NOAA Technical Report NOS CO-OPS 042

Ocean Systems Test and Evaluation Program

Microwave Air Gap-Bridge Clearance Sensor Test, Evaluation, and Implementation Report

Silver Spring, Maryland
May, 2005

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Center for Operational Oceanographic Products and Services (CO-OPS)
National Ocean Service (NOS)
National Oceanic and Atmospheric Administration (NOAA)
U.S. Department of Commerce

The CO-OPS mission is to deliver the operational environmental products and services necessary to support NOAA's Environmental Stewardship and Environmental Assessment and Prediction Missions. CO-OPS provides the focus for operationally sound observation and monitoring capability coupled with environmental predictions to provide the quality data and information needed to support the cross-cutting NOS Primary Goals of Navigation, Coastal Communities, Habitat, and Coastal Hazards.

Ocean Systems Test & Evaluation Program

The CO-OPS Ocean Systems Test and Evaluation Program facilitates the transition of new technology to an operational status, selecting newly developed sensors or systems from the research and development community and bringing them to a monitoring setting. OSTEP provides a quantifiable and defensible justifications for the use of existing sensors, and methods for selecting new systems. The program establishes and maintains field reference facilities where, in cooperation with other agencies facing similar challenges, devices are examined in a non-operational field setting. Through OSTEP, sensors are evaluated, quality control procedures developed, and maintenance routines generated. The quality of the reference systems used in the field are assured by both rigorous traceable calibrations and redundant sensors.

The Program receives guidance from the Ocean Systems Test & Evaluation Advisory Board.

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NOTICE

Ocean Systems Test and Evaluation Program

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CO-OPS STATEMENT OF ACCEPTANCE

CO-OPS management personnel have reviewed this document and concur that the evaluated sensor/system, when deployed and implemented as described herein, will meet the defined requirements and is suitable for operational use. While additional testing may lead to superior performance or more economical operation, the existing sensor/system configuration is sufficient as described.

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EXECUTIVE SUMMARY

The National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) manages several programs to monitor the Nation's coastal waters, including PORTS® (Physical Oceanographic Real-Time System). PORTS® provides ship masters and pilots with accurate, real-time information to help avoid groundings and collisions. CO-OPS requires an expanding suite of instruments to provide critical data from bays and harbors to support the maritime community.

Many harbors are depth-constrained, and many bridge heights also limit safe vessel passage. With increasing vessel size and vessel traffic, there is a continually increasing risk of overhead allision with bridges. Some vessels may also avoid entering or departing a harbor because of bridge clearance (i.e. air gap) limitations. The economic gains potentially realized by both increased commerce and the avoidance of allisions are considerable, and a clear requirement for air gap information has been voiced by the maritime industry.

Concerns over bridge allisions and resulting litigation prompted the Port Authority of New York and New Jersey (PANYNJ), the United States Coast Guard (USCG), the Maryland Port Administration (MPA) and the Port of Long Beach (PLB) to request and/or fund the development and installation of air gap sensors. Houston/Galveston and San Francisco have also expressed interest in air gap sensors. In response to these requests, CO-OPS has entered into agreements with several entities to procure a commercially available microwave air gap sensor and conduct tests and evaluations to ensure satisfactory performance of the sensor.

CO-OPS evaluated three types of air gap sensor technologies that measure the air gap, (or distance from the lowest structure of a bridge to the water surface) within the navigational zone. Based on these evaluations, the microwave air gap bridge clearance sensor technology best meets the requirements for this need. After evaluations and dialogue with vendors, CO-OPS selected the MIROS SM-094 microwave air gap sensor to further test for air gap measurement applications.

PURPOSE

The purpose of this report is to describe, in detail, the steps taken to confirm that the proposed air gap sensor is suitable for the required application. It includes a brief review of the requirements, a rationale for the selection of the sensor, a description of the incrementally-challenging tests used in evaluating the performance of the sensor, a discussion of the margin of error (error budget) of those tests and the sensor itself, a description of the test data and metadata management, and finally, a description of the potential tools available for real-time quality control (QC) of air gap data.

This report is one of several documents that will be promulgated. The other reports within this suite of documents include:

- Deployment of Air Gap Measurement Systems: A Manual Describing Field Installation, Trigonometric Leveling, and Maintenance Procedures
- Air Gap Implementation Process Checklist
- Air Gap Introductory Flyer

RESULTS/CONCLUSIONS

Six MIROS SM-094 microwave air gap sensors were subjected to a rigorous and extensive series of bench and field tests conducted from May 2001 through March 2004. The testing has demonstrated that the SM-094 meets or exceeds the CO-OPS requirements for range, resolution, power consumption, signal processing, data output, and all-weather operation. It provides satisfactory performance, as long as the operational use adheres to the manufacturer’s guidelines.

There were several issues that surfaced during the test and evaluation period, including instrument calibration, failure of sensors under extreme conditions, and long-term deployments. The accuracy of the manufacturer’s calibration was questioned; therefore CO-OPS must conduct operational sensor calibrations on each air gap sensor prior to operational use. At present, the best calibrations are obtained in-situ, through precise trigonometric leveling using a Total Station and a Next Generation Water Level Measurement System (NGWLMS) gauge.

Two air gap sensor housings have malfunctioned due to water intrusion - one understandably leaked when the pier, (where the sensor was installed) was pounded by twenty-seven-foot waves during Hurricane Isabel. To correct this problem, CO-OPS is now using after-market sealants, and the manufacturer is investigating alternate housings in an effort to remedy the water intrusion issue.

The long-term deployment issue cannot be addressed until further testing is conducted.

The selected sensor has been tested over a three-year period, at several locations and under a wide variety of conditions. The manufacturer has implemented corrective actions where deficiencies were identified. The device has proven to be immune to rain, snow, temperature extremes, waves, vibration, radio frequency (RF) noise, and other potential interferences. It has exceeded precision requirements to the extent that CO-OPS is now beginning to investigate the use of this technology for standard observations of water level. All test results are documented and are freely available electronically.

Most significantly, the introduction of air gap to the CO-OPS “tool bag” has shown that, through the private/Federal PORTS® partnership and the matrix-managed OSTEP, a new data product can be developed. CO-OPS is presently embracing many other new technologies that will require personnel and process adaptation. The success of the air gap development shows that it can be done, and done well.

1.0 INTRODUCTION

As many harbors are depth-constrained, many bridge heights also limit safe vessel passage. With increasing vessel size, there is a continually increasing risk of overhead allision with bridges. Vessels may also avoid entering or departing a harbor because of bridge clearance (i.e. air gap) limitations. The potential economic gains to be realized by both increased commerce and the avoidance of allisions are considerable, and as a result, a clear requirement for air gap information has been voiced by the maritime industry.

Tides are a major source of variation in bridge clearance. Additional sources include river stage (water depth), wind and wave setup, bridge altitude variations caused by varying traffic loads, and temperature-related structural expansion and contraction. Sources of noise for detection of air gap include bridge vibration, waves, and water level setup or set down caused by water current interaction with bridge supports. Sampling techniques must consider these noise sources to avoid bias and to extract the maximum accuracy possible from the sensor. No two bridges will offer the same conditions or results with various technologies. For example, in 1999, CO-OPS participated with the National Geodetic Survey (NGS) in the static air gap determination of the U.S. Route 17 Cooper River bridges in Charleston, South Carolina. Traditional trigonometric surveys, continuous Global Positioning System (GPS) observations, and water level data were successfully used to establish the air gap with an accuracy of better than one centimeter. In this case, the GPS observations showed there was virtually no movement of the bridge.

The bridges for which air gap sensors have been requested have clearances of approximately 150 feet, but others have requested observations at bridges with larger clearances. For example, a barge delivering a new crane to the Port of Richmond in San Francisco Bay came within inches of the Richmond bridge, prompting the request for a quick response air gap installation. “Despite its vertical clearance of 185 feet, the bridge has been struck by passing ships several times. However, it has never sustained sufficient damage for it to be closed, not even when bumped by a Navy radar vessel and a veteran World War II warship on the same day.” (Reference: http://www.lib.berkeley.edu/Exhibits/Bridge/rsr.html)

Just as all other data disseminated via PORTS®, the air gap observations must be quality-controlled and verifiable to accepted standards. Several users have also requested a local “billboard” displaying the clearance near the bridge. While such a request is understandable, the real-time quality control of the display itself must be considered (e.g. how to ensure against failure of a digital display segment). Neither this requirement nor a fast response capability has been addressed at this time.

2.0 USER REQUIREMENTS AND SENSOR

2.1 User Requirements

The potential users of air gap sensor data have requested continuous, real-time observations of the clearance beneath a bridge with an accuracy of ±15 centimeters (cm) (six inches). Since the precise meaning of this specification has not been defined by the users, this value is used only to roughly determine the requirement (the topic is discussed further in the Section 9.3). CO-OPS further reduces this accuracy requirement to ±75 millimeters (mm) (three inches) in order to maintain an initial level of quality assurance, and considers the value to represent two standard deviations of the difference between the final system output and a reference observation.

The system must provide useful observations of air gap every six minutes in real time, corrected for any sensor mounting offset on the bridge from low steel. It must operate in all weather conditions and survive in the hostile bridge environment, where vibration can be a significant issue. The test procedures listed in Appendix A show the potential sensor perturbations that the air gap sensor/system must tolerate.

2.2 Sensor Selection

A variety of air gap sensor technologies are available, including GPS/acoustic water level observations, laser ranging devices, and microwave radar sensors. A GPS/acoustic water level system simply observes the bridge height and water levels in the vicinity of the bridge, deriving the air gap from the difference between the two observations. This system makes use of well-established technology and is immune to fog or rain. However, the drawbacks include high cost (requiring the installation of both a water level gauge and differential GPS receivers), the requirement of two operational sensors to derive the desired measurement, and the potential compounding of observational errors from the two systems.

In response to a request for air gap information from the Charleston Branch Pilots Association, CO-OPS and NGS personnel conducted GPS leveling, traditional leveling, and trigonometric leveling studies to evaluate and verify each method. GPS receivers were installed on the Grace Memorial and the Silas Pearman bridge superstructures to monitor bridge motion, and at the Pilot's station to serve as a GPS control point to provide differential corrections to the GPS data. Traditional leveling rod surveys were run from the bridge to a network of surrounding benchmarks, and trigonometric height determinations were made using a Leica Total Station. The results (see Appendix K) show that GPS and trigonometric leveling techniques agreed well and could be useful tools for the observation of air gap.

Laser ranging sensor technology is also well established, although the use of this technology for ranging to a water surface is not widespread. Advantages of a laser sensor include low cost, small size, and long range. However, laser operation is inadequate in limited visibility situations, such as fog and rain.

A microwave sensor has the advantage of a relatively large footprint on the water surface, providing a spatial integration in contrast to a laser's single point. It is also immune to fog and rain. As a result, a microwave-based detector has been selected.

There were few commercial microwave altimeter sensors with a sufficient range available at the time of sensor selection. MIROS representatives discussed their plans for advances to their existing sensor, indicating a willingness to incorporate the latest technology to match CO-OPS' requests. MIROS also had the largest existing user base, and was the most responsive to OSTEP inquiries. For these reasons, the MIROS SM-094 was identified as the sensor that was most likely to meet the users' requirements.

3.0 DEVELOPMENT OF TEST PLANS

CO-OPS personnel, through a contract to the Mitretek Corporation, developed a MIROS Microwave Air Gap Sensor Detailed Test Plan (Test Plan); an overview of the specific series of tests identified and described in the plan provided to OSTEP follows:

- Sensor air gap reading against fixed target
- Sensor programmable functions
- Sensor recovery after power supply interruption
- Sensor operation under varied power supply output
- Custom developed software test
- Accuracy of sensor at varied distances from target
- Accuracy at varied alignment of sensor to water surface
- Accuracy of reporting under different configuration of sensor programmable functions
- Temperature impact on accuracy
- Rain impact on accuracy
- Humidity impact on accuracy
- Icing on sensor surface impact on accuracy
- Vibration impact on accuracy
- Ice on water surface impact on accuracy
- Varied sea condition impact on accuracy
- Natural conditions (combination of environmental factors)
- Operational deployment on Norfolk & Portsmouth Belt Line railroad bridge
- Reliability test and data collection about failures

Appendix A contains a summary of these test procedures.

Data files and associated metadata describing the data collected during the functional test, the bench test, and the controlled field test (to a hard target) have been placed in the publicly available OSTEP FTP (File Transfer Protocol) site located at ftp://ftp.fod.noaa.gov/, OSTEP/AirGap/ MIROS Validation.

4.0 DISCUSSION OF FIELD STANDARDS

Several tools were obtained to test and evaluate the selected microwave sensors. They are discussed in the following paragraphs.

4.1 Total Station

Trigonometric surveys (similar to those conducted for the air gap study of the Charleston bridges) can provide accurate and traceable observations of clearance at a point in time. Such observations have the longest history of use and are not constrained by the "clear sky, top of the bridge" requirements of GPS. However, the surveys are labor-intensive and only provide an instantaneous observation.

To assist with surveys, CO-OPS has acquired a Leica Total Station (model TC2003, serial number 439213) for the routine annual surveys of air gap sensor installations, with the cost distributed among several PORTS® installations.

4.2 Invar Tape

CO-OPS procured from Cooper Tools a 200-foot (') steel tape serial number 12662, which is directly traceable to the National Institute of Standards and Technology (NIST). A certificate from Cooper Tools contains a full description of the process relating tape #12662 to the NIST standard. The certificate, dated 28 May 2003, is attached as Appendix B.

4.3 Field Baseline

On 8 January 2004 a precision air gap baseline was established in the CO-OPS Chesapeake Facility parking lot using the Leica Total Station. This baseline was established to ensure precise examination of ranges obtained from microwave air gap sensors and laser range finders. Two parallel lines, defined by marked railroad spikes driven into the asphalt, were placed and marked at 50.0001 meters (m) as measured by the Total Station, with center points on the parallel lines marked to ensure that the air gap sensor and the target can be aligned.

Input parameters to the Total Station (temperature, barometric pressure) were also observed. Temperature was obtained using both an Omega TPD31 temperature sensor and the shielded air tunnel thermistor on the tripod. Barometric pressure was monitored using a Paroscientific 760-16B field standard (serial number 71336).

After the baseline was established, the two Laser Technology Impulse LR laser range finders were tested on the same two tripods used to build the baseline, with a mirror target. Serial number i07728 (the "new" sensor dated 20 August 2002) consistently read about five centimeters (cm) too long. Serial number i06021 (the "older" sensor dated 9 November 2000) consistently read 50.00 m (no offset). However, past field use of these two devices over water has shown that the newer unit typically gives a more consistent reading, with higher scatter seen in the older unit.

The Cooper Tools 200' steel tape (#12662) was used to verify the length of the air gap 50-meter (m) baseline. It was laid on the ground and pulled to a tension of 20 pounds (lbs). Air temperature was 50 degrees Fahrenheit (° F) in the sun and 36° F in the shade. With no corrections applied for either temperature or the fact that the tape followed the non-level pavement surface, a baseline measurement between the baseline center spikes of 50.0088 m (164 feet 0.85 inches) was obtained.

The temperature correction for the steel tape yielded improved results. The correction factor is 0.00000645 feet per degree F different from 68° F. We assumed the tape was at 50° F because it was laying in the sun. Shrinkage (due to contraction of the cold steel tape) made the tape read 5.8 mm longer. The temperature-corrected tape reading for the 50 m baseline is then 50.0030, resulting in a difference of less than three mm between the tape and the Total Station.

The tape value should not be used to replace the measure of 50.0001 obtained using the Total Station. It is noted that the tape value compares favorably, is longer (presumably because of the non-level surface the tape laid upon), and provides the best traceable standard (in terms of ease and in-hand documentation). Test result details are archived in files located at ftp://ftp.fod.noaa.gov/, OSTEP/AirGap.

4.4 Laser Range Finder

CO-OPS procured a Laser Technology Impulse 200LR laser range finder (which meets the requirements and costs only $2,500) for the evaluation and operation of air gap sensors. A laser is not suitable for continuous-range observations because of weather effects on the sensor. However, recent advances in the technology have reduced cost and increased the precision, making the sensor a good choice for fast, accurate distance measurements—just as required for validation and monitoring of a microwave air gap sensor.

A Laser Technology Impulse 200LR is fitted with an optional inclinometer, a necessary feature to ensure accurate vertical ranging. The following specifications apply:

Maximum range	575 m
Accuracy	3 cm at 50 m range
Resolution	1 cm
Inclinometer accuracy	+/- 0.1 degree
Laser wavelength	904 nanometers (nm)

This rangefinder uses a 904-nm infrared laser, while many others use a visible red laser. Light at 904 nm is quickly absorbed by water and has very little chance of penetrating the air/water interface, reflecting from a submerged object, again penetrating the water/air interface and completing the trip back to the rangefinder. The light is either successfully reflected at the interface or simply absorbed, ensuring an accurate range. Range finders operating at visible wavelengths will experience difficulties with returns from submerged objects in clear water. While the manufacturer of the Laser Technology Impulse 200LR has twice indicated the device will not provide returns from a water surface, CO-OPS personnel have found that it does so reliably. It is, however, a noisier measurement compared to the microwave sensor.

4.5 Next Generation Water Level Measurement System (NGWLMS)

Present water level stations use advanced sensor technology (NRC, 1986), improved instruments, digital recording, satellite communication, and additional geophysical instruments. Many stations also measure wind speed and direction, barometric pressure, air and water temperature. These are used to interpret the sea level records, perform scientific analyses of the natural phenomena in the coastal zone, and, when disseminated to mariners through PORTS®, provide real-time environmental conditions suitable for navigational decision making (NRC, 1986; 1996).

The system that accomplishes these tasks is known as the Next Generation Water Level Measurement System (NGWLMS). The NGWLMS (Figure 1) was developed by NOS to modernize the water level (WL) station (e.g., Scherer, 1986;

Mero and Stoney, 1988). A NGWLMS is a stand-alone system that acquires, stores, and transmits water level, weather, and other data from the field unit (Edwing, 1991). The main requirement for the unit is to accurately measure water level information with low power consumption, high reliability, and defined accuracy. The goal is to monitor water levels with an accuracy of better than one cm, as the present global estimate of sea level rise is 0.15 cm per year. Considering all of the variability in water level measurements (resulting from the various factors noted earlier), this level of accuracy presents a challenge for instrumentation and research. The NGWLMS water level sensors have an accuracy of approximately 1.0 cm for each sample (Schultz, et al., 1998).

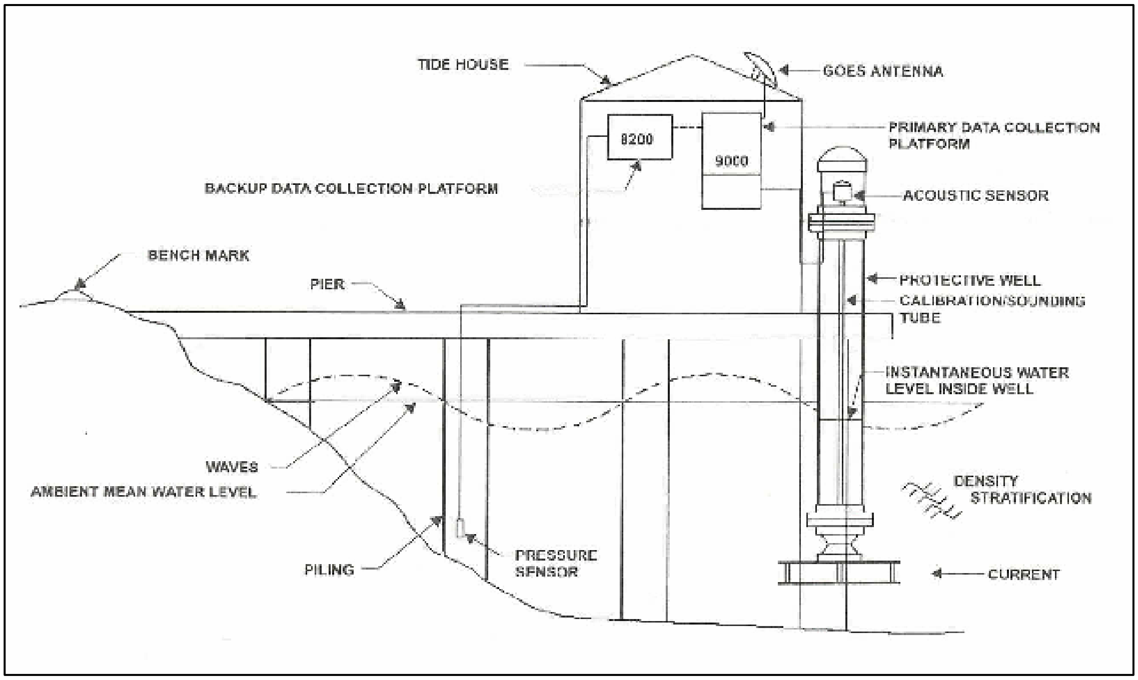

Figure 1. The NGWLMS station

Instruments. The NGWLMS field unit is an automated system for data acquisition and transmission. It was developed and procured from off-the-shelf components in the mid-1980s, and underwent extensive evaluation prior to delivering data from which operational products are developed. In addition, the internal firmware (and some of the internal modules of the field unit) has received periodic upgrades to maintain or enhance capabilities.

The Data Collection Platform (DCP) (Figure 2) consists of a Sutron 9000 Remote Terminal Unit (RTU). This is a modular unit that contains a power supply, communications controller, Geostationary Operational Environmental Satellite (GOES) transmitter, central processor unit, memory expansion module, telephone modem, general purpose Input/Output (I/O) module, and an Aquatrak water level sensor controller. The unit receives data from the sensors which measure the water level and geophysical parameters (Edwing, 1991). This measurement subsystem accommodates up to eleven additional instrument channels. The field unit is fully-automated for remote installations. The unit's design and satellite data transmission streamlines the digital data relay and processing.

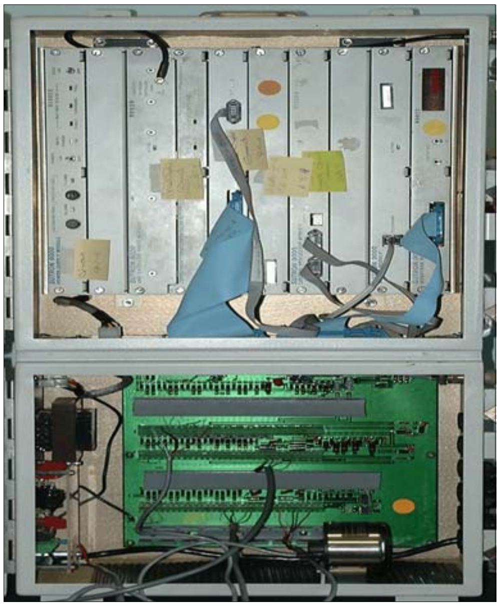

Figure 2. The Sutron 9000 Data Collection Platform

The instruments typically installed at a WL station are:

1. Primary water level sensor (an "Aquatrak" acoustic sensor);
2. Strain-gauge pressure transducer (for back-up water level measurements);
3. Anemometer (manufactured by R.M. Young for measuring wind speed, direction and maximum hourly gusts);
4. Thermistor (manufactured by Yellow Springs Instruments Corporation (YSI) for measuring air or water temperature; a Greenspan or Falmouth Scientific Instruments (FSI) water conductivity instrument);
5. Barometer (by Setra or Vaisala) for measuring atmospheric pressure (Edwing, 1991).

Since technology is constantly evolving, the mix of computers and sensors is subject to change in the future. For example, shaft-angle encoders and float/wire sensors are used instead of acoustic sensors because of the environment at the Great Lakes station. NOS is investigating the replacement of the acoustic sensor, which still requires a protective well, with a newer sensor, such as a microwave sensor.

Measurement of Water Levels. The primary requirement of a WL station is to accurately and reliably measure the varying water levels, often in hostile conditions. The primary water level sensor is a non-contact sensor, (i.e., the sensor never contacts the water). It consists of an acoustic transducer head connected to a one-half-inch diameter, vertical, polyvinyl chloride (PVC) tube open at the lower end, which is in the water. The water level in the tube moves up and down with the tide. The tube, and the sturdy environmental protective well housing which surrounds the tube, provide a limited damping effect. The protective well is a 15.24 cm (six-inch) diameter PVC well with a 5.08 cm (two-inch) inverted cone orifice in water. Typically, 45.7 cm (18-inch) diameter parallel plates at the orifice are also installed. This design reduces the unwanted mechanical filtering effects of a true protective well, while permitting the field unit to be sited in dynamic environments with wave action and high velocity currents. The design also reduces the errors (to wave motion and stream flow) associated with currents on the internal water level. This arrangement, as far as possible, gives a linear response to exterior changes in sea level (Scherer et al, 1981).

The acoustic head emits a sound pulse, which travels from the top of the tube to the water surface in the tube, and is then reflected up the tube. The reflected pulse is received by a transducer and the Aquatrak controller, or water level sensor module. The Sutron 9000 unit then calculates the distance to the water level using the travel time of the sound pulse (Sutron, 1988) with corrections for air temperature and density effects (Edwing, 1991).

In addition to the reflected pulse from the water level, there is also a reflection from a hole in the side of the sounding tube at an accurately-known distance from the transducer head, normally a distance of 1.22 m (four feet). The Aquatrak controller uses this measured reflection to continually self-calibrate the measuring system.

Temperature gradients in the protective well can introduce a source of systematic error. Two temperature thermistors are installed at two locations on the sounding tube to monitor temperature uniformity in the protective well (Edwing, 1991). A correction factor can be applied if a temperature gradient is observed in the protective well. At the present time only about four of 175 stations in the NGWLMS have such a correction routinely applied. A system of tidal bench-marks ensures the stability and continuity of the measurements and recovers the tidal datums (Edwing, Mero and Stoney, 1988).

The standard air gap deployment also makes use of two thermistors (but in a slightly different manner than in the water level measurement) to monitor the temperature outside and within the electronics housing. These temperatures can be used to examine bridge expansion/contraction/elevation responses to thermal variations. The internal temperatures are used to ensure that temperature extremes don’t exceed the specifications of the electronics.

5.0 LABORATORY TEST RESULTS

This section describes the test facilities, procedures, and documentation of the laboratory test results. The Test Plan (CO-OPS, February 2002) calls for laboratory performance tests to be carried out in an environmentally-controlled space. This was not feasible given the need for 10 m of unobstructed horizontal space. Therefore, a testing area was established in the parking lot of the CO-OPS Chesapeake Facility.

5.1 Test Conditions

The following six items (or conditions) were required in order to perform the static air gap tests (range 9 m and 10 m): 1) a moveable target which is microwave reflective; 2) a secure mounting device to hold the air gap sensor in a completely vertical position; 3) a testing area with at least 10 m of horizontal clearance; 4) a NIST-traceable metal Invar measuring tape; 5) a laser range finder aligned with the air gap sensor zero; and 6) a personal computer (PC) with data collection software to log both microwave and laser sensor readings.

5.2 Target

The 50 m range MIROS sensor has a five-degree beam width. For testing at up to 10 m, a 1.75 m x 1.75 m target is needed, based on a five-degree beam width. CO-OPS personnel constructed an 8' x 8' wooden target braced vertically to a standard shipping pallet (Figure 3). The target is easily repositioned by one person using a pallet jack. Sheet metal fastened to the target provides a completely reflective surface.

Figure 3. Air gap sensor test target

5.3 Air Gap Sensor Mount

CO-OPS personnel purchased a steel mounting bracket (designed for bridge installations) from the MIROS vendor. For testing purposes, the bracket was mounted to a wooden cable spool (Figure 4), carefully ensuring that the sensor was level and vertical. The entire system (spool plus sensors) is moveable using a forklift.

Figure 4. Air gap sensor mounting bracket

5.4 Metal Invar Measuring Tape

A NIST-traceable certified Invar tape was used to establish the distance between the air gap sensor zero, which is the green face of the instrument, and the test target (Figure 5). The limitations of precisely measuring this distance should be noted. Personnel carefully aligned the tape markings at each standard distance using a level and a straight edge. However, it was impossible to do this with absolute precision, therefore a potential source of measurement error was introduced. Additionally, because the target was mounted on a pallet, it was impossible to absolutely reoccupy the same position after each test movement. These positioning errors are evident in the test data.

Figure 5. View of alignment of the calibrated tape with the MIROS

5.5 Laser Range Finder

A Laser Technology Incorporated Impulse LR laser range finder was attached to the MIROS mounting bracket so that the zero of that instrument (specified by the manufacturer to be at the center of mounting bolt) aligns with the air gap sensor zero (Figure 6). The laser range finder was removed each evening because it is not weather-proof.

Figure 6. Laser range finder affixed to air gap sensor mounting bracket

5.6 Data Collection System

A standard desktop PC was configured with specialized testing software; the software logs five-second readings from both the microwave and laser, which are connected by direct cables to the serial ports of the PC.

The MIROS SM-094 altimeter employs a single tasking processor with limited capabilities, leading to timing inconsistencies when operated in a free-cycling mode. Consequently, the nominal two-Hz data rate yields infrequent occasions where as many as three or four observations are output during a one second period, or as few as none. Similarly, in the polled mode (command GV, Get Value) the SM-094 occasionally failed to respond. These deficiencies have been corrected through firmware modifications. Further, the vendor is introducing a new Digital Signal Processing (DSP) chip with greatly expanded capabilities. This hardware addition permits multi-tasking and output rates up to 100 Hz, which may be an important consideration for future use of the sensor as a water level sensor where corrections for wave forms may be required.

The SM-094 two-Hz RS232 ASCII (American Standard Code for Information Interchange) output provides two range values. Each range value may be filtered by a smoothing algorithm, which is controlled by a user-selected time constant. The default factory settings provide an unfiltered observation in the first value and a smoothed second value. The default time constant for the smoothed second value is 60 seconds, and several of the early tests used these unsmoothed or smoothed values for data examination. The altimeter also may be operated in a polled mode rather than free-cycling, by transmitting first a serial output off-command (SER=0), and then polling to obtain the two values by issuing the command GV. After the development of the new DCP hardware and software, only the unfiltered values were used, and they were obtained by polling the device at a one-Hz rate.

5.7 Test Procedures and Objectives

The tests described in Section 5.9 are laboratory functional performance tests. As stated above, all tests were carried out in the parking lot at the CO-OPS Chesapeake Facility. The test procedures were prescribed in the Test Plan (CO-OPS, February 2002).

Testing was conducted by incremental adjustment to a hard target with the following objectives:

1. Verify the system accuracy against a target at a fixed distance
2. Verify the capability to change user-selected measurement parameters and settings
3. Document the system performance after power outage
4. Document the system performance under decreased voltage of power supply
5. Document the system performance under different alignments to the target
6. Test whether the custom-developed software can receive and process data from the MIROS microwave air gap sensor
7. Test the end-to-end system with a direct connection between the MIROS microwave air gap sensor and the computer system that will receive and process data

5.8 Test Documentation and Test Data Archival

This test report constitutes the documentation of all formal tests, including scanned copies of the completed test logs (Appendix C) and a summary of test results. Two copies of original test data are stored on disc, one copy resides at the CO-OPS Chesapeake Facility, and the other resides at CO-OPS Headquarters in Silver Spring, Maryland. The original test logs, which are also kept at the CO-OPS Chesapeake Facility, are archived in binders specific to each sensor.

A Procomm log was opened to record all output (Table 1). Procomm Plus is a commercial terminal emulation program which permits flexible communications and file transfers between a PC and a digital device. Script files running under Procomm are used to control sensor and PC operations. Procomm is widely used by CO-OPS personnel to configure and operate sensors, and log the resulting data. The MIROS sensor requires approximately 16 seconds to lock on target. Because of the nature of these data, they are easily eliminated by a software filter for out-of-range data.

Table 1. A log records all output using Procomm software

```
******************************************************
MIROSaltimeter digital signal processing started
Noise spectrum is cleared
0.000 -94575670000000000.000
0.000 -94575670000000000.000
0.000 -94575670000000000.000
0.000 -94575670000000000.000
0.000 -94575670000000000.000
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0.000 -94575670000000000.000
96.000 96.000
96.000 96.000
96.000 96.000
96.000 96.000
96.000 96.000
96.000 96.000
96.000 96.000
96.000 96.000
96.000 96.000
10.009 10.009  ← Begin acquisition of valid data.
10.009 10.009
10.009 10.009
10.009 9.926
10.009 9.926
******************************************************
```

5.9 Detailed Test Results and Analysis

The operational installation of an air gap sensor requires precise and careful range calibration. CO-OPS personnel have found that the manufacturer's calibration is insufficient; therefore corrections to the manufacturer's calibration are necessary. The first estimate of the correction is determined using the 50 m reference range facility previously described. Another estimate may be obtained by comparing air gap observations from an uncorrected sensor to those obtained from a corrected operational sensor (the Reedy Point site has been used as an occasional reference). A final estimate is obtained in-situ after the installation at the operational site, using the Total Station and WL observations to calculate a reference air gap. These estimates are compared, with the most weight given to the in-situ estimate. A final offset value is selected and applied at the Data Acquisition System (DAS). The original manufacturer's calibration stored on the SM-094 is not altered. In addition to the calibration offset correction, the correction for the offset to low steel is also applied at the DAS.

5.9.1 Results of Test 1-Sensor Air Gap Reading Against a Fixed Target

Test 1 was conducted using the configuration described in Sections 5.1 through 5.8. Appendix C contains a scanned copy of the log sheet from Test 1. The factory defaults were used for the selectable parameters (Table 2). Appendix D contains more detail about these settings. Thirty minutes of test data were collected with the target positioned at 10 m, 9 m, then back to 10 m (Figures 7a, 7b, and 7c). During all three portions of Test 1, the MIROS sensor performed well within the ±75 mm (three-inch) uncertainty requirement, with a difference between the nominal (tape measured) distance and the mean of the MIROS data of −17 mm, +21 mm, and −15 mm respectively (MIROS minus steel tape values).

Table 2. **Factory Default Settings for Selectable Parameters**

min 100	freq 2
det 100	htc 0.5
wtc 4.5	atc 59.5
Win 6	ntc 0
tout 10	top 1
ser 1	ch 3.0 20.0

The laser range finder shows greater variability than the MIROS sensor, as evidenced in the two orders of magnitude difference between the standard deviations of the two measurement series. There is an offset in the means from the two different sensors which is not constant in value or direction mean - raw MIROS. For the first 10 m test, the laser measured longer by 15 mm; for the 9 m test, the laser measured shorter by 8 mm; and for the second 10 m test, the laser measured longer by only 5 mm. These differences (although interesting) are not significant, because they are within the uncertainty of the measurement.

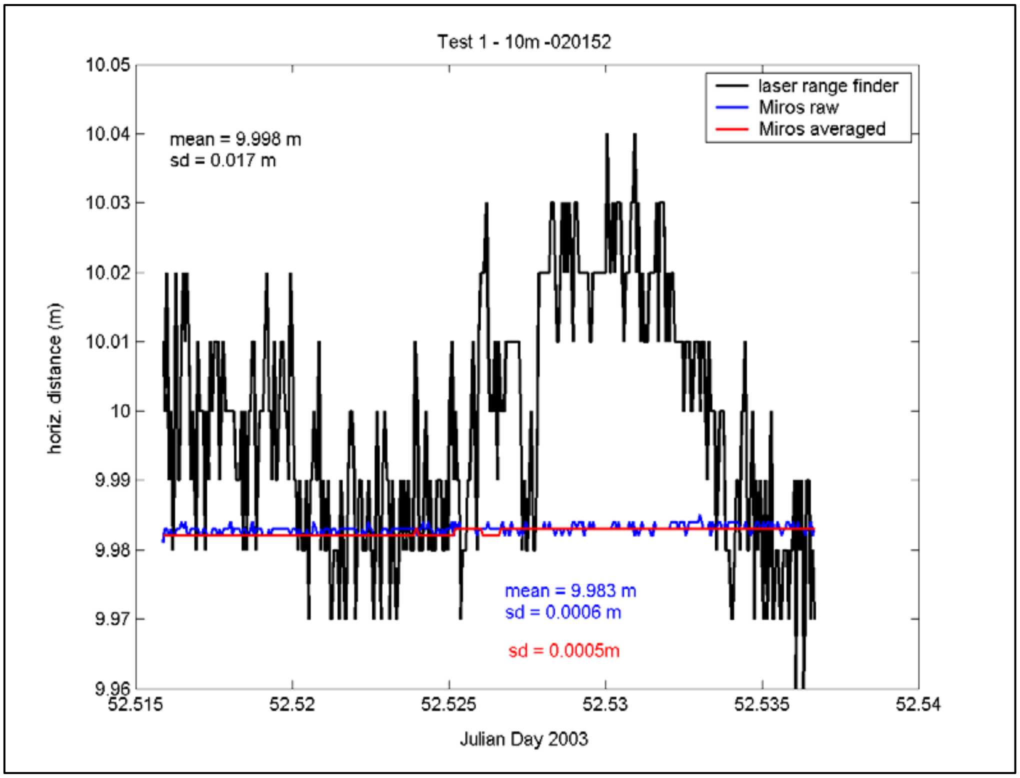


Figure 7a. Thirty minutes of test data against a fixed target positioned nominally at 10 m

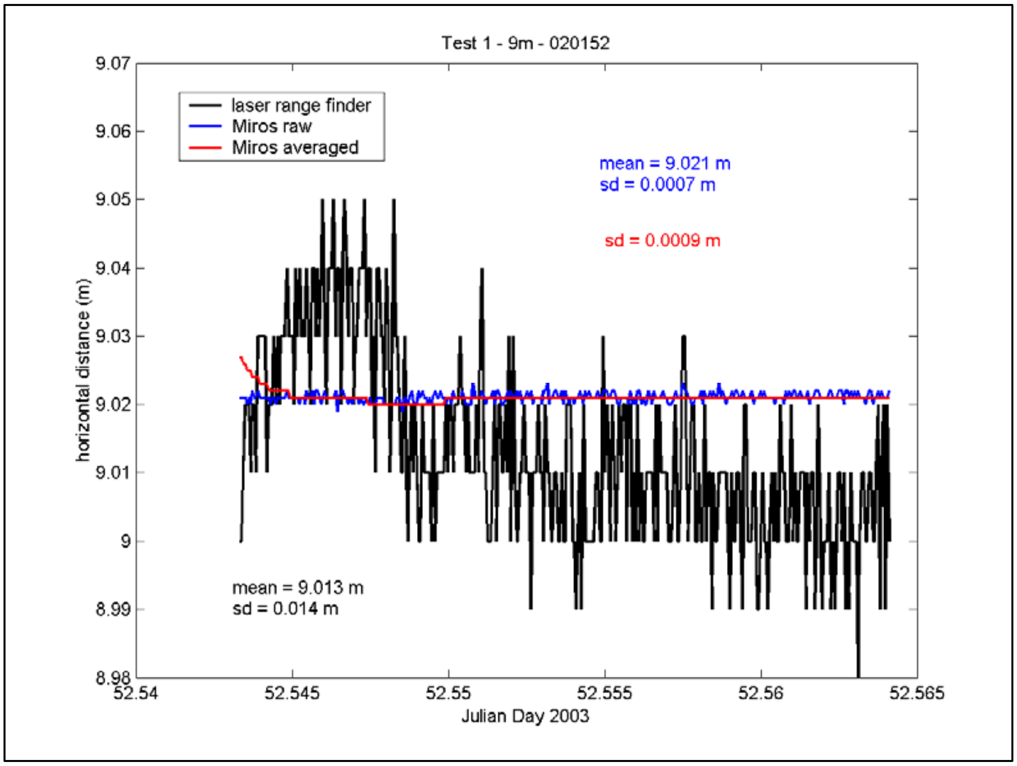


Figure 7b. Thirty minutes of test data against a fixed target positioned nominally at 9 m

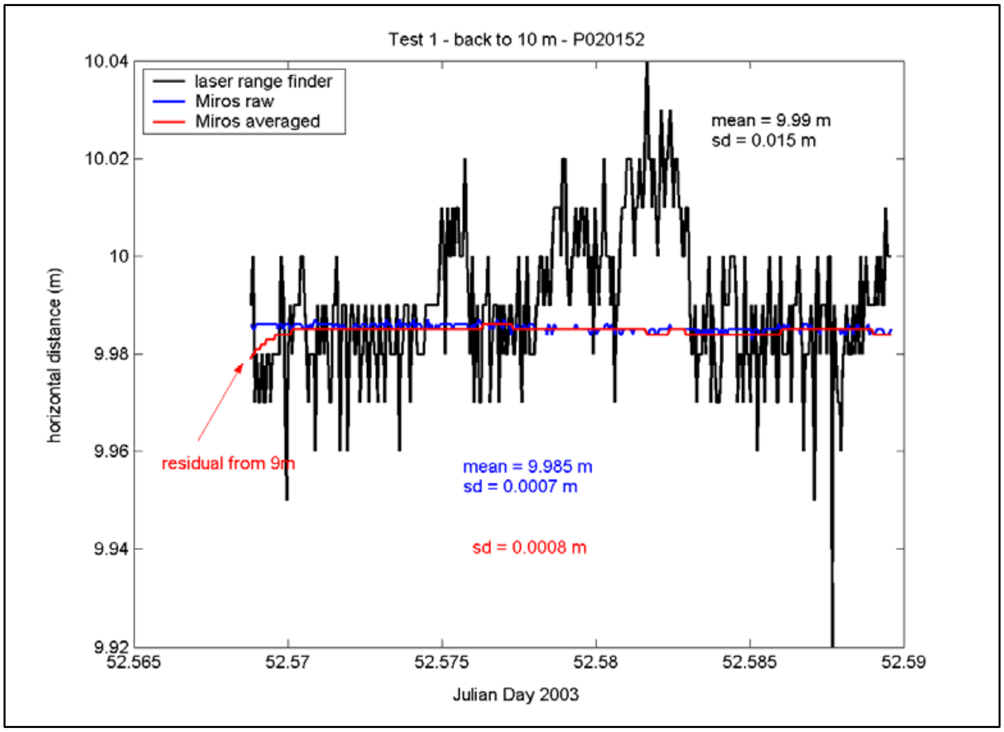


Figure 7c. Thirty minutes of test data against a fixed target. The target is moved back to 10 m. Notice the residual effect of 9 m in the averaged value (red line).

5.9.2 Results of Test 2 - Sensor Programmable Functions

Test 2 was conducted using the configuration described in Sections 5.1 through 5.8. Appendix C contains a scanned copy of the log sheet from Test 2. The factory default settings were changed one by one, and test measurements were collected. The values changed during testing are shown in red in Table 3. The first value listed is the default value, and the second value is the tested setting. Appendix D contains more detailed information about these settings.

Table 3. MIROS Factory Default Setting Changes

min 100 75	freq 2
det 100 50	htc 0.5
wtc 4.5	atc 59.5
Win 6	ntc 0
tout 10	top 1
ser 1	ch 3.0 20.0

Five minutes of test data were collected with the target positioned at 10 m and 9 m for each parameter change (Figures 8a-g). During all 16 portions of Test 2, the MIROS sensor performed well within the 75 mm uncertainty requirement. It is important to keep in mind that the target was hand-positioned each time with a pallet jack. Although there was a chalk line on the pavement, exact repositioning was impossible.

