

**USER'S GUIDE**  
**MODEL 4100 SERIES**  
**AQUATRAK®**

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***Corporation***

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**Warranty**

Aquatrak Corporation warrants its products to be free of defects in workmanship and material for a period of 12 months from date of shipment. During the warranty period, Aquatrak will repair or replace defective products at its own expense, subject to the following conditions:

1. The buyer must prepay all shipping, insurance, and associated costs to return the defective item to Aquatrak. Aquatrak pays return shipping and insurance.
2. The product must not have experienced misuse, neglect, and accidental damage or have been altered or repaired by the buyer during the warranty period.
3. This warranty and Aquatrak's obligation are in lieu of all other warranties.
4. Aquatrak is not liable for consequential or incidental damages, labor performed in conjunction with removal and replacement, loss of production, or any other loss incurred because of interruption of service or production of incorrect or incomplete data.

**CAUTIONARY NOTES**

**Note:**

*Used to call attention to a special feature or procedure, which must be followed for correct operation of the equipment.*

**Caution:**

*Used to call attention to a concern where damage to the equipment or injury to personnel may occur unless certain steps are followed.*

**Warning:**

*Used to call attention to an issue where serious personal injury or death may occur unless basic safety procedures are followed.*

**TYPICAL PARTS & MATERIALS REQUIRED**

	<u>Section</u>	<u>(✓)</u>
Aquatrak Installation Kit	2.1, 2.2, 2.3	_____
Protective Well	2.1, 2.3	_____
S.S. Straps for PVC Pipe (5)	2.1, 2.3	_____
Spacer Blocks for Well (5)	2.1, 2.3	_____
CPVC Primer	2.2	_____
CPVC Cement	2.2	_____
Trimming Knife	2.2	_____
Fine Grit Sandpaper	2.2	_____
S.S. Hose Clamp, 4 inch	2.3	_____
Silicone Grease	2.4	_____

**METRIC /ENGLISH CONVERSION FACTORS**

25.4 mm	=	1 inch	1 mm	=	0.0394 in
0.3048 meter	=	1 foot	1 meter	=	3.2808 ft.
0.454 kg	=	1 pound	1 kilogram	=	2.2 lb.
$^{\circ}F = \frac{9(^{\circ}C)}{5} + 32$		$^{\circ}C = \frac{5(^{\circ}F - 32)}{9}$			

## 1. INTRODUCTION TO THE AQUATRAK LIQUID LEVEL MEASURING SYSTEM

### 1.1 Improved Ability To Measure Absolute Liquid Level

Aquatrak is superior to traditional liquid level sensors and provides unsurpassed reliability and proven performance. Using a patented acoustic ratiometric technique, the Model 4100 Series can be used to measure water level in rivers, lakes, and groundwater, tidal and sea level changes, wave height and sea state and industrial tank ullage.

The AQUATRAK sensor provides accurate measurement of absolute liquid level in all weather conditions. Designed for rugged, unattended operation, the sensor has been field proven in adverse environments around the world for hydrology, oceanography, and hostile environment chemical and nuclear tank control systems.

#### Acoustic Ratiometric Measurement Benefits

The AQUATRAK sensor is "non-contacting" and is therefore not affected by many of the factors, that cause significant errors and maintenance problems with traditional stilling wells using float or pressure transducers. Traditional gauging stations can all be replaced with the AQUATRAK. The technology is immune to atmospheric effects such as temperature, humidity, and atmospheric pressure changes. Some of the many advantages include:

- ✓ Easy Installation
- ✓ mm Resolution
- ✓ Low Maintenance
- ✓ No Moving Parts
- ✓ Wide Dynamic Range
- ✓ Long Term Stability w/o Calibration
- ✓ Sea State Measurement
- ✓ Interface to RS-232 and SDI-12

#### Reliability

The AQUATRAK provides reliability unmatched by conventional technologies. Because there are no moving parts such as gears, bearings, or floats to wear out, the reliability is a function of the carefully selected electronic components. Reliability is further enhanced because all electronic components are out of the liquid - in fact, there is no conductive path to the liquid at all. This all but eliminates damage from lightning. Aquatrak has obtained a field proven reliability record of better than 1,000,000 hours mean time between failure (MTBF).

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## Proven Technology

The AQUATRAK sensors are based on technology developed and patented by Bartex and acquired by Aquatrak Corporation. The U.S. National Ocean Services (NOS) and the Australian National Tidal Facility have selected the Aquatrak Model 4100 gauge to be their primary standard instrument for tidal programs.

## AQUATRAK Components

The Model 4100 AQUATRAK comes complete with the following items:

Qty.		Qty.	
1	Transducer	1	Controller
1	Transducer Cable, (3 meters)	1	RS-232 Cable (3 feet)
1	SDI-12/Power Cable (3 feet)	1	Calibration Tube

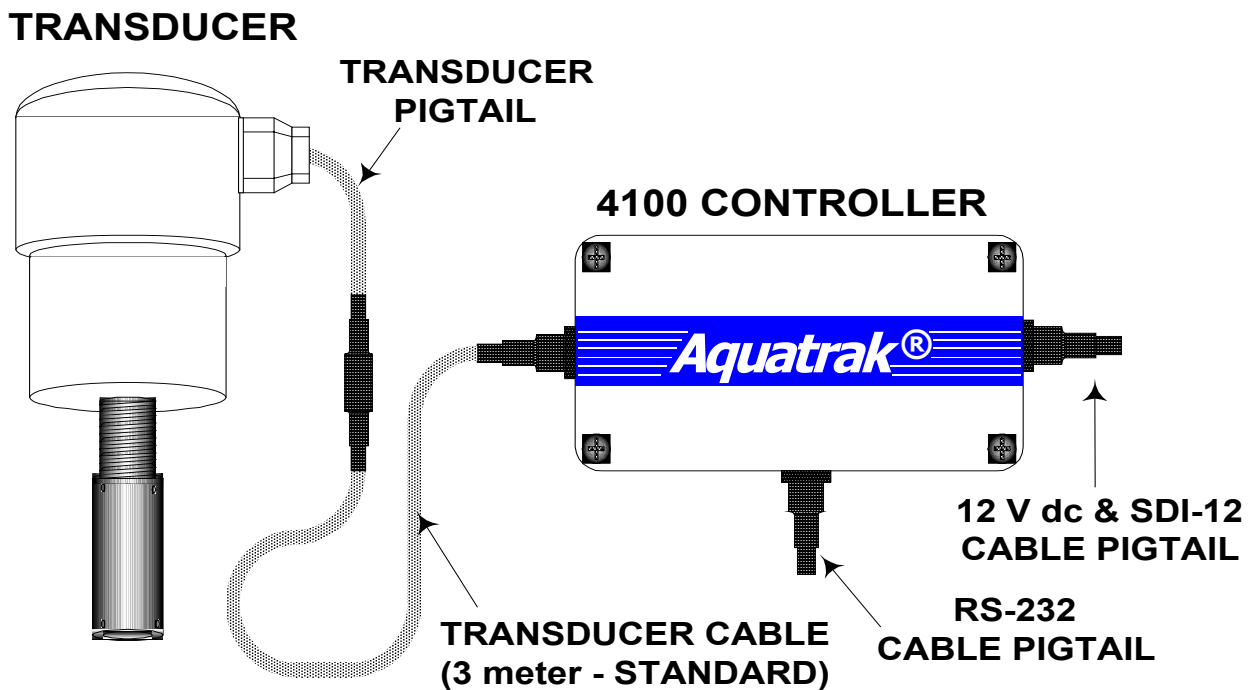


Figure 1.1-1 AQUATRAK Model 4100 Series Sensor

**1.2 Performance Specifications for the Model 4100 Series**

The Model 4100 Series AQUATRAK measures absolute liquid level in all indoor and outdoor conditions. Measurement is possible in open waters, stilling wells, ground wells, as well as in enclosed tanks.

Table 1.2-1. Specifications of the Model 4100 Series

<b>Performance Specifications</b>	
Dynamic Range	10 meters (35 ft) Standard 15 meters (50 ft) Optional 23 meters (75 ft) Special Order
Rate of Change	± 3 m/sec (10 ft/sec) max
Resolution	1 mm or 0.001 ft
Range Proportionate	1.2 – 2.4 / sec
Averaged over 2 – 255 Samples	1.0 / sec.
Calibration Accuracy	± 0.025 % Standard ± 0.01 % Optional
Nonlinearity	± 0.02 %
Repeatability	± 0.01 %
Long Term Drift	None over 1 year period
Temperature Drift	< 1 PPM / °C
Data Update Rate	User Selectable (Section 3.2.1)

<b>Electrical Specification</b>	
Supply Voltage	+10.5 to +14.5 Vdc
Operating Current	< 30 ma with RS232 < 30 ma with SDI-12
Quiescent Current	< 1 ma
Fusing	500 ma fast action fuse supplied (LITTELFUSE 216.500 or equivalent)
Transient Protection	All power and signal lines are protected by MOV
Interface	RS-232 ASCII and SDI-12 standard EIA-485 Optional

<b>Environmental Specification</b>	
Operating Temperature	- 40 to + 55 °C (- 40 to + 130 °F)
Storage Temperature	- 55 to + 60 °C (- 67 to + 140 °F)
Humidity	0 – 100%
Precipitation/Dust	NEMA-4X Corrosion Resistant

Table 1.2-1. Specifications of the Model 4100 Series (Continued)

Physical Specification	
Model 4100 Controller Box	175 mm L X 60 mm H X 80 mm W, @ 0.7 kg (7 in L X 2.5 in H, @ 1.5 lb.)
Sensor Head	90 mm diameter X 210 mm high, 1.2 kg (4 in diameter X 8 in high, 2.5 lbs.)
Cable Length	3 m (10 ft) supplied, up to 300 m available
Shipping Carton	1 Box – 0.01 m <sup>3</sup> (0.3 ft <sup>3</sup> ), 2.3 kg (5 lbs.) for transducer and controller 1 tube – 1.4 m <sup>3</sup> (4.5 ft <sup>3</sup> ), 0.9 kg (3 lbs.) for calibration tube

