Design of an Automated Data Acquisition System (ADAS) For a Site Specific Load Test on the London Avenue Outfall Canal I-Wall/Levee New Orleans, LA

Contract No. W912P9-05-D-0514
Task Order Number 4

Prepared for:

U.S. Army Corps of Engineers
St. Louis District

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EXECUTIVE SUMMARY

The US Army Corps of Engineers (USACE) plans to conduct a site specific hydrostatic load test on a portion of the existing I-Wall/Levee along the east edge of the London Avenue Outfall Canal in New Orleans, LA. Structural and geotechnical instrumentation combined with an Automated Data Acquisition System (ADAS) system will be installed to monitor the behavior of the levee and I-Wall for the duration of the load test.

Analyses of the levee and I-Wall by others indicated that the most likely cause of failure would be an increase in pore pressures in the materials below grade. The sequence of events leading to the failure of the I-Wall are thought to be largely due to the formation of a gap between the wall and soil on the canal side of the I-Wall as the wall deflects with increasing height of water. As the water rises in the canal, more deflection of the wall occurs, increasing the width and depth of the gap. The gap provides a hydraulic conduit whereby water in the canal can flow into a sand unit below grade. An increase in pore pressures in this sand unit may cause heave, sand boils, and piping on the protected side of the I-Wall. Hydraulic pressure in the gap may also cause translation of the wall if the passive resistance of the soil is exceeded.

Both structural and geotechnical instruments were selected to monitor the potential failure modes. An ADAS system will be installed to monitor the instruments in near real-time mode. The intent is to not only measure the deformations as they occur, but also to provide data for alerting the team conducting the test should target threshold levels of deformation be exceeded.

1.0 INTRODUCTION

1.1 Authorization

The Hurricane Protection Office (HPO) in New Orleans will perform a load test on the I-Wall and levee of the London Avenue Outfall Canal in New Orleans. This Automated Data Acquisition System (ADAS) Report provides a design for geotechnical and structural instrumentation, ADAS equipment, telemetry and data management systems that will be used for monitoring the load test. This Report was prepared by URS for the USACE as authorized by Contract No. W912P9-05-D-0514, Task Order No. 4 dated April 6, 2007.

1.2 Project Objective

The primary objective of this task order is to design instrumentation and an ADAS system to provide safety monitoring for the load test to be performed on the existing I-Wall and levee.

In addition, emerging measurement technologies are to be evaluated. Products produced by Sensametrics Inc. of Palo Alto, CA and Pinnacle Technologies, Inc. of Houston, TX may be included in the load test instrumentation to evaluate their potential for future use.

1.3 Purpose

The purpose of this document is as follows:

a. Summarize review of existing design documents and geotechnical reports.

b. Summarize observations made during a one-day site visit.

c. Present the selection of instruments and design details.

d. Present the design of the ADAS/Telemetry system.

e. Provide details of the database management and reporting system.

2.0 BACKGROUND

The USACE plans to conduct a site specific load test along a 150 ft portion of the existing I-Wall on the east bank of the London Avenue Outfall Canal in New Orleans, LA. Figure 1 identifies the location within the region. Figure 2 is a plan view of proposed instrumentation at the cofferdam, floodwall, levee, and adjacent protected side area. Figure 3 is a cross section through the levee near the center of the proposed load test location.

The USACE will construct a 3-sided, 150-foot by 25-foot, sheet pile cofferdam test cell on the canal side of the wall. There will be 25 ft long secondary containment sheet pile walls located on the north and south sides of the test cell. The cofferdam will extend into the I-Wall at two monolith joint locations in the concrete monoliths that cap the sheet pile wall. The USACE will pump water into the cofferdam, incrementally raising the test cell water level in a controlled fashion. The rising water in the cofferdam is intended to simulate the loads on the wall that would result from a high water event in the London Avenue Canal.

To conduct this test in a manner that limits damage to the wall and adjacent private property, the USACE will instrument the wall with electronic, manual, and visual devices that measure the response of the wall and its foundation to the applied loads. The basic ADAS system was designed using electronic devices that have performed well in similar applications. Other systems, including manual devices, will be used to provide redundancy.

The USACE requested that two emerging technologies be evaluated during the load test. These emerging technologies include fiber optic strain gages and MEMS based tiltmeters. These emerging technology systems may be installed “side-by-side” to the basic ADAS system for evaluation purposes. The data obtained from the emerging technology systems and their operational characteristics would be directly compared to data acquired using conventional instrumentation systems.

3.0 DOCUMENT REVIEW AND PERFORMANCE PARAMETERS

3.1 Document Review

Existing documents were reviewed to obtain a working knowledge of site-specific conditions. The following documents were reviewed:

1) Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System; Draft Final Report of the Interagency Performance Evaluation Task Force; Volume V – The Performance – Levees and Floodwalls; June 1, 2006. (Referred to herein as IPET Report).

2) Draft, Analysis of the London Avenue Canal Load Test – Section 1, Soil Structure Interaction Analysis, February 21, 2007. (Referred to herein as Soil Structure Interation Report.) This report was prepared by Mr. Neil Schwanz of the US Army Corps of Engineers St. Paul District.

3) Plans for Lake Pontchartrain, Louisiana and Vicinity; Hurricane Protection; High Level Plan; Orleans Parish, La.; London Ave. Outfall Canal, Parallel Protection; Mirabeau Ave. to Robert E. Lee Blvd., West Bank; Mirabeau Ave. to Leon C. Simon Blvd., East Bank; US Army Corps of Engineers New Orleans District; 1994. (USACE File No. H-2-30288)

4) Design Memorandum No. 19A; General Design; London Avenue Outfall Canal; Orleans Parish; Serial No. 59; New Orleans District, US Army Corps of Engineers; January 1989. (USACE File No. H-4-40295)

The IPET report included a discussion of the behavior of the London Avenue Canal. Numeric modeling was performed to estimate the performance of the levee and I-Wall based on the level of water within the canal. Results of the finite element soil-structure interaction analyses are included as Figure 4 of this report. (This was Figure No. 41 in the original IPET Report.) Centrifuge testing was also performed and reported to be consistent with these results. The IPET results are for modeling performed at the location of breaching of the wall during Hurricane Katrina. The I-Wall and levee at the site-specific load test did not breach during Hurricane Katrina.

The USACE performed Soil Structure Interaction Analysis FLAC modeling for the response of the I-Wall at the location of the site-specific load test. (FLAC stands for Fast Lagrangian Analysis of Continua.) Analyses were performed twice: once using data collected from in-situ pressure meter test, and once using data from laboratory triaxial compression strength tests. Results from this analysis are also included in Figure 4.

Figure 4 indicates a significant increase in movement, of the top of the I-Wall (greater than 0.15 ft), when the canal water elevation exceeds 6 ft. It is anticipated that design values selected for horizontal displacement will be those immediately prior to this large movement. It is assumed that if movement occurs beyond this level, it would be detrimental to the levee and wall.

Data from DM19A were used to estimate the approximate soil stratigraphy beneath the site. Profiles for stratigraphy under the east and west levees of the canal as well as under the center of the canal were provided. Based on the East Levee profile, the site consists of artificial fill to elevation –5 ft. Underlying the fill is a marsh layer (highly organic silt and clay) down to elevation –13 ft. Zones of sand and shells extend from the marsh layer down to approximate elevation –45 ft. Below the sand and shells, a clay layer (Bay-Sound Marine Deposit) exists. Stiff Pleistocene age clays exist at about El. –55 and below. The normal water level in the canal is understood to be between El. 0 to 1 ft except during rainfall events.

The 1994 plans were used to obtain the existing sheet pile information. According to the 1994 plans, the sheet piles consist of PZ-22 sections driven to an elevation of –22 ft.

3.2 Performance Parameters

The anticipated performance of the levee and I-Wall as water levels in the canal increase are as follows:

1) Increasing water level in the canal will cause increasing outward tilt/rotation of the levee and I-Wall.

2) As the I-Wall deflects, a “gap” will develop in the ground immediately adjacent to the wall on the flood side (canal side) of the levee.

3) As the water height in the canal continues to increase, the width and depth of the gap will continue to increase.

4) Near a canal water elevation of 6 ft $\pm$, the water in the canal will become hydraulically connected to the sand and shell units below the marsh deposits. Once this hydraulic connection is made, the pore pressures within the sand will increase.

5) The increase in pore pressures in the sand may cause heaving of the marsh clay top stratum and sand boils.

6) The levee and I-Walls will then experience potentially significant horizontal displacements.

This process is what is believed to have caused the distress in the levee and I-Wall during Hurricane Katrina. The load test now being performed will monitor the initial portion of this process. It is not intended to load the wall to failure. Instrumentation types were selected to monitor the behavior of the levee and I-Wall based on the performance parameters listed above.

4.0 SITE VISIT

On Wednesday April 18, 2007 Mr. Patrick Conroy (USACE St. Louis District) and Mr. Jim Hummert (URS-St. Louis) visited the test site area. Mr. Derek Boese and Mr. Rob Brown (New Orleans HPO) were also present for the site visit. The purpose of the site visit was to review the current site conditions and to discuss instrumentation plans and locations. The levee within the test site area was recently grubbed and graded to within 6 ft of adjacent property lines on the protected side of the levee. Grubbing of vegetation will still be required on the canal side of the I-Wall prior to starting the test cell construction. Following the site visit there was a meeting at the HPO to review current status of the test plans.

5.0 SELECTION OF INSTRUMENT TYPES

Based upon the anticipated hydrostatic loading of the levee and I-Walls, instrumentation was selected to monitor anticipated performance parameters. A list of performance parameters and the instrumentation types that were selected to monitor these parameters are given in Table 1. Efforts were made to select at least one level of redundancy for all key monitoring parameters. In addition two emerging technologies have been added to the test plan for evaluation purposes.

Surface Water Levels

Test cell water levels will be read automatically using 4-20ma pressure transducers housed in slotted standpipes attached to the inside of the sheetpile cofferdam. An adjacent staff gage will be used to make manual backup readings.

Canal water levels will be read automatically using 4-20ma pressure transducers housed in slotted standpipes attached to the outside of the cofferdam wall at the locations shown on Figure 1. Canal water levels are expected to show tidal influences and may fluctuate if significant rainfall occurs during the test period. A manually read staff gage will be located adjacent to the pressure transducer.

Subsurface Piezometric Levels

Open-standpipe piezometers will be installed in the sand stratum at approximately the existing tip elevation of the I-Wall sheet piles (approximately elevation -22 ft NGVD) by the USACE. These instruments will monitor increases in piezometric levels. Additional piezometers will be located off the toe of the slope on the protected side of the levee. These piezometers are intended to monitor the piezometric levels within the sand immediately beneath the marsh clay layer. Additional piezometers may be installed near the street (approximately 150 ft from the I-Wall) if access is granted. Figures 2 and 3 show the proposed instrument locations and elevations. Figure 6 provides installation details of the piezometers. All of the open-standpipe piezometers will be automated using 4-20ma strain gage pressure transducers. Manual backup readings of water levels within the open-standpipes will be made throughout the test.

I-Wall Tilt/Rotation

Tiltmeters will be attached to the I-Wall to measure the tilt/rotation of the wall during the test. (See Figure 5.) The tiltmeters will be read automatically by the ADAS system. Vibrating wire devices will be used, and MEMS tiltmeters may be used.

I-Wall/Levee Translation/Horizontal Surface Displacement

Crack monitors will be installed across the expansion joints (30 ft spacings) in the concrete I-Wall to monitor any movement across this joint as the test proceeds. Essentially, two points (one on each side of the joint) will be monitored for horizontal movement. An electronic vibrating wire crackmeter will be the primary instrument. (See Figure 7.) Manually read Avongard crack gages will be installed at each joint as well, for redundancy.

Surveying techniques will be used to measure both lateral and vertical movements of the I-Wall and levee ground surface. Survey prisms will be installed as part of survey monuments in a grid pattern on the berm on the protected side of the levee (refer to Figure 2). Survey prisms will also be attached to the top and base of the protected side of the I-Wall. The survey prisms will be read automatically using a robotic total station system.

I-Wall/Levee Flood Side "Gap"

To monitor the potential formation of a gap on the flood side of the wall, three instrument types will be used. First, pressure cells will be installed at the contact point between the I-Wall and the ground surface. It is anticipated that the formation of a gap will cause a decrease in pressure of soil against the I-Wall. In addition to the pressure cells, manual tell tales will be installed along the canal side of the wall. The tell tale will basically consist of an aluminum or plastic rod that is kept vertical against the wall within a protective casing or pipe, but will be allowed to move vertically. If a gap develops, then the tell tale will drop. (See Figure 8.)

The third instrument will be an automated vibrating wire crackmeter that will extend from Inclinometer IPI-1 to the base of the I-Wall on the canal side. This device will be installed in a shallow trench as shown on Figure 7.

Subsurface Lateral Deformation

Inclinometers will be installed across the berm along the centerline of the cofferdam to measure in-situ horizontal deformations with depth. Manual baseline readings will be obtained after installation of the inclinometer casing by the USACE. After collecting manual baseline readings, the inclinometers will be automated using vibrating wire in-place inclinometers (IPIs), as shown on Figure 6**.**

6.0 AUTOMATED DATA ACQUISITION SYSTEM (ADAS) / TELEMETRY

An Automated Data Acquisition System (ADAS) will be used to read selected instruments automatically on a pre-defined frequency. The ADAS will consist of two remote monitoring units (RMUs) using Campbell Scientific CR 10X dataloggers. The RMUs will be mounted on portable tri-pods located on the vacant lot near the test site. The RMUs will operate on solar recharged batteries. They will communicate with two or more laptop computers in the test trailer via hardwire connections. No radio telemetry is anticipated for this load test.

All automated instruments will be connected to multiplexers inside the RMU enclosures via signal cable that will be routed along the edge of the test site. The cables will run above grade in protective PVC conduit.

RMU 1 will be used to read the vibrating wire tiltmeters, pressure cells and open-standpipe transducers every 15 seconds. Action level thresholds will be set for each instrument to alert personnel of instrument readings that are out of allowable range. Instrument readings will be stored every five to fifteen minutes for reporting and plotting purposes.

RMU 2 will be used to read the vibrating wire in-place inclinometers and crackmeters every 30 seconds. Action levels will be set for each instrument sensor for early warning purposes. Instrument readings will be stored for further analysis at five to fifteen minute intervals.

Each RMU will be installed with lightning protection and grounding systems to protect the electronic equipment from lightning induced surges. All vibrating wire instruments being used for this test will have onboard surge protection devices. Additional surge protection is provided at the Campbell Scientific dataloggers. The grounding system will consist of one or more ground rods at each RMU location. The grounding system will be evaluated using Fall-of-Potential tests. The lighting protection system will consist of air terminals mounted on the top of each tri-pod. The air terminals will be bonded to the grounding system using appropriate copper down leads and mechanical bonding clamps.

The ADAS will be installed several days before the start of the test to compile baseline datasets for each instrument. In addition, multiple rounds of backup manual readings will also be made for comparison purposes. All instruments will be calibrated according to manufacturers' requirements prior to beginning the baseline measurements.

The RMUs will be programmed to collect both raw and reduced instrument readings. The instrument readings will be stored locally at each RMU and will be transmitted to the test system database on a frequent basis for plotting and reporting purposes. Instrument thresholds will be compared to instrument readings immediately at the dataloggers. Required alerts and action will be provided by the Campbell Scientific LoggerNet software or through relays connected to flashing lights and a signal horn.

Although it would be possible to configure the ADAS to automatically open the emergency water release valves on the cofferdam if certain instrument threshold values are exceeded, it may not be practical to implement this capability on the site specific load test. An alternate approach would be to use a flashing warning light and signal horn that could be automatically activated if certain threshold values are exceeded. The flashing light and signal horn could be mounted on top of the I-Wall at the center test panel. Since there will be onsite personnel around the clock throughout the test, they will be able to immediately take any action required to release water from the test cell in the event of an emergency.

Two IP based digital video cameras will be used to record the test. Cameras will be installed at the locations shown on Figure 2. Camera 1 will be positioned to monitor the water level within the test cell and to view the staff gage. Camera 2 will be positioned to view the test site area (protected side) including a view south along the I-Wall. Solar powered LED lights will be placed on the top of the I-wall to allow for visual observations of displacements using the cameras at night.

7.0 INSTRUMENTATION DATA MANAGEMENT AND REPORTING

During the site specific load test, both automated and manually collected data will be entered into an onsite database that will be installed on a database server within the test trailer. Automated instrument readings will be transmitted electronically for automatic importing. Manually collected instrument readings will be entered into the database shortly after they are taken.

For this test we plan to use Campbell Scientific LoggerNet and RTMC software for real-time instrument monitoring and threshold alarm annunciation. We plan to use the USACE WinIDP Instrumentation Database and Graphics program as the overall instrumentation database, plotting and reporting application.

The Campbell Scientific LoggerNet combined with their RTMC software will provide real-time monitoring of key instruments throughout the test. Instrument threshold alarms will be set within this application. The RTMC software will be configured to present visual status of the key instruments at all times.

WinIDP will be configured with all test instruments including both manual and automated instruments. WinIDP can be configured to generate time series plots, position plots and correlation plots automatically in a batch mode of operation. One or more color printers will be used to generate instrumentation plots throughout performance of the test. The robotic surveying and immerging technology devices will use databases independent of the WinIDP.

A data management plan will be prepared prior to initiation of the test. The data management plan will identify all data sources, processes and presentation requirements. A detailed listing of tabular reports and plots will be contained within the data management plan. The plan will include detailed QA/QC procedures to maintain the highest caliber of test data integrity.

8.0 EMERGING INSTRUMENTATION TECHNOLOGIES

As requested by USACE, we are evaluating the subcontracting of the services of two emerging instrumentation technology companies. The primary purpose is to evaluate these emerging technologies far use during a possible full-scale load test of the canal. These companies specialize in fiber optic and MEMS sensor technologies.

Sensametrics, Inc. of Palo Alto, CA (Sensametrics) specializes in developing battery operated strain gage and tiltmeter instruments that use MEMS technology. Their units include mesh RF telemetry capability to transmit instrument readings when defined threshold values are recorded. For the site specific load test, Sensametrics is planning to provide five remote tiltmeters that will be mounted near the center of each test I-Wall panel. These instruments will be configured to scan onboard tiltmeter sensors and signal an alert if programmed threshold values are exceeded.

Pinnacle Technologies of Houston, TX (Pinnacle) focuses on providing fiber optic based sensors for remote monitoring applications. Based upon conversations with Pinnacle, they propose to install two horizontal fiber optic cables across the five test panels one near the top and the second near the base of the I-Wall. The fiber optic cables will be secured to mandrels installed on each side of an expansion joint (on 30 ft centers). Embedded fiber optic strain gage sensors will be used to detect and quantify any movement across the expansion joints.

Both of the above companies would provide onsite personnel to install, operate, and monitor the instruments during the load test. Data acquisition and presentation will be independent from the overall test ADAS and instrumentation database system.

Throughout the test, comparisons will be made between these emerging instruments and the more conventional instruments that will be installed. If the USACE elects to conduct a full-scale test of the London Avenue Canal (approximately 2.5 miles in length), it will be important to identify lower cost options to instrument both sides of the canal.

9.0 DETAILED EQUIPMENT LIST, COST ESTIMATE, AND SCHEDULE

A detailed equipment list and cost estimate will be transmitted separately. For budget level cost estimation purposes, the procurement, installation, monitoring, and reporting for the ADAS system will be approximately $400,000. Estimated costs are still being obtained and tabulated at the time of this report.

The schedule for the load test will be provided by the Government. URS will provide a schedule for the instrumentation component of the load test after receiving the load test schedule. It is anticipated that the site specific load test will occur about mid-June.