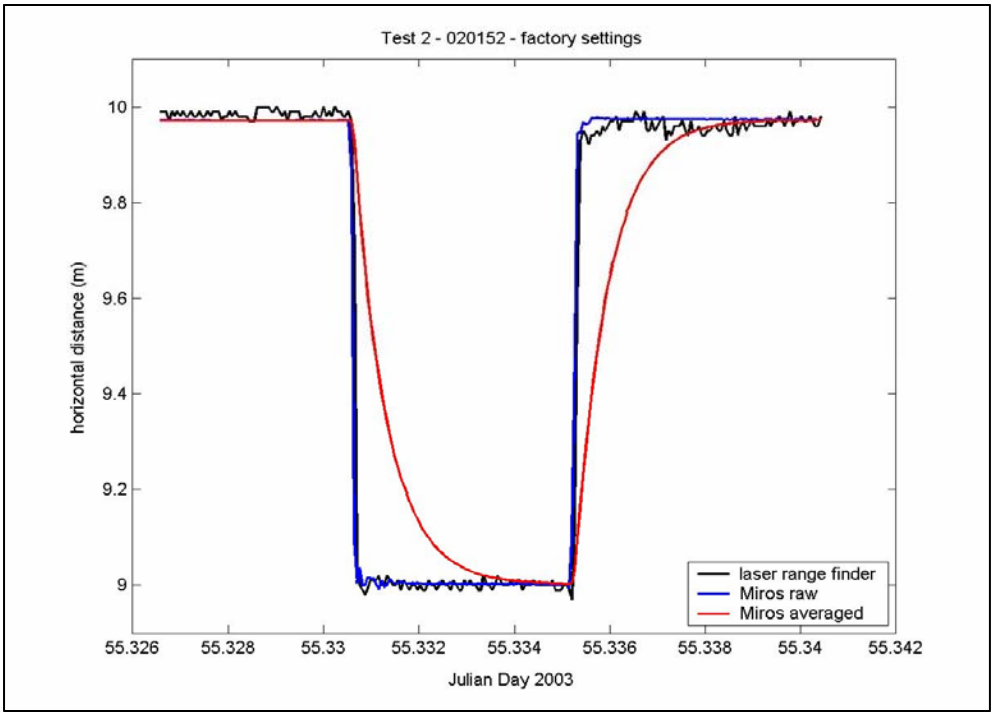


Figure 8a. Test of readings with all settings as delivered from the factory

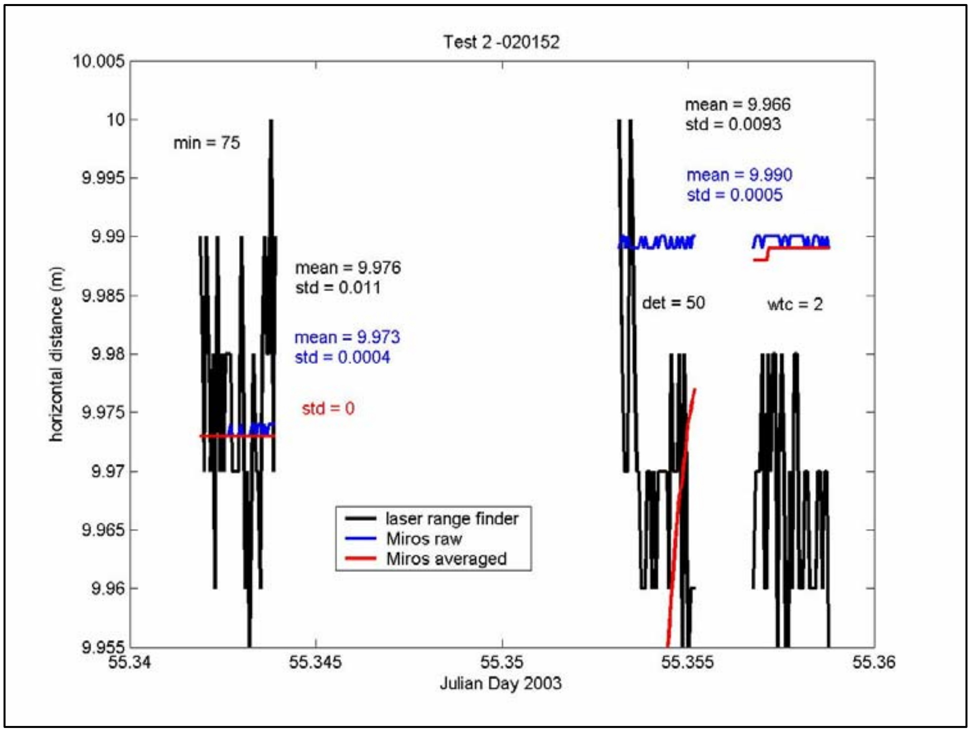


Figure 8b. Test of changing MIN, DET, and WTC with target positioned nominally at 10 m

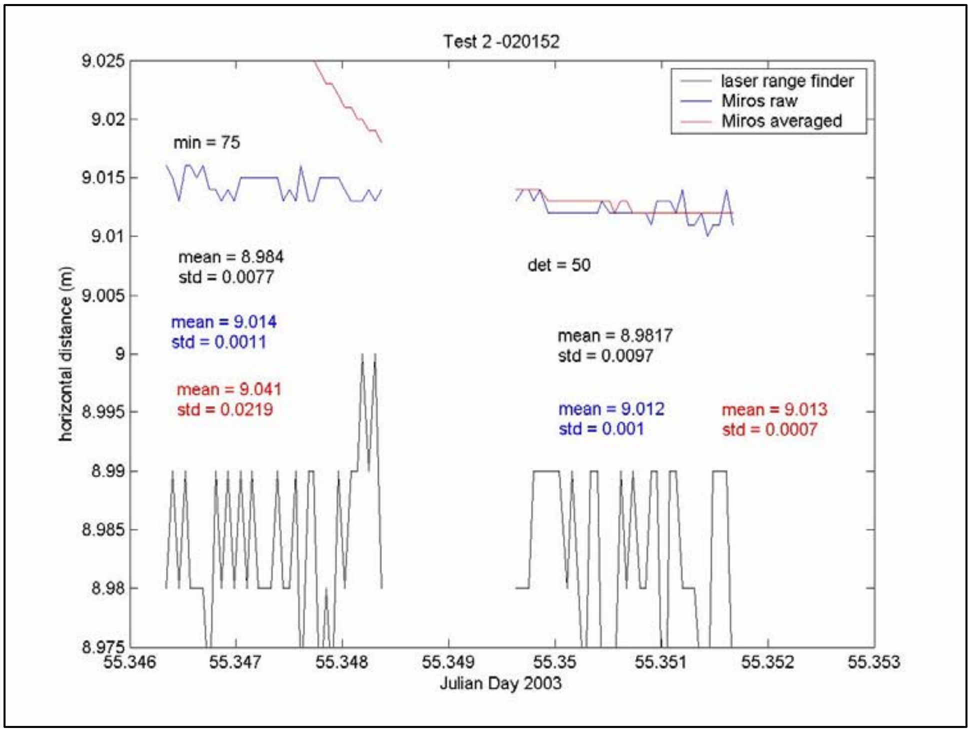


Figure 8c. Tests of changing MIN and DET with target nominally positioned at 9 m

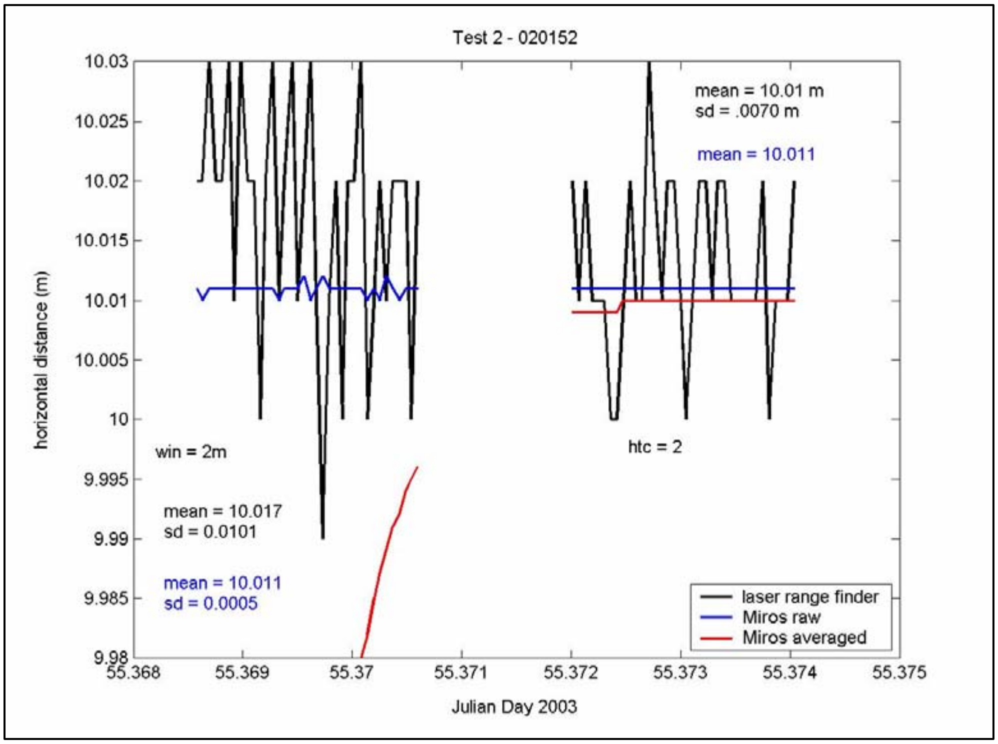


Figure 8d. Tests of changing WIN and HTC with target at ~ 10 m

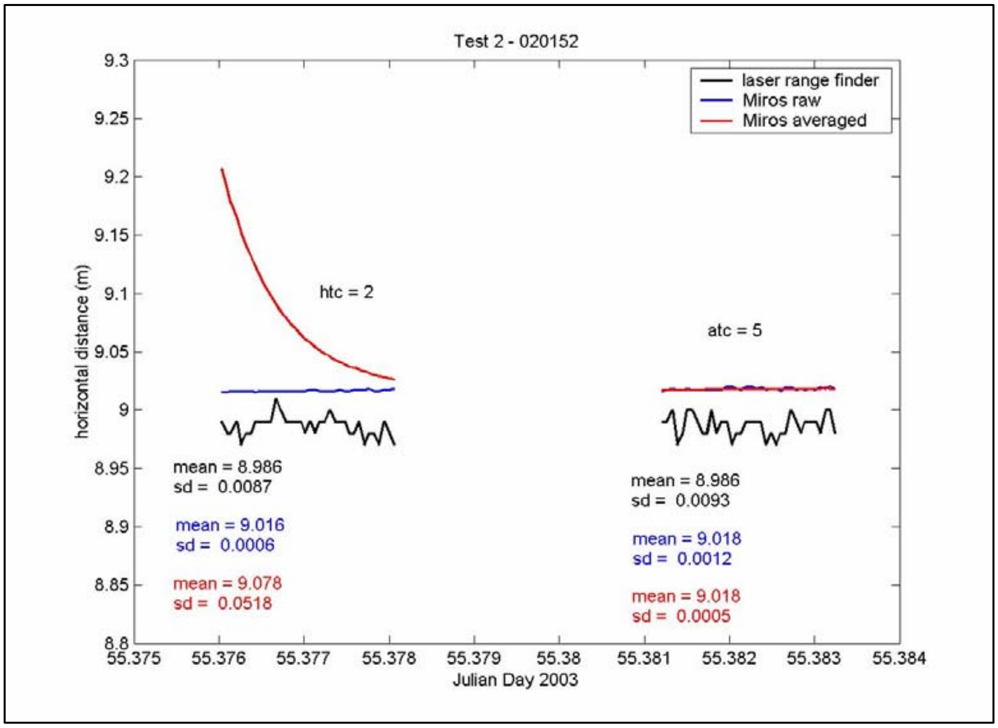


Figure 8e. Tests of changing HTC and ATC with target at ~ 9 m

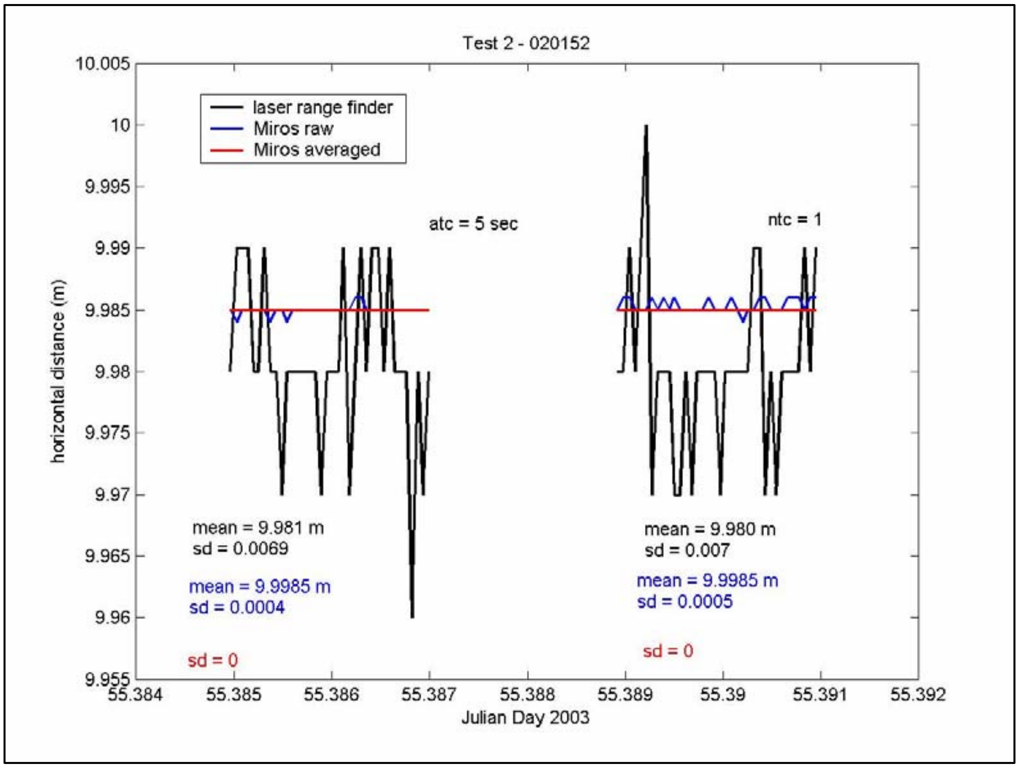


Figure 8f. Tests of changing ATC and NTC with target at ~ 10 m

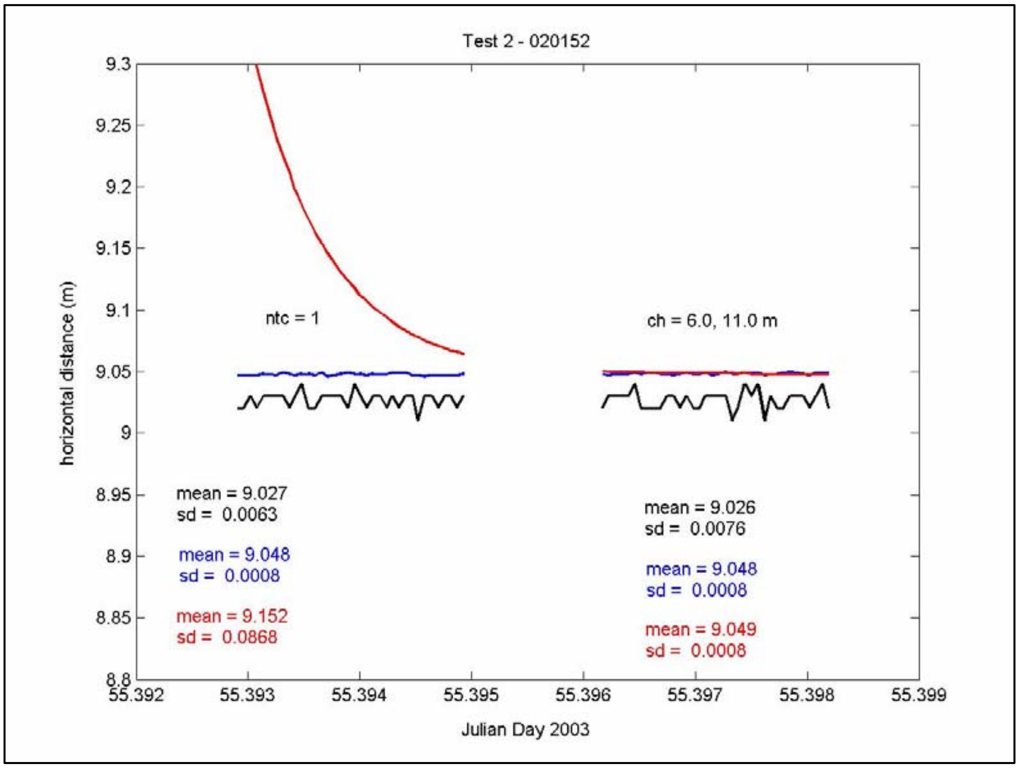


Figure 8g. Tests of changing NTC and CH with target at ~ 9 m

5.9.3 Results of Test 3 - Sensor Recovery After Power Interruption

Test 3 was conducted using the configuration described in Sections 5.1 through 5.8. Appendix C contains a scanned copy of the log sheet from Test 3. The factory default settings were used for the selectable parameters (Table 2).

Five minutes of test data were collected with the target positioned at 10 m, 9 m, and then back to 10 m (Figure 9a). The power supply was then unplugged for one minute. The long time that it takes for the averaged MIROS measurements to reach the new target distance after target repositioning reflects the effect of the long averaging constant (ATC = 59.5 sec). Figure 9b shows the readings after power was restored.

During both portions of Test 3, the MIROS sensor performed well within the 75 mm uncertainty requirement. The difference between the nominal (tape measured) distance and the mean of the MIROS data was 8 mm after power was restored. It is important to note that, since the specialized logging software samples every five seconds and ignores spurious data; it does not totally reflect the output of the MIROS after a power outage.

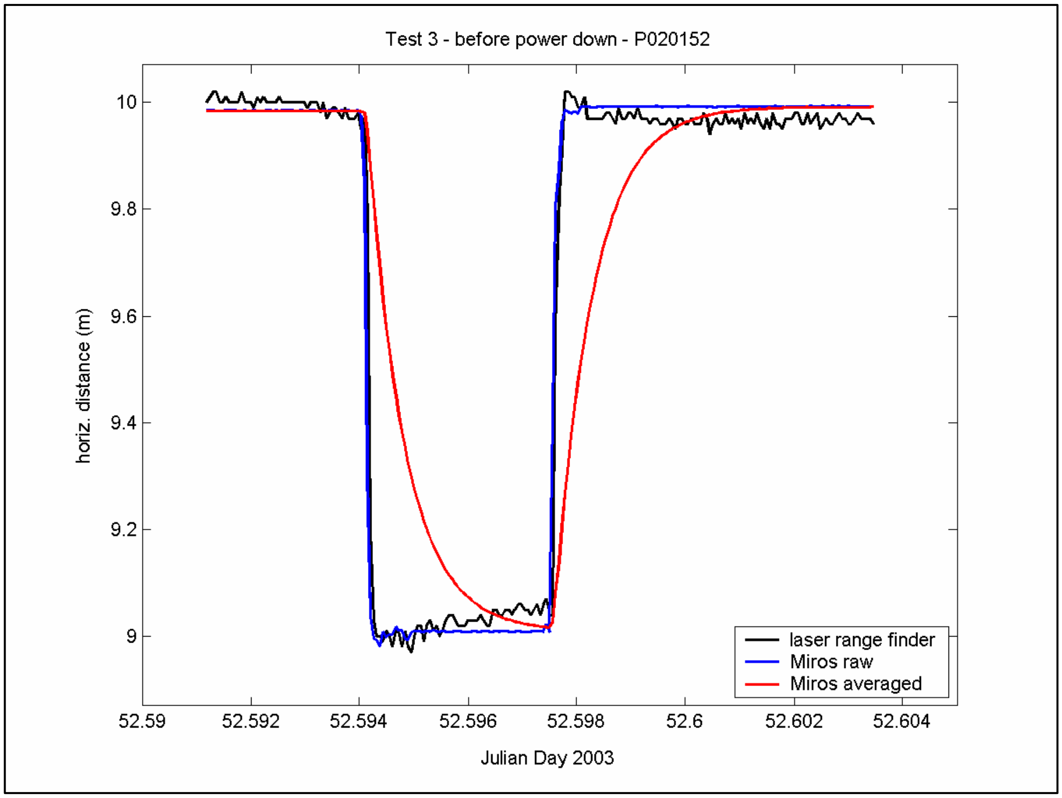


Figure 9a. Five minutes of test data with the target positioned at 10 m, 9 m, and 10 m

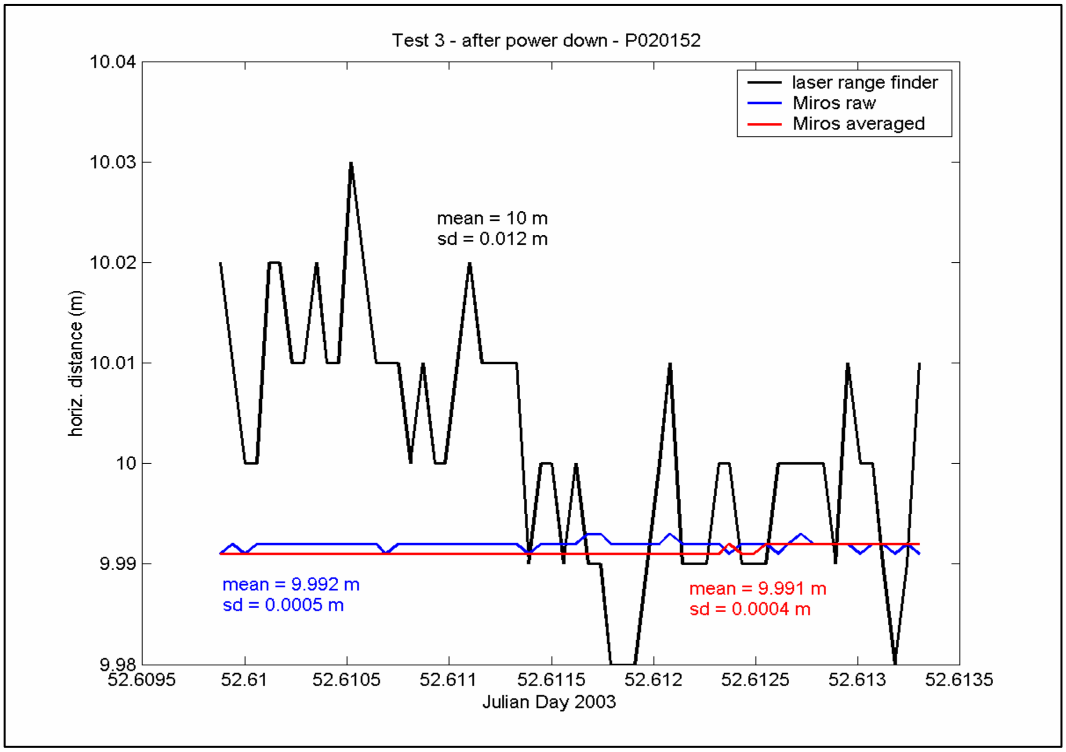


Figure 9b. Test results after power was restored

6.0 FIELD TEST RESULTS

CO-OPS personnel conducted a series of field tests using five different MIROS air gap sensors. Four of these units are the SM-094/50 fifty-meter range devices, and the fifth is an SM-094/85 eighty-five-meter range device.

Each field test incrementally provided additional information, as follows:

Chesapeake Bay Bridge Tunnel
First marine environment tested by OSTEP

St. Georges Bridge
First bridge, long-range marine environment for both SM-094 and laser range finder

USACE/Duck
First long-term comparison to NGWLMS

San Francisco
First use of Total Station, first use of 85-meter range SM-094

Crescent City New Orleans
First long-term bridge deployment using MIROS software

Reedy Point
First long-term bridge deployment using Xpert/9210 software

Each field test is further described Sections 6.1-6.6, along with the results from each test.

6.1 Chesapeake Bay Bridge Tunnel

The WL station at the Chesapeake Bay Bridge Tunnel (CBBT) is the primary site of the distributed OSTEP test facility. The first test of the SM-094/50 over open water was conducted at this readily accessible site. CO-OPS personnel examined the sensor response in the presence of tidal variations, waves, and currents. No leveling was conducted; the NGWLMS and SM-094 data were simply demeaned for comparison. The SM-094 was free cycling and logging to a laptop PC using a Procomm script file that time-stamped the incoming data and wrote it to a daily file. Figure 10 shows the Bayonne Bridge system (SM-094/50 serial number P010034) temporary mount over the access hatch used to gain access to the conductivity/temperature sensor (CT) and NGWLMS wells. The figure shows that the CT well is clearly within the five-degree beam of the air gap sensor. It was impossible to easily install the sensor with a clear beam path, yet the SM-094 returned a very satisfactory record that qualitatively matched the NGWLMS (Figure 11).

The results of this test showed that the sensor agreed with the NGWLMS WL gauge within approximately one cm. Since the SM-094 and the WL gauge were sampled at different times, direct differences were not computed. Visual comparison of the WL and the SM-094 time-series curves revealed that a single six-minute WL point at JD 194.76 (which appeared to be an outlier) was actually a point on a smooth anomalous waveform, thought to be caused by the wake of a submarine transiting the CBBT (Figure 12). Data and additional test documentation are available at ftp://ftp.fod.noaa.gov/, OSTEP/AirGap/CBBT.

Figure 10. SM-094 temporarily mounted over the access hatch

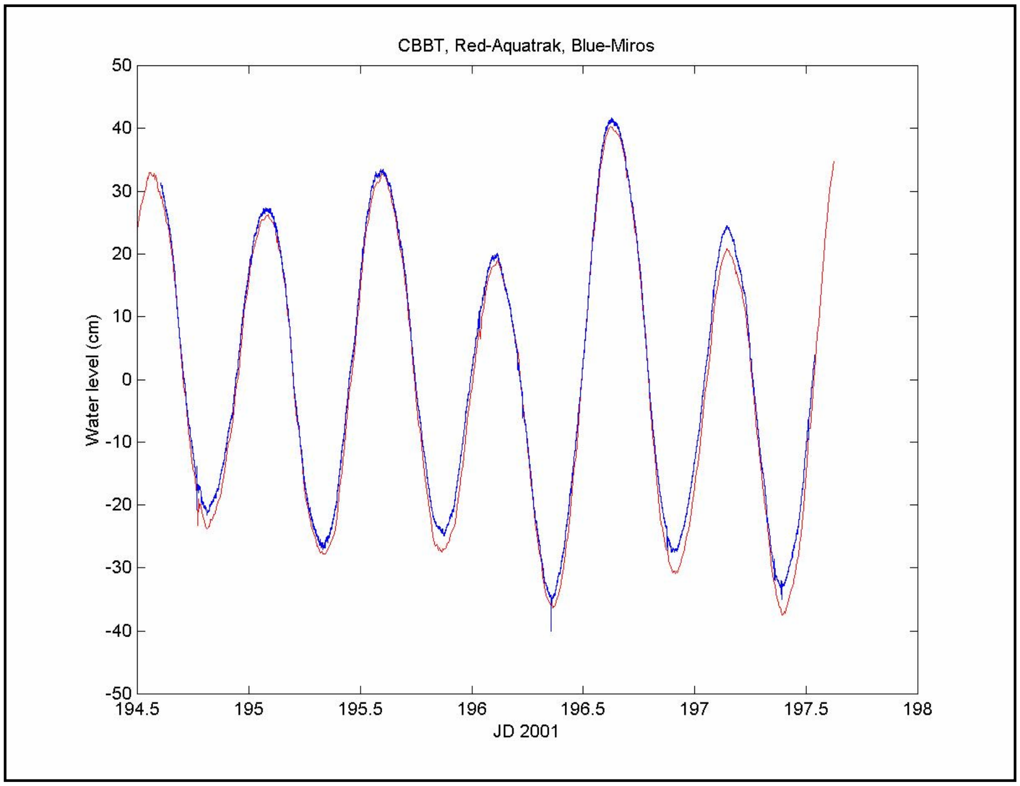


Figure 11. Comparison of CBBT water level sensor and air gap sensor

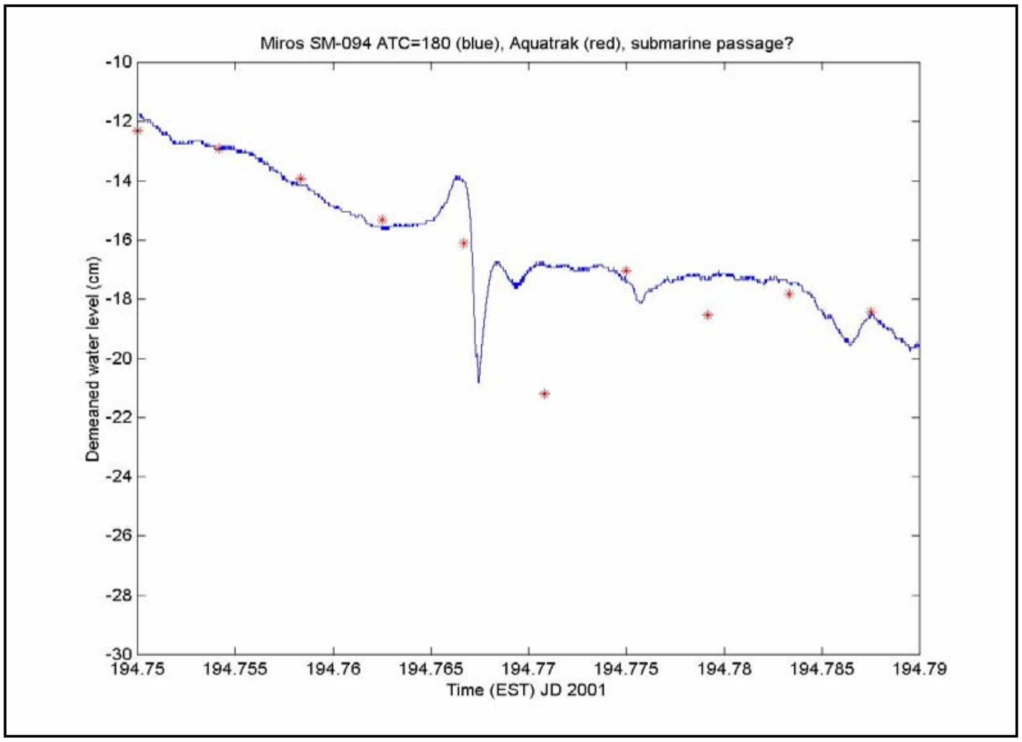


Figure 12. Detail of Figure 9 showing anomalous wave passages, possibly caused by a submarine

6.2 St. Georges Bridge

The first test of the SM-094/50 at an extended range to a water surface target was conducted on the St. Georges Bridge over the Chesapeake and Delaware (C&D) Canal, testing the sensor at a range of 135'. The United States Army Corps of Engineers (USACE) permitted a temporary installation of less-than-24-hours. The test satisfied some of the requirements set forth in the Test Plan, specifically Test 6.1—Field Operational Test and Evaluation, Natural Conditions. It was also the first data acquisition and comparison to the laser range finder at long range. Again, the SM-094 was free cycling and logging to a laptop PC using a Procomm script file that time-stamped the incoming data and wrote it to a daily file.

Data from the WL gauge at Reedy Point were used for comparison. The tidal amplitude diminishes considerably as one proceeds westward through the C&D canal, reducing the range by approximately 50 percent across the full length of the canal. A time offset of 18 minutes exists between the two sites (St. Georges Bridge leads Reedy Point, Figure 13).

Test results showed that the SM-094 continued to track within an accuracy of a few cm, even at the extended ranges. Figure 14 shows the demeaned difference time series with a standard deviation of just 2.2 cm. It was also found that the LR200 laser range finder yielded reliable returns from a water surface at the extended range.

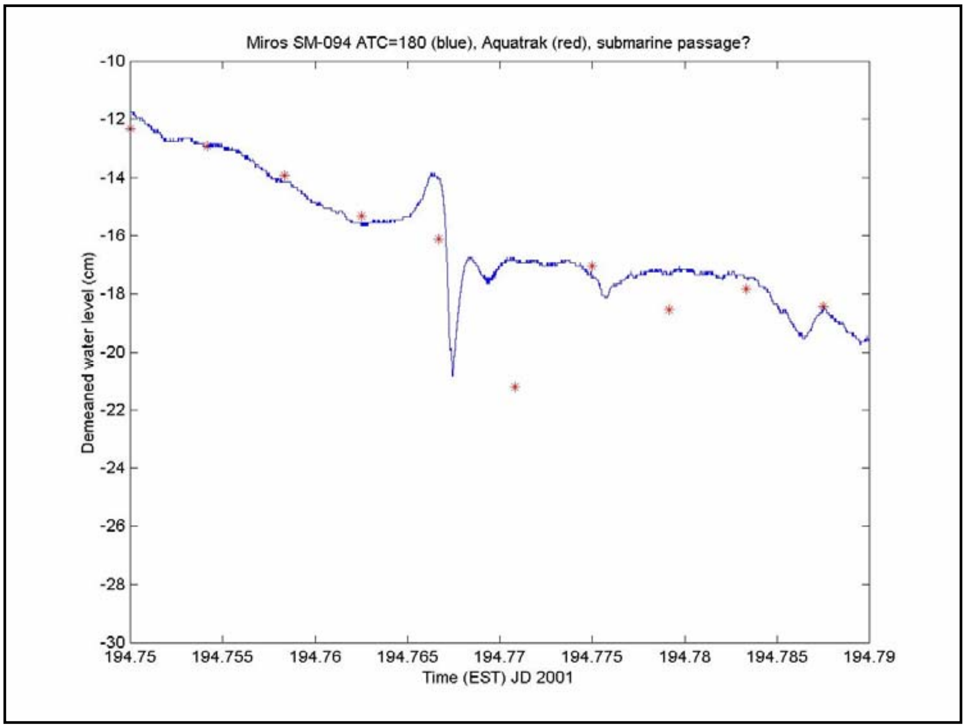


Figure 13. Comparison of WL and microwave air gap data after applying offset and zoning correction

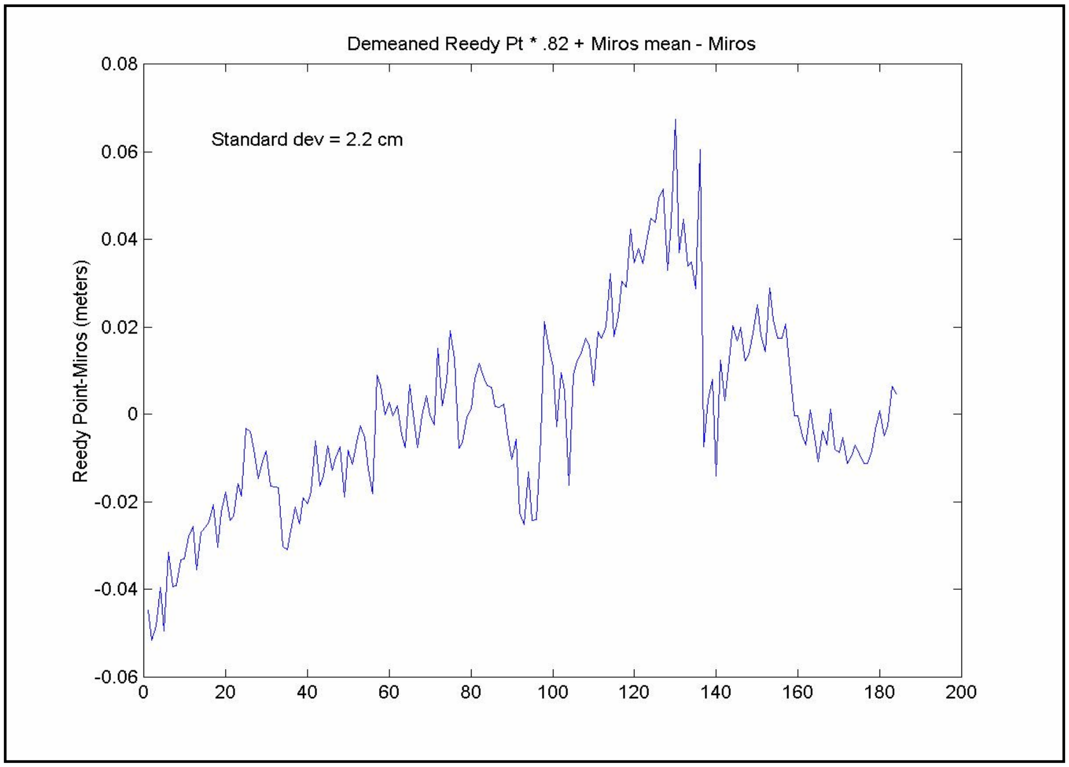


Figure 14. Demeaned Reedy Point.82 + MIROS mean

6.3 USACE Field Research Facility (FRF)/Duck

CO-OPS conducted a one-week deployment (1-8 August 2001) of the MIROS microwave altimeter for use as an air gap and water level measurement sensor at the USACE FRF in Duck, North Carolina. This site was chosen to provide maximum exposure to waves and to be co-located with a CO-OPS WL station.

Test Configuration. A MIROS microwave altimeter model SM-094/50 (with a maximum range of 50 m) was secured to the underside of the USACE FRF pier. The pier extends approximately 565 m from the shore where the water depth at the WL sensor is 8.83 m mean lower low water (MLLW). The MIROS sensor was approximately two m from the WL station, which housed a laptop PC used for data collection during the test. Care was taken to ensure that the MIROS beam was unobstructed by the pier pilings, however, wave interaction with the pilings may have caused noise in the signal. The SM-094 has a number of user-selectable parameters (Table 4). The averaging time constant (ATC) has considerable impact on the data output of the air gap sensor as it comes from the manufacturer. For the first few days of the experiment, ATC was set to 30 seconds. ATC was changed to 60 seconds on 3 August 2001. The manufacturer's explanation of each of these parameters is found in Appendix D.

Table 4. - Parameter Settings During the Experiment

Parameter	Setting	Parameter	Setting
MIN	100	FREQ	2 Hz
DET	100	HTC	0.5
WTC	4.5	ATC	30/60
WIN	6	NTC	0
TOUT	10	TOP	1

Data Sources and Processing. Quality-controlled water level data were obtained from the CO-OPS database. The data were demeaned over the same time period as the MIROS data and inverted to correspond to the downward-looking MIROS data. Sounding tube temperatures (T1, T2) were obtained from the Product and Services Division (PSD).

The SM-094/50 samples nominally at two Hz. Because the MIROS was in "free run" mode, some of the output data had gaps and times when three values per second were recorded. The decimal Julian day was calculated from the Procomm-stored time stamp. The MIROS data were then processed in two different ways for comparison with the WL.

First, both the raw and smoothed data were decimated to a six-minute time series by taking the first of the two-Hz values at each six-minute interval. The MIROS data were also decimated to one Hz (again by taking the first value), then run through a program to find the average and standard deviation of the 181 values around the six-minute value. In order to analyze the effect of employing the CO-OPS Data Quality Assurance Processing (DQAP) scheme used on WL data, the standard deviation calculated from the 181 points around the six-minute value was used to determine a three-sigma cut-off value. Values lying outside of the three-sigma range were rejected, and the mean and standard deviation were then recomputed. This process did not result in the rejection of many points.

Results. A cursory look at the MIROS data without applying any post processing (other than to decimate the two-Hz data to six-minute samples) reveals several features. First, the open coastal nature of the test site is clearly visible in the MIROS raw data, since it is observing waves on the ocean surface. The WL data show very little effect of waves because of the presence of the protective well and because of the CO-OPS standard DQAP that has been applied to derive the WL values. Wave array data collected at FRF show significant wave heights of nearly two meters on 1 August 2001, relaxing to only 0.5 meters at the end of the week. The energetic waves observed during deployment are evidenced by the high variability at the beginning of the time series. The standard deviation of these three time series is very similar, since it is dominated by tidal variability.

Using the WL data as the standard, the differences between the WL and the MIROS raw and smoothed data were calculated. As expected from the water level time series, the raw MIROS data did not agree well with the WL data. The mean of the absolute value of the difference is nearly 14 cm (standard deviation 14 cm). The data that have undergone smoothing within the MIROS sensor compare much better to the NGWLMS data, with a mean of just over one cm (standard deviation one cm).

It is important to note that the MIROS smoothing scheme and the CO-OPS DQAP (which acts as a smoother) produce different results. This difference can be seen by comparing the MIROS smoothed data (decimated to six-minute intervals) with the MIROS raw data (decimated first to one Hz) that has been processed using CO-OPS standard DQAP. During the time period with high wave action, the difference between these two schemes is greater than six cm. In order to provide consistent comparisons, the remaining analyses will show only NGWLMS and MIROS raw data that have been processed using the DQAP procedure.

The agreement between the MIROS and NGWLMS data is greatly improved by processing the MIROS data in the same manner as the NGWLMS (Figure 15). There is no appreciable difference between the MIROS raw and smoothed data after application of the DQAP algorithm, therefore only the MIROS raw data which have been processed using DQAP are shown.

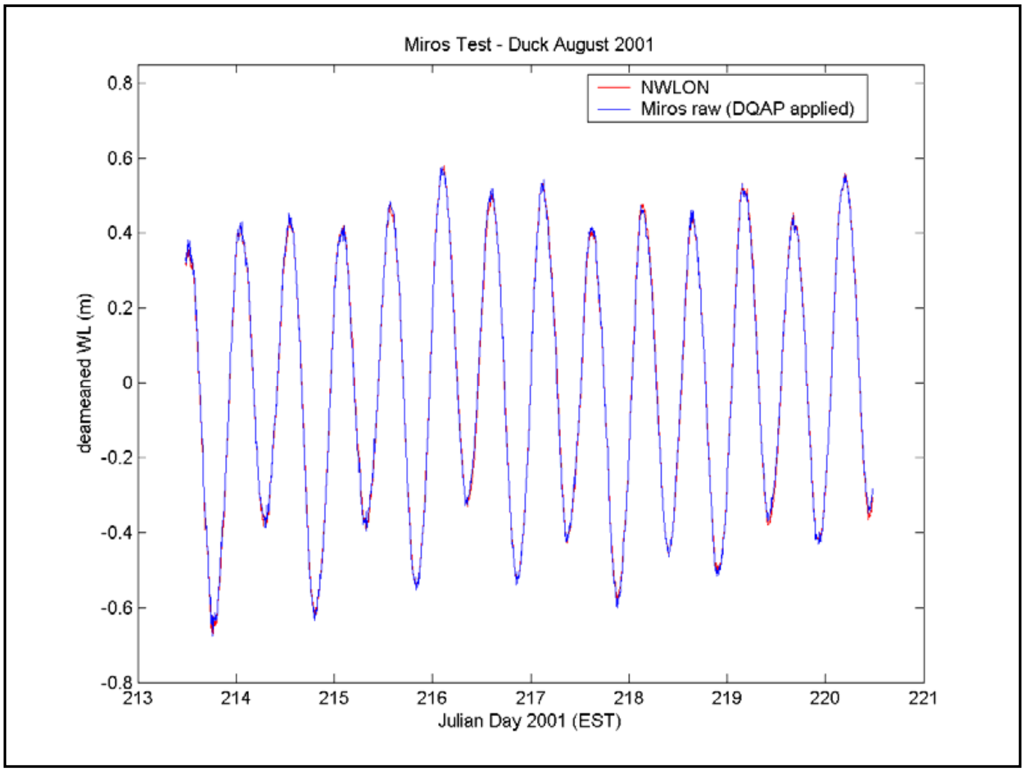


Figure 15. One week of comparison demeaned water level data from the Duck NWLON station (red) and the MIROS microwave air gap sensor (blue)

Again, using the NGWLMS data as the standard, the differences between the NGWLMS water level and the DQAP processed MIROS data were calculated. The mean of the absolute value of the difference between the NGWLMS and MIROS data is less than one cm (the standard deviation is also less than one cm). An interesting daily periodicity is evident in the difference of the two sets, perhaps pointing to a need to apply the temperature correction factor to the NGWLMS-measured water level based on the differences in sounding tube temperatures caused by diurnal temperature changes (Figure 16).

One concern about the MIROS was that the data would be excessively noisy due to the absence of any stilling hardware. The standard deviation obtained from averaging the 181 one-second values around the desired time or using the DQAP algorithm is larger than that for NGWLMS, but it is not an order of magnitude larger, nor even doubled (Figure 17). This important result translates into the ability to use CO-OPS standard water level QC rules for Continuous Operational Real-Time Monitoring System (CORMS) air gap monitoring (see Section 8.1).

