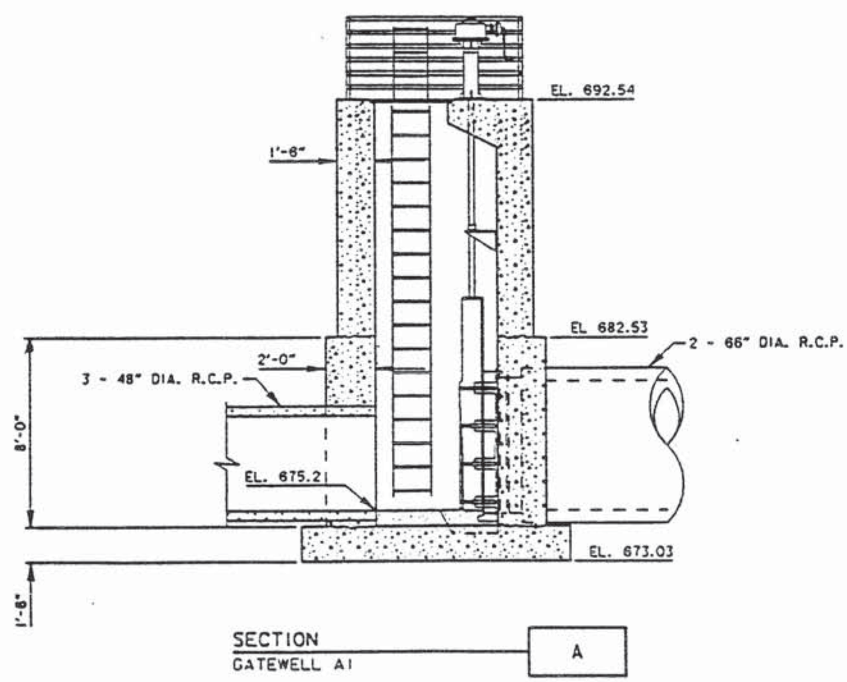
					2,484

Wt = 150 x 2,484 = 372,631 LBS

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 2 OF 22	FILE: HCOM.WK1
NAME OF OFFICE: ED-D-ES	COMPUTATION: GEOMETRY & DIMENSIONS		
SUBJECT: HOUSTON GDM -- GATEWELL DESIGN	SOURCE DATA:		
COMPUTED BY: PWS	CHECKED BY: MGE	APPROVED BY:	



PLAN
GATEWELL A1



SECTION
GATEWELL A1

FOR OFFICIAL USE ONLY

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 3 OF 22	FILE: HCOM.WK1

NAME OF OFFICE: ED-D-ES	COMPUTATION: VERTICAL WATER LOAD
SUBJECT: HOUSTON GDM -- GATEWELL DESIGN	SOURCE DATA:

COMPUTED BY: PWS	CHECKED BY: MGE	APPROVED BY:

WATER LOADS ON STRUCTURE

VOL WATER ON FOOTING

PERIMETER = 2 x (30 + 9) = 78 FT
FOOTING WIDTH = 1 FT
WALL HEIGHT = 18.006 FT

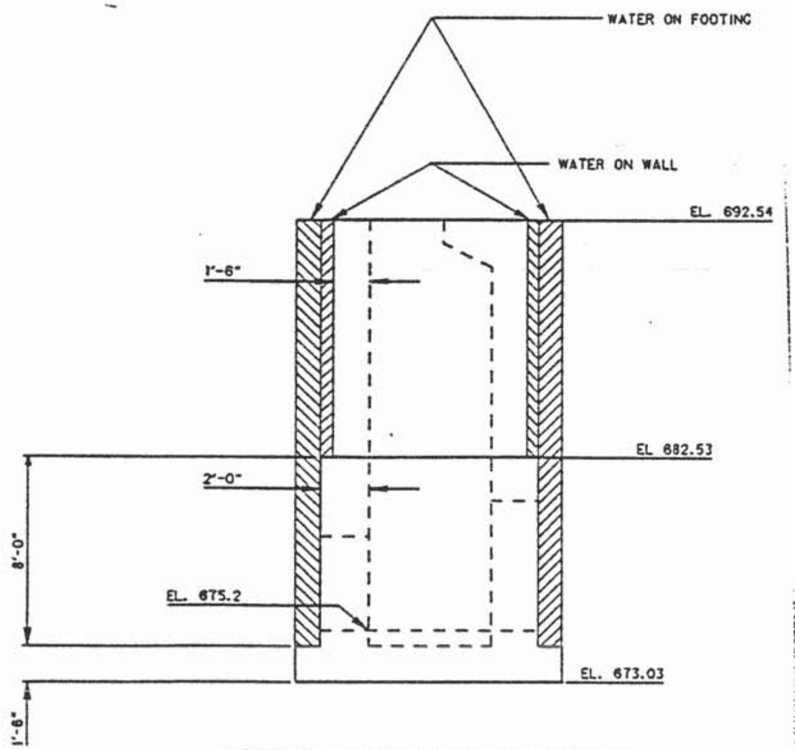
VOL = 78 x 1 x 18.006 = 1404.5 CU-FT

VOL WATER ON LOWER WALLS

PERIMETER = 2 x (28 + 8) = 72 FT
WIDTH = 0.5 FT
WALL HEIGHT = 10.006 FT

VOL = 72 x 0.5 x 10.006 = 360.24 CU-FT

WT OF WATER = $V\gamma_w$ =(1404.5 + 360.24) x 62.5 = 110,297 LBS



VERTICAL WATER LOADS ON GATEWELL
GATEWELL A1

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 4 OF 22	FILE: HCOM.WK1

NAME OF OFFICE: ED-D-ES	COMPUTATION: WEIGHT OF SOIL ON STRUCTURE
SUBJECT: HOUSTON GDM -- GATEWELL DESIGN	SOURCE DATA:

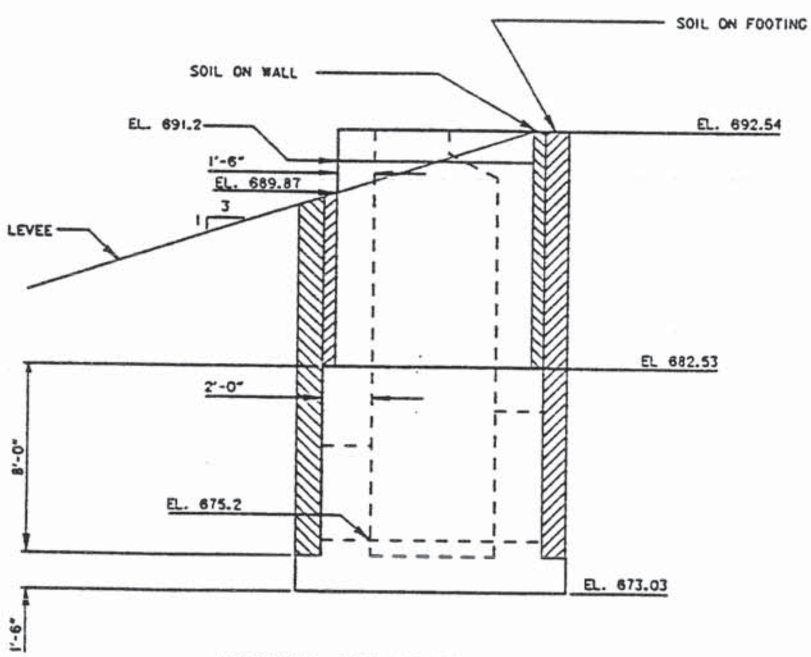
COMPUTED BY: PWS	CHECKED BY: MGE	APPROVED BY:

WEIGHT OF SOIL ON STRUCTURE

SLOPE	0.33
SOIL EL FRONT	692.54
SOIL EL BACK	689.87
SOIL EL SIDES (AVG)	691.20
TOP OF LOWER WALL	682.53

	LENGTH	WIDTH	HEIGHT	VOLUME
VOL SOIL ON FOOTING				
	30	1	18.01	540.2
	30	1	15.34	460.2
	9	1	16.67	300.12
VOL SOIL ON LOWER WALLS				
FRONT	28	0.5	10.01	140.09
BACK	28	0.5	7.34	102.76
SIDES	8	0.5	8.67	69.39
				1,613 CU-FT

TOTAL = 1613 x 68 = 108,861 LBS



VERTICAL SOIL LOADS ON GATEWELL
GATEWELL A1

FOR OFFICIAL USE ONLY

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 5 OF 22	FILE: NCOM.WK1
NAME OF OFFICE: ED-D-ES	COMPUTATION: UPLIFT & BOUYANCY		
SUBJECT: HOUSTON GDM -- GATEWELL DESIGN	SOURCE DATA:		
COMPUTED BY: PWS	CHECKED BY: MGE	APPROVED BY:	

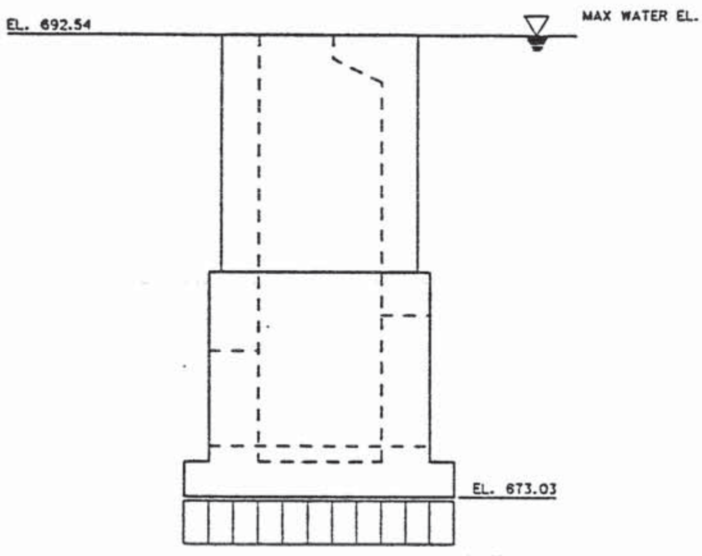
UPLIFT
======

* ASSUME FULL HYDROSTATIC HEAD EVENLY DISTRIBUTED BENEATH SLAB

u = 62.5 Z
A = 30 x 11 = 330 SQ FT
Z' = 19.51 FT

U = 330 x 19.506 x 62.5 = 402,325 LBS

SFf = (372631 + 108861)/(402325 - 110297) = 1.65



UPLIFT LOADS ON GATEWELL
GATEWELL A1

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 6 OF 22	FILE: HCOM.WK1

NAME OF OFFICE: ED-D-ES | COMPUTATION: HORIZONTAL SOIL LOADS ON HEADWALL

SUBJECT: HOUSTON GDM -- GATEWELL DESIGN | SOURCE DATA:

COMPUTED BY: PWS | CHECKED BY: MGE | APPROVED BY:

PLATE LOAD EFFECTS

* WORST CASE LOADING TAKEN AS
  (1) INSIDE IS EMPTY & WATER IS @ TOP OF GATEWELL (EL 692.54).
  (2) SOIL IS @ TOP OF GATEWELL (EL 692.54).
  (3) GOVERNING SOIL LOAD IS AT REST CONDITION.
  (4) BETA IS TAKEN AS UNITY.

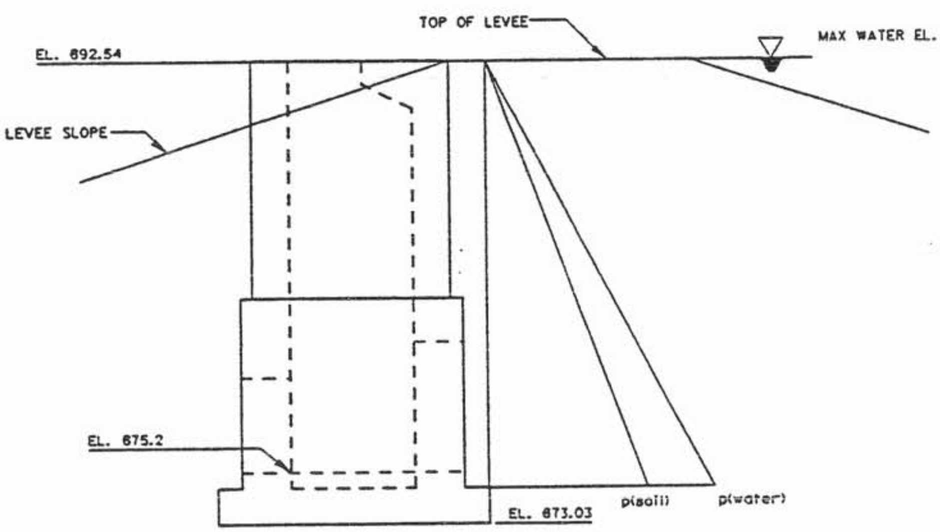
γ_{sat} = 130 PCF
γ_b = 67.5 PCF
γ_w = 62.5 PCF
PHI = 24 DGRS
hf = 1.3
DL = 1.4
LL = 1.7

$K_o = (1 - \sin\phi) = (1 - 0.4067) = 0.593$

EL TOP OF WALL = 692.54
EL BOT OF WALL = 674.53
H = 692.54 - 674.53 = 18.01 FT

FACTORED SOIL LOADS

BOUYANT SOIL (pb) = 1.3 x 1.7 x 0.5932 x 67.5 x 18.01 = 1,594 PSF
WATER (pw) = 1.3 x 1.7 x 62.5 x 18.01 = 2,487 PSF



HORIZONTAL SOIL & WATER LOADS ON GATEWELL
GATEWELL A1

NAME OF OFFICE: ED-D-ES	COMPUTATION: PLATE MODEL
SUBJECT: HOUSTON GDM -- GATEWELL DESIGN	SOURCE DATA:
COMPUTED BY: PWS	CHECKED BY: MGE
	APPROVED BY:

PLATE MODEL -- 3 SIDES FIXED - 1 SIDE FREE

a = 27 /2= 13.5 FT

b = 18.006 FT

b' = 18.006 FT

a/b = 0.75

b'/b = 1

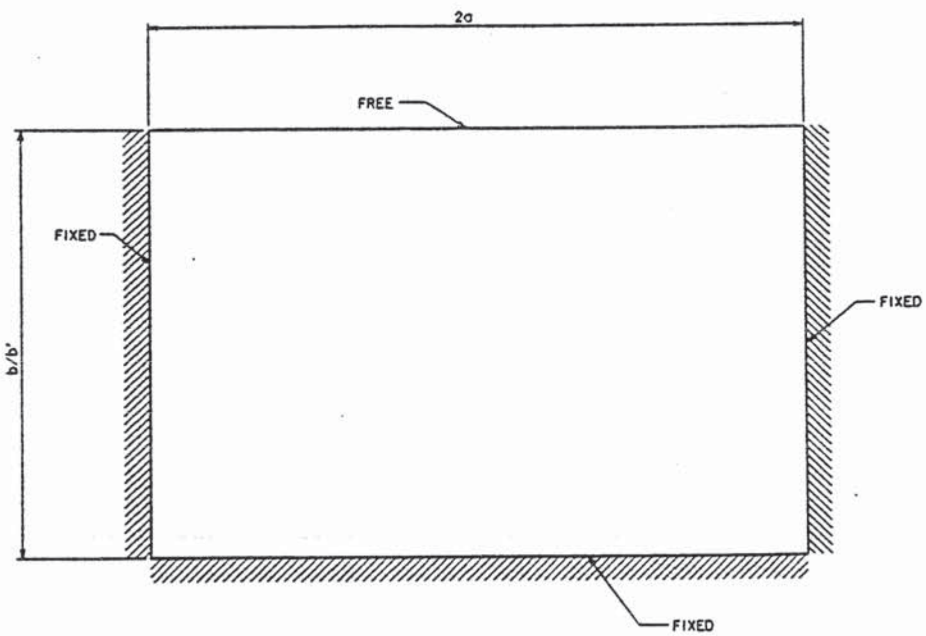


PLATE MODEL
GATEWELL A1

M = COEF x (pb + pw) x b^2

R = COEF x (pb + pw) x b

PLATE LOAD EFFECTS (MOMENTS)

X-MOMENTS: + Mx -- @ y/b = 0.6 & x/a = 0.0 (SEE ATTACHED TABLES)

C = 0.0426 FOR a/b = 0.75

+ Mx = (0.0426 x (1,594 + 2,487)x 18.006 ^2= 56,366 LB-FT

Y-MOMENTS: + My -- @ y/b = 0.0 & x/a = 1.0

C = 0.0584 FOR a/b = 0.75

+ My = (0.0584 x (1,594 + 2,487)x 18.006 ^2= 77,272 LB-FT

PLATE LOAD EFFECTS (SHEARS)

X-SHEARS: + Rx -- @Y/b = 0.4

C = 0.2542 FOR a/b = 0.75

+ Rx = (0.2542 x (1,594 + 2,487)x 18.006 = 18,679 LBS

Y-SHEARS: + Ry -- @ X/a = 1.0

C = 0.4055 FOR a/b = 0.75

+ Ry = (0.4055 x (1,594 + 2,487)x 18.006 = 29,797 LB-FT

NAME OF OFFICE: ED-D-ES | COMPUTATION: CONCRETE CAPACITY

SUBJECT: HOUSTON GDM -- GATEWELL DESIGN | SOURCE DATA:

COMPUTED BY: PWS | CHECKED BY: MGE | APPROVED BY:

CONCRETE CAPACITY (FLEXURE)

DESIGN PARAMETERS

fc' = 4,000 PSI	ϕ(FLEX.) = 0.9	COVER = 3 IN
fy = 60,000 PSI	ϕ(SHEAR) = 0.85	WIDTH, b = 12 IN
RHOmin = 200/fy = 0.0033		

ϕMn = ϕ(.85)(fc')a(b)(d-a/2) >= Mu
a = As(fy)/.85(fc')b
d = t - cover - db/2

t = 24 IN   As = NO 8 's @ 9 IN = 1.0471 SQ IN

d = 24 - 3 - 0.50 = 20.5 IN
a = 1.0471 x 60000 /(0.85 x 4000 x 12)= 1.540 IN
RHO = 1.0471 /(20.5 x 12)= 0.0042

ϕMn = 0.9 x 0.85 x 4000 x 1.5399 x 12
x(20.5 - 0.7699)= 1115.71 K-IN

1115.7 / 12 = 92.98 K'

Mx -- OMn/Mu = 92.98 / 56.37 = 165% OK
My -- OMn/Mu = 92.98 / 77.27 = 120% OK

CONCRETE CAPACITY (SHEAR)

ϕVc = ϕ(2)(fc')^.5bd = .85 x 2 x 63.245 x 12 d =1290.2 d

ϕVc = 1290.2 x 20.5 = 26,449 LBS

Rx -- ϕVc/Vu = 26.449 / 18.68 142% OK
Ry -- ϕVc/Vu = 26.449 / 29.80 89% *

* NOTE: SHEAR EXCEEDED OVER APPROXIMATELY THE CENTRAL 25% OF WALL BASE ONLY DUE TO CONSERVATIVE VALUE OF SOIL PRESSURE (0 C VALUE, INFINITELY SLOPING BACKFILL) SAY OK ON THE SHEAR.

HOUSTON FLOOD CONTROL PROJECT

LOADS & AFFECTS ON GATEWELL WALL
PLATE MOMENT & SHEAR COEFFICIENTS
PLATE MOMENTS & REACTIONS -- 3 SIDES FIXED 1 SIDE FREE

A = 13.5 ft B = 18.01 ft A/B = 0.750
pw = 2,487 psf pb = 1,594 psf

UNIFORMLY VARYING LOAD
A/B= 0.75

	Mx						My						Rx	Ry
y/b x/a	0.0	0.2	0.4	0.6	0.8	1.0	0.0	0.2	0.4	0.6	0.8	1.0		
1	406	196	13	-115	-190	-214	0	0	0	0	0	0	1061	4055
0.8	433	177	-3	-119	-184	-205	87	31	-12	-42	-61	-67	2077	3923
0.6	426	145	-26	-124	-174	-189	85	10	-55	-102	-130	-139	2408	3496
0.4	349	91	-39	-102	-130	-138	70	-11	-75	-115	-137	-143	2542	2666
0.2	163	31	-17	-31	-33	-33	33	1	0	14	29	35	1337	1256
0	0	28	64	93	111	117	0	139	320	465	554	584	-195	-196

COMBINED LOAD EFFECTS

A/B=	0.75													
1	53,720	25,934	1,720	(15,216)	(25,140)	(28,315)	0	0	0	0	0	0	7,796	29,797
0.8	57,292	23,420	(397)	(15,745)	(24,346)	(27,125)	11,511	4,102	(1,588)	(5,557)	(8,071)	(8,865)	15,262	28,827
0.6	56,366	19,186	(3,440)	(16,407)	(23,023)	(25,007)	11,247	1,323	(7,277)	(13,496)	(17,201)	(18,392)	17,694	25,689
0.4	46,178	12,041	(5,160)	(13,496)	(17,201)	(18,259)	9,262	(1,455)	(9,924)	(15,216)	(18,127)	(18,921)	18,679	19,590
0.2	21,567	4,102	(2,249)	(4,102)	(4,366)	(4,366)	4,366	132	0	1,852	3,837	4,631	9,824	9,229
0	0	3,705	8,468	12,305	14,687	15,481	0	18,392	42,341	61,526	73,302	77,272	(1,433)	(1,440)
	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
	57,292	25,934	8,468	12,305	14,687	15,481	11,511	18,392	42,341	61,526	73,302	77,272		
	0	3,705	(5,160)	(16,407)	(25,140)	(28,315)	0	(1,455)	(9,924)	(15,216)	(18,127)	(18,921)		

+Mx max 57,292
-Mx max (28,315)

+My max 77,272
-My max (18,921)

Rx max 18,679

Ry max 29,797

FOR OFFICIAL USE ONLY

NAME OF OFFICE: ED-D-ES | COMPUTATION: MOMENT & REACTION COEFFICIENTS

SUBJECT: HOUSTON GDM -- GATEWELL DESIGN | SOURCE DATA:

COMPUTED BY: PWS | CHECKED BY: MGE | APPROVED BY:

MOMENTS AND REACTIONS FOR RECTANGULAR PLATES

			M_x						M_y					
	y/b	R_x \ x/a	0	0.2	0.4	0.6	0.8	1.0	0	0.2	0.4	0.6	0.8	1.0
a/b = 1/8	1.0	+.0082	+.0004	+.0002	+.0000	-.0001	-.0002	-.0002	0	0	0	0	0	0
	0.8	+.0231	-.0011	+.0005	-.0000	-.0003	-.0005	-.0005	+.0002	+.0001	+.0000	-.0000	-.0001	-.0001
	0.6	+.0496	+.0021	+.0009	+.0001	-.0006	-.0009	-.0011	+.0004	+.0002	+.0000	-.0001	-.0002	-.0002
	0.4	+.0751	+.0031	+.0014	+.0001	-.0008	-.0014	-.0016	+.0006	+.0003	+.0000	-.0002	-.0003	-.0003
	0.2	-.0942	+.0038	+.0016	+.0000	-.0010	-.0017	-.0019	+.0008	+.0003	-.0000	-.0003	-.0005	-.0005
	0	+.0460	0	+.0001	+.0003	+.0005	+.0006	+.0006	0	+.0005	+.0014	+.0023	+.0028	+.0030
		R_x \ R_y	+.0460	+.0136	+.0543	+.0839	+.1004	+.1056						
a/b = 1/4	1.0	+.0147	+.0022	+.0012	+.0002	-.0006	-.0012	-.0014	0	0	0	0	0	0
	0.8	+.0523	+.0046	+.0022	+.0002	-.0012	-.0021	-.0024	+.0009	+.0005	+.0002	-.0000	-.0002	-.0002
	0.6	+.1015	+.0083	+.0037	+.0002	-.0023	-.0038	-.0042	+.0017	+.0007	-.0000	-.0005	-.0009	-.0010
	0.4	+.1514	+.0114	+.0049	+.0001	-.0032	-.0051	-.0057	+.0023	+.0008	-.0004	-.0013	-.0019	-.0021
	0.2	+.1494	+.0102	+.0037	-.0004	-.0030	-.0043	-.0047	+.0020	+.0004	-.0011	-.0022	-.0029	-.0031
	0	+.0304	0	+.0004	+.0010	+.0016	+.0020	+.0021	0	+.0020	+.0052	+.0081	+.0100	+.0107
		R_x \ R_y	+.0304	+.0309	+.1052	+.1563	+.1856	+.1950						
a/b = 3/8	1.0	+.0189	+.0056	+.0040	+.0008	-.0020	-.0039	-.0045	0	0	0	0	0	0
	0.8	+.0855	+.0117	+.0055	+.0006	-.0031	-.0054	-.0062	+.0023	+.0012	+.0004	-.0002	-.0005	-.0007
	0.6	+.1541	+.0176	+.0075	+.0001	-.0049	-.0079	-.0088	+.0035	+.0013	-.0006	-.0020	-.0029	-.0032
	0.4	+.2107	+.0208	+.0079	-.0007	-.0061	-.0090	-.0099	+.0042	+.0005	-.0019	-.0042	-.0058	-.0061
	0.2	+.1631	+.0145	+.0045	-.0012	-.0042	-.0057	-.0061	+.0029	-.0001	-.0022	-.0039	-.0048	-.0051
	0	+.0102	0	+.0005	+.0020	+.0030	+.0035	+.0040	0	+.0039	+.0099	+.0152	+.0188	+.0200
		R_x \ R_y	+.0102	+.0474	+.1462	+.2154	+.2526	+.2645						
a/b = 1/2	1.0	+.0326	+.0151	+.0038	+.0015	-.0046	-.0094	-.0097	0	0	0	0	0	0
	0.8	+.1315	+.0216	+.0099	+.0007	-.0059	-.0099	-.0112	+.0043	+.0020	+.0002	-.0011	-.0019	-.0022
	0.6	+.1972	+.0273	+.0106	-.0005	-.0079	-.0119	-.0132	+.0055	+.0015	-.0020	-.0047	-.0064	-.0070
	0.4	+.2421	+.0277	+.0092	-.0019	-.0082	-.0115	-.0125	+.0055	+.0004	-.0042	-.0076	-.0097	-.0104
	0.2	+.1607	+.0150	+.0041	-.0017	-.0044	-.0055	-.0058	+.0032	-.0002	-.0026	-.0035	-.0044	-.0046
	0	-.0045	0	+.0014	+.0033	+.0050	+.0061	+.0065	0	+.0068	+.0167	+.0252	+.0307	+.0325
		R_x \ R_y	-.0045	+.0744	+.1932	+.2699	+.3103	+.3238						
a/b = 3/4	1.0	+.1061	+.0455	+.0196	+.0013	-.0115	-.0190	-.0214	0	0	0	0	0	0
	0.8	+.2077	+.0433	+.0177	-.0003	-.0119	-.0184	-.0205	+.0057	+.0031	-.0012	-.0042	-.0061	-.0067
	0.6	+.2406	+.0426	+.0145	-.0026	-.0124	-.0174	-.0189	+.0085	+.0010	-.0055	-.0102	-.0130	-.0139
	0.4	+.2542	+.0349	+.0091	-.0039	-.0102	-.0130	-.0135	+.0070	-.0011	-.0075	-.0115	-.0137	-.0143
	0.2	+.1337	+.0163	+.0031	-.0017	-.0031	-.0033	-.0033	+.0033	+.0001	-.0006	+.0014	+.0029	+.0035
	0	-.0195	0	+.0023	+.0064	+.0093	+.0111	+.0117	0	+.0139	+.0320	+.0465	+.0554	+.0584
		R_x \ R_y	-.0195	+.1256	+.2356	+.3496	+.3923	+.4055						

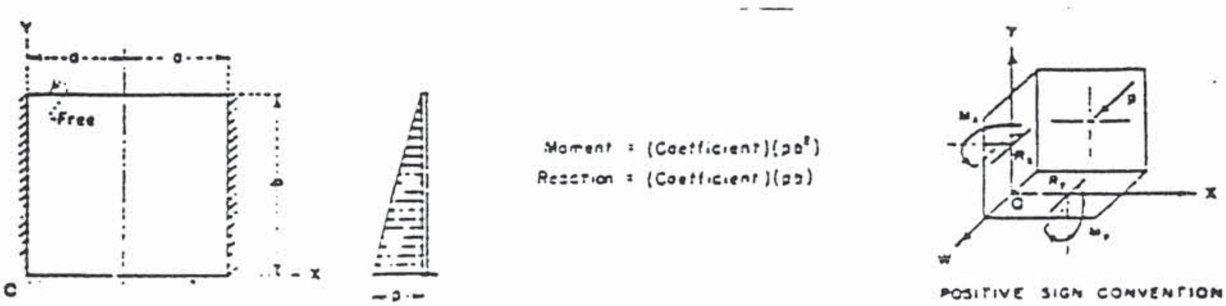


FIGURE 4.—*Plate fixed along three edges, moment and reaction coefficients, Load IV, uniformly varying load.*

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 12 OF 22	FILE: HCOM.WK1

NAME OF OFFICE: ED-D-ES	COMPUTATION: PIPE CLASSIFICATION
SUBJECT: HOUSTON GDM -- RCP DESIGN	SOURCE DATA:

COMPUTED BY: PWS	CHECKED BY: MGE	APPROVED BY:

DESIGN PROCEDURES

REFERENCES:

EM 1110-2-2902; CONDUITS, CULVERTS AND PIPES
AMERICAN CONCRETE PIPE ASSOCIATION; CONCRETE PIPE DESIGN HANDBOOK
CRETEX PRECAST CONCRETE PRODUCTS; MANUFACTURER'S PRODUCT INFORMATION

SYMBOLS

All = LxW = AREA OF DISTRIBUTED LIVE LOAD ABOVE TOP OF PIPE
bc = ID + 2t
bd = 1.5 x bc = WIDTH OF DITCH AT TOP OF PIPE
Cd = LOAD COEFFICIENT FOR TRENCH INSTALLATION = f(He/bd)
G = MOIST OR SATURATED UNIT WEIGHT OF SOIL
H = DEPTH OF TOP OF PIPE BELOW CONSTRUCTION LOAD
He = HEIGHT OF FILL ABOVE PIPE
= EL TOP OF LEVEE = EL TOP OF PIPE
Hf = HEIGHT OF FILL ABOVE NATURAL GROUND LINE
Hh = HEIGHT OF PIPE ABOVE HORIZONTAL MID-PIPE
= He +ID/2 t
Hp = HEIGHT OF CONDUIT ABOVE FOUNDATION = p x bc
ID = INSIDE DIA OF PIPE

L' = LENGTH OF CONSTRUCTION TIRE/TREAD LOAD
L = DISTRIBUTED LENGTH OF CONSTRUNCTION LOAD @ TOP OF PIPE = L' + 2H
Le = EQUIVALENT LENGTH OF LIVE LOADED PIPE
= L + 1.75(3/4)bc
P = TOTAL CONSTRUCTION LOAD
p = PROJECTION RATIO = HEIGHT OF BEDDING ABOVE BOTTOM OF PIPE/OUTSIDE PIPE DIA
Pe = LATERAL EARTH LOADS ON PIPE
Sl = LESSER OF OUTSIDE HORIZONTAL SPAN OF PIPE, bc, OR W
t = PIPE THICKNESS
W' = WIDTH OF CONSTRUCTION LOAD TIRE/TREAD
W = DISTRIBUTED WIDTH OF CONSTRUCTION LOAD @ TOP OF PIPE = W' + 2H
We = VERTICALLY DISTRIBUTED SOIL LOAD ON TOP OF PIPE

1. EARTH LOADS, We & Pe

A. TRENCH
We1 = MAX OF Cd x G x bd^2 & G x bc x H
Pe1 = G x Hh x TAN^2(45-PHI/2)

B. NEG PROJ
We2 = MAX OF Cd x G x bd^2 + [Hf/(He+Hp) x (1.5 x G x bc x Hh - Cd x G x bd^2)] &
G x bc Hh x [.5xHf/(He+Hp) + 1]
Pe2 = G x Hh x TAN^2(45-PHI/2) +
Hf/(He + Hp) x [.5 x G x Hh - G x Hh x TAN^2(45-PHI/2)]

C. POS PROJ
We3 = 1.5 x G x bc x Hh
Pe3 = .5 x G x Hh

2. LIVE LOADS, Wl

A. CONSTRUCTION -- 50,000 LB CAT W/ 2- 5 ' x 25 ' TREADS

Wl = (P x L x Sl)/(Le x All)

DESIGN PROCEDURES

3. BEDDING FACTORS

Bedding Class as described in EM 1110-2-2902:
(1) IMPERMISSIBLE
(2) ORDINARY
(3) FIRST CLASS
(4) CONCRETE CRADLE

A. EARTH LOAD --

Earth Load --

TRENCH & NEG PROJ,

BEDDING CLASS	Bf
(2)	1.5
(3)	1.9
(4)	2.5

POS PROJ,

Bf = 1.431/[Xp-(Xa/3)]
where Xa = f(p) and Xp = f(bedding type)
and p = Projection Ratio

BEDDING TYPE	p	Xa	Xp
(2)	0.9	0.655	0.840
(3)	0.7	0.594	0.707
(4)	0.6	0.834	0.505

B. LIVE LOAD

AS RECCOMMENDED BY MANUFACTURER, Bf = 1.5

4. D-LOAD (D-0.01)

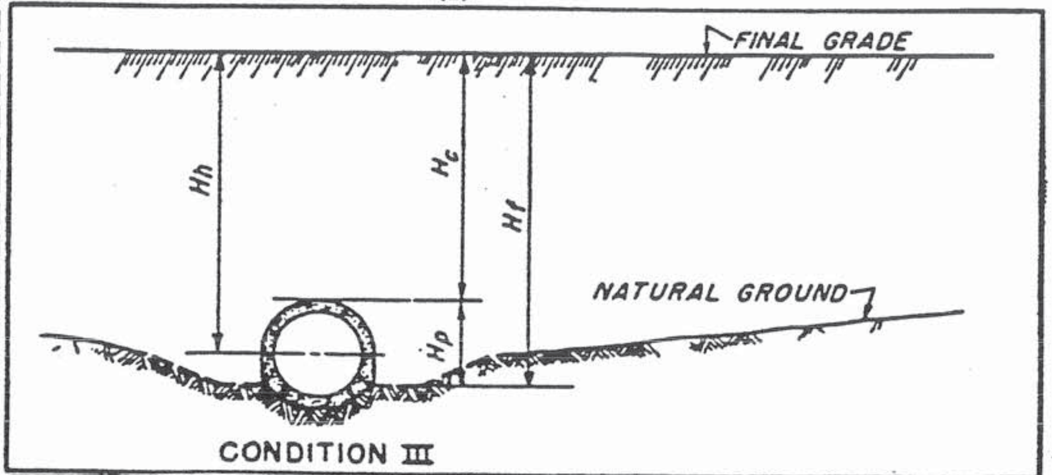
D(0.01) = [(We/Bf + Wl/Bf) x SF]/ID

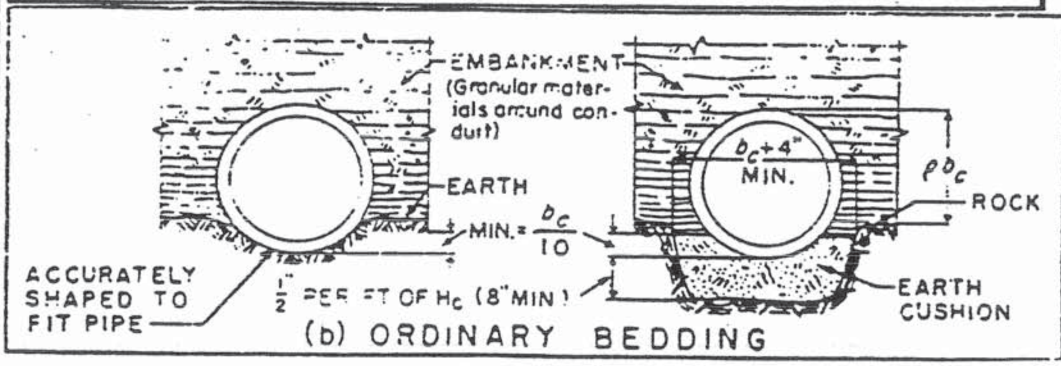
ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 14 OF 22	FILE: HCOM.WK1

NAME OF OFFICE: ED-D-ES	COMPUTATION: PIPE CLASSIFICATION	
SUBJECT: HOUSTON GDM -- RCP DESIGN	SOURCE DATA:	
COMPUTED BY: PWS	CHECKED BY: MGE	APPROVED BY:

PIPE CLASS EXAMPLE

ASSUME: CONDITION III(POSITIVE PROJECTION INSTALLATION)
BEDDING CLASS (2)





H_c = depth of fill (over top of pipe)
ρ = projection ratio ; ratio of the vertical distance between the top of the conduit and the natural ground surface adjacent to the conduit, to bc

EM 1110-2-2902, Appendix III, 3 Mar 1969

1. PIPE LOADS -- EARTH LOAD

	EL TOL	EL INV	DIA	t(IN)	bc	Hh
A.	692.54	675.2	5.5	6.5	6.583	14.59
B.	683.9	674	3.5	4.5	4.250	8.15

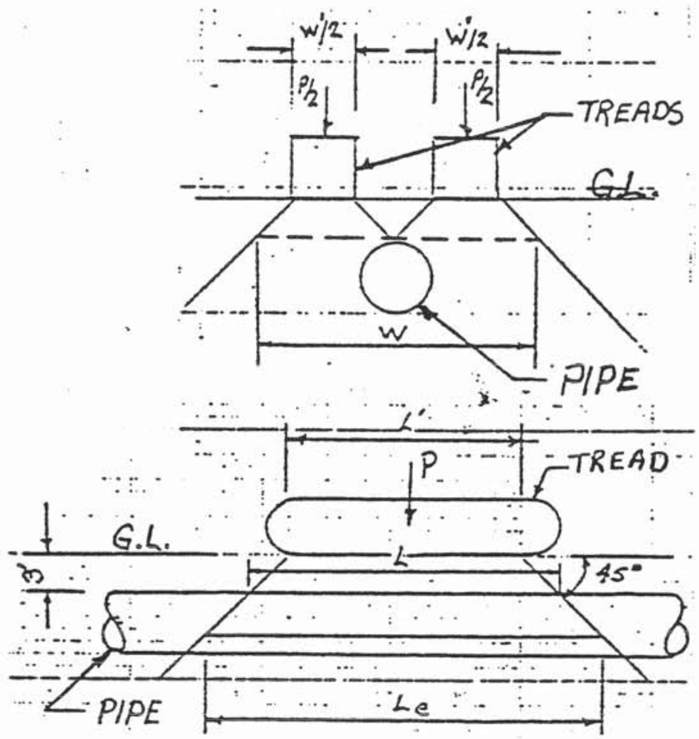
G = 130 PCF   bc= 6.58 FT   Hh = 14.59 FT
bc= 4.25 FT   Hh = 8.15 FT

A. We = 1.5 x 130 x 6.583 x 14.59 = 18,730 LBS/FT
B. We = 1.5 x 130 x 4.250 x 8.15 = 6,754 LBS/FT

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 15 OF 22	FILE: HCOM.WK1
NAME OF OFFICE: ED-D-ES	COMPUTATION: PIPE CLASSIFICATION		
SUBJECT: HOUSTON GDM -- RCP DESIGN	SOURCE DATA:		
COMPUTED BY: PWS	CHECKED BY: MEE	APPROVED BY:	

PIPE CLASS EXAMPLE (CONT.)

	P =	50,000	LBS
	L' =	25	FT
	W' =	5	FT
	H =	3	FT
A.	bc =	6.58	FT
B.	bc =	4.25	FT



CONSTRUCTION LOAD

L = 25 + 2 x 3 = 31 FT
W = 5 + 2 x 3 = 11 FT

All = 31 x 11 = 341 SQFT

Sl = bc = 6.5833 FT

6.5833 < 11 , S1 = 6.583 FT (A.)
4.25 < 11 , S1 = 4.250 FT (B.)

Le = 31 + 1.75 x 0.75 x 6.5833 = 39.640 FT (A.)
11 + 1.75 x 0.75 x 4.25 = 16.578 FT (B.)

Wl = 50,000 x 31 x 6.58333 /(39.640 x 341) = 755 LBS/FT (A.)
50,000 x 31 x 4.25 /(16.578 x 341) = 1,165 LBS/FT (B.)

HS20 LOAD Wl = 430 LBS/FT FOR 42" DIA. PIPE. THEREFORE CONSTRUCTION LOAD CONTROLS.
(SEE TABLE ON FOLLOWING PAGE).

NAME OF OFFICE: ED-D-ES | COMPUTATION: HIGHWAY LOADS ON R.C.P. TABLE

SUBJECT: HOUSTON GDM -- RCP DESIGN | SOURCE DATA:

COMPUTED BY: PWS | CHECKED BY: MGE | APPROVED BY:

TABLE FROM AMERICAN CONCRETE PIPE ASSOCIATION CONCRETE PIPE DESIGN MANUAL

TABLE 45

HIGHWAY LOADS ON CIRCULAR PIPE

POUNDS PER LINEAR FOOT

PIPE SIZE D IN INCHES	B_c (ft.)	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	PIPE SIZE D IN INCHES
12	1.33	3780	2080	1470	1080	760	550	450	380	290	230	190	160	130	12
15	1.63	4240	2360	1740	1280	900	660	540	450	350	280	230	190	160	15
18	1.92	4110	2610	1970	1460	1030	750	620	520	400	320	260	220	190	18
21	2.21	3920	2820	2190	1620	1150	840	690	580	450	360	300	250	210	21
24	2.50	4100	3010	2400	1780	1270	930	760	640	500	400	330	280	240	24
27	2.79	3880	2940	2590	1930	1380	1010	830	700	560	440	360	300	260	27
30	3.08	3620	2830	2770	2070	1480	1080	890	750	590	480	390	330	280	30
33	3.38	3390	2930	2950	2200	1580	1160	960	810	630	510	420	360	300	33
36	3.67	3190	2810	2930	2330	1670	1230	1020	860	670	550	450	380	330	36
39	3.96	3010	2670	2850	2440	1760	1290	1070	910	710	580	480	410	350	39
42	4.25	2860	2550	2770	2560	1840	1360	1130	950	750	610	510	430	370	42
48	4.83	2590	2330	2620	2480	1990	1470	1230	1040	820	670	560	470	410	48
54	5.42	2360	2150	2490	2360	2050	1580	1320	1120	890	730	610	520	440	54
60	6.00	2170	1990	2450	2250	1960	1680	1400	1190	950	780	650	560	480	60
66	6.58	2010	1850	2520	2160	1880	1640	1480	1260	1010	830	700	590	510	66
72	7.17	1870	1730	2580	2190	1810	1570	1510	1330	1060	880	740	630	540	72
78	7.75	1750	1630	2630	2240	1770	1520	1460	1390	1110	920	780	660	570	78
84	8.33	1650	1540	2730	2290	1810	1460	1410	1360	1160	960	810	690	600	84
90	8.92	1550	1460	2530	2330	1850	1470	1360	1310	1210	1000	850	720	630	90
96	9.50	1470	1380	2410	2290	1880	1500	1330	1270	1250	1040	880	750	650	96
102	10.08	1390	1320	2300	2190	1910	1530	1350	1240	1290	1070	910	780	680	102
108	10.67	1320	1260	2200	2090	1830	1560	1380	1230	1330	1110	940	810	700	108
114	11.25	1260	1200	2110	2010	1760	1540	1410	1260	1362	1140	970	830	730	114
120	11.83	1210	1150	2020	1930	1700	1480	1420	1280	1400	1170	990	860	750	120
126	12.42	1160	1100	1940	1860	1640	1430	1380	1300	1430	1200	1020	880	770	126
132	13.00	1110	1060	1870	1800	1580	1380	1330	1290	1460	1220	1040	900	790	132
138	13.58	1070	1020	1800	1730	1530	1340	1290	1250	1490	1250	1070	920	810	138
144	14.17	1020	980	1740	1670	1480	1300	1250	1210	1470	1280	1090	940	830	144

DATA:
1. Unsurfaced roadway.
2. Loads – AASHTO HS 20, two 16,000 lb. dual-tired wheels, 4 ft. on centers, or alternate loading, four 12,000 lb. dual-tired wheels, 4 ft. on centers with impact included.

NOTES:
1. Interpolate for intermediate pipe sizes and/or fill heights.
2. Critical loads:
   a. For H = 0.5 and 1.0 ft., a single 16,000 lb. dual-tired wheel.
   b. For H = 1.5 through 4.0 ft., two 16,000 lb. dual-tired wheels, 4 ft. on centers.
   c. For H > 4.0 ft. alternate loading.
3. Truck live loads for H = 10.0 ft. or more are insignificant.

NAME OF OFFICE: ED-D-ES	COMPUTATION: PIPE CLASSIFICATION
SUBJECT: HOUSTON GDM -- RCP DESIGN	SOURCE DATA:
COMPUTED BY: PWS	CHECKED BY: MGE
	APPROVED BY:

PIPE CLASS EXAMPLE (CONT.)

3. BEDDING FACTORS

A. EARTH LOADING BEDDING FACTORS:

FOR POSITIVE PROJECTION INSTALLATION, & BEDDING CLASS (2)

p = 0.9
Xa = 0.655
Xp = 0.84

Bf = 1.431 /(0.84 - 0.655 / 3.00) = 2.30

B. LIVE LOAD BEDDING FACTOR

AS RECCOMMENDED BY MANUFACTURER, Bf= 1.5 (USE)
AS PER EM 1110-2-2902 Bf= 2.30

4. REQUIRED D-LOAD

SF = 2
ID = 4 FT (A.)
ID = 3 FT (B.)

