Technical Report No. IV.

Review of USACE Excavation and Backfill Guidelines and Practices Near Flood Control Structures

Technical Report to

Katrina Canal Breaches Consolidated Litigation

[Civil Action Number: 05-4182 "K" (2)]

United States District Court

Eastern District of Louisiana

Pertains to MR-GO, Robinson [No. 06-2268]

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Synopsis

This report summarizes work performed for the Katrina Canal Breaches Consolidated Litigation (USDC, E.D. La. No. 05-4182 “K”) related to analyses of the failure of the east flood wall of the Inner Harbor Navigation Channel (IHNC) during hurricane Katrina.

This report is organized into three sections:

1) A summary of USACE seepage design guidelines as well as USACE excavation and backfill protocols,

2) Analysis of the decommissioning plans and design analyses for the IHNC navigation lock structure replacement project and determination of adherence to the identified USACE seepage guidelines as well as adherence to USACE excavation and backfill protocols, and

3) A listing of documents reviewed in preparation of this report.

Summary

All USACE design guidelines pertaining to flood protection systems require seepage analyses to be performed as part of design (USACE, 1989; USACE, 1993a; USACE, 1994; and USACE, 2000. The specific criteria in these Engineering Manuals do not specifically state zones of influence for triggering of seepage evaluations, but they clearly demonstrate the intent that any foundation condition that may impact the seepage potential under a levee must be evaluated.

The IHNC Lock Replacement Project required, as part of the site preparation and demolition, the removal of subsurface debris and abandoned utilities. Very limited documentation was available for this review to assess the specific protocols employed during the demolition phase of this project. However, the following conclusions can be reached based on the available information:

1. USACE design guidelines clearly establish the requirement to evaluate seepage impacts on flood control structures as a result of subsurface activity in the proximity of existing flood protection elements;
2. The demolition and excavation activities as part of the IHNC Lock Replacement Project were well-within the zone of influence for existing flood protection elements and change in seepage effects should have been evaluated during the interim construction period between demolition activities and completion of the new flood protection system associated with the new navigation lock. However, no analyses were made available that demonstrated these evaluations were completed as part of the IHNC Lock Replacement Project.

USACE Seepage Guidelines

All USACE design guidelines pertaining to flood protection systems require seepage analyses to be performed as part of design (USACE, 1989; USACE, 1993a; USACE, 1994; and USACE, 2000. The specific criteria in these Engineering Manuals do not specifically state zones of influence for triggering of seepage evaluations, but they clearly demonstrate the intent that any foundation condition that may impact the seepage potential under a levee must be evaluated.

EM 1110-2-1913, Design and Construction of Levees (USACE, 2000):

> *Without control, underseepage in pervious foundations beneath levees may result in (a) excessive hydrostatic pressures beneath an impervious top stratum on the landside, (b) sand boils, and (c) piping beneath the levee itself. Underseepage problems are most acute when a pervious stratum underlies a levee and extends both landward and riverward of the levee and where a relatively thin top stratum exists on the landside of the levee.*

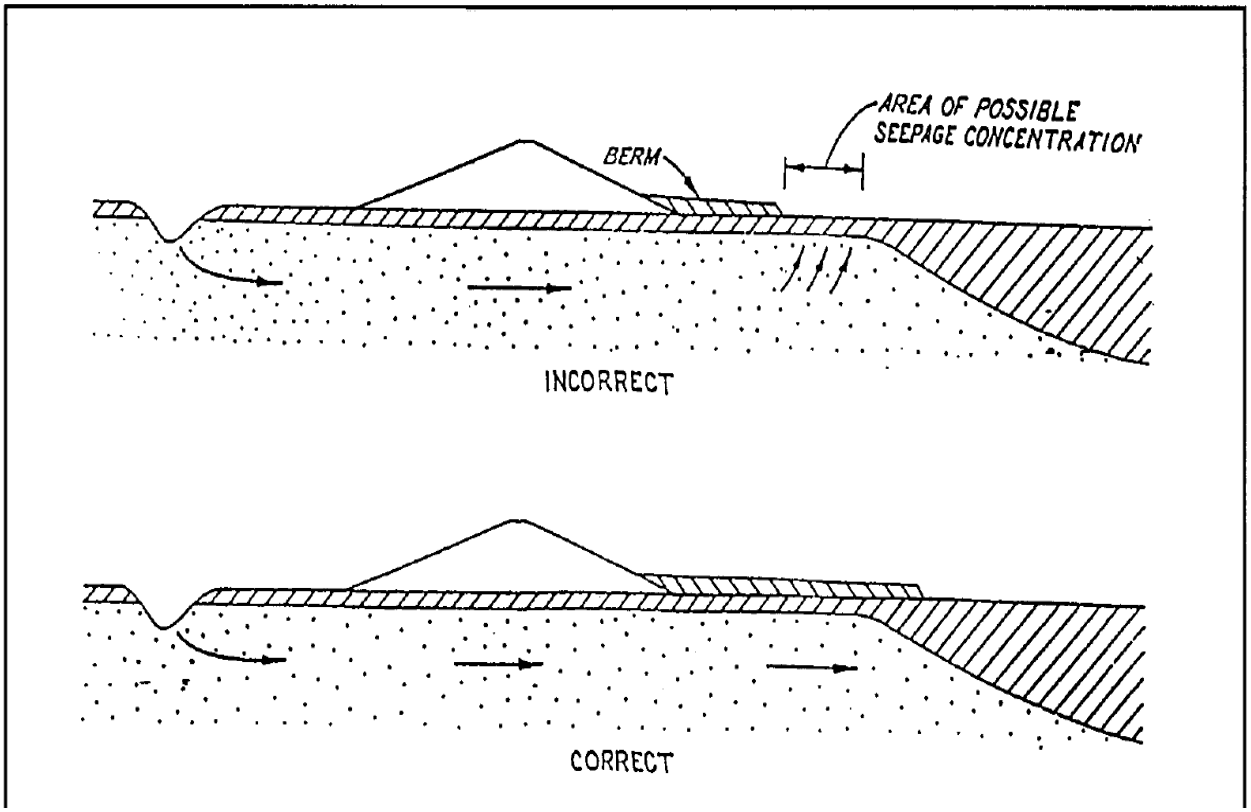


Figure 1.1. The presence of a 'hole' in the 'impermeable' foundation materials on the 'flood side' of the levee requires appropriate mitigation (installation of a landside seepage berm in this example from EM 1110-2-1913). Note that the 'hole' is situated outside the 'footprint' of the levee.