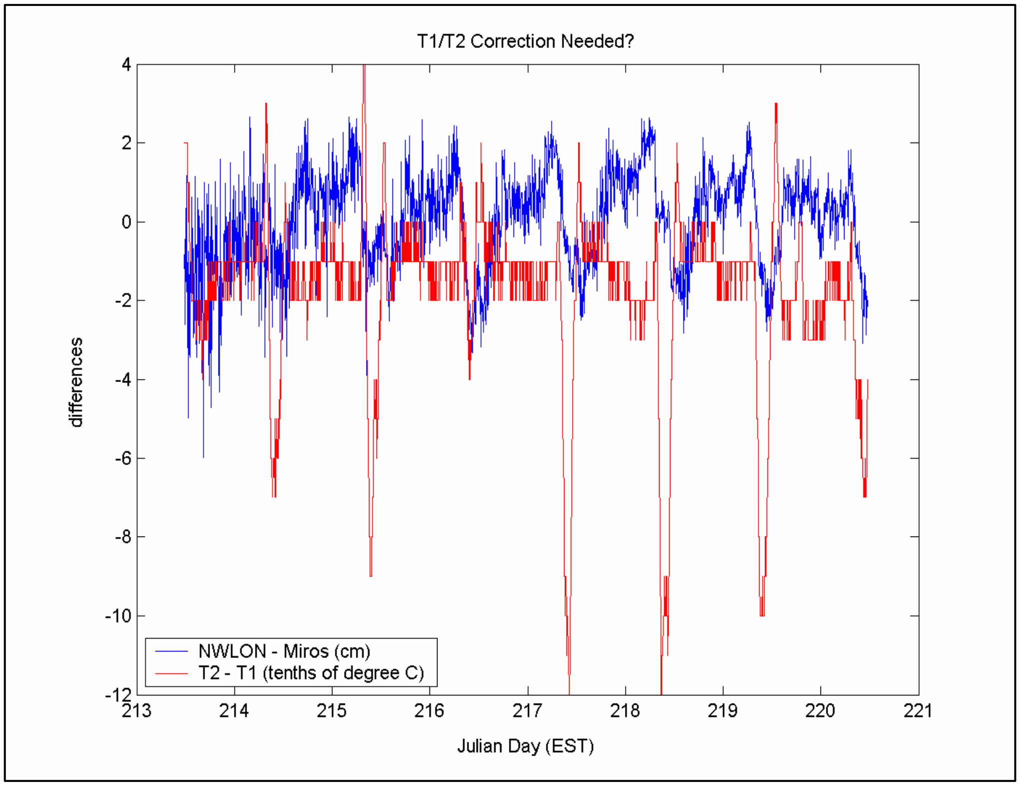


Figure 16. Comparison of the temporal pattern of the difference in WL between NGWLMS and MIROS with the difference in temperature along the Aquatrak sounding tube

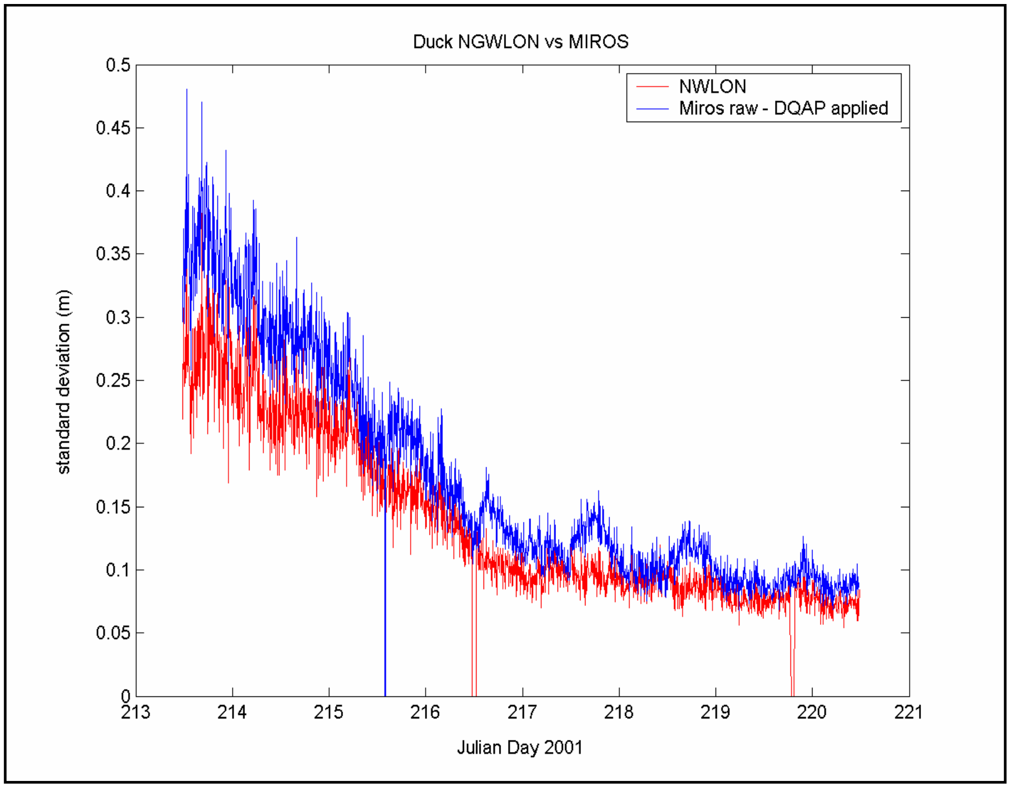


Figure 17. Standard deviation (m) of NGWLMS (red) and MIROS (blue) water level data

FRF/Duck Conclusions and Future Testing. The average difference between NOS-verified water level data and MIROS air gap data processed in a similar manner is less than one cm. The maximum difference is only six cm, and all differences are within the CO-OPS specified requirement for air gap accuracy of ±75 mm (3 inches). The users reported accuracy requirement for air gap is ±15 cm (six inches). The daily periodicity observed in the difference data correlate with peaks in sounding tube temperature gradients, suggesting that application of the temperature correction to the NGWLMS data would further reduce the differences. The standard deviation (sigma) of the MIROS data is of the same order of magnitude as that of NGWLMS, which greatly simplifies operational transition, since standard CORMS QC algorithms for water level can be used.

It is important to note that after this test was conducted, Hurricane Isabel (September 2004) brought 27-foot waves (the largest ever observed at the FRF) to the end of the pier. Both the SM-094/50 and the NGWLMS failed within the same sample interval. Breaking waves bent the SM-094 mount and caused water intrusion past the gasket. As a result, CO-OPS personnel requested and the manufacturer installed a new gasket. The NGWLMS installation failed when the entire protective well shifted, bending the massive stainless steel supports, and snapping the sounding tube.

Test result details are archived in files located at ftp://ftp.fod.noaa.gov, OSTEP/AirGap.

6.4 San Francisco-Oakland Bay Bridge

During the period 11-14 June 2002, NOS and NGS personnel conducted an air gap study at the San Francisco-Oakland Bay Bridge to collect data because massive cranes bound for the Port of Oakland (Figure 18) would be passing under the bridge. This test provided the first bridge installation with precision trigonometric survey by NGS and CO-OPS personnel using the new CO-OPS Total Station (Figure 19). It was also the first use of the extended 85 m range MIROS SM-094 procured for the USCG demonstration project in New Orleans. Finally, it provided the first direct observation of influence of a vessel transit under the sensor.

Data collected included:

- Approximately 70 hours of continuous MIROS microwave air gap sensor data, observations at two Hz, with the sensor mounted on the bridge (Figure 20);
- Approximately 270 bridge height observations relative to a tide staff, using a Total Station;
- Approximately 100 manual tide staff readings.

Figure 18. Port of Oakland: Cranes passing beneath the San Francisco-Oakland Bay Bridge

Figure 19. Total Station leveling operations on the San Francisco-Oakland Bay Bridge

Figure 20. Temporary air gap installation on the bridge

These observations provide two independent height determinations from the MIROS sensor to the water level: 1) the direct MIROS readings, and 2) the calculated Total Station plus tide staff height.

The observations show considerable high-frequency variability at amplitudes of interest. Both the MIROS sensor and the Total Station observations show bridge motion and/or air gap changes of approximately one cm/sec, making interpolation to the six-minute tide staff observations pointless. CO-OPS personnel obtained 46 "coincident" observations at six-minute intervals from these data sets (Table 5). Here, coincident is defined as observations occurring within NGWLMS ±30 seconds of a tide staff reading. In Table 5, Adjusted Tide Staff readings are heights from the 18-foot reference point on the tide staff to the water surface. Data are shown graphically in Figure 21.

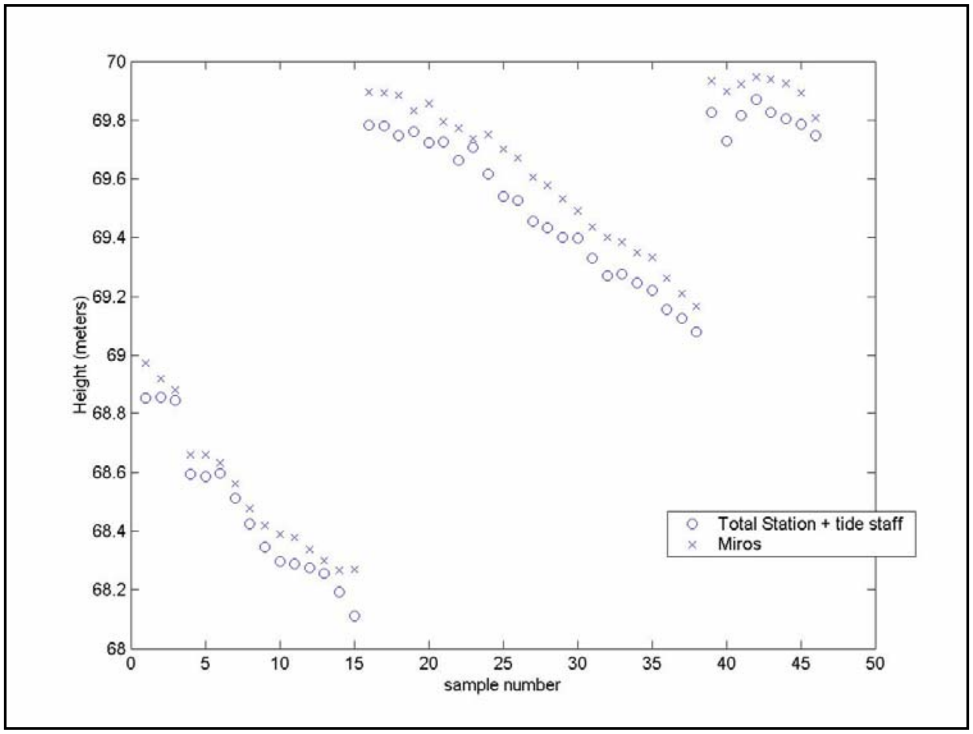


Figure 21. Total Station plus tide staff compared to MIROS data

Preliminary comparisons between the two measurements show that the MIROS measured 9.8 cm (3.86 inches) larger than the Total Station, with a standard deviation of 3.6 cm (1.4 inches). The mean difference may well be an overlooked or incorrect calculation, or perhaps a calibration adjustment. A significant positive test result is the low standard deviation, well below the air gap sensor accuracy requirement.

Test result details are archived in files located at ftp://ftp.fod.noaa.gov/, OSTEP/Airgap/SF.

Table 5. Raw Tide Staff versus Adjusted

Month	Day	Year	HR(GMT)	Min	Tide Staff (ft)	Tide Staff (meters)	Tot Sta height (meters)	Tot Sta+ TideStaff (meters)	MIROS (meters)	Diff (meters)
6.0000	12.0000	2.0000	18.0000	6.0000	7.0000	3.3528	65.5010	68.8538	68.9740	0.1202
6.0000	12.0000	2.0000	18.0000	12.0000	7.1000	3.3223	65.5320	68.8543	68.9190	0.0647
6.0000	12.0000	2.0000	18.0000	18.0000	7.2500	3.2766	65.5680	68.8446	68.8800	0.0354
6.0000	12.0000	2.0000	18.0000	54.0000	8.0000	3.0480	65.5450	68.5930	68.6590	0.0660
6.0000	12.0000	2.0000	19.0000	0	8.1000	3.0175	65.5690	68.5865	68.6600	0.0735
6.0000	12.0000	2.0000	19.0000	6.0000	8.2000	2.9870	65.6100	68.5970	68.6330	0.0360
6.0000	12.0000	2.0000	19.0000	18.0000	8.4000	2.9261	65.5850	68.5111	68.5600	0.0489
6.0000	12.0000	2.0000	19.0000	30.0000	8.7000	2.8346	65.5910	68.4256	68.4760	0.0504
6.0000	12.0000	2.0000	19.0000	42.0000	8.9000	2.7737	65.5720	68.3457	68.4180	0.0723
6.0000	12.0000	2.0000	19.0000	48.0000	9.0000	2.7432	65.5540	68.2972	68.3890	0.0918
6.0000	12.0000	2.0000	19.0000	54.0000	9.1000	2.7127	65.5760	68.2887	68.3790	0.0903
6.0000	12.0000	2.0000	20.0000	0	9.1500	2.6975	65.5760	68.2735	68.3380	0.0645
6.0000	12.0000	2.0000	20.0000	6.0000	9.2500	2.6670	65.5880	68.2550	68.3000	0.0450
6.0000	12.0000	2.0000	20.0000	12.0000	9.3500	2.6365	65.5570	68.1935	68.2660	0.0725
6.0000	12.0000	2.0000	20.0000	18.0000	9.4500	2.6060	65.5040	68.1100	68.2680	0.1580
6.0000	13.0000	2.0000	16.0000	6.0000	4.2000	4.2062	65.5780	69.7842	69.8940	0.1098
6.0000	13.0000	2.0000	16.0000	12.0000	4.3000	4.1758	65.6050	69.7808	69.8910	0.1102
6.0000	13.0000	2.0000	16.0000	18.0000	4.3000	4.1758	65.5710	69.7468	69.8830	0.1362
6.0000	13.0000	2.0000	16.0000	24.0000	4.4000	4.1453	65.6150	69.7603	69.8310	0.0707
6.0000	13.0000	2.0000	16.0000	30.0000	4.4000	4.1453	65.5780	69.7233	69.8570	0.1337
6.0000	13.0000	2.0000	16.0000	36.0000	4.4500	4.1300	65.5970	69.7270	69.7940	0.0670
6.0000	13.0000	2.0000	16.0000	42.0000	4.5000	4.1148	65.5470	69.6618	69.7720	0.1102
6.0000	13.0000	2.0000	16.0000	48.0000	4.5500	4.0996	65.6080	69.7076	69.7370	0.0294
6.0000	13.0000	2.0000	16.0000	54.0000	4.7000	4.0538	65.5640	69.6178	69.7490	0.1312
6.0000	13.0000	2.0000	17.0000	6.0000	4.8500	4.0081	65.5310	69.5391	69.7020	0.1629
6.0000	13.0000	2.0000	17.0000	12.0000	4.9000	3.9929	65.5350	69.5279	69.6710	0.1431
6.0000	13.0000	2.0000	17.0000	24.0000	5.0500	3.9472	65.5080	69.4552	69.6060	0.1508
6.0000	13.0000	2.0000	17.0000	30.0000	5.1500	3.9167	65.5170	69.4337	69.5780	0.1443
6.0000	13.0000	2.0000	17.0000	36.0000	5.3000	3.8710	65.5300	69.4010	69.5320	0.1310
6.0000	13.0000	2.0000	17.0000	42.0000	5.4500	3.8252	65.5720	69.3972	69.4900	0.0928
6.0000	13.0000	2.0000	17.0000	48.0000	5.5000	3.8100	65.5210	69.3310	69.4360	0.1050
6.0000	13.0000	2.0000	17.0000	54.0000	5.7500	3.7338	65.5360	69.2698	69.4020	0.1322
6.0000	13.0000	2.0000	18.0000	0	5.8500	3.7033	65.5730	69.2763	69.3840	0.1077
6.0000	13.0000	2.0000	18.0000	6.0000	5.9500	3.6728	65.5720	69.2448	69.3490	0.1042
6.0000	13.0000	2.0000	18.0000	12.0000	6.1000	3.6271	65.5940	69.2211	69.3320	0.1109
6.0000	13.0000	2.0000	18.0000	18.0000	6.1500	3.6119	65.5430	69.1549	69.2620	0.1071
6.0000	13.0000	2.0000	18.0000	24.0000	6.2500	3.5814	65.5440	69.1254	69.2110	0.0856
6.0000	13.0000	2.0000	18.0000	30.0000	6.4000	3.5357	65.5430	69.0787	69.1670	0.0883
6.0000	14.0000	2.0000	16.0000	12.0000	4.0500	4.2520	65.5740	69.8260	69.9330	0.1070
6.0000	14.0000	2.0000	16.0000	18.0000	4.0500	4.2520	65.4770	69.7290	69.8980	0.1690
6.0000	14.0000	2.0000	16.0000	24.0000	4.0000	4.2672	65.5490	69.8162	69.9220	0.1058
6.0000	14.0000	2.0000	16.0000	30.0000	4.0000	4.2672	65.6030	69.8702	69.9460	0.0758
6.0000	14.0000	2.0000	16.0000	36.0000	4.0000	4.2672	65.5590	69.8262	69.9380	0.1118
6.0000	14.0000	2.0000	16.0000	42.0000	4.0500	4.2520	65.5520	69.8040	69.9260	0.1220
6.0000	14.0000	2.0000	16.0000	48.0000	4.1000	4.2367	65.5490	69.7857	69.8920	0.1063
6.0000	14.0000	2.0000	16.0000	54.0000	4.2000	4.2062	65.5410	69.7472	69.8080	0.0608

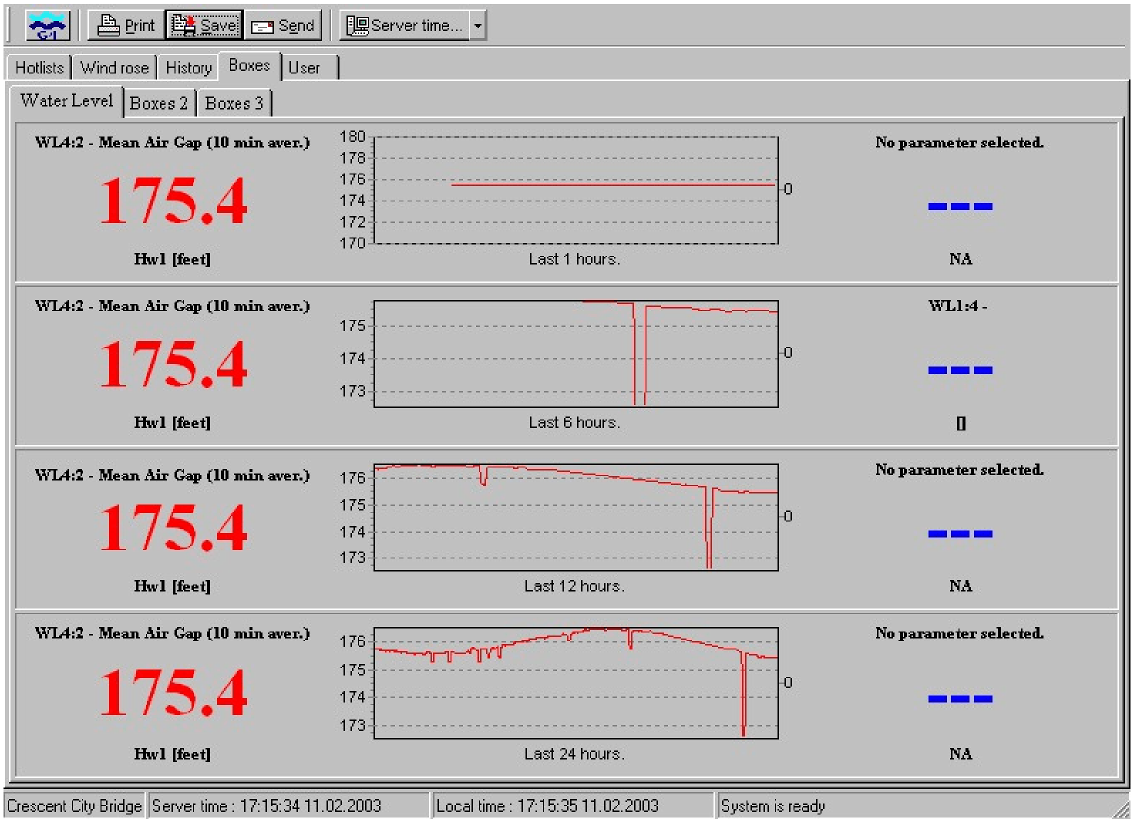
6.5 Crescent City, New Orleans

In September 2001, CO-OPS entered into an agreement with the USCG to procure a commercially available microwave air gap sensor. The agreement set forth the expectations from CO-OPS and the USCG, with CO-OPS assuming responsibility for procurement of the agreed-upon microwave air gap sensor, performance of tests and evaluations for satisfactory performance, installation on a mutually acceptable bridge, and operation for demonstration to signatories of the agreement.

This test provided the first long-term (one year) installation at long range. It was a demonstration of the commercial off-the-shelf system, and MIROS supplied the hardware and software, with no CO-OPS software or DCP involved. The bridge operator declined to provide a power source, so the installation was solar-powered. Data were transmitted to the New Orleans Vessel Traffic System (VTS) office at the standard output rate of two Hz using 0.1 watt Maxstream spread spectrum radios. Air gap plots were displayed using the Oracle-based MIROS software. CO-OPS personnel revisited Crescent City and documented several installation issues.

Radio link. During a service call on 10 February 2003, CO-OPS personnel found that the Maxstream spread spectrum radio link had degraded, with perhaps only one-third of the data being transmitted. Personnel enabled retries on the radios and installed a much higher gain (13 decibel [dB]) antenna, but there was no improvement in data reception. The addition of 100 feet of strategically-placed cable, (30 feet away, 10 feet lower, and rotated 15 degrees north of the transmit antenna) resulted in the reception of 99 percent of the expected data - over a three-hour and 20-minute test period.

Software. Once the received data rate increased, the software began to plot. The screen was configured to show ten-minute mean values over a variety of time scales instead of plots showing ten-minute minimums (min) & maximums (max), because the min/max plots only showed the spikes in the data (Figure 22).



WL4:2 - Mean Air Gap (10 min aver.)
175.4
Hwl [feet]

No parameter selected.

NA

WL4:2 - Mean Air Gap (10 min aver.)
175.4
Hwl [feet]

WL1:4 -

[]

WL4:2 - Mean Air Gap (10 min aver.)
175.4
Hwl [feet]

No parameter selected.

NA

WL4:2 - Mean Air Gap (10 min aver.)
175.4
Hwl [feet]

No parameter selected.

NA

Crescent City Bridge | Server time : 17:15:34 11.02.2003 | Local time : 17:15:35 11.02.2003 | System is ready

Figure 22. Ten-minute mean values over a variety of times

Comparison of Laser Rangefinder to MIROS Microwave Air Gap Sensor at the Crescent City Bridge. A Laser Technology Impulse 200 laser range finder (with internal tilt sensor for vertical height calculation) was mounted adjacent to, and at the same elevation as, the MIROS air gap sensor (Figure 23). Data were acquired about every three seconds, time-stamped, and logged to a laptop PC over a thirty-minute period.

Figure 23. Laser range finder installed adjacent to microwave air gap sensor

The plots of the raw laser data, the raw MIROS data, and the smoothed MIROS data are shown in Figure 24. The mean offset between the two raw data series is 7.9 cm (3.1 inches), with the laser reading the shorter distance. Subsequent testing of additional MIROS SM-094 units has lead to the conclusion that the factory calibration results in readings that are approximately three inches too great at 50 m. Section 9.1 further addresses the calibration issue.

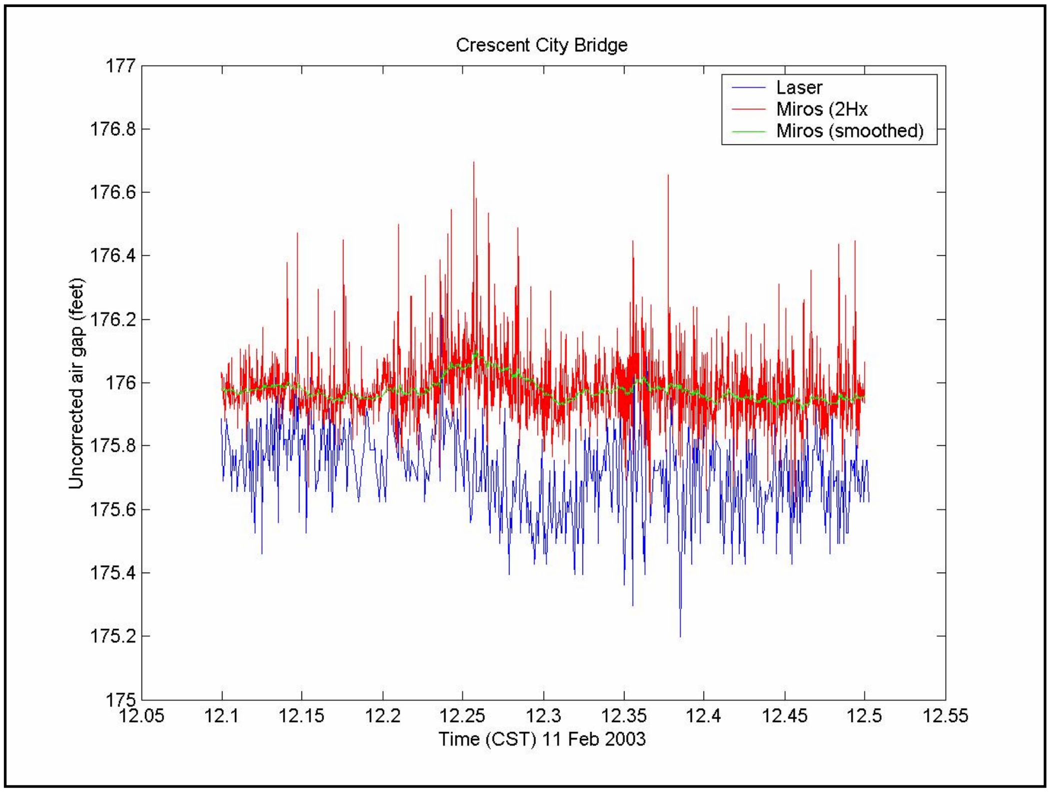


Figure 24. Plots of the raw laser and MIROS data and the smoothed MIROS data

When comparing the two absolute air gap time series, both sensors perform well. It appears that either device can provide air gap to the required ± six-inch specification. The advantage of the MIROS is that it is an all-weather sensor. Also, the laser is measuring a single point, while the MIROS footprint is approximately five m (15') in diameter.

Figure 25 shows a plot of the smoothed MIROS air gap data for the same time period at a better scale and a much better behaved curve. Note that the entire vertical scale of the plot is 7.6 cm (three inches). The two peaks are likely real, since there are similarities in the laser data. Such local small scale perturbations would not correlate with the Carrolton gauge eight miles upstream, and would look like noise in the absence of the collaborating laser data.

These data sets and full resolution plots/figures are available on our FTP site at ftp://ftp.fod.noaa.gov, OSTEP/AirGap/USCGNewOrleans/LaserRF.

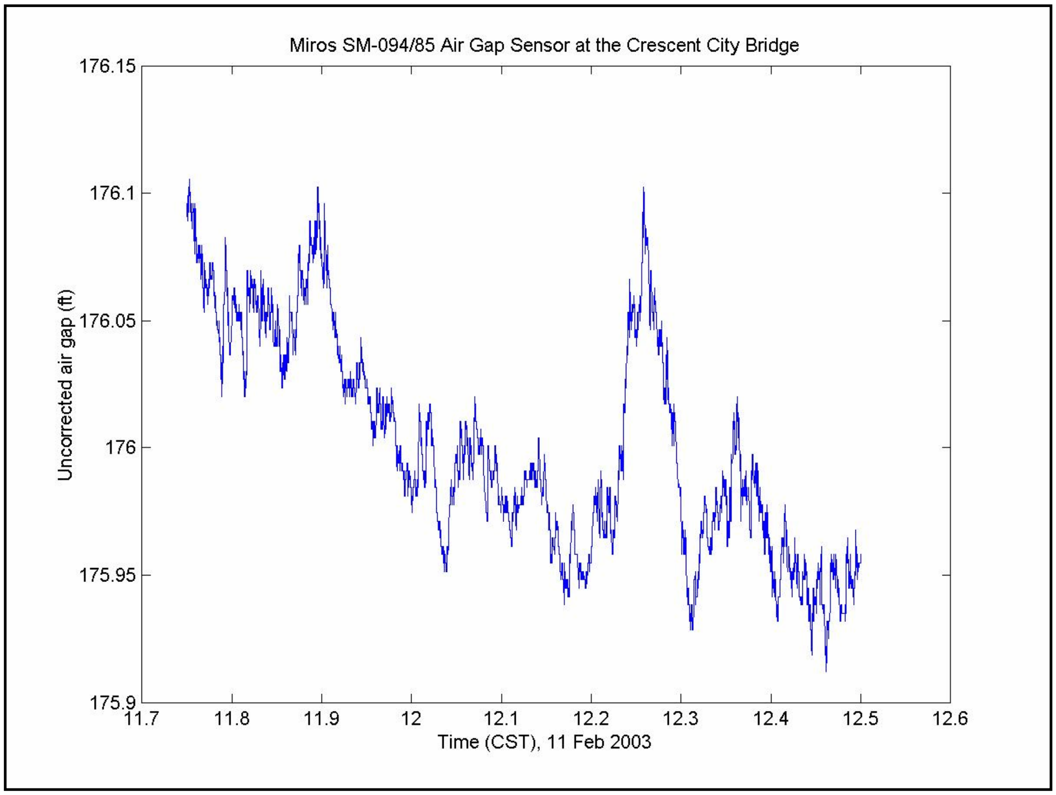


Figure 25. Smoothed MIROS air gap data

6.6 Reedy Point and Chesapeake City

The MPA funded the installation of two air gap sensors for the Reedy Point and Chesapeake City bridges over the C&D Canal, as part of the Chesapeake Bay PORTS®. The Reedy Point sensor was installed in June 2003, and the Chesapeake City installations occurred in October 2003. These two installations were used to develop an operational configuration, and then became the first operational air gap sensors on 01 March 2004.

Air gap data collected at each bridge during this pre-operational period were used to develop QC criteria. At both locations a Sutron Xpert Lite was used as the DCP. Software (described in more detail in Section 7.0) on the DCP produced a mean air gap, standard deviation, and number of outliers for each six-minute sample. This information is recorded in a standard "PORTS tag" file (see Section 7.3). Software was written to generate QC flags associated with air gap data output from the "PORTS tag" file using the same format and code scheme described in the PUFFF documentation (Evans et al., 1998). These flags are sent to and interpreted by CORMS (see Section 8.1) software and presented to the CORMS operators for their information and possible action. A Standard Operating Procedure (SOP), written for the CORMS operators by Michael Connolly, provides instruction for action based on the QC flag values.

Occasional large negative spikes are observed in the data series from both bridges. Although the negative spikes are very likely ship passages, dissemination of these points may give the impression that the sensor is inaccurate, so the decision was made to flag these points as an error (denoted with an F = Failure). These values are not disseminated, but these errors do NOT mean the instrument has failed and does not cause CORMS to turn off dissemination of the air gap data.

The following series of graphs and statistics show how these data were used to develop the QC criteria. At Reedy Point, 91 days of data were used. Figure 26 shows the raw air gap data and associated statistics that were used to establish the lowest and highest acceptable air gap values. Figure 27 shows a time series of standard deviation values obtained for each six-minute observation, and the associated statistics shown on that figure were used to assign an upper-bound for an acceptable standard deviation. Figure 28 shows the number of outliers discarded for each six-minute sample, used to establish the upper limit of outliers permitted while still providing a six-minute result. There are two temperature sensors, one at the instrument (external) and one in the electronics box (internal); however T1 and T2 have not been assigned quality flags because lab tests have demonstrated that temperature does not affect the accuracy of this microwave sensor. Figure 29 shows a time series of first differences (delta) used to determine an acceptable sample-to-sample rate of change.

Similarly, a month of data from Chesapeake City was used (Figures 30-33) to develop the QC criteria for that location. The criteria are contained in Tables 6-7.

Table 6. **QC Criteria for Reedy Point**

Lowest	Highest	Delta	
41.5	45.3	0.5	Observed air gap (m)
0	15	0.0	Outliers (count)
0.0	0.5	0.0	Standard deviation (m)

Table 7. **QC Criteria for Chesapeake City**

Lowest	Highest	Delta	
41.5	45.3	0.5	Observed air gap (m)
0	0.5	0.0	Outliers (count)
0.0	0.5	0.0	Standard deviation (m)

Figure 34 shows the final operational air gap web page for these two Chesapeake Bay PORTS® sensors.

CO-OPS asked the NGS to conduct trigonometric leveling of these sensors as an independent check of the elevations determined by CO-OPS trigonometric leveling efforts. NGS determined the elevation of the Reedy Point MIROS device on 17 March 2004 and determined the elevation of the Chesapeake City MIROS device on 18 March 2004. A full report of this successful elevation check can be found in Appendix E.

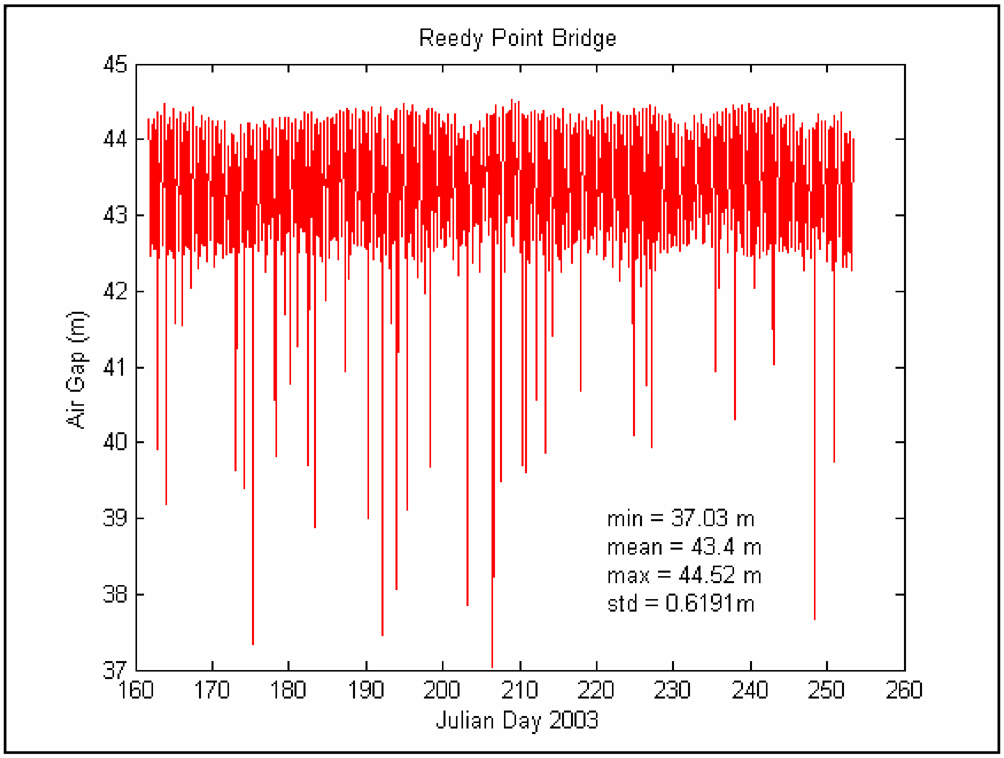


Figure 26. Air gap at the navigation channel light on Reedy Point Bridge

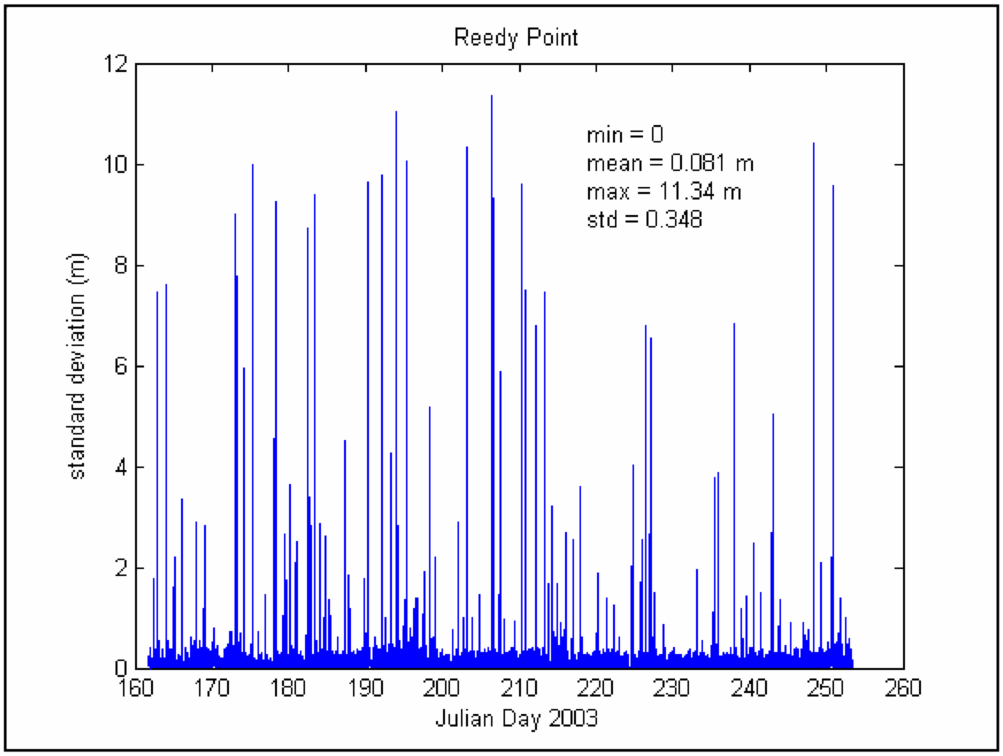


Figure 27. Standard deviation of air gap data when processed through DQAP

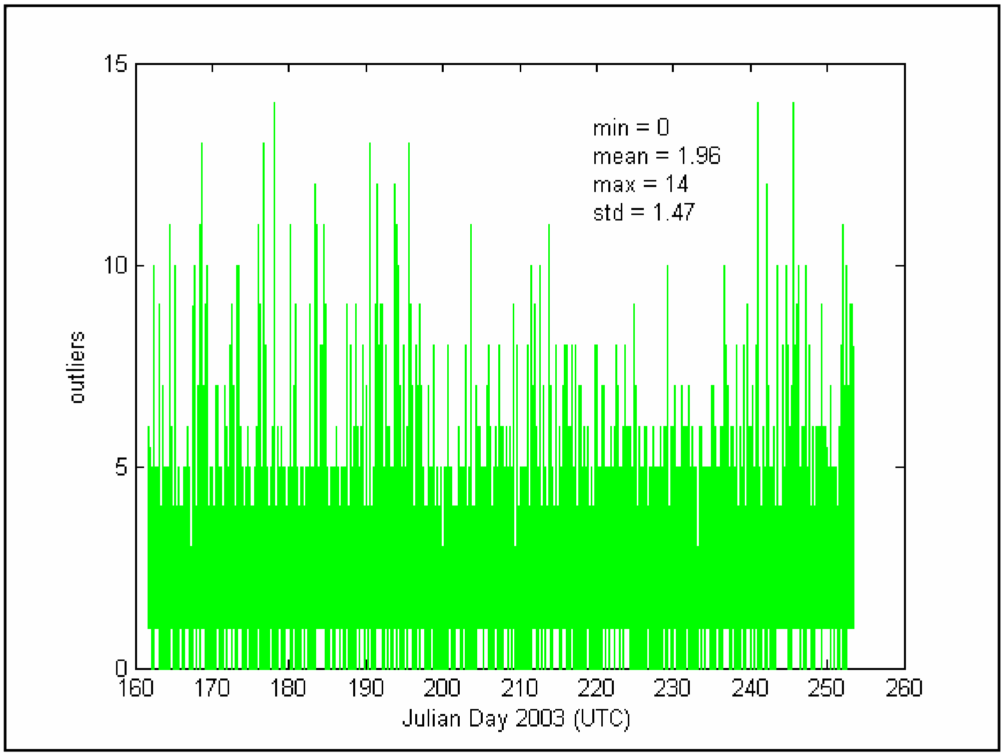


Figure 28. Number of one-second values rejected from the six-minute average done by DQAP at Reedy Point

