HAMMOND
LEVEE SYSTEM
Little Calumet River

EMERGENCY FLOOD PROTECTION HANDBOOK

US Army Corps of Engineers®

U. S. Army Corps of Engineers
Chicago District
231 South LaSalle Street
Suite 1500
Chicago, Illinois 60604

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PROJECT SUMMARY

LOCATION

RIVER: LITTLE CALUMET RIVER
SIDE OF RIVER: NORTH BANK
STATE: INDIANA
CITY: HAMMOND
WEST END: LYMAN AVE
EAST END: CANADIAN NATIONAL RAILWAY

PROJECT DETAILS

LENGTH OF LEVEE (ft):	**17,425**
LENGTH OF FLOODWALL (ft):	**13,200**
GATE STRUCTURES:	**45**
PUMP STATIONS:	**9**

-JACKSON AVE (152,000 gpm)
-TAPPER AVE (16,400 gpm)
-SOUTHSIDE (210,000 gpm)
-WALNUT AVE (117,800 gpm)
-CABELA'S (15,892 gpm)
-INDIANAPOLIS BLVD (182,000 gpm)
-SOUTH KENNEDY (57,370 gpm)
-KENNEDY APTS (15,000 gpm)
-SOUTHEAST HESSVILLE (110,500 gpm)

STREET CLOSURES: **4**

-CALUMET AVE (599.2 NAVD88)
-NORTHCOTE AVE (598.6 NAVD88)
-RAILROAD (602.0 NAVD88)
-KENNEDY AVE (598.9 NAVD88)

OVERFLOW SECTION: **4**

-RIVERSIDE PARK
-CABELA'S
-KENNEDY/CLINE AVENUE (NORTH)
-INTERSTATE PLAZA

LEVEED AREA (acres): **2,500**

CONTACT INFORMATION

LEVEE OWNER:

LITTLE CALUMET RIVER BASIN DEVELOPMENT COMMISSION (LCRBDC)
900 RIDGE ROAD, SUITE H
MUNSTER, INDIANA 46321
PHONE NUMBER: (219) 595-0599

US ARMY CORPS OF ENGINEERS DISTRICT OFFICE:

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LOCAL EMERGENCY CONTACTS:

HAMMOND POLICE DEPARTMENT	(219) 853-6490
EMERGENCY MANAGEMENT DIRECTOR	(219) 314-5446
PUBLIC WORKS & SAFETY PRESIDENT	(219) 853-6382

ADDITIONAL CONTACT INFORMATION:

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PROJECT DESCRIPTION

Levees and floodwalls are constructed on both sides of the Little Calumet River to provide flood protection for the communities of Highland, Munster, Hammond, Griffith, and Gary. In addition, the project provides flood protection to a portion of the vital I-80/94 transportation corridor and provides recreation facilities to these communities.

The Little Calumet River Local Flood Protection and Recreation Project in the City of Hammond includes riverbank levees, floodwall, pumping stations, and interior flood control features. Other features consist of recreation facilities, river gages, and miscellaneous other features, bridge/culvert replacements, and utility remediation/relocations.

When flood conditions are anticipated, flood fighting actions are to be performed as indicated in the following sections of this handbook.

INTRODUCTION

As it is often impossible to place well experienced individuals in all supervisory capacities during high water emergencies, this manual has been prepared to serve as a ready reference guide for this levee system. This manual suggests the best methods of providing advance protection during floods, and of effecting emergency repairs efficiently, economically and in the shortest practicable time.

The procedures outlined in this handbook are considered standard. They should, therefore, be followed as closely as possible. It is not intended that personal initiative be destroyed in dealing with unusual emergencies. On the contrary, if danger occurs along a levee, such a scenario demands immediate action using the materials and labor at hand. However, as an emergency is not a time for experimentation, these proven methods should be employed wherever possible.

If the City of Hammond and Lake County anticipate that they will be unable to adequately prepare for or fight a flooding event, will require additional materials for a flood fight, need technical advice or if any damage occurs to the levee system, the U.S. Army Corps of Engineers, Chicago District should be contacted immediately for assistance.

This manual is only a ready reference guide. Additional information is available in the O&M Manuals for each levee segment.

LEVEE PATROLS

When a major rain event is predicted, inspection and maintenance records shall be checked, if possible, to determine if all components of the levee are in proper condition to protect against a flood. Any required maintenance or repairs shall be completed before the start of the flooding, if possible. If time does not permit for repairs prior to the onset of flooding, temporary measures shall be utilized during the flood fight. The levee features shall be inspected when the river is expected to be at or above a 2-year flood level to evaluate the general condition of the levee, floodwalls, and gates.

The Emergency Operations Center (EOC) should be activated and levees patrols shall increase to twice daily when the river reaches or is predicted to be above a 10-year level.

Action	At USGS Gage	At USGS Gage
Warning Levels	**Little Cal @ Munster**	**Little Cal @ Hammond**
Conduct daily levee patrols	11.4	10.6
Activate EOC—Increase levee patrols to 2x per day	13.1	12.6

Table 1. Levee Patrol Action Responses

Patrolling operations should locate potential danger zones to permit prompt actions and correction of any conditions that endanger the integrity of the levee. Implementation of emergency actions shall be done under the direction of local representatives experienced and/or trained in flood fighting activities. Certain levee sections, which should be addressed per special concerns, are listed in Table 2.

The levees and floodwalls shall be patrolled to be certain that:

a. No sand boils or unusual wetness on the protected side of the levee;
b. No indications of cracks or slides developing on the levee;
c. Scour of the levee embankment is not occurring at pump station outfalls and drainage outlets;
d. No low points on the levee exist which may be overtopped, excluding designed overflow sections.
e. No leakage is observed at joints in floodwalls;
f. No movement or tilting observed of the floodwalls;
g. No other conditions exist which might endanger the structure.

ANY ISSUES NOTED SHALL BE IMMEDIATELY REPORTED TO THE EMERGENCY OPERATIONS CENTER.

If an EOC has not been set up, contact the Little Calumet River Basin Commission to report any issues observed.

Table 2: Special Concerns

GENERAL LOCATION	SPECIAL CONCERN(S) OF POTENTIAL ACTION(S) OR KNOWN CONDITION(S)	POTENTIAL RESULTING PROBLEM(S)
Levee/ Floodwall Interfaces	Seepage, Scour or Erosion	Embankment piping, separation of embankment from floodwall
Levee Tie-ins With Road & Railroad Embankments	Seepage	Embankment piping, separation of embankment masses
Closure Structures	Seepage, Movement	Sudden Instability
Utility Pipeline Crossing Beneath Line-of-Protection	Seepage	Foundation soil piping and/ or heave/uplift
Utility Pipeline Crossing Over Line-of-Protection	Wave Wash, Scour, Slope Attack	Embankment erosion
Levee/Outlet Structure Interfaces	Wave Wash, Scour	Embankment erosion
Outlet Structure Crossing Through Line-of-Protection	Seepage	Embankment piping
Culvert/ Discharge Pipes	Seepage	Embankment piping near pipe, differential settlement

Levee Overtopping / Evacuation:

Levee overtopping occurs when flood elevations exceed that of the levee crest; causing floodwater to flow over the levee embankment. It is seldom that an entire levee system is overtopped at once. Prior survey data and Inspections will identify possible low areas. Inspections during a flood will show the low spots where the overtopping will first occur. Regardless of how small a low section may be, the danger from overtopping is critical. Water flowing over a levee crown may wash away material and create a breach in the levee. Once a breach has developed in a levee, it is extremely difficult, if not impossible, to close it until after the flood waters recede. Consequently, overtopping should be prevented as much as possible, without undue risk to flood fighting personnel, for levee reaches not designed as an "overflow section".

Overflow sections were designed for this project to allow for controlled levee overtopping for flood events that exceed the design flood event. **FLOOD FIGHTING PERSONNEL NEED TO BE AWARE OF THE OVERFLOW SECTIONS AND NOT ATTEMPT TO PREVENT OVERTOPPING AT THESE LOCATIONS.** The overflow locations were selected in areas where flooding damages would be minimal and help prevent overtopping

at other locations along the levee. See Figure 2 for the locations of overflow sections. Figure 2 also identifies the area to be evacuated in the event of levee overtopping.

Tables 3, 4, and 5 show the Emergency Action trigger levels based on river stage at the applicable gage. The response level definitions for possible overtopping are:

<u>Alert</u>: This warning level will likely be issued before any imminent threat of overtopping. This puts the local communities on notice that there could be an possible overtopping problem. This level is intended to notify community flood responders that an excavation may be needed if flood conditions worsen, but requires no further action at that time.

<u>Mobilize</u>: Notify all threatened residents of possible levee overtopping, and should prepare for potential evacuation. No evacuation should start at this time.

<u>Evacuate</u>: The decision to issue the Evacuation warning will be given by the appropriate official. The order to evacuate will be circulated to all threatened residents. Residents must also be informed of evacuation routes and the location of shelters for the evacuated residents. Every effort should be made to ensure that the effected residents comply with the evacuation order.

Table 3. Overflow Action Responses

At USGS Gage	Overflows	
Little Cal @ Munster	Evacuation Warning Levels	
feet	Riverside Park	Cabela's
18	Evacuate	Evacuate***
17	Warning	Warning
16	Alert	Alert

****If the control structure is overtopped evacuate Cabela area*

Table 4. Overflow Action Responses

At USGS Gage	Overflows
Little Cal @ Hammond	Evacuation Warning Levels
feet	Industrial Plaza
18	Evacuate
17	Warning
16	Alert

Table 5. Overflow Action Responses

At USGS Gage	Overflows
Little Cal @ Highland	Evacuation Warning Levels
feet	Kennedy/Cline
20	Evacuate
19	Warning
18	Alert

GATE CLOSURES

Numerous pipes of different sizes and types, penetrate under, through and over the levee in many locations. Refer to Figure 3 and 4, and Table 6 for known pipe locations and depths. Gravity drains are of particular concern during a flood event as these can carry flood water to the protected side of the levee. Gravity drains have been fitted with 1 or 2 gates or valves to prevent river water from backing up the pipe and flooding low areas within the protected area of the levee. See Figure 3 and 4 for gatewell, gate, and culvert and information, as well.

Gate inspections must be performed frequently to verify that all flap gates and check valves are operational and are not stuck in an open position. If a flap gate or check valve is malfunctioning, the secondary closure should be implemented to minimize backflow flooding of areas behind the levee. The Levee Patrol must verify that the inlet drainage ditches, the culverts, and trash racks are not blocked. Additionally, the Levee Patrol needs to check that the gatewells for the secondary closure gates are free from debris or excessive sediment deposits, and that the gate closures can be accomplished

If a flap gate or check valve malfunctions at any time during a flood event, crews must be prepared to activate the secondary closure and **REPORT THE SITUATION TO THE EMERGENCY OPERATIONS CENTER.** For culverts through the line-of-protection equipped with only a flap gate or check valve, monitoring must proceed as described for outlets equipped with double closures. In the event flap gate failure is noted during a flood event, the inlet on the riverside must be blocked with sandbags or other inert material so that high river stage waters cannot flood the interior of the levee through the malfunctioning gate/valve. Recommended methods for emergency closure of manhole and gatewell structures are shown in Appendix A, Emergency Flood Fighting Techniques.

Closed sluice gates shall be reported to the Emergency Operations Center and re-opened as soon as possible following the flood so gravity drainage can resume. This will reduce localized ponding and loads on the pump stations after the flood has dissipated.

Electric portable operators for the sluice gates have been provided as part of the project. The electric drill requires an electric generator/power supply. Another type of operator, a gas powered handheld unit, is also available with the LCRBDC however it is less practical than the electric operator. All operators are 2”x2” driven and have 2-1/16” drivers. Portable operators must be available to inspectors and emergency crews in the event of a flap gate or check valve failure. Portable operators must be checked prior to use during a flood event to make certain that they are functional which would include all necessary equipment, fuel, electric cords, and power supplies.

TABLE 6. Pipe Penetrations *(Refer to Figure 3 for locations of pipes)*

ID	P/G	DIA.	MAT.	TYPE	CONNECTION	CLOSURE	INVERT ELEV. (NAVD)
HA-1	G	24	RCP	PRJ - Gravity Outlet	N1-3 North of I-80/94	Check Valve	586.7
HA-U1	G	18	CLAY	UTIL - Combined Sewer	Riverside		581.8
HA-2	G	24	RCP	PRJ - Gravity Outlet	N1-4 South of I-80/94	Check Valve	589.8
HA-3	G	24	RCP	PRJ - Gravity Outlet	N2-1 West of 177th Street	Check Valve	588.7
HA-U2	G	18	CLAY	UTIL - Combined Sewer	Riverside		580.7
HA-4	P	84	RCP	PRJ - Jackson PS	N2-2 Jackson PS	Sluice Gate	590.1
HA-5	G	24	RCP	PRJ - Gravity Outlet	N2-3	Check Valve	589.7
HA-U3	P	18		UTIL - Waterline			588.2
HA-6	G	36	RCP	PRJ - Gravity Outlet	N2-4	Check Valve & Sluice Gate	587.2
HA-7	G	24	RCP	PRJ - Gravity Outlet	N2-5 West of Calumet Ave	Check Valve	588.2
HA-8	G	54	RCP	PRJ - Gravity Outlet	N2-6 West of Calumet Ave	Check Valve & Sluice Gate	588.7
HA-U4	G	14		UTIL - Telephone Duct			587.7
HA-U5	P	12		UTIL - Waterline	Munster		593.55
HA-9	G	24	RCP	PRJ - Gravity Outlet	N3-1 South of Euclid Ave	Check Valve	591.2
HA-10	P	36	RCP	PRJ - Tapper PS	N3-2 Tapper PS Outlet	Sluice Gate	581.9
HA-11	G	24	RCP	PRJ - Gravity Outlet	N3-3 East of Tapper PS	Check Valve	586.7
HA-12	P	84	RCP	PRJ - Southside PS Outlet	N3-4 West of Columbia Ave	Flap Gate & Sluice Gate	585.7
HA-U6	P	12		UTIL - Gasline			592.6

P / G Pressure or gravity line PRJ - Project Feature UTIL - Utility

TABLE 6 (Continued). Pipe Penetrations *(Refer to Figure 3 for locations of pipes)*

ID	P/G	DIA.	MAT.	TYPE	CONNECTION	CLOSURE	INVERT ELEV. (NAVD)
HA-U7	G	30		UTIL - Combined Sewer	Riverside / Munster		574.7
HA-13	G	36	RCP	PRJ - Gravity Outlet	N3-5 West of Columbia Ave	Check Valve & Sluice Gate	588.7
HA-U8	P	16	CIP	UTIL - Waterline			591.2
HA-14	G	30	RCP	PRJ - Gravity Outlet	East Columbia Ave Gatewell	Check Valve & Sluice Gate	589.2
HA-U9	P	14		UTIL - B/P Oil Line			591.5
HA-U10	P	18		UTIL - B/P Oil Line			589.6
HA-U11	P	12		UTIL - B/P Oil Line			590.2
HA-15a	P	48	RCP	PRJ - Walnut PS	Walnut PS Outet	Flap Gate	586.4
HA-15b	P	36	RCP	PRJ - Walnut PS	Walnut PS Outet	Check Valve	586.4
HA-15c	P	60	RCP	PRJ - Walnut PS	Walnut PS Outet	Flap Gate	586.4
HA-16	G	60	RCP	PRJ - Gravity Outlet	Northcote Gated Sluice	Check Valve & Sluice Gate	587.7
HA-U12	G	12		UTIL - AT & T Duct			591.5
HA-U13	G	12		UTIL - Combined Sewer	Riverside / Baring PS		581.4
HA-U14	P	6		UTIL - Gas Line			595.28
HA-U15	P	8		UTIL - Gas Line			596.7
HA-17	P	36	RCP	PRJ - Cabela PS	Cabela Pump Station	Sluice Gate	589.6
HA-18 a-d	P	18	RCP	PRJ - Cabela PS	Cabela Pump Station	Flap Gate	589.6
HA-19	G	24	RCP	PRJ - Gravity Outlet	5-7C West of Indianapolis	Flap Gate	588.9
HA-U16	P	20		UTIL - Sanitary	Force Main		579.7

P / G Pressure or gravity line PRJ - Project Feature UTIL - Utility

TABLE 6 (Continued). Pipe Penetrations *(Refer to Figure 3 for locations of pipes)*

ID	P/G	DIA.	MAT.	TYPE	CONNECTION	CLOSURE	INVERT ELEV. (NAVD)
HA-20	G	48	RCP	PRJ - Gravity Outlet	East of Indian-apolis	Flap Gate & Sluice Gate	589.5
HA-21 a-c	P	96	RCP	PRJ - Indianapo-lis PS	Indianapolis PS Outet	Flap Gate & Sluice Gate	578.7
HA-22	G	24	RCP	PRJ - Gravity Outlet	6-3C	Flap Gate	589.7
HA-23	G	24	RCP	PRJ - Gravity Outlet	6-5C	Flap Gate	591.1
HA-U17 a-o	P			UTIL - Pipeline Corridor	15 Piplines from 8" to 30"		Varies
HA-24	G	24	RCP	PRJ - Gravity Outlet	East of Railroad	Flap Gate & Sluice Gate	590.7
HA-25	G	24	RCP	PRJ - Gravity Outlet	6-7C	Flap Gate	-0.3
HA-U18	G	12		UTIL - Phone Conduit			591.7
HA-26a	G	54	RCP	PRJ - Gravity Outlet	6-8C West of Kennedy Ave	Flap Gate & Sluice Gate	589
HA-26b	G	54	RCP	PRJ - Gravity Outlet	6-8C West of Kennedy Ave	Flap Gate & Sluice Gate	589
HA-27a	P	24	RCP	PRJ - S Kennedy PS	S Kennedy PS Outlet	Flap Gate	588.5
HA-27b	P	48	RCP	PRJ - S Kennedy PS	S Kennedy PS Outlet	Flap Gate & Sluice Gate	587.4
HA-U19	G			UTIL - Phone Conduit			596.7
HA-U20	P	18		UTIL - Force Sanitary			585.7
HA-U21	P	18		UTIL - Water Main			585.7
HA-28	G	54	RCP	PRJ - Gravity Outlet	7-3C East of Kennedy	Flap Gate & Sluice Gate	589.7

P / G Pressure or gravity line   PRJ - Project Feature   UTIL - Utility

TABLE 6 (Continued). Pipe Penetrations *(Refer to Figure 3 for locations of pipes)*

ID	P/G	DIA.	MAT.	TYPE	CONNECTION	CLOSURE	INVERT ELEV. (NAVD)
HA-U22	P	18		UTIL - Water Main			585.7
HA-29	P	24	DIP	PRJ-Kennedy Apts PS	Kennedy Apts PS Outlet	Flap Gate	590.2
HA-30	G	24	RCP	PRJ - Gravity Outlet	7-1C	Flap Gate & Sluice Gate	588.2
HA-31	G	36	RCP	PRJ - Gravity Outlet	7-2C	Flap Gate & Sluice Gate	588.9
HA-32	P	54	RCP	PRJ-Southeast Hessville PS	Southeast Hess-ville PS Outlet	Flap Gate	588.7
HA-33	G	24	RCP	PRJ - Gravity Outlet	Outlet 172	Flap Gate	589.7
HA-34	G	24	RCP	PRJ - Gravity Outlet	Outlet 173	Flap Gate	589.5
HA-35	G	42	RCP	PRJ - Gravity Outlet	Outlet 175 West of Cline	Flap Gate & Sluice Gate	589.5
HA-36	G	24	RCP	PRJ - Gravity Outlet	Oulet 8-3C West of Cline	Flap Gate	590.2
HA-37	G	18	CMP	INDOT	West of Cline		591.9
HA-38	G	66	RCP	INDOT - Gravity Outlet	East of Cline, in interchange	Check Valve & Sluice Gate	588.0

P / G Pressure or gravity line   PRJ - Project Feature   UTIL - Utility

PUMP STATIONS

A total of 9 pump stations are within the Hammond Levee system. These pump stations are designed to operate automatically to pump out water from within the levee system to minimize interior flooding. Figure 5 shows the pump station locations and related information about the individual pump stations.