TABLES

Table 1
London Avenue Canal
Site Specific Load Test
Instrumentation Table

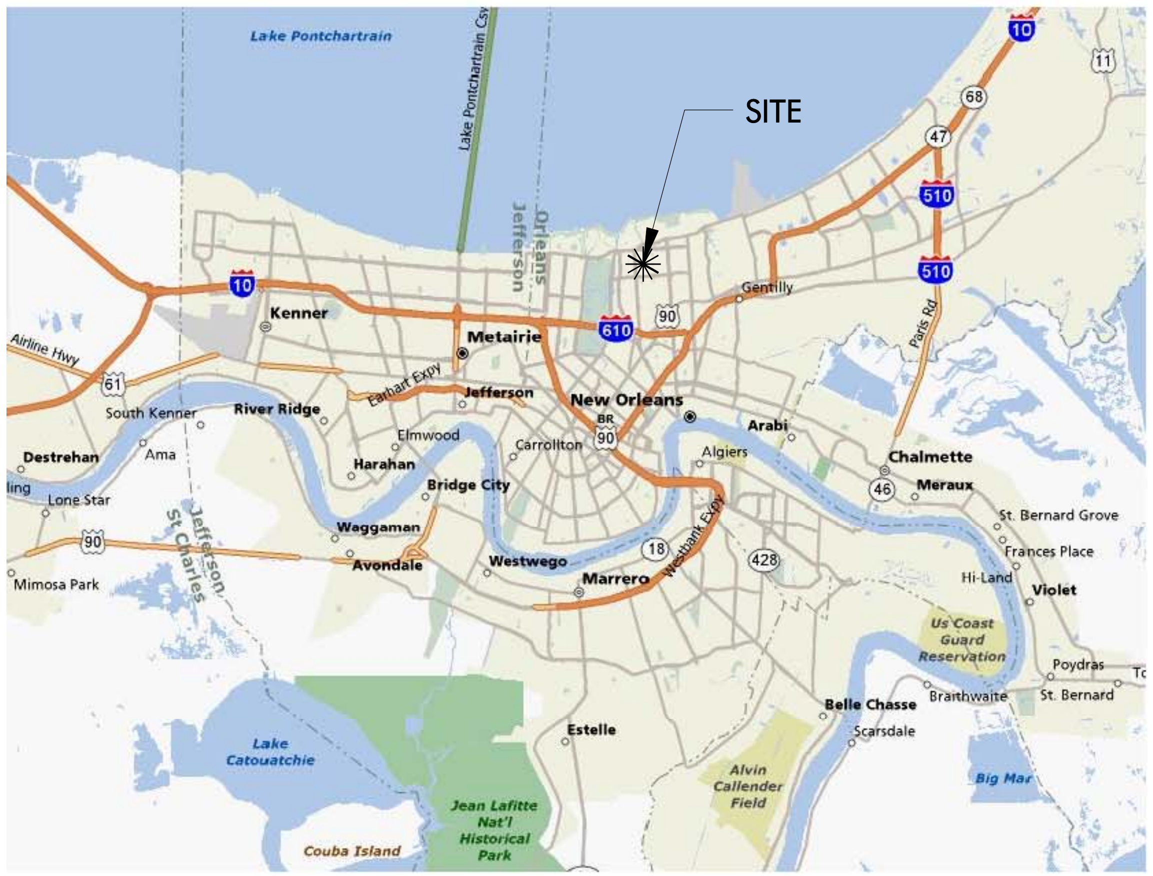
Parameter to be Measured	Purpose	Instrument Type	Manufacturer/Model Number	Range	Resolution	Provided By	Primary or Backup	Comments
Surface Water Levels	To Monitor Canal and Cofferdam Test Water Surface Elevation	4-20ma Pressure Transducer	Geokon Model 3400	0 to 14.5 psi	+/- .25% full-scale	USACE Inventory	Primary	To be installed in open standpipes mounted to opposite sides of cofferdam
		Manual Staff Gage	TBD	0 to Elevation +10	0.01 ft	Contractor	Manual Backup	To be mounted adjacent to standpipes housing surface water level transducers described above.
Subsurface Piezometric Levels	To Monitor Piezometric Water Levels	4-20ma Pressure Transducer	Geokon Model 3400	0 to 14.5 psi	+/- .25% full-scale	USACE Inventory	Primary	To be installed in open-standpipe piezometers as shown on Instrumentation Plan
		Manual Depth to Water Measurement	Open Standpipe Piezometer	Ground surface to ~ EL Tip of Sheet Piles	0.1 inch	USACE	Manual Backup	Manual measurements to be made hourly during each load increment holding period. Being installed by USACE
I-Wall Rotation/Tilt	To Monitor Tilt or Rotation of I-Wall	Vibrating Wire Tilt Meter	Geokon Model 6350 Uniaxial	+/- 10 degrees	10 arc seconds	URS	Primary	To be installed near center of each "panel".
		MEMS Tiltmeter	Sensametrics	TBD	TBD	Sensametrics	Secondary	To be installed near center of each "panel". This is an **emerging technology** to be evaluated during the site specific load test
I-Wall/Levee Translation/Horizontal Surface Displacement	To Monitor Horizontal/Vertical Movement of I-Wall/Levee System	Survey Prisms (located on top and at base of I-wall, top of levee, mid-slope and toe of levee)	Leica (model TBD)	+/- 1 Ft	+/- 0.04 inches (1 mm)	URS Subcontract Surveyor	Primary	Anticipate using automated (robotic) electronic distance measurement (EDM) device
		Fiber Optic Strain Gage	Pinnacle Technologies	TBD	TBD	Pinnacle Technolgies	Secondary	To be installed across each expansion joint (5 joints total). This is an **emerging technology** to be evaluated during the site specific load test
		Survey Monuments (located on top, mid-slope and toe of levee	Field Fabricated (concrete post with steel threaded pipe to mount prisms)	+/- 1 Ft	0.01 Ft	URS Subcontract Surveyor	Manual Backup	
		Manual Crack Gage	Avongard Gages	0.75 inch horizontal 0.375 inch vertical	0.04 inches (1mm)	URS	Manual Backup	
		Vibrating Wire Crackmeter	Geokon Model 4420	0 to 4 inches	0.001 inches	URS	Backup	
I-Wall/Levee Flood Side "Gap"	To Monitor Concrete/Soil Interface for Potential Gap	Concrete/Soil Pressure Meters –hydraulic jack-up type	Geokon Earth Pressure Cell Model 4810 w/pressurizing tube	TBD	TBD	URS	Primary	
		Vibrating Wire Crackmeter	Geokon Model 4420	0 to 4 inches	0.001 inches	URS	Secondary	
		Tell Tales	Field Fabricated	TBD	TBD	URS	Manual Backup	
Subsurface Lateral Deformation	To Monitor Potential Subsurface Lateral Deformation	In-Place Automated Inclinometers	Geokon VW Inclinometers Model 6300	+/- 10 degrees	+/- 10 arc seconds	URS	Primary	
		Manually Read Inclinometer (Before/After Test)	SINCO or Geokon Manual Probe	+/- 10 degrees	+/- 10 arc seconds	URS	Manual Backup	Inclinometer casings will be installed by USACE

Table 2
London Avenue Canal
Site Specific Load Test
Approximate Instrumentation Location Table

Instrumentation Type	Instrument ID	Station	Offset from Canal Side I-Wall Face (ft)	Comment
Crackmeter	CM-1	108+20	0	Need to field locate at corner of cofferdam.
	CM-2	108+20	1	Install across joint in concrete monoliths.
	CM-3	108+50	1	Install across joint in concrete monoliths.
	CM-4	108+80	1	Install across joint in concrete monoliths.
	CM-5	109+10	1	Install across joint in concrete monoliths.
	CM-6	109+40	1	Install across joint in concrete monoliths.
	CM-7	109+70	1	Install across joint in concrete monoliths.
	CM-8	109+70	0	Need to field locate at corner of cofferdam.
	CM-9	108+95	-1	Install between inclinometer and I-wall.
Inclinometer	IPI-1	108+95	-3	Will include approximately 6 in-place inclinometers.
	IPI-2	108+95	3	Will include approximately 6 in-place inclinometers.
	IPI-3	108+95	23	Will include approximately 6 in-place inclinometers.
Piezometer	PZ-1	108+08	3	Piezometer tip to be just below tip of sheet piles.
	PZ-2	108+50	3	Piezometer tip to be just below tip of sheet piles.
	PZ-3	108+92	3	Piezometer tip to be just below tip of sheet piles.
	PZ-3A	109+01	3	Piezometer tip to be just below tip of sheet piles.
	PZ-4	109+40	3	Piezometer tip to be just below tip of sheet piles.
	PZ-5	109+82	3	Piezometer tip to be just below tip of sheet piles.
	PZ-6	108+92	39	Piezometer tip to be just below clay/sand contact.
	PZ-6A	109+01	39	Piezometer tip to be just below clay/sand contact.
	PZ-7	108+92	52	Piezometer tip to be just below clay/sand contact.
	PZ-7A	109+01	52	Piezometer tip to be just below clay/sand contact.
	PZ-8	109+70	-20	Piezometer tip at approximately El. -2
	PZ-9	109+70	-20	Piezometer tip at approximately El. -2
	PZ-10	108+20	146	Piezometer tip to be just below clay/sand contact.
	PZ-11	108+92	146	Piezometer tip to be just below clay/sand contact.
	PZ-12	109+70	146	Piezometer tip to be just below clay/sand contact.
Pressure Cell	PC-1	108+47	0	
	PC-2	108+92	0	
	PC-3	109+37	0	
Staff Gauge	SG-1	109+70	-17	
	SG-2	109+70	-17	
Survey Prism	SP-1	108+05	0	At top of I-Wall.
	SP-1A	108+05	0	Installed in I-Wall several inches above existing grade.
	SP-2	108+38	0	At top of I-Wall.
	SP-2A	108+38	0	Installed in I-Wall several inches above existing grade.
	SP-3	108+68	0	At top of I-Wall.
	SP-3A	108+68	0	Installed in I-Wall several inches above existing grade.
	SP-4	108+98	0	At top of I-Wall.
	SP-4A	108+98	0	Installed in I-Wall several inches above existing grade.
	SP-5	109+28	0	At top of I-Wall.

Instrumentation Type	Instrument ID	Station	Offset from Canal Side I-Wall Face (ft)	Comment
Survey Prism (continued)	SP-5A	109+28	0	Installed in I-Wall several inches above existing grade.
	SP-6	109+58	0	At top of I-Wall.
	SP-6A	109+58	0	Installed in I-Wall several inches above existing grade.
	SP-7	109+85	0	At top of I-Wall.
	SP-7A	109+85	0	Installed in I-Wall several inches above existing grade.
Survey Monument	SM-1	108+05	3	
	SM-2	108+38	3	
	SM-3	108+68	3	
	SM-4	108+98	3	
	SM-5	109+28	3	
	SM-6	109+58	3	
	SM-7	109+85	3	
	SM-8	108+05	23	
	SM-9	108+38	23	
	SM-10	108+68	23	
	SM-11	108+98	23	
	SM-12	109+28	23	
	SM-13	109+58	23	
	SM-14	109+85	23	
	SM-15	108+05	39	
	SM-16	108+38	39	
	SM-17	108+68	39	
	SM-18	108+98	39	
	SM-19	109+28	39	
	SM-20	109+58	39	
	SM-21	109+85	39	
	SM-22	108+05	44	
	SM-23	108+68	52	
	SM-24	108+98	52	
	SM-25	109+85	44	
	SM-26	108+68	146	
	SM-27	108+98	146	
	SM-28	109+28	146	
Tell Tale	TT-1	108+53	0	
	TT-2	108+80	0	
	TT-3	108+98	0	
	TT-4	109+10	0	
	TT-5	109+43	0	
Tiltmeter	TM-1	108+35	0	
	TM-2	108+65	0	
	TM-3	108+95	0	
	TM-4	109+25	0	
	TM-5	109+55	0	

FIGURES



NEW ORLEANS

0 20,000'

SCALE: 1"=20,000'

N

SITE LOCATION MAP

0 5,000'

SCALE: 1"=5,000'

N

NOTE: SITE ADDRESS IS 5772 WARRINGTON DRIVE

US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

U. S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

URS
1001 Highlands Plaza Drive West, Suite 300
St. Louis, Missouri 63110
(314) 429-0100
PROJECT No. 21561824.00001

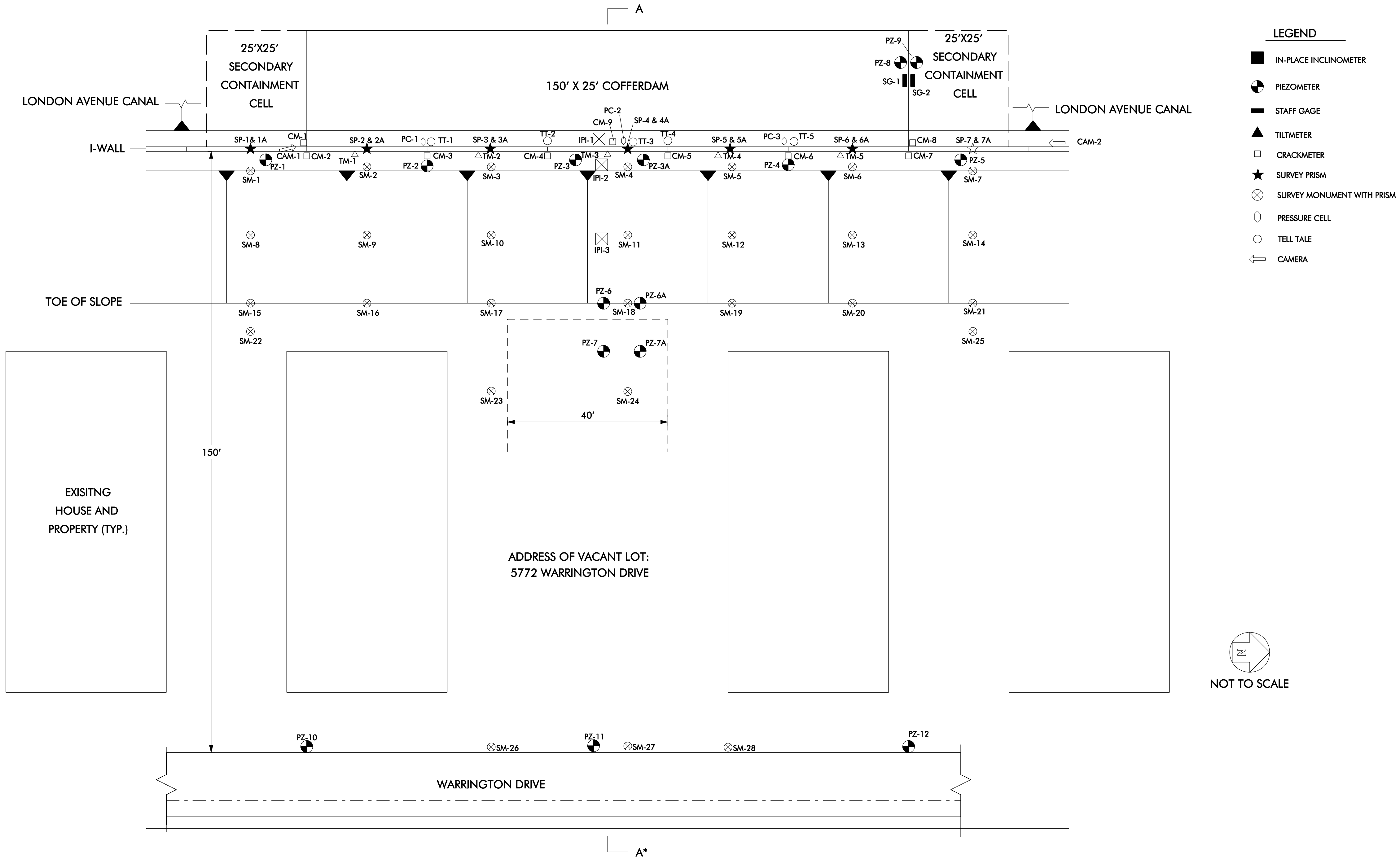
DESIGNED BY: KB	DATE: APRIL 2007
DWN BY: DAB	CKD BY: BR
SOLICITATION NO.:	
SUBMITTED BY: KENNETH BERRY, P.E.	CONTRACT NO.:
FILE NAME: FIGURE 1.DGN	FILE NUMBER:
SIZE: ANSI B	PLOT SCALE: 1:1
PLOT DATE: 04/18/2007	

NEW ORLEANS EAST
USACE - ST LOUIS DISTRICT OFFICE LEVEE UPGRADES
ORLEANS PARISH, LA.

LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

SITE LOCATION MAP

SHEET IDENTIFICATION NUMBER
FIGURE 1



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FILE NAME: FIGURE 2.DGN
SIZE: ANSI B
PLOT SCALE: 1:1
DATE: APRIL 2007
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CONTRACT NO.:
FILE NUMBER:
PLOT DATE: 04/18/2007

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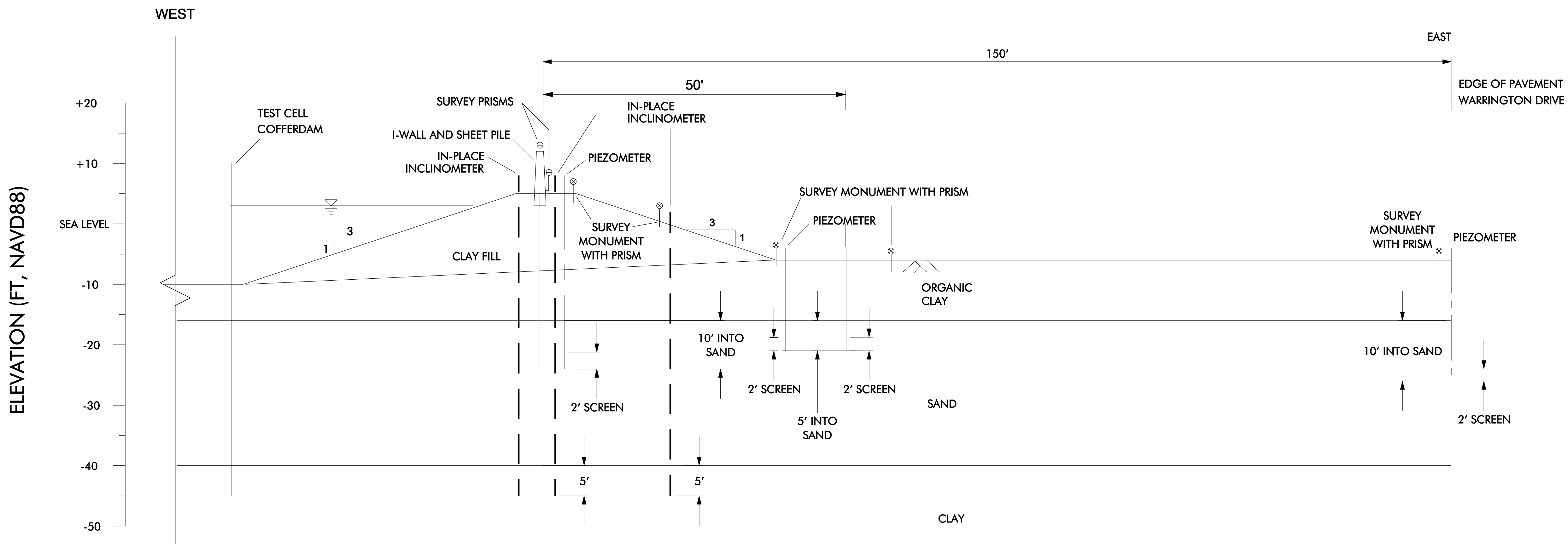
ORLEANS PARISH, LA.
LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

PLAN VIEW

SHEET IDENTIFICATION NUMBER
FIGURE 2



SECTION A-A*

LEGEND

INCLINOMETER

PIEZOMETER

SURVEY MONUMENT / PRISM

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FILE NAME: FIGURE 3.DGN
SIZE: ANSI B
PLOT SCALE: 1:1
DATE: APRIL 2007
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
PLOT DATE: 04/18/2007

NEW ORLEANS EAST
USACE - ST LOUIS DISTRICT OFFICE LEVEE UPGRADES
ORLEANS PARISH, LA.
LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

CROSS-SECTIONAL
VIEW OF SITE

SHEET
IDENTIFICATION
NUMBER
FIGURE 3

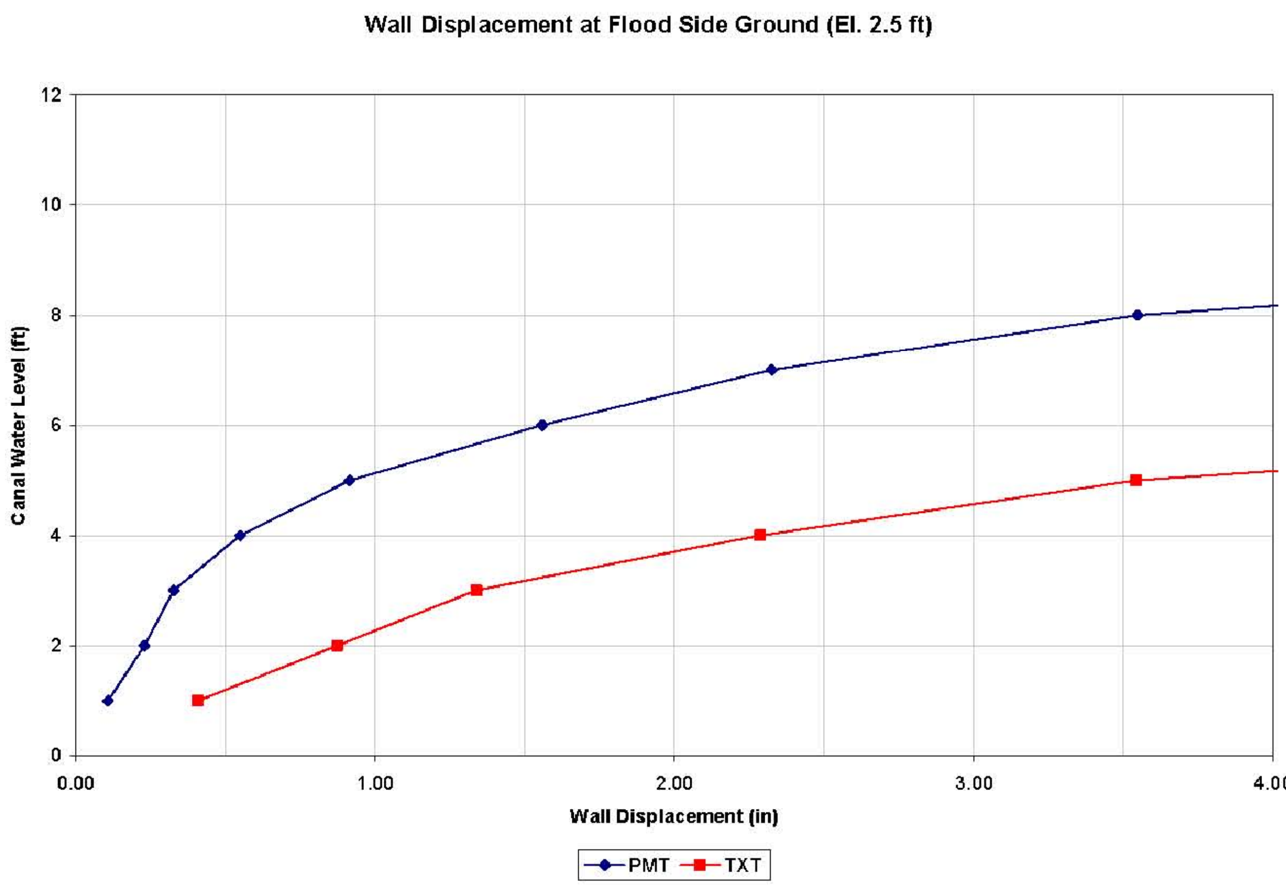

Figure 20 Wall Displacements at the Top of Levee.

