National Cooperative Highway Research Program

NCHRP Report 397A

Sonar Scour Monitor

Installation, Operation, and Fabrication Manual

Transportation Research Board
National Research Council

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Sonar Scour Monitor

Installation, Operation, and Fabrication Manual

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Staff
Transportation Research Board

This report consists of separate manuals that provide specific fabrication, installation, and operation guidance for two scour monitoring devices. The findings of the study in which these fixed devices for measuring maximum scour depth were developed, tested, and evaluated are reported in a companion document. These reports will be of immediate interest to hydraulics engineers, bridge management engineers, and bridge maintenance engineers.

Scour is the primary cause of bridge failure in the United States. Because scour holes generally fill in as streamflows diminish, post-flood inspections are not adequate to determine fully the extent of scour damage. Methods of measuring the maximum scour depth are needed in the management of scour-susceptible bridges and unknown-foundation bridges.

These manuals and the companion report, published as *NCHRP Report 396*, are the culmination of NCHRP Project 21-3, which consisted of three phases. Phase I, which was reported in *NCHRP Research Result Digest 189*, developed four mandatory and eight desirable characteristics for scour monitoring devices and identified four classes of instruments—sounding rod, sonic fathometer, buried/driven rod, and other buried devices—likely to provide these characteristics.

In Phase II, the most promising devices were evaluated under field conditions. The objective of these evaluations was to determine accuracy, dependability, and durability under a broad range of stream types, flow conditions, and bridge geometries. On the basis of these evaluations, the magnetic sliding collar and the sonar-based devices were identified as appropriate for further refinement. These two monitors meet all of the mandatory requirements and most of the desirable characteristics established for scour monitoring devices. There was no report on the Phase II research.

These manuals, which are the product of Phase III, provide guidance for selecting the device most suitable for a bridge and its location. Detailed instructions, including fabrication drawings and parts lists, are included to permit the fabrication of the monitors in most machine shops. Instructions for operation and maintenance are also given.

CONTENTS

PART I INSTALLATION AND OPERATION

CHAPTER 1

SYSTEM DESCRIPTION

1.1 DESCRIPTION

The sonar scour monitor is a conventional sonar instrument connected to a datalogger that can provide an ongoing record of scour depth. The sonar scour monitor is the result of research that was conducted under NCHRP Project 21-3, *Instrumentation for Measuring Scour at Bridge Piers and Abutments.* Refer to *NCHRP Report 396* for detailed findings from this research project, and for interpretation and appraisal of information derived from laboratory and field testing of bridge scour instrumentation.

A sonar instrument (also known as a fathometer or sonic sounder) measures distance based on the travel time of a sound wave through water. The sonar scour monitor consists of a low-cost, recreational-type sonar (sometimes referred to as a "fish-finder") connected to a datalogger that tells the sonar when to turn on, how much data to collect, and when to turn off. The device can be programmed to take measurements on a regular basis (for example, every 60 min), and can track both scour and refill processes. Telemetry of the data is also possible with this instrument.

1.2 MAJOR COMPONENTS

The instrument consists of an instrument enclosure with the sonar, the datalogger, and a 12-volt battery that powers the instrument. A solar panel and regulator are used to charge the battery. The transducer for the sonar is mounted below the water surface at the location to be monitored.

This device is particularly well suited to large bridges and deep water conditions with minimal debris loading, such as bridges in coastal areas that cross tidal inlets and bays. The instrument can be used at inland, riverain locations when the transducer is located to minimize problems related to debris. In particular, debris accumulation on or under the transducer can interfere with the sonar signal reaching the channel bottom. This instrument is also well suited to measure scour at piers and vertical wall abutments, and in some instances, can be adapted for use at spill-through (sloping) abutments.

The major components of the sonar scour monitor include

1. **Instrument Enclosure.** The instrument enclosure contains the sonar instrument, datalogger, solar panel regulator, and battery. The solar panel can be an integral part of the instrument enclosure, or mounted separately depending on solar orientation (the solar panel should face south for maximum solar gain).
2. **Transducer Mount.** The transducer for the sonar must be mounted below the water to take a measurement. The transducer can be permanently mounted to the pier or abutment underwater (as in Figure 1); however, this typically requires a diver for installation and subsequent servicing. A special mounting bracket allows the transducer to be installed and serviced from above the water surface (as in Figure 2). The mounting bracket is called an "above-water, serviceable, transducer-mounting bracket."
3. **Connecting Conduit.** A rigid or flexible conduit is required to route the wire from the transducer to the instrument enclosure.

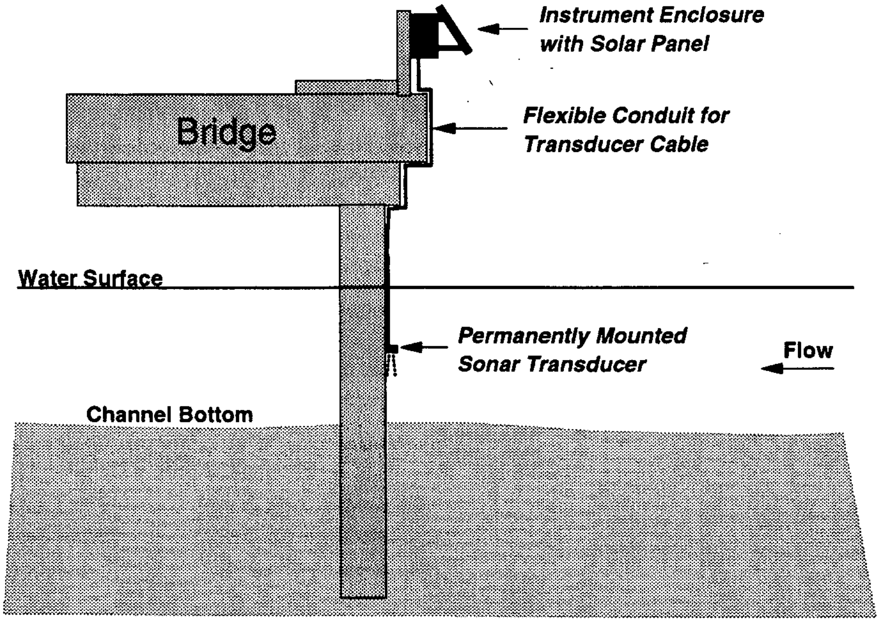


Figure 1. Sonar scour monitor with transducer permanently mounted.

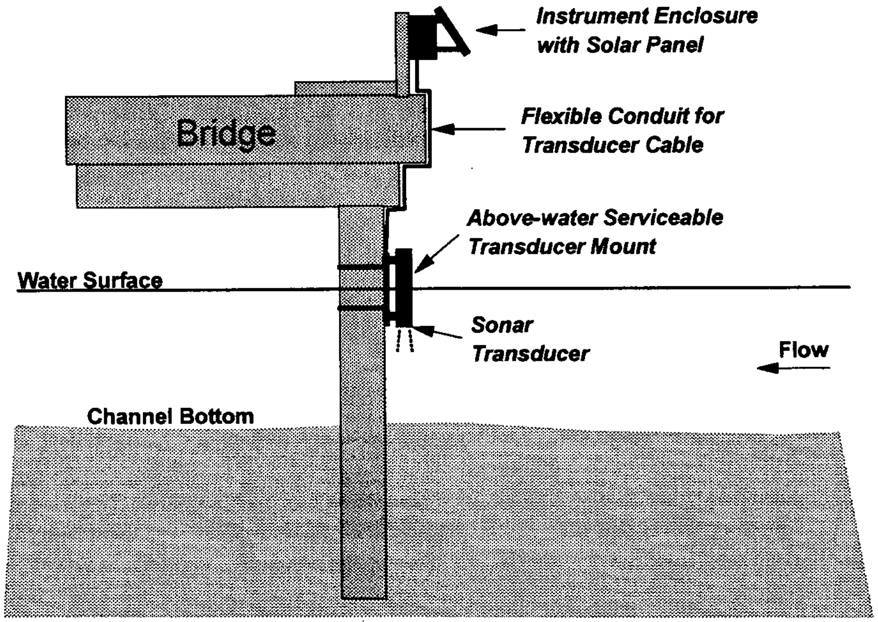


Figure 2. Sonar scour monitor with above-water, serviceable, transducer-mounting bracket.

CHAPTER 2

APPLICATION GUIDELINES

2.1 ANALYSIS OF THE ENVIRONMENT

Most streams that highways cross are alluvial; that is, the streams are formed in materials that have been and can be transported by the stream. In alluvial stream systems, it is the rule rather than the exception that banks will erode; sediments will be deposited; and floodplains, islands, and side channels will undergo modification with time. Alluvial channels continually change position and shape as a consequence of hydraulic forces exerted on the bed and banks. These changes may be gradual or rapid and may be the result of natural causes or human activities. As a result, the deepest portion of the channel (called the thalweg) and/or the location of greatest scour at a bridge crossing can change from one flood to the next, or even during a given flood (see Figure 3).

Scour is the result of the erosive action of flowing water, excavating and carrying away material from the bed and banks of streams. *Local scour* involves the removal of a small portion of the channel near piers, abutments, spurs and embankments. *Contraction scour* involves the removal of material from the bed across all or most of the width of the channel and is caused by the contraction of flow by bridges or approaches. *Degradation* is the long-term lowering of the streambed over relatively long distances. Scour is generally thought of in terms of vertical change; however, horizontal changes in the bankline also occur as a result of scour processes.

Different materials scour at different rates. Loose granular soils are quickly eroded by flowing water, while cohesive or cemented soils are more scour-resistant. Scour generally occurs on the rising limb of a flood and is at maximum near peak flow. The local scour hole at a bridge pier, or cross section undergoing contraction scour, can refill on the receding limb of the flood (see Figure 4).

A sonar scour monitor can track both scour and refill processes. However, since the instrument is not on continuously, but is turned on and off at a prescribed sample interval, this interval must be short enough that the maximum scour is identified.

The inherent instability of alluvial channels complicates the placement of fixed scour instrumentation. Initially, the location of maximum scour needs to be determined, and then the potential for shifting of the maximum scour location should be considered. Even if the location of maximum scour is not expected to change, the angle of attack of the flow may be different from one flood to the next, or may change during a given flood. For example, in a meandering stream channel, the low-flow thalweg is typically different from the high-flow thalweg (see Figure 5).

Consequently, the location of maximum scour can change (e.g., Bridge 2 in Figure 5), as can the angle of attack (Bridge 1 in Figure 5). If the meander pattern changes over time, as often occurs, this change can further impact the scour conditions at the bridge. Therefore, evaluating the location of maximum scour and the preferred location to install fixed instrumentation at a given bridge is difficult and can be very subjective. Complex situations could require the use of specialized expertise.

As a general rule, the maximum scour typically occurs in the deepest portion of the channel. Comparative cross sections from bridge inspection files can be useful in locating the deepest portion of the channel and potential changes in this location over time. At a given pier, the maximum scour generally occurs at the upstream face. However, if the skew angle of the attacking flow is large, the location of maximum scour may shift from the upstream face of the pier to the side of a pier or even to the downstream face. Furthermore, a high-skew angle at a pier in the overbank (for example where flow is turning the corner around an abutment) may cause greater scour than that occurring at a main channel pier where the flow is deep and fast, but well aligned with the pier. Field observation of skew angles during high-flow conditions can be useful in evaluating the location of maximum scour. Alternatively, evaluation of cross-channel flow patterns with a two-dimensional (2-D) computer model can be useful in predicting the location of maximum scour. Without specialized information, the best approach is to locate the instrumentation based on field observations, and be prepared to relocate the instrument if the maximum scour does not occur where expected during a significant flood event.

For bridges located in bends, the greatest scour generally occurs at the outside of the bend; although the location of maximum scour may shift toward the inside during large floods as the high-flow path shifts. Again, field observation of flow patterns and currents under relatively high-flow conditions can provide insight, as can use of comparative cross sections or analysis with 2-D models. Without this information, it is generally best to locate the instrument near the outside of the bend.

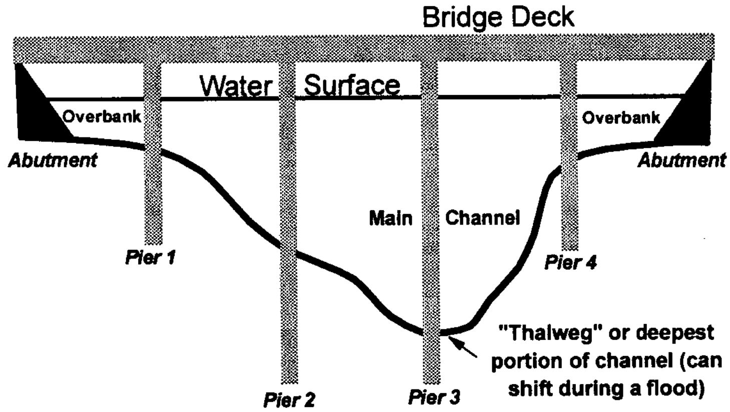


Figure 3. Sketch of typical channel cross section.