During a flood event, the pump stations are to be regularly monitored to ensure the pumps and critical equipment are operational. Immediate notification shall be made in the event of equipment malfunction and/or pump cycling is too frequent, or if the pump station loses power or is flooding. Only skilled electricians and mechanics shall perform necessary tests and repairs. Operating personnel for the pump stations shall be present during tests.

ANY PROBLEMS WITH PUMPS OR PUMP STATION OPERATIONS SHALL BE REPORTED TO THE EMERGENCY OPERATIONS CENTER IMMEDIATELY.

ROAD CLOSURES

Roadway and railroad closures are critical features of the levee system to prevent flooding during high river stages, but seriously impact travel within the area when they are installed. Due to the relatively short time it takes for the Little Calumet River to rise in response to significant rainfall events, road closures may need to be implemented based on anticipated stages tied to precipitation amounts. Anticipated closures based on varying precipitation amounts for 3, 6, and 12 hour periods are shown in Tables 10 through 12 to provide a general understanding of types of rainfall events and results.

INSTALLATION OF ANY ROAD CLOSURE MUST BE PERFORMED IN COMMUNICATION WITH THE EMERGENCY OPERATIONS CENTER.

Flood fight closure locations and anticipated assembly time are shown in Figure 6 for the overall levee system and in Figures 7 through 10 for the individual road closures. Local officials will have to make certain that sufficient labor, equipment and materials are on hand for the installation of the closure.

Critical, trigger, monitoring precipitation/stage elevations to be used to determine the requirement for assembly of roadway and railroad closures are listed in Table 13. In addition, Table 13 indicates response levels based on river stage. The response levels are defined as follows:

<u>Level 1 – Alert</u>

This warning level will likely be issued after several inches of rain (2-3) have fallen and more is forecast, but well before any imminent threat of road flooding. This puts the local communities on notice that there could be a flooding problem. This level is intended to notify community road closure crew workers that they may be needed if flood conditions worsen, but requires no further action at that time.

<u>Level 2 – Mobilize</u>

If heavy rains continue to fall and/or the river stage rises to within approximately 3 feet of the roadway flooding level with more rain forecast, the warning to mobilize will be given to affected communities. With this warning, the road closure crews are to proceed to the community garage area, work yards, or other predetermined rendezvous points. All equipment needed for the closures should be loaded on trucks or checked to be certain it is all intact if preloaded, and the work crews should be ready to proceed to the closure sites at a moment's notice.

<u>Level 3 – Take Action/Make Closures</u>

The decision to take action and close the gates should be made by EM personnel onsite. It is recommended that the closure be made when very high rainfall level has fallen and/or river stage is about 1 foot below the street level and is projected to continue to rise.

THE EMERGENCY OPERATIONS CENTER MUST BE NOTIFIED IMMEDIATELY IF THE RIVER RISES TO WITHIN 1-FT OF THE STREET LEVEL.

Refer to Tables 7 through 9 which list the appropriate action level for each road closure based on gage stage height.

Table 7. Road Closure Action Responses

At USGS Gage	Closures	
Little Cal @ Munster	Flood Warning Action Levels	
feet	Northcote*	Calumet
17		Action
16		Mobilize
15	Action/598**	Alert
14	Mobilize*	
13	Alert*	

**Alert and Mobilize should be based on Precipitation as the first resort for this location*

***use elevation on west side of control structure for action*

Table 8. Road Closure Action Responses

At USGS Gage	Closures
Little Cal @ Hammond	Flood Warning Action Levels
feet	Railroad (N)
16.7	Action
15.7	Mobilize
14.7	Alert

Table 9. Road Closure Action Responses

At USGS Gage	Closures
Little Cal @ Highland	Flood Warning Action Levels
feet	Kennedy Avenue*
16	Action
15	Mobilize
14	Alert

**Alert and Mobilize should be based on Precipitation as the first resort for this location*

Table 10. Projected Actions for Project Feature Operation – 3 Hour

LOCATION	HEC-RAS RIVER MILE	PROJECT FEATURE	3-HOUR PRECIPITATION * (inches)											
			2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Illinois-Indiana State Line	16.043	Overflow Structure				3	4							
Calumet Avenue	17.601	Road Closure				1		2						
Riverside Park	18.102	Overflow Structure					3			4				
Northcote Avenue	19.079	Road Closure			1		2							
Cabela's	19.239	Overflow Structure						3						4
Railroad	18.955	RR Closure					1			2				
Kennedy Avenue	18.692	Road Closure			1		2							
Kennedy Avenue – Cline Avenue North	17.235	Overflow Structure						3					4	

These tables (6-8) are based on rainfall events of uniform intensity and uniform areal distribution of rainfall for the period specified. Variations of rainfall intensity and areal distribution can impact watershed runoff response.

Table Key:

1. Monitor precipitation and stages for potential road/rail closure operation
2. Road/rail closure likely under these precipitation conditions
3. Monitor precipitation and river stage for potential levee overtopping
4. Overflow likely under there precipitation conditions

Table 11. Projected Actions for Project Feature Operation – 6 Hour

LOCATION	HEC-RAS RIVER MILE	PROJECT FEATURE	6-HOUR PRECIPITATION * (inches)											
			2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Illinois-Indiana State Line	16.043	Overflow Structure				3	4							
Calumet Avenue	17.601	Road Closure					1		2					
Riverside Park	18.102	Overflow Structure					3				4			
Northcote Avenue	19.079	Road Closure			1		2							
Cabela's	19.239	Overflow Structure						3						4
Railroad	18.955	RR Closure						1			2			
Kennedy Avenue	18.692	Road Closure			1		2							
Kennedy Avenue – Cline Avenue North	17.235	Overflow Structure							3					4

These tables (6-8) are based on rainfall events of uniform intensity and uniform areal distribution of rainfall for the period specified. Variations of rainfall intensity and areal distribution can impact watershed runoff response.

Table Key:

1. Monitor precipitation and stages for potential road/rail closure operation
2. Road/rail closure likely under these precipitation conditions
3. Monitor precipitation and river stage for potential levee overtopping
4. Overflow likely under there precipitation conditions

Table 12. Projected Actions for Project Feature Operation – 12 Hour

LOCATION	HEC-RAS RIVER MILE	PROJECT FEATURE	12-HOUR PRECIPITATION * (inches)											
			2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Illinois-Indiana State Line	16.043	Overflow Structure					3	4						
Calumet Avenue	17.601	Road Closure					1			2				
Riverside Park	18.102	Overflow Structure					3					4		
Northcote Avenue	19.079	Road Closure			1		2							
Cabela's	19.239	Overflow Structure							3					
Railroad	18.955	RR Closure						1			2			
Kennedy Avenue	18.692	Road Closure			1			2						
Kennedy Avenue – Cline Avenue North	17.235	Overflow Structure							3					

Table Key:

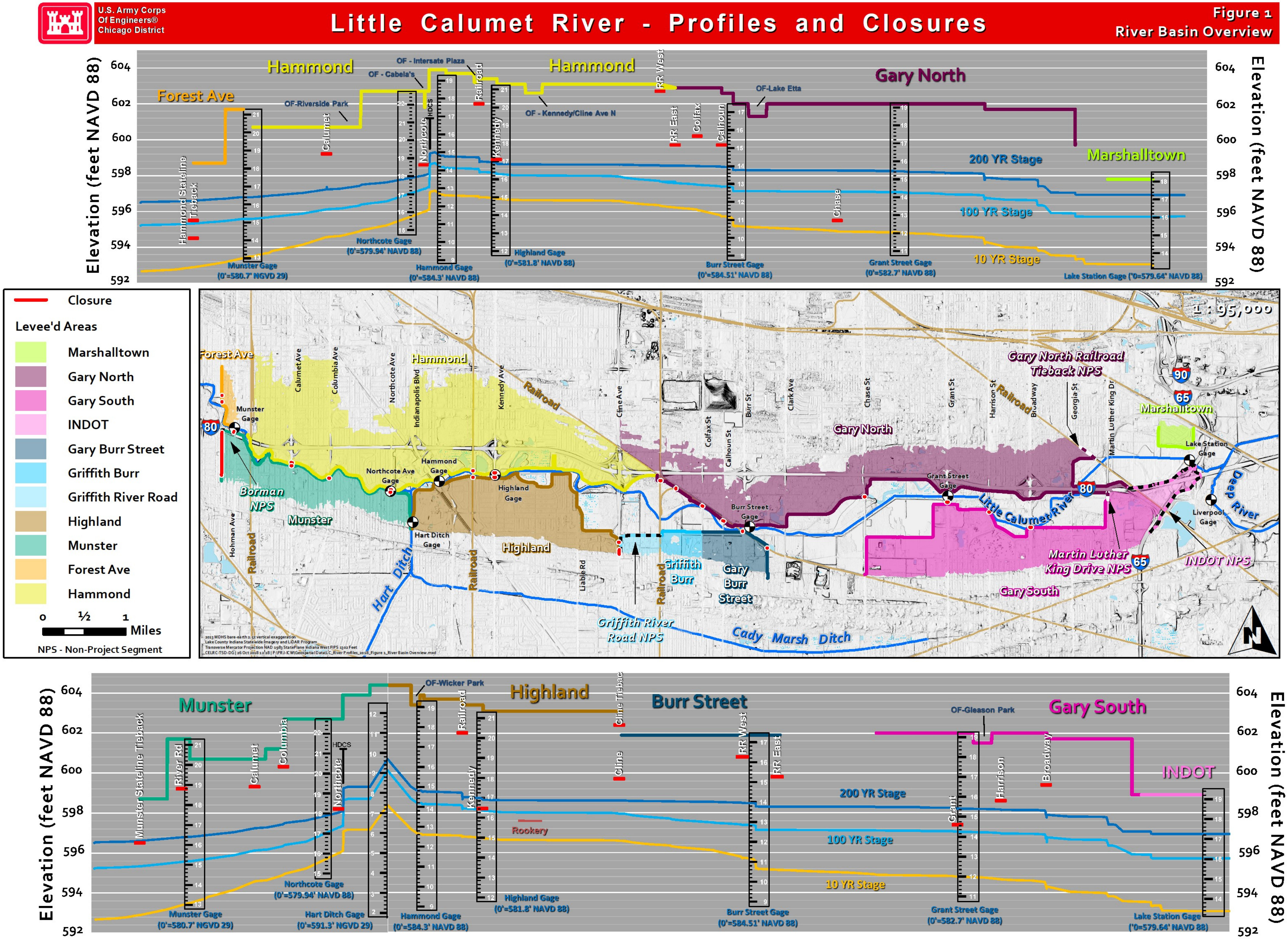
1. Monitor precipitation and stages for potential road/rail closure operation
2. Road/rail closure likely under these precipitation conditions
3. Monitor precipitation and river stage for potential levee overtopping
4. Overflow likely under there precipitation conditions

**These tables (6-8) are based on rainfall events of uniform intensity and uniform areal distribution of rainfall for the period specified. Variations of rainfall intensity and areal distribution can impact watershed runoff response.*

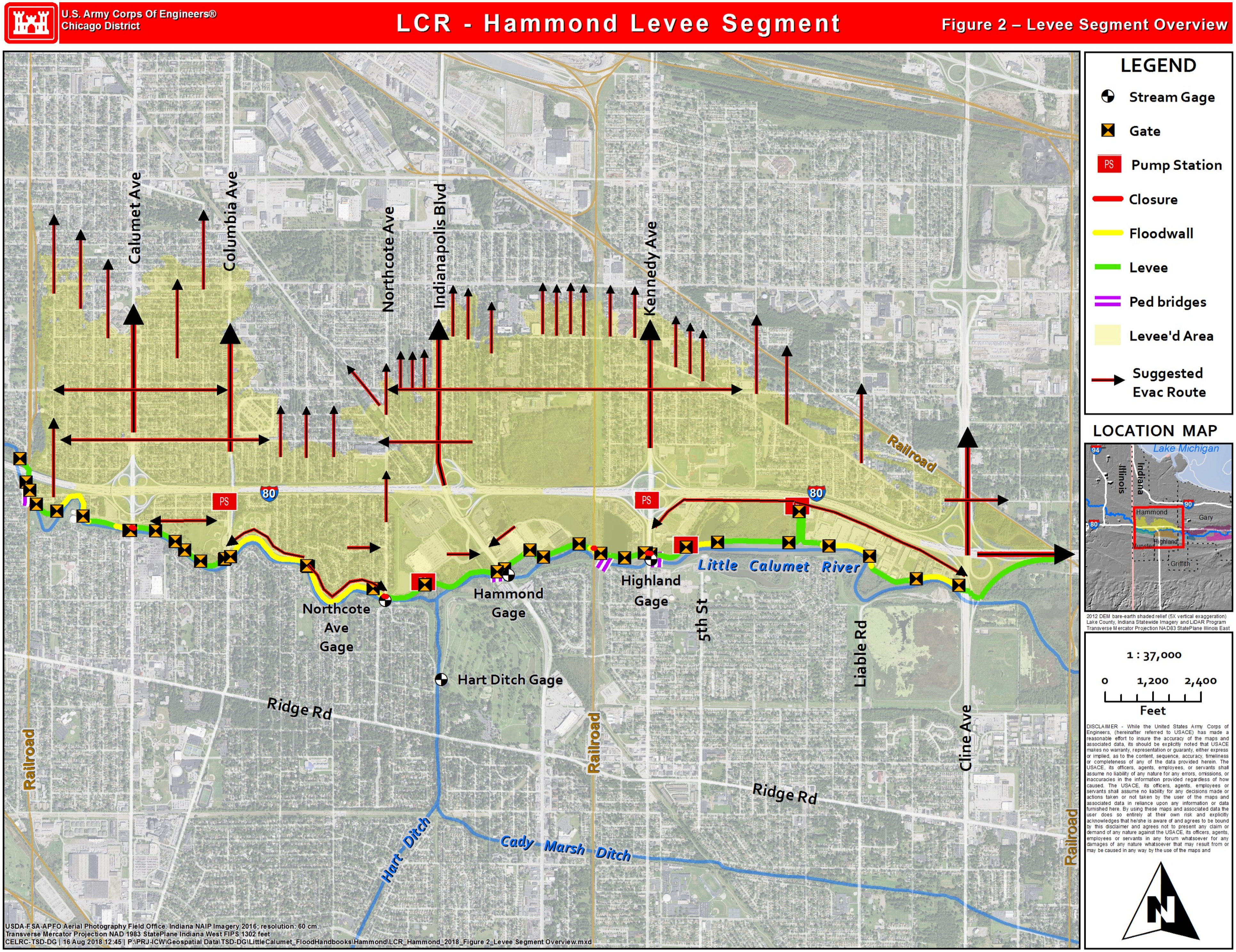
Table 13. Critical Monitoring Stages for Closures Based on River Stage Conditions

CLOSURE LOCATION	REFERENCE STAFF GAGE	MIN. CLOSURE ELEVATION (ft NAVD)	LEVEE CREST ELEVATION (ft NAVD)	DESIGN CLOSURE HEIGHT (FT)
Calumet Avenue	Munster	599.2	600.7	1.5
Northcote Avenue	Munster	598.6	602.7	4.1
Railroad	Munster	602.0	603.4	1.4
Kennedy Avenue	Burr	598.9	603.4	4.5

MAPS


U.S. Army Corps Of Engineers® Chicago District
Little Calumet River - Profiles and Closures
Figure 1
River Basin Overview
Elevation (feet NAVD 88)
Forest Ave
Hammond
Gary North
Marshalltown
OF - Intersate Plaza
OF - Cabela's
OF-Riverside Park
OF - Kennedy/Cline Ave N
OF-Lake Etta
200 YR Stage
100 YR Stage
10 YR Stage
Munster Gage (0'=580.7' NGVD 29)
Northcote Gage (0'=579.94' NAVD 88)
Hammond Gage (0'=584.3' NAVD 88)
Highland Gage (0'=581.8' NAVD 88)
Burr Street Gage (0'=584.51' NAVD 88)
Grant Street Gage (0'=582.7' NAVD 88)
Lake Station Gage ('0=579.64' NAVD 88)
Closure
Levee'd Areas
Marshalltown
Gary North
Gary South
INDOT
Gary Burr Street
Griffith Burr
Griffith River Road
Highland
Munster
Forest Ave
Hammond
0 ½ 1 Miles
NPS - Non-Project Segment
1 : 95,000
Borman NPS
Gary North Railroad Tieback NPS
Griffith River Road NPS
Martin Luther King Drive NPS
INDOT NPS
Little Calumet River
Hart Ditch
Cady Marsh Ditch
Deep River
Hart Ditch Gage
Liverpool Gage
Munster
Highland
Burr Street
Gary South
INDOT
OF-Wicker Park
OF-Gleason Park
Rookery
Hart Ditch Gage (0'=591.3' NGVD 29)