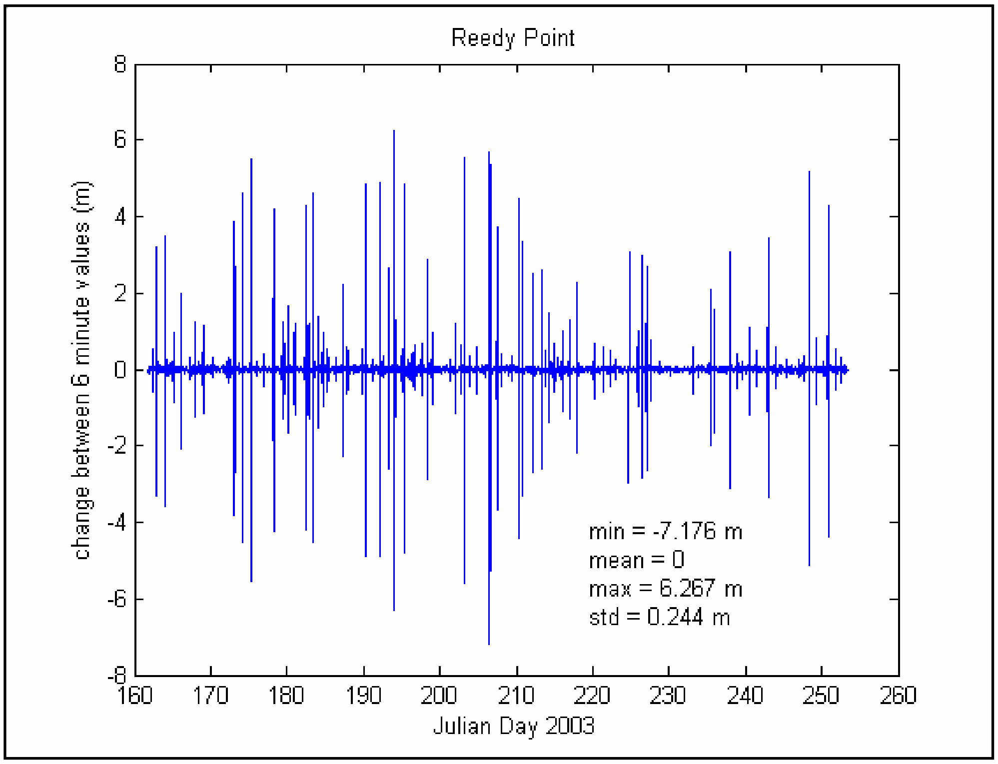


Figure 29. Change (delta) in air gap between successive six-minute samples

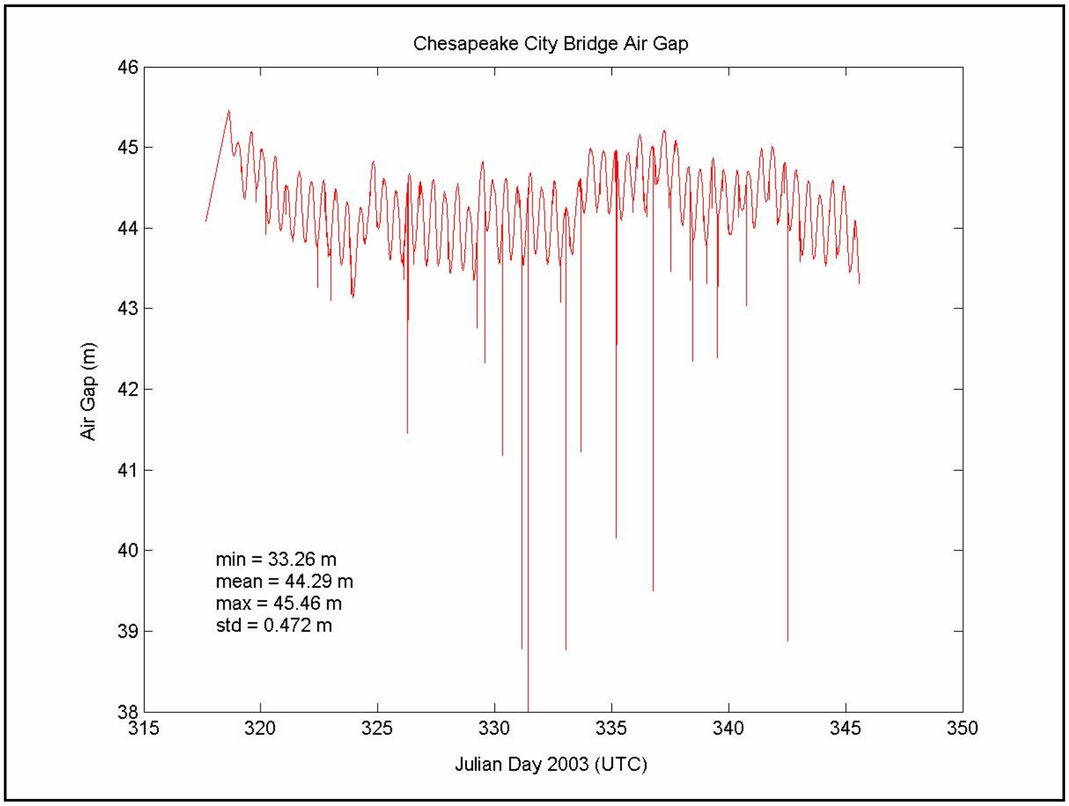


Figure 30. Air gap at the navigation channel light on Chesapeake City Bridge

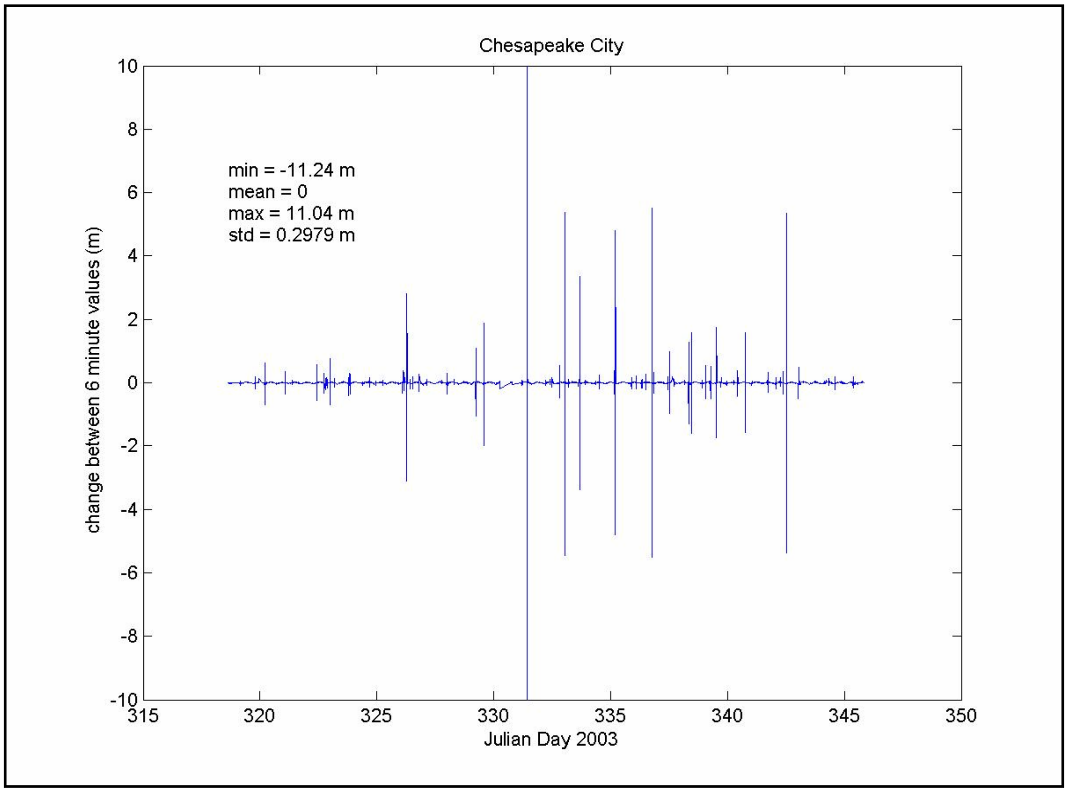


Figure 31. Change (delta) in air gap between successive six-minute samples

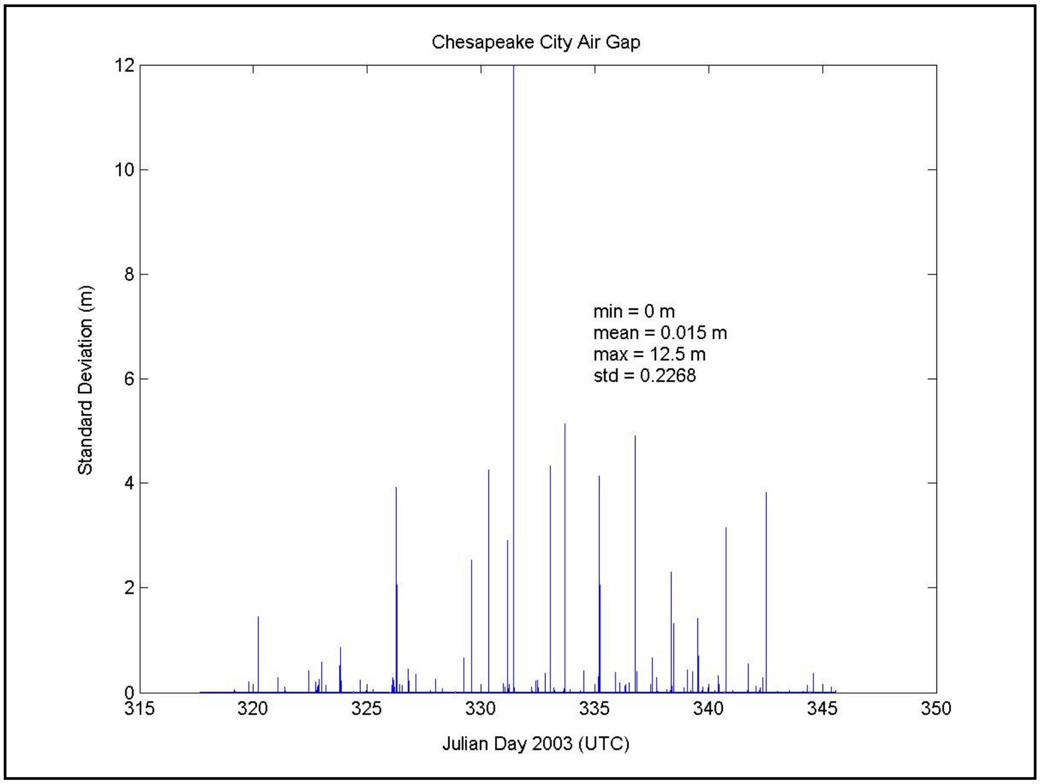


Figure 32. Standard deviation in air gap when processed through DQAP

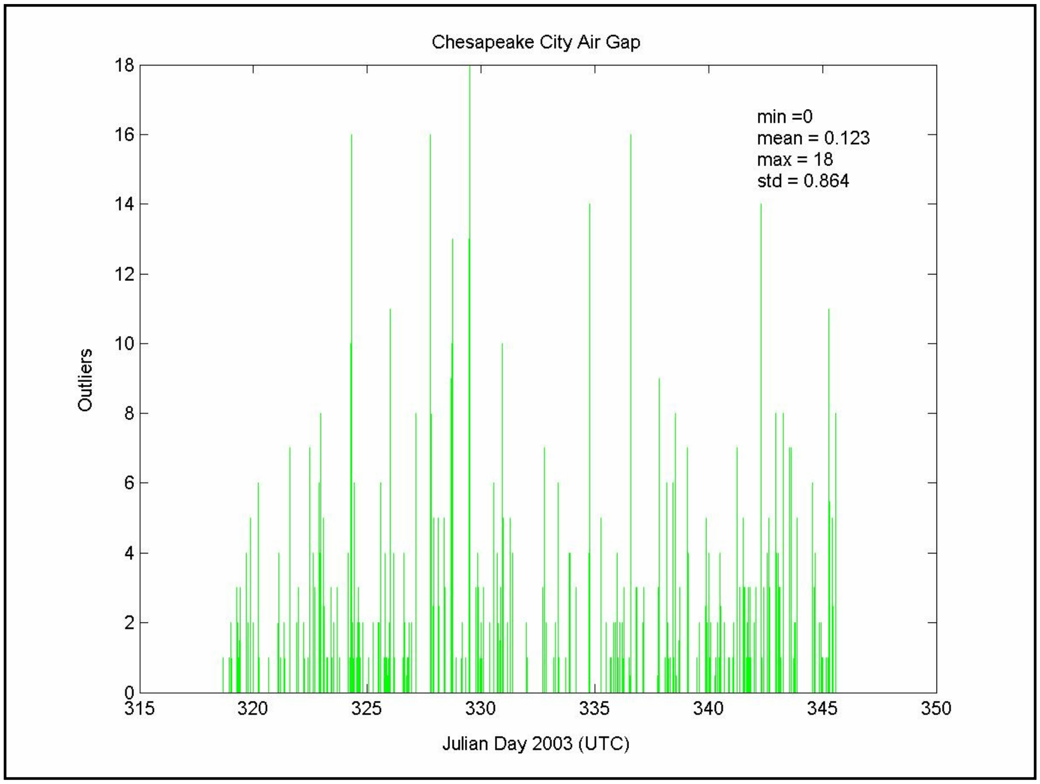


Figure 33. Number of one-second values rejected form the six-minute average done by DQAP

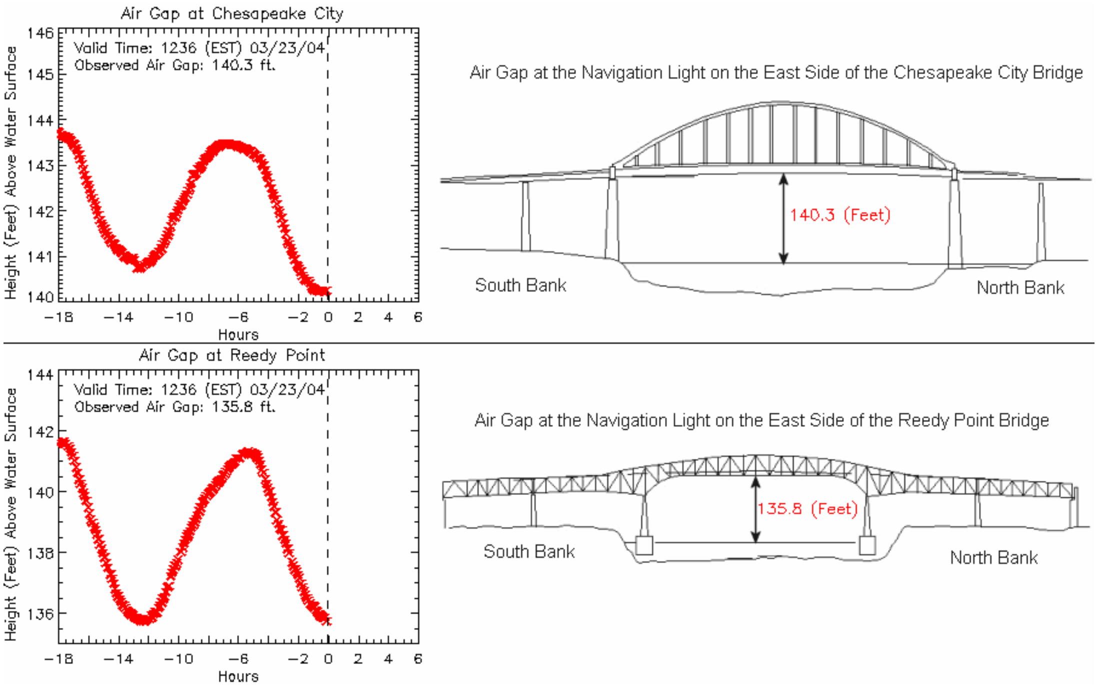


Figure 34. Chesapeake Bay PORTS®: Operational Air Gap Web Page

7.0 DEVELOPMENT OF DATA COLLECTION SYSTEM

A data collection system is required in order to gather, store, and support data retrieval. CO-OPS is presently converting to a new DCP—the Sutron Xpert/9210. The Xpert and the 9210 hardware use a Windows CE operating system, a popular operating system that increases the quantity of programs available to support the device. Software to support data acquisition from the SM-094 to the Xpert/9210 was generated through a contract to Sutron. This software, known as a Sutron Dynamic Linked Library (DLL or SLL) works in concert with other existing SLLs to acquire, process, and provide air gap data at the CO-OPS standard six-minute sample interval.

The SM-094 offers two methods of data output: free-cycling and polled. When free-cycling, the SM-094 provides a continuous two-Hz output, for a total of 720 data points, during a six-minute interval. An optional advanced data filter with a user-selectable time constant can be applied to either or both of two data records. CO-OPS has chosen to operate the SM-094 in polled mode. Rather than using all available data and the advanced filter, the DCP polls the SM-094 at a one-Hz rate for three minutes during the six-minute sample interval. The air gap data are processed exactly as the NGWLMS data are processed in order to provide a measure of continuity, and to ensure a more equitable intercomparison with water levels derived from an NGWLMS station.

The NGWLMS algorithm used, known as the Data Quality Assurance Processing (DQAP), is as follows: during a six-minute sample interval centered on each tenth of an hour, 181 one-second samples are acquired (polled) and averaged. A three standard deviation outlier rejection test is applied and the mean and standard deviation are recalculated. The output record consists of the recalculated mean, the recalculated standard deviation, and the number of discarded outliers. This DQAP process has been incorporated into the air gap SLL acquisition module.

7.1 SLL Installation, Test, and Operation

Sutron provided SLL installation, test, and operation procedures. These processes are described in the Air Gap DLL Users Manual (Appendix G). The manual also describes troubleshooting techniques to assist operators in the installation, test, and operation procedures.

7.2 DCP-Generated Errors/Status Codes

The air gap SLL can produce two status messages (no data returned and loss of synchronization) and one error message (COM port communications failure). The Air Gap DLL Users Manual (Appendix G) contains more detail on these messages and their meanings.

7.3 Air Gap Data Flow

Air gap sensor data are collected using two distinct methods: (1) using a PORTS® Data Acquisition System (DAS), (2) using six-minute GOES.

A centralized or local DAS collects data from the air gap sensor by polling the DCP. The DAS has no direct connection or interaction with the air gap sensor, but uses the DCP as a go-between to acquire the DQAP data.

The DAS acquires the data from the DCP by using one of several communication methods. Once a connection is made to the DCP, the DAS enters a special login which triggers the DCP to output the last data sample collected from the air gap sensor. The DCP outputs the data in a pre-determined format called a PORTS TAG. The PORTS TAG has the following format:

```
NOS 85519111 09/08/2004 13:06:00
         Q1 (   43.332   0.015   4.000   24.197   23.292
         L1 <   12.174
         DAT     0.000
         SNS    0.000

         REPORT COMPLETE
```

After the DAS has acquired the air gap data, it begins a series of steps to process and QC the data. As a result of the processing, the DAS produces a PUFFF (PORTS Uniform Flat File Format) file, a PORTS® standard data format. A detailed description of the PUFFF documentation is available at http://co-ops.nos.noaa.gov/publications/pufff4.pdf.

The DAS then sends data to Silver Spring for ingestion into the CO-OPS databases. The data are transferred from the DAS to TESTPORT, a server in Silver Spring, which adds no value to the data but acts as a “traffic cop” by transferring data to the appropriate servers (all of which are protected behind the CO-OPS firewall) throughout CO-OPS.

The air gap data are distributed, along with all the other data types collected in the form of PUFFF files, to a number of CO-OPS servers that are involved in the ingestion process (Figure 35). The data ingestion server (DIS) acquires, processes, generates QC flags, and loads the data into the DMS (CO-OPS databases). The CORMS server (Section 8.1) provides an interface for the CORMS operators to see the flags that are generated at the DAS. It allows the operators to stop and start dissemination of sensor data. The users then access the data using various interfaces that CO-OPS has developed.

Air gap data can also be acquired using NOAA's GOES satellite. Data from the DCP are transmitted via the satellite every six minutes. Data are received by the National Environmental Satellite, Data, and Information Service (NESDIS) and stored on data servers for retrieval by the DIS. NESDIS also rebroadcasts the data over DOMSAT (Domestic Satellite), which is the primary method used by CO-OPS to retrieve the data. Once the DIS acquires the satellite data, the data follows a similar path as data collected by the DAS. It is important to note that air gap data follows the same path as other CO-OPS data types.

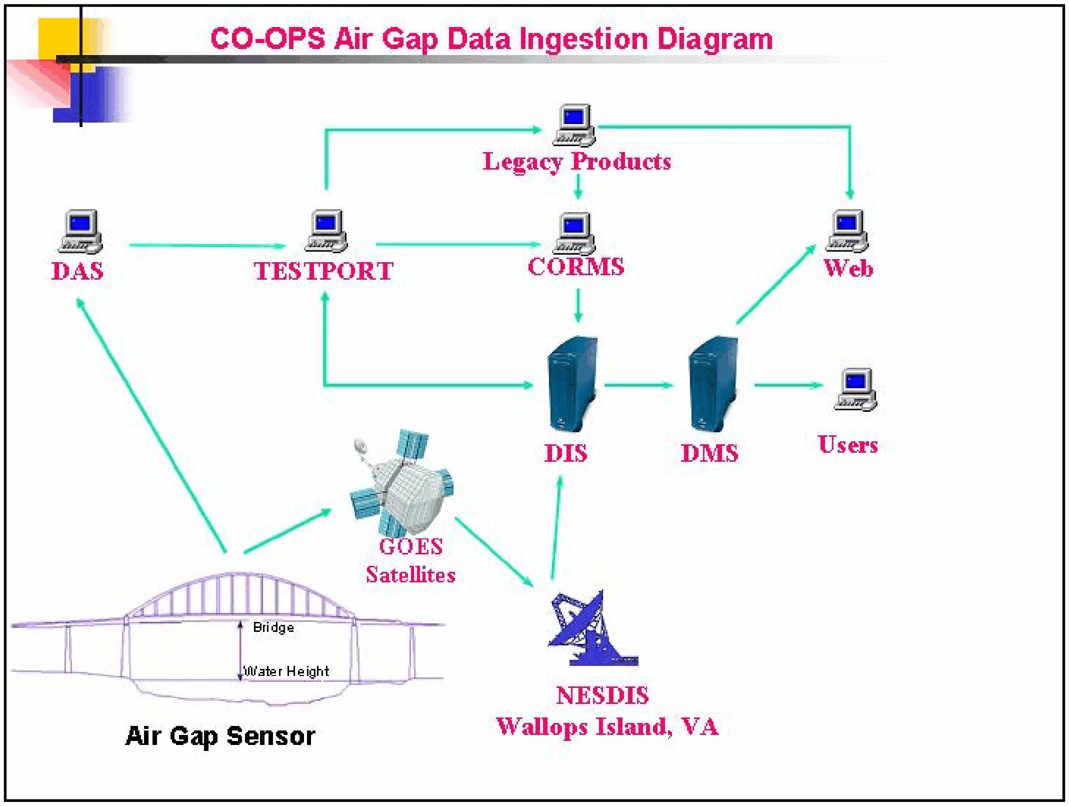


Figure 35. Air gap data flow

8.0 DATA QUALITY CONTROL/QUALITY ASSURANCE

Dissemination of high quality data is a priority for CO-OPS. Bridge clearance data, by nature of how they will be used, require particular attention to quality assurance (QA). Fortunately, QA/QC of air gap data from fixed bridges bears many similarities to QA/QC of water level data—a field in which CO-OPS has much expertise.

8.1 CORMS

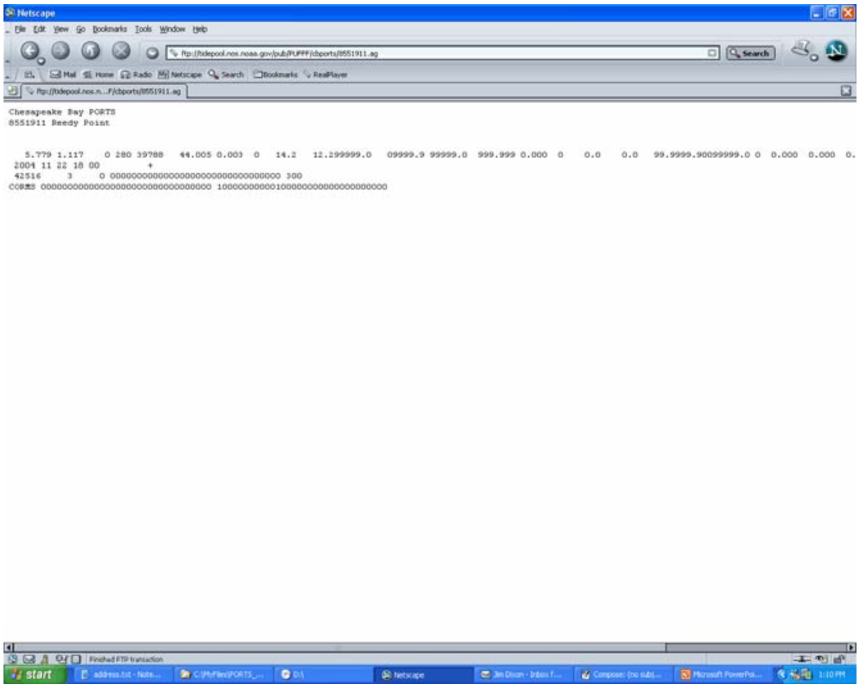
The objective of CORMS is 24-hour monitoring and quality control to ensure the availability and accuracy of water level, meteorological, current observations, and other parameters that are used for navigation and safety-of-life and property decisions. CORMS is a quality-control and decision-support system that combines real-time communications, data analysis, system monitoring, graphical user interface (GUI), and system "watch dog" and notification capability.

CORMS functions include:

- Ingest real-time and near real-time data and information;
- Determine data completeness;
- Monitor data quality;
- Generate statistics used to evaluate system performance;
- Provide decision-making information for possible field team response;
- Communicate to real-time and near real-time users the identification of invalid or suspect data.

8.2 Sensor Quality Control Flags for CORMS

Air gap data are fed to the CORMS system just like any other sensor that CORMS monitors. The CORMS Operators have SOPs for all instrument data types, including air gap. The CORMS SOP for air gap instrumentation (Appendix H), reveals that CORMS has multiple paths for monitoring air gap sensors. For example, there are web-based tools that visually display an air gap time series, as well as the point measurements (Figure 36). The Main CORMS application continuously maintains the status of the air gap sensor and allows the operator to see the CORMS flags in more detail. There are also text-based files (Figure 37) that allow the CORMS operators to see the raw data collected.



```
Chesapeake Bay PORTS
8551911 Reedy Point


  5.779 1.117    0 280 39788   44.005 0.003  0   14.2   12.299999.0   09999.9 99999.0  999.999 0.000  0    0.0    0.0   99.9999.90099999.0 0  0.000  0.000  0.
 2004 11 22 18 00        +
 42516     3     0 0000000000000000000000000000000 300
CORMS 0000000000000000000000000000000 1000000000010000000000000000000
```

Figure 36. Air gap time-series and point measurements for Reedy Point

CBPORTS
Wed Sep 22 17:57:15 2004 GMT

Name	Type	Time Stamp (GMT)	Quality Control Flags
Chesapeake City	ag	17:45	ALL DATA GOOD
Reedy Point	ag	17:48	ALL DATA GOOD
Money Point	mt	17:48	ALL DATA GOOD
Money Point	ct	17:48	ALL DATA GOOD
Bay Bridge Tunnel	wl	17:48	ALL DATA GOOD
Bay Bridge Tunnel	mt	17:48	ALL DATA GOOD
Bay Bridge Tunnel	ct	17:48	ALL DATA GOOD
Windmill Point	wl	17:48	ALL DATA GOOD
Lewisetta	wl	17:48	ALL DATA GOOD
Lewisetta	mt	17:48	ALL DATA GOOD
Kiptopeke Beach	wl	17:48	ALL DATA GOOD
Kiptopeke Beach	mt	17:48	ALL DATA GOOD
Solomons Island	wl	17:48	ALL DATA GOOD
Solomons Island	mt	17:48	ALL DATA GOOD
Annapolis	wl	17:48	ALL DATA GOOD
Baltimore	wl	17:48	WOWI
Baltimore	ct	17:48	ALL DATA GOOD
Chesapeake City	wl	17:48	ALL DATA GOOD
Chesapeake City	mt	17:48	ALL DATA GOOD

Figure 37. CORMS site monitoring

CO-OPS processes perform air gap data QC at multiple locations during the ingestion process—when data are collected at the DAS and when data arrives at the DIS. CORMS Operators conduct QA by visual inspection of the data through the use of the CORMS interface and various plotting tools.

The DAS provides point-to-point QC of the air gap data as data are collected via the following checks:

- **Time Check**

  The time associated with each data sample is compared to the DAS system clock. The DAS uses a time range of 15 minutes into the past to two minutes into the future. If the time of the data are outside this range, then the DAS flags these data as bad. The time check was implemented to handle clock drift at the DCP.

- **Absolute Range**

  The computed air gap value must be between a pre-determined lower and upper limit. The upper and lower limits were determined by analysis of the data for each specific air gap location. If air gap value is greater than or equal to the upper limit and less than or equal to the lower limit, the DAS flags the data as bad.

- **Outliers**

  The number of outliers from the air gap measurement must be less than or equal to a pre-determined value. The value was determined by analysis of the data. If the number of outliers for a particular sample exceeds the pre-determined value, the DAS flags the data as bad.

- **Standard Deviation**

  The standard deviation of the air gap value must be less than or equal to a pre-determined value. The value was determined by analysis of the data. If the value of the standard deviation for a particular sample exceeds the pre-determined value, the DAS flags the data as bad.

Table 8 provides the values used for the air gap checks and stored on the DAS. The file that contains these values, called a criteria file, is transferred along with the data every six minutes.

Table 8. Values Used for the Air Gap Checks

Station	Absolute Range (m)		Standard Deviation (m)	Outliers
	Lower	Upper		
Chesapeake City	**41.6**	**45.6**	**0.1**	**15**
Reedy Point	**40.2**	**44.0**	**0.1**	**15**

Once the data have been acquired and QC'd at the DAS, they are transferred to Silver Spring for distribution to various systems as detailed in Figure 35.

The DIS acquires air gap data from the DAS or from GOES if the station is configured to do so; the DIS performs the same checks as the DAS using the same limits and ranges outlined in the DAS QC.

9.0 UNCERTAINTY ESTIMATES

As stated previously, air gap users have requested an air gap observation with an accuracy of ±75 mm (six inches). It has not been specified precisely what this value indicates—it could be interpreted to be the value of one, two, three or more standard deviations of a sample population.

The **stated** accuracies of the MIROS microwave sensor and the Laser Technologies laser range finder—and the **known** accuracies of the water level measurements at Money Point, traditional trigonometric leveling procedures, and GPS observations—all greatly exceed the required air gap accuracy. The final air gap observations easily exceed the required accuracy.

9.1 Calibration

The operational installation of an air gap sensor requires a precise and careful range calibration effort. CO-OPS personnel have found that the manufacturer's calibration is insufficient, and that corrections to the manufacturer's calibration are necessary. The first estimate of the correction is determined using the 50 m reference range facility previously described. Another estimate may be obtained by comparing air gap observations from an uncorrected sensor to those obtained from a corrected operational sensor (the Reedy Point site has been used as an occasional reference - see Section 6.6). A final estimate is obtained in-situ after the installation at the operational site, using the Total Station and WL observations to calculate a reference air gap. These estimates are compared, with the most weight given to the in-situ estimate. A final offset value is selected and applied at the DAS. The original manufacturer's calibration stored on the SM-094 is not altered. In addition to the calibration offset correction, the correction for the offset to low steel is also applied at the DAS.

9.2 Traceability

Our principal traceable reference is the Cooper Tools 200' long steel tape, previously described in Section 4.2 and also in Appendix B. This tape is used to confirm all other linear length measurements (laser, Total Station, microwave altimeter). Temperature corrections to observations obtained from the steel tape are applied as described in the calibration certificate.

9.3 Error Identification

There are errors in the sensor observation combined with errors external to the measurement in all of the validation methods used during these tests. For example, the Laser Technologies laser range finder has a stated accuracy of 2-3 cm at 50 m., Errors arising from measurements of mounting hardware were added to this known error. Each component of the mounting hardware was measured, with an error of approximately 1-2 mm. All of these errors are simply added together to provide the maximum possible error, which presumes that the maximum possible error has indeed occurred in each measurement, and that in each case, the error has the same sense (no offsetting errors have occurred). The more accepted method is to combine the errors in a root mean square (RMS)-sense, presuming that errors occur in a more random manner. Each measurement taken during the course of the tests had an error bar associated with that measurement. These error bars were summed in both RMS and total sense.

9.4 Error Budget

The altimeter test's total error budget included four components:

1. Errors associated with the sensor itself, such as uncompensated electronic circuit temperature dependencies, receiver noise, output resolution;
2. Errors related to signal path propagation rate variations, dependent upon unmeasured parameters such as temperature, barometric pressure, and humidity;
3. Errors generated as target noise, which includes significant consideration about the definition of "water level" (over what space and time scales?);
4. Errors that may arise during the data processing and product generation.

These four components are addressed in the following paragraphs.

Regarding sensor errors, a measure of the sensor noise floor was obtained by the range variation observed during tests in which all other perturbations were constrained. In practical applications this cannot be achieved, but it can be approximated. These tests include the bench and field tests described in Section 5.9.1. Total errors attributable to the sensor itself are typically less than one mm (one standard deviation).

Regarding signal path propagation rate dependencies, the inherent assumption is that the transmitted signal travels at the nominal speed of light, defined as 299,792,458 m/sec in a vacuum, but rounded to $3 * 10^8$ in the sensor firmware. The earth's atmosphere will reduce this velocity. Density variations caused by changes in temperature, barometric pressure, and humidity will cause speed variations, but the effect is negligible over this relatively short path length. This source of error is minimal, which is essentially why this technology was selected.

Target noise includes those target characteristics that require definition. The surface to which the range is desired undulates over a wide variety of periods and amplitudes, and the measurement of this range is defined by spatial and temporal considerations, including mechanical and mathematical filters. The existing measurement of water level within NOS includes precise definitions of mechanical and electronic filtering, as well as computational signal processing.

Filtering variations can generate very different answers, which is why CO-OPS has elected to sample and process observations from differing acoustic and microwave ranges using the same algorithm. While this retains the same mathematical smoothing, there is a fundamental difference in the physical smoothing of the acoustic (NGWLMS) and microwave techniques. The reference acoustic WL is physically smoothed by a narrow orifice, protective well, and sounding tube. The microwave altimeter is physically smoothed by the beam-width of the transmitted signal, which translates into a variable footprint size, dependent upon range. The signal returned to the sensor includes target range variations caused by waves with this footprint. These variations are addressed by the internal sensor continuous wave frequency modulation (CWFM) signal processing capability, which turns a rough sea surface observation into a broader signal peak, but does not shift the location of that peak in the frequency domain.

Errors that arose during the data processing and product generation were the easiest to manage, as they were fully controlled. Such errors include resolution of constants used in calculations, which are easily modified to reduce or eliminate the error. The total error has been found to be well below what is required. An accuracy of a few centimeters (± one inch) has been demonstrated, where an accuracy of ±75mm (six inches) was requested (Table 9). CO-OPS has begun evaluating microwave devices for use as a primary NGWLMS sensor, which requires an accuracy measured in millimeters. For that application, a more thorough understanding of each of the error sources will be necessary.

Table 9. **Error Sources**

Error Source	Error (mm)
Sensor	**1**
Path	**1**
Target	**20**
Data Processing	**15**
TOTAL	**37**
RMS TOTAL	**25**

9.4 Further Testing

OSTEP will continue testing the MIROS air gap sensor in order to continually refine the understanding of the performance of the sensor and to optimize the application. An operational test on USACE Cape Cod Canal under ice flow conditions is scheduled for the winter of 2004-2005. Other studies planned include long-term drift, corrosion, and vibration studies.

10.0 OPERATIONAL IMPLEMENTATION

10.1 Installation

The installation of an air gap sensor on a bridge requires careful consideration of unique field difficulties. These factors include vibration, corrosion, data transmission, and others. Service intervals should be scheduled to inspect the installation and prevent failure before it occurs.

Bridge vibration caused by heavy traffic must be mitigated by using vibration-resistant fasteners. Field technicians must use nylon insert nuts (aircraft fasteners), Loctite, and/or lock washers at all times. Mounting frames should be overbuilt to withstand continuous vibration. Electronic components should be fastened inside the enclosure, preferably with rubber shock mounts.

Corrosion can be reduced by using non-metallic components whenever possible. When using metallic components, dissimilar metals must be electrically isolated to prevent galvanic corrosion.

Data transmission is accomplished using either line-of-sight radio or GOES. In each case a clear antenna path close to the electronics housing is required. Sensor location selection should include this consideration.

Recommended maintenance intervals are:

- Visual inspection every two months
- Annual verification by in-situ calibration using trigonometric leveling
- Battery replacement every two years

Insufficient experience with the sensor exists at present to address longer term reliability issues. A three- or five-year sensor refurbishment may or may not be required.

10.2 Sensor Offsets

There are two sensor offsets that must be considered. The location of the air gap sensor creates the first offset scenario, because the sensor is not located precisely at low steel of the bridge. The correction is made by subtracting out the low steel offset.

The second offset is a result of the manufacturer's calibration insufficiency, as addressed in Section 9.1. The most precise measurement is derived from the tide gauge plus the Total Station.

11.0 CONCLUSIONS

PORTS® partners voiced a requirement for a bridge air gap sensor to support safe and economic maritime commerce. CO-OPS agreed to develop the capability to provide the required data, and this development process has been successful. Following a rigorous evaluation of existing technologies, a sensor was selected, fully evaluated, and found to meet all requirements. Data delivery pathways were established, QA/QC parameters determined and implemented, and air gap products were developed. Bench and field references for use as standards during operational acceptance testing and field verification have been identified, described, and documented; ultimately, all requirements have been met or exceeded. The creation of this new capability has been embraced by the maritime community, as witnessed by the quick interest and follow-on requests for air gap sensors at many additional locations.

The selected sensor has been tested over several years, at several locations and under a wide variety of conditions. The manufacturer has implemented corrective actions where deficiencies were identified. The device has proven to be immune to rain, snow, temperature extremes, waves, vibration, RF noise, and other potential interferences. It has exceeded precision requirements to the extent that CO-OPS is now beginning to investigate the use of this technology for standard observations of water level. All test results are documented and are freely available electronically.

Most significantly, the introduction of air gap to the CO-OPS "tool bag" has shown that, through the private/Federal PORTS® partnership and the matrix-managed OSTEP, a new data product can be developed. CO-OPS is presently embracing many other new technologies which will require personnel and process adaptation. The success of the air gap development shows that it can be done, and done well.

12.0 ACKNOWLEDGEMENTS

OSTEP is a matrix-managed program and consequently draws upon many CO-OPS resources. The success of the entire program and this air gap sensor evaluation is a tribute to the dedication of all CO-OPS personnel who have enthusiastically accepted additional tasks to improve our products and services.

Bridges are invariably cold, noisy, dirty, and dangerous. The elevated level of risk requires extra attention, caution, and dedication. Special thanks go to Warren Krug and John Stepnowski (CO-OPS), as well as John Abbitt and Jennifer Dussault (REMSA contractors), for providing valuable support**.**

We also would like to thank:

The Sutron Corporation, under contract to CO-OPS, for providing an air gap DLL;

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Karen Grissom (REMSA) for providing C&D Bridge access request documentation;

Dave Hatcher (CO-OPS) for helping to establish the 50 meter Reference Range at CO-OPS Chesapeake Facility;

Warren Krug, Philip Libraro, and Chris McGrath (CO-OPS) for their long hours developing air gap data communications and DCP operations;

Mike Evans, Geoff French, and Robert Gillium (CO-OPS Information Systems Division) for development of the web services and QA/QC procedures;

Mike Connolly (CO-OPS Products and Services Division) for the implementation of those QA/QC procedures in CORMS;

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Ed Carlson
Curt Smith
Audie Murray
Frank Marion

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Jim Tomlin
Larry Brown
Doug Patterson
Bobby Parlier
Heather Sachs

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Finally, thanks to the Port Authority of New York and New Jersey for funding the first acquisition of a microwave air gap sensor. PANYNJ personnel who deserve special thanks: Patrick McKeon and Ron Borup.

13.0 REFERENCES

Bethem, T .D., and H.R. Frey, Operational Physical Oceanographic Real-Time Dissemination, IEEE, Oceans Proc., V 01.2, 864-867, 1991.

Bosley, K. T. and K. W. Hess, Development of an Experimental Nowcast/Forecast System for Chesapeake Bay Water Levels, Estuarine and Coastal Modeling Proceedings of the Conference American Society of Civil Engineers, Alexandria, Virginia, October 1997.

Burton, J., A NWS Guide to the Use of NWLON and PORTS Computer-Based Products, NOAA Technical Report NOS CO-OPS 026, Silver Spring, MD, pp30, 2000.

Coastal Engineering Manual, U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory, 1979-present.

Deitemyer, D.H., Effects of December 1992 Northeaster on Water Levels: Data Report, NOAA Tech. Memo. NOS OES 006, Silver Spring, MD, 1993.

Defense Hydrographic Initiative, H;ydrographic Source Assessment System, Tech. Rep. and Tutorial on the Standard Vertical Datum, The Standard Vertical Datum Working Group Report, t.996.

DeLoach, S.R., 1995, GPS Tides: A Project to Determine Tidal Datums with the Global Positioning System, U.S. Army Corps of Engineers, Topographic Engineering Center, Alexandria, VA, pp. 110, 1995.

Edwing, R.F., Next Generation Water Level Measurement System (NGWLMS) site design, preparation, and installation manual, NOAA National Ocean Service, Silver Spring, MD, pp. 214, 1991.

Frey, Henry R. and Gerald F. Appell, Editors, NOS Strategic Petroleum Reserve Support Project: Final Report Volume Two - Measurements and Data Quality Assurance. March 1981.

Mero, T.N., and W.M. Stoney, A description of the National Ocean Service Next Generation Water Level Measurement System, Proceedings of the Third Biennial NOS International Hydrographic Conf., Baltimore, MD, 109-116, 1988.

National Research Council, Committee on Information for Port and Harbor Operations, Marine Board, Commission on Engineering and Technical Systems, Advances in Environmental Information Services for Ports: An Assessment of Uses and Technology, National Academy Press, Washington, D.C., pp. 63, 1996.

National Research Council, Committee on Maritime Advanced Information Systems, Marine Board, Commission on Engineering and Technical Systems, Vessel Navigation and Traffic Services for Safe and Efficient Ports and Waterways: Interim Report,, National Academy Press, Washington, D.C., pp. 98, 1986.

Scherer, Wolfgang,, William M Stoney.,Thomas N. Mero,, Michael O'Hargan,, William Michael Gibson,, James R Hubbard, Michael I. Weiss, Ole Varmer, Brenda Via, Daphne M. Frilot, Kristen Tronvig, Contributors and Stephen K. Gill, and John R. Schultz, Editors, NOS Special Publication NOS CO-OPS 1: Tidal Datums and Their Applications. February 2001.

Scherer, W.D., National Ocean Service's Next Generation Water Level Measurement System, , FIG, International Congress of Surveyors. Toronto. Vol, 4,232-243.1986.

Scherer, W.D., T.N. Mero, and P.I. Libraro, Preliminary Report on STEDEX II (The Second Sensor Technique Evaluation Duck Experiment) of the Water Level Measurement System Project,, Technical Report, Office of Ocean Technology and Engineering Services, 1981

Schultz, John, NOAA Technical Report NOS CO-OPS 023. Procedures for Estimating the Measurement Uncertainty of Operational Instruments, November 1999:

14.0 ACRONYMS

ASCII	American Standard Code for Information Interchange
ATC	Averaging Time Constant
CBBT	Chesapeake Bay Bridge Tunnel
C & D	Chesapeake and Delaware
cm	Centimeter
CO-OPS	Center for Operational Oceanographic Products and Services
CORMS	Continuous Operational Real-Time Monitoring System
CT	Conductivity/Temperature sensor
CWFM	Continuous Wave Frequency Modulation
DAS	Data Acquisition System
dB	Decibels
DCP	Data Collection Platform
DIS	Data Ingestion Server
DLL	Dynamic Linked Library
DMS	Database Management System
DOMSAT	Domestic Satellite
DQAP	Data Quality Assurance Processing
DSP	Digital Signal Processing
FRF	Field Research Facility
FSI	Falmouth Scientific Instruments
FTP	File Transfer Protocol
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
GUI	Graphical User Interface
GV	Get Value
Hz	Hertz
I/O	Input/Output
m	Meter
mm	Millimeter
MMAGSDTP	Mitretek MIROS Air Gap Sensor Detailed Test Plan
MLLW	Mean Lower Low Water
MPA	Maryland Port Administration
NESDIS	National Environmental Satellite, Data, and Information Service
NGS	National Geodetic Survey
NGWLMS	Next Generation Water Level Measurement System
NIST	National Institute of Standards and Technology
nm	Nanometer
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NRC	National Research Council
NWLON	National Water Level Observation Network
NWLP	National Water Level Program
OSTEP	Ocean Systems Test and Evaluation Program
OSTEF	Ocean Systems Test and Evaluation Facility

PANYNJ	Port Authority of New York and New Jersey
PC	Personal Computer
PLB	Port of Long Beach
PORTS®	Physical Oceanographic Real-Time System
PSD	Products and Services Division
PUFFF	PORTS® Uniform Flat File Format
PVC	Polyvinyl Chloride
QC	Quality Control
RMS	Root Mean Square
RTU	Remote Terminal Unit
RF	Radio Frequency
SLL	Sutron Dynamic Linked Library
SOP	Standard Operating Procedure
USACE	United States Army Corps of Engineers
USACE/FRF	United States Army Corps of Engineers / Field Research Facility
USCG	United States Coast Guard
WL	Water Level
YSI	Yellow Springs Instrument Corporation
° Fahrenheit	Degrees Fahrenheit

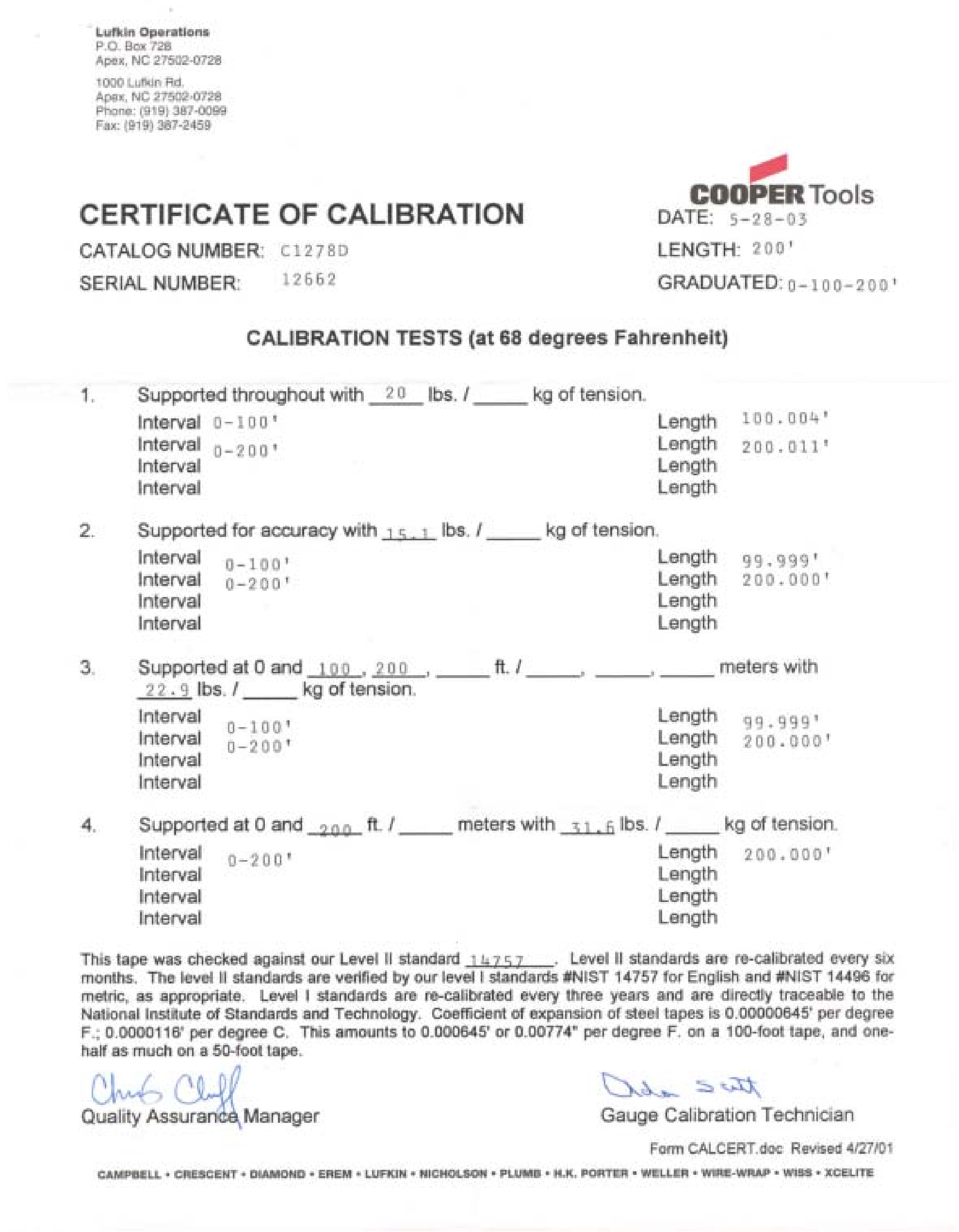
APPENDICES

APPENDIX A MIROS MICROWAVE AIR GAP SENSOR TEST SUMMARY (TEST PROCEDURES)

TEST	SHORT DESCRIPTION	CONTROLLED MEASUREMENT	EXPECTED RESULTS OR MEASUREMENT OF UNCERTAINTY
1. Sensor air gap reading against fixed target	Taking reading against fixed target, vertically against water surface, horizontally against Invar surface	Invar tape	+/- 75 millimeters
2. Sensor programmable functions	To test correct response to changed parameters, change all programmable parameters, one by one, and take reading while changing distance between sensor and fixed surface	Invar tape	Programmable functions take their effect
3. Sensor recovery after power supply interruption	While taking reading against fixed surface, unplug the power supply, restore the power supply, and continue the test	Invar tape	Sensor recovers and continues to send correct reading
4. Sensor operation under varied power supply output	Perform accuracy test of sensor reading under varied power supply output	Invar tape	Sensor provides accurate reading using battery power supply
5. Custom developed software test	Perform test of data processing by DCP component (statistical calculations and storing results into output file using correct data structure and formats		Converted units represent correct results based on unit conversion table
6. Accuracy of sensor at varied distances from target	Perform sensor accuracy test while changing distance between sensor and fixed surface using a range from 10 to 150 feet	Invar tape	+/- 75 millimeters
7. Accuracy at varied alignment of sensor to water surface	Perform sensor accuracy test between sensor surface and fixed target surface by raining and lowering the sensor.	Invar tape	+/- 75 millimeters
8. Accuracy of reporting under different configuration of sensor programmable functions	Perform sensor accuracy test while changing programmable parameters to determine the best set up for operational environment	Invar tape	Selected parameter set up will deliver uncertainty of +/- 75 millimeters
9. Temperature	Perform sensor accuracy test	Invar tape	Consistent reading with

impact on accuracy	while changing sensor exposure to temperature		uncertainty +/- 75 millimeters during the test
10. Rain impact on accuracy	Perform sensor accuracy test while changing sensor exposure to rain	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
11. Humidity impact on accuracy	Perform sensor accuracy test while changing sensor exposure to humidity	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
12. Icing on sensor surface impact on accuracy	Perform sensor accuracy test while surface is covered by icing	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
13. Vibration impact on accuracy	Perform sensor accuracy test while changing sensor exposure to vibration	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
14. Ice on water surface impact on accuracy	Perform sensor accuracy test against water surface with floating ice blocks	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
15. Varied sea condition impact on accuracy	Perform sensor accuracy test while changing sensor exposure to simulated sea conditions (waves)	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
16. Natural conditions (combination of environmental factors)	Perform sensor accuracy test while changing sensor exposure to combination of environmental factors	Invar tape	Consistent reading with uncertainty +/- 75 millimeters during the test
17. Operational deployment on N&PBL railroad bridge	Perform sensor accuracy in field deployment environment over long period of time	GPS, Invar tape, water level gauge, laser range finder Environmental data	Sensor provides reliable reading over period of deployment With uncertainty of +/- 75 millimeters
18. Reliability test and data collection about failures	Collect and log all sensor failures during the field deployment test		MTBF is at least 5,000 hrs.