PMT= USED SOIL MODULI FROM PRESSURE METER TESTS
TXT= USED SOIL MODULI FROM LABORATORY TRIAXIAL TESTS

SOURCE: SOIL STRUCTURE INTERACTION ANALYSIS REPORT

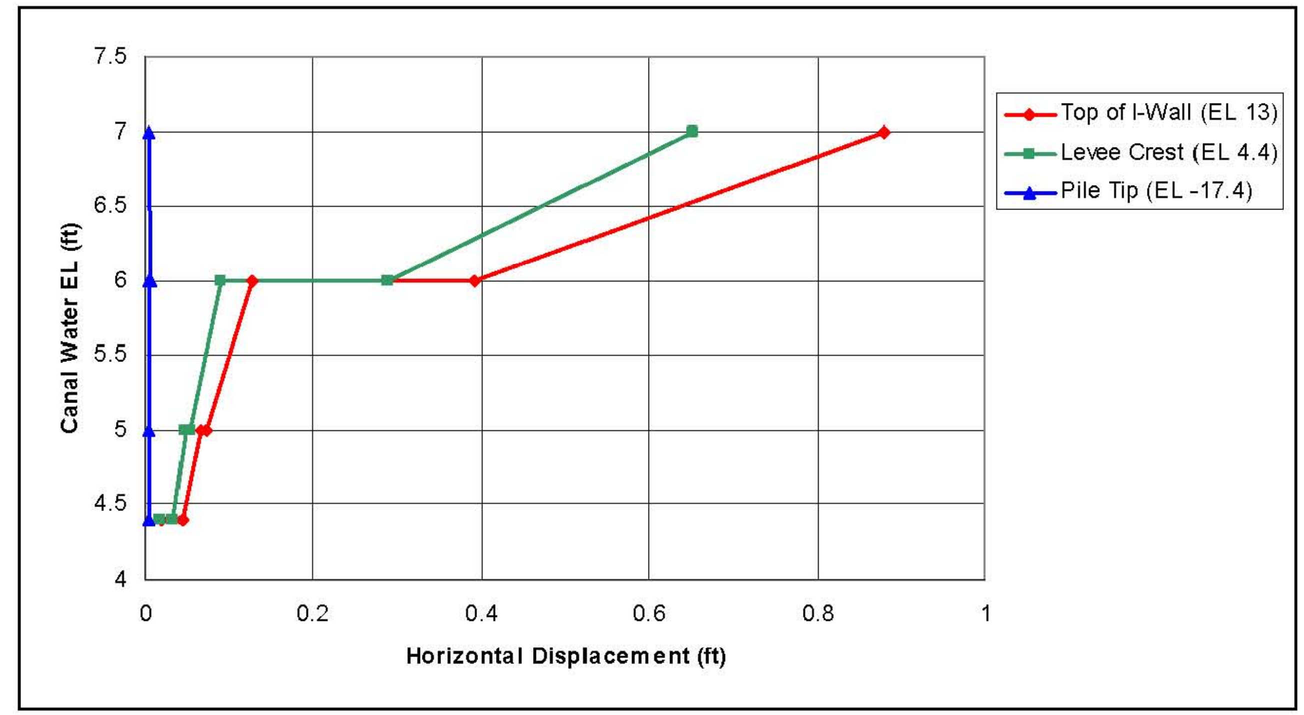

Figure 41. Horizontal Sheet Pile Deformations versus Canal Water Elevation Computed Using Average Stiffness Values for the London Avenue Canal North Breach

SOURCE: IPET DRAFT REPORT

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SIZE: ANSI B
PLOT SCALE: 1:1
DATE: APRIL 2007
SOLICITATION NO.:
CONTRACT NO.:
FILE NUMBER:
PLOT DATE: 04/18/2007

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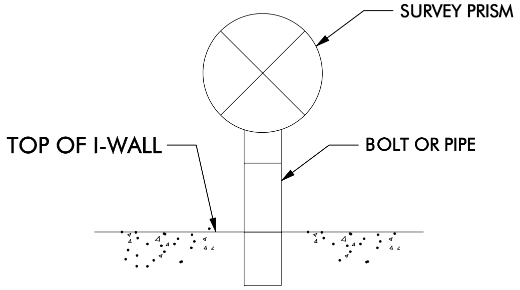
ORLEANS PARISH, LA.

LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST
IPET PLOT OF HORIZONTAL
DEFORMATION VS. CANAL
WATER ELEVATION

SHEET IDENTIFICATION NUMBER
FIGURE 4

NOTE: TILTMETERS WILL BE BOLTED TO WALL

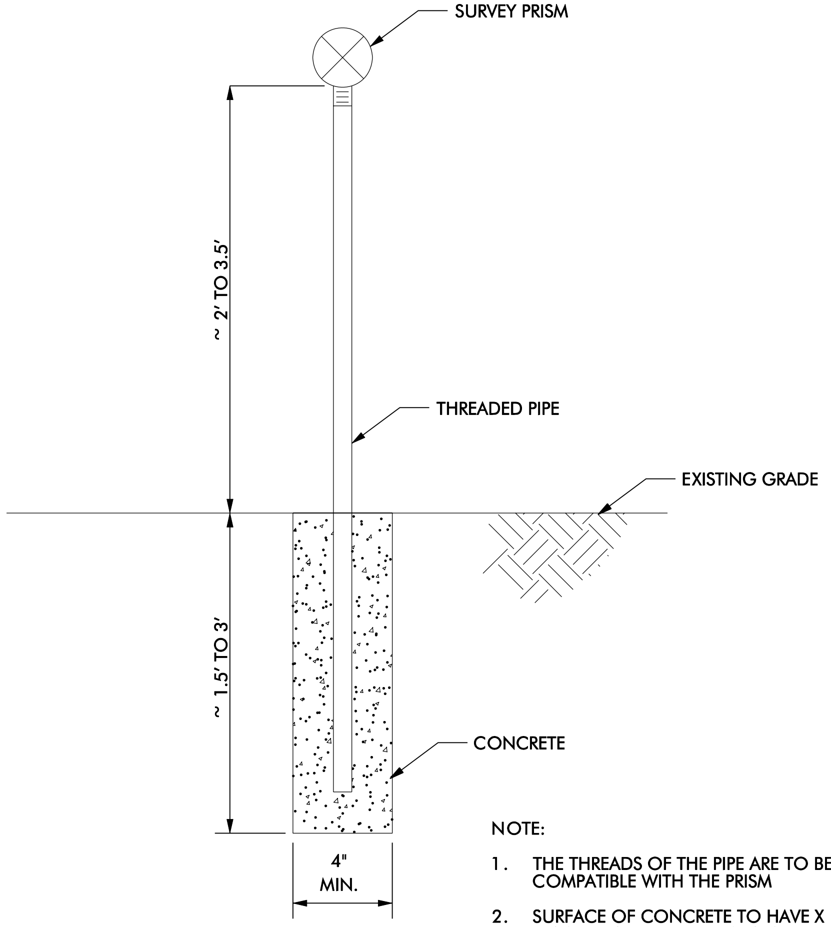
VIBRATING WIRE TILT SENSOR



SURVEY PRISM

(NOT TO SCALE)

NOTE: BOLT OR PIPE IS TO BE INSTALLED INTO I-WALL. THE THREADS OF THE BOLT/PIPE ARE TO BE COMPATIBLE WITH THE PRISM.



NOTE:

1. THE THREADS OF THE PIPE ARE TO BE COMPATIBLE WITH THE PRISM
2. SURFACE OF CONCRETE TO HAVE X PLACED ON THE FRESH CONCRETE FOR RESIDENT SURVEYING SHOULD IT BE DESIRED

SURVEY MONUMENT

(NOT TO SCALE)

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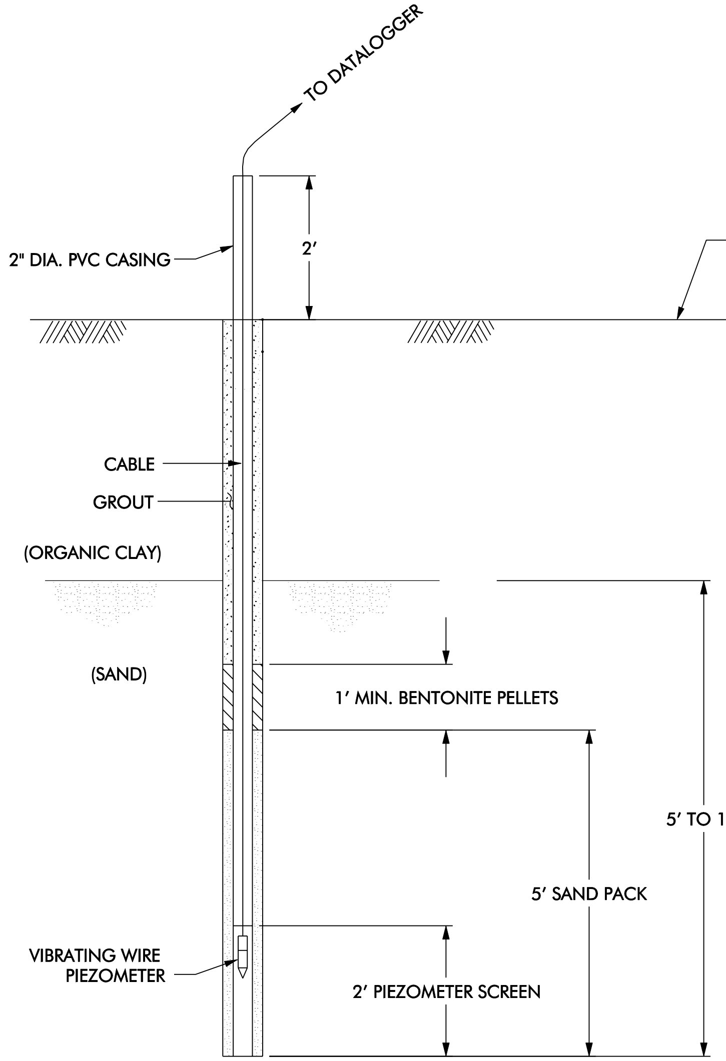
SUBMITTED BY: KENNETH BERRY, P.E.		CONTRACT NO.: W912P8-00-C-XXXX
FILE NAME: FIGURE 5.DGN		FILE NUMBER: H-8-46560
SIZE: ANSI B	PLOT SCALE: 1:1	PLOT DATE: 04/18/2007

NEW ORLEANS EAST
USACE - ST LOUIS DISTRICT OFFICE LEVEE UPGRADES
ORLEANS PARISH, LA.

LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

TILT METER SURVEY PRISMS AND SURVEY MONUMENT DETAILS

SHEET IDENTIFICATION NUMBER
FIGURE 5



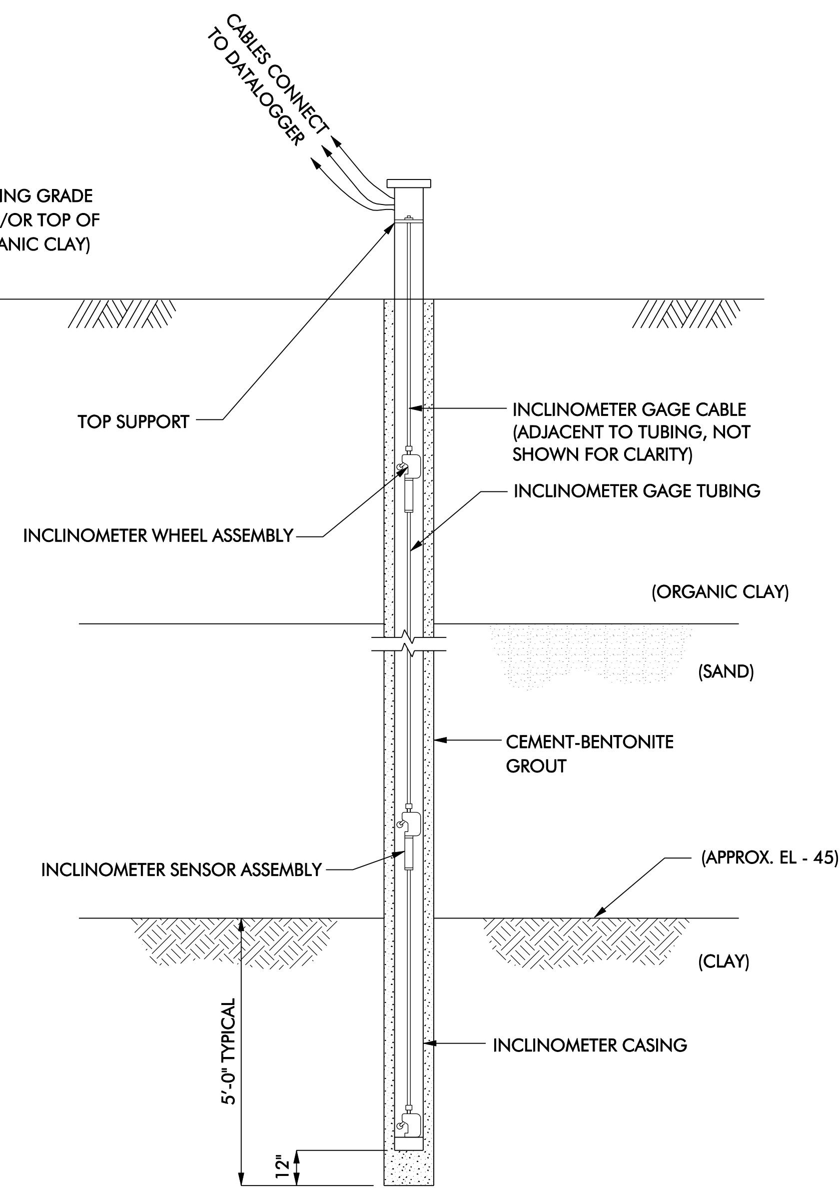
TYPICAL VIBRATING WIRE PIEZOMETER INSTALLATION

(NOT TO SCALE)

NOTES:

1. INSTALL A WELL COVER OR QUAZITE BOX FOR PIEZOMETERS NEAR SIDEWALK, IF NECESSARY.

2. CASING TO BE INSTALLED BY OTHERS.



IN-PLACE INCLINOMETER DETAIL

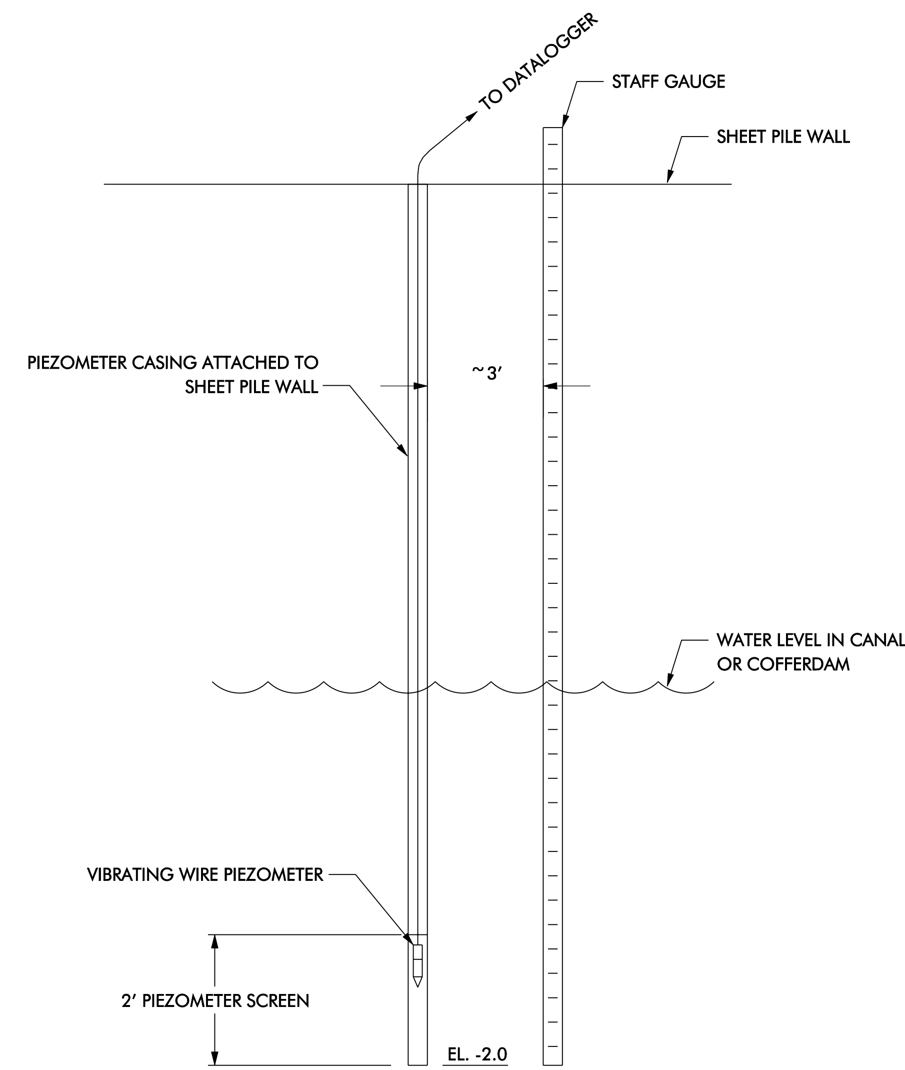
(NOT TO SCALE)

NOTES:

1. 2 FOOT OF STICK UP SHOULD BE PROVIDED FOR INCLINOMETERS INSTALLED ON PROTECTED SIDE OF LEVEE.