MAPS


U.S. Army Corps Of Engineers®
Chicago District
LCR - Hammond Levee Segment
Figure 2 – Levee Segment Overview
LEGEND
Stream Gage
Gate
PS
Pump Station
Closure
Floodwall
Levee
Ped bridges
Levee'd Area
Suggested Evac Route
LOCATION MAP
Lake Michigan
Illinois
Indiana
Hammond
Gary
Highland
Griffith
94
90
80
2012 DEM bare-earth shaded relief (5X vertical exaggeration)
Lake County, Indiana Statewide Imagery and LiDAR Program
Transverse Mercator Projection NAD83 StatePlane Illinois East
1 : 37,000
0 1,200 2,400
Feet
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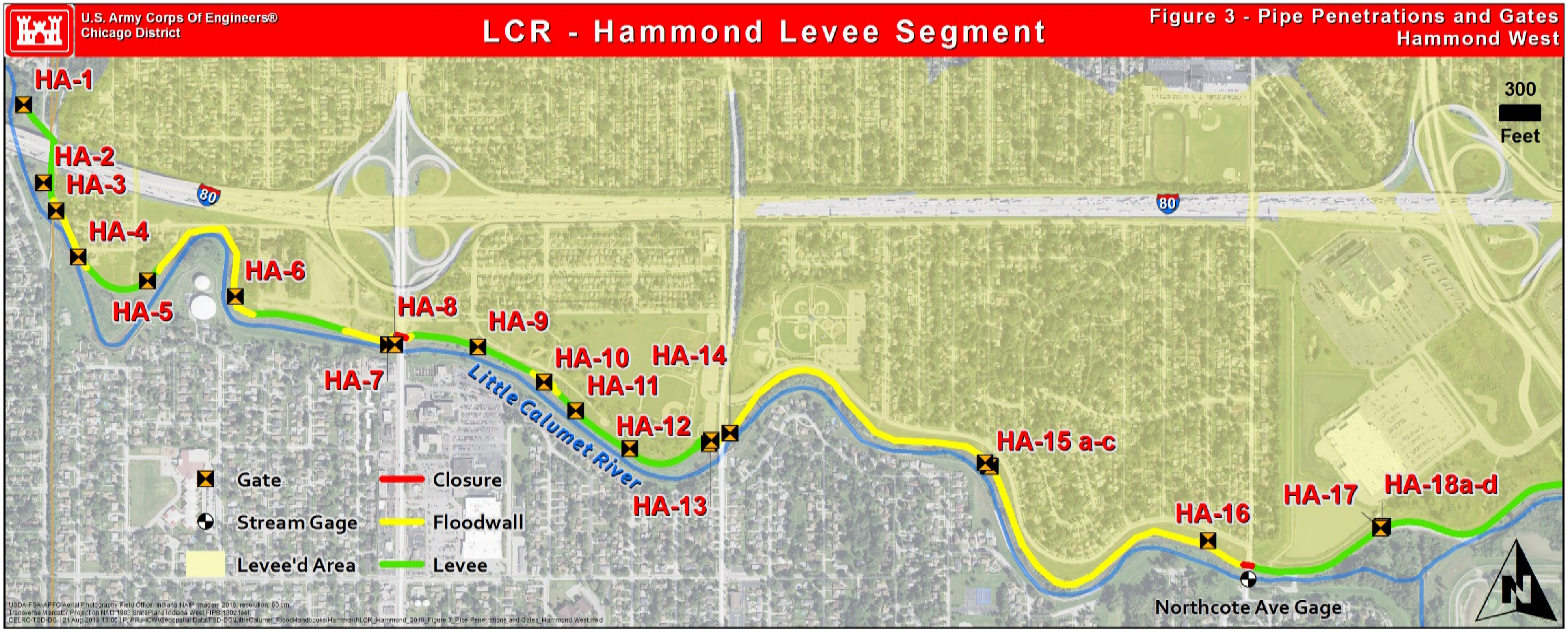
N
Calumet Ave
Columbia Ave
Northcote Ave
Indianapolis Blvd
Kennedy Ave
Railroad
80
PS
Little Calumet River
Northcote Ave Gage
Hammond Gage
Highland Gage
Hart Ditch Gage
5th St
Liable Rd
Cline Ave
Ridge Rd
Hart Ditch
Cady Marsh Ditch
USDA-FSA-APFO Aerial Photography Field Office. Indiana NAIP Imagery 2016; resolution: 60 cm.
Transverse Mercator Projection NAD 1983 StatePlane Indiana West FIPS 1302 feet
CELRC-TSD-DG | 16 Aug 2018 12:45 | P:\PRJ-ICW\Geospatial Data\TSD-DG\LittleCalumet_FloodHandbooks\Hammond\LCR_Hammond_2018_Figure 2_Levee Segment Overview.mxd

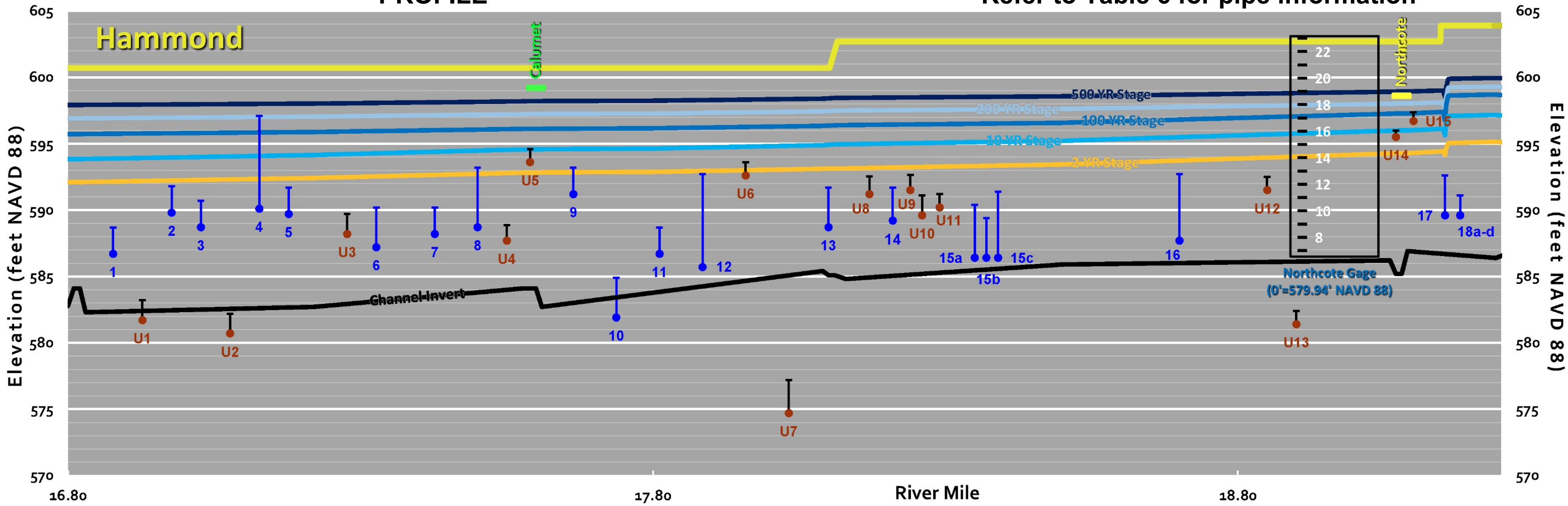
MAPS

**Refer to Table 6 for pipe information

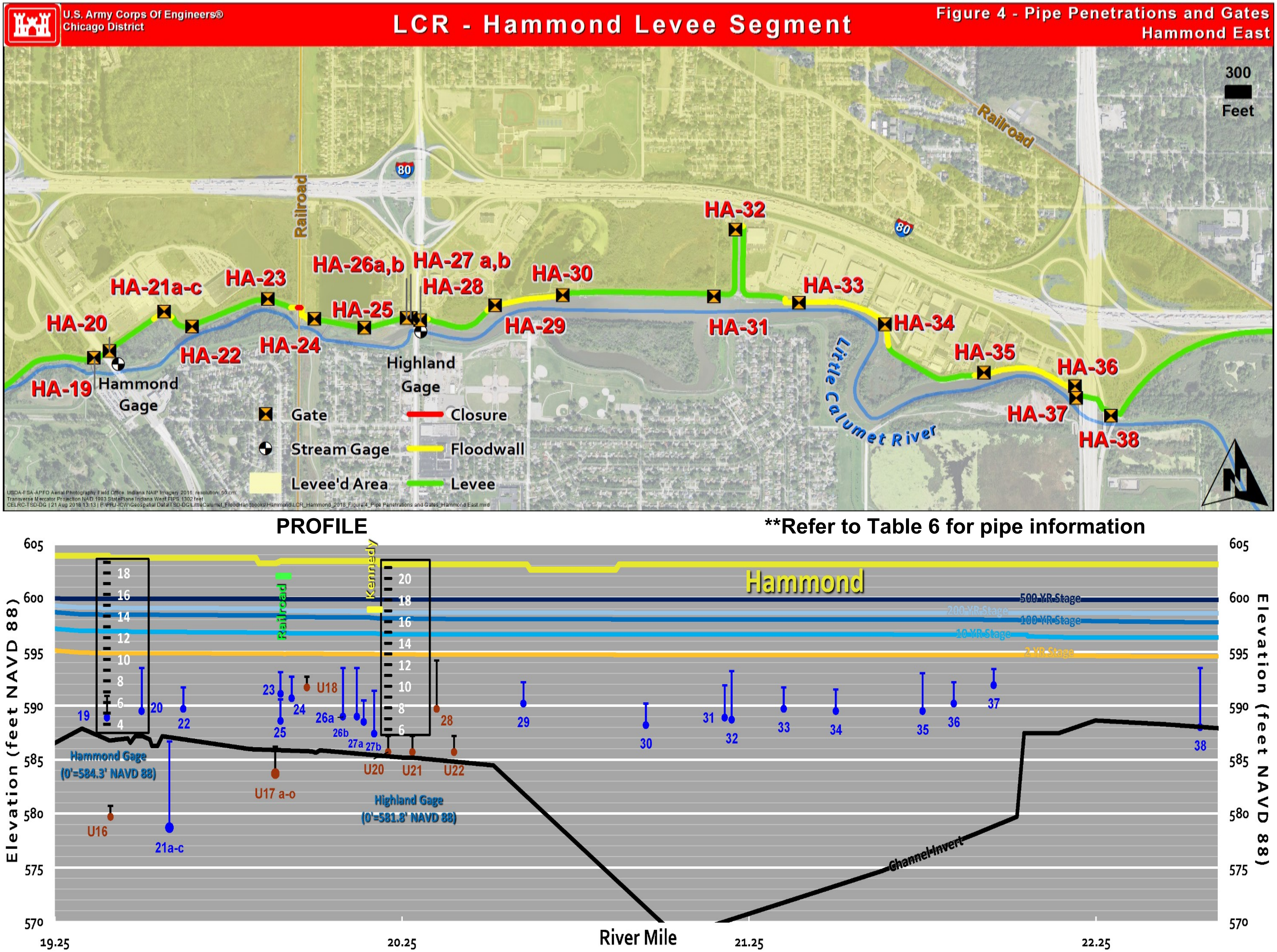


PROFILE

**Refer to Table 6 for pipe information



MAPS



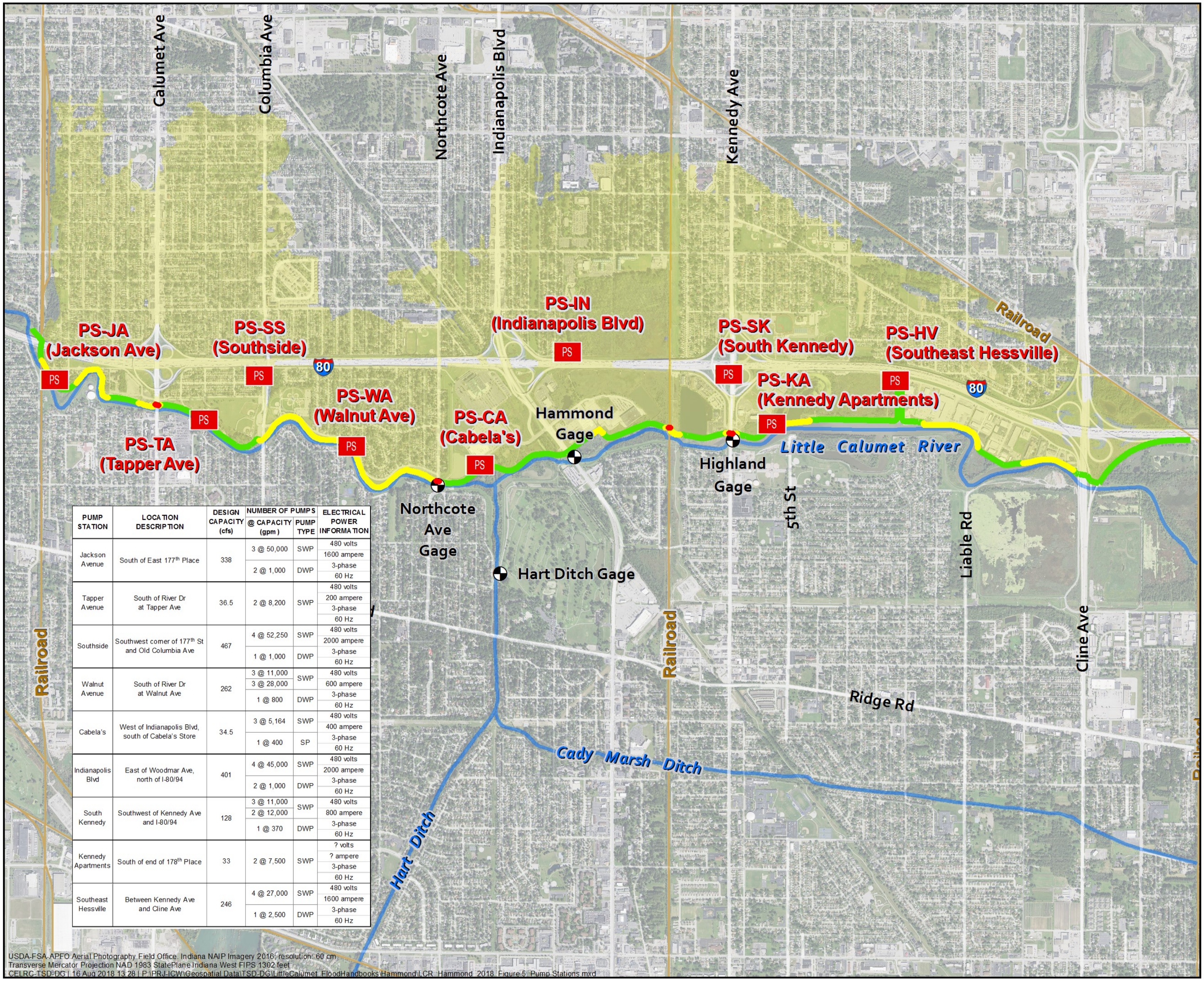
U.S. Army Corps Of Engineers®
Chicago District
LCR - Hammond Levee Segment
Figure 4 - Pipe Penetrations and Gates
Hammond East
300
Feet
Railroad
80
HA-19
HA-20
HA-21a-c
HA-22
HA-23
HA-24
HA-25
HA-26a,b
HA-27 a,b
HA-28
HA-29
HA-30
HA-31
HA-32
HA-33
HA-34
HA-35
HA-36
HA-37
HA-38
Hammond Gage
Highland Gage
Little Calumet River
Gate
Stream Gage
Levee'd Area
Closure
Floodwall
Levee
PROFILE
**Refer to Table 6 for pipe information
Elevation (feet NAVD 88)
Hammond
Kennedy
Railroad
500 YR Stage
200 YR Stage
100 YR Stage
10 YR Stage
2 YR Stage
Hammond Gage
(0'=584.3' NAVD 88)
Highland Gage
(0'=581.8' NAVD 88)
Channel Invert
U16
U17 a-o
U18
U20
U21
U22
19
20
21a-c
22
23
24
25
26a
26b
27a
27b
28
29
30
31
32
33
34
35
36
37
38
River Mile
19.25
20.25
21.25
22.25
605
600
595
590
585
580
575
570

MAPS

U.S. Army Corps Of Engineers®
Chicago District

LCR - Hammond Levee Segment

Figure 5 - Pump Stations

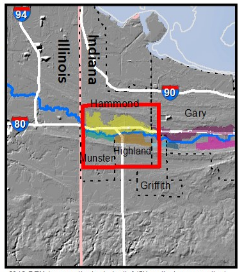


PUMP STATION	LOCATION DESCRIPTION	DESIGN CAPACITY (cfs)	NUMBER OF PUMPS @ CAPACITY (gpm)	PUMP TYPE	ELECTRICAL POWER INFORMATION
Jackson Avenue	South of East 177th Place	338	3 @ 50,000	SWP	480 volts, 1600 ampere
			2 @ 1,000	DWP	3-phase, 60 Hz
Tapper Avenue	South of River Dr at Tapper Ave	36.5	2 @ 8,200	SWP	480 volts, 200 ampere, 3-phase, 60 Hz
Southside	Southwest corner of 177th St and Old Columbia Ave	467	4 @ 52,250	SWP	480 volts, 2000 ampere
			1 @ 1,000	DWP	3-phase, 60 Hz
Walnut Avenue	South of River Dr at Walnut Ave	262	3 @ 11,000 3 @ 28,000	SWP	480 volts, 600 ampere
			1 @ 800	DWP	3-phase, 60 Hz
Cabela's	West of Indianapolis Blvd, south of Cabela's Store	34.5	3 @ 5,164	SWP	480 volts, 400 ampere
			1 @ 400	SP	3-phase, 60 Hz
Indianapolis Blvd	East of Woodmar Ave, north of I-80/94	401	4 @ 45,000	SWP	480 volts, 2000 ampere
			2 @ 1,000	DWP	3-phase, 60 Hz
South Kennedy	Southwest of Kennedy Ave and I-80/94	128	3 @ 11,000 2 @ 12,000	SWP	480 volts, 800 ampere
			1 @ 370	DWP	3-phase, 60 Hz
Kennedy Apartments	South of end of 178th Place	33	2 @ 7,500	SWP	? volts, ? ampere, 3-phase, 60 Hz
Southeast Hessville	Between Kennedy Ave and Cline Ave	246	4 @ 27,000	SWP	480 volts, 1600 ampere
			1 @ 2,500	DWP	3-phase, 60 Hz

LEGEND

- Stream Gage
- PS Pump Station
- Closure
- Floodwall
- Levee
- Levee'd Area

LOCATION MAP

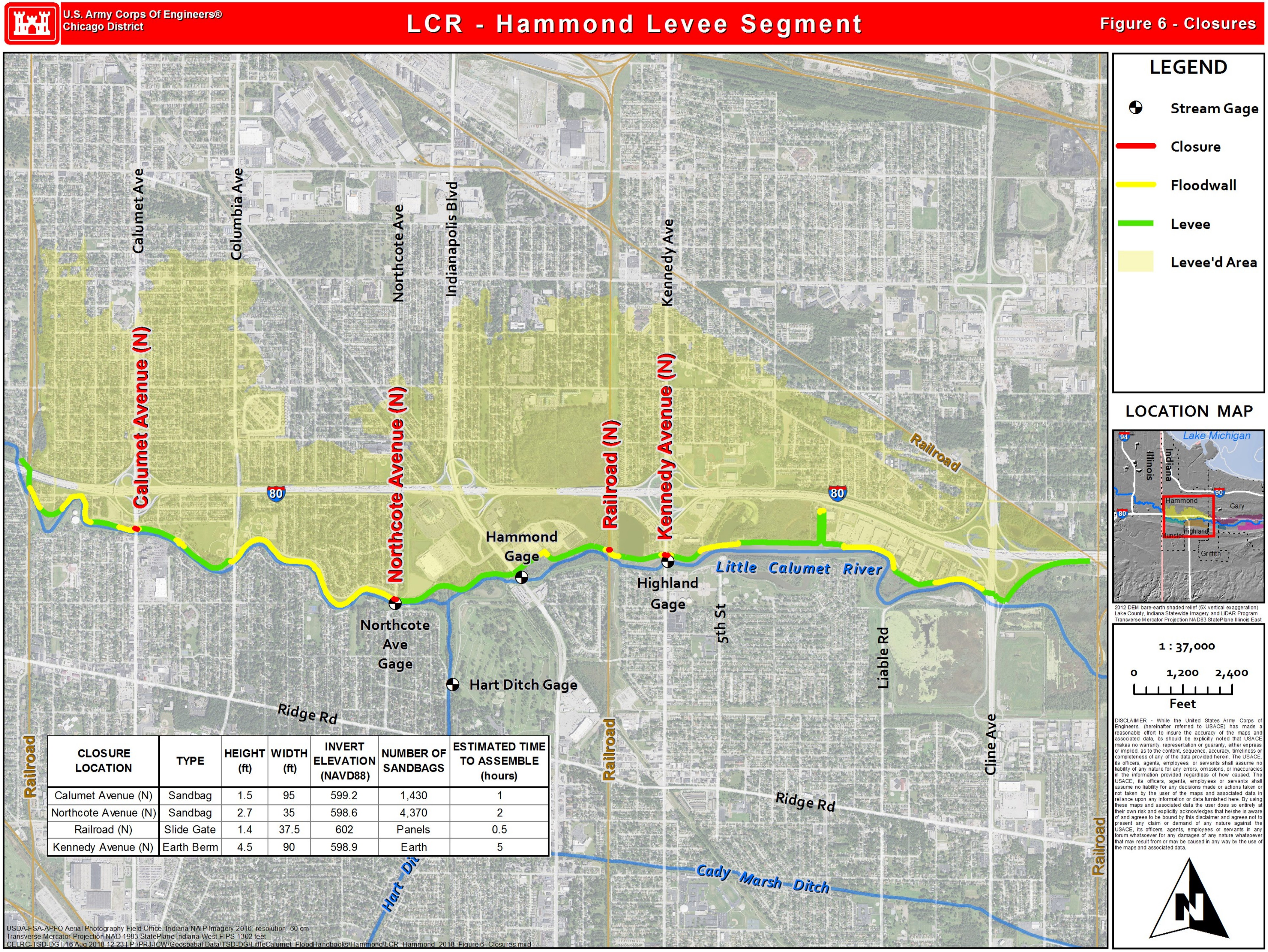


2012 DEM bare-earth shaded relief (5X vertical exaggeration)
Lake County, Indiana Statewide Imagery and LiDAR Program
Transverse Mercator Projection NAD83 StatePlane Illinois East