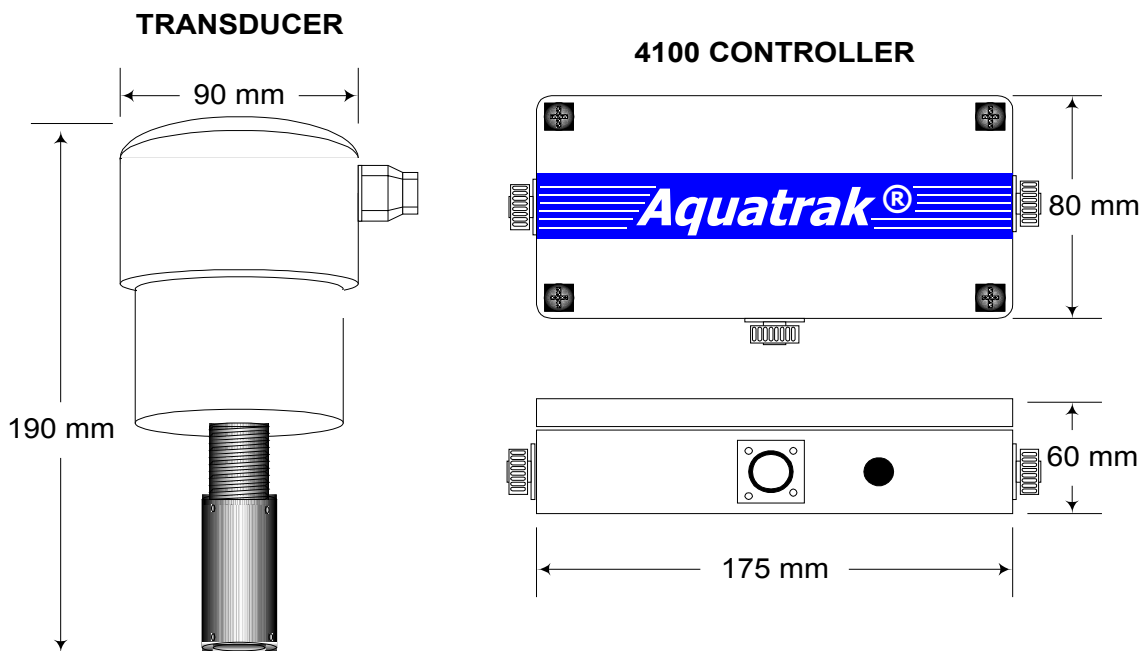


Figure 1.2-1 Dimensions of the Model 4100 Series Controller and Transducer

## 1.3 How the AQUATRAK Measures Liquid Level

The Aquatrak patented ratiometric technique, based on fixed points, and is critical to high levels of accuracy, resolution, and long term stability.

The AQUATRAK sensor uses a very simple but accurate technology to measure liquid level. Driven by a microprocessor, a series of electrical pulses are transmitted from the Model 4100 Controller to the transducer. The transducer converts the electrical pulses into acoustic pulses and sends them to the water surface via a sounding tube.

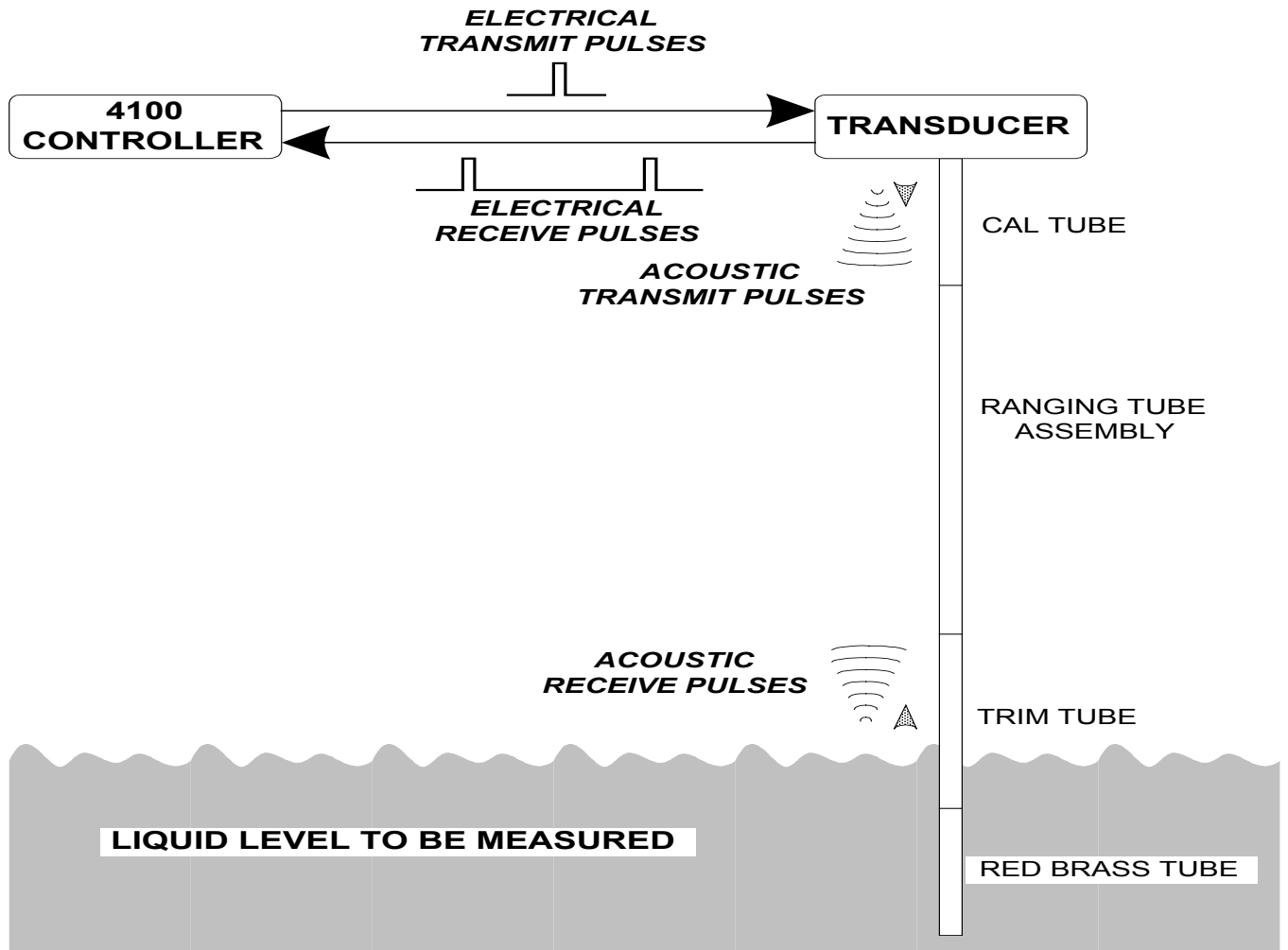
As shown in figure 1.3-1, the pulses pass through a calibration tube (Cal Tube), one or more ranging tubes, a trim tube, and a "red brass" tube. The tube protects the acoustic energy from such adverse environmental effects as wind, rain, and snow. The functions of the various tubes (collectively known as the "sounding tube") is as follows:

- ✓ The Cal Tube provides a return echo from a known distance
- ✓ The range tube(s) channel the acoustic pulses to and from the surface
- ✓ The trim tube allows minor corrections to the tube so that the overall tube length is 0.2 meters (0.5 ft) shorter than the protective well orifice.
- ✓ The "red brass" tube provides a measure of antifouling to keep the end of the tube free of marine growth and algae.

As the acoustic signal passes down through the Cal tube an echo is produced that is returned to the Model 4100 Controller receiver. When the pulse strikes the liquid surface another echo is produced which is also returned to the Model 4100 receiver. The patented ratiometric technique is based upon a pulse time of travel comparison within the known (through the cal tube) to an unknown distance to the liquid level (through the sounding tube).

Under host control, the Model 4100 Controller initiates the transducer, times and stores the cal echo, and times and stores the liquid level return echo. The on-board microprocessor calculates the ratio, applies any programmed offsets, performs engineering conversions, and stores the data awaiting a data request from the host data logger or PC. The host computer does not have to perform any calculations to determine the water level because the Model 4100 provides this information in directly readable ASCII engineering units.

The sea state (wave height) may be approximated by multiplying the standard deviation from each measurement by a constant whose value is site and installation dependent. For a damped orifice, protected well, the multiple is approximately 5 (depends on dampening). For a fully open, unprotected well (undamped), the multiple is 3.8.



Note: Protective well not shown

Figure 1.3-1 AQUATRAK Measurement Diagram

## 1.4 Accessories for the AQUATRAK Model 4100 Series

**Note:**

*Several accessories are available from Aquatrak for the AQUATRAK Model 4100 Series. Contact the Sales Office for more information.*

### AQUATRAK Installation Kit - P/N 28-3000-NG (x)

Every installation requires the use on an installation kit to properly install the sensor. The "(x)" in the part number refers to the inside diameter of the protective well (standpipe) supplied by the user. The inside dimension of the standpipe is needed so that the correct size, centering clip is provided. The parts are supplied with the installation kit (P/N 28-3000-NG-6) are shown below in Figure 1.4-1. For other accessories, please contact Aquatrak.

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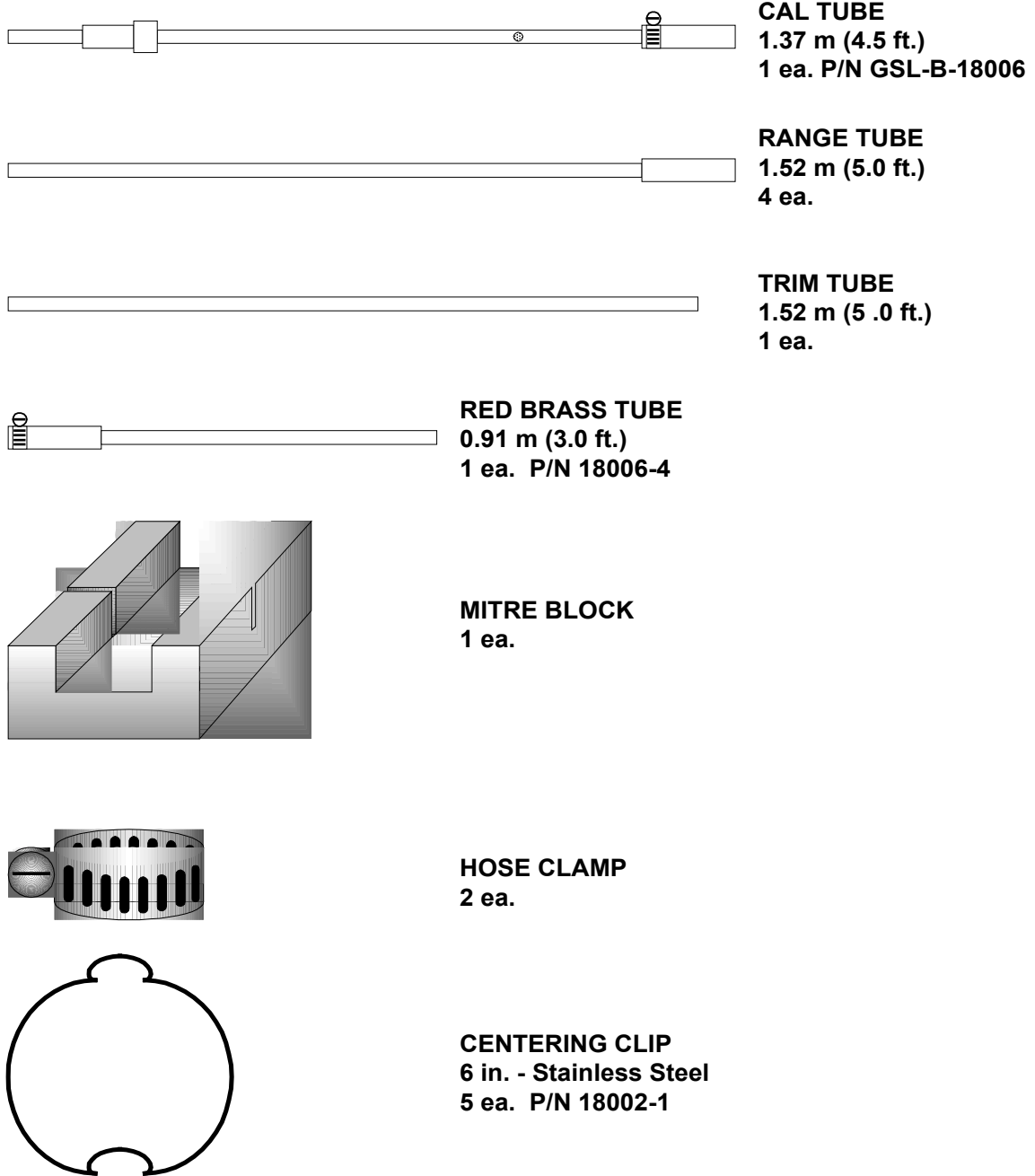