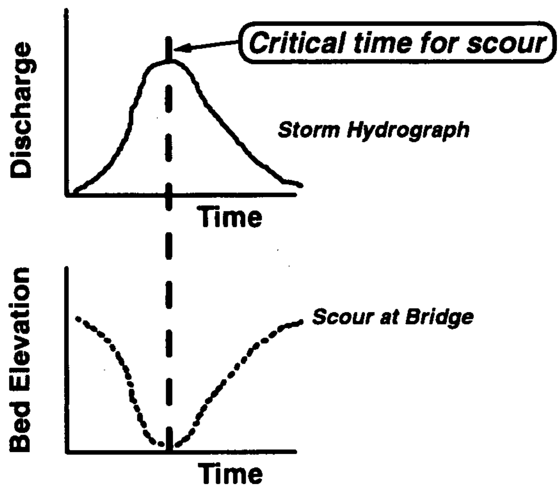


Figure 4. Sketch of the changes in scour depth during a flood.

The effect of debris can also have a very significant influence on the location of greatest scour. Debris accumulation has the effect of increasing the effective width of a pier, which increases the scour depth (see Figure 6). Therefore, if debris tends to accumulate more along one side of a channel than the other, expect greater scour depths at the piers on the debris-laden side of the channel. The presence of debris does complicate instrument installation, and may affect instrument operation.

Additional information on instrument application factors is provided in *NCHRP Report 396.* Detailed information on scour is provided in "Evaluating Scour at Bridges" (*Hydraulic Engineering Circular No. 18,* Richardson and Davis [1995]). Detailed information on stream stability is provided in "Stream Stability and Scour at Highway Structures" (*Hydraulic Engineering Circular No. 20,* Lagasse et al. [1995]).

2.2 ANALYSIS OF THE STRUCTURE

A sonar scour monitor is particularly well suited to large bridges and deep water conditions with minimal debris loading, such as bridges in coastal areas that cross tidal inlets and bays. At these locations, debris accumulation is generally not a problem, and the deep water that often exists eliminates the use of other types of scour instruments.

The instrument can also be used at inland, riverain locations when the transducer is located to minimize problems from debris. Debris accumulation on a pier can interfere with the sonar signal reaching the channel bottom. If debris is a problem, the transducer can be mounted near the channel

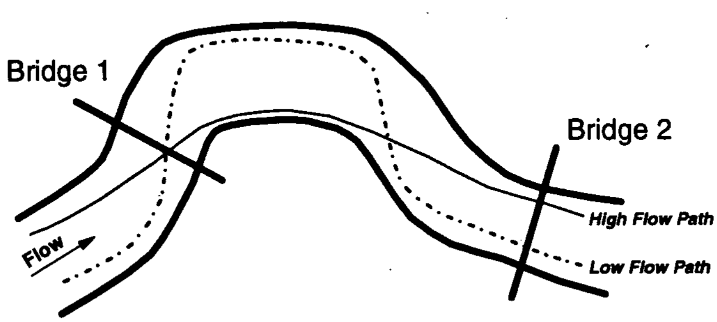


Figure 5. Sketch of changing flow paths during flooding.

Figure 6. Debris collection on a pier.

bottom to minimize the potential of debris collecting between the transducer and channel bottom. However, this may not completely eliminate the problem since waterlogged debris can sink.

A sonar scour monitor is also well suited to measure scour at piers and vertical wall abutments, and in some instances, can be adapted for use at spill-through (sloping) abutments. The problem at spill-through abutments is that the abutment toe-of-slope and potential scour zone are generally not located near a structural member of the bridge to which the transducer can be attached. A mounting bracket attached from the bridge deck or superstructure vertically downward to the toe-of-slope location would be susceptible to debris damage and excessive hydraulic loading, and in many cases, would be impractical because of the height of the bridge off the water. Otherwise, the only other alternative is a mounting bracket traversing the abutment slope itself to the toe-of-slope location. Neither of these solutions is ideal, and generally speaking, a more appropriate instrument to consider would be an automated magnetic sliding collar scour monitor for use at spill-through abutments.

At locations where ice develops in the winter, the conduit with the transducer cable must be adequately protected from impact and crushing. A heavy wall conduit can be used and/or the conduit can be routed up the backside of the pier; however, an alternative solution is to route the transducer cable in a conduit located inside the pier. This concept can be incorporated on a new bridge during design, while on an existing bridge, it may be possible to cut a slot in the pier, install the conduit, and grout over the slot (see Figure 7).

If a large pile cap or spread footer exists, the transducer will have to be located or oriented to "see" beyond the pile cap or footer. It may be possible to permanently mount the transducer on the vertical face of the pile cap or spread footer. However, if the initial distance from the transducer to the channel bottom is less than the minimum depth capability of the sonar (typically 0.5 m [1.5 ft]), the instrument would not provide accurate depth data until scour began to occur. Alternatively, the transducer can be mounted higher up on the pier and angled out so that the sound wave misses the pile cap or footer (Figure 8).

Sonar scour monitors may not work well at bridge locations with significant turbulence and air entrainment. Air entrainment, and particularly large quantities of air bubbles in the water, affect the transmission of the sound wave and the ability of the sonar transducer to get a good return reading. Therefore, the turbulence conditions at the bridge piers and abutments should be noted and the transducer located to avoid areas with excessive turbulence. Similarly, high-sediment concentrations can affect the accuracy of sonar readings.

Figure 7. Transducer conduit retrofitted into pier (transducer is located just inside the bottom of the pipe).

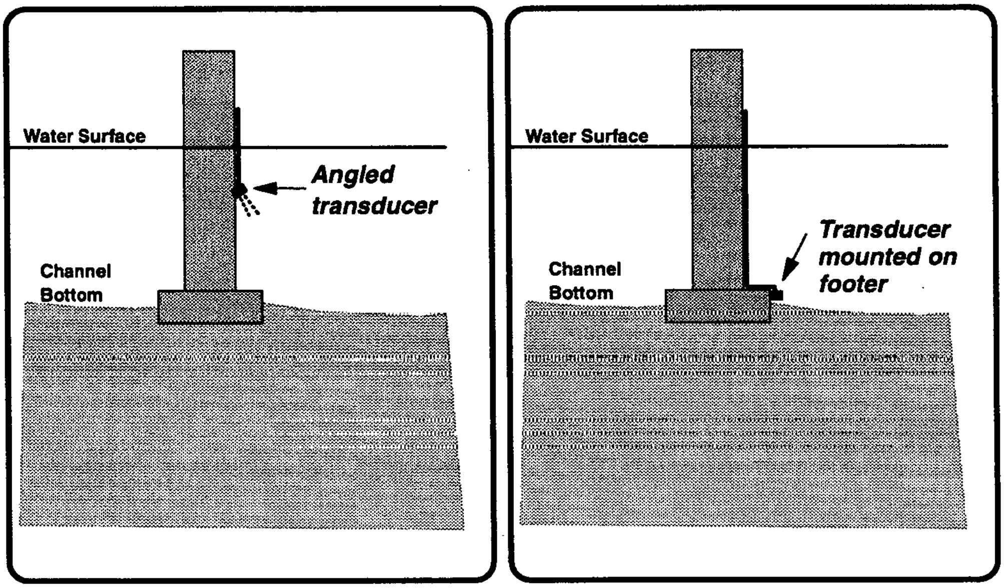


Figure 8. Transducer-mounting options with a pile cap or spread footer.

CHAPTER 3

INSTALLATION AND STARTUP

Sections 3.1 and 3.2 describe necessary steps for site preparation and assembly.

3.1 SITE PREPARATION

1. After selecting the pier or abutment for installation, remove any existing debris that might interfere with installation of the transducer or transducer cable conduit.
2. Evaluate the best location for the instrument enclosure. Factors to be considered include accessibility for servicing, vandalism concerns, length of transducer cable run, and requirements for mounting hardware.
3. Evaluate the solar orientation and select the best location for the solar panel. If the instrument enclosure will be located on the south side of the bridge, it may be possible to attach the solar panel to the instrument enclosure. Otherwise, separate mounting hardware will be required.

3.2 ASSEMBLY

Sonar Instrument

1. The sonar selected for use must have the capability to output depth information to a datalogger. For recreational-type (fish-finder) sonars, this is possible through what is known as a National Marine Electronics Association (NMEA) output capability, a feature typically found on the more deluxe models.
2. NMEA output is 4800-baud, 7-bit, and no parity. NMEA output can communicate through RS-232 protocol, and therefore, can be connected to the serial port on a computer and viewed in terminal mode. The information is output as a sequential ASCII data string that includes depth data and other variables.
3. For the LowranceTM model LMS-350A, for example, the depth information is part of an ASCII sentence that looks like "$SDDBT, 3.1, f,,,,*10", where 3.1 is the depth in feet.
4. If a different sonar is used, the information and sentence structure in the NMEA output must be known so that the datalogger can be programmed to locate and store the depth information.

Datalogger

5. The datalogger must be able to communicate with the selected sonar NMEA sentence. The 4800-baud rate used in the NMEA output is not available on some dataloggers, limiting the alternatives for use in the sonar scour monitor.
6. To minimize power consumption, the datalogger must be able to turn on the sonar at the selected sample interval, collect the data, and turn the sonar back off.
7. The datalogger should have some prescreening or filtering capabilities to reduce erroneous data collection. An algorithm that has been successful is to program the datalogger to look for a number of readings in a row within some specified tolerance. The criteria that was typically used during test installations for NCHRP Project 21-3 were three readings in a row within 0.1 m (0.3 ft). When this criteria was met, the selected readings were averaged and recorded.
8. The ETI Instruments, Inc. EI/MDL datalogger communicates at 4800-baud rate and implements the recommended algorithm. It was also designed with menus that facilitate programming and downloading of the data. The EI/MDL has SDI-12 output capability to allow communication with other instruments that use this language protocol (see Appendix C—Equipment Suppliers).
9. Other dataloggers may also be used. For example, the Campbell™ CR-10X may be used with an optional SC-100 baud rate converter. The CR-10X is a general purpose datalogger that has more features than are required for use in the sonar scour monitor. As a general purpose datalogger, the suggested algorithm must be programmed into the CR-10X prior to use (see Appendix C).
10. Data storage and retrieval can occur by one of several techniques depending on the datalogger used. Common techniques include downloading stored data to a laptop computer through the RS-232 serial port, or using removable data storage devices (e.g., PCMCIA cards).

Battery and Solar Panel

11. A 12-volt sealed gel-cell instrument battery should be used.

12. The battery size and solar panel selected must be based on local solar conditions and the power consumption of the instrument.
13. Most recreational-type (fish-finder) sonars draw about 0.5 amp; however, to ensure adequate power, check the manufacturer's specifications prior to sizing the battery and solar panel. For many installations, a 12 amp-hr battery and a 20-watt solar panel will be adequate.
14. Local solar conditions (or more specifically, the duration of sunny versus cloudy weather) define the battery capacity and solar panel output necessary. Cloudy conditions define how long the battery must last before recharging resumes. The duration of sunny conditions determines how fast the recharging must occur and the output of the solar panel.
15. Available battery capacity is reduced in cold weather. To minimize power-related problems, it is recommended that the battery always be oversized, as cold temperature and other environmental factors can affect battery performance.
16. The size of the solar panel should be increased if less than ideal mounting orientation must be used. However, to minimize power-related problems, it is also recommended that the solar panel always be oversized, as other environmental factors, such as dust, dirt, or snow accumulation can reduce solar panel efficiency.
17. A solar panel regulator should be used to prevent battery overcharging and discharging at night or during overcast conditions.
18. Solar panel manufacturers can assist with selecting the correct solar panel in a given location.

Instrument Enclosure

19. The instrument enclosure and electronics can be assembled prior to arriving at the job-site. This allows testing of all electronics before installation and will expedite the on-site work.
20. The instrument enclosure should be large enough to hold the sonar instrument, datalogger, and battery.
21. A smaller instrument enclosure attached to the main instrument enclosure can be used to house the RS-232 download cable. This eliminates the need to open the main enclosure for downloading purposes and minimizes the potential for unintentional alteration or damage to the main instrument components by inexperienced users.