1 : 37,000

0 1,200 2,400
Feet

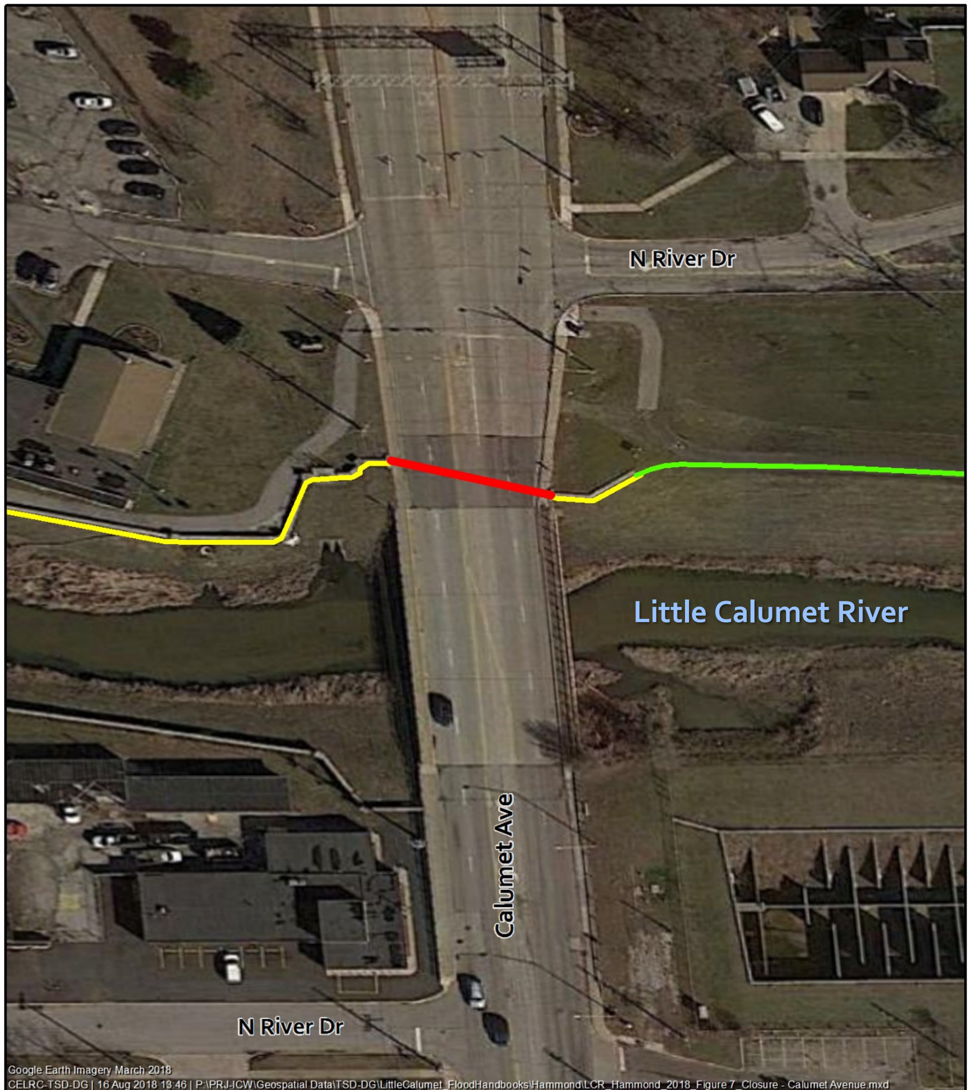
MAPS



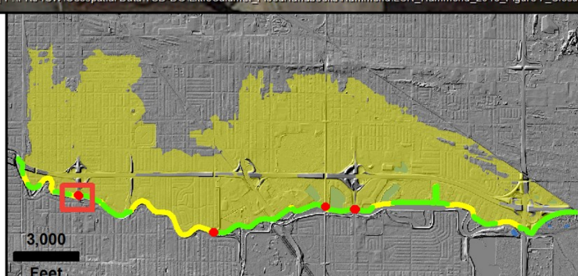
CLOSURE LOCATION	TYPE	HEIGHT (ft)	WIDTH (ft)	INVERT ELEVATION (NAVD88)	NUMBER OF SANDBAGS	ESTIMATED TIME TO ASSEMBLE (hours)
Calumet Avenue (N)	Sandbag	1.5	95	599.2	1,430	1
Northcote Avenue (N)	Sandbag	2.7	35	598.6	4,370	2
Railroad (N)	Slide Gate	1.4	37.5	602	Panels	0.5
Kennedy Avenue (N)	Earth Berm	4.5	90	598.9	Earth	5

LCR - Hammond Levee Segment

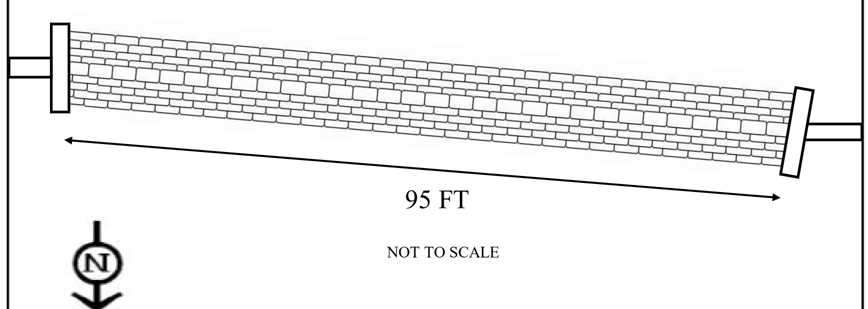
Figure 7
Calumet Ave Closure



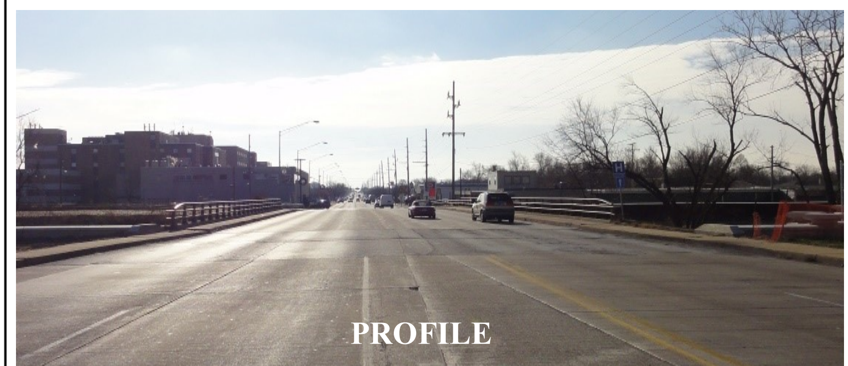
Closure
Floodwall
Levee
Levee'd Area



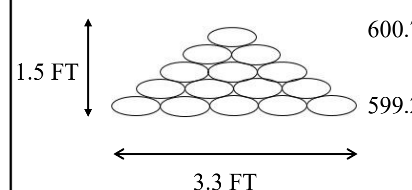
60
Feet



PLAN



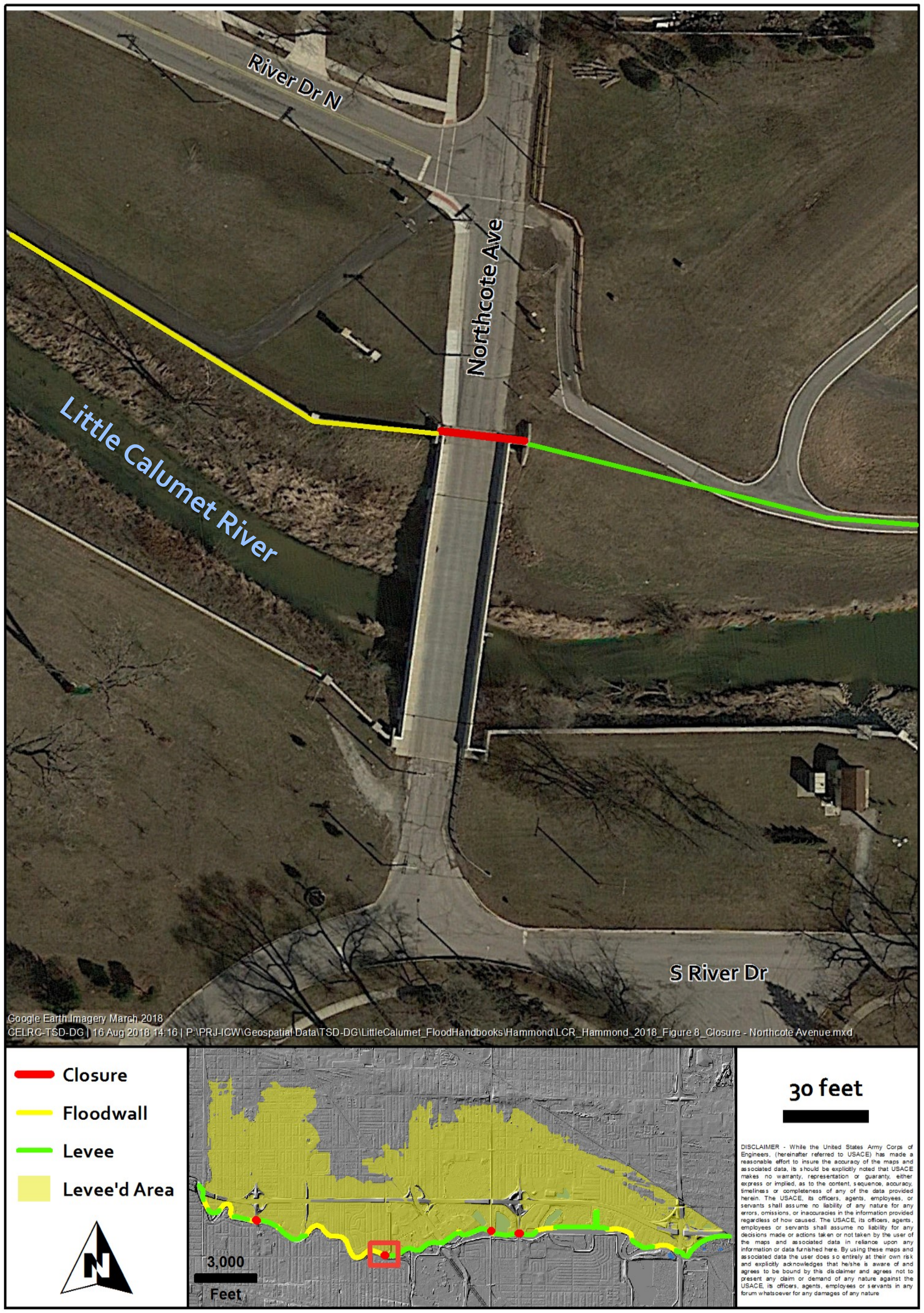
Closure Name: Calumet Ave (N)
Closure Type: Sandbag
Invert Elevation: **599.2 ft** NAVD88
Materials Required: **1,430 Sandbags**
Est. Time to Install: **1.0 hours**
Est. Crew Size: **25 people**
Equipment Needed:
- Sandbagger
- Front End Loader

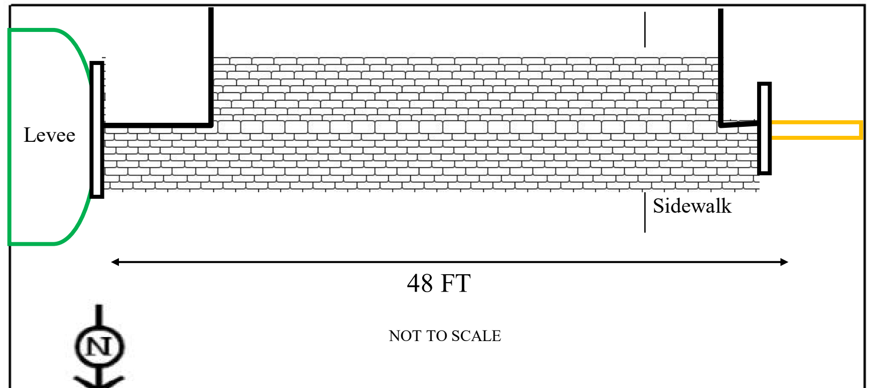


CROSS SECTION

LCR - Hammond Levee Segment

Figure 8
Northcote Ave Closure

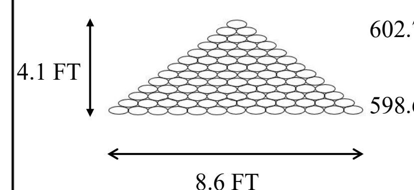




PLAN

PROFILE

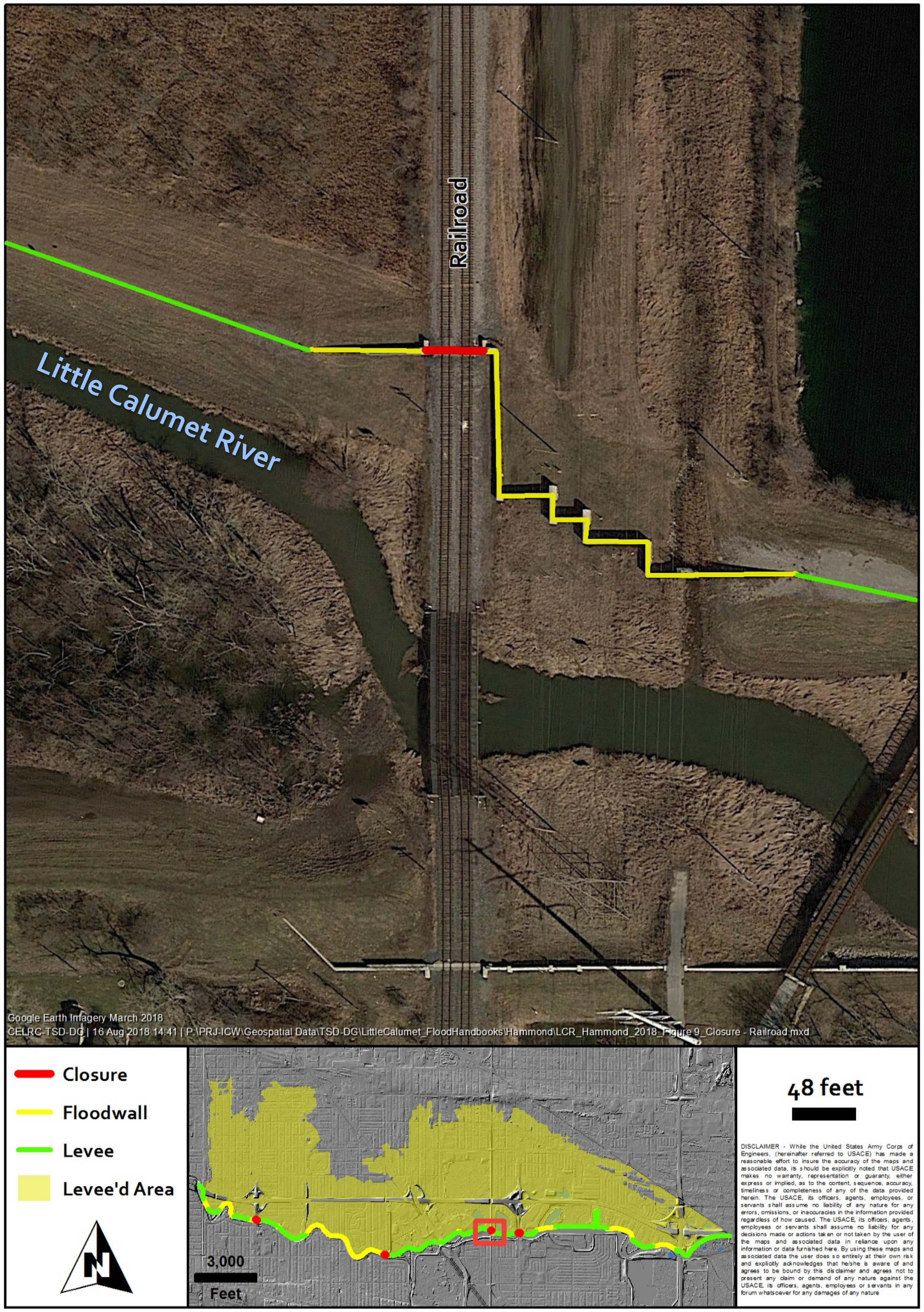
Closure Name: Northcote Ave
Closure Type: Sandbag
Invert Elevation: **598.6 ft NAVD88**
Materials Required: **4,370 Sandbags**
Est. Time to Install: **2.0 hours**
Est. Crew Size: **25 people**
Equipment Needed:
- Sandbagger
- Front End Loader

