Investigation of the Performance of the New Orleans Flood Protection Systems in Hurricane Katrina on August 29, 2005

Volume II: Appendices

by

R. B. Seed, R. G. Bea, R. I. Abdelmalak, A. G. Athanasopoulos, G. P. Boutwell, J. D. Bray,
J.-L. Briaud, C. Cheung, D. Cobos-Roa, J. Cohen-Waeber, B. D. Collins, L. Ehrensing, D. Farber,
M. Hanemann, L. F. Harder, K. S. Inkabi, A. M. Kammerer, D. Karadeniz, R.E. Kayen, R. E. S. Moss, J. Nicks,
S. Nimmala, J. M. Pestana, J. Porter, K. Rhee, M. F. Riemer, K. Roberts, J. D. Rogers, R. Storesund,
A. V. Govindasamy, X. Vera-Grunauer, J. E. Wartman, C. M. Watkins, E. Wenk Jr., and S. C. Yim

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This report contains the observations and findings of an investigation by an independent team of professional engineers and researchers with a wide array of expertise. The materials contained herein are the observations and professional opinions of these individuals, and do not necessarily reflect the opinions or endorsement of any other group or agency.

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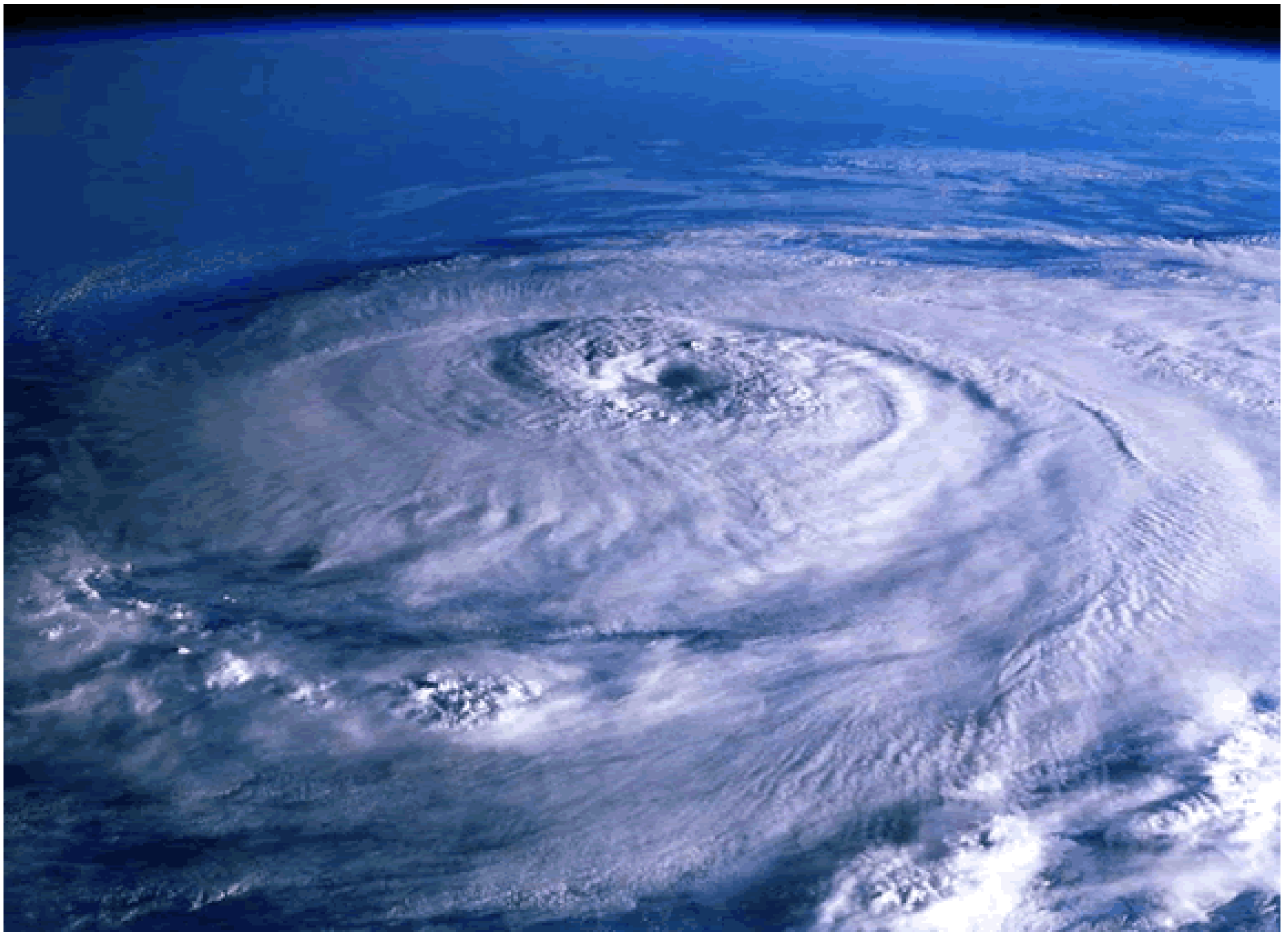

Source: www.noaa.gov

This report is dedicated to the people of the greater New Orleans region;
to those that perished, to those that lost friends and loved ones,
and to those that lost their homes, their businesses, their place of work,
and their community.

New Orleans has now been flooded by hurricanes six times
over the past century; in 1915, 1940, 1947, 1965, 1969 and 2005.

It must be our goal that it not be allowed to happen again.

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A.1 Introduction

Preservation of information regarding the magnitude and geometry of structural and geotechnical deformations is paramount for the analysis of levee failure modes. This chapter describes the areas of focus and methodology used in laser mapping of surface evidence of levee deformation and distress at eleven areas within the greater New Orleans area. The area of focus extends from the 17th Street Canal in the Orleans East Bank area, to the Entergy power plant in the New Orleans East area. The NSF-sponsored investigation team included two researchers from the United States Geological Survey (USGS), who brought to the field area a terrestrial laser mapping tool to perform laser scanning or LIDAR (LIght Detection And Ranging) data collection. The laser mapping effort was conducted over 5 days from October 9-14, 2005. An additional day of data collection was performed on March 15, 2006 at the Orleans Canal Pump Station during a follow-up survey effort to collect high-accuracy control point data via differential GPS surveying. The objective of the laser scanning effort was to obtain precise measurements of the ground surface to map soil displacements at each levee site, the non-uniformity of levee height freeboard, depth of erosion where scour occurred, and distress in structures at incipient failure. Toward that end, eleven sites were visited for LIDAR scanning (Figure A-1). The sites, along with their global position coordinates (WGS84 Datum) and the number of individual scans collected at each site are outlined in Table A-1. Because several of the sites are less than one kilometer apart (i.e. Sites 2 & 3, Sites 4 & 5, and Sites 6 & 7), individual scans from each of these site pairs were collected and developed as a single LIDAR model and are listed jointly.

A.2 Methodology

The terrestrial LIDAR method, a 3D laser scanning technique, consists of sending and collecting laser pulses from surface objects to build a point file of three-dimensional coordinates. The time of travel for a single pulse return from a surface is measured along a known trajectory such that the distance from the laser and consequently the exact location can be computed. In addition, visual data on points located within and outside of the laser range can be obtained through the use of a CCD color sensor. A unique aspect of the LIDAR method is the rapid rate of data collection. The USGS laser scanning system can measure the location of up to 8,000 surface points in one second. Thus within a few minutes, an entire surface, be it a structure or levee, can be imaged efficiently with a point file that contains several million position points. The point files from collected scans are typically transformed into three-dimensional surfaces so that cross-sections can be generated and volumetric calculations can be performed between consecutively scanned surfaces.

The LIDAR technique has been successfully utilized by members of the reconnaissance team in a wide range of environments, most recently, for studies involving coastal bluff change along the California coast (Collins and Sitar; 2004, 2005), and in earthquake reconnaissance studies (Kayen et al., 2004; Kayen et al., in press). Complete details of the laser scanning process can be found in these references.

In the study of damage to the levee systems protecting the New Orleans area, the USGS scanning laser, a Riegl Z210 scanner (Riegl, 2005), was utilized as a tripod mounted survey instrument (Figure A-2). To improve the imagery and increase the efficient transportation of the sensor between scans, the tripod was elevated to a fixed platform on the roof of the field vehicle. Elevating the scanner to approximately 4 meters above the ground reduced shadow zones and extended coverage of each scan. Each laser scan collected approximately 2.3 million data points, scanning an azimuthal range up to 336 degrees and an elevation range of positive 40 degrees to negative 40 degrees measured from the horizontal. The laser was set up over existing survey benchmarks where available, to tie the data into georeferenced coordinates. However, for the most part, a separate, local coordinate system was utilized for each site for initial data processing. An additional site visit was made to New Orleans in March 2006 to collect high-accuracy survey data to process and georeference all of the acquired data sets. Details on these procedures are provided in this report.

Multiple scans were collected to fill in “shadow zones” of locations not directly in the line of sight of the laser and to expand the range and density of the point data. Processing of the data was performed using the I-SiTE software program (I-SiTE, 2005) specifically designed to handle laser data. Specific details of the processing procedures used at each site are provided with each location’s summary.

The range of radial target distances for natural targets is approximately 2 m - 400 m and at these distances the point measurement accuracy is 0.8-1.5 cm, depending on specific laser settings. Time required for scanning at fine-scale density of points (e.g., 2.3 million targeted points) is 4 minutes. In New Orleans, the fine-scale resolution was used to scan the levee sections in most cases. At the highest resolution, the angular separation of the vertical line scans is 0.01°. Thus, the near-field point separation is less than 1 mm and the separation of the farthest data at 400 m can be about 7 cm.

The angular position of the laser-pulse leaving the scanner is controlled by precise stepper-motors within the unit. The scanner makes millions of individual x, y, z position measurements that together form a “point cloud” data set of information about the solid objects that return reflected pulses. The USGS scanner has an optical sensor that records reflective color and intensity. With the addition of a color channel, the natural appearance of the surface can be draped on to the three dimensional surface model. Several useful applications of the color and intensity channels are to (1) extract non-topographic textural information about the target; (2) identify color-based lithologic changes in the target; and (3) enhance and identify georeference reflectors that send back the strongest reflected signal. On some occasions (less than 10 scans) during the team’s reconnaissance mission, schedules necessitated night-time data collection such that real-color scans were not collected. This only affected the color imagery of the data, not the positional accuracy or resolution of the point files.

In most cases, after arriving at a site, the scanner was mounted on a tripod on the roof of the field vehicle. In other configurations, the laser was placed on a tripod on the ground, or on its side, for example on the top of an I-wall section to scan downwards into toe scour

(Figure A-3). Typically, the scanner is set upright and leveled, with the unit rotating horizontally.

3-D laser scanners cannot see behind objects, therefore the first surface encountered casts a shadow over areas blocked from the view of the scanner. For example, it can be seen in a scan of the levee at the east side, north breach of the Inner Harbor Navigational Canal ("IHNC", locally referred to as the "Industrial Canal") (Figure A-4) that shadows are cast by near-field objects like the exhumed sheet pile foundation over the debris behind it. As the incident-angle of the laser point decreases, proportionally larger shadows are cast on the ground behind the target. Therefore, to minimize shadow zones and get full coverage of the target surface using terrestrial LIDAR, the scanner is moved to a number of locations surrounding the target zone (Figure A-5). The levee scans involved 7 to 29 scanner set-ups to cover the entire feature and surrounding area and to minimize the number of shadow areas. Using multiple setups provided both a convenient way to limit the number of shadow zones while also increasing the resolution of the data collected and the boundaries of the scanned area.

A.3 Georeferencing of LIDAR survey data

Due to the difficult logistics of the initial data collection reconnaissance, each LiDAR data set was collected and processed using a local coordinate system, centered on the origin of the first scan collected at each site. This provided a basis for understanding each site's morphology and for making relative measurements within a single site. However, this also limited the ability to make absolute measurements in terms of other georeferenced data sets, including elevation measurements relative to sea-level datums. A dedicated survey effort was therefore conducted from March 13-17, 2006 to collect high-accuracy survey data on local control points identified within each sites LiDAR data set. Survey data was collected at eight of the data sets (Site 1: 17th Street Canal, Site 2 and 3: London Ave. Canal, Site 4 and 5: IHNC Breaches, Site 6: Lakeside Airport Levee, and Site 11: Orleans Canal Pump Station and Spillway). Georeferencing data was not collected at Sites 8, 9, and 10, and these sites remain as locally referenced data sets.

Data was collected on cultural features clearly visible with the scans sets (house roof corners, fence posts, concrete foundation corners, etc.) using the USGS' in-house GPS survey capabilities. Using a network of base stations throughout the New Orleans area, approximately 15 local control points were collected at each site with centimeter-level accuracy. A registration procedure was then performed for each data set to transform the locally referenced data to real-world coordinates, referenced to NAD83, UTM Zone 15 for the horizontal projection, and NAVD88 for the vertical datum. The georeferencing procedures resulted in a registered fit of local to GPS survey points on the order of 10 centimeters, with the exception of Sites 4 and 5 (IHNC Breaches). The georeferenced status for each site investigated in this study is presented in Table 1 for reference.

A.4 Processing of LIDAR Imagery

At each levee site, the topographical surroundings were imaged on seven or more individual scans, together consisting of many millions of data points. The investigation team utilized the I-SiTE surface modeling software package, to both collect the scan point-cloud data and allow for post processing of multiple scans into geo-referenced solid surfaces.

After data are acquired, there are a suite of standard processing steps needed to produce a surface model. First, the multiple scans are either locally or absolutely geo-referenced to one-another. A least squares "best-fit" match is made between scans, augmented by precise survey measurements made with a total station or differential global positioning satellite (e.g., real time kinematic RTK-GPS, or Omnistar HP-differential GPS). Filters are then used to eliminate unwanted data. For example, typically filters are applied to remove vegetation-related data points so as to observe the "bare" earth. Finally, the filtered data serves as the working digital terrain model (DTM) that is used to render a solid surface of the object (ground). Again, different surface modeling schemes can be used to fuse and render a surface from multiple scans. The surface model represents a highly accurate virtual representation of the ground that can be used for documentation and change detection of volumes, areas, and distances.

A.5 Data Coverage: LIDAR scan sites at Levee Breaks within the New Orleans Area

Figures A-6 through A-13 define the approximate bounds of highly detailed continuous LIDAR data. Considerable data exist outside of these bounds, though they are not continuous and may have shadow effects. In general, point to point spacing of individual LIDAR data points within the outlined areas is on the order of 25 mm providing an extremely dense coverage of all objects within each site. However, typical surfaces generated from the data are typically filtered to a minimum point separation of 10 to 50 cm when greater accuracy is not required.

A.6 Analysis Examples of Levee Deformation Using LIDAR Data

Laser mapping allows for highly accurate computation of rotation, length, area, and volume. Rotational displacement was common at areas of levee I-wall distress. For example, the east side of the London Avenue Canal immediately south of Robert E. Lee Boulevard suffered distress and lateral deformation associated with incipient failure of the levee. This movement is along a section of wall diagonally northeast of the west side breach across the canal. In Figure A-14, an oblique image of the distressed wall can be seen from the south. The wall, preserved in incipient failure, leans toward the levee maintenance road and landside portion of the levee. In the right-hand background, is the bridge abutment on Robert E. Lee Blvd for reference.

Considerable vegetation grows along the banks of the canal sides of the levees that are less maintained for growth than the landside neighborhood-side of the levee wall. Thin slices of the point-cloud data orthogonal to the alignment of the levee wall (Figure A-15) display highly accurate cross sections of the distressed I-wall at London Canal. Segment (a) is toward the south (left) of Figure A-14 and has a modest 1.9 degree rotational deformation. Near the position of maximum distress, the I-wall has 5.0 degrees of rotational deformation toward the landside of the levee.

The London Canal levee failure (west side) and distressed wall (east side) are both immediately south of the bridge crossing at Robert E. Lee Boulevard. A significant gap in height between the lower un-walled bridge abutment and the I-wall prevents water from overtopping these I-walls. The height gap differs slightly between the walls located north and south of the bridge, due either to differing design heights or differential settlement following construction. At the distressed I-wall section on the southeast corner of the bridge, LIDAR surveys and visual inspection indicated the gap at this location was approximately 1.7 meters (5.6 feet). Therefore, water rising in the canal would overtop the bridge abutment and begin to flood the surrounding community when the water level was 1.7 meters (5.6 feet) below the top of the I-wall. Figure A-16 shows this considerable wall gap, as well as moderate scour at the southeast edge of the bridge abutment (Figure A-16a). On the northeast corner of the bridge abutment near the north levee wall, LIDAR surveys indicate the gap at this location to be approximately 1.51 meters (5.0 feet). Figure A-17 and A-18 show this gap, as well as a scour trench at the base of the northeast abutment (Figure A-18a).

There was no evidence of overtopping of the levee walls or erosion scour anywhere along this section of the canal except at the gap at the bridge. The LIDAR and scour evidence therefore indicate that the floodwalls along the London Canal section, south of the Robert E. Lee Boulevard Bridge were not overtopped prior to failure of the levee wall.

Measurement of displacement along the 17th Street Canal breach can be made by identifying the blocks of ground formerly within the intact levee that slid eastward toward the landside of the levee. Figure A-19 is an overview image of a portion of the 17th Street point cloud data set consisting of 11 individual scans. In this image, the bridge crossing over the canal at Robert E. Lee Blvd. (also called the Hammond Highway) is toward the upper left (north). A dense cluster of points is visible at the levee breach in the center of the image as are the houses in the affected area. Close in to the levee breach in Figure A-20, the remaining I-wall can be seen in alignment with the crest of the replacement structure. Here, a total breach repair width of 142 meters (466 ft) as measured between intact I-wall sections has been calculated directly from the LIDAR data set. A cross section taken through this area is shown in Figure A-21. A multi-section view is shown, consisting of a section of the intact southern I-wall overlain over the failed section of the levee. The geometry of the emergency repair embankment is clearly visible. The sections also show the magnitude of the displacement of several earth blocks that moved away from the levee break during failure. The LIDAR data shows that blocks translated approximately 14 meters (46 ft) as measured from the existing alignment of the cyclone fence line to its new position within the displaced blocks. From the perspective shown in Figure A-21, it can also be seen that the width of the 17th St. Canal has been reduced about 6 meters (20 ft) by the placement of the earthen embankment.

A final example of the use of the LIDAR data is shown in Figure A-22. Here, the dimensions of the scour trench in the vicinity of the east side IHNC – south breach are outlined. This view shows the depth of scour adjacent to the I-wall and into the embankment so that a direct comparison of the scour depth to sheet pile embedment can be made.

A.7 Summary

The LIDAR data presented herein present the scope of available data coverage of the failed sections of the New Orleans levee system following Hurricane Katrina. The methodology for processing the data has been outlined to provide important background information for maps, section views and calculations developed from the data and presented elsewhere in this report. Examples of specific applications of the utility of the data have also been presented to provide information on how the data sets may be utilized in ongoing and future investigations of the performance of the levee systems.

A.8 References

Collins, B.D. and Sitar, N. (2004) Application of High Resolution 3D Laser Scanning to Slope Stability Studies, 39th Symposium on Engineering Geology and Geotechnical Engineering, Butte, Montana, pp. 79-92.

Collins, B.D. and Sitar, N. (2005). Monitoring of Coastal Bluff Stability Using High Resolution 3D Laser Scanning, *ASCE Geo-Frontiers Special Publication 138:*- Site Characterization and Modeling, Remote Sensing in Geotechnical Engineering, E.M. Rathje, ed., ASCE, Austin, Texas, Jan 24-26, 2005.

I-SiTE (2005). I-SiTE 3D Laser Imaging Software (www.isite3d.com).

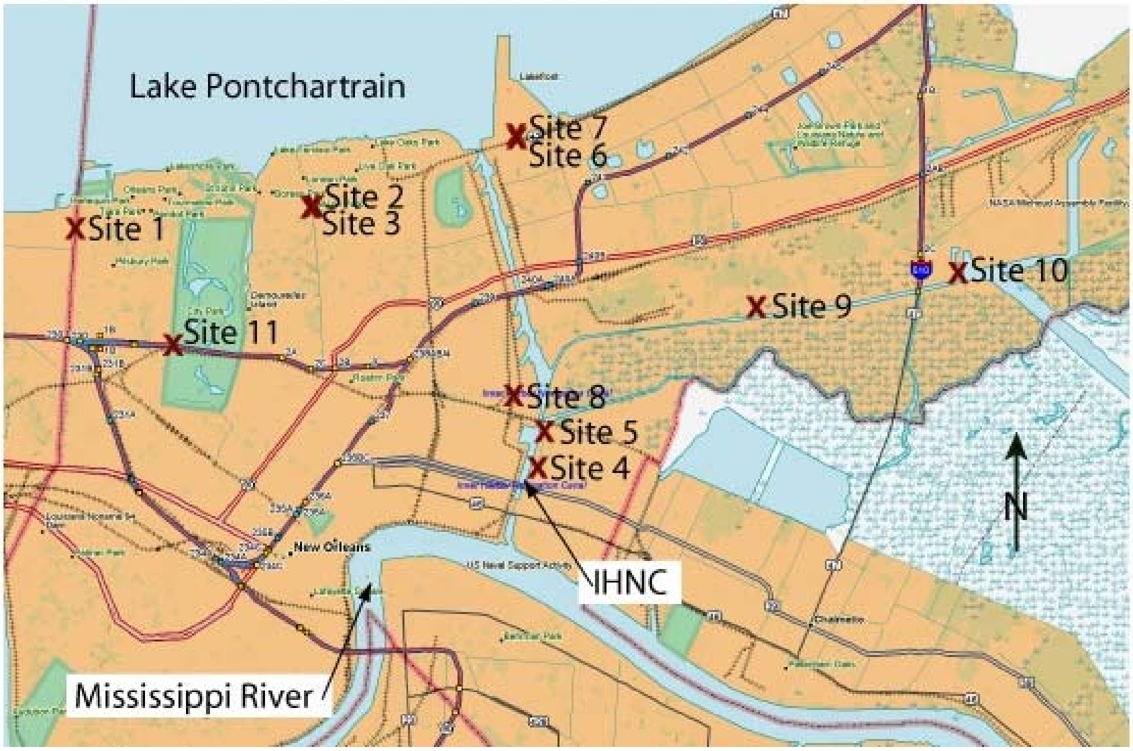
Kayen, R.,, Barnhardt, W., Carkin, B., Collins, B.D., Grossman, E.E., Minasian, D., Thompson, E. (2004) Imaging the M7.9 Denali Fault Earthquake 2002 Rupture at the Delta River Using LiDAR, RADAR, and SASW Surface Wave Geophysics, Eos Trans. AGU,85(47), Fall Meet. Suppl., Abstract S11A-0999.

Kayen, Robert, Robert T. Pack, James Bay, Shigetoshi Sugimoto, and Hajime Tanaka (In Press) Ground-LIDAR Visualization Of Surface And Structural Deformations Of The Niigata Ken Chuetsu, 23 October 2005, Earthquake, EERI, *Earthquake Spectra.*

Riegl (2005). Riegl 2D and 3D Measurement Systems (www.rieglusa.com).

Table A-1 LIDAR Site Description Summary

LIDAR Site Number	Location	Latitude	Longitude	Number of LIDAR scans	Data Georefer -enced?
1	17th Street Canal	N30.0172°	W90.1214°	20	Yes
2	London Ave. Canal, North on east side	N30.0210°	W90.0704°	29 with Site 3	Yes
3	London Ave. Canal, North on west side	N30.0206°	W90.0708°	29 with Site 2	Yes
4	IHNC East Side, South Breach 9th Ward	N29.97243°	W90.02194°	13	Yes
5	IHNC East Side, North Breach 9th Ward	N29.97873°	W90.02042°	14	Yes
6	Lakefront Airport Levee Transition Breach	N30.03367°	W90.02622°	14 with Site 7	Yes
7	Lakefront Airport Levee I-Wall	N30.03436°	W90.02641°	14 with Site 6	Yes
8	Structural Distressed I-Wall at Container Wharf	N29.98614°	W90.0272°	20	No
9	Erosionally Distressed Earth Levee	N30.00200°	W89.97500°	14	No
10	Entergy Plant I-Wall Scour	N30.00900°	W89.93171°	20	No
11	Orleans Canal Pump Station and Spillway	N29.99476°	W90.10070°	7	Yes



Source: Delorme TopoUSA

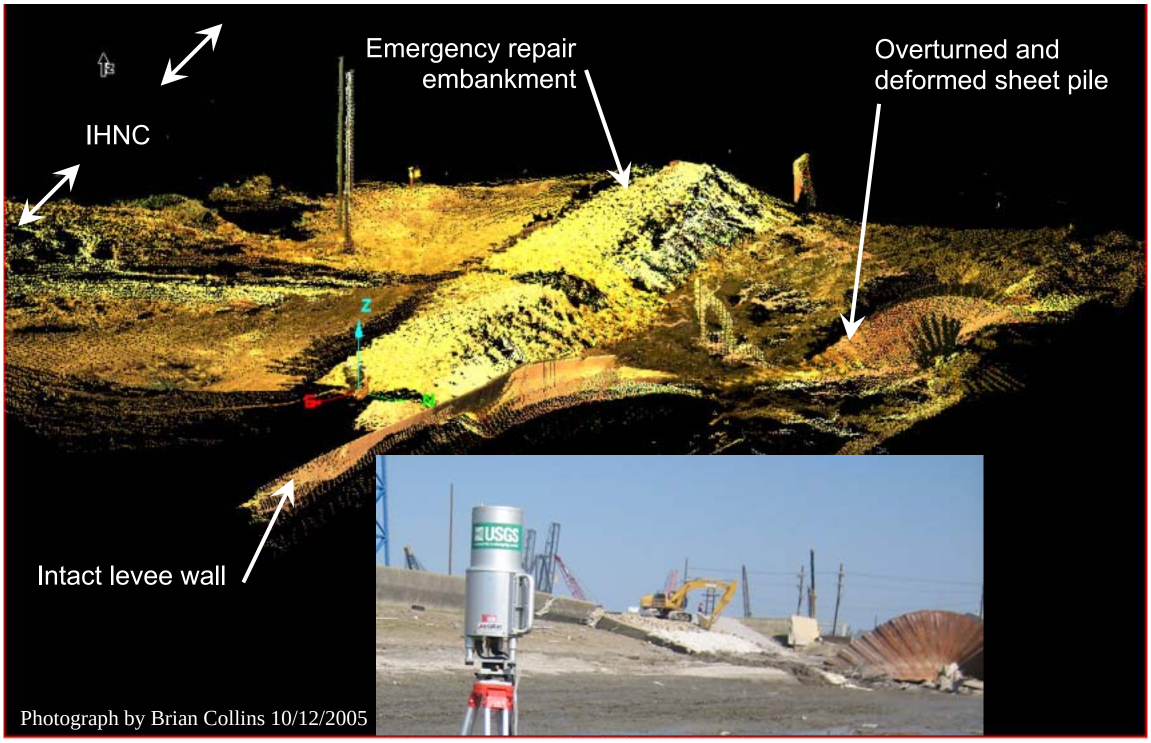
Figure A-1: The eleven sites investigated by the laser mapping method reside within the boundary of Orleans Parish.

Photograph by Robert Kayen 10/13/2005

Figure A-2: Entergy Plant I-Wall scanned using the USGS Coastal and Marine Geology Team terrestrial LIDAR unit and tripod mounted to the roof of our field vehicle. The fixed roof base allowed for the leveling of the tripod and LIDAR instrument on sloping ground.

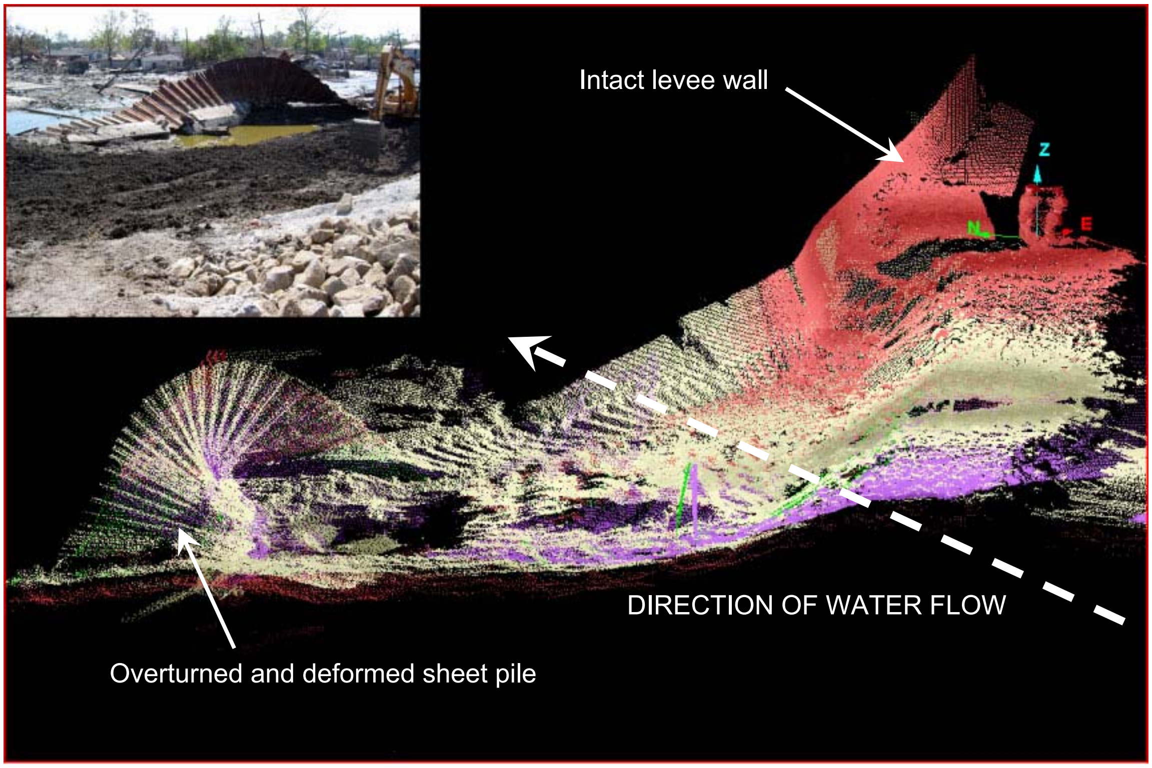
Photograph by Robert Kayen 10/10/2005

Figure A-3: LIDAR scan system on top of the east I-wall at the London Avenue Canal. Scans of the canal side translational gap were made by placing the LIDAR on its side so the axis of rotation was horizontal.



Photograph by Brian Collins 10/12/2005

Figure A-4. For complete coverage of the IHNC-North levee breach the laser was moved around objects that cast shadows. The sheet pile foundation and levee were imaged from both sides to complete the 3-D model.



Photograph by Robert Kayen 10/11/2005

Figure A-5: From another perspective, four separate LIDAR scans can be seen in the merged data file, each colored separately to differentiate them (red; white, purple, green). At the IHNC - North Site, 14 scans were merged into a single composite file.

Source: Modified from http://ngs.woc.noaa7.gov/storms/katrina/24425575.jpg

Figure A-6: Site 1, 17th Street Canal: (N30.0172° W90.1214°)

Source: modified from Google maps

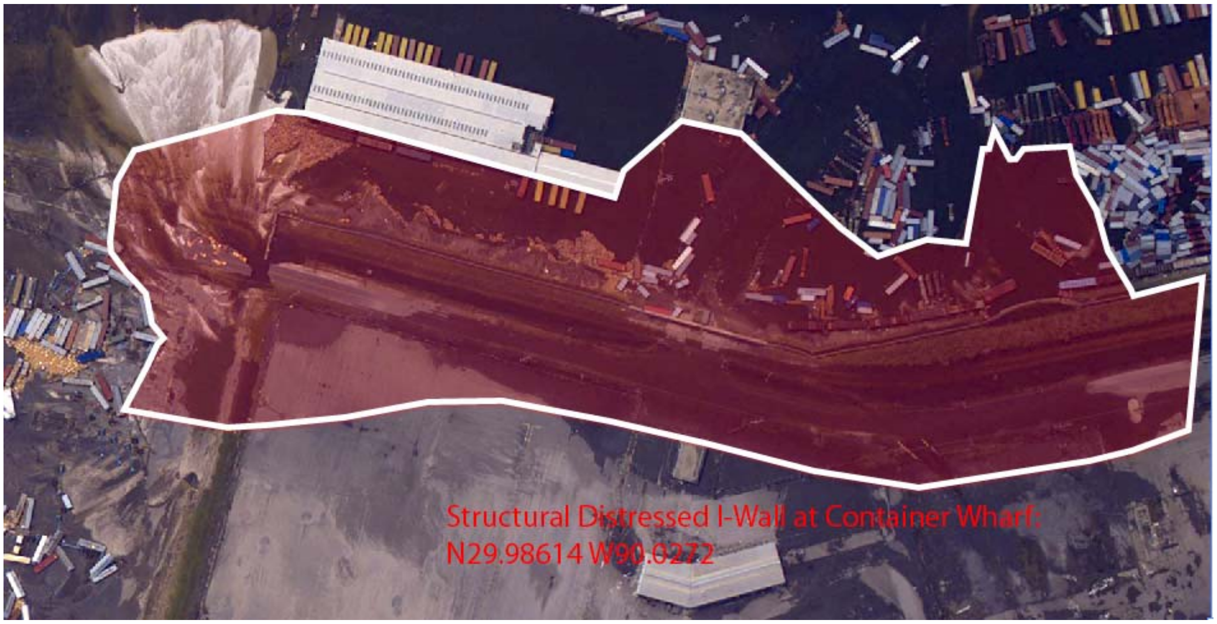
Figure A-7: Sites 2 & 3, London Ave. Canal, North on east side: (N30.0210° W90.0704°) and west side: (N30.0206° W90.0708°).

Source: modified from http://www.digitalglobe.com/images/katrina/new_orleans_surekote_levee_aug31_2005_dg.jpg

Figure A-8: Sites 4 & 5, IHNC – South Breach: N29.97243° W90.02194° IHNC North Breach: N29.97873° W90.02042°.

Source: Modified from http://ngs.woc.noaa.gov/storms/katrina/

Figure A-9: Sites 6 & 7, Lakefront Airport Levee Transition Breach: (N30.03367° W90.02622°) and Airport Levee I-Wall: (N30.03436°



Source: Modified from http://ngs.woc.noa7.gov/storms/katrina/

Figure A-10: Site 8, Structural Distressed I-Wall at Container Wharf: (N29.98614° W90.0272°)

Source: Modified from http://ngs.woc.noaa.gov/storms/katrina/

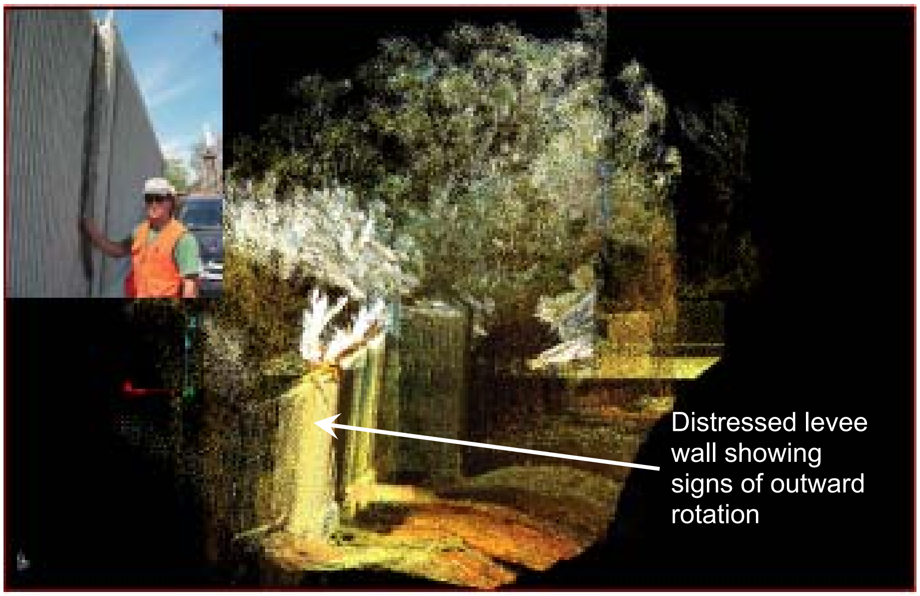
Figure A-11: Site 9, Earthen Levee Section Distressed by Overtopping Erosion at N30.00200°, W89.97500°

Source: Modified from http://ngs.woc.noaa.gov/storms/katrina/

Figure A-12: Site 10, Entergy Plant I-Wall Scour at N30.00900°, W89.93171°

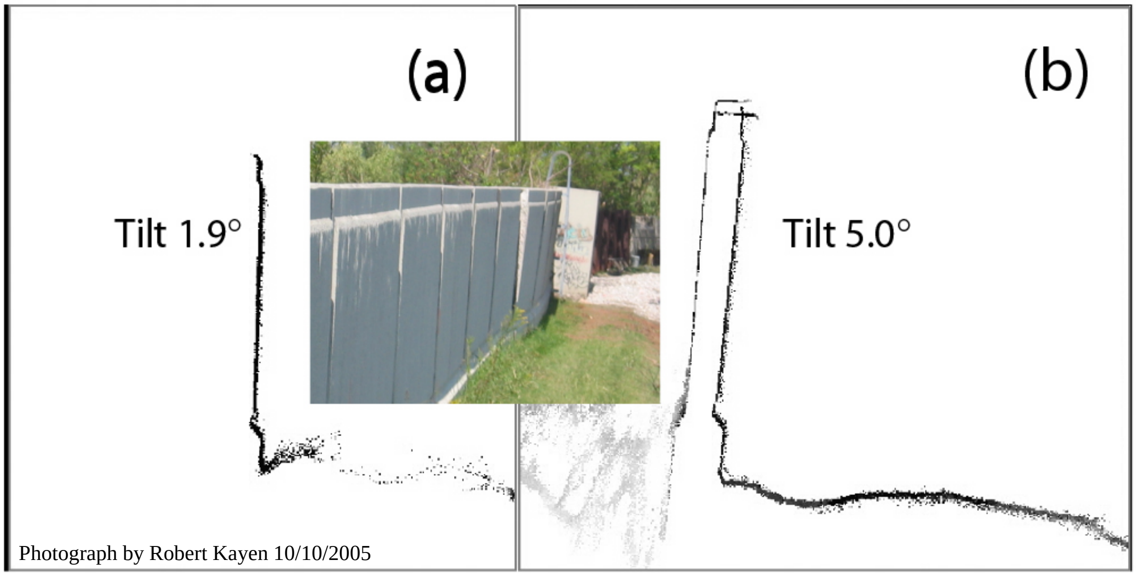
Source: Modified from http://ngs.woc.noaa.gov/storms/katrina/

Figure A-13: Site 11, Orleans Canal Pump Station Spillway at N29.99476°, W90.10070°



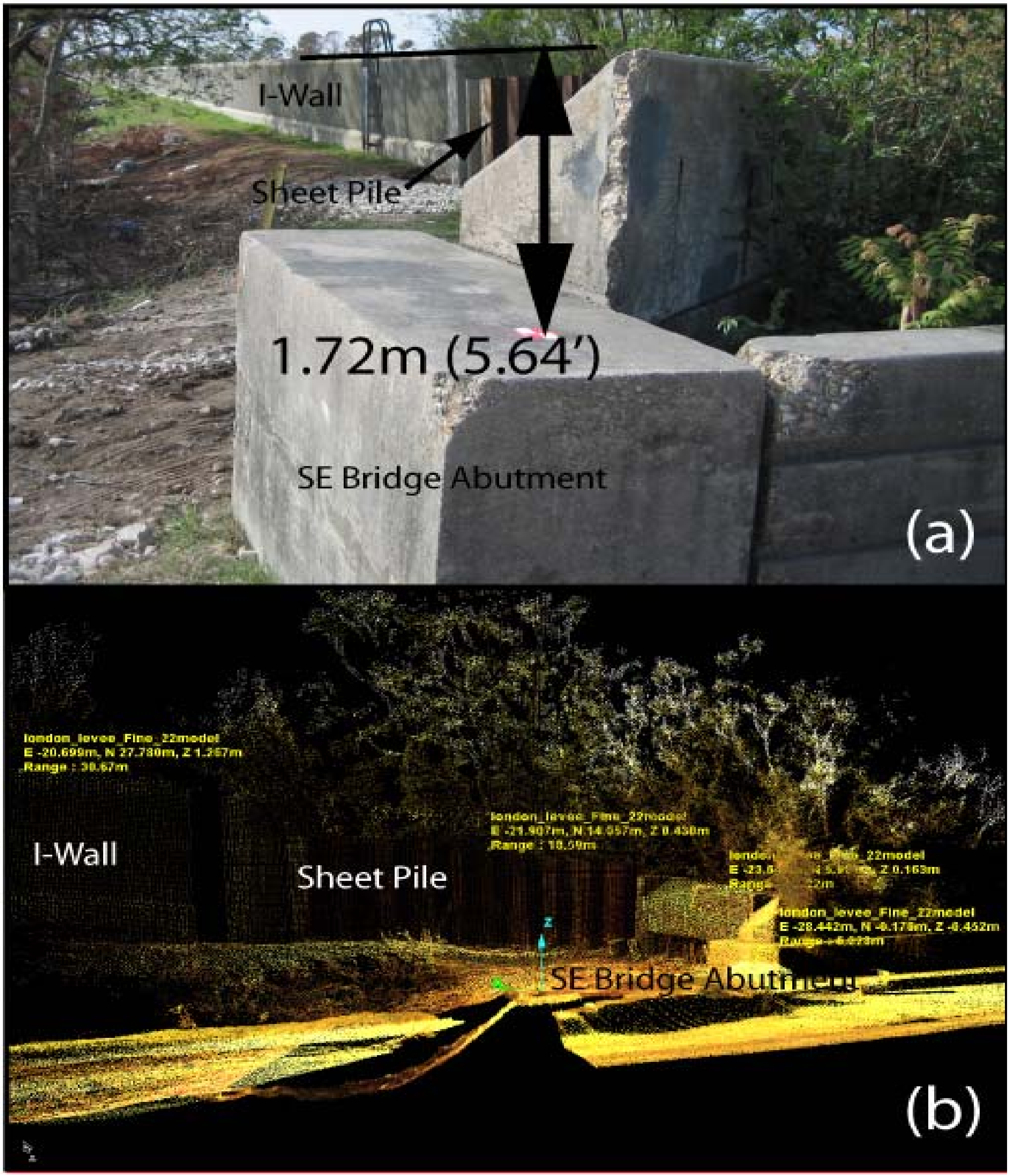
Photograph by Robert Kayen 10/10/2005

Figure A-14: Leaning I-wall of a distressed portion of the London Avenue Canal. The wall leans toward the levee maintenance road and landside portion of the levee. In the right-most background is the abutment of the bridge on Robert E. Lee Blvd. along with vegetation on the canal side of the levee.



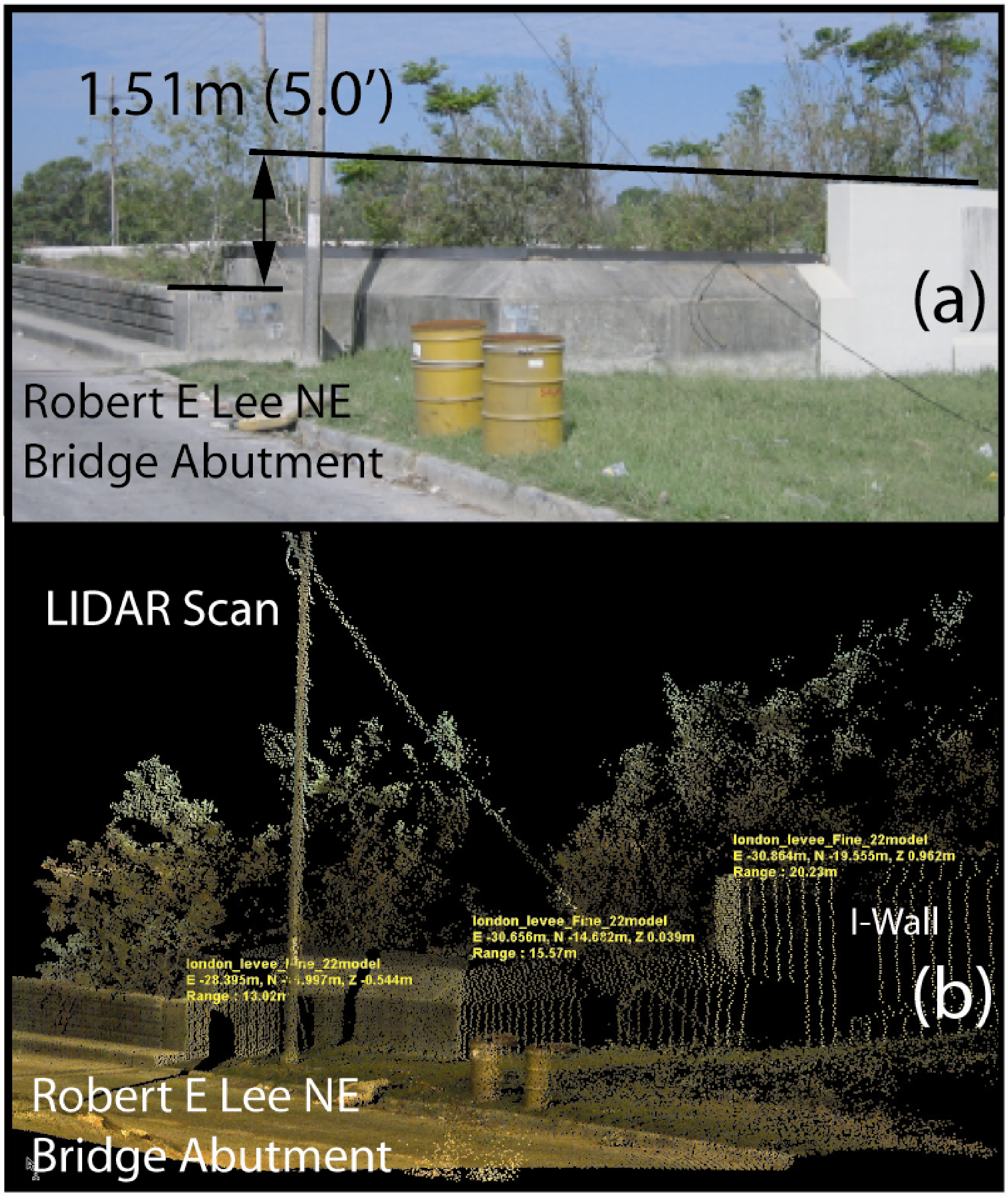
Photograph by Robert Kayen 10/10/2005

Figure A-15: Cross sections through two segments of distressed I-wall at London Avenue Canal. Segment (a) is toward the south (left) of Figure A-14 and has a modest 1.9 degree rotational deformation toward the landside of the levee. Near a position of maximum distress, the I-wall has 5.0 degrees of rotational deformation.



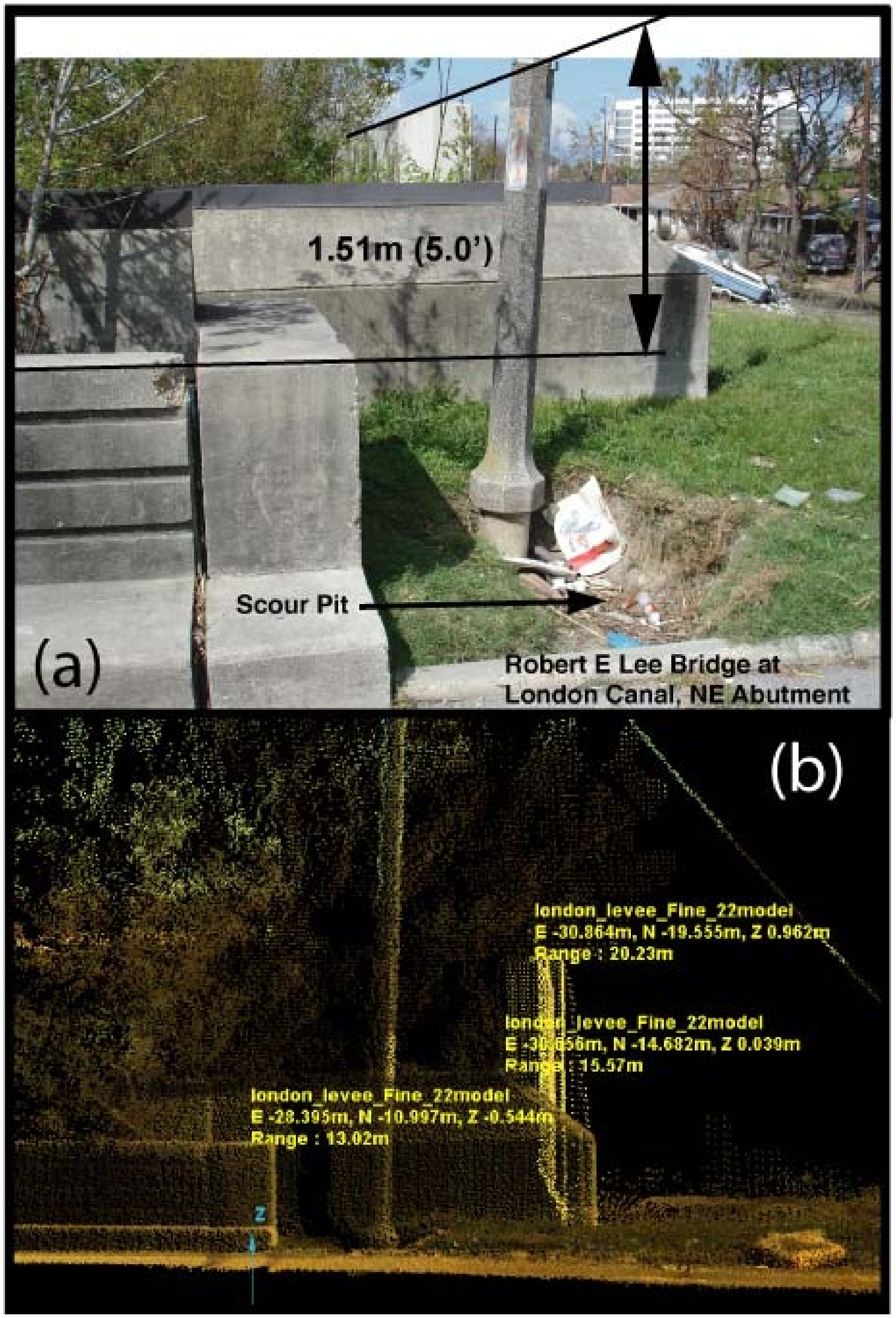
Photograph by Brian Collins 10/11/2005

Figure A-16: Photograph of the southeast abutment of the London Avenue Canal bridge at Robert E. Lee Blvd (a), and LIDAR scan of the same location (b). New soil and rock apparently fills scour and sink hole erosion beneath the abutment. The relative height gap between the bridge abutment and the flood wall is 1.72 meters (5.6 feet). Local coordinates are shown.



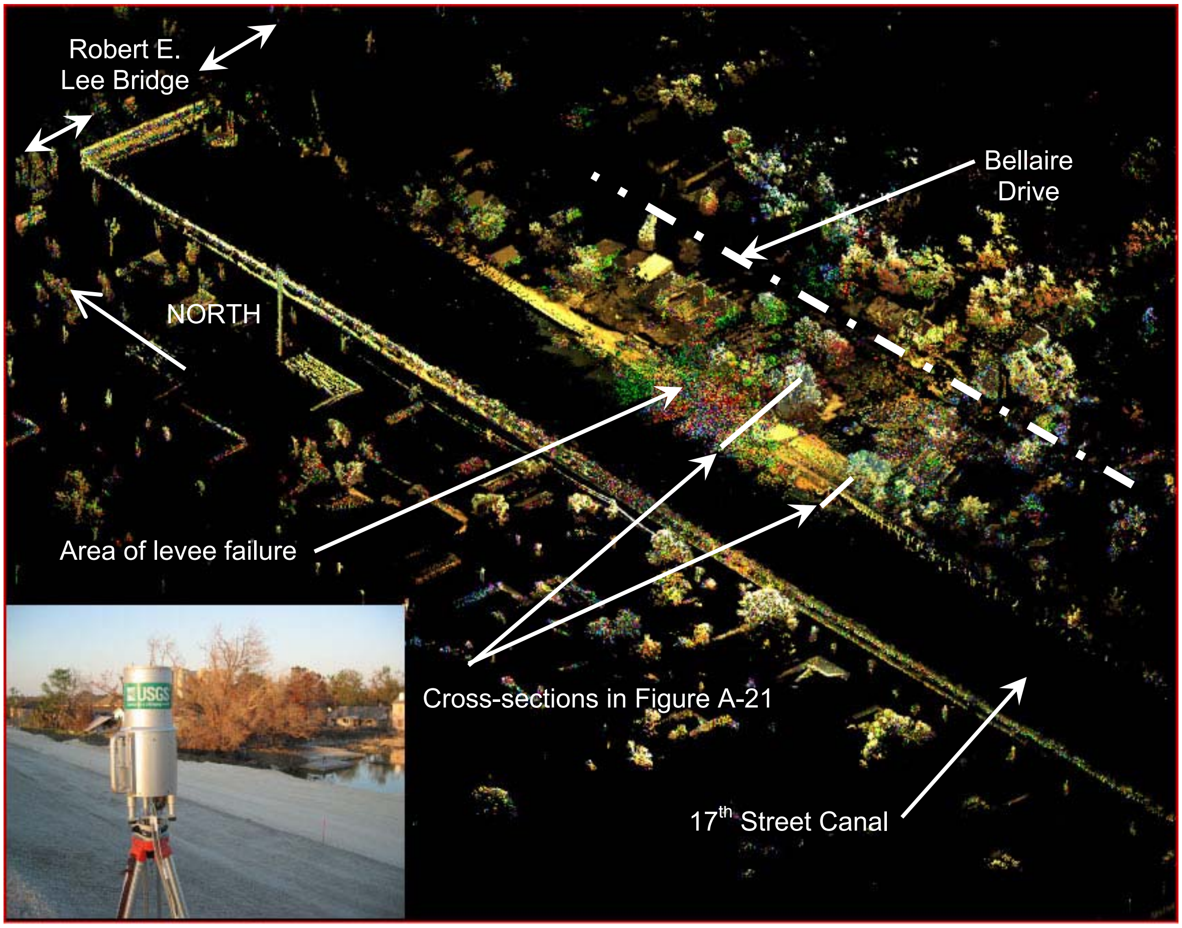
Photograph by Brian Collins 10/11/2005

Figure A-17: The northeast abutment of the London Avenue Canal bridge on Robert E. Lee Blvd. in photograph taken from the lower portion of the bridge approach-fill embankment (a), and corresponding LIDAR scan (b). The wall gap here is 1.51 meters (5.0 feet). Local coordinates are shown.



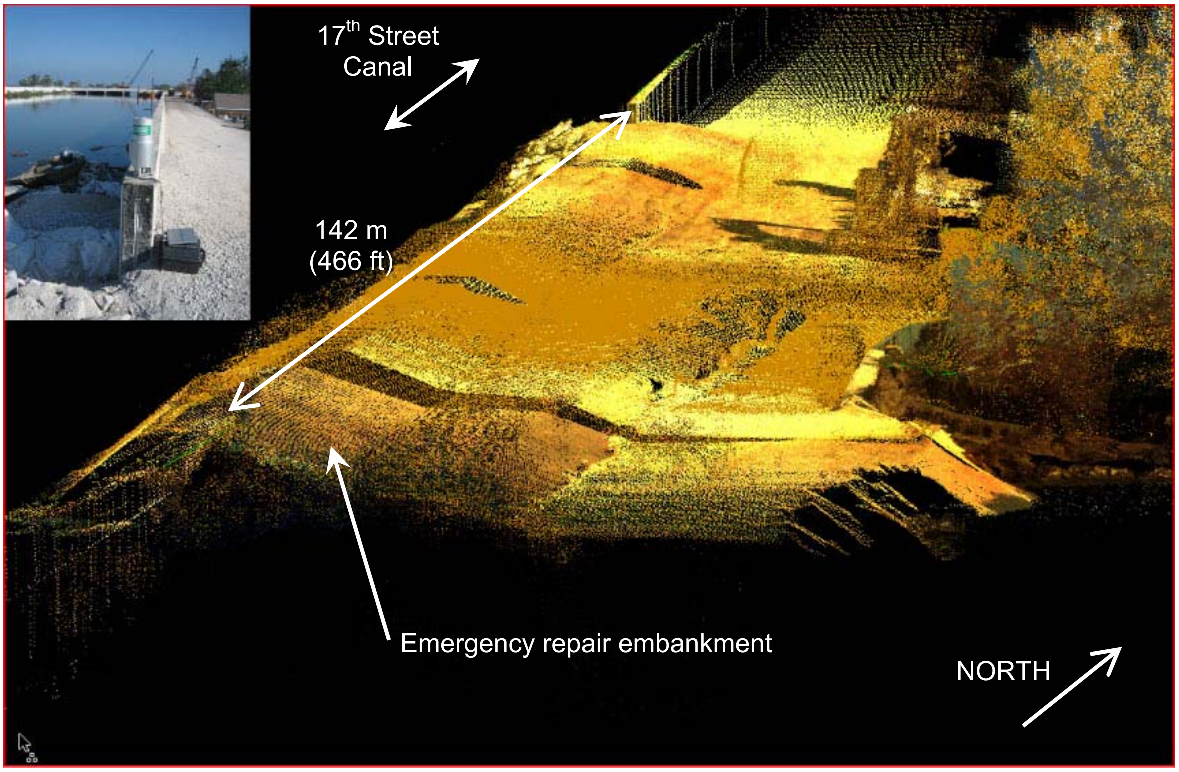
Photograph by Lee Wooten

Figure A-18 Photograph taken directly south and adjacent to the northeast abutment of the Robert E. Lee Bridge (a), and corresponding LIDAR scan of the same location (b). A scour trench is clearly visible beneath the abutment. The wall gap here is 1.51 meters (5.0 feet). Local coordinates are shown.



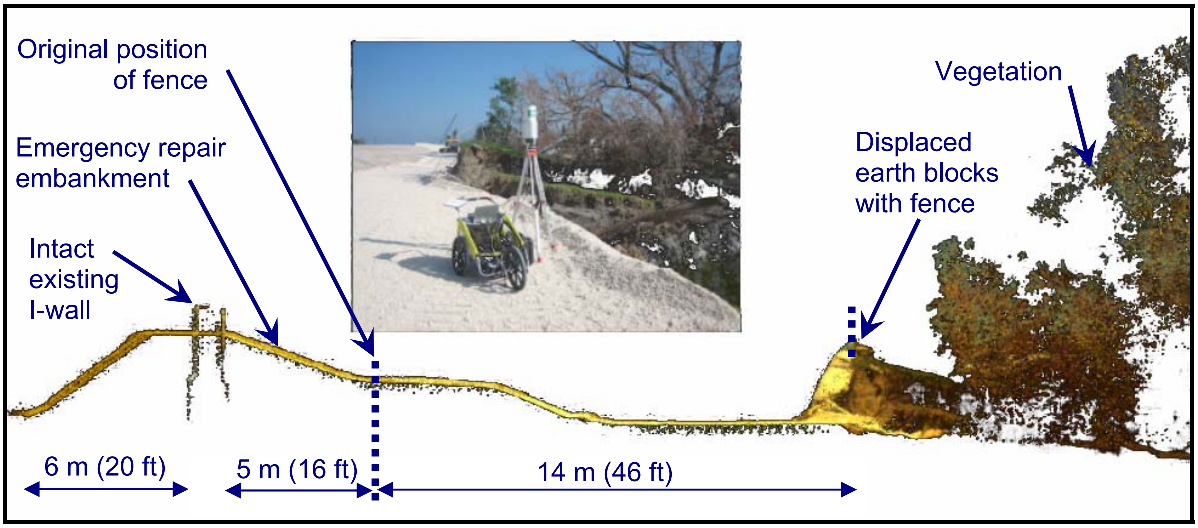
Photograph by Robert Kayen 10/9/2005

Figure A-19: Overview oblique image of the 17th Street Canal area in the vicinity of the breach. The Robert E. Lee Blvd. Bridge is to the north (upper left) and the breach area is to the upper right (east). Houses within the neighborhood breach area and the scour pond were imaged from the new levee and Bellaire Drive.



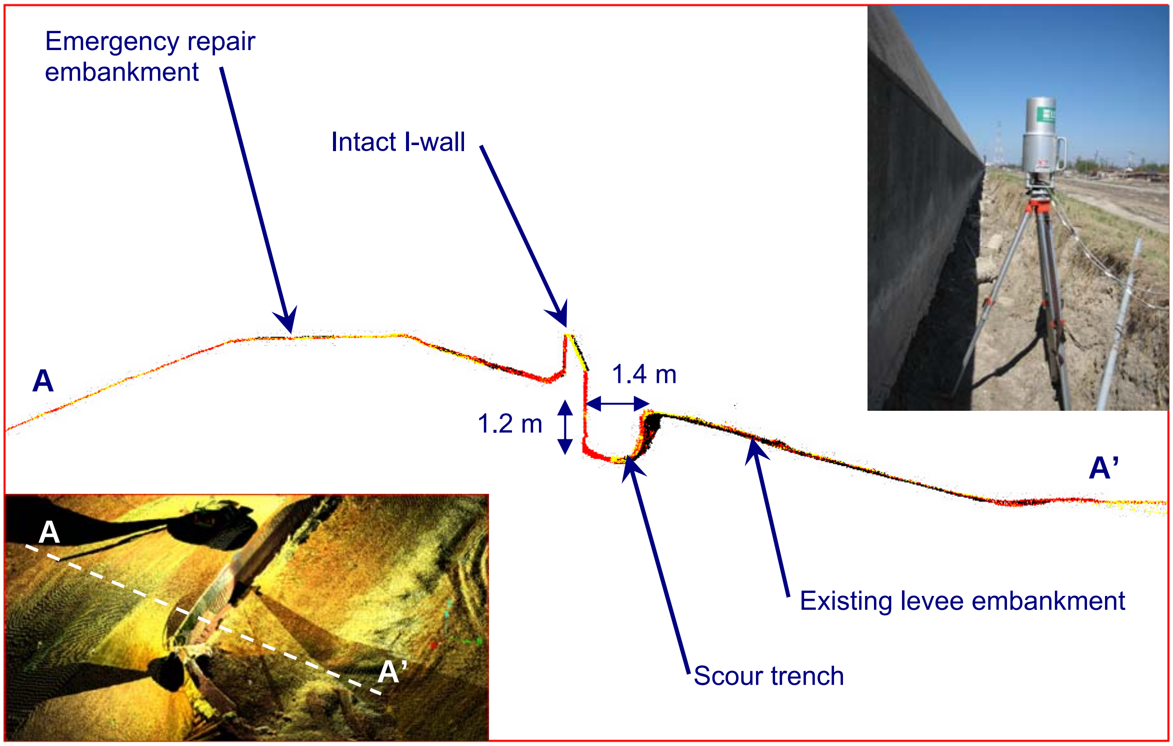
Photograph by Brian Collins 10/10/2005

Figure A-20. An oblique close-in image of the as built replacement levee at the 17th Street Canal breach from the south. The remaining I-wall is visible on either side of the earthen embankment.



Photograph by Brian Collins 10/10/2005

Figure A-21 Cross-section of the 17th Street Canal breach looking northward. Measurement of the lateral translation of the landside soil levee from its original position is approximately 14 meters (46 ft). The I-wall in this image is offset (out of the page) from the slide block.



Photograph by Brian Collins 10/11/2005

Figure A-22: Measurement of scour trench dimensions at the IHNC – South site.

APPENDIX B: BORING LOGS

As part of the field investigation 39 borings were performed at the sites of interest, as listed in Table B.1. The borings were performed by Soil Testing Engineers Inc. between 1/30/06 and 2/22/06, and 4/7/06 and 4/13/06. All fieldwork activities were conducted by members of ILIT under the direct supervision of senior members of the team.

Two drilling rigs were used for the geotechnical exploration: an F-350 truck-mounted rig with a 15ft tower (CME-75) and an “ARDACO” bogey rig for sites where access was difficult. Both rigs used 4” mud-rotary wash with a side discharge bit. Shallow borings were initially advanced using a 4-inch diameter auger. A small geoprobe was used to auger down to target depths for Field Vane Shear Testing in sites that were inaccessible by the other two rigs.

Three different types of borings were performed: (a) borings for continuous sampling for geologic characterization, (b) conventional geotechnical borings selectively sampled for laboratory tests of engineering properties and (c) borings for providing access for Field Vane Shear Testing.

Within the boreholes three types of sampling methods were used: (a) continuous sampling with 3” thin-walled Shelby Tubes (ASTM D1587-00) and extruded on site for geologic characterization, (b) “undisturbed” sampling at selected depths with 3” thin-walled, fixed-piston Shelby Tubes (ASTM D1587-00), where the tube mouth was modified to eliminate over-cutting and thus reduce sample disturbance due to rebound (Lunne and Lacasse 1994), and (c) disturbed sampling by performing the Standard Penetration Test (ASTM D1586-99), where cohesionless material was present.

The progression of the fieldwork program was based on an iterative process between the initial program and the new data as it was being collected from the field. The sampling process initiated with the continuous borings and continuous sampling to obtain a detailed description of the stratigraphy by extruding all samples on-site.

Upon completion of each day of fieldwork all boreholes were grouted using cement grout and bentonite pellets.

The pages that follow show plan views of the sites at which our investigation team performed borings, showing the locations of each boring. These are followed by the logs of these borings. Each boring log also has local GPS coordinates (x, y, and z) to help to further locate these borings.

17th STREET CANAL

BORING NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
17-CON-1	30.01739	90.12071	-6.5
17-CON-2	30.01718	90.12112	-2
17-CON-3	30.0172	90.12118	-2
17-CON-4	30.01709	90.12109	-1.8
17-CON-4 A	30.01708	90.12107	-1.8
17-CON-5	30.01731	90.12199	4.31
17-CON-6	30.01827	90.12056	-7
17-CON-7	30.01799	90.12126	3.8
17-CON-8	30.01826	90.1206	-7
17-CON-9	30.01705	90.12076	-6
17-CON-10	30.0172	90.12117	-2
17-CON-11	30.01654	90.12002	-6
17-BOR-1	30.0174	90.12069	-6.5
17-BOR-2	30.01619	90.12143	4
17-BOR-3	30.01636	90.12075	-6.6
17-BOR-4	30.01728	90.12197	4.3
17-BOR-5	30.01639	90.12212	4.3
17-BOR-6	30.01829	90.12059	-7
17-BOR-6 A	30.01828	90.12059	-7

LONDON AVENUE CANAL NORTH, EAST BANK

BORING NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LAC-CON-1	30.02097	90.0703	-7.7
LAC-BOR-1	30.02095	90.07031	-7.7
LAC-BOR-1 A	30.02094	90.06992	-8
LAC-BOR-2	30.02064	90.07024	-8
LAC-BOR-3	30.02135	90.07025	-8.2
LAC-BOR-4	30.01998	90.07014	-8.5

Note: Geographic coordinates are based on WGS84 datum.

LONDON AVENUE CANAL NORTH, WEST BANK

BORING NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LACW-CON-1	30.02044	90.07138	-5.6
LACW-BOR-1	30.02049	90.07135	-5.6
LACW-BOR-2	30.02049	90.07106	2.8
LACW-BOR-3	30.02129	90.07094	3.1
LACW-BOR-4	30.01951	90.07813	2.6

LONDON AVENUE CANAL SOUTH, EAST BANK

BORING NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LACS-CON-1	30.00915	90.06941	-0.15
LACS-CON-3	30.00851	90.06908	-2.3
LACS-BOR-1	30.00912	90.0694	-0.15
LACS-BOR-2	30.07985	90.06931	4.6
LACS-BOR-3	30.00849	90.06908	-2.3

INNER HARBOR NAVIGATION CANAL, EAST BANK

BORING NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
IHNC-N-CON-1	29.97865	90.02022	-3.4
IHNC-N-BOR-1	29.9786	90.0202	-3.4
IHNC-S-CON-1	29.97038	90.02313	0.93
IHNC-S-CON-2	29.97118	90.0227	-2.7
IHNC-S-CON-3	29.97246	90.0225	-2.3
IHNC-S-BOR-1	29.97039	90.02315	0.93
IHNC-S-BOR-2	29.97116	90.0227	-2.7
IHNC-S-BOR-3	29.97244	90.02251	-2.3

LONDON AVENUE CANAL NORTH, EAST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LAC-CPT-1	30.02097	90.07027	-7.7
LAC-CPT-2	30.02062	90.07026	-8
LAC-CPT-3	30.02135	90.07053	-8.2
LAC-CPT-4	30.01998	90.07032	-8.5

Note: Geographic coordinates are based on WGS84 datum.

LONDON AVENUE CANAL NORTH, WEST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LACW-CPT-1	30.02044	90.07136	-5.6
LACW-CPT-2	30.02048	90.07104	2.8
LACW-CPT-3	30.02131	90.07094	3.1
LACW-CPT-4	30.01953	90.07082	2.6

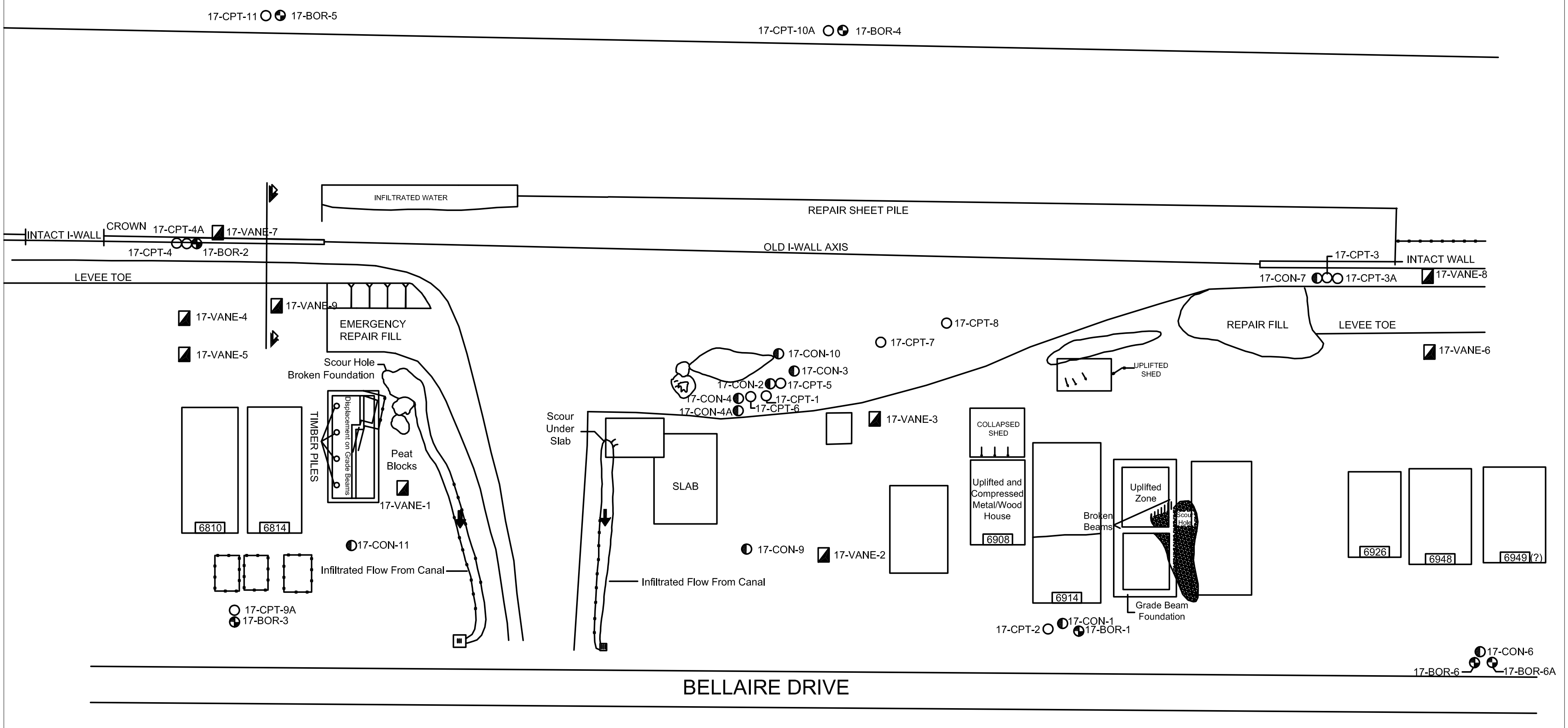
LONDON AVENUE CANAL SOUTH, EAST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LACS-CPT-1	30.00908	90.0694	-0.15
LACS-CPT-2	30.00797	90.06931	4.6
LACS-CPT-3	30.0085	90.06907	-2.3

INNER HARBOR NAVIGATION CANAL, EAST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
IHNC-N-CPT-1	29.9787	90.02049	-3.38
IHNC-S-CPT-1	29.97035	90.02314	0.93
IHNC-S-CPT-2	29.97126	90.02292	-2.7
IHNC-S-CPT-3	29.97248	90.02257	-2.3

Note: Geographic coordinates are based on WGS84 datum.



LEGEND

○ 17-CPT-#	Cone Penetration Test
◐ 17-CON-#	Continuous Boring
● 17-BOR-#	Geotechnical Boring
◪ 17-VANE	Field Vane Test
–▪–▪–▪–	Fence

17th Street Canal
APPROXIMATE ILIT BORING, CPT, VANE LOCATIONS
New Orleans, Louisiana

SIZE

DATE 05/06/2006

DWG NO. 17th Boring & CPT Plan

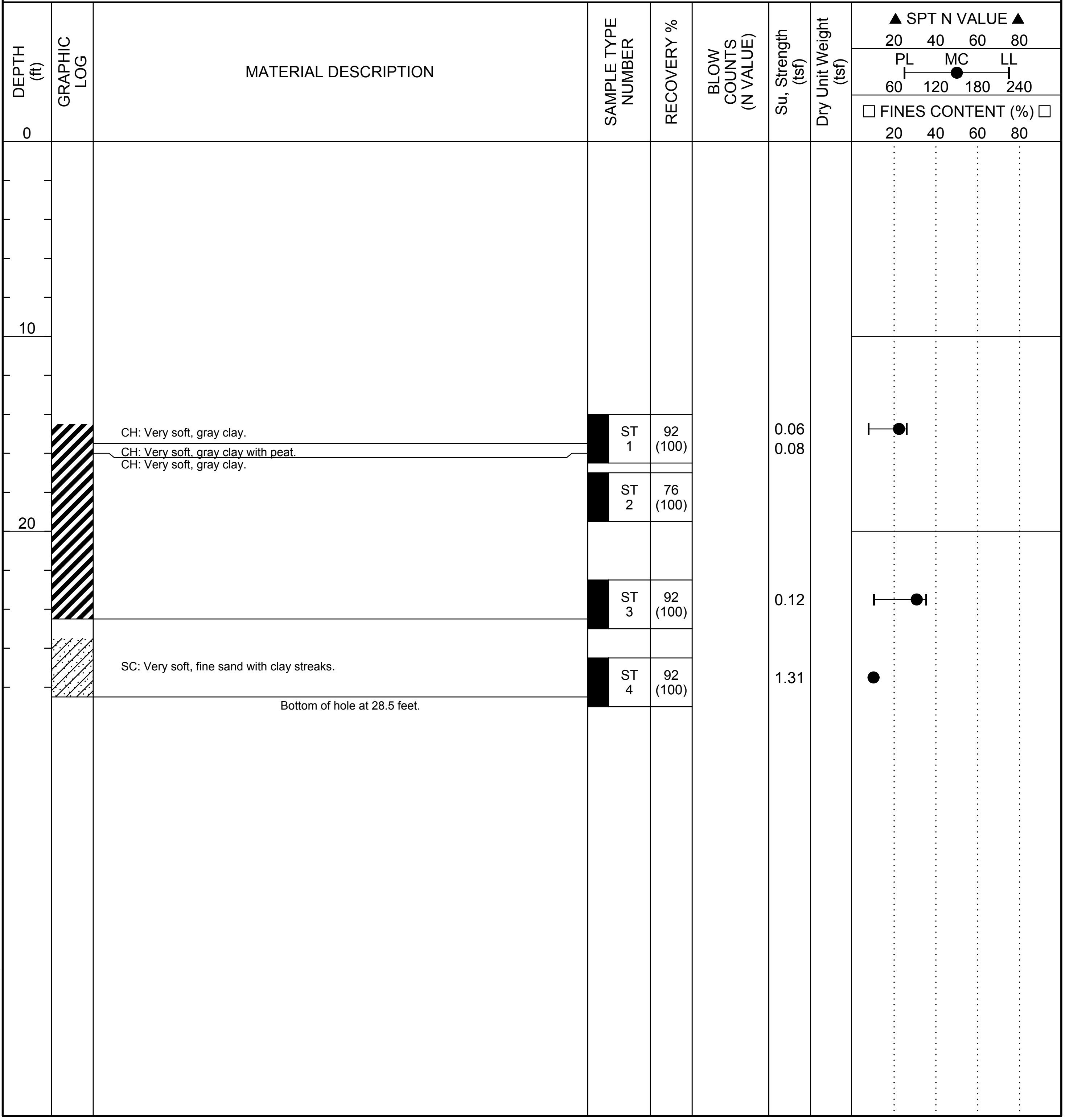
SCALE Not Drawn To Scale

SHEET

BORING NUMBER 17-BOR-1

UC Berkeley
Davis Hall
Berkeley, California

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 1/31/06 **COMPLETED** 1/31/06
GROUND ELEVATION -6.5 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES 6' East of driveway of 6914 Bellaire Drive
AFTER DRILLING ---



MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
CH: Very soft, gray clay.	ST 1	92 (100)		0.06 0.08	
CH: Very soft, gray clay with peat.					
CH: Very soft, gray clay.	ST 2	76 (100)			
	ST 3	92 (100)		0.12	
SC: Very soft, fine sand with clay streaks.	ST 4	92 (100)		1.31	

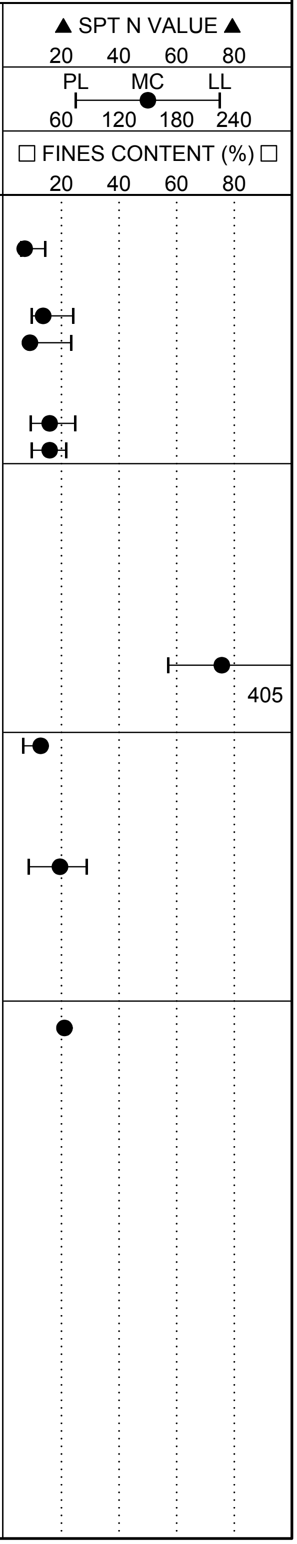
Bottom of hole at 28.5 feet.

BORING NUMBER 17-BOR-2

UC Berkeley
Davis Hall
Berkeley, California

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/3/06 **COMPLETED** 2/3/06
GROUND ELEVATION 4.0 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0						
	FILL: Stiff, brown slightly silty clay with stone and gravel.	ST 1	43 (100)		1.46	
	FILL: Stiff, dark gray, organic clay to gray and tan clay with 1/2"-1" silt layer.	ST 2	63 (100)		1.31	
	CH: Medium, gray clay with silt seams and layers 1/2"-1".				0.62	
10	CH: Soft, dark gray clay with silt seams and organics.	ST 3	93 (100)		0.27 0.88	
	No Recovery. Re-drive with smaller tube to get disturbed sample. Sample # 17-BOR-2-4* CH: Gray clay mixing with organic matter.	ST 4*	90 (100)			
	OH: Very fibrous marsh, roots, wood.	ST 5	93 (100)			
	OH: Medium, dark gray organic clay with peat.	ST 6	50 (100)		0.75	
20	CL-ML: Soft, gray, slightly silty clay.	ST 7	93 (100)		0.21	
	CH: Soft, gray clay with alternate layers of fine sand and silt.	ST 8	90 (100)		0.21	
30	CH: Soft gray clay with silt seams.	ST 9	93 (100)		0.18	
	Bottom of hole at 32.0 feet.					



BORING NUMBER 17-BOR-3

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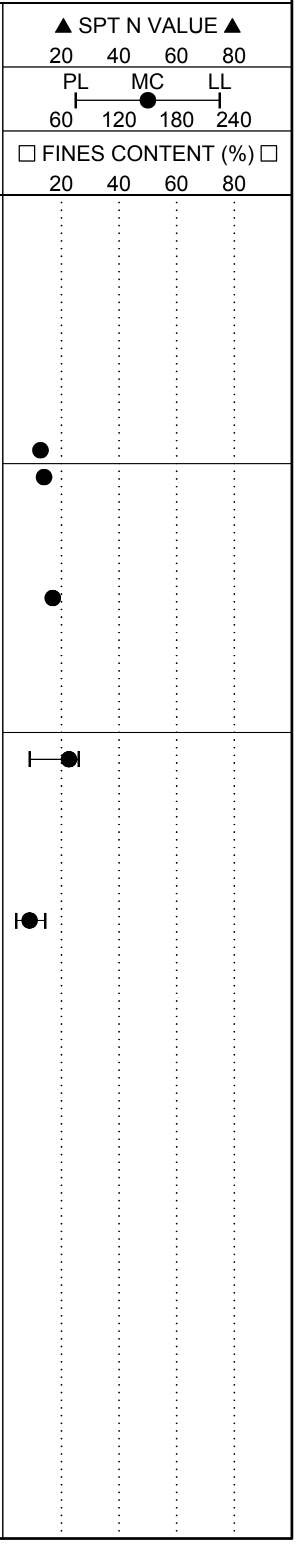
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/6/06 **COMPLETED** 2/6/06
GROUND ELEVATION -6.45 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	SC: Brown clayey sand, roots (6"), black/brown clayey fine sand, roots, organic matter (4"), gray/black sand with many roots transitions to light brown sand (3"), firm gray clay, signs of shells (1").	ST A	40 (100)			
	Top- SM: Brown silty sand. Bottom- OL: Black organic matter.	ST 1	50 (100)			
	OL: Marsh, mixing zone, gray CH and OH, transitions to CH. Bottom- CH: Gray clay.	ST 2	65 (100)			
10	Top- CL-ML: Silty, gray clay. CH: Very soft, dark gray clay with wood and shell fragments.	ST 3	73 (100)		0.11 0.11	
	CH: Very soft, gray clay with silty clay layers.	ST 4	90 (100)		0.12	
20	CH: Very soft, gray clay.	ST 5	92 (100)		0.11	
	CLS: Very soft, gray, very sandy clay with shell.	ST 6	92 (100)		0.14	
	Bottom of hole at 28.0 feet.					



BORING NUMBER 17-BOR-4

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UC Berkeley
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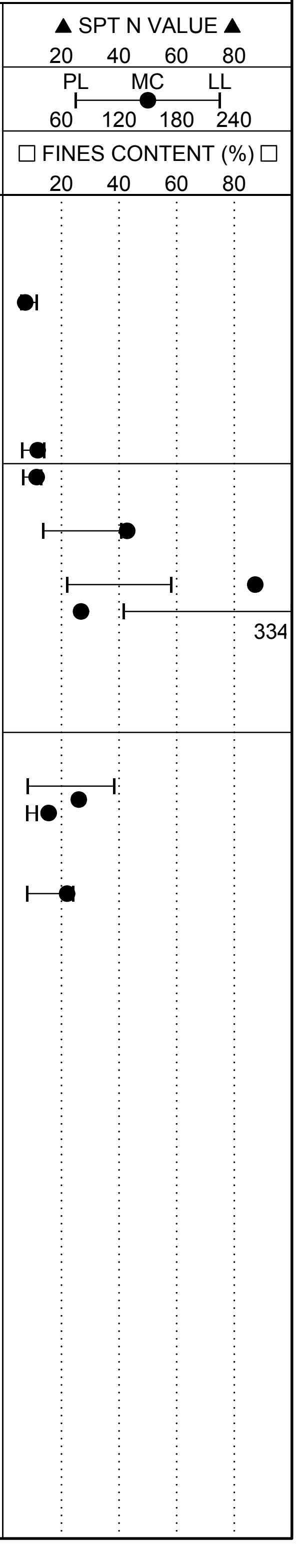
Berkeley, California

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (West)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/7/06 **COMPLETED** 2/7/06
GROUND ELEVATION 4.31 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft) 0	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
	FILL: Stiff, tan and brown clay with silt.	ST 1	38 (100)		0.65	
10	CL-ML: Medium, gray clay with silt and fine sand, alternating layers and traces of organic matter.	ST 2	80 (100)		0.33	
	CH: Medium, gray clay with silt seams and wood.				0.31	
	CH: Soft, gray and brown clay with peat and organics.	ST 3	87 (100)		0.25	
	OH: Soft, dark gray organic clay with peat.	ST 4	63 (100)		0.19	
	OH: Medium, dark gray organic clay with peat.				0.27	
	(roots)	ST 5	67 (100)			
20		ST 6	53 (100)			
	CH: Very soft, gray clay.	ST 7	92 (100)		0.1	
	SM-SC: Soft gray silty sand to silty clay (alternate layers).				0.29	
	CH: Soft, gray clay with alternating layers of silty, fine sand.	ST 8	93 (100)		0.19	
	Bottom of hole at 27.0 feet.					



BORING NUMBER 17-BOR-5

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Berkeley, California

CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (West)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 2/7/06 **COMPLETED** 2/7/06

GROUND ELEVATION 4.31 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

AT TIME OF DRILLING ---

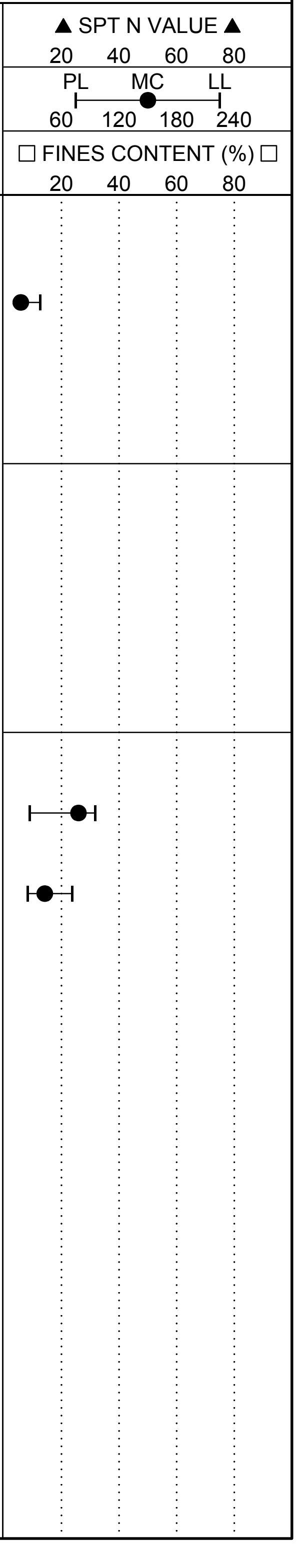
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES at the last 2', drill rig deviated from vertical

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0							
		FILL: Very stiff, tan and brown clay with silt.	ST 1	35 (100)		1.66	
		CL-ML: Brown silty clay.					
10		WOOD: Wood and shells.	ST 2	40 (100)			
		OL: Dark brown/black organic, half of area is wood.	ST 3	67 (100)			
		OL: Wood, organic clay.	ST 4				
		Wood, roots, organic matter.	ST 5				
20		CH: Very soft, gray clay with silt lenses and wood.	ST 6	92 (100)		0.12	
		CH: Soft, gray clay with alternating seams of silty fine sand.	ST 7	90 (100)		0.18	
		Bottom of hole at 27.0 feet.					



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Berkeley, California

BORING NUMBER 17-BOR-6

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/20/06 **COMPLETED** 2/20/06
GROUND ELEVATION -6.6 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
	▨	Sample# 17-BOR-6-1 was not retrieved so after 17-BOR-6 was completed,moved ~3' and sampled 5' to 7' with 20.5"/30". Sample# 17-BOR-6A-1.	ST 1	68 (100)				
	▨	CH: Gray clay, traces of organic matter, shells.	ST 2	77 (100)				
10	▨	CH: Gray clay, silt lenses.	ST 3	90 (100)				
		Bottom of hole at 12.0 feet.						

BORING NUMBER 17-CON-1

PAGE 1 OF 1

UC Berkeley
Davis Hall
Berkeley, California

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 1/31/06 **COMPLETED** 1/31/06
GROUND ELEVATION -6.5 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
∇ **AT TIME OF DRILLING** 4.0 ft / Elev -10.5 ft
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES 6' East of driveway of 6914 Bellaire Drive
AFTER DRILLING ---

DEPTH (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
	░	SM: Loose, dark brown, silty fine sand, moist, with occasional root mass, and organic matter. FILL: Very loose, dark brown, silty fine sand, moist, with fine pea-sized gravel.	ST	75 (100)				
	∇	SM: Brown, silty fine sand, moist, with shell fragments. with trace amount of 1"-1.5" subrounded gravel OL: Brown-black organics, moist, trace shells and sand. Changed to 4" mud rotary drill	ST	30 (100)				
		No Recovery, 2.5" diameter concrete block.	ST	0 (100)				
	▨	FILL: Shell fill with pea gravel, 1" to 2" subangular gravel, and dark brown, very moist silty clay (CH). CH: Gray clay, trace amounts of organic material (fibrous peat), trace of fine angular gravels.	ST 1	68 (100)				
10	▨	CH: Soft, gray clay, thin silt lenses, decreasing fine gravel content.	ST	80 (100)				
	▨	CH: Soft, gray clay, moist, with occasional shells and fibrous material and trace organic matter. medium to high plasticity silt lens at 11.3' and 11.5'.	ST 2	100 (100)				
	▨	CH: Gray clay, with shell fragments and silt lens at 13.5' and 13.75'. CH: Gray clay, trace of organic matter and decreasing shell content, silt lenses closely spaced.	ST	85 (100)				
	▨	CH: Soft grading to firm, gray clay, with trace of organic matter. 2" silt pocket at 14.3'.	ST	95 (100)				
	▨	CH: Soft to firm, gray clay, with trace organic matter.	ST	95 (100)				
20	▨	CH: Gray clay, with trace of organic matter.	ST	98 (100)				
	▨	CH: Very soft, gray clay, trace of silt, very moist.	ST 3	85 (100)				
	▨	CH: Gray clay. Very soft zone at 23.6'.	ST 4	93 (100)				
	▨	CH: Gray clay, grading to stiffer 25.3' to 26.0'.	ST	93 (100)				
	▨	CH: Gray clay, occasional lens of medium subrounded gray and white sand. Transition layer of soft gray plastic clay (CH), moist. increasing trace of sand and shell fragments.	ST 5	100 (100)				
30	░	SM: Loose, gray silty sand with clay, moist, trace amounts of shells. decreasing fines content with depth.						
		3" diameter Shelby tubes used. Extruded and logged onsite. At 4' depth, changed to rotarty mud drill (4"). 5 bulk samples taken. Bottom of hole at 30.0 feet.						

BORING NUMBER 17-CON-2

UC Berkeley
Davis Hall
Berkeley, California

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/1/06 **COMPLETED** 2/1/06
GROUND ELEVATION -2 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		MH: Firm, brown silt, moist, with fine sand, organic matter and wood.	ST 1	40 (100)				
		ML: Moderately stiff, brown sandy silt with clay, moist, with 1.5"-2" thick fine and uniform sand lenses and fine root mass.	ST 2	55 (100)				
		grading stiffer and sandier as root mass increases	ST 3	75 (100)				
		WOOD: Damaged tube between 6' and 8'. Changed to 4" diameter mud rotary drill.						
		OL: Dark brown, organic silt, with partially decomposed organic material, thin to 3/8" diameter wood fragments. Very strong organic odor. Rapidly loosing fluid in borehole. Water rising from hole or CPT-1 drilled close by. Bentonite added to boring fluid.	ST 4	75 (100)				
10		CH: Soft, gray clay, moist, with organic matter and partially decomposed wood. strong organic odor.	ST 5	75 (100)				
		Very moist, clearly increasing plasticity and decreasing organic content and fibrous material.	ST 6	85 (100)				
		Very soft clay, grading to firmer from about 14.8', trace of fine roots. ML: Medium plasticity, gray clayey silt, grading to stiffer, very moist.	ST 7	95 (100)				
		CH: Very soft, gray clay, trace of organic matter and roots. ML: Gray, medium plasticity silt. 1"-2" very fine uniform, moist sand lenses.	ST 8	95 (100)				
		CH: Soft, gray silty clay, high water content. transitions to clayey silt (ML), grading to more firm from 18.5'.	ST 9	95 (100)				
20		Very soft, clay, with 1"-1.5" silt lenses, trace thin wood fragments and roots. grading to stiffer.	ST 10	100 (100)				
		Firm, light gray to gray clay, moist, with trace organic matter and thin silt lenses.	ST 11	100 (100)				
			ST 12	90 (100)				
		Soft, gray clay, moist, with trace wood and organic matter.	ST 13	90 (100)				
		High moisture content with partially decomposed wood, strong organic odor.	ST 14	95 (100)				
30		Firm, gray clay, with fine uniform sand lenses 1.5"-2" thick. trace of fresh water (oyster) shells from 31'-32'.						
		Firm, gray clay, with silt lenses 1" thick. transitions to sand, grading stiffer. SP: Loose, gray, fine, uniform sand, very moist, with trace of shells.	ST 15	95 (100)				
		CLS: Firm, gray sandy clay, fine uniform sand pocket from 34'-34.4'.	ST 16	100 (100)				
		Bottom of hole at 36.0 feet.						

BORING NUMBER 17-CON-3

PAGE 1 OF 1

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/1/06 **COMPLETED** 2/1/06
GROUND ELEVATION -1.7 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		WOOD						
10		OL: Dark brown, organic silt, with organic matter, roots, and fibrous material. Root-induced diagonal crack zone at 9.5'.	ST 1	70 (100)				
		CH: Very soft, gray clay intermixed with black organic silt, saturated, strong organic odor. Transition to gray high plasticity clay, grading to stiffer, moist, with organic matter, roots, and wood.	ST 2	70 (100)				
		Bottom of hole at 14.0 feet.						

BORING NUMBER 17-CON-4

PAGE 1 OF 1

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/3/06 **COMPLETED** 2/3/06
GROUND ELEVATION -1.8 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		Drilled to 9.5' with mud rotary.						
10		OH: Intermixing of dark brown, organic silt with fibrous material and organic matter, with gray high plasticity clay (CH).	ST 1	70 (100)				
		Bottom of hole at 11.5 feet.						

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BORING NUMBER 17-CON-4A

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 2/3/06 **COMPLETED** 2/3/06

GROUND ELEVATION -1.7 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

AT TIME OF DRILLING ---

LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		OL: Dark brown, organic silt, very high moisture content, with organic matter and roots, with some gray clays down to 6.8'.	ST 1	75 (100)				
		OH: Very soft, gray clay mixed with dark brown and black silt (OH), and tan clay (CH), very high moisture content.	ST 2	60 (100)				
10	▨	CH: Grades to stiffer clay, decrease in water content. End of intermixing zone. Gray clay, with trace of organic matter.						
		Bottom of hole at 10.0 feet.						

BORING NUMBER 17-CON-5

PAGE 1 OF 1

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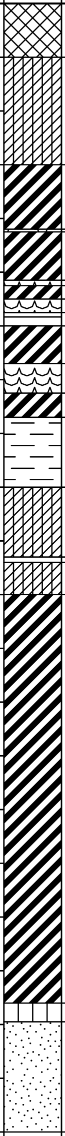
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (West)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/7/06 **COMPLETED** 2/7/06
GROUND ELEVATION 4.31 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---



DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0	FILL: Dark brown clay, thin layer of crushed rock, with shells. Wood, concrete followed by stiff, dark brown clay with fine sand.	ST 1	65 (100)				
	CL-ML: Firm to stiff, gray-brown silty clay with shells. Red-brown, fill material consisting of silty clay.	ST 2	55 (100)				
	Stiff, gray silty clay, less silty fines. Silty clay, clay includes reddish brown traces. Gray silty clay.	ST 3	85 (100)				
	CH: Firm to stiff, gray brown clay with reddish traces and shells. Clay, contains mostly crushed shells.	ST 4	75 (100)				
	SHELL: Shell layer followed by black organic traces. CH: Firm, gray silty clay with silt lenses, grades stiffer with more silt at 9.4'. Brown, medium stiff clay with reddish traces and lower silt content.	ST 5	80 (100)				
10	Gray clay with shells. OH: Organic layer with wood and black organic matter. CH: Medium stiff clay becomes softer before becoming more organic.	ST 6	90 (100)				
	OH: Black organic matter. WOOD CH: Gray clay with black organic clay.	ST 7	43 (100)				
	OH: Firm, black clay with wood, silt, strong odor. Dark gray clay with roots, organics wood and roots for the 1st 3", strong odor. 3" to 6" contains plastic organic clay, shells, and gravel up to 2" in diameter.	ST 8	98 (100)				
	CH: Gray clay with wood. Wood at 15.4' Shells, roots, and organics, strong odor.	ST 9					
	First 1' sheared by wood. Large amount of organics and roots throughout. 3" chunk of wood CL-ML: Silty clay with organics and roots throughout. Very soft up 18.8'.	ST 10					
20	Becomes stiffer silty clay. OL: Organics with wood and odor. CL-ML: Gray, silty clay. Clay is firm until 1.3' where it becomes softer.	ST 11					
	CH: Gray, high plasticity clay with silt lens at 1.1', becomes more silty after 1.1', traces of black organic throughout and roots at the base of the sample.	ST 12					
	Gray silty high plasticity clay with silt lenses every few inches. Large silt lens at 24.6'. Stiff, clean plastic clay from 25.3' to end. Silt lenses absent in this layer.	ST 13					
	Clay with wood at 26.3' to 26.4'. Stiffer, gray silty clay with silt lenses. Appears to be fine sand mixed into the silt lenses from 27.45' to the end of the sample.	ST 14					
	Firm, gray, silty plastic clay.	ST 15					
30	Gray, softer clay, 1" sized gravel at 30.1'. Very soft 1/2" inclusion of plastic clay with high water content in filled root track from 30.3' to 30.6'. Silt lens at 30.7', firm, silty clay to the end of the sample.	ST 16					
	Soft, gray plastic clay with even softer zones surrounding roots. Many shells and filled roots. Shells at 32.5' that is 1 5/8" across. This material is very soft, plastic, and has high water content until a silt lens at 32.8'. Firm clay from 32.8' to the end.	ST 17					
	Roots in very soft clay through to 34.25'. Secondary intersitial clay in root tracks, very soft high water content very plastic clay. Stiff clay.	ST 18					
	Soft root track through clay until 37', highly plastic, high water content in soft filling.	ST 19					
	Silt lens. SP: Dirty gray sand containing shell particles for last 1".	ST 20					
40	Dirty gray, medium grained sand throughout, contains shell fragments.	ST 21					
	Bottom of hole at 42.0 feet.						

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BORING NUMBER 17-CON-6

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/20/06 **COMPLETED** 2/20/06
GROUND ELEVATION -6.6 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING N/A
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES 6946 Bellaire Drive
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		TOPSOIL: Organic matter with roots (moist), topsoil and sediments, tan-brownish yellow sand.	ST 1	35 (100)				
		Brownish yellow sand, topsoil and sediments.	ST 2	40 (100)				
		Topsoil and sediments. OL: Organic silty matter with tan sand in the middle of cross section, roots. Grading to organic clay, roots, traces of red organic matter, strong odor.	ST 3	73 (100)				
		CH: Soft, gray clay with traces of organic matter grading to high PI gray clay with roots and shell fragments.	ST 4	43 (100)				
10		Soft, gray clay, shell fragments.	ST 5	43 (100)				
		Soft, gray clay, silt lens at 11.4' (~1" thick).	ST 6	95 (100)				
		Soft, gray clay.	ST 7	90 (100)				
		Bottom of hole at 14.0 feet.						

BORING NUMBER 17-CON-7

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/20/06 **COMPLETED** 2/20/06
GROUND ELEVATION 3.8 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
▽ **AT TIME OF DRILLING** 13.5 ft / Elev -9.7 ft
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
▼ **.25hrs AFTER DRILLING** 12.2 ft / Elev -8.4 ft

DEPTH (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
		Auger first 2'.						
		FILL: Medium Firm, tan-brown, sandy clay with silt (CL) and trace amount of roots.	ST 1	55 (100)				
		Tan and gray clay with silt (CH) and small brick fragments. ML: Light gray, soft clayey silt, moist, with organic matter and roots.	ST 2	88 (100)				
		OH: Dark brown and black, soft organic silt, moist, with roots and organic matter, trace amount of reddish-brown stains.		100 (100)				
		Dark brown-black very soft organic silt, with trace of fine sand, organic matter, roots and organic odor.	ST 3	70 (100)				
10		Intermixig zone. Dark brown organic silt mixed with very fine gray silty sand (SM), and gray clay (CH), very low density organics (OH). CH: Dark brown and gray clay with lenses of fine gray sand. CL: Soft, gray silty clay, moist, trace amount of roots and organic matter.	ST 4	78 (100)				
		OH: Very soft, black organic silt, low density, moist, with some gray clay, roots, and organic odor.	ST 5	90 (100)				
		CH: Intermixing zone. Very soft, dark brown-black organic silt (OH), moisture content increases with depth, mixed with gray clay (CH), and very fine silty sand (SM). Sand lens @11.5', horizontal crack on interface. Trace of wood and roots. ML: Very soft, gray, medium plasticity clayey silt, very moist.	ST 6	75 (100)				
		OH: Very soft, dark brown, fibrous organic silt, very moist, low density , with significant amount of wood and strong organic odor. WOOD	ST 7	95 (100)				
		OH: Black organic silt, with decomposed organic matter, saturated. WOOD (single core of wood in tube) fragments and roots.	ST 8	100 (100)				
		CH: Very soft, dark gray and brown, high plasticity clay with fine sand lenses, organic matter and roots.						
		OH: Very soft, black-dark brown fibrous organic silt with trace amount of roots and strong organic odor, transitions to gray clays (CH).						
		CH: Medium firm, gray clay, trace of shells and organic matter. 1" to 2" thick silt pockets. Bottom of hole at 19.0 feet.						

BORING NUMBER 17-CON-8

PAGE 1 OF 1

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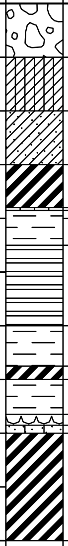
CLIENT ILIT (Independent Levee Investigation Team)	**PROJECT NAME** 17th Street Canal (East)
PROJECT NUMBER	**PROJECT LOCATION** 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/20/06 **COMPLETED** 2/20/06	**GROUND ELEVATION** -2.0 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE	**GROUND WATER LEVELS:**
DRILLING METHOD Mud Rotary	**AT TIME OF DRILLING** N/A
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa	**AT END OF DRILLING** ---
NOTES	**AFTER DRILLING** ---



DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		GP: Stiff, gravel fill, light brown, silty-sandy clay, dark brown clay, traces of black organic.						
		CL-ML: Gray-brown clayey silt, interchanging with gray-brown silty clay, layered with brown, red lenses.						
		CLS: Interchanging of medium stiff clay, silt, fine sand in gray, brown, orange, red colors.						
		CH: Brown, gray clay with shells.						
		SP: Very fine sand or silt lens.						
		OL: Black organic matter, fibrous, with roots.						
10		OL: Organic matter, fibrous (Marsh). WOOD drilled through wood						
		OL: Black organic matter with roots.						
		CH: Gray clay with silt lenses.						
		OL: Black organic matter, roots and wood, strong odor (Marsh).						
		OH: Contact with clay happens vertically (Marsh).						
		SM: Silty fine sand.						
		CH: Mixing gray clay with black organic matter. gray clay with fine sand clay with roots						
20		becomes firmer, silt content increases clayey silt with fine sand, trace roots						
		Bottom of hole at 20.0 feet.						

BORING NUMBER 17-CON-9

PAGE 1 OF 1

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/20/06 **COMPLETED** 2/20/06
GROUND ELEVATION -6.6 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
▽ **AT TIME OF DRILLING** 0.0 ft / Elev -6.6 ft
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0	▩	▽ FILL: Loose, tan, fine, uniform sand (SP), with brick fragments and trace of organic matter.	ST 1	90 (100)				
	⁘ 〰	SM: Loose, brown, silty sand, saturated, with organic matter and roots. OH: Dark brown-black organic silt, saturated, with strong organic odor and light brown stains.	ST 2	40 (100)				
	〰	Extremely soft, black-dark brown organic silt, low density, very high water content, vertically aligned roots and wood fragments, strong organic odor.	ST 3	78 (100)				
	▨	CH: Transition to very soft, gray clay, high water content, with organic matter and trace of roots. Intermixing zone. Very soft, gray clay mixed with black, soft organic silt (OH), very high water content.	ST 4	58 (100)				
		Very soft, gray clay with fine sand lenses (1" to 2" thick) with trace amount of organic matter. Bottom of hole at 8.0 feet.						

BORING NUMBER 17-CON-10

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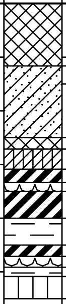
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 2/20/06 **COMPLETED** 2/20/06
GROUND ELEVATION -2 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING ---
LOGGED BY C. Cheung **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		FILL: Stiff, brown silty clay.						
		FILL: Gray, gravelly fill.						
		SC: Light brown to brown, clayey silty sand.						
		SM/SC to CL: Light brown, silty, clayey sand.						
		CH: Dark brown clay fill.						
		CL-ML: Firm, dark gray silty clay. Silt to fine sand lens.						
		CH: Gray clay, silty fine sand lens, mixing with above.						
		OH: Gray clay mixing with organics.						
		CH: Mixing gray clay with silt and fine sand, 7'4" cleaner gray clay.						
		OL: Dark brown organics, roots, fibrous.						
10		CH: Soft, light gray clay.						
		OH: Mixing of gray clay with black, fibrous organic matter.						
		OL: Dark brown, fibrous organics.						
		ML: Wood with silt.						
		Bottom of hole at 11.0 feet.						

BORING NUMBER 17-CON-11

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 2/20/06 **COMPLETED** 2/20/06

GROUND ELEVATION -6 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

∇ **AT TIME OF DRILLING** 0.0 ft / Elev -6.0 ft

LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		∇ No Recovery. Recently deposited sediment.	ST 1	0 (100)				
		OH: Very soft, black-dark brown organic silt, saturated, with organic matter, roots, wood, strong organic odor. Bottom is mixed with gray clay (CH).	ST 2	55 (100)				
		OH: Intermixing zone. Black organic silt, mixed with gray clay (CH). Extrememly soft, very high water content with organic matter and wood.	ST 3	100 (100)				
		CH: Very soft, gray clay, high water content, trace of organic matter and roots. 1" thick silt lenses.						
		CH: Very soft, gray clay with organic matter, wood and roots. Trace of black organic silt, very moist.	ST 4	84 (100)				
		Bottom of hole at 8.0 feet.						

Base map: IPET

LEGEND

🟩 London 2006 ILIT Field Vane

● London 2006 ILIT Boring and Cone Penetration Test
LAC-BOR-#: Boring
LAC-CON-#: Continuous Boring
LAC-CPT-#: Cone Penetration Test

LONDON AVENUE CANAL (NORTH)
APPROXIMATE ILIT BORING, CPT, VANE LOCATIONS
New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	05/04/2006	LACSitePlan	

SCALE Not Drawn To Scale

SHEET

BORING NUMBER LACW-BOR-1

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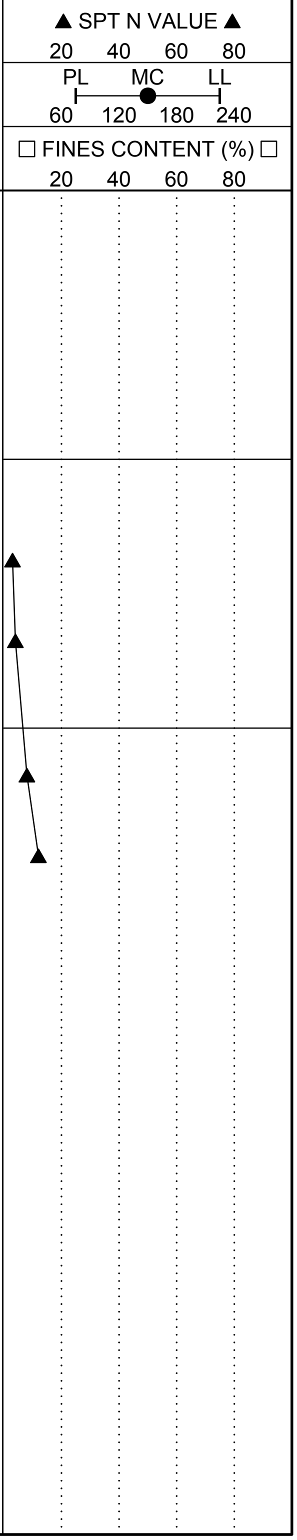
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Outfall Canal - North (West)
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 2/13/06 **COMPLETED** 2/13/06
GROUND ELEVATION -5.6 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Auger
AT TIME OF DRILLING 6'
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES Frontyard of 6109 Pratt Dr. (West-outside breach).
.25hrs AFTER DRILLING 5'

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0		Auger to 4'.					
		Top- CH: Gray clay. Bottom- SM: silty sand	ST 1	80 (100)			
10			ST 2	73 (100)			
		SP: Very loose, gray sand, saturated.	SS	61 (100)	1-1-2 (3)		
		SP: Very loose, gray sand, saturated.	SS	33 (100)	3-2-2 (4)		
20			SS		4-4-4 (8)		
		Loose, fine, gray sand with shell fragments, strong organic odor.	SS		7-7-5 (12)		

*Bottom of hole at 60.0 feet.
Bottom of hole at 25.5 feet.



BORING NUMBER LACW-BOR-2

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Outfall Canal - North (West)

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 2/14/06 **COMPLETED** 2/14/06

GROUND ELEVATION 2.8 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Hollow Stem Auger

AT TIME OF DRILLING N/A

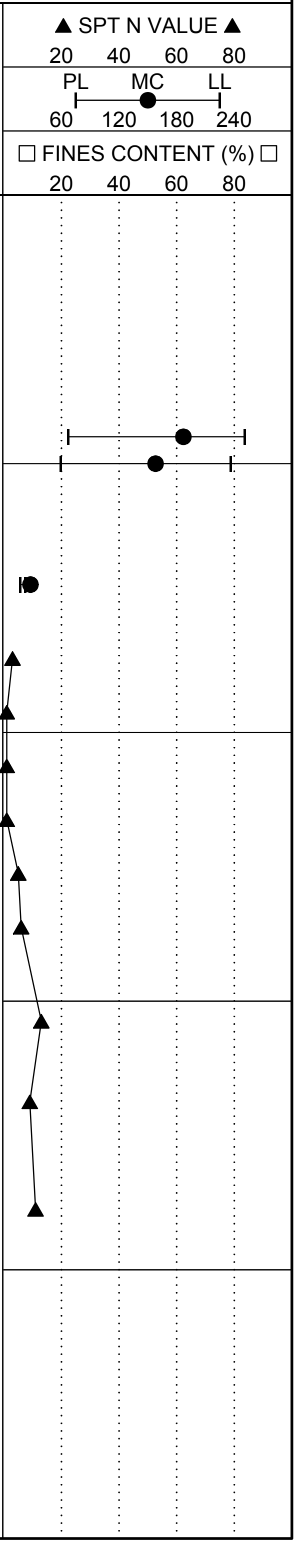
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0		GP: Gravel fill (emergency repair). Augered to 5' using a hollow-stem auger.					
		Bottom- OL: Organic matter, roots, wood.	ST 1	43 (100)			
10		OH: Soft, dark organic clay with peat.	ST 2	67 (100)		0.13 0.12	
		Bottom- CL-ML: Gray, sandy, silty clay.	ST 3	67 (100)			
		SM: Gray silty fine sand.	ST 4	63 (100)			
		Attempted to sample 16' to 18', no recovery, so cleaned 6" and performed SPT at 16.5'.	SS	33 (100)	1-2-1 (3)		
20			SS	100 (100)	1-0-1 (1)		
			SS	100 (100)	0-0-1 (1)		
			SS	44 (100)	1-1-0 (1)		
			SS	44 (100)	2-3-2 (5)		
			SS	44 (100)	1-3-3 (6)		
30			SS	56 (100)	3-5-8 (13)		
		SP: Light gray sand.	SS	61 (100)	2-4-5 (9)		
			SS	56 (100)	4-5-6 (11)		
40		Bottom of hole at 40.0 feet.					



BORING NUMBER LACW-BOR-3

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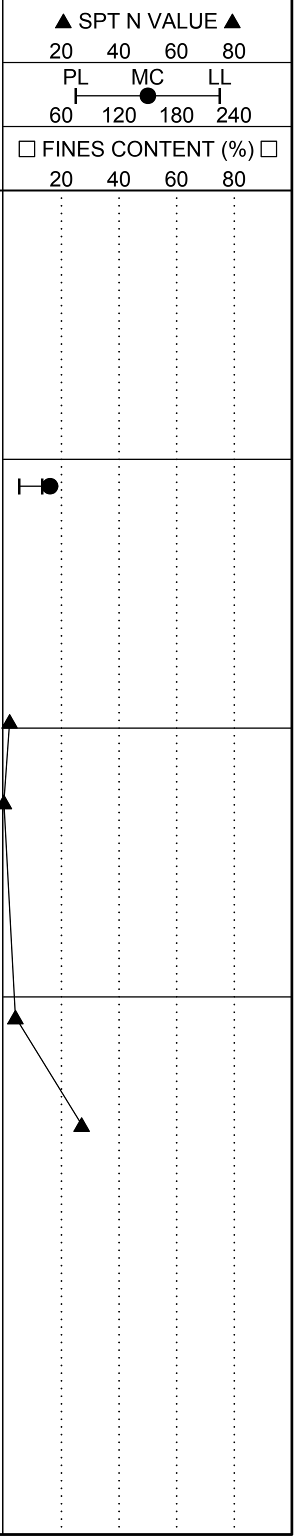
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Outfall Canal - North (West)
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 2/14/06 **COMPLETED** 2/14/06
GROUND ELEVATION 4.47 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Auger
AT TIME OF DRILLING 6'-6.5'
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
N/Ahrs AFTER DRILLING N/A

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	Augered through 2' of emergency repair gravel.					
	FILL: Brown clay.	ST 1	47 (100)		3.0	
	FILL: Stiff, brown clay.	ST 2	40 (100)		1.25	
	CLS to SC: Dark gray, sandy clay to clayey sand, light-brown oxidation root tracks. becoming cleaner light gray sand (sugar sands)	ST 3	78 (100)		.5	
10	MLS: Silt content increases, very fine sand with traces of organics. Increasing organic traces with depth, sandy silt matrix. OH: Dark organic clay, alternate layers of sand, silt, and clay.	ST 4	68 (100)		0.28	
	OL: Organic matter, fibrous, roots, black to 5", continuous organics but not as much fibrous mixing with gray clay. no roots, no fiber. peat and clay. increase in gray clay content with depth.	ST 5	43 (100)			
	OH: Dark gray clay, wood, organic. Sample extruded because low recovery.					
		ST 6	80 (100)			
20	OL: Organic matter.	SS	83 (100)	2-1-1 (2)		
	SM: Gray silty sand.	SS	67 (100)	1-0-0 (0)		
	SM: Gray silty sand.					
30	SP: Gray, light gray sand.	SS	67 (100)	1-2-2 (4)		
	SP: Light gray, gray sand.	SS	67 (100)	5-10-17 (27)	1.25	
	Bottom of hole at 35.5 feet.					



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BORING NUMBER LACW-BOR-4

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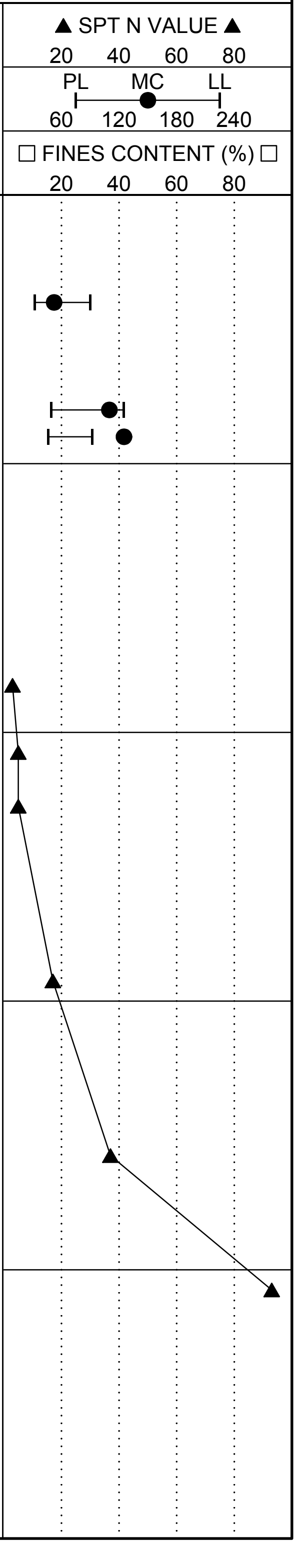
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Outfall Canal - North (West)
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 2/14/06 **COMPLETED** 2/14/06
GROUND ELEVATION 2.6 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Auger
AT TIME OF DRILLING N/A
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES 30ft. South of south end of Breach, Levee Crest.
N/Ahrs AFTER DRILLING N/A

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0		Auger to 2.5'.					
		FILL: Tan clay.	ST 1	40 (100)			
		OH: Stiff, organic clay with roots.				0.54	
		FILL: Stiff, brown clay.	ST 2	43 (100)			
		SP: Light brown (tan), fine sand. 2" from bottom, trace of organics (?).					
		OH: Medium, gray organic clay with wood and peat.	ST 3	70 (100)		0.25	
10		CH: Soft, gray clay with peat and wood.				0.17	
		OH: Black, dark brown organic clay.	ST 4	47 (100)			
		WOOD: wood or big root.					
		OL: Marsh.					
		SC: Clayey sand.	ST 5	87 (100)			
		No recovery. Change to SPT.					
		SM: Gray, loose, silty sand, saturated.	SS	56 (100)	2-2-1 (3)		
20		With shell fragments.	SS	72 (100)	2-2-3 (5)		
		SP: Gray, loose, fine uniform sand with shell fragments and trace silt.	SS	56 (100)	3-3-2 (5)		
		Auger 28.5' depth.					
30		SP: Gray, loose, fine, uniform sand with shell fragments and trace silt, grading denser.	SS	83 (100)	4-7-10 (17)		
		Auger to 35' depth.					
		SP: Light gray, dense, fine uniform sand, subangular particles with shell fragmens and trace amount of roots. Changed to split-spoon. Used older split-spoon with oxide on inner walls.	SS	83 (100)	11-16-21 (37)		
40		Gray, very dense, fine, uniform sand, subangular particles, trace shell fragments.	SS		36-41-52 (93)		
		Bottom of hole at 41.5 feet.					



BORING NUMBER LACW-CON-1

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Outfall Canal - North (West)

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 2/13/06 **COMPLETED** 2/13/06

GROUND ELEVATION -5.6 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Hollow Stem Auger

AT TIME OF DRILLING 6'

LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES Frontyard of 6109 Pratt Dr.

.25hrs AFTER DRILLING 5'

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		SM: Dark brown, deposited sediment.						
		ML: Dark brown, sandy silt with organic matter, trace clay, wood and brick fragments (FILL).	ST 1	30 (100)				
		SM: Very loose, dark gray and brown silty sand with organic matter and roots, moist. CH: Transitions to gray clay. Gray clay with trace of organic matter, wood and fine sand.	ST 2	80 (100)				
		SM: Medium dense, gray silty sand, saturated, fine-subrounded. SP: Loose, gray sand. SC: Extremely loose, gray clayey sand, fine, subangular, saturated zone from 6.7' to 6.9'.	ST 3	70 (100)				
10		CL: Very soft, gray sandy clay, with trace wood and organic matter. High water content SP: Very loose, gray, very fine sand, trace silt, shells and organic matter. Brown stiff clay lenses.	ST 4	65 (100)				
		Loose, gray, very fine uniform sand with trace organic matter, roots, and wood fragments, saturated.	ST 5	35 (100)				
20		Auger down to 25'. Drilling fluid added.						
		Dropped sample. Re-pushed samples and obtained 1.8' recovery. SP: Gray, medium dense, fine to medium sand, subangular, with shell fragments and trace organic matter, strong organic odor.	ST 6	90 (100)				
30		Augered down to 35'.						
		No sample recovered.						
40		Auguered down to 44'.						
		CH: Gray clay with trace of sand and shells. Sample not extruded.						
		Bottom of hole at 46.0 feet.						

BORING NUMBER LAC-BOR-1

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Ave. Canal - North (East)

PROJECT NUMBER

PROJECT LOCATION London Ave. Canal, New Orleans, Louisiana

DATE STARTED 2/10/06 **COMPLETED** 2/10/06

GROUND ELEVATION -7.7 ft N.A.V.D. **HOLE SIZE** N/A

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

▽ **AT TIME OF DRILLING** 1.8 ft / Elev -9.5 ft

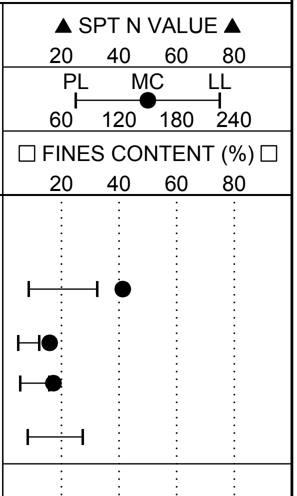
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES

▼ **.25hrs AFTER DRILLING** 1.3 ft / Elev -9.0 ft

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	▼▽					
	TOPSOIL: Topsoil sediments. Sample extruded because of low recovery. Very soft organic clay.	ST 1	20 (100)		0.06	
	CH: Soft, gray clay with fine sand.	ST 2	85 (100)		0.13	
	CH: Very soft, clay with 1/2" sand layer at bottom.	ST 3	90 (100)		0.07	
	CLS: Very soft, gray sandy clay with wood and clay pockets.	ST 4	80 (100)		0.06	
10	SP: Firm, gray fine sand with 2" clayey sand layer.				0.15	
	Bottom of hole at 10.5 feet.					



BORING NUMBER LAC-BOR-1A

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Ave. Canal - North (East)

PROJECT NUMBER

PROJECT LOCATION London Ave. Canal, New Orleans, Louisiana

DATE STARTED 2/16/06 **COMPLETED** 2/16/06

GROUND ELEVATION -7.7 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

AT TIME OF DRILLING ---

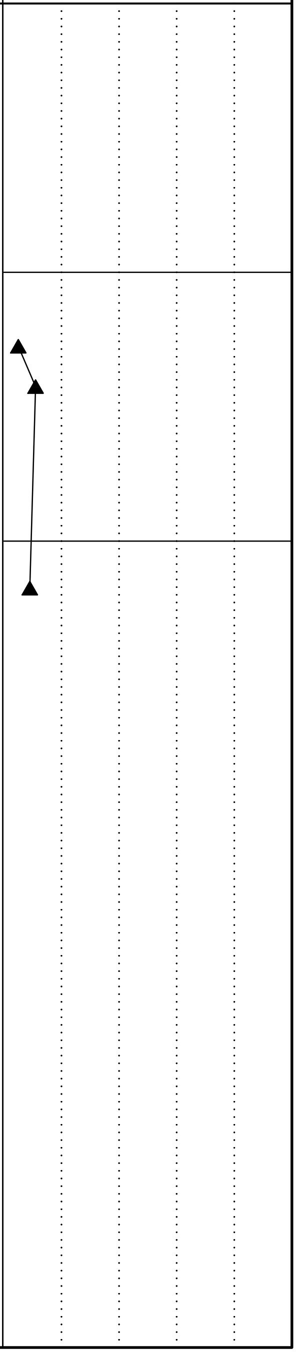
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES Front yard of 6076 Warrington Dr. (East of distressed section)

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 60 120 180 240 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		Bottom- OL: Black organics.	ST 1	92 (100)				
		OL: Gray, black and dark brown organic silty sand with organic matter, roots.	ST 2	27 (100)				
		No Recovery. Osterberg sampler damaged.	ST 3	0 (100)				
10		Augered to 12ft. Started Standard Penetration Test.						
		SP: Very loose, gray, saturated, clean, uniform sand, with shell fragments.	SS		1-3-2 (5)			
		SP: Gray, saturated, clean, uniform sand, with shell fragments, grading denser.	SS		6-6-5 (11)			
		Augered to 21ft.						
20								
		SP: Gray, saturated, clean, uniform sand, with shell fragments.	SS		4-4-5 (9)			
		Bottom of hole at 22.5 feet.						



BORING NUMBER LAC-BOR-2

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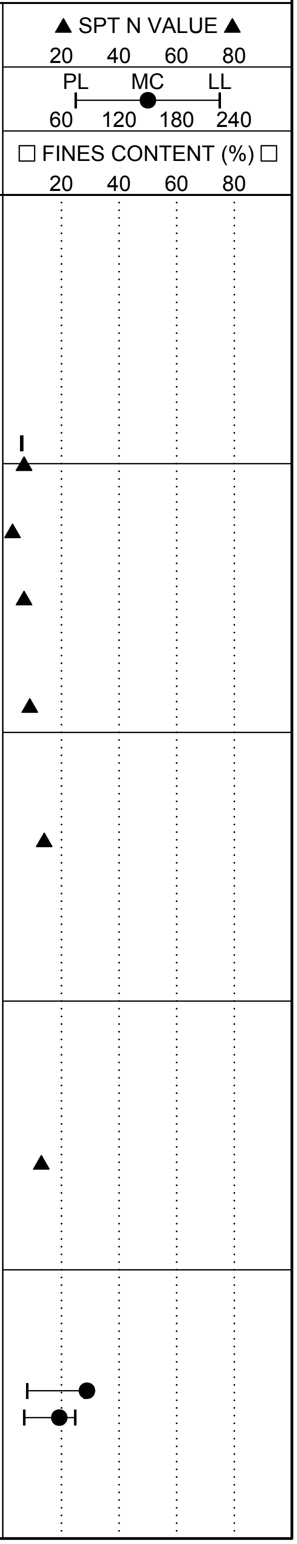
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Ave. Canal - North (East)
PROJECT NUMBER
PROJECT LOCATION London Ave. Canal, New Orleans, Louisiana
DATE STARTED 2/10/06 **COMPLETED** 2/11/06
GROUND ELEVATION -6.4 ft N.A.V.D. **HOLE SIZE** N/A
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
▽ **AT TIME OF DRILLING** 1.3 ft / Elev -7.7 ft
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
▼ **.17hrs AFTER DRILLING** 1.2 ft / Elev -7.6 ft

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0		▼ Drilled the first 4'.					
			ST 1	93 (100)			
			ST 2				
10		Stopped @3:30pm 02/10/06 Started @10:40am 02/11/06	ST 3		2-3-4 (7)		
		SP: Light gray sand, organic odor. trace amounts of shells			1-2-1 (3)		
		gray sand			3-3-4 (7)		
20					4-4-5 (9)		
		light gray, clean sand			7-7-7 (14)		
30							
		Tried to get a sample of clay below sand but sample was sand with clay lens.			5-5-8 (13)		
40							
		CH: Medium, gray clay with some silt.	ST 4	92 (100)		0.3	
		CH: Medium, gray clay with silt seams and shell fragments.				0.32	
		The night of 02/10/06 rained so rope for SPT on 02/11/06 was wet. Bottom of hole at 46.0 feet.					



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BORING NUMBER LAC-BOR-3

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Ave. Canal - North (East)

PROJECT NUMBER

PROJECT LOCATION London Ave. Canal, New Orleans, Louisiana

DATE STARTED 2/11/06 **COMPLETED** 2/11/06

GROUND ELEVATION -7.5 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

∇ **AT TIME OF DRILLING** 9.0 ft / Elev -16.5 ft

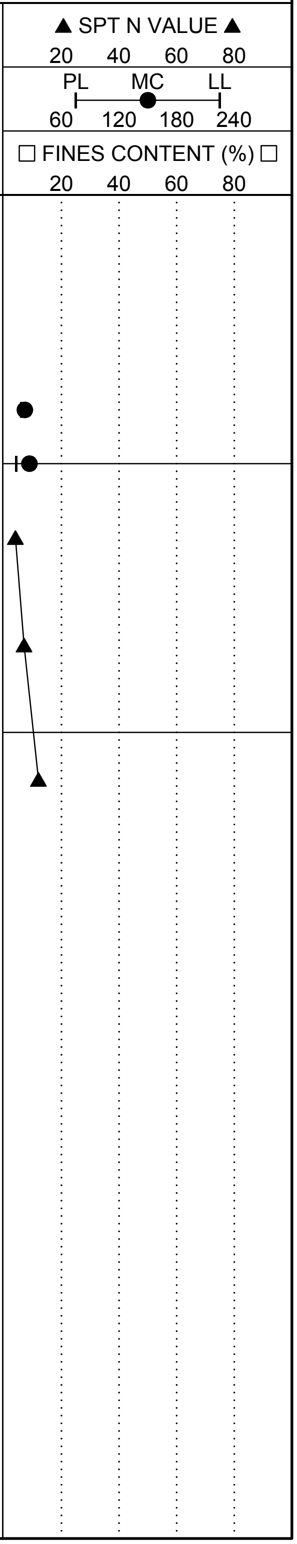
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES

AFTER DRILLING N/A

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	TOPSOIL: Augered through first 2' of fill.					
	SM: Gray silty sand with some dark brown organics. From top 2" to 3", transitions with gray clay with a lot (~50%) of shells about 7" to 9". signs of organic matter and roots at ~13". increasing organic content and roots with depth. OL: Organic matter, fibrous.	ST 1	60 (100)			
		ST 2	40 (100)			
	CLS: Medium, gray sandy clay to sand.	ST 3	60 (100)		0.27	
10	∇ SC: Firm, gray sand with clay.	ST 4	68 (100)		0.37	
		SS	(100)	1-2-2 (4)		
		SS	(100)	3-3-4 (7)		
20						
		SS	(100)	4-4-8 (12)		
	Bottom of hole at 22.5 feet.					



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BORING NUMBER LAC-BOR-4

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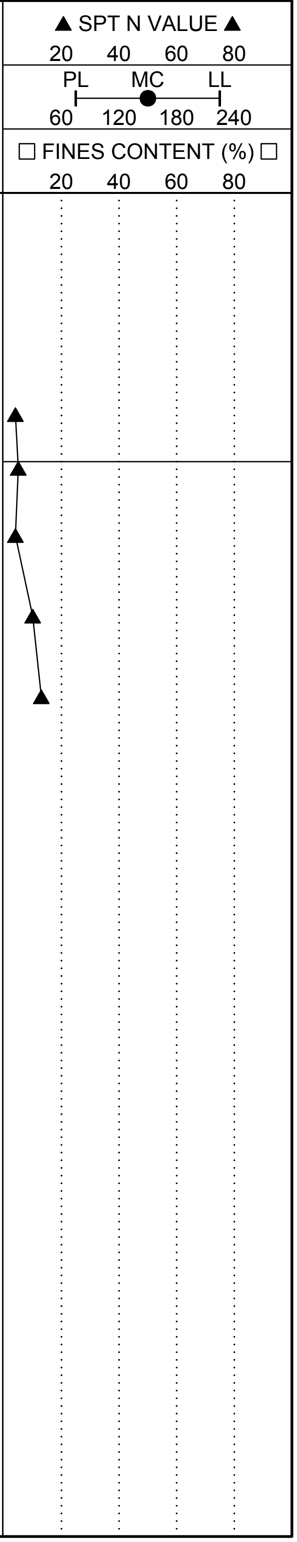
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Ave. Canal - North (East)
PROJECT NUMBER
PROJECT LOCATION London Ave. Canal, New Orleans, Louisiana
DATE STARTED 2/11/06 **COMPLETED** 2/11/06
GROUND ELEVATION -7.0 ft N.A.V.D. **HOLE SIZE** N/A
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
▽ **AT TIME OF DRILLING** 1.5 ft / Elev -8.5 ft
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
▼ **.25hrs AFTER DRILLING** 1.5 ft / Elev -8.5 ft

DEPTH (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
		▼	ST 1	82 (100)			
		Did not recover soil, too weak perhaps due to rain of previous night.	ST 2	0 (100)			
		SP: Gray sand with fines.	SS	44 (100)	1-2-2 (4)		
10		SP: Gray sand with fines.	SS	44 (100)	1-3-2 (5)		
		SC: Soft, clayey sand to cleaner sand.	SS	67 (100)	2-2-2 (4)		
		SP: Almost clean sand, strong organic odor.	SS	83 (100)	4-5-5 (10)		
		SP: Clean, gray sand.	SS	89 (100)	3-6-7 (13)		
		Bottom of hole at 19.5 feet.					



BORING NUMBER LAC-CON-1

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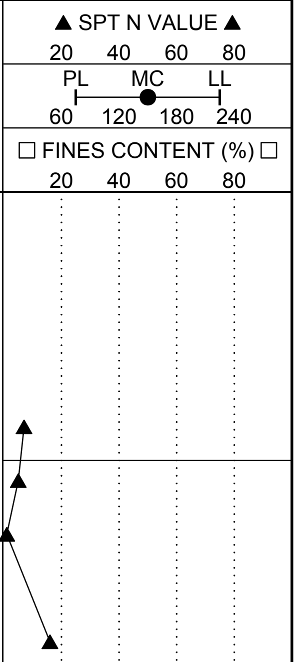
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Ave. Canal - North (East)
PROJECT NUMBER
PROJECT LOCATION London Ave. Canal, New Orleans, Louisiana
DATE STARTED 2/8/06 **COMPLETED** 2/8/06
GROUND ELEVATION -7.7 ft N.A.V.D. **HOLE SIZE** N/A
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
∇ **AT TIME OF DRILLING** 2.8 ft / Elev -10.5 ft
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES
▼ **.25hrs AFTER DRILLING** 1.7 ft / Elev -9.4 ft

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	TOPSOIL: Dark brown silty clay, roots.	ST 1	35 (100)			
	OH: Black organic clay, roots (fibrous), strong organic odor. CL-ML: Gray silty clay, trace organics, transitions to gray silty clay.	ST 2	63 (100)			
	SC: Gray, fine (sugar) sand with some silt. OH: Organic clay, roots. CL-ML: Gray silty clay.	ST 3	80 (100)			
	SC-SM: Gray silty, clayey sand. SM: Gray sand. No recovery	ST 4	0 (100)			
	SM: Gray silty sand.	SS 5	100 (100)	5-4-3 (7)		
10		SS 6	67 (100)	3-2-3 (5)		
		SS 7	67 (100)	0-0-1 (1)		
	No recovery.					
	SP: Light gray, clean sand, strong organic odor, shells seen half way through split spoon.	SS 8	100 (100)	4-6-10 (16)		
	Bottom of hole at 17.5 feet.					



Base map: Google Earth

LEGEND

🔴	SLON-#.05C	USACE 2005 CPT
🔵	LACS-CPT-#	ILIT 2006 CPT
⊕	LACS-BOR-#	ILIT 2006 BORING
◐	LACS-CON-#	ILIT 2006 CONTINUOUS BORING

LONDON AVENUE CANAL (SOUTH)
APPROXIMATE ILIT BORING AND CPT LOCATIONS
New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	04/21/2006	LACS BOR & CPT SitePlan	

SCALE Not Drawn To Scale

SHEET

BORING NUMBER LACS-BOR-1

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Outfall Canal -South

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 2/16/06 **COMPLETED** 2/16/06

GROUND ELEVATION -.15 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

AT TIME OF DRILLING 8.5 ft / Elev -8.7 ft

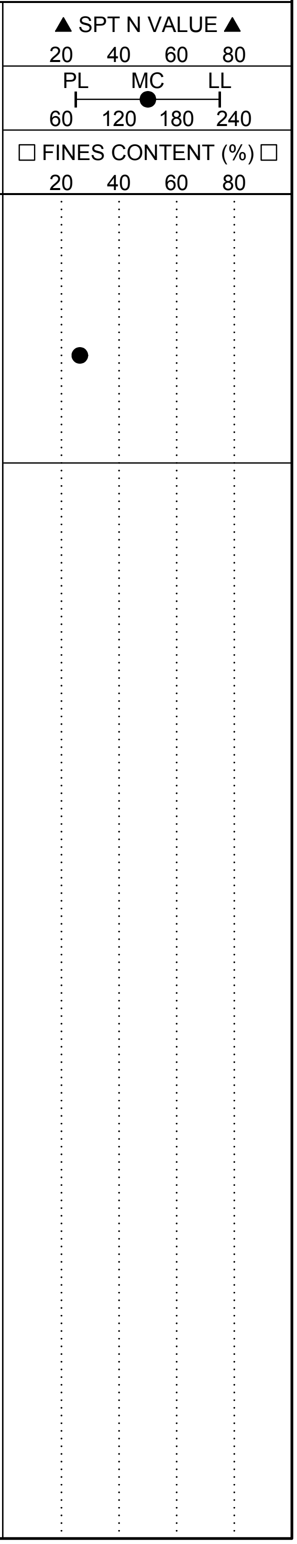
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES ~40ft (?) north of breach on protected side.

.25hrs AFTER DRILLING 8.1 ft / Elev -8.3 ft

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0							
		Bottom-FILL: Tan clay.	ST 1	48 (100)			
		CH: Soft, gray clay with organics.	ST 2	62 (100)			
		Auger to 8.5'.					
10		SC: Interface of clays and sands sampled. Bottom-Loose sand, 3" gap between sample and bottom of tube.	ST 3	70 (100)			
		Bottom of hole at 10.5 feet.					



BORING NUMBER LACS-BOR-2

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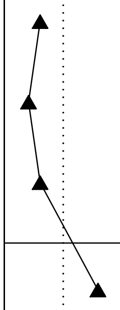
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Outfall Canal -South
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 2/16/06 **COMPLETED** 2/16/06
GROUND ELEVATION 4.6 ft N.A.V.D. **HOLE SIZE** 5"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING N/A
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES ~20ft south of breach
AFTER DRILLING ---

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	GP: Emergency fill. Augered through first 5'.					
		ST 1	40 (100)			
10		ST 2	67 (100)			
20		ST 3	90 (100)			
		SS	67 (100)	3-5-7 (12)		
		SS	44 (100)	2-3-5 (8)		
		SS	67 (100)	4-6-6 (12)		
30		SS	83 (100)	11-18-14 (32)		
	Bottom of hole at 32.5 feet.					

▲ SPT N VALUE ▲
20 40 60 80
PL MC LL
60 120 180 240
☐ FINES CONTENT (%) ☐
20 40 60 80



BORING NUMBER LACS-BOR-3

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Outfall Canal -South

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 2/15/06 **COMPLETED** 2/15/06

GROUND ELEVATION -2.3 ft N.A.V.D. **HOLE SIZE** 6"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Mud Rotary

AT TIME OF DRILLING N/A

LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES 100ft east from old sheetpile wall

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		Hollow-stem auger to 5'.						
			ST 1	57 (100)				
		Interface sampled.	ST 2	55 (100)				
10	░	SP: Loose, saturated sands.	☒ SS	67 (100)	2-6-9 (15)			▲
		Bottom of hole at 11.5 feet.						

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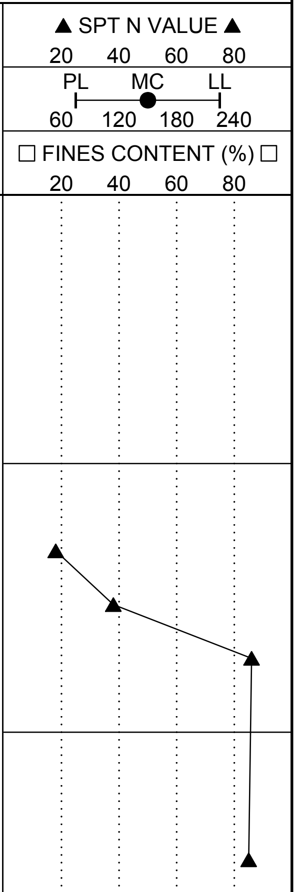
BORING NUMBER LACS-CON-1

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Outfall Canal -South
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 2/14/06 **COMPLETED** 2/15/06
GROUND ELEVATION -.15 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
∇ **AT TIME OF DRILLING** 8.5 ft / Elev -8.7 ft
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES North of breach, inboard slope of levee, 5ft north of LACS-BOR-1.
▼ **.25hrs AFTER DRILLING** 8.0 ft / Elev -8.2 ft

DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	SP: Light gray, very fine sand with shell fragments, recently deposited sediment. Auger to 2'.					
	FILL: Stiff, tan-brown, medium plasticity clay (CL) with sand and traces of wood and roots. Reddish-brown stains (oxide) and fine sand lenses.	ST 1	43 (100)			
	FILL: Tan-brown medium plasticity clay, moist, grading stiffer. SC: Loose, very fine, uniform clayey sand lens, very moist.	ST 2	75 (100)			
	CH: Stiff, dark brown-black and gray clay, very moist, with organic matter, roots, and 1" thick sand lens. CH: Very soft, tan and gray clay with trace organic matter and very fine sand lenses, very high water content.	ST 3	65 (100)			
10	SC: Clayey sand lens. CH: Medium firm, gray clay, grading to stiffer with depth, very moist, with roots and wood fragments, and root induced channels of small diameters (diameter<1mm).	ST 4	55 (100)			
	CL: Firm, gray sandy clay, saturated, transition zone. SP: Gray, clean fine, uniform sand, subangular to subrounded particles, saturated, traces of wood and strong organic odor.	ST 5	110 (100)			
	Change to Split-spoon sampler. SP: Medium dense, light gray and tan, very fine sand, very moist with shell fragments. Boring stopped 02/14/06 @14', 17:15. Restarted 02/15/06, 09:25.	SS	67 (100)	6-6-12 (18)		
	Boring stopped 02/14/06 @14', 17:15. Restarted 02/15/06 @09:25. 0.5' cleaned with 4" diameter auger. SP: Medium dense, light gray, fine uniform sand, with organic odor.	SS	67 (100)	11-16-22 (38)		
	Clean hole- auger 0.5'. SP: Dense, light gray-white, clean, uniform sand, fine and grading to medium coarse subangular particles, moist, organic odor.	SS	73 (100)	20-36-50 (86)		
20	Augered 6'.					
	SP: Dense, light gray and white, fine to medium coarse sand, subangular particles.	SS		21-35-50 (85)		
	Bottom of hole at 25.5 feet.					



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BORING NUMBER LACS-CON-3

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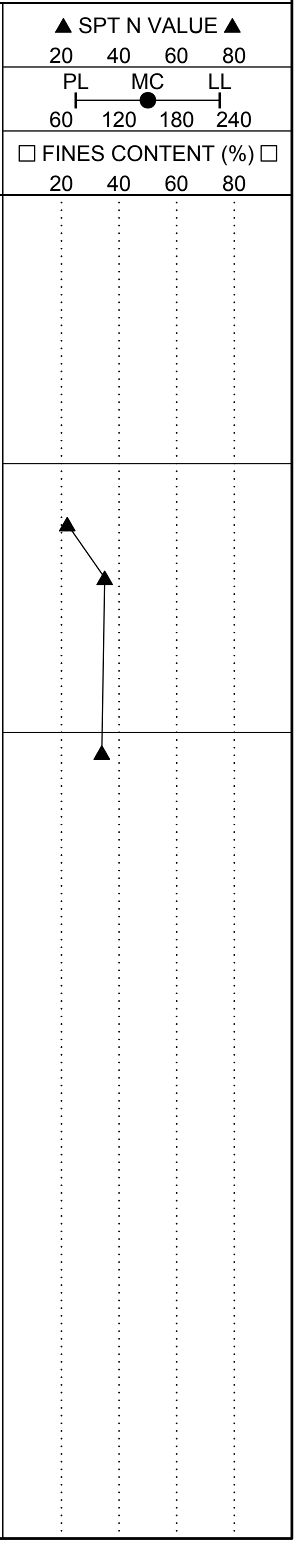
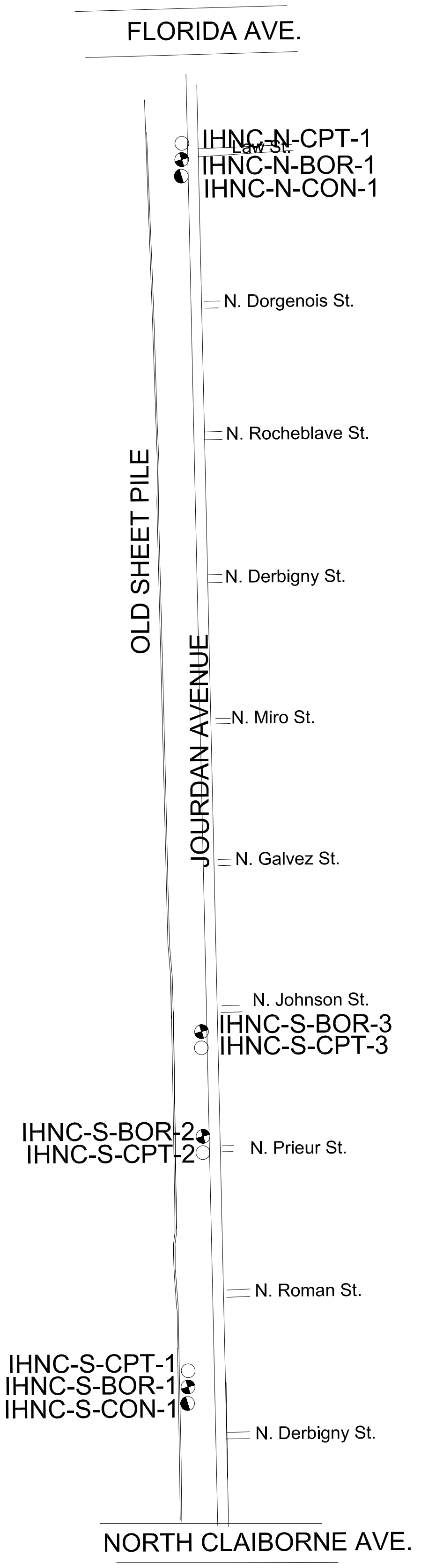
CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Outfall Canal -South
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 2/15/06 **COMPLETED** 2/15/06
GROUND ELEVATION -2.3 ft N.A.V.D. **HOLE SIZE** 6"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Mud Rotary
AT TIME OF DRILLING N/A
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES East bank. Backyard of house on Warrington & Wilton Dr.
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0		GP: Gravel-repair fill. Hollow-stem auger to 5'. water velocity determined on toe of repair fill, approximately 30' West.					
		CH: Soft, gray clay with 3/8" wood fragments, traces of organic matter, very moist. CH: Gray clay, grading to firmer, high water content, with root channels and reddish-brown (oxide?) stains surrounding the channels. These elements appear to be opened and connected.	ST 1	70 (100)			
		CH: Soft, light gray clay with abundant shell gragments and wood, very high moister conent, reddish-brown oxide stained root channels.	ST 2	88 (100)			
10		SC: Very soft, gray fine, uniform clayey sand, subangular, very high water content, trace wood and roots. SP: Loose, gray, fine sand with organic matter and roots, grading to denser with depth.	ST 3	83 (100)			
		SP: Light gray, uniform sand, very moist, subangular to subrounded particles. SP: Loose, light gray-white fine, uniform sand, grading to denser with depth, subangular to subrounded particles, slight organic odor.	SS	50 (100)	3-8-14 (22)		
		Clean hole- auger 0.5'.					
			SS	61 (100)	2-10-25 (35)		
		Clean hole- auger 5'.					
20		SP: Medium dense sand. Same material as 13.5' to 15'.	SS		13-15-19 (34)		
		Bottom of hole at 21.5 feet.					





LEGEND

◕ IHBR-N-BOR-#	IHNC NORTH 2006 ILIT BORING
◐ IHNC-N-CON-#	IHNC NORTH 2006 ILIT CONTINUOUS BORING
○ IHNC-S-CPT-#	IHNC NORTH 2006 ILIT CONE PENETRATION TEST
◕ IHBR-S-BOR-#	IHNC SOUTH 2006 ILIT BORING

LOWER NINTH WARD
APPROXIMATE ILIT BORING & CPT LOCATIONS

New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	04/21/2006	IHNC BOR & CPT SitePlan	

SCALE	SHEET
Not Drawn To Scale	

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BORING NUMBER IHNC-N-BOR-1

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME Lower Ninth Ward
PROJECT NUMBER
PROJECT LOCATION Lower Ninth Ward, New Orleans, Louisiana
DATE STARTED 2/21/06 **COMPLETED** 2/21/06
GROUND ELEVATION -3.38 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Auger
AT TIME OF DRILLING N/A
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES Middle of North breach (Florida Ave.)
AFTER DRILLING ---

DEPTH (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
	■	Had to drill on the street because of concrete blocks found ~2' to 3' deep where initial location of borehole was selected. Augered through asphalt.						
		OL: Black, organic matter, roots, gray clay.	ST 1	30 (100)				
10	▨	CL: Dark brown, silty clay, roots, silty fines.	ST 2	53 (100)				
	▨	CH: Very soft, gray and dark gray clay with peat.	ST 3	77 (100)		0.09		●
	▥	CL-ML: Gray, silty clay, some very fine sand, roots.	ST 4	90 (100)				
		Bottom of hole at 15.0 feet.						

BORING NUMBER IHNC-S-BOR-1

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME Lower Ninth Ward

PROJECT NUMBER

PROJECT LOCATION Lower Ninth Ward, New Orleans, Louisiana

DATE STARTED 2/17/06 **COMPLETED** 2/17/06

GROUND ELEVATION .93 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Hollow Stem Auger

AT TIME OF DRILLING N/A

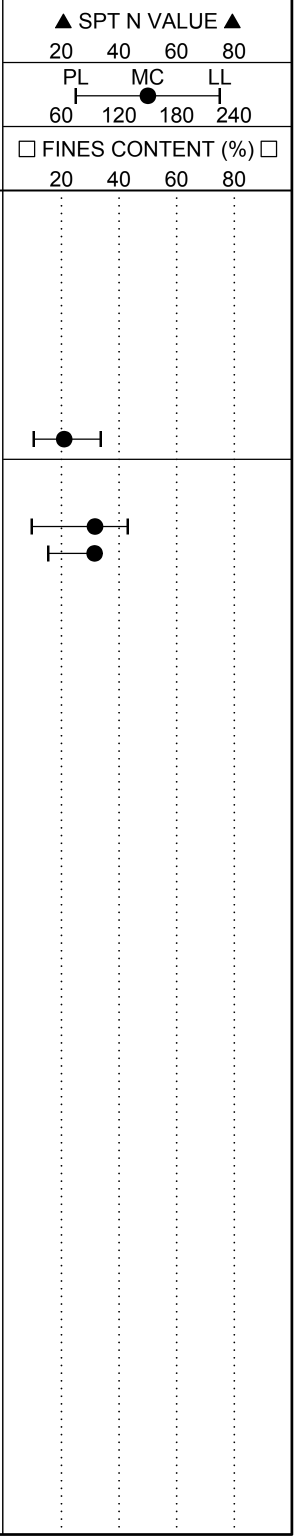
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES South end of South breach (Claiborne)

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)
0	▩	FILL: Augered through the first 6' to go through placed fill by USACE (fill came from old levee and was dumped).					
10	▨	CH: Medium, gray clay.	ST 1	37 (100)		0.42	
	▤	WOOD	ST 2	68 (100)			
	▨	CH: Soft, gray clay with organics and wood.	ST 3	63 (100)		0.13 0.19	
		Bottom of hole at 14.0 feet.					



BORING NUMBER IHNC-S-BOR-2

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME Lower Ninth Ward

PROJECT NUMBER

PROJECT LOCATION Lower Ninth Ward, New Orleans, Louisiana

DATE STARTED 2/17/06 **COMPLETED** 2/17/06

GROUND ELEVATION -2.7 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Hollow Stem Auger

AT TIME OF DRILLING N/A

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES Middle of South breach (Claiborne)

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		Augered through first 4' to get below fill.						
		roots	ST 1	53 (100)				
		CH: Gray clay.	ST 2	62 (100)				
10			ST 3	72 (100)				
			ST 4	90 (100)				
		Bottom of hole at 13.0 feet.						

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BORING NUMBER IHNC-S-BOR-3

PAGE 1 OF 1

CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME Lower Ninth Ward

PROJECT NUMBER

PROJECT LOCATION Lower Ninth Ward, New Orleans, Louisiana

DATE STARTED 2/21/06 **COMPLETED** 2/21/06

GROUND ELEVATION -2.3 ft N.A.V.D. **HOLE SIZE** 4"

DRILLING CONTRACTOR STE

GROUND WATER LEVELS:

DRILLING METHOD Hollow Stem Auger

AT TIME OF DRILLING ---

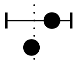
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos

AT END OF DRILLING ---

NOTES

AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		Dry auger down to 7'.						
	▨	Top- CH: Gray clay. Bottom- CH: Gray clay and brown OH, roots.	ST 1	53 (100)				
10								
	▨	CH: Very soft, gray clay with peat.	ST 2	77 (100)		0.08 0.11		
	▨	Bottom- Gray clay.	ST 3	77 (100)				
		Bottom of hole at 15.5 feet.						



BORING NUMBER IHNC-S-CON-1

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME Lower Ninth Ward
PROJECT NUMBER
PROJECT LOCATION Lower Ninth Ward, New Orleans, Louisiana
DATE STARTED 2/17/06 **COMPLETED** 2/17/06
GROUND ELEVATION .93 ft N.A.V.D. **HOLE SIZE** 4"
DRILLING CONTRACTOR STE
GROUND WATER LEVELS:
DRILLING METHOD Hollow Stem Auger
AT TIME OF DRILLING ---
LOGGED BY D. Cobos-Roa **CHECKED BY** A. Athanasopoulos
AT END OF DRILLING ---
NOTES South side of South breach, on emergency fill east of sheet pile.
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Su, Strength (tsf)	Dry Unit Weight (tsf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0		Augered down to 40' on emergency repair fill.						
		CH: Firm, light brown gray clay with trace of roots and some root-channels with oxide stains.	ST 1	70 (100)				
		Transition to gray clay, moderately firm, moist, with increasing amount of wood and roots.						
		OH: Very soft, dark brown-black organic clay with roots and wood, increasing water content. Bottom 0.4ft is wood.	ST 2	30 (100)				
		WOOD: Bottom 0.3' tube is mixed with soft, gray clay, very moist. Wood recovered from 5.6' to 8.3'.						
		WOOD	ST 3	90 (100)				
10		CH: Very soft, gray clay, saturated, with large amount of wood fragments and roots.						
		High moisture content with trace organic matter, wood, and significant amount of roots. Grading to firmer with depth. Unable to perform vane due to large amount of roots and wood in sample.	ST 4	78 (100)				
		Bottom of hole at 12.0 feet.						

APPENDIX C: CPT LOGS

As part of the field investigations, 26 Piezo-Cone Penetrometer Tests (CPTU) were performed at the sites of interest, as listed in Table C.1. These CPT probes were performed by Soil Testing Engineers Inc. between 1/30/06 and 2/22/06. All fieldwork activities were conducted by members of the Independent Levee Investigation Team (ILIT) under the direct supervision of senior members of the team.

The CPTs were performed according to the ASTM D 5778, using an electric piezo-cone conforming to the ASTM standards. The pore pressure measurements were obtained at the base of the cone sleeve, immediately above the conical cone “tip”, as illustrated in Figure C-1. The sleeve friction was re-zeroed at the start of each probe, and the porous stone was saturated before each test.

The Figures that follow present a series of plan views showing the locations of the CPTU probes performed by our investigation team, followed by the logs of these CPTU probes. Each CPTU log also has local GPS coordinates (x, y, and z) to help to locate these.

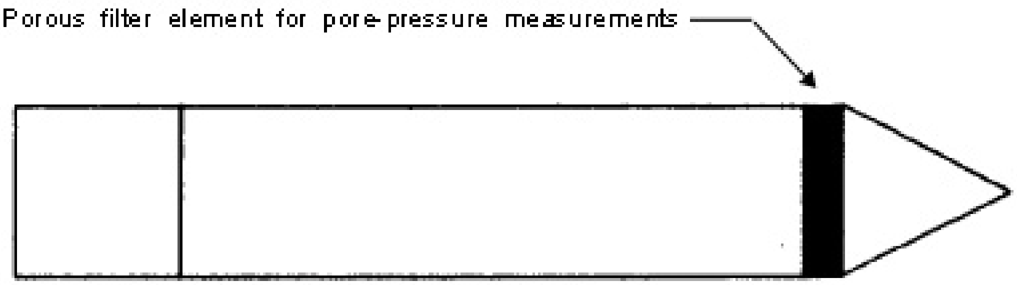


Figure C-1: Typical piezo-cone used by STE Inc. showing the location of the porous filter element

17th STREET CANAL

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
17-CPT-1	30.01716	90.12109	-1.9
17-CPT-2	30.01793	90.1207	-6.5
17-CPT-3	30.01804	90.12125	3.8
17-CPT-3 A	30.01805	90.12125	3.8
17-CPT-4	30.01626	90.1215	4
17-CPT-4 A	30.0162	90.12155	4
17-CPT-5	30.01718	90.12108	-2
17-CPT-6	30.01711	90.12109	-1.8
17-CPT-7	30.01736	90.12116	0.5
17-CPT-9 A	30.01636	90.12077	-6.6
17-CPT-10	30.01731	90.12202	4.31
17-CPT-11	30.01641	90.12212	4.31
17-CPT-12	30.01824	90.12057	-6.6

LONDON AVENUE CANAL NORTH, EAST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LAC-CPT-1	30.02097	90.07027	-7.7
LAC-CPT-2	30.02062	90.07026	-8
LAC-CPT-3	30.02135	90.07053	-8.2
LAC-CPT-4	30.01998	90.07032	-8.5

LONDON AVENUE CANAL NORTH, WEST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LACW-CPT-1	30.02044	90.07136	-5.6
LACW-CPT-2	30.02048	90.07104	2.8
LACW-CPT-3	30.02131	90.07094	3.1
LACW-CPT-4	30.01953	90.07082	2.6

Note: Geographic coordinates are based on WGS84 datum.

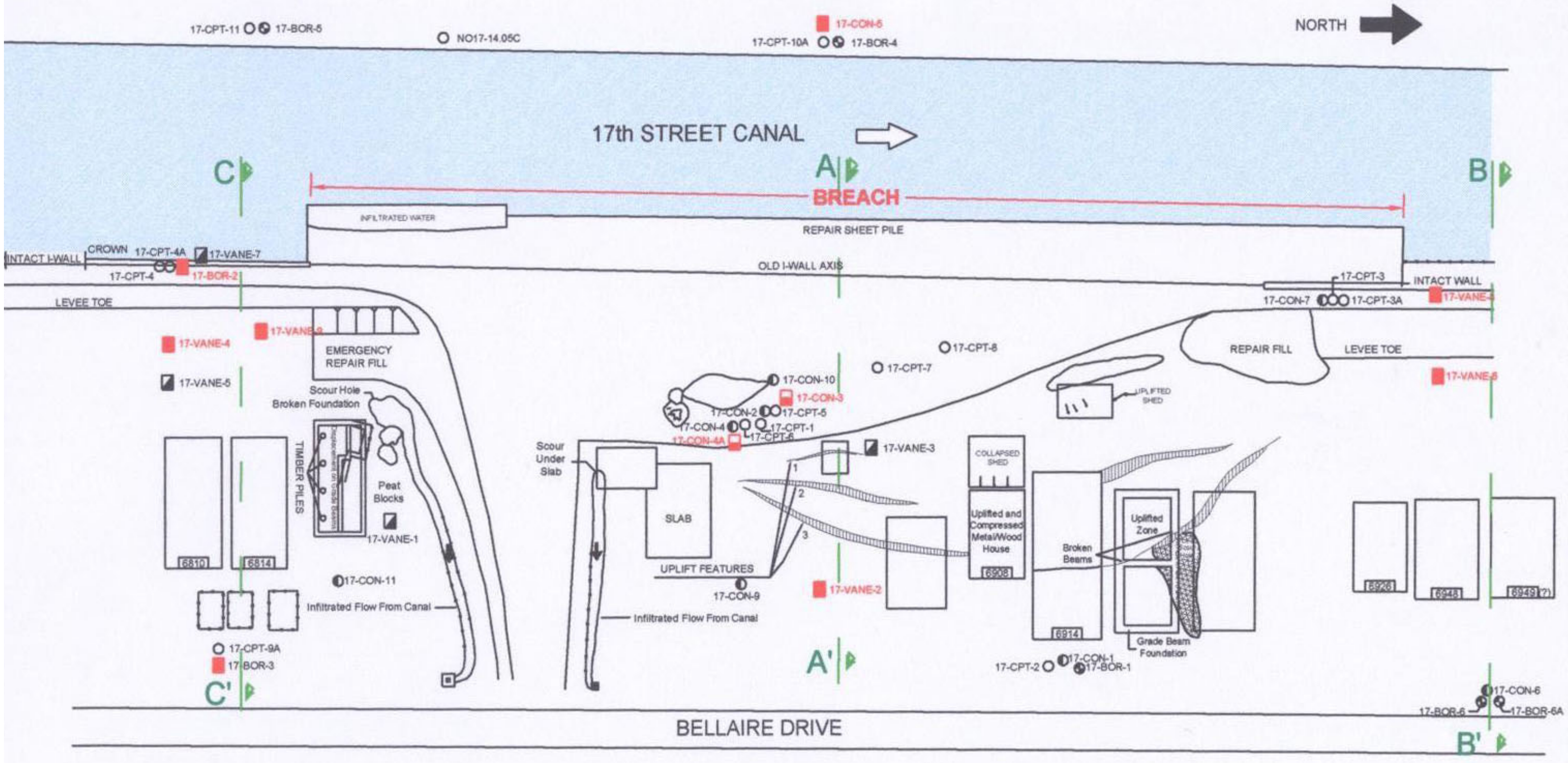
LONDON AVENUE CANAL SOUTH, EAST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
LACS-CPT-1	30.00908	90.0694	-0.15
LACS-CPT-2	30.00797	90.06931	4.6
LACS-CPT-3	30.0085	90.06907	-2.3

INNER HARBOR NAVIGATION CANAL, EAST BANK

CPT NUMBER	Latitude (N)	Longitude (W)	Elevation (MSL)
IHNC-N-CPT-1	29.9787	90.02049	-3.38
IHNC-S-CPT-1	29.97035	90.02314	0.93
IHNC-S-CPT-2	29.97126	90.02292	-2.7
IHNC-S-CPT-3	29.97248	90.02257	-2.3

Note: Geographic coordinates are based on WGS84 datum.



LEGEND

○	17-CPT-#	Cone Penetration Test
◐	17-CON-#	Continuous Boring
⊗	17-BOR-#	Geotechnical Boring
◪	17-VANE	Field Vane Test
⊟		Sheared
🟥		Unsheared (Weak Zone)
—•—•—		Fence

17th Street Canal
APPROXIMATE ILIT BORING, CPT, VANE LOCATIONS
New Orleans, Louisiana

SIZE	DATE	DWG NO.
	05/06/2006	17th Boring & CPT Plan

SCALE Not Drawn To Scale
SHEET

State Project

Site Name 17th Street Canal- East Bank

Performed By Geo Engineering UCB and STE

Sounding No. 17-CPT-1

Ground Elevation -1.9

Location N30.01716 W90.12109

center of breach, 15' NE of displaced block

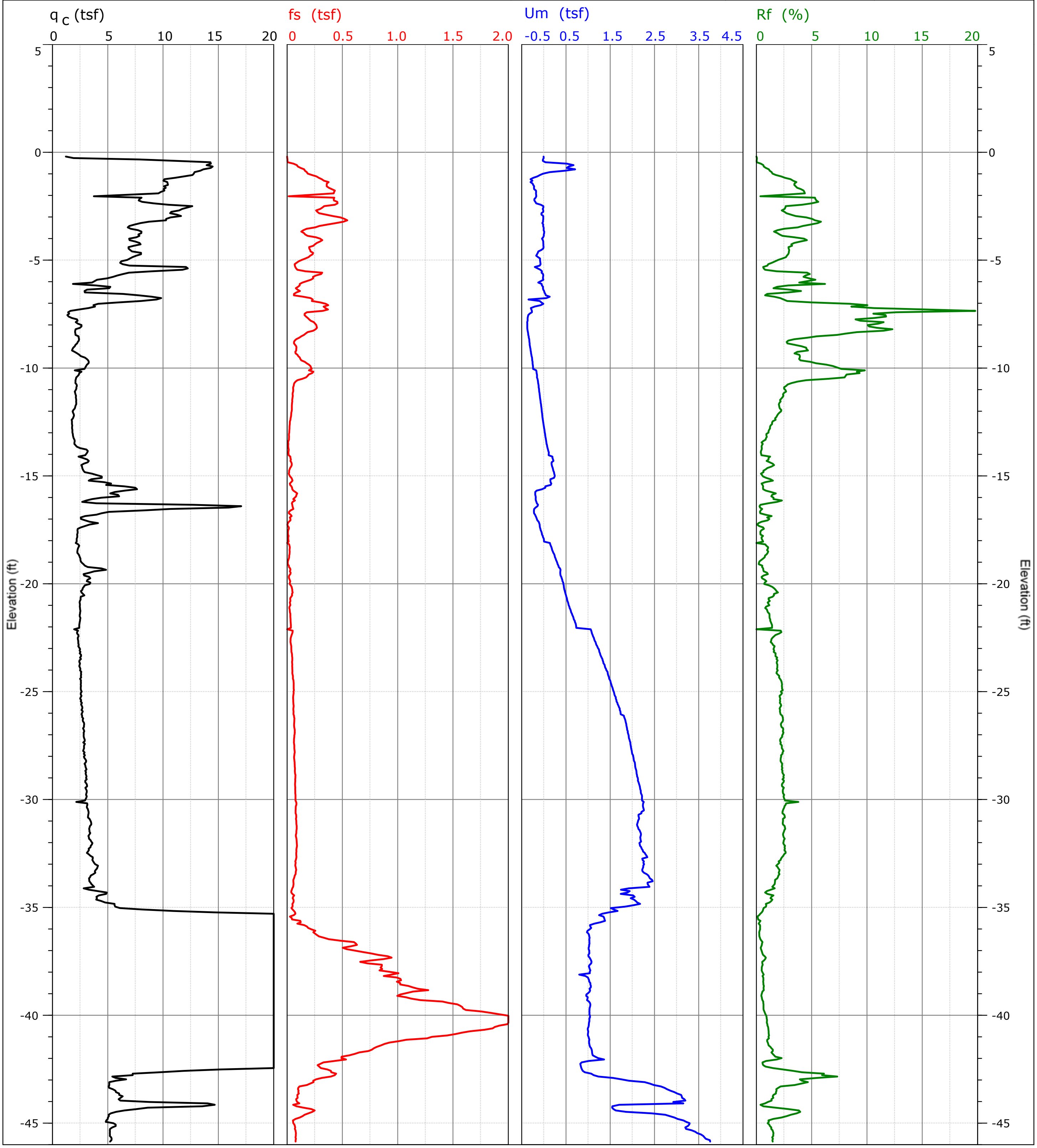
Logger: A. Athanasopoulos

SHEET 1 of 1

Logger: D. Cobos

Date Completed 1/31/2006

Cone #



fs --> Sleeve Friction

q c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

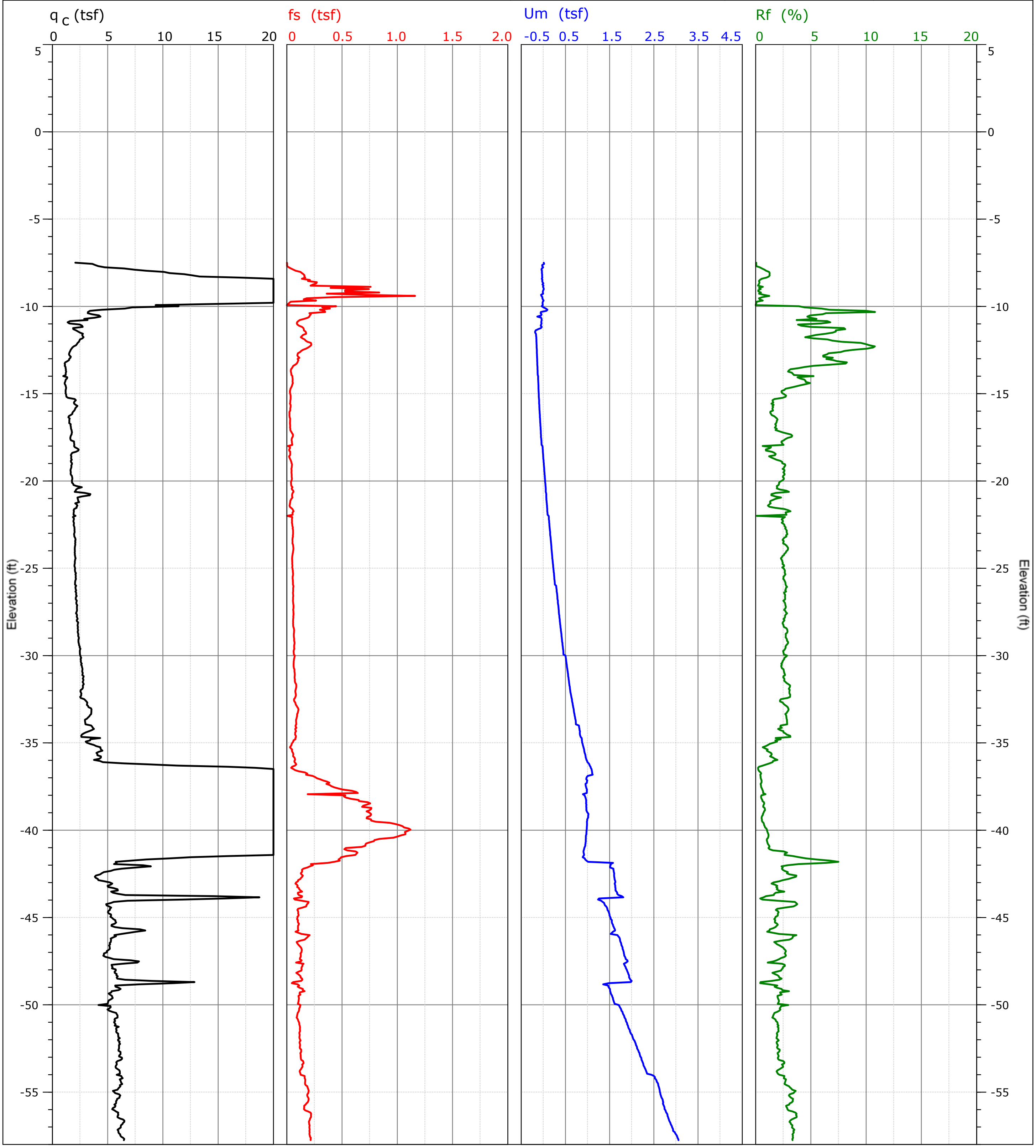
Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	**Site Name** 17th Street Canal- East Bank	**Performed By** Geo Engineering UCB and STE	**Sounding No.** 17-CPT-2	**Ground Elevation** -6.5

Location N30.01933 W90.1207 center of breach, 6' east of driveway 6914 Belaire Dr.	**Logger: Athanasopoulos**	**SHEET 1 of 1**
	Logge: D. Cobos	**Date Completed** 1/31/06
	Cone #	



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project

Site Name
17th Street Canal- East Bank

Performed By
Geo Engineering UCB and STE

Sounding No.
17-CPT-3

Ground Elevation
3.8

Location
N30.01804 W90.12125

30' north of breach, levee crest

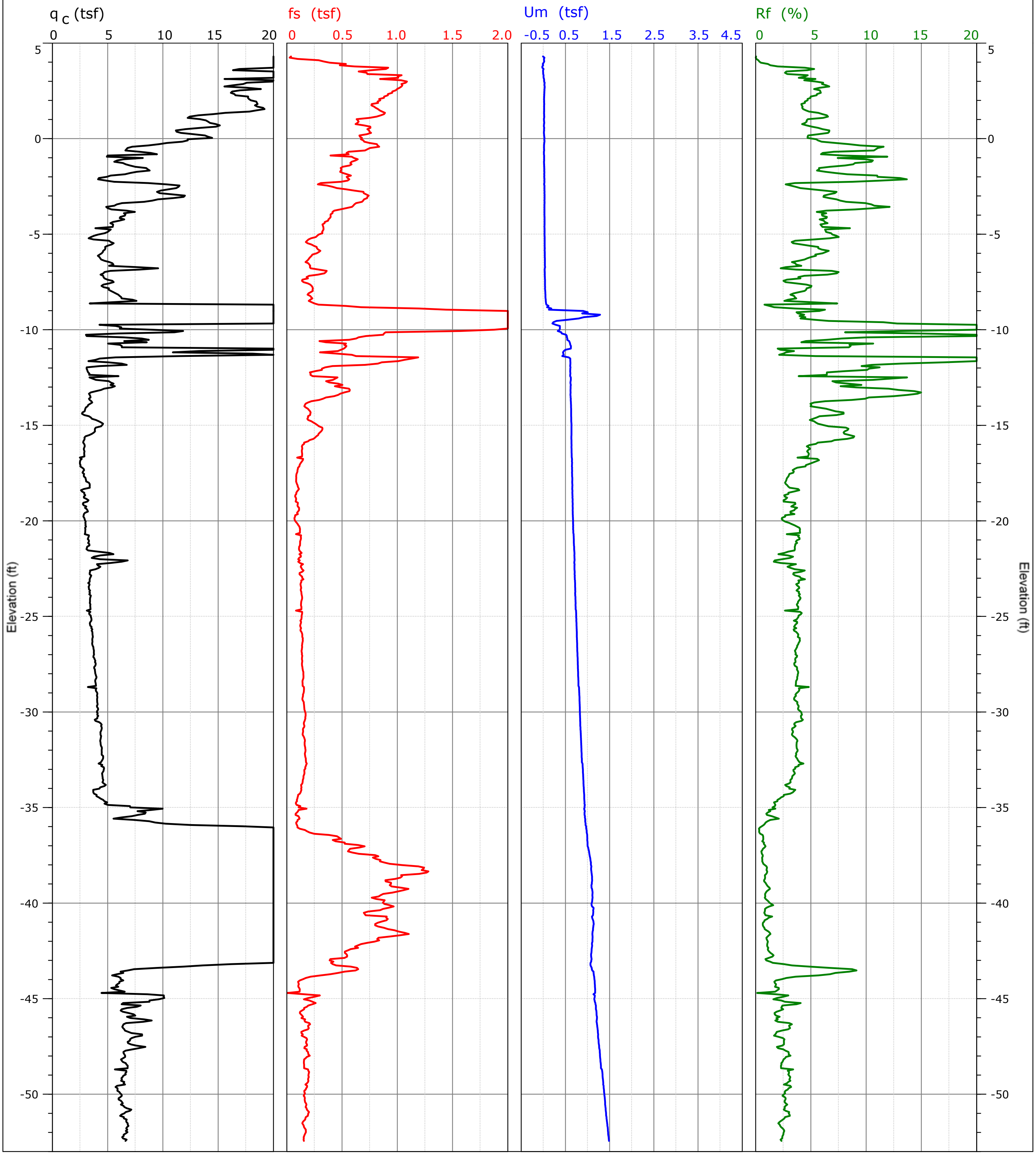
Logger: A. Athanasopoulos

Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed
2/02/06



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	17th Street Canal- East Bank	Geo Engineering UCB and STE	17-CPT-3A	3.8

Location

N30.01805 W90.12125

30' north of breach, levee crest

Logger: A. Athanasopoulos

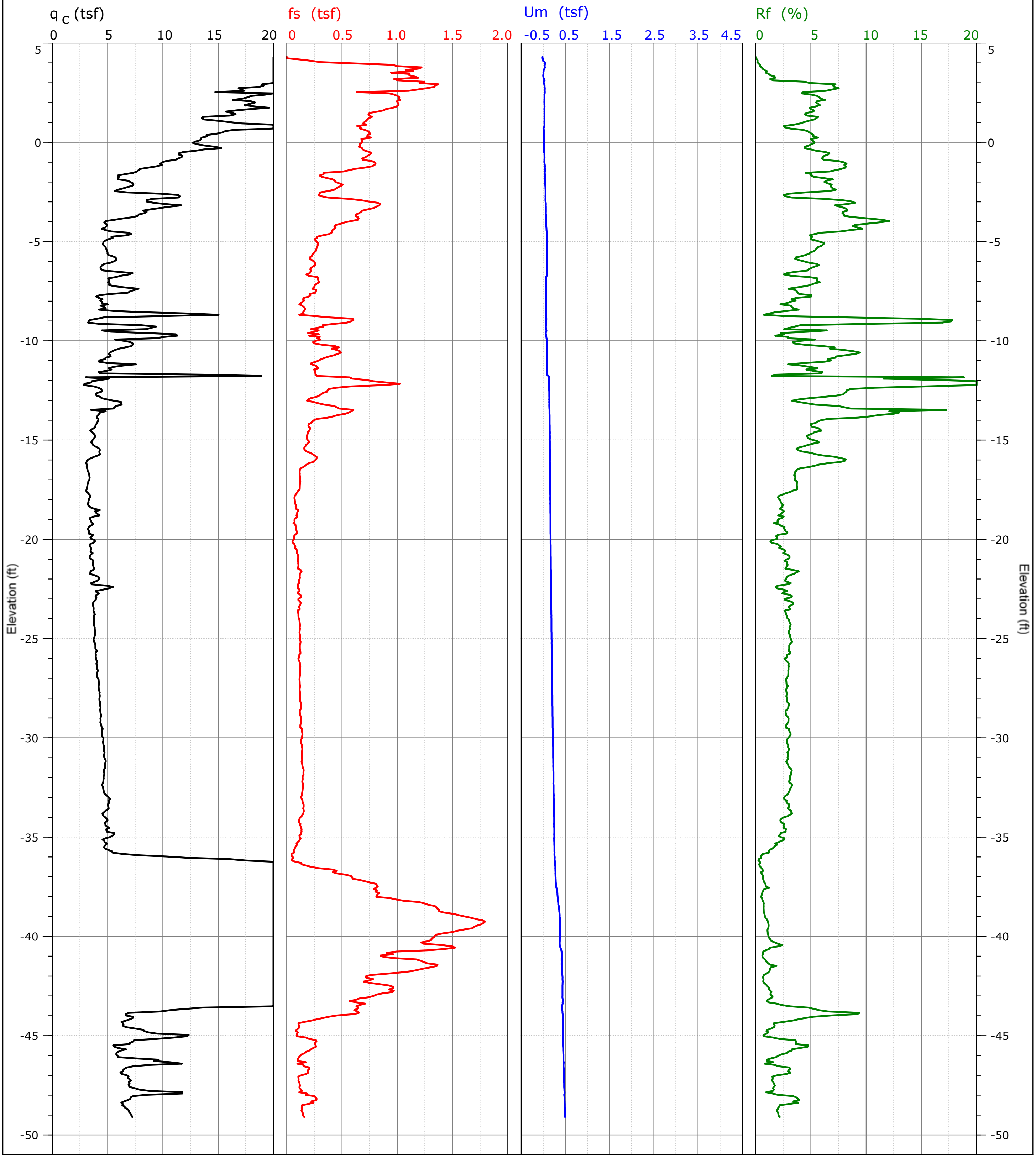
Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed

2/02/06



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	17th Street Canal- East Bank	Geo Engineering UCB and STE	17-CPT-4A	4.0

Location

N30.0162 W90.12155

30' south of breach, levee crest

Logger: A. Athanasopoulos

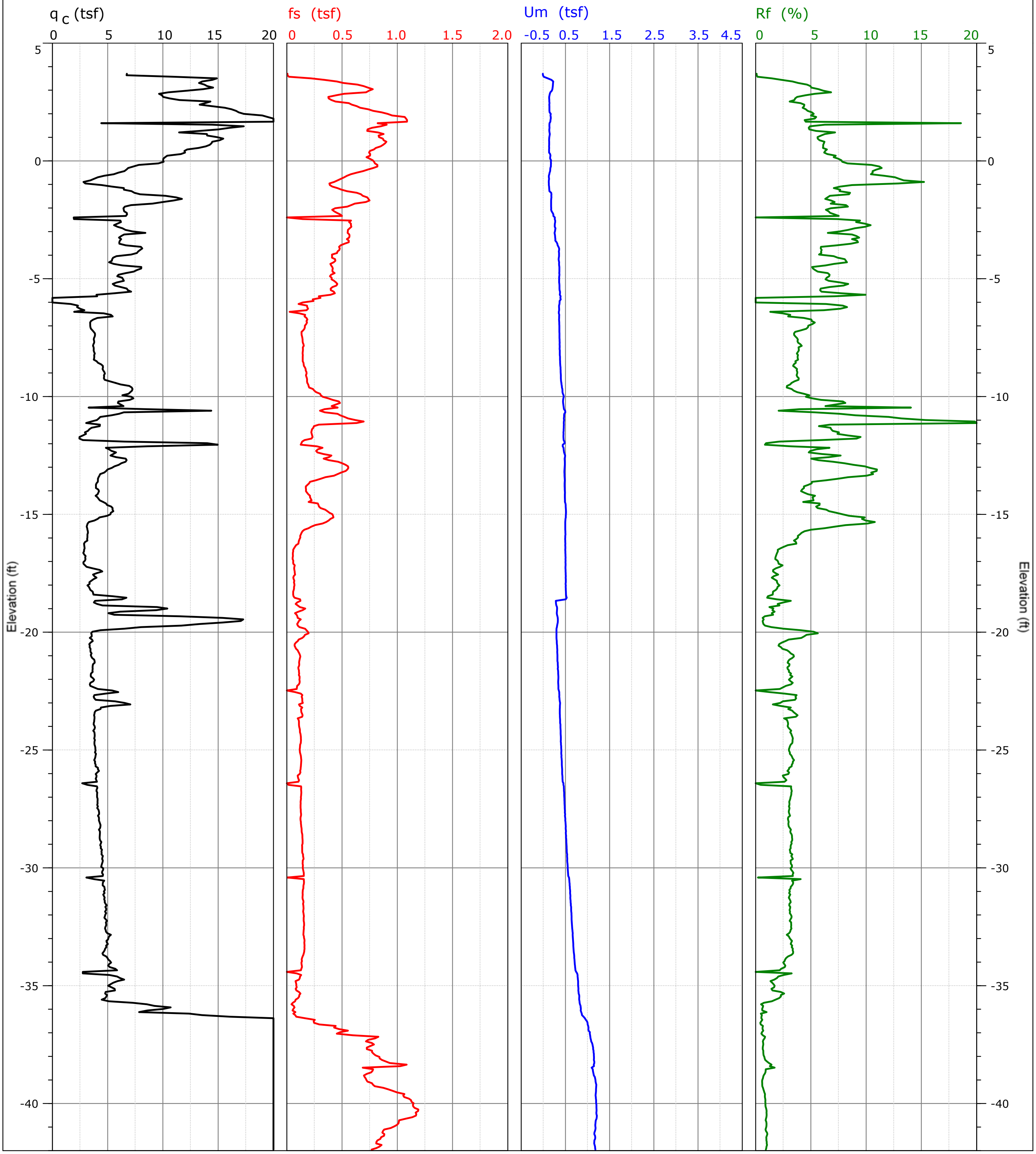
Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed

2/02/06



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	17th Street Canal- East Bank	Geo Engineering UCB and STE	17-CPT-5	-2.0

Location

N30.01718 W90.12108

next to displaced block, 5' north of 17-CPT-1

Logger: A. Athanasopoulos

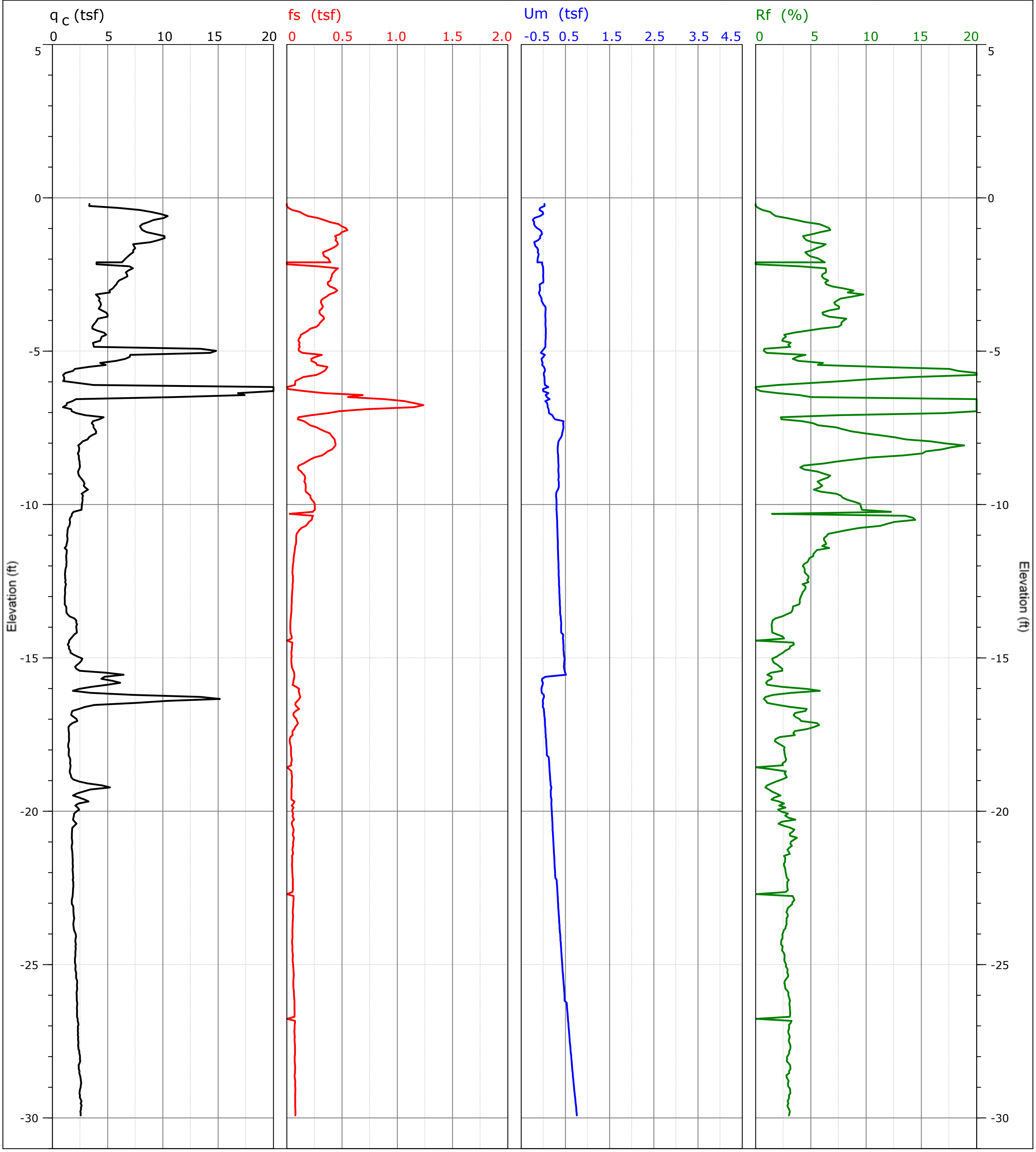
Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed

2/03/06



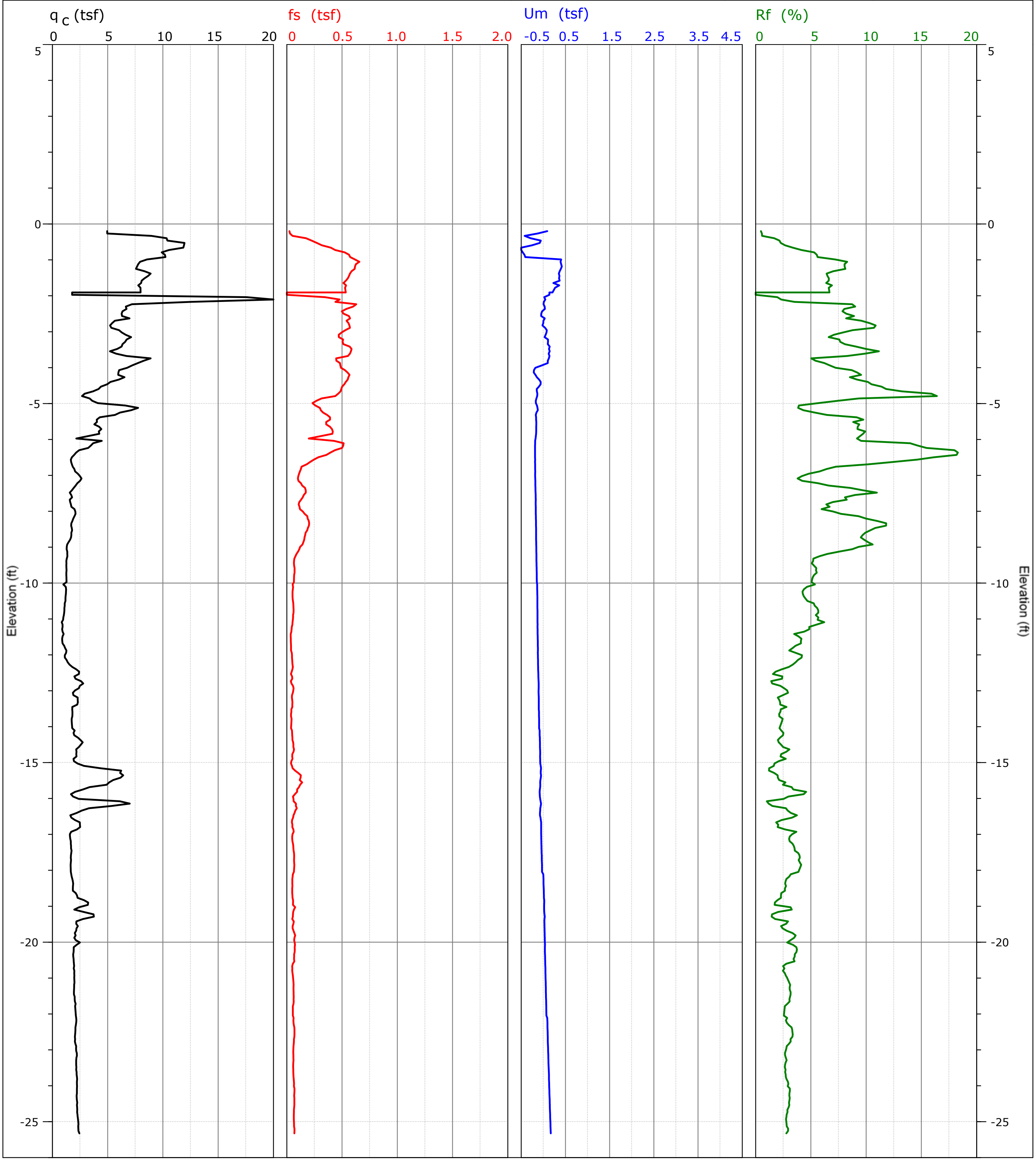
fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	17th Street Canal- East Bank	Geo Engineering UCB and STE	17-CPT-6	-1.8

Location N30.01711 W90.12109 next to displaced block, 5' south of 17-CPT-1	**Logger: A. Athanasopoulos**	**SHEET 1 of 1**
	Logger: D. Cobos	**Date Completed** 2/03/06
	Cone #	



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	**Site Name** 17th Street Canal- East Bank	**Performed By** Geo Engineering UCB and STE	**Sounding No.** 17-CPT-7	**Ground Elevation** 0.5

Location
N30.01736 W90.12116
north of displaced block, next to USACE fence

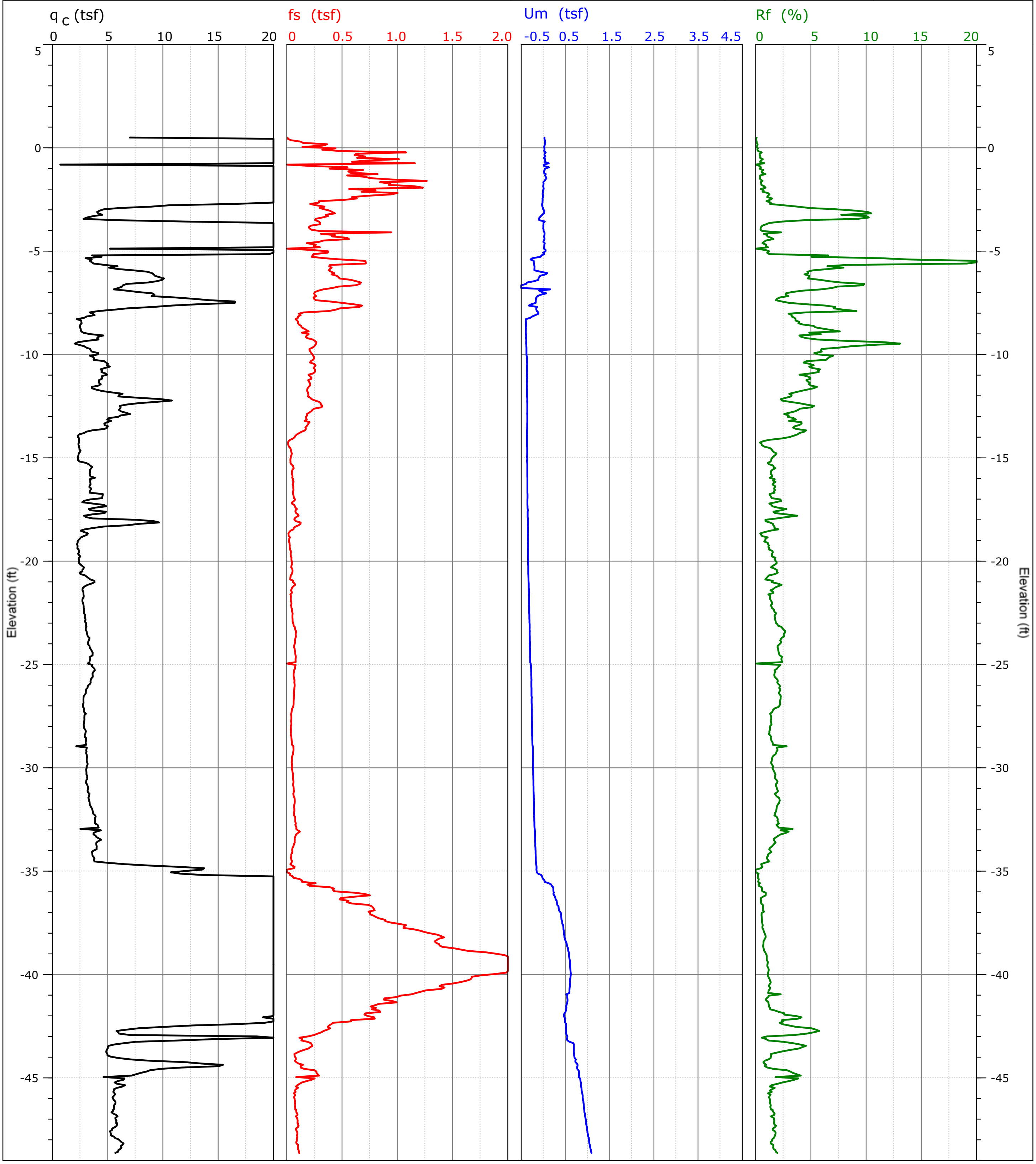
Logger: A. Athanasopoulos

Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed
2/03/06



fs --> Sleeve Friction
qc --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

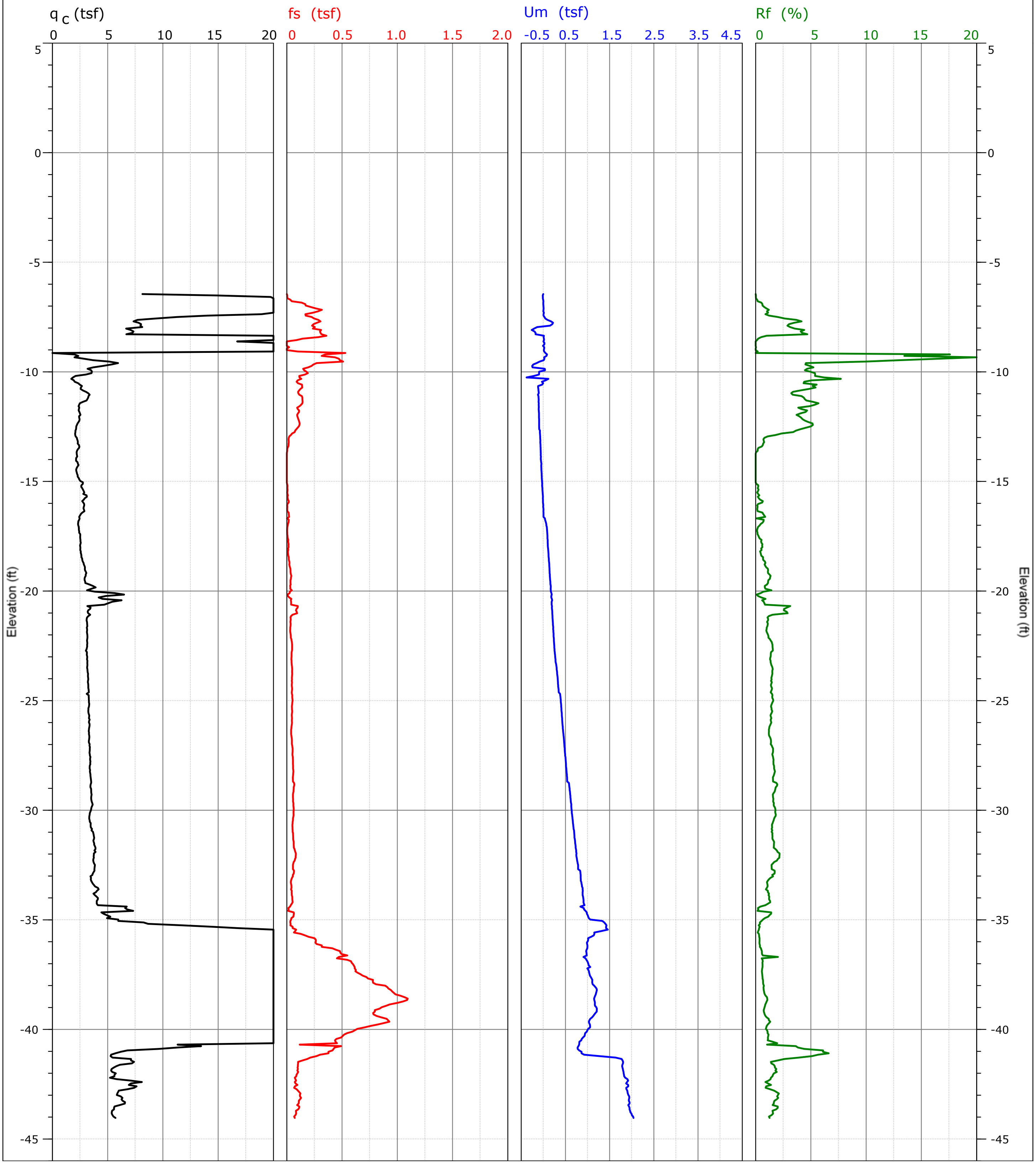
State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	17th Street Canal- East Bank	Geo Engineering UCB and STE	17-CPT-9A	-6.6

Location

N30.01636 W90.12077

south of breach, between 6810 and 6814 Belaire Dr.