Additional evaluation zones are recommended in EM 1110-2-1913 in Appendix B:

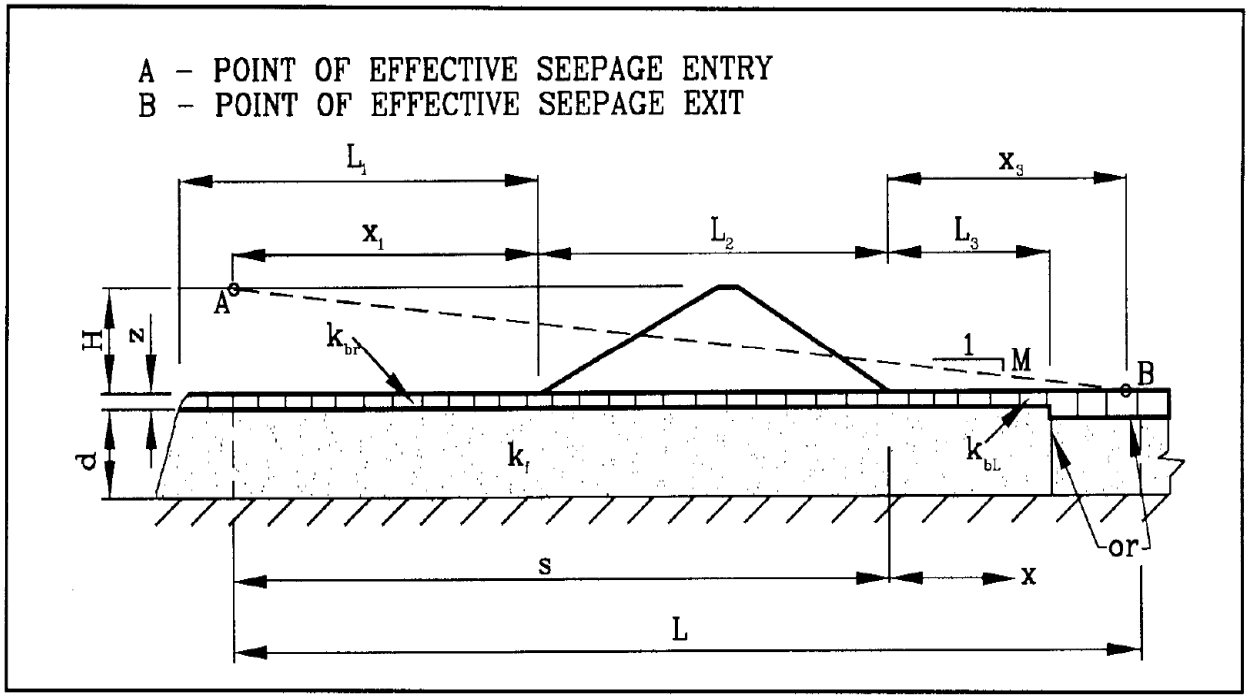


Figure 1.2. Identification of spatial zones judged to influence seepage behavior beneath levees, as outlined in EM 1110-2-1913.

Special conditions, such as pipeline crossings beneath levee footprints are highlighted in EM 1110-2-1923 (USACE, 2000):

> *General. The installation of pipes or other structures within the levee or foundation probably requires the greatest care and closest supervision and inspection of any aspect of levee construction. Most failures of levee systems have initiated at the soil-structure interface and therefore every effort must be made to ensure that these areas are not susceptible to piping. Of overriding importance is good compaction of the backfill material along the structure. (underline added for emphasis) Pipes installed by open trench excavation should be installed in the dry and a dewatering system should be used*

where necessary. Pipes installed by directional drilling, microtunneling, or other trenchless methods requires special consideration.

b. Pipes crossing through or beneath levees

…After the trench has been excavated, it should be backfilled to the pipe invert elevation. In impervious zones, the backfill material should be compacted with mechanical compactors to 95 percent standard density at about optimum water content…First-class bedding should be used for concrete pipe and other rigid pipe, as shown in EM 1110-2-2902, except no granular bedding should be used in impervious zones…Pipes crossing beneath levees also require special consideration. Such crossings should be designed by qualified geotechnical engineers…Penetration through the top stratum of fine-grained materials may concentrate seepage at those locations…

EM 1110-2-2502, Retaining and Flood Walls (USACE, 1989):

<u>General Considerations</u>. Water-retaining structures are subject to through-seepage, underseepage, and seepage around their sides or ends. Seepage control is a primary consideration for flood wall design. Uncontrolled seepage may result in water pressures and uplift forces on the wall base in excess of design assumptions and consequent structural instability…Seepage control entails the design of measures to ensure that seepage pressures and velocities are maintained below tolerable values…As flood walls are usually found on alluvial materials, pervious zones of significant thickness are often present at some depth below relatively impervious top stratum materials and may be hydraulically connected…Because of horizontal stratification of alluvial deposits, the

horizontal permeability may be greatly in excess of the vertical permeability…Underseepage control measures vary because the selection and design of appropriate control scheme is highly dependent on site-specific conditions, particularly the stratification and permeability of foundation materials, availability of right-of-way, and local construction practices and costs.

g. Basements and other Excavations. The seepage aspects and the foundation stability of walls which have had basements excavated on either side of and adjacent to the wall since the original design and construction were completed should be investigated.

EM 1110-2-2504, Design of Sheet Pile Walls (USACE, 1994):

Where seepage occurs, the differential water pressure is dissipated by vertical flow beneath the sheet pile wall. This distribution of the unbalanced water pressure can be obtained from a seepage analysis. The analysis should consider the permeability of the surrounding soil as well as the effectiveness of any drains if present. Techniques of seepage analysis applicable to sheet pile wall design include flow nets, line of creep method, and method of fragments. These simplified techniques may or may not yield conservative results. Therefore, it is the designer's responsibility to decide whether the final design should be based on a more rigorous analysis, such as finite element method. Upward seepage in front of the sheet pile wall tends to reduce the effective weight of the soil, thus reducing its ability to offer lateral support. In pervious material the effects of upward seepage can cause piping of material away from the wall or, in extreme cases, causes the soil to liquefy. Lengthening the sheet pile, thus increasing the seepage path, is one effective method of accommodating seepage. For sheet pile walls that retain backfill,

a drainage collector system is recommended. Some methods of seepage analysis are discussed in EM 1110-2-1901.