2. INCLINOMETER ON CANAL SIDE OF LEVEE TO HAVE TOP OF CASING AT ELEVATION 8.0.

3. CASING INSTALLATION TO BE PERFORMED BY OTHERS.



WATER SURFACE LEVEL INSTRUMENTS

(NOT TO SCALE)

US ARMY CORPS OF ENGINEERS
NEW ORLEANS DISTRICT

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DESIGNED BY: KB | DWN BY: CHS | CKD BY: BR | SUBMITTED BY: KENNETH BERRY, P.E. | FILE NAME: FIGURE 6.DGN | SIZE: ANSI B | PLOT SCALE: 1:1 | DATE: APRIL 2007 | SOLICITATION NO.: | CONTRACT NO.: | FILE NUMBER: | PLOT DATE: 04/18/2007

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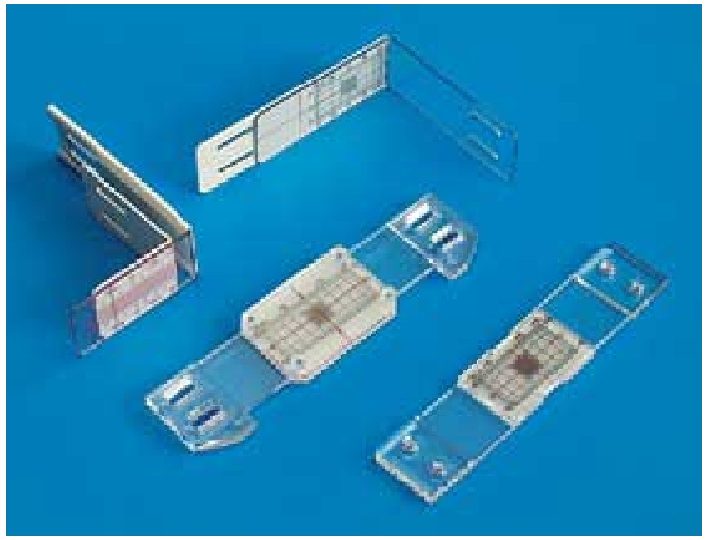
LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

INCLINOMETER AND PIEZOMETER DETAILS

SHEET IDENTIFICATION NUMBER
FIGURE 6

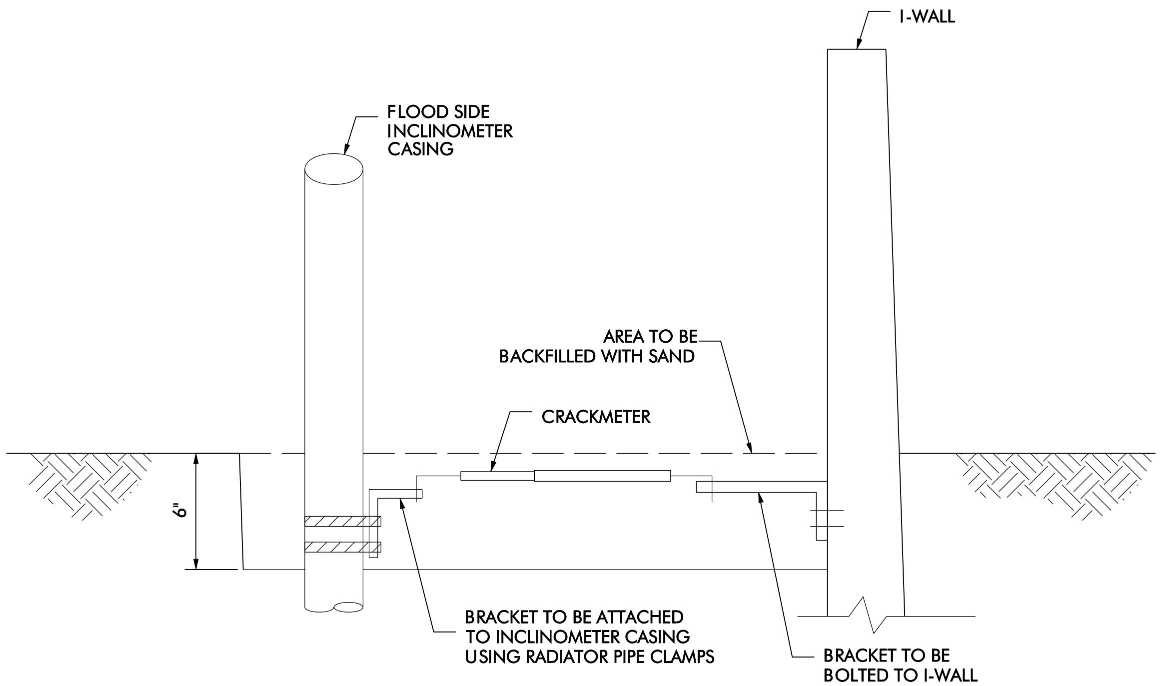


MANUAL CRACKMETER

EACH MONITOR CONSISTS OF TWO PLATES THAT OVERLAP FOR PART OF THEIR LENGTH. ONE PLATE IS CALIBRATED IN MILLIMETERS AND THE OTHER IS TRANSPARENT AND MARKED WITH A HAIRLINE CURSOR

VIBRATING WIRE CRACKMETER

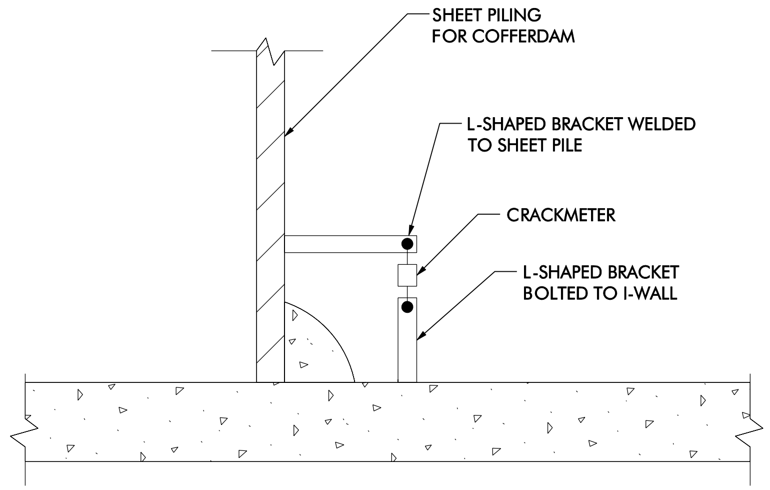
NOTE:
CRACKMETERS AT JOINTS IN I-WALL ARE TO BE INSTALLED SUCH THAT DEVICE STRADDLES JOINT WITH ONE END INSTALLED ON EACH SIDE OF JOINT.



CRACKMETER INSIDE COFFERDAM

(NOT TO SCALE)

NOTE:
A PRESSURE CELL AND TELL TALE WILL BE INSTALLED IN THE VICINITY OF THIS LOCATION. THESE DEVICES ARE NOT SHOWN FOR CLARITY.



CRACKMETERS AT EXTERIOR CORNERS OF COFFERDAM

(NOT TO SCALE)

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SUBMITTED BY: KENNETH BERRY, P.E.		CONTRACT NO.: W912P8-00-C-XXXX
FILE NAME: FIGURE 7.DGN		FILE NUMBER: H-8-46560
SIZE: ANSI B	PLOT SCALE: 1:1	PLOT DATE: 04/18/2007

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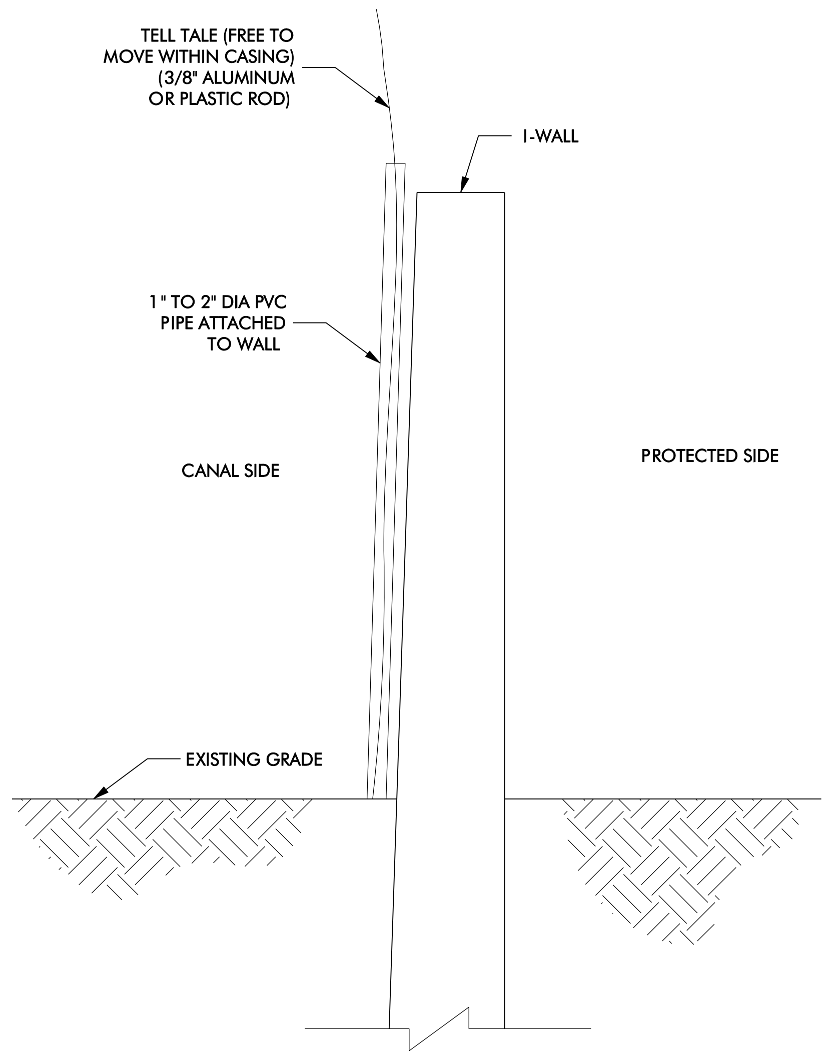
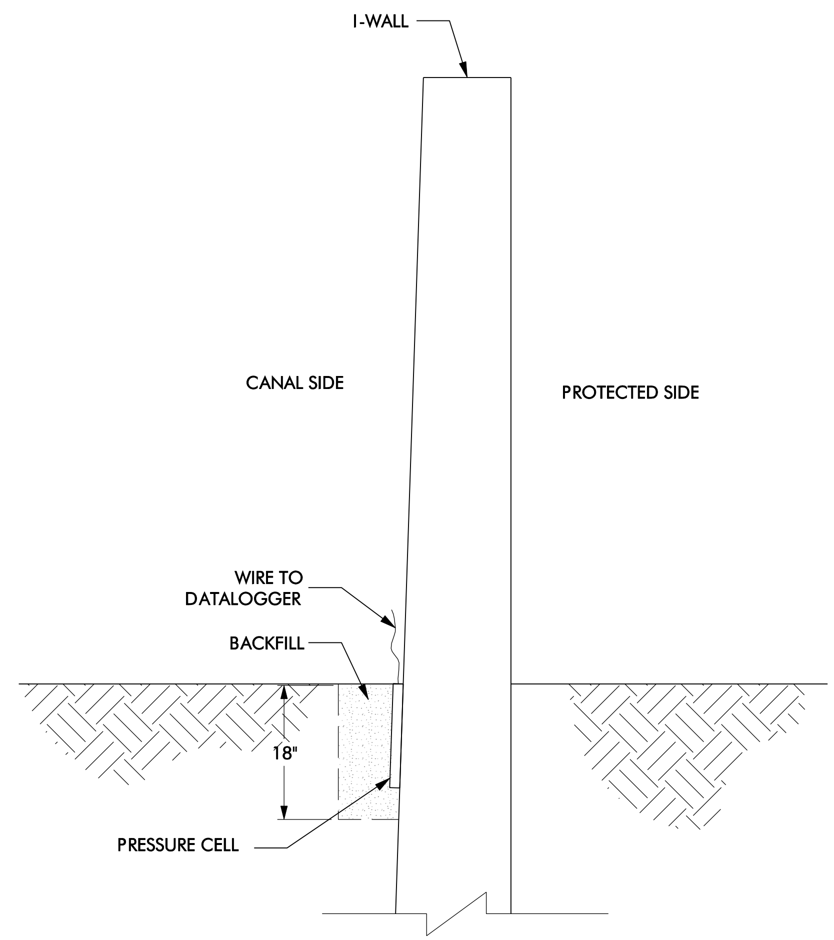
NEW ORLEANS EAST
ORLEANS PARISH, LA.
LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST
CRACKMETER DETAILS

SHEET IDENTIFICATION NUMBER
FIGURE 7



TELL TALE

(NOT TO SCALE)



PRESSURE CELL

(NOT TO SCALE)

NOTE:

DETAIL SHOWS A SCHEMATIC OF THE I-WALL. THE ACTUAL WALL HAS A GREATER THICKNESS AT THE GROUND SURFACE THAN AT THE TOP. AN ARCHITECTURAL FINISH ON THE WALL ALSO EXISTS. THE ATTACHMENT OF THE TELL TALE GUIDE WILL BE MADE FLUSH AT THE GROUND SURFACE. BLOCKING OR THE INSTALLATION OF BRACKETS MAY BE REQUIRED HIGHER ON THE WALL.

NOTE:

TEST PIT OF PRESSURE CELL SHALL BE BACKFILLED WITH CEMENT GROUT

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SUBMITTED BY: KENNETH BERRY, P.E.
FILE NAME: FIGURE 8.DGN
FILE NUMBER:
SIZE: ANSI B
PLOT SCALE: 1:1
PLOT DATE: 04/18/2007

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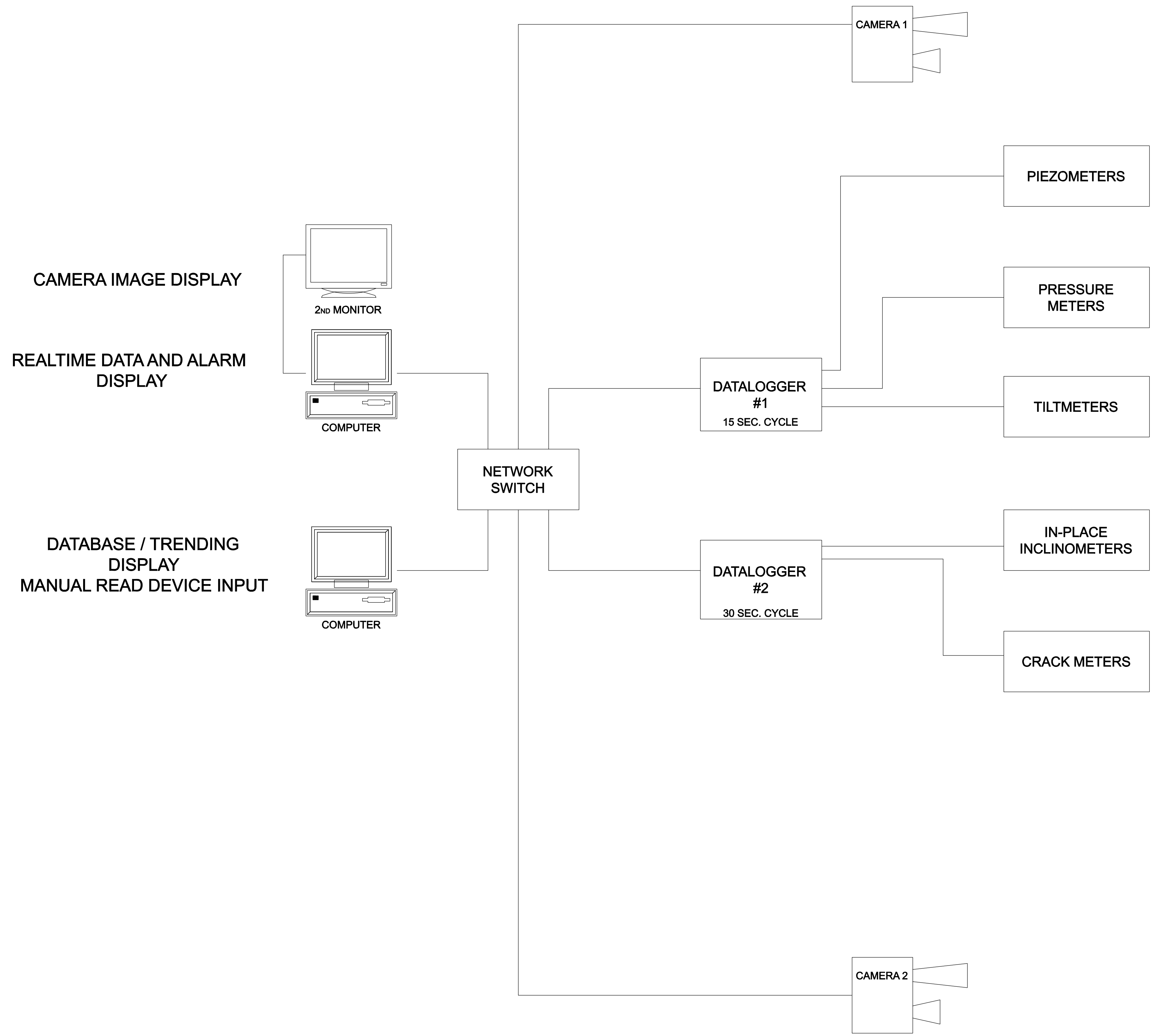
ORLEANS PARISH, LA.
LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

PRESSURE CELLS AND TELL TALE DETAILS

SHEET IDENTIFICATION NUMBER
FIGURE 8



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FILE NAME: FIGURE 9.DGN		FILE NUMBER:
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ORLEANS PARISH, LA.

LONDON AVENUE CANAL
SITE SPECIFIC LOAD TEST

ADAS BLOCK DIAGRAM

SHEET IDENTIFICATION NUMBER
FIGURE 9

Model 3400 Semiconductor Piezometer / Pressure Transducers

The Model 3400 Semiconductor Piezometers and Pressure Transducers are intended for dynamic measurements of fluid and/or pore water pressures in standpipes, boreholes, embankments, pipelines, pressure vessels, reservoirs, etc. They are also used for static pressure movement where the readout system is incompatible with vibrating wire type transducers. Three transducer output options are available.

Specifications

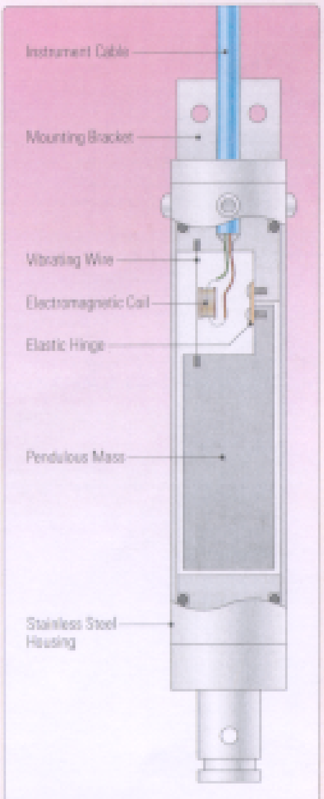
Standard Ranges	0.1, 0.15, 0.25, 0.4, 0.6, 1.0, 1.6, 2.5, 4.0 MPa
Over-Range	2 x rated pressure
Output	10 mV/v, 4-20 mA, 0-5 V
Accuracy	±0.25% F.S. or better
Linearity	< 0.5% F.S.
Temperature Range	–20°C to +80°C
Length x Diameter	194 x 32 mm

Vibrating Wire Tiltmeter

Applications

The Model 6350 Vibrating Wire Tiltmeter is designed to measure tilt in structures including...

- Buildings
- Dams
- Embankments
- Slopes
- Excavation walls
- Open pits



• *Vibrating wire tilt sensor construction.*

• *Model 6350 Vibrating Wire Tiltmeter shown with mounting bracket assembly.*

Operating Principle

The Model 6350 Tiltmeter is designed for attachment to structures, on either a vertical or horizontal surface by means of an adjustable bracket, and for the subsequent measurement of any tilting that may occur.

When at rest, in a vertical configuration, a pendulous mass inside the sensor, under the force of gravity, attempts to swing beneath the elastic hinge on which it is supported but is restrained by the vibrating wire. As the tilt increases or decreases the mass attempts to rotate beneath the hinge point and the tension in the vibrating wire changes, altering its vibrational frequency. This frequency is measured using the Geokon Model GK-401, GK-403 or GK-404 Readout Box, or the Model 8020 Micro-10 Datalogger, and is then converted into an angular displacement by means of calibration constants supplied with the sensor.

Advantages and Limitations

Vibrating wire tiltmeters combine a high range with high sensitivity, and very high calibration accuracy. They have excellent long-term stability and their temperature dependence is close to zero.