Logger: A. Athanasopoulos	**SHEET 1 of 1**
Logger: C. Watkins	**Date Completed** 2/06/06
Cone #	



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	17th Street Canal- West Bank	Geo Engineering UCB and STE	17-CPT-10A	4.31

Location

N30.01731 W90.12202

Orpheum Ave., north of Ash St., levee crest

Logger: A. Athanasopoulos

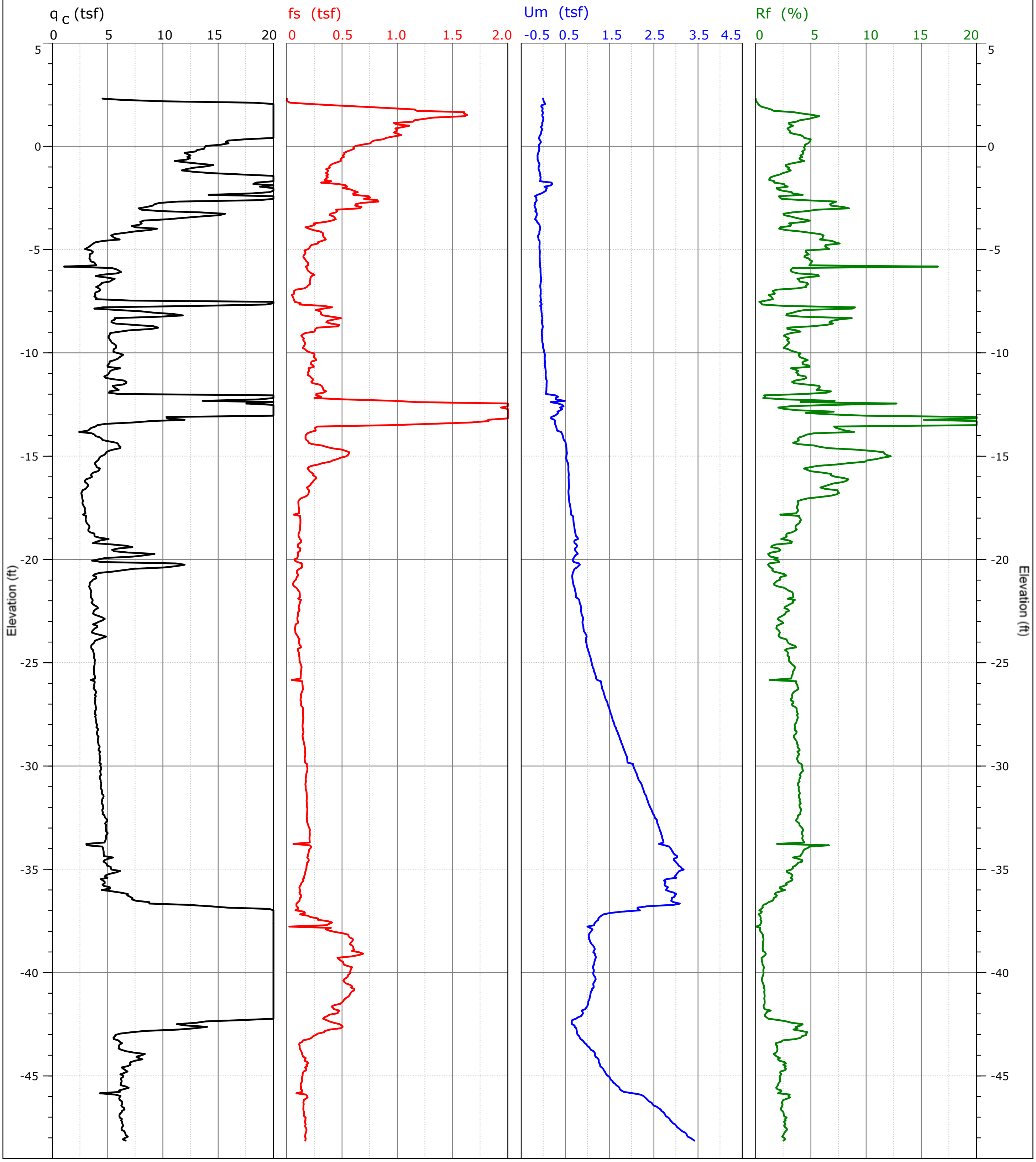
Logger: C. Watkins

Cone #

SHEET 1 of 1

Date Completed

2/06/06



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project

Site Name 17th Street Canal- West Bank

Performed By Geo Engineering UCB and STE

Sounding No. 17-CPT-11

Ground Elevation 4.31

Location
N30.01641 W90.12212
Orpheum Ave., between Ash St., and Poplar St.
south of 17-CPT-10, levee crest

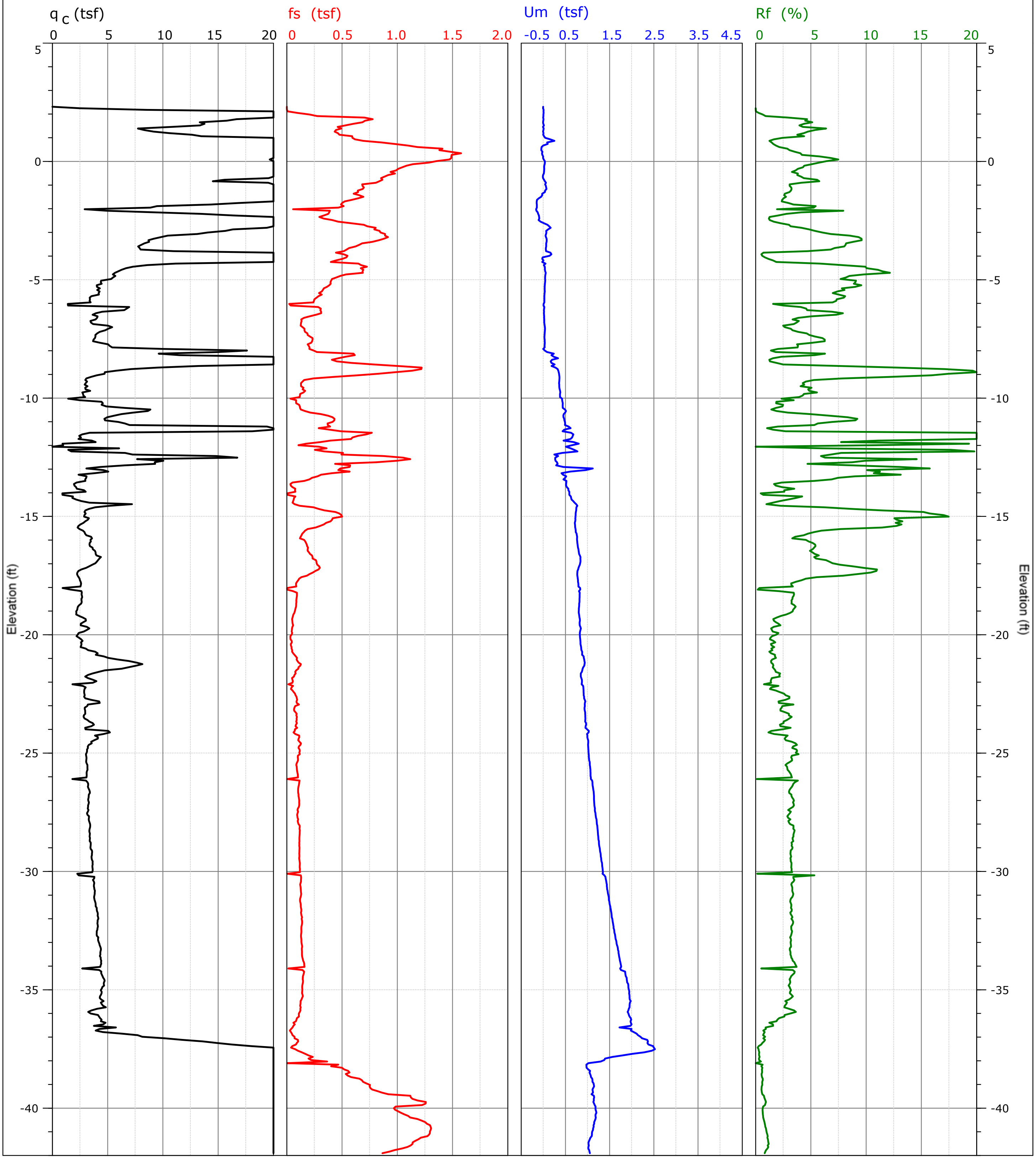
Logger: A. Athanasopoulos

SHEET 1 of 1

Logger: C. Watkins

Date Completed 2/07/06

Cone #



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

Base map: IPET

LEGEND

☐ London 2006 ILIT Field Vane

● London 2006 ILIT Boring and Cone Penetration Test
LAC-BOR-#: Boring
LAC-CON-#: Continuous Boring
LAC-CPT-#: Cone Penetration Test

LONDON AVENUE CANAL (NORTH)
APPROXIMATE ILIT BORING, CPT, VANE LOCATIONS
New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	05/04/2006	LACSitePlan	

SCALE		SHEET
SCALE	Not Drawn To Scale	SHEET

State Project

Site Name
London Ave. Canal North
West Bank

Performed By
Geo Engineering UCB and STE

Sounding No.
LACW-cpt1

Ground Elevation
-5.6

Location
N30.02044 W90.07136

middle of breach, frontyard of 6109 Pratt Drive

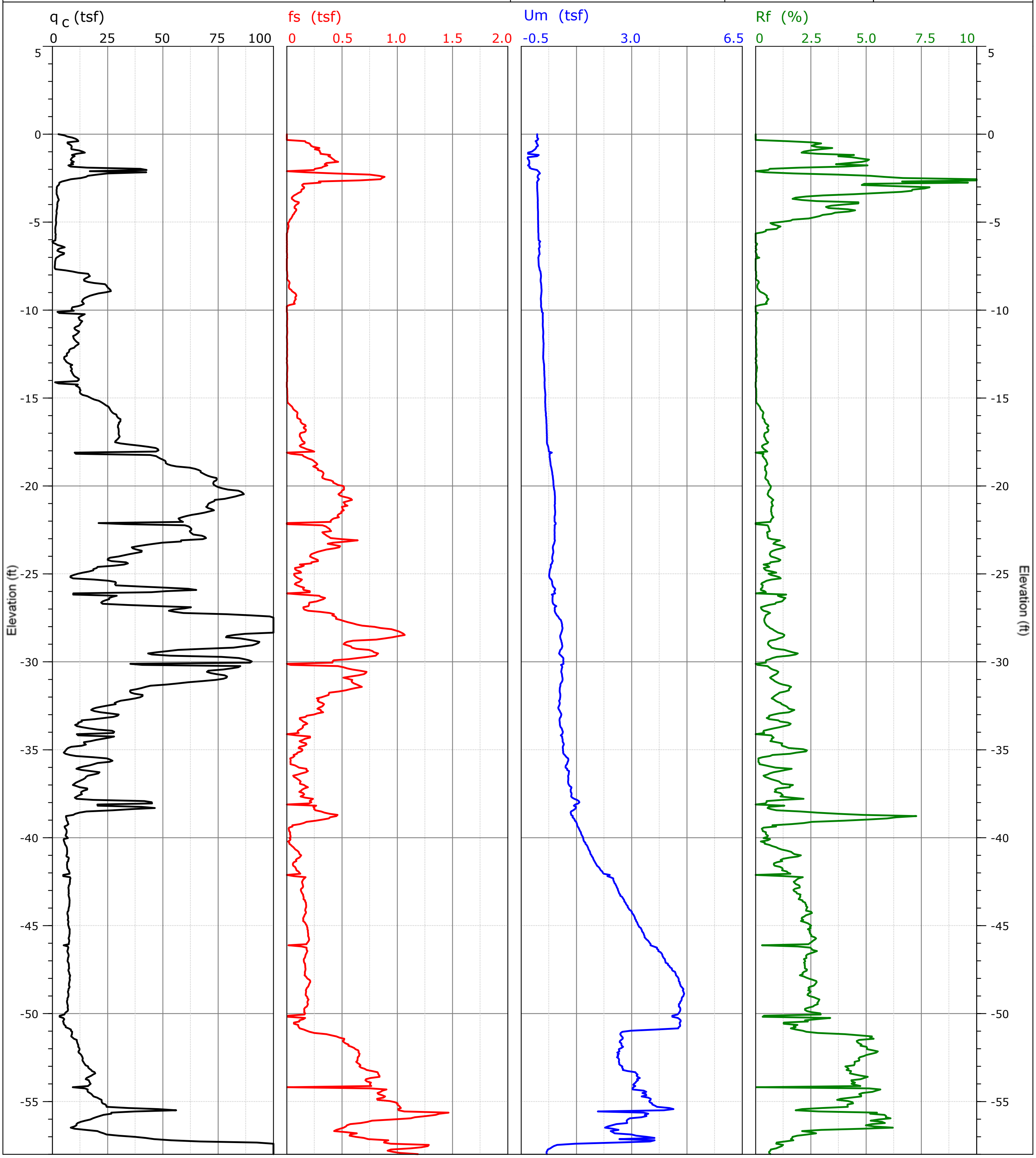
Logger: D. Karadeniz

SHEET 1 of 1

CPT Operator

Date Completed
2/07/06

Cone #



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	London Ave. Canal North West Bank	Geo Engineering UCB and STE	LACW-cpt2	2.8

Location

N30.02048 W90.07104

middle of breach, pre-Katrina levee toe

Logger: D. Karadeniz

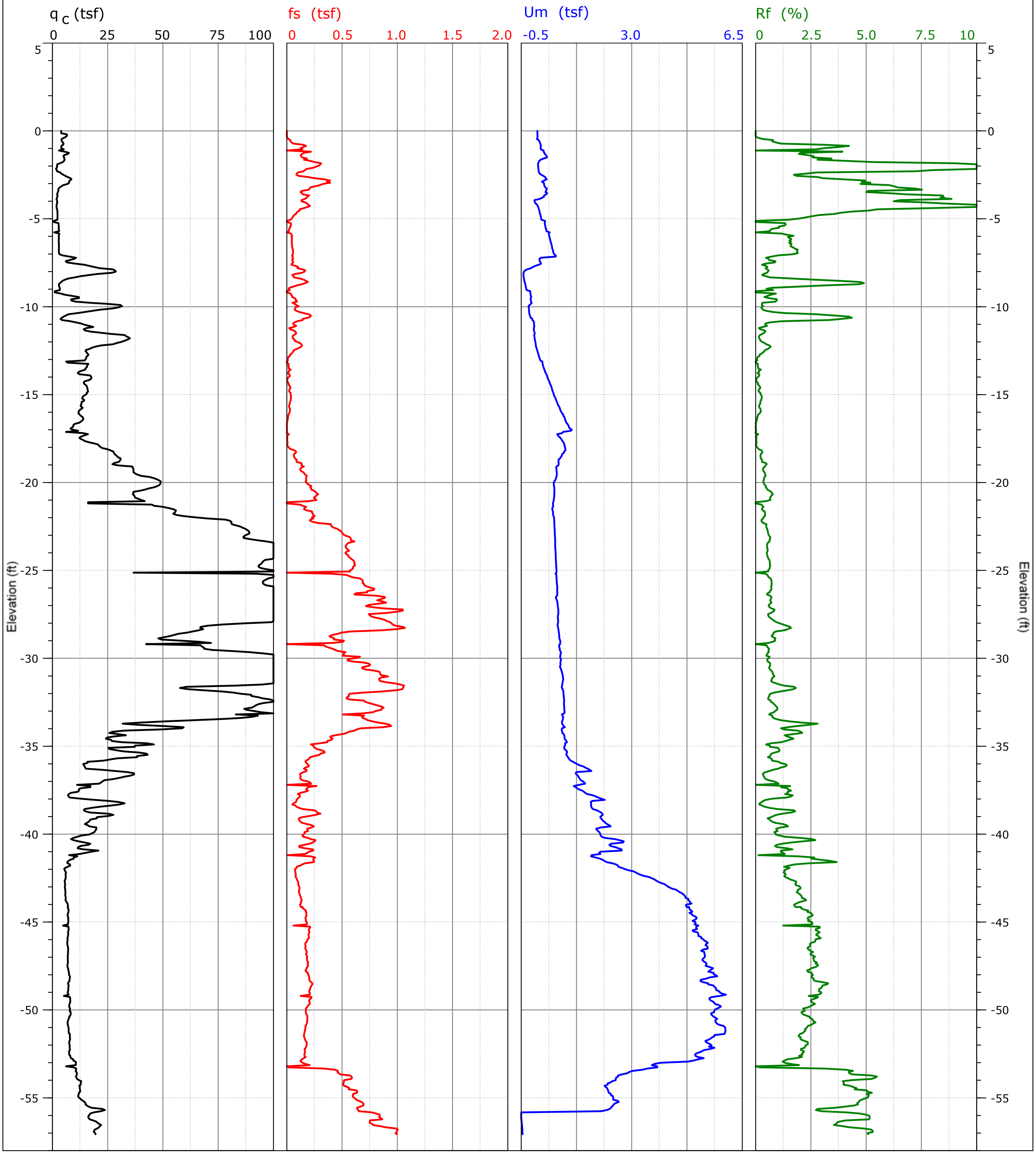
SHEET 1 of 1

CPT Operator

Date Completed

2/07/06

Cone #



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	London Ave. Canal North West Bank	Geo Engineering UCB and STE	LACW-cpt3	

Location

N30.02131 W90.07094

north of breach, on the levee, next to Robert E. Lee bridge

Logger: D. Karadeniz

CPT Operator

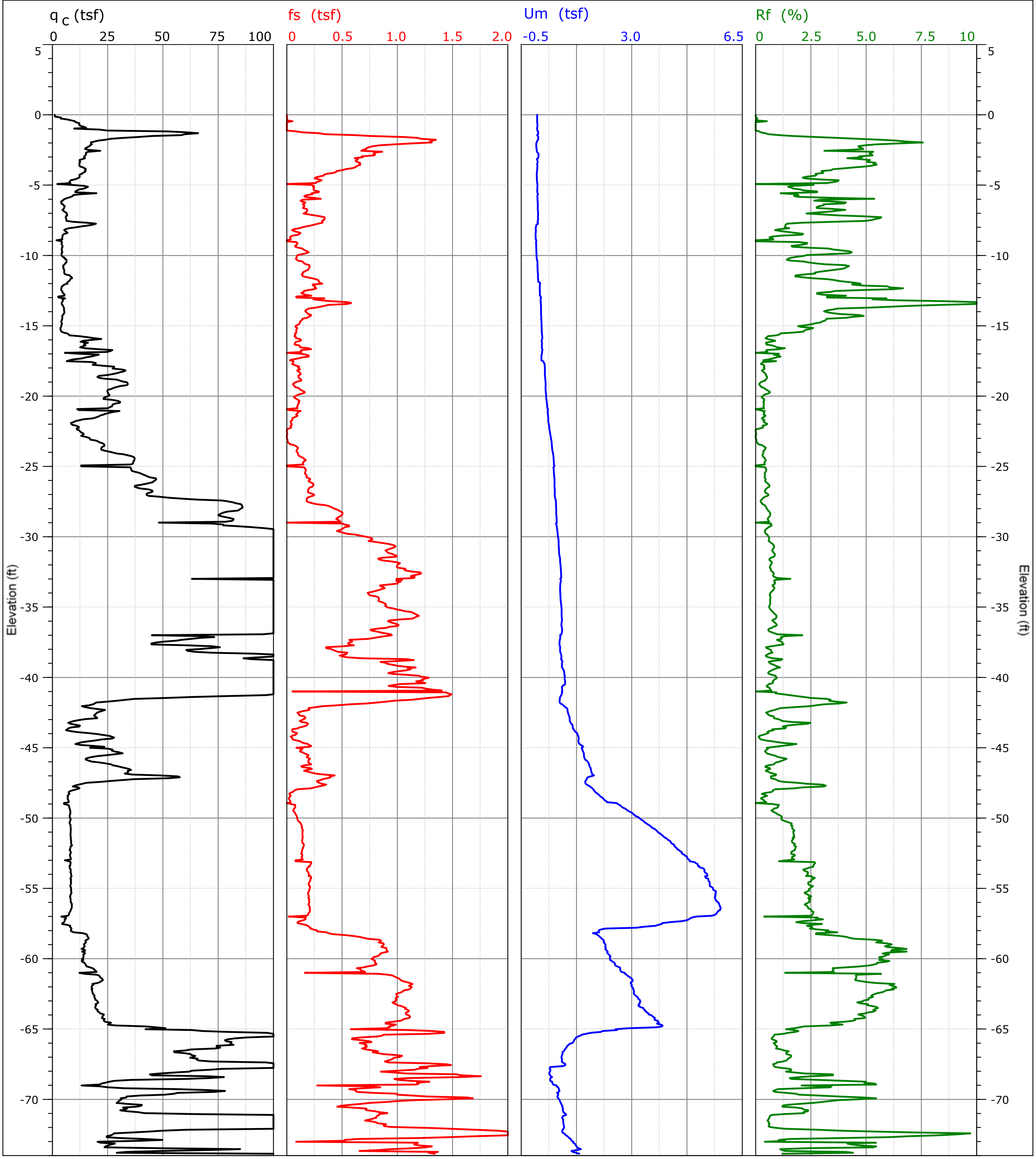
Cone #

SHEET 1 of 1

Date Completed

2/07/06

STE Inc.



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

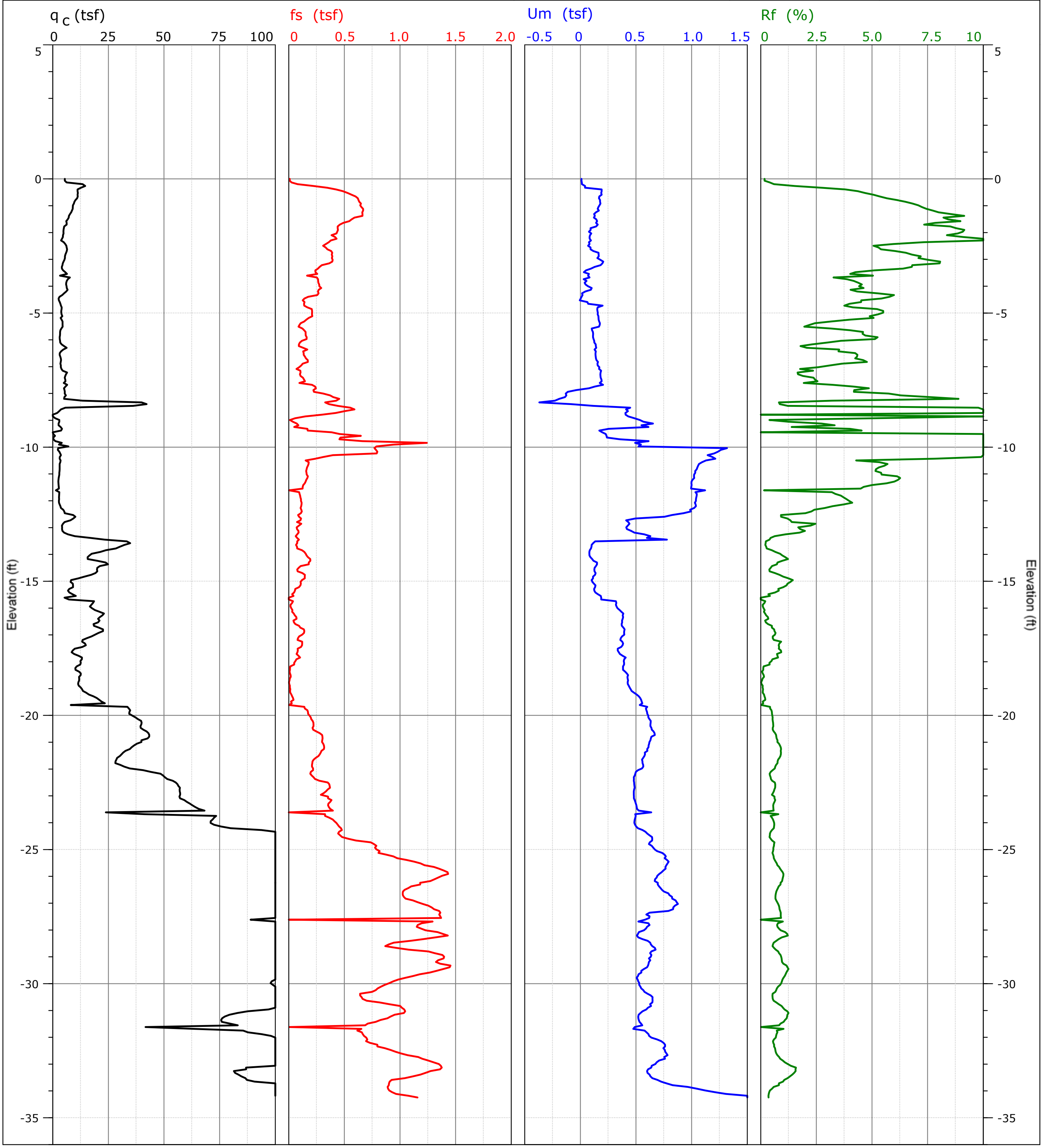
Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	**Site Name** London Ave. Canal North West Bank	**Performed By** Geo Engineering UCB and STE	**Sounding No.** LACW-cpt4	**Ground Elevation** 2.6

Location N30.01953 W90.07082 30' south end of breach, levee crest	**Logger: D. Karadeniz**	**SHEET 1 of 1**
	CPT Operator	**Date Completed** 2/07/06
	Cone #	



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	London Ave. Canal North East Bank	Geo Engineering UCB and STE	LAC-cpt1	-7.7

Location

N30.02097 W90.07027

back yard of 6076 Warrington Drive

Logger: A. Athanasopoulos

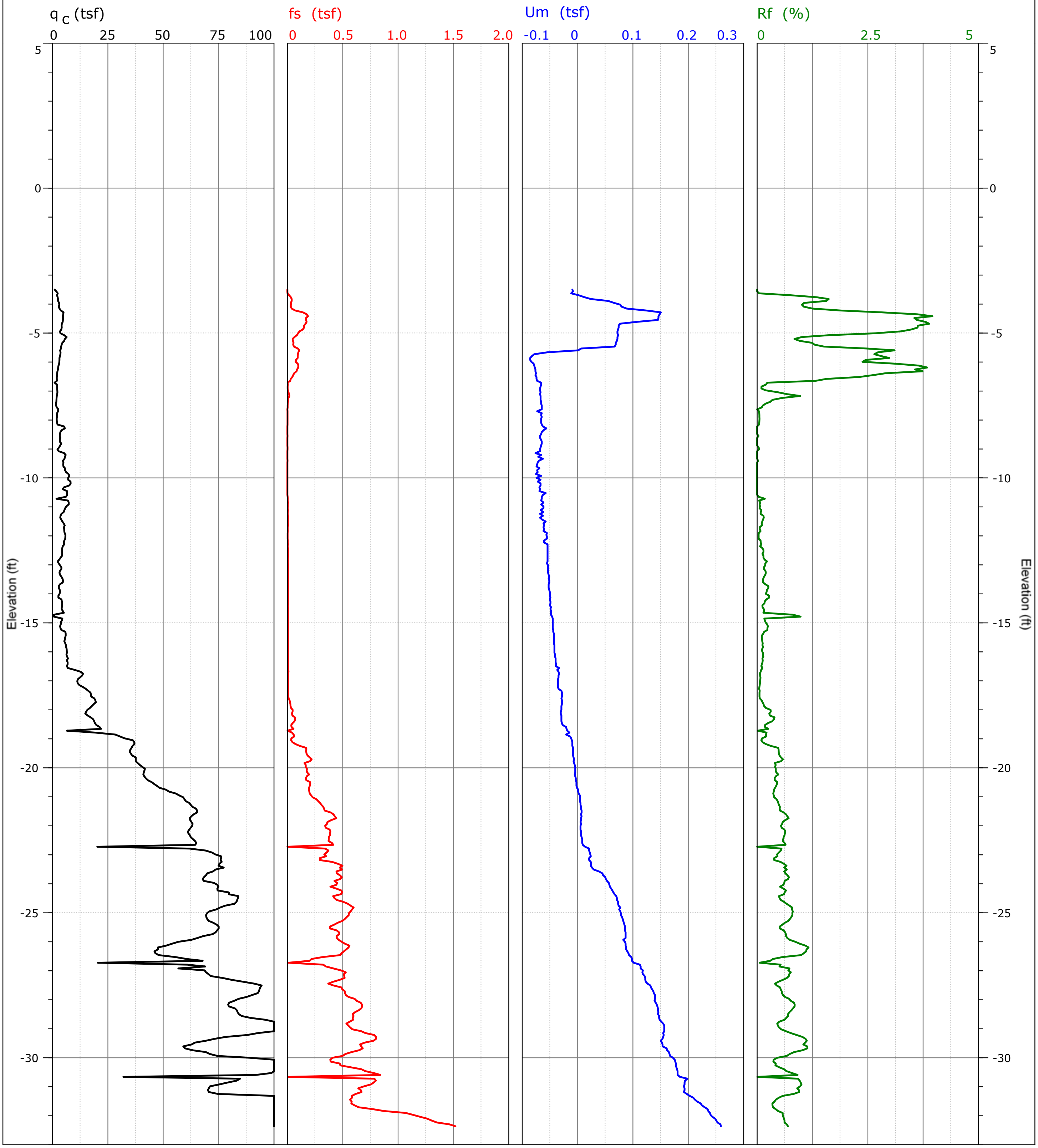
SHEET 1 of 1

Logger:

Date Completed

2/10/06

Cone #



fs --> Sleeve Friction
qc --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project

Site Name London Ave. Canal North East Bank

Performed By Geo Engineering UCB and STE

Sounding No. LAC-cpt2

Ground Elevation

Location N30.02062 W90.07026

120' South of LAC-CPT-1

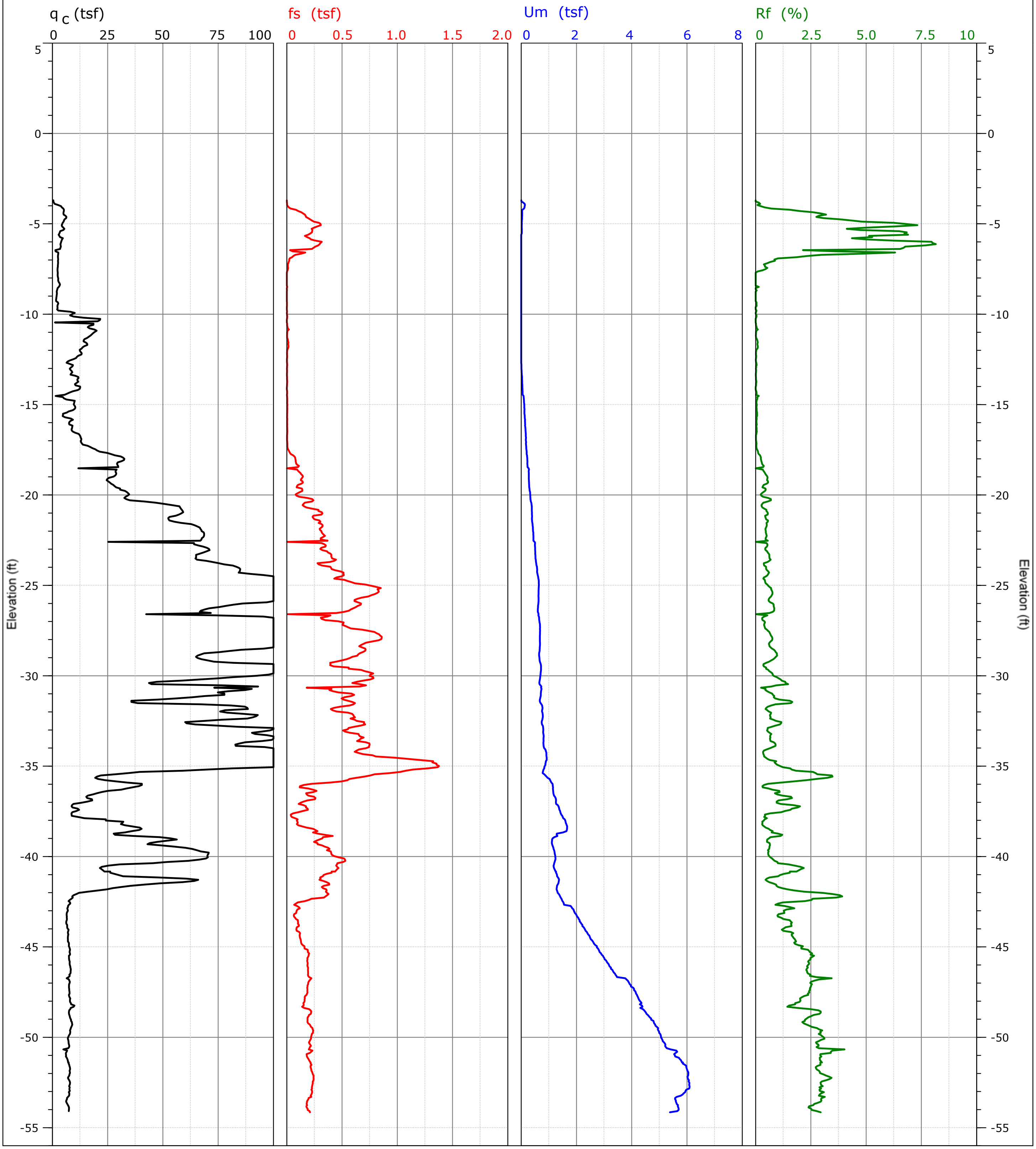
Logger: A. Athanasopoulos

SHEET 1 of 1

Logger:

Date Completed 2/09/06

Cone #



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project

Site Name London Ave. Canal North East Bank

Performed By Geo Engineering UCB and STE

Sounding No. LAC-cpt3

Ground Elevation

Location

N30.02135 W90.07053

130' north of LAC-CPT-1

Logger: A. Athanasopoulos

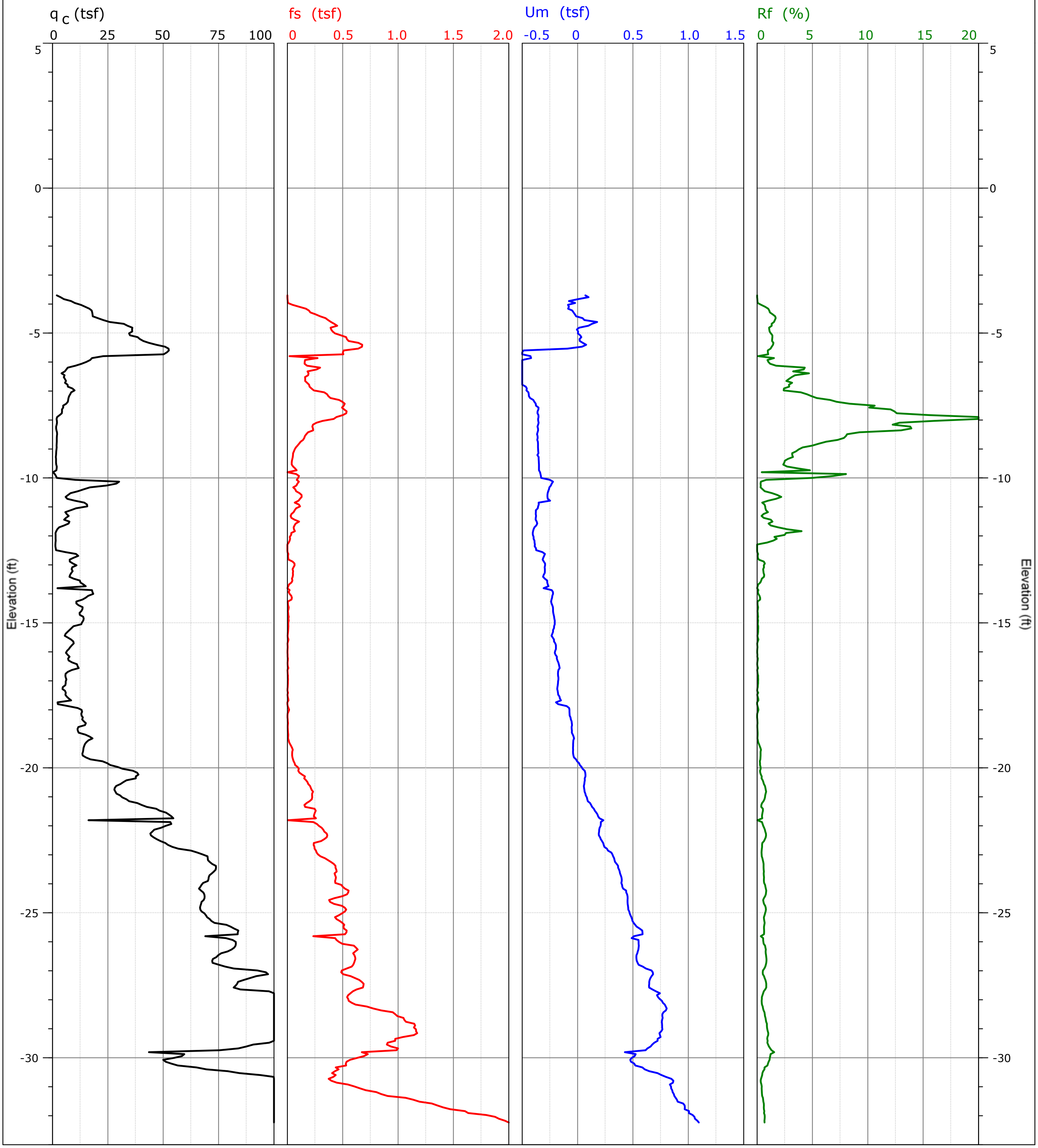
SHEET 1 of 1

Logger:

Date Completed

2/08/06

Cone #



fs --> Sleeve Friction

q c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	London Ave. Canal North East Bank	Geo Engineering UCB and STE	LAC-cpt4	

Location
N30.01998 W90.07032
280' south of LAC-CPT-1

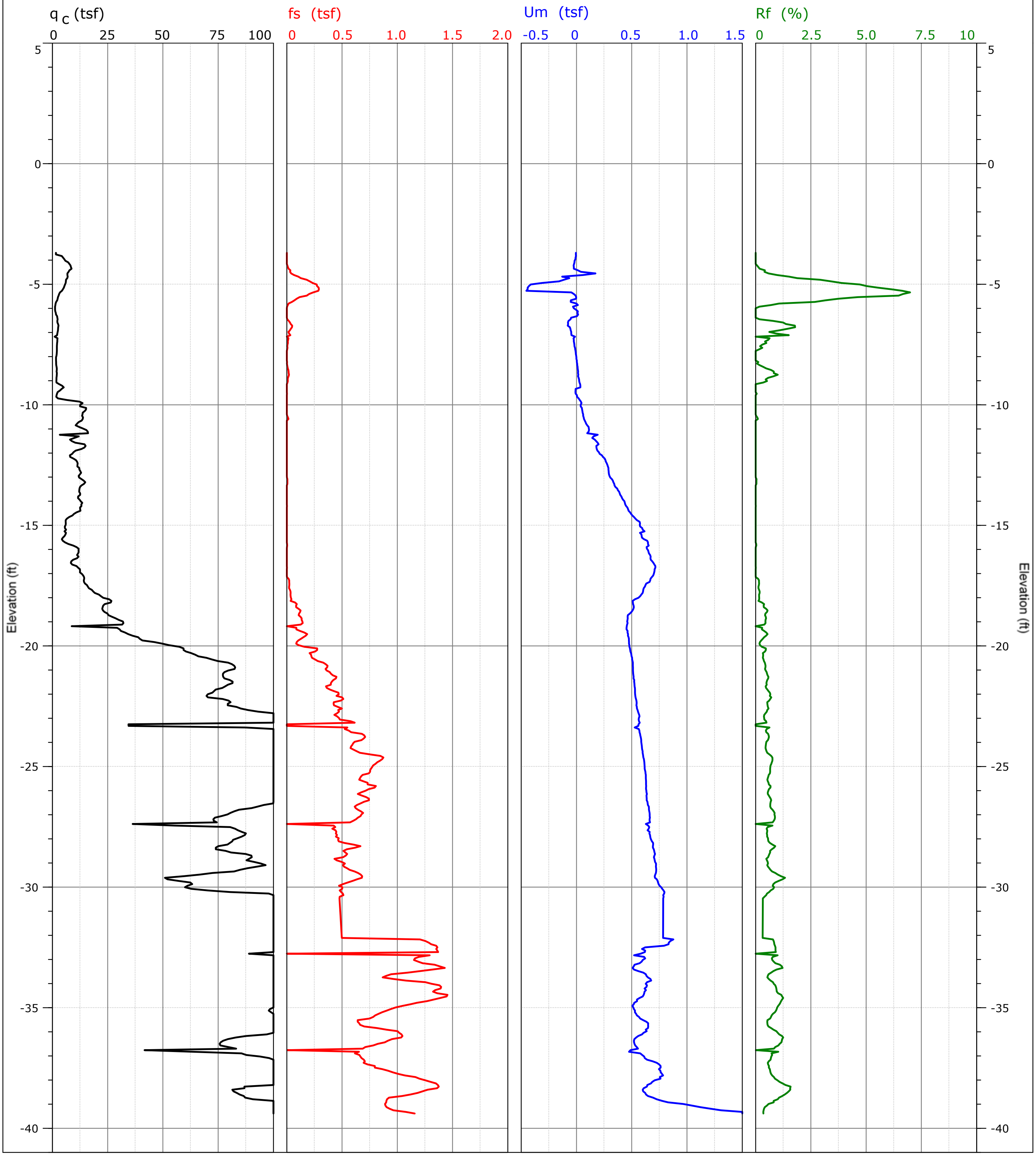
Logger: A. Athanasopoulos

SHEET 1 of 1

Logger:

Date Completed
2/09/06

Cone #



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

Base map: Google Earth

LEGEND

●	SLON-#.05C	USACE 2005 CPT
●	LACS-CPT-#	ILIT 2006 CPT
⊕	LACS-BOR-#	ILIT 2006 BORING
◐	LACS-CON-#	ILIT 2006 CONTINUOUS BORING

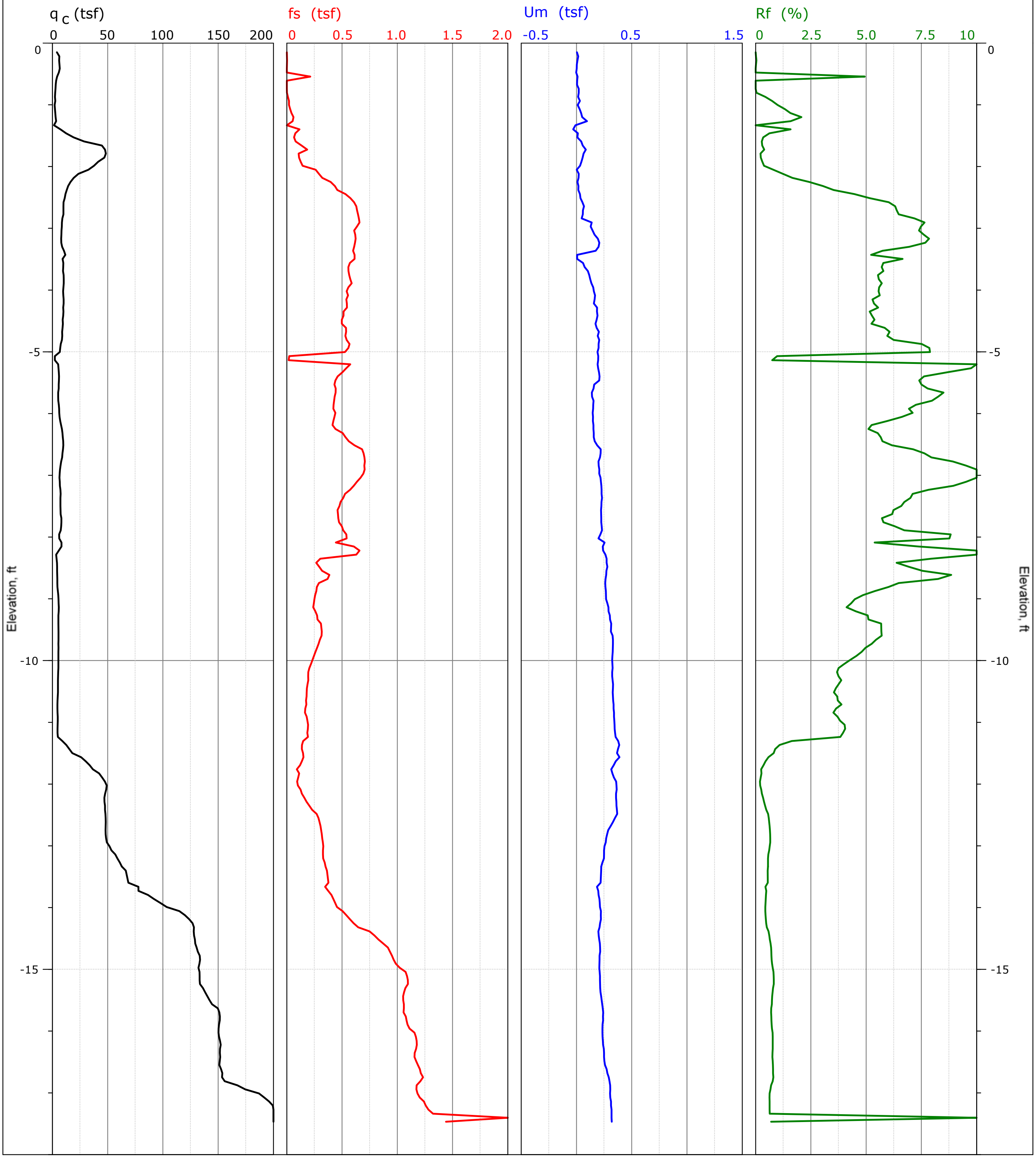
LONDON AVENUE CANAL (SOUTH)
APPROXIMATE ILIT BORING AND CPT LOCATIONS
New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	04/21/2006	LACS BOR & CPT SitePlan	

SCALE Not Drawn To Scale
SHEET

State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	London Ave. Canal South	Geo Engineering UCB and STE	LACS-1	-0.15

Location		
N30.00908 W90.0694 40' north of breach, levee slope	**Logger: A. Athanasopoulos**	**SHEET 1 of 1**
	Logger: D. Cobos	**Date Completed** 2/16/06
	Cone #	



fs --> Sleeve Friction
q_C --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	London Ave. Canal- South	Geo Engineering UCB and STE	LACS-2	4.6

Location N30.00797 W90.06931

30' south of breach, on emergency repair fill

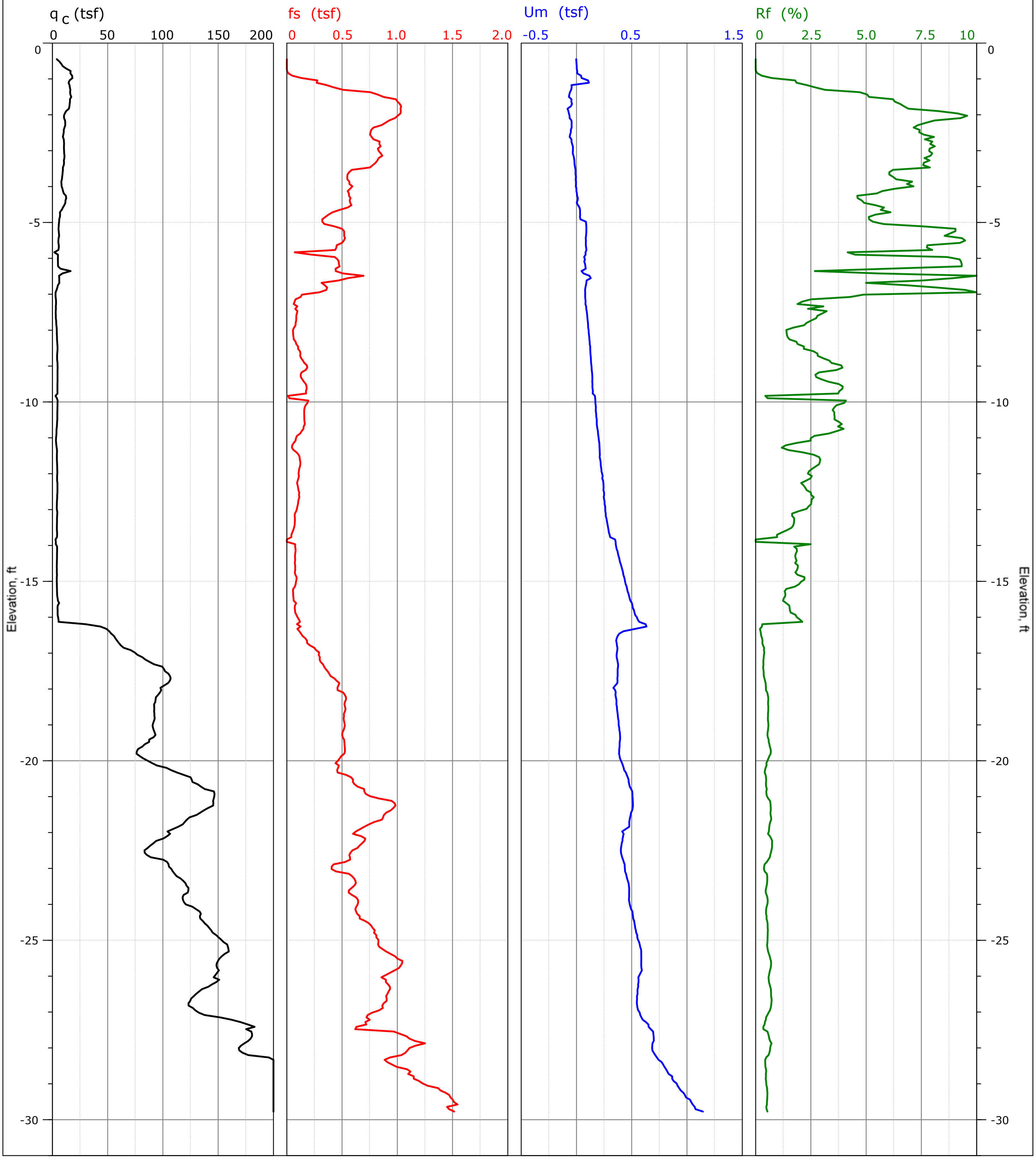
Logger: A. Athanasopoulos

Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed 2/16/06



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	Site Name	Performed By	Sounding No.	Ground Elevation
	London Ave. Canal- South	Geo Engineering UCB and STE	LACS-3	4.6

Location N30.0085 W90.06907
middle of breach, backyard of house
on Warrington Dr. and Wilton Dr.

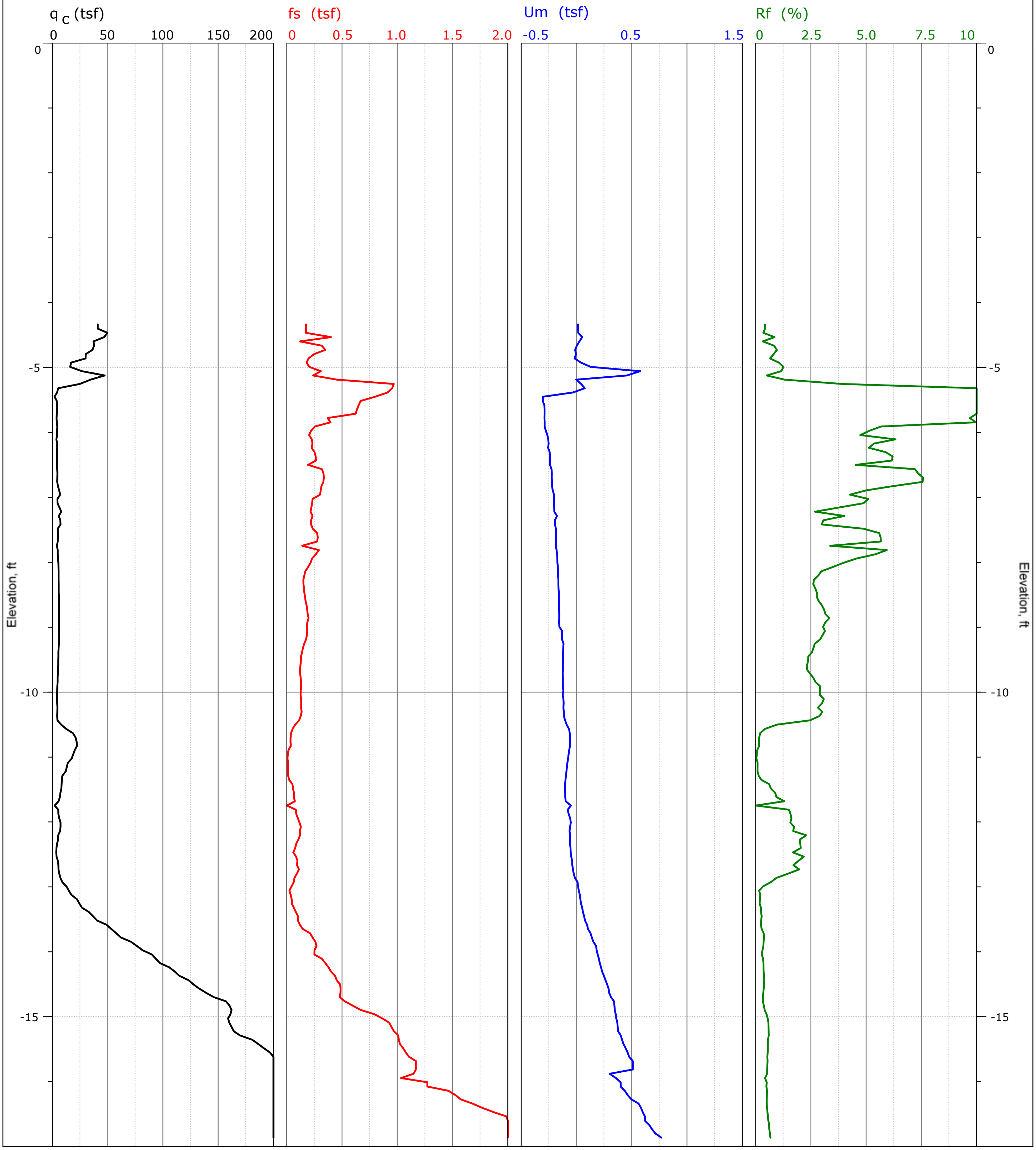
Logger: A. Athanasopoulos

SHEET 1 of 1

Logger: D. Cobos

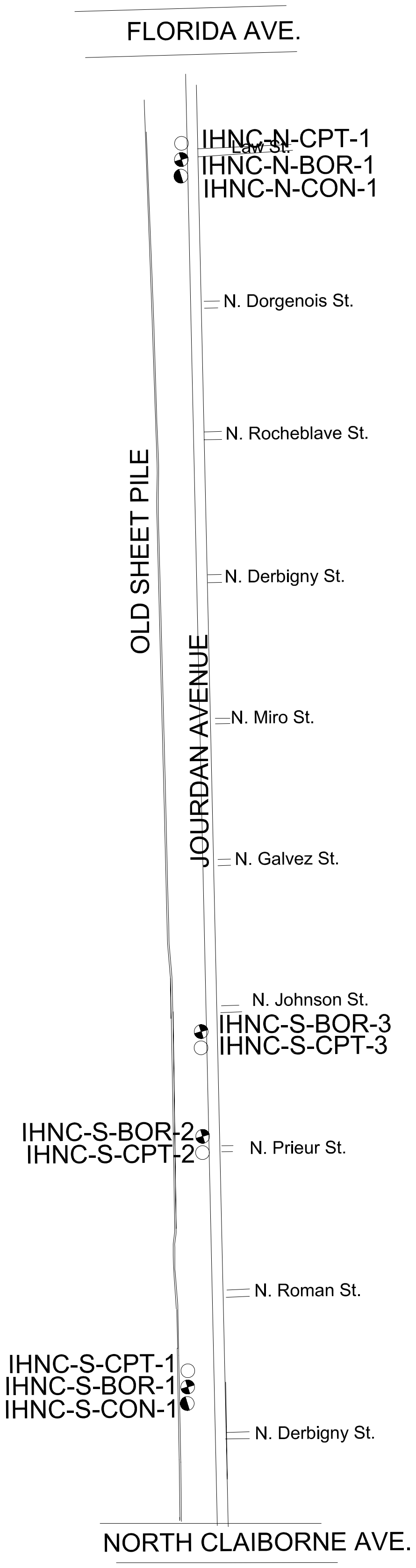
Date Completed 2/16/06

Cone #



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group



LEGEND

◕	IHBR-N-BOR-#	IHNC NORTH 2006 ILIT BORING
◐	IHNC-N-CON-#	IHNC NORTH 2006 ILIT CONTINUOUS BORING
○	IHNC-S-CPT-#	IHNC NORTH 2006 ILIT CONE PENETRATION TEST
◕	IHBR-S-BOR-#	IHNC SOUTH 2006 ILIT BORING

LOWER NINTH WARD
APPROXIMATE ILIT BORING & CPT LOCATIONS

New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	04/21/2006	IHNC BOR & CPT SitePlan	

SCALE	SHEET
Not Drawn To Scale	

State Project

Site Name
IHNC North- East Bank

Performed By
Geo Engineering UCB and STE

Sounding No.
IHNC-N-1

Ground Elevation
-3.38

Location
N29.9787 W90.02049
middle of north breach (south of Florida Ave.)

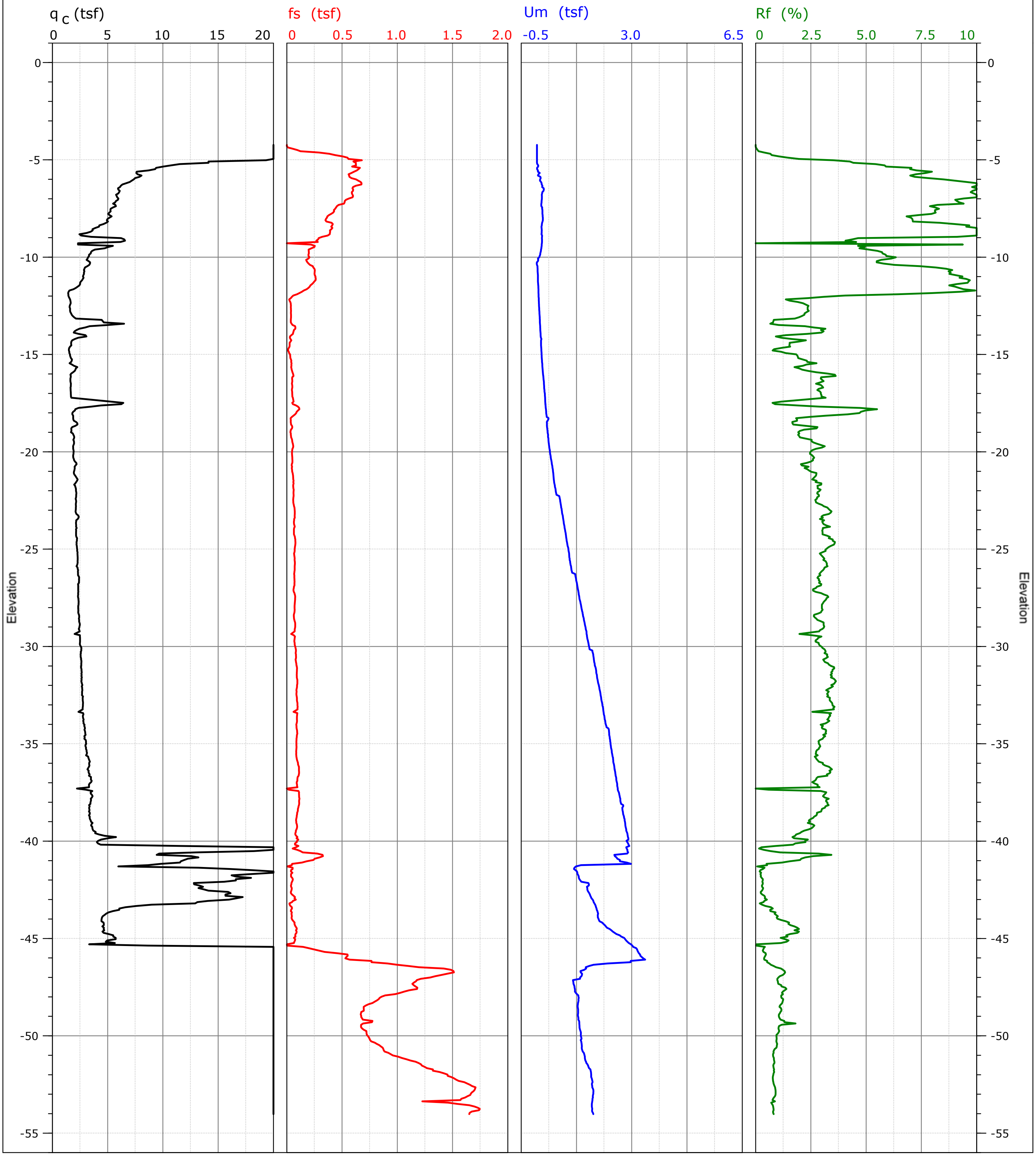
Logger: A. Athanasopoulos

Logger: D. Cobos

Cone #

SHEET 1 of 1

Date Completed
2/21/06



fs --> Sleeve Friction
q_C --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

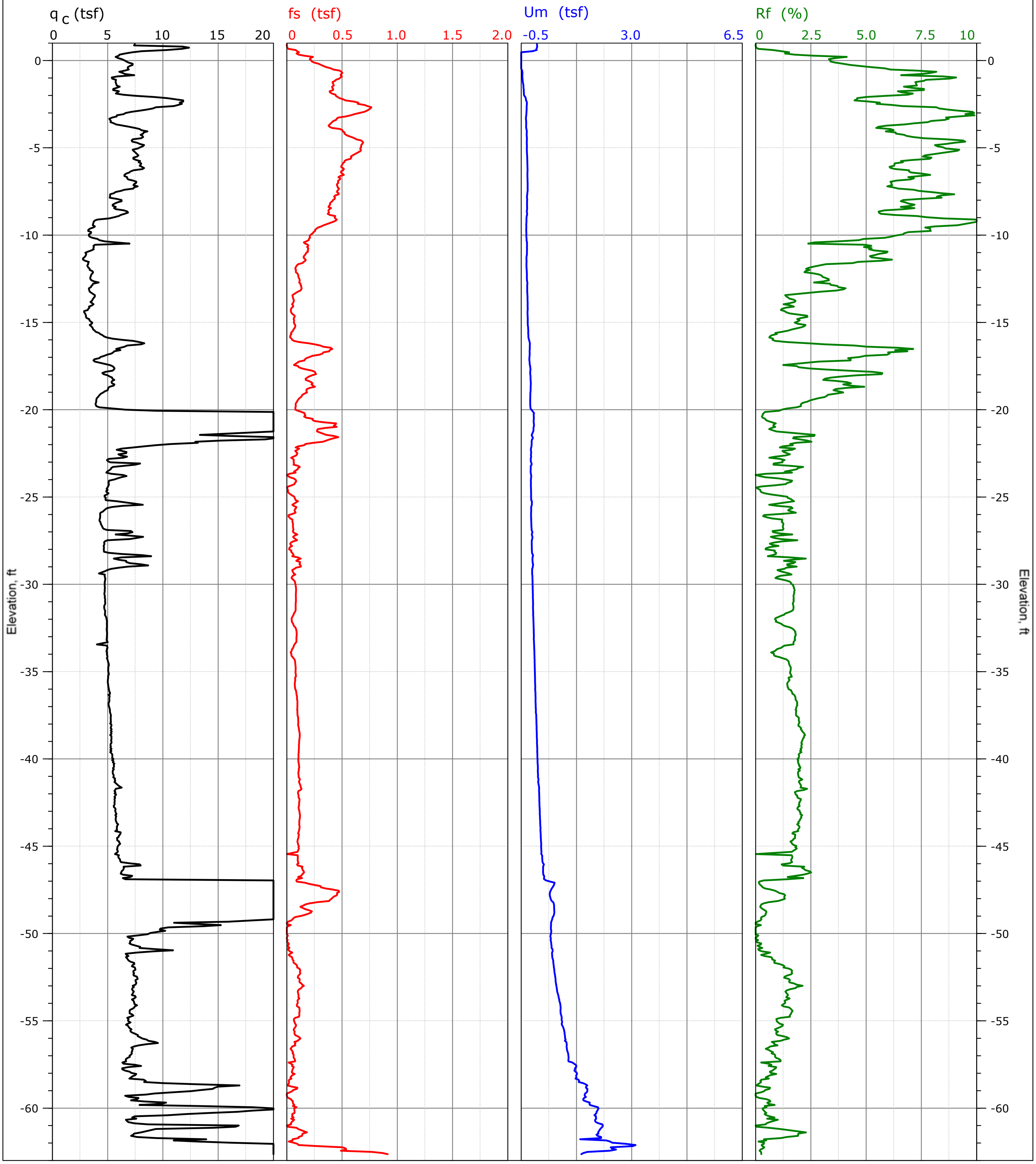
State Project	**Site Name**	**Performed By**	**Sounding No.**	**Ground Elevation**
	IHNC South- East Bank	Geo Engineering UCB and STE	IHNC-S-1	0.93

Location

N29.97035 W90.02314

south of south breach, ~600' north of Claiborne bridge

Logger: A. Athansopoulos	**SHEET 1 of 1**
Logger: D. Cobos	**Date Completed**
Cone #	2/17/06



fs --> Sleeve Friction
qc --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:

Juan Gabriel Vera-Grunauer
CVA Consulting Group

State Project

Site Name IHNC South- East Bank

Performed By Geo Engineering UCB and STE

Sounding No. IHNC-S-2

Ground Elevation -2.7

Location N29.97126 W90.02292

middle of south breach, ~1050' north of Claiborne bridge

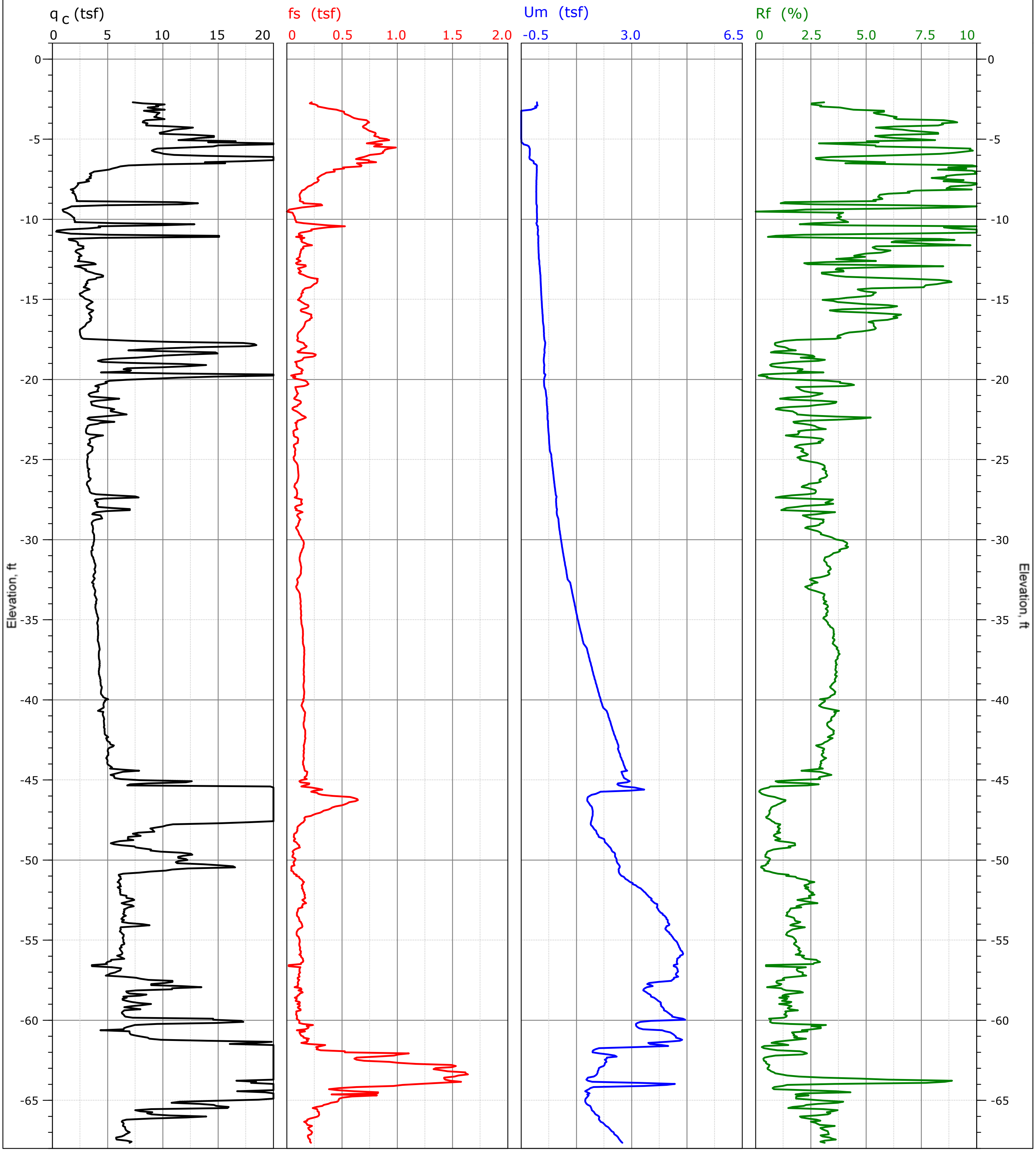
Logger: A. Athanasopoulos

SHEET 1 of 1

Logger D. Cobos

Date Completed 2/16/06

Cone #



fs --> Sleeve Friction

q_c --> Cone Resistance

Um --> Pore pressure measured

Rf --> Friction Ratio = fs/qc

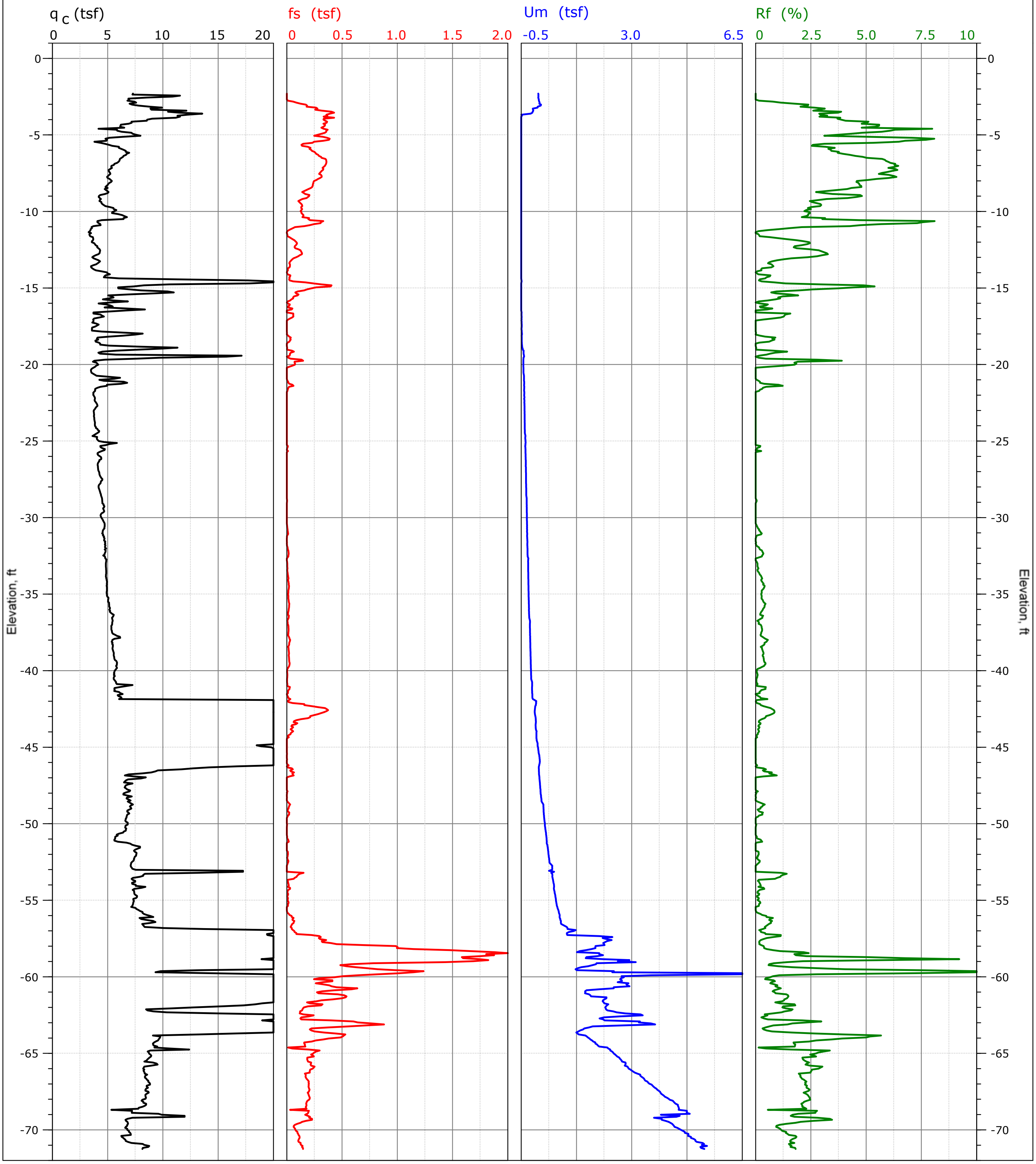
Log Developer:

Juan Gabriel Vera-Grunauer

CVA Consulting Group

State Project	**Site Name** IHNC South- East Bank	**Performed By** Geo Engineering UCB and STE	**Sounding No.** IHNC-S-3	**Ground Elevation** -2.3

Location N29.97248 W90.02257 north of south breach, ~1500' north of Claiborne bridge	**Logger: A. Athanasopoulos**	**SHEET 1 of 1**
	Logger: D. Cobos	**Date Completed** 2/21/06
	Cone #	



fs --> Sleeve Friction
q_c --> Cone Resistance
Um --> Pore pressure measured
Rf --> Friction Ratio = fs/qc

Log Developer:
Juan Gabriel Vera-Grunauer
CVA Consulting Group

APPENDIX D: STE Laboratory Testing

Soil Testing Engineers Inc. performed a series of laboratory tests on the samples retrieved during the field investigation by ILIT. Tests performed included

a) Atterberg Limits, ASTM D 4318

b) Triaxial Unconfined Compression Test, ASTM D 2166

c) Triaxial Unconsolidated Undrained Compression Test, ASTM D 2850

d) Laboratory Vane Shear Test

e) Consolidation Test, ASTM D 2435

Results of these tests are summarized in the Figures and Tables that follow.

Table D.1: Laboratory Testing Results

Project: New Orleans Levee Study

Client: Independent Levee Investigation Team (ILIT)

File No.: 06-1004
Date: 3/22/2006

Sample Identification				Strength Test Data				Classification Data								
										Atterberg Limits						
Boring No.	Depth (ft.)	Test Type	Decription	Compressive Strength (tons/sq.ft.)	Lateral Pressure (psi.)	Vane Shear (tons./sq.ft.)	Type of Failure strain at Failure	Moisture Content (%)	Dry Density (lbs./cu.ft.)	1 point			3 point			Other Data
										LL	PL	PI	LL	PL	PI	
17-2-1	1-3	U,1pt Att	Stiff brown slightly silty clay w/stone and gravel	1.46	-	-	Multi @ 8%	21.7	100.9	43	18	25	-	-	-	
17-2-2	4-6 top	U,3pt Att	Stiff dark gray organic clay to gray and tan clay w/ 1/2"-1" silt layer	1.31	-	-	Yield @ 10%	40.9	75	-	-	-	72	29	43	
	4-6 bott.	U,3pt Att	Medium gray clay with silt seams and layers 1/2"-1"	0.59	-	-	Multi @ 6.5%	27.1	88.7	-	-	-	70	26	44	
17-2-3	8-10 top	uu,consol, 1 &3 pt Att, vane	Soft dark gray clay with silt seams and organics	0.26	4.13	.145/.005	Yield @ 10%	47.8	62.8	-	-	-	74	28	46	
	8-10 bott	uu,consol, 1 &3 pt Att, vane	Soft dark gray clay with silt seams and organics	0.88	4.13	.45/.08	Yield @ 10%	47.8	70.7	65	29	36	65	26	39	
17-2-6	17-19 bott	uu,consol, 1 pt Att, vane	Medium dark gray organic clay w/ peat	0.75	10.63	.47/.05	Yield @ 10%	227.2	21.7	405	171	234	-	-	-	
	17-19 top	Vane	Medium dark gray organic clay w/ peat	-	-	.45/.04	-	-	-	-	-	-	-	-	-	
17-2-7	19.5-21.5	uu,consol, 3 pt Att, vane	Soft gray slightly silty clay	0.41	11.5	.28/.01	Yield @ 10%	38.3	82	-	-	-	38	20	18	
17-2-8	24-26	UU 1pt ATT consol , vane	Soft gray clay w/ alt. Layers of fine sand and silt	0.41	14	.33/.02	Yield @ 10%	58.4	62.5	86	26	60	-	-	-	
17-2-9	30-32	UU, consol Vane	Soft gray clay with silt seams	0.35	18.2	.23/.01	Yield @ 10%	63.1	58.9	-	-	-	-	-	-	
17-6A-1	5-6	UU,1pt Att, Vane	Very soft dark gray to brown peat	0.15	3	.15/.03	Yield@ 10%	199.3	22.4	493	165	328	-	-	-	
	6-7	UU,1pt ATT, Vane	Very soft gray clay	0.13	3.83	.03/.005	Yield @ 10%	99.9	46.5	80	24	56	-	-	-	
17-1-1	14.5-15.0	UU, 1 pt Att	Very soft gray clay	0.11	8.85	-	Yield @ 10%	67	53.2	78	23	55	-	-	-	
	15.5-16	UU,1pt ATT consol,vane	Very soft gray clay with peat	0.15	8.85	.075/.03	Yield @ 10%	67.9	54	89	26	63	-	-	-	
17-1-2	17-19	U,Cu,1 pt Att, 3pt Att	Very soft gray clay with organics	0.09	10.6	-	Yield @ 10%	73.7	54.6	88	28	60	88	28	60	
17-1-3	22.5-24.5	UU,consol , 1pt Att,vane	Very soft gray clay	0.24	13.6	0.14/.025	Yield @ 10%	92.4	46.9	106	31	75	-	-	-	
17-1-4	26.5-28.5	UU,consol,Gss	Firm gray fine sand with clay streaks	2.63	15.94	-	Yield @ 10%	30.2	86.7	-	-	-	-	-	-	
17-3-3	9-10	UU,vane	Very soft gray silty clay w/wood & shell frags.	0.19	5.9	.065/.035	Yield @ 10%	38.1	81.2	-	-	-	-	-	-	
	10-11	UU,Vane	Very soft dark gray clay w/ wood & shell fragments	0.22	5.9	.025/.015	Yield @ 10%	41.8	77.1	-	-	-	-	-	-	
17-3-4	14-16	UU,consol	Very soft gray clay with silty clay layers	0.23	8.85	-	-	50.9	68.4	-	-	-	-	-	-	
17-3-5	20-22	UU,consol 3pt Att	Very soft gray clay	0.22	12.4	-	Yield @ 10 %	67.8	57	-	-	-	78	27	51	
17-3-6	26-28	UU,1 pt Att	Very soft gray very sandy clay with shell	0.28	15.94	-	Yield @ 10 %	26.9	83.3	43	13	30	-	-	-	
17-4-1	3-5	U,1&3pt Att	Stiff tan and brown clay with silt	1.29	-	-	Vertical @ 7.1%	22.3	102.1	33	18	15	34	18	16	
17-4-2	9-10 top	UU,1 pt Att	Medium gray clay with silt and fine sand alternating layers and traces of organic matter	0.65	5.9	-	Bulge @ 9%	35.2	81.5	42	19	23	-	-	-	
	10-11 bott	UU, 1pt Att	Medium gray clay with silt seams and wood	0.62	5.9	-	Yield @ 10%	34.1	84.3	39	20	19	-	-	-	
17-4-3	11.5-13.5	UU ,hydro 1 pt Att	Soft gray and brown clay with peat and organics	0.49	7.5	-	Yield @ 10%	128.4	38.6	122	41	81	-	-	-	
17-4-4	14-15 top	UU,1pt Att Vane	Soft dark gray organic clay with peat	0.38	8.85	.085/.04	-	261.8	22.9	174	66	108	-	-	-	
	15-16 bott	UU,1pt Att Vane	Medium dark gray organic clay with peat	0.54	8.85	.335/.04	-	80.3	40.7	334	125	209	-	-	-	
17-4-7	21.5-23.5 top	UU,1pt ATT, Vane	Very soft gray clay	0.19	14.4	0.11/0.02	Yield @ 10%	78	53.4	115	25	90	-	-	-	

Legend: U = Unconfined compressive strength ASTM D2166 UU = Triaxial unconsolidated undrained compressive strength ASTM D2850

Att = Atterberg Limit determination ASTM D4318 Consol = Consolidation Astm D2435 vane = Minature vane shear

Table D.1: Laboratory Testing Results (cont'd)

Project: New Orleans Levee Study

Client: Independent Levee Investigation Team (ILIT)

File No.: 06-1004
Date: 3/22/2006

Sample Identification				Strength Test Data				Classification Data								Other Data
										Atterberg Limits						
										1 point			3 point			
Boring No.	Depth (ft.)	Test Type	Decription	Compressive Strength (tons/sq.ft.)	Lateral Pressure (psi.)	Vane Shear (tsf.)	Type of Failure strain at Failure	Moisture Content (%)	Dry Density (lbs./cu.ft.)	LL	Pl	PI	LL	PL	PI	
17-4-7	22.5-23.5	UU,1pt Att , consol	Soft gray silty sandy to silty clay (alt. Layers)	0.57	14.4	-	Yield @ 10%	46.6	77.9	34	24	10	-	-	-	
17-4-8	25-27	UU, 1pt Att, Vane	Soft gray clay with alternating layers of silty fir sand	0.38	15.9	.10/.05	Yield @ 10%	65.8	59.7	72	24	48	-	-	-	
17-5-1	3-5	U,1pt Att	Very stiff tan and brown clay with silt	3.32	-		Vertical @ 7.4%	17.6	107.4	38	17	21	-	-	-	
17-5-6	22-24	UU,1pt Att, Vane	Very soft gray clay with siltlenses and wood	0.24	14.41	.125/.01	Yield @ 10%	77.7	54.2	95	27	68	-	-	-	
17-5-7	25-27	UU, consol , 1 pt Att,Vane	Soft gray clay w/ alternating seams of silty fine sand	0.36	16.71	.215/.04	Yield @ 10%	42.7	70.7	71	25	46	-	-	-	
LAC-1-1	3-4	UU,3pt Att,	Very soft gorganic clay	0.13	2.95	-	Yield @ 10%	123.8	38.7	-	-	-	97	26	71	
	5-6	UU,Hydro, 1pt Att,consol	Soft gray clay with fine sand	0.25	2.95	.22/.03	Yield @ 10%	47.7	78.2	37	15	22	-	-	-	
LAC-1-2	6-8	UU,1pt Att Vane	Very soft clay w/ 1/2" sand layer @ bottom	0.14	4.13	0.06/.005	Yield @ 10%	51.7	74.1	47	17	30	-	-	-	
LAC-1-3	8.5-9.5	UU,1pt Att consol,vane	Very soft gray sandy clay w/ wood & clay pockets	0.11	5.6	.005/0.0	Yield @10%	32.6	72.3	82	25	57	-	-	-	
	9.5-10	UU,Hydro	Firm gray fine sand with 2" clayey sand layer	0.29	5.6	-	Bulge @4%	30.2	90.2	-	-	-	-	-	-	
LAC-2-4	44-45	UU,1pt. Att	Medium gray clay with some silt	0.59	26.6	-	Yield @ 10%	86.5	54.5	84	24	60	-	-	-	
	45-46	UU,consol, 1 pt Att	Medium gray clay w/silt seams& shell frags.	0.65	26.6	-	Yield @10%	57.8	66.6	74	21	53	-	-	-	
LAC-3-3	7.5-8.5	UU,consol, 1 pt Att	Medium gray sandy clay to sand	0.53	4.3	-	Vertical @ 4%	21.8	103.3	19	18	1	-	-	-	
LAC-3-4	9-11	UU,3 pt Att, consol	Firm gray sand with clay	0.73	5.9	-	Bulge @7%	26.6	96.6	-	-	-	13	13	NP	
LACW-2-2	8.5-9.5	UU,1pt Att, Vane	Soft Dark gray organic clay with peat	0.26	4.3	0.08/0.01	Yield @ 10%	187	26.7	251	67	184	-	-	-	
	9.5-10.5	UU,1pt Att, Vane	Very Soft Dark gray organic clay with peat	0.23	4.3	0.07/0.01	Yield @ 10%	158	29.9	236	59	177	-	-	-	
LACW-2-4	13.5-15.5	Hydro	Frim gray silty fine sand	-	-	.055/.02	-	27.7	-	22	17	5	-	-	-	
LACW-3-4	10-12	UU,1pt Att, vane	Medium dark gray organic clay alternate layers of sand,silt and clay	0.56	6.49	0.26/.03	Yield @ 10%	48.1	76.4	40	16	24	-	-	-	
LACW-4-1	3.5-4.5	U, 1 pt Att	Stiff dark gray organic clay w/ roots	1.05	-	-	Vertical @ 9%	52.3	66.7	90	32	58	-	-	-	
LACW-4-3	7.5-8.5	U,1 pt Att	Medium gray organic clay w/ wood & peat	0.5	-	-	Vertical @ 7%	109.9	41.3	125	49	76	-	-	-	
	8.5-9.5	U,1 pt Att	Soft gray clay with peat & wood	0.34	-	-	Vertical @ 8%	125.1	37.5	92	46	46	-	-	-	

Legend: U = Unconfined compressive strength ASTM D2166 UU = Triaxial unconsolidated undrained compressive strength ASTM D2850
Att = Atterberg limit determination ASTM D4318 Consol = Consolidationtest ASTM D2435 vane = Minature vane shear

Table D.1: Laboratory Testing Results (cont'd)

Project: New Orleans Levee Study

Client: Independent Levee Investigation Team (ILIT)

File No.: 06-1004
Date: 4/8/2006

Sample Identification				Strength Test Data				Classification Data								Other Data
										Atterberg Limits						
Boring No.	Depth (ft.)	Test Type	Decription	Compressive Strength (tons/sq.ft.)	Lateral Pressure (kips./sq.ft.)	Vane Shear (kips./sq.ft.)	Type of Failure strain at Failure	Moisture Content (%)	Dry Density (lbs./cu.ft.)	1 point			3 point			
										LL	Pl	PI	LL	PL	PI	
LACS-1-2	5-7	1pt Att, vane	Soft gray clay with organics	-	-	0.45/.09	-	79.1	-	156	50	106	-	-	-	Sample ravialed while extruding
LACS-1-3	8.5-10.5	UU,gss,Vane	Medium gray clay w/ fine sand @ bottom	0.62	4.2	.29/.03	Yield @ 10%	32.5	78.5	-	-	-	-	-	-	
LACS-3-1	5-7	UU,1pt Att Vane	Stiff gray clay	1.07	3.54	.49/.15	yield@10%	28.1	91.4	56	19	37	-	-	-	
LACS-3-2	7.5-9.5	UU,3pt Att, Vane	Soft gray clay	0.47	5	.28/.05	Bukgr @ 8%	50.3	66.2	-	-	-	116	29	87	
IHNCS-1-1	8-9	Vane	Medium gray clay	-	-	0.52/.03	-	-	-							
	7.5-9.5	UU,1pt Att Vane	Medium gray clay	0.85	4	0.35/.01	Yield @ 10%	62.8	62.7	101	31	70	-	-	-	
IHNCS-1-3	12-13	UU,1pt Att	Soft gray clay with wood	0.25	7.38	-	Yield @ 10%	94.9	46.2	129	29	100	-	-	-	
	13-14	UU,3pt Att vane,1pt Att	Soft gray clay with wood	0.27	7.96	0.15/.005	Yield @ 10%	94.5	44.1	138	34	104	139	35	104	
IHNCS-3-2	11.5-12.5	UU,1pt Att Vane	Very soft gray clay with peat	0.16	7.08	.025/0.0	Yield @ 10%	78.3	53.9	98	31	67	-	-	-	
	12.5-13.5	UU	Very soft gray clay	0.22	7.67	-	Yield @10%	57.2	64.5							
IHNCN-1-3	10-12	UU	Very soft gray & dark gray clay with peat	0.18	6.49	-	Yield @ 10%	67.9	58.1							

Legend: U = Unconfined compressive strength ASTM D2166 UU = Triaxial unconsolidated undrained compressive strength ASTM D2850
Att = Atterberg Limit determination ASTM D4318 Consol = Consolidation ASTM D2435 Vane = Minature vane shear gss = Grain size sieve ASTM D422

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff brown slightly silty clay w/stone and gravel
Type of Failure: Multi @ 8%
Boring No.: 17-2-1
Depth (ft): 1-3

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1212.8

Area (in^2) = 6.492
Moisture Content (%) = 21.66%
Wet Density (pcf) = 122.7
Dry Density (pcf) = 100.9

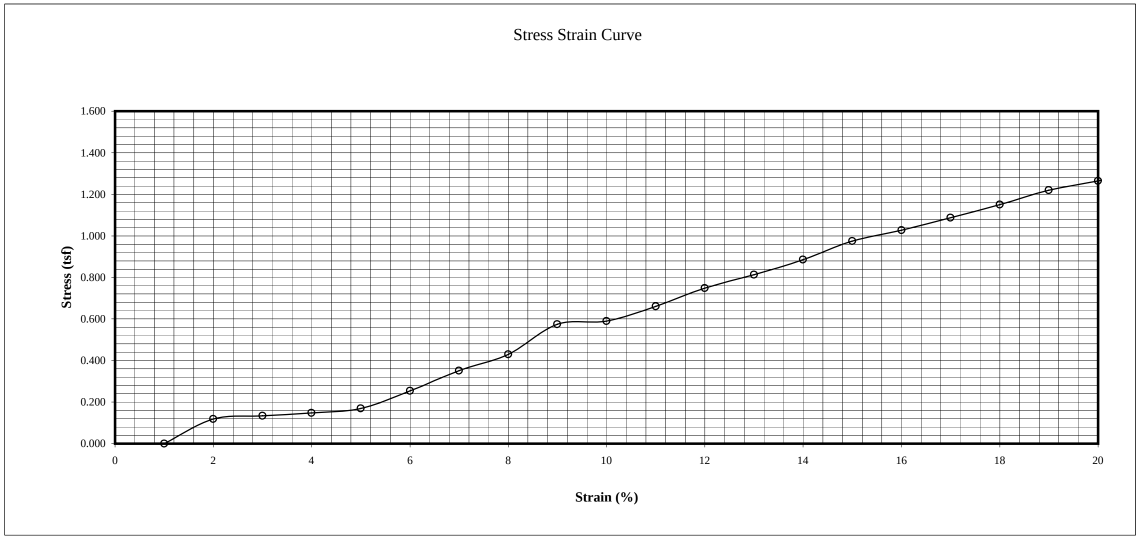
Wet wt. 173.86
Dry at. 148.06
Can wt. 28.96

Test Data:
Cell Pressure (psi) = 0.0
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729025

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	32	0.345	0.119
0.040	36	0.690	0.134
0.060	40	1.034	0.148
0.080	46	1.379	0.170
0.100	69	1.724	0.253
0.120	96	2.069	0.351
0.140	118	2.414	0.430
0.160	158	2.759	0.574
0.180	163	3.103	0.590
0.200	183	3.448	0.660
0.220	208	3.793	0.748
0.240	227	4.138	0.813
0.260	248	4.483	0.885
0.280	274	4.828	0.975
0.300	290	5.172	1.028
0.320	308	5.517	1.088
0.340	327	5.862	1.150
0.360	348	6.207	1.220
0.380	362	6.552	1.264
0.400	378	6.897	1.315
0.420	393	7.241	1.362
0.440	406	7.586	1.402
0.460	416	7.931	1.431
0.480	423	8.276	1.450
0.500	428	8.621	1.462
0.520	428	8.966	1.456
0.540			
0.560			
0.580			
0.600			



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STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Still dark gray organic clay to gray & tan clay w/1/2-1" silt layer
Type of Failure: Yield @ 10%
Boring No.: 17-2-2
Depth (ft): 4-6 top

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1046.9

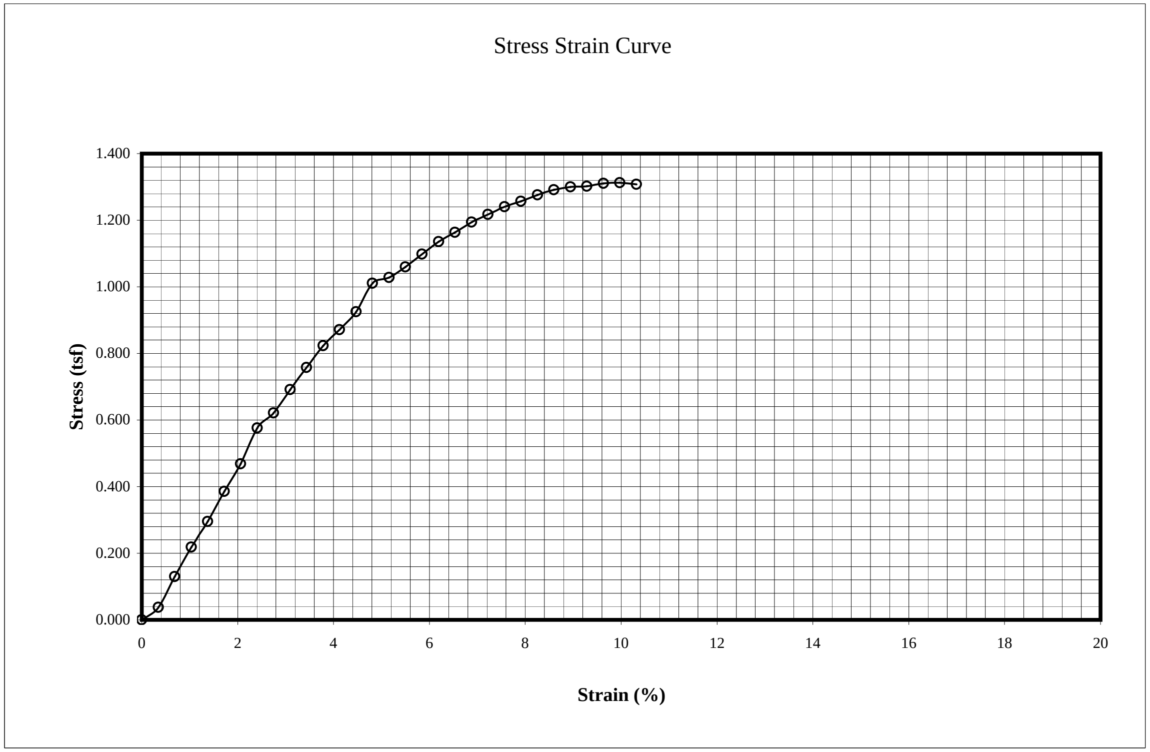
Area (in^2) = 6.492
Moisture Content (%) = 40.88%
Wet Density (pcf) = 105.7
Dry Density (pcf) = 75.0

Wet wt. 130.16
Dry at. 98.84
Can wt. 22.22

Test Data:
Cell Pressure (psi) = 0.0
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	10	0.344	0.037
0.040	35	0.688	0.130
0.060	59	1.032	0.218
0.080	80	1.376	0.295
0.100	105	1.720	0.386
0.120	128	2.064	0.469
0.140	158	2.408	0.576
0.160	171	2.752	0.622
0.180	191	3.096	0.692
0.200	210	3.440	0.758
0.220	229	3.784	0.824
0.240	243	4.128	0.871
0.260	259	4.472	0.925
0.280	284	4.816	1.010
0.300	290	5.160	1.028
0.320	300	5.504	1.060
0.340	312	5.848	1.098
0.360	324	6.192	1.136
0.380	333	6.536	1.163
0.400	343	6.880	1.194
0.420	351	7.224	1.217
0.440	359	7.568	1.240
0.460	365	7.912	1.256
0.480	372	8.256	1.276
0.500	378	8.600	1.291
0.520	382	8.944	1.300
0.540	384	9.288	1.302
0.560	388	9.632	1.311
0.580	390	9.976	1.312
0.600	390	10.320	1.307



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay w/ silt seams and layers 1/2-1"
Type of Failure: Multi @ 6.5%
Boring No.: 17-2-2
Depth (ft): 4-6 bot

Sample Data:
Diameter (in.) = 2.875
Height (in) = 4.0
Weight (gm) = 768.9

Area (in^2) = 6.492
Moisture Content (%) = 27.14%
Wet Density (pcf) = 112.8
Dry Density (pcf) = 88.7

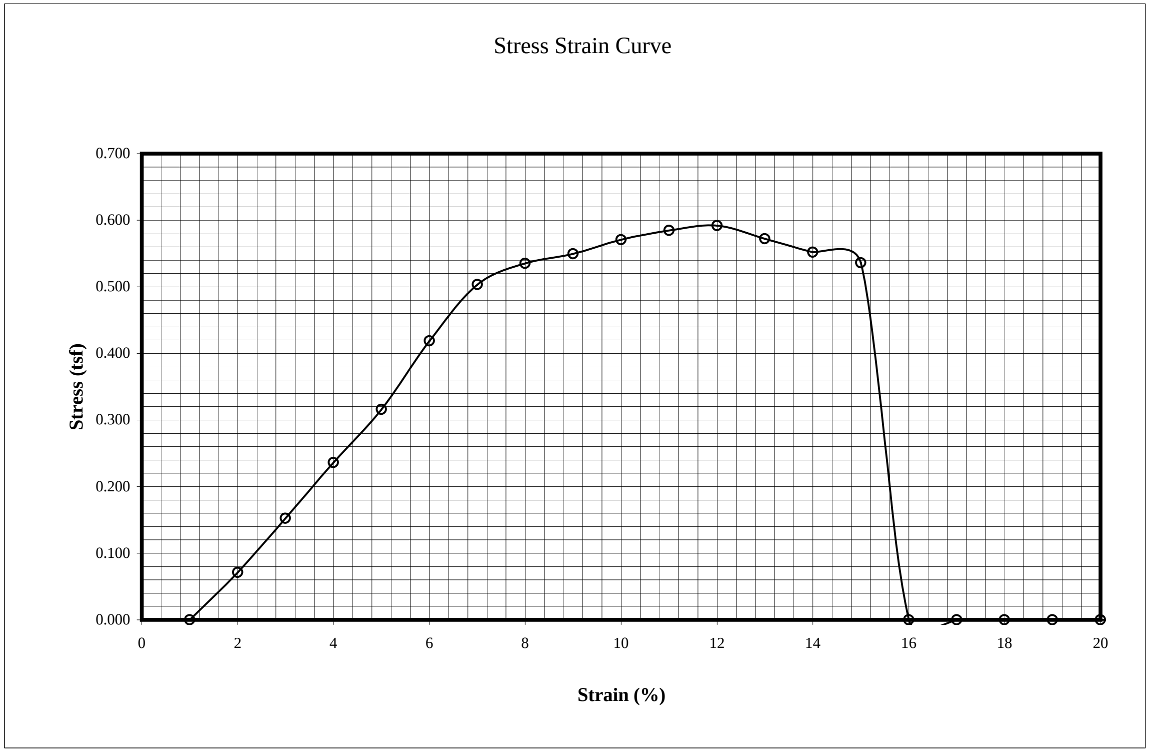
Wet wt. 196.48
Dry at. 160.31
Can wt. 27.02

Test Data:
Cell Pressure (psi) = 0.0
Height Correction = 0.957
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	20	0.500	0.071
0.040	43	1.000	0.152
0.060	67	1.500	0.236
0.080	90	2.000	0.316
0.100	120	2.500	0.419
0.120	145	3.000	0.503
0.140	155	3.500	0.535
0.160	160	4.000	0.550
0.180	167	4.500	0.571
0.200	172	5.000	0.585
0.220	175	5.500	0.592
0.240	170	6.000	0.572
0.260	165	6.500	0.552
0.280	161	7.000	0.536
0.300			
0.320			
0.340			
0.360			
0.380			
0.400			
0.420			
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray clay with silt seams and organics
Type of Failure: Yeild @ 10%
Boring No.: 17-2-3
Depth (ft): 8-10 top

Sample Data:
Diameter (in.) = 2.875
Height (in) = 4.5
Weight (gm) = 711.4

Area (in^2) = 6.492
Moisture Content (%) = 47.75%
Wet Density (pcf) = 92.8
Dry Density (pcf) = 62.8

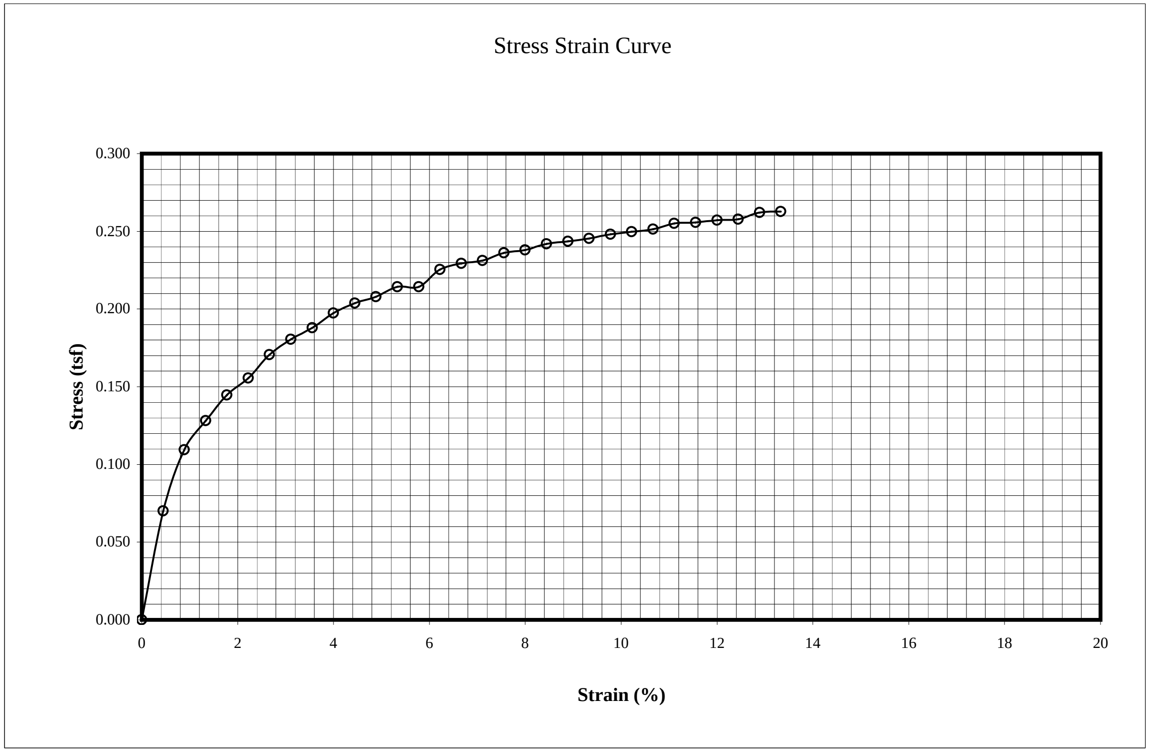
Wet wt. 111.12
Dry at. 83.88
Can wt. 26.83

Test Data:
Cell Pressure (psi) = 4.1
Height Correction = 0.976
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	6.5	0.444	0.070
0.040	10.2	0.889	0.109
0.060	12.0	1.333	0.128
0.080	13.6	1.778	0.145
0.100	14.7	2.222	0.156
0.120	16.2	2.667	0.171
0.140	17.2	3.111	0.180
0.160	18.0	3.556	0.188
0.180	19.0	4.000	0.197
0.200	19.7	4.444	0.204
0.220	20.2	4.889	0.208
0.240	20.9	5.333	0.214
0.260	21.0	5.778	0.214
0.280	22.2	6.222	0.225
0.300	22.7	6.667	0.229
0.320	23.0	7.111	0.231
0.340	23.6	7.556	0.236
0.360	23.9	8.000	0.238
0.380	24.4	8.444	0.242
0.400	24.7	8.889	0.244
0.420	25.0	9.333	0.245
0.440	25.4	9.778	0.248
0.460	25.7	10.222	0.250
0.480	26.0	10.667	0.251
0.500	26.5	11.111	0.255
0.520	26.7	11.556	0.256
0.540	27.0	12.000	0.257
0.560	27.2	12.444	0.258
0.580	27.8	12.889	0.262
0.600	28.0	13.333	0.263



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray clay with silt seams and organics
Type of Failure: Yeild @ 10%
Boring No.: 17-2-3
Depth (ft): 8-10 bot

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1034.3

Area (in^2) = 6.492
Moisture Content (%) = 47.75%
Wet Density (pcf) = 104.4
Dry Density (pcf) = 70.7

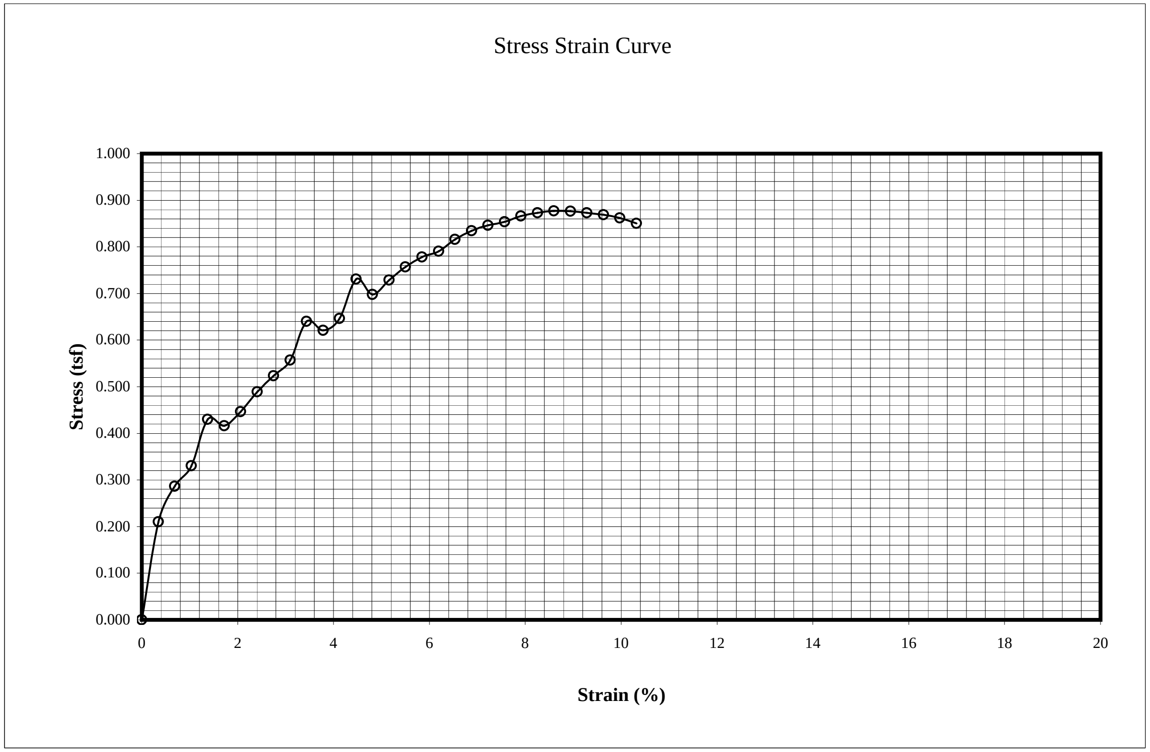
Wet wt. 134.9
Dry at. 98.05
Can wt. 20.87

Test Data:
Cell Pressure (psi) = 4.1
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	19.0	0.344	0.210
0.040	26.0	0.688	0.286
0.060	30.1	1.032	0.330
0.080	39.3	1.376	0.430
0.100	38.2	1.720	0.416
0.120	41.1	2.064	0.446
0.140	45.2	2.408	0.489
0.160	48.5	2.752	0.523
0.180	51.8	3.096	0.557
0.200	59.8	3.440	0.640
0.220	58.2	3.784	0.621
0.240	60.8	4.128	0.646
0.260	69.0	4.472	0.731
0.280	66.1	4.816	0.698
0.300	69.3	5.160	0.729
0.320	72.2	5.504	0.757
0.340	74.5	5.848	0.778
0.360	76.0	6.192	0.791
0.380	78.7	6.536	0.816
0.400	80.8	6.880	0.834
0.420	82.2	7.224	0.846
0.440	83.3	7.568	0.854
0.460	84.8	7.912	0.866
0.480	85.8	8.256	0.873
0.500	86.5	8.600	0.877
0.520	86.8	8.944	0.877
0.540	86.8	9.288	0.873
0.560	86.7	9.632	0.869
0.580	86.3	9.976	0.862
0.600	85.5	10.320	0.850



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium dark gray organic clay w/peat
Type of Failure: Yellow @ 10%

Boring No.: 17-2-6
Depth (ft): 17-19

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 702.4

Area (in^2) = 6.492
Moisture Content (%) = 227.16%
Wet Density (pcf) = 70.9
Dry Density (pcf) = 21.7

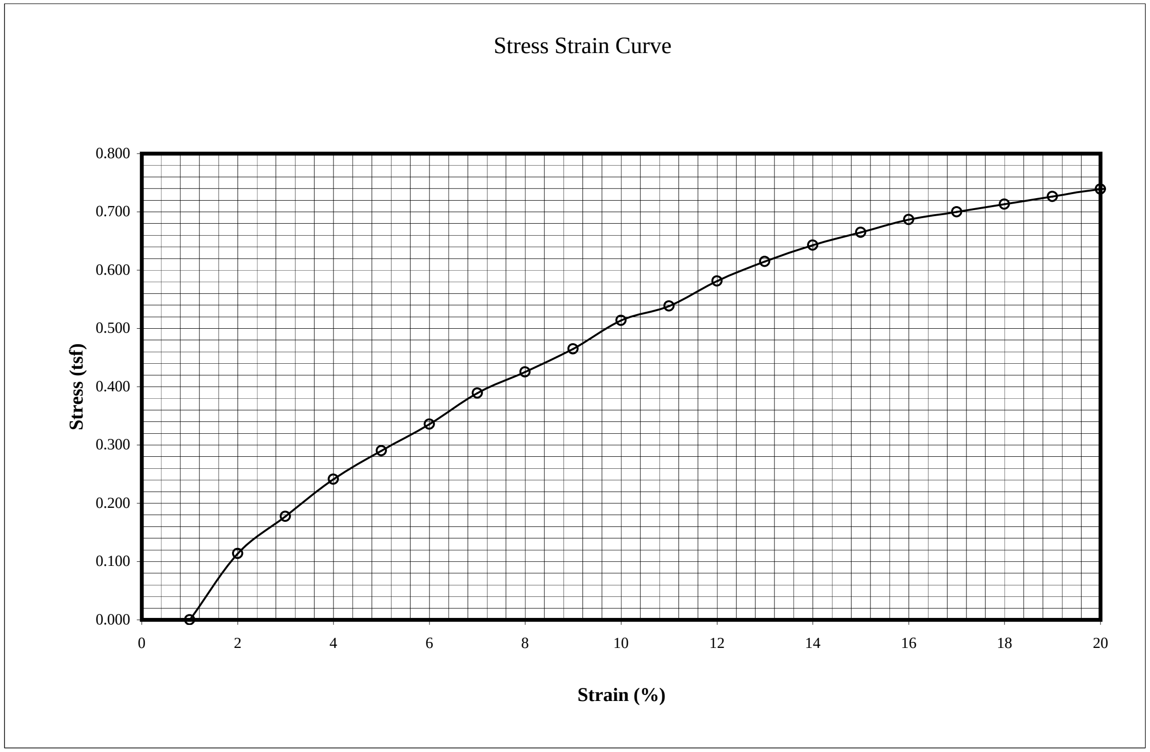
Wet wt. 89.54
Dry at. 41.86
Can wt. 20.87

Test Data:

Cell Pressure (psi) = 10.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	10.3	0.344	0.114
0.040	16.1	0.688	0.177
0.060	22.0	1.032	0.241
0.080	26.5	1.376	0.290
0.100	30.8	1.720	0.336
0.120	35.8	2.064	0.389
0.140	39.3	2.408	0.425
0.160	43.1	2.752	0.465
0.180	47.8	3.096	0.514
0.200	50.3	3.440	0.539
0.220	54.5	3.784	0.582
0.240	57.8	4.128	0.615
0.260	60.7	4.472	0.643
0.280	63.0	4.816	0.665
0.300	65.3	5.160	0.687
0.320	66.8	5.504	0.700
0.340	68.3	5.848	0.713
0.360	69.8	6.192	0.726
0.380	71.3	6.536	0.739
0.400	72.0	6.880	0.744
0.420	72.8	7.224	0.749
0.440	73.3	7.568	0.751
0.460	73.2	7.912	0.748
0.480	71.7	8.256	0.730
0.500	64.8	8.600	0.657
0.520	63.2	8.944	0.638
0.540	62.5	9.288	0.629
0.560	61.8	9.632	0.619
0.580	60.8	9.976	0.607
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray slightly silty clay
Type of Failure: Yellow @10%

Boring No.: 17-2-7
Depth (ft): 19.5-21.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1123.3

Area (in^2) = 6.492
Moisture Content (%) = 38.34%
Wet Density (pcf) = 113.4
Dry Density (pcf) = 82.0

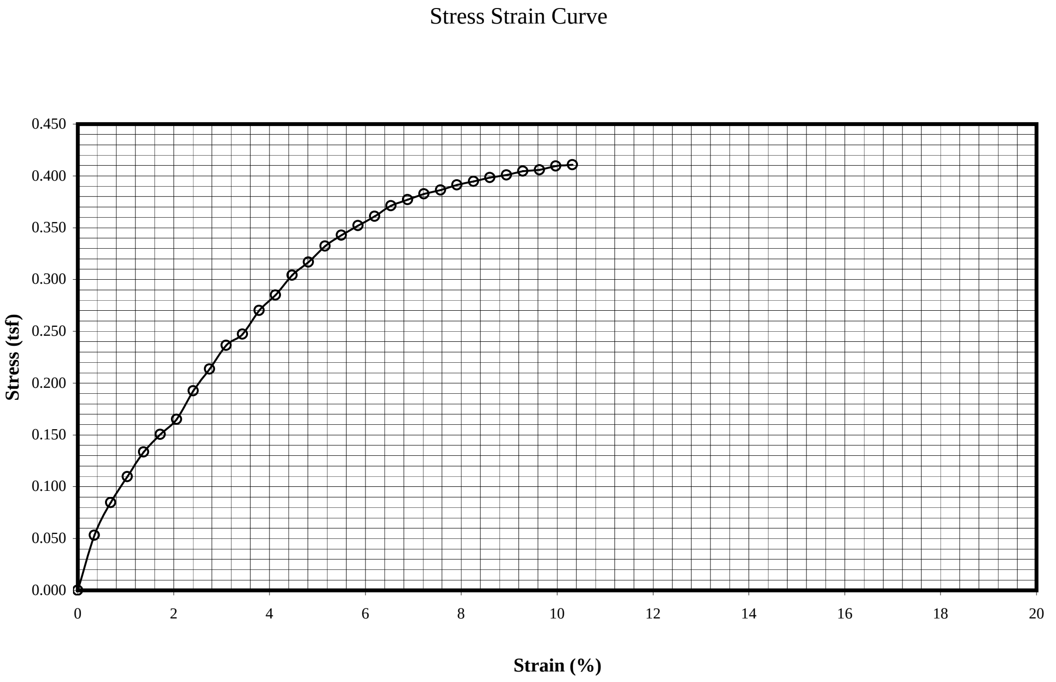
Wet wt. 139.84
Dry at. 108.02
Can wt. 25.02

Test Data:
Cell Pressure (psi) = 11.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	4.8	0.344	0.053
0.040	7.7	0.688	0.085
0.060	10.0	1.032	0.110
0.080	12.2	1.376	0.133
0.100	13.8	1.720	0.150
0.120	15.2	2.064	0.165
0.140	17.8	2.408	0.193
0.160	19.8	2.752	0.214
0.180	22.0	3.096	0.236
0.200	23.1	3.440	0.247
0.220	25.3	3.784	0.270
0.240	26.8	4.128	0.285
0.260	28.7	4.472	0.304
0.280	30.0	4.816	0.317
0.300	31.6	5.160	0.332
0.320	32.7	5.504	0.343
0.340	33.7	5.848	0.352
0.360	34.7	6.192	0.361
0.380	35.8	6.536	0.371
0.400	36.5	6.880	0.377
0.420	37.2	7.224	0.383
0.440	37.7	7.568	0.386
0.460	38.3	7.912	0.391
0.480	38.8	8.256	0.395
0.500	39.3	8.600	0.398
0.520	39.7	8.944	0.401
0.540	40.2	9.288	0.404
0.560	40.5	9.632	0.406
0.580	41.0	9.976	0.409
0.600	41.3	10.320	0.411



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/alt. Layers of fine sand & silt
Type of Failure: Yield @10%
Boring No.: 17-2-8
Depth (ft): 24-26

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 980.3

Area (in^2) = 6.492
Moisture Content (%) = 58.43%
Wet Density (pcf) = 98.9
Dry Density (pcf) = 62.5

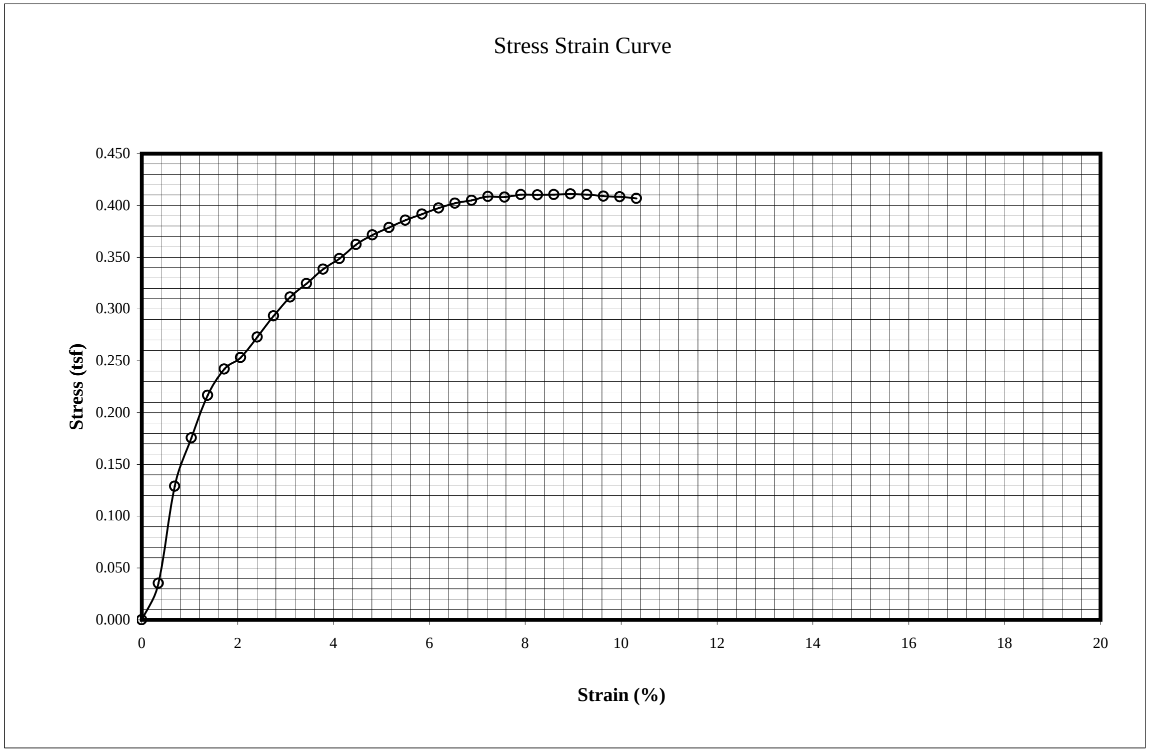
Wet wt. 183.45
Dry at. 123.96
Can wt. 22.14

Test Data:
Cell Pressure (psi) = 14.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.2	0.344	0.035
0.040	11.7	0.688	0.129
0.060	16.0	1.032	0.176
0.080	19.8	1.376	0.217
0.100	22.2	1.720	0.242
0.120	23.3	2.064	0.253
0.140	25.2	2.408	0.273
0.160	27.2	2.752	0.293
0.180	29.0	3.096	0.312
0.200	30.3	3.440	0.324
0.220	31.7	3.784	0.338
0.240	32.8	4.128	0.349
0.260	34.2	4.472	0.362
0.280	35.2	4.816	0.372
0.300	36.0	5.160	0.379
0.320	36.8	5.504	0.386
0.340	37.5	5.848	0.392
0.360	38.2	6.192	0.397
0.380	38.8	6.536	0.402
0.400	39.2	6.880	0.405
0.420	39.7	7.224	0.409
0.440	39.8	7.568	0.408
0.460	40.2	7.912	0.411
0.480	40.3	8.256	0.410
0.500	40.5	8.600	0.411
0.520	40.7	8.944	0.411
0.540	40.8	9.288	0.410
0.560	40.8	9.632	0.409
0.580	40.9	9.976	0.408
0.600	40.9	10.320	0.407


Stress Strain Curve

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay with silt seams
Boring No.: 17-2-9
Depth (ft): 30-32

Type of Failure: Yield @10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 952.2

Area (in^2) = 6.492
Moisture Content (%) = 63.12%
Wet Density (pcf) = 96.1
Dry Density (pcf) = 58.9

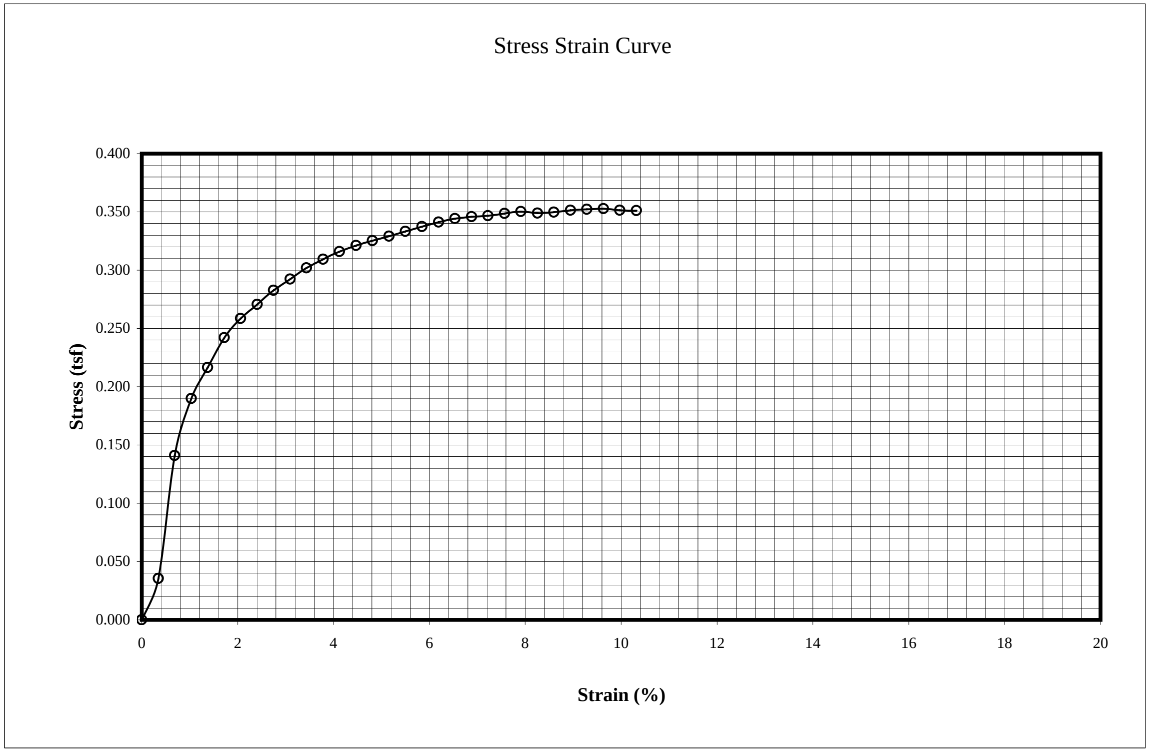
Wet wt. 165.18
Dry at. 112.45
Can wt. 28.91

Test Data:

Cell Pressure (psi) = 18.2
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.2	0.344	0.035
0.040	12.8	0.688	0.141
0.060	17.3	1.032	0.190
0.080	19.8	1.376	0.217
0.100	22.2	1.720	0.242
0.120	23.8	2.064	0.259
0.140	25.0	2.408	0.271
0.160	26.2	2.752	0.283
0.180	27.2	3.096	0.292
0.200	28.2	3.440	0.302
0.220	29.0	3.784	0.309
0.240	29.7	4.128	0.316
0.260	30.3	4.472	0.321
0.280	30.8	4.816	0.325
0.300	31.3	5.160	0.329
0.320	31.8	5.504	0.333
0.340	32.3	5.848	0.337
0.360	32.8	6.192	0.341
0.380	33.2	6.536	0.344
0.400	33.5	6.880	0.346
0.420	33.7	7.224	0.347
0.440	34.0	7.568	0.349
0.460	34.3	7.912	0.350
0.480	34.3	8.256	0.349
0.500	34.5	8.600	0.350
0.520	34.8	8.944	0.351
0.540	35.0	9.288	0.352
0.560	35.2	9.632	0.353
0.580	35.2	9.976	0.351
0.600	35.3	10.320	0.351


Stress Strain Curve

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft dark gray to brown peat
Type of Failure: Yield @10%
Boring No.: 17-6A-1
Depth (ft): 5-6

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 662.9

Area (in^2) = 6.492
Moisture Content (%) = 199.32%
Wet Density (pcf) = 66.9
Dry Density (pcf) = 22.4

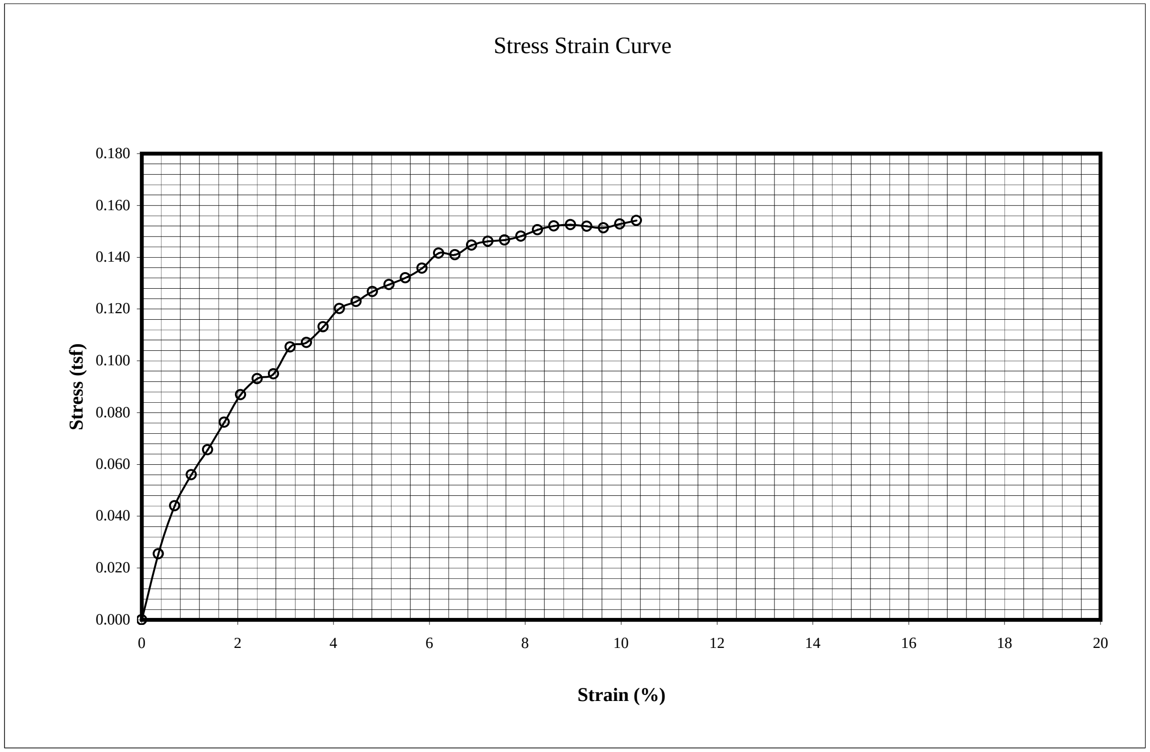
Wet wt. 141.12
Dry at. 65.16
Can wt. 27.05

Test Data:
Cell Pressure (psi) = 3.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	2.3	0.344	0.025
0.040	4.0	0.688	0.044
0.060	5.1	1.032	0.056
0.080	6.0	1.376	0.066
0.100	7.0	1.720	0.076
0.120	8.0	2.064	0.087
0.140	8.6	2.408	0.093
0.160	8.8	2.752	0.095
0.180	9.8	3.096	0.105
0.200	10.0	3.440	0.107
0.220	10.6	3.784	0.113
0.240	11.3	4.128	0.120
0.260	11.6	4.472	0.123
0.280	12.0	4.816	0.127
0.300	12.3	5.160	0.129
0.320	12.6	5.504	0.132
0.340	13.0	5.848	0.136
0.360	13.6	6.192	0.141
0.380	13.6	6.536	0.141
0.400	14.0	6.880	0.145
0.420	14.2	7.224	0.146
0.440	14.3	7.568	0.147
0.460	14.5	7.912	0.148
0.480	14.8	8.256	0.151
0.500	15.0	8.600	0.152
0.520	15.1	8.944	0.152
0.540	15.1	9.288	0.152
0.560	15.1	9.632	0.151
0.580	15.3	9.976	0.153
0.600	15.5	10.320	0.154



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @10%
Boring No.: 17-6A-1
Depth (ft): 6-7

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 920.5

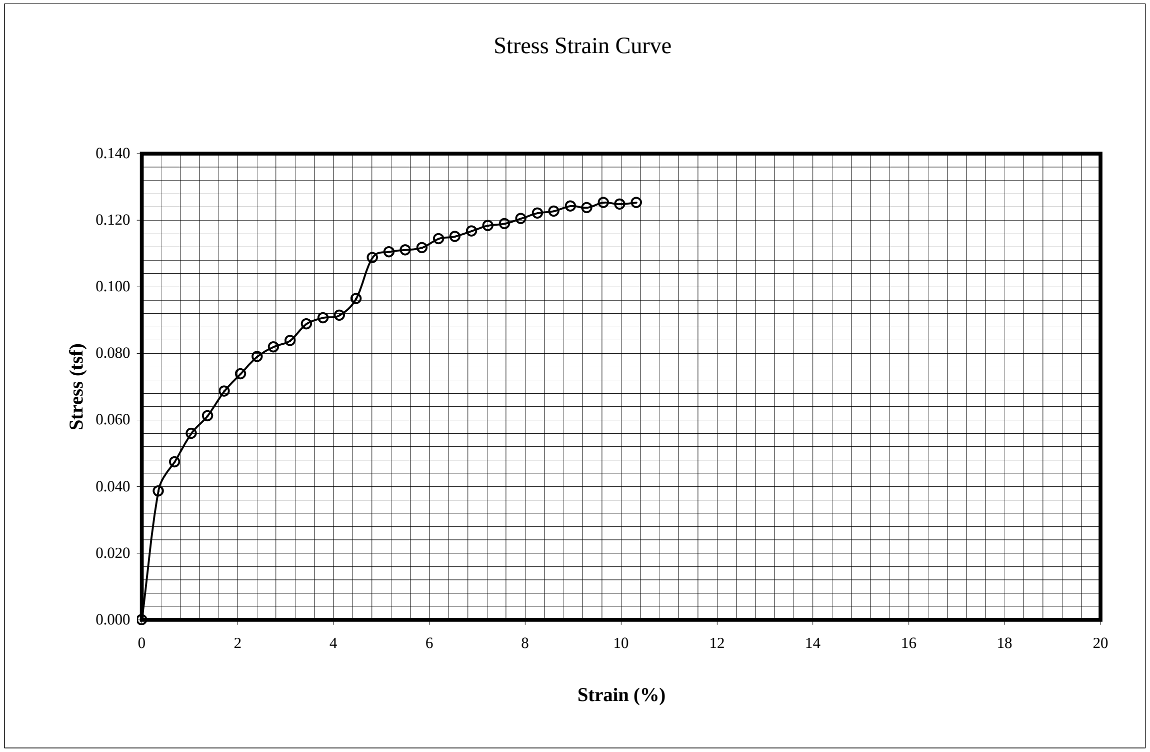
Area (in^2) = 6.492
Moisture Content (%) = 99.88%
Wet Density (pcf) = 92.9
Dry Density (pcf) = 46.5

Wet wt. 193.2
Dry at. 110.91
Can wt. 28.52

Test Data:
Cell Pressure (psi) = 3.8
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.5	0.344	0.039
0.040	4.3	0.688	0.047
0.060	5.1	1.032	0.056
0.080	5.6	1.376	0.061
0.100	6.3	1.720	0.069
0.120	6.8	2.064	0.074
0.140	7.3	2.408	0.079
0.160	7.6	2.752	0.082
0.180	7.8	3.096	0.084
0.200	8.3	3.440	0.089
0.220	8.5	3.784	0.091
0.240	8.6	4.128	0.091
0.260	9.1	4.472	0.096
0.280	10.3	4.816	0.109
0.300	10.5	5.160	0.110
0.320	10.6	5.504	0.111
0.340	10.7	5.848	0.112
0.360	11.0	6.192	0.114
0.380	11.1	6.536	0.115
0.400	11.3	6.880	0.117
0.420	11.5	7.224	0.118
0.440	11.6	7.568	0.119
0.460	11.8	7.912	0.121
0.480	12.0	8.256	0.122
0.500	12.1	8.600	0.123
0.520	12.3	8.944	0.124
0.540	12.3	9.288	0.124
0.560	12.5	9.632	0.125
0.580	12.5	9.976	0.125
0.600	12.6	10.320	0.125



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @10%
Boring No.: 17-1-1
Depth (ft): 14.5-15

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 880.0

Area (in^2) = 6.492
Moisture Content (%) = 66.96%
Wet Density (pcf) = 88.8
Dry Density (pcf) = 53.2

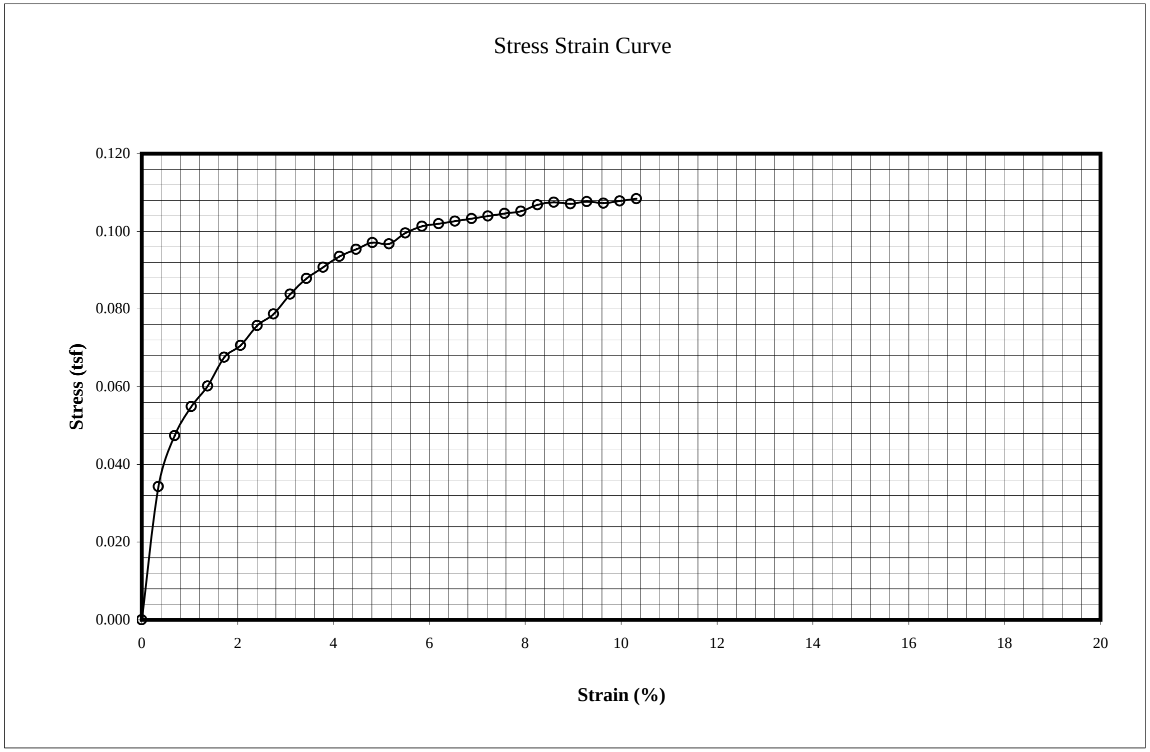
Wet wt. 212.49
Dry at. 136.12
Can wt. 22.07

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.1	0.344	0.034
0.040	4.3	0.688	0.047
0.060	5.0	1.032	0.055
0.080	5.5	1.376	0.060
0.100	6.2	1.720	0.068
0.120	6.5	2.064	0.071
0.140	7.0	2.408	0.076
0.160	7.3	2.752	0.079
0.180	7.8	3.096	0.084
0.200	8.2	3.440	0.088
0.220	8.5	3.784	0.091
0.240	8.8	4.128	0.094
0.260	9.0	4.472	0.095
0.280	9.2	4.816	0.097
0.300	9.2	5.160	0.097
0.320	9.5	5.504	0.100
0.340	9.7	5.848	0.101
0.360	9.8	6.192	0.102
0.380	9.9	6.536	0.103
0.400	10.0	6.880	0.103
0.420	10.1	7.224	0.104
0.440	10.2	7.568	0.105
0.460	10.3	7.912	0.105
0.480	10.5	8.256	0.107
0.500	10.6	8.600	0.107
0.520	10.6	8.944	0.107
0.540	10.7	9.288	0.108
0.560	10.7	9.632	0.107
0.580	10.8	9.976	0.108
0.600	10.9	10.320	0.108



uu17-1-1

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with peat
Type of Failure: Yield @10%
Boring No.: 17-1-1
Depth (ft): 15 .5-16

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 899.1

Area (in^2) = 6.492
Moisture Content (%) = 67.91%
Wet Density (pcf) = 90.8
Dry Density (pcf) = 54.0

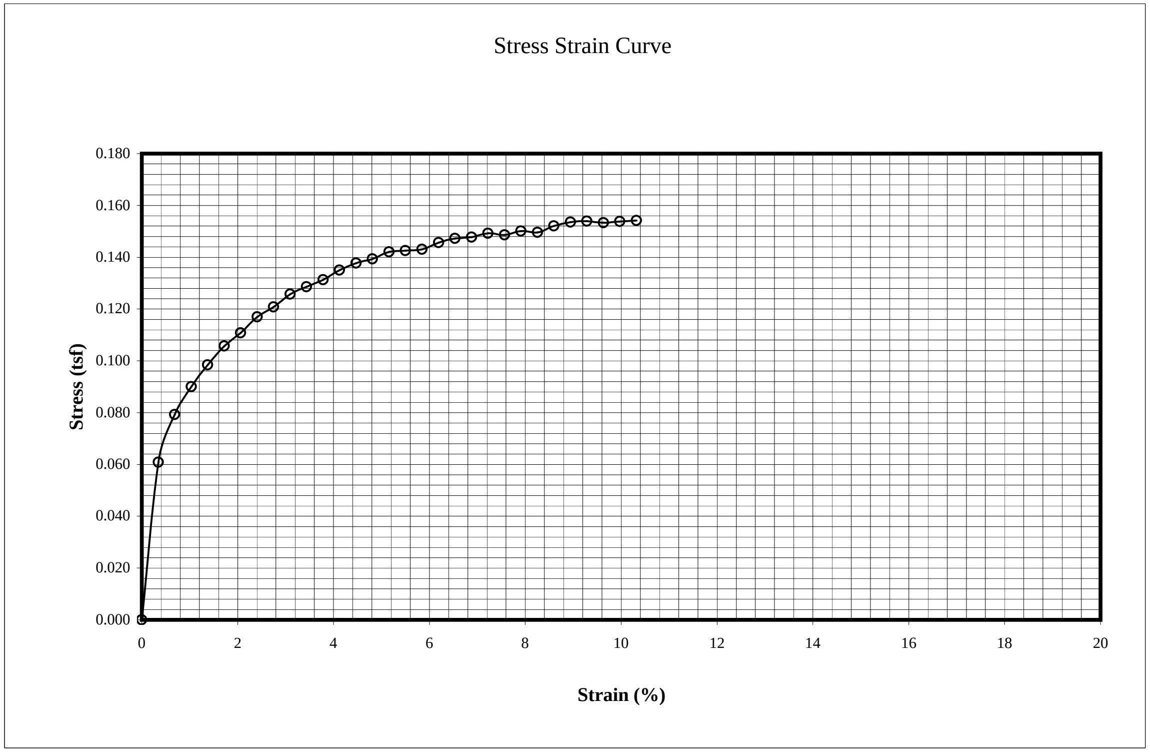
Wet wt. 240.13
Dry at. 154.52
Can wt. 28.46

Test Data:

Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	5.5	0.344	0.061
0.040	7.2	0.688	0.079
0.060	8.2	1.032	0.090
0.080	9.0	1.376	0.098
0.100	9.7	1.720	0.106
0.120	10.2	2.064	0.111
0.140	10.8	2.408	0.117
0.160	11.2	2.752	0.121
0.180	11.7	3.096	0.126
0.200	12.0	3.440	0.129
0.220	12.3	3.784	0.131
0.240	12.7	4.128	0.135
0.260	13.0	4.472	0.138
0.280	13.2	4.816	0.139
0.300	13.5	5.160	0.142
0.320	13.6	5.504	0.143
0.340	13.7	5.848	0.143
0.360	14.0	6.192	0.146
0.380	14.2	6.536	0.147
0.400	14.3	6.880	0.148
0.420	14.5	7.224	0.149
0.440	14.5	7.568	0.149
0.460	14.7	7.912	0.150
0.480	14.7	8.256	0.150
0.500	15.0	8.600	0.152
0.520	15.2	8.944	0.154
0.540	15.3	9.288	0.154
0.560	15.3	9.632	0.153
0.580	15.4	9.976	0.154
0.600	15.5	10.320	0.154



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with organics
Type of Failure: Yield @ 10%
Boring No.: 17-1-2
Depth (ft): 17-19

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 940.3

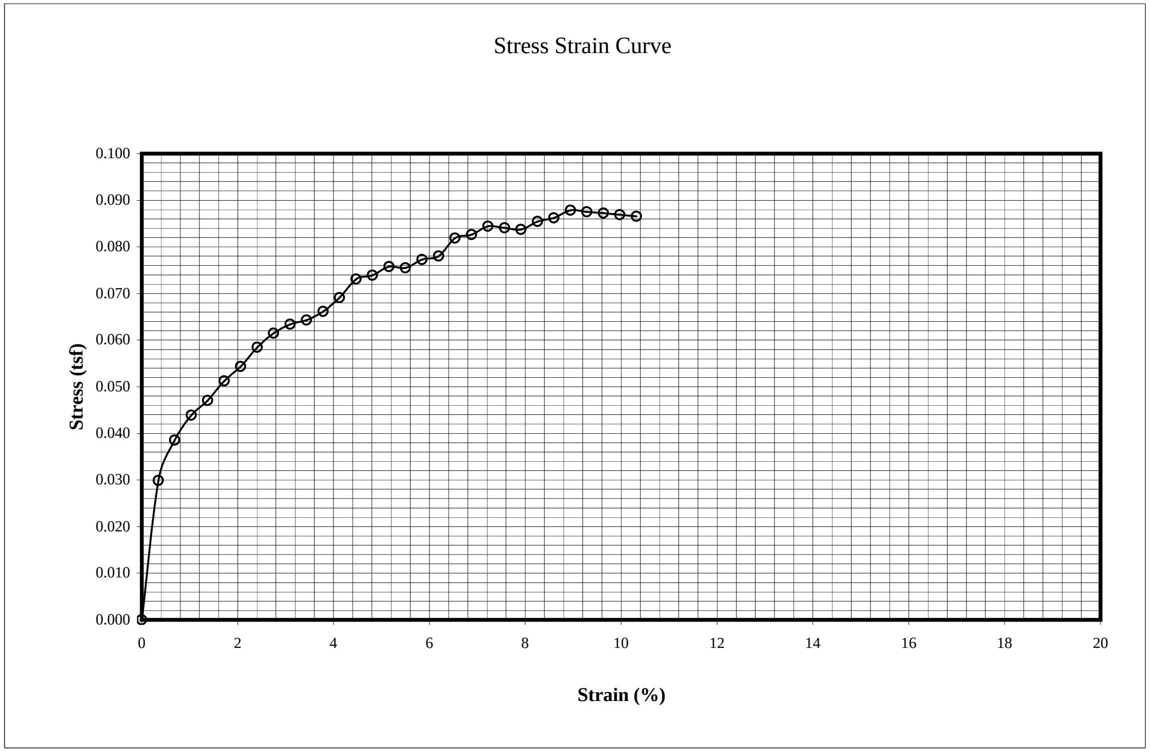
Area (in^2) = 6.492
Moisture Content (%) = 73.71%
Wet Density (pcf) = 94.9
Dry Density (pcf) = 54.6

Wet wt. 116.16
Dry at. 77.49
Can wt. 25.03

Test Data:
Cell Pressure (psi) = 10.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	2.7	0.344	0.030
0.040	3.5	0.688	0.039
0.060	4.0	1.032	0.044
0.080	4.3	1.376	0.047
0.100	4.7	1.720	0.051
0.120	5.0	2.064	0.054
0.140	5.4	2.408	0.058
0.160	5.7	2.752	0.061
0.180	5.9	3.096	0.063
0.200	6.0	3.440	0.064
0.220	6.2	3.784	0.066
0.240	6.5	4.128	0.069
0.260	6.9	4.472	0.073
0.280	7.0	4.816	0.074
0.300	7.2	5.160	0.076
0.320	7.2	5.504	0.075
0.340	7.4	5.848	0.077
0.360	7.5	6.192	0.078
0.380	7.9	6.536	0.082
0.400	8.0	6.880	0.083
0.420	8.2	7.224	0.084
0.440	8.2	7.568	0.084
0.460	8.2	7.912	0.084
0.480	8.4	8.256	0.085
0.500	8.5	8.600	0.086
0.520	8.7	8.944	0.088
0.540	8.7	9.288	0.088
0.560	8.7	9.632	0.087
0.580	8.7	9.976	0.087
0.600	8.7	10.320	0.087



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @10%
Boring No.: 17-1-3
Depth (ft): 22.5-24.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 906.2

Area (in^2) = 6.492
Moisture Content (%) = 92.37%
Wet Density (pcf) = 90.3
Dry Density (pcf) = 46.9

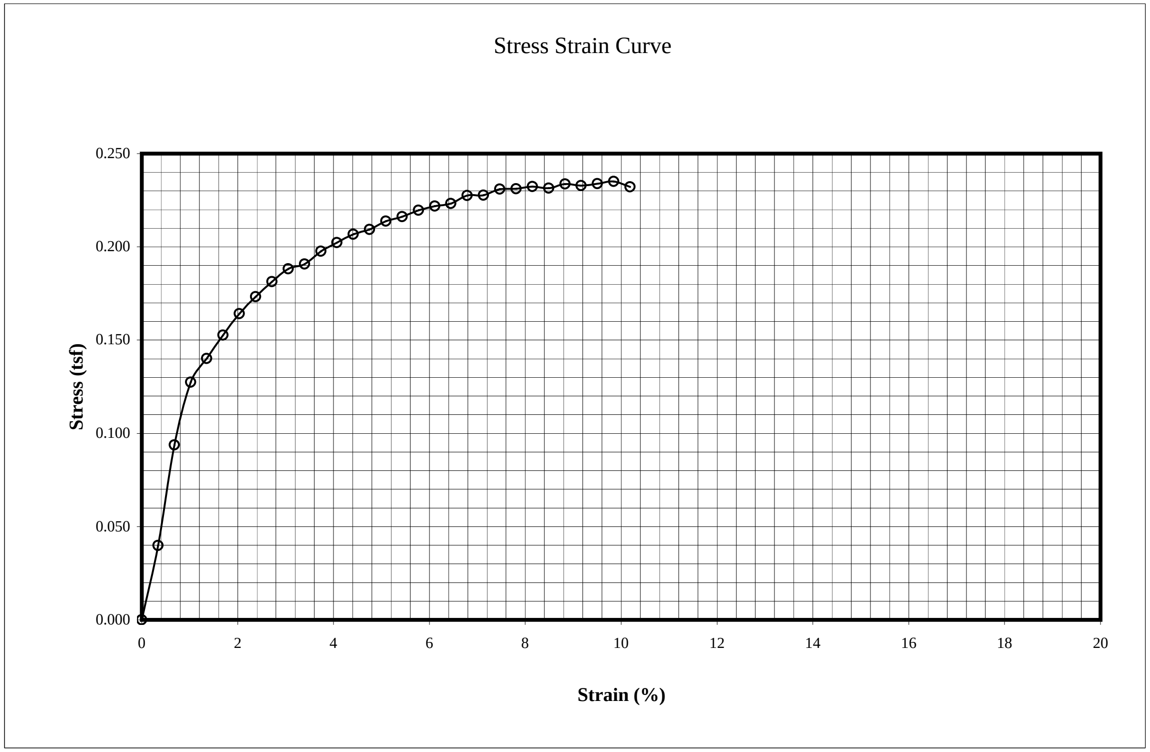
Wet wt. 104.96
Dry at. 66.58
Can wt. 25.03

Test Data:
Cell Pressure (psi) = 13.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.6	0.340	0.040
0.040	8.5	0.679	0.094
0.060	11.6	1.019	0.127
0.080	12.8	1.358	0.140
0.100	14.0	1.698	0.153
0.120	15.1	2.037	0.164
0.140	16.0	2.377	0.173
0.160	16.8	2.716	0.181
0.180	17.5	3.056	0.188
0.200	17.8	3.396	0.191
0.220	18.5	3.735	0.198
0.240	19.0	4.075	0.202
0.260	19.5	4.414	0.207
0.280	19.8	4.754	0.209
0.300	20.3	5.093	0.214
0.320	20.6	5.433	0.216
0.340	21.0	5.772	0.220
0.360	21.3	6.112	0.222
0.380	21.5	6.452	0.223
0.400	22.0	6.791	0.228
0.420	22.1	7.131	0.228
0.440	22.5	7.470	0.231
0.460	22.6	7.810	0.231
0.480	22.8	8.149	0.232
0.500	22.8	8.489	0.231
0.520	23.1	8.829	0.234
0.540	23.1	9.168	0.233
0.560	23.3	9.508	0.234
0.580	23.5	9.847	0.235
0.600	23.3	10.187	0.232



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Firm gray fine sand with clay streaks
Type of Failure: Yield @10%
Boring No.: 17-1-4
Depth (ft): 26.5-28.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1132.5

Area (in^2) = 6.492
Moisture Content (%) = 30.20%
Wet Density (pcf) = 112.8
Dry Density (pcf) = 86.7

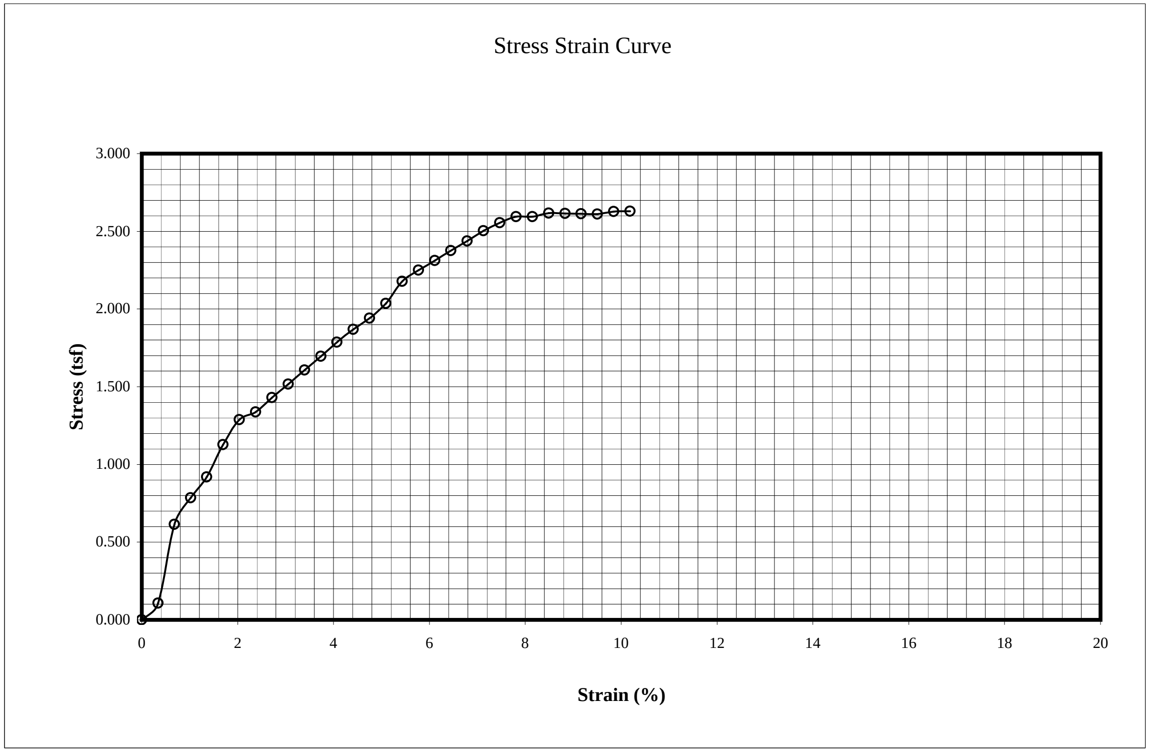
Wet wt. 200.08
Dry at. 160.4
Can wt. 28.99

Test Data:
Cell Pressure (psi) = 15.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	9.6	0.340	0.106
0.040	55.7	0.679	0.614
0.060	71.5	1.019	0.785
0.080	84.0	1.358	0.919
0.100	103.4	1.698	1.128
0.120	118.4	2.037	1.287
0.140	123.5	2.377	1.338
0.160	132.4	2.716	1.429
0.180	141.0	3.056	1.517
0.200	149.9	3.396	1.607
0.220	158.7	3.735	1.695
0.240	167.9	4.075	1.787
0.260	176.2	4.414	1.869
0.280	183.7	4.754	1.941
0.300	193.4	5.093	2.036
0.320	207.5	5.433	2.177
0.340	215.2	5.772	2.250
0.360	221.9	6.112	2.312
0.380	228.9	6.452	2.376
0.400	235.7	6.791	2.438
0.420	242.9	7.131	2.503
0.440	248.9	7.470	2.555
0.460	253.7	7.810	2.595
0.480	254.5	8.149	2.594
0.500	257.8	8.489	2.617
0.520	258.4	8.829	2.614
0.540	259.3	9.168	2.613
0.560	260.1	9.508	2.611
0.580	262.6	9.847	2.627
0.600	263.9	10.187	2.630



uu17-1-4

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray silty clay w/wood & shell fragments
Boring No.: 17-3-3
Depth (ft): 9-10

Type of Failure: Yield @10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1111.1

Area (in^2) = 6.492
Moisture Content (%) = 38.06%
Wet Density (pcf) = 112.1
Dry Density (pcf) = 81.2

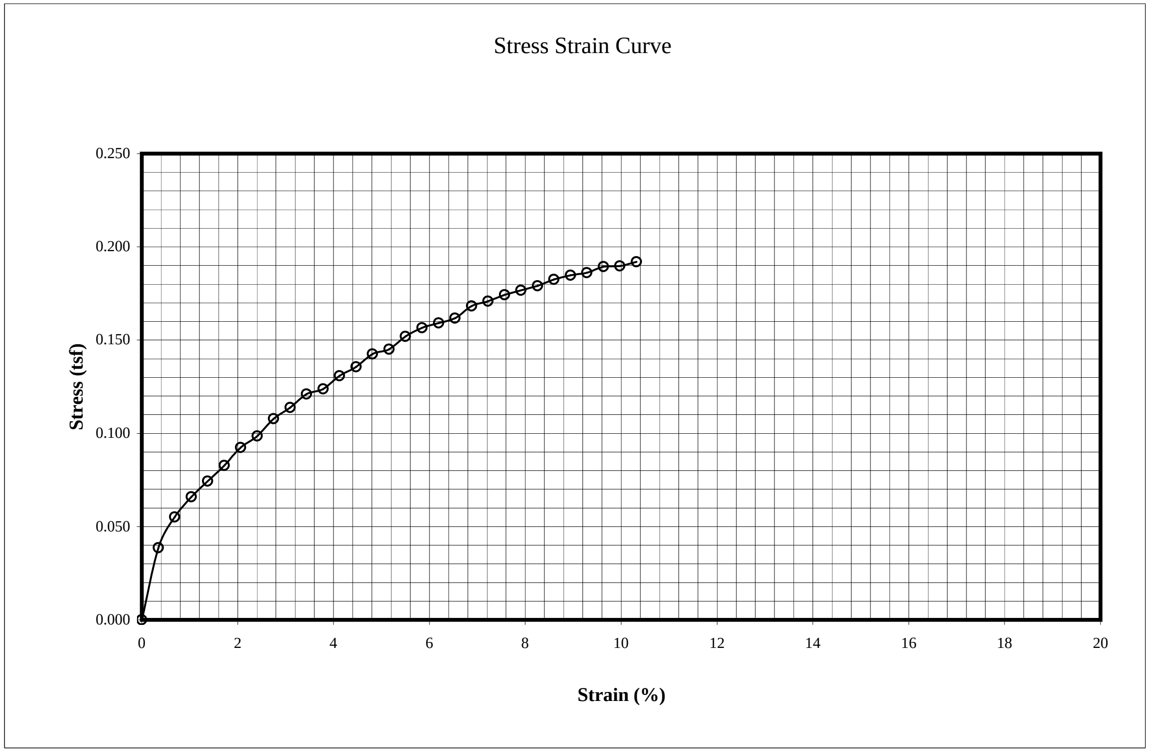
Wet wt. 178.58
Dry at. 134.4
Can wt. 18.32

Test Data:

Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.5	0.344	0.039
0.040	5.0	0.688	0.055
0.060	6.0	1.032	0.066
0.080	6.8	1.376	0.074
0.100	7.6	1.720	0.083
0.120	8.5	2.064	0.092
0.140	9.1	2.408	0.098
0.160	10.0	2.752	0.108
0.180	10.6	3.096	0.114
0.200	11.3	3.440	0.121
0.220	11.6	3.784	0.124
0.240	12.3	4.128	0.131
0.260	12.8	4.472	0.136
0.280	13.5	4.816	0.143
0.300	13.8	5.160	0.145
0.320	14.5	5.504	0.152
0.340	15.0	5.848	0.157
0.360	15.3	6.192	0.159
0.380	15.6	6.536	0.162
0.400	16.3	6.880	0.168
0.420	16.6	7.224	0.171
0.440	17.0	7.568	0.174
0.460	17.3	7.912	0.177
0.480	17.6	8.256	0.179
0.500	18.0	8.600	0.182
0.520	18.3	8.944	0.185
0.540	18.5	9.288	0.186
0.560	18.9	9.632	0.189
0.580	19.0	9.976	0.190
0.600	19.3	10.320	0.192



uu17-3-3

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft dark gray silty clay w/wood & shell fragments
Type of Failure: Yield @10%
Boring No.: 17-3-3
Depth (ft): 10-11

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1083.5

Area (in^2) = 6.492
Moisture Content (%) = 41.80%
Wet Density (pcf) = 109.4
Dry Density (pcf) = 77.1

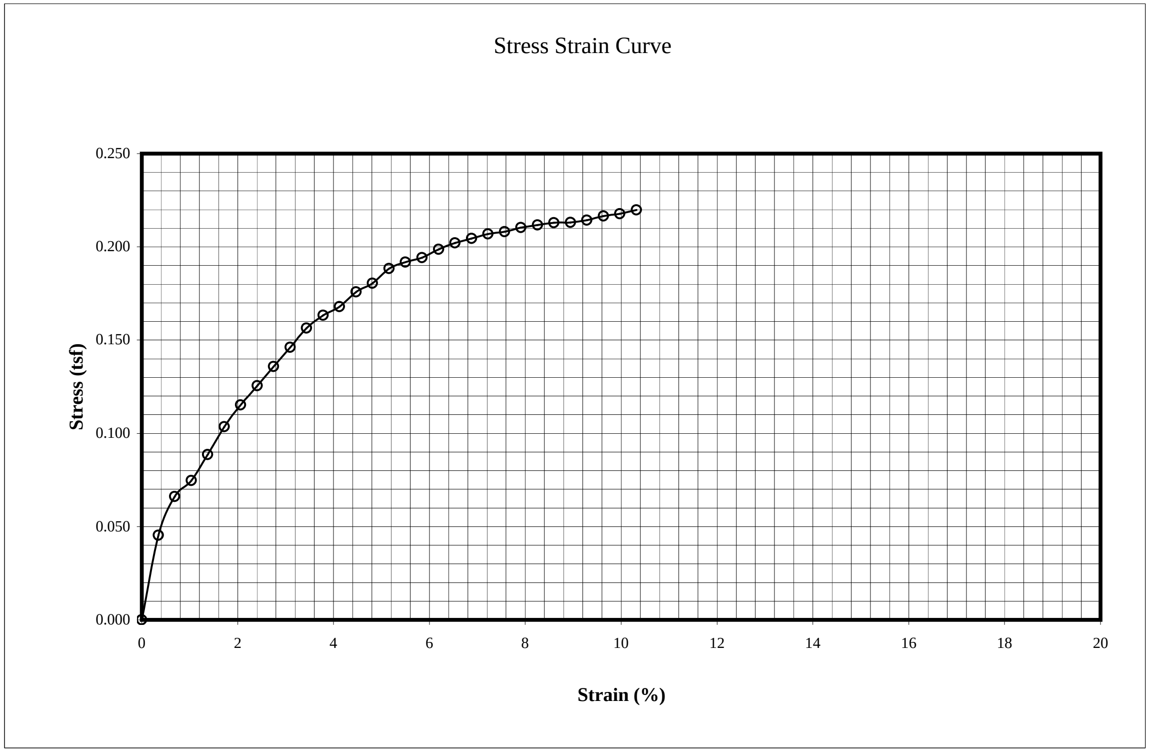
Wet wt. 191.49
Dry at. 141.25
Can wt. 21.06

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	4.1	0.344	0.045
0.040	6.0	0.688	0.066
0.060	6.8	1.032	0.075
0.080	8.1	1.376	0.089
0.100	9.5	1.720	0.104
0.120	10.6	2.064	0.115
0.140	11.6	2.408	0.126
0.160	12.6	2.752	0.136
0.180	13.6	3.096	0.146
0.200	14.6	3.440	0.156
0.220	15.3	3.784	0.163
0.240	15.8	4.128	0.168
0.260	16.6	4.472	0.176
0.280	17.1	4.816	0.181
0.300	17.9	5.160	0.188
0.320	18.3	5.504	0.192
0.340	18.6	5.848	0.194
0.360	19.1	6.192	0.199
0.380	19.5	6.536	0.202
0.400	19.8	6.880	0.204
0.420	20.1	7.224	0.207
0.440	20.3	7.568	0.208
0.460	20.6	7.912	0.210
0.480	20.8	8.256	0.212
0.500	21.0	8.600	0.213
0.520	21.1	8.944	0.213
0.540	21.3	9.288	0.214
0.560	21.6	9.632	0.216
0.580	21.8	9.976	0.218
0.600	22.1	10.320	0.220

Stress Strain Curve



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with silty clay layers
Type of Failure:
Boring No.: 17-3-4
Depth (ft): 14-16

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1036.3

Area (in^2) = 6.492
Moisture Content (%) = 50.88%
Wet Density (pcf) = 103.2
Dry Density (pcf) = 68.4

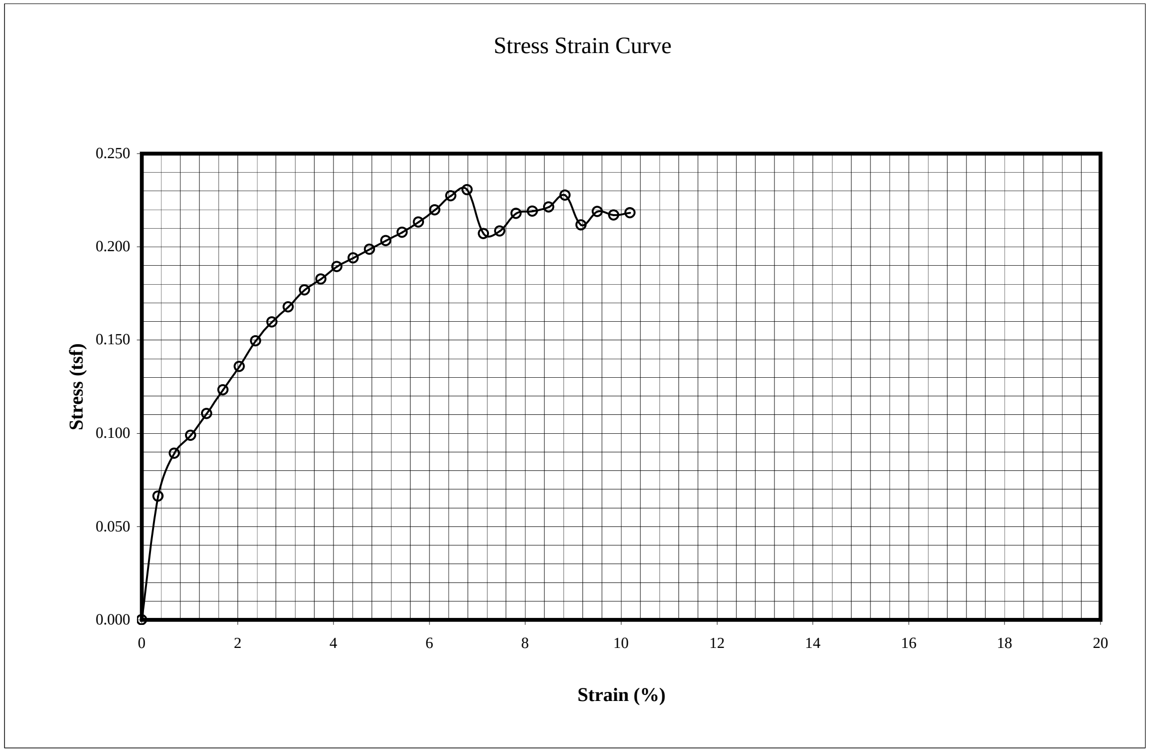
Wet wt. 112.6
Dry at. 81.68
Can wt. 20.91

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	6.0	0.340	0.066
0.040	8.1	0.679	0.089
0.060	9.0	1.019	0.099
0.080	10.1	1.358	0.111
0.100	11.3	1.698	0.123
0.120	12.5	2.037	0.136
0.140	13.8	2.377	0.149
0.160	14.8	2.716	0.160
0.180	15.6	3.056	0.168
0.200	16.5	3.396	0.177
0.220	17.1	3.735	0.183
0.240	17.8	4.075	0.189
0.260	18.3	4.414	0.194
0.280	18.8	4.754	0.199
0.300	19.3	5.093	0.203
0.320	19.8	5.433	0.208
0.340	20.4	5.772	0.213
0.360	21.1	6.112	0.220
0.380	21.9	6.452	0.227
0.400	22.3	6.791	0.231
0.420	20.1	7.131	0.207
0.440	20.3	7.470	0.208
0.460	21.3	7.810	0.218
0.480	21.5	8.149	0.219
0.500	21.8	8.489	0.221
0.520	22.5	8.829	0.228
0.540	21.0	9.168	0.212
0.560	21.8	9.508	0.219
0.580	21.7	9.847	0.217
0.600	21.9	10.187	0.218



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @ 10%
Boring No.: 17-3-5
Depth (ft): 20-22

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 960.6

Area (in^2) = 6.492
Moisture Content (%) = 67.79%
Wet Density (pcf) = 95.7
Dry Density (pcf) = 57.0

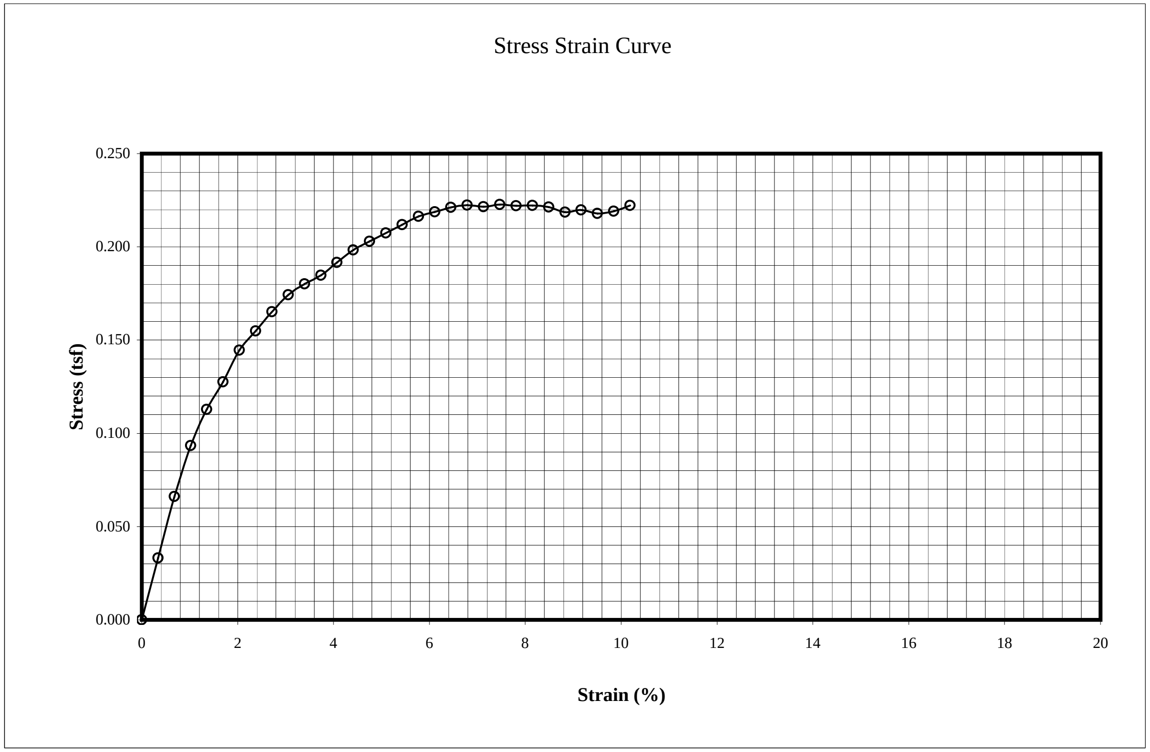
Wet wt. 146.08
Dry at. 96.04
Can wt. 22.22

Test Data:
Cell Pressure (psi) = 12.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.0	0.340	0.033
0.040	6.0	0.679	0.066
0.060	8.5	1.019	0.093
0.080	10.3	1.358	0.113
0.100	11.7	1.698	0.128
0.120	13.3	2.037	0.145
0.140	14.3	2.377	0.155
0.160	15.3	2.716	0.165
0.180	16.2	3.056	0.174
0.200	16.8	3.396	0.180
0.220	17.3	3.735	0.185
0.240	18.0	4.075	0.192
0.260	18.7	4.414	0.198
0.280	19.2	4.754	0.203
0.300	19.7	5.093	0.207
0.320	20.2	5.433	0.212
0.340	20.7	5.772	0.216
0.360	21.0	6.112	0.219
0.380	21.3	6.452	0.221
0.400	21.5	6.791	0.222
0.420	21.5	7.131	0.222
0.440	21.7	7.470	0.223
0.460	21.7	7.810	0.222
0.480	21.8	8.149	0.222
0.500	21.8	8.489	0.221
0.520	21.6	8.829	0.218
0.540	21.8	9.168	0.220
0.560	21.7	9.508	0.218
0.580	21.9	9.847	0.219
0.600	22.3	10.187	0.222



uu17-3-5

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray very sandy clay with shell
Type of Failure: Yield @ 10%
Boring No.: 17-3-6
Depth (ft): 26-28

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1060.3

Area (in^2) = 6.492
Moisture Content (%) = 26.88%
Wet Density (pcf) = 105.6
Dry Density (pcf) = 83.3

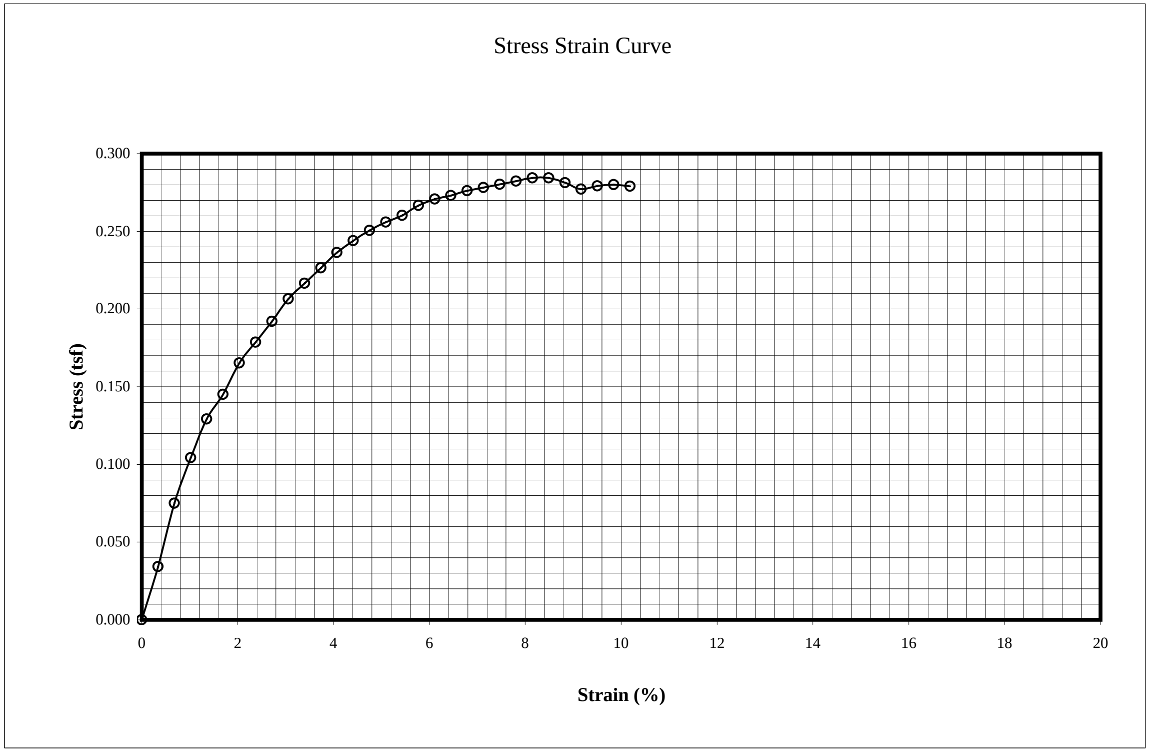
Wet wt. 153.77
Dry at. 126.81
Can wt. 26.52

Test Data:
Cell Pressure (psi) = 15.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.1	0.340	0.034
0.040	6.8	0.679	0.075
0.060	9.5	1.019	0.104
0.080	11.8	1.358	0.129
0.100	13.3	1.698	0.145
0.120	15.2	2.037	0.165
0.140	16.5	2.377	0.179
0.160	17.8	2.716	0.192
0.180	19.2	3.056	0.207
0.200	20.2	3.396	0.217
0.220	21.2	3.735	0.226
0.240	22.2	4.075	0.236
0.260	23.0	4.414	0.244
0.280	23.7	4.754	0.250
0.300	24.3	5.093	0.256
0.320	24.8	5.433	0.260
0.340	25.5	5.772	0.267
0.360	26.0	6.112	0.271
0.380	26.3	6.452	0.273
0.400	26.7	6.791	0.276
0.420	27.0	7.131	0.278
0.440	27.3	7.470	0.280
0.460	27.6	7.810	0.282
0.480	27.9	8.149	0.284
0.500	28.0	8.489	0.284
0.520	27.8	8.829	0.281
0.540	27.5	9.168	0.277
0.560	27.8	9.508	0.279
0.580	28.0	9.847	0.280
0.600	28.0	10.187	0.279


Stress Strain Curve

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff tan and brown clay with silt
Type of Failure: Vertical @ 7.1%
Boring No.: 17-4-1
Depth (ft): 3-5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1253.1

Area (in^2) = 6.492
Moisture Content (%) = 22.25%
Wet Density (pcf) = 124.8
Dry Density (pcf) = 102.1

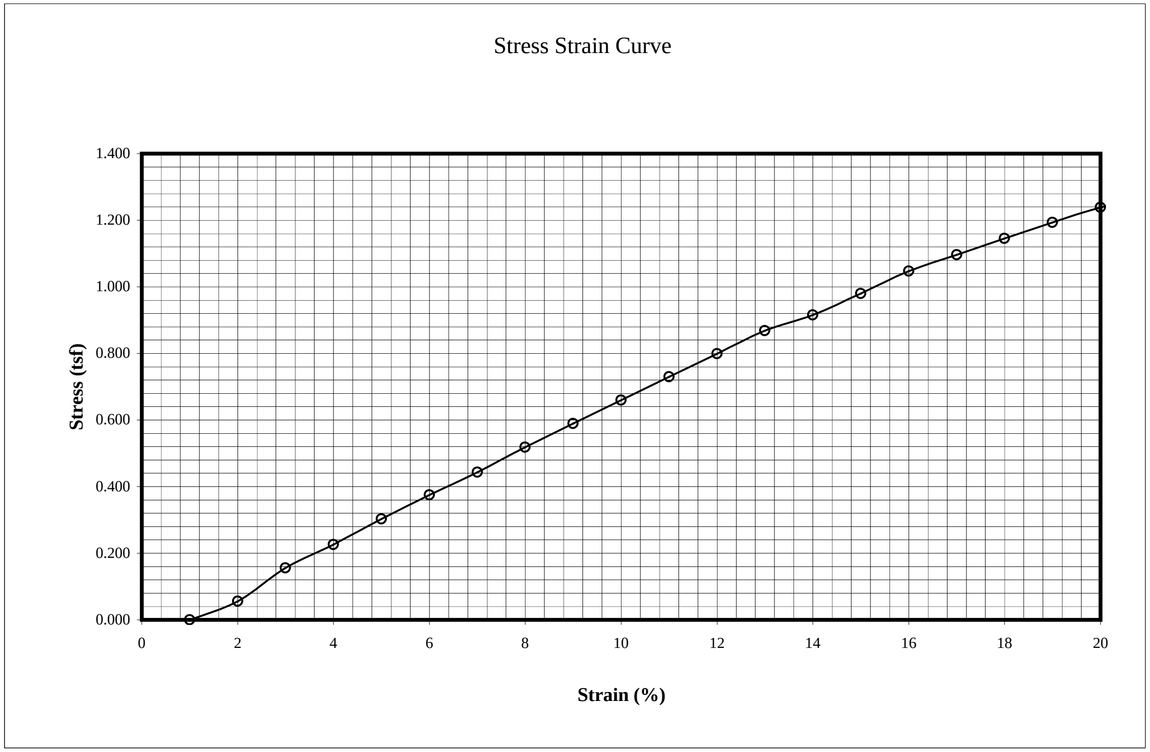
Wet wt. 194.78
Dry at. 164.15
Can wt. 26.47

Test Data:
Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	15	0.340	0.056
0.040	42	0.679	0.156
0.060	61	1.019	0.226
0.080	82	1.358	0.302
0.100	102	1.698	0.375
0.120	121	2.037	0.443
0.140	142	2.377	0.518
0.160	162	2.716	0.589
0.180	182	3.056	0.660
0.200	202	3.396	0.730
0.220	222	3.735	0.799
0.240	242	4.075	0.868
0.260	256	4.414	0.915
0.280	275	4.754	0.979
0.300	295	5.093	1.047
0.320	310	5.433	1.096
0.340	325	5.772	1.145
0.360	340	6.112	1.194
0.380	354	6.452	1.238
0.400	364	6.791	1.269
0.420	372	7.131	1.292
0.440	372	7.470	1.287
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Med gray clay w/silt & fine sand alt layers & traces of organic matter
Type of Failure: Bulge @ 9%
Boring No.: 17-4-2
Depth (ft): 9-10

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1091.2

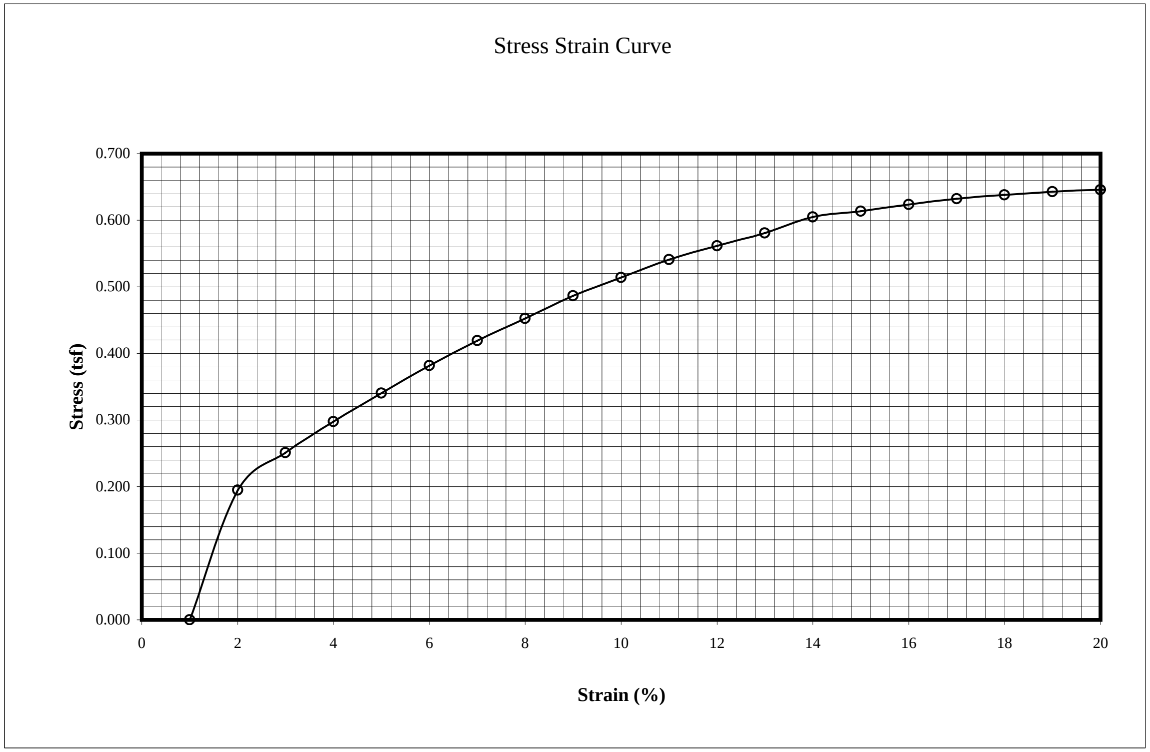
Area (in^2) = 6.492
Moisture Content (%) = 35.17%
Wet Density (pcf) = 110.1
Dry Density (pcf) = 81.5

Wet wt. 147.97
Dry at. 115.26
Can wt. 22.25

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	17.6	0.344	0.195
0.040	22.8	0.688	0.251
0.060	27.1	1.032	0.297
0.080	31.1	1.376	0.340
0.100	35.0	1.720	0.382
0.120	38.6	2.064	0.419
0.140	41.8	2.408	0.452
0.160	45.1	2.752	0.486
0.180	47.8	3.096	0.514
0.200	50.5	3.440	0.541
0.220	52.6	3.784	0.561
0.240	54.6	4.128	0.581
0.260	57.1	4.472	0.605
0.280	58.1	4.816	0.613
0.300	59.3	5.160	0.624
0.320	60.3	5.504	0.632
0.340	61.1	5.848	0.638
0.360	61.8	6.192	0.643
0.380	62.3	6.536	0.646
0.400	62.5	6.880	0.645
0.420	62.5	7.224	0.643
0.440	62.0	7.568	0.636
0.460	61.0	7.912	0.623
0.480	60.3	8.256	0.614
0.500	59.5	8.600	0.603
0.520			
0.540			
0.560			
0.580			
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay with silt seams and wood
Type of Failure: Yield @ 10%
Boring No.: 17-4-2
Depth (ft): 10-11