EM 1110-2-1901, Seepage Analysis and Control for Dams (USACE, 1993a):

General. All dams on earth foundations are subject to underseepage. Seepage control in earth foundations is necessary to prevent excessive uplift pressures and piping through the foundation…The purpose of the project, i.e., long-term storage, flood control, hydropower, etc., may impose limitations on the allowable quantity of seepage…

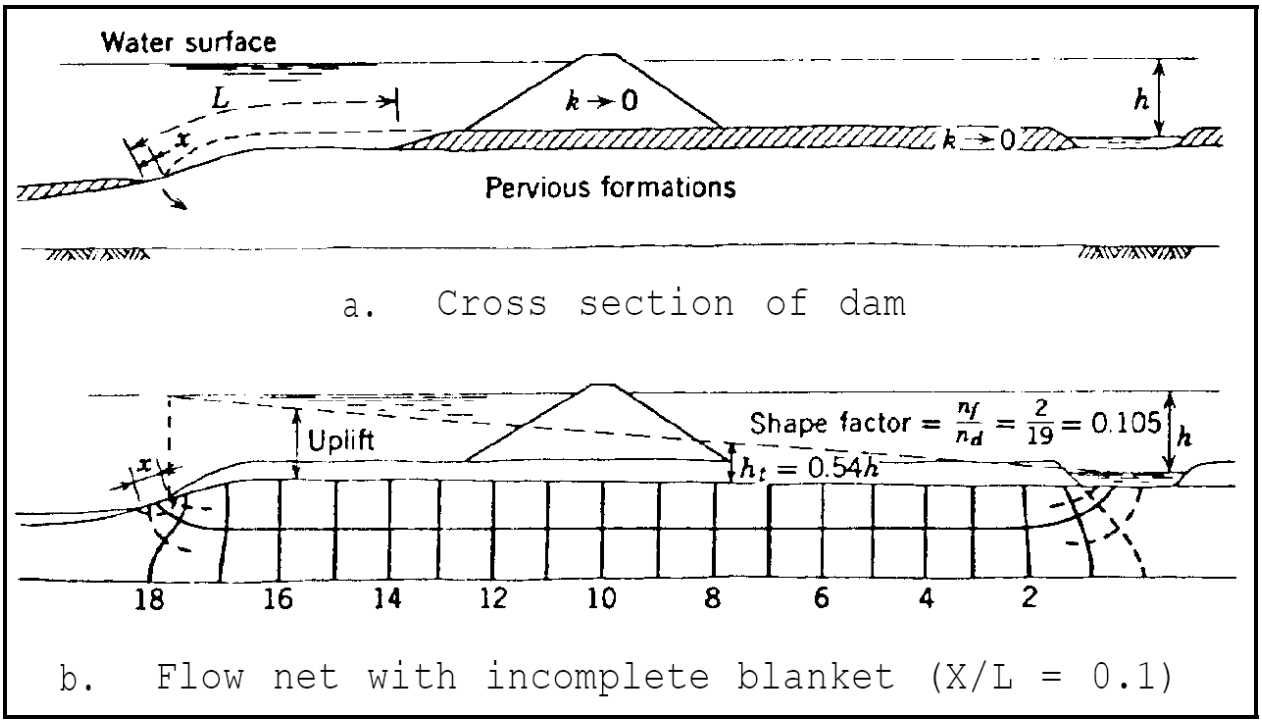


Figure 1.3. The presence of a 'hole' in the 'impermeable' foundation materials on the 'flood side' of the levee requires appropriate analyses (EM 1110-2-1901). Note that the 'hole' is situated significantly outside the 'footprint' of the levee.

Figure 1.3 shows a graphic that the presence of a 'hole' in the 'impermeable' foundation materials on the 'flood side' of a levee requires appropriate analyses.

The Kansas City District of the United States Army Corps of Engineers was found to have guidelines specific to construction activities near existing flood protection structures. Our literature search was unable to find an equivalent guideline for the New Orleans District of the United States Army Corps of Engineers (however, these guides may exist, but may not have been made 'public' for access to non-USACE personnel).

The Kansas City District guidelines state (USACE, 1993b):

> *The sponsor should 'control' all construction on his Flood Protection Unit, especially within the 'critical area.' This is not an attempt to restrict commercial development, since much construction would not be detrimental to the flood protection project if done properly. That construction which would be detrimental to the integrity of the flood protection can be constructed with compensating features. Almost anything can be built if properly designed. In addition, all pipes, lines, and any other below ground structural features within the critical area should comply with special Corps requirements.*

The Kansas City District defines the 'critical area' (USACE, 2008) as:

> *The critical area is generally considered the area from 300 feet riverward to 500 feet landward of a flood control project centerline. In some instances, the critical area is extended beyond 500 feet if any impact on the flood control project can be considered…Local sponsors are responsible for controlling all construction which occurs within the critical area. The Corps of Engineers provides engineering review to ensure that any work within or near the flood control unit does not reduce the level of*

protection and to assure the continued integrity of the flood control system…The designer should verify they have the most recent guidance prior to beginning design. Both the construction and permanent cases should be addressed within the submittal. In general, the designer should address the impact on the flood control project's seepage (through and under), stability (earthen and structural), ponding area storage, hydraulic conveyance (channels, drainage structures, and ditches), restoration of all features to original condition, and maintenance of flood protection within the critical area during construction. The designer should coordinate with the local sponsor and become familiar with features of the flood control project in the vicinity of the proposed work. Common features include earthen embankments, flood walls, stability berms, underseepage berms, rock slope protection, foreshore and landward blankets, pressure relief wells, collector pies, toe drains, drainage structures and ditches, ponding areas, closure structures, pump stations, levee ramps, and levee turnouts.

Only the Kansas City District guidelines (identified as part of our literature review) identified specific protocols with respect to excavation and backfill within critical areas of flood control structures (USACE, 2008). These protocols include the following:

General. Excavation and backfill in the critical area of a flood control project could have a direct impact on the stability of the flood control project. Improper excavation in the levee embankment or in the critical area can create unstable slopes and slope failures, which damage the levee embankment or flood protection structure. Additional damages to the levee embankment or flood protection structure can also be caused by underseepage conditions associated with piping and heave. This removal of material

from the flood control structure foundation (piping) can ultimately produce collapse of a levee embankment or floodwall. All excavation and backfill activities within the critical area are to be reviewed and approved by the COE and the local sponsor before construction begins.

Thus, the USACE guidelines clearly require seepage conditions that may impact a flood control structure to be analyzed and appropriate mitigation efforts implemented should unacceptable seepage gradients be found to exist. This requirement is found in all USACE design guidelines associated with flood control structures and levees.