APPENDIX B COOPER TOOLS CERTIFICATE OF TRACEABILITY TO NIST



Lufkin Operations
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Phone: (919) 387-0099
Fax: (919) 387-2459

COOPER Tools

CERTIFICATE OF CALIBRATION

CATALOG NUMBER:	C1278D	DATE:	5-28-03
SERIAL NUMBER:	12662	LENGTH:	200'
		GRADUATED:	0-100-200'

CALIBRATION TESTS (at 68 degrees Fahrenheit)

1. Supported throughout with 20 lbs. / _____ kg of tension.

Interval	0-100'	Length	100.004'
Interval	0-200'	Length	200.011'
Interval		Length	
Interval		Length	

2. Supported for accuracy with 15.1 lbs. / _____ kg of tension.

Interval	0-100'	Length	99.999'
Interval	0-200'	Length	200.000'
Interval		Length	
Interval		Length	

3. Supported at 0 and 100, 200, _____ ft. / _____, _____, _____ meters with 22.9 lbs. / _____ kg of tension.

Interval	0-100'	Length	99.999'
Interval	0-200'	Length	200.000'
Interval		Length	
Interval		Length	

4. Supported at 0 and 200 ft. / _____ meters with 31.6 lbs. / _____ kg of tension.

Interval	0-200'	Length	200.000'
Interval		Length	
Interval		Length	
Interval		Length	

This tape was checked against our Level II standard 14757. Level II standards are re-calibrated every six months. The level II standards are verified by our level I standards #NIST 14757 for English and #NIST 14496 for metric, as appropriate. Level I standards are re-calibrated every three years and are directly traceable to the National Institute of Standards and Technology. Coefficient of expansion of steel tapes is 0.00000645' per degree F.; 0.0000116' per degree C. This amounts to 0.000645' or 0.00774" per degree F. on a 100-foot tape, and one-half as much on a 50-foot tape.

Chris Cluff
Quality Assurance Manager

Gauge Calibration Technician

Form CALCERT.doc Revised 4/27/01

CAMPBELL • CRESCENT • DIAMOND • EREM • LUFKIN • NICHOLSON • PLUMB • H.K. PORTER • WELLER • WIRE-WRAP • WISS • XCELITE

APPENDIX C SCANNED COPIES OF THE COMPLETE TEST LOGS

Test # N/A Test Name ~~RA~~ BATTERY DRAW #1

Tester's Name MARK BUSHNELL

Brief Description of Test Procedure Configure system as planned for USCG installation in New Orleans (SM-094/85 unit 2/rec thru Maxstream to Miros computer/software). Battery powered, monitored w/ E-link. 24 AH BATTERIES, BRIEF SHORT DURING HOOKUP REDUCED CAPACITY

Start Date and Time (GMT or local) 8/21 13:00 local

End Date and Time (GMT or local) 8/26/02 09:00 LOCAL

Location FOD /OSTEP office

Lab/Environmental Data (or source for time series or data file name):

Air Temp	78° F	Wind Speed	N/A
Baro		Wind Direction	N/A
Humidity	40%	Water Temp	N/A

Miros Model/Serial Number MIROS SM094/85 #010166

Comparison Standard (S/N) KOMELLON 6633

Test Data or Data File Names (if files provide original media, FTP location, and backup)

Procomm log PW0Z.CAP OSTEP PUBLIC SITE

Tester's Signature Mark Bushnell

Test # ____________ Test Name BATTERY DRAW #2

Tester's Name MARK BUSHNELL

Brief Description of Test Procedure SAME AS BATTERY DRAW #1 BUT w/ 2 40 AHR BATTERIES

Start Date and Time (GMT or local) 8/26/02 11:00 LOCAL

End Date and Time (GMT or local) 9/5/02 09:00 LOCAL

Location FOD/OSTEP OFFICE

Lab/Environmental Data (or source for time series or data file name):

Air Temp	78°F	Wind Speed	N/A
Baro		Wind Direction	N/A
Humidity	40%	Water Temp	N/A

Miros Model/Serial Number SM094/85 #01016B

Comparison Standard (S/N) KOMELLON 4633

Test Data or Data File Names (if files provide original media, FTP location, and backup)

Y:\ARO PW03.CAP OSTEP PUBLIC SITE

FTP:

Tester's Signature

Test # 1/5.1-5.4 Test Name Sensor Air gap reading against Fixed Target

Tester's Name Bosley, Kate

Brief Description of Test Procedure Test Plan page 61 - modified target is metal filing cabinent ~4 m away

Start Date and Time ([✓ GMT] or local) 10/18/02 06:28 PM

End Date and Time (GMT or local) 10/18/02 [illegible]

Location FOD/ROO lab

Lab/Environmental Data (or source for time series or data file name):

Air Temp ______ Wind Speed ______

Baro ______ Wind Direction ______

Humidity ______ Water Temp ______

Miros Model/Serial Number 5M-094 Golden Gate 85m SN P010166

Comparison Standard (S/N) no laser range finder

Test Data or Data File Names (if files provide original media, FTP location, and backup)

calibrated tape reader 3.942 m using vertical from green face to floor to filing cabinet

data stored on fujitsu C: data/Air Gap/Ag 1018a.dat Ag 1018.dat

then moved miros to 3.461 at 18:45 and ran ~~for~~ until 19:16

Tester's Signature ______

STOPPED AT 10:47
10/21/02 TO INSTALL
NEW CABLE

Test # part of 8 Test Name

Tester's Name Bushnell

Brief Description of Test Procedure test of adjusting offset for New Orleans deploy

Start Date and Time (GMT or [✓ local]) 10/23/02 10:12

End Date and Time (GMT or local)

Location Bushnell office

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number SM94/85

Comparison Standard (S/N) P010166 not comparing

Test Data or Data File Names (if files provide original media, FTP location, and backup)

using procomm script to Bushnell laptop

attempted to changed offset to -5000mm return +1553.6 mm

" " " offset to -999 changed it to -999m

2^{15}

-3276 mm is greatest negative offset it will except

+3276 mm is greatest possitive offset " " "

note - offset was returned -885 as delivered from manufacturer

Tester's Signature Mark Bushnell

+ ability to change comm

This test also proves reliability of laptop + procomm connection to the New Orleans Miros

Test # ____________ Test Name ____________

Tester's Name Kate Bosley

Brief Description of Test Procedure

dried out trying to see if still works

Start Date and Time (GMT or local) Oct 3, 2003

End Date and Time (GMT or local) Oct 6, 2003

Location parking lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number P020143

Comparison Standard (S/N) ____________

Test Data or Data File Names (if files provide original media, FTP location, and backup)

10.11m measured w/ certified tape

Tester's Signature Kathy T Bosley

Test # ____________ Test Name Bushnell / Bosley

Tester's Name long term stability 2

Brief Description of Test Procedure install at Duck

Start Date and Time (GMT or [✓ local]) 4/16/03 PM

End Date and Time (GMT or local) ____________

Location NE corner of pier handrail

Lab/Environmental Data (or source for time series or data file name):

Air Temp	22.5 °C	Wind Speed	4.7 m/s / gust 7.1 m/s
Baro	1015.8	Wind Direction	223°
Humidity		Water Temp	8.6°C

Miros Model/Serial Number SM-094/10W S/N 020143

Comparison Standard (S/N) laser range finder one measurement
will use NWLON

Test Data or Data File Names (if files provide original media, FTP location, and backup)

stored on Argonaut in tide house will be retrieved periodically

originally had trouble because factory offset had been changed. Settings on attached paper

Tester's Signature ____________

4/16/03

Duck pier

ael

min	100	
det	100	
wtc	0.5sec	
win	6 m	
tout	10 sec	
ser		
freq	8	
htc	0.5sec	
atc	4.5	
ntc	0.0	
top	1	
ch	5	12m

meas	385 mm/ch	−627 mm
fft	64	
fft-time	46.33	
tot	69.33	
Sweep	5.6	
range	20	
ant	10	
as type	2	
as gain	10.5	

5/29/03

installing expect
+ temp probe
+ modem

min	100	
det	100%	
wtc	0.5se	
win	6 m	
tout	10 sec	
ser		
freq	2 Hz	
htc	0.1 sec	
atc	30.0 sec ←*	
ntc	0.0	
top	1	
ch	5	12

	375 mm/ch	−627
fft	64	
fft time	46.32	
totime	75.62	
sweep	5.60	
range	20 m	
ant	10 deg	
as type	2	
as gain	10.5%	

Test # 1 Test Name Fixed Target

Tester's Name Kathryn T. Bosley

Brief Description of Test Procedure 30 minutes @ 10m, 9m, 10m

Start Date and Time (GMT or local) 9/2/2003 09:09:12 local

End Date and Time (GMT or local) 9/2/2003 11:08 "

Location FOD parking lot & warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp ______ Wind Speed ______

Baro ______ Wind Direction ______

Humidity ______ Water Temp ______

Miros Model/Serial Number 020149 SW rev 6.4a 50m range 5° beam width

Comparison Standard (S/N) invar tape laser range finder i07728 August 20, 2002

Test Data or Data File Names (if files provide original media, FTP location, and backup)

nfig min 100
det 100%
wtc 4.5 sec
win 6.0 m
tout 10 sec
freq 2Hz
htc 0.5 sec
ntc 0.0 sec
top ch 2.0
20.0m

meas 375 mm/ch -913.0 mm
fft 256
ffr time 226.47 msec
foto time 308.84 msec
sweep time 22.21 msec
range 50m
art 5 deg
as type 1
as gain 0.0%
as offset 0mV

09020909.dat 10m?.
0902 10033 .dat 9m?
09021037.dat 10m?.

Tester's Signature Kathryn T. Bosley

Test # 2 Test Name programmable functions

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure test accuracy w/ changed settings

Start Date and Time (GMT or local) 09/02/2003 12:26:50 local

End Date and Time (GMT or local) 09/02/

Location FOD parking lot + warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp

Wind Speed

Baro

Wind Direction

Humidity

Water Temp

Miros Model/Serial Number SM094/50 020149 SW ver 6.4a

Comparison Standard (S/N) laser range finder i 07728

Test Data or Data File Names (if files provide original media, FTP location, and backup)

min 50 10m 09021226.dat
9m 09021233.dat

det 50 9m 0902 1240.dat
10m 0902 1249. dat

wtc 10sec 10m 0902 1257.dat
9m 0902 1305.dat

win 2m 9m 09021401.dat
10m 09021502.dat

Tout 5sec 10m 09021509.dat
9m 09021516.dat

htc 2sec 9m

Tester's Signature

Test # 3 Test Name Sensor Recovry aftr Power Interupt

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure 10 minuts power off 5 min 10 min on

Start Date and Time (GMT or local) 09/02/2003 11:08 local

End Date and Time (GMT or local) 09/02/2003 11:34 local

Location FOO parking lot & warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number 020149 swver 6.4a SM-094/50 N

Comparison Standard (S/N) laser range finder i07728
in var tap

Test Data or Data File Names (if files provide original media, FTP location, and backup)

Miros config same as test #1 begin ending config

(42 secs) 09021108.dat
09021124.dat

power cut 1118 47sec
up 1124 25 sec

min
det
wtc
win
tout
freq
Dktc
ntc
top
ch

meas
fft
fft time
tot time
sweep time
range
ant 5 deg
as type
as gain
as offset

Tester's Signature ____________

Test # 1 Test Name Fixed Target

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure

30 min @ 10m + 30 min @ 9m + 30 min 10m

Start Date and Time (GMT [✓ or local]) 2/21/03 12

End Date and Time (GMT or [✓ local]) 2/21/03 14:09

Location FOB warehouse + lot

Lab/Environmental Data (or source for time series or data file name): Money Pt PORTS ↓

Air Temp 44°F

Wind Speed calm

Baro 1018mb ↓

Wind Direction

Humidity [illegible]

Water Temp 40°F sewells

Miros Model/Serial Number 020152 SM 94/50m

Comparison Standard (S/N) laser 107728
metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

02211222.dat 10m
02211302.dat 9m
02211339 KTB .dat 10m

ALL (from factory)

Min	100	
det	100%	
wtc	4.5	
win	6.m	
tout	10	
sel	1	
seq	2	
htc	0.5	
atc	59.5	
ntc	0	
top	1	
ch	3.0	20.0

Tester's Signature Kathryn T Bosley

Test # ______________ Test Name Search for Offset/Gain Correction

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure J. Oyler established very precise 50m baseline. Unit from Reedy Point will be tested against it

Start Date and Time (GMT or [✓ local]) 1/20/04 11:36

End Date and Time (GMT or [✓ local]) 1/23/04 ~09:20

Location FOD parking lot

Lab/Environmental Data (or source for time series or data file name): from Money Pt.

Air Temp ______________ Wind Speed ______________

Baro ______________ Wind Direction ______________

Humidity ______________ Water Temp ______________

Miros Model/Serial Number SM 094/50m P020152

Comparison Standard (S/N) trig survey - metal tape see attached.

Test Data or Data File Names (if files provide original media, FTP location, and backup)

01201136.DAT has several hours of us moving tgt etc

01201433 – 01211113.DAT hourly files at 30m

01211449 → 01220849.DAT 2 hr " at 40m

1/21/04 ~ 2PM local moved sensor to 40m

→ 01220824 – 01230824.DAT also 40m

settings

SWV 6.4a

min	100
det	100
wtc	4.5 sec
win	6m
tout	10 sec
htc	0.5 sec
atc	29.5 sec
ntc	0.0 sec
top	1
ch	2 50m

Tester's Signature Kathryn T. Bosley

meas 375mm/ch −853mm

Test # 2 Test Name *Programmable Functions*

Tester's Name *Kathryn T Bosley*

Brief Description of Test Procedure *verify functionality of all settings.*
vary only one setting at a time

Start Date and Time (GMT or [✓ local]) *2/24/03 07:50:17*

End Date and Time (GMT or [✓ local]) *2/24/03 09:40*

Location *FOD Warehouse lot*

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number *020152 SM 94/50 m*

Comparison Standard (S/N) *laser 107728*
metal tape

Kathy T Bosley

Test Data or Data File Names (if files provide original media, FTP location, and backup)

02240750.dat	10 → 9 → 10m	w/ factory settings
02240812.dat	min = 75	10 m
02240818.dat	" "	9m
02240823.dat	det = 50%	"
02240828.dat	" "	10m
02240833 (44).dat	wtc = 2	10m
02240838.dat	" "	9m
02240845 (41).dat	win = 2 m	9m
02240850.dat	"	10m
02240855 (42).dat	Htc = 2	10 m
02240901 (24).dat	"	9m

Tester's Signature

02240909.dat	atc = 5 sec	9m
02240914.dat	"	10m
02240920.dat	ntc = 1	10m
02240925.dat	"	9m

ALL (from factory) (only settings possible now?)

min	100	
det	100 %	
wtc	4.5	4.6 sec
win	6 m	
tout	10	
ser freq	2 Hz	
htc	0.5	0.6
atc	59.5	59.6
ntc	0	
top	1	
ch	3.0	20.0

02240930 (25).dat	ch 6.0	11.0 m	9m
02240935.dat	"	"	10m

after putting all back to factory settings
02240943.dat 10m

Test # 6 part of Test Name Long Range

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure against target longways of parking lot

Start Date and Time (GMT or [✓ local]) 06/02-2003 ~~05-30-2003~~ 10:~~01~~ 23:~~42~~ 05 10:11:40

End Date and Time (GMT or local)

Location FOD lot + warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number SM/094 50m S/N 020152

Comparison Standard (S/N) laser 106021 (old one)

Test Data or Data File Names (if files provide original media, FTP location, and backup)

non steel tape (? pull) 120' 3" = 36.65 m

data

06021001.dat -re 10:01
06021023.dat
06021623.dat
06022223.dat
06030423.dat

settings

min	100
det	100%
wtc	4.6 se
win	6 m
freq	2 Hz
	0.6 sec
htc	
atc	54.5
ntc	0
rop	1
ch n	4 50m
	5 deg

Tester's Signature

meas 375.0 mm/ch -853.0 mm

Test # 3 Test Name Power Interupt

Tester's Name Kate Bosley

Brief Description of Test Procedure cut off power log after return of power

Start Date and Time (GMT or local) 2/21/03 14:11

End Date and Time (GMT or local) 2/21/03 14:43

Location FOD warehouse + lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number SM94/50m 020152

Comparison Standard (S/N) laser 107728
metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

0221 1411 .dat reading before power interupt
02211438.dat " after " "

vary power.log procomm log

Tester's Signature Kathryn T. Bosley

Test # 4 Test Name Variable Power

Tester's Name K. Bosley

Brief Description of Test Procedure

vary power and record Miros response

Start Date and Time (GMT or [✓ local]) 2/24/03 10:40

End Date and Time (GMT or [✓ local]) 2/24/03 14:12

Location FOD lot warehouse

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number 020152 SM94/50m

Comparison Standard (S/N) laser 107728
metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

02241042.dat reading @ 24V
0224 1319.dat 24V

1322:08 ↓ to 23V
1325:13 ↓ to 22V
~~132 ↓ to 21V~~
13:28:13 ↓ to 20V
13:31:23 ↓ to 18V
1334:18 ↓ to 16V
1337:23 ↓ to 14V
134018 ↓ to 12V
134328 ↓ to 10V

13:46:28 ↓ 9V
13:49:23 ↓ 8V
13:52:28 ↓ 7V
13.55:08 ↓ 6V
phil's program stoped

Tester's Signature Kathy J Bosley

Test # 1 Test Name Sensor Air Gap Reading Against Fixed target

Tester's Name Kathryn T. Bosley

Brief Description of Test Procedure

~~Laser~~ cert tape used to position metal sheeted target at 10m
Then at 9m
Then back to 10m

Start Date and Time (GMT or [✓ local]) 01-16-2003 13:00

End Date and Time (GMT or local) 14:48

Location FOD warehouse & parking lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	1.5 m/s hand held
Baro	10234 mb hand held ↓ PORTS	Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number P010162 SM094/50m

Comparison Standard (S/N) ~~[illegible]~~ laser range finder SN 106021
Nov. 9, 2000

Test Data or Data File Names (if files provide original media, FTP location, and backup)

cat files together in ..OSTEP/AirGap/P010162/test1.dat

individual files are 01161258.DAT 01161319.DAT on floppy &
01161306.DAT 01161327. "
01161314.DAT 01161418 "
01161443 "

ssues 2000 laser range finder has ~15cm offset to other known distances
but is only range finder we can talk to. SN #; 07728 8/20/2002
reads 10.01 consistently
when manually
fired from test position

Tester's Signature Kathryn T Bosley

Test # 3 **Test Name** Power Failure

Tester's Name Kate Bosley

Brief Description of Test Procedure

shut off power - make sure Miros recovers after 1 minute (note difference on test plan page 68
• page 38

Start Date and Time (GMT or [✓ local]) 02/06/03 1109

End Date and Time (GMT or [✓ local]) 02/06/03 1245

Location FOD warehouse + lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp ____________ **Wind Speed** ____________

Baro ____________ **Wind Direction** ____________

Humidity ____________ **Water Temp** ____________

Miros Model/Serial Number SM094/50m P010162

Comparison Standard (S/N) laser SN 107728
metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

reading before power = 02061109.dat

running procom after power interr
~ 30 secs of noise
then running phil's program
02061124(21).dat after power interrupt
to view all info also have a
procomm log poweroff.log

important note **
settings taken from factory condition (rather than)
test plan

	MIN	100	
	det	100.0%	entered 4.2
	wtc	4.1 sec	
	WIN	6.0 m	
	tout	10.0 sec	
	sea freq	2 Hz	
	htc	0.3 sec	entered 0.5 sec
	atc	179.3	entered 179.75
	ntc	29.4	" 29.75
	top	1	
just for parking lot test →	ch	5.0	15.0m

Tester's Signature Kathy Bosley

Test # 4 **Test Name** varying power supply

Tester's Name Kate Bosley

Brief Description of Test Procedure attach voltage regulator & see how Miros performs w/ varying power

Start Date and Time (GMT or [✓ local]) 02/06/03 1253

End Date and Time (GMT or [✓ local]) 02/06/03 1415

Location FOD warehouse + lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp		**Wind Speed**	
Baro		**Wind Direction**	
Humidity		**Water Temp**	

Miros Model/Serial Number SM094/50m P010162

Comparison Standard (S/N) laser # 107728
metal tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

02061253.dat = 15minutes "reading at 24V" note error in test plan page 71

02061309.dat set up w/ voltage regulator

at ~1311 ↓ 23V
~1313 $\downarrow^2$ 22V
~1315 $\downarrow^2$ 21V
~1317 $\downarrow^2$ 20V
~1319 $\downarrow^2$ 19V
~1333 $\downarrow^2$ 18V
~1337 $\downarrow^2$ 17V
~1340 $\downarrow^2$ 16V

at ~1342 $\downarrow^2$ 15V
~1344 $\downarrow^2$ 14V
~1346 $\downarrow^2$ 13V
~1348 $\downarrow^2$ 12V
~1350 $\downarrow^2$ 11V
$\downarrow^2$ 10V
~1352 $\downarrow^2$ 09V
~1354
~1356 $\downarrow^2$ 08V
~1358 $\downarrow^2$ 07V * begin to see a few [illegible] values

at ~1400 $\downarrow^2$ 06V
~1402 $\downarrow^2$ 05V
blatant errors
~1404 $\downarrow^2$ 04V
↓ 03V

procommlog
varypower.log

Tester's Signature Kate Bosley

file 02061416 contains run overnight @ 12V

Test # ____________ Test Name Looking at long range offset

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure parking lot on trig established baseline

Start Date and Time (GMT [✓ or local]) 1/23/04 09:31:29

End Date and Time (GMT or local) ____________

Location ____________ this unit was pulled from Duck on 1/22/04

Lab/Environmental Data (or source for time series or data file name):

Air Temp		Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number 50m SM094 / P010162 (OSTEP) 5° beam width

Comparison Standard (S/N) ____________

Test Data or Data File Names (if files provide original media, FTP location, and backup)

min	100
det	100
wtc	4 sec
win	6 m
tout	10 sec
htc	0 sec
atc	29.5 sec
ntc	29 sec
top	1
ch	5 50m

meas 3750 mm/ch -870.0 mm

fft 256

fft time 226.54 msec

371.29 msec

22.22 "

as type 0

gain 0 %

offset 0 mv

data files

01230931.DAT

40m target 01231131.DAT

stopped unexpectedly

01231234.DAT

01231434.DAT

01231700.DAT

01231900.DAT

01232100.DAT →

Tester's Signature ____________

Test # 2 Step 5 Test Name Sensor Programable Function

Tester's Name Kathryn T Bosley

Brief Description of Test Procedure Change settings & test at 10 m & 9m

Start Date and Time (GMT or [✓ local]) 01/28/2003 9:22:33 w/ positioning

End Date and Time (GMT or local) TBC on new day

Location FOD warehouse & lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp Cold

Wind Speed

Baro

Wind Direction

Humidity

Water Temp

Miros Model/Serial Number SM-094/50m P010162

old Laser range finder Comparison Standard (S/N) SN 106021 Nov 9, 2000 + invar tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

01280942.dat → "setting one" - 10m
01280009.dat → " " - 9m
01281017.dat → MIN=75 - 9m
01281029.dat → " " -10m
01281040.dat → DET=75 - 10m
0128 [illegible] 1105.dat → DET=75 - 9m
0128 [illegible] 1132.dat → wtc = 0.3 (set 0) - 9m
01281145.dat → " " - 10m
01281155.dat → WIN = 2m - 10m

MIN	100
Det	50
wtc	1
win	1
tout	10
su	
Freq	2
Htc	1
atc	1
ntc	0
ch	1-50

Tester's Signature KTB

contin

Test # 2 Step 5 Test Name Sensor Programable F.

Tester's Name Kate Bosley

Brief Description of Test Procedure change settings & test at 10m & 9m continuation of 1/28 testing w/ returned laser range finder

Start Date and Time (GMT or [✓ local]) 2/6/03 0941

End Date and Time (GMT or local) 2/6/03 1050

Location FOO warehouse & lot

Lab/Environmental Data (or source for time series or data file name):

Air Temp	colder	Wind Speed	
Baro		Wind Direction	
Humidity		Water Temp	

Miros Model/Serial Number SM 094/50m P010162

Comparison Standard (S/N) new laser range finder SN 107728
invar tape

Test Data or Data File Names (if files provide original media, FTP location, and backup)

02060941 .dat → win=2m - 9m
02060948(24) .dat → HTC=5sec - 9m
02061003(21) .dat → " - 10m
02061011(13) .dat → ATC= 90sec - 10m
02061020(52) .dat → " - 9m
02061028(10) .dat → NTC = 10sec - 9m
02061044(40) .dat → " 10m

Tester's Signature Kathy T Bosley

APPENDIX D MIROS SETTING PARAMETERS

7 SOFTWARE PARAMETER SETTINGS

SM-048/2 and all SM-094 versions are basically running the same software. Configuration changes required to adapt SW to the different versions cannot be done by the user because hardware modifications are also required to achieve specified measurement performance.

Some signal processing parameters may be changed from the default values by the user by connecting an ASCII terminal to the RS232 port of the MIROS Microwave Range Finder.

By typing the command

```
ALL < > CR/LF
```

(no argument) the current parameter settings are printed (typical example - for actual settings please see test report for the specific range finder);

```
min                      100
det                      50 (%)
wtc                      1.0 (sec)
win                       6.0 (m)
tout                     10.0 sec
ser                      1
freq                     2 (Hz)
htc                      1 (sec)
atc                      60 (sec)
ntc                      30 (sec)
top                      1
ch                       20 -40 (m)

SM-094/50 Miros Range finder  SW ver. 6.4
Maximum range            50 m
Ant. beam width          5 deg
```

The following signal processing parameters may be selected by the user:

<u>Minimum signal level</u>

The minimum signal level may be set by the command

```
MIN <level> CR/LF
```

where <level> is a real number in the dimension of internal units.

Detection level

The detection level is set in % of the peak value by the command

```
det<% of peak> CR/LF
```

where <% of peak> is a real number in the dimension of %.

Tracking window time constant

The time constant of the tracking window my be set by the command

```
wtc<timeconst in sec> CR/LF
```

where <timeconst in sec> is a real number in the dimension of seconds. A value of 0 turns the filter off.

Tracking window size

The size of the tracking window is set by the command

```
win <absolute size in metres> CR/LF
```

where <absolute size in metres> is a real number in the dimensions of metres.

Lost signal time-out

Time-out value for lost signal is set by the command:

```
tout <time-out in seconds> CR/LF
```

where <time-out in seconds> is a real number in the dimensions of seconds.

Analogue or digital signal output

By typing the command

```
ser <x> CR/LF
```

analogue or digital signal output is selected.

x=O gives analogue output
x= I gives digital output

Digital data output rate

The digital data output rate my be selected by typing

```
freq <rate> CR/LF
```

where "rate" may be

SM-O48/2	2,4 or 8 (measurements pr second)
SM-O94/10:	2,4 or 8 (measurements pr second)
SM-O94/20:	2 or 4 (measurements pr second)
SM-O94/50:	2 (measurements pr second)
SM-O94/85:	2 (measurements pr second)

Data output averaging time constants

The output channels may be averaged by different time constants. Time constant may be changed by typing

```
htc <time-constant> CR/LF
```

and

```
atc <time-constant> CR/LF
```

for the two output channels respectively. "time constant" is an integer in the unit of seconds

Suppression of unwanted fixed echoes

Unwanted, fixed echoes may be suppressed by subtracting an averaged signal vector from each new measurement. The averaging time constant is user selectable:

```
ntc <time-constant> CR/LF
```

where "time-constant" is an integer in the unit of seconds. Setting "time-constant"=O turns off the updating of the average signal vector.

Two different modes exists for estimating the averaged signal vector. The mode may be selected using the command:

top<x>CR/LF

where "x" may be 0 or 1:

x= 1 means that the strongest echo does not contribute to the average background echo estimate. This is the default mode and is suitable for stationary targets.

x=O means that all echoes contribute to the average background echo estimate. This mode is suitable only for very dynamic targets.

The command

```
resn <>CR/LF
```

sets the average signal vector to zero. In order to turn off the suppression of unwanted fixed echoes completely set "ntc"=O and type "resn".

By typing the command

```
info 8<> CR/LF
```

the estimated average signal vector ("noise vector") will be printed to the screen. If all elements equals zero suppression will not take place.

Actual measurement range

The actual measurement range may set within the limits given by the maximum range for each version. By typing

```
ch < min max> CR/LF
```

where "min" and "max" are real numbers in the unit of metres. "max" must be less than the given maximum range. If for example a SM-O94/50 is used for bridge airgap monitoring and the actual distance from the bridge down to the water surface may vary from 35 to 45 m the values of "min" and "max" may be set accordingly. This will completely eliminate all echoes from outside of this range.

The analogue output signal will be scaled according to the measurement range. 0 V will correspond to "min" and 1 0 V to "max".

Reading data on command (get value)

If the range finder is used for measurements of average distances and the user is not interested in

APPENDIX E NGS ELEVATION DETERMINATION SURVEY

National Geodetic Survey
Geodetic Services Division
Instrumentation & Methodologies Branch

Field Report
Reedy Point/Chesapeake City Bridges - Miros Elevation Determination Survey
March 17 & 18, 2004

Report by: Kendall L. Fancher

Purpose

CO-OPS has installed a MIROS microwave altimeter instrument (air gap measuring device) on two bridges (Reedy Point & Chesapeake City) along the C & D Canal in Maryland and Delaware. The MIROS is a microwave altimeter capable of determining the distance from the electronic phase center of the device to a water surface. This information is very useful to ships whose maximum height approaches that of the available bridge clearance. Due to the location of these devices, CO-OPS used trig leveling as a means of transferring the Mean Lower Low Water (MLLW) heights to the electronic phase centers of these devices from nearby tidal bench marks. Standard Second-order, class 1 leveling procedures (maximum length, 60 meters, between leveling instrument and survey rod) to the MIROS device, mounted over the side center of the bridge would prove to be extremely difficult, if not impossible. NGS was asked to conduct trig leveling to the electronic phase centers of these devices as an independent check of the elevations determined by CO-OPS trig leveling efforts. Roy Anderson and I determined the elevation of the Reedy Point MIROS device, by trig levels, on the 17th of March. We determined the elevation of the Chesapeake City MIROS device, by trig levels, on the 18th of March. Jeff Oyler and Brad Wynn, tended the trig target at both MIROS devices. These devices are located in areas on the bridges that require special safety gear to access.

Survey Procedures

The same survey procedures were used for both the Reedy Point Bridge and Chesapeake City bridge MIROS surveys. The same instrument (Wild TC2002 s/n 359817) was used for both surveys. Parts Per Million (PPM) corrections, based upon atmospheric conditions, (air temperature and barometric pressure) were determined and applied during the surveys as needed.

1) The Wild TC2002 vertical index error was determined using the manufacturers standard check and adjust procedures and the correction applied and stored in the instrument.

2) The trig target pole bubbles were checked for plumb.

3) The trig target heights were calibrated and determined to be of equal value.

4) A tidal bench mark was selected to serve as primary vertical control for the trig leveling. The selection of this bench mark was dictated by proximity to the MIROS device and the bench mark having a published MLLW elevation.

5) The stability of the selected vertical control station was verified by conducting trig leveling to a second tidal bench mark (two mark tie). The Wild TC2002 was set up between the two bench marks in a location to minimize stadia imbalance (equal distance between back sight and fore sight targets). Two sets of direct and reverse observations were recorded to both the back sight (primary vertical control station) and fore sight (check bench mark). The mean average of the back sight and fore sight observations were used to determine an observed elevation difference between the bench marks. This observed elevation difference was compared to the observed elevation difference between the two bench marks taken from second-order, class 1 leveling field abstracts provided by CO-OPS. Second-order, class 1 tie allowances were determined based upon the observed distance between the bench marks. The field abstracts provided to NGS are included with this report.

6) The Wild TC2002 instrument was set up in a location that provided a good angle of observation to the MIROS device and minimized the stadia imbalance between the back sight and fore sight as much as was possible. From this location, a single shot section was used to trig level from the primary vertical control station to the MIROS electronic phase center. Five sets of direct and reverse readings were recorded to both the back sight and fore sight. The mean average of the fore sights and back sights were used to determine the observed elevation difference between the primary vertical control station and the MIROS electronic phase center.

7) The Wild TC2002 instrument height was reset. From this location, a single shot section was used to trig level from the MIROS electronic phase center to the primary vertical control station. Five sets of direct and reverse readings were recorded to both the back sight and fore sight. The mean average of the fore sights and back sights were used to determine the observed elevation difference between the MIROS electronic phase center and the primary vertical control station.

8) A Second-order, class 1 allowable closure was determined based upon the observed distances between the back sight and fore sight. The observed elevation differences between the forward and reverse sections were evaluated to insure that they agreed within the allowable closure tolerance.

Trig Target Calibration

Rod 1			Rod 2
D	-0.1143	D	-0.1147
R	-0.1150	R	-0.1147
mean	-0.1147	mean	-0.1147

Reedy Point Bridge

Two Mark Tie (855 1910 C TIDAL to 855 1910 B TIDAL)

Check between observed forward and reverse sections = 0.0007m
Allowable check 0.0033m

Check between observed elevation difference and abstract elevation difference = 0.0031m
Allowable check 0.0033m

Determination of Elevation to MIROS Electronic Phase Center

Check between observed forward and reverse sections = 0.0011m
Allowable check 0.004m

Published elevation of 855 1910 C TIDAL = 3.148m (MLLW)

Mean of observed elevation differences (forward and reverse sections) = 41.2095m

Elevation of MIROS electronic phase center is (3.148m + 41.2095m) = 44.3575m (MLLW)

Mean of observed elevation difference from 855 1910 C TIDAL to additional foresight to “low steel below obstruction light” = 40.1118m

Elevation of “low steel below obstruction light” is (3.148m + 40.1118m) = 43.2598m (MLLW)

Chesapeake City Bridge

Two Mark Tie (NO 3 1972 to U 2 1931 6.834)

Check between observed elevation difference and abstract elevation difference = 0.0001m
Allowable check 0.001m

Determination of Elevation to MIROS **bracket**

Note–Previous surveys conducted by CO-OPS had been to the bracket rather than the electronic phase center.

Check between observed forward and reverse sections = 0.0012m
Allowable check 0.0045m

Published elevation of NO 3 1972 = 2.455m (MLLW)

Mean of observed elevation differences (forward and reverse sections) = 42.2472m

Elevation of MIROS bracket is (2.455m + 42.2472m) = 44.7022m (MLLW)

Published elevation of NO 3 1972 = 2.455m (MLLW)

Mean of observed elevation difference from Instrument to NO 3 1972 (second set) = 0.6055m

Mean of observed elevation difference to additional foresight “MIROS electrical phase center” = 42.8838m

Mean of observed elevation difference to additional foresight “bottom of navigation light” = 41.6314m

Mean of observed elevation difference to additional foresight “low steel” = 41.9831m (MLLW)

Elevation of MIROS electronic phase center is (2.455m+(42.8838m-0.6055m)) = 44.7333m (MLLW)
Elevation of “bottom of navigation light” is (2.455m=(41.6314-0.6055m)) = 43.4809m (MLLW)
Elevation of “low steel” is (2.455m = (41.9831-0.6055m)) = 43.8326m (MLLW)

Recommendations for future air gap height determination surveys:

1) When installing the MIROS instrument determine a bench mark point (reference point) on the electronic phase center. Be consistent with a common reference point selection for all MIROS devices. Ensure that during the installation of the MIROS device that the selected reference point remains accessible for direct occupation by a trig target pole.

2) If possible conduct near simultaneous trig observations (requires two instruments, preferably one setup close to the MIROS and the other instrument close to the bench mark) reading the same targets to reduce the refractive effects of unbalanced shots and inconsistent air layers. Near simultaneous trig observations would cancel out this source of error.

3) If near simultaneous trig observations are not feasible, conduct a separate and independent determination of the MIROS electronic phase center height. RTK GPS could provide such a separate and independent height determination. This would serve as a means of detecting any large errors that might be induced while trig leveling.

4) Trig target poles should be calibrated before each survey and bubbles checked to ensure they have not strayed. Reduce sources of error by maintaining a back sight and fore sight with equal prism heights whenever possible. Avoid having to add corrections for different prism heights.

5) The amount of expansion and contraction of bridge frameworks, due to seasonal atmospheric conditions should be examined for each location. Conducting trig leveling to the MIROS during the winter and again during the summer, might provide insight into the magnitude, of the elevation change, if any, occurring at each bridge

APPENDIX F REEDY POINT AND CHESAPEAKE CITY TRIGONOMETRIC SURVEY DATA

```
       ******* R E C O V E R Y         D E S C R I P T I O N *******

             SSN: 0220
     Designation: 855 1910 R 72 W
             PID:
 Approx. Latitude: 393242N                                State: DE
Approx. Longitude: 0753450W                              County: NEW CASTLE
Approx. Elevation:                                    Disk From: US ARMY
CORPS OF ENG
           Stamping: R 72 W

      Surface Mark
             Type: Survey disk
    Magnetic code: N
          Setting: SET INTO THE TOP OF A CONCRETE MONUMENT
        Rod depth:                               Sleeve Depth:

 Mark condition reported in descriptive text by - NOS on 06112003, chief of
                                   party
```

THIS MARK IS DESTROYED

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE
CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE WEST SIDE
OF U.S. HIGHWAY 9
NEAR THE SOUTH END OF THE BRIDGE LEADING OVER THE CANAL, 121.3 M (398.0
FT) NE
OF THE JUNCTION OF ROUTE 9 AND SOUTH REEDY POINT ROAD, 59.62 M (195.60 FT)
SOUTH OF THE SOUTH END OF THE BRIDGE, 7.19 M (23.59 FT) SW OF THE
CENTERLINE OF
ROUTE 9, AND 0.21 M (0.69 FT) WEST OF THE CURB.