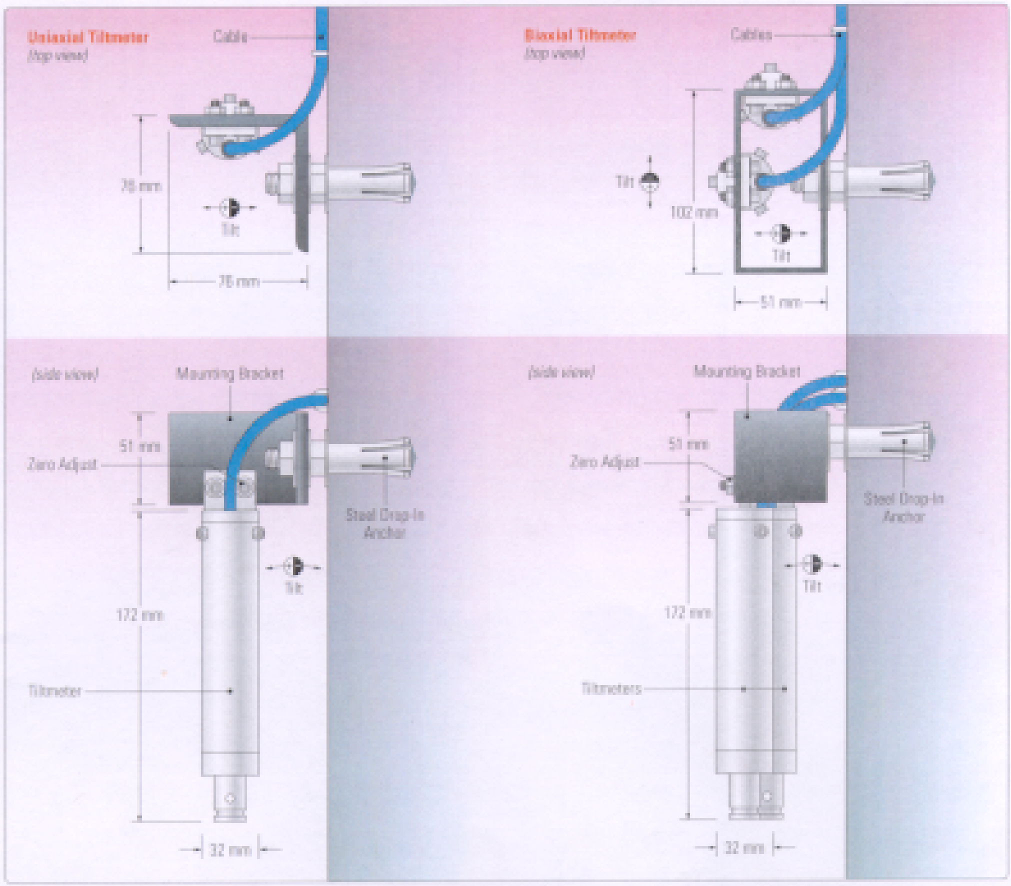
The sensor output is a frequency, which can be transmitted over long cables, and renders the sensors less susceptible to the effects of moisture intrusion.

Biaxial measurements can be achieved by mounting the sensors in pairs, each member oriented at 90 degrees to the other.

Damping fluid may be added to the sensor to counteract the effect of any vibrations of the structure.

In-built shock absorbers protect the sensor from shock loading.

- *Model 6350 installation using a custom mounting bracket designed for concrete face rock fill dam applications (shown with protective cover removed).*



- *Installation details and dimensions for the Model 6350 Uniaxial (left) and Biaxial versions (right).*

System Components

The basic transducer is mounted inside a stainless steel housing equipped with a lug for mounting the sensor to an adjustable bracket. The bracket is bolted to the structure using hardware supplied with the sensor, which includes a 3/8-inch drop-in anchor. Special biaxial mounting brackets and protective enclosures are also available.

A thermistor mounted inside the sensor housing permits the measurement of temperatures.

Readout is accomplished using a Geokon Model GK-401, GK-403 or GK-404 Readout Box.

Technical Specifications

Standard Range[1]	±10°
Resolution	±10 arc seconds (±0.05 mm/m)
Accuracy[2]	±0.1% F.S.
Temperature Range	−20°C to +50°C
Shock Survival	50 g
Length × Diameter[3]	139 × 32 mm

[1] Other ranges available on request.
[2] Established under laboratory conditions.
[3] Transducer only.

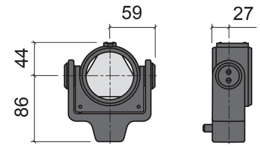
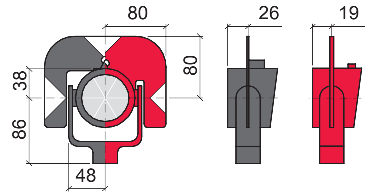
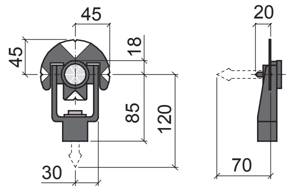
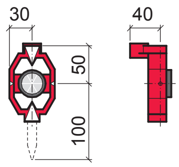
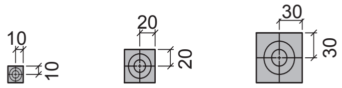
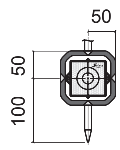
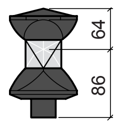
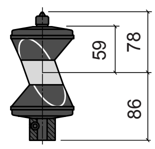
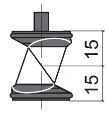
GEOKON

The World Leader in Vibrating Wire Technology™

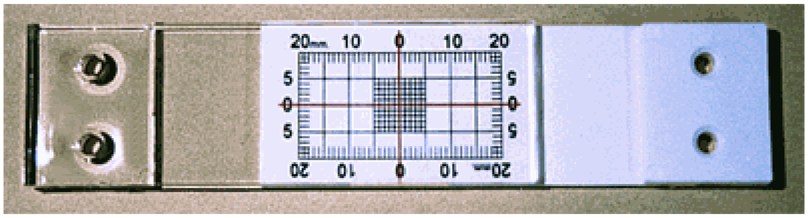
Geokon, Incorporated
48 Spencer Street
Lebanon, NH 03766
USA

1 • 603 • 448 • 1562
1 • 603 • 448 • 3216
geokon@geokon.com
www.geokon.com

Product Information
Prism dimensions

Prisms	Constants [mm]	
Circular prism GPH1P	0.0	
Circular prism GPR121/111	0.0	
Miniprism GMP101	+17.5	
Miniprism GMP111 GMP111-0	+17.5 0.0	
Reflective tape	+34.4	
Flat prism CPR 105	+34.4	
360° prism GRZ4	+23.1	
360° prism GRZ122	+23.1	
360° Mini prism GRZ101	+30.0	

...**The Avongard Crack Monitor** is a simple and effective gauge to measure the movement of cracks in brick, concrete, or masonry structures.



The Avongard Crack Monitor consists of two overlapping acrylic plates. One plate is white with a black millimeter grid, while the other is transparent with red crosshairs centered over the grid. Once the Crack Monitor is in position across a crack, the crosshairs shift vertically or horizontally on the grid if movement occurs,so that anyone can easily see and track crack movement .

Specifications

Material	: Plexiglass® acrylic
Dimensions (each plate)	: 1.25 x 4 x 0.25 in.
Dimensions (overall)	: 1.25 x 5.75 x 0.25 in.
Dimensions (grid)	: 1.5 x 0.75 in / 40 x 20mm
Discrimination	: 0.5 mm
Max. width movement	: 0.750 in / 20mm
Max. upward movement	: 0.375 in / 10mm
Coeff. Thermal Expansion	: 3.80 x 10-5 in/in/°F
	: 6.84 x 10-5mm/mm/°C

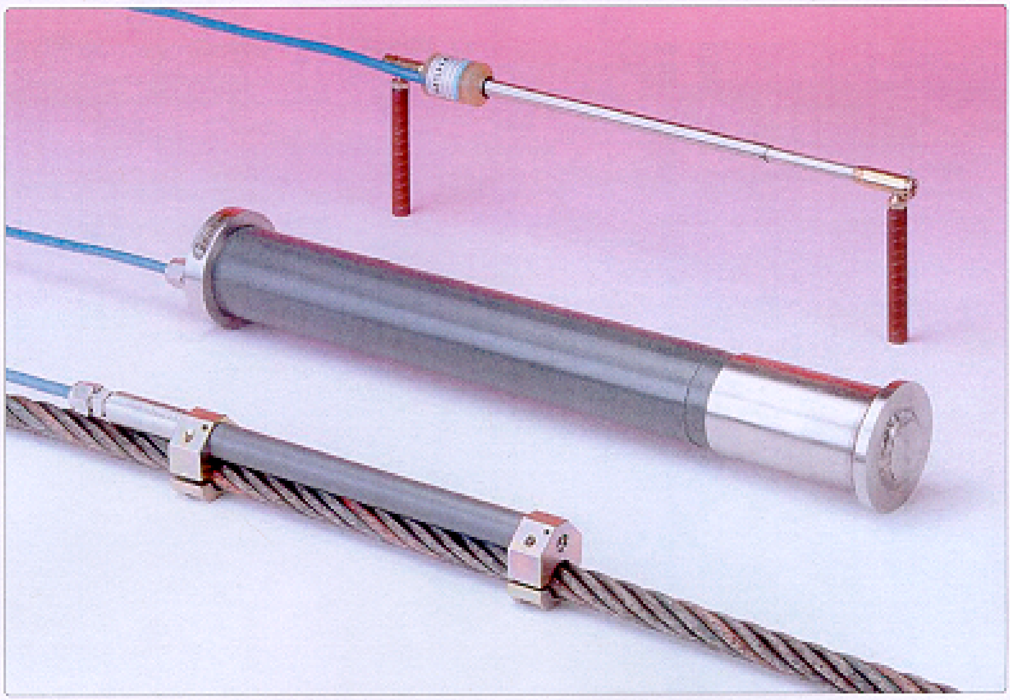
Vibrating Wire Displacement Transducers

Applications

The 4400 Series are designed to measure or monitor the...

- Expansion or contraction of a joint
- Strains in tendons and steel cables
- Movement across surface cracks and joints
- Closures in underground excavations, tunnels, etc.
- Displacements associated with landslides
- Movement of boulders, snow, etc. on unstable slopes

• Model 4420 Crackmeter installation.



• Model 4410 Strandmeter (front), Model 4400 Embedment Jointmeter (center) and Model 4420 Crackmeter (rear).

Operating Principle

Geokon vibrating wire displacement transducers are designed to measure displacements across joints and cracks in concrete, rock, soil and structural members.

In essence, the transducer consists of a vibrating wire in series with a tension spring. Displacements are accommodated by a stretching of the tension spring, which produces a commensurate increase in wire tension.

The wire and spring are connected to a free-sliding rod which protrudes from, and is free to slide inside, a protective outer tube. An o-ring seal prevents water from entering.

The frequency signal is transmitted through the cable to the readout location, conditioned, and displayed on portable readouts or dataloggers.

Advantages and Limitations

The 4400 Series Displacement Transducers are fabricated entirely from stainless steel and are waterproof to 1.75 MPa, which, coupled with their excellent long-term stability, guarantees reliability and performance in even the harshest environments.

An advantage of vibrating wire displacement transducers over more conventional linear potentiometers (or LVDT's) lies mainly in the use of a frequency, rather than a voltage, as the output signal. Frequencies may be transmitted over long lengths of electrical cable without appreciable degradation caused by variations in cable resistance or leakage to ground. This allows for a readout location that may be over a thousand meters from the transducer.

Thermistors are provided with all transducers for temperature measurement.

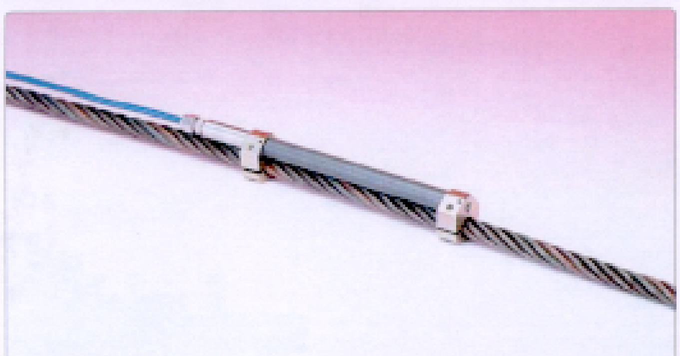
Model 4400 Embedment Jointmeter

Model 4400 Embedment Jointmeter shown with socket removed.

The Model 4400 is designed for use in construction joints; e.g. between lifts in concrete dams. In use, a socket is placed in the first lift of concrete and, when the forms are removed, a protective plug is pulled from the socket. The gage is then screwed into the socket, extended slightly and then concreted into the next lift. Any opening of the joint is then measured by the gage which is firmly anchored in each lift. The sensing gage itself, is smaller than the protective housing, and a degree of shearing motion is allowed for by the use of ball-joint connections on the gage.

A tripolar plasma surge arrestor is located inside the housing and provides protection from electrical transients such as those that may be induced by lightning.

Model 4410 Strandmeter



Model 4410 Strandmeter.

The Model 4410 Strandmeter is designed to measure strains in tendons and steel cables, including bridge tendons, cable stays, ground anchors, tiebacks, etc. Two clamps at each end of the strandmeter hold it firmly onto the cable. Various size clamps are available.

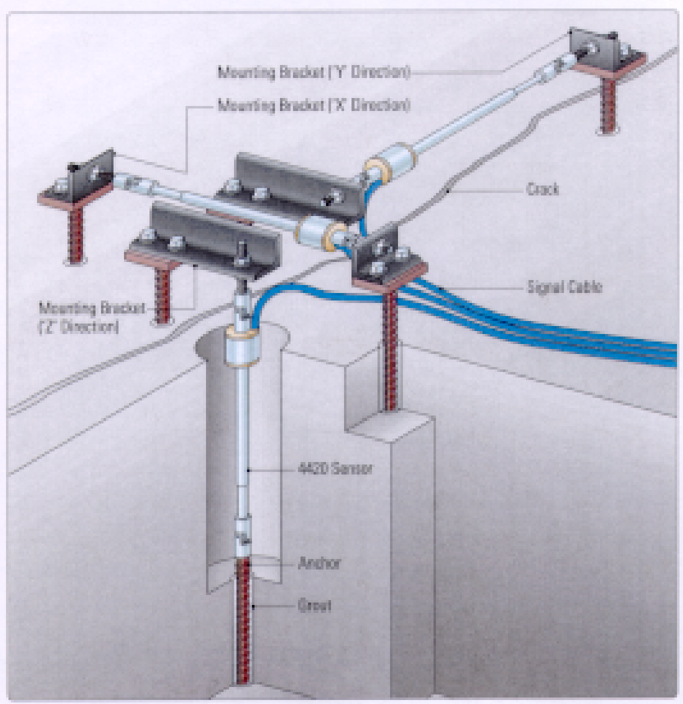
Model 4420 Crackmeter

Model 4420 Crackmeter.

The Model 4420 Crackmeters are designed to measure movement across joints such as construction joints in buildings, bridges, pipelines, dams, etc.; tension cracks and joints in rock and concrete.

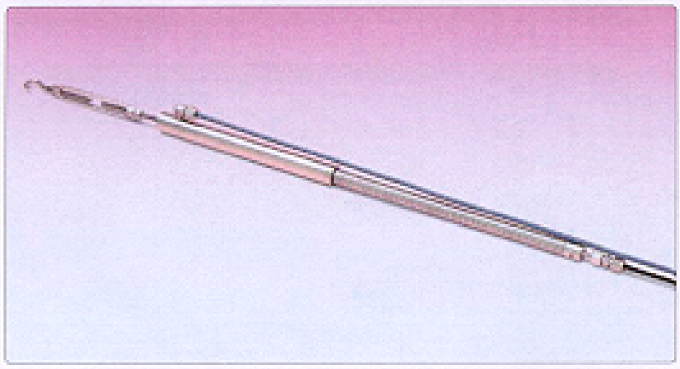
The sensor is installed by attaching the ends to anchors (with ball joints) that have been grouted, bolted, welded or bonded on opposite sides of the crack or fissure that is to be monitored. 3-D mounting brackets are also available which allow transducers to be installed to measure displacements in three orthogonal directions, as are special clamps that allow transducers to be attached to a variety of earth reinforcements and geogrids.

Special versions are offered for underwater use, where water pressures exceed 1.7 MPa, and for use in cryogenic or elevated temperature regimes (contact Geokon for details).



Three Model 4420 Crackmeters configured as a single 3-D Crackmeter.

Model 4425 Convergence Meter



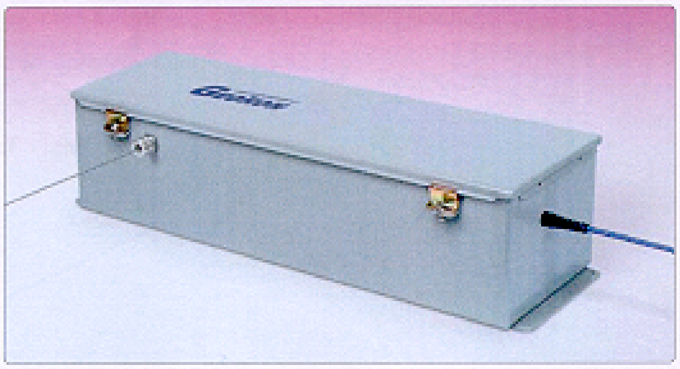
• Model 4425 Convergence Meter.

The Model 4425 Convergence Meter is designed to detect deformation in tunnels and underground caverns by measuring the contraction (or elongation) between 2 anchor points fixed in the walls of the tunnel or cavern.

The Model 4425 consists of a spring-tensioned vibrating wire transducer assembly, turnbuckle, 6 mm diameter connecting rods (stainless steel, fiberglass or graphite), rod clamp, and a pair of anchor points. Changes in distance between the 2 anchors are conveyed by the connecting rods and measured by the transducer.

The Model 4425 can operate in horizontal, inclined or vertical orientations. In areas where construction traffic is expected or where the instrument may be left in an exposed location, some form of protective housing should be considered.

Model 4427 Long-Range Displacement Meter

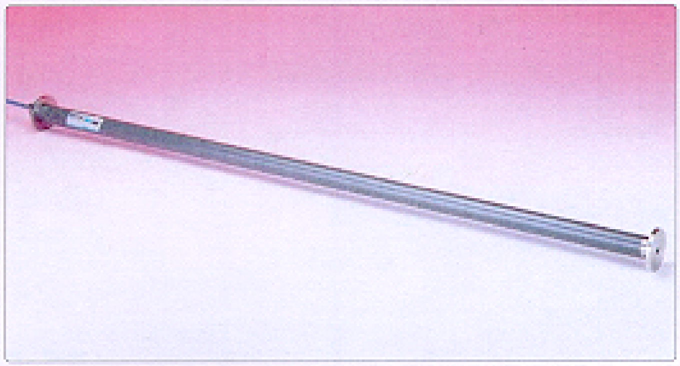


• Model 4427 Long-Range Displacement Meter.

The Model 4427 Long-Range Displacement Meter is ideally suited for the measurement of large displacements associated with landslides. The Model 4427 can also be used for monitoring the movement of boulders, snow, etc., on unstable slopes.

The Model 4427 consists of a vibrating wire displacement transducer coupled to a spring motor drive by means of a lead screw. As the cable is pulled, the motor drum rotates and advances the lead screw. Thus the rotation is converted into a linear displacement which is measured by the vibrating wire displacement transducer.

Model 4430 Deformation Meter

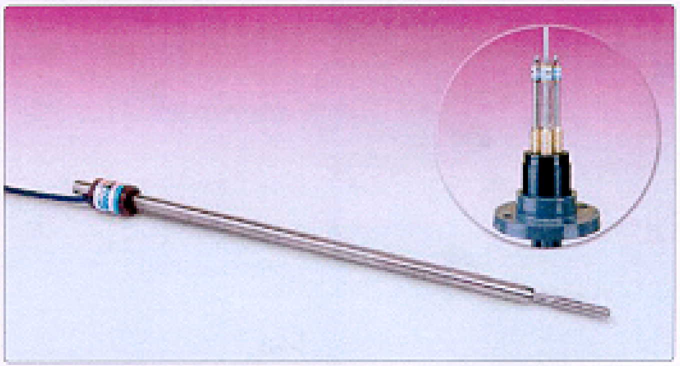


• Model 4430 Deformation Meter.

The Model 4430 Deformation Meter is designed to measure axial strains or deformations in boreholes in rock, concrete or soil. It can also be embedded in soils in embankments such as earth dams and highway fills. The Model 4430 can be installed in series to give a total deformation profile along a particular axis. Base lengths of the gage can vary from a minimum of 1 meter to over 25 meters.

When used in rock in horizontal or inclined downward boreholes, grouting is the most common method of installation. In vertical boreholes, a special grouting apparatus and hydraulic or snap-ring anchors are required. Direct placement or pre-wiring to a rebar cage allows use in concrete.

Model 4450 Displacement Transducer



• Model 4450 Displacement Transducer and Extensometer Head Assembly (inset).

The Model 4450 Displacement Transducer provides remote readout capability for Borehole Extensometers (see the Geokon Model A-3, A-4, A-5, A-6 Rod-Type Borehole Extensometers data sheet for more information). They are particularly useful where other types of vibrating wire sensors are used and/or for installations where long cable runs are required.

The Model 4450 can also be installed between borehole anchors, in conjunction with the requisite length connecting rod, to provide a permanent, in-place incremental extensometer (contact Geokon for details).