Overview of IHNC Lock Replacement Project

Partial preliminary plans were available for review from the IPET website (IPET, 2008). The available plans were not complete or comprehensive for the entire project, so the understanding communicated from the available design documents is not he IHNC Lock Replacement Project. Figure 1.4 shows a 300-foot buffer around the existing flood protection I-wall in the eastern area of the IHNC where demolition occurred. Figure 1.5 shows the extents (yellow dashed line) associated with the IHNC Lock Replacement Project design reports and plans available from the IPET website.

Figure 1.6 shows the location of the IHNC Lock Replacement Project design report project limits in relation to the North and South flood wall failures into the Lower Ninth Ward.

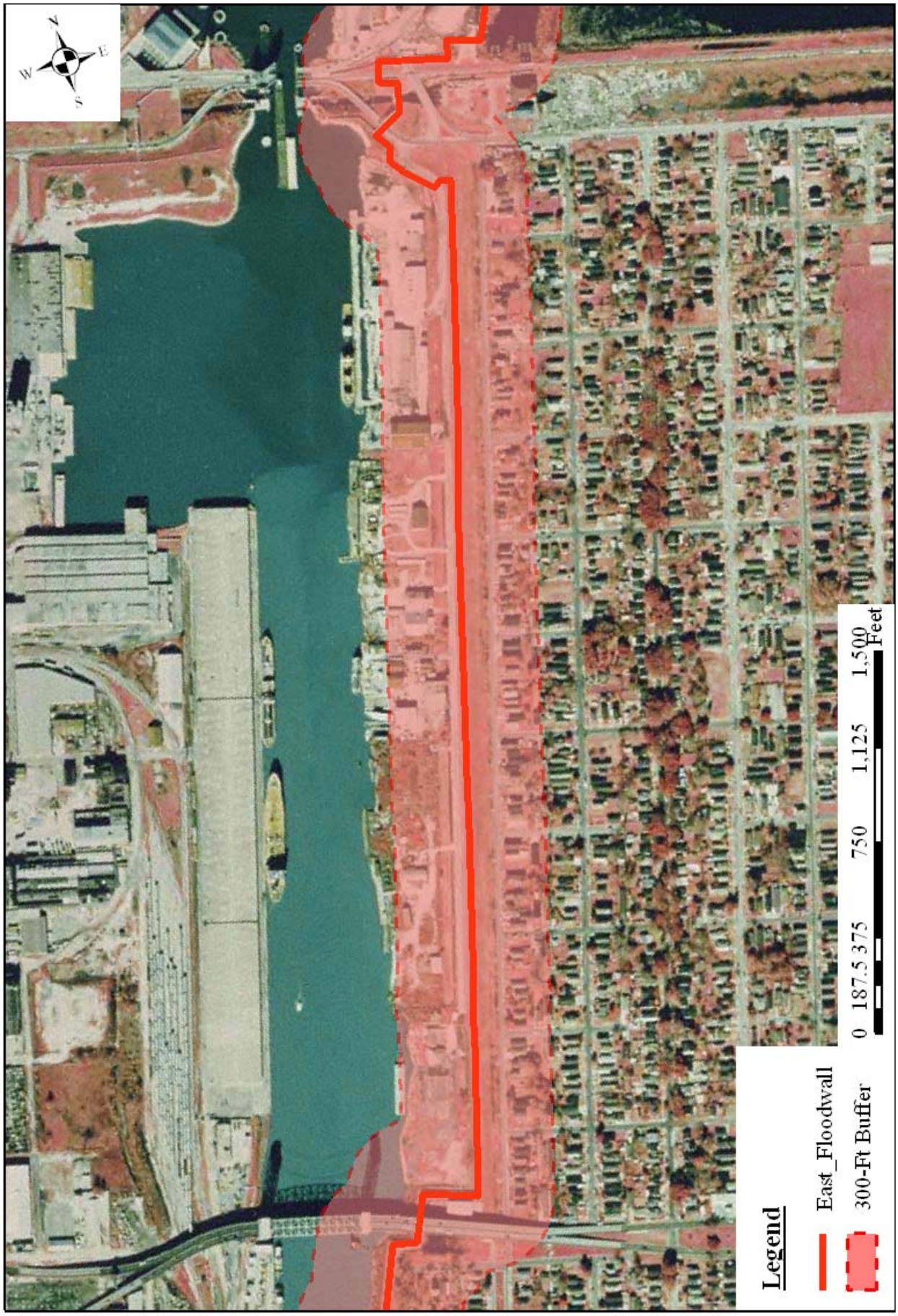


Figure 1.1. Extents of a 300-foot buffer around the existing flood protection I-wall.