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
DATABASE = Sybase PROGRAM = datasheet, VERSION = 6.98
         1   National Geodetic Survey,  Retrieval Date = MARCH 16, 2004
JU2188 ********+*++******+*********++*****+*+*******+*********************+
JU2188 TIDAL BM     - This is a Tidal Bench Mark.
JU2188 DESIGNATION - 855 1910 C TIDAL
JU2188 PID   - JU2188
JU2188 STATE/COUNTY- DE/NEW CASTLE
JU2188 USGS QUAD    - DELAWARE CITY (1993)
JU2188
JU2188       *CURRENT SURVEY CONTROL
JU2188
JU2188*   NAD 83(1986)- 39 33 25.(N)    075 34 34.    (W)    SCALED
JU2188*   NAVD 88   -      2.244 (meters)      7.36   (feet) ADJUSTED
JU2188
JU2188 GEOID HEIGHT-       -33.39 (meters)     GEOID03
JU2188 DYNAMIC HT - 2.243 (meters)      7.36 (feet) COMP
JU2188 MODELED GRAV-       980,127.3    (mgal) NAVD 88
JU2188
JU2188 VERT ORDER - FIRST  CLASS II
JU2188
JU2188.The horizontal coordinates were scaled from a topographic map and have
JU2188.an estimated accuracy of +/- 6 seconds.
JU2188
JU2188.The orthometric height was determined by differential leveling
JU2188.and adjusted by the National Geodetic Survey in June 1991.
JU2188
JU2188.This Tidal Bench Mark is designated as VM 381
JU2188.by the Center for Operational Oceanographic Products and Services.
JU2188
JU2188.The geoid height was determined by GEOID03.
JU2188
JU2188.The dynamic height is computed by dividing the NAVD 88
JU2188.geopotential number by the normal gravity value computed on the
JU2188.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
JU2188.degrees latitude (g = 980.6199 gals.).
JU2188
JU2188.The modeled gravity was interpolated from observed gravity values.
JU2188
JU2188;       North  East   Units Estimated Accuracy
JU2188;SPC DE -      172,850.     186,300.     MT (+/- 180 meters Scaled)
JU2188
JU2188                     SUPERSEDED SURVEY CONTROL
JU2188
JU2188.No superseded survey control is available for this station.
JU2188
JU2188_U.S. NATIONAL GRID SPATIAL ADDRESS: 18SVJ505787(NAD 83)
JU2188_MARKER: DJ = TIDAL STATION DISK
JU2188_SETTING: 49 = STAINLESS STEEL ROD W/O SLEEVE (10 FT.+)
JU2188_STAMPING: 1910 C 1979
JU2188_MARK LOGO: NOS
JU2188_PROJECTION: PROJECTING 1 CENTIMETERS
JU2188_MAGNETIC: I = MARKER IS A STEEL ROD
JU2188_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
JU2188_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
JU2188+SATELLITE: SATELLITE OBSERVATIONS - March 09, 2003
JU2188_ROD/PIPE-DEPTH: 9.14 meters
JU2188
JU2188 HISTORY      - Date Condition    Report By
JU2188 HISTORY      - 1979 MONUMENTED   NOS
JU2188 HISTORY      - 1979 GOOD   NGS
```

JU2188 HISTORY - 19950328 POOR NJGS
JU2188 HISTORY - 20010919 GOOD NGS
JU2188 HISTORY - 20030309 GOOD USPSQD

```
JU2188
JU2188                            STATION DESCRIPTION
JU2188
JU2188'DESCRIBED BY NATIONAL GEODETIC SURVEY 1979
JU2188'2.1 MI SE FROM DELAWARE CITY.
JU2188'2.1 MILES SOUTHEAST ALONG STATE ROUTE 9 FROM THE INTERSECTION OF
JU2188'CLINTON STREET IN DELAWARE CITY, THENCE 0.8 MILE NORTH ALONG OLD
JU2188'ROUTE 9, THENCE 0.3 MILE EAST ALONG DUTCH NECK ROAD TO THE MARK ON
JU2188'THE RIGHT, B.M. 1910 C 1979 IS A STANDARD NOS DISK STAMPED 1910 C
JU2188'1979 CRIMPED ON TOP OF 30 FOOT DEEP DRIVEN STAINLESS STEEL ROD
JU2188'SURROUNDED BY 4 INCHES P.V.C. PIPE AND CONCRETE KICK PAD. THE MARK
JU2188'IS 0.2 MILES WEST OF PIER, 22.0 FEET SOUTH OF CENTER OF DIRT ROAD
JU2188'ALONG SOUTH SIDE OF CANAL, 45.0 FEET SOUTH AND IN LINE WITH POWER
JU2188'POLE 85 WITH LIGHT, ABOUT 10 FEET SOUTH OF EDGE OF ROAD AND 6 INCHES
JU2188'ABOVE GROUND.
JU2188'THE MARK IS 1 FT N FROM A WITNESS POST.
JU2188'THE MARK IS ABOVE LEVEL WITH ROAD.
JU2188
JU2188                            STATION RECOVERY (1995)
JU2188
JU2188'RECOVERY NOTE BY NEW JERSEY GEODETIC SURVEY 1995 (ECB)
JU2188'RECOVERED AS DESCRIBED WITH THE FOLLOWING CHANGES. THE DITCH THAT THE
JU2188'STATION IS SET NEAR HAS BEEN WIDENED SINCE THE LAST RECOVERY. THE
JU2188'DISK AND THE ROD WERE FOUND FIRMLY WEDGED AGAINST THE INSIDE OF THE
JU2188'PLASTIC PIPE.
JU2188
JU2188                            STATION RECOVERY (2001)
JU2188
JU2188'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 2001 (JMW)
JU2188'0.8 KM SOUTHWESTERLY ALONG CLINTON STREET FROM THE POST OFFICE IN
JU2188'DELAWARE CITY,
JU2188'THENCE 3.5 KM SOUTHERLY ALONG STATE HIGHWAY 9, THENCE 1.3 KM NORTHERLY
JU2188'ALONG REEDY
JU2188'POINT ROAD, THENCE 0.5 KM EASTERLY ALONG A GRAVELED ROA
```

http://www.ngs.noaa.gov/cgi-bin/ds pid.prl/13/16/2004

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
DATABASE = Sybase PROGRAM = datasheet, VERSION = 6.98
1        National Geodetic Survey,    Retrieval Date = MARCH 16, 2004
JU 2 1 8 9 * * * * * * * * + * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
JU2189 TIDAL BM           - This is a Tidal Bench Mark.
JU2189 DESIGNATION - 855 1910 B TIDAL
JU2189 PID         - JU2189
JU2189 STATE/COUNTY- DE/NEW CASTLE
JU2189 USGS QUAD          - DELAWARE CITY (1993)
JU2189
JU2189   *CURRENT SURVEY CONTROL
JU2189
JU2189* NAD 83(1991)- 39 33 29.67449(N)    075 34 25.05431(W)        ADJUSTED
JU2189* NAVD 88           -         2.366 (meters)     7.76     (feet) ADJUSTED
JU2189   ________________________________________________________________
JU2189 X            -         1,226,760.738 (meters)        COMP
JU2189 Y            -4,768,803.475 (meters)       COMP
JU2189 Z-           4,040,271.335 (meters)        COMP
JU2189 LAPLACE CORR-  -2.93 (seconds)     DEFLEC99
JU2189 ELLIP HEIGHT-  -31.04 (meters)     (02/12/02) GPS OBS
JU2189 GEOID HEIGHT-  -33.39 (meters)     GEOID03
JU2189 DYNAMIC HT -   2.365 (meters)      7.76 (feet) COMP
JU2189 MODELED GRAV- 980,127.1            (mgal)     NAVD 88
JU2189
JU2189 HORZ ORDER - A
JU2189 VERT ORDER - FIRST       CLASS II
JU2189 ELLP ORDER - FOURTH      CLASS I
JU2189
JU2189.This is a reference station for the REEDY POINT 1
JU2189.National Continuously Operating Reference Station (RED1).
JU2189
JU2189.The horizontal coordinates were established by GPS observations
JU2189.and adjusted by the National Geodetic Survey in February 2002.
JU2189
JU2189.The orthometric height was determined by differential leveling
JU2189.and adjusted by the National Geodetic Survey in June 1991.
JU2189
JU2189.This Tidal Bench Mark is designated as VM 376
JU2189.by the Center for Operational Oceanographic Products andServices.
JU 218 9
JU2189 The X, Y, and Z were computed from the position and the ellipsoidal ht.
JU2189
JU2189 The Laplace correction was computed from DEFLEC99 derived deflections.
JU2189
JU2189.The ellipsoidal height was determined by GPS observations
JU2189.and is referenced to NAD 83.
JU2189
JU2189.The geoid height was determined by GEOID03.
JU2189
JU2189.The dynamic height is computed by dividing the NAVD 88
JU2189.geopotential number by the normal gravity value computed on the
JU2189.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
JU2189.degrees latitude (g = 980.6199 gals.).
JU2189
JU2189.The modeled gravity was interpolated from observed gravity values.
JU218.9
JU2189;  North      East       Units Scale Factor Converg.
JU2189;SPC DE             -   172,993.451        186,510.713       MT 0.99999724       -0 05 59.9
JU2189;UTM 18             - 4,378,885.481        450,721.217       MT 0.99962990       -0 21 55.2
JU2189
JU2189!  - Elev Factor x Scale Factor =           Combined Factor
JU2189'3.35 MI SE FROM DELAWARE CITY. JU2189'2.1
```

```
JU2189!SPC DE -      1.00000487 x  0.99999724 =  1.00000211
JU2189!UTM 18        -    1.00000487 x     0.99962990 =     0.99963477
JU2189
JU2189                           SUPERSEDED SURVEY CONTROL
JU2189
JU2189 NAVD 88 (02/12/02)       2.37    (m)            7.8     (f) LEVELING     3
JU2189
JU2189.Superseded values are not recommended for survey control.
JU2189.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
JU2189.See filed data.txt to determine how the superseded data were derived.
JU2189
JU2189_U.S. NATIONAL GRID SPATIAL ADDRESS: 18SVJ5072178885(NAD 83)
JU2189_MARKER: DJ = TIDAL STATION DISK
JU2189_SETTING: 49 = STAINLESS STEEL ROD W/O SLEEVE (10 FT.+)
JU2189_STAMPING: 1910 B 1979
JU2189_MARK LOGO: NOS
JU2189_PROJECTION: PROJECTING 0 CENTIMETERS
JU2189_MAGNETIC: N = NO MAGNETIC MATERIAL
JU2189_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
JU2189_SATELLITE: THE SITE LOCATION WAS REPORTED AS NOT SUITABLE FOR
JU2189+SATELLITE: SATELLITE OBSERVATIONS - March 09, 2003
JU2189_ROD/PIPE-DEPTH: 9.75 meters
JU2189

JU2189 HISTORY         Date      Condition         Report  By
JU2189 HISTORY         1979      MONUMENTED        NOS
JU2189 HISTORY         1979      GOOD              NGS
JU2189 HISTORY        - 19950328 POOR              NJGS
JU2189 HISTORY         20000228  GOOD              NGS
JU2189 HISTORY         20010919  GOOD              NGS
JU2189 HISTORY         20030309  GOOD              USPSQD
JU2189
JU2189                              STATION DESCRIPTION
JU2189

JU2189'DESCRIBED  BY NATIONAL GEODETIC SURVEY 1979
```

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL
DELAWARE

NOAA Chart: 12277	**Latitude:**	**390 33.5' N**
USGS Quad: DELAWARE CITY	**Longitude:**	**750 34.4' W**

To reach the tidal bench marks from the intersection of Clinton Street and State Highway 9 in Delaware City, proceed 3.5 km (2.2 mi) south on Highway 9 over the Reedy Point bridge to South Reedy Point Road, turn right and continue 1.3 km (0.8 mi) to a gravel road that parallels the Chesapeake and Delaware Canal, then turn right and proceed 0.8 km (0.5 mi) to the Corps of Engineers T-pier. The bench marks are along South Reedy Point Road, the gravel road, and State Highway 9. The tide gauge and staff are on the pier, east of the bridge and on the south side of the canal.

TIDAL BENCHMARKS

PRIMARY BENCH MARK STAMPING: R 41 1979
DESIGNATION: R 41

MONUMENTATION: Bench Mark disk VM#: 383
AGENCY: National Geodetic Survey (NGS) PID#: JU2187
SETTING CLASSIFICATION: Bridge pier foundation

The primary bench mark is a disk set in the concrete foundation of the most easterly of the two concrete piers of the first row of bridge piers south of the south bank of the Chesapeake and Delaware canal, 16.70 m (54.8 ft) east of a gravel service road that parallels the bridge, 0.3 m (1 ft) south of the north face of the pier, and 0.02 m (0.8 ft) west of the west edge of the pier.

BENCH MARK STAMPING: 1910 B 1979
DESIGNATION: 855 1910 B TIDAL

MONUMENTATION: Tidal Station disk VM#: 376 AGENCY: National Ocean Survey (NOS) PID#: JU2189 SETTING CLASSIFICATION: Stainless steel rod

The bench mark is a disk located west of the pier on the south side of the dirt road along the canal bank, 129.2 m (424 ft) WSW of the SW corner of the pier, 12.07 m (39.6 ft) south of utility pole number 75 with light, and 6.40 m (21.0 ft) south of the center of the dirt road. The bench mark is 15 cm (0.5 ft) above ground, crimped to a stainless steel rod driven 9.8 m (32 ft) to refusal, and encased in a 4 inch PVC pipe with concrete kickblock.

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL
DELAWARE

NOAA Chart: 12277		**Latitude:**	**39o 33.5' N**
USGS Quad: DELAWARE CITY		**Longitude:**	**750 34.4' W**

TIDAL BENCHMARKS

BENCH MARK STAMPING: 1910 C 1979

DESIGNATION: 855 1910 C TIDAL

MONUMENTATION: Tidal Station disk VM#: 381 AGENCY: National Ocean Survey (NOS) PID#: JU2188
SETTING CLASSIFICATION: Stainless steel rod

The bench mark is a disk located on the south side of the dirt road along the canal bank, 0.3 km (0.2 mi) west of the pier, 13.72 m (45.0 ft) south of utility pole number 85 with light, 6.71 m (22.0 ft) south of the centerline of the dirt road, and 0.61 m (2.0 ft) north of a NOS witness post. The bench mark is 15 cm (0.5 ft) above ground, crimped to a stainless steel rod driven 9.1 m (30 ft) to refusal, and encased in a 4 inch PVC pipe with concrete kickblock.

BENCH MARK STAMPING: 1910 G 1982

DESIGNATION: 855 1910 G

MONUMENTATION:	Tidal Station disk	VM#:	382
AGENCY:	National Ocean Survey (NOS)	PID:	
SETTING CLASSIFICATION:	Stainless steel rod		

The bench mark is a disk set on the south side of the dirt road along the canal bank, on the extended centerline of the wood pier located on the bank, 26.06 m (85.5 ft) SW of a utility pole with light on the east side of the pier, 15.24 m (50.0 ft) south of the SW end of the pier, and 7.01 m (23.0 ft) south of the centerline of the dirt road. The bench mark is 0.3 m (1 ft) below ground, crimped to a stainless steel rod driven 8.8 m (29 ft) to refusal, and encased in a 4 inch PVC pipe with concrete kickblock.

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL
DELAWARE
NOAA Chart: 12277 Latitude: 390 33.5' N
USGS Quad: DELAWARE CITY Longitude: 750 34.4' W

TIDAL BENCHMARKS

BENCH MARK STAMPING: RP 3 1975
DESIGNATION: 855 1910 TIDAL RP 3

MONUMENTATION: Tidal Station disk VM#: 385 AGENCY: National Ocean Survey (NOS) PID#: JU2186
SETTING CLASSIFICATION: Concrete culvert head wall

The bench mark is a disk set in a concrete culvert headwall along the east side of South Reedy Point Road, 147.2 m (483 ft) south of the canal, 50.11 m (164.4 ft) west of bridge pier R38W, and 5.49 m (18.0 ft) east of the centerline of the road.

BENCH MARK STAMPING: RP 5 1975
DESIGNATION: 855 1910
TIDAL RP 5

MONUMENTATION: Tidal Station disk VM#: 386 AGENCY: National Ocean Survey (NOS) PID#: JU_218__5_ SETTING CLASSIFICATION: Concrete culvert head wall

The bench mark is a disk set in a concrete culvert headwall along the west side of South Reedy Point Road, 23.01 m (75.5 ft) NW of bridge pier R53W, 20.42 m (67.0 ft) SW of bridge pier R52W, 6.80 m (22.3 ft) SE of utility pole number DP&L 27, and 6.71 m (22.0 ft) west of the road centerline.

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL DELAWARE
NOAA Chart: 12277 **Latitude: 390 33.5' N**
USGS Quad: DELAWARE CITY **Longitude: 750 34.4' W**

TIDAL BENCH MARKS

BENCH MARK STAMPING: R 72 W
DESIGNATION: 855 1910 R 72 W

MONUMENTATION: Survey disk VM#: 12414
AGENCY: US Army Corps of Engineers (USE)
PID: SETTING CLASSIFICATION: Concrete monument

The bench mark is a disk set in a concrete monument located on the west side of U.S. Highway 9 near the south end of the bridge leading over the canal, 121.3 m (398 ft) NE of the junction of Route 9 and South Reedy Point Road, 59.62 m (195.6 ft) south of the south end of the bridge, 7.19 m (23.6 ft) SW of the centerline of Route 9, and 0.21 m (0.7 ft) west of the curb.

BENCH MARK STAMPING: 1910 H 1997
DESIGNATION: 855 1910 H

MONUMENTATION: Flange-encased Rod VM#: 13758
AGENCY: National Ocean Service (NOS)
PID: SETTING CLASSIFICATION: Stainless steel rod in sleeve

The bench mark is a flange encased rod located on the east side of South Reedy Point Road, 65.2 m (214 ft) south of the stop sign on the east side of the road, 4.50 m (14.8 ft) east of the road centerline, and 0.35 m (1.15 ft) west of a NOS fiberglass witness post. The datum point is the top of a stainless steel rod driven 17.4 m (57 ft) to refusal, in a grease filled sleeve extending to a depth of 1 m (3 ft), and encased in a 5-inch logo cap.

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL
DELAWARE

NOAA Chart: 12277		**Latitude:**	**390 33.5' N**
USGS Quad: DELAWARE CITY		**Longitude:**	**750 34.4' W**

TIDAL BENCH MARKS

BENCH MARK STAMPING: 1910 J 1997
DESIGNATION: 855 1910 J

MONUMENTATION:	Flange-encased Rod	VM#:	13759
AGENCY:	National Ocean Service (NOS)		
PID: SETTING CLASSIFICATION:	Stainless steel rod in sleeve		

The bench mark is a flange-encased rod located on the west side of South Reedy Point Road, 49.25 m (161.6 ft) north of power pole number 29, 33.60 m (110.2 ft) south of the south side of the driveway for the residence at 270 South Reedy Point Drive, 8.20 m (26.9 ft) west of the centerline of South Reedy Point Road, and 6.25 m (20.5 ft) SSE of power pole number 30. The datum point is the top of a stainless steel rod driven 18.0 m (59 ft) to refusal, in a grease filled sleeve extending to a depth of 1 m (3 ft), and encased in a 5-inch logo cap.

BENCH MARK STAMPING: 1910 K 1997
DESIGNATION: 855 1910 K

MONUMENTATION:	Flange-encased Rod	VM#:	13760
AGENCY:	National Ocean Service (NOS)		
PID: SETTING CLASSIFICATION:	Stainless steel rod in sleeve		

The bench mark is a flange-encased rod located on the east side of South Reedy Point Road, 19.30 m (63.3 ft) NE of power pole 6, 9.86 m (32.4 ft) west of the curb on the west side of Highway 9, 7.20 m (23.6 ft) east of the centerline of South Reedy Point Road, and 0.25 m (0.8 ft) west of an orange fiberglass NOS witness post. The datum point is the top of a stainless steel rod driven 11.9 m (39 ft) to refusal, in a grease filled sleeve extending to a depth of 1 m (3 ft), and encased in a 5-inch logo cap.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL
DELAWARE
NOAA Chart: 12277 **Latitude: 390 33.5' N**
USGS Quad: DELAWARE CITY **Longitude: 75o 34.4' W**

TIDAL DATUMS

Tidal datums at REEDY POINT, C&D CANAL based on:

LENGTH OF SERIES: 19 Years
TIME PERIOD: January 1983 - December 2001
TIDAL EPOCH: 1983-2001 CONTROL TIDE STATION:

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (10/25/1980) = 2.707
MEAN HIGHER HIGH WATER (MHHW) = 1.780
MEAN HIGH WATER (MHW) = 1.683
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.905
MEAN SEA LEVEL (MSL) = 0.890
MEAN TIDE LEVEL (MTL) = 0.869
MEAN LOW WATER (MLW) = 0.055
MEAN LOWER LOW WATER (MLLW) = 0.000
LOWEST OBSERVED WATERLEVEL (04/07/1982) = -1.222

Bench Mark Elevation Information	In METERS above:	
Stamping or Designation	MLLW	MHW
R 41 1979	1.620	-0.063
1910 B 1979	3.267	1.584
1910 C 1979	3.148	1.465
1910 G 1982	2.390	0.707
RP 3 1975	1.875	0.192
RP 5 1975	2.324	0.641
R 72 W	5.904	4.221
1910 H 1997	1.784	0.101
1910 J 1997	2.468	0.785
1910 K 1997	2.535	0.852

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Station ID: 8551910 PUBLICATION DATE: 04/21/2003 Name: REEDY POINT, C&D CANAL DELAWARE
NOAA Chart: 12277 **Latitude: 390 33.5' N**
USGS Quad: DELAWARE CITY **Longitude: 750 34.4' W**

DEFINITIONS

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at
National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at
National Geodetic Survey.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

TRIG. LEVELING-ONE OR TWO RODS

Proj. I.D. REEDY POINT BRIDGE

LINE TIE (2 MARK)

B.S. B PT.	B.S.	F.S. PT.	F.S.	F.S. + B.S.	ELEV.
1910 C 1979	D -0.0726	1910 C	D -0.1959		
DIST. 153.750	R -0.0726	DS. 152.916	R -0.1957		
	Mn -0.0726		Mn -0.1958	+0.1232	
	D		D		
	R		R		
	Mn		Mn		
1910 C		1910 B			
	D -0.1437		D -0.0210		
	R -0.1415		R -0.0191		
	Mn -0.1426		Mn -0.0201	-0.1225	
	D		D MEAN	0.1229	
	R		R FWD / REV		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
TARGET HEIGHT	CALIBRATION		Mn		
ROD 1	D ROD 2		D		
D -0.1143	R -0.1147		R		
R -0.1150	Mn -0.1147		Mn		
-0.11465	-0.1147	0.0005			
	D		D		
	R		R		
	Mn		Mn		

REMARKS

OVERCAST/COOL 1015
29.98 IN. 3/17/04
35.0 F
~~+10PPM~~
-10.9 PPM

33 MM ALLWD

C-B = +0.12010
C/B -0.1232 Trig Obs
.0031 MM ✓

B-C = +0.12010
B/C 0.1225
✓ .0024

WATER LEVEL STATION SITE REPORT

CO-OPS Form FODSR12-00f

SITE NAME **Reedy Point, DE**	**SITE ID NUMBER** **85519101**	**DATES VISITED** **6/11-12/03**

Established		Inspected	x	Repaired		Removed		**Team Leader**	**Rick James**

Latitude 39 33 30 N	Longitude 075 34 24 W	Time Meridian 75 W	**Other Team Members**	**Oliver Jones** **Dave Hatcher**

Station Owner and Local Contact Information	FOD Approval (signature)	Date	CO-OPS Review	Date

Facility US Corps Of Engineers Pier	Owners Name US Corps of Engineers	Station/Owner Street Address US Corps of Engineers

Owner Work Phone 410-885-5621	Owner Home Phone N/A	Owner E-Mail N/A	City Chesapeake City	State MD	Zip 21915

Local Contact N/A	Local Contact Street Address N/A	City N/A	State N/A	Zip N/A

Local Contact Home Phone N/A	Local Contact Work Phone N/A	E-Mail N/A	Date Last Trained N/A

Remarks: The station is located on the east end of the C&D canal just across the canal from Delaware city, DE. Well is on the Corps dock and the shelter is across the dirt road set on a concrete pad with chain link fence around it. THIS STATION IS PART OF THE DELAWARE PORTS

Equipment Shelter	Shelter Type 4'x6'x7' fiberglass building	Install Date 06/01/94	Lock Type combo	Power Supply ac/solar	Shelter Phone 302-832-2869

Remarks: The shelter is a 4'x6'x7' white fiberglass building which is located across the road from the pier secured to pressure treated wood frame, elevated three feet above and anchor bolted to a 10'x10'16" concrete pad. The shelter is surrounded by a 6' chain link fence. The gate lock combo and the shelter lock combo are 1910. Phone line in house and NOS sign on door. Station also has AC power. Phone surpressor was installed this inspection.

Wells/ Sump Description	Well	Dia.	Length	Material	Intake Type	Install Date	# Brackets
	aquatrak	6"	6.100 m	sch. 80 pvc	2" brass	06/15/94	3

Top Hat Type:	yes	Parallel Plate (y/n):	yes	Winterized (y/n):	no
Copper Insert (y/n):	yes	Well Pumped (y/n):	no	Heater Setting (F):	n/a

Brckt/Valve Description:

Remarks: The 6" aquatrak well is secured to a pier piling on the west side of the pier about 10' south of the T section. The well is secured with a s/s face clamp about five feet down from the top flange and two s/s long arm pile clamps about five feet apart below the face clamp. New T1 was run under pier and into house, 200 ft in length.

Permanent Station Inspection Notes (Pre-Visit Notification, Items stored in Enclosure, etc..)

This is a Ports site and CORMS must be notified before work is performed. AC power only works at night

Work Requests for Next Annual O&M

Crew fixed well temp problem but the cause of the problem is the A/C power which runs through the same conduit as our cables. The wires for the A/C power are shorting out and melting our cables to the aqua trak well and need to be fixed ASAP or more problems will occur.

Sutron 9000 -Vitel DCP	Type of DCP	DCP s/n	Install Date	OpSysVers	SDL Vers.	Battery Date	DCP Phone	
	Sutron 9000	91010	06/20/94	2.5 F	RKS 1.00X	09/12/02	302-832-2869	
Battery Type	Power Sup	Satellite	CCM	GPIO	Mem Exp	CPU	Modem	Aquatrak
12v 40 ahr	89518	88176	88040	911085	88003	910397	90659	90121
Backplane	Transition	Termination	AC/Step	VITEL DCP s/n		CPU	Mod Voice	Data Card
91037	91020	91005	91015					

Desicant (y/n): yes	DCP Attachment Description	Term board was replaced, 9000 was hit by lightning through phone line
Solar (y/n): yes		
AC (y/n): yes		

Remarks 9000 unit is mounted to a 3/4" backing board which is secured to the back wall of the gagehouse. All board serial numbers were checked. New desicant was installed thhis inspection.

Sutron 8200/8210	DCP s/n	Install Date	Prog Vers.	Pwr Source	Tiny Basic Version	Battery Type	Battery Date	Amp Gain
8200/82107	91038	06/20/94	2.1	12v / solar		12v 24ahr	06/27/00	46.57
8200 Primary(y/n)	CPU s/n	Modem s/n	GOES s/n	Intercon s/n	Sensor Slope	TSU Ram pack installed (y/n): no Spare TSU Ram pack in TH (y/n): no Desicant changed (y/n): ycs		
no	88052	N/A	N/A	88092	348			

Remarks The sutron 8200 is mounted to the backing board next to the 9000 unit. New guts were installed in the 8200 this inspection. Desicant was also changed.

Aquatrak Sensor	Install Date	Aq. Hd. s/n	CalTube s/n	Sens Offset	Sndg Tube L	Brass Tube	T1/T2 Sep	# Bails
	6/11/2003	1271-3510	1322	1.1098	6.025	0.914	1.524	4
Aquatrak changed (y/n): ycs	Sounding Tube Test							C 1 Entered
	Display	+ Coeff 1	= Sum	- S Tube L	= Difference*	* Allowable Tolerance is +/- 0.06 M or 0.2 ft		
	4.875	1.110	5.985	6.025	-0.040			1.11

Remarks A California leveling plate was installed on well. New head and cal tube installed (old style) Sounding tube was cleaned and ping tested good. COE 1 was changed to 1.110 @ 0950 edt on 6/11/03

Paros/ Digiquartz	N1 s/n	Install Date	Model	Range	Vent	Flow	Feed	NOTE: N1 is the primary lower orifice. T1 is secondary upper orifice.
Orifice Delta	T1 s/n	Install Date	Model	Range	Vent	Flow	Feed	

Remarks

Backup Sensor	Manufacture	Sensor s/n	Install Date	Snsr Config	ManifoldTyp.	Tank PSI	Feed Psi	Flow Rate
	IMO	L401391	06/20/94	bubbler	dry purge	2125	10	5
	High Press Manufact.	N_2 High Press s/n	Install Date	Coeff 1	Coeff 2	Below ETG (GL)		
	Barksdale	20227	09/12/02	3000	3			

Remarks IMO pressure sensor is Teed into the bubbler tubing inside the gage shelter. Sensor was checked for leaks, none found. Tank was not changed

GOES & Antenna	GOES ID#	Channel	Xmit Time	Xmit Interval	Xmit Power	Antenna s/n	Azimuth	Elevation
	334BB742	117E	0:37:03	1 hour	42	90021	215	41 degrees
	GMT Time Offset: 5		Cable Leng: 30'		Cable Type:		Mag Var:	

Remarks The goes antenna is mounted on the gagehouse roof with standard alum. bracket and s/s hardware.

Solar Panels	Purpose	Panel s/n	Install Date	Angle	Watts	Cable L	Remarks
	9000	FW94D28479113	06/22/94	45	30	30'	Both panels are mounted on the tidehouse roof with standard alum brackets and s/s carriage head bolts.
	8200	JP93I250000000	06/20/94	45	15	20'	
	LS RADIO	5132	09/12/02				

Ancillary Sensors	Air Temp N/A	Manufact.	Install Date	Coeff 1	Water Temp yes	Manufact. ysi	Install Date 07/16/98	Coeff 1 "2.9400"
Remarks	Water temp. probe is attached to the sounding tube at the bottom with plastic wire ties.							

Wind	Manu/Model N/A	Install Date	Coeff 1	Coeff 2	Cable Leng.	Height 21 ft	Mast Type shakespeare	Install Date 07/16/98
Remarks								

Barometer N/A	Manufact.	Install Date	PBM//SD	Baro//PBM	MSL//SD	Baro//MSL 0.000	Elev Corr. 0.000	Cal Corr.
Total Corr. 0.000	Coeff. # 2 0.000	Barometer Calibration	Time	Baro	Portable	Difference	If the difference exceeds +/- 1.0 mBar replace the barometer. If the difference is < 1.0mBar, but >0.3mBar, then apply elevation & calibration corrections & input new Coeff 2	
						0.000		
Remarks						0.000		

Conductivity	Manufact.	Install Date	Coeff 1	Coeff 2	Coeff 3	Sensor Cleaned (y/n)		Initial Rdg.
Initial Temp	I Loop 1	I Loop 2	I Loop 3	F Loop 1	F Loop 2	F Loop 3	Final Rdg.	Final Temp
Remarks								

Visibilty	Manufact.	Install Date	Cal. Date	Height	
Remarks					

Rain Guage	Manufact.	Install Date	Coeff 1	Coeff 2	
Remarks					

Dissolved O_2	Manufact.	Install Date	Coeff 1	Coeff 2	
Remarks					

Other	Serial #	Manufact.	Install Date	Coeff 1	Coeff 2	
Remarks						

Remarks	A fiberglass pole 21' high was installed with alum. base plate, anchor bolted into the concrete pad surrounding gagehouse. Pole has four 30 watt panels mounted w/ alum. brackets and s/s u-bolts. Two radio antenna,s are mounted on the top of pole which has alum. goalpost.

Tests	**Temp Sensor Test**					**Backup Pressure Sensor Test**					
Time	T 1	T 2	TA	TB	TW	Time	Sensor	Time	Sensor	Time	Sensor

T1 = Upper, T2 = Lower, TA = air, TB = backup, TW = water If the differential exceeds +/- 1.0 degree C, consult HQ. The average difference between sensor should be within +/- 0.3 degree C.

GOES Xmlt Test					
	Wattmeter	FWD	REF	Loop 1	Loop 2
DCP					
Antenna					

Note: If power at antenna is less than 7 watts, or there is significant line loss contact HQ. Significant line loss is defined as more than 3 watts per 10 meters of line

Dive Report	Station Inspected (y/n)	No	Divers:	
	Intake Cleaned (y/n) no	Marine Fouling Potential (H/M/L): L		Intake Elevation:
Remarks	No dive was made well was found to be clean.			

Shaft Angle Encoder	SAE s/n	Install Date	Float Dia	Tape Leng	Current Disp	Current ETG	ETG-Display	ResetC2(y/n)
							0.000	

Initial Encoder Setup			Remarks
Display	- ETG =	S14 Coeff 2	
		0.000	

Water Transfer	Hydraulic Corrector	Retained ZETG	Valve Elev	Reference Gauge Readings				
					ETG	Spike	Other	Difference*
				HydCor Zero				* The difference between Tape & Spike.
Remarks				Readings				
				Wtr Surface	0.000	0.000	0.000	0.000

ETG Description	
Spike Description	

Levels/ Surveying	Date	Datum	PBM Stamping	PBM Elev
	06/11/03	station	R 41	2.0310

Instrument Number	Rod 1 s/n	Rod 2 s/n	C-Shot Coeff	Downshot Req'd(y/n):	no
91612	25238	25904	-3.9	# of Marks Established:	0

Instrument Operator	Rodman 1	Rodman 2	# of Marks Recovered:	8
Rick James	Oliver Jones	Dave Hatcher	# of Marks Connected:	8

Aquatrak Coefficient Calculations

Aq Coeff 2A PBM above Site Datum (HQ #11)	Aq Coeff 2B Leveling Pt above PBM from Levels	Aquatrak Coeff 2 (2A+2B=2)	Accepted Coeff 2	Difference (change if >+/- 0.006M)
2.03100	3.11605	5.14705	5.14800	-0.00095

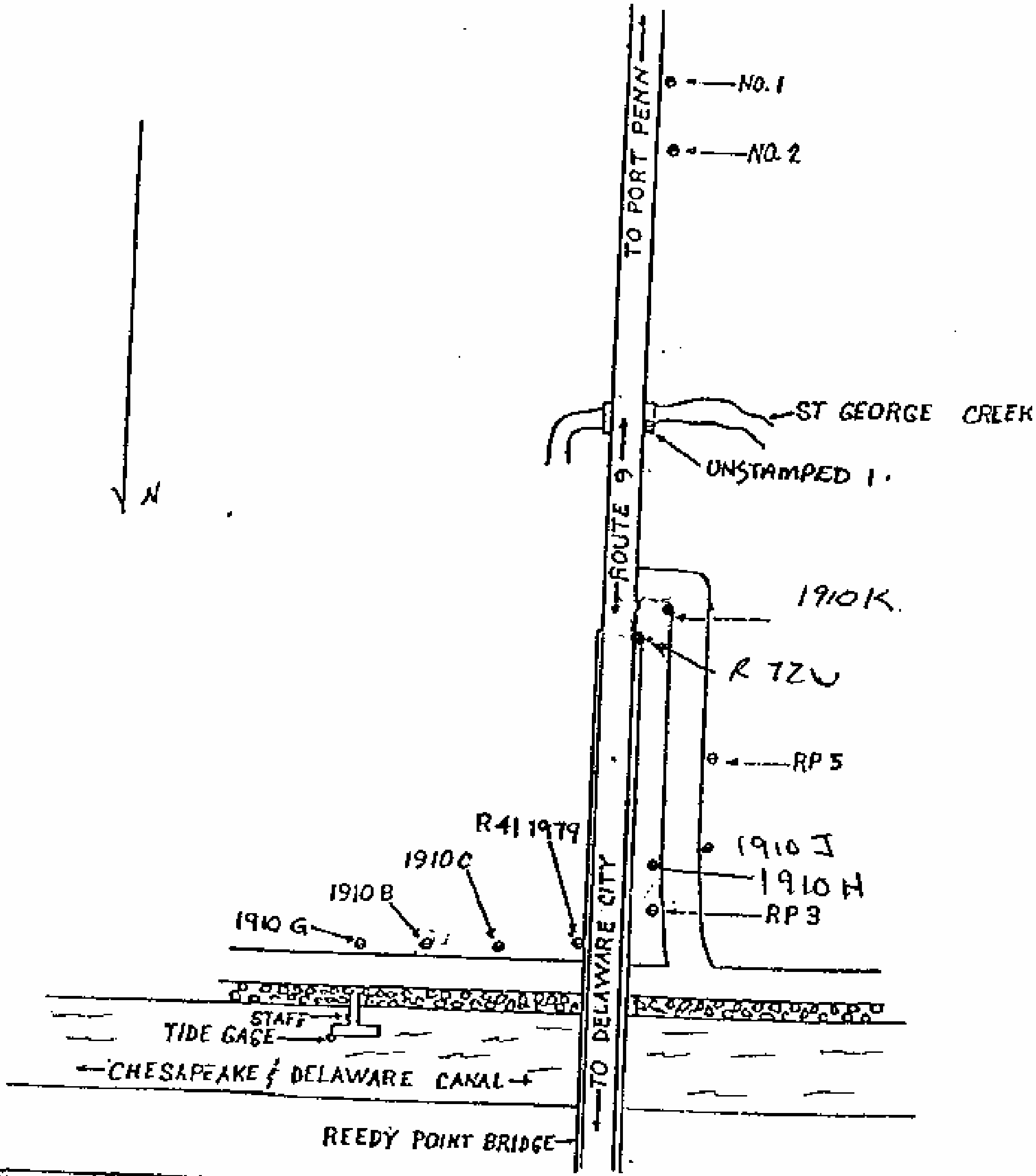
Coeff 2 Changed (y/n): no **New Value:** **Date:** **Time:**

Ref Gauge or BM	Latest Inspection	Present Inspection	Change	Recovered(y/n)
ETG			0.00000	
SPIKE			0.00000	
AQUATRAK	5.14370	5.14705	-0.00335	Y
R 41 PBM	2.03100	2.03100	0.00000	Y
RP 3	2.28650	2.28642	0.00008	Y
1910 C	3.55910	3.55897	0.00013	Y
1910 B	3.67859	3.67907	-0.00048	Y
1910 G	2.80120	2.80121	-0.00001	Y
RP5		2.73546	-2.73546	Y
1910 J		2.87817	-2.87817	Y
1910 K		2.94313	-2.94313	Y
			0.00000	N
			0.00000	N

GPS	Benchmark	GPS Elev.	Level Elev.	Difference	Benchmark	GPS Elev.	Level Elev.	Difference
				0.00000				0.00000
				0.00000				0.00000
				0.00000				0.00000
				0.00000				0.00000
				0.00000				0.00000
Remarks	All bench marks recovered were recovered in good condition, 1910 H and RP 72 W are destroyed							

Miscellaneous Comments (Station History,Motel Contacts, etc...)

Two of the solar panels on the fiberglass pole,serial numbers I0106291842407 and I0105041768934 are for the current meter batteries and the other two panels, serial numbers I0106291842373 and I0105041768937 are for the LOS radio antenna batteries.



MA FORM 76-186
[illegible]

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

BENCHMARK SKETCH

STATION NAME REEDY POINT DB	FIELD UNIT SLP 1 MJM	DRAWN BY M. McGOURTY	DATE 9-83
	STATION NO. 855-1910	REVISED BY B. WYNN	DATE 9/87
		REVISED BY	DATE
		REVISED BY	DATE

```
                         8551910.ABS
    ABSTRA Version 5.21 -- October 1991  Wed Jun 11 19:03:57 2003


                               -*- FIELD ABSTRACT -*-
030611-030611         HGZ L26421  2     6.0 MM ORDER 2 CLASS 1     PAGE  1
2003 LEVELING TO TIDE STATIONS IN DELAWARE
855 1910 REEDY POINT

        FROM              START   F/B  DIST    ELEV DIFF       -(F+B)  MEAN DIFF   I
           TO                          TOTAL                    TOTAL  FLD ELEV    C
                                       (KM)      (MT)           (MM)    (MT)

 0211 R 41                                                              2.03100
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0211 R 41                6111445 F    0.24    0.25503  *@   0.77       0.25542  1
 0215 855 1910 TIDAL R    6111627 B    0.24   -0.25580  *@                       1
                               SL 1    0.24                  0.77       2.28642
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0215 855 1910 TIDAL R    6111456 F    0.42    0.59278  *@  -2.06       0.59175  1
 0217 855 1910 J          6111609 B    0.42   -0.59072  *@                       1
                               SL 1    0.66                 -1.29       2.87817
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0217 855 1910 J          6111515 F    0.16   -0.14265  *@  -0.12      -0.14271  1
 0218 855 1910 TIDAL R    6111602 B    0.16    0.14277  *@                       1
                               SL 1    0.82                 -1.41       2.73546
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0218 855 1910 TIDAL R    6111522 F    0.62    0.20806  *@  -0.78       0.20767  1
 0219 855 1910 K          6111544 B    0.62   -0.20728  *@                       1
                               SL 1    1.44                 -2.19       2.94313
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0211 R 41                6111422 B    0.48   -1.52681  *@  -2.32       1.52797  1
 0214 855 1910 C TIDAL    6111637 F    0.51    1.52913  *@                       1
                                       0.48                 -2.32       3.55897
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0214 855 1910 C TIDAL    6111407 B    0.31   -0.11958  *@  -1.03       0.12010  1
 0213 855 1910 B TIDAL    6111657 F    0.31    0.12061  *@                       1
                                       0.80                 -3.35       3.67907
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0213 855 1910 B TIDAL    6111358 B    0.14    0.87792  *@  -0.12      -0.87786  1
 0212 855 1910 G          6111711 F    0.13   -0.87780  *@                       1
                                       0.93                 -3.47       2.80121
-- -- -- -- -- -- -- -- -- -- --       -- --  -- -- -- -- --  -- -- --  -- -- --
 0212 855 1910 G          6111346 B    0.04   -2.34560  *@  -0.48       2.34584  1
 0208 TBM 855 1910 AQU    6111352 F    0.04    2.34608  *@                       1
                                       0.98                 -3.95       5.14705
       ELEVATION REJECTION AND ERROR CODES

C - section elevation difference was rejected for cause
    ie. *43* record rejection code set to "F"
R - section elevation difference was rejected by Halperin rejection algorithm
@ - section elevation difference does not include refraction correction
* - section elevation difference does not include rod correction


  INSTRUMENT CODE       INSTRUMENT              RODS

           1          243 - 91612    396 - 25238     396 - 25904

                          LEVEL LINE SECTION RUNNING TREE

  0211 (0215
        0217
        0218
                                   Page 1
```

******* RECOVERY DESCRIPTION*******

SSN: 0211
Designation: R 41
PID: JU2187
Approx. Latitude: 393326N State: DE
Approx. Longitude: 0753455W County:
NEW CASTLE
Approx. Elevation: 0.714M Disk From: NATIONAL GEODETIC SU
Stamping: R 41 1979

Surface Mark
Type: Bench Mark disk
Magnetic code: N
Setting: BRIDGE PIER FOUNDATION
Rod depth: Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI)SE FROM DELAWARE CITY, ALONG THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL AT THE STATE ROUTE 9 BRIDGE, THE PRIMARY BENCH MARK IS SET IN THE CONCRETE FOUNDATION OF THE MOST EASTERLY OF THE TWO CONCRETE PIERS OF THE FIRST ROW OF BRIDGE PIERS SOUTH OF THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, 16.70 M (54.79 FT) EAST OF A GRAVEL SERVICE ROAD THAT PARALLELS THE BRIDGE, 0.3 M (1.0 FT) SOUTH OF THE NORTH FACE OF THE PIER, AND 0.02 M (0.07 FT) WEST OF THE WEST EDGE OF THE PIER.

********* RECOVERY DESCRIPTION*********

```
            SSN:  0212
    Designation:  855 1910 G
            PID:
Approx. Latitude:   393328N                 State: DE
 Approx. Longitude:  0753416W                County: NEW CASTLE
 Approx. Elevation:                          Disk From: NATIONAL OCEAN SURVEY
       Stamping:  1910 G 1982

    Surface Mark
           Type:  Tidal Station disk
  Magnetic code:  N
        Setting:  STAINLESS STEEL ROD
      Rod depth:  8.8                                  Sleeve Depth:
```

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS SET ON THE SOUTH SIDE OF THE DIRT ROAD ALONG THE CANAL BANK, ON THE EXTENDED CENTERLINE OF THE WOOD PIER LOCATED ON THE BANK, 26.06 M (85.50 FT) SW OF A UTILITY POLE WITH LIGHT ON THE EAST SIDE OF THE PIER, 15.24 M (50.00 FT) SOUTH OF THE SW END OF THE PIER, AND 7.01 M (23.00 FT) SOUTH OF THE CENTERLINE OF THE DIRT ROAD. THE BENCH MARK IS 0.3 M (1.0 FT) BELOW GROUND, CRIMPED TO A STAINLESS STEEL ROD DRIVEN 8.8 M(28.9 FT) TO REFUSAL, AND ENCASED IN A 6 INCH PVC PIPE WITH CONCRETE KICKBLOCK.

******* RECOVERY DESCRIPTION*******

SSN: 0213
Designation: 855 1910 B TIDAL
PID: JU2189
Approx. Latitude: 393327N
Approx. Longitude: 0753423W
Approx. Elevation: 2.366M
Stamping: 1910 B 1979

State: DE
County: NEW CASTLE
Disk From: NATIONAL OCEAN SURVEY

Surface Mark

Type:TidalStation
disk Magnetic code:N
Setting: STAINLESS STEEL ROD

Rod depth: 9.
Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED WEST OF THE PIER ON THE SOUTH SIDE OF THE DIRT ROAD ALONG THE CANAL BANK, 129 M (423.2 FT) WSW OF THE SW CORNER (OF THE PIER, 12.07 M (39.60 FT) SOUTH OF UTILITY POLE NUMBER 75 WITH LIGHT, 6.40 M (21.00 FT) SOUTH OF THE CENTER OF THE DIRT ROAD. THE BENCH MARK IS 0.15 M (0.49 FT) ABOVE GROUND, CRIMPED TO A STAINLESS STEEL ROD DRIVEN 9.8 M (32.2 FT) TO REFUSAL, AND ENCASED IN A 5 INCH PVC PIPE WITH ALUMINUM ACCESS COVER AND CONCRETE KICKBLOCK.

```
   ******* R E C O V E R Y                     D E S C R I P T I O N*******

              SSN: 0214
      Designation: 855 1910 C TIDAL
              PID: JU2188
Approx. Latitude: 393325N                    State: DE
Approx. Longitude: 0753434W                  County: NEW CASTLE Approx.
Elevation: 2.244M                            Disk From: NATIONAL OCEAN SURVEY
         Stamping: 1910 C 1979

      Surface Mark
             Type: Tidal Station disk
     Magnetic code: N
          Setting: STAINLESS STEEL ROD
        Rod depth: 9.1                              Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.
```

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH BANK OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE SOUTH SIDE OF THE DIRT ROAD ALONG THE CANAL BANK, 0.3 KM (0.20 MI) WEST OF THE PIER, 13.72 M (45.01 FT) SOUTH OF UTILITY POLE NUMBER 85 WITH LIGHT, 6.71 M (22.01 FT) SOUTH OF THECENTERLINE OF THE DIRT ROAD, AND 0.61 M (2.00 FT) NORTH OF A NOS WITNESS POST. THE BENCH MARK IS 0.15 M (0.49 FT) ABOVE GROUND, CRIMPED TO A STAINLESS STEEL ROD DRIVEN 9.1 M (29.9 FT) TO REFUSAL, AND ENCASED IN A 5 INCH PVC PIPE WITH ALUMINUM ACCESS COVER AND CONCRETE KICKBLOCK.

******* RECOVERY DESCRIPTION*******

SSN: 0215
Designation: 855 1910 TIDAL RP 3
PID: JU2186
Approx. Latitude: 393322N
State: DE
Approx. Longitude: 0753453W
County: NEW CASTLE
Approx. Elevation: 0.969M
Disk From: NATIONAL OCEAN SURVEY
Stamping: RP 3 1975

Surface Mark
Type: Tidal Station disk
Magnetic code: N
Setting: CULVERT HEADWALL
Rod depth:
Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS SET IN A CONCRETE CULVERT HEADWALL ALONG THE EAST SIDE OF SOUTH REEDY POINT ROAD, 147 M (482.3 FT) SOUTH OF THE CANAL, 11 M (164.40 FT) WEST OF BRIDGE PIER R38W, AND 5.49 M (18.01 FT) EAST OF THE CENTERLINE OF THE ROAD.

******* RECOVURY DESCRIPTION*******

SSN: 0216
Designation: 855 1910 H
PID:
Approx. Latitude: 393323N
Approx. Longitude: 0753458W
Approx. Elevation:
Stamping: 1910 H 1997

State: DU
County: NEW CASTLE
Disk From: NATIONAL OCEAN SURVEY

Surface Mark
Type: Flange-encased Rod
Magnetic code: N
Setting: STAINLESS STEEL ROD IN SLEEVE
Rod depth: 17.4 Sleeve Depth: 1

Mark condition reported *in* descriptive text by - NOS *on* 06112003, chief of party

THIS MARK WAS NOT RECOVERED AND IS BELIEVED DESTROYED

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE AND DELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE EAST SIDE OF SOUTH REEDY POINT ROAD, 65.2 M (213.9 FT) SOUTH OF THE STOP SIGN ON THE EAST SIDE OF THE ROAD, 4.50 M (14.76 FT) EAST OF THE ROAD CENTERLINE, AND 0.35 M (1.15 FT) WEST A NOS FIBERGLASS WITNESS POST. THE DATUM POINT IS THE TOP OF A STAINLESS STEEL ROD DRIVEN 17.4 M (57.1 FT) TO REFUSAL, IN A GREASE FILLED SLEEVE EXTENDING TO A DEPTH OF 1 M (3.3 FT) , AND ENCASED IN A 5-INCH LOGO CAP.