D(0.01) = (18,730 / 2.30 + 755 / 1.50) x 2 / 5.50 = 3,141.84 #/FT
D(0.01) = (6,754 / 2.30 + 1,165 / 1.50) x 2 / 3.50 = 2,120.64 #/FT

D-LOAD FOR ASTM CLASS V = 3,000LBS/FT/FT

HEADWALL DESIGN

1. REQUIRED PIPE COVER
   REF: ETL: 1110-2-307; FLOTATION STABILITY CRITERIA FOR CONCRETE HYDRAULIC STRUCTURES

SFf = (Ws + Wc + S)/(U - Wg)
- Ws = Weight of Structure and Bouyant Soil on Structure
- Wc = Weight of Water Within the Structure
- S = Surcharge Loads
- U = Uplift forces Acting on Base of Structure
- Wg = Weight of Water Above the Structure
- SFf = 1.5 for Normal Operation
- = 1.3 for Unusual Operation

$Ws = \gamma b * A1 + Wp$ $\quad Wg = \gamma_w * A1$

$U = \gamma_w * A2$ $\quad Wc = S = 0$

$A1 = d*h + d^2/2 - 1/2 * \pi * d^2/4 = d^2 * (h/d + 0.107)$

$A2 = d(h + d) = d^2 * (h/d + 1)$

$SFf = Ws/(u - Wg) = (\gamma b * A1 + Wp)/\gamma_w(A2 - A1)$

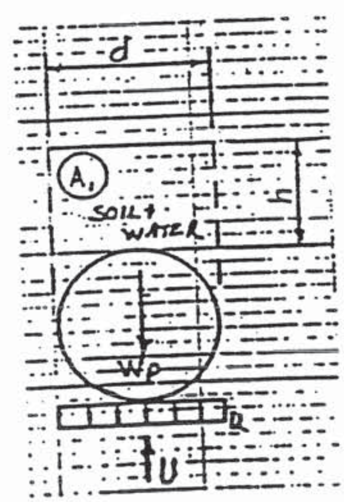
$= [\gamma b * d^2(h/d + 0.107) + Wp]/(0.893 * \gamma_w * d^2)$

Therefore,

$h = (([SFf(0.893 * \gamma_w * d^2) - Wp]/(\gamma b * d^2)) - 0.107) * d$

For: SFf = 1.3 ; γ_w = 62.5 psf ; γd = 4.8333 ft. ; Wp = 885 #/' ; d^2 = 23.36 sq.ft. ; b = 67.5 psf

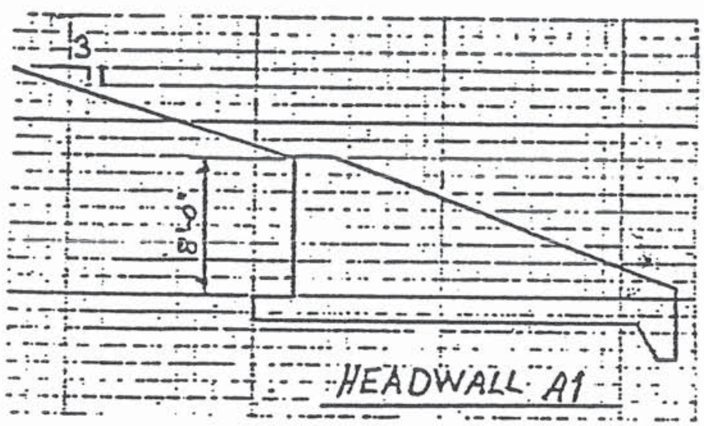
$h = ((\;(1.3 \times 0.893 \times 62.5 \times 23.36) - 885)\,/\,(67.5 \times 23.36) - 0.107) \times 4.83 = 1.97$



2. SOIL PARAMETERS

γ_m = 120 psf γ_{sat} = 130 psf γ_b = 67.5 psf

A. Driving Side



ϕ = 24 dgrs
c = 250 psf
B = 0.333

Ko = (1-sinϕ)(1+sinB) = (1 - 0.4067)(1 + 0.316)= 0.781

3. FACTORED LOADS ON WALL -- LOAD CASE I

LOAD FACTORS -- LOAD CASE I   LL = 1.7
DL = 1.4
Hf = 1.3

For Outlet A1, Wall height h = 8 ft.

M = Ko*γsat*h^3/6 = 0.7808 x 130 x 512 / 6 = 8,662 lb.ft.

Mu = LL*Hf*M   1.7 x 1.3 x 8,662 = 19,144 lb.ft.

V = Ko*γsat*h^2/2= 0.7808 x 130 x 64 / 2 = 3,248 lbs.

V_u = 1.7 x 1.3 x 3,248 = 7,179 lbs.

4. REINFORCED CONCRETE DESIGN

A. Design Parameters

fc' = 4,000 psi   t = 18 in.   As = #6's@9"= 0.59 sq.in.
fy = 60,000 psi   cover = 2 in.   b = 12 in.
ϕ = 0.9 (MOMENT)   ϕ = 0.85 (SHEAR)

B. Moment Capacity

ϕMn = ϕ(.85)(fc')a(b)(d-.5a) >= Mu
a = As(fy)/.85(fc')b
d = t - cover - db/2

d = 18 - 2 - 0.375 = 15.625 in.
a = 0.59 x 60000 /(0.85 x 4000 x 12)= 0.87 in.

ϕMn = 0.9 x 0.85 x 4000 x 0.8662 x 12 x
x(15.625 - 0.433)= 483233 k.in.

= 40,269 k.ft.
==================

ϕMn > Mu OK

C. Shear Capacity

ϕVc=ϕ*2√fc'*bw*d = 0.85 x 2 x 63.245 x 12 x 15.62 = 20,160 lbs.
==================

ϕVc > Vu OK

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 21 OF 22	FILE: HCOM.WK1
NAME OF OFFICE: ED-D-ES	COMPUTATION: QUANTITIES		
SUBJECT: HOUSTON GDM -- MISC. CONTROL FEATURES	SOURCE DATA:		
COMPUTED BY: PWS	CHECKED BY: GRS	APPROVED BY:	

MISC. FEATURES

A. SANITARY OUTLET -- 18" DIP W/ GATE VALVE UNDER LEVEE
TO CONNECT TO EXISTING VITRIFIED CLAY PIPE

EL TOP OF LEVEE = 689.6 LEVEE WIDTH = 10 ft.
EL TOE OF LEVEE = 672.0 SIDE SLOPES = 0.333

HEIGHT = 17.6 ft.

LENGTH = 2 x 17.6 / 0.3333 + 10 = 115.6

QUANTITIES
==========

120 LF	18" DIP
1 EA	18" GATE VALVE & STEM
1 EA	CAST IRON FLOOR BOX W/ COVER
1 EA	MANHOLE COVER
18 LF	60" RISER
1 EA	MANHOLE BASE
2 EA	VITIRIFIED CLAY PIPE TO DIP CONNECTORS

B. NATURAL GASLINE OUTLET -- 2" GASLINE PIPE WITH GATE VALVE

EL TOP OF LEVEE = 686.9 LEVEE WIDTH = 10 ft.
EL TOE OF LEVEE = 674.0 SIDE SLOPES = 0.333

HEIGHT = 12.9 ft.

LENGTH = 2 x 12.9 / 0.3333 + 10 = 87.4

QUANTITIES
==========

90 LF	18" DIP
1 EA	18" GATE VALVE & STEM
1 EA	CAST IRON FLOOR BOX W/ COVER
1 EA	MANHOLE COVER
13 LF	60" RISER
1 EA	MANHOLE BASE

ST PAUL DISTRICT COMPUTATION SHEET	DATE: 26 FEBRUARY 1992	PAGE 22 OF 22	FILE: HCOM.WK1
NAME OF OFFICE: ED-D-ES	COMPUTATION: QUANTITIES		
SUBJECT: HOUSTON GDM -- MISC. DRAINAGE FEATURES	SOURCE DATA:		
COMPUTED BY: PWS	CHECKED BY: GRS	APPROVED BY:	

C. DRAINAGE CATCH BASINS

1. EL TOP OF LEVEE = 682 PIPE EXTENSIONS = 40 ft.
   EL TOE OF LEVEE = 675.5

   HEIGHT = 6.5 ft.

   QUANTITIES

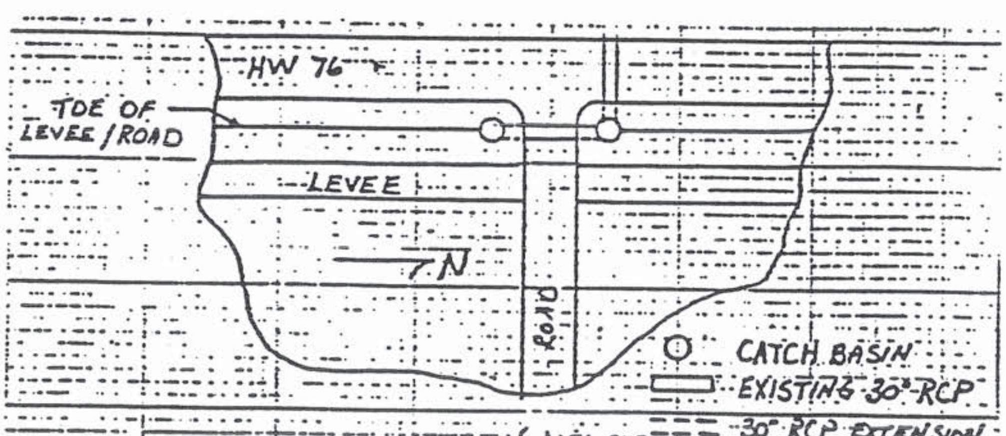
1 EA	CONE RISER
1 EA	60" RISER
1 EA	MANHOLE COVER
1 EA	MANHOLE BASE
40 LF	30" RCP

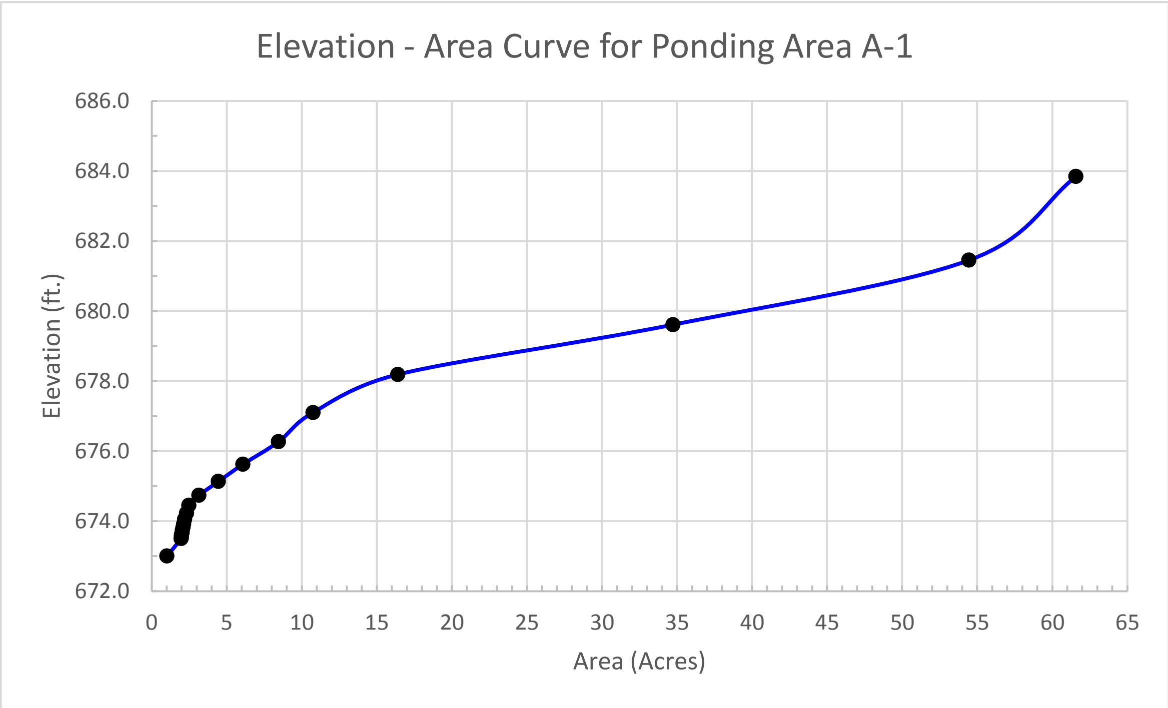
2. EL TOP OF LEVEE = 681.5 PIPE EXTENSIONS = 20 ft.
   EL TOE OF LEVEE = 675.5

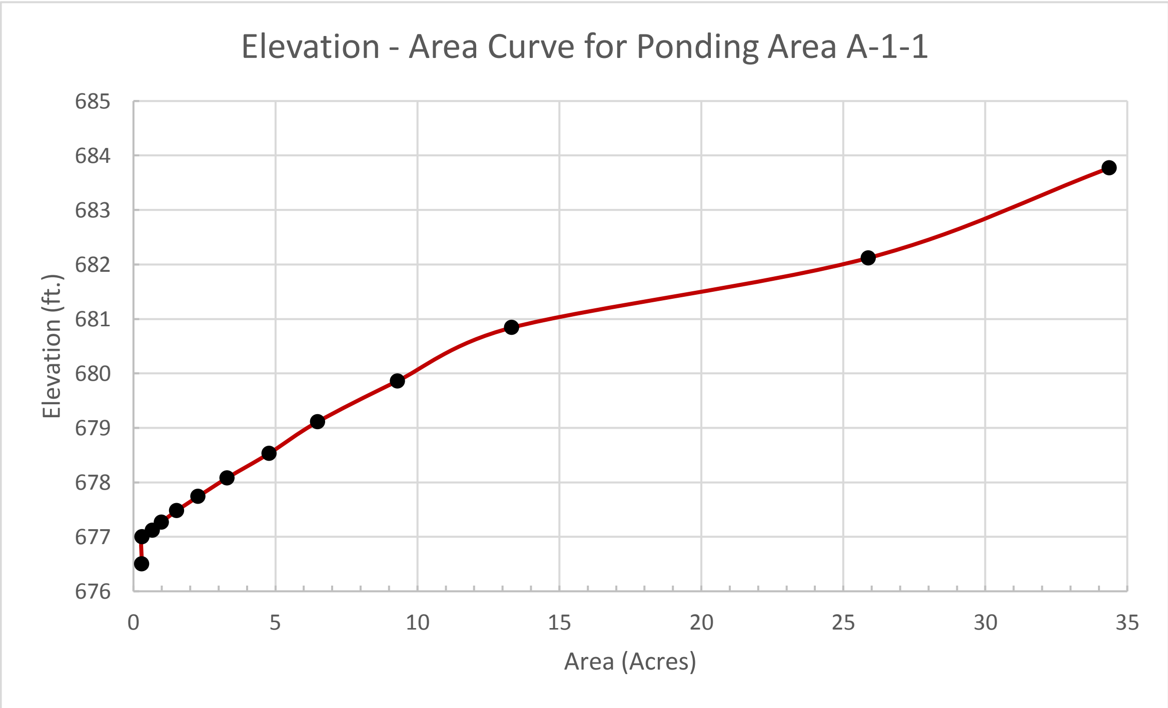
   HEIGHT = 6 ft.

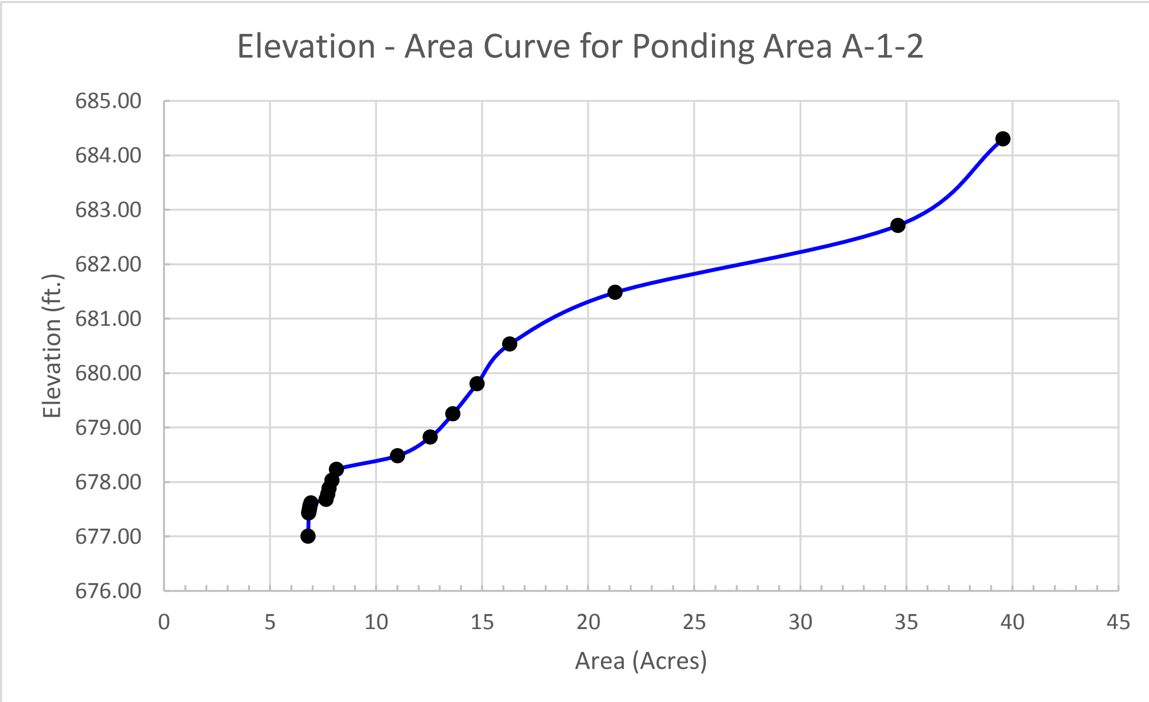
   QUANTITIES

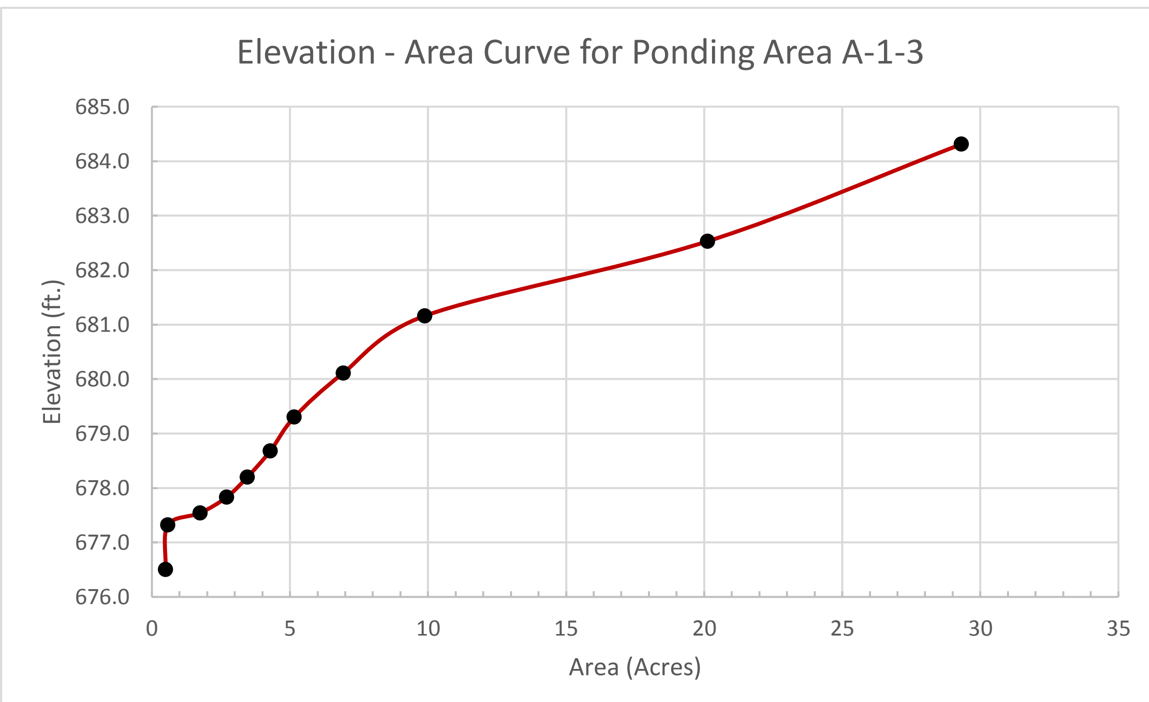
1 EA	CONE RISER
1 EA	60" RISER
1 EA	MANHOLE COVER
1 EA	MANHOLE BASE
20 LF	30" RCP

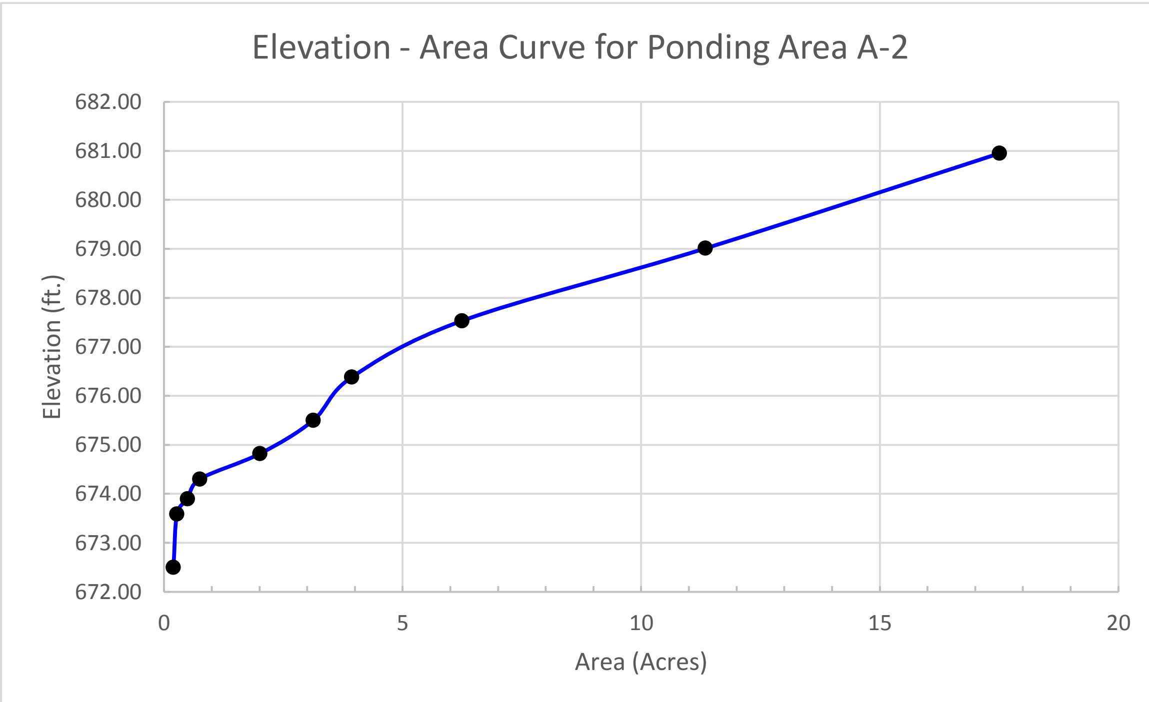


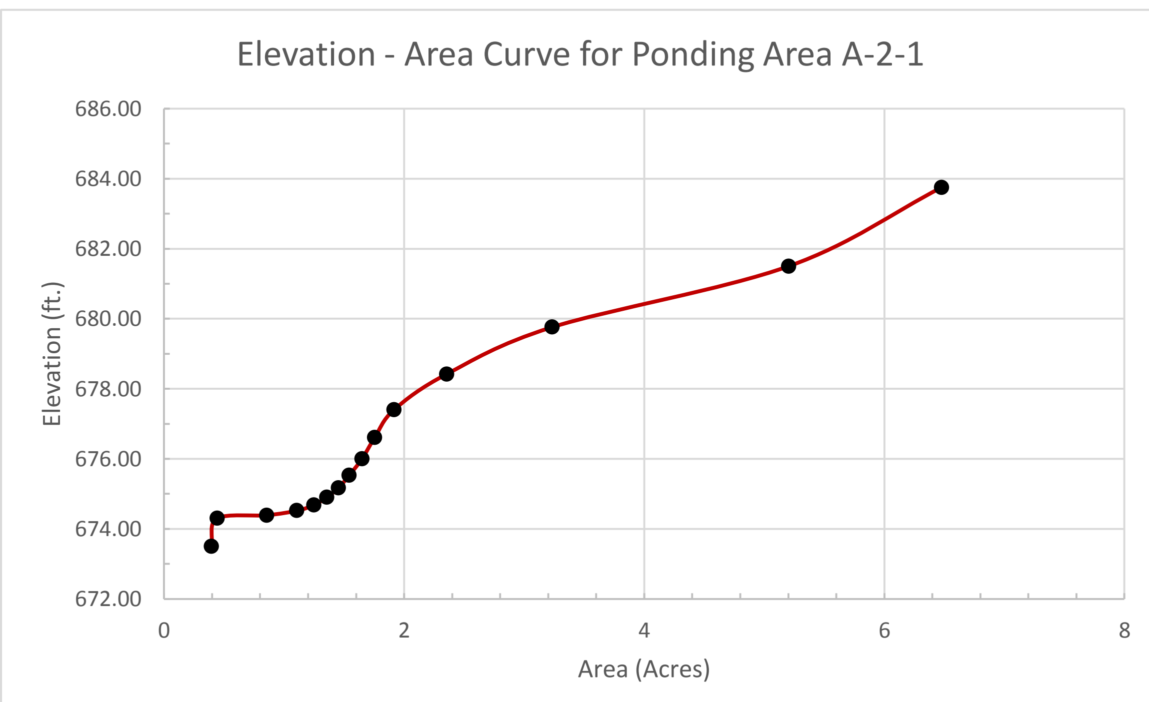

Elevation - Area Curve for Ponding Area A-1
Elevation (ft.)
686.0
684.0
682.0
680.0
678.0
676.0
674.0
672.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Area (Acres)