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1120.7

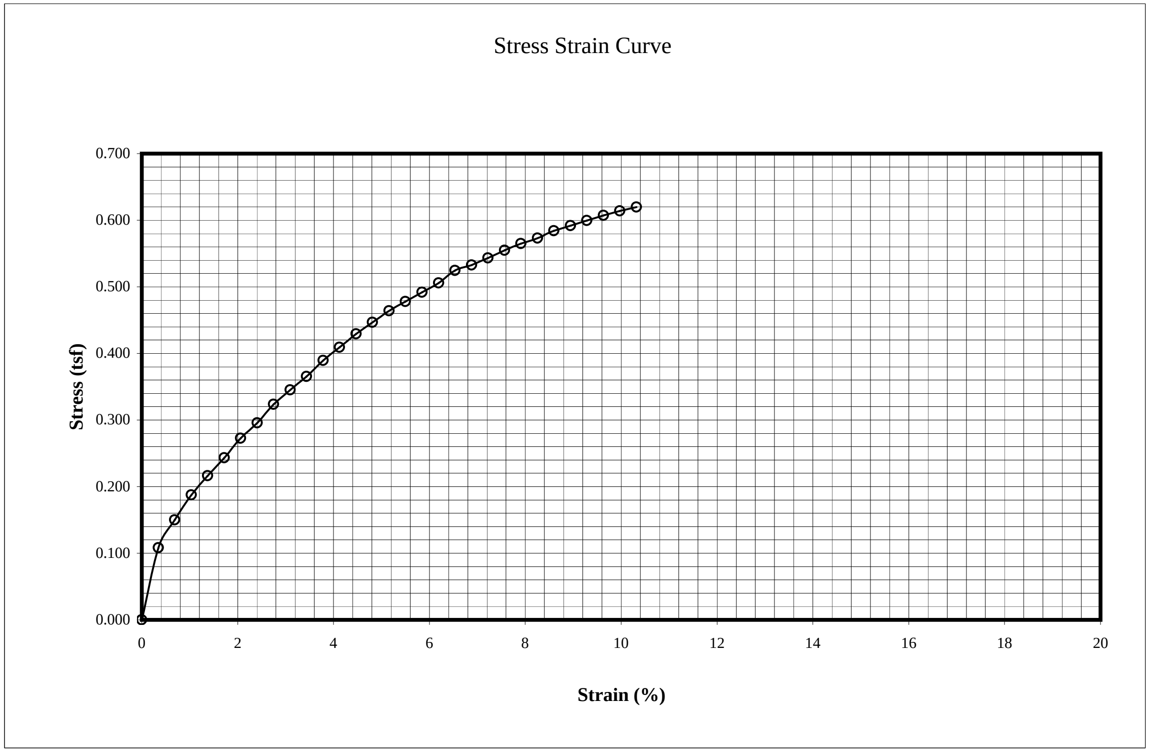
Area (in^2) = 6.492
Moisture Content (%) = 34.12%
Wet Density (pcf) = 113.1
Dry Density (pcf) = 84.3

Wet wt. 182.31
Dry at. 141.25
Can wt. 20.9

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	9.8	0.344	0.108
0.040	13.6	0.688	0.150
0.060	17.1	1.032	0.188
0.080	19.8	1.376	0.217
0.100	22.3	1.720	0.243
0.120	25.1	2.064	0.273
0.140	27.3	2.408	0.295
0.160	30.0	2.752	0.324
0.180	32.1	3.096	0.345
0.200	34.1	3.440	0.365
0.220	36.5	3.784	0.389
0.240	38.5	4.128	0.409
0.260	40.5	4.472	0.429
0.280	42.3	4.816	0.447
0.300	44.1	5.160	0.464
0.320	45.6	5.504	0.478
0.340	47.1	5.848	0.492
0.360	48.6	6.192	0.506
0.380	50.6	6.536	0.525
0.400	51.6	6.880	0.533
0.420	52.8	7.224	0.543
0.440	54.1	7.568	0.555
0.460	55.3	7.912	0.565
0.480	56.3	8.256	0.573
0.500	57.6	8.600	0.584
0.520	58.6	8.944	0.592
0.540	59.6	9.288	0.600
0.560	60.6	9.632	0.607
0.580	61.5	9.976	0.614
0.600	62.3	10.320	0.620



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray and brown clay with peat and organics
Type of Failure: Yield @ 10%
Boring No.: 17-4-3
Depth (ft): 11.5-13.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 885.7

Area (in^2) = 6.492
Moisture Content (%) = 128.43%
Wet Density (pcf) = 88.2
Dry Density (pcf) = 38.6

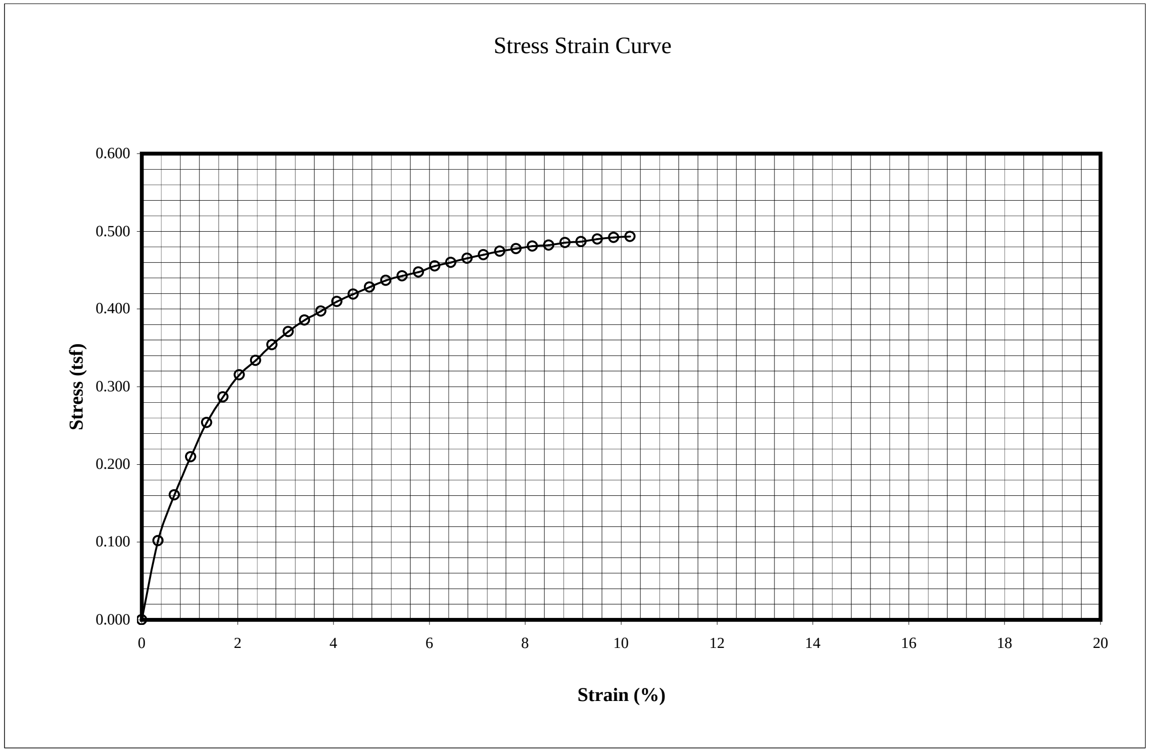
Wet wt. 162.94
Dry at. 83.74
Can wt. 22.07

Test Data:
Cell Pressure (psi) = 7.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	9.2	0.340	0.102
0.040	14.6	0.679	0.161
0.060	19.1	1.019	0.210
0.080	23.2	1.358	0.254
0.100	26.3	1.698	0.287
0.120	29.0	2.037	0.315
0.140	30.8	2.377	0.334
0.160	32.8	2.716	0.354
0.180	34.5	3.056	0.371
0.200	36.0	3.396	0.386
0.220	37.2	3.735	0.397
0.240	38.5	4.075	0.410
0.260	39.5	4.414	0.419
0.280	40.5	4.754	0.428
0.300	41.5	5.093	0.437
0.320	42.2	5.433	0.443
0.340	42.8	5.772	0.447
0.360	43.7	6.112	0.455
0.380	44.3	6.452	0.460
0.400	45.0	6.791	0.465
0.420	45.6	7.131	0.470
0.440	46.2	7.470	0.474
0.460	46.7	7.810	0.478
0.480	47.2	8.149	0.481
0.500	47.5	8.489	0.482
0.520	48.0	8.829	0.486
0.540	48.3	9.168	0.487
0.560	48.8	9.508	0.490
0.580	49.2	9.847	0.492
0.600	49.5	10.187	0.493



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray organic clay with peat
Type of Failure:
Boring No.: 17-4-4
Depth (ft): 14-15

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 830.0

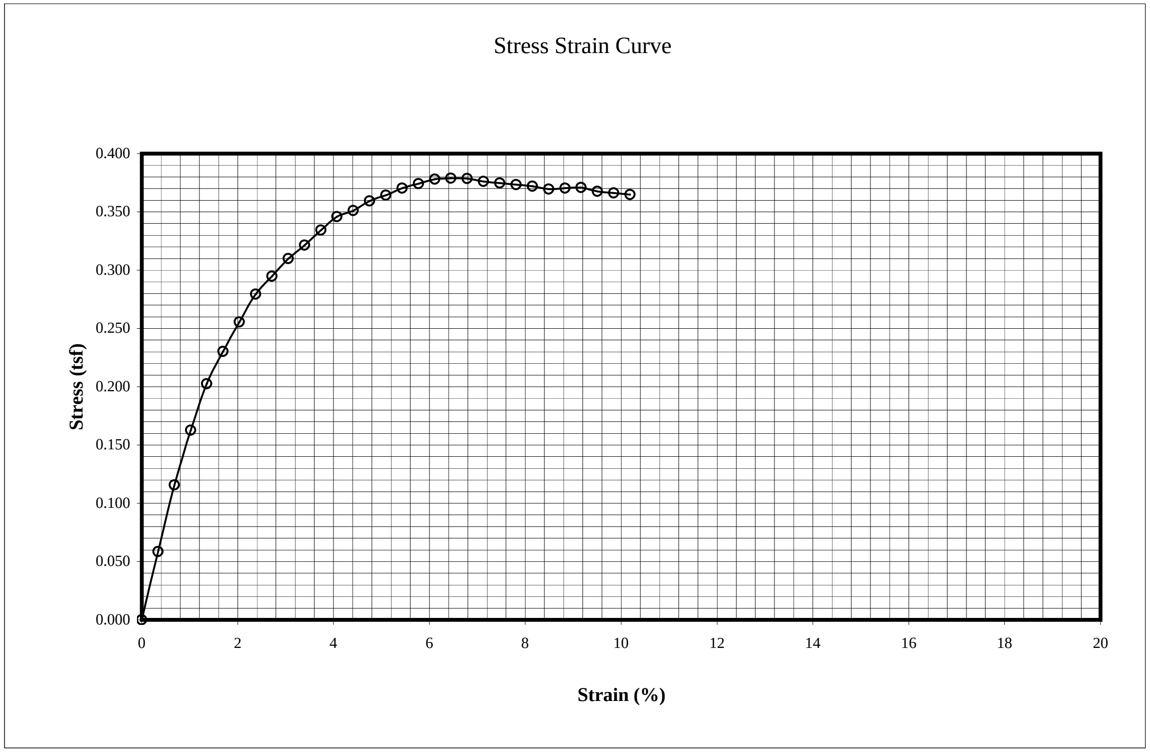
Area (in^2) = 6.492
Moisture Content (%) = 261.81%
Wet Density (pcf) = 82.7
Dry Density (pcf) = 22.9

Wet wt. 126.99
Dry at. 54.52
Can wt. 26.84

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	5.3	0.340	0.059
0.040	10.5	0.679	0.116
0.060	14.8	1.019	0.163
0.080	18.5	1.358	0.202
0.100	21.1	1.698	0.230
0.120	23.5	2.037	0.255
0.140	25.8	2.377	0.279
0.160	27.3	2.716	0.295
0.180	28.8	3.056	0.310
0.200	30.0	3.396	0.322
0.220	31.3	3.735	0.334
0.240	32.5	4.075	0.346
0.260	33.1	4.414	0.351
0.280	34.0	4.754	0.359
0.300	34.6	5.093	0.364
0.320	35.3	5.433	0.370
0.340	35.8	5.772	0.374
0.360	36.3	6.112	0.378
0.380	36.5	6.452	0.379
0.400	36.6	6.791	0.379
0.420	36.5	7.131	0.376
0.440	36.5	7.470	0.375
0.460	36.5	7.810	0.373
0.480	36.5	8.149	0.372
0.500	36.4	8.489	0.370
0.520	36.6	8.829	0.370
0.540	36.8	9.168	0.371
0.560	36.6	9.508	0.367
0.580	36.6	9.847	0.366
0.600	36.6	10.187	0.365



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium dark gray organic clay with peat
Type of Failure:
Boring No.: 17-4-4
Depth (ft): 15-16

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 736.1

Area (in^2) = 6.492
Moisture Content (%) = 80.25%
Wet Density (pcf) = 73.3
Dry Density (pcf) = 40.7

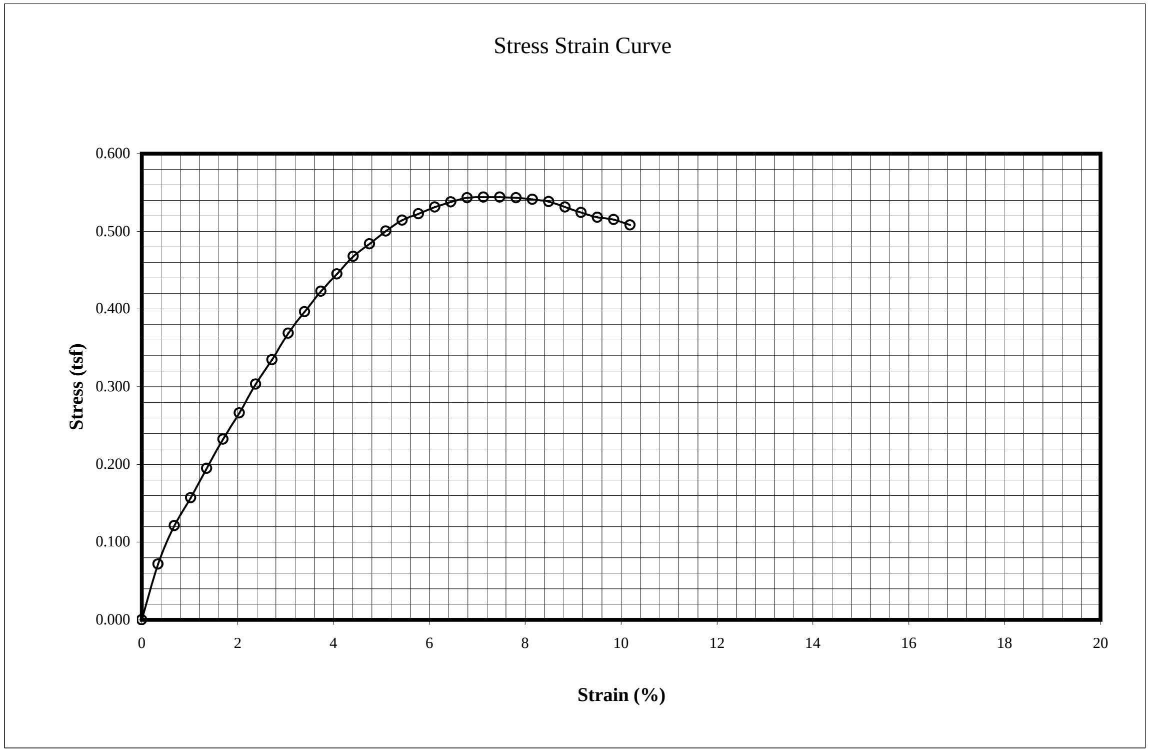
Wet wt. 147.46
Dry at. 91.67
Can wt. 22.15

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	6.5	0.340	0.072
0.040	11.0	0.679	0.121
0.060	14.3	1.019	0.157
0.080	17.8	1.358	0.195
0.100	21.3	1.698	0.232
0.120	24.5	2.037	0.266
0.140	28.0	2.377	0.303
0.160	31.0	2.716	0.335
0.180	34.3	3.056	0.369
0.200	37.0	3.396	0.397
0.220	39.6	3.735	0.423
0.240	41.8	4.075	0.445
0.260	44.1	4.414	0.468
0.280	45.8	4.754	0.484
0.300	47.5	5.093	0.500
0.320	49.0	5.433	0.514
0.340	50.0	5.772	0.523
0.360	51.0	6.112	0.531
0.380	51.8	6.452	0.538
0.400	52.5	6.791	0.543
0.420	52.8	7.131	0.544
0.440	53.0	7.470	0.544
0.460	53.1	7.810	0.543
0.480	53.1	8.149	0.541
0.500	53.0	8.489	0.538
0.520	52.5	8.829	0.531
0.540	52.0	9.168	0.524
0.560	51.6	9.508	0.518
0.580	51.5	9.847	0.515
0.600	51.0	10.187	0.508



uu17-4-4 (2)

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Boring No.: 17-4-7
Depth (ft): 21.5-22.5

Type of Failure: Yield @ 10%

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 942.1

Area (in^2) = 6.492
Moisture Content (%) = 77.95%
Wet Density (pcf) = 95.1
Dry Density (pcf) = 53.4

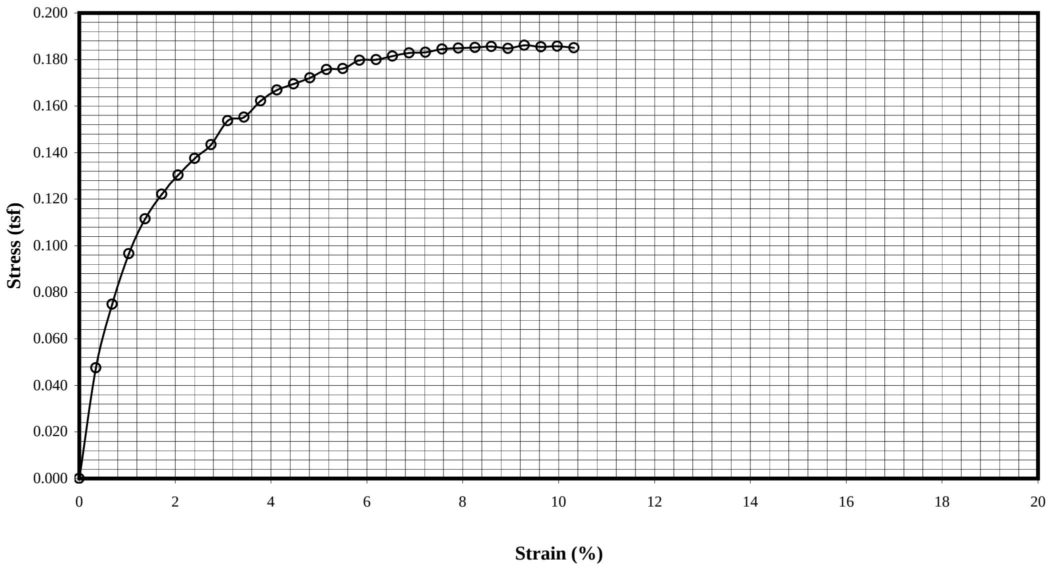
Wet wt. 146.82
Dry at. 92.09
Can wt. 21.88

Test Data:
Cell Pressure (psi) = 14.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	4.3	0.344	0.048
0.040	6.8	0.688	0.075
0.060	8.8	1.032	0.097
0.080	10.2	1.376	0.112
0.100	11.2	1.720	0.122
0.120	12.0	2.064	0.130
0.140	12.7	2.408	0.137
0.160	13.3	2.752	0.143
0.180	14.3	3.096	0.154
0.200	14.5	3.440	0.155
0.220	15.2	3.784	0.162
0.240	15.7	4.128	0.167
0.260	16.0	4.472	0.170
0.280	16.3	4.816	0.172
0.300	16.7	5.160	0.176
0.320	16.8	5.504	0.176
0.340	17.2	5.848	0.180
0.360	17.3	6.192	0.180
0.380	17.5	6.536	0.181
0.400	17.7	6.880	0.183
0.420	17.8	7.224	0.183
0.440	18.0	7.568	0.185
0.460	18.1	7.912	0.185
0.480	18.2	8.256	0.185
0.500	18.3	8.600	0.186
0.520	18.3	8.944	0.185
0.540	18.5	9.288	0.186
0.560	18.5	9.632	0.185
0.580	18.6	9.976	0.186
0.600	18.6	10.320	0.185

Stress Strain Curve



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray silty sandy clay (alt. Layers)
Type of Failure: Yield @ 10%
Boring No.: 17-4-7
Depth (ft): 22.5-23.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1131.0

Area (in^2) = 6.492
Moisture Content (%) = 46.61%
Wet Density (pcf) = 114.2
Dry Density (pcf) = 77.9

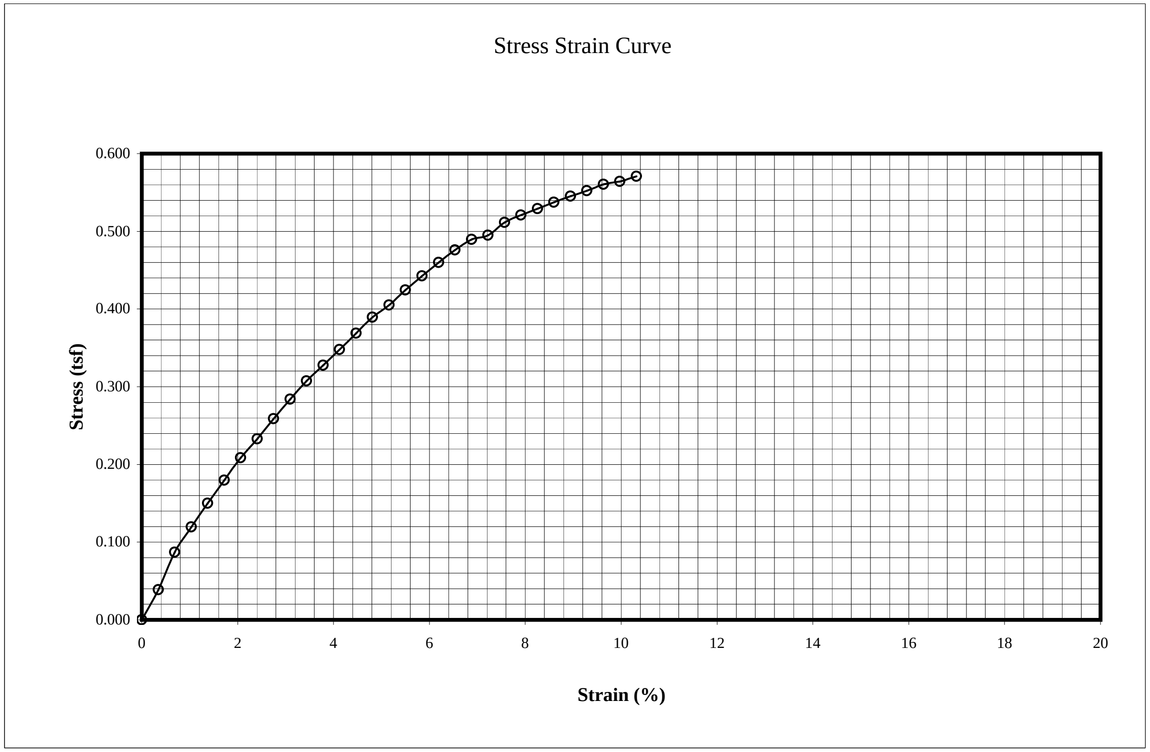
Wet wt. 204.42
Dry at. 146.12
Can wt. 21.05

Test Data:
Cell Pressure (psi) = 14.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.5	0.344	0.039
0.040	7.9	0.688	0.087
0.060	10.9	1.032	0.120
0.080	13.7	1.376	0.150
0.100	16.5	1.720	0.180
0.120	19.2	2.064	0.209
0.140	21.5	2.408	0.233
0.160	24.0	2.752	0.259
0.180	26.4	3.096	0.284
0.200	28.7	3.440	0.307
0.220	30.7	3.784	0.328
0.240	32.7	4.128	0.348
0.260	34.8	4.472	0.369
0.280	36.9	4.816	0.390
0.300	38.5	5.160	0.405
0.320	40.5	5.504	0.424
0.340	42.4	5.848	0.443
0.360	44.2	6.192	0.460
0.380	45.9	6.536	0.476
0.400	47.4	6.880	0.490
0.420	48.1	7.224	0.495
0.440	49.9	7.568	0.512
0.460	51.0	7.912	0.521
0.480	52.0	8.256	0.529
0.500	53.0	8.600	0.537
0.520	54.0	8.944	0.545
0.540	54.9	9.288	0.552
0.560	55.9	9.632	0.560
0.580	56.5	9.976	0.564
0.600	57.4	10.320	0.571



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/alt. Layers of silty fine sand
Boring No.: 17-4-8
Depth (ft): 25-27

Type of Failure: Yield @ 10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 981.4

Area (in^2) = 6.492
Moisture Content (%) = 65.80%
Wet Density (pcf) = 99.1
Dry Density (pcf) = 59.7

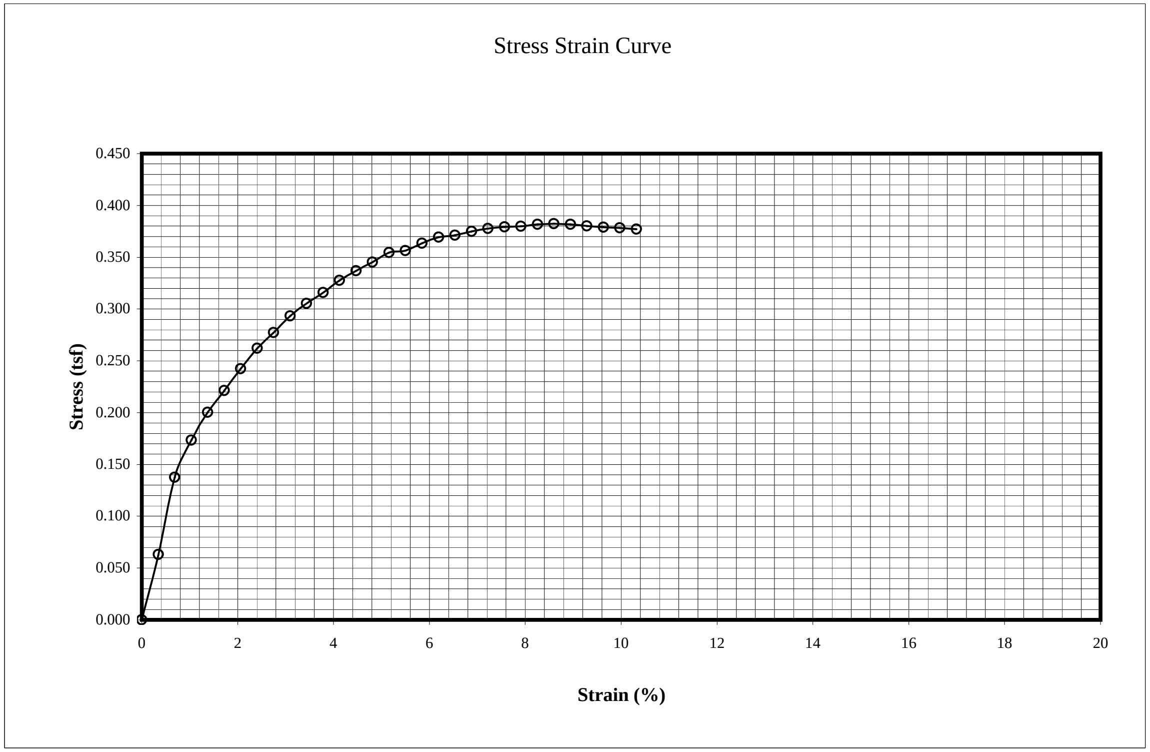
Wet wt. 159.49
Dry at. 104.48
Can wt. 20.88

Test Data:

Cell Pressure (psi) = 15.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	5.7	0.344	0.063
0.040	12.5	0.688	0.138
0.060	15.8	1.032	0.173
0.080	18.3	1.376	0.200
0.100	20.3	1.720	0.221
0.120	22.3	2.064	0.242
0.140	24.2	2.408	0.262
0.160	25.7	2.752	0.277
0.180	27.3	3.096	0.293
0.200	28.5	3.440	0.305
0.220	29.6	3.784	0.316
0.240	30.8	4.128	0.327
0.260	31.8	4.472	0.337
0.280	32.7	4.816	0.345
0.300	33.7	5.160	0.354
0.320	34.0	5.504	0.356
0.340	34.8	5.848	0.363
0.360	35.5	6.192	0.369
0.380	35.8	6.536	0.371
0.400	36.3	6.880	0.375
0.420	36.7	7.224	0.378
0.440	37.0	7.568	0.379
0.460	37.2	7.912	0.380
0.480	37.5	8.256	0.382
0.500	37.7	8.600	0.382
0.520	37.8	8.944	0.382
0.540	37.8	9.288	0.380
0.560	37.8	9.632	0.379
0.580	37.9	9.976	0.378
0.600	37.9	10.320	0.377



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very stiff tan and brown clay with silt
Type of Failure: Vertical @ 7.4%
Boring No.: 17-5-1
Depth (ft): 3-5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1267.3

Area (in^2) = 6.492
Moisture Content (%) = 17.59%
Wet Density (pcf) = 126.3
Dry Density (pcf) = 107.4

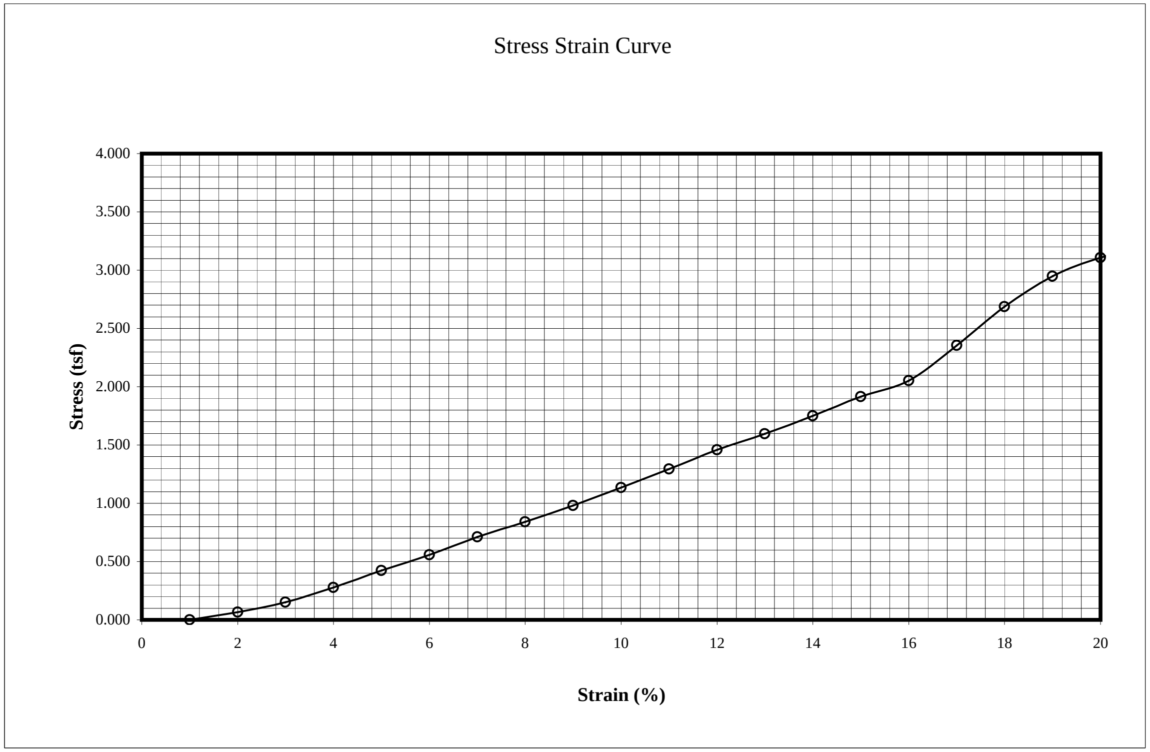
Wet wt. 162.22
Dry at. 142.28
Can wt. 28.9

Test Data:
Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	18	0.340	0.067
0.040	41	0.679	0.152
0.060	75	1.019	0.278
0.080	115	1.358	0.424
0.100	152	1.698	0.559
0.120	194	2.037	0.711
0.140	230	2.377	0.840
0.160	270	2.716	0.982
0.180	313	3.056	1.135
0.200	358	3.396	1.293
0.220	405	3.735	1.458
0.240	445	4.075	1.596
0.260	490	4.414	1.751
0.280	538	4.754	1.916
0.300	578	5.093	2.051
0.320	620	5.433	2.353
0.340	660	5.772	2.686
0.360	692	6.112	2.948
0.380	712	6.452	3.107
0.400	725	6.791	3.205
0.420	736	7.131	3.286
0.440	742	7.470	3.324
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with siltlenses and wood
Type of Failure: Yield @ 10%
Boring No.: 17-5-6
Depth (ft): 22-24

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 954.4

Area (in^2) = 6.492
Moisture Content (%) = 77.69%
Wet Density (pcf) = 96.3
Dry Density (pcf) = 54.2

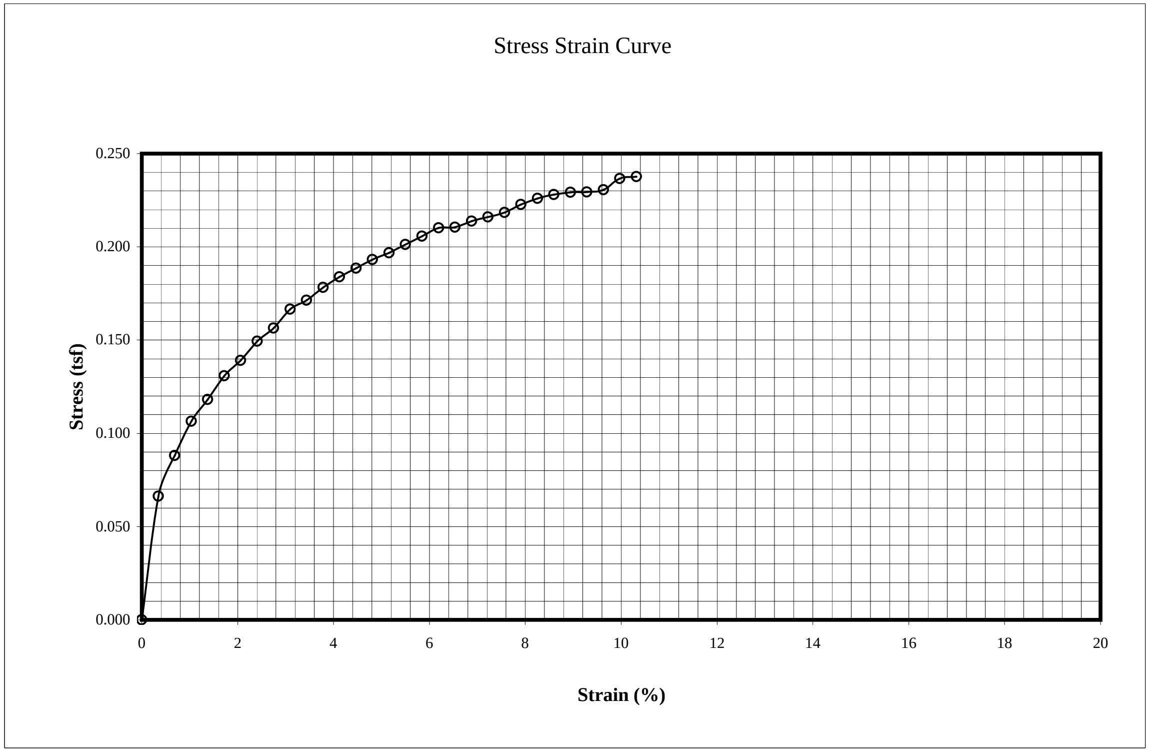
Wet wt. 136.11
Dry at. 85.72
Can wt. 20.86

Test Data:
Cell Pressure (psi) = 14.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	6.0	0.344	0.066
0.040	8.0	0.688	0.088
0.060	9.7	1.032	0.106
0.080	10.8	1.376	0.118
0.100	12.0	1.720	0.131
0.120	12.8	2.064	0.139
0.140	13.8	2.408	0.149
0.160	14.5	2.752	0.156
0.180	15.5	3.096	0.167
0.200	16.0	3.440	0.171
0.220	16.7	3.784	0.178
0.240	17.3	4.128	0.184
0.260	17.8	4.472	0.189
0.280	18.3	4.816	0.193
0.300	18.7	5.160	0.197
0.320	19.2	5.504	0.201
0.340	19.7	5.848	0.206
0.360	20.2	6.192	0.210
0.380	20.3	6.536	0.210
0.400	20.7	6.880	0.214
0.420	21.0	7.224	0.216
0.440	21.3	7.568	0.218
0.460	21.8	7.912	0.223
0.480	22.2	8.256	0.226
0.500	22.5	8.600	0.228
0.520	22.7	8.944	0.229
0.540	22.8	9.288	0.229
0.560	23.0	9.632	0.231
0.580	23.7	9.976	0.237
0.600	23.9	10.320	0.238



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/alt. Seams of silty fine sand
Boring No.: 17-5-7
Depth (ft): 25-27

Type of Failure: Yield @ 10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 999.2

Area (in^2) = 6.492
Moisture Content (%) = 42.65%
Wet Density (pcf) = 100.8
Dry Density (pcf) = 70.7

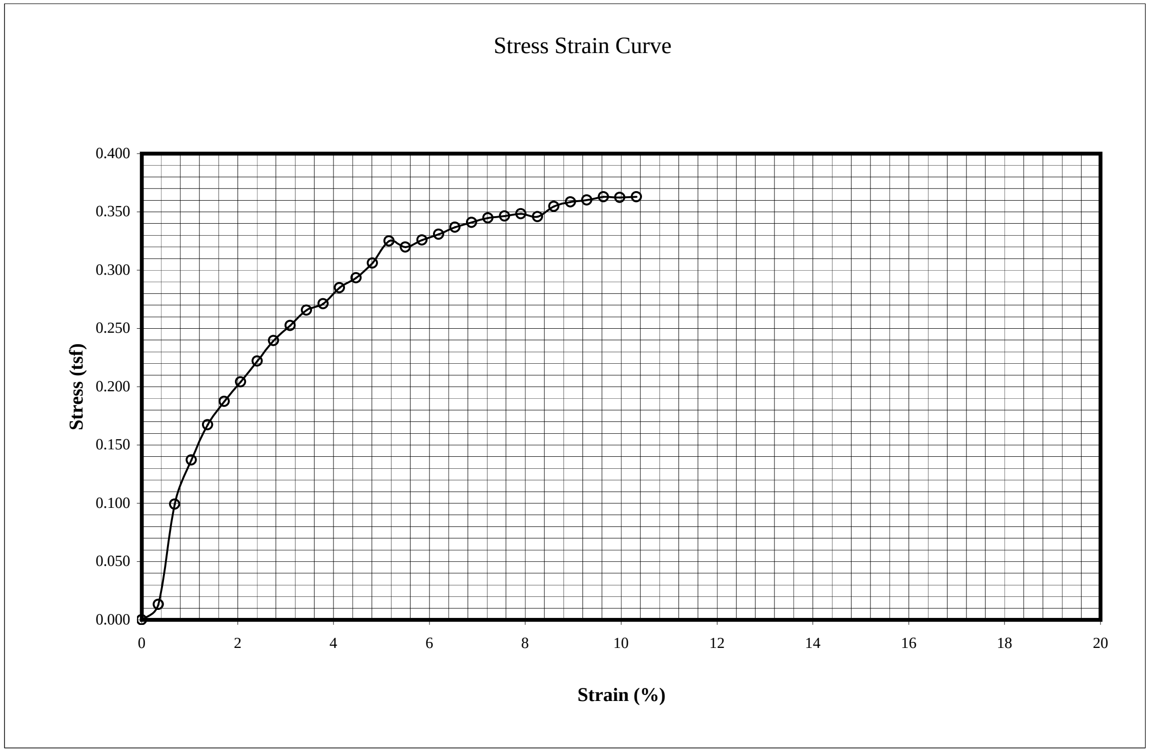
Wet wt. 143.77
Dry at. 107.04
Can wt. 20.92

Test Data:

Cell Pressure (psi) = 16.7
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	1.2	0.344	0.013
0.040	9.0	0.688	0.099
0.060	12.5	1.032	0.137
0.080	15.3	1.376	0.167
0.100	17.2	1.720	0.187
0.120	18.8	2.064	0.204
0.140	20.5	2.408	0.222
0.160	22.2	2.752	0.239
0.180	23.5	3.096	0.253
0.200	24.8	3.440	0.266
0.220	25.4	3.784	0.271
0.240	26.8	4.128	0.285
0.260	27.7	4.472	0.293
0.280	29.0	4.816	0.306
0.300	30.9	5.160	0.325
0.320	30.5	5.504	0.320
0.340	31.2	5.848	0.326
0.360	31.8	6.192	0.331
0.380	32.5	6.536	0.337
0.400	33.0	6.880	0.341
0.420	33.5	7.224	0.345
0.440	33.8	7.568	0.347
0.460	34.1	7.912	0.348
0.480	34.0	8.256	0.346
0.500	35.0	8.600	0.355
0.520	35.5	8.944	0.359
0.540	35.8	9.288	0.360
0.560	36.2	9.632	0.363
0.580	36.3	9.976	0.362
0.600	36.5	10.320	0.363



uu17-5-7

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft organic clay
Type of Failure: Yield @ 10%
Boring No.: LAC-1-1
Depth (ft): 3-4

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 852.6

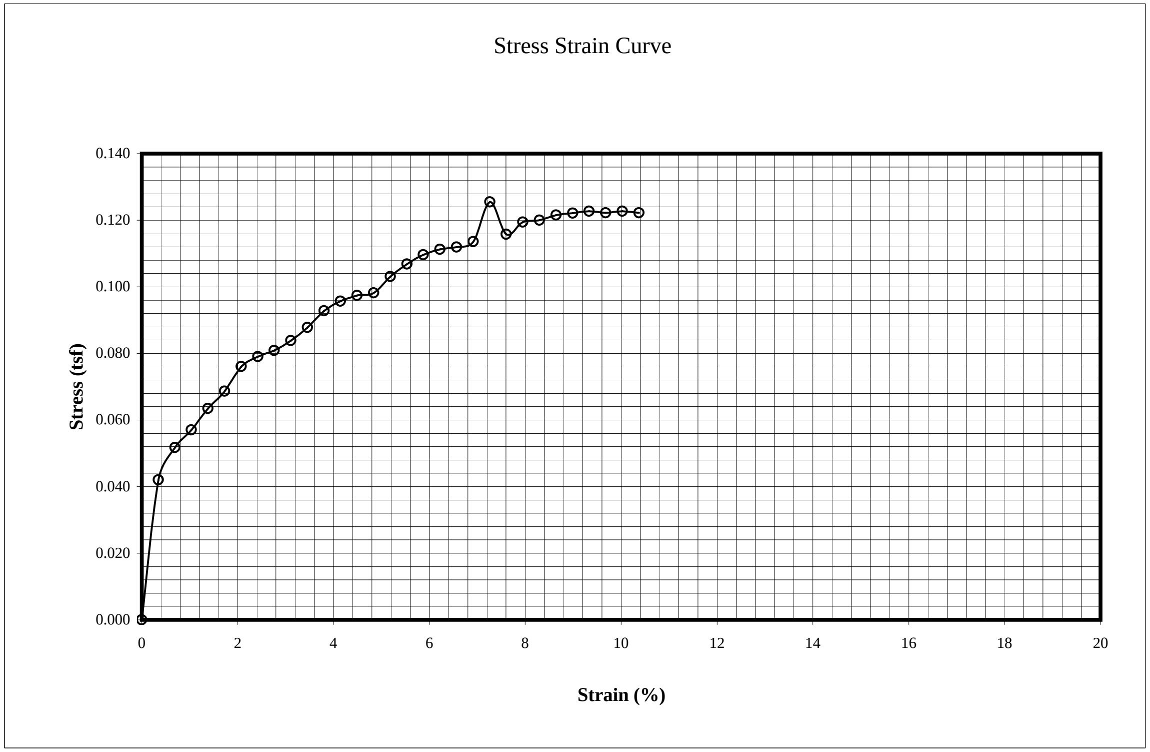
Area (in^2) = 6.492
Moisture Content (%) = 123.75%
Wet Density (pcf) = 86.5
Dry Density (pcf) = 38.7

Wet wt. 142.26
Dry at. 75.15
Can wt. 20.92

Test Data:
Cell Pressure (psi) = 3.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.8	0.346	0.042
0.040	4.7	0.691	0.052
0.060	5.2	1.037	0.057
0.080	5.8	1.383	0.063
0.100	6.3	1.729	0.069
0.120	7.0	2.074	0.076
0.140	7.3	2.420	0.079
0.160	7.5	2.766	0.081
0.180	7.8	3.111	0.084
0.200	8.2	3.457	0.088
0.220	8.7	3.803	0.093
0.240	9.0	4.149	0.096
0.260	9.2	4.494	0.097
0.280	9.3	4.840	0.098
0.300	9.8	5.186	0.103
0.320	10.2	5.532	0.107
0.340	10.5	5.877	0.110
0.360	10.7	6.223	0.111
0.380	10.8	6.569	0.112
0.400	11.0	6.914	0.114
0.420	12.2	7.260	0.125
0.440	11.3	7.606	0.116
0.460	11.7	7.952	0.119
0.480	11.8	8.297	0.120
0.500	12.0	8.643	0.122
0.520	12.1	8.989	0.122
0.540	12.2	9.334	0.123
0.560	12.2	9.680	0.122
0.580	12.3	10.026	0.123
0.600	12.3	10.372	0.122



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay with fine sand
Type of Failure: Yield @ 10%
Boring No.: LAC-1-1
Depth (ft): 5-6

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1143.7

Area (in^2) = 6.492
Moisture Content (%) = 47.68%
Wet Density (pcf) = 115.4
Dry Density (pcf) = 78.2

Wet wt. 198.4
Dry at. 143.55
Can wt. 28.51

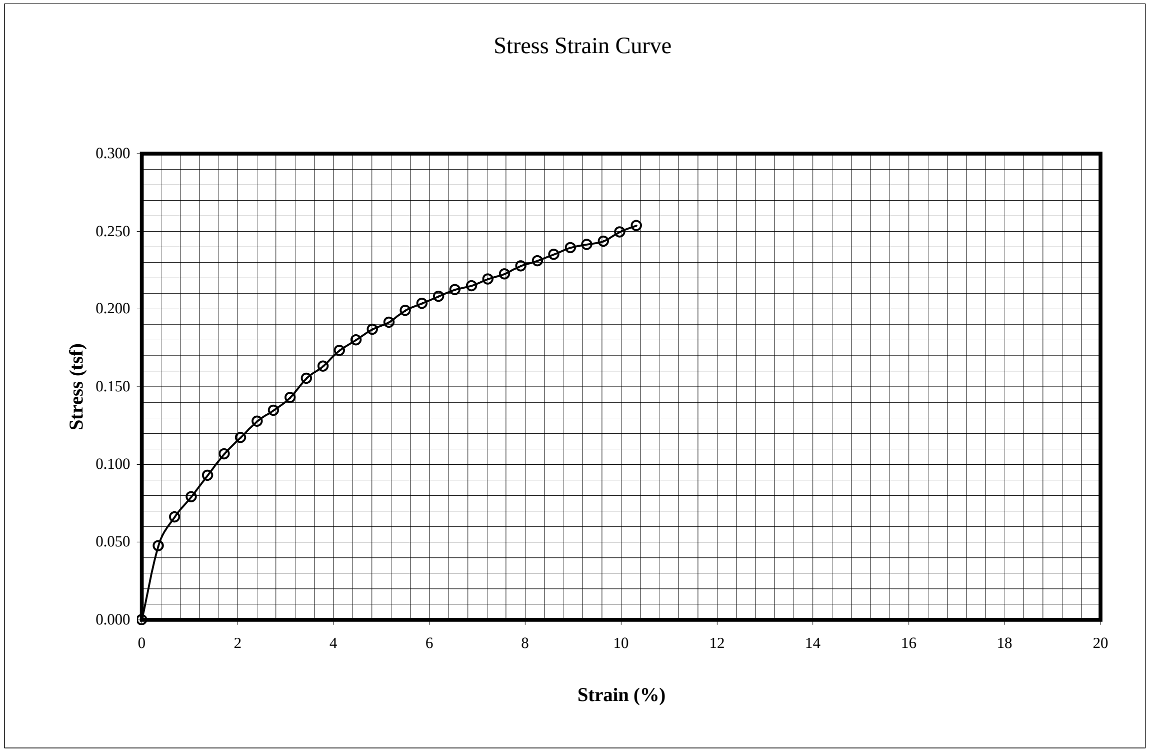
Test Data:

Cell Pressure (psi) = 3.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	4.3	0.344	0.048
0.040	6.0	0.688	0.066
0.060	7.2	1.032	0.079
0.080	8.5	1.376	0.093
0.100	9.8	1.720	0.107
0.120	10.8	2.064	0.117
0.140	11.8	2.408	0.128
0.160	12.5	2.752	0.135
0.180	13.3	3.096	0.143
0.200	14.5	3.440	0.155
0.220	15.3	3.784	0.163
0.240	16.3	4.128	0.173
0.260	17.0	4.472	0.180
0.280	17.7	4.816	0.187
0.300	18.2	5.160	0.191
0.320	19.0	5.504	0.199
0.340	19.5	5.848	0.204
0.360	20.0	6.192	0.208
0.380	20.5	6.536	0.213
0.400	20.8	6.880	0.215
0.420	21.3	7.224	0.219
0.440	21.7	7.568	0.222
0.460	22.3	7.912	0.228
0.480	22.7	8.256	0.231
0.500	23.2	8.600	0.235
0.520	23.7	8.944	0.239
0.540	24.0	9.288	0.241
0.560	24.3	9.632	0.244
0.580	25.0	9.976	0.250
0.600	25.5	10.320	0.254



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft clay w/ 1/2" sand layer at bottom
Type of Failure: Yield @ 10%
Boring No.: LAC-1-2
Depth (ft): 6-8

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1111.1

Area (in^2) = 6.492
Moisture Content (%) = 51.65%
Wet Density (pcf) = 112.4
Dry Density (pcf) = 74.1

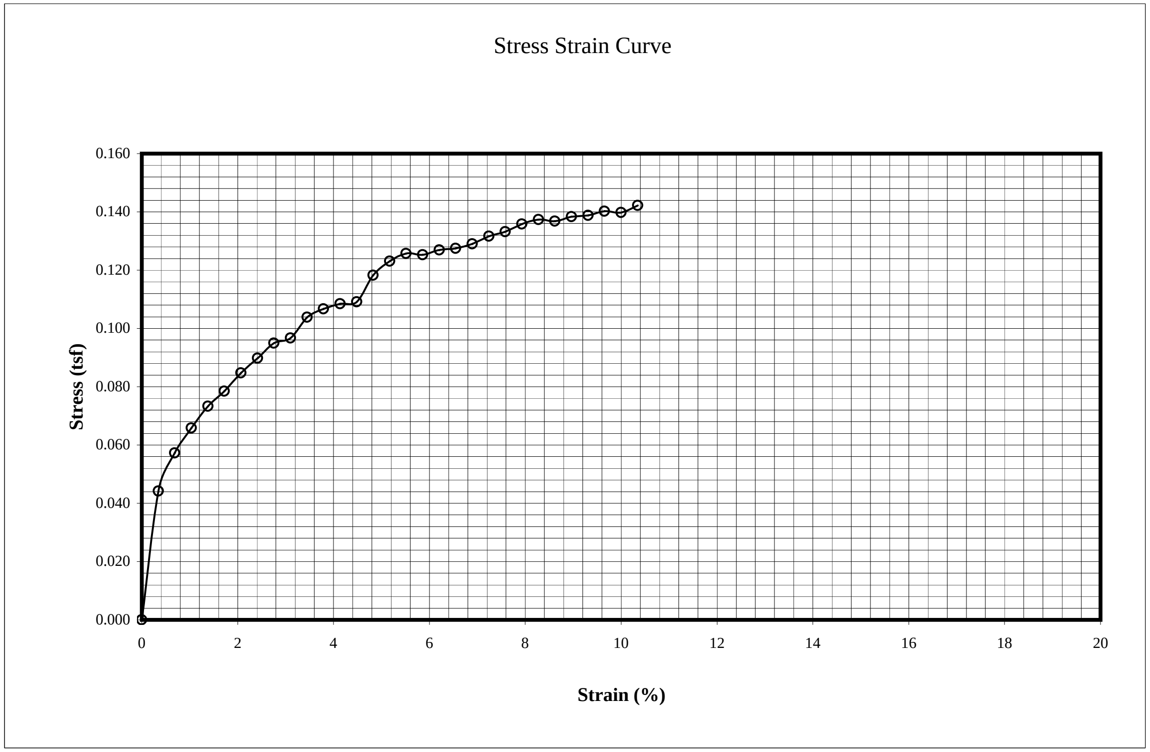
Wet wt. 151.2
Dry at. 108.24
Can wt. 25.06

Test Data:
Cell Pressure (psi) = 4.1
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	4.0	0.345	0.044
0.040	5.2	0.690	0.057
0.060	6.0	1.034	0.066
0.080	6.7	1.379	0.073
0.100	7.2	1.724	0.078
0.120	7.8	2.069	0.085
0.140	8.3	2.414	0.090
0.160	8.8	2.759	0.095
0.180	9.0	3.103	0.097
0.200	9.7	3.448	0.104
0.220	10.0	3.793	0.107
0.240	10.2	4.138	0.108
0.260	10.3	4.483	0.109
0.280	11.2	4.828	0.118
0.300	11.7	5.172	0.123
0.320	12.0	5.517	0.126
0.340	12.0	5.862	0.125
0.360	12.2	6.207	0.127
0.380	12.3	6.552	0.127
0.400	12.5	6.897	0.129
0.420	12.8	7.241	0.132
0.440	13.0	7.586	0.133
0.460	13.3	7.931	0.136
0.480	13.5	8.276	0.137
0.500	13.5	8.621	0.137
0.520	13.7	8.966	0.138
0.540	13.8	9.310	0.139
0.560	14.0	9.655	0.140
0.580	14.0	10.000	0.140
0.600	14.3	10.345	0.142



uuLAC-1-2

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray sandy clay w/wood & clay pockets
Type of Failure: Yield @ 10%
Boring No.: LAC-1-3
Depth (ft): 8.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 947.4

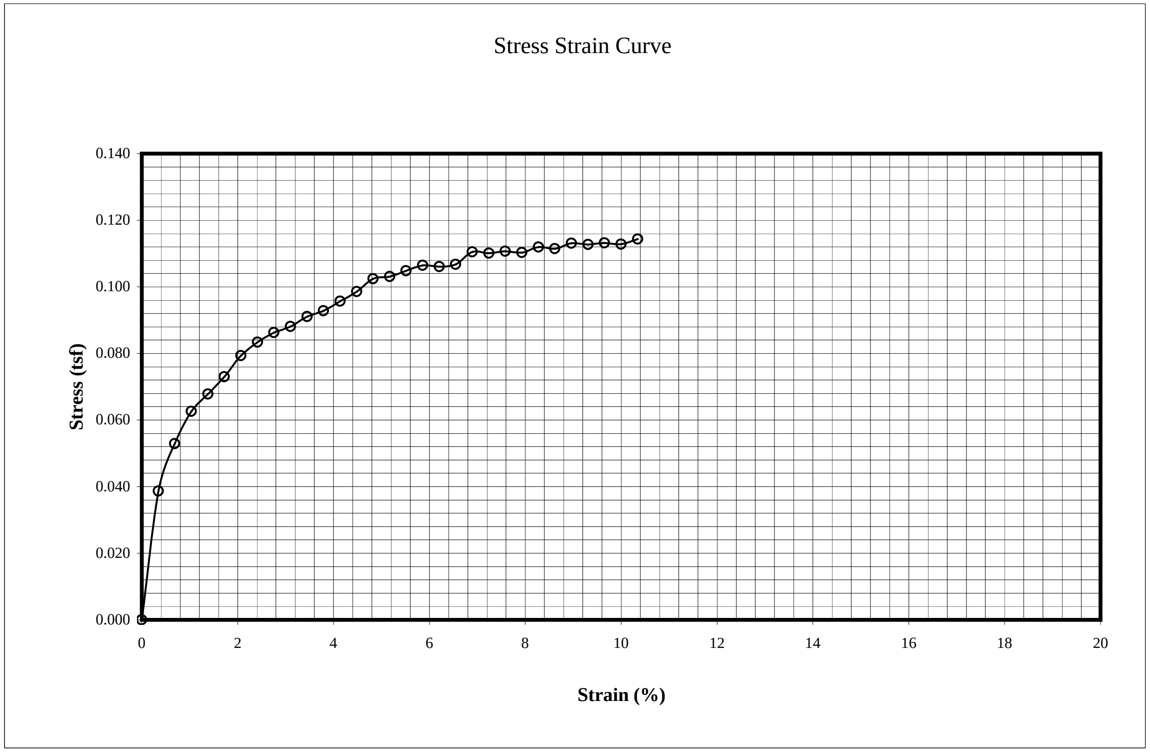
Area (in^2) = 6.492
Moisture Content (%) = 32.58%
Wet Density (pcf) = 95.9
Dry Density (pcf) = 72.3

Wet wt. 185.35
Dry at. 145.26
Can wt. 22.22

Test Data:
Cell Pressure (psi) = 5.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.5	0.345	0.039
0.040	4.8	0.690	0.053
0.060	5.7	1.034	0.063
0.080	6.2	1.379	0.068
0.100	6.7	1.724	0.073
0.120	7.3	2.069	0.079
0.140	7.7	2.414	0.083
0.160	8.0	2.759	0.086
0.180	8.2	3.103	0.088
0.200	8.5	3.448	0.091
0.220	8.7	3.793	0.093
0.240	9.0	4.138	0.096
0.260	9.3	4.483	0.099
0.280	9.7	4.828	0.102
0.300	9.8	5.172	0.103
0.320	10.0	5.517	0.105
0.340	10.2	5.862	0.106
0.360	10.2	6.207	0.106
0.380	10.3	6.552	0.107
0.400	10.7	6.897	0.110
0.420	10.7	7.241	0.110
0.440	10.8	7.586	0.111
0.460	10.8	7.931	0.110
0.480	11.0	8.276	0.112
0.500	11.0	8.621	0.111
0.520	11.2	8.966	0.113
0.540	11.2	9.310	0.113
0.560	11.3	9.655	0.113
0.580	11.3	10.000	0.113
0.600	11.5	10.345	0.114



uuLAC-1-3

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Firm gray fine sand with 2" clayey sand layer
Type of Failure: Bulge @ 4%
Boring No.: LAC-1-3
Depth (ft): 9.5-10.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1160.9

Area (in^2) = 6.492
Moisture Content (%) = 30.18%
Wet Density (pcf) = 117.5
Dry Density (pcf) = 90.2

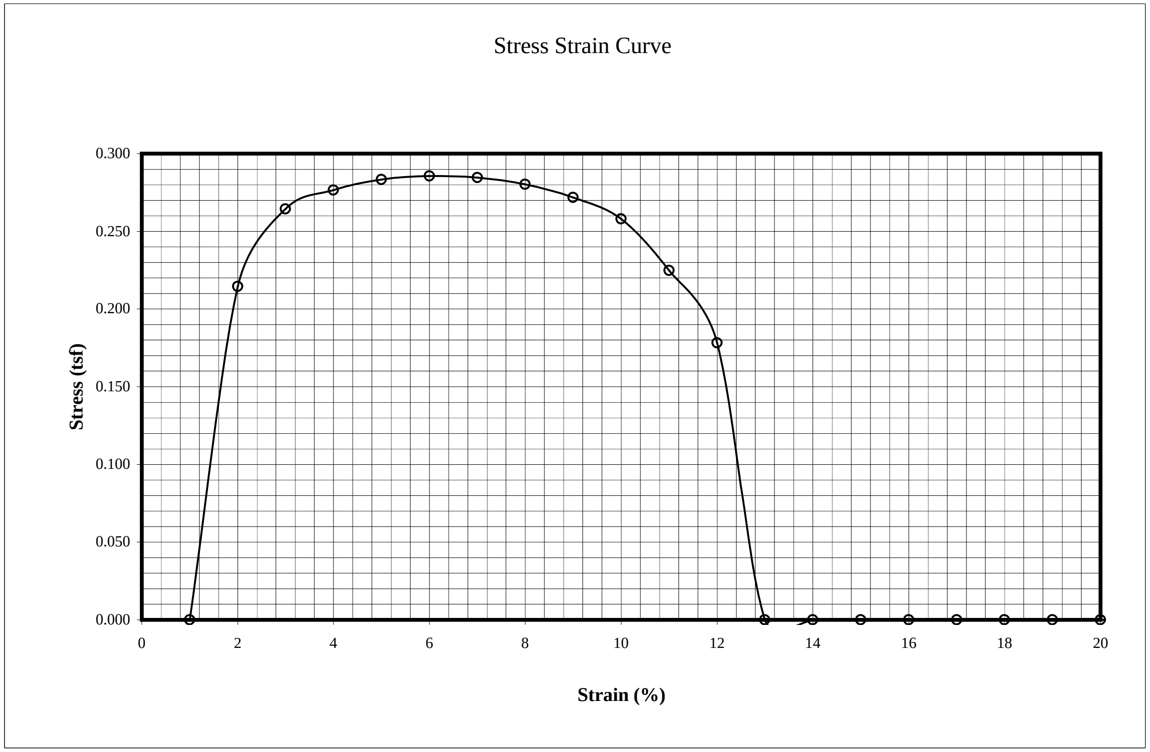
Wet wt. 197.24
Dry at. 158.25
Can wt. 29.07

Test Data:
Cell Pressure (psi) = 5.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	19.4	0.345	0.214
0.040	24.0	0.690	0.264
0.060	25.2	1.034	0.277
0.080	25.9	1.379	0.283
0.100	26.2	1.724	0.286
0.120	26.2	2.069	0.285
0.140	25.9	2.414	0.280
0.160	25.2	2.759	0.272
0.180	24.0	3.103	0.258
0.200	21.0	3.448	0.225
0.220	16.7	3.793	0.178
0.240			
0.260			
0.280			
0.300			
0.320			
0.340			
0.360			
0.380			
0.400			
0.420			
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay with some silt
Type of Failure: Yeild @ 10%
Boring No.: LAC-2-4
Depth (ft): 44-45

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1006.6

Area (in^2) = 6.492
Moisture Content (%) = 86.46%
Wet Density (pcf) = 101.6

Dry Density (pcf) = 54.5

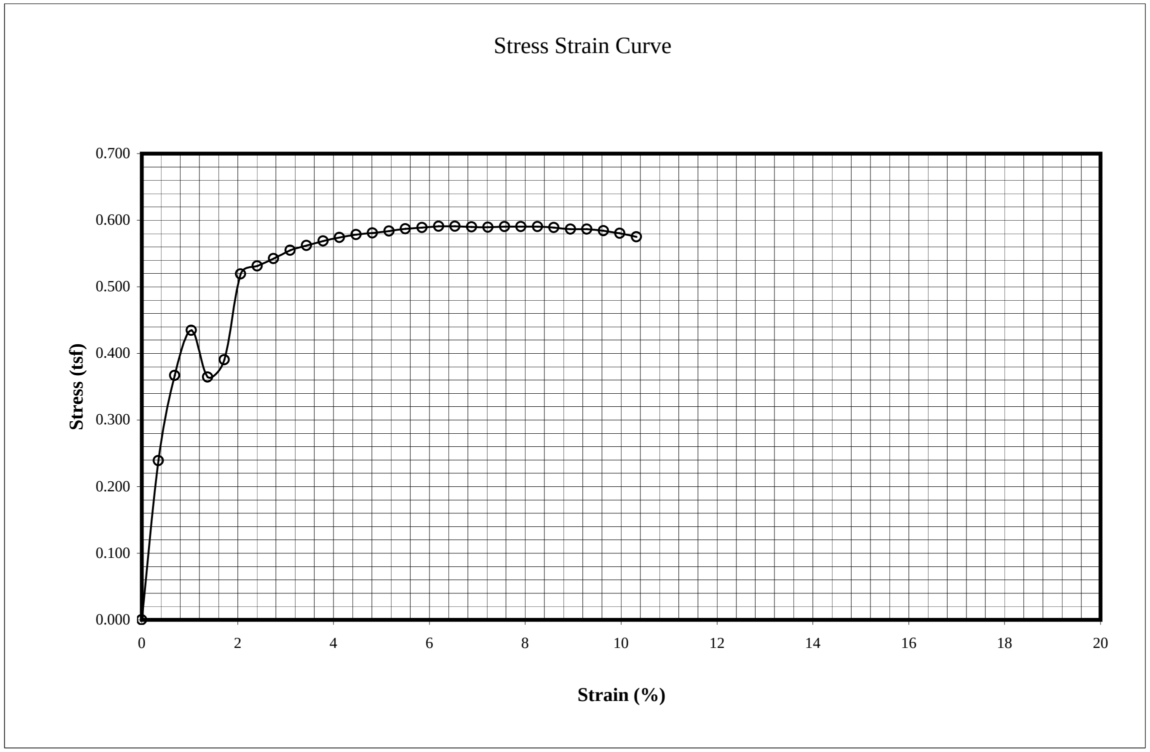
Wet wt. 207.31
Dry at. 124.65
Can wt. 29.05

Test Data:
Cell Pressure (psi) = 26.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	21.6	0.344	0.239
0.040	33.3	0.688	0.367
0.060	39.6	1.032	0.435
0.080	33.3	1.376	0.364
0.100	35.8	1.720	0.390
0.120	47.8	2.064	0.519
0.140	49.1	2.408	0.531
0.160	50.3	2.752	0.543
0.180	51.6	3.096	0.555
0.200	52.5	3.440	0.562
0.220	53.3	3.784	0.569
0.240	54.0	4.128	0.574
0.260	54.6	4.472	0.578
0.280	55.0	4.816	0.581
0.300	55.5	5.160	0.584
0.320	56.0	5.504	0.587
0.340	56.4	5.848	0.589
0.360	56.8	6.192	0.591
0.380	57.0	6.536	0.591
0.400	57.1	6.880	0.590
0.420	57.3	7.224	0.590
0.440	57.6	7.568	0.590
0.460	57.8	7.912	0.590
0.480	58.0	8.256	0.590
0.500	58.1	8.600	0.589
0.520	58.1	8.944	0.587
0.540	58.3	9.288	0.587
0.560	58.3	9.632	0.584
0.580	58.1	9.976	0.580
0.600	57.8	10.320	0.575



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay w/silt seams & shell fragments
Type of Failure: Yeild @ 10%
Boring No.: LAC-2-4
Depth (ft): 45-46

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1041.3

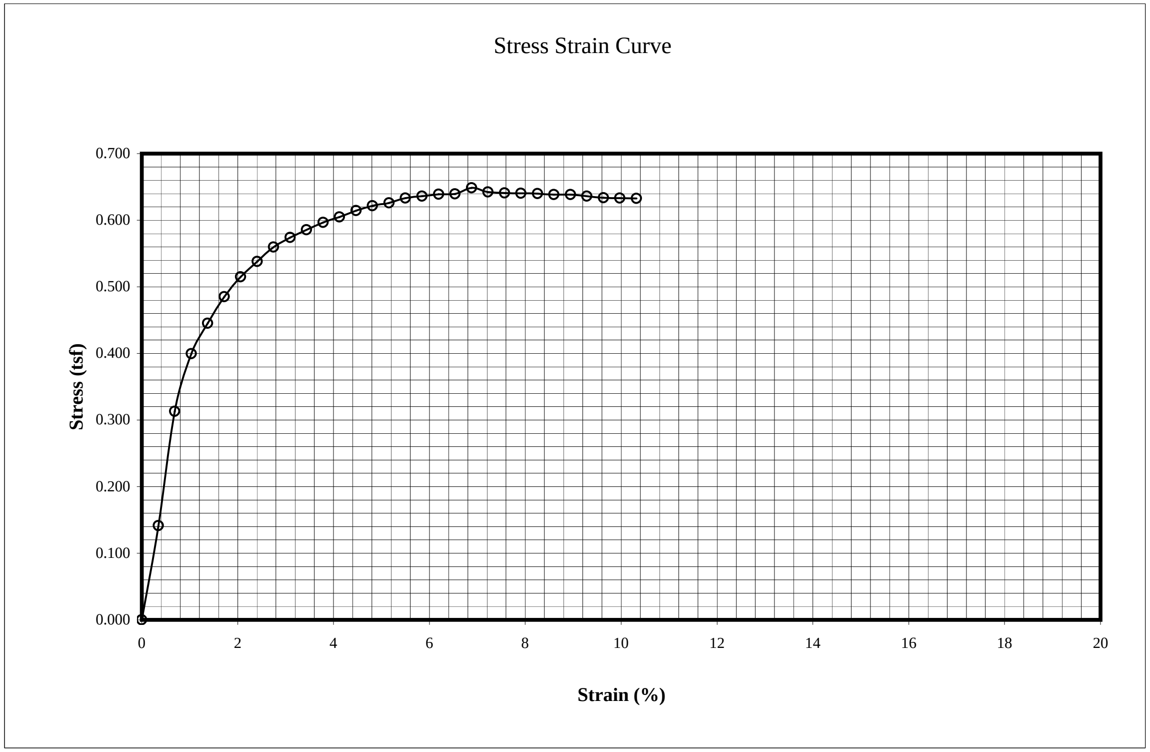
Area (in^2) = 6.492
Moisture Content (%) = 57.75%
Wet Density (pcf) = 105.1
Dry Density (pcf) = 66.6

Wet wt. 195.39
Dry at. 131.96
Can wt. 22.12

Test Data:
Cell Pressure (psi) = 26.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	12.8	0.344	0.141
0.040	28.4	0.688	0.313
0.060	36.4	1.032	0.400
0.080	40.7	1.376	0.445
0.100	44.5	1.720	0.485
0.120	47.4	2.064	0.515
0.140	49.7	2.408	0.538
0.160	51.9	2.752	0.560
0.180	53.4	3.096	0.574
0.200	54.7	3.440	0.586
0.220	55.9	3.784	0.597
0.240	56.9	4.128	0.605
0.260	58.0	4.472	0.615
0.280	58.9	4.816	0.622
0.300	59.5	5.160	0.626
0.320	60.4	5.504	0.633
0.340	60.9	5.848	0.636
0.360	61.4	6.192	0.639
0.380	61.7	6.536	0.640
0.400	62.8	6.880	0.649
0.420	62.4	7.224	0.642
0.440	62.5	7.568	0.641
0.460	62.7	7.912	0.640
0.480	62.9	8.256	0.640
0.500	63.0	8.600	0.639
0.520	63.2	8.944	0.638
0.540	63.2	9.288	0.636
0.560	63.2	9.632	0.633
0.580	63.4	9.976	0.633
0.600	63.6	10.320	0.633



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray sandy clay to sand
Type of Failure: Vertical @ 4%
Boring No.: LAC-3-3
Depth (ft): 7.5-8.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1246.1

Area (in^2) = 6.492
Moisture Content (%) = 21.80%
Wet Density (pcf) = 125.8
Dry Density (pcf) = 103.3

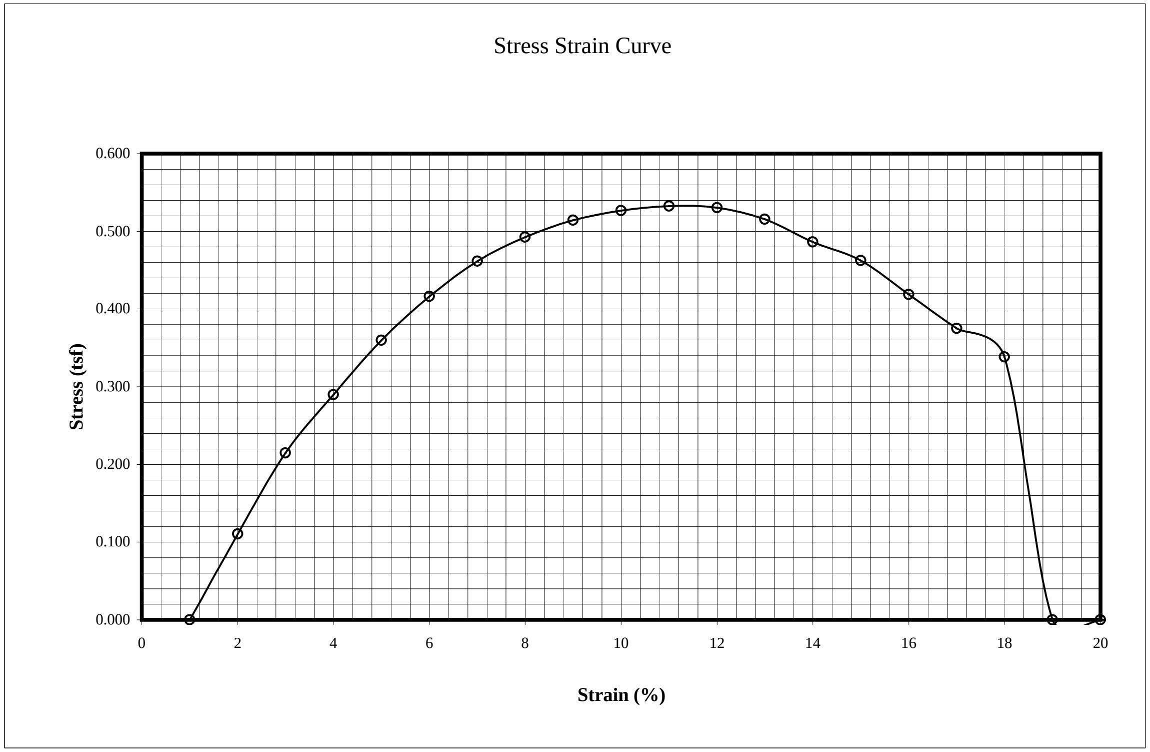
Wet wt. 193.85
Dry at. 164.29
Can wt. 28.69

Test Data:
Cell Pressure (psi) = 4.3
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	10.0	0.344	0.111
0.040	19.5	0.688	0.215
0.060	26.4	1.032	0.290
0.080	32.9	1.376	0.360
0.100	38.2	1.720	0.416
0.120	42.5	2.064	0.462
0.140	45.5	2.408	0.492
0.160	47.7	2.752	0.514
0.180	49.0	3.096	0.527
0.200	49.7	3.440	0.532
0.220	49.7	3.784	0.530
0.240	48.5	4.128	0.516
0.260	45.9	4.472	0.486
0.280	43.8	4.816	0.462
0.300	39.8	5.160	0.419
0.320	35.8	5.504	0.375
0.340	32.4	5.848	0.338
0.360			
0.380			
0.400			
0.420			
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



uuLAC-3-3

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Firm gray sand with clay
Boring No.: LAC-3-4
Depth (ft): 9-11

Type of Failure: Bulge @ 7%

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1208.9

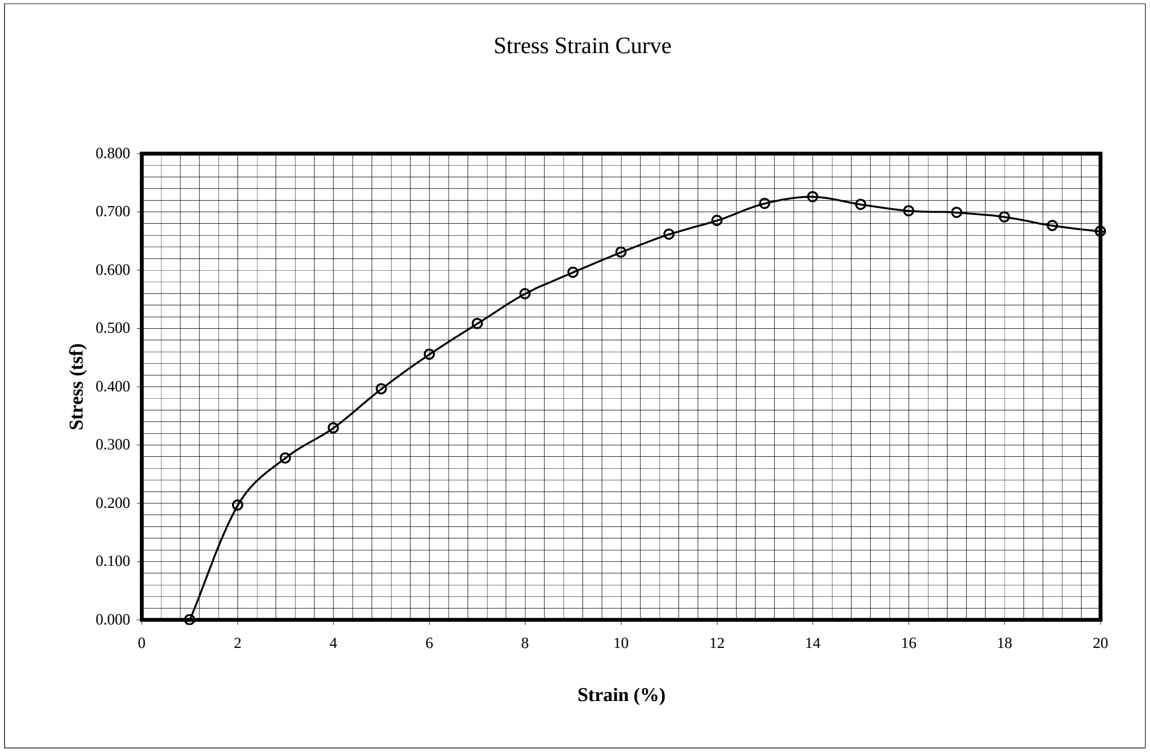
Area (in^2) = 6.492
Moisture Content (%) = 26.58%
Wet Density (pcf) = 122.3
Dry Density (pcf) = 96.6

Wet wt. 151.05
Dry at. 123.97
Can wt. 22.08

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	17.8	0.345	0.197
0.040	25.2	0.690	0.278
0.060	30.0	1.034	0.329
0.080	36.2	1.379	0.396
0.100	41.8	1.724	0.456
0.120	46.8	2.069	0.508
0.140	51.7	2.414	0.560
0.160	55.3	2.759	0.596
0.180	58.7	3.103	0.631
0.200	61.8	3.448	0.662
0.220	64.2	3.793	0.685
0.240	67.2	4.138	0.714
0.260	68.5	4.483	0.726
0.280	67.5	4.828	0.712
0.300	66.7	5.172	0.701
0.320	66.7	5.517	0.699
0.340	66.2	5.862	0.691
0.360	65.0	6.207	0.676
0.380	64.3	6.552	0.666
0.400	63.7	6.897	0.658
0.420	62.8	7.241	0.646
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray organic clay with peat
Type of Failure: Yield @ 10%
Boring No.: LACW-2-2
Depth (ft): 8.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 759.7

Area (in^2) = 6.492
Moisture Content (%) = 186.97%
Wet Density (pcf) = 76.7
Dry Density (pcf) = 26.7

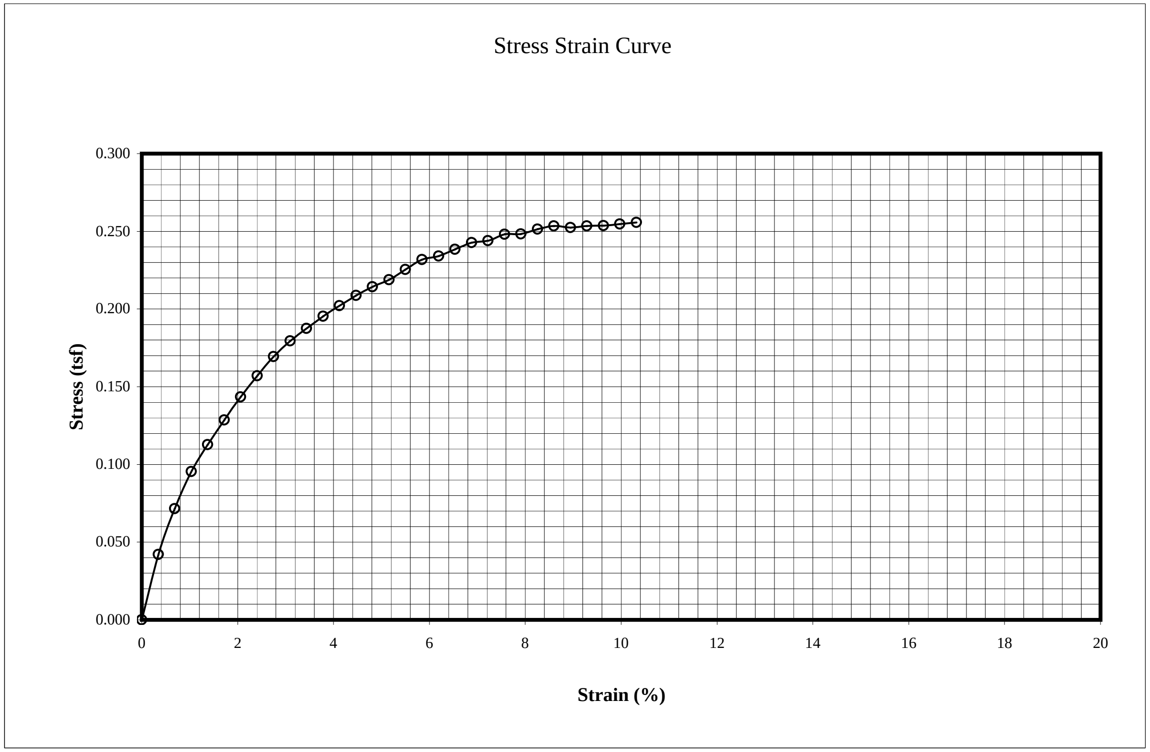
Wet wt. 133.17
Dry at. 64.01
Can wt. 27.02

Test Data:
Cell Pressure (psi) = 4.3
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.8	0.344	0.042
0.040	6.5	0.688	0.072
0.060	8.7	1.032	0.095
0.080	10.3	1.376	0.113
0.100	11.8	1.720	0.129
0.120	13.2	2.064	0.143
0.140	14.5	2.408	0.157
0.160	15.7	2.752	0.169
0.180	16.7	3.096	0.179
0.200	17.5	3.440	0.187
0.220	18.3	3.784	0.195
0.240	19.0	4.128	0.202
0.260	19.7	4.472	0.209
0.280	20.3	4.816	0.214
0.300	20.8	5.160	0.219
0.320	21.5	5.504	0.225
0.340	22.2	5.848	0.232
0.360	22.5	6.192	0.234
0.380	23.0	6.536	0.238
0.400	23.5	6.880	0.243
0.420	23.7	7.224	0.244
0.440	24.2	7.568	0.248
0.460	24.3	7.912	0.248
0.480	24.7	8.256	0.251
0.500	25.0	8.600	0.253
0.520	25.0	8.944	0.252
0.540	25.2	9.288	0.254
0.560	25.3	9.632	0.254
0.580	25.5	9.976	0.255
0.600	25.7	10.320	0.256



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very Soft dark gray organic clay with peat
Type of Failure: Yield @ 10%
Boring No.: LACW-2-2
Depth (ft): 9.5-10.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 764.5

Area (in^2) = 6.492
Moisture Content (%) = 157.95%
Wet Density (pcf) = 77.2
Dry Density (pcf) = 29.9

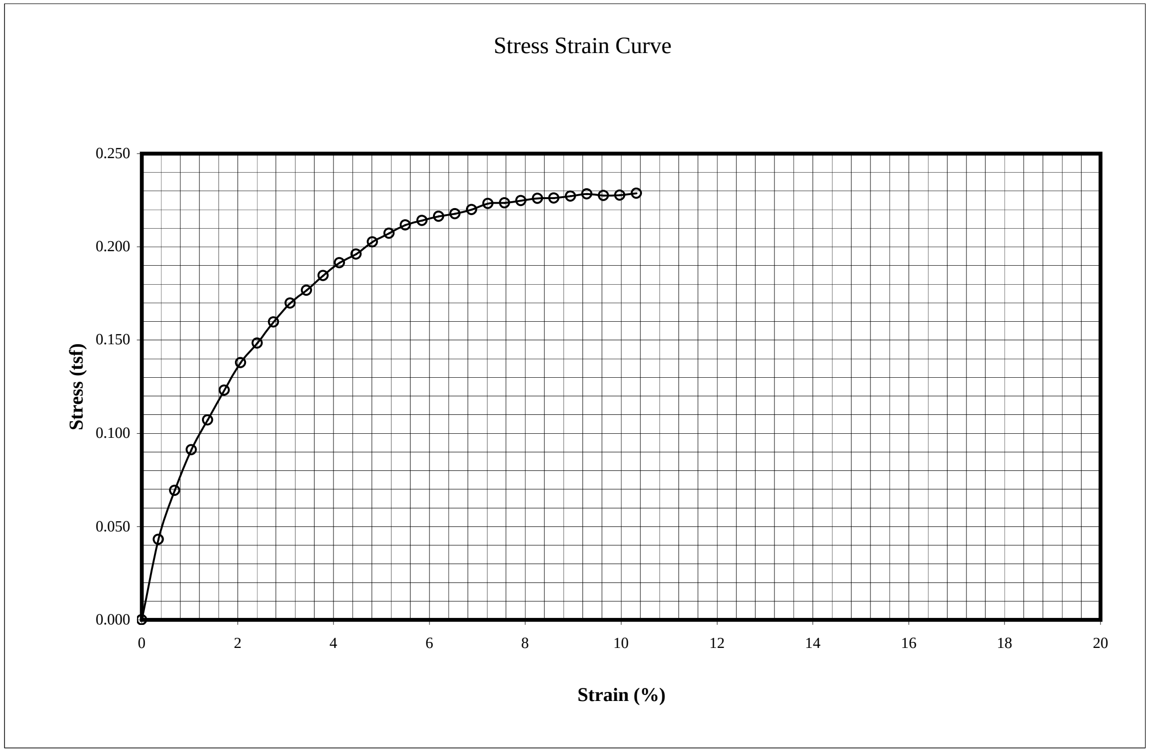
Wet wt. 135
Dry at. 70.05
Can wt. 28.93

Test Data:
Cell Pressure (psi) = 4.3
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.9	0.344	0.043
0.040	6.3	0.688	0.069
0.060	8.3	1.032	0.091
0.080	9.8	1.376	0.107
0.100	11.3	1.720	0.123
0.120	12.7	2.064	0.138
0.140	13.7	2.408	0.148
0.160	14.8	2.752	0.160
0.180	15.8	3.096	0.170
0.200	16.5	3.440	0.177
0.220	17.3	3.784	0.185
0.240	18.0	4.128	0.191
0.260	18.5	4.472	0.196
0.280	19.2	4.816	0.203
0.300	19.7	5.160	0.207
0.320	20.2	5.504	0.212
0.340	20.5	5.848	0.214
0.360	20.8	6.192	0.216
0.380	21.0	6.536	0.218
0.400	21.3	6.880	0.220
0.420	21.7	7.224	0.223
0.440	21.8	7.568	0.223
0.460	22.0	7.912	0.225
0.480	22.2	8.256	0.226
0.500	22.3	8.600	0.226
0.520	22.5	8.944	0.227
0.540	22.7	9.288	0.228
0.560	22.7	9.632	0.228
0.580	22.8	9.976	0.228
0.600	23.0	10.320	0.229



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium dark gray organic clay alt. Layers of sand silt & clay
Type of Failure: Yield @ 10%
Boring No.: LACW-3-4
Depth (ft): 10-12

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1120.8

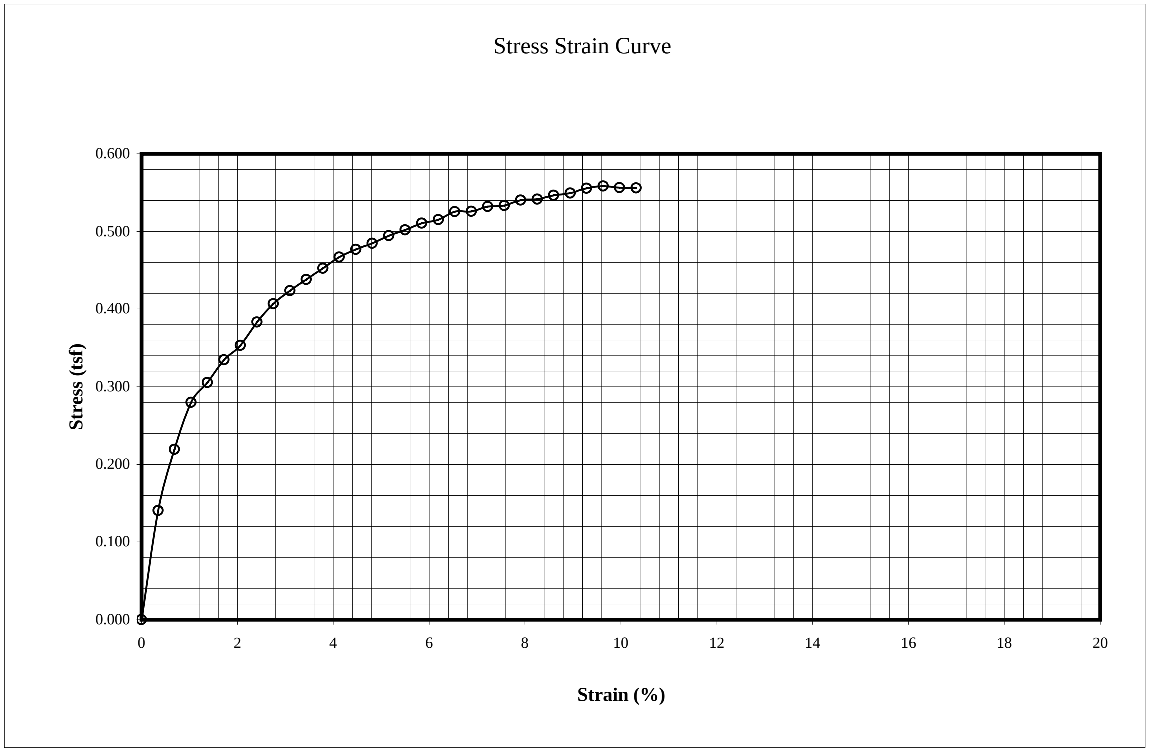
Area (in^2) = 6.492
Moisture Content (%) = 48.11%
Wet Density (pcf) = 113.1
Dry Density (pcf) = 76.4

Wet wt. 205
Dry at. 145.69
Can wt. 22.42

Test Data:
Cell Pressure (psi) = 6.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	12.7	0.344	0.140
0.040	19.9	0.688	0.219
0.060	25.5	1.032	0.280
0.080	27.9	1.376	0.305
0.100	30.7	1.720	0.335
0.120	32.5	2.064	0.353
0.140	35.4	2.408	0.383
0.160	37.7	2.752	0.407
0.180	39.4	3.096	0.423
0.200	40.9	3.440	0.438
0.220	42.4	3.784	0.452
0.240	43.9	4.128	0.467
0.260	45.0	4.472	0.477
0.280	45.9	4.816	0.485
0.300	47.0	5.160	0.494
0.320	47.9	5.504	0.502
0.340	48.9	5.848	0.511
0.360	49.5	6.192	0.515
0.380	50.7	6.536	0.526
0.400	50.9	6.880	0.526
0.420	51.7	7.224	0.532
0.440	52.0	7.568	0.533
0.460	52.9	7.912	0.540
0.480	53.2	8.256	0.541
0.500	53.9	8.600	0.546
0.520	54.4	8.944	0.549
0.540	55.2	9.288	0.555
0.560	55.7	9.632	0.558
0.580	55.7	9.976	0.556
0.600	55.9	10.320	0.556



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff dark gray organic w/roots
Type of Failure: Vertical @ 9%
Boring No.: LACW-4-1
Depth (ft): 3.5-4.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 4.6
Weight (gm) = 790.1

Area (in^2) = 6.492
Moisture Content (%) = 52.32%
Wet Density (pcf) = 101.7
Dry Density (pcf) = 66.7

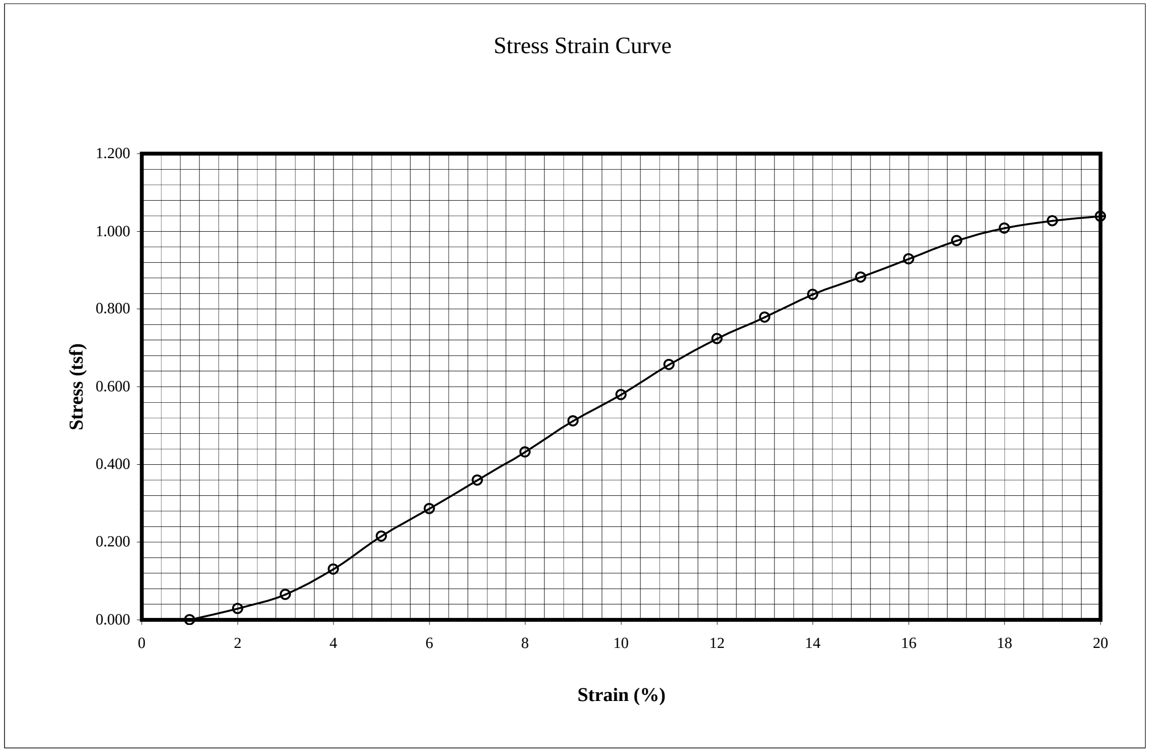
Wet wt. 145.27
Dry at. 105.17
Can wt. 28.52

Test Data:
Cell Pressure (psi) =
Height Correction = 0.978
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	8	0.439	0.029
0.040	18	0.877	0.065
0.060	36	1.316	0.130
0.080	60	1.754	0.215
0.100	80	2.193	0.286
0.120	101	2.632	0.359
0.140	122	3.070	0.432
0.160	145	3.509	0.511
0.180	165	3.947	0.579
0.200	188	4.386	0.657
0.220	208	4.825	0.724
0.240	225	5.263	0.779
0.260	243	5.702	0.838
0.280	257	6.140	0.882
0.300	272	6.579	0.929
0.320	287	7.018	0.975
0.340	298	7.456	1.008
0.360	305	7.895	1.027
0.380	310	8.333	1.039
0.400	314	8.772	1.047
0.420	314	9.211	1.042
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray organic clay w/wood & peat
Type of Failure: Vertical @ 7%
Boring No.: LACW-4-3
Depth (ft): 7.5-8.5

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 858.9

Area (in^2) = 6.492
Moisture Content (%) = 109.93%
Wet Density (pcf) = 86.7
Dry Density (pcf) = 41.3

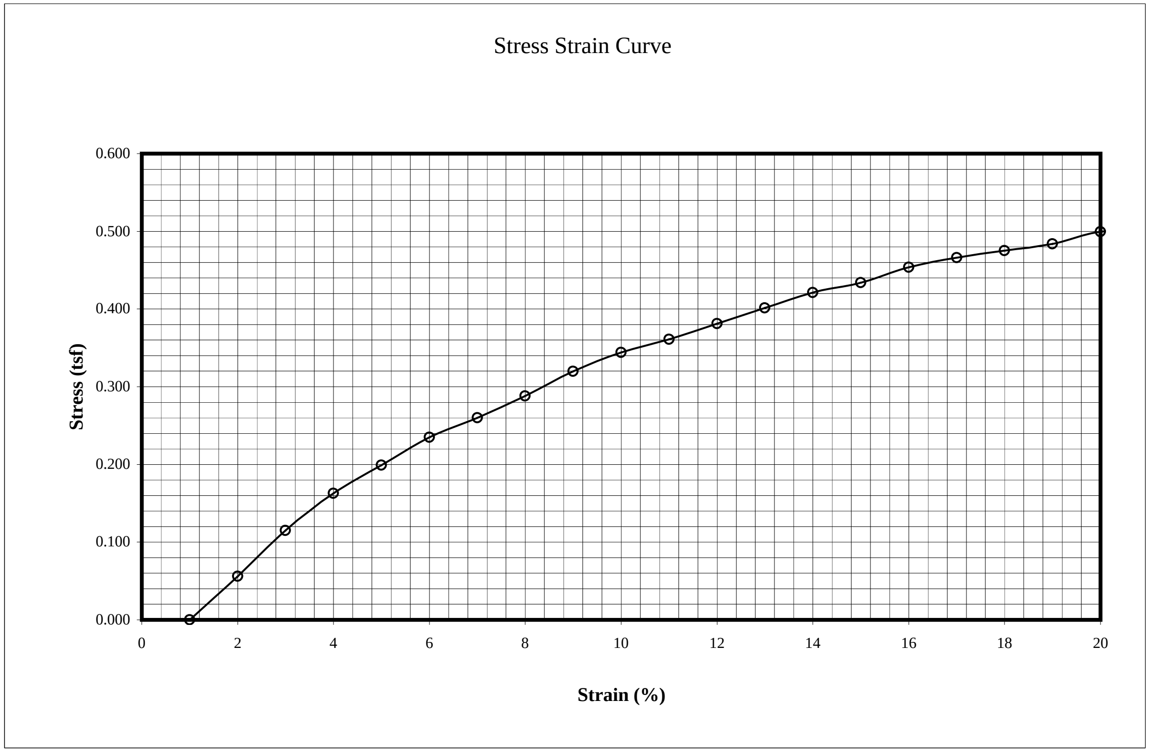
Wet wt. 134.15
Dry at. 78.49
Can wt. 27.86

Test Data:

Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	15	0.344	0.056
0.040	31	0.688	0.115
0.060	44	1.032	0.163
0.080	54	1.376	0.199
0.100	64	1.720	0.235
0.120	71	2.064	0.260
0.140	79	2.408	0.288
0.160	88	2.752	0.320
0.180	95	3.096	0.344
0.200	100	3.440	0.361
0.220	106	3.784	0.381
0.240	112	4.128	0.401
0.260	118	4.472	0.421
0.280	122	4.816	0.434
0.300	128	5.160	0.454
0.320	132	5.504	0.466
0.340	135	5.848	0.475
0.360	138	6.192	0.484
0.380	143	6.536	0.500
0.400	143	6.880	0.498
0.420	143	7.224	0.496
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			


Stress Strain Curve

uuLACW-4-3

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay with peat & wood
Type of Failure: Vertical @ 8%
Boring No.: LACW-4-3
Depth (ft): 8.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 836.6

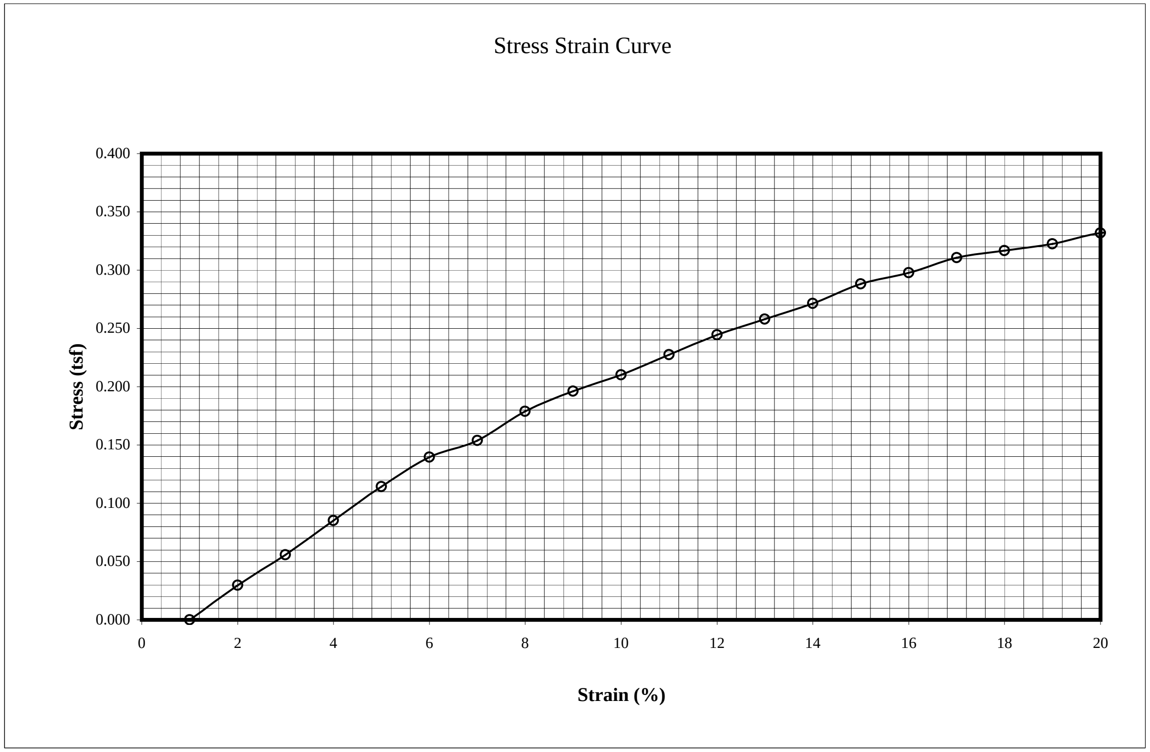
Area (in^2) = 6.492
Moisture Content (%) = 125.09%
Wet Density (pcf) = 84.4
Dry Density (pcf) = 37.5

Wet wt. 105.4
Dry at. 59.13
Can wt. 22.14

Test Data:
Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	8	0.344	0.030
0.040	15	0.688	0.056
0.060	23	1.032	0.085
0.080	31	1.376	0.114
0.100	38	1.720	0.140
0.120	42	2.064	0.154
0.140	49	2.408	0.179
0.160	54	2.752	0.196
0.180	58	3.096	0.210
0.200	63	3.440	0.227
0.220	68	3.784	0.245
0.240	72	4.128	0.258
0.260	76	4.472	0.271
0.280	81	4.816	0.288
0.300	84	5.160	0.298
0.320	88	5.504	0.311
0.340	90	5.848	0.317
0.360	92	6.192	0.323
0.380	95	6.536	0.332
0.400	96	6.880	0.334
0.420	97	7.224	0.336
0.440	98	7.568	0.339
0.460	98	7.912	0.337
0.480	98	8.256	0.336
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay w/fine sand at bottom
Type of Failure: Yield @ 10%
Boring No.: LACS-1-3
Depth (ft): 8.5-10.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1030.8

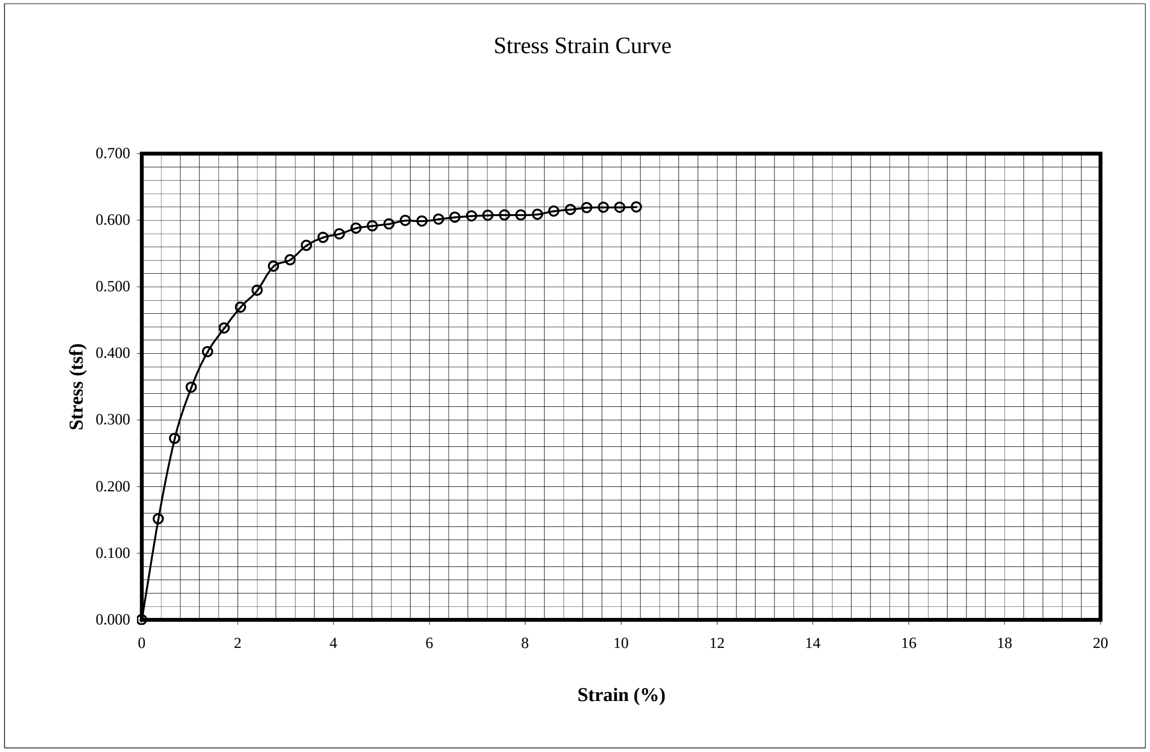
Area (in^2) = 6.492
Moisture Content (%) = 32.46%
Wet Density (pcf) = 104.0
Dry Density (pcf) = 78.5

Wet wt. 223.35
Dry at. 174.08
Can wt. 22.3

Test Data:
Cell Pressure (psi) = 4.2
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	13.7	0.344	0.151
0.040	24.7	0.688	0.272
0.060	31.8	1.032	0.349
0.080	36.8	1.376	0.403
0.100	40.2	1.720	0.438
0.120	43.2	2.064	0.469
0.140	45.7	2.408	0.495
0.160	49.2	2.752	0.531
0.180	50.3	3.096	0.541
0.200	52.5	3.440	0.562
0.220	53.8	3.784	0.574
0.240	54.5	4.128	0.580
0.260	55.5	4.472	0.588
0.280	56.0	4.816	0.591
0.300	56.5	5.160	0.594
0.320	57.2	5.504	0.599
0.340	57.3	5.848	0.598
0.360	57.8	6.192	0.601
0.380	58.3	6.536	0.604
0.400	58.7	6.880	0.606
0.420	59.0	7.224	0.607
0.440	59.3	7.568	0.608
0.460	59.5	7.912	0.608
0.480	59.8	8.256	0.608
0.500	60.5	8.600	0.613
0.520	61.0	8.944	0.616
0.540	61.5	9.288	0.619
0.560	61.8	9.632	0.619
0.580	62.0	9.976	0.619
0.600	62.3	10.320	0.620



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff gray clay
Boring No.: LACS-3-1
Depth (ft): 5-7

Type of Failure: Yield @ 10%

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1160.0

Area (in^2) = 6.492
Moisture Content (%) = 28.06%
Wet Density (pcf) = 117.1
Dry Density (pcf) = 91.4

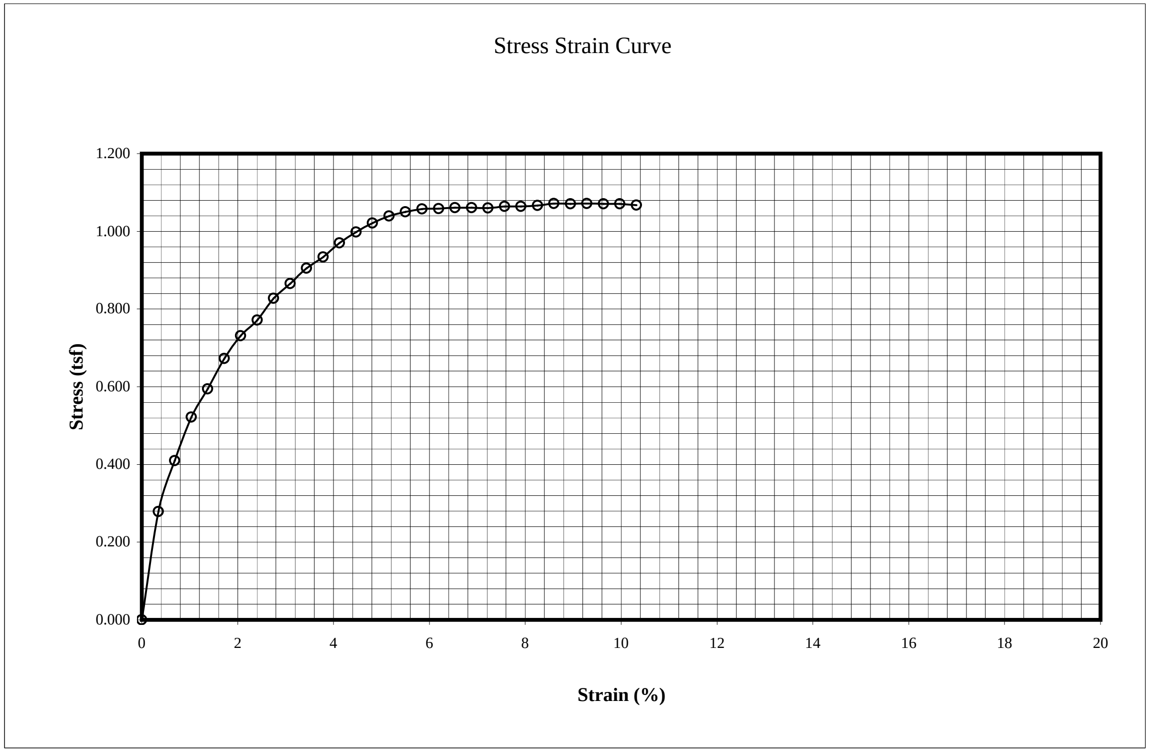
Wet wt. 218.55
Dry at. 177.01
Can wt. 28.96

Test Data:
Cell Pressure (psi) = 3.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	25.2	0.344	0.279
0.040	37.2	0.688	0.410
0.060	47.5	1.032	0.521
0.080	54.3	1.376	0.594
0.100	61.7	1.720	0.673
0.120	67.3	2.064	0.731
0.140	71.3	2.408	0.772
0.160	76.7	2.752	0.827
0.180	80.5	3.096	0.865
0.200	84.5	3.440	0.905
0.220	87.5	3.784	0.934
0.240	91.2	4.128	0.970
0.260	94.2	4.472	0.998
0.280	96.7	4.816	1.021
0.300	98.8	5.160	1.039
0.320	100.2	5.504	1.050
0.340	101.3	5.848	1.058
0.360	101.7	6.192	1.058
0.380	102.3	6.536	1.060
0.400	102.7	6.880	1.061
0.420	103.0	7.224	1.060
0.440	103.8	7.568	1.064
0.460	104.2	7.912	1.064
0.480	104.8	8.256	1.066
0.500	105.7	8.600	1.071
0.520	106.0	8.944	1.070
0.540	106.5	9.288	1.071
0.560	106.8	9.632	1.070
0.580	107.2	9.976	1.070
0.600	107.3	10.320	1.067



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray caly
Boring No.: LACS-3-2
Depth (ft): 7.5-9.5

Type of Failure: Bulge @ 8%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 984.9

Area (in^2) = 6.492
Moisture Content (%) = 50.25%
Wet Density (pcf) = 99.4
Dry Density (pcf) = 66.2

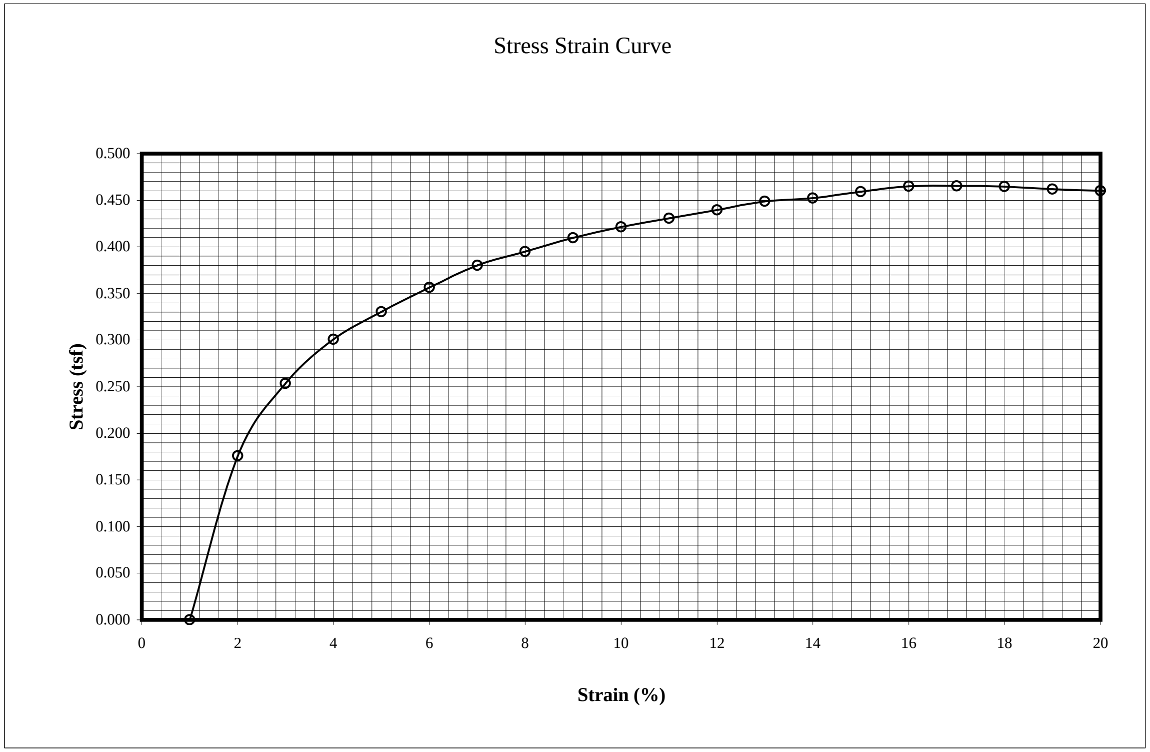
Wet wt. 224.64
Dry at. 158.43
Can wt. 26.67

Test Data:

Cell Pressure (psi) = 5.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	15.9	0.344	0.176
0.040	23.0	0.688	0.253
0.060	27.4	1.032	0.301
0.080	30.2	1.376	0.330
0.100	32.7	1.720	0.356
0.120	35.0	2.064	0.380
0.140	36.5	2.408	0.395
0.160	38.0	2.752	0.410
0.180	39.2	3.096	0.421
0.200	40.2	3.440	0.431
0.220	41.2	3.784	0.440
0.240	42.2	4.128	0.449
0.260	42.7	4.472	0.452
0.280	43.5	4.816	0.459
0.300	44.2	5.160	0.465
0.320	44.4	5.504	0.465
0.340	44.5	5.848	0.465
0.360	44.4	6.192	0.462
0.380	44.4	6.536	0.460
0.400	44.4	6.880	0.459
0.420	44.4	7.224	0.457
0.440	44.0	7.568	0.451
0.460	43.5	7.912	0.444
0.480	43.2	8.256	0.440
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay
Type of Failure: Yield @ 10%
Boring No.: IHNCS-1-1
Depth (ft): 7.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1009.3

Area (in^2) = 6.492
Moisture Content (%) = 62.77%
Wet Density (pcf) = 102.1
Dry Density (pcf) = 62.7

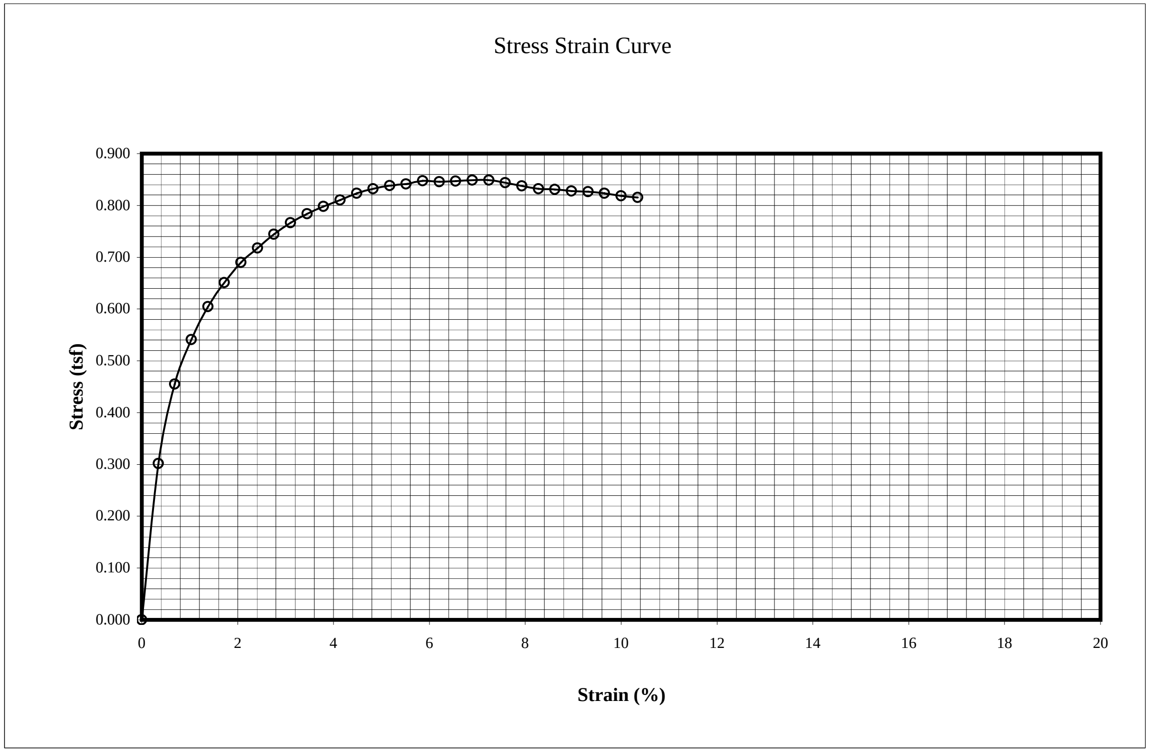
Wet wt. 98.15
Dry at. 70.36
Can wt. 26.09

Test Data:
Cell Pressure (psi) = 4.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	27.3	0.345	0.302
0.040	41.3	0.690	0.455
0.060	49.3	1.034	0.541
0.080	55.3	1.379	0.605
0.100	59.7	1.724	0.651
0.120	63.5	2.069	0.690
0.140	66.3	2.414	0.718
0.160	69.0	2.759	0.744
0.180	71.3	3.103	0.766
0.200	73.2	3.448	0.784
0.220	74.8	3.793	0.798
0.240	76.2	4.138	0.810
0.260	77.7	4.483	0.823
0.280	78.8	4.828	0.832
0.300	79.7	5.172	0.838
0.320	80.3	5.517	0.841
0.340	81.2	5.862	0.848
0.360	81.3	6.207	0.846
0.380	81.7	6.552	0.847
0.400	82.2	6.897	0.849
0.420	82.5	7.241	0.849
0.440	82.3	7.586	0.843
0.460	82.0	7.931	0.837
0.480	81.8	8.276	0.832
0.500	82.0	8.621	0.831
0.520	82.0	8.966	0.828
0.540	82.2	9.310	0.827
0.560	82.2	9.655	0.824
0.580	82.0	10.000	0.818
0.600	82.0	10.345	0.815



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/wood
Boring No.: IHNCS-1-3
Depth (ft): 12-13

Type of Failure: Yield @ 10%

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 890.0

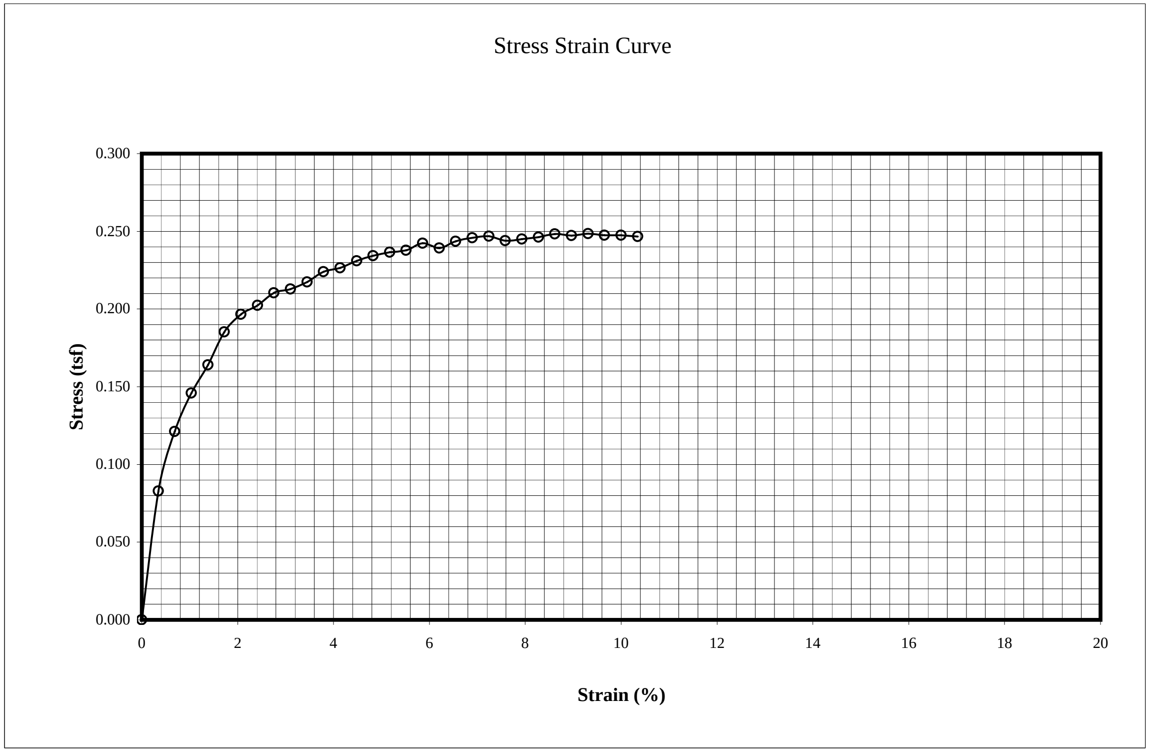
Area (in^2) = 6.492
Moisture Content (%) = 94.94%
Wet Density (pcf) = 90.0
Dry Density (pcf) = 46.2

Wet wt. 124.85
Dry at. 74.21
Can wt. 20.87

Test Data:
Cell Pressure (psi) = 7.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	7.5	0.345	0.083
0.040	11.0	0.690	0.121
0.060	13.3	1.034	0.146
0.080	15.0	1.379	0.164
0.100	17.0	1.724	0.185
0.120	18.1	2.069	0.197
0.140	18.7	2.414	0.202
0.160	19.5	2.759	0.210
0.180	19.8	3.103	0.213
0.200	20.3	3.448	0.217
0.220	21.0	3.793	0.224
0.240	21.3	4.138	0.226
0.260	21.8	4.483	0.231
0.280	22.2	4.828	0.234
0.300	22.5	5.172	0.237
0.320	22.7	5.517	0.238
0.340	23.2	5.862	0.242
0.360	23.0	6.207	0.239
0.380	23.5	6.552	0.244
0.400	23.8	6.897	0.246
0.420	24.0	7.241	0.247
0.440	23.8	7.586	0.244
0.460	24.0	7.931	0.245
0.480	24.2	8.276	0.246
0.500	24.5	8.621	0.248
0.520	24.5	8.966	0.247
0.540	24.7	9.310	0.248
0.560	24.7	9.655	0.247
0.580	24.8	10.000	0.248
0.600	24.8	10.345	0.247



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/wood
Type of Failure: Yield @ 10%
Boring No.: IHNCS-1-3
Depth (ft): 13-14

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 847.5

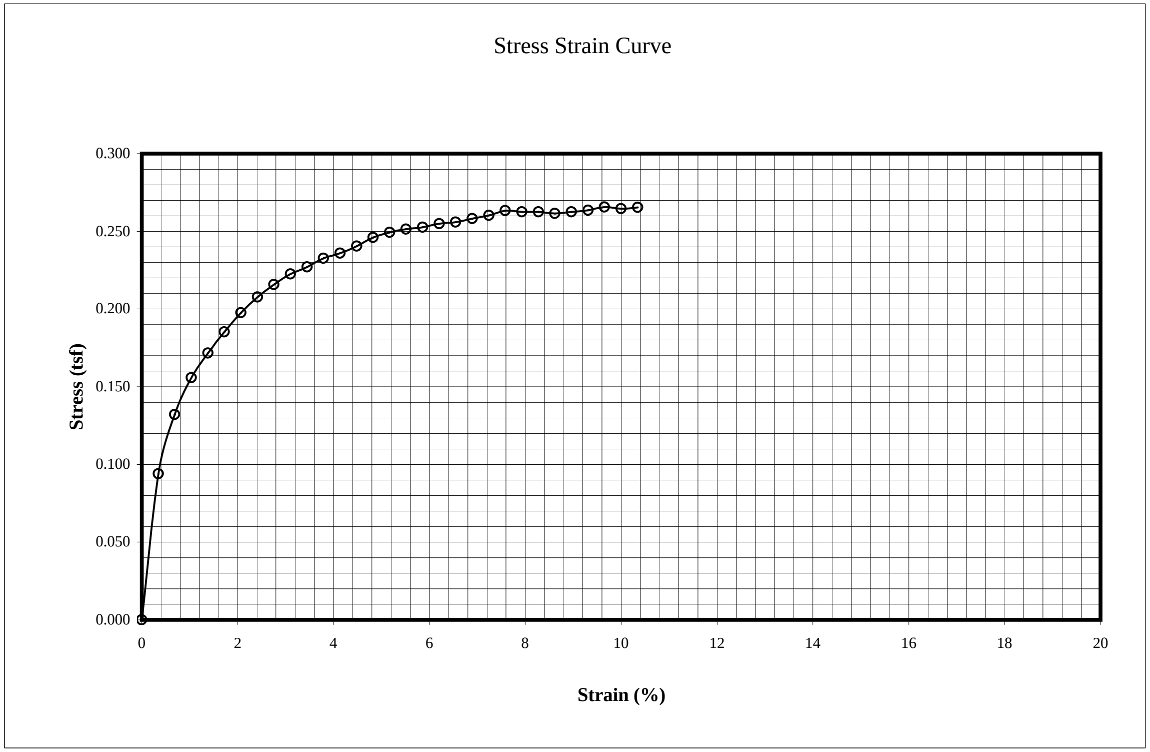
Area (in^2) = 6.492
Moisture Content (%) = 94.48%
Wet Density (pcf) = 85.7
Dry Density (pcf) = 44.1

Wet wt. 130.39
Dry at. 77.82
Can wt. 22.18

Test Data:
Cell Pressure (psi) = 8.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	8.5	0.345	0.094
0.040	12.0	0.690	0.132
0.060	14.2	1.034	0.156
0.080	15.7	1.379	0.172
0.100	17.0	1.724	0.185
0.120	18.2	2.069	0.198
0.140	19.2	2.414	0.208
0.160	20.0	2.759	0.216
0.180	20.7	3.103	0.222
0.200	21.2	3.448	0.227
0.220	21.8	3.793	0.233
0.240	22.2	4.138	0.236
0.260	22.7	4.483	0.240
0.280	23.3	4.828	0.246
0.300	23.7	5.172	0.249
0.320	24.0	5.517	0.251
0.340	24.2	5.862	0.253
0.360	24.5	6.207	0.255
0.380	24.7	6.552	0.256
0.400	25.0	6.897	0.258
0.420	25.3	7.241	0.260
0.440	25.7	7.586	0.263
0.460	25.7	7.931	0.262
0.480	25.8	8.276	0.262
0.500	25.8	8.621	0.261
0.520	26.0	8.966	0.262
0.540	26.2	9.310	0.264
0.560	26.5	9.655	0.266
0.580	26.5	10.000	0.264
0.600	26.7	10.345	0.265



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay w/peat
Type of Failure: Yield @ 10%
Boring No.: IHNCS-3-2
Depth (ft): 11.5-12.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 950.1

Area (in^2) = 6.492
Moisture Content (%) = 78.30%
Wet Density (pcf) = 96.1
Dry Density (pcf) = 53.9

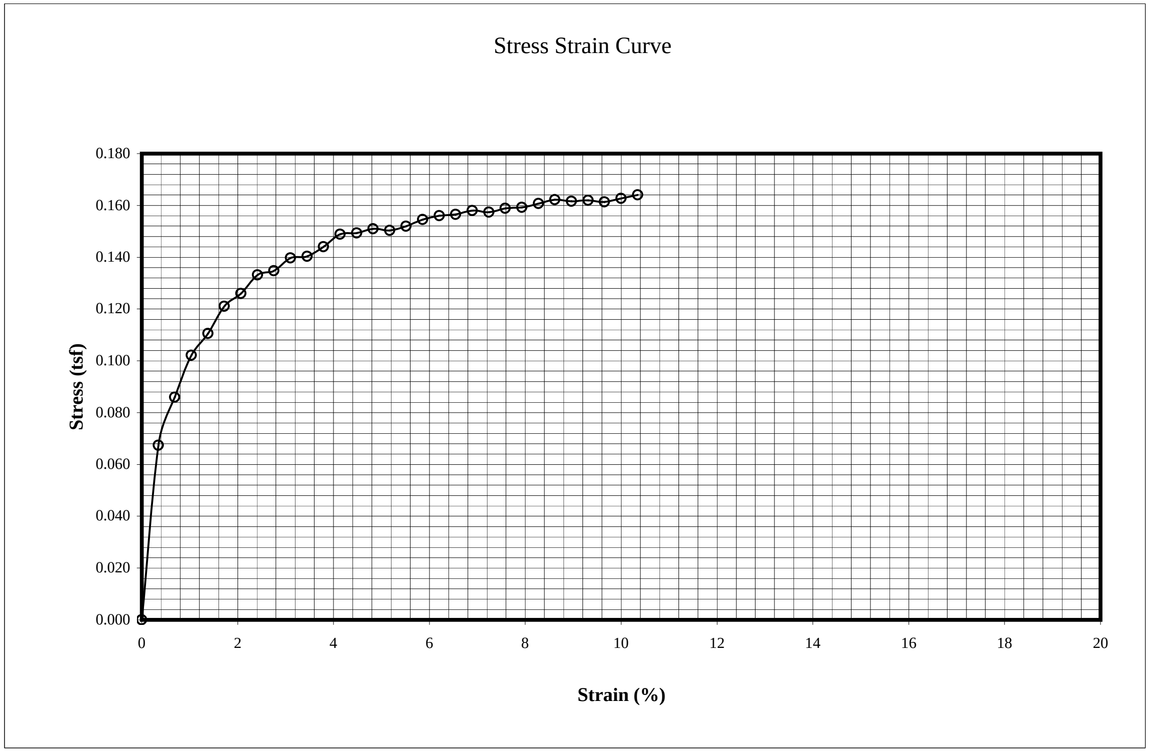
Wet wt. 136.01
Dry at. 85.46
Can wt. 20.9

Test Data:
Cell Pressure (psi) = 7.1
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	6.1	0.345	0.067
0.040	7.8	0.690	0.086
0.060	9.3	1.034	0.102
0.080	10.1	1.379	0.110
0.100	11.1	1.724	0.121
0.120	11.6	2.069	0.126
0.140	12.3	2.414	0.133
0.160	12.5	2.759	0.135
0.180	13.0	3.103	0.140
0.200	13.1	3.448	0.140
0.220	13.5	3.793	0.144
0.240	14.0	4.138	0.149
0.260	14.1	4.483	0.149
0.280	14.3	4.828	0.151
0.300	14.3	5.172	0.150
0.320	14.5	5.517	0.152
0.340	14.8	5.862	0.155
0.360	15.0	6.207	0.156
0.380	15.1	6.552	0.156
0.400	15.3	6.897	0.158
0.420	15.3	7.241	0.157
0.440	15.5	7.586	0.159
0.460	15.6	7.931	0.159
0.480	15.8	8.276	0.161
0.500	16.0	8.621	0.162
0.520	16.0	8.966	0.162
0.540	16.1	9.310	0.162
0.560	16.1	9.655	0.161
0.580	16.3	10.000	0.163
0.600	16.5	10.345	0.164



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @ 10%
Boring No.: IHNCS-3-2
Depth (ft): 12.5-13.5

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1001.6

Area (in^2) = 6.492
Moisture Content (%) = 57.18%
Wet Density (pcf) = 101.3

Dry Density (pcf) = 64.5

Wet wt. 133.27
Dry at. 95.32
Can wt. 28.95

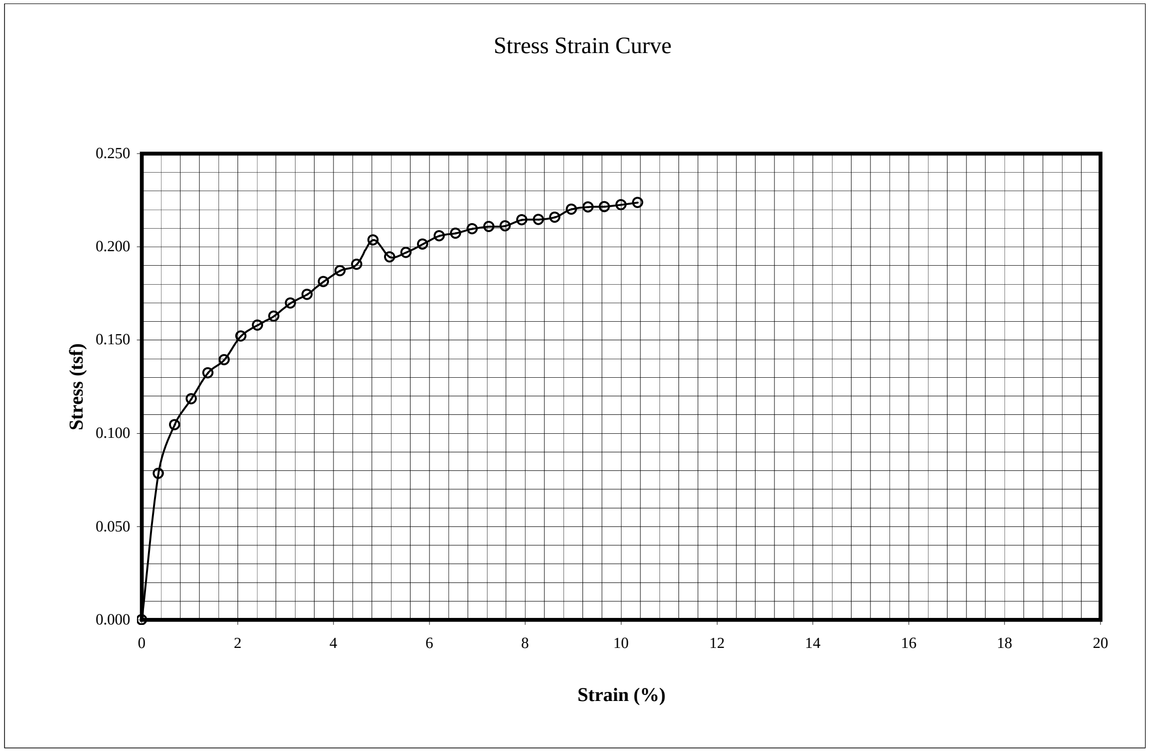
Test Data:

Cell Pressure (psi) = 7.7
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	7.1	0.345	0.078
0.040	9.5	0.690	0.105
0.060	10.8	1.034	0.119
0.080	12.1	1.379	0.132
0.100	12.8	1.724	0.140
0.120	14.0	2.069	0.152
0.140	14.6	2.414	0.158
0.160	15.1	2.759	0.163
0.180	15.8	3.103	0.170
0.200	16.3	3.448	0.175
0.220	17.0	3.793	0.181
0.240	17.6	4.138	0.187
0.260	18.0	4.483	0.191
0.280	19.3	4.828	0.204
0.300	18.5	5.172	0.195
0.320	18.8	5.517	0.197
0.340	19.3	5.862	0.201
0.360	19.8	6.207	0.206
0.380	20.0	6.552	0.207
0.400	20.3	6.897	0.210
0.420	20.5	7.241	0.211
0.440	20.6	7.586	0.211
0.460	21.0	7.931	0.214
0.480	21.1	8.276	0.215
0.500	21.3	8.621	0.216
0.520	21.8	8.966	0.220
0.540	22.0	9.310	0.221
0.560	22.1	9.655	0.221
0.580	22.3	10.000	0.223
0.600	22.5	10.345	0.224



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray & dark gray clay w/peat
Type of Failure: Yield @ 10%
Boring No.: IHNCN-1-3
Depth (ft): 10-12

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 962.5

Area (in^2) = 6.492
Moisture Content (%) = 67.92%
Wet Density (pcf) = 97.6
Dry Density (pcf) = 58.1

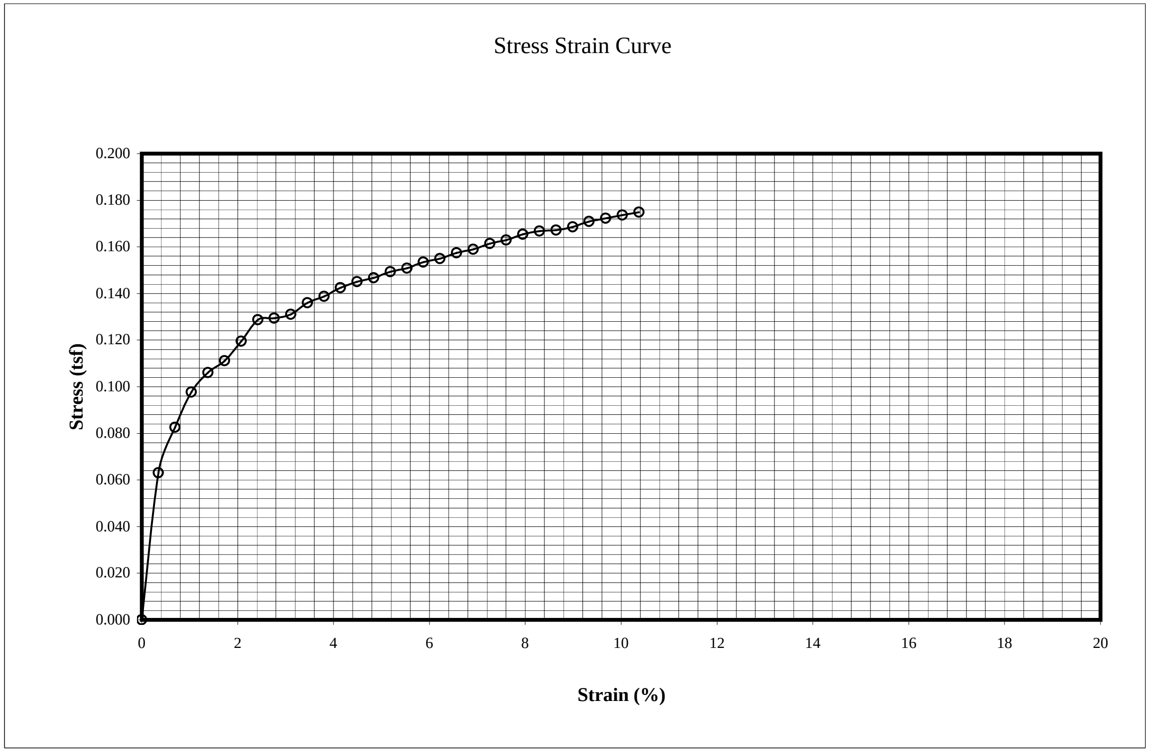
Wet wt. 182.11
Dry at. 119.39
Can wt. 27.05

Test Data:
Cell Pressure (psi) = 6.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	5.7	0.346	0.063
0.040	7.5	0.691	0.083
0.060	8.9	1.037	0.098
0.080	9.7	1.383	0.106
0.100	10.2	1.729	0.111
0.120	11.0	2.074	0.119
0.140	11.9	2.420	0.129
0.160	12.0	2.766	0.129
0.180	12.2	3.111	0.131
0.200	12.7	3.457	0.136
0.220	13.0	3.803	0.139
0.240	13.4	4.149	0.142
0.260	13.7	4.494	0.145
0.280	13.9	4.840	0.147
0.300	14.2	5.186	0.149
0.320	14.4	5.532	0.151
0.340	14.7	5.877	0.153
0.360	14.9	6.223	0.155
0.380	15.2	6.569	0.157
0.400	15.4	6.914	0.159
0.420	15.7	7.260	0.161
0.440	15.9	7.606	0.163
0.460	16.2	7.952	0.165
0.480	16.4	8.297	0.167
0.500	16.5	8.643	0.167
0.520	16.7	8.989	0.169
0.540	17.0	9.334	0.171
0.560	17.2	9.680	0.172
0.580	17.4	10.026	0.174
0.600	17.6	10.372	0.175



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff brown slightly silty clay w/stone and gravel
Boring No.: 17-2-1
Depth (ft): 1-3

Type of Failure: Multi @ 8%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1212.8

Area (in^2) = 6.492
Moisture Content (%) = 21.66%
Wet Density (pcf) = 122.7
Dry Density (pcf) = 100.9

Wet wt. 173.86
Dry at. 148.06
Can wt. 28.96

Test Data:

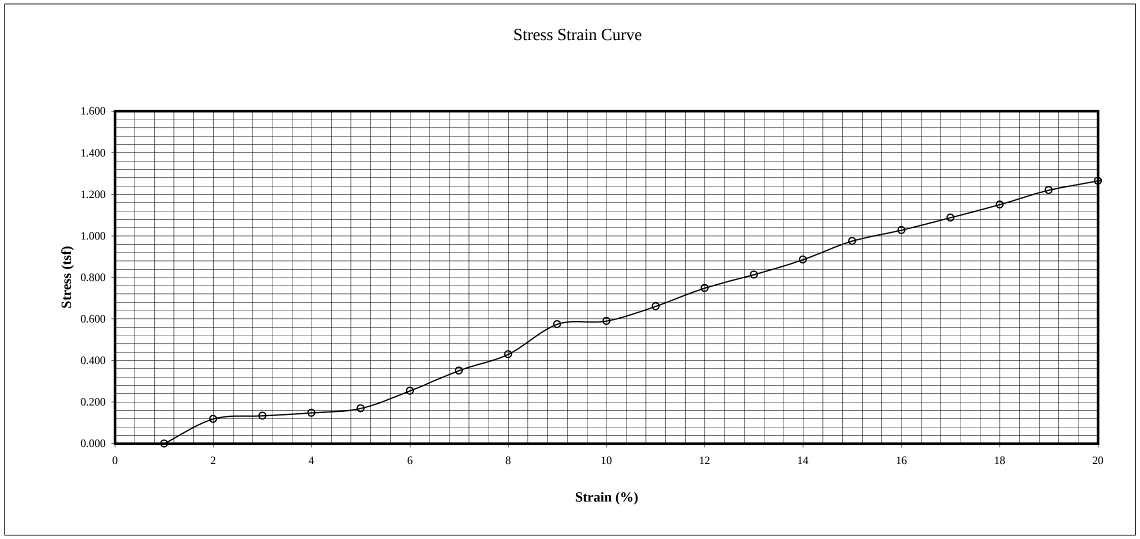
Cell Pressure (psi) = 0.0
Height Correction = 1.000
Proving Ring No.= 9839

0.337

2.197729025

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	32	0.345	0.119
0.040	36	0.690	0.134
0.060	40	1.034	0.148
0.080	46	1.379	0.170
0.100	69	1.724	0.253
0.120	96	2.069	0.351
0.140	118	2.414	0.430
0.160	158	2.759	0.574
0.180	163	3.103	0.590
0.200	183	3.448	0.660
0.220	208	3.793	0.748
0.240	227	4.138	0.813
0.260	248	4.483	0.885
0.280	274	4.828	0.975
0.300	290	5.172	1.028
0.320	308	5.517	1.088
0.340	327	5.862	1.150
0.360	348	6.207	1.220
0.380	362	6.552	1.264
0.400	378	6.897	1.315
0.420	393	7.241	1.362
0.440	406	7.586	1.402
0.460	416	7.931	1.431
0.480	423	8.276	1.450
0.500	428	8.621	1.462
0.520	428	8.966	1.456
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Still dark gray organic clay to gray & tan clay w/1/2-1" silt layer
Type of Failure: Yield @ 10%
Boring No.: 17-2-2
Depth (ft): 4-6 top

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1046.9

Area (in^2) = 6.492
Moisture Content (%) = 40.88%
Wet Density (pcf) = 105.7
Dry Density (pcf) = 75.0

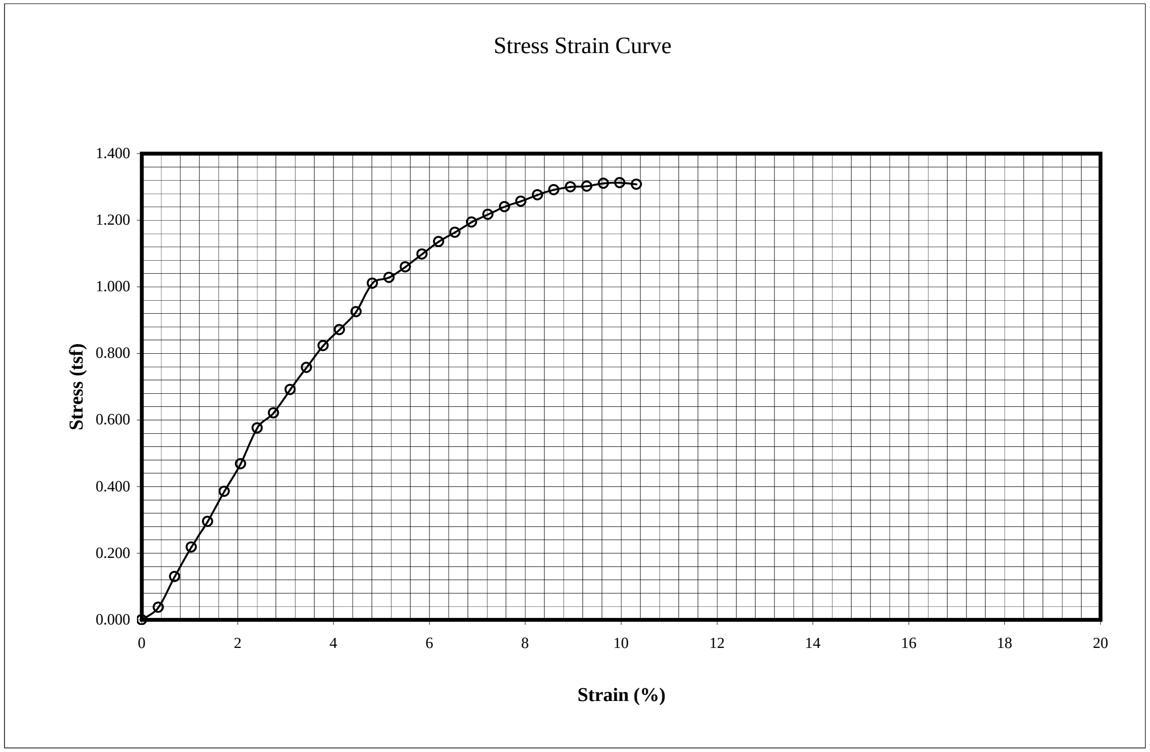
Wet wt. 130.16
Dry at. 98.84
Can wt. 22.22

Test Data:
Cell Pressure (psi) = 0.0
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	10	0.344	0.037
0.040	35	0.688	0.130
0.060	59	1.032	0.218
0.080	80	1.376	0.295
0.100	105	1.720	0.386
0.120	128	2.064	0.469
0.140	158	2.408	0.576
0.160	171	2.752	0.622
0.180	191	3.096	0.692
0.200	210	3.440	0.758
0.220	229	3.784	0.824
0.240	243	4.128	0.871
0.260	259	4.472	0.925
0.280	284	4.816	1.010
0.300	290	5.160	1.028
0.320	300	5.504	1.060
0.340	312	5.848	1.098
0.360	324	6.192	1.136
0.380	333	6.536	1.163
0.400	343	6.880	1.194
0.420	351	7.224	1.217
0.440	359	7.568	1.240
0.460	365	7.912	1.256
0.480	372	8.256	1.276
0.500	378	8.600	1.291
0.520	382	8.944	1.300
0.540	384	9.288	1.302
0.560	388	9.632	1.311
0.580	390	9.976	1.312
0.600	390	10.320	1.307



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STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay w/ silt seams and layers 1/2-1"
Type of Failure: Multi @ 6.5%
Boring No.: 17-2-2
Depth (ft): 4-6 bot

Sample Data:
Diameter (in.) = 2.875
Height (in) = 4.0
Weight (gm) = 768.9

Area (in^2) = 6.492
Moisture Content (%) = 27.14%
Wet Density (pcf) = 112.8
Dry Density (pcf) = 88.7

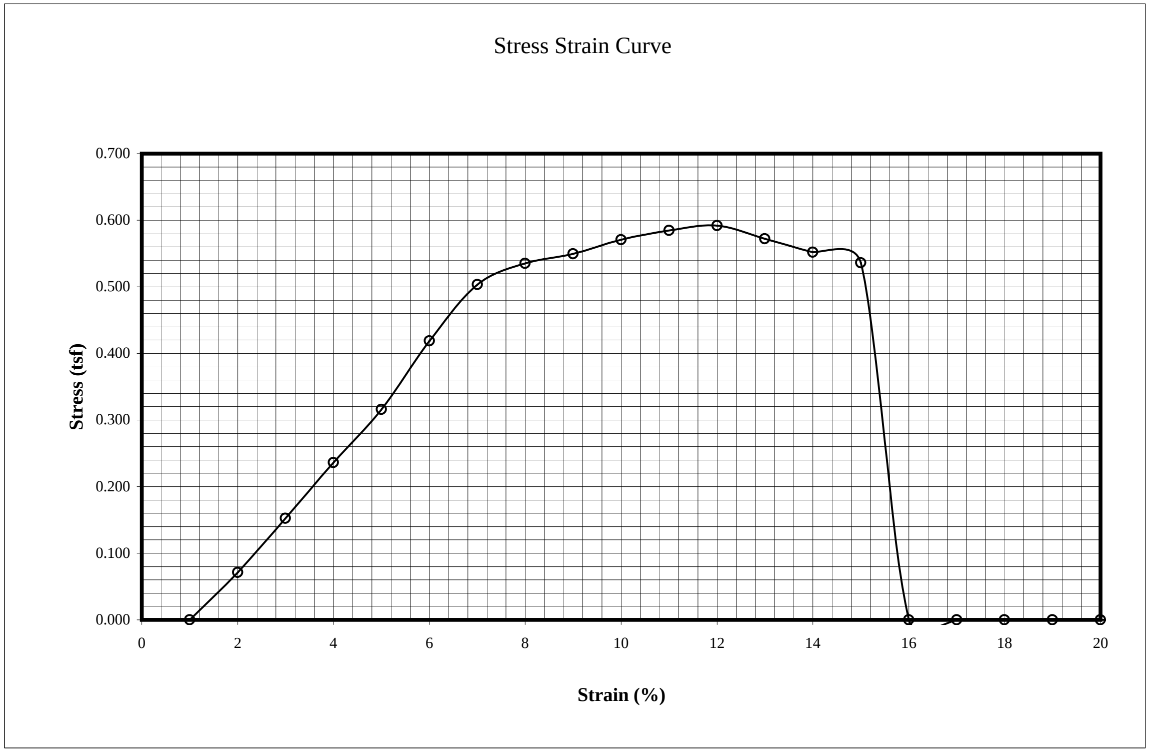
Wet wt. 196.48
Dry at. 160.31
Can wt. 27.02

Test Data:
Cell Pressure (psi) = 0.0
Height Correction = 0.957
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	20	0.500	0.071
0.040	43	1.000	0.152
0.060	67	1.500	0.236
0.080	90	2.000	0.316
0.100	120	2.500	0.419
0.120	145	3.000	0.503
0.140	155	3.500	0.535
0.160	160	4.000	0.550
0.180	167	4.500	0.571
0.200	172	5.000	0.585
0.220	175	5.500	0.592
0.240	170	6.000	0.572
0.260	165	6.500	0.552
0.280	161	7.000	0.536
0.300			
0.320			
0.340			
0.360			
0.380			
0.400			
0.420			
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray clay with silt seams and organics
Type of Failure: Yeild @ 10%
Boring No.: 17-2-3
Depth (ft): 8-10 top

Sample Data:
Diameter (in.) = 2.875
Height (in) = 4.5
Weight (gm) = 711.4

Area (in^2) = 6.492
Moisture Content (%) = 47.75%
Wet Density (pcf) = 92.8
Dry Density (pcf) = 62.8

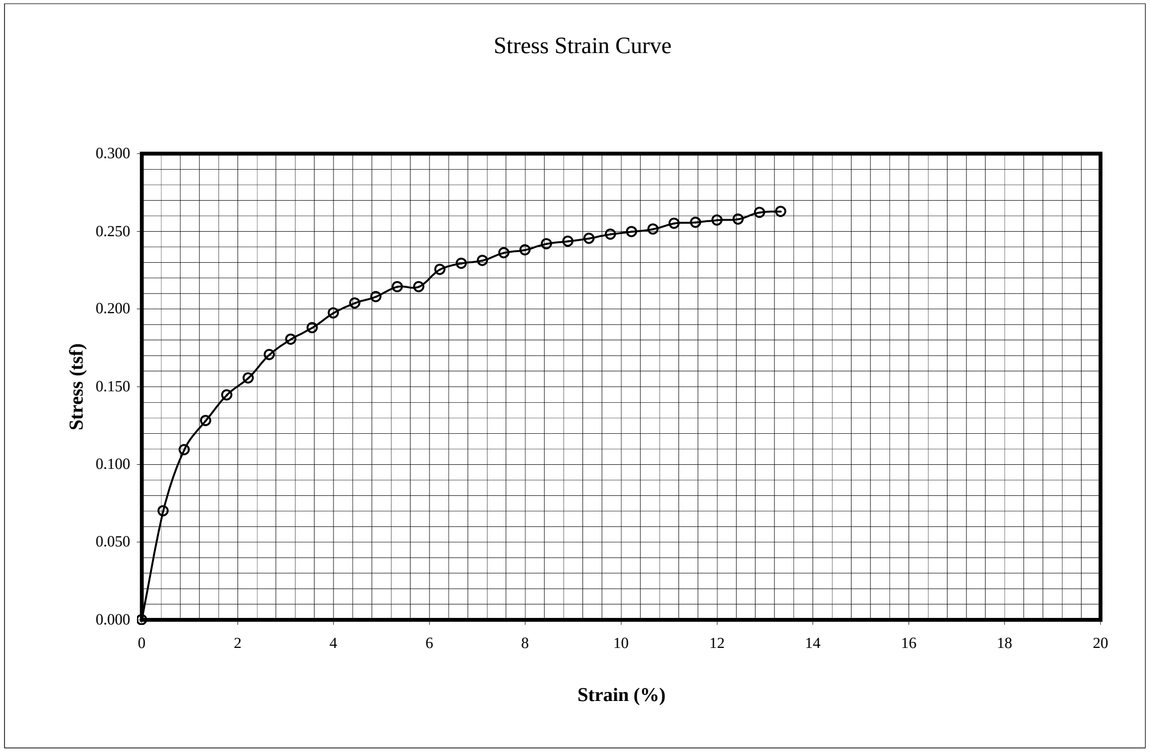
Wet wt. 111.12
Dry at. 83.88
Can wt. 26.83

Test Data:
Cell Pressure (psi) = 4.1
Height Correction = 0.976
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	6.5	0.444	0.070
0.040	10.2	0.889	0.109
0.060	12.0	1.333	0.128
0.080	13.6	1.778	0.145
0.100	14.7	2.222	0.156
0.120	16.2	2.667	0.171
0.140	17.2	3.111	0.180
0.160	18.0	3.556	0.188
0.180	19.0	4.000	0.197
0.200	19.7	4.444	0.204
0.220	20.2	4.889	0.208
0.240	20.9	5.333	0.214
0.260	21.0	5.778	0.214
0.280	22.2	6.222	0.225
0.300	22.7	6.667	0.229
0.320	23.0	7.111	0.231
0.340	23.6	7.556	0.236
0.360	23.9	8.000	0.238
0.380	24.4	8.444	0.242
0.400	24.7	8.889	0.244
0.420	25.0	9.333	0.245
0.440	25.4	9.778	0.248
0.460	25.7	10.222	0.250
0.480	26.0	10.667	0.251
0.500	26.5	11.111	0.255
0.520	26.7	11.556	0.256
0.540	27.0	12.000	0.257
0.560	27.2	12.444	0.258
0.580	27.8	12.889	0.262
0.600	28.0	13.333	0.263



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STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray clay with silt seams and organics
Type of Failure: Yeild @ 10%
Boring No.: 17-2-3
Depth (ft): 8-10 bot

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1034.3

Area (in^2) = 6.492
Moisture Content (%) = 47.75%
Wet Density (pcf) = 104.4
Dry Density (pcf) = 70.7

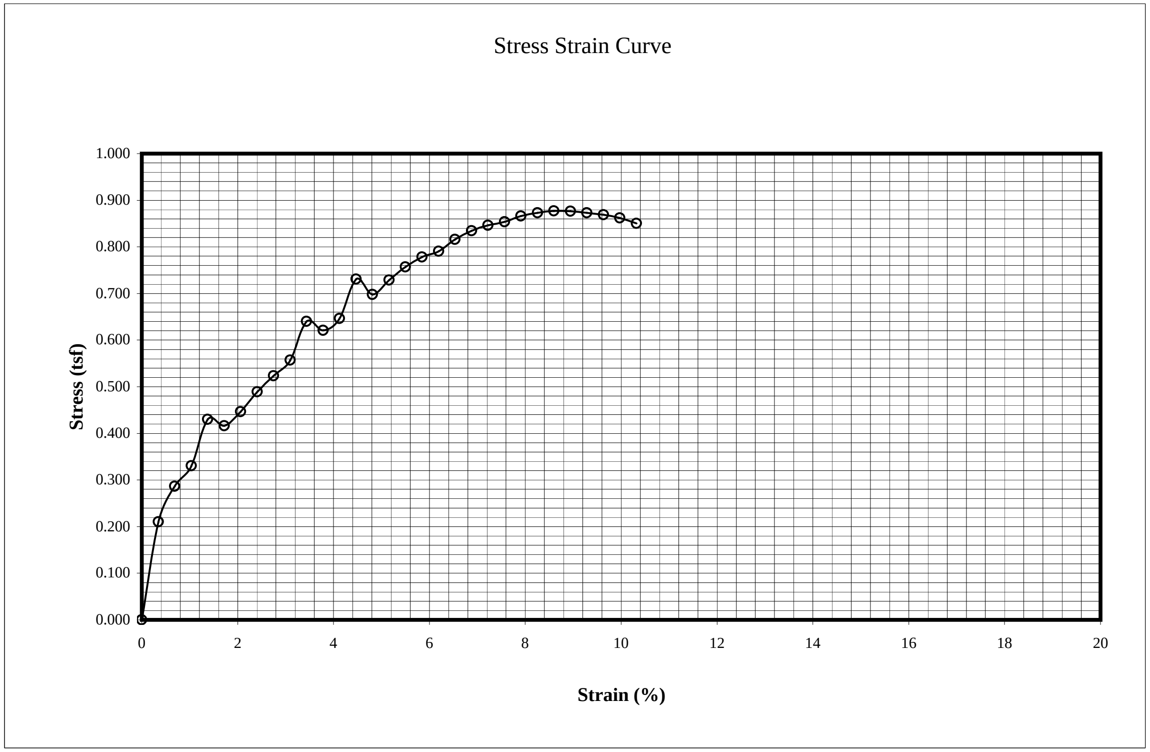
Wet wt. 134.9
Dry at. 98.05
Can wt. 20.87

Test Data:
Cell Pressure (psi) = 4.1
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	19.0	0.344	0.210
0.040	26.0	0.688	0.286
0.060	30.1	1.032	0.330
0.080	39.3	1.376	0.430
0.100	38.2	1.720	0.416
0.120	41.1	2.064	0.446
0.140	45.2	2.408	0.489
0.160	48.5	2.752	0.523
0.180	51.8	3.096	0.557
0.200	59.8	3.440	0.640
0.220	58.2	3.784	0.621
0.240	60.8	4.128	0.646
0.260	69.0	4.472	0.731
0.280	66.1	4.816	0.698
0.300	69.3	5.160	0.729
0.320	72.2	5.504	0.757
0.340	74.5	5.848	0.778
0.360	76.0	6.192	0.791
0.380	78.7	6.536	0.816
0.400	80.8	6.880	0.834
0.420	82.2	7.224	0.846
0.440	83.3	7.568	0.854
0.460	84.8	7.912	0.866
0.480	85.8	8.256	0.873
0.500	86.5	8.600	0.877
0.520	86.8	8.944	0.877
0.540	86.8	9.288	0.873
0.560	86.7	9.632	0.869
0.580	86.3	9.976	0.862
0.600	85.5	10.320	0.850



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium dark gray organic clay w/peat
Type of Failure: Yield @ 10%
Boring No.: 17-2-6
Depth (ft): 17-19

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 702.4

Area (in^2) = 6.492
Moisture Content (%) = 227.16%
Wet Density (pcf) = 70.9
Dry Density (pcf) = 21.7

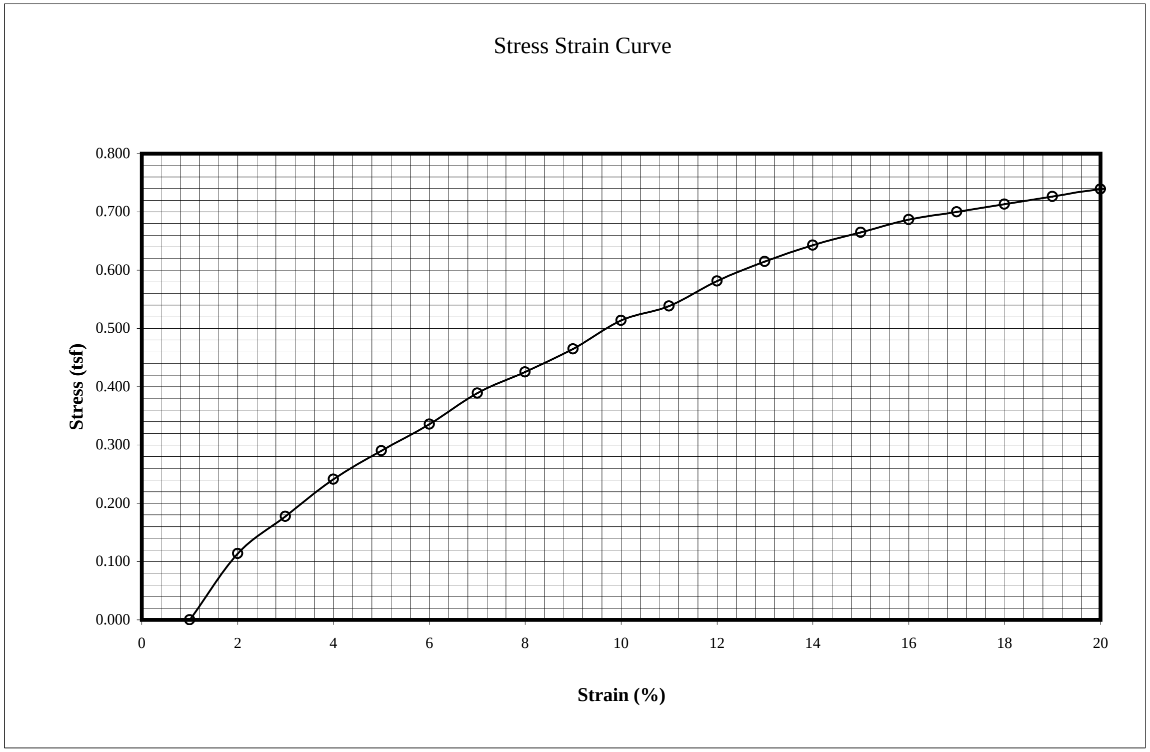
Wet wt. 89.54
Dry at. 41.86
Can wt. 20.87

Test Data:
Cell Pressure (psi) = 10.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	10.3	0.344	0.114
0.040	16.1	0.688	0.177
0.060	22.0	1.032	0.241
0.080	26.5	1.376	0.290
0.100	30.8	1.720	0.336
0.120	35.8	2.064	0.389
0.140	39.3	2.408	0.425
0.160	43.1	2.752	0.465
0.180	47.8	3.096	0.514
0.200	50.3	3.440	0.539
0.220	54.5	3.784	0.582
0.240	57.8	4.128	0.615
0.260	60.7	4.472	0.643
0.280	63.0	4.816	0.665
0.300	65.3	5.160	0.687
0.320	66.8	5.504	0.700
0.340	68.3	5.848	0.713
0.360	69.8	6.192	0.726
0.380	71.3	6.536	0.739
0.400	72.0	6.880	0.744
0.420	72.8	7.224	0.749
0.440	73.3	7.568	0.751
0.460	73.2	7.912	0.748
0.480	71.7	8.256	0.730
0.500	64.8	8.600	0.657
0.520	63.2	8.944	0.638
0.540	62.5	9.288	0.629
0.560	61.8	9.632	0.619
0.580	60.8	9.976	0.607
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray slightly silty clay
Type of Failure: Yield @10%
Boring No.: 17-2-7
Depth (ft): 19.5-21.5

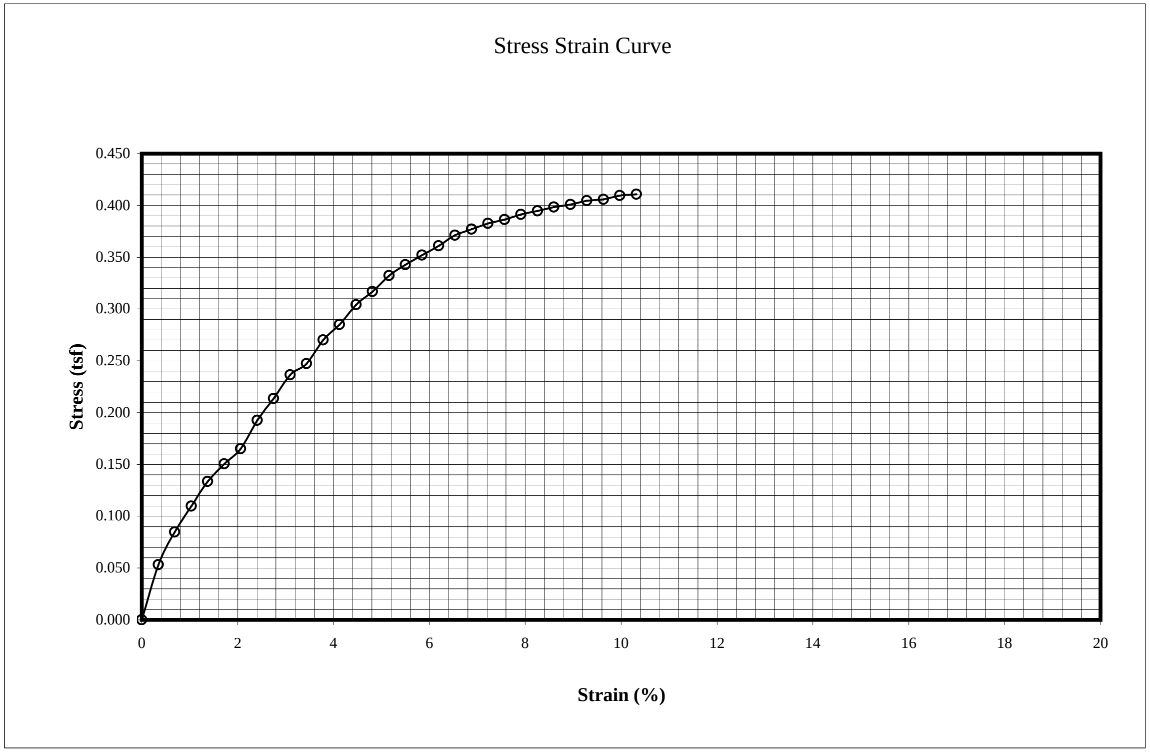
Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1123.3
Area (in^2) = 6.492
Moisture Content (%) = 38.34%
Wet Density (pcf) = 113.4
Dry Density (pcf) = 82.0

Wet wt. 139.84
Dry at. 108.02
Can wt. 25.02

Test Data:
Cell Pressure (psi) = 11.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	4.8	0.344	0.053
0.040	7.7	0.688	0.085
0.060	10.0	1.032	0.110
0.080	12.2	1.376	0.133
0.100	13.8	1.720	0.150
0.120	15.2	2.064	0.165
0.140	17.8	2.408	0.193
0.160	19.8	2.752	0.214
0.180	22.0	3.096	0.236
0.200	23.1	3.440	0.247
0.220	25.3	3.784	0.270
0.240	26.8	4.128	0.285
0.260	28.7	4.472	0.304
0.280	30.0	4.816	0.317
0.300	31.6	5.160	0.332
0.320	32.7	5.504	0.343
0.340	33.7	5.848	0.352
0.360	34.7	6.192	0.361
0.380	35.8	6.536	0.371
0.400	36.5	6.880	0.377
0.420	37.2	7.224	0.383
0.440	37.7	7.568	0.386
0.460	38.3	7.912	0.391
0.480	38.8	8.256	0.395
0.500	39.3	8.600	0.398
0.520	39.7	8.944	0.401
0.540	40.2	9.288	0.404
0.560	40.5	9.632	0.406
0.580	41.0	9.976	0.409
0.600	41.3	10.320	0.411



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/alt. Layers of fine sand & silt
Type of Failure: Yield @10%
Boring No.: 17-2-8
Depth (ft): 24-26

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 980.3

Area (in^2) = 6.492
Moisture Content (%) = 58.43%
Wet Density (pcf) = 98.9
Dry Density (pcf) = 62.5

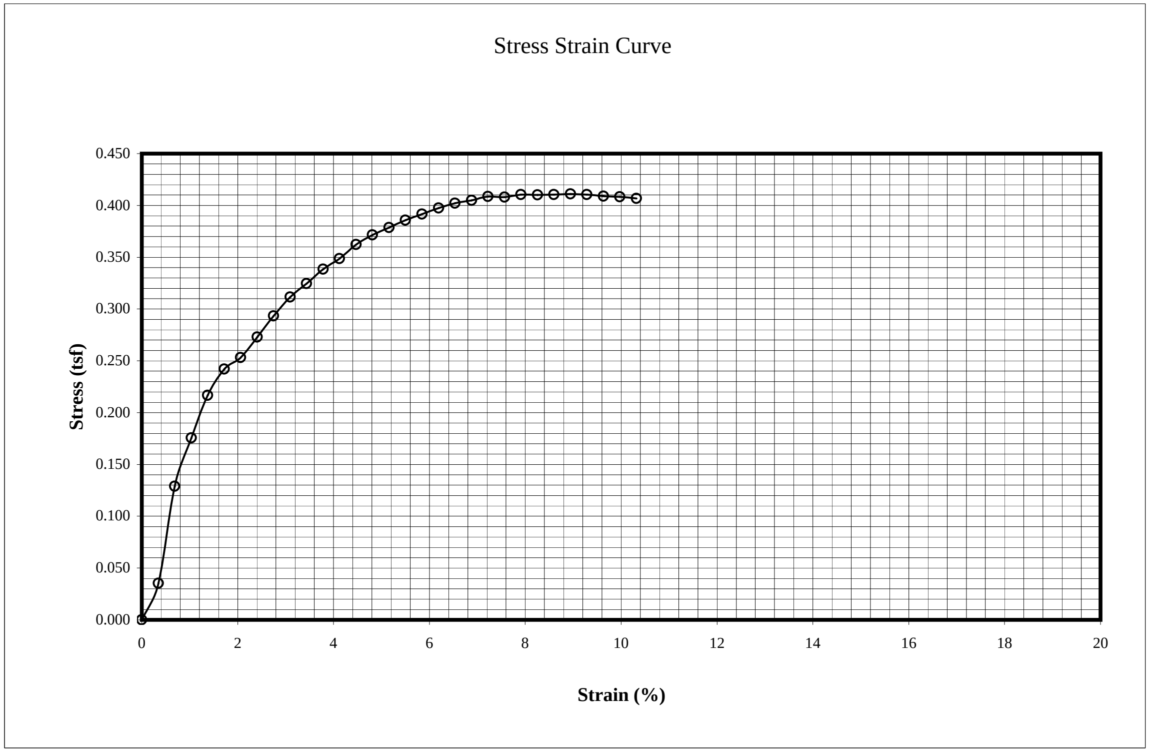
Wet wt. 183.45
Dry at. 123.96
Can wt. 22.14

Test Data:
Cell Pressure (psi) = 14.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.2	0.344	0.035
0.040	11.7	0.688	0.129
0.060	16.0	1.032	0.176
0.080	19.8	1.376	0.217
0.100	22.2	1.720	0.242
0.120	23.3	2.064	0.253
0.140	25.2	2.408	0.273
0.160	27.2	2.752	0.293
0.180	29.0	3.096	0.312
0.200	30.3	3.440	0.324
0.220	31.7	3.784	0.338
0.240	32.8	4.128	0.349
0.260	34.2	4.472	0.362
0.280	35.2	4.816	0.372
0.300	36.0	5.160	0.379
0.320	36.8	5.504	0.386
0.340	37.5	5.848	0.392
0.360	38.2	6.192	0.397
0.380	38.8	6.536	0.402
0.400	39.2	6.880	0.405
0.420	39.7	7.224	0.409
0.440	39.8	7.568	0.408
0.460	40.2	7.912	0.411
0.480	40.3	8.256	0.410
0.500	40.5	8.600	0.411
0.520	40.7	8.944	0.411
0.540	40.8	9.288	0.410
0.560	40.8	9.632	0.409
0.580	40.9	9.976	0.408
0.600	40.9	10.320	0.407



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay with silt seams
Type of Failure: Yellow @10%
Boring No.: 17-2-9
Depth (ft): 30-32

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 952.2

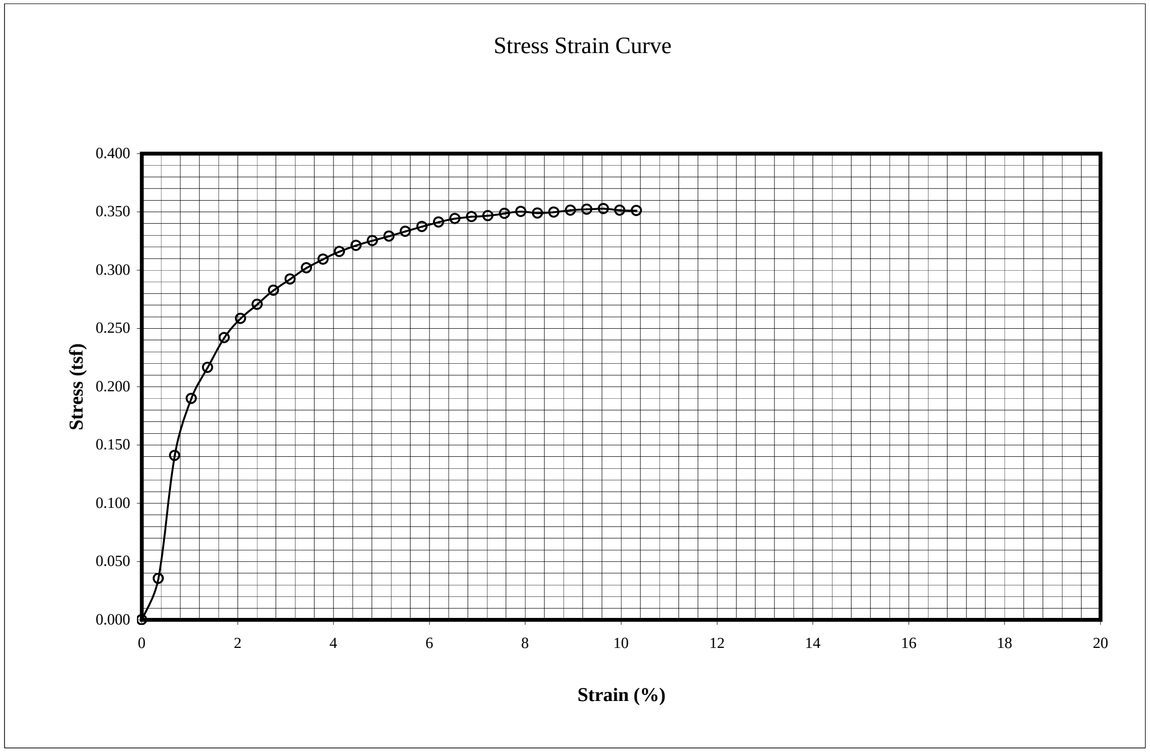
Area (in^2) = 6.492
Moisture Content (%) = 63.12%
Wet Density (pcf) = 96.1
Dry Density (pcf) = 58.9

Wet wt. 165.18
Dry at. 112.45
Can wt. 28.91

Test Data:
Cell Pressure (psi) = 18.2
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.2	0.344	0.035
0.040	12.8	0.688	0.141
0.060	17.3	1.032	0.190
0.080	19.8	1.376	0.217
0.100	22.2	1.720	0.242
0.120	23.8	2.064	0.259
0.140	25.0	2.408	0.271
0.160	26.2	2.752	0.283
0.180	27.2	3.096	0.292
0.200	28.2	3.440	0.302
0.220	29.0	3.784	0.309
0.240	29.7	4.128	0.316
0.260	30.3	4.472	0.321
0.280	30.8	4.816	0.325
0.300	31.3	5.160	0.329
0.320	31.8	5.504	0.333
0.340	32.3	5.848	0.337
0.360	32.8	6.192	0.341
0.380	33.2	6.536	0.344
0.400	33.5	6.880	0.346
0.420	33.7	7.224	0.347
0.440	34.0	7.568	0.349
0.460	34.3	7.912	0.350
0.480	34.3	8.256	0.349
0.500	34.5	8.600	0.350
0.520	34.8	8.944	0.351
0.540	35.0	9.288	0.352
0.560	35.2	9.632	0.353
0.580	35.2	9.976	0.351
0.600	35.3	10.320	0.351



uu17-2-9

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft dark gray to brown peat
Type of Failure: Yield @10%
Boring No.: 17-6A-1
Depth (ft): 5-6

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 662.9

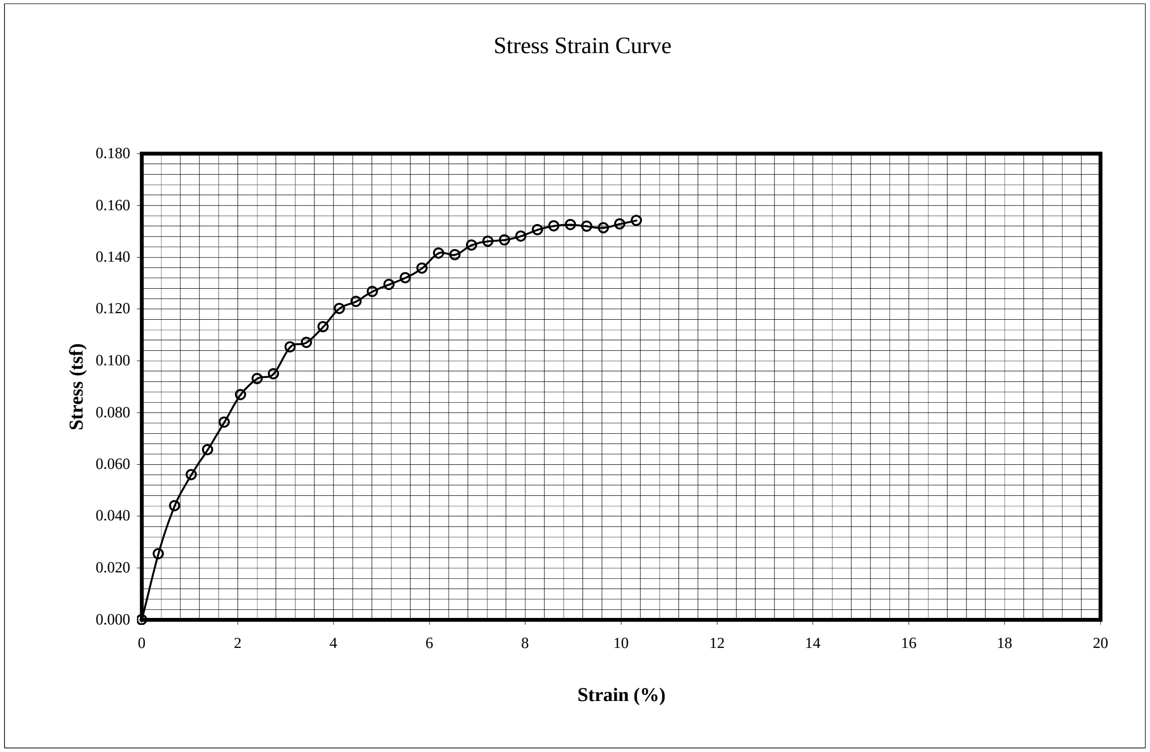
Area (in^2) = 6.492
Moisture Content (%) = 199.32%
Wet Density (pcf) = 66.9
Dry Density (pcf) = 22.4

Wet wt. 141.12
Dry at. 65.16
Can wt. 27.05

Test Data:
Cell Pressure (psi) = 3.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	2.3	0.344	0.025
0.040	4.0	0.688	0.044
0.060	5.1	1.032	0.056
0.080	6.0	1.376	0.066
0.100	7.0	1.720	0.076
0.120	8.0	2.064	0.087
0.140	8.6	2.408	0.093
0.160	8.8	2.752	0.095
0.180	9.8	3.096	0.105
0.200	10.0	3.440	0.107
0.220	10.6	3.784	0.113
0.240	11.3	4.128	0.120
0.260	11.6	4.472	0.123
0.280	12.0	4.816	0.127
0.300	12.3	5.160	0.129
0.320	12.6	5.504	0.132
0.340	13.0	5.848	0.136
0.360	13.6	6.192	0.141
0.380	13.6	6.536	0.141
0.400	14.0	6.880	0.145
0.420	14.2	7.224	0.146
0.440	14.3	7.568	0.147
0.460	14.5	7.912	0.148
0.480	14.8	8.256	0.151
0.500	15.0	8.600	0.152
0.520	15.1	8.944	0.152
0.540	15.1	9.288	0.152
0.560	15.1	9.632	0.151
0.580	15.3	9.976	0.153
0.600	15.5	10.320	0.154



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @10%
Boring No.: 17-6A-1
Depth (ft): 6-7

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 920.5

Area (in^2) = 6.492
Moisture Content (%) = 99.88%
Wet Density (pcf) = 92.9
Dry Density (pcf) = 46.5

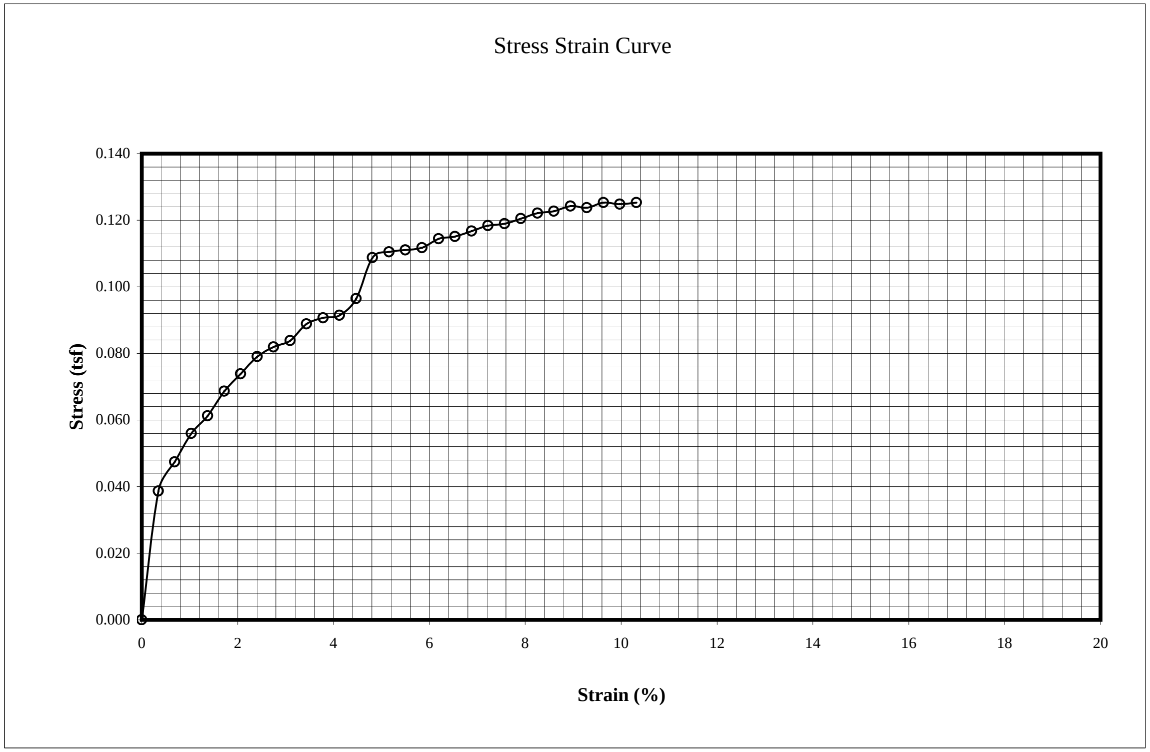
Wet wt. 193.2
Dry at. 110.91
Can wt. 28.52

Test Data:
Cell Pressure (psi) = 3.8
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.5	0.344	0.039
0.040	4.3	0.688	0.047
0.060	5.1	1.032	0.056
0.080	5.6	1.376	0.061
0.100	6.3	1.720	0.069
0.120	6.8	2.064	0.074
0.140	7.3	2.408	0.079
0.160	7.6	2.752	0.082
0.180	7.8	3.096	0.084
0.200	8.3	3.440	0.089
0.220	8.5	3.784	0.091
0.240	8.6	4.128	0.091
0.260	9.1	4.472	0.096
0.280	10.3	4.816	0.109
0.300	10.5	5.160	0.110
0.320	10.6	5.504	0.111
0.340	10.7	5.848	0.112
0.360	11.0	6.192	0.114
0.380	11.1	6.536	0.115
0.400	11.3	6.880	0.117
0.420	11.5	7.224	0.118
0.440	11.6	7.568	0.119
0.460	11.8	7.912	0.121
0.480	12.0	8.256	0.122
0.500	12.1	8.600	0.123
0.520	12.3	8.944	0.124
0.540	12.3	9.288	0.124
0.560	12.5	9.632	0.125
0.580	12.5	9.976	0.125
0.600	12.6	10.320	0.125



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @10%
Boring No.: 17-1-1
Depth (ft): 14.5-15

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 880.0

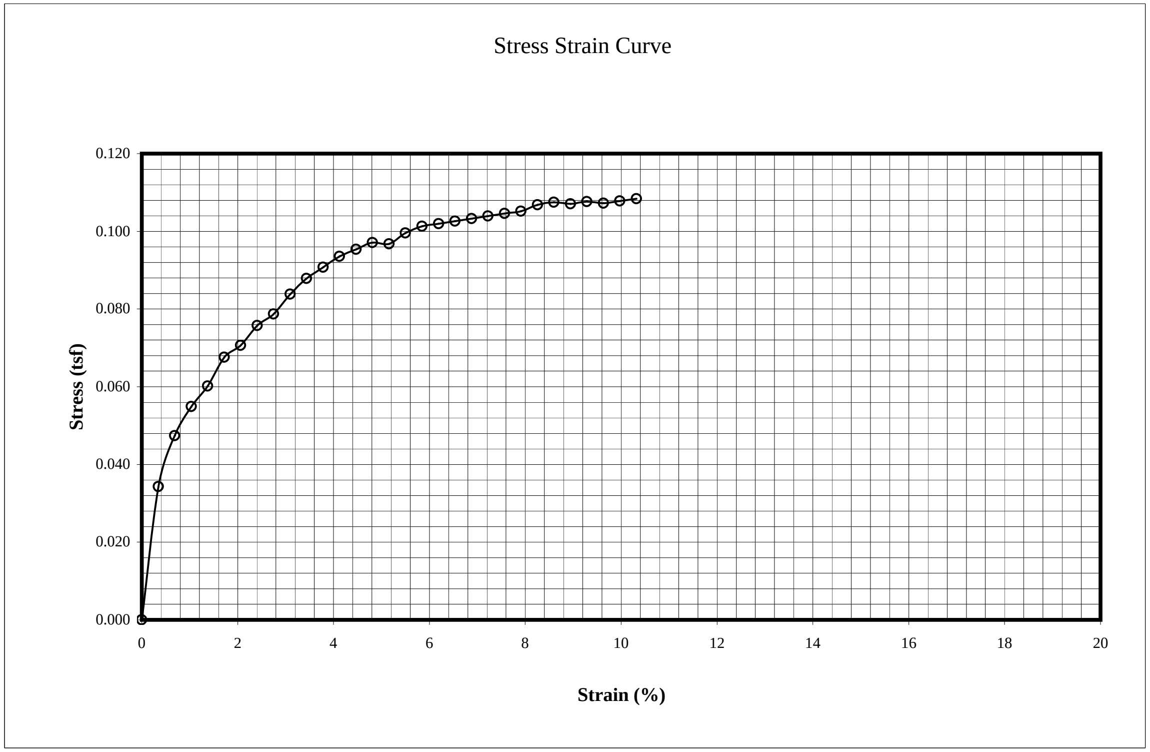
Area (in^2) = 6.492
Moisture Content (%) = 66.96%
Wet Density (pcf) = 88.8
Dry Density (pcf) = 53.2

Wet wt. 212.49
Dry at. 136.12
Can wt. 22.07

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.1	0.344	0.034
0.040	4.3	0.688	0.047
0.060	5.0	1.032	0.055
0.080	5.5	1.376	0.060
0.100	6.2	1.720	0.068
0.120	6.5	2.064	0.071
0.140	7.0	2.408	0.076
0.160	7.3	2.752	0.079
0.180	7.8	3.096	0.084
0.200	8.2	3.440	0.088
0.220	8.5	3.784	0.091
0.240	8.8	4.128	0.094
0.260	9.0	4.472	0.095
0.280	9.2	4.816	0.097
0.300	9.2	5.160	0.097
0.320	9.5	5.504	0.100
0.340	9.7	5.848	0.101
0.360	9.8	6.192	0.102
0.380	9.9	6.536	0.103
0.400	10.0	6.880	0.103
0.420	10.1	7.224	0.104
0.440	10.2	7.568	0.105
0.460	10.3	7.912	0.105
0.480	10.5	8.256	0.107
0.500	10.6	8.600	0.107
0.520	10.6	8.944	0.107
0.540	10.7	9.288	0.108
0.560	10.7	9.632	0.107
0.580	10.8	9.976	0.108
0.600	10.9	10.320	0.108



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with peat
Type of Failure: Yield @10%
Boring No.: 17-1-1
Depth (ft): 15 .5-16

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 899.1

Area (in^2) = 6.492
Moisture Content (%) = 67.91%
Wet Density (pcf) = 90.8
Dry Density (pcf) = 54.0