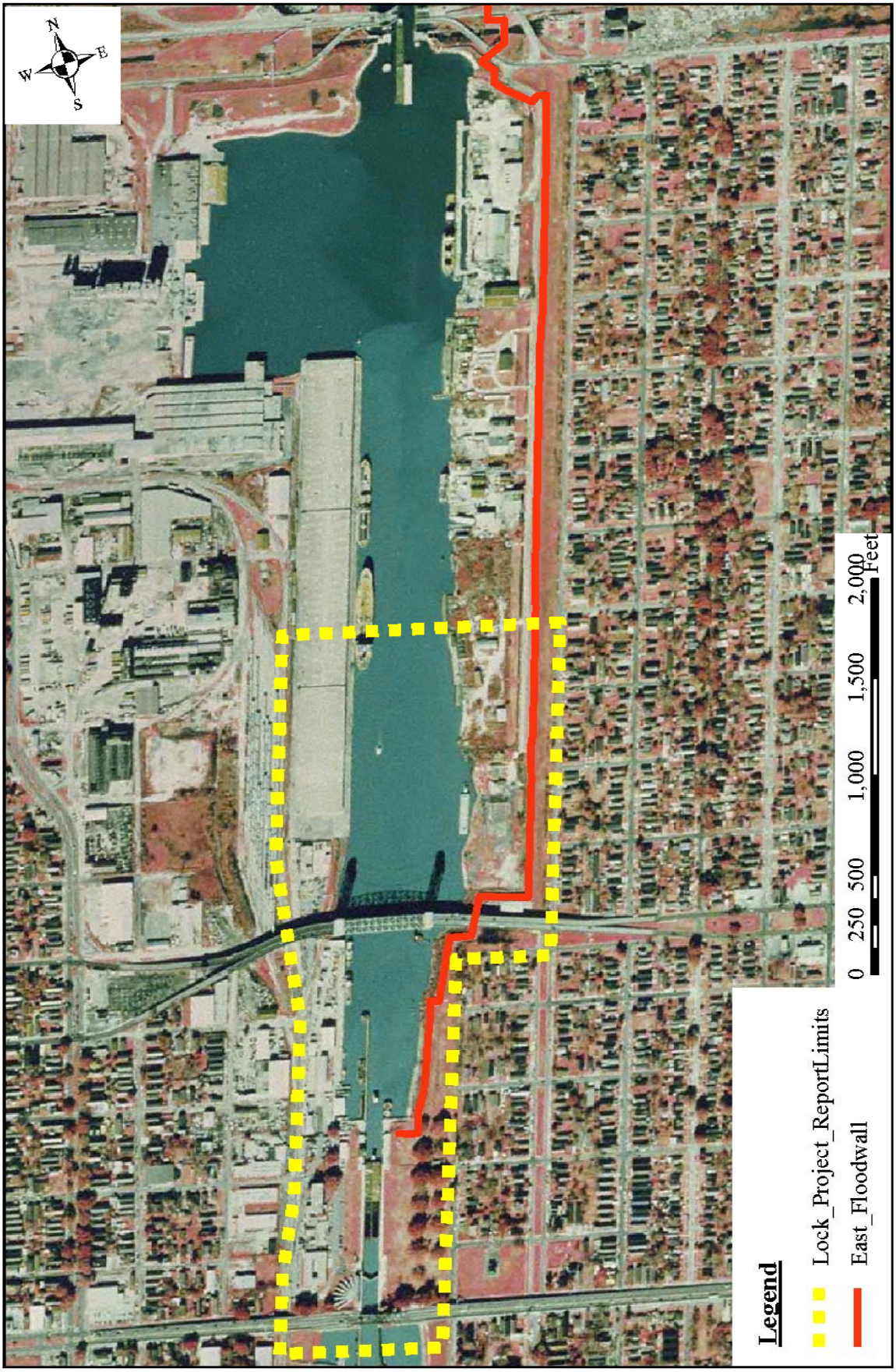


Figure 1.5. The project limits (yellow dashed line) associated with the IHNC Lock Replacement project available for review from IPET website.

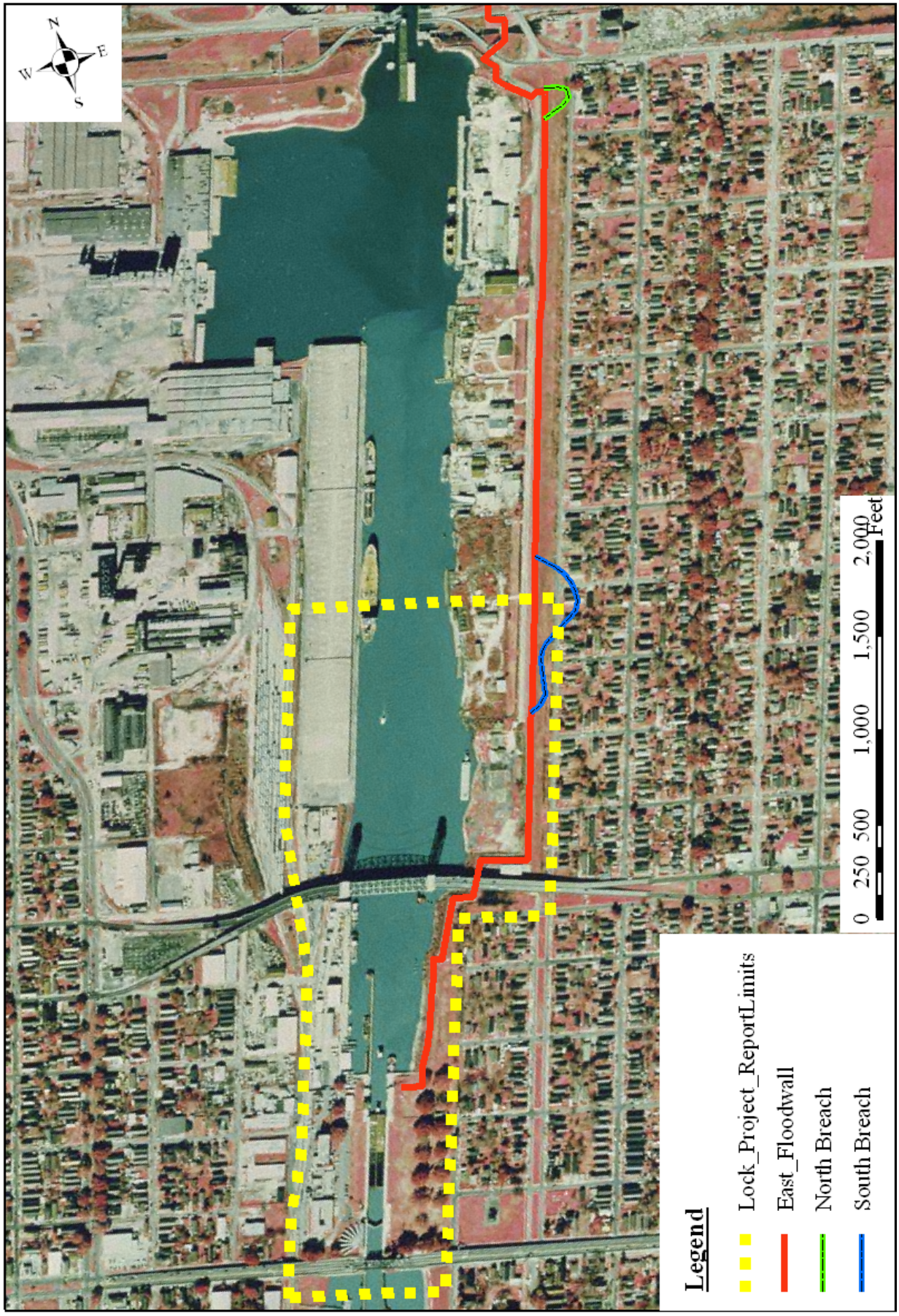


Figure 1.6. The project limits (yellow dashed line) associated with the IHNC Lock Replacement project relative to the North and South flood wall failure locations.

The project was authorized under the design service contract DACW29-99-D-0022, through the U.S. Army Corps of Engineers, New Orleans District. The replacement project impacted existing flood protection elements along the eastern and western sides of the Inner Harbor Navigation Channel.