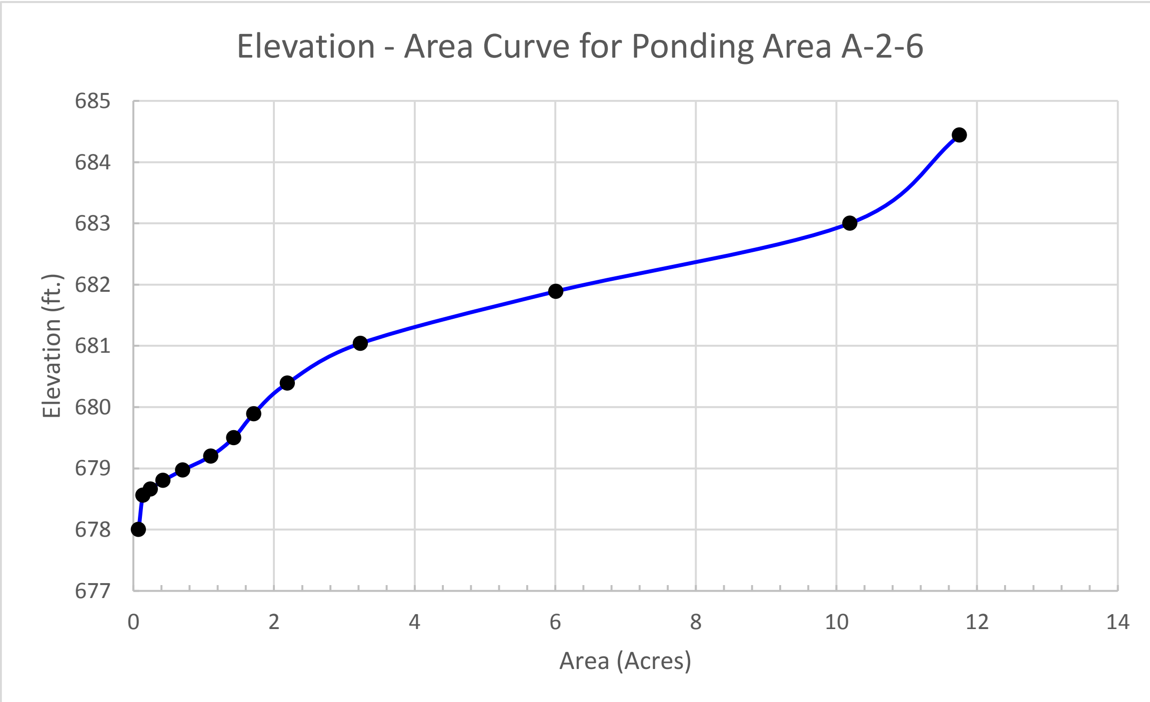

Elevation - Area Curve for Ponding Area A-1-1
Elevation (ft.)
685
684
683
682
681
680
679
678
677
676
0
5
10
15
20
25
30
35
Area (Acres)

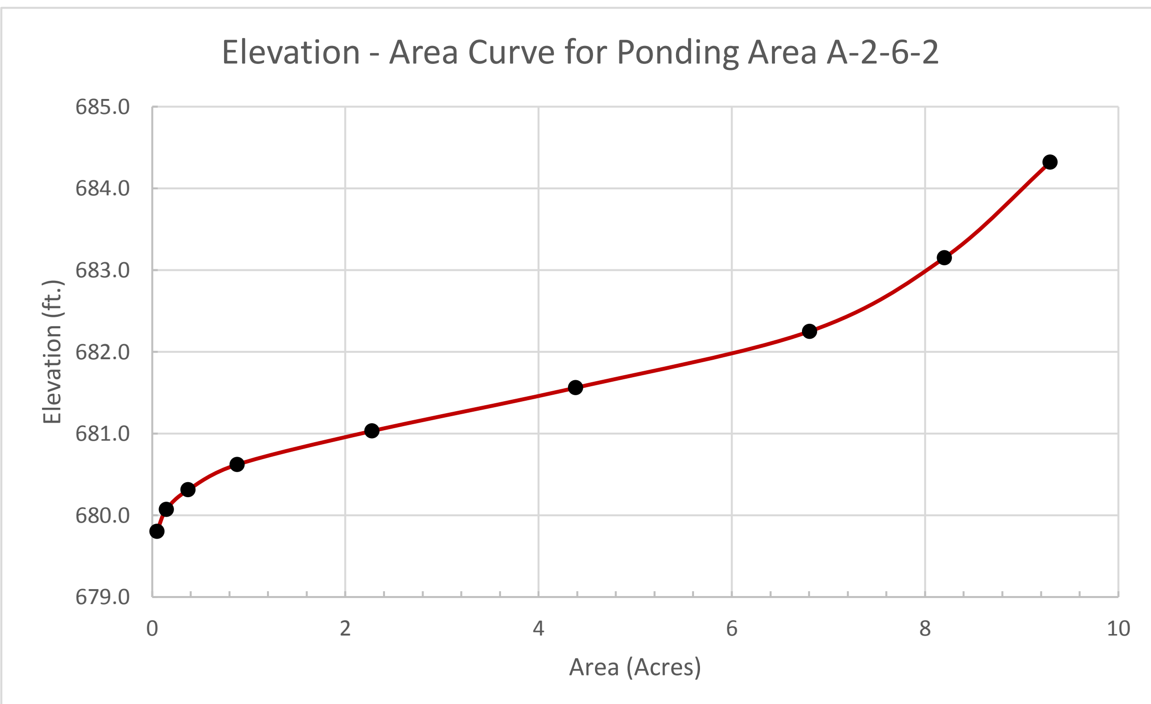

Elevation - Area Curve for Ponding Area A-1-2
685.00
684.00
683.00
682.00
681.00
680.00
679.00
678.00
677.00
676.00
Elevation (ft.)
0
5
10
15
20
25
30
35
40
45
Area (Acres)

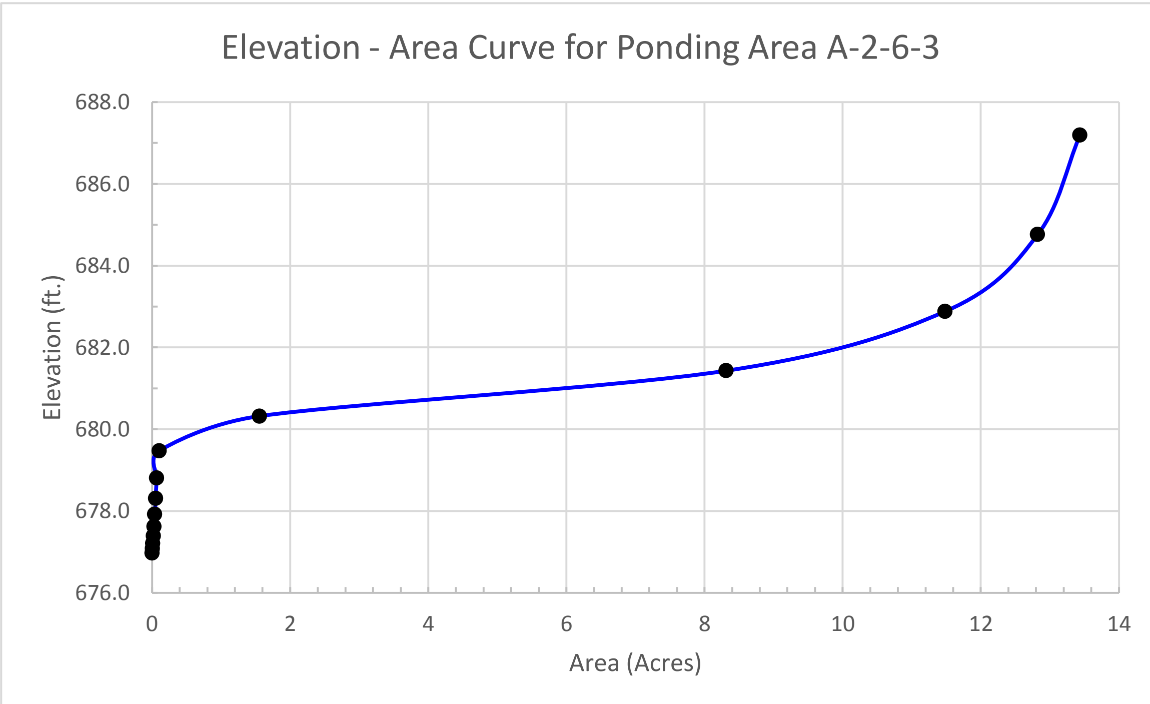

Elevation - Area Curve for Ponding Area A-1-3
685.0
684.0
683.0
682.0
681.0
680.0
679.0
678.0
677.0
676.0
Elevation (ft.)
0
5
10
15
20
25
30
35
Area (Acres)

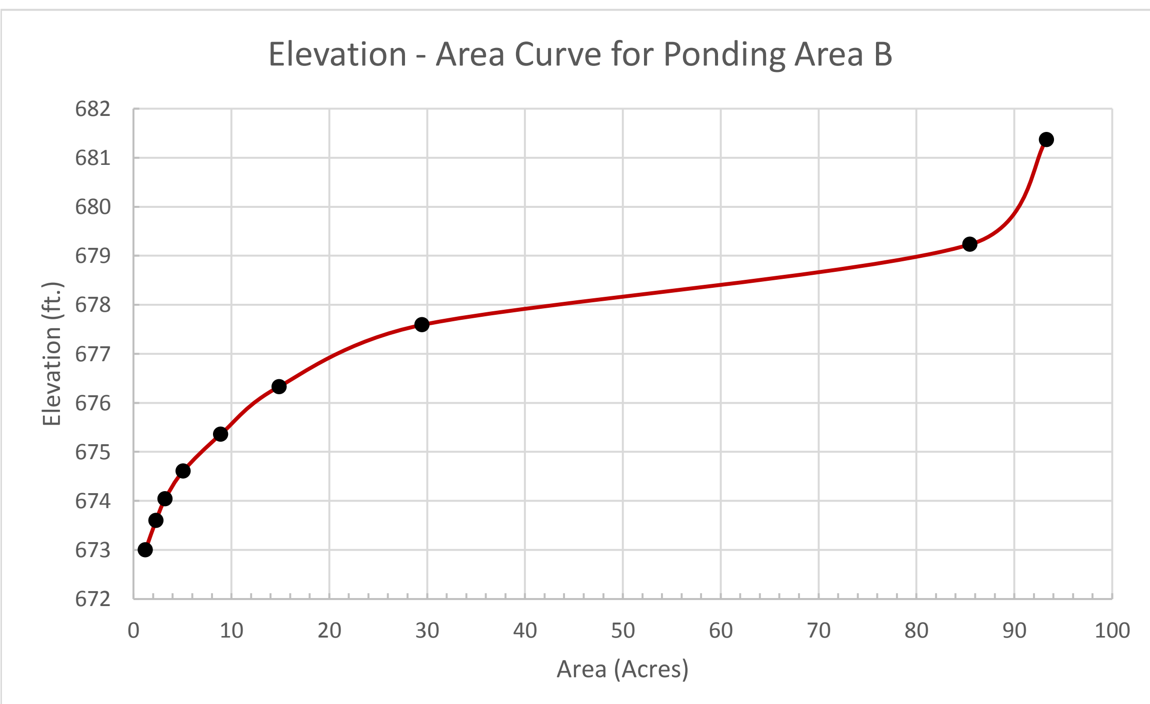

Elevation - Area Curve for Ponding Area A-2
682.00
681.00
680.00
679.00
678.00
677.00
676.00
675.00
674.00
673.00
672.00
Elevation (ft.)
0
5
10
15
20
Area (Acres)


Elevation - Area Curve for Ponding Area A-2-1
686.00
684.00
682.00
680.00
678.00
676.00
674.00
672.00
Elevation (ft.)
0
2
4
6
8
Area (Acres)


Elevation - Area Curve for Ponding Area A-2-6
Elevation (ft.)
685
684
683
682
681
680
679
678
677
0
2
4
6
8
10
12
14
Area (Acres)


Elevation - Area Curve for Ponding Area A-2-6-2
Elevation (ft.)
685.0
684.0
683.0
682.0
681.0
680.0
679.0
0
2
4
6
8
10
Area (Acres)


Elevation - Area Curve for Ponding Area A-2-6-3
Elevation (ft.)
688.0
686.0
684.0
682.0
680.0
678.0
676.0
0
2
4
6
8
10
12
14
Area (Acres)


Elevation - Area Curve for Ponding Area B
Elevation (ft.)
682
681
680
679
678
677
676
675
674
673
672
0
10
20
30
40
50
60
70
80
90
100
Area (Acres)

Appendix B – Subsurface Investigation Report

BRAUN INTERTEC
The Science You Build On.

Braun Intertec Corporation
2309 Palace Street
La Crosse, WI 54603

Phone: 608.781.7277
Fax: 608.781.7279
Web: braunintertec.com

September 30, 2015

Project B1506754

Ms. Christina Peterson
City of Houston
105 West Maple Street
Houston, Minnesota

Re: Report of Subsurface Exploration and Soil Laboratory Testing
Houston Levee Certification
Root River Basin
Houston, Minnesota

Dear Ms. Peterson:

We are pleased to present this report providing a summary of the results of soil borings and laboratory testing for exploration locations on the levee in Houston, Minnesota.

In summary, we drilled 23 standard penetration test borings, sampled at approximate 2- foot intervals to depths of 10 feet and 5-foot intervals below that. We performed moisture content, grain size analysis, plastic and liquid limits, consolidated undrained triaxial with pore pressure measurements, direct shear and hydraulic conductivity laboratory testing. The Log of Boring sheets and our laboratory testing results for our penetration test borings are attached to this letter.

Thank you for making Braun Intertec your geotechnical consultant for this project. If you have questions about this report, or if there are other services that we can provide in support of our work to date, please call Nicole Carlson or Brandon Wright at 608.721.7277.

Sincerely,

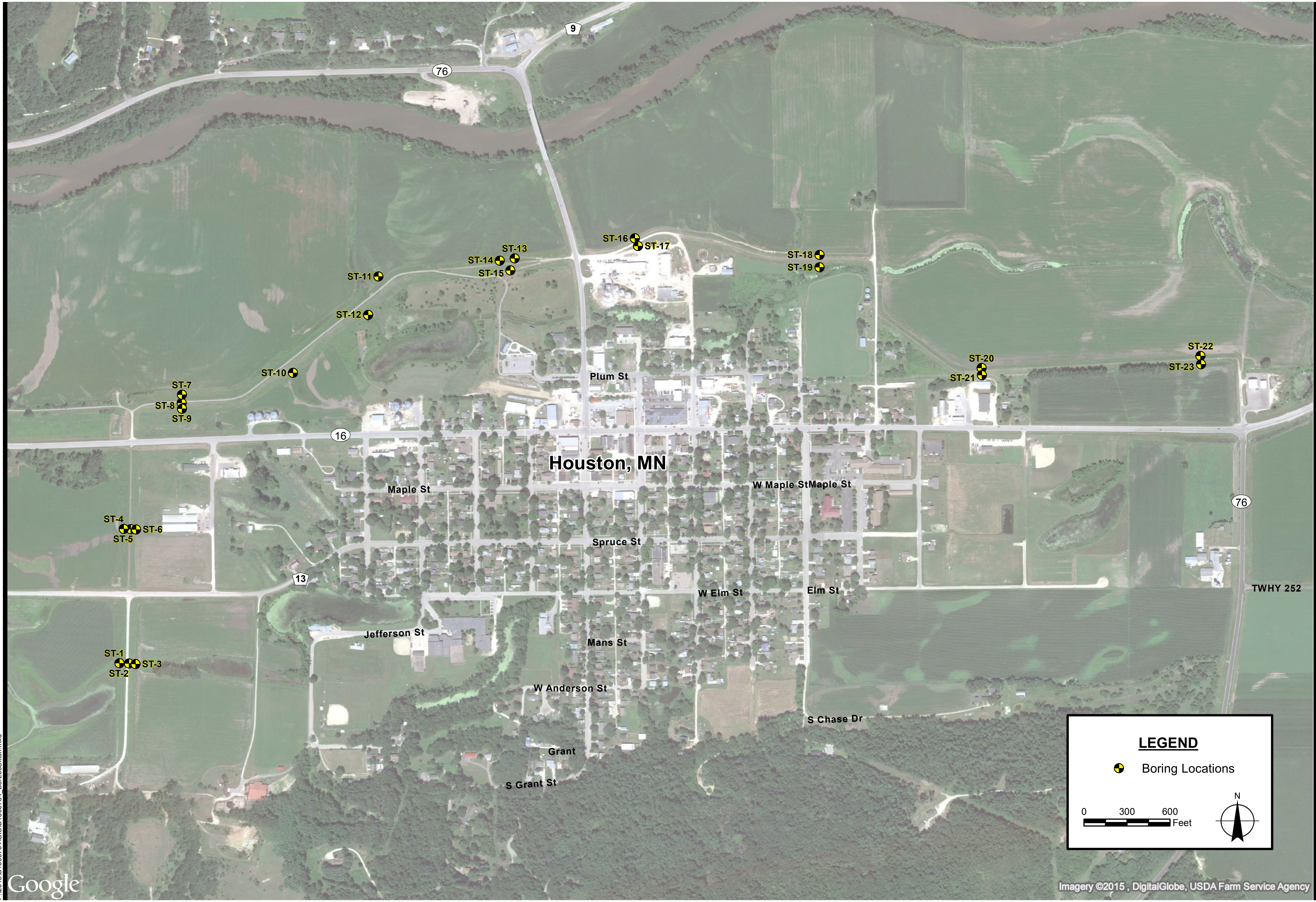
BRAUN INTERTEC CORPORATION

Nicole A. Carlson
Staff Engineer

Brandon K. Wright, PE
Senior Engineer

cc. Ms. Karen Wiemeri – Mead & Hunt
Mr. Jim Botz – Mead & Hunt

AA/EOE



BRAUN INTERTEC
11001 Hampshire Avenue So.
Minneapolis, MN 55438
PH. (952) 995-2000
FAX (952) 995-2020

BORING LOCATION SKETCH
GEOTECHNICAL EXPLORATION
HOUSTON LEVEE CERTIFICATION
HOUSTON, MINNESOTA

Project No:	B1506754
Drawing No.	B1506754_BorLocSktch
Scale:	1 in = 600 ft
Drawn By:	CMF
Date Drawn:	08/06/15
Checked By:	BW
Last Modified:	8/26/15
Sheet: 1 of 1	Fig. 1

F:\2015\B1506754\GIS\B1506754_BorLocSktch.mxd

BRAUN INTERTEC

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 1**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/11/15** | SCALE: **1" = 5'**

Elev. feet 683.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
682.5	0.7	TS	SANDY LEAN CLAY, with Gravel, dark brown, moist. (Topsoil)	22			
681.2	2.0	FILL	FILL: Silty Sand, with Gravel, fine-grained, brown, moist.				
680.2	3.0	FILL	FILL: Poorly Graded Sand, fine-grained, tan, moist.	10	▽	40	LL=49, PI=26
679.2	4.0	FILL	FILL: Silty Sand, fine-grained, dark brown, moist.				Thin wall sample taken at 4-feet to 6-feet in offset boring.
		OL	ORGANIC CLAY, black, saturated, rather soft to medium. (Alluvium)	4		60	
				6		35	
				5		36	
668.2	15.0	SP	POORLY GRADED SAND, fine-grained, gray, wet, loose. (Alluvium)	9			
667.2	16.0		END OF BORING.				

Water observed at a depth of 4-feet with a cave-in depth of 8-feet immediately after withdrawal of auger.

Boring then grouted.

Benchmark (BM): Exploration locations and surface elevations were staked and surveyed by Mead & Hunt.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:46

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 2**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/10/15** | SCALE: **1" = 5'**

Elev. feet 692.9	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
691.9	1.0	AGG	12-inches of Aggregate Base.				
689.9	3.0	FILL	FILL: Silt, trace of organics, brown, moist.	11			
680.9	12.0	FILL	FILL: Poorly Graded Sand, fine-grained, brown, moist.	13			
				9			
			Silt lenses from 7-feet to 12-feet.	14			
				48			
674.9	18.0	FILL	FILL: Lean Clay, dark gray-brown, wet.	6		27	
669.9	23.0	OL	ORGANIC CLAY, black, saturated, medium. (Alluvium)	6	▽ (18 ft)	14	LL=55 PI=28
660.9	32.0	ML	SILT, dark gray, saturated, very loose. (Alluvium)	4			
				*			*Thin wall sample.
				3			
			END OF BORING.				
			Water observed at a depth of 18-feet with a cave-in depth of 22 1/2-feet immediately after withdrawal of auger.				
			Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:47

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 3**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/11/15** | SCALE: **1" = 5'**

Elev. feet 683.1	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
682.6	0.5	TS	SANDY ORGANIC CLAY, black, moist. (Topsoil)				
681.6	1.5	FILL	FILL: Poorly Graded Sand with Silt, fine-grained, brown, moist.	7			
681.1	2.0	FILL	FILL: Lean Clay, with Sand, dark brown, moist.	13	▽		
677.6	5.5	FILL	FILL: Lean Clay, gray-brown, wet saturated.	3*			*No Recovery.
670.1	13.0	OL	ORGANIC CLAY, black to dark brown, saturated, rather soft to soft. (Alluvium)	4, 3		40	LL=43, PI=19 Thin wall sample taken at 8-feet to 10-feet in offset boring.
667.1	16.0	ML	SILT, gray-brown, saturated, very loose. (Alluvium)	3			

END OF BORING.

Water observed at a depth of 4-feet with a cave-in depth of 8-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:47

LOG OF BORING

BRAUN INTERTEC

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: ST- 4 LOCATION: See Attached Boring Location Sketch.

DRILLER:	B. Oldenburg	METHOD:	3 1/4" HSA, Autohammer	DATE:	8/11/15	SCALE:	1" = 5'

Elev. feet 681.9	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
681.2	0.7	TS	ORGANIC CLAY, dark brown, moist. (Topsoil)				
678.9	3.0	CL	SANDY LEAN CLAY, brown, wet. (Alluvium)	4		24	
665.9	16.0	SP	POORLY GRADED SAND, fine-grained, brown, wet to waterbearing, very loose to medium dense. (Alluvium)	4*			*No Recovery.
				16	▽	17	P200=3.0%
				7			
				10			
				11			
			END OF BORING. Water observed at a depth of 6-feet with a cave-in depth of 7-feet immediately after withdrawal of auger. Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:47

LOG OF BORING

BRAUN INTERTEC

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 5**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/11/15** | SCALE: **1" = 5'**

Elev. feet 693.7	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
693.2	0.5	AGG	6-inches of Aggerate Base.				
687.7	6.0	FILL	FILL: Silt, tan, moist.	22, 29, 24			
687.2	6.5	FILL	FILL: Poorly Graded Sand with Silt, fine-grained, brown, moist.				
686.2	7.5	FILL	FILL: Lean Clay, with Sand, dark brown, moist.	30		15	
685.7	8.0	FILL	FILL: Poorly Graded Sand, fine-grained, tan, moist.				
685.2	8.5	FILL	FILL: Silt, brown, moist.				
684.7	9.0	FILL	FILL: Poorly Graded Sand, fine-grained, tan, moist.	9		13	
680.7	13.0	FILL	FILL: Lean Clay, gray-brown, wet.				
675.7	18.0	CL	LEAN CLAY, black to gray-brown, wet, medium. (Alluvium)	6		23	
672.7	21.0	OL	ORGANIC CLAY, dark gray, saturated, rather soft. (Alluvium)	4	▽		
666.7	27.0	SP-SM	POORLY GRADED SAND with SILT, with Gravel, fine-grained, light gray, waterbearing, medium dense. (Alluvium)	*, 14			*Thin wall sample.
662.7	31.0	SP	POORLY GRADED SAND, fine-grained, light gray, waterbearing, medium dense. (Alluvium)	20			
			END OF BORING.				