Figure 1.4-1 Parts Supplied with the Installation Kit



## 2. INSTALLATION OF THE Model 4100 AQUATRAK

### 2.1 Protective Well (Standpipe) Installation

**Caution:**

*The Model 4100 AQUATRAK should be installed in a properly designed well to protect it from physically damaging elements and to minimize thermal effects from direct sunlight.*

The protective well may be made from any well-ventilated material. An example of a suitable material is 4 or 6 inch Schedule 40 PVC drain field pipe. Drain field pipe has numerous holes along the length, which allow needed ventilation. In severe locations where large waves or floating debris may be a problem, Schedule 80 pipe is recommended. Note that the pipe size chosen must match the centering clip diameter in the installation kit. If a P/N 28-3000-NG (4) installation kit was ordered, use 4-inch pipe.

The protective well location is often determined by the availability of a support structure such as a pier or piling. Accessibility and security of the site should also be considered.

The following factors should be considered when locating the protective well:

1. **Thermal Environment** - The optimal installation will insure that the air in the entire protective well is at the same temperature. Temperature differentials may cause errors in the level measurement. In general, locate the well on the north side of a pier (in the Northern Hemisphere) and avoid locations where the upper portions of the well will be in direct sunlight while the lower portions will be shaded.

**Note:**

*The goal is to provide an isothermal environment inside the well. The ambient temperature is immaterial.*

2. **Physical Considerations** - The protective well must be braced to the supporting pier to withstand the expected sea state conditions. In river gauging applications, consideration must be made for floating debris. The protective well should be mounted vertically.
3. **Availability of Indoor Location** - Be sure to carefully measure the distance that the transducer cable will have to run between the transducer head at the top of the protective well and the desired location of the Model 4100 controller. The standard cable length is 3 meters (10 feet).

The design of the well depends on several factors such as the highest high and lower low water levels, bottom depth, and wave height. Several rules apply including:

- ✓ The lower orifice of the well should be approximately 1 m off the bottom to keep the bottom materials from entering the well.
- ✓ The top of the well should be ~1 m above the deck level to allow for easy access.

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- ✓ The Transducer must be at least 1.5 m above the expected extreme high water (including wave height).

Calculate the overall length, "W", using the formulas and figure below. Remember that the standard installation kit will only extend 9.88 m (32.4 ft). If the protective well length must be longer than 9.88 m, additional range tubes must be purchased.

**A** = Minimum Cal Tube clearance  
= 1.5 meters

**B** - Additional length as needed by deck elevation

**C** - (highest water - lowest water) + 2X wave allowance

**D** - Additional safety factor as needed

**E** = B + C + D

**F** = Red brass tube length  
= 0.9 meter

**G** = Orifice offset  
= 0.1 meter

**W** = Total well length  
= A + E + F + G

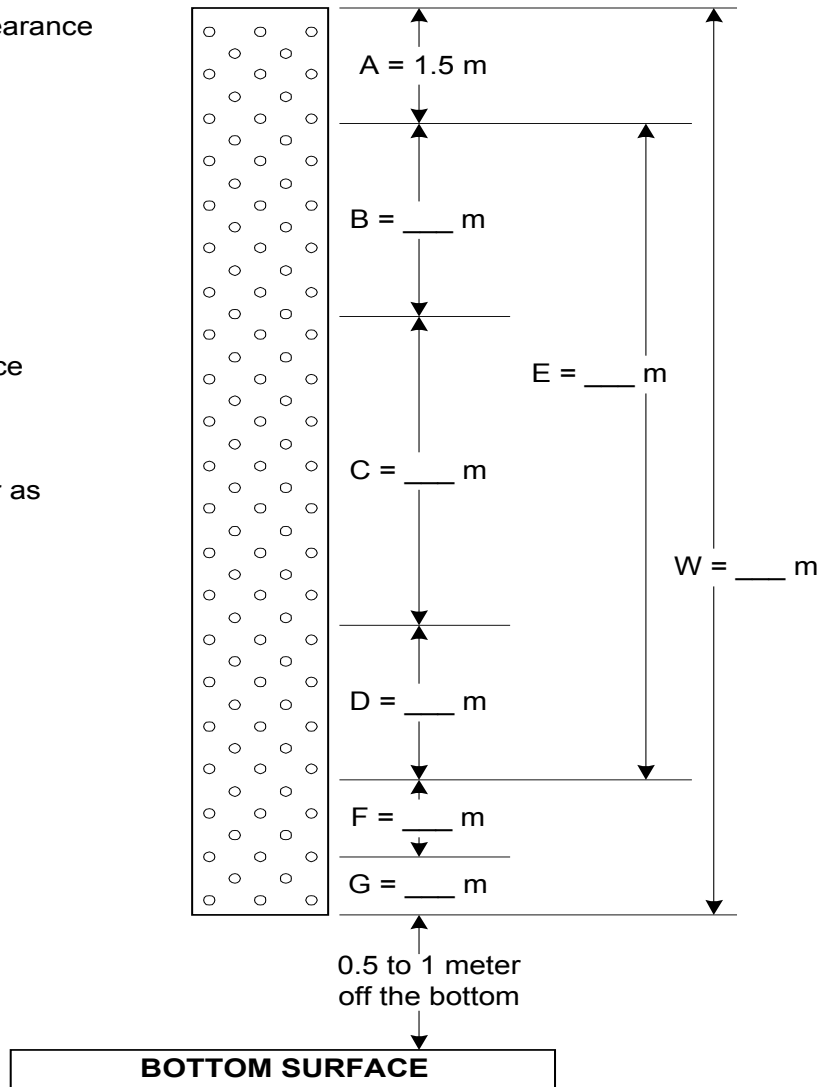


Figure 2.1-1 Protective Well Length Calculator

Cut the protective wells pipe squarely so that the top opening is horizontal when mounted. Securely mount the protective well to a piling using non-corrosive user-supplied straps or clamps every meter of length.

## 2.2 Assembly of the Sounding Tubes

**Caution**  
*After calculating the tube length, the tubes must be carefully cemented together with no gaps or internal cement beads, which may cause erroneous readings.*

### Sounding Tube Length Calculation

The overall sounding tube length is a function of the protective well length calculated earlier and the length of the sounding tubes in the installation kit. The sounding tube is made up of the following tubes:

- Calibration tubes (1) length fixed and is never altered
- Red brass tube (1) length fixed and is usually not altered
  
- Range tubes (4) alter length by using more or less whole tubes
- Trim tube (1) alter length by using whole, not using, or by cutting to length

Using the protective well length calculated in Section 2.1, calculate the overall sounding tube length as shown below:

Protective well length \_\_\_\_\_ meter  
 Bottom orifice offset   .1   meter  
 \_\_\_\_\_ meters, sounding tube assembly total length  
 (known as "length" in rows 3 & 4 of table below)

Now that the length of the sounding tube assembly is known, use the table below to determine the number of range tubes needed and the length to cut the trim tube.

Table 2.2-1 Required Range Tubes

Ranging Length W/O Cutting	# of Sections Cal Range Trim Brass	If Length is Less Than	Cut Trim Tube to	And Use X Range Tubes
2.29 m – (7.5 ft)	1 0 0 1	N/A	N/A	0
3.81 m – (12.5 ft)	1 0 1 1	3.81 m – (12.5 ft)	3.81 m – (12.5 ft) - length	0
5.33 m – (17.5 ft)	1 1 1 1	5.33 m – (17.5 ft)	5.33 m – (17.5 ft) - length	1
6.86 m – (22.5 ft)	1 2 1 1	6.86 m – (22.5 ft)	6.86 m – (22.5 ft) - length	2
8.38 m – (27.5 ft)	1 3 1 1	8.38 m – (27.5 ft)	8.38 m – (27.5 ft) - length	3
9.91 m – (32.5 ft)	1 4 1 1	9.91 m – (32.5 ft)	9.91 m – (32.5 ft) - length	4

## Sounding Tube Assembly

Tools and materials needed:

- |                              |                        |               |
|------------------------------|------------------------|---------------|
| 1) AQUATRAK installation kit | 2) Hacksaw, fine tooth | 3) PVC primer |
| 4) PVC cement                | 5) Trimming knife      | 6) Sandpaper  |

**Note:**

*Before beginning the following installation steps below visually inspect and verify that each tube is clean and free of burrs and obstacles. If necessary, use the trim knife or sandpaper to smooth the edges. Layout the tubes on a clean surface and "dry" fit them in the order they will be connected.*

- ✓ Using a hacksaw and miter block cut the trim tube to the length determined in column 4 of Table 2.2-1. Using the trim knife and/or sandpaper carefully deburr the inside and outside of the cut end.
- ✓ Using the PVC primer, lightly coat the uncut end of the trim tube and the coupler end of one of the range tubes.