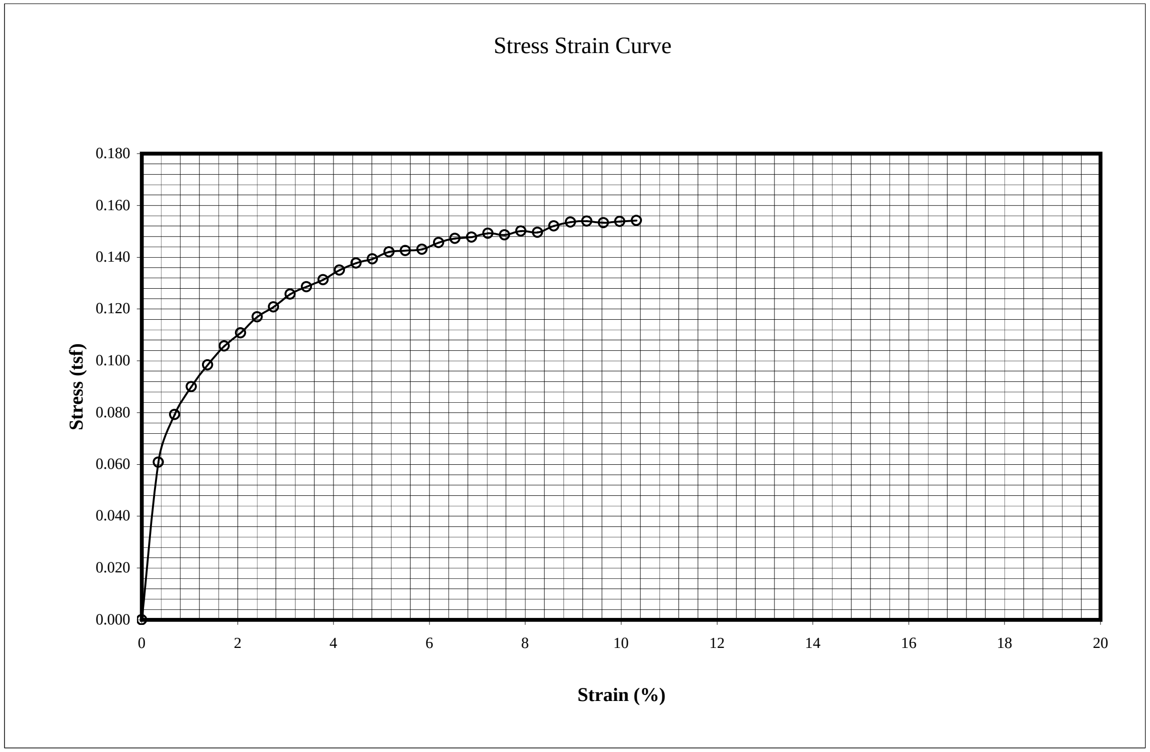
Wet wt. 240.13
Dry at. 154.52
Can wt. 28.46

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	5.5	0.344	0.061
0.040	7.2	0.688	0.079
0.060	8.2	1.032	0.090
0.080	9.0	1.376	0.098
0.100	9.7	1.720	0.106
0.120	10.2	2.064	0.111
0.140	10.8	2.408	0.117
0.160	11.2	2.752	0.121
0.180	11.7	3.096	0.126
0.200	12.0	3.440	0.129
0.220	12.3	3.784	0.131
0.240	12.7	4.128	0.135
0.260	13.0	4.472	0.138
0.280	13.2	4.816	0.139
0.300	13.5	5.160	0.142
0.320	13.6	5.504	0.143
0.340	13.7	5.848	0.143
0.360	14.0	6.192	0.146
0.380	14.2	6.536	0.147
0.400	14.3	6.880	0.148
0.420	14.5	7.224	0.149
0.440	14.5	7.568	0.149
0.460	14.7	7.912	0.150
0.480	14.7	8.256	0.150
0.500	15.0	8.600	0.152
0.520	15.2	8.944	0.154
0.540	15.3	9.288	0.154
0.560	15.3	9.632	0.153
0.580	15.4	9.976	0.154
0.600	15.5	10.320	0.154



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with organics
Type of Failure: Yield @ 10%
Boring No.: 17-1-2
Depth (ft): 17-19

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 940.3

Area (in^2) = 6.492
Moisture Content (%) = 73.71%
Wet Density (pcf) = 94.9
Dry Density (pcf) = 54.6

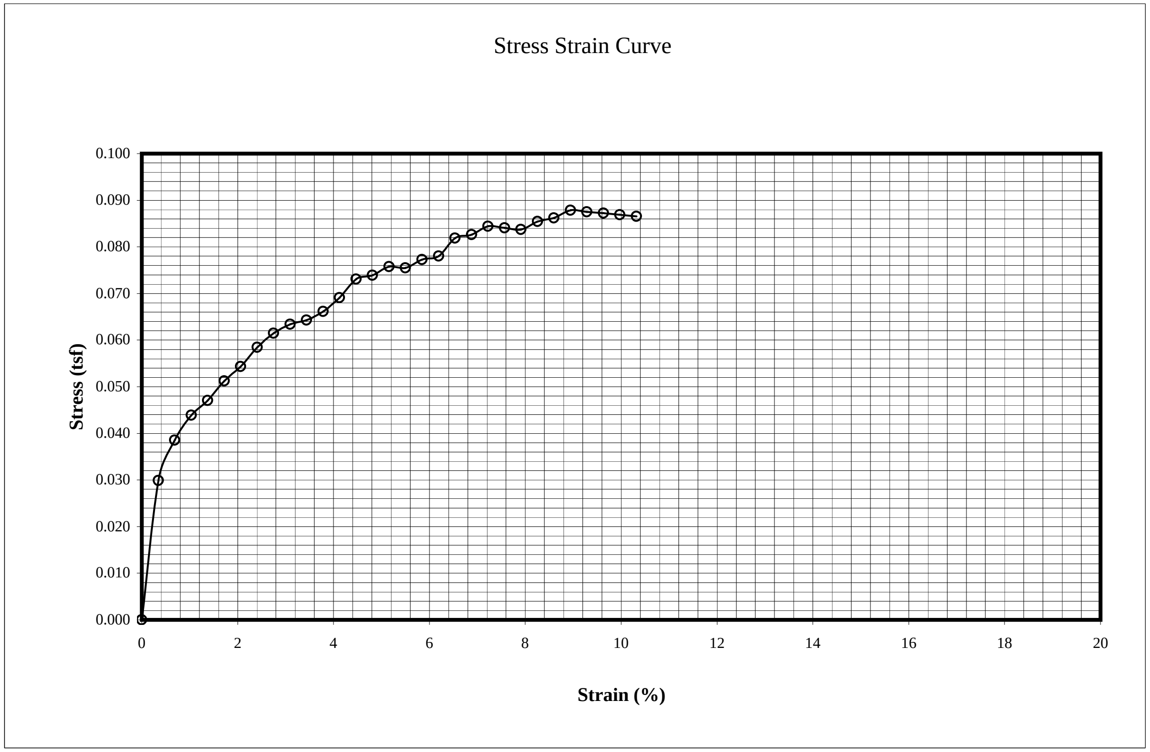
Wet wt. 116.16
Dry at. 77.49
Can wt. 25.03

Test Data:
Cell Pressure (psi) = 10.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	2.7	0.344	0.030
0.040	3.5	0.688	0.039
0.060	4.0	1.032	0.044
0.080	4.3	1.376	0.047
0.100	4.7	1.720	0.051
0.120	5.0	2.064	0.054
0.140	5.4	2.408	0.058
0.160	5.7	2.752	0.061
0.180	5.9	3.096	0.063
0.200	6.0	3.440	0.064
0.220	6.2	3.784	0.066
0.240	6.5	4.128	0.069
0.260	6.9	4.472	0.073
0.280	7.0	4.816	0.074
0.300	7.2	5.160	0.076
0.320	7.2	5.504	0.075
0.340	7.4	5.848	0.077
0.360	7.5	6.192	0.078
0.380	7.9	6.536	0.082
0.400	8.0	6.880	0.083
0.420	8.2	7.224	0.084
0.440	8.2	7.568	0.084
0.460	8.2	7.912	0.084
0.480	8.4	8.256	0.085
0.500	8.5	8.600	0.086
0.520	8.7	8.944	0.088
0.540	8.7	9.288	0.088
0.560	8.7	9.632	0.087
0.580	8.7	9.976	0.087
0.600	8.7	10.320	0.087



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @10%
Boring No.: 17-1-3
Depth (ft): 22.5-24.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 906.2

Area (in^2) = 6.492
Moisture Content (%) = 92.37%
Wet Density (pcf) = 90.3
Dry Density (pcf) = 46.9

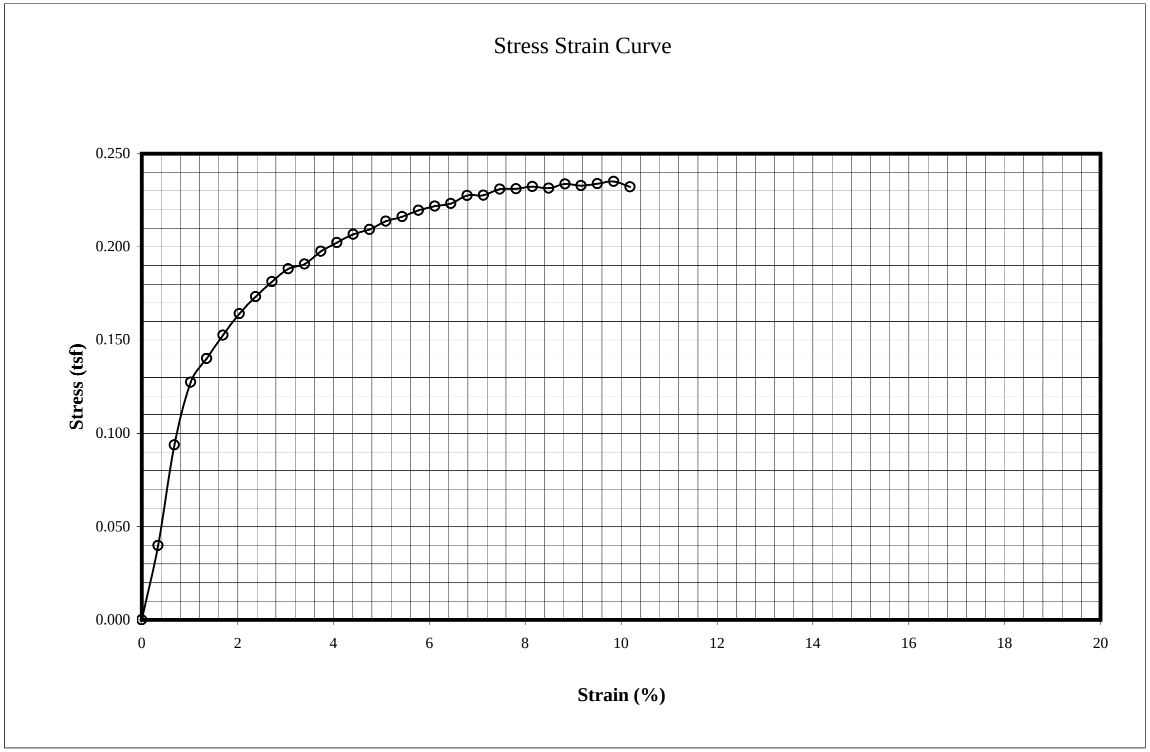
Wet wt. 104.96
Dry at. 66.58
Can wt. 25.03

Test Data:
Cell Pressure (psi) = 13.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.6	0.340	0.040
0.040	8.5	0.679	0.094
0.060	11.6	1.019	0.127
0.080	12.8	1.358	0.140
0.100	14.0	1.698	0.153
0.120	15.1	2.037	0.164
0.140	16.0	2.377	0.173
0.160	16.8	2.716	0.181
0.180	17.5	3.056	0.188
0.200	17.8	3.396	0.191
0.220	18.5	3.735	0.198
0.240	19.0	4.075	0.202
0.260	19.5	4.414	0.207
0.280	19.8	4.754	0.209
0.300	20.3	5.093	0.214
0.320	20.6	5.433	0.216
0.340	21.0	5.772	0.220
0.360	21.3	6.112	0.222
0.380	21.5	6.452	0.223
0.400	22.0	6.791	0.228
0.420	22.1	7.131	0.228
0.440	22.5	7.470	0.231
0.460	22.6	7.810	0.231
0.480	22.8	8.149	0.232
0.500	22.8	8.489	0.231
0.520	23.1	8.829	0.234
0.540	23.1	9.168	0.233
0.560	23.3	9.508	0.234
0.580	23.5	9.847	0.235
0.600	23.3	10.187	0.232



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Firm gray fine sand with clay streaks
Type of Failure: Yield @10%
Boring No.: 17-1-4
Depth (ft): 26.5-28.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1132.5

Area (in^2) = 6.492
Moisture Content (%) = 30.20%
Wet Density (pcf) = 112.8
Dry Density (pcf) = 86.7

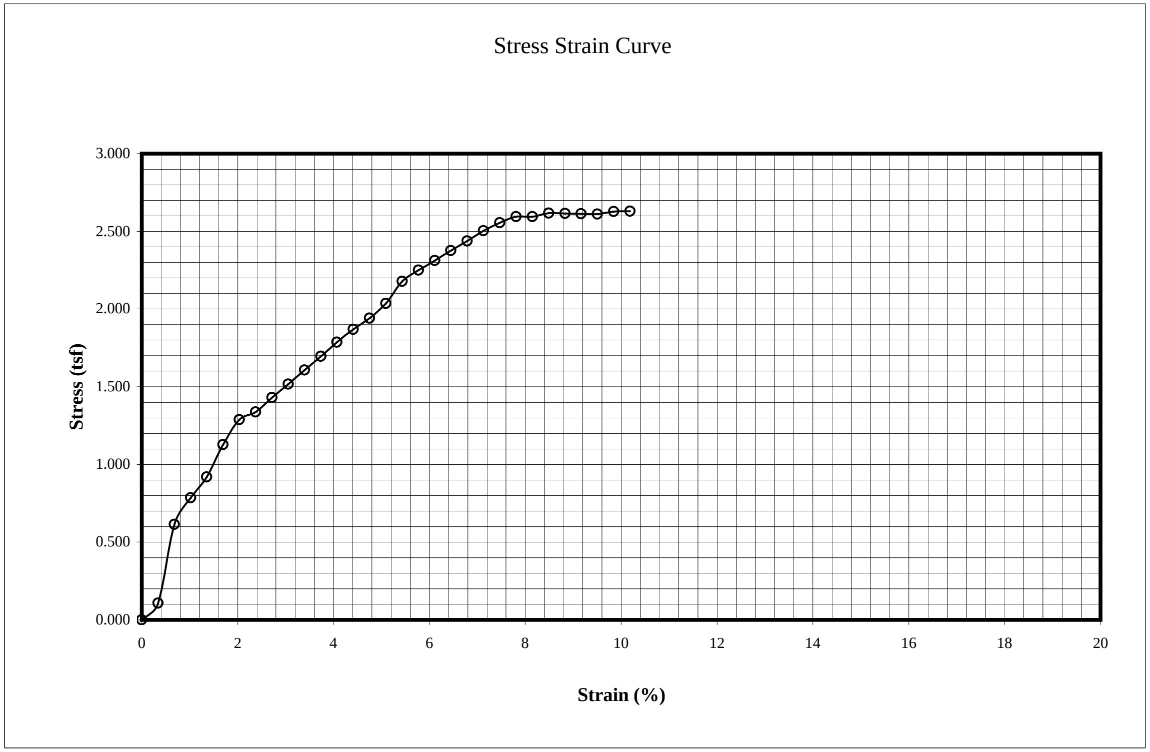
Wet wt. 200.08
Dry at. 160.4
Can wt. 28.99

Test Data:
Cell Pressure (psi) = 15.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	9.6	0.340	0.106
0.040	55.7	0.679	0.614
0.060	71.5	1.019	0.785
0.080	84.0	1.358	0.919
0.100	103.4	1.698	1.128
0.120	118.4	2.037	1.287
0.140	123.5	2.377	1.338
0.160	132.4	2.716	1.429
0.180	141.0	3.056	1.517
0.200	149.9	3.396	1.607
0.220	158.7	3.735	1.695
0.240	167.9	4.075	1.787
0.260	176.2	4.414	1.869
0.280	183.7	4.754	1.941
0.300	193.4	5.093	2.036
0.320	207.5	5.433	2.177
0.340	215.2	5.772	2.250
0.360	221.9	6.112	2.312
0.380	228.9	6.452	2.376
0.400	235.7	6.791	2.438
0.420	242.9	7.131	2.503
0.440	248.9	7.470	2.555
0.460	253.7	7.810	2.595
0.480	254.5	8.149	2.594
0.500	257.8	8.489	2.617
0.520	258.4	8.829	2.614
0.540	259.3	9.168	2.613
0.560	260.1	9.508	2.611
0.580	262.6	9.847	2.627
0.600	263.9	10.187	2.630



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray silty clay w/wood & shell fragments
Type of Failure: Yield @10%
Boring No.: 17-3-3
Depth (ft): 9-10

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1111.1

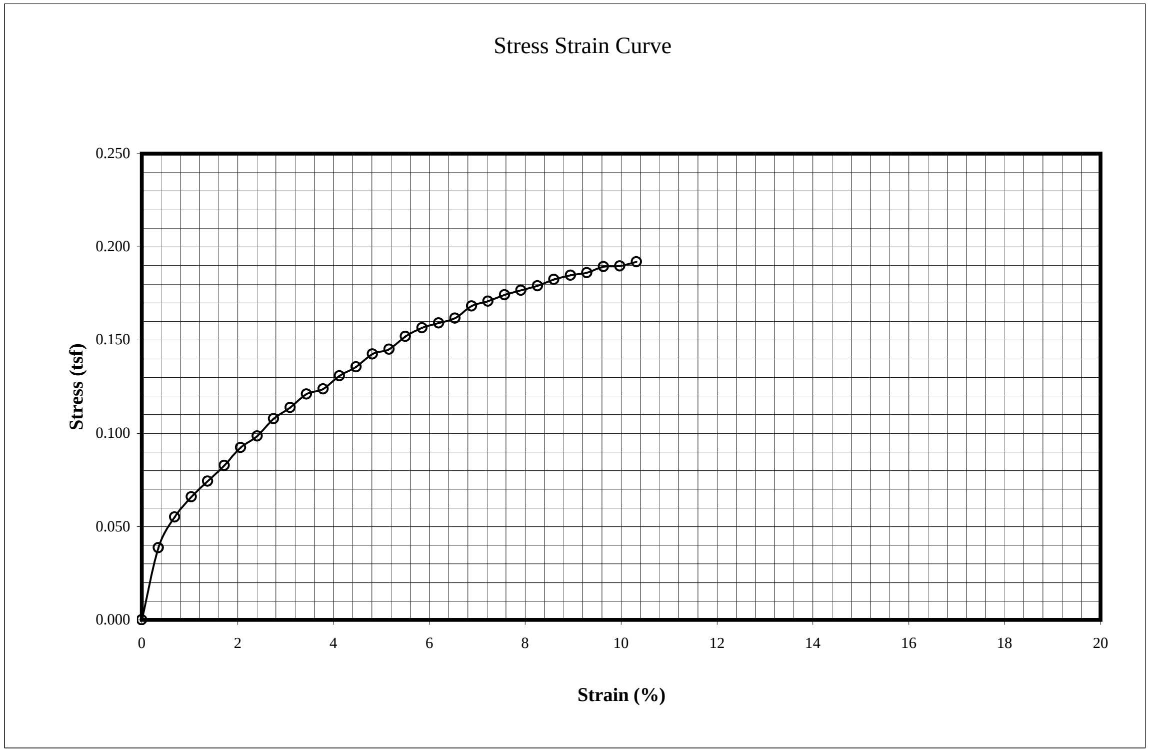
Area (in^2) = 6.492
Moisture Content (%) = 38.06%
Wet Density (pcf) = 112.1
Dry Density (pcf) = 81.2

Wet wt. 178.58
Dry at. 134.4
Can wt. 18.32

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.5	0.344	0.039
0.040	5.0	0.688	0.055
0.060	6.0	1.032	0.066
0.080	6.8	1.376	0.074
0.100	7.6	1.720	0.083
0.120	8.5	2.064	0.092
0.140	9.1	2.408	0.098
0.160	10.0	2.752	0.108
0.180	10.6	3.096	0.114
0.200	11.3	3.440	0.121
0.220	11.6	3.784	0.124
0.240	12.3	4.128	0.131
0.260	12.8	4.472	0.136
0.280	13.5	4.816	0.143
0.300	13.8	5.160	0.145
0.320	14.5	5.504	0.152
0.340	15.0	5.848	0.157
0.360	15.3	6.192	0.159
0.380	15.6	6.536	0.162
0.400	16.3	6.880	0.168
0.420	16.6	7.224	0.171
0.440	17.0	7.568	0.174
0.460	17.3	7.912	0.177
0.480	17.6	8.256	0.179
0.500	18.0	8.600	0.182
0.520	18.3	8.944	0.185
0.540	18.5	9.288	0.186
0.560	18.9	9.632	0.189
0.580	19.0	9.976	0.190
0.600	19.3	10.320	0.192



uu17-3-3

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft dark gray silty clay w/wood & shell fragments
Type of Failure: Yield @10%
Boring No.: 17-3-3
Depth (ft): 10-11

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1083.5

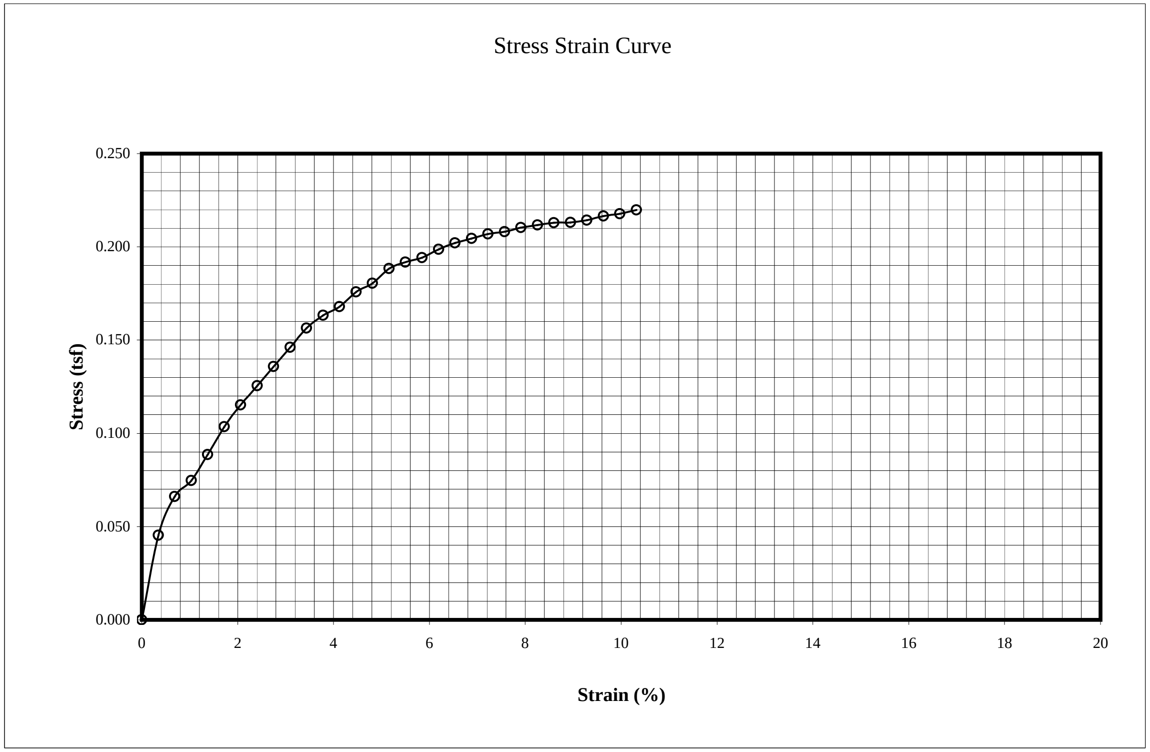
Area (in^2) = 6.492
Moisture Content (%) = 41.80%
Wet Density (pcf) = 109.4
Dry Density (pcf) = 77.1

Wet wt. 191.49
Dry at. 141.25
Can wt. 21.06

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	4.1	0.344	0.045
0.040	6.0	0.688	0.066
0.060	6.8	1.032	0.075
0.080	8.1	1.376	0.089
0.100	9.5	1.720	0.104
0.120	10.6	2.064	0.115
0.140	11.6	2.408	0.126
0.160	12.6	2.752	0.136
0.180	13.6	3.096	0.146
0.200	14.6	3.440	0.156
0.220	15.3	3.784	0.163
0.240	15.8	4.128	0.168
0.260	16.6	4.472	0.176
0.280	17.1	4.816	0.181
0.300	17.9	5.160	0.188
0.320	18.3	5.504	0.192
0.340	18.6	5.848	0.194
0.360	19.1	6.192	0.199
0.380	19.5	6.536	0.202
0.400	19.8	6.880	0.204
0.420	20.1	7.224	0.207
0.440	20.3	7.568	0.208
0.460	20.6	7.912	0.210
0.480	20.8	8.256	0.212
0.500	21.0	8.600	0.213
0.520	21.1	8.944	0.213
0.540	21.3	9.288	0.214
0.560	21.6	9.632	0.216
0.580	21.8	9.976	0.218
0.600	22.1	10.320	0.220



uu17-3-3 (2)

STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with silty clay layers
Type of Failure:
Boring No.: 17-3-4
Depth (ft): 14-16

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1036.3

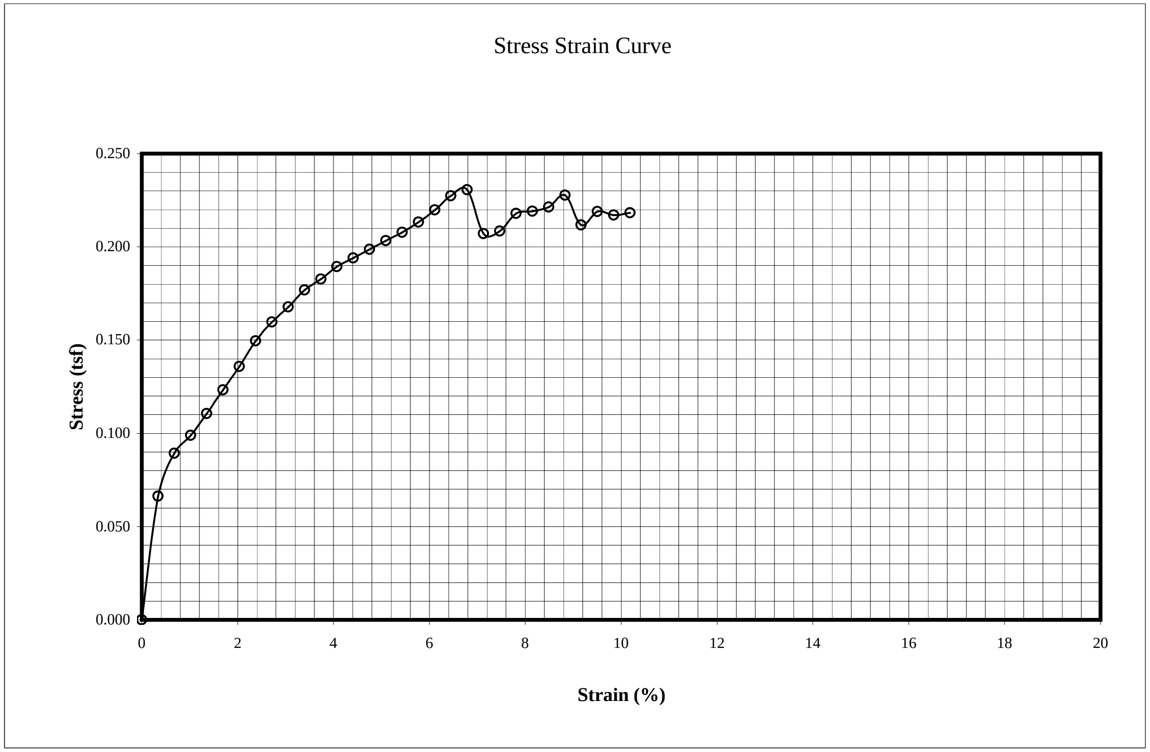
Area (in^2) = 6.492
Moisture Content (%) = 50.88%
Wet Density (pcf) = 103.2
Dry Density (pcf) = 68.4

Wet wt. 112.6
Dry at. 81.68
Can wt. 20.91

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	6.0	0.340	0.066
0.040	8.1	0.679	0.089
0.060	9.0	1.019	0.099
0.080	10.1	1.358	0.111
0.100	11.3	1.698	0.123
0.120	12.5	2.037	0.136
0.140	13.8	2.377	0.149
0.160	14.8	2.716	0.160
0.180	15.6	3.056	0.168
0.200	16.5	3.396	0.177
0.220	17.1	3.735	0.183
0.240	17.8	4.075	0.189
0.260	18.3	4.414	0.194
0.280	18.8	4.754	0.199
0.300	19.3	5.093	0.203
0.320	19.8	5.433	0.208
0.340	20.4	5.772	0.213
0.360	21.1	6.112	0.220
0.380	21.9	6.452	0.227
0.400	22.3	6.791	0.231
0.420	20.1	7.131	0.207
0.440	20.3	7.470	0.208
0.460	21.3	7.810	0.218
0.480	21.5	8.149	0.219
0.500	21.8	8.489	0.221
0.520	22.5	8.829	0.228
0.540	21.0	9.168	0.212
0.560	21.8	9.508	0.219
0.580	21.7	9.847	0.217
0.600	21.9	10.187	0.218



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @ 10%
Boring No.: 17-3-5
Depth (ft): 20-22

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 960.6

Area (in^2) = 6.492
Moisture Content (%) = 67.79%
Wet Density (pcf) = 95.7
Dry Density (pcf) = 57.0

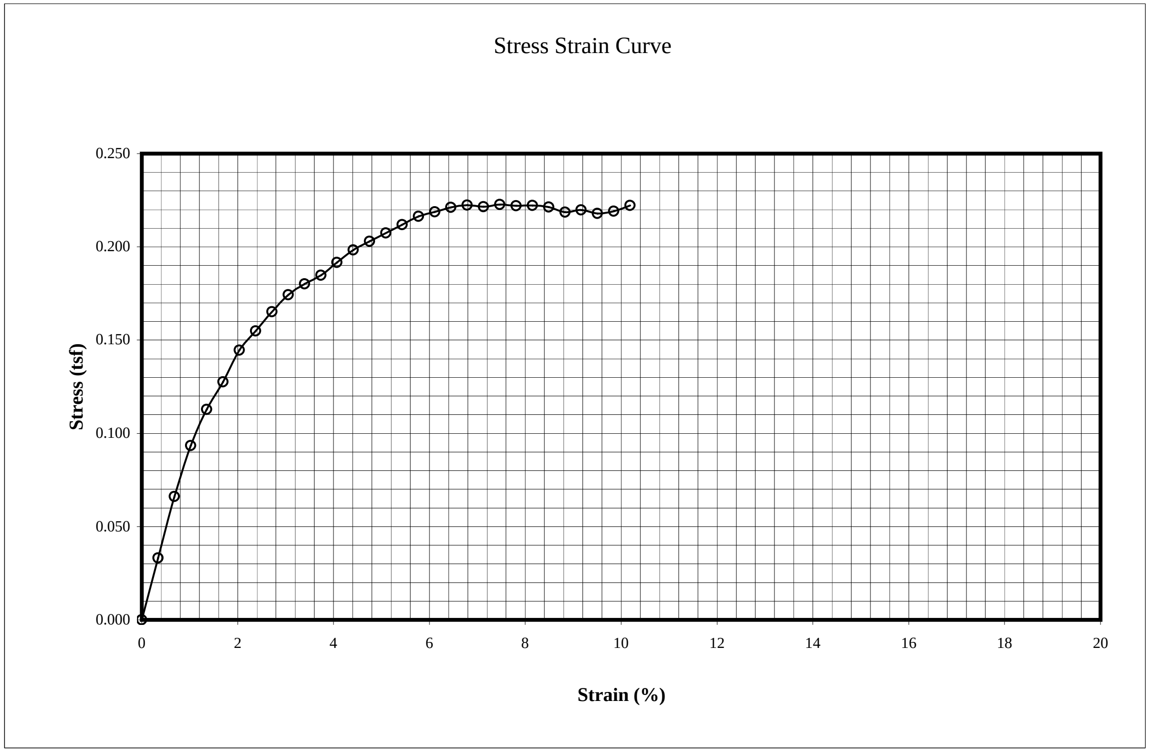
Wet wt. 146.08
Dry at. 96.04
Can wt. 22.22

Test Data:
Cell Pressure (psi) = 12.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.0	0.340	0.033
0.040	6.0	0.679	0.066
0.060	8.5	1.019	0.093
0.080	10.3	1.358	0.113
0.100	11.7	1.698	0.128
0.120	13.3	2.037	0.145
0.140	14.3	2.377	0.155
0.160	15.3	2.716	0.165
0.180	16.2	3.056	0.174
0.200	16.8	3.396	0.180
0.220	17.3	3.735	0.185
0.240	18.0	4.075	0.192
0.260	18.7	4.414	0.198
0.280	19.2	4.754	0.203
0.300	19.7	5.093	0.207
0.320	20.2	5.433	0.212
0.340	20.7	5.772	0.216
0.360	21.0	6.112	0.219
0.380	21.3	6.452	0.221
0.400	21.5	6.791	0.222
0.420	21.5	7.131	0.222
0.440	21.7	7.470	0.223
0.460	21.7	7.810	0.222
0.480	21.8	8.149	0.222
0.500	21.8	8.489	0.221
0.520	21.6	8.829	0.218
0.540	21.8	9.168	0.220
0.560	21.7	9.508	0.218
0.580	21.9	9.847	0.219
0.600	22.3	10.187	0.222



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray very sandy clay with shell
Type of Failure: Yield @ 10%
Boring No.: 17-3-6
Depth (ft): 26-28

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1060.3

Area (in^2) = 6.492
Moisture Content (%) = 26.88%
Wet Density (pcf) = 105.6
Dry Density (pcf) = 83.3

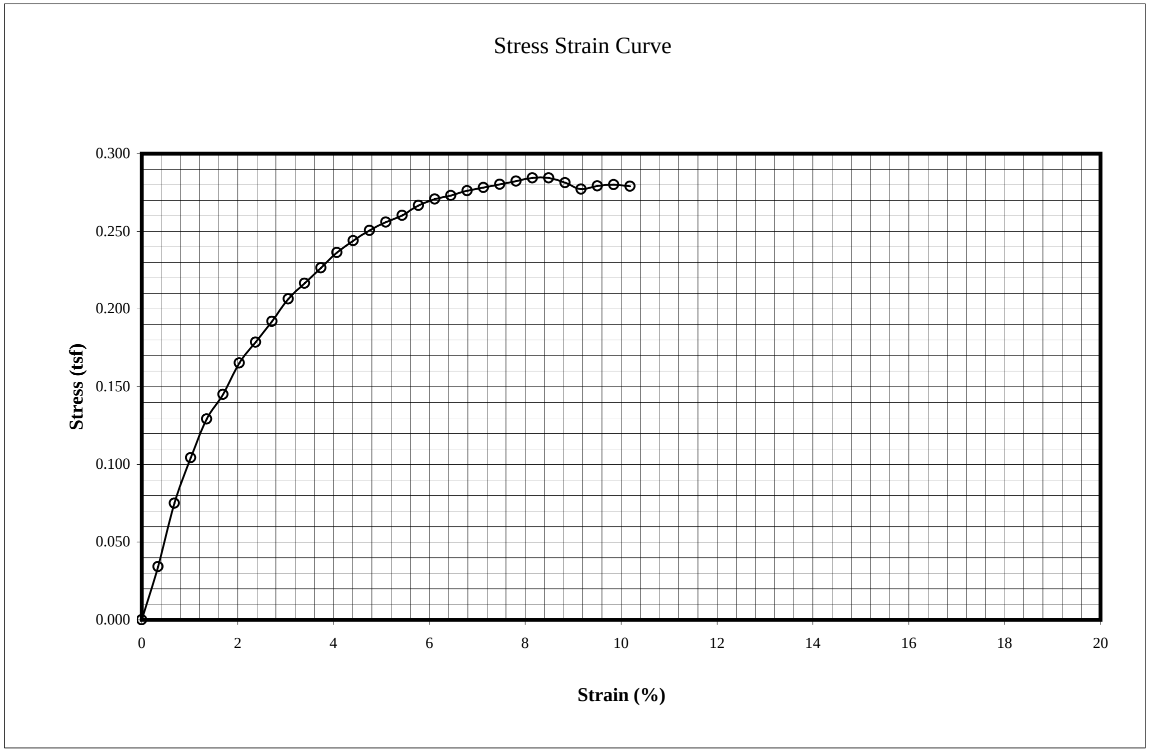
Wet wt. 153.77
Dry at. 126.81
Can wt. 26.52

Test Data:
Cell Pressure (psi) = 15.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.1	0.340	0.034
0.040	6.8	0.679	0.075
0.060	9.5	1.019	0.104
0.080	11.8	1.358	0.129
0.100	13.3	1.698	0.145
0.120	15.2	2.037	0.165
0.140	16.5	2.377	0.179
0.160	17.8	2.716	0.192
0.180	19.2	3.056	0.207
0.200	20.2	3.396	0.217
0.220	21.2	3.735	0.226
0.240	22.2	4.075	0.236
0.260	23.0	4.414	0.244
0.280	23.7	4.754	0.250
0.300	24.3	5.093	0.256
0.320	24.8	5.433	0.260
0.340	25.5	5.772	0.267
0.360	26.0	6.112	0.271
0.380	26.3	6.452	0.273
0.400	26.7	6.791	0.276
0.420	27.0	7.131	0.278
0.440	27.3	7.470	0.280
0.460	27.6	7.810	0.282
0.480	27.9	8.149	0.284
0.500	28.0	8.489	0.284
0.520	27.8	8.829	0.281
0.540	27.5	9.168	0.277
0.560	27.8	9.508	0.279
0.580	28.0	9.847	0.280
0.600	28.0	10.187	0.279



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff tan and brown clay with silt
Type of Failure: Vertical @ 7.1%
Boring No.: 17-4-1
Depth (ft): 3-5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1253.1

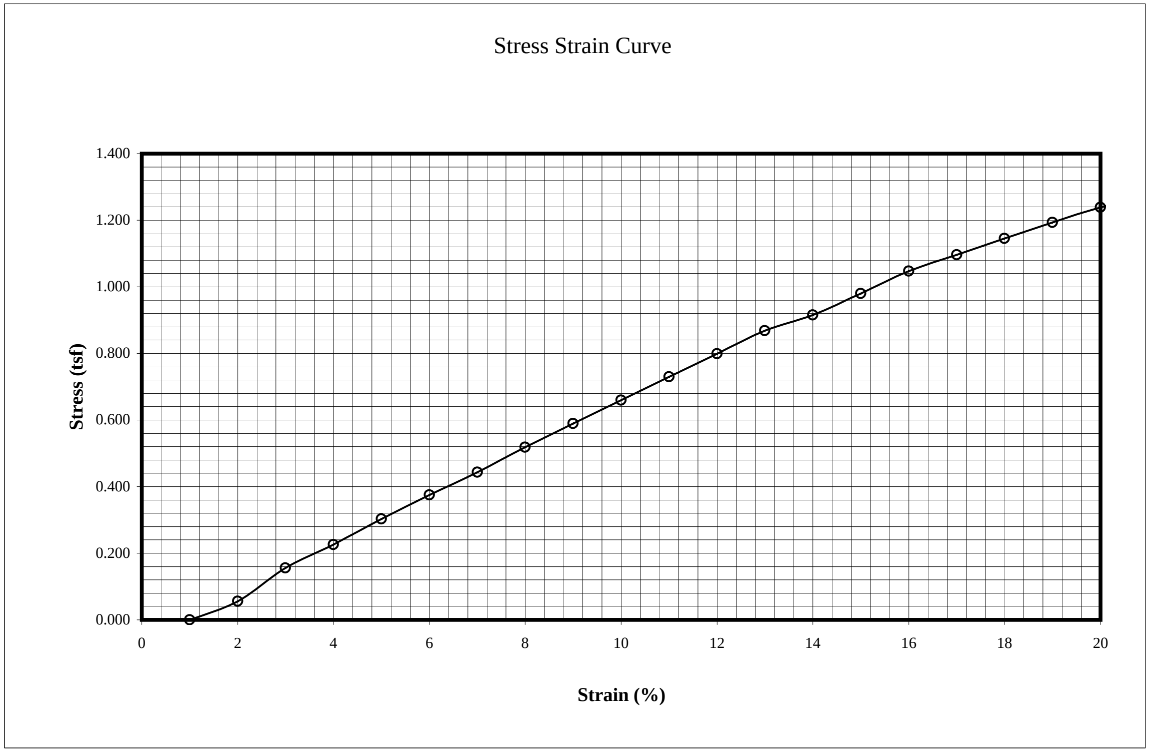
Area (in^2) = 6.492
Moisture Content (%) = 22.25%
Wet Density (pcf) = 124.8
Dry Density (pcf) = 102.1

Wet wt. 194.78
Dry at. 164.15
Can wt. 26.47

Test Data:
Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	15	0.340	0.056
0.040	42	0.679	0.156
0.060	61	1.019	0.226
0.080	82	1.358	0.302
0.100	102	1.698	0.375
0.120	121	2.037	0.443
0.140	142	2.377	0.518
0.160	162	2.716	0.589
0.180	182	3.056	0.660
0.200	202	3.396	0.730
0.220	222	3.735	0.799
0.240	242	4.075	0.868
0.260	256	4.414	0.915
0.280	275	4.754	0.979
0.300	295	5.093	1.047
0.320	310	5.433	1.096
0.340	325	5.772	1.145
0.360	340	6.112	1.194
0.380	354	6.452	1.238
0.400	364	6.791	1.269
0.420	372	7.131	1.292
0.440	372	7.470	1.287
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Med gray clay w/silt & fine sand alt layers & traces of organic matter
Boring No.: 17-4-2
Depth (ft): 9-10

Type of Failure: Bulge @ 9%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1091.2

Area (in^2) = 6.492
Moisture Content (%) = 35.17%
Wet Density (pcf) = 110.1
Dry Density (pcf) = 81.5

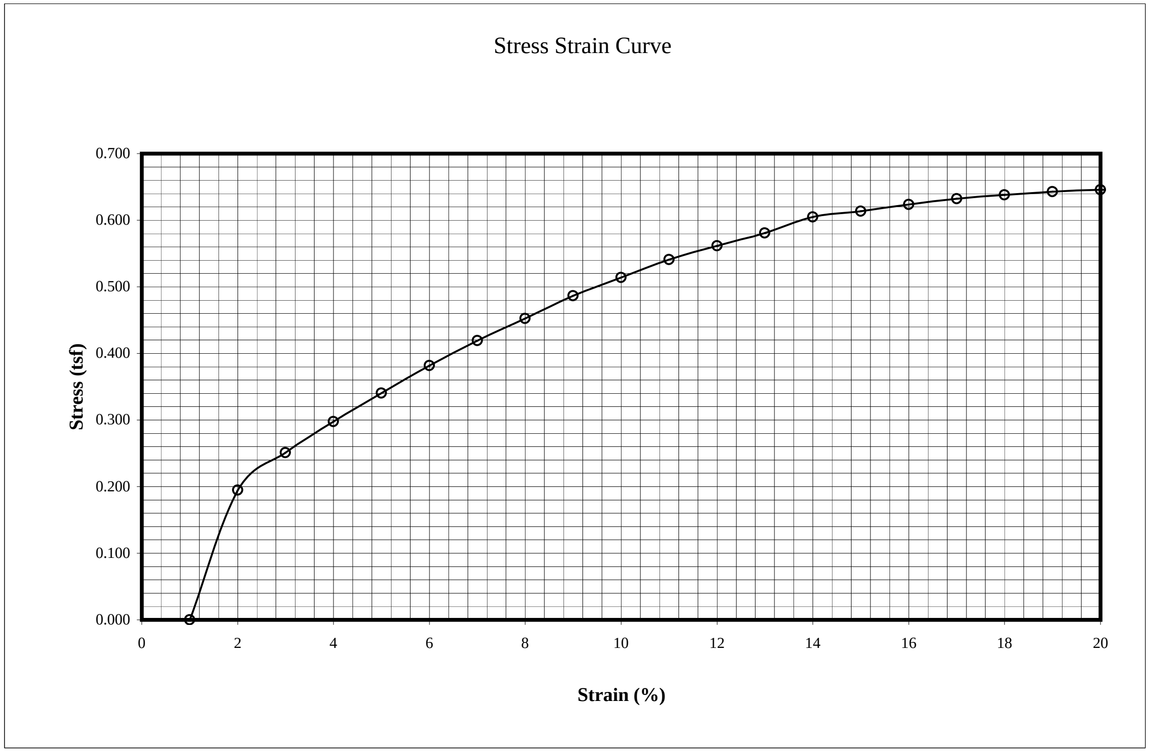
Wet wt. 147.97
Dry at. 115.26
Can wt. 22.25

Test Data:

Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	17.6	0.344	0.195
0.040	22.8	0.688	0.251
0.060	27.1	1.032	0.297
0.080	31.1	1.376	0.340
0.100	35.0	1.720	0.382
0.120	38.6	2.064	0.419
0.140	41.8	2.408	0.452
0.160	45.1	2.752	0.486
0.180	47.8	3.096	0.514
0.200	50.5	3.440	0.541
0.220	52.6	3.784	0.561
0.240	54.6	4.128	0.581
0.260	57.1	4.472	0.605
0.280	58.1	4.816	0.613
0.300	59.3	5.160	0.624
0.320	60.3	5.504	0.632
0.340	61.1	5.848	0.638
0.360	61.8	6.192	0.643
0.380	62.3	6.536	0.646
0.400	62.5	6.880	0.645
0.420	62.5	7.224	0.643
0.440	62.0	7.568	0.636
0.460	61.0	7.912	0.623
0.480	60.3	8.256	0.614
0.500	59.5	8.600	0.603
0.520			
0.540			
0.560			
0.580			
0.600			



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay with silt seams and wood
Type of Failure: Yield @ 10%
Boring No.: 17-4-2
Depth (ft): 10-11

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1120.7

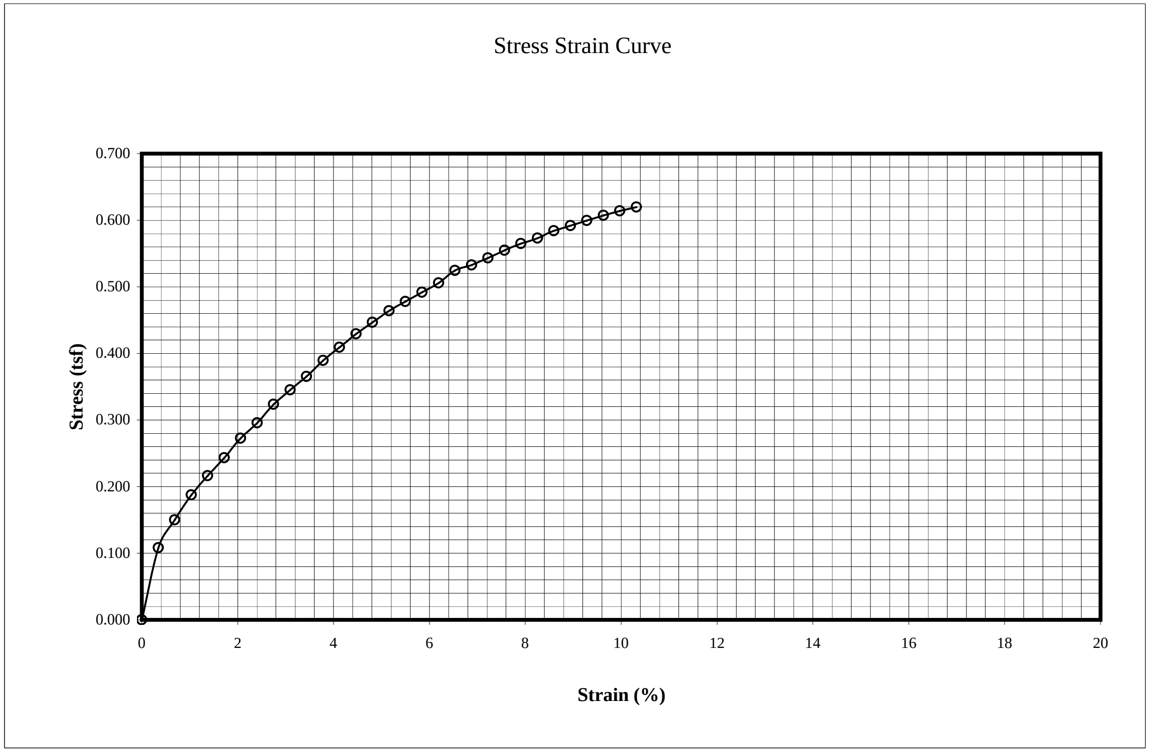
Area (in^2) = 6.492
Moisture Content (%) = 34.12%
Wet Density (pcf) = 113.1
Dry Density (pcf) = 84.3

Wet wt. 182.31
Dry at. 141.25
Can wt. 20.9

Test Data:
Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	9.8	0.344	0.108
0.040	13.6	0.688	0.150
0.060	17.1	1.032	0.188
0.080	19.8	1.376	0.217
0.100	22.3	1.720	0.243
0.120	25.1	2.064	0.273
0.140	27.3	2.408	0.295
0.160	30.0	2.752	0.324
0.180	32.1	3.096	0.345
0.200	34.1	3.440	0.365
0.220	36.5	3.784	0.389
0.240	38.5	4.128	0.409
0.260	40.5	4.472	0.429
0.280	42.3	4.816	0.447
0.300	44.1	5.160	0.464
0.320	45.6	5.504	0.478
0.340	47.1	5.848	0.492
0.360	48.6	6.192	0.506
0.380	50.6	6.536	0.525
0.400	51.6	6.880	0.533
0.420	52.8	7.224	0.543
0.440	54.1	7.568	0.555
0.460	55.3	7.912	0.565
0.480	56.3	8.256	0.573
0.500	57.6	8.600	0.584
0.520	58.6	8.944	0.592
0.540	59.6	9.288	0.600
0.560	60.6	9.632	0.607
0.580	61.5	9.976	0.614
0.600	62.3	10.320	0.620



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray and brown clay with peat and organics
Type of Failure: Yield @ 10%
Boring No.: 17-4-3
Depth (ft): 11.5-13.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 885.7

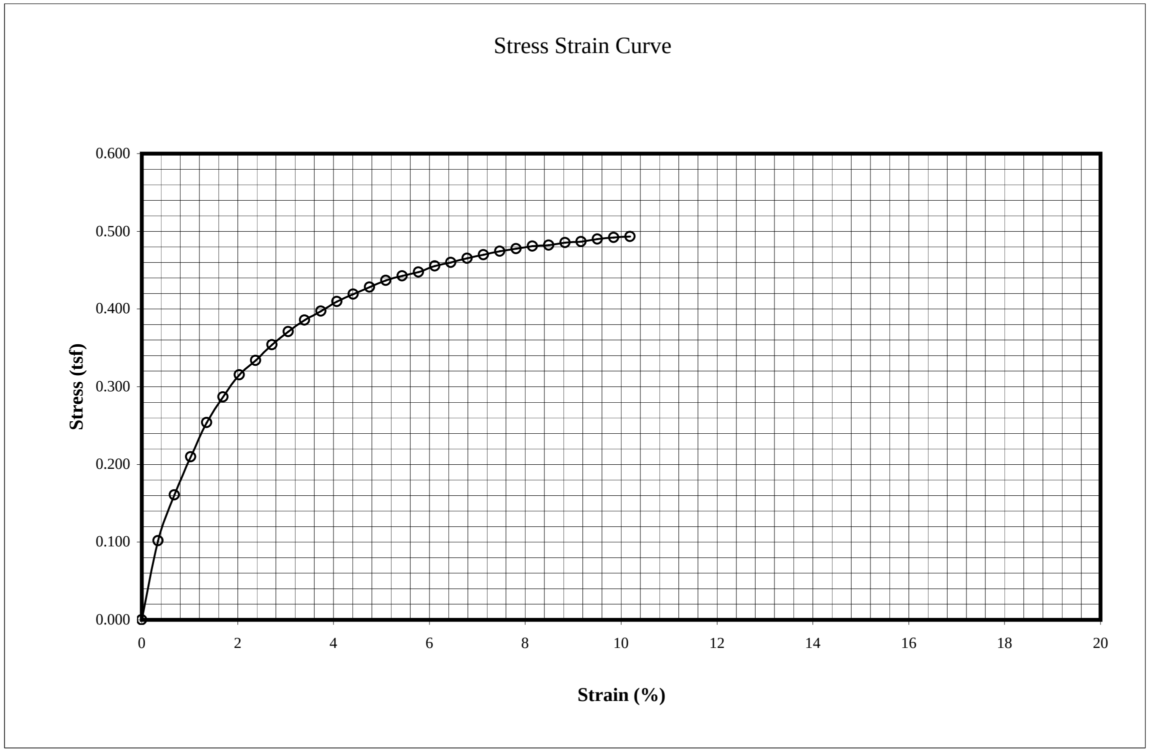
Area (in^2) = 6.492
Moisture Content (%) = 128.43%
Wet Density (pcf) = 88.2
Dry Density (pcf) = 38.6

Wet wt. 162.94
Dry at. 83.74
Can wt. 22.07

Test Data:
Cell Pressure (psi) = 7.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	9.2	0.340	0.102
0.040	14.6	0.679	0.161
0.060	19.1	1.019	0.210
0.080	23.2	1.358	0.254
0.100	26.3	1.698	0.287
0.120	29.0	2.037	0.315
0.140	30.8	2.377	0.334
0.160	32.8	2.716	0.354
0.180	34.5	3.056	0.371
0.200	36.0	3.396	0.386
0.220	37.2	3.735	0.397
0.240	38.5	4.075	0.410
0.260	39.5	4.414	0.419
0.280	40.5	4.754	0.428
0.300	41.5	5.093	0.437
0.320	42.2	5.433	0.443
0.340	42.8	5.772	0.447
0.360	43.7	6.112	0.455
0.380	44.3	6.452	0.460
0.400	45.0	6.791	0.465
0.420	45.6	7.131	0.470
0.440	46.2	7.470	0.474
0.460	46.7	7.810	0.478
0.480	47.2	8.149	0.481
0.500	47.5	8.489	0.482
0.520	48.0	8.829	0.486
0.540	48.3	9.168	0.487
0.560	48.8	9.508	0.490
0.580	49.2	9.847	0.492
0.600	49.5	10.187	0.493



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray organic clay with peat
Type of Failure:
Boring No.: 17-4-4
Depth (ft): 14-15

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 830.0

Area (in^2) = 6.492
Moisture Content (%) = 261.81%
Wet Density (pcf) = 82.7
Dry Density (pcf) = 22.9

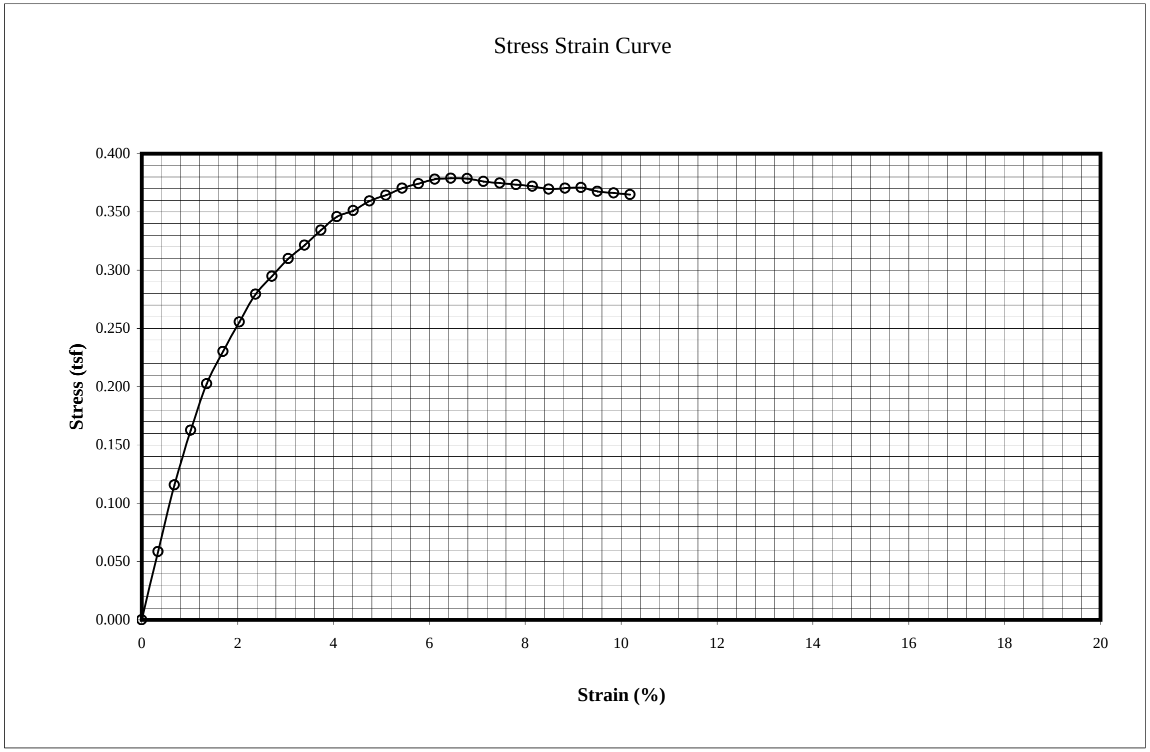
Wet wt. 126.99
Dry at. 54.52
Can wt. 26.84

Test Data:
Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	5.3	0.340	0.059
0.040	10.5	0.679	0.116
0.060	14.8	1.019	0.163
0.080	18.5	1.358	0.202
0.100	21.1	1.698	0.230
0.120	23.5	2.037	0.255
0.140	25.8	2.377	0.279
0.160	27.3	2.716	0.295
0.180	28.8	3.056	0.310
0.200	30.0	3.396	0.322
0.220	31.3	3.735	0.334
0.240	32.5	4.075	0.346
0.260	33.1	4.414	0.351
0.280	34.0	4.754	0.359
0.300	34.6	5.093	0.364
0.320	35.3	5.433	0.370
0.340	35.8	5.772	0.374
0.360	36.3	6.112	0.378
0.380	36.5	6.452	0.379
0.400	36.6	6.791	0.379
0.420	36.5	7.131	0.376
0.440	36.5	7.470	0.375
0.460	36.5	7.810	0.373
0.480	36.5	8.149	0.372
0.500	36.4	8.489	0.370
0.520	36.6	8.829	0.370
0.540	36.8	9.168	0.371
0.560	36.6	9.508	0.367
0.580	36.6	9.847	0.366
0.600	36.6	10.187	0.365



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium dark gray organic clay with peat
Boring No.: 17-4-4
Depth (ft): 15-16

Type of Failure:

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 736.1

Area (in^2) = 6.492
Moisture Content (%) = 80.25%
Wet Density (pcf) = 73.3
Dry Density (pcf) = 40.7

Wet wt. 147.46
Dry at. 91.67
Can wt. 22.15

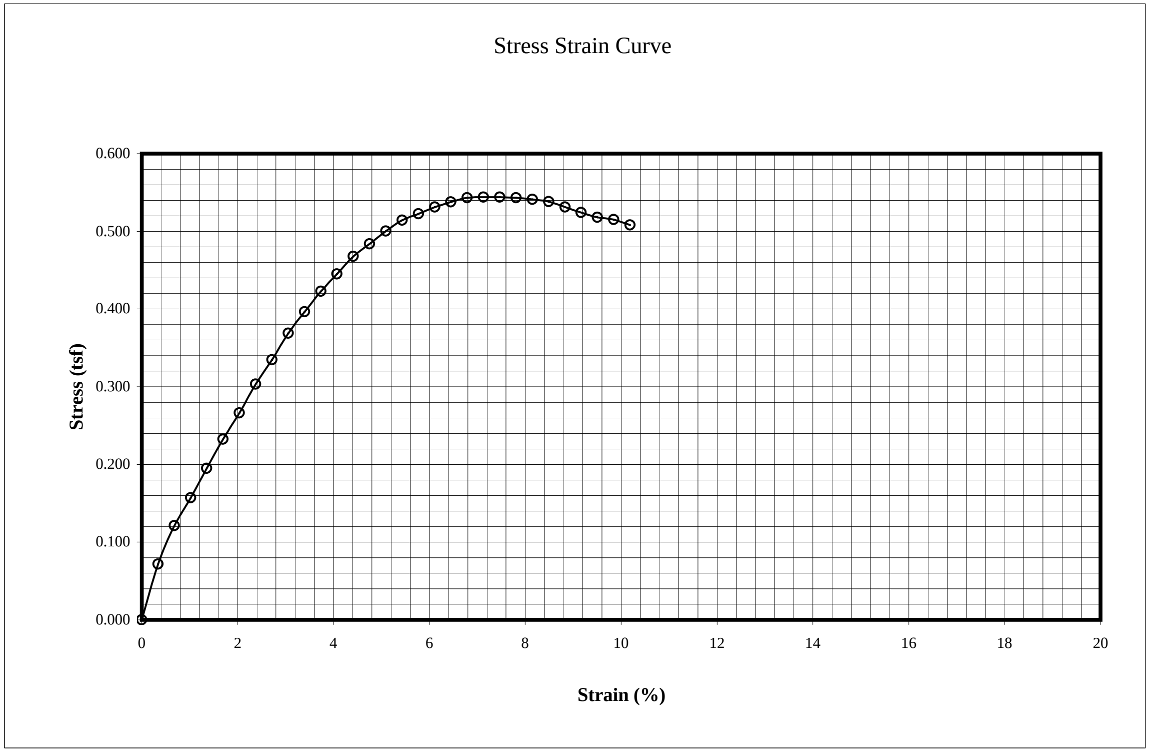
Test Data:

Cell Pressure (psi) = 8.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	6.5	0.340	0.072
0.040	11.0	0.679	0.121
0.060	14.3	1.019	0.157
0.080	17.8	1.358	0.195
0.100	21.3	1.698	0.232
0.120	24.5	2.037	0.266
0.140	28.0	2.377	0.303
0.160	31.0	2.716	0.335
0.180	34.3	3.056	0.369
0.200	37.0	3.396	0.397
0.220	39.6	3.735	0.423
0.240	41.8	4.075	0.445
0.260	44.1	4.414	0.468
0.280	45.8	4.754	0.484
0.300	47.5	5.093	0.500
0.320	49.0	5.433	0.514
0.340	50.0	5.772	0.523
0.360	51.0	6.112	0.531
0.380	51.8	6.452	0.538
0.400	52.5	6.791	0.543
0.420	52.8	7.131	0.544
0.440	53.0	7.470	0.544
0.460	53.1	7.810	0.543
0.480	53.1	8.149	0.541
0.500	53.0	8.489	0.538
0.520	52.5	8.829	0.531
0.540	52.0	9.168	0.524
0.560	51.6	9.508	0.518
0.580	51.5	9.847	0.515
0.600	51.0	10.187	0.508



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Type of Failure: Yield @ 10%
Boring No.: 17-4-7
Depth (ft): 21.5-22.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 942.1

Area (in^2) = 6.492
Moisture Content (%) = 77.95%
Wet Density (pcf) = 95.1
Dry Density (pcf) = 53.4

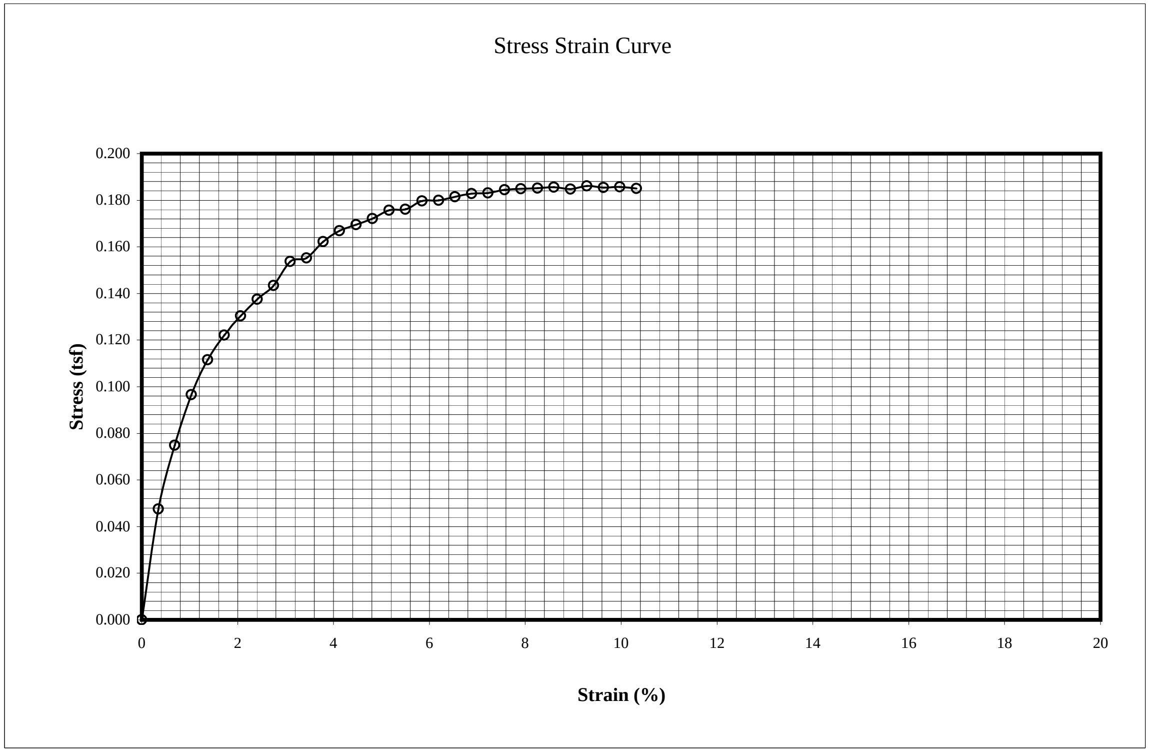
Wet wt. 146.82
Dry at. 92.09
Can wt. 21.88

Test Data:
Cell Pressure (psi) = 14.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	4.3	0.344	0.048
0.040	6.8	0.688	0.075
0.060	8.8	1.032	0.097
0.080	10.2	1.376	0.112
0.100	11.2	1.720	0.122
0.120	12.0	2.064	0.130
0.140	12.7	2.408	0.137
0.160	13.3	2.752	0.143
0.180	14.3	3.096	0.154
0.200	14.5	3.440	0.155
0.220	15.2	3.784	0.162
0.240	15.7	4.128	0.167
0.260	16.0	4.472	0.170
0.280	16.3	4.816	0.172
0.300	16.7	5.160	0.176
0.320	16.8	5.504	0.176
0.340	17.2	5.848	0.180
0.360	17.3	6.192	0.180
0.380	17.5	6.536	0.181
0.400	17.7	6.880	0.183
0.420	17.8	7.224	0.183
0.440	18.0	7.568	0.185
0.460	18.1	7.912	0.185
0.480	18.2	8.256	0.185
0.500	18.3	8.600	0.186
0.520	18.3	8.944	0.185
0.540	18.5	9.288	0.186
0.560	18.5	9.632	0.185
0.580	18.6	9.976	0.186
0.600	18.6	10.320	0.185



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray silty sandy clay (alt. Layers)
Type of Failure: Yield @ 10%
Boring No.: 17-4-7
Depth (ft): 22.5-23.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1131.0

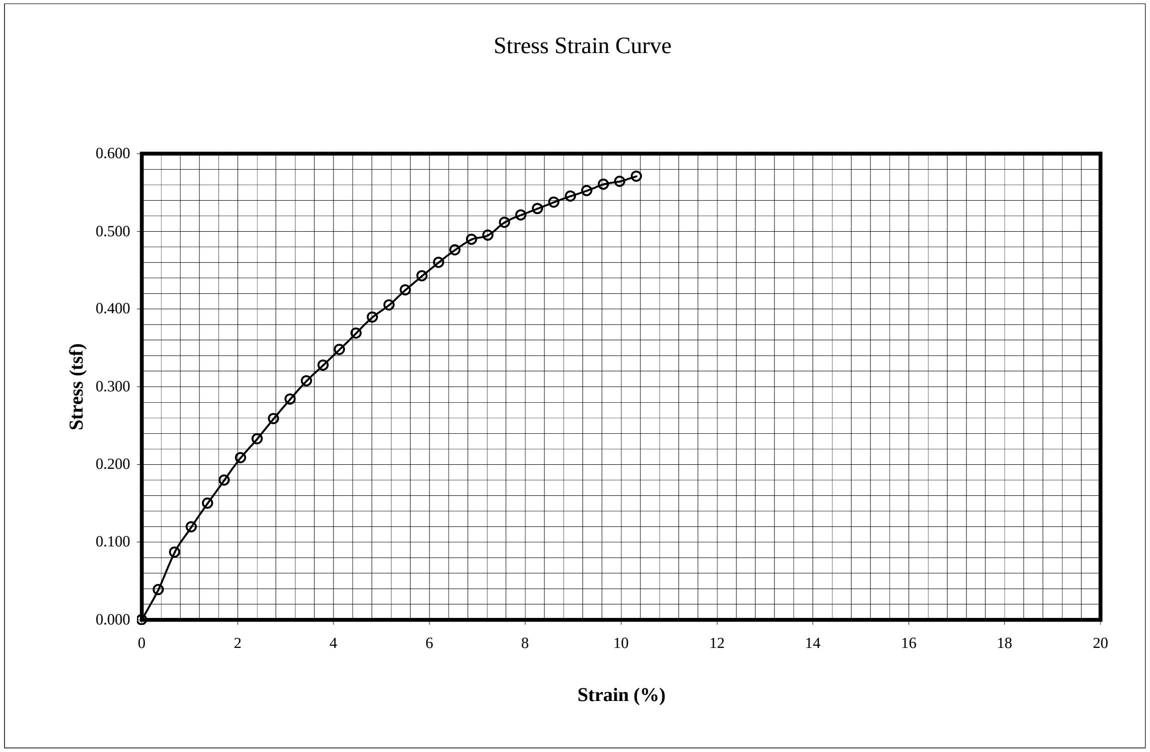
Area (in^2) = 6.492
Moisture Content (%) = 46.61%
Wet Density (pcf) = 114.2
Dry Density (pcf) = 77.9

Wet wt. 204.42
Dry at. 146.12
Can wt. 21.05

Test Data:
Cell Pressure (psi) = 14.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	3.5	0.344	0.039
0.040	7.9	0.688	0.087
0.060	10.9	1.032	0.120
0.080	13.7	1.376	0.150
0.100	16.5	1.720	0.180
0.120	19.2	2.064	0.209
0.140	21.5	2.408	0.233
0.160	24.0	2.752	0.259
0.180	26.4	3.096	0.284
0.200	28.7	3.440	0.307
0.220	30.7	3.784	0.328
0.240	32.7	4.128	0.348
0.260	34.8	4.472	0.369
0.280	36.9	4.816	0.390
0.300	38.5	5.160	0.405
0.320	40.5	5.504	0.424
0.340	42.4	5.848	0.443
0.360	44.2	6.192	0.460
0.380	45.9	6.536	0.476
0.400	47.4	6.880	0.490
0.420	48.1	7.224	0.495
0.440	49.9	7.568	0.512
0.460	51.0	7.912	0.521
0.480	52.0	8.256	0.529
0.500	53.0	8.600	0.537
0.520	54.0	8.944	0.545
0.540	54.9	9.288	0.552
0.560	55.9	9.632	0.560
0.580	56.5	9.976	0.564
0.600	57.4	10.320	0.571



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/alt. Layers of silty fine sand
Type of Failure: Yield @ 10%
Boring No.: 17-4-8
Depth (ft): 25-27

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 981.4

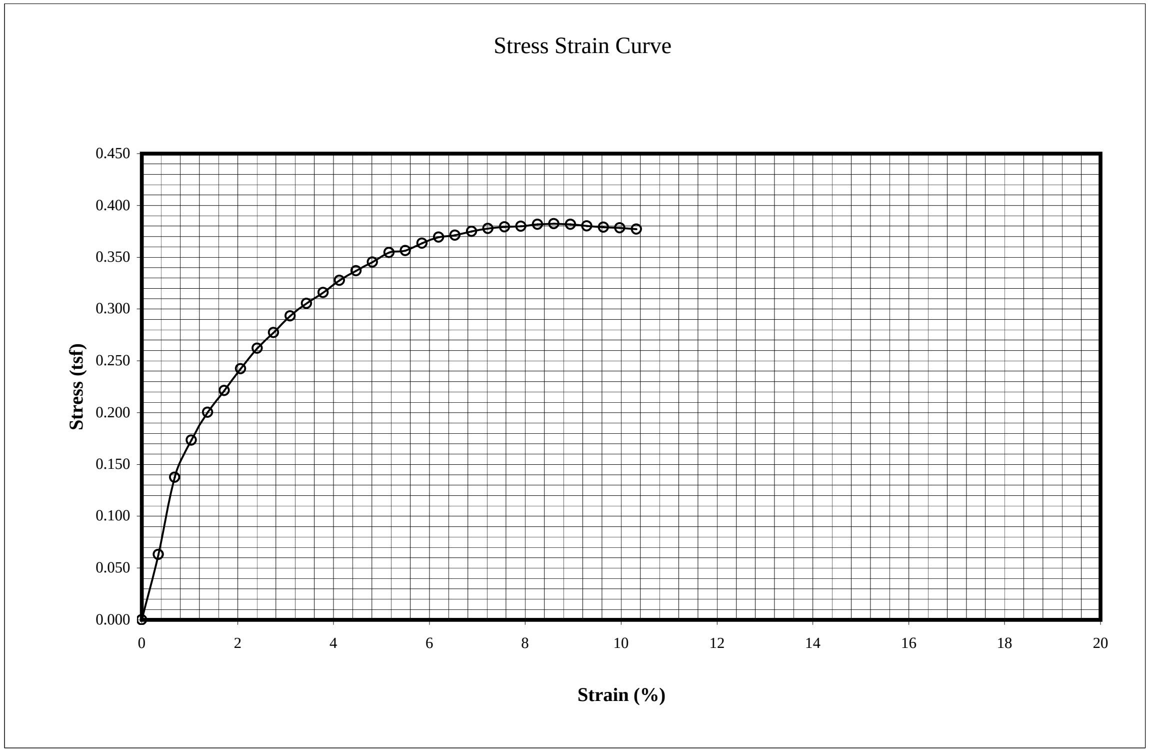
Area (in^2) = 6.492
Moisture Content (%) = 65.80%
Wet Density (pcf) = 99.1
Dry Density (pcf) = 59.7

Wet wt. 159.49
Dry at. 104.48
Can wt. 20.88

Test Data:
Cell Pressure (psi) = 15.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0.0	0.000	0.000
0.020	5.7	0.344	0.063
0.040	12.5	0.688	0.138
0.060	15.8	1.032	0.173
0.080	18.3	1.376	0.200
0.100	20.3	1.720	0.221
0.120	22.3	2.064	0.242
0.140	24.2	2.408	0.262
0.160	25.7	2.752	0.277
0.180	27.3	3.096	0.293
0.200	28.5	3.440	0.305
0.220	29.6	3.784	0.316
0.240	30.8	4.128	0.327
0.260	31.8	4.472	0.337
0.280	32.7	4.816	0.345
0.300	33.7	5.160	0.354
0.320	34.0	5.504	0.356
0.340	34.8	5.848	0.363
0.360	35.5	6.192	0.369
0.380	35.8	6.536	0.371
0.400	36.3	6.880	0.375
0.420	36.7	7.224	0.378
0.440	37.0	7.568	0.379
0.460	37.2	7.912	0.380
0.480	37.5	8.256	0.382
0.500	37.7	8.600	0.382
0.520	37.8	8.944	0.382
0.540	37.8	9.288	0.380
0.560	37.8	9.632	0.379
0.580	37.9	9.976	0.378
0.600	37.9	10.320	0.377



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very stiff tan and brown clay with silt
Boring No.: 17-5-1
Depth (ft): 3-5

Type of Failure: Vertical @ 7.4%

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.9
Weight (gm) = 1267.3

Area (in^2) = 6.492
Moisture Content (%) = 17.59%
Wet Density (pcf) = 126.3
Dry Density (pcf) = 107.4

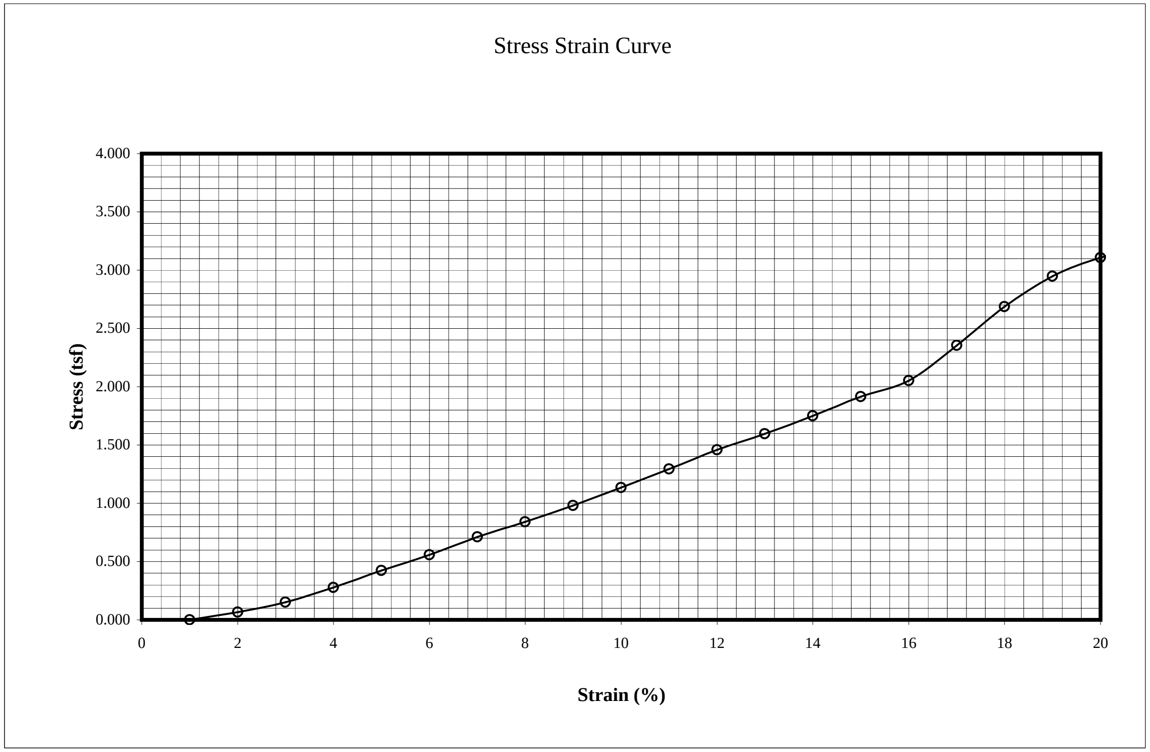
Wet wt. 162.22
Dry at. 142.28
Can wt. 28.9

Test Data:
Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	18	0.340	0.067
0.040	41	0.679	0.152
0.060	75	1.019	0.278
0.080	115	1.358	0.424
0.100	152	1.698	0.559
0.120	194	2.037	0.711
0.140	230	2.377	0.840
0.160	270	2.716	0.982
0.180	313	3.056	1.135
0.200	358	3.396	1.293
0.220	405	3.735	1.458
0.240	445	4.075	1.596
0.260	490	4.414	1.751
0.280	538	4.754	1.916
0.300	578	5.093	2.051
0.320	620	5.433	2.353
0.340	660	5.772	2.686
0.360	692	6.112	2.948
0.380	712	6.452	3.107
0.400	725	6.791	3.205
0.420	736	7.131	3.286
0.440	742	7.470	3.324
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay with siltlenses and wood
Boring No.: 17-5-6
Depth (ft): 22-24

Type of Failure: Yield @ 10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 954.4

Area (in^2) = 6.492
Moisture Content (%) = 77.69%
Wet Density (pcf) = 96.3
Dry Density (pcf) = 54.2

Wet wt. 136.11
Dry at. 85.72
Can wt. 20.86

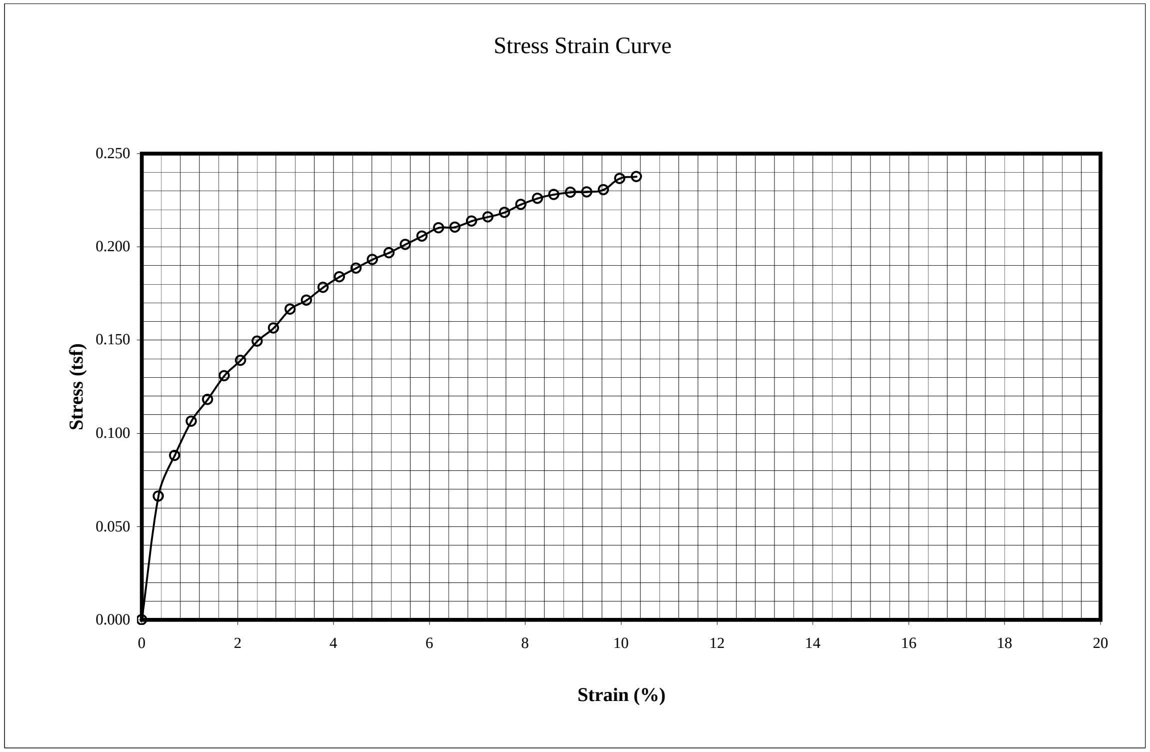
Test Data:

Cell Pressure (psi) = 14.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	6.0	0.344	0.066
0.040	8.0	0.688	0.088
0.060	9.7	1.032	0.106
0.080	10.8	1.376	0.118
0.100	12.0	1.720	0.131
0.120	12.8	2.064	0.139
0.140	13.8	2.408	0.149
0.160	14.5	2.752	0.156
0.180	15.5	3.096	0.167
0.200	16.0	3.440	0.171
0.220	16.7	3.784	0.178
0.240	17.3	4.128	0.184
0.260	17.8	4.472	0.189
0.280	18.3	4.816	0.193
0.300	18.7	5.160	0.197
0.320	19.2	5.504	0.201
0.340	19.7	5.848	0.206
0.360	20.2	6.192	0.210
0.380	20.3	6.536	0.210
0.400	20.7	6.880	0.214
0.420	21.0	7.224	0.216
0.440	21.3	7.568	0.218
0.460	21.8	7.912	0.223
0.480	22.2	8.256	0.226
0.500	22.5	8.600	0.228
0.520	22.7	8.944	0.229
0.540	22.8	9.288	0.229
0.560	23.0	9.632	0.231
0.580	23.7	9.976	0.237
0.600	23.9	10.320	0.238



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/alt. Seams of silty fine sand
Type of Failure: Yield @ 10%
Boring No.: 17-5-7
Depth (ft): 25-27

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 999.2

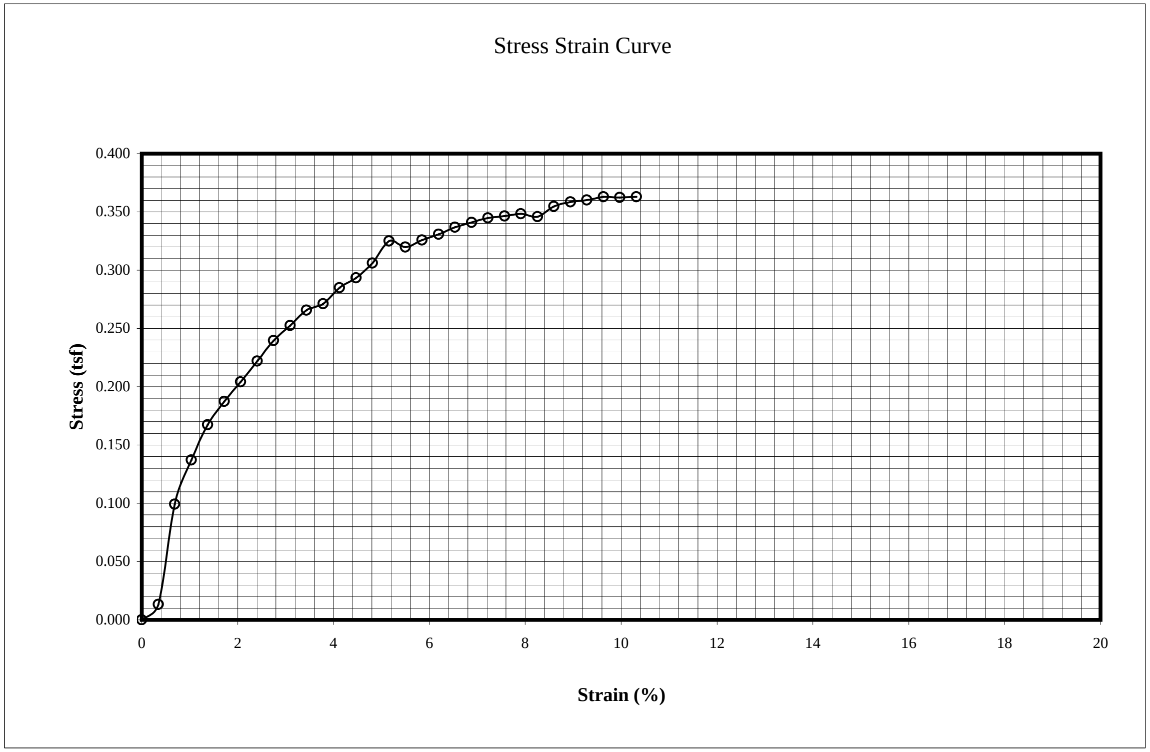
Area (in^2) = 6.492
Moisture Content (%) = 42.65%
Wet Density (pcf) = 100.8
Dry Density (pcf) = 70.7

Wet wt. 143.77
Dry at. 107.04
Can wt. 20.92

Test Data:
Cell Pressure (psi) = 16.7
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	1.2	0.344	0.013
0.040	9.0	0.688	0.099
0.060	12.5	1.032	0.137
0.080	15.3	1.376	0.167
0.100	17.2	1.720	0.187
0.120	18.8	2.064	0.204
0.140	20.5	2.408	0.222
0.160	22.2	2.752	0.239
0.180	23.5	3.096	0.253
0.200	24.8	3.440	0.266
0.220	25.4	3.784	0.271
0.240	26.8	4.128	0.285
0.260	27.7	4.472	0.293
0.280	29.0	4.816	0.306
0.300	30.9	5.160	0.325
0.320	30.5	5.504	0.320
0.340	31.2	5.848	0.326
0.360	31.8	6.192	0.331
0.380	32.5	6.536	0.337
0.400	33.0	6.880	0.341
0.420	33.5	7.224	0.345
0.440	33.8	7.568	0.347
0.460	34.1	7.912	0.348
0.480	34.0	8.256	0.346
0.500	35.0	8.600	0.355
0.520	35.5	8.944	0.359
0.540	35.8	9.288	0.360
0.560	36.2	9.632	0.363
0.580	36.3	9.976	0.362
0.600	36.5	10.320	0.363



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft organic clay
Boring No.: LAC-1-1
Depth (ft): 3-4

Type of Failure: Yield @ 10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 852.6

Area (in^2) = 6.492
Moisture Content (%) = 123.75%
Wet Density (pcf) = 86.5
Dry Density (pcf) = 38.7

Wet wt. 142.26
Dry at. 75.15
Can wt. 20.92

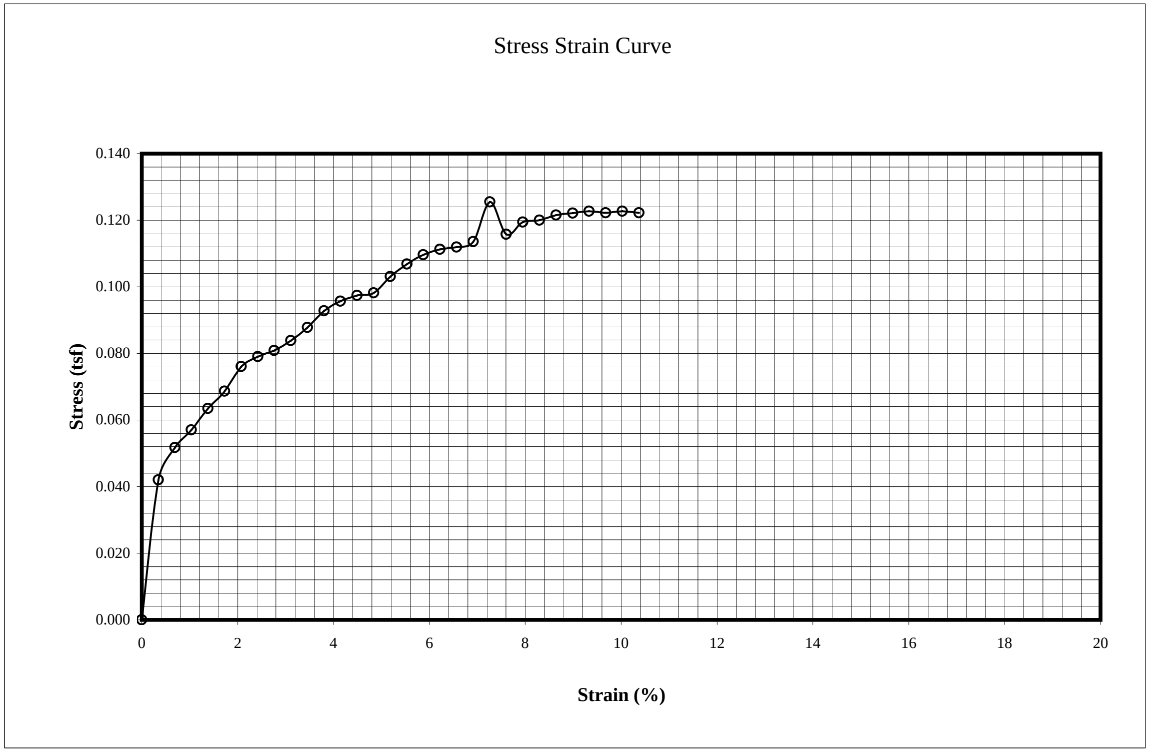
Test Data:

Cell Pressure (psi) = 3.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.8	0.346	0.042
0.040	4.7	0.691	0.052
0.060	5.2	1.037	0.057
0.080	5.8	1.383	0.063
0.100	6.3	1.729	0.069
0.120	7.0	2.074	0.076
0.140	7.3	2.420	0.079
0.160	7.5	2.766	0.081
0.180	7.8	3.111	0.084
0.200	8.2	3.457	0.088
0.220	8.7	3.803	0.093
0.240	9.0	4.149	0.096
0.260	9.2	4.494	0.097
0.280	9.3	4.840	0.098
0.300	9.8	5.186	0.103
0.320	10.2	5.532	0.107
0.340	10.5	5.877	0.110
0.360	10.7	6.223	0.111
0.380	10.8	6.569	0.112
0.400	11.0	6.914	0.114
0.420	12.2	7.260	0.125
0.440	11.3	7.606	0.116
0.460	11.7	7.952	0.119
0.480	11.8	8.297	0.120
0.500	12.0	8.643	0.122
0.520	12.1	8.989	0.122
0.540	12.2	9.334	0.123
0.560	12.2	9.680	0.122
0.580	12.3	10.026	0.123
0.600	12.3	10.372	0.122



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay with fine sand
Type of Failure: Yield @ 10%
Boring No.: LAC-1-1
Depth (ft): 5-6

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1143.7

Area (in^2) = 6.492
Moisture Content (%) = 47.68%
Wet Density (pcf) = 115.4
Dry Density (pcf) = 78.2

Wet wt. 198.4
Dry at. 143.55
Can wt. 28.51

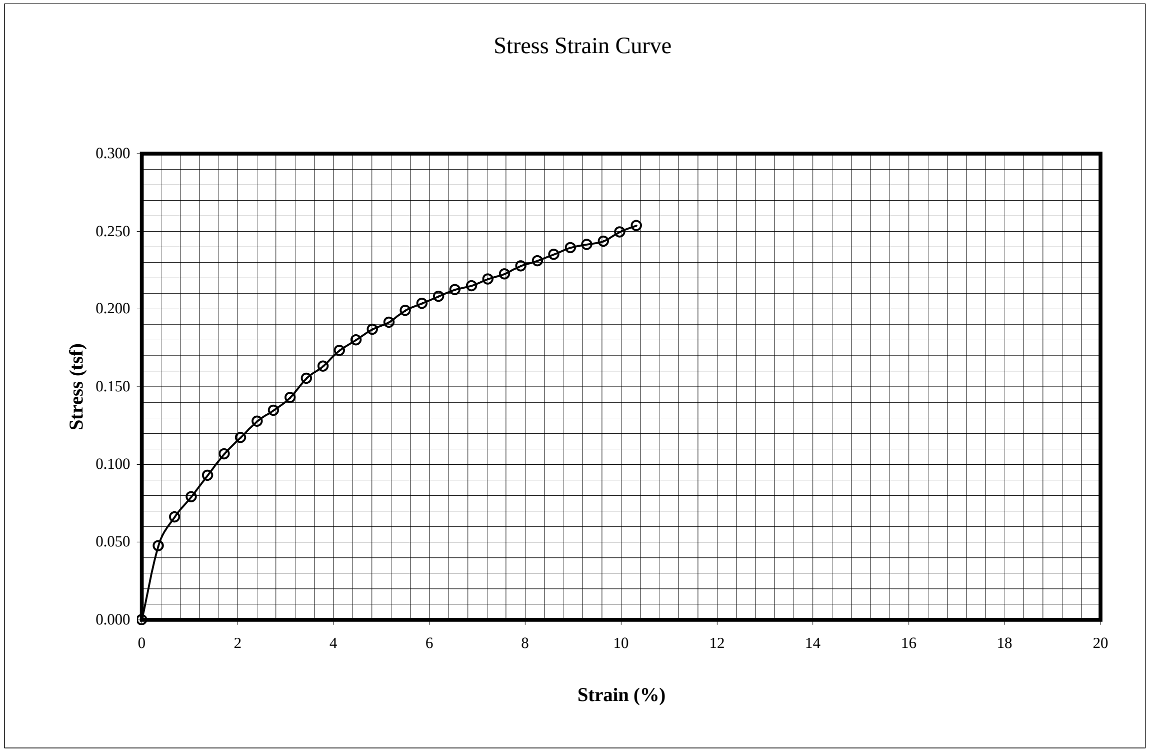
Test Data:

Cell Pressure (psi) = 3.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	4.3	0.344	0.048
0.040	6.0	0.688	0.066
0.060	7.2	1.032	0.079
0.080	8.5	1.376	0.093
0.100	9.8	1.720	0.107
0.120	10.8	2.064	0.117
0.140	11.8	2.408	0.128
0.160	12.5	2.752	0.135
0.180	13.3	3.096	0.143
0.200	14.5	3.440	0.155
0.220	15.3	3.784	0.163
0.240	16.3	4.128	0.173
0.260	17.0	4.472	0.180
0.280	17.7	4.816	0.187
0.300	18.2	5.160	0.191
0.320	19.0	5.504	0.199
0.340	19.5	5.848	0.204
0.360	20.0	6.192	0.208
0.380	20.5	6.536	0.213
0.400	20.8	6.880	0.215
0.420	21.3	7.224	0.219
0.440	21.7	7.568	0.222
0.460	22.3	7.912	0.228
0.480	22.7	8.256	0.231
0.500	23.2	8.600	0.235
0.520	23.7	8.944	0.239
0.540	24.0	9.288	0.241
0.560	24.3	9.632	0.244
0.580	25.0	9.976	0.250
0.600	25.5	10.320	0.254



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft clay w/ 1/2" sand layer at bottom
Type of Failure: Yield @ 10%
Boring No.: LAC-1-2
Depth (ft): 6-8

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1111.1

Area (in^2) = 6.492
Moisture Content (%) = 51.65%
Wet Density (pcf) = 112.4
Dry Density (pcf) = 74.1

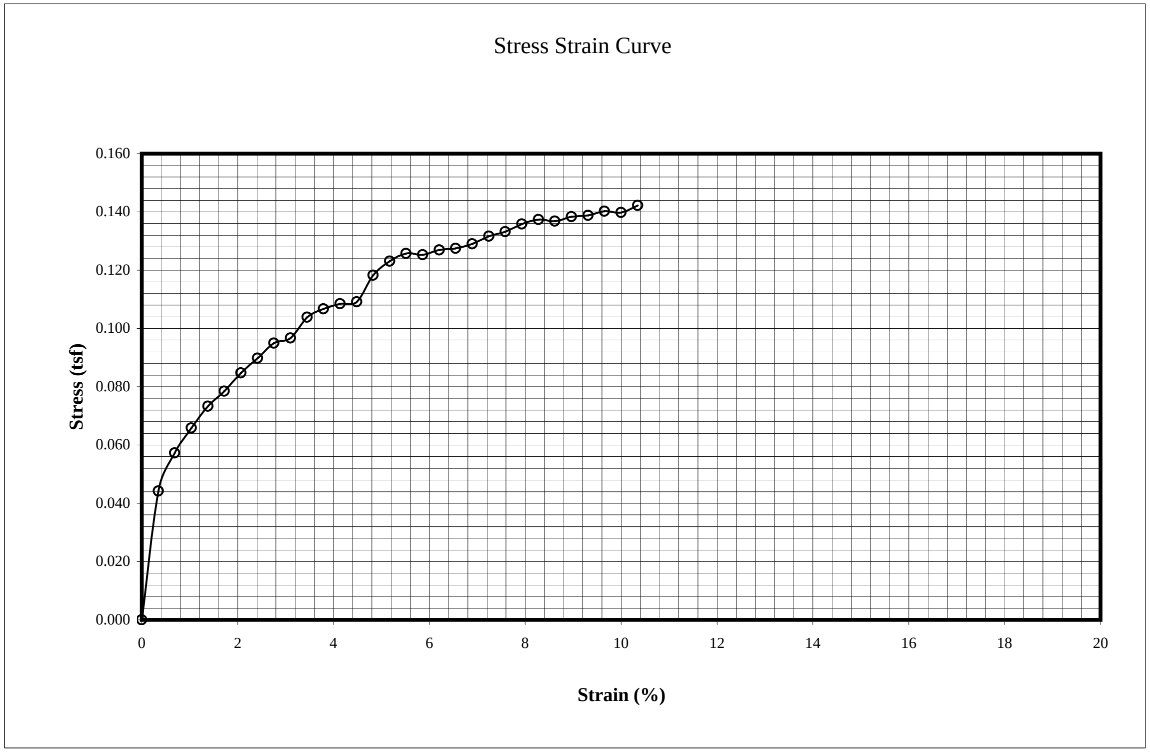
Wet wt. 151.2
Dry at. 108.24
Can wt. 25.06

Test Data:
Cell Pressure (psi) = 4.1
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	4.0	0.345	0.044
0.040	5.2	0.690	0.057
0.060	6.0	1.034	0.066
0.080	6.7	1.379	0.073
0.100	7.2	1.724	0.078
0.120	7.8	2.069	0.085
0.140	8.3	2.414	0.090
0.160	8.8	2.759	0.095
0.180	9.0	3.103	0.097
0.200	9.7	3.448	0.104
0.220	10.0	3.793	0.107
0.240	10.2	4.138	0.108
0.260	10.3	4.483	0.109
0.280	11.2	4.828	0.118
0.300	11.7	5.172	0.123
0.320	12.0	5.517	0.126
0.340	12.0	5.862	0.125
0.360	12.2	6.207	0.127
0.380	12.3	6.552	0.127
0.400	12.5	6.897	0.129
0.420	12.8	7.241	0.132
0.440	13.0	7.586	0.133
0.460	13.3	7.931	0.136
0.480	13.5	8.276	0.137
0.500	13.5	8.621	0.137
0.520	13.7	8.966	0.138
0.540	13.8	9.310	0.139
0.560	14.0	9.655	0.140
0.580	14.0	10.000	0.140
0.600	14.3	10.345	0.142



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray sandy clay w/wood & clay pockets
Type of Failure: Yield @ 10%
Boring No.: LAC-1-3
Depth (ft): 8.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 947.4

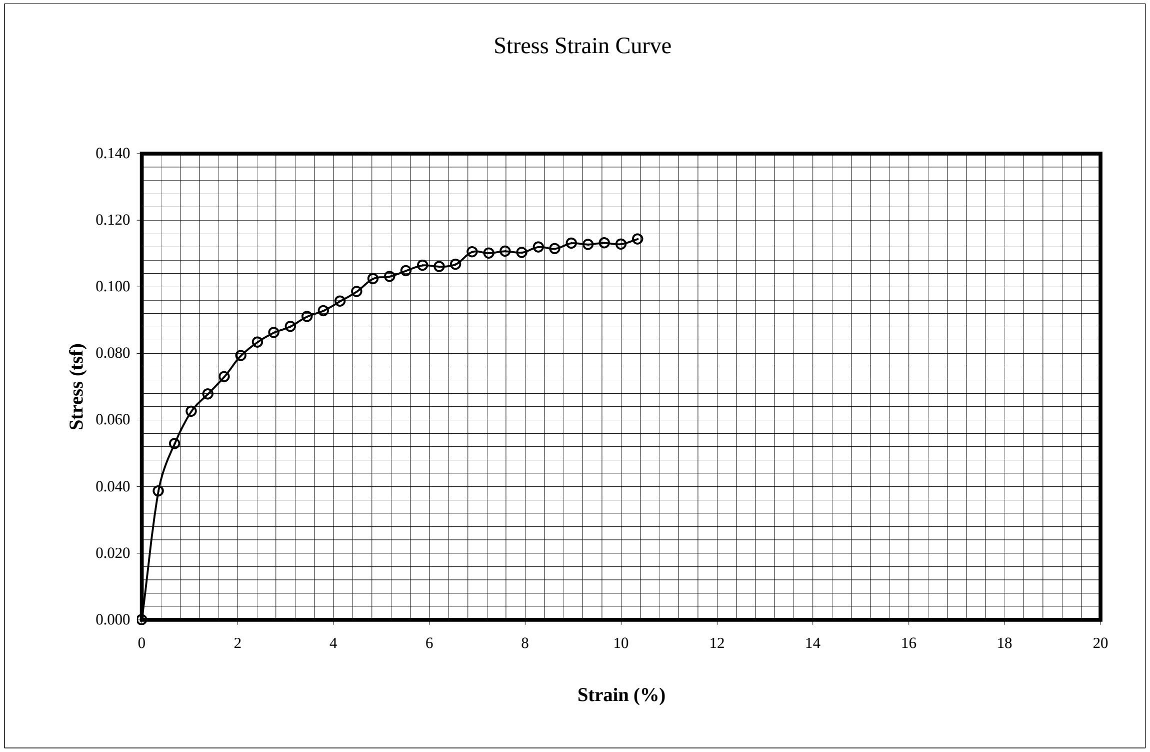
Area (in^2) = 6.492
Moisture Content (%) = 32.58%
Wet Density (pcf) = 95.9
Dry Density (pcf) = 72.3

Wet wt. 185.35
Dry at. 145.26
Can wt. 22.22

Test Data:
Cell Pressure (psi) = 5.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.5	0.345	0.039
0.040	4.8	0.690	0.053
0.060	5.7	1.034	0.063
0.080	6.2	1.379	0.068
0.100	6.7	1.724	0.073
0.120	7.3	2.069	0.079
0.140	7.7	2.414	0.083
0.160	8.0	2.759	0.086
0.180	8.2	3.103	0.088
0.200	8.5	3.448	0.091
0.220	8.7	3.793	0.093
0.240	9.0	4.138	0.096
0.260	9.3	4.483	0.099
0.280	9.7	4.828	0.102
0.300	9.8	5.172	0.103
0.320	10.0	5.517	0.105
0.340	10.2	5.862	0.106
0.360	10.2	6.207	0.106
0.380	10.3	6.552	0.107
0.400	10.7	6.897	0.110
0.420	10.7	7.241	0.110
0.440	10.8	7.586	0.111
0.460	10.8	7.931	0.110
0.480	11.0	8.276	0.112
0.500	11.0	8.621	0.111
0.520	11.2	8.966	0.113
0.540	11.2	9.310	0.113
0.560	11.3	9.655	0.113
0.580	11.3	10.000	0.113
0.600	11.5	10.345	0.114



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Firm gray fine sand with 2" clayey sand layer
Type of Failure: Bulge @ 4%
Boring No.: LAC-1-3
Depth (ft): 9.5-10.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1160.9

Area (in^2) = 6.492
Moisture Content (%) = 30.18%
Wet Density (pcf) = 117.5
Dry Density (pcf) = 90.2

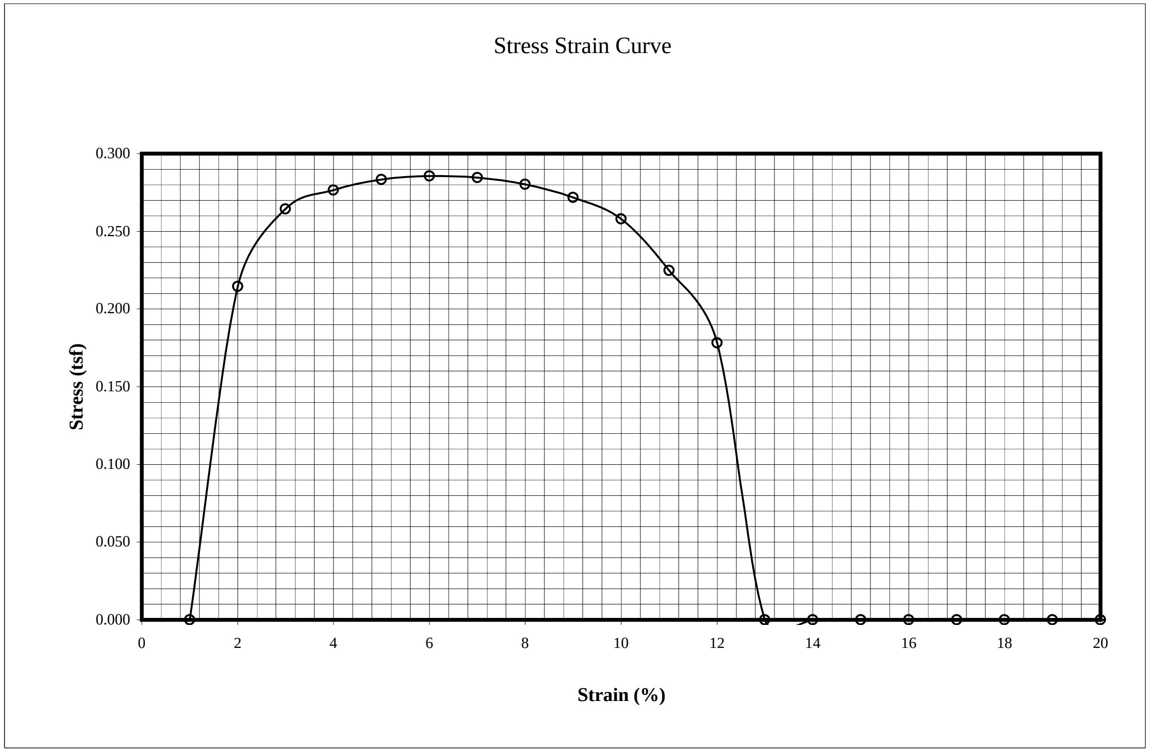
Wet wt. 197.24
Dry at. 158.25
Can wt. 29.07

Test Data:
Cell Pressure (psi) = 5.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	19.4	0.345	0.214
0.040	24.0	0.690	0.264
0.060	25.2	1.034	0.277
0.080	25.9	1.379	0.283
0.100	26.2	1.724	0.286
0.120	26.2	2.069	0.285
0.140	25.9	2.414	0.280
0.160	25.2	2.759	0.272
0.180	24.0	3.103	0.258
0.200	21.0	3.448	0.225
0.220	16.7	3.793	0.178
0.240			
0.260			
0.280			
0.300			
0.320			
0.340			
0.360			
0.380			
0.400			
0.420			
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay with some silt
Type of Failure: Yeild @ 10%
Boring No.: LAC-2-4
Depth (ft): 44-45

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1006.6

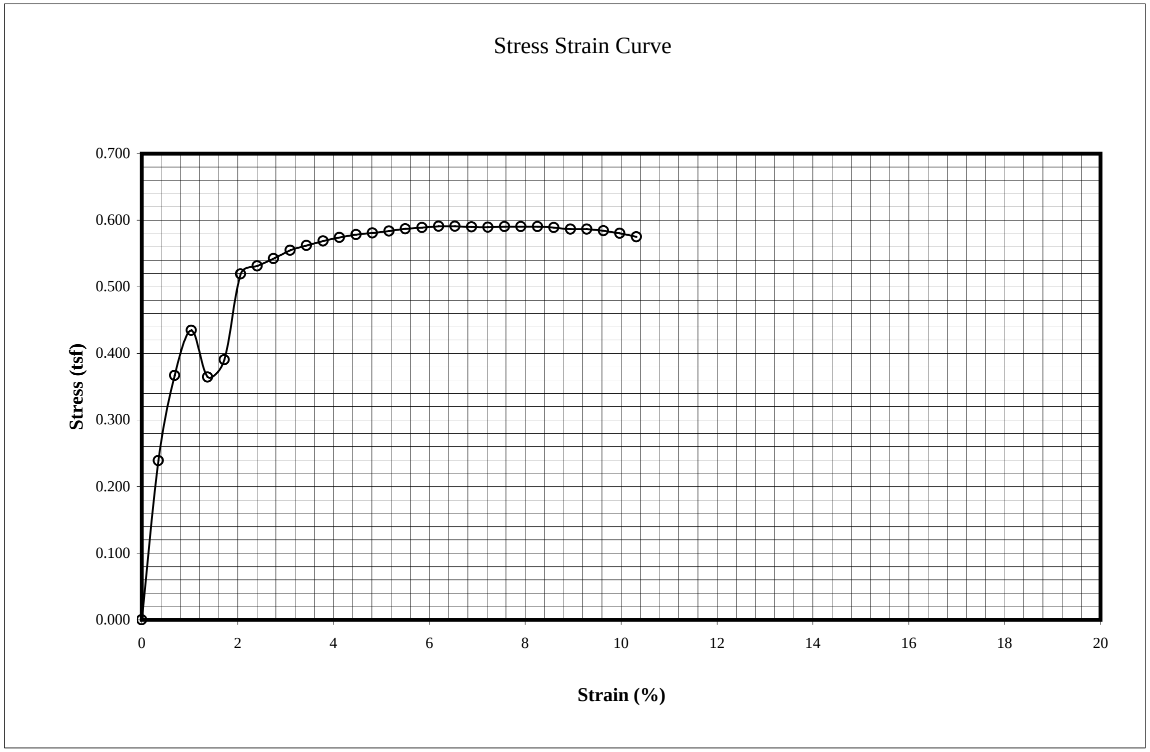
Area (in^2) = 6.492
Moisture Content (%) = 86.46%
Wet Density (pcf) = 101.6
Dry Density (pcf) = 54.5

Wet wt. 207.31
Dry at. 124.65
Can wt. 29.05

Test Data:
Cell Pressure (psi) = 26.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	21.6	0.344	0.239
0.040	33.3	0.688	0.367
0.060	39.6	1.032	0.435
0.080	33.3	1.376	0.364
0.100	35.8	1.720	0.390
0.120	47.8	2.064	0.519
0.140	49.1	2.408	0.531
0.160	50.3	2.752	0.543
0.180	51.6	3.096	0.555
0.200	52.5	3.440	0.562
0.220	53.3	3.784	0.569
0.240	54.0	4.128	0.574
0.260	54.6	4.472	0.578
0.280	55.0	4.816	0.581
0.300	55.5	5.160	0.584
0.320	56.0	5.504	0.587
0.340	56.4	5.848	0.589
0.360	56.8	6.192	0.591
0.380	57.0	6.536	0.591
0.400	57.1	6.880	0.590
0.420	57.3	7.224	0.590
0.440	57.6	7.568	0.590
0.460	57.8	7.912	0.590
0.480	58.0	8.256	0.590
0.500	58.1	8.600	0.589
0.520	58.1	8.944	0.587
0.540	58.3	9.288	0.587
0.560	58.3	9.632	0.584
0.580	58.1	9.976	0.580
0.600	57.8	10.320	0.575



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay w/silt seams & shell fragments
Type of Failure: Yeild @ 10%
Boring No.: LAC-2-4
Depth (ft): 45-46

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1041.3

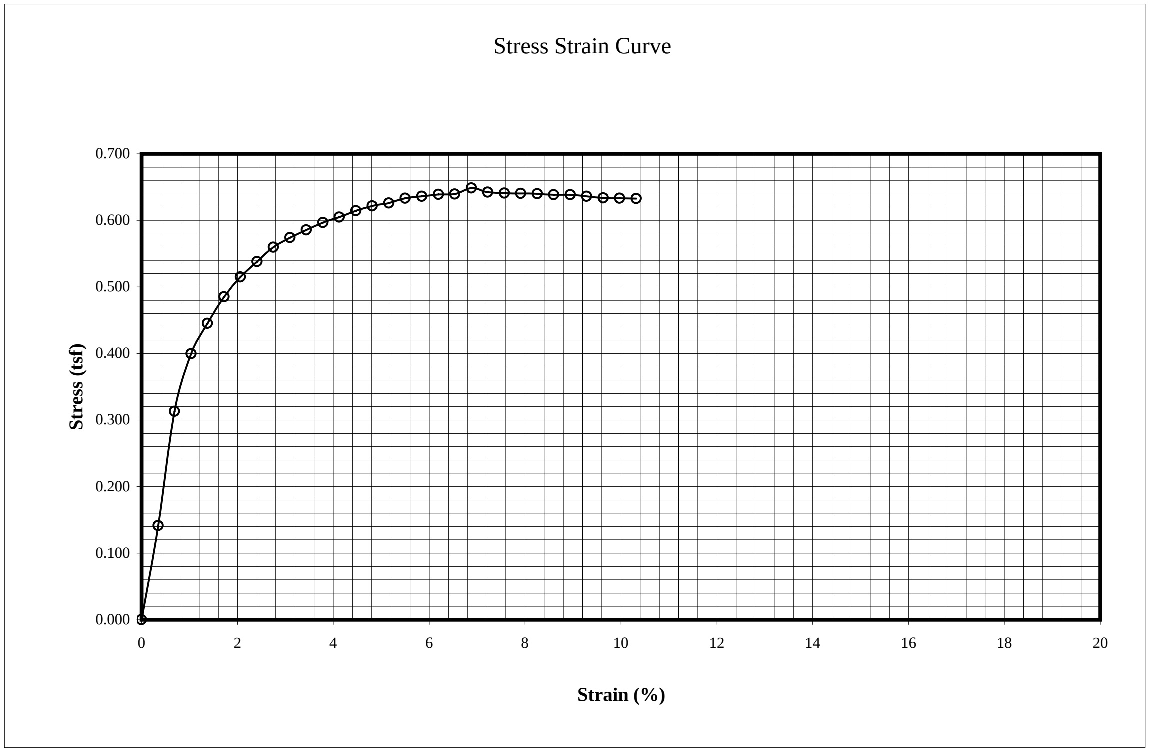
Area (in^2) = 6.492
Moisture Content (%) = 57.75%
Wet Density (pcf) = 105.1
Dry Density (pcf) = 66.6

Wet wt. 195.39
Dry at. 131.96
Can wt. 22.12

Test Data:
Cell Pressure (psi) = 26.6
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	12.8	0.344	0.141
0.040	28.4	0.688	0.313
0.060	36.4	1.032	0.400
0.080	40.7	1.376	0.445
0.100	44.5	1.720	0.485
0.120	47.4	2.064	0.515
0.140	49.7	2.408	0.538
0.160	51.9	2.752	0.560
0.180	53.4	3.096	0.574
0.200	54.7	3.440	0.586
0.220	55.9	3.784	0.597
0.240	56.9	4.128	0.605
0.260	58.0	4.472	0.615
0.280	58.9	4.816	0.622
0.300	59.5	5.160	0.626
0.320	60.4	5.504	0.633
0.340	60.9	5.848	0.636
0.360	61.4	6.192	0.639
0.380	61.7	6.536	0.640
0.400	62.8	6.880	0.649
0.420	62.4	7.224	0.642
0.440	62.5	7.568	0.641
0.460	62.7	7.912	0.640
0.480	62.9	8.256	0.640
0.500	63.0	8.600	0.639
0.520	63.2	8.944	0.638
0.540	63.2	9.288	0.636
0.560	63.2	9.632	0.633
0.580	63.4	9.976	0.633
0.600	63.6	10.320	0.633



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray sandy clay to sand
Type of Failure: Vertical @ 4%
Boring No.: LAC-3-3
Depth (ft): 7.5-8.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1246.1

Area (in^2) = 6.492
Moisture Content (%) = 21.80%
Wet Density (pcf) = 125.8
Dry Density (pcf) = 103.3

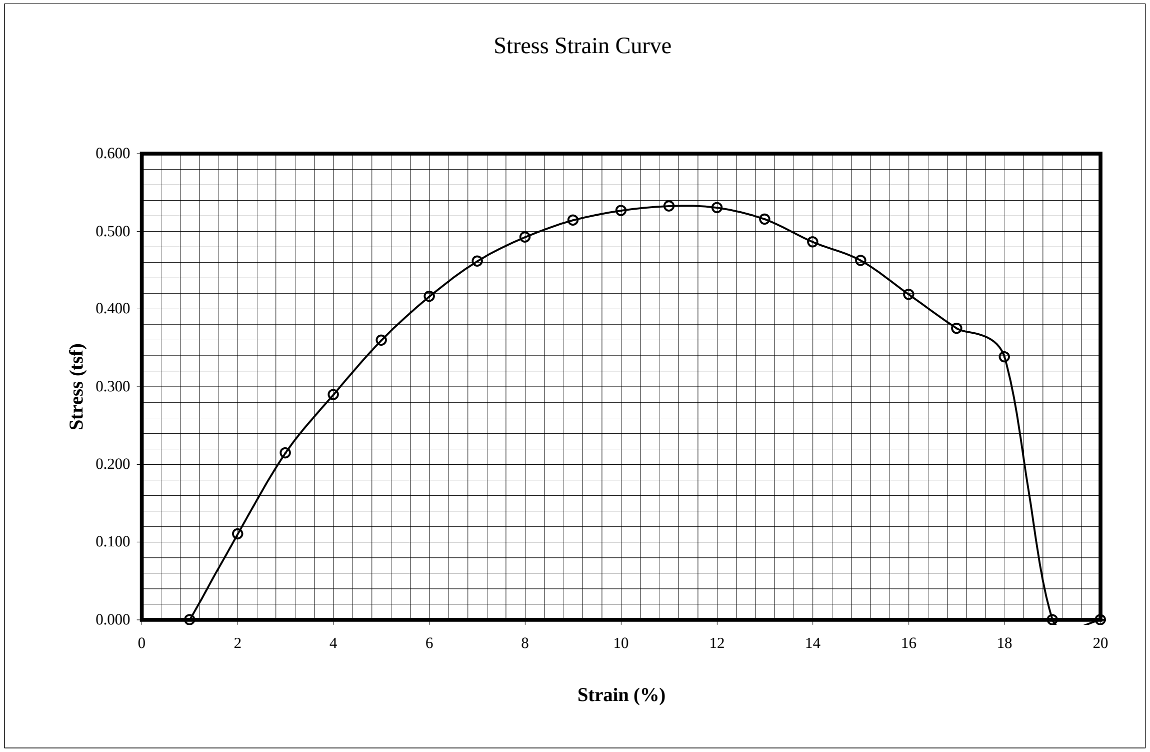
Wet wt. 193.85
Dry at. 164.29
Can wt. 28.69

Test Data:
Cell Pressure (psi) = 4.3
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	10.0	0.344	0.111
0.040	19.5	0.688	0.215
0.060	26.4	1.032	0.290
0.080	32.9	1.376	0.360
0.100	38.2	1.720	0.416
0.120	42.5	2.064	0.462
0.140	45.5	2.408	0.492
0.160	47.7	2.752	0.514
0.180	49.0	3.096	0.527
0.200	49.7	3.440	0.532
0.220	49.7	3.784	0.530
0.240	48.5	4.128	0.516
0.260	45.9	4.472	0.486
0.280	43.8	4.816	0.462
0.300	39.8	5.160	0.419
0.320	35.8	5.504	0.375
0.340	32.4	5.848	0.338
0.360			
0.380			
0.400			
0.420			
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Firm gray sand with clay
Type of Failure: Bulge @ 7%
Boring No.: LAC-3-4
Depth (ft): 9-11

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1208.9

Area (in^2) = 6.492
Moisture Content (%) = 26.58%
Wet Density (pcf) = 122.3
Dry Density (pcf) = 96.6

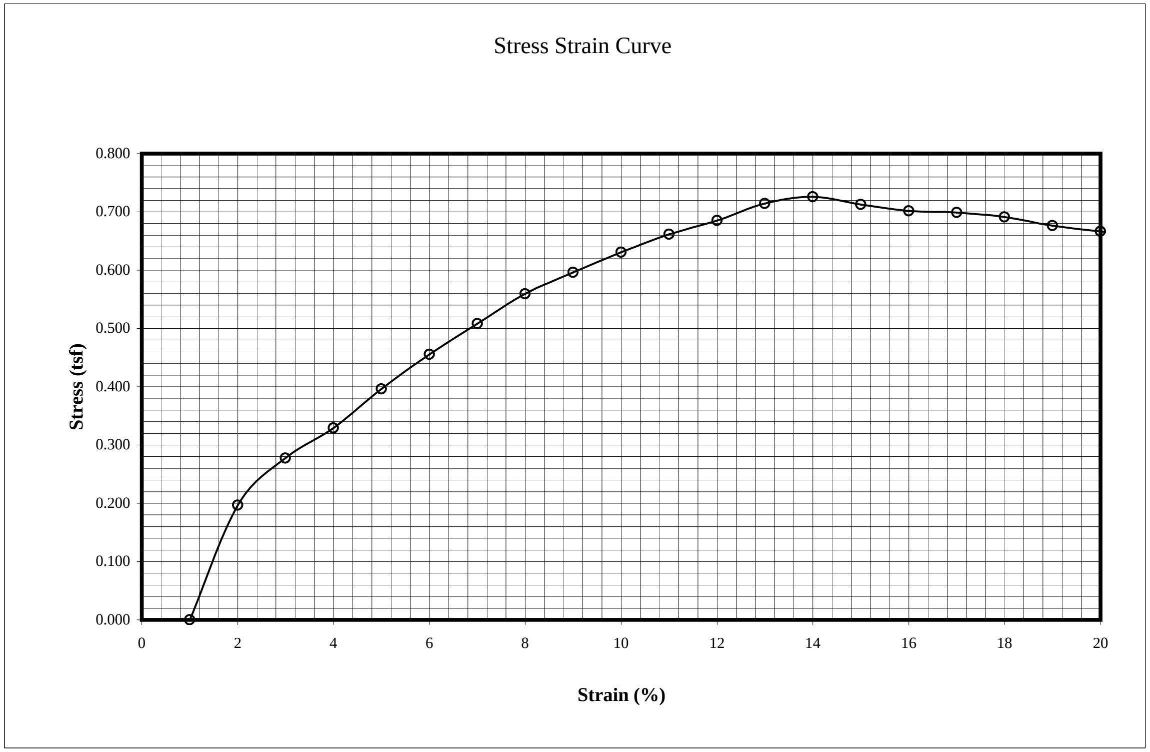
Wet wt. 151.05
Dry at. 123.97
Can wt. 22.08

Test Data:

Cell Pressure (psi) = 5.9
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	17.8	0.345	0.197
0.040	25.2	0.690	0.278
0.060	30.0	1.034	0.329
0.080	36.2	1.379	0.396
0.100	41.8	1.724	0.456
0.120	46.8	2.069	0.508
0.140	51.7	2.414	0.560
0.160	55.3	2.759	0.596
0.180	58.7	3.103	0.631
0.200	61.8	3.448	0.662
0.220	64.2	3.793	0.685
0.240	67.2	4.138	0.714
0.260	68.5	4.483	0.726
0.280	67.5	4.828	0.712
0.300	66.7	5.172	0.701
0.320	66.7	5.517	0.699
0.340	66.2	5.862	0.691
0.360	65.0	6.207	0.676
0.380	64.3	6.552	0.666
0.400	63.7	6.897	0.658
0.420	62.8	7.241	0.646
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft dark gray organic clay with peat
Type of Failure: Yield @ 10%
Boring No.: LACW-2-2
Depth (ft): 8.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 759.7

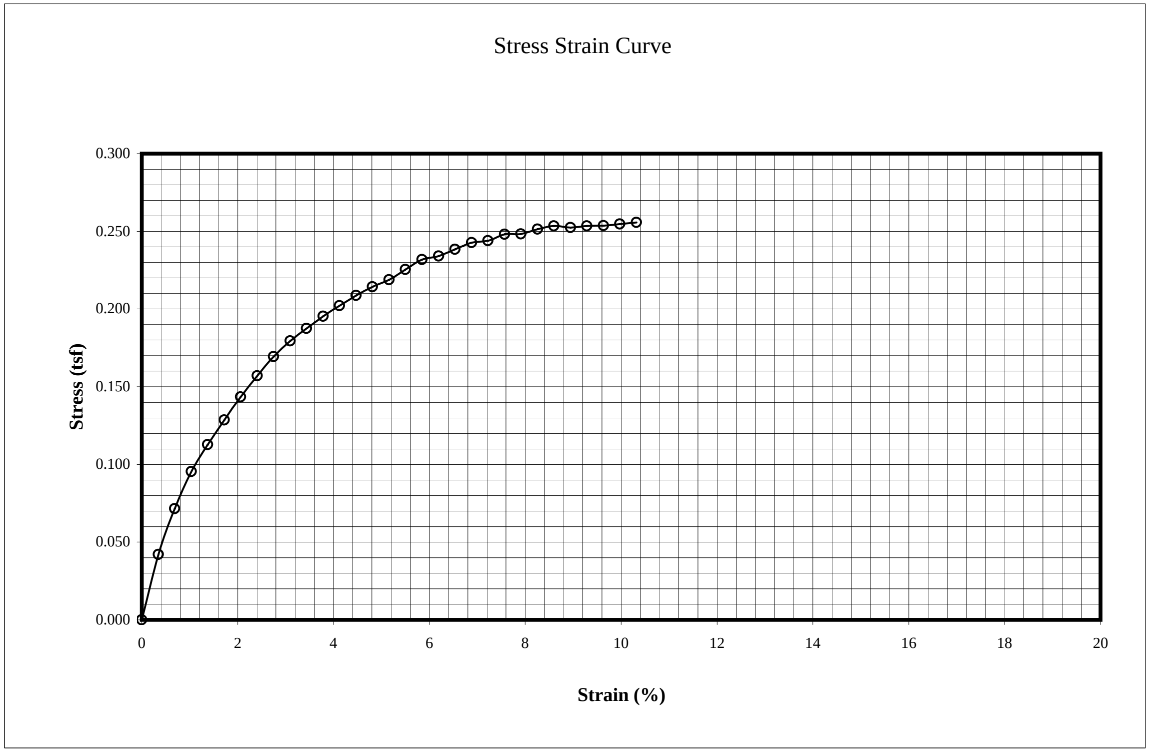
Area (in^2) = 6.492
Moisture Content (%) = 186.97%
Wet Density (pcf) = 76.7
Dry Density (pcf) = 26.7

Wet wt. 133.17
Dry at. 64.01
Can wt. 27.02

Test Data:
Cell Pressure (psi) = 4.3
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.8	0.344	0.042
0.040	6.5	0.688	0.072
0.060	8.7	1.032	0.095
0.080	10.3	1.376	0.113
0.100	11.8	1.720	0.129
0.120	13.2	2.064	0.143
0.140	14.5	2.408	0.157
0.160	15.7	2.752	0.169
0.180	16.7	3.096	0.179
0.200	17.5	3.440	0.187
0.220	18.3	3.784	0.195
0.240	19.0	4.128	0.202
0.260	19.7	4.472	0.209
0.280	20.3	4.816	0.214
0.300	20.8	5.160	0.219
0.320	21.5	5.504	0.225
0.340	22.2	5.848	0.232
0.360	22.5	6.192	0.234
0.380	23.0	6.536	0.238
0.400	23.5	6.880	0.243
0.420	23.7	7.224	0.244
0.440	24.2	7.568	0.248
0.460	24.3	7.912	0.248
0.480	24.7	8.256	0.251
0.500	25.0	8.600	0.253
0.520	25.0	8.944	0.252
0.540	25.2	9.288	0.254
0.560	25.3	9.632	0.254
0.580	25.5	9.976	0.255
0.600	25.7	10.320	0.256



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very Soft dark gray organic clay with peat
Type of Failure: Yellow @ 10%
Boring No.: LACW-2-2
Depth (ft): 9.5-10.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 764.5

Area (in^2) = 6.492
Moisture Content (%) = 157.95%
Wet Density (pcf) = 77.2
Dry Density (pcf) = 29.9

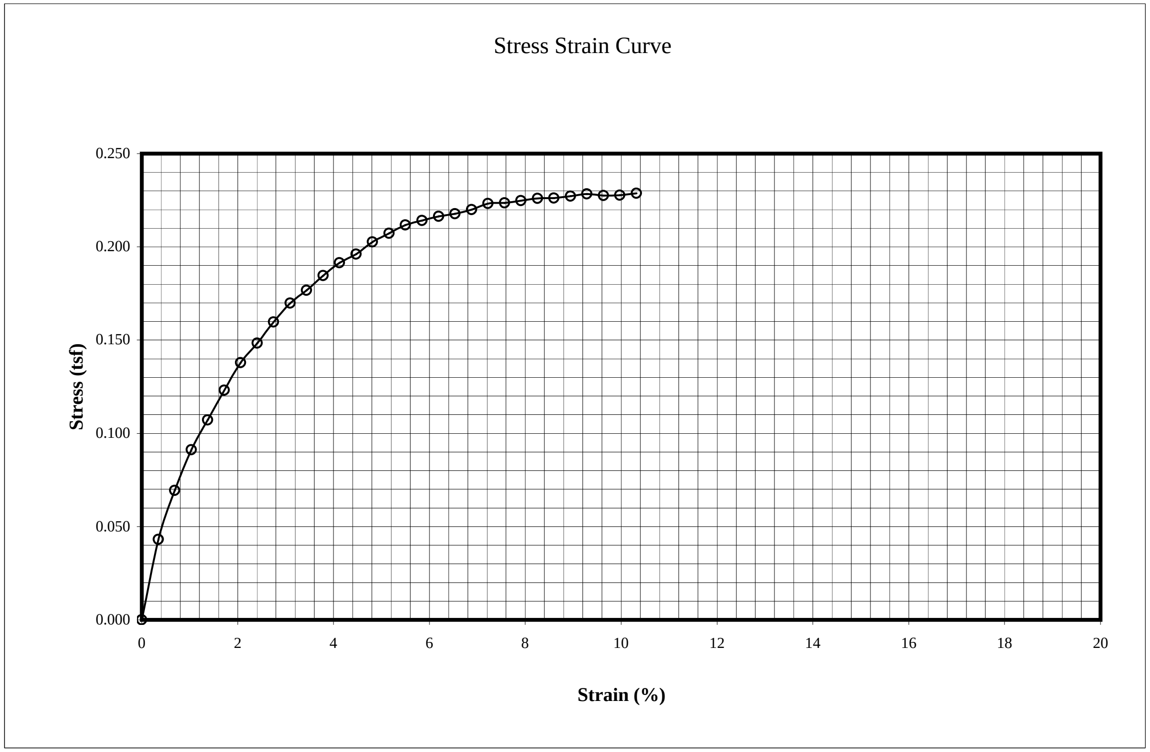
Wet wt. 135
Dry at. 70.05
Can wt. 28.93

Test Data:
Cell Pressure (psi) = 4.3
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	3.9	0.344	0.043
0.040	6.3	0.688	0.069
0.060	8.3	1.032	0.091
0.080	9.8	1.376	0.107
0.100	11.3	1.720	0.123
0.120	12.7	2.064	0.138
0.140	13.7	2.408	0.148
0.160	14.8	2.752	0.160
0.180	15.8	3.096	0.170
0.200	16.5	3.440	0.177
0.220	17.3	3.784	0.185
0.240	18.0	4.128	0.191
0.260	18.5	4.472	0.196
0.280	19.2	4.816	0.203
0.300	19.7	5.160	0.207
0.320	20.2	5.504	0.212
0.340	20.5	5.848	0.214
0.360	20.8	6.192	0.216
0.380	21.0	6.536	0.218
0.400	21.3	6.880	0.220
0.420	21.7	7.224	0.223
0.440	21.8	7.568	0.223
0.460	22.0	7.912	0.225
0.480	22.2	8.256	0.226
0.500	22.3	8.600	0.226
0.520	22.5	8.944	0.227
0.540	22.7	9.288	0.228
0.560	22.7	9.632	0.228
0.580	22.8	9.976	0.228
0.600	23.0	10.320	0.229



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium dark gray organic clay alt. Layers of sand silt & clay
Type of Failure: Yield @ 10%
Boring No.: LACW-3-4
Depth (ft): 10-12

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1120.8

Area (in^2) = 6.492
Moisture Content (%) = 48.11%
Wet Density (pcf) = 113.1
Dry Density (pcf) = 76.4

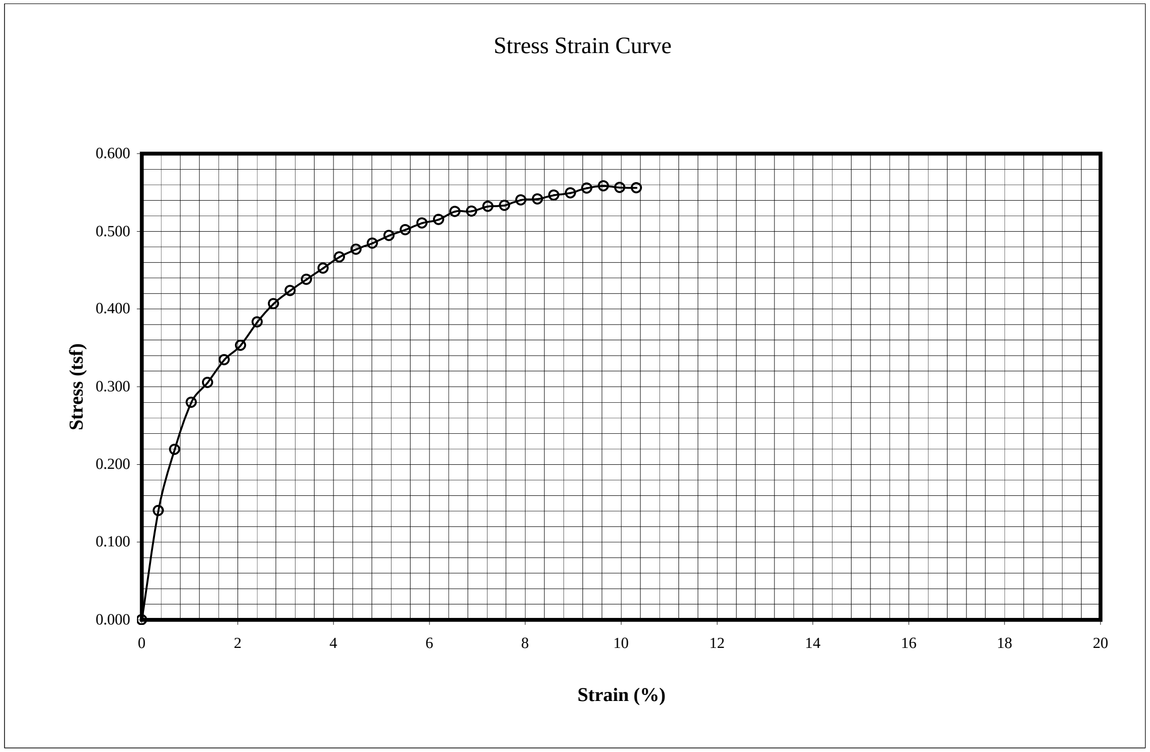
Wet wt. 205
Dry at. 145.69
Can wt. 22.42

Test Data:
Cell Pressure (psi) = 6.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	12.7	0.344	0.140
0.040	19.9	0.688	0.219
0.060	25.5	1.032	0.280
0.080	27.9	1.376	0.305
0.100	30.7	1.720	0.335
0.120	32.5	2.064	0.353
0.140	35.4	2.408	0.383
0.160	37.7	2.752	0.407
0.180	39.4	3.096	0.423
0.200	40.9	3.440	0.438
0.220	42.4	3.784	0.452
0.240	43.9	4.128	0.467
0.260	45.0	4.472	0.477
0.280	45.9	4.816	0.485
0.300	47.0	5.160	0.494
0.320	47.9	5.504	0.502
0.340	48.9	5.848	0.511
0.360	49.5	6.192	0.515
0.380	50.7	6.536	0.526
0.400	50.9	6.880	0.526
0.420	51.7	7.224	0.532
0.440	52.0	7.568	0.533
0.460	52.9	7.912	0.540
0.480	53.2	8.256	0.541
0.500	53.9	8.600	0.546
0.520	54.4	8.944	0.549
0.540	55.2	9.288	0.555
0.560	55.7	9.632	0.558
0.580	55.7	9.976	0.556
0.600	55.9	10.320	0.556



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff dark gray organic w/roots
Type of Failure: Vertical @ 9%
Boring No.: LACW-4-1
Depth (ft): 3.5-4.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 4.6
Weight (gm) = 790.1

Area (in^2) = 6.492
Moisture Content (%) = 52.32%
Wet Density (pcf) = 101.7
Dry Density (pcf) = 66.7

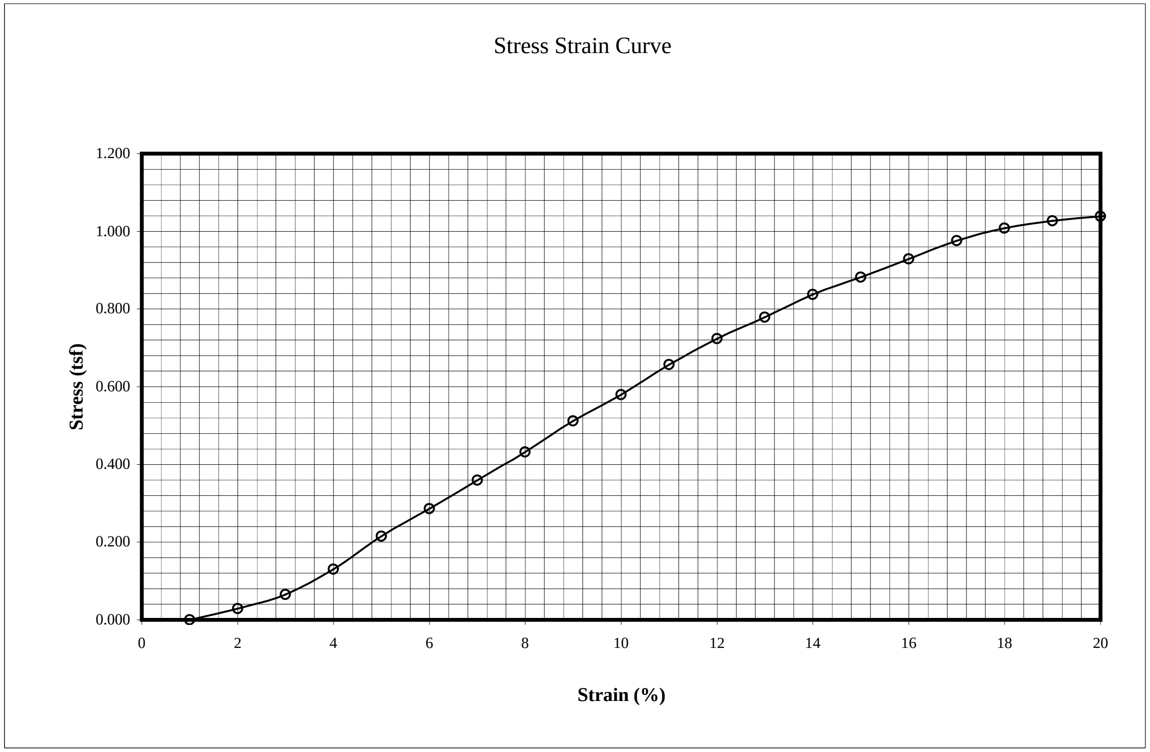
Wet wt. 145.27
Dry at. 105.17
Can wt. 28.52

Test Data:
Cell Pressure (psi) =
Height Correction = 0.978
Proving Ring No.= 9839

0.337

2.197729

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	8	0.439	0.029
0.040	18	0.877	0.065
0.060	36	1.316	0.130
0.080	60	1.754	0.215
0.100	80	2.193	0.286
0.120	101	2.632	0.359
0.140	122	3.070	0.432
0.160	145	3.509	0.511
0.180	165	3.947	0.579
0.200	188	4.386	0.657
0.220	208	4.825	0.724
0.240	225	5.263	0.779
0.260	243	5.702	0.838
0.280	257	6.140	0.882
0.300	272	6.579	0.929
0.320	287	7.018	0.975
0.340	298	7.456	1.008
0.360	305	7.895	1.027
0.380	310	8.333	1.039
0.400	314	8.772	1.047
0.420	314	9.211	1.042
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray organic clay w/wood & peat
Type of Failure: Vertical @ 7%
Boring No.: LACW-4-3
Depth (ft): 7.5-8.5

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 858.9

Area (in^2) = 6.492
Moisture Content (%) = 109.93%
Wet Density (pcf) = 86.7
Dry Density (pcf) = 41.3

Wet wt. 134.15
Dry at. 78.49
Can wt. 27.86

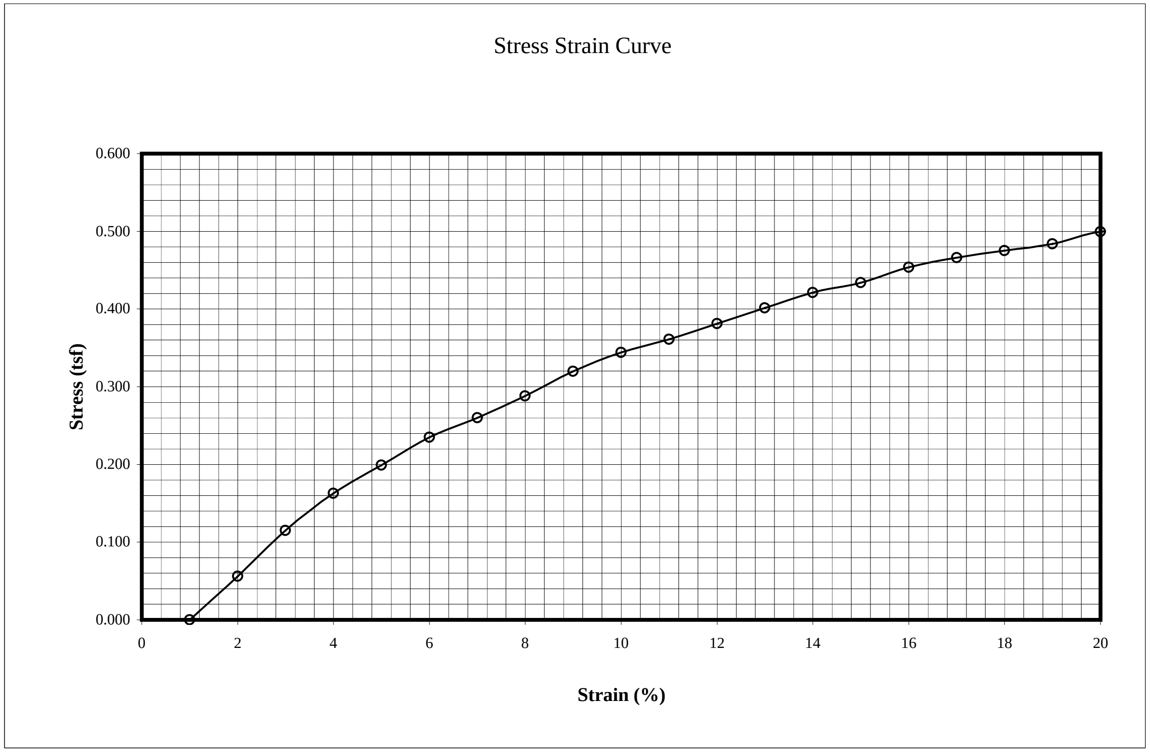
Test Data:

Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	15	0.344	0.056
0.040	31	0.688	0.115
0.060	44	1.032	0.163
0.080	54	1.376	0.199
0.100	64	1.720	0.235
0.120	71	2.064	0.260
0.140	79	2.408	0.288
0.160	88	2.752	0.320
0.180	95	3.096	0.344
0.200	100	3.440	0.361
0.220	106	3.784	0.381
0.240	112	4.128	0.401
0.260	118	4.472	0.421
0.280	122	4.816	0.434
0.300	128	5.160	0.454
0.320	132	5.504	0.466
0.340	135	5.848	0.475
0.360	138	6.192	0.484
0.380	143	6.536	0.500
0.400	143	6.880	0.498
0.420	143	7.224	0.496
0.440			
0.460			
0.480			
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay with peat & wood
Type of Failure: Vertical @ 8%
Boring No.: LACW-4-3
Depth (ft): 8.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 836.6

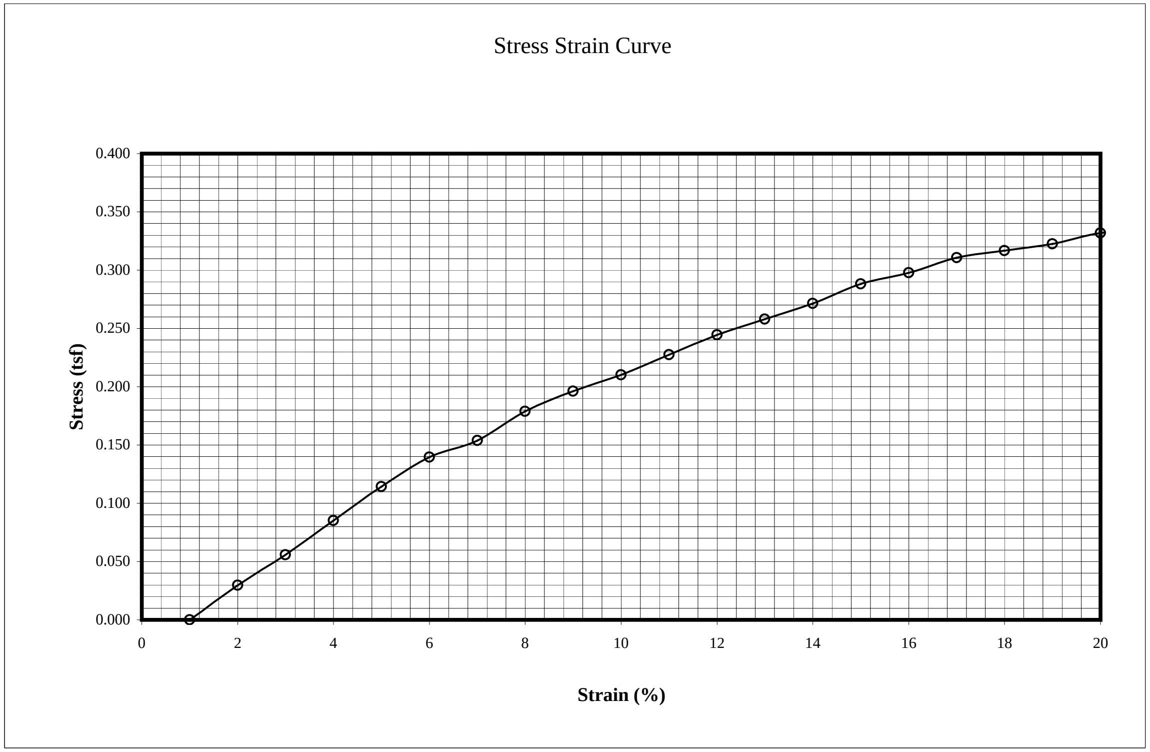
Area (in^2) = 6.492
Moisture Content (%) = 125.09%
Wet Density (pcf) = 84.4
Dry Density (pcf) = 37.5

Wet wt. 105.4
Dry at. 59.13
Can wt. 22.14

Test Data:
Cell Pressure (psi) =
Height Correction = 1.000
Proving Ring No.= 9839
0.337

2.197729

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	8	0.344	0.030
0.040	15	0.688	0.056
0.060	23	1.032	0.085
0.080	31	1.376	0.114
0.100	38	1.720	0.140
0.120	42	2.064	0.154
0.140	49	2.408	0.179
0.160	54	2.752	0.196
0.180	58	3.096	0.210
0.200	63	3.440	0.227
0.220	68	3.784	0.245
0.240	72	4.128	0.258
0.260	76	4.472	0.271
0.280	81	4.816	0.288
0.300	84	5.160	0.298
0.320	88	5.504	0.311
0.340	90	5.848	0.317
0.360	92	6.192	0.323
0.380	95	6.536	0.332
0.400	96	6.880	0.334
0.420	97	7.224	0.336
0.440	98	7.568	0.339
0.460	98	7.912	0.337
0.480	98	8.256	0.336
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay w/fine sand at bottom
Type of Failure: Yield @ 10%
Boring No.: LACS-1-3
Depth (ft): 8.5-10.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1030.8

Area (in^2) = 6.492
Moisture Content (%) = 32.46%
Wet Density (pcf) = 104.0
Dry Density (pcf) = 78.5

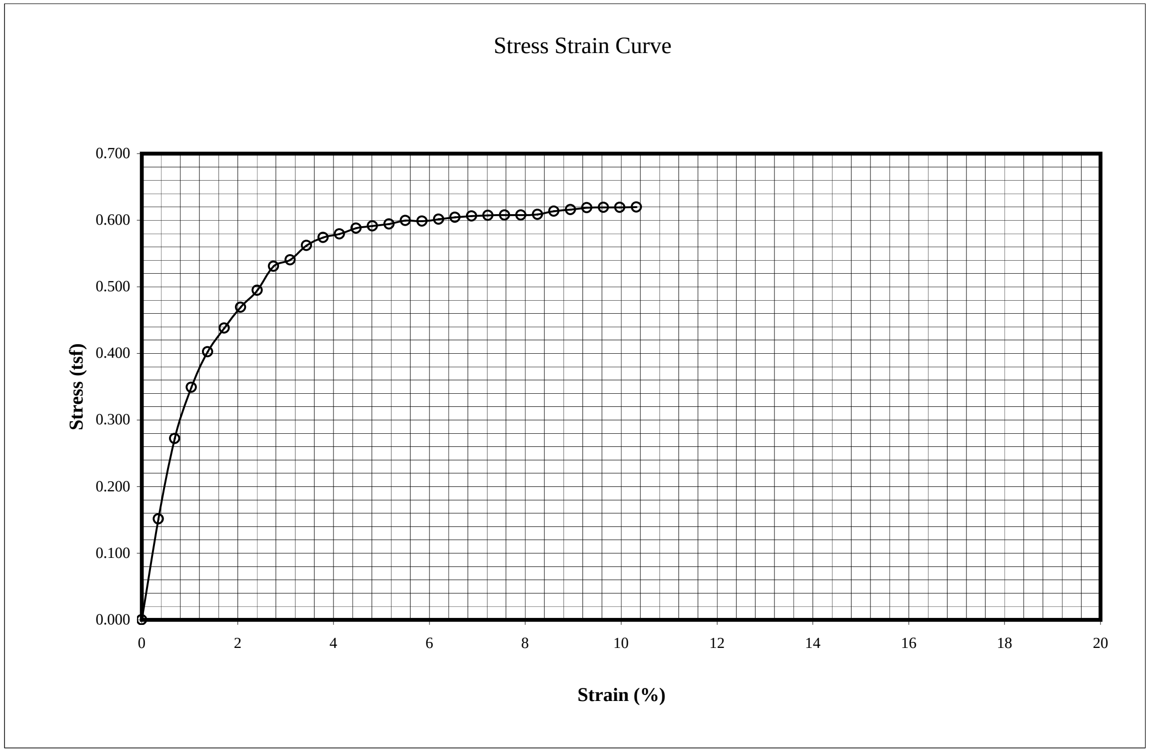
Wet wt. 223.35
Dry at. 174.08
Can wt. 22.3

Test Data:
Cell Pressure (psi) = 4.2
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	13.7	0.344	0.151
0.040	24.7	0.688	0.272
0.060	31.8	1.032	0.349
0.080	36.8	1.376	0.403
0.100	40.2	1.720	0.438
0.120	43.2	2.064	0.469
0.140	45.7	2.408	0.495
0.160	49.2	2.752	0.531
0.180	50.3	3.096	0.541
0.200	52.5	3.440	0.562
0.220	53.8	3.784	0.574
0.240	54.5	4.128	0.580
0.260	55.5	4.472	0.588
0.280	56.0	4.816	0.591
0.300	56.5	5.160	0.594
0.320	57.2	5.504	0.599
0.340	57.3	5.848	0.598
0.360	57.8	6.192	0.601
0.380	58.3	6.536	0.604
0.400	58.7	6.880	0.606
0.420	59.0	7.224	0.607
0.440	59.3	7.568	0.608
0.460	59.5	7.912	0.608
0.480	59.8	8.256	0.608
0.500	60.5	8.600	0.613
0.520	61.0	8.944	0.616
0.540	61.5	9.288	0.619
0.560	61.8	9.632	0.619
0.580	62.0	9.976	0.619
0.600	62.3	10.320	0.620



uuLACS-1-3

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UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Stiff gray clay
Type of Failure: Yield @ 10%
Boring No.: LACS-3-1
Depth (ft): 5-7

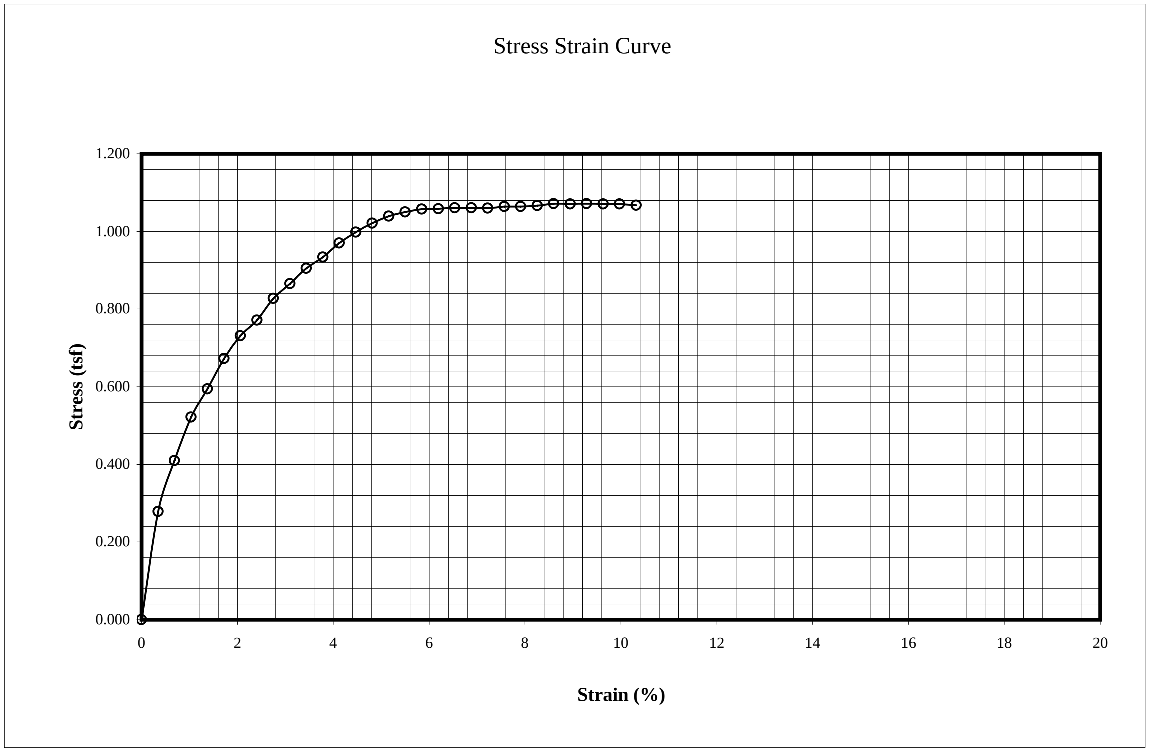
Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1160.0
Area (in^2) = 6.492
Moisture Content (%) = 28.06%
Wet Density (pcf) = 117.1
Dry Density (pcf) = 91.4
Wet wt. 218.55
Dry at. 177.01
Can wt. 28.96

Test Data:
Cell Pressure (psi) = 3.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	25.2	0.344	0.279
0.040	37.2	0.688	0.410
0.060	47.5	1.032	0.521
0.080	54.3	1.376	0.594
0.100	61.7	1.720	0.673
0.120	67.3	2.064	0.731
0.140	71.3	2.408	0.772
0.160	76.7	2.752	0.827
0.180	80.5	3.096	0.865
0.200	84.5	3.440	0.905
0.220	87.5	3.784	0.934
0.240	91.2	4.128	0.970
0.260	94.2	4.472	0.998
0.280	96.7	4.816	1.021
0.300	98.8	5.160	1.039
0.320	100.2	5.504	1.050
0.340	101.3	5.848	1.058
0.360	101.7	6.192	1.058
0.380	102.3	6.536	1.060
0.400	102.7	6.880	1.061
0.420	103.0	7.224	1.060
0.440	103.8	7.568	1.064
0.460	104.2	7.912	1.064
0.480	104.8	8.256	1.066
0.500	105.7	8.600	1.071
0.520	106.0	8.944	1.070
0.540	106.5	9.288	1.071
0.560	106.8	9.632	1.070
0.580	107.2	9.976	1.070
0.600	107.3	10.320	1.067



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray caly
Type of Failure: Bulge @ 8%
Boring No.: LACS-3-2
Depth (ft): 7.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 984.9

Area (in^2) = 6.492
Moisture Content (%) = 50.25%
Wet Density (pcf) = 99.4
Dry Density (pcf) = 66.2

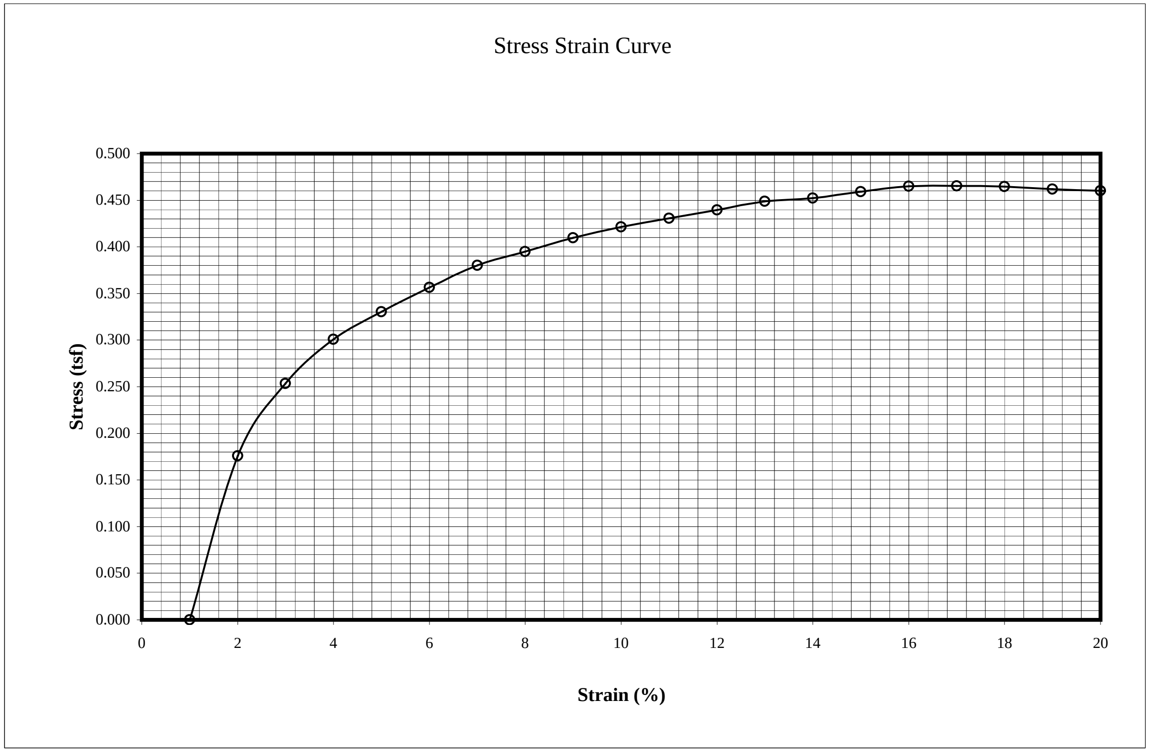
Wet wt. 224.64
Dry at. 158.43
Can wt. 26.67

Test Data:
Cell Pressure (psi) = 5.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	15.9	0.344	0.176
0.040	23.0	0.688	0.253
0.060	27.4	1.032	0.301
0.080	30.2	1.376	0.330
0.100	32.7	1.720	0.356
0.120	35.0	2.064	0.380
0.140	36.5	2.408	0.395
0.160	38.0	2.752	0.410
0.180	39.2	3.096	0.421
0.200	40.2	3.440	0.431
0.220	41.2	3.784	0.440
0.240	42.2	4.128	0.449
0.260	42.7	4.472	0.452
0.280	43.5	4.816	0.459
0.300	44.2	5.160	0.465
0.320	44.4	5.504	0.465
0.340	44.5	5.848	0.465
0.360	44.4	6.192	0.462
0.380	44.4	6.536	0.460
0.400	44.4	6.880	0.459
0.420	44.4	7.224	0.457
0.440	44.0	7.568	0.451
0.460	43.5	7.912	0.444
0.480	43.2	8.256	0.440
0.500			
0.520			
0.540			
0.560			
0.580			
0.600			



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Medium gray clay
Type of Failure: Yield @ 10%
Boring No.: IHNCS-1-1
Depth (ft): 7.5-9.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1009.3

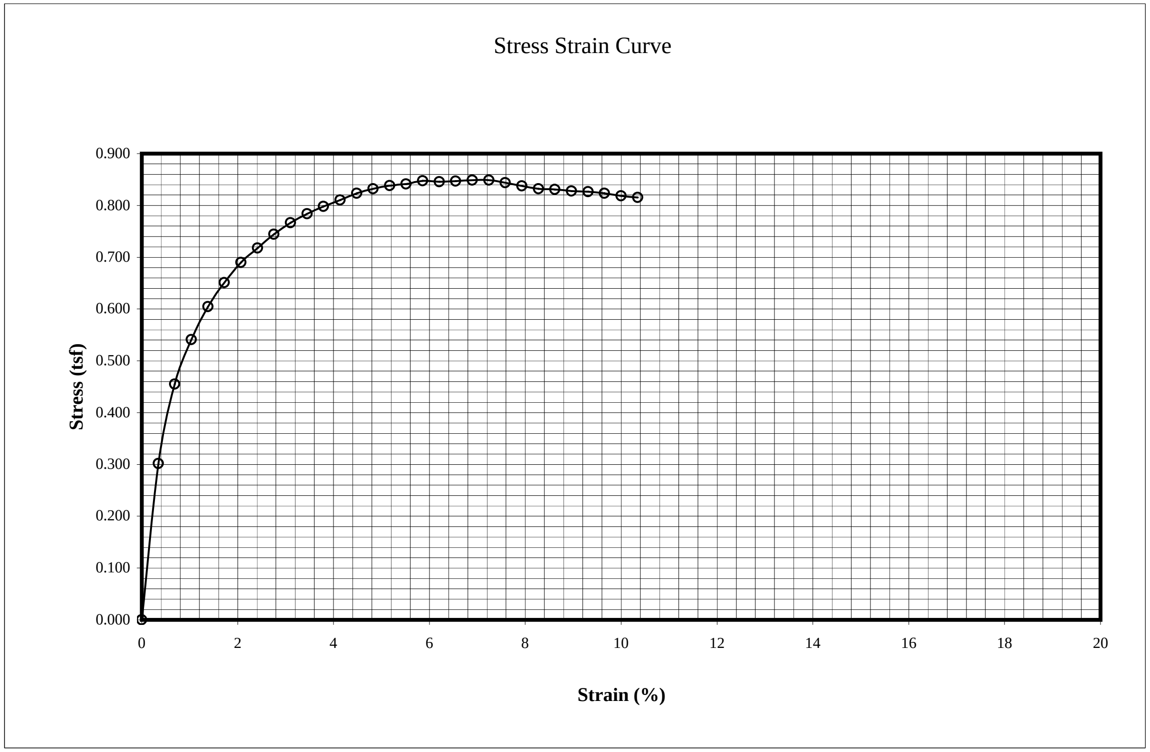
Area (in^2) = 6.492
Moisture Content (%) = 62.77%
Wet Density (pcf) = 102.1
Dry Density (pcf) = 62.7

Wet wt. 98.15
Dry at. 70.36
Can wt. 26.09

Test Data:
Cell Pressure (psi) = 4.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	27.3	0.345	0.302
0.040	41.3	0.690	0.455
0.060	49.3	1.034	0.541
0.080	55.3	1.379	0.605
0.100	59.7	1.724	0.651
0.120	63.5	2.069	0.690
0.140	66.3	2.414	0.718
0.160	69.0	2.759	0.744
0.180	71.3	3.103	0.766
0.200	73.2	3.448	0.784
0.220	74.8	3.793	0.798
0.240	76.2	4.138	0.810
0.260	77.7	4.483	0.823
0.280	78.8	4.828	0.832
0.300	79.7	5.172	0.838
0.320	80.3	5.517	0.841
0.340	81.2	5.862	0.848
0.360	81.3	6.207	0.846
0.380	81.7	6.552	0.847
0.400	82.2	6.897	0.849
0.420	82.5	7.241	0.849
0.440	82.3	7.586	0.843
0.460	82.0	7.931	0.837
0.480	81.8	8.276	0.832
0.500	82.0	8.621	0.831
0.520	82.0	8.966	0.828
0.540	82.2	9.310	0.827
0.560	82.2	9.655	0.824
0.580	82.0	10.000	0.818
0.600	82.0	10.345	0.815



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/wood
Type of Failure: Yield @ 10%
Boring No.: IHNCS-1-3
Depth (ft): 12-13

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 890.0

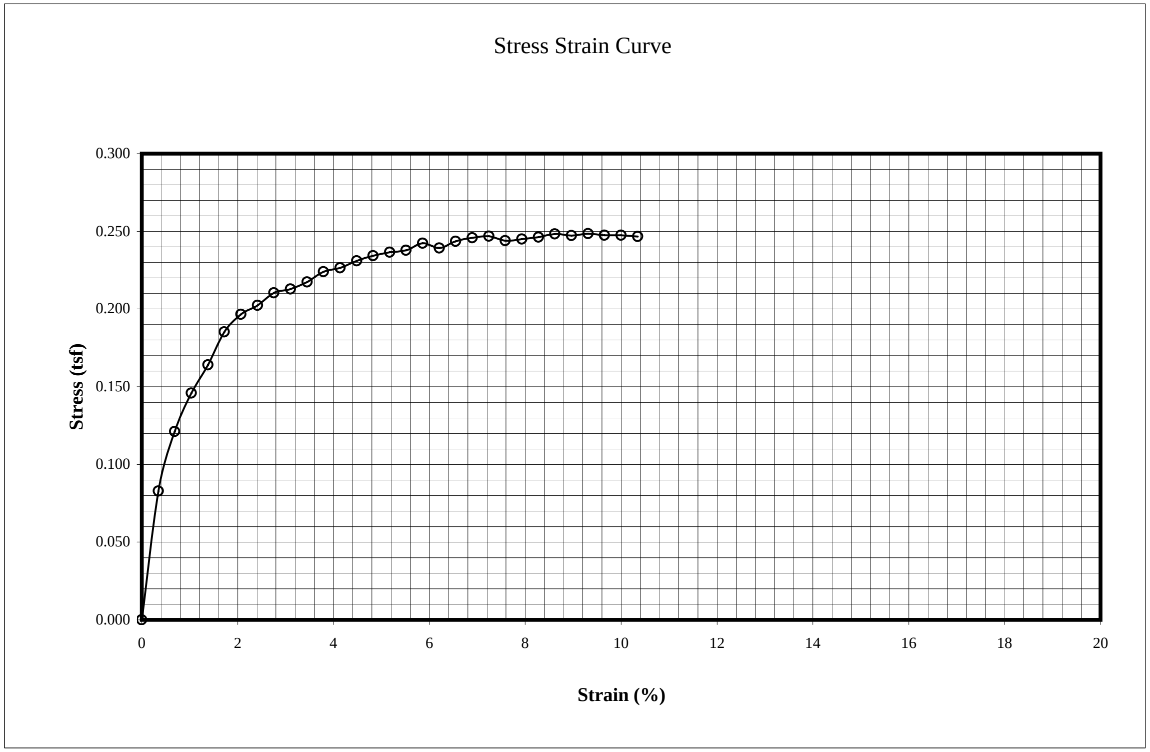
Area (in^2) = 6.492
Moisture Content (%) = 94.94%
Wet Density (pcf) = 90.0
Dry Density (pcf) = 46.2

Wet wt. 124.85
Dry at. 74.21
Can wt. 20.87

Test Data:
Cell Pressure (psi) = 7.4
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	7.5	0.345	0.083
0.040	11.0	0.690	0.121
0.060	13.3	1.034	0.146
0.080	15.0	1.379	0.164
0.100	17.0	1.724	0.185
0.120	18.1	2.069	0.197
0.140	18.7	2.414	0.202
0.160	19.5	2.759	0.210
0.180	19.8	3.103	0.213
0.200	20.3	3.448	0.217
0.220	21.0	3.793	0.224
0.240	21.3	4.138	0.226
0.260	21.8	4.483	0.231
0.280	22.2	4.828	0.234
0.300	22.5	5.172	0.237
0.320	22.7	5.517	0.238
0.340	23.2	5.862	0.242
0.360	23.0	6.207	0.239
0.380	23.5	6.552	0.244
0.400	23.8	6.897	0.246
0.420	24.0	7.241	0.247
0.440	23.8	7.586	0.244
0.460	24.0	7.931	0.245
0.480	24.2	8.276	0.246
0.500	24.5	8.621	0.248
0.520	24.5	8.966	0.247
0.540	24.7	9.310	0.248
0.560	24.7	9.655	0.247
0.580	24.8	10.000	0.248
0.600	24.8	10.345	0.247



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Soft gray clay w/wood
Type of Failure: Yield @ 10%
Boring No.: IHNCS-1-3
Depth (ft): 13-14

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 847.5

Area (in^2) = 6.492
Moisture Content (%) = 94.48%
Wet Density (pcf) = 85.7
Dry Density (pcf) = 44.1

Wet wt.	130.39
Dry at.	77.82
Can wt.	22.18

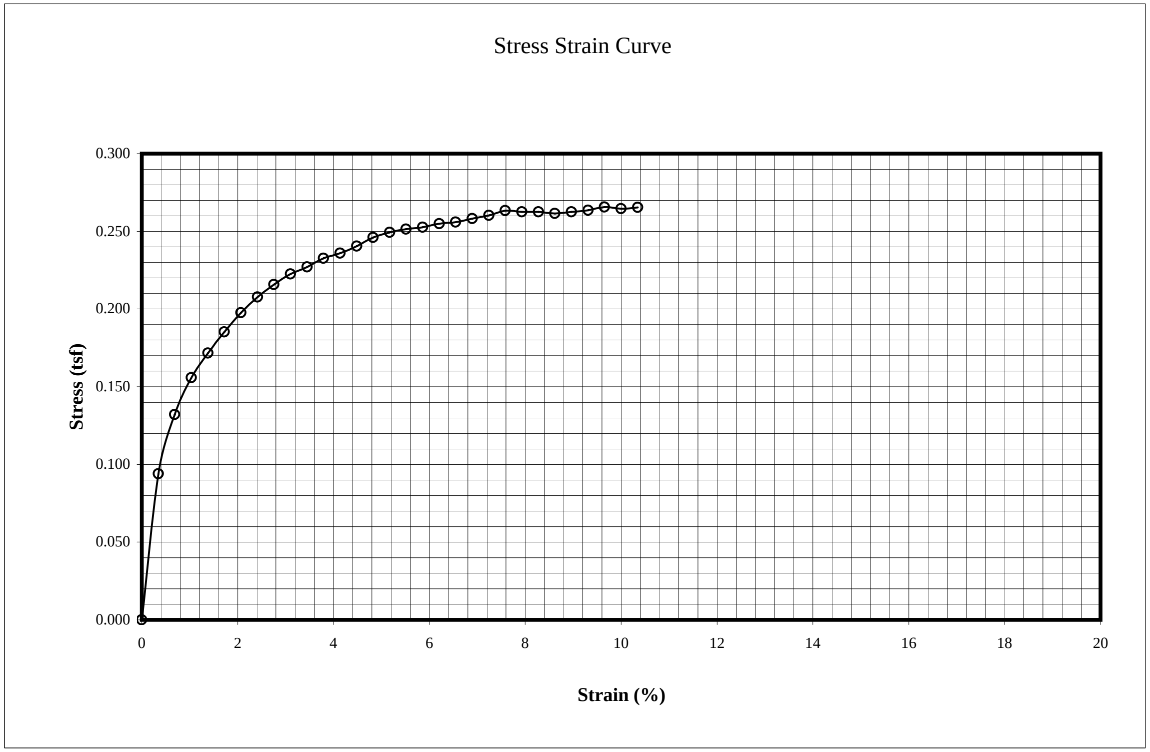
Test Data:

Cell Pressure (psi) = 8.0
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	8.5	0.345	0.094
0.040	12.0	0.690	0.132
0.060	14.2	1.034	0.156
0.080	15.7	1.379	0.172
0.100	17.0	1.724	0.185
0.120	18.2	2.069	0.198
0.140	19.2	2.414	0.208
0.160	20.0	2.759	0.216
0.180	20.7	3.103	0.222
0.200	21.2	3.448	0.227
0.220	21.8	3.793	0.233
0.240	22.2	4.138	0.236
0.260	22.7	4.483	0.240
0.280	23.3	4.828	0.246
0.300	23.7	5.172	0.249
0.320	24.0	5.517	0.251
0.340	24.2	5.862	0.253
0.360	24.5	6.207	0.255
0.380	24.7	6.552	0.256
0.400	25.0	6.897	0.258
0.420	25.3	7.241	0.260
0.440	25.7	7.586	0.263
0.460	25.7	7.931	0.262
0.480	25.8	8.276	0.262
0.500	25.8	8.621	0.261
0.520	26.0	8.966	0.262
0.540	26.2	9.310	0.264
0.560	26.5	9.655	0.266
0.580	26.5	10.000	0.264
0.600	26.7	10.345	0.265



STE

UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay w/peat
Type of Failure: Yield @ 10%
Boring No.: IHNCS-3-2
Depth (ft): 11.5-12.5

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 950.1

Area (in^2) = 6.492
Moisture Content (%) = 78.30%
Wet Density (pcf) = 96.1
Dry Density (pcf) = 53.9

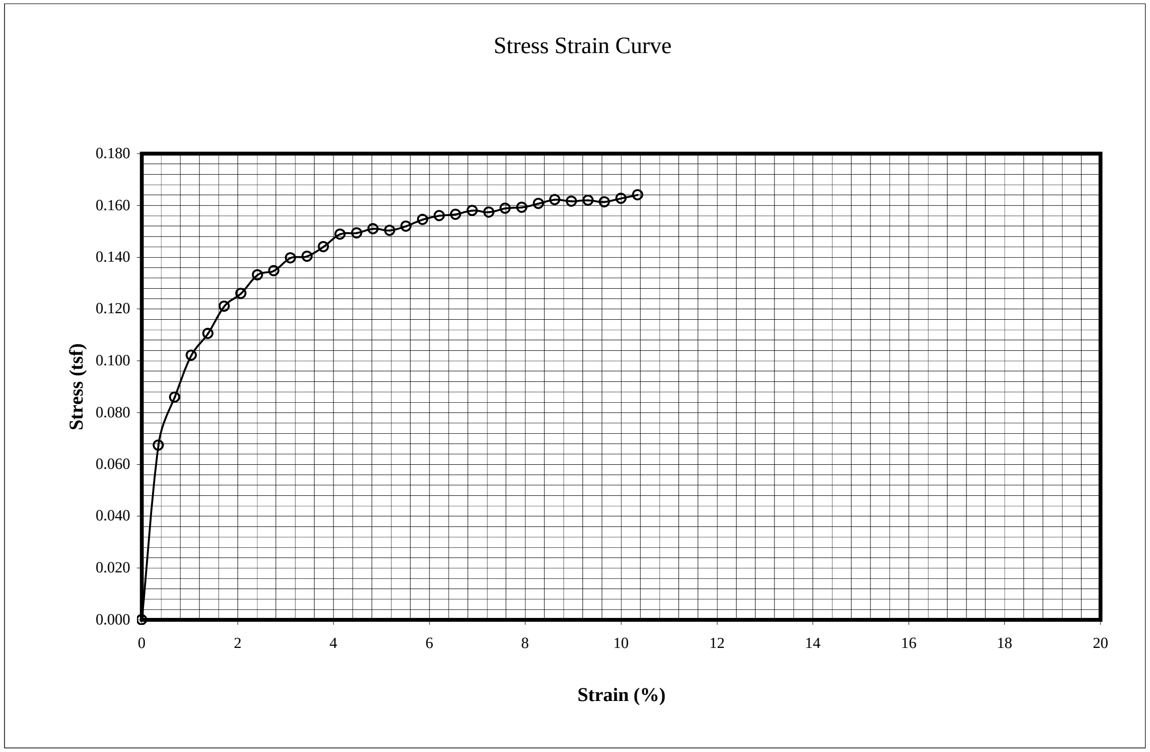
Wet wt. 136.01
Dry at. 85.46
Can wt. 20.9

Test Data:
Cell Pressure (psi) = 7.1
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	6.1	0.345	0.067
0.040	7.8	0.690	0.086
0.060	9.3	1.034	0.102
0.080	10.1	1.379	0.110
0.100	11.1	1.724	0.121
0.120	11.6	2.069	0.126
0.140	12.3	2.414	0.133
0.160	12.5	2.759	0.135
0.180	13.0	3.103	0.140
0.200	13.1	3.448	0.140
0.220	13.5	3.793	0.144
0.240	14.0	4.138	0.149
0.260	14.1	4.483	0.149
0.280	14.3	4.828	0.151
0.300	14.3	5.172	0.150
0.320	14.5	5.517	0.152
0.340	14.8	5.862	0.155
0.360	15.0	6.207	0.156
0.380	15.1	6.552	0.156
0.400	15.3	6.897	0.158
0.420	15.3	7.241	0.157
0.440	15.5	7.586	0.159
0.460	15.6	7.931	0.159
0.480	15.8	8.276	0.161
0.500	16.0	8.621	0.162
0.520	16.0	8.966	0.162
0.540	16.1	9.310	0.162
0.560	16.1	9.655	0.161
0.580	16.3	10.000	0.163
0.600	16.5	10.345	0.164



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray clay
Boring No.: IHNCS-3-2
Depth (ft): 12.5-13.5

Type of Failure: Yield @ 10%

Sample Data:

Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 1001.6

Area (in^2) = 6.492
Moisture Content (%) = 57.18%
Wet Density (pcf) = 101.3
Dry Density (pcf) = 64.5

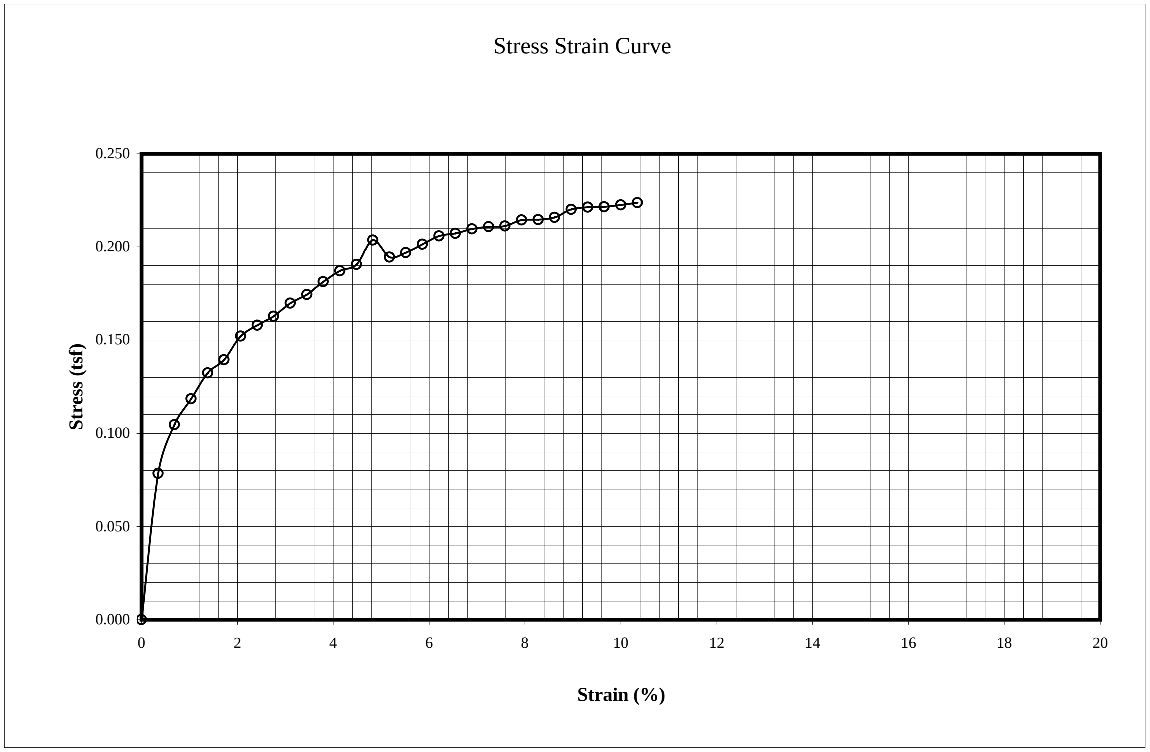
Wet wt. 133.27
Dry at. 95.32
Can wt. 28.95

Test Data:

Cell Pressure (psi) = 7.7
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA			
Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	7.1	0.345	0.078
0.040	9.5	0.690	0.105
0.060	10.8	1.034	0.119
0.080	12.1	1.379	0.132
0.100	12.8	1.724	0.140
0.120	14.0	2.069	0.152
0.140	14.6	2.414	0.158
0.160	15.1	2.759	0.163
0.180	15.8	3.103	0.170
0.200	16.3	3.448	0.175
0.220	17.0	3.793	0.181
0.240	17.6	4.138	0.187
0.260	18.0	4.483	0.191
0.280	19.3	4.828	0.204
0.300	18.5	5.172	0.195
0.320	18.8	5.517	0.197
0.340	19.3	5.862	0.201
0.360	19.8	6.207	0.206
0.380	20.0	6.552	0.207
0.400	20.3	6.897	0.210
0.420	20.5	7.241	0.211
0.440	20.6	7.586	0.211
0.460	21.0	7.931	0.214
0.480	21.1	8.276	0.215
0.500	21.3	8.621	0.216
0.520	21.8	8.966	0.220
0.540	22.0	9.310	0.221
0.560	22.1	9.655	0.221
0.580	22.3	10.000	0.223
0.600	22.5	10.345	0.224



UNCONFINED COMPRESSION TEST/UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

Project Name: Levee Study
File No.: 06-1004

Material : Very soft gray & dark gray clay w/peat
Type of Failure: Yield @ 10%
Boring No.: IHNCN-1-3
Depth (ft): 10-12

Sample Data:
Diameter (in.) = 2.875
Height (in) = 5.8
Weight (gm) = 962.5

Area (in^2) = 6.492
Moisture Content (%) = 67.92%
Wet Density (pcf) = 97.6
Dry Density (pcf) = 58.1

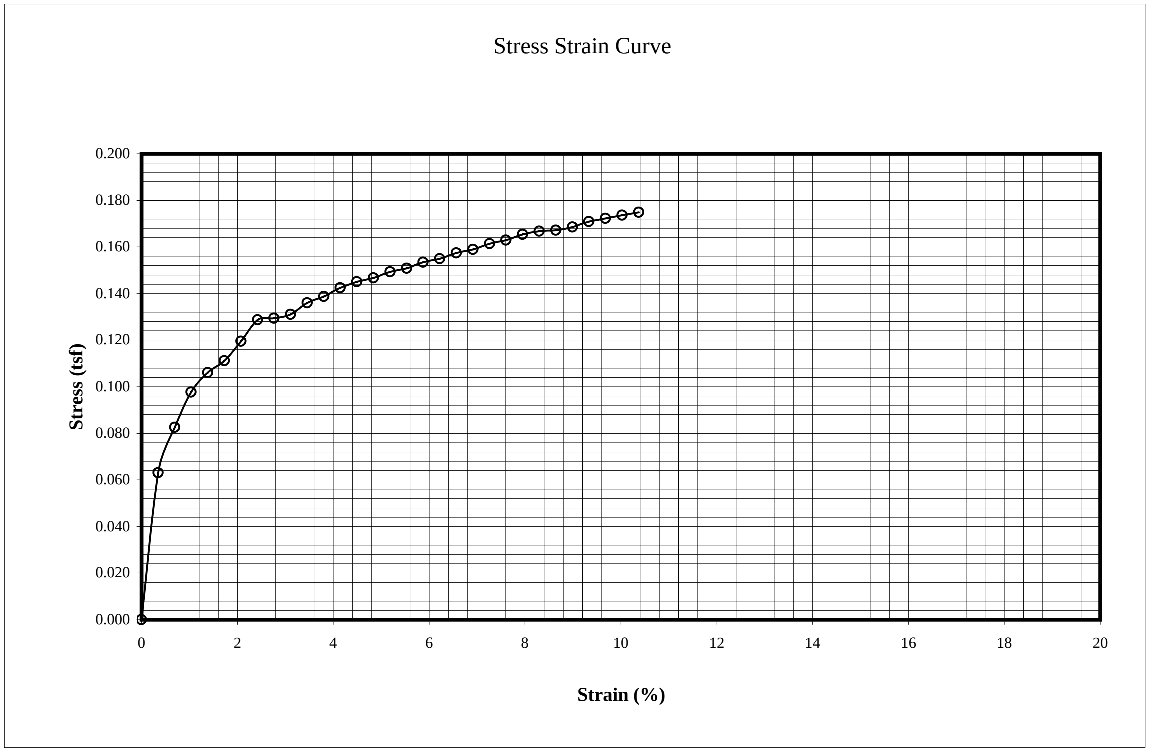
Wet wt. 182.11
Dry at. 119.39
Can wt. 27.05

Test Data:
Cell Pressure (psi) = 6.5
Height Correction = 1.000
Proving Ring No.= 2011
1

6.521451

TEST DATA

Strain Dial	Strength Dial	Strain (%)	Stress (tsf)
0.000	0	0.000	0.000
0.020	5.7	0.346	0.063
0.040	7.5	0.691	0.083
0.060	8.9	1.037	0.098
0.080	9.7	1.383	0.106
0.100	10.2	1.729	0.111
0.120	11.0	2.074	0.119
0.140	11.9	2.420	0.129
0.160	12.0	2.766	0.129
0.180	12.2	3.111	0.131
0.200	12.7	3.457	0.136
0.220	13.0	3.803	0.139
0.240	13.4	4.149	0.142
0.260	13.7	4.494	0.145
0.280	13.9	4.840	0.147
0.300	14.2	5.186	0.149
0.320	14.4	5.532	0.151
0.340	14.7	5.877	0.153
0.360	14.9	6.223	0.155
0.380	15.2	6.569	0.157
0.400	15.4	6.914	0.159
0.420	15.7	7.260	0.161
0.440	15.9	7.606	0.163
0.460	16.2	7.952	0.165
0.480	16.4	8.297	0.167
0.500	16.5	8.643	0.167
0.520	16.7	8.989	0.169
0.540	17.0	9.334	0.171
0.560	17.2	9.680	0.172
0.580	17.4	10.026	0.174
0.600	17.6	10.372	0.175



APPENDIX E: UC Berkeley Laboratory Testing and ILIT In-Situ Field Vane Shear Testing

A series of laboratory tests were performed at the GeoEngineering Laboratory at the University of California at Berkeley on selected “relatively undisturbed” samples that were retrieved during the field investigation in New Orleans. Tests performed included

a) Particle size sieve analysis, ASTM D 422

b) Atterberg Limits, ASTM D 4318

c) Permeability Test (Falling Head Method)

d) Direct Shear Test

e) Laboratory Vane Shear Test

Results of these tests are presented in this Appendix.

In addition, in-situ field vane shear tests (FVST; ASTM D2573) were performed at selected locations to evaluate peak and residual undrained soil shear strengths. These results are also presented in this Appendix.

Laboratory vane shear tests were performed to assess the undrained peak and residual shear strengths of cohesive materials serving as foundations for some of the levee embankments in New Orleans. A special set of procedures were developed for the sampling and laboratory vane shear testing of the sensitive organic clayey silt layer found at the 17th Street Canal breach site. This sensitive layer was very thin (typically 3/4” to 4”), it exhibited very low undrained shear strength and high sensitivity, and it was hidden under a layer of leaves and thin roots (and often intermixed, at least in part, with this obstructing overlying layer of organic detritus.)

Filed samples were “targeted by performing borings and CPT, as necessary, to precisely determine the depth of this critical layer at any given location. An additional boring was then performed adjacent to the previous boring(s) and/or CPT, and this “targeted sampling” borehole was drilled to within approximately 6-inches of the top of the targeted layer. A three-foot long, specially modified Shelby tube was then used to “oversample” the targeted layer; this oversampling captured approximately 2 to 2.5 feet of more competent material from below the highly sensitive layer, effectively “plugging” the base of the sampler so that the overall sample could be recovered. The 3-inch diameter Shelby tubes were modified by eliminating the “overcut” at the cutting lip, so that lateral expansion of the sample as it entered the tube would be eliminated.

Once the samples had been carefully transported to the laboratory, in order to reach the desired depth the soil was carefully hand-excavated from the end of the tube in 2-inch stages using a spoon and sharp blade. After each 2-inch layer had been slowly excavated, the tube was then cut with a rotary hand pipecutter (with stiffeners to reduce oval-disturbance. The process was repeated until the characteristic layer of organic and wind blown detritus was encountered, at which point the detritus was carefully hand-picked from the tube as hand excavation proceeded. The leaves and thin roots were carefully removed to expose the top of the targeted layer, so that the vane could be inserted.

Since this layer was very thin, to avoid pushing the vane through the layer, once the layer was encountered in the Shelby Tube the vane was only inserted so that the metal blades were completely inside the soil, but not under it. That meant that the shear strength at the top of the rotating vane was not measured, and so a correction to the conventional (e.g.: ASTM) “vane factor” was required. For the vane geometry used (see Figure E.2) the required vane correction factor was found to be 0.84 times the conventional vane factor if the vane had been adequately embedded as to register full “top of vane” shear resistance. The vane shear test was performed at a rotational rate of 2 degrees/sec; a rate selected to represent relative rate of shear displacement behavior of interest with regard to the field cases being investigated.

As part of the field investigation, Field Vane Shear Tests were also performed at the 17th Street Canal breach site and at the London Avenue Canal distressed section. The results are presented in terms of peak and residual undrained shear strength. The dimensions of the vane used for these FVST tests are shown in Figure E-3. Rates of vane rotation were 1° per minute until the peak shear strength had been well-exceeded. The vane was then rotated five times, and then the residual strength measurement was again made at a rotational rate of 1° per minute.

Figure E-1: Laboratory vane shear testing of the thin layer of sensitive organic silty clay

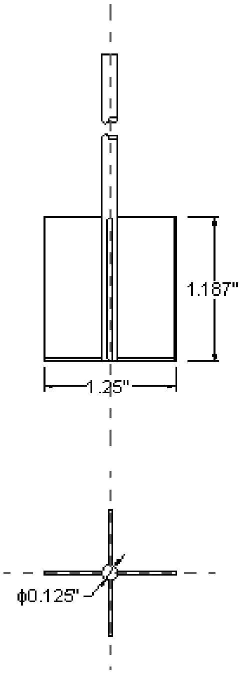


Figure E-2: Geometry and dimensions of laboratory vane

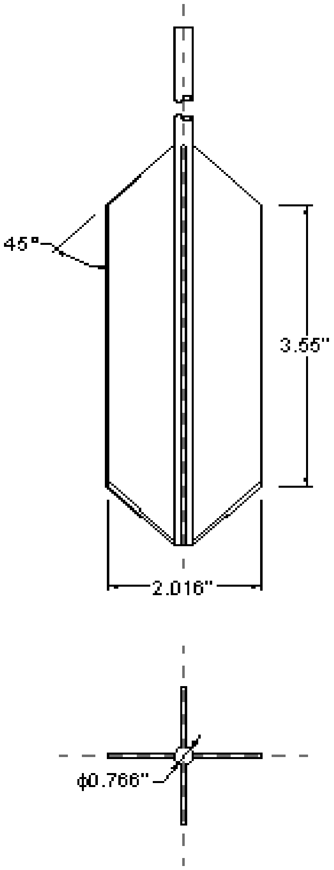


Figure E-3: Geometry and dimensions of field vane.