Water observed at a depth of 18-feet with a cave-in depth of 20-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:47

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 6**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/11/15** | SCALE: **1" = 5'**

Elev. feet 684.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
683.5	0.9	TS	ORGANIC CLAY, dark brown, moist. (Topsoil)				
680.4	4.0	OL	ORGANIC CLAY, with Sand, dark brown, moist, stiff to medium. (Alluvium)	13 11		19 18	
678.4	6.0	ML	SILT, gray-brown, wet, very loose. (Alluvium)	10		24	
676.4	8.0	CL	LEAN CLAY, gray-brown, wet, rather soft. (Alluvium)	4	▽	22	
671.4	13.0	OL	ORGANIC CLAY, black, wet, rather soft. (Alluvium)	4		32	Thin wall sample taken at 8-feet to 10-feet in offset boring. LL=38 PI=17
668.9	15.5	SP	POORLY GRADED SAND, medium-grained, brown, wet to waterbearing, loose. (Alluvium)				
668.4	16.0	CL	LEAN CLAY, gray, saturated, medium. (Alluvium)	8			

END OF BORING.

Water observed at a depth of 8-feet with a cave-in depth of 8-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 7**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/11/15** | SCALE: **1" = 5'**

(See Descriptive Terminology sheet for explanation of abbreviations)

Elev. feet 679.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
678.3	0.9	TS	SILTY SAND, fine-grained, dark brown, moist. (Topsoil)			
676.2	3.0	FILL	FILL: Silt, tan, moist.	14	▽	
675.2	4.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, trace of gravel, brown, waterbearing, medium dense. (Alluvium)	15		
663.2	16.0	SP	POORLY GRADED SAND, fine- to medium-grained, trace of gravel, brown, waterbearing, medium dense to loose. (Alluvium)	12, 6, 10, 5		
			END OF BORING.			

Water observed at a depth of 3-feet with a cave-in depth of 7 1/2-feet immediately after withdrawal of auger.

Boring then grouted.

BRAUN INTERTEC

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 8**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/12/15** | SCALE: **1" = 5'**

Elev. feet 694.6	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
693.4	1.2	BIT	3-inches of Bituminous over 11-inches of Aggregate.				
690.1	4.5	FILL	FILL: Silt, tan, moist.	12 16			
688.6	6.0	FILL	FILL: Clayey Sand, fine-grained, dark brown, moist.	24			
676.6	18.0	FILL	FILL: Poorly Graded Sand with Silt, fine-grained, tan to light tan, moist.	13 10 19		4	P200=6.9%
674.1	20.5	SP-SM	POORLY GRADED SAND with Silt, fine-grained, brown, wet, medium dense. (Alluvium)				
671.6	23.0	SP	POORLY GRADED SAND, fine- to medium-grained, brown, wet, medium dense. (Alluvium)	11	▽		
663.6	31.0	SP	POORLY GRADED SAND, fine- to medium-grained, gray, waterbearing, medium dense. (Alluvium)	12 11		12	P200=1.4%
			END OF BORING. Water observed at a depth of 23-feet with a cave-in depth of 15-feet immediately after withdrawal of auger. Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST- 9**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/12/15** | SCALE: **1" = 5'**

Elev. feet 682.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
680.9	1.3	TS	SILTY SAND, fine-grained, dark brown, moist. (Topsoil)	12		
680.2	2.0	SM	SILTY SAND, fine-grained, dark brown, moist, medium dense. (Alluvium)			
678.2	4.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, brown, moist, medium dense. (Alluvium)	11	▽	
669.2	13.0	SP	POORLY GRADED SAND, fine- to -medium-grained, brown to gray, waterbearing, loose. (Alluvium)	10, 7		
666.2	16.0	SP	POORLY GRADED SAND, medium- to coarse-grained, trace of gravel, gray, waterbearing, loose. (Alluvium)	6		

END OF BORING.

Water observed at a depth of 4-feet with a cave-in depth of 6 1/2-feet immediately after withdrawal of auger.

Boring then grouted.

BRAUN INTERTEC

LOG OF BORING

Braun Project B1506754 **GEOTECHNICAL EVALUATION** **Houston Levee Certification** **Root River Basin** **Houston, Minnesota**	BORING: **ST-10** LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/12/15**	SCALE: **1" = 5'**

Elev. feet 680.1	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
678.5	1.6	TS	CLAYEY SAND, fine-grained, dark brown, moist. (Topsoil)	10			
678.1	2.0	FILL	FILL: Clayey Sand, fine-grained, dark brown, moist.				
673.1	7.0	FILL	FILL: Organic Clay, dark brown, moist to wet. (Alluvium)	8		12	LL=28 PI=10
				6		60	
672.1	8.0	PT	PEAT.	2	▽		
671.1	9.0	OL	ORGANIC CLAY, black, saturated, soft. (Alluvium)				
664.1	16.0	SP	POORLY GRADED SAND, fine- to mediun-grained, gray, waterbearing, very loose to loose. (Alluvium)	4			
				7			

END OF BORING.

Water observed at a depth of 8-feet with a cave-in depth of 8-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: ST-11 LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/14/15	SCALE: 1" = 5'

Elev. feet 675.1	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
673.6	1.5	TS	SILTY SAND, fine-grained, dark brown, damp. (Topsoil)	5			
670.1	5.0	CL	SANDY LEAN CLAY, with mottling 4 to 5-feet, dark brown, saturated, soft to medium. (Alluvium)	3	▽	38	LL=43, PI=18 Thin wall sample taken at 3-feet to 5-feet in offset boring.
659.1	16.0	SP	POORLY GRADED SAND, fine-grained, gray, wet to waterbearing, loose. (Alluvium)	7 7 6 6			
			END OF BORING. Water observed at a depth of 5-feet with a cave-in depth of 8 1/2-feet immediately after withdrawal of auger. Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: ST-12 LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/12/15	SCALE: 1" = 5'

Elev. feet 678.1	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
676.6	1.5	TS	CLAYEY SAND, fine-grained, dark brown, moist. (Topsoil)	11			
674.1	4.0	FILL	FILL: Clayey Sand, fine-grained, with layers of Poorly Graded Sand, dark brown, moist.	4			
670.1	8.0	FILL	FILL: Sandy Lean Clay, dark brown, wet.	5 3	▽	36 34	
669.6	8.5	FILL	FILL: Wood pieces, tan.				
669.1	9.0	FILL	FILL: Poorly Graded Sand, fine-grained, gray, waterbearing.	2			
668.1	10.0	PT	PEAT.				
662.1	16.0	SP	POORLY GRADED SAND, fine-grained, gray, waterbearing, medium dense. (Alluvium)	12			

END OF BORING.

Water observed at a depth of 8-feet with a cave-in depth of 8 1/2-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

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Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: ST-13 LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/12/15	SCALE: 1" = 5'

Elev. feet 681.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
680.9	0.3	TS	SILTY SAND, fine-grained, brown, moist. (Topsoil)	16		
679.2	2.0	FILL	FILL: Sandy Organic Clay, dark brown, moist.			
676.2	5.0	FILL	FILL: Poorly Graded Sand, fine- to medium-grained, tan, moist.	25		
675.2	6.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, gray-brown, moist, medium dense. (Alluvium)	23	▽	
665.2	16.0	SP	POORLY GRADED SAND, fine-grained, trace of gravel, tan, waterbearing, very loose to medium dense. (Alluvium)	7 4 16		

END OF BORING.

Water observed at a depth of 6-feet with a cave-in depth of 11 1/2-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

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Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST-14**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/12/15** | SCALE: **1" = 5'**

Elev. feet 681.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
680.8	0.6	AGG	7-inches of Aggregate Base.				
		FILL	FILL: Silt, tan, moist.	10			
				12		18	P200=98%
				12			
				9			
				12			
665.9	15.5	SP	POORLY GRADED SAND, fine-grained, brown, moist to waterbearing, medium dense to loose. (Alluvium)	18			
				10		20	P200=1.8%
658.4	23.0	SP	POORLY GRADED SAND, fine-grained, gray, waterbearing, loose. (Alluvium)	8			
653.4	28.0	SP	POORLY GRADED SAND, fine- to medium-grained, trace of gravel, gray, waterbearing, medium dense. (Alluvium)	21			
650.4	31.0		END OF BORING.				

Water observed at a depth of 18-feet with a cave-in depth of 16-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: ST-15 LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: 8/12/15	SCALE: 1" = 5'

Elev. feet 681.1	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
680.3	0.8	AGG	9-inches Aggregate Base.			
678.1	3.0	FILL	FILL: Sandy Lean Clay, dark brown, moist.	14		
675.1	6.0	FILL	FILL: Poorly Graded Sand, fine-grained, brown, moist.	24 11		
674.1	7.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, dark brown, wet, loose. (Alluvium)		▽	
668.1	13.0	SP	POORLY GRADED SAND, fine- to medium-grained, tan, waterbearing, loose. (Alluvium)	7 5		
665.1	16.0	SP	POORLY GRADED SAND, fine- to medium-grained, trace of gravel, gray, waterbearing, medium dense. (Alluvium)	18		
			END OF BORING. Water observed at a depth of 7-feet with a cave-in depth of 12-feet immediately after withdrawal of auger. Boring then grouted.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST-16**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/13/15** | SCALE: **1" = 5'**

Elev. feet 680.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
679.7	0.7	TS	SILTY SAND, fine-grained, dark brown, damp. (Topsoil)				
676.4	4.0	CL	LEAN CLAY, slightly organic, dark brown, moist, medium. (Alluvium)	8 6	▽	12 30	
674.4	6.0	ML	SILT, dark brown, saturated, very loose. (Alluvium)	4			
672.4	8.0	ML	SILT, with Sand, dark brown, saturated, very loose. (Alluvium)	3			
667.4	13.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, gray-brown, waterbearing, very loose. (Alluvium)	2			
664.4	16.0	SP	POORLY GRADED SAND, fine- to medium-grained, brown, waterbearing, loose. (Alluvium)	6			
			END OF BORING. Water observed at a depth of 4-feet with a cave-in depth of 8-feet immediately after withdrawal of auger. Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: **ST-17** LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/13/15**	SCALE: **1" = 5'**

Elev. feet 685.0	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
683.0	2.0	TS	SILTY SAND, fine-grained, brown, damp. (Topsoil)	8		
682.5	2.5	FILL	FILL: Organic Clay, with Sand, dark brown, moist.			
682.0	3.0	FILL	FILL: Clayey Sand, fine-grained, brown, moist.	9		
681.0	4.0	FILL	FILL: Silt, gray, moist.			
680.0	5.0	FILL	FILL: Poorly Graded Sand with Silt, fine-grained, brown, moist.	7	▽	
679.0	6.0	TS	LEAN CLAY, slightly organic, dark brown, wet. (Buried Topsoil)	4		
672.0	13.0	CL	LEAN CLAY, with Sand, dark brown, saturated, rather soft. (Alluvium)	4		Thin wall sample taken at 8-feet to 10-feet in offset boring.
669.0	16.0	SP	POORLY GRADED SAND, fine-grained, brown, waterbearing, very loose. (Alluvium)	4		
			END OF BORING. Water observed at a depth of 6-feet with a cave-in depth of 12 1/2-feet immediately after withdrawal of auger. Boring then grouted.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: **ST-18** LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/13/15**	SCALE: **1" = 5'**

Elev. feet 679.3	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
678.6	0.7	TS	SILTY SAND, fine-grained, dark brown, damp. (Topsoil)			
676.3	3.0	FILL	FILL: Lean Clay, dark brown, moist.	6		
673.3	6.0	FILL	FILL: Poorly Graded Sand, fine-grained, tan, moist.	8 10		
671.3	8.0	SP-SM	POORLY GRADED SAND with SILT, fine-grained, brown, wet, loose. (Alluvium)	10	▽	
666.3	13.0	SP	POORLY GRADED SAND, fine-grained, brown, waterbearing, loose. (Alluvium)	8		
663.3	16.0	SP	POORLY GRADED SAND, fine- to medium-grained, gray, waterbearing, loose. (Alluvium)	6		
			END OF BORING. Water observed at a depth of 8-feet with a cave-in depth of 10 1/2-feet immediately after withdrawal of auger. Boring then grouted.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: **ST-19** LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/13/15**	SCALE: **1" = 5'**

Elev. feet 677.2	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
675.7	1.5	TS	SILTY SAND, fine-grained, brown, moist. (Topsoil)	6	▽		
675.2	2.0	FILL	FILL: Lean Clay, slightly organic, dark brown, moist.				
		CL	LEAN CLAY, with thin layers of Sand, dark brown, saturated, soft. (Alluvium)	3		29	
				3		45	Thin wall sample taken at 4-feet to 6-feet in offset boring.
				3		36	
				2		36	
661.2	16.0			2			
659.2	18.0	CL	SANDY LEAN CLAY, dark brown, saturated, very soft.	1			
			END OF BORING. Water observed at a depth of 2-feet with a cave-in depth of 18-feet immediately after withdrawal of auger. Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST-20**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/13/15**	SCALE: **1" = 5'**

Elev. feet 679.1	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
678.2	0.9	TS	SILTY SAND, fine-grained, dark brown, moist. (Topsoil)				
677.1	2.0	FILL	FILL: Sandy Lean Clay, dark brown, wet.	11			
672.1	7.0	SP-SM	POORLY GRADED SAND with SILT, brown, wet, loose. (Alluvium)	10 6			
666.1	13.0	CL	LEAN CLAY, with Sand, gray, saturated, soft to rather soft. (Alluvium)	2 4	▽	16 20	
663.1	16.0	SP	POORLY GRADED SAND, fine- to medium-grained, brown, waterbearing, very loose. (Alluvium)	3			

END OF BORING.

Water observed at a depth of 7-feet with a cave-in depth of 13-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

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Braun Project B1506754 GEOTECHNICAL EVALUATION Houston Levee Certification Root River Basin Houston, Minnesota	BORING: **ST-21** LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg	METHOD: 3 1/4" HSA, Autohammer	DATE: **8/13/15**	SCALE: **1" = 5'**

Elev. feet 680.6	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	MC %	Tests or Notes
680.1	0.5	TS	SILTY SAND, fine-grained, brown, damp. (Topsoil)	7			
678.6	2.0	FILL	FILL: Sandy Lean Clay, dark brown, moist.				
677.6	3.0	FILL	FILL: Sandy Lean Clay, brown, moist.				
674.6	6.0	SC	CLAYEY SAND, fine-grained, brown, moist to waterbearing, rather stiff. (Alluvium)	9 9	▽		
667.6	13.0	SC	CLAY SAND, fine-grained, brown, waterbearing, very loose. (Alluvium)	4 4		21	P200=23%
664.6	16.0	SP	POORLY GRADED SAND, fine-grained, brown, waterbearing, very loose. (Alluvium)	4			
			END OF BORING. Water observed at a depth of 5-feet with a cave-in depth of 9-feet immediately after withdrawal of auger. Boring then grouted.				

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING

BRAUN INTERTEC

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST-22**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/14/15** | SCALE: **1" = 5'**

Elev. feet 677.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
676.9	0.5	TS	SILTY SAND, fine-grained, dark brown, damp. (Topsoil)			
676.4	1.0	FILL	FILL: Silty Sand, fine-grained, brown, moist.	16	∇	
675.4	2.0	FILL	FILL: Poorly Graded Sand, fine-grained, brown, moist.			
671.9	5.5	CL	LEAN CLAY, with Sand, gray-brown, saturated, medium. (Alluvium)	6 4*		Thin wall sample taken at 4-feet to 6-feet in offset boring. *No Recovery.
664.4	13.0	SP	POORLY GRADED SAND, fine-grained, gray-brown, waterbearing, very loose. (Alluvium)	2 3		
661.4	16.0	SP	POORLY GRADED SAND, fine-grained, gray, waterbearing, loose. (Alluvium)	6		

END OF BORING.

Water observed at a depth of 2-feet with a cave-in depth of 7 1/2-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:48

BRAUN INTERTEC

LOG OF BORING

Braun Project B1506754
GEOTECHNICAL EVALUATION
Houston Levee Certification
Root River Basin
Houston, Minnesota

BORING: **ST-23**

LOCATION: See Attached Boring Location Sketch.

DRILLER: B. Oldenburg | METHOD: 3 1/4" HSA, Autohammer | DATE: **8/14/15** | SCALE: **1" = 5'**

Elev. feet 677.7	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
677.0	0.7	TS	SILTY SAND, fine-grained, dark brown, damp. (Topsoil)			
675.7	2.0	FILL	FILL: Sandy Lean Clay, dark brown, moist.	10		
673.7	4.0	SC	CLAYEY SAND, fine-grained, brown, wet, medium. (Alluvium)	7	▽	
671.7	6.0	CL	SANDY LEAN CLAY, gray-brown, saturated, medium. (Alluvium)	6		
664.7	13.0	SP	POORLY GRADED SAND, tan, waterbearing, medium dense to loose. (Alluvium)	13 5		
661.7	16.0	SP	POORLY GRADED SAND, fine- to medium-grained, tan, waterbearing, loose. (Alluvium)	6		

END OF BORING.

Water observed at a depth of 4-feet with a cave-in depth of 7-feet immediately after withdrawal of auger.

Boring then grouted.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\LACROSSE\2015\B15-06754.GPJ BRAUN_V8_CURRENT.GDT 9/30/15 09:48

BRAUN INTERTEC

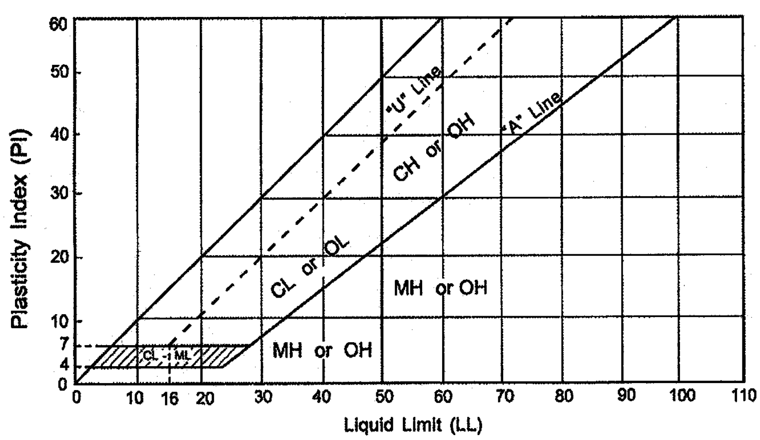
Descriptive Terminology of Soil

ASTM INTERNATIONAL

Standard D 2487 – 11
Classification of Soils for Engineering Purposes
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [a]				Soils Classification: Group Symbol	Soils Classification: Group Name [b]
Coarse-grained Soils more than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines [e]	$C_u \geq 4$ and $1 \leq C_c \leq 3$ [c]	GW	Well-graded gravel [d]
			$C_u < 4$ and/or $1 > C_c > 3$ [c]	GP	Poorly graded gravel [d]
		Gravels with Fines More than 12% fines [e]	Fines classify as ML or MH	GM	Silty gravel [d f g]
			Fines classify as CL or CH	GC	Clayey gravel [d f g]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines [i]	$C_u \geq 6$ and $1 \leq C_c \leq 3$ [c]	SW	Well-graded sand [h]
			$C_u < 6$ and/or $1 > C_c > 3$ [c]	SP	Poorly graded sand [h]
		Sands with Fines More than 12% [i]	Fines classify as ML or MH	SM	Silty sand [f g h]
			Fines classify as CL or CH	SC	Clayey sand [f g h]
Fine-grained Soils 50% or more passed the No. 200 sieve	Silts and Clays Liquid limit less than 50	Inorganic	PI > 7 and plots on or above "A" line [j]	CL	Lean clay [k l m]
			PI < 4 or plots below "A" line [j]	ML	Silt [k l m]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OL	Organic clay [k l m n]
				OL	Organic silt [k l m o]
	Silts and clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay [k l m]
			PI plots below "A" line	MH	Elastic silt [k l m]
		Organic	Liquid limit - oven dried / Liquid limit - not dried < 0.75	OH	Organic clay [k l m p]
				OH	Organic silt [k l m q]
Highly Organic Soils		Primarily organic matter, dark in color and organic odor		PT	Peat

a. Based on the material passing the 3-inch (75mm) sieve.
b. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders or both" to group name.
c. $C_u = D_{60}/D_{10}$ $C_c = \frac{(D30)^2}{D_{10} \times D_{60}}$
d. If soil contains ≥15% sand, add "with sand" to group name.
e. Gravels with 5 to 12% fines require dual symbols:
   GW-GM well-graded gravel with silt
   GW-GC well-graded gravel with clay
   GP-GM poorly graded gravel with silt
   GP-GC poorly graded gravel with clay
f. If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.
g. If fines are organic, add "with organic fines: to group name.
h. If soil contains ≥15% gravel, add "with gravel" to group name.
i. Sand with 5 to 12% fines require dual symbols:
   SW-SM well-graded sand with silt
   SW-SC well-graded sand with clay
   SP-SM poorly graded sand with silt
   SP-SC poorly graded sand with clay
j. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.
k. If soil contains 10 to 29% plus No. 200, add "with sand" or "with gravel" whichever is predominant.
l. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.
m. If soil contains ≥ 30% plus No. 200 predominantly grave, add "gravelly" to group name.
n. PI ≥ 4 and plots on or above "A" line.
o. PI < 4 or plots below "A" line.
p. PI plots on or above "A" lines.
q. PI plots below "A" line.



Laboratory Tests

DD	Dry density, pcf	**OC**	Organic content, %
WD	Wet density, pcg	**S**	Percent of saturation, %
MC	Natural moisture content, %	**SG**	Specific gravity
LL	Liquid limit, %	**C**	Cohesion, psf
PL	Plastic limits, %	**Ø**	Angle of internal friction
PI	Plasticity index, %	**qu**	Unconfined compressive strength, psf
P200	% passing 200 sieve	**qp**	Pocket penetrometer strength, tsf

Particle Size Identification

Boulders................. over 12"
Cobbles .... 3" to 12"
Gravel
  Coarse .... 3/4" to 3"
  Fine................ No. 4 to 3/4"
Sand
  Coarse .... No. 4 to No. 10
  Medium .... No. 10 to No. 40
  Fine................ No. 40 to No. 200
Silt .... <No. 200, PI< 4 or below "A" line
Clay .... <No. 200, PI ≥ 4 and on or about "A" line

Relative Density of Cohesionless Soils

Very Loose............ 0 to 4 BPF
Loose..................... 5 to 10 BPF
Medium dense .... 11 to 30 PPF
Dense .... 31 to 50 BPF
Very dense............ over 50 BPF

Consistency of Cohesive Soils

Very soft................ 0 to 1 BPF
Soft .... 2 to 3 BPF
Rather soft .... 4 to 5 BPF
Medium .... 6 to 8 BPF
Rather stiff .... 9 to 12 BPF
Stiff .... 13 to 16 BPF
Very stiff................. 17 to 30 BPF
Hard....................... over 30 BPF

Drilling Notes

Standard penetration test borings were advanced by 3 1/4" or 6 1/4" ID hollow-stem augers, unless noted otherwise. Jetting water was used to clean out auger prior to sampling only where indicated on logs. All samples were taken with the standard 2" OD split-tube samples, except where noted.