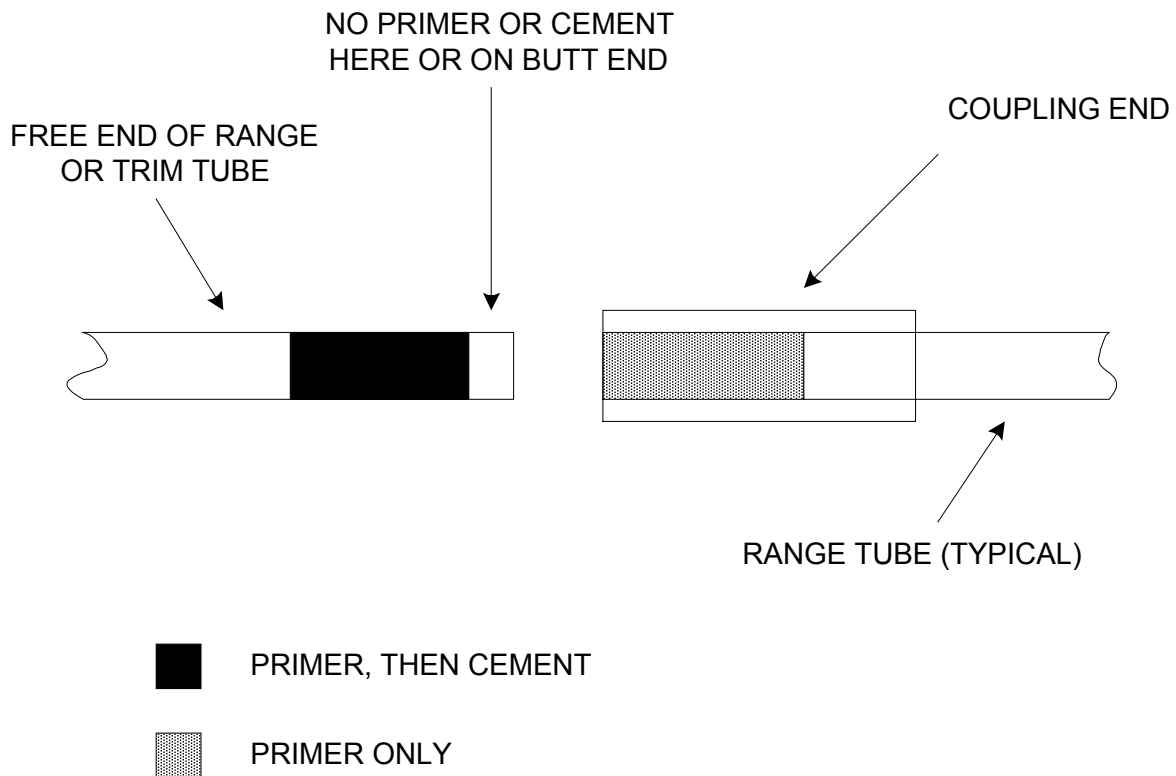


Figure 2.2-1 Cement Details

- ✓ Apply PVC cement sparingly to the uncut end of the trim tube in an even band ~1 cm from the end. Do not apply any cement to the butt end of the tube or allow it to enter the inside of tube.

- ✓ Immediately insert the cemented trim tube end into the primed coupler end of the range tube. Use a firm, twisting motion until the tube bottoms out in the coupler.
- ✓ Repeat the previous 3 steps to join the remaining range tubes. The number of range tubes needed was determined in column 5 of the table.
- ✓ Attach the red brass tube coupling to the bottom of the cut end of the trim tube using one of the hose clamps provided in the installation kit.
- ✓ Connect the coupler end of the cal tube to the top end of the range tube using one of the hose clamps provided in the installation kit.
- ✓ Wait at least 30 minutes before moving or handling the sounding tube assembly to allow the cement to cure.
- ✓ Place a hand on either side of each joint and twist firmly to test the integrity of the connection.

## 2.3 Mounting the Sounding Tube Assembly in the Well

**Note:**

*After cutting the top of the protective well, pipe the assembled transducer and sounding tube is lowered into the well and secured.*

### Preparation of the protective well top orifice

Using a hacksaw, cut the top opening of the protective well to a depth of ~ 4 cm (1.5 inch) making 2 cuts at right angles as shown in Figure 2.3-1. These cuts allow the user-supplied hose clamp to compress and secure the transducer in the well.

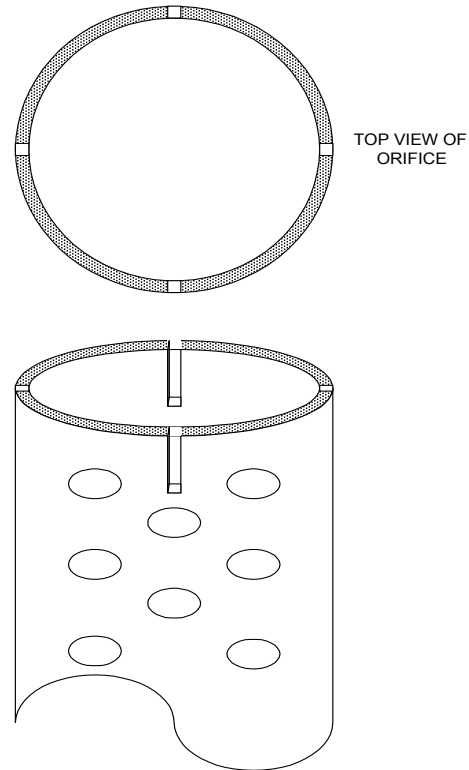


Figure 2.3-1 Protective Well Cutting Guide

### Installing the transducer in the protective well

Attach the centering clips from the installation kit to the sounding tube assembly by clipping them over the sounding tube sections. The lowest clip should be just above the red brass/trim tube coupling (i.e.; on the lowest part of the trim tube). Evenly space the remaining clips over the length of the sounding tube with the last of the five clips attached just above the cal tube/top range tube coupling (i.e.; on the lower part of the cal tube). One clip every 1.5 meters (5 ft) is usually adequate. Rotate the clips so that they are at right angles to each other.

Gently lower the assembly into the protective well. Stop lowering the assembly when the top of the tube is ~ 0.5 meter above the top of the well. Slip the stainless steel coupler of the transducer over the top end of the cal tube. Fully bottom the tube into the seat of the transducer coupler and tighten the 2 lower set screws securely.

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Finish lowering the transducer and sounding tube assembly into the well until the step flange of the transducer sits squarely on the top orifice of the protective well. Use a hose clamp (user-supplied) to compress the top of the well until it tightens around the transducer body and holds it securely.

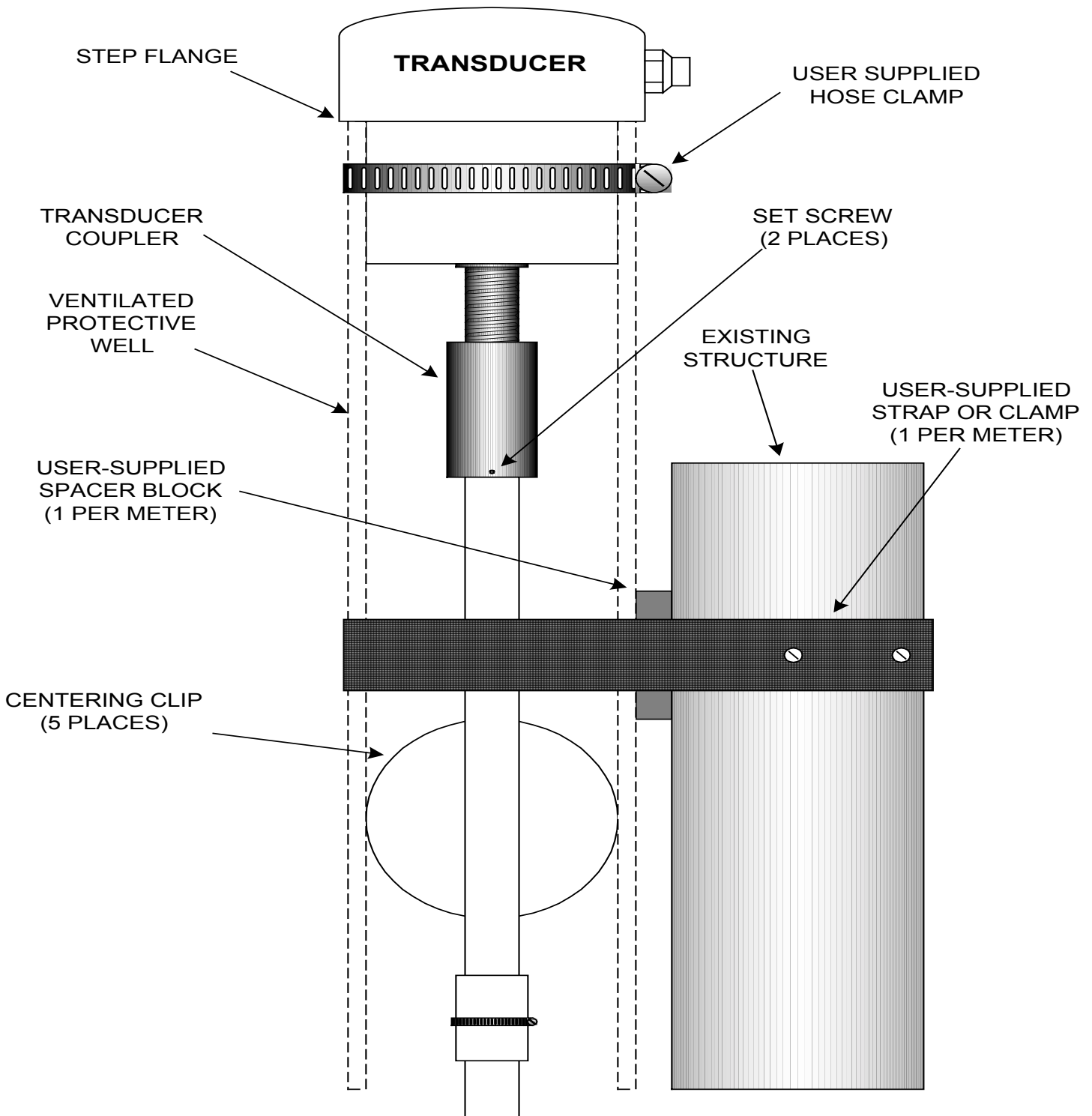


Figure 2.3-2 Final Installation Diagram

## 2.4 Making the Electrical Connections

**Note:**

*The normal installation of the AQUATRAK requires the user to supply a 12 VDC power source and a data collection device capable of operating with either RS-232 or SDI-12 serial communications.*

### Transducer Connector - No Assembly Required

The transducer head has a short pigtail cable that is terminated with a 5-pin male Amphenol in-line connector. Using a small amount of silicone grease, lightly coat the mating surfaces of the Amphenol connectors on both the pigtail and the longer transducer cable. Plug the 2 connectors firmly together.

### RS-232 Cable - Assembly Required

If an ASCII terminal or personal computer (PC) will be used to as the serial communications device, wire the 3-foot pigtail cable (supplied with the controller) as shown in the Table 2.4-1 below and in Figure 2.4-1.

Table 2.4-1 RS-232 Wiring Identification

Pin #	Function	Wire Color	DB9*
1	Ground	Black	5
2	DTR In	Green	4
3	Data Out	Red	2
4	Data In	White	3

\* *For other PC connectors check functional connection*

**Caution:**

*If the host RS-232 device can not assert an active DTR, insulate the green wire (pin 2 Do Not Connect) of the cable to prevent it from shorting. Refer to Section 3.1 for details of J5 jumper installation to force DTR.*

### Power and SDI-12 Cable - Assembly Required

This connector supplies both power to and SDI-12 communications for the sensor. If the RS-232 communications mode is selected, do not wire the SDI-12 pins.