Transducer

22. Recreational sonar transducers are typically available with either a wide (18–20 deg) or narrow (8–10 deg) cone angle. The cone angle describes the beam width of the sound wave as it propagates through water. A narrow cone angle provides a smaller footprint and higher resolution and is recommended for use in a sonar scour monitor.
23. The transducer can be installed in the selected transducer-mounting bracket (i.e., a permanently attached bracket or the above-water, serviceable-type bracket) in the shop to expedite the on-site work.
24. The minimum sounding distance for most recreational-type sonars is about 0.5 m (1.5 ft). Below this depth, the instrument cannot acquire a stable reading; that is, it cannot "lock on" to the bottom. Therefore, to provide an ongoing data record, the transducer should be mounted at least 0.5 to 1.0 m (1.5 to 3.0 ft) above the channel bottom. Alternatively, the transducer can be mounted lower if no data are necessary until the scour process begins.
25. Most recreational-type sonar transducers come with 7-m (25-ft)-long transducer cables. If a longer cable run is required from the transducer to the instrument enclosure, most manufacturers have extension cables (also typically 7 m [25 ft] long) with waterproof plugs that may be used. Alternatively, some manufacturers use a commonly available cable type (e.g., coax) that can be spliced to create a long cable.
26. Note that as the cable length increases, the signal strength decreases—which can influence sonar performance. However, this factor is generally not a problem given the shallow depths typically involved in scour measurements (e.g., typically less than 15 m [50 ft], while a typical sonar used can easily sound 10 times that distance, or 150 m [500 ft]).
27. One field installation successfully used a 100-m (325-ft) cable run. In this installation the transducer was mounted 1 m (3.2 ft) above riprap around a pier. Therefore, the sounding distance was short and the return signal off the rock riprap was strong.
28. Check with the sonar manufacturer when considering long cable runs or splicing cable.
29. Antifouling paint will minimize the growth of marine organisms on the transducer face at tidal installations. Most antifouling products have a useful life of 1 year; therefore, annual maintenance will be required.

3.3 INSTALLATION AND SUPPORT EQUIPMENT

After site preparation and initial assembly are complete, the typical steps required for installation include

Step 1: Mount the instrument enclosure at the selected location.
Step 2: If the solar panel is not mounted to the instrument enclosure, install the solar panel at the selected location and route the wiring in electrical conduit to the location of the instrument enclosure.
Step 3: Mount the transducer assembly.
Step 4: Route the transducer cable in a conduit to the instrument enclosure.

On small bridges with little or no flow in the channel, a ladder can be used during installation. Otherwise, an under bridge inspection truck will be required. Attaching the necessary brackets to secure the conduit from the transducer to the instrument enclosure typically requires concrete anchors, although, on small piers, stainless steel Band-it™ can be used effectively.

Figure 9 shows a completed installation of a sonar scour monitor.

Figure 9. Completed sonar scour monitor (solar panel in center; above-water, serviceable, transducer-mounting bracket to right; instrument enclosure above transducer-mounting bracket, but not visible).

3.4 STARTUP

Step 1: After completing the installation, confirm the operation of the instrument by programming a short sample interval on the datalogger (e.g., 5 min).

Step 2: Allow the instrument to collect several data points before downloading.

Step 3: Make a sounding with a tape measure, leadline, or portable sonar to establish the known streambed elevation and confirm that the data collected matches within 0.15 m (6 in.).

Step 4: If necessary, apply a temperature or density correction to the measured readings (see Chapter 4).

Step 5: Establish a datum for the location of the transducer for future measurements. This can be accomplished directly by measuring the transducer location, or indirectly based on the independent sounding taken to confirm instrument operation.

Step 6: Reprogram the datalogger for the desired sample interval (e.g., 60 min), close the instrument shelter and lock or otherwise secure, as required.

CHAPTER 4

OPERATION AND DATA ACQUISITION

4.1 THEORY OF OPERATION

The sonar scour monitor implements sonar technology in a low-cost sonar device fabricated from off-the-shelf components. The instrument can measure both scour and refill on an ongoing basis. A datalogger tells the sonar when to turn on, how much data to collect, and when to turn off. Power is provided by a battery and solar panel.

4.2 OPERATOR FUNCTIONS

The datalogger must be programmed according to the manufacturer's procedures. The programming is used to set the sample interval and define the algorithm used for prescreening and filtering the data to minimize erroneous information. Once operational, data collection occurs automatically at the prescribed sample interval. The operator must then periodically download the collected data and perform any required maintenance on the instrument.

4.3 DATA ACQUISITION, ANALYSIS, AND INTERPRETATION

Data Acquisition

Data acquisition should occur according to the established schedule for that particular instrument. The sample interval should be set on the basis of typical duration of a scour-producing flood, the expected rate of change of scour, datalogger storage capacity relative to the frequency of downloading, and battery and solar panel capacities. A 60-min sample interval typically provides sufficient data to define the scour conditions while keeping battery and solar panel sizes reasonable. However, in geographic regions where flooding occurs with short durations and large peak flows, and the streambed is highly erodible (e.g., in the southwestern United States), a shorter sample interval should be considered (e.g., every 15 min).

At 15- to 60-min sample intervals, most available dataloggers can store months and even years of data; however, it is recommended that, as a minimum, downloading occur on a monthly basis. Otherwise, a potentially serious scour problem might not be identified in a timely manner. Additionally, it is important to periodically inspect the instrument to ensure all components are functioning and to ground truth the data to ensure accuracy.

Analysis and Interpretation

A sonar measurement is based on the elapsed time that an acoustic pulse takes to travel from a generating transducer to the waterway bottom and back. Based on the velocity of sound in water, the sonar instrument converts this travel time to a distance. Most recreational sonars assume that the velocity of sound is constant. For example, the Lowrance™ LMS-350A sonar assumes that the velocity of sound is 1,463 m/s (4,800 ft/s), which is representative of freshwater at a temperature of about 16°C (60°F). However, in water, the velocity of sound varies with density, which is primarily a function of temperature and suspended or dissolved solids content. Therefore, if the ambient water temperature and suspended or dissolved content are not near the values implicitly assumed by the sonar (based on the speed of sound used to compute distance), an error will result.

This error is often not significant for scour-monitoring purposes. For example, when freshwater is near freezing, the maximum flow depth that can be measured with an LMS-350A, without exceeding an error of +0.3 m (+1 ft), is about 9 m (30 ft). Similarly, when the water is quite warm (near 27°C [80°F]), the maximum flow depth that can be measured, without exceeding an error of −0.3 m (−1 ft), is about 12 m (40 ft).

The effect of dissolved solids content, for example, salinity when using a sonar scour monitor at a tidal inlet, is less important than the effects of temperature. However, when both the temperature and salinity are significantly different from the assumed conditions (freshwater at 16°C [60°F]), the combined effects can become important. For example, an instrument was installed on Johns Pass on the Gulf of Mexico near St. Petersburg, Florida. At this site, the water temperature ranged from 16–32°C (60–90°F), and the instrument was installed at a pier where the mean water depth was about 14 m (45 ft). The combined effect of temperature, salinity, and large depth measurements resulted in errors as large as 0.75 m (2.5 ft).

Correction for velocity of sound variations can be made in a post-processing mode; that is, after the fact, if the temper-

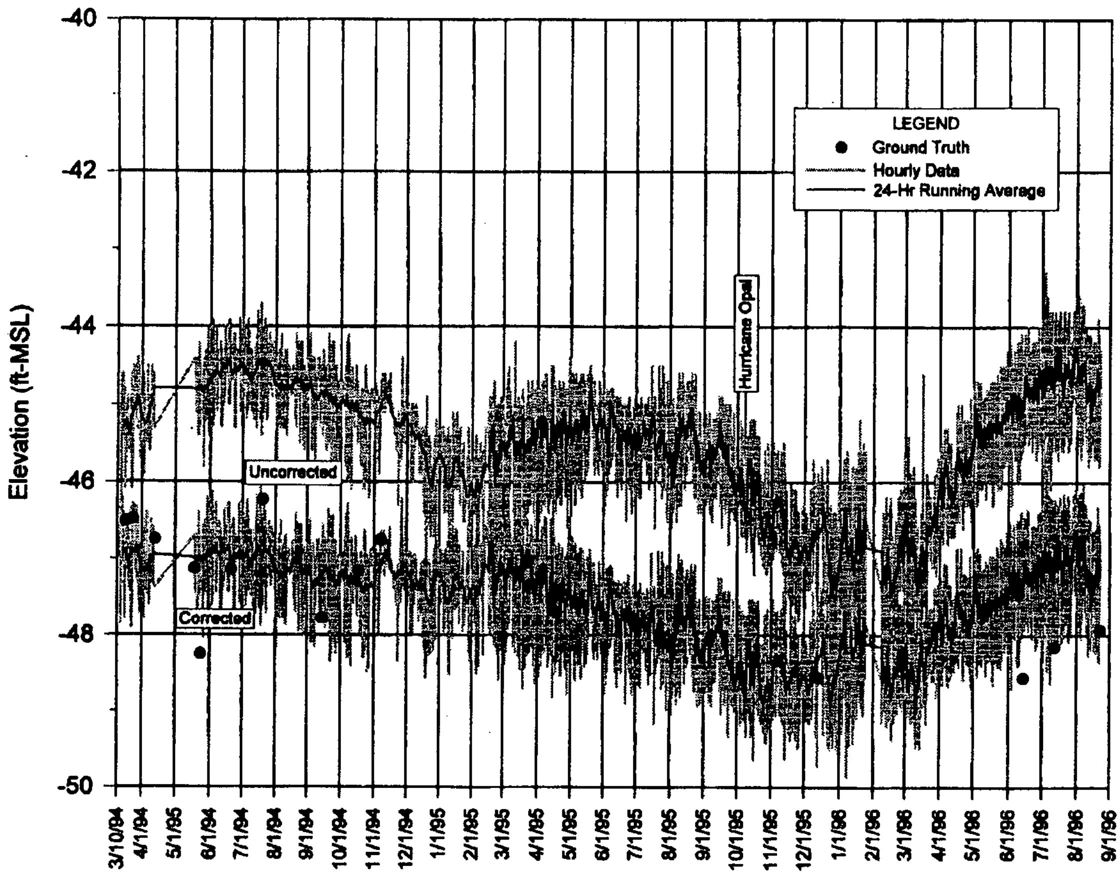


Figure 10. Uncorrected and corrected sonar scour monitor data for a deep-water tidal installation (gray band is data collected at 60-min intervals; black line is a moving average line to show trends).

ature and salinity at the time of measurement are known or can be estimated. An empirical equation for the velocity of sound, given temperature and salinity, is

$$V = 1449 + 4.6\,(^\circ C) - 0.055\,(^\circ C^2) + 0.0003\,(^\circ C^3)$$
$$+ (1.39 - 0.012\,(^\circ C))(S - 35) + 0.017\,(d)$$

where

V = Velocity of sound, m/s
°C = Temperature in Celsius
S = Salinity, ppt (parts per thousand)
d = depth, m

Therefore, given temperature and salinity, the true velocity of sound at the time of measurement can be estimated. The correction is then based on a simple ratio of the true velocity of sound to the assumed velocity of sound, or

$$D_{actual} = D_{measured} \times (V_{true} / V_{assumed})$$

Figure 10 shows the sonar depth before and after correction for a deep-water tidal installation and illustrates the error that can occur with significant temperature and salinity variations from the assumed values. Note that because of the seasonal temperature variations, the error was not constant throughout the year. As a result, the general trend of scour was misrepresented in the original data (e.g., note suggested refill in early 1995 in the uncorrected data). After the corrections were applied, a consistent downward trend was identified prior to January 1996.

CHAPTER 5

TROUBLESHOOTING, MAINTENANCE, AND SERVICING

5.1 TROUBLESHOOTING

Problem

The sonar instrument does not turn on at the scheduled sample intervals.

Solution

1. Check the battery voltage and all power connections.
2. If the battery voltage is low (less than 11 volts), check the output of the solar panel with the sun shining and make sure it is producing at least 15 volts before the regulator and about 13.5 volts after the regulator.
3. If the solar panel is functioning properly, either (1) the battery is faulty or was drawn down by lack of solar energy for recharging (e.g., an extended period of overcast weather) or (2) the datalogger is leaving the sonar on for too long, or cycling too frequently, from either an error in programming or a faulty datalogger.
4. In either case, replace the battery with a fully charged battery and evaluate the datalogger functioning for a short sample interval (e.g., 5 min). If the datalogger appears to be functioning properly, reprogram for the regular sample interval and periodically check the battery voltage (e.g., every week) to ensure proper operation.
5. If the datalogger appears to be malfunctioning, check the programming or follow the manufacturer's troubleshooting instructions.

Problem

The sonar readings are erratic.

Solution

1. Check for debris under the transducer. Remove debris as required.
2. Check for algae or marine organisms on the transducer. Clean as required.