Power auger borings were advanced by 4" or 6" diameter continuous flight, solid-stern augers. Soil classifications and strata depths were inferred from disturbed samples augered to the surface, and are therefore, somewhat approximate.

Hand auger borings were advanced manually with a 1 1/2" or 3 1/4" diameter auger and were limited to the depth from which the auger could be manually withdrawn.

BPF: Numbers indicate blows per foot recorded in standard penetration test, also known as "N" value. The sampler was set 6" into undisturbed soil below the hollow-stem auger. Driving resistances were then counted for second and third 6" increments, and added to get BPF. Where they differed significantly, they are reported in the following form: 2/12 for the second and third 6" increments, respectively.

WH: WH indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

WR: WR indicates the sampler penetrated soil under weight of rods alone; hammer weight, and driving not required.

TW: TW indicates thin-walled (undisturbed) tube sample.

Note: All tests were run in general accordance with applicable ASTM standards.

Borehole	Depth (feet)	Water Content (%)	Classification
ST-1	4.5	59.6	Organic Clay (OL)
ST-1	6.5	34.5	Organic Clay (OL)
ST-1	8.5	36.3	Organic Clay (OL)
ST-2	14.5	29.7	Lean Clay (CL)
ST-4	0.5	23.5	Lean Clay (CL)
ST-5	6.5	14.8	Lean Clay (CL)
ST-5	8.5	12.7	Silt (ML)
ST-5	14.5	23.4	Lean Clay (CL)
ST-6	0.5	18.7	Organic Clay (OL)
ST-6	2.5	17.9	Organic Clay (OL)
ST-6	4.5	23.7	Silt (ML)
ST-6	6.5	22.2	Lean Clay (CL)
ST-10	5	59.9	Organic Clay (OL)
ST-12	4.5	36.4	Sandy Lean Clay (CL)
ST-12	6.5	34.1	Sandy Lean Clay (CL)
ST-16	0.5	12.1	Lean Clay (CL)
ST-16	2.5	29.2	Lean Clay (CL)
ST-19	2.5	28.6	Lean Clay (CL)
ST-19	4.5	44.5	Lean Clay (CL)
ST-19	6.5	35.7	Lean Clay (CL)
ST-19	8.5	36.3	Lean Clay (CL)
ST-20	6.5	16.2	Lean Clay (CL)
ST-20	8.5	20.1	Lean Clay (CL)

Borehole	Depth (feet)	Water Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Max Particle Size(mm)	%<#200 Sieve	Classification
ST-1	4	39.1	49	23	26			Organic Clay (OL)
ST-2	19.5	14.4	55	27	28			Organic Clay (OL)
ST-3	8	45.4	43	24	19			Organic Clay (OL)
ST-4	5	16.7				2	3	Poorly Graded Sand (SP)
ST-6	8	31.6	38	21	17			Organic Clay (OL)
ST-8	8	14.8				4.75	7	Poorly Graded Sand w/ Silt (SP-SM)
ST-8	25	12.7				9.5	1	Poorly Grade Sand (SP)
ST-10	4	11.6	28	12	10			Organic Clay (OL)
ST-11	3	38	43	25	18			Lean Clay (CL)
ST-14	4	17.9				2	98	Silt (ML)
ST-14	20	20				4.75	2	Poorly Graded Sand (SP)
ST-21	8	20.8				4.75	23	Clayey Sand (SC)

Braun Project B1506754
Houston Levee Certification
Root River Basin
Houston, MN

Laboratory Results Summary

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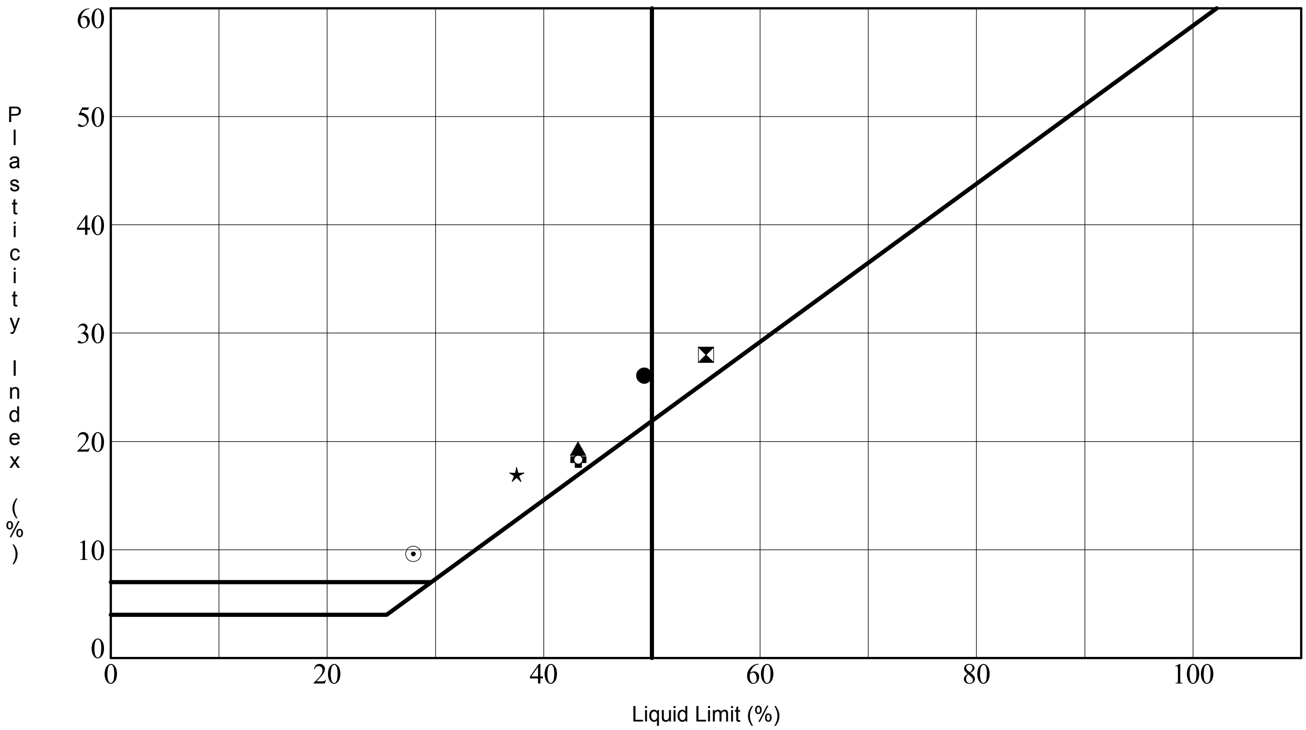

	Specimen Identification		LL	PL	PI	Fines	Classification
●	ST- 1	4.0'-6.0'	49	23	26		
⧗	ST- 2	19.0'-21.0'	55	27	28		
▲	ST- 3	8.0'-10.0'	43	24	19		
★	ST- 6	8.0'-10.0'	38	21	17		
⊙	ST-10	4.0'-6.0'	28	18	10		
✿	ST-11	3.0'-5.0'	43	25	18		

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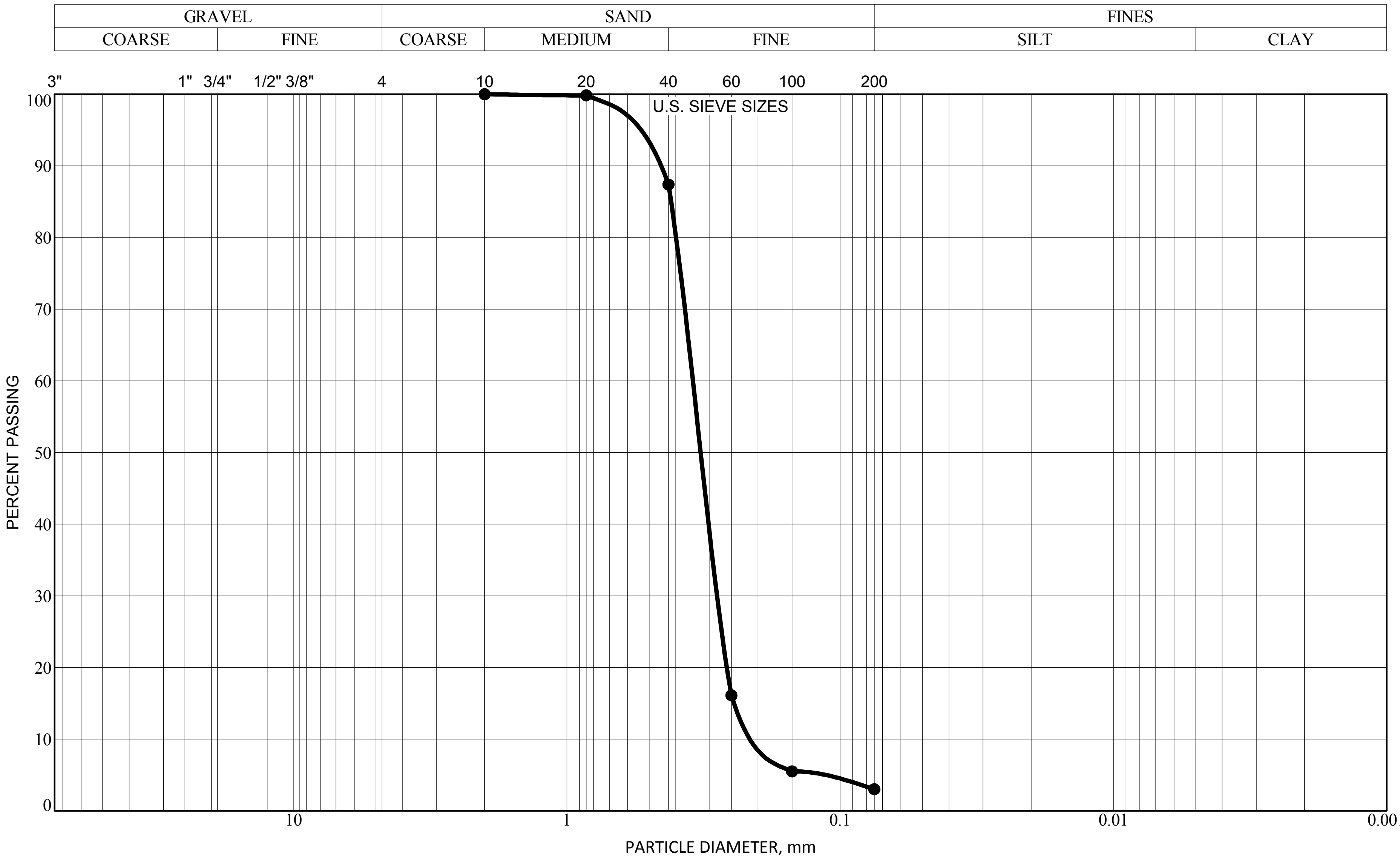
Houston Levee Certification
Root River Basin
Houston, MN

ATTERBERG LIMITS RESULTS

BRAUN INTERTEC

GRAIN SIZE ACCUMULATION CURVE (ASTM)



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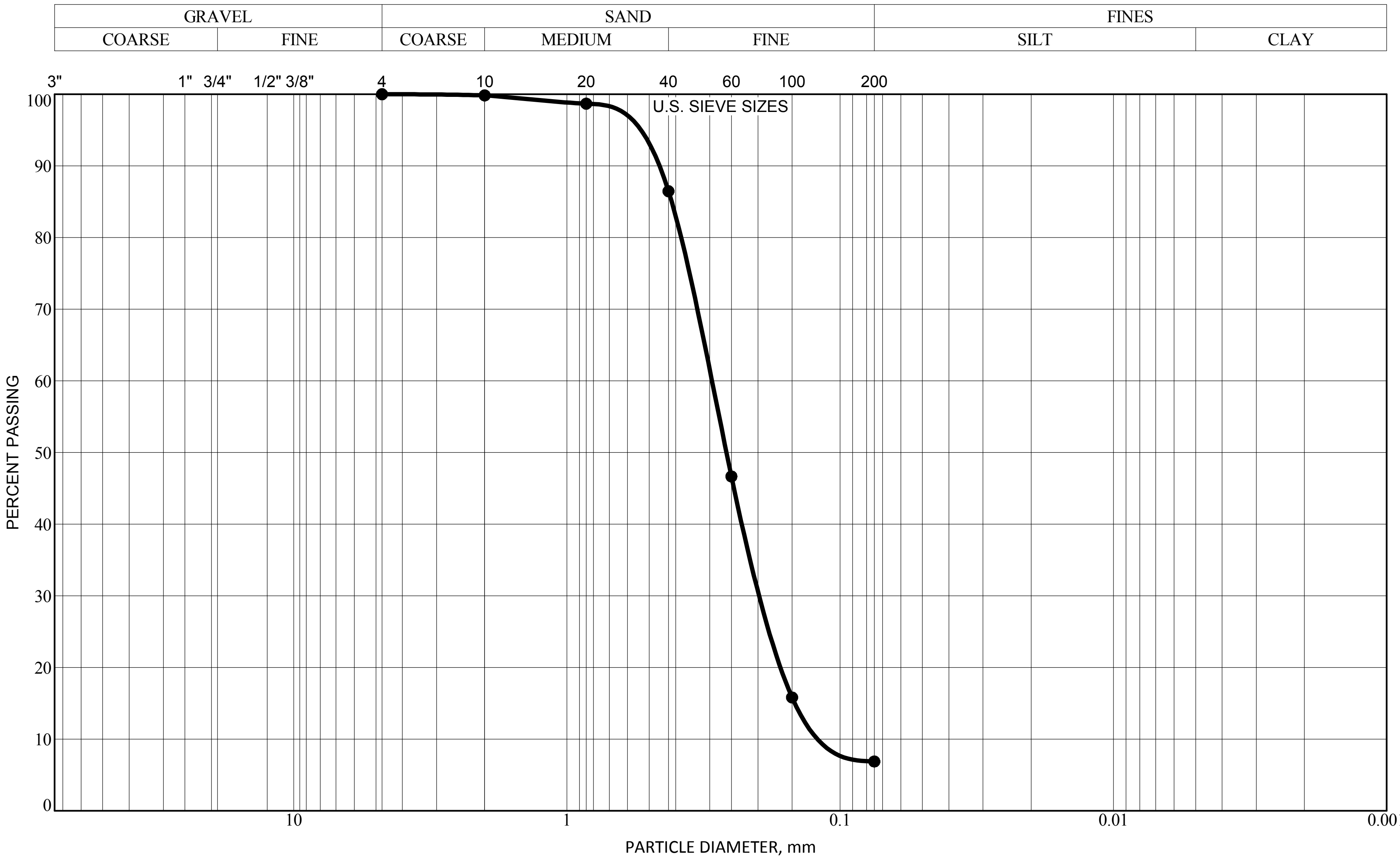
Braun Project B1506754
Houston Levee Certification
Root River Basin
Houston, MN

BORING: ST- 4 DEPTH: 5.0'-6.0'

GRAVEL	0.0%
SAND	97.0%
FINES	3.0%
D60=0.347 D30=0.277 D10=0.186	Cu=1.9 Cc=1.2

CLASSIFICATION:
POORLY GRADED SAND(SP)

GRAIN SIZE ACCUMULATION CURVE (ASTM)



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Houston Levee Certification
Root River Basin
Houston, MN

BORING: ST- 8 DEPTH: 8.0'-15.0'

GRAVEL	0.0%
SAND	93.1%
FINES	6.9%

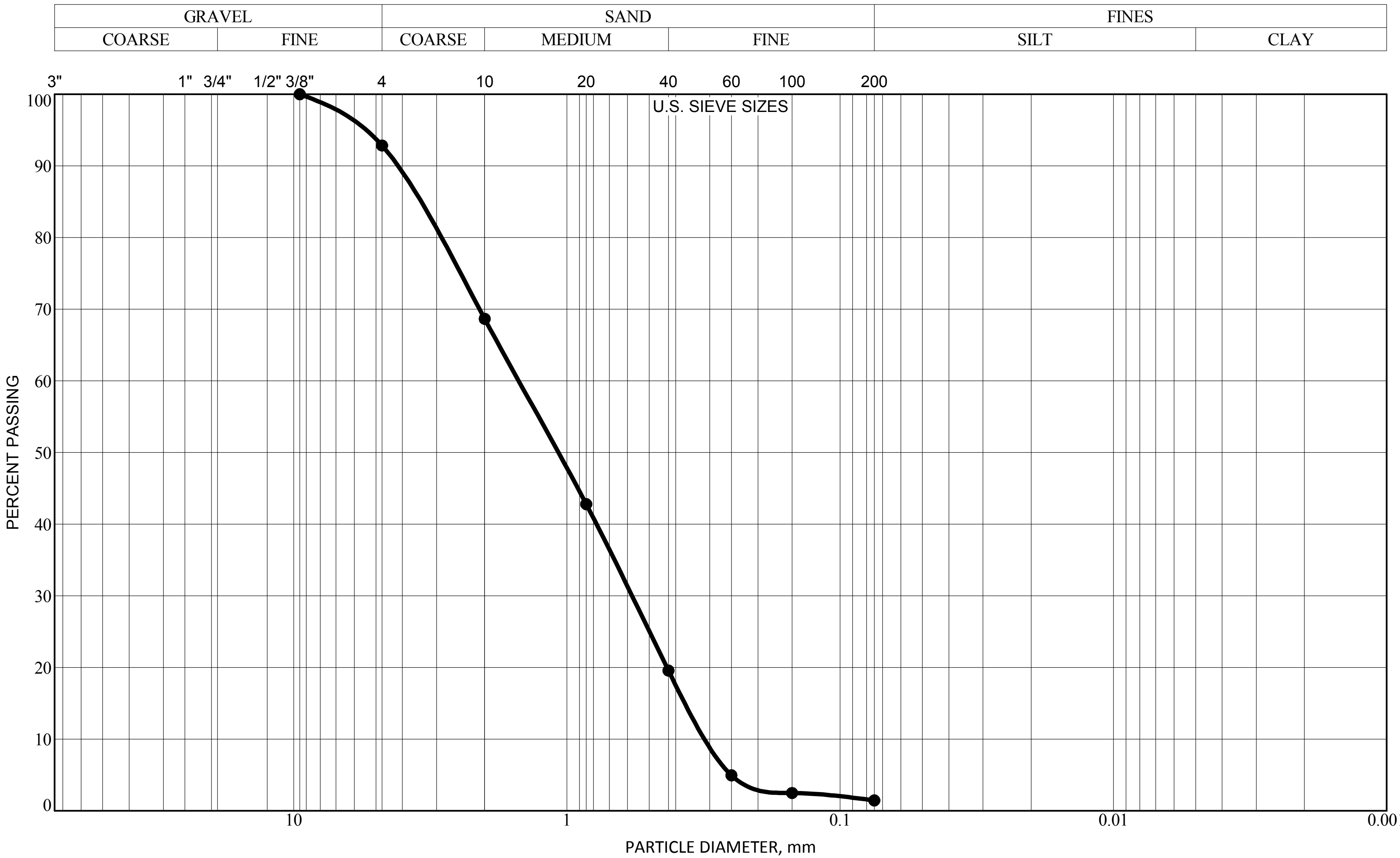
D60=0.299
D30=0.190
D10=0.096

Cu=3.1
Cc=1.3

CLASSIFICATION:
POORLY GRADED SAND with SILT(SP-SM)

BRAUN INTERTEC

GRAIN SIZE ACCUMULATION CURVE (ASTM)



BRAUN[SM] INTERTEC

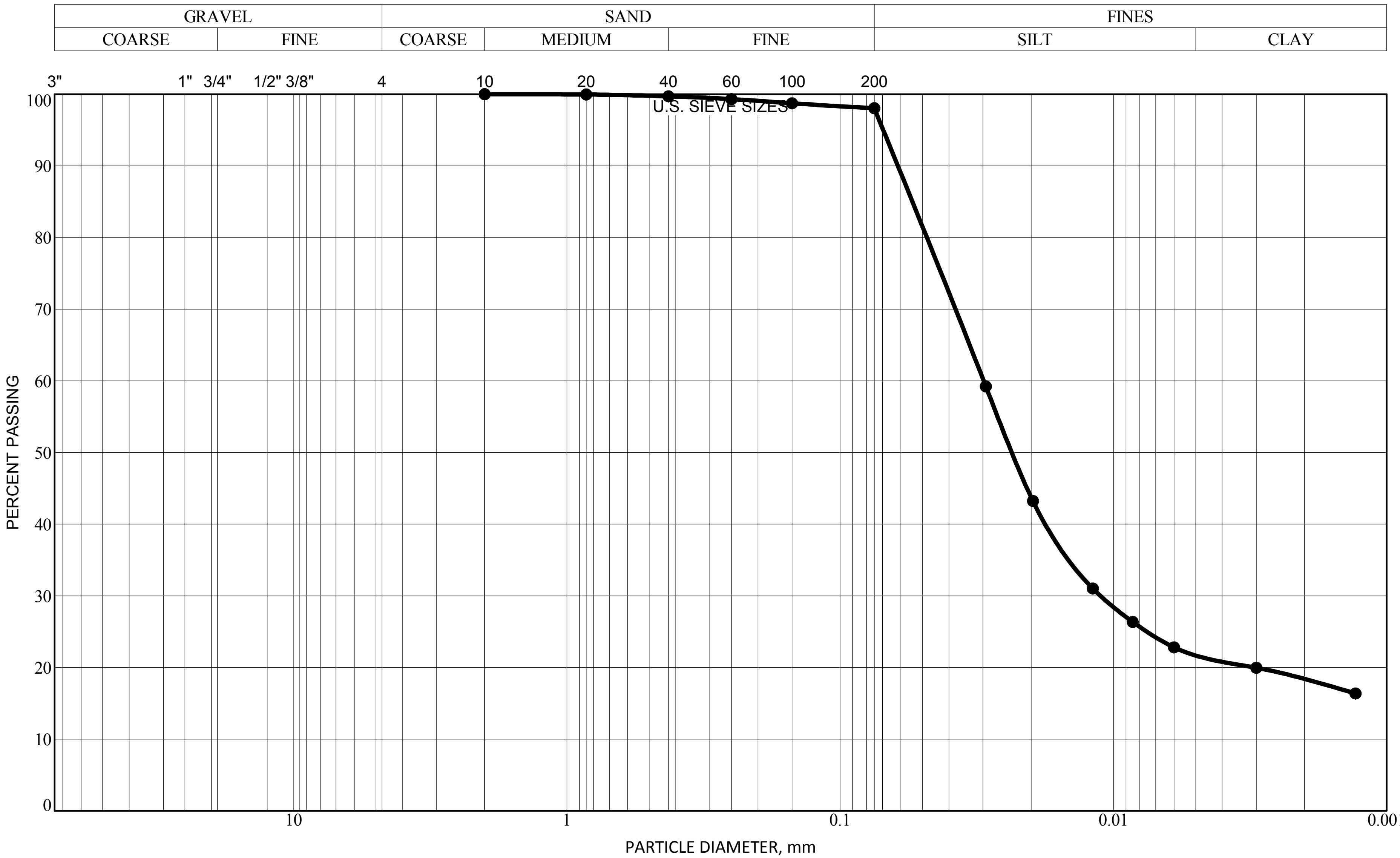
Braun Project B1506754
Houston Levee Certification
Root River Basin
Houston, MN

BORING: ST- 8 DEPTH: 25.0'-30.0'

GRAVEL	7.2%
SAND	91.4%
FINES	1.4%
D60=1.502	Cu=5.0
D30=0.580	Cc=0.7
D10=0.300	

CLASSIFICATION:
POORLY GRADED SAND(SP)

GRAIN SIZE ACCUMULATION CURVE (ASTM)