The design information available for review indicates that the intent of the project was to provide design details associated with the construction of a new navigation lock north of North Claiborne Avenue. The existing flood protection system (floodwalls, levees, closure structures) would be replaced by new flood protection components. The new channel for the proposed lock structure would be deepened to -23 feet (NGVD) for a Barge Lock and -37 feet (NGVD) for a Ship Lock alternative (BCG, 2000).

Also available for review were Site Preparation and Demolition plans (USACE, 1998a). These plans indicate locations of existing structures as well as the location of major utilities. The utilities are labeled as SWB (Sewerage and Water Board) and NOSPI (New Orleans Public Service Incorporated). It is assumed that water and sewage lines are associated with SWB marking and natural gas and electrical supply are associated with NOSPI. Figure 1.7 shows the approximate locations of utilities with respect to the Lower Ninth Ward with a 1998 Digital Ortho Quarter Quadrangle photograph. Figures 1.8 and 1.9 show the same utilities, but with a 2004 DOQQ and 2006 DOQQ background photo.

The site preparation and demolition drawings clearly identify structures to be removed. It was not clear, based on the available information, the exact extents and nature of the excavations

required to remove all the onsite subsurface debris (underground storage tanks, water and sewage utilities, natural gas pipelines (if any), contaminated soil zones, buried obstructions (rail cars, barges, etc.), and other items located below grade.

In addition to discrete land-based excavations, the new lock project also required the channel to be deepened in order to accommodate the draft associated with the anticipated navigation traffic. The IHNC channel was dredged to a depth of approximately -32 feet (NGVD) in the area of the southern breach site (WINK, 2002), as shown in Figure 1.10.



Figure 1.7. Locations of utility crossings over the east IHNC I-wall (1998 DOQQ).

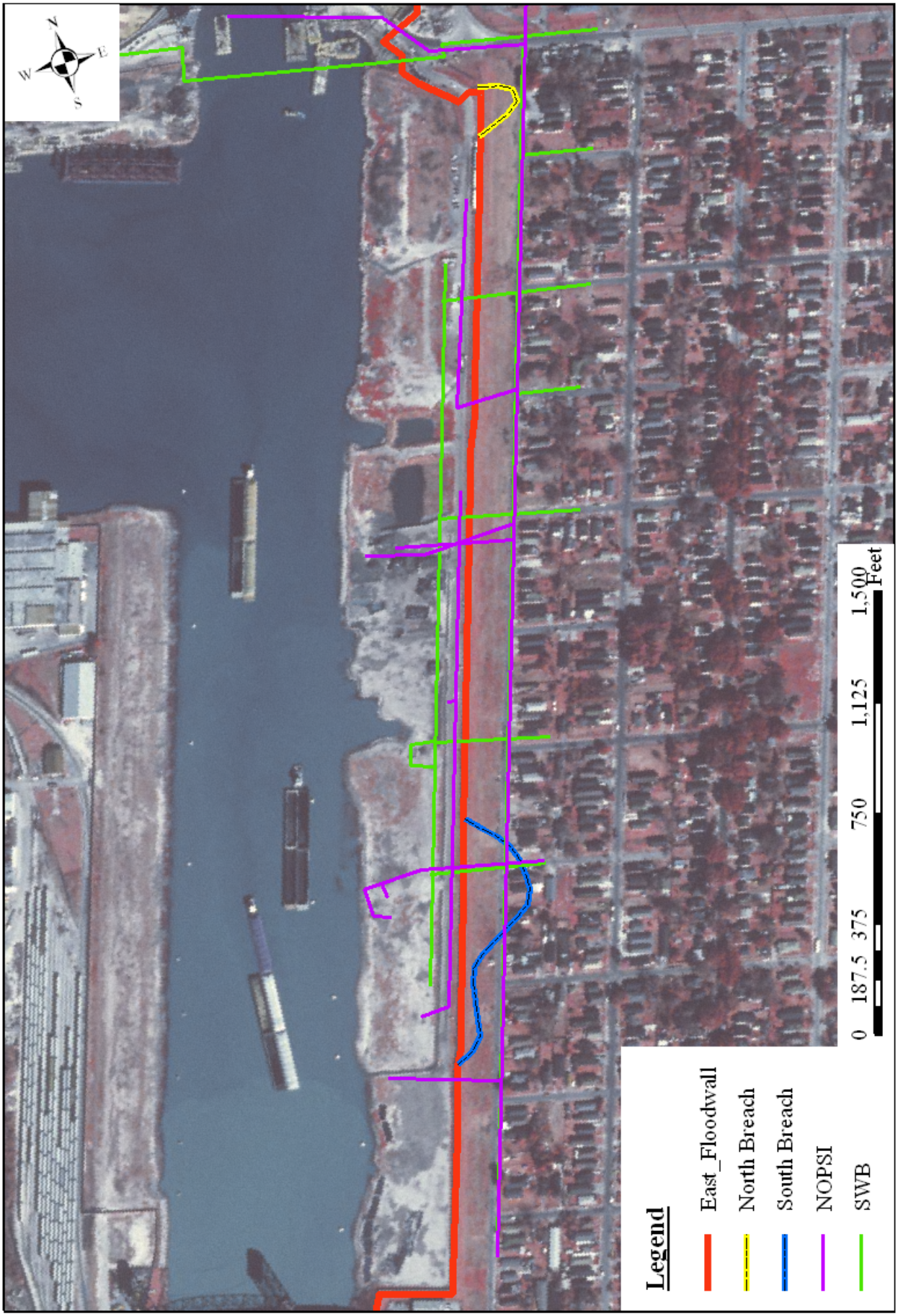


Figure 1.8. Locations of utility crossings over the east IHNC I-wall (2004 DOQQ).