5.2 MAINTENANCE AND SERVICING

1. A primary maintenance concern with a sonar scour monitor is debris collecting on the transducer or the conduit leading up to the bridge deck. If debris is found on the transducer or is bending or crushing the pipe, it should be removed.
2. Submerged, waterlogged debris may also potentially sink beneath a transducer mounted very near the channel bottom. The only way to evaluate this potential concern is with a ground truth measurement or inspection by a diver. A ground truth measurement is simply a measurement of the scour condition by some alternate technique to evaluate instrument performance.
3. Ground truthing or dive inspection should be a regular part of the maintenance program for any scour instrument.
4. Any algae in freshwater or marine organisms in seawater must be removed from the transducer face.
5. Painting the transducer with a conventional marine antifouling paint has been effective in controlling marine organisms, but the transducer must be periodically repainted to maintain effectiveness. Experience suggests that the useful life of an antifouling paint treatment is about 12 months. This type of maintenance is most efficiently completed with an above-water, transducer-mounting bracket and a spare transducer insert. When maintenance is required, the old transducer can be removed and the replacement installed in a short amount of time with only one trip to the bridge site.

5.3 ANNUAL SERVICING

1. Inspect the conduit and cable run for damage and repair or replace as necessary.
2. Inspect the electronics enclosure and clean out any spiders, mice nests, and so on. Check the door gasket and/or seal.
3. Check and clean the solar panel.

CHAPTER 6

ENHANCEMENTS

Telemetry and early warning devices can be incorporated into a sonar scour monitor, based in part on the capability of the datalogger selected. Telemetry can be either local telemetry or long-distance telemetry.

Local telemetry is used to transmit data from an instrument enclosure on the bridge to a location at the edge of the bridge near the abutment. This might be advantageous if a lane closure is required to safely service the instrument enclosure, or if the instrument enclosure is located in the middle of a long bridge. In these situations, a local telemetry system could be used to download the instrument without going to the main instrument enclosure. Radio frequency (RF) receivers using conventional techniques or spread spectrum technology can be employed for local telemetry. Local telemetry can also be used when the cost of running cable and conduit becomes expensive.

Long-distance telemetry allows downloading data without visiting the bridge site. There are a number of telemetry methods available, including microwave networks, UHF/VHF networks, satellite systems, and cellular phone-based systems.

An early warning system can also be added to a sonar scour monitor by having some type of warning light or signal activated when scour reaches a certain depth. Effective use of this enhancement requires first defining the scour-critical elevation, and second, effectively communicating to all responsible parties the nature of the warning system and the action to be taken when it is activated.

Note: For more detail on enhancements such as telemetry or early warning possibilities, see *NCHRP Report 396.* While none of these enhancements was investigated in detail during Project 21-3, demonstrations of feasibility for several enhancement options were completed.

PART II FABRICATION

CHAPTER 7

SYSTEM SCHEMATICS AND SPECIFICATIONS

7.1 MAJOR COMPONENTS

The major components of a sonar scour monitor are

1. Instrument enclosure,
2. Transducer-mounting bracket, and
3. Conduit for transducer cable.

The following sections detail the fabrication of each of these major components. Detailed, scaled construction drawings are provided in Appendix A, and referenced by sheet number. *Sheet 1* is a conceptual sketch showing a typical installation of a sonar scour monitor with an above-water, transducer-mounting bracket. Photographs, schematics, and a parts list for a typical installation are shown in Appendix B, and a list of equipment suppliers is provided in Appendix C.

7.2 INSTRUMENT ENCLOSURE

1. The instrument enclosure needs to be a weathertight, vandal-resistant enclosure. The instrument enclosure shown on *Sheet 2* is a molded, fiberglass polyester enclosure that is weathertight and lockable.
2. As shown on *Sheet 2*, a smaller instrument enclosure can be attached to the main instrument enclosure to provide access to the download cable without opening the main enclosure.
3. *Sheet 2* also shows the solar panel bolted to the lid of the enclosure. If the instrument enclosure is not on the south side of the bridge, the solar panel will have to be mounted separately.
4. In areas where vandalism is a concern, it is recommended that a steel enclosure be used, or the fiberglass enclosure placed inside a steel vandal resistant housing.
5. A typical interior layout of the instrument enclosure is shown on *Sheet 3*. The instrument enclosure must be large enough to contain the sonar instrument, datalogger, battery, solar panel regulator, and associated wiring.

7.3 TRANSDUCER HOUSING

The transducer can be permanently attached to the bridge, or housed in the "above-water, serviceable, transducer-mounting bracket" developed under NCHRP Project 21-3. When attaching the transducer permanently to the bridge, it is recommended that a small steel housing be placed around the transducer to protect it and to deflect any debris or ice. The transducer and its protective housing can be bolted directly to the bridge using appropriate concrete anchors. Information related to constructing and installing an above-water, serviceable, transducer-mounting bracket follows.

1. An above-water, serviceable, transducer-mounting bracket is illustrated in *Sheet 4*. The transducer is mounted to the transducer insert and can be extracted from the mounting bracket by removing the cap at the top and pulling on the handle of the transducer insert.
2. The entire mounting bracket can be angled outward so that battered piles, spread footings, or other bridge foundation components do not interfere with the sonar signal.
3. The above-water, serviceable, transducer-mounting bracket is built with schedule 80 PVC pipe and fittings (*Sheets 5 and 6*). In areas where debris loading or impact is a concern, a steel structure can be fabricated and attached over the transducer mount for protection. Alternatively, the mounting bracket itself can be fabricated from steel pipe and fittings. Plastic pipe is particularly recommended in tidal installations where corrosion is a concern.
4. The transducer insert for the above-water, serviceable, transducer-mounting bracket is shown on *Sheet 7*. The insert holds the transducer and centers it as it is positioned in the transducer-mounting bracket. The design shown is based on a Lowrance™ PD-N 8-degree transducer. For a different transducer, modify the design as required.

7.4 CONDUIT

The conduit for the transducer cable must be routed from the transducer mount to the instrument enclosure. If debris and ice are not a factor, flexible conduit can be used and will save time and money during installation. Otherwise, rigid conduit should be used. The conduit can be routed up the backside of a pier or otherwise placed to minimize potential debris and ice damage. Secure the conduit with standard con-

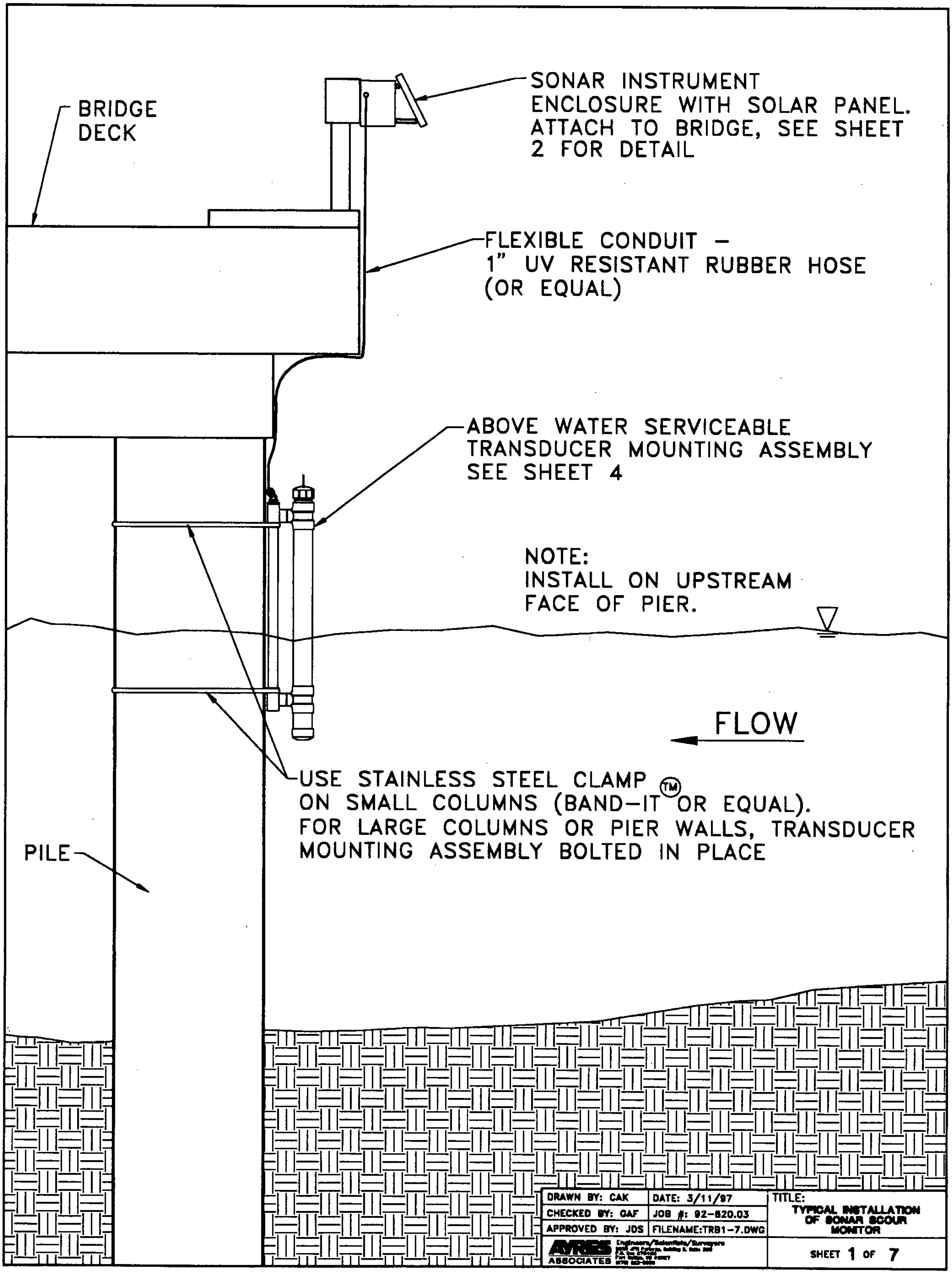
duit clamps and concrete anchors; on small piers stainless steel Band-it™ can be used.

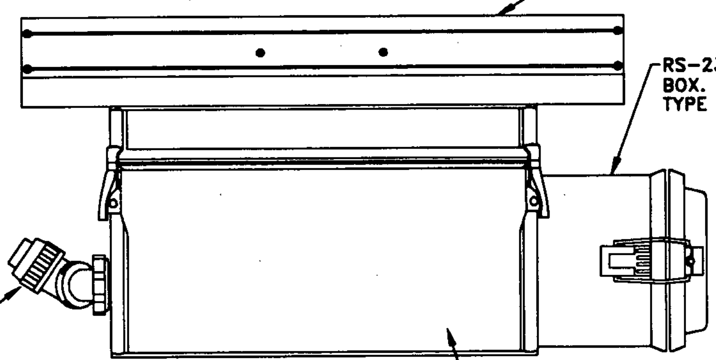
7.5 TYPICAL INSTALLATION FOR SONAR SCOUR MONITOR

Installation photographs, schematics, and a parts list for a typical low-cost, above-water, serviceable sonar instrument are included as Appendix B. While no two installations of a sonar instrument will be identical (depending on bridge geometry and stream characteristics), the photographs and schematics of Appendix B provide guidance on a typical installation. A detailed parts list and wiring diagram for electric components are also included. It should be noted that the connections shown are specific to the instruments illustrated.