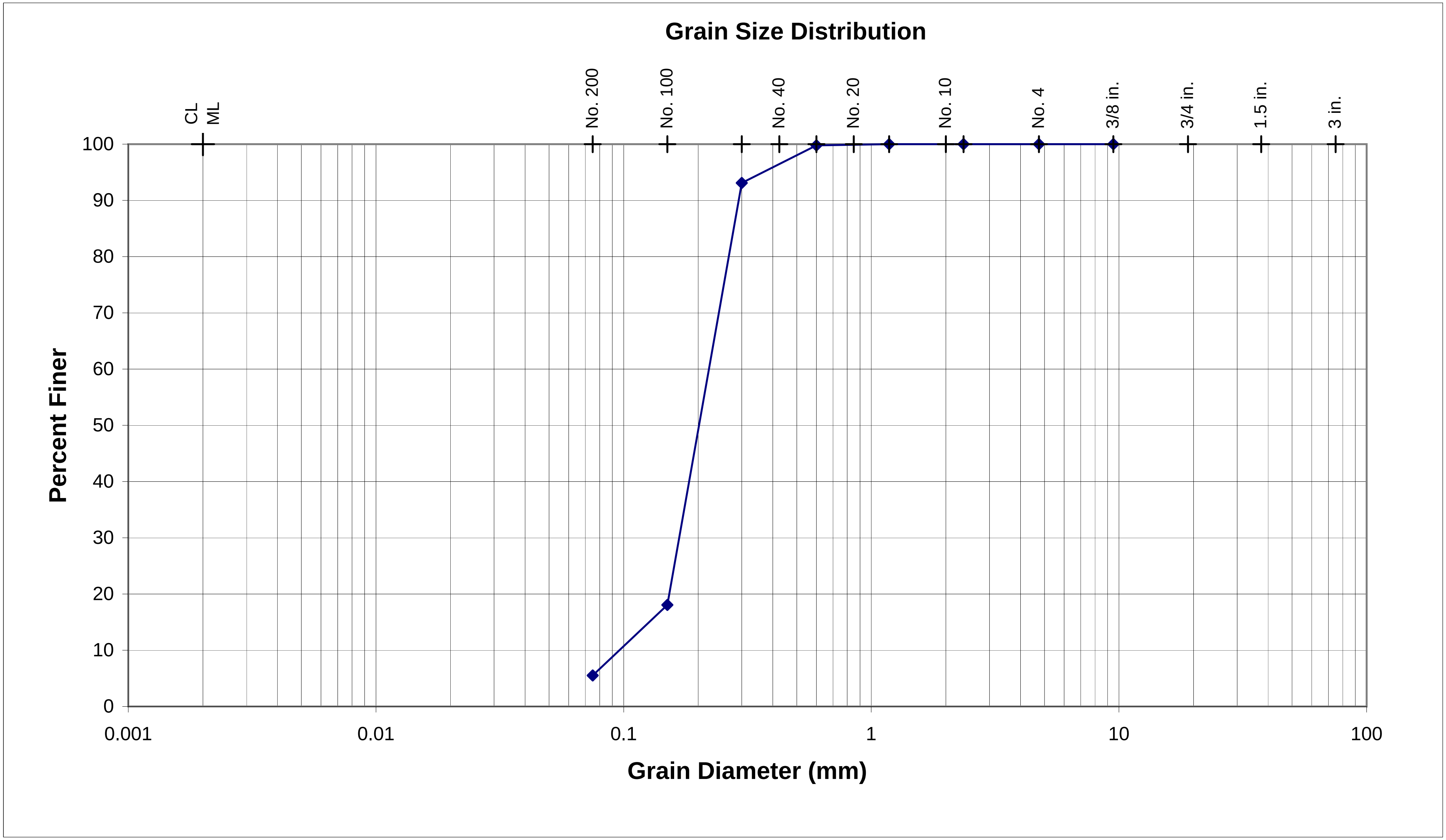
Particle-Size Analysis

ASTM D 422

Project Name:	New Orleans Levee Investigation	Tested By:	Julien Cohen-Waeber	Date:	04/07/06
Project No. :		Input By:	Julien Cohen-Waeber	Date:	04/07/06
Boring No.:	LAC-BOR-1	Checked By:	Diego Cobos-Roa		
Sample No.:	LAC-BOR-1-2	Depth (ft.)	9.5		

Soil Identification: Poorly Graded Sand (SP), Grey, with trace clay

% Sand: 94.5 % Silt: NA % Clay: trace USCS: SP

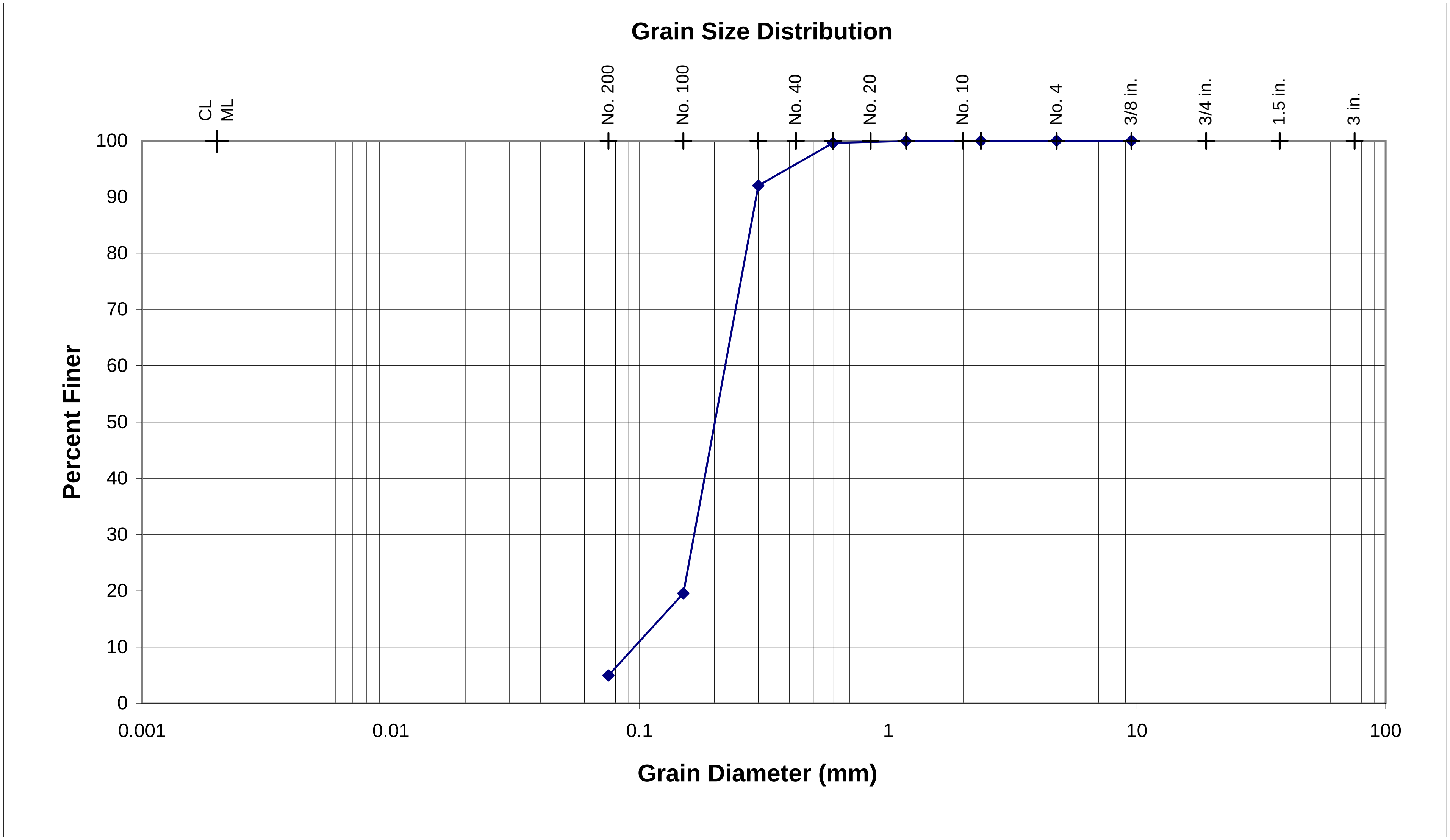


Particle-Size Analysis

ASTM D 422

Project Name:	New Orleans Levee Investigation	Tested By:	Julien Cohen-Waeber	Date:	04/07/06
Project No. :		Input By:	Julien Cohen-Waeber	Date:	04/07/06
Boring No.:	LAC-BOR-1	Checked By:	Diego Cobos-Roa		
Sample No.:	LAC-BOR-1-2	Depth (ft.)	10.0		
Soil Identification:	Poorly Graded Sand (SP) Grey, with trace Clay				

% Sand: 95.1 % Silt: NA % Clay: trace USCS: (SP) Poorly Graded Sand



ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/13/06
Boring No.: 17-BOR-6
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: 17-BOR-6-2
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE24
Elevation (ft.): -15.3
Soil Identification: Grey Silty Clay (CL) trace fine sand, with few shells.

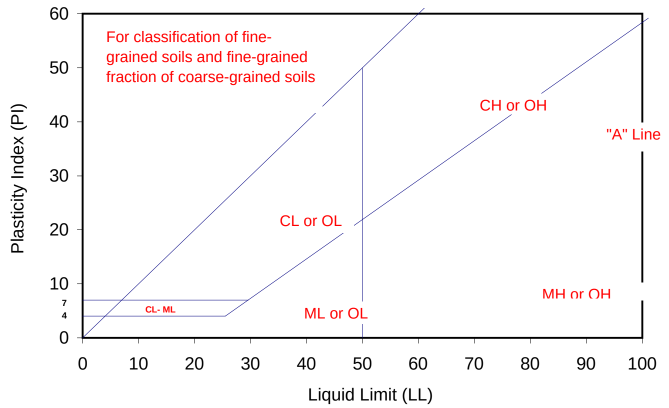
TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				42	27	15	
Wet Wt. of Soil + Cont. (g)				37.30	36.80	35.00	
Dry Wt. of Soil + Cont. (g)				31.40	30.70	29.20	
Wt. of Container (g)				15.90	16.20	16.10	
Moisture Content (%) [Wn]				38.06	42.07	44.27	

Liquid Limit	**41.6**
Plastic Limit	
Plasticity Index	
Classification	

PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

$$LL = Wn(N/25)^{0.12}$$



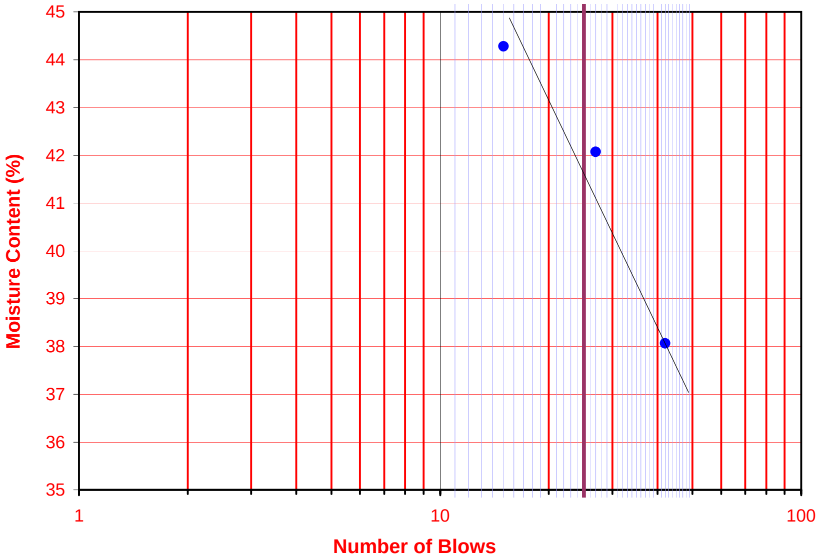
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/13/06
Boring No.: LAC-BOR-2
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: LAC-BOR-2-3
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE30
Elevation (ft.): -13.0
Soil Identification: Grey Sandy Clay (CL) very Sandy

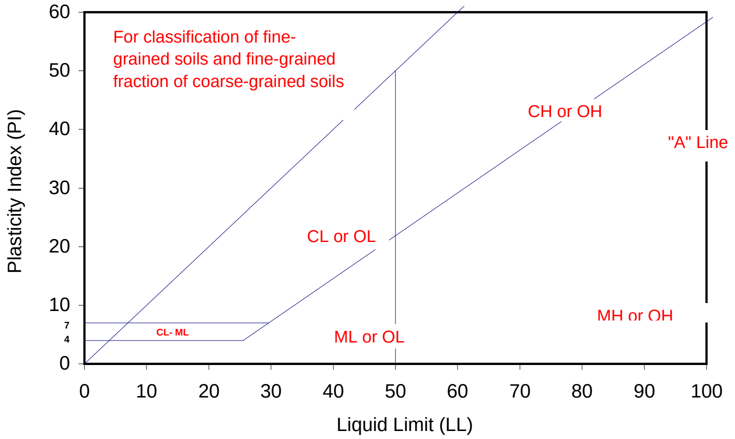
TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				19	23	41	12
Wet Wt. of Soil + Cont. (g)				40.00	32.20	36.00	35.60
Dry Wt. of Soil + Cont. (g)				33.50	27.80	30.90	30.00
Wt. of Container (g)				16.10	15.60	15.20	16.00
Moisture Content (%) [Wn]				37.36	36.07	32.48	40.00

Liquid Limit	**35.5**
Plastic Limit	
Plasticity Index	
Classification	

PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

$$LL = Wn(N/25)^{0.12}$$



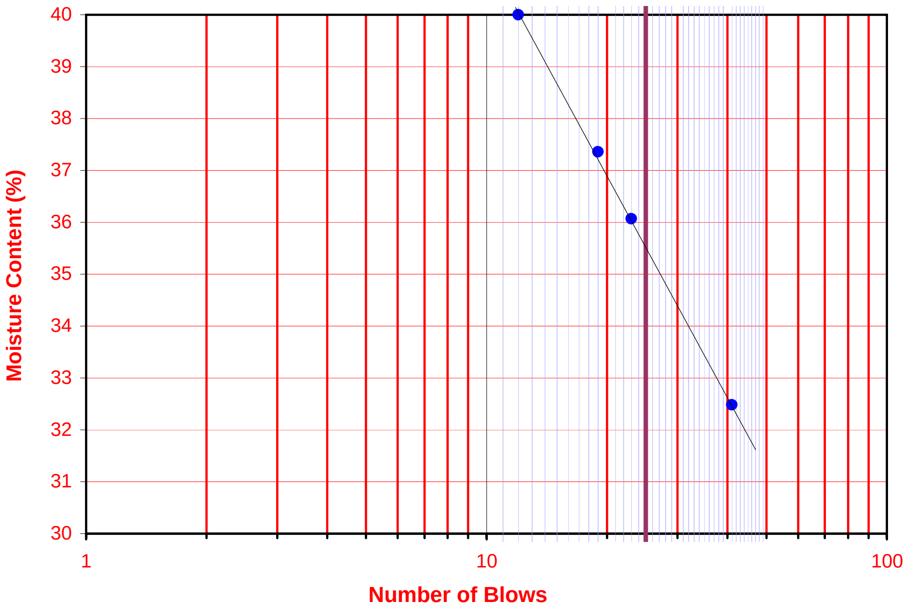
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



Berkeley Engineering

ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/13/06
Boring No.: 17-BOR-6
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: 17-BOR-6-3
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE39
Elevation (ft.): -18.0
Soil Identification: Grey Clay with trace Silt (CH) Hight Plasticity, few shells.

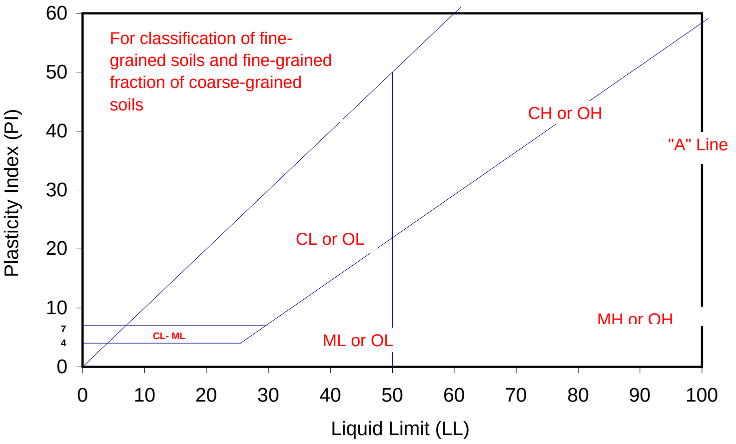
TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				38	21	15	
Wet Wt. of Soil + Cont. (g)				33.60	32.60	33.70	
Dry Wt. of Soil + Cont. (g)				25.80	25.20	25.40	
Wt. of Container (g)				16.10	16.10	15.70	
Moisture Content (%) [Wn]				80.41	81.32	85.57	

Liquid Limit	**81.7**
Plastic Limit	
Plasticity Index	
Classification	

PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

$LL = Wn(N/25)^{0.12}$



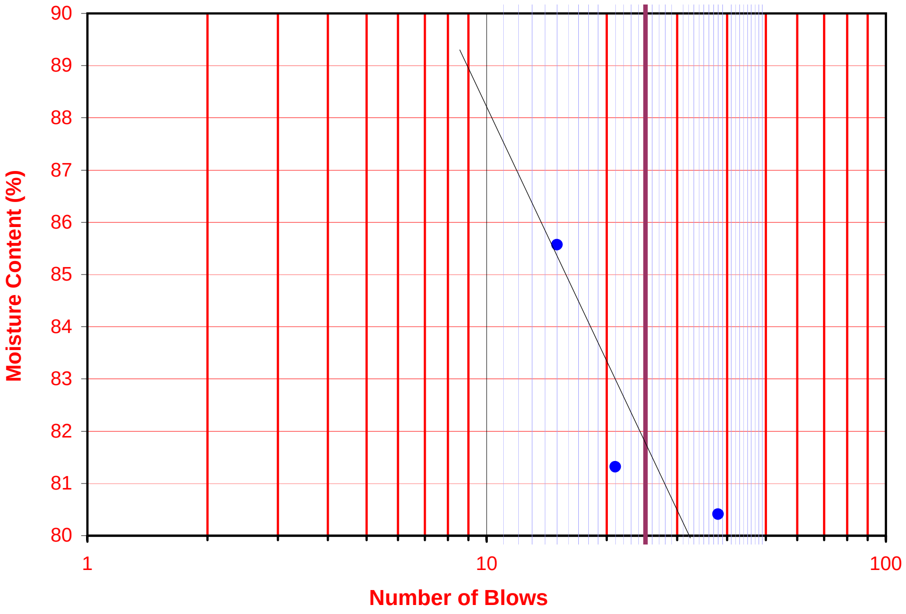
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/13/06
Boring No.: 17-BOR-6
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: 17-BOR-6-3
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE40
Elevation (ft.): -18.3
Soil Identification: Grey Clay (CH) High Plasticity.

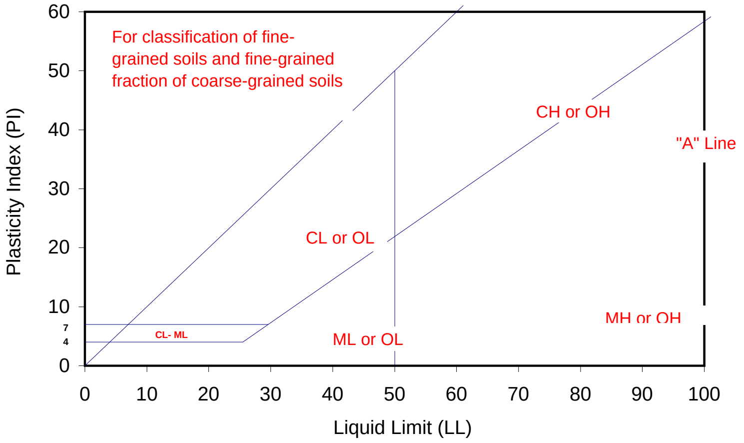
TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				39	27	14	
Wet Wt. of Soil + Cont. (g)				32.30	32.70	31.80	
Dry Wt. of Soil + Cont. (g)				25.50	25.50	24.80	
Wt. of Container (g)				15.90	15.30	15.60	
Moisture Content (%) [Wn]				70.83	70.59	76.09	

Liquid Limit	**72.5**
Plastic Limit	
Plasticity Index	
Classification	

PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

$LL = Wn(N/25)^{0.12}$



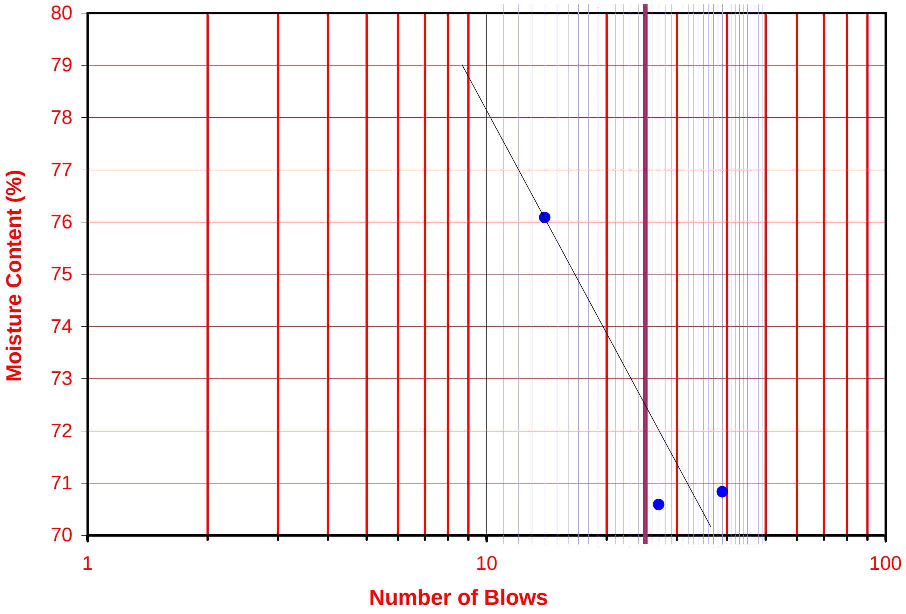
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



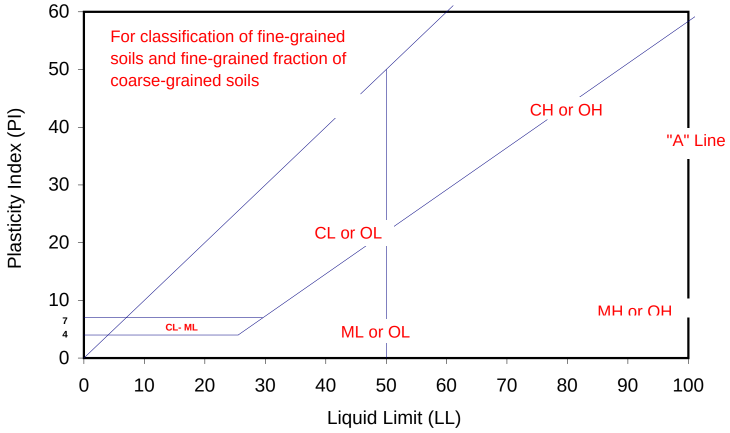
ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/15/06
Boring No.: 17-BOR-6
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: 17-BOR-6-3
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE41
Elevation (ft.): -18.5
Soil Identification: Grey Silty Clay (CL) plastic.

TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				48	22	15	
Wet Wt. of Soil + Cont. (g)				34.30	32.60	34.30	
Dry Wt. of Soil + Cont. (g)				28.20	26.50	27.70	
Wt. of Container (g)				16.10	15.60	16.00	
Moisture Content (%) [Wn]				50.41	55.96	56.41	

Liquid Limit	**54.2**
Plastic Limit	
Plasticity Index	
Classification	



PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

LL =Wn(N/25)$^{0.12}$

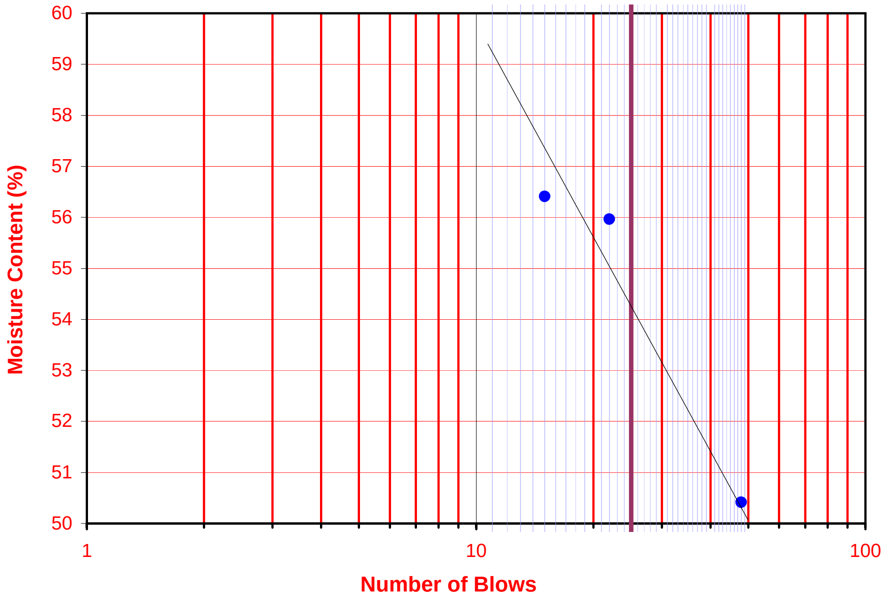
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/15/06
Boring No.: 17-BOR-6
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: 17-BOR-6-3
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE42
Elevation (ft.): -18.9
Soil Identification: Grey Silty Clay (CL) very plastic

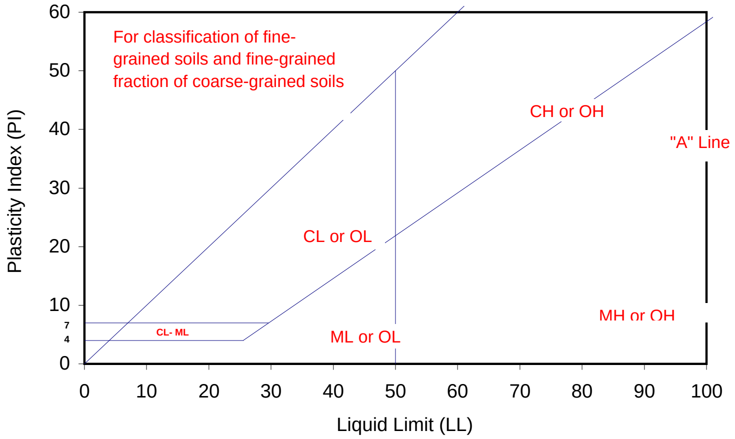
TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				44	31	17	
Wet Wt. of Soil + Cont. (g)				33.10	32.40	31.00	
Dry Wt. of Soil + Cont. (g)				26.00	25.70	24.40	
Wt. of Container (g)				15.60	15.90	15.70	
Moisture Content (%) [Wn]				68.27	68.37	75.86	

Liquid Limit	**72.0**
Plastic Limit	
Plasticity Index	
Classification	

PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

$LL = Wn(N/25)^{0.12}$



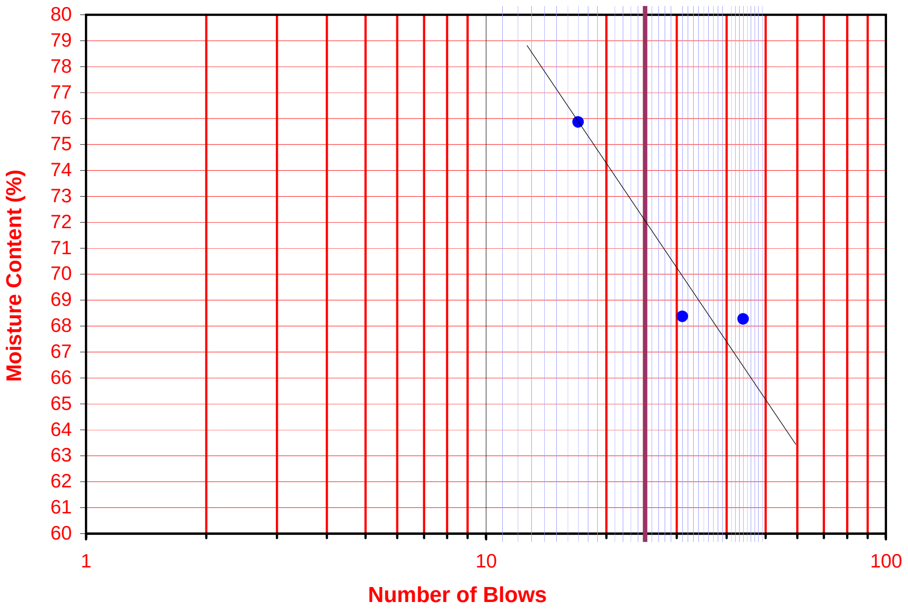
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/15/06
Boring No.: LAC-BOR-1A
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: LAC-BOR-1A-1
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE49
Elevation (ft.) -10.7
Soil Identification: Black to Dark Grey Silty Clay (CL), with organics

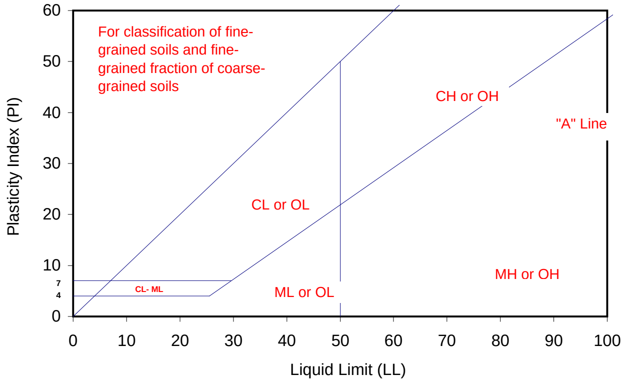
TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				36	32	23	15
Wet Wt. of Soil + Cont. (g)				26.70	29.00	26.10	30.10
Dry Wt. of Soil + Cont. (g)				18.90	20.10	19.00	20.30
Wt. of Container (g)				15.40	16.00	15.90	16.00
Moisture Content (%) [Wn]				222.86	217.07	229.03	227.91

Liquid Limit	**222.5**
Plastic Limit	
Plasticity Index	
Classification	

PI at "A" - Line = 0.73(LL-20) 147.825

One - Point Liquid Limit Calculation

$$LL = Wn(N/25)^{0.12}$$



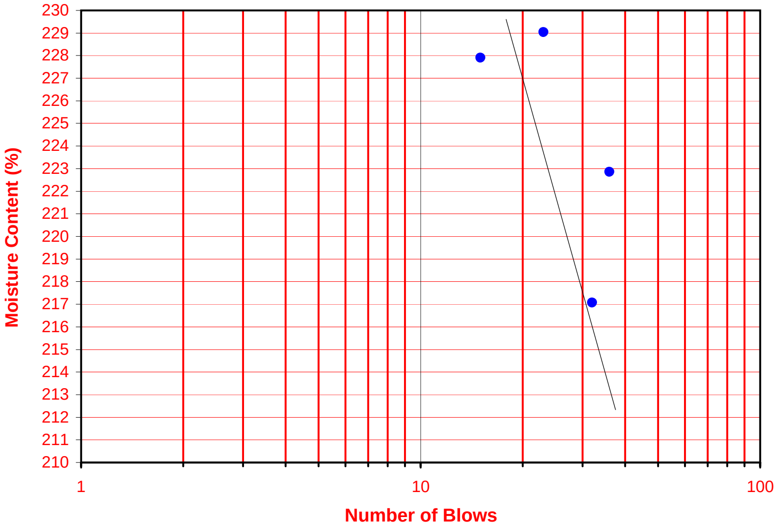
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



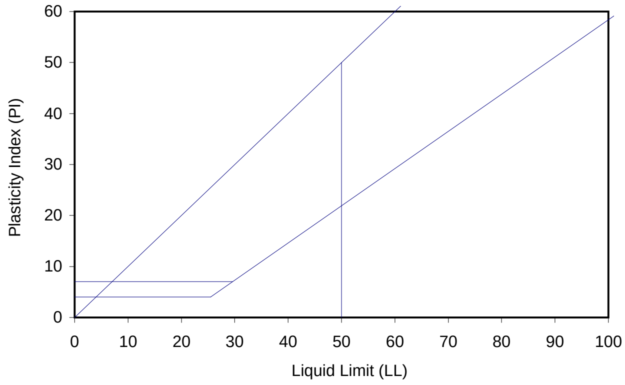
ATTERBERG LIMITS

ASTM D 4318

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 04/13/06
Boring No.: LAC-BOR-1A
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: LAC-BOR-1A-1
Checked By: Adda Athanasopoulos
Lab Vane Test No.: NOVANE52
Elevation (ft.) -11.2
Soil Identification: Grey to Dark Grey, Sandy Clay (CL) Trace Organics

TEST	PLASTIC LIMIT			LIQUID LIMIT			
NO.	1	2	3	1	2	3	4
Number of Blows [N]				27	22	15	
Wet Wt. of Soil + Cont. (g)				33.80	36.50	38.60	
Dry Wt. of Soil + Cont. (g)				28.10	30.40	31.40	
Wt. of Container (g)				15.60	15.90	16.10	
Moisture Content (%) [Wn]				45.60	42.07	47.06	

Liquid Limit	**43.3**
Plastic Limit	
Plasticity Index	
Classification	



PI at "A" - Line = 0.73(LL-20) =

One - Point Liquid Limit Calculation

$$LL = Wn(N/25)^{0.12}$$

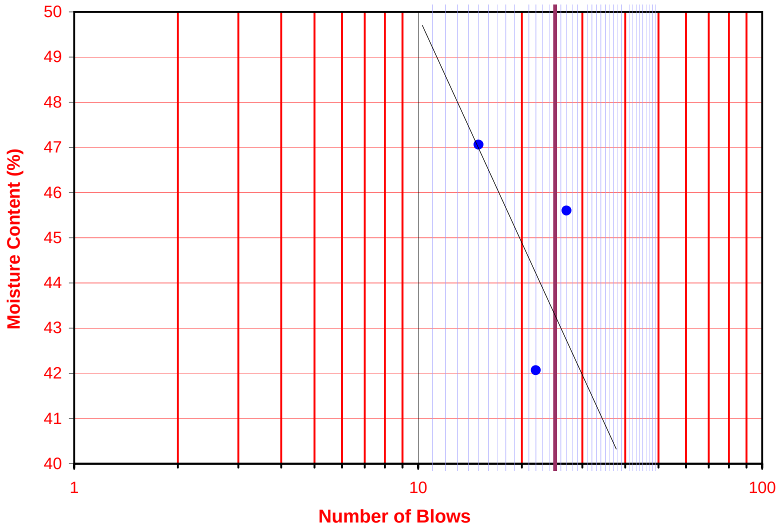
PROCEDURES USED

☐ Wet Preparation
Multipoint - Wet

☐ Dry Preparation
Multipoint - Dry

☐ Procedure A
Multipoint Test

☐ Procedure B
One-point Test



DIRECT SHEAR TEST

Project Name:	New Orleans Levee Investigation	Tested By:	Julien Cohen-Waeber	Date:	04/30/06
Boring No.:	LACW-BOR-1	Input By:	Julien Cohen-Waeber	Date:	05/14/06
Sample No.:	LACW-BOR-1-2	Checked By:	Adda Athanasopoulos		
Lab Test No.:	1	Elevation (ft.):	-14.8		
Soil Identification:	Grey Silty Sandy Clay (CL)				

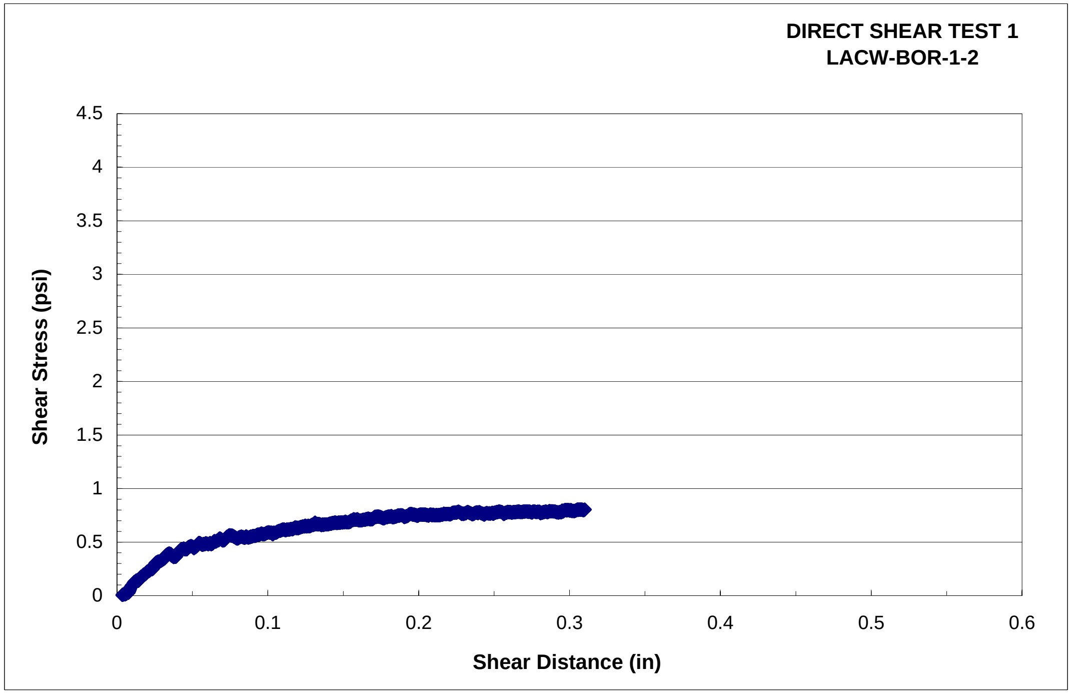
SHRP_Equipment_Corporation
Automatic_Testing_System_v.3.11

	1	
OVERBURDEN:	4.5	divs
	248.1231	psf

SHEAR RATE:	4.1E-05	in/s
TOTAL DISP:	0.3065	in
MAX SHEAR STRESS:	0.804	psi
	115.776	psf
$S_{u,DS}$	57.888	psf
approx $S_{u,TX}$	75.3	psf

Displacements	
initial (in)	final (in)
0.5635	0.87

Total Time (sec)
7476



DIRECT SHEAR TEST

Project Name: New Orleans Levee Investigation

Boring No.: LACW-BOR-1

Sample No.: LACW-BOR-1-2

Lab Test No.: 2

Soil Identification: Grey Silty Sand (SM)

Tested By: Julien Cohen-Waeber Date: 04/30/06

Input By: Julien Cohen-Waeber Date: 05/14/06

Checked By: Adda Athanasopoulos

Elevation (ft.): -15.4

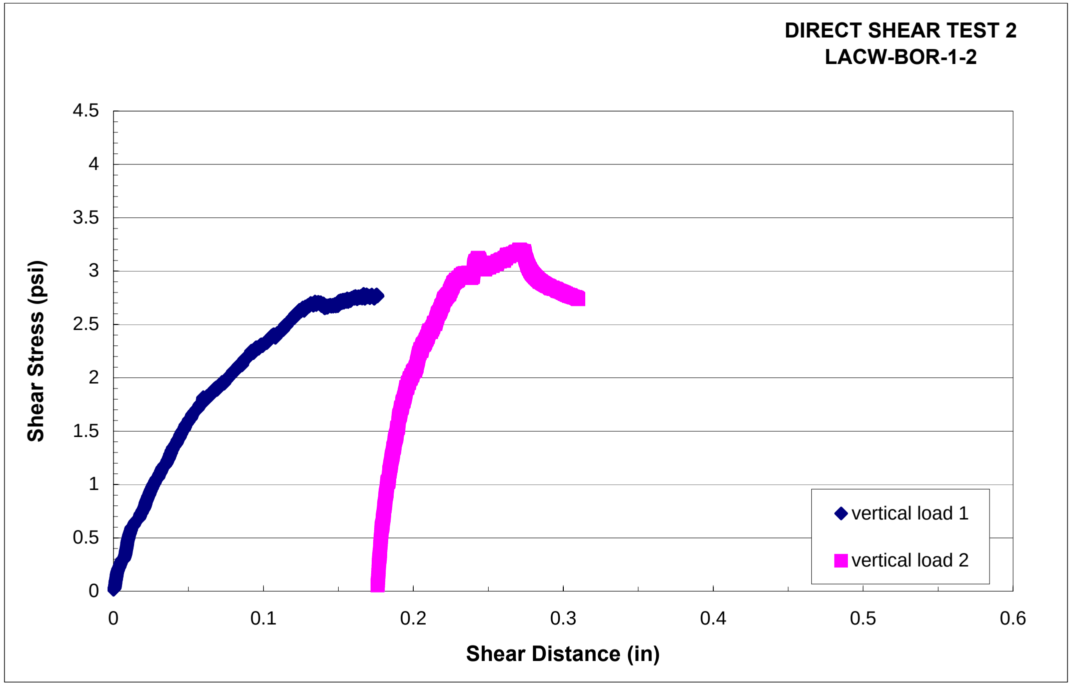
SHRP_Equipment_Corporation
Automatic_Testing_System_v.3.11

	1	2
OVERBURDEN:	0.9	18 divs
	856.6892	1965.489 psf

SHEAR RATE:	3.17E-05 in/s
TOTAL DISP:	0.31 in
MAX SHEAR STRESS:	2.76 psi
	397.44 psf
Φ	25 deg

Displacements	
initial (in)	final (in)
0.476	0.786

Total Time (sec)
9780



DIRECT SHEAR TEST

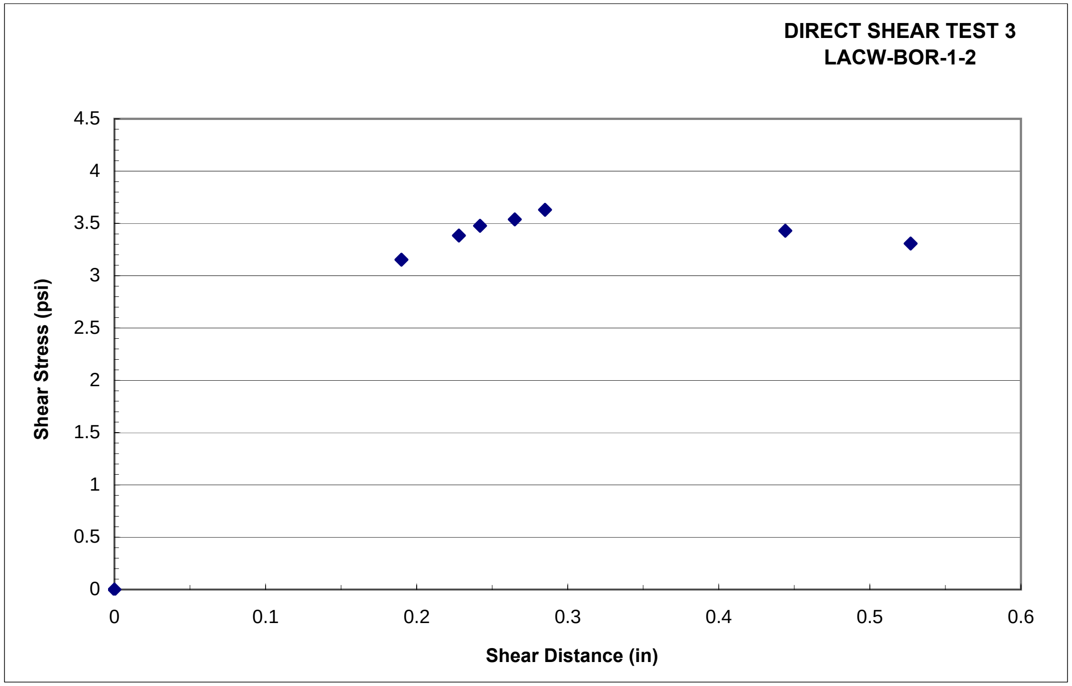
Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 05/01/06
Boring No.: LACW-BOR-1
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: LACW-BOR-1-2
Checked By: Adda Athanasopoulos
Lab Test No.: 3
Elevation (ft.): -15.8
Soil Identification: Grey Sand with Clay and Silt (SP)

SHRP_Equipment_Corporation
Automatic_Testing_System_v.3.11

	1
OVERBURDEN:	0.9 divs
	856.6892 psf
SHEAR RATE:	4.88E-05 in/s
TOTAL DISP:	0.527 in
MAX SHEAR STRESS:	3.631 psi
	522.864 psf
Φ	31.3 deg

Displacements	
initial (in)	final (in)
0.33	0.857

Total Time (sec)
10800



DIRECT SHEAR TEST

Project Name: New Orleans Levee Investigation

Boring No.: LAC-BOR-4

Sample No.: LAC-BOR-4-5

Lab Test No.: 4

Soil Identification: Grey Silty Clay (CL)

Tested By: Julien Cohen-Waeber   Date: 05/01/06

Input By: Julien Cohen-Waeber   Date: 05/14/06

Checked By: Adda Athanasopoulos

Elevation (ft.): -19.9

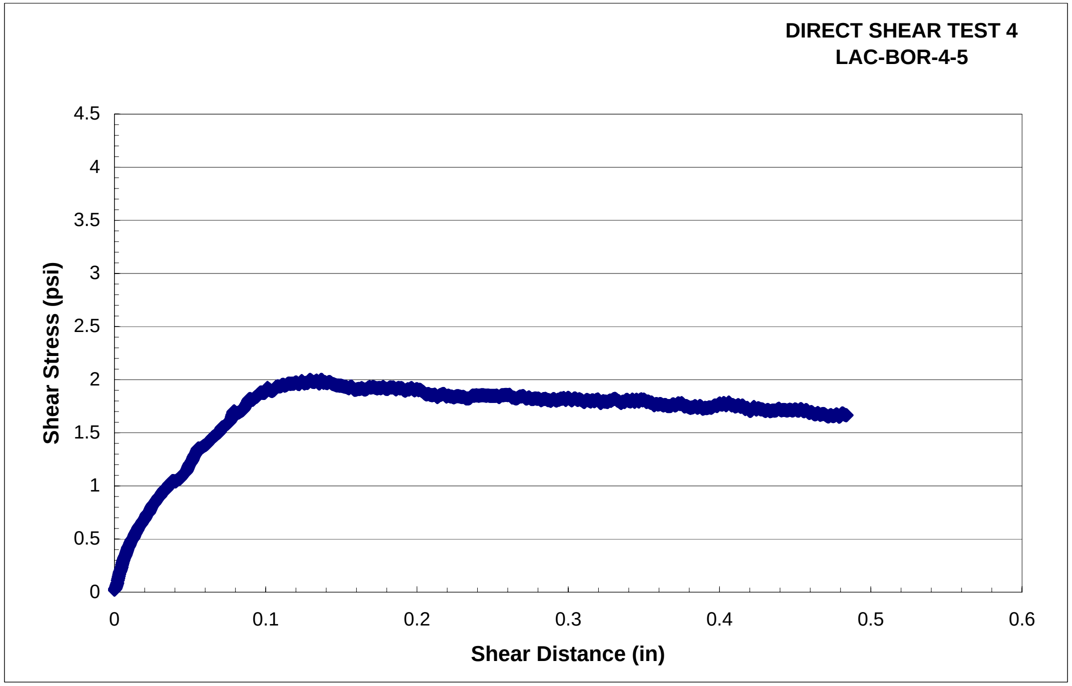
SHRP_Equipment_Corporation
Automatic_Testing_System_v.3.11

	1	
OVERBURDEN:	0.9	divs
	856.6892	psf

SHEAR RATE:	0.000106	in/s
TOTAL DISP:	0.484	in
MAX SHEAR STRESS:	1.9992	psi
	287.8848	psf
Su,DS	143.9424	psf
approx Su,TX	187.1	psf

Displacements	
initial (in)	final (in)
0.404	0.888

Total Time (sec)
4551



DIRECT SHEAR TEST

Project Name:	New Orleans Levee Investigation	Tested By:	Julien Cohen-Waeber	Date:	05/01/06
Boring No.:	LAC-BOR-4	Input By:	Julien Cohen-Waeber	Date:	05/14/06
Sample No.:	LAC-BOR-4-5	Checked By:	Adda Athanasopoulos		
Lab Test No.:	5	Elevation (ft.):	-20.5		
Soil Identification:	Grey Silty Clay with trace Sand (CL)				

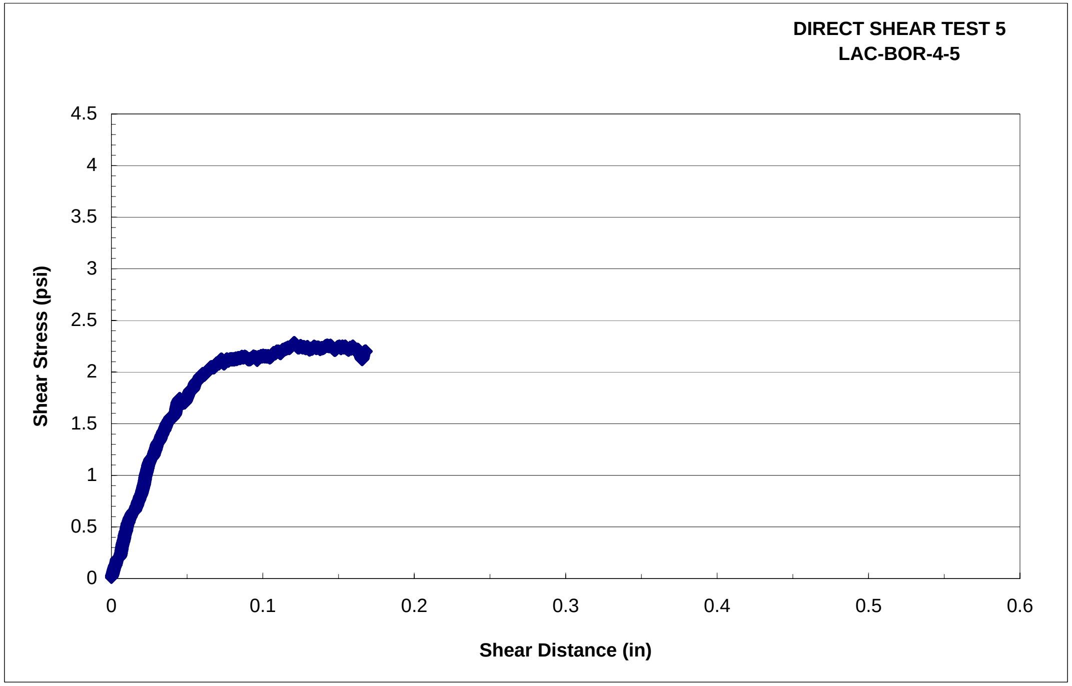
SHRP_Equipment_Corporation
Automatic_Testing_System_v.3.11

	1
OVERBURDEN:	0.9 divs
	856.6892 psf

SHEAR RATE:	6.05E-05 in/s
TOTAL DISP:	0.168 in
MAX SHEAR STRESS:	2.2512 psi
	324.1728 psf
Su,DS	162.0864 psf
approx Su,TX	210.7 psf

Displacements	
initial (in)	final (in)
0.29	0.458

Total Time (sec)
2775



DIRECT SHEAR TEST

Project Name: New Orleans Levee Investigation
Tested By: Julien Cohen-Waeber
Date: 05/01/06
Boring No.: LAC-BOR-2
Input By: Julien Cohen-Waeber
Date: 05/14/06
Sample No.: LAC-BOR-2-3
Checked By: Adda Athanasopoulos
Lab Test No.: 6
Elevation (ft.): -15.4
Soil Identification: Grey Sandy Clay / Clayey Sand (SC/CL),

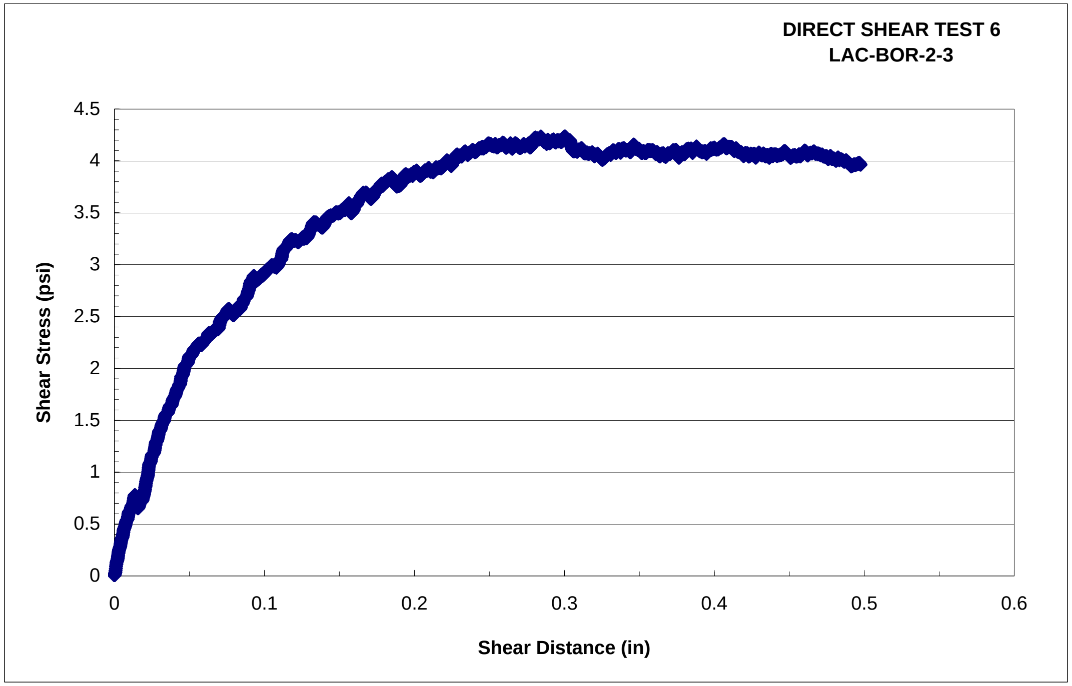
SHRP_Equipment_Corporation
Automatic_Testing_System_v.3.11

	1	
OVERBURDEN:	0.9	divs
	856.6892	psf

SHEAR RATE:	5.22E-05	in/s
TOTAL DISP:	0.4975	in
MAX SHEAR STRESS:	4.1868	psi
	602.8992	psf
Su,DS	301.4496	psf
approx Su,TX	391.9	psf

Displacements	
initial (in)	final (in)
0.4955	0.993

Total Time (sec)
9522



PERMEABILITY TEST (FALLING HEAD METHOD)

Project Name:	New Orleans Levee Investigation	Tested By:	Julien Cohen-Waeber	Date:	05/06/06
Boring No.:	LAC-BOR-2	Input By:	Julien Cohen-Waeber	Date:	05/14/06
Sample No.:	LAC-BOR-2-3	Checked By:	Adda Athanasopoulos		
Lab Test No.:	1	Elevation (ft.):	-15.1		
Soil Identification:	Grey Silty Sand (SM) Fine Sand.				

Sample Dimentions:

				1	**2**
Beaker wt:	285.28 g		**Soil Height:**	14.92	15.08 cm
wt Beaker + dry Soil:	534.99 g				
wt Soil:	249.71 g		**avg height:**	15 cm	
Beaker Diam:	3.7846 cm				
Beaker Area:	11.249 cm^2				
Sample Density:	1.480 g/cm^3				

Water Cylinder:

	1	**2**
Volume:	775	1570 cc
Drop in water Level:	30	60 cm^2
Cylinder Area:	25.833	26.17 cm^2
Avg Area:	26 cm^2	

TEST DATA AND RESULTS:

Test No.	**Height**			**Time**		**HYDRAULIC CONDUCTIVITY**	
	h_o cm	h_1 cm	h_2 cm	h_o to h_1 s	h_0 to h_2 s	$k_{(0-1)}$ cm/s	$k_{(0-2)}$ cm/s
1	160	130	100	2625	6105	2.74E-03	2.67E-03
2	160	130	100	2435	5810	2.96E-03	2.80E-03

Berkeley Engineering

PERMEABILITY TEST (FALLING HEAD METHOD)

Project Name: New Orleans Levee Investigation Tested By: Julien Cohen-Waeber Date: 05/06/06
Boring No.: LAC-BOR-2 Input By: Julien Cohen-Waeber Date: 05/14/06
Sample No.: LAC-BOR-2-3 Checked By: Adda Athanasopoulos
Lab Test No.: 2 Elevation (ft.): -15.9
Soil Identification: Grey Silty Sand (SM) Fine Sand.

Sample Dimentions:

Beaker wt: 285.28 g
wt Beaker + dry Soil: 534.99 g
wt Soil: 249.71 g
Beaker Diam: 3.7846 cm
Beaker Area: 11.249 cm^2

Sample Density: 1.626 g/cm^3

	1	**2**	
Soil Height:	13.652	13.653	cm
avg height:	13.6525		cm

Water Cylinder:

	1	**2**	
Volume:	775	1570	cc
Drop in water Level:	30	60	cm^2
Cylinder Area:	25.833	26.17	cm^2

Avg Area: 26 cm^2

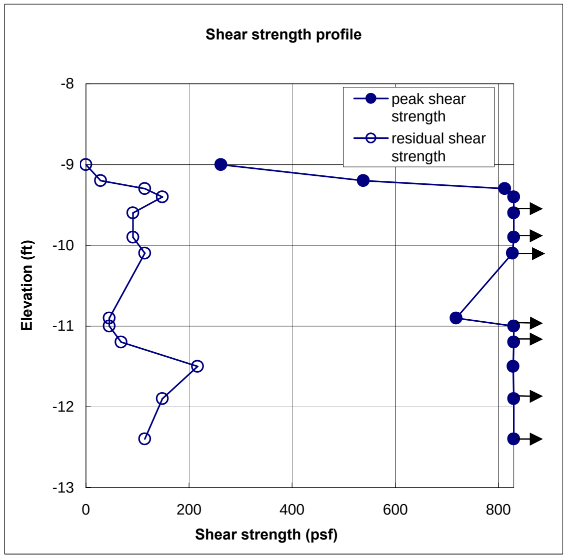
TEST DATA AND RESULTS:

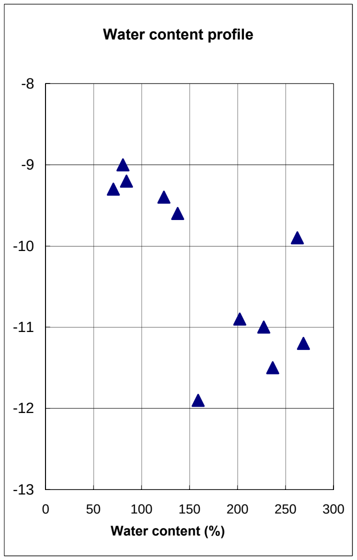
Test No.	**Height**			**Time**		**HYDRAULIC CONDUCTIVITY**	
	h_o cm	h_1 cm	h_2 cm	h_o to h_1 s	h_0 to h_2 s	$k_{(0-1)}$ cm/s	$k_{(0-2)}$ cm/s
1	160	130	100	7905	19515	8.29E-04	7.60E-04

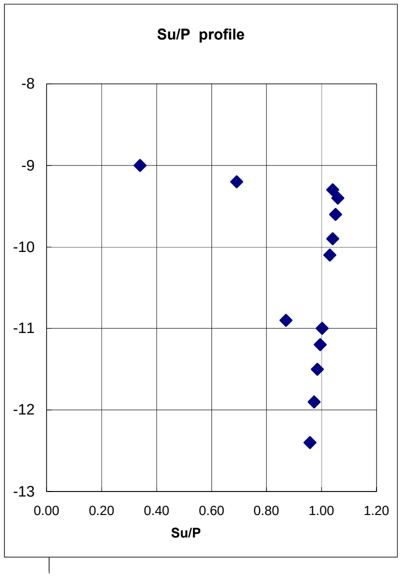
Project Name: New Orleans Levee Investigation
Project No. :
Boring No.: 17-BOR-2
Sample No.: 17-BOR-2-4 and 17-BOR-2-5

Tested By: Diego Cobos-Roa
Adda Athanasopoulos
Depth (ft): 12 to 16.5
G.E. (ft): 3.8
W.T. (ft): -1

		measured		corrected*					
vane test #	**elevation (ft)**	**peak (psf)**	**residual (psf)**	**peak (psf)**	**residual (psf)**	**material**	**w (%)**	**σ'vo (psf)**	**Su/P**
N.O. Vane1	-9	230	0	262.2	0	CH/OH	80.8	773	0.34
N.O. Vane2	-9.2	472	25	538.08	28.5	CH/OH	84.2	778	0.69
N.O. Vane3	-9.3	713	100	812.82	114	CH/OH	70.8	781	1.04
N.O. Vane4	-9.4	728	130	*829.92*	148.2	CH/OH	123.2	784	1.06
N.O. Vane5	-9.6	728	80	*829.92*	91.2	CH/OH	137.6	789	1.05
N.O. Vane6	-9.9	728	80	*829.92*	91.2	CH/OH	262.2	798	1.04
N.O. Vane7	-10.1	726	100	827.64	114	CH/OH		803	1.03
N.O. Vane31	-10.9	630	40	718.2	45.6	very fibrous marsh	202.4	825	0.87
N.O. Vane32	-11	728	40	*829.92*	45.6	very fibrous marsh	227.2	828	1.00
N.O. Vane33	-11.2	728	60	*829.92*	68.4	very fibrous marsh, roots, wood	268.7	834	1.00
N.O. Vane34	-11.5	727	190	828.78	216.6	very fibrous marsh, roots, wood	236.5	842	0.98
N.O. Vane35	-11.9	728	130	*829.92*	148.2	very fibrous marsh, roots, wood	159.1	853	0.97
N.O. Vane36	-12.4	728	100	*829.92*	114	very fibrous marsh, roots, wood	328.7	867	0.96





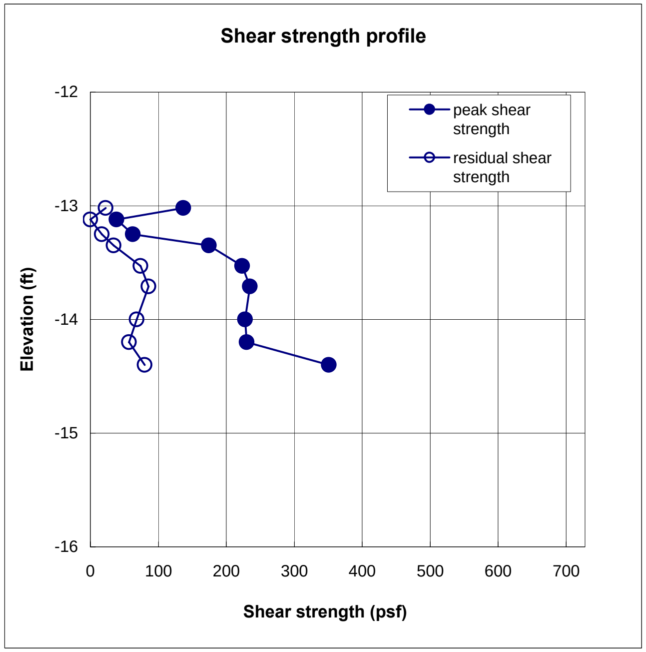


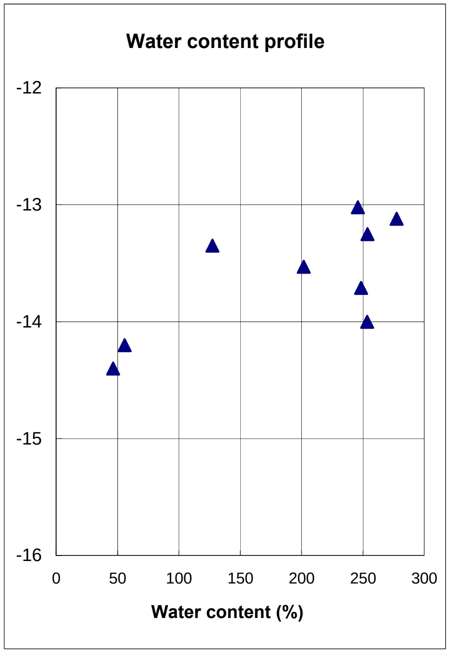
* See text, page E-1.

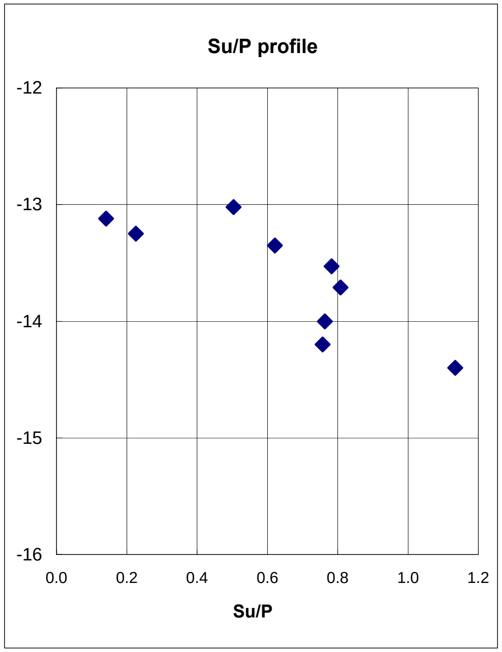
*** italic indicates maximum reading for the laboratory vane device*

Project Name:	New Orleans Levee Investigation	Tested By:	Diego Cobos-Roa Adda Athanasopoulos
Project No. :			
Boring No.:	17-BOR-3	Depth (ft):	6 to 8
Sample No.:	17-BOR-3-2	G.E. (ft):	-6.6
		W.T. (ft):	-8

		measured		corrected*					
vane test #	**elevation (ft)**	**peak (psf)**	**residual (psf)**	**peak (psf)**	**residual (psf)**	**soil description**	**w (%)**	**σ'vo (psf)**	**Su/P**
N.O. Vane8	-13.02	120	20	136.8	22.8	marsh	246	271.6	0.50
N.O. Vane9	-13.12	34	0	38.76	0	marsh	277.6	274.3	0.14
N.O. Vane10	-13.25	55	15	62.7	17.1	marsh	253.9	277.9	0.23
N.O. Vane11	-13.35	153	30	174.42	34.2	marsh	127.4	280.7	0.62
N.O. Vane12	-13.53	196	65	223.44	74.1	marsh, (+CH)	201.7	285.6	0.78
N.O. Vane13	-13.71	206	75	234.84	85.5	CH w/OH	248.6	290.6	0.81
N.O. Vane14	-14	200	60	228	68.4	CH w/OH	253.5	298.6	0.76
N.O. Vane15	-14.2	202	50	230.28	57	CH	56	304.1	0.76
N.O. Vane16	-14.4	308	70	351.12	79.8	CH	46.6	309.6	1.13





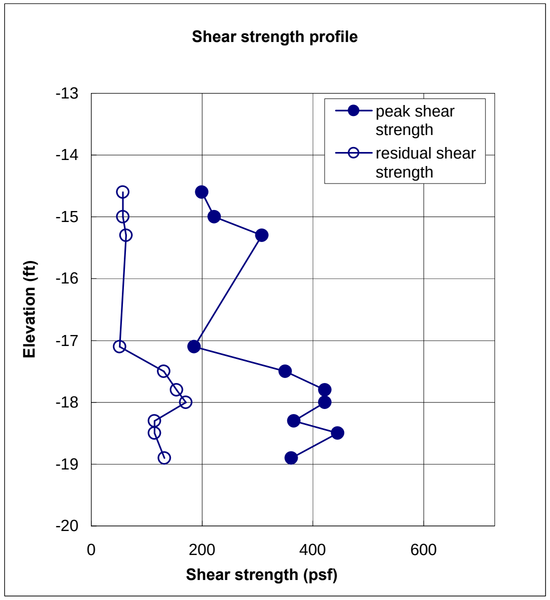


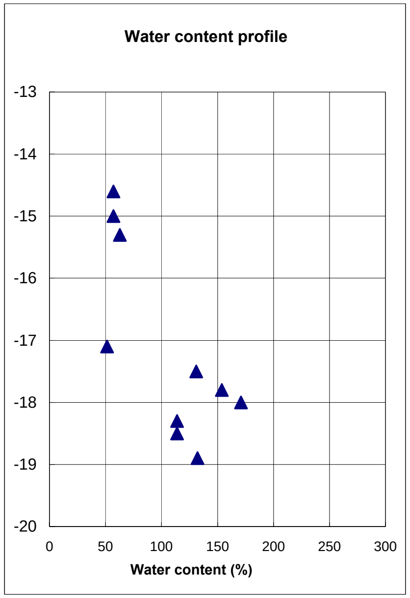
* See text, page E-1.

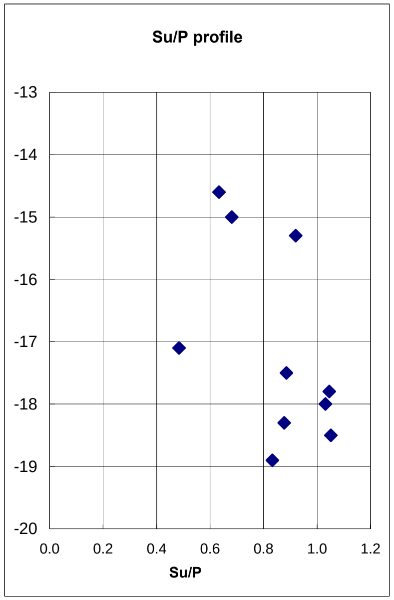
Project Name: New Orleans Levee Investigation
Project No. :
Boring No.: 17-BOR-6
Sample No.: 17-BOR-6-2 and 17-BOR-6-3

Tested By: Diego Cobos-Roa
Adda Athanasopoulos
Depth (ft): 7.5 to 12
G.E. (ft): -6.6
W.T. (ft): -8

		measured		corrected*					
vane test #	**elevation (ft)**	**peak (psf)**	**residual (psf)**	**peak (psf)**	**residual (psf)**	**soil description**	**w (%)**	**σ'vo (psf)**	**Su/P**
N.O. Vane22	-14.6	175	50	199.5	57	grey CH, traces organic, shells	90.4	315.16	0.63
N.O. Vane23	-15	195	50	222.3	57	grey CH, traces organic, shells	60.9	326.2	0.68
N.O. Vane24	-15.3	270	55	307.8	62.7	grey CH (some silt), less shells	40.8	334.48	0.92
N.O. Vane25	-17.1	163	45	185.82	51.3	light grey CL/CH, some silt	73.4	384.16	0.48
N.O. Vane26	-17.5	307	115	349.98	131.1	grey CH	95.5	395.2	0.89
N.O. Vane27	-17.8	370	135	421.8	153.9	grey CH	84.7	403.48	1.05
N.O. Vane39	-18	370	150	421.8	171	grey CH	55.8	409	1.03
N.O. Vane40	-18.3	321	100	365.94	114	grey CH	83.5	417.28	0.88
N.O. Vane41	-18.5	390	100	444.6	114	grey CH	61.4	422.8	1.05
N.O. Vane42	-18.9	317	116	361.38	132.24	grey CH	88.9	433.84	0.83





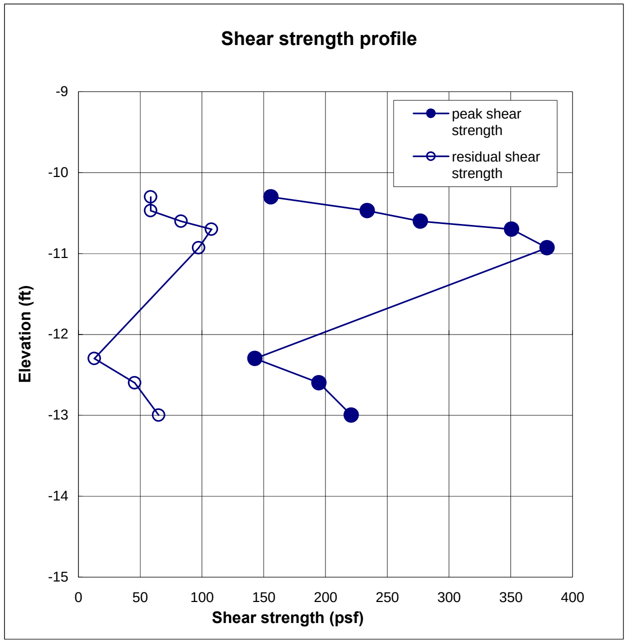


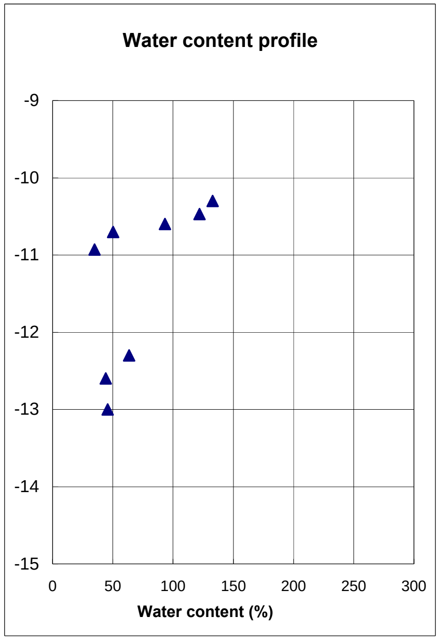
*See text, page E-1.

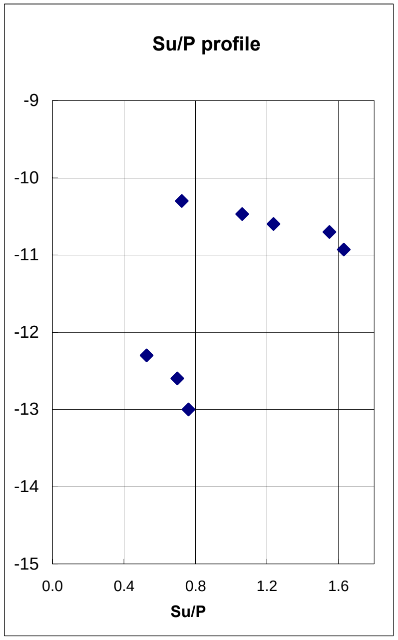
Project Name: New Orleans Levee Investigation
Project No. :
Boring No.: LAC-BOR-2
Sample No.: LAC-BOR-2-2 and LAC-BOR-2-3

Tested By: Diego Cobos-Roa
Adda Athanasopoulos
Depth (ft): 6 to 10
G.E. (ft): -6.4
W.T. (ft): -8

		measured		corrected*					
vane test #	**elevation (ft)**	**peak (psf)**	**residual (psf)**	**peak (psf)**	**residual (psf)**	**soil description**	**water content (%)**	**σ'vo (psf)**	**Su/P**
N.O. Vane17	-10.3	136.8	51.3	155.952	58.482	gray-black CH, org. matter, wood, org. odor	132.8	215.48	0.72
N.O. Vane18	-10.47	205.2	51.3	233.928	58.482	gray-black CH, org. matter, wood, org. odor	122	220.172	1.06
N.O. Vane19	-10.6	242.82	72.96	276.8148	83.1744	gray-black CH, org. matter, wood, org. odor	93.3	223.76	1.24
N.O. Vane20	-10.7	307.8	94.62	350.892	107.8668	gray CH w/ traces black org. matter	50.2	226.52	1.55
N.O. Vane21	-10.93	332.88	85.5	379.4832	97.47	gray clayey silt	34.7	232.868	1.63
N.O. Vane28	-12.3	125.4	11.4	142.956	12.996	gray CH w/ traces black org. matter	63.5	270.68	0.53
N.O. Vane29	-12.6	171	39.9	194.94	45.486	grey CH	44.2	278.96	0.70
N.O. Vane30	-13	193.8	57	220.932	64.98	gray clayey silt	45.6	290	0.76





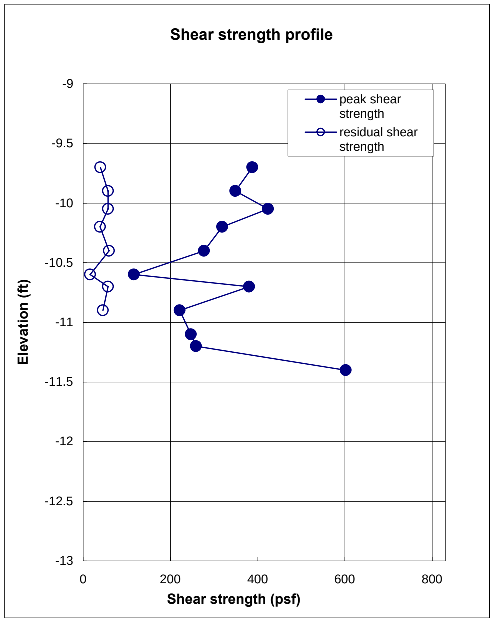


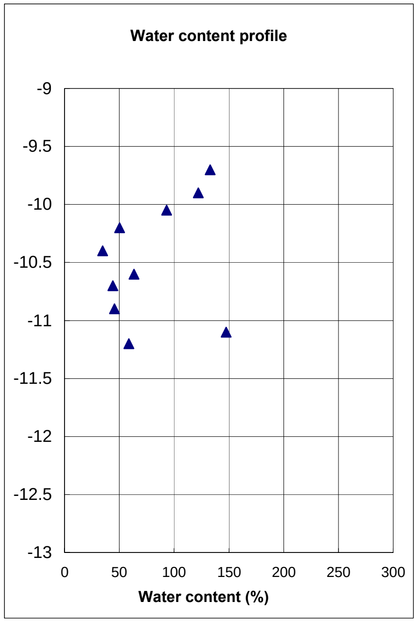
*See text, page E-1.

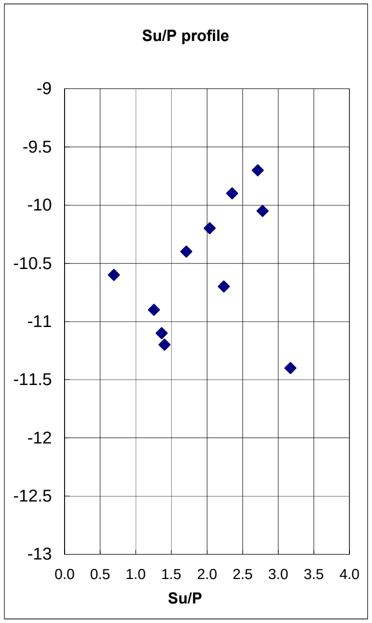
Berkeley Engineering

Project Name:	New Orleans Levee Investigation	Tested By:	Diego Cobos-Roa Adda Athanasopoulos
Project No. :			
Boring No.:	LAC-BOR-1A	Depth (ft):	2 to 4
Sample No.:	LAC-BOR-1A-1	G.E. (ft):	-7.7
		W.T. (ft):	-9

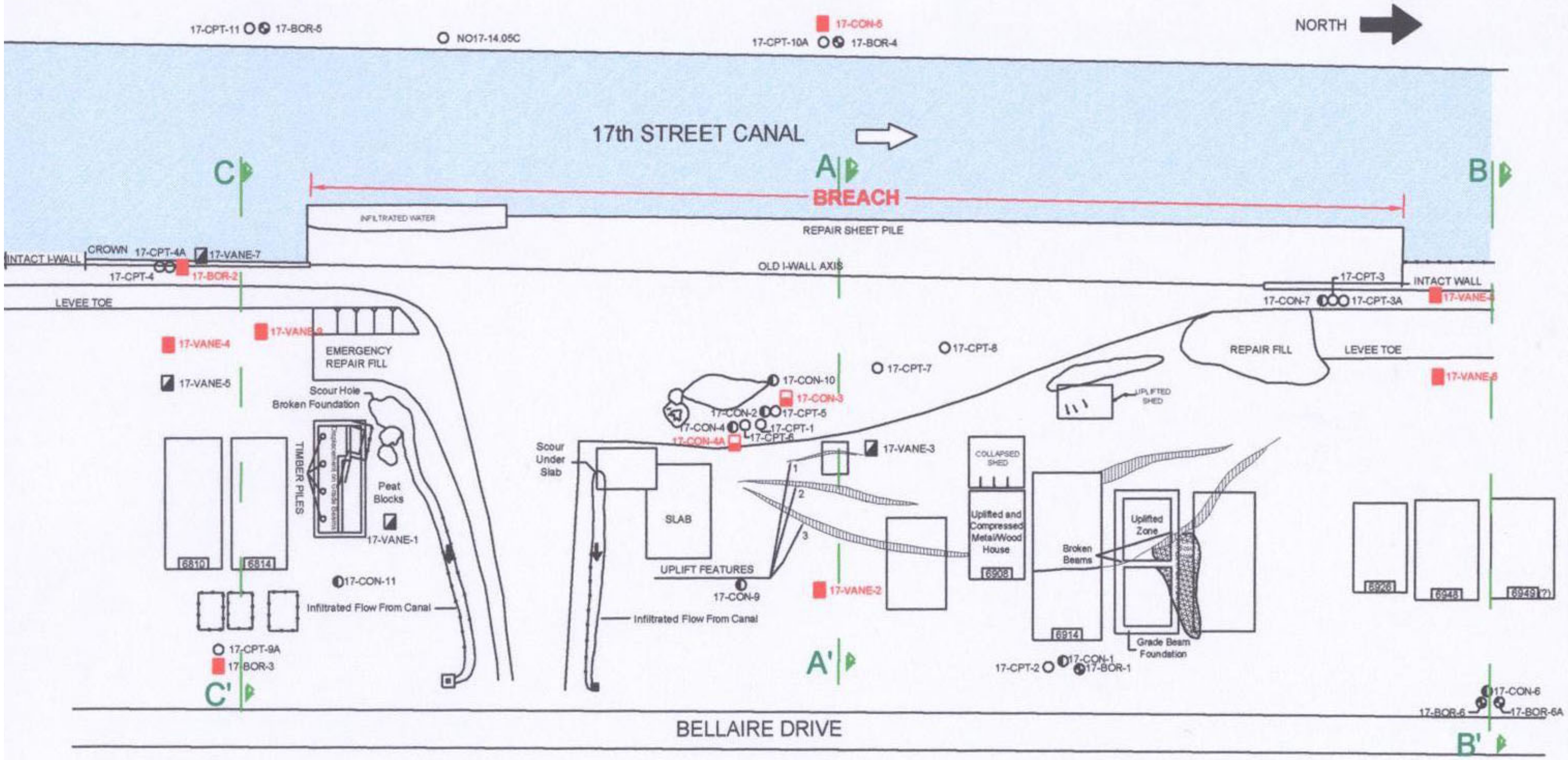
				corrected					
vane test #	**depth (ft)**	**peak (psf)**	**residual (psf)**	**peak (psf)**	**residual (psf)**	**soil description**	**water content (%)**	**σ'vo (psf)**	**Su/P**
NO VANE 43	-9.7	340	35	387.6	39.9	matter, wood, org. odor	132.8	142.82	2.71
NO VANE 44	-9.9	306	50	348.84	57	matter, wood, org. odor	122	148.34	2.35
NO VANE 45	-10.05	372	50	424.08	57	matter, wood, org. odor	93.3	152.48	2.78
NO VANE 46	-10.2	280	34	319.2	38.76	gray CH w/ traces black org. matter	50.2	156.62	2.04
NO VANE 47	-10.4	243	52	277.02	59.28	gray clayey silt	34.7	162.14	1.71
NO VANE 48	-10.6	102	14	116.28	15.96	gray CH w/ traces black org. matter	63.5	167.66	0.69
NO VANE 49	-10.7	334	50	380.76	57	grey CH	44.2	170.42	2.23
NO VANE 50	-10.9	194	40	221.16	45.6	gray clayey silt	45.6	175.94	1.26
NO VANE 51	-11.1	217	50	247.38	57	gray clayey silt	147.4	181.46	1.36
NO VANE 52	-11.2	227	56	258.78	63.84	gray clayey silt	58.6	184.22	1.40
NO VANE 53	-11.4	528	10	601.92	11.4	gray clayey silt		189.74	3.17


Shear strength profile


Water content profile


Su/P profile

*See text, page E-1.



LEGEND

○ 17-CPT-#	Cone Penetration Test
◐ 17-CON-#	Continuous Boring
◉ 17-BOR-#	Geotechnical Boring
◪ 17-VANE	Field Vane Test
🟥	Sheared
🟥	Unsheared (Weak Zone)
—•—•—•—	Fence

17th Street Canal
APPROXIMATE ILIT BORING, CPT, VANE LOCATIONS
New Orleans, Louisiana

SIZE	DATE 05/06/2006	DWG NO. 17th Boring & CPT Plan
SCALE	Not Drawn To Scale	SHEET

BORING NUMBER 17-VANE-1

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 4/11/06 **COMPLETED** 4/11/06

GROUND ELEVATION -6 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES South end of breach, East of emergency repair fill.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		CH: Gray CH and black organic matter (mixing zone).	1			176.2	47	
5		CH: Gray CH and black organic matter (mixing zone).	2			152.7	70.5	
		CH: Gray CH and black organic matter (mixing zone).	3			199.7	82.2	
		CH: Gray CH and black organic matter (mixing zone).	4			164.4	82.2	
10		CH: Gray CH and black organic matter (mixing zone).	5			187.9	94	
		CH: Gray CH, high PI. Bottom of hole at 10.7 feet.	6			199.7	94	

GEOTECH BH PLOTS ILIT, FIELD VANES, 17TH STREET.GPJ GINT US LAB.GDT 5/3/06

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BORING NUMBER 17-VANE-2

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 3/12/06 **COMPLETED** 3/12/06

GROUND ELEVATION -6.44 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES Center of breach, outside disturbed area (by school bus).

AFTER DRILLING ---

Depth (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
		Fill	7			364.1	23.5	
5		Marsh	8			158.6	41.1	
		Marsh	9			47.0	5.9	
		CH: Gray CH and black organic matter (mixing zone).	10			23.5	11.7	
		CH: Very soft, high PI, gray CH.	11			35.2	23.5	
		CH: Soft, gray CH.	12			105.7	47.0	
		Bottom of hole at 8.4 feet.						

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BORING NUMBER 17-VANE-3

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 3/13/06 **COMPLETED** 3/13/06

GROUND ELEVATION -1.78 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES North-East of displaced block.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
5		Fill	13			411.1	23.5	
		Fill mixing with fibrous organic clay.	14			328.9	82.2	
		Marsh	15			164.4	23.5	
10		CH: Gray CH and black organic matter (mixing zone).	16			105.7	11.7	
		CH: Very soft, high PI, gray CH.	17			117.5	35.2	
		CH: Soft, gray CH.	18			140.9	52.9	

Bottom of hole at 12.5 feet.

BORING NUMBER 17-VANE-4

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 4/8/06 **COMPLETED** 4/8/06

GROUND ELEVATION -6 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES South end of breach, levee toe.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		Non-engineered CL fill.	19			117.5	23.5	
		Very fibrous marsh, wood.	20			305.4	23.5	
		Black organic matter.	21			82.2	7	
5								
		Black organic matter, roots, wood.	22			115.1	37.6	
		Black organic matter.	23			124.5	18.8	
		Black organic matter mixing with gray clay.	24			187.9	51.7	
		Bottom of hole at 9.3 feet.						

BORING NUMBER 17-VANE-5

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME 17th Street Canal (East)
PROJECT NUMBER
PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana
DATE STARTED 4/8/06 **COMPLETED** 4/8/06
GROUND ELEVATION -6 ft **HOLE SIZE**
DRILLING CONTRACTOR
GROUND WATER LEVELS:
DRILLING METHOD Field Vane
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES South end of breach, levee toe.
AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		Organic matter.	25			152.7	23.5	
5		CH/OH	26			176.2	44.6	
		CH/OH	27			164.4	35.2	
		CH/OH	28			129.2	47	
		Marsh, contact with gray CH.	29			52.9	11.7	
		Gray CH, traces organic.	30			164.4	72.8	
		Bottom of hole at 8.4 feet.						

BORING NUMBER 17-VANE-6

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 4/9/06 **COMPLETED** 4/9/06

GROUND ELEVATION -5 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES North end of breach, levee toe, 6949 Bellaire St.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 / PL MC LL 60 120 180 240 / ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		Organic matter.	31			234.9	70.5	
		Organic matter, strong odor .	32			187.9	47	
5		Organic matter.	33			150.3	30.5	
		Organic matter.	34			211.4	47	
		Intermixing of black organic with gray clay.	35			129.2	47	
		Intermixing of black organic with gray clay. Bottom of hole at 9.6 feet.	36			129.2	52.9	

BORING NUMBER 17-VANE-7

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 4/11/06 **COMPLETED** 4/11/06

GROUND ELEVATION 3.8 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES South end of breach, levee crest.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
5								
10								
		Non-engineered CL fill.	37			446.3	94	
		Non-engineered CL fill.	38			123.3	49.3	
		Dark gray CH, traces organic.	39			111.6	49.3	
		Dark gray CH, traces organic, top of marsh.	40			152.7	65.8	
15		Marsh, wood.	41			246.7	47	
		Black organic matter.	42			129.2	44.6	
		Bottom of hole at 15.2 feet.						

BORING NUMBER 17-VANE-8

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 4/11/06 **COMPLETED** 4/11/06

GROUND ELEVATION 4 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES North end of breach, levee crest.

AFTER DRILLING ---

Depth (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
5								
10								
		Gray, silty, sandy CL, traces black organic.	43			352.4	94	
		Organic matter, 80% wood.	44			211.4	70.5	
15								
		Organic matter, 80% wood.	45			47	29.4	
		Bottom of hole at 16.6 feet.						

BORING NUMBER 17-VANE-9

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME 17th Street Canal (East)

PROJECT NUMBER

PROJECT LOCATION 17th Street Canal, New Orleans, Louisiana

DATE STARTED 4/11/06 **COMPLETED** 4/11/06

GROUND ELEVATION -6 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES South end of breach, levee toe.

AFTER DRILLING ---

Depth (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
5		Black organic matter, mixing with gray CH.	46			176.2	35.2	
		Dark gray CH, traces organic.	47			54	28.2	
		Dark gray CH, traces organic.	48			39.9	16.4	
10		Gray CH (fibrous).	49			129.2	54	
		Bottom of hole at 10.0 feet.						

Base map: IPET

LEGEND

☐ London 2006 ILIT Field Vane

● London 2006 ILIT Boring and Cone Penetration Test
LAC-BOR-#: Boring
LAC-CON-#: Continuous Boring
LAC-CPT-#: Cone Penetration Test

LONDON AVENUE CANAL (NORTH)
APPROXIMATE ILIT BORING, CPT, VANE LOCATIONS
New Orleans, Louisiana

SIZE	DATE	DWG NO.	REV
	05/04/2006	LACSitePlan	

SCALE		SHEET
	Not Drawn To Scale	

BORING NUMBER LAC-VANE-1

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Canal

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 3/15/06 **COMPLETED** 3/15/06

GROUND ELEVATION -4.68 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES LAC (East)- at max. tilt of wall, by the swimming pool

AFTER DRILLING ---

Depth (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
		Organic silty clay, some roots. Bottom of hole at 2.5 feet.	1			199.7	11.7	

GEOTECH BH PLOTS ILIT, FIELD VANES, LONDON AVE CANAL.GPJ GINT US LAB.GDT 5/4/06

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BORING NUMBER LAC-VANE-2

CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Canal

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 3/15/06 **COMPLETED** 3/15/06

GROUND ELEVATION -4.0 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES LAC (East)- between swimming pool and toe of levee

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		Organic clay.	2			105.7	35.2	
5		Organic matter mixing with gray clay.	3			140.9	52.9	
		Gray clay with organic matter.	4			47.0	2.3	
		Bottom of hole at 5.2 feet.						

BORING NUMBER LAC-VANE-3

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Canal

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 3/15/06 **COMPLETED** 3/15/06

GROUND ELEVATION -3.0 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES LAC (East)- south end of rockfill, at levee toe.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
5		Stiff marsh.	5			540.3	35.2	
		Organic matter mixing with gray clay.	6			199.7	35.2	
		High PI gray clay, traces of organic matter.	7			94	5.9	
		High PI gray clay, traces of organic matter.	8			94	5.9	
		Bottom of hole at 7.1 feet.						

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BORING NUMBER LAC-VANE-4

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Canal

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 4/10/06 **COMPLETED** 4/10/06

GROUND ELEVATION 4.3 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES LAC North (East)- south end of rockfill, levee crest.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
5								
10								
		Marsh with dark gray CH.	9			117.5	58.7	
15		Marsh with dark gray CH, wood. Bottom of hole at 15.2 feet.	10			105.71	11.75	

BORING NUMBER LAC-VANE-5

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Canal
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 4/10/06 **COMPLETED** 4/10/06
GROUND ELEVATION 4.3 ft **HOLE SIZE**
DRILLING CONTRACTOR
GROUND WATER LEVELS:
DRILLING METHOD Field Vane
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES LAC North (East)- south end of rockfill, levee crest.
AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
5								
10		Marsh with dark gray CH.				129.2	65.8	
		Marsh with dark gray CH, wood.				199.7	23.5	
		Bottom of hole at 11.4 feet.						

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BORING NUMBER LAC-VANE-6

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CLIENT ILIT (Independent Levee Investigation Team)

PROJECT NAME London Avenue Canal

PROJECT NUMBER

PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana

DATE STARTED 4/10/06 **COMPLETED** 4/10/06

GROUND ELEVATION -6.5 ft **HOLE SIZE**

DRILLING CONTRACTOR

GROUND WATER LEVELS:

DRILLING METHOD Field Vane

AT TIME OF DRILLING ---

LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa

AT END OF DRILLING ---

NOTES LAC North (East)- south end of rockfill, 50ft from levee toe.

AFTER DRILLING ---

Depth (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
0								
		Marsh, roots.	13			117.5	23.5	
5		Marsh, roots.	14			70.5	23.5	
		Organic clay, sandy at the tip.	15			25.8	11.7	
		Bottom of hole at 5.8 feet.						

BORING NUMBER LAC-VANE-7

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CLIENT ILIT (Independent Levee Investigation Team)
PROJECT NAME London Avenue Canal
PROJECT NUMBER
PROJECT LOCATION London Avenue Canal, New Orleans, Louisiana
DATE STARTED 4/10/06 **COMPLETED** 4/10/06
GROUND ELEVATION -6.5 ft **HOLE SIZE**
DRILLING CONTRACTOR
GROUND WATER LEVELS:
DRILLING METHOD Field Vane
AT TIME OF DRILLING ---
LOGGED BY A. Athanasopoulos **CHECKED BY** D. Cobos-Roa
AT END OF DRILLING ---
NOTES LAC North (East)- 6060 & 6078 Warrington St., 50' from levee toe.
AFTER DRILLING ---

Depth (ft) 0	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	Peak Strength (psf)	Residual Strength (psf)	▲ SPT N VALUE ▲ 20 40 60 80 PL MC LL 60 120 180 240 ☐ FINES CONTENT (%) ☐ 20 40 60 80
		Dar brown-black silty organic clay.	18			152.7	35.2	
		Organic clay.	16			108.1	35.2	
5		Mixing of black and gray organic clay.	19			140.9	21.1	
		Dark brown organic clay.	17			117.5	35.2	
		Bottom of hole at 5.0 feet.						

APPENDIX F: LOOKING BACK

> ***We must expect more catastrophes like Hurricane Katrina - and possibly even worse. In fact, we will have compounded the tragedy if we fail to learn the lessons - good and bad - it has taught us and strengthen our system of preparedness and response. We cannot undo the mistakes of the past, but there is much we can do to learn from them and to be better prepared for the future. This is our duty.***
>
> Frances Gragos Townsend
> Assistant to the President for Homeland Security and Counterterrorism
> *The Federal Response to Hurricane Katrina, Lessons Learned*
> Report to the President of the United States, February 2006

F.1 Synopsis of History of the New Orleans Flood Defense System 1965 - 2005

This synopsis of the history of the New Orleans Flood Defense System (NOFDS) starts in 1965 in the period following hurricane Betsy. This is only the most recent phase in a history of the NOFDS that dates back 300 hundred years.

September 1965: Hurricane Betsy sweeps over New Orleans with winds exceeding 100 miles per hour and tides up to 16 feet above mean sea level. Betsy was the most destructive hurricane on record to strike the Louisiana coast. It inundated an area of some 4,800 square miles, killed 81 persons within the state, caused about 250,000 people to be evacuated and disrupted transportation, communication, and utility service throughout the eastern coastal area of Louisiana for many months. East New Orleans, St. Bernard Parish, and the Lower Ninth Ward were particularly hard hit. Residents blamed flooding on the Mississippi River Gulf Outlet (MR-GO, completed 1961) and its connection to the Gulf Inter-Coastal Water Way (GIWW) and the Industrial Canal (Inner Harbor Navigation Canal, IHNC). Earlier in the year, the Orleans Levee Board began driving sheet pilings on the 17th Street canal and other drainage canal levees that had been raised following flooding caused by a hurricane in 1947. Maintenance dredging was initiated by the Corps of Engineers on the MR-GO.

October 1965: Congress authorized the Corps of Engineers plan to strengthen the NOFDS to protect from flooding caused by a storm surge or rainfall associated with a Standard Project Hurricane (SPH, estimated to have a 200 to 300 year return period), which is roughly the same as what is now classified as a fast moving Category 3 hurricane. The Corps proposed massive floodgates and barriers on the far end of Lake Pontchartrain to stop hurricane surges from the Gulf of Mexico (Barrier Plan). Also included were additional protection to areas around the lake in the parishes of Orleans, Jefferson, St. Bernard, and St.

Charles. This protection included a series of levees along the lakefront and concrete floodwalls along the Inner Harbor Navigation Canal. This plan was selected over another alternative, known as the High Level Plan which excluded the barriers and flood gates and instead employed higher levees. The Barrier Plan was favored because it was believed to be much less expensive and quicker to construct. Although federally authorized, it was a joint federal, state, and local effort with the federal government paying 70 percent of the costs and the state and local agencies paying 30 percent. *The Corps was responsible for project design and construction. State and local interests were responsible for operations and maintenance of the flood controls.* The project was forecast to take about 13 years to complete (1978) and cost about $85 million.

October 1968: The Corps of Engineers performed field tests of levee construction in the Atchafalaya Basin. These test sections were built in 1964 and 1965 to investigate the performance of new levee designs. The sections were instrumented and their performance monitored during and after construction. Important information was developed regarding characterizations of the soil properties and how these should be used in analyzing levee stability factors of safety. Definitive differences were found between soil strengths near the centers and at the toes of the levee test sections. Differences in factors of safety due to different analysis methods were analyzed and it was noted that the method used at that point in time by the Corps of Engineers tended to over-predict the overall factors of safety.

August 1969: Construction of floodwalls along the Inner Harbor Navigation Canal, started in 1966, was almost completed as was an earthen levee elevated to 12 feet along Lakeshore Drive from West End Boulevard to the Inner Harbor Navigation Canal when hurricane Camille surge conditions produced similar surge conditions to those of hurricane Betsy. Temporary sheet piling had been driven by the Orleans Levee Board to increase their effective height. *Only minor flooding occurred in the project area.* Hurricane Camille (Category 5 hurricane) crossed the Mississippi coast at Pass Christian and devastated the coastal communities along the Mississippi coast to Biloxi Alabama.

November 1969: Corps of Engineers issues report on Standard Project Hurricane surge and wave conditions for St. Bernard Parish. Effects of MR-GO and its adjacent levee are incorporated into these conditions.

December 1973: In order to accelerate construction, the Orleans Levee board financed and constructed portions of the floodwalls along the Inner Harbor Navigation Canal and these were virtually completed at this time.

August 1976: Corps of Engineers estimate that he cost of the improved NOFDS had risen to $352 million, and its completion delayed to 1991. In a review of progress, the Comptroller General's Report to the Congress (1976) observed: "…its (Corps of Engineers) own belated completion of design, plans, and specifications, has contributed to the delays." The Citrus Back Levee, Michoud Slip Levee, New Orleans East Back Levee, New Orleans East South Point to Gulf Intercoastal Water Way were substantially completed as was the flood protection structure at Bayou Bienvenue.

December 1977: In reaction to a suit brought by a coalition of local fishermen and the Save Our Wetlands environmental group in 1976, the Fifth Federal District Court ruled the Environmental Impact Statement for the Corp's Barrier Plan was inadequate and enjoined construction of the entire project. The Court ordered the Corps of Engineers to produce an environmental impact report on the proposed Barrier Plan. The injunction was subsequently modified to permit construction of the levee and floodwall elements of the hurricane protection plan.

September 1979: NOAA issues official revisions to Standard Project Hurricane guidelines first issued during 1959 and used as a basis for the authorization of the Lake Pontchartrain and Vicinity congressional authorization. These revised SPH guidelines increased the sustained and maximum wind speeds, and modified the hurricane radius to the maximum winds and forward speeds. These changes resulted in increases in the surge and wave heights over those in the original SPH. *These changes were not reflected in later design guidelines for the flood protection system.*

April 1980: Flooding overtops east side of the London Avenue canal south of Robert E Lee, where 200 feet of sheet piling had been removed at a point where the levee was eroding.

January 1981: Stability analysis performed by consulting engineers Modjeski and Masters shows that proposed higher levees for the 17th Street canal would fail in high water. Factors of safety less than 1.3 and as low as 0.8 were found for substantial portions of the canal. Additional studies were recommended.

September 1981: Corps of Engineers issues a design memorandum and revised environmental impact statement in which it is observed: "There is an unresolved issue with regards to the three main outfall canals in New Orleans which empty into Lake Pontchartrain along the reach known as the New Orleans Lakefront. Return levees flank these gravity drainage canals for a considerable distance inland from the lake, tying into lift pump stations at the head of the canals. *Since the time of project authorization, it has been determined that the return levees are inadequate in terms of both grade and stability*." Work was underway to raise the lakefront levees to a height of 16 feet.

August 1982: At this time, only about half of the improved NOFDS project had been completed. Costs were estimated to have grown to $757 million, not including any work along the drainage canals, and project completion had slipped to 2008. The General Accounting Office (1982) observed: "We believe that improved planning is needed by the Corps to resolve certain environmental, technical, and financial issues. Environmental concerns have remained unresolved for almost 5 years after a court injunction prohibited the Corps from constructing certain parts of the projects. The Corps is considering a change in its solution of providing protection from constructing barrier structures at the entrance to the lake and the raising of some levee heights (Barrier Plan) to constructing much higher levees with no barriers (High Level Plan)." The report observed: "Costly project work at the drainage canals has not been reported to the Congress, and technical and financial concerns which may impede project completion remain unresolved." Further this report observed: *"Subsequent to project authorization and based on the Weather Bureau's new data pertaining to hurricane severity (NOAA 1979), the Corps determined that the levees along the three main drainage canals, which drain major portions of New Orleans and empty into Lake Pontchartrain, were not high enough since they are subject to overflow by hurricane surges."*

A report issued to Modjeski and Masters by Eustis Engineering notes following installation of piezometers to determine water pressures on both sides of the canal (17th Street) "*..the planned improvements to deepen and enlarge the canal may remove the seal that has* *apparently developed on the bottom and side slopes, thereby allowing a buildup of such pressures in the sand stratum (under the levee).”* Further, it was noted “*computations indicate the possibility of a blow-out during extreme high water in the canal. Unless more definitive information can be developed regarding the potential hydrostatic uplift pressure at the levee toe through this reach, measures should be taken to prevent a blow-out during extreme high water conditions*.” Additional correspondence addressed preventative measures including a 65-foot long (deep) sheet pile cutoff wall and a concrete lining for the canal.

November 1984: The Corps of Engineers encounter project delays and cost increases due to design changes caused by technical issues, environmental concerns, legal challenges, and local opposition to various aspects of the project. Foundation problems were encountered during construction of levees and floodwalls which increased construction time; delays were also encountered in obtaining rights-of-ways. The Corps of Engineers presents an alternative to the Barrier Plan identified as the High Level Plan. The Corps of Engineers propose to build floodgates on the canals, but local officials want to construct floodwalls on the levees.

December 1984: Report issued to St. Bernard Parish, NOAA and the Louisiana Department of Natural Resources on the MR-GO bank stabilization. The history of construction, ship traffic, channel dredging, and erosion were documented together with recommendations for protective measures to help prevent further erosion and destruction of wetlands.

July 1985: The Corps of Engineers reach agreements with state and local agencies to proceed with the High Level Plan based on construction of floodwalls on the levees. The Corps of Engineers make a decision to continue use of 1983 benchmark elevations even though National Geodetic Survey information indicates that these elevations are one or more feet low: “Hurricane protection projects which are partially complete will use the NGS benchmarks current at the time of construction of the first increment of the project” (1965).

July 1987: Construction was virtually completed on the lakefront levees and floodwalls raising these defenses to an elevation of approximately 18 feet in accordance with the Corps of Engineers’ High Level Plan.

June 1988: The Corps of Engineers issues a technical report documenting results from a full-scale field load test performed on a PZ-27 sheet pile wall located in the Atchafalaya Basin south of Morgan City. Flood loading was simulated by ponding water against the wall which was founded in soft clays similar to those underlying the New Orleans area. *The wall was designed to carry an 8 foot head of water with a factor of safety of 1.25. The wall ‘failed’ (rapidly increasing wall displacements) when the water head reached 8 feet. A gap developed between the loaded sheet pile and the supporting soil on the water side (indicated by slope indicators located in the soils and on the piles).* The Corps of Engineers Waterways Experiment Station (WES) was contracted to perform additional analyses of the data.

August 1988: The Corps of Engineers issues Design Memorandum 19 for the Orleans Avenue outfall canal work. *Issues were raised regarding the factors of safety for use in design of the flood walls and evaluation of the levee stability (specified to be a minimum of 1.3), quality control problems with reporting the soil characteristics, how soil shear strengths are averaged and selected for the foundation layers, the presence of very low shear strength layers, challenges associated with dredging the canal so that the embankment stability would not be threatened, and concerns for seepage from the canal to the protected sides. Changes in* *the SPH developed in 1979 were not reflected in changes in the flood protection design elevations*.

December 1988: The Corps of Engineers Waterways Experiment Station issues a report that proposes a new method for soil-structure interaction analysis of floodwalls. The report shows that during loading of a floodwall the deformations and strains in the sheet piling are controlled by the movements of the soil supporting the sheet piling. *It was noted that as the water level rises, the increased loading may produce separation of the soil from the pile on the flood side (a tension crack develops behind the wall). Intrusion of free water into the tension crack produces additional hydrostatic pressures on the wall side of the crack and equal and opposite pressures on the soil side of the crack. This part of the loading was noted to be a function of the levee soil - sheet pile system deformations.*

January 1989: The Corps of Engineers issues Design Memorandum 19A for the London Avenue outfall canal work. *Issues are raised concerning how the levee stability analyses are performed (including the shapes of the failure surfaces) and how the soil shear strengths are treated in the analyses. Concerns for differences in soil shear strengths along and at the toes of the levees are raised.*

September 1989: The Waterways Experiment Station issues a report on analyses of sheet pile walls based on the E99 tests performed in 1985. The work indicates that deep-seated movements in the levee foundation control the magnitude of the sheet-pile deflection with the result that the height of water loading that can be sustained by a particular I wall is controlled by the stability of foundation as determined by a slope stability analysis. *It was concluded that conventionally determined deflections of the sheet piling were a poor criterion for design because movements were caused by deformations in the foundation and not the cantilever action of the sheet piles.*

March 1990: The Corps of Engineers issues Design Memorandum 20 for the 17th Street outfall canal work. *There are discussions concerning analysis of the soil shear strengths, the shapes of the failure surfaces for stability analyses and factors of safety for evaluation of the levees and sheet pile walls.*

August 1990: The Orleans Levee Board initiates work on the 17th Street canal levee. The levee board elected to take the lead to achieve savings because the New Orleans Sewerage and Water Board planned to deepen and widen the canal to meet their drainage needs. The Corps of Engineers issued permits to the New Orleans Sewerage and Water Board in 1984 and 1992. The work required modifications to the existing levees and floodwalls. After the dredging, the bottom was 18.5 feet below sea level (below the bottom of the sheet piling), and the canal side levee on the Orleans side had been shaved so narrow, water now touched the wall. Concerns were again raised on details associated with how the levee stability analyses were being performed including concerns about factors of safety, analysis of soil shear strengths, and shape of the slope stability analyses geometries.

October 1990: Congress orders the Corps of Engineers to begin raising the levees on the London and Orleans avenues drainage canals.

September 1997: Two technical papers published in the Electronic Journal of Geotechnical Engineering (www.ejge.com) summarize results from the E99 sheet pile load tests performed in 1985 and the subsequent research conducted at the Corps of Engineers Waterways Experiment Station. Advanced analytical methods developed during the period

1982 - 1989 for determining the deformations developed in levees and the interaction of sheet pile floodwalls with the levees were summarized. In the first paper (Oner et al, 1997a) in the section on Incremental Loading (p.10) it was noted "*The rising water produces several loading effects on a flood wall system. Most apparent is the hydrostatic pressure on the exposed wall above the ground surface. This part of the loading is independent of system deformations. …As the water level rises, the increased loading may produce separation of the sol from the pile on the flood side (i.e., a "tension crack" develops behind the wall). Intrusion of free water into the tension crack produces additional hydrostatic pressure on the wall side of the crack and equal and opposite pressures on the soil side of the crack. This part of the loading is a function of system deformations*."

February 1998: Decision reached by administrative judge, member, Corps of Engineers Board of Contract Appeals regarding a construction claim filed by the Pittman Construction Company for difficulties encountered while constructing a section of the floodwall on the 17th Street canal (in vicinity of breach). It was Pittman's contention that the lack of structural integrity of the existing sheet pile around which the concrete was poured and the weakness of the soils resulted in difficulties in pouring the concrete walls to the required tolerances. Pittman's expert witness, *Dr. Herbert Roussel, concluded that the soils is so weak and may have been further weakened by the additional driving of the sheet pile that increasing the penetration ca not get the deflection within tolerance*. Questions were also raised concerning the reasonableness of the specified tolerances for the concrete flood walls (0.25 inches in 10 feet). The claim was rejected by the Corps of Engineers Board of Contract Appeals.

September 1998: Hurricane Georges was headed directly for New Orleans but turned and made landfall instead at Biloxi, Mississippi. Storm tides reached 2 to 3 feet in Lake Pontchartrain and flooded the New Orleans Lakefront Airport. Only minor flooding occurred in the greater New Orleans area.

May 2005: The estimated cost of construction for the completed enhanced NOFDS was estimated to be $738 million with an estimated completion date of 2015. A Corps of Engineers report on the High Level Plan indicated that construction work on the project was 60 - 90 percent complete in different areas. Work on bridge replacement and floodproofing was underway along Orleans Avenue and London Avenue canals and on the Hammond Highway bridge over the 17th Street canal. During the last 10 years (1996-2005), federal appropriations generally declined from about $15-20 million annually in the earlier years to about $5-$7 million in the last three years. The Corps of Engineers noted that the appropriated amount for 2005 was insufficient to fund new construction contracts. The Corps of Engineers also noted it could spend $20 million in 2006 on raising levees that had settled and needed to be raised to provide the design-level of protection.

August 2005: Hurricane Katrina strikes the NOFDS with winds that exceeded 140 miles per hour and a surge that ranged from approximately 10 to 11 feet (Lake Pontchartrain) to 14 to 18 feet (Lake Borgne) flooding more than 85% of the city. The NOFDS failed catastrophically. More than 1,500 people died as a result of the flooding (about 400 more are currently missing). Failure of the NOFDS constitutes the single most catastrophic and costly failure of a civil engineered system in the history of the United States.

F.2 Learning from Failures

Detailed studies have been made of more than 600 well documented major failures and accidents involving engineered systems (Turner 1978; Whittow 1979; Petroski 1985; 1994; Allison 1993; Roberts 1993; Sowers 1993; Groeneweg 1994; Lancaster 1996; Dorner 1996; Dumas 1999; Perrow 1999; Bea 2000; Chiles 2002). These studies include recent accidents including the Challenger and Columbia space shuttles (Vaughn 1996, 1997; Columbia Accident Investigation Board 2003), the collapse of the World Trade Center towers, the failures of the Three Mile Island and Chernobyl nuclear power plants , the Teton dam collapse, the Union Carbide Bhopal chemical plant catastrophe, failures of the offshore platforms Occidental Piper Alpha and Petrobras P36 and the groundings of the oil tankers Torry Canyon, Amoco Cadiz, Exxon Valdez and Braer. Sufficient reliable documentation is available about these failures and accidents to understand the roles of the various components that comprised the systems during their life-cycle phases leading to the accident or failure. In many cases, personnel who participated in the events were interviewed to gain additional insights about how and why the accidents and failures developed. Extensive care was exercised to neutralize biases in this work (e.g., triangulation of multiple reliable sources, use of different assessors with different backgrounds) (Hale et al. 1997; Center for Chemical Process Safety 1994; Rasmussen et al. 1987).

Background from these detailed studies (conducted over a 15-year period) provided important analysis templates that helped development of understanding of the failure of the NOFDS. Results from these studies are summarized in this Chapter. In addition, because it has particular relevance to this investigation, a summary will be presented of results from the investigation of the NASA Columbia accident. This summary will be preceded by introduction of the primary concepts associated with high and low reliability organizations.

F.2.1 Engineered Systems

The studies indicated that the *system* involved in development of failures needed to be carefully defined and evaluated (Bea 2006). Seven primary interactive, inter-related, and highly adaptive components were defined to help characterize engineered systems: 1) structure (provides support for facilities and operations), 2) hardware (facilities, control systems, life support), 3) procedures (formal, informal, written, computer software), 4) environments (external, internal, social), 5) operators (those who interface directly with the system), 6) organizations (institutional - organizational frameworks in which operations are conducted), and 7) interfaces among the foregoing.

The studies clearly identified the importance of system interfaces in the development of failures. Breakdowns in communications and other actions frequently developed at the interfaces between the operators and the organizations that controlled resources, means, and methods. Communication malfunctions at organization-to-organization interfaces, information filtering, distortion, and ‘stove-piping’ communication barriers in large bureaucratic organizations were even more prevalent.

An important part of this system is the Technology Delivery System (TDS) involved in development, operation, and maintenance of the engineered system. Technology is a social process by which specialized knowledge from science and experience is employed to deliver a system to meet specific needs of a society. The TDS is an ensemble of institutions involving the public, government, and enterprise (industry) which are linked by webs of information channels. Inputs to the TDS consist of technical knowledge, natural resources, capital, human talents, and value preferences. Outputs are the intended goods and services to provided by the engineered system, including unintended and unwelcome consequences. The basic elements of a TDS are further developed in Appendix H.

The studies showed it was essential to identify how the system developed throughout its life-cycle to the point of failure including development of concepts, design, construction, operation, and maintenance. The history (heritage) of a system generally had much to do with development of failures. The studies indicated that in a very large number of cases, the seeds for failure were sown very early in the life of a system; preceding and during the concept development and design phases. These seeds were allowed to flourish during the construction, operation and maintenance phases, and with the system in a weakened flawed and defective condition, when severely challenged, it failed.

F.2.2 Causes of Failures

Uncertainties that were primary contributors to the accidents and failures were organized into four major categories: 1) natural variability (information insensitive), 2) analytical modeling uncertainties (information sensitive), 3) human and organizational performance uncertainties, and 4) knowledge related uncertainties. This organization of uncertainties was developed to permit definition of means and measures that could be used to help manage the causes and effects of the uncertainties.

The studies showed that the causative factors most often (80 % or more) involved human, organizational and knowledge related uncertainties (Reason 1990, 1997; Perrow 1999; Bea 2000, 2006). These were identified as *Extrinsic Factors (not belonging to the essential nature of the system)*. Frequently, these factors are identified as *human errors.* The remaining 20% of the factors involved natural and analytical model related uncertainties. These were identified as *Intrinsic Factors (belonging to the essential nature of the system)* (Vick 2002).

Of the Extrinsic Factors, about 80% of these developed and became evident during operations and maintenance activities; frequently, the maintenance activities interacted with the operations activities in an undesirable way. Of the failures that occurred during operations and maintenance, more than half were traced to seriously flawed engineering concept development and design. The physical system may have been designed according to accepted standards and yet was seriously flawed due to limitations and imperfections embedded in the standards and/or in how they were used. Frequently, engineered systems were designed that could not be built, operated, and maintained as originally intended. Changes (work-arounds) were made during the construction process to allow the construction to proceed; flaws were introduced by these changes or flaws were introduced by the construction process itself. After the structure was placed in operation, modifications were made in an attempt to make it workable or to facilitate operations, and in the process additional flaws were introduced. Thus, during operations and maintenance phases, operations personnel were faced with a seriously deficient or defective system that could not be operated and maintained as intended.

A useful analogy to describe the Extrinsic Factors was that of a ‘spear’ (Reason 1997) The *pointed end* of the spear represented the operators (operating teams) who are responsible for performing the activities during the life-cycle development of the system. The *blunt end* or shaft of the spear represented the organizations that controlled means, methods, and resources. The activity at the pointed end of the spear was largely determined by what happened along the shaft of the spear; the TDS.

The 20% of the causation factors that involved natural and model related uncertainties represented residual risks that developed from exceedances of the criteria and conditions used to design, construct, operate, and maintain the system. These could identified as *'acts of god'* (Bernstein 1996; Molak 1996; Prigogine 1997).

F.2.3 Magnitudes of Failures

An important discriminating difference between major (catastrophic) and not-so-major failures involved the *magnitude of consequences* developed during and after the failures. Not-so-major failures generally involved only a few people, a few malfunctions or breakdowns, and small magnitude consequences. Major or catastrophic failures involved of many people and their organizations, a multitude of malfunctions or breakdowns developed over long periods of time, and very large magnitudes of consequences (direct, indirect, on-site, off-site, short-term, long-term). Frequently, organizations construct barriers to prevent failure causation to be traced in this direction. In addition, until recently, the legal process focused on the proximate causes of failures (*human errors*). There have been some recent major exceptions to this focus; the important roles of organizational and institutional malfunctions in accident causation have been recognized in court and in public. Not-so-major accidents, if repeated very frequently, can lead to major losses and it is obvious that it is important to develop approaches and strategies to address both categories of accidents.

F.2.4 Breaching Defenses

Most failures involved never to be exactly repeated sequences of events and multiple breakdowns or malfunctions in the components that comprise a system. Failures resulted from breaching multiple defenses that were put in place to prevent them. These events are frequently dubbed incredible or impossible. After many of these failures, it was observed that if only one of the barriers had not been breached, the accident or failure would not have occurred. Experience adequately showed that it was extremely difficult, if not impossible, to recreate accurately the time sequence of the event that actually took place during the period leading to failure. Unknowable complexities generally pervade this process because detailed information on failure development is not available, is withheld, or is distorted by memory. Hindsight and confirmational biases are common as are distorted recollections. Stories told from a variety of viewpoints involved in the development of a failure are the best way to capture the richness of the factors, elements, and processes that unfold in the development of a failure.

Defenses against breaching could be organized into *proactive, interactive, and reactive* categories (Bea 2000). These categories represented the timeframes in which activities were conducted to defend the system against failure. Reason (1997) suggested the analogy of Swiss Cheeze; failures could develop when 'holes' in these three defenses aligned. The larger the number and sizes of the holes, then the more likely they were to align and allow a failure to develop. While generally a lot of attention was given to proactive measures, insufficient attention was given to interactive and reactive defenses.

Development of effective reactive defenses often degraded because of an unwillingness or inability to recognize the 'truth', measures employed to depress development of accurate facts, and deficiencies introduced because of a wide variety of unrecognized biases (e.g., recall, hindsight, rational, control, wishful thinking, small samples, knowledge, correlation, perception, belief, confirmational, reductive). Searches were often conducted to assign blame and distribute pain. Often, once the facts and truth were known, there were efforts to restrain communications or put a 'spin' on the information so it would not appear as unfavorable as it was. In general, there were very numerous and large holes in reactive defenses.

Development of ineffective interactive defenses often developed because their importance was not recognized (Klein 1999). A key example of interactive defenses was quality control (quality assurance is a proactive measure). Often the wrong things were inspected by the wrong people at the wrong times using the wrong things and for the wrong reasons. Proper detection, analysis and correction of potential flaws was inhibited by a variety of problems (Sasou and Reason 1997). In many cases, even though very thorough proactive quality assurance procedures and processes were developed, they were not followed (violations). Often insufficient resources were allocated to implementation of interactive defenses. In general, there were very numerous and large holes in the reactive defenses (Weick and Sutcliffe 2001).

F.2.5 Knowledge Challenges

One sobering observation concerning many accidents and failures is that their occurrence is directly related to knowledge (information) access and development. Information access and development challenges were organized into two general categories: *unknown knowables*, and *unknown unknowables*. The first category represents information access and understanding challenges (Weick 1995; Klein 1999). The information exists but is either ignored, not used, not accessed, or improperly used. This category is identified as rejection - misuse of technology. Others identify this category as *'predictable surprises'* (Bazerman and Watkins 2004).

The second category - *unknown unknowables* - represents limitations in knowability or knowledge. There are significant limitations in abilities to project system developments or characteristics very far in space or time. Human abilities to know all the things that are potentially important to the future success of systems is limited. Often, there are major limitations in knowledge concerning new or innovative systems and the environments in which these systems will be developed and exist. There is ample history of accidents and failures due to both of these categories of challenges to knowledge. They appear to be most important during the early phases of constructing and operating engineered systems; *burn-in failures*. Things develop that one did not know or could not know in advance. They also appear to be most important during the late life-cycle phases; *wear-out failures*. In this case, the quality characteristics of the system have degraded due to the effects of time and operations (frequently exacerbated by improper or ignored maintenance) and the hazards posed by unknown knowables and unknown unknowables interact in undesirable ways. This recognition poses a particularly important limitation on proactive risk analyses that are conducted before systems are constructed and put in service; in a predictive sense, one can only analyze what one understands or knows. The most effective approach identified during these studies is *interactive* risk *assessment and management* (National Academy of Engineering 2004; Klein 1998; Weick and Sutcliffe 2001). Interactive risk assessment and management can be facilitated through a variety of people and system enhancements which promote abilities to detect, analyze, and correct challenges to quality and reliability before they are allowed to propagate to failures (Loosemore 2000).

F.2.6 Organizational Malfunctions

Analysis of the history of failures of engineered systems provides many examples in which organizational and institutional malfunctions were primarily responsible for the failures (Wenk 1986, 1998; Dorner 1997; Hopkins 1999, 2000; Reason 1997; Vaughn 1996; Columbia Accident Investigation Board 2003). Organization malfunction is defined as a departure from acceptable or desirable practice on the part of a group or groups of individuals that results in unacceptable or undesirable results (Roberts and Bea 2001a, 2001b). Frequently, the organization develops high incentives for maintaining and increasing production; meanwhile hoping for quality and reliability (*rewarding 'A' while hoping for 'B')* (Roberts 1993; Roberts and Libuster 1993). The formal and informal rewards and incentives provided by an organization have a major influence on the performance of operators and on the quality and reliability of engineered systems. In a very major way, the performance of people is influenced by the incentives, rewards, resources, and disincentives provided by the organization. Many of these aspects are embodied in the organization's culture (shared beliefs, artifacts). This culture largely results from the organization's history (development and evolution). For many successful organizations, success breeds arrogance that can lead to failure (lethal arrogance). Cultures are extremely resistant to change.

Several major organizational malfunctions developed because of down-sizing and out-sourcing practices adopted in response to pressures to increase organizational efficiency. Loss of corporate memories (leading to repetition of errors), inadequate core competencies in the organization, creation of more difficult and intricate communications and organization interfaces, degradation in morale, unwarranted reliance on the expertise of outside contractors, cut-backs in quality assurance and control, and provision of conflicting incentives (e.g. cut costs, yet maintain quality) are examples of activities that lead to substantial compromises in the intended quality of systems. Much of the down-sizing ('right-sizing'), outsourcing ('hopeful thinking'), and repeated cost-cutting ('remove the fat until there is no muscle or bone') seems to have its source in modern 'business consulting.' While some of this thinking can help promote 'increased efficiency' and maybe even lower CapEx (Capital Expenditures), the robustness (damage and defect tolerance) of the organization and the systems it creates are greatly reduced. Higher OpEX (Operating Expenditures), more 'accidents', and unexpected compromises in desired quality and reliability can be expected; particularly over the long-run.

Experience indicates that one of the major factors in malfunctions is the organization's culture (Reason 1997; Merry 1998; Meshkati 1995). Organizational culture is reflected in how action, change, and innovation are viewed; the degree of external focus as contrasted with internal focus; incentives provided for risk taking; the degree of lateral and vertical integration of the organization; the effectiveness and honesty of communications; attention to the potentials for failures; diligence in the use of information; particularly bad or unwelcome news (lethal arrogance); autonomy, responsibility, authority and decision making; rewards and incentives; and orientation toward the quality of performance contrasted with the quantity of production. One of the major culture elements is how managers in the organization react to suggestions for change in management and the organization. Given the extreme importance of quality and reliability, it is essential that these managers see suggestions for change (criticism?) in a positive manner. This is extremely difficult for some managers because they do not want to relinquish or change the strategies and processes that helped make them managers.

F.2.7 Engineering Challenges

New technologies compound problems of latent system flaws (structural pathogens) (Reason 1997). Excessively complex design, close coupling (failure of one component leads to failure of other components) and severe performance demands on systems increase the difficulty in controlling the impact of human malfunctions even in well operated systems. The field of ergonomics (people-hardware interfacing) has much to offer in helping create ‘people friendly’ engineered systems. Such systems are designed for what people will and can do, not what they should do. Such systems facilitate construction (constructability), operations (operability), and maintenance (maintainability, reparability).

It is becoming painfully clear that the majority of engineering design codes and guidelines do not provide sufficient direction for creating robust, damage/defect tolerant systems. Thinking about sufficient damage tolerance and inherent stability needs rethinking. Thinking about designing for the ‘maximum incredible’ events needs more development. While two engineered systems can both be designed to ‘resist the 100-year conditions’ with exactly the same probabilities of failure, the two structures can have very different robustness characteristics. The minimum CapEx system will not have a configuration, excess capacity, ductility , or appropriate correlation to allow it to weather the inevitable defects and damage that should be expected to develop during its life. Sufficient damage tolerance almost invariably results in increases in CapEx; the expectation and the frequent reality is that OpEx will be lowered. But one must have a long-term view for this to be realized.

Robustness (defect and damage tolerance) can be developed through a combination of four key elements. The first is appropriate configuration of the elements that comprise the system. The second is excess capacity built into the system elements that will allow ‘overloads’ to be carried without compromising the basic quality and reliability characteristics of the system. The third is ductility or an ability to stretch without breaking so that overloads can be shifted to other under-loaded elements. The fourth is appropriate correlation of the elements; for series (weak link) type systems, high degrees of correlation are needed to reduce the likelihood of weak links; for parallel (redundant) type systems, low degrees of correlation are needed to help insure independence in performance.

Other strategies to achieve robust systems include those of fail-safe and inherently-safe design. In fail-safe design the system is configured and proportioned so that when its ‘capacities’ are exceeded the system fails in a way that does not compromise basic safety requirements. In design of intrinsically safe systems, the system is configured so that there are fewer inherent hazards, there is a reduced probability of unwanted events, there is reduced inventory and damage potential (reduced severity), there are fewer people exposed, there is reduced scope for smaller incidents to escalate and overwhelm the facilities, and there is a clear focus on simplicity, reliability and longevity to reduce exposure.

This work has clearly shown that the foregoing statements about structure and hardware robustness apply equally well to organizations and operating teams; frequently, this is termed organizational redundancy. Proper configuration, excess capacity, ductility, and appropriate correlation play out in organizations and teams in the same way they do in a structure and hardware. When the organization or operating team encounters defects and damage – and is under serious stress, the benefits of robustness become evident. A robust organization or operating team is not a repeatedly downsized (lean and mean), out-sourced, and financially strangled organization. A robust organization is a *High Reliability Organization (HR0)* (Roberts 1989, 1990, 1993; Weick and Sutcliffe 2001; Columbia Accident Investigation Board 2003).

Software and engineering guideline errors in which incorrect and inaccurate algorithms were coded into computer programs or written into engineering guidelines have been at the root cause of several recent failures of engineered systems. Extensive software and guidelines testing and validation is required to assure that the desired performance and results are realized. Of particular importance is the provision of qualified independent checking processes and people using those process who can be used to validate the results from analyses and engineering work. High quality procedures need to be verifiable based on first principles, results from testing, and field experience.

Given the rapid pace at which significant industrial and technical developments are taking place, there is a tendency to make design guidelines, construction specifications, and operating manuals more and more complex. Such a tendency is apparent in many current guidelines used for designing engineered systems. In many cases, poor organization and documentation of software and procedures has exacerbated the tendencies for humans to make errors. Simplicity, clarity, completeness, accuracy, and good organization are desirable attributes in procedures developed for the design, construction, maintenance, and operation of engineered systems.

F.2.8 Initiating, Contributing, Compounding Events

These studies illustrate the failure development process as organized into three categories of events or stages: *1) initiating, 2) contributing, and 3) propagating*. The dominant initiating events were developed by operators (e.g. design engineers, construction, maintenance personnel) performing erroneous acts of commission; what is carried out has unanticipated and undesirable outcomes. The other initiating events are acts or developments involving omissions (something important left out, often intentional short-cuts and violations). Communications breakdowns (withheld, incomplete, untrue, not timely) were a dominant category of the initiating events. Various categories of violations (intentional, unintentional) were also very prevalent and were highly correlated with organizational and social cultures.

The dominant contributing events were organizational malfunctions (about 80%); these contributors acted directly to encourage or trigger the initiating events. Communication malfunctions, interface failures (organization to operations), culture malfunctions (excessive cost cutting, down-sizing, outsourcing, and production pressures), unrealistic planning and preparations, and violations (intentional departures from acceptable practices) were dominant categories of these organizational malfunctions.

The dominant propagating events also were found to be organizational malfunctions (about 80%); these propagators were responsible for allowing the initiating events to unfold into a failure or accident. With some important additions, the dominant types of malfunctions were the same as the contributing events. The important additions concerned inappropriate selection and training of operating personnel, failures in quality assurance and quality control (QA/QC), brittle structures and hardware (damage and defect intolerant), and ineffective planning and preparations.

F.2.9 High and Low Reliability Organizations: The NASA Columbia Accident Investigation

> ***The organizational causes of this accident are rooted in the Space Shuttle Program's history and culture, including the original compromises that were required to gain approval for the Shuttle Program, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterizations of the Shuttle as operational rather than developmental, and lack of an agreed national vision. Cultural traits and organizational practices detrimental to safety and reliability were allowed to develop, including: reliance on past success as a substitute for sound engineering practices (such as testing to understand why systems were not performing in accordance with requirements/specifications); organizational barriers which prevented effective communication of critical safety information and stifled professional differences of opinion; lack of integrated management across program elements; and the evolution of an informal chain of command and decision-making processes that operated outside the organization's rules.***
>
> **Columbia Accident Investigation Board (2003)**

The findings documented in the Columbia Accident Investigation Board (CAIB) Report (2003) have particular relevance to development of insights about how technology can have *unintended consequences* or *revenge effects* when an organizational - institutional culture of low reliability is allowed to develop. After introducing the concepts of High and Low Reliability Organizations, findings of the CAIB regarding the organizational - institutional issues will be summarized .

F.2.10 High Reliability Organizations

Studies of HRO (High Reliability Organizations) has shed some light on the factors that contribute to errors made by organizations and risk mitigation in HRO. HRO are those organizations that have operated relatively error free over long periods of time making consistently good decisions resulting in high quality and reliability operations. A variety of HRO ranging from the U. S. Navy nuclear aircraft carriers to the Federal Aviation Administration Air Traffic Control System have been studied.

The HRO research has been directed to define what these organizations do to reduce the probabilities of serious errors (Roberts, 1989). Reduction in error occurrence is accomplished by the following:

- Command by exception or negation,
- Redundancy,
- Procedures and rules,
- Training,
- Appropriate rewards and punishment
- Ability of management to “see the big picture”.

Command by exception (management by exception) refers to management activity in which authority is pushed to the lower levels of the organization by managers who constantly monitor the behavior of their subordinates. Decision making responsibility is allowed to migrate to the persons with the most expertise to make the decision when unfamiliar situations arise (employee empowerment).

Redundancy involves people, procedures, and hardware. It involves numerous individuals who serve as redundant decision makers. There are multiple hardware components that will permit the system to function when one of the components fails.

Procedures that are correct, accurate, complete, well organized, well documented, and are not excessively complex are an important part of HRO. Adherence to the rules is emphasized as a way to prevent errors, unless the rules themselves contribute to error.

HRO develop constant and high quality programs of training. Training in the conduct of normal and abnormal activities is mandatory to avoid errors. Establishment of appropriate rewards and punishment that are consistent with the organizational goals is critical.

Lastly, Roberts defines an HRO organizational structure as one that allows key decision makers to understand the big picture. These decision makers with the big picture perceive the important developing situations, properly integrate them, and then develop high reliability responses.

In recent organizational research reported by Roberts and Libuser (1993), they analyzed five prominent failures including the Chernobyl nuclear power plant, the grounding of the Exxon Valdez, the Bhopal chemical plant gas leak, the mis-grinding of the Hubble Telescope mirror, and the explosion of the space shuttle Challenger. These failures were evaluated in the context of five hypotheses that defined “risk mitigating” organizations. The failures provided support for the following five hypotheses.

- Risk mitigating organizations will have extensive process auditing procedures. Process auditing is an established system for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills would be included in this category as would be equipment testing. Follow ups on problems revealed in prior audits are a critical part of this function.
- Risk mitigating organizations will have reward systems that encourage risk mitigating behavior on the part of the organization, its members, and constituents. The reward system

is the payoff that an individual or organization gets for behaving one way or another. It is concerned with reducing risky behavior.

- Risk mitigating organizations will have quality standards that meet or exceed the referent standard of quality in the industry.
- Risk mitigating organizations will correctly assess the risk associated with the given problem or situation. Two elements of risk perception are involved. One is whether or not there was any knowledge that risk existed at all. The second is if there was knowledge that risk existed, the extent to which it was acknowledged appropriately or minimized.
- Risk mitigating organizations will have a strong command and control system consisting of five elements: a) migrating decision making, b) redundancy, c) rules and procedures, d) training, and e) senior management has the big picture.

Weick, Sutcliffe, and Obstfeld (1998) have extended these concepts to characterize *how* organizations can organize for high reliability. Their extensive review of the literature and studies of HRO indicate that organizing in effective HRO's is characterized by:

- Preoccupation with failure – any and all failures are regarded as insights on the health of a system, thorough analyses of near-failures, generalize (not localize) failures, encourage self-reporting of errors, and understand the liabilities of successes.
- Reluctance to simplify interpretations – regard simplifications as potentially dangerous because they limit both the precautions people take and the number of undesired consequences they envision, respect what they do not know, match external complexities with internal complexities (requisite variety), diverse checks and balances, encourage a divergence in analytical perspectives among members of an organization (it is the divergence, not the commonalties, that hold the key to detecting anomalies).
- Sensitivity to operations – construct and maintain a cognitive map that allows them to integrate diverse inputs into a single picture of the overall situation and status (situational awareness, 'having the bubble'), people act thinkingly and with heed, redundancy involving cross checks, doubts that precautions are sufficient, and wariness about claimed levels of competence, exhibit extraordinary sensitivity to the incipient overloading of any one of it members, sensemaking.
- Commitment to resilience – capacity to cope with unanticipated dangers after they have become manifest, continuous management of fluctuations, prepare for inevitable surprises by expanding the general knowledge, technical facility, and command over resources, formal support for improvisation (capability to recombine actions in repertoire into novel successful combinations), and simultaneously believe and doubt their past experience.
- Under-specification of structures – avoid the adoption of orderly procedures to reduce error that often spreads them around, avoid higher level errors that tend to pick up and combine with lower level errors that make them harder to comprehend and more interactively complex, gain flexibility by enacting moments of organized anarchy, loosen specification of who is the important decision maker in order to allow decision making to migrate along with problems (migrating decision making), move in the direction of a garbage can structure in which problems, solutions, decision makers, and choice opportunities are independent streams flowing through a system that become linked by

their arrival and departure times and by any structural constraints that affect which problems, solutions and decision makers have access to which opportunities.

F.2.11 Low Reliability Organizations

Weick, Sutcliffe, and Obstfeld (1998) observe that low reliability organizations (LROs) are characterized by a focus on success rather than failure, and efficiency rather than reliability. In these organizations the cognitive infrastructure is underdeveloped, failures are localized rather than generalized, and highly specified structures and processes are put in place that develop inertial blind spots that allow failures to cumulate and produce catastrophic outcomes. Efficient organizations practice stable activity patterns and when they encounter unusual cognitive processes these often result in errors. They do the same things in the face of changing events, these changes go undetected because people are rushed, distracted, careless, or ignorant.

LROs are characterized by expensive and inefficient learning. Diversity in problem solving is not welcomed. Information, particularly 'bad' or 'useless' information is not actively sought, failures are not taken as learning lessons, and new ideas are rejected; lethal arrogance. Communications are regarded as wasteful and hence the sharing of information and interpretations between individuals is stymied. Divergent views are discouraged, so that there is a narrow set of assumptions that sensitize it to a narrow variety of inputs.

Success breeds confidence and fantasy, managers attribute success to themselves, rather than to luck, and they trust procedures to keep them appraised of developing problems. Under the assumption that success demonstrates competence, LROs drift into complacency, inattention, and habituated routines which they often justify with the argument that they are eliminating unnecessary effort and redundancy. Down-sizing and out-sourcing are used to further the drives of efficiency. Insensitivity is developed to overloading and its effects on judgement and performance. Redundancy (robustness) is eliminated or reduced in the same drive resulting in elimination of cross checks, assumption that precautions and existing levels of training and experience are sufficient, and dependence on claimed levels of competence. With outsourcing, it is now the supplier, not the buyer, that must become preoccupied with failure. But, the supplier is preoccupied with success, not failure, and because of low-bid contracting, often is concerned with the lowest possible cost success. The buyer now becomes more mindless and if novel forms of failure are possible, the loss of a preoccupation with failure makes the buyer more vulnerable to failure. LROs tend to lean toward anticipation of expected surprises, risk aversion, and planned defenses against foreseeable accidents and risks; unforeseeable accidents and risks are not recognized or believed.

F.2.12 Columbia Accident Investigation Board Findings

The following quotations from the Columbia Accident Investigation Board (CAIB) Report provide important insights into how NASA in the span of three decades developed into a LRO.

> ***Accident Theories****: To develop a thorough understanding of accident causes and risk, and to better interpret the chain of events that led to the Columbia accident, the Board turned to the contemporary social science literature on accidents and risk and sought insight from experts in High*

Reliability, Normal Accident and Organizational Theory. High Reliability Theory argues that organizations operating high-risk technologies, if properly designed and managed, can compensate for inevitable human shortcomings, and therefore avoid mistakes that under other circumstances would head to catastrophic failures. Normal Accident Theory, on the other hand, has a more pessimistic view of the ability of organizations and their members to manage high-risk technology. Normal Accident Theory holds that organizational and technological complexity contributes to failures. Organizations that aspire to failure-free performance are inevitably doomed to fail because of the inherent risks in the technology they operate. Normal Accident models also emphasize systems approaches and systems thinking, while the High Reliability model works from the bottom up: if each component is highly reliable, then the system will be highly reliable and safe.

Though neither High Reliability Theory nor Normal Accident Theory is entire appropriate for understanding this accident, insights from each figured prominently in the Board's deliberation. Fundamental to each theory is the importance of strong organizational culture and commitment to building successful safety strategies.

***What Went Wrong**: The Board believes the following considerations are critical to understand what went wrong during STS-107.*

1) *Commitment to a Safety Culture: NASA's safety culture has become reactive, complacent, and dominated by unjustified optimism. Over time, slowly and unintentionally, independent checks and balances intended to increase safety have been eroded in favor of detailed processes that produce massive amounts of data and unwarranted consensus, but little effective communication. Organizations that successfully deal with high-risk technologies create and sustain a disciplined safety system capable of identifying, analyzing, and controlling hazards throughout a technology's life cycle.*

2) *Ability to Operate in Both a centralized and Decentralized Manner: The ability to operate in a centralized manner when appropriate, and to operate in a decentralized manner when appropriate, is the hallmark of a high-reliability organization.*

3) *Importance of Communication: At every juncture of STS-107, the Shuttle Program's structure and processes, and therefore the managers in charge, resisted new information.*

4) *Avoiding Oversimplification: The Columbia accident is an unfortunate illustration of how NASA's strong cultural bias and its optimistic organizational thinking undermined effective decision-making.*

5) *Conditioned by Success: Even when it was clear from the launch videos that foam had struck the Orbiter in a manner never before seen, the Space Shuttle Program managers were not unduly alarmed. They could not imagine why anyone would want a photo of something that could be fixed after landing. More importantly, learned attitudes about foam strikes diminished*

management's wariness of their danger. The Shuttle Program turned the experience of failure into the memory of success.

6) *Significance of Redundancy: The Human Space Flight Program has compromised the many redundant processes, checks, and balances that should identify and correct small errors. Redundant systems essential to every high-risk enterprise have fallen victim to bureaucratic efficiency. Years of workforce reductions and outsourcing have culled from NASA's workforce the layers of experience and hands-on systems knowledge that once provided a capacity for safety oversight. Safety and Mission Assurance personnel have been eliminated, careers in safety have lost organizational prestige, and the Program now decides on its own how much safety and engineering oversight it needs.*

Organizational Development: *The Board's investigation into the Columbia accident revealed two major causes with which NASA has to contend: one technical, the other organizational. The Board studied the two dominant theories on complex organizations and accidents involving high-risk technologies. These schools of thought were influential in shaping the Board's organizational recommendations, primarily because each takes a different approach to understanding accidents and risk.*

The Board determined that high-reliability theory is extremely useful in describing the culture that should exist in the human space flight organization. NASA and the Space Shuttle Program must be committed to a strong safety culture, a view that serious accidents can be prevented, a willingness to learn from mistakes, from technology and from others, and a realistic training program that empowers employees to know when to decentralize or centralize problem-solving.

The Board believes normal accident theory has a key role in human space flight as well. Complex organizations need specific mechanisms to maintain their commitment to safety and assist their understanding of how complex interactions can make organizations accident-prone. Organizations can not put blind faith into redundant warning systems because they inherently create more complexity, and this complexity in turn often produces unintended system interactions that can lead to failure.

The Shuttle Program's complex structure erected barriers to effective communication and its safety culture no longer asks enough hard questions about risk. Safety culture refers to an organization's characteristics and attitudes - promoted by its leaders and internalized by its members - that serve to make safety the top priority.

By their very nature, high-risk technologies are exceptionally difficult to manage. Complex and intricate, they consist of numerous interrelated parts. Standing alone, components may function adequately, and failure modes may be anticipated. Yet when components are integrated into a total system and work in concert, unanticipated interactions can occur that can lead to catastrophic outcomes. the risks inherent in these technical systems are *heightened when they are produced and operated by complex organizations that can also break down in unanticipated ways.*

Despite periodic attempts to emphasize safety, NASA's frequent reorganizations in the drive to become more efficient reduced the budget for safety, sending employees conflicting messages and creating conditions more conducive to the development of a conventional bureaucracy than to the maintenance of a safety-conscious research-and-development organization. Over time, a pattern of ineffective communication has resulted, leaving risks improperly defined, problems unreported, and concerns unexpressed. The question, is why?

The Shuttle Independent Assessment Team's report documented these changes, noting that the size and complexity of the Shuttle system and of the NASA / contractor relationships place extreme importance on understanding, communication, and information handling. among other findings, the Shuttle Independent Assessment Team observed that: The current Shuttle program culture is too insular. There is a potential for conflicts between contractual and programmatic goals; There are deficiencies in problem and waiver-tracking systems; the exchange of communication across the shuttle program hierarchy is structurally limited, both upward and downward.

The Board believes that deficiencies in communication, including those spelled out by the shuttle Independent Assessment Team, were a foundation for the Columbia accident. These deficiencies are byproducts of a cumbersome, bureaucratic, and highly complex Shuttle Program structure and the absence of authority in two key program areas that are responsible for integrating information across all programs and elements in the Shuttle Program.

Principles of Organizational Change: *The Board consistently searched for causal principles that would explain both the technical and organizational system failures. The Board's analysis of organizational causes supports the following principles that should govern the changes in the agency's organizational system.*

Leaders create culture. It is their responsibility to change it. Top administrators must take responsibility for risk, failure, and safety by remaining alert to the effects their decisions have on the system. Leaders are responsible for establishing the conditions that lead to their subordinates' successes or failures. The past decisions of national leaders - the White House, Congress, and NASA Headquarters - set the Columbia accident in motion by creating resource and schedule strains that compromised the principles of a high-risk technology organization. The measure of NASA's success became how much costs were reduced and how efficiently the schedule was met."

Changes in organizational structure should be made only with careful consideration of their effect on the system and their possible unintended consequences. Changes that make the organization more complex may create new ways that it can fail. When changes are put in place, the risk of error initially increases, as old ways of doing things compete with new. Institutional

> *memory is lost as personnel and records are moved and replaced. Changing the structure of organizations is complicated by external political and budgetary constraints, the inability of leaders to conceive of the full ramifications of their actions, the vested interests of insiders, and the failure to learn from the past."*
>
> *Strategies must increase the clarity, strength, and presence of signals that challenge assumptions about risk. Twice in NASA history, the agency embarked on a slippery slope that resulted in catastrophe. Each decision, taken by itself, seemed correct, routine, and indeed, insignificant and unremarkable. Yet in retrospect, the cumulative effect was stunning. In both pre-accident (Challenger, Columbia) periods, events unfolded over a long time and in small increments rather than in sudden and dramatic occurrences. NASA's challenge is to design systems that maximize the clarity of signals, amplify weak signals so they can be tracked, and account for missing signals. A safety team must have equal and independent representation so that managers are not again lulled into complacency by shifting definitions of risk. It is obvious but worth acknowledging that people who are marginal and powerless in organizations may have useful information or opinions that they don't express. Even when these people are encouraged to speak, the find it intimidating to contradict a leader's strategy or a group consensus. Extra effort must be made to contribute all relevant information to discussion of risk. Because ill-structured problems are less visible and therefore invite the normalization of deviance, they may be the most risky of all.*

F.2.13 Summary

The history of major accidents involving engineered systems clearly shows that the vast majority of these accidents have their roots firmly embedded in human and organizational malfunctions or breakdowns. While the majority of these accidents develop during the operations and maintenance phases, the studies also clearly show that the majority of the flaws in the system are developed during the concept development and design phases.

A key signature of major accidents is that they generally develop over long periods of time, involve large numbers of people and different organizations, and involve a multitude of breakdowns or malfunctions; there is no such thing as a 'root cause' to explain these accidents. These major accidents are focused in organizational - institutional breakdowns; malfunctions of the Technology Delivery System that is used to develop, operate, and maintain the engineered systems. What is frequently indicated as an 'engineering failure' (or 'pilot error') is in fact a failure of the Technology Delivery System.

Breakdowns in Technology Delivery Systems are most often present in Low Reliability Organizations (LROs) and interfaces between such organizations. LROs are characterized by a focus on success rather than failure, and efficiency rather than reliability. The cognitive infrastructure is underdeveloped, failures are localized rather than generalized, and highly specified structures and processes are put in place that develop inertial blind spots that allow failures to cumulate and produce catastrophic outcomes. They do the same things in the face of changing events, these changes go undetected because people are rushed, distracted, careless, or ignorant. LROs are characterized by expensive and inefficient learning.

Diversity in problem solving is not welcomed. Information, particularly 'bad' or 'useless' information is not actively sought, failures are not taken as learning lessons, and new ideas are rejected; lethal arrogance. Divergent views are discouraged, so that there is a narrow set of assumptions that sensitize the LRO to a narrow variety of inputs. Under the assumption that success demonstrates competence, LROs drift into complacency, inattention, and habituated routines. Down-sizing and out-sourcing are used to further the drives of efficiency. Insensitivity is developed to overloading and its effects on judgement and performance. Robustness (damage and defect tolerance) is eliminated or reduced in the same drive resulting in elimination of cross checks, assumption that precautions and existing levels of training and experience are sufficient, and dependence on claimed levels of competence. With outsourcing, it is now the supplier, not the buyer, that must become preoccupied with failure. But, the supplier is preoccupied with success, not failure, and because of low-bid contracting, often is concerned with the lowest possible cost success. The buyer now becomes more mindless and if novel forms of failure are possible, the loss of a preoccupation with failure makes the buyer more vulnerable to failure. LROs tend to lean toward anticipation of expected surprises, risk aversion, and planned defenses against foreseeable accidents and risks; unforeseeable accidents and risks are not recognized or believed.

F.3 Quotations from Key Reports and Papers

F.3.1 Townsend, F. F. (2006). *The Federal Response to Hurricane Katrina, Lessons Learned*, Report to the President of the United States, The White House, Washington, DC, February.

Katrina creates an opportunity - indeed an imperative - for a national dialogue about true national preparedness, especially as it pertains to catastrophic events. We are not as prepared as we need to be at all levels within the country: Federal State, local, and individual. Hurricane Katrina obligates us to re-examine how we are organized and resourced to address the full range of catastrophic events - both natural and man-made. The storm and its aftermath provide us with the mandate to design and build such a system.

The magnitude of Hurricane Katrina does not excuse our inadequate preparedness and response, but rather it must serve as a catalyst for far-reaching reform and transformation. To do this, we must understand Hurricane Katrina in its proper context.

The storm surge, extreme amounts of rain, and high winds stressed the city's complex 350 mile levee system to its breaking point. Several of the levees and flood walls were overtopped, and some were breached through the day of landfall. It was this overtopping and breaches of the levee system that lead to the catastrophic flooding of New Orleans. In addition to the levee and floodwall breaches, many of the pumping stations - which would have otherwise removed water from the city and prevented some of the flooding - stopped working due to power outages and flooded pumping equipment.

Some overtopping of the levees was expected due to the intensity of the storm, which would result in localized flooding. However, such overtopping would not have lead to the catastrophic events that occurred due to the levee and flood wall breaches. Further, the New

Orleans Flood and Hurricane Protection System is designed so that individual breaches will not lead to catastrophic flooding. The compartmented design, with four main basins, is intended to minimize the threat of flood to the entire system. Thus, had only one basin experienced serious overtopping or a breach, it would have been possible to avoid the catastrophic flooding New Orleans experienced.

New Orleans flooded as the levees and flood walls gave way and the pumping stations stopped operating; at its height, approximately 80 percent of New Orleans was filled with water up to twenty feet deep. This unprecedented flooding transformed Hurricane Katrina into a "Catastrophe within a catastrophe" as the storm shattered the lives of countless residents and presented State and local officials with challenges far exceeding their capabilities.

We must expect more catastrophes like Hurricane Katrina - and possibly even worse. In fact, we will have compounded the tragedy if we fail to learn the lessons - good and bad - it has taught us and strengthen our system of preparedness and response. We cannot undo the mistakes of the past, but there is much we can do to learn from them and to be better prepared for the future. This is our duty.

F.3.2 Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina, 2006. *A Failure of Initiative*, U.S. Government Printing Office, Washington, DC.

The preparation for and response to Hurricane Katrina show we are still an analog government in a digital age. We must recognize that we are woefully incapable of storing, moving, and accessing information - especially in times of crisis. Many of the problems we have identified can be categorized as 'information gaps' - or at least problems with information-related implications, or failures to act decisively because information was sketchy at best. Better information would have been an optimal weapon against Katrina. Information sent to the right people at the right place at the right time.

We reflect on the 9/11 Commission's finding that 'the most important failure was one of imagination.' the Select Committee believes Katrina was primarily a failure of initiative. But there is, of course, a nexus between the two. Both imagination and initiative - in other words, *leadership* - require good information. And a coordinated process for sharing it. And a willingness to use information - however imperfect or incomplete - to fuel action.

The levees protecting New Orleans were not built to survive the most severe hurricanes. It was a well-known and repeatedly documented fact that a severe hurricane could lead to overtopping or breaching of the levees and flooding of the metropolitan area. In fact, for years the U.S. Army Corps of Engineers (USACE) has had a written plan for dewatering (i.e. draining) New Orleans in such a contingency.

Once construction of the levees was completed by USACE, the responsibilities for operating and maintaining the levees were split among many local organizations, which is the standard cooperation agreement for carrying out flood control projects nationwide. The costs of constructing these projects are shared, with operation and maintenance being a 100 percent local responsibility. These include levee boards in each parish, as well as separate water and sewer boards. The number of organizations involved, and disagreements among them, makes accountably diffuse and creates potential gaps and weaknesses in parts of the flood protection system. In one case, improvements to levee strength which may have mitigated or prevented some of the critical breaches that flooded downtown New Orleans were rejected by the competing local organizations. There also appear to have been lapses in both maintenance and inspections of selected levees, including those that breached. Also, prior to Hurricane Katrina, residents along these same levees reported they were leaking, another potential lapse in maintenance.

Despite the well-known importance of the levees, and the consequences of failure, the local levee boards responsible for maintaining and operating the levees did not have any warning system in place. While federal regulations require that they monitor levees during periods of potential flooding, the requirement is impractical to implement during a hurricane. In addition to no warning system, the loss of communications and situational awareness, and only sporadic reports of flooding from a variety of sources, made it difficult to confirm that there were breaches in the levees and then to assess the damage. These factors, as well as physical difficulties of getting to the breach sites, combined to delay repair of the levee breaches.

A lot of hurricanes threaten the Gulf coast every year, and New Orleans is particularly vulnerable because of its location and topography. The majority of the metropolitan area is below sea level. Over the years, the city has continued to sink, due to drainage, subsidence, and compaction of the soils. As an example of previous damage, Hurricane Betsy brought extensive destruction to New Orleans when it made landfall in Louisiana in September 1965. Unfortunately, many of the descriptions and photos from Hurricane Betsy sound and look familiar to our nation as it considers the damage from Hurricane Katrina, forty years later.

After Hurricane Betsy in 1965, federal and state governments proposed a number of flood control projects to deal with the threat of hurricanes and the flooding they might cause in New Orleans. These included a series of control structures, concrete floodwalls, and levees along Lake Ponchartrain and several other waterways. One of the major projects is formally called the Lake Ponchartrain and Vicinity, Louisiana Hurricane Protection Project. This project included levees along the Lake Ponchartrain lakefront, the 17th Street Canal, the London Avenue Canal, the Orleans Avenue Canal, the Intercoastal waterway, the Industrial Canal, The Mississippi River Gulf Outlet, and other areas. Although the project was federally authorized, it was a joint federal, state, and local effort with shared costs.

“The levees protecting New Orleans were not designed to withstand the most severe hurricanes. According to USACE’s plans for dewatering New Orleans, ‘the hurricane protection system is not designed for the largest storms and as a result, the metropolitan area is vulnerable to flooding from hurricane storm surges.’ USACE originally designed the levees around New Orleans to protect against a hurricane intensity that might occur once every 200-300 years.

According to USACE, the ‘standard project hurricane’ was used to design the New Orleans levees and is roughly equivalent to a fast moving, or moderate category 3 hurricane. However, there is no direct comparison of the standard project hurricane to a specific category on the Saffir-Simpson Hurricane Scale - which did not exist when the levees were designed. As shown in the table below, the standard project hurricane is equivalent to a hurricane with category 2 winds, category 3 storm surge, and category 4 barometric pressure.

In addition, there is no ‘standard’ hurricane - the actual forces that levees need to withstand are a function of several factors. According to the preliminary NSF study, ‘the actual wind, wave, and storm surge loadings imposed at any location within the overall flood protection system are a function of location relative to the storm, wind speed and direction, orientation of levees, local bodies of water, channel configurations, offshore contours, vegetative cover, etc.. They also vary over time as the storm moves through the region.' Similarly, USACE documents indicate that overtopping will depend upon the intensity of the storm, the track that the center or eye of the storm follows and the speed at which it travels along the track.

Although the Lake Ponchartrain project is named a hurricane protection project, a number of factors other than saving lives and property are included in the design of such projects. For example, in addition to protection urban and community lives and health, the design of such projects must include environmental and economic effects, and ensure that benefits of the completed project outweigh its cost of construction. In discussing the design of the Lake Ponchartrain project in a 1978 hearing, USACE District Commander for New Orleans, Colonel Early Rush, stated 'Even Though economists may, and in this case did, favor protection to a lower scale to produce a higher ratio of benefits to costs, the threat of loss of human life mandated using the standard project hurricane.

Even with its hurricane protection system, it was common knowledge that New Orleans was susceptible to hurricane-caused flooding. The risks of a major hurricane and flooding in New Orleans had been covered in the general media - by Scientific American (October 2001) and National Geographic (October 2004) - as well as in emergency management literature. A recent article in the Natural Hazards Observer stated: 'When Hurricane Katrina came ashore on August 29, she ended decades of anticipation. There were few hazards in the United States more studied by scientists and engineers and there was ample warning that a strong storm could cause the City of New Orleans to flood.

Because of the well-known potential for flooding, USACE has had a plan for several years for draining New Orleans - *Dewater Plan, Greater Metropolitan Area, New Orleans, Louisiana*, dated August 18, 2000. This plan provides details on the hurricane protection system and describes methods to get the water out after catastrophic flooding from a hurricane. The premise of the plan is that a category 4 or 5 hurricane may produce storm surge water levels of sufficient height to overtop the existing protection system. The plan lays out a series of scenarios that could occur and suggests appropriate emergency responses to dewater the area. For example, in one case…'There is catastrophic flooding due to complete overtopping of the levees and floodwalls and inundation of the protected area. There will be extensive and severe erosion of levees and perhaps complete breaches. Due to the high water levels, all of the pumping stations will probably be flooded with major damages….The levee districts and drainage departments may be dysfunctional to some degree.

In more recent years, well before Hurricane Katrina, questions were raised about the ability of the Lake Ponchartrain project to withstand more powerful hurricanes than the 'standard project hurricane,' such as a category 4 or 5 hurricane. USACE had discussed undertaking a study of modifications needed to increase the strength of the exiting levees, but no formal study was undertaken.

Several organizations are responsible for building, operating, and maintaining the levees surrounding metropolitan New Orleans. USACE generally contracts to design and build the levees. After construction USACE turns the levees over to a local sponsor. USACE regulations state that once a local sponsor has accepted a project, USACE may no longer expend federal funds on construction or improvements. this prohibition does not include repair after a flood. Federally authorized flood control projects, such as the Lake Ponchartrain project, are eligible for 100 percent federal rehabilitation of damaged by a flood.

The local sponsor has a number of responsibilities. In accepting responsibilities for operations, maintenance, repair, and rehabilitation, the local sponsor signs a contract (called Cooperation Agreement) agreeing to meet specific standards of performance. This agreement makes the local sponsor responsible for liability for that levee. For most of the levees surrounding New Orleans, the Louisiana Department of Transportation and Development was the sate entity that originally sponsored the construction. After construction, the state turned over control to local sponsors. These local sponsors accepted completed units of the project from 1977 to 1987, depending on when the specific units were completed. The local sponsors are responsible for operation, maintenance, repair, and rehabilitation of the levees when the construction of the project, or a project unit, is complete.

The local sponsors include a variety of separate local organizations. For example, different parts of the Lake Ponchartrain and Vicinity Louisiana Hurricane Protection Project, were turned over to four different local sponsors - to include the Orleans, East Jefferson, Lake Borgne, and Ponchartrain levee districts. In addition ,there are separate water and sever districts that are responsible for maintaining pumping stations.

The different local organizations involved had the effect of diffusing responsibility and creating potential weaknesses. For example, levee breaches and distress were repeatedly noted at transition sections, where different organizations were responsible for different pieces and thus two different levee or wall systems joined together. According to USACE, ‘at sections where infrastructure elements were designed and maintained by multiple authorities, and their multiple protection elements came together, the weakest (or lowest) segment or element controlled the overall performance.

Both USACE and the local sponsors have ongoing responsibility to inspect the levees. Annual inspections are done both independently by USACE and jointly with the local sponsor. In addition, federal regulations require local sponsors to ensure that flood control structures are operating as intended and to continuously patrol the structure to ensure no conditions exist that might endanger it.

Records reflect that both USACE and the local sponsors kept up with their responsibilities to inspect the levees. According to USACE, in June 2005, it conducted an inspection of the levee system jointly with the state and local sponsors. In addition, GAO reviewed USACE’s inspection reports from 2001 to 2004 for all completed project units of the Lake Ponchartrain project. These reports indicated the levees were inspected each year and had received ‘acceptable’ ratings.

However, both the NSF-funded investigators and USACE officials cited instances where brush and even trees were growing along the 17th Street and London Avenue canals levees, which is not allowed under the established standards for levee protection. Thus, although the records reflect that inspections were conducted and the levees received acceptable ratings, the records appear to be incomplete or inaccurate. In other words, they failed to reflect the tree growth, and of course, neither USACE nor the local sponsor had taken corrective actions to remove the trees.

In addition, there was apparently seepage from one canal before Hurricane Katrina, indicating problems had developed in the levee after construction. Specifically, residents of New Orleans who live along the 17th Street Canal said water was leaking from the canal and seeping into their yards months before Hurricane Katrina caused the levee system to collapse. The leaks, they said, occurred within several hundred feet of the levee that later failed.

Because the eye of Katrina passed just slightly to the east of New Orleans, the hurricane threw unusually severe wind loads and storm surges on the flood protection systems. The surge overtopped large sections of the levees during the morning of August 29 east of New Orleans, in Orleans and St. Bernard Parish, and it also pushed water up the Intercoastal waterway and into the Industrial Canal. The water rise in Lake Ponchartrain strained the floodwalls along the canals adjacent to its southern shore, including the 17th Street Canal and the London Avenue Canal. Breaches along all of these canals led to flooding of 80 percent of New Orleans to depths up to 20 feet. The flooding of central New Orleans led to the most widespread and costly damage of the hurricane. It also lead to the difficulties encountered by emergency responders that are documented elsewhere in this report.

Despite the well-known importance of the levees, and the consequences of failure, the local levee boards responsible for maintaining and operating the levees do not have any warning system in place. Federal regulations require local sponsors to ensure that flood control structures are operating as intended and to continuously patrol the structure during flood periods to ensure that no conditions exist that might endanger it. However, it would be impractical to monitor the levees during a hurricane.

There were also physical barriers that made assessments and repair difficult. Specifically, emergency repair operations to close some of the breaches were seriously hampered by lack of access roads. USACE regulations generally require access roads on top of levees to allow for inspections, maintenance, and flood-fighting operations, and most USACE levees built in the United States meet this requirement. However, in New Orleans, exceptions were made to these regulations because of its highly urban nature. Access roads were foregone when it was decided to use I-walls in the levee crowns to minimize right-of-ways into surrounding neighborhoods. When Hurricane Katrina led to the breaches in the levees, the lack of access roads atop the levees resulted in very significant increases in time and cost to repair the damaged areas.

Hundreds of miles of levees were constructed to defend metropolitan New Orleans against storm events. These levees were not designed to protect New Orleans from a category 4 or 5 monster hurricane, and all of the key players knew this. The original specifications of the levees offered protection that was limited to withstanding the forces of a moderate hurricane. Once constructed, the levees were turned over to local control, leaving the USACE to make detailed plans to drain New Orleans should it be flooded.

The Local sponsors - a patchwork quilt of levee and water and sewer boards - were responsible only for their own piece of levee. It seems no federal, state, or local entity watched over the integrity of the whole system, which might have mitigated to some degree the effects of the hurricane. When Hurricane Katrina came, some of the levees breached - as many had predicted they would - and most of New Orleans flooded to create untold misery.

The forces that destroyed the levees also destroyed the ability to quickly access damage and make repairs. The reasons for the levee failures appear to be some combination of nature's wrath (the storm was just too large) and man's folly (an assumption that the design, construction, and maintenance of the levees would be flawless). While there was not failure to predict the inevitability and consequences of a monster hurricane - Katrina in this case - there was a *failure of initiative* to get beyond design and organizational compromises to improve the level of protection afforded.

F.3.3 Report of the Committee on Homeland Security and Governmental Affairs. *Hurricane Katrina, A Nation Still Unprepared*, United States Senate, Washington, DC, May 2006.

The Contribution of the Mississippi River Gulf Outlet to Damage from Hurricane Katrina

Congress authorized construction of the Mississippi River Gulf Outlet (MRGO) in 1956 to facilitate commercial shipping access to the Port of New Orleans from the Gulf of Mexico. Upon its completion in 1965, the MRGO provided a route 40 miles shorter than the alternative up the Mississippi River. The MRGO also provides a connection from the Gulf of Mexico to the Gulf Intracoastal Waterway (GIWW), which is a recreational and commercial waterway running east-west from Texas to Florida. Though the MRGO produced commercial benefits, those benefits came at a cost to the environment. The Corps estimates that the construction of the channel led to substantial loss of wetlands, which, as noted above, help slow and decrease the power of storms before they hit populated areas.

The MRGO also contributed to a potential "funnel" for storm surges emerging from Lake Borgne and the Gulf into the New Orleans area. The "funnel" was created by the intersection of the MRGO from the southeast and the GIWW from the northwest into the confined channel, referred to as the GIWW/MRGO that separates New Orleans East and the Ninth Ward/St. Bernard Parish. The levees on the south side of the MRGO and the levees on the north side of the GIWW converge from being about 10 miles apart where they straddle Lake Borgne to a few hundred yards apart where the MRGO merges into the GIWW. The western part of the "funnel" is a 6 mile-long section of the combined GIWW/MRGO which was enlarged by a factor of three when the MRGO was built in order to expand from a barge channel to accommodate oceangoing vessels.

Prior to Hurricane Katrina, many warned that the potential funnel would accelerate and intensify storm surges emerging from Lake Borgne and the Gulf into the downtown New Orleans area. The funnel had been described as a "superhighway" for storm surges or the "Crescent City's Trojan Horse" that had the potential to "amplify storm surges by 20 to 40 percent," according to some storm modeling. Researchers at LSU believed that in creating this funnel, "the US Army Corps of Engineers had inadvertently designed an excellent storm surge delivery system - nothing less - to bring this mass of water with simply tremendous 'load' - potential energy - right into the middle of New Orleans.

The extent to which MRGO, and the funnel it helped create actually contributed to the hurricane's damage is still being investigated, but there have been some preliminary findings. A recent report issued by the Corps' IPET concluded that the portion of MRGO running from the GIWW to the Gulf (called "Reach 2") did not significantly impact the height of Katrina's storm surge, not because the "funnel" effect was nonexistent, but because the storm was so great it nullified the impact of either the wetlands or the 35 intersection of the MRGO and the GIWW - the funnel - at the height of the surge.

The building of MRGO and the combined GIWW/MRGO resulted in substantial environmental damage, including a significant loss of wetlands that had once formed a natural barrier against hurricanes threatening New Orleans from the east. MRGO and the GIWW/MRGO provided a connection between Lake Borgne and Lake Pontchartrain that allowed the much greater surge from Lake Borgne to flow into both New Orleans and Lake Pontchartrain. These channels further increased the speed and flow of the Katrina surge into New Orleans East and the Ninth Ward/St. Bernard Parish, increasing the destructive force against adjacent levees and contributing to their failure. As a result, MRGO and the combined GIWW/MRGO resulted in increased flooding and greater damage from hurricane Katrina.

The Roles and Responsibilities of the U.S. Army Corps of Engineers, the Louisiana Department of Transportation and Development and the Orleans Levee District:

The U.S. Army Corps of Engineers

Levee systems of the size needed to protect the New Orleans area are often collaborative efforts between federal and local governments. The federal role in such projects is carried out by the Corps, an agency within the Department of Defense (DOD) charged with both military and civilian missions. Military missions are assigned within the military command structure, while civilian flood control projects are authorized by Congress in legislation.

Flood-control projects usually begin when a community feels a need for protection and contacts the Corps. If the Corps does not already have the statutory authority to respond, then Congress may grant it. After initial studies, the Corps may enter into a project cooperation or assurance agreement with a local sponsor acting on behalf of the community. The assurance agreements for projects generally set forth roles of the parties, including payment obligations, design and construction responsibilities, and operations and maintenance (O&M) duties before and after the project is complete.

The levee system that protects most of New Orleans, including areas that experienced major breaches and flooding during Katrina - such as the 17th Street and London Avenue Canals, New Orleans East, and most of St. Bernard Parish - is a Corps project called the Lake Pontchartrain and Vicinity Hurricane Protection Project (Lake Pontchartrain Project). There are several other federal cost-shared projects that protect other parts of southeastern Louisiana. The Corps' involvement in these projects was mostly through its New Orleans District, one of the Corps' largest with more than 1,200 employees and part of the Corps' Mississippi Valley Division headquartered in Vicksburg, Mississippi. When Katrina made landfall, the New Orleans District was under the command of Colonel Richard P. Wagenaar, who had assumed control only six weeks before.

The assurance agreements for the Lake Pontchartrain Project made the Corps responsible for designing and constructing the project. Local sponsors provided the land for levee construction and rights-of-way, and agreed to share the cost. The Corps was to turn the completed project over to the local sponsors for O&M consistent with the Corps' standards, i.e., making sure the flood-control system actually works on a day-to-day basis and protects those living inside the system. 10 To help the local sponsor do this, the Corps is required by its rules and regulations to provide the local sponsor with an operations manual" and then conduct annual inspections to be sure the local sponsor is doing what it is supposed to do.

In addition to its authority to build flood-control projects, the Corps also has statutory authority in federal cost-share flood-control projects like the Lake Pontchartrain Project to act in anticipation of, or response to, flood emergencies. In this role, the Corps may help the local sponsors deal with the flood threat to the levee system, and aid state and local governments trying to prevent flood damage. This "flood-fighting" authority is authorized by Public Law 84-99, also known as the "Flood Act." In the days following Katrina, the Corps used its Flood Act authority to close off the levee breaches at the 17th Street and London Avenue Canals, which were filling the city with water, and to make other emergency repairs.

The Orleans Levee District

One of the local sponsors for the Lake Pontchartrain Project was the Orleans Levee District, one of the first five levee districts created by the state in 1879. The levee districts, which were established to be a funding source for and to ensure local involvement in levee construction and operation, all had the same general duty: to do what was necessary to "insure the thorough and adequate protection of the lands of the district from damage by flood ... for the adequate drainage control of the district."

Like the Corps under the Flood Act, the levee districts have broad statutory obligations in addition to their obligations under their assurance agreements on individual levee projects. For example, regardless whether a project was being designed and constructed by the Corps or had been turned over for O&M to the local sponsor, state law charged the levee districts with adopting rules and regulations for maintaining a "comprehensive levee system." State law authorized them to obtain engineering assistance from the Louisiana Department of Transportation and Development (LA DOTD) in Baton Rouge if they needed additional technical expertise.' State law also required levee-district board members to attend once during their term in office an educational program on how to care for and inspect levees.

To carry out their primary duty of flood control, state law not only authorized the levee districts to serve as local sponsors for federal cost-share projects, but also to raise money pursuant to taxing and bonding authorities. In the unique case of the Orleans Levee District, it was also authorized to engage in various business enterprises, 20 making the Orleans Levee District a unique entity with some governmental qualities (taxing and bonding authority) and some corporate qualities: the authority to engage in for-profit businesses like operating the Lakefront Airport, running two marinas along Lake Pontchartrain, and leasing dock space to a riverboat casino.

The revenues the Orleans Levee District earned from the businesses and its taxing and bonding authority were substantial. The Orleans Levee District financial statements for the fiscal year ending June 30, 2005, show it collected more than $24 million from property taxes and $14 million from its business-type activities in the previous 12 months. The same report said the district had $21 million in unallocated general funds and $13 million in a "special levee improvement fund. The levee improvement fund, according to the levee district's former president, Jim Huey, could "only be used for flood protection projects and/or flood-related projects.

Although the levee district's primary responsibility was flood protection it spent large amounts on non-flood related activities (e.g., the licensing of a casino or the operation of an airport and. marinas or the leasing of space to a karate club, beautician schools or restaurants) rather than apply the money to flood protection or emergency preparedness. 25 For example, the Orleans Levee District's Emergency Operations Center (EOC) sat outside the protection of the levee system at the Lakefront Airport, vulnerable to the very hurricanes the levee system was designed to protect against. For years the district had, studied moving its EOC inside the flood protection system, but never did. The levee district's Chief Engineer, Stevan Spencer, described the situation as a "very bad joke" that dated back to at least 1998, when Hurricane Georges flooded the airport. Spencer said "there was never funding" to move the EOC. Yet in 2003, the Orleans Levee District spent $2.4 million to repair the "Mardi Gras Fountain" in a park near Lake Pontchartrain. When Katrina made landfall, Orleans Levee District staff had to be rescued, mostly by boat, from the flooded EOC at the airport before they could survey damage or assist with repair efforts at the 17th Street and London Avenue Canals.

The Orleans Levee District was also aware of a levee in New Orleans East that was considered to be three feet below its design height. Levee-district board minutes and conversations with Corps personnel suggest that paying for repairs to this low levee was considered to be the Corps' responsibility. Federal funding was unavailable, but instead of paying for the repairs itself and asking for reimbursement from the Corps, as it had with previous projects, the levee district merely sent letters to its Congressional delegation asking for federal funding.

Pressed to explain how the Orleans Levee District made spending decisions, Huey offered no direct explanation, but focused on the district's multiple obligations - not only was the district responsible for flood control, but it also had statutory requirements to maintain recreational space and was authorized by state law to engage in non-flood related business ventures. A review of the levee-district board minutes of recent years revealed that the board and its various committees spent more time discussing its business operations than it did the flood-control system it was responsible for operating and maintaining.

The Louisiana Department of Transportation and Development (LA DOTD)

Though not a party to the assurance agreements for the Lake Pontchartrain Project, LA DOM and its Office of Public Works (OPW) have statutory responsibilities to assist and oversee certain levee district functions. State law tasks LA DOM with approving any activity that might compromise the levees, and with administering training sessions to levee-district board members and their inspectors on caring for and inspecting levees.

To the extent training sessions were held, they were organized by the Association of Levee Boards of Louisiana, an organization that lists Edmund Preau as its Secretary Treasurer. Preau is an Assistant Secretary in LA DOTD and leads the OPW within the Department, which is responsible for LA DOTD's levee-related activities.

When Huey, who served on the levee district's board for more than 13 years (nine as president), was read the section of state law describing the training requirement, he said it was the first he had heard of it. Huey explained: "You know what that is? That's going up to a workshop for a weekend and having a crawfish boil up here and hear a couple people talk about some things and they get a little piece of paper and they honored the law Huey was then asked whether the Association sessions addressed how to inspect levees. He responded, "No, nothing. LA DOTD also had the statutory responsibility to "review" each levee district's emergency-operations manual every two years . According to Preau, this review entailed checking whether relevant contact information had been updated and whether the levee district had included any new flood-control systems within its jurisdiction in its planning. The review entailed no assessment of whether the levee district had stockpiled materials or had the personnel necessary to assess an emergency and respond accordingly. Preau said he assumed any more elaborate review would have been done by the Louisiana Office of Homeland Security and Emergency Preparedness (LOHSEP).

Louisiana's Emergency Operations Plan (EOP) made the LA DOTI) the primary state agency overseeing Emergency Support Function (ESF-3), Public Works and Engineering. ESF-3 encompassed critical infrastructure in the state, including the "construction, maintenance and repair of state flood control works. ESF-3 also dictated that, "When an emergency is imminent, the ESF 3 Coordinator [who is to be designated by LA DOTD Secretary Johnny Bradberry] will assess the potential impact of the threat on the state's infrastructure and work with other authorities to ensure that any necessary immediate repairs or arrangements for critical structures and facilities are initiated. ESF-3 also said, "As the emergency progresses, the coordinator will monitor the status of the infrastructure and effect emergency repairs where needed and feasible."

The LA DOTD did not acknowledge or accept its responsibility under ESF-3. Preau told Committee investigators that he didn't think the provision applied to LA DOM "I'm not sure what that means, because we don't have any state flood control works. State doesn't own any flood control works. By Preau's reading, a levee project was covered only if it was owned by the state, not simply if it was in the state. As Preau read it, LA DOTD had no responsibility to coordinate with levee districts on critical facilities like the Lake Pontchartrain Project. This response is problematic: the responsibilities articulated under ESF-3 are specifically delegated to the LA DOTD, and the plain language employed by the State's Emergency Operations Plan cannot be unilaterally dismissed as meaningless by the people it covers.

The result was that neither LA DOTD nor any state agency made sure that the state's levee districts were integrated into the state's emergency-planning process, much less genuinely prepared for an emergency. As a result, when Katrina made landfall, no Orleans Levee District personnel were located at, or in contact with, emergency managers in Baton Rouge; nor was any mechanism in place to request additional support from the state. Not withstanding Preau's insistence that the LA DOTD had no responsibilities under ESF-3 for the levee system, LA DOTD ultimately played an active role in efforts to close levee breaches in New Orleans in the aftermath of Katrina.

Design and Construction of the Lake Pontchartrain Project

During Katrina, levees and floodwalls were overwhelmed throughout the New Orleans area, and in several places were breached. Some of these failures occurred in parts of the Lake Pontchartrain Project. Understanding the link between the breaches and the nature and organization of the Lake Pontchartrain Project requires some background. Congress authorized the Lake Pontchartrain Project in the Flood Control Act of 1965 to provide hurricane protection to areas around Lake Pontchartrain in Orleans, Jefferson, St. Bernard, and St. Charles Parishes. The project called for design and construction of about 125 miles of levees and floodwalls to be completed by 1978 at a cost of $85 million. The project was still not complete when Katrina hit, and its cost had grown to more than $750 million as of 2005 .

As authorized by Congress, the project was to protect the area from what the Corps called the “Standard Project Hurricane” (SPH), a model storm “based on the most severe combination of meteorological conditions considered reasonably characteristic of that region.” The SPH was developed in 1959 by what was then called the United States Weather Bureau, which updated the SPH after the devastating impact of Hurricane Betsy in 1965. The SPH was revised again in 1970, 1977, and 1979 by the Weather Bureau’s successor, the National Oceanic and Atmospheric Administration (NOAA). There is no evidence that design parameters of the Lake Pontchartrain Project were modified in light of NOAA’s changes to the reference-model storm.

Nevertheless, the Corps has repeatedly maintained that the SPH was the equivalent of a fast-moving Category 3 storm on the Saffir-Simpson scale - a measurement scale that rates the strength of hurricanes on a scale of Category I to Category 5, with Category 5 being the most intense. For example, at a press conferences immediately after the storm, Lieutenant General Carl Strock, the Commander of the Corps and its Chief of Engineers, explicitly said that the Corps “knew” that the levee system “would protect from a Category 3 hurricane,” and the page on the Lake Pontchartrain Project on the Corps’ website after Katrina said, “The SPH is equivalent to a fast-moving Category 3 hurricane.”

This claim is misleading: the Saffir-Simpson scale was not adopted until 1977, 12 years after the Lake Pontchartrain Project was authorized. Al Naomi, the Corps’ Senior Project Manager for the project, acknowledged that the Corps never conducted a formal study comparing the SPH to the Saffir-Simpson scale, so the claim that the Lake Pontchartrain Project provided Category 3 protection was at best a rough estimate, and at worst, simply inaccurate:

> *SPH has ... wind speed, central pressure, and surge. You go in and say what is my wind speed for an SPH? You look at it. It’s a very high Category 2 storm on the Saffir-Simpson Scale. I look at my central pressure for SPH. I go to the Saffir-Simpson Scale, it’s a mid-range Cat 4. 1 say what is my surge? SPH surge in the lake at two and a half [feet] on the Saffir-Simpson that is a Category 3 range. What am I going to tell the Rotary Club? What do I have? Generally in talking to the hydrologist, you can say it’s about equivalent to a fast moving Cat 3. It’s not really that, but for their understanding that is what you can say. That is what we say. What happens is the press gets this and it says we have Cat 3 protection. That is not really true. It’s SPH protection which may be equivalent to a fast moving Cat 3 storm.*

However, the view that the hurricane protection system could protect the greater New Orleans region from a moderate and/or fast-moving Category 3 storm was widely held within the Corps’ New Orleans District. Prior to Hurricane Katrina, the New Orleans District issued numerous news releases to the general public (some of which are referenced below), stating that the hurricane protection system provided some level of Category 3 protection:

- *December 19, 200 1, N. 0. hurricane bridge contract awarded, Corps, Levee Board will floodproof two bridges in Gentilly: “The bridge floodproofing will protect neighborhoods along the London Avenue, Orleans Avenue and 17th Street canals from storm surges from Lake Pontchartrain. The system of levees,* *floodwalls and bridges is designed to protect against fast-moving Category 3 hurricanes."*

- *May 27, 2003, Cross Bayou Drainage Structure to reduce flooding in St. CharlesParish: "The structure is part of the Lake Pontchartrain Hurricane Protection Project and is the second of five such structures to be built in St. Charles Parish These contracts, to be completed in 2004, will result in a levee system that provides protection from a Category 3 storm for St. Charles Parish"*

- *August 21, 2003, Filmore Bridge in Gentilly will reopen on Friday, Aug. 22. Mirabeau Bridge is closing Wednesday, Aug. 27 for hurricane floodproofing: "The systems of levees, floodwalls and bridges is designed to protect against fast moving Category 3 hurricanes. This view was also held by the Corps' New Orleans District Commander (Col. Wagenaar 63) and the District's Emergency Manager (Michael Lowe). Further, the same representations were made in more substantive Corps written materials.*

Moreover, the Lake Pontchartrain Project, as it stood in the path of Katrina, was still not complete as designed. Some portions were still under construction, and soil subsidence (sinking) had left portions of the project with less elevation above sea level than intended. In other words, some elements of the project were not even high enough to protect against the Standard Project Hurricane, let alone a genuine Category 3 hurricane.

The Corps was well aware of this fact. As Jerry Colletti, the New Orleans District's Manager for Completed Works explained, the Corps never tried "to provide full-level protection on an annual basis.... we just can't raise everything to the design height for each storm that would come through."

Meanwhile, the National Weather Service (NWS) concluded from a new model of projected storm surges that the Lake Pontchartrain Project would be more vulnerable to hurricanes than previously thought - that more Category 3 and even certain Category 2 hurricanes would overtop parts of the levee system and produce flooding. Dr. Wilson Shaffer, who studies storm surges at NWS, said this discovery was shared with the Corps, perhaps as early as 2003, but certainly by 2004. The findings were also shared with LOHSEP and with state and local emergency managers at the Louisiana Emergency Preparedness Association's June conferences in 2004 and 2005 . At a minimum, this information should have prompted a fresh look at the adequacy of the Lake Pontchartrain Project, but like the NOAA updates to the Standard Project Hurricane in the 1970s, it does not appear that either the state or the Corps took any action to respond to the new information.

Effect of Subsidence on the Level of Protection

As noted earlier, the level of protection provided by the levee system was affected not only by its design, but also by geologic subsidence, or regional sinking. The entire coastal region of Louisiana had been subsiding for millions of years, as the enormous weight of the sediments continually deposited by the Mississippi River enters the Gulf of Mexico, pushing down on the earth's crust. Human activities like extracting oil and natural gas, pumping water, raising buildings, and even adding to levees and floodwalls all accelerate subsidence. (See Chapter 9.) As the entire region subsides, the effective height of the levees above sea level, and thus the level of protection they provide, decreases. A recent report concluded that a section of levee that was overtopped and failed during Katrina was nearly three feet below its design height.

All of these factors should have persuaded the Corps to reconsider its public claims that the Lake Pontchartrain Project provided Category 3 level protection.

Operation and Maintenance (O&M)

Maintaining a flood control system is essential, but is complicated in southeast Louisiana by the recurring need to rebuild levees to compensate for subsidence. The Corps is not supposed to turn over a project until it is complete; until then, the Corps is responsible for O&M. Once a project is turned over, the local sponsor must conduct O&M to Corp standards "to obtain maximum benefits." This includes checking for "undue settlement" of the levee, water seeping through or under it, and growth of damaging brush, and taking immediate action to address potential emergencies.

Because the Lake Pontchartrain Project was not complete, according to the Corps' Senior Project Manager for the project, none of it had been formally turned over to the local sponsor, but remained in an "interim" status:

> *There are still pieces that have to be done. We are not going to turn over a piece of the project until every piece in that ring of protection is completed. If there is one little thing left to do I think by regulation - I could be wrong - I think we have to have the entire system 100 percent complete so we turn over the entire segment that is protected, a certain area of the City.*

Nonetheless, the Corps did nominally turn over parts of the project to local sponsors to maintain when it determined that construction on that particular part or "reach" was complete. The Corps sent letters to the Orleans Levee District and others to this effect, informing each district that it now had O&M responsibility for that unit. Personnel within the Corps' New Orleans District referred to these letters as "turnover letters" even though they were not the "official total project completion turnover" letters. The Orleans Levee District did not respond to these letters or even acknowledge their receipt.

When the Committee asked for copies of the de-facto turnover letters, it received only a limited response. The letters submitted did not cover the entire project, and some were pre-1965, before the project was even authorized. In short, the exact legal status of the project segments and the degree to which the Corps and local sponsors like the Orleans Levee District were truly responsible for maintenance is at best uncertain.

Other conflicting and irregular procedures in the turnover process went beyond the turnover letters. The Corps was supposed to require local sponsors to report semiannually to its District Engineer on inspection and O&M for the flood-control system. Colletti, the Corps' Operations Manager for Completed Works, explained that the Corps unilaterally decided not to require the Orleans Levee District to provide the report. In addition, for each completed work, the Corps is required to give the local sponsor an operations manual . Colletti said his office gave no such manual to the Orleans Levee District for levees and floodwalls, but merely provided a one-page set of guidelines similar to a part of the Code of Federal Regulations that detailed obligations of local sponsors.

The Corps' observance of rules and regulations for completed projects took the form of a required annual inspection conducted around June 1 - the start of hurricane season - by representatives from the Corps, the Orleans Levee District, the LA DOTD, and other interested parties (e.g., the City and the Port of New Orleans). These inspections appear to have taken about four hours, covered at least a hundred miles of levees and floodwalls, and would usually involve a motorcade that would stop at pre-determined spots to allow the group to look over an area and discuss issues. The purpose of the inspections, according to the Corps, was to ensure O&M compliance by the local sponsor, but not to test the system's actual structural integrity or measure whether it was at design height. Perhaps the most colorful explanation of the annual inspection was offered by former Orleans Levee District president Huey, who suggested that the event was more of a social occasion than a genuine technical inspection:

> *They normally meet and get some beignets [pastries] and coffee in the morning and get to the buses. And the colonel and the brass are all dressed up. You have corrunissioners, they have some news cameras following you around and you have your little beignets and then you have a nice lunch somewhere or whatever. And that's what the inspections are about.*

Ineffective Inspection Regime

The weaknesses of this inspection approach can be seen in the last pre-Katrina annual inspection of the Lake Pontchartrain Project in May 2005. It apparently did not address some known vulnerabilities. The W-30 Floodgate along the Inner Harbor Navigation Canal had been destroyed by a train accident in 2004 by the New Orleans Public Belt Railroad . This gate was intended to close off the levee at a point where the railroad track passed through it. The railroad had provided money for repairs, but the floodgate was still broken when Katrina struck, even though Huey, then board president, told an April 5, 2005, levee-district board meeting that he considered the broken gate to be an "emergency." Under state law, Huey had the authority to address such emergencies without going through the standard contracting process. Asked why he did not use his emergency authority to repair the gate before hurricane season, Hue simply said, "I do not know. My bottom line straightforward answer: I don't know."

Another problem apparently not dealt with in the annual inspection was a levee in New Orleans East that was three feet short of its design height. Like the W-30 floodgate, the problem remained unaddressed when Katrina made landfall, even though Naomi, the Corps' Senior Project Manager, considered repair "vital" to protecting the city. In addition, Corps rules and regulations for completed works require local sponsors, like the Orleans Levee District, to fix defects promptly. Finally, the Corps' rules on levees require local sponsors to ensure that "No trees exist, the roots of which might extend under the wall and offer accelerated seepage paths." However, one of the forensic teams investigating the levees' failure, and Corps officials, found trees growing along the 17th Street and London Avenue Canals. In spite of the major defects requiring repairs, the Orleans Levee District's Chief Engineer said he expected the district to get "an outstanding review in regards to the maintenance of the levees" from the 2005 inspection.

The Committee learned during its investigation that the 17th Street and London Avenue Canal floodwalls weren't part of the 2005 inspection because they were inaccessible by car. It appears likely that they were never inspected by the Corps after construction was finished in the early 1990s, partially because the floodwalls abutted private property which made them difficult, but certainly not impossible, to access. It seems likely that the only physical inspections they received would have been conducted by Orleans Levee District personnel mowing the grass, making visual inspections, and identifying problems like holes dug by wild animals, significant erosion, etc. The personnel responsible for this work received no specialized training on care or inspection of levees and floodwalls, and supporting documentation of these inspections comprised nothing more than worker timesheets indicating the work conducted, such as mowing the grass, the location of the work, and the hours spent doing the job.

When asked who was responsible for fixing problems once they were identified, Orleans Levee District leadership explained that there was an undocumented understanding that "major" problems would be brought to the attention of the Corps and "minor" problems would remain the responsibility of levee district personnel . However, and as noted by the Orleans Levee District Chief Engineer, Steven Spencer, the district's total in-house, engineering expertise amounted to three engineers , a level of expertise not on par with the challenges posed by the hurricane protection system within the jurisdiction of the Orleans Levee District.

The only other inspection the Orleans Levee District claims to have made of the levees was a field survey of floodwall heights every two to three years to check for subsidence. If the Orleans Levee District did, in fact, conduct these surveys, they did not identify the severity of the subsidence along the 17th Street and London Avenue Canals documented by the Corps' forensic team. The Orleans Levee District certainly did not conduct any structural analysis of the floodwalls; nevertheless, when asked by the Committee about the quality of the Orleans Levee District's operations and maintenance regime over the years, Colletti said that the Corps "felt that they've done an outstanding job."

The Orleans Levee District's O&M practices and the passive oversight by the Corps did not meet what experts consider to be the standard of care for a flood control system like the Lake Pontchartrain Project. For example, in a letter to the Committee, Dr. Ernst G. Frankel of the Massachusetts Institute of Technology explained that visual surveys are not sufficient because potentially catastrophic voids can occur well below the surface of the levees. To expose internal degradation, holes must be drilled in the levees to retrieve core samples for analysis. Acoustic equipment can be used to scan the density of material layers at various depths. No entity conducted such an analysis of the New Orleans flood-control structures, nor were efforts made by the Levee District to obtain equipment to improve its inspection regime. Professor Frankel added that inspection of levees below the waterline was also necessary to detect hidden threats to their integrity. The Orleans Levee District's simple visual inspections failed in this respect as well.

Lack of Coordination with the Sewerage and Water Board of New Orleans

Because New Orleans and surrounding parishes are below sea level and ringed by levees, rain and flood waters that enter must be pumped out. The Sewerage and Water Board of New Orleans (the Water Board) has the responsibility for maintaining a system of pumps and canals for this purpose. (The Water Board also runs the municipal water and sewer systems.) Floodwalls along two of these drainage, or outfall, canals sustained major breaches - the 17th Street and London Avenue Canals. However, the Orleans Levee District and the Corps, at least to the extent the Corps had not turned over the entire project to the local sponsor, are responsible for the floodwalls that line these canals.

In the aftermath of Katrina, the New Orleans Times-Picayune newspaper reported that six months before Katrina, several residents near the 17th Street Canal reported to the Water Board that they had found water in their yards. A similar report was carried by National Public Radio. Following the Times Picayune report, the Water Board conducted an inquiry into these allegations and concluded that the water reported by these property owners was coming from a water-service line and not from the canal. This conclusion was documented in a letter from the Water Board to the Times-Picayune and provided to the Committee. The 17th Street Canal floodwall broke within several hundred feet of where the water seepage was reported. The Committee was not able to independently confirm either the news reports or the Water Board's explanation. However, it is clear that the Water Board had no plan in place or arrangement with either the Corps or the Orleans Levee District to address this sort of situation. The Water Board's Executive Director, Marcia St. Martin, explained how her organization dealt with such situations:

> *What we do is if a person says that there's water that's ponding in front of my house, we look to see whether or not a Board asset, which is the water meter, has a defect or a leak. If we determine it has a defect or a leak, we repair it. If we determine it's not coming from the Board's asset, we say to the customer, "It has to be a private property leak and you need to seek the services of a plumber.*

The Corps has relied on local residents to inform it about these types of problems, but had no public outreach program to urge residents to do so. When the Corps did receive reports of seepage or other issues, it had no process to formally document and address the issues. Likewise, the Orleans Levee District had no plan to reach out or communicate with residents to encourage the identification or the sharing of reports of leakage or other problems."