- ✓ Power Connection - The user supplied power supply must be capable of supplying 50 ma @12 VDC. Wire the cable as shown in the Table 2.4-2 and in Figure 2.4-1.
- ✓ SDI-12 Connection - If a SDI-12 capable data collection device is being used, wire the cable as shown in the table below and in Figure 2.4-1.

Table 2.4-2. SDI-12 and Power Wiring Identification

Pin #	Function	Wire Color
1	Ground	Black
2	+12 VDC Power	Red

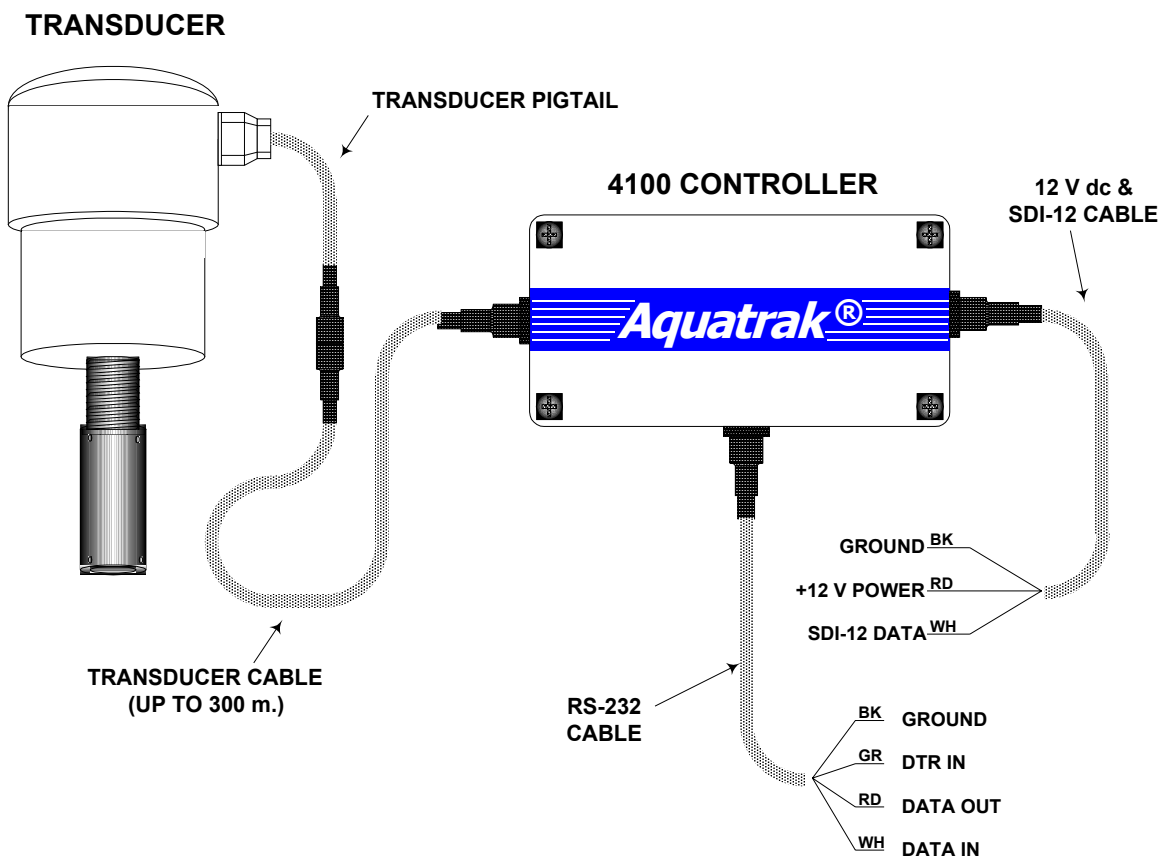


Figure 2.4-1 Cable Details



## 3. PROTOCOLS & COMMUNICATIONS

### 3.1 Jumper and Operating Modes

**Note:**

*The Model 4100 Controller must be connected to a data acquisition system (DAS) capable of communicating with either RS-232 or SDI-12.*

The sensor is factory configured for SDI-12 communications as follows:

ASCII / 7 bit / Even parity / 1 stop bit / 1200 baud

#### Jumper Selections

The Model 4100 Controller has three (3) jumpers (J2, 4, and 5), which may be configured by the user. To gain access to the jumpers, disconnect power to the controller and remove the 4 screws on the top cover. Figure 3.1-1 illustrates the position of the jumpers.

- ✓ J2 - Not used
- ✓ J4 - Micro-Power Mode

In normal operation, the Model 4100 Controller is in a low power (~ 1 ma) sleep mode until awakened to take a measurement. This mode of operation is selected when J4 is in the off position (factory default). To awaken the Model 4100 to take measurements, the Data Acquisition System (DAS) must send a <BREAK> of at least 12 ms duration.

If the DAS is not capable of sending a <BREAK>, install the jumper across the 2 pins of J4. This will prevent the Model 4100 from entering the sleep mode and make it constantly ready to accept commands. Power consumption will be ~ 30 ma for SDI-12 operation (~ 30 ma for RS 232 operation) when the J4 jumper is installed.

- ✓ J5 - Data Terminal Ready (DTR)

When using RS-232 communications, the factory default requires that a DTR be sent from the DAS to the Model 4100 Controller before the Model 4100 will transmit data. This mode of operation is selected when J5 is in the off position (factory default). To initiate communications with the Model 4100, the host must assert DTR by setting it high.

If the RS-232 host can not assert an active DTR, install the jumper across the 2 pins of J5. This will force DTR internally in the Model 4100 and allow it to transmit data.

## Modes of Operation

- ✓ Standby

In the Standby state, power to the Model 4100's microprocessor is turned off to reduce power consumption to ~1 ma. A <BREAK> signal of at least 12 ms through either the RS-232 or SDI-12 port is required to awaken the Model 4100 from the Standby mode. If the J4 jumper is installed, sending a <BREAK> is unnecessary since the Model 4100 will always be in the Awake state.

- ✓ Command

In the Awake State, the Model 4100 is in the Command mode, waiting to accept either valid commands or to enter the Menu mode. If jumper J4 is installed, the Model 4100 will remain in the Command mode indefinitely. If jumper J4 is not installed, the Model 4100 will remain in the command mode for 10 seconds after receiving a <BREAK> before returning to the Standby mode.

- ✓ Menus

From the Command mode, sending an <ESC> will put the Model 4100 in the Menu mode. This feature is only available through the RS-232 port. It is used to establish the user settings and to initiate measurements.

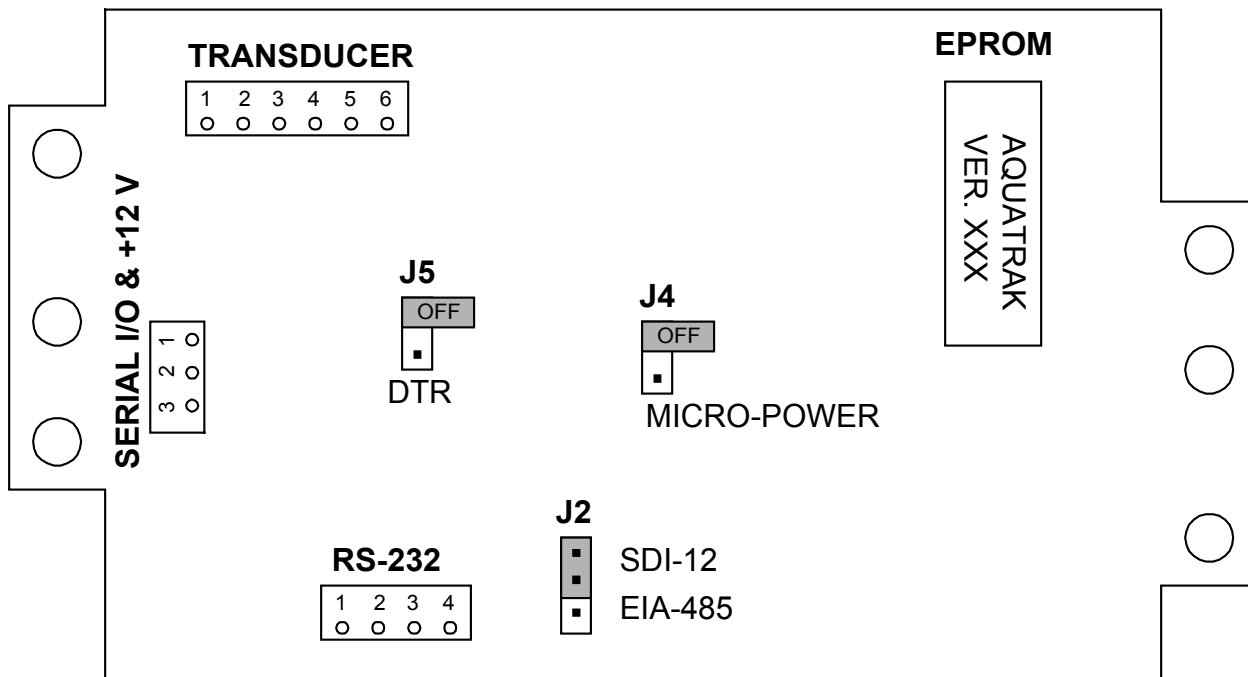


Figure 3.1-1 Model 4100 Jumper Locations

## 3.2 Operation with the RS-232 Protocol

**Note:**

*When RS-232 is selected as the operating protocol, the Model 4100 can operate in either the command mode or the menu mode.*

The signal interface consists of a 4-wire RS-232C connection with the transmit (Tx), receive (Rx), data terminal ready (DTR) and circuit common pins being used. Connecting the RS-232 cable to the Model 4100 Controller automatically switches the Model 4100 from the SDI-12 port to the RS-232 port and disables SDI-12 operation.

### Basic Steps To Establish RS-232 Communications

- ✓ Connect the host computer to the RS-232 port on the Model 4100 Controller.
- ✓ Establish communications with PROCOMM<sup>®</sup> or similar communications program. Set the program for the following parameters:
  - 8 bit / No parity / 1 stop bit / 1200 baud / Half or full duplex
- ✓ If the host computer is not capable of providing an active DTR signal, install a jumper across the 2 pins of J5 in the Model 4100 Controller enclosure.
- ✓ If the host computer is not capable of sending a <BREAK> signal of at least 12 ms in duration, install a jumper across the 2 pins of J4 in the Model 4100 Controller enclosure.

Note that data transmittals from the Model 4100 contain blank spaces between data fields for ease of parsing by commonly available spreadsheet programs. Each data transmittal line is terminated with a carriage return <CR> and line feed <LF>.