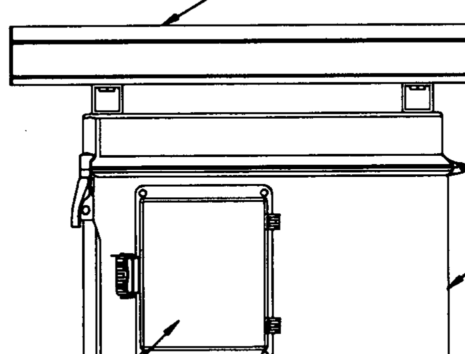
APPENDIX A

INSTALLATION AND FABRICATION DRAWINGS FOR SONAR SCOUR MONITOR


BRIDGE DECK
SONAR INSTRUMENT ENCLOSURE WITH SOLAR PANEL. ATTACH TO BRIDGE, SEE SHEET 2 FOR DETAIL
FLEXIBLE CONDUIT - 1" UV RESISTANT RUBBER HOSE (OR EQUAL)
ABOVE WATER SERVICEABLE TRANSDUCER MOUNTING ASSEMBLY SEE SHEET 4
NOTE: INSTALL ON UPSTREAM FACE OF PIER.
FLOW
USE STAINLESS STEEL CLAMP ON SMALL COLUMNS (BAND-IT(TM) OR EQUAL). FOR LARGE COLUMNS OR PIER WALLS, TRANSDUCER MOUNTING ASSEMBLY BOLTED IN PLACE
PILE
DRAWN BY: CAK
DATE: 3/11/97
CHECKED BY: GAF
JOB #: 92-520.03
APPROVED BY: JDS
FILENAME:TRB1-7.DWG
AYRES ASSOCIATES
Engineers/Scientists/Surveyors
TITLE: TYPICAL INSTALLATION OF SONAR SCOUR MONITOR
SHEET 1 OF 7



FRONT VIEW



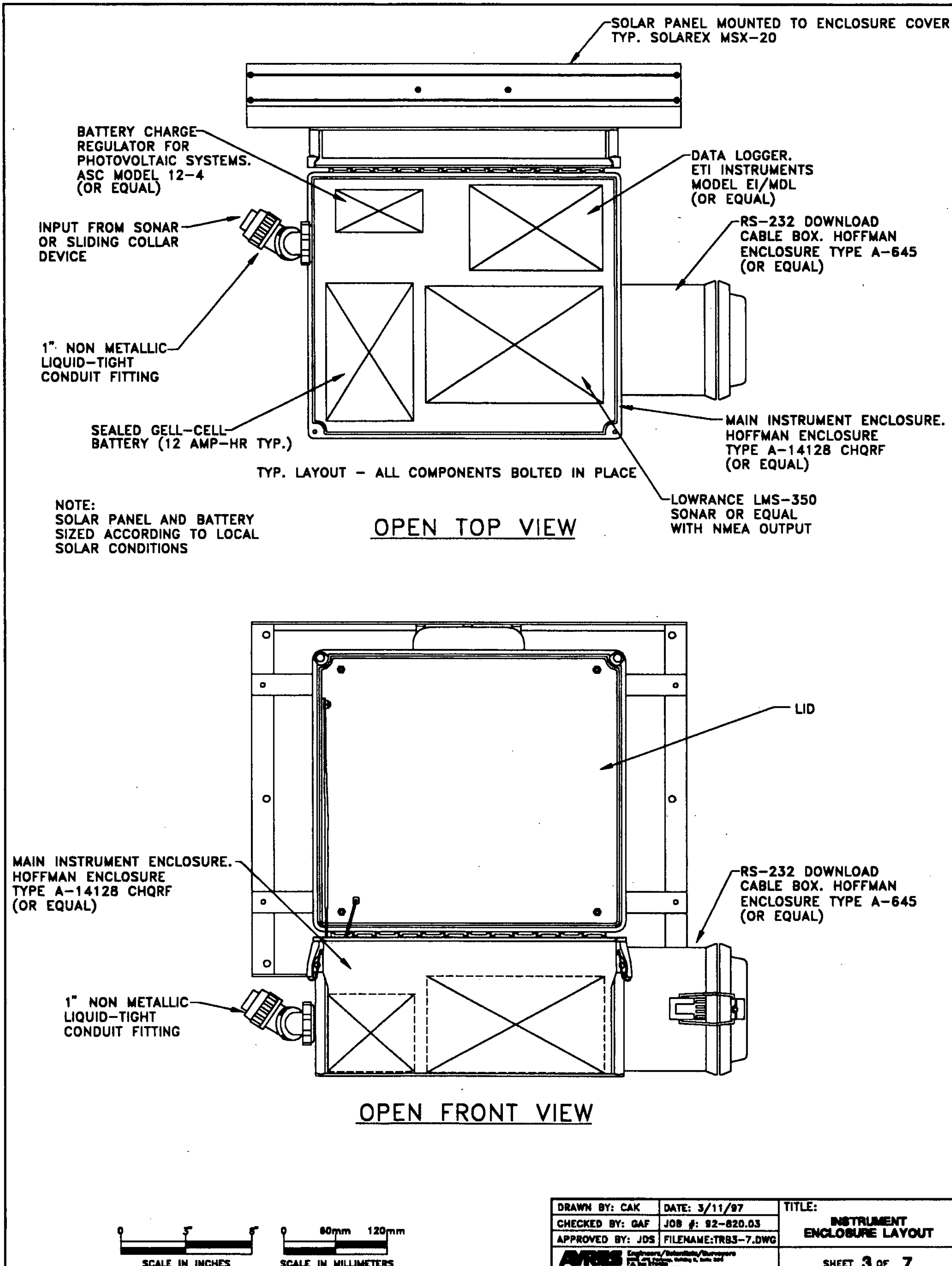
SIDE VIEW

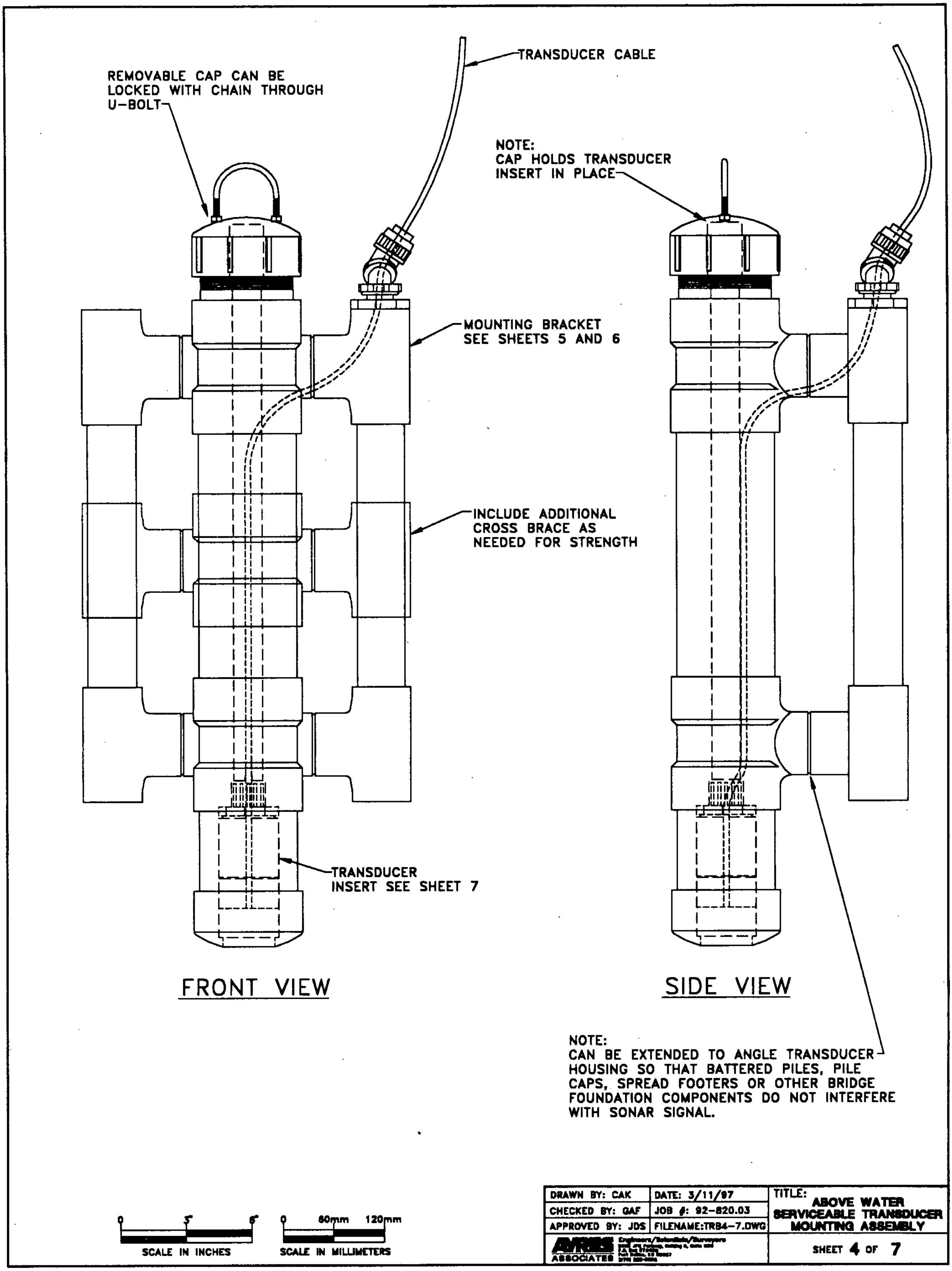
NOTE:
SOLAR PANEL SIZE MAY CHANGE DUE
TO MOUNTING AND SOLAR EXPOSURE.

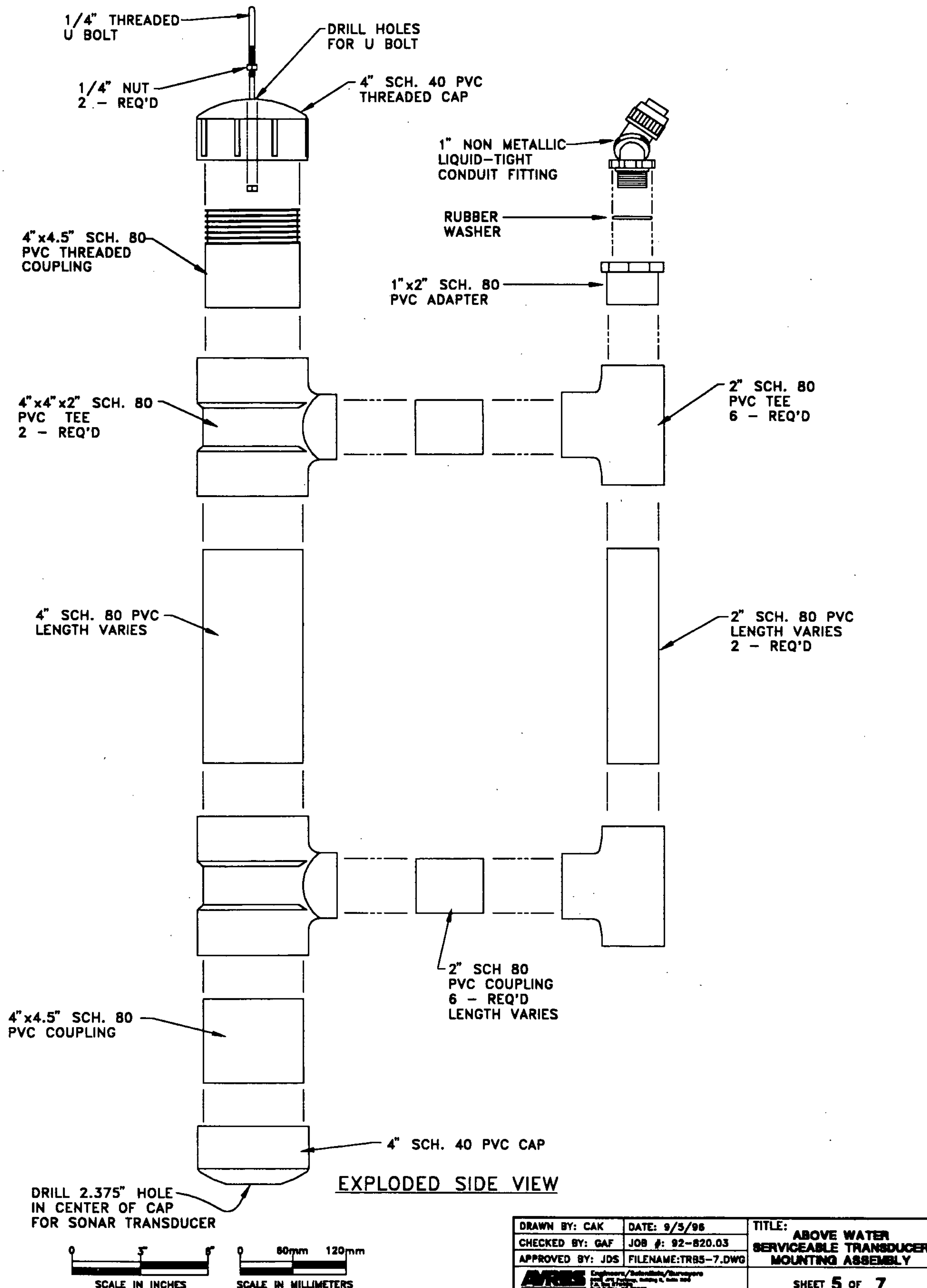
0 3" 6"
SCALE IN INCHES

0 60mm 120mm
SCALE IN MILLIMETERS

DRAWN BY: CAK	DATE: 3/11/97	TITLE: INSTRUMENT ENCLOSURE WITH ATTACHED SOLAR PANEL
CHECKED BY: GAF	JOB #: 92-820.03	
APPROVED BY: JDS	FILENAME:TRB2-7.DWG	
AYRES ASSOCIATES		SHEET 2 OF 7