Subsidence in the Metropolitan New Orleans Area

In addition to design and construction issues, soil subsidence - "the lowering or sinking of [the] earth's surface" - has impaired the protection offered by the New Orleans levee system. In the New Orleans area, subsidence is caused primarily by the cumulative weight of millions of years of soil and silt deposits left by the Mississippi River as it enters the Gulf of Mexico. The sediment literally presses down on the earth's crust, causing the land to sink. As a result, the water level rises, gradually increasing its vulnerability to tides and storms. The levees themselves can also subside because of their own weight pressing down on the swampy soils upon which they are built.

As a result, it appears that the level of protection actually provided by the levee system in the New Orleans region, at the time of Katrina, was significantly less than intended: many sections of the levees and floodwalls were substantially below their original design elevations, an effective loss of protection. For example, the structures associated with the Inner Harbor Navigation Canal were originally constructed to an elevation of 15 feet (relative to mean sea level) but are now just over 12 feet, a typical loss of approximately 2.7 feet in elevation over the lifetime of the project. The report noted that "subsidence is occurring at a rate of up to one inch every three years" in the New Orleans region.

Subsidence routinely creates problems for those trying to construct levees and other structures at known heights above sea level. As stated in one MET report, due to the complex and variable subsidence in Southeast Louisiana, "establishing an accurate vertical reference for measurements has been a constant challenge." Unfortunately, until the October 2005 release (by the U.S. Department of Commerce's National Oceanic and Atmospheric Administration's (NOAA) National Geodetic Survey) of updated locations of 85 benchmarks located in southern Louisiana, which showed heights (elevations) accurate to between 2 and 5 centimeters (roughly I to 2 inches), surveyors, engineers, and the U.S. Army Corps of Engineers in New Orleans evaluated the levees and structures built and in use with vertical heights that had not been calibrated nor checked for several years.

As a result, it appears that the levees were not built and maintained at the proper level above sea level. Since the level of protection that the levees provide is so closely related to their height above sea level, and thus their ability to block increased water levels driven by hurricanes, the failure to build and maintain the levees at the proper elevation diminished the level of protection they would provide.

F.3.4 American Society of Civil Engineers External Review Panel (ERP). Letter to LTG Carl Strock, Chief of U.S. Army Corps of Engineers, February 20, 2006.

Four critical areas that warrant urgent and thorough examination:

Organizational issues: No one person or organization is in charge of the New Orleans hurricane protection system. Local levee districts are responsible for maintaining the levees. Local parishes are responsible for operating pump stations (and even for deciding whether they will be operated during a hurricane). Numerous penetrations affecting such infrastructure as rail lines, bridges, and roadways have been made below the tops of levees and floodwalls under various jurisdictions. Construction contracts are awarded piecemeal, sometimes resulting in abrupt discontinuities in the elevations of floodwalls or levees. Even within the U.S. Army Corps of engineers differing levels of responsibility exist at the district, division, and headquarters levels. The City of New Orleans, the state of Louisiana, and perhaps other entities also are involved in hurricane protection for New Orleans.

The ERP sees clearly that organizational complexities and the ways in which decisions are made are among the most important factors that influenced the performance of the hurricane protection system. Organizational effectiveness has been and will continue to be questioned, with justification. It is impossible for the ERP to conceive a mechanism through which the levee system can be rebuilt and operated effectively and efficiently with such organizational discontinuities and chaos. The ERP recommends that organizational issues be assessed critically and thoroughly as soon as possible.

System issues: The hurricane protection system of New Orleans evolved over a long period of time. The system is not an integrated, well-thought-out system; rather, it is a joined series of individual pieces conceived and constructed piecemeal. Examples include the following: (1) the canals, which evolved over a period of decades to accommodate the pumping technologies available at the time and the continuing land reclamation northward toward Lake Pontchartrain (even though the logic of having many miles of exposed levee and floodwalls along the canals as opposed to closing off the mouths of the canals with a gate or short section of levee, is weak at best); (2) the connections between rigid structures and earthen levees, which experienced numerous failures during Katrina; (3) discontinuities and differences in crest elevations of levees and floodwalls; and (4) the pumps, which were designed to remove rainwater and infiltrating groundwater but, when not turned on, are not protected from backflow and exacerbate flooding during a hurricane.

A logical hurricane protection system for New Orleans would integrate components and the management of components, would be robust and resilient, and would contain a level of redundancy sufficient that, if a levee failed, all would not be lost. A system wide strategy would also ensure that critical structures - for example, pumping stations, hospitals, places of refuge, and electrical generation and distribution nodes - were protected. The lack of a broader, system-oriented strategy exerted a major deleterious influence on the performance of the system and deserves serious consideration.

System development: It is obvious that the hurricane protection system for New Orleans failed miserably during Katrina. That the system was so clearly overwhelmed and failed so catastrophically demonstrates to the ERP that fundamental flaws were part of how the system was conceived and developed. For example, what was the basis for selecting the standard project hurricane and, hence, the authorized level of protection? What process was in place to review the safety of the design as new knowledge evolved over time? How safe and redundant was the system intended to be upon design? Was adequate funding in place to ensure that satisfactory design standards could be implemented? How were safety margins for design established, and are they appropriate in light of new knowledge and the risks involved? How was the potential for loss of life factored into decision making?

Overtopping of levees: A fundamental flaw in the floodwalls and levees is that they include no means of accommodating overtopping that does not inflict major damage or destruction. Once the levees were overtopped during Katrina, rushing water eroded away many sections of levee and in other cases undermined floodwalls. Most of the 350 miles of levees in New Orleans are unprotected from devastating damage and potentially total destruction if overtopped. No mater how high the levees are built, a possibility always remains of a hurricane causing a surge elevation that is even higher than the one for which the levees were designed.

One of the lessons of Katrina that is already obvious is that once the levees were overtopped, destruction was catastrophic. In addition to the tragic loss of life, there were at least two other critical results: extensive and catastrophic flooding and an enormous destruction of capital investment. The question is not whether the levees will again be overtopped but when and by how much they will be overtopped. The levees need to be protected from catastrophic failure resulting from overtopping.

On multiple occasions, statements by top Corps officials have assured the public that the levee system will be adequately safe, and its risks sufficiently low for displaced residents to return to the city by June 1. These statements have seriously compromised task 10 (risk assessment) efforts by introducing a motivational bias that predetermines the outcome of its risk determinations. This undermines the credibility of task 10 and ultimately of the Corps itself. The lesson to be learned is that task 10 will not produce technically sound risk estimates unless there is full support and cooperation from the Corps at the highest levels for unbiased outcomes free of any appearance of manipulation of predetermined conclusions.

F.3.5 Committee on New Orleans Regional Hurricane Protection Projects, National Academy of Engineering and the National Research Council, 2006. Report to The Honorable John Paul Woodley, Assistant Secretary of the Army, Civil Works, Washington, DC, February.

The New Orleans and southeastern Louisiana hurricane protection system includes many engineering, geologic, hydraulic and hydrologic, administrative, and economic and cultural features that interact in complex ways. the levees, floodwalls, and other protective structures in New Orleans and southeast Louisiana have been constructed in a region of active alluvial deposition, subsidence, and fluvial dynamics. The Mississippi River delta, for example, has changed location several times in the past 5,000 years. the region is underlain by deep deposits of recent sediments with high clay content and by sites with varying rates of geologic subsidence - conditions that pose many stringent engineering challenges.

In addition to geologic and engineering considerations, there is a long history of piecemeal construction and maintenance of the system. Construction of levees and floodwalls in the New Orleans area dates to early stages of urban development in the area. An important event in this history was Hurricane Betsy in 1965. Betsy was responsible for 75 deaths and billions of dollars of property damage, prompting efforts to create a regional program of hurricane protection. In the aftermath of Betsy, Congress authorized construction of a hurricane protection system to protect areas in the vicinity of Lake Pontchartrain and surrounding parishes from storm surges. The various projects that make up this system are paid for with a combination of federal state, and local funds. The decision-making and investment processes that have lead to the development of the system have involved numerous stakeholders for more than 50 years.

Primary responsibility for design and construction of hurricane protection projects has been assigned to the U.S. Army Corps of Engineers. Actual project construction has been contracted to numerous private sector firms. Once projects are constructed and fully completed, responsibility for their maintenance is often assigned to local authorities. Since 1965, approximately 125 miles of levees, concrete floodwalls, and other structures have been built in the New Orleans region. Not all projects authorized for construction by the U.S. Congress, however, had been completed as of August, 1005. The hurricane protection structures that existed in New Orleans and the surrounding area in August 2005 were not a single system constructed as part of a unified plan; rather, the system had been added to and repaired by different administrative units - federal, state, and local - operating with different mandates, levels of resources, and staff backgrounds and capacities. No single entity has been fully “in charge” of constructing and maintaining all hurricane protection structures, complicating efforts at systematic repair and construction and efforts to retrieve and assess data on historical decisions and pre-existing conditions.

F.3.6 U.S. Government Accountability Office, Army Corps of Engineers History of the Lake Pontchartrain and Vicinity Hurricane Protection Project, Statement of Anu Mittal, Director Natural Resources and Environment, Testimony Before the Committee on Environment and Public Works, U.S. Senate, November 9, 2005; also Testimony Before the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives, September 28, 2005.

What the GAO Found

Congress first authorized the Lake Pontchartrain and Vicinity, Louisiana Hurricane Protection Project in the Flood Control Act of 1965. The project was to construct a series of control structures, concrete floodwalls, and levees to provide hurricane protection to areas around Lake Pontchartrain. the project, when designed, was expected to take about 13 years to complete and cost about $85 million. Although federally authorized, it was a joint federal, state, and local effort.

The original project designs were developed based on the equivalent of what is now called a fast-moving Category 3 hurricane that might strike the coastal Louisiana region once in 200-300 years. As GAO reported in 1976 and 1982, since the beginning of the project the Corps has encountered project delays and cost increases due to design changes caused by technical issues, environmental concerns, legal challenges, and local opposition to portions of the project. As a result, in 1982, project costs had grown to $757 million and the expected completion date had slipped to 2008. None of the changes made to the project, however, are believed to have had any role in the levee breaches recently experienced as the alternative design selected was expected to provide the same level of protection. In fact, Corps officials believe that flooding would have been worse if the original proposed design had been built. When Hurricane Katrina struck, the project, including about 125 miles of levees, was estimated to be from 60-90 percent complete in different areas with an estimated completion date for the whole project of 2015. The floodwalls along the drainage canals that were breached were complete when the hurricane hit.

The current estimated cost of construction for the completed project is $738 million with the federal share being $528 million and the local share $210 million. Federal allocations for the project were $458 million as of the enactment of the fiscal year 2005 federal appropriation. This represents 87 percent of the federal government’s responsibility of $528 million with about $70 million remaining to complete the project. Over the last 10 fiscal years (19965-2005), federal appropriations have totaled about $128.6 million and Corps reprogramming actions resulted in another $13 million being made available to the project. During that time, appropriations have generally declined from about $15 - 20 million annually in the earlier years to about $5-7 million in the last three fiscal years. while this may not be unusual given the state of completion of the project, the Corps’ project fact sheet from May 2005 noted that the President’s budget request for fiscal years 2005 and 2006, and the appropriated amount for fiscal year 2005 were insufficient to fund new construction contracts. The Corps had also stated that it could spend $20 million in fiscal year 2006 on the project if the funds were available. The Corps noted that several levees had settled and needed to be raised to provide the level of protection intended by the design.

During the first 17 years of construction on the barrier plan, the Corps continued to face project delays and cost increases due to design changes caused by technical issues, environmental concerns, legal challenges, and local opposition to various aspects of the project. For example, foundation problems were encountered during construction of levees and floodwalls which increased construction time; delays were also encountered in obtaining rights-of-ways from local interests who did not agree with all portions of the plan. By 1981, cost estimates had grown to $757 million for the barrier plan, not including the cost of any needed work along the drainage canals, and project completion had slipped to 2008. At that time, about $171 million had been made available to the project and the project was considered about 50 percent complete, mostly for the lakefront levees which were at least partially constructed in all areas and capable of providing some flood protection although from a smaller hurricane than that envisioned in the plan.

More importantly, during the 1970s, some features of the barrier plan were facing significant opposition from environmentalists and local groups who were concerned about environmental damages to the lake as well as inadequate protection from some aspects of the project. The threat of litigation by environmentalists delayed the project and local opposition to building the control complexes at Rigolets and Chef Menteur had the potential to seriously reduce the overall protection provided by the project. This opposition culminated in a December 1977 court decision that enjoined the Corps from constructing the barrier complexes, and certain other parts of the project until a revised environmental impact statement was prepared and accepted. After the court order, the Corps decided to change course and completed a project reevaluation report and prepared a draft revised Environmental Impact Statement in the mid-1980s that recommended abandoning the barrier plan and shifting to the high-level plan originally considered in the early 1960s.

In recent years, questions have been raised about the ability of the project to withstand larger hurricanes than it was designed for, such as a Category 4 or 5, or even a slow-moving Category 3 hurricane that lingered over the area and produced higher levels of rainfall. Along this line, the Corps completed in 2002 a reconnaissance or pre-feasibility study on whether to strengthen hurricane protection along the Louisiana coast. A full feasibility study was estimated to take at least five years to complete and cost about $8 million. In March 2005, the Corps reported that it was allocating $79,000 to complete a management plan for the feasibility study and a cost-share agreement with local sponsors. The President's fiscal year 2006 budget request did not include any funds for the feasibility project.

F.3.7 U.S. General Accounting Office, Improved Planning Needed by the Corps of Engineers to Resolve Environmental, Technical, and Financial Issues on the Lake Pontchartrain Hurricane Protection Project, Report to the Secretary of the Army, August 17, 1982.

Although the Corps' District Office in New Orleans considers this $924 million project a high priority, its completion date has slipped from 1978 to 2008. In the 17 years since congressional authorization in 1965, only about one-half of the project has been completed.

We believe that improved planning is needed by the Corps to resolve certain environmental, technical and financial issues. Environmental concerns have remained unresolved for almost 5 years after a court injunction prohibited the Corps from constructing certain parts of the project. The Corps is considering a change in its solution of providing protection from constructing barrier structures at the entrance to the lake and the raising of some levee heights (the barrier plan) to constructing much higher levees with no barriers (the high-level plan).

Various problems and conditions have caused delays in the project. Specifically: Engineering and environmental concerns have caused delays in project completion. Costly project work at the drainage canals has not been reported to the Congress, and technical and financial concerns which may impeded project completion remain unresolved. Current project financing by the local sponsors has not been assured because of limited resources. Project cost estimates are understated, and a project plan has not been formally adopted.

The local sponsors agreed with information in a draft of this report, but were concerned over their financial capability to meet their share of project costs. They believed the project construction could be pursued more expeditiously. One sponsor believed that Corps standards may be too high to obtain adequate, affordable, and speedy protection.

F.3.8 Houck, O. (2006). "Can We Save New Orleans?", Tulane Environmental Law Journal, Vol 19, Issue 1, 1-68, New Orleans, Louisiana.

On the other hand, for the City That Care Forgot to call anything 'fantasy' is a bit bold, and everything about the run-up to the Katrina disaster had fantasy written all of it: on slab development, on fill development, subdivisions in wetlands (protected by wooden fences), condos on beaches (protected by nothing), canals as senseless as the Mississippi River Gulf Outlet (MRGO), oil and gas channels by the thousands, coastal mitigation programs that failed to work (failed even to materialize), disappearing levee money, tinker-toy levee plans, what-the-hell levee construction, drive-by-and-when's-lunch levee inspections – and we haven't even gotten to FEMA yet. Detailed reporting in local papers, science colloquiums, National Geographic, NOVA and government planning sessions predicting this very storm in this very way with these very results were tossed away like so many Mardi Gras beads. So there is plenty of fantasy to go around.

We know a couple of things more, going in. For openers, we are short on land building materials. We live on a sinking delta, and the silts and plant mass that created it and offset its natural rate of subsidence are down to a fraction of their volumes a century ago. We have a lot less to work with than Mother Nature did. Even within the city, we are sinking. Post-Katrina surveys are finding many buildings about a half a foot lower than they were thought to be, and down by two feet in the East. Which is not good.

We also know that we are terribly late to the restoration game, about 1,900 square miles late, what is left is largely sick, and what we've managed to recoup over the past few years couldn't stand up to the latest storms. The newly restored marshes of the $80 million Canaervon diversion project ended on the rooftops in St. Bernard.

We know, worse, news, that hurricanes are coming more frequently now and with greater anger, that our levees are subpart, and – although it still seems to escape the grasp of the President and the Louisiana congressional delegation in Washington, D.C. – that the seas are rising and that global warming will raise them by more than a foot within the lifetimes of our children.

You would think that flood control and the protection of the City of New Orleans would be job one for the U.S. Army Corps of Engineers. And you would be wrong. It isn't, and it never was. ...The Army's field engineers were the only government entity around with the ability to blow things up and move dirt around, and so this became their job, to maintain navigation on the navigable waters of the United States. Navigation was interstate commerce, the means of interstate commerce, and it made money for people. Flood control, by contrast, was seen as a form of land use, a local affair, cemented in place when the federal government ceded lands to local levee boards in the 1850's, in part to persuade them to stay loyal to the Union. That part didn't work so well, but it set a mold for local levee boards that we have yet to change. It also further cemented the mindset that navigation comes first.

The Flood Control Act of 1936 opened a huge candy store, something like the discovery of gold at Sutters Mill, only this time the miners ere in Washington and wearing suits. Ostensibly authorizing the Corps of pursue projects for 'flood control and related purposes,' the other purposes quickly took over and by the 1960s the country was being dammed, drained, pumped, and leveed by hundreds of Corps projects feeding real estate development, energy production, soybean crops and right on down to recreational lakes with wave machines and the McCurtin County Catfish Farm. The Act's one caveat, that the benefits of these projects 'to whomsoever they may accrue,' was turned into a weapon of destruction, with the Corps discovering benefits so chimeric that they became legend in the fields of government and political science, the object of ridicule in the press that the government should participate in these projects 'if the benefits to whomever they may accrue are in excess of the estimated costs,' and recurrent calls for Corps Reform. Not to worry; the Corps had the ally that mattered, the Congress of the United States.

The rise of the water project bonanza has had several large consequences for flood control in south Louisiana. Basically, it eclipsed it. The first consequence is that flood control has no head. Unlike every other federal activity in the country, this one is overseen and directed by the Corps, members of Congress, local levee districts and lobbyists among which are found some of Louisiana's most illustrious power brokers: Bob Livingston, Bennet Johnston, John Breaux, Jimmy Hayes, just to start the list. Congress determines budgets, and promotion from Colonel to General. For Colonels heading the New Orleans District, it has been a trial by fire that has made and ended careers. It also produces conformity. When project funding for hurricane protection along Lake Pontchartrain dwindled in the early 1990s, nobody squawked out loud: a former director of the Corps Waterways Experiment Center in Vicksburg explained to the New York Times, 'I don't think it was culturally in the system for the corps to say this is crazy.' Whatever the merits of this diffusion of authority, it does not produce coherent flood control.

All of which works as long as there are no floods. Then, they become somebody else's fault. The didn't fund me. Well, you didn't ask. So it goes, and so it went after Katrina.

The second impact is that the program is not based on the completion of a few major projects but, rather, on spreading construction money and benefits around as many projects and about-to-be-made-happy constituencies as possible. This is true at the national level, where water resources bills are passed in omnibus fashion, meaning that they are approved in one big lump with something inside for everyone's district. Those brave or fiscally minded souls who object to a particularly sad entry end up ostracized or worse; one year the leadership announced the Pinocchio award for members who stuck their noses into other member's water resources projects.

So it is at the Louisiana level as well. Every cycle there is something in there for everyone, your new port, my new waterway, their pumps and drainage upstream. In this mix, New Orleans is just one more open beak among the chicks. It is not in the Corps' political interest and it is not in the Congress's political interest to satisfy one beak at the expense of others. The political objective is to spread the food around as widely as possible, and if that takes more time it also keeps more contractors working in more parts of the state. Inviolate Rule of Politics: Happier people is better than fewer happy people. Inevitable Effect of Rule: Short change for hurricane protection for the City of New Orleans.

Case in point: Louisiana has received nearly $2 billion for Corps water projects over the past 5 years. It has for time immemorial received the lion's share of water resources funding, with California, Texas, Illinois and Florida distant seconds (around $1.2 billion each over the last 5 years), and no one else even close. It's not a question of getting money down here. It's where it goes. In 2002, the Bush Administration rejected a Corps request for $27 million for additional hurricane protection along Lake Ponchartrain of which the Congress only restored $5.7 million in its appropriations. Meanwhile, Congress was boosting funding for the $780 million Industrial Canal Lock (the most expensive on record), a $194 million dredging project for the New Iberia, and tens of millions more on canals like the MRGO.

A third consequence of the game is that flood control for developed urban areas comes in last. The sad fact is, it doesn't make money for anyone. By leveeing off wetlands for new development makes lots of money in real estate (set aside the fact that the homes and streets will subside and begin to flood from spring rains). Floating boats also produces identifiable payouts (albeit they are calculated by asking shippers if they would like to use the canal once it is built, which is a little like using Monopoly money; very few Corps waterways live up to their traffic predictions, and some are ludicrously underused). Even converting cypress swamps to soybeans has a market price. By contrast, lives saved by levees don't receive economic benefits in the decisions that justify Corps projects and determine their funding priorities. Nor do they attract powerful lobbyists. The Industrial Canal lobby can afford to put ex-senators, congressmen and entire law firms on its payroll. The City of New Orleans, on the other hand is broke, and one doubts that St. Bernard and Plaquemine even field full-time representatives in Washington. Money talks.

A final most perverse effect of the water resources game is that it produces projects that not only conflict with flood control for money and fame, but cause floods as well. Big ones. The role of the MRGO in the Katrina and Rita flooding is by now undeniable. What remains impressive, however, is the tenacity with which the Corps and the Louisiana congressional delegation hung on to this project – indeed, continue to hang onto it – against the pleas of the St. Bernard Police Jury, the Lake Pontchartrain Basin Foundation, and coastal scientists who have been complaining that it had destroyed 20,000 acres of the Parish, was killing much of the lakeshore, and was going to bring major hurricanes right into the city. These claims were never rebutted. They were simply ignored.

What we have here, then, is a game that is not focused on flood control, and never has been. It has been focused on making money first for people with boats and then for as many people as possible, even when that has meant increasing hurricane risks and putting other people right into harm/s way. It has been denial about its impacts, and remains largely in denial. And it as been accompanied by a similar series of body blows to the coastal zone from another sources which is even more powerful and difficult to turn around: the oil and gas industry.

The impact of oil and gas extraction on the natural systems of the Louisiana coast is hard to exaggerate. The initial space of the access canals is relatively minor. It's what happens next that matters. The canals erode, exacerbated by wave wash from passing boats. In 10 years the widths have doubled; then they double again. While intact, the spoil banks cut off the natural drainage for hundreds of yards around, impounding half of the marsh and drowning the other half. Up the canal comes saltwater from the gulf. The grasses go belly up, the root masses die, the soils are released, the whole thing falls apart. Recent studies by the United States Geological survey discover a related phenomenon. The industry has excavated billions of gallons of brines, salts, and minerals from under the wetlands, much of it close to the surface, following which - surprise! - they caved in. Marsh erosion or subsurface extraction: pick your weapon, they both kill.

About 70 years ago, Louisiana made a deal with the oil and gas industry. the industry would get what it wanted; the state would get a piece of the take. In Plaquemines Parish the industry took nearly everything, save what it paid back to Leander Perez. The state's near slavish defense of the industry since that time is a matter of legend; Bennett Johnston was commonly referred to as the Senator from Oil, and his successor was one of the three Democratic votes to open the arctic wildlife refuge to oil and gas and to remove the rights of states to decide on drilling off their coasts. It's in the genes. As Louisiana moved forward on its coastal restoration plan, it would ask the federal government for massive amounts of money. Part of the rationale, no small part, was to protect the oil and gas industry's pipelines and infrastructure through the coastal zone. Nowhere, however, did the state ask the industry to pay a penny for the restoration that would save its base. Over 10,000 miles of canals are now eroding and the marshes are caving in and somebody big is walking away from the table.

There is something special about Louisianans when it comes to flood control. We could call it courage. We could call it denial. Or we could call it anything in between and probably all of them and not be wrong. but Louisianans settled a state that flooded regularly from the north and from the south, from rivers and the Gulf, and some of its most gripping stories - Lanterns on the Levee, Last Island - are scenes of tragedy from high winds and waters that no book or film could fully capture. and yet we built, and built again. For a long while, we tended to build elevated homes, on ridges, and kept the boats handy for what we knew would come. Then we raised levees. when they didn't work we got the federal government to raise levees and built out back into the swamps and put in pumps. Before long we were building on slab. and still we flooded. We lead the nation in flood losses. No reason not to. The federal government pays us for it.

And so we had a cozy game of build-flood-and-get-paid going until coastal erosion weighed in, and the onset of an awesome and unanticipated season of hurricanes that, apparently, has only just begun. Louisiana towns that used to sit well inland were finding themselves on the front line with the Gulf of Mexico, which has been coming north at about 10 to 30 meters a year. A 1990 report by the National Academy of Sciences recommended mapping the erosion zones and moving new construction away from them through the flood insurance program. there were no takers. Five years later, FEMA recommended that the government at least chart the zones. No takers either. Nor on its almost annual pleas to raise the flood insurance rates to something close to real life. Louisiana knows a good thing when it sees it.

The northeast gets its railroad subsidies, the far west gets grazing and timber subsidies; this one is ours.” “The hurricanes came. They have, of course, always come, and when Betsy and Camille came ashore in the late 1960s the nation gasped. There were record storms, record damages, record loss of life, we must do something. What we did was go back on the same beaches and vulnerable strips of coastal wetlands and build the same stuff, only more expensive. there was a lull while it all came together - the casinos, the high rises, a building boom on Grand Isle, ditto Holly Beach, ditto a boomlette that was just starting down in the marshes of St Bernard, ditto all around Lake Pontchartrain - all subsidized by people who don’t enjoy houses on the shore. No longer quaint low-end bungalows. Some very expensive housing for our wealthiest fellow citizens who get below cost flood insurance and income tax deductions for their second home mortgages. Another hayride.

Global temperatures rise and fall over geologic time. As they rise and fall, they produce sea changes in life history, species go extinct, civilizations advance and disappear. There is a normal range of variation. but the current climate is warming at a rate without precedent for the last several hundred thousand years.

So what? Here in Louisiana we will be warmer in summer (think, maybe, 103 degrees at Jazz fest), warmer in winter, and considerably drier (think about sugar, soybeans, rice and other wet-soil crops). Without winter freezes we’ll have a lot more insects - mosquitoes, termite and cockroach numbers soared between 1990 and 1995 when there were no killing frosts - and the bayous will be blanketed with alge blooms. We’re tough. We can handle that. Pass the pesticides.

What will be a little harder to handle is sea level rise. A heated ocean expands, and - according to the most definitive international panel on climate change yet assembled - the oceans will rise from a half a foot to three feet, absolute. that’s before we get to subsidence in places like Louisiana, where the relative rise could go to four feet. And that’s before adding increasing snowmelt and the run from polar glaciers. For which we add another half a foot. It’s already happening. Rocky Mountain peaks are going dry. The famed snows of Kilimanjaro have about disappeared. Temperatures around the North Pole are rising so rapidly that a new sea route is opening between the oceans, expected to be clear even for unarmored ships within the next 30 years. Native Inuit report seeing warm weather birds, beyond anything in the legends of their people.

Four feet is a killer for South Louisiana. On a landscape as flat as the coastal zone, and where building elevations are in the single digits, relative sea rise of only a few inches covers an enormous amount of ground. Worse for New Orleans, which is buffered by coastal systems, for coastal towns that fish, trap and work their natural resources, and even for the oil and gas industry whose wells and pipelines lie increasingly exposed in open water above sinking bottoms, a few inches of relative sea rise will be enormously hard to match with coastal restoration programs. The game is not static. It’s like trying to score touchdowns but they keep moving the goalposts back. Way back. Think about trying to devise a way to rebuild 1,000 square miles of Louisiana wetlands already lost and another 20 to 30 each year, against the relentless pressure of the Gulf of Mexico. Now add this: you will have to build and maintain the whole thing several more feet into the air.

And now we add this. an increasing body of data shows a strong correlation between warmer seas and violet hurricanes. And more frequent ones. It makes sense: warm waters are hurricane food, which is why the season comes at the end of the summer. The doubters have since weighed in with their list of unprovens - which is the way science works, healthy science anyway - and the case is not ironclad. But there seems to be good evidence that global warming is not only destroying Louisiana's defenses, it is also fueling what could be, any year, its ultimate storms.

Are We Serious Yet? Because we certainly haven't been serious up to this point at all. Katrina and Rita have to be the most well predicted and publicized disasters in history, and we did next to nothing to stave them off or to prepare for the hits. In August 2005, a couple of weeks before the storms, a Homeland Security brochure came in the mail on hurricane preparedness. It consisted of a map marking evacuation routes out of town, with major revelations like the existence of I-10 and I-59.

Meanwhile, we continued to treat flood control as the stepchild of navigation projects that were in large part boondoggles, and in full measure drained monies and attention away from the hurricane protection needs of the Crescent City. We treated the whole water resources effort more like a re-election machine than a serious program, run by local interests, lobbyists, congressmen and ex-congressmen who are glued to the status quo. We let the largest party in coastal destruction walk away from the table without paying, while we in turn pay no end of public subsidies for people to build and live in the hurricane hit zone. We turn our back on the pall of jeopardy that global warming and rising seas throw over the future of the region; worse, we advocate against doing anything about it. And that's just in Washington.

Back home, the scene is little more encouraging. We have a dysfunctional system for building levees, and even more dysfunctional one for maintaining them, aggravated by a Byzantine arrangement of levee boards, port authorities, and other bodies that so fragment the process that it seems primarily directed towards maintaining political alliances and local perks. Post-Katrina down here has been like the Wizard of Oz. When the curtain is finally pulled back, there are a couple of flood control guys in suits and uniforms and they haven't a clue. If they are not protected by sovereign immunity, they are facing the largest negligence verdict in history.

Hurricane Betsy brought a rude awakening to New Orleans and the Army Corps of Engineers. for more than a century they had been putting bigger and better locks on the front door, against the high spring floods of the Mississippi River. Now it was plain that the big one would come in the back door, with the capricious, violet, and increasingly frequent hurricanes of late summer and fall. And so, in 1965, Congress authorized the Corps to proceed with a plan to protect the city and the region from the east and south: the Lake Pontchartrain and Vicinity Hurricane Protection Project. It would defend against a Betsy-type storm, winds up to 100 mph, waves at maybe ten feet. It would take about 13 years to complete, with an estimated price tag of $85 million.

The Corps had two basic options, a high-level plan relying on levees fronting Pontchartrain along New Orleans and Jefferson Parish, or a lower set of levees, fronted by barriers 40 miles out at the inlets to Lake Pontchartrain across the Rigolets and the Chef Menteur pass. Initially, the barriers prevailed. They were seen as less costly, quicker to build (higher levees would require more time for the fill to settle), and - what many considered to be the driving factor at the time - they would allow for the drainage and development of wetlands in St. Charles Parish and New Orleans East where in the Corp's words 'protection would not be incrementally justified.' Indeed, some 79% of benefits came from protecting new wetland development; protection New Orleans came in a distant second.

Developing the wetlands was in high swing at the time. New Orleans itself had just finished expanding over marshes and swamps to the edge of the lake. (The streets and houses hadn't started to crack open yet.) President Lyndon Johnson was partner (with his wife and Dallas Cowboys owner Clint Murchison) in a project to develop new Orleans East (a Lenin's tomb-like monument along I-10 still bears the name), and had managed to finesse federal highway regulations to build three interchanges for the venture. A similar venture along the St Charles lakefront advertised scenes of upland development complete with contented dairy cows so obviously deceptive that it was shut down after protest by the Louisiana Attorney General. What these developers wanted, of course, was exactly what environmentalists feared. The barrier plan looked like a stalking horse for wetland development, New Orleans piggybacking the scheme.

The plan had another problem. It would block off most of the Rigolets and Chef passes, which were the migration corridors for the aquatic life of the interior lakes. Lake Pontchartrain had been the seafood market for the city, and crabbing along its banks was in the family memory of thousands of local families. Commercial fishers were worried as well and, despite Corps statements that gates in the barriers would maintain necessary flows, a groundswell of opposition grew on both sides of the lake. A poll by Congressman Bob Livingston showed his constituents doubting the barriers, causing him to express reservations as well. an Environmental lawsuit challenged the impact statement on the plan, which the Corps later admitted was a cursory job. Like so many such lawsuits at the time, the court found the statement inadequate and required the Corps to write a new one. Most of the time the Corps did just that, and then proceed with its original plan. In this case, though, the Corps changed its mind.

In 1982, its review completed, the Corps announced for the high levee option. It would turn out to be less expensive after all, they found, less harmful to the environment and more 0protecteditve as well. (Among other things it would guard against waves kicked up by hurricane-force winds across the lake itself). And so the project marched forward, its costs ballooning to an estimated $757 million, towards a pre-Katrina estimated completion date of 2015. At that point the Corps had thrown up 125 miles of levees around the city, in various stages of readiness. The all-important interior canal walls - the ones that failed - were parts of the project declared to be complete. Appropriations for the project were declining, however, from some $15-20 million annually in the early years to about $5-7 million in recent years. The monies were going elsewhere.

So when Katrina and Rita hit the fan, it was little surprising that two former Corps employees, high level ones at that, told the *L.A. Times* that environmentalists had drowned the city with their lawsuit. The Wall Street Journal, ever eager for news like that, and a pack of right wing blogs picked up the cry, which carried to Washington DC and the House Resources Committee. The Committee, in turn, ever eager for news like that, held hearings on it, absent the benefit of witnesses who had participated either in the project or the case. The United States Justice Department, ever eager for news like that, even asked its field offices to report any and all environmental cases that had obstructed Corps flood projects. None were ever disclosed.

In the end, the story flopped. The Chief of Engineers and the Government Accounting Office, which had been bird-dogging the project for years, both testified before other committees that the barrier plan would not have protected New Orleans any better than functioning levees, and in fact could have worsened the flooding by trapping the storm surge against the city. As serious investigations proceeded, it became clear that the problem was not the high levee plan. Category 3 levees would have kept the city dry. Instead, the city got tinker toys and they fell apart.

F.3.9 Member Scholars of the Center for Progressive Reform (2005). *An Unnatural Disaster: The Aftermath of Hurricane Katrina*, Center for Progressive Reform Publication, CPR Publication #512, September.

Hurricane Katrina tragedy is not a ‘wake-up call,’ as some have described it; rather, it is a consequence of past wake-up calls unheeded. By any reasonable measure, government failed the people of New Orleans. Hurricane Katrina was a natural disaster of enormous proportion, but its tragic consequences have been made even worse by an unnatural disaster - the failure of our government adequately to anticipate, prepare for, and respond to the devastation that the hurricane brought. One very powerful message of the ideology that now dominates both the executive and legislative branches of the federal government is that actions have consequences. The Katrina tragedy has demonstrated that inaction also has serious consequences.

New Orleans sat in the path of Katrina like a stretch of road with too little banking and with no one having taken responsibility for its repair. In this case, the government failures that preceded Katrina and made it worse seem to span a wide range of environmental, natural resource, disaster-planning, and emergency-response functions for which we rely upon government. Identifying those systematic and programmatic contributors to the Katrina disaster will give us the information we need to demand that government do better.

The proper response to Hurricane Katrina is action at every level of public life to restore the critical protections and safety nets that only government can provide for the people.

Today, government must again play an active role in protecting its citizens from the visibly power forces of nature and from the less visible, but equally powerful forces of policy-making that is sometimes slanted away from protecting and serving the public and toward protecting profit margins.

In addition, we strongly recommend that Congress create an independent commission to pursue these questions, in an atmosphere free of the bitter partisan strife that seems to swamp both houses in anticipation of the 2006 mid-term elections. The notion of a bipartisan, objective congressional investigation, promoted by the President, does not seem possible or desirable given the rancor of recent days.

The failure of New Orleans' levees was preceded by a failure of environmental protection and planning. Louisiana's coastal plain contains one of the largest expanses of coastal wetlands in the contiguous United States, but it is being lost at a rate of 6,600 acres per year. the main culprit in wetlands loss in the area is the vast network of levees, navigational channels, and oil-and-gas infrastructure. Important though the network is to safety and commerce, it accelerates coastal land loss by reducing the natural flow of a river's freshwater and sediment to wetland areas where lost land would then naturally be replenished. In addition, the area's major navigational channels pose their own special threat to flood control by sometimes acting as 'hurricane highways,' allowing storms to sweep inland, past marshland, like liquid bulldozers.

Broken Levees: Predictions that Came True. Over a period of many years, scientists had predicted that a strong storm could breach the levees, and some had predicted what appears to be the precise sequence of breaches that flooded the city. The failure to protect New Orleans resulted from inadequate planning by the Army Corps of Engineers (Corps), and from the failure of the federal government to fund badly needed improvements once those limitations were recognized. Neither the Corps nor Congress adequately accounted for the loss of life and property that would occur if a catastrophic hurricane hit New Orleans.

"Moreover, although the Mississippi River-Gulf Outlet (MRGO) canal was a primary cause of the flooding, it is seldom used and heavily subsidized by taxpayers. Less than three percent of the New Orleans port's cargo traffic uses the MRGO, less than a ship a day. Although New Orleans' vulnerability was widely predicted, the Corps declined to move forward with enhancements to the levee and flood wall system because 'no clear bureaucratic mandate exists for reassessing the blueprints once levees are built.' Moreover, when Congress has appropriated money to protect New Orleans better, the Corps has not been in a hurry to get the job done. Finally, the Bush Administration and its predecessors have failed to fund Corps requests.

Why the City Flooded. The water that flooded New Orleans did not flow over the levees situated between the lake and the city. Instead, it appears that the surge flowed up the 17th Street and London Avenue canals and caused one breach of the floodwall along the 17th Street canal and two breaches of the floodwall along the London Avenue canal. In other words, the water moved to the path of least resistance - the floodwalls along the canals.

The city also flooded because the levee system did not protect it from the 'end around' exposure that occurred during Hurricane Katrina. The hurricane surge entered Lake Borgne from the Gulf of Mexico and proceeded up the MRGO canal to the Industrial canal in the heart of New Orleans. Hurricane Katrina appears to have destroyed as much as 90 percent of the levees and flood walls along the MRGO canal in St. Bernard Parish as it pushed up the narrowing canal from Lake Borgne to the conjunction of the MRGO canal with the Industrial canal. Colonel Richard Wagenaar, the Corps head engineer for the New Orleans district, reported that the eastern levees were 'literally leveled in places'. That same surge probably caused the breaches in the floodwalls along the Industrial canal.

We Knew This Would Happen. Not long after the levees broke and water from Lake Pontchartrain on the north and Lake Borgne on the east began to fill New Orleans, President Bush told television correspondent Diane Sawyer that no one could have foreseen the breach of those levees. In fact, over a period of many years, scientists had predicted that a strong storm could also breach the levees. Scientists especially feared that even a relatively weak storm coming from the right direction would push a wall of water into the heart of New Orleans from Lake Borgne through the funnel-shaped MRGO canal and into the Industrial canal, destroying the levees along the canal and flooding much of St. Bernard Parish and the Lower Ninth Ward. It now appears that this is exactly what happened.

Moreover, the risks posed by the MRGO canal were evident. In 2002, the Corps of Engineers acknowledged that ‘the MRGO levee is more likely to be affected than the area on the lake itself.’ Proponents of closing the canal pointed out that, with the erosion of the wetlands in the unleveed stretches south and east of the city, it had ‘evolved into a shotgun pointed straight at New Orleans’.

The Failure to Protect: Bad Planning, Skewed Priorities. The failure to protect New Orleans resulted from inadequate planning by the Corps to save the city, and from the failure of federal government to fund badly needed improvements once those limitations were recognized. Neither the Corps nor Congress adequately accounted for the loss of life and property that would occur if a catastrophic hurricane hit New Orleans.

The hurricane protection plan that was implemented after 1985 by the Corps was designed to protect the city against the ‘standard project’ hurricane that roughly corresponds to a fast-moving Category 3 storm. Scientists had for years prior to the storm predicted that the levee system woulc not withstand a Category 4 or Category 5 storm. Hurricane Katrina struck the Louisiana / Mississippi coast as a Category 4 storm.

Moreover, although the MRGO canal was a primary cause of the flooding, it is seldom used and heavily subsidized by taxpayers. The canal, which was completed in 1968, is a deep draft seaway channel that extends for approximately 76 miles east and southeast of New Orleans into Brenton Sound and the Gulf of Mexico. It was designed to shorten the distance for ships from the eastern shipping lanes of the gulf to New Orleans, but it has never lived up to its predicted economic expectations. Less than three percent of the New Orleans port’s cargo traffic uses the MRGO; this amounts to less than one ship per day. According to one estimate, the government spends $7 to 8 million dollars per year (about $10,000 for every large vessel that uses the canal) just to maintain the canal.

Although the vulnerability of New Orleans to a catastrophe was well known and widely predicted, the Corps has floundered in its efforts enhance the protection of New Orleans from Lake Pontchartrain. In an award winning series of articles on the levee system, The Times-Picayune concluded that the Corps of Engineers has declined to move forward with enhancements to the levee and floodwall system because ‘no clear bureaucratic mandate exists for reassessing the blueprints once levees are bu9ilt.’ For example, an attempt in 1996 to reevaluate the Lake Pontchartrain levees broke down in disputes over modeling and other bureaucratic disagreements. When Congress has appropriated money to protect New Orleans better, the Corps has not been in a hurry to get the job done. For example, the Congress in 1999 appropriated money for a $12 million study to determine how much it would cost to protect New Orleans from a Category 5 hurricane, but the study had not even been launched as of September 2005.

In addition, the Bush Administration has failed to fund Corps requests. Mike Parker, a former Republican Congressman from Mississippi who was until 2002 the chief of the Corps, was forced to resign when he publicly sated to the Senate Budget Committee that the national interest was being harmed by President Bush's proposal to cut over $2 billion from the Corps' $6 billion budget. The Bush Administration rejected an Corps request for $27 million to pay for hurricane protection projects along Lake Pontchartrain and proposed a budget of only $3.7 million for the projects, but the Corps still had to delay seven levee improvement contracts. After Hurricane Katrina struck, Mr. Parker stated that President Bush had not adequately funded improvements to the very levees in New Orleans that had been breached; indeed, Mr. Parker stated that had full funding been authorized 'there would be less flooding than you have.' an official Corps memo dated May 2005, long after Parker left the agency, seemed to corroborate this possibility. It stated that the bush Administration funding levels for fiscal years 2005 and 2006 were not enough to pay for new construction on the New Orleans levees.

There are now strong indications that the critical floodwalls along the outlet canals did not breach because the water surged over them and eroded their support but because they were not capable of withstanding even the surge of a Category 3 hurricane. Whether this failure of the floodwalls was attributable to poor design or poor construction and maintenance remains to be seen, but in either case the Corps and the local levee authorities bore the responsibility for ensuring that the floodwalls were adequately designed, built, and maintained.

Although it is tempting to blame the current administration for the failure to fund critical levee improvement projects, the truth is that improving the Lake Pontchartrain levees has been a low priority for many administrations, Democratic and Republican, and for Congress. The Bush Administration and Congress have had other priorities over a longer period of time than the last four years. In fact, it seems clear that even the Louisiana congressional delegation has on occasion insisted that the Corps direct its resources to projects like a $194 million project for deepening the Port of Iberia and replacing the lock on the Industrial canal.

The Bush Administration and Congress are influential in setting budget priorities because the Corps is very reluctant to participate in the process of setting priorities for its projects. Moreover, once the Corps has determined that the benefits of a proposed project exceed its costs, the Corps leaves it to Congress to decide through the appropriations process which projects receive funding and which do not. Congress is ordinarily willing to consider passing appropriations for large public works projects, however, only in the wake of major disasters or after years and years of study.

The reasons why New Orleans and its vulnerable citizens were not better protected are clear. The levee system was not designed to protect the city from more than a Category 3 hurricane system and there was little administration or congressional support for making improvements in the levee system despite the fact that its limitations were widely recognized.

According to the Government Accountability Office (GAO), the Corps' guidance (Engineer Regulation 1105-2-100) directs analysts to address the issue of prevention of loss of life when evaluating alternative plans, but they are not required to formally estimate the number of lives saved or lost as a potential effect of a project.

F.3.10 Braun, S. and Vartabedian, R. (2005). "The Politics of Flood Control," Los Angeles Times, December 25.

NEW ORLEANS -- When the U.S. Army Corps of Engineers and New Orleans levee officials joined forces in July 1985 to protect the city from a long-feared hurricane, the two agencies could not agree on how to proceed. It was the beginning of a dysfunctional partnership that ushered in two decades of chronic government mismanagement.

Corps engineers wanted to install gates in front of the city's three main internal canals to protect against violent storm surges from Lake Pontchartrain. The Orleans Levee District, the city's flood protection agency, preferred to build higher flood walls for miles along the canals. For five years, neither side yielded.

But in October 1990, a deft behind-the-scenes maneuver by the levee board forced the corps to accept higher flood walls. As Senate and House negotiators gathered to craft the Water Resources Development Act of 1990, Louisiana's congressional delegation quietly inserted a lobbyist's phrasing ordering the corps to raise the levee walls. "It was stealth; legislative trickery," recalled New Orleans lawyer Bruce Feingerts, who lobbied for the levee board. "We had to push every button at our disposal."

The gambit was a crucial victory over the Corps by the Orleans levee district, the most powerful and well-financed among 18 Louisiana boards that supervise more than 340 miles of storm levees across the hurricane-prone southern half of the state. The Corps had to abandon its floodgate plan and shoulder 70% of the project's costs while allowing the Orleans board to hire its own consultants to design the strengthened levees.

But their fractious partnership proved disastrous. While the Corps and the Orleans board settled into an acrimonious 15-year relationship, spending $95 million to buttress the city's canal levees, their shared supervision failed to detect crucial weaknesses inside the flood walls before Hurricane Katrina struck. "No one felt the urgency, none of us," said Lambert C. Boissiere Jr., a former Orleans levee commissioner. "The corps and our own engineers told us the levees were strong enough. They were all dead wrong."

Structural inspections were cursory. Maintenance was minimal. A confusing regulatory patchwork of ownership over the levees and canals blurred the lines of authority -- all shortcomings cited by independent engineering teams analyzing the levees' collapse.

Although the Corps and federal officials kept a tight leash on funding, the Orleans board spent money lavishly, diverting resources to high-stakes investments such as casinos and marinas. The levee board's unusual authority to hire its own consultants allowed its officials to select firms that regularly gave campaign contributions to politicians with influence over levee board business.

Left unchecked because of repeated failures by the Louisiana Legislature to reform the levee board system, critics say, the Orleans district operated its own patronage system. "The New Orleans board had the reputation of being one of the worst -- by worst, I mean more political than professional," said former Louisiana Gov. Charles E. "Buddy" Roemer III, a Republican whose Orleans board appointees launched the 1990 power play in Congress.

When Katrina hit in late August, floodwater from Lake Pontchartrain burst through the walls of the 17th Street and London Avenue levees, where steel foundations gave way in porous soil. Storm water also flowed through a 200-foot gap in the Orleans Avenue levee, a section left unfinished due to Bush administration funding cuts.

Last week, the corps announced plans to seal off the three broken canals with permanent barriers and relocate New Orleans' pump houses from inside the city to the lakeshore -- at a cost of $3.1 billion. The corps' move to abandon the old flood-control system it built with the Orleans board came as a bitter coda to a 20-year relationship.

<u>Least Cost Project</u>. Money was the most pressing concern in July 1985, when Orleans levee officials signed "assurances" -- an official commitment -- to join the corps in buttressing New Orleans' hurricane protection system. The Corps' traditional preference for a "least cost" project made floodgates a far more attractive option -- at $20 million -- than the $60-million estimate for raising the levees. We were caught between the [Reagan] administration saying keep the cost down, and Congress and New Orleans officials saying spend more," said Fred H. Bayley III, then the Corps' director of engineering for the Lower Mississippi Valley Division.

But the Corps' proposed "butterfly-valve gate" -- a concrete-and-steel barrier that would open to let out water and close to seal off storm surges -- was untested in high storm conditions. The corps' plan also clashed with the city's practice of using its system of antiquated pump stations -- two miles inside the city -- to force floodwater out into the lake through the canals. Officials with the New Orleans Sewerage and Water Board who supervised the canals feared that in a major hurricane, the gates would jam with debris and canals would back up, submerging the city.

Corps engineers had been fixated on floodgates since the 1970s, when the agency proposed using towering gates to block off surges at the far eastern end of the lake. That plan was the corps' response to Hurricane Betsy, a storm that hit New Orleans in 1965, swamping the city's Lower 9th Ward, killing at least 75 people and causing more than $1 billion in property damage.

Louisiana's congressional delegation, led by Democratic Sens. Russell Long and J. Bennett Johnston, won legislative approval for the barrier plan. But by the early 1980s, the project was shelved, scuttled by a judge's order, opposition by environmental and business groups, and bickering levee boards.

The Corps, convinced that raising levees was risky, shifted its plans, proposing to build gates at the lakeshore. Higher flood walls required deep sheet piles -- heavy-gauge steel foundations -- sunk into the soft coastal soil to brace against water pressure. To raise the levees properly, corps engineers warned that houses along the 17th Street and London Avenue levees might have to be razed. But the corps refused to absorb the costs, and the levee board shied from taking on neighborhood groups -- a pivotal early error.

Eager to show off their prototype, corps engineers herded city officials into the Army's cavernous Hydraulics Lab in Vicksburg, Miss. The hinged doors opened and closed easily. But city sewerage officials peppered the engineers with doubting questions. Indeed, according to a November 1987 Corps report, the "original design did not perform as intended." Only when corps engineers altered the model, "the gate design performed satisfactorily."

Despite the skepticism, Corps officials moved firmly to clear a path for the floodgate plan. The Corps ruled that it would not pay for raising the levees because the city's canals were used for local drainage, not navigation -- beyond the scope of the Corps' authority over river and waterway projects.

The decision forced Orleans levee officials to gamble. Although the corps refused to pay for raising the levees, the Lake Pontchartrain, La., and Vicinity High-Level Plan was still in its planning stages. Under the drawn-out design process, levee officials still had the ability to research their own alternative -- at the board's cost. They aimed to keep the levee-raising option alive by hiring their own design consultants, then using political leverage to win their levee-raising plan later.

<u>Involving Politics</u>. From the Orleans levee office on Stars and Stripes Boulevard to the governor's mansion in Baton Rouge, Louisiana's political veterans knew the unstated rules of the levee-building game. There were scores of qualified civil engineers in New Orleans, all angling to score lucrative public contracts. Many firms boasted former Corps engineers who knew how the Corps worked and had friends still in the service.

"The Corps had these relationships with the levee boards," Roemer recalled acidly. "In their conversations, the levee board would ask the Corps: 'What do we need to do to have safety and economic development?' And the Corps would give unofficial answers. Then the levee board would hire a consulting engineer and go to the window the Corps had opened. It was sweet."

Normally, the Corps used its own contractors to design and build flood-control projects. But with the Corps' approval, levee boards could hire consultants as a way to pay their 30% local share of a project's cost. In hindsight, said the Corps' commander, Lt. Gen. Carl A. Strock, the decision to let the Orleans board hire its own contractors was "an unusual practice for us." Some Corps veterans worried about the intrusion of local politics and budget complications. "Generally, when there were more layers involved, it got more difficult," Bayley said.

The political lines stretched to Louisiana's governors, who chose the majority of commissioners on local levee boards. In 1985, the power in Baton Rouge was Roemer's predecessor, Democratic Gov. Edwin Edwards, who had installed New Orleans lawyer Emile Schneider as levee board president. Schneider moved quickly. The board issued $50 million in bonds, then began hiring private engineers. The consultants were chosen on their qualifications. But politics and hiring sometimes mixed, said former commissioners.

All three engineering consultants who were selected by the Orleans board to design the levees contributed to the political campaigns of officials with sway over the board. Burk-Kleinpeter Inc., the engineering firm that designed the raised London Avenue flood wall, gave $5,000 to Edwards in 1991 before he won the 1992 governor's race. Walter Baudier also donated during the period that his firm, Design Engineering Inc., planned the Orleans Avenue levee. Baudier gave $2,200 to Roemer in 1987 and $3,000 to Edwards in 1991. "Everybody gave to everybody," Baudier said. "That neutralized any advantage."

Baudier's firm was also awarded a separate contract with the Orleans district, coordinating other levee board projects. Louisiana's legislative analyst criticized the arrangement in 1992, warning of potential conflicts between the firm's dual roles. Baudier insists his firm dealt only with financing and did not "review other people's designs." Levee board contractors also frequently gave campaign money to Francis C. Heitmeier, a powerful state legislator from New Orleans who has long wielded influence over Orleans levee district affairs. Among Heitmeier's donors from 1996 through 2002 were Baudier ($5,000), Burk-Kleinpeter ($10,000), and Modjeski and Masters Inc., an engineering firm that designed the 17th Street levee ($750). Officials with Burk-Kleinpeter and Modjeski and Masters did not return calls seeking comment.

For years, former Orleans levee officials say, Heitmeier, who headed the state Senate's public works committee and now its Finance Committee, was influential in levee board decisions on hiring, policy and contracts. Roemer was stymied by Heitmeier when he tried to reform the levee board system and wrest contracts away from local authorities. His "biggest battles," Roemer said, were with Heitmeier. Just last month, Heitmeier again played obstructionist, helping to snuff out a post-Katrina attempt by reformers to create a unified state levee board. Critics howled. Heitmeier shrugged. "They can say what they want," he said.

Questions About Depth. By 1990, faced with spiraling costs for its gates at the 17th Street canal, the Corps agreed to pay for raised levees there. But the Corps still insisted on gates at Orleans and London avenues. Even before the Corps made its concession, the board had acted on its own, hiring a construction firm to drive sheet piles at 17th Street.

The Orleans board's impatience with the Corps was shared by neighboring levee agencies. In recent years, Plaquemines Levee District President Benny Rousselle twice ordered crews to raise levees along a local highway despite formal Corps orders to desist. And earlier this year, the East Jefferson Levee District bolstered its side of the 17th Street levee by a foot and a half without the corps' approval. "When you deal with the Corps, it takes years of studies," Rousselle said.

Corps engineers were openly peeved in 1990 when they learned about the Orleans board's decision. The move posed "an undesirable situation for this office and the Corps," Bayley wrote to the corps' district commander. Bayley also warned that work crews were not driving the steel foundations deep enough. It was the first alarm about shallow sheet piles under the levee.

Despite the Corps' recent insistence that 17th Street's foundations were properly designed at 17 feet below sea level, a National Science Foundation team of engineering experts has described the pile depths as inadequate.

By autumn of 1990, the Orleans board had also quietly hired Bruce Feingerts, a former aide to Russell Long, to lobby in Washington for levee expansion. Feingerts had discovered that the levees of Orleans and London avenues might win federal funding if he could persuade Congress to expand the coverage of the post-Betsy hurricane plan passed in 1965. Sens. Johnston and John B. Breaux agreed to help, Feingerts said, as did most of the state delegation. When Senate and House versions of the 1990 Water Resources bill neared passage in October, Feingerts went into action. Johnston recalled that former Louisiana Rep. Jimmy Hayes was the "point man" as a House manager for conference negotiations.

Now a Washington lobbyist, Hayes did not respond to interview requests. But a former aide, Rhod Shaw, said he often aided New Orleans projects and "would have been carrying whatever the delegation wanted." The military engineers were "asleep at the wheel," Feingerts said. "If they had seen it coming, they would have blown a gasket." The final bill passed with his language intact: “The conferees direct the Corps to treat the outfall canals as part of the overall hurricane project.”

As new levee construction projects geared up at Orleans and London avenues, work crews at the 17th Street canal were struggling with construction obstacles. Unable to operate from the land side of the canal because property lines backed tightly up against the levee, construction crews had to maneuver by barge up the canal with a 300-foot crane to drive steel piles and raise the concrete wall.

Lakeview resident Bud Thaller stormed outside one day when his house began to shake violently. A levee crew driving foundations at 17th Street with a vibrating hammer had just struck a sandbar. The foreman shrugged when Thaller approached. He told me they were having a hard time getting the piles in, Thaller recalled.

Boh Brothers, a Louisiana construction firm, was the first of three companies to drive sheet piles under the levee walls. They were joined by concrete specialists, some working for the Orleans board, others hired by the Corps and the sewerage board. A parade of inspectors and engineers also crowded over the site, so many that “it could get confusing,” recalled Boh Vice President Dale Biggers, then a crew foreman.

The Corps was always the final authority -- even overseeing the number of hammer blows used to drive in the sheet piles. But on any given day, crews also had to coordinate with state and city officials and inspectors for Modjeski and Masters, the levee board’s design consultant. The question of who performed the inspections is crucial because engineering experts have had difficulty learning how on-site decisions were made.

“No one was in charge,” said Raymond Seed, a UC Berkeley engineering professor leading a National Science Foundation inquiry. Seed’s team has heard allegations that piles were deliberately shortchanged. The Justice Department is investigating.

Structural engineer Herbert J. Roussel Jr., who testified for a construction firm that sued the corps during one dispute, recalled Army engineers as dismissive: “The Corps had an attitude problem. It was: ‘We’re the Army Corps of Engineers. We know what we’re doing and you don’t.’ “

Levee board officials complained about excessive Corps delays. They were slow. We’d come up with a design, and the corps would always send them back,” Boissiere said.

Army engineers raised their own complaints. Baudier’s firm was removed as Orleans Avenue designer in 1992, accused by the Corps of missing deadlines. As sections of the flood walls were finished piece by piece through the mid-1990s, the levee board’s emphasis turned to the mundane chores of grass-cutting and maintenance. That left ample time for board business that had little to do with flood protection.

<u>Outside Interests.</u> When lawyer Robert Harvey was installed as the Orleans district’s president in 1992, the levee board was a recreation powerhouse. A year after Mississippi River floods swamped New Orleans in 1927, Louisiana political legend Huey Long had prodded the state Legislature to allow the Orleans board to expand its influence into parks, beaches and other “places of amusement.

By the late 1980s, the board operated an airport, two marinas and lakeshore rental properties, but the agency was hemorrhaging money. Leases went unfilled at the airport, and its South Shore Marina had too many vacant boat slips. Instead of scaling back, Harvey accelerated the board's outside interests. The tough-talking lawyer won his post after contributing $5,000 to the 1991 campaign of Gov. Edwards, an old friend. "It's a plum job," Harvey recalled. "Your connection with the governor is close. You have 300 employees, lots of contracts."

When Edwards pushed for state gambling -- a position that led to his federal corruption conviction in 2001 -- Harvey wooed the Bally's gambling empire to locate a casino boat at a dock owned by the levee board. The boat brought in millions in gambling taxes, but other Harvey projects fell flat. A flirtation with film studios went nowhere. A series of probes by the state auditor found cases of financial mismanagement, conflicts of interest and risky investments. At one point, six attorneys were working for the board without formal contracts. And Harvey was accused by the New Orleans Metropolitan Crime Commission of padding the levee board payroll with old friends. The controversies took their toll. Harvey resigned in 1995, followed by an FBI probe of his levee board tenure. "They didn't find anything," Harvey said.

His successor, James P. Huey, waded into his own controversies. Huey's board hired his wife's first cousin, George Carmouche, as a lobbyist in Baton Rouge. After Katrina struck, the board sublet a Baton Rouge office from Carmouche. And Huey pocketed nearly $100,000 in back pay, failing to first obtain permission from state lawyers. He returned the money after resigning under pressure. Huey, who did not respond to interview requests, is under investigation by state and federal authorities.

At the same time, the newly raised flood walls received haphazard scrutiny. Harvey recalls staring jealously at East Jefferson Levee District's well-trimmed border of the 17th Street canal, then at untamed foliage and trees massed along the Orleans levee wall. "I'd look at the Orleans side and get depressed," he said.

Neither the corps nor the Orleans board had a rigorous program for scanning for structural defects. Instead, the two agencies joined twice a year for five-hour-long inspection tours. A caravan of officials would make random stops along the floodwalls. Sometimes corps officials issued citations. Then they would head out for long lunches. "That was always on the agenda," said former Orleans commissioner Peggy Wilson.

On one tour, Wilson was joined by only one other levee board official. When they stopped briefly at the levees, corps officials seemed in a rush. "I kept asking them what I was supposed to look for, puddles of water?" she said. They said, 'Oh, don't worry.' The agencies relied largely on maintenance crews and neighbors to flag levee problems. "If something structural came up, we'd tell the corps," said retired Orleans levee board crewman Ed Robbins."

But at 17th Street, Corps engineers were a rare sight, recalled Eric Moskau, a commercial real estate agent who has lived near the flood wall since 2001. "I'd just see them driving out near the walls," Moskau said. "I always wondered exactly what they did out there."

<u>17th Street</u>. When Katrina's swells blew out huge chunks of 17th Street's cement wall on the morning of Aug. 30, Harvey was prepared for disaster. Years of interagency spats with the Corps and his own engineers had left him a skeptic. He bought an inflatable rubber boat and stored it in the attic of his house near the 17th Street levee. When floodwaters rose,

Harvey dragged down his boat and began rescuing neighbors. “Nobody wanted to go into a starvation mode and pay for real protection in the halls of Congress,” he said afterward.

Since 2001, the Bush administration had repeatedly turned down requests from the levee board and the Louisiana delegation for more flood protection. When Katrina struck, Orleans Avenue’s levee walls held firm. But when Walter Baudier, the levee’s original designer, drove out with another engineer to the canal weeks later, he was stunned to find a 200-foot gap between the levee wall and the pump station. The wall was left unfinished because of the government’s refusal to fund the project, according to the corps and levee officials. The gap allowed floodwater to flow freely into the city.

Near the breach at 17th Street, an 18-foot section of levee wall ended up in Moskau’s living room. Displaced to Idaho, Moskau returned weeks later to survey the damage. He hiked over hardened mud, gaping at the two-block-long rupture. Crowds of red-shirted corps engineers swarmed nearby, directing repairs. There were more engineers, he realized, than he had seen in the four years he had lived near the levee. The government was just like everybody who lived near the levee,” Moskau said later. “They took those walls for granted.

F.3.11 Vartabedian, R. and Braun, S. (2006). “Fatal Flaws: Why the Walls Tumbled in New Orleans,” Los Angeles Times, January 17.

NEW ORLEANS -- In the frantic days after Hurricane Katrina, the Army Corps of Engineers scrambled to plug a breach on the 17th Street levee, dropping massive sandbags from a fleet of helicopters. But the engineers were baffled: The sandbags kept disappearing into the watery breach. The pit eventually swallowed 2,000 sandbags, each weighing between 3,000 and 20,000 pounds. It was an early sign that the hurricane had opened an extraordinarily deep hole in the foundation of the storm wall, pointing to a fundamental breakdown in the engineering of the city’s levee system.

Investigators recently told The Times that the 17th Street levee failed because its engineers made a series of crucial mistakes, one of which was to base the levee design on the average strength of the soil rather than on the strength of its weakest layer. The errors may reflect a loss of expertise during the 1990s, when the corps sharply downsized its soil laboratories. The faulty soil analysis is one of many defects or flaws in concept, design, construction and maintenance that left many of the levees in New Orleans especially vulnerable to Katrina. Environmental miscalculations, including the loss of natural protection from marshes, added to the problems. The errors might have been offset had the corps required larger safety margins, and that raises questions about the corps’ internal culture.

Although the levees’ shortcomings became apparent shortly after the hurricane hit, experts are only now pinpointing the underlying causes of the collapses. What they find will determine who bears the political and legal responsibility for the flood and provide a technical basis for any future levee system to protect New Orleans from a monster storm. The levee failures were among the most costly engineering errors in the United States, measured by lives lost, people displaced and property destroyed, said half a dozen historians and disaster experts.

Katrina flooded New Orleans with about 250 billion gallons of water and killed more than 1,000 people. “I don’t think there is anything comparable in recent American history,” said retired engineering professor Edward Wenk Jr., a science advisor to three presidents and investigator of the Exxon Valdez accident.

Early blame for the levee failures has fallen largely on the Army Corps of Engineers, the principal architect of a 40-year project to protect New Orleans from hurricanes. Corps officials say they will accept responsibility for the failures if investigations prove that their supervision of the system was deficient. “What I don’t think we understand yet is the forces that caused those failures,” said Lt. Gen. Carl Strock, corps commander and its chief of engineers. “A failure is really where a design does not perform as intended. If forces we designed for were exceeded, there may not be a design failure.

However, a preliminary report funded by the National Science Foundation has found evidence of design flaws in the city’s concrete storm walls, where at least six catastrophic failures caused half of the flooding. A handful of technical, civil and criminal investigations are underway, including an effort by the Justice Department to look for possible criminal negligence. The corps is conducting the federal government’s official investigation, despite widespread concern that only an independent board of investigators is likely to be impartial.

The corps was slow to make public all of its engineering paperwork on the levees and has still not produced a full record of the internal correspondence that occurred during the last 15 years. Moreover, it is not examining what role its organization and culture played in technical lapses, which, Wenk said, typically are at the root of engineering disasters. The corps says it has addressed those concerns by recruiting outside experts to participate in its investigation. The agency is expected to make its final report in June.

The corps is attempting to temporarily repair 50 miles of damaged levees before the hurricane season next June. The Bush administration announced last month it would spend $3.1 billion for temporary levee repairs and limited upgrades in the next several years. However, many local leaders believe the levee system must be strengthened to withstand the strongest possible hurricane -- a Category 5 -- to restore full confidence in the city. Katrina, a Category 5 storm over the Gulf of Mexico, weakened to a Category 3 by the time it hit New Orleans.

Making his ninth visit to New Orleans since Katrina struck, President Bush last week praised the $3.1-billion initiative but said nothing about Category 5-level protection. And, according to the corps, even the temporary repairs and limited upgrades will not protect the city from another Category 3 storm, which has winds up to 130 mph and storm surges as high as 12 feet above normal.

Meanwhile, more than four months after the hurricane, investigators are still coming to grips with the levee system’s technical failures and shortcomings that paved the way for Katrina’s destruction.

Weak, Slippery Soil. No levee failure was more dramatic than the breach at the 17th Street Canal, where a 465-foot section of concrete wall gave way Aug. 29, flooding the affluent Lakeview section of New Orleans. Floodwaters were 3 to 5 feet below the top of the levee wall when it collapsed. The soil under the levee, composed of layers of loose clay and softer organic peat, was too weak to handle the weight of the water pushing against the levee walls.

The earthen base of the levee slid backward by about 45 feet, taking the concrete storm wall along for the ride. The whole system relied in part on heavy-gauge steel beams, called sheet piling, driven into the soil for reinforcement. But they only went to a depth of 17 feet below sea level, not deep enough to provide a strong foundation, National Science Foundation investigators say.

In rebuilding the damaged sections of the canal levees, the corps is sinking sheet piling 45 feet, and in some areas is using heavier gauge piling up to 70 feet deep. The corps says the deeper piles are needed because soil in the damaged areas is even weaker than before Katrina.

The levee design was overseen by the corps but assigned to two firms: Eustis Engineering, which analyzed the soil under the levee; and Modjeski and Masters Consulting Engineers, which did the structural design. (Neither firm returned phone calls seeking comment.). The levee design depended on crucial soil measurements along the canal that began in 1981. Technicians drilled for soil samples 300 to 500 feet apart to measure the strength of the soil.

The soil tests provided accurate and complete data about the weak soils, but government and private design engineers made three crucial errors analyzing the information, said Bob Bea, a UC Berkeley engineering professor who is part of the National Science Foundation investigating team. First, engineers determined the overall strength of the soil by averaging different layers and different sections along the banks of the canal. But it was the weakest layers of soil that would determine the overall strength, and using the average gave the engineers a false confidence, Bea said.

Second, the levee design failed to account for the fact that the soil would weaken significantly once the canals were full of water and the soil became saturated, Bea said. Soil tests conducted before the levees were built showed the soil's shear strength was about four times greater than after Katrina. The engineers incorrectly believed that sediment in the canals would prevent water from intruding through foundations, but dredging and other activity disturbed that natural seal, he said.

Finally, the engineers miscalculated how the levee foundation could slide, if it did fail. They assumed the greatest risk of failure was in one of the stronger layers of soil, whereas it failed in a weaker layer.

Since Katrina, the corps has proposed installing storm gates that would seal off the 17th Street Canal, along with the city's two other major drainage canals. Once the canals were sealed off from Lake Pontchartrain, hurricane surges would no longer be able to travel through them into the heart of the city.

Not long after construction started on the levee, signs of trouble popped up. The company that built the 17th Street storm wall, Pittman Construction, warned the corps in the early 1990s that the pilings were unstable and had caused problems during construction. The company filed a claim for more money but lost its case. "Pittman told the corps he was concerned about the weak soils," said Herbert Roussel, a consulting engineer hired by the company's owner, A.E. Pittman. "The corps acted as though it was his problem."

Loss of Expertise. As questions about the soils were being raised, the corps shut down its soils lab in the New Orleans district and curtailed its geotechnical research lab in

Vicksburg, Miss. The labs had long performed crucial soil analysis and research for projects around the country, but the corps' leadership wanted staff engineers to oversee outside contractors, said Bill Marcuson, the former director of the New Orleans soils lab and president-elect of the American Society of Civil Engineers.

"That trend leads to less in-house capability and competence," Marcuson said. "If the corps is not physically doing research, it is hard to evaluate the quality of others' research." Strock said the moves were part of a larger federal government trend to save money by turning over work to the private sector. He conceded that the practice "eroded our technical capability," but said the damage was limited.

But Bea countered that the agency lost significant technical capability, particularly in its large civilian workforce. "They don't have the number of people or the quality of people that they used to," said Bea, who began his engineering career with the corps.

Levees Without Armor. Along many levee sections, particularly those on the waterway known as the Industrial Canal, water poured over the tops of storm walls and cascaded down the backside, scouring and weakening the foundations. Eventually, the walls collapsed. If they had remained standing, they would have acted as a buffer and slowed the pace of flooding.

The levees could have survived the overtopping if the backs of the walls had had concrete or heavy stone pads at their base, a protection known as "armoring." Some of the storm walls in New Orleans were built with armored foundations and significantly stronger sheet piling, known as T-walls. Those levees did not fail and incurred far less damage during Katrina.

The corps generally assumed that hurricane flood waters would not rise high enough to spill over the levees. But most outside experts say that assumption was a mistake. "There are only two kinds of levees: those that have been overtopped and those that will be overtopped some day," said Gerald Galloway, a levee expert at the University of Maryland. He added that armoring "is not cheap or simple."

The corps is replacing some failed sections of levees with T-walls. Brig. Gen. Robert Crear, the corps' district engineer in New Orleans, said the agency was preparing to armor many levees under the $3.1-billion rebuilding program. The armoring will include placing beds of rock or concrete at the base of the walls to prevent erosion in future storms.

Thin Safety Margins. Doubts about the corps' oversight have also flared over the low margin for error designed into the canal floodwalls. Engineers design structures to withstand forces far greater than the maximum anticipated loads to compensate for uncertainties in their own understanding and for possible defects in construction.

According to Wenk, the engineering expert, public structures typically have safety margins as high as four, meaning they are four times as strong as it is anticipated they will need to be. Corps documents indicate that engineers approved a margin of 1.3 for the floodwalls. That meant the walls were designed to be 30% stronger than the maximum stress expected from a hurricane flood surge. Wenk said he was astounded by such a low factor, particularly for a system that protected such a large urban area.

Strock agreed that the issue needed close attention. "I was not aware before this event that the factor was 1.3," he said. Critics have questioned whether the corps devoted sufficient attention to safety, and Strock acknowledged that the low safety margins "may get back to the cultural issue."

Overgrown Trees, Brush. Years of neglected maintenance in southern Louisiana may have contributed to the heavy flooding, engineering experts said. The growth of large trees near the 17th Street Canal levee may have helped undermine the floodwall. Katrina's strong winds blew down a massive oak near the levee breach and investigators believe the roots of the tree pulled out a large plug of soil from the embankment.

The Orleans Levee District is responsible for maintenance and employs work crews to trim grass along the levee slope. But trees and bushes sprouted from the yards of private homes near the breach site and were left untrimmed for years because of opposition from homeowners and the failure of levee officials to move aggressively. The Orleans Levee District could have taken action, critics say. Just across the 17th Street Canal, the levee wall owned by the neighboring East Jefferson Levee District is regularly shorn of trees and heavy brush. "It is a major concern," said Jim Baker, superintendent of operations for the East Jefferson Levee District. "If you have a tree blow over, it can open up a good size hole. I don't like trees growing on our levees."

Lost Wetlands Barrier. Closer to the Gulf of Mexico, a different kind of environmental miscalculation also contributed to the disaster. Environmentalists, political leaders and engineers warn that decades of neglect and corps-sponsored dredging led to the disappearance of vital wetlands, allowing hurricane storm surges to threaten New Orleans.

When Hurricane Katrina roared up the Gulf of Mexico, it spawned a storm surge toward New Orleans through a navigation channel known as the Mississippi River Gulf Outlet, or MRGO. The outlet was built from marsh and wetlands by the corps in the early 1960s to allow large ships quicker access to the Port of New Orleans. Originally designed as a 300-foot-wide channel, the outlet has widened to more than 3,000 feet, the result of repeated dredging by the corps and of ships' wakes.

You can put more surge through a wider body," said Thomas Sands, a retired corps general who headed the New Orleans district. "When I was district engineer, the erosion along the MRGO was horrible." The project also allowed salt water to penetrate and destroy hundreds of square miles of wetlands that acted as a natural flood barrier.

Henry "Junior" Rodriguez, president of St. Bernard Parish, said that the heavy flooding that topped his community's levees during Katrina was far worse than during Hurricane Betsy in 1965. "Listen, we didn't even have levees during Hurricane Betsy and the flooding wasn't as bad," Rodriguez said.

After Katrina, the corps has pledged to halt dredging of the MRGO for at least a year and is considering proposals to scale it back. The agency is also proposing to channel sediments and freshwater into the marshes to reduce future wetlands losses, though the National Research Council recently termed the current proposals inadequate.

We will never be able to rebuild the coast we had 50 years ago, but the wetlands still out there can be preserved," said Carlton Dufrechou, executive director of the Lake Pontchartrain Basin Foundation, a leading environmental group in the region. "If we do nothing, the gulf will be lapping at the edges of New Orleans in future decades," Dufrechou said. “And if the MRGO stays open, you might as well put a bull’s-eye on the city and tell everybody to clear out on June 1 when the hurricane season starts.

F.3.12 Irons, L. (2005). “Hurricane Katrina as a Predictable Surprise,” Homeland Security Affairs, Vol. I, Issue 2, Article 7, http://hsaj.org/hs a.

How can a surprise be predictable? Paradoxically, many people think low-probability events are just that: low probability; not impossible but very unlikely. People find it difficult to sustain a high level of preparedness for events that are unlikely to happen on any given day, especially if the preparation requires spending scarce time and resources. As Max Bazerman and Michael Watkins observe in their recent book, Predictable Surprises: The Disasters You Should Have Seen Coming, And How To Prevent Them, ‘We don’t want to invest in preventing a problem that we have not experienced and cannot imagine with great specificity.

Bazerman and Watkins outline four major characteristic traits of predictable surprises.

1. Leaders know problems exist and will not solve themselves.
2. Organizational members realize a problem is getting worse.
3. Fixing the problem requires significant cost in the present with no immediate benefit (rewards for avoiding the costs of prevention are uncertain but potentially larger than incurring the costs).
4. Humans tend to maintain the status quo if it functions (minorities protect their own interests, subverting efforts by leaders to implement change.

One basic lesson to learn from Hurricane Katrina is that organizations managing preparedness for flood control and hurricanes, such as the U.S. Army Corps of Engineers, as well as organizations managing responses to disasters, such as FEMA, can benefit from developing learning organizational processes. Those same processes make it more likely that staff will avoid surprises by recognizing them, prioritizing the challenges, and mobilizing resources to prevent them from developing.

A basic step in preparing an organization to use the affect of its people to enhance their efficiency and effectiveness is for its leadership to admit that it is not perfect, that operations require continuous improvement. Professional criticisms of operational performance must flow up the organization as well as down, with the organization encouraging such contributions. Indeed, a learning organization does the following:

- defines a clear mission, designed to inspire workers to do their best;
- creates a culture that emphasizes professionalism;
- provides top-notch technical training;
- provides leadership development for managers;
- pushes responsibility down the ranks so employees in the field are authorized to act quickly; and
- advocates continuous improvement.

Learning organizations are challenges to promote a level of awareness sufficient to enable surprise-avoidance capability from their members. Indeed, the structure of large and complex organizations increases the difficulty leaders' face in anticipating predictable surprises. As the complexity of organizations, or even project teams, increases, the way expertise is coordinated tends to develop into silos. Organizational silos often disperse responsibility as well as information. In other words, organizational silos encourage staff to 'let someone else' deal with recognized problems, essentially supporting surprise-conducive processes.

Leadership is a key point of interest when considering the way organizations attempt to avoid, or mitigate the impact of, predictable surprises. There is little dispute of the point that local, state, and federal leaders knew about the vulnerability of the New Orleans' levee protection system and the threats it posed to the city. Although some officials initially claimed that non one expected the levees and flood walls in New Orleans to collapse, most experts knew about the vulnerability for many years.

The evidence indicates the U.S. Army Corps of Engineers knew about the threat of breaches, as opposed to overtopping, since the early 1980s. Moreover, all concerned agencies, including those at the local, state, and federal levels, knew about the threat of overtopping and consequent flooding in even a Category 3 hurricane.

Improving the levee and floodwall system in New Orleans was a recognized challenge for decades, as was the challenge of a receding delta providing less protection to the New Orleans area from storm surges resulting from a hurricane. The Breaux Act of 1990 created a task force involving several federal agencies and gave it the mission of restoring wetlands. The task force received only forty million dollars per year to stop the erosion of the delta. A University of New Orleans study estimated the effort averted only about two percent of the overall loss, leaving an erosion rate of twenty-five square miles of delta per year.

Basic flaws in the design of the levee protection system were first recognized over two decades ago, before the wetlands were so diminished. An outside contractor, Eustis engineering, was the first to express concerns about the levee vulnerability to breaching in the early 1980s. In 1981, the New Orleans Sewerage & Water Board developed a plan to improve street drainage by dredging the 17th Street Canal. The Corps of Engineers issued permits to do the dredging in 1984 and 1992, though the Corps was not a partner in the Project. Eustis Engineering contracted to do a design study for Modjeski and Masters, the consulting engineers on the project, and performed soil investigations on a section of the 17th Street Canal from south of the Veterans Memorial Boulevard bridges to just north of those structures. They found that 'the planned improvements to deepen and enlarge the canal may remove the seal that has apparently developed on the bottom and side slopes, thereby allowing a buildup of such pressures in the sand stratum.' Eustis' concerns about a 'blow-out', or breach, of the levee were strong enough that the company recommended test dredging before the final design. the company recommended that, without test dredging, the bottom of the canal needed sealing with a concrete liner or building a seepage cutoff wall, like sheet pilings, to a depth of 65 feet below sea level versus the existing 12 feet. Engineers studying the levee breaches consider the report by Eustis significant because the stretch of canal the firm studied is widely considered to exhibit stronger soil layers than those that breached during Hurricane Katrina.

The most puzzling point about the dredging project is that the Corps of Engineers planned to follow the project by raising the floodwall from 10 feet to 14.5 feet. It is unclear whether the Corps paid attention to the contractor's concerns since most of the documents related to the work remain unavailable to the public. Although the Corps of Engineers was not a direct partner in the dredging, it was aware of the work and knew it would have an impact on its later project. Indeed, contractors working for the Corps on the later project raised their own concerns about the soil and foundations of the levee.

Reports indicate that key sections of the levee system's soil and foundation, particularly the floodwall on the 17th Street Canal where much of the serious flooding occurred, posed serious problems for the contractors involved. Court papers from 1998 show that Pittman Construction indicated to the Corps of Engineers as early 1993 that the soil and foundation for the walls were 'not of sufficient strength, rigidity and stability' to build on. The construction company claimed that the Corps of Engineers did not provide it with complete soil data when it developed a bid on the levee project.

Though the construction company lost its suit against the Corps of Engineers, the gist of their complaints about the condition of the soil and existing foundation was not disproven. Engineers now say the difficulties Pittman Construction faced were early warning signs that the Corps of Engineers ignored.

The Corps of Engineers officially disputed the points made by Pittman Construction regarding the soil condition, though it now seems clear that the crucial breaches in New Orleans occurred in levees where the floodwall foundations were not as deep as the canals and that the Corps of Engineers was aware of the issue. The soil then allowed water to percolate under the levee and floodwalls, weakening the structure so that the storm surges from Hurricane Katrina moved it entirely, or breached it. Would an organization with processes in place to support ongoing learning, and surprise-avoidance, fail to recognize the legitimacy of the contractor's point rather than argue about purely budgetary issues related to the contract?

The U.S. Army Corps of Engineers is historically an insular agency, known for doing things its own way. It is not possible to say whether surprise-avoidance processes are in place at the Corps of Engineers, until the public receives more access to internal documents. The failure of Corps' staff to recognize and prioritize the challenges of levee upgrades and receding wetlands to the city of New Orleans, and surrounding areas, strongly suggests that surprise-conducive processes characterize its organization. the Corps' organization has over the past few decades outsourced more work, lost many engineers to private industry, and consequently suffered a diminished capacity to attract top-notch engineers.

Bazerman and Watkins note that predictable surprises play out over long time frames, sometimes longer than the typical tenure of organizational leaders. They contend 'this creates a variation on the free-rider problem. Why, a leader might ask, should I be the one to grapple with this problem and take all the heat when nothing is likely to go wrong during my watch? In other words, members of the U.S. Army Corps of Engineers, conceivably, made a collective bet that the unlikely occurrences that, in fact, did end up happening, were not worth the expense, form a professional or organizational initiative point of view. …The sheer magnitude of the problems faced in the New Orleans levee protection system probably appeared overwhelming to members of an organization enduring ongoing budget concerns and staff turnover.

Consider the scale of the plans offered to fix the levee challenges: a plan floated in early 2001 involved two to three billion dollars proposed to divert sediment from the Mississippi River back into the delta, rather than allow the sediment to wash down the levee system and dump into deep water. The project was compared to the four billion dollar restoration initiative for the Florida Everglades. However, these projects are typically funded through matching grants in which the state has to match a federal dollar with one of its own. Louisiana was only able to match each dollar with fifteen to twenty-five cents. Facing the scale of such a challenge, and the state's limited ability to pay for its share of the costs, the response of most people was to maintain the status quo. the result was a catastrophic disaster that cost many times the few billion dollars needed to initiate a full-scale rebuilding program for the levee protection system and the surrounding wetlands. Essentially, those responsible for the levee protection system in New Orleans saved money in the short term only to permit one of the largest disasters in American history to occur over the long haul.

The U.S. Army Corps of Engineers currently finds its authority questioned by many, not because of the competence of its engineers' expertise, but rather due to concerns about its organizational processes that allowed such basic design flaws to go without sustained questioning by engineers exercising professional judgement.

New Orleans had dodged the bullet many times, with the major force of hurricanes skirting around the area. Nevertheless, most people with a reason to know about it were aware that a Category 3 hurricane posed a severe threat to the New Orleans' levee protection system, and a Category 5 hitting land as a Category 4, as with Katrina, posed a catastrophic threat.

The occurrence of a hurricane like Katrina was not unexpected in New Orleans; neither were the complications faced in the aftermath of the storm. Given this understanding, and the neglect in preparing for a hurricane like Katrina, as well as the ineffective response preparations, it seems reasonable to assert that Katrina as well as its aftermath was a predictable surprise. The threats posed by the hurricane, and the likely aftermath, were well known and unsurprising to most who thought about the hurricane threat to New Orleans. Unfortunately, much of the local, state, and federal leadership, especially the U.S. Army Corps of Engineers, appears to have remained complacent about preparing the levees for a catastrophic hurricane.

F.3.13 Congressional Research Service Report for Congress (2005). *Protecting New Orleans: From Hurricane Barriers to Floodwalls*, N. T. Carter, Washington DC, December.

Understanding why New Orleans' hurricane protection system failed is essential for moving beyond simply making repairs to damaged levees and floodwalls. Knowing why the floodwalls failed is central to assessing the city's vulnerability to storm surge flooding and deciding on how to most effectively combine approaches for managing flood risk during rebuilding efforts (.e.g, investing in coastal wetlands loss and hurricane protection infrastructure, requiring flood-proofing in certain areas, and mapping areas for the federal flood insurance program.

The original design of the Lake Pontchartrain project was sent to Congress in July 1965. The project was designed to protect the city from a standard hurricane for the region, which was roughly equivalent to a Category 3 hurricane on the Saffir-Simpson Scale. The standard hurricane was defined as high sustained wind speeds reasonably characteristic for a specified coastal location. Reasonably characteristic was defined as only a few hurricanes on record over the general region had been recorded to have more extreme wind and other meteorological characteristics. The standard hurricane was determined by the U.S. Weather Service.

Two months later in September 1965, Hurricane Betsy, a Category 3 hurricane, struck Louisiana's coast, causing damage in New Orleans. Congress authorized construction of the Lake Pontchartrain project in the Flood Control Act of 1965, enacted in October 1965. Modifications to the authorization have been made in subsequent legislation. Since that original design, there have been two major developments in the project relevant to current investigations into the floodwall failures: (1) the shift from the barriers at the inlets to Lake Pontchartrain to higher levees along the lake; and (2) the shift from floodgates at the mouth of the city's storm water outfall canals that drain into Lake Pontchartrain to higher floodwalls along the length of the canals.

The original July 1965 Lake Pontchartrain project design consisted of the Barrier Plan for constructing inlet barriers at Lake Pontchartrain's three main tidal entrances as well as levees and floodwalls for surge protection. The barriers generally would remain open and allow for navigation, and would close during coastal storms to reduce storm surges from entering the lake. Based on updated weather data and experience learned during the city's flooding in September 1965 by Hurricane Betsy, changes in project were sought before construction began. For almost two decades, technical issues, environmental concerns, legal challenges, and local opposition to various components slowed construction.

The design that the Corps eventually chose was the High-Level Plan which consists of higher levees and floodwalls, instead of the originally planned inlet barriers and lower levees and floodwalls. The change from the Barrier Plan to the High-Level Plan was approved by the Corps chief of Engineers in February 1985; both the barrier and the high-level plans were designed to protect from the rough equivalent of a fast-moving Category 3 hurricane. The Chief's decision to adopt the High Level Plan was based on a 1984 project reevaluation study conducted by the agency in response to a 1977 court injunction on the construction of inlet barriers until an adequate Environmental Impact Statement (pursuant to the National Environmental Policy Act of 1969 P.L. 91-190) was completed. the reevaluation study recommended the change because 'the High level Plan has greater net benefits, is less damaging to the environment, and is more acceptable to the public' than the Barrier Plan.

To drain the city of storm water (i.e., accumulated rainfall), the city pumps water into three outfall canals - the 17th Street canal, the Orleans Avenue canal, and the London Avenue canal - that flow into Lake Pontchartrain. The pumps are located at the southern ends of the canals, away from the lake. To protect the city from rising water in Lake Pontchartrain during hurricanes, levees were built along the length of the canals. The levees along the outfall canals were considered adequate when the Corps developed the original design for the Lake Pontchartrain project that was sent to Congress in July 1965.

Subsequent to the U.S. Weather Bureau's adoption of a more severe standard hurricane for the region, the Corps determined that the levees along the outfall canals were inadequate in their height and stability to protect the city from the standard hurricane. The Corps eventually integrated hurricane protection for the canals into its Lake Pontchartrain project. The Corps considered improved canal protection necessary regardless of the selection of the Barrier or High-Level Plan. The two basic canal options evaluated were: ‘butterfly’ floodgates at the mouths of the outfall canals that would close when water levels in Lake Pontchartrain exceeded levels in the canals (known as fronting protection); and higher and stronger levees and floodwalls along the canals (known as parallel protection).

The Orleans Levee District and the Sewerage and Water Board of New Orleans favored parallel protection over floodgates; they were concerned that the operation of the butterfly floodgates would reduce the ability to pump storm water out of the city during storms. The Corps analyzed the options and recommended parallel protection for the 17th Street Canal; in contrast, the Corps recommended butterfly flood gates for the Orleans and London Avenue canals. The Corps concluded that the butterfly floodgate plan for the London Avenue canal ‘fully satisfies the project’s mandate to provide protection against the hurricane generated tidal surges and yet provides the maximum latitude for operation of local interest interior drainage (i.e., storm water removal). The butterfly control valve plan has been shown to be the least costly fully responsive plan. When compared to the parallel protection plan it is approximately three times less costly’.

The conclusion for the Orleans Avenue canal was similar; the Corps found the butterfly gates to fully satisfy the project purpose of hurricane storm surge protection and to be one-fifth the cost of parallel protection.

Rather than having the Corps proceed with construction of the butterfly floodgates, the Orleans Levee District decided to construct on its own most elements of the parallel protection on the Orleans and London Avenue canals. this local construction was designed in accordance with Corps criteria, so that the parallel protection would be incorporated into the larger Lake Pontchartrain project. The Corps recommended that the federal cost-share contribution for the parallel protection of the two canals be capped at 70% of the less-costly butterfly floodgates design. In H. Rept. 101-966, the Conference Report for the Water Resources Development Act (WRDA) of 1990 (P.L. 101-640), Congress directed the Corps to consider favorably parallel protection for the two canals and for the federal government to bear part of the costs, but did not specify what percentage of the cost. This report was followed by the Energy and Water Development Appropriations Act of 1992 (P.L. 102-104) in which Congress stated: ‘The Secretary of the Army is authorized and directed to provide parallel hurricane protection along the entire lengths of the outfall canals and other pertinent work necessary to complete an entire parallel protection system, to be cost shared as an authorized project feature, The Federal cost participation in which shall be 70 percent of the total cost of the entire parallel protection system, and the local cost participation in which shall be 30 percent of the total cost of such entire parallel protection system’.

Concerns about levee and floodwall reliability are compounded by concerns about the level of protection provided by the existing infrastructure given New Orleans’ increasing vulnerability to hurricane storm surge. Land in the city has subsided; barrier islands and wetlands have been disappearing; and sea levels have risen. These factors have raised concerns about the ability of the city’s infrastructure to provide Category 3 protection. According to the project justification sheet included in the Administration’s Corps FY 2006 budge request, ‘the project was initially designed in the 1960s, and a reanalysis was performed for part of the project in the mid-1980s. Continuing coastal land loss and settlement of land in the project may have impacted the ability of the project to withstand the design storm.' The challenge of protecting New Orleans could become even greater. According to some scientists, higher sea surface temperatures may result in increased hurricane intensity. Climate change concerns and other factors have raised questions about whether both estimates of the likelihood of hurricanes of various strengths and past infrastructure investment decisions based on these estimates need to be reevaluated.

Hurricane Katrina has resulted in some questioning why a Category 4 or 5 hurricane protection system was not in place for New Orleans, and whether it should be part of the rebuilding effort. The Corps currently only as congressional authorization for a Category 3 system; additional congressional authorization would be necessary to build a more protective system Discussions of Category 4 or 5 protection for the city often include the extent to which coastal wetlands restoration may play a role in reducing the city's vulnerability to storm surge and whether some of the regional navigation improvements may increase storm surge vulnerability. these discussions raise broader policy issues related to the appropriate level of investment to protect against low probability-high consequence events; to protect against loss of life and economic disruption; and whether structural storm and flood control measures provide a false sense of security in vulnerable areas like New Orleans. The corps' cost estimates are $1.6 billion to return coastal Louisiana's federal levees and floodwalls to pre-Katrina conditions by June 2006, and an additional $3.5 billion to increase protection for New Orleans from Category 3 to Category 5. State officials have estimated the cost of Category 5 protection and wetlands restoration for all of coastal Louisiana as high as $32 billion. Most local stakeholders argue for the inclusion of coastal wetlands restoration in any plan to improve hurricane protection.

Understanding why the hurricane protection system failed in New Orleans is essential to moving beyond simply making repairs, to identifying and reducing vulnerabilities in the system, addressing coastal wetlands loss, and rebuilding the city. Nonetheless, the Corps is having to proceed with available information in order to perform repairs to the failed floodwalls and other breaches to meet the June 2006 deadline, which marks the start of the hurricane season. Consequently, congressional oversight of New Orleans' hurricane protection is likely to continue as the nation grapples with decisions on what type and level of hurricane protection to provide New Orleans and other coastal areas around the nation, and who should bear responsibility and costs for protection in coastal, floodplain, and other hazard-prone areas.

F.3.14 Congressional Research Service Report for Congress (2005). *Flood Risk Management: Federal Role in Infrastructure,* N. T. Carter, October, Washington DC.

The U.S. Army Corps of Engineers is responsible for much of the federal investment in flood control and storm protection infrastructure. Corps involvement in flood control construction is predicated on the project being in the national interest, which is determined by the likelihood of widespread and general benefits, a shortfall in the local ability to solve the water resources problem, the national savings achieved, and precedent and law.

The 100-year flood standard was established at the recommendation of a group of experts in the late 1960s. 'It was selected because it was already being used by some agencies, and it was thought that a flood of that magnitude and frequency represented a reasonable probability of occurrence and loss worth protection against and an intermediate level that would alert planners and property owners to the effects of even greater floods. The adoption of the 100-year flood standard in many respects guides perceptions of what is an acceptable level of vulnerability. The 100-year flood standard is a vulnerability standard, and not a risk standard. Thus, the question of does the 100-year flood standard combined with threat and consequence information result in an acceptable level of risk remains largely unaddressed; this question is especially relevant for low probability, high consequence events such as a Category 4 hurricane hitting a major urban center.

Attempting to provide at least 100-year flood protection largely drives local floodplain management and infrastructure investments, resulting in a measure of equity within and across communities. That equity in vulnerability, however, results in uneven levels of risk because flooding of different communities has different consequences, such as differences in the potential loss of life, social disruption, structures damaged, and economic impact because of variations in land use and development patterns.

The residual flood risk behind levees or downstream of dams remains largely unaccounted for in the National Flood Insurance Plan and often is not incorporated into individual, local, and state decision-making. Residual risk is the portion of risk that remains after flood control structures have been built. Risk remains because of the likelihood of the measures' design being surpassed by floods' intensity and of structural failure of the measures. Often when the designs of flood control structures are surpassed or when structures fail for other reasons, the resulting flood is catastrophic, as shown by the floodwall breaches in New Orleans (LA) with Hurricane Katrina. The consequences of floods increase as development occurs behind levees and below dams; ironically, this development may occur because of the flood protection provided. The nation's risk of low-probability events (e.g., 150-year flood, or Category 4 hurricane) having high-consequences in terms of lives lost, economic disruption, and property damage is increased by overconfidence in the level and reliability of structural flood protection for events that are less probability than the 100-year flood.

The risk posed by low-probability events may be underestimated by the current methods for analyzing flood control investments. The benefit-cost analyses compiled to support federal decision-making for water resources projects focus on the 'national economic development benefits' of investments; regional, social, and environmental benefits may be analyzed but often are largely excluded from the decision-making. Moreover, the Corps generally limits its benefit-cost analyses of the consequences of flooding to damages. That is, estimated benefits from flood control infrastructure investments are primarily the avoided losses to existing structures and land uses.

The Corps' benefit-cost analysis of a project may result in a recommended plan for flood control infrastructure providing for protection greater than or less than the 100-year flood. Local project sponsors can request that a 'locally preferred alternative' be built, instead of the plan identified by the benefit-cost analysis. The National Flood Insurance Plan creates incentives for communities to support flood control alternatives providing at least the 100-year level of protection, but the program provides few incentives for more protection. For some local leaders and communities, the financial capital required to cost-share a Corps flood control project may represent a barrier to pursuing greater protection.

The Corps' benefit-cost analysis does not constitute a comprehensive risk analysis, because the consequences considered are largely limited to property damage, leaving out other potential consequences, such as loss of life, public heath problems, and economic and social disruption. ..Although potential loss of life is noted in Corps feasibility reports, there are no Corps regulations or guidelines for how to incorporate loss of life into the agency's benefit-cost analyses. …Therefore, although preventing loss of life is a goal of federal flood control policy, current practice results in property damage being the primary consequence metric used for making Corps flood control investment decisions. A related benefit-cost analysis issue commonly debated is whether there is a bias toward lower levels of flood protection for low-income communities due to their lower property values. another commonly debated issue is whether there is a bias toward structural flood control measures over nonstructural options (e.g. buyouts of structures in flood-prone areas).

Because the Corps' benefit-cost analyses are focused on damages, the Corps projects funded in the Administration's FY 2006 request are those that reduce the most damages per dollar spent, which may not be the projects most efficient at reducing risk more broadly. Also, the remaining benefits to remaining costs (RB/RC) metric is used for multiple types of Corps water resources projects - navigation, flood control, and storm protection. Because the Corps benefit-cost procedures vary by project type, comparisons of the RB/RC ratio of navigation projects, flood control, and storm protection projects may be misleading, especially if significant benefits derived from projects, such as the potential benefits of lives saved, are not quantified. In other words, benefit-cost analyses as applied by the Corps are tools for informing decisions on individual projects but were not performed with the intent to determine the most cost-effective projects. Metrics that include consequences in addition to damages could be combined and weighted to produce a risk-ranking for flood control projects; however, attempts to prioritize the Corps budget across multiple types of water resources projects continues to be a challenge because of the varying and inter-related types of benefits and costs of ecosystem restoration, flood control, navigation, and multi-purpose projects.

A fundamental question being raised in the aftermath of Hurricanes Katrina and Rita is: do current federal policy, programs, practices result in an acceptable level of aggregate risk for the nation? Risk management is being increasingly viewed as a method for setting priorities for managing some hazards in the United States. Because floodplain and coastal development are largely managed by local governments, some aspects of national flood risk management likely would be unwelcome and infeasible, and could be perceived as resulting in an inequitable distribution of flood protection. For example, if floods in large urban concentrations are perceived as representing a greater risk for the nation, federal resources may be directed away from protecting smaller communities and less-populated states. Two of the concerns raised in discussions of greater emphasis on risk analysis in the development and design of specific projects are that risk analysis may result in lower levels of protection being implemented in some areas, and that information and knowledge are insufficient to perform an adequate analysis. However, an argument can be made that the federal government has an interest in reducing risks resulting in national consequences, and in prioritizing federal involvement and appropriations accordingly.

"actors complicating the determination of the nation's flood risk include changing conditions and incomplete information. For example, many flood control projects were built decades ago using the available data and scientific knowledge of the period that may have underestimated flood hazards for particular areas. Similarly, there are issues with changes in risk over time due to processes such as land loss, subsidence, sea-level rise, reduced natural buffers, urban development, and infrastructure aging. For existing dams, there is some information on consequences of failure as measured by loss of life, economic loss, environmental loss, and disruption of lifeline infrastructure (such as bridges and power grids); however, the database with this information only tracks the amount and type of losses, not the likelihood of failure.

A risk-reduction approach for organizing federal flood-related investments likely would incorporate many structural and nonstructural flood management measures already being considered and implemented, but change their priority and mix. Options considered in a risk-centered approach may include shifting federal policy toward wise use of flood-prone areas (e.g. rules or incentives to limit some types of development in floodplains), incorporating residual risk and differences in riverine and coastal flood risk into federal programs (e.g. residual risk premiums as part of the National Flood Insurance Program), creating a national inventory and inspection program for levees, promoting greater flood mitigation and damage mitigation investments, re-evaluating operations of flood control reservoirs for climate variability and uncertainty, and investing in technology and science for improved understanding of the flooding threats.

Hurricanes Katrina and Rita have focused the nation’s attention once again on issues that flood experts have debated for decades. The disasters have renewed public concerns about reliability of the nation’s aging flood control levees and dams. The debate over what is an acceptable level of risk - especially for low-probability, high-consequence events - and who should bear that risk is taking place not only in the states affected by the hurricanes, but nationally. The concerns being raised range widely, including interest in providing more protection for concentrated urban populations, risk to the nation’s public and private economic infrastructure, support for reducing vulnerability by investing in natural buffers, and equity in protection for low-income and minority populations.

The response to Hurricanes Katrina and Rita have included discussions of expanding mitigation activities (such as floodproofing structures and buyouts of structures on the most flood-prone lands), investing in efforts to restore natural flood and storm surge attenuation, and assuring vigilant maintenance of existing flood control structures, as well as interest in new and augmented structural flood protection measures. Although major flood events, such as the Midwest Flood of 1993, generally spur these discussions, the policy changes implemented often are incremental. The 109th Congress, like previous Congresses, faces a challenge in reaching consensus on how to proceed on anything other than incremental change because of the wealth of constituencies and communities affected by federal flood policy. Another practical challenge is the division of congressional committee jurisdictions over the federal agencies and programs involved in flood mitigation, protection, and response.

For example, Senate Committees that would likely have jurisdiction over elements of any comprehensive change in federal flood policy would include Banking, Housing, and Urban Affairs; Environment and Public Works; and Homeland Security and Government Affairs.

F.3.15 Office of Management and Budget (2006). *Agency Scorecards*, Washington, DC.

Good intentions and good beginnings are not the measure of success. What matters in the end is completion: performance and results. Not just making promises, but making good promises.

The scorecard employs a simple 'traffic light' grading system common today in well-run businesses: green for success, yellow for mixed results, and red for unsatisfactory. Scores are based on five standards for success defined by the President's Management Council and discussed with experts throughout government and academe, including individual fellows from the National Academy of Public Administration.

The Corps of Engineers ratings: Human Capital - yellow, Competitive Sourcing - Red, Financial Performance - Red, Enhancing E-Government - Red, and Budget Performance and Integration - Red

Reducing the Construction Backlog. Between 2000 and 2005, funding for the Corps construction program increased by 30 percent in nominal terms. Much of this increase was for work on projects with relatively low benefits or outside of the Corps' three main mission areas: 1) facilitating commercial navigation; 2) reducing damages caused by floods and storms; and 3) restoring aquatic ecosystems. During the same period, the Corps construction workload grew at an unmanageable rate and more projects faced construction delays, as additional projects were authorized without funding for timely completion. This growth trend has resulted in a $50 billion cost to complete authorized projects, of which only $15 billion is for projects that are both within the Corps' main mission areas and meet current economic and environmental performance standards. Funding new projects further stresses the Corps' workload as these projects inevitably compete for funding with ongoing projects that offer much greater benefits, relative to their costs. As a result, some projects cost more than they need to, and most projects are completed many months - and sometimes years - later than they could.

F.3.16 Senator Susan Collins and Senator Joseph Liberman, Senate Homeland Security Committee Holds Hurricane Katrina Hearing to Examine Levees in New Orleans, Press Release, November 2, 2005.

Examining why the levees in New Orleans failed following Hurricane Katrina is a crucial part of our committee's investigation. While some of the flood walls and levees were overtopped, something much more catastrophic happened that was not anticipated. Some of the levees and flood walls failed outright, leaving gaping holes through which water rushed uncontrollably into the neighborhoods of New Orleans.

This flooding caused enormous destruction and tragic loss of life that would not have occurred if the levees had held. The people of New Orleans put their faith in the levee system and unless the cause of this failure is investigated and addressed, New Orleans will remain a city in jeopardy.

A lot of the flooding of New Orleans should not have happened, and would not have happened if not for human error and the 0possibility of malfeasance suggested by one of our witnesses in the design and construction of the city's levees.

Today’s testimony about the inadequacy of the levees to protect the people of New Orleans is as disheartening, as heartbreaking, as infuriating, and ultimately as embarrassing as the scenes of degradation and despair that we saw in the immediate aftermath of Hurricane Katrina.

Both Senators expressed their concern by the fact that the levees were constructed to withstand a Category 3 hurricane. But while Katrina was only a Category 1 when it hit parts of New Orleans, the levees still failed, causing 80 percent of the city to flood, more than twice as much as would have occurred had the levees held.

F.3.17 Senator Susan Collins (2005). “Hurricane Katrina: Who’s In Charge of the New Orleans Levees?” Hearing Statement Before Homeland Security and Governmental Affairs Committee, December 15, Washington, DC.

While the levees were absolutely critical to the survival of the city, our November 2nd hearing demonstrated that this last line of defense was fatally flawed in design, construction, or maintenance. The people of New Orleans and surrounding parishes depended on the levees to protect them. It now appears their faith had little foundation. Even though the hurricane caused extensive damage, it was the flooding from the levee breaches that actually destroyed the City of New Orleans.

The Army Corps of Engineers, the Orleans Levee District, and the Louisiana Department of Transportation and Development are the key players. But they each played their parts in a system fragmented by overlapping obligations and inexplicable past practices. Once the levees were constructed the Army Corps of engineers is expected to: turn over completed sections to the Orleans Levee District; perform an annual inspection with the District; and review the semi-annual reports filed by the District.

The Orleans Levee District is charged by law with: operating and maintaining the levees; conducting a quarterly inspection of the levees at least once every 90 days; and filing a semi-annual report with the Army Corps. The Louisiana Department of Transportation is obligated by state law to: approve the soundness of the engineering practice and the feasibility of the plans and specifications submitted by the Orleans Levee District; conduct training of the District’s commissioners; and review the District’s emergency plans.

Today we will hear about the reality, about the confusion on issues as fundamental as control, the misunderstandings, and what appear to be outright abdications of responsibility.” “the uncertainty about control, combined with overlapping responsibility for emergency management, affected the repair efforts at one of the breach sites after Hurricane Katrina. In a staff interview, the Commander of the New Orleans District of the Army Corps of Engineers described the confusion: ‘Who is in charge? Where’s the Parish President? Where is the Mayor? And then the State?…Who is in charge?”

F.3.18 Herman Leonard and Arnold Howitt (2006). “Katrina as Prelude: Preparing for and Responding to Future Katrina-Class Disturbances in the United States,” Testimony U.S. Senate Homeland Security and Governmental Affairs Committee, Washington DC, March 8.

The inescapable reality is that the United States - its governmental units and its society as a whole - is not now and never has been prepared adequately to deal with a disaster the scale of Hurricane Katrina. … but while there were individual failures involved, the story is not principally a story of individual failures - it is, instead, a story of failures of systems and of failures to construct systems in advance that would have permitted and helped to produce better performance and outcomes.

The leadership failures that contributed to the events we witnessed on the Gulf Coast last August and September began long, long before Katrina came ashore. It literally took centuries to make the mistakes that rolled together to make Katrina such a vast natural and human-made calamity. First, for hundreds of years, people have been constructing and placing large amounts of previous (human lives) and expensive (infrastructure, homes, communities) value in new Orleans and along the Gulf Coast in the known path of severe storms. Second, for decades, we have been living with inadequately designed, built, or maintained man-made protections (levees, building codes, pumps, and so on), and have pursued policies and interventions that actively contributed to the destruction of the natural buffers (salt marshes, dunes, and other natural barriers) against the hazards created by placing value in harm’s way. Third for years - at least since 9/11, but even before that - we have known that we had systems of preparation and response that would prove inadequate against truly large scale disasters. Fourth, in the days and hours before Katrina’s landfall, we failed to mobilize as effectively as we might have those systems that we did have in place. And fifth, the days following the impact, we did not execute even the things that we were prepared to do as quickly and smoothly as we should have.

How do we not, in the future, find ourselves again with those same regrets? Our work needs to begin with a judicious and honest assessment of threats, followed by investments in prevention and mitigation and by construction of response systems that will be equal to a larger of class of disturbances than we have previously allowed ourselves to contemplate.

F.3.19 Congressional Research Service (2003). *Army Corps of Engineers Civil Works Program: Issues for Congress*, Issue Brief for Congress, N. Carter and P. Sheikh, Washington DC, May 21.

The Corps is a unique federal agency located in the Department of Defense with military and civilian responsibilities; it is staffed predominantly by civilians. Through its military program, the Corps provides engineering, construction, and environmental management services to the Army, Air Force, government agencies, and foreign governments. the Corps military program is currently active in restoring the capability for oil production, oil refining, and gas processing as well as other activities in Iraq.

At the direction of Congress, the Corps plans, builds, operates, and maintains a wide range of water resources facilities under its civil works program. The Corps’ oldest civil responsibilities are creating navigable channels and controlling floods. during the last decade, Congress has increased Corps responsibilities in the areas of ecosystem restoration, environmental infrastructure, and other non-traditional activities such as disaster relief and remediation of formerly used nuclear sites. The economic and environmental impacts of Corps projects can be significant locally and regionally, and at times are quite controversial.

The civil works budget of the Corps consists primarily of funding for the planning, construction, and maintenance of specific projects; appropriations are made as part of the Energy and Water Development Appropriations bills. Funding for Corps civil works has often been a contentious issue between the Administration and Congress, with appropriations typically providing more funding than the Administration has requested, regardless of which political party controls the white House and Congress.

Congress typically authorizes Corps projects as part of a biennial consideration of a Water Resources Development Act (WRDA). The trend in the last decade has been to authorize projects earlier in the development and review process than in the past. Congress might authorize a project following a review by the Assistant Secretary of the Army for Civil Works and the Executive Office of the President, Office of Management and Budget (OMB) and a favorable Chief of Engineers report; on the basis of a favorable Chief's report without senior administrative review; or contingent on a favorable Chief's report being completed within a year. Most projects authorized since WRDA 1996 have not undergone senior administrative or OMB review prior to receiving congressional authorization.

Contingent authorization, authorization prior to OMB review, and another practice - authorization in appropriations bills - have been criticized by some Members of Congress and Corps critics. The critics contend that contingent authorization rushes projects through critical stages of the development process and that congressional decisions are made without basic project information. They also argue that authorizations prior to senior review by the Administration result in insufficient review from a national perspective.

There also has been criticism regarding the type of projects authorized in recent WRDAs. Local sponsors of navigation and flood control projects fear that the Corps' growing involvement in ecosystem restoration and other new responsibilities detracts from the agency's more traditional missions.

Criticism of Corps project development has been raised for decades, particularly since the growth of the environmental opposition to large water resources development projects in the 1970s. Although Congress passed greater local cost-sharing requirements in 19865, it has enacted few changes to how the Corps develops and evaluates projects.

In response to two events in 2000, support for changing how the Corps undertakes and reviews projects has gained some momentum. First, the Washington Post published a series of articles raising questions about the integrity of the Corps planning process. Second, a Corps economist when public as a whistleblower contending that Corps officials manipulated a benefit-cost analysis to support expensive lock improvements on the Upper Mississippi River-Illinois Waterway.

The Bush Administration has generally approached reform as a fiscal issue linked primarily to the agency's growing construction backlog. Over the longer term, many more projects have received authorization than appropriations, resulting in a backlog consisting of over 500 'active' authorized projects with a federal cost of approximately $44 billion. To reduce the construction backlog, the President's FY 2004 budget request focuses the agency's civil works activities on specific projects within the agency's water resources missions of navigation, flood control, and environmental restoration. during the 1990s, Congress continued biennial authorizations of navigation and flood control projects and began authorizing more environmental activities and non-traditional projects.

In contrast, legislative proposals during the 107th and 106th Congresses consisted less of fiscal reforms and more of improved project development processes and review procedures. In 2003, Corps officials testified on how the agency is 'transforming' itself in response to the criticism levied against its practices. Corps officials defended the integrity of the agency's review processes and detailed recent efforts to further strengthen it.

There are currently two initiatives to change the operation of the Corps civil works program: the government-wide President's Management Agenda and an Army initiative referred to as the Third Wave. Neither initiative specifically targets the Corps, but both encompass Corps activities. The President's Management Agenda was undertaken by the Bush Administration as part of a movement toward more entrepreneurial government; one of the five components of the President's Management Agenda is a competitive sourcing initiative. The President's Management Agenda directed executive agencies to competitively source commercial activities in order to produce quality services at a reasonable cost through efficient and effective competition between public and private sources. The administration mandated for FY 2002 and FY 2003 the competition of 5% and 10%, respectively, of the positions performing commercial activities at agencies, including the Corps.

The Army's Third Wave initiative is broader than the President's Management Agenda. The Third Wave is a search for ways to improve the Army's operations by focusing its energies on its core war-fighting competencies. This includes a review of all positions and functions (i.e., entire areas of responsibilities and missions, such as wetlands regulation) that are not part of the Army's core military competencies. Actions that can be considered under the Third Wave for non-core functions and positions include competitive sourcing, privatization, transfer of responsibilities to other agencies, and divestiture. A significant portion of the Corps workforce was included in the first phase of the third Wave because much of the water resources work performed by the Corps is not considered essential to the Army's war fighting competencies.

F.3.20 U.S. General Accounting Office (2003). Corps of Engineers Improved Analysis of Costs and Benefits Needed for Sacramento Flood Protection Project, Report to Congressional Requesters, GAO-04-30, Washington DC, October.

The Corps did not fully analyze likely cost increases for the Common Features Project or report them to Congress in a timely manner. Corps guidance generally directs the Corps to seek new spending authority from Congress if it determines, before issuing the first construction contract, that it cannot complete the project without exceeding its spending limit. A severe storm in January 1997 demonstrated vulnerabilities in the American River levees and alerted the Corps of the need to do additional work to close the gaps in the cut-off walls at bridges and other areas and extend the depth of some cut-off walls from about 20 feet to about 60 feet. Although these design changes were likely to increase project costs significantly, the Corps did not use cost risk analysis, or any other analysis, to determine the potential extent of the increases. the Corps then began constructing the redesigned American River levee improvements without communicating to Congress the project's potential exposure to substantial cost overruns. In 2002, when the Corps finally updated project costs, it had already completed or contracted at a much higher cost for most of the American River levee improvements that were authorized in 1996. Because of the reporting delay, Congress did not have the opportunity to determine whether, at these higher costs, building these levee improvements was an efficient and effective use of public funds. by 2003, the corps had committed most of the funding authorized for the entire Common Features Project to the 1996

American River work, thereby leaving the 1999 work and the Natomas Basin improvements without funding.

In response to the criticism that the Corps had failed to design the levee protection to account for seepage that caused failure of some of the levees in the 1997 flooding, the Corps replied to the GAO: "The Army stated that the levee improvements were not originally designed to withstand the destructive effect of seepage and that this design was not an error. Rather, an unknown condition (i.e., the potential for destructive seepage under the levees) resulted in design changes and increased costs.

The Corps made several mistakes in estimating the economic benefits for the American River levee improvements. First, in 1996, the Corps incorrectly calculated the economic benefits by over-counting the residential properties that the levees would protect. The actual number of protected residential properties was about 20 percent less than the number that the Corps estimated. although the Corps updated its benefit estimate in 2002, it again made mistakes in estimating benefits because it incorrectly determined that the levee improvements authorized in 1999 would protect a larger area from flooding that they will and used an inappropriate methodology to determine the amount of flood damages the levee improvements would prevent. However, it is also important to recognize that the levee improvements may reduce the loss of human lives in the event of a flood, which is a benefit that is not included in the Corps' analysis. Second, although the Corps' policy calls for reporting a range of benefits from the levee improvements and the likelihood of realizing them, in 2002 the Corps reported only a single estimate of benefits. The Corps did not provide a range of benefits to Congress because it did not use the most current version available of its computer software, which could have performed the analysis. Finally, although the Corps has a three-tiered quality control process to ensure that it prepares economic analyses accurately and appropriately, this process did not identify the mistakes we found, which raises questions about the effectiveness of the Corps quality control process.

It is important to remember that, in addition to the economic benefits from preventing property damage, levee improvements may reduce the risk of loss of human lives, which is a benefit that is not included in the Corps' calculations. According to the Corps, about 305,000 people live within the American River floodplain and the number of lives lost because of levee failure would depend on a variety of factors, such as the size of the flood, warning time, time of day, and availability of evacuation routes. Because of the many factors involved and the lack of historical data, the Corps was not able to estimate the number of lives that would be lost as a result of levee failure and flooding in the Sacramento area.

The Corps' guidance (Engineer Regulation 1105-2-100) directs the Corps to address the issue of prevention of loss of life when evaluating alternative plans - which the Corps did. However, the Corps is not required to formally estimate the number of lives saved or lost as a potential effect of a project. In situations where historical data exist, the Corps has the option to estimate the number of persons potentially affected by a project, and include this number as an additional factor for the consideration of decision makers.

It is critical that decision making and priority setting be informed by accurate information and credible analysis. Reliable information form the Corps about costs and benefits for the American River component of the Common Features Project has not been present to this point. the analysis on which Congress has relied contained significant mistakes.

and of most relevance today, the analyses for the remaining work do not provide a reliable economic basis upon which to make decisions concerning the American River levee improvements authorized in the WRDA of 1999. To provide a reliable economic basis for determining whether these improvements are a sound investment, the Corps' analysis needs to adequately account for the risk that project costs could increase substantially, correctly count and value the properties the project would protect, and include information on the range of potential project costs and benefits.

F.3.21 Heinzerling, L. and Ackerman, F. (2002). "Pricing the Priceless: Cost-Benefit Analysis of Environmental Protection," Georgetown Environmental Law and Policy Institute, Georgetown University Law Center.

Proponents of cost-benefit analysis make two basic arguments in its favor. First, use of cost-benefit analysis ostensibly leads to more efficient allocation of society's resources by better identifying which potential regulatory actions are worth undertaking and in what fashion. advocates of cost-benefit analysis also contend that this method produces more objective and more transparent government decision-making by making more explicit the assumptions and methods underlying regulatory actions.

In fact, cost-benefit analysis is incapable of delivering what it promises. First cost-benefit analysis cannot produce more efficient decisions because the process of reducing life, health, and the natural world to monetary values is inherently flawed. Efforts to value life illustrate the basic problems. Cost-benefit analysis implicitly equates the risk of death with death itself, when in fact they are quite different and should be accounted for separately in considering the benefits of regulatory actions. Cost-benefit analysis also ignores the fact that citizens are concerned about risks to their families and others as well as themselves, ignores the fact that market decisions are generally very different from political decisions, and ignores the incomparability of many different types of risks to human life. the kinds of problems which arise in attempting to define the value of human life in monetary terms also arise in evaluating the benefits of protecting human health and the environment in general.

Second, the use of discounting systematically and improperly downgrades the importance of environmental regulation. While discounting makes sense in comparing alternative financial investments, it cannot reasonably be used to make a choice between preventing non-economic harms to present generations and preventing similar harms to future generations. Nor can discounting reasonably be used to even make a choice between harms to the current generation; the choice between preventing an automobile fatality and a cancer death should not turn on prevailing rates of return on financial investments. In addition, discounting tends to trivialize long-term environmental risks, minimizing the very real threat our society faces from potential catastrophes and irreversible environmental harms, such as those posed by global warming and nuclear waste.

Third, cost-benefit analysis ignores the question of who suffers as a result of environmental problems and, therefore, threatens to reinforce existing patterns of economic and social inequality. Cost-benefit analysis treats questions about equity as, at best, side issues, contradicting the widely shared view that equity should count in public policy. Poor countries, communities, and individuals are likely to express less willingness to pay to avoid environmental harms simply because they have fewer resources. Therefore, cost-benefit analysis would justify imposing greater environmental burdens on them than on their wealthier counterparts. With this kind of analysis, the poor get poorer.

Finally, cost-benefit analysis fails to produce the greater objectivity and transparency promised by its proponents. For the reasons described above, cost-benefit analysis rests on a series of assumptions and value judgments that cannot remotely be described as objective. Moreover, the highly complex, resource-intensive, and expert-driven nature of this method makes it extremely difficult for the public to understand and participate in the process. Thus, in practice, cost-benefit analysis is anything but transparent.

F.4 References

Allinson, R. E. (1993). *Global Disasters - Inquiries in Management Ethics*, Prentice Hall, New York

Bazerman, M. H., and Watkins, M. D. (2004). *Predictable Surprises, The Disasters You Should Have Seen Coming, and How to Prevent Them*, Harvard Business School Press, Boston, MA.

Bea, R.G. (2000). *Achieving Step Change in Risk Assessment & Management (RAM)*, Centre for Oil and Gas Engineering, University of Western Australia Press, Nederland, Western Australia; also *Human & Organizational Factors in Design & Reliability of Offshore Structures*, Doctor of Philosophy Thesis, Centre for Oil and Gas Engineering, the University of Western Australia.

Bea, R.G. (2006). "Human and Organizational Factors in Geotechnical Engineering." *J. Geotechnical and Geoenvironmental Engrg.*, ASCE, 132 (5).

Bernstein, P.L. (1996). *Against the Gods, The Remarkable Story of Risk*, John Wiley & Sons, Inc.

Center for Chemical Process Safety (1994). *Guidelines for Preventing Human Error in Process Safety*, American Institute of Chemical Engineers, New York.

Chiles, J.R. (2002). *Inviting Disaster, Lessons from the Edge of Technology*, Harper Business Publishers.

Columbia Accident Investigation Board (2003). *Report Volume I*, Government Printing Office, Washington DC.

Dorner, D. (1996). *The Logic of Failure, Why Things Go Wrong and What We Can Do to Make Them Right,* Metropolitan Books, Henry Holt and Co., New York.

Dumas, L.J. (1999). *Lethal Arrogance, Human Fallibility and Dangerous Technologies*, St. Martin's Press.

Groeneweg, J. (1994). *Controlling the Controllable*, DSWO Press, Leiden University, The Netherlands.

Hale, A., Wilpert, B., and Freitag, M. (1997). *After The Event, From Accident to Organizational Learning*, Pergamon Press, Elsevier Sciences Ltd., Oxford, UK.

Hopkins, A. (1999). *Managing Major Hazards*, Allen & Unwin, St Leonards NSW, Australia.

Hopkins, A. (2000). *Lessons from Longford, The Esso Gas Plant Explosion*, CCH Australia Limited, Sydney, NSW.

Klein, G. (1999). *Sources of Power*, The MIT Press, Cambridge, MA.

Lancaster, J. (1996). *Engineering Catastrophes, Causes and Effects of Major Accidents*, Abington Publishing, Cambridge, UK.

Loosemore, M. (2000). *Crisis Management in Construction Projects*, ASCE Press, Reston, VA.

Merry, M. (1998). "Assessing the Safety Culture of an Organization." *J. Safety and Reliability Society*, Vol. 18, No. 3, Manchester, UK.

Meshkati, N. (1995). "Cultural Context of the Safety Culture: A Conceptual Model and Experimental Study." *Proceedings of the International Topical Meeting on Safety Culture in Nuclear Installations*, U. S. Nuclear Regulatory Commission, Washington, DC.

Molak, V. (1997). *Fundamentals of Risk Analysis and Risk Management*, CRC Lewis Publishers.

National Academy of Engineering (2004). *Accident Precursor Analysis and Management, Reducing Technological Risk Through Diligence*, the National Academies Press, Washington DC.

Perrow, C. (1999). *Normal Accidents: Living with High Risk Technologies*, Princeton Univ. Press, Princeton, NJ.

Petroski, H. (1985). *To Engineer is Human: The Role of Failure in Successful Design*, St. Martins Press, New York, NY.

Petroski, H. (1994). *Design Paradigms, Case Histories of Error and Judgment in Engineering*, Cambridge University Press, Cambridge, UK.

Prigogine, I (1997). *The End of Certainty, Time, Chaos, and the New Laws of Nature*, the Free Press, London, UK.

Reason, J. (1990). *Human Error*, Cambridge University Press, London, UK.

Reason, J. (1997). *Managing the Risks of Organizational Accidents*, Ashgate Publishers, Aldershot, UK.

Roberts (1993). *New Challenges to Understanding Organizations*, McMillan Pub., New York.

Roberts, K. H. (1989). "New Challenges in Organizational Research: High Reliability Organizations." *Industrial Crisis Quarterly*, Elsevier Sciences Pub. B.V., Amsterdam, Netherlands, 20-26.

Roberts, K. H., and Bea, R. G. (2001a). “Must Accidents Happen? Lessons from High-Reliability Organizations.” *Academy of Management Executive*, 15(3), Academy of Management, New York, 1-9.

Roberts, K. H., and Bea, R. G. (2001b). “When Systems Fail.” *Organizational Dynamics*, 29 (3) 179-191, Elsevier Science, Inc., New York.

Roberts, K. H., (1990). “Some Characteristics of High Reliability Organizations.” *Organization Science*, Vol. 1, New York, NY.

Roberts, K. H., and Libuster, C. (1993). “From Bhopal to Banking: Organizational Design Can Mitigate Risk.” *Organizational Dynamics*, Spring, Academy of Management, New York.

Sasou, K. and Reason, J. (1999). “Team Errors: Definition and Taxonomy.” *Reliability Engineering and System Safety*, 65, Elsevier Science Ltd., 1-9.

Shrivastava, P. (1992). *Bhopal: Anatomy of a Crisis*, Paul Chapman, London, UK.

Sowers, G. F. (1993). “Human Factors in Civil and Geotechnical Engineering Failures.” *J. Geotech. Engrg.*, 119 (2), 238-256.

Townsend, F.F. (2006). *The Federal Response to Hurricane Katrina, Lessons Learned*. Report to the President of the United States, The White House, Washington DC.

Turner. B. A. (1978). *Man-Made Disasters*, Wykeham Publishers, London, UK.

Vaughan, D. (1996). *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA*, University of Chicago Press, Chicago, IL.

Vaughan, D. (1997). “The Trickle-Down Effect: Policy Decisions, Risky Work, and the Challenger Tragedy,” *California Management Review*, Vol. 39, No. 2, University of California, Berkeley, CA.

Vick, S.G. (2002). *Degrees of Belief, Subjective Probability and Engineering Judgment*, ASCE Press, Reston, VA.

Weick, K.E. (1995). *Sensemaking in Organizations*, Sage Pub., Thousand Oaks, CA.

Weick, K.E., and Sutcliffe, K.M. (2001). *Managing the Unexpected*, Jossey-Bass, San Francisco.

Weick, K.E., et al (1998). “Organizing for High Reliability: Processes of Collective Mindfulness.” *Research in Organizational Behavior*, Stow and Sutton (Eds.)

Wenk, E., Jr. (1986). *Tradeoffs, Imperatives of Choice in a High-Tech World*, Johns Hopkins University Press, Baltimore, MD.

Wenk, E., Jr. (1998). *The Double Helix: Technology and Politics*, Manuscript Prepared for Publication, University of Washington, Seattle, WA.

Whittow, J. (1979). Disasters, *The Anatomy of Environmental Hazards*, The University of Georgia Press, Athens, GA.

APPENDIX G: LOOKING FORWARD

The inescapable reality is that the United States - its governmental units and its society as a whole - is not now and never has been prepared adequately to deal with a disaster the scale of Hurricane Katrina. … but while there were individual failures involved, the story is not principally a story of individual failures - it is, instead, a story of failures of systems and of failures to construct systems in advance that would have permitted and helped to produce better performance and outcomes. The leadership failures that contributed to the events we witnessed on the Gulf Coast last August and September began long, long before Katrina came ashore. It literally took centuries to make the mistakes that rolled together to make Katrina such a vast natural and human-made calamity.

First, for hundreds of years, people have been constructing and placing large amounts of previous (human lives) and expensive (infrastructure, homes, communities) value in New Orleans and along the Gulf Coast in the known path of severe storms. Second, for decades, we have been living with inadequately designed, built, or maintained man-made protections (levees, building codes, pumps, and so on), and have pursued policies and interventions that actively contributed to the destruction of the natural buffers (salt marshes, dunes, and other natural barriers) against the hazards created by placing value in harm's way. Third for years - at least since 9/11, but even before that - we have known that we had systems of preparation and response that would prove inadequate against truly large scale disasters. Fourth, in the days and hours before Katrina's landfall, we failed to mobilize as effectively as we might have those systems that we did have in place. And fifth, the days following the impact, we did not execute even the things that we were prepared to do as quickly and smoothly as we should have.

How do we not, in the future, find ourselves again with those same regrets? Our work needs to begin with a judicious and honest assessment of threats, followed by investments in prevention and mitigation and by construction of response systems that will be equal to a larger of class of disturbances than we have previously allowed ourselves to contemplate.

Herman Leonard and Arnold Howitt (2006)
Preparing for and Responding to Future Katrina-Class Disturbances in the United States
Testimony U.S. Senate Homeland Security and Governmental Affairs Committee
Washington DC, March 8.

G.1 High Reliability Organization: The USN Nuclear Propulsion Program

A high reliability organization (HRO) is one that successfully works with extremely complex, potentially hazardous technologies by operating at extremely high levels of reliability and safety. We can extend this definition to include organizations that operate at extremely high levels of quality. Quality is defined as freedom from unanticipated defects and the ability to satisfy the serviceability, safety, compatibility, and durability requirements of those that own, operate, design, construct, regulate, and are affected by the engineered system.

Research has shown that serious accidents involving hazardous systems can be prevented through intelligent organizational design and management. HROs are thus organizations that must operate in a challenging environment requiring the use of advanced engineering methods in which the cost of failure is so great that it needs to be avoided all together. High reliability theory does not take the naive stance that *people* have the ability to behave with perfect rationality. However the theory does assert that *organizations* can compensate for human frailties and can therefore be significantly more rational and effective than individuals.

Over the years, high reliability theorists have identified four critical causal factors that constitute a HRO (Sagan 1993):

> *…the prioritization of safety and reliability as a goal by political elites and the organization's leadership; high levels of redundancy in personnel and technical safety measures; the development of a "high reliability culture" in decentralized and continually practiced operations; and sophisticated forms of trial and error organizational learning.*

While the exact mix of strategies appropriate in a given case depends on the nature of a particular problem, the catastrophe-aversion strategy outlined above should be applicable to virtually any risky technology (Marone and Woodhouse 1986). In this section, we will briefly look at some of the characteristics of the United States Navy's Nuclear Reactor Program under Hyman G. Rickover's leadership that made it a HRO.

G.1.1 The USN Nuclear Propulsion Program

> *... the Naval Nuclear Propulsion Program embodies unsurpassed engineering and sustained excellence that few technical programs in or out of government can claim. In every area of performance, standards, safety, and environmental care, the Naval Nuclear Propulsion Program has excelled. ...*

Former President Bill Clinton

The Naval Nuclear Propulsion Program is a joint Department of Defense / Energy program formed between 1947 and 1948 following WWII under the direction of then Captain Hyman G. Rickover. Its goal was to utilize the new knowledge developed during the war to research, design, construct, operate, and maintain all nuclear-powered submarines. Later the organization's scope was broadened to include all U.S. nuclear-powered warships (i.e., aircraft carriers). Previous studies have argued that the Nuclear Propulsion Program (a.k.a. the Naval Reactors (NR) program) is an archetypal HRO and has all four critical elements identified by high reliability theory (Columbia Accident Investigation Board 2003). NR has over 900 reactor-years of experience with nuclear technology with an unblemished safety record. As a result, many important observations regarding public high reliability organizations can be drawn from looking at the NR program under Rickover's command including:

- People are the most important element to an organization's reliability. An extraordinary amount of time and resources are needed to ensure proper selection, education, and training of the personnel.
- Complex jobs cannot be executed reliably with transient personnel.
- Scientist or engineers should not make assumptions if they truly do not understand the environment of the problem.

One characteristic of a HRO is that it fits into what W. Richard Scott has called the "closed rational systems" approach in organization theory. The HRO are *rational* in the sense that they set up highly formalized structures that are oriented toward the achievement of clear and consistent goals. They are *closed* in the sense that great effort is put into minimizing the effects the environment outside the organization has on the achievement of its objectives.

In this respect, the Naval Reactors program was intentionally formed under both the US Navy Bureau of Ships (BuShips) and the Department of Energy's Atomic Energy Commission (AEC). The BuShips has the authority to design, build, and maintain all US naval ships. NR's association with BuShips gave the agency the legal authority to sign contracts, spend money, and approve ship design features. The 1946 Atomic Energy Act on the other hand states that the responsibility and authority for anything atomic is in the AEC's hands. This includes atomic fuel procurement, fabrication, reprocess, reactor safety inspections & evaluations. Therefore Rickover intentionally established the NR program to be in the AEC to give it the legal authority to sign contracts and make arrangements to deal with classified atomic materials and information. This "dual citizenship" of sorts served to give the NR program the legal authority to do its job with a minimum degree of outside interference.

Within Naval Reactors, strong, clear, and open communications continues to be paramount to the organization's success. Rickover continually made the point to the media that he had no organizational structure. In 1980, with a total of 359 engineering, financial, naval, and clerical personnel in his Washington office, he solemnly issued an elaborate organization chart to the media. Only the title, date, and signature were in English; the numerous squares bore Chinese characters (Duncan 1990). Rickover was attempting to communicate, albeit sarcastically, that NR has as little communication barriers as possible in the organization to enable people to communicate with whomever they felt was the most capable of answering their question. This quality is crucial in ensuring the future safety and reliability of the program. Regardless of how well trained and educated personnel may be, a channel to communicate information to the highest levels of the organization's management without barriers is often needed.

It is worth mentioning while the NR program seeks to minimize the degree of outside interference other organizations had on its ability to design, construct, and operate nuclear submarines, NR is dependent on private contractors and institutions in both the public and private sector in fulfilling its mission. NR addresses this challenge by working to ensure that their own personnel be at least as knowledgeable as the outsourcer's staff. This allows NR to perform reliable oversight of outsourced activities by decreasing the likelihood of being misled, and internally provides the capability of leading outsourced duties at the desired level of quality if the outsourcer is unable. Rickover for example had an extensive amount of knowledge about industry and the level of quality they can achieve if appropriately encouraged. This allowed him to outsource work to private contractors and still maintain a high quality engineering product. This further highlights the importance of recruiting and maintaining a highly qualified engineering workforce even if the agency continues to expand its outsourcing efforts in the hope of improving efficiency.

As the nation begins to consider how it might ‘re-engineer’ the Army Corps of Engineer’s Civil Works program in light of Katrina, it is important that the Corps relationships with other private and public organizations that might enhance or diminish the quality of water resource projects also be evaluated. This includes relationships with the White House, Congress, local and state governments, and private contractors.

G.1.2 Personnel Recruitment and Retention

Complex jobs cannot be accomplished effectively with transients.

Extensive historical investigations of engineered systems where quality was compromised, and this led to a catastrophic consequence (i.e., human life or financial) were performed by the authors, and it was concluded that 80% of these failures were due to human or organizational factors. Of these HOF failures in engineering systems, most occur during their operation or maintenance as a result of errors in design or construction. Therefore, to effectively build and maintain an organization that reliably designs and constructs large-scale complex engineering systems, a lot of time and care must be put into its personnel. Rickover shared this belief and in 1979 testified before the subcommittee on energy research and production of the House Committee on Science and Technology following the Three-Mile Island incident (Rickover 1979):

> *Properly running a sophisticated technical program requires a fundamental understanding of and commitment to the technical aspects of the job and a willingness to pay infinite attention to the technical details. I might add, infinite personal attention. This can only be done by one who understands the details and their implications. The phrase, “The Devil is in the details” is especially true for technical work. If you ignore those details and attempt to rely on management techniques or gimmicks you will surely end up with a system that is unmanageable, and problems will be immensely more difficult to solve. At Naval Reactors, I take individuals who are good engineers and make them into managers. They do not manage by gimmicks but rather by knowledge, logic, common sense, and hard work and experience.*

The challenging and exciting projects at the NR program have allowed the agency to recruit, select and maintain a highly qualified personnel workforce. At the time of its founding, the US Navy Nuclear Reactors program was one of the premier engineering organizations a young person could hope to work for. The organization was leading the world in advancing science and technology with respect to reactor design. The excitement of working on cutting-edge projects allowed the organization to successfully recruit from the cream of the Navy Engineering Duty Officer (EDO) community, National Laboratories, and the submarine force (Krahn, unpublished manuscript, 1992).

From this pool, the NR program’s senior leadership (Rickover included) spent a significant amount of time evaluating and selecting prospective NR engineering personnel. As noted earlier in this investigation, approximately 80% of engineering system failures are caused by human errors (Bea 2006). In order to effectively reduce the probability of failure, it is critical that the performance of the men and women that directly interface with its design, construction, operation, and maintenance be improved. One way to effectively improve personnel performance is to spend more time selecting individuals who have "the right stuff" and less time trying to "train" individuals who don't. The right stuff in the NR program was identified to be a combination of desirable technical and behavioral traits. Often times, especially in engineering, employees are selected almost exclusively on practical technical competence. In addition to this, the NR program also assesses the behavioral traits through personal interviews. In addition to other traits this interview serves to understand an engineer's ethics when exposed to anything from normal to high levels of pressure/stress. Rickover highlighted the objective of this part of the selection process in the NR program (Rockwell 1992):

> *…what I'm trying to find out is how they will behave under pressure. Will they lie, or bluff, or panic, or wilt? Or will they continue to function with some modicum of competence and integrity? I can't find that out with routine questions. I've got to shake 'em up. That's the only way I'll know….*

Engineering organizations charged with designing, constructing, operating, or maintaining complex engineering systems cannot do so successfully with low personnel retention. When an engineering organization has a large turnover, one can expect low morale and dedication amongst personnel as well as high error rates. Although the effect of turnover level on organizational performance depends critically on the nature of the system in which the turnover occurs, generally an organization can expect disruption of social and communication structures, increased training and assimilation costs, and decreased cohesion and commitment of members who stay (Arthur 1994). Additionally, the organization can expect lower levels of organizational memory and learning.

The NR program shared the belief that complex jobs cannot be accomplished effectively with transients. To minimize the agency's turnover rate, the NR program required that all prospective engineering personnel be volunteers. Furthermore, the personnel were continually offered the kind of challenges and rewards in their work such that they could overlook the shortcomings of their monetary compensation as typical in many public-sector organizations. This allows the organization to benefit fully from their knowledge, experience, and corporate memory (Rockwell 1992). This includes the reporting of near-misses, which as we will see later is a crucial element to managing risk in a complex system (i.e., organizational learning).

Former director of the Naval Nuclear Propulsion program, Admiral "Skip" Bowman, discussed some of the program's issues with respect to retention following a decrease in submarine orders after the Cold War:

> *Although the build rate had changed dramatically, the importance of maintaining tight controls didn't change, and the demographics of the organization became an issue. Were we going to wake up six years from now and find that the old guard had tuned gray and gone away and that we hadn't watched closely enough the professional development of the youngsters who need to be stepping in as section heads? We looked at the retention pattern at Naval Reactors, and it wasn't good. So we dramatically changed the opportunities for professional development and worked at making young engineers feel more and more a part of this organization – to create a niche where they could feel comfortable supporting their own desires, aspirations, and families.*

The Naval Reactor program would not survive very long if the personnel were not clearly dedicated to their jobs. For this reason the NR program can be said to follow what human resource researchers have called a *commitment* versus a *control* human resource system. Commitment human resource systems focus on developing committed employees who can be trusted to use their discretion to carry out job tasks in ways that are consistent with organizational goals (e.g., quality). In contrast, control human resource system's objective is to improve efficiency by enforcing employee compliance with specified rules and procedures and basing rewards on some measurable output criteria. Generally, organizations that adopt this strategy have a much higher percentage of non-dedicated personnel that are hence more likely to violate the formal and informal procedures in the organization and less inclined to adopt management's leadership in creating a quality culture within the organization (Arthur 1994).

G.1.3 Engineering Assumptions

A critical aspect to life-cycle engineering is the treatment of uncertainties. In design and construction, many traditional engineering approaches are deterministic and thus require "conservative" assumptions of random variables. These variables can include anything from the price of steel to the compressive strength of concrete. The industry has notably established a variety of inspection and testing activities that improve our ability to predict the performance of our systems.

In designing the first nuclear powered submarine, many engineers who have never been on a submarine were asked to make very important design decisions. Rickover felt it was critical that any engineer or scientist not make assumptions if they truly did not understand the materials being used and environment the finished submarine must operate in. This includes the internal (e.g., temperature), external (e.g., squalls or blast loads), and social (e.g., training/knowledge of crew or variable operational stress climates) environments. Rickover used videos to help impress upon engineers the nature of the problem they are being asked to design. Furthermore, the organization went to great lengths to minimize communication barriers so that information could be transferred freely directly to the people who need it.

G.1.4 Conclusion

> *... Particularly noteworthy are the conservative rugged designs, standardized plants, thorough testing, comprehensive plant maintenance, emphasis on correcting small problems before they can grow, and the high degree of selection, training, and qualification of officers and enlisted personnel who operate the plants. These high standards and achievements continue to be reflected in the quality and competence of the Naval Reactors Headquarters and field organizations, including their dedicated laboratories, shipyards, manufacturing activities, and training facilities. ...*

Chairman, U.S. Nuclear Regulatory Commission, Shirley Jackson

Failure was never an acceptable option for Rickover. While this was due in part to the widely reported fact the Navy was looking for 'any' reason to get rid of Rickover and the program, it was also because the consequences of a nuclear reactor failure are incredibly high. The flooding of New Orleans has made it abundantly clear that the consequences of a poorly designed, constructed, and maintained water resource and flood protection infrastructure are also far too high for our country to sustain.

Many of the organizations responsible for building and maintaining flood protection in New Orleans, including the U.S. Army Corps of Engineers and the local levee districts, can learn a lot from High Reliability Theory and the example that the Naval Nuclear Propulsion Program continues to set. The fluid organizational structure, vibrant exchange of ideas (coupled with developed communication skills), and coherent training programs are to be desired by many public and private organizations. The structure of the organization allowed anyone to do whatever it is they saw that needed to be done, and to seek the necessary resources to do it. People were limited only by their own abilities and not by formal titles and organizational charts. The Corps leadership along with Congress and the White House must recognize the important role technical people have within the Civil Works program and take major steps to create an environment that stresses quality and reliability to its personnel, and that can clearly be seen through all ranks of the organization.

G.2 Findings from Other Studies: Organizing for Success

G.2.1 Report of the Committee on Homeland Security and Governmental Affairs (2006). Hurricane Katrina, A Nation Still Unprepared, United States Senate, Washington, DC, May.

A vital part of the Hurricane Katrina story lies in nearly two centuries of natural and manmade changes to the Louisiana coastline. When New Orleans was settled in 1718, the primary flood threat was the Mississippi River, not the Gulf of Mexico, which was separated from the city by an expansive coastal landscape that served as a buffer from storms emerging from the Gulf.

That protective landscape no longer exists. The ever changing and disappearing coastline left New Orleans more susceptible to hurricanes and contributed to the damage inflicted by Katrina. Should this trend continue, New Orleans and the rest of coastal Louisiana will become ever more vulnerable to damage from future storms, and efforts to protect the city with levees and floodwalls will be progressively undermined.

While a comprehensive analysis of coastal Louisiana's environmental challenges and potential remedies is beyond the scope of this report, this section briefly examines some of the potential impacts of Louisiana's altered landscape on hurricane protection.

Louisiana's Changing Coastal Landscape is Increasing Hurricane Vulnerability

The Louisiana coastline is changing more rapidly than the coastline of any other part of the country and, as a result, becoming more vulnerable to hurricanes. Over the last 70 years, Louisiana has lost over 1,900 square miles of coastal land - an area roughly the size of Delaware. At the peak of the trend in the 1960s and 1970s, Louisiana was losing 40 square miles of coastal land per year. This loss has slowed in recent years, primarily because the most vulnerable lands have already disappeared, but Louisiana is still losing 10 square miles of coastal land per year. As a civil engineering magazine put it, "in southeastern Louisiana a football field worth of wetlands sinks into the sea every 30 minutes."

These coastal lands primarily consist of wetlands, including extensive cypress swamps and grass marshes. But Louisiana's barrier islands (an elongated chain of islands running parallel to the coast and serving as a barrier against waves) and even many higher ridges, which were formed by large amounts of sediment piling up along past banks of the Mississippi River, are also disappearing. The U.S. Geological Survey (USGS) projects that an additional 700 square miles could be lost by 2050 if no further actions are taken to halt or reverse current processes.

The Mississippi River is the single most important factor in sustaining coastal Louisiana. The river brings water, sediments, and nutrients from 41 percent of the land area of the contiguous U.S. to the coast of Louisiana. Prior to the extensive building of levees and dams along the Mississippi, the river carried nearly 400 million tons of sediment to the Louisiana Coast every year - enough to cover 250 square miles one-foot deep in sediment. The growing wetlands fed by the accumulating sediments, nutrients, and fresh water of the Mississippi have added 9,600 square miles of land to the Louisiana coastline over the last 6,000 years - a rate of 1.25 square miles per year. At its peak, this land, known as the Mississippi deltaic plane, accounted for nearly 20 percent of the land area of present-day Louisiana, including New Orleans.

Major causes of land loss in Louisiana have been identified. Dams and diversions along the Mississippi River and its tributaries have greatly reduced the amount of sediment that reaches coastal Louisiana, and levees force the remaining sediment so far offshore that it falls directly onto the outer continental shelf and beyond, where it no longer contributes to sustaining or building coastal lands. By blocking natural flooding cycles, levees prevent fresh water and nutrients from the Mississippi River from nourishing and sustaining wetlands. Ten major navigation canals and more than 9,000 miles of pipelines servicing approximately 50,000 oil and gas production facilities in coastal Louisiana result in a large direct loss of land and also contribute to wetland loss from saltwater intrusion and dredging.

The Louisiana deltaic plane is essentially sinking, in a process known as subsidence, which occurs naturally as sediments deposited by the Mississippi are compacted over time. Oil and gas production further contribute to subsidence, potentially causing local subsidence three times greater than the highest natural subsidence rates. Finally, sea level is rising, primarily as a result of global warming.

The deterioration of Louisiana's coastal landscape of barrier islands, wetlands and higher ridges, and the effects of subsidence, have made coastal communities more vulnerable to hurricane flooding. New Orleans, in particular, is widely considered to be more vulnerable to hurricanes both because land in the city has subsided and because much of the barrier islands and wetlands that once surrounded the city have disappeared.

Many of the mechanisms by which barrier islands, shoals, marshes, forested wetlands, and other features of the coastal landscape protect against hurricanes are well-known. Geologic features such as barrier islands or the land mass associated with wetlands can block or channel flow, slow water velocities, and reduce the speed at which storm surge propagates. These effects can significantly restrict the volume of water available to inundate the mainland.

Forested wetlands can greatly diminish wind penetration, reducing surface waves and storm surge. Shallow water depths weaken waves via bottom friction, interactive damping and braking, while vegetation provides additional frictional drag and further limits wave buildup. Where wetlands and shallow waters are in front of levees, they absorb wave energy and reduce the destructiveness of storm waves on the levees.

Depending on the rate of relative sea-level rise, healthy coastal wetlands can maintain a near sea-level landscape by trapping sediments or accumulating organic material, thus helping to counter subsidence and global sea-level rise. In contrast, when Louisiana's coastal wetlands deteriorate and disappear, the land held in place by the wetlands undergoes wave erosion, eventually washing away and leaving behind open water 10 to 12 feet deep.

On the other hand, the quantitative impact of wetlands and other coastal features on hurricane protection is poorly known. Anecdotal data accumulated after Hurricane Andrew suggests a storm-surge reduction along the Louisiana coast of about three inches per mile of marsh. During Hurricane Katrina, bottom friction and breaking reduced the average height of the highest one-third of waves from 55 feet in deep water (with peak waves above 80 feet), to 18 feet in shallower water outside of the barrier island east of New Orleans, to a fraction of that height in protected areas.

Researchers at the Louisiana State University (LSU) Hurricane Center found that, during Hurricane Katrina, levees protected by wetlands had a much higher survival rate than those bordering open water. For example, large sections of the Mississippi River Gulf Outlet (MRGO) levees that had little or no wetlands separating them from Lake Borgne disintegrated, while the nearby 20-Arpent Canal levee, protected by a buffer of marsh and wooded wetlands, remained standing. According to LSU researchers, an area about the size of a football field with the tree density equal to that found in most Louisiana swamps would reduce wave energy in a storm by approximately 90 percent. These researchers further found that friction from marsh grasses and shrubs reduced water speed from Hurricane Katrina in some places from seven feet per second to three feet per second.

Subsidence is also contributing substantially to hurricane vulnerability. Subsidence occurs across the entire region, and therefore impacts not only natural features such as wetlands and barrier islands, but also man-made structures such as buildings and levees. According to a recent report by the U.S. Army Corps of Engineers (Corps) Interagency Performance Evaluation Task Force (IPET, June 1, 2006), which examines the hurricane protection levee system, the average rate of subsidence across the area is 0.6 feet over a decade. The rate of subsidence is frequently greater under cities and towns than under natural features: when areas are drained in order to prepare them for buildings, organic material in the soil decomposes and leads to further subsidence. In addition, the levees themselves further subside due to their own weight pressing down on the unstable soils of the New Orleans area. As a result, the effectiveness of the levee system deteriorates over time as both the levees and the region subside. The IPET report concluded that some portions of the hurricane protection system around New Orleans are almost two feet below their original elevations, further increasing their own vulnerability, and that of the areas they are designed to protect, to the power of hurricanes.

The changes to Louisiana's coastline have serious implications for the long-term sustainability of the region. Land subsidence and predicted global sea-level rise during the next 100 years mean that areas of New Orleans and vicinity now 5 to 10 feet below mean sea level will likely be 8 to 13 feet or more below mean sea level by 2100. At the same time, the loss of wetlands, barrier islands, and other natural features could eliminate protection from waves and allow for higher and faster moving storm surges. According to the National Academy of Sciences, these trends will make much of Louisiana's southern delta uninhabitable without substantial new engineering projects. In the long-term, New Orleans and other regions of the

Louisiana deltaic plane cannot be protected without taking proper account of the tremendous change that is continuing to occur to Louisiana's coastal landscape.

G.2.2 Senator Susan Collins (2006). "Opening Statement", Committee on Homeland Security and Government Affairs, Hurricane Katrina: Recommendations for Reform," Washington DC, March 8.

The excuse we have heard from some government officials throughout this investigation, that Katrina was an unforeseeable ultra-catastrophe, has not only been demonstrated to have been mistaken, but also misses the point that we need to be ready for the worst that nature or evil men can throw at us. Powerful though it was, the most extraordinary thing about Katrina was our lack of preparedness for a disaster so long predicted.

This is not the first time the devastation of a natural disaster brought about demands for a better, more coordinated government response. In fact, this process truly began after a series of natural disasters in the 1960s and into the 1970s. One of those disasters was Hurricane Betsy, which hit New Orleans in 1965. The similarities with Katrina are striking: levees overtopped and breached, severe flooding, communities destroyed, thousands rescued from rooftops by helicopters, thousands more by boat, and too many lives lost.

Katrina revealed that this kaleidoscope of reorganizations has not improved our disaster management capability during these critical years. Our purpose and our obligation now is to move forward to create a structure that brings immediate improvement and guarantees continual progress. This will not be done by simply renaming agencies or drawing new organizational charts. We are not here to rearrange the deck chairs on a ship that, while perhaps not sinking, certainly is adrift.

This new structure must be based on a clear understanding of the roles and capabilities of all management agencies. It must establish a strong chain of command that encourages, empowers, and trusts frontline decision-making. It must replace ponderous, rigid bureaucracy with discipline, agility, cooperation, and collaboration. It must build a stronger partnership among all levels of government with the responsibilities of each partner clearly defined, and it must hold them accountable when those responsibilities are not met.

G.2.3 Newt Gingrich (2006). "Why New Orleans Needs Saving," *Time Magazine*, March 6.

Shortly after Hurricane Katrina devastated New Orleans, Speaker of the House Dennis Hastert wondered aloud whether the Federal Government should help rebuild a city much of which lies below sea level. The most tough-minded answer to that question demonstrates that rebuilding and protecting new Orleans is in the national interest. Reason: The very same geological forces that created that port are what make it vulnerable to Category 5 hurricanes and also what make it indispensable.

If engineering the Mississippi made New Orleans vulnerable, it also created enormous value. New Orleans is the busiest port in the U.S.; 20% of all U.S. exports and 60% of our grain exports, pass through it. Offshore Louisiana oil and gas wells supply 20% of domestic oil production. but to service that industry, canals and pipelines were dug through the land, greatly accelerating the washing away of coastal Louisiana. The state's land loss now totals 1,900 sq. miles. That land once protected the entire region from hurricanes by acting as a sponge to soak up storm surges. If nothing is done, in the foreseeable future an additional 700 sq. mi. will disappear, putting at risk port facilities and all the energy-producing infrastructure in the Gulf.

There is no debate about the reality of that land loss and its impact. On that the energy industry and environmentalists agree. There is also no doubt about the solution. Chip Groat, a former director of the U.S. Geological Survey, says, "This land loss can be managed, and New Orleans can be protected, even with projected sea-level rise." Category 5 hurricane protection for the region, including coastal restoration, storm-surge barriers and improved levees, would cost about $40 billion - over 30 years. Compare that with the cost to the economy of less international competitiveness (the result of increased freight charges stemming from loss of the efficiencies of the port of New Orleans), higher energy prices and more vulnerable energy supplies. Compare that with the cost of rebuilding the energy and port infrastructure elsewhere. Compare that with the fact that in the past two years, we have spent more to rebuild Iraq's wetlands than Louisiana's. National interest requires this restoration. Our energy needs alone require it. Yet the White Houses proposes spending only $100 million for coastal restoration.

Washington also has a moral burden. It was the Federal Government's responsibility to build levees that worked, and its failure to do so ultimately led to New Orleans' being flooded. The White House recognized that responsibility when it proposed an additional $4.2 billion for housing in New Orleans, but the first priority remains flood control. Without it, individuals will hesitate to rebuild, and lenders will decline to invest.

How should flood control be paid for? States get 50% of the tax revenues paid to the Federal Government from oil and gas produced on federally owned land. States justify that by arguing that the energy production puts strains on their infrastructure and environment. Louisiana gets no share of the tax revenue from the oil and gas production on the outer continental shelf. Yet that production puts an infinitely greater burden on it than energy production form other federal territory puts on any other state. If we treat Louisiana the same as other states and give it the same share of tax revenue that other states receive, it will need no other help from the government to protect itself. Every day's delay makes it harder to rebuild the city. It is time to act. It is well past time.

G.2.4 Houck, O. (2006). "Can We Save New Orleans?", Tulane Environmental Law Journal, Vol 19, Issue 1, 1-68, New Orleans, Louisiana.

So What Do We Do? Here is what we know. It is not just the tire, it's the car. And it's not just the car, it's the driver. Nothing in the system has made a numero uno priority either of protecting New Orleans from hurricanes or to restoring even hanging onto - the Louisiana coast. We have a flood control program, a navigation program, a permitting program, a coastal management program, a flood insurance program, a coastal restoration program - just for openers - and they do not talk to each other. They are riddled with conflicts, basically headless, basically goal-less, weakened by compromises and refusal outright to deal with first causes and first needs. So, this is a tall order.

We also know this. As they came ashore, there were really two Katrinas. One blew through the levees into New Orleans and St. Bernard, and topped the ones further south. The other smashed into coast-front development in a wide swath from Alabama to Texas, wiping out the first half-mile or so of Pass Christian, Waveland, Gulfport, Biloxi, half of Grand Isle, and all the way over to Holly Beach. Same set of storms, but the run-up for one was negligence, and the run-up for the other was arrogance. Building behind levees is one thing; you have some reason to think they'll hold up. Building on the edge of the gulf and thumbing your nose at it is another.

The vision for New Orleans is relatively clean. The city is a given, fixed in its history, architecture, economy and culture and these contributions call for maintaining it, as is, for as long as we can. Nobody needs to reinvent New Orleans: we simply need to get it back. Its protection will cost a fortune, and will take more than anyone wants to concede (and no small amount of luck, as we race the clock against the near-term hurricane seasons). But at least we know what we are driving at. Whether we succeed will depend on levees, flood gates, rational storm water management within the city walls, conservative building elevations, levees and one thing more: a viable coastal zone to buffer them, without which the system will not hold over time.

So here is the starting point: exactly what we do want the Louisiana coast to look like, to do for us, for say, the next century? …Earth to Louisianans: you really can't have this cake and eat it too. With all due respect, it is not just a matter of doing everything we want 'smarter.' It is a matter of getting straight what we want, and what comes first. … what comes next is the hardest step for any American community to take, and shall be heresy in South Louisiana. A plan. The mere mention of planning raises blood pressures and brings on cries of Godless Communism. …What we have had in the city of New Orleans and along the entire gulf coast is planning by default (local attorney Bill Borah calls it 'planning by surprise'). Planning takes place. It's just that we haven't taken part in it. Where water resources are concerned, it starts with real estate developers, port authorities, levee boards and other outside-the-ballot-box enterprises, their projects facilitated and funded by the Army Corps of Engineers. In their minds, the only question is a technical one: what kind of engineering do we need to get our project done? The system has produced the expected results: more rip-rap here, more drainage there, and levees to the horizon. The goal is - although it is never stated anywhere - to develop as much of the coast as possible. When you add the projects up, they determine the destiny of the city and South Louisiana.

What is apparent is that these levees, designed by engineers and approved by Congress, are the basic planning documents for the future of South Louisiana. What is north of these levees will be developed. What is south of them will be anyone's guess, although not for long; the map on global warming shows these coastal marshes gone within a century. De facto, we end up with a wall. Not all that adequate a wall, by the way. Only Category three, if that. Can you imagine the costs of maintaining even a Category three levee system winding back and forth to the Gulf from New Orleans to Texas" Can we imagine what will happen when development piles in behind it, and then gets flooded? Do we already know, from Lakeview and New Orleans East, what happens to land elevations behind levees once they are drained and paved?

Our choice is to start this process from the other end. If we do, another range of options open. There are a dozen major towns across the southern tier with thousands of homes and residents, and they deserve protection. But the way to provide it may be with the same kind of ring levee systems that protects (or should) New Orleans and its surrounding parishes, supplemented by flood gates at the mouths of the main canals. Or, it may mean peninsular levee systems down the historic ridges of the bayous, protecting what has always been the high ground. …Problem is, we have lacked the process - we have lacked even the language - for such a discussion. In addition to scientists and engineers, we may need some social workers. In saying this, I am most serious.

The Dutch have been fighting the North Sea for a thousand years, and their historic methods - dikes, drainage canals and pumps - look quite familiar, as does their continuing and accelerated rate of subsidence. Parts of the coast are now 23 feet below the level of the sea. The temporary successes of this engineering look familiar too, always followed by greater, catastrophic losses. Finally, in 1953 a major hurricane blew in and left 1,800 bodies in its wake, 50,000 destroyed homes and 350,00 acres of flooded land. In a country half the size of Louisiana.

Vowing 'Never Again,' the country devised a new plan. Back in 1932, they had dikes off the Zuiderzee, an estuary twice the size of Lake Pontchartrain, with a barrier more than 20 miles long. Their new Delta Plan would apply that same strategy to the entire Atlantic Coast. They dammed every one of their major rivers, some of them multiple times. They diked off their estuaries, diked off entire seas, and reduced their coastline by more than two-thirds. The water is the enemy, explained a professor of engineering. 'You don't let the enemy, before the fight starts, penetrate your territory.'

They won. At a cost of about $18 billion over some 40 years, they completed their first rounds of the Delta plan and they haven't flooded since. They predict their strategy to hold for the next 500 years. At the same time they moved aggressively to fill lands behind their coastal barriers, 'polders' created literally from the sea. The polders produced fruit and vegetables. So far, it was all win-win.

Then another bill came in. Over half the estuaries disappeared, and those remaining were in trouble. Coastal fisheries were hammered. At the mouth of two of Europe's major rivers, the Meuse and the Rhine, the Grevelingen was the largest and most productive estuary on the Atlantic coast. Within two weeks of completing the barrier across it the mussels and shellfish were dead. The government tried to turn what is now a lake behind the barrier to tourism, but the water was, and remains, so contaminated that it is unfit for human contact. It is covered with toxic algae and more than 5 billion feet of polluted sludge has settled on the bottom. They had made a dead zone. …. Interfering with natural processes and natural systems is always a bad thing, says one. 'Mother nature is the best engineer'.

There is also a question of commitment. The Netherlands is a small country, and it has dedicated itself to fighting the sea. It cannot afford not to. Sixty percent of its land is below sea level. Louisiana, as valuable as it is to the nation and to those of us who live here, is only one piece of America, and America's attention span for this or any other endeavor is limited. So will be federal funding, and we are still in the heyday of a petroleum economy that cannot and will not, last. Unless Louisiana goes in a direction that is more self-sustaining over the long term, it could (end) up with a large white elephant on its hands.

Perhaps the most important lesson from the Netherlands experience is how it has since evolved. As noted, Dutch engineers have tried to retrofit their structures to accommodate natural processes, to recreate natural processes, with mixed success. Easier to do that from the start. As a matter of engineering strategy, they have now explicitly rejected big-levee and big-drainage solutions as unworkable. They have instead come to rely on multiple layers of defense, redundant in the safety they provide, and none designed to provide full protection on their own. Most significantly, they have changed their philosophy from 'flood control' to 'water management,' and are tiptoeing to the next logical, indeed the only logical step: people management. It is rather remarkable.

Meanwhile, in its most recent report, under the title Lessons Learned, the Netherlands Water Partnership says: The Netherlands is changing its approach to water. The country will have to make more frequent concessions. The report explains, we will have to relinquish open space to water, and not take back existing open spaces, in order to curb the growing risk of disaster due to flooding. Giving space does not mean the height of ever taller levees or depth by channel dredging. Rather, space in the sense of flood plains. …Only by relinquishing our space can we set things right; if this is not done in a timely manner, water will sooner or later reclaim the space on its own, perhaps in a dramatic manner.

If a sustainable coast is the goal, we need a map of what we can sustain. That map, in turn, should drive what we do for restoration and for human development, and for its protections. …If on the other hand, we start from the position of maintaining as much of the coastal zone and its natural storm barriers as we can, we meet a different set of possibilities. We interfere with natural processes as little as possible; remove barriers to them, and over time move to the traditional places Louisianans have always lived, the ridges of the natural bayous and distributaries leading to the gulf. We protect those zones. We also protect critical infrastructure for oil and gas, fisheries and essential navigation canals. For the rest, we let nature have the space it needs to rebuild and it will protect us in turn.

We also need new mapmakers. We have always thought of coastal management in terms of engineering, and engineering agencies are well funded at every level from the Corps to local levee districts, politically supported from top to bottom, and largely autonomous. …The nice thing about engineering is that it seems so certain. It may be faulty and the building may fall over, but it responds to numbers and rules of physics. We are comforted by it. Usually, it works, or we would never take an airplane ride. And so we like engineering solutions. Among other things, they made living in this part of the world possible. They also look impressive, big dams and canals. And, down inside, they allow us to move dirt and water around which we have all done and enjoyed from early childhood. Hard structure engineering has a great deal of history, money, and human nature going for it. Which is why we have lots of engineering maps.

Coast 2100, We can now put the puzzle together. In a post-Katrina world of greater urgency, funding and public awareness of the plight of New Orleans and the Louisiana coastal zone, we have the opportunity to go beyond Coast 2050, take it off the leash and see where we can really go: Coast 2100. Before suggesting a few principles for that new plan, let us reach two understandings.

The first is that restoring coastal Louisiana is a national issue and will require remedies beyond this state. We lie at the receiving end of a large watershed, and some of what we need has been turned off and other stuff that is hurting us has been turned on. The Corps districts need to talk to each other, the EPA has to step up to the plate, and upstream states have to change some habits too. If the nation's taxpayers are going to be asked to spend more money than America spent on the Marshall Plan to fix all of post-war Europe, then they have a right to expect a national effort.

The second is the funding. When it comes to restoring the city of New Orleans itself, the funding should be federal. Not just restoring the levees, the city. However you look at it, and with plenty of supporting actors, the Corps of Engineers drowned New Orleans and the sight of individual homeowners trying to rip out, detoxify and rebuild their homes is one of the most unjust features of a post-Katrina world. New Orleans is a federal responsibility. You flood somebody, you pay.

Conventional wisdom holds that the Corps is immune from liability for its role in the levee failures, and case law supports that conclusion. *United States v. James*, 478 U.S. 597, 612 (1986). On the other hand, it seems a far stretch to say that 1929 statute dealing exclusively with Corps works on the Mississippi River should immunize the Corps for activities in a different location, of a different nature, at a later time. Whatever the legal merits, the federal government's moral obligation to repair the catastrophic damaged caused by its own agents seems clear. The obligation is not simply to provide better flood control; it is to repair the harm.

With these understandings, here are ten criteria for a coastal plan with the maximum long-term chance of success:

1. Draw the maps. Not just a flood protection plan. …To be sure, we need to know what the engineering possibilities are. But they beg the question, engineering to do what? Right now, we have the cart before the horse.

2. Review the bidding. The Corps and other agencies have projects pending that could seriously compromise an all-out effort to restore the coastal zone. …That Congress has already authorized them is not persuasive. Like MRGO, they were authorized in a very different day under very different circumstances. Katrina changed the equation. They need to be looked at again, new restoration map in hand. They should be consistent with the future, not the past.

3. Free the upstream sediments. The Mississippi today at the latitude of New Orleans carries about 80 million tons of sediment a year. An impressive figure, until we realize that a century and half ago it carried about 400 million….The point is that most of those silts today lie behind dams on the upper watershed. We need them, and the Mississippi is their natural conveyor belt. The bumper sticker should read: Free the Mississippi 400 Million.

4. Free the rivers. Which, until today, we have tiptoed around with a few, very expensive freshwater diversion structures whose efficacy has been further compromised by their capacity and politics….We can cut sills in the levees to replicate natural crevasses, and let the river do its thing.

5. Cut upstream fertilizers. …The upstream states are in denial, so is Louisiana for that matter, and EPA is in hiding. It is time to insist. A less polluted river is not a matter of aesthetics. It is a matter of survival.

6. Heal the marsh. Which is hemorrhaging from the inside out. Push in the spoil banks. Crevasse the ones that remain. Plant grass. Pretend we're farmers. We can build wetlands, if necessary, by hand. Not fully - manmade marshes still come out looking a little weird - but we need to rebuild a base for natural processes to then improve upon. A coast fully ceded to open water will be harder to restore.

7. Stop the bleeding. We will have to make historic commitments to hold onto even the base of coastal wetlands we currently enjoy, an order of magnitude beyond the ambition of Coast 2050. Meanwhile, we continue to permit dredging and filling of the same wetlands for access canals, waste dumps, new subdivisions and the like. Every acre of the coast we allow to be destroyed is certain loss. ..An ounce of prevention is worth a ton of restoration.

8. Make space for natural processes. Elevate roads and railroads. Open new floodways. Move oyster leases, consolidate energy, port and navigation facilities, zone development within protected areas and let the rest rebuild. We shouldn't try to storm-proof the coastal zone, and the more we try to storm-proof the more we will loose.

9. Dare to think retreat. …People and structures in the most vulnerable areas should be offered the opportunity to relocate in protected areas, at full and fair compensation. The costs of such a program will be more than offset by the savings in the attempt to protect these same residences forever, and in reduced looses to future storms. The more we delay this process, the harder it will be.

10. Face global warming. It is real. And it makes everything else we do to save the coast infinitely more difficult, if not impossible.

Senator Landrieu inserted an $800 million appropriation into the 2005-06 budget, directing the Corps to conduct such a study for both New Orleans and all of South Louisiana on a very tight schedule; a scant six months for a draft plan. It may seem curious to some that, for these purposes, we would go back to the very agency that built failing levees in the first place and has shown historic resistance to thinking outside the box. Such is the abiding faith of the congressional delegation in its historic water resources partner. It is what Congress knows. The output of such a process is likely to be the maximum development model. It is what the Corps Knows. An alternative model is not yet on the table.

The technical decisions here, form the outset, call for a broader base than that of the Corps. The Corps is qualified to make engineering and technical decisions. But as history shows, decisions of this magnitude should be reviewed by an entity that is truly independent, also expert, and with the authority to remand an unsupported conclusion. It could be the National Academy of Sciences, although the Academy is not structured to provide long-term services. It could be an empowered state agency. What ever the vehicle, well-qualified and independent review seems essential.

As the Katrina relief debacle illustrated, shared responsibilities are necessary, but joint command is fatal. …but, our job calls for a new command with a single, unfragmented mandate - to save the Louisiana coastal zone - and the capacity to ensure that all other players are working towards that goal. This authority's first job is to prepare the maps that guide all that follows. Its second job is to review ongoing projects, flood-control and otherwise, that could affect the success of their plans. Its third job is to integrate restoration, development and flood control initiatives - in that order - to achieve long term sustainability. An agency with less autonomy, or with a different set of priorities, will not succeed.

Can We Save New Orleans? Here is our choice. We can live with nature next time around, or we can fight it for all the turf we can take and spend fortunes trying to defend it. When it comes to floods and hurricanes, a little space goes a long way. ….more problematically, we are likely to propose large outer barriers to protect the city as well, a second ring across the Rigolets and to the south. We are likely to extend these barriers, leaky or otherwise, across the entire Louisiana coast, for as far as the money will go. That is what we have always done, it is what the Corps of Engineers knows how to do, it avoids the need to plan, it sets up killings in real estate, and it is the easy path for politicians. Of course, it will be increasingly hard to maintain for even this century, the costs in trying will be enormous, and when there are failures more people will die. But those consequences are for another day. We are living now.

The point of this Essay is that we have a choice. Rather than start with the premise that we are going to protect as much of the Louisiana coast as we can from hurricanes and then graft on some restoration measures, we can start with the premise that we are going to restore as much of the Louisiana coast as we can and then see what we need to do, within that context, to protect people from hurricanes. The approaches are not the same, and they will lead to two very different futures. We are entitled to see the second one, before we are handed the first as a fait accompli. The first one is being prepared, by the Corps, on an unrealistically hasty schedule, as we speak.

There is another engineering outfit on the scene, however. Mother Nature. The best way to restore coastal Louisiana and to provide long-term safety for New Orleans and other coastal residents is to help nature get back in the game, and then stand back. Not very far back. Just far enough for it to work for us: a natural, self-sustaining, horizontal, first and major line of defense spinning off renewable resource dividends for generations to come. We can have a coast and live and work in it safely for a very long time. Just not everywhere, and doing every damn thing we want. Can we save New Orleans? It'll be a journey. Will we? Depends on no rain in the morning, and the path we choose.

G.2.5 Netherlands Water Partnership (2005). *Dutch Expertise, Water Management & Flood Control*, Delft, The Netherlands, November.

Climate changes are increasing the likelihood of flooding and water-related problems. In addition population density continues to increase, as does the potential for economic growth, and consequently, the vulnerability to economic and social disaster. two undesirable developments that, in terms of safety, exacerbate one another - a grown risk with even larger consequences. As such, the safety risk is growing at a n accelerated pace (safety risk - chance multiplied by consequence).

The Netherlands is changing its approach to water. This change involves the idea that the Netherlands will have to make more frequent concessions. We will have to relinquish open space to water, and not take back existing open spaces, in order to curb the growing risk of disaster due to flooding, we will also need to limit water-related problems and be able to store water for expected periods of drought. By this we do not mean space in terms of the height of ever taller levees or depth through continued channel dredging, but space in the sense of flood plains. This approach will require more area, but in return we will increase our safety and limit water related problems. Safety is an aspect that must plan a different role in spatial planning. Only by relinquishing our space can we set things right; if this is not done in a timely manner, water will sooner or later reclaim the space on its own, perhaps [in a] dramatic manner.

We are developing a new risk management approach that includes determining how far the government can and should go in providing protection against high water levels and how much it can and should spend for that purpose. We will base the approach on factors including the 'safe Netherlands roadmap.' In that project, the Ministry has joined forces with provincial governments and water boards to gauge the likelihood and consequences of flooding in each levee 'ring' (an area that is completely surrounded by levees).

The consequences of flooding are also taken into account in the Dutch risk management approach. Human and economic values also determine risk standards. Which means that not just technical expertise in dealing with flood management is needed, but also socio-economic experience. We support the decision-making process by providing scenarios, alternatives and public relations advice.

The Netherlands is divided into compartments with different risk levels of flooding. High density areas with greater human and economic interest, like Rotterdam and Amsterdam, are surrounded with stronger levees than rural areas and therefore have a lower risk level from flooding than others. One of the most difficult policy decisions the Dutch face in the next decade is to decide what level of protection is necessary, acceptable and cost-effective for each compartment.

Our standards are accepted risks related to the design-criteria of our dikes. Those standards are laid down in the Flood Defense Act. For the economically most important and densely populated part of the country, we design our dikes and dunes to be strong enough to withstand a storm-situation with a probability of 1 to 10,000 a year. That means that a Dutchman - if he should live a 100 years - has a chance of 1 percent to witness such an event. For our parliament, these odds became the acceptable standard. For the less important coastal areas we calculate the probability of 1 to 4,000 and along the main rivers 1 to 1,250.

G.2.6 Interagency Floodplain Management Review Committee (1994). *Sharing the Challenge: Floodplain Management into the 21st Century*, Report to Administration Floodplain Management Task Force, Washington DC, June.

Over the last 30 years the nation has learned that effective floodplain management can reduce vulnerability to damages and create a balance among natural and human uses of floodplains and their related watersheds to meet both social and environmental goals. The nation, however, has not taken full advantage of this knowledge. The United States simply has lacked the focus and incentive to engage itself seriously in floodplain management. The 1993 flood has managed to focus attention on the floodplain and has provided the incentive for action.

The Interagency Floodplain Management Review Committee proposes a better way to manage the floodplains. It begins by establishing that all levels of government, all businesses and all citizens have a stake in properly managing the floodplain. All of those who support risk behavior, either directly or indirectly, must share in floodplain management and in the costs of reducing that risk. The federal government can lead by example; but state and local governments must manage their own floodplains. Individual citizens must adjust their actions to the risk they face and bear a greater share of the economic costs.

While development of the region has produced significant benefits, it has not always been conducted in a wise manner. As a result, today the nation faces three major problems:

First, as the Midwest Flood of 1993 has shown, people and property remain at risk, not only in the floodplains of the upper Mississippi River Basin, but also throughout the nation. Many of those at risk do not fully understand the nature and the potential consequences of that risk; nor do they share fully in the fiscal implications of bearing that risk.

Second, only in recent years has the nation come to appreciate fully the significance of the fragile ecosystems of the upper Mississippi River Basin. Given the tremendous loss of habitat over the last two centuries, many suggest that the nation now faces severe ecological consequences.

Third, the division of responsibilities for floodplain management among federal, state, tribal and local governments needs clear definition. Currently, attention to floodplain management varies widely among and within federal, state, tribal and local governments.

Now is the time to:

Share responsibility and accountability for accomplishing floodplain management among all levels government and with all citizens of the nation. The federal government cannot go it alone nor should it take a dominant role in the process.

Establish, as goals for the future, the reduction of the vulnerability of the nation to the dangers and damages that result from floods and the concurrent and integrated preservation and enhancement of the natural resources and functions of floodplains. Such an approach seeks to avoid unwise use of the floodplain, to minimize vulnerability when floodplains must be used, and to mitigate damages when they do occur.

Organize federal programs to provide the support and the tools necessary for all levels of government to carry out and participate in effective floodplain management.

G.2.7 Input from Citizens of the Greater New Orleans Area; Levees.Org

We the citizens of Levees.Org are pleased to submit the issues that we believe are critical to the future of New Orleans and southern Louisiana.

Mission. Flood protection must be the primary mission of the entity in charge of design and construction of the flood protection system. The US Army Corps of Engineers views their mission as not rocking the boat and following Congress' authorization. We feel that is the wrong mission.

Cost/Benefit. The Dutch have developed sophisticated and rigorous cost benefit analysis focused on protecting property and lives. This has guided hard decisions about what to protect and what to give back to nature. Decisions must be based upon sound cost benefit analysis and not politics.

Peer Review. There must be real-time independent peer review of the Corps' projects and practices to assure that the right projects are being done right. This review can be done both at the state level via the local levee boards and via private groups formed by local business and environmental interest. The review must be done concurrently so as not to delay time-sensitive projects.

Outrage. Finally, we at Levees.Org wonder: Where is the outrage? Over a thousand have died, a hundred thousand homes have been destroyed, and a historic American city lies in ruins. This was not a natural disaster. This was a manmade disaster caused by deeply ingrained institutional problems of the US Army Corps of Engineers and Congress. Every American should be outraged.

It is our hope that, through the expert opinion revealed in the National Science Foundation report, that the nation and Congress will come to a better understanding of the issues concerning August 29, 2005. Hopefully, finally, we can all agree on what caused the Greater New Orleans Flood and begin the process of rebuilding New Orleans and southern Louisiana and making its citizens whole.

Respectfully submitted by
Sandy Rosenthal
Founder, Levees.Org
www.levees.org

G.2.8 Congressional Research Service (2005). *Aging Infrastructure: Dam Safety*, Report for Congress, K Powers, Washington DC, September 29.

While dams have multiple benefits, they also represent a risk to public safety and economic infrastructure. This risk stems from two sources: the likelihood of a dam failure and the damage it would cause. While dam failures are infrequent, age, construction deficiencies, inadequate maintenance, and seismic or weather events contribute to the likelihood. To reduce the risk, regular inspections are necessary to identify deficiencies and then corrective action must be taken.

To identify deficiencies that could cause dam failures, the federal government established inspection requirements for the nation's federal dams. Once deficiencies are identified, most agencies finance repairs through their operation and maintenance accounts. Funding mechanisms vary for larger rehabilitation activities. At the Bureau of Reclamation, for example, most larger repairs are conducted with annual appropriations to its dam safety program. At some other agencies, dam rehabilitation must compete with other construction projects for funding.

At non-federal dams, safety is generally a state responsibility, though some federal assistance has been provided. Funding through the National Dam Safety Program, which is authorized through FY 2006, helps states improve their dam safety programs and train inspectors. In addition, the Federal Energy Regulatory Commission and the Department of Labor, Mine Safety and Health Administration require regular inspections at the non-federal dams within their jurisdiction. Even so, there are concerns that most state dam safety programs have inadequate staff and funds to effectively inspect or monitor all of the dams for which they are responsible. Further, there are concerns that states, local governments, and other non-federal dam owners may not have the financial resources to maintain and rehabilitate their dams.

Following the failure of the levees at Lake Pontchartrain in 2005, it is likely that there will be increased scrutiny of flood control infrastructure and the structural stability of high hazard-potential dams. Further, there has been periodic pressure for Congress to pass legislation authorizing federal support for rehabilitation work at non-federal dams. Demand for such assistance is likely to increase, but there is currently no federal policy that describes the conditions under which federal funding is appropriate, nor has congress established criteria for prioritizing funding among non-federal projects.

G.2.9 Sparks, R. E. (2006). "Rethinking, Then Rebuilding New Orleans," Issues in Science and Technology, National Academy Press, Winter 2006, p 33-39, Washington DC.

New Orleans will certainly be rebuilt. But looking at the recent flooding as a problem that can be fixed by simply strengthening levees will squander the enormous economic investment required and, worse, put people back in harm's way. Rather, planners should look to science to guide the rebuilding, and scientists now advise that the most sensible strategy is to work with the forces of nature rather than trying to overpower them. This approach will mean letting the Mississippi River shift most of its flow to a route that the river really wants to take; protecting the highest parts of the city from flooding and hurricane-generated storm surges while retreating from the lowest parts; and building a new port city on higher ground that the Mississippi is already forming through natural processes. The long-term benefits - economically and in terms of human lives - may well be considerable.

To understand the risks that New Orleans faces, three sources need to be considered. They are the Atlantic Ocean, where hurricanes form that eventually batter coastal areas with high winds, heavy rains, and storm surge; the gulf of Mexico, which provides the water vapor that periodically turns to devastatingly heavy rain over the Mississippi basin; and the Mississippi River, which carries a massive quantity of water from the center of the continent and can be a source of destruction when the water overflows its banks. It also is necessary to understand the geologic region in which the city is located: the Mississippi Delta.

If Hurricane Katrina, which in 2005 pounded New Orleans and the delta with surge and heavy rainfall, had followed the same path over the Gulf 50 years ago, the damage would have been less, because more barrier islands and coastal marshes were available then to buffer the city. Early settlers on the barrier islands offshore of the Delta built their homes well back from the beach, and they allowed driftwood to accumulate where it would be covered by sand and beach grasses, forming protective dunes. The beach grasses were essential because they helped stabilize the shores against wind and waves and continued to grow up through additional layers of sand. In contrast to a cement wall, the grasses would recolonize and repair a breach in the dune. Vegetation offers resistance to the flow of water, so the more vegetation a surge encounters before it reaches a city, the greater the damping effect on surge height. The greatest resistance is offered by tall trees intergrown with shrubs; next are shorter trees intergrown with shrubs; then shrubs; followed by supple seedlings or grasses; and finally, mud, sand, gravel, or rock with no vegetation.

Of course, the vegetation has its limits: Hurricanes uproot trees and the surge of salt or brackish water can kill salt-intolerant vegetation. Barrier islands, dunes, and shorelines can all be leveled or completely washed away by waves and currents, leaving no place for vegetation to grow. the canals cut into the Delta for navigation and to float oil-drilling platforms out to the gulf disrupted the native vegetation by enabling salt or brackish water to penetrate deep into freshwater marshes. The initial cuts have widened as vegetation dies back and shorelines erode without the plant roots to hold the soil and plant leaves to dampen wind- or boat-generated waves.

The ecological and geological sciences can help determine to what extent the natural system can be put back together, perhaps by selective filling of some of the canals and by controlled flooding and sediment deposition on portions of the Delta through gates inserted in the levees.

If New Orleans is to be protected against both hurricane-generated storm surges from the sea and flooding from the Mississippi river, are there alternative cost-effective approaches other than just building levees higher, diverting floods around New Orleans, and continuing the struggle to keep the Mississippi River from taking its preferred course to the sea? Yes, as people in other parts of the world have demonstrated.

Could the same approach be taken in the Delta, in the new Atchafalaya lobe? Advocates for rebuilding New Orleans in its current location point to the 1,000+ year levees and storm surge gates that the Dutch have built. But the Netherlands is one of the most densely populated countries in Europe, with 1,000 people per square mile, so the enormous cost of building such levees is proportional to the value of the dense infrastructure and human population there. The same is not true in Louisiana, where there are approximately 100 people per square mile, concentrated in relatively small parcels of the Delta. This low population density provides the luxury of using Delta lands as a buffer for the relatively small areas that must be protected.

However, the Dutch should be imitated in several regards. First, planners addressing the future of New Orleans should take a lesson from the long-term deliberate planning and project construction undertaken by the Dutch after their disastrous flood of 1953. These efforts have provided new lands and increased flood protection along their coasts and restored floodplains along the major rivers. Some of these projects are just now being realized, so the planning horizon was at least 50 years.

Planners focusing on New Orleans also would be wise to emulate Dutch efforts to understand and work with nature. Specifically, they should seek and adopt ways to speed the natural growth and increase the elevation of the new Atchafalaya lobe and to redirect sediment onto the Delta south of New Orleans to provide protection from storm waves and surges. A key question for the Federal Emergency Management Agency (FEMA), the FEMA equivalents at the state level, planners and zoning officials, banks and insurance companies, and the Corps of Engineers is whether it is more sustainable to rebuild the entire city and a higher levee system in the original locations or to build a ‘new’ New Orleans somewhere else, perhaps on the Atchafalaya lobe.

Under this natural option, old New Orleans would remain a national historic and cultural treasure, and continue to be a tourist destination and convention city. Its highest grounds would continue to be protected by a series of strengthened levees and other flood-control measures. City planner sand the government agencies (including FEMA) that provide funding for rebuilding must ensure that not all of the high ground is simply usurped for developments with the highest revenue return, such as convention centers, hotels, and casinos. the high ground also should include housing for the service workers and their families, so they are not consigned again to the lowest-lying, flood-prone areas. The flood-prone areas below sea level should be converted to parks and planted with flood-tolerant vegetation. If necessary, these areas would be allowed to flood temporarily during storms.

At the same time, the Corps, in consultation with state officials, should guide and accelerate sediment deposition in the new Atchafalaya lobe, under a 50- to 100-year plan to provide a permanent foundation for a new commercial and port city. If old New Orleans did not need to be maintained as a deepwater port, then more of the water and sediment in the Mississippi could be allowed to flow down the Atchafalaya, further accelerating the land-building. The new city could be developed in stages, much as the Dutch have gradually increased their polders. The port would have access to the Mississippi River via an exiting lock (constructed in 1963) that connects the Atchafalaya and the Mississippi, just downstream of the Old River Control Structure.

This plan will no longer force the Mississippi River to go down a channel it wants to abandon. The shorter, steeper path to the sea via the Atchafalaya might require less dredging that the Mississippi route, because the current would tend to keep the channel scoured. Because the Mississippi route is now artificially long and much less steep, accumulating sediments must be constantly dredged, at substantial cost. Traditional river engineering techniques that maintain the capacity of the Atchafalaya to bypass floodwater that would otherwise inundate New Orleans also might be needed to maintain depths required for navigation. These techniques include bank stabilization with revetments and wing dikes that keep the main flow in the center of the channel where it will scour sediment.

Action to capitalize on the natural option should begin immediately. The attention of the public and policymakers will be focused on New Orleans and the other Gulf cities for a few more months. The window of opportunity to plan a safer, more sustainable New Orleans, as well as better flood management policy for the Mississippi and its tributaries, is briefly open. Without action, a new New Orleans - a combination of an old city that retains many of its historic charms and a new city better suited to serve as a major international port - will go unrealized. And the people who would return to New Orleans rebuilt as before, but with higher levees and certain other conventional flood control works, will remain unduly subjected to the wrath of hurricanes and devastating floods. No one in the Big Easy should rest easy with this future.

G.2.10 Curole, W. (2005). *Comprehensive Hurricane Protection Plan Guidelines*, General Manager, South Lafourche Levee District Presentation to French Quarter Citizens Group, November 2005.

Wendell Curole provided the following concepts for provision of a comprehensive hurricane protection plan for populated areas of southern Louisiana:

- *Protection of evacuation routes with a hurricane levee system or flood proofing.*
- *Plan for freshwater and sediment diversion projects to regain natural protection from storm surges.*
- *Coordinate on-going flood studies by the Corps of Engineers and others. State and local officials should decide when and where the flood protection should be directed.*
- *Keep the public informed of the threat a hurricane poses to them and their property.*
- *Increase level of already constructed hurricane protection levees to Category 4 or 5 standards.*
- *Plan for internal drainage from the upper reaches of the drainage basin to the barrier islands: a) Gravity drainage through water control structures in the hurricane levee, b) Interior drainage levees, c) Pump systems, d) Channel improvements.*
- *Protection of infrastructure (highways, navigation channels).*
- *Stress elevation in construction of bu9ildings through education not regulation.*

Curole stressed that "the most dependable way to protect from all types of flooding (river, rainfall, or hurricane) is constructing buildings with as high an elevation as possible."

G.2.11 Lopez, J. (2005). *The Multiple Lines of Defense Strategy to Sustain Louisiana's Coast*. Report to Lake Pontchartrain Basin Foundation, New Orleans.

The tragedies of Hurricanes Katrina and Rita in 2005 have revealed to the world the enormous challenge Louisiana now faces. South Louisiana appears to have entered a period when the convergence of two powerful forces is working against its survival. Since the 1950's, the processes driving coastal loss have continued only slightly abated. Since 1990, meteorological and oceanic processes driving tropical systems have more frequently generated Category 4 and 5 hurricanes. More destructive hurricanes are predicted for coming decades. South Louisiana's ongoing peril is the continued overlap of weakened hurricane protection with more frequent and intense hurricanes.

In light of this predicament, how can the coast and culture of south Louisiana survive? The survival of a culture and a region is at stake. Hurricanes Katrina and Rita may have narrowed the field of discussion from what we might want, down to what we absolutely need. There is a growing consensus that what is needed is a pragmatic and effective strategy to integrate both coastal habitat restoration and engineered flood protection, such as levees. This strategy must be established soon and while under duress. The next hurricane season will always be just 180 days away.

This is a plan of how to merge coastal habitat restoration and engineered flood protection. When both are achieved, the ecology and economy of the region can continue and together they will save and sustain Louisiana’s Coast for future generations. This can be achieved and this is how it may be done.

The examples shown and areas discussed in this report focus on the delta portion of the Louisiana coast; however, the same principles are applied to the entire coast of Louisiana. Maps of the Chennier plain in southwestern Louisiana are under development.

The Multiple Lines of Defense Strategy proposes that two key elements of the coast be managed and perpetuated that will together sustain the coast. The two planning elements are:

1) Utilizing natural and manmade features which directly impede storm surge or reduce storm damage (Lines of Defenses),
2) Establishing and sustaining the wetland habitat goals (Target Habitat Types).

These two, when integrated, can sustain the coast. This strategy is not a new restoration technology; rather, it is a new strategy to coordinate and prioritize conventional restoration methods and projects for coastal habitats.

This coastal management vision acknowledges the reality that environmental habitat restoration and engineered flood protection are not separable goals. It is unlikely that sufficient flood protection in south Louisiana can be accomplished by a “levees only” strategy. It is also true that adequate flood protection cannot be accomplished by simply restoring coastal habitats. Both habitat restoration and engineered flood protection must proceed in a coordinated plan which maximizes regional benefits and minimizes costs. Because there are substantial costs associated with both coastal habitat restoration and engineered flood protection, their financial justifications are codependent on a sustainable coastal economy.

The Lines of Defense include the Gulf of Mexico shelf, the barrier islands, the sounds, marsh landbridges, natural ridges, manmade ridges, flood gates, flood levees, pump stations, home & building elevations, and evacuation routes. Identification of these Lines of Defense on a map allows hydrologists, levee district managers, emergency personnel, etc. to all share a common landscape template to evaluate, abate, and monitor flood risk or other storm impacts.

The Target Habitat Types include swamp, fresh marsh, intermediate marsh, brackish marsh and salt marsh. Maintaining the target salinity regime and then optimally managing the habitat types, puts all the natural resources and resource managers on the same page with a unified biological and natural resource vision. Since each habitat has a differing profile of vegetation, fisheries, soils, hydrology, waterfowl, etc., it is imperative that geographic areas of each habitat be identified to optimize restoration and management for the needs for each habitat type. The establishment and maintenance of the Target Habitat Types requires a corresponding salinity gradient goal. This salinity gradient would be maintained by controlled river reintroductions and, if needed, hydrologic restoration.

Types for coastal planning are useful separately to articulate and develop projects. However, additional value is gained by overlaying of these elements on a single map. This integrated map becomes the central coastal management planning tool since it depicts a unifying landscape vision for the coast, embracing environmental habitat restoration and engineered flood protection. The Lines of Defense define priority areas for coastal habitat restoration; that is, the "where" of restoration. The target habitats types define potential restoration methods or limitations of coastal habitat restoration; that is, the "how" of restoration. This complimentary relationship together focuses restoration finding on priority areas and guides the type of restoration possible or required. Coastal habitat restoration using traditional restoration techniques may proceed while producing ecologic benefits and enhancing flood protection to the coastal infrastructure. The integrated map may satisfy the National Research Council recommendation to include an explicit map of the desired future condition or goals for the coast.

At least two important results of the Multiple Lines of Defense Strategy should be noted. One is that a natural ridge's ecologic function is recognized as generally being a hydrologic barrier. This makes their ecologic function compatible with using them as economic corridors. Natural ridges such as Bayou Lafourche may be leveed and still retain its ecologic function, which opens an economic corridor with flood protection. A second result is that restoration is generally focused on remaining marsh, and avoids large areas where previous heavy wetland loss has occurred. This may avoid areas with chronic causes for wetland loss that may be ongoing, such as subsidence.

In summary, the proposal described here is a unified vision for the coast which embraces environmental habitat restoration as well as engineered flood protection. Goals can be clearly articulated through maps of the Target Habitat Types and Lines of Defense. The Multiple Lines of Defense Strategy should be evaluated quickly for the entire Louisiana coast to begin implementation if it is deemed to be warranted.

The eleven Lines of Defense are:

1st: Offshore shelf within the Gulf of Mexico. The offshore shelf ranges in depth from 300 feet at the shelf edge to zero depth at the gulf shoreline. Its width vanes from a few miles to hundreds of miles. The primary benefit of the shallow shelf is to dramatically reduce wave height and wave energy from an approaching tropical system. A negative aspect of the shelf is that it will promote higher storm surges inland. The variable influences on storm surges due to the geometry of the shelf needs to be considered for storm surge analysis. Also, dredging activities on the shelf should avoid increasing shoreline erosion by wave refraction around dredge holes. The gulf fisheries and the oil and gas industry are key economic aspects of the shelf. Examples: Narrow shelf at the mouth of Mississippi River & Wide shelf offshore from Cameron Parish

2nd: Barrier Islands. The Louisiana barrier island shoreline is characterized by fragmented barriers or shoals with low vertical profiles and low sand content. However, barrier islands provide an important wave barrier for interior sounds and coastal marsh. The primary benefits of barrier islands are the near-complete reduction in wave height and the slight reduction in storm surge further inland. A negative aspect of barrier islands is their ephemeral nature and unpredictable local impacts to them from hurricanes. Barrier islands also have significant recreational aspects such as fishing and birding. Examples: Chandeleur Islands and Grand Isle

3rd: Sounds. The primary benefit of the sounds is to provide a relatively shallow water buffer to deep water currents. Sounds do have a negative aspect during storms by allowing waves to re-generate on the on the sound side of barrier islands. Also, sounds may cause storm surge and wave erosion on the back side of barrier islands.