### Quick Check to Test Basic System Operation

**Note:**

*The following sections using RS-232 assume that both J4 and J5 jumpers are installed (on). If they are not installed, the host computer must supply a continuous DTR and a <BREAK> prior to each data request.*

- ✓ Press <ESC> to enter the MAIN MENU from the Command Mode.

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Verify that the Model 4100 returns the following response:

Aquatrak Model 4100 V1.15 Menu	
1.	User Settings
2.	Continuous, no delay
3.	Continuous, no counts printed
4.	Continuous, print counts
5.	Continuous Averaging
Q.	Return to Command Mode

- ✓ Enter a <2> and see that the Model 4100 begins to transmit a short data string at one-second intervals until <ESC> is entered.
- ✓ Verify that the one second data format is as follows:

xxx.xxx      1      99

Where 'xxx.xxx' is the liquid level measurement, '1' is the number of cal tubes (one cal tube is normal and the factory default value), and '99' is the data quality indicator for "No Errors".

- ✓ If the data quality indicator is not '99', interpret the reported numeric code from the data quality (DQ) table below:

Table 3.2-1 RS-232 Data Quality Indicator Table

DQ Code	Description	DQ Code	Description
0	4100 Inoperative	100	Liquid level out of range
99	No errors detected	101	Out of range & no 1 <sup>st</sup> Cal
1	1 <sup>st</sup> Cal undetected	102	Out of range & no 2 <sup>nd</sup> Cal
2	2 <sup>nd</sup> Cal undetected	103	Out of range & no 2 <sup>nd</sup> Cal
3	3 <sup>rd</sup> Cal undetected	104	Out of range & no 3 <sup>rd</sup> Cal
4	4 <sup>th</sup> Cal undetected	105	Out of range & no 4 <sup>th</sup> Cal
5	5 <sup>th</sup> Cal undetected	106	Out of range & no 5 <sup>th</sup> Cal
6	6 <sup>th</sup> Cal undetected	107	Out of range & no 6 <sup>th</sup> Cal
7	7 <sup>th</sup> Cal undetected		

- ✓ Enter <Q> to return the Model 4100 to the Command Mode.

## 3.2.1 RS-232 MAIN MENU Description

### **Note:**

*The MAIN MENU mode offers a series of menu choices that allow the operator to command the Model 4100 to make measurements.*

### MAIN MENU activation:

- ✓ To enter the MAIN MENU from the Command Mode, press <ESC> and verify Model 4100 returns the following response:

Aquatrak Model 4100 V1.15 Menu

1. Access the USER SETTINGS to change program configurations
2. Measurements, RANGE PROPORTIONATE, Output measurement ONLY
3. Measurements, 1 Hz, Output measurement ONLY
4. Measurements, WITH COUNTS, Output ALL DATA
5. Continuous NOS Averaging
- Q. Return to Command Mode

### Description of the MAIN MENU response:

The first line lists the firmware version number that was in use when this manual was prepared. The version number returned by your sensor may be different. Note that the <ESC> key may be pressed to return to the Menu.

- ✓ Entering a <1> provides access to the USER MENU fully described in Section 3.2.2.
- ✓ Entering a <2> causes the Model 4100 to make measurements at the maximum rate, (proportional to the distance from the transducer to the water level) and outputs the measurement in the following format:

**13.175      1      99**

Where **13.175** is the level measurement in the units selected (meters or feet) in the USER MENU, **1** is the number of cal tubes, and **99** is the data quality indicator for "No Errors" (see figure 3.2-1). Spaces are always inserted between data fields.

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- ✓ Entering a <3> causes the Model 4100 to make measurements at the rate of once per second and prints the measurement only in the following format:

**13.175          1          99**

Where **13.175** is the level measurement in the units (meters or feet) selected in the USER MENU, **1** is the number of cal tubes, and **99** is the data quality indicator for "No Errors".

- ✓ Entering a <4> causes the Model 4100 to make measurements at the rate of one per second and prints all the data in the following format (typical):

**43.048          1          99          280535          26037**

Where **43.048** is the level measurement in the units (meters or feet) selected in the USER MENU, **1** is the number of Cal tubes, **280535** is the total number of counts received, and **26037** is the number of Cal counts received. In this example, 1 Cal tube was used. Had 2 Cal tubes been used, the "1" would have been replaced by a "2" and a second set of Cal counts would have followed the first set of Cal counts.

- ✓ Entering a <5> causes the Model 4100 to make averaged measurements with the National Ocean Service (NOS) algorithm and prints all the data in the following format (typical):

**43.048          1.030 0          1.0          99          26037**

Where **43.048** is the level measurement in the units (meters or feet) selected in the USER MENU, **1.030** is the standard deviation, **0** is the number of outliers discarded prior to calculation, **1.0** is the number of Cal tubes, and **26037** is the number of Cal counts received.

**Note:**

*The average wave height may be approximated by multiplying the standard deviation value obtained with the NOS algorithm by 5.*

- ✓ Entering a <Q> causes the Model 4100 to return to the Command Mode.

## 3.2.2 RS-232 USER MENU Description

**Note:**

*The USER MENU mode offers a series of menu choices that allow the operator to optimize the configuration of the Model 4100 for site specific needs.*

### USER Menu Activation

- ✓ Press <1> from the MAIN MENU and verify the Model 4100 returns the following:

CURRENT USER SETTINGS	
1. Maximum number of cals:	1
2. Polarity (D) down (U) up:	U
3. Offset (xxx.xxx):	0.000
4. Sensor Address:	0
5. Samples To Average	181
6. Enter ID, 13 chars:	XXX (SN)
7. Protocol (R) RS232 (S) SDI-12	S
8. Baud Rate:	1200
9. Units (F) Feet (M) Meters:	M
D. Set M! Type. (0, 1, 2, or 3):	0
A. Calculate offset automatically	
Q. Return to previous menu	

The factory default values for each user setting are shown in the right column of the table above. If the user chooses different settings, those values will be displayed when the USER MENU is selected.

### Description of the USER MENU response

- ✓ Entering a <1> allows the user to specify the number of valid reference signals the Model 4100 will accept. The number of 'cals' entered should equal the number of cal tubes installed (normally 1). A <0> will cause the Model 4100 to calculate the measured level based on the speed of sound at 20 degrees C (343.37 m/s). **The factory default is '1'.**
- ✓ Entering a <2> allows the user to set the level polarity for up or down. Entering a <U> specifies that the calculated level will increase as the liquid rises above the '0' offset entered. Entering a <D> specifies that the calculated level will increase as the liquid falls below the offset. **The factory default is <D>.**
- ✓ Entering a <3> allows the user to add or subtract an offset. Entering a value other than zero causes the calculated level to shift (offset) by the amount entered. An 'offset' may be used to compensate for the difference between the site surveyed "Bench Mark" (Datum) and the transducer '0' as calculated in Section 4.2. **The factory default is '0'.**
- ✓ Entering a <4> allows the user to select a sensor address. Entering a value between 0

and 9 provides a unique address when the Model 4100 is configured for the SDI-12 protocol. **The factory default is '0'.**

- ✓ Entering a <5> allows the user to specify the number of measurement samples (from 2 to 255) to average for each data request. Averaging is only performed when a <5> "Continuous NOS Averaging" data request is selected from the MAIN MENU. **No factory default.**
- ✓ Entering a <6> allows the user to assign an alphanumeric identification, up to 13 characters long. Entering an alphanumeric identification causes the sensor to return this "ID" upon specific requests. **The factory default is the unit serial number.**
- ✓ Entering a <7> allows the user to establish the communications protocol. Entering an <R> selects the RS-232 protocol. Entering an <S> selects the SDI-12 protocol with 1200 baud. **The factory default is <S>.**
- ✓ Entering an <8> allows the user to change the baud rate. Enter one of the following baud rates (bits per second) if using the RS-232 protocol: 300, 1200, 4800, or 9600. The SDI-12 protocol automatically selects 1200 as the only baud rate.
- ✓ Entering a <9> allows the user to specify the unit of measure used when the Model 4100 reports the measured level. Entering <F> selects 'feet' and <M> selects 'meters'. **The factory default is <M>.**
- ✓ Entering a <D> allows the user to set the default measurement type when using the SDI-12 type commands. It designates "M1", "M2", or "M3" as the response to a M! **The factory default is <0>.**
- ✓ Entering an <A> allows the user to automatically adjust the Model 4100 water level to an on-site staff gauge or other known reference. If the exact water height is known, the Model 4100 can be automatically adjusted to read the same by entering the known water level. Additional information on this command is provided in Section 4.1. **No factory default.**
- ✓ Entering a <Q> returns the Model 4100 to the MAIN MENU.

**Note:**

*Both the 'Offset' and the 'Units' **must** be entered in the same units of measure. Changing the units of measure from <F> to <M> with the 'Units' function does not automatically change the 'Offset' units of measure from feet to meters!*

## 3.3 Operation With The SDI-12 Protocol

### **Note:**

*The Model 4100-default configuration is set for SDI-12, a serial digital interface standard for hydrological and environmental sensors.*

The Model 4100 is factory configured for SDI-12 operation. SDI-12 is a commonly used low power, multi-drop (up to 10 sensors) signal and power bus. The interface consists of a 3-wire connection for power, signal, and common. For a complete description of the current SDI-12 specification, contact the U.S. Geological Survey, Bay St. Louis, MS.

The Model 4100 supports all SDI-12 commands except those that obviate the host system from performing multi-tasking. Specifically, the AQUATRAK 1) does not abort measurements on the 2nd break command, 2) does not support the "A!" command, and does not lose data after 100 ms (it is held for 10 seconds). In addition, the Model 4100 supports some additional non SDI-12 specific commands, which perform useful functions in the operation of the sensor.

### **Basic Steps To Establish Communications**

- ✓ Disconnect the RS-232 host from the Model 4100 and reconnect the weather-tight cap on the port.
- ✓ Verify that the J-4 and J-5 jumpers on the Model 4100 board are in the off position.
- ✓ Connect the DAS to the SDI-12 connector and program it for the SDI-12 default parameters:

7 bit / Even parity / 1 stop bit / 1200 baud

Note that data blocks from the Model 4100 contain leading signs and no blank spaces between data fields. Carriage return <CR> and line feed <LF> are not used for data requests to the Model 4100 but are used in the sensor response.

### **Quick Check to Test Basic System Operation**

### **Note:**

*The following sections assume that the user has programmed the DAS for the SDI-12 measurement and data commands "aM!" as described in Section 3.3.2.*

- ✓ Transmit the "0I"! Command to the Model 4100. If the sensor address is "0" (factory default), this command is entered as "0I!"

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- ✓ Verify that the Model 4100 returns the following response:

010 AQUATRAK 4100 xxx yyyyyy

Where xxx is the firmware version number and yyyyyy is the unit ID (may be serial number).