******* RECOVERY DESCRIPTION *******

SSN: 217
Designation: 855 1910 J
PID:
State: DE
County: NEW CASTLE
Disk From: NATIONAL OCEAN SERVICE

393330N

Approx. Latitude:0753424W
Approx. Longitude:1910 J 1997
Approx. Elevation:
Stamping:

Surface Mark Flange-encased Rod
Type:
Magnetic code: N

Setting: STAINLESS STEEL ROD IN SLEEVE
Rod depth: 18.0 Sleeve Depth: 1

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE ANDDELAWARE CANAL, THE BENCH MARK IS LOCATED ON THE WEST SIDE OF SOUTH REEDY POINT ROAD, 49.25 M (161.58 FT) NORTH OF POWER POLE NUMBER 29, 33.60 M (110.24 FT) SOUTH OF THE SOUTH SIDE OF THE DRIVEWAY FOR THE RESIDENCE AT 270 THE REEDY POINT DRIVE, 8.20 M (26.90 FT) WEST OF THE CENTERLINE OF SOUTH REEDY POINT ROAD, AND 6.25 M (20.51 FT) SSE OF POWER POLE NUMBER 30. THE DATUM POINT IS THE TOP OF A STAINLESS STEEL ROD DRIVEN 18.0 M (59.1 FT) TO REFUSAL, IN A GREASE FILLED SLEEVE EXTENDING TO A DEPTH OF 1 M (3.3 FT) , AND ENCASED IN A 5-INCH LOGO CAP.

******* RECOVERY DESCRIPTION *******

SSN: 0218
Designation: 855 1910 TIDAL RP 5
PID: JU2185

Approx. Latitude: 393304N
Approx. Longitude: 0753449W
Approx. Elevation:

State: DE
County: NEW CASTLE
Disk From: NATIONAL OCEAN SURVEY

Stamping: RP 5 1975

Surface Mark
Type: Tidal Station disk Magnetic code: N
Setting: CONCRETE CULVERT HEADWALL
Rod depth: Sleeve Depth:

Recovered in Good condition by - NOS on 06112003, chief of party RDJ.

RAD 6/11/03

4.7 KM (2.90 MI) SE FROM DELAWARE CITY, ON THE SOUTH SIDE OF THE CHESAPEAKE ANDDELAWARE CANAL, THE BENCH MARK IS SET IN A CONCRETE CULVERT HEADWALL ALONG THE WEST SIDE OF SOUTH REEDY POINT ROAD, 23.01 M (75.49 FT) NW OF BRIDGE PIER R53W, 20.42 M (66.99 FT) SW OF BRIDGE PIER R52W, 6.80 M (22.31 FT) SE OF UTILITY POLE NUMBER DP+L 27, AND 6.71 M (22.01 FT) WEST OF THE ROAD CENTERLINE.

TRIG. LEVELING-ONE OR TWO RODS

3-18-04

Proj. I.D. CHESAPEAK CITY BRIDGE- MIROS

27.8397m B.S. PT.	B.S.	26.9956 F.S. PT.	F.S.	F.S. + B.S.	ELEV.
U 2	D +0.7538	TIDAL 3	D +0.9821		+0.22726 ⊛
	R +0.7534		R +0.9798		
	Mn +0.7536		Mn +0.9810~~75~~		+0.2274
			33		
	D		D		+0.0001 ✓
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		

REMARKS

2 mark tie

ppm - 10.5
start - 1021 mb @0930
3.9°C

⊛ ~~Observ~~ obs. elev. dif. from leveling

TRIG. LEVELING-ONE OR TWO RODS

Proj. I.D. CHESAPEAK CITY BRIDGE MIROS 3-18-04 Pa

PTLY CLDY/COOL

START 1100 B.S. PT.	B.S.	F.S. PT.	F.S.	F.S. + B.S.	ELEV.
TIDAL 3	D +0.5455	MIROS	D + 42.7988		TIDE 3 - 2.455 ML
	R+ 0.5385	7. BRAKET	R + 42.7867	121	
	Mn+ 0.5420		Mn ~~42.78735~~		
TIDAL 3		MIROS	+ 42.79275		
	D+0.5415	BRAKET	D+42.7976		
225	R+0.5370		R+42.7786	~~19~~85.5762	
	Mn+0.5392		Mn ~~42.783~~ +		
TIDAL 3		MIROS	42.7881		
	D 0.5432	BRAKET	D+42.7951		
	R 0.5320	1.0752	R+42.7704	85.5655	
	Mn 0.5376	.5376	Mn 42.78275	42.78275	
TIDAL 3	~~0.5488~~	MIROS			
	D+ 0.5488	BRAKET	D+ 42.8026		
	R+ 0.5399	1.0887	R+ 42.7794	85.5820	
	Mn+ 0.544354		Mn+ 42.7910		
TIDAL 3		MIROS			
	D+ 0.5447	BRAKET	D+ 42.7971		
	R+ 0.5403	1.0850	R+42.7834	85.5805	
	Mn 0.5425		Mn 42.79024		
STOP - ΣMN	- 0.5412	ΣMN	42.7890		42.2478
	D		D		
	R		R		
START-1135	Mn		Mn		
MIROS		TIDAL 3			
BRAKET	D+42.8563	~~BRAKE~~	D +0.6076		
	R+42.8461	85.7024	R +0.6048	1.2124	
	Mn 42.8512		Mn+ 0.6062	42.2450	
MIROS		TIDAL 3			
BRAKET	D+42.8636		D+0.6100		
	R+42.8427	85.7043	R+0.6016	1.2116	
	Mn+42.85325		Mn+ 0.6058	42.2475	
MIROS		TIDAL 3			
BRAKET	D + 42.8638		D+ 0.6093		
	R + 42.8419	85.7057	R+ 0.6016	12109	
	Mn+ 42.85285		Mn+ 0.60545		
MIROS		TIDAL 3			
BRAKET	D+42.8581		D+0.6066		
	R+42.8427	85.7008	R+0.5997	12063	
	Mn+42.8504		Mn+0.60315		
MIROS		TIDAL 3			
BRAKET	D+42.8610		D+0.6096		
	R+42.8446	85.7056	R+0.6039	12 135	
	Mn 42.8528		Mn 0.60675		42.2466

STOP-1225 42.8521 REMARKS 0.6055

DISTANCE π → TIDAL 3 → 185.6001

π → MIROS → 385.2348

Set 1, TIME - 1055
TEMP 6.8C
BARO 1021 MB
PPM -7.5

~~1135~~
SET 2 - TIME - 1135
TEMP 7.0
BARO 1021
PPM -7.5

MN R21
42.8204
- 0.42.2472
TIDAL 3 2.455
44.7022

TRIG. LEVELING-ONE OR TWO RODS

Proj. I.D. CHESAPEAK CITY BRIDGE MIROS 3-18-04 Pa

B.S. PT.	B.S.	DIST → F.S. PT.	385.2348 M F.S.	F.S. + B.S.	ELEV.
TIDAL 3	D	MIROS	D+42.8914		
	R	LABEL	R+42.8765	85.7679	
	Mn		Mn+42.88395		
	D	MIROS	D+42.8921		
	R	LABEL	R+42.8753	85.7674	
	Mn		Mn 42.8837		
			(42.8838)		
	D		D		
	R		R		
	Mn		Mn	+42.8838	MN
			TIDAL 3	2.455	
	D		D	45.3388	
	R		R		
	Mn		Mn		
		BOTTOM of			
	D	NAV LITE	D+41.6340		
	R		R+41.6277	83.2617	
	Mn		Mn 41.63085		
	D		D+41.6483		
	R		R+41.6556	83.2639	
	Mn		Mn 41.63195		
			(41.6314)	~~83.2628~~	
	D		D	41.6314	
	R		R		
	Mn		Mn		
		LOW STEEL			
	D		D + 4~~1~~2.0003		
	R		R+41.9671	83.9674	
	Mn		Mn 41.9837		
			9956		
	D		D +41.~~9693~~		
	R		R+41.9693	83 9649	
	Mn		Mn 41.98245		
	D		D 41.9831		
	R		R		
	Mn		Mn		
	D		D		
	R		R		
	Mn		Mn		

REMARKS

~~3.1~~CM Diff for BRAKET/LABEL
317

~~MIRROS~~ elev. MEAN ~~Σ sum~~ @

MIRROS BRACKET elev. ~~MEAN Σ sum~~ ~~44.7022~~ ~~42.8528~~

MIRROS ~~45.3388~~ ~~42.8838~~

-0.0310 (44.7022 + 0.0310) - 44.7332

NAV LIGHT - 43.4808

WATER LEVEL STATION SITE REPORT

CO-OPS Form FODSR12-00f

SITE NAME **Chesapeake City, MD**	**SITE ID NUMBER** **857-3927**	**DATES VISITED** **08/20-23/03**

Established	X	Inspected		Repaired		Removed		**Team Leader**	**Stepnowski**

Latitude N 39 31 39	Longitude W 075 48 35	Time Meridian 75 W	**Other Team Members**	**Metzger**

Station Owner and Local Contact Information	FOD Approval (signature)	Date	CO-OPS Review	Date

Facility C.O.E. Chesapeake City	Owners Name US. Army Corps of Engineers	Station/Owner Street Address 815 Bethel Rd

Owner Work Phone (410) 885-5621	Owner Home Phone	Owner E-Mail	City Chesapeake City	State MD	Zip 21915

Local Contact Mr. Doug Patterson	Local Contact Street Address SAME AS ABOVE	City	State	Zip

Local Contact Home Phone	Local Contact Work Phone	E-Mail	Date Last Trained

Remarks: The tide station is located at the west end of the Coprs of Engineers Base Chesapeake City. Field crew should call base before going to site to perform any work.

Equipment Shelter	Shelter Type 6'x6'x7' Fiberglass Enclosure	Install Date 08/20/03	Lock Type Combo 1807	Power Supply AC**/ Solar	Shelter Phone (410) 885-5174

Remarks: ** AC Power is on only at night, AC is tied in the light system for the base and is operated by a photo-cel. The 6'X6' fiberglass enclosure is secured to a 6'x6'x2" aluminum frame frame that is secured to a 10'x7'x9" concrete foundation with 4 5"x3/4" S/S wedge anchors. The enclosure is located at the west end of the COE base, at the end of the main road on the base.

Wells/ Sump Description	Well	Dia.	Length	Material	Intake Type	Install Date	# Brackets
	Aquatrak	4"	5.33 M	Sch 80 PVC (W)	Double Cone	08/21/03	5

Top Hat Type: Standard	Parallel Plate (y/n): Yes	Winterized (y/n):
Copper Insert (y/n): Yes	Well Pumped (y/n):	Heater Setting (F):

Brckt/Valve Description: Two 4" S/S face Clamps / Three 4" Long Arm Pile Clamps (LAPC).

Remarks: The Protective well is secured to a 12" wooden pile with 5 S/S clamps (2 face clamps & LAPC), the protective well is located at the west end of the COE base and near the NW corner of the Sheet-pile bulkhead. All hardware is 1/2" S/S steel.

Permanent Station Inspection Notes (Pre-Visit Notification, Items stored in Enclosure, etc..)

The AC power is supplied to the enclosure only at night, AC power operates on a photo-cel. The phoneline D-mark point is located in the basement of the Administration building (Main office) at the east end of the base. The phoneline runs from the D-mark under ground to a panel in a small red shed near the COE pier on the north side of the harbor. Phoneline then runs under ground to a one story cinderblock building (the carpenter shop) to another panel in the center bay of the carpenter shop. From the panel in the carpenter shop the phoneline runs throught the raffters to a 11/2" conduit under the road to the gauge enclosure.

Work Requests for Next Annual O&M

Seven Bench marks were recovered during the installation, five surface marks and two deep rod marks. One more deep rod (3-D) should be established.

Sutron 9000 -Vitel DCP	Type of DCP	DCP s/n	Install Date	OpSysVers	SDL Vers.	Battery Date	DCP Phone	
	Sutron 9000	91026	08/21/02	2.5 F	KS 1.00x	08/21/03	(410) 885-5174	
Battery Type	Power Sup	Satellite	CCM	GPIO	Mem Exp	CPU	Modem	Aquatrak
12v 38 Amp	951264	90059	999786	89007	88019	91081	90637	90105
Backplane	Transition	Termination	AC/Step	**VITEL** DCP s/n		CPU	Mod Voice	Data Card
88018	979526	88061	90045					

Desicant (y/n): No Solar (y/n): Yes AC (y/n): Yes**	DCP Attachment Description	The Sutron 9000 is mounted to the west wall of the enclosure on a 3/4" plywood backing board using 3/8" S/S hardware.
Remarks	** AC power is suppied to the enclosure only at night, the AC pooperates by a Photo-cel.	

Sutron 8200/8210	DCP s/n	Install Date	Prog Vers.	Pwr Source	Tiny Basic Version	Battery Type	Battery Date	Amp Gain
8200/8210?	89020	08/21/03	2.1	Solar / DC		12v 24 Amp	08/21/03	46.57
8200	CPU s/n	Modem s/n	GOES s/n	Intercon s/n	Sensor Slope	TSU Ram pack installed (y/n): Spare TSU Ram pack in TH (y/n): Desicant changed (y/n): No		
Primary(y/n) NO	90521-2			90164	105.6			
Remarks	The Sutron 8200 is secured to the west wall of the enclosure on the a 3/4" plywood backing board using 3/8" S/S steel hardware.							

Aquatrak Sensor	Install Date	Aq. Hd. s/n	CalTube s/n	Sens Offset	Sndg Tube L	Brass Tube	T1/T2 Sep	# Bails
	8/22/2003	979-3256	448	1.1183	5.365	0.91 m	1.52 M	4
Aquatrak changed (y/n): No	Sounding Tube Test					* Allowable Tolerance is +/- 0.06 M or 0.2 ft		C 1 Entered
	Display	+ Coeff 1	= Sum	- S Tube L	= Difference*			
	4.227	1.118	5.345	5.365	-0.020			1.118
Remarks	The Aquatrak and sounding tube are configured to meet the standards set by NOS for the Sutron 9000. COE#1 was entered 1.118 @ 1500 EDST on 08/22/2003.							

Paros/ Digiquartz	N1 s/n	Install Date	Model	Range	Vent	Flow	Feed	NOTE: N1 is the primary lower orifice. T1 is secondary upper orifice.
Orifice Delta	T1 s/n	Install Date	Model	Range	Vent	Flow	Feed	
Remarks								

Backup Sensor	Manufacture	Sensor s/n	Install Date	Snsr Config	ManifoldTyp.	Tank PSI	Feed Psi	Flow Rate
	KPSI	0200943	08/21/03	Bubbler	Dry Purge	2350	14	32 CCM
	High Press Manufact.	N_2 High Press s/n	Install Date	Coeff 1	Coeff 2	Below ETG (GL)		
	Barksdale	N/A	08/21/03	3000	4			
Remarks	The KPSI Redundant Water level sensor is secured to the plywood backing board between the Sutron 9000 and the Dry Purge system. The Barsdale High Pressure sensor is mounted to the N2 tank regulator in the SE corner of the enclosure.							

GOES & Antenna	GOES ID#	Channel	Xmit Time	Xmit Interval	Xmit Power	Antenna s/n	Azimuth	Elevation
	334D4708	113	0:28:33	1 Hr		169326		45 Deg.
	GMT Time Offset: 4		Cable Leng: 16.8 M		Cable Type: RG-8/U		Mag Var: 11 Deg.	
Remarks	The GOES antenna is mounted to the top of a 20' Fiberglass tower, the antenna is secured with a S/S bracket and 5" U-bolt.							

Solar Panels	Purpose	Panel s/n	Install Date	Angle	Watts	Cable L	Remarks
	Sutron 9000	FI9908051512745	08/21/03	45	30	15 M	Both Sutron 9000 & 8200 solar panels are mounted to the Fiberglass tower with brackets supplied by manufacturer.
	Sutron 8200	FE95G12621539	08/21/03	45	30	15 M	

Ancillary Sensors	Air Temp	Manufact.	Install Date	Coeff 1	Water Temp	Manufact.	Install Date	Coeff 1
					Yes	YSI	08/22/03	
Remarks								

Wind	Manu/Model	Install Date	Coeff 1	Coeff 2	Cable Leng.	Height	Mast Type	Install Date
							Fiberglass	08/20/03
Remarks	The Fiberglass tower is mounted to an aluminum hinged plate, the plate is secured to the concrete foundation with four 3"x1/2" S/S wedge anchor bolts.							

Barometer	Manufact.	Install Date	PBM//SD	Baro//PBM	MSL//SD	Baro//MSL	Elev Corr.	Cal Corr.
						0.000	0.000	
Total Corr.	Coeff. # 2	Barometer Calibration	Time	Baro	Portable	Difference	If the difference exceeds +/- 1.0 mBar replace the barometer. If the difference is <1.0mBar, but >0.2mBar, then apply elevation & calibration correctors & input new Coeff 2.	
0.000	0.000					0.000		
Remarks						0.000		

Conductivity	Manufact.	Install Date	Coeff 1	Coeff 2	Coeff 3	Sensor Cleaned (y/n)		Initial Rdg.
Initial Temp	I Loop 1	I Loop 2	I Loop 3	F Loop 1	F Loop 2	F Loop 3	Final Rdg.	Final Temp
Remarks								

Visibilty	Manufact.	Install Date	Cal. Date	Height	
Remarks					

Rain Guage	Manufact.	Install Date	Coeff 1	Coeff 2	
Remarks					

Dissolved O_2	Manufact.	Install Date	Coeff 1	Coeff 2	
Remarks					

Other	Serial #	Manufact.	Install Date	Coeff 1	Coeff 2	
Remarks						

Remarks	

Tests	**Temp Sensor Test**					**Backup Pressure Sensor Test**					
Time	T 1	T 2	TA	TB	TW	Time	Sensor	Time	Sensor	Time	Sensor

T1 = Upper, T2 = Lower, TA = air, TB = backup, TW = water. If the differential exceeds +/- 1.0 degree C, consult HQ. The average difference between sensor should be within +/- 0.3 degree C.

GOES Xmit Test

	Wattmeter	FWD	REF	Loop 1	Loop 2
DCP					
Antenna					

Note: If power at antenna is less than 7 watts, or there is significant line loss contact HQ. Significant line loss is defined as more than 3 watts per 10 meters of line.

Dive Report	Station Inspected (y/n)	No	Divers:	Walker Dive Company
	Intake Cleaned (y/n)		Marine Fouling Potential (H/M/L):	Intake Elevation:
Remarks	Two subsurface long arm pile clamps and two brass omega clamps were installed by a contract dive company as noted above.			

Shaft Angle Encoder	SAE s/n	Install Date	Float Dia	Tape Leng	Current Disp	Current ETG	ETG-Display	ResetC2(y/n)
							0.000	

Initial Encoder Setup			Remarks
Display	- ETG =	S14 Coeff 2	
		0.000	

Water Transfer	Hydraulic Corrector	Retained ZETG	Valve Elev
Remarks			

Reference Gauge Readings				
	ETG	Spike	Other	Difference*
HydCor Zero Readings				* The difference between Tape & Spike
Wtr Surface	0.000	0.000	0.000	0.000

ETG Description	
Spike Description	

Levels/ Surveying	Date	Datum	PBM Stamping	PBM Elev
	08/23/03	Site Datum	U 21931 6.834	3.1580

Instrument Number	Rod 1 s/n	Rod 2 s/n	C-Shot Coeff
91581	25905		-1

Instrument Operator	Rodman 1	Rodman 2
Chris Metzger	John Slepnowski	

Downshot Req'd(y/n):	No
# of Marks Established:	0
# of Marks Recovered:	7
# of Marks Connected:	6

Aquatrak Coefficient Calculations

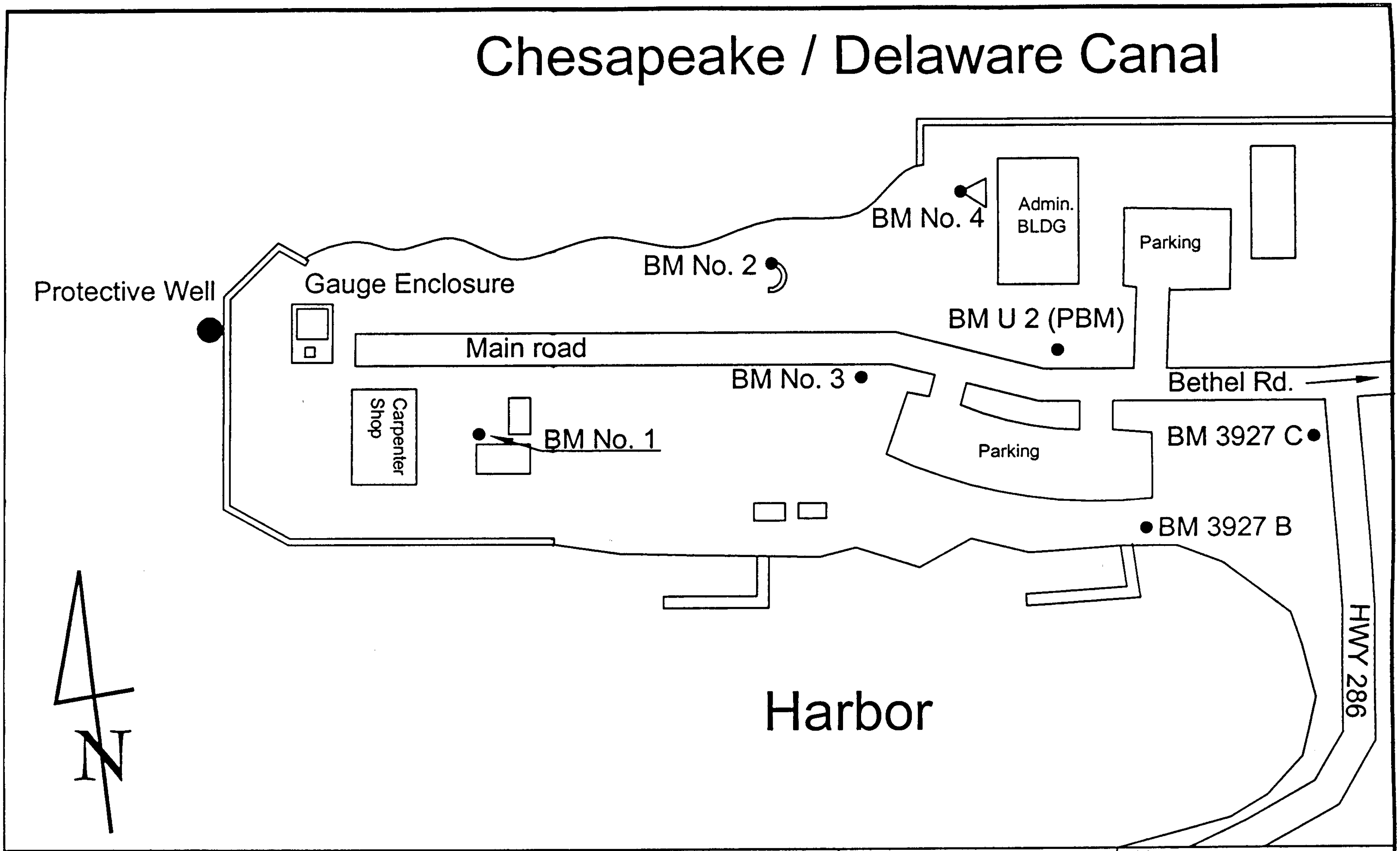
Aq Coeff 2A PBM above Site Datum (HQ #11)	Aq Coeff 2B Leveling Pt above PBM from Levels	Aquatrak Coeff 2 (2A+2B=2)	Accepted Coeff 2	Difference (change if >+/- 0.006M)
3.15800	1.15363	4.31163		4.31163

Coeff 2 Changed (y/n):	NO	**New Value:**	4.312	**Date:**	09/02/03	**Time:**	1430 GMT

Ref Gauge or BM	Latest Inspection	Present Inspection	Change	Recovered(y/n)
ETG			0.0000	
SPIKE			0.0000	
AQUATRAK		4.3116	-4.3116	Established
Tidal No. 1		3.2448	-3.2448	Recovered
Tidal No. 3		3.3853	-3.3853	Recovered
Tidal No. 2		4.3480	-4.3480	Recovered
Tidal No.4		5.2498	-5.2498	Recovered
3927 B		2.1538	-2.1538	Recovered
			0.0000	
			0.0000	
			0.0000	
			0.0000	
			0.0000	

GPS	Benchmark	GPS Elev.	Level Elev.	Difference	Benchmark	GPS Elev.	Level Elev.	Difference
				0.00000				0.00000
				0.00000				0.00000
				0.00000				0.00000
				0.00000				0.00000
				0.00000				0.00000
Remarks								

Miscellaneous Comments (Station History,Motel Contacts, etc...)



U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL OCEAN SERVICE BENCHMARK SKETCH	FIELD UNIT	DRAWN BY J.Stepnowski	DATE 858-3927
		REVISED BY	DATE
STATION NAME CHESAPEAKE CITY, MD.	STATION NUMBER 857-3927	REVISED BY	DATE
		REVISED BY	DATE

```
                        8573927.ABS
   ABSTRA Version 5.21 -- October 1991  Tue Sep 02 09:58:51 2003


                            -*- FIELD ABSTRACT -*-
030823-030823          HGZ L26422  7     6.0 MM ORDER 2 CLASS 1      PAGE  1
2003 LEVELING TO TIDE STATIONS IN MARYLAND
857 3927 CHESAPEAKE CITY

        FROM              START    F/B  DIST    ELEV DIFF        -(F+B)  MEAN DIFF   I
             TO                         TOTAL                     TOTAL   FLD ELEV   C
                                        (KM)      (MT)             (MM)     (MT)

 0711 U 2                                                                  3.15800
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
 0711 U 2                 8231252 F    0.07    -1.00384   *@  -0.70      -1.00419  1
 0716 857 3927 B          8231301 B    0.07     1.00454   *@                       1
                               SL 1    0.07                   -0.70       2.15381
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
 0711 U 2                 8231244 B    0.05    -0.22714   *@  -0.23       0.22726  1
 0713 857 3927 TIDAL 3 8231310 F    0.05     0.22737   *@                       1
                                       0.05                   -0.23       3.38526
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
 0713 857 3927 TIDAL 3 8231151 F    0.04     0.96278   *@  -0.18       0.96270  1
 0714 857 3927 TIDAL 2 8231215 B    0.04    -0.96884  R*@                       1
                          8231227 F    0.04     0.96274   *@                       1
                          8231238 B    0.04    -0.96258   *@                       1
                               SL 1    0.09                   -0.41       4.34796
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
 0714 857 3927 TIDAL 2 8231159 F    0.07     0.90184   *@  -0.11       0.90179  1
 0715 857 3927 TIDAL 4 8231206 B    0.07    -0.90173   *@                       1
                               SL 1    0.16                   -0.52       5.24975
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
 0713 857 3927 TIDAL 3 8231136 B    0.16     0.14033   *@   0.22      -0.14044  1
 0712 TIDAL 1 STA 62      8231319 F    0.16    -0.14055   *@                       1
                                       0.21                   -0.01       3.24482
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
 0712 TIDAL 1 STA 62      8231119 B    0.06    -1.06679   *@  -0.03       1.06681  1
 0708 TBM 857 3927 AQU 8231340 F    0.06     1.06682   *@                       1
                                       0.27                   -0.04       4.31163

       ELEVATION REJECTION AND ERROR CODES

C - section elevation difference was rejected for cause
    ie. *43* record rejection code set to "F"
R - section elevation difference was rejected by Halperin rejection algorithm
@ - section elevation difference does not include refraction correction
* - section elevation difference does not include rod correction


  INSTRUMENT CODE       INSTRUMENT             RODS

         1             243 - 91581    396 - 25905     396 - 25905

                         LEVEL LINE SECTION RUNNING TREE

  0711 (0716)
  0713 (0714
        0715)
  0712
  0708

                                  Page 1
```

```
-------  ---  ----------------------------------------------------------------------------

                 ******* R E C O V E R Y     D E S C R I P T I O N *******

                SSN: 0711
        Designation: U 2
                PID: JU1833
 Approx. Latitude: 393138N                              State: MD
Approx. Longitude: 0754825W                            County: CECIL
Approx. Elevation:                                  Disk From: NGS
          Stamping: U 2 1931 6.834

      Surface Mark-
              Type: Bench Mark disk
     Magnetic code: N
           Setting: SET INTO THE TOP OF A CONCRETE MONUMENT
         Rod depth:                          Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08202003, chief of party JRS.

---------------------  ----------------------------------------------------------------
FROM CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM
THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND
DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A
PAVED ROAD TO THE U.SCORPS OF ENGINEERS ADMINISTRATION BIULDING.  THE BENCH
MARK IS SET FLUSH IN A 0.24 METER (0.79 FT) SQUARE CONCRETE MONUMENT SOUTH OF
THE COE ANDIMISTRATION BIULDING, 14.57 METERS (47.80 FT) SOUTH OF THE WEST
WALL FOR THE STEPS LEADING TO THE BASEMENT OF THE ADMINISTRATION BIULDING,
10.27 METERS (33.69 FT) NORTH OF THE CENTERLINE OF MAIN ROAD, 8.56 METERS
(26.08 FT) WEST OF THE WEST EDGE OF THE SIDEWALK LEADING TO THE ADMINISTRATION
BIULDING, AND 0.15 ABOVE THE GROUND.
```

******* RECOVERY DESCRIPTION *******

SSN: 0712
Designation: TIDAL 1 STA 62
PID: JU1835
Approx. Latitude: 393139N
Approx. Longitude: 0754834W
Approx. Elevation:
Stamping: NO 1 1938

State: MD
County: CECIL
Disk From: CGS

Surface Mark-
Type: Tidal Station disk
Magnetic code: N
Setting: SIDEWALK
Rod depth:
Sleeve Depth:

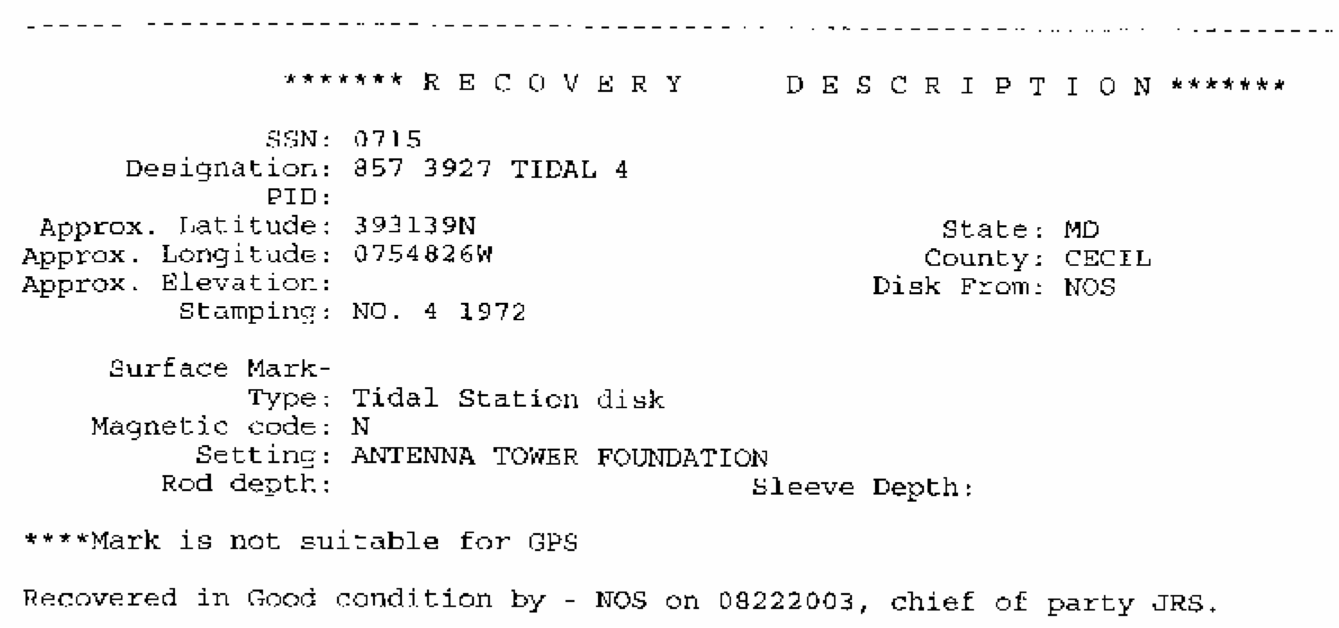
****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

FROM CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.SCORPS OF ENGINEERS ADMINISTRATION BIULDING. THE BENCH MARK IS SET FLUSH IN CONCRTE WALKWAY AT THE NW CORNER OF A SINGLE STORY WHITE BRICK BUILDING (BRIDGE REPAIR SHOP) NEAR THE WEST END OF THE COE PROPERTY 20.48 METERS (67.19 FT) SOUTH OF THE CENTERLINE OF MAIN ROAD, 0.52 METERS (1.71 FT) NORTH OF THE NORTH WALL OF THE BRICK BUILDING, AND 0.46 METERS (1.51 FT) EAST OF THE WEST WALL OF THE BRICK BUILDING.

```
--------------------------------------------------------------------------------
          ******* R E C O V E R Y     D E S C R I P T I O N *******

            SSN: 0713
    Designation: 857 3927 TIDAL 3
            PID:
 Approx. Latitude: 393138N                             State: MD
Approx. Longitude: 0754828W                           County: CECIL
Approx. Elevation:                                 Disk From: NOS
         Stamping: NO. 3 1972

     Surface Mark-
            Type: Tidal Station disk
   Magnetic code: N
         Setting: CONCRETE FOUNDATION
       Rod depth:                       Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

--------------------------------------------------------------------------------
FROM CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM
THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND
DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A
PAVED ROAD TO THE U.SCORPS OF ENGINEERS ADMINISTRATION BIULDING.  THE BENCH
MARK IS SET FLUSH IN NW CONCRETE PUMP WELL LOCATED SW OF THE COE
ADMINISTRATION BUILDING, 5.94 METERS (19.49 FT) NORTH OF THE NW CORNER OF A
VENTILATOR SHAFT, 4.63 METERS (15.19 FT) SOUTH OF THE CENTERLINE OF THE MAIN
ROAD, AND 4.45 SW OF THE SOUTHERNMOST OF TWO STEEL GATE POSTS FOR A ROAD GATE.
```

```
--------------------------------------------------------------------------------

            ******* R E C O V E R Y   D E S C R I P T I O N *******

                SSN: 0714
        Designation: 857 3927 TIDAL 2
                PID:
   Approx. Latitude: 393138N                         State: MD
  Approx. Longitude: 0754829W                       County: CECIL
  Approx. Elevation:                             Disk From: USCGS
           Stamping: NO. 2 1938

      Surface Mark-
               Type: Tidal Station disk
     Magnetic code: N
            Setting: STONE RETAINING WALL
          Rod depth:                          Sleeve Depth:

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

--------------------------------------------------------------------------------
FROM CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM
THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND
DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A
PAVED ROAD TO THE U.SCORPS OF ENGINEERS ADMINISTRATION BIULDING.  THE BENCH
MARK IS SET FLUSH IN THE TOP OF A STONE RETAINING WHICH IS AROUND THE BETHEL
BRIDGE LIGHTHOUSE, 73.71 METERS (241.83 FT) WEST OF THE WEST FACE OF THE COE
ADMINISTRATION BUILDING, 16.32 METERS (53.54 FT) NORTH OF THE CENTERLINE OF
THE ROAD ON BASE, 9.0 METERS (29.5 FT) SOUTH OF THE RIP-RAP BULKHEAD OF THE
CHESAPEAKE / DELAWARE CANAL, 3.10 METERS (10.17 FT) EAST OF THE WEST END OF
THE STONE RETAINING WALL AROUND THE BETHEL BRIDGE.
```



```
             ******* R E C O V E R Y     D E S C R I P T I O N *******

               SSN: 0715
       Designation: 857 3927 TIDAL 4
               PID:
  Approx. Latitude: 393139N                         State: MD
 Approx. Longitude: 0754826W                       County: CECIL
 Approx. Elevation:                             Disk From: NOS
          Stamping: NO. 4 1972

     Surface Mark-
              Type: Tidal Station disk
    Magnetic code: N
           Setting: ANTENNA TOWER FOUNDATION
         Rod depth:                            Sleeve Depth:

****Mark is not suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.
```

CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY
THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPE
ELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHE
PAVED ROAD TO THE U.S. CORPS OF ENGINEERS ADMINISTRATION BUILDI
ENCH
SET FLUSH IN THE CONCRETE FOUNDATION OF THE WESTERNMOST LEG OF
LEGS OF A 49.0 METER (160.8 FT) HIGH STEEL RADIO ANTENNA 40.57
S
10 FT) NORTH OF THE CENTERLINE OF THE MAIN ROAD, 16.73 METERS (5
E OF THE OUTSIDE NW CORNER OF THE REINFORCED BULKHEAD ON THE SOU
OF THE CHESAPEAKE / DELAWARE CANAL, AND 8.87 METERS (29.10 FT)
E NW CORNER OF THE OBSERVATION ADDITION TO THE TWO STORY COE
ISTRATION BUILDING.

******* RECOVERY DESCRIPTION *******

```
               SSN: 0716
       Designation: 857 3927 B
               PID:
 Approx. Latitude: 393135N                          State: MD
Approx. Longitude: 0754825W                        County: CECIL
Approx. Elevation:                              Disk From: NOS
          Stamping: 3927 B 1982

     Surface Mark-
              Type: Tidal Station disk
     Magnetic code: N
           Setting: GALVANIZED STEEL ROD
         Rod depth: 7.0                     Sleeve Depth:
```

****Mark is suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

FROM CHESAPEAKE CITY. ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD TO THE U.SCORPS OF ENGINEERS ADMINISTRATION BIULDING. THE BENCH MARK IS LOCATED SE OF THE COE ADMINISTRATION, 34.59 METERS (113.48 FT) SW OF THE CENTERLINE OF THE MAIN ROAD, 10.58 METERS (34.71 FT) NNE OF THE CENTER OF THE SOUTHERNMOST SECTION OF A DOCK ON THE NORTH SHORE OF THE HARBOR, 4.48 METERS (14.70 FT) SE OF THE CONCRETE WALKWAY LEADING TO THE DOCK, AND 0.61 METERS (2.00 FT) EAST OF THE EASTERNMOST POLE SUPPORTING THE ECELTRICAL BOXES.

******* RECOVERY DESCRIPTION*******

SSN: 0717
Designation: 857 3927 C
PID: 393135N
Approx. Latitude: 0754824W
Approx. Longitude: 3927 C 1982
Approx. Elevation: Tidal Station
Stamping:

State: MD
County: CECIL
Disk From: NOS disk

Surface MarkType:
Magnetic code:
Setting: N
Rod depth: GALVANIZED 5.0 STEEL ROD

Sleeve Depth:

****Mark is** suitable for GPS

Recovered in Good condition by - NOS on 08222003, chief of party JRS.

CHESAPEAKE CITY ABOUT 1.3 KM (0.80 MI) EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.2 KM (0.10 MI) NORTHEAST ALONG A PAVED ROAD To THE U.S. CORPS OF ENGINEERS ADMINISTRATION BUILDING. THE BENCH MARK NEAR THE END OF COE FACILITY JUST EAST OF THE MAIN GATE, 18.78 METERS (61.61 FT) SW OF THE CENTERLINE OF THE MAIN ROAD LEADING TO THE COE FACILITY, 14.48 METERS (47.51 FT) SE OF THE EASTERNMOST PICNIC TABLE, 8.99 METERS (29.49 FT) NW OF THE CENTERLINE OF STATE HIGHWAY 286, AND 0.61 METERS (2.00 FT) NW OF A UTILITY POLE NUMBER 17318. ENCASED IN IN A 4 INCH PVC PIPE WITH CAP.

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
DATABASE = Sybase ,PROGRAM = datasheet, VERSION = 6.98
1        National Geodetic Survey,   Retrieval Date = MARCH 16, 2004
JU1833 ***********************************************************************
JU1833  TIDAL BM     -  This is a Tidal Bench Mark.
JU1833  DESIGNATION -  U 2
JU1833  PID          -  JU1833
JU1833  STATE/COUNTY-  MD/CECIL
JU1833  USGS QUAD    -  ELKTON (1992)
JU1833
JU1833                         *CURRENT SURVEY CONTROL
JU1833  ___________________________________________________________________
JU1833* NAD 83(1986)-  39 31 38.     (N)    075 48 25.      (W)    SCALED
JU1833* NAVD 88      -          1.727  (meters)       5.67   (feet)  ADJUSTED
JU1833  ___________________________________________________________________
JU1833  GEOID HEIGHT-        -33.30  (meters)                      GEOID03
JU1833  DYNAMIC HT   -          1.726  (meters)       5.66   (feet)  COMP
JU1833  MODELED GRAV-     980,132.0   (mgal)                       NAVD 88
JU1833
JU1833  VERT ORDER   -  FIRST     CLASS I
JU1833
JU1833.The horizontal coordinates were scaled from a topographic map and have
JU1833.an estimated accuracy of +/- 6 seconds.
JU1833
JU1833.The orthometric height was determined by differential leveling
JU1833.and adjusted by the National Geodetic Survey in June 1991.
JU1833
JU1833.This Tidal Bench Mark is designated as VM 3167
JU1833.by the Center_for_Operational_Oceanographic_Products_and_Services.
JU1833
JU1833.The geoid height was determined by GEOID03.
JU1833
JU1833.The dynamic height is computed by dividing the NAVD 88
JU1833.geopotential number by the normal gravity value computed on the
JU1833.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
JU1833.degrees latitude (g = 980.6199 gals.).
JU1833
JU1833.The modeled gravity was interpolated from observed gravity values.
JU1833
JU1833;                     North         East     Units  Estimated Accuracy
JU1833;SPC MD       -   207,210.     502,580.      MT  (+/- 180 meters Scaled)
JU1833
JU1833                          SUPERSEDED SURVEY CONTROL
JU1833
JU1833  NGVD 29 (??/??/??)    1.965  (m)            6.45   (f) ADJUSTED    1 1
JU1833
JU1833.Superseded values are not recommended for survey control.
JU1833.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
JU1833.See file dsdata.txt to determine how the superseded data were derived.
JU1833
JU1833 U.S. NATIONAL GRID SPATIAL ADDRESS: 18SVJ306755(NAD 83)
JU1833 MARKER: DB = BENCH MARK DISK
JU1833 SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
JU1833_STAMPING: U 2 1931 6.834
JU1833_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
JU1833+STABILITY: SURFACE MOTION
JU1833
JU1833  HISTORY      - Date      Condition          Report By
JU1833  HISTORY      - 1931      MONUMENTED         CGS
JU1833  HISTORY      - 1971      GOOD               NGS
JU1833
```

```
JU1833
                                   STATION DESCRIPTION
JU1833
JU1833'DESCRIBED BY NATIONAL GEODETIC SURVEY 1971
JU1833'0.9 MI E FROM CHESAPEAKE CITY.
JU1833'ABOUT 0.8 MILE EAST ALONG STATE HIGHWAY 286 FROM THE SOUTHWEST
JU1833'END OF THE U.S. HIGHWAY 213 BRIDGE OVER THE CHESAPEAKE AND
JU1833'DELAWARE CANAL AT CHESAPEAKE CITY, THENCE 0.1 MILE NORTHWEST
JU1833'ALONG A PAVED ROAD TO THE U.S. CORPS OF ENGINEERS ADMINISTRATION
JU1833'BUILDING, 61.9 FEET SOUTHWEST OF THE SOUTHWEST CORNER OF THE
JU1833'BUILDING, 33 FEET NORTH OF THE CENTER LINE OF THE ROAD, 31.1
JU1833'FEET WEST OF THE CENTER OF THE SOUTH END OF THE CONCRETE STEPS
JU1833'TO THE BUILDING, ABOUT 1/2 FOOT ABOVE THE LEVEL OF THE ROAD,
JU1833'AND SET IN THE TOP OF A CONCRETE POST PROJECTING 4 INCHES.