4th: Marsh Landbridges. Marsh landbridges are areas of emergent marsh with relative continuity compared to adjacent bays, sounds or areas of significant marsh/land loss. Ideally, landbridges connect other elevated landforms such as natural ridges. Since some ridges are developed and have adjacent levees, marsh landbridges may also bridge adjacent levee systems and economic corridors. Marsh landbridges compose much of the residual internal framework of the coast which reduces fetch and shoreline erosion of interior marshes and lagoons. Landbridges impede storm surge movement inland and protect other emergent marsh areas that may perform the same function. Some landbridges are threatened themselves by various processes of marsh loss and need to be sustained through restoration and maintenance. The landbridges represent an increasing fraction of the remaining emergent marsh of the coast and provide typical high productivity and fishery benefits typical of coastal wetlands. Examples: East Orleans landbridge, Biloxi Marsh landbridge, Barataria Basin landbridge, Upper Terrebonne Bay landbridge, Grand Lake-White Lake landbridge, Western Marsh Island landbridge, south Calcasieu Lake landbridge

5th: Natural Ridges. In southeast and central Louisiana, most natural ridges are the natural levees of abandoned distributary channels. These channels now act as tidal channels and are often colloquially named bayous or rivers. In southwest Louisiana, most natural ridges are chenniers running parallel to the Gulf coastline. Natural ridges may have continuous elevation of several feet and, therefore, will impede overland flow across the ridge and potentially reduce storm surge. Natural ridges often define (at least historically) the hydrologic basins of the coast. Natural ridges are most effective when they have at least 6 feet of elevation and well drained soils to maintain upland forests. Forests will also slow the movement of overland flow and may also provide a wind barrier. Natural ridges tend to be the economic corridors across the coast including primary state highways and coastal communities. These highways are also likely to be evacuation routes. Examples: Bayou la Loutre, Bayou Lafourche

6th: Manmade Soil Foundations. Manmade soil foundations for transportation may provide incidental benefit to storm surges. Railroads, highways and spoil banks may run parallel to the coast and locally provide a manmade ridge several feet in height. These foundations may have settled and may need improvement to provide reliable transportation routes without chronic flooding. If highway improvements are contemplated, the effects on storm surge may be considered. Examples: Highway 90, Hwy 82.

7th: Flood Gates. Flood gates are typically designed to withhold flood water and, therefore, remain open under most conditions. Flood gates are generally open so as not to impede navigation or natural ebb and flow of tides and aquatic organisms. Flood gates would be closed during a threat of flooding and to reduce flood tides in channels. Because of the generally low elevation of the coast, the effectiveness of flood gates may depend on the nearby topography or constructed features such as levees or spoil banks. Examples: Bayou Bienvenue, Bayou Dupre

8th: Flood protection levees. Flood protection levees are designed and constructed for flood protection of municipalities or other coastal infrastructure features. Levees are generally designed to be an absolute barrier defining a flood side and a protected side. The intent is to have zero storm surge flooding on the protected side, but an unintended consequence may be to increase water levels on the flood side. Levees are generally not designed to be overtopped or to withstand significant wave erosion. Exceptions include “potato levees” or other low relief levees designed to reduce flooding from non-storm tides. Typical hurricane protection levees protect limited portions of the coast with intense economic development. Examples: St. Bernard levee, Jefferson and Orleans Parish levees on Lake Pontchartrain

9th: Flood protection pumping. Pumping stations are generally within leveed areas and are used to reduce flood risk from rainfall and are not designed to pump out flood water from a significant levee breach. Most pumping stations are not prepared with fuel, staff or other requirements to be effective to pump out flood water from a significant levee breach. Generally, these are large capacity pumps which displace water vertically above the water level on the flood side of the levee. Pumping stations are generally to protect areas of intense development. Examples: Orleans and Jefferson Parish's pumping stations

10th: Elevated homes and businesses. All homes and businesses in south Louisiana are subject to being flooded if they are not elevated above the normal land elevation. Even those behind levees are not 100% safe. Hurricanes Katrina and Rita made this painfully clear. Ah attempts to reduce storm surge height or its extent are limited by the intensity and attributes of particular storm events. Since there will always be the potential of a storm exceeding the limits of protection from storm surges, immovable assets such as homes and businesses should be elevated to the appropriate flood elevation risk. This is the last line of defense for immovable assets. Elevated homes also provide important side benefits such as improved protection from termites and more economic capacity to re-level or raise the houses due to settlement or increased flood risk. Example: pre-1940 housing in New Orleans, LUMCON, Marina del Ray in Madisonville

11th: Evacuation. Evacuation routes are typically highways, but could also include other means of transportation such as railroads, air transportation, etc. Evacuation routes are the last line of defense for people or moveable assets. Evacuation routes and procedures should be established for the coast. Ideally, evacuation routes may also serve as re-entry routes for first responders and as routes to re-populate after a storm event. Evacuation routes are generally selected based on capacity to move a large number of people to safer areas as a storm approaches the coast. Some routes may be subject to flooding quickly and need to be improved. Examples: Regional contra-flow evacuation plan for southeast Louisiana.

G.2.12 Committee on the Restoration and Protection of Coastal Louisiana (2006). *Drawing Louisiana's New Map*, Ocean Studies Board, National Research Council, The National Academies Press, Washington DC.

Coastal wetlands develop within a fine balance of many geomorphologic and coastal ocean processes. Relative sea level rise, wave action, tidal exchange, river discharges, hurricanes and coastal storms, and the rates of sediment accretion due to sediment deposition and accumulation of organic material play particularly important roles. The interplay of these processes and the wetland's resilience to natural or anthropogenic perturbations determine its sustainability. Some of the processes of land loss and gain in the Louisiana coastal area are natural and have occurred for centuries. Others are the result of human activities in the wetlands and the watershed of the Mississippi River system.

Annual land loss rates in coastal Louisiana have varied over the last 50 years, declining from a maximum of 100 square kilometers (km^2) per yr (39 square miles [mi^2] per yr) for the period 1956—1978. Cumulative loss during this 50-year period in Louisiana represents 80 percent of the coastal land loss in the entire United States. Initial efforts to prevent catastrophic land loss were implemented under the federal Coastal Wetlands Planning, Protection, and

Restoration Act (CWPPRA) in partnership with Louisiana's efforts through Act 6 (L.A.R.S. 49:213 et *seq.).* Passed in 1990, CWPPRA called for the development of a comprehensive Louisiana Coastal Wetlands Restoration Plan (P.L. 101-646 §303.b). The first such plan was completed in 1993 and has been in use since that time. In addition, the Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority prepared a plan for the coast in 1998 entitled *Coast 2050: Toward a Sustainable Coastal Louisiana* (Coast 2050).

Coast 2050 was developed under a number of federal and state legislative mandates and is the result of recognition by federal, state, and local agencies that a single plan and coordinated strategy were needed. Coast 2050 was then appended to the 1999 U.S. Army Corps of Engineers 905(b) reconnaissance report. In October 2003, a draft comprehensive study *(Louisiana Coastal Area, LA—Ecosystem Restoration: Comprehensive Coastwide Ecosystem Restoration Study* [draft LCA Comprehensive Study]) for implementing coastal restoration was released. After reviewing the draft LCA Comprehensive Study, the U.S. Office of Management and Budget requested a near-term approach to focus the scope of work and maintain restoration momentum. The resulting final version of *Louisiana Coastal Area (LCA), Louisiana—Ecosystem Restoration Study* (LCA Study) was released by USACE in November 2004. As plans for completion of the LCA Study were being finalized, Louisiana's Office of the Governor requested that the National Academies review the LCA Study's effectiveness for long-term, comprehensive restoration development and implementation.

The LCA Study and its envisioned successors are unique in many respects, including geographic scope, pervasiveness of the destructive processes involved, complexity of potential impacts to stakeholders, success of preceding efforts to achieve stakeholder consensus, and documentation of earlier planning and restoration efforts. Indeed, the environmental and social challenges confronting coastal Louisiana in the near and distant future are without precedent in North America. Clearly, execution of the LCA Study alone will not achieve its stated goal "to reverse the current trend of degradation of the coastal ecosystem," although successful completion of some of the projects outlined in the LCA Study will reduce this trend, thereby representing an important step toward the goal of sustaining or expanding wetlands in some local areas. By definition, the activities proposed in the LCA Study were intended to provide a foundation for successful future restoration and protection efforts, including those developed and implemented in response to hurricanes like Katrina and Rita.

Taken individually, the majority of the projects proposed in the LCA Study are based on commonly accepted, sound scientific and engineering analyses. It is not clear, however, that in the aggregate, whether or not these projects represent a scientifically sound strategy for addressing coastal erosion at the scale of the affected area. Thus, at foreseeable rates of land loss, the level of effort described by the LCA Study will likely decrease land loss only in areas adjacent to the specific proposed projects. As stated in numerous USACE policy statements and recommended in past NRC reports, planning and implementation of water resources projects (including those involving environmental restoration) should be undertaken within the context of the larger system. A group of projects within a given watershed or coastal system may interact at a variety of scales to produce either beneficial or deleterious effects. Cost-effectiveness analyses discussed in the LCA Study and in supporting documents reflect an effort to identify least-cost alternatives but do not appear to reflect a system-wide effort to maximize beneficial synergies among various projects. The selection of any suite of individual projects in future efforts to restore coastal Louisiana should include a clear effort to maximize the beneficial, synergistic effects of individual projects to minimize or reverse future land loss. Further, because there is a finite availability of water flow and sediment and many of the proposed projects must function for decades to deliver maximum benefit, care should be taken to ensure that implementation of an individual project does not preclude other strategies or elements that are being considered for the future. To achieve this, the development of an explicit map of the expected future landscape of coastal Louisiana should be a priority as the implementation of the LCA Study moves ahead.

The approaches advanced in the LCA Study focus largely on proven engineering and other methods to address land loss at the local scale. In general, individual projects appear to be based on commonly accepted, sound scientific and engineering analyses. The emplacement of 61 kilometers [km]) (38 miles [mi]) of revetment along the banks of MRGO as one of the five major wetland restoration projects proposed in the LCA Study, however, does not appear to be consistent with the study's stated goals. Despite an estimated cost of $108.3 million, this project is expected to reduce land loss by only 0.5 km^2 per yr (0.2 mi^2 per yr) over the next 50 years. (Louisiana is projected to lose an average of 26.7 km^2 per yr [10.3 mi^2 per yr] over the next 50 years.) Although the location of the land loss may make it more significant, the need for and potential value of this project are directly related to the outcome of a study being conducted by USACE, scheduled for completion in FY 2005, to evaluate the potential decommissioning of MRGO for deep draft navigation. In addition to questions regarding the appropriateness of this particular project, its selection casts doubt on the rigor of the ranking and selection process. The selection of the restoration efforts of MRGO as one of the five major projects to be carried out as part of the LCA Study should be reconsidered in light of the limitations of expected benefits and the results of ongoing studies on the decommissioning of MRGO for deep draft navigation. If a decision is made to decommission MRGO, various options could be considered, including complete closure, that would significantly reduce the need to strengthen the levees along its route. If partial closure is chosen, perhaps maintaining MRGO for shallow draft vessels, some of the work along the outlet may still be required. Restoration efforts requiring planning would be more fully informed once a final decision has been made.

Conflicting stakeholder interests represent one of the greatest barriers to robust coastal restoration efforts in Louisiana. A dominant human-related component of land loss is the constraint on the river system imposed by spoil banks and levees, but these features also provide benefits to a range of stakeholders. By minimizing the cost of dredging and reducing uncontrolled flooding in inhabited and agricultural areas, these features support important local economic activities. Many of Louisiana's inhabited areas are located on natural levees formed by deposition on the floodplain during major floods. Valuable agricultural land was originally maintained at an elevation above water level through flood-derived sedimentation but is now protected by levees, which preclude new sediment introduction. Obviously, the prospects are low that sediment-rich water will be intentionally allowed to flood broad expanses of urban and agricultural land to maintain elevation with the pace of relative sea level rise.

As discussed above, locating individual projects in an effort to maximize positive synergistic effects will tend to concentrate efforts into selected areas within coastal Louisiana. Although distributing individual projects, and the benefits associated with them, across the entire region may be less contentious, such an approach will either drive up the total cost or reduce the likelihood of success for a given amount of effort and expenditure. Successfully implementing a project selection strategy that maximizes synergistic effects of individual projects will require greater popular support for a comprehensive plan both from within the state and at the national level. Such support will likely come about only through greater public involvement in the decision-making process of a comprehensive plan. Louisiana's restoration goals should be better defined and more clearly communicated to the public. This means that maps of the region and projected land-use patterns with and without various restoration projects should be circulated. Without a clarified definition of the temporal and spatial dimensions of "restoration," unrealistic expectations and disappointments are likely. The projections can be revised as additional data become available and a better understanding is developed through the adaptive management program and the science plan.

Although some inhabited areas will require relocation in order to carry out some proposed wetland restoration efforts, it will be difficult to persuade those affected by local relative sea level rise to abandon their property without a program of financial compensation and a social plan to maintain the cultural integrity of the affected communities. It is important that decisions involving relocation and compensation following Hurricanes Katrina and Rita, or in response to future events, be made in such a manner as to minimize the likelihood of additional relocation or disruption in response to future restoration efforts. The appropriate decisions and responses after major storms have to reflect a broad consensus about the future nature of coastal Louisiana and may have to include managed retreat. Managed retreat and various restoration strategies should include early and active stakeholder participation and concurrence. Relocation could occur either gradually with a few families at a time or at a much higher rate in areas severely affected by Katrina and Rita or future events. This is not intended to preclude reoccupation of the many areas affected by the recent hurricanes or similar events in the future. Rather, this approach is intended to minimize the potential for disrupting lives and property a second time as efforts to protect and restore Louisiana unfold in coming years.

Finally, the LCA Study calls for a long-term study of the possibility of establishing a new lobe of active delta development through a diversion near Donaldsonville, Louisiana. Termed the Third Delta, this proposed restoration feature was among a group of possible features that was shown to yield limited benefits at a substantially higher cost than the projects identified for funding in the LCA Study. An alternative scenario for retention of sand and silt now lost beyond the shelf break would involve diverting the main flow of the Mississippi River toward the west of its present main channel somewhere between New Orleans and Head of Passes. An intermediate and long-term consequence of this action would be the abandonment of the active Birdsfoot Delta by the Mississippi River. A clear benefit would be the nourishment of eroding coastal reaches to the west. Although this alternative has been widely acknowledged as possible, its feasibility, for various reasons, has not been considered seriously by USACE. Therefore, it is not yet possible to assess the potential advantages and disadvantages of Birdsfoot Delta abandonment at this time. Obviously, implementation of such a strategy would have to be accompanied by the creation of a deep navigation access channel somewhere downstream of New Orleans but upstream of Head of Passes. Though the size of the area it would impact would still make it controversial, some consideration should be given to an alternative or companion to the planned Third Delta, such as a larger-scale diversion closer to the Gulf of Mexico, that would capture and deliver greater quantities of coarse and fine sediments for wetland and barrier island development and maintenance.

The LCA Study states that "execution of the LCA [Study] would make significant progress towards achieving and sustaining a coastal ecosystem that can support and protect the environment, economy, and culture of southern Louisiana and thus contribute to the economy and well-being of the nation." The economic analysis provided within the LCA Study and its supporting documents, however, includes only cost-benefit analyses of alternative approaches to meet ecosystem restoration objectives, as is consistent with USACE policy for evaluating projects proposed as National Environmental Restoration efforts. Evaluating the benefits of restoring coastal Louisiana in terms of national economic interests, as implied by the statement of task, would have required USACE planners to carry out analyses more consistent with proposing the effort as a National Economic Development project. USACE officials appeared to view the efforts described within the LCA Study as falling under National Environmental Restoration as opposed to National Economic Development and, thus, did not attempt to identify and meaningfully quantify the contribution to the economy of the nation. Since the information necessary to evaluate proposed coastal Louisiana efforts in terms of the national economy is not provided in the LCA Study, there is insufficient information available for the committee to comment credibly. Carrying out such an analysis would require significant effort and resources beyond those available to the committee in the 10 months following the release of the LCA Study in November 2004. This said, some components of such an analysis can be articulated.

The LCA Study presents sufficient information about the importance of some components of the natural and built environment in coastal Louisiana (e.g., system of deep water ports, oil and gas receiving and transmission facilities, complex and extensive urban landscape, robust commercial fishery) to demonstrate that substantial economic interests are at stake in coastal Louisiana and that these interests have national significance. The immediate impacts of Katrina underscore the importance of New Orleans, and adjacent areas of the Gulf Coast, to the national economy. Establishing the true, national economic significance of efforts to restore coastal wetlands in Louisiana as proposed in the LCA Study, however, must go beyond simply identifying and characterizing these components and should include an analysis of how specific restoration efforts will preserve or enhance the value of these components (i.e., some restoration efforts may have little influence on the vulnerabilities of specific components of the natural and built environment in coastal Louisiana) and should determine how the national economy would respond to the loss or degradation of components (e.g., what is the capacity for similar components in other regions to compensate for the loss and on what time scales?). If, as implied by the statement of task, greater emphasis is to be placed on the national economic benefits of restoring and protecting coastal Louisiana, future planning efforts should incorporate meaningful measures of the economic significance of these projects to the nation consistent with procedures normally employed to determine the value of a project or a suite of projects for National Economic Development. As a greater understanding of the short- and long-term economic impacts of Katrina and Rita becomes available, a more meaningful effort to evaluate the national economic significance of protecting the natural and built environment in coastal Louisiana will be possible. Such information would provide an important context for decision making; however, it will still be important to understand the role wetlands play in protecting specific components of the overall system and to determine how specific restoration efforts can enhance that protection. While wetlands and adjacent barrier islands and levees are known to reduce impacts from waves, their more complex role in reducing storm surge is less well known. Surges contain multiple components, including barometric tide effects, wind stress-induced setup, wave-induced setup, and Coriolis forces. As was pointed out repeatedly in the public media during Katrina and Rita, in the northern hemisphere the eastern side of a hurricane tends to drive water northward in a counterclockwise manner. If a storm stalls off a coast for a significant period of time, it will continue to drive water onshore for a prolonged period, regardless of the nature of any intervening wetland or barrier island. Thus, the potential for reducing risk due to storm surge from a particular storm is more difficult to predict.

Conversely, the significance of the coastal Louisiana wetlands to the nation in terms of both their inherent uniqueness and the ecosystem services they provide is more thoroughly documented in the LCA Study, its predecessor reports, and the scientific literature. Although efforts to restore and protect Louisiana's wetlands will likely provide some unknown but potentially significant protection against coastal storms and hurricanes, those efforts should not be evaluated primarily on their significance for National Economic Development.

The two major components of the LCA Study, a series of restoration and demonstration projects designed to be implemented over a 10-year time frame and the development of a robust intellectual infrastructure to inform future project design and implementation, are at the heart of the phased approach referred to in the statement of task. This approach has decided advantages and disadvantages. As is clear from the LCA Study, simply keeping pace with land loss in Louisiana will require an ongoing effort. Any substantial gains in the next few decades will require a robust effort, an effort that needs to be well informed by a thorough understanding of both the natural physical and ecological processes involved and the viability of various restoration techniques to address land loss at a massive scale. Establishing methods that allow projects to evolve in the face of increased understanding is prudent. Conversely, limiting project selection to those features where construction can be initiated in 5-10 years presents a significant handicap for laying the groundwork for a comprehensive, multidecadal effort.

For example, the 10-year implementation criterion resulted in the selection of projects that already existed in the USACE and the CWPPRA planning process. This time constraint precluded consideration of projects with solid potential for long-term benefits that had not yet been fully designed (precluding the initiation of construction in 5-10 years). Similarly, this criterion and the need to demonstrate solid near-term success likely precluded large-scale and innovative projects that (1) affect significant sediment delivery to the system (such as abandonment of the Birdsfoot Delta), (2) maximize synergistic effects for reducing land loss over longer time scales by the selection of strategically located or larger-scale projects, or (3) address some of the difficult issues associated with stakeholder response. While the efforts preceding the LCA Study have achieved a laudable degree of unanimity among stakeholders on the conceptual restoration plan, this unanimity will be tested by the difficult decisions associated with implementation of the larger-scale projects designed to achieve a more effective delivery of sediment, water, and nutrients over a larger area. The project selection procedure requires more explicit accounting of the synergistic effects of various projects and improved transparency of project selection to sustain stakeholder support. Furthermore, beneficial, synergistic interaction among projects cannot be assumed but should be demonstrated through preconstruction analysis.

It is important to note that, by definition, the activities proposed within the LCA Study are intended to lay a foundation for more effective and robust efforts to preserve and protect coastal Louisiana. By its own analysis, the LCA Study points out that constructing the five restoration features it proposes would reduce land loss by about 20 percent (from 26.7 km^2 per yr [10.3 mi^2 per yr] to 22.3 km^2 per yr [8.6 mi^2 per yr]) at an estimated total cost of roughly $864 million (or $39,400 per hectare [$15,900 per acre]) over the 50-year life of the projects, not including maintenance and operational costs.

Actual land building will be experienced only in areas adjacent to the implemented projects. The significant investment represented by these projects and the efforts to develop the tools and understanding necessary to support future restoration and protection efforts will yield a substantial return of benefits only if future projects are carried out in a comprehensive manner.

The funding required to carry out the activities described in the LCA Study should be recognized as the first of a funding continuum that will be required if substantial progress is to be made. A comprehensive plan to produce a more clearly articulated future distribution of land in coastal Louisiana is needed. Such a plan should identify clearly defined milestones to be achieved through a series of synergistic projects at a variety of scales. (While a comprehensive plan is needed, this does not necessarily imply endorsement of the draft LCA Comprehensive Study, which was not formally released or reviewed as part of this study.) The review detailed in this report found no instance where the proposed activities, if initiated, would preclude development and implementation of a more comprehensive approach. Conversely, many examples were identified where implementing the proposed activities would support a more comprehensive approach. Thus, the efforts proposed in the LCA Study should be implemented, except where specific recommendations for change have been made in this report and only in conjunction with the development of a comprehensive plan.

As the State of Louisiana and the nation begin to recover from Katrina and Rita, efforts to restore wetlands in Louisiana will likely compete with reconstruction and levee maintenance or enhancement efforts. As this report and numerous other NRC reports have pointed out, efforts to design and implement water resource projects (including environmental restoration and flood control projects) should be carried out within a watershed and coastal system context. Ongoing discussion of long-term response to Katrina and Rita underscores the need to consider restoration and reconstruction as a seamless process that should be informed by a coherent, comprehensive plan that addresses the issues raised in this report. Therefore, efforts to rebuild the Gulf Coast and reduce coastal hazards in the area should be integral components of an effective and comprehensive strategy to restore and protect coastal Louisiana wetlands.

G.2.13 Working Group for Post-Hurricane Planning for the Louisiana Coast, A New Framework for Planning the Future of Coastal Louisiana after the Hurricanes of 2005, University of Maryland Center for Environmental Science, Cambridge, January 26, 2006.

The principal messages abstracted from our report are the following:

1. The large-scale deterioration of coastal landscapes, particularly during the past fifty years, threatens the sustainability (viability over this century) of both human habitation and the rich natural resource base of coastal Louisiana. Storm events such as hurricanes have both negative and positive effects on wetlands that dominate these landscapes, but deterioration of these wetlands is mostly caused by human activities that both disrupt natural processes building the coastal landscape (river inputs, sedimentation, tidal fluctuation, etc.) and accelerate destructive processes (altered hydrology, subsidence, etc.). **In the long term, hurricane protection for larger population centers, including the New Orleans region, can only be secured with a combination of levees and a sustainable coastal landscape.** This will require adapting to changing conditions by re-establishing the constructive processes associated with distributing Mississippi River water and sediments across the coastal landscape, as well as alleviating the other destructive effects of past or future human activities.
2. The sustainable coastal landscape must include extensive marshes and swamps and the bayous, coastal barriers and ridges that characterize the Mississippi deltaic plain and the

Chenier plain in the southwest. If natural processes are not interrupted, coastal wetlands are able to sustain themselves over hundreds of years even where the land is subsiding or the sea level is rising. **With presently observed subsidence rates and anticipated acceleration of sea-level rise, most - although not all - of the coastal landscape could be maintained through the 21st century. And with efficient management of the river's resources, this landscape could be expanded in some places.** However, this result can only be achieved with very aggressive, strategic, and well-informed restoration efforts, varying in size and objective but integrated within a landscape management plan.

3. Hurricanes Katrina and Rita provide poignant evidence that no longer can coastal ecosystem management and restoration, flood protection, and navigation be planned, executed and maintained independently. **We must integrate planning, investment and management decisions under a new framework in order to secure these multiple purposes, while recognizing: the forces of nature; the imperative to protect life, property and communities; the value of natural resources and ecosystem services; the environmental and economic sustainability of the solutions; and financial constraints.** Furthermore, planning to support this integrated decision making must be an adaptive process that creates and uses new knowledge about this "working coast." Integrated management requires that coastal landscape restoration alternatives be screened through a "storm damage reduction filter" (e.g., how might they reduce risks and how quickly might the result be realized?). Conversely, hurricane storm damage reduction or navigation alternatives should be screened through an "environmental consequences filter" (e.g., how might the elements affect ecosystem services and the sustainability of the landscape?). This does not mean that restoration features are justified only because they significantly reduce storm damages-many are required to sustain environmental resources or build landscapes away from population centers. It does mean that priorities must be determined by multiple benefits more than has been the case in past planning.

4. **The near-term critical restoration features selected by Louisiana Coastal Area Ecosystem Restoration Study should be reexamined and prioritized to assure that they provide environmentally and economically sustainable approaches that advance both ecosystem restoration goals and support storm damage reduction.** While a truly integrated planning process has not yet been developed, there is sufficient understanding to prioritize near-term restoration features based on their likely contribution to the effectiveness of existing and intended storm damage reduction efforts, as well as advancing ecosystem restoration. Furthermore, long-term restoration strategies for the four geographic subprovinces should be refined by incorporating integrated objectives and framed around critical foundation features.

5. **Federal and State governments should engage scientists, economists, engineers, government officials, communities and stakeholders to develop a spatially explicit vision of a future coastal Louisiana that incorporates long-term challenges, opportunities and overarching goals.** As recently stressed by the National Research Council, such a vision should guide integrated, multiobjective management within geomorphic subprovinces and along the entire coast throughout the planning and project implementation process. Stakeholders should participate in formulating and evaluating alternatives that recognize the opportunities and limitations associated with maintaining the status quo under the perilous, urgent and changing circumstances. The vision should anticipate future changes that may affect options, for example energy scarcity, climate change and demographic shifts. As

adaptations occur and new projects are realized, the vision for the coast can be revised in light of changing landscape and socioeconomic conditions, knowledge of the system, and social preferences.

6. The President and Congress have mandated studies of potential supplements to the existing but strengthened storm protection works. Particular attention is being given to a continuous peripheral coastal defense (a hurricane barrier) similar to that used in the Netherlands. Although the systematic approach of the Dutch is commendable, substantial differences between the Netherlands and south Louisiana limit the applicability of their model, including contrasts in human settlement patterns, land uses, geology, hydrodynamics and coastal ecology. Maintaining functioning estuarine ecosystems and self-sustaining wetlands inside and adjacent to such peripheral defenses would be extremely difficult, if not impossible, because extended levees and floodgates would obstruct key hydrological processes that maintain the coastal landscape. The relatively dispersed populations and low intensity of land use may make investment in such a barrier difficult to justify. Rather than simply adopting the Dutch approach, the plan for Louisiana should recognize the different Louisiana setting and take advantage of its characteristic coastal landscape. **Storm damage reduction should be achieved through a combination of stronger inner defenses around larger population centers; broader, self-sustaining wetland landscapes that reduce storm surge and wave fetch; restrictions along artificial channels to limit storm surge propagation; and maintaining barrier islands along selected areas of the coast.** This may include lower elevation, semi-porous barriers placed between the levees protecting population centers and the open coast that attenuate storm surge but allow tidal exchange. However, any such barriers should be compatible with sustainable coastal landscapes. To the extent possible, extensive wetland areas should not be enclosed by levee systems.

7. Navigation channels that cut across the coastal gradient have resulted in substantial degradation of wetland habitats, thus increasing hurricane surge vulnerability. **Future integrated planning and decision making should recognize, account for and mitigate the disruption of coastal landscape dynamics when formulating and evaluating navigation channel expansion, maintenance or abandonment.** One of these channels, the Mississippi River Gulf Outlet (MRGO), is likely to be decommissioned as a deep-draft navigation channel as a result of the risks it poses and its weak economic contribution. However, even if mostly closed it will remain a feature on the coastal landscape that has to be integrated into a coastal restoration and storm damage reduction strategy for the vulnerable east side of Greater New Orleans.

8. A new management framework requires improved organizational arrangements for coordinating and integrating planning, decision making, implementation and evaluation. **A joint Federal-State body should be given the responsibility and organizational and fiscal support for guiding the program.** The Corps, or another appropriate agency, would continue to have the responsibility to design, construct and, if authorized, operate and maintain projects. An integrated assessment group and an engineering and science program focused on reducing decision-relevant uncertainties (scientific and otherwise) would support decision making in an adaptive management process.

9. **Authorization and financing should be separated from the Water Resources Development Act process.** The integrated planning process, engineering and science program and smaller investment projects should be supported by a programmatic

authorization and a more reliable appropriation stream. Funding for larger projects should be provided through a Congressionally-chartered coastal investment corporation.

10. **Project planning should rely on innovative decision-support analyses that engage stakeholders and responsible agencies in resolution of conflicts and in identifying and synergies among projects.** The analyses would formulate and evaluate project alternatives using performance measures derived from the policies, goals and objectives of the Nation and the region. Significant areas of risk and uncertainty will be highlighted for decision making, as well as for establishing monitoring and research priorities for the adaptive management program.

Expanded Hurricane Protection

As made clear by the President's announcement, initial efforts to improve hurricane protection will focus on strengthening existing levees and floodwalls protecting urban areas. An in-depth analysis of the feasibility and environmental consequences of expanded hurricane protection (EHP) is beyond the scope of the framework developed here. The Corps of Engineers is currently assessing the feasibility of such an expanded and enhanced protection system, the details of which are not yet in the public domain. Based on general information made available to the working group we discuss four possible protection strategies and their implications for restoration and conservation of coastal ecosystems:

Strategy 1: Protect only New Orleans and larger population centers by strengthening existing protection systems without providing additional flood protection farther out in the coastal zone. Restoration would focus on the same activities that were being planned before the hurricanes, but with more attention to the coastal landscapes adjacent to urban areas.

Strategy 2: Construct storm surge barriers along the inner coastal zone between population centers and the outer coast. Openings in the system for water management could provide potential opportunities for restoration and conservation but altered hydrologic conditions inside the barrier could also have potential negative impacts (e.g., changes in salinity and tidal regimes and reductions in soil accretion due to sediment starvation) that should be considered. Opportunities would still exist for restoration outside the barrier system.

Strategy 3: Establish a first line of defense along the existing coastline, e.g., by maintaining barrier islands, to dampen storm surges. This would potentially minimize the destructive impacts of hurricanes, but modeling should be conducted to quantify the likely benefits. These "speed bumps" would be far from the urban areas with extensive open water and wetlands behind them and, when overtopped, may not adequately reduce the storm surge to prevent extensive damage farther inland. A benefit of outer speed bumps is that they could provide opportunities for landward restoration and continue to allow for sediment deposition during storms. However, these barriers would be highly erosive features requiring long-term maintenance.

Strategy 4: Combine elements of strategies 2 and 3. This would provide the greatest opportunity for both protection of populations and conservation of coastal landscapes. The outer ring of speed bumps limits hydrologic impacts to existing wetlands and also provides opportunities for additional restoration in areas behind the features. The inner series of partial barriers (scenario 2) would provide the same opportunities as described above but synergy between the two protection systems would potentially allow for additional restoration opportunities outside of the inner ring of barriers.

Organization and Funding

The existing plans for strengthening storm damage reduction, initiating the LCA ecosystem restoration, and maintaining and improving navigation infrastructure provide a foundation for planning, but cannot be the only basis for future investments. As we have repeatedly stressed, future decisions on projects and their operations must be informed by an integrated assessment of contributions of these and other projects to the multiple economic, environmental, social and cultural objectives. Such integrated assessment will identify conflicts, synergies and opportunities for securing multiple purposes. The value of, and possibilities for, integrated assessment are illustrated by the preliminary analysis and evaluation included above. Importantly, a future integrated planning process should be structured and supported as an adaptive management program that recognizes and reduces uncertainties to improve the effectiveness of future decision making. Some of those decision-critical uncertainties have been highlighted earlier in this report.

A complex of state and federal agencies already exists with missions, budgets and authorities affecting planning, investment and implementation. However, improvements to the existing organizational, funding and planning structures will be needed to meet planning needs and expedite project implementation by the Corps and the State.

The organizational and funding barriers that have inhibited the adoption of an integrated planning and adaptive decision making process persist. Both new organization and funding reforms are needed to support coastal planning and project implementation by the Corps and the state. We recognize that there are many ways in which the government can organize to carry out integrated planning and decision making as long as the organization, funding and analytical needs for such a new process are served. To better illustrate these concepts, and organizational possibilities, the Working Group offers one such approach.

Maritime Transportation Planning

While the President and Congress have mandated the Corps to take actions and develop investment plans for hurricane protection and ecosystem restoration, they were silent on planning maritime transportation investments. Similarly, the scope of the Coastal Protection and Restoration Authority (CPRA) recently created by the Louisiana Legislature does not seem to encompass maritime transportation. However, a marine transportation network that will continue to be maintained and upgraded over time characterizes the Louisiana coast. Marine transportation interests are primarily concerned with: (1) the availability of a system of reliable channels; (2) transit time from to and from port to deep water; and (3) a minimization of cargo handling costs. These goals will continue to be advanced through new project proposals and maintenance of existing projects. As discussed earlier, some elements of the navigation network can be detrimental to hurricane protection and coastal landscapes. Moreover, innovatively conceived navigation realignments and utilization of existing channels could enhance sediment dispersal through the coastal wetlands or reduce storm damages. Therefore, consideration of plan formulation and evaluation for marine transportation investments should be incorporated into the more comprehensive study authorities and re-organization plans, such as those proposed below.

A New Framework for Coastal Louisiana

Federal Intragovernmental Coordination

At present, the Federal program for coastal planning is led by the Corps of Engineers, but it is not clear how the responsibilities of the other federal agencies will be represented going forward. The new integrated management framework would require tradeoffs that impact agency responsibilities and the streamlining of NEPA and other reviews. It requires the Federal government to speak with one voice. The Comprehensive Everglades Restoration Program (CERP) has been working to overcome interagency coordination barriers and may offer useful experiences, if not a model. The Corps is the lead agency for CERP, but there is extensive involvement by other federal agencies. The federal agencies have joined a Memorandum of Understanding (MOU) specifying a dispute resolution process and a time line for resolution. An interagency MOU, similar to that prepared for the CERP, should be signed by the federal agencies with significant participation in coastal Louisiana planning.

The Corps itself is organized along "business lines" including (a) navigation, (b) flood and storm and flood hazard management and (c) ecosystem restoration. The business line organization can create organizational barriers to integrated planning and evaluation. These organization barriers exist both at the districts and headquarters. Also, Corps planning and funding mechanisms are currently not well structured to meet the challenge of integrated and adaptive management. The Corps headquarters should create a unit, led by a Senior Executive, charged with fostering innovations in the planning and assessment approaches required for the integrated management of the Louisiana coastal area, as well as for CERP, Missouri, Upper Mississippi, the Columbia River and other areas where the multiple missions of the Corps can be best achieved through more integrated management.

Coastal Louisiana Authority

The Corps and the state, as well as partner federal agencies, have developed working relationships through the LCA, the CWPPRA, and as cost-share partners on local navigation and storm damage reduction projects. However, differences persist in viewpoint, ranging from cost-sharing responsibilities to project priorities. For example, project selection through the CWPPRA Task Force sometimes led to individual agency advocacy and agreements that accommodated the different agencies demands, rather than true integration.

Louisiana has created a new Coastal Protection and Restoration Authority (CPRA) to centralize and integrate its coastal efforts and the Legislature will shortly be considering additional legislation for consolidation of the numerous levee districts. However, there is still a need in coastal Louisiana to clarify the federal-state responsibilities for planning, to make and implement joint decisions, and in so doing to expedite outcomes and ensure coordination with water resource and other activities of the federal and state governments. A Federal-State body, which we will for convenience refer to as the "Coastal Louisiana Authority" (it could alternately be a "board" or 64 commission"), should be established to fulfill this role. The CLA would be comprised of a small number of members with appointments made by the President and the Governor of Louisiana. The group would have a small administrative staff and an executive director, as necessary to execute its functions. Its authorization should be subject to periodic review and renewal by the Congress and the state. The CLA could report to the President and Governor or operate under the administrative jurisdiction and support of an appropriate federal agency to ensure coordination with the water resources and other activities of the federal government.

The CLA's responsibilities and powers would be limited to three areas. First, it would be responsible for leading the development of joint federal-state policies that govern an integrated investment and management program (discussed later in this section) and for revising those policies over time as new knowledge emerges, and social, economic and environmental conditions change. Second, the CLA would review and approve the use of the programmatic funds (see discussion of authorization and funding, below) allocated for adaptive management and the science and technology program, as well as other uses discussed below. Third, the CLA would direct, receive and use analyses of its Coastal Assessment Group (CAG) and, based on those analyses, stakeholder input and coordination with the Mississippi River Commission and the Louisiana CPRA, would make funding recommendations for significant investments (those that exceed a defined threshold). The recommendations of the CLA would be an affirmation that the proposed project has been formulated and evaluated in full consideration of the agreed policies. Based on such recommendations the Corps, or another appropriate agency, would have the responsibility to design, construct and, if authorized, operate and maintain the recommended project.

Coastal Assessment Group

The CLA would base its advice on analyses conducted under the direction of a Coastal Assessment Group (CAG). The CAG should have a professional staff with a full range of skills and perspectives (multiple purposes and multiple disciplines including natural science, social science, economics, and engineering). However, the staff would remain small, but could be expanded to address specific tasks with personnel from the state and federal agencies on temporary assignment.

The CAG would have two roles. First, the CAG would be responsible for executing the integrated assessment to assure that each proposed project investment in storm protection, navigation and coastal restoration takes advantage of synergies and avoids and mitigates conflicts among purposes. Also the CAG would report whether and to what extent different economic, environmental and social objectives are served. The integrated planning process would be led by the CAG, however detailed project design, basic data acquisition and modeling, and other tasks contributing to project execution would be done in the existing agencies, principally the Corps and the state. Second, the CAG would be responsible for the direction and oversight of the Coastal Engineering and Science Program (CESP) in order to assure that the work of that program is targeted to the decision making needs of the CLA.

Coastal Engineering and Science Program

A Coastal Engineering and Science Program office would build on the concepts developed for the LCA Science and Technology Program, but would be broadened to address storm damage reduction and maritime transportation, encompassing the natural science, engineering, social science and economics applications deemed relevant to the integrated management framework. In particular, it would be responsible and accountable for supporting adaptive management, including participatory decision making, and ensuring rigorous, independent peer review. A key responsibility of the managers of the CESP is to respond to the oversight of the CAG and assure that the scientific uncertainties deemed relevant to decision making are addressed through the program. The CESP would rely on scientists and engineers in agencies, universities and the private sector to perform most of the required research, modeling, and monitoring. Consequently, the office staff would remain small.

Programmatic Authorization and Funding

While the total composition and costs of the integrated planning and investment program can not be determined at present, it is necessary for the Administration and the Congress to make a significant and certain up-front commitment of funds and establish new procedures for expeditiously funding this program over time.

No less than two hundred million dollars per year, for a 10year period, should be authorized by the Congress to support the CLA and the CAG. Appropriations should follow that authorization. The agencies receiving the appropriations would manage those funds consistent with the guidance of the CLA for: (a) the integrated systems planning program; (b) the CESP research on decision-critical technical uncertainties, including funding pilot projects to test project design concepts; and (c) comprehensive post-implementation monitoring and assessment. Also, the CLA would be authorized to allocate funds for projects costing less than some threshold, e.g. $25 million, with project execution being the responsibility of the Corps and the State. In the future, consideration should be given to administering the existing CWPPRA program through the CLA some time after the efficacy of the CLA has been established.

Programmatic funding would loosen the restrictions on adaptive management costs as a percentage of total project costs, as well as the requirements for separate authorization for each component project. With a certain funding stream there could be a continuity of programs and staff, an adequately funded and reasonably managed engineering and science support program, and accelerated planning for implementation of smaller projects.

Louisiana Coastal Investment Corporation. The CLA could recommend authorization and appropriations for Corps projects that exceed the thresholds in the programmatic authority, or for project maintenance, through the existing WRDA and appropriations processes. However, reliance on authorization through the uncertain WRDA process (the last WRDA was passed in 2000) seriously risks delay and programmatic incoherence. A more predictable and flexible alternative approach would be to legislatively create an entity, for convenience referred to as the Louisiana Coastal Investment Corporation 60 (LCIC), as an independent funding authority for new projects and their maintenance. The LCIC would receive recommendations from the CLA and would fund projects meeting investment criteria established by Congress when it authorizes the LCIC policies. The corporation would be given the authorization to issue bonds with maturities of up to 50 years to finance investment projects to meet the three purposes of storm protection, marine transportation and coastal landscape restoration. An initial bonding authority of $5-10 billion appears to be justified by the extensive storm protection, navigation and restoration needs of the region.

The long-term bonding authority aligns the financing of the new investments with the long-term benefits they provide. The federal government would guarantee the bonds. In addition the Congress could set a financial limit on the bonding authority when the corporation is chartered. The Congress could review the LCIC on a five-year basis, could dissolve the corporation at those times or choose to raise or lower the bonding authority. The bonds could be repaid with a combination of funding sources that may include, but would not be limited to: future federal appropriations; fees on port, waterway or pipeline users; wetlands permitting fees; receipts from Outer Continental Shelf (OCS) mineral revenues; and non-federal cost sharing payments. Intergovernmental cost-sharing requirements would be established by a Congressional formula and a legally binding agreement to make payments that contribute to retiring the bonds would be required before issuing any bond.

Professional Staffing

An essential element in enhancing the credibility and soundness of planning and implementation is an agency’s internal staff capabilities. The Corps of Engineers is facing a significant loss of staff numbers and capability through retirement, just at the time that the demands for its skills are increasing. Indeed, the integrated planning process will demand a wider array of skills from the engineering, hydrologic, geological, biological and social sciences than is currently available in the agency or in federal or state agencies generally. Also, the effectiveness of the long-term program requires the institutional memory that develops within a permanent and professional staff. This is not to suggest that all the work needs to be done by agency staff. However, if much of the work is done by contract, agency professionalism and competence are essential for comprehending advice from outside experts and translating it into useful information to support decision making. The Corps and the bodies recommended here must have the ability to recruit and the ability to retain talented personnel.

G.3 References:

Arthur, J. B. (1994). "Effects of Human Resource Systems on Manufacturing Performance and Turnover." *The Academy of Management Journal*, 37(3), pp 670-686.

Bowman, F. L. (2005). "ADM Skip Bowman: In His Own Words." *Undersea Warfare Magazine*, 7(2).

Duncan, F. (1990). *Rickover and the Nuclear Navy: The Discipline of Technology*, Naval Institute Press, Annapolis, MD.

Marone, J.G., and Woodhouse, E.J. (1986). *Strategies for Regulating Risky Technologies*, University of California Press, Berkeley, CA.

Columbia Accident Investigation Board (2003). "The Accident's Organizational Causes." *Columbia Accident Investigation Board Report*, Vol. 1, pp 177-194.

Rickover, H.G. (1979). "Testimony: Nuclear Power Plant Safety Systems." *Subcommittee of the House Committee on Science and Technology*, 96th Congress, 1st Session, pp 1039.

Rockwell, T. (1992). *The Rickover Effect: How One Man Made a Difference*, Naval Institute Press, Annapolis, MD

Sagan, S. (1993). *The Limits of Safety*, Princeton University Press, Princeton, NJ.

United States Army Corps of Engineers (2002). "USACE Strategic Workforce Planning." *USACE Command Brief*, <http://www7.nationalacademies.org/ffc/usace.pdf> (Mar. 30, 2006).

APPENDIX H: HOW SAFE IS SAFE?

Coping with Mother Nature, Human Nature and Technology's Unintended Consequences

by

Dr. Edward Wenk, Jr.

H.1 Preface

This treatise on risk was prepared a backdrop for the analysis of the cause and cure of massive flooding of New Orleans associated with the hurricane Katrina. I do not regard myself as a theorist in the field of risk management. Instead, I have led a professional life of exposure to elevated risks, of managing risks to which others were exposed, and of advising public officials at the highest levels of government on strategies of risk abatement. From extended observations at ringside, I have down-loaded and sorted memories so as to share experiences that define fundamental properties of all risk environments created by acts of nature, from human frailty and from unintended consequences of technology.

The product is not an encyclopedia of risky situations, nor a how-to handbook on risk management. It is not a post-crisis analysis of Katrina nor of its calamity twins. It is not a check off list of **what** parameters to think about in the risk equation, but rather a tool on **how** to think about the quintessential questions of “How safe is safe” and of the exercise of social responsibility to limit harm.

This treatise has been prepared for readers ranging from professionals in risk management to non-specialists with heavy portfolios to adopt and implement policies to shield citizens from threats of bodily harm or of property damage. Finally, it is directed toward citizens exposed to involuntary risks who feel responsible for participating in civil decisions that affect their safety and security and that of the community.

This survey, suggested methodologies of assessment, and conclusions related to Katrina are based on case studies starting with the wreck of the *Exxon Valdez* where the author was directly involved with the post-mortem analysis. Other cases include the spacecraft *Challenger*, the eruption of Mt. St Helens volcano, the Bhopal, India, chemical spill, the air attack on the twin towers, 9/11, the failure of intelligence for opening the war on Iraq, and about 100 artificial cases prepared over two decades by graduate students in the Program for Social Management of Technology at the University of Washington. The perspective for analysis is systems based and interdisciplinary, elaborated in *Tradeoffs: Imperatives of Choice in a High Tech World* (1986).

The contributions of others with whom I studied and worked deserves emphatic acknowledgement. Indeed, virtually all my bosses over a lifetime deserve accolades as teachers. To the point of this treatise, I want to thank those who read the manuscript and followed my entreaty for robust criticism: Profesors Robert Bea, Naj Meshkati, Robb Moss, Mary Raum, and Karlene Roberts, Dr. Anita Auerbach, George Lindamood, Flo Broussard and Kofi Inkabi.

I especially want to thank Naomi Pascal for her gifted editing that raised the stature of the essay to the highest professional standards, and Professor Robert Bea for inviting my participation in the Katrina project. It has been an exciting experience.

H.2 Introduction

H.2.1. How Safe is Safe?

The Katrina Hurricane disaster in 2005 exposed a technological failure of inadequate defense against a predictable, risky and potentially lethal event. Recent studies, including this latest one from the University of California at Berkeley, focus on death and destruction from flood waters that were released by collapse of levees. Studies of cause acknowledge the extreme forces of nature but also cite the human and organizational errors (HOE) that now occur more conspicuously because the engineering of physical parameters has been refined. HOE failures now exceed mechanical sources.

Because protection against human weaknesses is more art than science, the study of cause and of remediation requires a context for risk analysis. As systems based and interdisciplinary, that depiction should be of help to non-specialists with policy and management responsibilities so as to understand the enigmatic question of "How safe is safe?" In other words, what level of risk is acceptable when making decisions on public safety and security.

Risk is usually defined as a condition where either an action or its absence poses threats of socially adverse consequences, sometimes extreme. Risk happens from acts of nature, from weaknesses of human nature, and from side effects of technology, all situations that mix complex technical parameters with the variables of social behavior. Although each risk event is unique, all display commonalities that permit systemic analysis and management. These recurring properties lead to certain principles.

To begin, the acceptability of risk cannot be extracted from science or mathematics; it is a social judgment. The spectrum of risk thus embraces both the physical world defined by natural laws, and the human world loaded with beliefs instead of facts, values, ambiguities and uncertainties. Among other features, the physical world may be thought of as a mechanism whose behavior follows principles of cause-and-effect because each internal element has fixed properties regardless of which function it is expected to perform. On the other hand, the human world performs more like an organism whose components are not fixed but may grow, be altered by the thrust of external events and by interplay with other internal elements.

Following a notion that what you can't model you can't manage, a systems model is needed to represent the processes by which both physical and societal factors are defined, interconnected and interact. Such technology-based human support systems are labeled by their intended social functions-----food production, shelter, military and homeland security, communications, transportation, health care, energy production, conservation of natural resources, water supply and sanitation, education and even entertainment. In our modern era, all these functions have been enormously strengthened by applications of scientific knowledge, then applied through engineering.

It helps to think of technology as more than the hardware of planes, trains and computers. Rather, it is a social system comprising many organizations, synchronized by a web of communications for a common purpose. It is energized by forces of free market demand, of popular demand for security and quality of life, and by forces of scientific discovery and innovation. It is best understood as a technological delivery system (TDS) that applies scientific knowledge to achieve society's needs and wants

Technology then acts like an amplifier of human performance. With water wheel, steam engine and bomb, it amplifies human muscle. With the computer it amplifies the human mind and memory. It also amplifies social activity, mobility, quality and length of life.

A paradox arises when technologies introduced for specific benefits also spawn side effects. These can induce complexity, conflict and even chaos. Most of these are unwanted by some sector of stakeholders, now or in the future. This paradox is dramatized when technologies are introduced to defend against violence of nature or against human and organizational error but themselves spring unintended and possibly dangerous consequences.

The investigation of risk and of measures to contain it within safe limits requires both hindsight and foresight. The past can illuminate failures, their causes and their control as lessons for engaging new ventures and threats. The future commands the exercise of foresight, an imaginative preparation of scenarios stirred by such questions as, "what might happen, if," or "what might happen, unless." Those inquiries should then examine the timing of impacts (immediate or hibernating) and identity of players on the risk horizon who trigger risk, those parties responsible for risk abatement and those adversely affected now or in the future.

Modeling then becomes essential to represent a full cast of stakeholders and their inter-relationships, including both the private and the public sectors. The concept of a technology delivery system (TDS) discussed later is simply an attempt to model how the real world works.

The responsibility to manage risk stems from the American Constitution, from custom , and from a growing body of public law. Federal, state, and local governments are heavily involved in all of the technologies itemized previously, contrary to popular belief that technology is private industry's territory. With waterways, for example, the Army Corps of Engineers (USACE) has a predominant statutory responsibility. That accords with the historic federal stewardship of national infrastructure, from roads, shipping channels, harbors and canals to airplane routes and the Internet.

That achievement carries significant but subtle implications. For one thing, safety costs money. The federal budget is constantly challenged to meet a rainbow of different demands, the total of which always exceeds Congressional appropriations. The mismatch must then be reconciled through tradeoffs at the highest policy levels stretching all the way to the President of the United States and the Congress.

Indeed, the President becomes the nation's systems manager because all agencies responsible for citizen security report to the Chief Executive, because he is arbiter of budget priorities and author of annual budget requests. He is held to account for quality of performance and for design of public policies if authority or performance is lacking. Serious threats of nature also require the mustering of resources that are available only through the armed services of which the President is Commander-in-Chief.

Often, a focus on power of the Federal Government misses a major premise of democratic governance. As the Declaration of Independence states, those who govern should do so only with the consent of the governed; we would say the informed consent.

This notion is reflected in such regulatory legislation as the National Environmental Policy Act (NEPA). Section 102(2)c. It requires estimates of harm that could result from technological initiatives, along with alternatives to accomplish the same goals but with less harm. After preparation, these environmental impact statements (EIS) are made available for public comment and possible amendment. The point is that this process makes every citizen a part of government to negotiate the question of how safe is safe and thus provide citizens the levels of safety and security that they desire.

Implied is a prospective national policy that those put in harm's way have a voice in what otherwise could be involuntary exposure to risk. This principle leaves implementation of the concept to the responsible federal agencies, subject to Constitutional safeguards. That doctrine of anticipation was the policy spine of NEPA and the 1972 legislation to create Congress's Office of Technology Assessment (OTA).

That agency functioned as radar for the ship of state to estimate future effects of today's decisions. It was killed in an overnight action by House Speaker Newt Gingrich in 1995. In one sense, OTA served as a risk manager for the Congress and the agency's production of unbiased reports gained commendation, sufficient to WARRANT its rehabilitation in a new policy venue sharply focused on risk management.

Managing risk demands attention to operational details. For example, *informed* consent assumes that every citizen has access to the facts, all the facts. And it assumes they are readily understood by individuals without specialized training. Here the print and electronic media become conveyers of raw information to help citizens judge their exposure, but also to serve as watchdogs through investigatory journalism as an independent check on truth. This condition places a burden of responsibility on both the media and citizens to grasp the risk equation sufficiently to better understand their own risk exposure and their risk tolerance, thus to frame their informed consent.

Despite a tendency to flare the sensational, the media can enrich understanding with a backstory because disasters so agitate a functioning system as to reveal the full cast of stakeholders, their roles in increasing or decreasing risk and their degree of injury. Managing editors require that the subject "have legs" to justify time and space of repeated coverage.

Even if this process works perfectly, the outcomes would not be free of conflict. An individual's judgment on matters that threaten lives, property and the natural world is heavily colored by their portfolio of values. Moreover, different stakeholders have different interests to guard. In deciding how safe is safe, disparate views may require bargaining so as to reach a consensus.

A serious problem then surfaces when all parties argue from their short-term self interest. Little attention is accorded the longer term. Left out of the bargaining process is our progeny, the future generations. It can then be argued that the federal government should not simply act as umpire but try to balance long- with short-term effects using foresight, to compare options that do not penalize children by harm or bankruptcy.

The engineering profession has long practiced social responsibility by a technique of over-design, to compensate for uncertainties in loading, in materials, in quality of construction and maintenance, etc. This may be accomplished by adopting some multiple of loading as a margin of safety ranging from 1.4 to 5.0. How these margins are set and by whose authority is of critical importance, especially where tradeoffs with cost or other compelling factors such as deadlines may compromise the intended reduction of risk.

This method of safety assurance is more applicable to design of mechanisms not subject to human and organizational errors. The term "errors," incidentally, is shorthand for a broad spectrum of individual and societal weaknesses that include ignorance, blunder, folly, mischief, pride, greed and hubris.

Protecting structures against violence of nature such as with earthquakes, volcanic eruptions, tsunamis, floods, landslides, hurricanes, pestilence, droughts and disease may utilize the concept of over-design, based on meteorological, hydrological, seismic and geophysical data of past extreme events; e.g. the highest flood or most severe seismic event in a century. Equally pertinent is the scale of losses. Beside the previous techniques of safety enhancement is one of redundancy where, for example, commercial airliners are required to have at least two engines, one of which may suffice to assure a soft landing.

Protecting structures against violence of terrorists entails additional practices of a customized precautionary principle. This intervention may be adopted as a preventative measure or one of damage control.

Learning from documented failures is a powerful method for reducing risks of repeated losses. Another is to learn from close shaves. Many dangerous events fortunately culminate in only an incident rather than an accident, but the repetition of similar incidents can serve as early warning of danger. Indeed, the logging and analysis of such events on the nation's airways partially accounts for their impressive safety record. A system for reporting close encounters was installed decades ago. Anticipating the possibility that perpetrators of high risk events might be reluctant to blow the whistle on themselves, the Federal Aviation Administration that has cognizance arranged for NASA to collect incident date and to sanitize it to protect privacy of the incident reporter. NASA also screens reports to identify patterns as early warning of a dangerous condition. Similar systems are in place for reporting incidents with nuclear power plants.

With the growing recognition of human factors in accidents or in failures to limit damage, a class of situations has been uncovered entailing uncommonly high risks but conspicuously good safety records. In the Navy, for example, high risks attend the crew on submarines and on carrier based aircraft. Yet accident rates are paradoxically low.

Careful analysis has shown that certain qualities of leadership and organizational culture foster integrity, a sense of responsibility among all participants, a tolerance by authority figures for dissent, and consensus on common goals of safe performance.. Especially has high safety performance been correlated with an institutional culture that was bred from the top of the management pyramid. The most critical element of that culture was mutual trust among all parties in a technological delivery system.

Long experience with military and paramilitary organizations such as first responders proves the value of rehearsals to reduce risks and control damage. Of special virtue is proof of satisfactory communications. Evaluation of dry runs has repeatedly turned up serious problems in communication. So has post-accident analysis of real events when delays or blunders in communication of warnings and rescue operations cost lives.

This leads to recognition that successful management of risk depends ultimately on the prudent exercise of political power by leaders at every level. Deficiencies may still remain in political will, in fiscal resources, in vigilance, and in ethics. Hard to define and to measure, these elements may sadly define themselves in emergencies by their absence.

To sum up, the context for analyzing the levee failures from Hurricane Katrina illustrates several realities. The most compelling imperative of life is survival. Yet the experience of living teaches that there is no zero risk. Some exposures must be tolerated as “normal,” whether in rush hour traffic or coping with nature, with human nature or with unintended consequences of technology.

In this modern era, society has demanded better protection against threats to life, to peace, justice, health, liberty, .life style, private property and to the natural environment. These challenges are not new, but two things have changed—the increased potency of technology and increased coverage by media. Technological factors are more robust in speed of delivery and in potential harm. Media covers events live, 24/7, and worldwide. Events anywhere have repercussions everywhere. The better informed public tends increasingly to be risk averse. Apprehension and fear peak after a calamity with demands for better protection through better governance. Higher expectations are legitimate because so many threats just itemized are due to human and organizational errors either in catering technologies to meet market demand or in guarding against hazards. This current study shows that the Katrina event fits that pattern. Government at all levels failed to provide security to citizens before and during the catastrophic flooding. Victims are justified in asking how did this pathology of a mundane levee technology develop? How can that knowledge be applied to prevent a reoccurrence? Then there is the quintessential question of “How safe is safe?”

As said earlier, answers cannot be found only from natural laws of science. Safety is a social judgment. Those exposed to risk have a right to information about their exposure to danger and about the strategic issues of protection.

Ultimately, these decisions are made by government, and that process entails wrestling for power. In that matrix of conflicting interests, in our democracy, this authority should flow from citizens taking responsibility to become informed on their exposure to risk and to assure the opportunity to express an informed consent.

At the federal level, both the President and the Congress need objective, expert advice and counsel to fulfill their responsibilities under the Constitution. They also need to increase their respect for independent analysis of risks in order to restore citizen trust.

The preceding situation analysis opens a window on a number of issues treated in more detail in subsequent sections:

- The design of precautionary measures requires inspired foresight, to fantasy alternative futures:
- Tradeoffs are inevitable between short- and long-range events and consequences, between safety and cost, between special interests and social interests, between who wins and who loses and who decides.
- All human support systems entail technology, and all technologies project unintended consequences.
- Society embraces a spectrum of values that often conflict, as with the goals of efficiency in the private sector and of sustainability and social justice in the public
- Key decisions regarding citizen safety and security are made by government through public policies to manage risk. These policies dominate the legislative agenda.

- This mandate imposes a heavy burden on the President and on the Congress, both bodies requiring access to authentic and immediate information.
- Making decisions and assuring implementation draws on political capital in the structure of authority by the exercise of political power and political will.
- In our democracy, this authority should flow from citizens following the principle that those who govern do so at the informed consent of the governed.
- The quality of risk management can best be judged by the effects on future generations.
- The geography of risk crosses boundaries as between federal, state and local entities, and between the United States and other nations.
- Different cultures have different risk tolerances, including attitudes distinguishing voluntary from involuntary risk.
- Analysis of risk and its control extracts lessons from past failures, although the most catastrophic events are so rare as to frustrate projections.

This portfolio of issues illustrates the anatomy of risk and the complexity of its management. They sound a wake-up call for deeper understanding by those responsible for risk management and by those attentive citizens who are exposed and are entitled to a voice in the decision process.

H.2.2. Risk Analysis as a Survival Skill

Humans have always lived at risk. From early times, we experienced threats of hunger, natural disasters and extremes of weather, dangers of accident and violence at the hands of other people. Brutality wasn’t just physical. Some threats were psychological and emotional as by deprivation of human rights, freedom and dignity, of equitable access to resources and of opportunities for self-expression. Only a tiny elite lived with reasonable security; others were dominated, exploited and enslaved.

A big bang of change occurred with a twin enlightenment of democracy and of modern technologies. People live longer. Quality of life is higher and more widely and evenly spread. Everywhere, citizens expect government to provide overarching security.

With progress, however, have come new risks. Nuclear, biological and chemical weapons expose every human to extinction, and weapon delivery systems can be so distributed and hidden as to make total safety pure fantasy.. On the other hand, arms control treaties of 1963 on non-proliferation and limits to testing demonstrated how nations can negotiate risk reduction for common survival, even in a hot atmosphere of a cold war. That same ingenuity is required to manage twenty-first century risks.

Periodically, philosophers and theologians have peered into that future, some with lenses colored by optimism, others by the obverse. By the 1930s, a literature emerged of pure speculation and conjecture. Some promised only entertainment; some was serious and usually pessimistic. By the 1960s, risks were being charted by scientists and engineers..

In 1962, for example, Rachel Carson wrote in *Silent Spring* about the loss of bird song because DDT sprayed to wipe out malaria laden mosquitoes had side effects. Egg shells of birds were thinned enough to halt reproduction. That wigwag captured public attention that echoed in the chambers of policy making. In 1970, the United States adopted the National Environmental

Policy Act to protect the environment broadly. It required analysis of ecological, economic, and social impacts triggered by technological initiatives. It also required their publication and opportunities for citizen reaction.

This achievement challenged the public process as to whether society was prepared to deal with the new information on which to form judgments of safety.

In 1972, two related events occurred. First, the United States Congress awakened to the unintended consequences of technology and founded a new advisory agency, the Office of Technology Assessment, the OTA. It was mandated to look ahead and unpeel the ubiquitous side effects of almost every technology. The Act brought the future into the decision process in a vigorous spirit of early warning.

Second, a group of European corporate executives (called the Club of Rome) took time away from their internal management to study and publicize extreme pathological trends in the world at large. Interactions were examined among spiraling population, rising insults to the environment, limits on food production, on such natural resources as energy, and on effects of urbanization. The study, *Limits to Growth,* sounded an alarm that in perhaps 75 years, dangerous trends would become irreversible. Although the study's methodology was questioned, its warnings attracted world wide, policy level attention.

As the public became aware of the two faces of technology, the future was probed not only of physical limits to the carrying capacity of the planet, but limits to human knowledge, ingenuity, judgment, objectivity, and mastery of problem solving. My contribution to the inquiry was to test a portfolio of dangers from unintended consequences of technology against two measures of risk reduction. One lay in defensive technology. The other lay in the muscular practice of politics!

Table H.1 summarizes conclusions reached in 1977, almost 30 years ago and published in *Margins for Survival,* 1979. The different forms of menace have all happened at one or another scale, including terrorists with weapons of mass destruction (WMD) in Japan. The most effective pre-crisis intervention still seems to be through politics, not new techniques. The poorest guesses were on imminence. Perhaps the author was spooked by total immersion in doomsday subject matter of that era and a close shave with the Cuban missile crisis.

These projections are interesting but not as important as planning a risk analysis strategy for survival. While government has that responsibility, a post-mortem of *Katrina* may reveal endemic malfunctioning and the need for broader awareness and involvement of citizens.

Lessons From Disasters and Close Shaves

Engineers remember that until two centuries ago, they learned mostly from failures, Occasionally, they still do. Katrina and 9/11 have been cruel teachers.. With a global span of high-speed communications, we can study catastrophes at great distances. We can construct a rich case book to extract patterns of risk that are universal because natural phenomena are global and new technologies no longer have geographical, national, economic or cultural boundaries. Even our humanitarian concerns encompass people everywhere.

The short compendium that follows is not intended to be comprehensive. It is only a sample of events selected from a swarm of news stories where media editors and TV producers thought them important enough to earn repeated headlines. As the media jargon goes, "the stories had legs." The initial story had many sequels. That publicity was justified by the scale of impact in lives or property lost, by the surprise lack of early warning, by the likelihood of the pattern being repeated so as to deserve hyper vigilance, and by effectiveness or its failure with damage control.

Table H.1: Menaces, Outcomes, Probabilities, and Interventions

Menace	Worst Case Casualties (millions)	Worst Case Imminence (years)	Probabilities and Trends		Pre-Crisis Intervention		
					Minimum Time (years)	Successful Means (scale 1 - 10)	
						Technical	Political
WMD, Terrorism	30	0	High	⇑	10	8	2
Famine, Natural Disasters	1,000	10	High	⇑	15	8	5
Environmental Accidents	2,000	25	Medium	⇑	15	8	7
Climate Change	1,500	75	Low	⇑	50	3	7
Urban Chaos	500	15	High	⇑	30	5	3
Resource Depletion	1,500	30	High	⇑	20	7	4
Economic Collapse	1,000	15	Medium	⇑	15	6	5
Institutional Collapse	500	15	Medium	⇑	25	5	5
Decline in Values	2,000	25	Medium	⇒	20	7	3

Consider these large scale disasters, perceived threats, or close shaves:

1) Hostile Military or Diplomatic Actions

A-Bombing Hiroshima and Nagasaki, 1945
Soviet Space Shot, 1957
Cuban Missile Crisis, 1962
Capture of U.S. naval vessel in Tonkin Gulf, 1967

Actions by Terrorists

Truck bomb damages New York's World Trade Center, 1992
Bombing of Oklahoma City federal building, 1995
Bombing of U.S. Marine Barracks in Lebanon, 1983
Bombing of U.S. embassy in Kuwait, 1983
Bombing of U.S. naval vessel in Yemen, 2000
PanAm #103 exploded over Scotland, 1988
Airplanes crash into World Trade Center and Pentagon, 9/11/2001

Violations of the Environment

Torrey Canyon tanker spill, 1967
Exxon Valdez tanker spill, 1989
Gas emissions damaging the atmosphere's ozone layer
Greenhouse Gas emissions triggering global warming

DDT and PCBs distributed in waters, worldwide

Technology-related Disasters

Rash of steamboat boiler explosions, 1830s
Explosion of chemical plant in Bhopal, India, 1984
Nuclear power accident at Chernobyl, Ukraine, 1986
Challenger spacecraft failed on reentry, 1986
Infrastructure lags behind urban growth
Long outages of electricity, phones, water and waste disposal
Failure of whole systems
One thousand Savings and Loan Bankruptcies, 1980s
Health care fraud and lack of coverage
Continued shrinkage of passenger railroads in U.S.

Acts of Nature

Tsunami in Indonesia, 2005
Earthquake in Kashmir, 2005
Katrina Hurricane on U.S. Gulf Coast, 2005
Global flu epidemic, 1918
Drought and famine, Africa
Evolution of Avian Flu to threaten humans, 2005

Resource Depletion

Increase in energy demand not matched by new supplies
Depletion of ground water resources

Pathological Violence by People

Holocaust, Germany and occupied Europe 1939
Genocide, Sudan, 2001
Genocide, Uganda, 1985
Genocide, Iraq, 1996
Suicide bombers in Israel
Loss of freedom by concentration and control of media

All these threats share common elements: hazards potentially affecting greater numbers of people than ever before, risks extended geographically and through the future. All involve technology and require human intervention in both prevention and mitigation. In most cases, this depends on government, through legislation, specifically tighter regulation.

Each threat has three back stories: the history and immediate context for the main event, the event and its effects, and the post event consequences and application of lessons learned.. Present at every stage are challenges to decision making, mainly by public officials. The political stage is tense: anxiety, frustration and stress rise over lack of crisis prevention and of damage control plans, over weak communication networks, over conflicts among parties at interest, over threats to the status of the decision makers themselves. Spotlights focus on first responders, but ultimately on the nation’s Commander in Chief. The President is functionally the nation’s system manager!

This inventory demonstrates the close bond between technology and government, the centerpiece of a book by this author, *The Double Helix: Technology and Democracy in the American Future*. As these examples are tweaked in the following sections, the reader should focus on a particular class of technologies, those installed to deal with extreme violence of nature or of terrorists, either to prevent disasters or to limit and ameliorate damage.

H.2.3. Tradeoffs Between Risks, Cost of Mitigation and Performance

Safety costs money. That unwelcome truth creates dilemmas in the social management of all technologies as demonstrated in trends of safety measures for automobiles. Here is a sketch of that evolution

Looking back, during World War II, the production lines of cars gave way to production of armaments; fuel was strictly rationed. With peace, the pent-up consumer demand exploded. One unintended consequence was a sharp rise in highway fatalities. As a creature of auto manufacturers, the National Safety Council opened a publicity campaign to reduce accidents, pointed at “the nut behind the steering wheel.” The industry blamed crashes entirely on driver error. Up until then, the most significant improvement in auto safety had been a requirement for brake lights. The public bought that rationale and began training drivers in high schools but ignored safety measures for vehicles themselves.

As fatalities continued to rise, newspapers featured weekend carnage, for example on Route 1 between Baltimore and Washington, D.C. The public became agitated but it lacked mechanisms for protest other than the AAA. Even insurance companies were silent. Safety advocacy then grew following Ralph Nader’s model of credible documentation. Things happened.

State and federal governments mandated turn signals, shatter proof windshields, rear view mirrors, tubeless tires, winter treads, emission controls, seat belts, and stiff penalties for DWI. In most cases, the industry resisted initiatives on grounds that improving safety would boost cost and, following elementary economics, would shrink the customer base. Battling the industry were national leaders in engineering, in public health and in consumer rights. The era of citizen activists and responsive government was just dawning and industry had to be dragged, screaming and kicking, toward safer cars.

Albeit not with mathematical equations, the public asserted how safe is safe. Their tolerance for fatalities in the U.S. hovered around 50,000 per year. Beyond that mortality rate, drivers demanded improvements and were willing to pay the added costs.

This story echoes earlier advances in railroad safety and then air transportation. It is also a model of what has happened over the last century regarding citizen protection by immunization, requirements for pure food and drugs, and by preservation of such common property as air and fresh water. Apart from these tangible measures, similar interventions by government were demanded for the less visible harm of monopoly pricing, security trading fraud, etc.

Before elaborating further on the concept of tradeoffs, it is useful to extract further lessons from the case of transportation. Here are some:

First, the public began to say “how safe is safe.” Until after World War II, the cast of inventors, entrepreneurs and manufacturers soft-pedaled the issue of auto safety and targeted most research on fatigue failure of axles. Protection was expected by regulatory processes of government, but in the contest between sources of risk and victims, the most vigorous lobbying came from industry, not drivers.

That changed dramatically by the 1960s. For one thing, the love affair with cars made imperative more and safer highways. Federal support of farm-to-market roads underwent a quantum leap with1956 legislation to build a national network of superhighways that had been sketched first in 1923 by General Pershing. The breakthrough was intense public support, inflamed by advocacy of the Hearst newspaper empire. The Public Roads Administration set higher standards for states to follow in highway design and construction, on sight distance by limits on grades, curvature, width, lane separation and freedom from intersections.

The public had found its voice for safer roadbeds to be funded through taxes, and that imperative of risk management slowly leaked over to the cars themselves.

A second lesson was that with safety awareness and education, the public would pay higher car prices for greater safety. Note that the issue was pressed not by car companies or by government but by the public, media and public-interest associations. Then insurance companies reacted to the suits for negligence brought successfully against manufacturers, highlighted by evidence that risks were known to the companies but not mitigated voluntarily. That pattern improved with legislation mandating recalls. Today, safety sells cars. What a switch!

A third lesson lies in how the growth in public appetite for technology required growth in public services to manage risk. A corollary is that government stepped in only after the fact, practically never in the spirit of preventive medicine. That stance of reaction rather than proaction as a doctrine of anticipation stems from historical American antipathy to big government, and partly from the power of lobbies to influence political leadership. As elaborated later, technology has become more political and politics more technological. Sometimes, that reality stings..

A fourth lesson is that the government's role in modern life has greatly increased simply to manage risk. Most of the recent (and not just reorganized) agencies of government were created for the troublesome purpose of regulation. That theme harmonizes with the Constitutional mandate, among others, "to promote the general welfare."

One problem is that each risk is managed by different criteria and different agencies with different cultures, vertically through federal, state and local bodies, and horizontally within each layer. The first broad attempt to improve the risk management process was Section 102(2)c of the National Environmental Policy Act of 1970 requiring environmental impact statements. With a ground swell of popular support, it capped the 1968 presidential election with all candidates driven by public sentiment to stand for environmental protection. The courts later stretched the scope of the act to encompass social and economic dimensions of the human environment and not just those to preserve nature.

That breadth was sharpened by 1972 legislation to create the Office of Technology Assessment (OTA). Its purpose was to provide radar for the ship of state, an early warning system for Congress that required every technological initiative of the federal government to postpone implementation until an assessment was completed focused on questions of, "what might happen, if, or what might happen, unless." This gave public advocates a handle to dig out potentially harmful consequences and through the political process gain mitigation. OTA was killed in 1995. A similar provision for foresight was mandated in the 1976 mandate creating the White House Office of Science and Technology Policy; it has been ignored.

The preceding brief that was concerned with tradeoffs between safety and cost used auto safety as an example. Similar patterns are present in other modes of transportation, by sea, by air and by railroad. A second mode of tradeoff is present when independent parameters of design performance interact with both safety and cost. The most compelling example is with combat submarines.

As context for this case study, recall that submarine hulls must be designed to withstand the intense hydrostatic pressure of surrounding sea water when submerged to operating depth. Given the catastrophic nature of hull failure and the exposure of crew to such risks, precautions are taken to compensate for uncertainties in design theories, in materials, workmanship, aging, or from operating error. This additional strength usually entails additional weight and that poses a dilemma..

Submarines operate close to neutral buoyancy. This affords diving simply by admitting sea water to external ballast tanks. Surfacing then entails blowing the ballast tanks with compressed air carried on board. With such a delicate balance of weights between the sub’s hull, propulsion, weapons, life-support functions, crew and sustenance. the incentive for adding strength to reduce risk to crew and sub itself carries a serious penalty. The weight for additional strength must be traded with weights of other components required for combat.

The design process requires serial trial-and-error calculations, varying the safety margin. For civil construction, the building codes dictate a factor of four. For special boilers, it may be as small as three. For submarines, that high a margin would prejudice war fighting characteristics, and practice for naval subs has been as small as 1.7. For research subs, it has been set as low as 1.4. For sightseeing subs, it has been set at 4. The 1.7 level means that for a sub designed to operate safely at 700 feet, its crushing strength would be about 1100 feet.

The risk of such a small margin is accepted because for each new class of subs, complex calculations are refined, confirmed by tests of small scale models in a pressure tank, then warranted by a heavily instrumented deep submergence trial of the first one operating. Other assurances lie in superior workmanship in hull assembly with x-ray examination of welds and close tolerances on shape. Operation at sea assumes high competence of crew.

In other ways, similar margins are introduced in all technologies as an act of social responsibility. The public exposed to risk is seldom consulted, and this raises a major issue in risk management that is epitomized by the familiar notion of “Informed Consent.”

H.2.4. Voluntary versus Involuntary Risk

Exposure to risk may be voluntary or involuntary. The two types differ in definition in the acceptable levels of risk and in the degree to which the public expects government to regulate safety. When citizens believe they are in danger with limited options to escape, and when a large number of people is simultaneously exposed, the public demands greater protection. Here are some examples.

When planes became more numerous and larger, there were more crashes and more passengers lost. The public demanded more stringent regulation and enforcement.. Commercial airlines were regarded as common carriers in which people lose control over costs, comfort, privacy, schedules, routes, intermediate stops, destinations and risk.. Except for short flights, other modes could not compete in speed so that the primary tradeoff was in cost of tickets. As in all common carriers, by air, rail or sea, people felt at involuntary risk and demanded more protection. With encouragement by members of Congress, most of whom fly home every weekend, intense oversight has been mandated regarding equipment, pilot training, traffic rules, maintenance, etc. The annual death rate peaked at about 200 per year and is now much lower, far lower than for travel by car.

In contrast, passengers in private planes--termed “general aviation,”--enjoy all the previous options but at a higher transportation cost To keep that within bounds, this class of passenger tacitly accepts higher risks revealed by more fatalities per million passenger- miles compared to commercial aviation. Because these passengers usually have options to fly by safer commercial aircraft, FAA risk analysis deems the higher risk acceptable because general aviation risk is voluntary rather than involuntary.

A more mundane example lies in skiing. Cable lifts are regulated by local authorities as common carriers because the clientele are regarded as at involuntary risk in having no options to gain the top and no options to exit at intermediate elevations. Lift safety is carefully regulated. Coming down, however, skiers are on their own, at voluntary risk. If the number of accidents going up were as numerous as those coming down, there would be hell to pay from public complaints and from lift operators hit with higher insurance premiums and possibly more liability suits.

This question of voluntary versus involuntary risk gets blurred in consumer protection, especially with pharmaceuticals and medical apparatus. Both in liability jurisprudence and in safety standards, a major issue arises on which type of risk is present, and for each type, how does the public decide on acceptable limits.

That enigma is further strengthened because of a growing public distrust of manufacturers. Statistics from drug trials have been faulty (Merck) and short circuits in heart rejuvenators have been concealed (Guidant). This malfeasance injects another uncertainty in the calculus of risk---- the pressures of the health industry on Congress to let free market forces control safety with a minimum of government interference. That could work only if the public is literate on drug therapy; that is unrealistic.

The situation is further tangled by paradoxes in health affairs on the virtues and penalties of single payer health delivery and by advances in technology teasing consumers to believe there is a cure for every ailment, at diminishing risk.

Regulation of safety for miners at involuntary risk under ground began 100 years ago after annual fatalities exceeded 2,000. Occupational safety is now broadly regulated by OSHA

H.2.5. Coping with Threats to Life, Liberty, Property and the Environment

Restated for emphasis, the most compelling imperative of life is survival. For most humans, that condition is more than biological. It means being both alive and free. Toward that end, living teaches that there is no zero risk, that some exposures must be tolerated as “normal.” In the last two technological centuries, however, society has demanded that threats to life, to peace, justice, health, property, liberty, life style, sustainability and the natural environment be minimized. Such stewardship was anticipated in a preface to the Constitution whereby founders of the nation committed our fedewral government to assume responsibility to tame these risks.

Life also teaches that threats to survival are episodic, that citizen and media sensitivity to both threats and appropriate response waxes and wanes. Apprehension and fear peak immediately after a calamity, then subside to a stable level that depends on pain of the consequences and proximity to the event, chronological and geographic. The size and continuity of news headlines mirrors and often arouses public awareness. With Hurricane Katrina, chagrin was triggered over impacts of a natural and recurring phenomenon that exposed failure of government at all levels to take precautionary steps for safety and security. The loss of life and property and the subsequent neglect of victims then led to outrage. People ask, Why did a tragedy on this grand scale occur? How can it be prevented from happening again?

This essay is not a post-crisis analysis of Katrina or of its disaster kin. For one thing, critical data are still being evaluated. However, it is clear from a number of interim reports already issued by other bodies that the failure can be attributed to human and organizational error. This source of calamity has also been found in a wide spectrum of disasters,: the nuclear accident at Chernobyl, the oil spill by the *Exxon Valdez* discussed later, Human factors lie behind the failure of intelligence and initiation of the Iraq war, sinking of the *Titanic*, terrorists crashing planes into New York's twin towers , 9/11, loss of the spacecraft *Challenger*, and the chemical spill at Bhopal, India. This source, incidentally, includes failure to anticipate potential disasters, make damage control plans, take accident avoidance measures, or make prudent choices as between safety and cost.

It is worth reiterating that the answer to "How safe is safe" cannot be deduced from natural laws of science and mathematics. It is a social judgment. Assuming people comprehend that there is no zero risk, what level do citizens accept or at least tolerate?

This inquiry is most often left to experts because the public thinks risk analysis is accessible only to professionals. Yet, individuals make many decisions each day without consulting authority. Ponder the close shaves in highway traffic, the choices of home remedies for illness, the strenuous avoidance by those allergic to nuts, the tradeoffs in investments between return and risk. Albeit in new forms, modern risks have antecedents.

Always, there have been accidents from ignorance, error, blunder, folly, greed and hubris.

One new reality is that powerful technologies add to the risk portfolio. The public and policy makers need to understand that technology is more than a technique, more than palpable hardware. It is a social system of organizations interconnected and animated for all life support functions.. Clearly, technology has a huge effect on all human affairs, not only for what it can do **for** us, but also what technology can do **to** us.

Every technology, however, has unintended consequences. Many increase complexity, conflict, personal stress and socio-economic strains. To the point of this discourse, technology such as in health care can ameliorate risks but it can also trigger risks. With many medical procedures the patient must sign "informed consent" acknowledging awareness of threats to life and function. Parenthetically, that practice deserves refinement because simply listing potential injuries does not illuminate the probabilities.

Because of modern information technology, events anywhere have effects everywhere and immediately. The village has morphed into an inhabited planet. While technology has historically driven weapons development of the spear and chariot, nuclear devices now spin a risk of mass extermination. Perpetrators may not be nations but anonymous and ubiquitous terrorists. We have also advanced the risk of a slow tsunami by global warming that melts the ice cap so that the oceans flood low lying habitation in coastal wetlands and alter agricultural seasons.

As context to the strategic issues in risk management, consider these features:

- Dangers can be grouped according to origin, from natural causes, from human behavior, and from unintended consequences of technology such as environmental damage from mining runoff.
- The design of precautionary measures requires inspired and vigorous foresight—to fantasy what might happen, if, or unless, and a comparison of options to identify those that minimize harm.
- Foresight mandates tradeoffs as between short and long range events and consequences, as between safety and cost, between special interests and social interests, between who wins and who loses and who decides.
- Technology can best be understood as a "Technological Delivery System," that applies scientific knowledge to achieve society's needs and wants. A TDS models reality with inputs of knowledge, fiscal, natural and human resources synchronized by a network of communications. Outputs are both intended and unintended. The system is driven and steered by three operating instructions---market place economics, public policies, and social norms.
- Technology lies at the core of all human support systems.
- Conflicts arise from different values in the private sector as compared with the public. Strategies to achieve desired goals contrast efficiency against sustainability and social justice
- All technologies trigger side effects; most are harmful to some community of specified or accidental stakeholders, now or in the future.
- Key decisions regarding technology in terms of outcomes are not made by scientists or engineers, or by executives in the private sector. Rather they are made through the public policy process, in the U.S. as defined by the Constitution, the President, the Congress and the Courts.
- The decision process inevitably entails wrestling for power; its intensity depends upon what is at stake as between winners and losers.
- The most compelling decisions are negotiated as "politics," here defined as the legitimate process by which stakeholders negotiate their individual interests against collective interest within a structure of authority.
- In our democracy, this authority should flow from citizens following the doctrine that those who govern do so with the informed consent of the governed.
- Decisions in this class can be judged by their impacts on future generations.
- Technology has also shrunk time and distance so that isolation is no longer dictated by geography. We live in "one world."
- The management of risk should be based on lessons from failures. However, data may be sparse with rare events of catastrophic scale.
- Different cultures have different risk tolerances. Moreover, there are significant distinctions as between voluntary and involuntary risk.
- Once there is agreement on "how safe is safe," tension is likely to continue between the sources of risk and those harmed. In the interest of social and economic justice, all three branches of government play pivotal roles.

- Since enactment of the National Environmental Policy Act in 1970, a process of impact analysis has been required of all federal technology initiatives. It applies to other classes of threat extended by legislation in 1972 that created the Office of Technology Assessment to serve Congress as a system of early warning of dangers from new technological initiatives.
- The media plays a critically important role as a source of information to all citizens and parties at interest about threats and public safety, about failures of institutions responsible for precautions, and as an editorial source of advocacy for citizens marginalized in the power structure.

H.3 Government's Responsibility for Security

H.3.1. Risk Management: Our Constitution, Public Policy, and our Culture

Restated, the TDS is a symbolic network assembled for a specific purpose with socially desirable outcomes. It incorporates customized organizational components, internally differentiated, hierarchically interrelated, and interconnected by a lacework of communications. While this production function is generally the territory of private enterprise, all elements of the system influence decisions by business management; the most powerful signals link government to the enterprise managers. .In eight different ways, public policies hammered through government shape strategic decisions in the private sector as much as the market place of all citizens. Consider these categories:

- **Providing an umbrella of security for citizens** as set forth in the preamble to the Constitution. Translated to "normal risks," providing security is the core of managed risk It is exemplified by preparing for the common defense. That priority for federal funding in 2005 exceeded support for all other federal functions, combined. Beyond threats from organized national states and from terrorists, security also relates to domestic tranquility, social and economic justice, and especially promotion of the general welfare when life, health and property are threatened by natural calamities. Civic responsibilities now include preserving health of the environment and natural species.
- **Purchasing technology** for national defense that also generates full employment and technology spin-off whereby military innovations cater to the civilian market, e.g., satellite assisted global positioning devices (GPSS).
- **Directing economic assistance to private enterprise** has been accepted as a tradition to foster prosperity and social satisfaction, not to mention economic vitality to assure a healthy tax base. In 1845, the government granted railroads a ribbon of land for trans-continental service. Wider than needed for track, these grants let rail lines profit from sales of excess land to track-side factories. The Corps of Engineers surveyed most of the mountain route at no cost to the companies, following a maritime subsidy of charting coastal waters for safety of commercial shipping Other subventions include a rainbow of tax breaks, import quotas and market guarantees.
- **Providing indirect economic assistance to private enterprise** through support for higher education, for most of the nation's basic and applied research, for such services as the Export-Import bank, launching of commercial communications satellites, weather forecasting, and guidance for American companies doing business overseas. In short, government funds our social overhead.

- **Influencing the capital market** by deficit borrowing, fiscal and tax policies, by manipulation of interest rates, balance of payments and facilitation of venture capital for new starts and ability to meet foreign competition.
- **Functioning as steward of common property resources** such as fresh water, forests, fisheries minerals and pasture on federal property that includes petroleum reserves on the outer continental shelf, and the radio frequency spectrum.
- **Building or financing infrastructure** such as of shipping channels, highways, airways, Amtrak, intangibles of the radio frequency spectrum, and the Internet.
- **Regulating** private technological activities that may be inimical to the public interest. These interventions range from anti-trust legislation, abolition of child labor, safety of transportation and mining, to purity of food, air and water, occupational health, effectiveness and safety of drugs, toxic waste disposal and other measures attending hazards of powerful new technologies.

These functions led to growth in government size and scope, the unintended consequences of greater dependence on high technology. All trigger conflicts, especially on the issue of the appropriate role of government in a society that considers itself a capitalist democracy. History teaches that regulatory legislation was consistent with Constitutional law and later of custom. The courts expect government to make the most fundamental and influential decisions contributing to security. Beyond “national security” that justified our attack on Iraq, government regulates by ranking social priorities, allocating resources, helping to organize economic, social and political activity, and tries to resolve conflicts among contending parties. That menu carries no warranty, however, on performance.

Some conflicts arise, incidentally, from ideology: when those asserting conservative doctrine believe that the best government is the least government. Some conflict arises from the concept of federalism, the cyclic tension between state and federal governments. Some arises because claims on the public purse are not matched to resources so that losers perceive themselves as victims of a game for winners.

Persistent conflict arises because most hardware of technology is produced by the private sector and its Wall Street performance balances only direct costs against profit but not the indirect costs, the externalities, the unintended consequences. Because citizens have only limited opportunities to voice the pain of side effects, government is expected to act as a surrogate. Even when represented by public interest bodies, remedies can only be enforced by government operating under legislative mandates. That damage control, however, is not guaranteed..

The act of governing begins with identification of issues, dramatized by political actors to focus political energies on the choices ahead. Often that process sounds exclusively like wrestling by special interests for influence on the outcome. At some point, differences are negotiated for a consensus on public policies as to become laws..

In other words, public policies are what governments do or what they may not do. They are the primary guidance signals by which a pluralistic society sets the course for the future. These policies should also set the ground rules, for example, of opportunities to express a collective judgment on “How safe is safe.”

Public policies deal with both ends and means. Two legislative steps are required, of authorization and of appropriations. Ultimately, all policies require the President's signature, making the incumbent the nation's uncertified systems manager.

Evidence is clear that government has grown because of technology, and technology blossomed because of government. As uncomfortable as is this trend for some, especially around April 15, one way to look at the new or growing functions is to test their content against a concept of "enhancing security by managing risk."

H.3.2. Resolution by Political Power and Political Will

The word, "Politics," suffers from erosion of its high status in Greek culture, 2500 years ago. It was meant to define a social process by which individuals with differing opinions could argue and try to persuade contrarians of their preferred course of action. This was the grist of democracy, the honorable steps to generate consensus.

Now, the word, politics, is often modified by a second one, "dirty." That derogation implies that tactics of argument violate social norms of truth and fair play. Indeed, the phrase has been stretched to imply that all political actions are contaminated, either by distortions of content or by foul play.

In the political arena when stakes are high, there are many temptations to stray from a moral ideal. However, the historic definition still works. Simply put, politics is the mechanism by which the parties at risk with divergent opinions reach agreement on what risk level is acceptable. The political process, however, goes beyond argumentation. It offers a structure of power to resolve differences, then to enforce an action plan to achieve the goals about which there was debate. In the United States, while that power lies in the three branches of government, from earlier disclosures and discussion, in the present era, the President and Executive Branch dominate the stage.

Presumably, voices of different constituencies have been heard and the Chief Executive has determined the degree of popular support essential for success of a particular course. Penalties are assessed for having to use political capital to win a preferred alternative. Since a president's political capital ebbs and flows, each decision event imposes a political risk. As with risks to security, in politics there is hardly ever zero risk.

Indeed, all the stakeholders are at political risk before, during and after a quest for consensus. Each must choose how much existing political capital they can risk. That strategic reality colors the entire context of risk management because the outcome can seldom be settled on rational grounds alone. Risk managers understand distinctions between the desirable against the feasible.

At policy levels, all players have access to varying amounts of power. The party with the most may not prevail, however, unless there is a conscious decision to exercise political will as well as power.

In a democracy, the media have a major role similar to that in the economic operations of the free market. For it to work best, there is a tacit assumption that all parties have ready access to the same base of information. That assumption also applies in political warfare.

In the theater of risk, that principle may not hold. Parties at risk seldom have the same information as those managing risk. We also must distinguish between voluntary and involuntary risk because social judgments for these two cases are vastly different. It is one thing if the parties at risk are advised in advance which mode they are subject to. It is another thing to be subject to involuntary risk surreptitiously.

In an age when small disturbances can have disproportionate effects, integrity of all negotiating parties may be more important to risk management than technical virtuosity. .

Human nature, however, may shatter this ambition. As suggested earlier, the term politics snaps the mind to electoral politics. Included are the strategies and tactics of ethical lobbying, electioneering, and legislative horse-trading, Still, the politics of public life, as the TDS suggests, is more than about governmental structure and process. Indeed, deciding how safe is safe is what democracy is all about.

Democracy is not a spectator sport. Citizens should regard themselves as part of government. This role requires civic literacy and commitment to shared values. Civic discourse should avoid intense partisanship and hidden influences of campaign funding. Values, unobtrusive and subtle, lie at the heart of political process,. thus connecting more and more dots on the TDS.

This focus on ethics applies to other venues---corporate board rooms, academia's cloistered walls, and religious institutions. They differ greatly with regard to what is at stake, to measures of integrity, to an organization's culture, its ethical standards and its style of conflict resolution, the degrees of coercion exerted by management's power to control its environment.

In the interest of earning public esteem or minimizing exposure to liability claims, organizations and individuals must balance temptations to conceal, distort, exaggerate or lie about facts against the harm they may do. The public interest is all too often sacrificed for private benefit, tempered only by the self-conscious exercise of social responsibility.

Building trust takes time, especially in an electronic era when participants in a transaction may be strangers. Personal contact to test integrity by intuition may be squeezed out.

The issue of trust has always been with us, but recent polls uncloak a new low in public confidence in all our institutions. This is not surprising. Innumerable business executives have been indicted or jailed for misbehavior, for which the 2006 Enron trials serve as a poster child. Simultaneously, charges have been brought against Abramoff, the best known of Washington's lobbyists. Several members of Congress face felony charges, have left office, resigned or are awaiting trial. In both public business and private business, many display an inordinate appetite for wealth as well as power.

Although not subject to proof, the public seems to demand higher ethical standards in public service than in commerce. There may be a danger, however, that the distinctions have been blurred. Social indicators as well as economic indicators suggest a weakening of all the nation's vital signs. The future for children is less promising than for their parents.

This theme has been examined by a growing chorus of public interest bodies such as Common Cause, Move On, ACLU, Natural Resources Defense Council, Interfaith Alliance, etc. Over a broad spectrum of predicaments that seed new or more threatening risks, there is neglect of harmful long term costs balanced against short term benefits. The fault lies in limits to foresight blended with inflated political and corporate ambitions, hubris and greed.

H.3.3. The President and the Congress: Needs for Advice and Counsel

Given society's encounter with different and more threatening risks over the last half century, the burden of responsibilities on the Chief Executive and the Legislature has grown enormously. Risk management is not a function that can be outsourced. At the same time, it is difficult to shoehorn all risk-related functions into a single aunit. Consolidation of homeland security functions into a megasize cabinet-level agency still requires coordination with such other departments as State, Defense, Commerce, Interior, Labor and so on. Only the President and Vice President have the Constitutional authority and the operational centrality to effect a seamless integration of bureaucratic resources each exposure to danger requires.

The problem is that both the President and the Congress are suffocating under workloads that drain energy because new threats arise without relief from earlier ones, and because the technical management of risk requires expertise that is in short supply. Especially lacking is an independent staff for both branches of government to provide advice and counsel in a *modus operandi* committed to a doctrine of anticipation.

To be sure, both branches have sensed a need for professional expertise related to other complex, even arcane, functions. Both branches have responded by creation of specialty staff arms. The Executive Office of the President was created in 1939 and has added numerous special subdivisions as circumstances dictated. These include the National Security ouncil, the CIA, the Office of Management and Budget, the Council on Environmental Quality, the Office of Science and Technology Policy, even FEMA at one time. Congress has created for itself the General Accountability Office, the Congressional Budget Office and the Congressional Research Service. These latter three have earned a high reputation for integrity, non partisanship and insulation from political pressures to tweak facts to fit ideology.

This issue of staffing to deal with catastrophic risk is raised here to alert the reader to arguments arising from substantive issues that may suggest a review of staff capabilities to match the challenge of security in a more dangerous and complex world.

As detailed elsewhere, a small staff could follow methods of impact analysis developed over 25 years of experience with the National Environmental Policy Act and be available in a dire emergency to keep the President well informed. Experience of the Congressional Office of Technology Assessment could also be resuscitated..

H.4 Technology and Its Side Effects

H.4.1. Beyond Technique, Technology as Social Process

The term, "technology" has a rainbow of definitions and deserves clarification on usage here. Very simply, technology is considered a social process by which specialized knowledge from science and empirical experience is employed through engineering to deliver a system to meet specific human needs and wants. But not just through engineering. Other fields of knowledge such as economics, social and political science, psychology and even philosophy must be tapped and synthesized with technique.

This concept carries virtues and problems. One virtue is the distinction thus drawn between the notions of "engineering" and "technology." Confusion arises because institutions of higher learning have used both words as equivalents in their titles [MIT, CIT, GIT, RPI, etc.]

The problem triggered by technology's broader definition is the mixture of disciplines that are not familiar to engineering practitioners. I have joked with colleagues about engineers treating the world as though it were uninhabited except by Newton's laws and their kin. Students in Civil Engineering learn how to design bridges for specified traffic over a specified span, but are generally unable to answer questions of why build the bridge at all, and if so, why there?

In 1970, I clarified the definition with a mental model of a delivery system, a ”Technological Delivery System.” As shown in Figure H.1, the TDS meets a standard definition of a “system” in having inputs, outputs, organizational components and information linkages. The inputs comprise knowledge plus human, natural, and fiscal resources. The outputs are of two kinds, the desired goods or services plus unintended consequences, most of which are harmful to some people or to the natural environment, immediately or in the future.

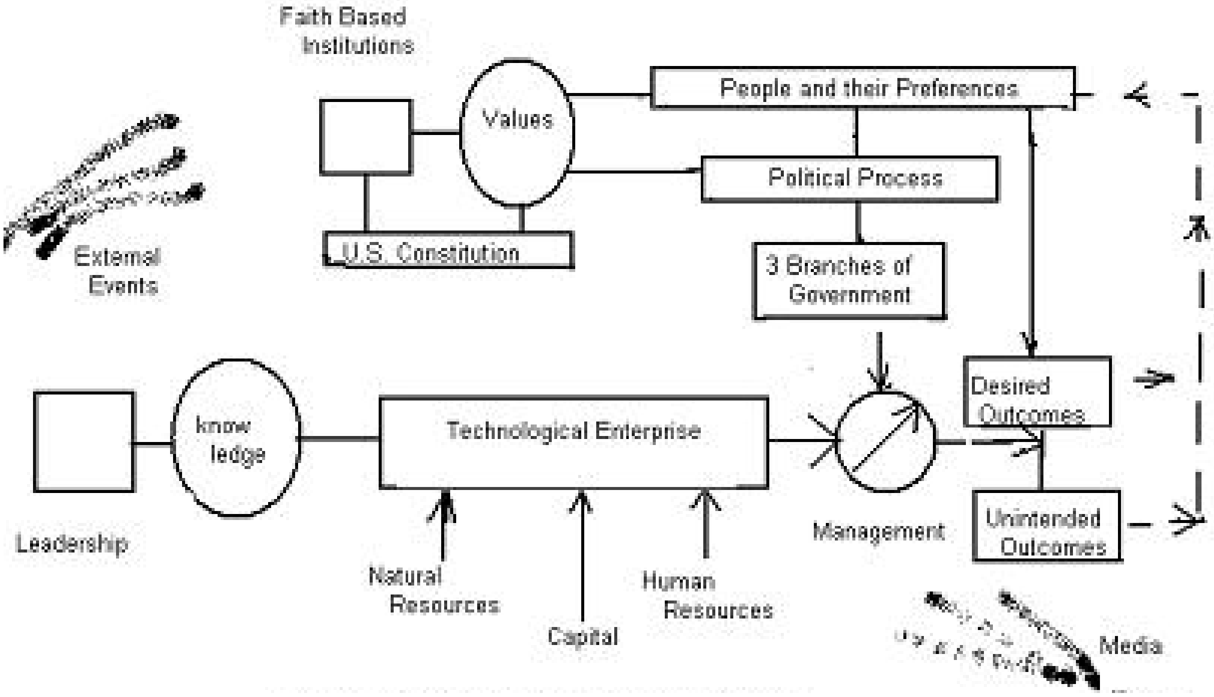


Figure H.1: Technology Delivery System

To tour the diagram, we start with technological enterprise, what the economist, John Kenneth Galbraith termed a “technostructure.” It is assembled by entrepreneurial leadership, motivated by the push of innovation or by the pull of external market demand. Under resourceful management, the enterprise feeds on capital, human resources, natural resources including energy and on knowledge. These are inputs.

The system then spins two kinds of output, the intended goods and services and the unintended and often unwelcome.. Such powerful processes fuse technical, economic, social, political and cultural factors.

There are two instruments of these influences, (1)the institutions of government reflecting structure and processes specified in the Constitution, and (2)faith based institutions following a wide range of value-oriented doctrines.

All of these functions and their vehicles are portrayed in the TDS diagram. Their communication linkages are portrayed by solid lines. There are, however, other powerful influences that cannot be encapsulated because their influences are spread throughout the system. These are impacts of external events and messages from the media.

Metaphorically speaking, the TDS is like a wiring diagram for a stereo set. The system not static, however, but is animated. The TDS equivalent to music coming through a stereo is the communication traffic leading to public policy..

The message content is shaped and steered by three operating instructions, the invisible hand of the free market place, public policy, and values embedded in the culture that ignite moral vision and mold conduct.

Validity of this analytical model was tested over two decades by graduate students who applied it to nearly 100 different technologies. The purpose over many years was to capture commonalities, that is, patterns of performance. They are condensed to 12 axioms, some mentioned previously:

- Technology empowers all life support systems---food production, transportation, communications, military security, shelter, urban infrastructure, health affairs, environmental management, energy production, banking, criminal justice, education, entertainment, even religious institutions.
- While manifest as hardware--planes, trains and automobiles--technology is best understood as just described, as a purposeful arrangement of public and private organizations synchronized by information networks.
- Most hardware is conceived, designed, produced, and marketed by private enterprise in a capitalist industrial economy under a mantra of “efficiency.”
- All technologies spawn surprise side effects, most unwanted by some sector now or in the future..
- All technologies pose risks from accidents triggered by human or organizational error with unprecedented scale and geographical distribution. .Accident prevention must thus be integrated with engineering design.
- Technology generates wealth and enhances living standards, but it also fosters materialism, concentrates rewards, and increases appetites for both..
- Major decisions about technology are not made by scientists, engineers or business executives. The most salient are in the design of public policies.

Technology thus tends to concentrate political power, just as power tends to concentrate technologies as corporate structures.

- We enjoy what technology does *for* us, ignoring what it can do *to* us. One counter trend is shifting from “Can we do it?” to “Ought we do it?” and “Can we afford it?”
- These cultural impacts appear as paradoxes: more communications but less sense of community, more information but less understanding, more machines for living but less leisure. Technology distorts perceptions of time and tends to focus on the short run at the expense of longer term costs and benefits. It also distorts perceptions of space because the entire planet is wired,
- Technology tends to weaken human relationships and to foster self-indulgence and isolation.

- In an age glorifying information, we neglect its transformation into knowledge and then into understanding. These steps require time for cogitation and for preparing the mind.
- Despite its material benefits, technology induces anxieties and stress because the pace of change seems to exceed natural human rhythms, and because of greater complexity, multiple information feedback loops, and uncertainties about the future.

H.4.2. Technology's Unintended Consequences

One of the three classes of risk deals with unintended consequences of technology. As with hurricane Katrina, there may be combinations of forces by nature, by human error and by technology's side effects. This drama entails machines whose function is valued for its benefits, but which spontaneously also birth serious disadvantages.. To define this phenomenon more emphatically, I argue that all technologies have unintended consequences, most but not all of which pose surprise costs on innocent victims, to the extreme of lethality. Even when catastrophes are foreseen, they may not be preventable because intervention is too impracticable, too costly or too unpopular.

Once I thought the technology of immunization was an exception because the number of lives saved far exceeds the tiny number of people injured by this prophylaxis. Then I was reminded that this benefit partly accounts for the planet's overpopulation and hunger. Even life-saving measures have malignant side effects. Incidentally, the technology of prevention is more than a needle or a spray; it includes all elements of a TDS, especially many layers of government..

Economists call these subsidiary features "externalities," a characterization of costs that implies a studied neglect in the calculus of economic performance by shifting the burden to other actors beyond the boundary of a particular organization...

Another euphemism reborn during the recent Iraqi wars is "collateral damage." Whatever the term, risk analysis carries a premise that every technology plays "Jekyll and Hyde." So we must learn to live with ubiquitous risk. Risk happens.

Consider these concrete examples. Nuclear weapons at the pinnacle of national defense left hazardous waste at the manufacturing plants, with long radioactive half lives. At the Hanford, Washington, weapons plant, leakage of single shell underground tanks is migrating toward the Columbia River to threaten drinking water down stream. Civilian nuclear power has dangerous byproducts that, 30 years after pledges of safe disposal at Yucca Flats, Nevada, continue to fuel debate.

Automobile transportation discussed earlier for its evolution of safety has had enormous consequences besides people killed or maimed. There are air pollution, noise, stress, lost time and wasted fuel from dense traffic, superhighways puncturing urban centers, disruption of rural life by housing developments, and an insatiable thirst for fuel that shapes geopolitics with oil producing states. The American system for health care entails costs of 16 percent of the nation's GDP, or in other terms, $1,500 per GM vehicle, almost ten percent of the sticker price..

As we struggle with these relentless gremlins of high-tech society, the public that ordains how safe is safe has become more sensitive to involuntary exposure to risk and seeks protection from the perpetrators through political action.. Citizens demand governmental action.

The management of risk is perhaps the greatest challenge of the modern world-- risks of terrorist nuclear bombs, risks of global warming, risks of corporate or national bankruptcy, indeed risks across the portfolio catered earlier. The dilemmas are intensified because society looks neither sideways nor ahead. At best, vision stretches to Monday morning.

That cost of being nearsighted is widely understood. The commercial world took precautions against losses of ships and cargo through insurance companies hundreds of years ago. When these costs mounted, reinsurance was invented to share risks. Now, we seek protection against the full repertoire of hazards, partly out of greater literacy about risk through the media, , partly because we have become a litigious society, partly because the insurance business can be quite profitable.

Government is a reluctant partner of the private sector in dealing with risk by a wide range of instruments. Farmers depend on price supports for their products in the face of crop uncertainties and on tariffs to blunt foreign competition. Flood insurance was offered when corporate America chose not to indemnify the vulnerable. The nuclear power industry was protected by a powerful cap on liability, and a swarm of federal and state measures have been proposed or enacted to cap liability with suits on medical malpractice.

For all parties in technological delivery systems, consciousness has risen on the imperative of foresight. Now a different question arises: If all technologies trigger side effects, why? Was this always true?

Consider the TDS of farming 150 years ago. The family farmer took title to some land, planted and reaped with steam propelled tractors, chewed fingernails when weather turned hostile with drought or freezing or a late, wet spring. At harvest time, farmers took produce directly to market and often sold directly to the local consumer without any middle men. The farmer took all the risks of crop failure. The TDS was a primitive combination of only three entities, the land owner, the farmer and the customer.

In 1878, the Hatch Act created the Department of Agriculture with the objective of producing more food of superior quality at lower cost. With federal assistance, science and technology began to replace tradition and folk lore. Government funded an education system of agriculture colleges and research laboratories, and extension services translate academic findings for field hands. Then with the 1930s depression, government sponsored numerous subventions to hedge against soil blowing away and creating a dust bowl and against other disabilities..

With these advances, the private sector found new and profitable enterprises, manufacturing farm machinery and trucks, distilling fuel and chemicals, contracting to build farm-to-market roads, harvesting seed, selling pumps for artificial irrigation. And the private sector lent farmers money to buy seed and fertilizer for the next season, and to expand acreage as machinery made larger plots amenable to management. In a perspective of the economy, the Ag-business blossomed as organizational size and heft offered efficiencies not available to the family farmer. Their demise as a side effect has become a topic for concern.

In recent decades, transportation by sea, land and air made possible the sale and consumption of food far from the producer, and at reasonable cost. That condition had a downside also in turning the entire planet into a single market place. Try to trace where the tuna fish were caught that you find locally in cans.

This story is dramatized by comparing the simple TDS of 1900 with that today. The increase in number of components in the TDS, information circuits, speed of transportation, sophistication and complexity of modern farming, the need to follow world prices, supply and demand, spread of blight and disease, the cost of money, and possible climate change adds to complexity and challenge. These influences also add to risk, especially as the system engages a highly decentralized cast of uncontrollable characters. Each element of a TDS introduces some market advantage but also some additional risk of uncertainty depending on which political force is strongest and has access to the policy apparatus.

In the calculus of risk, the most compelling requirement in a TDS is a viable information system. That technology is necessary but not sufficient. To produce desired outcomes, information must be transformed to knowledge, then to understanding, and finally to the exercise of foresight so as to minimize unintended consequences.. That motivation and capability to look ahead may be more important in managing risk than new scientific discoveries and technological techniques.

Parenthetically, humans have always been curious about the future, especially regarding the role of fate. The Hebrew Bible tells a story of rewards for forecasting years of famine and years of plenty. Astrological calendars to read portents from the planets and stars dates back 5,000 years and is still found in today's newspapers. Individuals who claimed to divine the future held honored posts in many societies. Some still inhabit stock brokerages. Games of GO, checkers and chess are won by plotting several moves ahead.

Looking ahead assumes greater significance in modern cultures that treasure speed. Progress in computer science hinges on speed of chips, modems and services.. Autos are rated by the shortest time to reach 60 miles per hour. Failing to look ahead more attentively has higher costs. A clean windshield and an unimpaired driver may be the metaphor for safety. In atmospheric fog, we slow down. In social fog, we complain.

That conditioning has its rewards and we need to seek this kind of analogy when dealing with other situations to probe ahead so that glittering benefits do not blind us to their dangers.

In that respect, society shifted gears in the 1960s regarding insults to the environment. The public acted through the political process to look ahead through environmental impact analysis at what might happen, if, and the tradeoffs for perceived long term benefits against costs, and for finding the optimum delivery system.

This concern for the future of our children was broadened by the concept of technology assessment in the Congressional Research Service in 1964 that systemized a doctrine of anticipation. It has nine steps:

- Define the technology delivery system in terms of purpose (ends) and content (means) of hardware and operating systems.
- Define the economic, political, ecological and social context, and the institutions comprising the TDS and their behaviors.
- Establish a base of facts, uncertainties and conditional consequences.
- Forecast what is foreseeable with awareness of how the hardware and software advance, how public attitudes change and how management learns.
- Imagine action alternatives to mitigate risk and trace impacts of side effects
- Identify impacted parties, including future generations

- For each option, compare positive and negative impacts
- Design a policy and implementation plan that has the best promise of reconciling achievement of goals with satisfactions of different stakeholders.
- Monitor and report post-implementation performance

The Congress deserves praise for adopting this legislative remedy to near sightwedness and tunnel vision. It is unfortunate that the Congress didn't peer ahead at what the longer term penalties could be for zeroing out the OTA

H.4.3. What You Can't Model You Can't Manage

This section's title is an aphorism that states, unless you can build a mental model to represent reality attempts to manage will fail. On the principle of linkage between cause and effect, it may be possible to examine an event and describe *what* happened, but not *why*. Measures to reduce risk may end in futility.

Toward using the TDS as that generic model to conduct analyses, managing risk entails mapping the interaction of people, politics and technology. Across a spectrum of multiple stakeholders with different cultures and conflicting purposes, the universal goal is to achieve socially satisfactory outcomes. The TDS architecture combines seventeen components diagrammed on page 26. That static map can be switched on by discerning system dynamics.

To explain, for each life support system, a TDS is assembled by entrepreneurial leadership in response to market demand or to the opportunity created by invention and innovation. Aware of requisite inputs of human, natural, capital and information resources to spin out the desired outcomes, management acts. In the investors' expectation of profit, the free market mechanism spins to do its thing.

Citizens also use the market mechanism to signal their displeasure with unintentional and undesirable outcomes. For over a century, however, experience has taught that market forces don't suffice. Government is obliged *post facto* to enter the arena with a pallet of regulations for reward and punishment. The TDS shows these dual avenues for people to express their preferences, one by purchases directly in a mall and one by public policies hosted by political process All three branches of government participate.

In our democracy, the political process serves as a steering system. Thus the earlier appellation of the President as the nation's system manager.

From analysis of decisions generated in the TDS case studies, we observe that both society and its political apparatus are strongly shaped by values of society as a whole and of key individuals in the decision chain. In a sense, the primary sources of values are the U.S. Constitution and indelible influences of early education in a variety of faith based institutions.

Two other conditions drive policy design, external circumstances and the media. . Consider this sequence of events: the Great Depression of the 1930s, the attack on Pearl Harbor, the Marshall Plan, the Soviet space shot in 1957, assassinations of President Kennedy, Robert Kennedy and Martin Luther King, the resignation of Richard M. Nixon, the multiple bombings by terrorists and the Iraqi war. All left scars on individual citizens and the national psyche.

As to the media, a revolution has occurred in techniques within information technology. Both the geographic span and the speed of communications grew rapidly in text and graphics, in both print and electronic media. Within the technology of electoral politics, in campaigning since the 1960 election, the purchase of TV time has become imperative. As Marshall McLuhan predicted, the medium has become the message

Yet another recent development is the concentration of media ownership. Objectivity became vulnerable to manipulation by lies and misuse of news as propaganda. On the positive side, however, the press continues as the “fourth branch “ of government. From the birth of the nation with the Declaration of Independence the backbone of power is said to lie with “we, the people.” That social process is exercised only if “those who govern do so at the consent of the governed.” That famous expression should be modified to say “informed consent of the governed,” informed by the media that can also double as advocates for citizen rights.

Beyond aiding political literacy of the electorate, the media facilitate all internal elements in the TDS having access to the same base of information. That faculty is crucial to synchronizing all elements of the TDS to achieve outcomes that have been negotiated by bargaining among stakeholders. Given society’s fractionation by geography, by wealth and income, by urban vs. rural, native vs. immigrant, white collar vs. blue, by religious faith and tradition, by aesthetic preferences, etc., without a free and talented press, there is no way the TDS could perform as intended

This reservoir of constantly changing information is now widely available, 24 hours every day. Stock prices change daily. However, public policies take longer to germinate, a trial of patience but also a salvation against impetuosity, secret deals and hysteria. Social norms change more slowly, usually no faster than in one generation. The sociologist Margaret Meade argued that, in her time, it took three.

Again, the media portray the instant situation, but with few exceptions, the client is expected to place current events in historical perspective, a process noted more for its absence than its presence.

The two TDS elements of external events and media content are in a constant state of turmoil. This is what animates the system of otherwise relatively fixed components.

In short, coping with risks from acts of Nature, of Human Nature and from unintended influences of technology requires understanding of the statics and the dynamics of the socio-technical process. With an operating model and assuming a consensus on goals and implementation processes, all of the stakeholders can separately contribute to the system design to deliver satisfactory life support systems.

Risk analysis starts with mapping the enterprises introduced either to further human progress or to shield it from harm.

H.4.4. Over-Design as a Safety Margin

Engineers learn from failures. By post-mortems, most are found due to inadequate knowledge of variables: the service loading, the service life, properties of materials, quality of materials, metal fatigue, quality control in fabrication, vulnerability to deterioration, operator error, poor maintenance, application of design theory beyond known limits, even human mischief. Beyond uncertainties with novel designs, we must acknowledge human and organizational error.

Several empirical techniques have been adopted to enhance safety. One is the principle of redundancy. Hospitals and high rise buildings typically have independent backup electrical systems if primary sources power fail.

The second mode of risk management in engineering is to practice over-design. The simplest examples can be found with buildings where structures intended to carry a certain floor , wind or earthquake loading are designed instead with some multiple like four as mandated by a local building code.

That multiplier is termed the "safety margin." Its size is arbitrary, a matter of judgment in order to exercise social responsibility by groups of professionals who act as surrogates for the public.

When I was with the U.S. Navy and responsible for strength design of submarine hulls, I learned that the safety margin for decades had been a low 1.7, with no structural weaknesses The submarines *Thresher* and *Scorpion* have been lost subsequently but not believed from hull collapse. This margin was in the same range as that for aircraft and for the same reason, to minimize weight of the hull. Otherwise, in a delicate balance with buoyancy, equipment to meet specified ship performance of speed, endurance, armament, etc. might have to be limited and thus penalize war fighting capability. The design solution, however, generates a paradox. Operating submerged is highly dangerous because of vulnerability to enemy action and the tendency of structural failure to be instantaneous, catastrophic, and without early warning. To reduce that risk to crew, the margins should be high. That desideratum has a cost, however. Inordinate safety is at the sacrifice of function.

I also recognized that the prospect of nuclear propulsion required a step increase in hull diameter. That raised doubts as to whether past structural design methods were valid with the larger boats.. A further growth in diameter was anticipated as subs became missile launching platforms. Past design methods thus warranted reevaluation by both theoretical and experimental techniques. Research involved complex mathematical analysis of ring stiffened cylinders, and the theoretical strength compared with structural response of models in a pressure chamber to simulate hydrostatic loading when submerged. The research was extended beyond contemporary requirements. Traditional design methods were found inadequate and thus were upgraded.

The low safety margin was also reviewed and was deemed valid because of these considerations: high confidence in quality control during fabrication: in materials being carefully screened to meet specifications; in the X-rays of all welds; in careful control of tolerances for out-of-roundness; and in inspections for deterioration after extended service at sea. There was also high confidence in responsible operators, especially confidence that they would not dive below the approved maximum depth for each class..

With these precautions, there was a history of submarine structures never failing from design errors. The 1.7 margin was continued. Subsequently I raised questions on validity of my analysis because nuclear propulsion promised higher speed and unprecedented frequency of dives. With the sea pressure then fluctuating more often, hull components were subject to metal fatigue, especially those experiencing unprecedented tension rather than compression. Precautions to limit risk were adopted, in effect increasing the safety margin.

A somewhat different issue arose in the design of nuclear boilers, here subject to constant internal rather than fluctuating external pressure. The universally adopted boiler code of the American Society of Mechanical Engineers called for a design with a margin of 5 over the operating pressure. The thick shell selected to enhance safety could, paradoxically, have an opposite effect. Radiation from nuclear fuel tends to weaken steel with extended exposure. Thicker would not necessarily be stronger. The safety margin for nuclear service was first reduced to 4, then to 3, expecting special care in fabrication and operation as with.

There are other ways to over-design. In civil engineering, dams must sustain hydrostatic pressure on the upstream face corresponding to the height of water impounded. With severe storms, stream runoff could increase the water level above that of the spillway and raise hydrostatic pressure substantially. Strength design of dams thus requires an assumption as to the height of water above the spillway, and this is selected on the basis of stream flow statistics measured over an arbitrary period of time. The longer the interval selected for severe storms, the greater the height of runoff and thus the greater the pressure used in the design calculations. The pressure assumed with the “perfect storm” is further increased by a safety margin to accommodate all of the uncertainties mentioned earlier for metal structures.

Of passing interest may be historical learning from failure. Early Gothic cathedrals with the airy flying buttresses fell down after a few years and led to pragmatic studies of cause. Mostly, it was due to uneven settlement of the foundation soil under the weight of the rock walls. Cracks in masonry followed, then total collapse. The solution was not to make the structure stronger and degrade its aesthetic appeal but to pile building materials on the site for gravity to compact the soil before construction began..

There is a further example of learning in the emerging age of science. In the 1820’s when steam propulsion began to replace sails, boiler explosions on Mississippi River vessels began to take a large toll of human life. Skippers would race each other. The reckless and ruthless ones, bribed by gamblers to try and win, extracted additional propulsion by disabling safety valves. Explosions followed killing scores. Outraged by these losses, citizens demanded that government intervene.

The first research on boiler strength was sponsored in 1830 by the federal government at Franklin Institute, Philadelphia. No doubt, the investigation extended the engineering of boilers to employ safety margins sufficient to accommodate material deficiencies and also consequences of human blunder and folly.

That risky practice of pushing the performance envelope continues to this day, often in tradeoffs of safety for cost. Consider this personal experience of a tradeoff for hubris. Immediately after a sub completed its deep submergence trial, I watched in astonishment as the skipper took over command and ordered a crash dive at about 30 degrees. Here was the background. Two identical vessels had been built in different shipyards and both were instrumented for their deep dives so as to compare dive-induced stresses as indicators of comparative construction quality. The skipper had my permission for the second, crash dive, except on this one he deliberately skidded below the certified maximum depth. Why? So he could boast at diving the deepest of all subs in the fleet.

Skippers of Mississippi River boats and hot combat pilots and submarine skippers have juvenile counterparts on the nation’s highways. Managing these risks goes beyond the control of any engineering designer. Additional precautions are demanded by challenges beyond the laws of nature, the laws of human nature. These concern the ethics of safety.

In a high tech world the complexity of technological delivery systems denies to those exposed to risk the opportunity to participate in decisions as to what levels are acceptable. Initial decisions are made by engineers at the design stage, where practice is guided by law, by licensing and by professional codes of practice.

Such protocols have been published, for example, by the National Society of Professional Engineers and the American Society of Mechanical Engineer. Consider these interpretations:

- Hold paramount the safety, health and welfare of the public.
- Uphold the law, beginning with the Constitution.
- Be honest; serve the public, customers, clientele and staff with fidelity.
- Be vigilant of malfeasance and corruption; do not punish dissent and legitimate whistle-blowing.
- Recall that all technologies have unintended consequences, many harmful, so make a practice of looking ahead to anticipate and prevent loss in human life, health, property, intended function or the natural environment.
- In daily operations, demonstrate from the highest levels of internal management respect for truth, openness and equity in benefits when making tradeoffs.
- Counter one-way communication and loss of personal relationships by the growing reliance on electronic apparatus.

Sadly, these principles sound like a farce when one tracks the trends from media reports of indictments and jail of corporate executives convicted of felonies. Elected members of Congress are not totally immune to charges of corruption, of lying, and of fraud. Decisions on involuntary risk must earn trust of all exposed.

H.5 Bed Rock Values in Public Policy

H.5.1. The Rainbow of Stakeholders

Some readers may be discombobulated by a discourse on values in a treatise about risk. At the least, it may seem inappropriate. In defense, I draw on experience in the policy milieu, with both the Congress and the White House. As a science and technology advisor, I endeavored to collect and analyze facts and report their role in the design of policy.. My clients, however, based their decisions on more than the facts. Directly or unselfconsciously, they listened to values of their constituents and their own.

Consider these two loaded questions---“what role, if any, should philosophy of life play in risk assessment?” and “Whose values dictate choice?” These values may be as stark as that of human life, or as subtle as truth, the whole truth. I would argue that the dominant issues of our times are harshly ethical and beyond guidance by science, market place economics, by public law or their combination. Unintended consequences of technologically rich activities threaten innocent victims with repercussions more intense, more far reaching, more swiftly injected and potentially irreversible than in the past. Hard edged and hard wired innovations seduce us with clear benefits, but their side effects often stretch the risk horizon beyond accessible technological fixes.

The disaster in New Orleans spawned by hurricane Katrina is a case in point. The technology of levee protection is reported to have failed because in design a safety margin of 1.3

did not accommodate the uncertain integrity of underlying layers of soil. The resulting flood wiped out people and property.

So with dangers that result from choice and not chance, we seek protection by doctrines of anticipation, of foresight to deal with the reality of uncertainty. The point is that these choices are not just choices of technique. They are tough moral choices that require moral vision. How many lives must be lost at a dangerous intersection before costly traffic signals are installed? How do we decide?

Basic principles lie in lessons from history, from philosophy, from Shakespeare and from spiritual values of sacred texts. People must decide how safe is safe, and establish social norms on degrees of tolerance for risk, This process is especially vital if lives, liberty or the pursuit of happiness are threatened and if risks have human origins, escalate because of human failings with extreme consequences.

Two scales of consequences need review, those which occur immediately and those which may hibernate and explode decades later as a bitter legacy for our children. Leakage of radioactive waste stored since the 1940s at the nuclear weapons factory at Hanford, Washington is a poster child of negligence. Indeed, how actions or inactions threaten our children can be a yardstick of successful risk management.

Introducing this longer term perspective exposes limits in the process of risk management. At policy levels, acceptable risk is usually negotiated by opposing parties. Often, both argue from their estimates of short term self interest. Surrogates for children are not present at the bargaining table except when society mandates the government to play that surrogate role and not simply be an umpire.

Dimensions of the future shine in the National Environmental Policy Act of 1970 and the Technology Assessment Act creating the OTA in 1972. A blanket policy with global reach was drafted in 1980 as a Bill of Rights for Future Generations by Jacques Yves Cousteau and has been considered by the United Nations. Beyond an abstraction, this concept would require impact assessments beyond cost/benefit analyses, to test risk-centered choice by imperatives of social responsibility. This ingredient of public policy was punched into public awareness with a paradigm shift in the 1970s. In what was a vigorous technology-driven culture, the question, “Can we do it?” was balanced with “Ought we?”

Questions of moral vision pivot on the exercise of foresight. This does not mean claiming to predict the future as does astrology. As a vehicle of early warning, it means asking, “What, if?” This powerful tool exposes a surprise.

Whoever controls technology controls the future. That axiom has a twin. Whoever controls technology in effect raises our children. Perhaps that is already happening. The media, electronic games and cell phones, popular musicians, advertisers and their agencies may have more influence on our children than do parents or religious faith.

If this situation accurately maps reality, and society really does care about its progeny, then risk management must balance the short and long term interests by more than commercial values. Without abandoning rights of private property and canons of capitalism, decisions must be tested by norms of social and economic justice.

While American society may commit to high ethical standards, an objective survey of print media of record reveals the frequency of breaches not only of ethics but also of law. Powerful members of Congress have been indicted and sentenced for a wide range of transgressions. So have corporate officers as with the Savings and Loan scandals of the 1980s and extending to trials of Enron executives in 2006.

Part of the problem is bare faced corruption. But another part of the problem lies in our heterogeneous population. We don't have one public but many different publics, and when polled on their preference as to acceptable levels of risk they show major variations. These may be differentiated by wealth, by proximity to the source of danger, by social, religious, and political ideology, by urban vs. rural, by regional cultures, parental counseling and by ethnic origins, The point is that reconciling diversity in risk tolerance challenges the mustering of consensus.

On that issue, we in a democracy have rich experience from practicing the thesis that those who govern do so by the consent of the governed. Implied is "informed " consent. Then the question rises as to who does the informing; is the source objective and do citizens have minds prepared to interpret information they receive, for example to understand the critical tradeoffs of safety for cost.

Polls on citizen perceptions of comparative risks are not encouraging. One overarching conclusion to the medley of issues raised is the intense complexity of our technological delivery systems.

The reader might now be convinced that the design of technological systems must meet the social needs and safety preferences of a broad spectrum of stakeholders. That achievement is a political act. Once again, we must look to the nation's systems manager, the President, to muster credibility, coherence and consensus.

H.5.2. Conflict Management to Balance Benefits and Costs

Three premises condition this analysis. All the support systems of our society have a core of technology that we depend on, first, to the degree that we are totally dependent on it as the Zeitgeist of modern life. Second, technology blends technical systems with social systems. Third, benefits and costs may not be balanced. We applaud mounting living standards but overlook technology's cultural impacts greater than those of religion, philosophy, ethnic traditions, social mores and a growing body of law..

Technology sows complexity not just in hardware but also in delivery systems. In less than two centuries what began as small, orderly and predictable systems and at a human scale have become large, remote and incomprehensible, sometimes hazardous and even catastrophic. In that vulnerability, social performance demands virtuoso intelligence (both kinds) and striking leadership. Modern communications facilitate achievement but a convenient capability can overload human resources by more transmissions, more invisible actors, and more actions, reactions and overreactions.

Decision making at all levels suffers from ambiguity of facts, commercial pressures from muscular lobbies, a noisy public forum for serial conflicts and personal idiosyncrasies. Add duplicity, lying, fraud and other crimes to recognize that the key issues are ethical and both business and government suffer from gross violations of trust. Moreover, familiar relationships of cause and effect yield to confusion and incoherence. As said before, we cheer what technology does *for* us while neglecting what it does *to* us. The challenge to the engineer *cum* problem solver is reconciling direct benefits against hidden surprises of unwanted impacts.

Achieving a compromise between benefits and penalties entails reconciling goals, values and organizational cultures as between business and government, and within both sectors.

In essence, risk management requires a social strategy of foresight that does not come naturally either to individuals or to society. Parsing the concept, foresight entails strategic vision, pre-crisis planning, contingency resources, fixing what is broken and entrepreneurship to explore new opportunities. Finally, there must be political will to do the people's business and not solely that of vested interests and political supporters. And there must be respect for high integrity.

Neither market economics nor public law suffices to frame protection for future generations. Both societal steering and propulsion depend on the human psyche, on courage, integrity, resilience, ingenuity, free will, self-sacrifice and hope for a better future for all people. These constitute humanity's survival kit in a technological world.

In short, user-friendly technology with its harmful gremlins must be visualized as a social rather than technical enterprise. It acts like an amplifier. With lever and wheel, and the bomb, it amplifies human muscle. With the computer, it amplifies the human mind, its memory and speed of calculation. Technology is also a social amplifier. With modern banking, communications and transportation, catastrophes anywhere have effects everywhere. Two minutes after President Reagan was shot in 1981, the gold market in Zurich began to twitch. In 2005, the Katrina hurricane induced a similar shock to the price of crude oil.

This reality of an interconnected world—what columnist, Thomas Friedman, deems a flattening of a world with metaphoric mountain ranges stems from the gift of electronic communications, what we identify as information technology, IT. Telegraph wires morphed to telephony, vacuum tubes in radios and television to silicon chips. Add satellites and fiber optics. With such innovations, it became feasible to assemble highly complex TDSs to meet more strenuous demands.

In short, information constitutes the TDS's nervous system. As visualized in the earlier diagram, information channels are crucial to synchronize all of the 17 normal components of every TDS. The information age displays a ballooning of traffic over greater distances and moving faster. Security is enhanced by early warnings of tsunamis, hurricanes or degraded by mischief by spam artists and terrorists.

There are, however, unintended side effects. Every morning on bringing up Windows, many people suffer an information explosion, or perhaps implosion. Beyond junk and spam, the volume suffocates priority messages. The firehose of bytes lacks any warranty as to truth. Paradoxically, wider access to information is not necessarily accompanied by deeper understanding. Technologies introduced to reduce risk can inadvertently increase them.

For example, information overload induces stress, especially when making decisions. Outcomes may be uncertain and errors threaten punishment. We have the luxury of more choices but less time to choose. In a frantic search for truth, facts may be elusive or laden with the mists of probability. The social context and preferences shift unpredictably. When the technological delivery system engages competing players, each with a self-interested economic or political agenda, no actor has the comfort of ever being in control.

That shock is dramatized when adding to the TDS diagram a suit of feedback loops that exist in the social process. My own research efforts to accommodate that reality and explore repercussions totally failed.

Suffice it so say that the culture of modern society is the 800 pound gorilla in the room; our culture has not spawned a guidance system to harmonize with technology propelled change. Since it is unproductive to speculate on where the culture may be going, we must focus instead on how to cope with the role of culture in designing technologies with concern for costs as well as benefits but measured by parameters well beyond the narrow incentive of economic self-interest.

Confusion engendered by complexity and interdependence makes all the more relevant the earlier aphorism on modeling.

H.5.3. Tensions Between Industry and Government

Two major components of technological delivery systems, industry and government, have a paradoxical relationship. Neither can get along without the other, yet their relationship is marked by enduring tension. Government depends on a vigorous, healthy industry to drive the economy, from which to create jobs and extract a tax base. Industry thus depends on government to create a favorable economic climate, including direct financial assistance. That congenial partnership, however, is accompanied by an adversarial stance with government's obligation to serve as regulator. Industry, in its boisterous role as innovator and entrepreneur, acts in its profit-driven self interest which often collides with social interest. Corporations are expected to turn a profit, but in this era equal emphasis is placed by Wall Street on the creation of wealth. The so-called free market fails by various distortions and excesses that violate norms of economic justice or have severely harmful consequences. With government mandated to protect citizens from harm--physical, economic and psychological--we observe a muscular wrestling match.

Merging corporate and public purposes to nourish a vigorous economy is strained when industry fails to get its way. Government is accused of blocking "free enterprise." Industry then adopts defensive measure to weaken or block the legislative process or administration of laws already passed. It has been so since the nation's birth.

Tired of pressures to ease constraints, Congress invented special regulatory bodies to act on its behalf and set the rules and penalties for violations. Thus were created agencies to regulate the economic life of railroads, buses and trucks, merchant shipping and airlines, and later regulation for passenger safety. Soon other independent agencies were founded to deal with safety of food, drugs, water and air, of the mining industry, of the workplace, and with preservation of the environment. Private enterprise countered by seeking to corrupt regulatory bodies by urging appointments of individuals known to be favorably disposed to their interests, thus undermining the regulatory process from within. Headlines single out the FCC, FDA, EPA, NRA, FTC and others.

In recent years, industry has adopted two other tactics. In this television age, the influence of that medium on public opinion is essential to political campaigning. Candidates for election and reelection raise funds to purchase broadcast time. Industry found a potent avenue to grease access to policy makers.

A second tactic is for lobbyists to be present at what used to be off limits to outsiders, closed sessions when members of Congress negotiate final wording in a bill or final agreement on budgets. Midnight conferences are opportunities to insert clever loopholes or pork barrel bridges to nowhere to benefit a community and facilitate reelection. Today, there are 34,000 registered lobbyists in the nation's capital, roughly sixty-five for each member of Congress.

This phenomenon caught the public's ear for the first time with President Eisenhower's complaint in his farewell address about the self serving greed of the military industrial complex. That was almost a half century ago. The iron triangles of industry, a government agency and senior members of Congress on appropriations committees are today even more powerful. Perpetuation of what President Dwight Eisenhower called the war machine, the "military industrial complex," regained public attention in the 2006 movie, "Why We Fight."

The central problem is clear. Industry cannot regulate itself. Self interest always trumps public interest. In the context of risk management, this history is important because the avalanche of new technologies has opened more risks from side effects. When industry fails in exercising social responsibility, conscientious government is obliged to intervene.

That condition complicates the management of risk. A contest erupts between the sources of risk and those who are the victims. Thus is exposed a cultural contradiction of capitalism in that it works best under an umbrella of social norms.

Contrary to popular belief that government is too zealous a regulator, the reality is that it has been diffident. Very rarely does it act in anticipation of harm; almost always government reacts when the severity of impacts has aroused public opinion to a boiling point that political leaders cannot ignore. Even then, industry fumes at fiscal and social accountability and seeks new avenues to get its way, fair or foul. Take the case of Boeing aircraft now challenged by government charges ranging from theft of a competitor's papers to complicity in hiring a former government contract officer.

In many respects, the tension between government and industry is a sign of health of both. Too much friction can distract both parties from their optimum performance. On the other hand, too little tension could lead to or be a signature of a corporate state.

In the context of risk management, such an evolution of governance would trigger two problems. Business and government have vastly different values. Commerce measures success by short-run profit, growth in size and market share, and respect by Wall Street brokers. Its legal concerns center on protection of property rights and against accountability. Its culture is strongly task oriented and its management style that of an independent CEO with a tame board of directors. Government, on the other hand, is concerned with freedom and human rights, social and economic justice, including concern for future generations. The structure of government mandates principles of building consensus and of accountability.

The second problem arises from a tendency of technology to concentrate wealth and power. In just the recent decade, acquisitions to morph into mega-corporations have been conspicuous in military-space technology, in petroleum operations, in both print and electronic media, in air transportation, and other areas with questionable benefits to all but shareholders. Violations of corporate ethics have earned serial headlines.

Government is not immune to sleazy and even illegal activities. Members of Congress from both major parties have been indicted and jailed. Others have resigned. A major fuss has been raised because White House officials are alleged to have leaked the identity of a CIA agent in a crude attempt to intimidate the role of the agent's spouse in contradicting President Bush's assertion that Saddam Hussein sought nuclear weapons.

While this unhealthy situation may seem foreign to risk management, the effective functioning of democracy and of technological delivery systems depends not only on the discipline of law but on mutual trust. Citizens cannot be expected to master all of the facts and analysis dealing with complex technical issues. In the main, citizens must depend on government to provide protection against the ultra-violet rays of the sun, from the exaggerated claims of pharmaceuticals, from terrorists bent on torching a calamity or from their holding a nation hostage with threats to detonate a nuclear device.

It is in this situation that we observe a confluence of science and engineering with disciplines of public administration, business administration, economics, psychology, sociology, history, communications, law and even theology.

H.6 The Ethics of Informed Consent

H.6.1. The Role of Media in Exposing Risks

On the earlier sketch of a standard TDS, the media were shown as a blurred image. That representation is intended to reflect the ubiquity of media as a source of vital information to all TDS constituents. For those potentially exposed to risk, this capacity serves either as early warning for slowly evolving events or as instruction from another's harmful experience on how to offer informed consent when it is invited.

This critical role carries a burden of social responsibility for the media... Information should obviously be accurate, based on authoritative sources, even handed, timely and accessible to non-technical stakeholders. The year 2005 is overloaded with natural disasters that could not be prevented, where vulnerability was not heeded, and where media played a crucial role. With the tsunami in Indonesia and the earthquake in Pakistan, the number of deaths and injuries and extent of property losses exemplify inept emergency preparedness. The situation along the Gulf coast with hurricane Katrina reveals in post-mortems similar painful deficiencies, but there is also evidence of miscalculation by government stewards who had a mandate to protect lives and property under recurring circumstances.

Earlier we noted that government's style is more one of reacting to a threat in some proportion to public demands for protection. Silence gives consent. The authority responsible for designing and building levees to contain the New Orleans' flood waters, the Army Corps of Engineers, balanced their estimates of safety versus cost. Because of limitations on appropriations by the Congress in the final moments of bargaining over pork barrel allotments to competing claimants, they took precautions for a hurricane of intensity 3 rather than 4 or 5. Still to be determined is the fine detail of negotiations in Appropriation Committees of both Houses, as to whether information was available on the relationship of costs to the degree of flood protection.

Consultation with the public through levee boards was apparently not effective in the power structure. In that chain of political activity, citizens and local officials seemed unaware of the tradeoffs that put the city's safety at risk.

It can be argued that those at risk should have a say in decisions vital to their safety. Because of secrecy surrounding funding decisions, the consequences are unlikely to be known in advance except by zealous probing of reporters. Even that expectation may not be met where news organizations or reporters have cozy relationships with decision authorities in both government and commerce. Both parties thrive on leaks.

There are other challenges to investigative journalism. Probing too aggressively may violate cannons of national security or personal privacy. The pace of information may exceed the human capacity for information processing. Objectivity may be subverted by news organs with self interest threatened. Mega-corporations that own the broadcast networks also own subsidiaries that may be the subject of unwanted publicity over their failures to protect citizens adequately.

That dilemma of self- versus public interest also applies with individual stakeholders. Copper smelters in the Puget Sound area emitted smokestack fumes of arsenic and lead that poisoned nearby soils in which children played. The plant's owner asked affected citizens to choose between continued emissions versus correction so costly as to jeopardize the plant and sacrifice jobs. Jobs won the contest until the plant was shut down by bankruptcy. By themselves, accurate information and positing options did not alone lead to a socially responsible outcome.

Often, stakeholders face information overload that includes unreliable sources. Moreover, transmission speeds overtake a natural cadences in human affairs, Add frustration when an inquiry is funneled through a chain of telephone button pushing, perhaps to lead to an ominous and anonymous, "The computer is down." When a voice is reached, its artificiality drains away any sense of communication with another resident of the planet. Some prefer to be safely uninvolved even at the expense of losing control to an invisible authority structure. Squeezed out by information technology (IT) is a dialectic process wherein after each conversation, live participants may change.

A similar effect occurs with emotionally loaded information as, for example, live TV reporting of battles in Iraq or of destruction of New Orleans. Pictures have greater punch than prose. Intense images brand our minds, injecting content without context. Revised patterns of belief structures alter our perception of reality, even our sense of time. The medium has become the message.

Even the content suffers mutation because of techniques exploiting volume and speed of transmission. Side effects are shorter attention spans and subversion of purpose from education to persuasion, to market a brand of politics or of faith like a soap product.

If the premise is adopted that safety is a social judgment, society must have both timely information and objective analysis to convert that bundle to a state of knowledge. The treasured jewel of understanding emerges amidst a further stage of discourse and debate and mulling where individuals hear many sides of an argument, consult their memory and critical thinking, then make up their mind and join with others of like mind.

That stage occurs last when public preferences reach decision authority, a member of Congress for example. Voices of we, the people, may best be heard if an individual finds and helps fund a public interest organization to serve as collective advocate. On the TDS, that process can be visualized as a lump in the box of citizen preferences.

As footnotes, we have to understand that information flowing in a TDS is both substantive *in* the process, and administrative *about* the process. That is, participants need a mental model of the particular case to learn the cast of actors on the political stage, their culture, interests they guard, avenues of access, and the timetable of action.

Whatever the dynamics of a particular issue, seldom does it gain attention in isolation. Environmental policy interacts with fiscal policy. Farm policy is affected by foreign policy, and U.S. policies have to be weighed in the context of free trade, globalization and outsourcing, and now the uncertainties of terrorism.

There are further complications. Incoming information must pierce a garment of emotion. What I may say is not necessarily what you hear. As a metaphor, assume that every one wears a helmet. This is a screen of past learning, biases, attitudes about change, conflict, and especially experiences that leave scars. In penetrating the helmet, the new information is distorted, attenuated, or filtered out completely. This is especially dangerous in political leaders.

Most pathologies of information processing have counterparts in the media itself, the merchant communicators of common information. Given that the media is an intelligence function serving business, citizens and government officials equally they are often considered a fourth branch of government. The integrity of the press is thus at least as critical as that of public institutions. Confidence in that process can be shaken with revelations of media on corporate or government payrolls. One wonders what Orwell had in mind as the precursor to the central control of information in his metaphoric "1984.".

Now the media encounter new stresses of deadlines with 24/7 reporting, of penalties they pay if found in error or, worse, treating handouts as news. They are trapped by an appetite for leaks while facing the risk of spilling classified beans.

Business depends on the media regarding equity markets, indicators of future profits or losses, shifts in tax and fiscal policies, investor confidence, threats to oil supplies, and stability of foreign governments. What happens in Washington must be followed carefully

Even elected leaders sift the news, polls, editorial feedback on political performance. President Bush seems to be an exception, proud to receive news only through trusted staff messengers.. Scholars who follow world and domestic affairs feast on media reports, perhaps alone in subjecting them to close scrutiny for accuracy, objectivity and balance. Several privately financed foundations engage in the same watchdog function.

Of all the organs of a TDS, the press has the most seminal responsibility for facts and their understanding so as to what is at stake and in time to practice democracy. In a complex, confusing and noisy world, that's a high expectation.

As newspaper advertising shrinks, more daily papers feel threatened and seek defensive measures to stay alive. TV as increasingly the media of choice forces producers and anchors to mix in entertainment at the expense of analysis in depth. Text is dumbed down, and the flash card style of ads causes viewers to be numbed down.

Most telling about the media is its strategic influence in every TDS. It is the prime source of facts and their future implications; they play a legitimate role as a Greek Chorus of early warning about a rainbow of threats and loss of a shared vision; through editorials, they can serve as advocates for victims, as did the New Orleans *Times Picayune*,. Sometimes that zealousness is overdone. Coverage of Clinton's sexual encounter with an intern played to a prurient interest in body fluids and DNA confirmation. In a feeding frenzy led by Republicans in Congress, the media were willing partners in this American tragedy.

McLuhan had it right four decades ago. The medium not only morphs the message; it morphs the messenger. The lesson to be learned again and again is that democracy depends on truth. In his fictional 1948 account, Orwell projected a nation's slide toward being a corporate state. It happened when partners in business and government gained control of the media. Perhaps his scenario was a metaphor, accurate except with regard to timing.

In this author's view, there is no more critical role for media than reporting the facts on national security, the validity of perceived threat and response, the compromise of truth in the interest of political victory, and the tradeoffs of national treasure and honor negotiated out of sight.

H.6.2. The Power of Informed Consent

First, reader, take time for a deep breath.. Some who have progressed this far may feel frustrated in not finding a handbook on risk management. The author promised none but apologizes if he inadvertently raised such expectations. This exploration focuses on the context, not on *what* to think about but *how* to think about "how safe is safe."

That question triggers as many as 20 issues that characterize operations of a standard technological delivery system. With each having 17 major components, I focus here on information networks that connect organizations and function as their nervous system to detect the external world and to synchronize the internal parts.

One role is to assure that the tacit consent of those at risk is an informed consent. People cannot feel safe if they are left in the dark. From very early childhood, humans want to know, and it is the obligation both of sources of risk and the security conscious government (which can also double as a source of risk) to assure that satisfaction.

That process, however, has several impediments. As explained before, history teaches that all technologies have side effect, many harmful. And it teaches that the vendors of technology are not always forthcoming about the unwanted and possibly lethal consequences. To counter that secrecy, for example, the FDA requires pharmaceutical houses to embroider their advertising with cautions about abstaining with some existing health conditions, and about physiological effects of hyper sensitivity. Parenthetically, these catalogues of possible risks are silent on the frequency with which products pose particular threats. If very rare, the risks are ignored. There are no warnings on peanut butter because those who are ultra sensitive are assumed to have had close shaves and practice risk avoidance.

This example illustrates how potential victims need to face risk with a prepared mind. Otherwise, they might not understand a label that warns that, even though a food product contains no peanuts, it was processed in a plant that also handled peanut confections. This act of social responsibility by the vendor reflects on the ubiquity of threats and also the heightened awareness in our culture that risks of human origin could and should be minimized.

That scenario is played out in news headlines almost daily. Consider the wrangle over proposed wind farms in Nantucket Sound off Cape Cod. Assessment of environmental impact mandates that all side effects be publicized and evaluated by the public and by a government agency. These side effects constitute hazards to navigation where traffic is dense, disruption of fisheries, and visual pollution of waterfront property. These costs are weighed against benefits of generating non-polluting energy, even if more costly. Public commentary at hearings will be considered before a policy is set.

One problem is that individual stakeholders do not often attend these sessions. Some who do attend often fail to do their homework to explain concerns and also fail to consider tradeoffs that require compromise. Others, however, may be effectively represented by public interest organizations that buttress their arguments with facts and importance of transforming information to knowledge and then to understanding.

Converting information to knowledge requires assessing the credibility of source, the consistency with other sources, an explanation of contradictions, and finally an enrichment of initial basic information with vital context. A final stage of understanding occurs when knowledge is squeezed to identify implications for the issue at hand. Content is merged with context. For example, recognizing that a particular technology can be harmful is elaborated by identifying the full rainbow of parties at risk, including the virtual stakeholders, the future generations.

In a next step, all elements of risk analysis are mustered, especially the distillation from history of past failures, of the frequency of the threat (probability) and the scale of consequences if not prevented or damage controlled.. That history is especially important to rank interventions by degrees of their success and the tradeoffs entailed, especially of benefits versus cost. A further challenge arises in converting all benefits and all costs to a common currency because both have intangible as well as tangible elements. Both have a combination of immediate versus long term effects.

Illumination of context requires description of the political process by which the threat and response is mediated. The TDS can serve as a generic model to identify organizational participants, from perpetrators of risk to its amelioration.

All the desired information may not be readily available. In the political theater, complexities of the facts and the confetti of ethics leads participants to put a premium on confidence in the authority and objectivity of the information source.

Consider these realities. First, in the frenetic atmosphere of policy making, those responsible for decisions rely more on verbal rather than written material, especially if it is boiled down. Who talks to whom is highly significant. Lobbyists know that members of Congress cogitate over an upcoming vote as they walk from their office building to the Capitol. On that trek, advocates would like to be the escort and have the last word.

These intricacies are of great importance. Recall the two-year, continuing investigation by a special counsel of who leaked the name of a female CIA operative to intimidate her spouse who was charging administration malfeasance. In political maneuvering, most information is tainted by self interest of the source. This is rare but not unknown in the technical community as well. Congress has access to such credible facts and analysis in the Government Accountability Office, the Congressional Budget Office and the Congressional Research Service.

In his Executive Office, the president also has access to presumably objective information, but such support may be distorted by incompetent appointees.

In short, the paramount role of information in risk assessment is to help those exposed to risk understand their predicament and have an opportunity to express their consent or dissent. That critical comprehension demands a preparation of mind so as to distill information effectively to knowledge and then to understanding.

I was involved with risks of oil spills by tankers from a 1971 filing of omissions in the Environmental Impact Statement regarding the marine extension of the pipeline to the 1989 investigation of the *Exxon Valdez* disaster. In 2006, there are still repercussions from boisterous complaints of fishermen and indigenous peoples whose livelihood was hurt. They won a legislative provision for government supported citizen watchdogs to reduce future risks. That safety measure is relevant to the study of Katrina.

H.7 Lessons From The Past

H.7.1. The *Exxon Valdez as* a Metaphor for System Failure

The 2005 hurricane Katrina and its melancholy aftermath of death and economic havoc have been reported in American media in great detail, sufficient to illuminate the imperative of foresight and damage control measures to prevent a nightmare recurrence. Similar data were generated by a massive tsunami in Indonesia and Sri Lanka and an earthquake in Pakistan. All three were extremes of rare natural phenomena that could not have been prevented but deserved better emergency preparedness. History records similar disasters caused by human or organizational error.(HOE) that could have been prevented and the adversity minimized. In what follows, the oil spill of the tanker *Exxon Valdez* in Prince William Sound, Alaska, is summarized as a metaphor for system failure, of an accident waiting to happen.

On March 24, 1989, the tanker loaded with 50 million gallons of Alaskan crude fetched up on Bligh Reef in Prince William Sound and spilled 11 million. Oil leaked for four hours at a rate of 1,000 gallons per second! With the slick staining a spectacular wilderness, damaging habitat, fishing and tourism, blame was immediately focused on blunders by the ship's operators. Given the calm sea and clear night, how could this have happened? Were there no lessons on safety measures from the first supertanker spill off Land's End, England in 1967 and others worldwide.

The spill animated intense media coverage focused both on the harm to the environment and wildlife and on the frenzied efforts to contain and cleanup the oil. Less photogenic but equally vital were revelations of almost total system failure in terms of accident prevention and emergency preparedness.

As with every shock to routine human affairs, the curtain was opened on the stakeholders impacted by the accident and others responsible for cause, for prevention or for limiting damage. Investigations were mounted by several federal agencies as well as by Exxon, and by a citizens' commission appointed by Alaska Governor Steve Cowper, which included the author of this treatise.

That probe attacked questions of what happened and why, and how to keep such a calamity from recurring. The commission's report issued in January 1990 told some alarming stories. In applying the TDS concept to map the oil delivery system, we find almost every entity contributed to the disaster.

Obviously, the ship operators were the immediate cause of the accident. The master was in his cabin; a mate was steering; and a lookout presumably at the bow who should have spotted a navigation light on the wrong side of the ship except that she was at the pilot house chatting. By their negligence, many others contributed to the disaster.

For example, to limit first costs, the Exxon Corporation chose to build the largest possible ship with the thinnest permissible plating, the least compartmentation, and single hull rather than double hull construction except under the engine room. There was no redundancy in propulsion or steering. None of these steps to enhance safety would have prevented the accident but a double hull could have reduced the volume of spill.

Human error was obvious. Exxon had retained a master with a history of alcohol abuse, ran the ship with the smallest possible crew (reduced twice with Coast Guard approval) on the assumption of an uneventful voyage and immunity to sleep deprivation. Both these corporate policies reveal a classical tradeoff of safety for profit.

The Commission also faulted Alyeska, the operator of the Valdez loading terminal and responsible for spill prevention and emergency response. Exposed were apathy, incompetence, and carelessness. That company proved incapable of reacting during the short window of opportunity for containment before the spill spread widely and irretrievably. The U.S. Coast Guard was also faulted for reducing power of their radar monitoring the inlet in order to cut expenses, such that their human operator did not provide continuous surveillance. Moreover, the Coast Guard had approved the disembarking of a pilot short of Bligh Reef where the accident occurred. After the spill, the agency found that its containment and cleanup fund was depleted and not refreshed from penalty fines so that contractors couldn't be hired on the spot to limit damage.

The State of Alaska had anticipated the possibility of the *Exxon Valdez* type of accident but their environmental watchdogs neither barked nor bit. An accident of this scale had not happened during the 12 years of shipping oil, complacency had set in, and legislators under pressure from Alyeska had eased contingency safety requirements.

From this snapshot, several lessons emerge. When serious consequences follow acts of nature or of human failures, the mind becomes aware of the large number of constituents and stakeholders in the TDS and their complex linkages. Paradoxically, many functions were installed for redundancy in navigation to prevent such grounding. .

This leads to the surprise concept of "organizational error," a pathology identified by Sociologist Charles Perrow in 1985. He characterized oil delivery systems as error-inducing rather than safety-promoting. This idiosyncrasy accompanies organizational cultures that implicitly accept untoward levels of risk in conscious tradeoffs. Such organizations are not the direct source of accident but they set the stage for human error to occur at lower levels. Indeed, 80 percent of accidents are found due to human factors, most attributed to organizational culture. Research confirms that the imperative of safety begins at an organization's top management with explicit or implicit penalties of reward and punishment for subordinates.

Even when top management signals priority for safety, other subtle influences undermine the delivery system. TDS's entail so many components that functional coherence is destroyed by complexity. Moreover, in the chain of command, each level is expected to make choices that unfortunately may prove to be parochial and short term, indifferent to conflicts with a master policy or plan, and focused on shielding higher authority. Financial considerations rule, and public relations are used to minimize corporate liability rather than risk to the public. In 1989, the oil transportation industry suffered more than most delivery systems from all these deficiencies.

The Alaska Commission filed 58 recommendations to reduce risks of a spill and enhance containment and cleanup response. The 15 most relevant are summarized below:

- Prevention of oil spills must be the keystone policy of all in oil shipping.
- Because many individuals and communities are at risk, citizens should be involved in oversight. This echoes the notions that safety is a social judgment, that those exposed to risk should have a say on protection.
- The nation and states need strong, alert and fully funded regulatory authorities.

- Top management of private oil transportation must be committed to safety
- Citizens in a democracy have a role in all aspects of risk management.
- Federal technical standards and safety requirements should not preclude more stringent measurers by states for prevention and spill response..
- Double hulls and other advances in tanker design should be required at an accelerated time table.
- Traffic control systems should be mandatory, not voluntary
- Crew levels should reflect the need to avoid fatigue and additional crew required by emergency conditions.
- The role of insurance companies to reduce risk should be revisited
- Corporations transporting hazardous materials should be required by the SEC to file safety reports along with the fiscal data of quarterly reports.
- A report should be prepared annually by federal authorities to track progress
- The state should empower itself to take over response to a spill in the absence of swift and effective federal action (again, redundancy)
- An available funding mechanism is needed to facilitate immediate response
- The state should fund a system of emergency economic assistance to fill holes in citizen safety nets

Some of these recommendations were swiftly adopted, especially those aimed at state responsibility. Based on the Commission report, the State of Alaska instituted stricter safety measures, including the requirement for each loaded tanker to be escorted by two large tugs, thus providing more assured redundancy in navigation and power to intercept a disabled tanker swiftly.

Similar recommendations were made by the author in a 1982 study of tanker safety in Puget Sound and were initially ignored. In 1990, however, the the federal government acted; but under pressure from the oil industry, Congress extended the date to replace single hull tankers with double hulls. Some companies, however, acted immediately, especially with the success of liability suits against Exxon by native populations whose businesses were injured by the spill.

Corporate response has been spotty, with litigation over damages on the order of one billion dollars long in the courts. Other observations can be sifted from the Commission report. With engineering improvements in machinery and electronics, the proportion of accidents attributed to human factors has increased; the Norwegian safety authority for shipping states up to 80 percent of the total. The Intergovernmental Maritime Organization of the U.N. emphasizes that corporate commitment to safety begins at the top. Accidents often expose corporate cultures that bond staff and management to a common set of values that conflict with those of society as a whole. Implications are treated later on social responsibility of the firm

This anatomy of an accident illustrates in a modern, interconnected society that an error by a single individual led to damages of over $3 billion. Other examples have been widely cited such as the failure of a chemical plant in Bhopal, India, and the nuclear power station at

Chernobyl. In retrospect, most long-term and persistent dangers arise from weaknesses in people and in their institutions.

On a personal note, for this author being appointed to the *Exxon Valdez* Commission was a depressing irony. In a sense, I was there at the beginning. In 1967, I was in England when the *Torry Canyon* went on the rocks at Land's End as a result of human error. It was the first major spill by a supertanker. On return to my post at the White House, I instituted an Executive Order for President Johnson of a national contingency plan of containment and cleanup.

When I moved to Seattle in 1970, I witnessed the vulnerability of Puget Sound that would serve as a port for oil to be shipped by pipeline and tanker from the Prudhoe Bay, Alaska. Although an environmental impact statement had been required for safety of the pipeline, the filing ignored the hazards of spills along both the Alaskan and Washington coasts. At a hearing in Washington, D.C., I delivered a risk analysis to amend the EIS. The second version nodded at maritime hazards but was weak enough to justify publication of a second alarm, this time in a journal of the ASCE. In 1975, I chaired a study committee for the state legislature that led to federal regulations for Puget Sound requiring a tug escort and limits to tanker size. In 1982, a comprehensive report on navigation safety was published with additional analysis of risks with tanker traffic and the need to strengthen Coast Guard surveillance.

With the appointment to the Alaska Commission, I felt like the fabled tar baby, stuck forever to studies of tanker accidents.

H.7.2. Deficits of Foresight, Vigilance, Contingency Resources, Political Will, and Trust

Contemplating their survival leads most citizens to feel secure when risks are known and convincingly held to acceptable limits. While that accomplishment may be an impossible dream, the human family has advanced in comprehending that threats to survival are not inescapable whims of fate. While many believe, like the ancient Greeks and Romans, that the gods punish human transgressions with disasters, society presently believes risks can and must be controlled.

This protection is especially demanded with risks of human origin. Thus, society has boot-strapped its understanding of cause-and-effect so as to prevent many malignant consequences or at least to act defensively to contain the degree of harm.

Within that abstraction is a chain of understandings, some with ancient roots. The time is long past for people anywhere to achieve the desired security as individuals. For better or worse, each of us is imbedded in a distinctive culture and subculture on which we must depend to be alive and free. The most critical element of that society is trust.

The problem with trust is its undependability, notwithstanding its prominent role in a democracy. Connections between trust, lying and ethics earned attention as far back as Aristotle. The subject has gained distinguished analysis ever since, recently in the book on “Lying” by Sissela Bok and sermons by Solzhenitzen. Consider the following headlines in the New York Times for a single day, January 4, 2006:

- Lobbyist Abramoff Accepts Plea Deal in a Corruption Case
- Bribery Investigation to Reach into Congress(Rep. Nye and others)
- The National Security Agency(NSA) first Acted on its Own to Broaden Spying
- on the Subject of Leaks (on domestic spying)

- U.S. not Told of 2 Deaths during Study of Heart Drug (Johnson and Johnson)
- 6 Ex-Putnam Officials Accused of Fraud
- Judge Orders Ex-HealthSouth Chief to Repay $48 Million
- Windows Patch not Ready (Microsoft vulnerability)

That same day, a tragedy unfolded in West Virginia with the deaths of 12 men in a mine that had been cited with over 200 safety violations in the last two years. The coal company bears responsibility, but so does the federal government which discovered the violations but failed to act. Pressures on members of Congress and the Bush White House led to reduced budgets for mine inspectors and to allow dangerous mines to remain open.

A week earlier, the headlines exposed fraud in scientific results announced by a stem-cell scientist in South Korea. In four books published between 1979 and 1999, I listed similar breeches with examples of Boeing (Bribing contract officials), General Motors hiding dangers of the rear engine *Corvair*, Ford concealing a vulnerable fuel tank on the *Pinto,* the unresolved super scandals of ENRON and World Com currently in the courts.

These observations lead to the melancholy conclusion, that key organizations are as lacking in moral principles as are individuals whose human nature has uncorrected flaws. Compared with that of individuals, however the scale of corporate malfeasance is far greater.

Experience reveals that it takes a spectacular accident or crisis to so agitate a quietly humming TDS as to expose the institutions involved, their communications networks as well as their life style.

Some organizations demonstrate solid integrity, revealed by a concern for safety, doctrinal foresight, a tolerance for dissent, alacrity in damage control, self discipline and acceptance of responsibility. Many do not. They engage in cover-ups, deflection of blame and substitution of public relations for problem solving.

The pathologies of ethics are not limited to the private sector. We still remember the Watergate and Iran-Contra scandals germinating in the White House. Much more recently, these negative and positive aspects were conspicuous in reports of Katrina-related flooding and its aftermath of system failures..

Public and private organizations differ, however, regarding their attitudes toward ethical lapses. The public expects a high level of moral vision in public servants, and so feels more justified in publicizing their weaknesses as in the case of President Clinton and Monica Lewinsky than with private enterprise.

The public cherishes privacy and, given the corporations’ legal status in protection of its officers from liability, is more inclined to accept the secret life of corporate officers and boards. Compared to fifty years ago, consider how obscure names of corporate officers have become.

To explain, organizations have personalities, cultural attributes and values similar to those of individuals. When public safety is at stake, the public has a right to expect the same standards of values for corporate officers as they do for officials of government. These personal qualities include intelligence, integrity, respect for the law, common sense and compassion, capacity to listen and learn, emotional stability under stress and deep understanding of the social contract of America.

President Calvin Coolidge tried to epitomize that focus with the statement, “The business of America is business.” In terms of function, a more appropriate term would be, “The business of America is technology.” If technology was defined as the social process mapped by the TDS, the significance of values would be clear in their shaping ethical qualities of all system components.

The earlier headlines make clear that our society has serious gaps in the practice of ethics. It follows that every brand of risk is intensified where integrity is compromised; instead, it should be the keystone of every organization’s culture.

Not all news is bad. There are striking examples of courageous integrity. After completion of New York’s City Service skyscraper, design engineers found that the specifications for strength of structural steel were in error and not reported until after completion. Apart from bruised pride, the admission opened the hazard of powerful lawsuits. Yet the social responsibility to protect the public prevailed; additional structural elements were installed. There is heroic power in doing the right thing.

Attention to ethics has not been sufficiently emphasized in our schools of business, and this is reflected in the behavior of graduates. Most believe that evidence of sound management lies in external rewards through rise in stock prices, and internal kudos for maintaining tight control. Here is where fault lines appear in our basic values.

Missing is an awareness that human organizations are organisms and not mechanisms. With mechanisms, cause and effect are coupled predictably. Not so with organisms. Their behaviors are less certain, cause and effect blurred. External influences such as terrorism, intense global competition, or occulted fate undermine certainty,

One thing, however, is fairly certain----whoever controls technology controls the future. No wonder Orwell’s speculations regarding the corporate state have been resurrected. That reality would be less likely in a society that honors diversity rather than central control. Diversity works only with a shared set of values that nurture trust. Without trust, the system of governance works only by coercion.

The nation’s founders surely recognized that truth but did not incorporate their moral vision in the Constitution. Some elements were added by amendments, the Bill of Rights.. History reveals, however a strong moral climate was suffused in the population through religious doctrines. They may have assumed that such discipline would be permanent despite acknowledging that democracy was an unproven experiment.

In the aftermath of Katrina, it was clear that systemic shortages other than in ethics were present and these are being dissected by the media. Shortfalls include the effects of human and organizational errors, of shortages in foresight, in vigilance to detect early warnings of danger, in contingency resources to limit damage and then to repair what’s broken, and finally a shortage of political will to exercise the leverage of power to get the right things done and done urgently, and then to do these things right. Today, most failures do not involve hard-edged technology but rather human ware.

Here lies another contradiction. In our democracy that underlines egalitarianism, power is thought of as suspect and even malign. There are, however, benign purposes for the exercise of power, and these need honoring in the human ambition for survival.

To be emphasized is the imperative role of citizens as a part of government. They should be part of the power structure as suggested in the TDS. Only then will those who govern do so with the informed consent of the governed. This was the perspective of the nation's founders and it could be lost amidst the buzz of intricate social processes, especially cases of unprincipled advocacy by society's powerful economic interests. The antidote to the disproportionate influence by special interests starts with more transparency of policy affairs.

One way to understand the web of influences on risk management is to think of our high-tech society as steered by three sets of IT operating instructions. One set is the free hand of the economic market place. A second is public policy, much of it regulation to manage risk. The third set is values that animate the moral parameters of the other two. . Underpinning these arguments is an implicit assumption that citizens realize government is not the only machinery of governance. We, the people, have a critical role. Most urgent is to meet the deficiencies exposed by the case studies---the lack of foresight, vigilance, contingency resources, time, political will and trust.

Most essential is foresight. Government officials and citizens can then focus on emerging issues of security, seek the facts, compare remedial alternatives, and unintended consequences of each. With information and trust, citizens could make their views known on acceptable levels of risk in the spirit of catastrophe avoidance. Officials should recognize this citizen role in a participatory democracy and welcome an informed and concerned electorate.

H.8 Thinking About The Future

H.8.1. Evaluating Social Choice by Outcomes for the Children

For many centuries, philosophers have taught that the quality of a civilization can be judged by how it treats its children. With that rationale, the quality of decisions made today for managing risk can be judged by consequences observed tomorrow as outcomes for our children. In other words, today's decisions on acceptable risk can best be judged by results observed 10 to 20 years hence. These results become legacies for future generations-- social, political, economic and ecological. With such criteria for success, those responsible for risk assessment must look ahead in order to make operational the questions, "What might happen, if, or What might happen, unless?"

Imaginative analysts might nominate answers, but trouble may still occur when the issue requires a policy decision that spins winners and losers. Assuming that all stakeholders are represented at a bargaining session, it is likely that compromises are reached among different advocates. Almost all will argue from their short term advantage, with no advocate for hypothetical children. The short term triumphs because society chooses to lock its barn door too late.

This vulnerability in public policy was sketched for the U.S. Congress in 1965 by its CRS Science Policy Research group, leading to creation of the Office of Technology Assessment in 1972. Requests from members and committees led to roughly 50 reports a year until the agency was zero budgeted by House speaker Newt Gingrich in 1995. The OTA left a valuable library of risk assessments that permit comparison of different methodologies. All were endowed with a futures perspective.

That resource also demonstrates the importance of values in every society.. For example, studies reveal a paradigm shift in the 1970's regarding technology's wrenching of social norms. The question about potent innovation and asked with pride, "Can we do it? shifted to the questions of “Should we?” In simple terms, this requires a look at the medical mandate to “do no harm.”

If my earlier contention is true that whoever controls technology controls the future, and if we judge the acceptability of a technological development (or its misguided absence) by the effects on the children, we can conclude that whoever controls technology in effect is raising our children. That shocking characterization of shifts in our values may already be happening..

That prospect can be a useful wedge to understand the impact of values on today’s decisions and thus on the future for our progeny. This leads to an inescapable question on which values dominate our culture and that of the deciders who extract from our circumstances answers to “How safe is safe?”

In America’s diverse population, one size answer doesn’t fit us all. Each brand of risk and its stadium of different interests is likely to generate a different outcome. Therein lies another level of perplexity in dealing with risk. There is no standard pattern. Today’s solutions are unlikely to be suitable tomorrow. Living with risk isn’t easy.

H.8.2. Foresight as an Imperative in Risk Management

Safety and security depend on fantasy, on imagining what might happen and then how to prevent harm or at least minimize the event’s impact. Risk management demands a mind set of looking ahead, practicing a doctrine of anticipation. That notion can be sampled in a series of books on Science Policy by the most frequent citations in the indices. It is also possible to track changes in what one author (Wenk) emphasized as important over a span of 22 years, 1979 to 1999, in connecting technology and the future to people and to politics:

*Margins for Survival: Overcoming Political Limits in Steering Technology, 1979

*Tradeoffs: Imperatives of Choice in a High-Tech World---1986

*Making Waves: Engineering, Politics and the Social Management of Technology---1995

*The Double Helix: Technology and Democracy in the American Future---1999

For each book, the most often cited index terms were:

<u>Margins for Survival, 1979</u>: Anticipation, [Foresight, Early Warning, Future, Long-term,] Behavior of political leaders, Cultural values, Decision processes, Government, Information, Nuclear hazards, Technology and Society, Threat and response, Time.

<u>Tradeoffs, 1986:</u> Citizen Participation, Congress, Decision processes, Ethics, Foresight [Anticipation, Future, Long range,] Government, Industry, Information, Media, Political processes, Risk assessment, Technology

<u>Making Waves, 1995</u> Accidents, Business, Coordination, Economics, Engineering, Ethics, Foresight, Government [Congress, President, Policy,] Organizational behavior, Risk, Technology, Values

<u>The Double Helix,1999:</u>: Business, Economics, Ethics, Foresight, Government, Information, Media, Safety and Risk, Technology, Time

A fast scan of these citations unlocks two paradoxes. The featured topics sound more like books in the behavioral sciences than in engineering. That slant was rationalized in a 1995 paper, “Teaching Engineering as a Social Science.” published by the American Society for Engineering

Education. Its thesis was simple, that everything engineers do is to meet needs and wants of people. That suggests learning about human nature as well as laws of nature.

The second enigma was the power of some topics to command attention over a long period when the interaction of technology and society was in flux. The concept of *foresight* deserves special attention.

Many people meet this concept as children when taught to pass a football to where the receiver is perceived to be when the ball arrives. Boy Scouts are engraved with the motto, “Be Prepared.” Many young people encounter the future pragmatically in the quest for a college scholarship that depends heavily on high school grades and recognition of leadership earned years before. . Those studies, incidentally, seldom focused on the way ahead; History and English Lit necessarily looked backward. Students met futurist Jules Verne through their vicarious curiosity to explore both the geographical and the scientific frontiers. Beginning in 1933, a series of world’s fairs were held in North America, speculating on the future in exhibits and programs: in Chicago, Cleveland, New York, Seattle, Montreal, Spokane and Vancouver. Not until the October 4, 1957 Soviet space spectacular did the entire nation engage the future as the meshing of technology with society and public policy for safety and survival.

It bears repeating that the importance of foresight follows from a reality that all technologies have unintended consequences, some potentially lethal. Shrinking these risks is the core of social responsibility of professional engineers. Practice entailed two different strategies. One is to coral information as to what might happen (in the future), if, or unless. Skillful probing should then lead to stages of care in design to reduce risks. The second strategy was to take precautions against a range of uncertainties by over-design, the use of safety margins.

Both strategies, however, encounter potholes, tradeoffs with other design parameters such as cost, reliability, weight or delivery schedules, and thus with performance. Both strategies stumble for yet another reason. By our culture and possibly by our genes, modern humans have difficulty looking ahead. Anthropologists assert that humans are the only mammals even capable of imagining the future. Seasonal migrations of birds and animals seem spun by instinct, not fantasy. Moreover, early humans were compelled to satisfy immediate needs of food, water and safety so that the longer range perspectives were irrelevant.

Modern humans still suffer from pathologies of the short run. The monograph, *Margins for Survival*, lists sixteen, all dealing with human behavior. That discovery should teach that managing risk crashes into a type of sound barrier that challenges a way of thinking beyond equations and number crunching. Practicing foresight depends on individual and group behavior, what we call social process. Only with this far horizon can risk managers accommodate and compensate for individual and organizational error and its siblings. The three operating instructions for the process were mentioned earlier. Foresight has one other critical product. It instructs us on how to achieve our greatest challenge, making the world a better and safer place for our progeny. Indeed, how a society treats its children is a measure of civilization. In policy terms, that idea stretches back to drafting of the American Constitution.

With the dilemmas of our time, it would be tempting to draft a cook book on foresight, a universal method of forecasting what might happen, if. That quest is fruitless because every case is different. Some dangers, however, repeat themselves such that projections of the future follow trajectories of the past. We learn from failures.

That aphorism puts a premium on history, not just a chronology of key events but also an understanding of different layers of individual and organizational functions, responsibilities, leadership patterns, institutional cultures, communications, resources available, etc.

The past can be prologue.

H.8.3. Pathologies of the Short Run

All risks and measures to enhance safety embody dimensions of time. These intervals range from nanoseconds in computer chips to decades of human longevity, to centuries of tectonic movements. In the context of risk management, the most crucial interval lies ahead, in the immediate future and the distant. Survival is the imperative of the future, both short and long term. Common sense dictates looking ahead, but we are so conditioned to seek immediate gratification that short term goals and strategies trump the longer term, regardless of how much more significant they are. The culture seems indifferent to future penalties of current choice.

This exercise of foresight should be distinguished from prediction, the attempt to satisfy human curiosity about tomorrow's weather, the longevity of a family member, the performance of the stock market. Daily newspapers still carry horoscopes and astrologers still practice an ancient art that extends back to pre-Biblical times. The sagacity of foresight lies in asking questions about alternative, conditional futures--- what might happen, if or unless in relation to acts of nature or acts of people.

There are many pathologies of the short run. Consider the reward structure in commerce. In their narrow self-interest, CEO's are torn between boosting long-term performance of a firm against winning the Wall Street beauty contest next Monday. Shareholders lack patience; so do money managers of mutual funds. Executives also lack incentives for long term strategies because they expect to move on and prudent foresight may bring credit to their successors.

The reward structure in politics is similar. Incumbents sense what earns voter esteem and promise rewards in the next election. Shorter term issues, especially if paraded in headlines, are more rewarding. Seldom are elected officials bold enough to inform an electorate of the distinction between the long and the short run consequences.

To be sure, the future is clouded with uncertainty. In our technological era, we are confounded with complexity of both machines and social processes. Linkages of effect with cause are frustrated because human systems do not have the fixed properties of mechanisms. They are organisms.

In smaller communities of the past, everyone shared information about how their local TDS worked. The social contract was more transparent. Now in large and complex communities, early warnings may be weak. Fretting over the unknown carries emotional burdens eased by ignoring the future. That pattern can explain the unwitting storage of radioactive waste 50 years ago at a weapons factory where it is leaking. Residents knew of the danger since it began, but good jobs drowned out a faint and sporadic protest until very recently.

In general, the public seems indifferent to these longer term issues, partly out of feelings of incompetence and powerlessness. The perceived loss in control leads to weary acceptance of political decisions that are "piecemeal, provisional, parochial, uncoordinated, insubstantial and lacking in prophetic moral vision."

Organizations are known for their resistance to change, for their aging in such a way as to lose alacrity in response to threats (as in New Orleans with Katrina). Energies are directed to self preservation by combating forces uncongenial to well entrenched beliefs. Change can be threatening When dilemmas lack clear solutions, it is more comfortable to avoid action or change in direction. Leaders find bliss by selective ignorance. Such escapes are irresponsible but they are especially attractive when the queue of problems is relentless and new ones erupt before earlier ones have been resolved. Avoiding the future also reduces the risk that a look ahead may uncover mistakes of the past.

In this inventory of pathologies, there is also a perceived shortage of time. That seems anomalous in an era when technology promised to save time and permit mulling over options in the decision theater. Yet the tyranny of a backlog and the frenetic atmosphere of policy making blocks both rational choice and conflict resolution.

Caught in the crossfire, leaders get nervous and either seek immediate relief by impetuosity or are paralyzed by a commitment to the past. Under stress, once again the short term wins. Society leans to a conservative stance because it has lost confidence in itself to manage technology.

This catalogue of pathologies should sound familiar. It exposes how inimical they are to democratic process. Nominating and comparing options takes time, as does an honest debate on who wins and who loses. With unsettled issues accumulating, none receive adequate attention in the policy theater, even less in the media to help inform citizenry to do their duty. When these issues are covered, the media demand instant accountability, live on TV, leaving no time to deal with complexity and context.

When debates are held, advocates argue from their parochial, short term perspectives. No one in the decision pyramid has the patience or energy to look through the mists ahead to practice prophylaxis or take collision avoidance action.

Add problems of information overload, stress of uncertainty, imperatives of reelection, new crises world wide, many beyond remediation. Loss in virtues of foresight and character can lead to exhaustion of stamina and to impetuous judgment.

The operating directions I proposed almost a half century ago came from an innovative concept of technology assessment. Simply put, TA is a method for looking ahead. The OTA’s organic legislation spelled out these paraphrased details:

- Define the TDS, its purposes, its stakeholders, its organizational components and information links.
- Define the technical, social, economic, political and ecological context and the estimated behavior of different system participants.
- Establish a base of hard facts and of uncertainties.
- Forecast what is foreseeable about impacts and about evolution of hardware, software and social ware.
- Generate alternatives of policy and implementation plans including doing nothing, and trace consequences, both desired and unwanted.
- Identify impacted parties, including future generations and effects on each.

- by asking, "What might happen, if, to whom, and when?" Incidentally, this methodology has a mirror image in environmental impact analysis.

Imagine the prize of successful performance of public policies if all initiatives were subject to this mode of analysis.

H.8.4. Early Warning of Close Encounters.

Early risk management drew on common sense, imagination, familiarity with human nature and with contemporary cultures rather than science. Now it also draws on science and engineering, and on learning from failure. For threats that recur frequently, impact statistics are a great help. For threats that occur rarely and especially those with extreme consequences, data are too sparse to extract probabilities for numerical risk analysis as defined previously. That condition springs a paradox.

Admitting there are limits to available information, foresight is still essential. Beyond infrequent accidents or natural catastrophes, we learn from incidents, "close encounters." These events would be similar in patterns of cause and effect to those having severe impact, but in these cases the trajectory to tragedy was arrested either by the lucky tapering of circumstances or by timely and effective accident avoidance maneuvers..

Everyone lives with dangers. Repeated close shaves, however, serve as early warning of a hazardous environment, a hazardous situation or our own impaired judgment. Projected to the future, this store of experience is a survival tool. It doesn't work with slow learners or fools. It does work, however, on an institutional basis where data on close shaves are collected and analyzed in real time in the spirit of prevention or damage control.

The collective benefit of that monitoring is dramatically illustrated by the case of airline safety. For several decades, the FAA has required operating personnel to report close shaves. Analysis of events that were often repeated served as early warning of danger. Participants included pilots, traffic controllers, maintenance inspectors and occasionally passengers.

Because the FAA has authority to punish violators of rules, it was aware that those committing errors might be reluctant to report themselves. As a precaution, FAA contracted with a neutral government agency, NASA, to collect and analyze data, preserving their anonymity but reporting the "hot spot" patterns that deserve immediate risk reduction measures. As a result, accidents on the nation's airways have been conspicuously limited over a period when air traffic sharply increased.

The same reporting system was proposed by the author in a 1982 report on navigation safety in Puget Sound where newly operating tankers carrying crude oil posed a serious environmental hazard.. The Department of Transportation adopted the proposal, issued reporting rules and forms, and selected its laboratory in Cambridge, Massachusetts as the neutral, data collection agent rather than the U.S. Coast Guard which has regulatory authority. Communication of this risk management technique to ship operators was so poor, however, that few reports were filed and the DOT abandoned the system.

The virtue of close encounter reporting remains and has been adopted in other risky situations. Operators of nuclear power plants are required by the Nuclear Regulatory Commission to file such reports, even using telephony to warn operators of similar plants of similar vulnerabilities.

The public is well aware of product recalls mandated by various agencies where intervention is based on the frequency of identical hazards, some creating accidents, some only incidents, the close shaves. Broader applications are obvious.

H.9 The Anatomy of Risk - A Summary

In virtually all human affairs, some risk is normal. The consequences of neglect may be grave, if not now then in the future. There follows a distillation of points raised earlier on how to think about the risk situation as a prelude to risk management.

- Risk is a highly complex condition, especially challenging because it combines abstruse technical factors with diverse and uncertain elements of societal behavior; and because the consequences may cause great harm.
- Three frontiers of risk pose threats, extremes of nature, weaknesses in human nature, and the unintended consequences of technology
- All technologies spawn side effects, most unwanted by some sector of the population, now or in the future
- .Each risk condition is unique, but two theorems for analysis have found wide application to facilitate understanding
- The first is based on the notion that what you can't model you can't manage.
- This leads to a generic framework to structure intertwined laws of nature and of human nature, what is termed a Technological Delivery System, a TDS.
- The second tool is based on the notion that risk does not yield to rigorous technical analysis because acceptable risk is a social judgment.
- Risk analysis using a TDS depends on three premises of governance.
- The first is that those exposed to involuntary risk should have a say in their intensity of risk exposure.
- The second is that when economics of the free market, existing laws and local governments fail to meet that level of safety, the federal government is charged to assume responsibility to lower the threshold of threat to levels that citizens demand.
- That achievement, however, has both direct and indirect costs, so that significant tradeoffs are necessary between safety and expense.
- Because of cultural diversity in America, achieving consensus on acceptable risk releases a fog of conflict and uncertainty
- .Bargaining develops among stakeholders; lobbying becomes endemic.
- Typically, each argues from their immediate, short-term self-interest such that little attention is paid to long-term effects, including on future generations.
- The third precept is that the federal government not just serve as umpire, but balance long- with short-term factors, thus serving as a surrogate for progeny

- In this chain of argument, a question arises as to whether the public that is to be consulted as to risk tolerance has adequate factual information and grasp of the risk equation so as to render not just consent but informed consent.
- Two TDS elements help with that illumination, the print and electronic media, and past or recent events. Those so agitate a TDS that the full cast of stakeholders is revealed, their roles in posing a threat, in preventing or limiting the damage or in their capture as victims.
- Study of past and recent events offers a rich opportunity to learn from failure. Most of these failures can be traced to human and organizational errors.
- Those lessons should tutor emergency preparedness through the self-conscious exercise of foresight, to limit impacts to choice and not chance
- Potent levers of foresight are the questions, “What, if or unless; when and to whom.” This is the spine of technology assessment that was institutionalized in 1972 for Congress as radar for the ship of state. That capability was lost in 1995. Perhaps it needs rethinking for both branches of government.
- Engineering practice treats uncertainties by over-design with safety margins
- How these are set and by whom are critical.
- The role and performance of the federal government can be evaluated to ascertain effectiveness of regulation for risk reduction and damage control
- Dissection of these events should reveal the strength and weaknesses of existing legislative authority, the match between appropriations and need, the identification of leadership to integrate and activate emergency preparedness and crisis response among federal and lower authorities.
- A customized TDS should help illuminate who is responsible for what among organizational components, but a critical element is the quality of communications to assure that basic information is shared and that otherwise piecemeal actions are synchronized to assure systemic functioning..
- As to federal involvement, the President becomes the nation’s uncertified systems manager because all agencies responsible for citizen safety and security report to the Chief Executive, because he is held to account for their satisfactory performance and must initiate new public policies if authority or performance is weak, because many dangerous natural phenomena entail common property of air, land or water, and because in extreme cases the military arm of which he is Commander in Chief must be mustered.
- Ultimately, the President is responsible for protection from terrorism, extremes of nature, from dangers of technology’s side effects and from human frailties of ignorance, error, blunder, folly, mischief, greed and hubris.
- This burden must be processed with foresight to exercise political power and political will, especially to meet shortages of vigilance, resources and trust.
- Government is both mandated and constrained by public policies, and these are rooted in values that differ widely among stakeholders.
- One source of conflict arises between industry and government because there are sharp differences between these entities in goals and in tactics based on their internal values.

Industry honors efficiency and measures success by profit and generation of wealth. Government honors sustainability and measures success by economic and social justice.

- Some tension between these two power centers is healthy but excessive tension can be corrosive
- The quality of social and political choice is revealed by the heritage each generation leaves its children
- Citizens need to realize that government is "We, the People!" that democracy is not a spectator sport and that each citizen has responsibility for risk management through public policies and citizen watchdogs.
- The risk management process depends critically on mutual trust of all parties.

H.9.1. Applying These Concepts to Katrina

This treatise was prepared for this study of the Katrina disaster. The diagnosis of causes for the calamity demanded a sifting of the foregoing issues for steps to meet the federal government's responsibilities and accountability to anticipate threats and to prevent and to mitigate losses of life and property.

Three measures emerged from the most salient lessons and the most potent interventions to avert a repetition of the flooding disaster.

- To enhance the management of all modes of risk, the responsibilities for vigilance and decision making at the tip of the authority structure should be clarified and strengthened, perhaps with a new unit in the Executive Office of the President.
- To buttress the legislative responsibilities of the Congress, additional technical staff should be appointed to assure adequate revenues to manage risk and to monitor performance of the Executive Branch in its duties of care.
- To reflect that citizens at risk are entitled to information regarding their exposure and opportunities to participate in governance, new processes should be authorized at a local level to foster informed consent and dissent and to function early warning in disaster-prone areas.

Such measures have great promise in the spirit of preventing another lethal flood in New Orleans. They present opportunities to deal with a much broader array of threats—to life, peace, justice, health, liberty, private and common property

These cardinal recommendations arise from Constitutional law and from a history of public policies that establish the Federal Government as the most senior authority for providing safety and security. Moreover, the technological engines of the last century have added to natural causes a new class of dangers arising from human and organizational errors and from unintended consequences of technologies switched on for their benefits.

This double helix of technology and governance leads to awareness that the President is the nation's uncertified systems manager. Responsibilities accrue from the President being the Chief Executive supervising all federal departments and agencies and responsible for their disaster preparedness, their exercise of foresight and for adequacy of their funding. As Commander in Chief of the armed services, he has direct and immediate access to potent physical and human resources both to prepare for emergencies and to offer rescue and salvage assistance after a disaster.

.The age of electronic communications has heavily affected the functioning of the White House in its connections to the outside world. Events anywhere have repercussions everywhere. Message traffic is more complex, demands faster analysis and response, and entails a denser web of possibly differing participants.

One psychological effect is to force attention to immediate issues rather than the important. Pressures to deal with the unremitting queue of short-term dilemmas squeezes out attention to longer-term challenges. The future is neglected, thus seeding an enormous penalty for future generations, including the burden of public debt.

Decision making in every White House has other impediments. Apart from the standard approach of framing issues and options, the incumbent has to assess the impact of choice on political power and political will. Each quandary imposes stresses on political capital. With a press intent on not becoming a sycophant and losing their role as the fourth estate, that Greek chorus is noisy and distracting, and in a democracy, not centrally controlled. So the President must be aware of the public perception of issues at hand and their intertwining with unresolved preceding issues.

That latter condition is reflected in a new reality of government organization. There was a time when the missions and roles of individual departments were highly specialized and compartmented. Today, issues leak well beyond the province of single agency. This imposes a more intense requirement at the top for coordination and integration of functions of several agencies. Only the President and the Vice President have the authority of being elected and occupy a central position of leadership of all departments and agencies.

In a nutshell, the President needs help of a special cadre of advisors experienced in and focused on catastrophic risks of all kinds. Organizationally, they should not become a layer between him and agency heads. This staff should be mandated to look ahead, to think in the future tense, to adopt a stance of being proactive in the sense of preventative medicine rather than reactive, to balance long- with short-range factors free of partisan politics.

The staff director should have direct access to the President at all times to offer early warnings such as intelligence agencies do for military security, to share urgent information without its filtering in the White House chain of command. In addition, the director should have the authority to convene emergency sessions of appropriate cabinet officers to gain their inputs and cooperation when circumstances demand immediate collaboration and to serve as a monitor of disparate and incoherent responses.

This new capability could be a Council for Catastrophic Risk Management in the Executive Office of the President The interim Council on Marine Resources and Engineering Development, PL89-454, could be a model.

The Congress needs a symmetrical capability, especially in its orientation to the future. Such a resource existed between 1973 and 1995 in its Office of Technology Assessment. That organic legislation should be revisited to see if its engines need restarting but with a more specific focus on risk management. The procedural methodology is sketched on pages 30 and 31.

Finally, there is a major and unprecedented role for citizens who should be considered part of governance in the spirit that those who govern do so at the informed consent of the governed. This is the population exposed to risk. Authorities for risk management should make sure that those vulnerable have information regarding their condition and a reciprocal ability to respond to requests for their informed consent especially regarding tradeoffs, say safety for cost.

In addition they could function as watchdogs to serve as early warning on the ground of disasters waiting to happen as well as monitors of agencies charged with prevention, containment and remediation. This function was deemed essential to help protect Prince William Sound from another disastrous oil spill.

One central purpose should animate all three of these entities, separately and in tandem. They should address the question, “How Safe is Safe?” That investigation demands foresight in the spirit of the injunction, “Without vision, the people perish.”

APPENDIX I: EROSION TEST RESULTS ON NEW ORLEANS LEVEE SAMPLES

I.1 THE EFA: EROSION FUNCTION APPARATUS

The EFA (Briaud et al. 1999, Briaud et al., 2001a) was conceived by Dr. Briaud in 1991, designed in 1992, and built in 1993 (Fig. 1). The sample of soil, fine-grained or not, is taken in the field by pushing an ASTM standard Shelby tube with a 76.2 mm outside diameter(ASTMD1587). One end of the Shelby tube full of soil is placed through a circular opening in the bottom of a rectangular cross section pipe. A snug fit and an O-ring establish a leak proof connection. The cross section of the rectangular pipe is 101.6 mm by 50.8 mm. The pipe is 1.22 m long and has a flow straightener at one end. The water is driven through the pipe by a pump. A valve regulates the flow and a flow meter is used to measure the flow rate. The range of mean flow velocities is 0.1 m/s to 6 m/s. The end of the Shelby tube is held flush with the bottom of the rectangular pipe. A piston at the bottom end of the sampling tube pushes the soil until it protrudes 1 mm into the rectangular pipe at the other end. This 1 mm protrusion of soil is eroded by the water flowing over it.

I.1.1 EFA test procedure

The procedure for the EFA test consists of

1. Place the sample in the EFA, fill the pipe with water, and wait one hour.
2. Set the velocity to 0.3 m/s.
3. Push the soil 1 mm into the flow.
4. Record how much time it takes for the 1 mm soil to erode (visual inspection)
5. When the 1 mm of soil is eroded or after 30 minutes of flow whichever comes first, increase the velocity to 0.6 m/s and bring the soil back to a 1 mm protrusion.
6. Repeat step 4.
7. Then repeat steps 5 and 6 for velocities equal to 1.0 m/s, 1.5 m/s, 2 m/s, 3 m/s, 4.5 m/s, and 6 m/s. The choice of velocity can be adjusted as needed.

I.1.2 EFA test data reduction

The test result consists of the erosion rate dz/dt versus shear stress τ curve (Fig. 1). For each flow velocity v, the erosion rate dz/dt (mm/hr) is simply obtained by dividing the length of sample eroded by the time required to do so.

$$dz/dt = h/t \qquad (1)$$

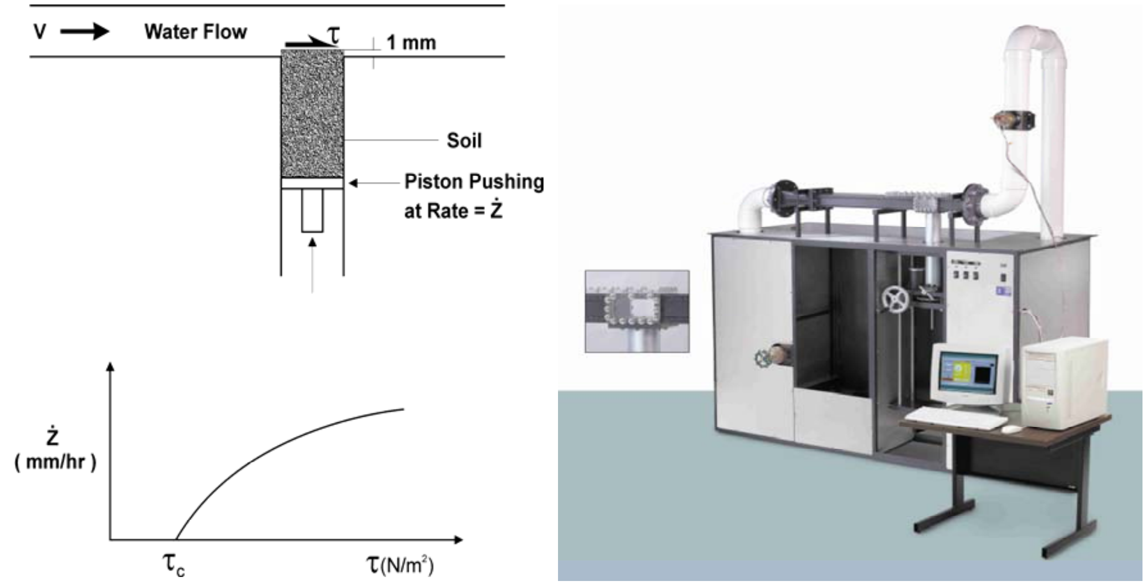


Fig. 1 - EFA (Erosion Function Apparatus) from Briaud et al. (2001)

where h is the length of soil sample eroded in a time t. The length h is 1 mm and the time t is the time required for the sample to be eroded flush with the bottom of the pipe (visual inspection through a Plexiglas window). After several attempts at measuring the shear stress τ in the apparatus it was found that the best way to obtain τ was by using the Moody Chart (Moody, 1944) for pipe flows.

$$\tau = f \rho v^2/8 \quad (2)$$

Where τ is the shear stress on the wall of the pipe, f is the friction factor obtained from Moody Chart (Fig. 2), ρ is the mass density of water (1000 kg/m3), and v is the mean flow velocity in the pipe. The friction factor f is a function of the pipe Reynolds number Re and the pipe roughness ε/D. The Reynolds number is $Re = vD/\nu$ where D is the pipe diameter and ν is the kinematic viscocity of water (10^{-6} m^2/s at 20^0C). Since the pipe in the EFA has a rectangular cross section, D is taken as the hydraulic diameter $D = 4A/P$ (Munson et al., 1990) where A is the cross sectional flow area, P is the wetted perimeter, and the factor 4 is used to ensure that the hydraulic diameter is equal to the diameter for a circular pipe. For a rectangular cross section pipe:

$$D = 2ab/(a + b) \quad (3)$$

where a and b are the dimensions of the sides of the rectangle. The relative roughness ε/D is the ratio of the average height of the roughness elements on the pipe surface over the pipe diameter D. The average height of the roughness elements ε is taken equal to $0.5D_{50}$ where D_{50} is the mean grain size for the soil. The factor 0.5 is used because it is assumed that the top half of the particle protrudes into the flow while the bottom half is buried into the soil mass. During the test, it is possible for the soil surface to become rougher than just $0.5\ D_{50}$; this occurs when the soil erodes block by block rather than particle by particle. In this case the value used for ε is estimated by the operator on the basis of inspection through the test window.