- ✓ Transmit the aM!, aD0!, aD1!, and aD2! Command sequence to the Model 4100.
- ✓ Verify that the Model 4100 returns the following response to each data (D) request:

aD0! Returns correct water level  
aD1! Returns correct number of cal tubes used (normally 1)  
aD2! Returns error code (normally 99)

- ✓ If the reported water level does not appear to be correct, see Sections 3.3.1 and 4.0 for user set-up parameters and offset calculations.
- ✓ If the number of cal tubes reported is not equal to the number of cal tubes used in the installation, the user set-up parameters will have to be changed as described in Section 3.3.1.
- ✓ If the error code is not '99', interpret the reported numeric code from the data quality (DQ) table below:
- ✓

Table 3.2.2-1. SDI Data Quality Indicator Table

DQ Cod	Description	DQ Code	Description
0	4100 inoperative	100	Liquid level out of range
99	No errors detected	101	Out of range & no 1st Cal
1	1st Cal undetected	102	Out of range & no 2nd Cal
2	2nd Cal undetected	103	Out of range & no 3rd Cal
3	3rd Cal undetected	104	Out of range & no 4th Cal
4	4th Cal undetected	105	Out of range & no 5th Cal
5	5th Cal undetected	106	Out of range & no 6th Cal
6	6th Cal undetected	107	Out of range & no 7th Cal
7	7th Cal undetected		

### 3.3.1 SDI-12 User Programmable Parameters and Verification

**Note:**

*Through the SDI-12 interface, it is possible to alter and verify the user programmable parameters held in EEPROM to optimize the Model 4100 configuration.*

#### User Programmable Features

Changing the configuration with these commands may be performed in either the RS-232 (Command mode) or SDI-12 protocols. All commands must begin with the proper sensor address (the first character in the block with values from 0-9). When a parameter is altered, the Model 4100 will reread the altered parameter from EEPROM to confirm that the value was entered correctly.

Additional information on the user features may be found in Section 3.1.1.2.

- ✓ Change sensor address:

DAS Command	aXAc!
	Where <c> is the new address from 0-9 Default is 0)
4100 Response	<CR LF>New Address: c <CR LF>

- ✓ Change number of samples to average:

DAS Command	aXSnnn!
	Where <nnn> is the new number of samples from 2 to 255
4100 Response	<CR LF>Samples to Average: nnn<CR LF>

- ✓ Change maximum number of cal tubes: (4000 Series Transducer Only)

DAS Command	aXCn!
	Where <n> is the new number of cal tubes from 0-7 (Default is 1)
4100 Response	<CR LF>Cal points to use: n<CR LF>

- ✓ Change measurement units:

DAS Command	aXUc!
	Where <c> is either (F) feet or (M) meters (Default is M)
4100 Response	<CR LF>Units (F) feet (M) meters: F or M<CR LF>

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- ✓ Change polarity:  

DAS Command	aXPc!
	Where <c> is either (U) up or (D) down (Default is U)
4100 Response	<CR LF>Polarity (U)p (D)own: U or D<CR LF>
  
- ✓ Change protocol:  

DAS Command	aXRc!
	Where <c> is either (S) SDI-12 or (R) RS-232 (Default is S)
4100 Response	<CR LF>Protocol (R)S232 (S)DI-12: R or S<CR LF>
  
- ✓ Change offset:  

DAS Command	aXOnnn.nnn
	Where <nnn.nnn> is the new offset value (Default is 0)
4100 Response	<CR LF>New Offset: nnn.nnn<CR LF>
  
- ✓ Recalculate Offset:  

DAS Command	aXLnnn.nnn
	Where <nnn.nnn> is the new offset value (Default is 0)
4100 Response	<CR LF>New Offset: nnn.nnn<CR LF>
  
- ✓ Change Wave Multiplier:  

DAS Command	aXWnnn.nnn
	Where <nnn.nnn> is the new multiplier value (Default is 3.8)
4100 Response	<CR LF>New Offset: nnn.nnn<CR LF>
  
- ✓ Select 2 foot CAL Tube:  

DAS Command	aXT2! Or aX2!
4100 Response	<CR LF>sensor changed to 2 foot Cal Tube<CR LF>
  
- ✓ Select 4 foot CAL Tube:  

DAS Command	aXT4! Or aT4!
4100 Response	<CR LF> sensor changed to 4 foot Cal Tube<CR LF>

## ✓ Set Print Command:

DAS Command aX?  
4100 Response <CR LF>print command set<CR LF>

## ✓ Select CAL Response:

DAS Command aXT4! Or aT4!  
4100 Response <CR LF>cal response type: m or ft <CR LF>

## ✓ Select Maximum Range:

DAS Command aXDnn.n response maximum range  
4100 Response <CR LF>Maximum range: nn.n<CR LF>

**Note :**

*Both the 'Offset' and the 'Units' must be entered in the same units of measure. Changing the units of measure from <F> to <M> with the 'Units' function does not automatically change the 'Offset' units of measure from feet to meters*

**Configuration Verification**

The current user parameter configuration may be verified using the aV! verify command. the initial sensor response will be **a00110<CR LF>**. When the sensor is ready to receive the verify data commands, it will transmit the Data Ready **a<CR LF>** block.

aV! Perform verify function

aD0! a+<samples to average><CR LF>  
aD1! a+<polarity ASCII decimal value><CR LF>  
(Where U = 85 and D = 68)  
aD2! a+<sensor offset><CR LF>  
aD3! a+<maximum cals to use><CR LF>  
aD4! a+<Units ASCII decimal value><CR LF>  
(Where F = 70 and M = 77)  
aD5! a + pulse + cal blank + liq blank + range + cal length

## 3.3.2 SDI-12 Command Mode and Response Descriptions

**Note:**

*In the Command Mode, the Model 4100 responds to 5 measurement commands and as many as 6 data commands to capture all the measurement data.*

When in the Command Mode, a specific sequence must be followed to obtain the measured level from the Model 4100 as shown below:

Table 3.3.2-1 SDI-123 Command Sequence

<u>Host</u>		<u>Model 4100</u>
Request Measurement (M command)	→	
	←	Send "seconds until ready and # of data points"
	←	Send "Data Ready"
Request Data (D command)	→	
	←	Send Data

- ✓ Character Format

7 data bits                      even parity                      1 stop bit

- ✓ Character Description

**HOST COMMAND**

a = 4100 address  
M = Measurement  
D = Data request  
# = Sub routine  
! = Execute

**4100 RESPONSE**

a = 4100 address  
ttt = Seconds until ready  
nnn = Number of characters  
a<CR LF> = Data Ready

**Note:**

*Data requests must be made within 10 seconds of the data ready flag request if the Model 4100 micro power mode is selected, (no jumper in J4).*

- ✓ Measurement (M) and Data (D) Commands

aM!                      Initiate single measurement only  
aD0!                      Returns water level  
aD1!                      Returns number of cals  
aD2!                      Returns error code

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aM1!	Initiate single measurement only
aD0!	Returns cal count # 1
aD6!	Returns total cal and total liquid counts
aM2!	Initiate averaged measurements
aD0!	Returns averaged water level
aD1!	Returns standard deviation
aD2!	Returns number of outliers discarded
aD3!	Returns average # of calcs used
aD4!	Returns error code
aM3!	Initiate averaged measurements
aD0!	Returns averaged water level
aD1!	Returns standard deviation
aD2!	Returns number of outliers discarded
aD3!	Returns average # of calcs used
aD4!	Returns error code
aD6!*	Returns cal count # 6, 7, total cal, & total liquid
	(* may exceed the SDI-12 block time limitation of 0.38 seconds)
aMAtt!	Perform average measurement after tt seconds and hold data for one minute
aD0!	Returns averaged water level
aD1!	Returns standard deviation
aD2!	Returns number of outliers discarded
aD3!	Returns average # of calcs used
aD4!	Returns error code
	(* this command is not specified by SDI-12 but it allows the host to specify when the measurement is taken)

### Typical Example Sequence to Receive Averaged Data

Assume that the Model 4100 address is 0 and that averaged data is to be requested

<b>Host</b> → Send "0M2!"	This will awaken the Model 4100 and have it begin collecting 181 samples of data (averaging default). "0" is the Model 4100 address and "M2!" is the command to initiate averaged measurements.
<b>4100</b> → Send "0ttn"	This data tells the host that the data will be ready in ttt seconds. "0" is the Model 4100 address and "n" is the number of data points available.
<b>4100</b> → Send "0 CR/LF"	This data tell the host that data is ready and may be requested (within 10 seconds or the data is lost). The "0" is the Model 4100 address and the CR/LF causes the host to carriage return and skip a line.
<b>Host</b> → Send "0D0!"	This command will cause the Model 4100 to output the averaged water height data only.
<b>4100</b> → Send "+/-XX.XXX <CR LF>	This data is the height of the water level in the units of measure selected with the USER SETTINGS.



## 4. AQUATRAK OPERATION

### 4.1 Leveling the Sensor to a Known Water Level - Option 1

**Note:**

*Now that the AQUATRAK is installed and communicating with the host, it must be leveled to a known datum point in order to provide meaningful water level information.*

If the Model 4100 is being installed in close proximity to a standard water level staff, the AQUATRAK can be offset to read the same water level as the staff. This is the simplest method of leveling the sensor.

In Figure 4.1-1, the illustration shows an AQUATRAK transducer collocated with a staff gauge reading a water level of 7.1 feet. If the staff has been surveyed (i.e.; referenced to a bench mark), the automatic offset feature of the Model 4100 may be used to match the Model 4100 reported water level with that read from the staff. Follow the steps below to match the Model 4100 to the staff:

- ✓ Send an <ESC> to the Model 4100 to cause it to enter the MAIN MENU.
- ✓ At the MAIN MENU, enter a "1" to enter the USER MENU.
- ✓ At the USER MENU, verify that the polarity selected is "U" for up.
- ✓ If not set to U, enter a "2" to change the polarity - enter a "U" when prompted by the Model 4100.
- ✓ Enter an "A" to change the automatic offset - enter the correct water level from the staff (7.1 in this example).
- ✓ Enter a "Q" to return to the MAIN MENU.

The Model 4100 will now read the same as the staff since the Model 4100 was offset by exact water height on the staff level. As the water rises on the staff, the Aquatrak Model 4100 water level reading will increase, as the water falls, the Model 4100 reading will decrease.