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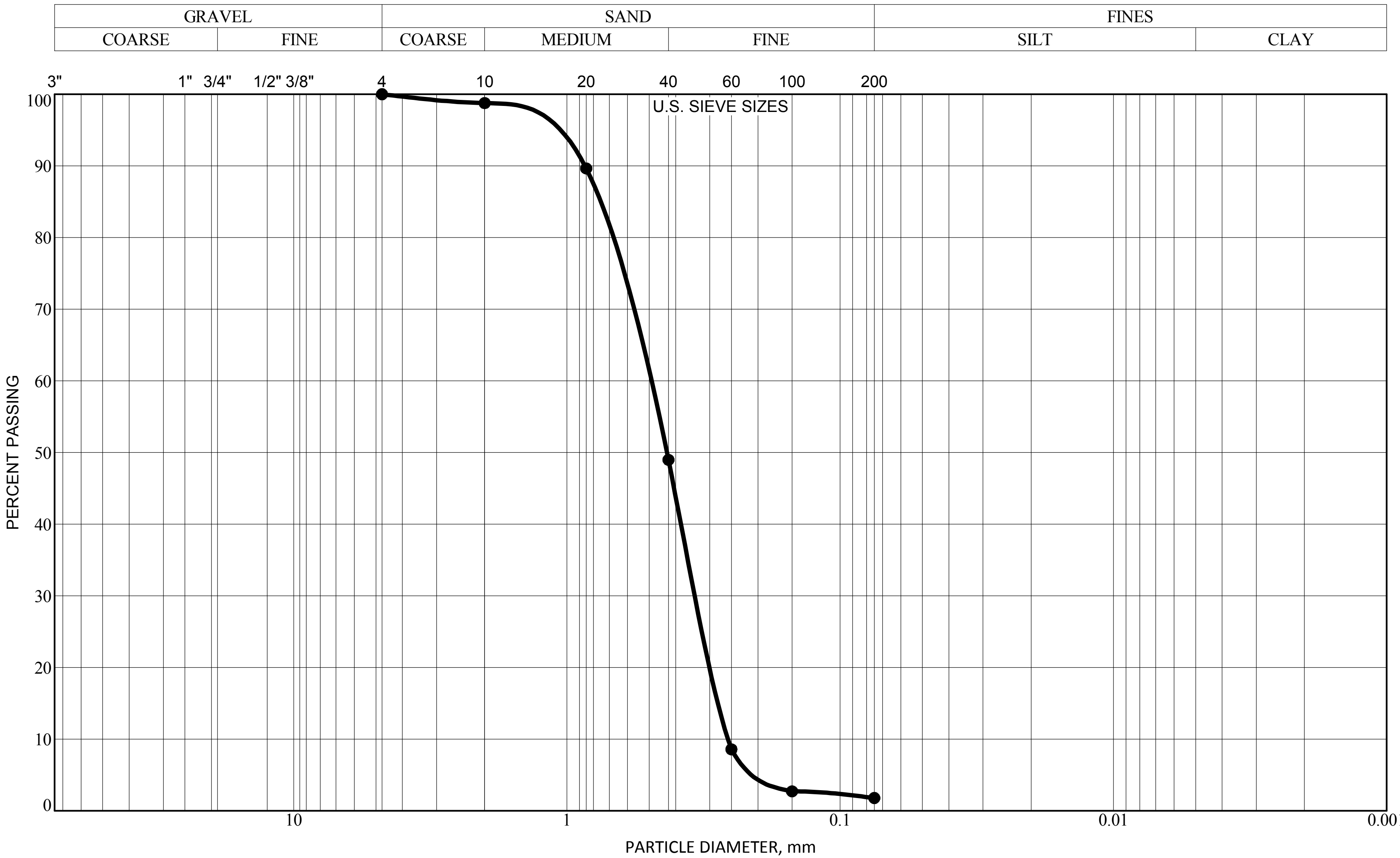
Houston Levee Certification
Root River Basin
Houston, MN

BORING: ST-14 DEPTH: 4.0'-6.0'

GRAVEL	0.0%
SAND	2.0%
SILT	76.0%
CLAY	22.1%
D60=0.030	Cu=
D30=0.011	Cc=
D10=	

CLASSIFICATION:
SILT (ML)

GRAIN SIZE ACCUMULATION CURVE (ASTM)



BRAUN INTERTEC

Braun Project B1506754
Houston Levee Certification
Root River Basin
Houston, MN

BORING: ST-14 DEPTH: 20.0'

GRAVEL	0.0%
SAND	98.2%
FINES	1.8%
D60=0.513	Cu=2.0
D30=0.331	Cc=0.8
D10=0.255	

CLASSIFICATION:
POORLY GRADED SAND(SP)

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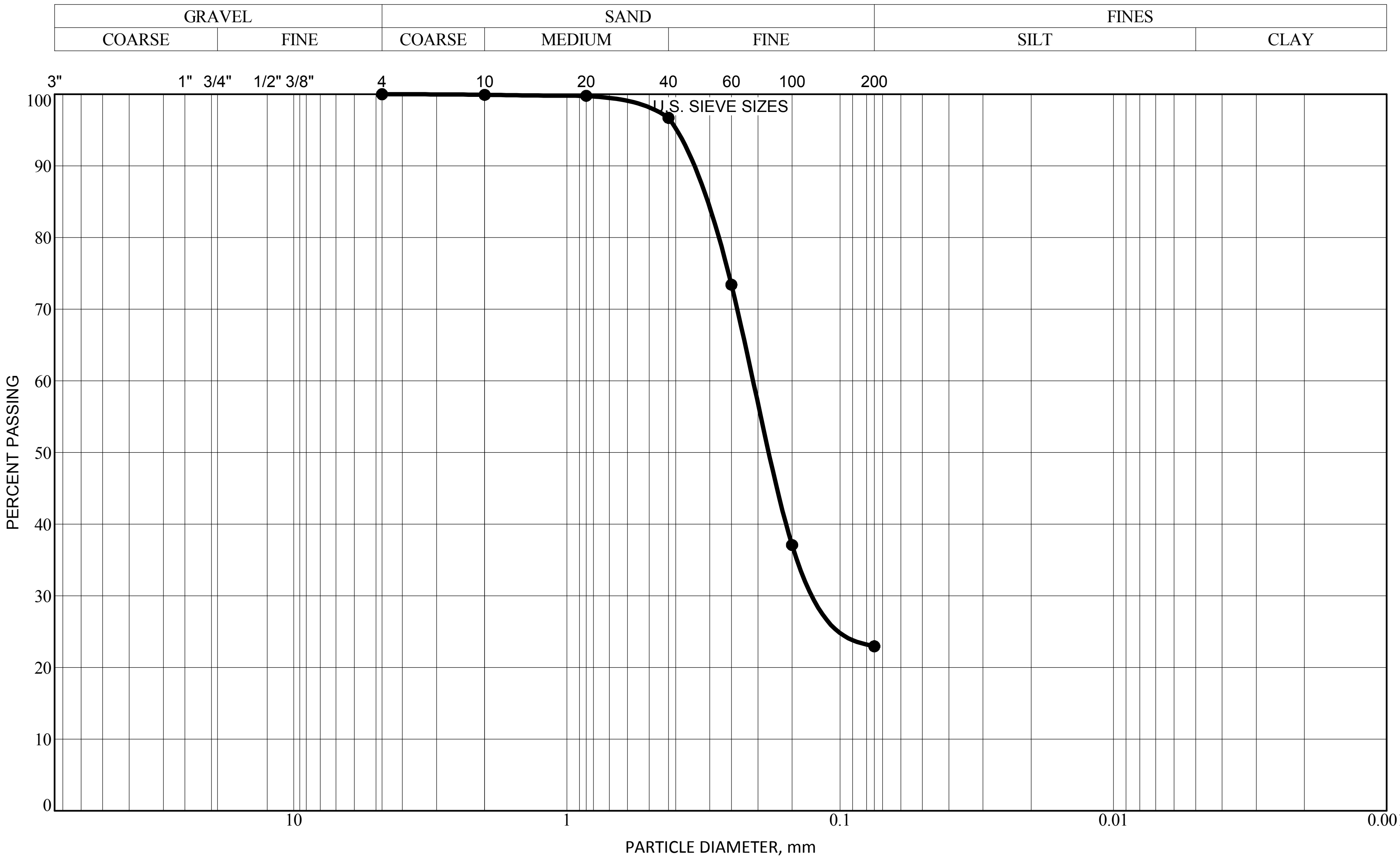
GRAIN SIZE ACCUMULATION CURVE (ASTM)



Braun Project B1506754 **Houston Levee Certification** **Root River Basin** **Houston, MN** BORING: ST-21 DEPTH: 8.0'-10.0'	GRAVEL 0.0% SAND 77.0% FINES 23.0% D60=0.207 D30=0.106 D10=	Cu= Cc=	CLASSIFICATION: CLAYEY SAND (SC)

BRAUN[SM] INTERTEC

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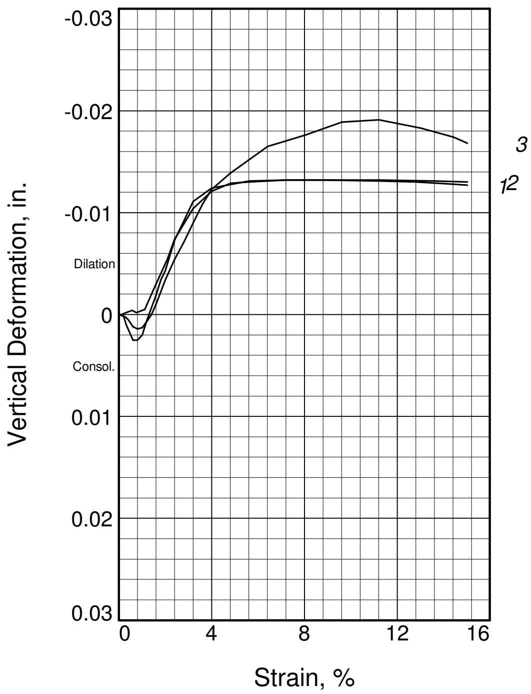
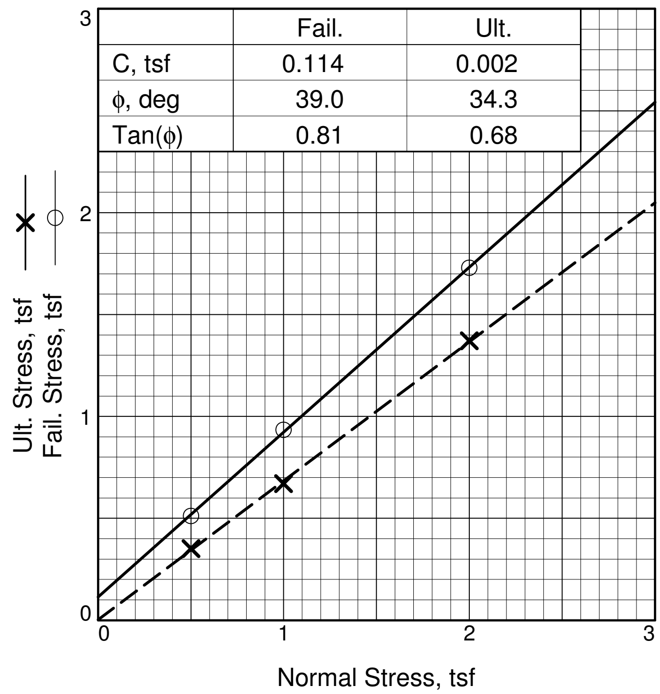
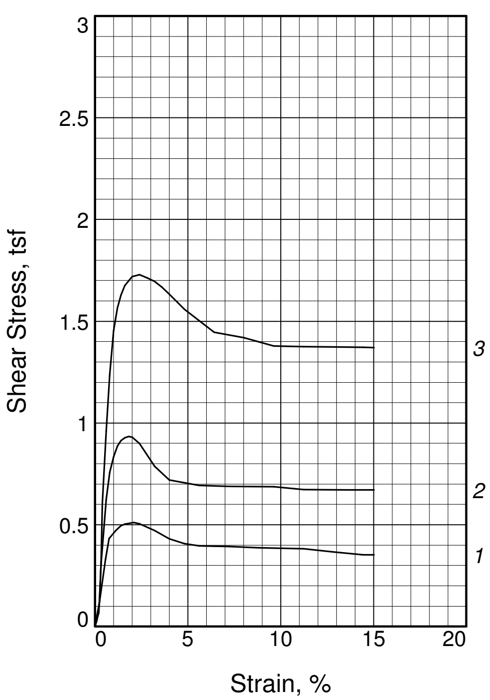




	Fail.	Ult.
C, tsf	0.114	0.002
ϕ, deg	39.0	34.3
Tan(ϕ)	0.81	0.68



	Sample No.	1	2	3
Initial	Water Content, %	4.0	3.7	3.7
	Dry Density, pcf	104.7	109.1	107.7
	Saturation, %	17.7	18.4	17.5
	Void Ratio	0.6101	0.5451	0.5657
	Diameter, in.	2.495	2.495	2.495
	Height, in.	1.002	0.992	0.981
At Test	Water Content, %	3.6	3.6	3.3
	Dry Density, pcf	107.3	112.0	110.0
	Saturation, %	17.0	19.3	17.0
	Void Ratio	0.5713	0.5046	0.5317
	Diameter, in.	2.495	2.495	2.495
	Height, in.	0.978	0.966	0.960
	Normal Stress, tsf	0.500	1.000	2.000
	Fail. Stress, tsf	0.511	0.934	1.729
	Strain, %	2.1	1.8	2.4
	Ult. Stress, tsf	0.352	0.671	1.371
	Strain, %	15.0	15.0	15.0
	Strain rate, %/min.	1.00	1.00	1.00

Sample Type: Remold

Description: POORLY GRADED SAND, brown (SP)

Assumed Specific Gravity= 2.70

Remarks: Direct Shear ASTM D 3080

Client: City of Houston

Project: Houston Levee Certification
Root River Basin, Houston, MN

Sample Number: ST-8 **Depth:** 8-15'

Proj. No.: B1506754 **Date Sampled:**

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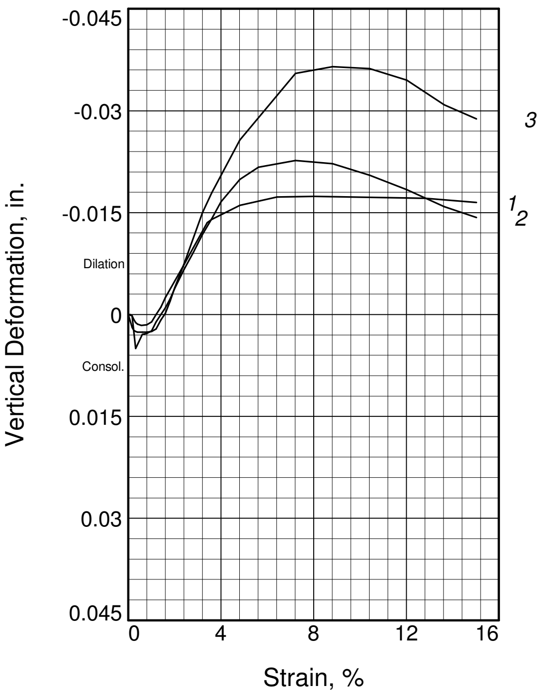
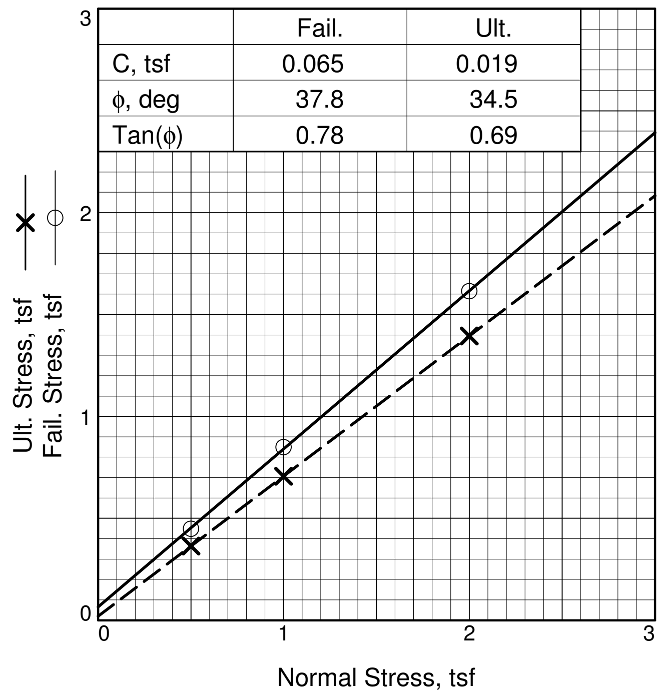
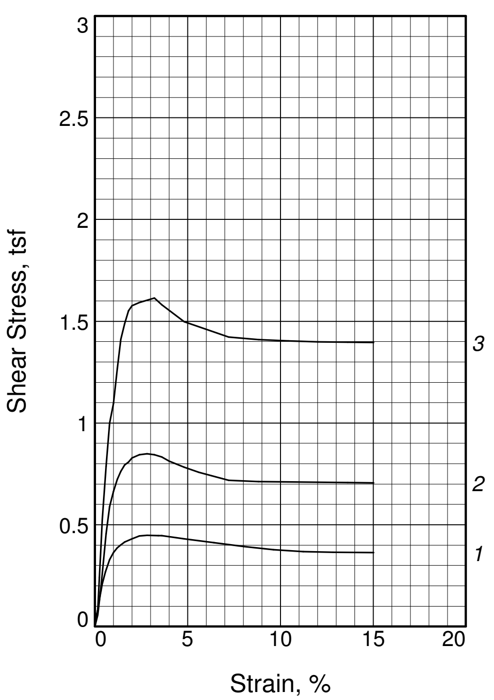
Figure 1





	Fail.	Ult.
C, tsf	0.065	0.019
ϕ, deg	37.8	34.5
Tan(ϕ)	0.78	0.69



	Sample No.	1	2	3
Initial	Water Content, %	4.0	4.2	4.2
	Dry Density, pcf	113.3	116.1	114.3
	Saturation, %	22.1	25.1	23.9
	Void Ratio	0.4877	0.4516	0.4742
	Diameter, in.	2.495	2.495	2.495
	Height, in.	1.040	1.000	1.040
At Test	Water Content, %	17.2	15.6	16.3
	Dry Density, pcf	114.5	117.4	116.7
	Saturation, %	98.2	96.7	99.1
	Void Ratio	0.4726	0.4360	0.4439
	Diameter, in.	2.495	2.495	2.495
	Height, in.	1.029	0.989	1.019
	Normal Stress, tsf	0.500	1.000	2.000
	Fail. Stress, tsf	0.448	0.849	1.614
	Strain, %	2.8	2.8	3.2
	Ult. Stress, tsf	0.364	0.706	1.395
	Strain, %	15.0	15.0	15.0
	Strain rate, %/min.	1.00	1.00	1.00

Sample Type: Remold
Description: POORLY GRADED SAND, brown (SP)

Assumed Specific Gravity= 2.70
Remarks: Direct Shear ASTM D 3080

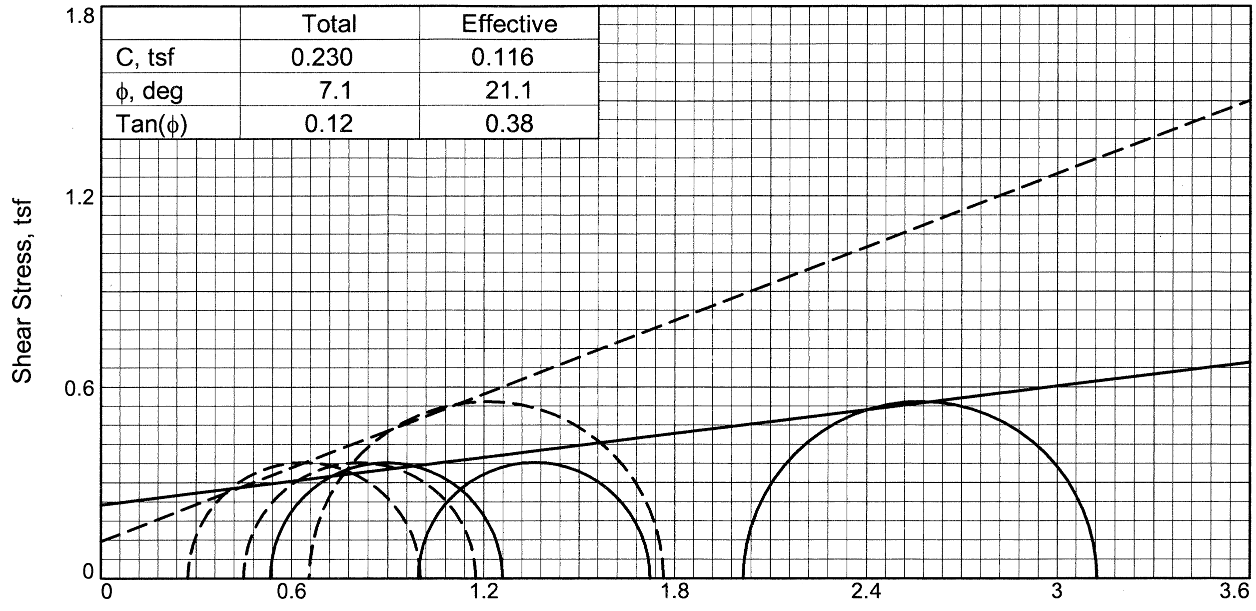
Figure 2

Client: City of Houston

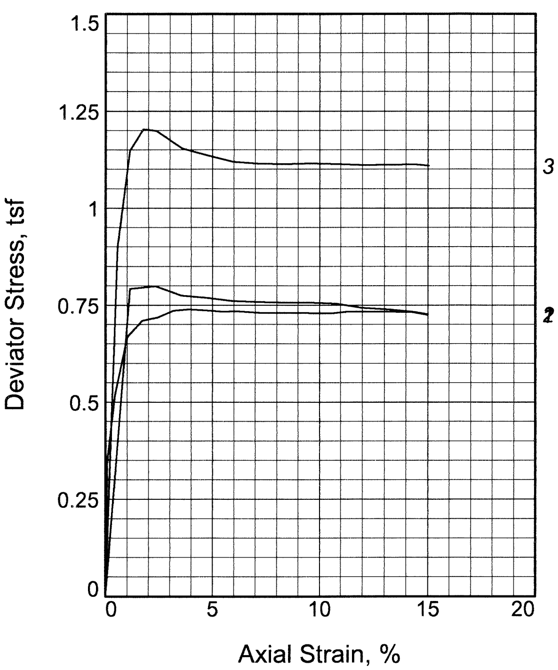
Project: Houston Levee Certification
Root River Basin, Houston, MN
Sample Number: ST-8 **Depth:** 25-30'

Proj. No.: B1506754 **Date Sampled:**

BRAUN INTERTEC



	Total	Effective
C, tsf	0.230	0.116
ϕ, deg	7.1	21.1
Tan(ϕ)	0.12	0.38



	Sample No.	1	2	3
Initial	Water Content, %	30.3	26.4	29.2
	Dry Density, pcf	91.1	90.3	89.6
	Saturation, %	96.1	82.3	89.3
	Void Ratio	0.8499	0.8672	0.8815
	Diameter, in.	1.406	1.388	1.432
	Height, in.	2.794	2.791	2.773
At Test	Water Content, %	30.7	31.0	31.1
	Dry Density, pcf	92.1	91.7	91.6
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.8301	0.8372	0.8409
	Diameter, in.	1.401	1.381	1.422
	Height, in.	2.784	2.776	2.753
	Pore Pressure Parameter B	1.0	1.0	1.0
	Consolidation Pressure, tsf	0.53	1.00	2.02
	Back Pressure, tsf	6.60	6.13	5.11
	Cell Pressure, tsf	7.13	7.13	7.13
	Peak Deviator Stress, tsf	0.74	0.80	1.20
	Total Pore Pr., tsf	6.70	6.74	6.22
	Ultimate Deviator Stress, tsf	0.73	0.73	1.11
	Total Pore Pr., tsf	6.68	6.85	6.47
	Maj. Eff. Stress at Ultimate, tsf	1.17	1.00	1.77
	Min. Eff. Stress at Ultimate, tsf	0.45	0.27	0.66

Type of Test:
CU with Pore Pressures

Sample Type: Thinwall

Description: LEAN CLAY, brown (CL)

Assumed Specific Gravity= 2.70

Remarks: Rate of strain is 0.001 in/min. Failure criteria is based on the ultimate stress which occurs at 15% strain. Samples were saturated for 10 days and consolidated for 3 days.