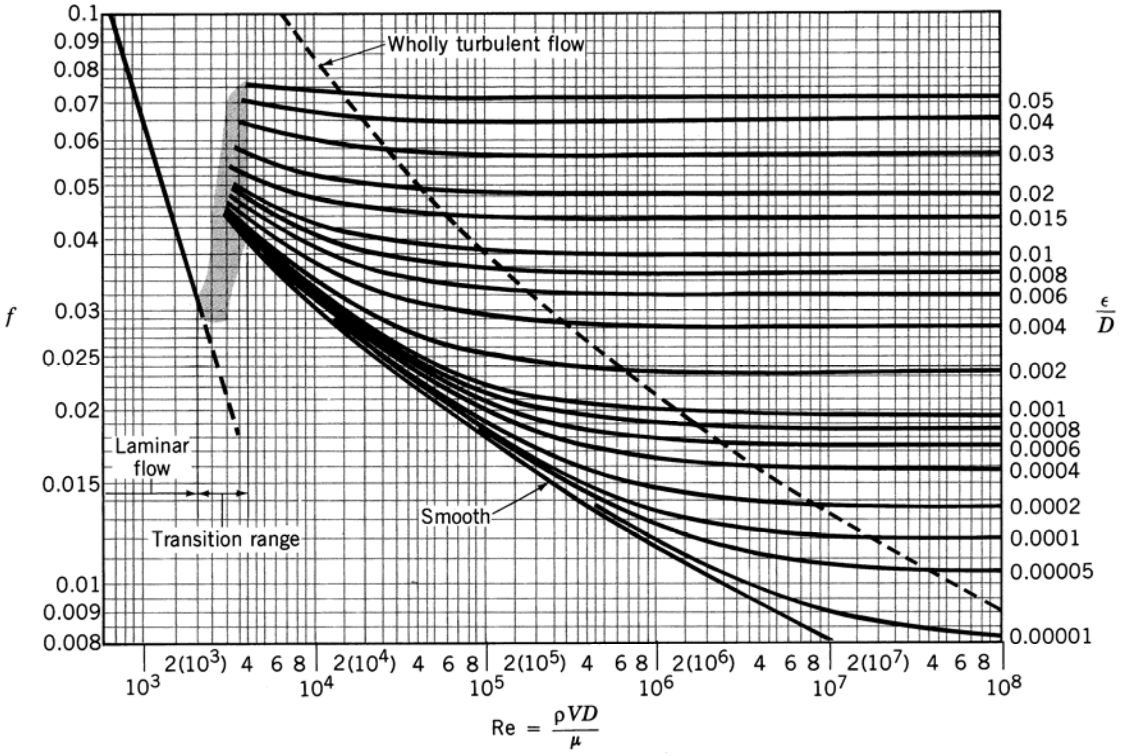


Fig. 2 - Moody Chart (reprinted with permission from Munson et al. 1990)

I.2 SOIL AND WATER SAMPLES USED FOR EROSION TESTS

A total of 11 locations were identified for studying the erosion resistance of the levee soils. Emphasis was placed on levees which were very likely overtopped. These locations are labeled S1 through S15 for Site 1 through Site 15 on Fig. 3. The samples were taken by pushing a Shelby tube when possible or using a shovel to retrieve soil samples into a plastic bag. For example at Site S1, the drilling rig was driven on top of the levee, stopped at the location of Site 1, a first Shelby tube was pushed with the drilling rig from 0 to 2 ft depth and then a second Shelby tube was pushed from 2 to 4 ft depth in the same hole. These two Shelby tubes belonged to boring B1. The drilling rig advanced a few feet and a second location B2 at Site S1 was chosen; then two more Shelby tubes were collected in the same way as for B1. This process at Site S1 generated 4 Shelby tube samples designated

- S1-B1-(0-2ft)
- S1-B1-(2-4ft)
- S1-B2-(0-2ft)
- S1-B2-(2-4ft)

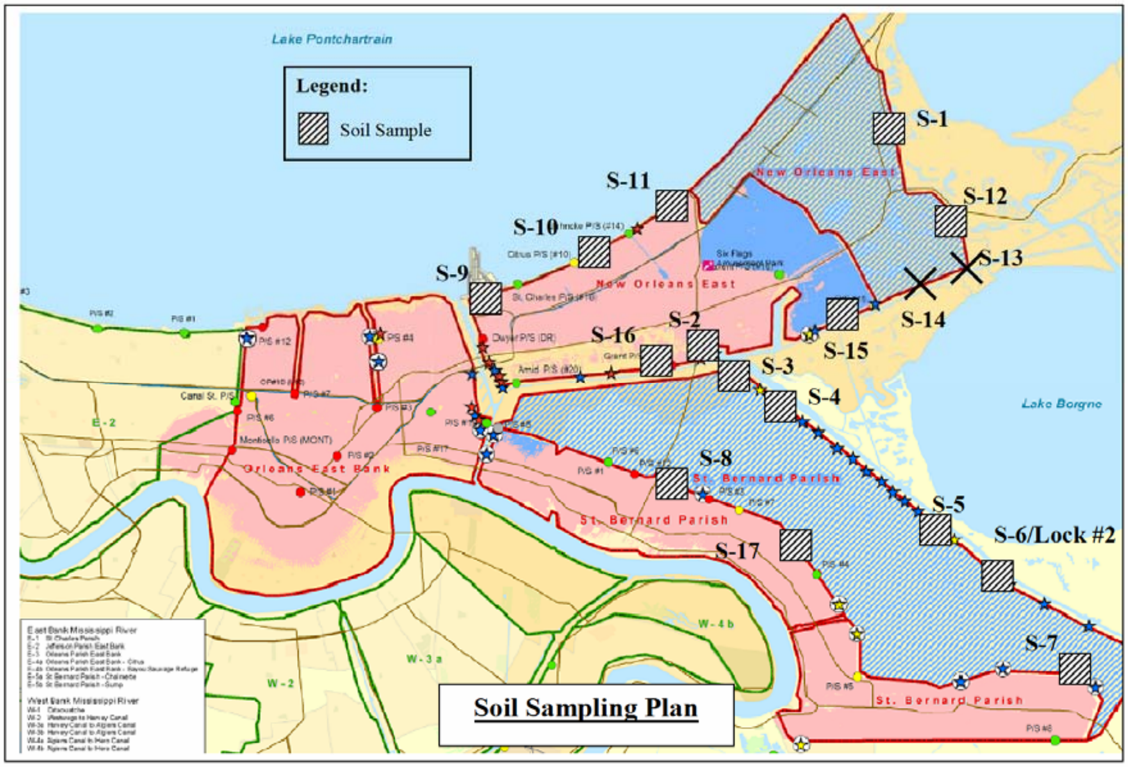


Fig. 3 – Location of samples

Four such Shelby tubes were collected from sites S1, S2, S3, S7, S8, and S12. In a number of cases, Shelby tube samples could not be obtained because access for the drilling rig was not possible (e.g.: access by light boat for the MRGO levee) or pushing a Shelby tube did not yield any sample (clean sands). In these cases, grab samples were collected by using a shovel and filling a plastic bag. The number of bags collected varied from 1 to 4. Plastic bag samples were collected from sites S4, S5, S6, S11, and S15. The total number of sites sampled for erosion testing was therefore 11. These 11 sites generated a total of 23 samples. One of the samples, S8-B1-(2-4ft), exhibited two distinct layers during the EFA tests and therefore led to two EFA curves. All in all 24 EFA curves were obtained from these 23 samples: 14 performed on Shelby tube samples and 10 on bag samples. The reconstitution of the bag samples in the EFA is discussed later.

Water salinity has an effect on erosion. The salinity of the water was determined by using the soil samples collected at the sites. Samples S11 and S15 were selected because one was on the Lake Pontchartrain side and the other on the Lake Borgne side. The procedure consisted of:

1. Dry the soil (about 70 g) in an oven for 12 hr
2. Weigh a quantity of soil, e.g. 10 g and place it in a PE bottle
3. Add deionized (DI) water in the ratio of 2 ml water for one sample and 5 ml water for another sample to each gram of soil

4. Soil: DI water = 10 g: 20 ml or 10g: 50 ml
5. Shake the bottle to thoroughly mix the soil and water
6. Allow the soil to settle for 12 hr
7. Use a pH meter (Orion model 420 A) to measure the pH and a calibrated conductivity meter (Corning model 441) to measure the conductivity of the water.
8. Perform a calibration of the conductivity meter by using known concentrations of salt.
9. Use the conductivity to salinity calibration curve to obtain the salinity of the water created in steps 1 to 7.

Then it becomes necessary to correct the salinity of this water because the amount of water added to the soil for the salinity determination test does not correspond to the amount of water available in the soil pores in its natural state (in the levee). This is done by calculating the amount of water available in the pores of the samples in its natural state. This requires the use of the void ratio and the degree of saturation of the samples calculated using simple phase diagram relationships. The results obtained are shown in Table 1.

Table 1 – Salinity and pH of water associated with the samples

	pH	Salinity (ppm)
Sample S11	8.61	3287
Sample S15	8.09	4199
Typical sea water	7.9	30000 to 35000
Typical tap water	7.0	500

I.3 EROSION FUNCTION APPARATUS (EFA) TEST RESULTS

I.3.1 Sample preparation

No special sample preparation was necessary for the samples which were in Shelby tubes. The Shelby tube was simply inserted in the hole on the bottom side of the rectangular cross section pipe of the FEA (described previously).

For bag samples obtained by using a shovel to collect the soil, there was a need to reconstruct the sample. These samples were prepared by re-compacting the soil in the Shelby tube (Fig. 4). The same process as the one used to prepare a sample for a Proctor compaction test was used. Since it was not known what the compaction level was in the field, two extreme levels of compaction energy were used to recompact the samples. The goal was to bracket the erosion response of the intact soil.

For the high compaction effort (100% of Modified Proctor compaction effort), the sample was compacted in an 18-inch long Shelby tube as follows:

1) The total sample height was 6 inches. The sample was compacted in eight layers.
2) To form each layer, the soil was poured into the Shelby tube from a height of 1 inch above the top of the tube.
3) The soil was compacted using a 10 lb hammer (Modified Proctor hammer) with a drop height of 1.5 feet. Each layer was compacted by 8 hammer blows, i.e. 8 blows/layer.
4) This process was repeated until a 6 inch sample was obtained.
5) The corresponding compaction energy was equal to the Standard Modified Proctor Compaction energy.

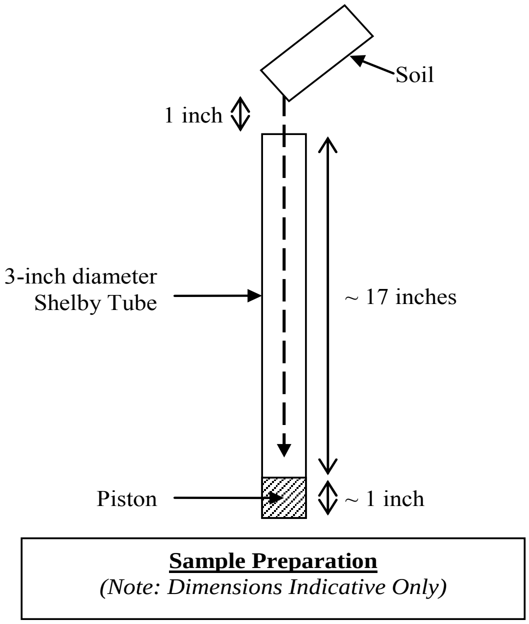


Fig. 4 – Soil preparation by re-compaction for bag samples

For the low compaction effort (1.63% of Modified Proctor compaction effort), the sample was compacted in an 18-inch long Shelby tube as follows.

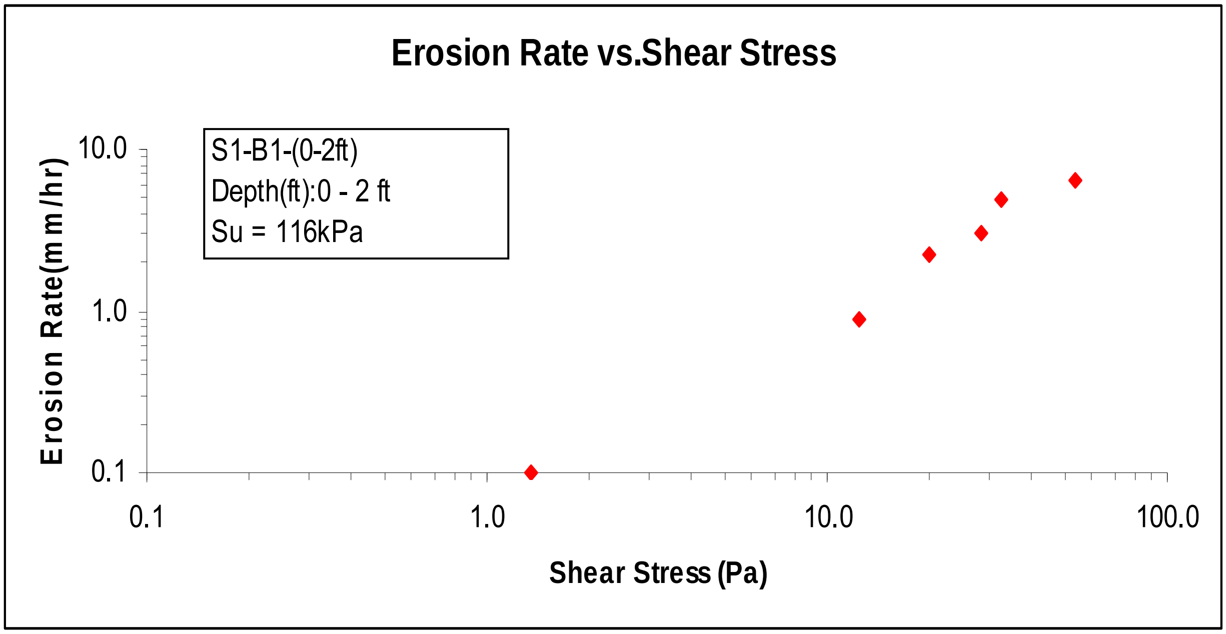
1. The total sample height was 6 inches. The sample was compacted in eight layers.
2. To form each layer, the soil was poured into the Shelby tube from a height of 1 inch above the top of the tube.
3. The soil was compacted using a 10 lb hammer (Modified Proctor hammer) with a drop height of 1 inch. Each layer was compacted by 3 hammer blows, i.e. 3 blows/layer.
4. This process was repeated until a 6 inch sample was obtained.
5. The corresponding compaction energy was 1.63% of the Standard Modified Proctor Compaction energy.

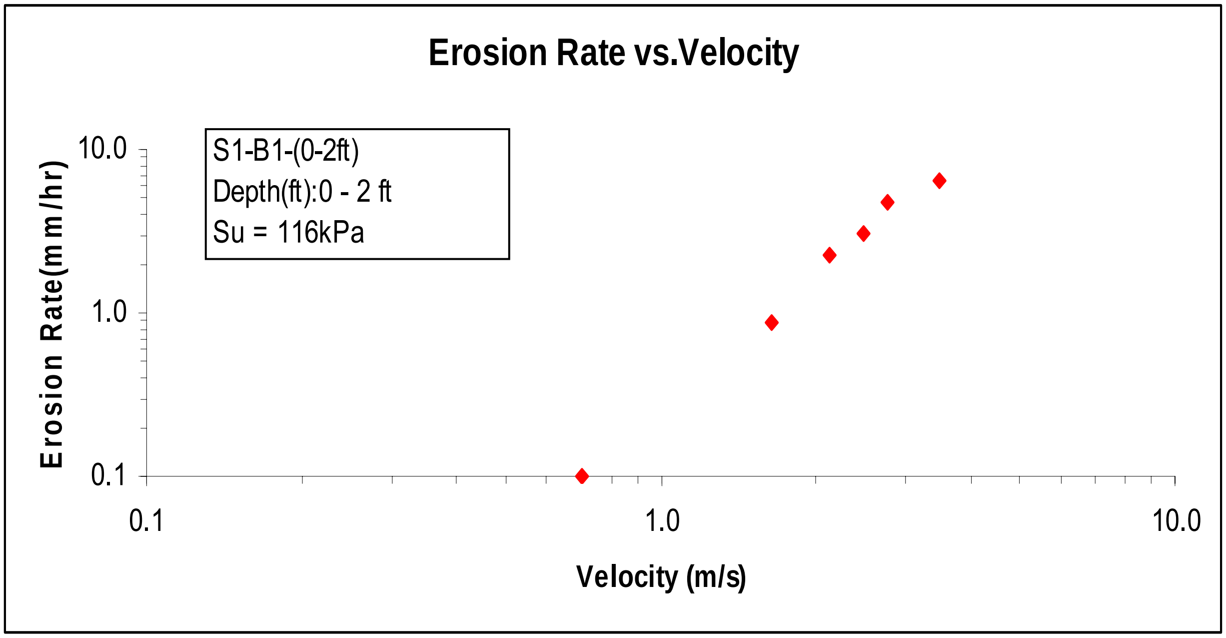
Summary test data for all erosion samples are presented in the following section.

EFA TEST RESULTS

EFA Test Results for Sample No. S1-B1-(0-2ft)-TW

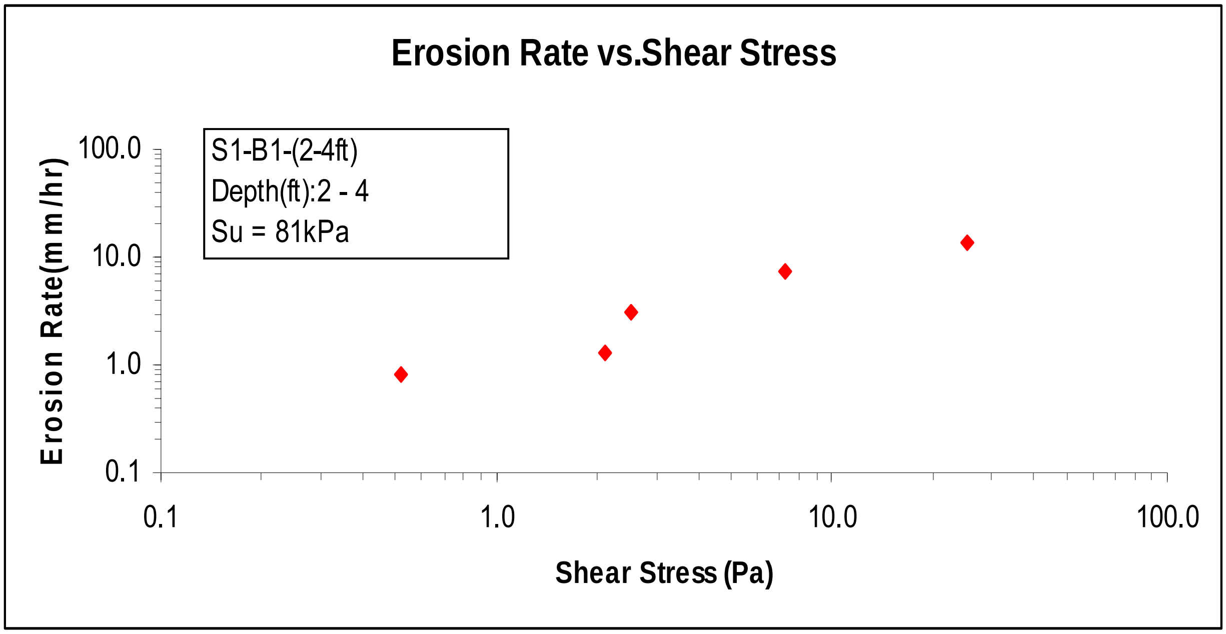
Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

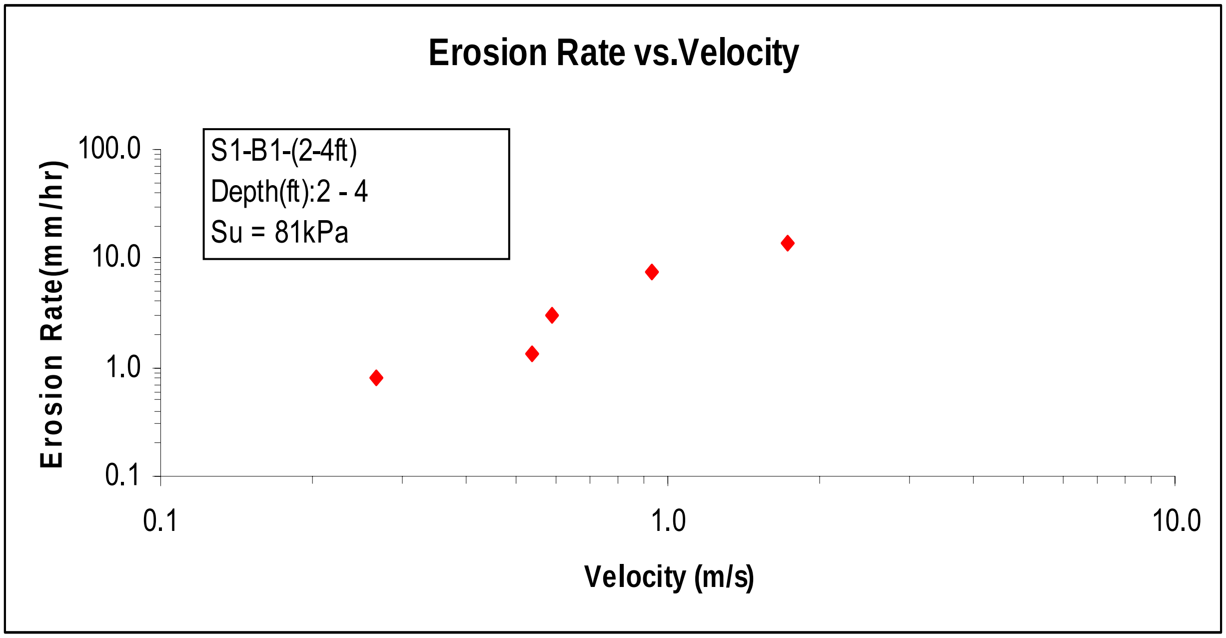




EFA Test Results for Sample No. S1-B1-(2-4ft)-SW

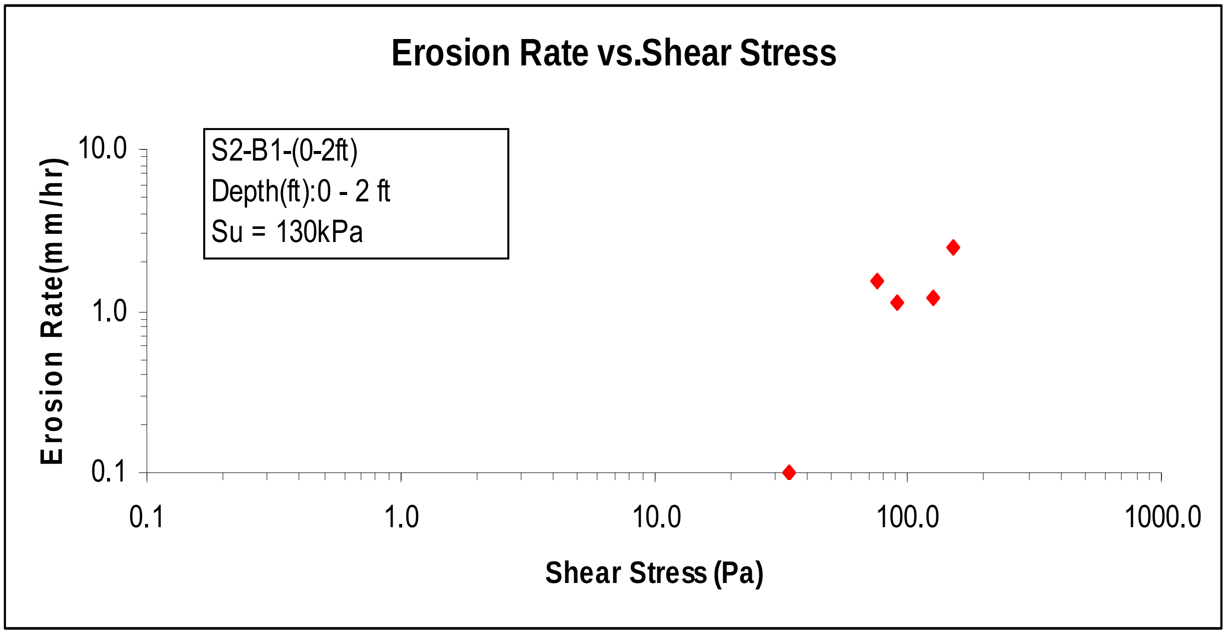
Sample Type: Shelby Tube
Water Salinity: 35.6 PPT (Salt Water)
Compaction Effort: N/A

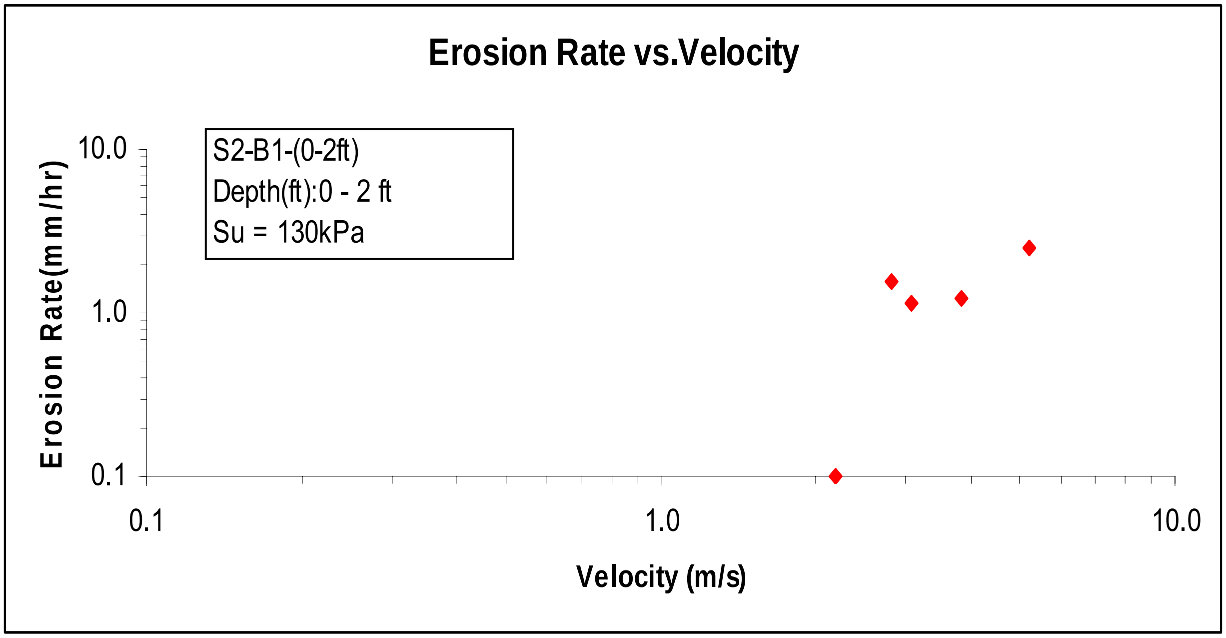




EFA Test Results for Sample No. S2-B1-(0-2ft)-TW

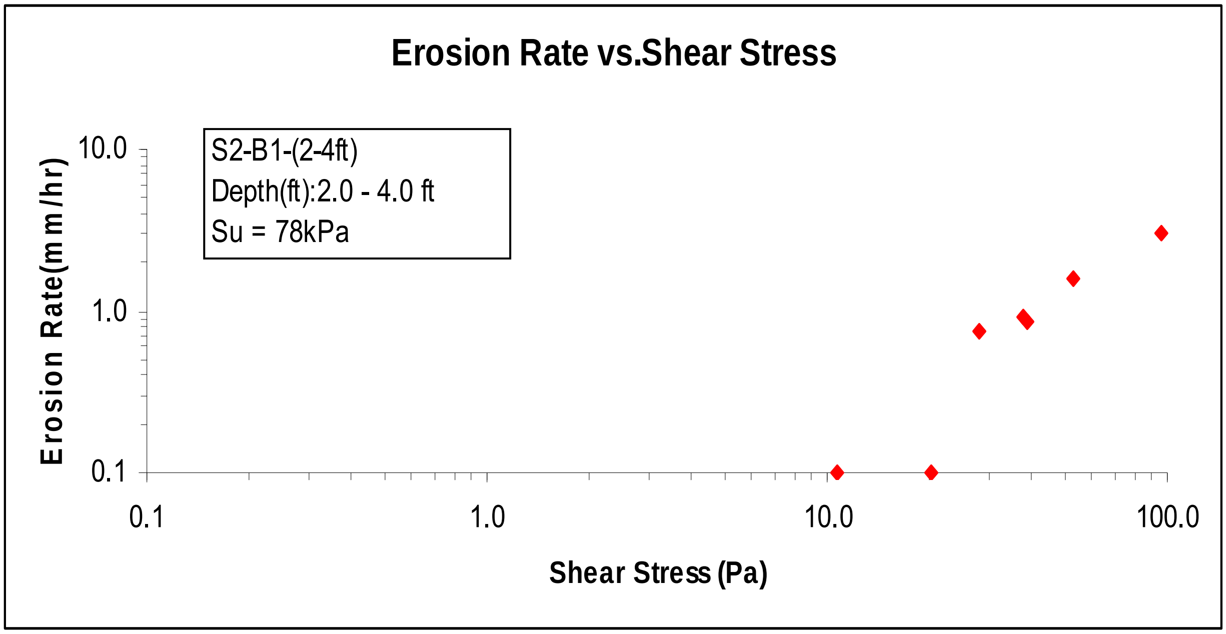
Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

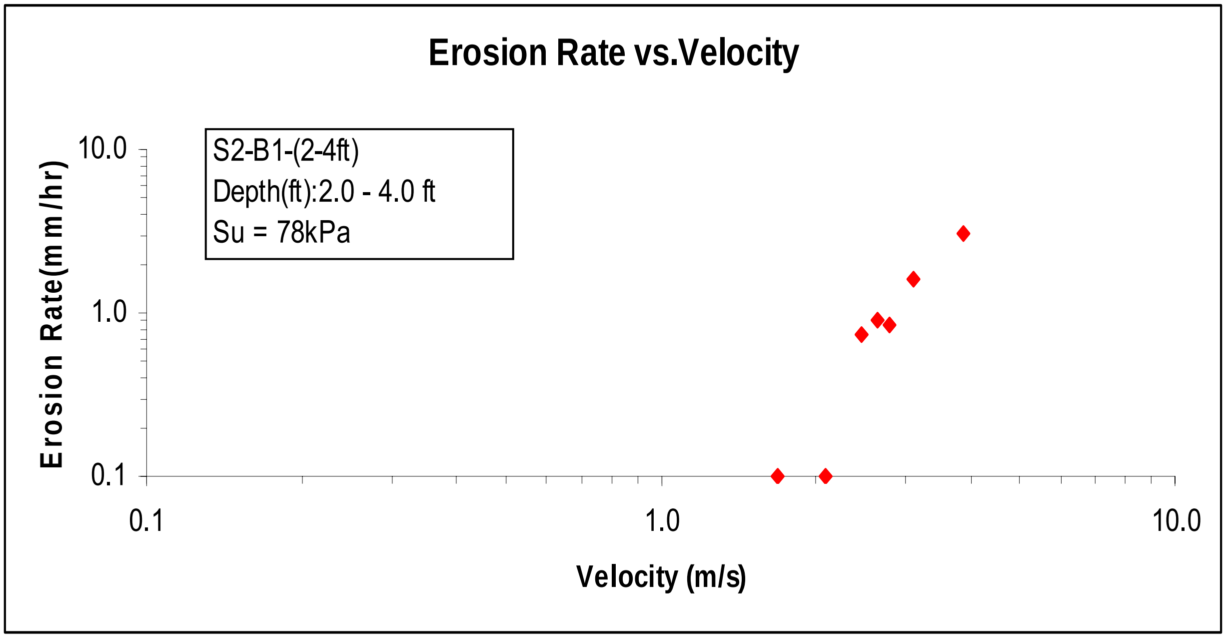




EFA Test Results for Sample No. S2-B1-(2-4ft)-SW

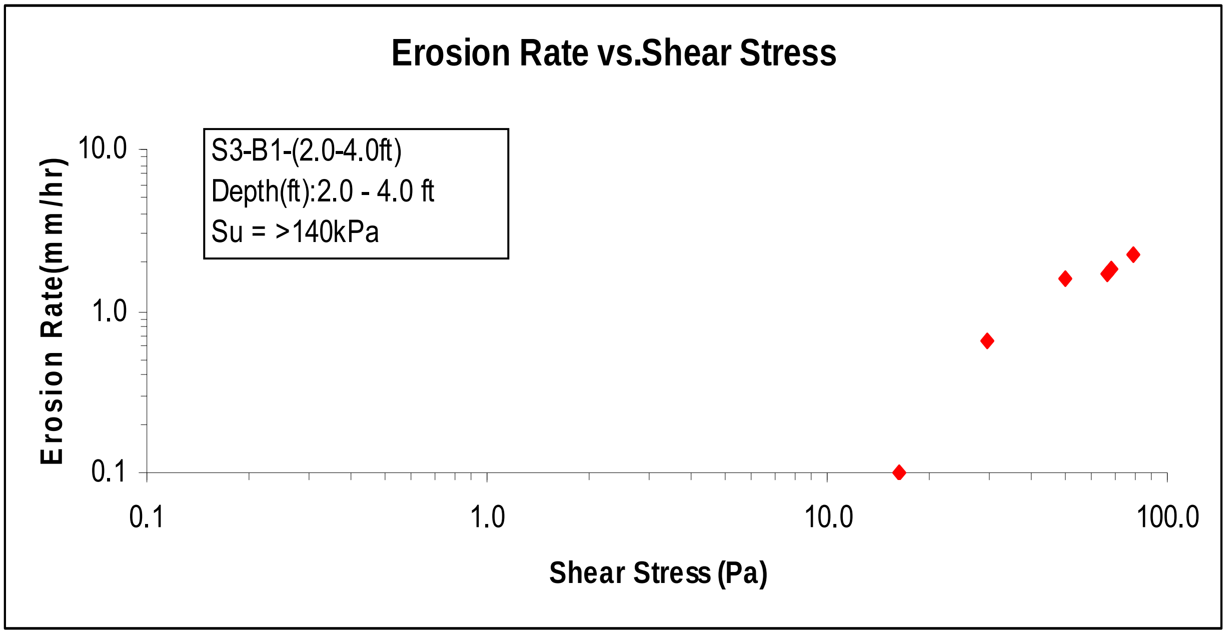
Sample Type: Shelby Tube
Water Salinity: 36.9 PPT (Salt Water)
Compaction Effort: N/A

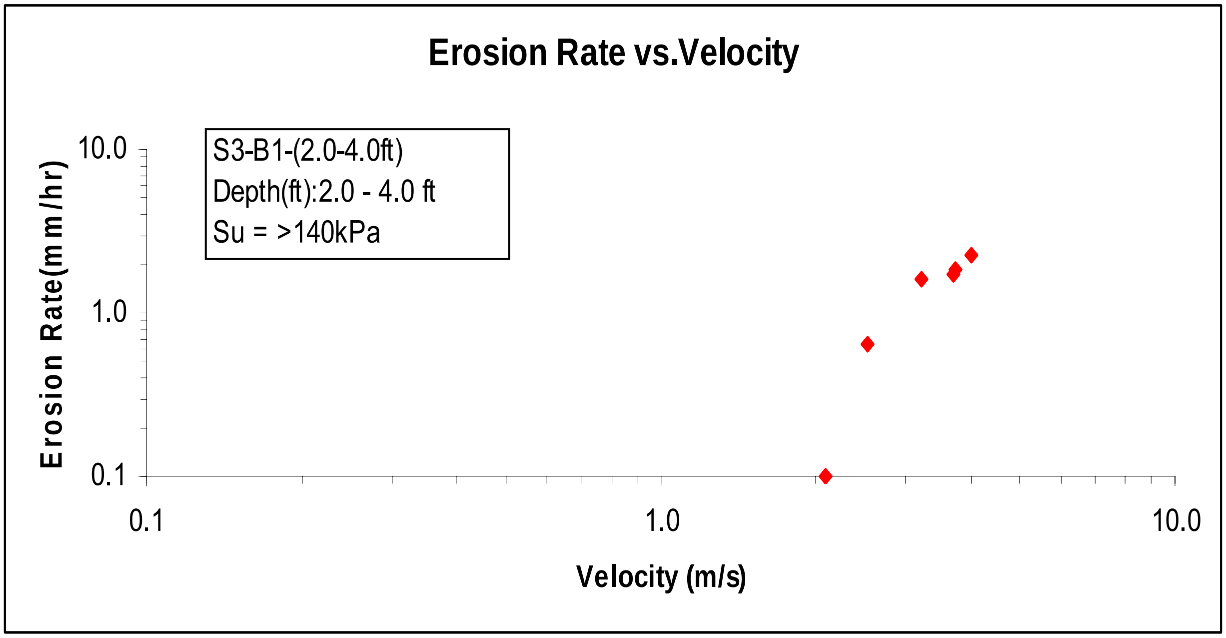




EFA Test Results for Sample No. S3-B1-(2-4ft)-SW

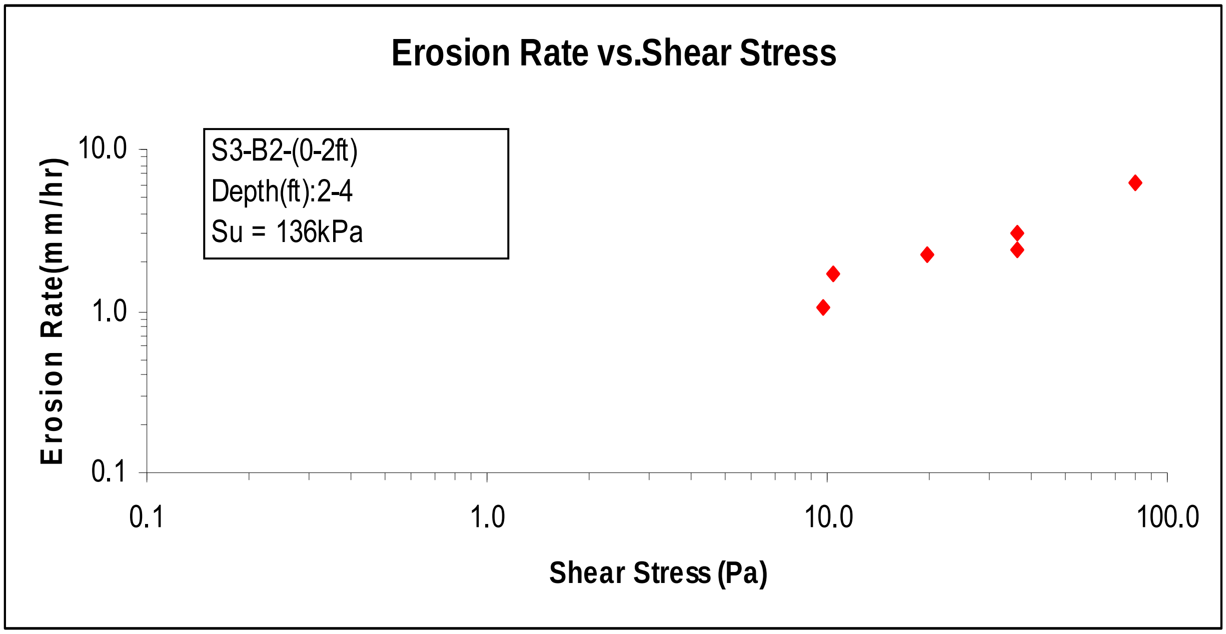
Sample Type: Shelby Tube
Water Salinity: 35.8 PPT (Salt Water)
Compaction Effort: N/A

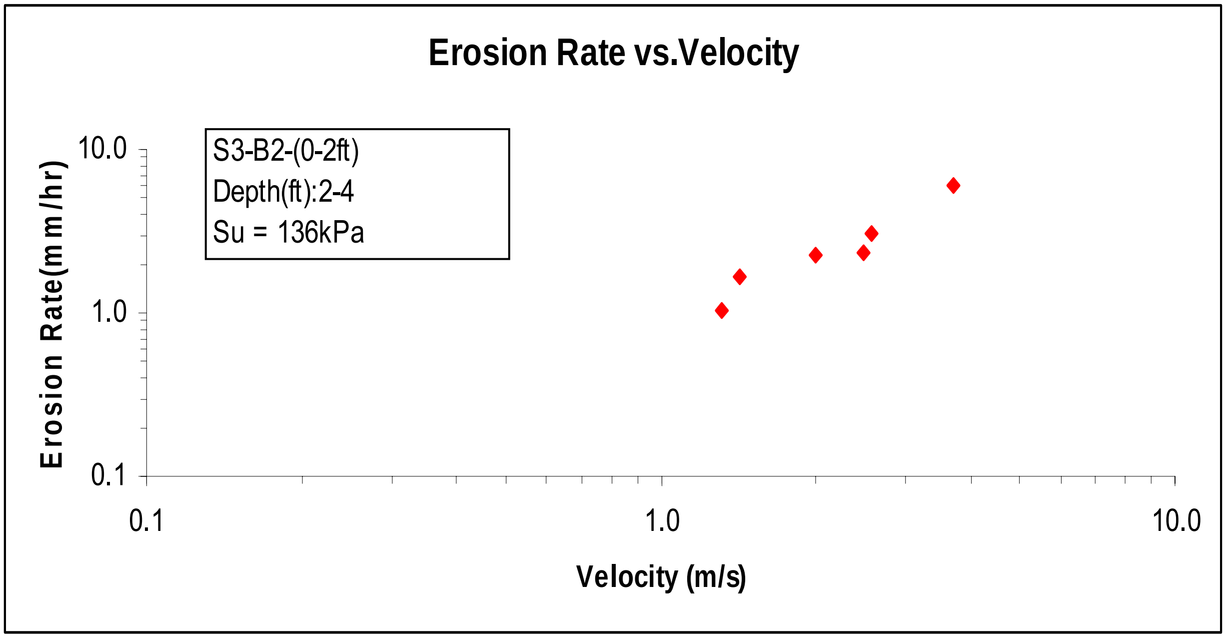




EFA Test Results for Sample No. S3-B2-(0-2ft)-SW

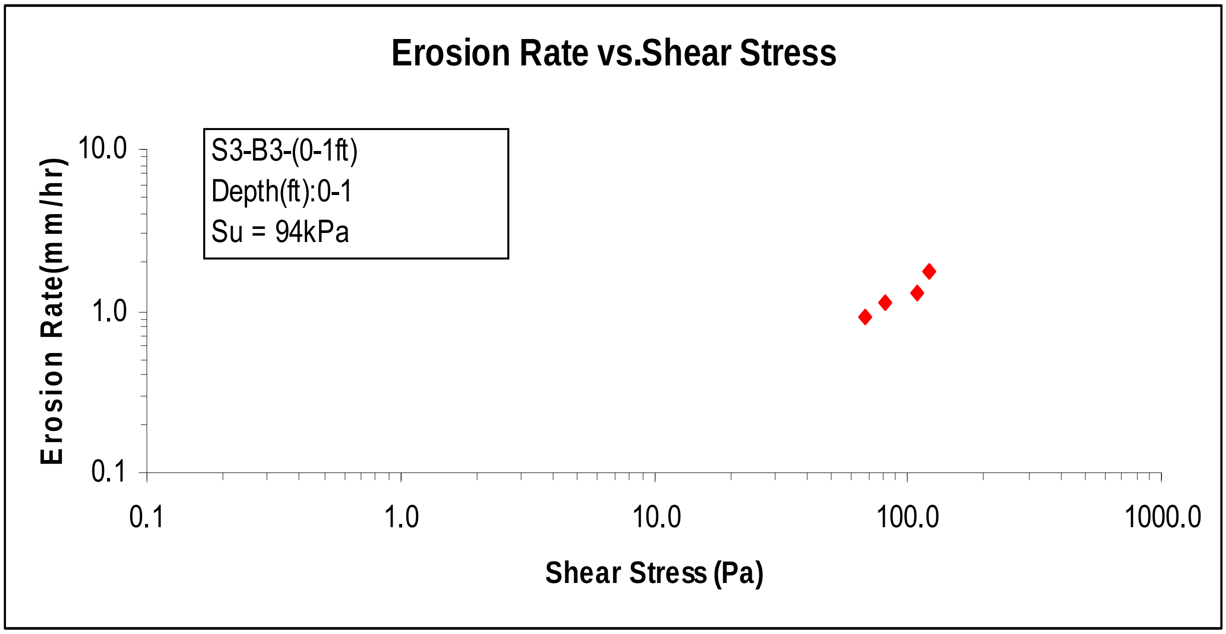
Sample Type: Shelby Tube
Water Salinity: 36.5 PPT (Salt Water)
Compaction Effort: N/A

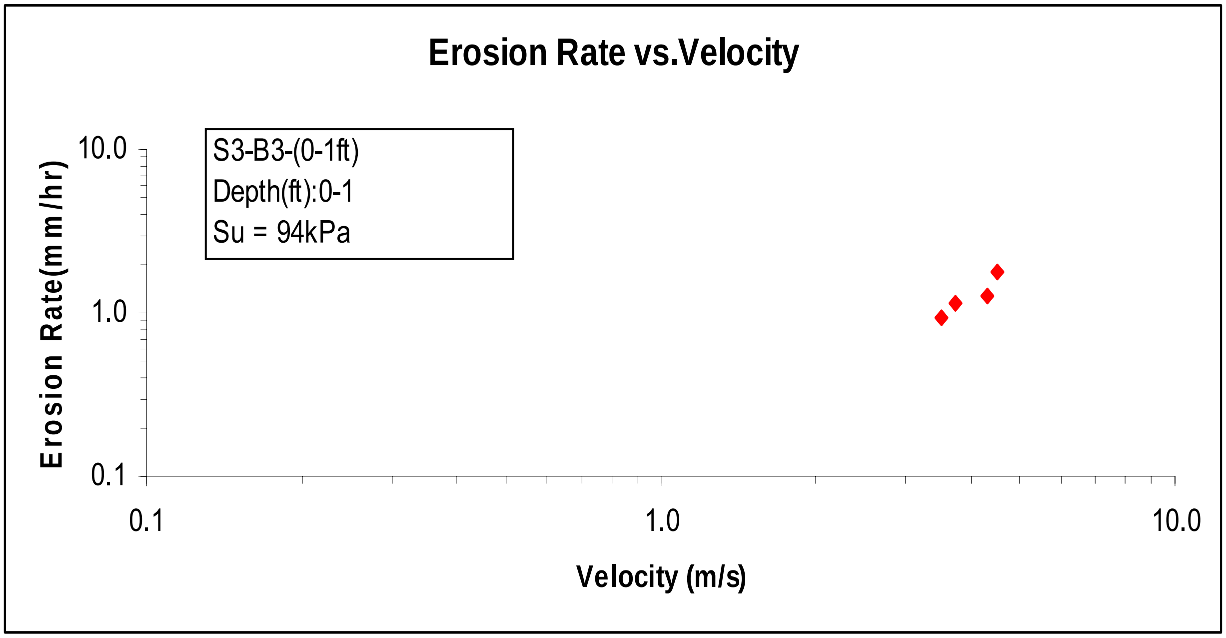




EFA Test Results for Sample No. S3-B3-(0-1ft)-SW

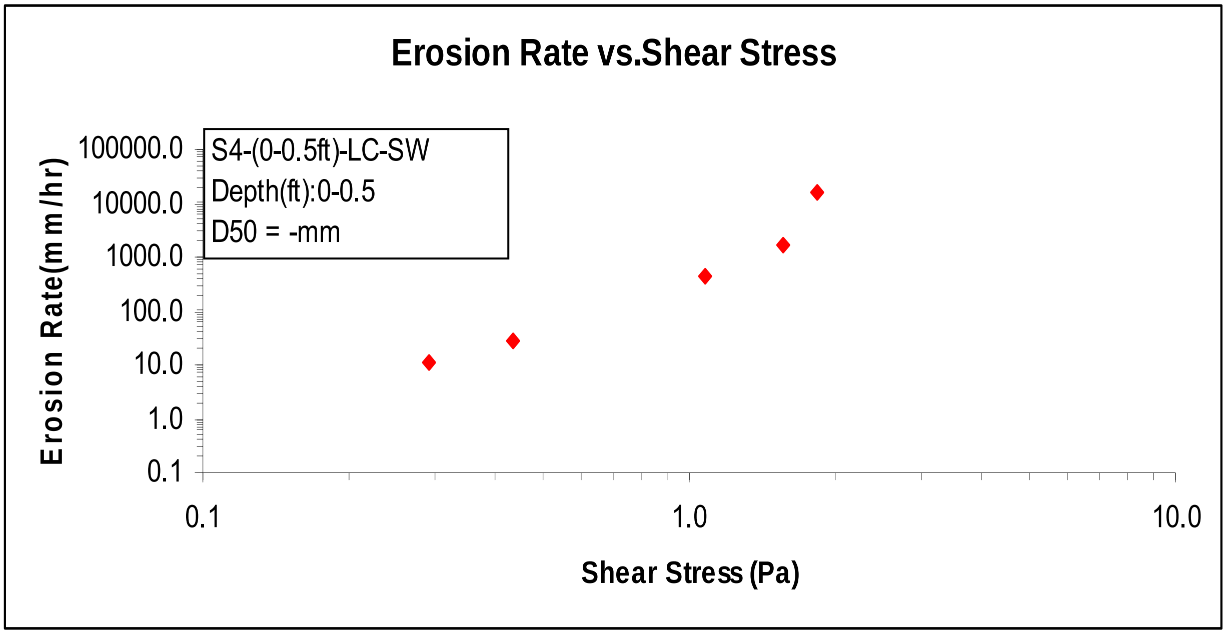
Sample Type: Shelby Tube
Water Salinity: 36.4 PPT (Salt Water)
Compaction Effort: N/A

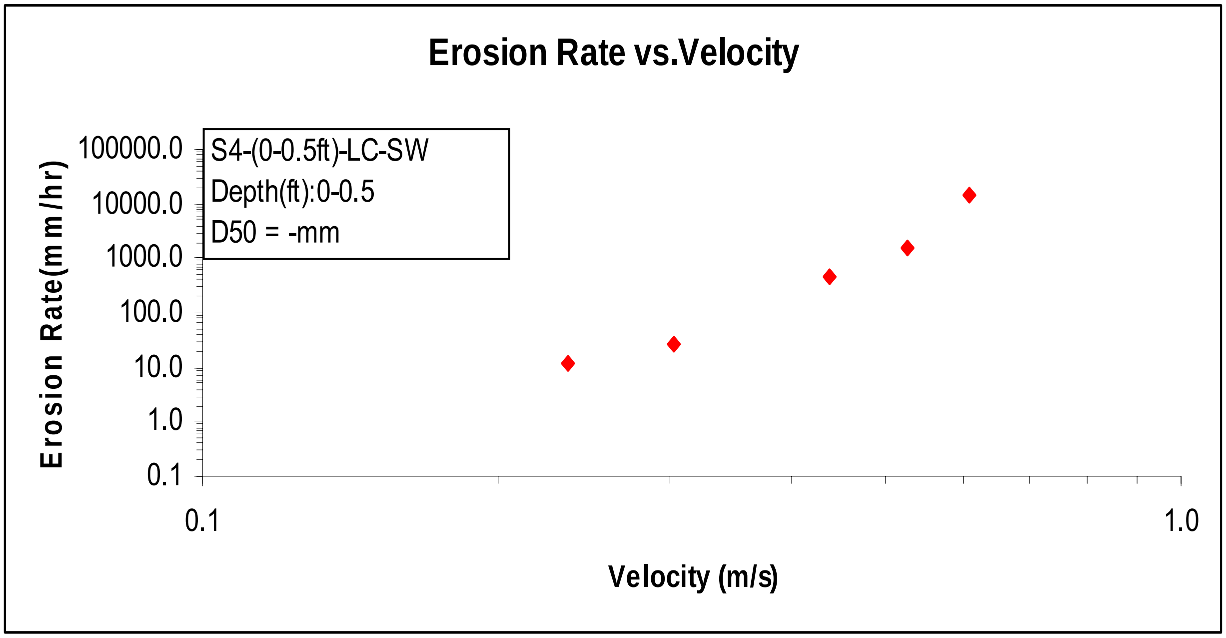




EFA Test Results for Sample No. S4-(0-0.5ft)-LC-SW

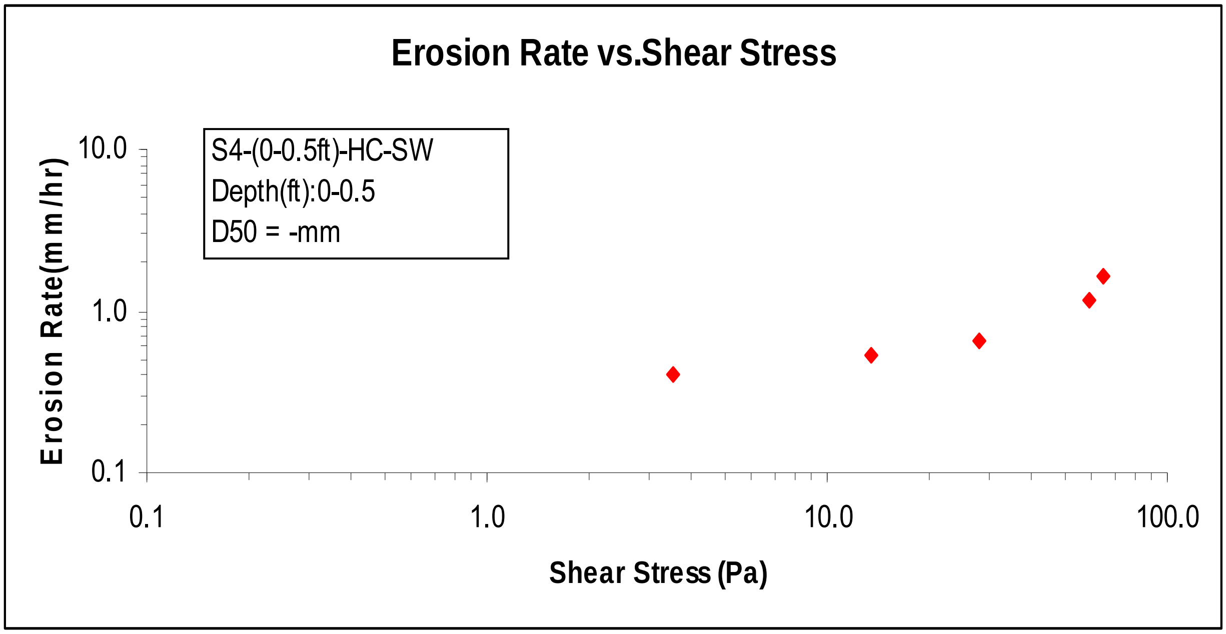
Sample Type: Bulk Sample
Water Salinity: 36.1 PPT (Salt Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction

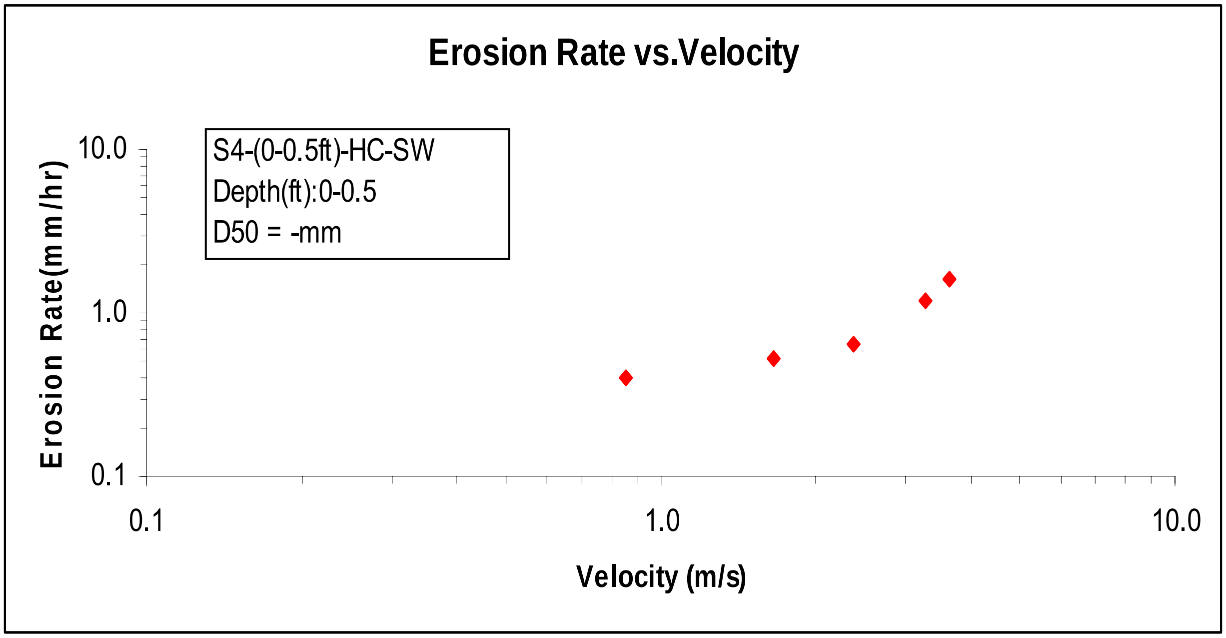




EFA Test Results for Sample No. S4-(0-0.5ft)-HC-SW

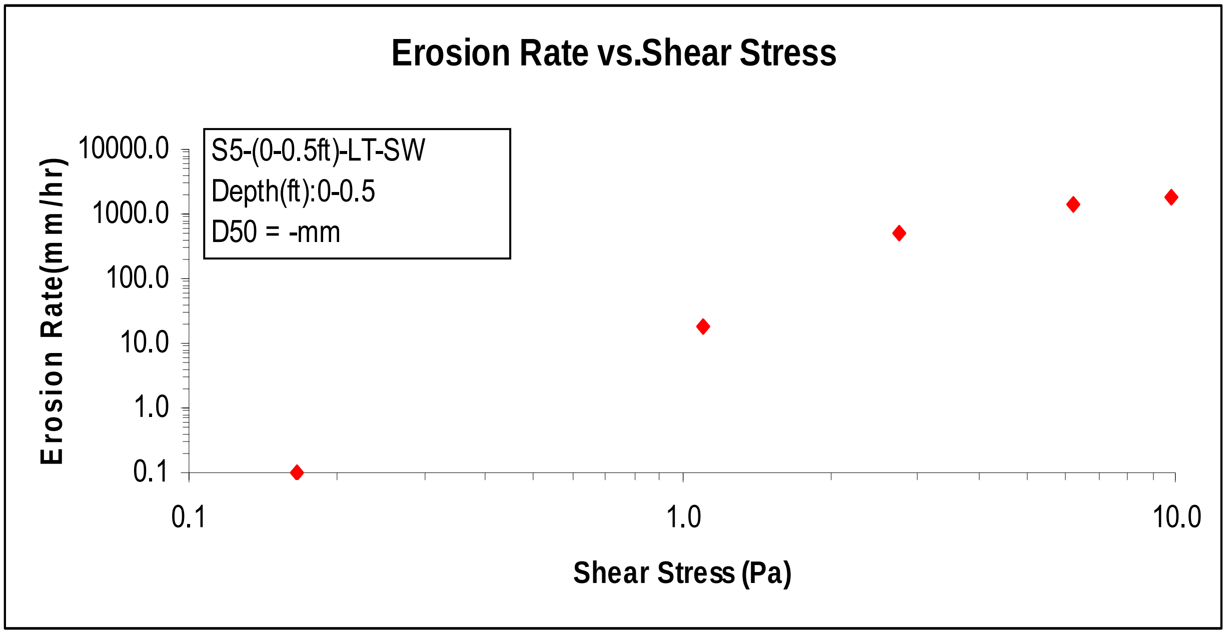
Sample Type: Bulk Sample
Water Salinity: 35.7 PPT (Salt Water)
Compaction Effort: High = 100% Modified Proctor Compaction

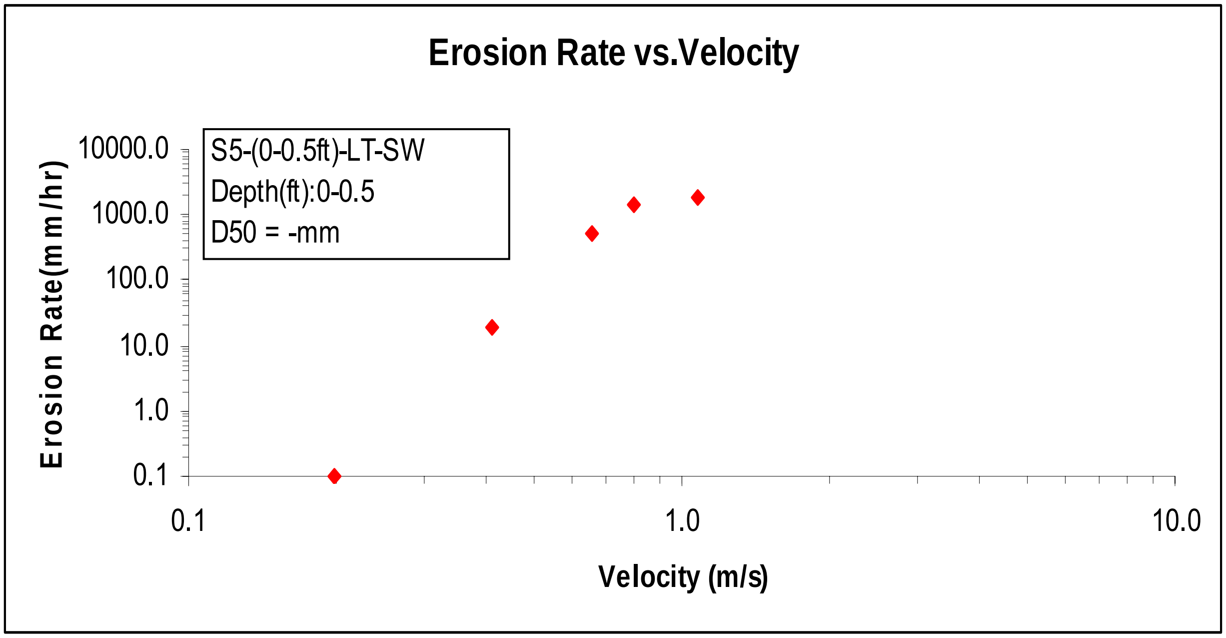




EFA Test Results for Sample No. S5-(0-0.5ft)-LT-SW

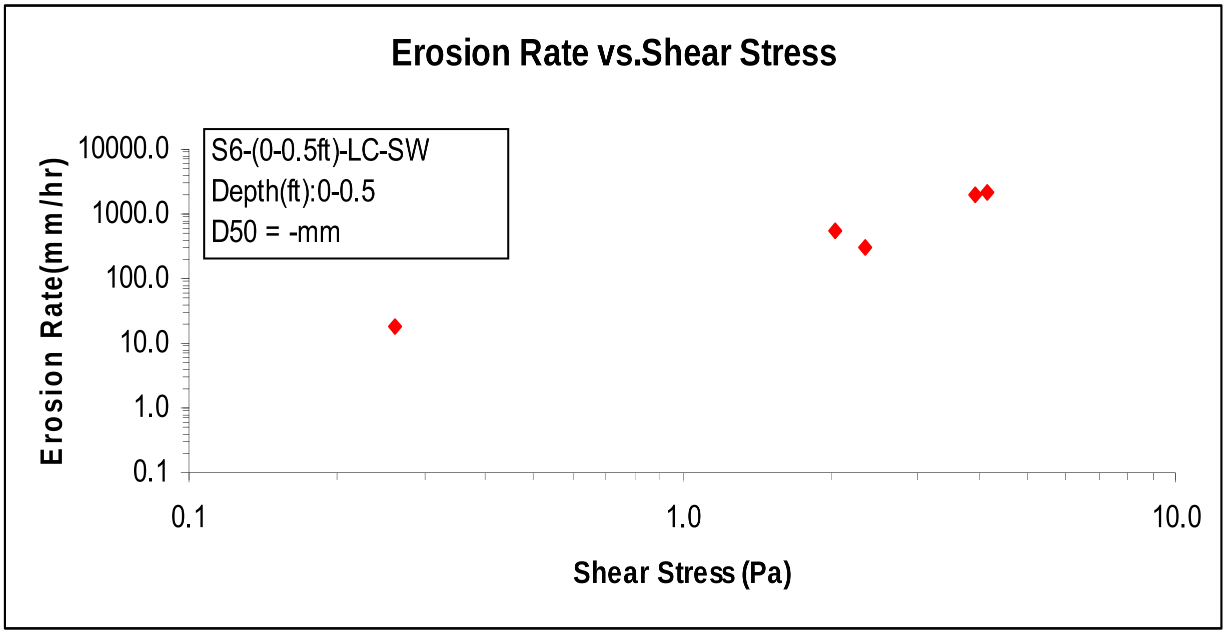
Sample Type: Bulk Sample
Water Salinity: 36.2 PPT (Salt Water)
Compaction Effort: Light Tamping

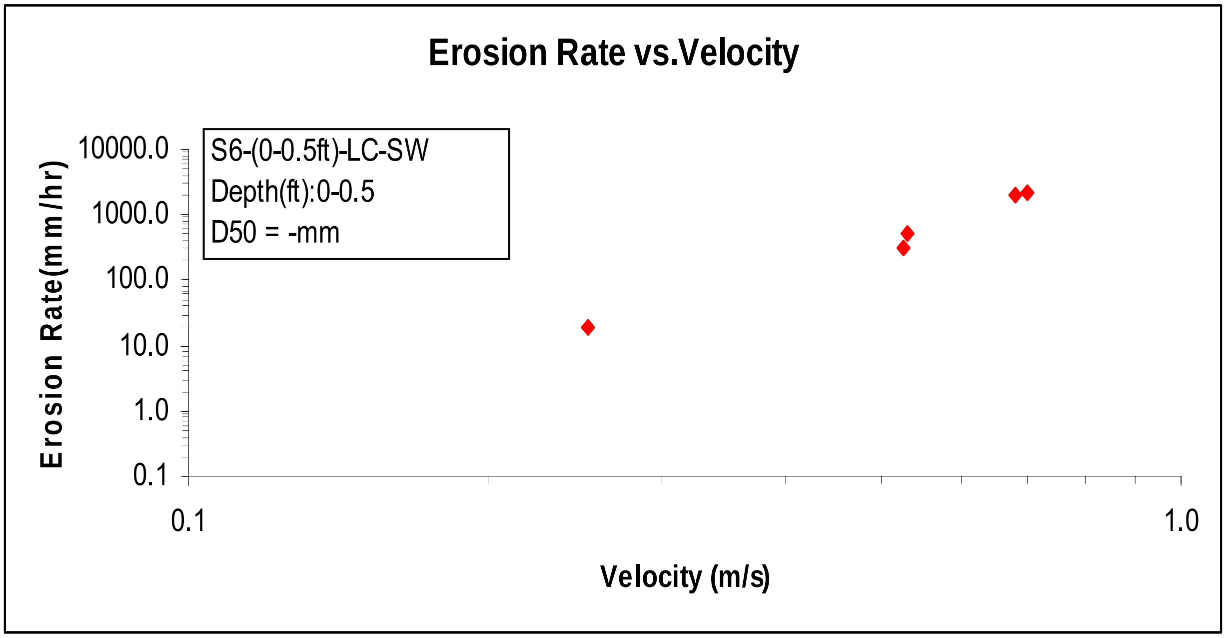




EFA Test Results for Sample No. S6-(0-0.5ft)-LC-SW

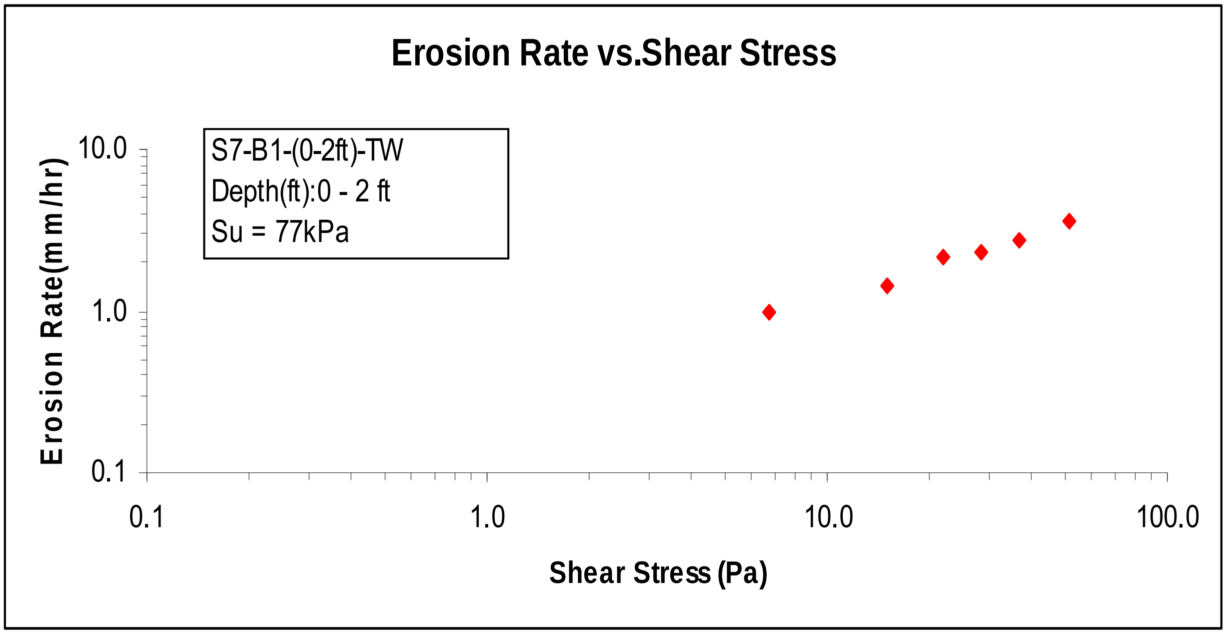
Sample Type: Bulk Sample
Water Salinity: 36.5 PPT (Salt Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction

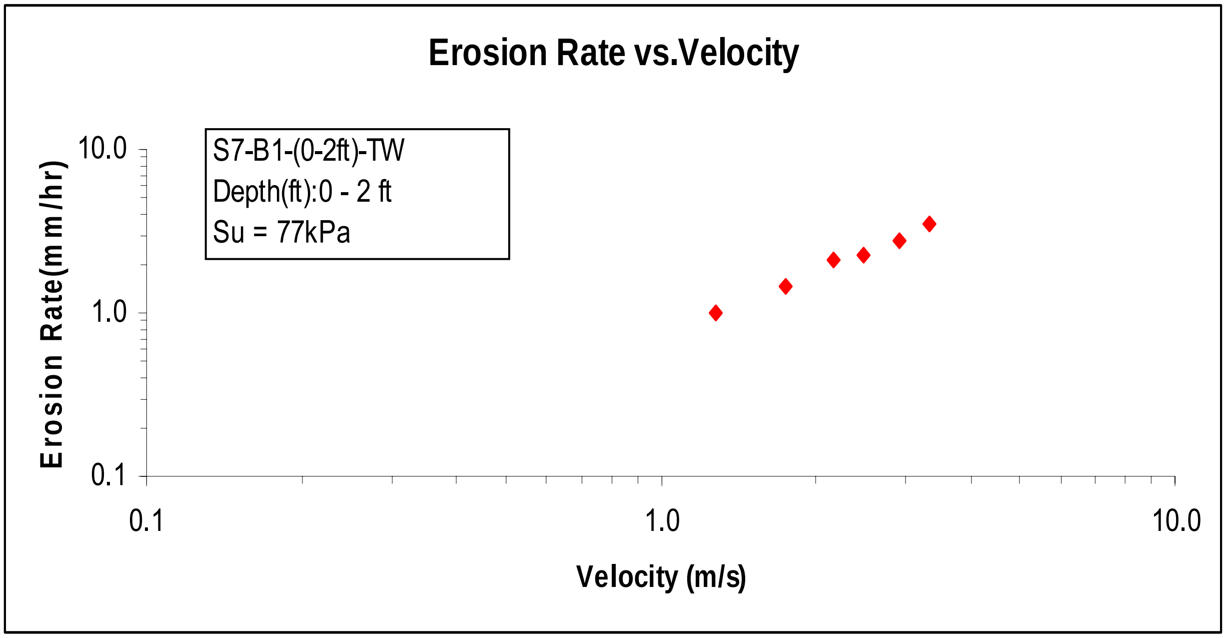




EFA Test Results for Sample No. S7-B1-(0-2ft)-TW

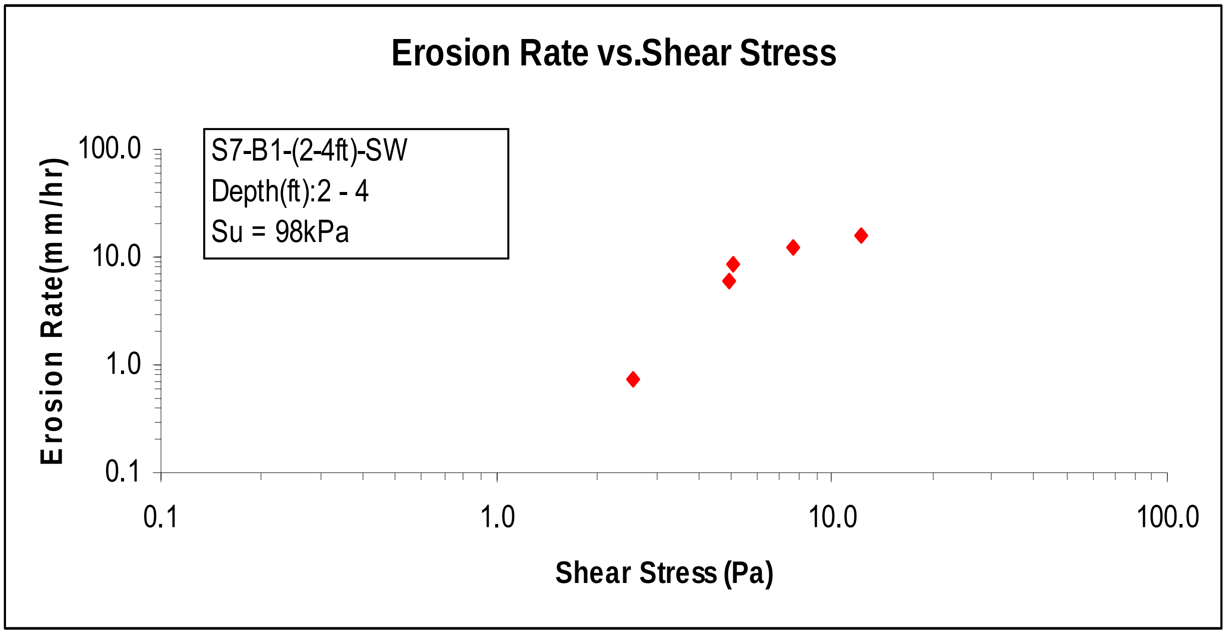
Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

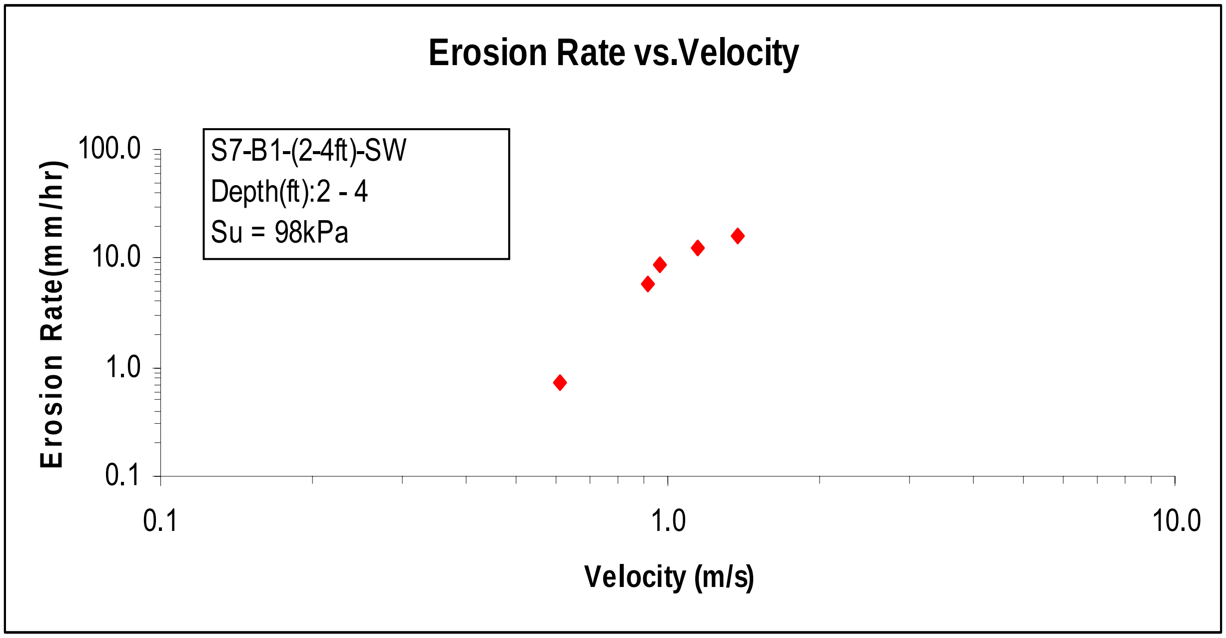




EFA Test Results for Sample No. S7-B1-(2-4ft)-SW

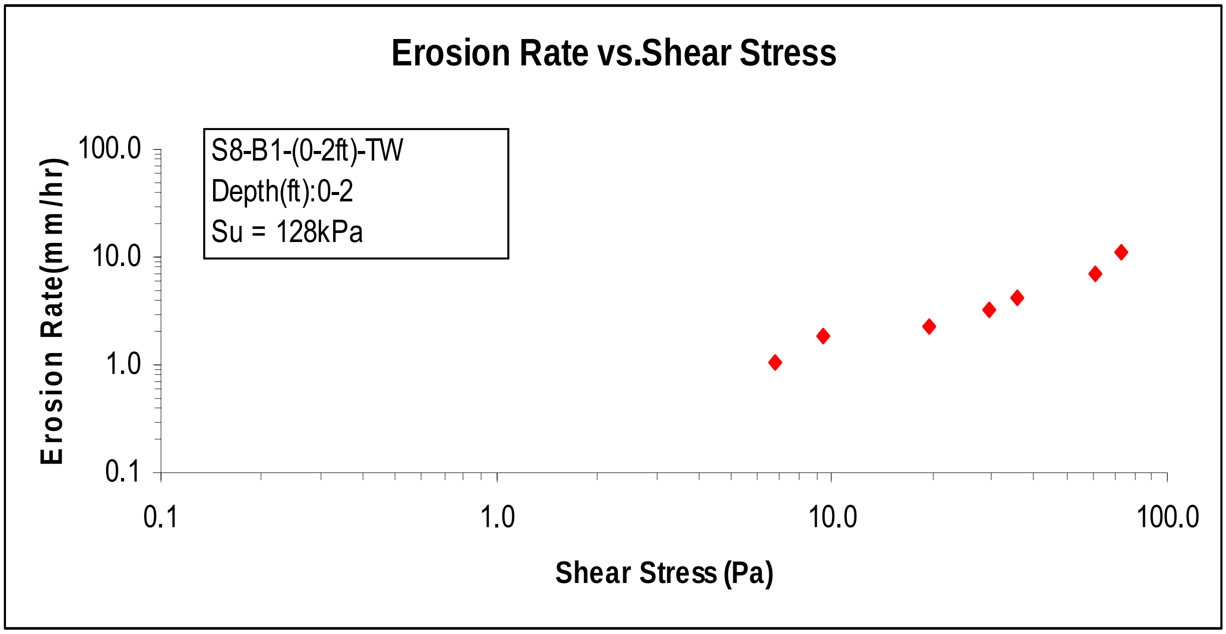
Sample Type: Shelby Tube
Water Salinity: 36.9 PPT (Salt Water)
Compaction Effort: N/A

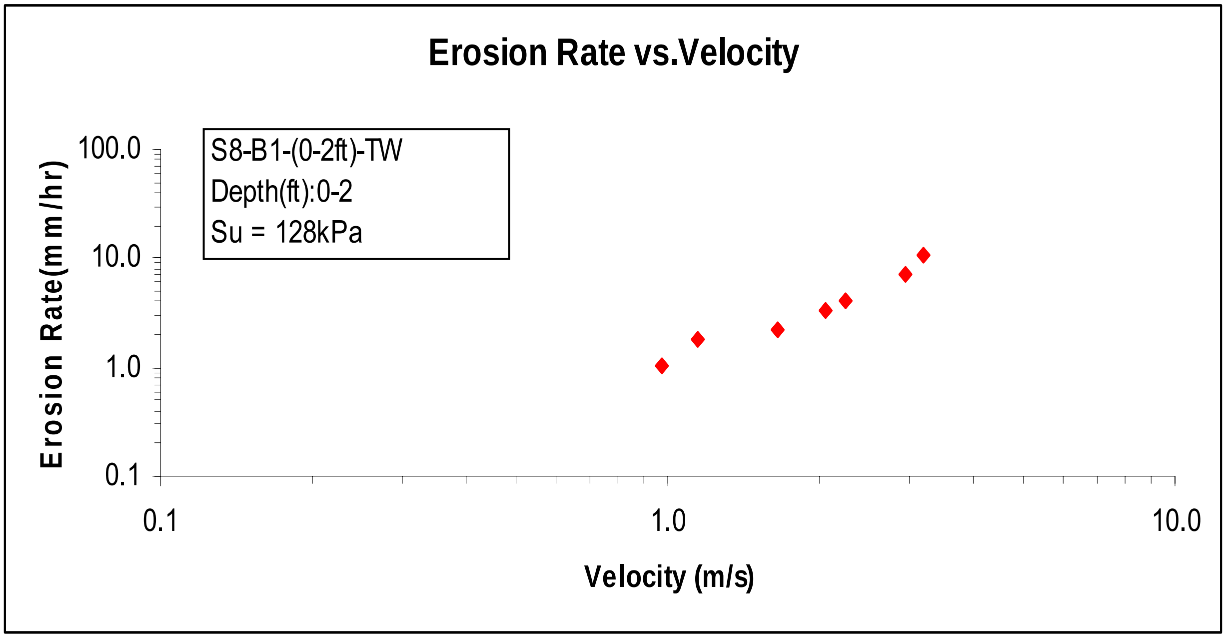




EFA Test Results for Sample No. S8-B1-(0-2ft)-TW

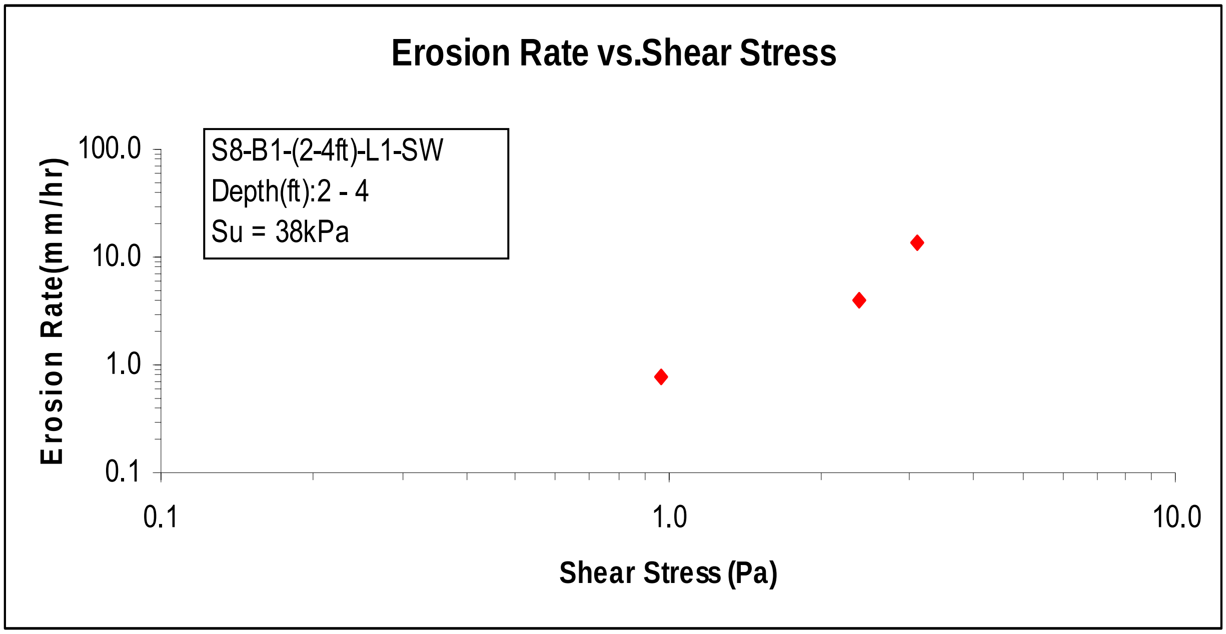
Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

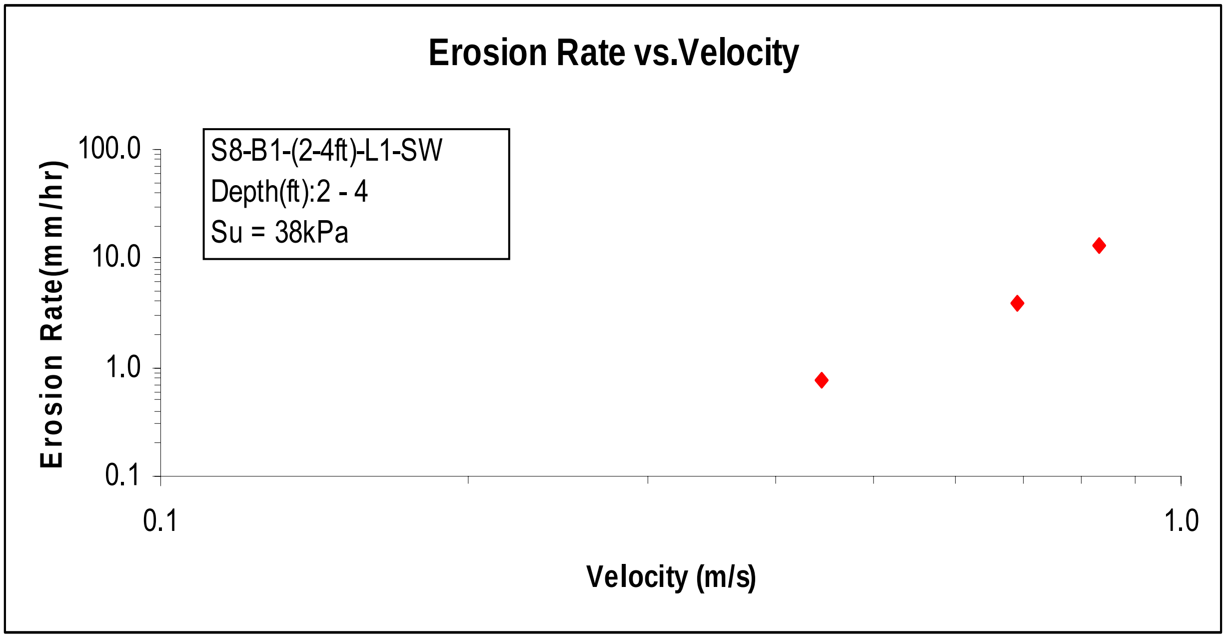




EFA Test Results for Sample No. S8-B1-(2-4ft)-L1-SW

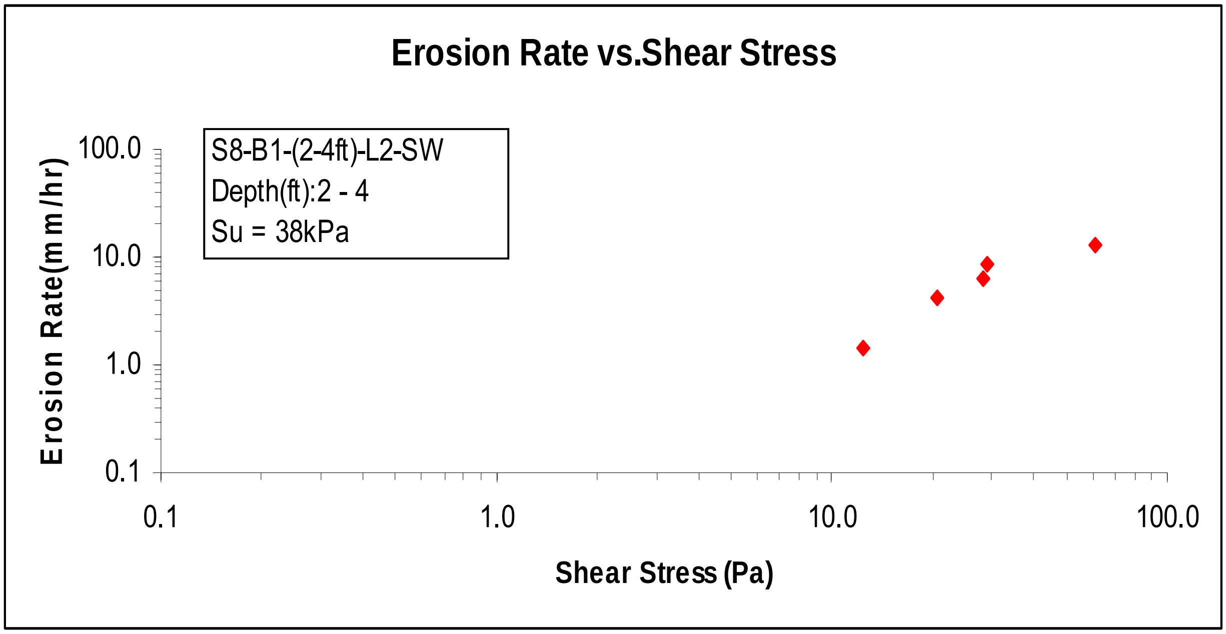
Sample Type: Shelby Tube
Water Salinity: 38.3 PPT (Salt Water)
Compaction Effort: N/A

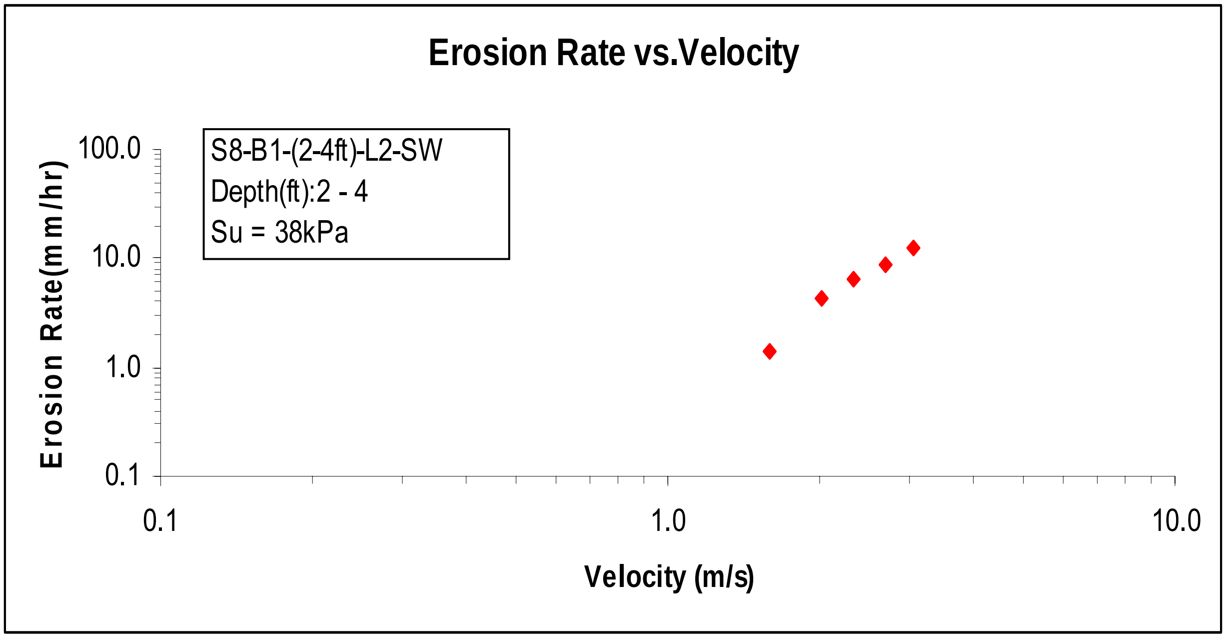




EFA Test Results for Sample No. S8-B1-(2-4ft)-L2-SW

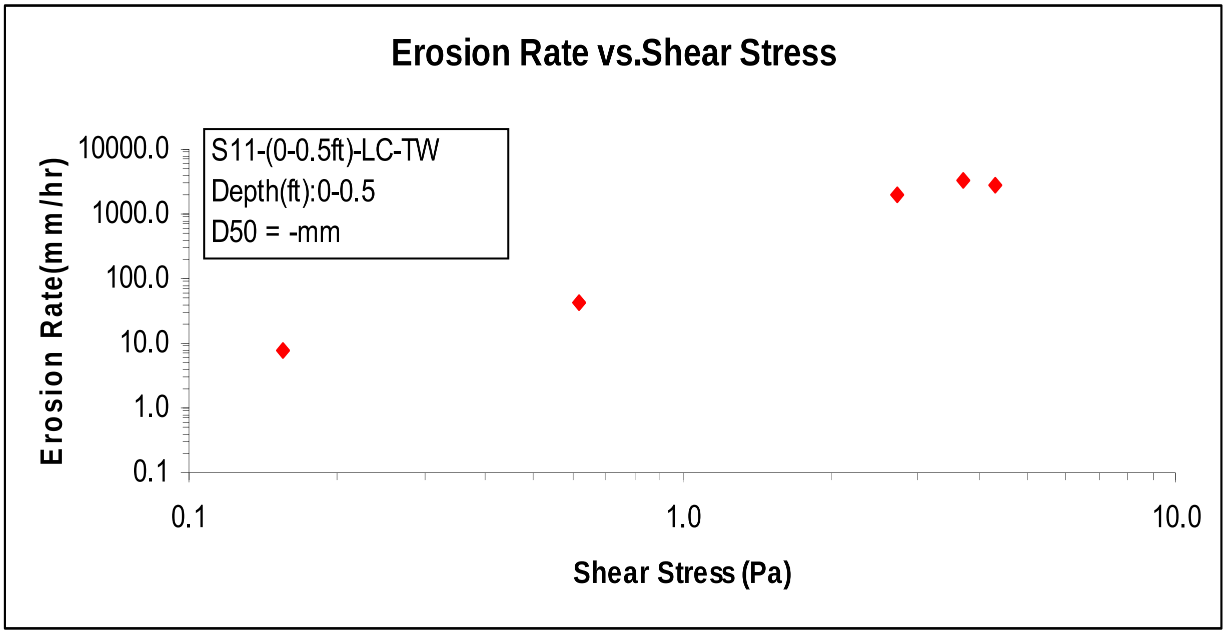
Sample Type: Shelby Tube
Water Salinity: 38.3 PPT (Salt Water)
Compaction Effort: N/A

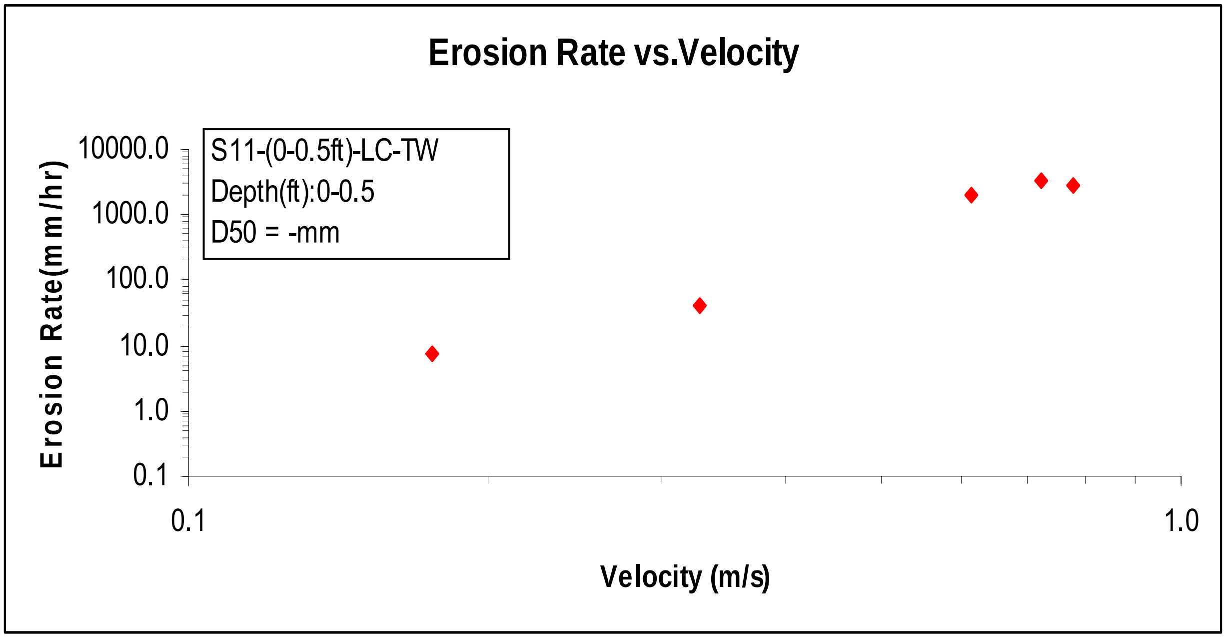




EFA Test Results for Sample No. S11-(0-0.5ft)-LC-TW

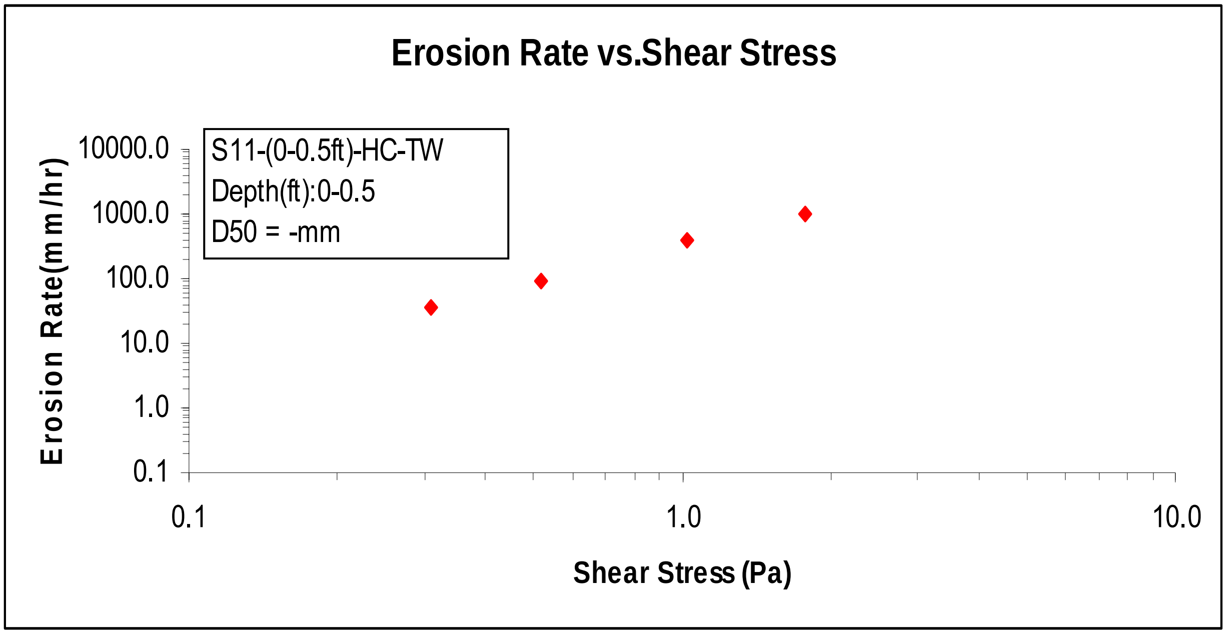
Sample Type: Bulk Sample
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction

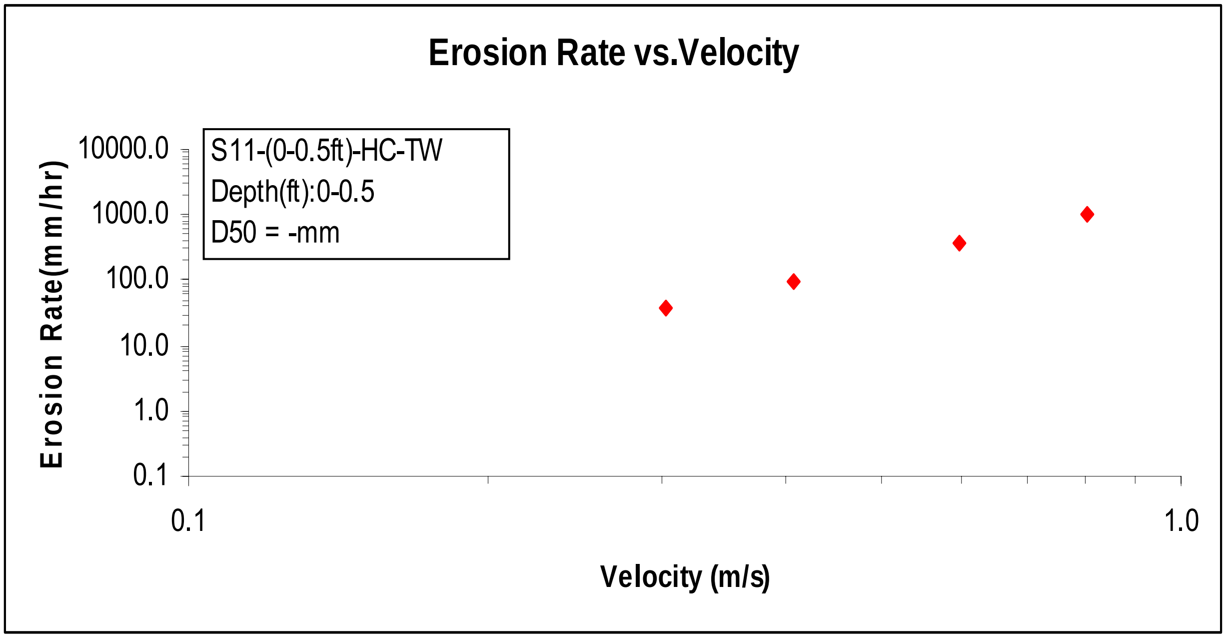




EFA Test Results for Sample No. S11-(0-0.5ft)-HC-TW

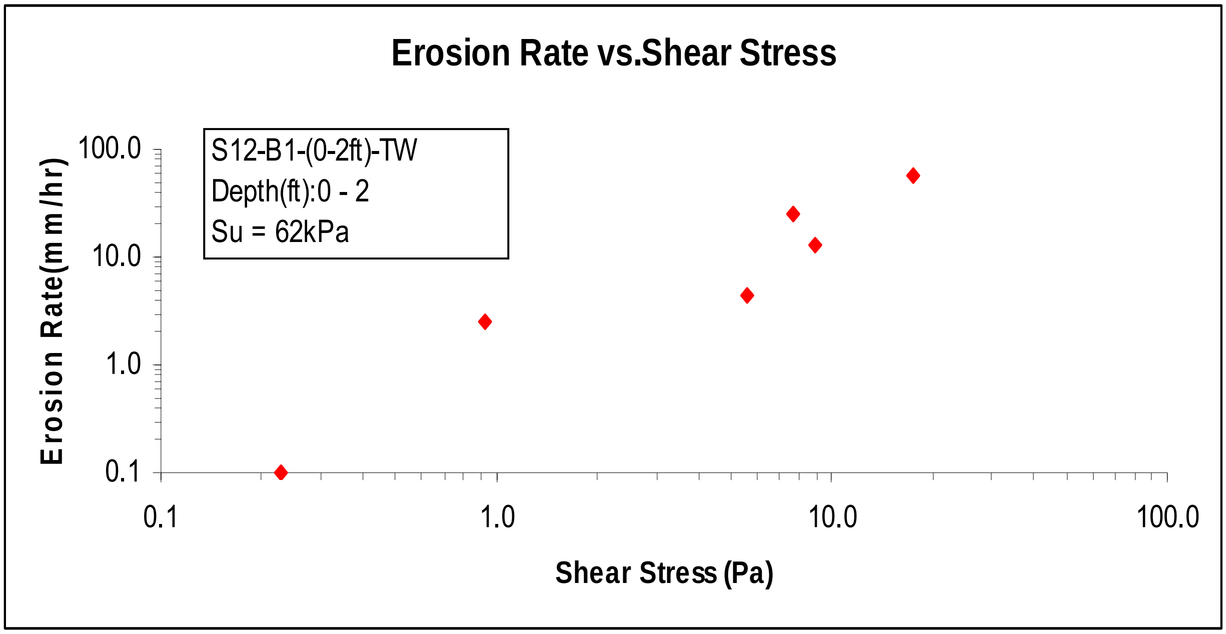
Sample Type: Bulk Sample
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: High = 100% Modified Proctor Compaction

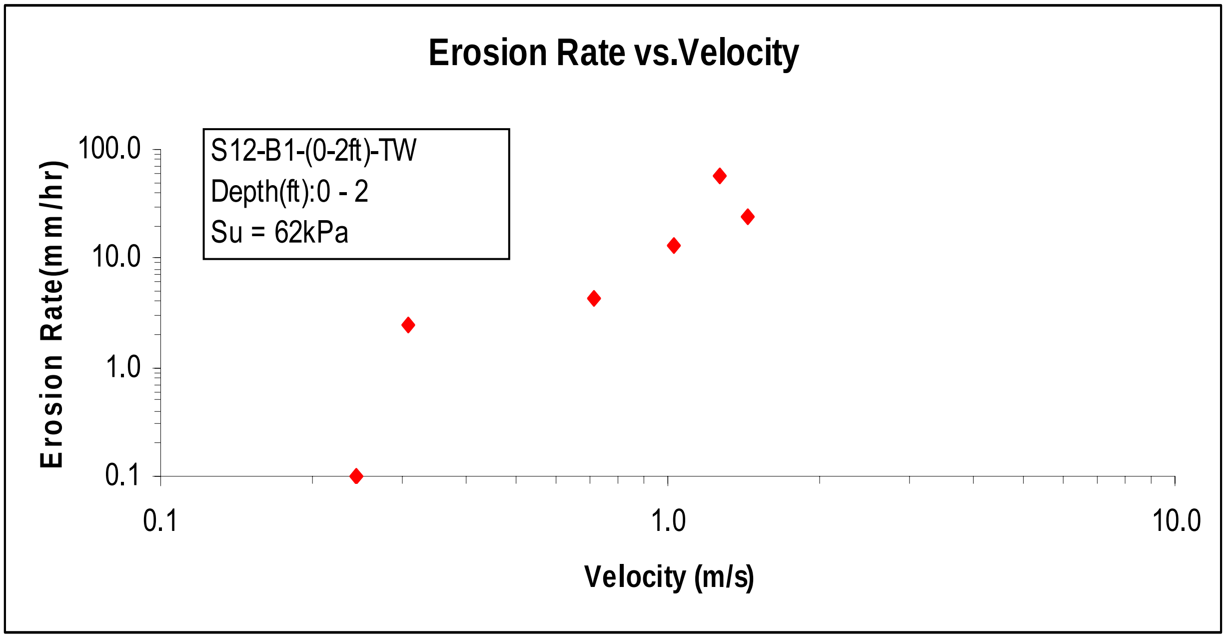




EFA Test Results for Sample No. S12-B1-(0-2ft)-TW

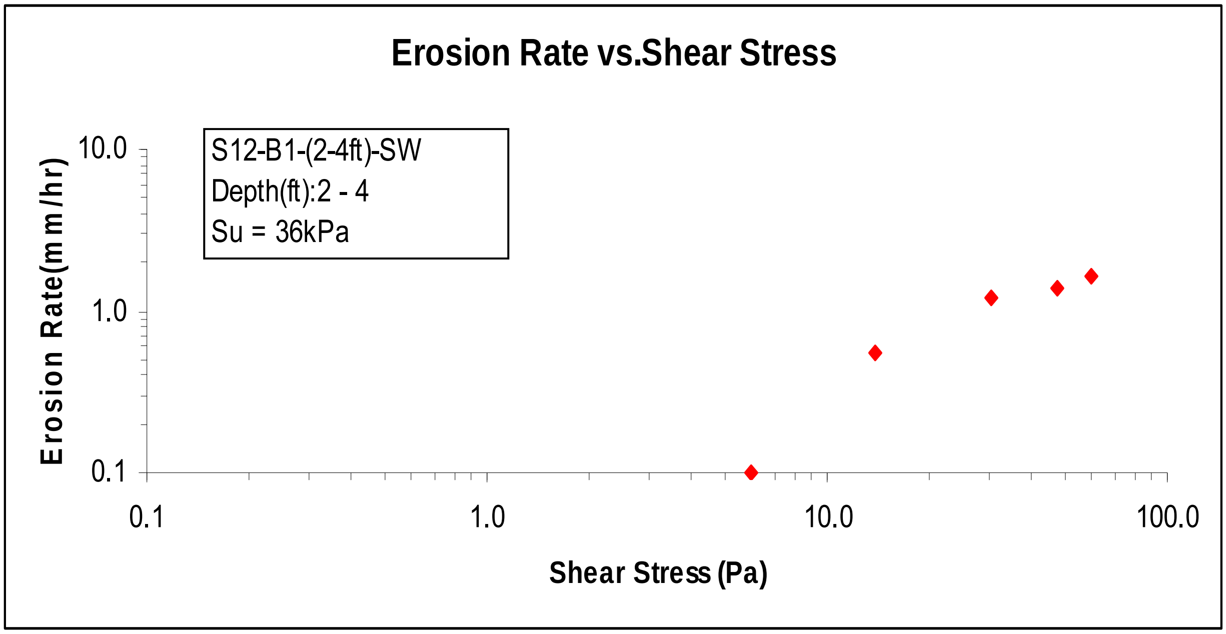
Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

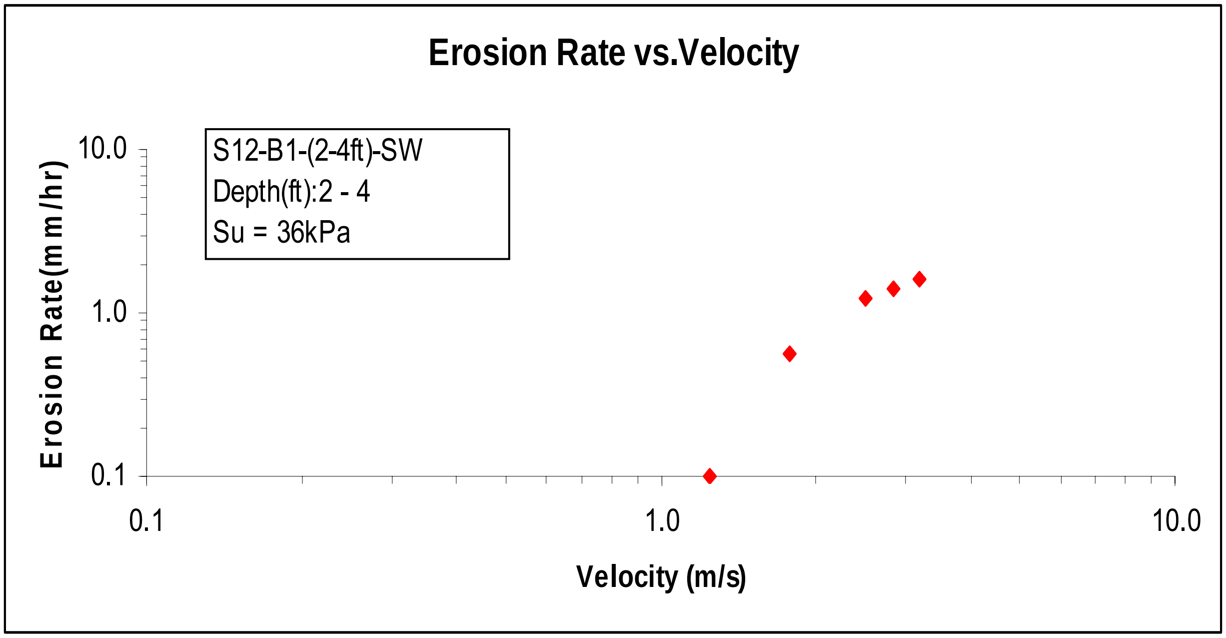




EFA Test Results for Sample No. S12-B1-(2-4ft)-SW

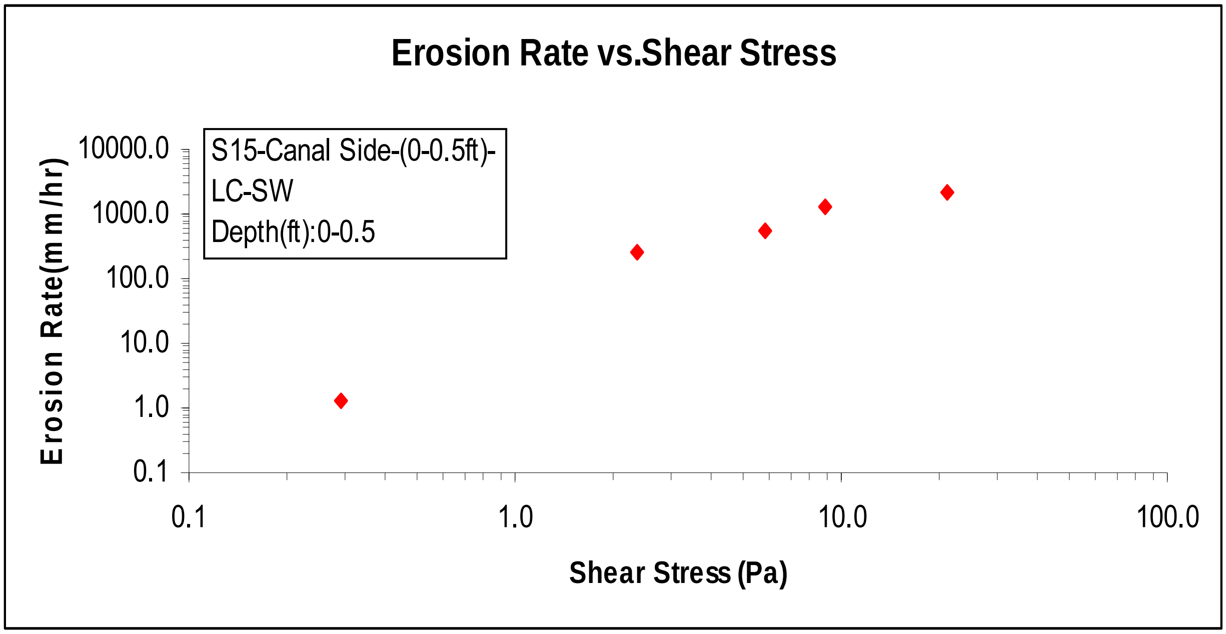
Sample Type: Shelby Tube
Water Salinity: 36.0 PPT (Salt Water)
Compaction Effort: N/A

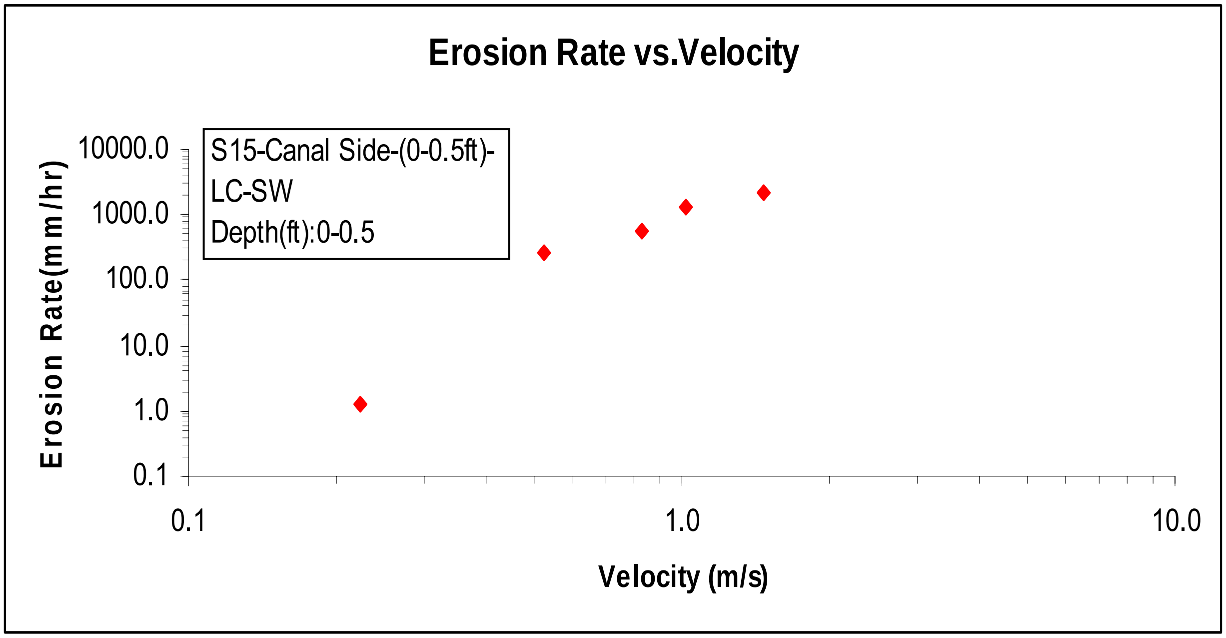




EFA Test Results for Sample No. S15-Canal Side-(0-0.5ft)-LC-SW

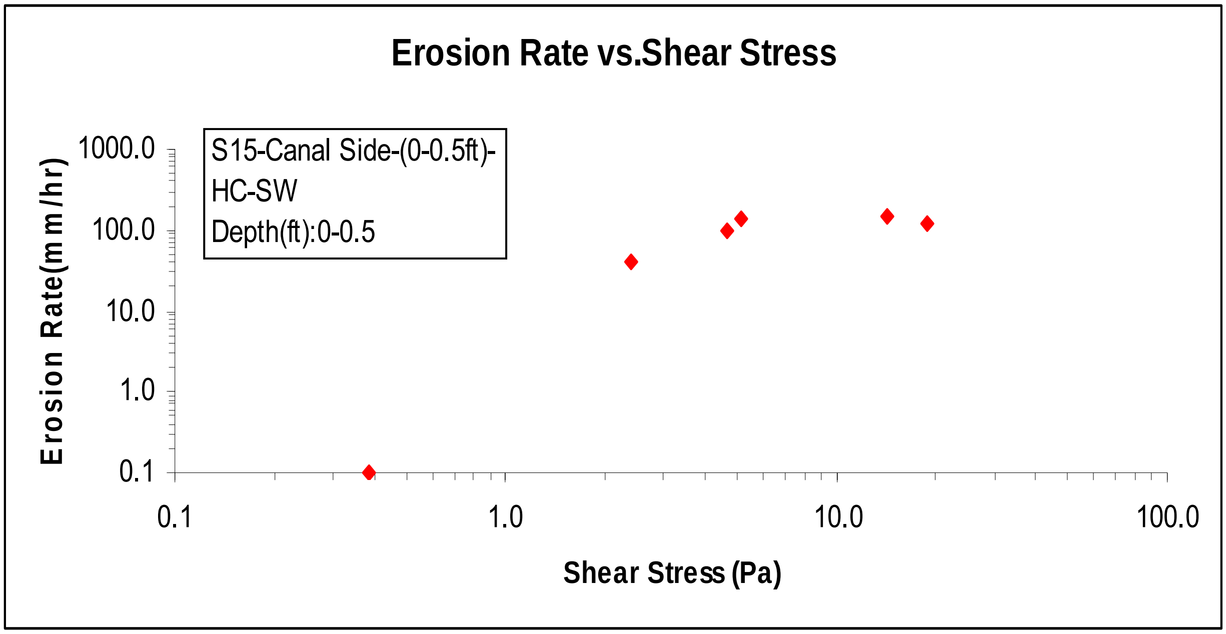
Sample Type: Bulk Sample
Water Salinity: 36.4 PPT (Salt Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction

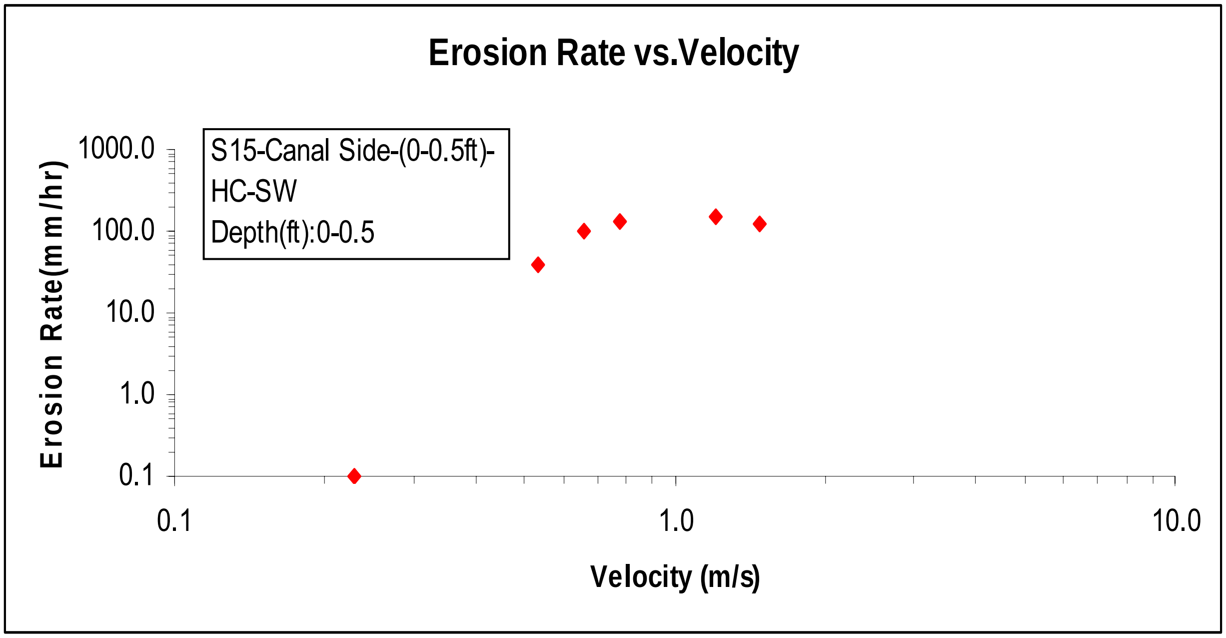




EFA Test Results for Sample No. S15-Canal Side-(0-0.5ft)-HC-SW

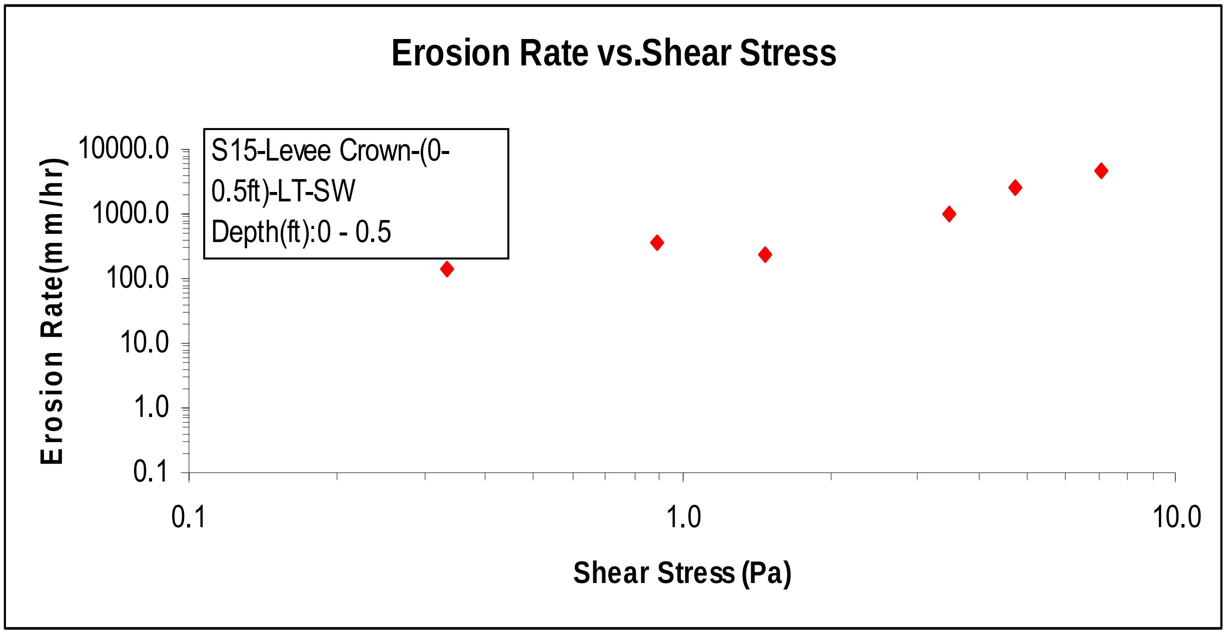
Sample Type: Bulk Sample
Water Salinity: 36.5 PPT (Salt Water)
Compaction Effort: High = 100% Modified Proctor Compaction

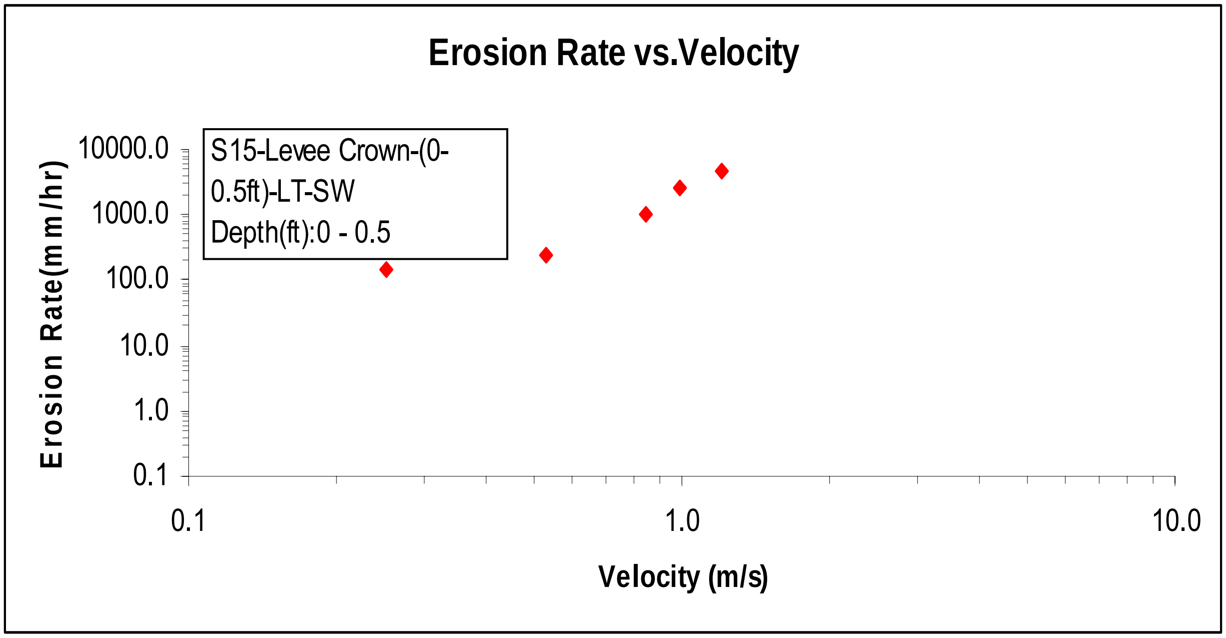




EFA Test Results for Sample No. S15-Levee Crown-(0-0.5ft)-LT-SW

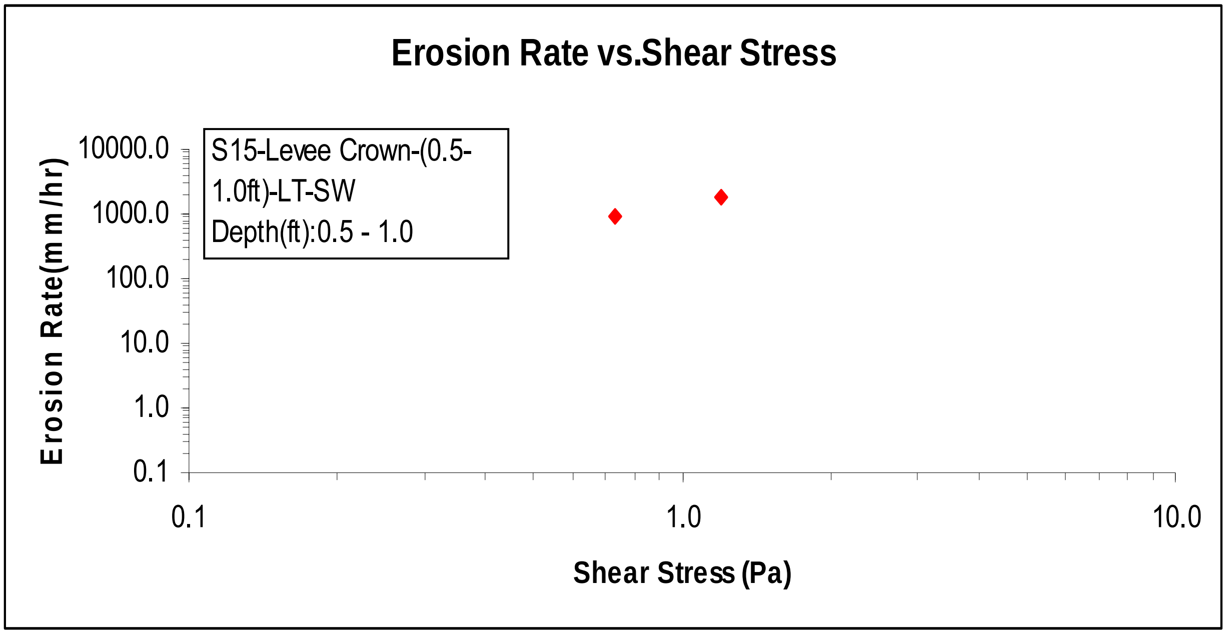
Sample Type: Bulk Sample
Water Salinity: 36.7 PPT (Salt Water)
Compaction Effort: Light Tamping

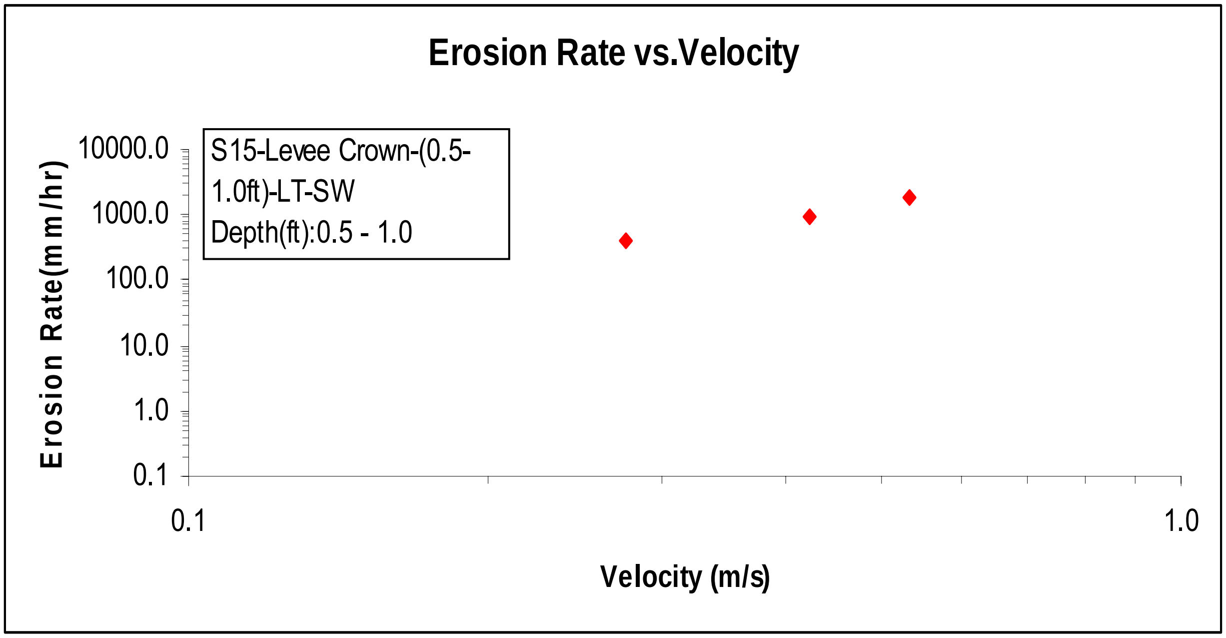




EFA Test Results for Sample No. S15-Levee Crown-(0.5-1.0ft)-LT-SW

Sample Type: Bulk Sample
Water Salinity: 35.9 PPT (Salt Water)
Compaction Effort: Light Tamping

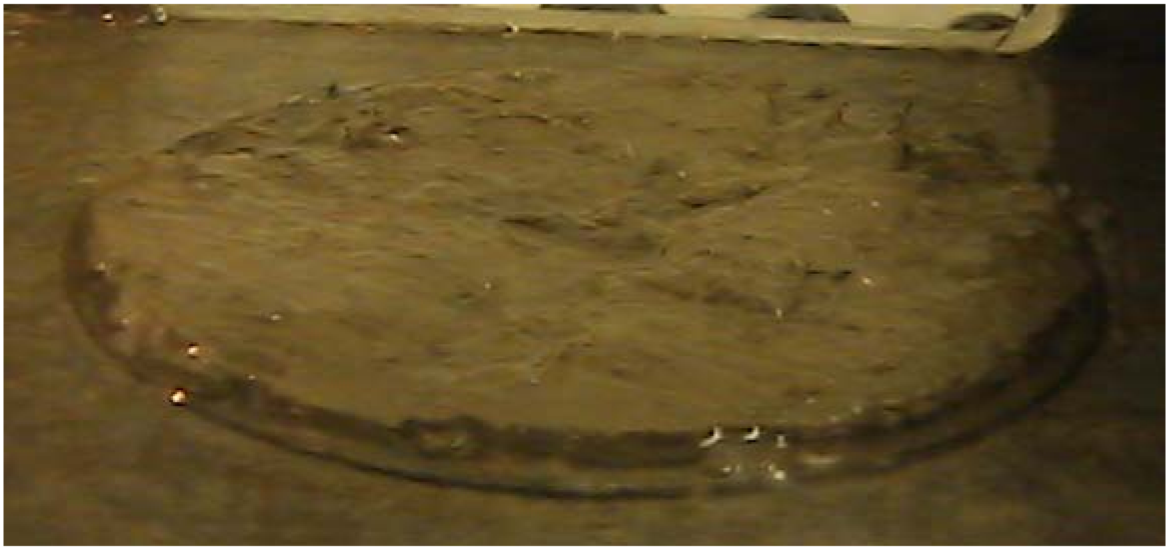




PHOTOS OF THE SAMPLES

EFA Test Results for Sample No. S1-B1-(2-4ft)-SW

Sample Type: Shelby Tube
Water Salinity: 35.6 PPT (Salt Water)
Compaction Effort: N/A

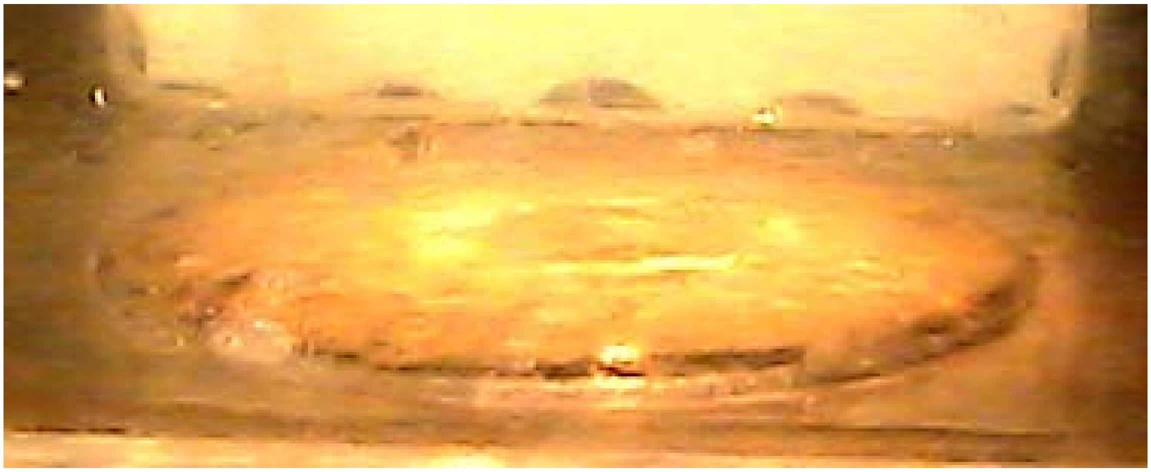


EFA Test Results for Sample No. S2-B1-(2-4ft)-SW

Sample Type: Shelby Tube
Water Salinity: 36.9 PPT (Salt Water)
Compaction Effort: N/A

EFA Test Results for Sample No. S3-B1-(2-4ft)-SW

Sample Type: Shelby Tube
Water Salinity: 35.8 PPT (Salt Water)
Compaction Effort: N/A



EFA Test Results for Sample No. S5-(0-0.5ft)-LT-SW

Sample Type: Bulk Sample
Water Salinity: 36.2 PPT (Salt Water)
Compaction Effort: Light Tamping

EFA Test Results for Sample No. S6-(0-0.5ft)-LC-SW

Sample Type: Bulk Sample
Water Salinity: 36.5 PPT (Salt Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction

EFA Test Results for Sample No. S7-B1-(2-4ft)-SW

Sample Type: Shelby Tube
Water Salinity: 36.9 PPT (Salt Water)
Compaction Effort: N/A

EFA Test Results for Sample No. S8-B1-(0-2ft)-TW

Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

EFA Test Results for Sample No. S11-(0-0.5ft)-LC-TW

Sample Type: Bulk Sample
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction

EFA Test Results for Sample No. S12-B1-(0-2ft)-TW

Sample Type: Shelby Tube
Water Salinity: 0.4 PPT (Tap Water)
Compaction Effort: N/A

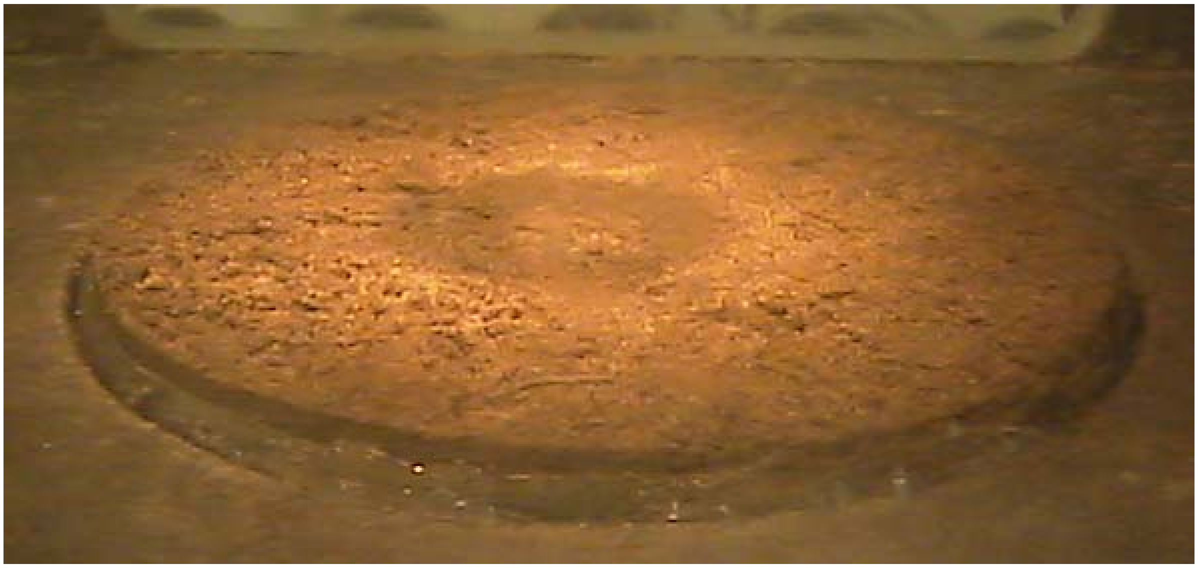
EFA Test Results for Sample No. S12-B1-(2-4ft)-SW

Sample Type: Shelby Tube
Water Salinity: 36.0 PPT (Salt Water)

Compaction Effort: N/A

EFA Test Results for Sample No. S15-Canal Side-(0-0.5ft)-LC-SW

Sample Type: Bulk Sample
Water Salinity: 36.4 PPT (Salt Water)
Compaction Effort: Low = 1.6% Modified Proctor Compaction



EFA Test Results for Sample No. S15-Canal Side-(0-0.5ft)-HC-SW

Sample Type: Bulk Sample
Water Salinity: 36.5 PPT (Salt Water)

Compaction Effort: High = 100% Modified Proctor Compaction

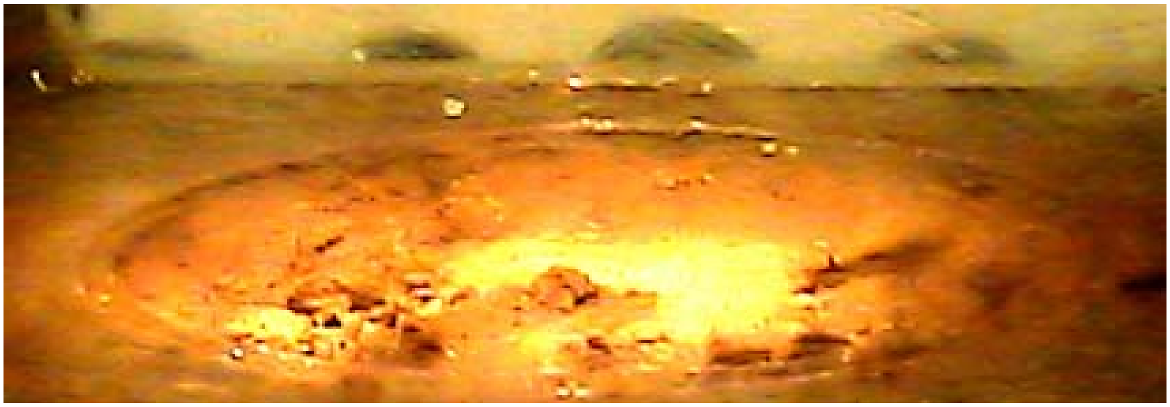
EFA Test Results for Sample No. S15-Levee Crown-(0-0.5ft)-LT-SW

Sample Type: Bulk Sample
Water Salinity: 36.7 PPT (Salt Water)
Compaction Effort: Light Tamping

EFA Test Results for Sample No. S15-Levee Crown-(0.5-1.0ft)-LT-SW

Sample Type: Bulk Sample
Water Salinity: 35.9 PPT (Salt Water)

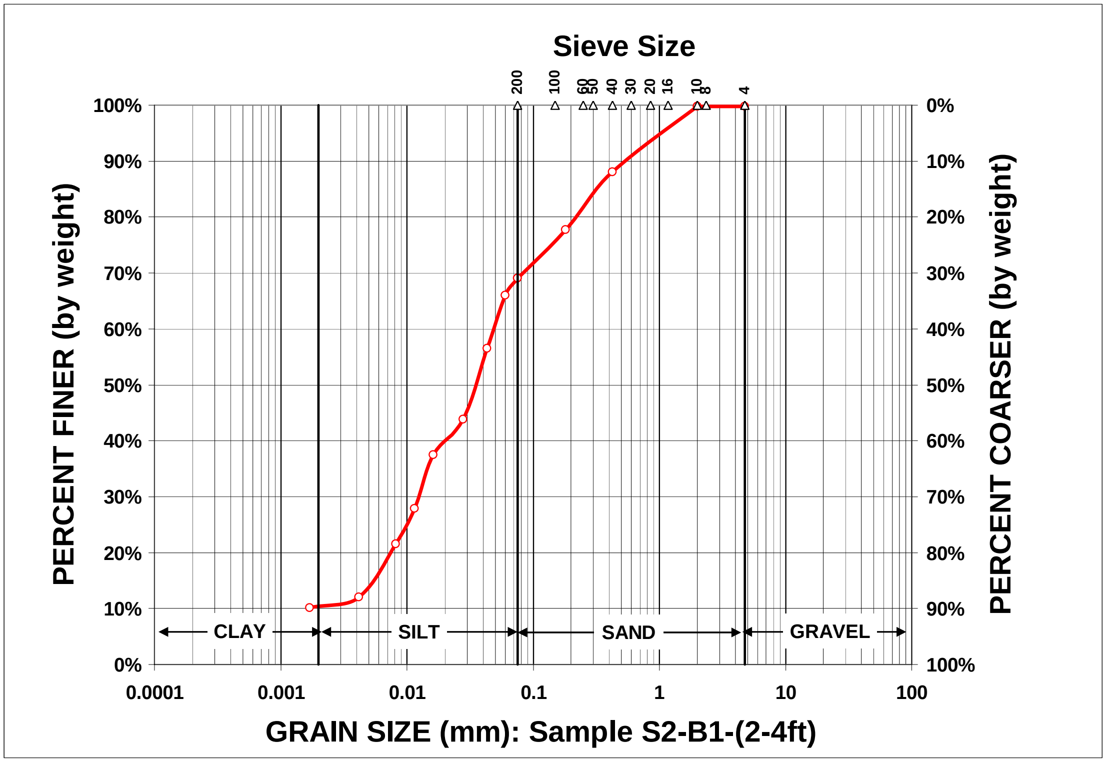
Compaction Effort: Light Tamping

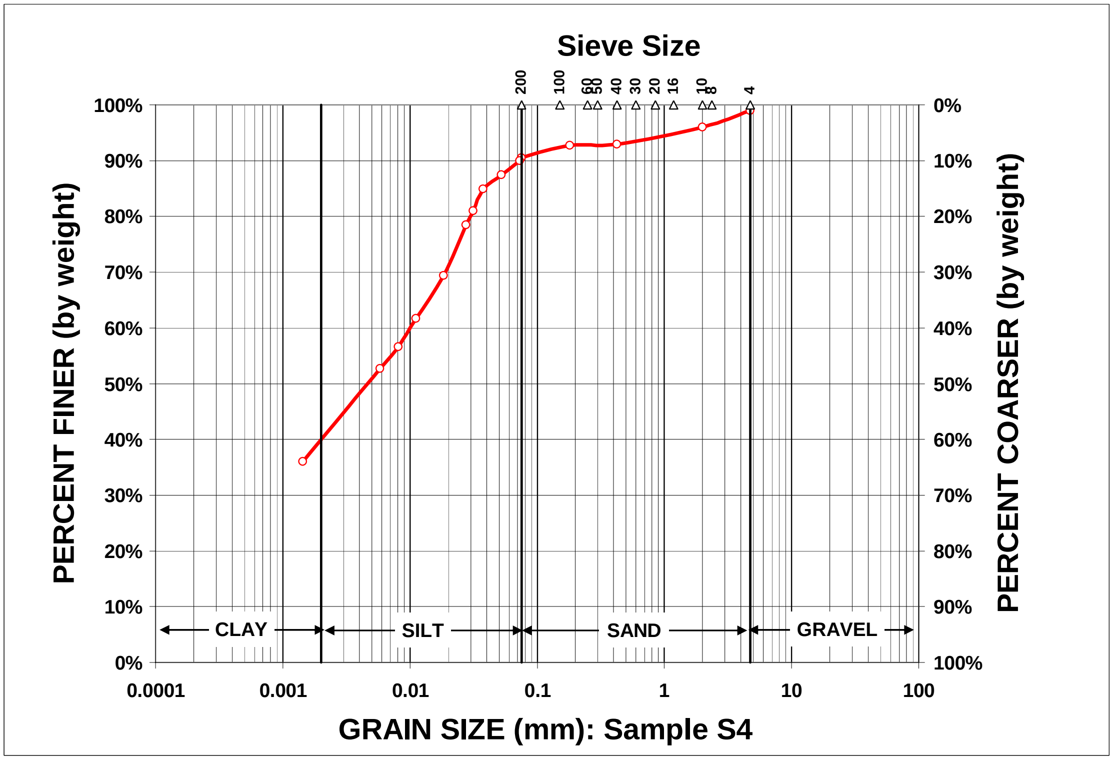


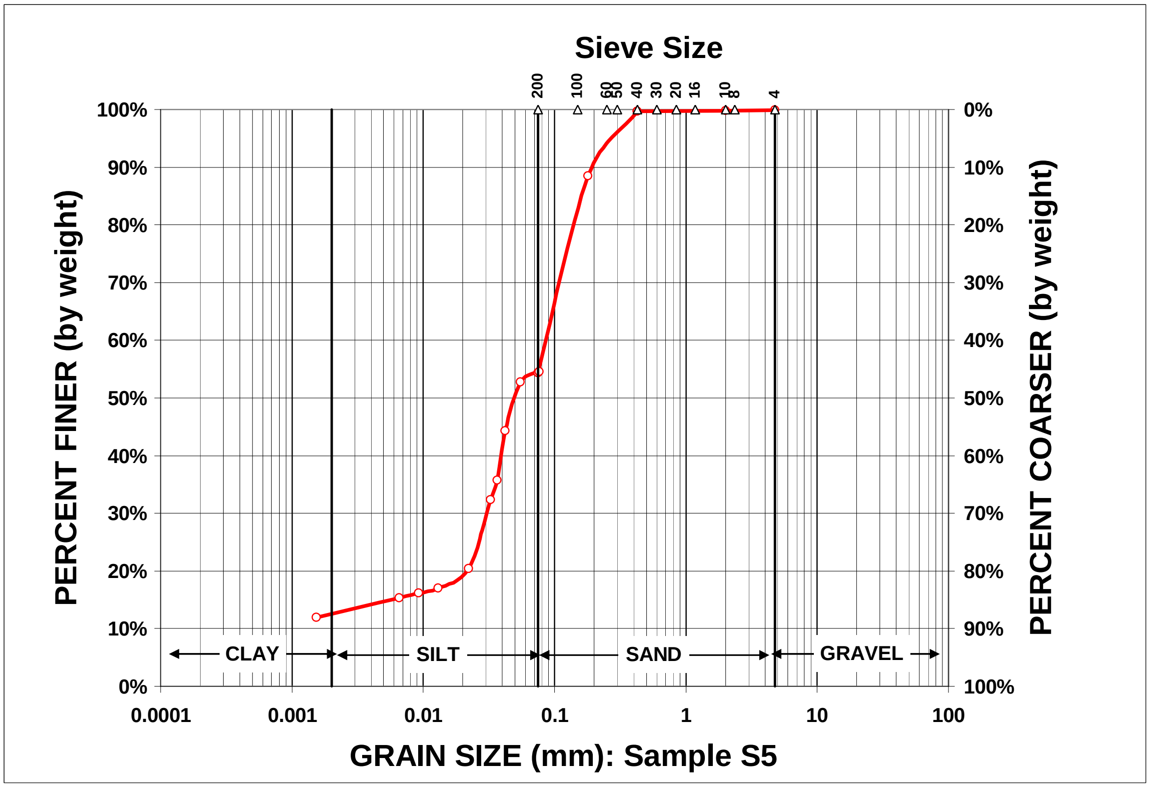
INDEX PROPERTIES OF SOIL SAMPLES

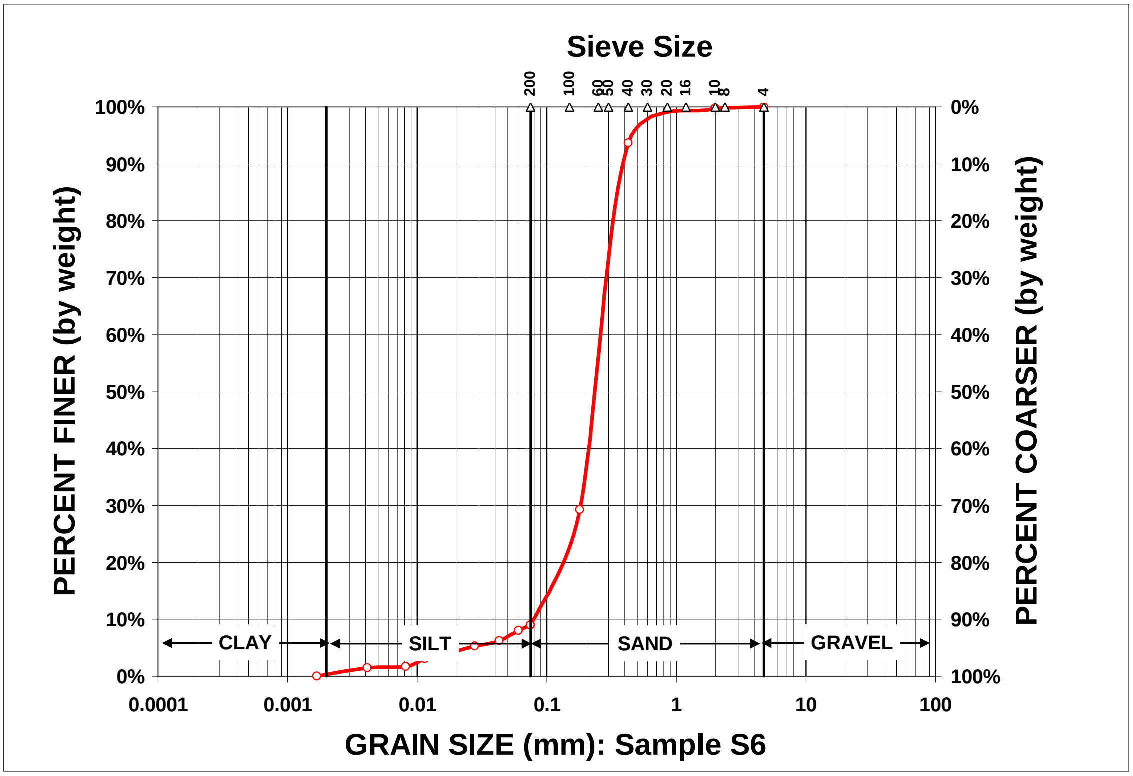
Sample	Soil Description	Classification	γ_t (kN/m3)	γ_{dry} (kN/m3)	w (%)	Tested at Texas A&M University					Tests Performed by STE			
						% fines	LL	PL	PI	Organic Content%	% fines	LL	PL	PI
S1-B1-(0-2ft)-TW	Clay with hard clay grain mixture	CH	20.23	15.37	31.66	-	71	25	46	3.09	89.9	65	22	43
S1-B1-(2-4ft)-SW	Clay with rootlets	CH	19.10	15.69	21.77	-	56	19	37	1.91				
S2-B1-(0-2ft)-TW	Clay with rootlets	CL	19.74	17.00	16.11	-	46	17	29	16.94	67.2	49	17	32
S2-B1-(2-4ft)-SW	Clay	CL	20.26	16.71	21.23	69.1	41	16	25	1.62				
S3-B1-(2-4ft)-SW	Clay	CL-CH	17.60	13.86	27.00	-	48	17	31	2.50	90.3	54	19	35
S3-B2-(0-2ft)-SW	Clay with some sand	CH	20.20	17.26	31.66	-	69	23	46	-				
S3-B3-(0-1ft)-SW	Clay	CL-CH	17.16	13.95	23.00	-	32	12	20	2.60				
S4-(0-0.5ft)-LC-SW	Clat with some sand	CL	13.87	10.42	33.14	90.5	60	30	30	8.16	-	-	-	-
S4-(0-0.5ft)-HC-SW	Clay with some sand		17.69	13.23	33.14									
S5-(0-0.5ft)-LT-SW	Silt-Clay		21.85	18.15	20.40	54.4	-	-	-	0.69	-	-	-	-
S6-(0-0.5ft)-LC-SW	Sand w/Some Clay	SP	13.45	12.79	5.21	8.9	-	-	-	0.71				
S7-B1-(0-2ft)-TW	Clay	CH	17.39	13.73	26.65	-	68	24	44	3.78	90.1	78	32	46
S7-B1-(2-4ft)-SW	Clay with hard clay grain mixture	CH	16.52	13.42	23.04	-	-	-	-	7.14				
S8-B1-(0-2ft)-TW	Clay with 1.5" thick grass on top of sample	CH	17.71	13.38	32.34	-	-	-	-	-	97.3	85	36	49
S8-B1-(2-4ft)-L1-SW	Clay with 2 layers	CH	18.74	14.00	33.87	-	-	-	-	2.28				
S8-B1-(2-4ft)-L2-SW	Clay with 2 layers	CH	18.74	14.00	33.87	-	54	21	33	15.37				
S11-(0-0.5ft)-LC-TW	Sand	SP	12.30	12.23	1.02	0.1	-	-	-	0.32	-	-	-	-
S11-(0-0.5ft)-HC-TW	Sand	SP	13.26	13.12	1.02		-	-	-	0.35				
S12-B1-(0-2ft)-TW	Clay with decomposed wood	CH	14.77	10.19	44.94	-	67	27	40	16.91	92	67	21	46
S12-B1-(2-4ft)-SW	Clay	MH-CH	17.56	12.64	38.94	-	58	32	26	5.28				
S15-CanalSide-(0-0.5ft)-LC-SW	Sand w/Some Clay	SM	13.85	12.21	13.43	29.9	-	-	-	1.28	-	-	-	-
S15-CanalSide-(0-0.5ft)-HC-SW	Sand w/some clay		19.63	17.31	13.43		-	-	-					
S15-LeveeCrown-(0-0.5ft)-LT-SW	Sand w/Some Clay		13.29	11.94	11.29		-	-	-	2.16				
S15-LeveeCrown-(0.5-1ft)-LT-SW	Sand w/Some Clay		13.57	12.46	8.93		-	-	-	1.01				

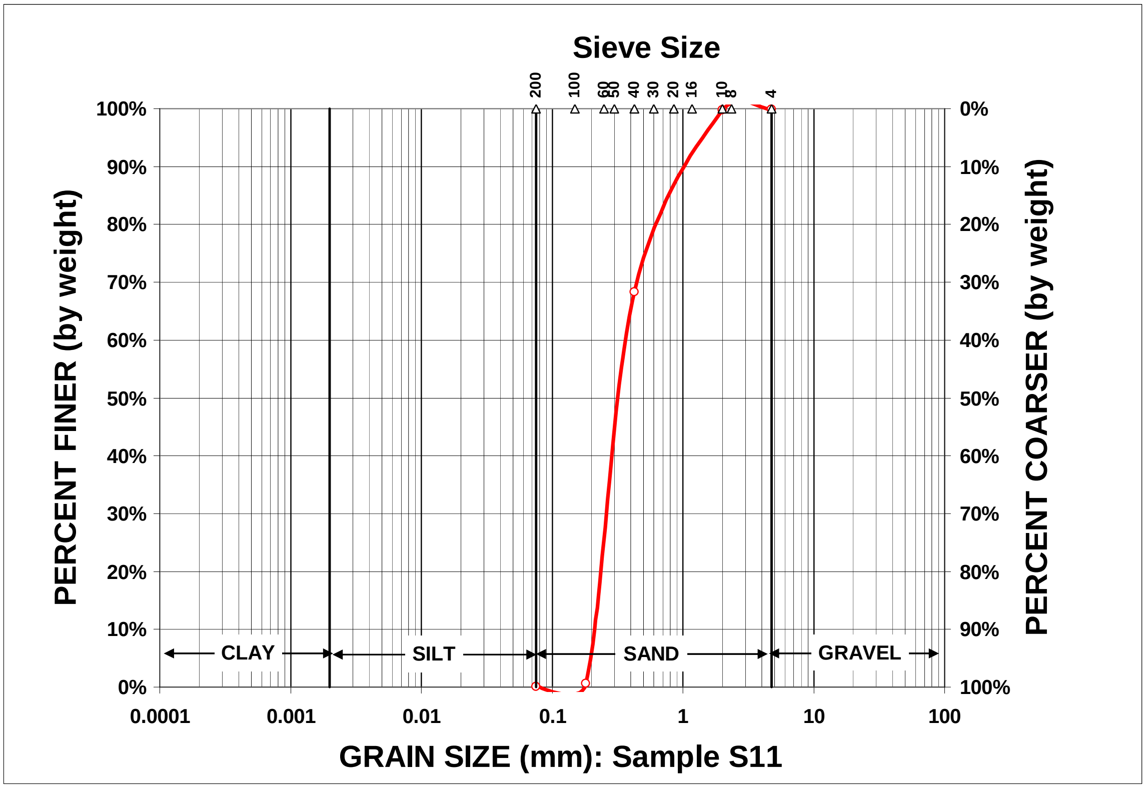
GRAIN SIZE ANALYSIS CARRIED OUT AT TEXAS A&M UNIVERSITY

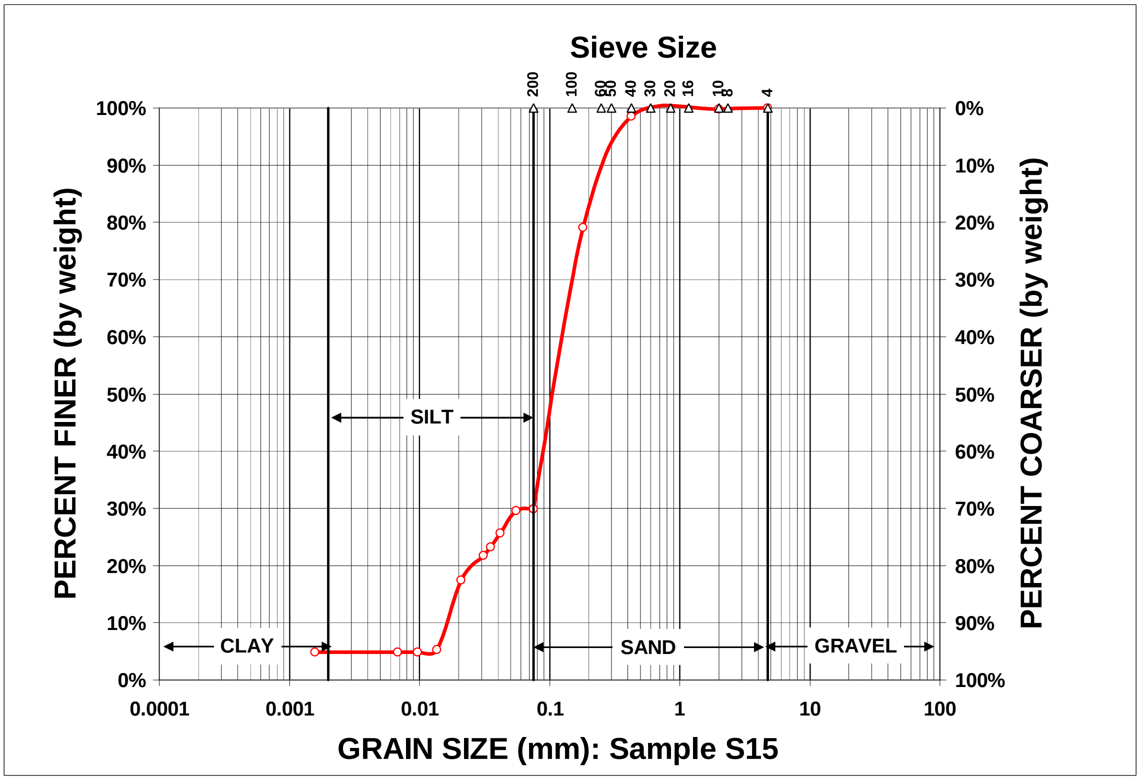




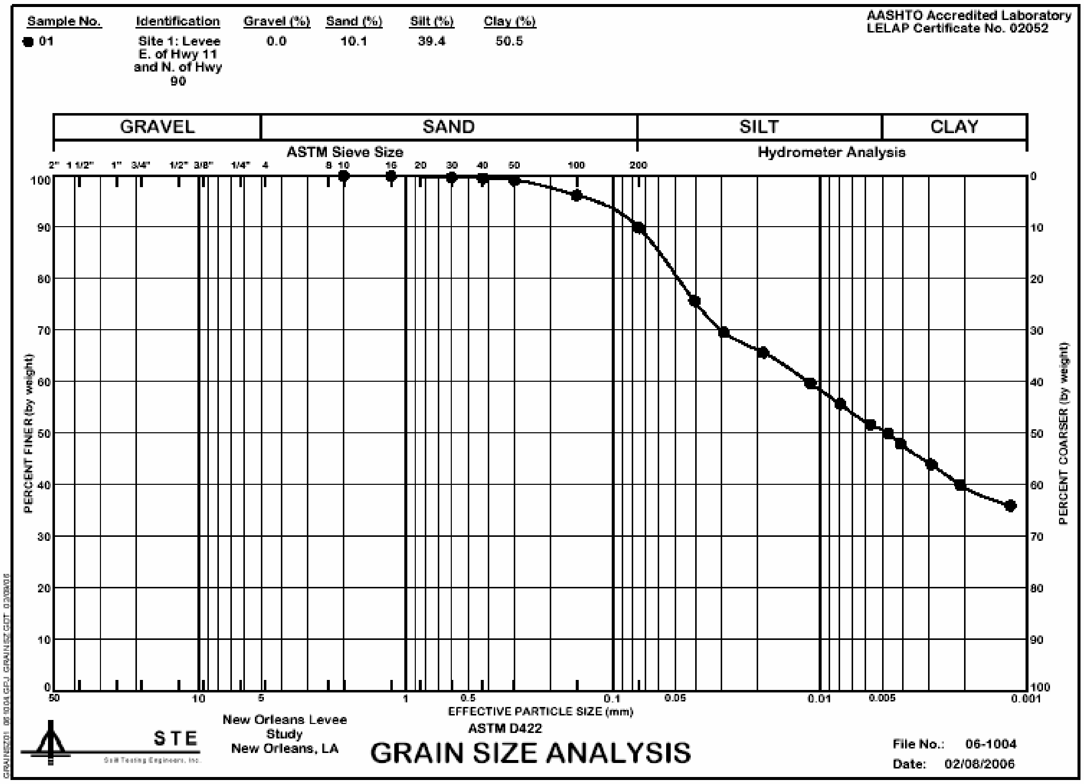

Sieve Size
200
100
60
50
40
30
20
16
10
8
4
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT FINER (by weight)
PERCENT COARSER (by weight)
CLAY
SILT
SAND
GRAVEL
0.0001
0.001
0.01
0.1
1
10
100
GRAIN SIZE (mm): Sample S5


Sieve Size
200
100
60
50
40
30
20
16
10
8
4
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT FINER (by weight)
PERCENT COARSER (by weight)
CLAY
SILT
SAND
GRAVEL
0.0001
0.001
0.01
0.1
1
10
100
GRAIN SIZE (mm): Sample S6


Sieve Size
200
100
60
50
40
30
20
16
10
8
4
PERCENT FINER (by weight)
PERCENT COARSER (by weight)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CLAY
SILT
SAND
GRAVEL
0.0001
0.001
0.01
0.1
1
10
100
GRAIN SIZE (mm): Sample S11


Sieve Size
200
100
60
50
40
30
20
16
10
8
4
PERCENT FINER (by weight)
PERCENT COARSER (by weight)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
CLAY
SILT
SAND
GRAVEL
0.0001
0.001
0.01
0.1
1
10
100
GRAIN SIZE (mm): Sample S15

GRAIN SIZE ANALYSIS CARRIED OUT BY SOIL TESTING ENGINEERS, INC.



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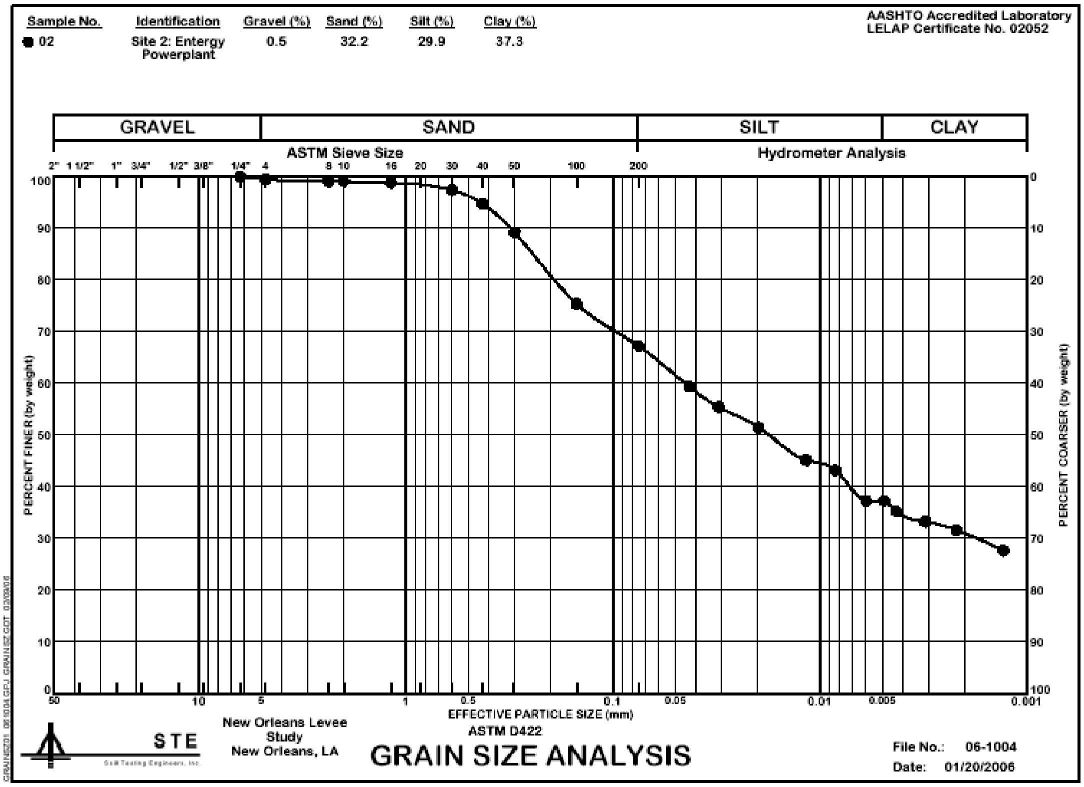
Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 01	Site 1: Levee E. of Hwy 11 and N. of Hwy 90	0.0	10.1	39.4	50.5

New Orleans Levee Study
New Orleans, LA

ASTM D422

GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006



Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 02	Site 2: Entergy Powerplant	0.5	32.2	29.9	37.3

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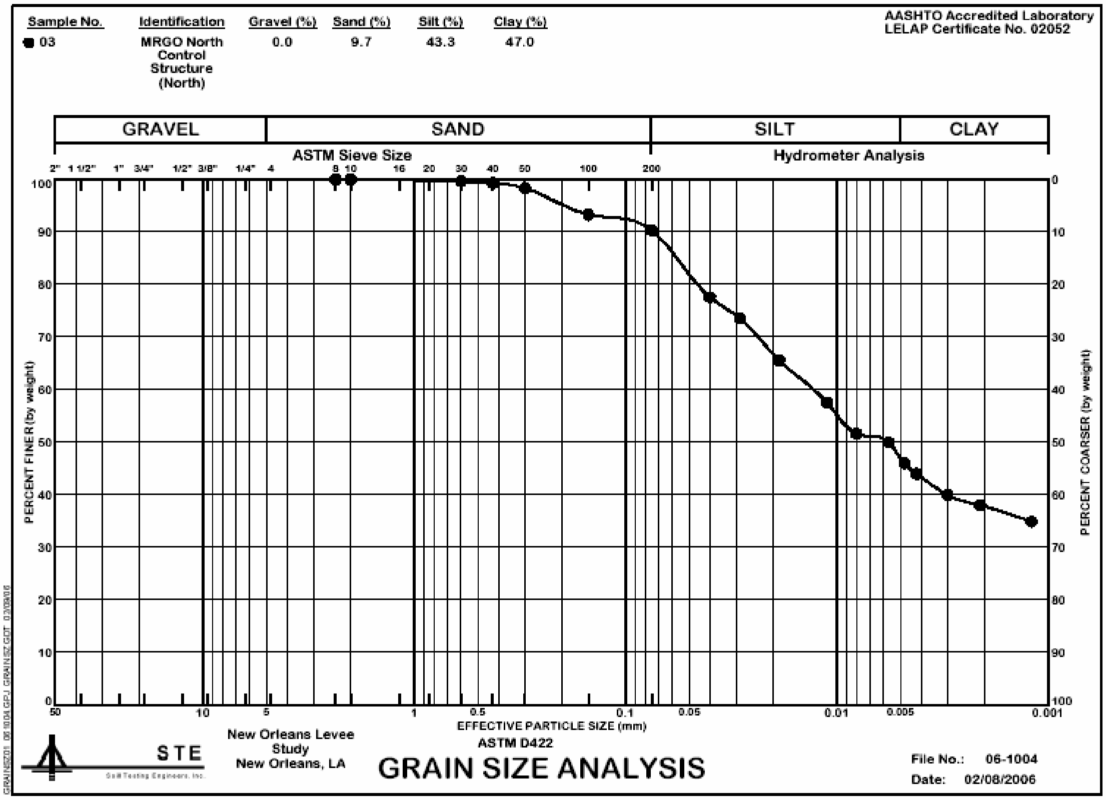
New Orleans, LA

GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 01/20/2006



Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 03	MRGO North Control Structure (North)	0.0	9.7	43.3	47.0

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New Orleans, LA

GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 04	St. Bernard Parish South-Site 7	0.0	9.9	27.8	62.3

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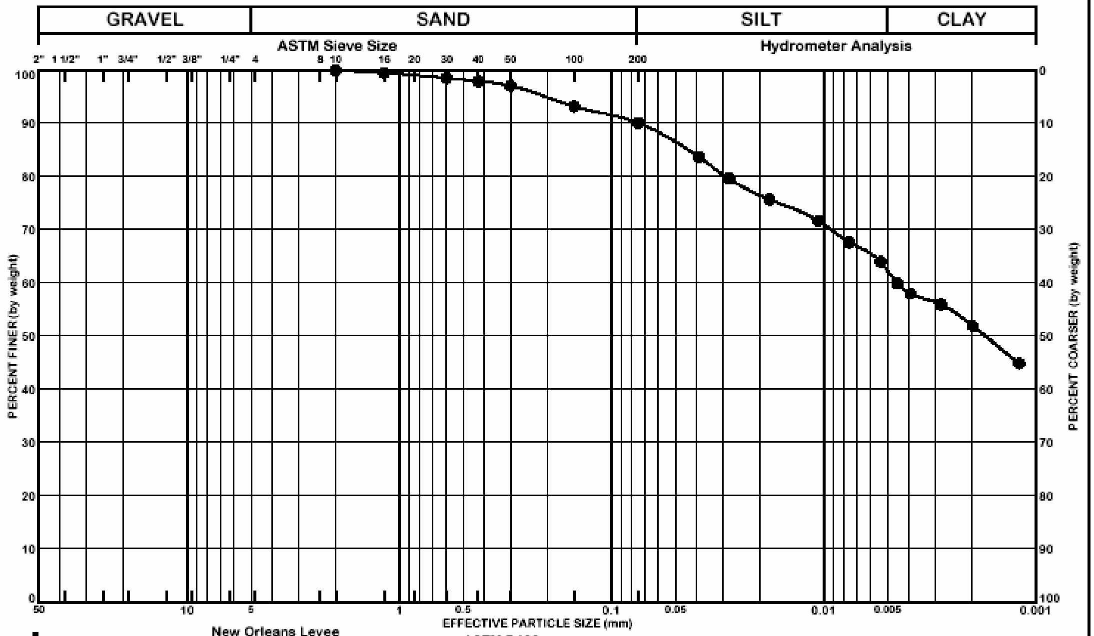

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GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

GRAINSIZE01 06 1004.GPJ GRAINSZ.GDT 02/08/06

Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 05	St. Bernard Parish North-Site 8	0.0	2.7	34.2	63.2

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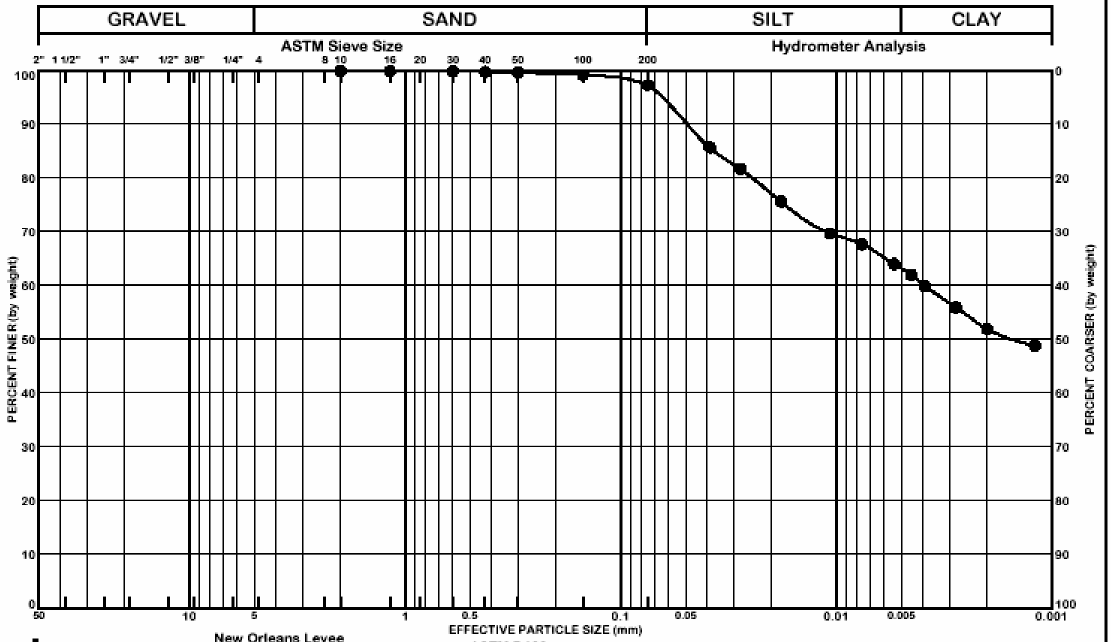

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GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

GRAINSIZE01 06 1004.GPJ GRAINSZ.GDT 02/08/06

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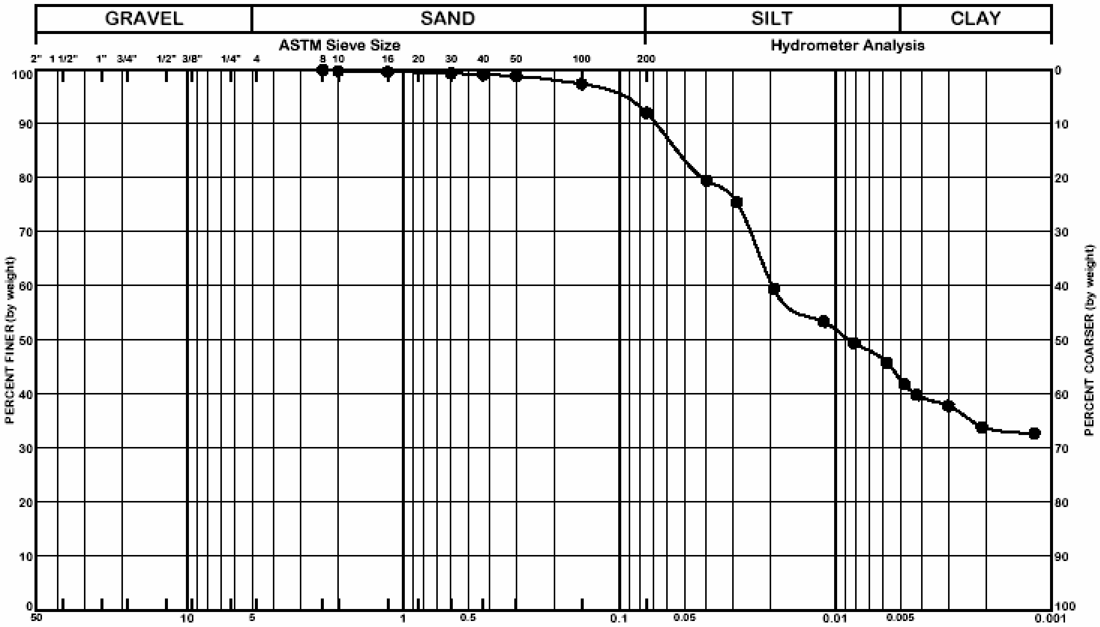
Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 06	Lakefront Airport Transition Levee-Site 9	0.0	7.9	49.3	42.8



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GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

GRAINSIZE01 06-1004.GPJ GRAINSIZE.GDT 02/08/06

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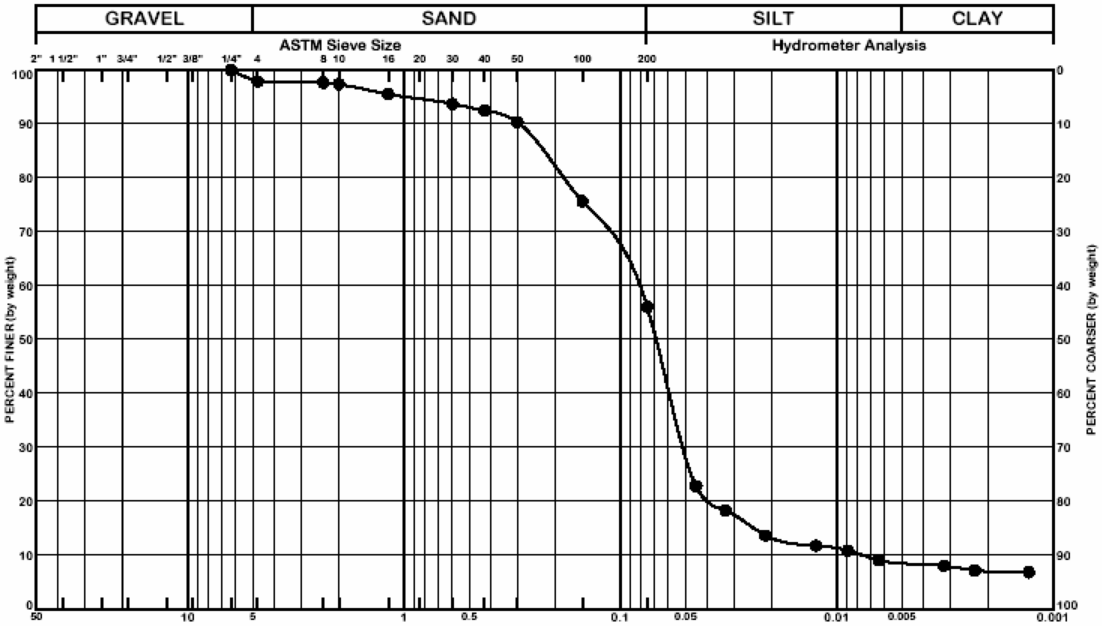
Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 07	Hayne Blvd.-Site 10	2.1	41.8	47.3	8.7



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GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

GRAINSIZE01 06-1004.GPJ GRAINSIZE.GDT 02/08/06

Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 08	Site 12- Orleans East, Southeast RR Transition	0.0	8.0	33.2	58.8

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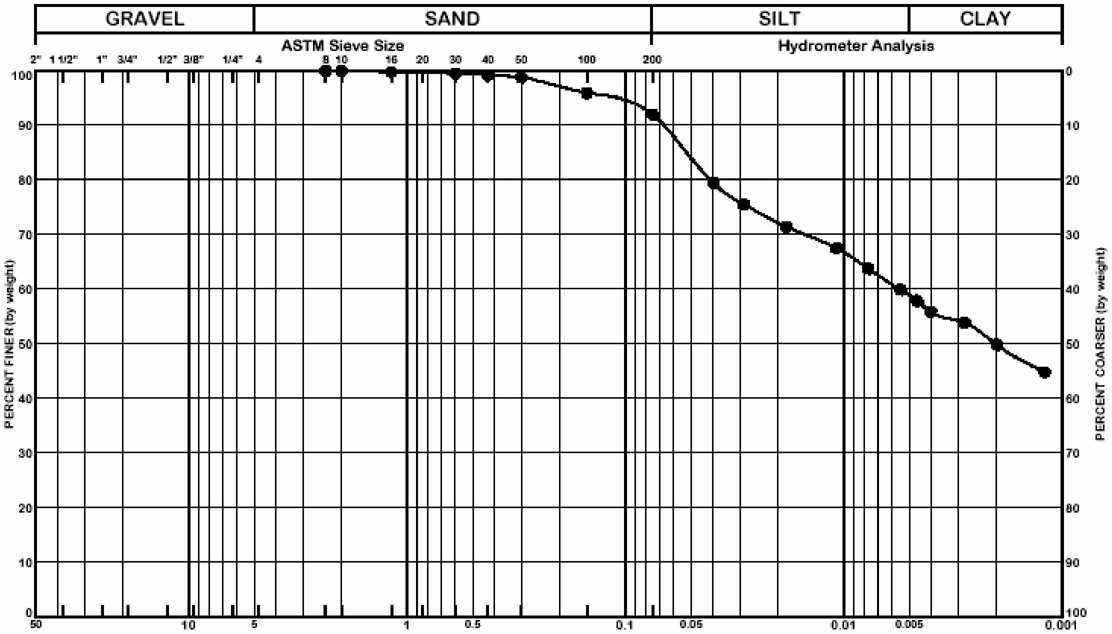

EFFECTIVE PARTICLE SIZE (mm)
ASTM D422

GRAINSIZ01 06-1004.GPJ GRAINSIZ.GDT 02/08/06

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Study
New Orleans, LA

GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 09	Levee West of Entergy Plant Site 16	0.0	25.5	36.0	38.4

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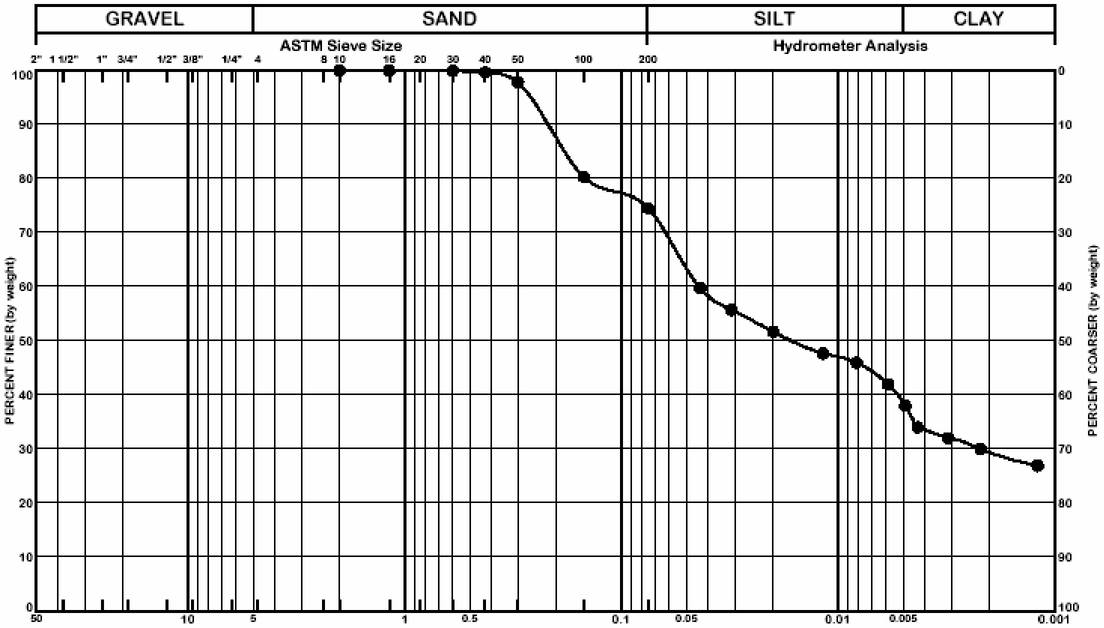

EFFECTIVE PARTICLE SIZE (mm)
ASTM D422

GRAINSIZ01 06-1004.GPJ GRAINSIZ.GDT 02/08/06

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GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 10	Site 19- St. Bernard North (N.29.92541,W89.89484)	0.0	3.2	41.1	55.7

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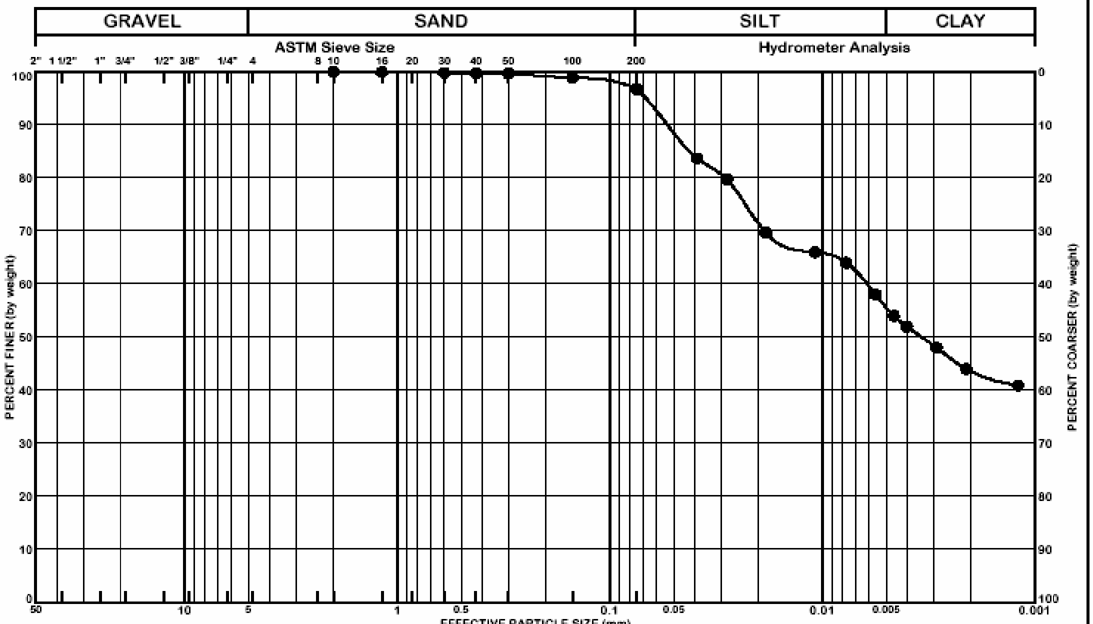

GRAINSZ01 06-1004.GPJ GRAIN.SZ.GDT 02/09/06

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GRAIN SIZE ANALYSIS

File No.: 06-1004
Date: 02/08/2006

Sample No.	Identification	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
● 11	Composite of Site 7 S-2 & Site 7 MRGO S-1	0.0	36.9	36.4	26.7

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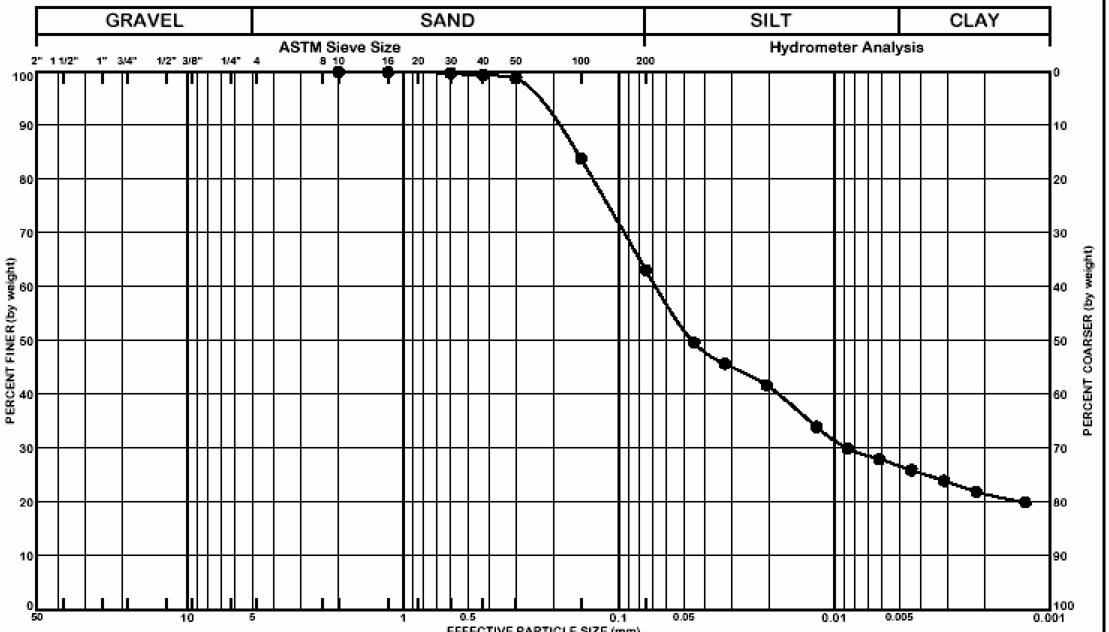

GRAINSZ01 06-1004.GPJ GRAIN.SZ.GDT 02/09/06

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