Technical Specifications

Model	Standard Ranges[1]	Resolution	Accuracy	Nonlinearity	Temperature Range[1]	Dimensions
4400 Embedment Jointmeter	12.5, 25, 50, 100 mm	0.025% F.S.	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	*Length:* 406 mm *Flange Diameter:* 51 mm
4410 Strandmeter	20,000 με	< 5 με	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	*Length:* 203 mm *Clamp Width:* 45 mm
4420 Crackmeter	12.5, 25, 50, 100, 150 mm	0.025% F.S.	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	*Lengths:* 318, 362, 527 mm *Coil Diameter:* 25 mm
4425 Convergence Meter	25, 50, 100, 150 mm	0.025% F.S.	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	*Transducer Lengths:* 356, 508, 838 mm *Transducer Diameter:* 25 mm
4427 Long-Range Displacement Meter	1, 2 m (without resetting)	0.025% F.S.	±1.0% F.S.	—	−30°C to +60°C	*Enclosure (L × W × H):* 610 × 152 × 152 mm
4430 Deformation Meter	25, 50, 100 mm	0.02% F.S.	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	*Length:* varies *Flange Diameter:* 50 mm
4450 Displacement Transducer	12.5, 50, 100, 150, 300 mm	0.02% F.S.	±0.1% F.S.	< 0.5% F.S.	−20°C to +80°C	*Lengths:* 210, 212, 270, 410 mm *Coil Diameter:* 19 mm

[1] *Other ranges available on request.*

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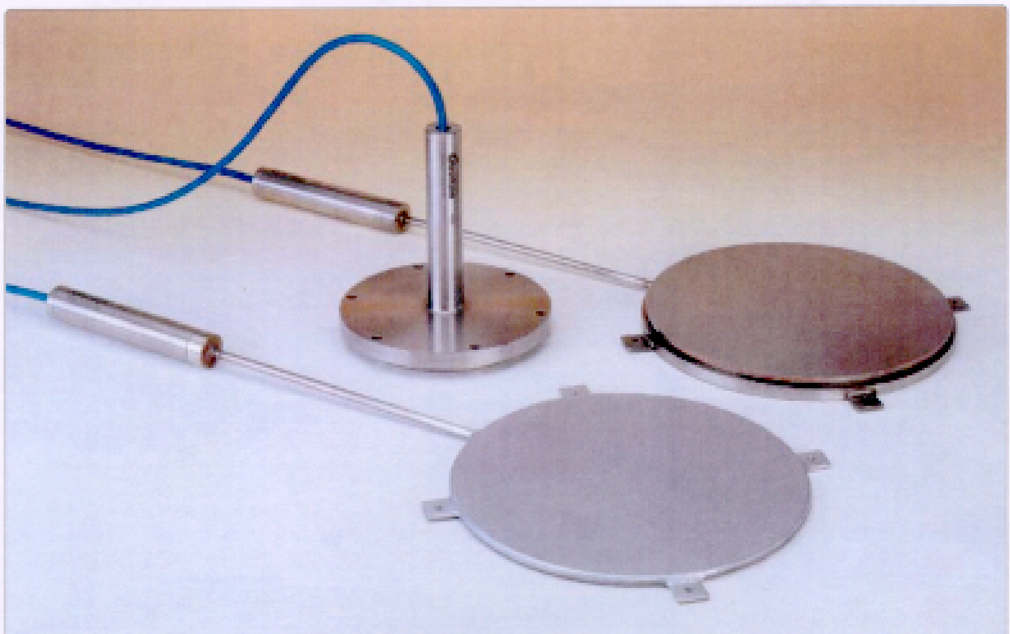
Earth Pressure Cells



• *Model 4800 Earth Pressure Cell (front), Model 4820 Jackout Pressure Cell (center) and Model 4810 Contact Pressure Cell (rear).*

Applications

Earth Pressure Cells provide a direct means of measuring total pressures, i.e. the combination of effective soil stress and pore water pressure, in or on...

- Bridge abutments
- Diaphragm walls
- Fills and embankments
- Retaining walls surfaces
- Sheet piling
- Slurry walls
- Tunnel linings

They may also be used to measure earth bearing pressures on foundation slabs and footings and at the tips of piles.

Operating Principle

Earth Pressure Cells are constructed from two stainless steel plates welded together around their periphery and separated by a narrow gap filled with hydraulic fluid. External pressures squeeze the two plates together creating an equal pressure in the internal fluid. A length of stainless steel tubing connects the fluid filled cavity to a pressure transducer that converts the fluid pressure into an electrical signal transmitted by cable to the readout location.

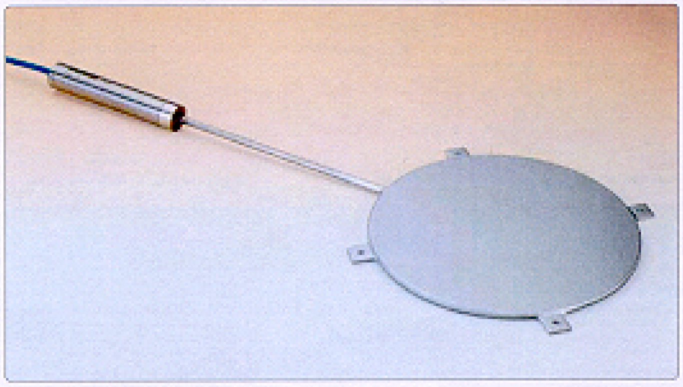
Advantages & Limitations

The 4800 Series Earth Pressure Cells use vibrating wire pressure transducers and thus have the advantages of long term stability, reliable performance with long cables and insensitivity to moisture intrusion. All models also include a thermistor for temperature measurements and a gas discharge tube for lightning protection. Where dynamic stress changes are to be measured a semi-conductor type pressure transducer is substituted (see Model 3500).

Cell performance depends strongly on the surrounding soil properties. It would be prohibitively expensive to calibrate a cell in the soil type specific to the application being contemplated. However, studies have shown that the most consistent cell performance is achieved using cells of maximum stiffness with aspect ratios D/t >10 (D is the diameter of the cell, t the thickness). With Geokon cells, maximum stiffness is achieved by using hydraulic oil with less than 2 ppm of dissolved gas and aspect ratios generally greater than 20 to 30. Tests on Geokon cells in various types of soil have shown that the cells over-register the soil pressure by less than 5 percent. This is probably no greater than the inherent variability of the soil pressure distribution in the ground.

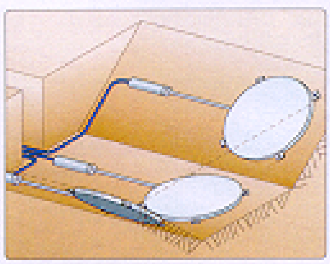
Typical of all closed hydraulic systems, earth pressure cells are sensitive to temperature changes which cause the internal fluid to expand at a different rate than the surrounding soil giving rise to spurious fluid pressure changes. The magnitude of the effect depends to a greater extent on the elasticity of the surrounding soil, i.e., on the degree of compaction and confinement, and is difficult to predict and correct for. The built-in thermistor is helpful in separating these spurious effects from real earth pressure changes.

Model 4800, 4815 Earth Pressure Cells



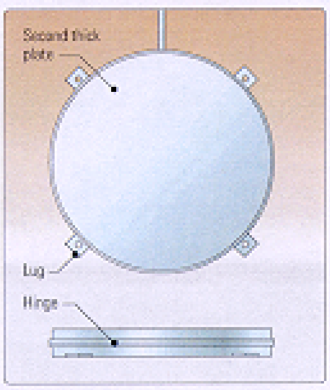
• *Model 4800 Earth Pressure Cell.*

Model 4800 cells are constructed from two thin pressure sensitive plates. They can be positioned in the fill at different orientations so that soil pressures can be measured in two or three directions. Special armored cables are recommended in earth dam applications.



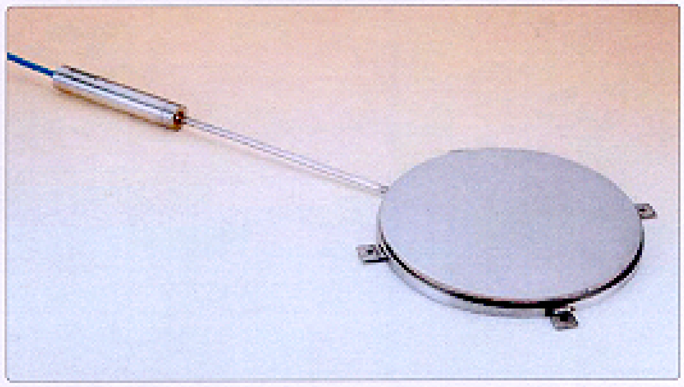
• *Model 4800 Earth Pressure Cells installed in fill for soil pressure measurement in three directions.*

The **Model 4815** is a special cell that effectively reduces the severity of point loading when used in granular materials. The modification uses two thick plates welded together at a flexible hinge that helps provide more uniform pressure distribution.



• *Model 4815 pressure cell, with two thick plates, for use in granular materials.*

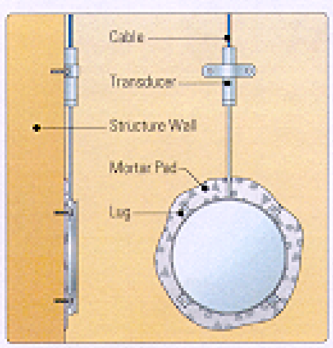
Model 4810 Contact Pressure Cells



• *Model 4810 Contact Pressure Cell for attachment to existing concrete surfaces.*

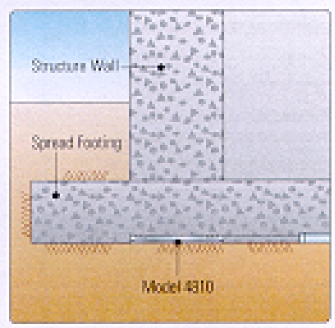
The Model 4810 Contact Pressure Cell is designed to measure soil pressures on structures. The backplate of the cell which bears against the external surface of the structure is thick enough to prevent the cell from warping. The other plate is thin and is welded to the backplate in a manner which creates a flexible hinge to provide maximum sensitivity to changing soil pressures.

Lugs on the side provide a means of mounting the cell to concrete forms or to steel or concrete surfaces. A mortar pad beneath the backplate ensures good contact with the structure surface. Cells are best installed flush with the surface to which they are attached. The fill material next to the cell should be screened to remove pieces larger than 10 mm.



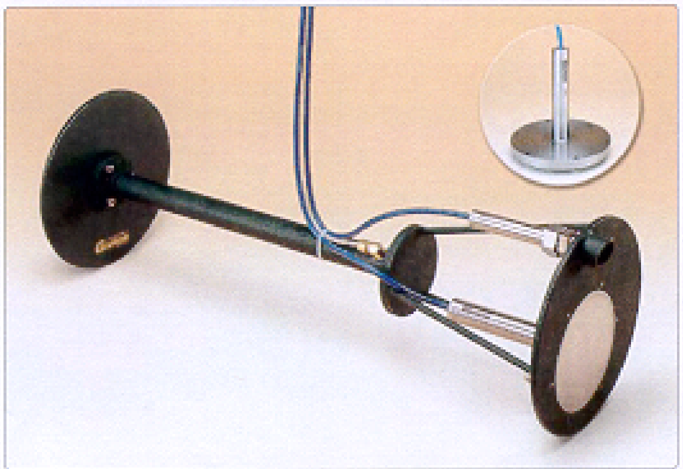
• *Side and frontal views of the Model 4810 installed on existing structure.*

Cells installed at the base of slabs and footings to measure bearing loads should always be positioned inside the concrete with the sensitive face pressed against the compacted fill. Cells placed in the fill below the concrete often become decoupled from the soil pressure due to the impossibility of adequately compacting the fill around the cell.



• *Model 4810 installation in a spread footing.*

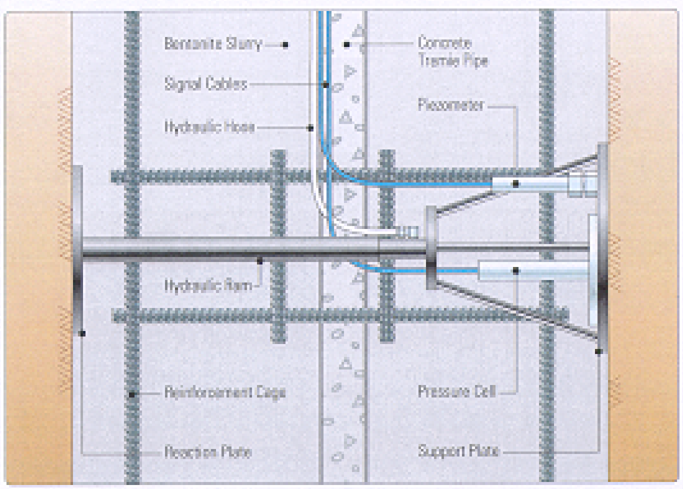
Model 4820 Jackout Pressure Cells



• *Model 4820 shown in hydraulic ram assembly with piezometer and alone (inset).*

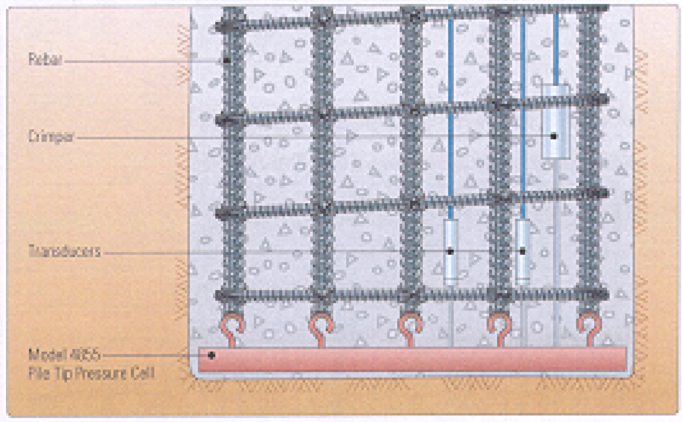
The Jackout Pressure Cell is designed for installation in diaphragm walls (slurry waalls) to monitor soil pressures on the walls as excavation proceeds. This allows the build-up of excessive pressures to be detected in time to take remedial measures.

The Jackout Pressure Cell assembly consists of the cell mounted on a support plate, a reaction plate and a hydraulic ram. This assembly is attached, in its retracted position, to the reinforcement cage and is lowered into the slurry trench along with the cage. When the cage is in position the hydraulic ram is extended by means of a hand pump situated at the top of the wall and connected to the ram by a hydraulic hose. Pressure is applied forcing the reaction plate and the cell against the walls of the trench. This pressure is maintained while the concrete is tremied into the trench and until the concrete cures. The cell may be supplemented by a piezometer attached to the support plate to measure pore water pressures.



• *Jackout Pressure Cell assembly installed in diaphragm wall.*

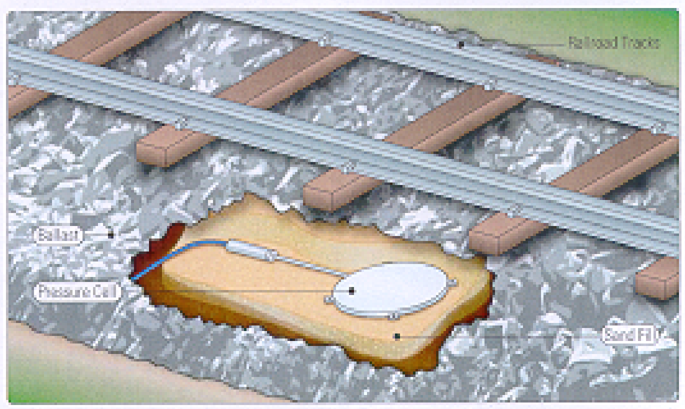
Model 4855 Pile-Tip Pressure Cells



• *Model 4855 Pile-Tip Pressure Cell installation*

The Model 4855 Pile-Tip Load Cell is used to measure pile-tip loads in cast-in-place concrete piles (caissons). Like the Model 4810, the pile-tip pressure cell has a thick upper plate. The cell is manufactured to be close to the diameter of the pile and the back plate is supplied with hooks or sections of rebar to allow the cell to be connected to the bottom of the reinforcement cage. Two vibrating wire pressure transducers are connected to the cell to provide some redundancy in the event that one transducer is damaged during installation. An added feature is a remote "crimping" mechanism to allow the cell to be inflated slightly so as to ensure good contact between the cell and the surrounding concrete.

Model 3500 Series Earth Pressure Cells



• *Model 3500 Earth Pressure Cell installed under railroad tracks.*

The 3500 Series is similar in design to the 4800 Series but the vibrating wire transducer is replaced by a semi-conductor type transducer (to enable the measurement of dynamic pressures) which can have an output of 2mV/V, 0-5VDC or 4-20mA. Typical applications are the measurement of traffic induced stresses on roadway sub grades, airport runways or under railroad tracks.

Technical Specifications

	4800	4810	4815	4820	4855	3500
Transducer Type	Vibrating Wire	Vibrating Wire	Vibrating Wire	Vibrating Wire	Vibrating Wire	Semi-conductor
Output	2000-3000 Hz	2000-3000 Hz	2000-3000 Hz	2000-3000 Hz	2000-3000 Hz	2 mV/V, 0-5 VDC or 4-20 mA
Standard Ranges[1]	70, 170, 350, 700 kPa; 1, 2, 3, 5, 7.5, 20 MPa	350, 700 kPa; 1, 2, 3, 5 MPa	350, 700 kPa 1, 2, 3, 5 MPa	350, 700 kPa; 1, 2, 3, 5 MPa	3, 5, 7, 10.5 MPa	100, 250, 400, 600 kPa; 1, 2.5, 6 MPa
Over Range	150% F.S. (maximum)	150% F.S. (maximum)	150% F.S. (maximum)	150% F.S. (maximum)	150% F.S. (maximum)	150% F.S. (maximum)
Resolution	±0.025% F.S.	±0.025% F.S.	±0.025% F.S.	±0.025% F.S.	±0.025% F.S.	Infinite
Accuracy[2]	±0.1% F.S.	±0.1% F.S.	±0.1% F.S.	±0.1% F.S.	±0.1% F.S.	±0.5% F.S.
Linearity	< 0.5% F.S.	< 0.5% F.S.	< 0.5% F.S.	< 0.5% F.S.	< 0.5% F.S.	< 0.5% F.S.
Thermal Effect on Zero	< 0.05% F.S.	< 0.05% F.S.	< 0.05% F.S.	< 0.05% F.S.	< 0.05% F.S.	< 0.05% F.S.
Typical Long-Term Drift	< 0.02% F.S./yr	< 0.02% F.S./yr	< 0.02% F.S./yr	< 0.02% F.S./yr	< 0.02% F.S./yr	< ±0.02% F.S./yr
Standard Cell Dimensions[3] (H × D)	6 × 230 mm	12 × 230 mm	25 × 230 mm	12 × 150 mm	25 × varies	12 × 230 mm
Transducer Dimensions (L × D)	150 × 25 mm	150 × 25 mm	150 × 25 mm	150 × 25 mm	150 × 25 mm	150 × 32 mm
Excitation Voltage	2.5-12 V swept square wave	2.5-12 V swept square wave	2.5-12 V swept square wave	2.5-12 V swept square wave	2.5-12 V swept square wave	10 V maximum
Material	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel	304 Stainless Steel
Temperature Range[1]	−20°C to +80°C	−20°C to +80°C	−20°C to +80°C	−20°C to +80°C	−20°C to +80°C	−20°C to +80°C

Note: PSI = kPa × 0.14503, or MPa × 145.03
[1]Other ranges available on request.
[2]Calibrated accuracy of the pressure sensor.
[3]Other sizes available on request.