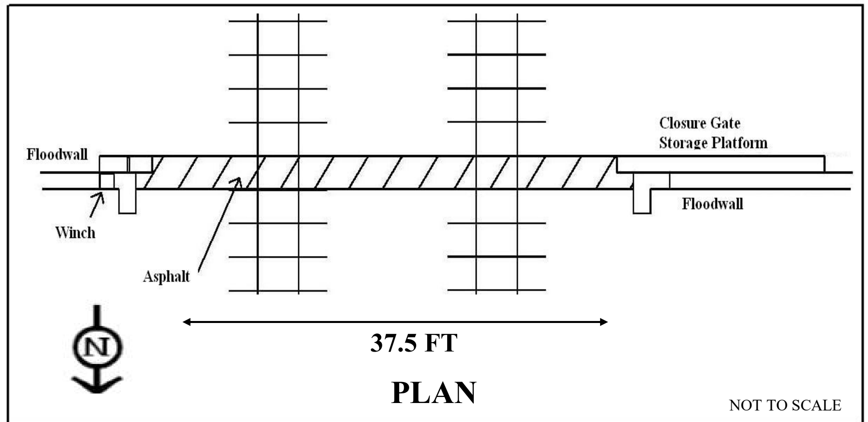


CROSS SECTION

LCR - Hammond Levee Segment

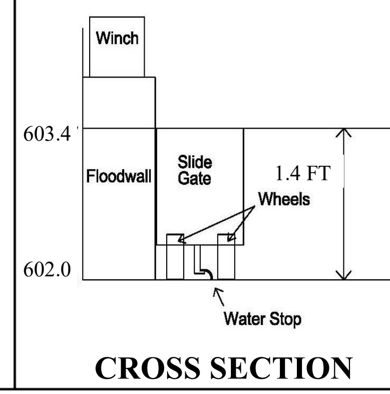
Figure 9
Railroad Closure





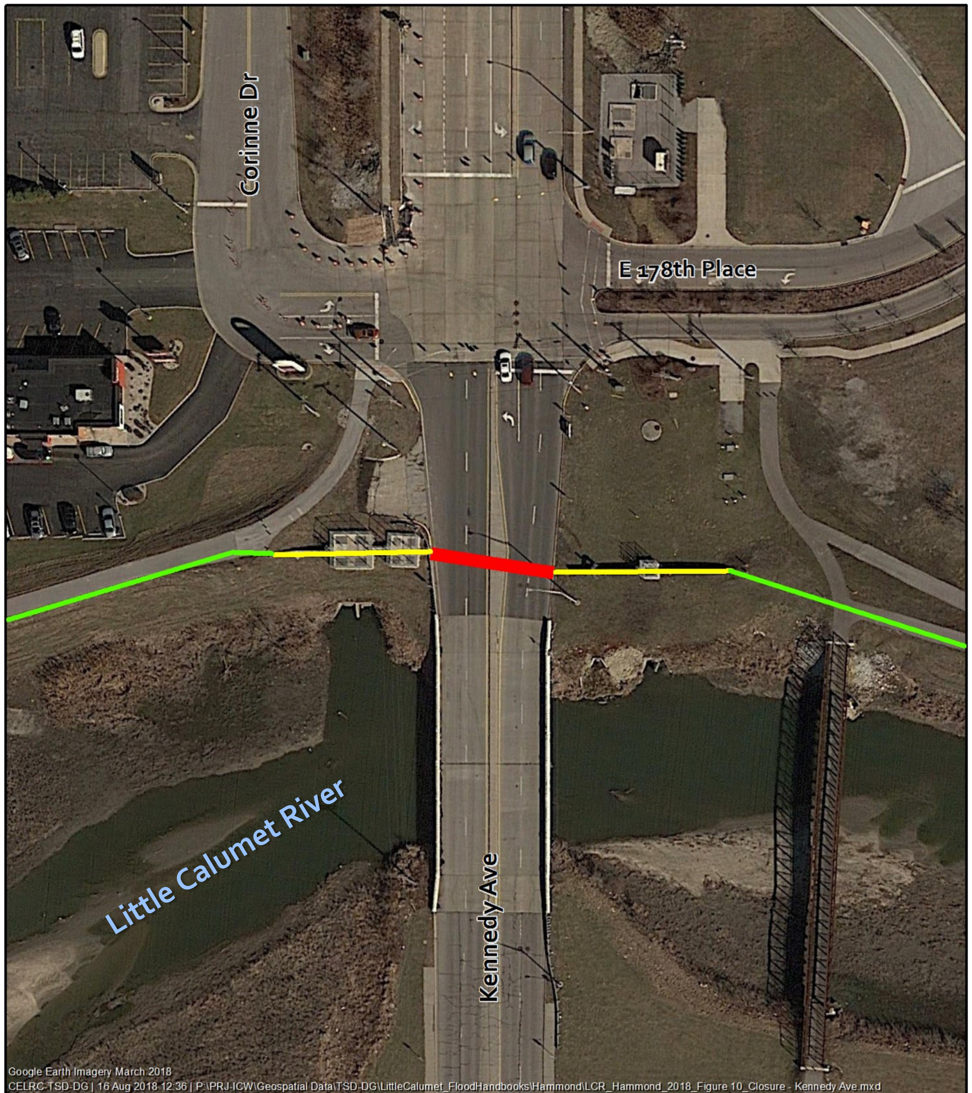
Closure Name: Railroad
Closure Type: Slide Gate
Invert Elevation: 602 ft NAVD88
Materials Required: None
Est. Time to Install: 1 hour
Est. Crew Size: 3 people
Equipment Needed:
Power Wrench

Contact Norfolk Southern RR POC

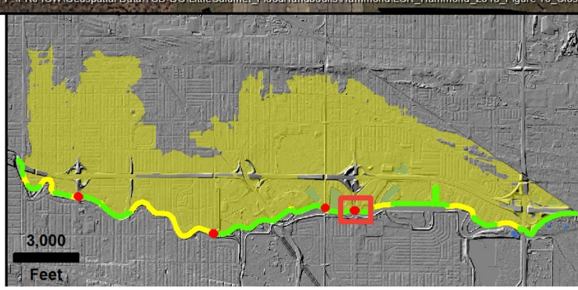


LCR - Hammond Levee Segment

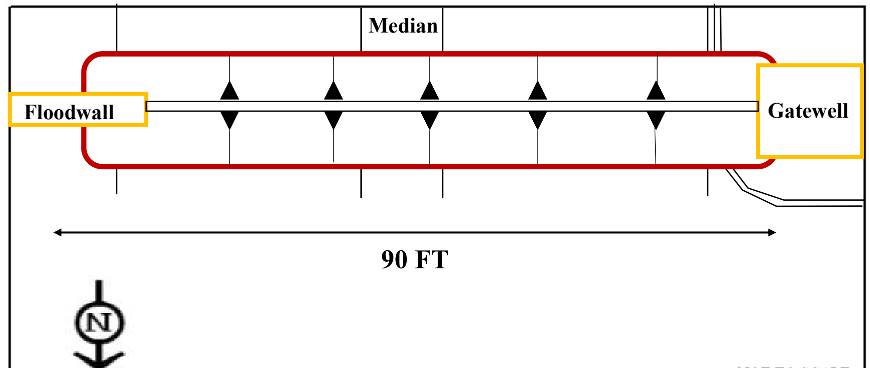
Figure 10
Kennedy Ave Closure



- Closure
- Floodwall
- Levee
- Levee'd Area



60 feet

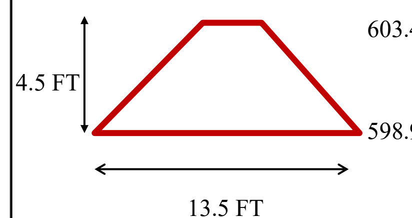


PLAN

NOT TO SCALE

Closure Name: Kennedy Avenue
Closure Type: Earth Berm
Invert Elevation: **598.9 ft** NAVD88
Materials Required:
- Sand
- Plastic Sheeting
- Sandbags

Est. Time to Install: **4 hours**
Est. Crew Size: **5 people**
Equipment Needed:
- Front End Loader
- Dump Truck



CROSS SECTION

APPENDIX A - EMERGENCY FLOOD FIGHTING TECHNIQUES

I. INTRODUCTION

1. **Flood Fighting.** This can be defined as those emergency operations that are taken in advance of and during a flood to prevent or minimize damages to public and private property. Flood fighting includes the hasty construction of emergency levees; the overbuilding of existing levees or natural river banks; ring and U-shaped levees constructed around facilities or areas of high property value; preservation of vital facilities including water treatment plants and wells; power and communication facilities; protection of sanitary and storm sewer systems; and provisions for interior drainage treatment during flood stages. Flood fighting plans should acknowledge that it may not be feasible to protect entire communities based on economic or time and equipment considerations; therefore, evacuation of certain areas may be a necessary facet of an emergency operation.

2. **Recommended Local Organization.** Each community with a flood history should establish an organization and written plans for the purpose of conducting flood fighting operations. These plans should include identification of flood-prone areas and previous high water marks; flood fighting or evacuation plans; delegation of responsibilities; lists of important suppliers of materials and special equipment; lists of local contractors; and establishment of earth borrow sites, etc. The plan should further provide for the establishment of an emergency operation center and list various assistance programs available, either through the State or Federal government. Further assistance in developing these plans can be provided by the State or local Civil Defense Director in the area.

II. FLOOD BARRIER CONSTRUCTION

1. **Introduction.** The two basic features of an emergency levee system include the flood barrier, generally constructed of earth fill, and the related interior drainage treatment. It is desirable that individuals assigned to a flood-fight situation have prior knowledge of flood barrier construction, interior drainage, and related flood-fight problems which they may encounter. They should also be acquainted with the past flood emergency efforts, historical flood stages, and forecasted stages for the community. The following information will provide personnel with guidelines based on actual experience. However, it cannot be over emphasized that individual resourcefulness is a key element in a successful flood fight.

2. **Borrow Area and Haul Road.** The two prime requisites for a borrow area are that adequate material be available and that the site be accessible at all times. The quantity estimate plus an additional 50 percent should provide the basis for the area requirement. The area must be located so that it will not become isolated from the project by high water. The borrow area should also be located where the present water table, if known, and the water table levels caused by high water will not hinder or stop its use. If possible, a borrow area should be selected which will provide suitable

materials for levee construction as covered below. Local contractors and local officials are the best source of information on available borrow areas. If undeveloped, the area should be cleared of brush, trees, and debris, with topsoil and surface humus being striped. In early spring, it will probably be necessary to rip the area to remove frozen material. An effort should be made to borrow from the area in such a manner that the area will be relatively smooth and free-draining when the operation is complete. The haul road may be an existing road or street, or it may have to be constructed. To mitigate damages it is highly desirable to use unpaved trails and roads, or to construct a road if the haul distance is short. In any case, the road should be maintained to avoid unnecessary traffic delays. The use of flagmen and warning signs is mandatory at major pedestrian crossings. A borrow area, or source of sand for sandbags, should also be located promptly. This can become a critical item of supply in some areas due to long haul, project isolation, etc. It may become necessary to stockpile material near anticipated trouble areas.

3. **Equipment.** One of the important considerations in earthwork construction is the selection of proper equipment to do the work. Under emergency conditions, obtaining normally specified earthwork equipment will be difficult and the work will generally be done with locally available equipment. It may be wise to call for technical assistance in the early contract stage to insure that proper and efficient equipment use is proposed. If possible, compaction equipment should be used in flood-barrier construction. This may involve sheepsfoot, rubber-tired, or vibratory rollers. Scrapers should be used for hauling when possible because of speed (on short haul) and large capacity. Truck haul, however, has been the most widely used. A ripper is almost essential for opening borrow areas in the early spring. A bulldozer of some size is mandatory on the job to help spread dumped fill and provide minimum compaction.

4. **Construction Contract.** The initiation of a construction contract under emergency conditions is very unique in that sole judgment as to the competence and capabilities of the contractor lies with field personnel. Field personnel, therefore, must be somewhat knowledgeable in construction operations. The initial contract is very important in that it delineates what equipment must be accounted for on the project and what is available for construction. During construction, if it becomes obvious that the equipment provided by the initial contract is inadequate to provide reasonably good construction or timely completion, a new or supplemental contract may be required. Procedures are the same as in the initial contract. Flexibility may be built into the original contract if it can be foreseen that additional pieces of equipment will ultimately be used.

5. **Supplies.** Early anticipation of flood fight problems will aid greatly in providing necessary and sufficient supplies on hand. These include sandbags, polyethylene, pumps, etc. The importance of initiative, resourcefulness, and foresight of the individual on the project cannot be over emphasized. Technical assistance may be invaluable in locating potential problem areas which, with proper materials at hand, could be alleviated early.

6. **Slope Protection.**

A) **General.** Methods of protecting levee slopes from current scour, wave wash, seepage, and debris damage are numerous and varied. However, during a flood emergency, time, availability of materials, cost and construction capability preclude the use of all accepted methods of permanent slope protection. Field personnel must decide the type and extent of slope protection the emergency levee will need. Several methods of protection have been established which prove highly effective in an emergency. Again, resourcefulness on the part of the field personnel may be necessary for success.

B) **Polyethylene and Sandbags.**

1) **General.** Experience has shown that a combination of polyethylene (poly) and sandbags is one of the most expedient, effective, and economical methods of combating slope attack in a flood situation. Poly and sandbags can be used in a variety of combinations, and time becomes the factor that may determine which combination to use. Ideally, poly and sandbag protection should be placed in the dry. However, many cases of unexpected slope attack will occur during high water, and a method for placement in the wet is covered below. See Plates **2** and **3** for suggested methods of laying poly and sandbags. Since each flood fight project is generally unique (river, personnel available, materials, etc.), specific details of placement and materials handling will not be covered. Personnel must be aware of resources available when using poly and sandbags.

2) **Toe Anchorage and Poly Placement.** Anchoring the poly along the riverward toe is important for a successful job. It may be done in three different ways: 1) After completion of the levee, a trench excavated along the toe, poly placed in the trench, and the trench backfilled; 2) Poly placed flat-out away from the toe, and earth pushed over the flap; and 3) Poly placed flat-out away from the toe and one or more rows of sandbags placed over the flap. The poly should then be unrolled up the slope and over the top enough to allow for anchoring with sandbags. Poly should be placed from downstream to upstream along the slopes and overlapped at least 2 feet. The poly is now ready for the “hold-down” sandbags.

3) **Slope Anchorage.** It is mandatory that poly placed on levee slopes be held down. An effective method of anchoring poly is a grid system of sandbags, unless extremely high velocities, heavy debris, or a large amount of ice is anticipated. Then a solid blanket of bags over the poly should be used. A grid system can be constructed faster and requires fewer bags and much less labor than a total covering. Various grid systems include vertical rows of lapped bags, two-by-four lumber held down by attached bags, and rows of bags held by a continuous rope tied to each bag. Poly has been held down by a system using two bags tied with rope and the rope saddled over the levee crown with a bag on each slope.

4) **Placement in the Wet.** In many situations during high water, poly and sandbags placed in the wet must provide the emergency protection. Wet placement may also be required to replace or maintain damaged poly or poly displaced by current action. Plate **3** shows a typical section of levee covered in the wet. Sandbag anchors are formed at the bottom edge and ends of the poly by bunching the poly around a fistful of hand or rock and tying the sandbags to this fist-sized ball. Counterweights consisting of two or more sandbags connected by a length of ¼ inch rope are used to hold the center portion of the poly down. The number of counterweights will depend on the uniformity of the levee slope and current velocity. Placement of the poly consists of first casting out the poly sheet with the bottom weights and then adding counterweights to slowly sink the poly sheet into place. The poly, in most cases, will continue to move down slope until the bottom edge reaches the toe of the slope. Sufficient counterweights should be added to insure that no air void exist between the poly and the levee face and to keep the poly from flapping or being carried away in the current. For this reason, it is important to have enough counterweights prepared prior to the placement of the sheet.

5) **Overuse of Poly**. In past floods there has been a tendency to overuse and in some cases misuse poly on slopes. For example, on well compacted clay embankments, in areas of relatively low velocities, use of poly would be unnecessary. Also, placement of poly on landward slopes to prevent seepage must not be done. It will only force seepage to another exit and may prove detrimental. A critical analysis of a situation should be made toward less waste and more efficient use of these materials and available manpower. However, if a situation is doubtful, poly should be used rather than risk a failure, with the critical areas receiving priority.

C) **Riprap.** Riprap is a positive means of providing slope protection and has been used in a few cases where erosive forces were too large to effectively control by other means. Objections to using riprap when flood fighting are:

1) rather costly;

2) large amount necessary to protect a given area;

3) availability; and

4) little control over its placement, particularly in the wet.

D) **Groins.** In the past, small groins, extending 10 feet or more into the channel were effective in deflecting current away from the levees. Groins can be constructed by using sandbags, car bodies, snow fence, rock, compacted earth, or any other substantial materials that are available. Preferably groins should be placed in the dry and at locations where severe scour may be anticipated. Consideration of the hydraulic aspects of placing groins should be given, because haphazard placement may be detrimental. Hydraulic technical assistance should be sought if doubts arise in the use of groins. Construction of groins during high water will be very difficult and results will generally be minimal. If something other than compacted fill is used, some form of anchorage or bonding should be provided. (For example, car bodies tied together, or snow fence anchored to a tree beyond the toe of the levee.)

E) **Log Booms.** Log booms have been used to protect levee slopes from debris or ice attack. Logs are cabled together and anchored with a dead man in the levee. The boom will float out in the current and, depending on log size, will deflect floating objects.

F) **Miscellaneous Measures.** Several other methods of slope protection have been used. Straw bales pegged into the slope may be successful against wave action, as is straw spread on the slope and overlain with snow fence. Car bodies laid on the slope may also be effective in reducing scour.

7. **Sandbag Dikes.** The sandbag dike should not be considered as a primary flood barrier. The main objections to their use are that the materials (bags and sand) are quite costly; they require a tremendous amount of manpower; and are time consuming to construct. Sandbag dikes should be used where a very low and relatively short barrier is required and earth fill would not be practicable, such as in the freeboard range along an arterial street. They are very useful in constricted areas such as around or very close to buildings, where rights-of-way would preclude using earth fill. They are also useful where temporary closure is required, such as roads and railroad tracks. A polyethylene seepage barrier should be incorporated into the sandbag structure. The poly must be on the riverward slope and brought up immediately behind the outermost layer of bags. The poly should be keyed-in to a trench and anchored or, at best, lapped under the sandbags for anchorage. See Plate **1** for recommended practices in sandbag dike construction. A few points to be aware of in sandbag construction are:

A) sand, or predominantly sandy or gravelly material should be used;

B) extremely fine, clean sand, such as washed mortar sand, should be avoided;

C) bags should be ½ full;

D) bags should be lapped when placing;

E) bags should be tamped tightly in place; and

F) the base width should be wide enough to resist the head at high water.

Sandbagging is also practical for raising a narrow levee, or when construction equipment cannot be used. Sandbag raises should be limited to 3 feet.

8. **Miscellaneous Flood Barriers.** In addition to earth fill and sandbag levees, other types of flood barriers are available. They are the flashboard and the box levees, both of which are constructed using lumber and earth fill (see Plate **4**). They may be used for capping a levee or as a barrier in highly constricted areas. Two disadvantages in using these barriers are the long construction time involved and very high cost. Therefore, these barriers are not recommended, unless a very unusual situation warrants their use.

Other types of flood barriers are available commercially and have been used by the USACE. These systems are:

- Hesco Bastion containers are granular filled, membrane lined wire baskets that are pinned together to form a continuous structure. The framework is welded mesh and the lining is geotextile. See Plate **8** for an example.
- Rapid Deployed Floodwall (RDFW): Rapid Deployment Flood Wall consists of granular filled, plastic grid units that connect together with both horizontal and vertical tabs to form a continuous structure. See Plate **9** for an example.
- Port-a-dam: The port-a-dam consists of impermeable membrane liner that is supported by a steel frame, as shown in Plate **10**.
- AquaBarrier: Water filled bags, as shown in Plate **11**.

III. EMERGENCY INTERIOR DRAINAGE TREATMENT

1. **General.** High river stages often disrupt the normal drainage of sanitary and storm sewer systems, render sewage treatment plants inoperative, and cause backup in sewers and the discharge of untreated sewage directly into the river. When the river recedes, some of the sewage may be trapped in low lying pockets to remain as a possible source of contamination. Hastily constructed dikes intended to keep out river waters may also seal off normal outlet channels for local runoff, creating large ponds on the landward side of the dikes, making the levees vulnerable from both sides. If the ponding is excessive, it may nullify the protection afforded by the dikes even if they are not overtopped. Sewers may also back up because of this ponding.

2. **Preliminary Work.** In order to arrive at a reasonable plan for interior drainage treatment, several items of information must be obtained by field personnel. These are:

A) Size of drainage area.

B) Pumping capacity and/or ponding required.

C) Basic plan for treatment.

D) Storm and sanitary sewer and water line maps, if available.

E) Location of sewer outfalls (abandoned or in use)

F) Inventory of available local pumping facilities.

G) Probable location of pumping equipment.

H) Whether additional ditching is necessary to drain surface runoff to ponding and /or pump locations.