SOLAR PANEL MOUNTED TO ENCLOSURE COVER
TYP. SOLAREX MSX-20
BATTERY CHARGE REGULATOR FOR PHOTOVOLTAIC SYSTEMS. ASC MODEL 12-4 (OR EQUAL)
DATA LOGGER. ETI INSTRUMENTS MODEL EI/MDL (OR EQUAL)
INPUT FROM SONAR OR SLIDING COLLAR DEVICE
RS-232 DOWNLOAD CABLE BOX. HOFFMAN ENCLOSURE TYPE A-645 (OR EQUAL)
1" NON METALLIC LIQUID-TIGHT CONDUIT FITTING
SEALED GELL-CELL BATTERY (12 AMP-HR TYP.)
MAIN INSTRUMENT ENCLOSURE. HOFFMAN ENCLOSURE TYPE A-14128 CHQRF (OR EQUAL)
TYP. LAYOUT - ALL COMPONENTS BOLTED IN PLACE
LOWRANCE LMS-350 SONAR OR EQUAL WITH NMEA OUTPUT
NOTE: SOLAR PANEL AND BATTERY SIZED ACCORDING TO LOCAL SOLAR CONDITIONS
OPEN TOP VIEW
LID
MAIN INSTRUMENT ENCLOSURE. HOFFMAN ENCLOSURE TYPE A-14128 CHQRF (OR EQUAL)
RS-232 DOWNLOAD CABLE BOX. HOFFMAN ENCLOSURE TYPE A-645 (OR EQUAL)
1" NON METALLIC LIQUID-TIGHT CONDUIT FITTING
OPEN FRONT VIEW
0 3" 6"
SCALE IN INCHES
0 60mm 120mm
SCALE IN MILLIMETERS
DRAWN BY: CAK
DATE: 3/11/97
CHECKED BY: GAF
JOB #: 92-820.03
APPROVED BY: JDS
FILENAME:TRB3-7.DWG
AYRES ASSOCIATES
TITLE: INSTRUMENT ENCLOSURE LAYOUT
SHEET 3 OF 7


TRANSDUCER CABLE
REMOVABLE CAP CAN BE LOCKED WITH CHAIN THROUGH U-BOLT
NOTE: CAP HOLDS TRANSDUCER INSERT IN PLACE
MOUNTING BRACKET SEE SHEETS 5 AND 6
INCLUDE ADDITIONAL CROSS BRACE AS NEEDED FOR STRENGTH
TRANSDUCER INSERT SEE SHEET 7
FRONT VIEW
SIDE VIEW
NOTE: CAN BE EXTENDED TO ANGLE TRANSDUCER HOUSING SO THAT BATTERED PILES, PILE CAPS, SPREAD FOOTERS OR OTHER BRIDGE FOUNDATION COMPONENTS DO NOT INTERFERE WITH SONAR SIGNAL.
0 3" 6"
SCALE IN INCHES
0 60mm 120mm
SCALE IN MILLIMETERS
DRAWN BY: CAK
DATE: 3/11/97
CHECKED BY: GAF
JOB #: 92-820.03
APPROVED BY: JDS
FILENAME:TRB4-7.DWG
AYRES ASSOCIATES
Engineers/Scientists/Surveyors
TITLE: ABOVE WATER SERVICEABLE TRANSDUCER MOUNTING ASSEMBLY
SHEET 4 OF 7



EXPLODED SIDE VIEW

DRAWN BY: CAK	DATE: 9/5/96	TITLE: ABOVE WATER SERVICEABLE TRANSDUCER MOUNTING ASSEMBLY
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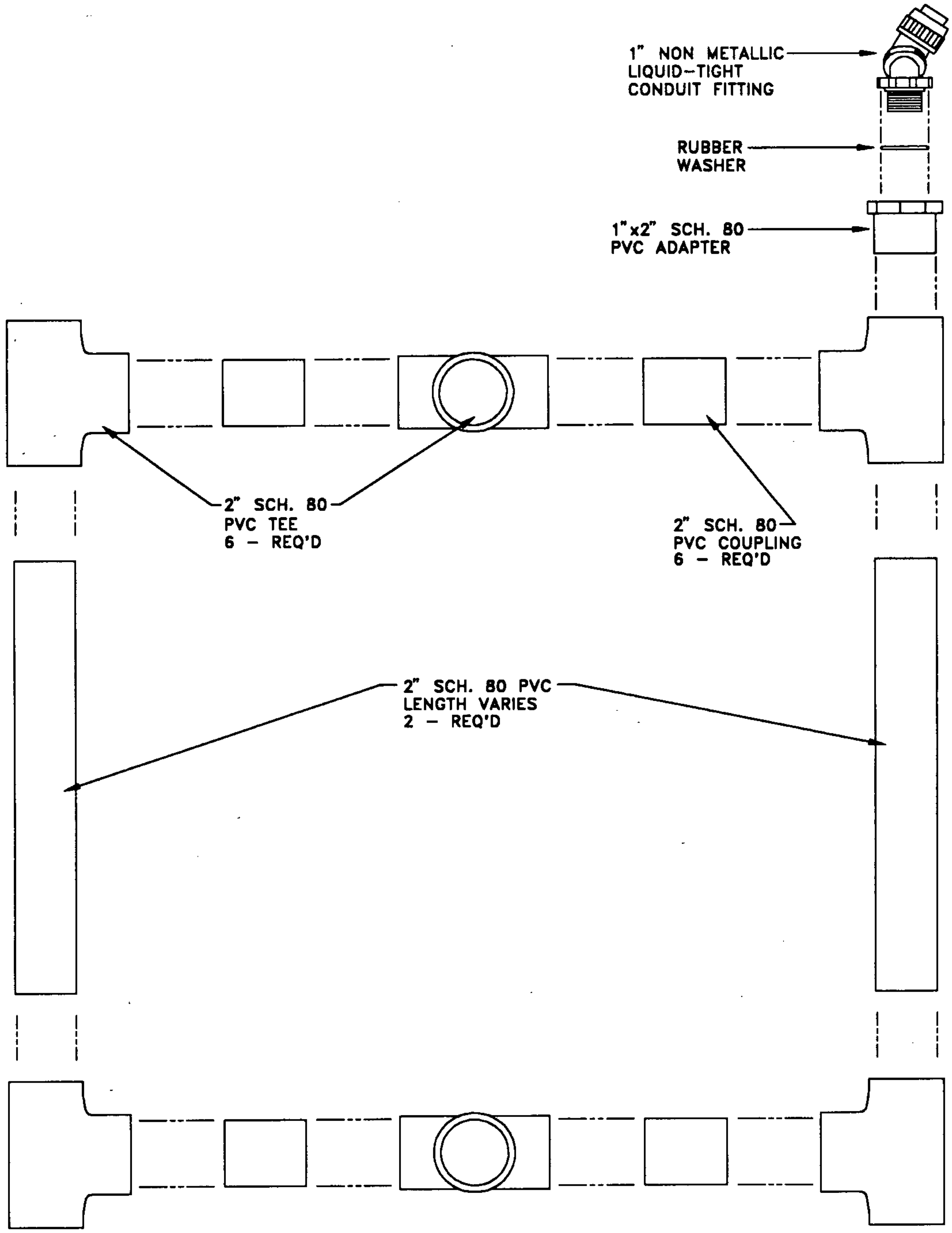
APPROVED BY: JDS	FILENAME:TRB5-7.DWG	
AYRES ASSOCIATES		SHEET 5 OF 7

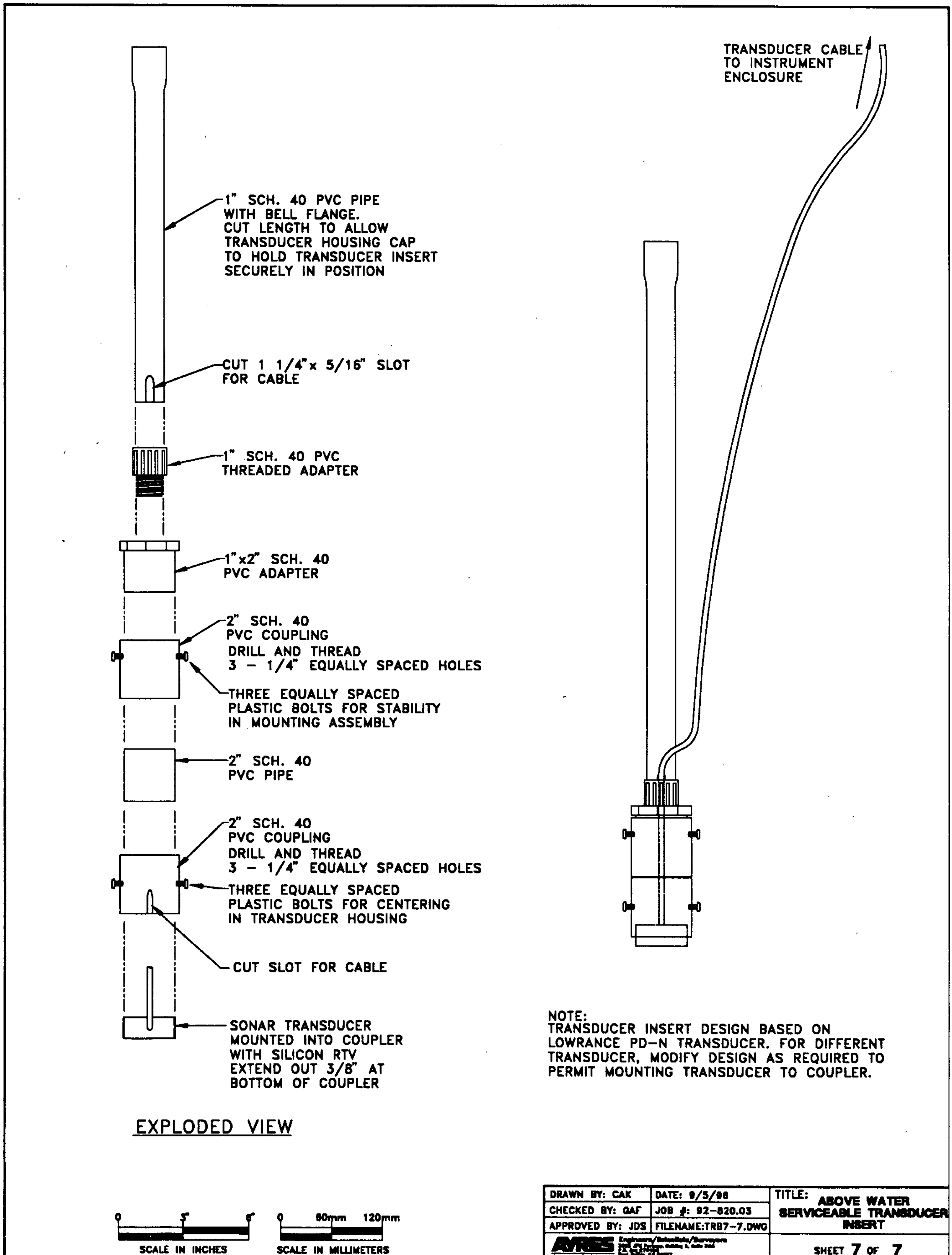


EXPLODED FRONT VIEW

0 3" 6"
SCALE IN INCHES

0 60mm 120mm
SCALE IN MILLIMETERS

DRAWN BY: CAK	DATE: 3/11/97	TITLE: ABOVE WATER SERVICEABLE TRANSDUCER MOUNTING ASSEMBLY
CHECKED BY: GAF	JOB #: 92-820.03	
APPROVED BY: JDS	FILENAME:TRB6-7.DWG	
AYRES ASSOCIATES		SHEET 6 OF 7


TRANSDUCER CABLE
TO INSTRUMENT
ENCLOSURE
1" SCH. 40 PVC PIPE
WITH BELL FLANGE.
CUT LENGTH TO ALLOW
TRANSDUCER HOUSING CAP
TO HOLD TRANSDUCER INSERT
SECURELY IN POSITION
CUT 1 1/4"x 5/16" SLOT
FOR CABLE
1" SCH. 40 PVC
THREADED ADAPTER
1"x2" SCH. 40
PVC ADAPTER
2" SCH. 40
PVC COUPLING
DRILL AND THREAD
3 - 1/4" EQUALLY SPACED HOLES
THREE EQUALLY SPACED
PLASTIC BOLTS FOR STABILITY
IN MOUNTING ASSEMBLY
2" SCH. 40
PVC PIPE
2" SCH. 40
PVC COUPLING
DRILL AND THREAD
3 - 1/4" EQUALLY SPACED HOLES
THREE EQUALLY SPACED
PLASTIC BOLTS FOR CENTERING
IN TRANSDUCER HOUSING
CUT SLOT FOR CABLE
SONAR TRANSDUCER
MOUNTED INTO COUPLER
WITH SILICON RTV
EXTEND OUT 3/8" AT
BOTTOM OF COUPLER
EXPLODED VIEW
NOTE:
TRANSDUCER INSERT DESIGN BASED ON
LOWRANCE PD-N TRANSDUCER. FOR DIFFERENT
TRANSDUCER, MODIFY DESIGN AS REQUIRED TO
PERMIT MOUNTING TRANSDUCER TO COUPLER.
0 3" 6"
SCALE IN INCHES
0 60mm 120mm
SCALE IN MILLIMETERS
DRAWN BY: CAK
DATE: 9/5/96
CHECKED BY: GAF
JOB #: 92-820.03
APPROVED BY: JDS
FILENAME:TRB7-7.DWG
AYRES ASSOCIATES
TITLE: ABOVE WATER SERVICEABLE TRANSDUCER INSERT
SHEET 7 OF 7

APPENDIX B

TYPICAL INSTALLATION FOR SONAR SCOUR MONITOR

Purpose

This appendix is intended to illustrate a typical installation of a low-cost, above-water, serviceable sonar scour monitor. A series of photographs illustrates site characteristics, major system components, and installation details. While no two installations of a sonar instrument will be identical (depending on bridge geometry and stream characteristics), the photographs provide guidance on a typical installation. A schematic wiring diagram for electronic components and a detailed parts list for this installation are included. It should be noted that the connections shown in the wiring diagram are specific to the instruments used at this site.