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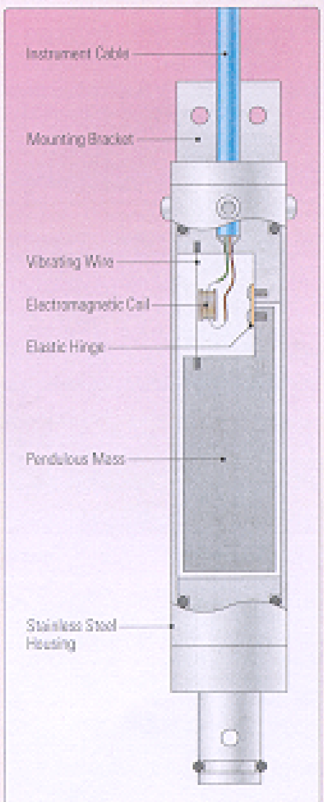
Model 6300

Vibrating Wire In-Place Inclinometer

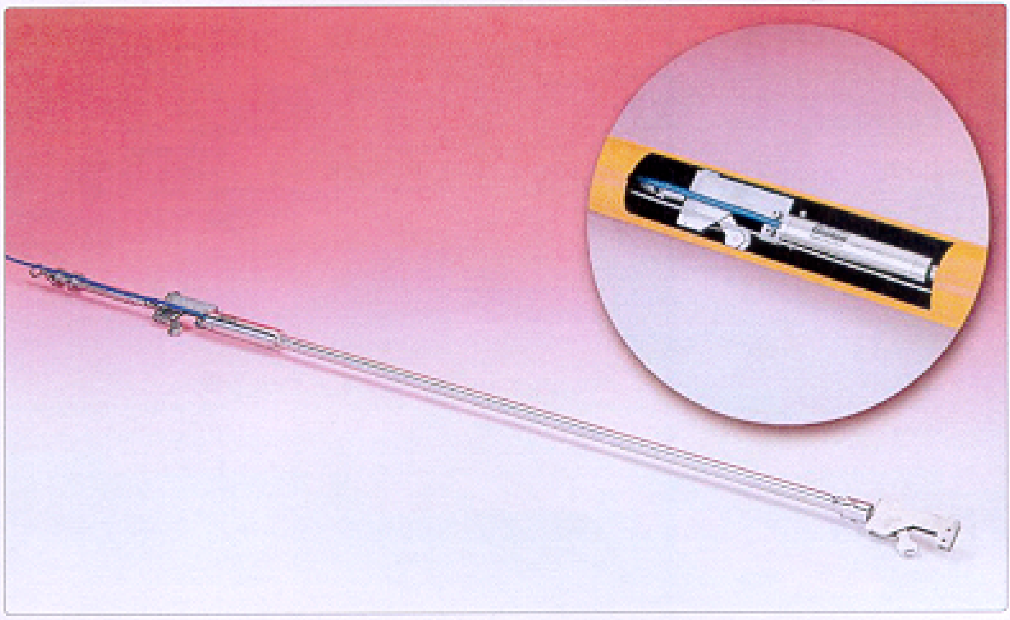
Applications

The remote, continuous, and automatic monitoring of...

- **The stability of natural slopes, landslides and embankments**
- **The stability of slurry walls, sheet piling and tie-back walls around excavations**
- **Lateral ground movements and differential settlements in, around and above tunnels and underground openings**



• *Vibrating wire tilt sensor construction.*



• *Model 6300 VW In-Place Inclinometer. Inset photo reveals installation detail with section of Model 6500 Inclinometer Casing removed.*

Operating Principle

The Model 6300 Vibrating Wire In-Place Inclinometer consists of a string of Vibrating Wire tilt sensors mounted on lengths of stainless steel tubing which are linked together by universal joints. A spring-loaded wheel assembly designed to engage the grooves of conventional inclinometer casing is located at each joint. The string of sensors is installed inside the casing with all the sensor cables passing to the surface where they are connected to Terminal Boxes or Dataloggers.

Movements of the ground deflect the casing causing one or more of the inclinometer segments (length L) to undergo changes of inclination ($\Delta\theta$). Summation of all these tilts in the form Σ L sinθ, are plotted to give profiles of lateral deflection. Each tilt sensor contains a thermistor to permit temperatures to be recorded.

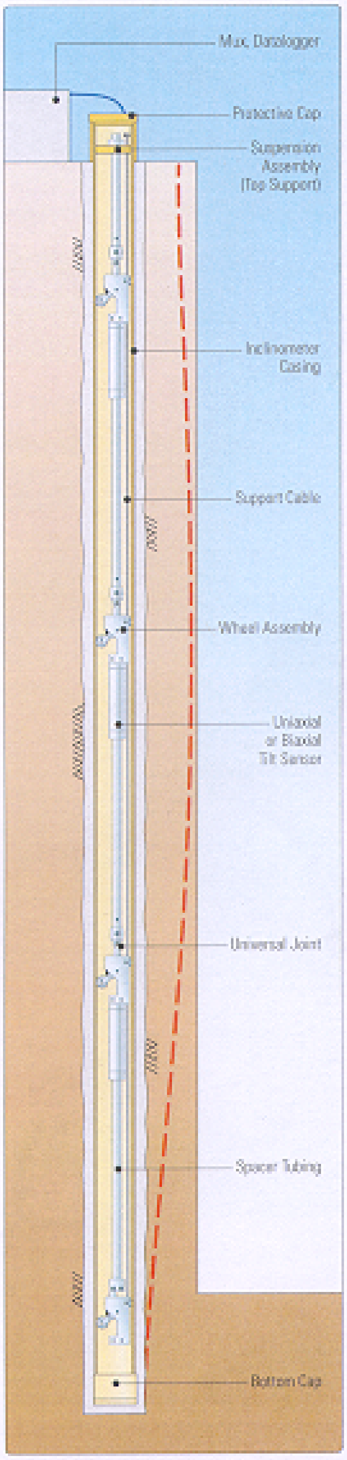
Advantages and Limitations

Vibrating Wire tilt sensors have many advantages. They have a wide range combined with high sensitivity, which makes them ideally suited for use in installations which deviate excessively from the vertical. Their long-term stability is excellent and their temperature dependence is close to zero.

The sensor output is in the form of a varying frequency which can be transmitted over very long cables without loss of accuracy. The simplicity of the design also makes this sensor less susceptible to lightning damage than most others.

Limitations include cost which, even though comparable to or less than other systems, may limit the number of sensors in any one installation. Because of this, the deflection profile obtained may not be as detailed as profiles obtained with conventional inclinometer probes. Costs can be controlled by limiting the tilt sensor placement only to those zones where the largest deflections are anticipated.

The Model 6300 incorporates novel shock absorbers for protection during transportation and installation, but some care in handling is still required.



• *Typical application to monitor the stability of a foundation wall.*

System Components

Components of the Vibrating Wire In-Place Inclinometer are shown at left. The tilt sensors may be either uniaxial or biaxial, with wheel assemblies and universal joints separated by spacer tubing of various lengths determined by the required interval between the tilt sensors.

The upper end of the system is suspended from a top support and the lower end requires a special bottom wheel assembly to which a support cable is attached.

For more installation details ask for the Model 6300 In-Place Inclinometer Installation Manual and the Model 6500 Inclinometer Casing Installation Manual.

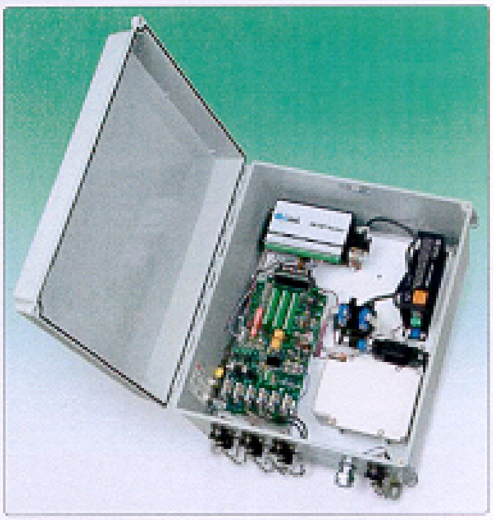
Data Acquisition

Tilt sensors are read with the standard GK-403 Vibrating Wire Readout Box. For automatic monitoring, readout is best accomplished using the Geokon Micro-10 datalogger or any other datalogger capable of reading vibrating wire sensors (Campbell Scientific CR10X, Data Electronics Datataker 600, Geomation Model 2380, etc.). Other dataloggers can be accommodated using the Geokon Single Coil Autoresonant Adapter (SCA).

Technical Specifications

Standard Range[1]	±10°
Resolution[2]	±10 arc seconds (±0.05 mm/m)
Accuracy	±0.1% F.S.
Operating Frequency Range	1200-3500 Hz
Plucking Coil Resistance	180 Ω
Materials	304 Stainless Steel
Electrical Cable	4 conductor Polyurethane jacket, 4.7 mm dia.
Thermal Zero Drift	±0.01% F.S./°C (±4 arc seconds/°C)
Thermistor Operating Range	−20°C to +80°C
Thermistor Operating Accuracy	±0.5°C
Sensor Dimensions	187 × 32 mm dia.
Sensor Weight	0.9 kg

[1]Other ranges available on request.
[2]Depends on readout equipment.



• *Micro-10 Datalogger*

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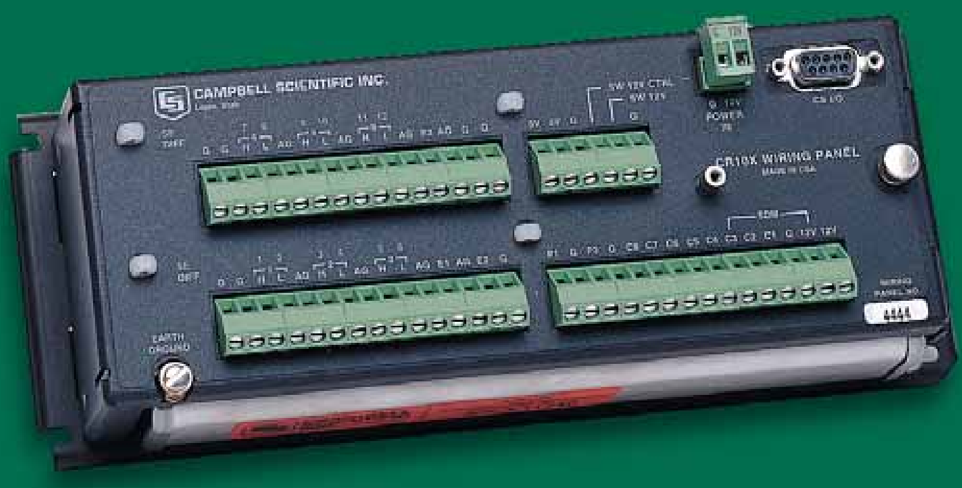
CR10X Measurement and Control System

A Rugged Instrument with Research-Grade Performance



CAMPBELL SCIENTIFIC, INC.
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CR10X Measurement and Control System

A Rugged Instrument with Research-Grade Performance

The CR10X is a rugged measurement and control system that delivers accurate, reliable measurements in a variety of applications. Designed for both research and day-to-day monitoring operations, the CR10X combines the ability to measure virtually any sensor with the control capability to respond to specific site conditions (e.g., open flood gates, turn fans off/on). From simple to complex, Campbell Scientific data acquisition systems are at work on every continent, at sea, and in space.

Measurement Example — Weather Station

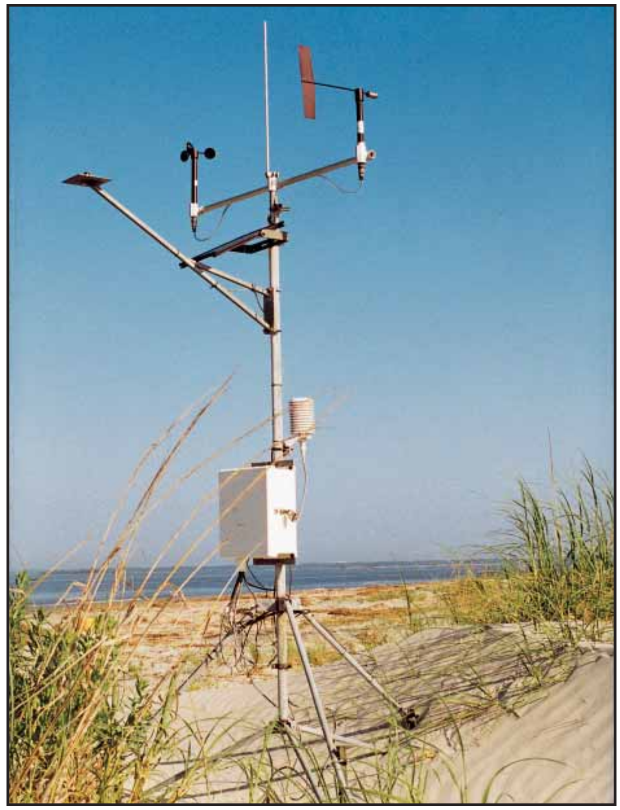
Measurements: The CR10X measures wind speed and direction, air temperature, relative humidity, precipitation, barometric pressure, soil moisture and temperature, and solar radiation. Scan rates are programmable from 1/64 second to 2.5 hours.

Data Processing: Output intervals for raw or processed data are user-specified. Typically, hourly and daily summaries (e.g., maxima, minima, averages, histograms) are stored. Conditional outputs, such as rainfall intensity, can also be processed and stored.

Data Storage: The non-volatile Flash memory and lithium-backed SRAM store up to 62,000 data points—equating to more than three months of data when typical hourly and daily outputs are stored from a typical meteorological application. An optional memory expansion allows the CR10X to store more than one million data points—or about 12 years' worth of meteorological data.

Data Retrieval: Data can be transferred to a computer using telephones (including cellular or voice-synthesized), radio telemetry, short-haul modems, satellite transmitters, multi-drop modems, Ethernet, or storage modules.

12-Volt Power: The low-power design allows the CR10X to operate up to one year on a 7 Ahr, unregulated 12 Vdc source, depending on scan rate, number of sensors, data retrieval method, and external temperature.



Measurement and Control Example — Head Gates

Measurements: The CR10X measures water level upstream, downstream, and in a diversion ditch.

Data Storage/Processing/Retrieval: Data are recorded over time, showing trends. The CR10X calculates flow and summarizes the data as averages, maxima, or totals. A PC, PDA or keyboard display can show both real-time and summarized data.

Equipment Control: The CR10X controls multiple headgates based on measured conditions, flow, or time. The control capabilities of the CR10X allow levels to be maintained, even in the absence of a manager. The gates can also be controlled remotely by the water master if conditions change.

Alarms: If high or low water levels are detected, the CR10X can initiate on-site alarms, data or voice-synthesized warning calls, or activate pagers.

Cover Photos At left: CR10X. From top right: *Water Resources* Reservoir gate control via radio telemetry, Emery County, Utah; *Industrial/Automotive* Super Comp dragster performance testing, (photo courtesy of RPM photography); *Meteorology* Weather station installation, St. Mary's Lake, Glacier National Park, Montana; *Geotechnical/Historical Preservation* CR10X monitors cracks in the southwest bastion of fort, Castillo de San Marcos National Monument, St. Augustine, Florida.

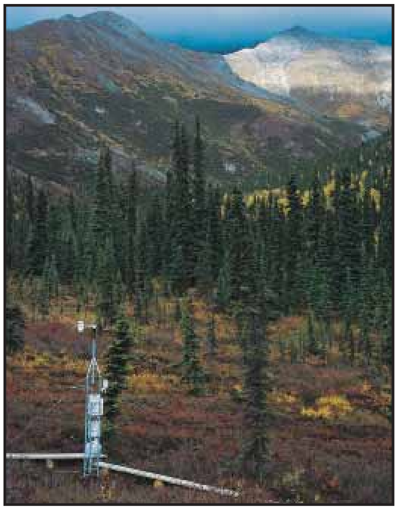
Applications

The measurement precision, flexibility, long-term reliability, and economical price of the CR10X make it ideal for scientific, commercial, and industrial applications.

Meteorology

The CR10X is used in long-term climatological monitoring, meteorological research, and routine weather measurement applications. Sensors the CR10X can measure include:

- cup, propeller, and sonic anemometers
- tipping bucket and weighing rain gages
- wind vanes
- evaporation pans and lysimeters
- pyranometers
- ultrasonic distance sensors
- thermistors, thermocouples, and RTDs
- capacitance and strain gage barometric pressure sensors
- RH sensors
- cooled mirror hygrometers



Weather station at Denali National Park, Alaska, monitors meteorological and soil conditions.

The CR10X can output data in your choice of units (e.g., wind speed in miles per hour, meters per second, or knots). Standard CR10X outputs include wind vector averaging, sigma, theta, histograms, saturation vapor pressure, and vapor pressure from wet / dry bulb temperatures.

Air Quality

The CR10X can monitor and control gas analyzers, particle samplers, and visibility sensors. The CR10X can also automatically control calibration sequences and compute conditional averages that exclude invalid data (e.g., data recorded during power failures or calibration intervals).

Network of approximately 20 stations continuously monitors air quality, northern Oquirrh Mountains, Utah.

Agriculture and Agricultural Research

The versatility of the CR10X allows measurement of agricultural processes and equipment in applications such as:

- plant water research
- canopy energy balance
- machinery performance
- plant pathology
- crop management decisions
- food processing / storage
- frost prediction
- irrigation scheduling
- integrated pest management

Typical agricultural research sites integrate meteorological, soil, and crop measurements.

Soil Moisture

The CR10X is compatible with the following soil moisture measurement technologies:

- **Soil moisture blocks** are inexpensive sensors that estimate soil water potential.
- **Matric water potential sensors** also estimate soil water potential but are more durable than soil moisture blocks.
- **Time-Domain Reflectometry Systems (TDR)** use a reflectometer controlled by a CR10X to accurately measure soil water content. Multiplexers allow sequential measurement of a large number of probes by one reflectometer, reducing cost per measurement.
- **Self-contained water content reflectometers** are sensors that emit and measure a TDR pulse.
- **Tensiometers** measure the soil pore pressure of irrigated soils and calculate soil moisture.

Industry

Vehicle Testing

The CR10X performs well in cold / hot temperature, high altitude, off-highway, and cross-country tests. It can measure temperature, fuel flow, velocity, acceleration, engine RPM, force, displacement, and electrical system load. The CR10X is often interfaced to a dashboard-mounted heads up display for luminescent data display in real time.

HVAC Systems

The CR10X optimizes HVAC performance by monitoring and controlling pumps, fans, and starter motors.

Process Control

Both product and assembly line status can be monitored simultaneously, providing on-line quality control while minimizing production down-time.

Water Resources

The CR10X is well-suited to remote, unattended monitoring of hydrologic conditions. Many hydrologic sensors, including SDI-12 sensors, interface directly to the CR10X.

Typical hydrologic measurements:

- **Water level** is monitored with incremental shaft encoders, double bubblers, ultrasonic level transducers, resistance tapes, or strain gage or vibrating wire pressure transducers. Some shaft encoders require a QD1 Interface. Vibrating wire transducers require an AVW1, AVW4, or AVW100 Interface.
- **Well draw-down tests** use a pressure transducer measured at logarithmic intervals or at a rate based on incremental changes in water level.
- **Ionic conductivity** measurements use one of the switched excitation ports from the CR10X.
- **Samplers** are controlled by the CR10X as a function of time, water quality, or water level.
- **Alarm and pump actuation** are controlled through digital I/O ports that operate external relay drivers.

Datalogger measures water level using a shaft encoder, then calculates flow. The data are telemetered, via radio, to the water master for further processing, review, and archive. Stilling well at diversionary dam, Emery County, Utah.

Mining, Earth Science, and Geotechnical

The small size, low power requirements, and wide operating temperature range of the CR10X make it a good choice for these remote, typically harsh applications. Multiple CR10Xs can be accessed via telemetry allowing monitoring and review of measurements across an entire study area. Vibrating wire sensors, strain gages, load cells, pressure transducers, linear and string potentiometers, GPS receivers, and frequency output devices are regularly used in these systems.

Historical Preservation

Weather measurements on the Sphinx provided input for its preservation, Cairo, Egypt.

The CR10X's small size, versatility, and expandability allow it to simultaneously monitor environmental variables that could be detrimental to works of art (e.g., relative humidity, solar radiation, air temperature, water table level, gas concentrations). By using multiplexers or SDMs, these parameters (and others) can be monitored at a number of locations in a building or across a structure. This enables comprehensive monitoring, management, remediation efforts, and documentation.

Other Applications

- Avalanche control, snow science, and Arctic research
- Highway and pavement studies
- Sporting events
- Space research

Our dataloggers measured the effects of gravity on a test structure aboard a NASA low-gravity flight.

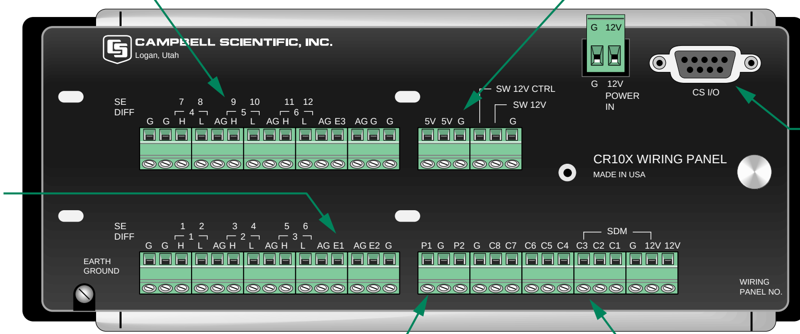
System Description

The CR10X consists of a Measurement and Control Module and a detachable Wiring Panel. The Mean Time Between Failures (MTBF) for the CR10X is over 180 years. Standard operating range is -25° to +50°C; an optional extended range of -55° to +85°C is available.

6 Differential (12 single-ended) Analog Inputs for measuring voltage levels on five software selectable voltage ranges.

3 Switched Excitation Channels for precision excitation of sensors or short-term actuation of external devices. Excitation is programmable over a ±2500 mV range.