I) Location of septic tanks and drain fields (abandoned or in use).

3. **Pumps, Types, Sizes and Capacities.**

A) **Storm Sewer Pumps.** Table 1 indicates the size of pump needed to handle the full flow discharge from sewer pipes up to 24" in diameter. Table 2 shows sizes and capacities of agricultural type pumps which may be useful in ponding areas.

B) **Fire Engine Pumps.** The ordinary fire pumper has a 4-inch suction connection and a pumping capacity of about 750 gpm. Use only if absolutely necessary.

C) **Pump Discharge Piping**. The Crisafulli pumps are generally supplied with 50-foot lengths of butyl rubber hose. Care must be taken to prevent damage to the hose. Irrigation pipe or small diameter culverts will also serve as discharge piping. Care should be taken to extend pump discharge lines riverward far enough to not cause erosion of the levee. On 12-inch or larger lines substantial anchorage is required. These pumps must not be operated on slopes greater than 20 degrees from horizontal.

D) **Sanitary Sewage Pumping**. During high water, increased infiltration into sanitary sewers may necessitate increased pumping at the sewage treatment plant or at manholes at various locations to keep the system functioning. To estimate the quantity of sewage, allow 100 gallons per capita per day for sanitary sewage and an infiltration allowance of 15,000 gallons per mile of sewer per day. In some cases, it will be necessary to pump the entire amount of sewage, and in other cases

only the added infiltration will have to be pumped to keep a system in operation.

Example: Estimate pumping capacity required at an emergency pumping station to be set up at the first manhole above the sewage treatment plant for a city of 5,000 population and approximately 30 miles of sewer (estimated from map of City). In this case, it is assumed that the treatment plant will not operate at all.

Computation:

Required capacity = (infiltration) + (sewage)

Sewage: $\dfrac{\text{5000 per x 100 g/per/day}}{\text{24 hrs x 60 min}}$ = 347 gpm

Infiltration : $\dfrac{\text{15000 g/mi/day x 30 mi}}{\text{24 hrs x 60 min}}$ = 312 gpm

Required pumping capacity: 659 gpm. From Table 3, use one 4-inch pump or its equivalent.

TABLE NO. 1

Matching Pipe Size to Pump Size

Sewer Pipe Size	Probable Required Pump Size
6 inch	2 inch
8 inch	2 to 3 inch
10 inch	3 to 4 inch
12 inch	4 to 6 inch
15 inch	6 to 8 inch
18 inch	6 to 10 inch
21 inch	8 to 10 inch
24 inch	10 to 12 inch

TABLE NO. 2

Crisafulli Pumps — Model CP 2” to 24”

Size	Gal Per Min	Head	Elec. H.P.	Gas or Diesel H.P.
2"	150		1	
4"	500		7.5	15
6"	1000		10	20
8"	3000	10'	15	25
12"	5000		25	40
16"	9500		40	65
24"	25000		75	140
Size	Gal Per Min	Head	Elec. H.P.	Gas or Diesel H.P.
2"	130		1	
4"	490		10	20
6"	850		15	25
8"	2450	20'	20	35
12"	3750		30	50
16"	8000		45	85
24"	19000		100	190
Size	Gal Per Min	Head	Elec. H.P.	Gas or Diesel H.P.
2"	120		1	
4"	475		12	25
6"	795		20	35
8"	2150	30'	25	45
12"	3450		35	70
16"	7100		60	125
24"	16600		125	250

(Use high head pumps for heads over 20’)

TABLE NO. 3

Marlow Self Priming Centrifugal Pumps

Size	AGC Rating*	Capacity**	Horsepower
1-1/2"	4M	67 gpm	1.8 hp
2"	7-10M	117-167 gpm	2.3-4.9 hp
3"	20-30M	334-500 gpm	4.9-11.2 hp
4"	30-40M	500-665 gpm	20-38.8 hp
6"	90M	1500 gpm	43.5 hp
8"	125M	2080 gpm	62 hp
10"		3330 gpm	62 hp

* *(gallons per hour, thousands)*
** *(at 25 foot head)*

4. **Metal Culverts.**

A) Pumping of ponded water is usually preferable to draining the water through a culvert since the tail water (drainage end of culvert) could increase in elevation to a point higher than the inlet, and water could back up into the area being protected. Installation of a flap gate at the outlet end may be desirable to minimize backup.

B) Table 4 shows the capacity of corrugated pipe culverts on a flat slope, with H factor (head) representing the difference between the headwater level and tail water level, assuming the outlet is submerged. If the outlet is not submerged the head equals the difference in elevation between the head water level and 0.6 of the diameter of the pipe measured from the bottom of the pipe upward. The capacity would change for smooth pipe, pipe laid on a slope, or if headwalls or wing walls are used.

C) If a culvert is desired to pass water from a creek through a levee, a computation of a drainage basin by an engineer is required to determine pipe size.

5. **Preventing Backflow in Sewer Lines.**

A) Watertight sluice gates or flap gates are one answer. Emergency stoppers may be constructed of lumber, sandbags, or other materials, using poly as a seal, preferably placed on the discharge end of the outfall pipe.

B) Plates **6-7** illustrate methods of sealing off the outlet openings of a manhole with standard materials which are normally available so that the manhole may be used as an emergency pumping station.

TABLE 4

Capacity of Corrugated Metal Pipe Culverts
Without Headwalls and With Outlet Submerged
(outlet control-full flow)
(Circular)

Length = 20 Feet

Diameter in Inches	CUBIC FEET PER SECOND (Head on Pipe in Feet)																
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.8**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
12	1.0	1.4	1.7	2.0	2.2	2.4	2.8	3.1	3.4	3.7	4.0	4.2	4.4	5.0	5.4	5.8	6.2
15	1.7	2.4	2.9	3.4	3.8	4.1	4.8	5.3	5.8	6.3	6.8	7.1	7.5	8.4	9.2	9.9	11
18	2.6	3.6	4.4	5.2	5.7	6.2	7.2	8.0	8.8	9.5	10	11	11	13	14	15	16
21	3.6	5.1	6.2	7.2	8.0	8.8	10	11	12	13	14	15	16	18	19	21	22
24	4.9	6.8	8.4	9.6	11	12	14	15	17	18	19	20	21	24	26	28	30
27	6.2	8.8	11	12	14	15	18	20	21	23	25	26	28	31	34	36	39
30	7.8	11	14	16	17	19	22	25	27	29	32	33	35	39	42	46	49
36	12	16	20	23	26	28	33	37	40	43	46	49	52	57	63	68	72
42	16	23	28	32	36	39	45	51	55	60	64	68	71	79	86	93	100
48	22	30	37	43	48	52	60	68	74	80	85	90	94	106	117	125	134
54	28	39	48	55	61	67	78	87	94	102	109	116	121	136	149	160	171
60	34	48	59	68	76	83	96	107	118	126	134	142	150	167	182	197	210

Length = 40 Feet

Diameter in Inches	CUBIC FEET PER SECOND (Head on Pipe in Feet)																
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.8**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
12	0.8	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.8	3.0	3.2	3.4	3.6	4.0	4.4	4.8	5.1
15	1.4	1.9	2.4	2.7	3.1	3.4	3.9	4.3	4.8	5.2	5.5	5.9	6.2	6.9	7.6	8.2	8.8
18	2.1	3.0	3.7	4.3	4.8	5.2	6.0	6.8	7.4	8.0	8.6	9.0	9.6	11	12	13	14
21	3.0	4.3	5.3	6.1	6.8	7.4	8.6	9.6	11	12	12	13	14	15	17	18	19
24	4.2	5.9	7.2	8.4	9.4	10	12	13	15	16	17	18	19	21	23	25	27
27	5.5	7.8	9.6	11	12	14	16	17	19	21	22	23	25	28	30	33	35
30	7.0	9.8	12	14	16	17	20	22	24	26	28	30	31	35	36	42	44
36	10	15	18	21	24	26	30	33	36	39	42	45	47	53	58	62	66
42	15	21	26	30	33	36	42	47	51	55	59	62	66	74	80	88	93
48	20	28	35	40	45	49	56	63	69	74	80	84	89	99	109	118	127
54	26	36	45	51	57	63	72	81	89	96	103	109	115	128	140	152	163
60	32	45	55	64	72	78	90	100	110	120	128	136	143	160	175	190	202

Length = 60 Feet

Diameter in Inches	CUBIC FEET PER SECOND (Head on Pipe in Feet)																
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.8**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
12	0.7	1.0	1.2	1.4	1.6	1.7	2.0	2.2	2.4	2.6	2.8	2.9	3.1	3.5	3.8	4.1	4.4
15	1.2	1.7	2.1	2.4	2.7	3.0	3.4	3.8	4.2	4.5	4.8	5.1	5.4	6.0	6.6	7.1	7.6
18	1.9	2.7	3.3	3.8	4.2	4.6	5.3	5.9	6.5	7.0	7.5	8.0	8.4	9.3	10	11	12
21	2.7	3.9	4.8	5.5	6.1	6.6	7.7	8.7	9.5	10	11	12	12	14	15	16	17
24	3.8	5.4	6.6	7.6	8.4	9.2	11	12	13	14	15	16	17	19	21	22	24
27	5.0	7.1	8.7	10	11	12	14	16	17	19	20	21	22	25	27	29	31
30	6.4	9.0	11	13	14	16	18	20	22	23	25	27	28	32	35	37	40
36	9.7	14	17	19	22	24	27	31	33	36	38	41	43	48	52	56	60
42	14	19	24	28	31	34	39	44	48	51	55	58	61	68	74	80	86
48	19	27	32	38	42	46	53	59	64	69	74	78	82	92	100	108	116
54	24	34	42	48	54	59	68	77	83	90	96	102	108	120	131	142	152
60	31	43	53	61	68	74	86	97	105	113	120	128	135	150	166	178	190

IV. FLOOD FIGHT PROBLEMS

1. **General.** Problem situations which arise during a flood fight are varied and innumerable. The problems covered below and in "Emergency Interior Drainage Treatment" are those which are considered most critical to the integrity of the flood barrier system. It would be impossible to enumerate all of the problems, such as supplies, personnel, communication, etc., which field personnel must handle. The most valuable asset of field personnel under emergency conditions is their common sense. Many problems can be solved instantly and with less effort through the application of good common sense and human relations. Problems, such as those below, can be identified early only if a well organized levee patrol system with a good communication system exists. The problems are presented with the assumption that high water is on the levee slopes.

2. **Overtopping.** Overtopping of a levee is the flowing of water over the levee crown. Since most emergency levees are of an urban nature, overtopping should be prevented at any cost. Over topping will generally be caused by:

   A) unusual hydrologic phenomena which causes a much higher stage than anticipated;

   B) insufficient time in which to complete the flood barrier;

   C) unexpected settlement of the barrier.

   Generally, the flood barriers are constructed 2 feet above the crest prediction. If the crest prediction is raised during construction, additional height must be added to the barrier, increased predictions or settlement will call for some form of capping. Capping should be done with earth fill or sandbags, using normal construction procedures.

3. **Seepage.** Seepage is percolation of water through or under a levee, generally appearing first at the landside toe. Seepage through the levee is applicable only to a relatively previous section. Seepage, as such, is generally not a problem unless:

   A) the landward levee slope becomes saturated over a large area;

   B) seepage water is carrying material from the levee; or

   C) pumping capacity is exceeded.

   Seepage which causes severe sand boils and piping is covered below. Seepage is difficult to eliminate, and attempts to do so may create a much more severe condition. Pumping of seepage should be held to a minimum, based on the maximum ponding elevation without damages. Seepage should be permitted if no apparent ill-effects are observed, and if adequate pumping capacity is available. If seepage causes sloughing of the landward slope, it should be flattened to a 1V on 4H maximum. Material for flattening should be at least as pervious as the embankment material.

4. **Sand Boils.**

A) **Description.** A sand boil is the rupture of the top foundation stratum landward of a levee caused by excess hydrostatic head in the substratum. Even when a levee is properly constructed and of such mass to resist the destructive action of floodwater, water may seep through a sand or gravel stratum under the levee and break through the ground surface on the landside in the form of bubbling springs. When such eruptions occur, a stream of water bursts through the ground surface, carrying with it a volume of sand or silt which is distributed around the hole. A sand boil may eventually discharge relatively clear water, or the discharge may contain quantities of sand and silt, depending upon the magnitude of pressure and the size of the boil. They usually occur within 10 to 300 feet from the landside toe of the levee, and in some instances have occurred up to 1,000 feet away.

B) **Destructive Action.** Sand boils can produce three distinctly different effects on a levee, depending upon the condition of flow under the levee.

C) **Piping Flow.** Piping is the active erosion of subsurface material as a result of substratum pressure and concentration of seepage in the localized channels. The flow breaks out at the landside toe in the form of one or more large sand boils. Unless checked, this flow causes the development of a cavern under the levee, resulting in the subsidence of the levee and possible overtopping. This cause can be easily recognized by the slumping of the levee crown.

D) **Non-Piping Flow.** In this case, the water flows under pressure beneath the levee without following a defined path, as in the case above. This flow results in one or more boils outcropping at or near the landside toe. The flow from these boils tends to undercut and ravel the landside toe, resulting in sloughing of the landward slope. Evidence of this type of failure is found in undercutting and raveling at the landside toe.

E) **Saturating Flow.** In this case, numerous small boils, many of which are scarcely noticeable, outcrop at or near the landside toe. While no boil may appear to be dangerous in itself, the consequence of the group of boils may cause flotation (“quickness”) of the soil, thereby reducing the shearing strength of the material at the toe, where maximum shearing stress occurs, to such an extent that failure of the slope through sliding may result.

F) **Combating Sand Boils.** All sand boils should be watched closely, especially those within 100 feet of the toe of the levee. All boils should be conspicuously marked with flagging so that patrols can

locate them without difficulty and observe changes in their condition. A sand boil which discharges clear water in a steady flow is usually not dangerous to the safety of the levee. However, if the flow of water increases and the sand boil begins to discharge material, corrective action should be undertaken immediately. The accepted method of treating sand boils is to construct a ring of sandbags around the boil, building up a head of water within the ring sufficient to check the velocity of flow, thereby preventing further movement of sand and silt. See Plate **5** for technique in ringing a boil. Actual conditions at each sand boil will determine the exact dimensions of the ring. The diameter and the height of the ring depends on the size of the boil and the flow of water from it. In general, the following considerations should control:

1) the base width of the sandbag section should be no less than 1 ½ times the contemplated height;

2) include weak ground near the boil within the ring;

3) the ring should be a sufficient size to permit stacking operations to keep ahead of the flow of water.

The height of the ring should only be necessary to stop movement of soil, and not as high as to completely eliminate seepage. The practice of carrying the ring to the river elevation is not necessary and may be dangerous in high stages. If seepage flow is completely stopped, a new boil will likely develop beyond the ring; this boil could then suddenly erupt and cause considerable damage. Where many boils are found to exist in a given area, a ring levee of sandbags should be constructed around the entire area and, if necessary, water should be pumped into the area to provide sufficient weight to counterbalance the upward pressure.

5. **Erosion.** Erosion of the riverside slope is one of the most severe problems which will be encountered during a flood fight. Emergency operations to control erosion have been presented earlier under “Slope Protection.”

6. **Storm and Sanitary Sewers.**

A) **Problems.** Existing sewers in the protected area may cause problems because of seepage into the lines, leakage through blocked outlets to the river, manhole pumps not spread throughout the sewer system, and old or abandoned sewer locations which were not found during pre-flood preparations. Any of these conditions can cause high pressures in parts of the sewer system and lead to the collapse of lines at weak points and blowing off of manhole covers.

B) **Solutions.** During the flood fight, continued surveillance of possible sewer problems is necessary. If the water level in a manhole approaches the top, additional pumps in manholes may alleviate the problem. In sanitary sewers, additional pumping may be required at various locations in the system to provide continued service to the homes in the protected area. When pumps are not available, manholes may have to be ringed with sandbags or by some other method which allows the water to head up above the top of the manhole. To eliminate the problem of disposing of this leakage from manholes, the ring dike would have to be raised above the river water surface elevation. This creates high pressures on the sewer and should not be done. As with sand boils, it is best to ring the manhole part way to reduce the head and dispose of what leakage occurs. Directly weighing down manhole covers with sandbags or other items is not recommended where high heads are possible. A 10-foot head on a manhole cover 2 feet in diameter would exert a force of 2,060 lbs. Thus, a counterweight of more than a ton would have to be placed directly on the cover.

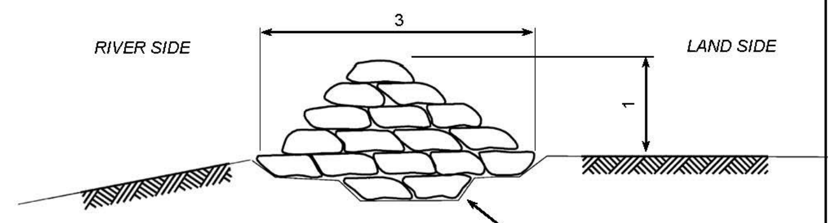
7. **Causes of Levee Failures.** In addition to the problems covered above, the following conditions could contribute to failure:

A) Joining of a levee to a solid wall, such as concrete or piling.

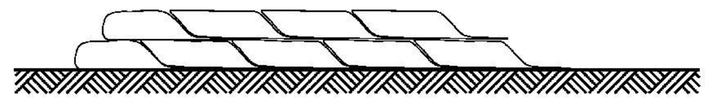
B) Structures projecting from the riverside of levee.

C) A utility line crossing or a drain pipe through the fill.

D) Tops of stop logs on roads or railroad tracks at a lower elevation than the levee.



DIKE SECTION



METHOD OF LAPPING SACKS

DIKE HEIGHT	NUMBER OF SANDBAGS REQUIRED FOR LENGTH OF DIKE									
	50 FT	100 FT	150 FT	200 FT	250 FT	300 FT	400 FT	500 FT	750 FT	1000 FT
1 FT	300	600	900	1,200	1,500	1,800	2,400	3,000	4,500	6,000
2 FT	1,050	2,100	3,150	4,200	5,250	6,300	8,400	10,500	15,750	21,000
3 FT	2,250	4,500	6,750	9,000	11,250	13,500	18,000	22,500	33,750	45,000
4 FT	3,900	7,800	11,700	15,600	19,500	23,400	31,200	39,000	58,500	78,000

NOTES:

1. START UPSTREAM.
2. STRIP SOD BEFORE LAYING.
3. ALTERNATE DIRECTION OF SACKS WITH BOTTOM LAYER PARALLEL TO FLOW.
4. NEXT LAYER PERPENDICULAR TO FLOW, ETC.
5. LAP UNFILLED PORTION UNDER NEXT SACK.
6. TYING OR SEWING SACKS NOT NECESSARY.
7. TAMP THOROUGHLY IN PLACE, SACKS SHOULD BE APPROXIMATELY ½-FULL OF SAND.