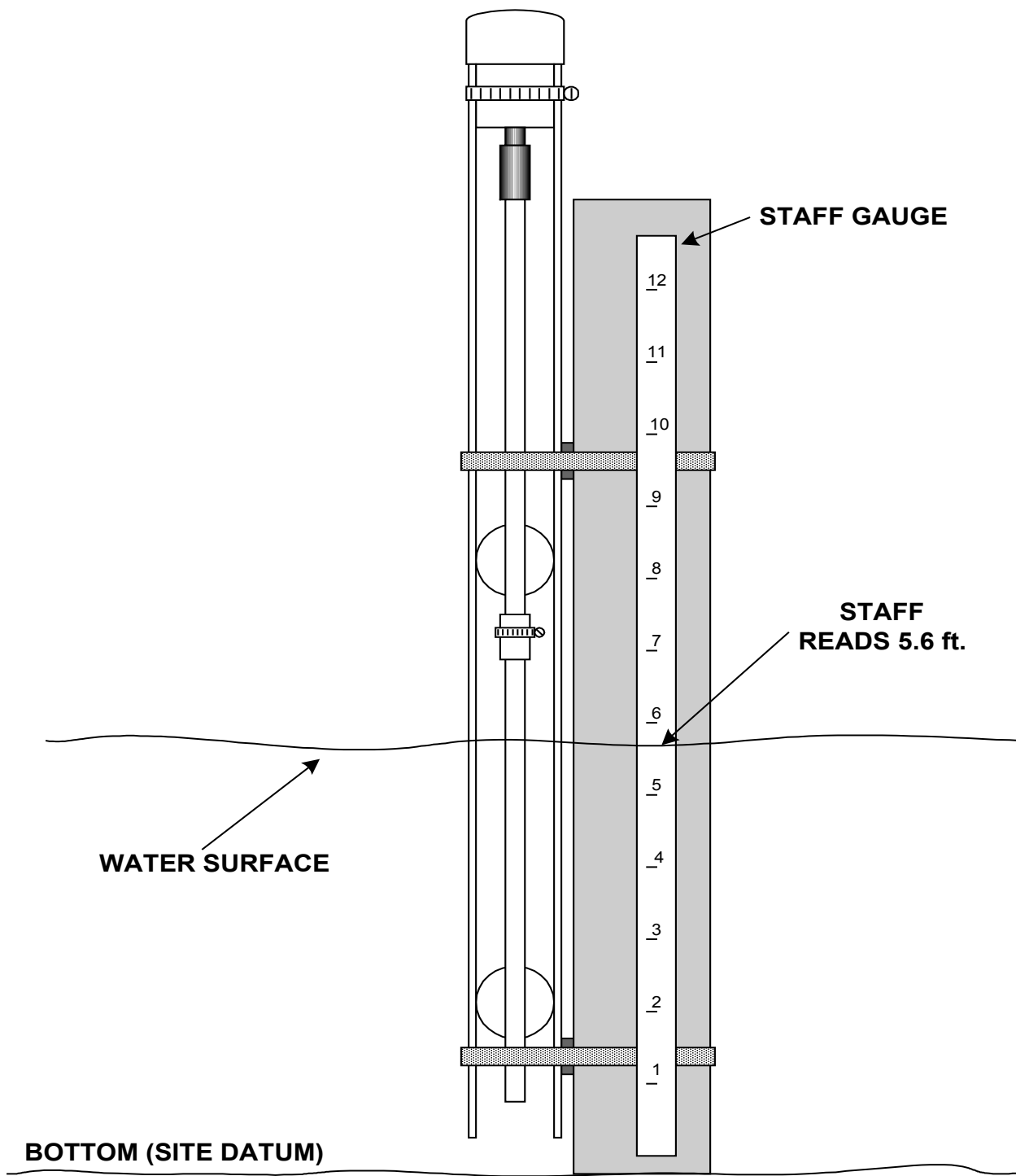


Figure 4.1-1 Leveling the Sensor to a Staff Gauge

**4.2 Leveling the Sensor to a Primary Benchmark - Option 2**

**Note:**

*Now that the Model 4100 AQUATRAK is installed and communicating with the host, it must be leveled to a known datum point in order to provide meaningful water level information.*

**Caution:**  
*The establishment of the primary bench mark (PBM) may require the services of a trained surveyor.*

If a surveyed water level staff is not available, the Model 4100 must be leveled to another reference. A common reference point is the local primary benchmark (PBM) which may be considered to be the zero datum. When the Model 4100 is first installed and operated, it will correctly report the raw water level height from sensor zero to the surface. But the raw water level must now be referenced to a known point (datum) to have a significant (absolute) meaning to the user.

A convenient leveling reference point on the sensor is at the bottom of the stainless steel collar on the bottom of the transducer. The distance between the bottom of the collar and the transducer zero is precisely measured at the factory and recorded on the AQUATRAK CALIBRATION CERTIFICATE as the '0' Offset. This distance is shown as the "S" dimension in Figure 4.2-1.

To calculate the offset, determine whether the zero datum point will be above or below the transducer. Then, survey the length "X" between the zero reference and the bottom of the transducer collar. Use one of the two formulas below to calculate the offset (depending on zero datum location).

**Zero Datum Above**

$$\text{Offset} = \begin{matrix} - & \text{_____} & \text{(X)} \\ & \text{_____} & \text{(S)} \\ & \text{=====} & \end{matrix}$$

**Zero Datum Below**

$$\text{Offset} = \begin{matrix} & \text{_____} & \text{(X)} \\ & \text{_____} & \text{(S)} \end{matrix}$$

Once the offset is determined, enter the value into the Model 4100 using either the RS-232 User Menu described in Section 3.2.2 or the SDI-12 User Programmable features described in Section 3.3.1. Setting the polarity to down (D) will cause falling water levels to show an increasing distance from the zero reference.

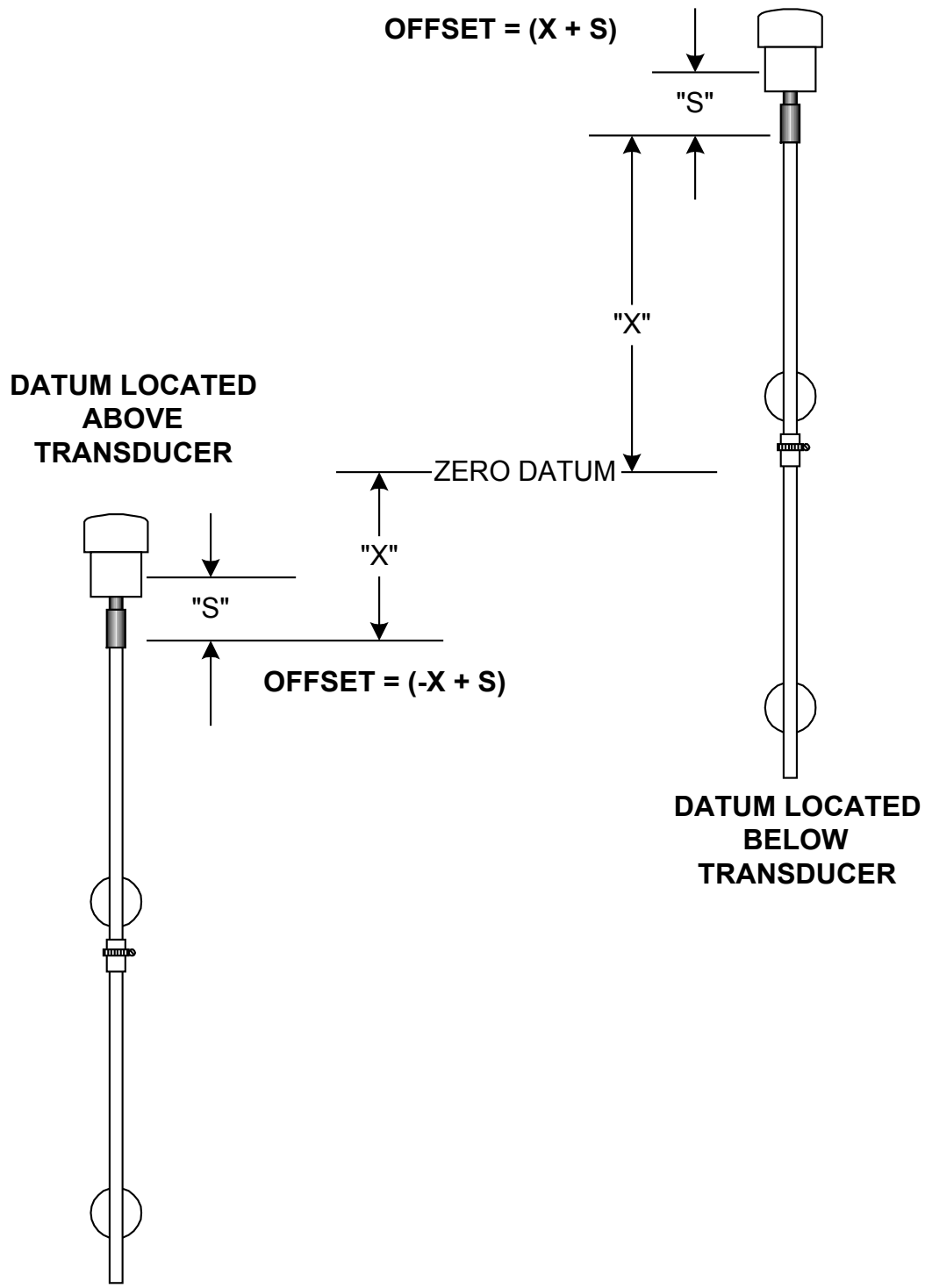


Figure 4.2-1 Leveling the Sensor to a Datum

**APPENDIX**

**TECHNICAL SPECIFICATION OF  
MODEL 4100 SERIES AQUATRAK**

<b>Measurement</b>		<b>Accuracy</b>	
Dynamic Range		Calibration	
Standard	>10 meters (35 feet)	Standard	$\pm 0.025\%$
Optional	>15 meters (50 feet)	Optional	$\pm 0.01\%$
Special	23 meters (75 feet)	Nonlinearity	$\pm 0.02\%$
Rate of Change	$\pm 3$ m/sec. ( $\pm 10$ feet)	Precision, Repeatability	$\pm 0.01\%$
Units	Metric (English)	Stability, Drift, 1 year	0
Resolution	1 mm (0.001 feet)	Temperature Drift	< 1 ppm/°C
Rate Proportionate	1.2 = 2.4 per sec.		
Rate Averaged 2 to 255:	1.0 per sec.		
Interval	Host determined		
 <b>Electrical</b>		 <b>ASCII Serial Communication</b>	
Voltage, d.c.	$12.5 \pm 2$ volts	Selectable baud rate:	300 to 9600
Operating Current	< 30 ma	RS-232	N-8-1
Quiescent Current	< 1 ma	SDI-12	E-7-1
Average Power	20 mW (4 sample average)	EIA-485	Consult. Factory
 <b>Environmental</b>		 <b>Physical</b>	
Operating Temperature	-40 to 55°C	Controller 4100	
Storage Temperature	-55 to 60°C	Size	23 x 9 x 6 cm (9 x 3.5 x 2.5 inch)
Humidity	0 to 100%	Weight	1.5 lbs. (0.68 kg.)
		Sensor	
		Size	9 cm dia. 21 cm ht.) (4 inch dia. 8 inch. ht.)
		Weight	2.5 lbs. (1.14 kg.)
		<b>Shipping (1 carton)</b>	5 lbs. (2.23 kg.)