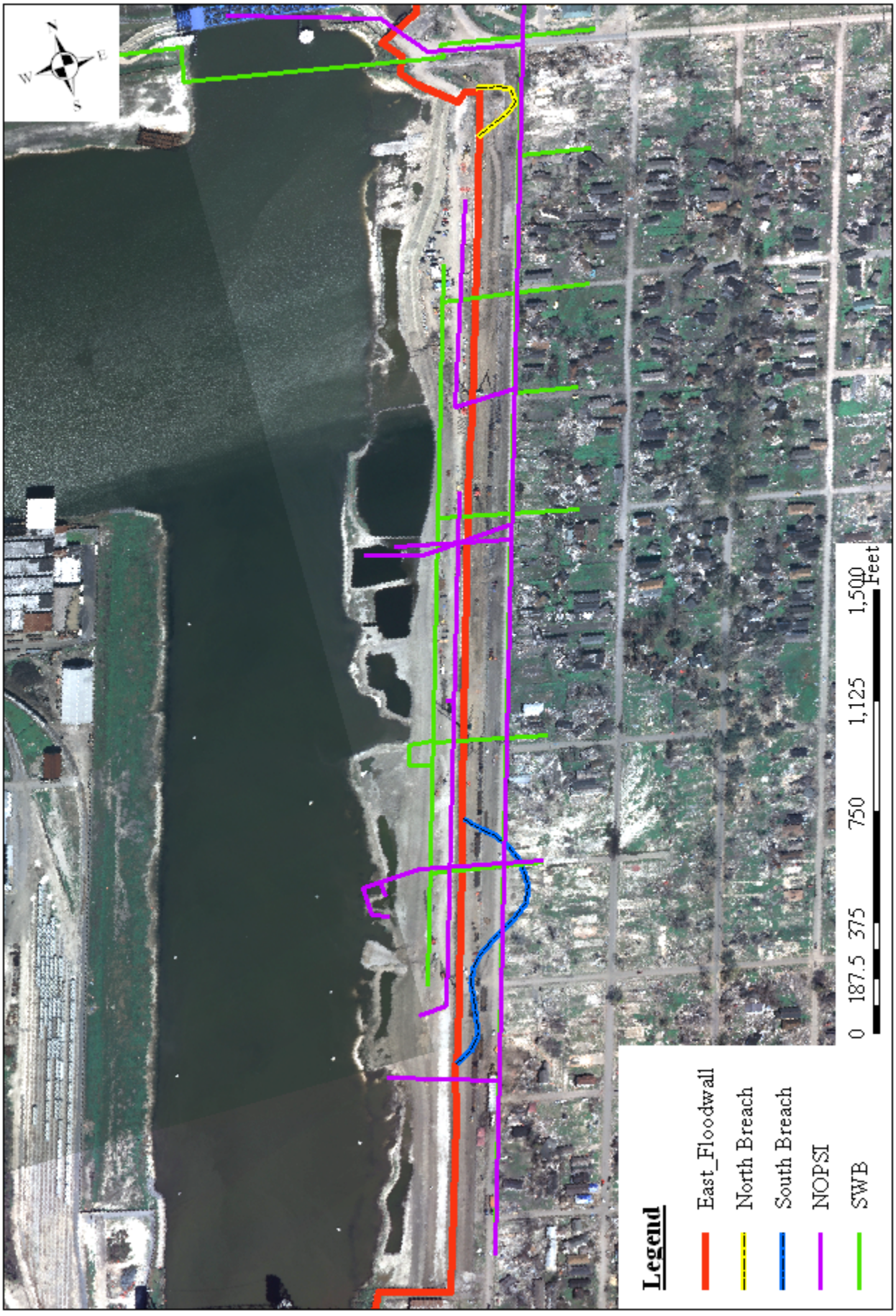


Figure 1.9. Locations of utility crossings over the east IHNC I-wall (2006 DOQQ).

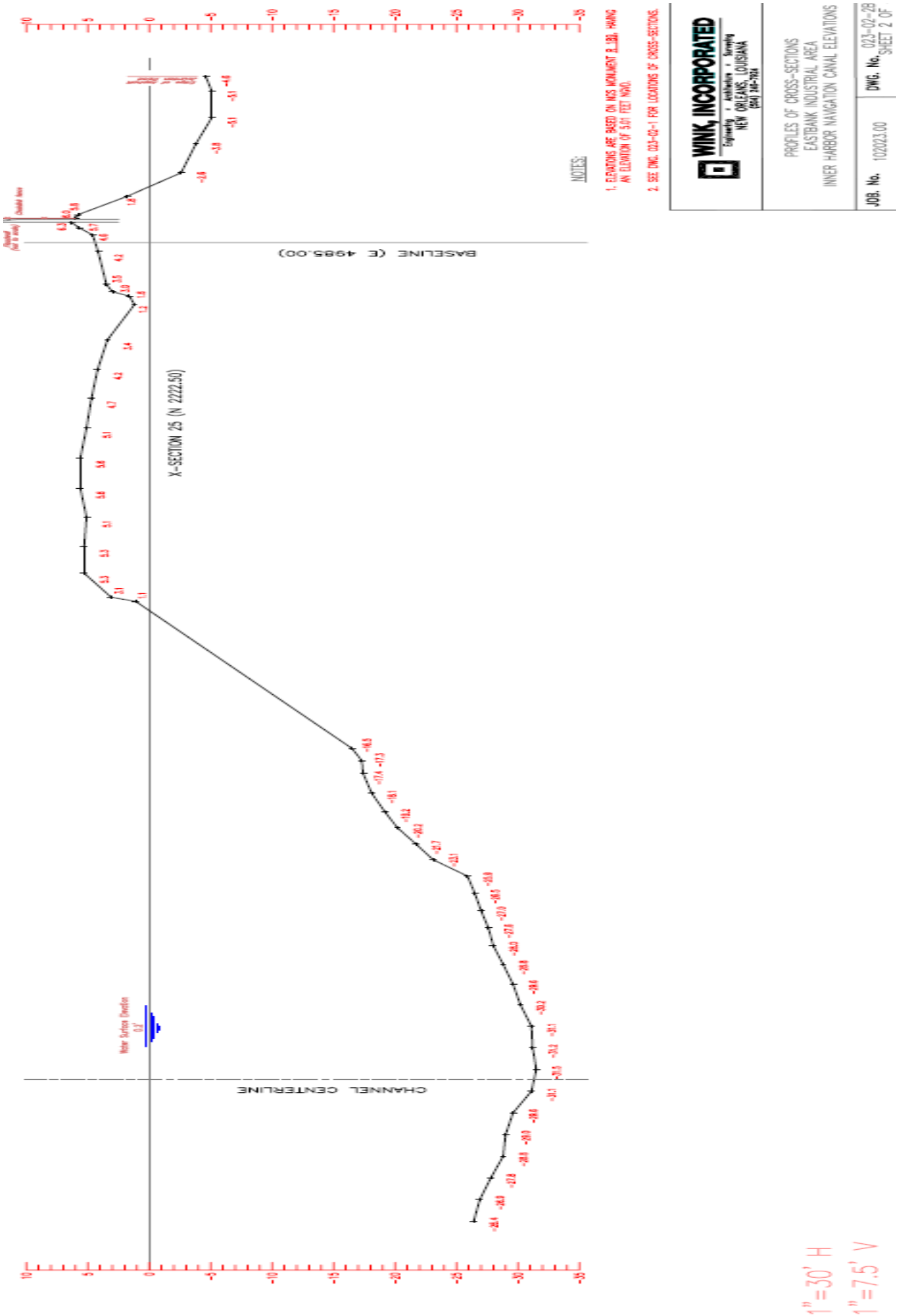


Figure 1.10. The IHNC channel was dredged to about El. -32 feet (NGVD).