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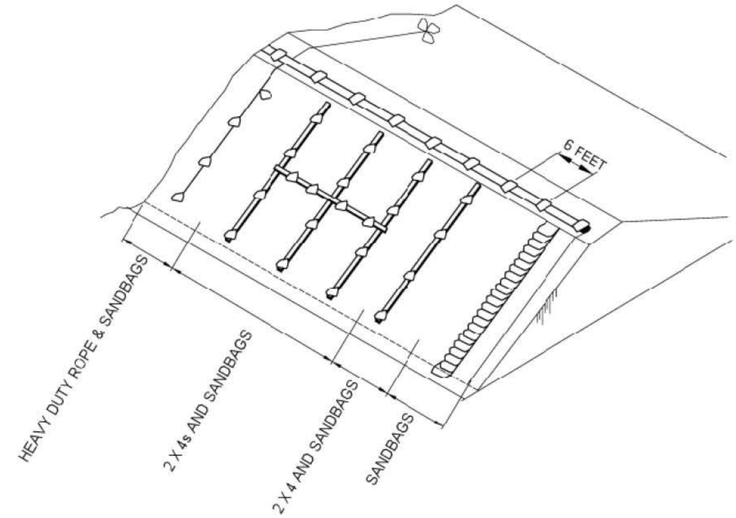
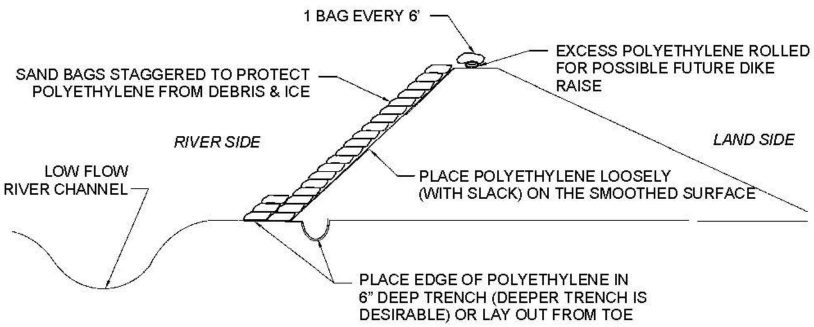
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD FOR
SANDBAG LEVEE CONSTRUCTION

Plate 1



ONE METHOD OF ANCHORING POLYETHYLENE IN THE DRY



SECTION

RECOMMENDED POLYETHYLENE

1st - 6 MIL BLACK
2nd - 6 MIL CLEAR
3rd - 4 MIL BLACK
4th - 4 MIL CLEAR
5th - 2 MIL BLACK OR CLEAR USE AS A LAST RESORT

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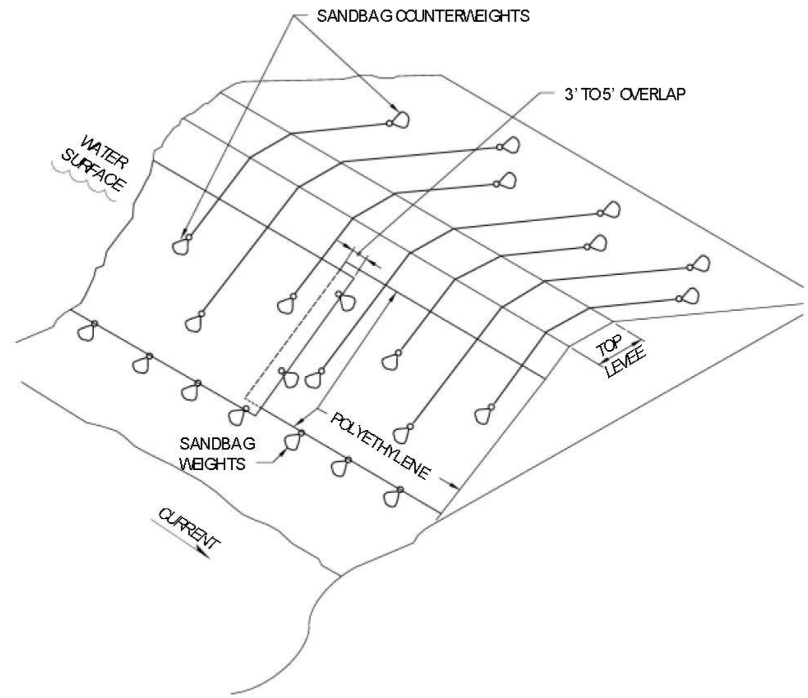
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD FOR
PLACEMENT OF POLYETHYLENE SHEETING ON TEMPORARY LEVEES (WHEN PLACED IN THE DRY)

Plate 2



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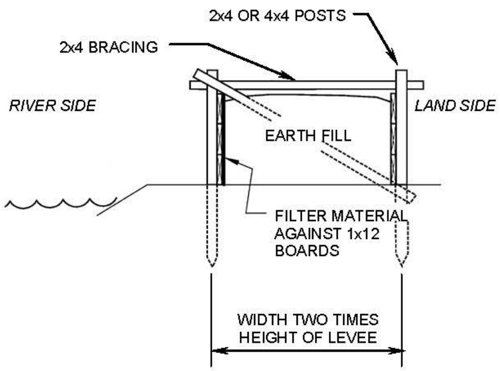
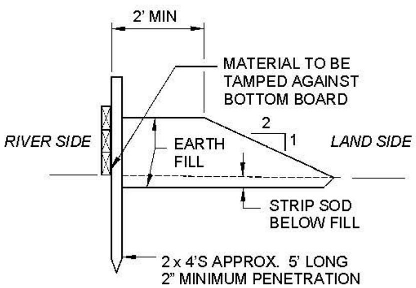
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD FOR
PLACEMENT OF POLYETHYLENE SHEETING ON TEMPORARY LEVEES (WHEN PLACED IN THE WET)

Plate 3



BOX LEVEE (2)



FLASH BOARD LEVEE (1)

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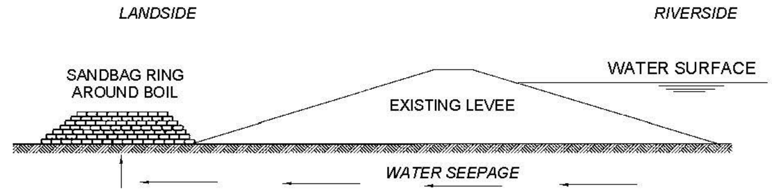
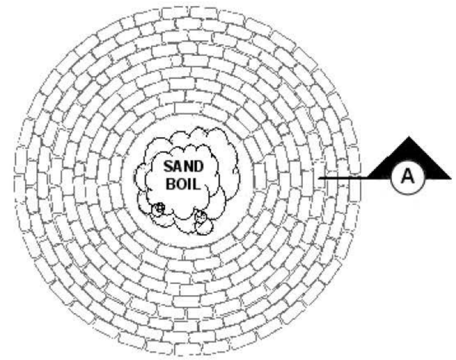
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED DESIGN FOR TEMPORARILY
RAISING LEVEE HEIGHTS USING
FLASHBOARDS AND BOX LEVEES

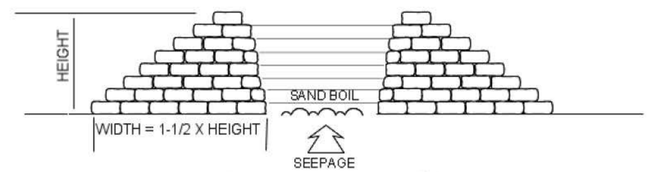
Plate 4



ELEVATION



PLAN VIEW



SECTIONAL ELEVATION (A)

NOTES:

1. BOTTOM WIDTH TO BE NO LESS THAN 1-1/2 TIMES THE HEIGHT. TIE INTO LEVEE IF BOIL IS NEAR TOE.
2. ENTIRE BASE TO BE CLEARED AND SCARIFIED.
3. LOOSE EARTH TO BE USED BETWEEN ALL SACKS.
4. ALL JOINTS TO BE STAGGERED.

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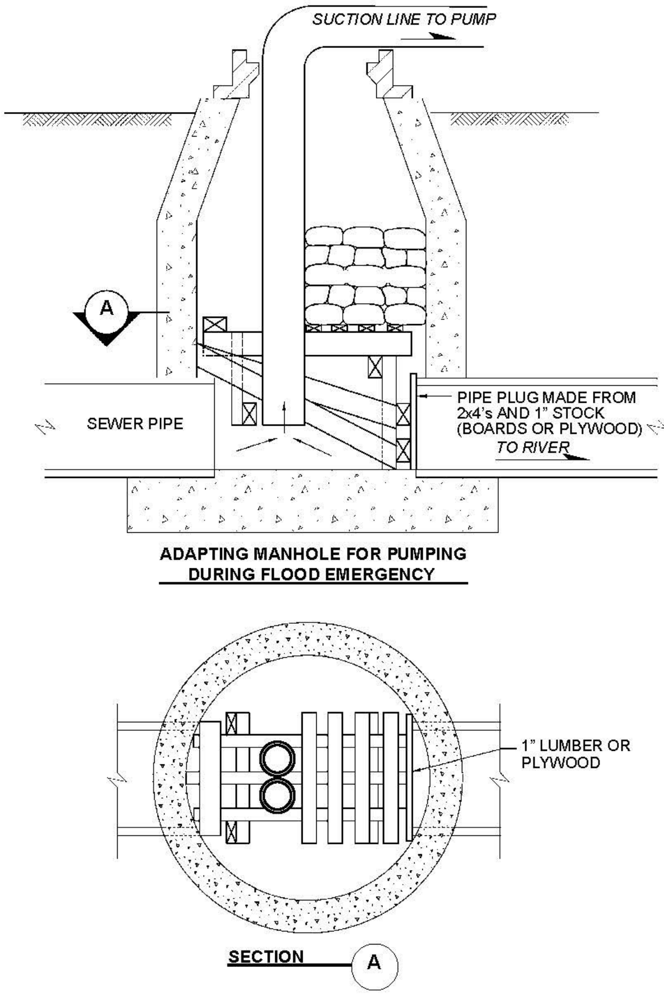
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD FOR
RINGING SAND BOILS

Plate 5



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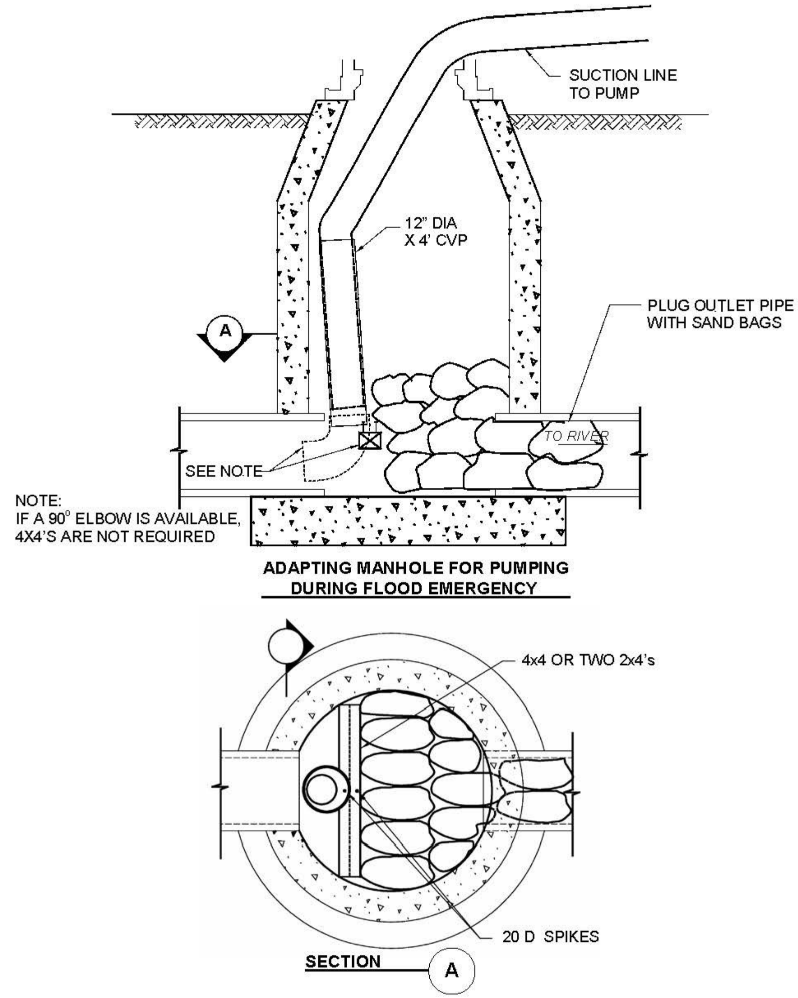
EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD FOR
ADAPTING MANHOLE FOR PUMPING
(METHOD 1)

Plate 6



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EMERGENCY FLOOD CONTROL ACTIVITIES
RECOMMENDED METHOD FOR
ADAPTING MANHOLE FOR PUMPING
(METHOD 2)