Site Description

The site selected to illustrate a typical installation of a sonar scour monitor is on Nassau Sound where the State Route 105 (AIA) bridge crosses the mouth of the Nassau River on the Atlantic coast north of Jacksonville, Florida. This site, designated FL2 during NCHRP Project 21-3 (see Figures B-1 and B-2), is a very active tidal estuary, which has a sand bed and has experienced scour problems in the past. Florida DOT District 2 has installed crutch piling at several bents near the south bridge abutment as a scour countermeasure. As shown in Figure B-2, a sonar scour monitor and a magnetic sliding collar device were installed at the north end of the bridge on the ocean side. Note: A description of the magnetic sliding collar device installed on this bridge is provided in *NCHRP Report 396.*

This low-level bridge has 85 pile bents. The sonar instrument was installed on Bent 53 (numbered from the south abutment) in a water depth of approximately 8 m (26 ft). The normal tidal range at this site is 0.8 m (2.5 ft) and mean current velocity about 0.9 m/s (3 ft/s). Approximately 0.6 m (2 ft) of fluctuating scour had been noted in past bridge inspection reports on the east (ocean) side of this bent. The bridge top of curb was approximately 4.6 m (15 ft) above the water and the pile cap was 762 mm (30 in.) high and 838 mm (33 in.) wide. The 457-mm (18-in.) square concrete piles were slightly battered and inset approximately 406 mm (16 in.) from the face of the pile cap. The bridge is shown in Figures B-3 and B-4.

Installation

The installation of the sonar scour monitor is shown in Figures B-5 and B-6. The fabrication of the mounting assembly was as detailed in Appendix A, Sheets 1 through 7. At a tidal site with little possibility for debris, but potential corrosion problems, the unit was fabricated from Schedule 80 PVC. (Note: On Sheet 5 of 7, several components are available only as Schedule 40 PVC). In debris or ice-prone environments, the mounting assembly could be fabricated from Schedule 40 steel or stainless steel components. The use of an under bridge inspection truck and boat from Florida DOT District 2 greatly facilitated the installation of the mounting assembly (Figures B-5 and B-6). Note: Other mounting configurations for a sonar scour monitor are illustrated in *NCHRP Report 396.*

The unit was secured to the concrete piling by stainless steel strapping as shown in Figure B-6 so that the transducer face was below water. Figures B-7 and B-8 show the instrument enclosure and bridge rail mounting brackets. The mounting bracket pivot shown in Figure B-8 allowed mounting the instrument enclosure and solar panel below the level of the bridge rail to reduce the potential for vandalism.

Figure B-9 shows electronic equipment installed in the instrument enclosure, including the sonar instrument, data logger, and battery. In the case of a Lowrance™ LMS-350A Sonar, as used in this installation, an aluminum strap was required over the power switch to hold it in the "on" position. The ETI instruments EI/MDL datalogger could then control the on-off operation of the sonar by supplying power at the scheduled sample intervals through a relay circuit. The schematic wiring diagram (see Figure B-10) shows the connections required for the specific instruments used at this site. Figures B-11 and B-12 show the completed installation and the use of a laptop computer to program the instrument to begin collecting data.

Parts List

A complete parts list for the sonar scour monitor installed on the Nassau Sound bridge follows at the end of this appendix.

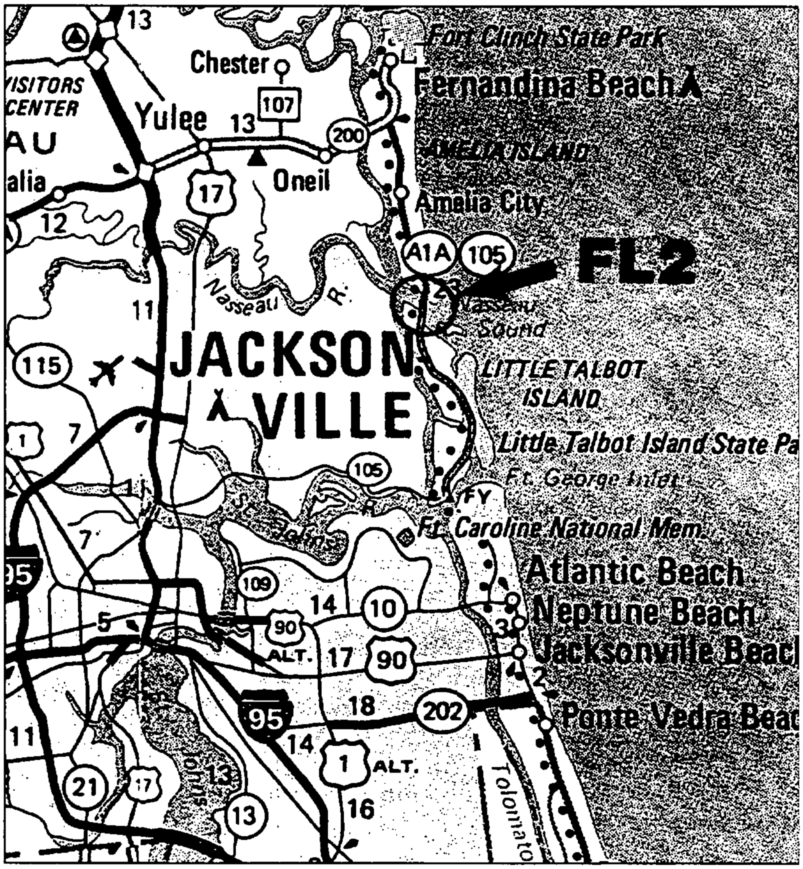


Figure B-1. Location map for Nassau Sound Bridge.

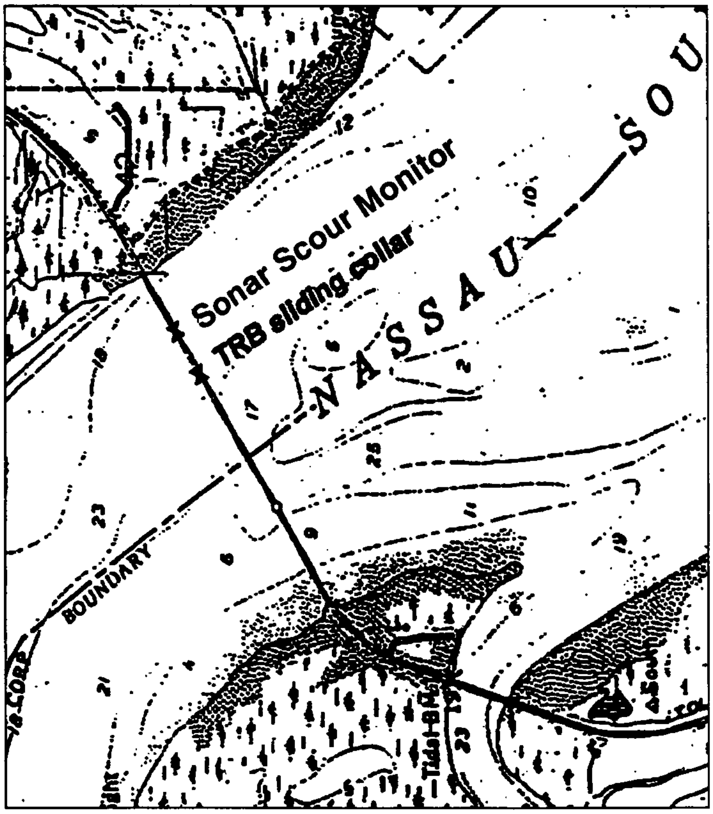


Figure B-2. Nassau Sound Bridge showing location of instruments.

Figure B-3. Nassau Sound Bridge.

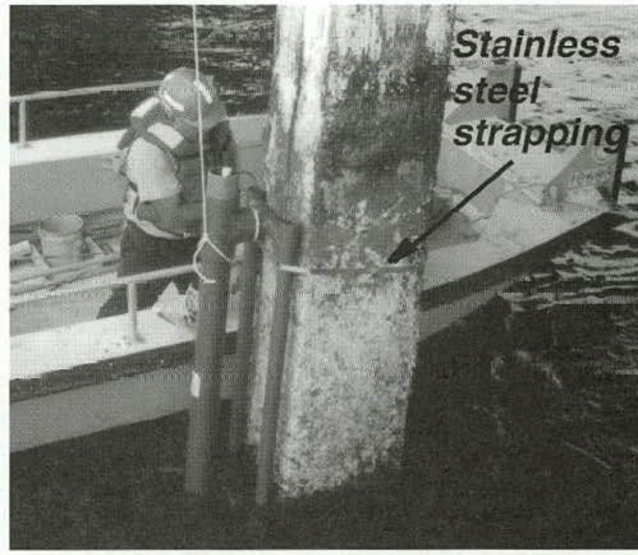


Figure B-6. Securing transducer-mounting assembly in place.

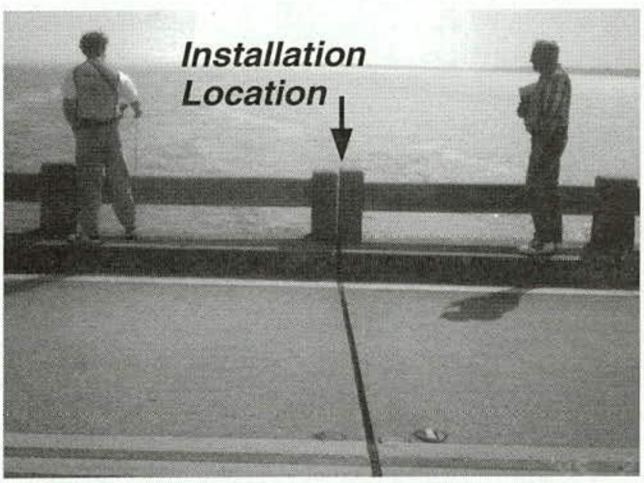


Figure B-4. Bridge deck showing installation location.

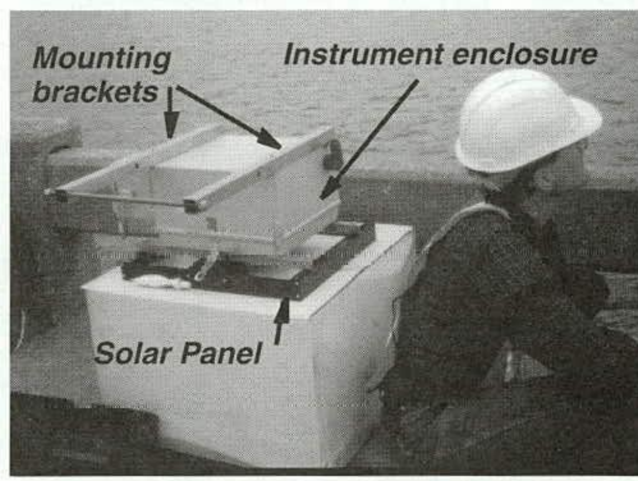


Figure B-7. Instrument enclosure prior to installation.

Figure B-5. Positioning transducer-mounting assembly.

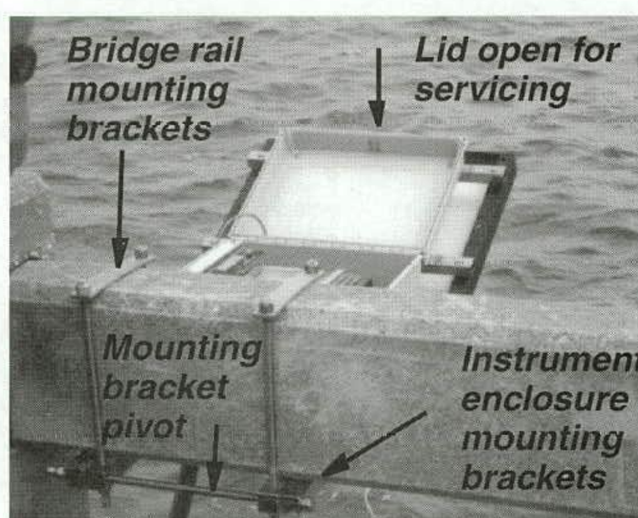


Figure B-8. Instrument enclosure mounted to bridge rail.