IHNC Lock Replacement Project Excavation & Backfill Discussion

The IHNC Lock Replacement Project required, as part of the site preparation and demolition, the removal of subsurface debris and abandoned utilities. Very limited documentation was available for this review to assess the specific protocols employed during the demolition phase of this project. However, the following conclusions can be reached based on the available information:

1. USACE design guidelines clearly establish the requirement to evaluate seepage impacts on flood control structures as a result of subsurface activity in the proximity of existing flood protection elements;

2. The demolition and excavation activities as part of the IHNC Lock Replacement Project were well-within the zone of influence for existing flood protection elements and change in seepage effects should have been evaluated during the interim construction period between demolition activities and completion of the new flood protection system associated with the new navigation lock. However, no analyses were made available that demonstrated these evaluations were completed as part of the IHNC Lock Replacement Project.

IHNC Lock Replacement Project Documents Reviewed

A number of documents were reviewed to gain insight into the excavation and backfill protocols established by the USACE near existing flood protection system components, as part of their IHNC lock replacement project. It is important to note that only the documents made available

to us at the time of our study were reviewed. Should additional documentation become available, we reserve the right to examine these documents and update our findings.

The following documents were reviewed:

- "Inner Harbor Navigation Canal Lock Replacement Project, Orleans Parish, Louisiana, Lateral Flood Protection Design Report, Contract no. DACW 29-99-D-0022," Prepared for: Department of the Army, New Orleans District, Corps of Engineers, New Orleans, Louisiana. Prepared by: Brown, Cunningham, Gannuch, Engineers, Architects, Consultants. October 2000.

- "Inner Harbor Navigation Canal Lock Replacement Project, Orleans Parish, Louisiana, Design Documentation Report No. 1, Site Preparation and Demolition, Volume No. 2 of 8," Prepared for: Department of the Army, New Orleans District, Corps of Engineers, New Orleans, Louisiana. Prepared by: Waldemar S. Nelson and Company, Inc, Engineers and Architects, New Orleans, Louisiana and Dames and Moore, Inc., New Orleans, Louisiana. February 1999.

- "Inner Harbor Navigation Canal Lock Replacement Project, Orleans Parish, Louisiana, Design Documentation Report No. 1, Site Preparation and Demolition, Volume No. 4 of 8," Prepared for: Department of the Army, New Orleans District, Corps of Engineers, New Orleans, Louisiana. Prepared by: Waldemar S. Nelson and Company, Inc, Engineers and Architects, New Orleans, Louisiana and Dames and Moore, Inc., New Orleans, Louisiana. February 1999.

- "Inner Harbor Navigation Canal Lock Replacement Project, Orleans Parish, Louisiana, Design Documentation Report No. 1, Site Preparation and Demolition, Volume No. 5 of

8," Prepared for: Department of the Army, New Orleans District, Corps of Engineers, New Orleans, Louisiana. Prepared by: Waldemar S. Nelson and Company, Inc, Engineers and Architects, New Orleans, Louisiana and Dames and Moore, Inc., New Orleans, Louisiana. February 1999.

- "Inner Harbor Navigation Canal Lock Replacement Project, Orleans Parish, Louisiana, Design Documentation Report No. 1, Site Preparation and Demolition, Volume No. 6 of 8," Prepared for: Department of the Army, New Orleans District, Corps of Engineers, New Orleans, Louisiana. Prepared by: Waldemar S. Nelson and Company, Inc, Engineers and Architects, New Orleans, Louisiana and Dames and Moore, Inc., New Orleans, Louisiana. February 1999.

- "Inner Harbor Navigation Canal Lock Replacement Project, Orleans Parish, Louisiana, Design Documentation Report No. 1, Site Preparation and Demolition, Volume No. 7 of 8," Prepared for: Department of the Army, New Orleans District, Corps of Engineers, New Orleans, Louisiana. Prepared by: Waldemar S. Nelson and Company, Inc, Engineers and Architects, New Orleans, Louisiana and Dames and Moore, Inc., New Orleans, Louisiana. February 1999.

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- “Inner Harbor Navigation Canal, Lock Replacement Project, Design Memorandum No. 1, Site Preparation and Demolition, Plan,” U. S. Army Engineer District, New Orleans. File No. H-2-45013, Plates 3, 4 and 5 (CAD Files IHNC3.DGN, IHNC4.DGN, and IHNC5.DGN). March 1998a.

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United States Army Corps of Engineers. "Engineering and Design, Design of Sheet Pile Walls, EM 1110-2-2504," Department of the Army, U.S. Army Corps of Engineers, Washington D.C. 20314-1000. <http://www.usace.army.mil/publications/eng-manuals/em1110-2-2504/toc.htm>. March 31, 1994.

United States Army Corps of Engineers. "Inner Harbor Navigation Canal, Lock Replacement Project, Design Memorandum No. 1, Site Preparation and Demolition, Plan," U. S. Army Engineer District, New Orleans. File No. H-2-45013, Plates 3, 4 and 5 (CAD Files IHNC3.DGN, IHNC4.DGN, and IHNC5.DGN). March 1998a.

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United States Army Corps of Engineers. "Engineering and Design, Design and Construction of Levees, EM 1110-2-1913," Department of the Army, U.S. Army Corps of Engineers, Washington D.C. 20314-1000. <http://www.usace.army.mil/publications/eng-manuals/em1110-2-1913/toc.htm>. April 30, 2000.

United States Army Corps of Engineers. Kansas City District. "Geotechnical Design and Dam Safety Section – Construction Guidance Page," <http://www.nwk.usace.army.mil/local_protection/guidance.html>. Accessed May 12, 2008.

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WINK Incorporated. "Profiles of Cross-Sections, Eastbank Industrial Area, Inner Harbor Navigation Canal Elevations," Job No. 102023.00, DWG No. 023-02-2B, Sheet 2 of 4. 2002.