Plate 7

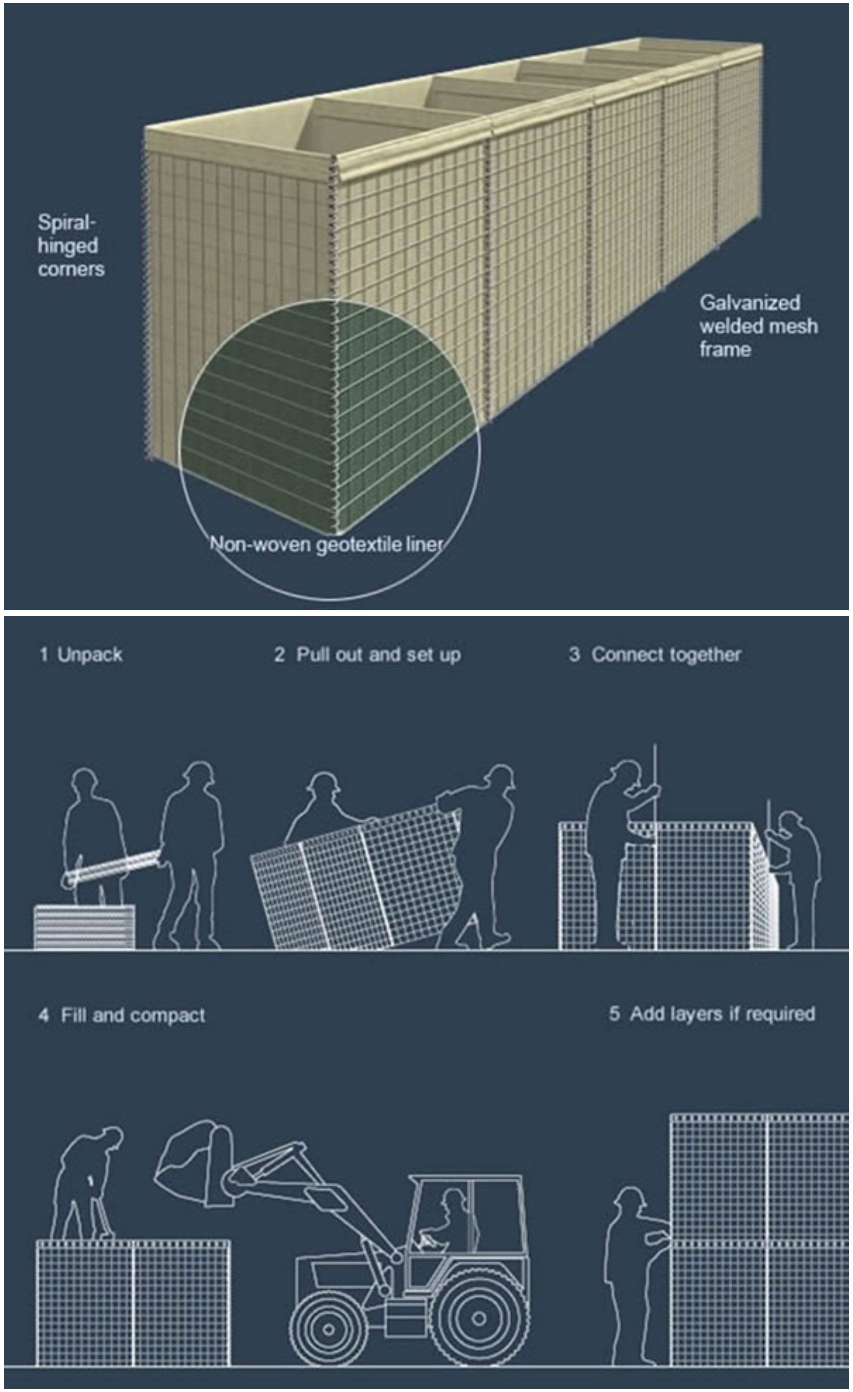

Plate 8: Hesco Bastion

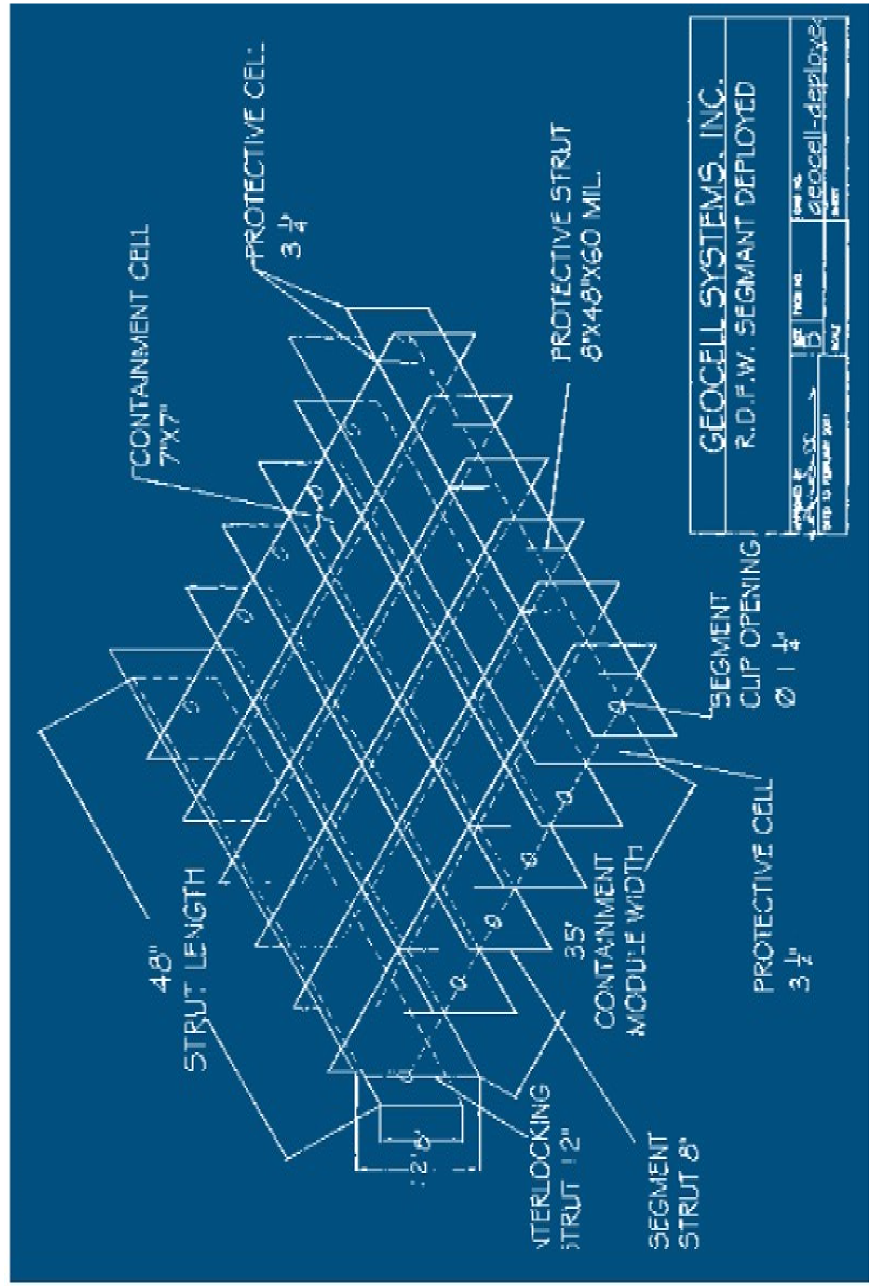

Plate 9: Rapid Deployed Floodwall

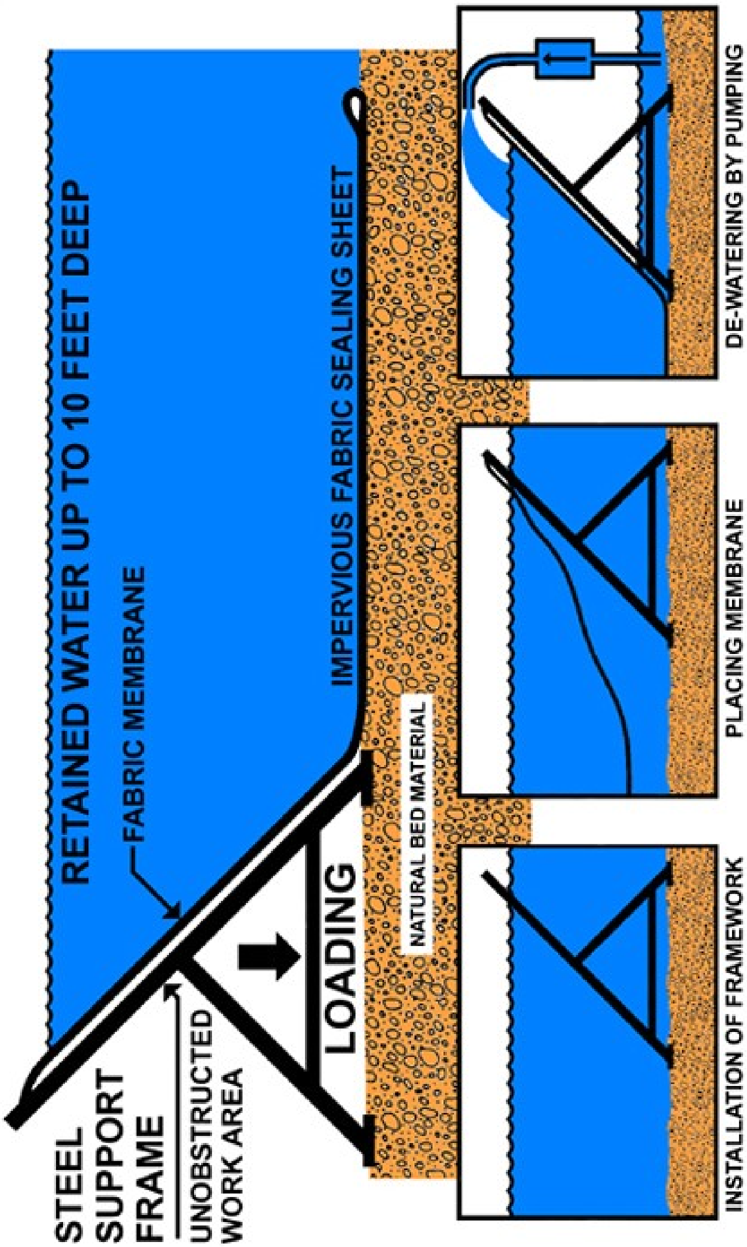

Plate 10: Port-a-dam

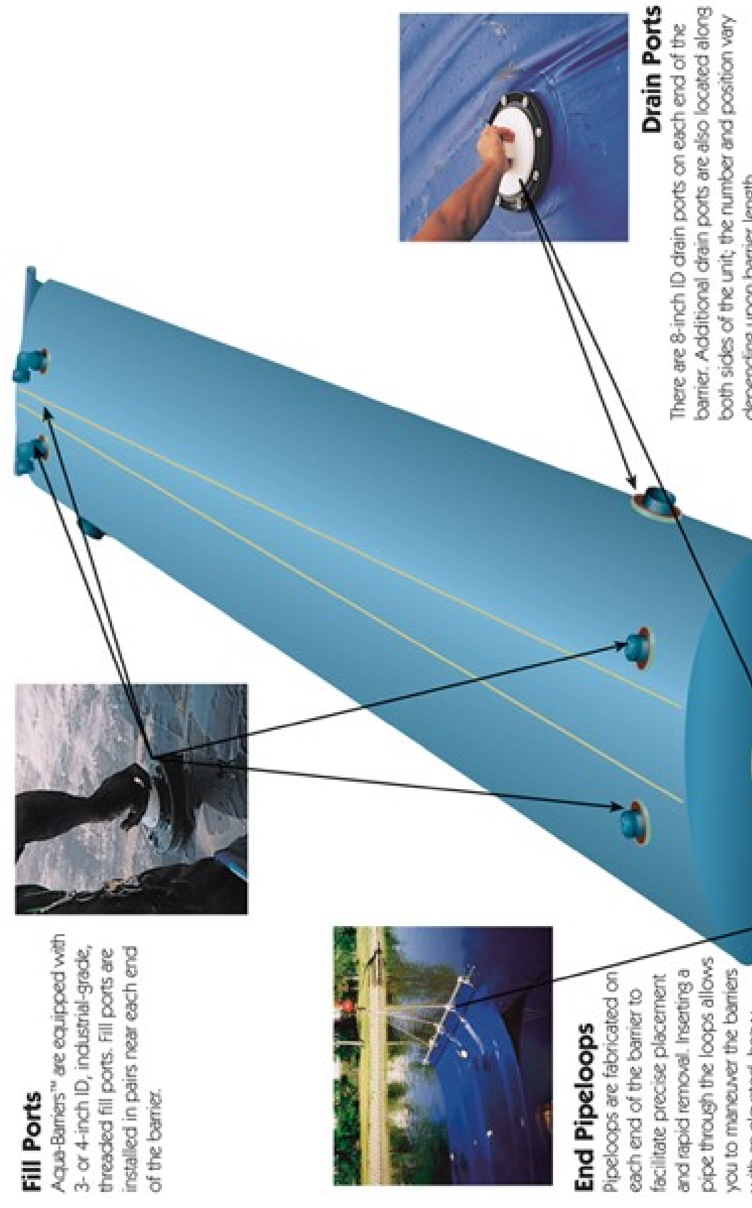

Plate 11: Aqua–Barrier

Plate 12: Mechanical Sandbagger

APPENDIX B - SURVEILLANCE AND MONITORING

I. DEFINITIONS

1. **<u>High flow emergency</u>** - The high flow emergency level indicates that flooding is occurring on the river system, but there is no apparent threat to the integrity of the dam/levee system. The high flow emergency level is used by the dam/levee system owner to convey to outside agencies that downstream areas may be affected by the project's release. USACE water management policies and procedures are to be used for external communications of flood conditions resulting from a high flow operational release. Dam/Levee safety and water management communications must be closely coordinated in situations where high flow operational releases are either warranted in response to a dam/levee safety emergency or coincide with a dam/levee safety emergency.

2. **<u>Non-breach emergency</u>** - The non-breach emergency level is appropriate for an event at a dam/levee that will not, by itself, lead to a breach, but requires investigation, increased monitoring/mitigation, and notification of internal and/or external personnel. The project owner/operator's primary goal is to communicate risk and response activities within the USACE chain of command. The need to perform external communication is situational, based on level of awareness through unofficial channels. Internal dam/levee safety, and possibly emergency management status, is elevated. Upward internal reporting is required.

3. **<u>Potential breach emergency</u>** - The potential breach emergency level indicates that conditions are developing at the dam/levee that could lead to breach. Potential breach should convey that time is available for analyses, decisions, and actions before the dam/levee could fail. The project owner's/operator's primary goals are to intervene to attempt to prevent breach and to communicate risk to downstream or leveed area stakeholders. Upward internal reporting and external communication are required.

4. **<u>Imminent breach emergency</u>** - The imminent breach emergency level indicates time has run out and the dam/levee has breached, is breaching, or is about to breach. Imminent breach typically involves a continuing and progressive loss of material from the dam/levee. It is not usually possible to determine what a complete breach will take to develop. Therefore, once a decision is made there is no time to prevent a breach, the imminent breach emergency warning must be issued. The primary goal is to communicate risk to downstream or leveed area stakeholders. Upward internal reporting and external communication are required.

Chart 1. Boils and Piping (Landside) for Levees

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	New seepage. There is a new wet or soft area on the downstream embankment slope or vicinity of the embankment toe that is not normal or has not been previously documented.	• Observe periodically. • Verify seepage water is clear and does not move material. • Confer with USACE.	• Size and location • Time condition noted • Quantity of puddled water and runoff	In most cases, minor wet areas are caused by precipitation or controlled seepage during high pool levels. However, serious seepage problems may be detected early by discerning observations.
Non-Breach Emergency	Boils/Heavy seepage. Concentrated seeps, or boils that stabilize with clear flowing water. Boil activity appears to be limited to shallow strata.	• Monitor entire embankment frequently. • Confer with USACE and control seepage by appropriate remedial measures (remedial measures may include ringing the area with sandbag or earthen dike, inverted filter over the area, pumping existing relief wells, or installing well points or other new system to relieve subsurface water pressures)	• Size and location • Time condition noted • Flow rate estimate • Status and condition of remedial measures	During flood stages, seepage areas must be monitored frequently as outlined in the surveillance plan.
Potential Breach Emergency	Piping. Active boils removing material from foundation or embankment and causing subsidence. Cloudy or muddy water and increasing flow rates.	• Monitor entire embankment frequently. • Investigate flow at upstream entrance. • Place inverted filter over downstream outlet of piping.	• Size and location • Time condition noted • Flow rate estimate • Status and condition of remedial measures	Distress is large enough that sandbag dikes will likely be ineffective. Inverted filters are the recommended remedial action.
Imminent Breach Emergency	Severe Piping/Subsidence. Large boils carrying material at an increasing rate, with a vortex.	• Monitor levee and downstream area for seepage, sinkholes, boils, vortex, etc. • Locate upstream entrance and attempt to reduce flow • Place inverted filter over downstream outlet of piping	• Size and location • Time condition noted • Flow rate estimate • Status and condition of remedial measures	The embankment is susceptible to catastrophic subsidence, and safety of workers is a concern.

Chart 2. Erosion (Riverside Slope) for Levees

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	Observed distress to riprap or revetments while under normal pool level and outflow conditions.	Observe periodically. Coordinate repair work with USACE. Confirm extent of failure zone.	• Location and dimensions of distress • Wave action associated with cause	
Non-Breach Emergency	Embankment revetment is displaced. Erosion is evident by caving or ground loss.	Place rock and bedding from emergency stockpiles.	• Location and dimensions of distress • River levels • Wind conditions	Approach cautiously and check for erosion below waterline.
Potential Breach Emergency	Embankment revetment is displaced during flood conditions. Erosion is evident by caving or ground loss. Progressive erosion threatens levee failure.	Place rock from emergency stockpile. Consider self launching rock berms.	• Photographs • Dimensions of ground loss • River levels • Wind conditions	Erosion below water line could cause sudden slides, and is dangerous to personnel and equipment.
Imminent Breach Emergency	Extensive erosion is threatening a slide failure that would result in overtopping the levee.	Attempt to place rock from emergency stockpile.	• Photographs • Dimensions of ground loss • River levels • Wind conditions	Erosion below water line could cause sudden slides, and is dangerous to personnel and equipment.

Chart 3. Slides (Riverside and Landside) for Levees

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	Shallow Sloughing of Topsoil or Riprap - Slide does not threaten the embankment core or crest height, and the cause has been determined. The cause is not related to seepage from the river.	• Observe periodically • Coordinate repair work with USACE. • Confirm extent of failure zone.	• Location • Time first noticed • Water emergence on slope • River elevation • Monitor offset with periodic readings	Slide does not pass through crest and does not extend into the embankment more than 5 ft (measured perpendicular to the slope)
Non-Breach Emergency	Small Localized Slide or Longitudinal Cracking - Crack has formed near the crest, or on the embankment slopes. The crack is open or there is vertical offset.	• Confer with USACE and investigate cause.	• Crack aperture • Length • Growth rate • Location • Offset • Observation times	The cause is unknown or there is potential expansion.
Potential Breach Emergency	Slope Failure Threatens the Embankment Core - Deep seated failure mass encompasses the levee crest, but remnant embankment maintains freeboard about the river level.	• Establish a monitoring program. • Construct stability berm on the downstream toe of the slide.	• Location • Time first noticed • Water emergence on slope • River elevation, • Monitor offset with periodic readings	Stage material and use equipment standby.
Imminent Breach Emergency	Massive Slope Failure - Deep seated failure mass encompasses the levee crest, and remnant embankment is expected to slump below river level.	• Monitor continuously. • Attempt to prevent or delay a breach by constructing a downstream stability berm, relieving seepage pressure, and maintaining freeboard.	• Location, • Time first noticed • Water emergence on slope • River elevation • Monitor lateral offset and crest elevation with periodic readings	• Borrow material from embankment section as necessary to avoid overtopping. • Avoid unnecessary weight addition to upper portion of failure mass. • Consider benching the failure mass to rapidly increase passive resistance and reduce active force.

Chart 4. Transverse Cracking (See Slides for longitudinal cracking) for Levees

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	Discontinuous Crack - Minor crack in crest that does not extend completely through the levee, or minor cracking on the embankment surface.	• Observe periodically. • Report to USACE.	• Location, • Aperture • Depth sounding • Orientation to crest • Pattern/linearity • Continuity • River elevation	Random and transverse cracks can develop during extended dry periods due to desiccation and shrinkage of the soil.
Non-Breach Emergency	Open and Continuous Crack - Crack extends completely through levee. River level and forecast levels are below base of crack.	• Observe constantly until repair work is completed. • Coordinate with USACE. • Trenching and backfilling or other means of filling crack will be required after the extent of the crack is determined.	• Same as above	Large open cracks may be associated with slides, liquefaction, or advanced seepage distress.
Potential Breach Emergency	Water Leakage Through Crack - Crack extends completely though levee. Water is passing through the crack. Erosion od the crack can be prevented or leakage can be plugged with available resources.	• Plug the upstream entrance. Confer with USACE to use appropriate filter materials to minimize failure potential of the plug. • Seal crack.	• Same as above	
Imminent Breach Emergency	Crack Erosion – Leakage intensity is increasing. Crack erosion will initiate formation of a breach. Remedial measures have been ineffective.	• Attempt to prevent or delay a breach by plugging or replugging the upstream entrance.	• Same as above	

Chart 5. Tilting, Sliding, or Settlement of Concrete Structures for Floodwalls

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	There are no significant areas of tilting, sliding, or settlement that would endanger the integrity of the structure.	• Observe periodically. • Report to USACE.	• Time • Location	
Non-Breach Emergency	There are areas of tilting, sliding, or settlement (either active or inactive) that need to be repaired. The maximum offset, either laterally or vertically, does not exceed 2 inches unless the movement can be shown to be no longer actively occurring. The integrity of the structure is not in danger.	• Observe constantly until repair work is completed. • Coordinate with USACE. •	• Time first noticed • Location • Offset	
Potential Breach Emergency	There are areas of tilting, sliding, or settlement (either active or inactive) that threaten the structure's integrity and performance. There is movement that has resulted in failure of the waterstop (possibly identified by daylight visible through the joint). Differential movement of greater than 2 inches between any two adjacent monoliths, either laterally or vertically. Also, if the floodwall is of I-wall construction, then any visible or measurable tilting of the wall toward the protected side that has created an open horizontal crack on the riverside base of a monolith.	• Establish a monitoring program. • Construct a stability berm on the landside.	• Time first noticed • Location • Offset	Stage material and use equipment standby.
Imminent Breach Emergency	There is active tilting, sliding, or settlement that is impacting the structure's integrity and performance. The top of the wall is expected to collapse below the river level.	• Attempt to prevent or delay a breach by constructing a stability berm on the landside.	• Time first noticed • Location • Offset	Safety of workers is a concern.

Chart 6. Seepage and Monolith Joints for Floodwalls

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	• No evidence or history of unrepaired seepage, saturated areas, or boils. • The joint material is in good condition. The exterior joint sealant is intact and cracking/ desiccation is minimal. Joint filler material and/or waterstop is not visible at any point.	• Observe periodically. • Verify seepage water is clear and does not move material. • Confer with USACE.	• Size and location • Time condition noted • Quantity of puddled water and runoff	In most cases, minor wet areas are caused by precipitation or controlled seepage during high pool levels. However, serious seepage problems may be detected early by discerning observations.
Non-Breach Emergency	• Evidence or history of minor unrepaired seepage or small saturated areas at or beyond the landside toe but not on the landward slope of levee. No evidence of soil transport. • The joint material has appreciable deterioration to the point where joint filler material and/or waterstop is visible in some locations.	• Monitor entire wall frequently. • Confer with USACE and control seepage by appropriate remedial measures. This needs to be repaired or replaced to prevent spalling and cracking during freeze/ thaw cycles, and to ensure water tightness of the joint.	• Size and location • Time condition noted • Flow rate estimate • Status and condition of remedial measures	During flood stages, seepage areas must be monitored frequently as outlined in the surveillance plan.
Potential Breach Emergency	• Evidence of active seepage, extensive saturated areas, or boils. Evidence of soil transport. • Water leaking through joints.	• Monitor entire wall frequently. • Investigate flow.	• Size and location • Time condition noted • Flow rate estimate • Status and condition of remedial measures	
Imminent Breach Emergency	• Severe piping showing cloudy or muddy water and increasing flow rates.	• Locate upstream entrance and attempt to reduce flow	• Size and location • Time condition noted • Flow rate estimate • Status and condition of remedial measures	Safety of workers is a concern.

Chart 7. Foundation of Concrete Structures for Floodwalls

Emergency Level	Problem (Mechanism and Common Observations)	Corrective Action (Remedial Measures)	Data to be Reported	Remarks
High Flow Emergency	No active erosion, scouring, or bank caving that might endanger the structure's stability.	• Observe periodically. • Coordinate repair work with USACE. • Confirm extent of failure zone.	• Location and dimensions of distress • Wave action associated with cause	
Non-Breach Emergency	There are areas where the ground is eroding towards the base of the structure. Efforts need to be taken to slow and repair this erosion, but it is not judged to be close enough to the structure or to be progressing rapidly enough to affect structural stability before the next inspection. The erosion is not closer than twice the wall's visible height. Additionally, rate of erosion is such that the wall is expected to remain stabile until the next inspection.	Place rock and bedding from emergency stockpiles.	• Location and dimensions of distress • River levels • Wind conditions	Approach cautiously and check for erosion below waterline.
Potential Breach Emergency	Erosion or bank caving observed that is closer to the wall than the limits described above, or is outside these limits but may lead to structural instabilities before the next inspection. Additionally, if the floodwall is of I-wall or sheet pile construction, the foundation is unacceptable if any turf, soil or pavement material got washed away from the landside of the I-wall as the result of a previous overtopping event.	Attempt to place rock from emergency stockpile.	• Photographs • Dimensions of ground loss • River levels • Wind conditions	Erosion below water line could cause sudden slides, and is dangerous to personnel and equipment.
Imminent Breach Emergency	Extensive erosion is threatening a slide failure that would result in overtopping the wall.	Attempt to place rock from emergency stockpile.	• Photographs • Dimensions of ground loss • River levels • Wind conditions	Erosion below water line could cause sudden slides, and is dangerous to personnel and equipment.

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