Figure CU Triax ASTM D 4767

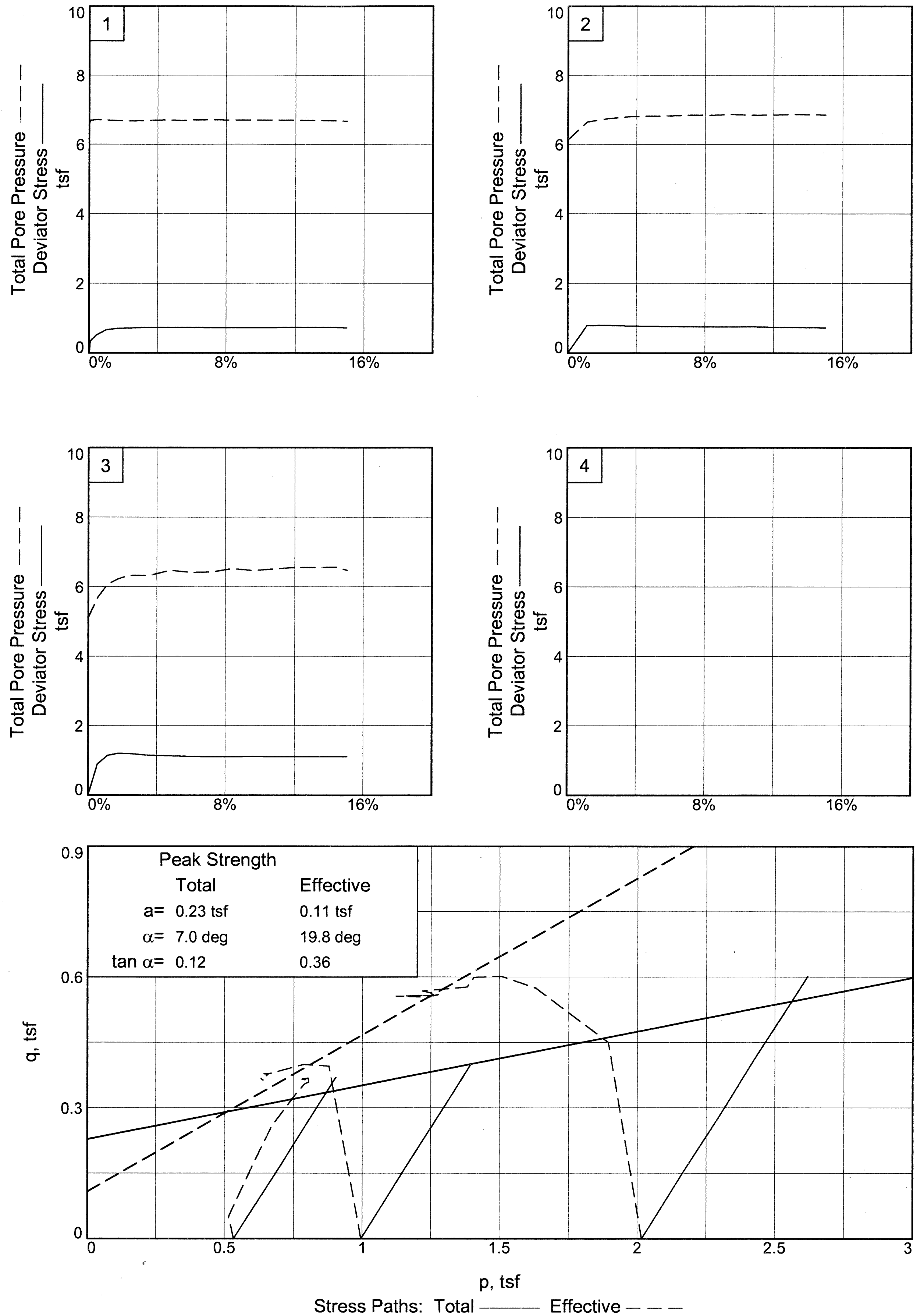
Client: City of Houston

Project: Houston Levee Certification
Root River Basin, Houston, MN

Sample Number: ST-17 **Depth:** 8-10'

Proj. No.: B1506754 **Date Sampled:**

BRAUN INTERTEC



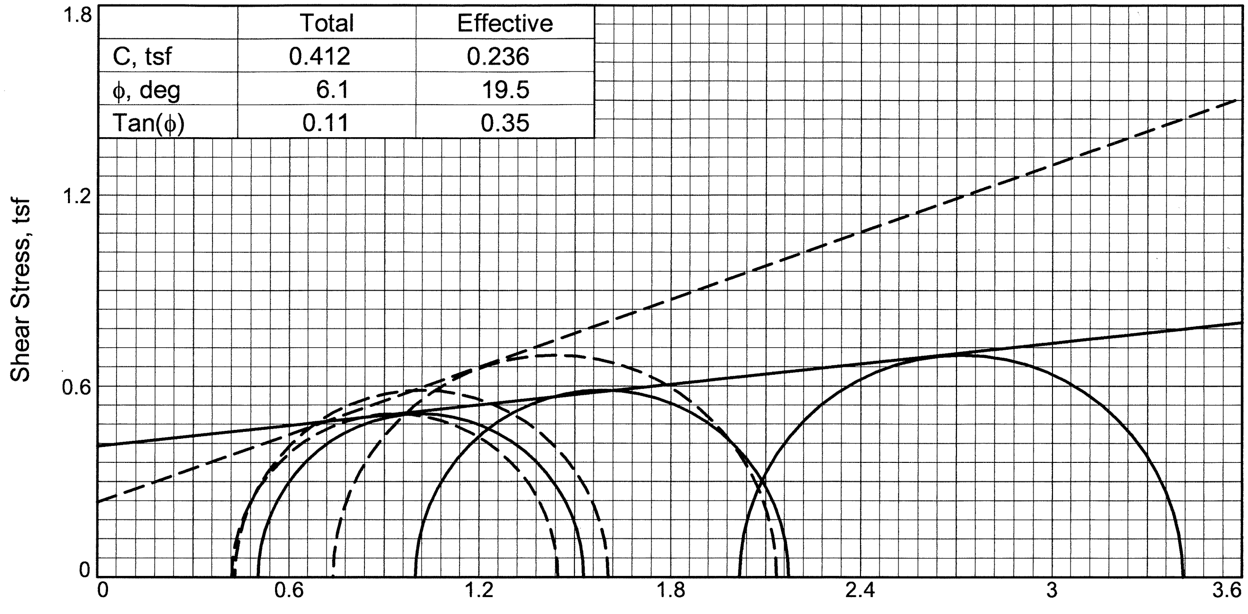
Client: City of Houston

Project: Houston Levee Certification

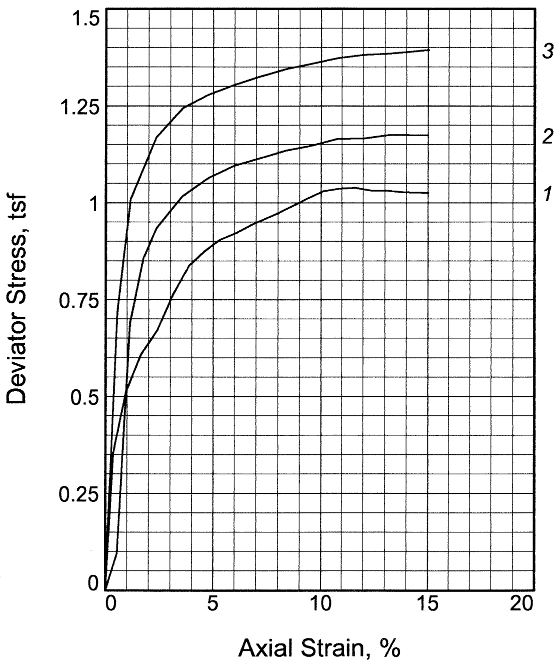
Depth: 8-10' **Sample Number:** ST-17

Project No.: B1506754 **Figure** _______

Braun Intertec



	Total	Effective
C, tsf	0.412	0.236
ϕ, deg	6.1	19.5
Tan(ϕ)	0.11	0.35



	Sample No.	1	2	3
Initial	Water Content, %	45.4	39.3	42.7
	Dry Density, pcf	75.9	82.4	77.6
	Saturation, %	99.1	99.8	96.9
	Void Ratio	1.2612	1.0827	1.2112
	Diameter, in.	1.389	1.390	1.389
	Height, in.	2.783	2.786	2.793
At Test	Water Content, %	45.0	38.2	42.3
	Dry Density, pcf	76.7	83.8	79.3
	Saturation, %	100.0	100.0	100.0
	Void Ratio	1.2369	1.0492	1.1639
	Diameter, in.	1.384	1.382	1.379
	Height, in.	2.773	2.771	2.773
	Pore Pressure Parameter B	1.0	1.0	1.0
	Consolidation Pressure, tsf	0.51	1.00	2.02
	Back Pressure, tsf	6.64	6.13	5.11
	Cell Pressure, tsf	7.15	7.13	7.13
	Peak Deviator Stress, tsf	1.04	1.17	1.39
	Total Pore Pr., tsf	6.75	6.71	6.39
	Ultimate Deviator Stress, tsf	1.03	1.17	1.39
	Total Pore Pr., tsf	6.73	6.70	6.39
	Maj. Eff. Stress at Ultimate, tsf	1.45	1.61	2.13
	Min. Eff. Stress at Ultimate, tsf	0.42	0.43	0.74

Type of Test:
CU with Pore Pressures

Sample Type: Thinwall

Description: ORGANIC CLAY, dark brown (OL)

Assumed Specific Gravity= 2.75

Remarks: Rate of strain is 0.001 in/min. Failure criteria is based on the ultimate stress which occurs at 15% strain. Samples were saturated for 10 days and consolidated for 3 days.

Figure CU Triax ASTM D 4767

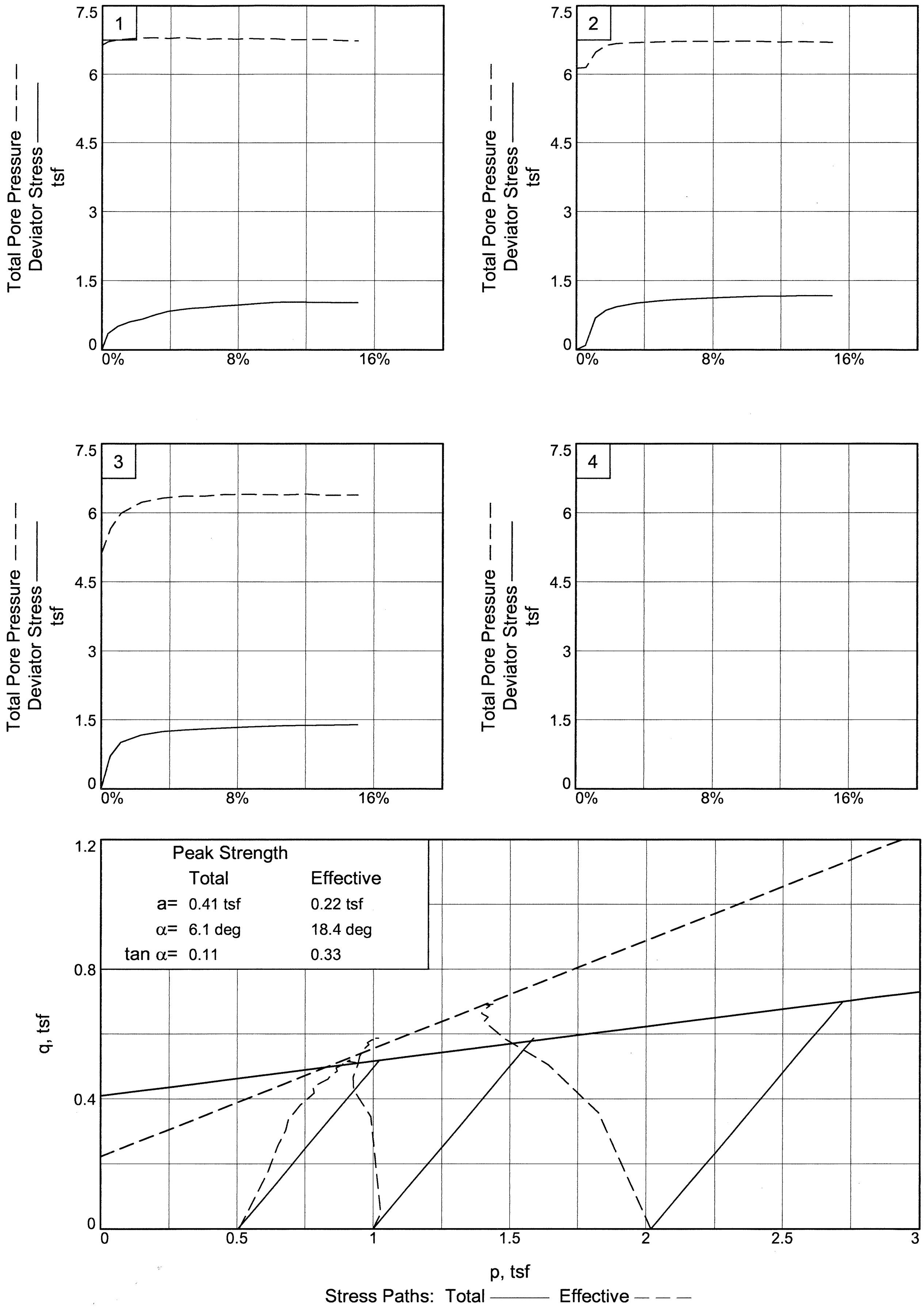
Client: City of Houston

Project: Houston Levee Certification
Root River Basin, Houston, MN

Sample Number: ST-3 **Depth:** 8-10'

Proj. No.: B1506754 **Date Sampled:**

BRAUN℠ INTERTEC



Client: City of Houston

Project: Houston Levee Certification

Depth: 8-10' **Sample Number:** ST-3

Project No.: B1506754 **Figure** ______

Braun Intertec

Braun Intertec Corporation
11001 Hampshire Avenue South
Minneapolis, MN 55438
Phone: 952.995.2000

Material Test Report

Report No: MAT:W15-008027-S1
Issue No: 2

Client: Christina Peterson
City of Houston
PO Box 667
Houston, MN, 55943
Project: B1506754
Houston Levee Certification
Root River Basin
Houston, MN, 55943
TR: Nicole Carlson, ncarlson@braunintertec.com

Laboratory Results Reviewed by:

Jim Streier
Geotechnical Laboratory
Date of Issue: 9/29/2015

Sample Details

Sample ID: W15-008027-S1
Alternate Sample ID:
Sampled By: Drill Crew
Sampling Method: Soil Boring Shelby Tube
Date Sampled:
Date Submitted:
Specification:
Source:
Material Type: Organic Clay
Sample Location: ST-1, 4-6'

Other Test Results

Description	Method	Result	Limits
Temperature (ºC)	ASTM D 5084 - 03	22.0	
Cell Pressure (lb/in²)		99.0	
Top Pressure (lb/in²)		91.0	
Bottom Pressure (lb/in²)		94.0	
Effective Pressure (lb/in²)		5.0	
Pressure Differential (lb/in²)		3.0	
Permeant		De-aired tap water	
Assumed Specific Gravity		2.750	
Initial Sample Height (in)		2.792	
Final Sample Height (in)		2.792	
Initial Sample Diameter (in)		1.392	
Final Sample Diameter (in)		1.392	
Initial Sample Cross-Section Area (in²)		1.522	
Final Sample Cross-Section Area (in²)		1.522	
Initial Sample Volume (in³)		4.249	
Final Sample Volume (in³)		4.249	
Initial Sample Mass (g)		89.80	
Final Sample Mass (g)		89.80	
Initial Dry Density (lb/ft³)		80.5	
Final Dry Density (lb/ft³)		80.5	
Initial Moisture Content (%)		39.1	
Final Moisture Content (%)		40.3	
Initial Saturation (%)		97	
Final Saturation (%)		100	
Initial Hydraulic Gradient		27.4	
Ending Hydraulic Gradient		28.4	
Hydraulic Conductivity (cm/s)		2.93E-08	
Corrected Hydraulic Conductivity (cm/s)		2.79E-08	
Date Tested		9/16/2015	

Particle Size Distribution

Method:
Drying by:
Date Tested:

Sieve Size	% Passing	Limits

Chart

Comments

N/A

BRAUN INTERTEC

Braun Intertec Corporation
11001 Hampshire Avenue South
Minneapolis, MN 55438
Phone: 952.995.2000

Material Test Report

Report No: MAT:W15-008027-S2
Issue No: 2

Client: Christina Peterson
City of Houston
PO Box 667
Houston, MN, 55943
Project: B1506754
Houston Levee Certification
Root River Basin
Houston, MN, 55943
TR: Nicole Carlson, ncarlson@braunintertec.com

Laboratory Results Reviewed by:

ISO/IEC 17025

Jim Streier
Geotechnical Laboratory
Date of Issue: 9/29/2015

Sample Details

Sample ID: W15-008027-S2
Alternate Sample ID:
Sampled By: Drill Crew
Sampling Method: Soil Boring Shelby Tube
Date Sampled:
Date Submitted:
Specification:
Source:
Material Type: Organic Clay
Sample Location: ST-6, 8-10'

Other Test Results

Description	Method	Result	Limits
Temperature (ºC)	ASTM D 5084 - 03	22.0	
Cell Pressure (lb/in²)		99.0	
Top Pressure (lb/in²)		91.0	
Bottom Pressure (lb/in²)		94.0	
Effective Pressure (lb/in²)		5.0	
Pressure Differential (lb/in²)		3.0	
Permeant		De-aired tap water	
Assumed Specific Gravity		2.810	
Initial Sample Height (in)		2.795	
Final Sample Height (in)		2.795	
Initial Sample Diameter (in)		1.388	
Final Sample Diameter (in)		1.388	
Initial Sample Cross-Section Area (in²)		1.513	
Final Sample Cross-Section Area (in²)		1.513	
Initial Sample Volume (in³)		4.229	
Final Sample Volume (in³)		4.229	
Initial Sample Mass (g)		103.1	
Final Sample Mass (g)		103.1	
Initial Dry Density (lb/ft³)		92.8	
Final Dry Density (lb/ft³)		92.8	
Initial Moisture Content (%)		31.6	
Final Moisture Content (%)		31.6	
Initial Saturation (%)		100	
Final Saturation (%)		100	
Initial Hydraulic Gradient		30.1	
Ending Hydraulic Gradient		31.3	
Hydraulic Conductivity (cm/s)		7.09E-08	
Corrected Hydraulic Conductivity (cm/s)		6.76E-08	
Date Tested		9/16/2015	

Particle Size Distribution

Method:
Drying by:
Date Tested:

Sieve Size	% Passing	Limits

Chart

Comments

N/A

BRAUN INTERTEC

Braun Intertec Corporation
11001 Hampshire Avenue South
Minneapolis, MN 55438
Phone: 952.995.2000

Material Test Report

Report No: MAT:W15-008027-S3
Issue No: 1

Client: Christina Peterson
City of Houston
PO Box 667
Houston, MN, 55943

Project: B1506754
Houston Levee Certification
Root River Basin
Houston, MN, 55943

TR: Nicole Carlson, ncarlson@braunintertec.com

Laboratory Results Reviewed by:

ISO/IEC 17025

Jim Streier
Geotechnical Laboratory
Date of Issue: 9/16/2015

Sample Details

Sample ID: W15-008027-S3
Alternate Sample ID:
Sampled By: Drill Crew
Sampling Method: Soil Boring Shelby Tube
Date Sampled:
Date Submitted:
Specification:
Source: Native
Material Type: Lean Clay
Sample Location: ST-17, 8-10'

Other Test Results

Description	Method	Result	Limits
Temperature (ºC)	ASTM D 5084 - 03	22.0	
Cell Pressure (lb/in²)		99.0	
Top Pressure (lb/in²)		91.0	
Bottom Pressure (lb/in²)		94.0	
Effective Pressure (lb/in²)		5.0	
Pressure Differential (lb/in²)		3.0	
Permeant		De-aired tap water	
Initial Sample Height (in)		2.794	
Final Sample Height (in)		2.794	
Initial Sample Diameter (in)		1.406	
Final Sample Diameter (in)		1.406	
Initial Sample Cross-Section Area (in²)		1.553	
Final Sample Cross-Section Area (in²)		1.553	
Initial Sample Volume (in³)		4.338	
Final Sample Volume (in³)		4.338	
Initial Sample Mass (g)		103.7	
Final Sample Mass (g)		103.7	
Initial Dry Density (lb/ft³)		91.1	
Final Dry Density (lb/ft³)		91.1	
Initial Moisture Content (%)		30.3	
Final Moisture Content (%)		31.3	
Initial Saturation (%)		96	
Final Saturation (%)		100	
Initial Hydraulic Gradient		40.1	
Ending Hydraulic Gradient		30.7	
Hydraulic Conductivity (cm/s)		9.59E-07	
Corrected Hydraulic Conductivity (cm/s)		9.14E-07	
Date Tested		9/16/2015	

Particle Size Distribution

Method:
Drying by:
Date Tested:

Sieve Size	% Passing	Limits

Chart

Comments

N/A

Appendix C – Engineer’s Estimates

HOUSTON LEVEE CERTIFICATION - PHASE II

RAISE LEVEE TO MEET FREEBOARD

RAISE LEVEE STA. 62+60 TO STA. 64+00 6-INCHES
RAISE LEVEE STA. 71+75 TO STA. 114+00 6-INCHES

ENGINEER'S ESTIMATE

ITEM	UNIT	QUANT.	UNIT PRICE	ESTIMATED COST
MOBILIZATION	LS	1	$ 2,000.00	$ 2,000.00
EROSION CONTROL	LS	1	1,000.00	1,000.00
CL. 1 AGGREGATE BASE	TON	1800	15.00	27,000.00
RESTORATION	LS	1	2,500.00	2,500.00
	SUBTOTAL			$ 32,500.00
	35% CONTINGENCIES			11,380.00
	15% PLANNING			4,880.00
	10% ADMIN			3,250.00
	TOTAL			$ 52,010.00

LEVEE STA. 118+00 TO STA. 121+00 RAISE BITUMINOUS 6-INCHES

ITEM	UNIT	QUANTITY	UNIT PRICE	ESTIMATED COST
MOBILIZATION	LS	1	$ 3,000.00	$ 3,000.00
TRAFFIC CONTROL	LS	1	1,000.00	1,000.00
EROSION CONTROL	LS	1	1,000.00	1,000.00
MILL BITUMINOUS SURFACE (1.0")	SY	800	2.00	1,600.00
BITUMINOUS BASE COURSE, 4-INCHES	TON	200	60.00	12,000.00
BITUMINOUS WEARING COURSE, 2-INCHES	TON	100	65.00	6,500.00
BITUMINOUS TACK COAT	GAL	40	5.00	200.00
SHOULDER BASE AGGREGATE (CV) CI	CY	100	30.00	3,000.00
STRIPING	LS	1	6,000.00	6,000.00
RESTORATION	LS	1	1,500.00	1,500.00
	SUBTOTAL			$ 35,800.00
	35% CONTINGENCIES			12,530.00
	15% PLANNING			5,370.00
	10% ADMIN			3,580.00
	TOTAL			$ 57,280.00