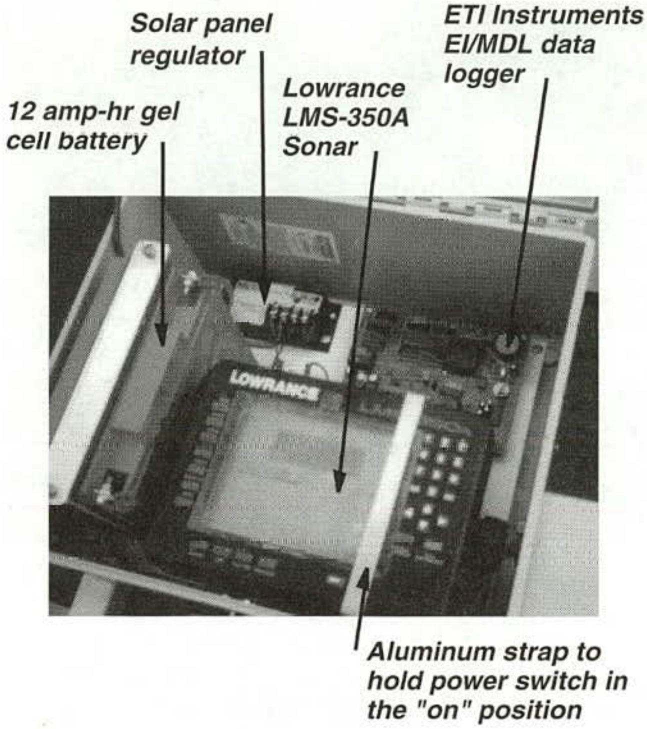


Figure B-9. Equipment installed in instrument enclosure.

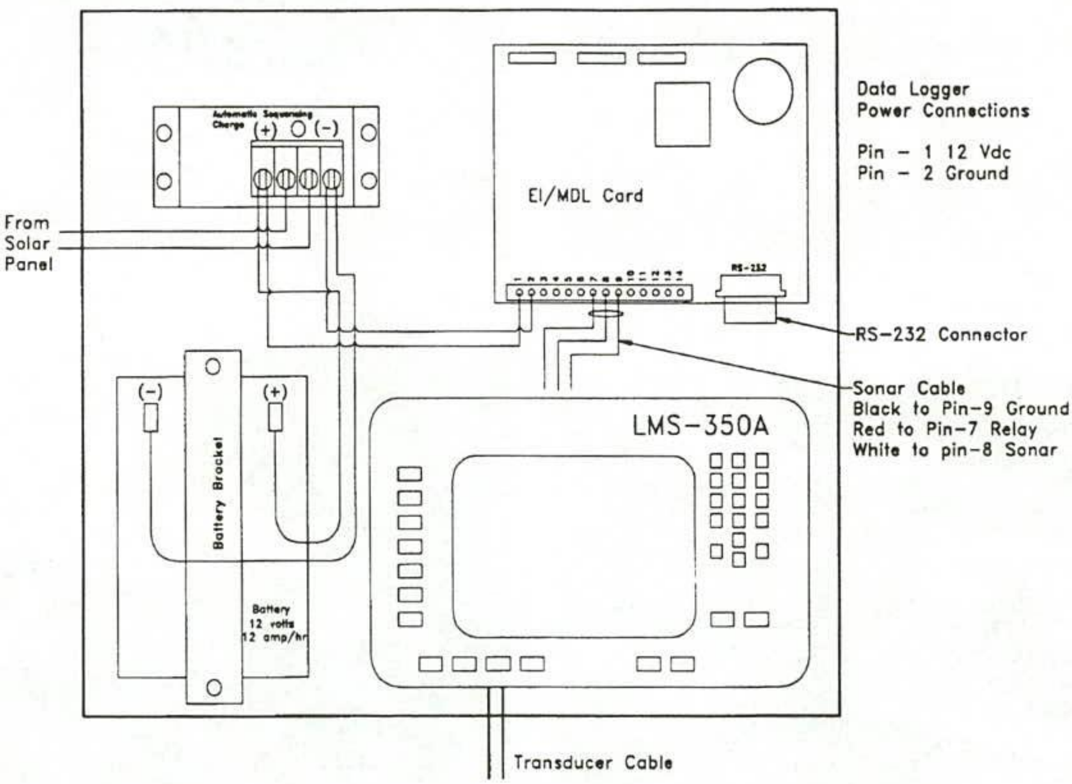


Figure B-10. Schematic wiring diagram for typical sonar scour instrument electronic components.

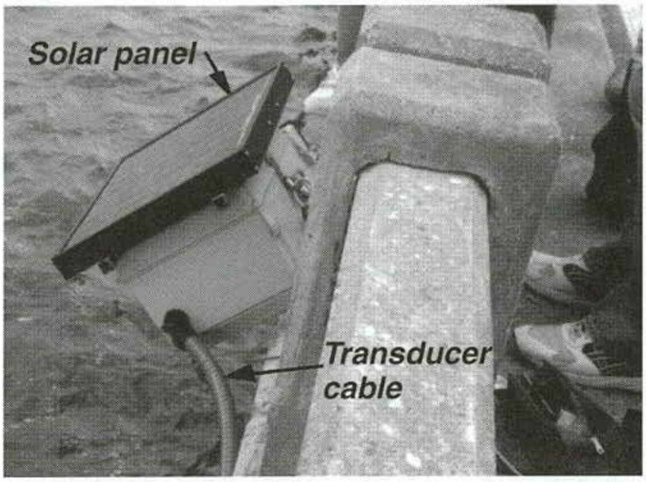


Figure B-11. Completed installation.

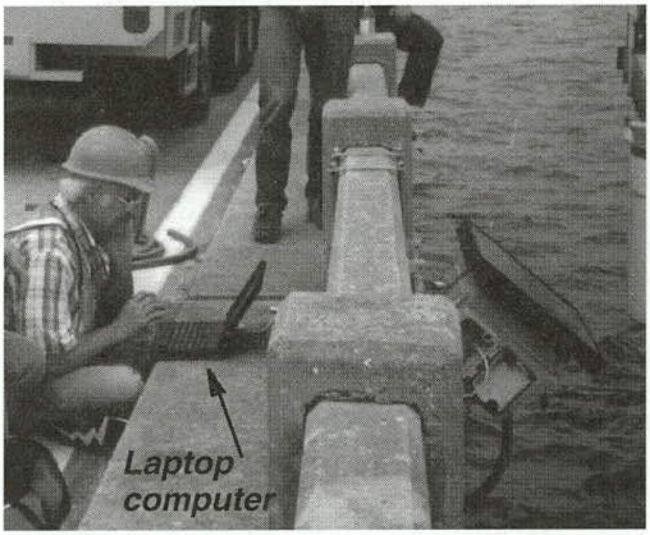


Figure B-12. Programming the instrument to collect data.

LOW COST, ABOVE-WATER, SERVICEABLE SONAR SCOUR MONITOR

Typical Parts List - Example: Nassau Sound, Florida

Description	Supplier	Quantity
1. Enclosure, fiberglass	Hoffman, PN A14128CHQRFG	1
2. Back Panel	Hoffman, PN A1412-AL	1
3. Sonar - Lowrance LMS 350A	Lowrance Electronics, Inc.	1
4. Solar Panel	Solarex, Model MSX-20	1
5. Solar Panel Regulator	ASC 12-4	1
6. Fitting, flexible conduit, 1 inch	Hubbell	2
7. Mounting Bracket for Solar Panel including:	Fabricated	
Square tubing, stainless steel, 1x1x20 inch		1
Bolts, stainless steel, solar panel to bracket, 1/4x20x1/2 inch		4
Bolts, stainless steel, bracket to enclosure, 1/4x 20x1-1/2 inch		4
Lock washers, stainless steel, star, 1/4 inch		8
Nuts, stainless steel, 1/4x20 inch		8
8. Cable, solar panel to enclosure, 2 conductor, 36 inches	Belden, PN 9740	1

LOW COST, ABOVE-WATER, SERVICEABLE SONAR SCOUR MONITOR Typical Parts List - Example: Nassau Sound, Florida		
Description	**Supplier**	**Quantity**
9. Battery, (Example: Yuasa brand), 12 volts, 12 amp-hr	Newark Electronics	1
10. Enclosure, RS-232 cable, fiberglass	Hoffman, PN A-65-JFGQR	1
11. RS-232 Cable, 6 feet, DB9 male and DB9 female connectors	Local electronics supplier	1
12. Brackets, mounting equipment enclosure to bridge rail, includes:	Fabricated	
Square tubing, stainless steel, 1x1x29 inch		2
Square tubing, stainless steel, 1x1x8 inch		2
Square tubing, stainless steel, 1x1x7 inch		2
Bolts, all-thread, stainless steel, 3/8x10 inch		4
Nuts, stainless steel, 3/8 inch		12
Bolt, hinge pin, stainless steel, 3/8x16 inch		1
13. Above Water Serviceable Transducer Mounting Assembly, all PVC Schedule 80, except as noted:	Fabricated	
Tee, 2x2x2 inch		6
Tee, 4x4x2 inch		2
Bushing, 4x2 inch		2
Nipple, 2x4 inch		6
Pipe, 2x50 inch		2

LOW COST, ABOVE-WATER, SERVICEABLE SONAR SCOUR MONITOR Typical Parts List - Example: Nassau Sound, Florida		
Description	**Supplier**	**Quantity**
Pipe, 4x48 inch		1
Pipe, 4x12 inch		1
Pipe, 4x6 inch		1
Cap, 4 inch, schedule 40 PVC		1
Cap, modified, 4 inch, schedule 40 PVC		1
Bushing, 2 inch slip to 1 inch, threaded		1
Fitting, flexible conduit 2 inch slip to 1 inch flexible conduit		1
U-bolt, stainless steel, threaded, 1/4 inch		1
Nut, stainless steel, 1/4 inch		2
Washer, rubber, 1 inch		1
Coupling, 4x4.5 inch, threaded on one end		1
14. Above Water Serviceable Transducer Insert - All PVC Schedule 40 except as noted:	Fabricated	
Coupler, 1 inch		2
Nipple, 2x4 inch		1
Bolts, nylon, 3/8 inch		6
Bushing, 2x1 inch		1
Pipe, 1x68 inch, bell flange on one end		1
Threaded Adapter, 1 inch		1

LOW COST, ABOVE-WATER, SERVICEABLE SONAR SCOUR MONITOR Typical Parts List - Example: Nassau Sound, Florida		
Description	**Supplier**	**Quantity**
15. Attachment Hardware:	Local supplier	
Bandit®, stainless steel, 110 inch		4
Bandit®, clamps		4
Bandit®, tool (required)		1
16. Flexible Conduit, EconoFlex, multi-purpose, 1 inch, 25 feet, 200 PSI rated (red), (Gates Rubber Company)	Local supplier	1
17. Electronics Interface/Memory Data Logger	ETI Instrument Systems, Inc.	1

APPENDIX C

EQUIPMENT SUPPLIERS

Supplier	Equipment
Lowrance Electronics, Inc. 12000 East Skilley Drive Tulsa, Oklahoma 74128 Local Marine Source	Sonar Fathometer, Model LMS-350A Sonar Fathometer (Hummingbird, Apelco, Furuno, Eagle, etc.)
ETI Instruments Systems, Inc. 1317 Webster Avenue Fort Collins, Colorado 80524	EI/MDL Datalogger Interface
Campbell Scientific, Inc. 815 West 1800 North Logan, Utah 84321 Handar, Inc. 1288 Reamwoold Ave. Sunnyvale, California 94089 Sutron Corp. 21300 Ridgetop Circle Sterling, Virginia 20166	Model CR-10X Datalogger Datalogger Datalogger
Hoffman A Pentair Company 900 Ehlen Drive Anoka, Minnesota 55303-7504	Equipment Enclosure
Applied Energy Technology LTD P.O. Box 243 Swisher, Iowa 52338 Astro Power One Solar Park Newark, Delaware 19711 Siemens Solar Industries P.O. Box 6032, Dept. TR-91 Camarillo, California 93011 Solar-Web Products P.O. Box 2200 #388 Sarasota, Florida 34230 Solarex Corp 1335 Piccard Dr. Rockville, Maryland 20850 United Solar System Corp 1100-T Maple Rd. Troy, Michigan 48084	Solar Power Components Solar Power Components Solar Power Components Solar Power Components Solar Power Components Solar Power Components

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The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation

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