2 Pulse Counting Channels for switch closures, high frequency pulses, or low level ac measurement.



Power and Ground Connections for 12 V external batteries or per-ipherals or for 5 V peripherals. Switched 12 V terminal is controlled by any digital output.

9-Pin CS I/O Port for connection of data storage, retrieval, and telecommunications peripherals.

8 Digital Inputs/Outputs for output control, sensing status, and reading SDM peripherals or SDI-12 sensors.

Measurement and Control Module

The module measures sensors, drives direct communications and telecommunications, reduces data, controls external devices, and stores data and programs in on-board, non-volatile storage. The electronics are RF shielded and glitch protected by the sealed, stainless steel canister. A battery-backed clock assures accurate timekeeping. The module can simultaneously provide measurement and communication functions.

The CR10X contains a comprehensive set of processing, math, and program control instructions to build a datalogger program. The maximum rate the CR10X can execute its program is 64 times per second. (The maximum rate a single input can be measured is 750 samples per second.) Data and programs are stored either in non-volatile Flash memory or battery-backed SRAM. The standard memory stores 62,000 data points. Optional versions store up to one million data points.

Datalogger Operating Systems

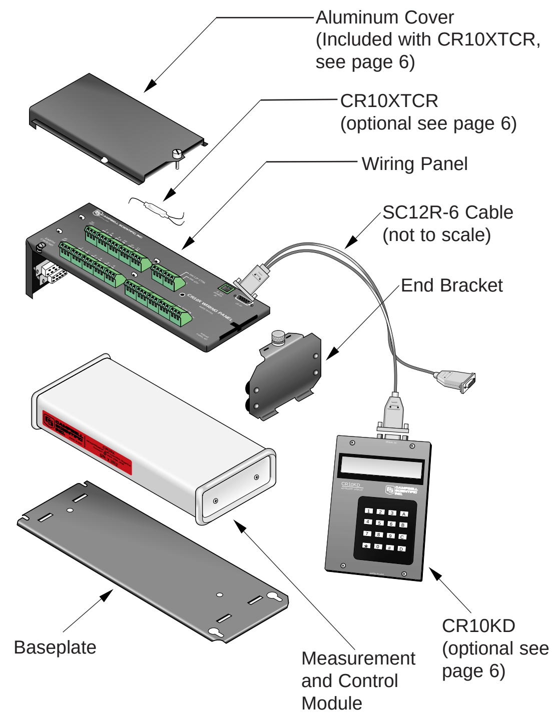
Options for the CR10X Operating System (OS) include array-based, table, Pakbus, Modbus, and ALERT. The array-based OS stores arrays of data at specified intervals or when a measured condition has been met. Two final storage areas are provided for storing the arrays. Table OS groups similar data in separate tables. Pakbus OS enables the CR10X to communicate with CR200-series dataloggers that are in the same network. Pakbus OS stores data in the same format as the table OS. The Modbus OS allows the CR10X to interface with SCADA or MMI software, and ALERT OS allows the CR10X to be used in an ALERT system. Operating System is specified at time of CR10X purchase but can be changed easily if application needs change.

SC12 and SC12R-6 Cables

The SC12 is a two-foot cable that connects communication devices to the CR10X's 9-pin serial port. The SC12 is shipped with most of our communication devices, including our phone modems, satellite transmitters, and keyboard display. The SC12R-6 is a six-foot cable that is purchased separately.

Wiring Panel

The Wiring Panel includes screw terminals for sensor connections and a 9-pin CS I/O port. An end bracket attaches the Wiring Panel to the Control Module and to an enclosure-mounted or free-standing baseplate. The Control Module easily disconnects from the Wiring Panel allowing field replacement without rewiring the sensors. Gas tubes on the wiring panel provide rugged electrostatic discharge protection.



Peripherals

Typical field-based CR10X systems include a data retrieval option, power supply, and environmental enclosure. Peripherals that expand the CR10X's measurement and control capabilities are also available.

Data Storage and Retrieval Options

To determine the best option for your application, consider the accessibility of your site, availability of services (e.g., cellular phone or satellite coverage), quantity of data to collect, and desired time between data-collection sessions.

Telephone Networks use landlines or cellular CDMA transceivers for communications between the datalogger and PC. Our voice-synthesized modem allows a CR10X to "speak" to you or transmit data to a computer.

Radio Frequency (RF) Communications are supported via UHF, VHF, spread spectrum, or meteor burst radios.

Direct Links use either an SC32B Interface or an SC-USB Interface to provide an optically isolated connection between the CR10X and a laptop or desktop computer. The SC32B connects to a computer RS-232 port and the SC-USB connects to a USB port.

PDAs can set the CR10X's clock, monitor real-time data, retrieve data, graph data, and transfer CR10X programs. PDAs with a Palm™ OS require PConnect software (purchased separately). These PDAs communicate with the CR10X via a direct serial connection, spread spectrum radio, or the SC-IRDA infrared wireless interface. PDAs with a Windows® CE OS require PConnectCE software (purchased separately). These PDAs communicate with the CR10X via a direct serial connection or spread spectrum radio.

Short Haul Modems provide local communications between the CR10X and a PC with an RS-232 serial port.

Multidrop Interface links a central computer to one or more dataloggers over a distance of 4000 ft.

Satellite Transmitters transmit data via the GOES, or Argos, satellite systems. Campbell Scientific's SAT HDR GOES transmitter has been certified by NESDIS for High Data Rates (HDR).

Ethernet Communications Peripherals allow the CR10X to communicate over a local network or the Internet.

Storage Modules reliably store data and datalogger programs. This allows you to transport programs between the datalogger and PC or use the storage modules to serve as an independent backup of the datalogger data. The storage modules are not compatible with the Table and Pakbus datalogger operating systems.

CR10KD Keyboard Display programs the CR10X, manually initiates data transfer, and displays data. One CR10KD can be carried from station to station in a CR10X network.

Other Displays such as the DataView Display Unit and the DSP4 Heads Up Display can be used with the CR10X. DataView provides a two-line, 32-character LCD that displays one real-time value, a description, and units. The DSP4 Heads Up Display is typically used in vehicle testing applications.

A satellite transmitter provides telecommunications for remote Argentine stations where phone lines are impractical.

Thermocouple Reference Thermistor

Campbell Scientific offers the CR10XTCR which provides a temperature reference for thermocouple measurements. It requires one single-ended analog input channel. A cover that reduces temperature gradients along the input terminals is included.

Channel Expandability

The already formidable measurement and control capabilties can be expanded using CSI multiplexers and Synchronous Devices for Measurement (SDMs). SDMs are addressable peripherals that expand digital I/O ports, plus interval channels analog output ports, and datalogger measurement capabilities. Up to 16 SDMs can be connected to three CR10X control ports.

Multiplexers increase the number of sensors that can be measured by a CR10X by sequentially connecting each sensor to the datalogger. Several multiplexers can be connected to, and controlled by, a single CR10X.

Enclosures

A CR10X housed in a weather-resistant enclosure can collect data under extremely harsh conditions. The enclosure protects the CR10X from dust, water, sunlight, or pollutants. Typically a 12" x 14" or 16" x 18" enclosure is used. They are NEMA 4X enclosures modified for cable entry. The enclosures attach to a flat surface, 1.00" to 1.25" IPS pipe, or vertical mast or leg of a tripod or tower. These white fiberglass-reinforced polyester enclosures are UV-stabilized and reflect solar radiation, reducing temperature gradients inside the housing. An internal mounting plate is prepunched for easy system configuration and exchange of equipment in the field. A lockable hasp adds security.

Power Supplies

Any 12 Vdc source can power the CR10X; a PS100 or BPALK is typically used. The PS100 includes one 7 Ahr rechargeable battery, charged with ac power (requires the optional wall charger) or a solar panel. The BPALK consists of eight non-rechargeable D-cell alkaline batteries with a 7.5 Ahr rating at 20°C. An external AA-cell pack that supplies power while the D-cells are replaced is included.

The BP12 and BP24 battery packs are also available. The BP12 and BP24 have nominal ratings of 12 and 24 Ahrs, respectively. The batteries should be connected to a charging regulator and a charging source. For information about analyzing your system's power requirements, see our Power Supply product literature or Application Note 5-F. Both can be obtained from: www. campbellsci.com

Systems that include high current drain peripherals such as satellite transmitters or are located where it's inconvenient to replace batteries might require batteries with larger Ahr capacities than our PS100 or BPALK. Campbell Scientific offers the BP12 and BP24 battery packs for these systems.

Software Packages

Campbell Scientific software supports datalogger programming, communications between the datalogger and PC, and data display. Brief descriptions follow; for more information, see our literature or Web site.

Starter Software

Our Starter Software can be downloaded at no charge from www.campbellsci.com / resource.html. Our Resource CD also provides this software as well as PDF versions of our literature and manuals.

SCWin Program Builder creates datalogger programs requiring only sensor measurement and data output. It supports 120 sensors and multiplexers.

PC200W Starter Software allows you to transfer a program to, or retrieve data from, a CR10X via a direct communications link.

Datalogger Support Software

The LoggerNet 2.X-series is our full-featured software package that supports:

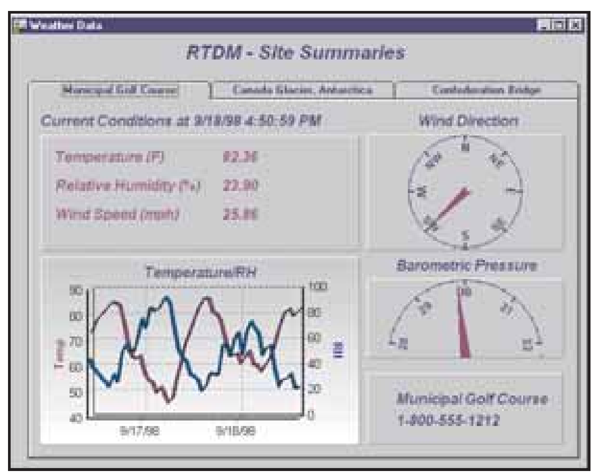
- direct connection and telecommunications links
- combinations of communication options (e.g., phone-to-RF)
- manual and scheduled data collection
- programming for most commercially available sensors as well as devices such as SDMs, multiplexers, and relays
- storage module communication
- multitab data displays that can include alarms, sliders, graphs, toggles, tables and / or gauges

Campbell Scientific offers several programs that are intended to be used with our LoggerNet software. All of these programs require a licensed copy of LoggerNet running on a PC. The programs are:

- **Baler** stores LoggerNet data into new files so that the data can be imported to a data base or third-party analysis program
- **RTMC Web Server** converts real-time data displays into HTML files
- **RTMCRT** allows remote PCs to display and print real-time data
- **LoggerNetData** allows users at remote PCs to post-process LoggerNet data, generate reports, and display LoggerNet data
- **CSI OPC server** allows third-party OPC compatible graphic packages to view our datalogger data
- **LoggerNet-SDK** allows software developers to create and freely distribute custom applications that communicate with our dataloggers

Real-Time Data Monitor (RTDM)

RTDM allows experienced users to create custom graphic screens. RTDM supports automatic generation of JPEG output for Internet display. Developer and display-only versions are also available.



RTDM is powerful, versatile software that can display real-time or archived data in bar, lines, area, or point charts. Automatic generation of JPEG outputs facilitates displaying information on Internet pages.

CR10X Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years.

PROGRAM EXECUTION RATE

Program is synchronized with real-time up to 64 Hz. One channel can be measured at this rate with uninterrupted data transfer. Burst measurements up to 750 Hz are possible over short intervals.

ANALOG INPUTS

NUMBER OF CHANNELS: 6 differential or 12 single-ended, individually configured. Channel expansion provided by AM16/32 or AM416 Relay Multiplexers and AM25T Thermocouple Multiplexers.

ACCURACY: ±0.1% of FSR (-25° to 50°C); ±0.05% of FSR (0° to 40°C); e.g., ±0.1% FSR = ±5.0 mV for ±2500 mV range

RANGE AND RESOLUTION:

Full Scale Input Range (mV)	*Resolution (µV) Differential*	*Resolution (µV) Single-Ended*
±2500	333	666
±250	33.3	66.6
±25	3.33	6.66
±7.5	1.00	2.00
±2.5	0.33	0.66

INPUT SAMPLE RATES: Includes the measurement time and conversion to engineering units. The fast and slow measurements integrate the signal for 0.25 and 2.72 ms, respectively. Differential measurements incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors.

Fast single-ended voltage:	2.6 ms
Fast differential voltage:	4.2 ms
Slow single-ended voltage:	5.1 ms
Slow differential voltage:	9.2 ms
Differential with 60 Hz rejection:	25.9 ms
Fast differential thermocouple:	8.6 ms

INPUT NOISE VOLTAGE (for ±2.5 mV range):
Fast differential: 0.82 µV rms
Slow differential: 0.25 µV rms
Differential with 60 Hz rejection: 0.18 µV rms

COMMON MODE RANGE: ±2.5 V

DC COMMON MODE REJECTION: >140 dB

NORMAL MODE REJECTION: 70 dB (60 Hz with slow differential measurement)

INPUT CURRENT: ±9 nA maximum

INPUT RESISTANCE: 20 Gohms typical

ANALOG OUTPUTS

DESCRIPTION: 3 switched, active only during measurement, one at a time.

RANGE: ±2.5 V

RESOLUTION: 0.67 mV

ACCURACY: ±5 mV; ±2.5 mV (0° to 40°C)

CURRENT SOURCING: 25 mA

CURRENT SINKING: 25 mA

FREQUENCY SWEEP FUNCTION: The switched outputs provide a programmable swept frequency, 0 to 2.5 V square wave for exciting vibrating wire transducers.

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR10X provides ratiometric bridge measurements of 4- and 6-wire full bridge, and 2-, 3-, and 4-wire half bridges. Precise dual polarity excitation using any of the switched outputs eliminates dc errors. Conductivity measurements use a dual polarity 0.75 ms excitation to minimize polarization errors.

ACCURACY: ±0.02% of FSR plus bridge resistor error.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the duration of a specified number of cycles. Any of the 12 single-ended analog input channels can be used. Signal attentuation and ac coupling are typically required.

INPUT FREQUENCY RANGE:

Signal peak-to-peak[1] Min.	*Max.*	*Min. Pulse w.*	*Max Freq.[2]*
500 mV	5.0 V	2.5 µs	200 kHz
10 mV	2.0 V	10 µs	50 kHz
5 mV	2.0 V	62 µs	8 kHz
2 mV	2.0 V	100 µs	5 kHz

[1]Signals centered around datalogger ground
[2]Assuming 50% duty cycle

RESOLUTION: 35 ns divided by the number of cycles measured

ACCURACY: ±0.01% of reading (number of cycles ≥100) ±0.03% of reading (number of cycles <100)

TIME REQUIRED FOR MEASUREMENT: Signal period times the number of cycles measured plus 1.5 cycles + 2 ms

PULSE COUNTERS

NUMBER OF PULSE COUNTER CHANNELS: 2 eight-bit or 1 sixteen-bit; software selectable as switch closure, high frequency pulse, and low level ac.

MAXIMUM COUNT RATE: 16 kHz, eight-bit counter; 400 kHz, sixteen-bit counter. Channels are scanned at 8 or 64 Hz (software selectable).

SWITCH CLOSURE MODE
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Maximum Bounce Time: 1 ms open without being counted

HIGH FREQUENCY PULSE MODE
Minimum Pulse Width: 1.2 µs
Maximum Input Frequency: 400 kHz
Voltage Thresholds: Count upon transition from below 1.5 V to above 3.5 V at low frequencies. Larger input transitions are required at high frequencies because of input filter with 1.2 µs time constant. Signals up to 400 kHz will be counted if centered around +2.5 V with deviations ≥ ±2.5 V for ≥ 1.2 µs.
Maximum Input Voltage: ±20 V

LOW LEVEL AC MODE
(Typical of magnetic pulse flow transducers or other low voltage, sine wave outputs.)

Input Hysteresis: 14 mV

Maximum ac Input Voltage: ±20 V

Minimum ac Input Voltage:

(Sine wave mV RMS)	Range (Hz)
20	1.0 to 1000
200	0.5 to 10,000
1000	0.3 to 16,000

DIGITAL I/O PORTS

8 ports, software selectable as binary inputs or control outputs. 3 ports can be configured to count switch closures up to 40 Hz.

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low < 0.1 V

OUTPUT RESISTANCE: 500 ohms

INPUT STATE: high 3.0 to 5.5 V; low -0.5 to 0.8 V

INPUT RESISTANCE: 100 kohms

SDI-12 INTERFACE STANDARD

Digital I/O Ports C1-C8 support SDI-12 asynchronous communication; up to ten SDI-12 sensors can be connected to each port. Meets SDI-12 Standard version 1.2 for datalogger and sensor modes.

CR10XTCR THERMOCOUPLE REFERENCE

POLYNOMIAL LINEARIZATION ERROR: Typically <±0.5°C (-35° to +50°C), <±0.1°C (-24° to +45°C).

INTERCHANGEABILITY ERROR: Typically <±0.2°C (0° to +60°C) increasing to ±0.4°C (at -35°C).

CE COMPLIANCE (as of 09/01)

STANDARD(S) TO WHICH CONFORMITY IS DECLARED:
EN55022: 1995 and IEC61326:2002

EMI and ESD PROTECTION

IMMUNITY: Meets or exceeds following standards:
ESD: per IEC 1000-4-2; ±8 kV air, ±4 kV contact discharge
RF: per IEC 1000-4-3; 3 V/m, 80-1000 MHz
EFT: per IEC 1000-4-4; 1 kV power, 500 V I/O
Surge: per IEC 1000-4-5; 1 kV power and I/O
Conducted: per IEC 1000-4-6; 3 V 150 kHz-80 MHz

Emissions and immunity performance criteria available on request.

CPU AND INTERFACE

PROCESSOR: Hitachi 6303

PROGRAM STORAGE: Up to 16 kbytes for active program; additional 16 kbytes for alternate programs. Operating system stored in 128 kbytes Flash memory.

DATA STORAGE: 128 kbytes SRAM standard (approximately 60,000 data values). Additional 2 Mbytes Flash available as an option.

OPTIONAL KEYBOARD DISPLAY: 8-digit LCD (0.5" digits)

PERIPHERAL INTERFACE: 9 pin D-type connector for keyboard display, storage module, modem, printer, card storage module, and RS-232 adapter.

BAUD RATES: Selectable at 300, 1200, 9600 and 76,800 bps for synchronous devices. ASCII communication protocol is one start bit, one stop bit, eight data bits (no parity).

CLOCK ACCURACY: ±1 minute per month

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN: 1.3 mA quiescent, 13 mA during processing, and 46 mA during analog measurement.

BATTERIES: Any 12 V battery can be connected as a primary power source. Several power supply options are available from Campbell Scientific. The Model CR2430 lithium battery for clock and SRAM backup has a capacity of 270 mAhr.

PHYSICAL SPECIFICATIONS

SIZE: 7.8" x 3.5" x 1.5" - Measurement & Control Module; 9" x 3.5" x 2.9" - with CR10WP Wiring Panel. Additional clearance required for serial cable and sensor leads.

WEIGHT: 2 lbs

WARRANTY

Three years against defects in materials and workmanship.

We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

CAMPBELL SCIENTIFIC, INC.
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The following are the proposed "Scope of Work" written for Pinnacle Technologies, Inc. and Sensametrics, Inc. This information is being included for informational purposes only.

Proposed Scope of Work for Pinnacle Technologies, Inc.

Provide monitoring of the existing I-Wall using fiber optic technology. Measure displacement strains of five concrete monoliths. Measurements are to be made near the top of the wall and near the bottom of the wall. Therefore, there should be two rows of monitoring. It is understood that the fiber optic cable will be attached to the I-Wall through the use of mandrels located near each expansion joint.

All equipment and labor necessary to install the instruments provided by Pinnacle are to be included. It will be required that personnel from Pinnacle be on-site to install and monitor the instruments provided by Pinnacle. The Government will supply 120V AC power, temporary field trailer (or shipping container), lighting, on-site security, and drinking water. Pinnacle will need to provide a back-up power source for their instruments. In addition, Pinnacle will need to provide all equipment necessary to read their instruments and provide on site data reduction and reporting.

Proposed Scope of Work for Sensametrics

Provide monitoring of the existing I-Wall using tiltmeters that use MEMS technology. Measure tilt at five concrete monoliths.

All equipment and labor necessary to install the instruments provided by Sensametrics are to be included. It will be required that personnel from Sensametrics be on-site to install and monitor the instruments provided by Sensametrics. The Government will supply 120V AC power, temporary field trailer (or shipping container), lighting, on-site security, and drinking water. Sensametrics will need to provide a back-up power source for their instruments. In addition, Sensametrics will need to provide all equipment necessary to read their instruments and provide on site data reduction and reporting.