 *** retrieval complete.
Elapsed Time = 00:00:01
```

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8573927 **PUBLICATION DATE: 05/01/2003**
Name: CHESAPEAKE CITY
MARYLAND
NOAA Chart: 12277 **Latitude: 390 31.6' N**
USGS Quad: ELKTON **Longitude: 750 48.6' W**

To reach the tidal bench marks from the south end of the State Highway 213 bridge over the Chesapeake and Delaware (C & D) Canal at Chesapeake City, proceed south on State Highway 213 for 0.89 km (0.55 mi) and take the South Chesapeake City exit, continue 0.3 km (0.2 mi) NNE (towards canal) from the base of the exit to a signpost directing the way to the C & D Canal Museum, turn right and follow the curving road for 0.2 km (0.1 mi) to a T-intersection, turn right and follow the curving road for 0.6 km (0.4 mi) to a T-intersection, turn left and proceed 0.08 km (0.05 mi) to the main gate of the U.S. Army Corps of Engineers (COE) facility and the C & D Canal Museum. The bench marks are located on the COE grounds. The tide gage and staff were located at the SW corner of the bulkhead at the west end of the COE grounds.

TIDAL BENCH MARKS

PRIMARY BENCH MARK STAMPING: U 2 1931 6.834
DESIGNATION: U 2

MONUMENTATION:	Bench Mark disk	VM#:	3167
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID#:	JU1833
SETTING CLASSIFICATION:	Concrete monument		

The primary bench mark is a disk set flush in a 0.24 m (0.8 ft) square concrete monument south of the COE administration building, 14.57 m (47.8 ft) south of the west concrete wall for the steps leading to the basement of the administration building, 10.27 m (33.7 ft) north of the centerline of the main road, 8.56 m (28.1 ft) west of the west edge of a sidewalk leading to the administration building, and 0.15 m (0.5 ft) above the ground.

Station ID:	**8573927**	**PUBLICATION DATE: 05/01/2003**		
Name:	**CHESAPEAKE CITY MARYLAND**			
NOAA Chart:	**12277**		**Latitude:**	**390 31.6' N**
USES Quad:	**ELKTON**		**Longitude:**	**750 48.6' W**

TIDAL BENCH MARKS

BENCH MARK STAMPING: NO 1 1938
DESIGNATION: TIDAL 1 STA 62

MONUMENTATION: Tidal Station disk
AGENCY: US Coast and Geodetic Survey (USC&GS)
SETTING CLASSIFICATION: Concrete walkway
VM#: 3168
PID#: JU1835

The bench mark is a disk set in a concrete walkway at the NW corner of a single story white brick building (Bridge Repair Shop), located near the west end of the COE grounds, 20.48 m (67.2 ft) south of the centerline of the main road, 0.52 m (1.7 ft) north of the north wall of the building, and 0.46 m (1.5 ft) east of the west wall of the building.

BENCH MARK STAMPING: NO 3
1972 DESIGNATION: 857
3927 TIDAL 3

MONUMENTATION: Tidal Station disk
AGENCY: National Ocean Survey (NOS)
SETTING CLASSIFICATION: Concrete foundation
VM#:3170
PID:

The bench mark is a disk set flush in the NW corner of a concrete pump well located SW of the COE administration building, 5.94 m (19.5 ft) north of the NW corner of a ventilator shaft, 4.63 m (15.2 ft) south of the centerline of the main road, and 4.45 m (14.6 ft) SW of the southernmost of two steel gate posts for a road gate.

Station ID: **8573927** **PUBLICATION DATE: 05/01/2003**
Name: **CHESAPEAKE CITY**
MARYLAND
NOAA Chart: **12277** **Latitude:** **390 31.6' N**
USGS Quad: **ELKTON** **Longitude:** **750 48.6' W**

TIDAL BENCHMARKS

BENCH MARK STAMPING: NO 4 1972
DESIGNATION: 857 3927
TIDAL 4

MONUMENTATION:	Tidal Station disk	VM#:	3171
AGENCY:	National Ocean Survey (NOS):	PID:	
SETTING CLASSIFICATION:	Tower foundation		

The bench mark is a disk set flush in the concrete foundation of the westernmost of the three legs of a 49 m (160 ft) high steel radio antenna, 40.57 m (133.1 ft) north of the centerline of the main road, 16.73 m (54.9 ft) SE of the outside NW corner of the reinforced steel bulkhead on the south shore of the C & D Canal, and 8.87 m (29.1 ft) SW of the NW corner of the C & D Cana observation addition to the two story administration building.

BENCH MARK STAMPING: 3927 A 1982
DESIGNATION: 857 3927 A

MONUMENTATION:	Tidal Station disk	VM#:	3172
AGENCY:	National Ocean Survey (NOS)	PID:	
SETTING CLASSIFICATION:	Galvanized steel rod		

The bench mark is a disk located at the west end of the main road through the COE facility, 18.32 m (60.1 ft) ENE of a large fixed crane, 16.64 m (54.6 ft) NW of the NW corner of the carpenters shop, 8.69 m (28.5 ft) south of the reinforced steel bulkhead of the C & D Canal, and 0.61 m (2.0 ft) west of the southernmost stanchion of the ARMCO barrier. The bench mark is set 9 cm (0.3 ft) below ground level, crimped to a galvanized steel rod driven 12 m (40 ft) to refusal, and encased in a 4-inch PVC pipe with cap and concrete kickblock. (Note: a large wrench is needed to remove the cap.)

Station ID: 8573927 **PUBLICATION DATE: 05/01/2003**
Name: CHESAPEAKE CITY
MARYLAND
NOVA Chart: 12277 **Latitude: 390 31.6' N**
USES Quad: ELECTION **Longitude: 750 48.6' W**

TIDAL BENCHMARKS

BENCH MARK STAMPING: 3927 B
1982 DESIGNATION: 857 3927 B

MONUMENTATION:	Tidal Station disk	VM#:	3173
AGENCY:	National Ocean Survey (NOS)	PID:	
SETTING CLASSIFICATION:	Galvanized steel rod		

The bench mark is a disk located SE of the COE administration building, 34.59 m (113.5 ft) SW of the centerline of the main road, 10.58 m (34.7 ft) NNE of the center of the most southeastern section of a dock on the north shore of the harbor, 4.48 m (14.7 ft) SE of the edge of the concrete runway to the dock, and 0.61 m (2.0 ft) east of the easternmost pole supporting electrical boxes. The bench mark is set 9 cm (0.3 ft) below ground level, crimped to a galvanized steel rod driven 7 m (24 ft) to refusal, and encased in a 4-inch PVC pipe with cap and concrete kickblock. (Note: a large wrench is needed to remove the cap.)

BENCH MARK STAMPING: 3927 C 1982
DESIGNATION: 857 3927 C

MONUMENTATION:	Tidal Station disk	VM#:	3174
AGENCY:	National Ocean Survey (NOS)	PID:	
SETTING CLASSIFICATION:	Galvanized steel rod		

The bench mark is a disk located at the SE end of the COE facility, east of the main gate, 18.78 m (61.6 ft) SW of the centerline of the main road, 14.48 m (47.5 ft) SSE of the easternmost picnic table, 8.99 m (29.5 ft) NNW of the centerline of State Highway 286, and 0.61 m (2.0 ft) NNW of utility pole 17318. The bench mark is set 9 cm (0.3 ft) below ground level, crimped to a galvanized steel rod driven 5 m (16 ft) to refusal, and encased in a 4-inch PVC pipe with cap and a concrete kickblock. (Note: A large wrench is needed to remove the cap.)

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8573927
Name: CHESAPEAKE CITY
MARYLAND
NOAA Chart: 12277
USGS Quad: ELKTON

PUBLICATION DATE: 05/01/2003

Latitude: 39ø 31.6' N
Longitude: 75ø 48.6' W

TIDAL DATUMS

Tidal datums at CHESAPEAKE CITY based on:

LENGTH OF SERIES: 48 MONTHS
TIME PERIOD: April 1979 - March 1983
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 8574680 BALTIMORE, FORT MCHENRY, PATAPSCO RIVER

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (09/06/1979) = 2.036
MEAN HIGHER HIGH WATER (MHHW) = 1.005
MEAN HIGH WATER (MHW) = 0.941
MEAN TIDE LEVEL (MTL) = 0.505
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.500
MEAN SEA LEVEL (MSL) = 0.487
MEAN LOW WATER (MLW) = 0.069
MEAN LOWER LOW WATER (MLLW) = 0.000
LOWEST OBSERVED WATER LEVEL (04/05/1975) = -1.107

Bench Mark Elevation Information	In METERS above:	
Stamping or Designation	MLLW	MHW
U 2 1931 6.834	2.228	1.287
NO 1 1938	2.328	1.387
NO 3 1972	2.455	1.514
NO 4 1972	4.317	3.376
3927 A 1982	1.977	1.036
3927 B 1982	1.224	0.283
3927 C 1982	1.467	0.526

Station ID: 8573927 **PUBLICATION** DATE: 05/01/2003
Name: CHESAPEAKE CITY
MARYLAND
NOAA Chart:12277 **Latitude: 390 31.6' N**
USGS Quad: ELKTON **Longitude: 750 48.6' W**

DEFINITIONS

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the US. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD 29 and NAVD 88 are fixed geodetic datums whose` elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

APPENDIX G AIR GAP DLL USERS MANUAL

SUTRON XPERT/XLITE SLL

MIROS AIR GAP WATER LEVEL SENSOR
Serial Interface Driver

AirGapWL

For:
National Ocean Survey
Chesapeake, Virginia

October 21, 2002
Sutron Corporation
21300 Ridgetop Circle
Sterling, Virginia, USA 20166

PURPOSE

The purpose of this SLL is to allow users to connect a MIROS Air Gap water level sensor to one of the COM ports on a Sutron XPert or XLite (Model 9210) data logger. The purpose of the sensor is to provide the distance from the sensor's location (normally the deck of a bridge) to a water surface. This SLL adds an Input (sensor) block to the XPert/XLite. The block handles serial communications with an Air Gap sensor connected to one of the serial ports. The sensor can be sampled by a standard Measure block at tested rates up to once per second. Note that the Air Gap block has two (2) outputs labeled WL1 and WL2. These correspond to the two water levels returned by the sensor when data are requested. Refer to the Miros documentation for an explanation of the difference between the two outputs.

SCOPE

This document contains:

Instructions for installing the SLL on an XPert
Instructions for connecting an Air Gap sensor to an XPert
Operating Instructions
Error Messages and Troubleshooting

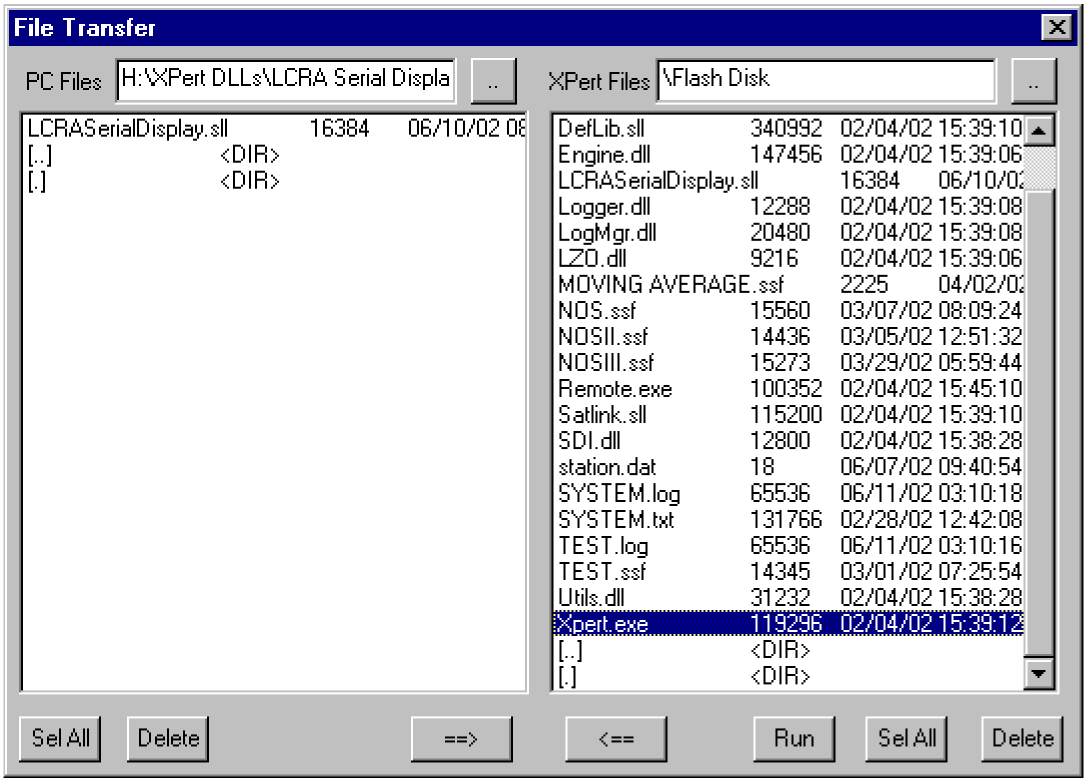
SOFTWARE INSTALLATION

INSTALLING AN SLL

It is important to ensure that the SLL is compatible with the version of XPert software you are running. Log on to the XPert with SETUP privileges. Go to the STATUS tab and press the ABOUT button. Verify that the software is version 1.2.05 or higher.

SLLs are installed by copying the .SLL file to the \Flash Disk folder on the XPert. The easiest way to accomplish this is to use Sutron's XTerm utility. Connect a PC or laptop computer to COM 1 on the XPert. The steps to load the SLL are as follows:

Run XTerm
If the XPert application is running, go to the STATUS tab and press the Exit App button to shut it down. (The new SLL will not take effect until the application is stopped and restarted.)
Press the File Transfer button. The File Transfer window is illustrated in Figure 1.



PC Files H:\XPert DLLs\LCRA Serial Displa

```
LCRASerialDisplay.sll          16384      06/10/02 08
[..]                   <DIR>
[.]                    <DIR>
```

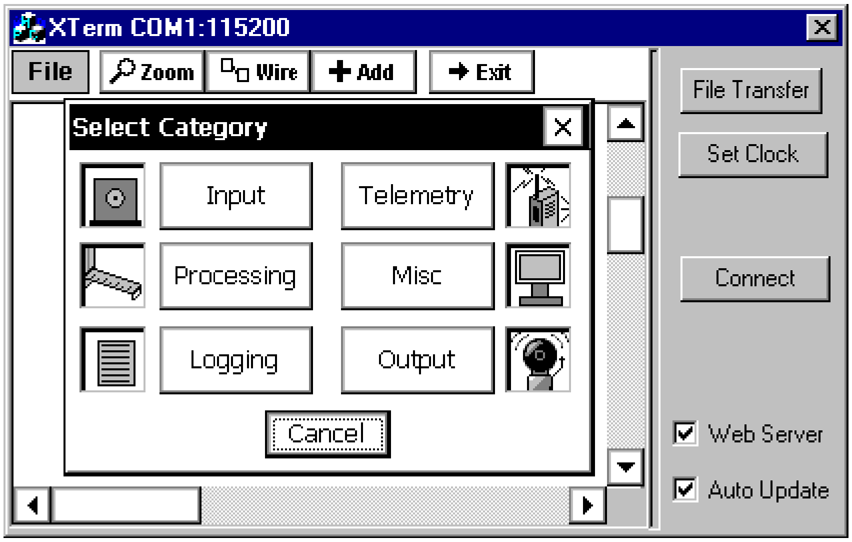
XPert Files \Flash Disk

```
DefLib.sll          340992   02/04/02 15:39:10
Engine.dll          147456   02/04/02 15:39:06
LCRASerialDisplay.sll       16384     06/10/02
Logger.dll          12288    02/04/02 15:39:08
LogMgr.dll          20480    02/04/02 15:39:08
LZO.dll             9216     02/04/02 15:39:06
MOVING AVERAGE.ssf          2225      04/02/02
NOS.ssf             15560    03/07/02 08:09:24
NOSII.ssf           14436    03/05/02 12:51:32
NOSIII.ssf          15273    03/29/02 05:59:44
Remote.exe          100352   02/04/02 15:45:10
Satlink.sll         115200   02/04/02 15:39:10
SDI.dll             12800    02/04/02 15:38:28
station.dat         18       06/07/02 09:40:54
SYSTEM.log          65536    06/11/02 03:10:18
SYSTEM.txt          131766   02/28/02 12:42:08
TEST.log            65536    06/11/02 03:10:16
TEST.ssf            14345    03/01/02 07:25:54
Utils.dll           31232    02/04/02 15:38:28
Xpert.exe           119296   02/04/02 15:39:12
[..]                <DIR>
[.]                 <DIR>
```

FIGURE 1. – XTERM FILE TRANSFER WINDOW

Set the left hand panel (PC Files) to display the folder on the PC containing the SLL to be loaded
Make sure the right hand panel (XPert Files) is pointed to \Flash Disk
Highlight the SLL file and press the right-pointing arrow at the bottom of the screen to copy the SLL to the flash disk
You will be asked to confirm the operation. Press OK.
After the SLL load is completed you may restart the XPert application. You may do this by scrolling to the bottom of the \Flash Disk panel (XPert Files), selecting XPert.exe, and pressing the RUN button at the bottom of the window. Powering off and on will also work if an Autoexec.bat file is defined on the XPert.

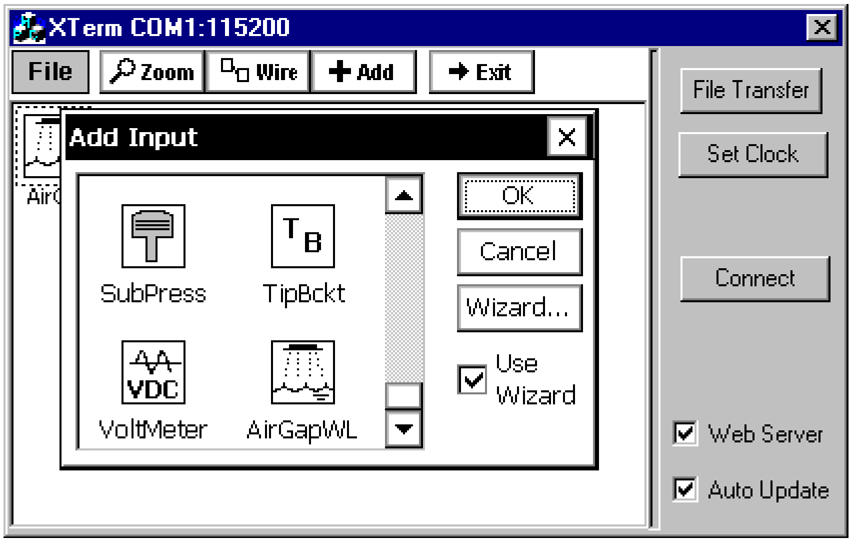
Verify that the SLL has loaded correctly. Log on to the XPert application (either through the front panel or using XTerm) with SETUP access privileges. Go to the SETUP tab and press the ADD button. The Select Category window (Figure 2) will appear.



☑ Web Server
☑ Auto Update

FIGURE 2. – CATEGORY WINDOW FOR SELECTING BLOCK TYPE

Select Input as the block type.



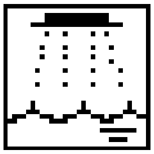
☑ Use Wizard

☑ Web Server

☑ Auto Update

FIGURE 3. – INPUT MODULE WINDOW

You will see the Air Gap sensor block with the following icon as an available input (Figure 3).



AirGapWL

If the block is not available, or you received an error message when the XPert application started, then try powering down the XPert and restarting it. If you still can't find the block or you still receive an error message, it is likely that the SLL is not compatible with the version of XPert software that you are running. Contact Sutron to obtain the latest updates.

If the block is available, the installation is successful. Press Cancel twice (once in the Input Module window and once in the Select Category window) to return to the Setup window. Using the Air Gap block in a setup is covered later in this manual.

HARDWARE REQUIREMENTS AND WIRING

COM PORT CONNECTIONS

Output Connection

No XPert output connection is required.

Input Connection

The Air Gap sensor block requires a connection to one of the available COM ports on the XPert. The default port is COM 2, but COM 2 through COM 4 (COM 8 with optional I/O expansion on XPert) may be selected as part of the setup.

The connection from the XPert to the Air Gap sensor is a standard, straight-wired (not null modem) male-female DB-9 cable.

analog connections

None required.

digital connections

None required.

operating instructions

setup

The Air Gap sensor block is a passive input. That is, it must be measured in order to obtain values. This is normally done by wiring the Air Gap block to a Measure block. The Air Gap block has been tested at sample rates up to once per second. Note that the Air Gap block has two (2) outputs labeled WL1 and WL2. These correspond to the two water levels returned by the sensor when the GV command is issued. Refer to the Miros documentation for an explanation of the difference between the two outputs.

Note that no RS-232 serial settings are required. The Air Gap block sets the selected input port to 9600 bps, no parity, 8 data bits, and one stop bit.

Test Setup

Figure 4. illustrates a simple test setup that may be used to determine if the Air Gap block is operating properly.

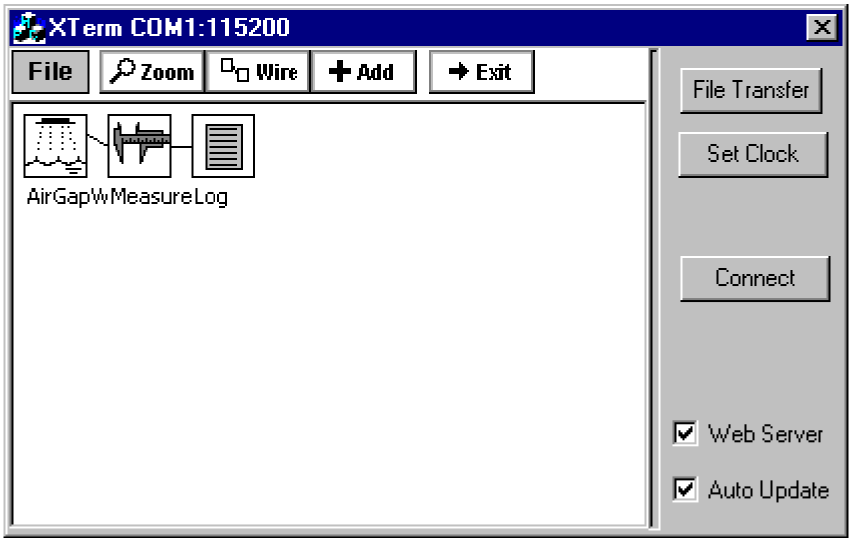
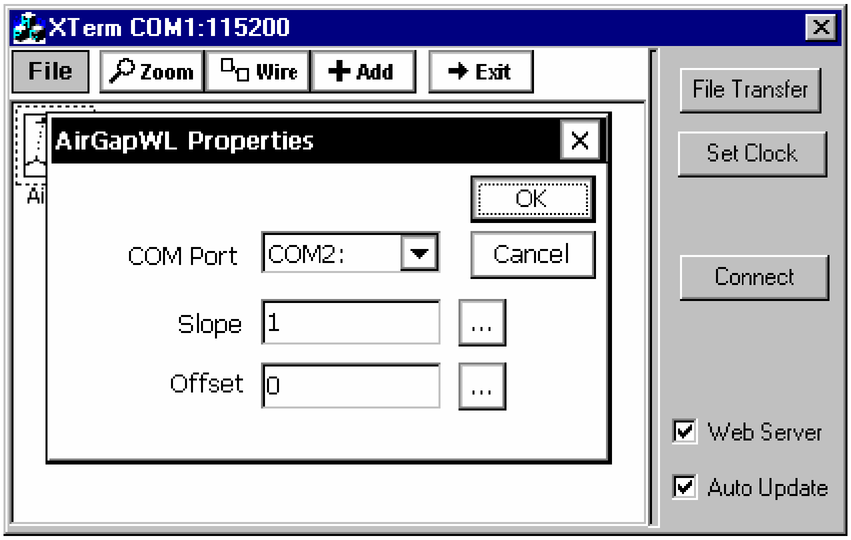


FIGURE 4. – TEST SETUP FOR AIR GAP SENSOR

The test setup uses one Air Gap block, one Measure block, and one Log block.

The test setup is named AirGapTest.ssf. It can be copied to the \Flash Disk on the XPert and loaded through the SETUP tab File Open menu option.

Test an Air Gap sensor by connecting it to an available COM port. After the wiring is complete, go to the SETUP tab and click on the Air Gap icon. Select the Edit Properties option. The following dialog window will open:



COM Port COM2:

Slope 1

Offset 0

☑ Web Server

☑ Auto Update

FIGURE 5. – SERIAL DISPLAY PROPERTIES WINDOW

Select the COM port to which the display is connected (default is COM 2). Set the Slope and Offset parameters (Output equals input times slope plus offset) if you want to scale the outputs. Click on OK.

Set the properties of the Measure block so that the Air Gap sensor is sampled frequently – for example every 5 seconds. Click on OK.

Go to the MAIN tab and turn recording on. (If recording was on when you entered SETUP then you will have the opportunity to turn it back on when you exit SETUP mode.) Examine the Status tab to ensure that there are no communications errors. View the log to see the sensor readings.

Normal Setup

There is no fundamental difference between a normal setup and the test setup except for processing. Typically the Air Gap block will be wired to a Measure block. The Measure block can be wired directly to the Log or to a DQAP block that filters and/or averages the output values. DQAP provides several outputs including average, standard deviation, and outlier count. Refer to the standard XPert documentation for information on DQAP.

Operations

When recording is turned on the Air Gap block sets the selected COM port properties to N-8-1 at 9600 bps. It then issues the Air Gap SER0 command to put the sensor into sampled mode. (The default Air Gap sensor mode is “streaming” with output of water levels at rates greater than once per second.) The software then looks for the returned message from the sensor indicating that the mode has been reset.

When the Air Gap sensor block is measured it issues the Air Gap GV command. The GV command requests data values. The sensor returns two water levels filtered in different ways. Both are available as outputs from the Air Gap block.

If the user has changed the Slope and Offset parameters in the Air Gap block properties then the values are first multiplied by the slope and then the offset is added. The Slope and Offset apply to both water levels. That is, there is no separate slope and offset for each one.

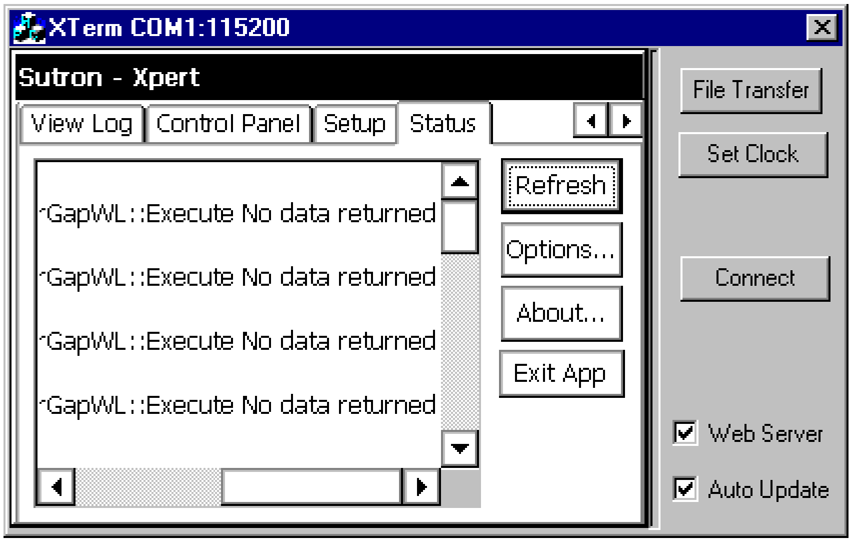
error messages and troubleshooting

error messages

The Air Gap block can produce two status messages and one error message. The messages and their meanings are presented in the following table.

Message	**Explanation**
CAirGapWL::Execute No data returned	When the Air Gap block issued the GV command to the sensor there was no data returned. That is, the input buffer was blank.
CAirGapWL::Execute Com out of synch	Line noise will occasionally cause corrupted characters in the data values. When this happens the software may not be able to correctly parse the data. The software will loose synchronization with the sensor for one or more sample intervals until all of the air gap error messages are cleared from the input buffer.
CAirGapWL::Execute OpenComm n failed	The Air Gap block was not able to establish communications with the selected COM port (number n).

Error messages will appear on the XPert Status tab as illustrated in Figure 6



```
~GapWL::Execute No data returned
~GapWL::Execute No data returned
~GapWL::Execute No data returned
~GapWL::Execute No data returned
```

FIGURE 6. - XPERT STATUS TAB WITH ERROR MESSAGES

troubleshooting

The following table presents common problems and their solution.

Problem	Solution
Unable to open the selected COM port	Likely wiring problem. Make sure that the DB-9 to air bap sensor connection is wired properly. Make sure that pins 2 and 3 (TXD/RXD) are not reversed in your cable. Test that the air gap sensor is generating output by connecting a PC or laptop to in and establishing a Hyperterm session with the sensor. Try issuing the SER0 and SER1 commands and the GV command to test the sensor.
XPert displays an hourglass cursor when recording is turned on.	The air gap sensor is connected to the wrong COM port. Go to the SETUP tab and edit the properties of the display block to match the port or move the DB-9 cable to the correct port. NOTE: If the hourglass is displayed it will eventually (about 4 minutes) time out and recording will start.
Error messages appear in the STATUS panel.	Error messages indicate severe errors. The most likely cause is a wiring error in the DB-9 cable or a hardware failure on the XPert.

It is possible to determine if the Air Gap block is operating by connecting a laptop computer to the COM port selected for the sensor. Establish a Hyperterm or other terminal emulator session with the port at 9600-N-8-1. When recording is turned on you should be able to see the XPert issue the SER0 command as well as the GV commands. Note that the commands only contain a carriage return and DO NOT contain a line feed character. This affects the appearance of the output in a terminal session. (It may be necessary to use a null modem cable for the connection.)

APPENDIX H CORMS NOTIFICATION STANDARD OPERATING PROCEDURE (SOP)

CORMS Notification of CO-OPS Staff for Air Gap Sensor Problems

Updated: 15 March 2004

Introduction and Purpose

Air Gap is the measured distance between the height, in this case a bridge, over water and the surface of the water. Historically, ship traffic was not considered on some of the smaller navigable bodies of water. Dredging to change channel depths and shorter routes combined with the economic benefits of larger ships with larger cargo produced a requirement for more accurate measurement. CO-OPS has conducted extensive research on an air gap instrument and is prepared to install these sensors as part of our suite of real time monitoring sensors. The first two deployed, located in the C&D Canal, have generated enthusiasm in the shipping community. Refining our monitoring skills of these sensors will be important for the future.

PROCEDURE

1. The CORMS Operator should monitor each of these sensors in the combined PICS graphics and also in the three day Air Gap, water Level and wind. These data are consider part of the PORTS complement of sensors and as such should be monitored as on the same schedule as Chesapeake Bay PORTS.

2. To view the air gap bring up the Chesapeake PICS graphics. Locate the Chesapeake City and Reedy Point station rows. Locate the Air Gap columns and click on the associated red circles. The PICS time series graphics will appear.

3. The Air Gap sensor has several built in error checking routines. As well as a standard flag for failure no data, there are tests for excessive standard deviation and number of outliers. At the moment, the QC flags are not integrated into the Main CORMS screens. Go to either of the two links below and review the data. Embedded in the data string at the end of the top line is the area for flags. Either the bit is set or not

Chesapeake City
ftp://tidepool.nos.noaa.gov/pub/outgoing/PUFFF/cbports/8573928.ag

Reedy Point
ftp://tidepool.nos.noaa.gov/pub/outgoing/PUFFF/cbports/8551911.ag

4. While doing your PICS check should you observe that the data is not

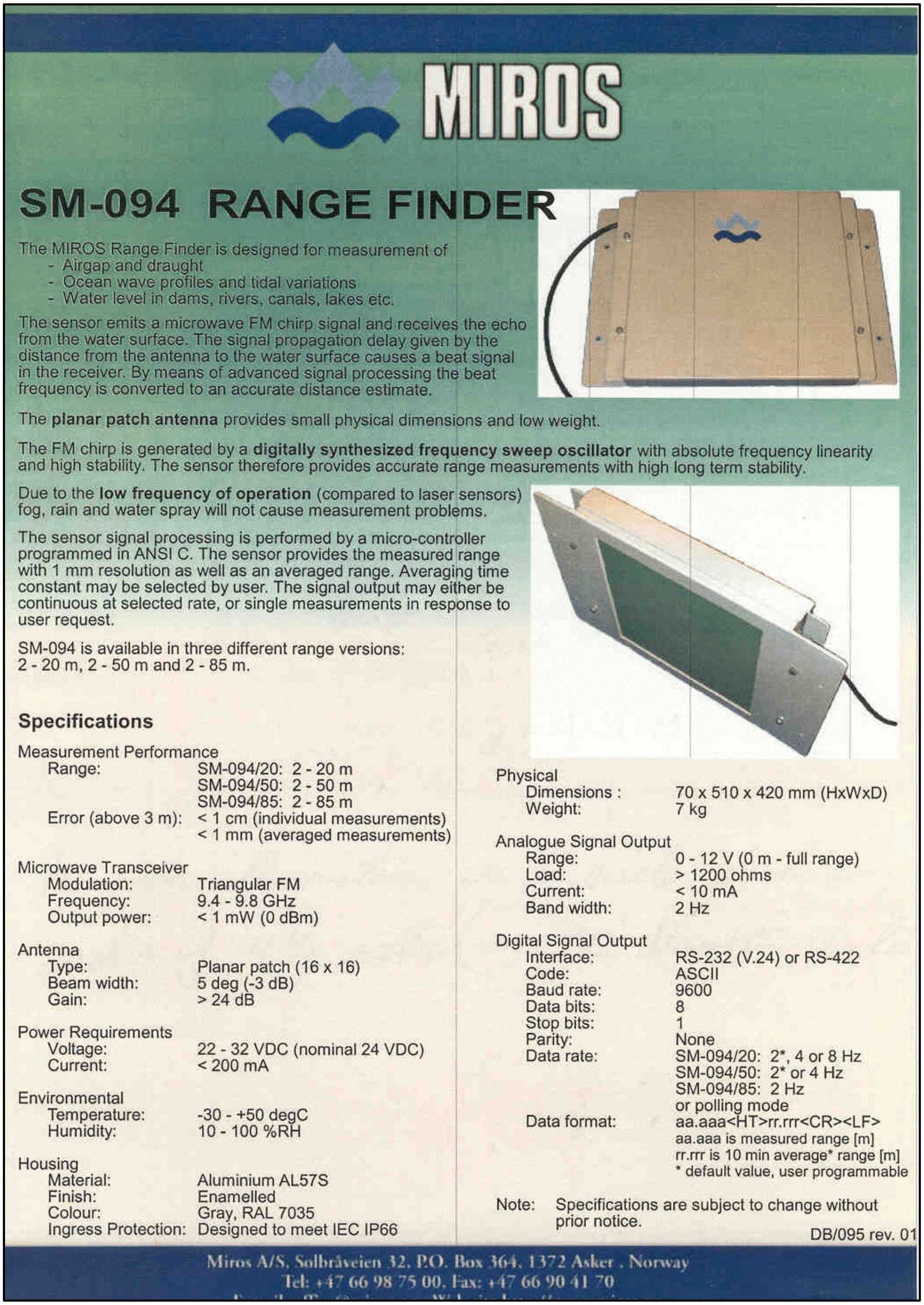
available, refer to this link for explanation of the error being received. If the failure is not caused by FNOD, Failure No Observed Data, use the following link to go to the offline links and review the data there.

http://developers.co-ops.nos.noaa.gov:8083/cbports/AirGap.html

This link will plot data that has failed QC along with good data and allow you to visually inspect the data. If the error continues for longer than 4 samples, and it is not a Failure No Observed Data error and the data appears to be tracking correctly, page the on call ISD personnel.

5. Should the data fail Quality Control with a Standard Deviation or Outlier error, notify the PORTS Operations Manager immediately during business hours. After business hours until 9PM notify the PORTS Operations Manager. For Failure No Data errors, notify the appropriate individuals for Chesapeake Bay PORTS by E-Mail.

APPENDIX I. MIROS SM-094 MANUFACTURER SPECIFICATION SHEET



MIROS

SM-094 RANGE FINDER

The MIROS Range Finder is designed for measurement of
- Airgap and draught
- Ocean wave profiles and tidal variations
- Water level in dams, rivers, canals, lakes etc.

The sensor emits a microwave FM chirp signal and receives the echo from the water surface. The signal propagation delay given by the distance from the antenna to the water surface causes a beat signal in the receiver. By means of advanced signal processing the beat frequency is converted to an accurate distance estimate.

The **planar patch antenna** provides small physical dimensions and low weight.

The FM chirp is generated by a **digitally synthesized frequency sweep oscillator** with absolute frequency linearity and high stability. The sensor therefore provides accurate range measurements with high long term stability.

Due to the **low frequency of operation** (compared to laser sensors) fog, rain and water spray will not cause measurement problems.

The sensor signal processing is performed by a micro-controller programmed in ANSI C. The sensor provides the measured range with 1 mm resolution as well as an averaged range. Averaging time constant may be selected by user. The signal output may either be continuous at selected rate, or single measurements in response to user request.

SM-094 is available in three different range versions:
2 - 20 m, 2 - 50 m and 2 - 85 m.

Specifications

Measurement Performance

Range:	SM-094/20: 2 - 20 m SM-094/50: 2 - 50 m SM-094/85: 2 - 85 m
Error (above 3 m):	< 1 cm (individual measurements) < 1 mm (averaged measurements)

Microwave Transceiver

Modulation:	Triangular FM
Frequency:	9.4 - 9.8 GHz
Output power:	< 1 mW (0 dBm)

Antenna

Type:	Planar patch (16 x 16)
Beam width:	5 deg (-3 dB)
Gain:	> 24 dB

Power Requirements

Voltage:	22 - 32 VDC (nominal 24 VDC)
Current:	< 200 mA

Environmental

Temperature:	-30 - +50 degC
Humidity:	10 - 100 %RH

Housing

Material:	Aluminium AL57S
Finish:	Enamelled
Colour:	Gray, RAL 7035
Ingress Protection:	Designed to meet IEC IP66

Physical

Dimensions :	70 x 510 x 420 mm (HxWxD)
Weight:	7 kg

Analogue Signal Output

Range:	0 - 12 V (0 m - full range)
Load:	> 1200 ohms
Current:	< 10 mA
Band width:	2 Hz

Digital Signal Output

Interface:	RS-232 (V.24) or RS-422
Code:	ASCII
Baud rate:	9600
Data bits:	8
Stop bits:	1
Parity:	None
Data rate:	SM-094/20: 2*, 4 or 8 Hz SM-094/50: 2* or 4 Hz SM-094/85: 2 Hz or polling mode
Data format:	aa.aaa<HT>rr.rrr<CR><LF> aa.aaa is measured range [m] rr.rrr is 10 min average* range [m] * default value, user programmable

Note: Specifications are subject to change without prior notice.

DB/095 rev. 01

Miros A/S, Solbråveien 32, P.O. Box 364, 1372 Asker . Norway
Tel: +47 66 98 75 00, Fax: +47 66 90 41 70

APPENDIX J
PUFFF AIR GAP DATA

PUFFF air gap data details are available at:
http://co-ops.nos.noaa.gov/publications/pufff4.pdf

APPENDIX K

CHARLESTON BRIDGE PROJECT

NOAA, NOS, NGS

PURPOSE

Determine the precise "AIR GAP" of the bridges (distance at Mean High Water and the bottom of the bridge)

METHODS TO BE USED

- **GPS**
- **Trig-Leveling**
- **Classical Leveling**

MOUNTING THE ANTENNAS

TRIG-LEVELING

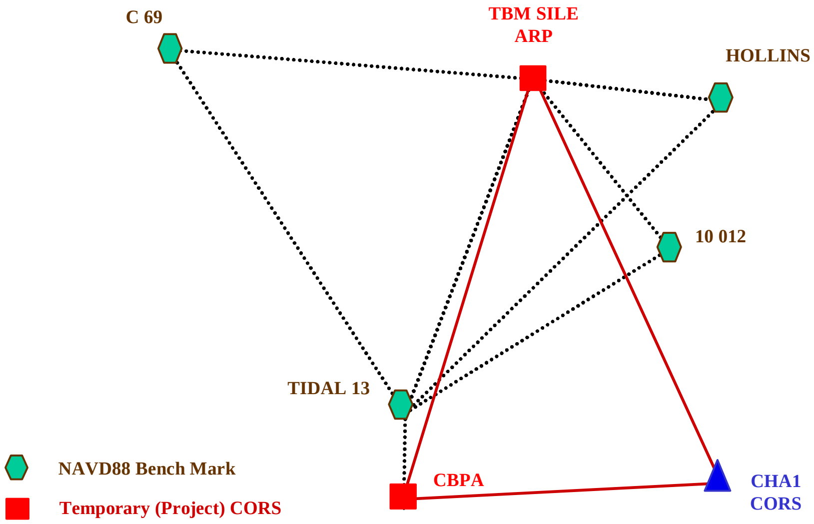
NOAA, NOS, NGS

GPS OCCUPATION

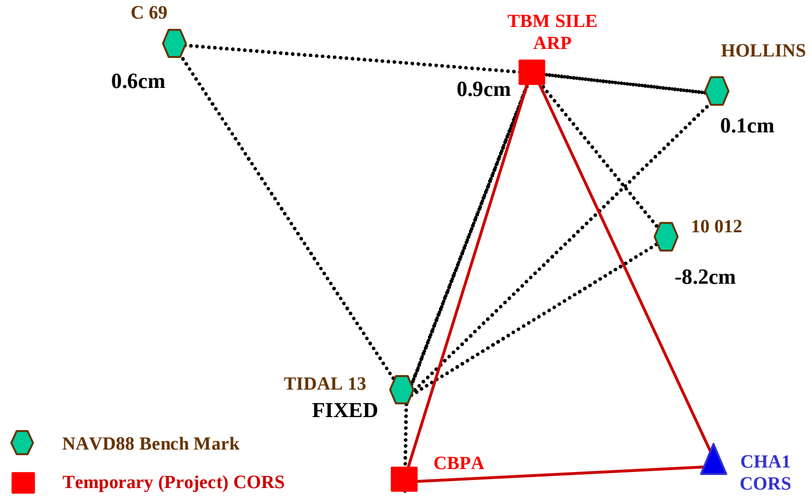
NOAA, NOS, NGS

CLASSICAL LEVELING

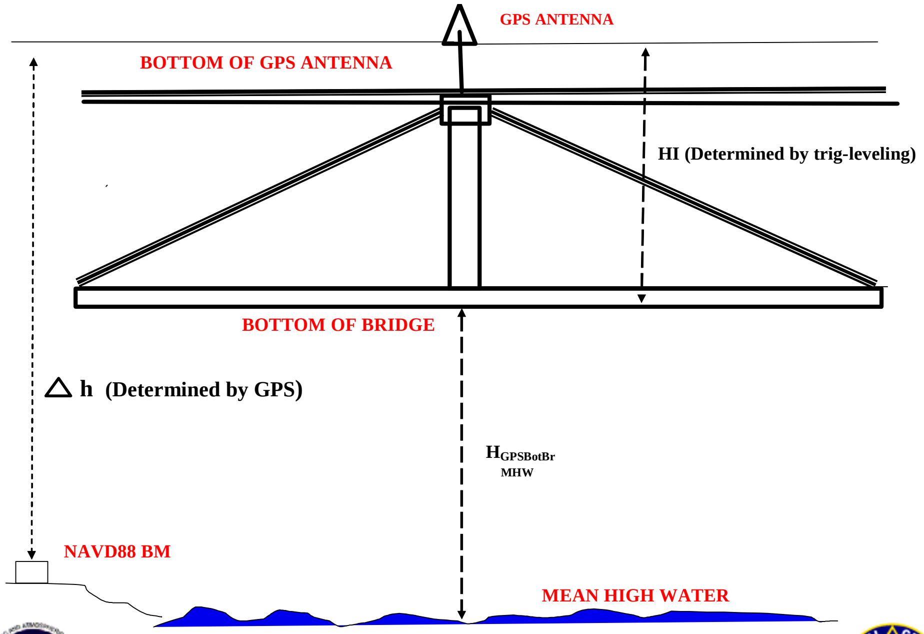
Charleston Bridge Network



Free Vertical Adjustment minus NAVD88 Published



NOAA, NOS, NGS



NOAA, NOS, NGS

KNOWNS

HI = Height of the bottom of the bridge to the top of the antenna mounting bracket
= 18.608 m

NAVD88 BM = 2.219 m

Geoid Heights = -33.140 at the NAVD88BM
(GEOID99) = -33.145 at the GPS Antenna on top of bridge

Mean High Water = 2.04 ft above NAVD88

Δh = Height from NAVD88BM to the top of the antenna mounting bracket (mean of two- one hour GPS observations)
= 62.987m

NOAA, NOS, NGS

Height of the bottom of the bridge above Mean High Water

HEIGHT OF THE BOTTOM OF THE BRIDGE ABOVE MEAN HIGH WATER

$H_{GPSANT} = H_{NAVD88BM} + \Delta H_{GPS}$
$H_{NAVD88BM} + [\Delta h - \Delta N]$
$2.219 + [62.987 - ((-33.145) - (-33.140))]$
$2.219 + 62.992$

$H_{\substack{GPSANT\\NAVD88}} = 65.211$

$HI = -18.608$

$H_{GPSBotBr}$ = 46.603 m or 152.897 Ft.

NAVD88 - MHW = -204 Ft.

$H_{\substack{GPSBotBr\\MHW}}$ = 150.856 Ft.

NOAA, NOS, NGS

COMPARISION
OF
ORHTOMETRIC HEGHTS
NAVD88

GPS METHOD

HGPSANT = 65.211 m

TRIG-LEVELING

HGPSANT = 65.203 m

DIFFERENCE = 0 .8 cm

NOAA, NOS, NGS

CONCLUSION

GPS

METHODS

WORK

NOAA, NOS, NGS